



**HAL**  
open science

## **KEOPS: Scientific Challenges and technical Steps**

Bruno Valat, Pierre-Marie Gori, François-Xavier Schmider, Bruno Lopez,  
Farrokh Vakili

► **To cite this version:**

Bruno Valat, Pierre-Marie Gori, François-Xavier Schmider, Bruno Lopez, Farrokh Vakili. KEOPS: Scientific Challenges and technical Steps. EAS Publications Series, 2007, 1st ARENA Conference on "Large Astronomical Infrastructures at CONCORDIA, prospects and constraints for Antarctic Optical/IR Astronomy", 25, pp.295-299. 10.1051/eas:2007110 . hal-00417135

**HAL Id: hal-00417135**

**<https://hal.science/hal-00417135>**

Submitted on 28 Mar 2024

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# KEOPS: SCIENTIFIC CHALLENGES AND TECHNICAL STEPS

B. Valat<sup>1, 2</sup>, P.-M. Gori<sup>1</sup>, F.-X. Schmider<sup>1</sup>, B. Lopez<sup>3</sup> and F. Vakili<sup>1</sup>

**Abstract.** The recent site testing pointed out the potential of Dome C for Next Generation Optical Interferometer. KEOPS (Kilo parsec Explorer Optical Planet Search) is proposed in a context which also considers the post VLTI perspectives. This interferometer will be composed of 36 telescopes with a maximal baseline of 1 km. This instrument will open new horizons: stellar imaging, circumstellar environment studies, extra solar planet detection, Earth like planet search. The possibility of observations in double field mode takes advantage of the large isopistonc angle to give access to faint objects (see Elhalkouj 2006). It allows active galactic nuclei and cosmological observations. The achievement of that project implies different steps. The first one could be MYKERINOS, proposed by LUAN. This prototype interferometer, composed of 3 telescopes of 40 cm, demonstrates technological feasibility, completes the specific site characterisation and contributes to validate the scientific program objectives.

## 1 Introduction

Recent site testing has shown that Dome C in Antarctica has a high potential for astrophysical observations due to the structure of the atmosphere turbulence. Most of the turbulence is concentrated in the first 30 m (Vernin 2006). A ground layer adaptive optic (GLAO) systems, or the installation of telescopes on 30-meter towers, to reach high angular resolution observations. Despite the presence of the boundary layer, which produces an average seeing of 1.6 arcsec at the ground level, the other characteristics of the optical turbulences are exceptionally good. The isopistonc angle and the coherence time are larger at Dome C than any other

---

<sup>1</sup> Laboratoire Universitaire d'Astrophysique de Nice UMR 6525, Université de Nice Sophia Antipolis, France

<sup>2</sup> AlcatelAleniaSpace, France

<sup>3</sup> Observatoire de la Côte d'Azur, Département GEMINI, Nice, France

tested place the on ground. These two parameters are critical for the interferometry. In the first section the impacts of these parameters on actual interferometry and the gain obtained thanks to the atmosphere characteristics at Dome C are explained. In the second section, we describe the project of large interferometer KEOPS (Kilo parsec Explorer Optical Planet search). However, building such a project requires to test all site parameters relevant to high angular resolution. In this frame the LUAN propose to study a prototype interferometer called Mykerinos.

