THE SUNDIAL IN THE MANUSCRIPT 225 OF RIPOLL

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In August 1835, nearly a thousand years after its foundation, the monastery of Ripoll was savagely assaulted, all the monks were murdered, graves desecrated and the buildings burnt down. In that fire a large part of the library was destroyed, so that only a few hundred of the works in the great book collection were saved through being deposited in the *Arxiu de la Corona d'Arago* [Crown of Aragon Archives]. Amongst these survivors there was a manuscript successively titled *Liber de Horis*, later *Tratado de Astronomia y del Relox* and today is known as *Manuscript Rivipullensi 225*.

The manuscript 225 is from the second half of the 10th century and contains a miscellaneous compilation of several older treaties collated from previous essays, translations and transcriptions of other manuscripts, many of Arabic origin and all of them having a scientific content.

The writing of this type of compilation, often used in the 10th century, originated with the need to have manuals of the didactic kind which could be used by instructors and their students when teaching or learning subjects such as astronomy, geometry, surveying, mechanics and gnomonics. The practical aim of these subjects was, amongst others, the measurement of distances, heights and depths, forecasting eclipses and other astronomical phenomena, to determine the hours by day or night, and the construction of appropriate devices to accomplish these aims such as quadrants, water-clocks and sundials.

Thus manuscript 225 has the undeniable character of a practical manual. Its size of 13 cm height by 11 cm width makes it look like a book for consultation which can be slipped easily into the pocket, it contains slightly more than two hundred folios of parchment which give a combined thickness of 2 cm. In contrast with its appearance, the contents are of a very great cultural importance.

The main subject appearing in ms 225 is on the astrolabe, an instrument known only by the Arabs at that time. They had inherited it from the Greeks through such treatises as those of Johannes Philopon (4th century), Theon of Alexandria (4th century) and Claudius Ptolemy [c AD 90-168] (2nd century); and through Catalonia it was introduced for the first time to occidental Europe.

This was the very important thesis formulated in 1935 by Dr Josep Maria Millàs i Vallicrosa from his study of ms 225, published in his *Assaig d'Historia de les Idees Fisiques i Mathemàtiques a la Catalunya Medieval* [Historical Essay of the Ideas in Physics and Mathematics in medieval Catalan], and its impact has not yet disappeared.

Three of the chapters of ms 225 entitled: "Astrolabii sententiae, De nominibus laborum laboratorum in ipsa tabul", and "Capitula horologii regis Ptolemei", together form a treatise of the use of the astrolabe which appears to be a direct translation of an original Arabic text, the transcription of which is attributed to Sunifred Llobet, Archdeacon of Barcelona, who was involved with the cultural activities at Ripoll.

A further chapter, entitled "De Mensura astrolapsus" complements the previous chapters and gives some ideas about the construction of the astrolabe; it seems to be the summarized version of another original Arabic text which was included with the previously mentioned texts. The translation and summary of this fragment is attributed by Millàs to the aforesaid Llobet from Barcelona. The following chapters entitled "De utilitalibus astrolabii" and "De mensura astrolabii" form another treatise on the construction and use of astrolabes but written in a more accurate and literary style, it looks like a review, with modifications, also by Llobet, of the translations previously mentioned. That is to say we have before us two complete treatises on the astrolabe from Sunifred Llobet's hand; the first being a direct translation from the Arabic text, whereas the second is revised to be more suitable to occidental usage and with a more accurate text but still based upon the orginal Arabic text.

Another chapter of ms 225 which is of interest with its relation to the measurement of time is the so-called "Componitur orologium cum astrolabii quarta parte" which is a direct translation from the Arabic in respect of the astronomical applications of the quadrant with the cursor, amongst which it is remarkable to find the determination of the temporary hour as a function of the date and height of the sun. Without completely exhausting the contents of the ms, and before confining this article to the main subject, it may be mentioned that there is a chapter devoted to the description of a water alarm clock with mechanical features. It was commented on by Maddison, Scott and Kent in "An Early Medieval Water Clock", *Antiquarian Horology*, Vol III, No 12, September 1962, pp 348-353.

Another chapter, in which are given instructions for the construction of a sundial, will now be dealt with immediately. Within the length of seven pages of ms 225, [folios 94 to 97], is a text describing a sundial, with necessary instructions being given for its layout and construction. The sundial described is a horizontal type with hour lines engraved for temporary hours on a circular flat stone, in the centre of which the gnomon stands vertically.

