# Maghrebian Astronomy at the Time of Ramon Llull

**Julio Samsó.** Professor of Arabic and Islamic Studies, Universitat de Barcelona

It is a well-known fact that Ramon Llull (1232-1316) visited the Maghreb on several occasions: Tunis in 1292, Bougie in 1307 and both cities between 1314 and 1315. It was while in Paris in 1297, however, that he put the finishing touches to his *Tractatus novus de astronomia* ("Book of the Seven Planets") – in reality more of a treaty on astrology – in which he attempted to apply his *Ars Nova* to the art of astrological prediction. In spite of the fact that our author's astronomical and astrological knowledge did not really compare with what it would have been possible to learn in the Maghreb, it is nonetheless interesting to chart, broad brush, the basic elements of the astronomy that developed in this region during Llull's lifetime, within the framework of what is a manifestly al-Andalusian scientific tradition.

Let us begin with a text by Ibn Khaldun, which I translate from Quatremère's version: "The general public have a multitude of works available to them, written by authors both ancient and modern, including al-Battani [died 929] and Ibn al-Kammad [died Cordoba, 1116/1117]. Modern-day Maghrebis use the *zīj* [a manual of astronomy containing numerical tables], attributed to Ibn Ishaq [died between 1193 and 1222]. They claim that Ibn Ishaq put this manual together from observations and that a Jewish expert in astronomy and mathematics, who was in Sicily, showed interest in his observations, subsequently providing him with the most accurate materials regarding the positions and movements of the planets. Maghrebis were so interested in his [Ishaq's] work because of the sound basis from which they believe it to have been developed. Ibn al-Banna [1256-1321] summarised it [Ishaq's *zīj*] into another version, which he entitled *Minhāŷ* ['Method']. This was an enormous success with readers owing to the simplicity of the operations that he outlined."

The above excerpt is of obvious interest as it highlights the fundamental role played by Ibn Ishaq al-Tunisi – astronomer, founder of this school and contemporary of Ramon Llull – who worked in the cities of Tunis and Marrakech. This said, Ibn Khaldun seems to be of the opinion that Ibn Ishaq's work was really the result of an anonymous Sicilian Jew's own observations, which were sent over to Tunis from Sicily. There is little more that can be said on this matter since the *zīj* that Ibn Ishaq began (and which was to remain unfinished) is no longer in existence. The essential fruits of his labours were, however, reused by three "editors" of his book (of whom Ibn Khaldun mentions only one: Ibn al-Banna), whom I will now proceed to discuss. One of these versions was produced by another anonymous Tunisian astronomer, whose work has been placed somewhere between 1266 and 1281. This version can be found in manuscript Hyderabad Andra Pradesh State Library 298. Table 5 of this revision offers a list of 24 astronomers who have determined "by way of observations" (most likely fictitious) the position of the solar apogee and the obliquity of the ecliptic. The last two astronomers listed are a Giyam ben Yahhar (Sicily, 1188-1189) and our very own Abu

l-Abbas ibn Ishaq (Tunis, 1193). This citation led to Giyam ben Yahhar's being identified as the purported Sicilian Jew mentioned by Ibn Khaldun, and there were subsequently a succession of vain attempts at tracking down this character amongst the Sicilian Jews of the time. The reason for the confusion lies, without a doubt, in an orthographic mix-up: Giyam ben Yahhar can, in Arabic script, be easily confused with Giyam ben Ruyyar, from which we can extrapolate William son of Roger, one of Sicily's Norman kings – someone who, for chronological reasons, could not be William I, son of Roger II of Sicily (who reigned from 1154 to 1166), but instead his son William II (who reigned from 1166 to 1189). The above Ibn Khaldun citation seems to refer to an anonymous Jewish astronomer who worked under the auspices of King Roger II.

