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CONCORDIASTRO/Italy: A Solar High-Resolution Observation Program at Dome-C

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Abstract. CONCORDIASTRO is the Nice-Napoli joint project for site testing of the Dome C for solar and stellar astronomy in the visible. CONCORDIASTRO/Italy is the solar physics part of this project, whose the Napoli team has the principal responsibility. Beyond the well-known interest for the helioseismology, CONCORDIASTRO/Italy pointed out that, because of its special atmospheric conditions, Dome C promises to be one of the best sites on Earth to perform high-resolution solar physics. Here we review the basis for this statement and the solar observations program planned by CONCORDIASTRO/Italy.

Key words. Sun: site testing – Antarctica

1. Introduction

Since the end of '70s and for several years after, Antarctica has been for solar physics the best site to do observational helioseismology. Nowadays, when this job is easier performed by ground-based networks, the iced continent, and Dome C in particular, can still attract the solar observer because of the unique opportunity to observe in the IR wavelengths, where the antarctic sky has an incomparable, high transmission, and, moreover, with the promise of long-lasting observations with a high spatial resolution in a broad wavelength range of the solar spectrum. In many cases in which the antarctic location is in competition with the space, observing from Antarctica will become the winning choice if general purpose instrumentation was available. Instrumentation with various and easily to change setups, a quite often required condi-

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tion for solar physics, won't probably never be possible in space. Further, the combination of high-spatial resolution and full-disk observations at the same time necessarily produces a huge amount of scientific data, which can be received by the scientists only with enormous difficulties, if the instrumentation is not on the ground.

Our project aims to verify the solar seeing quality at Dome C site, installing a 40 cm telescope designed to acquire both high-spatial resolution and full-disk images in selected wavelength ranges. The solar program is part of the joint French-Italian project, CONCORDIASTRO, for probing the astronomical quality of Dome C during both the antarctic day and night. If the expectation of excellent seeing conditions at Dome C will be confirmed, the proposed observations can immediately produce data of high scientific impact. After our antarctic campaign, the solar telescope will be open as an international facility to solar observations in the frame of the Concordia Program.

2. The program

The solar project consists of three main steps:

- Installation of a 40 cm aperture telescope (e.g. see Fig. 1) at Dome C for high resolution and full-disk imaging at different spectral ranges: the core of the Ca II K line, in order to sample the solar atmospheric layers corresponding to the high photosphere and low chromosphere, in addition to the continuum in the visible range, for the photosphere.
- Acquisition of time series of solar intensity images at different spatial resolutions and wavelengths in the visible range.
- Data analysis focused on: i) qualification of the solar seeing at Dome C, and ii) study of the physical connection between the small scale events and the excitation of the global resonant oscillations on the Sun.

3. Discussion

We will determine the seeing quality for solar observations directly with the use of high resolution images, by both analysing the size of the smallest visible solar features – e.g. micropores, intergranular lanes, white light bright points (see Fig. 2) – and applying the advanced technique of "blind deconvolution" (Jefferies and Christou 1993). Moreover, we will indirectly estimate the Modulation Transfer Function (MTF) with recently developed techniques based on intermediate spatial resolution data (Toner and Jefferies, 1993; Bell et al., 1999) like the full-disk images typically used in helioseismology. The intermediate and high resolution data will be also analysed to study the solar oscillations and their relation to the seismic events at small spatial scales. The high resolution data will be 3D Fourier-analysed (i.e. two spatial and one temporal dimension), whereas the full-disk data will be decomposed spatially into spherical harmonics and temporally into Fourier components. The results will be compared with the mathematical model of the theory of multivariate random processes (Koopmans, 1995, Severino et al. 2001).

