An Off-Axis Telescope Concept for Antarctic Astronomy

G. Moretto, I. Vauglin, M. Langlois, N. Epchtein

G. Moretto, I. Vauglin, M. Langlois, N. Epchtein. An Off-Axis Telescope Concept for Antarctic Astronomy. Semaine de l'Astrophysique Française, Jun 2012, Nice, France. in2p3-00741375

HAL Id: in2p3-00741375
https://hal.in2p3.fr/in2p3-00741375
Submitted on 12 Oct 2012

SF2A 2012
S. Boissier, P. de Laverny, N. Nardetto, R. Samadi, D. Valls-Gabaud and H. Wozniak (eds)

AN OFF-AXIS TELESCOPE CONCEPT FOR ANTARCTIC ASTRONOMY

G. Moretto[1], I. Vauglin[2], M. Langlois[2] and N. Epchtein[3]

Abstract. The site of the CONCORDIA station at Dome C on the Antarctic Plateau offers exceptional atmospheric and environmental conditions for astronomical observations over a wide range of wavelengths and is uniquely favorable to infrared astronomy. To make the best use of these exceptional environment, especially the very low sky brightness throughout the near- and mid-infrared, we must develop a telescope offering the highest possible dynamic range for photometry, a high angular resolution and a wide-field. In these conditions, a modest-sized 2m off-axis telescope achieves comparable sensitivity to that of a larger ground-based 8-10m class telescope or a same sized space-borne ones.

Keywords: off-axis telescope, infrared astronomy, Antarctic astronomy

1 Introduction

The properties of the atmosphere above the Antarctic Plateau are known to be unique on the Earth surface. Atmospheric turbulence is concentrated in a thin layer of a few tens of meters, the sky transparency, particularly in the infrared, is considerably increased and the thermal infrared sky background radiation is lower by a factor of 10 to 20 in the 2-3 μm windows (Philips et al. 1999). The combination of these advantages makes a 2m class telescope comparable to an 8m one in a conventional site in terms of sensitivity.

The Antarctic Plateau is thus likely to become in the coming decades a new major platform for advanced astronomical observations. A medium/large aperture telescope on the Antarctic Plateau have the potential to undertake tasks previously thought to be possible only in space, for example, the imaging and crude spectroscopy of Earth-like extra-solar planets (Angel, Lawrence and Storey, 2004). In the short/medium term, it is expected that infrared imaging and spectro-imaging surveys, from Antarctica could play an critical role in the context of the future large ground based and space projects such as E-ELT, JWST, LSST, EUCLID, GAIA.

Three astrophysical key-domains for an optical/IR facility had been identified in the ARENA vision (2010), namely (1) the search and characterization of Type Ia supernovae and the investigation of the distant Universe, (2) the stellar populations and evolution in the local group of galaxies, (3) the identification and characterization of extra-solar planets.

We present here a new preliminary concept of telescope able to achieve the three above mentioned key-domains. Such concept offers a wide range of cutting edge technological investigations that would definitely overcome the scope of Antarctic astronomy.

