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A PROJECT FOR AN INFRARED SYNOPTIC SURVEY FROM ANTARCTICA WITH THE POLAR LARGE TELESCOPE (PLT)

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Abstract. The *Polar Large Telescope (PLT)* aims at performing a new generation of astronomical *Infrared Synoptic Survey from Antarctica (ISSA)*. It would carry out for the first time large scale periodic imaging surveys at $\sim 0.3''$ angular resolution in the short thermal infrared (2-5 μm) range benefiting from the extremely dry, cold, and stable polar atmosphere. The PLT consists of a 2.5m class telescope equipped with a 250–Mpixel infrared camera. The survey would produce diffraction limited images at 2 μm covering a total of $\sim$ 5000 square degrees, explore the time domain from seconds to years down to m_{AB}=25.5 in K_d, generate alerts of transients and react quickly to alerts from other ground based or space borne facilities.

Keywords: Infrared Surveys, Telescope, Antarctic Astronomy

1 An Infrared Synoptic Survey from Antarctica

Large scale astronomical surveys in the infrared (TMSS, IRAS, 2MASS, DENIS, UKIDSS, Spitzer, VISTA, WISE, AKARI, etc..) have lead to enthralling breakthroughs in most critical areas of astrophysics during the last half century (see *e.g.*, Price 2009, and references therein for a review). All-sky or large sky fractions surveys beyond the $K_s$band (cut-off at 2.3 μm) from the Earth are unfortunately hampered by the excessive level of the sky thermal background emission and are therefore impracticable. On the other hand, a space mission cannot provide at the same time, wide field coverage AND high angular resolution.

The Antarctic Plateau actually offers an interesting option, because of its unique atmospheric properties (Burton 2010). One of the greatest advantages over conventional ground sites is indeed the low sky brightness in the near infrared (Walden *et al.* 2005; Philips *et al.* 2009). This property is particularly beneficial to the exploitation of the *"hot"* part of the 2 μm window between 2.3 and 2.5 μm that the K_s filter cuts-off to get rid of excessive thermal background, and to a lesser extent the 3 μm window. Moreover, Antarctic sites which have been already assessed such as Dome C or Dome A feature a turbulent layer by far much thinner (a few meters up to a few tens of meters) than above any other sites on the ground (Aristidi *et al.* 2009). The PLT is aimed at exploiting these properties to provide superb images at $\sim 0.3''$ resolution and carry out the first *Infrared Synoptic Survey from Antarctica (ISSA)*.

Moreover, the PLT, like the LSST, will explore the time domain through repeated visits of a selection of large areas of the sky, to track possible transients, monitor large numbers of variable objects, emit alerts and respond to alerts of other ground based or space surveyors at other wavelengths.

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2 Science Cases

The scientific niches for a 2 metre class telescope in Antarctic environment have been detailed in 3 papers (see Lawrence *et al.* 2009abc) for the Australian project PILOT and in the final report of the specialized working group of the EC network ARENA (Burton *et al.*, 2010). However, the PLT science cases significantly differ from the PILOT ones, because, i) it focuses on a smaller range of wavelengths, ii) it features a much larger FOV, and iii) it explores the time domain for the first time in the infrared.

At the present time three main astrophysical fields would greatly benefit from the PLT. These topics are in common with other instruments that will operate at the same period, and in particular the LSST. The PLT and the LSST data would thus be managed using similar procedures. Both surveys will be able to alert each other during the overlapping period of operation for an optimal follow–up of transient events.

