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Perspective of interometry in Antarctica

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Abstract: The recent Dome C site testing shows its potential for interferometry. This article presents a part of discussion about the site characteristics measured by E. Aristidi et al. during the polar night. In section 2, the site characteristics are described. In section 3, the Mykerinos prototype interferometer is exposed. This instrument can be the first step before the implementation of future large Antarctic interferometers. It will allow characterizing the best instrument specifications, test technology in extreme conditions, and check the performances predicted for interferometer from Dome C. Its baseline and precision will allow studies of hot Jupiters with small apertures.

1 Introduction

The Concordia base is located at Dome C at the altitude of 3300 meters. The weather of this site is exceptional: coldness and dryness; the temperature around -70°C during winter night, and only 5g per cm^2 per year of snow fall. These conditions are accompanied by a clear sky and a low atmospheric absorption. New site tests show that with 96% of clear days between February and May (data from E. Aristidi, 2005) this site is one of the clearest places on the Earth. The topography of the site is very interesting. The ground is practically horizontal over 100 kilometers. It is possible to build a 1 km baseline interferometer without heavy earthwork. Building stable structures on this area is made easier because of the low wind speed.

The building of the Italian-French polar station Concordia started in 1999. It has been available for winter stay since last year. This allows new tests of the site characteristics with the DIMM experiment during the polar night.

The results of these tests briefly mentioned in the next chapter are very promising for interferometry. We proposed a prototype interferometer Mikerinos, as a first step for large interferometer in Antarctica. We present the first studies of the performances of this prototype.

2 Site atmosphere characteristics

The last site testing was carried out by E. Aristidi (E. Aristidi et al.,2005) thanks to 3 kinds of experiments:

The first measurement method measures integrated optical disturbance with the DIMM and the telescopes GSM (Ziad et al., 2002). They measure the outer scale L_0, isoplanar angle θ_0, the

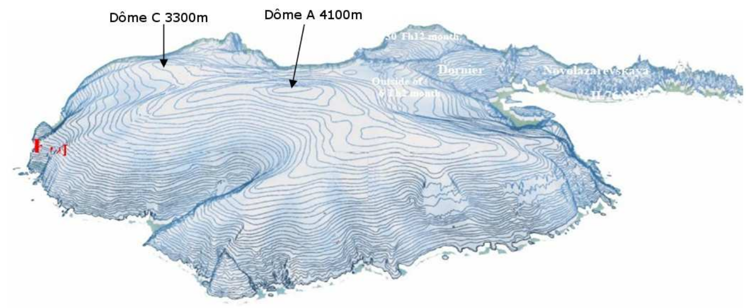

Figure 1: Dome C location on Antarctica map

Site	Seeing (FWHM in ”)	Isoplanetic angle in ”
Paranal	0.66	1.91
La Silla	0.87	1.25
Maidanak	0.70	2.47
South Pole	1.74	3.23
Dome C (summer)	0.54	6.8

Table 1: Seeing and Isoplanetic angle on different sites compared to Dome C during the summer. Winter season data are under analysis.

coherence time τ_0, and the seeing quality r_0. These experiments show that Dome C (as shown the Table 1) has one of the best seeing on earth. Moreover it has a wide isoplanetic angle. This angle defines the maximal stars separation between the tracked star in an interferometer and studied star. If this angle is wide, finding a bright star for the fringe tracking is greatly relaxed. (Elhalkouj et al., IAUC, 2005)

The second measurements were carried out in situ with balloons. These measurements give the refractive index structure constant C_n^2 as a function of the altitude. This experiment (shown on the Figure 2) shows clearly that the ground layer is responsible for the largest part of the atmospheric turbulence (as exposed on the Table 2). This ground layer is limited to about 30 meters. It plays a fundamental role during winter session. (Aristidi et al.,2005) Above this level, the seeing is excellent. The r_0 value is twice better than at Paranal. The coherence time is around 9.6 ms wether is 3.3 ms at Paranal. This two parameters define the so called coherence volume, ie the number of photon per speckle per coherence time. That is to say they define the limit magnitude which allows the fringe tracking with an interferometer. This limit is proportional to r_0^2 times τ_0. Therefore limit magnitude at Dome C is between 2 and 4 mag over Paranal one.

Parameters	Dimm (March - May 2005)	Balloons (10) intergrated from 8m	Balloons (10) intergrated from 30m
Seeing (”)	1.0	1.2	0.4
$\tau_0(ms)$		6.8	9.6
θ_0 (”)	3.3	3.6	3.2

Table 2: Seeing, τ_0 and θ_0 measured by the Dimm, and by the balloons, the balloon measures are integrated from 8 meters to 30 meters

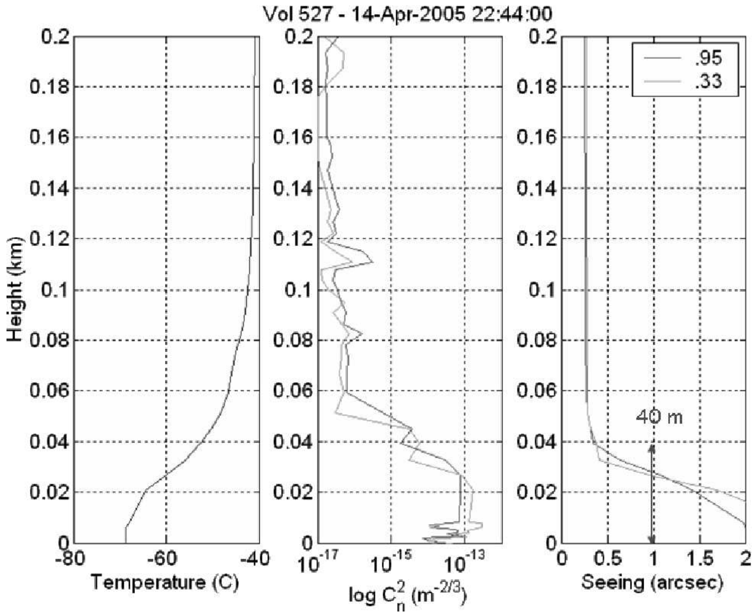

Figure 2: Example of balloons measurement; the right curve is the Temperature as function of altitude, the middle curve is the refractive index structure constant C_n^2 and the left curve is the seeing (integrated from the C_n^2). These graphics show a boundery layer limited to 40 m.

