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DAYTIME SITE TESTING AT DOME C: RESULTS OF 2003-2004 CAMPAIGN

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Abstract. We present results of daytime site testing at Dome C in summer 2003-2004. Daytime seeing has been monitored during $2\frac{1}{2}$ months a DIMM on the bright star Canopus, giving median value of 0.54 arcsec. An every-day best seeing period has been observed around 5pm with seeing around 0.3 arcsec. First isoplanatic angle measurements, based on stellar scintillation, were also performed during the month of January, 2004, and gave median value of 6.8 arcsec.

1 Introduction

A site-testing program (part of the Concordiastro project) has been initiated 4 years ago at Dome C. The goal is to monitor, during the polar night, the atmospheric turbulence expected to be very weak. The first DIMM instrument (Sarazin and Roddier, 1990) has been tested for this purpose during the summer season 2002-2003 (Aristidi *et al.*,2003). The exceptional transparency of the Antarctic sky made possible to measure the seeing on a bright star at any time of the day, even with the Sun being at an elevation angle of 38°. During the last summer campaign 2003-2004 we installed two telescopes to monitor the daytime seeing and isoplanatic angles.

2 Instrumentation

Concordiastro telescopes were placed over the top of a wooden platform erected last year. The data collected from the top of this platform, 7 meters above the snow, avoid the always possible surface layer turbulence. The platform is distant 300 m from the Concordia towers and 800 m from the summer camp; these somewhat

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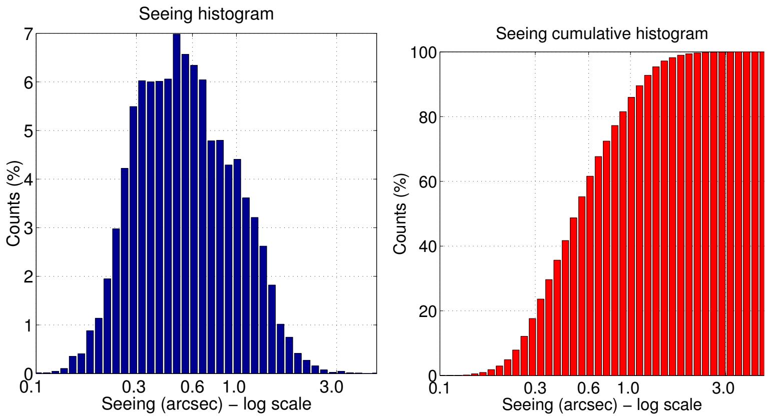

Fig. 1. Seeing histogram (left) and cumulative histogram (right). Seeing axis are logarithmic. These histograms are computed on 17148 estimates covering $2\frac{1}{2}$ months.

large distances limit the pollution due to human activity. Indeed, we dit not notice any systematic effect on the turbulence measurements when the star was above the station.

Two telescopes were operated this year. One was set up in DIMM configuration for seeing measurements, the other one being devoted to isoplanatic angle monitoring. Optical tubes are Celestron 11 (28 cm aperture, 2.8 m focus) fixed on an Astrophysics 900 equatorial mount. One of the optical tube (the DIMM one) was made in INVAR to limit mechanical deformations due to temperature fluctuations. Each telescope was equiped with a digital CCD camera, operating in the visible (300 − 1000 nm), observing through a barlow ×2 lens. The pixel size of 10 μm is consistent with the spatial sampling of the Airy Disc in 2×2 binning mode. This binning mode was used to improve speed; frame rate was then faster than last year (Aristidi *et al.*, 2003), up to 9000 images per 2 mn. The camera is placed inside a thermostated box, ensuring a temperature never colder than −20°C. Digital image signal was then transported by a 20 m cable to a PCI controler board inside a laboratory container.

The DIMM measures the differential motion of two stellar images at the focus of a small telescope. A mask with two sub-apertures is located at the entrance pupil. A prism is added on one of the sub-apertures, so that two images of the same star are observed at the focus. The differential motion of these two images is related to the Fried parameter. Our DIMM is based upon the instrumental concept described by Vernin and Munoz (1995).

The isoplanatic angle monitor (hereafter IAM) measures the scintillation of a stellar image at the focus of the telescope. The telescope is equiped with a dedicated pupil mask consisting in a circular 10 cm diameter aperture with 4cm central obstruction. As described by Ziad *et al.*(2000), this allows to compute the isoplanatic angle from the scintillation index.

