5.1 Extant Manuscripts of al-Ṣūfī's Book

Al-Ṣūfī's '*Book of the Fixed Stars*' dating from around A.D. 964, is one of the most important medieval Arabic treatises on astronomy. This major work contains an extensive star catalogue, which lists star co-ordinates and magnitude estimates, as well as detailed star charts. Other topics include descriptions of nebulae and Arabic folk astronomy. As I mentioned before, al-Ṣūfī's work was first translated into Persian by al-Ṭūsī. It was also translated into Spanish in the 13th century during the reign of King Alfonso X.

The introductory chapter of al-Ṣūfī's work was first translated into French by J.J.A. Caussin de Parceval in 1831. However in 1874 it was entirely translated into French again by Hans Karl Frederik Schjellerup, whose work became the main reference used by most modern astronomical historians. In 1956 al-Ṣūfī's Book of the fixed stars was printed in its original Arabic language in Hyderabad (India) by Dārat al-Ma'aref al-'Uthmānīa. It was later re-published in Beirut (Lebanon) from the Hyderabad copy by Dār al-Āfāq al-Jadīdah in 1981. At present no English translation of this important treatise exists. In order to remedy this omission, I have made this detailed study of al-Ṣūfī's work, including the preparation of an English translation. However, before I started I had to identify the extant manuscripts of the '*Book of the Fixed Stars*'. Then I had to identify the criteria with which to choose the manuscripts which were used as the bases for the translation and discussions.

5.1.1 List of Extant Manuscripts of al-Ṣūfī's Book

It is a measure of the popularity of this book that many manuscripts are still preserved in libraries throughout the world Figure 17 . However, tracking down several of these manuscripts involved extensive travel worldwide and much library research. The reaction of some librarians or museums has not always been positive or helpful; however, in the end I managed to locate as many as 35 manuscripts and acquired copies of the major ones which are needed for this study. The list below shows the manuscripts of al-Ṣūfī's work which I found from the various references and library catalogs, some of which I managed to study personally. They are grouped by country or location of the library where they are being kept. However, other manuscripts might still be held in other libraries or in private collections. Some manuscripts have also been recently digitized for public viewing or research. Therefore I have included the website locations where these manuscripts can be located.

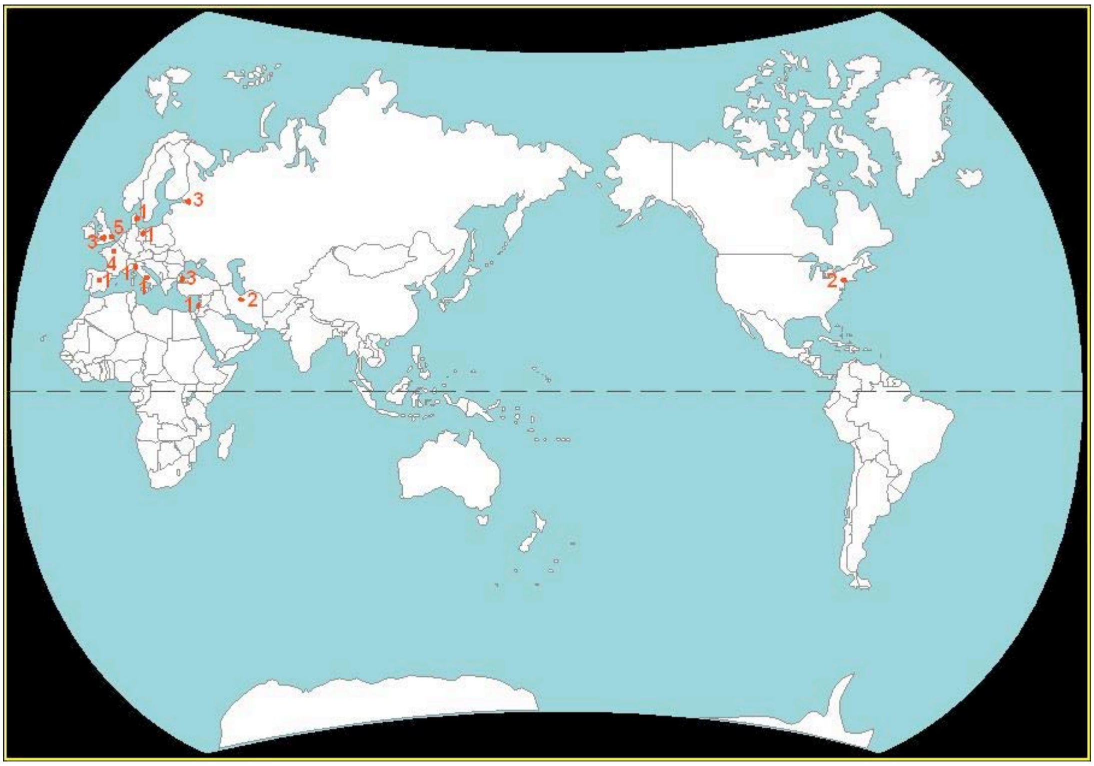


Figure 17 location of manuscripts

1. Oxford, Bodleian Library, MS Marsh 144, dated A.H. 400 / A.D. 1009.

Size: 265 x 180 mm; 419 pages; Layout: written in 15 lines.

2. Oxford, Bodleian Library, MS Pocock 257, dated A.H. 706 / A.D. 1306.

3. Oxford, Bodleian Library, MS Huntingdon 212, dated A.H. 769 / A.D. 1367.

4. Istanbul. Topkapi Sarayi, MSS 3493, dated A.H. 525 / A.D. 1131

5. Istanbul. Topkapi Sarayi, MSS 2595, date unknown.

6. Istanbul. Topkapi Sarayi, MSS 2642, date unknown.

7. Istanbul. Sulaymania Library, Ms number unknown, dated A.H. 529 / A.D. 1135.

A facsimile copy of this manuscript is found in Beirut (American University of Beirut) (MS 520:S94sa) which is taken from a copy from another facsimile copy found at the University of Damascus in Syria.

8. Berlin, Ahlwardt 5658-5660, dated A.H. 620 / A.D.1233.

9. Vatican, Rossi 1033, dated A.H. 621 / A.D. 1224.

10. Paris Bibliotheque Nationale de France, MS Arabe 5036, dated A.H. 833 / A.D. 1430. http://gallica.bnf.fr/ark:/12148/btv1b60006156

11. Paris Bibliotheque Nationale de France, MS Arabe 2488, date unknown.

12. Paris Bibliotheque Nationale de France, MS Arabe 2489, date unknown.

13. Paris Bibliotheque Nationale de France, MS Arabe 2490, date unknown.

14. Copenhagen, Royal Library, MS 83, dated A.H. 1010 / A.D. 1601.
This manuscript was the one used by Schjellerup in his French translation in 1874.

15. St Petersburg, Bibliotheque Imperiale de St Petersburg, MS 191 dated A.H. 1015 / A.D. 1606. This manuscript was the second one used by Schjellerup in his French translation in 1874.

16. St Petersburg, Institute des Langues Oriental, MS 185, dated A.H. 405 / A.D. 1015.
Note: the date of this manuscript is doubtful because according to Schjellerup this manuscript was written in *Ta'līq* style which was not used as early as the 11th century; therefore this manuscript could date to the 15th or 16th century A.D. (Kunitzsch, 1986).

17. St Petersburg, Bibliotheque Imperiale de St Petersburg, MS 190 dated 15th or 16th century A.D.

18. Beirut, American University of Beirut, MS 520:S94 sA, dated A.H. 1122 / A.D. 1711. Size: 215 x 160 mm; 110 pages; Layout: written in 27 lines; *Naskhī* style.

19. New York, The Metropolitan Museum of Art, no 13.160.10, dated 14th century A.D.

20. New York, The Metropolitan Museum of Art, no 1975.192.2, dated 18th century A.D.

21. London, British Library, OR 5323, dated 14th century A.D.

22. London, British Library, ADD 7488, dated 17th century A.D.

23. London, British Library, OR 1407 dated A.H. 1074 / A.D. 1663.

24. London, British Library, IO ISL 621, dated 17th century A.D.

25. London, British Library, IO ISL 2389, dated 18th century A.D.

26. Madrid, library Escurial, MS No 915, dated A.H. 1173 / A.D. 1760.

27. Bologna, les Manuscript Orientaux Collection Marsigli, MS 422, date unknown.

28. Tehran, Majles library, MS 197, date unknown.

29. Tehran, Majles library, MS 196, date unknown.

30. Tunis, Bibliotheque Nationale de Tunisie, MS 8093, dated A.H. 1030 / A.D. 1621.
Size: 225 x 140 mm; 190 pages; Layout: written in 17 lines.

31. Hyderabad, Asafiya library, Ms number unknown, date unknown.

32. Washington, Library of congress, Ms Number unknown, dated A.H. 1142/A.D. 1730.
Size: 250 x 150 mm; 176 pages; Layout: written in 19 lines. This copy is based on Ulugh Beg's copy made in A.D. 1430 which is found at The Bibliothèque Nationale de France in Paris (MS5036). http://www.wdl.org/en/item/2484

33. Cairo, the Egyptian Dar books, Ms Number unknown, dated A.H. 1043 / A.D. 1633.
34. Princeton, Princeton University Library, Garrett no. 2259Y, dated A.H. 1015 / A.D. 1607.
http://diglib.princeton.edu/view?_xq=pageturner&_index=1&_inset=1&_start=1&_doc=/mets/islamic2259y.mets.xml

35. Doha, The Museum of Islamic Art in Doha, Ms # M1-02-98-90, dated A.H. 519 / A.D. 1125; this manuscript was acquired by the Museum of Islamic Art in Doha in 1998 from the Sotheby's London auction house.

There are also other manuscripts which fall under the title of 'Sufi Latinus' corpus. There are 8 extant copies of these Latin manuscripts which were based on al-Ṣūfī's '*Book of* *the Fixed Stars*'. According to Kunitzsch (1965; 1986) the longitude values and the style of drawing are no doubt derived from the Arabic al-Ṣūfī manuscripts. In the title of one of those manuscripts which is located at the Bibliotheque Nationale de France in Paris we find the name of the author as 'Ebennesophy'. This is one of the first examples whereby al-Ṣūfī was referred to as Ibn al-Ṣūfī. I have not included any of these manuscripts in the above list since I do not believe that the 'Sufi Latinus' corpus represent a genuine or an accurate picture on al-Ṣūfī's work which we can rely on. These manuscripts are:

- Paris, Arsenal 1036.
- Gotha, Forschungsbibliothek, MS M II 141, dated A.D. 1428.
- Prag, Strahov Library, MS D.A. II, 13.
- Berlin, Kupferstichkabinett, MS Hamilton 556.
- Munich, Clm 826.
- Catania, MS Catin 85.
- Vienna, MS 5318.
- Kues, Cusanus-Stift, MS 207.

Finally, I would just like to make a note here on the main sources which modern scholars and historians have been using in their studies of al-Ṣūfī's work and other similar topics. The first is the French translation by Schjellerup which was published in 1874. This translation was produced based on the Copenhagen Manuscript MS83 dated A.D. 1601. However, since Schjellerup used a rather late manuscript in his translation I believe that his work might lack the reliability needed to reflect the potential of al-Ṣūfī's work. The other source is the Hyderabad publication of al-Ṣūfī's '*Book of the Fixed Stars'* which was printed in Arabic in 1956. This production was edited by Muḥammad Nizām al-Dīn based on five manuscripts. The first was the Istanbul MSS 3493, the second was the Vatican Rossi 1033, the third was the Berlin 5658-5660, the fourth was the Paris MS Arabe 5036 and the last was the Hyderabad copy, for which there is no manuscript number and date. This Hyderabad copy was later re-published in Beirut by Dār al-Āfāq al-Jadīdah in 1981. Even though this work was based on several manuscripts, the oldest known manuscript - which is the Marsh144 copy - was not utilized. According to Kunitzsch (1986) and the investigation which I made myself, the Hyderabad copy contains many errors which do not make it very reliable. However, it is the only clearly-printed Arabic copy of al-Ṣūfī's work readily available to the public and is found in many libraries worldwide. In a later section of this discussion (Chapter 5.12) I have identified some of the differences in coordinates and magnitude values found between these two sources and the main manuscripts which I used as the bases for this work. This exercise was made for one constellation only in order to show some of the mistakes present in these sources and to show the importance of producing a reliable text of al-Ṣūfī's work from the oldest and best-kept manuscripts available to us.

5.1.2 Criteria for Identifying the Book for Translation

Unfortunately not many manuscripts can be used for this study. I have cited several criteria which I used to choose the most suitable manuscripts as the bases for translation. I will try to give examples of these criteria using several manuscripts which I found at the British Library in London.

- Dating of the Manuscript

The first and the most important criterion for choosing the manuscript was the date of the manuscript. The date in this context is the date at which the manuscript was copied or re-written. All these manuscripts were written by hand by copyist or scribes from an original which was probably written by al-Ṣūfī himself. Unfortunately the original copy of al-Ṣūfī's manuscript is no longer extant. In many of these manuscripts the date of the copy was not mentioned. Therefore, it was sometimes a little difficult to put an exact date on a manuscript copy. However, dating can be approximated based on paleographic techniques and calligraphy types. I have indicated in the list below all those manuscripts for which the date is not known and these cannot be used for this translation exercise. However, other manuscripts carry a definite date which was usually written at the end of the manuscript, such as the example of the British library manuscript number OR1407. On the last page of this manuscript we can clearly see that it is dated A.H. 1074 which is equivalent to A.D. 1663 (Figure 18). The criterion for the date which I selected for choosing the best manuscript is that it should not be older than A.H. 500, which is almost 100 years after al-Ṣūfī's death. The younger the manuscript the more likely the mistakes of the copyist will grow.

 Figure 18  figure 19

- Legibility of Handwriting

In addition to questions of date, the legibility of handwriting was another issue which I considered in identifying a manuscript for study. The handwriting of some of these manuscripts was not very clear. This reflected the style or the interest of the copyist. For example, the copyist of British Library manuscript number OR1407 again was not only very neat, but took a real interest in the substance of what he was copying. This scribe, for instance, compiled an index of the constellations at the beginning of the manuscript which was not originally a part of al-Ṣūfī's work (Figure 19). Unfortunately this manuscript was not among the manuscripts used in this study because it is dated to A.H. 1074 which is more than 600 years after al-Ṣūfī's death.

- Complete Manuscript

Another criterion for choosing a manuscript was whether it was complete. I have found several manuscripts of the '*Book of the Fixed Stars*' which were deficient, some with many diagrams, star charts or tables incomplete or even missing. Such an example is manuscript IO ISL 621 in the British Library which dates to the 17th century (Figure 20). As we can see, the tables in this manuscript were not completed. Even though the images of the constellations and stars were drawn in gold (Figure 21), the stars were not numbered and many stars were missing. Several constellation tables were also not complete with the last two constellations missing.

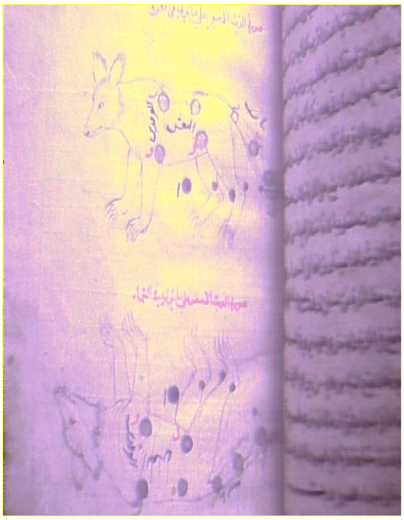


Figure 20

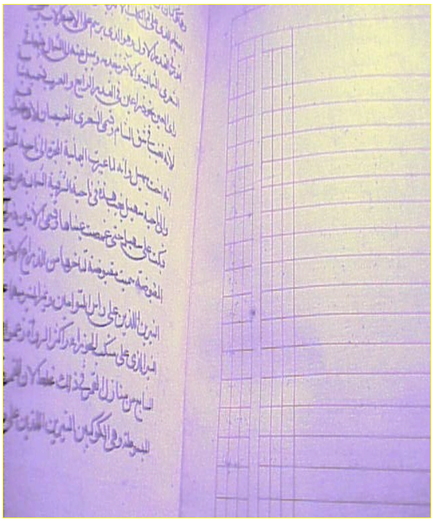


Figure 21

* Obvious Mistakes

The last of the criteria was the obvious mistakes which I found in some of these manuscripts. In the Manuscript ADD 7488 in the British Library which was dated to the 17th century we have an example of an obvious mistake, with ‘Abd al-‘Azīz rather than ‘Abd al-Raḥmān cited as part of al-Ṣūfī's name. This particular manuscript is also incomplete. The last constellation listed is Argo Navis. The last eight constellations, from Hydra to Piscis Austrinus, are missing. Therefore, such a manuscript could not be a suitable candidate in our work on al-Ṣūfī’s book.

* Table 3: The Manuscripts and Identification Criteria.

Manuscript	Copy Date of Manuscript	Legibility	Completeness & Mistakes	Criteria Description
Oxford, MS Marsh 144	A.H. 400	Clear hand writing	Incomplete manuscript	Before A.H. 500 however the last chapter is in-complete.
Oxford, Ms Pocock 257	A.H. 706	Clear hand writing	Complete manuscript	After A.H. 500
Oxford, Ms Huntingdon 212	A.H. 769	Clear hand writing	Complete manuscript	After A.H. 500
Istanbul, MSS 3493	A.H. 525	Clear hand writing	Complete manuscript	After A.H. 500
Istanbul, MSS 2595	Unknown	Clear hand writing	Complete manuscript	Unknown date
Istanbul, MSS 2642	Unknown	Clear hand writing	Complete manuscript	Unknown date
Istanbul Ms number	A.H. 529	Clear hand	Complete	After A.H. 500

Unknown		writing	manuscript	
Berlin, 5658-5660,	A.H. 620	Clear hand writing	Complete manuscript	After A.H. 500
Vatican, Rossi 1033	A.H. 621	Clear hand writing	Complete manuscript	After A.H. 500
Paris, MS Arabe 5036,	A.H. 833	Very clear hand writing	Complete manuscript	After A.H. 500 a very well written copy
Paris, MS Arabe 2488	Unknown	Clear hand writing	Complete manuscript	Unknown date
Paris, MS Arabe 2489	Unknown	Clear hand writing	Complete manuscript	Unknown date
Paris, MS Arabe 2490	Unknown	Clear hand writing	Complete manuscript	Unknown date
Copenhagen, MS 83	A.H. 1010	Clear hand writing	Complete manuscript	After A.H. 500
St Petersburg, MS 191	A.H. 1015	Clear hand writing	Complete manuscript	After A.H. 500
St Petersburg, MS 185	A.H. 405 Date uncertain	Clear hand writing	Complete manuscript	Date uncertain should be 15th century A.D.
St Petersburg, MS 190	15th century A.D.	Clear hand writing	Complete manuscript	After A.H. 500
Beirut, MS 520:S94sA	A.H. 1122	Clear hand writing	Complete manuscript	After A.H. 500
New York, 13.160.10	14th century A.D.	Clear hand writing	In-complete manuscript	After A.H. 500
New York, 1975.192.2	18th century A.D.	Clear hand writing	Complete manuscript	After A.H. 500
London, ADD 7488	17th century A.D.	Clear hand writing	Incomplete manuscript with mistakes	After A.H. 500
London, OR 5323	14th century A.D.	Clear hand writing	Complete manuscript	After A.H. 500
London, OR 1407	A.H. 1074	Very clear hand writing and tables	Complete manuscript	After A.H. 500
London, IO ISL 621	17th century A.D.	Clear hand writing	Incomplete manuscript	After A.H. 500
London, IO ISL 2389	18th century A.D.	Clear hand writing	Incomplete manuscript	After A.H. 500
Madrid, MS No 915	A.H. 1173	Clear hand writing	Complete manuscript	After A.H. 500
Bologna, MS 422	Unknown	Clear hand writing	Complete manuscript	Unknown date
Tehran, MS 197	Unknown	Clear hand writing	Complete manuscript	Unknown date
Tehran, MS 196	Unknown	Clear hand writing	Complete manuscript	Unknown date
Tunis, MS 8093	A.H. 1030	Clear hand writing	Complete manuscript	After A.H. 500
Hyderabad, Ms # unknown	Unknown	Clear hand writing	Complete manuscript	Unknown date

Washington, Ms # unknown	A.H. 1142	Clear hand writing	Complete manuscript	After A.H. 500
Cairo, Ms # unknown	A.H. 1043	Clear hand writing	Complete manuscript	After A.H. 500
Princeton, Islamic Manuscripts, Garrett no. 2259Y, dated	A.H. 1015/ A.D. 1607	Clear hand writing	Incomplete manuscript, no tables, only single illustration per constellations	After A.H. 500
Doha, The Museum of Islamic Art in Doha, dated. Ms # M1-02-98-90	A.H. 519 / A.D. 1125	Clear hand writing	Complete manuscript	After A.H. 500

5.1.3 The Main Manuscripts Identified for Translation and Discussion.

The two main manuscripts which I have identified to be the bases of the translation and discussion are manuscript ‘Marsh144 and manuscript ‘MS5036’. However, I have also found some slight differences in coordinates and magnitude values between these two manuscripts. In a later section of these discussions I have identified some of these differences, which were probably due to scribal error at the time the manuscripts were copied. As we said earlier, all these manuscripts were written by hand over and over again and were handed down from one generation to another. So there must have been hundreds of these copies circulating at any one time. Unfortunately we do not have the original manuscript which was written by the author himself but we have the next best thing which is the copy by the author’s sons. However, I believe that the values in the Marsh144 manuscript are probably more accurate since it is an older manuscript; therefore the values which I indicated in the translation of the main text are based on the Marsh144 figures.

- The Marsh144 Manuscript

The Marsh144 manuscript is the earliest-known manuscript of the ‘*Book of the Fixed Stars*’. It is dated A.H. 400 / A.D.1009 only 23 years after al-Ṣūfī's death. According to the inscription on the last page of this manuscript (Figure 22) this copy was copied and illustrated by al-Ḥusaīn Ibn ‘Abd al-Raḥmān Ibn ‘Umar Ibn Muḥammad. The Marsh144 manuscript was actually written by al-Ḥusaīn who was the eldest son of al-Ṣūfī. It is now located at the Bodleian Library in Oxford. In 1959 a study of the Islamic constellation images was made by Emmy Wellesz based on this manuscript. The manuscript is 419 pages of the size 265 by 180 mm written in *Nasta'lik* style with 15 lines on each page. Black ink was used to draw all the figures as well as the tables and writing. The stars drawn in red and labeled in black, in both images, are part of the constellation. The stars drawn in black and labeled in red are outside the constellation. The stars drawn in black and not labeled are those not mentioned by Ptolemy.

According to the Bodleian Library records it was purchased by 'Narcissus Marsh' at the Jacob Golius's Library in Leiden in 1696. On page 419 of this manuscript we find the inscription of the previous owner by the name of 'Christianus Ravius' who purchased this copy in 1644. However from page 405 onward the manuscript shows more or less drastic repairs with the last page of this manuscript showing an incomplete table. According to the Latin inscription found at the margin on the last page 'Christianus Ravius' wrote that he supplied the missing parts of the text after having compared it with a more recent copy of the same work. These missing pages were probably the first eleven folios of this manuscript. This can be seen from the difference in handwriting between these folios compared to the remaining text. These first eleven folios also exhibit many mistakes as well as correction which were made by hand. The folios 252 to 269 have also been incorrectly arranged and should have been inserted between the folio 211 and 212. However, even with these shortcomings this manuscript is still considered the oldest and most reliable copy available of al-Ṣūfī's book. Therefore I have chosen this manuscript to be the basis for this study and I managed to acquire a facsimile copy of this work.

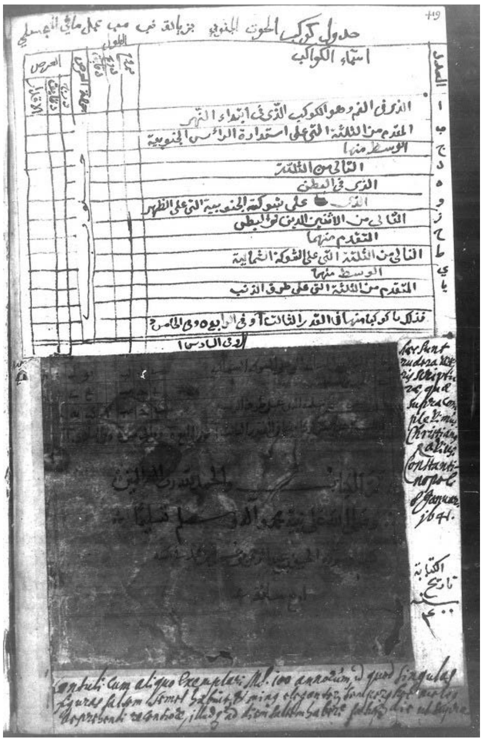


Figure 22 The Last Page of Marsh144 Manuscript

- The MS5036 Manuscript

The MS5036 manuscript is found at the National Library in Paris. It is dated A.H. 833 / A.D. 1430. The final page of his manuscript is shown in Figure 11. This copy was written for King Ulugh Bēg as is mentioned at the last page of this manuscript. As I said earlier, the text next to the last table of this manuscript states that the pictures were drawn according to the instructions of Ibn al-Ṣūfī and the data were taken from the copy of Naṣīr al-Dīn al-Ṭūsī. This is a very well-written manuscript with clear tables and pictures of the constellations. The stars which are part of the main constellation picture were drawn in gold while the stars drawn in red are outside the constellation. The manuscript contains 494 pages of the size 285 by 205 mm also written in *Nasta'lik* style with 13 lines on each page. Even though this manuscript was written much later, I needed another well-written but reliable copy to compare with and complete the last missing page of the Marsh144 manuscript. Since this copy was written for Ulugh Bēg from al-Ṭūsī's copy I believe that it is a good reliable copy of al-Ṣūfī's work which I could utilize. Therefore I have chosen this copy and I included the text of this manuscript whenever I needed to complement the work.

5.2 The Structure of al-Ṣūfī's Book and Star Catalog

The original Arabic name of al-Ṣūfī's book was '*Ṣuwar al-Kawākib al-Thamāniyah wa-al-Ārba'een*' which is simply translated as '*The 48 Constellations*'. However, it was later known by other names, the most famous of which are: '*Kitāb al-Kawākib al-Thābitah*' or the '*The Book of the Fixed Stars*' and '*Kitāb al-Kawākib al-Thābitah Muṣawaran*' or the '*The Illustrated Book of the Fixed Stars*'. This book was also known by another name which was: '*Kitāb Ṣuwar al-Samawīyah Muṣawaran*' or '*The Illustrated Book of the Heavenly Signs'*. I will begin this study of al-Ṣūfī's work with the description of the structure and layout of the '*Book of the Fixed Stars*'. Al-Ṣūfī's original Arabic text contained 55 astronomical tables as well as star charts of 48 constellations. Al-Ṣūfī commented in detail on every constellation before every section of those star charts. These tables and charts were written in the same order using the same structure and layout as in the *Almagest*. Al-Ṣūfī's book is divided into four main sections:

1. The Introductory Chapter

Al-Ṣūfī's introductory chapter is a very important part of his work. In it he explained the reasons for writing his book. He also included his strong criticisms of other works, especially those of al-Battānī and al-Daīnawari. He explained the method he used in writing his book and the technique he used for calculating the precession value. Al-Ṣūfī also identified the 48 constellations which, as he mentioned, were taken from Ptolemy's *Almagest*. He also mentioned that some ancient astronomers counted the number of stars in each constellation to be 917 stars that are included in the main constellations and 118 stars outside of the constellations. He then mentioned that other people also mistook the number of the stars in the sky to be 1025 stars only and this is wrong also because as he explained, there are many other stars of the 5th and 6th magnitude. He finally summarized the total number of brightly-observed stars to be 1022 except the three stars that are part of the Asterism '*al-Ḍafira'*. He also explained how the tables were compiled and the reason and method for using the dual constellations charts and images. (See translation and comments on al-Ṣūfī's introduction chapter)

2. The 21 Chapters of the Northern Constellations (Table 4):

#	Constellation name	# stars in	#stars out	Arabic names according to al-Ṣūfī
1	Ursa Minor	7	1	*al-Dub al-Aṣghar*

2	Ursa Major	27	8	*al-Dub al-Akbar*
3	Draco	31	-	*al-Tinnīn*
4	Cepheus	11	2	*Qīqāwūs; al-Multaheb*
5	Bootes	22	1	*al-'Awwā; al-Sayyāḥ ; al-Naqqār; Ḥāris al-Shamāl*
6	Corona Borealis	8	-	*al-Iklīl al-Shamālī; al-Fakka*
7	Hercules	28	1	*al-Jāthī 'ala Rukbateh; al-Rāqeṣ*
8	Lyra	10	-	*al-Silyāq; al-Wazza; al-Subeḥ; al-Ma'refa; al-Sulaḥfāt*
9	Cygnus	17	2	*al-Ṭā'er ; al-Dajāja*
10	Cassiopeia	13	-	*Dhāt al-Kursīy*
11	Perseus	26	3	*Barshāūsh ; Ḥāmel Ra's al-Ghūl*
12	Auriga	13	-	*Mumsek al-'Inān; al-'Inān; Mumsek al-A'ina*
13	Ophiuchus	24	5	*al-Ḥawwā'*
14	Serpens	18	-	*al-Ḥayyā*
15	Sagitta	5	-	*al-Sahem*
16	Aquila	9	6	*al-'Uqāb; al-Nasr al-Ṭā'er*
17	Delphinus	10	-	*al-Dalfīn*
18	Equuleus	4	-	*Quṭ'at al-Faras*
19	Pegasus	20	-	*al-Faras al-A'ẓam*
20	Andromeda	23	-	*al-Mara' al-Musalsala*
21	Triangulum	4	-	*al-Muthallath*

The total number of stars in the northern constellations is 330 which form the main body of the northern constellations and 29 stars outside of the constellations making a total of 359 stars. However, in his introductory chapter al-Ṣūfī mentioned that the total numbers of stars was 331 that are part of the northern constellations and 29 that are outside of the constellations totaling 360. This is because Ptolemy assigned 14 stars to the constellation Auriga whereas al-Ṣūfī only found 13; the last was not seen by him.

3. The Twelve Chapters of the Constellations of the Zodiac (table 5):

#	Constellation name	# stars in	#stars out	Arabic names according to al-Ṣūfī
1	Aries	13	5	*al-Ḥamal*
2	Taurus	32	11	*al-Thawr*
3	Gemini	18	7	*al-Tawāmān*
4	Cancer	9	4	*al-Saraṭān*
5	Leo	27	8	*al-Asad*
6	Virgo	26	6	*al-'Adhrā'; al-Sunbula*
7	Libra	8	9	*al-Zubānayn ; al-Mīzān*
8	Scorpio	21	3	*al-'Aqrab*
9	Sagittarius	31	-	*al-Rāmī; al-Qaws*
10	Capricorn	28	-	*al-Jadī*
11	Aquarius	42	3	*Sākib al-Mā' ; al-Dalw*
12	Pisces	34	4	*al-Samakatān ; al-Ḥūt*

The total number of stars in the Zodiac constellations is 289 which form the main body of the constellation and 60 stars outside of the constellation, with a total of 349 stars. However, in his introductory chapter al-Ṣūfī mentioned that the total numbers of stars was 289 that are part of the Zodiac constellations and 57 outside of the constellations, totaling 346 except for the asterism called '*al-Ḍafira'* which is a 3-star group.

4. The Southern Constellations which are 15 Constellations Chapters (table 6):

#	Constellation name	# stars in	#stars out	Arabic names according to al-Ṣūfī
1	Cetus	22		*Qītus*
2	Orion	38		*al-Jabbār; al-Jauzā'*
3	Eridanus	34		*al-Nahr*
4	Lepus	12		*al-Arnab*
5	Canis Major	18	11	*al-Kalb al-Akbar*
6	Canis Minor	2		*al-Kalb al-Mutaqadem; al-Kalb al-Aṣghar*
7	Argo Navis	45		*al-Safīna*
8	Hydra	25	2	*al-Shuja'*
9	Crater	7		*al-Bāṭīya*
10	Corvus	7		*al-Ghurāb*
11	Centaurus	36		*Qanṭurūs*
12	Lupus	18		*al-Sab'*
13	Ara	7		*al-Jamra; al-Majmara*
14	Corona Australis	13		*al-Iklīl al-Janūbī*
15	Piscis Austrinus	11		*al-Ḥūt al-Janūbī*

The total number of stars in the southern constellations is 295 which form the main body of the constellation and 13 outside of the constellation, with a total of 308 stars. However, in his introductory chapter al-Ṣūfī mentioned that the total numbers of stars was 297 that are part of the northern constellations and 19 outside of the constellations totaling 316 stars. This is because Ptolemy assigned 37 stars to the constellation Centaurus and 19 stars to the constellation Lupus, whereas al-Ṣūfī found one less star in each of these two constellations. The other difference is that Ptolemy added 6 stars to the last constellation Piscis Austrinus whereas al-Ṣūfī did not include these in his catalog nor does he mention them in the comments on this constellation in his book.

Each constellation chapter is in turn divided into three parts. The first part is a detailed written commentary describing the position of the stars, their numbers, magnitudes as well as many other details. Al-Ṣūfī also tried to identify the stars or group of stars according to the old Arabic tradition, by giving their old Arabic names and what the Arabs said about them. The Arabic text in Figure 23 is from a copy of a manuscript which was written by Ulugh Bēg in the 15th century. As we can see it is a very well-written and clear manuscript. It is one of the manuscripts that I used in the translation.

The second part of the constellation chapter is a table showing the coordinates and magnitude values for every constellation (see Figure 24). The stars in every constellation were divided into two groups. The first groups of stars were those that form the main image of the constellation. The other groups were the stars outside the image. Al-Ṣūfī used ecliptical coordinates**,** as did Ptolemy before him.

The last parts for each constellation chapter are the charts (see Figure 25). These were the dual charts depicting the stars as they appear in the sky and as they were drawn on a globe.

Figure 23 written commentary

Figure 24 Tables

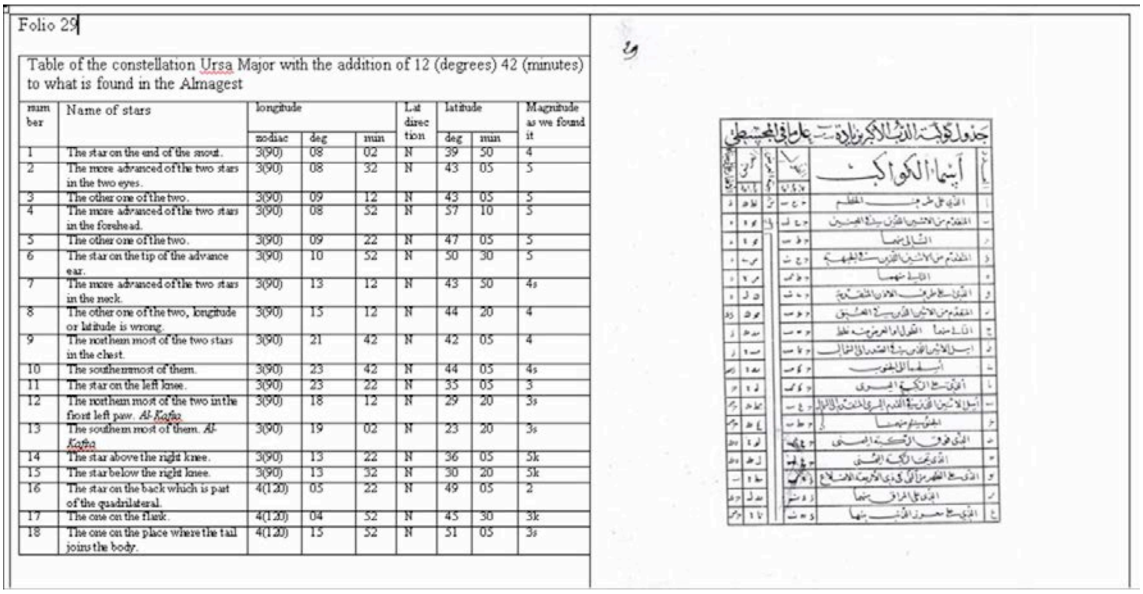
Figure 25 the charts

5.2.1 Method Used in Translating '*The Book of the Fixed Stars*'

The main effort to search for the hidden treasures in al-Ṣūfī's book started with the translation of this work from Arabic to English, especially the constellation commentaries. For every constellation al-Ṣūfī wrote a commentary which describes in detail the number of stars, their location and their magnitudes. Therefore, the information regarding the magnitude estimate in particular can be more reliably taken from the text than from the tables which might not be correctly copied.

The layout of the translation was as depicted in Figure 26 which shows the table or the star catalog for the constellation Ursa Major. Next to it is the corresponding English translation. At the top of this table al-Ṣūfī noted that he added 12 degrees 42 minutes to

Ptolemy's longitude to allow for precession. The first column gives the number of the star in the constellation. The second gives the description or name of the star. This sometimes included the star color, Arabic name and explanation on the position of the star in the constellation. The third group of columns gives the ecliptical longitude coordinates. It was also customary to divide the ecliptic into twelve 30 degrees divisions. Therefore when describing the longitude, al-Ṣūfī first wrote the number of that division then the remaining degrees and minutes in order to depict the complete longitude value. The fourth column gives the latitude direction of the star relative to the ecliptic. The fifth group of columns gives the latitude coordinates. And the last column gives the apparent magnitude estimates as the author found them.



Folio 29

Table of the constellation Ursa Major with the addition of 12 (degrees) 42 (minutes) to what is found in the Almagest

num ber	Name of stars	longitude			Lat direc tion	latitude		Magnitude as we found it
		zodiac	deg	min		deg	min	
1	The star on the end of the snout.	3(90)	08	02	N	39	50	4
2	The more advanced of the two stars in the two eyes.	3(90)	08	32	N	43	05	5
3	The other one of the two.	3(90)	09	12	N	43	05	5
4	The more advanced of the two stars in the forehead.	3(90)	08	52	N	57	10	5
5	The other one of the two.	3(90)	09	22	N	47	05	5
6	The star on the tip of the advance ear.	3(90)	10	52	N	50	30	5
7	The more advanced of the two stars in the neck.	3(90)	13	12	N	43	50	4s
8	The other one of the two, longitude or latitude is wrong.	3(90)	15	12	N	44	20	4
9	The northern most of the two stars in the chest.	3(90)	21	42	N	42	05	4
10	The southernmost of them.	3(90)	23	42	N	44	05	4s
11	The star on the left knee.	3(90)	23	22	N	35	05	3
12	The northern most of the two in the front left paw. *Al-Kafza*	3(90)	18	12	N	29	20	3s
13	The southern most of them. *Al-Kafza*	3(90)	19	02	N	23	20	3s
14	The star above the right knee.	3(90)	13	22	N	36	05	5k
15	The star below the right knee.	3(90)	13	32	N	30	20	5k
16	The star on the back which is part of the quadrilateral.	4(120)	05	22	N	49	05	2
17	The one on the flank.	4(120)	04	52	N	45	30	3k
18	The one on the place where the tail joins the body.	4(120)	15	52	N	51	05	3s

Figure 26 The Layout of the Translation

5.3 Maps in al-Ṣūfī's Book

Cartography or mapmaking has been an integral part of the human development for thousands of years. There is some evidence that suggest that the figurative paintings which were produced in the Lascaux Caves more than 12,000 years ago might have some reference to the phases of the Moon and the animal figures depicted in these caves might also suggest some reference to seasonality changes (Krupp, 1997: 122). Almost all ancient cultures such as the Babylonians, Greeks and Chinese created and used maps in order to help them explain and navigate their way through out the world. The first known maps were those of the heavens. Stellar cartography or 'Uranography' is the science of mapping or projecting representations of stars and other celestial bodies on to flat surfaces such as paper or stone or onto spherical objects. The art or science of Uranography started by observation of the sky, then by measuring the position of the stellar objects in order to produced star tables and maps or charts for use by astronomers and astrologers. A variety of instruments and techniques was developed to help produce these tables and charts such as angular measurements, light or magnitude determination methods, quadrants, astrolabes, globes and others.

The earliest ancient Greek scientist who is believed to have constructed a map of the world is Anaximander of Miletus (B.C. 611-546). One of the first Greek philosophers to draw the stars on a globe was Eudoxus of Cnidus (B.C. 408- 355). He was considered the first to represent the sky from outside looking in rather than as seen by an observer on the Earth (Harley & Woodward, 1987). In classical antiquity, maps were drawn by Hecataeus, Herodotus, Eratosthenes and Ptolemy using astronomical and mathematical techniques. The oldest available representation of the celestial sphere is the Farnese Atlas which is a 2nd century Roman marble copy of a statue of Atlas kneeling with a globe on his shoulders. The globe depicts the night sky as seen from outside the celestial sphere showing 41 out of the 48 classical Greek constellations as mentioned by Ptolemy. Chinese mapping of the stars began at much the same time as Greek celestial cartography. However, in general this did not make a significant contribution to the development of Islamic astronomy.

In the Middle Ages, Arab and Islamic scholars continued to produce stellar maps using methods which they found in Greek sources such as Ptolemy's *Almagest* and *Geography*. Astronomers and geographers working under Caliph al-Ma'mūn in the 9th century re-measured the distance on the Earth that corresponds to one degree of the celestial meridian in order to help them calculate the circumference of the Earth. al-Ma'mūn also patronized the production of a large map of the world, which has not survived. Historical records point to many important Arab and Islamic astronomers who worked on this subject and produced works resembling the Greek classical globes such as the Farnese Atlas and illustrated astronomical maps. The works of these scholars must have been known during the Middle Ages because al-Ṣūfī mentioned in his book that he saw a book by ‘Uṭārid with celestial maps and a celestial globe by al-Ḥarrānī which he both criticized because of the errors he found in them. Unfortunately none of these works is extant today. The earliest surviving celestial map in Islamic culture is to be found in an 8th century Umayyad palace called *Qaser al-Ūmāra'*. This palace contains a room with a dome on to which a painted fresco of the celestial heaven is drawn on the ceiling. The design of this fresco was drawn as if you are looking down on a globe and not as you would be looking to the sky. The constellations of *Qaser al-Ūmāra'* were based on classical or early medieval western Byzantine style.

5.3.1 The Characteristics and Development of al-Ṣūfī's Constellations Images

The Marsh144 manuscript by al-Ṣūfī is one of the oldest illustrated Islamic manuscripts which we know of today. One of al-Ṣūfī's innovations in charting the stars was the production of dual illustrations of each of Ptolemy's constellations. One illustration was as portrayed on a celestial globe. The other illustration as viewed directly in the night sky. At the end of the chapter on the constellation Ursa Minor, al-Ṣūfī explains why he produced two different sets of pictures and outlined the method of using these maps as follows:

> "For every constellation we have drawn two pictures: one as it is projected on the globe and the other as it is seen in the heavens. Hence we have covered both of the different cases, so there is no confusion for anyone who sees that what is viewed on the globe is different from what is in the heavens. When we want to see the constellation as it (really) is we lift the book over our heads and we look at the second picture (in the book). From beneath (the book) we are viewing (the constellation) as it is seen in the heavens."

Figure 27 is a picture of the constellation Equuleus from the manuscript Marsh144. The right figure shows the constellation as seen on a celestial globe. The left figure shows the constellation as it is seen in the sky. Figure 28 is a picture of the constellation Cancer from the Paris manuscript MS5063. In this latter illustration, the upper figure shows the constellation Cancer as seen on the celestial globe. The lower figure shows the constellation as it is seen in the sky. In this Figure the stars drawn in gold are considered part of the constellation picture while the stars drawn in red are bright enough to be noticed but are outside the constellation.

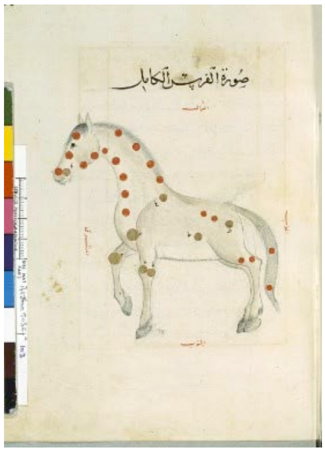
Figure 27 Figure 28

It is interesting to note that all the Arab and Islamic astronomers including al-Ṣūfī were inconsistent and incorrect in their depiction of the constellations. Ptolemy's original description of the constellations was based on an interior point of view; therefore Ptolemy described the figures of the constellation as if the observer would see the constellation figure from a central position looking up. However when the constellations are projected on a celestial globe then the exterior observer should be seeing the reverse of the constellation figures looking down on the globe. However in all Arab and Islamic globes the constellation figures are all drawn in front view therefore the images are mirrored in order to depict them looking towards the observer. It is unknown why the Arabs used such a system for drawing the constellations on the globes. Most probably they wanted to avoid depicting the figures whereby they are represented from the rear.

Since al-Ṣūfī's work was based on Ptolemy's *Almagest* therefore most of the rendering of the constellation figures resemble classical style similar to the Farnese globe constellations. However some of the figures have undergone a process of 'orientalization' which probably began before al-Ṣūfī started to write his work. This process was the result of misunderstanding some of the Greek mythology figures as well as copyist errors in some of the versions of the *Almagest*. The other diversion from classical style constellations was also due to influence of the *Anwā'* tradition in which al-Ṣūfī was very much interested. An example of such addition is to be found in the constellation Andromeda. Al-Ṣūfī makes three illustrations for this constellation. The first is the figure of Andromeda with her arms stretched out. The second is the figure of Andromeda with a fish covering her legs (Figure 29). The third illustration is with two fishes covering her body (Figure 30). Another example of this *Anwā'* tradition is the illustration of a full horse figure which is to be found between the constellation Equuleus and Pegasus (Figure 31). All these iconographies were not part of the original classical Greek tradition (Wellesz, 1965).

