Education and public outreach at the Carl Sagan Solar Observatory of the University of Sonora

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Received 13 April 2012; revised 8 October 2012; accepted 28 October 2012
Available online 18 February 2013

Abstract We discuss the importance of small solar observatories for EPO (Education and Public Outreach), mentioning why they are relevant and what kind of equipment and software require. We stress the fact that technological advances have made them affordable and that they should be widely available. This work is a result of our experience with one: The Carl Sagan Solar Observatory (CSSO). We briefly describe its status and the solar data obtained daily with students participation. We present examples of the data obtained in the visible, Ca II and two in Hα. Data which is widely used for education. Finally we talk about the capability for remote operation as an open invitation for collaboration in educational and scientific projects.

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Introduction

Astronomy is very effective in interesting the public in science, and in promoting careers in Science, Technology, Engineering and Mathematics (STEMs) [1,2]. The main objective of this work is to have an impact in Astronomy Education, through the use of emerging technologies [3] (in Optics, Electronics, Mechanical Engineering and Computer Science), as an opportunity for learning with real data obtained with authentic scientific instruments in small solar observatories. We present our experience with the CSSO, hoping this information may be relevant to those sharing a similar vocation for EPO. We argue that in the present, small solar observatories, equipped with state of the art equipment can be afforded by small universities, high schools, astronomy clubs, planetariums, etc., and that these facilities can be of great service to their respective communities and beyond, through the use of the Internet.

Solar observatory facilities

There are excellent ground and spaceborne observatories dedicated to study the Sun, normally sharing information through EPO programs [4]. Such facilities are leaders in the advancement of our knowledge of the Sun. But there are good reasons to justify the existence of small solar observatories. Mainly because they can make relevant scientific contributions. Examples of these are, the Hα observations taken by the Prairie View Solar Observatory, to study the longitudinal distribution of solar magnetic regions [5], or the bright Hα patches that are seen prior to the impulsive phase of powerful X10 flares [6]. Also worth mentioning, are the observations at the Hα telescope for Argentina (HASTA) [7–9] and the Ca II observations
at the Kanzelhöhe Observatory (KSO) [10], among several others. But as far as education in Solar Astronomy is concerned the main justification is simply, that there is no substitute for the act of astronomical observation by the students, preferably in the institution’s observatory. There, they can experience whatever is involved in the observation and actively participate in the complexities of scientific instrumentation. But, since only a handful of institutions offer this opportunity, efforts should be made to facilitate the remote use of observatories to interested parties elsewhere.

Why is it important to know about the Sun?

The Sun has been increasing in activity since the second half of 2011, in route to the maximum in 2013. But regardless of the solar cycle, there are always good reasons to study the Sun [11]. It is the star we can study in greatest detail for being a quarter of a million times closer than the nearest star to the Solar System. It is also the most relevant, for being the main energy provider of our planet. Furthermore, we have come to realize the importance of solar activity, because powerful explosions in the Sun sometimes trigger geomagnetic storms. Our technologically dependent society needs to be prepared for eventualities that could arise from extraordinary CMEs coming our way. The public needs to know about the Sun, and what better way to inform it than through images of sunspots, prominences, flares, etc., from the school backyard’s solar observatory.

What information can we obtain about the Sun with small solar telescopes?

In term of the general information we obtain with popular small solar telescopes, we may briefly mention that with telescopes in visible light we basically see the structure of the photosphere, along with the possible presence of sunspots. In contrast, with the Hα and Ca II telescopes we can study the chromosphere, where phenomena such as solar flares, may give rise to CMEs. There are several differences in the information we can get from Hα and Ca II, because they show features at different temperatures and depths of the chromosphere. Thus, the ability to observe the same region of the Sun in both lines has considerable advantages. The Hα line shows filaments (hence prominences), sunspots and plages and it is quite useful for predicting eruptions and flares. While the Ca II shows considerable detail in active regions rich in sunspots. Furthermore, it is straightforward with C II images to visualize the presence of magnetic fields; in fact the bright regions known as plages are associated to strong magnetic fields [12].