The main goal of the solar physics program is the characterisation of the Dome C site from the point of view of seeing. "Seeing" is the image degradation due to fluctuations of the refraction index along the path of the light through the earth's atmosphere down to the measuring instrument. Thus the seeing depends on the stability of the entire atmosphere along the line of sight. Moreover, the Sun heats every exposed surface of the telescope or placed in its vicinity, causing local turbulent convection which further degrades the image quality. The result is that, typically, even the best conventional sites for solar observations only offer intermittent good seeing conditions, for short periods during the day and for a few days a year. Longer observations can be achieved only by high technical efforts (e.g. adaptive optics).

Fig. 1. The 40cm aperture telescope currently in operation in the East tower of the OAC main building is a example of the instrument class that CONCORDIASTRO/Italy plan to install for solar site testing at Dome C.

Some site testing campaigns carried out in the past years at Dome C, have highlighted some characteristics of the atmosphere above the site (high stability, absence of wind and clouds) which promise extraordinary seeing conditions for long periods of time: the estimated average seeing in the infrared, at the zenith, for point-like sources, can be as low as 0.4", occasionally down to 0.2". These conditions are particularly favourable to programs requiring high spatial resolution or high sensitivity photometry.

Unlike stars, the Sun is an extended source, distant from zenith, therefore the above estimates of seeing do not apply directly to solar observations. With our program, we propose a determination of the seeing at Dome C directly from high-resolution solar observations.

Dome C promises observing conditions far better than those tested so far in other antarctic sites, such as South Pole (Harvey 1989) and Terra Nova Bay; the latter, for its weather characteristics is not fit for continuous, high-resolution observations. In perspective, Dome C is a site of choice for the development of research programs requiring uninterrupted series of full-Sun images with, at the same time, high angular and temporal resolution.