Figure 29

Figure 30



Figures 31

The constellation figures of manuscript Marsh144 especially the facial outlines were drawn according to style of the 9th century Abbasid period. They were rendered in a flat two-dimensional style. Their faces were drawn almost in profile while their bodies in full view usually with their arms stretched out. The turbans were depicted from a later 10th century style, an example of which can be found in the decorative pottery of that era. In later manuscripts of al-Ṣūfī's book the turbans as well as garments were also altered to reflect the dressing style of the era when these manuscripts were copied. However it is interesting to note here that the drawings of the jewelry, the garments and some of the constellations in the Marsh144 manuscript were also influenced by a much earlier period in history, as is found in the Art of the Sassanid era. An example of such Sassanid influence can be found in the illustration of the flying wings of Pegasus (Figure 32) which resembles Simurgh the Sassanian mythical flying creature (Figure 33).

Figure 32 Figure 33

By the time we reach the manuscript MS5063 we see that some of the illustrations have undergone an iconographical change which reflects the time that this manuscript was produced. This is evident in the illustration of constellation Cetus; when this is compared to the Marsh144 manuscript (Figure 34) we find a strong Chinese influence in the iconography of the beast which now resembles a Chinese dragon (Figure 35).

Figure 34 Figure 35

Another interesting constellation to note is the constellation Lyra or Lyre meaning the Harp. Al-Ṣūfī gave several names for this constellation: *al-Silyāq; al-Wazza; al-Ṣubh; al-Ma'arefa* and *al-Sulaḥfāt*. The word *al-Silyāq* was also written as al-*Shilyāq*; however, Kunitzsch corrected this name to *Salbāq* which was a kind of harp used by ancient Arabs (Kunitzsch & Smart, 2006: 44). The Marsh144 manuscript indeed depicts this constellation as a type of harp (Figure 36). However in many other eastern manuscripts Lyra was illustrated as a *Sulaḥfāt* or tortoise. Al-Ṣūfī mentioned that he saw this constellation drawn on some celestial globes as a *Sulaḥfāt*. An example of this is seen in the manuscript MS5063 (Figure 37). The other name given to this constellation which was probably based on the *Anwā'* tradition was *al-Wazza* meaning the Goose. This depiction was used in later western illustrations while adding the image of the harp superimposed on the image of the goose. Such an illustration can be found in Andreas Cellarius' *Harmonia Macrocosmica* which is a stellar catalogue published in 1660 and in Johann Hevelius' *Uranographia* printed in 1690 (Figure 38).

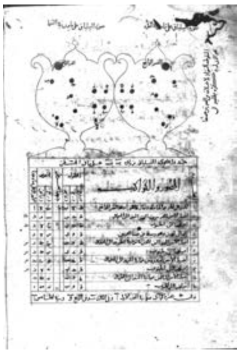


Figure 36

Figure 37

Figures 38

5.3.2 Accuracy of the Maps

An important issue concerns the accuracy of these maps. Were they really used as they were intended by al-Ṣūfī? It is apparent that as an observational astronomer and an instrument-maker al-Ṣūfī was very much concerned with the accuracy of the data he had and the way the maps should be used when observing the heavens or when constructing a celestial globe. Since the Marsh144 manuscript was written by the al-Ṣūfī's son therefore it might have been copied as close to the original as possible with regards to the illustrations and images of the constellation provided the son was as good as the father. However, these star maps might be considered an accurate depiction of the heavens according to al-Ṣūfī. Therefore it might also be safe to assume that these star charts were used to help the observer locate the main celestial bodies in the sky with ease and accuracy. As for the other manuscript MS5063, which was written for Ulugh Bēg who was also an important astronomer, his copy might have also been accurately produced and illustrated under the guidance of Ulugh Bēg himself for this purpose.

Therefore in order to investigate this question I have reproduced two star charts from al-Ṣūfī's manuscripts Marsh144 and MS5063 and a projection upon a modern chart showing the location of these stars in the constellation was then made. As can be seen from the projection of the chart from the manuscript Marsh144 for the constellation Orion (Figure 39) the chart is somewhat accurate and it could have been used as al-Ṣūfī intended it to be used.

The other projection of the chart is from the manuscript MS5063 for the constellation Ursa Minor (Figure 40). This chart can also be considered as a fairly accurate presentation of the constellation.

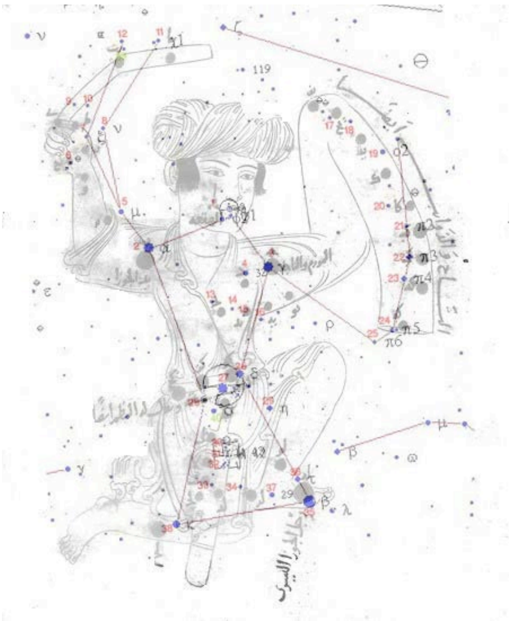


Figure 39 Projection of the Chart Manuscript Marsh144 for the Constellation Orion

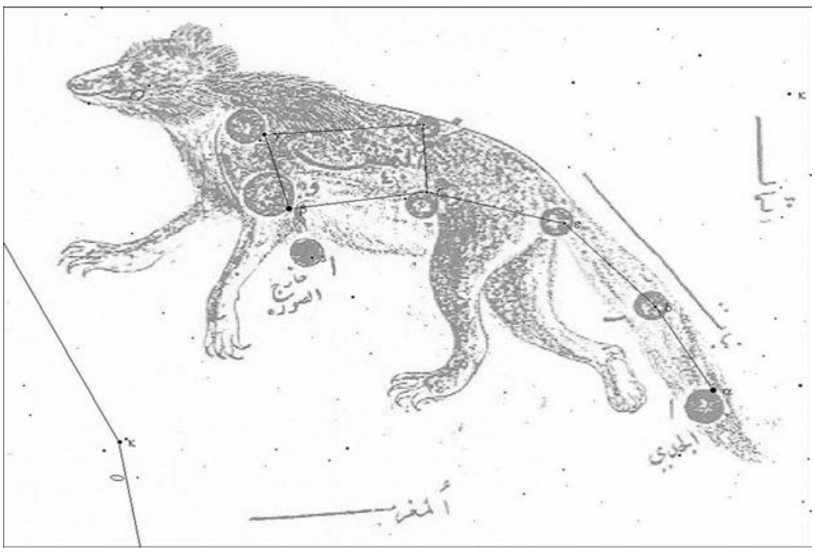


Figure 40 Projection of the Chart Manuscript MS5063 for the Constellation Ursa Minor

5.4 Al-Ṣūfī's Data Analysis and 3-step Magnitude System

As discussed above, al-Ṣūfī's star catalog was based on Ptolemy's classical work the Mathematike Syntaxis which was later called the *Almagest* by the Arabs. In his introductory chapter al-Ṣūfī corrected several observational errors in the works of his predecessors, like the famous Arab astronomer al-Battānī. He also exposed many of the faulty observations found in the various versions of the *Almagest*. However his major endeavor was to carefully define the boundaries of each constellation, and record the magnitudes and positions of stars using new and independent observations he made himself. For the epoch of his catalog al-Ṣūfī adopted the beginning of the year 1276 of the era of Alexander (*Thū al-Qarnaīn*) which corresponds to the year A.D. 964 (Kunitzsch, 1986). Al-Ṣūfī updated Ptolemy's stellar longitudes from A.D. 125 to A.D. 964 by adjusting for precession. However al-Ṣūfī mentioned that "Ptolemy used the observations of Menelaus' who made his observations in the year 845 of the year of Nabūkhat Nassar. Al-Ṣūfī also mentioned that: "The time difference between the observations of Menelaus and the date of Ptolemy is 41 years". He concluded that Ptolemy added 25 minutes to Menelaus' longitude values to account for precession. However it is still unknown why al-Ṣūfī refers to this fact because at this time there is no evidence or available text that mentions that Ptolemy used Menelaus observations other than al-Ṣūfī's claim (Grasshoff, 1990: 21).

At the end of al-Ṣūfī's introductory chapter he described in detail the method he used in constructing his catalog especially in calculating precession. For his epoch of A.D. 964 he applied the most accurate Arabic precession constant at that time of 1 deg in 66 years rather than the correct value of 1 deg in 71.2 years, thereby adding 12 degrees 42 minutes on Ptolemy's longitude value to allow for precession. Over the 839 years between the tables of Ptolemy and al-Ṣūfī, precession would actually amount to 11 deg 47 min. Hence by using 12 deg 42 min, al-Ṣūfī over-corrected Ptolemy's stellar longitudes by 55 min. Therefore, it would be unreasonable to compare the accuracy of al-Sufi's data with those of Ptolemy's because of this overcorrection which renders al-Ṣūfī's coordinates to be slightly more accurate then Ptolemy's. Al-Ṣūfī could not have been aware of this over-correction because his calculations were based on the *Almagest* and thus he did not discover the systematic error in Ptolemy's longitude even though Arabic and Islamic astronomers recognized earlier on that Ptolemy's value of precession was false. As for the ecliptic latitudes, al-Ṣūfī also explained in his introductory chapter that: "…since they (the stars) rotate around the poles of the ecliptic therefore they do not ever change".

The study and analysis of al-Ṣūfī's stellar data can be divided into two parts. The first is the study of the ecliptical longitude and latitude coordinates which where included in the stellar catalog. The second is the analysis of magnitude values which are found in both the chapters on the constellations as well as in the stellar catalog. As I mentioned earlier the study or analysis of the coordinate values is closely related to the study of the *Almagest*. Al-Ṣūfī relied heavily on Ptolemy's values where-by he merely adopted these coordinates which he found in the *Almagest* while adding 12 degrees 42 minutes on Ptolemy's longitude values to allow for precession. However, in many instances al-Ṣūfī mentioned that the coordinates of Ptolemy are incorrect. For example in the constellation Ursa Minor al-Ṣūfī states:

> "In some of (Ptolemy's) stars both the latitude and longitude are incorrect. This is because if they are marked on a (celestial) globe according to (Ptolemy's) table of latitude and longitude, especially (the stars of) *al-Na'esh*, we notice that the image (of the constellation) in the heavens does not correspond with what is (seen) on the globe"

Such a statement was repeated many times throughout the book, however it is again a surprise that our author did not follow up on these comments and correct what he thought to be Ptolemy's errors. This again might have been out of respect and in order to keep with the data which was found in the *Almagest*. The study of Ptolemy's coordinates was extensively covered in many research papers and books by prominent scholars such as Knobel, Peters, Newton, Toomer, Kunitsch and Grasshoff. Therefore the major analysis which I made for this study was to compare al-Ṣūfī's star magnitudes with modern values and with those found in the *Almagest*. I have tabulated the magnitude values of al-Ṣūfī and Ptolemy, together with the modern star magnitudes (table to be found in Appendix-A). Ptolemy's magnitude values and the star identification have been taken from G.J Toomer's book while the modern magnitude values were taken from the *Bright Star Catalogue*.

At first glance it would seem that about 50% of al-Ṣūfī's magnitude values were identical with those of Ptolemy's. The results showed that the magnitude values of 520 stars out of the total 1022 stars were identical between al-Ṣūfī and Ptolemy. Therefore one might wonder whether al-Ṣūfī only re-estimated the magnitudes of about half of the stars observed by Ptolemy. However, upon detailed comparison I found that out of these 520 stars only 206 stars have difference in values from the modern visual magnitude by more than 0.5 magnitude and only 56 stars where the difference in values from the visual magnitude is more than 1 magnitude. The results also showed that out of these 56 stars 22 stars have magnitudes of 5 or 6. This can also be understood because it is difficult to visually estimate some of these faint stars. Therefore a level of accuracy of 0.5 magnitudes is more than can be expected of eye estimation, either by al-Ṣūfī or Ptolemy for these stars. This conclusion is confirmed by the calculation of the standard error. Consequently I do not believe that al-Ṣūfī could have been more accurate in these stars by more than the 0.5 magnitudes. Another study conducted by Tomoko Fujiwara and Hitoshi Yamaoka (2005) on the magnitude estimates of old star catalogs also confirm the above result. Fujiwara and Yamaoka found that the 1st and the 6th magnitude stars in the old star catalogs should not be used in determining the current magnitude system because they exhibited a Malmquist bias where as all other stars magnitude in the old catalogs fit a logarithmic scale consistent with the light ratio of R = 2.512. However all this does not prove that al-Ṣūfī did or did not himself re-estimate all stars again.

Al-Ṣūfī and Ptolemy both added intermediate values to the magnitude class system for some stars. Ptolemy mentioned the words 'more-bright' and 'less-bright' for certain stars. However al-Ṣūfī expressed these intermediate magnitude values by the words '*Aṣghareh'* which means 'less' or '*Akbareh'* which means 'greater' and '*A'ẓameh'* which means 'much-greater'. Most scholars who studied al-Ṣūfī's work used the translation of Schjellerup (1874), who did not differentiate between the two words '*Akbareh'* and '*A'ẓameh'*. In Schjellerup's translation the magnitude was written as a middle value; for example 4-5 (between 4 and 5 magnitude). In their work on Ptolemy, Knobel & Peters (1915) and later Toomer (1998) as well as Grasshoff (1990) also relied upon Schjellerup's translation of al-Ṣūfī's data. They expressed Ptolemy's magnitudes by the words 'greater' and 'less'. They expressed these magnitudes on a 2-step system. By the 20th century this 2-step intermediate magnitude was numerically interpreted by a constant difference of (0.33) magnitude especially by Grasshoff. However, when we look at al-Ṣūfī's text in detail it is evident that he made a clear distinction between three intermediate magnitudes. I believe that al-Ṣūfī used what I have termed a 3-step intermediate magnitude system, which was more accurate than Ptolemy 2-step intermediate system. I think that with this system al-Ṣūfī managed to express all magnitude values by a constant difference of 0.25. For example the magnitude of the star 19 Ursa Major was expressed by al-Ṣūfī as "much greater than 3rd magnitude". This can be interpreted on the 3 step scale as (3 minus 0.5) which is equal to 2.5 magnitudes. The modern star magnitude is 2.44 which is a fairly close value. However if we are to interpret this on a 2-step scale as in Ptolemy then we get the magnitude value of 2.7. However it is unclear why al-Ṣūfī did not make this distinction in the tables when he clearly expressed this difference in the constellation chapters and comments.

One of the main topics of this study was to research this 3-step intermediate magnitude system which would shed new light on the accuracy and independence of al-Ṣūfī's work. Therefore in this part of the study I have made a complete analysis on al-Ṣūfī's magnitude values where the magnitude values were numerically interpreted by a constant difference of 0.25 magnitudes: that is +0.25 for 'less', -0.25 for 'greater' and -0.5 for 'much-greater'. Ptolemy's 2-step intermediate magnitude difference was interpreted by a constant of (0.3) magnitude. However, in order to analyze this topic further, all the data and information from al-Ṣūfī's book were collected in a table (see Appendix 8.1). The first three columns of this table show the number and the number sequence of the stars and constellations. The 4th to the 9th columns are the coordinated values according to al-Ṣūfī's tables. The 10th column shows the magnitudes of the stars according to al-Ṣūfī. I used the letters (s) for 'less', (k) for 'greater' and (m) for 'much-greater'. The 11th column shows the magnitudes after adjustment for the 3-step system and the 12th column for the 2-step system. This was done by adding the values +0.25 for 'less', -0.25 for 'greater' and -0.5 for 'much-greater' for the 3-step system while I added the values +0.3 or -0.3 for the 2-step system. The 13th column shows the magnitude according to Ptolemy. Here I used the magnitude which al-Ṣūfī attributed to Ptolemy. The 14th column shows Ptolemy's magnitudes after adjustment for the 2-step system. The 15th and 16th columns show the modern visual magnitude and the HR number for each star. Then I conducted an accuracy analysis for the magnitudes of al-Ṣūfī and Ptolemy by calculating the difference (Δ) between those values and the visual magnitudes in order to see if al-Ṣūfī had in mind a two-step or three-step magnitude systems. The statistical results of this analysis are summarized in (Table 7) which shows the Mean and the Standard Deviation for all 1022 stars combined:

Table 7 Statistical Data.

	Mean	standard deviation
al-Ṣūfī 3-step	-0.06	0.59
al-Ṣūfī 2-step	-0.09	0.59
Ptolemy	+0.07	0.71

From the above values it seems that the mean for the 3-step system is slightly better but barely statistically significant. The standard deviation is the same whether we apply the 3 or 2 step system whereas it is higher with Ptolemy. The dispersion in al-Ṣūfī's data is thus significantly less than in Ptolemy. The statistical results for al-Ṣūfī values according to the above table are not entirely conclusive between the 2-step and the 3-step systems. However, I still believe that al-Ṣūfī intended to use the 3-step system. The main reason for this assumption is the way al-Ṣūfī expressed or described the values of the stellar magnitudes in his book. For example, if we look at magnitude values in the constellation Gemini, it is clear that al-Ṣūfī was referring to three separate intermediate magnitudes (Table 8).

Table 8 al-Ṣūfī magnitudes for Constellation Gemini.

1	GEMINI	2
2	GEMINI	2
3	GEMINI	4(m)
4	GEMINI	4
5	GEMINI	4
6	GEMINI	4
7	GEMINI	4(k)
8	GEMINI	5(s)
9	GEMINI	5
10	GEMINI	3(s)
11	GEMINI	3
12	GEMINI	4(m)
13	GEMINI	3(s)
14	GEMINI	4(k)
15	GEMINI	4(k)
16	GEMINI	3(s)
17	GEMINI	3
18	GEMINI	4
19	GEMINI	4(s)
20	GEMINI	4(s)
21	GEMINI	5(s)
22	GEMINI	5(s)
23	GEMINI	5(s)
24	GEMINI	5(s)
25	GEMINI	4(s)

From the various magnitude values which we can see in the constellation Gemini, al-Ṣūfī made the distinction between (m) and (k) and he was not really concerned with word repetition or correct sentence structure. The above example shows that he expressed 4(m) and 4(k) consecutively then 4(k) twice. He also mentioned several (s) successively. These word repetitions for the various terms are to be found in many places through out the work. For example in the constellation Taurus, al-Ṣūfī wrote:

> "The third (star) is south of the second, close to it, and is much greater than 4^{th} magnitude, but it was mentioned by Ptolemy as 4^{th} magnitude exactly. The fourth (star) is the southernmost star of the four, south and close to the third, and is much greater then 4^{th} magnitude, but it was mentioned by Ptolemy as 4^{th} magnitude exactly".

Here also the term *A'ẓameh* (much-greater) was used repeatedly in order to give the exact value which was intended. Therefore the assumption of word repetition is not valid in this case. Al-Ṣūfī also used the word *Aṣghareh* (s) throughout his entire work and he repeated it many times consecutively in many locations through out his book. Therefore, if al-Ṣūfī was concerned with correct grammatical structure, why did he not use other words for the term 'less' (s) *Aṣghareh* even though there are many other words in Arabic vocabulary which could have been used for this case?

However, the question arises is why did al-Ṣūfī not include these distinctions in his tables of the constellations? One answer to this question might be that the original tables which were written by al-Ṣūfī possibly included these values, but they might have been omitted when the work was copied even by al-Ṣūfī's son. However, the other reason which is much more reasonable is that al-Ṣūfī did not deviate too much from the format of Ptolemy's catalogue out of respect for this standard reference work since he asserted that he is compiling the tables according to the Ptolemy's *Almagest*.

5.5 Stars Mentioned by al-Ṣūfī and not in the Almagest

In his written comments on the constellations, al-Ṣūfī mentioned some additional stars that were not included in Ptolemy's star catalog. However, it is surprising that al-Ṣūfī did not include these stars in his tables even though he identified many of them in detail and described their magnitudes and he even estimated their locations. One reason why al-Ṣūfī did not include these additional stars might have been out of respect for Ptolemy's catalogue which had long been a standard reference work in this field. In his introductory chapter al-Ṣūfī's clearly stated that the tables he produced were made according to Ptolemy's work; therefore he might have been inclined to follow the classical tradition to which he and all other scholars before him were used.

It is also surprising that there are very few Arabic or Islamic historical sources that mention these additional stars. However the major text which makes reference to these stars is the *Alfonsine IIII Libros de la Ochaua Espera* (*Four Books of the Eight Spheres*) which was also called *Libros de las Estrellas Fixas* (*Books on the Fixed Stars*). These works were produced in Toledo in A.D. 1256 but were based on the al-Ṣūfī's *Book of the Fixed Stars*. Book four of these *Alfonsine* texts was a statistical summary which included the number of stars in each constellation as well as Arabic names of stars according to Arabic folk astronomy (Samso et al., 1988). This book also included a general list of 84 stars taken from al-Ṣūfī's work which were not mentioned by Ptolemy.

In this part of the study I have identified a total number of 134 of these additional stars; 65 were located in the Northern constellations, 41 in the Zodiac constellations and 28 in the Southern constellations. Al-Ṣūfī mentioned these stars in his constellation commentaries but not in the tables and he clearly said that these stars were not mentioned by Ptolemy. In many instances al-Ṣūfī mentions that in several areas of the sky there are many stars but he fails to mention a definite number because of their large numbers. For example in the comments on the constellation Ursa Major al-Ṣūfī wrote that: "Throughout (the main image of the) constellation and outside of it, there are many stars of the 5^{th} and 6^{th} magnitudes. Additionally there is an infinite number of dim (stars) which are outside of the 6^{th} magnitude (classification)."

Therefore I have tried to identify in the below tables all the major stars that were mentioned by al-Ṣūfī. I have also tried to identify these stars by their HR number and I have included the magnitude that al-Ṣūfī assigns together with the modern magnitude for these stars. In the star number column, I continued with the sequence of the star number as per al-Ṣūfī in order to include these numbers in the star charts.

Table 9: Northern Stars mentioned by al-Ṣūfī but not by Ptolemy.

Number	Star number (as per al-Ṣūfī)	Star/s (HR)	Al-Ṣūfī Magnitude	Modern Magnitude	Explanations and Comments
1	36 Ursa Major	5062	Not mentioned	4.01	This is the star named Alcor. The Arabic name is *al-Suhā.* This star was not mentioned in Ptolemy; therefore it was not presented in al-Ṣūfī's chart. However al-Ṣūfī mentioned this star in his written explanation of this constellation. This is a very famous star in Arabic tradition, as al-Ṣūfī explained that this star was used to test eyesight.
2	37 Ursa Major	4518	4	3.71	Al-Ṣūfī mentioned this star in his written explanation of this constellation and he mentioned that it was not included in Ptolemy.
3-7	38 Ursa Major 39 Ursa Major 40 Ursa Major 41 Ursa Major 42 Ursa Major	4392 4248 4277 4288 4380	Al-Ṣūfī mentioned that these are of magnitude 5 or 6	4.99 4.71 5.05 5.08 4.78	Al-Ṣūfī mentioned in the written explanation that there is a group of stars that together with the twenty-second star form a circle. These stars were not mentioned by Ptolemy. These stars are all part of Ursa Major.
8	43 Ursa Major	4728	5.25	5.02	Al-Ṣūfī mentioned that this star is between the second of the two (stars) outside of the constellation, close to *Kabd al-Asad* and (the star) on the knee-bend. It is less than the 5th magnitude. It is much closer to the second (star) that is outside of constellation. This star is now included in constellation CVn.
9	44 Ursa Major	3648		5.13	Al-Ṣūfī explained that this star together with the seventh and eighth form a triangle and which form together with the ninth and the tenth another open angle (obtuse) triangle.
10-11	45 Ursa Major 46 Ursa Major	5023 5112	6 6	5.15 4.7	Al-Ṣūfī explained these two stars (5023 & 5112) are one *dhirāʿ* (2 deg 20 min) distance

					from each other. The actual distance between these two stars is approximately 2 deg 26 min.
12	32 Draco	6618	6	5.75	Al-Ṣūfī mentioned that in the middle of the 4 stars which are the second , third, fourth, and fifth there is a very faint star which was not mentioned by Ptolemy and which the Arabs call *al-Ruba'*.
13	14 Cepheus	8591	6	5.50	The Arabs call this star *Kalb al-Rāʻī* (shepherd's dog). Al-Ṣūfī mentioned that this is a faint star located between the left and right leg but closer to the left leg.
14-17	15,17,18,19 Cepheus	7701 7633 7740 7955	Not mentioned	5.39 4.96 4.30 4.51	Al-Ṣūfī mentioned that the fifth and sixth stars together with other stars form a circle of stars between the constellations of Draco and Cygnus. This circle of stars was called *al-Qidr*. In the image al-Ṣūfī drew four of these stars with the fifth and sixth which form the circle.
18-21	20,21,22,23 Cepheus	8317 8468 8615 8819	6(k) or 5(s)	4.56 4.79 5.08 4.41	Al-Ṣūfī mentioned that there is a line of stars between the second and third stars whose magnitude is either greater than 6th magnitude or less than 5th magnitude. I have tried to identify only a few of these stars. Al-Ṣūfī also mentioned that there are many 5th and 6th magnitude stars on the body and between the legs however these cannot be identified accurately since their location is a little vague.
22-24	24,25,26 Bootes	5502 5544 5575	5 5 6	4.6 4.55 5.71	These stars are above the nineteenth star which is on the right heel and they form a triangle.
25-28	27,28,29,30 Bootes	5370 5365 5330 5159	5 5 5 4	4.86 5.41 5.29 5.36	Al-Ṣūfī mentioned that there is a line of stars between the constellation Bootes and Virgo; however he identified the magnitudes of 4 stars: 3 of the 5th magnitude and 1 of the 4th magnitude.
29	31 Hercules	6159	6	4.84	
30-31	32,33 Hercules	6355 6337	6 6	4.91 4.98	

32-36	34,35 Hercules	6781 6685 6644 6571 6480	5(s) or 6 5(s) or 6 5(s) or 6 5(s) or 6 6(m)	5.86 5.46 5.12 5.77 5.74	
37	36 Hercules	6677	6	5.16	
	37,38 Hercules	6793 6872	Not mentioned	5.48 4.33	Al-Ṣūfī mentioned that there are many 6th magnitude stars between the eighteenth star of Hercules and the constellation Lyra which were not mentioned by Ptolemy. He also mentioned that there are many 6th magnitude stars between the twenty-fifth star of Hercules and the constellation Draco and one particular star of the 5th magnitude which is closer to the tip of the tongue of Draco; however it was not possible to identify this star with an acceptable degree of accuracy.
38	11 Lyra	7262	5	5.28	
39	20 Cygnus	8146	5	4.43	Al-Ṣūfī mentioned that this star is between the two stars outside of the constellation (the eighteenth and the nineteenth) and the twelfth star.
40-43	21,22,23,24 Cygnus	7834 7942 7866 7806	4(s) 4(s) 6 5	4.01 4.22 4.61 4.43	Al-Ṣūfī also mentioned that between these stars and the constellation Sagitta are many stars of the 6th magnitude which were not mentioned by Ptolemy.
					Al-Ṣūfī also mentioned that between the twelfth star and the constellation Delphinus are many stars of the 6th magnitude which were not mentioned by Ptolemy.
44	25 Cygnus	7405	5	4.44	Al-Ṣūfī mentioned that this star should have been on the beak and that it is brighter than the star on the head (second star which he mentioned to be 6 magnitude).
45-47	14, 15,16 Cassiopia	580 575 548	4 4 6	3.98 4.54 4.99	Al-Ṣūfī mentioned that there are three stars north of the seventh stars; two of the 4th magnitude and one of the 6th magnitudes. He also mentioned that next to these stars are many 6th magnitude stars which were not mentioned by Ptolemy.

48	14 Auriga	1995	5	4.52	This forms a double star with the fifth star. Al-Ṣūfī did not mention its magnitude, however he mentioned that the fifth star was of the 5th magnitude while Ptolemy mentioned it to be 4th magnitude. Al-Ṣūfī might have made a mistake here and switched between the two.
49	30 Ophiuchus	6493	5(m)	4.54	
50	31 Ophiuchus	6243	5	4.65	
51	32 Ophiuchus	6770	5 or 6	4.64	The double star with the twenty-ninth star of Ophiuchus. Al-Ṣūfī mentioned that it is a small or faint star.
52	33 Ophiuchus	6093	6	4.83	
53	34 Ophiuchus	6524	6	5.59	
54	19 Serpens	5843	5	5.33	
55	20 Serpens	5895	5 or 6	5.11	The double star with the eleventh star of the Serpens. Al-Ṣūfī mentioned that it is a small or faint star.
56	16 Aquila	Cr 399			Al-Ṣūfī identified this Nebula between the ninth star of Aquila and the constellation Sagitta. It is the open cluster Cr 399 which is also called Brocchi's cluster. He mentioned that this nebula contains stars of the 4th, 5th and 6th magnitude but most are of the 5th magnitude.
57	17 Aquila	7437	6	5.00	Al-Ṣūfī mentioned that this star is between the nebula and the constellation Sagitta.
58	18 Aquila	7193	4(s)	4.02	
59	19 Aquila	7149	6	4.83	
60	20 Aquila	7063	5	4.22	
61	21 Aquila	7032	5	4.90	
62	22 Aquila	7020	5	4.72	
63	23 Aquila	6973	4(m)	3.85	
64	24 Aquila	7007	6	5.84	
65	5 Triangulum	655	6	5.28	Double star with the fourth star of Triangulum.

Table 10: Zodiac Stars mentioned by al-Ṣūfī but not by Ptolemy.

Number	Star number (as per al-Ṣūfī)	Star/s (HR)	Al-Ṣūfī Magnitude	Modern Magnitude	Explanations and Comments
1	19 Aries	1005	4	5.28	Al-Ṣūfī did not exactly specify a magnitude; however, he mentioned that this star is

					similar to the tenth star which he stated as 4th magnitude.
2-3	20 Aries 21 Aries	569 623	4(s)=4.25 5(s)=5.25	4.79 4.98	Al-Ṣūfī mentions that these two stars are similar in magnitude to the two stars on the muzzle, which are 4(s) and 5(s).
4	22 Aries	613	6	5.03	Al-Ṣūfī mentioned that this star is close to the star al-*Nāṭiḥ* (which is the fourteenth star of Aries).
5	44 Taurus	1153	6	5.35	
6	45 Taurus	1159	6	5.91	
7	46 Taurus	1268	5	5.20	
8	47 Taurus	1990	5(s)=5.25	5.49	
9	48 Taurus	1253	6	5.33	
10	49 Taurus	1381	6	5.12	
11	50 Taurus	1389	6(m)=5.5	4.29	
12	51 Taurus	1427	5(s)=5.25	4.78	
13	52 Taurus	1394	6	4.49	
14	53 Taurus	1356	6	5.26	
15	54 Taurus	1149	Not mentioned	3.87	Additional stars of the Pleiades.
16	55 Taurus	1165	Not mentioned	2.87	Additional stars of the Pleiades.
17	56 Taurus	1142	Not mentioned	3.70	Additional stars of the Pleiades.
18	26 Gemini	2852	5	4.18	
19	27 Gemini	2973	5	4.28	
20-22	28 Gemini 29 Gemini 30 Gemini	2456 2503 2506	5 5 5	4.66 4.77 4.47	Al-Ṣūfī mentioned that these three stars form an arc which is between the constellation Orion and the asterism *al-Han'a* (the 6th lunar mansion)
23	33 Virgo	5044	Not mentioned	5.37	Double star with HR 5019.
24	34 Virgo	4824	6	6.19	Next to the eleventh star HR4828.
25	18 Libra	5824	6	4.96	
26	25 Scorpio	6143	6	4.23	
27	26 Scorpio	6166	6	4.16	
28	27 Scorpio	6081	5(s)=5.25	4.55	
29	28 Scorpio	6141	5(s)=5.25	4.79	
30	29 Scorpio	5885	6	4.64	
31	30 Scorpio	5904	6	4.59	
32	32 Sagittarius	7120	Not mentioned	5.00	Double star with 8 Sagittarius HR7116.
33	33 Sagittarius	7337	Not mentioned	4.01	Double star with 23 Sagittarius (HR7343).
34	34 Sagittarius	-	3	-	Al-Ṣūfī mentioned that there is a 3rd magnitude star between 23 Sagittarius and the constellation Piscis Australis; however the location was not precise enough

					to locate this star.
35	46 Aquarius	7845	5	5.65	
36	47 Aquarius	8496	6	5.34	
37	48 Aquarius	8590	Not mentioned	5.89	Al-Ṣūfī mentioned that this star is between 12 Aquarius and 23 Aquarius
38	49 Aquarius	8890	6	5.20	Al-Ṣūfī mentioned that this star is north of 30 Aquarius
39	50 Aquarius	8987	6	5.28	Double star with 31 Aquarius (HR8968)
40	39 Pisces	389	5	5.23	
41	39 Pisces	274	5	5.42	

Table 11: Southern Stars mentioned by al-Ṣūfī but not by Ptolemy.

Number	Star number (as per al-Ṣūfī)	Star/s (HR)	al-Ṣūfī Magnitude	Modern Magnitude	Explanations and Comments
1	23 Cetus	775	5	6.21	Between 3 and 5 Cetus.
2	24 Cetus	531	5	4.67	Close to 14 Cetus.
3	25 Cetus	583	5	5.41	South of 13 Cetus.
4	26 Cetus	329	6	5.82	Double star with 16 Cetus (HR 334).
5	39 Orion	2130		5.14	Double star with 12 Orion (HR 2135).
6	40 Orion	1931	4	3.81	
7	35 Eridanus	917	5	5.32	Double star with 15 Eridanus (HR925).
8	36 Eridanus	994	4	4.88	Double star with 21 Eridanus (HR1003).
9	37 Eridanus	794	4	4.11	
10	38 Eridanus	789	5	4.75	
11	39 Eridanus	1008	4	4.27	
12	40 Eridanus	963	3(s)=3.25	3.87	
13	46 Argo	3307	3(s)=3.25	1.86	
14	47 Argo	2787	Not mentioned	4.66	Double star with 12 Argo (HR2773).
15	48 Argo	3037	Not mentioned	5.23	Double star with 34 Argo (HR3055).
16	49 Argo	NGC2669 IC 2391			Al-Ṣūfī mentioned that next to 37 Argo is a nebula. He is probably referring to NGC2669.
17	28 Hydra	3492	5	4.36	Double star with 3 Hydra (HR3482).
18	29 Hydra	3709	5	4.80	
19	30 Hydra	3706	5	4.79	
20	31 Hydra	3636	6	5.77	
21	38 Centaurus	4933		4.27	Double star with 22 Centaurus.
22	20 Lupus	5457	6	6.07	Close to 2 Lupus.
23	21 Lupus	5494	6	5.74	Close to 2 Lupus.
24	8 Ara	6897	4	3.51	Double star with HR6934.
25	9 Ara	6934	6	4.96	

26	10 Ara	6905	5	4.13	
27	14 Corona Australis	6938	5	5.07	
28	12 Piscis Austrinus	8447	Not mentioned	4.92	Double star with 6 Piscis Austrinus (HR8431).

5.6 Color of Stars in al-Ṣūfī's Book

The color of the stars was never an important topic for ancient observers of the sky. There are very few ancient records on this subject or in ancient star catalogs. 'Red' was the color that attracted the most attention whilst the other colors such as 'white' or 'blue' were rarely mentioned. Ptolemy gave the color red to six stars in his catalog. These stars were Aldebaran, Arcturus, Betelgeuse, Pollux, Antares and strangely enough Sirius. One of the first Arab and Islamic authors to mention the color of the stars was al-Farghānī. In his discussion of Ptolemy's book al-Farghānī mentioned only the color of three red stars, Antares, Pollux, and Aldebaran. On the other hand al-Battānī did not attribute any color to any of the stars in his star catalog whereas Ulugh Bēg mentioned the color of four red stars, Antares, Pollux, Betelgeuse and Aldebaran but neglected Arcturus and Alpha Hydrae. The Alfonsine authors do not mention any remarks on the color of stars except the red color of Antares (*Qalb al-'Aqrab*) (Samso&Comes, 1988). By the time we reach the catalog of Tycho Brahe we find that it only mentions the color of Antares: as ruby red.

In the '*Book of the Fixed Stars*' al-Ṣūfī described seven stars with red color in particular. These stars were Aldebaran, Arcturus, Betelgeuse, Pollux, Alpha Hydrae, Algol and Antares. However al-Ṣūfī stays silent about the color of Sirius. He only describes it as a bright star on the mouth called *al-Kalb* (Dog). I have tried to give in the table below (Table 12) a brief summary on each of these eight stars along with what al-Ṣūfī mentioned about them. These stars were sometimes mentioned in the tables and other times in his comments on the constellations:

Table 12: Color of the stars according to al-Ṣūfī.

Number	Modern Star name & (HR) & Color Index	Star Numbers according to al-Ṣūfī	Description according to al-Ṣūfī
1	Aldebaran HR1457 B-V = 1.54	14 Taurus	From the table: The bright star, the reddish one of the letter (Δ) *al-Dāl* on the southern eye and it is *al-Dabarān*. From the comments: The fourteenth is the large bright red (star) on the south edge of the stars that resemble *al-Dāl*. It is located on the south eye and is drawn on *al-Īsterlāb* (the Astrolabe). It is called *al-Dabarān* and '*Ayn al-Thawr* (the eye of Taurus) and is of

			the 1st magnitude.
2	Arcturus HR5340 B-V = 1.23	23 Bootes	From the table: The star between the thighs called *al-Simāk al-Rāmiḥ*. From the comments: As for the one outside the constellation image it is the bright red star between the thighs. It is of the 1st magnitude and it is drawn on the *al-Īsterlāb* (Astrolabe). It is called *al-Simāk al-Rāmiḥ*.
3	Betelgeuse HR2061 B-V = 1.84	2 Orion	From the table: The bright reddish star on the right shoulder. From the comments: The second is the great bright red star located on the right *Mankib* (shoulder). It is less than the 1st magnitude. The distance between it and the three stars on the head is three Thira. It is (one of the stars that are) drawn on an Astrolabe. It is called *Mankib al-Jauzā'* (the shoulder of Orion) and also *Yad al-Jauzā'* (the hand of Orion).
4	Pollux HR2990 B-V = 1.00	2 Gemini	From the table: The reddish star on the head of the rear twin. From the comments: The second (star) follows the first on the head of the rear twin. It is a little south (of the first) with a distance of more than 2 *dhirā'* between them. It is also of the 2nd magnitude.
5	Alpha Hydrae HR3748 B-V = 1.45	12 Hydra	From the table: The bright one of these two close stars called *al-Fard*. From the comments: The twelfth star is the bright red star at the end of the neck and at the beginning of the back. It is of the 2nd magnitude. It is drawn on the *al-Īsterlāb* (Astrolabe). It is called '*Unuk al-Shujā'* (the Neck of Hydra). It is also called *al-Fard*.
6	Algol HR936 B-V= -0.05	12 Perseus	From the table: stars in the Gorgon's head: the bright one. From the comments: The twelfth star is the bright red star less than 2nd magnitude. Ptolemy mentioned it is exactly of the 2nd magnitude. It is on the gorgon's head. It is further than the eleventh star by two *Thira*. It is drawn on the Astrolabe. It is called *Rae's al-Ghūl* (Gorgon's Head).
7	Antares HR6134 B-V = 1.84	8 Scorpio	From the table: The middle one of these which is reddish and called *Qalb al-'Aqrab* (Antares). From the comments: The eighth is the bright red (star) that is close to the seventh.

			It is of the 2nd magnitude. It is (one of the stars that are) drawn on an Astrolabe. It is called *Qalb al-'Aqrab* (the heart of Scorpio). It is the eighteenth of the lunar mansions.
8	Sirius HR2491 B-V = 0.00	1Canis Major	From the table: The star in the mouth, the brightest, which is called *al-Kalb* (Dog) and *al-Shi'ra al-Yamāniya* and *al-'Abūr*. From the comments: The first star is the great bright star on the mouth. It is drawn on the Astrolabe. It is called *al-Yamāniya*.

The color index is a numerical expression that determines the color of a stellar object and thus its temperature. These indices are measured by determining the magnitude of an object using different kinds of filters; the U filter which transmits ultraviolet rays, the B filter which transmits blue light, and the V filter visible (green-yellow) light. The difference in magnitudes found with these filters is called the U-B or B-V color index. The smaller the color index, the bluer (or hotter) the object is. Conversely, the larger the color index, the redder (or cooler) the object is. Starting from the least red color (B-V) index of 1.0 for the star Pollux to the high color index of 1.84 for both the stars Betelgeuse and Antares, the above color indices are an obvious evidence for the reliability of the data for most of these stars - except when it comes to the two stars Sirius and Algol. The Sirius problem and consequent debate will be discussed in depth in the section below. As for the color of Algol, it is surprising for an acute observer such as al-Ṣūfī to assign the red color to this star. The star Algol is a short period close binary eclipsing system that changes magnitude from maximum 2.12 to minimum 3.39 in few days and the color index scarcely varies. al-Ṣūfī considered this star to be a bright star with less than 2nd magnitude (2.25) while Ptolemy assigned it the 2nd magnitude. Therefore the nature of the variability of this star is not a reason which explains the error of assigning the red color to this star. The only other explanation is that al-Ṣūfī was mistaken in this regard. A similar mistake was also made by Julius Schmidt who was the Director of Athens Observatory. He also observed Algol to be 'reddish yellow' in 1841 (Ceragioli, 1995).

5.6.1 The Debate on Color of the Sirius

A puzzling question in the history of astronomy concerning the star Sirius is whether this star changed color in the last 2000 years. For a long time in the past there used to be confusion on the actual color of Sirius. Ptolemy and many other Greek and Latin astronomers mentioned that the color of Sirius is red. Ptolemy described this star as "…the star in the mouth and is the brightest and is reddish in color." More than 1000 years later al-Ṣūfī stopped from attributing any color to Sirius, even though he mentioned the colors for other stars. It is a very well known fact today that the color of Sirius is bright white. So the question arises why there is such a difference in what the Greeks said about this star and what al-Ṣūfī wrote and what we know as a fact today? Has there been a change in the color of this star in the lat two millennia and why?

The first and most obvious answer to this problem is that Ptolemy might have made an error in assigning the color red to this star. Another answer is that during the course of history there might have been some errors in copying the ancient manuscripts which we know of today especially the *Almagest*. The reason for this is that Ptolemy does not mention the red Sirius in his astrological treatise, the *Tetrabiblos*. Therefore, during the course of history many Arabic, Islamic and Western astronomers might have overlooked this matter for these reasons. However such a description of a major star could not be easily disregarded especially since there were many other ancient Greek and Latin philosophers, poets and astronomers who corroborate Ptolemy by calling Sirius "Reddish" such as Aratus (3^{th} century B.C.), Cicero (1^{st} century B.C.), Horace (1^{st} century B.C.), and Seneca (1^{st} century A.D.). This fact was also enforced by an Assyrian cuneiform tablet which mentioned this star as "…reddish-white like molten copper…" (Rietschi, 1995).

According to Aristotelian philosophy the heavens or the 'Cosmos' was a physically unchanging order. This physical concept was the dominant view to which most scholars, philosophers and astronomers adhered to through out the Middle Ages. Therefore, the idea of Sirius changing color was not considered until the time of Tycho and Kepler. The Sirius debate seriously began in the eighteenth century with the study of variable stars. In 1790 Thomas Baker published a short article in the *Philosophical Transaction of the Royal Society* in favor of Sirius being red. The first physical mechanism for the redness of Sirius was proposed in 1839 by John Herschel. In his study of variable stars he mentioned that a 'cosmic' cloud might be an explanation for this phenomenon. However, in the nineteenth century with the development of the first theories of stellar evolution the idea of a red star changing color was dismissed. This argument was further confirmed by studies of ancient manuscripts especially with the publication in 1874 of Schjellerup's translation of al-Ṣūfī's *Book of the Fixed Star*. In his introduction to this translation Schjellerup discredited the evidence of Sirius being red and he attributed Ptolemy's remarks of a red Sirius to errors in copying and translating the *Almagest*. In 1882 yet another reason was added to this debate by

W.T. Lynn, which was the effect of atmosphere condition on observation. He explained that Sirius is the only bright star which can actually be seen at sunset or sunrise from the horizon and Ptolemy might have been referring to an observation of this star at this time close to the horizon when it could appear to be red due to the effect of the atmosphere.

The counter attack to these arguments did not take a very long time to happen. In 1892 a controversial astronomer by the name of T.J.J. See published a series of articles in the *Astronomy and Astrophysical Journal* in favor of the redness of Sirius. He also disregarded the atmospheric effect, since Ptolemy made his observations from Egypt where the atmosphere is usually clear at night and the fact that Ptolemy could not have made such a mistake on this most important of stars (See, 1927). However, See's historical arrangements were not favorably received by the scientific community-mainly due to See's personality as well as the scientific nature of this subject. By this time most astronomers preferred to endorse the astronomical facts, which have been achieved up to that date. These attacks have been spearheaded by astronomers such as Schiaparelli and Newcomb and continued in a series of articles between See and Schiaparelli until 1930's. This debate later died down with most astronomers favoring the idea of atmospheric effects rather then a star changing color.