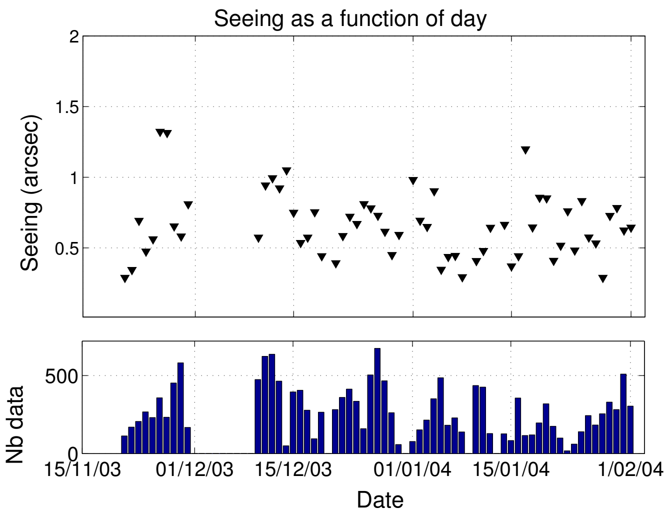

Fig. 2. Variation of the seeing during the summer campaign. Seeing values have been daily-averaged. The number of measurements is plotted on lower graph. As a seeing point is produced every 2 mn, the maximum number of values per day is 720. Note the absence of data during the 10 first days of December, due to a period of bad weather.

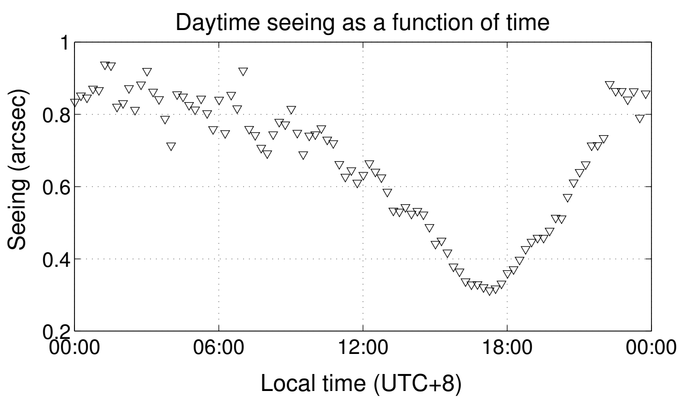

Fig. 3. Seeing versus local time, averaged over the whole campaign.

3 Results

The observations started on mid november 2003 just after the camp aperture. The telescopes were set on the top of the platform, the first days being devoted to the polar alignment of the mounts on a solar spot, then on the star Canopus. We want to notice here the extremely good weather we had on the first 16 days of the campaign, with clear coronal sky even at very low elevations above the horizon.

The temperature was around -50° most of the time during this period. The DIMM was operated from November, 21 to February, 2. The second telescope stopped after a few days of activity because of electronics problem. It had been restarted in the beginning of January and gave one month of isoplanatic angle measurements.

3.1 Seeing measurements

The theory of seeing estimation from differential motion of twin images of a star is described in Tokovinin (2002) and references therein. Every two minutes, the variance of longitudinal and transverse distances between the two images photocenters was computed on about 5000 individual frames (“longitudinal” means parallel to the aperture alignment). This gives two independent estimates of the seeing that should be similar. All measurements for which the relative difference between the two values is greater that 10% are then rejected. The seeing is calculated in the visible, for wavelength 500 nm.

Pixel size calibration was done by imaging the double star Alpha Centauri, whose angular separation $\rho = 10$ arcsec has been estimated from the orbit of Heinz (1960). Exposure times of 10 ms and 20 ms were used, allowing compensation from finite exposure time by linear extrapolation as described in Tokovinin (2002). A threshold is applied to all images to eliminate the sky background. Compensation from zenithal angle z has been made by the classical formula in $\cos z^{-3/5}$. Results are summarized in the following table.

