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The Status of the IRAIT Project

G. Tosti[1], M. Busso[1], O. Straniero[2] and C. Abia[3,⋆]

[1] Dipartimento di Fisica, Università di Perugia, via A. Pascoli, 06123 Perugia, Italy e-mail: tosti@fisica.unipg.it; busso@fisica.unipg.it
[2] INAF/Osservatorio di Collurania-Teramo, Italy, e-mail: straniero@te.astro.it
[3] Departamento de Física Teórica y del Cosmos, Universidad de Granada, Spain, e-mail: cabia@ugr.es

Abstract. The Antartic Plateau has been recognized to be one of the best sites from which to perform astronomical observations in the 2-20 μm atmospheric windows, due to the low emission, and to the high transparency and stability of the sky. For Mid Infrared wavelengths, the possibility of passively cooling the equipment offers also an important opportunity to reduce the background, thus establishing conditions intermediate between those of ground-based observatories and of space. In order to exploit these exceptional characteristics we have designed the first permanent telescope for IR observations to be operated at the Concordia station, an Italo-French facility established at Dome C (3200m o.s.l.). We describe here the telescope, named IRAIT, and its mid infrared camera that should be operative on the Plateau in the 2006-2007 campaign.

Key words. Infrared: Instrumentation – Infrared: survey – Antarctic astronomy – Antarctic Permanent Observatories

1. Introduction

The opening of the Italo-French base at Dome C (Candidi 2003), on the Antarctic plateau, offers a unique opportunity for infrared astronomy. In order to exploit it, we have designed a dedicated telescope called IRAIT (International Robotic Antarctic Infrared Telescope), as a first unit of a future permanent observatory: see Figures 1, 2 and (Tosti 2003). It is an 80-cm reflector, planned to start its work at Dome C during Summer 2006-2007 and to be possibly ready for winter operations in 2007. It will offer a testing facility, through long-wavelength imaging, for the quality of a site that has long been suggested as the best available on Earth. We sketch here a number of scientific fields that can be afforded efficiently within the limits of a robotic 80-cm telescope; this inevitably leads to foresee survey-mode operations, which are more suitable to be implemented as pre-packed sets of instructions to be transferred to the Antarctic base periodically. The telescope will have several squared arcmin of field, and interesting capabilities for the flux collection. One has indeed to remember that the performances at Dome C are expected to be at least a factor of 10 better than in other ground-based sites (see e.g. Busso 2002), so that an 80cm telescope

Send offprint requests to: M. Busso
⋆ On behalf of the IRAIT team
Correspondence to: via A. Pascoli, 06123 Perugia

may reach flux limits normally possible only with instruments of much larger size (2.5-3m).

According to the models we presently have, we estimate a transmission efficiency of the whole system near 0.7; the quantum efficiency of the detector (an arsenium-doped silicon array of 128x128 pixels) is near 0.6. Having a Pixel Field of View of about 1.1 arcsec we can derive a background noise at 10 μm of about 3 mJy in 1 hour of integration at the typical temperature of -50 C. At 20 μm this number should be doubled.

With the above estimate for the background, the actual flux measurable should be around 10mJy at 10 μm (2-3 times the background). With these possibilities in mind, we are confident that even a moderate-size telescope like ours will provide significant results in many fields. In section 2 we briefly summarize a few topics that can be addressed.

Dedicated equipment has been designed for studying the fields outlined below and a dedicated financial support has been obtained for this in Italy through two channels: PNRA (Programma Nazionale delle Ricerche in Antartide), which is in charge for the support of the telescope and building, and INAF (Istituto Nazionale di Astrofisica) which has the task of supporting and building the mid infrared camera AMICA (Antarctic Mid Infrared Camera). Recently, the collaboration has been extended including foreign institutes: a Spanish consortium including the University of Granada and the IEEC-CSIC-UPC of Barcelona has the task of designing and building the M2 mirror, and the moving optical element required for implementation of the specific techniques of infrared observations (wobbling and nodding), M3. In addition, a French consortium presently coordinated by the University of Nice (N. Epchtein) will upgrade an existing near- and mid-infrared camera to be used at IRAIT for the first light and during the first two summer campaigns. The telescope and auxiliary parts are described in Section 3, while the project of the Italian mid-infrared camera AMICA, which will be the final instrument, specifically optimized for the telescope, is outlined in Section 4.