2 Why an off-axis telescope in Antarctica?

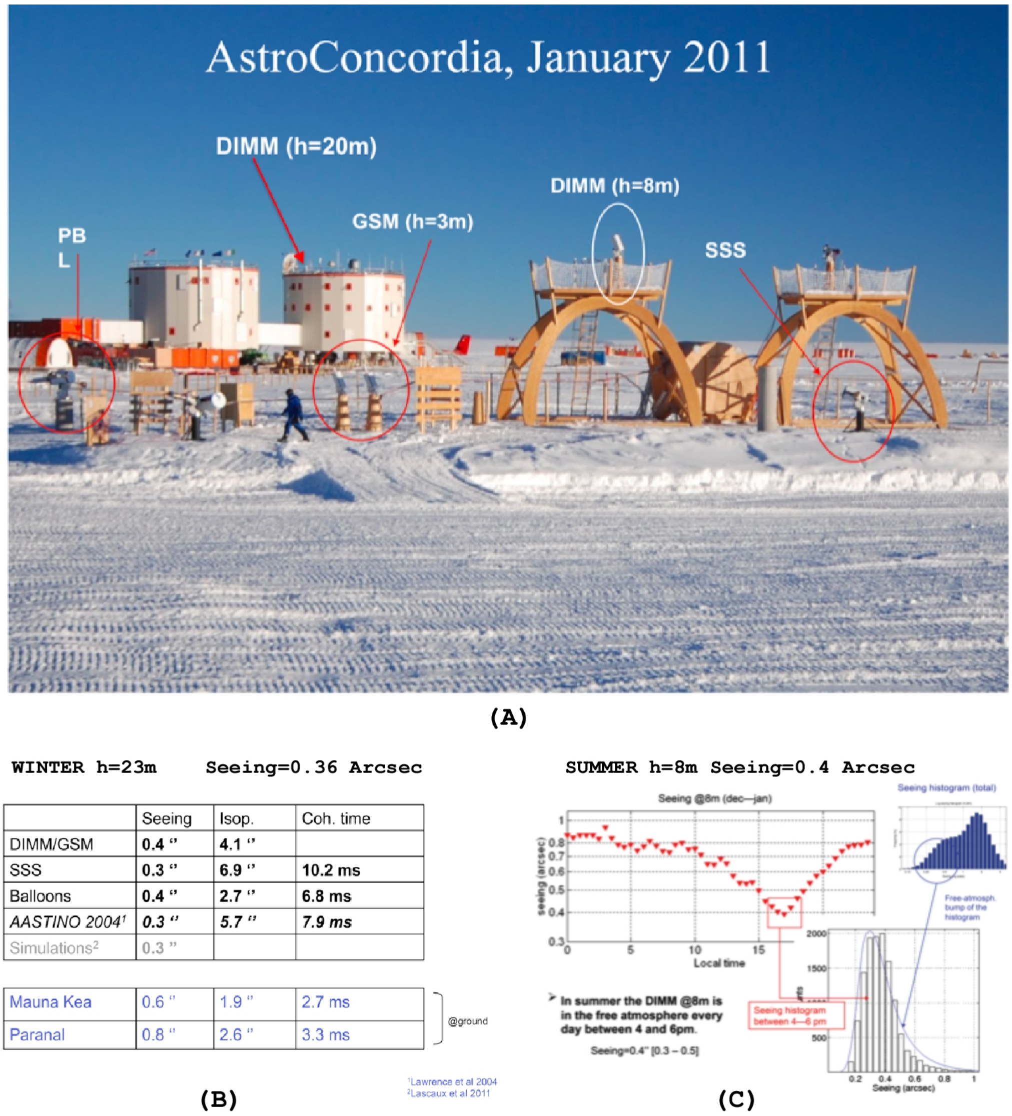
An off-axis telescope is the only way to capitalize the exceptional atmospheric and environmental antarctic conditions for astronomical observations in the near- and mid-infrared. An off-axis telescope provides an inherently low scattered light design because there are no obstruction in the beam. All mirrors can be robustly supported and articulated because of the easy access allowed by this design. All warm components, sources of the telescope self-thermal emission, will be out of optical beam minimizing its emissivity. Such a design reduces the sources

---

[1] Institute of Nuclear Physics of Lyon, IN2P3-CNRS, Université de Lyon, F-69622, Lyon, France

[2] Centre de Recherche Astrophysique de Lyon, UMR 5574, F-69230, Saint-Genis Laval, France, Université Lyon1, Université de Lyon, F-69622, Lyon, France

[3] Laboratoire Lagrange, UMR 7293, Université de Nice Sophia Antipolis, F-06000, Nice, France



(A)

WINTER h=23m Seeing=0.36 Arcsec

	Seeing	Isop.	Coh. time
DIMM/GSM	**0.4 "**	**4.1 "**	
SSS	**0.3 "**	**6.9 "**	**10.2 ms**
Balloons	**0.4 "**	**2.7 "**	**6.8 ms**
AASTINO 2004[1]	***0.3 "***	***5.7 "***	***7.9 ms***
Simulations[2]	0.3 "		

Mauna Kea	0.6 "	1.9 "	2.7 ms
Paranal	0.8 "	2.6 "	3.3 ms

@ground

[1]Lawrence et al 2004
[2]Lascaux et al 2011

(B)

(C)

Fig. 1. The French/Italian Concordia base at Dome C - showing in the backline the staff headquarters (two cylindrical structures) and in the frontline the seeing measurements instruments. The data for winter and summer seeing measurements are presented respectively by (D) and (C), from Aristidi et al. (2009)

of light scattering and self thermal emissivity.
This is a tremendous advantage for studies of planets near bright stars and faint nebulosity surrounding young stars, where planets may be forming. Moreover, it has no azimuthal PSF structure, no missing or interpolated wavefront errors. That is natural advantages for interferometry and adaptive optics performance!
Thus to have the highest possible dynamic range for photometry and angular resolution from the optical to thermal infrared, an off-axis design optimized for low scattered light and low emissivity is needed. Besides, a 3-mirror design optimized to get a wide field of view is called to achieve wide-field imaging.