2.1 Distant Universe

PLT is particularly appropriate to the exploration of the distant universe, notably wherever the dust extinction strongly hampers the optical observations, such as the disks and bulges of galaxies where the largest space density of stars -and thus of SN candidates - are found. Moreover, it will explore the time dimension during a period of 10 years at different time resolutions. The most promising domains encompass:

• a survey for pair-instability supernovae (via a dedicated periodically repeated wide field survey) and γ–ray burst afterglows (via alerts from high energy satellites, LSST detections), events which represent the final evolutionary stages of the first stars to form in the Universe,

• an ultra–deep survey to study galaxy structure, formation, and evolution via the detection of large samples of high redshift galaxies,

• a near-infrared search for Type Ia supernovae to obtain light curves that are largely unaffected by dust extinction and reddening, allowing tighter constraints to be placed on the expansion of the Universe and a study of a sample of moderate-redshift galaxy clusters aimed at understanding galaxy cluster growth, structure, and evolution.

2.2 Stellar formation and evolution, galactic ecology

Deep thermal infrared imaging is ideally suited to probe:

• the stellar content of our Galaxy and galaxies of the local groups, especially young stellar objects, stars in the late stage of evolution and very low mass stars. Repeated observations will provide hundred of thousands of light curves that will improve our knowledge of the mass loss process, enrichment of the interstellar medium in heavy elements and the internal physical processes occurring in the Asymptotic Giant Branch phase,

• disk of galaxies of the local group to study the processes of galaxy formation and evolution,

• nearby satellite galaxies to trace their outer morphology, structure, age and metallicity,

• repeatedly surveying the Magellanic Clouds in order to understand the star formation and evolution processes in galaxies of different metallicities. The Magellanic Clouds are continuously observable in excellent condition from Antarctica.

2.3 Very low mass stars, exoplanets and small bodies of the solar system

Areas in which PLT would be a very powerful tool are:

• the search for free-floating planetary-mass objects,

• the follow-up of gravitational microlensing candidate detections based on alerts from dedicated survey telescopes,

• a collection of high precision photometric infrared light curves for secondary transits of previously discovered exoplanets. PLT will have the possibility of observing nearly continuously during the antarctic winter and possibly all year round in the 3 μm window,

• the identification and infrared characterization of small bodies of the solar system (transneptunians, Gould belt, geocruisers...) in close connection with the LSST.

3 Instrumental Concept

3.1 Telescope

The telescope baseline benefits from the earlier PILOT phase A study (UNSW-AAO) (Lawrence *et al.* 2009abc), although it is optimized for the 2-4 μm, thus somewhat relaxing the optical constraits. The main characteristics of the telescope are summarized in Tab.1. One of the two Nassmyth foci would be equipped with the IR camera covering the 2-5 μm range and the second focus could possibly feed, in the future, another instrument such as *e.g.*, a mid–IR camera (8-30 μm) or a near–IR Integral Field Spectrograph.

The height above the ice at which the telescope would be set up is absolutely critical, for two main reasons, i) the turbulent ground layer (TGL) thickness at Dome C is as low as about 30 m with possible important fluctuations, ii) the temperature gradient may rise sharply in the TGL and strong variations of temperature often occur, especially in winter. Setting the telescope above the boundary layer, for instance on top of a ~ 30 m tower, is thus essential, but one must also definitely stabilize its temperature. A solution to fix the temperature of the telescope by blowing cold air from the ground level has been proposed in the PILOT phase A study.

Field of View	$\geq 1°$
Effective clear aperture	$\sim 2.5m$
Configuration	Ritchey-Chrétien, double Nasmyth foci
Etendue	$5m^2deg^2$
Spectral range	2-5 μm
Sky coverage	$5000°^2$
Final f ratio	f/5
Diameter of 80% encircled energy spot	$\leq 0.2''$

Table 1. Main characteristics of the telescope

3.2 Infrared Camera

Thanks to recent developments in the industrial production of larger infrared arrays (currently 4, but soon up to 16 Mpixels), it has been possible to develop facilities for surveys in the near infrared that are comparable to those in the visible, although at much higher cost. A reasonable trade-off between cost and performances points toward a 256–Mpixel FPA. The basic specifications of the PLT infrared camera are displayed in Tab. 2. A Ground Layer Adaptive Optics (GLAO) system would possibly equip the camera to alleviate residual turbulence above the telescope, or relax the constraint on the height of the tower (Travouillon *et al.* 2009).