2. Key programs for IRAIT operations

2.1. Star formation

We shall perform surveys in selected portions of Magellanic Clouds and of galactic molecular clouds, in order to compare star formation mechanisms at different metallicities and for different masses. This should allow us to obtain good statistics on Young Stellar Objects, Brown Dwarfs and circumstellar phenomena, leading to an inventory of ongoing star formation in the studied regions.

2.2. Final stages of stellar evolution.

A survey in this field should answer questions like: how different are the circumstellar envelopes at different metallicities (e. g. in Magellanic Clouds, in Dwarf Spheroidals and the Galaxy)? How large the sample must be to establish similarities/differences? A significant improvement in the C-star/M-star statistics is expected, thanks to observations of the features present in their mid-IR energy distribution, due to silicates and to SiC. We can also implement simple surveys of ionic line emission in the infrared (e.g. from noble gases) to understand the ionization conditions and the kinematics of Planetary Nebulae.

2.3. Minor solar system bodies.

Many small bodies of the Solar System can be studied: this will require suitable tracking techniques for fast moving objects. We plan to use information obtained by our surveys mainly to study the thermal emission of the Near Earth Asteroids.

2.4. Extragalactic studies

We shall be able to see many bright infrared galaxies, as a serendipitous outcome of our IR survey. In order to reach sufficient statistics on extragalactic objects we shall accumulate data over several seasons, to provide a catalogue of such objects in the southern sky. On individual objects, we shall be able to provide information

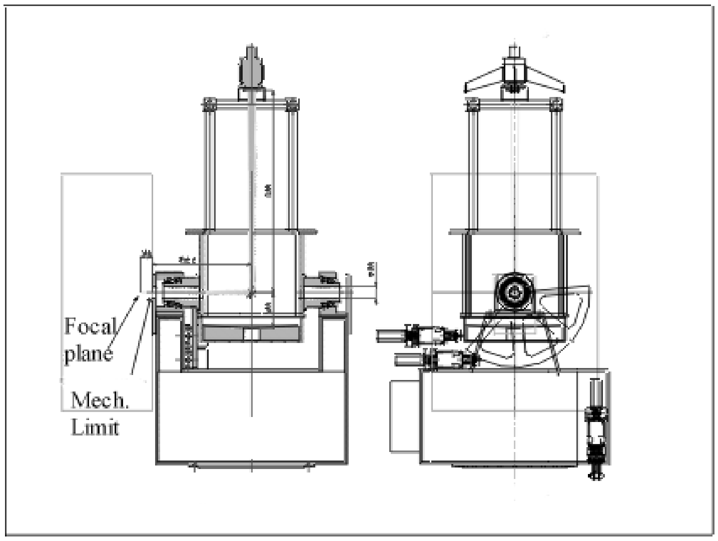

Fig. 1. Schematic drawing of the IRAIT telescope configuration. The azimuthal mounting and the two Nasmith foci are clearly visible.

on the infrared flux of many Active Galactic Nuclei (whose IR emission is often unknown).

3. The Telescope

3.1. Mechanics

A perspective view of the telescope mechanical layout is shown in Figures 1 and 2. A box-like modulus supporting the primary mirror is coupled to the fork via bearings in the two fork arms. The mirror cell is attached at the bottom of the modulus. The altitude drive gear wheel can be seen in both Figures 1 and 2. The secondary mirror M2 is suspended at the top end of the truss, and the tertiary mirror M3 is hosted above the primary mirror cell. The fork is mounted on a stiff azimuth support attached at a large slewing bearing.