In the mid-twentieth century the debate started again with the ever-emerging theories of binary star evolution. By this time Sirius was known to be a binary system composed of Sirius-A which is a 2.25 solar-mass main-sequence star and Sirius-B which is a 1.05 solar-mass white dwarf. Research also indicated that this system is surrounded by dust. Several astronomers tried to explain the redness of Sirius by several astrophysical mechanisms such as mass loss through solar wind, nova ejection, supernova explosions, interstellar dust absorption as well as a thermonuclear runaway (Holberg, 2007). However, none of these astrophysical explanations stood scientific ground and accurately explained the redness of Sirius. When we turn to records of ancient China the color of Sirius is described as white. Early details of this can be found in Edouard Chavannes (1898) translation of Sima Qian historical (*Shiji*) records compiled around B.C. 100 (Rietschi, 1995).

The Sirius debate will probably continue in the future until a reasonably accurate explanation is achieved. The study of variable stars is a fairly young science with abundant data available for only the past 100 years. The study of color change and long term variability of stars can only be made if what has been written about these stars is properly authenticated. The main ancient data which are available to researchers are to be found in the old star catalogs such as those produced by Ptolemy's and al-Ṣūfī's. Therefore, once the stellar identification and comparisons are made, it is possible to identify some of the reasons for change in the magnitudes and star colors. The final results from al-Ṣūfī's data will hopefully be better used in the field of applied historical astronomy such as the changing of star magnitudes, proper motion, or variable star analysis and will hopefully open new doors of investigations in these fields.

5.7 Stars Used on the Astrolabe in al-Ṣūfī's Book

The Astrolabe is an ancient analog calculator capable of working out several different kinds of problems in spherical astronomy. It was used for solving problems relating to the time and position of the Sun and stars in the sky. The astrolabe is thought to be a Greek invention. The stereographic projection was probably known by Hipparchus as early as B.C. 150. The oldest available treatise about stereographic projection and the astrolabe was the *Planispherium*, which was written by Ptolemy (Evans, 1998). However Ptolemy's astrolabe was a simple instrument, which was used as a star finder and not as an observational instrument for measuring the altitude of stars. It did not include many of the features found in later instruments (Webster, Roderick & Marjorie, 1998).

In his *al-Fahras*, al-Nadīm reported that the first person credited with constructing an *Isṭerlāb* (astrolabe) in the Islamic world was the eighth century mathematician and astronomer Muḥammad al-Fazārī. In A.D. 856 al-Faraghānī wrote one of the first detailed descriptions on this instrument (Lorch, 2005). By the 9th century the astrolabe was very much in use in the Arabic and Islamic world. It was later introduced to Europe from Islamic Spain (Andalusia) in the early 12th century. It was also introduced to China from the Islamic world in the 13th century (Webster, Roderick & Marjorie, 1998). Several types of astrolabes in the Arab and Islamic world were made. The most popular type was the planispheric astrolabe, on which the celestial sphere is projected onto the plane of the equator. Other types include the spherical astrolabe, Azarquil (al-Zarqālī) astrolabe and the mariner astrolabe which was a crude instrument used in navigation. The astrolabe was very much developed in the Arab and Islamic world and was extensively used as an astronomical instrument. Most of the astrolabes constructed in that period were made of brass and were about 10-15 cm in diameter. There are more than 600 surviving Arabic and Islamic astrolabes, the oldest are from the 9th and 10th centuries (King, 2005).

An astrolabe consists of a hollow disk (called mater) which holds one or more flat plates (called climates). Each plate is specially made for a specific latitude. They are engraved with a stereographic projection of circular lines which represent the celestial sphere. The disk also holds another frame or net called a spider (also called rete- in Arabic *al-'Ankabūt*) which is free to rotate on top of the flat plates. This frame or spider which acts as a star map is a projection of the ecliptic plane with pointers or indicators pointing to the position of the brightest stars in the sky. The early astrolabes included no more than 20 stars of the 1st and 2nd magnitudes. The earliest extant eastern astrolabe dated A.D. 927 contained only 17 stars, however later astrolabes had more than sixty stars positioned on the rete. The back of the disk (mater) includes a number of trigonometric scales which are used in various astronomical, timekeeping and other applications. The final piece of the astrolabe is a movable rectangular rod (alidade- in Arabic *al-'Iḍaḍah*) attached to the back face of the instrument. When the astrolabe is held vertically, the alidade can be rotated and a star sighted along its length, so that the star's altitude in degrees can be read from the graduated edge of the astrolabe. To use an astrolabe, you adjust the moveable components to a specific date and time. Once set, the entire sky, both visible and invisible, is represented on the face of the instrument. This allows a great many astronomical problems to be solved in a very visual way. Figure 41 shows the parts of the astrolabe with the spider at the top of the image.

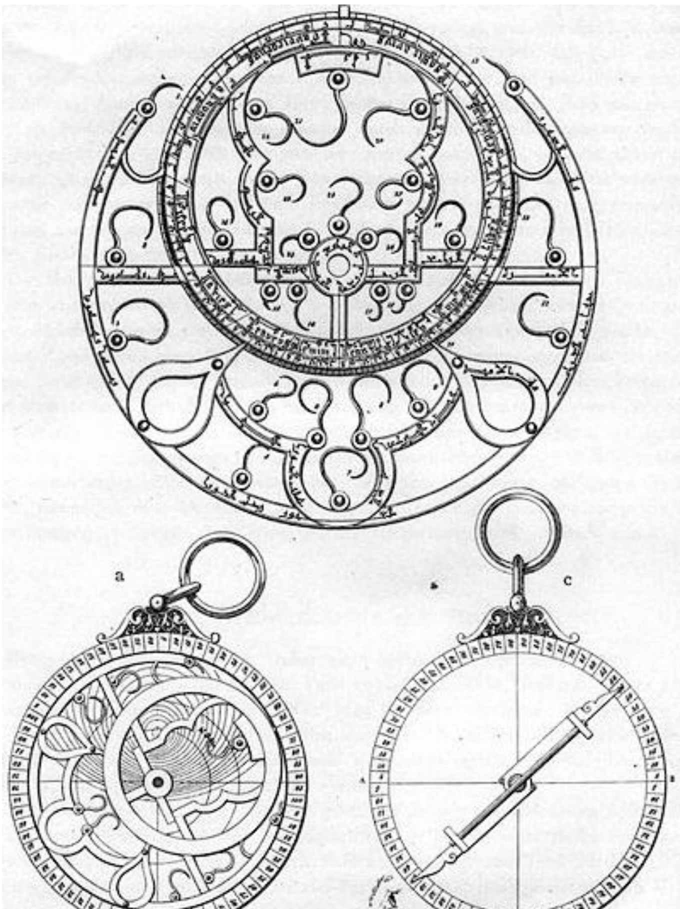


Figure 41

Al-Ṣūfī wrote extensively on the construction and use of the astrolabe (see biography section). In one of his treatises al-Ṣūfī described more than 1000 different uses for an astrolabe in fields such as astronomy, astrology, timekeeping, navigation, construction and surveying. Kunitzsch mentioned that in several of the al-Ṣūfī's works he identified as many as 55 stars which could be used on the astrolabe spider. Al-Ṣūfī's *Book of the Fixed Stars*, which included 44 of these stars, was the best and most accurate of al-Ṣūfī's works (Kunitzsch, 1990). This was one of the main reference to which many later astronomers and instrument makers used to identify the stars of the astrolabe.

However al-Ṣūfī did not make a list of the astrolabe stars but rather the information on these stars were scattered throughout the various sections of al-Ṣūfī's book. Therefore I have tried to identify below (Table 13) all the astrolabe stars found in al-Ṣūfī's book. I also included a brief summary on every one of these stars as they were mentioned by al-Ṣūfī. This summary included all the descriptions both from the tables as well as from the comments in the constellation chapters which mentioned these stars according to al-Ṣūfī. As can be seen from the various comments below, al-Ṣūfī very clearly indicated which stars were to be used on this instrument. He also indicated the various known names and the magnitudes either in the tables or in the comments. Al-Ṣūfī also mentioned 5 stars which were used on the southern astrolabes. Southern astrolabes were probably those instruments which were constructed and used by people living in the Southern Hemisphere.

Table 13: Stars used on the astrolabe in al-Ṣūfī's book.

Num	Modern star name +(HR)	Numbers according to al-Ṣūfī	Magnitude According to al-Ṣūfī	Names and Description according to al-Ṣūfī
1	Arcturus HR5340	23 Bootes	1	*al-Simāk al-Rāmiḥ* From the table: The star between the thighs called *al-Simāk al-Rāmiḥ*. From the comments: As for the one outside the constellation image it is the bright red star between the thighs. It is of the 1st magnitude and it is drawn on the astrolabe. It is called *al-Simāk al-Rāmiḥ*.
2	HR5793	1 Corona Borealis	2	*al-Munīr Min al-Fakka* From the table: The bright star in the crown. From the comments:

				The first star is the bright one of the 2nd magnitude. It is used on the astrolabe and is called *al-Munīr Min al-Fakka*.
3	HR6406	1 Hercules	3(s)= 3.25	*Rae's al-Jāthī* From the table: The star on the head. From the comments: The first star is the one on the head. It is in advance of the bright star on the head of *al-Ḥawwā* (constellation Ophiuchus). It is less than 3rd magnitude. Ptolemy mentioned it is exactly of the 3rd magnitude. It is incorrect to consider the magnitude of this star the same as the star on the head of *al-Ḥawwā*. It is drawn on the astrolabe and called *Rae's al-Jāthī.*
4	Vega HR7001	1 Lyra	1	*al-Nasr al-Wāqi'* From the table: The bright star on the shell called Lyra called *al-Nasr al-Wāqi'*. From the comments: The first one is the famous bright star of the 1st magnitude which is drawn on the astrolabe. It is called *al-Nasr al-Wāqi'*.
5	HR7417	1 Cygnus	3(s)=3.25	*Minqār al-Dajāja* From the table: The star on the beak. From the comments: The first of the constellation *al-Ta'er* (Cygnus) is the bright star on the beak behind the constellation of *al-Nasr al-Wāqi'*. Ptolemy mentioned it is exactly of the 3rd magnitude; however, it is less than 3rd magnitude. It is drawn on the astrolabe and called *Minqār al-Dajāja*.
6	Deneb HR7924	5 Cygnus	2	*Dhanab al-Dajāja* From the table: The bright star in the tail. From the comments: The fifth star is the bright one on the tail. It is of the 2nd magnitude. It is drawn on the astrolabe and is called Dhanab al-Dajāja.
7	HR12	12 Cassiopeia	3	*al-Kaff al-Khaḍīb* *Sinām al-Nāqa* From the table: The star on the middle of the back of the throne

				called *al-Kaff al-Khaḍīb*. From the comments: The twelfth star is the one on the middle of the back of the throne. It is drawn on the astrolabe. It is called *al-Kaff al-Khaḍīb* and *Sinām al-Nāqa*.
8	HR 1017	7 Perseus	2	*Janb Barshāūsh* From the table: The bright star in the right side. From the comments: The seventh is the bright star on the right side next to the sixth star. It is also outside of the galaxy touching its western edge. It almost forms a straight line with the sixth and fourth stars. It is of the 2nd magnitude. It is drawn on the astrolabe and called *Janb barshāūsh*.
9	Algol HR936	12 Perseus	2	*Ra's al-Ghūl* From the table: The stars in the gorgon head: the bright one. From the comments: The twelfth star is the bright red star less than 2nd magnitude. Ptolemy mentioned it is exactly of the 2nd magnitude. It is on the gorgon's head. It is distant from the eleventh star by two Thira. It is drawn on the astrolabe. It is called *Ra's al-Ghūl* (Gorgon's Head).
10	Capella HR1708	3 Auriga	1	*al-'Ayyūq* From the table: The star on the left shoulder called *al-'Ayyūq* From the comments: The third is the very bright star on its left shoulder. It is on the southern edge of the galaxy. It is of the 1st magnitude. It is drawn on the astrolabe and called *al-'Ayyūq*.
11	HR 6556	1 Ophiuchus	3	*Ra's al-Ḥawwā* From the table: The star on the head. From the comments: The first of its stars is the one on the head in front of *al-Nasraīn (the two eagles)*. Together they form an isosceles triangle with this star on the top and *al- Nasraīn* its base. It is drawn on the astrolabe and called *Ra's al-Ḥawwā*.
12	HR5854	9 Serpens	3	*'Unuq al-Ḥayya* From the table:

				The middle one of the three. From the comments: The ninth star is the one drawn on the astrolabe and called ‘*Unuq al-Ḥayya*.
13	Altair HR7557	3 Aquila	2(m)=1.5	*al-Nasr al-Ṭāir* From the table: The bright star on the place between the shoulders called *al-Nasr al-Ṭāir.* From the comments: The third star is the famous bright one which is drawn on the astrolabe. It is called *al-Nasr al-Ṭāir*. It is much greater than the 2nd magnitude.
14	HR7852	1 Delphinus	4(m)=3.5	*Dhanab al-Dulfin* From the table: The most advanced of the 3 stars in the tail. From the comments: The first is the bright star on the tail. It is much greater than 4th magnitude. Ptolemy mentioned it is less than 3rd magnitude. It is drawn on the astrolabe and called *Dhanab al-Dulfin.*
15	HR15	1 Pegasus	2(s)=2.25	*Surrat al-Faras* *Ra's al-Musalsala* From the table: The star on the navel which is common to the head of Andromeda. From the comments: The first star is the one on the navel. It is also in common with the one on the head of Andromeda. It is less than 2nd magnitude. It is drawn on the astrolabe and called *Surrat al-Faras* and *Ra's al-Musalsala.*
16	HR8739	2 Pegasus	2(s)=2.25	*Janāḥ al-Faras* From the table: The star on the rump and the wing tip. From the comments: The second star is on the rump at the end of the back. It is also drawn on the astrolabe and called *Janāḥ al-Faras*. It is less than 2nd magnitude. It is south of the first star with a distance between them of one *Rumḥ*
17	HR8775	3 Pegasus	2(s)=2.25	*Mankib al-Faras* From the table: The star on the right shoulder and the place where the leg joins it.

				From the comments: The third is the southernmost of the two stars: the first and the second. It is on the right shoulder and the start of the hand. The distance between it and the first is one *Rumḥ*. It is less than 2nd magnitude. It is drawn on the astrolabe and called *Mankib al-Faras.*
18	HR8781	4 Pegasus	2(s)=2.25	*Matn al-Faras* From the table: The star on the place between the shoulders and shoulder part of the wing. From the comments: The fourth star is the southern bright one on the back at the beginning of the neck. The distance between it and the third star is one *Rumḥ*. It is less than 2nd magnitude. It is drawn on the astrolabe and is called *Matn al-Faras*.
19	HR8308	17 Pegasus	3	*Fam al-Faras* From the table: The star in the muzzle. From the comments: The seventeenth star is drawn on the astrolabe and is called *Fam al-Faras*.
20	HR337	12 Andromeda	2(s)=2.25	*Janab al-Musalsala* *Baṭn al-Ḥūt* From the table: The southernmost of the 3 stars over the girdle. From the comments: The twelfth star is to the left side and it is the southernmost and brightest of the three stars in the middle behind the three stars on the shoulders. It is less than 2nd magnitude. Ptolemy mentioned it is exactly of the 3rd magnitude. However it is brighter than the southern star which is on the rump of Pegasus and the edge of the wing which Ptolemy considered to be of the 2nd magnitude. Therefore it is incorrect that this twelfth star and the first star between the shoulders of this constellation are of the same magnitude. It is drawn on the astrolabe and is called *Janab al-Musalsala* and also *Baṭn al-Ḥūt.*
21	HR603	15 Andromeda	3	*Rijl al-Musalsala* *al-ʻAnāq* From the table: The star over the left foot called *al-ʻAnāq*.

				From the comments: The fifteenth star is the bright one on the left foot. It is of the 3rd magnitude. It is drawn on the astrolabe and is called *Rijl al-Musalsala*.
22	HR544	1 Triangulum	3	*Ra's al-Muthallath* From the table: The star in the apex of the triangle. From the comments: The first of its stars is one on the apex of the triangle. It is of the 3rd magnitude. It is drawn on the astrolabe and is called *Ra's al-Muthallath*.
23	HR617	14 Aries	3(k)=2.5	*al-Nāṭiḥ* From the table: The star over the head, which Hipparchus calls "the one on the muzzle". From the comments: As for the stars outside of the constellation the first is the bright star north of the two stars on the horn. It is greater then 3rd magnitude. The distance between it and the northernmost of its stars is a distance of two Thira. It is drawn on the astrolabe and is called *al-Nāṭiḥ*.
24	Aldebaran HR1457	1 Taurus	1	*al-Dabarān* From the table: The bright star: the reddish one of the letter (Δ) *al-Dāl* on the southern eye and it is *al-Dabarān*. From the comments: The fourteenth is the large bright red (star) on the south edge of the stars that resemble *al-Dāl*. It is located on the south eye and is drawn on the astrolabe. It is called *al-Dabarān* and '*Ain al-Thawr* (the eye of Taurus) and is of the 1st magnitude.
25	Pollux HR2990	2 Gemini	2	*Ra's al-Taw'am* From the table: The reddish star on the head of the rear twin. From the comments: The second (star) follows the first on the head of the rear twin. It is a little south (of the first) with a distance of more than 2 Thira between them. It is also of the 2nd magnitude.
26	Regulus HR3982	8 Leo	1	*Qalb al-Asad* *al-Malikī* From the table: The star on the heart, called *al-Malikī* and *Qalb*

				al-Asad. From the comments: The eighth is the great bright star south of the four stars on the heart. It is of the 1st magnitude. It is called *al-Malikī*. It is drawn on the astrolabe and is called *Qalb al-Asad.*
27	HR4357	20 Leo	2	*Zhahr al-Asad* (lion's back) From the table: The rearmost of them. From the comments: As for the twentieth star it the most advanced of the two (nineteenth and the twentieth). It is of the 2nd magnitude. It is drawn on the astrolabe and is called *Zhahr al-Asad.*
28	HR4534	27 Leo	1	*Dhanab al-Asad* (lion's tail) *al-Ṣarfa* From the table: The star on the end of the tail. From the comments: The twenty seventh is the great bright star on the tail. It is of the 1st magnitude. It is behind the bright twentieth star on the body. It is drawn on the astrolabe and is called *Thanab al-Asad* and *al-Ṣarfa*.
29	Spica HR5056	14 Virgo	1	*al-Simāk al-A'zal* *al-Sunbula* *Sāq al-Asad* (the leg of the lion) *al-Rāmiḥ* From the table: The star on the left hand, called *al-Sunbula* and *al-Simāk al-A'zal.* From the comments: The fourteenth is on the left hand. It is a famous bright star less than the 1st magnitude. It is drawn on the astrolabe and is called *al-Simāk al-A'zal*. It is the fourteenth of the lunar mansions.
30	Antares HR6134	8 Scorpio	2	*Qalb al-'Aqrab* From the table: The middle one of these which is reddish and called *Qalb al-'Aqrab* (Antares). From the comments: The eighth is the bright red (star) that is close to the seventh. It is of the 2nd magnitude. It is (one of the stars that are) drawn on an astrolabe. It is called *Qalb al-'Aqrab* (the heart of Scorpio). It is

				the eighteenth of the lunar mansions.
31	HR 7343	23 Sagittarius	4(s)=4.25	*‘Urqūb al-Rāmī* From the table: The star on the front left hock. From the comments: The twenty-third star is on the tip of the left hand. It is south of the constellation Corona Australis by a distance of two and a half *Thira*. It is less than the 4th magnitude. Ptolemy mentioned it is of the 2nd magnitude. It is a double star because next to it is a close star which makes it a double star. It is drawn on the southern astrolabes as a star of the 2nd magnitude. It is called ‘*Urqūb al-Rāmī*.
32	HR8322	24 Capricorn	3	*Dhanab al-Jadī* From the table: The rearmost of them. From the comments: The twenty-fourth is the one in advance of the two. It is of the 3rd magnitude. It is drawn on the astrolabe and is called *Dhanab al-Jadī.*
33	HR8728	42 Aquarius	1	*Fam al-Ḥūt al-Janūbī* *al-Dhulaīm* From the table: The star at the end of the water and on the mouth of Piscis Austrinus called *al-Dhulaīm*. From the comments: The forty-second is the great bright star in advance and south of these last three stars. It is of the 1st magnitude. It is on the mouth of Piscis Austrinus. It is drawn on the astrolabe and is called *Fam al-Ḥūt al-Janūbī*.
34	HR911	2 Cetus	3	*al-Kaff al-Jadhmā* From the table: The three stars in the snout: the rearmost, on the end of the jaw. From the comments: From the stars on the head of constellation Cetus which should be drawn on the astrolabes and on the globes is the 2nd star on the snout called *al-Kaff al-Jadhmā.*
35	HR74	21 Cetus	3(s)=3.25	*Dhanab Qītus* From the table: The 2 stars at the ends of the tail-fins: the one on the northern tail-fin.

				From the comments: The twenty-first is drawn on the astrolabe and is called *Dhanab Qītus*.
36	Betelgeuse HR2061	2 Orion	1	*Mankib al-Jauzā'* *Yad al-Jauzā'* From the table: The bright reddish star on the right shoulder. From the` comments: The second is the great bright red star located on the right *Mankib* (shoulder). It is less than the 1st magnitude. The distance between it and the three stars on the head is three *Thira*. It is (one of the stars that are) drawn on an astrolabe. It is called *Mankib al-Jauzā'* (the shoulder of Orion) and also *Yad al-Jauzā'* (the hand of Orion).
37	Rigel HR1713	35 Orion	1	*Rijl al-Jauzā'* (the leg of Orion). From the table: The bright star in the left foot, which is (applied in) common to the water (of Eridanus). From the comments: The thirty-fifth is the large bright star on the left leg. It is of the 1st magnitude. It is (one of the stars that are) drawn on an astrolabe. It is called *Rijl al-Jauzā'* (the leg of Orion).
38	HR897	34 Eridanus	1	*Ākhir al-Nahr* From the table: The last star of the river, the bright one. From the comments: The thirty-fourth is in front of these three close stars. The distance between it and the closest of these three stars is four *Thira*. It is of the 1st magnitude. It is drawn on the southern astrolabes and is called *Ākhir al-Nahr*.
39	Sirius HR2491	1 Canis Major	1	*al-Shi'ra al-Yamāniya* *al-'Ayyūq* *al-Kalb* From the table: The star in the mouth, the brightest, which is called *al-Kalb* (Dog) and *al-Shi'ra al-Yamāniya* and *al-'Ayyūq*. From the comments: The first star is the great bright star on the mouth. It is drawn on the astrolabe. It is called *al-Yamāniya*.
40	Procyon	2 Canis Minor	1	*al-Shi'ra al-Shāmīya* *al-Shi'ra al-Ghumaiṣa*

	HR2943			From the table: The bright star just over the hindquarters, called *al-Shi'ra al-Shāmīya* and *al-Ghumaiṣa*. From the comments: One of them is the bright star of the 1st magnitude. It is drawn on the astrolabe and is called *al-Shi'ra al-Shāmīya*….The Arabs called it *al-Shāmīya* because it sets from the location of *al-Sham* (Greater Syria). They (also) call it *al- Shi'ra al-Ghumaiṣa.*
41	Canopus HR2326	44 Argo Navis	1	*Suhail* From the table: The more advanced of the 2 stars in the other steering-oar, called *Suhail*. From the comments: The forty-fourth is the great bright star on the end of the southern hemisphere. It is the furthest star of Argo in the south. It is of the 1st magnitude. It is drawn on the southern astrolabes and is called *Suhail*.
42	Alpha hydrae HR3748	12 Hydra	2	*'Unuq al-Shujā'* *al-Fard* From the table: The bright one of these two close stars called *al-Fard.* From the comments: The twelfth star is the bright red star at the end of the neck and at the beginning of the back. It is of the 2nd magnitude. It is drawn on the astrolabe. It is called '*Unuq al-Shujā'* (the Neck of Hydra). It is also called *al-Fard*.
43	HR4662	4 Corvus	3	*Janāḥ al-Ghurāb al-Ayman* From the table: The star in the advance, right wing. From the comments: The fourth star is on the right wing. It is in advance of the two bright stars on the wings. It is distant from the second bright star on the head towards the south a distance of one third of a *Thira*. It is of the 3rd magnitude. It almost forms a straight line together with the star on the head and the star on the beak. It is drawn on the astrolabe and is called *Janāḥ al-Ghurāb al-Ayman*.
44	HR5459	35 Centaurus	1	*Rijl Qanṭūris* (leg of Centaurus) From the table:

				The star on the end of the right front leg. From the comments: As for the thirty-fifth it is the rearmost of the two. It is of the 1st magnitude. It is located on the tip of the right hand of the animal. It is drawn on the southern astrolabes. It is called *Rijl Qanṭūris* (leg of Centaurus). It is very close to the horizon. Its height in all localities is less than (the star) *Suhail*.

5.8 Double Stars in al-Ṣūfī's Book

The word *Muḍ'af* was used many times in al-Ṣūfī's book to mean double star. For example in the constellation Orion, al-Ṣūfī wrote: "The twelfth star is to the rear of the two. It is less than the 5th magnitude. Ptolemy mentioned that it is exactly 5th magnitude. It is a *Muḍ'af* (double star) because there is a star next to it." In many cases al-Ṣūfī only mentioned the presence of a double star but in other cases he describes the location and the magnitude of these double stars. For example in the constellation Ara he wrote: "Behind the second star is another star also of the 4th magnitude. The distance between them is one third of a Thira. It was not mentioned by Ptolemy. This star is a double star because next to it is a star of the 6th magnitude which makes it a double". It is not clear whether these stars are actually physically double stars or are visually close stars as was seen at the time of al-Ṣūfī. Most of these stars are probably not double stars in the modern understanding of the word. However I have tried to make a small investigation on this subject to identify these stars and check if any are actually double stars or not. This exercise can also shed some light on the level of accuracy and the ability of this astronomer to resolve close pairs of stars. It also gives us an estimate on what was the minimum angular separation which al-Ṣūfī managed to achieve in his observation of these stars.

From al-Ṣūfī's description I tried to identify below all the double stars found in al-Ṣūfī's book (Table 14). In Column 3 of this table I included the HR number and magnitude of these stars with the first HR number for the main star as mentioned in the catalog. The second HR number and magnitude is for the companion star as per the description of al-Ṣūfī. I also included the coordinate of these stars after accounting for precession for the epoch of A.D. 960. For example the HR number for the first star is HR1995 which according to al-Ṣūfī has the magnitude of 5 and a modern magnitude of 4.52. Its RA coordinates is 4:38:8 and Dec +39:10:52. Whereas the HR number for the companion star is HR2012. Al-Ṣūfī did not assign a magnitude for this star however it has a modern magnitude of 3.97. Its RA coordinate is 4:40:25 and Dec +38:02:38. In column 4 of this table I calculated the angular distance between these stars in order to identify the minimum angular distance which al-Ṣūfī managed to achieve. In the last column of the table I included a brief summary on every one of these stars as they were mentioned by al-Ṣūfī. This summary included all the descriptions both from the tables as well as from the comments in the constellation chapters which mentioned these stars according to al-Ṣūfī.

Table 14: Double stars according to al-Ṣūfī

Number	Star Number according to al-Ṣūfī	-HR -Al-Ṣūfī' Magnitude -Modern Magnitude -Coordinates	Angular Distance	Description according to al-Ṣūfī
1	5 Auriga	HR1995 (5) (4.52) 4:38:8 +39:10:52 HR2012 (not mentioned) (3.97) 4:40:25 +38:02:38	1.22 deg	From the table: The star on the right elbow. From the comments: The fifth is on its right elbow. It is of the 5th magnitude. Ptolemy mentioned it as the 4th magnitude. This is a double star because next to it is a close star.
2	29 Ophiuchus	HR6771 (4) (3.73) 17:18:22 +09:59:46 HR6770 (small-faint star)=5 or 6 (4.64) 17:12:58 +09:10:17	1.57 deg	From the table: The lone star north of these 4. From the comments: The fifth (which is the twenty ninth star – fifth out side of the constellation) is the lone star to the north. It is farthest from the other four by a distance of two *dhirā'*. It is a double star because next to it is a small (faint) star close to it.
3	11 Serpens	HR5881 (4) (3.53) 14:56:10 +00:13:20 HR5895 (small-faint star)=5 or 6 (5.11) 14:57:54 +00:31:44	0.53 deg	From the table: The star after the next bend which is in advance of the left hand of Ophiuchus. From the comments: Then it bends towards the south-east by a distance of two Thira to the eleventh star which is a double star of the 4th magnitude. Next to it is a small (faint) star close to it which makes it a double star.
4	4 Triangulum	HR664 (3s)=3.25 (4.01) 1:17:59 +28:42:08	0.57 deg	From the table: The rearmost of the three. From the comments: The fourth is the southernmost star of less than the 3rd magnitude. Ptolemy mentioned

		HR655 (6) (5.28) 1:16:48 +28:11:58		it is exactly of the 3rd magnitude. It is a double star because next to it is a star of the 6th magnitude close to it, which was not mentioned by Ptolemy. It resembles the third star on the base in magnitude.
5	31 Virgo	HR5019 (5) (4.74) 12:24:01 -12:41:12 HR5044 (not mentioned) (5.37) 12:28:33 -12:08:13	1.24 deg	From the table: The middle one of these, which is a double star. From the comments: The fifth is to the rear of the two. It is a double star. The distance from the fourth star towards the south-east is one *dhirā'*. It is of the 5th magnitude.
6	8 Sagittarius	HR7116 (nebulous) (4.83) 17:51:27 -23:19:02 HR7120 (not mentioned) (5.00) 17:52:26 -23:16:04	0.23 deg	From the table: The star on the eye, which is nebulous and double. From the comments: The eighth is the nebulous star on the eye of Sagittarius. It is towards the north from the sixth star by a distance of two *dhirā'*.
7	23 Sagittarius	HR7343 (4s)=4.25 (4.29) 18:07:20 -45:55:57 HR7337 (not mentioned) (4.01) 18:07:01 -45:34:50	0.36 deg	From the table: The star on the front left hock. From the comments: The twenty third star is on the tip of the left hand. It is south of the constellation Corona Australis by a distance of two and a half *dhirā'*. It is less than the 4th magnitude. Ptolemy mentioned it is of the 2nd magnitude. It is a double star because next to it is a close star which makes it a double star. It is drawn on the southern astrolabes as a star of the 2nd magnitude. It is called '*Urqūb al-Rāmī.*
8	31Aquarius	HR8968 (5) (5.00) 22:45:23 -19:51:45 HR8987 (6)	2.83 deg	From the table: The more advanced of the 2 stars close together after the latter. From the comments: Next to the two close stars (the thirtieth and the thirty first) is a star of the 6th magnitude which makes it a double star. It

		(5.28) 22:48:02 -21:06:07		was not mentioned (by Ptolemy).
9	16 Cetus	HR334 (3s)=3.25 (3.45) 00:16:38 -15:50:49 HR329 (6) (5.82) 00:15:46 -15:27:15	0.45 deg	From the table: The more advanced of them. From the comments: The sixteenth is the more advanced of them. The distance between them is approximately two *dhirā'*. It is less than the 3rd magnitude. Ptolemy mentioned it is exactly of the 3rd magnitude. Under it is a close star of the 6th magnitude which makes it a double and which was not mentioned by Ptolemy.
10	12 Orion	HR2135 (5s)=5.25 (4.63) 5:02:43 +19:28:01 HR2130 (not mentioned) (5.14) 5:02:28 +19:00:37	0.46 deg	From the table: The rearmost of them. From the comments: The twelfth star is to the rear of the two. It is less than the 5th magnitude. Ptolemy mentioned that it is exactly 5th magnitude. It is a *Muḍ'af* (double star) because there is a star next to it.
11	15 Eridanus	HR925 (5) (5.26) 2:13:53 -12:02:00 HR917 (5) (5.32) 2:12:19 -12:08:34	0.40	From the table: The one in advance of this. From the comments: The fifteenth is in front of the fourteenth star towards the north. It is of the 5th magnitude while Ptolemy mentioned it is of the 4th. The distance between them is one *dhirā'*. It is a double star.
12	21 Eridanus	HR1003 (4) (3.69) 2:33:40 -25:53:47 HR994 (4) (4.88) 2:32:45 -26:40:05	1.25 deg	From the table: The middle one of these. From the comments: The twenty-first follows the twentieth. It is of the 4th magnitude. The distance between them is two *dhirā'*. It is a double star because to the south and close to it is a star which makes it a double.
13	8&9 Argo	HR2996	0.55	From the table:

		(4) (3.96) 7:02:17 -26:54:33 HR2993 (5) (4.59) 7:01:46 -26:22:29	deg	-The rearmost of them. -The middle one of the three. From the comments: The ninth is close to the eighth, a little inclined towards the north-west. The eighth star is double (with the ninth).
14	12 Argo	HR2773 (3) (2.70) 6:40:37 -35:37:51 HR2787 (not mentioned) (4.66) 6:41:32 -35:14:32	0.43 deg	From the table: The southernmost of them From the comments: The twelfth is south of the eleventh star. It is far from it with a distance between them of three *dhirā'*. It is of the 3rd magnitude. It is on the plank where the *Kawthal* (front sail) is built. It is a double star because next to it is a close star which makes it a double.
15	34 Argo	HR3055 (6) (4.11) 7:17:38 -44:05:00 HR3037 (faint)=5 or 6 (5.23) 7:16:11 -44:21:19	0.38 deg	From the table: The faint star to the rear of this. From the comments: The thirty-fourth is behind the thirty-third star. It is inclined towards the south with a distance between them of one third of a *dhirā'*. It is of the 6th magnitude. It is a double star because next to it is a faint star which makes it a double.
16	3 Hydra	HR3482 (4) (3.38) 7:51:07 +09:42:22 HR3492 (5s)=5.25 (4.36) 7:52:58 +09:09:41	0.71 deg	From the table: The northernmost of the 2 to the rear of these, which is about on the skull. From the comments: Next to the third is a star less than the 5th magnitude. Together with the third they form a double star. It was not mentioned by Ptolemy.
17	5&6 Corvus	HR4757 (3) (2.95) 11:36:49 -10:44:59	0.62 deg	From the table: -The more advanced of the 2 stars in the rear wing. -The rearmost of them. From the comments:

		HR4775 (4) (4.31) 11:38:58 -10:25:53		The sixth follows the fifth close to it with a distance of less than a *Shibr*. It is of the 4th magnitude. Together with the fifth they form a double star.
18	22 Centaurus	HR4940 (5) (4.71) 12:09:26 -42:46:31 HR4933 (not mentioned) (4.85) 12:06:51 -43:49:42	1.06 deg	From the table: The star in advance of this on the horse's back. From the comments: The twenty-second is in front of the twenty-first and oriented towards the south. The distance between them is two and half *dhirā'*. It is of the 5th magnitude. It is a double star because next to it is star which makes it a double star.
19	8 Ara	HR6897 (4) (3.51) 17:10:17 -45:40:50 HR6934 (6) (4.96) 17:15:02 -45:44:50	0.85 deg	From the table: (not in the table) From the comments: Behind the second star is another star also of the 4th magnitude. The distance between them is one third of a *dhirā'*. It was not mentioned by Ptolemy. This star is a double star because next to it is a star of the 6th magnitude which makes it a double.
20	5 Piscis Australis	HR8431 (5) (4.17) 21:05:53 -37:40:12 HR8447 (not mentioned) (4.92) 21:07:55 -37:15:26	0.54	From the table: The star on the belly. From the comments: The fifth star is in front of the first on the belly. It is of the 5th magnitude. The distance between it and the first is close to two *dhirā'*. It is a double star because next to it is a star which makes it a double.

From the Table 14 the minimum angular separation for the above *Muḍ'af* (double) stars (discounting the reference star) was achieved by 8 Sagittarius (star number according to al-Ṣūfī), which according to Ptolemy and al-Ṣūfī is both a nebulous and a double star. The two stars which are in the magnitude range which could be seen in this nebula are: HR7116 and HR7120. The angular separation between these two stars at the epoch of al-Ṣūfī was 0.23

degrees. It is an interesting point to note here that the star HR7120 is next to the globular cluster NGC6717 (magnitude 9.3). The two stars HR7116 and HR7120 together with the globular cluster might have been the cause of the comments that 8 Sagittarius is double and nebulous even though a globular cluster of magnitude 9.3 would be far below the limit of unaided eye visibility.

I have included in the below Table 15 the star 26 Ursa Major as a reference star, which is the star Mizar. Next to Mizar is the star Alcor. The angular separation between these two stars is 0.20 degrees. However al-Ṣūfī did not refer to these two stars as *Muḍ'af* or double but he only mentioned that adjacent to *al-'Anāq* (Mizar) is the star called *al-Suhā* (the neglected one (Kunitzsch, 2006)). It was well known that the Arabs were able to separate these two stars long before the time of al-Ṣūfī. These stars were used by the Arabs as an eyesight test for the ability to separate and distinguish between the two. The proverb "I showed him *al-Suhā* and he showed me the Moon" was used as a metaphor indicating the strength of ones eyesight meaning "I can distinguish the very small detail while he can only see large objects such as the Moon". The separation of 8 Sagittarius is quite close to the separation 26 Ursa Major. Even though this shows the ability of al-Ṣūfī as an accomplished observer, however he still did not achieve the level which was reached by the Arabs before him or the minimum visual separation with the unaided eye.

Table 15: Reference Star

Number	Star Number according to al-Ṣūfī	-HR -al-Ṣūfī' Magnitude -Modern Magnitude -Coordinates	Angular Distance	Description according to al-Ṣūfī
Reference star	26 Ursa Major	HR5054 *-al-'Anāq* -Mizar (2) (2.27) 12:40:47 +60:28:44 HR5062 *-al-Suhā* -Alcor (small-faint)=5 or 6 (4.01)	0.20 deg	From the table: The middle one. *al-'Anāq*. Above *al-'Anāq* is a small star adjacent to it which the Arabs call *al-Suhā*. In other Arab dialects it is (also) called by the name of: *al-Shitā'* and al-*Saidaq* and *Nu'aish*. This star has not been mentioned by Ptolemy. This star is also used by people to test their eyesight, for they say: "I showed him *al-Suhā* and he showed me the Moon".

		12:42:19 +60:31:55		

5.9 The Nebulae in al-Ṣūfī's Book

The term 'nebula' comes from the Latin word for cloud. A nebula is a cloud of dust and gas in space. In the past the term nebula was also used for distant galaxies, clusters and any other hazy patches of light which resembles a cloud among the stars. After the use of telescopes, the discovery of spectroscopy and the invention of photography, it was possible to distinguish real nebulae from galaxies.

The Arab and Islamic astronomers observed and identified several nebulae very early in their scientific endeavors. The Arabic term used for a nebula was *al-Saḥābi* which also means a cloud. In his major astronomical treatise (*al-Qānūn al-Mas'ūdī*), al-Bīrūnī describes *al-Saḥābiāt* (plural for nebula) by these words:

> "In the sky there are objects which do not resemble the stars in their round shape and by the bright light which they have. These are the *al-Laṭkhāt al-Bīḍ* (the white smears) called *al-Saḥābia* (nebula). Some believe that these (nebulae) are part of the (the Milky Way) galaxy; however they are both alike and both resemble clouds. These (nebulae) are believed to be an *Ishtibāk* (a mass) of small stars grouped together"

Al-Bīrūnī clearly distinguished between nebulae and the Milky Way and he described the nature of these nebulae as a concentration or group of stars. As for the Milky Way it was called *al-Majarra* in Arabic, which is directly translated as just 'the Galaxy'. According to al-Marzūqī, in his book *Kitāb al-Azminah wa al-Amkina*, he said: "…the ancient Arabs called *al-Majarra*: *Um al-Nujūm* (the mother of all stars) because there is no area in the sky which has more stars then it." The Arabs also called the Milky Way: *Sharj al-Sama'* (the dome of the sky) and *Nahr al-Majarra* (the galaxy river). However the name by which the Milky Way was mostly used was *Darb al-Tabbānah* (the path of straws). The term *Darb al-Tabbānah* describes a picture of farmers coming back from planting their fields while dropping straws every once in a while thus producing white patches on the ground. Abū Ḥanīfa al-Daīnawari also described the location of the galaxy in those words: "*al-Majarra* (the galaxy) is a connected circle like a ring. Even though it is narrow in some places and wide in others however this is due to its circular nature. It is most wide between (the Asterism) *Shawlat al-'Aqrab* (the sting of Scorpio) and *al-Nasrān* (the two constellations: Lyra and Aquila)".

From the above descriptions which we find in many historical references we see that the ancient Arabs were well aware of these cloud-like objects. The Arabic and Islamic scholars and astronomers later described in detail the nature and location of these nebulae as well as the Milky Way galaxy which they could clearly see in the sky. Al-Ṣūfī also refers to the nebulae as *al-Laṭkhā al-Saḥābiya* (the nebulous smear or smudge) and *al-Ishtibāk al-Saḥābi* (the nebulous mass). As his work was based on Ptolemy's book, al-Ṣūfī again identifies the five nebulae which Ptolemy mentioned before. However al-Ṣūfī goes further to describe several other nebulae which he observed himself or were previously identified by the Arabs.

From al-Ṣūfī's description I tried to identify below all the nebulae found in al-Ṣūfī's *Book of the Fixed Stars* (Table 16). I have included the modern names or designations which correspond to these nebulae. I also indicated the magnitude and surface brightness of these deep sky extended objects. By definition the magnitude of an extended astronomical objects such as galaxies and nebulae is the measure of the concentration of their light at a point source where as the surface brightness of an object is the measure of brightness or magnitude per square arc minute. Therefore the surface brightness of an object is a more practical way to estimate the degree of visibility of extended deep sky objects than using magnitude methods only. Finally in the last column of the table I have included a brief summary on every one of these nebulae as they were mentioned by al-Ṣūfī. This summary includes all the descriptions taken from both the tables as well as from the comments in the constellation chapters of al-Ṣūfī's book.

Table 16: Nebulae found in al-Ṣūfī's book

Number	Modern name & designation, Magnitude & Surface brightness	Star/Nebula & magnitude according to al-Ṣūfī	Description according to al-Ṣūfī
1	NGC 869/884 Open clusters Magnitude 5.30/6.10 Surface brightness 12.43/13.23	1 Perseus Nebula	From the table: The nebulous mass on the right hand. From the comments: The first of its stars is *al-Laṭkhā al-Saḥābiya* (nebulous smear) on the camel's thigh which we have talked about when we discussed the constellation Cassiopeia. It is on the edge of its (Perseus) right hand.
2	M44	1 Cancer	From the table:

	(NGC 2632) Open cluster Magnitude 3.10 Surface brightness 13.00	Nebula	The middle of *al-Ishtibāk al-Saḥābi* (nebulous mass) in the chest, called *al-Mi'laf* (Praesepe). From the comments: The first of its stars is a *Laṭkhā* (smear) which resembles a piece of cloud surrounded by four close stars with the patch in the middle. Two stars are in front and two are behind.
3	M7 (NGC 6575) Open Cluster Magnitude 3.30 Surface brightness 12.00 Or NGC6441 Globular cluster Magnitude 7.40 Surface brightness 11.6	22 Scorpio 4(s)=4.25	From the table: The nebulous star to the rear of the sting. From the comments: As for the three stars outside of the constellation, the first is a star to the rear of *al-Shawla* and behind the nineteenth star which is on the seventh joint. It is less than 4th magnitude. Ptolemy mentioned that it is a nebulous object. The distance between it and the nineteenth star which is on the seventh *Kharaza* (joint) is a little more than one *dhirā'*. And the distance between it and *al-Shawla* is close to one and a half *dhirā'*.
4	HR7116 HR7120 NGC6717 Globular cluster Magnitude 9.30 Surface brightness 12.00	8 Sagittarius Nebula	From the table: The star on the eye, which is nebulous and double. From the comments: The eighth is the nebulous star on the eye of Sagittarius. It is towards the north from the sixth star by a distance of two *dhirā'*.
5	CR69 Open cluster HR1879 HR1883 HR1876 HR1907 Magnitude 2.80 Surface	1 Orion Nebula	From the table: The nebulous star in the head of Orion, which consists of three close stars. From the comments: The first of its stars is the *Saḥābi* (nebula) on the head. This nebula is made up of three small stars close together forming a small *Muthallath* (triangle). Ptolemy mentioned it to be one star located in the middle of the triangle and he indicated its longitude and latitude in his book. It is located on the head between the two shoulders and further away towards the north but closer to the left shoulder.

	brightness 11.60		
6	CR399 Open cluster Magnitude 3.60 Surface brightness 12.95	----- Magnitude not mentioned	From the table: (Description is only mentioned in the comments on the constellation Aquila). From the comments (Constellation Aquila): There is an image of a bowl (cup) with its stars beginning from the bright star on the tail, continuing towards the north-west then going to the east to the base of the bowl; then towards the south-east until it reaches a nebula located north of two stars in the notch of the constellation Sagitta. The distance between the nebula and the top of the bowl is two *dhirā'* ; the nebula is located on the east edge and the bright star on the tail on its western edge.
7	M31 Andromeda Galaxy Magnitude 3.40 Surface brightness 13.50	---- Magnitude not mentioned	From the table: (Description is only mentioned in the comments on the constellation Andromeda) From the comments: The Arabs mentioned two lines of stars surrounding an image resembling a large fish below the throat of the Camel. Some of these stars belong to this constellation (Andromeda) and others belong to the constellation Pisces which Ptolemy mentioned as the twelfth constellation of the Zodiac. These two lines of stars begin from the *al-Laṭkhā al-Saḥābiya* (nebulous smear) located close to the fourteenth star which is found at the right side of the three (stars) which are above the girdle.
8	IC2391 Omicron Velorum open cluster Magnitude 2.50 Surface brightness 12.00	---- Magnitude not mentioned	From the table: (Description is only mentioned in the comments on the constellation Argo Navis) From the comments: Above the thirty-seventh star at a distance of one *dhirā'* there is a nebulous star.
9	Large Magellanic cloud Magnitude 0.40 Surface brightness 14.10	---- Magnitude not mentioned	From the table: (Description is only mentioned in the comments on the constellation Argo Navis) From the comments: Some claim that under the star *Suhail* (the star Canopus) is a star called *Qaḍam Suhail* (feet of *Suhail*) and under *Qaḍam Suhail* are many bright white stars which are not seen from Iraq and *Najd* (area north of Arabia). The people of *Tehāma* (area south of Arabia) call them *al-Baqar* (Oxen). Ptolemy does not mention any of this and we do not know if this is right or wrong.
10	M45 Pleiades	29 Taurus 30 Taurus 31 Taurus	From the table: -The Pleiades: the northern end of the advanced side. -the southern end of the advanced side.