The real challenge for Dome C is to find a way to get rid off the ground turbulence. Some solutions are studied at the LUAN like the use of towers, or the use of a ground layer adaptative optics system.

3 Interferometry projects

As explained in the last section such atmospheric conditions are interesting for interferometers. Several projects aim to set up such large interferometers. One of them is KEOPS (for Kilo Parsec Explorer Optical Planets finder) project proposed by F. Vakili (LUAN). It will be composed by thirty six 1.5 meter telescopes arranged on 3 concentric rings. The first ring is composed by 6 telescopes and the rings diameter is 250 meters, the second ring is composed by 12 telescopes and its diameter is 600 meters. The last ring is composed 18 telescopes with a diameter of 1000 meters. It will allow high angular resolution needed for lot of astronomical challenges, specially direct detection of exo earths. But such instrument is perfect to study stellar surfaces, to make extragalactic and black holes observations, to make direct imaging and micro lenses. Finally it will be useful for the studies of the mechanisms of planets formation.

Before building such interferometer the site should be properly characterized by a smaller interferometer. One prototype is studied at the LUAN: Mykerinos. This instrument should be able to work in extreme conditions.

3.1 Mykerinos specifications

This interferometer is composed of three 40 cm telescopes. Its baseline ranges is between 100 and 400 meters. This size will first allow characterizing of the site with an interferometer and allow to have a sufficient angular resolution to make science. It will operate in phase closure mode, allowing precise measurements in the visible domain. The studies have proved that limiting

Planet	Magnitude	angular separation from their star (in ")	star spectral type
HD108147	7.003	0.003	F8/G0 V
HD86	6.17	0.01	K1 V

Table 3: candidate planets detectable by the Mykerinos interferometer

magnitude for fringe tracking (cf Figure 3) and noise level should allow the observations and characterizations of several hot Jupiter. (Table 3)

3.2 Mykerinos challenges

Mykerinos is the first step before the creation of large Antarctica interferometers like KEOPS. Technology tests will be done with this small interferometer in order to validate the technologies for KEOPS. Mykerinos should be able to work in the Antarctica extreme conditions. Its size should allow it to be easily transportable in Antarctica. Precise visibility measurements are possible thanks to its large base line. The telescopes will be placed on individual towers to get rid off the ground turbulence layer.

3.3 Mykerinos science goal

Better than just a technology demonstrator and a site testing instrument, Mykerinos should be able to measure interesting stellar parameters. Its angular resolution allow to measure star diameters, rotation, darkening and aplanatism. More over the thermal atmospheric emission simulations show that at least two hot Jupiter could be detected (and the color of their atmospheres studied) with this a 40cm telescopes interferometer. The thermal emission of the Earth's atmosphere was simulated thanks to a black corps emitting at -70° Celsius. This simulation includes the atmosphere thermal emission, the photon noise and the read out noise. The Figure 3 shows the limits magnitude to track the fringe pattern with a signal to noise ratio equal to 1, a exposure time of 10 ms, and 40 cm telescope diameter. This result shows that at least two hot Jupiter are detectable with this instrument (see Table 3).

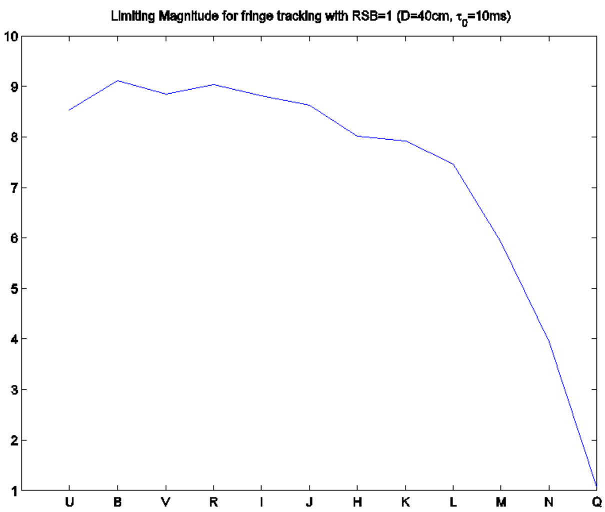

Figure 3: Limiting magnitude for fringe tracking with a signal to noise ration equal to 1, telescope diameter equal to 40 cm and τ_0 equal to 10 ms. (average conditions at 30 m)

4 Conclusions

The Dome C site is one of the most promising site to set up large interferometers. The atmospheric conditions and the free area are perfect for a large interferometer. In order to achieve the characterization of the site, the LUAN is building the Mykerinos interferometer prototype. This instrument will be needed to validate the technology for the next Antarctica interferometer generation. It will measure the isopistonic angle, and will already be of interest to study some hot Jupiters and bright exo zodiacal lights.

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