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HSUNSPOTS: A tool for the analysis of historical sunspot drawings

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A B S T R A C T

Valuable information about the evolution of solar activity is recorded in early sunspot drawings, especially during 17th–19th centuries. In this context, we have developed a computer program to analyze historical drawings showing the trajectories of sunspots across the solar disk. As an example, we have analysed the drawings published in the book *De heliometri structura et usu* by Zucconi (1760). These drawings span the period from April 1754 to June 1760. We present the Butterfly diagram for those years. The ending of solar cycle 0 and the beginning of solar cycle 1 are clearly noted in this diagram.

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1. Introduction

Early drawings of sunspots (from the beginning of the 17th century) have been extensively used to characterize solar activity during past centuries, extending the series of sunspot numbers back into the past (Vaquero and Vázquez, 2009). In this regard, studies of the solar activity based on the analysis of early sunspot observations are very important, owing to the intimate connection between the activity of the sun and the terrestrial climate. Moreover, these drawings can be also used to measure the position of sunspots and estimate the solar rotation rate by analyzing the changes in the position of the sunspots with time. In this regard, note that the only information on surface rotation during these centuries comes from contemporary drawings of the Sun including sunspots (Casas et al., 2006). In this way, note also that accurate and continuous records of the positions of the sunspots, used for determining the solar rotation rate, are only available for solar cycles since last decades of the 19th century (Royal Greenwich Observatory, 1980; Balthasar et al., 1986). The studies of solar rotation based on historical drawings of sunspots are important because of the link between solar activity and the solar dynamo (Tobias, 2009). In this regard, for example, some work has been performed using drawings from the so-called Maunder Minimum ($\sim$1645 to 1715). Some of these studies suggest that solar rotation was more differential during the Maunder Minimum than at the present time (Eddy et al., 1976; Ribes et al., 1987; Vaquero et al., 2002). However, historical drawings useful for the measurement of solar rotation are sparse. For this reason, the search and analysis of historical solar drawings to determine sunspot positions is an interesting task (Arlt, 2008, 2009).

The analysis of ancient solar drawings can be performed manually, by measuring the number and positions of the identifiable sunspots on each drawing, one by one, and transforming subsequently these positions to heliographic coordinates by standard methods (Beck et al., 1995; Roy and Clarke, 1989; Smart, 1977). However, this is a tedious task that could be shortened by using an automatic procedure. For this reason, we present here **HSUNSPOTS**, a software tool developed for analyzing solar drawings, which can be employed in the study of ancient solar records. In the following sections we describe, first, the software, and, next, as an example, we use it to analyze the solar drawings prepared by Zucconi (1760).

2. Description of the software

The program **HSUNSPOTS** is a windows-based computer tool especially developed to register, in an automatic way, the positions and areas of sunspots in solar drawings. It is intended for both historians of astronomy and solar physicists. This software has been developed over a C++ environment and runs under all Microsoft Windows platforms and will be available for GNU Linux operating systems soon. The low size of the application (about 1.2 MB) makes it very suitable for easy distribution.

HSUNSPOTS is based on the creation of user projects, which store information (including contact information) about the observer or analyzer and the location of the place of the daily observations. For each project, a sequence of observations can be