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From an analysis of the tables related to Ibn Ishaq's school that are still in existence, we conclude that the anonymous Sicilian Jew was not, in fact, behind the astronomical observations mentioned in Ibn Khaldun's text. By contrast, if we were to believe that the Tunisian historian's account contained a grain of truth, we might infer that what the Jewish astronomer had done was to send Ibn Ishaq observations that had been taken by Toledan astronomer al-Zarqali (died 1100), in Toledo and Cordoba, in the second half of the 11th century. Surviving sources clearly document the fact that Ibn Ishaq's school drew on materials derived from the writings of al-Zarqali – in particular, his *Tables of Toledo,* his *Treatise about the movement of fixed stars* and his book, *About the solar year.* Al-Zarqali's book was picked up and continued by his disciple Ibn al-Kammad, also mentioned by Ibn Khaldun, and its impact would go on to reverberate around Ibn Ishaq's Maghrebian school over the course of the 13th and 14th centuries. As such, a number of al-Andalusian materials were sent to the Maghreb around the beginning of the 13th century and, as we will go on to see, reintroduced to al-Andalus at the end of the same century.

As I have indicated above, it appears that Ibn Ishaq did not finish his work, leaving behind him only "cards" or "sheets" (*batā'iq*) of tabulated material, but no canons that explained how to use these tables. Ibn Ishaq's followers' work, however, entailed supplementing his tables with corresponding explanatory canons and completing, in certain cases, his numerical tables with information taken from other sources. The "editions" of which we are aware are as follows:

- That of the anonymous Tunisian (who died between 1266 and 1281), which survived in the aforementioned Hyderabad manuscript. This edition is an extensive work, edited and studied by A. Mestres, in which the anonymous author copied myriad tables and canons from al-Andalusian sources. Much of this material has little to do with Ibn Ishaq's own work, but the finished product is of huge significance as it conserves a wealth of documents the originals of which have been lost or only survive in Latin translation. This compilation is concrete proof of the importance of Maghrebian sources in the study of al-Andalusian astronomical tradition.
- That of Ibn al-Banna al-Marrakushi (1256-1321), entitled *Minhāŷ al-tālib li-ta'dīl al-kawākib* ("Specialist method for calculating the true positions of the planets"). This work could not be more different from the last one: it is short, concise and exceedingly

practical; enjoyed huge popularity (as referred to by Ibn Khaldun); and was consulted by Maghrebi astronomers up until the 19th century. Furthermore, Ibn al-Banna included in his tables certain modifications of form that aided their use: "displaced" central equations for the Sun and the planets, which enabled the user to disregard the equation's positive or negative sign; and an application of the Ptolemaic "lunar" method for the calculation of equations for the anomalies of Saturn and Jupiter which, like the Moon, have small epicycles.

- Another Tunisian astronomer, also a contemporary of Llull, was the progenitor of three different revised versions of Ibn Ishaq's *zīj*. This is Abu Abd Allah ibn al-Raqqam (died 1315), who was born – it is believed – in Murcia prior to James I taking the city in 1266 for Alfonso X of Castile. His family was compelled to emigrate to Ifriqiya, whilst Ibn al-Raqqam himself went to live in Tunis and Bougie, from where he made the move to Granada at the invitation of the Nazari ruler Muhammad II (reigned 1273-1302). The three *zījs* produced by this author, drawing on Ibn Ishaq's source materials, are as follows:

  a) *al-Zīŷ al-mustawfī li-man hāza min al-bast wa l-hazz al-awfar wa l-qist al-awfà* ("Astronomy manual, with tables, in which everything acquired by generous donation or good fortune in vast quantities is duly returned"). This is the most interesting and innovative of the three as it incorporates significant new information and a wealth of methods for solving problems in the field of spherical astronomy that are unrivalled in surviving Maghrebi and al-Andalusian sources. He must have produced the book in Tunis – seeing as the roots of the mean movements have been calculated for this city's meridian – after the 680th year of the Hijri calendar (680 AH or 1281-1282 AD), since it contains an incomplete table of stars dated at this time. The work was widely available in the Maghreb, where it was consulted, right up to the beginning of the 17th century, by *muwaqqits* (astronomers working in the employ of mosques, who were dedicated to solving astronomy-related problems of worship).