	Open cluster Magnitude 1.20 Surface brightness 11.00	32 Taurus 5 5 5 4	-The rearmost and narrowest end of the Pleiades. -The small star outside the Pleiades towards the north. From the comments: The Arabs called the twenty-ninth, the thirtieth, the thirty-first and the thirty-second, *al-Thurayyā* (the Pleiades). Inside (the Pleiades) are two stars or three together with the other four looking like a bunch of grapes that are close together. Therefore they considered them as one star and named it *al-Najem* (The Star) par excellence. They also named it *Nujūm al-Thurayyā* (the stars of the Pleiades). It was called *al-Thurayyā* because they were blessed by it and by its rise, and they claimed that the rain which falls when it *Naw* (sets) brings good luck. (*al-Thurayyā)* means a small fortune (the diminutive noun for fortune). They (the Arabs) diminutised it because its stars are close and small. They mentioned in their books that it is located on the *Aliet* (the buttocks or the fat tail of a sheep) of (the constellation) Aries, (however) it is located on the *Sinām* (hump) of Taurus. The distance between it and the last star on the buttocks of Aries is three *dhirā'* as is seen by the eye. It is the third of *Manāzil al-Qamar* (the lunar mansions).

5.9.1 Notes on the Nebulae found in al-Ṣūfī's Book

I have included below some comments on the above nebulae which were identified by al-Ṣūfī. I also included their modern pictures in order to describe and identify these objects much more clearly:

1. The double clusters NGC884 and NGC869 (Figure 42) were observed by many cultures such as the Greeks, Indians and others long before the time of al-Ṣūfī. These clusters were cataloged by Hipparchus as well as Ptolemy. These clusters are bright enough to be clearly seen by the naked eye.

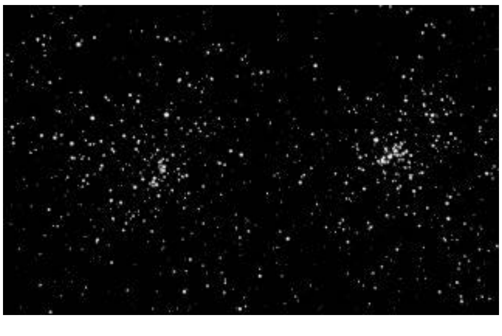


Figure 42 Double clusters NGC884 and NGC869.

In his comments al-Ṣūfī refers to the “camel’s thigh” which he mentioned also in his description of the constellation Cassiopeia. Al-Ṣūfī mentioned that the ancient Arabs described a picture of a camel which they identified between the constellation of Cassiopeia and Perseus.

2. The open cluster M44 (Figure 43) is another nebula which was clearly seen by the naked eye and recognized a long time ago by the Greeks and other cultures.

Figure 43 M44 open cluster.

3. Formerly the nebula which was associated with the star 22-Scorpio was considered to be the open cluster M7. It is interesting to note that al-Ṣūfī assigns a magnitude to the star 22-Scorpio of 4(s)=4.25. For all other nebulae he only mentions that they are nebulous objects. This procedure was also used in the *Almagest* therefore al-Ṣūfī again tried to adhere to Ptolemy’s method of description in this regard except for the star 22-Scorpio. However for the star 22-Scorpio al-Ṣūfī might have been referring to the star HR6630 (magnitude 3.21) which also has next to it the globular cluster NGC6441 (surface brightness 11.6). Al-Ṣūfī states that Ptolemy mentioned that this star is a nebulous object. He then goes on to determine the distance between this nebulous object and the nineteenth star which is on the seventh *Kharaza* (joint) as a little more than one *dhirā’*, and the distance between it and *al-Shawla* (stars 20/21 Scorpio) as close to one and a half *dhirā’*. From these distance approximations this nebula should be about 2 deg 20 min from the nineteenth star of Scorpio and 3 deg 30 min from the twentieth and the twenty first stars of Scorpio. I have calculated the distance between these nebulae and these stars and the results are indicated in the following table 17:

Table 17: Distance between Nebulae and Stars

Distance from NGC6441 to 19 Scorpio	Distance from NGC6441 to 21/20 Scorpio	Distance from M7 to 19 Scorpio	Distance from M7 to 21/20 Scorpio
2 deg 34 min	3 deg 38 min	4 deg 53 min	5 deg 07 min

From these approximate distances and the fact that one *dhirā'* is 2 deg 20 minutes according to al-Ṣūfī himself it looks more likely that the nebula which al-Ṣūfī was referring to in this case is the globular cluster NGC6441 and not M7 as was supposedly known. This distinction was first recognized by Manitius (1912) then by Peters and Knobel (1915) and later confirmed by Toomer in his translation of the *Almagest* (1984).

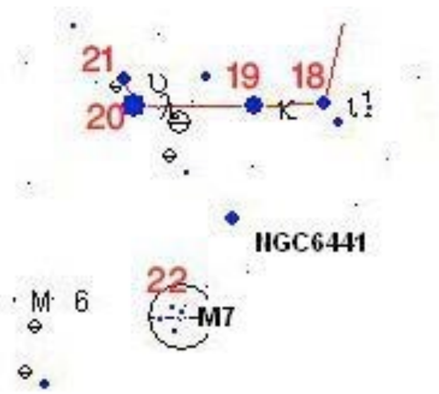


Figure 44: Map which shows NGC6441

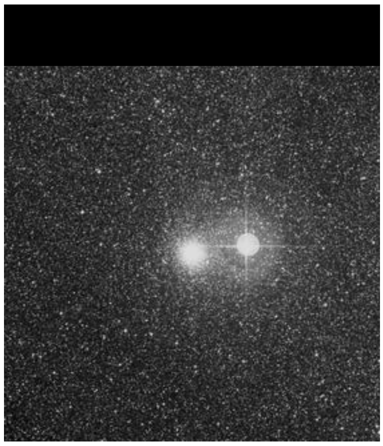


Figure 45: Image of NGC6441

Figure 44 is a map which shows that NGC6441 is much closer to the nineteenth, twentieth and the twenty-first stars of Scorpio than is M7. Figure 45 is an image of the globular cluster NGC6441 to the left of the star HR6630 taken from the Digitized Sky Survey

4. Al-Ṣūfī mentioned the star 8-Sagittarius as a double star together with a nebulous star. The two stars were identified as HR7116 and HR7120. Next to HR7120 is the NGC6717 globular cluster. Al-Ṣūfī might have been referring to these three objects as a nebulous asterism. I have obtained the image from the Digitized Sky Survey (Figure 46) which shows the star HR7116 on the right edge of the image and star HR7120 in the center with NGC6717 just under it.

Figure 46: Stars HR7116, HR7120 and globular cluster NGC6717.

5. The image below is of the open cluster CR69 with the star HR1879 centered in the middle. This image was obtained from the Digitized Sky Survey

Figure 47: CR69 open cluster.

6. The CR399 open cluster (see Figure 48) was first discovered by al-Ṣūfī and described in his *Book of the Fixed Stars*. It was later independently rediscovered by Giovanni Hodierna in 1654. It is also sometimes named *Brocchi's Cluster* after the astronomer D.F. Brocchi, who created a map of it in the 1920s. It was included in Collinder's 1931 catalog of open clusters and given the designation of Collinder 399.

Figure 48: CR399 open cluster.

7. Messier 31 (M31 is the famous Andromeda Galaxy (see Figure 49). It is the nearest large spiral galaxy to us. It was first discovered by al-Ṣūfī and described in his *Book of the Fixed Stars*. It was later included in early European star catalogs, for example Simon Marius in 1612, Giovanni Hodierna in 1654 and Charles Messier in 1764.

Figure 49: M31 Andromeda Galaxy.

8. The Omicron Velorum open cluster (CR399) was first discovered by al-Ṣūfī and described in his *Book of the Fixed Stars* (see Figure 50). It was later rediscovered by Abbe Lacaille in 1752 and he cataloged it as ‘Lac II.5’.

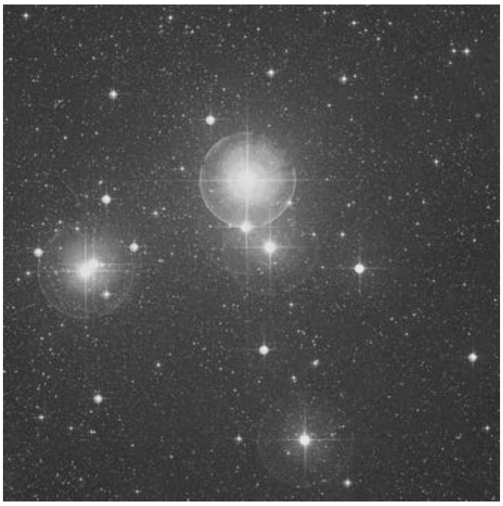


Figure 50: Omicron Velorum open cluster.

9. The Large Magellanic Cloud (Figure 51), together with its small neighbor the Small Magellanic Cloud, are well known objects in the southern hemisphere. They must have been very well recognized by ancient cultures living in the Southern Hemisphere. However there is very little preserved evidence to document these facts. Some Arab researchers claim that the earliest documented proof of observation of the Magellanic Clouds might be found in al-Ṣūfī's *Book of the Fixed Stars* (Mujahed, 1997). However, al-Ṣūfī only mentioned that there are stars under the stars of *Suhail* (Canopus) and *Qadam Suhail* (feet of *Suhail*) which the Arabs call *al-Baqar* (Oxen) but he does not mention that there is any nebula. This recent claim is probably due to the fact that *al-Baqar* was mentioned by the 15th century Arab seafarer Ibn-Majed who mentioned the Large Magellanic Cloud as a nebula and named it *al-Baqar* before it was documented by Magellan in A.D. 1519. However, al-Ṣūfī does not claim that he observed these stars himself. He attributed this to the southern people of Arabia (region of *Tehāma*). He admits that he does not know if this is right or wrong. This is a tribute to this author's scientific integrity whereby in the same paragraph he admits to making his observations from the city of Shiraz which according to the observation he made with the '*Aḍudī* Ring is 29 deg and 36 min and at this latitude these stars could not be seen.

Figure 51: Large Magellanic Cloud.

10. Al-Ṣūfī mentioned that inside the Pleiades (Figure 52) there are two stars or three together with the other four looking like a bunch of grapes. These additional stars are HR1149, HR1165 and HR1142. Therefore, together with the other four, al-Ṣūfī managed to observe seven stars of the Pleiades.

Figure 52: M45 Pleiades open cluster.

5.10 Old Arabic Astronomical Traditions in al-Ṣūfī's Work

When ancient civilization were watching the heavens they observed that many groups of stars formed patterns in the sky that resembled people, animals and objects similar to what they experienced in their daily lives. Among those early civilizations were the ancient Arabic cultures that inhabited what we call now the Middle East. They named many of the stars, which they observed according to their own experience, and the environment which they lived in. This endeavor started more than 3000 years even before the emergence of Islam, which transformed the history of the region. At first this scientific movement was connected to the development of the lunar calendar. It then transformed into the unique science of the lunar mansions. From this effort another study emerged which was called '*Ilm al-Anwā'*. The *Anwā'* were a form of astrological-meteorological system of predicting the weather and identifying the beginning of the seasons in order to specify the dates of festivals, holidays, pilgrimage and the best times for traveling and commerce (see Section 2.3). These ancient fields of study are what were to be called 'Arabic folk astronomy'. They were very popular among many Arab and Islamic religious and scientific scholars such as al-Battānī and al-Daīnawari, as well as al-Ṣūfī.

In his introductory chapter al-Ṣūfī divided those who study the stars into two groups. The first group was the astronomers *(Munajjimīn)*. The second group studied the Arabic method of the sciences of *al-Anwā'* and the Moon mansions. From this identification we can deduce that al-Ṣūfī considered 'Arabic folk astronomy' to be an important scientific field of study in its own right. He took upon himself to explain the development of this field as well as to identify all the various names of stars, asterisms, mansions and constellations as per the method of the Arabs. He also tried to correct many of the mistakes which were mentioned by previous authors in this subject such as al-Battānī and al-Daīnawari (see my translation of al-Ṣūfī's Introductory chapter Section 4.1).

I have tabulated below the names of stars and asterisms for some of the constellations that have been used in Arabic folk astronomy. This exercise is only to give an idea on the scope of information which is contained in each of the chapters on the constellations according to the explanation of al-Ṣūfī:

Table 18: Names of stars in constellation Ursa Minor as per Arabic folk astronomy.

Arabic Name	Name in Arabic	Star/s (HR)	Explanation
al-Farqadain	الفرقدين	5563, 5735	The meaning of this word in Arabic is: "The two calves".
Banāt Na'sh al-Ṣughra	بنات نعش الصغرى	The bier 5903, 6116, 5563, 5735 The daughters 424, 6789, 6322	"The little daughters of the bier (or coffin)". The Arabs likened the image of this constellation to three women "the daughters" who are pulling "a bier (or coffin)".
al-Juday	الجدي	424	"The kid or goat" (This is the polar star "Polaris". It is not to be confused with the constellation Capricorn even thought the Arabic folk name is the same as the constellation Capricorn).
Fa's al-Raḥā	فاس الرحا		"A type of a fish", which is round and looks like a round "grinding axe".

Table 19: Names of stars in constellation Ursa Major as per Arabic folk astronomy.

Arabic Name	Name in Arabic	Star/s (HR)	Explanation and comments
al-Mirāq	المراق	4295	The flank or groin.
al-Khaṭem	الخطم	3323	The snout.
Banāt Na'sh al-kubra	بنات نعش الكبرى	5191,5054,4905 4301,4295,4660,4554	"The great daughters of the bier (or coffin)". The Arabs likened the image of this constellation to three women "the daughters" (*Banat)* who are pulling "a bier (or coffin)". *al-Naeesh means the* bier (or coffin).
Bani Na'sh	بني نعش		The clan of *al-Na'sh* (bier).
Sarīr Banāt Na'sh	سرير بنات نعش	4301,4295,4660,4554	The bed of the daughters of the Bier. The coffin was sometimes referred to as a bed.
al-Qā'īd	القائد	5191	The leader.
al-'Anāq	العناق	5054	A young female goat.
al-Jūn	الجون	4905	The bull.
al-Suhā	السها	5062	The Arabic translation of the word means the neglected one. This is the star "Alcor". As al-Ṣūfī wrote, it is also called by other names which are: *al-Shitā'*, al-*Saidaq* and *Nu'aish.*
Kafazāt al-Ẓibā	قفزات الظبى	The first *Kafza* (*al-Kafza al-Ūla*)	The Arabic translation means: the leaps of a Gazelle.

al-Thu'ailibān *al-Qarā'in*	الثعيلبان القراين	4377, 4375 The second *Kafza* (*al-Kafza al-Thānīa*) 4033, 4069 The third *Kafza* (*al-Kafza al-Thālitha*) 3569, 3594	These six stars represent the footprints or leaps of a Gazelle. (*Al Kafazāt)* are also called by the Arabs by other names such as: *al-Thu'ailibān* and *al-Qarā'in.*
Athar Zulfa al-Ẓibā	اثر ظلفى الظبى		The hoof trail or footprints of a gazelle.
al-Ṣarfa	الصرفة	4534	This is the bright star called Denebola which is on the tail of (constellation) Leo.
al-Ḍafira, *al-Halba*	الظفيرة الهلبة	4357, 4300, 4259,4362	A group of stars above *al-Ṣarfa that* are (also) named by the Arabs *al-Halba*. These are four stars which are also found in the constellation of Leo.
al-Hawḍ	الحوض	3624, 3757, 3888, 3894, 3775, 3662, 3619	These stars form a semi-circle which is sometimes called *Sarīr Banat Na'sh*. Here al-Ṣūfī contradicts himself by naming *Sarīr* twice.
al-Ẓibā	الظبى	3323, 3354, 3403, 3576, 3616, 3771	It is translated to: Gazelle. These are the six stars on the eyebrow, the eyes, the ears and the snout.
Kibd al-Asad	كبد الاسد	4915	This is translated in Arabic to: the liver of the lion. This star is now in the modern constellation of Canes Venatici.

Table 20: Names of stars in constellation Taurus as per Arabic folk astronomy.

Arabic Name	Name in Arabic	Star/s (HR)	Explanation and comments
al-Thurayyā, *al-Najm,* *Nujūm al-Thurayyā*	الثريا النجم نجوم الثريا	1145,1156,1178,1188 Additional stars: 1149,1165,1142	The Arabs call the twenty-ninth, the thirtieth, the thirty-first and the thirty-second, al-*Thurayyā* (the Pleiades). Inside (the Pleiades) are two stars or three together with the other four looking like a bunch of grapes that are close together. Therefore they considered them as one star and named it *al-Najm* (The Star) par excellence. It is the third of *Manāzil al-Qamar* (the lunar mansions).

al-Dabarān, *Ain al-Thawr,* *Tāb' al-Najm,* *al-Tāb',* *al-Mijdaḥ,* *al-Mujdaḥ,* *Ḥadī al-Najm,* *al-fanīq*	الدبران عين الثور تابع النجم التابع المِجدح المُجدح حادي النجم الفنيق	1457	The star Aldebaran which is also known by the other name *Ain al-Thawr* (eye of Taurus). It is (also) called *Tāb' al-Najm* (star follower) and *Tālī al-Najm* (rear star) and *al-Mijdaḥ* where the letter M is accented, as well as *al-Mujdaḥ*. It is just called *al-Tāb'* (follower) by itself without adding the word *al-Najm* (star). It is also called *Ḥadī al-Najm* (star follower – follower of the Pleiades) and *al-fanīq* which means the great Camel. It is the fourth of *Manāzil al-Qamar* (the lunar mansions).
al-Qilāṣ, *Qilāṣa,* *Ghunaīma*	القلاص القلاصة غنيمة		The stars around (*Aldebaran)* are called *al-Qilāṣ* which are the small Camels. (The Arabs) claim that (these stars) are named *Qilāṣ* and also (named) *Ghunaīma.*
al-Kalbain	الكلبين	1392, 1387	The two close stars on the northern ear which are the twenty- first and the twenty-second are called *al-Kalbain* (the two dogs). They claim they are the dogs of Aldebaran.
al-Ḍayīqa	الضيقة		This means the small gap in Arabic. As al-Ṣūfī explained, the Arabs found between the setting of al-*Thurayyā* and Aldebaran a small difference or gap which they called *al-Ḍayīqa* (small/narrow gap).
al-Dāl	الدال	1346,1373,1411,1457,1409	The five (stars) which resemble (the Greek letter Δ) *al-Dāl.* These are the stars the Greeks call the 'Hyades'.

Table 21: Names of stars in constellation Scorpio as per Arabic folk astronomy.

Arabic Name	Name in Arabic	Star/s (HR)	Explanation and comments
al-Iklīl	الاكليل	5984, 5953, 5944	Al-Ṣūfī explains that the Arabs call the three stars on the forehead *al-Iklīl*. However, he also refers to his explanation about this when he mentioned the constellation Libra and that the story from the Arabs about this is wrong.
al-Qalb (the heart). *Qalb al-'Aqrab*	القلب	6134	This star is the middle of two other stars and is reddish in color as al-Ṣūfī explains. It is called *Qalb al-'Aqrab* by the Arabs and (Antares) by the Greeks.
al-Nīyāṭ	النياط	6084, 6165	The seventh star in front of *al-Qalb* and the ninth star behind it are called *al-Nīyāṭ*.
al-Fiqarāt (plural) *Fiqra* (singular)	الفقرات	6241 (1st joint) 6247 (2nd joint) 6262 (3rd joint) 6271 (3rd joint) 6380 (4th joint) 6553 (5th joint) 6615 (6th joint) 6580 (7th joint)	*Fiqarāt* means spinal vertebrae. Al-Ṣūfī mentions that the stars on the *Kharazāt* (joints) are called *al-Fiqarāt* or singularly *Fiqra.*
al-Shawla (the sting) *Shawlat al-'Aqrab,* *Shawlat al-Sura* *al-Ibra*	الشولة شولة العقرب شولة السرة الابرة	6527 6508	Al-Ṣūfī mentions that the two stars on the tip of the tail which are the twentieth and the twenty-first are called *al-Shawla*. These two are also called *Shawlat al-'Aqrab* or *Shawlat al-Sura* and are also called *al-Ibra* (the needle). They were called *al-Shawla* because they always rise up vertically. They are the nineteenth of the lunar mansions.

Table 22: Names of stars in constellation Orion as per Arabic folk astronomy.

Arabic Name	Name in Arabic	Star/s (HR)	Explanation and comments
al-Haq'a *Haq'a al-Jauzā'* *al-Taḥātī* *al-Taḥiyat*	الهقعة هقعة الجوزاء التحاتي التحيات	1879, 1880, 1876	Al-Ṣūfī mentioned that this nebula is a combination of three stars which resembles the points of the letter *Tha* (ث). (This letter in Arabic is written with three points on it.) Al-Ṣūfī also mentioned that the Arabs call this nebula by many

al-Taḥia *al-Athāfī*	التحية الاثافي		names and that it is the fifth of the lunar mansions.
Mankib al-Jauzā' *Yad al-Jauzā'* *Mirzam al-Jauzā'* *Rā'ī al-Jauzā'*	منقب الجوزاء يد الجوزاء مرزم الجوزاء راعي الجوزاء	2061	Ṣūfī Al mentioned that the second star was called *Mankib al-Jauzā'* and also *Yad al-Jauzā'*. He also explained that some of the Arabs called it *Mirzam al-Jauzā'* and this was wrong of them, because it was the practice of the Arabs to begin the name of any bright star by the word *Mirzam* like the two (stars) *Mirzam al-Shi'rayan*. (These stars are: *al-Shi'ra al-Yamāniya* which is the star Sirius and *al-Shi'ra al-Shāmīya* which is the star Procyon). Al-Ṣūfī also mentioned that the second star was also sometimes called *Rā'ī al-Jauzā'*.
al-Nājid *al-Mirzam*	الناجد المرزم	1790	Al-Ṣūfī also mentioned that the third star was called *al-Nājid* and it was also called by *al-Mirzam*.
Minṭaqat al-Jauzā' *Niṭāq al-Jauzā'* *al-Niẓām* *al-Naẓm*. *Naẓm al-Jauzā'* *Faqār al-Jauzā'*.	منطقة الجوزاء نطاق الجوزاء النظام النظم نظم الجوزاء فقار الجوزاء	1852, 1903, 1948	Al-Ṣūfī mentioned that the three bright stars on the middle of Orion which are the twenty-sixth, the twenty-seventh and the twenty-eight were called collectively as *Minṭaqat al-Jauzā'*, *Niṭāq al-Jauzā'*, *al-Niẓām* and also *al-Naẓm*. They were also mentioned as *Naẓm al-Jauzā'* and *Faqār al-Jauzā'*. The separation of the names came later on where by the twenty-sixth is now named 'Mintaka'. The twenty-seventh is named 'Alnilam' which was a derivative from the word *al-Niẓām*. And the twenty-eighth is named 'Alnitak'.
al-Laqaṭ *Saif al-Jabbār*.	اللقط سيف الجبار	1892, 1897, 1899	Al-Ṣūfī mentioned here also that the three stars which are the thirtieth, the thirty-first and the thirty-second were called collectively as *al-Laqaṭ* and also *Saif al-Jabbār* (sword of Orion).
Rijl al-Jauzā' *Rā'ī al-Jauzā'* *al-Nājid*	رجل الجوزاء راعي الجوزاء الناجد	1713	The thirty-fifth which is the great bright star on the left leg was called *Rijl al-Jauzā'* (leg of Orion) and also *Rā'ī al-Jauzā'* (Shepherd of Orion). It was also mentioned by some Arabs that the thirty-fifth which is on the left leg was called *al-Nājid*.
Tāj al-Jauzā'	تاج الجوزاء	1676,1638, 1580,	Ṣūfī Al mentioned that the nine

Dhawā'īb al-Jauzā'	ذوايب	1570, 1544, 1543, 1552, 1567, 1601	stars forming a curve that are on the pelt and which are from the seventeenth until the twenty-fifth were called *Tāj al-Jauzā'* (crown of Orion) and also *Dhawā'īb al-Jauzā'* (this is the skin of the lion which a hunter usually wraps around his hand).

Table 23: Names of stars in constellation Centaurus as per Arabic folk astronomy.

Arabic Name	Name in Arabic	Star/s (HR)	Explanation and comments
al-Shamārīkh	الشماريخ		The Arabs called both the constellations Centaurus and Lepus by the name of: *al-Shamārīkh.*
Hiḍār, *al-Wazn,* *Muḥlifain,* *Muḥnithain*	حضار الوزن محليفين محنثين	5659,5267	The Arabs called these two stars by these 4 names. However al-Ṣūfī was not sure which one of these names referred to which star.

5.11 Comments on the Chapter of the Constellation Ursa Minor

5.11.1 The Explanation of '*Fa's al Raḥā'*

In this chapter of the constellation Ursa Minor, al-Ṣūfī wrote about an image which was used in Arabic folk astronomy called *Fa's al-Raḥā*. It is an area which had been compared by the Arabs to the likeness of a fish. It is formed by two rows of stars forming two arcs as al-Ṣūfī explains. The first arc is formed by: "… the three stars on the tail, together with the fourth and sixth form a curved lin." The second arc starts with "… this star is connected with the star on the end of the tail, forming a line of dim stars which is curved like the first line." Al-Ṣūfī then explains that: "… these two arcs enclose an area with the shape of a fish, called *al-Fa's*; this may be compared with *Fa's al-Raḥā*, where the pole is in the middle. However, the equatorial pole is on the outside of the second arc, close to the nearest star on the line to the star *al-Juday*."

Al-Ṣūfī stated here that the pole is located in the middle of the image of this fish. However as an accomplished astronomer, al-Ṣūfī must have known that this is clearly not the case. Therefore the explanation for this matter is that he must have been stating what the Arabs have said about this area or this image of the fish with the pole at its centre. For he then explains: "… the equatorial pole is on the outside of the second arc, close to the nearest star on the line to the star *al-Juday*." (See below the explanation and location of this (nearest) star)

This explanation of the image of the fish is found in many other books on Arabic folk astronomy. The most important was that of Abū Ḥanīfa al-Daīnawri in his book on al-Anwā', where he clearly states that the Arabs: "… believe that the pole is in the middle of this image." However al-Daīnawri goes on to explain that "… it is not the case for the pole is close to a star next to *al-Juday* on this curve of dim stars. I found that these stars are the closest stars to the pole. I found that the distance between this star and the pole is less then one degree. However the pole is not a star but a point on the sphere."

Al-Ṣūfī must have known this explanation by Abu Hanifa al-Dinawari because in the introductory chapter of his book he mentioned that the book by Abū Ḥanīfa al-Daīnawri is the best book on Arabic folk astronomy even though he has some misgivings about the accuracy of some of al-Daīnawri's information and his observational skills. (See translation of al-Ṣūfī introductory chapter)

The below picture (Figure 53) shows the image of the constellation with the two curves forming an image of a fish. The middle red point is the estimated area where the Arabs believed the equatorial pole was located. Even though this point is slightly off center however it is a remarkable achievement to those Arab observers who where able to locate this point in the sky without the aid of any instruments, but only relied on their naked eyes. In Figure 54 the star chart for the constellation Ursa Minor has been re-calculated to the year A.D. 960 taking into account of precession. The nearest visible star to the pole at that time was the star HR 4893 with visual magnitude of 5.28. This star was probably the star mentioned by al-Daīnawri and al-Ṣūfī. The distance between the pole and the star is close to 1 degree. This also shows the remarkable accuracy and observation skills of al-Daīnawri and al-Ṣūfī in identifying almost the precise location of the equatorial pole in that period of time.

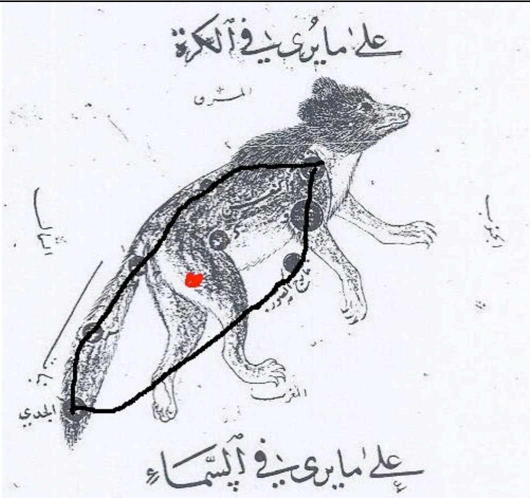


Figure 53: Constellation Ursa Minor with the two curves forming an image of a fish

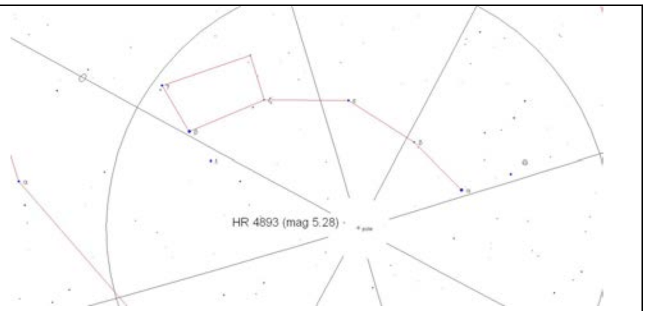


Figure 54: Chart for constellation Ursa Minor re-calculated to the year A.D. 960

5.11.2 The Directions for Using the Star Maps as per al-Ṣūfī Explanation

At the end of the chapter on Ursa Minor, al-Ṣūfī explains clearly the reasons why he made two different pictures. He also explains the method of using these maps where he wrote:

> "For every constellation we have drawn two pictures: one as it is projected on the globe and the other as it is seen in the heavens. Hence we have covered both of the different cases, so there is no confusion for anyone who sees that what is viewed on the globe is different from what is in the heavens. When we want to see the constellation as it is we lift the book over our heads and we look at the second picture. From beneath we are viewing it as it is seen in the heavens."

It is apparent that as an observational astronomer and an instrument-maker al-Ṣūfī was very much concerned with the accuracy of the data he had and the way it should be used correctly when constructing a celestial globe.

5.11.3 Star Names and Modern Designations of the Stars

I have included below in Table 24 all the stars that are included in al-Ṣūfī's star tables for constellation Ursa Minor. I have also included the HR, numbers so each star can be correctly identified. The stars' identification are according to Toomer's book. I also tabulated below the names of the stars according to the Arabic tradition and according to what was described by al-Ṣūfī, together with the modern star names and any other common name.

Table 24: Star Names and Modern Designations of the Stars for Ursa Minor Constellation

Star number (as per al-Ṣūfī)	HR	Star name and description (as per al-Ṣūfī)	Star name/s in Arabic tradition	Modern star name/s	Other star name/s
1 Ursa minor	424	The star on the end of the tail which is *al-Juday*	*al-Juday*	Polaris	Alruccabah, Cynosura, Phoenice, Lodestar, Pole Star, Tramontana, Angel Stern, Navigatoria, Star of Arcady, Yilduz, Mismar
2 Ursa minor	6789	The one next to it on the tail		Yildun	Vildiur, Gildun
3 Ursa minor	6322	The one next to that before the place where the tail joins the body			
4 Ursa minor	5903	The southern most of the stars in the advanced side of the rectangle			
5 Ursa minor	6116	The northern most of those in the same side			
6 Ursa minor	5563	The southern star in the rear side which is the brightest of *al-Farqadain*	Brightest of *al-Farqadain*	Kocab	Kochab, Kochah
7 Ursa minor	5735	The northern one in the same side which is the dimmest of *al-Farqadain*	Dimmest of *al-Farqadain*	Pherkad	Pherkad Major

8 Ursa minor	5430	The southern star parallel to *al-Farqadain*			

5.11.4 Modern Star Chart of Ursa Minor Constellation

In Figure 55 below I have included a modern star chart of Ursa Minor constellation showing the star's modern name, al-Ṣūfī designation number and HR number. The software used to generate above chart is: Cartes du Ciel version 2.76.

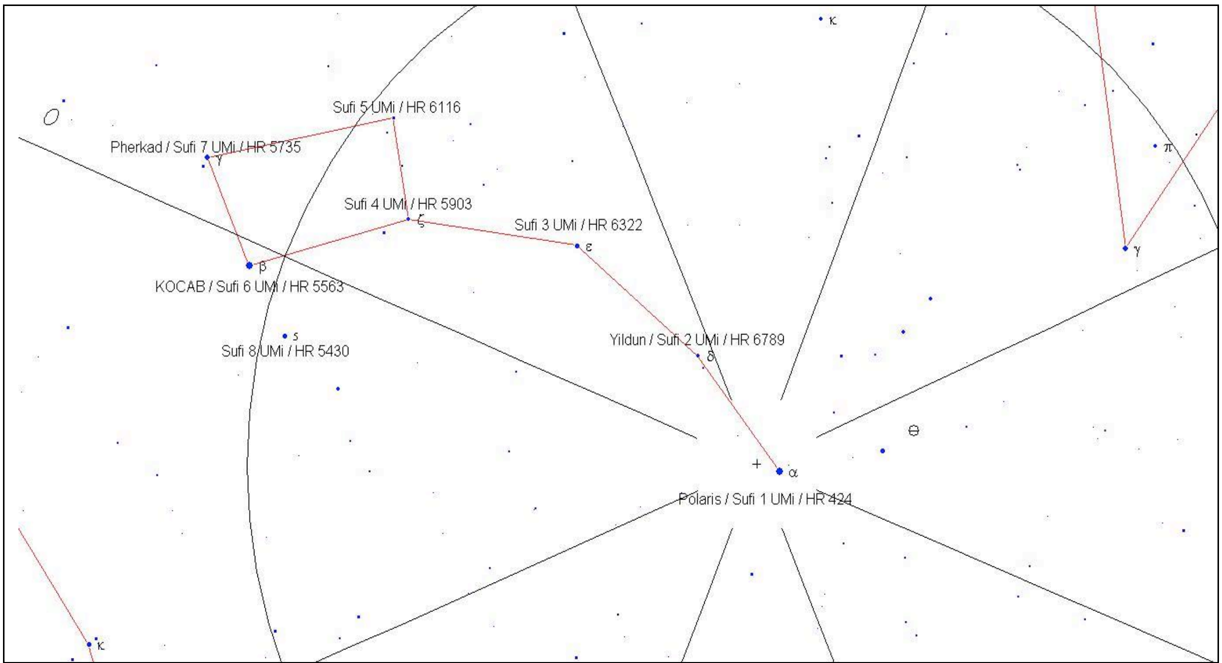


Figure 55: Modern Star Chart of Ursa Minor Constellation

5.12 Comments on the Chapter of the Constellation Ursa Major

5.12.1 Differences in Coordinates and Magnitudes between Manuscripts Marsh144 and MS 5036

The below table shows the differences in coordinates and magnitude values for the constellation Ursa Major which were identified in the manuscripts Marsh144 and MS5036. These differences were identified and compared with al-Ṣūfī's written description of the constellation. In the comments below I have also referred to other manuscripts, which are: The French translation by Schjellerup which was based on the rather late Copenhagen Manuscript MS83 dated A.D. 1601. The other is the London manuscript OR5323 dated 14th century A.D. The last is the Hyderabad copy which was based on several manuscripts but mainly that of MS5036; however I found that the Hyderabad edition contains many errors which do not make it very reliable.

Table 25: Differences in Coordinates and Magnitudes between Manuscripts.

Star number (as per al-Ṣūfī)	Lat. Marsh144	Lat. MS 5036	Mag. Marsh144	Mag. MS 5036	Explanations and Comments
7 Ursa major			4.25	3.75	The value in al-Ṣūfī's written description is 4s while the MS5036 chart shows it as 4k, however the Marsh144 chart shows it correctly as 4s.
17 Ursa major	45 30	44 30			The value for Lat indicated in Schjellerup French translation (based on the Copenhagen Manuscript MS83) is similar to the MS5036 which is 44 30.
34 Ursa major	20 20	23 05			The value for Lat indicated in Schjellerup French translation is 23 00 which is also a different value but closer to the MS5036 value. This proves that the copy of the Copenhagen manuscript is similar to the MS5036. The London manuscript OR5323 shows the Lat 20 20

5.12.2 Star names and modern designations of the stars

I have included below in Table 26 all the stars that are included in al-Ṣūfī's star tables for constellation Ursa Minor. I have also included the HR, numbers so each star can be correctly identified. The stars identifications are according to Toomer's book. I also tabulated below the names of the stars according to the Arabic tradition and according to what was described by al-Ṣūfī, together with the modern star names and any other common name.

Table 26: Star Names and Modern Designations of the Stars for Ursa Major

Star number (as per al-Ṣūfī)	HR	Star name and description (as per al-Ṣūfī)	Star name/s in Arabic tradition	Modern star name/s	Other star name/s
1 Ursa major	3323	The star on the end of the snout.	*al-Khaṭem*	Muscida	
2 Ursa major	3354	The more advanced of the two stars in the two eyes.			
3 Ursa major	3403	The other one of the two.			
4 Ursa major	3576	The more advanced of the two stars in the forehead.			
5 Ursa major	3616	The other one of the two.			
6 Ursa major	3771	The star on the tip of the advance ear.			
7 Ursa major	3624	The more advanced of the two stars in the neck.			
8 Ursa major	3757	The other one of the two, longitude or latitude are wrong.			
9 Ursa major	3888	The northern most of the two stars in the chest.			
10 Ursa major	3894	The southernmost of them.			
11 Ursa major	3775	The star on the left knee.			
12 Ursa major	3569	The northern most of the two in the front left paw. *al-Kafza*		Talitha	
13 Ursa major	3594	The southern most of them. *al-Kafza*			
14 Ursa major	3662	The star above the right knee.			
15 Ursa major	3619	The star below the right knee.			
16 Ursa major	4301	The star on the back which is part of the quadrilateral.		Dubhe	Dubb, al-dubb
17 Ursa major	4295	The one on the flank.	*al-Mirāq*	Merak	Mirak
18 Ursa major	4660	The one on the place where the tail joins		Megrez	Kaffa in Becvar

		the body.			
19 Ursa major	4554	The remaining one on the left hind thigh.		Phad	Phecda, Phekda, Phegda, Phekha, Phacd
20 Ursa major	4033	The more advanced of the two stars in the left hind paw. *al-Kafza*		Tania Borealis	Al-Kafza al-Thānīa
21 Ursa major	4069	The next one. *al-Kafza*		Tania Australis	
22 Ursa major	4335	The star on the left knee bends.			
23 Ursa major	4377	The northern most of the two stars in the right hind paw. *al-Kafza*		Alula Borealis	
24 Ursa major	4375	The southernmost of them. *al-Kafza*		Alula Australis	
25 Ursa major	4905	The first of the three stars on the tail next to the place where it joins the body. *al-Jaoun*	*al-Jūn*	Aliioth	Alioth, Aliath
26 Ursa major	5054	The middle one. *al-Inak*	*al-'Anāq*	Mizar	Mirzar, Mizat
27 Ursa major	5191	The third on the end of the tail. *al-Kaed*	*al-Qā'īd*	Alkaid	Benetnash, Benetnasch, Elkeid
28 Ursa major	4915	The star under the tail at some distance towards the south.	*Kibd al-Asad*		
29 Ursa major	4785	The rather faint star in advance of it.			
30 Ursa major	3705	The southernmost of the two stars between the front legs of Ursa Major and the head of Leo.			
31 Ursa major	3690	The one north of it.			
32 Ursa major	3800	The next of the remaining three faint stars.			
33 Ursa major	3809	The one in advance of this.			
34 Ursa major	3612	The one in advance again of the latter.			
35 Ursa major	3275	The star between the front legs (of Ursa Major) and Gemini.		Alsciaukat	Mabsuthat

5.12.3 Explanation of al-Ṣūfī's Distance Approximation

Throughout al-Ṣūfī's work the author indicated some measurements, which might seem to be a very general approximation to the measurement of distance between the stars. However, upon careful examination of this method, which was made by Schjellerup in his French translation of al-Ṣūfī's book, we can see that these measurements can be almost exactly defined in term of numerical distance values. These values are summarized as follows: one *dhirā'* = 2 deg 20 min; one *Shibr* = 1/3 *Thira*; one *Qasba* = 1/32 *Thira* and one *Rumḥ* = 14 deg. In the comments on the constellation Auriga al-Ṣūfī clearly mentioned that the value of one *dhirā'* is two degrees and one-third of a degree (20 minutes). For example in the constellation Ursa Major al-Ṣūfī mentioned that there are two stars close to the star *al-Qā'īd*. The distance between these two stars is one *Thira* and the distance between the closer of these two to *al-Qā'īd* is also close to one *Thira*. These two stars have not been mentioned by Ptolemy. Upon examination we can identify these two stars to be HR5023 and HR5112 and the distance between these two stars is almost 2 degrees and 26 min. The distance between *al-Qā'īd* and the closer of these two stars is also a little more then 2 degrees.

5.12.4 Modern Star Chart of Ursa Major Constellation

Figure 56 below is a modern Star chart of Ursa Major constellation. The stars indicated in red are the stars according to al-Ṣūfī's star number. The stars indicated in green are the stars mentioned by al-Ṣūfī in his comments but not included in the charts nor are included in Ptolemy. There was no place to include the star's modern name or the HR number for every star in this constellation, therefore I only included al-Ṣūfī star numbers where the details can be found in the above comments. The software used to generate above chart is Cartes du Ciel version 2.76.

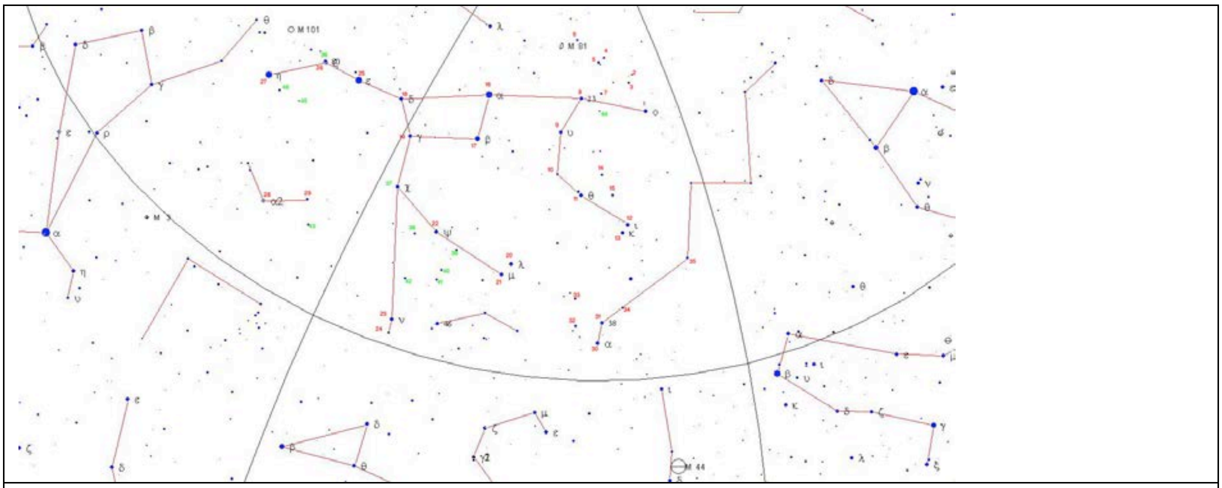


Figure 56: Modern Star Chart of Ursa Major Constellation

5.13 Comments on the Chapter of the Constellation Taurus

5.13.1 Star names and Modern Designations of the Stars

I have included below in Table 27 all the stars that are included in al-Ṣūfī's star tables for constellation Taurus. I have also included the HR, numbers so each star can be correctly identified. The stars identifications are according to Toomer's book. I also tabulated below the names of the stars according to the Arabic tradition and according to what was described by al-Ṣūfī, together with the modern star names and any other common name.

Table 27: Star Names and Modern Designations of the Stars for Taurus

Star number (as per al-Ṣūfī)	HR	Star name and description (as per al-Ṣūfī)	Star name/s in Arabic tradition	Modern star name/s	Other star name/s
1 Taurus	1066	The northernmost of the 4 stars in the cut-off position.			
2 Taurus	1061	The one after.			
3 Taurus	1038	The one after this also.			
4 Taurus	1030	The southernmost of the 4.			
5 Taurus	1174	The one on the rear of these, on the right shoulder blade.			
6 Taurus	1239	The star in the chest.			
7 Taurus	1320	The star in the right knee.			
8 Taurus	1251	The star on the right hock.			
9 Taurus	1473	The star on the left knee.			
10 Taurus	1458	The star on the left lower leg.			
11 Taurus	1346	The star on the nostrils in the face looks like the letter (Δ) *Dāl* from the books of the Greeks.		Hyadum I	
12 Taurus	1373	The one between this and the northern eye.		Hyadum II	
13 Taurus	1411	The one between it and the southern eye.			
14 Taurus	1457	The bright star the reddish one of the letter (Δ) *al-Dāl* on the southern eye and it is *Aldebaran.*	*al-Dabarān or Ain al-Thawr*	Aldebaran	Cor Tauri, Parilicium
15 Taurus	1409	The remaining one on the northern eye.		Ain	
16 Taurus	1547	The star on the place where the southern horn and the ear join the head.			