3 Optical design

A precise description of this off-axis 2.5m telescope for Antarctica is given in Moretto et al. (2012).
Optically speaking an off-axis telescope is not an asymmetric system, it is a decentered system preserving its bi-lateral symmetry. This means that the system preserves many of the optical performances, tolerances and sensitivities characteristics of the parent concentric system - a deal for system opto-mechanical alignment. A three-mirror decentered Paul-Baker (Paul, 1935; Baker, 1969) system is our guideline concept reference, where

some variation on the shape of the three mirrors is allowed to achieve good image quality across a wide field of view. One of the main constraints during such optimizations is the necessity to have compact designs, making it possible to be installed on top of a $\geq$20m high tower to overcome the boundary layer that extends between 2m to 23m (Gredel 2010).

A preliminary study gives the design presented in Fig.1. A baseline design for Dome C relies on a 2.5 meter unobstructed aperture M1 which should produce a F/8 system optimized over an 1deg x 1deg field of view. We generate a Paul-Baker configuration by adding auxiliary convex secondary mirror (M2) and a concave tertiary (M3).

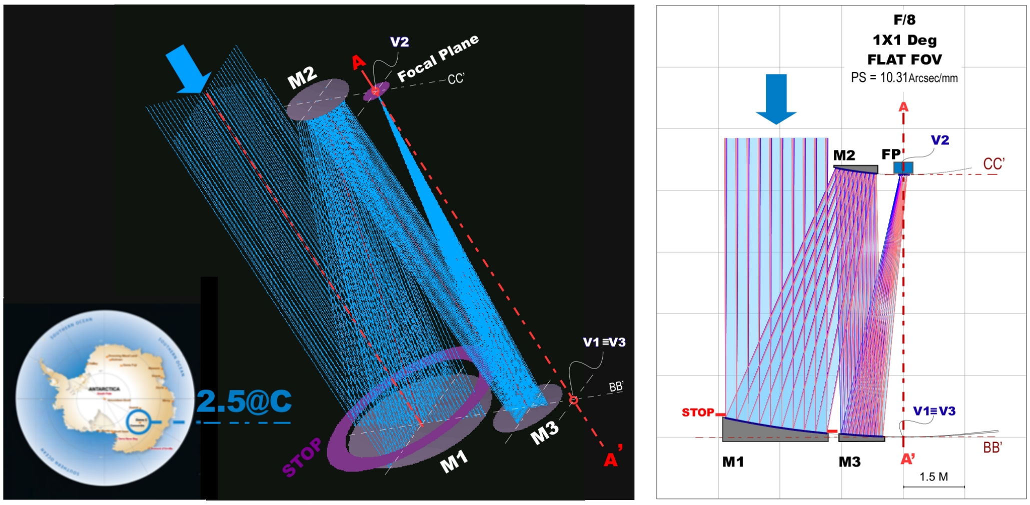


Fig. 2. The design of an off-axis telescope for Dome C. A 2.5 meter unobstructed aperture M1 yielding in a F/8 system optimized over a 1x1 deg FOV. AA is the parent mirrors M1, M2 and M3 optical axis. M1 and M3 verteces V1 and V3 are coincident as well as for M2 (V2) and FP. Note that the primary mirror M1, the secondary M2 and the tertiary M3 are not tilted mirrors but are a decentered piece of concentric system, preserving its bi-lateral symmetry.

The plate scale is 10.31 arcsec/mm. The decision on plate scale is a compromise between an optimal sampling for high resolution and a compact design. An effective focal length (EFL) of 20m produces a support structure long of $V1V2 = V1FP < 7m$, short enough for our proposes.