  b) *al-Zīŷ al-šāmil fī tahdīb al-Kāmil* ("Astronomy manual, containing tables, in which the Complete Table has been revised"). This work is less original than the previous one cited. In it, Ibn al-Raqqam supplements Ibn Ishaq's numerical tables with some canons copied directly from the *al-Zīŷ al-Kāmil fī l-Ta'ālīm* ("Mathematically complete astronomical table") by the Sevillan Ibn al-Ha'im (died 1205). This latter work comprises an extraordinary collection of astronomical canons that do not simply offer practical guidance on the use of the tables, but also delve into the underlying theory and give examples of its application. Neither the only surviving copy of the *Kāmil* nor the manuscript consulted by Ibn al-Raqqam contained numerical tables. For this reason, Ibn al-Raqqam amalgamated Ibn al-Ha'im's canons (having stripped out the mathematical examples) with Ibn Ishaq's numerical tables. To all this he added some 60 chapters – which are believed to have been his own work – on issues relating to spherical astronomy and astrology. This book was finished in Bougie in 678 AH/1279-1280 AD.

  c) *al-Zīŷ al-qawīm fī funūn al-ta'dīl wa l-taqwīm* ("Sound astronomy manual, containing tables, on the various methods for precisely calculating the positions of the planets") is without

doubt the most practical version of the three, as such resembling Ibn al-Banna's *Minhāŷ*. It is, put simply, a set of instructions for using Ibn Ishaq's tables. This work was started in Tunis, not before 680 AH/1281-1282 AD – it contains the same table of stars as appeared in the *Mustawfī*, although in this work the table is complete –, and was finished in Granada following the author's move to the city (the *zīj* contains a table and calculation method for determining if the new moon will be visible that could only be used at a latitude of 37º 10' – precisely the modern-day latitude of Granada). For this reason, it is not surprising that this is the only of Ibn al-Raqqam's three *zījs* discussed by the Granadan versatile authour Ibn al-Khatib.

Moreover, this third work is also interesting as it shows how al-Andalusian materials, having originated in the school of al-Zarqali and been taken up again by Ibn Ishaq in the early 13th century, returned to al-Andalus at the end of the same century. On the whole, it is clear to see that there was a good deal of movement of scientific resources on both sides of the Strait of Gibraltar, which made it possible for the anonymous Tunisian who compiled the documents now surviving in the Hyderabad revision to gain access to myriad lost al-Andalusian sources, and for Ibn al-Raqqam himself to discover the *al-Zīŷ al-Kāmil* by the Sevillan Ibn al-Ha'im.

The entire collection of sources that I have outlined briefly here relied on the astronomical theories developed by al-Zarqali towards the end of the 11th century. Using these doctrines, it is possible to work out the sidereal position of the planets, and it is for this reason that some of the aforementioned *zījs* continued to be used right up until the 19th century by astrologers drawing up sidereal horoscopes. It is possible to convert sidereal coordinates into tropical coordinates by applying the trepidation of the equinoxes theory, which suggests a fluctuation in the equinox points, the result of which is that the precession of the equinoxes can in some instances be positive and in others negative. On the other hand, the trepidation tables in both Ibn Ishaq's *zīj* and the others of which I have spoken reach a maximum value of 10º 24'. Indeed, al-Zarqali believed that the obliquity of the ecliptic (the angle formed between the ecliptic plane and the equatorial plane) fluctuated cyclically and the tables he drew up to calculate it extend from a maximum of 23º 53' (around the time of Ptolemy) to a minimum of 23º 33' (in his own time). To this two additions were made: a correction to Ptolemy's lunar model and the use of a solar model of variable eccentricity that, like the obliquity of the ecliptic, was also of a cyclical nature.