17 Taurus	1656	The southernmost of the 2 stars in the southern horn			
18 Taurus	1658	The northernmost of these			
19 Taurus	1910	The star on the tip of the southern horn			
20 Taurus	1497	The star on the northern horn triangle.			
Ptolemy 21 not included in al-Ṣūfī		"The star on the tip of the northern horn is the same star as the one on right leg of the constellation Auriga."			
21 Taurus (=Ptolemy 22)	1392	The northernmost of the 2 stars close together in the northern ear.	*al-Kalbain*		
22 Taurus	1387	The southern of them. The latitude as seen in the sky should be 00 00.	*al-Kalbain*		
23 Taurus	1256	The more advanced of the 2 small stars in the neck.			
24 Taurus	1329	The rearmost of them. Its latitude should be southerly because in the sky it is so.			
25 Taurus	1287	The quadrilateral in the neck, the southernmost star on the advanced side.			
26 Taurus	1269	The northernmost star on the advanced side.			
27 Taurus	1369	The southernmost star on the rear side.			
28 Taurus	1348	The northernmost one on the rear side.			
29 Taurus	1145	The Pleiades: the northern end of the advanced side.			Taygeta
30 Taurus	1156	The southern end of the advanced side.			Merope
31 Taurus	1178	The rearmost and narrowest end of the Pleiades.			Atlas
32 Taurus	1188	The small star outside the Pleiades towards the north.			
33 Taurus	1101	The star under the right foot and the shoulder blade.			
34 Taurus	1620	The most advanced of the 3 stars over the southern horn.			
35 Taurus	1739	The middle one of the three.			
36 Taurus	1810	The rearmost of them			
37 Taurus	1946	The northernmost of the 2 stars under the southern tip of the southern horn.			
38 Taurus	1985	The southernmost of them.			
39 Taurus	1875	The most advanced of the 5			

		stars under the northern horn.			
40 Taurus	1928	The one to the rear of this.			
41 Taurus	2002	The one to the rear again of the latter.			
42 Taurus	2034	The northernmost of the remaining rearmost 2.			
43 Taurus	2084	The southernmost of these two.			

5.13.2 The Explanation of '*al-Ḍayīqa'*.

At the end of this chapter on the constellation Taurus, al-Ṣūfī wrote about a location in the sky that the Arabs called *al-Ḍayīqa* which means 'the small gap' in Arabic. He dedicated almost two pages on this topic which might seem from first sight that it is a very important topic in traditional Arabic astronomy. However I believe that there are many astronomical concepts that the author tried to explain using this topic as an example in order confirm his scientific capability. The case below is an exercise in the idea 'Oblique Ascensions' which was a well-known concept in ancient and classical Greek astronomy. Therefore I will try here to analyze al-Ṣūfī's comments in order to identify some of these scientific astronomical ideas.

Al-Ṣūfī started by explaining that there are two close stars on the northern ear, and these stars are the twenty-first (HR1392) and the twenty-second (HR1387) which were called *al-Kalbain* (the two dogs). He then states that many Arab scholars narrate that these two stars are called *al-Ḍayīqa* because they believed that when the Moon slows down it stays in that location. However, he completely rejects this idea and states that this is wrong. He then explains in detail the reason why by saying that: "… the stars of *al-Thurayyā* are fifteen degrees of Taurus and these two stars are twenty-four and a half degrees of it. The distance between them and *al-Thurayyā* is nine degrees and the least amount the Moon travels in one day and one night when its is moving slowest and its most distance (from the Earth), is eleven degrees." Here we have several ideas which need further explanation. The Moon could not travel from *al-Thurayyā* directly to these two stars in the same or next day even when it is in its slowest and further orbit from the Earth. By this picture al-Ṣūfī explains several facts about the path and orbit of the Moon. First is that path of the Moon can be higher than the ecliptic. In the comments about the constellation Scorpio he explains that it is can reach up to five degrees further then the ecliptic. The other idea is that the orbit of the Moon is variable and the least amount the Moon travels in one day is eleven degrees. As al-Ṣūfī's work was based on Ptolemy's then it is safe to assume that he was well aware of the Ptolemy's epicycle and deferent system and the concept of the variable distance of the Earth and the Moon and the variable apparent speed of the Moon as well as the concept of the ‘Oblique Ascensions’. As we can see in Figure 57, which shows Ptolemy’s epicycle and deferent system, it is clear that the Moon-Earth distance varies depending on the time and position of the Moon in epicycle.

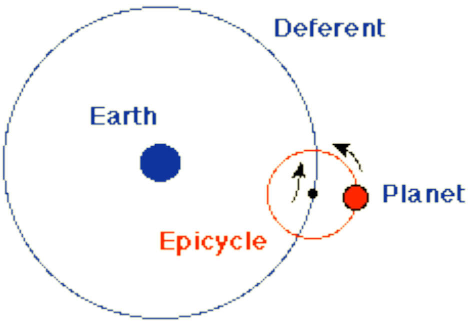
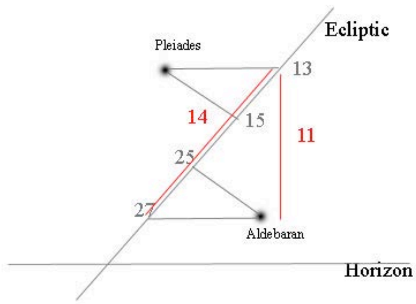
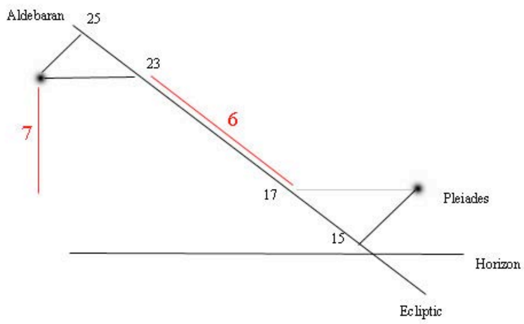


Figure 57 Ptolemy’s epicycle and deferent system

Next al-Ṣūfī explains that *al-Ḍayīqa* is the area or gap between *al-Thurayyā* and *al-dabarān* and not the two stars. He further explains that because the Arabs use *al-Anwā’* folk tradition this is why this area was called *al-Ḍayīqa.* Al-Ṣūfī explains that *al-Anwā’ or Naw’* “… is when a star sets in the west at dawn and when its *Raqīb* [companion star] rises in the east from under the light [of the Sun]. The *Raqīb* of each one is the fifteenth star [of the lunar mansions].” The *Naw’* of a star had been an area of controversy between Arab scholars on whether it is the rise or fall of a star. However, al-Ṣūfī here confirms that the *Naw’* of a star is not the rise but the fall of a star in the west at dawn. (Further explanations on *al-Anwā’* and lunar mansions are to be in the chapter on Arabic Folk astronomy)

Al-Ṣūfī then tries to go into detail on why this area or gap was called thus. His explanation is quite clear where he says that: “The middle of *al-Thurayyā* is on the fifteen degrees of Taurus and al-dabarān is on the twenty five degree of it. The distance on the degrees of the zodiac between them is ten degrees. However the latitude of *al-Thurayyā* in the north from its (zodiac) degrees is four degrees and few minutes. And the latitude of al-dabarān in the south is five degrees. And it is in the nature of the northern stars to rise before their (zodiac) degree rise and set after their (zodiac) degrees set, and the southern (stars) rise after their (zodiac) degree rise and set before their (zodiac) degrees set. Therefore *al-Thurayyā* approximately rises at thirteen degrees of Taurus and al-dabarān rises at twenty seven of it. Thereby the degrees between the rise of *al-Thurayyā* and al-dabarān are approximately fourteen degrees of the degrees of the zodiac and eleven degrees and a few minutes from the horizon in this third zone. And *al-Thurayyā* sets at seventeen degrees of Taurus because it sets after its zodiac degree. And al-dabarān sets at twenty three degrees of it because it sets before its zodiac degrees. Thereby the degrees between the setting of *al-Thurayyā* and al-dabarān are six degrees of the degrees of the zodiac and seven degrees from the horizon in this zone. The degrees of Taurus sets at the same time as the degrees of Scorpio rise. When they found between the setting of *al-Thurayyā* and al-dabarān this amount they called this gap between them *al-Ḍayīqa."* I have made below two diagrams in order to help explain the concept of the 'Oblique Ascensions' and what al-Ṣūfī was trying to convey. The first is Figure 58 shows the position and rising of *al-Thurayyā* and al-dabarān on May 13 at dawn in the east at the time of al-Ṣūfī. The second is Figure 59 shows the position and setting of *al-Thurayyā* and al-dabarān on November 13 at dawn in the west at the time of al-Ṣūfī. This is the *Naw'* of the *al-Thurayyā* and al-dabarān. We can see from below that because the Arabs considered the *Naw'* of a star as the setting at dawn and that the distance from the horizon between *al-Thurayyā* and al-dabarān is small (only 7 degrees) then they called this small gap *al-Ḍayīqa* which means 'the small or narrow gap' in Arabic. This is one important examples in which al-Sufi was trying to combine Greek astronomy with Arabic traditional astronomy.

 Rising of the Pleiades and Aldebaran at dawn from the East on May 13	 Setting of the Pleiades and Aldebaran at dawn in the west on Nov 13
Figure 58: The Rising of *al-Thurayyā* and al-dabarān on May 13	Figure 59: The Setting of *al-Thurayyā* and al-dabarān on November 13

One last idea which al-Ṣūfī mentioned in this section is the Third Zone. This was the concept of dividing the Earth into climes or zones which were called *clima*, plural *climata or klimata* which in Greek means 'inclination'. However there seems to have been some dispute among ancient Greek scholars as to the exact number or arrangement of these zones. According to Strabo the concept of the division of the Earth into zones began as early as the 6th century B.C. with a Greek scholar named Permenides of Elea. The number of zones accepted by Strabo was five, and he criticizes another scholar Polybius for making the number six. The five zones accepted by Strabo were as follows: the uninhabitable Torrid Zone lying in the region of the equator; a zone on either side of this extending to the tropic; and then the temperate zones extending in either direction from the tropic to the arctic regions. However Ptolemy in his *Geography* divided the northern temperate zone into seven zones. This division in seven zones may go back to notions of geography predating the idea of a spherical Earth introduced by Pythagoras in the 6th century BC. Medieval Arabs and Persian scholars such as al-Bīrūnī, al-Idrīsī as well as al-Ṣūfī adopted Ptolemy's system of seven climes and divided the latitudes of the Earth into seven habitable zones starting from the equator. According to al-Bīrūnī the third zone is from latitude 27 to 33 degrees hence the middle of this zone is at latitude 30 deg. Therefore, according to al-Ṣūfī's comments these observations have been made in the third zone, most probably in the city of Shiraz (Latitude: 29.53. Longitude: 52.58). This confirms the historical record which mentions that al-Ṣūfī has conducted his astronomical observations or maybe constructed an observatory in Shiraz.

5.13.3 Modern Star chart of Taurus constellation

Figure 60 below is a modern Star chart of Constellation Taurus. The stars indicated in red are the stars according to al-Ṣūfī's star number. The stars indicated in green are the stars mentioned by al-Ṣūfī in his comments but not included in the charts nor are included in Ptolemy. There was no place to include the star's modern name or the HR number for every star in this constellation, therefore I only included al-Ṣūfī star numbers where the details can be found in the above comments. The software used to generate above chart is Cartes du Ciel version 2.76.

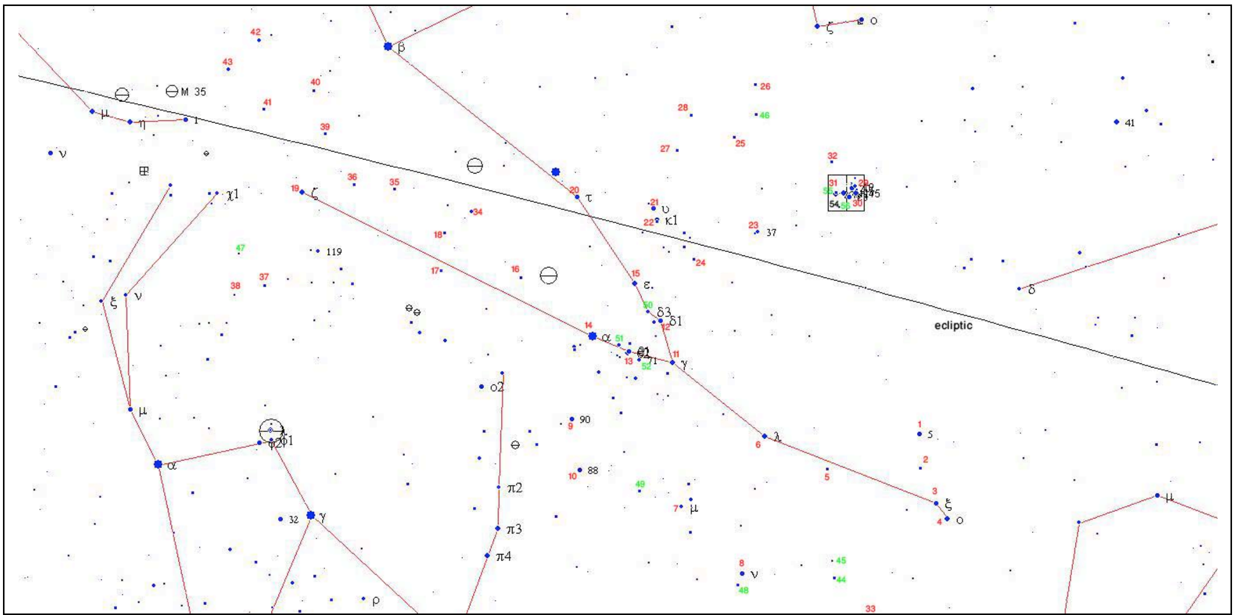


Figure 60: Modern Star Chart of Taurus Constellation

5.14 Comments on the Chapter of the Constellation Scorpio

5.14.1 Star Names and Modern Designations of the Stars

I have included below in Table 28 all the stars that are included in al-Ṣūfī's star tables for constellation Scorpio. I have also included the HR, numbers so each star can be correctly identified. The stars identifications are according to Toomer's book. I also tabulated below the names of the stars according to the Arabic tradition and according to what was described by al-Ṣūfī, together with the modern star names and any other common name.

Table 28: Star Names and Modern Designations of the Stars for Scorpio

Star number (as per al-Ṣūfī)	HR	Star name and description (as per al-Ṣūfī)	Star name/s in Arabic tradition	Modern star name/s	Other star name/s
1 Scorpio	5984	The northernmost of the 3 bright stars on the forehead.	*al-Iklīl*	Graffias	Grafias, Grassias, Acrab, Akrab, Elacrab
2 Scorpio	5953	The middle one of these.	*al-Iklīl*	Dschubba	Iclarkrau
3 Scorpio	5944	The southernmost of the three.	*al-Iklīl*		
4 Scorpio	5928	The star south again of this on one of the legs.			
5 Scorpio	6027	The southernmost of the 2 stars adjacent to the northernmost of the three bright one.		Jabbah	
6 Scorpio	5993	The southernmost of these.			
7 Scorpio	6084	The most advanced of the 3 bright stars in the body.	*al-Nīyāṭ*	Alniyat	
8 Scorpio	6134	The middle one of these which is reddish and called *Qalb al-'Aqrab* (Antares).	*-al-Qalb (the heart)* *-Qalb al-'Aqrab*	Antares	Cor Scorpii, Qalb al Aqrab, Vespertilio
9 Scorpio	6165	The rearmost of the 3.	*al-Nīyāṭ*		
10 Scorpio	6028	The advanced star of the 2 under these approximately on the last leg.			
11 Scorpio	6070	The rearmost of these.			
12 Scorpio	6241	The star in the first tail joint from the body.	*al-Fiqra*		
13 Scorpio	6247	The one after this in the 2nd joint.	*al-Fiqra*		
14 Scorpio	6262	The northern star of al-*Muḍ'af* (the double star) in the 3rd joint.	*al-Fiqra*		
15 Scorpio	6271	The southern star of the double star.	*al-Fiqra*		
16 Scorpio	6380	The one following in the 4th joint.	*al-Fiqra*		

17 Scorpio	6553	The one after that in the 5th joint.	*al-Fiqra*	Sargas	
18 Scorpio	6615	The next one again in the 6th joint.	*al-Fiqra*		
19 Scorpio	6580	The star in the 7th joint the joint next to the sting.	*al-Fiqra*		
20 Scorpio	6527	The rearmost of the 2 stars in the sting.	*-al-Shawla (the sting)* *-Shawlat al-'Aqrab* *-Shawlat al-Sura* *-al-Ibra*	Shaula	
21 Scorpio	6508	The more advanced of these.	*-al-Shawla (the sting)* *-Shawlat al-'Aqrab* *-Shawlat al-Sura* *-al-Ibra*	Lesath	Lesuth
22 Scorpio	6475	The nebulous star to the rear of the sting.		M7	
23 Scorpio	6492	The most advanced of the 2 stars to the north of the sting.			
24 Scorpio	6616	The rearmost of them.			

5.14.2 Modern Star Chart of Constellation Scorpio

Figure 61 below is a modern Star chart of Constellation Scorpio. The stars indicated in red are the stars according to al-Ṣūfī's star number. The stars indicated in green are the stars mentioned by al-Ṣūfī in his comments but not included in the charts nor are included in Ptolemy. There was no place to include the star's modern name or the HR number for every star in this constellation, therefore I only included al-Ṣūfī star numbers where the details can be found in the above comments. The software used to generate above chart is Cartes du Ciel version 2.76.

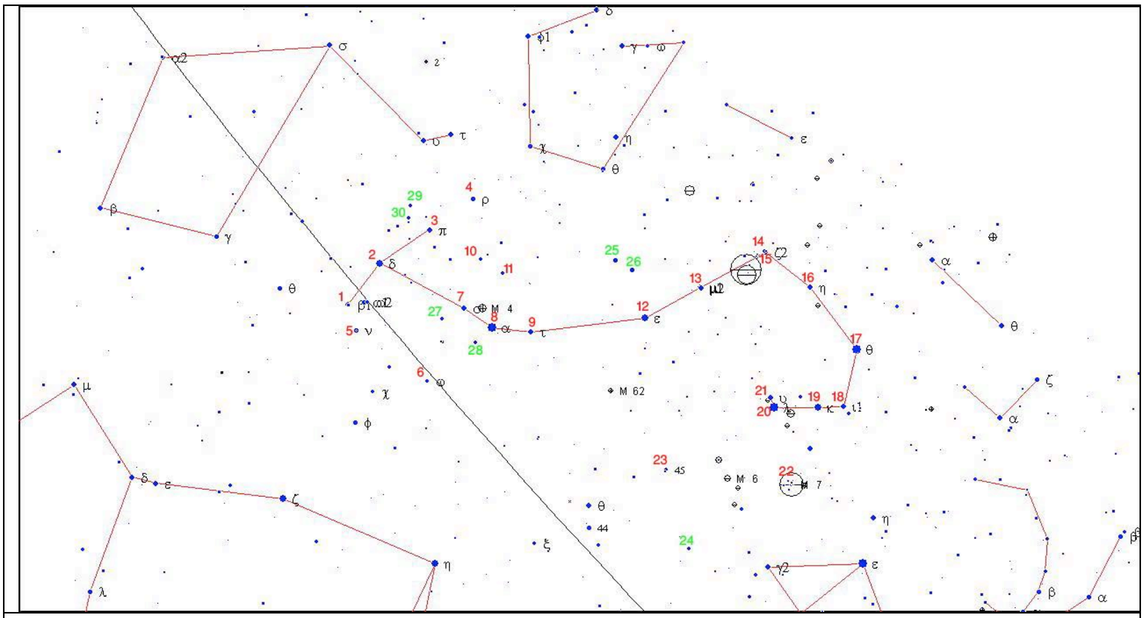


Figure 61: Modern Star Chart of Scorpio Constellation

5.15 Comments on the Chapter of the Constellation Orion

5.15.1 Star Names and Modern Designations of the Stars

I have included below in Table 29 all the stars that are included in al-Ṣūfī's star tables for constellation Scorpio. I have also included the HR, numbers so each star can be correctly identified. The stars identifications are according to Toomer's book. I also tabulated below the names of the stars according to the Arabic tradition and according to what was described by al-Ṣūfī, together with the modern star names and any other common name.

Table 29: Star Names and Modern Designations of the Stars for Orion

Star number (as per al-Ṣūfī)	HR	Star name and description (as per al-Ṣūfī)	Star name/s in Arabic tradition	Modern star name/s	Other star name/s
1 Orion	1879 1880 1876	The nebulous star in the head of Orion, which are the three close stars.	*-al-Haq'a* *-Haq'a al-Jauzā'* *- al-Taḥātī,* *-al-Taḥiyat* *- al-Taḥia* *- al-Athāfī*	Meissa	Heka
2 Orion	2061	The bright reddish star on the right shoulder.	*-Mankib al-Jauzā'* *-Yad al-Jauzā'* *-Mirzam al-Jauzā'*	Betelgeuse	Betelguex, Beteiguex, Betelgeuze, Al Mankib
3 Orion	1790	The star on the left shoulder.	*-al-Nājid* *-al-Mirzam*	Bellatrix	Amazon Star, the
4 Orion	1839	The one under this to the rear.			
5 Orion	2124	The star on the right elbow.			
6 Orion	2241	The star on the right forearm.			
7 Orion	2199	The quadrilateral in the right hand: The rear, double star on the southern side.			
8 Orion	2159	The advanced star on the southern side.			
9 Orion	2223	The rear one on the northern side.			
10 Orion	2198	The advanced one on the northern side			
11 Orion	2047	The more advanced of the 2 stars in the staff.			
12 Orion	2135	The rearmost of them.			

13 Orion	1934	The rearmost of the 4 stars almost on a straight line just over the back.			
14 Orion	1872	The one in advanced of this.			
15 Orion	1842	The one in advanced again of this.			
16 Orion	1811	The last and most advanced of the 4			
17 Orion	1676	The stars in the pelt on the left arm: The northernmost.	*-Tāj al-Jauzā* *-Dhawā'īb al-Jauzā'*		
18 Orion	1638	The 2nd from the northernmost.	*-Tāj al-Jauzā*		
19 Orion	1580	The 3rd from the northernmost.	*-Dhawā'īb al-Jauzā'*		
20 Orion	1570	The 4th from the northernmost.	*-Tāj al-Jauzā*		
21 Orion	1544	The 5th from the northernmost.	*-Dhawā'īb al-Jauzā'*		
22 Orion	1543	The 6th from the northernmost.	*-Tāj al-Jauzā*		
23 Orion	1552	The 7th from the northernmost.	*-Dhawā'īb al-Jauzā'*		
24 Orion	1567	The 8th from the northernmost.	*-Tāj al-Jauzā*		
25 Orion	1601	The last and the southernmost of those in the pelt.	*-Dhawā'īb al-Jauzā'*		
26 Orion	1852	The most advanced of the 3 stars on the belt.	*Minṭaqat al-Jauzā'*	Mintaka	
27 Orion	1903	The middle one.	*al-Niẓām* *al-Naẓm.* *Naẓm al-Jauzā'*	Alnilam	Alnihan, Alnitam
28 Orion	1948	The rearmost of the three.	*Niṭāq al-Jauzā'*	Alnitak	Alnitah
29 Orion	1788	The star near the handle of the sward.			
30 Orion	1892	The northernmost of the 3 stars joined together at the tip of the dagger.	*al-Laqaṭ* *Saif al-Jabbār*		
31 Orion	1897	The middle one.	*al-Laqaṭ* *Saif al-Jabbār*		
32 Orion	1899	The southernmost of the three.	*al-Laqaṭ* *Saif al-Jabbār*	Nair al Saif	Hatysa in Becvar
33 Orion	1937	The rearmost of the 2 stars under the tip of the sward.			

34 Orion	1855	The more advanced of them.		Thabit	Tabit
35 Orion	1713	The bright star in the left foot, which is (applied in) common to the water (of Eridanus).	*-Rijl al-Jauzā'* *-Rā'ī al-Jauzā'* *-al-Nājid*	Rigel	Algebar, Elgebar
36 Orion	1735	The star to the north of it in the lower leg over the ankle-joint.			
37 Orion	1784	The star under the left heel outside.			
38 Orion	2004	The star under the right rear knee.		Saiph	

5.15.2 Modern Star Chart of Constellation Orion

Figure 62 below is a modern Star chart of Constellation Scorpio. The stars indicated in red are the stars according to al-Ṣūfī's star number. The stars indicated in green are the stars mentioned by al-Ṣūfī in his comments but not included in the charts nor are included in Ptolemy. There was no place to include the star's modern name or the HR number for every star in this constellation, therefore I only included al-Ṣūfī star numbers where the details can be found in the above comments. The software used to generate above chart is Cartes du Ciel version 2.76.

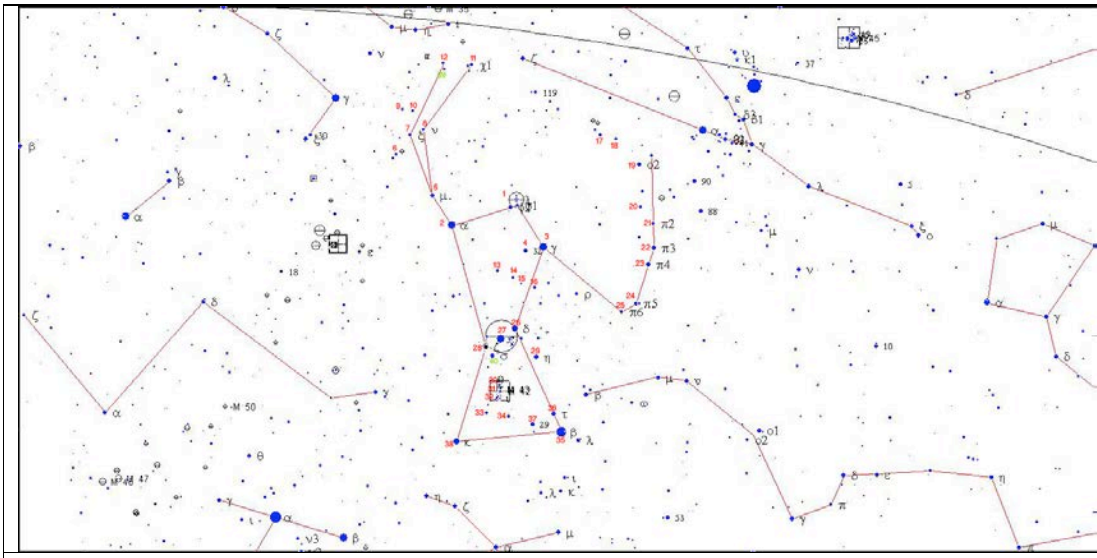


Figure 62: Modern Star Chart of Orion Constellation

5.16 Comments on the Chapter of the Constellation Centaurus:

5.16.1 Star names and modern designations of the stars:

I have included below in Table 30 all the stars that are included in al-Ṣūfī's star tables for constellation Scorpio. I have also included the HR, numbers so each star can be correctly identified. The stars identifications are according to Toomer's book. I also tabulated below the names of the stars according to the Arabic tradition and according to what was described by al-Ṣūfī, together with the modern star names and any other common name.

Table 30: Star Names and Modern Designations of the Stars for Centaurus

Star number (as per al-Ṣūfī)	HR	Star name and description (as per al-Ṣūfī)	Star name/s in Arabic tradition	Modern star name/s	Other star name/s
1 Centaurus	5192	The southernmost of the 4 stars in the head.			
2 Centaurus	5221	The northernmost of them.			
3 Centaurus	5168	The more advanced of the other, middle 2.			
4 Centaurus	5210	The rearmost of these, the last of the 4.			
5 Centaurus	5028	The star on the left advanced shoulder.			
6 Centaurus	5288	The star on the right shoulder.		Menkent	
7 Centaurus	5089	The star on the left shoulder-blade.			
8 Centaurus	5367	The four stare in the thyrsus. The northernmost of the advanced 2.			
9 Centaurus	5378	The southernmost of these.			
10 Centaurus	5485	The one of the other two which is at the tip of the thyrsus.			
11 Centaurus	5471	The last one south of the latter.			
12 Centaurus	5190	The most advanced of the 3 stars in the right side.			
13 Centaurus	5193	The middle one.			
14 Centaurus	5248	The rearmost of the three.			
15 Centaurus	5285	The star on the right upper arm.			
16	5440	The star on the right			

Centaurus		forearm.			
17 Centaurus	5576	The stars on the right hand.			
18 Centaurus	5231	The bright star in the place where the human body joins the horse.			
19 Centaurus	5260	The rearmost of the 2 faint stars to the north of this.			
20 Centaurus	5249	The more advanced of them.			
21 Centaurus	NGC 5139	The star on the place where the back joins the horse body.			
22 Centaurus	4940	The star in advanced of this on the horse back.			
23 Centaurus	4819	The rearmost of the stars on the rump.			
24 Centaurus	4802	The middle one.			
25 Centaurus	4743	The most advanced of the three.			
26 Centaurus	4621	The more advanced of the 2 stars close together on the right thigh.			
27 Centaurus	4638	The rearmost of them.			
28 Centaurus	5172	The star in the chest under the horse armpit.			
29 Centaurus	5132	The more advanced of the 2 stars under the belly.			
30 Centaurus	5141	The rearmost of them (Ptolemy) mentioned that it is of the 3rd magnitude however there is no star in this are which can be seen.			
31 Centaurus	4763	The star on the knee-bend of the right hind leg.		Gacrux	
32 Centaurus	4853	The star in the hock of the same leg.		Becrux	
33 Centaurus	4656	The star under the knee-bend of the left hind leg.			
34 Centaurus	4730	The star on the frog of the hoof on the same leg.		Acrux	
35 Centaurus	5459	The star on the end of the right front leg.	*Rijl Qanṭūris Ḥiḍār, Al-Wazn,*	Rigil Kentaurus	

			Muḥlifain, Muḥnithain,		
36 Centaurus	5267	The star on the knee of the left front leg.	*Hiḍār, Al-Wazn, Muḥlifain, Muḥnithain*	Agena	
37 Centaurus	4898	The star outside under the right hind leg.			

5.16.2 Modern Star Chart of Constellation Centaurus

Figure 63 below is a modern Star chart of Constellation Scorpio. The stars indicated in red are the stars according to al-Ṣūfī's star number. The stars indicated in green are the stars mentioned by al-Ṣūfī in his comments but not included in the charts nor are included in Ptolemy. There was no place to include the star's modern name or the HR number for every star in this constellation, therefore I only included al-Ṣūfī star numbers where the details can be found in the above comments. The software used to generate above chart is Cartes du Ciel version 2.76.

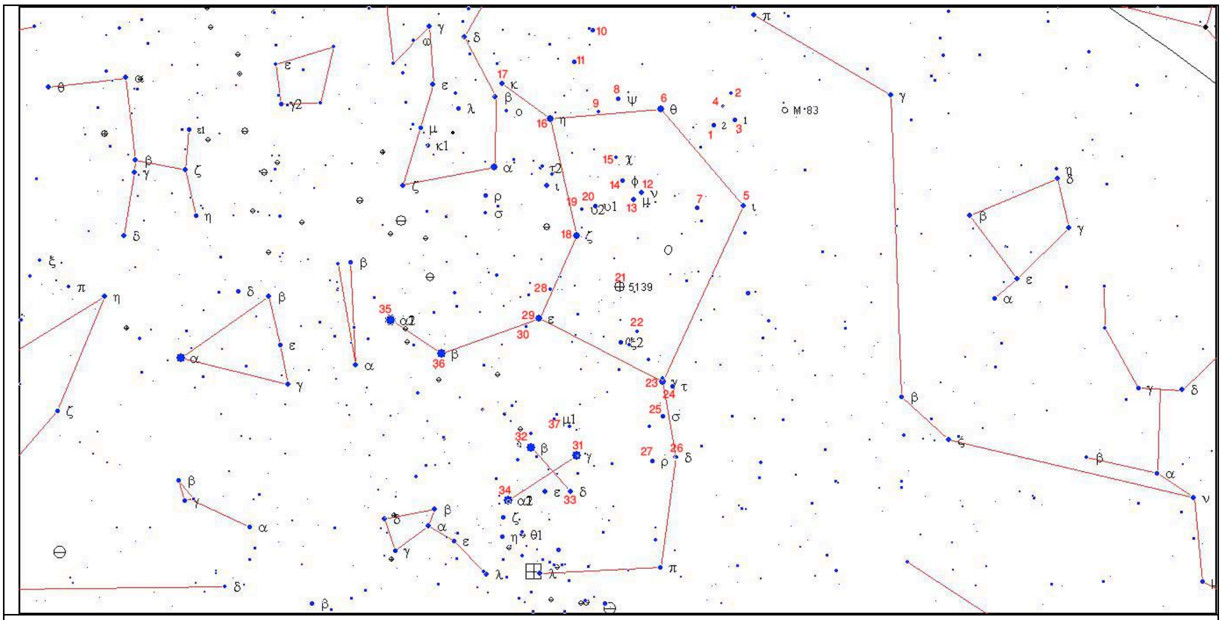


Figure 63: Modern Star Chart of Centaurus Constellation

6. Conclusion

Late one evening in the summer of A.D. 960 the 57 year old Persian astronomer ′Abd al-Raḥmān al-Ṣūfī was in the presence of the Buwayhid ruler, ‘Aḍud al-Dawla in the city of Shiraz. He wrote that “The grand prince ‘Aḍud al-Dawla, was visited by a renowned scholar while I was in his presence. The prince asked the astronomer about some of the known stars in the sky…” To his surprise the scholar was not able to distinguish between these stars correctly. He continued:

> “…when I saw that all these people who were well known and are leaders in this science so that people follow them and use their books without knowing the right from wrong …I found in their books many errors especially in the books of *al-Anwā’* and the stories which they obtained from the Arabs …the lunar mansions and the rest of the stars …I wanted many times to reveal this and expose it but I either felt sluggish or I had many things which occupied me from this task until God honored me with serving the benevolent king ‘Aḍud al-Dawla. ”

How could ′Abd al-Raḥmān al-Ṣūfī know that his book which was completed four years later in A.D. 964 was to become one of the most important medieval Arabic treatises in astronomy? This book was *Ṣuwar al-Kawākib al-Thamāniyah wa-al-Ārba'een* which was later known as *The Book of the Fixed Stars*. As we have seen in this study, this major work contained an extensive star catalogue, which lists star coordinates and magnitude estimates, as well as detailed star charts. It also included other topics such as the descriptions of stars, nebulae, and a good summary on old Arabic folk astronomy. My journey to discover this book has been as fascinating as the results, which came out of this effort.

I have begun this study by giving a general account on the key elements of Arabic and Islamic astronomy. I started the first chapter of this study with the history of ancient astronomy going on to the development of Babylonian astronomy. Then I made a brief description on the contribution of Greek astronomers leading up to Arabic and Islamic Astronomy. I also gave a general description on the Greek cosmological concept of the geocentric universe and the development of the Ptolemaic system with Deferent and Epicycle. Then I gave a brief history of the Arabic and Islamic empire from its early start to its golden age, as well as the main events, which shaped the development of science and astronomy during that time.

However in order to understand al-Ṣūfī's work it was important to understand some of the general characteristics of Arabic and Islamic astronomy. I started chapter 2.2 by giving a brief background on the religion of Islam and its contribution to the development of science and Astronomy. The effect of this religion was evident in al-Ṣūfī's work as well as in many other works during that period. The Greek cosmological geocentric model, where by the Earth is a sphere which lies at the center of a spherical heaven, was accepted as correct for over a thousand years by almost all Arabic and Islamic astronomers. The culmination of the Arab and Islamic science of astronomy was in the development of the astronomical tradition called *al-Zīj*. These were astronomical tables based on trigonometric and mathematical techniques. In this chapter I included a general account on observatories and astronomical instruments, which were used by al-Ṣūfī as well as by many other Arab astronomers of his time.

The third chapter of this section deals with old Arabic astronomical tradition. The lunar astronomical tradition was an important tool used by these old Arabs. This was merged with a form of astrological-meteorological experience that came to be known as the *Anwā'*. This system was used to predict the weather and to identify the beginning of the seasons in order to specify the dates of festivals, holidays, pilgrimage and the best times for traveling and commerce. In order to systemize this lunar motion, the Arabs divided the apparent path of the Moon in the sky into 28 divisions. These 28 divisions are called "*Manāzil al-Qamar*" or the Lunar Mansions.

The final chapter in part 2 of this thesis is a brief study on Ptolemy and his book called the *Almagest* which is a mathematical as well as an astronomical treatise, detailing the motions of the Stars, the Sun, the Moon and the five known planets at that time. The *Almagest* includes a catalog with descriptions, positions and magnitudes for 1022 stars grouped into 48 constellations for the epoch of A.D. 137. This work became the standard star catalogue used in the Western, Arab and Islamic worlds for over a thousand years.

In Part 3 of this thesis I started the first chapter with a brief biography on ′Abd al-Raḥmān al-Ṣūfī. However I was surprised that very little was known about al-Ṣūfī's life and career. From several important Arabic historical references I found that al-Ṣūfī's full name was: Abd al-Raḥmān, Ibn 'Umar, Ibn Muḥammad, Ibn Sahl, al-Rāzī, known as Abū al-Ḥusaīn al-Ṣūfī. I also found that al-Ṣūfī was born on Saturday the 14th of Muharram in the year A.H. 291 which corresponds to the 6th of December in 903. He died on Tuesday the 13th of Muharram in the year A.H. 376 which corresponds to 25th of May 986. I have also deduced several facts on al-Ṣūfī's life such as: The title of "*al-Rāzī*" which meant that he is from the city of *Rayy*, south east of the modern city of Tehran. Al-Ṣūfī was also a Persian not an Arab even though he wrote all his works in Arabic. The location of his death in not known, but most probably it was in Shiraz. From the introductory chapter of his work we know that he lived most of his life between the provinces of Rayy and Fars and in the cities of Rayy, Isfahan and Shiraz. In his work al-Ṣūfī wrote that he made his observations in Shiraz where he established his observatory. He also wrote that he visited Daīnawar, which is the home of the famous scholar and astronomer Abu Ḥanīfa al-Daīnawari. He also visited Isfahan to research a celestial globe constructed by another important astronomer of that period.

In this chapter I made a brief study on the political and social background of this period in order to understand the impact of the events which helped mould the life of our author. Al-Ṣūfī was born in the beginning of the 10^{th} century. From the time line of al-Ṣūfī's life we saw that he lived throughout most of the rule of the *Buwayhid* rulers. However the most significant scientific contributions of al-Ṣūfī were made during the reign of 'Aḍud al-Dawla who was one of the strongest of these rulers. The *Book of the fixed stars* was dedicated to 'Aḍud al-Dawla. However al-Ṣūfī also dedicated other books to other members of the *Buwayhid* dynasty. The title of *Ṣūfī* signifies that this person was part of an Islamic religious order. Since al-Ṣūfī was given this religious honorary title then we assume that he must have been influenced by such *Ṣūfī* movements during his time.

In his book al-Ṣūfī mentioned several important individuals. He also mentioned some of their works, which he commented upon and sometimes criticized in the introductory chapter of his work. The main person who was mentioned by al-Ṣūfī was of course Ptolemy. Al-Ṣūfī refers to Ptolemy 119 times in his Book. The other two main characters, which were frequently mentioned in al-Ṣūfī's work, were al-Battānī and Abu Ḥanīfa al-Daīnawari. Al-Ṣūfī criticized al-Battānī by stating that his star catalog is but a copy of Ptolemy's *Almagest* only with the correction for Precession. As for Abu Ḥanīfa al-Daīnawari he was another famous Persian scholar of the 10^{th} century. Al-Ṣūfī considered al-Daīnawari's work on Arabic Astronomical Tradition, called (*Kitab al-Anwā'*) or the *Book on Anwā'* to be the best written book on this subject. However al-Ṣūfī again criticized al-Daīnawari for his knowledge of the stars and their movements. In the second chapter 3.2 of this thesis I made a brief biographical study on all those individuals who were mentioned in al-Ṣūfī's book.

In chapter 3.3 I made a brief survey on all the works which were known to have been written by al-Ṣūfī. The first is, the *Book of the Fixed Stars,* which was al-Ṣūfī's most famous work and the topic of this study. The second is *Kitāb al-Urjūza fi al-Kawākib al-Thābitah Muṣawaran.* This is a Poem on the fixed stars. Some historians attributed this poem to al-Ṣūfī however this poem was probably written by al-Ṣūfī's son and not by al-Ṣūfī himself. Then we have *Kitāb al-Tathkira wa Matāreh al-Shu'a'* or *The Book of Information and Projection of the Rays*. Unfortunately it is no longer extant today. Al-Ṣūfī also wrote *Kitāb al-Madkhal Fi 'Ilm al-Āḥkām* (*Introductory Book to the Science of Astrology*), *Fi Sharḥ al-'Amal bi al-Kura* (*On the Explanation of the Use of the Celestial Globe*) and *Kitāb al-'Amal bi al-Isṭerlāb* (Book on using the Astrolabe). Finally there is *al-Zīj al-Ṣūfī.* This *Zīj* was mentioned by several important Arabic astronomers such as Ibn Yūnus in Cairo and Ibn-Ezra. Unfortunately it is also no longer extant.

Al-Ṣūfī mentioned in his Book that the observations he made were from the city of Shiraz, which is located south of Iran (Latitude: 29:53 and Longitude: 52:58). Al-Ṣūfī mentioned that the instrument, which was utilized for his observations, was an equatorial ring with a diameter of 250 cm, having a 5 min subdivision on its scale. This instrument was considerable in size and was thus called the *Aḍudi* Ring after the ruler Aḍud al-Dawla. He mentioned that it was used to determine the latitude of the city of Shiraz to be: 29 deg and 36 min. One of the Arabic historical references mentions that in 1043 there used to be in the Cairo library a celestial globe made of silver that was constructed by al-Ṣūfī for Aḍud al-Dawla. The weight of this globe was three hundred *dirhams* and it was purchased for three thousand *dinars*. Unfortunately this instrument is no longer available today. From the few available treaties written by al-Ṣūfī on the Astrolabe and the celestial Globe and from the available historical records, we know that al-Ṣūfī measured the obliquity of the ecliptic from the year A.D. 965 until A.D. 970 and located the vernal and the autumnal equinoxes and used several observational instruments such as a Sundial, a Quadrant, an Astrolabe, a Celestial Globe, and most probably different sizes of Rings such as the *Aḍudi* Ring. In chapter 3.4 of I tried to collect all references found in many Arabic historical references that were related to these instruments and the observatory in Shiraz

Many scientists and astronomers have based their astronomical observations on al-Ṣūfī's work. Through out history al-Ṣūfī's name was sometimes miss-spelled or miss-written. He has been named Esophi by Leo Africanus and Azophi by the Spanish Jewish astronomer Ibn Ezra. He was again mentioned by the name Azophi by the 16th century European map makers Albrecht Durer and by Peter Apian. In chapter 3.5 of this thesis, I tried to list some of the most important scholars and astronomers who have made use of al-Ṣūfī's work starting from al-Bīrūnī in the 11th centaury up to the beginning of the 20th century. Finally in the last chapter of this section I included a brief description on the crater on the Moon named Azophi and the main belt asteroid designated as "12621 al-Ṣūfī". I have identified this crater and included its picture as well as its coordinate and location on the Moon.

The main effort to revive the treasures hidden in al-Ṣūfī's book was in the translation of this work from Arabic to English. In part 4 of this thesis I started the translation with al-Ṣūfī's introductory chapter. This chapter is a very important part of his work. Al-Ṣūfī starts his introduction with the usual praise to God and prophet Muḥammad. He then divides those who are interested in learning of the stars into two groups. The first group includes the actual astronomers, which he called *al-Munajjimīn*. The other groups are those who study the Arabic *Anwā'* tradition. In this introductory chapter al-Ṣūfī criticizes the work of al-Battānī. He begins by praising al-Daīnawari's book on *Anwā'* then ends up with criticizing his knowledge on the stars. He writes about the reason he wrote his book and dedicates it to Aḍud al-Dawla. He explains the methods he used in calculating precession. Finally he explains why he made dual charts for the constellation and the method of using these charts. In this forth part of this thesis I tried to translate the main introductory chapter, the whole star catalog for the entire 48 constellations, as well as six complete constellation chapters of al-Ṣūfī's work. These constellations chapters are: Ursa Minor and Ursa Major of the Northern Constellations, Taurus and Scorpio of the Zodiac Constellations and Orion and Centaurus of the Southern Constellations. As I mentioned before that I did not translate all the constellation chapters of al-Ṣūfī's work because that would be beyond the scope of this thesis.

Before I started with the detailed study of al-Ṣūfī's work, and the complete English translation I had to identify the extant manuscripts of the *Book of the Fixed Stars*. There are many manuscripts that are still preserved in libraries throughout the world. Tracking of these manuscripts involved extensive travel worldwide and much library research. However, I managed to locate as many as 35 manuscripts and acquired copies of the major ones, which I needed for this study. I started the first chapter in part 5 of this thesis by listing all the existing manuscripts of al-Ṣūfī's work that I could find. I grouped these manuscripts by country or location of library they are being kept. Unfortunately not many manuscripts could be used for this study. I put several criteria that I used to choose the most suitable manuscript for the translation. The two main manuscripts which I identified to be the bases of the translation and discussion were the manuscript Marsh144 and MS5036. The Marsh144 manuscript is the earliest manuscript of the *Book of the Fixed Stars*. It is dated to 1009 only 23 years after al-Ṣūfī's death. This manuscript was actually copied by the authors' son himself. It is now located at the Bodleian library in Oxford. I managed to acquire a copy of this manuscript for this study and I used this as the bases of the English translation. The other manuscript is MS5036 which is found at the national library in Paris. It is dated to 1430. Even though this manuscript was written much later, however it is a much better written copy. Therefore in the translation I have relied on this manuscript whenever anything was not clear in manuscript Marsh144.