The text commences by giving the instructions to lay out the dial on the stone, with six concentric and equally spaced circles to represent the twelve months of the year, plus a diametrical line called the "meridian line" which cuts all the circles in half. As this text still has didactic clarity after nearly a millenium, which was the author's main intention for his disciples' use, I offer the reader a direct translation of the main paragraphs from the original Latin text:

> *In the nearest circle to the centre and at the left of the meridian line we will engrave the name of the month of June at one side, and at the other the month of July. In the second circle we will engrave May on the left of the line and August on the right, and so on until the sixth circle, where we will place the months of January and December.*

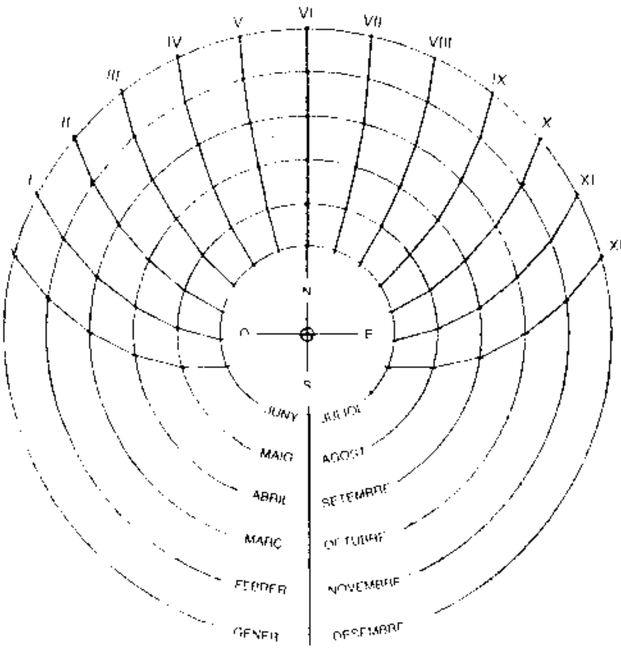

FIG 1 Reconstruction of the sundial described in ms 225, according to the explanations in the first part.

Later on, the ms indicates how to inscribe the hour divisions circles for each circle according to the relative duration of daylight hours in comparison with the night hours. [Seasonal or temporary hours where the day and night are divided into twelve parts of differing duration throughout the year].

We will divide the circle of the month of June and July in 24 parts starting from the meridian line, we will give 15 of these parts to the day time, whereas the others will be given to the night. The 15 parts corresponding to the day will have to be equallly divided on each side of the meridian line, that is to say, seven parts and half at each side. The arc of the middle [circle] formed by the 15 parts will be divided into the 12 diurnal hours, thus, six will be placed each side of the meridian line. We will have to repeat this same operation with all the other circles, taking into account, that the daily sector of the May and August month will include 14/24 parts of the circle. This sector will be divided in 12 hours, as in the previous case. the diurnal sector at the months of April and September will include 13/24 parts, and so on until the last circle, that will be equally divided in 12 parts. We must not doubt of awarding 10 hours to the diurnal space of the month of December, since the first days of this month have 10 hours and only the last ones have 9 hours. The same happens to the month of January; at the beginning of the month the days have 9 hours but at the end of the month they have 10 hours.

Following this, the symmetry of the duation of the days is discussed, starting at the winter solstice, the shortest day of the year which takes place on the twelfth day of January [resulting from the error in the reckoning by the Julian calendar by this time].

Consequently, the days eleven and twelve will be of the same duration, the same for the tenth and thirteenth, in this way, they will be increasing their duration by pairs until the arrival of the summer solstice, the longest day of the year which is the twelfth day of the calend of July, starting from it, the days will begin to progressively become shorter during the other six months.

In order to position the stone correctly, we will determine exactly at midday on any day, which is the moment when the sun reaches its maximum height. This moment will have to be fixed with the astrolabe [horoscope], and the stone will have to be moved until the meridian line coincides with the shadow of the gnomon. If we do not have an astrolabe we can orient the sundial with the help of the polar star, although it is much better to do it with the astrolabe.

Later we find another version of the layout of the hour divisions but over 7 monthly circles instead of the six just discussed.

If a man wishes to engrave seven circles on the stone, the first circle must be divided according to the 15 hours which is the length of the day in the month of June, the second according to the 14 day hours in May and July, the third according to the 13 day hours for April and August, and so on until the seventh circle, which must be divided according to the 9 day hours of December.

According to the author, the division of the sundial into seven circles has no advantage over the previous one. He ends his text relating to the sundial, advising us to note that, in order to distinguish them from the rest, the hour lines corresponding to the ends of the hours are marked with I, III, IX and XII (prima, tercia, sexta . . .), and also to do the same with the hour line that separates the night from the day, which is the line of the start of the first hour, that is to say, the hour lines are directly related to the religious services of the Church at that time.