![Fig. 1 The Sun in the visible, observed on September 20, 2011. The sunspot group complex with sunspot: 1295, 1296 and 1298 can be clearly seen. This complex produced C-class events the following day.](image)

Fig. 1

![Fig. 2 Full disk image of the Sun in Hα observed on April 5, 2012. Sunspot 1450 is the only one present (center right) in the image. Note also the large filament.](image)

Fig. 2

Material and methods

Basic equipment of a solar observatory

The equipment required for a solar observatory includes: telescopes; solar filters; telescope mounts; electronic cameras and an enclosure. It is also highly desirable to control everything with a computer with appropriate software, connected to the Internet.

The CSSO has a battery of four refractor telescopes: the 70 mm Hα telescope for taking full disk images of the Sun, which help determine the course of action during daily observations; the 120 mm visible light telescope fitted with a very wide Baader filter (400–700 nm, optical density 5); the 160 mm high resolution Hα telescope (656.3 nm and Δλ = 0.05 nm) and the 160 mm high resolution Ca II telescope (393.3 nm and Δλ = 0.1 nm).

We have found that the Celestron CGE PRO German equatorial mount is sufficient to carry the four solar telescopes, and that it can be controlled with a computer and TheSky6 software. This is a planetarium program that permits easy calculation of the position and movement of the Sun (or of any other celestial object in its data base). Another useful feature of TheSky6 is its ability to control a variety of telescope mounts, being the CGE PRO one of them. In normal operation, TheSky6 will link to the mount and using its internal model for the movement of the Sun will point to it upon re-
quest and will track it until otherwise instructed. It also permits any fine movement or adjustment that the user might desire to apply.

Classification of sunspots groups can be done with the old projection technique, but there are superior ways to do it. It is now possible to buy CCD cameras with small pixels, low noise, fast integration times and fast frame rates. Examples are: Lumenera, DMK, StarShoot, etc. For imaging in the visible we use the inexpensive Orion StarShoot III (1280 × 1024 5.2 μm × 5.2 μm pixels) with a Baader filter attached to a Celestron OMNI 120 mm f/8.33 refractor. For Hα and Ca II imaging we use two monochrome Lumenera SKYnyx 2-2 (1616 × 1232 4.4 μm × 4.4 μm, 15 fps), as well as the SKYnyx 2-0.

Another recent innovation has been the development of precision narrowband solar filters pioneered by Sidorin et al. [13,14]. He and Coronado Instruments Inc. developed Fabri Perot interferometers (etalons), which have advantages over other filters, such as not requiring power for operation. A single stacked etalon has a bandwidth of 0.07 nm, but a double stacked has 0.05 nm. This narrowness makes it possible to observe in detail chromospheric lines. In the CSSO we have a 160 mm f/7.5 refractor with a double stacked etalon for Hα, a 160 mm f/7.5 refractor with a single stacked etalon for C II, and a 70 mm Hα Coronado MaxScope. The 160 mm telescopes were custom made by Lunt (1942–2005), a generous collaborator in our projects.

Data acquisition at the CSSO

Due to its location (29°05′56″N, 110°57′15″W, 220 m AMSL) in the Sonoran Desert the CSSO enjoys clear skies, which allows almost daily operation (we have had years with more than 350 days of solar observations). Regarding the image quality, however, it will be more convenient to have the CSSO installed on a mountain site, and in fact we have made a proposal to change it (to a 2450 AMSL mountain called Cerro Azul, also located in Sonora, 200 km NE of Hermosillo). But economic reasons have prevented to go forward with this project at the present time. On the other hand, there are several advantages in having the telescope in the campus of Universidad de Sonora, because it allows us to have a strong interaction between users (many of these university students) and the CSSO. Excluding the dome (an Astrohaven 12′ dome), we estimate the total cost to be roughly US$30,000.

We observe the full disk in Hα; high resolution in Hα and Ca II; and in the visible. For data acquisition we capture series of hundreds of images of the region of interest. In each series the images are taken consecutively with the same parameters in the CCD control software. Lucam Recorder is the program used to acquire and record images using the Lumenera SkyNyx CCD cameras. This software permits basic data reduction such as dark image subtraction and flat field correction, and very important, it allows taking multiple images in a continuous mode.
The observations at the CSSO are done remotely, usually from a contiguous building to the observatory through Remote Desktop Connection (RDC), but they can equally be done from anywhere. To this purpose, we invite institutions and individuals to access the CSSO by contacting the authors via email to manifest your interest.