The study and analysis of al-Ṣūfī's book begins in the chapter 5.2 of this section of this thesis. It begins with the description of the structure of the book and the layout of the constellation chapters. Following that chapter 5.3 describes another important aspects of this study, which are the charts or the maps. One of al-Ṣūfī's innovations in charting the stars was the production of dual illustrations of each of Ptolemy's constellations: One illustration was as portrayed on a celestial globe, the other illustration as viewed directly in the night sky. These were considered a unique feature of al-Ṣūfī's work. Since al-Ṣūfī's work was based on Ptolemy's *Almagest* therefore most of the rendering of the constellation figures resemble classical style figures. However some of the figures have undergone a process of Orientalization as a result of misunderstanding of some of the Greek mythology figures as well as copyist errors in some versions of the *Almagest.* The other diversion from classical style constellation was also due to influence of the *Anwā'* tradition which al-Ṣūfī was very much interested in. An example of such addition is to be found in the constellations Andromeda. Al-Ṣūfī makes two additional illustrations for this constellation. The first is the figure of Andromeda with a fish covering her legs. The second is with two fishes covering her body. Some of the constellations in the Marsh144 manuscript were also influenced by another period in history which is found in the Art of the *Sassanid* era. An example of such *Sassanid* influence can be found in the illustration of the flying wings of Pegasus which resembles *Simurgh* the *Sassanian* mythical flying creature. Another interesting constellation to note is the constellation Lyra meaning the "Harp". Al-Ṣūfī gave several other names for this constellation which were based on the *Anwā'* tradition. Among these names was *al-Wazza* meaning the "Goose" and *al-Sulaḥfāt*, which is a "tortoise". The Marsh144 manuscript depicts this constellation as a kind of harp. However al-Ṣūfī mentioned that in many eastern works Lyra was illustrated as a *Sulaḥfāt* or a tortoise. In later western illustration this constellation was rendered as a harp superimposed on the image of the goose. Such an illustration can be found in Andreas Cellarius' stellar catalogue published in 1660 and in Johann Hevelius' *Uranographia* printed in 1690.

For the epoch of his catalog al-Ṣūfī adopted the beginning of the year 1276 of the era of Alexander the great (or *Thu al-Qarnain*) which corresponds to the year A.D. 964. However al-Ṣūfī mentioned that "Ptolemy used the observations of *Menelaus'* who made his observations in the year 845 of the year of *Naboukhat Nassar*. Al-Ṣūfī also mentioned that: "The time difference between the observations of *Menelaus* and the date of Ptolemy is 41 years". He concluded that Ptolemy added 25 minutes on *Menelaus* longitude values to account for precession. However it is still unknown why al-Ṣūfī refers to this fact because at this time there is no evidence or available text that mentions that Ptolemy used *Menelaus* observations other than al-Ṣūfī's claim. At the end of al-Ṣūfī's introductory chapter he described in detail the method he used in constructing his catalog especially in calculating precession. For his epoch of A.D. 964 he applied the most accurate Arabic precession constant at that time of 1 deg in 66 years rather than the correct value of 1 deg in 71.2 years, thereby adding 12 degrees 42 minutes on Ptolemy's longitude value to allow for precession. Over the 839 years between the tables of Ptolemy and al-Ṣūfī, precession would actually amount to 11 deg 47 min. Hence by using 12 deg 42 min, al-Ṣūfī over-corrected Ptolemy's stellar longitudes by 55 min. I started chapter 5.4 of this section with a brief analysis on the star coordinates in al-Ṣūfī's book before starting the magnitude analysis. Al-Ṣūfī and Ptolemy both added intermediate values to the magnitude class system for some stars. Ptolemy mentioned the words "more-bright" and "less-bright" for certain stars. However al-Ṣūfī expressed these intermediate magnitude values by the words "*Aṣghareh*" which means "less" or "*Akbareh*" which means "greater" and "*A'ẓameh*" which means "much-greater". Most scholars who studied al-Ṣūfī's work did not differentiate between the two words *Akbareh* and *A'ẓameh.* However when I looked at al-Ṣūfī's text in detail it was evident to me that he made a clear distinction between three intermediate magnitudes. I believe that al-Ṣūfī used what I have termed a 3-step intermediate magnitude system, which was more accurate than Ptolemy 2-step intermediate system. I think that with this system al-Ṣūfī managed to express all magnitude values by a constant difference of 0.25. One of the main topics of this study was to research this 3-step intermediate magnitude system, which would shed new light on the accuracy and independence of al-Ṣūfī's work. I have made a complete analysis on al-Ṣūfī's magnitude values whereby the magnitude values were numerically interpreted by a constant difference of 0.25 magnitudes: that is "+0.25" for "less", "-0.25" for "greater" and "-0.5" for "much-greater". Ptolemy's 2-step intermediate magnitude difference was interpreted by a constant of (0.3) magnitude. After the data collection I conducted an accuracy analysis for the magnitudes of al-Ṣūfī and Ptolemy by calculating the difference between these values and the modern visual magnitudes in order to see if al-Ṣūfī had in mind a two-step or three-step magnitude systems. The statistical results showed that the Mean for the 3-step system is slightly better. The standard deviation is the same whether we apply the 3 or 2 step system whereas it is higher with Ptolemy. The dispersion in al-Ṣūfī's data is thus significantly less than in Ptolemy. Even though the statistical results for al-Ṣūfī values might not be entirely conclusive to some, however I still believe that al-Ṣūfī intended to use the 3-step system. The main reason for this assumption is in the way al-Ṣūfī expressed or described the values of the stellar magnitudes in his book. From the many descriptions of the magnitude values which are found in constellation commentaries we see that al-Ṣūfī made clear distinction between the words *Akbareh* and *A'ẓameh.* In many instances we see that he expressed the terms *Aṣghareh* or *Akbareh* consecutively. As for the term *Aṣghareh*, al-Ṣūfī only used this word to indicate the meaning of less. He mentioned *Aṣghareh* in many cases through out the work. Therefore from the literary analysis of al-Ṣūfī's work I had the impression that he was not really concerned with word repetition or correct sentence structure. If al-Ṣūfī was concerned with the correct grammatical structure or with word repetition then he would not have used the term *Aṣghareh* in all his work even though there are many other words in Arabic vocabulary, which could have been used instead. Whereas he deliberately switched between the other two terms *Akbareh* and *A'ẓameh.*

In his written comments on the constellations al-Ṣūfī mentioned many additional stars that were not included in Ptolemy's star catalog. However it is surprising that al-Ṣūfī did not include these stars in his tables even though he identified many of them in detail and described their magnitudes and he even estimated their locations. In many instances al-Ṣūfī mentions that in several areas of the sky there are many stars but he fails to mention a definite number because of their large numbers. In chapter 5.5 of this thesis I have identified to a total number of 134 of these additional stars; 65 were located in the Northern constellations, 41 in the Zodiac constellations and 28 in the Southern constellations.

There are very few records on the color of stars in ancient star catalogs. "Red" was the color that attracted the most attention while the other colors such as "white" or "blue" were rarely mentioned. Ptolemy gave the color "red" to six stars in his catalog. These stars were *Aldebaran*, *Arcturus*, *Betelgeuse*, *Pollux*, *Antares* and strangely enough *Sirius*. In the *Book of the Fixed Stars* al-Ṣūfī described seven stars with red color. These stars were *Aldebaran*, *Arcturus*, *Betelgeuse*, *Pollux*, *Alpha Hydrae*, *Algol* and *Antares*. However al-Ṣūfī stays silent about the color of *Sirius*. He only describes it as a bright star on the mouth called *al-Kalb* (Dog). In chapter 5.6 of this study I tried to give a brief summary on each of these eight stars along with what al-Ṣūfī mentioned about them. The colors of these stars were sometimes mentioned in the tables and other times in his comments on the constellations.

The Astrolabe is an ancient analog calculator. It was used for solving problems relating to the time and position of the Sun and stars in the sky. The Astrolabe is thought to be a Greek invention. The first person credited with constructing an Astrolabe in the Islamic world was the eighth century astronomer Muhammad al-Fazari. By the 9th century the Astrolabe was very much in use in the Arab and Islamic world. Al-Ṣūfī wrote extensively on the construction and use of the Astrolabe. In one of his treatises al-Ṣūfī described more than 1000 different uses for an Astrolabe in fields such as astronomy, astrology, timekeeping, navigation, construction and surveying. Al-Ṣūfī's *Book of the Fixed Stars* included 44 of these astrolabe stars. It was the best and most accurate of al-Ṣūfī's works. However al-Ṣūfī did not make a list of the Astrolabe stars but rather the information on these stars were scattered throughout the various sections of the book. In chapter 5.7 I identified all the Astrolabe stars found in al-Ṣūfī's book. I also included a brief summary on every one of these stars as they were mentioned by al-Ṣūfī. This summary included all the descriptions both from the tables as well as from the comments in the constellation chapters that mentioned these stars.

In his book al-Ṣūfī mentioned the presence of 'double stars' which he referred to as *Muḍ'af* stars. In many case he describes their location and magnitude. From al-Ṣūfī's description I managed to identify as many as 20 of these *Muḍ'af* stars. I also calculated the angular distance between these stars in order to identify the minimum angular distance which al-Ṣūfī managed to achieve. From the results of this survey the minimum angular separation for these *Muḍ'af* stars was achieved by the star HR7116 and star HR7120 with a separation of 0.23 degrees. In this part of the study I have also included the star Mizar. Next to Mizar is the star Alcor. The angular separation between these two stars is 0.20 degrees. However al-Ṣūfī did not refer to these two stars as *Muḍ'af* but he only mentioned that adjacent to Mizar is the star called *al-Suhā* (the neglected one). It was well known that the Arabs were able to separate these two stars long before the time of al-Ṣūfī.

The next chapter in this study describes the Nebulea in al-Ṣūfī's book. Al-Ṣūfī refers to these nebulae as *al-Laṭkhāt al-Saḥābiya* (the nebulous smear or smudge) and *al-Ishtibāk al-Saḥābi* (the nebulous mass). Al-Ṣūfī again identified the five nebulae, which Ptolemy mentioned before. However he goes further to describe 10 nebulae, which he himself observed or were previously identified by the Arabs. From al-Ṣūfī's description I tried to identify all 10 of these nebulae or galaxies found in the *Book of the Fixed Star*s. It is now a well-known fact that al-Ṣūfī mentioned for the first time in recorded history the location of the Andromeda galaxy or M31.

Al-Ṣūfī considered Arabic folk astronomy to be an important scientific field of study in its own right. He took upon himself to identify all the various names of stars, asterisms, mansions and constellations as per the method of the Arabs. He also tried to correct many of the mistakes, which were mentioned by previous authors on this subject such as al-Battānī and al-Daīnawari. In chapter 5.10 of this thesis I tabulated the names of stars and asterisms that have been used in Arabic folk astronomy according to al-Ṣūfī. This table included the star name, the Arabic name, the HR number as well as the explanation and comments for every one of these stars. However for length purposes I made this study for only 6 of the constellations, which are: Ursa Minor, Ursa Major, Taurus, Scorpio, Orion and Centaurus. This exercise was only to give an idea on the importance of this subject in al-Ṣūfī's book and the scope of information that is contained in each of the constellation chapters.

The last six chapters of the study of al-Ṣūfī's book are the comments on the Constellations: Ursa Minor, Ursa Major, Taurus, Scorpio, Orion, and Centaurus. In these 6 chapters I made a detailed list of all the stars mentioned by al-Ṣūfī. This included the stars descriptions, which were included in al-Ṣūfī's star tables as well as the commentaries. I also included the HR number so each star can be correctly identified. I have again included the star names according to the old Arabic tradition as mentioned in al-Ṣūfī's book as well as some of the names, which have been given to these stars through out history. In these chapters I have also included a modern Star map in order to identify all the stars that were mentioned by al-Ṣūfī in these chapters.

As we have seen in this study al-Ṣūfī's work has been translated and used by many astronomers throughout history starting from al-Bīrūnī in A.D. 1030, the authors of the Alfonsine tables in 1252, and the famous prince and astronomer Ulugh Bēg in 1437. Modern astronomers such as Ideler (1809) and Knobel (1917) also referred to his work. The last modern translation of al-Ṣūfī's work was done in French by Schjellerup in 1874. In his introduction to this translation Schjellerup mentioned that:

> "These facts give to the work of al-Ṣūfī an importance which cannot be denied. Now the time has come when it shall be the duty of the future generations to study the work of the learned astronomers of the Levant and to reveal their importance and to draw conclusions there from."

Following the instructions of important scholars such as Schjellerup and Kunitzsch, I began my own voyage of discovery, which started, with the translation of al-Ṣūfī's work from Arabic to English. To my knowledge, this was the first time that a major English translation of this book was attempted. In this study I tried to translate as accurately as possible the first introductory chapter, six of the major constellation chapters as well as all the star catalogue which is found in this book. Al-Ṣūfī's star catalog was mainly based on Ptolemy's classical work '*the Mathmatike Syntaxis*' which was later called the *Almagest* by the Arabs. As we have seen earlier, al-Ṣūfī updated Ptolemy's stellar longitudes by adding 12 degrees 42 minutes on Ptolemy's longitude value to allow for precession, as he explained in the introductory chapter of his book. He applied the precession constant of 1 deg in 66 years rather than the correct value of 1 deg in 71.2 years. However, it is in the star magnitudes where al-Ṣūfī distinguished himself. He corrected many of the values, which were mentioned in previous catalogues. My analysis in this regard showed that al-Ṣūfī was very accurate in his description of these stellar magnitudes. From the description of the stars which are to be found in each of the constellation chapters, al-Ṣūfī adopted a unique system in expressing these magnitudes which I termed ‘the 3-step magnitude system’. The analysis of this system revealed that it was slightly more accurate then the older ‘2-step system’ used by Ptolemy and others. From the various discussions on al-Ṣūfī’s *Book of the Fixed Stars*, this work had a very important place in the history of Arabic and Islamic observational astronomy. As Winter (1955) said: “al-Ṣūfī not only corrected observational errors in the works of his predecessors, like the famous Arab astronomer al-Battānī, but he also exposed many of the faulty observations found in the various versions of the *Almagest*. He carefully defined the boundaries of each constellation, and recorded magnitudes and positions of stars using new and independent observations he made himself.”

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8.1 Table of Coordinates, Magnitudes and Magnitude Analysis.

The first three columns of this table 31 show the number and the number sequence of the stars and constellations. The 4th to the 9th columns are the coordinated values according to al-Ṣūfī's tables. The 10th column (SM) shows the magnitudes of the stars according to al-Ṣūfī. The 11th (SM1) column shows the magnitudes after adjustment for the 3-step system and the 12th column (SM2) for the 2-step system. The 13th column (PM) shows the magnitude according to Ptolemy. The 14th column (PMA) shows Ptolemy's magnitudes after adjustment for the 2-step system. The 15th (VIS) and 16th (HR) columns show the modern visual magnitude and the HR number for each star.

Table 31: Table of Coordinates, Magnitudes and Magnitude Analysis

Seq	R.#	Constellation	Zodiac	Deg	min	D.	Lat	min	SM	SM1	SM2	PM	PMA	VIS	HR
1	1	UMi	2(60)	12	52	N	66	0	3	3.00	3.00	3	3.00	2.02	424
2	2	UMi	2(60)	15	12	N	70	0	4	4.00	4.00	4	4.00	4.36	6789
3	3	UMi	2(60)	28	42	N	74	0	4	4.00	4.00	4	4.00	4.23	6322
4	4	UMi	3(90)	12	22	N	75	40	4	4.00	4.00	4	4.00	4.32	5903
5	5	UMi	3(90)	16	22	N	77	40	5(k)	4.75	4.70	4	4.00	4.95	6116
6	6	UMi	3(90)	29	52	N	72	50	2	2.00	2.00	2	2.00	2.08	5563
7	7	UMi	4(120)	8	52	N	74	50	3	3.00	3.00	2	2.00	3.05	5735
8	8	UMi	4(90)	25	42	N	71	10	4	4.00	4.00	4	4.00	4.25	5430
1	9	UMa	3(90)	8	2	N	39	50	4	4.00	4.00	4	4.00	3.36	3323
2	10	UMa	3(90)	8	32	N	43	5	5	5.00	5.00	5	5.00	5.47	3354
3	11	UMa	3(90)	9	12	N	43	5	5	5.00	5.00	5	5.00	4.60	3403
4	12	UMa	3(90)	8	52	N	47	10	5	5.00	5.00	5	5.00	4.76	3576
5	13	UMa	3(90)	9	22	N	47	5	5	5.00	5.00	5	5.00	4.80	3616
6	14	UMa	3(90)	10	52	N	50	30	5	5.00	5.00	5	5.00	4.56	3771
7	15	UMa	3(90)	13	12	N	43	50	4(s)	4.25	4.30	4	4.00	4.67	3624
8	16	UMa	3(90)	15	12	N	44	20	4	4.00	4.00	4	4.00	3.67	3757
9	17	UMa	3(90)	21	42	N	42	5	4	4.00	4.00	4	4.00	3.80	3888
10	18	UMa	3(90)	23	42	N	44	5	4(s)	4.25	4.30	4(s)	4.30	4.59	3894
11	19	UMa	3(90)	23	22	N	35	5	3	3.00	3.00	3	3.00	3.17	3775
12	20	UMa	3(90)	18	12	N	29	20	3(s)	3.25	3.30	3	3.00	3.14	3569
13	21	UMa	3(90)	19	2	N	28	20	3(s)	3.25	3.30	3	3.00	3.60	3594
14	22	UMa	3(90)	13	22	N	36	5	5(m)	4.50	4.70	4	4.00	4.83	3662
15	23	UMa	3(90)	13	32	N	33	20	5(m)	4.50	4.70	4	4.00	4.48	3619
16	24	UMa	4(120)	5	22	N	49	5	2	2.00	2.00	2	2.00	1.79	4301
17	25	UMa	4(120)	4	52	N	44	30	3(m)	2.50	2.70	2	2.00	2.37	4295
18	26	UMa	4(120)	15	52	N	51	5	3(s)	3.25	3.30	3	3.00	3.31	4660
19	27	UMa	4(120)	15	42	N	46	30	3(m)	2.50	2.70	2	2.00	2.44	4554
20	28	UMa	4(120)	5	22	N	29	20	3(s)	3.25	3.30	3	3.00	3.45	4033
21	29	UMa	4(120)	6	52	N	28	15	3(s)	3.25	3.30	3	3.00	3.05	4069
22	30	UMa	4(120)	14	22	N	35	15	3(s)	3.25	3.30	4(m)	3.70	3.01	4335
23	31	UMa	4(120)	22	35	N	25	50	3(s)	3.25	3.30	3	3.00	3.48	4377
24	32	UMa	4(120)	23	2	N	25	0	3(s)	3.25	3.30	3	3.00	3.66	4375
25	33	UMa	4(120)	24	52	N	53	30	2	2.00	2.00	2	2.00	1.77	4905
26	34	UMa	5(150)	0	42	N	55	40	2	2.00	2.00	2	2.00	2.27	5054
27	35	UMa	5(150)	12	32	N	54	0	2	2.00	2.00	2	2.00	1.86	5191

28	36	UMa	5(150)	10	32	N	39	45	3	3.00	3.00	3	3.00	2.90	4915
29	37	UMa	5(150)	2	52	N	41	20	5	5.00	5.00	5	5.00	4.26	4785
30	38	UMa	4(120)	27	42	N	17	15	4	4.00	4.00	4	4.00	3.13	3705
31	39	UMa	4(120)	26	2	N	19	10	4	4.00	4.00	4	4.00	3.82	3690
32	40	UMa	4(120)	25	52	N	20	0	6	6.00	6.00	F	6.00	4.55	3800
33	41	UMa	4(120)	24	52	N	22	45	4	4.00	4.00	F	6.00	4.81	3809
34	42	UMa	4(120)	23	52	N	20	20	6	6.00	6.00	F	6.00	4.56	3612
35	43	UMa	4(120)	12	42	N	22	15	6	6.00	6.00	F	6.00	4.25	3275
1	44	Dra	7(210)	9	22	N	76	30	5	5.00	5.00	4	4.00	5.80	6370
2	45	Dra	7(210)	24	32	N	73	30	4	4.00	4.00	4(s)	4.30	4.88	6554
3	46	Dra	7(210)	25	52	N	75	40	3(s)	3.25	3.30	3	3.00	2.79	6536
4	47	Dra	8(240)	10	2	N	80	20	4(m)	3.50	3.70	4	4.00	3.75	6688
5	48	Dra	8(240)	12	22	N	75	30	3(m) or 2(s)	2.25	2.30	3	3.00	2.23	6705
6	49	Dra	9(270)	50	22	N	82	20	5	5.00	5.00	4	4.00	4.98	6923
7	50	Dra	9(270)	15	2	N	78	15	5	5.00	5.00	4	4.00	5.04	7049
8	51	Dra	9(270)	11	32	N	80	20	5	5.00	5.00	4	4.00	4.77	6978
9	52	Dra	10(300)	2	12	N	81	10	5	5.00	5.00	4	4.00	4.66	7125
10	53	Dra	11(330)	20	42	N	81	40	4	4.00	4.00	4	4.00	4.59	7371
11	54	Dra	0	3	12	N	83	0	3(s)	3.25	3.30	4	4.00	3.07	7310
12	55	Dra	0	20	22	N	78	50	4(m)	3.50	3.70	4	4.00	3.83	7582
13	56	Dra	0	5	32	N	77	50	5(m)	4.50	4.70	4	4.00	4.51	7685
14	57	Dra	0	23	22	N	80	30	5(m)	4.50	4.70	5	5.00	4.66	7462
15	58	Dra	1(30)	4	22	N	81	40	5(m)	4.50	4.70	5	5.00	4.82	7180
16	59	Dra	1(30)	8	52	N	80	15	5(m)	4.50	4.70	5	5.00	4.45	7352
17	60	Dra	2(60)	26	2	N	84	30	4	4.00	4.00	4	4.00	4.58	6636
18	61	Dra	2(60)	3	2	N	83	30	4	4.00	4.00	4	4.00	3.55	6927
19	62	Dra	1(30)	24	32	N	84	50	4(m)	3.50	3.70	4	4.00	4.22	6920
20	63	Dra	4(120)	11	22	N	87	30	6	6.00	6.00	6	6.00	5.05	6566
21	64	Dra	4(120)	4	22	N	86	50	6	6.00	6.00	6	6.00	4.80	6596
22	65	Dra	5(150)	21	42	N	81	15	5	5.00	5.00	5	5.00	4.83	6223
23	66	Dra	5(150)	22	2	N	83	0	5	5.00	5.00	5	5.00	4.90	6315
24	67	Dra	5(150)	21	2	N	84	50	3	3.00	3.00	3	3.00	3.17	6396
25	68	Dra	5(150)	22	42	N	78	0	3	3.00	3.00	3	3.00	2.74	6132
26	69	Dra	5(150)	25	42	N	74	40	4	4.00	4.00	4(m)	3.70	4.01	5986
27	70	Dra	5(150)	25	22	N	70	0	3(s)	3.25	3.30	3	3.00	3.29	5744
28	71	Dra	4(120)	20	2	N	64	30	5(m)	4.50	4.70	4	4.00	4.65	5226
29	72	Dra	4(120)	23	52	N	65	30	3(s)	3.25	3.30	3	3.00	3.65	5291
30	73	Dra	4(120)	1	52	N	61	15	3(s)	3.25	3.30	3	3.00	3.87	4787
31	74	Dra	3(90)	25	52	N	56	15	3(s)	3.25	3.30	3	3.00	3.84	4434
1	75	Cep	1(30)	17	42	N	75	90	5(m)	4.50	4.70	4	4.00	4.39	7750
2	76	Cep	1(30)	15	42	N	64	15	4	4.00	4.00	4	4.00	3.22	8974
3	77	Cep	0	20	42	N	71	10	4(m) or 3(s)	3.25	3.30	4	4.00	3.23	8238
4	78	Cep	11(330)	29	22	N	69	0	3	3.00	3.00	3	3.00	2.44	8162
5	79	Cep	11(330)	22	2	N	72	0	4	4.00	4.00	4	4.00	3.46	7957
6	80	Cep	11(330)	22	42	N	74	0	4	4.00	4.00	4	4.00	4.22	7850
7	81	Cep	0	11	12	N	65	30	5	5.00	5.00	5	5.00	4.29	8417
8	82	Cep	0	20	12	N	62	30	4(m)	3.50	3.70	4(m)	3.70	3.52	8694
9	83	Cep	11(330)	29	2	N	60	15	5	5.00	5.00	5	5.00	4.19	8494
10	84	Cep	0	0	2	N	61	15	4	4.00	4.00	4	4.00	3.35	8465
11	85	Cep	0	1	42	N	61	20	6	6.00	6.00	5	5.00	5.04	8469

12	86	Cep	11(330)	26	22	N	64	0	5(k)	4.75	4.70	5	5.00	4.08	8316
13	87	Cep	0	4	2	N	59	30	4(m)	3.50	3.70	4	4.00	3.75	8571
1	88	Boo	5(150)	15	2	N	58	40	5(m)	4.50	4.70	5	5.00	4.54	5328
2	89	Boo	5(150)	16	52	N	58	20	5(m)	4.50	4.70	5	5.00	4.75	5340
3	90	Boo	5(150)	18	22	N	60	10	5(m)	4.50	4.70	5	5.00	4.05	5404
4	91	Boo	5(150)	22	22	N	54	40	5	5.00	5.00	5	5.00	4.18	5351
5	92	Boo	6(180)	2	22	N	49	0	3	3.00	3.00	3	3.00	3.03	5435
6	93	Boo	6(180)	9	22	N	53	50	4(m)	3.50	3.70	4(m)	3.70	3.50	5602
7	94	Boo	6(180)	18	22	N	48	40	4(m)	3.50	3.70	4(m)	3.70	3.47	5681
8	95	Boo	6(180)	18	22	N	53	15	4(s)	4.25	4.30	4	4.00	4.31	5733
9	96	Boo	6(180)	17	42	N	57	30	4(s)	4.25	4.30	4	4.00	5.02	5763
10	97	Boo	6(180)	20	22	N	46	10	5(m)	4.50	4.70	4(m)	3.70	5.58	5727
11	98	Boo	6(180)	21	12	N	45	30	5	5.00	5.00	5	5.00	5.51	5709
12	99	Boo	6(180)	21	17	N	41	20	5	5.00	5.00	5	5.00	4.93	5634
13	100	Boo	6(180)	19	22	N	41	50	5	5.00	5.00	5	5.00	4.54	5616
14	101	Boo	6(180)	19	42	N	42	30	5	5.00	5.00	5	5.00	5.67	5638
15	102	Boo	6(180)	20	22	N	40	20	5	5.00	5.00	5	5.00	4.81	5600
16	103	Boo	6(180)	12	42	N	40	15	3	3.00	3.00	3	3.00	1.95	5506
17	104	Boo	6(180)	8	22	N	41	40	4	4.00	4.00	4	4.00	4.46	5447
18	105	Boo	6(180)	7	42	N	42	10	4	4.00	4.00	4(m)	3.70	3.58	5429
19	106	Boo	6(180)	18	2	N	28	0	4(k) or 4	3.75	3.70	3	3.00	3.68	5478
20	107	Boo	6(180)	4	2	N	28	0	3	3.00	3.00	3	3.00	2.68	5235
21	108	Boo	6(180)	3	12	N	26	30	4	4.00	4.00	4	4.00	4.50	5185
22	109	Boo	6(180)	4	2	N	25	0	4	4.00	4.00	4	4.00	4.07	5200
23	110	Boo	6(180)	9	42	N	31	30	1	1.00	1.00	1	1.00	0.04	5340
1	111	CrB	6(180)	27	22	N	44	30	2	2.00	2.00	2	2.00	2.23	5793
2	112	CrB	6(180)	24	22	N	46	10	4	4.00	4.00	4	4.00	3.68	5747
3	113	CrB	6(180)	24	32	N	48	0	4(s)	4.25	4.30	5	5.00	4.14	5778
4	114	CrB	6(180)	26	22	N	50	30	6	6.00	6.00	6	6.00	5.56	5855
5	115	CrB	6(180)	29	52	N	44	45	4	4.00	4.00	4	4.00	3.84	5849
6	116	CrB	7(210)	1	52	N	44	50	4	4.00	4.00	4	4.00	4.63	5889
7	117	CrB	7(210)	4	2	N	46	10	4	4.00	4.00	4	4.00	4.15	5947
8	118	CrB	7(210)	4	22	N	49	20	4	4.00	4.00	4	4.00	4.99	5971
1	119	Her	8(240)	0	22	N	37	30	3(s)	3.25	3.30	3	3.00	2.73	6406
2	120	Her	7(210)	16	22	N	43	0	3	3.00	3.00	3	3.00	2.77	6148
3	121	Her	7(210)	54	22	N	40	10	3(s)	3.25	3.30	3	3.00	3.75	6095
4	122	Her	7(210)	10	42	N	37	10	4(s)	4.25	4.30	4	4.00	5.00	6008
5	123	Her	7(210)	29	22	N	48	0	3	3.00	3.00	3	3.00	3.14	6410
6	124	Her	8(240)	4	42	N	49	30	5	5.00	5.00	4(k)	3.70	4.41	6526
7	125	Her	8(240)	10	22	N	52	0	4	4.00	4.00	4(m)	3.70	3.42	6623
8	126	Her	8(240)	18	12	N	52	50	4	4.00	4.00	4(m)	3.70	3.83	6779
9	127	Her	8(240)	54	22	N	54	0	4	4.00	4.00	4(m)	3.70	4.41	6707
10	128	Her	8(240)	54	12	N	53	0	4	4.00	4.00	4(m)	3.70	3.70	6703
11	129	Her	7(210)	16	32	N	53	10	3	3.00	3.00	3	3.00	2.81	6212

12	130	Her	7(210)	22	52	N	53	30	4	4.00	4.00	4(m)	3.70	3.92	6324
13	131	Her	7(210)	22	42	N	56	10	5(s) or 6(m)	5.50	5.70	5	5.00	5.25	6332
14	132	Her	7(210)	28	52	N	38	30	5(s) or 6(m)	5.50	5.70	5	5.00	5.39	6377
15	133	Her	7(210)	26	42	N	59	50	4(k)	3.75	3.70	3	3.00	3.16	6418
16	134	Her	7(210)	28	2	N	60	20	5	5.00	5.00	4	4.00	4.65	6436
17	135	Her	7(210)	29	2	N	61	15	4	4.00	4.00	4(m)	3.70	4.72	6484
18	136	Her	8(240)	53	32	N	61	0	4	4.00	4.00	4	4.00	3.86	6695
19	137	Her	8(240)	4	52	N	69	20	4	4.00	4.00	4	4.00	3.80	6588
20	138	Her	7(210)	28	2	N	70	15	6	6.00	6.00	6	6.00	5.59	6464
21	139	Her	7(210)	29	32	N	71	15	6	6.00	6.00	6	6.00	5.80	6509
22	140	Her	8(240)	2	22	N	72	0	6	6.00	6.00	6	6.00	5.37	6574
23	141	Her	7(210)	53	22	N	60	15	4	4.00	4.00	4(m)	3.70	3.53	6220
24	142	Her	7(210)	8	2	N	63	0	4	4.00	4.00	4	4.00	4.20	6168
25	143	Her	6(180)	28	22	N	65	30	4 or 4(m)	4.00	4.00	4(m)	3.70	3.89	6092
26	144	Her	6(210)	26	2	N	63	40	4	4.00	4.00	4	4.00	4.26	6023
27	145	Her	6(180)	22	52	N	64	15	4	4.00	4.00	4	4.00	4.76	5982
28	146	Her	6(180)	23	52	N	60	0	5	5.00	5.00	4	4.00	4.62	5914
29	147	Her	7(210)	15	22	N	38	10	4	4.00	4.00	5	5.00	4.57	6117
1	148	Lyr	9(270)	0	2	N	62	0	1	1.00	1.00	1	1.00	0.04	7001
2	149	Lyr	9(270)	3	2	N	62	40	4(k)	3.75	3.70	4(k)	3.70	5.06	7051
3	150	Lyr	9(270)	3	2	N	61	0	4(k)	3.75	3.70	4(k)	3.70	4.36	7056
4	151	Lyr	9(270)	6	22	N	60	0	4	4.00	4.00	4	4.00	4.30	7139
5	152	Lyr	9(270)	52	42	N	61	20	4(s)	4.25	4.30	4	4.00	4.39	7298
6	153	Lyr	9(270)	52	22	N	60	20	4(s)	4.25	4.30	4	4.00	4.36	7314
7	154	Lyr	9(270)	3	42	N	56	10	3(s)	3.25	3.30	3	3.00	3.45	7106
8	155	Lyr	9(270)	3	32	N	55	0	4(s)	4.25	4.30	4(s)	4.30	5.25	7102
9	156	Lyr	9(270)	6	52	N	55	20	3	3.00	3.00	3	3.00	3.24	7178
10	157	Lyr	9(270)	6	42	N	54	45	5 or 5(s)	5.25	5.30	4(s)	4.30	4.93	7192
1	158	Cyg	9(270)	19	12	N	49	20	3(s)	3.25	3.30	3	3.00	3.08	7417
2	159	Cyg	9(270)	21	42	N	50	20	6(m)	5.50	5.70	5	5.00	4.69	7478
3	160	Cyg	9(270)	29	2	N	54	30	5	5.00	5.00	4(k)	3.70	3.89	7615
4	161	Cyg	10(300)	11	12	N	57	20	3(m)	2.50	2.70	3	3.00	2.20	7796
5	162	Cyg	10(300)	21	52	N	60	0	2	2.00	2.00	2	2.00	1.25	7924
6	163	Cyg	10(300)	2	2	N	64	40	3	3.00	3.00	3	3.00	2.87	7528
7	164	Cyg	10(300)	5	12	N	69	40	4(s)	4.25	4.30	4	4.00	4.49	7469
8	165	Cyg	10(300)	3	52	N	71	30	4	4.00	4.00	4(m)	3.70	3.79	7420
9	166	Cyg	9(270)	29	22	N	74	0	4	4.00	4.00	4(m)	3.70	3.77	7328
10	167	Cyg	10(300)	13	32	N	49	30	3	3.00	3.00	3	3.00	2.46	7949
11	168	Cyg	10(300)	16	32	N	52	10	4(s)	4.25	4.30	4(m)	3.70	4.53	7963
12	169	Cyg	10(300)	19	22	N	44	0	3	3.00	3.00	3	3.00	3.20	8115
13	170	Cyg	10(300)	22	42	N	55	10	4	4.00	4.00	4(m)	3.70	3.94	8028
14	171	Cyg	10(300)	27	12	N	57	0	4	4.00	4.00	4(m)	3.70	3.72	8079
15	172	Cyg	10(300)	33	52	N	64	0	4	4.00	4.00	4	4.00	3.79	7735

16	173	Cyg	10(300)	15	22	N	64	30	4	4.00	4.00	4	4.00	3.98	7751
17	174	Cyg	10(300)	24	52	N	63	45	5	5.00	5.00	5	5.00	5.44	7851
18	175	Cyg	10(300)	23	22	N	49	40	4	4.00	4.00	4	4.00	3.72	8130
19	176	Cyg	10(300)	26	32	N	51	40	4	4.00	4.00	4	4.00	4.23	8143
1	177	Cas	0	20	32	N	45	20	4(k)	3.75	3.70	4(m)	3.70	3.66	153
2	178	Cas	0	23	32	N	46	45	3	3.00	3.00	3	3.00	2.23	168
3	179	Cas	0	25	42	N	47	50	4	4.00	4.00	4	4.00	3.43	219
4	180	Cas	0	29	22	N	49	0	3(k)	2.75	2.70	3(m)	2.70	2.47	264
5	181	Cas	1(30)	3	22	N	45	30	3	3.00	3.00	3	3.00	2.68	403
6	182	Cas	1(30)	9	42	N	47	20	4	4.00	4.00	4	4.00	3.38	542
7	183	Cas	1(30)	14	22	N	47	20	4(s)	4.25	4.30	4	4.00	4.52	707
8	184	Cas	0	27	22	N	44	20	4(s)	4.25	4.30	4	4.00	4.33	343
9	185	Cas	1(30)	0	22	N	45	0	5	5.00	5.00	5	5.00	4.98	382
10	186	Cas	0	15	2	N	50	0	6	6.00	6.00	6	6.00	4.88	9071
11	187	Cas	0	27	42	N	52	40	4 or 4(s)	4.25	4.30	4	4.00	4.16	130
12	188	Cas	0	20	32	N	51	40	3	3.00	3.00	3	3.00	2.27	21
13	189	Cas	0	16	2	N	51	40	6	6.00	6.00	6	6.00	4.54	9045
1	190	Per	1(30)	9	22	N	40	30	-	-	-	-	-	-	ngc 869
2	191	Per	1(30)	13	52	N	37	30	4	4.00	4.00	4	4.00	3.76	834
3	192	Per	1(30)	15	22	N	34	30	3(s)	3.25	3.30	3(s)	3.30	2.93	915
4	193	Per	1(30)	10	12	N	32	20	4(s)	4.25	4.30	4	4.00	4.12	799
5	194	Per	1(30)	13	22	N	34	30	5	5.00	5.00	4	4.00	3.95	854
6	195	Per	1(30)	14	12	N	31	10	4	4.00	4.00	4	4.00	4.05	937
7	196	Per	1(30)	17	32	N	30	0	2	2.00	2.00	2	2.00	1.79	1017
8	197	Per	1(30)	18	2	N	27	50	4	4.00	4.00	4	4.00	4.36	1052
9	198	Per	1(30)	19	42	N	27	40	4	4.00	4.00	4	4.00	4.23	1087
10	199	Per	1(30)	20	22	N	27	20	3	3.00	3.00	3	3.00	3.01	1122
11	200	Per	1(30)	13	12	N	27	0	4	4.00	4.00	4	4.00	3.80	941
12	201	Per	1(30)	12	22	N	23	0	2(s)	2.25	2.30	2	2.00	2.12	936
13	202	Per	1(30)	11	52	N	21	0	4(s)	4.25	4.30	4	4.00	4.63	947
14	203	Per	1(30)	10	22	N	21	0	4(m)	3.50	3.70	4	4.00	3.39	921
15	204	Per	1(30)	9	32	N	22	15	4	4.00	4.00	4	4.00	4.70	879
16	205	Per	1(30)	27	32	N	28	15	4	4.00	4.00	4	4.00	4.61	1324
17	206	Per	1(30)	25	42	N	28	10	4	4.00	4.00	4	4.00	4.29	1261
18	207	Per	1(30)	25	2	N	25	0	4	4.00	4.00	4	4.00	4.04	1273
19	208	Per	1(30)	26	42	N	26	15	4	4.00	4.00	4	4.00	4.14	1303
20	209	Per	1(30)	24	52	N	24	30	5	5.00	5.00	5	5.00	4.85	1350
21	210	Per	1(30)	29	2	N	18	45	5	5.00	5.00	5	5.00	4.25	1454
22	211	Per	1(30)	19	32	N	21	50	4	4.00	4.00	4(m)	3.70	3.77	1135
23	212	Per	1(30)	21	22	N	19	15	3	3.00	3.00	3	3.00	2.89	1220
24	213	Per	1(30)	21	2	N	14	45	4	4.00	4.00	4	4.00	4.04	1228
25	214	Per	1(30)	16	52	N	12	0	3(s)	3.25	3.30	3(s)	3.30	3.83	1131
26	215	Per	1(30)	19	2	N	11	0	3(s)	3.25	3.30	3(m)	2.70	2.85	1203
27	216	Per	1(30)	24	32	N	18	0	5(s)	5.25	5.30	5	5.00	4.71	1306
28	217	Per	1(30)	27	42	N	31	0	5(s)	5.25	5.30	5	5.00	5.19	1314

29	218	Per	1(30)	7	22	N	20	40	5	5.00	5.00	6	6.00	4.23	840
1	219	Aur	2(60)	15	12	N	30	0	4	4.00	4.00	4	4.00	3.72	2077
2	220	Aur	2(60)	15	2	N	30	50	5	5.00	5.00	4	4.00	4.99	2029
3	221	Aur	2(60)	7	42	N	22	30	1	1.00	1.00	1	1.00	0.07	1708
4	222	Aur	2(60)	15	32	N	20	0	2	2.00	2.00	2	2.00	1.90	2088
5	223	Aur	2(60)	13	52	N	15	15	5	5.00	5.00	4	4.00	4.52	1995
6	224	Aur	2(60)	15	32	N	13	20	3	3.00	3.00	4(m)	3.70	2.62	2095
7	225	Aur	2(60)	4	42	N	20	40	4	4.00	4.00	4	4.00	2.99	1605
8	226	Aur	2(60)	4	52	N	18	0	4	4.00	4.00	4	4.00	3.17	1641
9	227	Aur	2(60)	4	42	N	18	0	4	4.00	4.00	4	4.00	3.75	1612
10	228	Aur	2(60)	2	32	N	10	10	3(s)	3.25	3.30	3(s)	3.30	2.69	1577
11	229	Aur	2(60)	8	22	N	5	0	2	2.00	2.00	3(m)	2.70	1.65	1791
12	230	Aur	2(60)	8	42	N	8	30	6	6.00	6.00	5	5.00	4.76	1843
13	231	Aur	2(60)	9	2	N	12	20	6	6.00	6.00	5	5.00	5.07	1805
14	232	Aur							-	-	-	-	-	-	2029
1	233	Oph	8(240)	7	32	N	36	0	3	3.00	3.00	3(m)	2.70	2.08	6556
2	234	Oph	8(240)	10	42	N	27	15	3(s)	3.25	3.30	4	4.00	2.77	6603
3	235	Oph	8(240)	11	42	N	26	45	4	4.00	4.00	4	4.00	3.75	6629
4	236	Oph	7(210)	26	2	N	33	0	4	4.00	4.00	4	4.00	4.38	6281
5	237	Oph	7(210)	27	22	N	31	50	3(s) or 4(m)	3.25	3.30	4	4.00	3.20	6299
6	238	Oph	7(210)	21	2	N	24	30	4	4.00	4.00	4	4.00	3.82	6149
7	239	Oph	7(210)	17	42	N	17	0	3	3.00	3.00	3	3.00	2.74	6056
8	240	Oph	7(210)	18	42	N	16	30	3(s)	3.25	3.30	3	3.00	3.24	6075
9	241	Oph	8(240)	9	22	N	15	0	5(m)	4.50	4.70	4	4.00	4.62	6567
10	242	Oph	8(210)	15	2	N	13	40	4(m)	3.50	3.70	4(s)	4.30	3.34	6698
11	243	Oph	8(240)	16	2	N	14	20	5	5.00	5.00	4	4.00	5.19	6733
12	244	Oph	8(240)	3	52	N	7	30	3	3.00	3.00	3	3.00	2.43	6378
13	245	Oph	8(210)	6	22	N	2	15	5(m) or 4(s)	4.50	4.70	4(m)	3.70	4.39	6445
14	246	Oph	8(240)	5	42	S	2	15	5(k) or 4(s)	4.75	4.70	4	4.00	5.33	6401
15	247	Oph	8(240)	7	2	S	1	1	4(k)	3.75	3.70	4(m)	3.70	3.27	6453
16	248	Oph	8(240)	7	42	S	0	20	4(s)	4.25	4.30	4	4.00	4.17	6486
17	249	Oph	8(240)	8	32	S	0	15	5	5.00	5.00	5	5.00	4.81	6519
18	250	Oph	8(240)	9	52	N	1	0	5(s)	5.25	5.30	5	5.00	4.87	6595
19	251	Oph	7(210)	24	52	N	11	50	3	3.00	3.00	3	3.00	2.56	6175
20	252	Oph	7(210)	23	22	N	5	20	5	5.00	5.00	5(m)	4.70	4.28	6147
21	253	Oph	7(210)	22	22	N	3	10	5	5.00	5.00	5	5.00	4.42	6118
22	254	Oph	7(210)	24	32	N	1	40	5	5.00	5.00	5(m)	4.70	4.50	6104
23	255	Oph	7(210)	25	2	N	0	40	5	5.00	5.00	5	5.00	4.45	6153
24	256	Oph	7(210)	23	22	N	0	45	5	5.00	5.00	4	4.00	4.27	6112
25	257	Oph	8(240)	14	42	N	28	10	4	4.00	4.00	4	4.00	4.64	6712
26	258	Oph	8(240)	15	22	N	26	20	4	4.00	4.00	4	4.00	3.97	6714
27	259	Oph	8(240)	13	2	N	25	0	4	4.00	4.00	4	4.00	4.45	6723
28	260	Oph	8(240)	16	2	N	27	0	4	4.00	4.00	4	4.00	4.03	6752