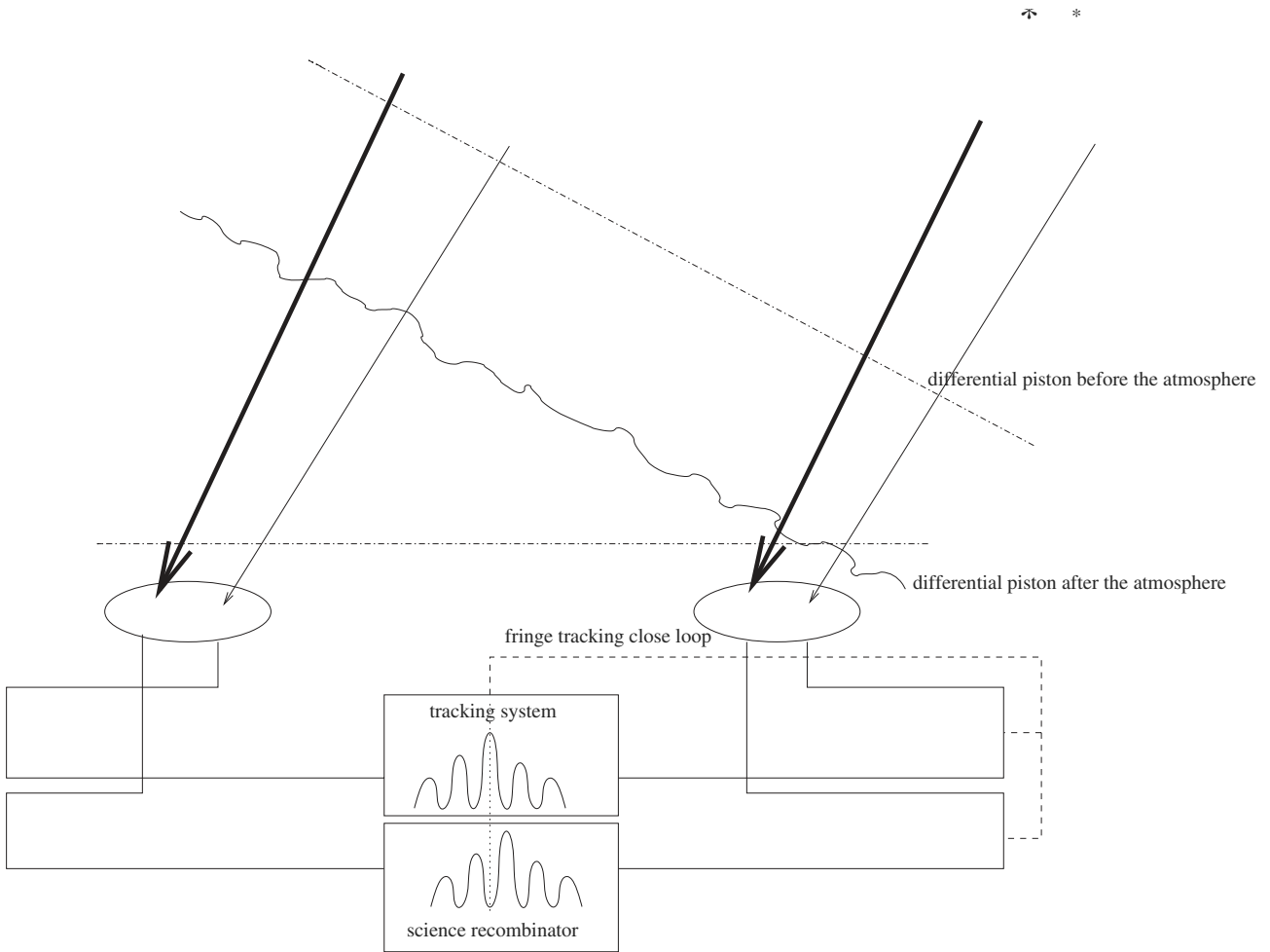
## **2 Main Limitations of Interferometer *Versus* Dome C Characteristics**

Since Michelson's measurement of the diameter of Betelgeuse, instruments have considerably evolved. Unfortunately one major limitation is their sensitivity: interferometers with 10 m class telescopes have a limited magnitude of about to 10. This limit can be extended to 15 for a few percents of the sky coverage by using off-axis co-phasing like in PRIMA faint object mode. Unfortunately this technique needs a bright star close to the "science star". The maximal angular separation between the "tracking star" and the "science star" is defined by the isopiston angle. This angle is the maximum angular separation between two objects which have their differential piston motion correlated. Figure 1 presents the principle of off-axis cophasing. The present limit of sensitivity does not allow a large number of observations of extra galactic objects. There are two ways to improve the limiting magnitude of interferometers, either using larger telescopes, or doing off axis cophasing. As explained before the off axis possibility depends strongly on the isopiston angle. Its value at Dome C is twice as large as it is at Paranal. Using this advantage will permit more than 50 percents of the sky to be observable with a 2 m telescope interferometer (see Elhalkouj 2006). Moreover the signal to noise ratio at Dome C could be better than anywhere else on ground for certain wavelength domains due to the low thermal background of the sky and low ambient temperature (see Storey 2004).