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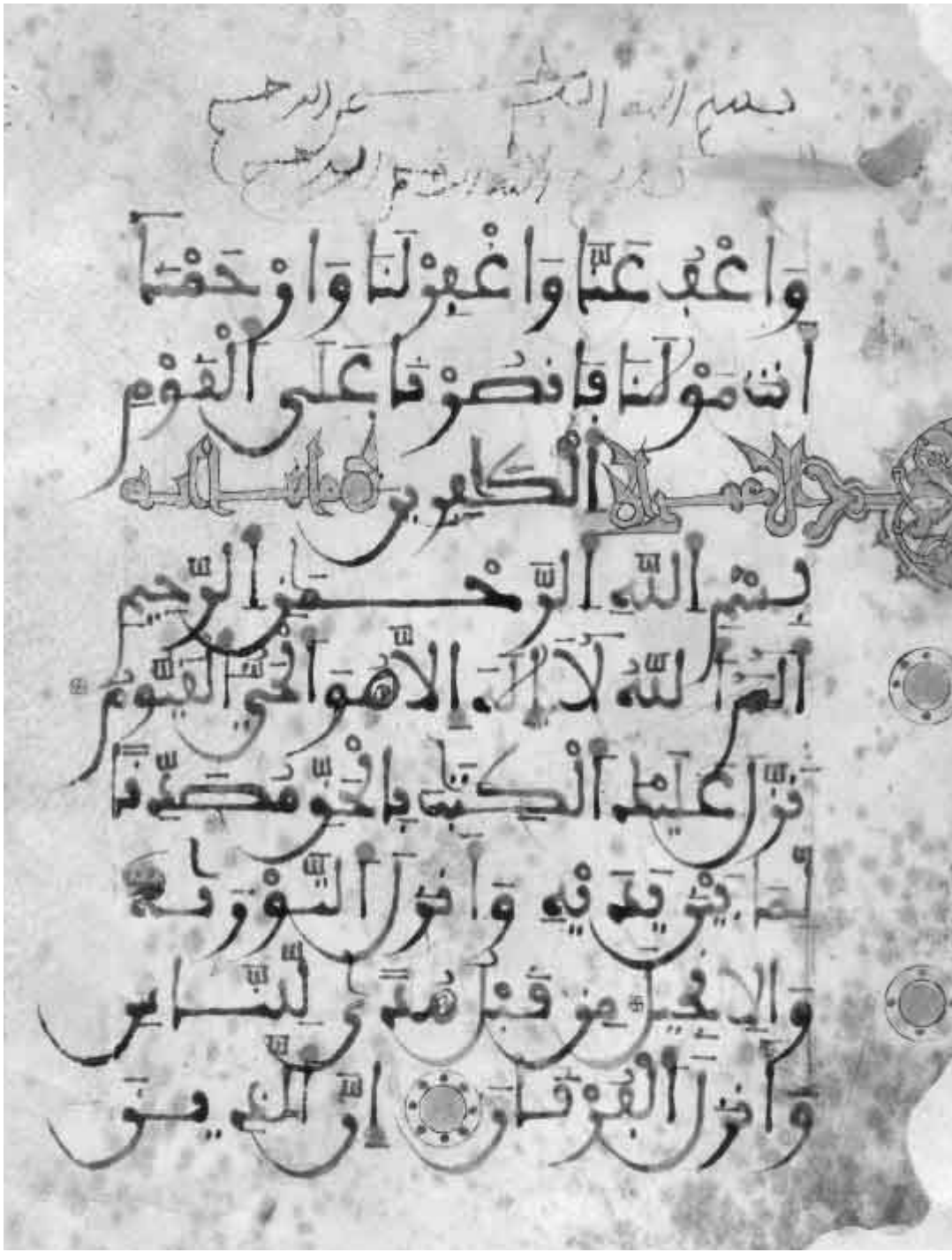
The aforementioned theories were contradicted by astronomical observations taken in the Maghreb and the East from the 13th century onwards. Ibn Azzuz al-Qusantini took observations in Fez using an armillary sphere, around 1344, and amended the parameters of Ibn Ishaq's mean planetary movements – although he did not dispute the theory on which these were based. One early 16th-century source compared the precession value for the 14th century, calculated using Ibn Ishaq's trepidation tables (in the order of some 10º), with that obtained, by way of observations, by Ibn Abi l-Sukr al-Magribi in Damascus in 1259 (12º or a little more). According to the same source, one Ali ben Yunus al-Balansi took observations in Cairo in 1331 and obtained a precession value of some 13º. A second source,