29	261	Oph	8(240)	17	22	N	33	0	4	4.00	4.00	4	4.00	3.73	6771
1	262	Ser	7(210)	1	32	N	38	0	4	4.00	4.00	4	4.00	4.52	5842
2	263	Ser	7(210)	4	22	N	40	0	4(s)	4.25	4.30	4	4.00	4.76	5899
3	264	Ser	7(210)	7	2	N	36	0	3(s)	3.25	3.30	3	3.00	3.85	5933
4	265	Ser	7(210)	4	42	N	34	15	3(s)	3.25	3.30	3	3.00	3.67	5867
5	266	Ser	7(210)	4	2	N	37	15	5	5.00	5.00	4	4.00	4.09	5879
6	267	Ser	7(210)	5	52	N	42	30	4(s)	4.25	4.30	4	4.00	4.83	5972
7	268	Ser	7(210)	4	22	N	29	15	3(s)	3.25	3.30	3	3.00	3.05	5788
8	269	Ser	7(210)	7	32	N	26	30	4	4.00	4.00	4	4.00	4.43	5868
9	270	Ser	7(210)	7	2	N	25	20	3	3.00	3.00	3	3.00	2.65	5854
10	271	Ser	7(210)	9	2	N	24	0	3(s)	3.25	3.30	3	3.00	3.71	5892
11	272	Ser	7(210)	11	22	N	16	30	4	4.00	4.00	4	4.00	3.53	5881
12	273	Ser	7(210)	20	52	N	16	15	5	5.00	5.00	5	5.00	4.63	6129
13	274	Ser	8(240)	6	22	N	10	30	4	4.00	4.00	4	4.00	4.33	5446
14	275	Ser	8(240)	9	42	N	8	30	4(m)	3.50	3.70	4(m)	3.70	3.54	6561
15	276	Ser	8(240)	10	32	N	10	30	4	4.00	4.00	4	4.00	4.26	6581
16	277	Ser	8(240)	16	22	N	20	0	4	4.00	4.00	4	4.00	4.62	6710
17	278	Ser	8(240)	21	22	N	21	15	4(m)	3.50	3.70	4(m)	3.70	3.26	6869
18	279	Ser	9(270)	1	2	N	27	0	4	4.00	4.00	4	4.00	3.87	7141
1	280	Sge	9(270)	22	52	N	39	20	4	4.00	4.00	4	4.00	3.47	7635
2	281	Sge	9(270)	19	22	N	39	10	6	6.00	6.00	6	6.00	5.00	7546
3	282	Sge	9(270)	18	32	N	39	50	5	5.00	5.00	5	5.00	3.82	7536
4	283	Sge	9(270)	16	22	N	39	0	5	5.00	5.00	5	5.00	4.37	7479
5	284	Sge	9(270)	16	2	N	38	40	5	5.00	5.00	5	5.00	4.37	7488
1	285	Aql	9(270)	19	52	N	26	50	6	6.00	6.00	4	4.00	5.52	7669
2	286	Aql	9(270)	17	32	N	27	10	3(s)	3.25	3.30	3	3.00	3.72	7602
3	287	Aql	9(270)	16	32	N	29	10	2(m)	1.50	1.70	2(m)	1.70	0.79	7557
4	288	Aql	9(270)	17	22	N	30	0	5	5.00	5.00	3(s)	3.30	5.11	7560
5	289	Aql	9(270)	15	52	N	31	30	3	3.00	3.00	3	3.00	2.72	7525
6	290	Aql	9(270)	18	42	N	31	30	6	6.00	6.00	5	5.00	5.28	7610
7	291	Aql	9(270)	12	22	N	28	40	6	6.00	6.00	5	5.00	4.45	7429
8	292	Aql	9(270)	13	52	N	26	40	6	6.00	6.00	5	5.00	5.17	7474
9	293	Aql	9(270)	4	52	N	36	20	3	3.00	3.00	3	3.00	2.99	7235
10	294	Aql	9(270)	16	52	N	21	40	3(s)	3.25	3.30	3	3.00	3.90	7570
11	295	Aql	9(270)	21	22	N	19	10	3	3.00	3.00	3	3.00	3.23	7710
12	296	Aql	9(270)	8	42	N	25	0	3(s)	3.25	3.30	4(m)	3.70	3.37	7377
13	297	Aql	9(270)	10	52	N	20	0	4(s)	4.25	4.30	3	3.00	4.36	7447
14	298	Aql	9(270)	12	22	N	15	30	5	5.00	5.00	5	5.00	4.95	7446
15	299	Aql	9(270)	3	52	N	18	10	3(s)	3.25	3.30	3	3.00	3.44	7236
1	300	Del	10(300)	0	22	N	29	10	4(m)	3.50	3.70	3(s)	3.30	4.03	7852
2	301	Del	10(300)	1	22	N	29	0	6	6.00	6.00	4(s)	4.30	5.43	7883
3	302	Del	10(300)	1	22	N	27	45	6	6.00	6.00	4	4.00	5.06	7896
4	303	Del	10(300)	1	12	N	32	0	3(s)	3.25	3.30	3(s)	3.30	3.63	7882
5	304	Del	10(300)	2	52	N	33	50	3(s)	3.25	3.30	3(s)	3.30	3.77	7906
6	305	Del	10(300)	4	2	N	32	0	3(s)	3.25	3.30	3(s)	3.30	4.43	7928
7	306	Del	10(300)	6	12	N	33	10	3(s)	3.25	3.30	3(s)	3.30	4.27	7948
8	307	Del	10(300)	0	12	N	34	0	6	6.00	6.00	6	6.00	5.38	7858
9	308	Del	10(300)	0	12	N	31	50	6	6.00	6.00	6	6.00	4.68	7871
10	309	Del	10(300)	1	42	N	31	30	6	6.00	6.00	6	6.00	5.72	7892
1	310	Equ	10(300)	9	2	N	20	30	4	4.00	4.00	7	7.00	3.92	8131

2	311	Equ	10(300)	10	42	N	20	40	6	6.00	6.00	7	7.00	5.16	8178
3	312	Equ	10(300)	9	2	N	25	20	5(s)	5.25	5.30	7	7.00	4.69	8097
4	313	Equ	10(300)	10	22	N	25	0	5(s)	5.25	5.30	7	7.00	4.49	8123
1	314	Peg	0	0	32	N	26	0	2(s)	2.25	2.30	2(s)	2.30	2.06	15
2	315	Peg	11(330)	24	52	N	12	30	2(s)	2.25	2.30	2(s)	2.30	2.83	8739
3	316	Peg	11(330)	14	52	N	31	0	2(s)	2.25	2.30	2(s)	2.30	2.42	8775
4	317	Peg	11(330)	9	22	N	19	40	2(s)	2.25	2.30	2(s)	2.30	2.49	8781
5	318	Peg	11(330)	17	12	N	25	30	4	4.00	4.00	4	4.00	4.60	8880
6	319	Peg	11(330)	17	42	N	25	0	4	4.00	4.00	4	4.00	4.40	8905
7	320	Peg	11(330)	11	42	N	35	0	5 or 3	3.00	3.00	3	3.00	2.94	8650
8	321	Peg	11(330)	11	12	N	34	30	5	5.00	5.00	5	5.00	4.79	8641
9	322	Peg	11(330)	8	52	N	29	0	4(k)	3.75	3.70	4	4.00	3.95	8667
10	323	Peg	11(330)	9	42	N	29	30	4(k)	3.75	3.70	4	4.00	3.48	8684
11	324	Peg	11(330)	1	32	N	18	0	3(s)	3.25	3.30	3	3.00	3.40	8634
12	325	Peg	11(330)	3	12	N	19	0	4(s)	4.25	4.30	4	4.00	4.19	8665
13	326	Peg	11(330)	4	2	N	15	0	6 or 5(s)	6.00	6.00	5	5.00	4.90	8717
14	327	Peg	11(330)	3	12	N	16	0	6 or 5(s)	6.00	6.00	5	5.00	5.16	8697
15	328	Peg	10(300)	22	2	N	16	50	3(s)	3.25	3.30	3	3.00	3.53	8450
16	329	Peg	10(300)	20	42	N	16	0	5(s)	5.25	5.30	4	4.00	4.84	8413
17	330	Peg	10(300)	18	2	N	22	30	3	3.00	3.00	3(m)	2.70	2.39	8308
18	331	Peg	11(330)	6	22	N	41	10	4	4.00	4.00	4(m)	3.70	4.29	8454
19	332	Peg	11(330)	5	22	N	34	15	4	4.00	4.00	4(m)	3.70	3.76	8430
20	333	Peg	10(300)	25	2	N	36	50	4	4.00	4.00	4(m	3.70	4.13	8315
1	334	And	0	8	2	N	24	30	3(s)	3.25	3.30	3	3.00	3.27	165
2	335	And	0	9	2	N	27	0	4	4.00	4.00	4	4.00	4.36	154
3	336	And	0	7	2	N	23	0	4	4.00	4.00	4	4.00	4.38	163
4	337	And	0	6	22	N	32	0	4(s)	4.25	4.30	4	4.00	4.52	68
5	338	And	0	7	22	N	33	30	4(s)	4.25	4.30	4	4.00	4.61	63
6	339	And	0	7	42	N	32	20	5(m) or 5(s)	5.25	5.30	5	5.00	5.18	82
7	340	And	0	2	22	N	41	0	4(m)	3.50	3.70	4	4.00	4.29	8965
8	341	And	0	3	22	N	42	0	4(m)	3.50	3.70	4	4.00	4.14	8976
9	342	And	0	4	52	N	44	0	4(m)	3.50	3.70	4	4.00	3.82	8961
10	343	And	0	6	52	N	17	30	4(s)	4.25	4.30	4	4.00	4.06	215
11	344	And	0	8	22	N	15	50	5(m)	4.50	4.70	4	4.00	4.42	271
12	345	And	0	16	32	N	26	20	2(s)	2.25	2.30	3	3.00	2.06	337
13	346	And	0	14	32	N	30	0	4	4.00	4.00	4	4.00	3.87	269
14	347	And	0	14	42	N	32	30	4(s)	4.25	4.30	4	4.00	4.53	226
15	348	And	0	29	32	N	28	0	3	3.00	3.00	3	3.00	2.26	603
16	349	And	0	29	52	N	37	20	4	4.00	4.00	4(m)	3.70	4.07	496
17	350	And	0	27	52	N	35	20	4(m)	3.50	3.70	4	4.00	3.57	464
18	351	And	0	25	2	N	29	0	4(m)	3.50	3.70	4	4.00	4.10	458

19	352	And	0	24	42	N	28	0	4	4.00	4.00	4	4.00	4.94	477
20	353	And	0	22	52	N	35	30	5	5.00	5.00	5	5.00	4.25	335
21	354	And	0	25	22	N	34	30	5(s) or 6	6.00	6.00	5	5.00	5.27	390
22	355	And	0	26	52	N	32	30	5(s) or 6	6.00	6.00	5	5.00	4.98	469
23	356	And	11(330)	24	22	N	44	0	4(m) or 4	3.50	3.70	3	3.00	3.62	8762
1	357	Tri	0	23	42	N	16	30	3	3.00	3.00	3	3.00	3.41	544
2	358	Tri	0	28	42	N	20	40	3	3.00	3.00	3	3.00	3.00	622
3	359	Tri	0	29	2	N	19	40	5(s)	5.25	5.30	4	4.00	4.87	660
4	360	Tri	0	29	32	N	19	0	3(s)	3.25	3.30	3	3.00	4.01	664
1	1	Ari	0	19	22	N	7	20	3(s)	3.25	3.30	3	3.00	4.75	546
2	2	Ari	0	20	22	N	8	20	3	3.00	3.00	3	3.00	2.64	553
3	3	Ari	0	23	42	N	7	40	5(s)	5.25	5.30	5	5.00	5.27	646
4	4	Ari	0	24	12	N	6	0	4(s)	4.25	4.30	4	4.00	5.62	669
5	5	Ari	0	19	12	N	5	30	5	5.00	5.00	5	5.00	5.10	563
6	6	Ari	1(30)	0	22	N	6	0	6	6.00	6.00	6	6.00	5.43	773
7	7	Ari	1(30)	4	2	N	4	50	5	5.00	5.00	5	5.00	4.63	887
8	8	Ari	1(30)	6	32	N	1	40	4	4.00	4.00	4	4.00	4.35	951
9	9	Ari	1(30)	8	2	N	2	30	4	4.00	4.00	4	4.00	4.89	972
10	10	Ari	1(30)	9	42	N	1	50	4	4.00	4.00	4	4.00	5.09	1015
11	11	Ari	1(30)	2	22	N	1	10	5	5.00	5.00	5	5.00	5.63	869
12	12	Ari	1(30)	0	42	N	1	30	5	5.00	5.00	5	5.00	5.49	847
13	13	Ari	0	27	42	N	5	15	4	4.00	4.00	4(m)	3.70	4.27	813
14	14	Ari	0	23	22	N	10	0	3(k)	2.50	2.70	3(m)	2.70	2.00	617
15	15	Ari	1(30)	4	22	N	10	10	4	4.00	4.00	4	4.00	3.63	838
16	16	Ari	1(30)	4	2	N	12	40	5	5.00	5.00	5	5.00	4.51	824
17	17	Ari	1(30)	2	22	N	11	10	5	5.00	5.00	5	5.00	4.66	801
18	18	Ari	1(30)	1	52	N	10	40	5(s)	5.25	5.30	5	5.00	5.30	782
1	19	Tau	1(30)	9	2	S	6	0	4	4.00	4.00	4	4.00	4.11	1066
2	20	Tau	1(30)	8	42	S	7	15	4	4.00	4.00	4	4.00	5.14	1061
3	21	Tau	1(30)	7	22	S	8	30	4(m)	3.50	3.70	4	4.00	3.74	1038
4	22	Tau	1(30)	7	2	S	9	15	4(m)	3.50	3.70	4	4.00	3.60	1030
5	23	Tau	1(30)	12	22	S	9	30	6	6.00	5.00	5	5.00	5.07	1174
6	24	Tau	1(30)	16	22	S	3	0	3	3.00	3.00	3	3.00	3.47	1239
7	25	Tau	1(30)	59	22	S	12	40	4	4.00	4.00	4	4.00	4.29	1320
8	26	Tau	1(30)	15	42	S	14	50	4(m)	3.50	3.70	4	4.00	3.91	1251
9	27	Tau	1(30)	24	52	S	10	0	4	4.00	4.00	4	4.00	4.27	1473
10	28	Tau	1(30)	15	42	S	13	0	4	4.00	4.00	4	4.00	4.25	1458
11	29	Tau	1(30)	21	42	S	5	45	3(s)	3.25	3.30	3(s)	3.30	3.65	1346
12	30	Tau	1(30)	23	2	S	4	15	3(s)	3.25	3.30	3(s)	3.30	3.76	1373
13	31	Tau	1(30)	23	32	S	5	50	3(s)	3.25	3.30	3(s)	3.30	3.84	1411

14	32	Tau	1(30)	25	22	S	5	10	1	1.00	1.00	1	1.00	0.85	1457
15	33	Tau	1(30)	24	32	S	3	0	3(s)	3.25	3.30	3(s)	3.30	3.53	1409
16	34	Tau	1(30)	29	52	S	4	0	5	5.00	4.00	4	4.00	5.10	1547
17	35	Tau	2(60)	3	2	S	5	0	5	5.00	5.00	5	5.00	5.00	1656
18	36	Tau	2(60)	2	42	S	3	30	5	5.00	5.00	5	5.00	5.29	1658
19	37	Tau	2(60)	10	22	S	4	30	3	3.00	3.00	3	3.00	3.00	1910
20	38	Tau	1(30)	28	22	S	4	0	4	4.00	4.00	4	4.00	4.28	1497
0	0	Tau													
21	39	Tau	1(30)	24	42	N	0	30	4	4.00	4.00	5	5.00	4.28	1392
22	40	Tau	1(30)	24	22	N	4	0	4	4.00	4.00	5	5.00	4.22	1387
23	41	Tau	1(30)	19	42	N	0	40	5	5.00	5.00	5	5.00	4.36	1256
24	42	Tau	1(30)	21	42	N	1	0	6	6.00	6.00	6	6.00	4.94	1329
25	43	Tau	1(30)	20	42	N	5	0	5	5.00	5.00	5	5.00	5.41	1287
26	44	Tau	1(30)	21	12	N	50	10	5	5.00	5.00	5	5.00	5.23	1269
27	45	Tau	1(30)	24	42	N	3	0	5	5.00	5.00	5	5.00	5.37	1369
28	46	Tau	1(30)	24	24	N	5	0	5	5.00	5.00	5	5.00	4.95	1348
29	47	Tau	1(30)	14	52	N	4	30	5	5.00	5.00	5	5.00	4.30	1140
30	48	Tau	1(30)	15	12	N	3	40	5	5.00	5.00	5	5.00	4.18	1142
31	49	Tau	1(30)	16	22	N	3	20	5	5.00	5.00	5	5.00	3.63	1165
32	50	Tau	1(30)	16	22	N	5	0	4	4.00	4.00	4	4.00	5.26	1188
33	51	Tau	1(30)	50	42	S	14	30	4	4.00	4.00	4	4.00	4.28	1101
34	52	Tau	2(60)	2	42	S	2	0	5	5.00	5.00	5	5.00	4.64	1620
35	53	Tau	2(60)	6	42	S	1	45	5	5.00	5.00	5	5.00	4.94	1739
36	54	Tau	2(60)	8	42	S	2	0	5	5.00	5.00	5	5.00	4.88	1030
37	55	Tau	2(60)	11	42	S	6	20	5	5.00	5.00	5	5.00	4.86	1990
38	56	Tau	2(60)	11	42	S	50	40	6(s)	6.25	6.30	5	5.00	6.00	1985
39	57	Tau	2(60)	9	42	N	2	40	5	5.00	5.00	5	5.00	5.38	1821
40	58	Tau	2(60)	11	42	N	1	0	5	5.00	5.00	5	5.00	5.18	1928
41	59	Tau	2(60)	13	42	N	1	20	5	5.00	5.00	5	5.00	4.86	2002
42	60	Tau	2(60)	15	2	N	3	20	5	5.00	5.00	5	5.00	4.58	2034
43	61	Tau	2(60)	16	2	N	1	15	5	5.00	5.00	5	5.00	4.82	2084
1	62	Gem	3(90)	6	2	N	9	40	2	2.00	2.00	2	2.00	1.98	2891
2	63	Gem	3(90)	9	22	N	6	15	2	2.00	2.00	2	2.00	1.14	2990
3	64	Gem	2(60)	29	22	N	10	0	4(m)	3.50	3.70	4	4.00	3.60	2540
4	65	Gem	3(90)	1	22	N	50	20	4	4.00	4.00	4	4.00	4.41	2697
5	66	Gem	3(90)	4	42	N	5	30	4	4.00	4.00	4	4.00	3.79	2821
6	67	Gem	3(90)	6	42	N	4	50	4	4.00	4.00	4	4.00	4.06	2905
7	68	Gem	3(90)	9	22	N	2	40	4(k)	3.75	3.70	4	4.00	3.57	2985
8	69	Gem	3(90)	4	22	N	2	40	5(s)	5.25	5.30	5	5.00	5.03	2808
9	70	Gem	3(90)	5	52	N	3	0	5	5.00	5.00	5	5.00	5.22	2846
10	71	Gem	2(60)	25	42	N	1	30	3(s)	3.25	3.30	3	3.00	2.98	2473
11	72	Gem	3(90)	4	22	S	0	30	3	3.00	3.00	3	3.00	3.79	2650
12	73	Gem	3(90)	0	57	S	2	30	4(m)	3.50	3.70	3	3.00	3.53	2777
13	74	Gem	3(90)	4	2	S	6	0	3(s)	3.25	3.30	3	3.00	3.58	2763
14	75	Gem	2(60)	19	12	S	1	30	4(k)	3.75	3.70	4(m)	3.70	3.28	2216
15	76	Gem	2(60)	20	52	S	1	15	4(k)	3.75	3.70	4(m)	3.70	2.88	2286
16	77	Gem	2(60)	22	52	S	3	30	3(s)	3.25	3.30	4(m)	3.70	4.15	2343
17	78	Gem	2(60)	24	42	S	50	30	3	3.00	3.00	3	3.00	1.93	2421
18	79	Gem	2(60)	27	22	S	10	30	4	4.00	4.00	4	4.00	3.35	2484

19	80	Gem	2(60)	16	52	S	0	40	4(s)	4.25	4.30	4	4.00	4.16	2134
20	81	Gem	2(60)	19	12	N	5	50	4(s)	4.25	4.30	4(m)	3.70	4.35	2219
21	82	Gem	2(60)	17	52	S	2	15	5(s)	5.25	5.30	5	5.00	5.27	2529
22	83	Gem	3(90)	11	2	S	1	20	5(s)	5.25	5.30	5	5.00	5.35	3086
23	84	Gem	3(90)	9	2	S	3	20	5(s)	5.25	5.30	5	5.00	4.88	3003
24	85	Gem	3(90)	8	42	S	4	30	5(s)	5.25	5.30	5	5.00	5.05	2938
25	86	Gem	3(90)	13	22	S	2	40	4(s)	4.25	4.30	4	4.00	5.63	3208
1	87	Cnc	3(90)	23	12	N	0	40	-	-	-	-	-	-	M44
2	88	Cnc	3(90)	20	22	N	1	15	4(s)	4.25	4.30	4(s)	4.30	5.33	3366
3	89	Cnc	3(90)	20	42	S	1	10	4(s)	4.25	4.30	4(s)	4.30	5.35	3357
4	90	Cnc	3(90)	23	2	N	2	40	4	4.00	4.00	4(m)	3.70	4.66	3449
5	91	Cnc	3(90)	24	2	S	0	10	4	4.00	4.00	4(m)	3.70	3.94	3461
6	92	Cnc	3(90)	29	12	S	5	30	4	4.00	4.00	4	4.00	4.24	3572
7	93	Cnc	3(90)	21	2	N	11	50	4	4.00	4.00	4	4.00	4.02	3475
8	94	Cnc	3(90)	14	22	N	1	0	5(s)	5.25	5.30	5	5.00	5.31	3176
9	95	Cnc	3(90)	20	12	S	7	30	4	4.00	4.00	3.7	3.70	3.52	3249
10	96	Cnc	4(120)	2	22	S	2	20	4(s)	4.25	4.30	4(s)	4.30	5.34	3669
11	97	Cnc	4(120)	4	22	S	5	40	4(s)	4.25	4.30	4(s)	4.30	5.24	3623
12	98	Cnc	3(90)	26	42	N	7	50	5	5.00	5.00	5	5.00	5.45	3595
13	99	Cnc	3(90)	29	42	N	5	15	5	5.00	5.00	5	5.00	5.14	3627
1	100	Leo	4(120)	1	2	N	10	0	4	4.00	4.00	4	4.00	4.46	3731
2	101	Leo	4(120)	3	52	N	7	30	4	4.00	4.00	4	4.00	4.31	3773
3	102	Leo	4(120)	7	2	N	12	0	3(s)	3.25	3.30	3	3.00	3.88	3905
4	103	Leo	4(120)	6	52	N	9	30	3(k)	2.75	2.70	3(k)	2.70	2.98	3873
5	104	Leo	4(120)	12	52	N	11	0	3	3.00	3.00	3	3.00	3.44	4031
6	105	Leo	4(120)	14	52	N	8	30	2	2.00	2.00	2	2.00	2.61	4057
7	106	Leo	4(120)	13	22	N	4	30	3	3.00	3.00	3	3.00	3.52	3975
8	107	Leo	4(120)	15	12	N	0	10	1	1.00	1.00	1	1.00	1.35	3982
9	108	Leo	4(120)	16	12	S	1	50	4	4.00	4.00	4	4.00	4.37	3980
10	109	Leo	4(120)	12	42	S	0	15	5	5.00	5.00	5	5.00	5.26	3937
11	110	Leo	4(120)	10	2	0	0	0	6	6.00	6.00	5	5.00	5.35	3866
12	111	Leo	4(120)	6	52	S	3	40	6	6.00	6.00	5	5.00	4.97	3782
13	112	Leo	4(120)	10	2	S	4	10	4(k)	3.75	3.70	4	4.00	3.52	3852
14	113	Leo	4(120)	15	12	S	4	15	4	4.00	4.00	4	4.00	4.70	3950
15	114	Leo	4(120)	21	52	S	0	10	4	4.00	4.00	4	4.00	3.85	4133
16	115	Leo	4(120)	19	42	N	4	0	6	6.00	6.00	6	6.00	5.46	4127
17	116	Leo	4(120)	25	42	N	5	20	6	6.00	6.00	6	6.00	5.48	4209
18	117	Leo	4(120)	25	2	N	2	20	6	6.00	6.00	6	6.00	5.34	4227
19	118	Leo	4(120)	24	2	N	12	15	5(m)	4.50	4.70	5	5.00	4.42	4300
20	119	Leo	4(120)	26	52	N	13	40	2	2.00	2.00	2(s)	2.30	2.56	4357
21	120	Leo	4(120)	27	2	N	11	20	5	5.00	5.00	5	5.00	5.57	4408
22	121	Leo	4(120)	29	2	N	9	40	3	3.00	3.00	3	3.00	3.34	4359
23	122	Leo	5(150)	3	2	N	5	50	3(s)	3.25	3.30	3	3.00	3.94	4399
24	123	Leo	5(150)	4	22	N	1	15	4(k)	3.75	3.70	4	4.00	4.05	4386
25	124	Leo	5(150)	4	22	S	5	50	4	4.00	4.00	4	4.00	4.95	4418
26	125	Leo	5(150)	10	12	S	3	0	5	5.00	5.00	5	5.00	4.30	4471

27	126	Leo	5(150)	7	12	N	11	50	1	1.00	1.00	1(s)	1.30	2.14	4534
28	127	Leo	4(120)	18	42	N	13	20	5	5.00	5.00	5	5.00	5.08	4192
29	128	Leo	4(120)	20	52	N	15	30	5	5.00	5.00	5	5.00	4.50	4259
30	129	Leo	5(150)	0	12	N	1	10	4(s)	4.25	4.30	4	4.00	4.63	4310
31	130	Leo	4(120)	29	52	S	0	30	5	5.00	5.00	5	5.00	4.99	4294
32	131	Leo	5(150)	0	42	S	2	40	5	5.00	5.00	5	5.00	4.84	4291
33	132	Leo	5(150)	7	32	N	30	0	5	5.00	5.00	7	7.00	4.36	4737
34	133	Leo	5(150)	7	2	N	25	0	5	5.00	5.00	7	7.00	4.95	4667
35	134	Leo	5(150)	11	12	N	25	30	5	5.00	5.00	7	7.00	4.81	4789
1	135	Vir	5(150)	9	2	N	4	15	5	5.00	5.00	5	5.00	4.03	4517
2	136	Vir	5(150)	9	42	N	5	40	5	5.00	5.00	5	5.00	4.85	4515
3	137	Vir	5(150)	13	22	N	8	0	5	5.00	5.00	5	5.00	4.12	4608
4	138	Vir	5(150)	12	52	N	5	30	5	5.00	5.00	5	5.00	4.66	4589
5	139	Vir	5(150)	11	42	N	0	10	3	3.00	3.00	3	3.00	3.61	4540
6	140	Vir	5(150)	20	57	N	1	10	3	3.00	3.00	3	3.00	3.89	4689
7	141	Vir	5(150)	25	52	N	2	50	3	3.00	3.00	3	3.00	3.66	4825
8	142	Vir	5(150)	29	52	N	2	50	6	6.00	6.00	5	5.00	5.99	4925
9	143	Vir	6(180)	3	42	N	1	40	4	4.00	4.00	4	4.00	4.38	4963
10	144	Vir	5(150)	27	2	N	8	30	3	3.00	3.00	3	3.00	3.38	4910
11	145	Vir	5(150)	20	52	N	13	50	5(s)	5.25	5.30	5	5.00	4.88	4828
12	146	Vir	5(150)	22	52	N	11	40	6	6.00	6.00	6	6.00	5.22	4847
13	147	Vir	5(150)	24	52	N	15	10	3	3.00	3.00	3(s)	3.30	2.83	4932
14	148	Vir	6(180)	9	22	S	2	0	1(s)	1.25	1.30	1	1.00	0.98	5056
15	149	Vir	6(180)	7	32	N	8	40	3(s)	3.25	3.30	3	3.00	3.37	5107
16	150	Vir	6(180)	9	2	N	3	20	5(s)	5.25	5.30	5	5.00	4.69	5095
17	151	Vir	6(180)	9	42	N	0	10	6	6.00	6.00	6	6.00	5.21	5100
18	152	Vir	6(180)	12	42	N	1	30	5(s)	5.25	5.30	4(s)	4.30	5.01	5150
19	153	Vir	6(180)	10	42	S	0	20	5(s)	5.25	5.30	5	5.00	5.25	5064
20	154	Vir	6(180)	14	22	N	1	30	5(s)	5.25	5.30	5	5.00	5.51	5173
21	155	Vir	6(180)	10	42	N	8	30	5	5.00	5.00	5	5.00	5.15	5232
22	156	Vir	6(180)	19	22	N	7	30	4	4.00	4.00	4	4.00	4.08	5338
23	157	Vir	6(180)	20	2	N	2	40	4	4.00	4.00	4	4.00	4.19	5315
24	158	Vir	6(180)	21	2	N	11	40	4(s)	4.25	4.30	4	4.00	4.81	5409
25	159	Vir	6(180)	22	42	N	0	30	4	4.00	4.00	4	4.00	4.52	5359
26	160	Vir	6(180)	25	22	N	9	50	4(m)	3.50	3.70	4	4.00	3.88	5487
27	161	Vir	5(150)	27	22	S	3	30	5	5.00	5.00	5	5.00	4.66	4813
28	162	Vir	6(180)	1	42	S	3	30	5	5.00	5.00	5	5.00	4.79	4902
29	163	Vir	6(180)	4	57	S	3	20	5	5.00	5.00	5	5.00	5.19	4955
30	164	Vir	6(180)	9	52	S	7	20	6	6.00	6.00	6	6.00	5.04	4981
31	165	Vir	6(180)	10	52	S	8	20	5	5.00	5.00	5	5.00	4.74	5019
32	166	Vir	6(180)	17	52	S	7	50	6	6.00	6.00	6	6.00	4.97	5196
1	167	Lib	7(210)	0	42	N	0	40	3(k)	2.75	2.70	2	2.00	2.75	5531
2	168	Lib	6(180)	29	42	N	2	30	5(s)	5.25	5.30	5	5.00	5.31	5523
3	169	Lib	7(210)	4	52	N	8	50	3(m)	2.50	2.70	2	2.00	2.61	5685
4	170	Lib	7(210)	0	22	N	8	30	5(s)	5.25	5.30	5	5.00	4.92	5586
5	171	Lib	7(210)	6	42	S	1	40	4	4.00	4.00	4	4.00	4.54	5652
6	172	Lib	7(210)	4	2	N	1	15	5(s)	5.25	5.30	4	4.00	5.20	5622
7	173	Lib	7(210)	10	32	N	4	45	4	4.00	4.00	4	4.00	3.91	5787
8	174	Lib	7(210)	15	42	N	3	30	4	4.00	4.00	4(s)	4.30	4.15	5908

9	175	Lib	7(210)	8	52	N	9	0	5	5.00	5.00	5	5.00	4.61	5777
10	176	Lib	7(210)	16	22	N	6	40	4(s)	4.25	4.30	4(s)	4.30	4.88	5941
11	177	Lib	7(210)	17	2	N	9	15	4(s)	4.25	4.30	4(s)	4.30	4.78	5978
12	178	Lib	7(210)	16	12	N	0	30	6	6.00	6.00	6	6.00	5.03	5902
13	179	Lib	7(210)	13	2	N	3	0	6	6.00	6.00	5	5.00	5.38	5814
14	180	Lib	7(210)	13	52	S	1	30	4	4.00	4.00	4	4.00	4.74	5838
15	181	Lib	7(210)	5	42	S	7	30	3(s)	3.25	3.30	3	3.00	3.29	5603
16	182	Lib	7(210)	13	52	S	8	10	4	4.00	4.00	4	4.00	3.58	5794
17	183	Lib	7(210)	14	42	S	9	40	4	4.00	4.00	4	4.00	3.66	5812
1	184	Sco	7(210)	19	2	N	1	20	3	3.00	3.00	3	3.00	2.62	5984
2	185	Sco	7(210)	18	22	S	1	40	3	3.00	3.00	3	3.00	2.32	5953
3	186	Sco	7(210)	18	22	S	5	0	3	3.00	3.00	3	3.00	2.89	5944
4	187	Sco	7(210)	18	42	S	50	50	4(m)	3.50	3.70	3	3.00	3.88	5928
5	188	Sco	7(210)	19	42	N	1	40	4	4.00	4.00	4	4.00	4.01	6027
6	189	Sco	7(210)	19	2	N	0	30	4	4.00	4.00	4	4.00	3.96	5993
7	190	Sco	7(210)	23	22	S	3	45	3(s)	3.25	3.30	3	3.00	2.89	6084
8	191	Sco	7(210)	25	22	S	4	0	2	2.00	2.00	2	2.00	0.96	6134
9	192	Sco	7(210)	17	12	S	5	30	3	3.00	3.00	3	3.00	2.82	6165
10	193	Sco	7(210)	22	10	S	6	10	5(s)	5.25	5.30	5	5.00	4.59	6028
11	194	Sco	7(210)	23	22	S	6	40	5(s)	5.25	5.30	5	5.00	4.78	6070
12	195	Sco	8(240)	1	12	S	11	0	3	3.00	3.00	3	3.00	2.29	6241
13	196	Sco	8(240)	1	32	S	15	0	3	3.00	3.00	3	3.00	3.08	6247
14	197	Sco	8(240)	2	42	S	18	40	4	4.00	4.00	4	4.00	4.73	6262
15	198	Sco	8(240)	2	52	S	19	30	4	4.00	4.00	4	4.00	3.62	6271
16	199	Sco	8(240)	5	52	S	19	30	3(s)	3.25	3.30	3	3.00	3.33	6380
17	200	Sco	8(240)	10	52	S	18	50	3	3.00	3.00	3	3.00	1.87	6553
18	201	Sco	8(240)	12	12	S	16	40	3(s)	3.25	3.30	3	3.00	3.03	6615
19	202	Sco	8(240)	11	42	S	15	20	3	3.00	3.00	3	3.00	2.41	6580
20	203	Sco	8(240)	10	12	S	13	20	3	3.00	3.00	3	3.00	1.63	6527
21	204	Sco	8(240)	9	42	S	13	30	3(s)	3.25	3.30	4	4.00	2.69	6508
22	205	Sco	8(240)	13	52	S	13	15	-	-	-	-	-	-	M7
23	206	Sco	8(240)	8	12	S	6	10	5	5.00	5.00	5	5.00	4.29	6492
24	207	Sco	8(240)	12	12	S	4	10	5	5.00	5.00	5	5.00	4.54	6616
1	208	Sgr	8(240)	17	12	S	6	20	3(s)	3.25	3.30	3	3.00	2.99	6746
2	209	Sgr	8(240)	20	22	S	6	30	3	3.00	3.00	3	3.00	2.70	6859
3	210	Sgr	8(240)	20	42	S	10	50	3(m)	2.50	2.70	3	3.00	1.85	6879
4	211	Sgr	8(240)	21	42	N	1	30	3	3.00	3.00	3	3.00	2.83	6913
5	212	Sgr	8(240)	19	2	S	2	50	4	4.00	4.00	4	4.00	3.86	6812
6	213	Sgr	8(240)	28	2	S	3	10	3	3.00	3.00	3	3.00	2.02	7121
7	214	Sgr	8(240)	25	42	N	3	50	4(k)	3.75	3.70	4	4.00	3.17	7039
8	215	Sgr	8(240)	27	52	N	0	45	-	-	-	-	-	-	7116
9	216	Sgr	8(240)	28	22	N	2	10	4	4.00	4.00	4	4.00	3.51	7150
10	217	Sgr	9(270)	0	22	N	1	30	4	4.00	4.00	4	4.00	3.77	7217

11	218	Sgr	9(270)	1	52	N	2	0	4	4.00	4.00	4	4.00	2.89	7264
12	219	Sgr	9(270)	4	2	N	2	50	5(s)	5.25	5.30	5	5.00	4.96	7304
13	220	Sgr	9(270)	5	2	N	4	30	4(s)	4.25	4.30	4	4.00	3.93	7340
14	221	Sgr	9(270)	5	32	N	6	30	4(s)	4.25	4.30	4	4.00	4.61	7342
15	222	Sgr	9(270)	8	22	N	5	30	6	6.00	6.00	6	6.00	5.06	7489
16	223	Sgr	9(270)	12	12	N	5	50	5(s)	5.25	5.30	5	5.00	5.02	7614
17	224	Sgr	9(270)	10	22	N	2	0	6	6.00	6.00	6	6.00	5.92	7561
18	225	Sgr	9(270)	5	2	S	1	50	5(s)	5.25	5.30	5	5.00	5.03	7362
19	226	Sgr	9(270)	7	32	S	2	50	4(s)	4.25	4.30	4	4.00	4.60	7440
20	227	Sgr	9(270)	2	42	S	2	30	5(s)	5.25	5.30	5	5.00	4.85	7292
21	228	Sgr	9(270)	0	22	S	4	30	4(k)	3.75	3.70	4(k)	3.70	3.31	7234
22	229	Sgr	8(240)	29	2	S	6	45	3	3.00	3.00	3	3.00	2.60	7194
23	230	Sgr	9(270)	0	22	S	23	0	4(s)	4.25	4.30	2	2.00	4.29	7343
24	231	Sgr	8(240)	29	42	S	18	0	4(s)	4.25	4.30	2(s)	2.30	3.97	7348
25	232	Sgr	8(240)	19	22	S	13	0	3(s)	3.25	3.30	3	3.00	3.11	6832
26	233	Sgr	9(270)	10	2	S	13	30	4(s)	4.25	4.30	3	3.00	4.37	7623
27	234	Sgr	9(270)	9	32	S	20	10	4(s)	4.25	4.30	3	3.00	4.13	7581
28	235	Sgr	9(270)	10	22	S	4	50	5	5.00	5.00	5	5.00	4.70	7597
29	236	Sgr	9(270)	11	32	S	4	50	5	5.00	5.00	5	5.00	4.83	7618
30	237	Sgr	9(270)	11	32	S	5	50	5	5.00	5.00	5	5.00	4.52	7604
31	238	Sgr	9(270)	12	22	S	6	30	5	5.00	5.00	5	5.00	4.58	7650
1	239	Cap	9(270)	20	2	N	7	20	3(s)	3.25	3.30	3	3.00	3.57	7754
2	240	Cap	9(270)	20	22	N	6	40	5(s)	5.25	5.30	6	6.00	4.76	7773
3	241	Cap	9(270)	20	2	N	5	0	3(s)	3.25	3.30	3	3.00	3.08	7776
4	242	Cap	9(270)	17	42	N	8	0	6(s)	6.25	6.30	6	6.00	6.34	7712
5	243	Cap	9(270)	21	42	N	0	45	6	6.00	6.00	6	6.00	5.94	7830
6	244	Cap	9(270)	21	22	N	1	45	6	6.00	6.00	6	6.00	5.25	7814
7	245	Cap	9(270)	21	32	N	1	30	6	6.00	6.00	6	6.00	4.78	7822
8	246	Cap	9(270)	18	52	N	0	40	6	6.00	6.00	5	5.00	5.28	7761
9	247	Cap	9(270)	24	22	N	3	50	6	6.00	6.00	6	6.00	5.22	7889
10	248	Cap	9(270)	24	32	N	0	50	6	6.00	6.00	5	5.00	5.10	7900

11	249	Cap	9(270)	23	32	S	6	30	4	4.00	4.00	4	4.00	4.11	7980
12	250	Cap	9(270)	24	22	S	8	40	4	4.00	4.00	4	4.00	4.13	7936
13	251	Cap	9(270)	29	22	S	7	40	4(s)	4.25	4.30	4	4.00	4.50	8080
14	252	Cap	10(300)	2	52	S	6	50	4(s)	4.25	4.30	4	4.00	3.74	8204
15	253	Cap	10(300)	3	2	S	6	0	5(m)	5.25	4.70	5	5.00	4.51	8213
16	254	Cap	10(300)	1	22	S	4	15	6	6.00	6.00	5	5.00	5.24	8127
17	255	Cap	9(270)	29	22	S	4	0	6	6.00	6.00	5	5.00	5.30	8087
18	256	Cap	9(270)	29	22	S	2	50	5(s)	5.25	5.30	5	5.00	4.84	8060
19	257	Cap	9(270)	29	22	0	0	0	4	4.00	4.00	4	4.00	4.07	8075
20	258	Cap	10(300)	3	42	S	0	50	4	4.00	4.00	4	4.00	4.28	8167
21	259	Cap	10(300)	6	2	S	4	45	4	4.00	4.00	4	4.00	4.68	8260
22	260	Cap	10(300)	7	42	S	4	30	4(s)	4.25	4.30	4	4.00	4.73	8288
23	261	Cap	10(300)	7	32	S	2	10	3(s)	3.25	3.30	3	3.00	3.68	8278
24	262	Cap	10(300)	9	2	S	2	0	3	3.00	3.00	3	3.00	2.87	8322
25	263	Cap	10(300)	9	32	N	0	20	5(s)	5.25	5.30	5	5.00	5.18	8283
26	264	Cap	10(300)	11	22	0	0	0	5	5.00	5.00	5	5.00	5.08	8351
27	265	Cap	10(300)	10	22	N	2	50	5	5.00	5.00	5	5.00	5.58	8319
28	266	Cap	10(300)	11	22	N	4	20	5	5.00	5.00	5	5.00	5.09	8311
1	267	Aqr	10(300)	13	2	N	15	45	6(s)	6.25	6.30	5	5.00	5.10	8277
2	268	Aqr	10(300)	19	2	N	11	0	3(s)	3.25	3.30	3	3.00	2.96	8414
3	269	Aqr	10(300)	17	52	N	9	40	5	5.00	5.00	5	5.00	4.69	8402
4	270	Aqr	10(300)	9	12	N	8	50	3(s)	3.25	3.30	3	3.00	2.91	8232
5	271	Aqr	10(300)	10	2	N	6	15	5	5.00	5.00	5	5.00	4.69	8264
6	272	Aqr	10(300)	0	22	N	5	30	6	6.00	6.00	3	3.00	4.51	8093
7	273	Aqr	9(270)	28	52	N	8	0	5(s)	5.25	5.30	4	4.00	4.73	7990
8	274	Aqr	9(270)	27	22	N	8	40	4(m)	3.50	3.70	3	3.00	3.77	7950
9	275	Aqr	10(300)	22	12	N	8	45	3(s)	3.25	3.30	3	3.00	3.84	8518
10	276	Aqr	10(300)	24	22	N	10	45	4(k)	3.75	3.70	3	3.00	4.66	8539
11	277	Aqr	10(300)	24	42	N	9	0	3(s)	3.25	3.30	3	3.00	4.42	8558
12	278	Aqr	10(300)	26	42	N	8	30	3(s)	3.25	3.30	3	3.00	4.02	8597
13	279	Aqr	10(300)	18	52	N	3	0	4	4.00	4.00	4	4.00	4.16	8499
14	280	Aqr	10(300)	19	42	N	3	10	5(s)	5.25	5.30	5	5.00	5.37	8512
15	281	Aqr	10(300)	21	22	S	0	50	4(s)	4.25	4.30	4	4.00	4.82	8573
16	282	Aqr	10(300)	14	22	S	1	40	4(s)	4.25	4.30	4	4.00	4.27	8418
17	283	Aqr	10(300)	15	52	N	4	0	6	6.00	6.00	6	6.00	5.46	8452
18	284	Aqr	10(300)	24	22	S	7	30	3	3.00	3.00	3	3.00	3.27	8709
19	285	Aqr	10(300)	24	2	S	5	0	4	4.00	4.00	4	4.00	4.01	8679
20	286	Aqr	10(300)	17	22	S	5	40	6	6.00	6.00	5	5.00	6.35	8544
21	287	Aqr	10(300)	21	2	S	10	0	5(s)	5.25	5.30	5	5.00	5.26	8670