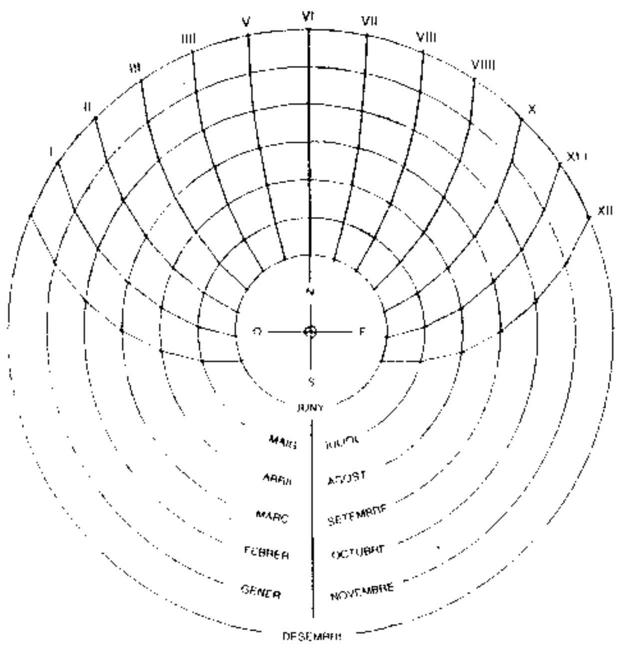

FIG 2 Reconstruction of the sundial described in the second version of ms 225, with seven circles in lieu of six.

There is no diagram accompanying the text, therefore two illustrations made according to my interpretation are attached. It must be said that they are substantially different to the sketch published by Dr Millàs (1931, p 205) to complement the brief presentation of this text.

At first sight, it might seem to be a difficult instrument to interpret, however on any day of the year there was only one hour circle applicable, the others were ignored as if they were not there. Once the correct hour circle was selected, according the time of the year, the observer would see that at sunrise the shadow of the gnomon over the first hour division on the west side [the only one not numbered] and which the ms call *the line which separates the day from the night.* As the sun begins to rise, the shadow of the gnomon, besides shortening, moves towards the next hour division, that marking the start of the second sector, in this way one can express the time by the fraction of the arc that the shadow has passed over. If the shadow has already covered the first quarter part of the segment, it could be said that it was a "quarter of the second hour", or a "quarter of two"; this could be the origin of the way of understanding the hours (in modern Catalan), in a logical way, whereas in other languages one would say that "it was a quarter past one".

The third hour correspond to the middle of the morning, the end of the sixth hour being midday, the none hour being in the middle of the afternoon, and the end of the twelfth hour coinciding with sunset, and similarly for all the days of the year.

This system was in general use until the appearance of mechanical clocks and the divisions of the day and night were called "Temporary" hours in contrast to equal parts. "Temporary" hours, resulting from dividing the daylight period from sunrise to sunset into 12 equal parts, vary in duration according to the changing duration of the day and night throughout the year, and only equal the "Equinoctial" hours at the time of an equinox. "Equinoctial" hours, before and even during medieval times, had a more limited application than temporary hours until the use of mechanical clocks became universal.

The sundial described in ms 225 was planned to be sited at a place where the longest day of the year (summer solstice) lasts 15 hours, and so the shortest day (winter solstice) lasts 9 hours. These conditions apply in all locations around 41° of geographic latitude. Consequently, in Ripoll which is sited at 42°, the sundial would have functioned perfectly, although the interpretation of "perfectly" must take into account the technical limitations of those far-off days and the primitive design of this sundial.

The author of the ms gives pre-eminence to the instructions for constructing the sundial with only six monthly circles, discarding the nine hours circle because, as he points out, there are only a few days in the year when this value needs to be taken into account. One must also state that the 15 diurnal hours of the summer solstice also can only be used a few days a year, whereas he includes a circle which will be in use for a period of two months. The second version of the sundial, that with seven circles, can be considered to be more rational, although in the ms it explicitly states that it does not have any advantage over the first. In practice, both designs would give quite acceptable results based upon the requirements of those ages.

The characteristics of this sundial has nothing in common with Arabic sundials, so we are led to suppose that the orginal sources of this text must be Latin, unless the idea originated in the culture of Ripoll, since no other sources of information are known with descriptions of sundials of similar characteristics.

The sundial, for many centuries, was the time measuring instrument *par excellence,* much easier to read than the astrolable or quadrant, and it could be used as a guide when graduating the hour divisions of candles or correcting the time shown by clepsydrae, and all the other contemporary instruments designed to preserve solar time during the night or during cloudy days.

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This article was first published in the Catalan language in Issue No 2 of *LA BUSCA DE PAPER,* the Bulletin of the Societat Catalana de Gnomonica, and is reproduced here by the courtesy of the Catalan Society of Gnomonics and the author Eduard Farré i Olivé. The Editor has slightly altered some parts to produce a more idiomatic text, and takes the responsibility for any errors thus introduced. It is a most valuable addition to the dialling information available to those who use English as a working language, and one must also salute the original author of the treatise for his clarity of description and constructional instructions.