Abu Abd Allah al-Baqqar, carried out new observations in Fez and came to the conclusion that the precession, in 1418, was around 12º. All of this led Maghrebian astronomers to acknowledge the limitations of al-Zarqali's model, seeing as how the precession values obtained through their observations significantly exceeded the maximum 10º 24' given in the tables of Ibn Ishaq.

A second source of conflict was al-Zarqali's theory regarding the cyclical nature of the obliquity of the ecliptic's fluctuations. The same sources as previously mentioned realised that, at their time, the obliquity's value should have risen above the minimum set out by al-Zarqali (23º 33') but that, in actual fact, observations were testifying to a reduction in this angle: Ibn al-Satir (died Damascus, c. 1350) and al-Mizzi (died Damascus, c. 1350) had obtained a reading of 23º 31' and an anonymous Maghrebian astronomer observed in Miknas (Meknes), in 602 AH/1205-1206 AD, an obliquity of 23º 32' 30", a value confirmed by a certain Ibn Hilal in Ceuta in the first half of the 14th century. A century later, one al-Hakim al-Mirrij obtained, in Marrakech in 704 AH/1304-1305 AD, a value of 23º 26' 57". And finally, another little-known figure, Ibn al-Taryuman, confirmed that the obliquity of the ecliptic, in around 1300, was 23º 26'.

As a result of these factors, the al-Zarqali tradition and the tables from the school of Ibn Ishaq were abandoned and replaced with eastern – and even Hispanic – tables. In 1394, the *Tāŷ al-azyāŷ* ("King of *zījs*") by Ibn Abi l-Sukr al-Magribi, the al-Andalusian-Maghrebian astronomer who was actually based in Damascus and Maragheh, was already widely known. It is worthy of note that the three surviving manuscripts of this work have been copied in the Maghreb. A date that has proved more difficult to pinpoint, but which is likely to be around the end of the 14th or beginning of the 15th century, saw the emergence of the *al-Zīŷ al-Ŷadīd* by Ibn al-Satir (died Damascus, 1375) in the region. This is the only known *zīj* to be founded on the new pre-Copernican planetary models that were developed, in the Muslim East, on the basis of the Maragheh School (13th century). The final eastern *zīj* to have been documented in the Maghreb, albeit significantly later (in the late 17th century), is that of Ulug Beg (died Samarkand, 1449). Shortly before this was discovered (in around 1624), al-Hayari (1570-after 1640), a *Morisco* exiled to Morocco, translated into Arabic the *Almanach Perpetuum* by Salamancan Jew Abraham Zacuto and his disciple José Vizinho – a book that had been printed, for the first time, in Leiria in 1496. This translation brought about a surprisingly wide dissemination of this work (stretching from Morocco to the Yemen), which continued until the 19th century and which indirectly introduced the world to the *Tablas alfonsíes* (*Alfonsine Tables*), given that Zacuto's work was essentially based on these tables.

Let me draw this article to a close on this note about the growth and decline of a school of astronomy of al-Andalusian origins that was extremely active in the Maghreb during the course of Llull's life and that evolved in three cities in particular (Tunis, Bougie and Marrakech), two of which had been visited by the Majorcan philosopher. If it seems as though Llull was unaware of this work, this is because his scientific interest in the field of planetary astronomy was relatively limited and because this area had little to do with his system of thought.



The Koran (manuscript 2336, Biblioteca de Catalunya).