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Solar observations carried out at the INAF - Catania Astrophysical Observatory

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Abstract. Solar observations at the INAF - Catania Astrophysical Observatory are carried out by means of an equatorial spar, which includes: a Cook refractor, used to make daily drawings of sunspot groups from visual observations; a 150-mm refractor with an Hα Lyot filter for chromospheric observations; a 150-mm refractor feeding an Hα Halle filter for limb observations of the chromosphere. The photospheric and chromospheric data are daily distributed to several international Solar Data Centers. Recently, a program of Flare Warning has been implemented, with the aim of determining the probability that an active region yields a flare on the basis of its characteristics deduced from optical observations. Some science results obtained by means of solar data acquired at the INAF - Catania Astrophysical Observatory, as well as by space-instruments data, are briefly described.

Key words: Sun: photosphere – Sun: chromosphere – Sun: ground-based observations

1. Introduction

Observations of the solar photosphere and chromosphere have been carried out at the Catania Astrophysical Observatory (OACt) since 1880, the year of its foundation. In Fig. 1 an example of the drawing of a sunspot made at the OACt in 1885 is reported (Contarino *et al.*, 2000). In 1894, in cooperation with G. Hale, Annibale Riccó carried out the first observations with a spectroheliograph on the Mt. Etna (3340 m above sea level) (Riccó, 1895). In 1906 Riccó started a regular program of solar patrol in the Hα and in the Ca II K lines in the old seat of the OACt. Solar observations were carried out with a certain continuity also during the world wars. In 1955 Mario G. Fracastoro organized the move of all the instruments for solar observations to the present seat located in the Cittá Universitaria in Catania.

A very important international cooperation between the OACt and NASA took place in 1973, with the ATM project of the Skylab mission. The OACt was involved during the phase of the instruments planning, and played the following roles during the manned mission:

Figure 1. Example of the drawing of a sunspot made at the Catania Astrophysical Observatory in 1885.

- alerting the astronauts when a flare was taking place, not to risk going outside the vehicle during a high energetic bombardment following the event;
- indicating the most interesting active regions where the ATM telescope had to be pointed.

Since 2001, the Catania Astrophysical Observatory has been one of the twelve observatories which, together with some former Institutes of the Consiglio Nazionale delle Ricerche, form the Italian National Institute of Astrophysics (INAF).

2. Solar patrol at the INAF - Catania Astrophysical Observatory

The observations of the solar photosphere and chromosphere (see Fig. 2) are carried out at the INAF - Catania Astrophysical Observatory by means of an equatorial spar equipped with (see Fig. 3):

- a Cook refractor (150/2230 mm), used to make drawings of sunspot groups and pores from visual observations;
- a 150-mm refractor (2300 mm focal length) feeding a Zeiss Hα Lyot filter (bandwidth of 0.25 or 0.50 Å, tunable filter range ± 1 Å) and a 2048×2048 E2V CCD array (in a patrol full-disk mode the camera can take chromospheric images every 150 s), with a dynamical range of 16 bit;