Number of data	17148
Mean seeing (arcsec)	0.65
Median seeing	0.54
Standart deviation	0.39
Maximum seeing	5.22
Minimum seeing	0.10

It may be noticed that daytime median seeing at Dome C is better than Paranal value, 0.66 arcsec, at night time (Sarazin, 2004). It is definitively better than night seeing of 1.7 arcsec observed at South Pole (Travouillon *et al.*, 2003). It is also far better than daytime seeings measured in tempered sites which are generally between 1 and 2 arcsec (see Beckers & Zhong, 2002 and refs. therein). Figure 1 gives the seeing histogram and points out the log-normal distribution of seeing values. These values may be compared to those published last year, after the summer season 2002-2003. We found median seeing of 1.2 arcsec, that is much higher than what we found this year. These differences appear to be explained by a strong local turbulence at the telescope level, since the telescope was black and exposed to the Sun 24 h per day. Since we had two telescopes in 2003-2004, one being black and the other white, we could register DIMM data at the same time to make a comparison. It is not completed yet, but first insight suggest a difference of 0.4 arcsec between the two DIMMs.

Figure 3 shows the evolution of seeing during the day. Each point corresponds to an average over the whole campaign. This curve exhibits a deep minimum near 5pm, where the seeing is of the order of 0.3 arcsec. Balloon soundings have shown

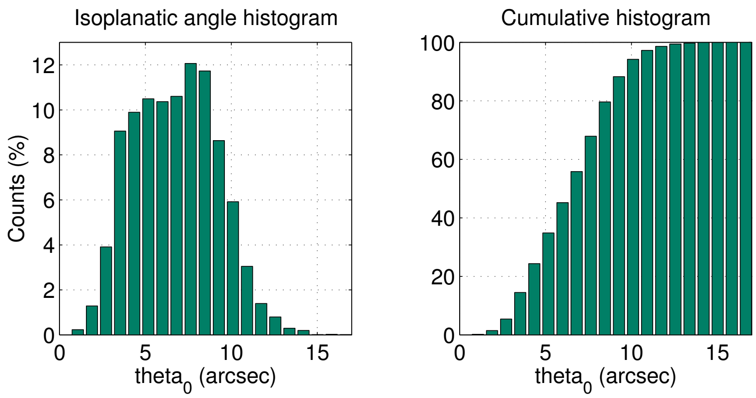

Fig. 4. Isoplanatic angle histogram

that the vertical temperature profile in the 200 first meters above the snow are almost flat at this time (Aristidi *et al.*, 2004a, 2004b). This is indeed good news for solar astronomers that can expect, almost every day, several hours of seeing better than 0.5 arcsec, making Dome C the best place in the world for solar imaging at high angular resolution.

3.2 Isoplanatic angle measurements

As suggested by Loos and Hodge (1979) (see also Ziad *et al.*, 2000), isoplanatic angle can be accessed from scintillation measurements as the focus of a 10 cm diameter telescope with 4 cm central obstruction. We dedicated a telescope for this purpose, and put at the entrance a mask with the required pupil. The star was here again Canopus.The use of a double exposure time permitted to compensate from finite exposure and to obtain instantaneous values. A 5σ threshold was applied to images to eliminate the sky background. We could monitor the isoplanatic angle for nearly one month; these were the first measurements ever made at Dome C. Results are summarized in table hereafter.

Number of data	6328
Mean θ_0 (arcsec)	6.8
Median θ_0 seeing	6.8
Standart deviation	2.4
Maximum θ_0	17.1
Minimum θ_0	0.7

Here again, Dome C values are far superior to those observed in temperate sites, ranging from 1 to 3 arcsec (Ziad *et al.*, 2000). First night estimations obtained from the MASS experiment by the Australian group (Lawrence *et al.*, 2004) give similar results. This is a good news for adaptive optics. Increasing isoplanatic angle by a factor 3 would increase by a factor 9 the field usable for calibrator search, and consequently the observable portion of sky, as discussed by Coudé du

Foresto *et al.*(2004).

4 Conclusion and perspectives

The data still need more processing. Additionnal parameters such as the surface layer influence will be probed on next summer season in 2004-2005. Complete summer results will be published in a following paper. Complementary site testing based on balloon borne experiment have already been published (Aristidi et al., 2004a, 2004b). All this show that Dome C has better daytime seeing and isoplanatic angles values than any other site in the world. These excellent results appear to be conforted by night-time measurement of Lawrence *et al.*(2004).

The future prospects of astronomy in this unique site are now somewhat conforted by our daytime measurements, as well as the first winter data of the australian group headed by J. Storey (Lawrence *et al.*, 2004). It becomes more and more obvious that infrared high angular resolution astronomy can be developed at Dome C. Some projects are already under discussion, such as the interferometers Keops and API proposed respectively by F. Vakili (Vakili et. al, 2004) and M. Swain (Swain et al., 2004).

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