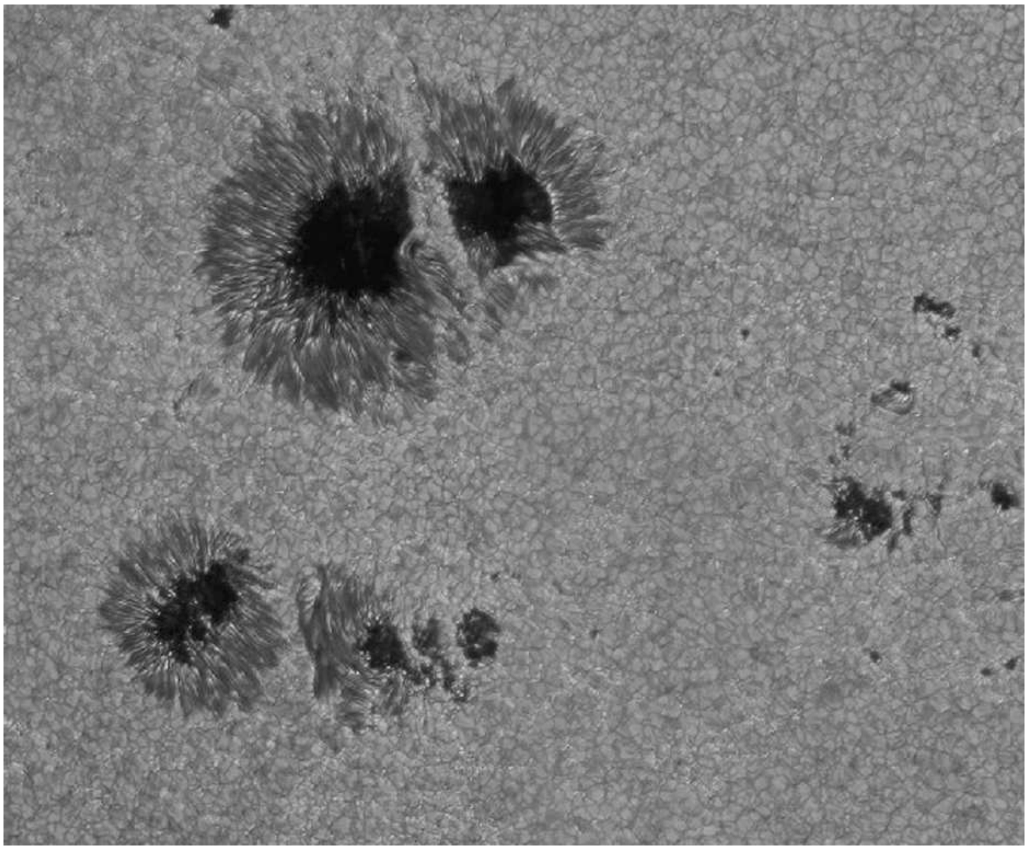

Fig. 2. A FOV of 143 x 118 arcsec corresponding to the active region AR 10018 on July 3, 2002 obtained with the DOT telescope in the G band at 430.5 nm. (courtesy of R.J. Rutten).

The importance of such programs is confirmed by the evolution of the helioseismic network GONG, that, nevertheless significant modifications of the type of the existing instrumentation are necessary, is upgrading to GONG++ to acquire full-disk images with an improved resolution of 2"x2" per pixels.

A research topic of current high interest, requiring long temporal series of high-resolution and full-disk observations, concerns the source of solar oscillations. Convective motions, transporting through the outer third of solar radius the energy produced in the interior, are believed to be the source of the observed oscillations, but the precise mechanism of excitation is still unclear. An interesting proposal is that oscillations are stochastically excited by numerous isolated seismic events, occurring at very small spatial scales (1" or less, Goode et al. 1998). On the other hand, global oscillations are evident in velocity and intensity fluctuation spectra as function of frequency and spherical degree, that are obtained by Fourier analysis and spherical harmonics decomposition of long temporal series of full-disk images of the solar surface.

The group of the Osservatorio Astronomico di Capodimonte has already significantly contributed to this research, in collaboration with other institutions (Deubner et al., 1990; Marmolino and Severino, 1991; Marmolino et al. 1993; Severino et al. 1998; Straus et al. 1999a and b; Oliviero et al 1999; Jimenez et al. 1999; Severino et al. 2001) and the observations proposed in this program for Dome C promise further important progress.

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References

Bell E.F., Hill F. and Harvey J.W., 1999, Solar Phys., 185, 15

Deubner, F.-L., Fleck, B., Marmolino, C., and Severino, G. 1990, A&A, 236, 509

Goode P.R., Strous, L.H., Rimmele, T.R., and Stebbins, R. 1998, Ap.J. 495, L27

Harvey, J.W. 1989, in "Astrophysics in Antartica", D.J. Mullan, M.A. Pomerantz T. Stanev (eds.), AIP 198, 227

Koopmans, L.H. 1995, "The Spectral Analysis of Time Series", Academic Press

Jefferies, S.M., Christou, J.C. 1993, Ap.J. 415, 862

Jimenez, A., Roca Cortes, T., Severino, G., Marmolino, C., and the VIRGO, GOLF, and MDI Teams 1999, Ap. J. 525, 1042

Marmolino C., and Severino G.1991, A&A, 242, 271

Marmolino C., Severino G., Deubner F.-L., Fleck B.: 1993, A&A, 278, 617

Oliviero, M., Severino, G., Straus, Th., Jefferies, S. M., Appourchaux, T.: 1999, Ap.J. 516, L45

Severino, G., Magri' M., Oliviero M., Straus Th., Jefferies, S.M.: 2001, Ap. J. 561, 1, 444

Severino G., Moretti P.F., Oliviero M., and the VAMOS team 2000, ESA SP–464, p. 337

Severino, G., Straus, Th., and Jefferies, S. M. 1998, ESA SP-418, p. 53

Straus, Th., Severino, G., Deubner, F.-L., Fleck, B., Jefferies, S. M., and Tarbell, T. 1999a, Ap.J. 516, 939

Straus, Th., Steffen, M., Severino, G., Freytag, B.: 1999b, ESA-SP, 448, p. 203¡CR¿

Toner C. G. and Jefferies S. M. 1993, Ap. J. 415, 852

Strous, L. H., Goode, P. R., Rimmele, T. R. 2000, Ap.J. 535, 1000