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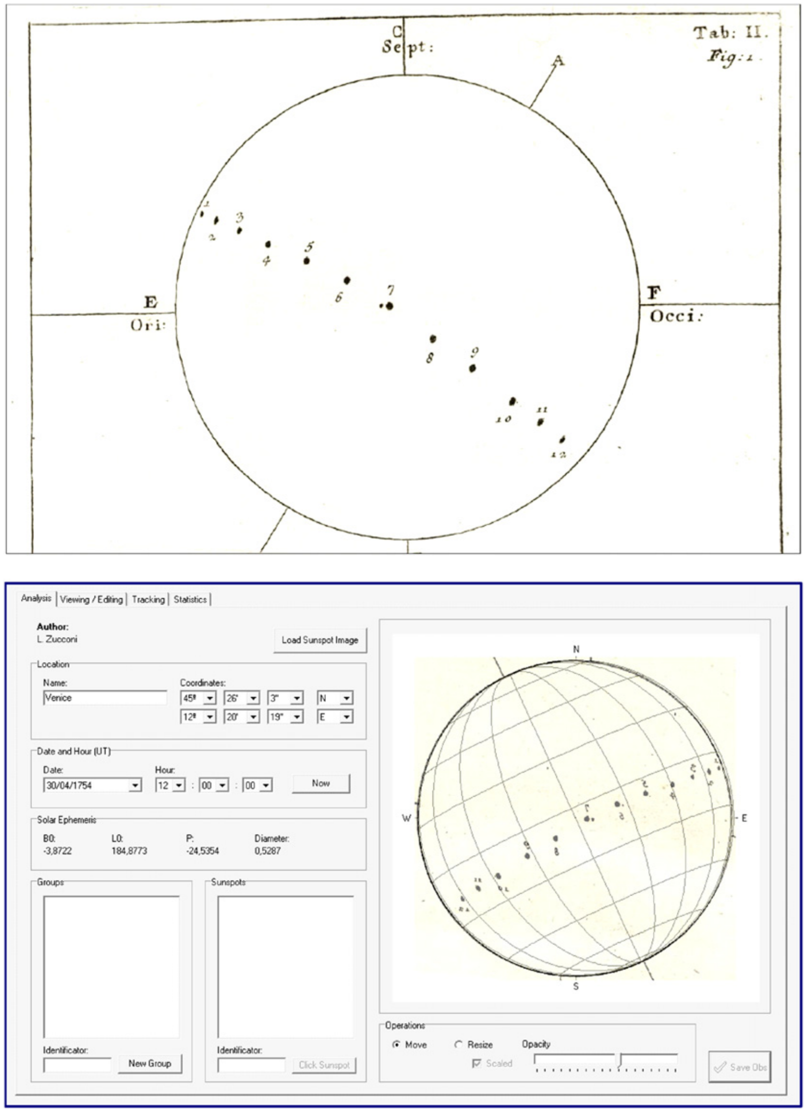

Fig. 1. A sunspot drawing by Zucconi (upper panel) analysed with HSUNSPOTS software (lower panel).

managed by just loading an image of the Sun on the desired day and marking with a click of the mouse, in a very intuitive way, the sunspots present in the picture. The file storing a user project follows a structure designed for the application, and it is completely interchangeable. In this way, an observer can distribute his project file to others to consult his observations or to complete with the other observer's data. In the near future, the application will be improved to be able to merge several users' projects (in order to distribute the observation work among different authors), or to export read only projects, for a safer distribution and publication.

It is possible to carry out several operations on the marked information, such as grouping the sunspots and labelling them to track the trajectory of these sunspots or groups over the solar disk; estimating the total sunspot area (which is related to solar activity); and showing the results in different kinds of charts. The application has been divided into four main windows.

2.1. Analysis window

This is the main option window (Fig. 1). It allows the user to load an image of the Sun, move it, rotate it, resize it and/or change its opacity in order to adjust the solar limb to a predefined template representing the state of the Sun (L_0, B_0, P angles and apparent diameter[1]). All the solar ephemeris information is firstly automatically calculated by transforming the observation date inserted by the user to the corresponding Julian Day, according to the expressions and tables detailed in Chapter 10 of Meeus (1998), and later using the Julian Day to automatically calculate the Sun's L_0, B_0, P angles and apparent diameter according to the expressions detailed in the Chapter 29 of the same book. In this regard, we have adopted the convention of placing the east limb (E) to the right and the west limb (W) to the left, in opposite of the other convention used (Phillips, 1992). When all the ephemeris have been calculated and the user has placed the image over the template, then it is possible to select, with a mouse click, the sunspots visible in the drawing. In this regard, the measurement of data such as the position and relative area of the sunspots is carried out in an automatic way by the program (using the auxiliary data L_0, B_0 and P for the date of the observation, previously calculated) and stored for use in subsequent windows.

[1] L_0 and B_0 are, respectively, the heliographic longitude and latitude of the centre of the solar disk. P is the position angle of the northern extremity of the axis of rotation, measured eastwards from the North Point of the solar disk.

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