Array type	HgCdTe HAWAII 4RG
Array size	$4k \times 4k$
FPA configuration	16 chips buttable end to end
Pixel size	10 μm
Pixel scale	$\leq 0.15''$
Final PSF FWHM	$0.3''$
Field of view of the camera	$40' \times 40'$
Filter set (3 minimal)	K_d, L_s, L'
Possible additional filters	K, K_s, M', Grism, narrow bands
Read out time (typical)	5 sec
Integration time per frame (typical)	100 s

Table 2. Main characteristics of the PLT near infrared camera

4 Performances and Operations

The PLT would be the most sensitive instrument ever installed on the ground at 2 μm pushing the limit at least 2 magnitudes below the VISTA achievement (Dalton *et al.* 2010). Table 3 summarizes the point source and extended object limiting sensitivities (in AB magnitudes) for a 5σ, 1 hour integration, assuming that the sky background is summed over 4 times the FHWM disc (for point sources), that the telescope temperature is stabilized at 227K with 5% emissivity, and the overall optical efficiency is 50% (including throughput, detector efficiencies, and secondary mirror obscuration) (adapted from Lawrence *et al.* 2009abc).

Band	λ (μm)	**R** ($\lambda/\Delta\lambda$)	**FWHM** ($''$)	$\mathbf{m_{AB}}$ mag.	$\mathbf{m_{AB}}$ /arc^2
K_d	2.40	10	0.32	25.3	24.7
L$'$	3.76	5.8	0.40	21.2	20.8
M	4.66	19	0.46	19.6	19.4

Table 3. Expected sensitivity of the PLT

The PLT would operate all year round during a foreseen 10-yr period. Dark time would be mostly dedicated to the 2 μm window, while bright time (summer and twilight) would be exclusively dedicated to the 3-5 μm range. Since PLT is not intended to make an *all-sky* survey, like LSST, the number of visits of each sky area will depend on their extension, and special scientific requests. The PLT would produce about 1 Tbyte of raw data per day (Tab.4). For lack of high–flow internet connection in Antarctica, they should be massively processed on–site. PLT data are planned to be eventually archived at the CC–IN2P3 in Lyon, already involved in the LSST data management, and would be made accessible to the community through a VO model.

	PLT	**LSST**
Image exposure time	30s	30s ($2 \times 15s$)
FOV (sq. deg.)	0.5	10
Sky coverage (sq. deg.)	5 000	20 000
Coverage time	4×24 hours	3 nights
Raw pixel data per 24 h period	0.5 to 1 Tb	15 Tb
Yearly archive rate	100 to 200 Tb	5.6 Pb
Number of visits per year *(indicative for PLT)*	25 @ K_d/ 90 @ L', M	100
Number of filters (baseline, mini, goal)	4, 3, 6	5, 3, 6
Image quality (average, maxi, goal) (arcsec)	0.40, 0.45, 0.35	0.56, 0.59, 0.53

Table 4. PLT and LSST observing strategies and data flows.

The PLT consortium involves ten research laboratories, agencies and industrial companies, and more than 50 researchers and engineers from 3 laboratories of the French CNRS, [*Fizeau (Nice), CRAL (Lyon), CC-IN2P3 (Lyon)*], the Institute of Atmospheric Sciences and Climate *(ISAC, Rome)* of the Italian CNR, European Industrial Engineering (EIE, Mestre, Italy), the Fraunhofer Institute (IPA) in Stuttgart, Germany, Institut Paul–Emile Victor (Brest, France), the Nansen Environmental and Remote Sensing Center (Bergen, Norway), RAMS-CON Management Consultants (Assling, Germany), SAFRAN (REOSC) France, the Science and Technology Facilities Council (STFC) and the University of New South–Wales (UNSW), Sydney, Australia.

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