The second critical point is the atmospheric stability. The quality of the calibration of the measurement strongly depends on the atmospheric stability. Above the boundary layer the atmosphere at Dome C is more stable than any where else on Earth, interferometric calibration could be more precise, and the sensitivity higher.

## **3 Kilo parsec Explorer Optical Planet Search (KEOPS); a Post VLT Instrument**

The last decade was marked by the construction of interferometers with large telescope apertures. The next future improvement will be the imaging capability. This requires at least 3, hopefully much more, cophased telescopes. The project KEOPS (see Vakili 2004, 2005) is one of this ambitious projects. It is composed of thirty six 1.5 meter telescopes. These telescopes are placed in 3 concentric rings;

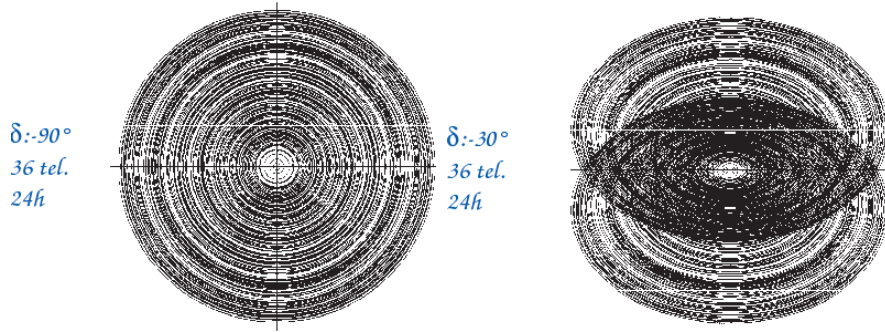


**Fig. 1.** Off-axis cophasing principle: the interference fringes are tracked with the flux of a bright star, chosen close enough to the science star, in order that the differential piston remains small.

6, 12 and 18 telescopes are set up on 300, 600, and 1000 m rings, respectively. The baseline size and the large number of telescopes will allow to take images at very high resolution. It has a resolution of 1 AU at 1 kpc. Figure 2 presents the Fourier plan coverage for an integration time of 24 h. KEOPS will be built on the Dome C plateau in order to take advantage of the clear and stable atmosphere there. One major goal for KEOPS is the exo-earth detection and characterisation. Such instrument can also study stellar surfaces, asteroseismology, circumstellar environments, extragalactic target, AGN, quasars. Before building such a huge infrastructure, site testing has to be completed thanks to a small interferometer prototype: Mykerinos.

## 4 Mykerinos

Mykerinos is a prototype interferometer composed of three 40 cm telescopes. The maximal baseline will be between 200 and 400 m. It will work in closure phase mode. It has 3 goals: site characterisation, technological demonstration and scientific objectives.



**Fig. 2.**  $u, v$  coverage after 24 h of continuous observation with KEOPS. Response for a target at  $30^\circ$  (*right*), and  $90^\circ$  declination (*left*), respectively.

#### 4.1 Site Characterisation

The evaluation of performances of future interferometers at Dome C requires to know specific site characteristics. The temporal behaviour of the atmosphere differential piston, and the isopiston angle are important parameters relevant to interferometry. They are presently estimated through a model. Actual measurements of this parameters are required in order to design the off axis co-phasing system and to know the limiting magnitude reachable by the system. All these measurements can be carried out thanks to a Michelson girder or a prototype interferometer. The LUAN plans to build Mykerinos with a double field system in order to be able to measure this parameter.