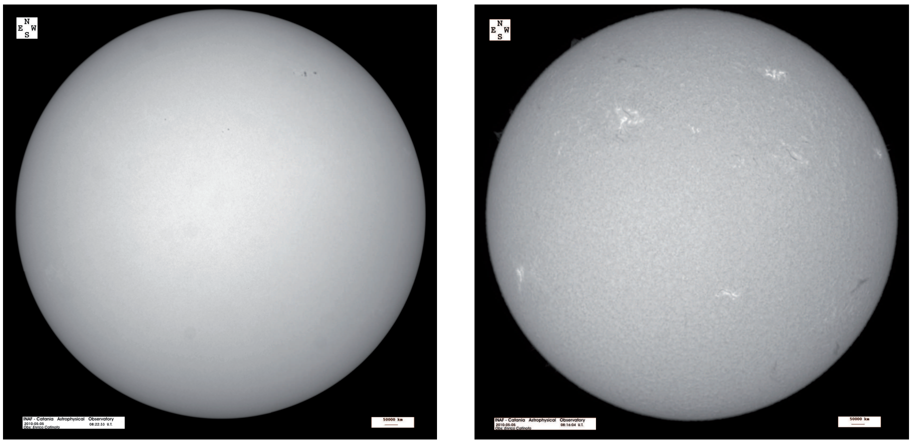

Figure 2. From left to right: images of the solar photosphere and chromosphere acquired at the INAF - Catania Astrophysical Observatory on 5 May 2010.

– a 150-mm refractor (2300 mm focal length) feeding an Hα Halle filter for chromospheric limb observations.

The program performed by means of these instruments includes: daily drawing of sunspots and pores by projection of the Sun image (given the characteristics of the instrument and mean seeing conditions, the number of pores that can be detected by visual inspection of the projected photospheric image results to be greater than that retrieved by the digitized images); digital image acquisitions (every 15 min) in the Hα line center and wings, besides than monitoring of transient phenomena, like flares and active prominences.

3. Data archive and distribution

The important heritage provided by more than one century of observations consists of several and different sets of data. The photographic archives mostly consist of synoptic full-disk photospheric and chromospheric observations, the latter taken with a spectroheliograph or with birefringent filters in the Ca II K and Hα lines. These observations, stored on plates and acetate negatives, date from 1926 to 1998.

In particular, the data on glass consist of chromospheric full-disk images in the Ca II $K_{2,3,2}$ line, about 5000 plates, 6×11 cm size, taken from 1963 to 1977 with a spectroheliograph. Images obtained by a former digitization (3287×2102 size, 8 bit gray scale, jpeg format) of a sample of these plates are available at `ftp://ftp.ct.astro.it/Sole02/K-1970/`.

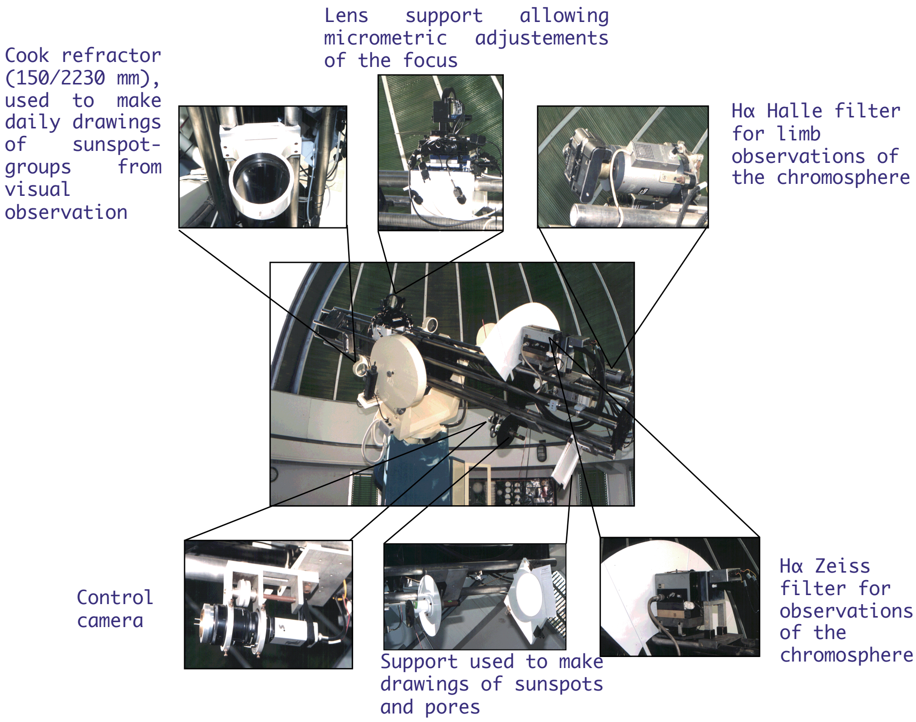

Figure 3. The equatorial spar at the INAF - Catania Astrophysical Observatory.