Data processing

To reduce the effect of seeing and bad tracking, the images are treated following a procedure based on software such as Registax or AviStack, meant to be used in small observatories. First, several images in a series are inspected to visually select “the best one”. This reference is then used to eliminate the most deviant ones. Next, the software arranges their positions to co-add them. The final step is to apply a wavelets mathematical filter. This is done to increase contrast selectively in specific scales on the image, thus accentuating either fine or coarse details, such as thin filaments or large sunspots.

Results and discussion

In this section we present examples of the results obtained at the CSSO for the four different telescope filter combinations. In http://www.astro.uson.mx/ we present daily images of the Sun, usually the full disk in Hz. It is also possible to access recent images. Furthermore, by clicking @stroTV Observación a live transmission from the CSSO, can be watched at the hours indicated. Likewise, by clicking on @stroTV Educación around the clock transmissions of educational programs produced by the Astronomy Area can be followed. These transmissions have been followed in schools and planetariums or anyone interested for more than a decade.

In Fig. 1 we present a visible image taken on September 20, 2011 with the Baader filter. What we see, is the solar photosphere with a sunspot group complex. Note the large sunspot dark central umbra, and the gray surrounding penumbral. Note also the range in sizes of the sunspots, all the way down to the smaller ones known as pores. This particular complex produced a C-class event the following day. It is important to mention that visual solar observation is the least expensive technique to implement; therefore it could be a good starting point towards building a Solar Observatory. Furthermore, by simply not using the filter (do not forget to put it back for the solar observation, because it is very dangerous to observe the Sun without a safe filter!), you have a stellar telescope. We occasionally use it for solar system objects, and have found that the resulting high quality images are excellent educational resources in their own right. Examples of these are: the observation of Jupiter’s satellites to determine its mass, and the observation of 433 Eros to determine its distance by parallax as well as the A.U.

The full disk Hz image of the Sun taken on April 5, 2011 is presented in Fig. 2. Images of this kind are primarily taken to have a general idea about the current level of solar activity, and are used to determine the regions of the Sun that will be studied at higher resolution on that particular day. Several surface features typical of chromospheric images are clearly seen in Fig. 2: a large and several small filaments, bright plages, a sunspot, and prominences (most noticeable in the lower part of the image). Note however, that the prominences are relatively faint in Fig. 2, because they require a higher integration time, which would saturate the inner disk. An alternative is to take two separate images, one with a short integration time and the second with a longer integration time. In the first we will see inner disk features such as filaments and flares, whereas in the second, prominences outside the disk will be observed. By superposing these images, we will be able to see all features in a single image. This is precisely what was done to obtain Fig. 3 in Ca II, with images obtained on September 29, 2011. This image presents considerable detail: active regions close to limb; large sunspot umbras and penumbra outlines; well defined prominences; plages, particularly around the sunspots closer to the center; the chromospheric network; faculae, etc.

It is also instructive to compare images taken with different filters. Fig. 4 presents images of the same region of the Sun in Ca II and H α. The differences are obvious. Images like this can lead to group discussions about the layers of the Sun, solar activity, etc.

Conclusions

The CSSO has taught us that a relatively small investment in a solar observatory can produce high quality data. We have found that high school and university students from different disciplines enthusiastically like to get involved in acquiring, processing, cataloging and in trying to make sense of the data, while for others it is more stimulant to work on instrumentation projects. Likewise, based on the CSSO data, programs for the public have been implemented. An example is the Virtual Solar Observation Project (PROSOL) implemented by A. Sánchez, which was followed by people from several Latin American countries. We have also found valuable our experience of transmitting the observation through the Internet, as well as allowing the CSSO to be used remotely from other institutions.

We conclude that solar observatories, necessarily linked in every respect to advanced science and technology, offer amazing rewards in terms of scientific and educational resources. Thus it is important to promote them as a complement to EPO stock resources.

Acknowledgements

The authors would like to acknowledge the late astronomer Antonio Sanchez Ibarra (1955–2009) for bringing the field of Solar Astronomy to the University of Sonora, and for his lifetime dedication to EPO. JS acknowledges support from PIFI 2010-2011. The authors would also like to thank the anonymous referee whose comments helped us to improve this paper.

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