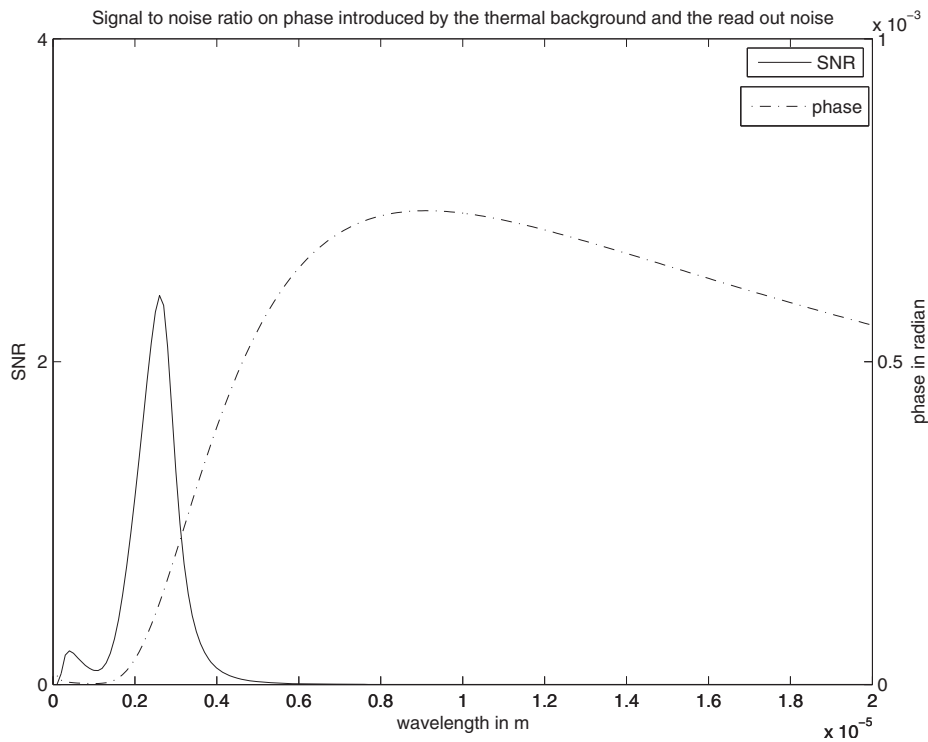
#### 4.2 Technological Test

The second reason to build such a prototype is to perform technological tests. The harsh conditions at Dome C require high reliability and high self working capability. All critical parts of an instrument at Dome C have to be tested extensively. The hard access at Dome C implies simple systems, that is why Mykerinos will use optical fibers for the beam transportation. In order to take benefit from the low thermal background most parts of the instrument have to be at the atmospherical temperature (down to  $-80^\circ\text{C}$ ).

The telescope, the field separators and the fiber system have to be tested in the conditions of Dome C. The other subsystems: the beam combiner, the delay lines have also to be designed for the cold conditions.

#### 4.3 Mykerinos Target

Mykerinos can also perform interesting science demonstration. Its long baseline allows to measure fundamental parameters with micro arcsec accuracy. It should be also able to observe high contrast binaries. Such instrument could also detect several Hot Jupiters thanks to the photo-center displacement technic. Figure 3 shows the signal to noise ratio on phase displacement for the extra solar planet GJ86.



**Fig. 3.** Simulation of the GJ86 photo-center displacement measured with Mykerinos in 10 h.

## 5 Conclusion

The Dome C site is very promising for astrophysics, particularly for interferometric observations. Building a large interferometer there requires preliminary steps. A prototype like Mykerinos is perfect for that goal.

## References

- Agabi, K., 2006, *Publ. Astron. Soc. Pac.*, 118, 344  
 Elhalkouj, T., 2006, *SPIE*, 6268E, 34E  
 Storey, J., 2004, *SPIE*, 5491, 169S  
 Vakili, F., 2004, Science cases for the next Generation Optical/Infrared Interferometric Facilities, *Proceedings of the 37th Liège International Astrophysical Colloquium*, 73  
 Vakili, F., 2004, *SPIE*, 5491, 1580  
 Vakili, F., 2005, *EAS Publ. Ser.*, 14, 211  
 Vernin, J., 2006, *Astronomy in Antarctica*, 26th Meeting of the IAU, Special Session SPS 7