The data recorded on acetate negatives concern photospheric (White Light) and chromospheric (Hα) full-disk observations, about 3×10^6 filtergrams (10^5 reels, 30 m each), taken from 1963 to 1998 with Halle and Zeiss filters.

Digitized jpeg images of the photosphere, chromosphere (in Hα) and scanned images of the drawings of the photosphere from 1998 to 2010 are available at `http://web.ct.astro.it/sun/archivio/Archivio.htm`. On request, fits files of the images (plus flat field and dark current files) of the photosphere and the chromosphere, can be provided. The photospheric and chromospheric data acquired at the INAF - OACt are distributed to international Solar Data Centers, like the SIDC in Brussels and the World Data Center for the Sunspot Index (NOAA - Boulder). Moreover, the chromospheric images are daily provided to the Global High Resolution Hα Network. Recently, the daily images of the Sun acquired at the equatorial spar are also provided, on request, to observers carrying out observational campaigns at the high resolution solar telescopes in the Canary Islands, like the THEMIS and the SST, as well as at the DST on Sac Peak.

4. Flare warning program

Recently, a service of flare warning, based on the characteristics of the sunspot groups present on the solar disk, has been implemented. This program is based on a previous investigation of the most suitable conditions for a sunspot group to host a flare, carried out by means of a study of the relationship between the morphological characters of sunspot groups and their evolution leading to M- and X-class flares (Ternullo *et al.*, 2006). The study was based on a statistical analysis of sunspot groups data acquired at INAF - OACt from 1996 to 2003. These data were correlated with M and X flares registered by the GOES satellite. The results have shown that the characteristics of sunspots having the highest probability of hosting flares are:

– number of sunspots in the group ≥ 15;
– number of pores in the group ≥ 30;
– sunspot group area $\geq 10^3$ millionths of the solar hemisphere (msh);
– longitudinal extension ≥ 20 degrees;
– Zurich class D, E, F;
– magnetic configuration β, $\beta\gamma$, $\beta\gamma\delta$;
– penumbra in the largest spot asymmetric, with a diameter ≥ 2.5 degrees;
– sunspot population density Compact.

Based on this analysis, in order to determine the flaring probability, the following parameters are used (see, *e.g.*, Contarino *et al.*, 2009):

– type of penumbra $t1$;
– morphology of the sunspot group $t2$;
– Zurich class $t3$;
– area of the sunspot group A;
– number of pores and sunspots SP.

The total flare rate of K class F_K is defined as the average of the flare rates calculated for each parameter:

$$F_K = \frac{F_K(t1) + F_K(t2) + F_K(t3) + F_K(A) + F_K(SP)}{5}\,. \qquad (1)$$

5. Science with INAF - OACt solar data

Using INAF - OACt sunspot data acquired during the period 1975 - 2008 (from drawings of the photosphere made by projection on Stoneyhurst disks, see Section 2 for an explanation of the reason of continuing the hand drawing till today), Ternullo (2010) studied the Butterfly Diagram (BD) for Carrington rotations 1625 - 2075. The results can be summarized as follows:

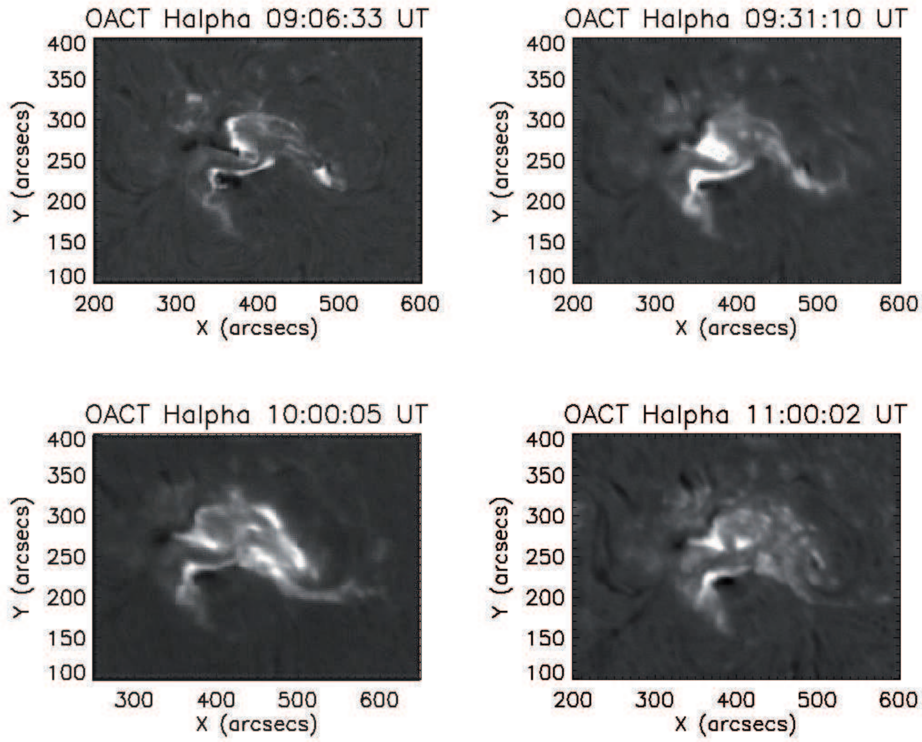

Figure 4. Evolution of the X3.8 two-ribbon flare observed on 17 January 2005 at the INAF - Catania Astrophysical Observatory in the Hα line.

- The diagram confirms the active regions tendency to repeatedly appear in activity nests limited in latitude. The spot mean latitude abruptly drifts equatorward or even poleward.
- Activity nests leave their signature in the BD, in the form of small portions (knots). The BD may be described as a cluster of knots. A knot may appear at either lower or higher latitudes than the previous ones.
- The fine structure of the BD suggests that the activity is split into two or more distinct activity waves (out of phase compared to each other), drifting equatorward (or poleward) at a rate higher than the spot zone as a whole.

Another recent example of the scientific relevance of solar data acquired at INAF - OACt concerns the results obtained from the investigation of a two-ribbon X3.8 flare occurred on 17 January 2005 in active region (AR) NOAA 10720.

The analysis was based on INAF - OACt images acquired during the time interval 07:51 - 12:45 UT, characterized by the angular resolution of $\sim$ 2 arcsec and the cadences of ~ 75 min and 40 s for the photospheric and chromospheric data, respectively. These data were compared with:

- 1600 Å TRACE images acquired during the time interval 07:05 - 12:23 UT with the cadence of ~ 30 s and the angular resolution of ~ 0.5 arcsec;
- X-ray RHESSI images in the 12 - 100 keV band acquired during the time intervals 07:20 - 08:04 UT and 09:40 - 09:50 UT with the angular resolution of ~ 12 arcsec;
- MDI/SOHO full-disk magnetograms with the cadence of $\sim$ 96 min from 00:00 UT on 12 January to 22:23 UT on 17 January and with the angular resolution of ~ 4 arcsec).

This investigation showed the presence of higher emissivity in the central part of the AR during the time interval 08:01 - 09:06 UT; in the eastern side between 09:06 - 11:26 UT; in the western side in the time interval 09:43 - 10:40 UT (see Fig. 4). Based on these results, we interpreted this behavior as due to an initial filament eruption that occurred in the central part of NOAA 10720, where a null point was located, and later on, as in a domino effect (see, *e.g.*, Zuccarello *et al.*, 2009), other filament destabilization or eruption took place in the eastern and western part of the active region.

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