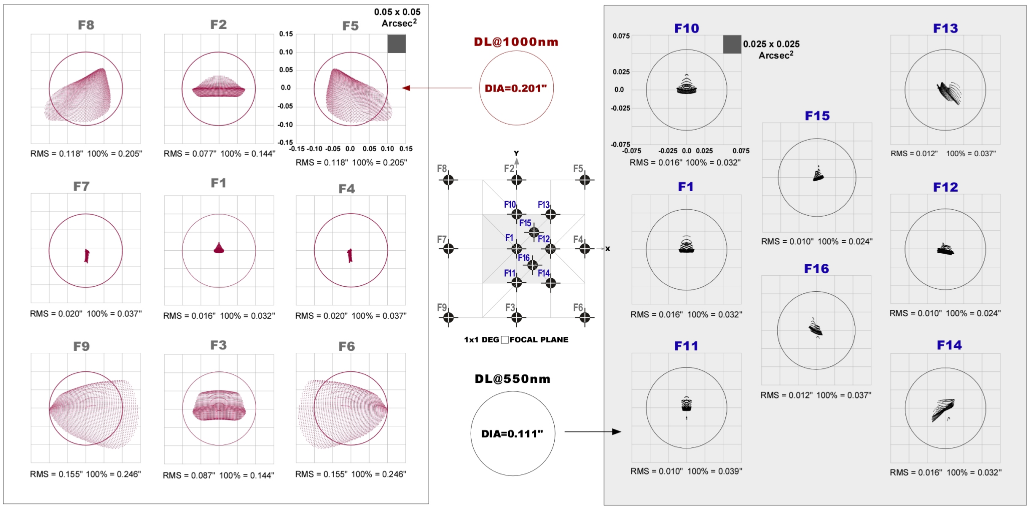
We consider a typical detector pixel size of 15 μm, which for an $EFL = 20m$ results in a sampling of $FWHM = 2.35$ pixels. This is the Nyquist criterion, the standard deviation. Some discussion has been flown confirming that a sampling of $FWHM = 3.5$ pixels or more is the optimal for high resolution.

The optical performance at the edges of 1x1 Deg2 FOV is show in Fig. 2. The PSF spots at corner-edges (F5, F6, F8, F9) of 1x1 Deg2 FOV are diffraction limited at 1000nm wavelength and elsewhere they are diffraction limited at 550nm or even better. Note that the blur in this system is only weakly dependent on the off-axis angle and the telescope will be entirely seeing limited.

4 Conclusions

In terms of feasibility there are several myths about off-axis telescopes. Many areas of modern astrophysics are not flux-limited but are rather dynamic-range limited. Simply collecting more photons will not solve the problem: for these topics, *we don't need bigger telescopes,* **we need better telescopes set up at exceptional sites**. We need off-axis telescopes! Moretto et al (2012) reviewed the technology of off-axis telescope and show their present feasibilyty.

This new telescope concept allows exceptional dynamic range for photometry and high angular resolution + wide field imaging and capitalizes the exceptional atmospheric and environmental Antarctic conditions for astronomical observations over the optical and thermal infrared wavelengths is what we proposed.



(A)

(B)

Fig. 3. The geometric optical performance over a flat FOV. (A) The PSF computed on the edge and center of a 1x1 deg2 FOV. The PSF computed across a 0.5 x 0.5 deg2 FOV is shown in (B). DL stands for diffraction limit diameter at 1000nm and 550nm wavelength. Note in (A) the spots F8&F5, F7&F4 and F9&F6 confirm the optical bi-lateral symmetry of a decentered system

References

Phillips, A., Burton, M.G., Ashley, M.C. et al., APJ 527, 1009, 1999

Aristidi, E., Fossat, E., Agabi, K. et al. 2009, A&A, 499, 955, 2009

Angel, R., Lawrence, J., Storey J., Proc. SPIE 5382 (Part 1), 76-84, 2004

ARENA consortium, 2009, A vision for European Astronomy and Astrophysics at the Antarctic station Concordia, Dome C in the next decade 2010-2020, ed., N. Epchtein, (Publisher Nova Terra)

Moretto G., Epchtein N., Langlois M., Vauglin I., Proc. of SPIE Vol. 8444, 84445E, 2012

Paul, M., Rev. Opt. 14, 169, 1935

Baker, J.G., IEEE Transactions of Aerospace and Electronic System, AES-5, 261, 1969.

Gredel, R., Proc. 3rd ARENA Conf., eds. L. Spinoglio & N. Epchtein, EDP EAS Ser. Vol. 40, 11, 2010

Moretto, G., Kuhn, J.R. and Goode P., Proc. of SPIE Vol. 8444, 8444OY, 2012