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A small collection of sunspot drawings made in the Royal Astronomical Observatory of the Spanish Navy in 1884

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Abstract

In this paper we analyze a small collection of sunspot drawings made at the Astronomical Observatory of the Spanish Navy in the period from April 1, 1884 to August 18, 1884. We calculate the area and the heliographic coordinates of the observed sunspots. From these coordinates, we obtain the solar rotation rate in this period. Finally, we compare our results with the data recorded by the Royal Greenwich Observatory.

Keywords: Sunspots; Solar rotation; Historical observations; Heliographic coordinates

1. Introduction

Sunspot counting and the measurement of their area and their displacement across the solar disk were tasks of great interest to astronomers of past centuries. Today, these observations are vital for studying the past behavior of the Sun (Vaquero, 2007; Clette et al., 2014). We can highlight several examples of such observations over history. The sunspot drawings made by Galileo in 1612 were studied by Casas et al. (2006), obtaining their positions and the solar rotation rate. The German astronomer Staudach observed and drew sunspots for almost 50 years (from 1749 to 1796). Arlt and Fröhlich (2012) used these drawings to estimate the solar differential rotation in the second half of the 18th century. Arlt et al. (2013) studied 8486 solar drawings made by S.H. Schwabe from 1825 to 1867. Recently, Diercke et al. (2015) have digitized the sunspot drawings made by G. Spörer from 1861 to 1894. All these contributions, together with the historical sunspot catalogues, can help to increase our knowledge of solar activity in the historical period (Casas and Vaquero, 2014; Vaquero et al., 2015; Lefevre and Clette, 2014).

The Royal Astronomical Observatory of the Spanish Navy located in San Fernando, Cádiz, was founded in 1753. It is the southernmost European observatory. Its archive preserves a remarkable collection of astronomical observations (Lafuente and Sellés, 1988; González-González, 1992, 2004). This article is based on the study of the 109 solar disk drawings preserved in the archive of the observatory (Section "Astronomy. Observations", Box 142). These drawings were made between April 1 and August 18, 1884. They provide details of sunspots every day. The original drawings were scanned at high

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resolution by archive staff of the Observatory. Each file has a size of approximately 60 MB. This allowed us to work with great precision to analyze each of the images, as solar diameter has a size of about 14×10^6 pixels. Fig. 1 shows, as an example, the drawing of the Sun on April 16, 1884. Several sunspot drawings display details such as darker regions in the umbra, penumbral filaments or light bridges (see Fig. 2 as example).

We obtained information from a total of 82 groups of sunspots. From the data of the areas and positions of these 82 groups, we were able to calculate the rotation rate of each group. Furthermore, we classified each group according to its spots' morphology, following the classification of Zurich. Finally, we compared our data with the data obtained by the Royal Greenwich Observatory in order to determine the degree of concordance between the two sets.

It is worth of mention that data independency is important in historical observations as it provides an extra test about the quality of these observations. In particular, some problems have been recently described in the first years of the solar records of the Royal Greenwich Observatory (Willis et al., 2013a, 2013b; Erwin et al., 2013), especially important to estimate the Sunspot Number (Clette et al., 2014). Therefore, the small set of observations presented here are of particular interest because they allow to develop a catalog of sunspot that can be compared with some historical observations of the Royal Greenwich Observatory.

2. Heliographic coordinates of sunspots

Our first task was to identify and classify all the sunspot groups shown in the drawings, using the well-known scheme of types of Zurich (Waldmeier, 1947). Although there are other methods of classification, in some cases are based (as in the Mcintosh scheme) on the magnetism of the sunspots, information not available here. By this reason, we have used only morphological criteria, as established in the Zurich classification. Identification of some groups was not evident. For these cases, we studied the path of sunspots over several days. Thereby, if all sunspots kept together we considered them belonging to the same group. Otherwise, we assigned the sunspots to different groups. An example is the group number 26 from our catalogue. This group appears in pictures from 26th April until 7th May. At first it seems that the sunspots belong to different groups, but in the later images all sunspots follow a similar path, therefore they are part of the same group. In this case, the group was classified as type C, later it became of type D and ends as type F. Note that this classification has been performed by the authors in a way completely independent of the previous classification in the RGO catalogue. Moreover, in regard to this, we have checked the daily sunspot number and sunspot group number, confirming that these values are basically the same that the values included in the RGO catalogue. As example, in Fig. 1, from left to right, we have identified three sunspots of types C, A and C, respectively. Table 1 represents the

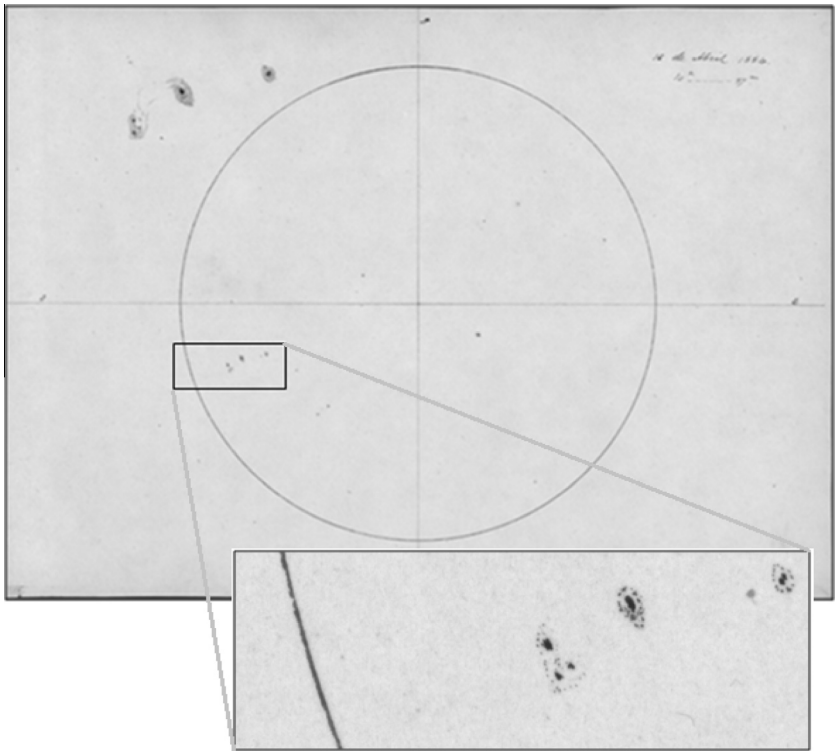

Fig. 1. Solar disk drawing for April 16th 1884, and the same with zoom.