22	288	Aqr	10(300)	20	32	S	9	0	5(s)	5.25	5.30	5	5.00	4.69	8649
23	289	Aqr	10(300)	27	42	N	2	0	4	4.00	4.00	4	4.00	5.03	8610
24	290	Aqr	10(300)	27	32	N	0	10	4(s)	4.25	4.30	4	4.00	3.74	8698
25	291	Aqr	11(330)	0	22	S	1	10	4(s)	4.25	4.30	4	4.00	5.43	8782
26	292	Aqr	11(330)	2	42	S	0	30	4(s)	4.25	4.30	4	4.00	4.22	8834
27	293	Aqr	11(330)	3	12	S	1	40	4	4.00	4.00	4	4.00	5.06	8850
28	294	Aqr	11(330)	1	42	S	3	30	4	4.00	4.00	4	4.00	4.21	8841
29	295	Aqr	11(330)	2	32	S	4	10	4	4.00	4.00	4	4.00	4.39	8858
30	296	Aqr	11(330)	3	32	S	8	15	5(s)	5.25	5.30	5	5.00	5.08	8866
31	297	Aqr	11(330)	5	22	S	12	0	5	5.00	5.00	5	5.00	5.00	8968
32	298	Aqr	11(330)	5	52	S	10	50	5	5.00	5.00	5	5.00	4.49	8988
33	299	Aqr	11(330)	4	22	S	14	0	5	5.00	5.00	5	5.00	4.82	8982
34	300	Aqr	11(330)	4	52	S	14	45	5	5.00	5.00	5	5.00	5.29	8998
35	301	Aqr	11(330)	5	52	S	15	40	5	5.00	5.00	5	5.00	5.18	9031
36	302	Aqr	10(300)	29	42	S	14	10	4	4.00	4.00	4	4.00	3.97	8892
37	303	Aqr	11(330)	0	12	S	15	0	4	4.00	4.00	4	4.00	4.71	8939
38	304	Aqr	11(330)	1	2	S	15	45	4	4.00	4.00	4	4.00	4.39	8906
39	305	Aqr	10(300)	24	32	S	14	50	4	4.00	4.00	4	4.00	4.47	8789
40	306	Aqr	10(300)	25	22	S	14	20	4	4.00	4.00	4	4.00	4.69	8817
41	307	Aqr	10(300)	25	52	S	14	0	4	4.00	4.00	4	4.00	3.66	8812
42	308	Aqr	10(300)	19	42	S	23	0	1	1.00	1.00	1	1.00	1.16	8728
43	309	Aqr	11(330)	9	22	S	15	30	4(m)	3.50	3.70	4(m)	3.70	4.55	9098
44	310	Aqr	11(330)	12	22	S	14	20	4(m)	3.50	3.70	4(m)	3.70	4.89	33
45	311	Aqr	11(330)	11	42	S	18	15	4(m)	3.50	3.70	4(m)	3.70	4.44	48
1	312	Psc	11(330)	4	22	N	9	15	4	4.00	4.00	4(m)	3.70	4.53	8773
2	313	Psc	11(330)	6	52	N	7	30	4(s)	4.25	4.30	4	4.00	3.69	8852
3	314	Psc	11(330)	8	42	N	9	20	4(s)	4.25	4.30	4	4.00	5.05	8878
4	315	Psc	11(330)	10	52	N	9	30	4	4.00	4.00	4	4.00	4.28	8916
5	316	Psc	11(330)	13	22	N	7	30	4	4.00	4.00	4	4.00	4.13	8969
6	317	Psc	11(330)	8	42	N	4	30	4	4.00	4.00	4	4.00	4.94	8911
7	318	Psc	11(330)	12	22	N	3	30	4	4.00	4.00	4	4.00	4.50	8984
8	319	Psc	11(330)	18	42	N	6	20	4	4.00	4.00	4	4.00	4.01	9072
9	320	Psc	11(330)	23	42	N	5	45	6	6.00	6.00	6	6.00	5.37	80
10	321	Psc	11(330)	25	42	N	3	45	6	6.00	6.00	6	6.00	5.67	132
11	322	Psc	11(330)	29	52	N	2	15	4	4.00	4.00	4	4.00	4.43	224
12	323	Psc	0	3	12	N	1	10	4	4.00	4.00	4	4.00	4.28	294
13	324	Psc	0	5	42	S	6	0	4	4.00	4.00	4	4.00	5.24	361
14	325	Psc	0	9	12	S	2	0	6	6.00	6.00	6	6.00	5.52	330
15	326	Psc	0	5	42	S	5	0	5	5.00	5.00	6	6.00	5.16	378
16	327	Psc	0	9	12	S	2	20	4(s)	4.25	4.30	4	4.00	4.84	434
17	328	Psc	0	11	22	S	4	40	4	4.00	4.00	4	4.00	4.44	489
18	329	Psc	0	13	22	S	7	45	4	4.00	4.00	4	4.00	4.62	549
19	330	Psc	0	15	12	S	8	30	4(m)	3.50	3.70	3	3.00	4.33	596
20	331	Psc	0	13	12	N	1	20	4	4.00	4.00	4	4.00	4.26	510
21	332	Psc	0	12	52	N	1	50	5(s)	5.25	5.30	5	5.00	5.57	463
22	333	Psc	0	13	2	N	5	20	4(m)	3.50	3.70	3	3.00	3.62	437
23	334	Psc	0	13	12	N	9	0	5	5.00	5.00	4	4.00	5.38	413
24	335	Psc	0	13	42	N	21	45	5	5.00	5.00	5	5.00	5.16	349
25	336	Psc	0	13	22	N	21	40	5	5.00	5.00	5	5.00	4.51	352

26	337	Psc	0	11	22	N	20	0	6(s)	6.25	6.30	6	6.00	5.42	274
27	338	Psc	0	10	22	N	19	50	6(s)	6.25	6.30	6	6.00	6.09	262
28	339	Psc	0	9	42	N	20	20	6(s)	6.25	6.30	6	6.00	7.00	230
29	340	Psc	0	8	22	N	14	20	4	4.00	4.00	4	4.00	5.34	310
30	341	Psc	0	9	2	N	13	0	4	4.00	4.00	4	4.00	5.55	328
31	342	Psc	0	10	22	N	12	0	4	4.00	4.00	4	4.00	4.66	351
32	343	Psc	0	14	52	N	17	0	4	4.00	4.00	4	4.00	4.76	383
33	344	Psc	0	12	32	N	15	20	4	4.00	4.00	4	4.00	4.65	360
34	345	Psc	0	12	42	N	11	45	4	4.00	4.00	4	4.00	5.97	397
35	346	Psc	11(330)	13	52	S	2	40	4	4.00	4.00	4	4.00	4.86	9067
36	347	Psc	11(330)	14	57	S	2	30	4	4.00	4.00	4	4.00	5.10	9087
37	348	Psc	11(330)	13	22	S	5	30	4	4.00	4.00	4	4.00	4.41	9089
38	349	Psc	11(330)	15	2	S	5	30	4	4.00	4.00	4	4.00	4.61	3
1	1	Cet	1(30)	0	22	S	7	45	4	4.00	4.00	4	4.00	4.70	896
2	2	Cet	1(30)	0	22	S	12	20	3	3.00	3.00	3	3.00	2.53	911
3	3	Cet	0	25	22	S	11	30	3	3.00	3.00	3	3.00	3.47	804
4	4	Cet	0	23	12	S	14	0	3(s)	3.25	3.30	3	3.00	4.07	779
5	5	Cet	0	22	2	S	8	10	4	4.00	4.00	4	4.00	4.86	754
6	6	Cet	0	25	22	S	6	20	4	4.00	4.00	4	4.00	4.28	718
7	7	Cet	0	20	22	S	4	10	4(s)	4.25	4.30	4	4.00	4.37	649
8	8	Cet	0	15	42	S	24	30	4	4.00	4.00	4	4.00	4.89	708
9	9	Cet	0	16	2	S	28	0	4	4.00	4.00	4	4.00	4.75	740
10	10	Cet	0	19	22	S	25	10	4	4.00	4.00	4	4.00	4.84	781
11	11	Cet	0	19	42	S	27	30	4(k)	3.75	3.70	3	3.00	4.25	811
12	12	Cet	0	4	42	S	25	20	3(s)	3.25	3.30	3	3.00	3.52	509
13	13	Cet	0	5	42	S	30	50	4	4.00	4.00	4	4.00	4.00	585
14	14	Cet	0	7	42	S	20	0	3(s)	3.25	3.30	3	3.00	3.73	539
15	15	Cet	0	2	22	S	15	20	3(s)	3.25	3.30	3	3.00	3.60	402
16	16	Cet	11(330)	27	42	S	15	40	3(s)	3.25	3.30	3	3.00	3.45	334
17	17	Cet	11(330)	23	42	S	13	40	6	6.00	6.00	5	5.00	5.19	235
18	18	Cet	11(330)	21	22	S	14	40	6	6.00	6.00	5	5.00	5.59	227
19	19	Cet	11(330)	22	2	S	13	0	5(s)	5.25	5.30	5(k)	4.70	4.76	194
20	20	Cet	11(330)	21	42	S	14	0	5(s)	5.25	5.30	5(k)	4.70	6.02	190
21	21	Cet	11(330)	17	2	S	9	40	3(s)	3.25	3.30	3(s)	3.30	3.56	74
22	22	Cet	11(330)	18	22	S	20	20	3(m	2.50	2.70	3	3.00	2.04	188
1	23	Ori	2(60)	9	42	S	13	50	-	-	-	-	-	-	1879
2	24	Ori	2(60)	14	42	S	17	0	1(s)	1.25	1.30	1(s)	1.30	0.50	2061
3	25	Ori	2(60)	6	42	S	17	30	2	2.00	2.00	2(m)	1.50	1.64	1790
4	26	Ori	2(60)	50	42	S	18	0	4(s)	4.25	4.30	4(s)	4.30	4.20	1839
5	27	Ori	2(60)	6	2	S	14	30	4	4.00	4.00	4	4.00	4.21	2124
6	28	Ori	2(60)	19	2	S	11	50	6	6.00	6.00	6	6.00	5.04	2241
7	29	Ori	2(60)	19	12	S	10	0	5	5.00	5.00	4	4.00	4.48	2199
8	30	Ori	2(60)	38	42	S	9	45	5	5.00	5.00	4	4.00	4.42	2159
9	31	Ori	2(60)	20	2	S	8	15	6	6.00	6.00	6	6.00	5.30	2223
10	32	Ori	2(60)	19	22	S	8	15	6	6.00	6.00	6	6.00	4.95	2198
11	33	Ori	2(60)	14	22	S	3	45	5	5.00	5.00	5	5.00	4.41	2047
12	34	Ori	2(60)	17	2	S	4	15	5(s)	5.25	5.30	5	5.00	4.63	2135
13	35	Ori	2(60)	10	12	S	19	40	4	4.00	4.00	4	4.00	4.57	1934
14	36	Ori	2(60)	9	2	S	20	0	6	6.00	6.00	6	6.00	5.36	1872
15	37	Ori	2(60)	8	2	S	20	20	6	6.00	6.00	6	6.00	5.46	1842

16	38	Ori	2(60)	6	52	S	20	40	5	5.00	5.00	5	5.00	4.59	1811
17	39	Ori	2(60)	3	12	S	8	0	4	4.00	4.00	4	4.00	4.82	1676
18	40	Ori	2(60)	2	2	S	8	10	4	4.00	4.00	4	4.00	4.68	1638
19	41	Ori	2(60)	0	42	S	10	15	4	4.00	4.00	4	4.00	4.07	1580
20	42	Ori	1(30)	29	2	S	12	50	4	4.00	4.00	4	4.00	4.65	1570
21	43	Ori	1(30)	27	52	S	14	15	4	4.00	4.00	4	4.00	4.36	1544
22	44	Ori	1(30)	27	32	S	15	50	3(s)	3.25	3.30	3	3.00	3.19	1543
23	45	Ori	1(30)	27	32	S	17	10	3(s)	3.25	3.30	3	3.00	3.69	1552
24	46	Ori	1(30)	18	2	S	20	20	3(s)	3.25	3.30	3	3.00	3.72	1567
25	47	Ori	1(30)	29	2	S	21	30	4	3.00	3.00	3	3.00	4.47	1601
26	48	Ori	2(60)	8	2	S	24	10	2	2.00	2.00	2	2.00	2.23	1852
27	49	Ori	2(60)	10	2	S	24	50	2	2.00	2.00	2	2.00	1.70	1903
28	50	Ori	2(60)	10	52	S	25	40	2	2.00	2.00	2	2.00	2.05	1948
29	51	Ori	2(60)	6	32	S	25	50	3(s)	3.25	3.30	3	3.00	3.36	1788
30	52	Ori	2(60)	9	12	S	28	40	4	4.00	4.00	4	4.00	4.59	1892
31	53	Ori	2(60)	9	22	S	29	10	3(s)	3.25	3.30	3(s)	3.30	6.39	1897
32	54	Ori	2(60)	9	42	S	29	50	3(s)	3.25	3.30	3	3.00	2.77	1899
33	55	Ori	2(60)	10	22	S	30	40	4(s)	4.25	4.30	4	4.00	4.80	1937
34	56	Ori	2(60)	8	52	S	30	50	4(s)	4.25	4.30	4	4.00	4.62	1855
35	57	Ori	2(60)	2	32	S	31	30	1	1.00	1.00	1	1.00	0.12	1713
36	58	Ori	2(60)	3	42	S	30	15	4(k)	3.75	3.70	4(k)	3.70	3.60	1735
37	59	Ori	2(60)	6	2	S	31	10	4	4.00	4.00	4	4.00	4.14	1784
38	60	Ori	2(60)	12	52	S	33	30	3(k)	2.75	2.70	3(k)	2.70	2.06	2004
1	61	Eri	2(60)	1	2	S	31	50	4	4.00	4.00	4(m)	3.70	4.27	1679
2	62	Eri	2(60)	1	32	S	28	15	4	4.00	4.00	4	4.00	2.79	1666
3	63	Eri	2(60)	0	42	S	29	50	5	5.00	5.00	4	4.00	4.81	1617
4	64	Eri	1(30)	27	22	S	28	15	4(s)	4.25	4.30	4	4.00	4.39	1560
5	65	Eri	1(30)	25	52	S	25	50	4	4.00	4.00	4	4.00	4.02	1520
6	66	Eri	1(30)	22	52	S	25	20	4	4.00	4.00	4	4.00	3.93	1463
7	67	Eri	1(30)	19	2	S	26	0	5(s)	5.25	5.30	5	5.00	5.17	1383
8	68	Eri	1(30)	18	12	S	27	0	4	4.00	4.00	4	4.00	4.47	1325
9	69	Eri	1(30)	15	32	S	27	50	4	4.00	4.00	4	4.00	4.04	1298
10	70	Eri	1(30)	9	42	S	32	7	3(s)	3.25	3.30	3	3.00	2.95	1231
11	71	Eri	1(30)	7	22	S	31	0	4	4.00	4.00	4	4.00	4.42	1162
12	72	Eri	1(30)	6	52	S	28	50	4(m)	3.50	3.70	3	3.00	3.54	1136
13	73	Eri	1(30)	4	42	S	28	0	3(s)	3.25	3.30	3	3.00	3.71	1084
14	74	Eri	0	29	52	S	25	30	4	4.00	4.00	3	3.00	4.80	984
15	75	Eri	0	27	32	S	23	50	5	5.00	5.00	4	4.00	5.26	925
16	76	Eri	0	24	52	S	23	50	4(m)	3.50	3.70	3	3.00	3.89	874
17	77	Eri	0	23	12	S	23	15	6	6.00	6.00	4	4.00	6.32	859
18	78	Eri	0	17	52	S	32	10	4	4.00	4.00	4	4.00	4.46	818
19	79	Eri	0	18	32	S	34	50	4(s)	4.25	4.30	4	4.00	4.75	850
20	80	Eri	0	21	32	S	38	30	4(m)	3.50	3.70	4	4.00	4.09	919
21	81	Eri	0	26	32	S	38	10	4	4.00	4.00	4	4.00	3.69	1003
22	82	Eri	1(30)	0	12	S	39	0	4	4.00	4.00	4	4.00	4.27	1088
23	83	Eri	1(30)	4	2	S	41	20	4	4.00	4.00	4	4.00	4.23	1173
24	84	Eri	1(30)	4	12	S	42	30	5(s)	5.25	5.30	5	5.00	5.24	1181
25	85	Eri	1(30)	4	52	S	43	15	4	4.00	4.00	4	4.00	4.65	1213
26	86	Eri	1(30)	7	22	S	43	20	4	4.00	4.00	4	4.00	4.66	1240
27	87	Eri	1(30)	16	52	S	50	20	4(s)	4.25	4.30	4	4.00	4.51	1453
28	88	Eri	1(30)	17	42	S	51	45	4	4.00	4.00	4	4.00	3.82	1464

29	89	Eri	1(30)	10	52	S	53	50	4	4.00	4.00	4	4.00	3.96	1393
30	90	Eri	1(30)	8	32	S	53	10	4(m)	3.50	3.70	4	4.00	3.56	1347
31	91	Eri	1(30)	0	32	S	53	0	4	4.00	4.00	4	4.00	5.11	1214
32	92	Eri	0	27	32	S	53	30	4	4.00	4.00	4	4.00	4.17	1195
33	93	Eri	0	24	32	S	52	0	4	4.00	4.00	4	4.00	4.59	1143
34	94	Eri	0	12	52	S	53	30	1	1.00	1.00	1	1.00	3.24	897
1	95	Lep	2(60)	2	22	S	35	0	5	5.00	5.00	5	5.00	4.45	1696
2	96	Lep	2(60)	2	32	S	36	30	5	5.00	5.00	5	5.00	4.36	1705
3	97	Lep	2(60)	4	2	S	35	40	5	5.00	5.00	5	5.00	5.30	1757
4	98	Lep	2(60)	4	2	S	36	40	5	5.00	5.00	5	5.00	4.29	1756
5	99	Lep	2(60)	1	52	S	39	15	4(k)	3.75	3.70	4(k)	3.70	3.31	1702
6	100	Lep	2(60)	28	52	S	45	15	4(m)	3.50	3.70	4(m)	3.70	3.19	1654
7	101	Lep	2(60)	8	32	S	41	30	3(s)	3.25	3.30	3	3.00	2.58	1865
8	102	Lep	2(60)	7	2	S	44	20	3(s)	3.25	3.30	3	3.00	2.84	1829
9	103	Lep	2(60)	18	42	S	44	15	4(k)	3.75	3.70	4(k)	3.70	3.80	2035
10	104	Lep	2(60)	11	42	S	45	50	4(k)	3.75	3.70	4(k)	3.70	3.60	1983
11	105	Lep	2(60)	12	42	S	38	20	4(k)	3.75	3.70	4(k)	3.70	3.55	1998
12	106	Lep	2(60)	15	22	S	38	10	4(k)	3.75	3.70	4(k)	3.70	3.71	2085
1	107	CMa	3(90)	0	22	S	39	10	1	1.00	1.00	1	1.00	-1.4	2491
2	108	CMa	3(90)	2	22	S	35	0	4(s)	4.25	4.30	4	4.00	4.06	2574
3	109	CMa	3(90)	4	2	S	36	30	5	5.00	5.00	5	5.00	5.00	2593
4	110	CMa	3(90)	6	2	S	37	45	4	4.00	4.00	4	4.00	4.12	2657
5	111	CMa	3(90)	8	2	S	40	0	4	4.00	4.00	4	4.00	4.37	2596
6	112	CMa	3(90)	3	12	S	42	40	5	5.00	5.00	5	5.00	4.68	2590
7	113	CMa	2(60)	28	52	S	41	15	5	5.00	5.00	5	5.00	4.43	2443
8	114	CMa	2(60)	28	42	S	42	30	5	5.00	5.00	5	5.00	3.95	2429
9	115	CMa	2(60)	23	42	S	41	20	3	3.00	3.00	3	3.00	1.98	2294
10	116	CMa	2(60)	27	22	S	46	30	5	5.00	5.00	5	5.00	4.33	2387
11	117	CMa	2(60)	28	52	S	45	50	5	5.00	5.00	5	5.00	4.54	2414
12	118	CMa	3(90)	7	22	S	46	10	4	4.00	4.00	4	4.00	3.02	2653
13	119	CMa	3(90)	4	22	S	47	0	5	5.00	5.00	5	5.00	3.87	2580
14	120	CMa	3(90)	9	22	S	48	45	3	3.00	3.00	3	3.00	1.84	2693
15	121	CMa	3(90)	6	22	S	51	30	3	3.00	3.00	3	3.00	1.50	2618
16	122	CMa	3(90)	5	42	S	54	10	4	4.00	4.00	4	4.00	3.98	2538
17	123	CMa	2(60)	22	22	S	53	45	3	3.00	3.00	3	3.00	3.02	2282
18	124	CMa	3(90)	14	52	S	50	40	3(s)	3.25	3.30	3(s)	3.30	2.45	2827
19	125	CMa	3(90)	2	12	S	25	15	4	4.00	4.00	4	4.00	4.99	2648
20	126	CMa	2(60)	22	42	S	61	30	4	4.00	4.00	4	4.00	5.02	2177

21	127	CMa	2(60)	24	2	S	58	45	5	5.00	5.00	4	4.00	4.37	2256
22	128	CMa	2(60)	25	42	S	57	0	4	4.00	4.00	4	4.00	3.85	2296
23	129	CMa	2(60)	26	52	S	56	0	5	5.00	5.00	4	4.00	4.48	2361
24	130	CMa	2(60)	10	42	S	55	30	4(s)	4.25	4.00	4	4.00	5.17	1996
25	131	CMa	2(60)	13	2	S	57	40	5	5.00	5.00	4	4.00	4.87	2056
26	132	CMa	2(60)	15	2	S	59	30	4(s)	4.25	4.00	4	4.00	4.36	2106
27	133	CMa	2(60)	11	42	S	59	40	3	3.00	3.00	2	2.00	3.11	2040
28	134	CMa	2(60)	8	42	S	57	40	3	3.00	3.00	2	2.00	2.64	1956
29	135	CMa	2(60)	4	52	S	59	30	4(s)	4.25	4.30	4	4.00	3.87	1862
1	136	CMi	3(90)	7	42	S	14	0	4	4.00	4.00	4	4.00	2.90	2845
2	137	CMi	3(90)	11	52	S	16	10	1	1.00	1.00	1	1.00	0.38	2943
1	138	Arg	3(90)	23	2	S	42	30	5	5.00	5.00	5	5.00	4.20	3102
2	139	Arg	3(90)	27	2	S	43	20	3	3.00	3.00	3	3.00	2.80	3185
3	140	Arg	3(90)	21	31	S	45	0	4(m)	3.50	3.70	4	4.00	3.34	3045
4	141	Arg	3(90)	21	22	S	46	0	5	5.00	5.00	4	4.00	4.50	3034
5	142	Arg	3(90)	18	2	S	45	30	5(s)	5.25	5.30	4	4.00	4.70	2944
6	143	Arg	3(90)	19	2	S	47	15	4(m)	3.50	3.70	3	3.00	4.50	2948
7	144	Arg	3(90)	18	2	S	49	30	4	4.00	4.00	4	4.00	4.64	2922
8	145	Arg	3(90)	22	2	S	49	30	4	4.00	4.00	4	4.00	3.96	2996
9	146	Arg	3(90)	21	12	S	49	15	5	5.00	5.00	4	4.00	4.59	2993
10	147	Arg	3(90)	26	42	S	49	50	4(s)	4.25	4.30	4	4.00	4.79	3113
11	148	Arg	3(90)	16	42	S	53	0	5(s)	5.25	5.30	4	4.00	5.35	2823
12	149	Arg	3(90)	16	42	S	58	40	3	3.00	3.00	3	3.00	2.70	2773
13	150	Arg	3(90)	22	52	S	55	30	5	5.00	5.00	5	5.00	4.53	2937
14	151	Arg	3(90)	24	52	S	58	40	5	5.00	5.00	5	5.00	4.84	2961
15	152	Arg	3(90)	26	22	S	57	15	4	4.00	4.00	4	4.00	3.61	3017
16	153	Arg	3(90)	29	12	S	57	45	4	4.00	4.00	4	4.00	4.49	3084
17	154	Arg	4(120)	3	52	S	58	20	2	2.00	2.00	2	2.00	2.25	3165
18	155	Arg	4(120)	0	52	S	60	0	5	5.00	5.00	5	5.00	3.73	3080
19	156	Arg	4(120)	3	42	S	59	20	5	5.00	5.00	5	5.00	5.52	3162
20	157	Arg	4(120)	5	42	S	56	40	5	5.00	5.00	5	5.00	4.45	3225
21	158	Arg	4(120)	7	2	S	57	0	5	5.00	5.00	5	5.00	4.44	3243
22	159	Arg	4(120)	18	22	S	51	30	4	4.00	4.00	4	4.00	5.82	3535
23	160	Arg	4(120)	18	52	S	55	40	4	4.00	4.00	4	4.00	4.07	3477
24	161	Arg	4(120)	16	42	S	57	10	4	4.00	4.00	4	4.00	4.14	3426
25	162	Arg	4(120)	21	52	S	60	0	4(k)	3.50	3.75	4(k)	3.70	3.91	3487
26	163	Arg	4(120)	21	42	S	61	15	4(k)	3.50	3.75	4(k)	3.70	3.84	3445
27	164	Arg	4(120)	12	52	S	51	30	4	4.00	4.00	3	3.00	3.97	3438
28	165	Arg	4(120)	12	2	S	49	0	4	4.00	4.00	3	3.00	3.68	3468
29	166	Arg	4(120)	10	42	S	43	30	4(s)	4.25	4.30	4	4.00	4.01	3518
30	167	Arg	4(120)	11	42	S	43	30	4(s)	4.25	4.30	4	4.00	4.89	3556
31	168	Arg	4(120)	26	52	S	54	30	2	2.00	2.00	2	2.00	2.21	3634
32	169	Arg	5(150)	0	12	S	51	15	3	3.00	3.00	2(s)	2.30	3.60	3786

33	170	Arg	3(90)	23	52	S	63	0	4(m)	3.50	3.70	4	4.00	3.24	2878
34	171	Arg	4(120)	1	42	S	64	30	6	6.00	6.00	6	6.00	4.11	3055
35	172	Arg	4(120)	12	42	S	63	50	2	2.00	2.00	2	2.00	1.78	3207
36	173	Arg	4(120)	21	12	S	64	40	4	4.00	4.00	2	2.00	3.47	3117
37	174	Arg	4(120)	27	52	S	65	40	3	3.00	3.00	3	3.00	3.62	3447
38	175	Arg	5(150)	4	2	S	65	30	3	3.00	3.00	3	3.00	1.96	3485
39	176	Arg	5(150)	8	42	S	66	20	3	3.00	3.00	2	2.00	4.49	3498
40	177	Arg	5(150)	13	42	S	62	50	4	4.00	4.00	3	3.00	2.50	3734
41	178	Arg	5(150)	20	42	S	62	15	4(m)	3.50	3.70	2	2.00	3.13	3803
42	179	Arg	2(60)	16	42	S	65	50	4	4.00	4.00	4(m)	3.70	3.96	2120
43	180	Arg	3(90)	2	52	S	65	40	3(s)	3.25	3.30	3	3.00	3.17	2451
44	181	Arg	2(60)	29	52	S	75	0	1	1.00	1.00	1	1.00	0.72	2326
45	182	Arg	3(90)	11	42	S	71	45	3(s)	3.25	3.30	3	3.00	2.93	2553
1	183	Hya	3(90)	26	42	S	15	0	4(s)	4.25	4.30	4	4.00	6.33	3418
2	184	Hya	3(90)	26	2	S	13	10	4	4.00	4.00	4	4.00	4.16	3410
3	185	Hya	3(90)	28	2	S	11	30	4	4.00	4.00	4	4.00	3.38	3482
4	186	Hya	3(90)	28	12	S	14	45	4	4.00	4.00	4	4.00	4.30	3454
5	187	Hya	4(120)	0	32	S	12	0	4(m)	3.50	3.70	4	4.00	3.11	3547
6	188	Hya	4(120)	3	2	S	14	40	6	6.00	6.00	6	6.00	4.97	3613
7	189	Hya	4(120)	6	2	S	19	20	4	4.00	4.00	4	4.00	3.88	3665
8	190	Hya	4(120)	11	32	S	15	20	4(s)	4.25	4.30	4	4.00	4.57	3787
9	191	Hya	4(120)	13	22	S	14	50	4(s)	4.25	4.30	4	4.00	3.91	3845
10	192	Hya	4(120)	11	12	S	17	10	4(s)	4.25	4.30	4	4.00	4.60	3759
11	193	Hya	4(120)	11	52	S	19	45	6(s)	6.25	6.30	6	6.00	5.37	3750
12	194	Hya	4(120)	12	42	S	20	30	2	2.00	2.00	2	2.00	1.98	3748
13	195	Hya	4(120)	18	42	S	26	30	4	4.00	4.00	4	4.00	5.06	3849
14	196	Hya	4(120)	21	22	S	26	0	4	4.00	4.00	4	4.00	4.12	3903
15	197	Hya	4(120)	23	52	S	23	15	4(k)	3.75	3.70	4	4.00	4.60	3970
16	198	Hya	5(150)	0	42	S	24	40	3(s)	3.25	3.30	3	3.00	3.81	4094
17	199	Hya	5(150)	2	42	S	23	0	4(s)	4.25	4.30	4	4.00	4.91	4171
18	200	Hya	5(150)	5	42	S	22	10	3	3.00	3.00	3	3.00	3.11	4232
19	201	Hya	5(150)	14	12	S	25	45	4	4.00	4.00	4(m)	3.70	4.48	4343
20	202	Hya	5(150)	15	2	S	30	10	4	4.00	4.00	4	4.00	4.94	4314
21	203	Hya	5(150)	24	52	S	31	20	4(k)	3.75	3.70	4	4.00	3.54	4450
22	204	Hya	5(150)	27	12	S	33	10	4	4.00	4.00	4	4.00	4.70	4494
23	205	Hya	5(150)	28	52	S	31	20	3	3.00	3.00	3	3.00	4.28	4552
24	206	Hya	6(180)	12	42	S	13	40	3(s)	3.25	3.30	4(k)	3.70	3.00	5020
25	207	Hya	6(180)	26	12	S	17	40	3(s)	3.25	3.30	4(k)	3.70	3.27	5287
26	208	Hya	3(90)	25	12	S	23	15	3	3.00	3.00	3	3.00	3.90	3314
27	209	Hya	4(120)	23	42	S	16	0	4	4.00	4.00	3	3.00	5.24	4042
1	210	Car	5(150)	9	2	S	23	0	4	4.00	4.00	4	4.00	4.08	4287
2	211	Car	5(150)	15	12	S	19	30	4	4.00	4.00	4	4.00	4.08	4405
3	212	Car	5(150)	12	42	S	18	0	4	4.00	4.00	4	4.00	3.56	4382
4	213	Car	5(150)	19	42	S	18	30	5(s)	5.25	5.30	4(k)	3.70	4.73	4514
5	214	Car	5(150)	52	2	S	13	40	4(s)	4.25	4.30	4	4.00	4.83	4402
6	215	Car	5(150)	21	52	S	16	10	4(s)	4.25	4.30	4(s)	4.30	5.18	4567

7	216	Car	5(150)	14	22	S	11	50	4(s)	4.25	4.30	4	4.00	4.70	4468
1	217	Crv	5(150)	28	2	S	21	40	3(s)	3.25	3.30	3	3.00	4.02	4623
2	218	Crv	5(150)	27	2	S	19	40	3	3.00	3.00	3	3.00	3.00	4630
3	219	Crv	5(150)	29	22	S	18	10	5	5.00	5.00	5	5.00	5.21	4696
4	220	Crv	5(150)	26	12	S	14	50	3	3.00	3.00	3	3.00	2.59	4662
5	221	Crv	5(150)	29	22	S	12	30	3	3.00	3.00	3	3.00	2.95	4757
6	222	Crv	5(150)	29	42	S	11	45	4	4.00	4.00	4	4.00	4.31	4775
7	223	Crv	6(180)	3	12	S	18	10	3	3.00	3.00	3	3.00	2.65	4786
1	224	Cen	6(180)	23	12	S	21	40	5	5.00	5.00	5(m)	4.70	4.19	5192
2	225	Cen	6(180)	22	42	S	18	50	5	5.00	5.00	5(m)	4.70	4.73	5221
3	226	Cen	6(180)	21	52	S	20	30	4	4.00	4.00	4(k)	3.70	4.23	5168
4	227	Cen	6(180)	22	42	S	20	0	5	5.00	5.00	5(m)	4.70	4.56	5210
5	228	Cen	6(180)	18	52	S	25	40	3	3.00	3.00	3	3.00	2.75	5028
6	229	Cen	6(180)	28	22	S	22	30	3	3.00	3.00	3	3.00	2.06	5288
7	230	Cen	6(180)	21	52	S	27	30	5	5.00	5.00	4	4.00	3.88	5089
8	231	Cen	7(210)	0	52	S	22	20	4(s)	4.25	4.30	4	4.00	4.25	5367
9	232	Cen	7(210)	1	52	S	23	45	4	4.00	4.00	4	4.00	4.42	5378
10	233	Cen	7(210)	4	42	S	18	15	4	4.00	4.00	4	4.00	4.05	5485
11	234	Cen	7(210)	5	12	S	20	50	4	4.00	4.00	4	4.00	4.00	5471
12	235	Cen	6(180)	26	2	S	28	20	4(m)	3.50	3.70	4(m)	3.70	3.41	5190
13	236	Cen	6(180)	26	42	S	29	20	4(m)	3.50	3.70	4(m)	3.70	3.04	5193
14	237	Cen	6(180)	27	52	S	28	0	4	4.00	4.00	4(m)	3.70	3.83	5248
15	238	Cen	6(180)	29	2	S	26	30	4(m)	3.50	3.70	4(m)	3.70	4.36	5285
16	239	Cen	7(210)	5	32	S	25	15	3	3.00	3.00	3	3.00	2.31	5440
17	240	Cen	7(210)	10	12	S	24	0	4(m)	3.50	3.70	4	4.00	3.13	5576
18	241	Cen	7(210)	0	42	S	33	30	3	3.00	3.00	2(m)	2.70	2.55	5231
19	242	Cen	7(210)	0	22	S	31	0	5	5.00	5.00	5	5.00	4.34	5260
20	243	Cen	6(180)	29	32	S	30	20	5	5.00	5.00	5	5.00	3.87	5249
21	244	Cen	6(180)	24	52	S	34	50	5	5.00	5.00	5	5.00	3.00	0
22	245	Cen	6(180)	21	42	S	37	40	5	5.00	5.00	5	5.00	4.71	4940
23	246	Cen	6(180)	18	52	S	40	0	3	3.00	3.00	3	3.00	2.17	4819
24	247	Cen	6(180)	17	42	S	40	20	5	5.00	5.00	4	4.00	3.86	4802
25	248	Cen	6(180)	15	22	S	41	0	5(m)	4.50	4.70	5	5.00	3.91	4743

26	249	Cen	6(180)	15	22	S	46	10	3	3.00	3.00	3	3.00	2.60	4621
27	250	Cen	6(180)	16	12	S	46	45	5	5.00	5.00	4	4.00	3.96	4638
28	251	Cen	7(210)	1	2	S	40	45	5(s)	5.25	5.30	4	4.00	4.65	5172
29	252	Cen	6(180)	29	2	S	43	0	3	3.00	3.00	2	2.00	2.30	5132
30	253	Cen							-	-	-	-	-	-	5141
31	254	Cen	6(180)	22	42	S	51	10	2	2.00	2.00	2	2.00	1.63	4763
32	255	Cen	6(180)	28	2	S	51	40	2	2.00	2.00	2	2.00	1.25	4853
33	256	Cen	6(180)	59	2	S	55	10	3(s)	3.25	3.30	4	4.00	2.80	4656
34	257	Cen	6(180)	23	52	S	55	20	2	2.00	2.00	2	2.00	0.83	4730
35	258	Cen	7(210)	21	2	S	41	10	1	1.00	1.00	1	1.00	0.01	5459
36	259	Cen	7(210)	6	52	S	45	20	2(m)	1.50	1.70	2	2.00	0.61	5267
37	260	Cen	6(180)	27	22	S	49	10	4(s)	4.25	4.30	4	4.00	3.28	4898
1	261	Lup	7(210)	10	42	S	24	50	3	3.00	3.00	3	3.00	2.68	5571
2	262	Lup	7(210)	8	32	S	29	10	3	3.00	3.00	3	3.00	2.30	5469
3	263	Lup	7(210)	13	42	S	21	15	4(m)	3.50	3.70	4	4.00	3.22	5695
4	264	Lup	7(210)	16	52	S	21	0	3(s)	3.25	3.30	4	4.00	2.78	5776
5	265	Lup	7(210)	15	42	S	25	10	4(m)	3.50	3.70	4	4.00	3.37	5708
6	266	Lup	7(210)	12	52	S	27	0	5	5.00	5.00	5	5.00	4.05	5626
7	267	Lup	7(210)	13	12	S	29	0	5	5.00	5.00	5	5.00	4.72	5605
8	268	Lup	7(210)	17	22	S	28	30	5	5.00	5.00	5	5.00	4.27	5683
9	269	Lup	7(210)	16	22	S	30	10	5	5.00	5.00	5	5.00	3.87	5646
10	270	Lup	7(210)	18	22	S	33	10	4(s)	4.25	4.30	5	5.00	3.41	5649
11	271	Lup							-	-	-	-	-	-	5453
12	272	Lup	7(210)	4	32	S	30	30	4(s)	4.25	4.30	4	4.00	3.55	5354
13	273	Lup	7(210)	5	42	S	29	20	5	5.00	5.00	4(k)	3.70	4.35	5396
14	274	Lup	7(210)	21	32	S	17	0	4	4.00	4.00	4	4.00	3.41	5948
15	275	Lup	7(210)	22	2	S	15	20	5	5.00	5.00	4(m)	3.70	4.23	5987
16	276	Lup	7(210)	18	22	S	13	20	5(m)	4.50	4.70	4	4.00	3.95	5883
17	277	Lup	7(210)	19	22	S	11	50	5(s)	5.25	5.30	4(m)	3.70	5.12	5925
18	278	Lup	7(210)	10	2	S	11	30	6	6.00	6.00	4	4.00	4.91	5660
19	279	Lup	7(210)	12	12	S	10	0	5(s)	5.25	5.30	4(m)	3.70	4.34	5686
1	280	Ara	8(240)	10	22	S	22	40	6	6.00	6.00	5	5.00	4.59	6537
2	281	Ara	8(240)	13	2	S	25	45	4	4.00	4.00	4	4.00	3.66	6743
3	282	Ara	8(240)	8	52	S	26	30	4(k)	3.75	3.70	4(k)	3.70	2.95	6510
4	283	Ara	8(240)	3	22	S	30	20	5(s)	5.25	5.30	5	5.00	4.06	6295
5	284	Ara	8(240)	7	52	S	34	10	4(s)	4.25	4.30	4(m)	3.70	3.34	6462
6	285	Ara	8(240)	7	42	S	33	20	4	4.00	4.00	4	4.00	2.85	6461
7	286	Ara	8(240)	3	32	S	34	0	4	4.00	4.00	4	4.00	3.13	6285
1	287	CrA	8(240)	21	52	S	21	30	4	4.00	4.00	4	4.00	3.51	6897
2	288	CrA	8(240)	24	22	S	21	0	6	6.00	6.00	5	5.00	5.49	7062

3	289	CrA	8(240)	25	52	S	20	20	6	6.00	6.00	5	5.00	5.36	7122
4	290	CrA	8(240)	27	32	S	20	0	5	5.00	5.00	4	4.00	4.75	7188
5	291	CrA	8(240)	28	52	S	18	30	5(s)	5.25	5.30	5	5.00	4.59	7242
6	292	CrA	8(240)	29	42	S	17	10	5	5.00	5.00	4	4.00	4.11	7259
7	293	CrA	8(240)	29	32	S	16	0	5	5.00	5.00	4	4.00	4.11	7254
8	294	CrA	8(240)	29	12	S	15	10	5	5.00	5.00	4	4.00	4.94	7226
9	295	CrA	8(240)	27	52	S	15	20	6	6.00	6.00	6	6.00	4.86	7152
10	296	CrA	8(240)	27	22	S	14	50	6	6.00	6.00	6	6.00	5.38	7129
11	297	CrA	8(240)	24	32	S	14	40	5(s)	5.25	5.30	5	5.00	5.13	7021
12	298	CrA	8(240)	22	22	S	15	50	5(s)	5.25	5.30	5	5.00	5.16	6942
13	299	CrA	8(240)	21	52	S	18	30	5	5.00	5.00	5	5.00	4.64	6951
1	300	PsA	10(300)	18	22	S	20	20	4	4.00	4.00	1	1.00	1.16	8728
2	300	PsA	10(300)	18	22	S	20	20	4	4.00	4.00	4	4.00	4.29	8576
3	301	PsA	10(300)	16	52	S	22	15	4	4.00	4.00	4	4.00	4.21	8720
4	302	PsA	10(300)	18	12	S	22	30	4	4.00	4.00	4	4.00	4.46	8695
5	303	PsA	10(300)	17	2	S	16	15	5	5.00	5.00	4	4.00	4.17	8628
6	304	PsA	10(300)	7	52	S	19	30	6(s)	6.25	6.25	5	5.00	4.50	8431
7	305	PsA	10(300)	13	52	S	15	10	5	5.00	5.00	4	4.00	6.43	8570
8	306	PsA	10(300)	11	32	S	14	40	5	5.00	5.00	4	4.00	5.43	8478
9	307	PsA	10(300)	7	52	S	15	5	5(k)	4.75	4.70	4	4.00	5.42	8386
10	308	PsA	10(300)	4	32	S	16	30	4	4.00	4.00	4	4.00	5.01	8326
11	309	PsA	10(300)	3	42	S	18	10	3(s)	3.25	3.30	4	4.00	4.34	8305
12	310	PsA	10(300)	8	42	S	22	15	3(s)	3.25	3.30	4	4.00	3.01	8353
13		PsA										3(s)	3.30	5.53	8069
14		PsA										3(s)	3.30	4.82	8151
15		PsA										3(s)	3.30	5.29	8229
16		PsA										5	5.00	5.77	8180
17		PsA										4	4.00	4.90	7965
18		PsA										4	4.00	4.67	8039

8.2 Excerpts of translation of Poem by al-Ṣūfī's Son

This is a Poem on the fixed stars. It is called "*al-Urjūza li Ibn al-Ṣūfī*" which means "The Poem by Ibn al-Ṣūfī". It is composed of 495 verses which are divided into 48 stanzas, one for each constellation. Every stanza describes the constellation in a simple and easy to understand language. The style is not exactly a literally poetic style; therefore it is called *Urjūza, which* means "Prose" rather then a poem. The writer was trying to compose an easy to memorize poem and not a scientific piece of work; therefore it does not include much detailed scientific information in many of the constellations.

Al-Qifṭī attributed this poem to al-Ṣūfī; however this poem was written by the son of al-Ṣūfī and not by al-Ṣūfī himself. The first 6 verses from this poem clearly identify the person who wrote this poem and to whom it was attributed. The second verse explains that this poem was written by Abū 'Alī the son of Abū al-Ḥusaīn al-Ṣūfī. The fourth verse states that this poem was dedicated to Shāhenshāh Abū al-Ma'ali Fakher al-Dīn, who was the second son of Rukn al-Dawla. Fakher al-Dawla took power in Rayy in A.D. 976 after his father's death. He took the title of Shāhenshāh in A.D. 984 until his death in A.D. 997; therefore this poem must have been composed some time between A.D. 984 and A.D. 997 and most probably after al-Ṣūfī's death in A.D. 986. However another reference (Kunitzsch, Encyclopedia Iranica) identifies Shāhenshāh Abū al-Ma'ali Fakher Din Allah as the *Artuqid* ruler in A.D. 1143; thus Kunitzsch rejects the claim that this poem was ever written during the time of al-Ṣūfī or by his son. However the final verses of this poem state that the information on the stars was taken from the book of al-Ṣūfī. Therefore it would be a strange coincidence that this Ibn al-Ṣūfī also has a father who was called Abū al-Ḥusaīn al-Ṣūfī who wrote a book on the stars from which the son composes a poem in this subject. A copy of this poem is to be found at the end of the below-mentioned manuscripts of al-Ṣūfī's Book of the fixed stars". This is why there was sometimes a little confusion as to who wrote the poem. This also explains another confusion, which is the name of al-Ṣūfī because he was referred to as Ibn al-Ṣūfī in many historical reference works.

- Vatican Library, Manuscript: MS Rossi 1033, Copy dated A.H. 621/A.D. 1224
- Paris Bibliotheque Nationale, Manuscript: Arab 979, Copy date unknown
- Munich library , Manuscript: Arab 870, Copy date unknown

I have translated below a few lines from *al-Urjūza* (Poem) by al-Ṣūfī's son. The first couplet forms the introductory to this poem. The second couplet is for the constellation Ursa

Minor. The last is the final excerpt from the last constellation Piscis Austrinus and the conclusion of this poem.

In the name of God the just the one	and God’s Mercy on Muḥammad
This is a treatise written by Abū ‘Alī	the son of Abū al-Ḥusaīn al-Ṣūfī
Describing the stars and their orbits	written for the king of kings
The king of the nation, Shāhenshāh	Abū al-Ma‘ali Fakher al-Dīn
God made him the king of his time	and did not take away his domain
Those who ask me about the stars	and what they hold of wonders
I took it from one who knows	adding my literary knowledge to it
Behold the depiction of the great sphere	and all it holds of the stars
Know that the closest to the pole	are stars in the image of a bear
They are seven if you count them	drawn with the pole on the same spot
There are two stars in this constellation	the distance between them is 2 *Shibr*
The Arabs call them *al-Farqadain*	under the brighter of the two
A small dim star not drawn	the Arabs of the desert call it *Fa’s al-Raḥā*
Yes and a star used to find the *Qiblah*	it is above the tail of the bear
Called *al-Juday* by the Arabs	from those close and far
It is close to the pole	other stars known by the Arabs
Called also *Banāt Na’es*h	together with *al-Fared* the old star
They are followed by stars in the south	some with light and others dim
They are called *al-Ḥūt* by the Romans	and those which are called astronomers
None of the Arabs mentioned them	nor were they mentioned by other names
These are the stars which	you find in the history books
They are known	by the scholars from *al-Kūfa*
Some by scholars of *al-Shām*	also by other well informed persons
There are other stars in the sky	nobody has heard of their names
The Arabs call them *al-Suhūla*	they are known by unpleasant names
Our father mentioned them in his book	so every one should be aware of them
Finally may God always pray	for the Prophet of his righteous religion
Muḥammad the selected one	and the chosen at the Day of Judgment
Then on his disciples and family	as long as the days and nights exist

8.3 Arabic Transliteration:

The Arabic language has a number of phonemes that have no equivalent in English. Therefore several different transliteration standards have been used to represent certain Arabic characters such as the ISO, DIN and the British BS standard. However I have tried to follow the Library of Congress transliteration rules in this thesis.

Dates:

Unless mentioned, all dates in the thesis use Anno Domini system (i.e. A.D. and B.C.). When Hijri dates (Islamic calendar) are noted, they will be indicated by the suffix A.H. (i.e. A.H. 657). When double dates are mentioned A.D. dates are preceded by Hijri Dates and separated by a slash (i.e. 657/1261 is A.H. /A.D.).