The optical support (OS) structure should maintain perfect alignment and pointing of the optics. The truss structure was made using welded box tubes: in this way we obtained a low mass and a compact system with a large moment of inertia. The design takes into account the vibrations induced by external forces and by the wind load (typically from 0 to 25 Hz, for the wind speeds detected at Dome C, v $\leq$ 16 m/s). A finite element analysis of the OS structure detected five vibration modes at relatively high and safe frequencies (above 80 Hz). The high symmetry of the OS structure ensures a uniform cooling, thus avoiding large thermal gradients. Thermal shields will be used to protect the telescope from selective heating induced by the sun during summer operations.

The azimuth axis uses a large slew bearing with cross rollers. In this way we obtain a quite compact system, with a low center of mass, capable of supporting high radial and axial loads and tilting moments. The azimuth bearing has an outer ring with an external spur gear of 360 teeth and is coupled to a pinion with 32 teeth. To guarantee precise pointing we use a counter-rotation motor-controlled system. The optical support structure is coupled to the fork my means of roller bearings protected with labyrinth seals designed by SKF. A sector of a spur gear, having 1080 mm pitch diameter and 360 teeth, and its corresponding pinion will allow the elevation axis to move. A cable derotation system from STENDALTO is adopted.

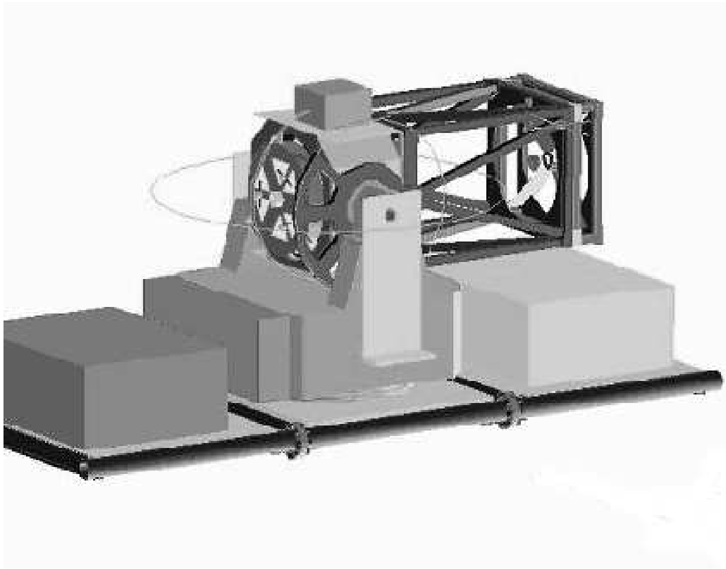

Fig. 2. View of the IRAIT telescope with the side boxes in which most of the electronic equipment will be hosted to allow insulation and heating

3.2. Optics

The M1 mirror is mounted on a 18-point floating waffle-tree structure, and has 8 lateral supports. The exploiting of both Nasmyth foci requires a switchable tertiary mirror (M3), to fold the beam from the secondary mirror (M2). One of the Nasmith stations will host the AMICA camera (see below), while the other is free and will be made available to other projects needing a test bench for future instruments to be optimized for Antarctica.

The mirrors M2 and M3 will operate in the open air, subject to the extreme Antarctic conditions, so that their design requires special care. Focusing and chopping will be made by M2, in a way suitable for the scientific goals of IRAIT, that foresee wide field surveys and extended sources.

Due to these requirements, the tilt amplitude will be of about 4'x4', which is adequate to our field in mid-Infrared. Such a performance is unique for tip-tilt systems. A Spanish company (NTE) is currently studying the design and building of the M2 and M3 mounting and movement system.

3.3. The Container

The telescope is integrated into a modified ISO20 container (3.5x3.5x6.05 m). In order to avoid the effects of vibrations and shocks during transportation we included 12 steel-rope insulators at the interface between the base of the telescope and the floor.

A hydraulic system provides the opening and closing of the structure; heating is provided to allow easy operations during the installation phase. At Dome C the container will be placed on a wood platform at the top of a small (4 m high) hill made of compressed ice, located at a distance between 300 and 500m from the Concordia Station.

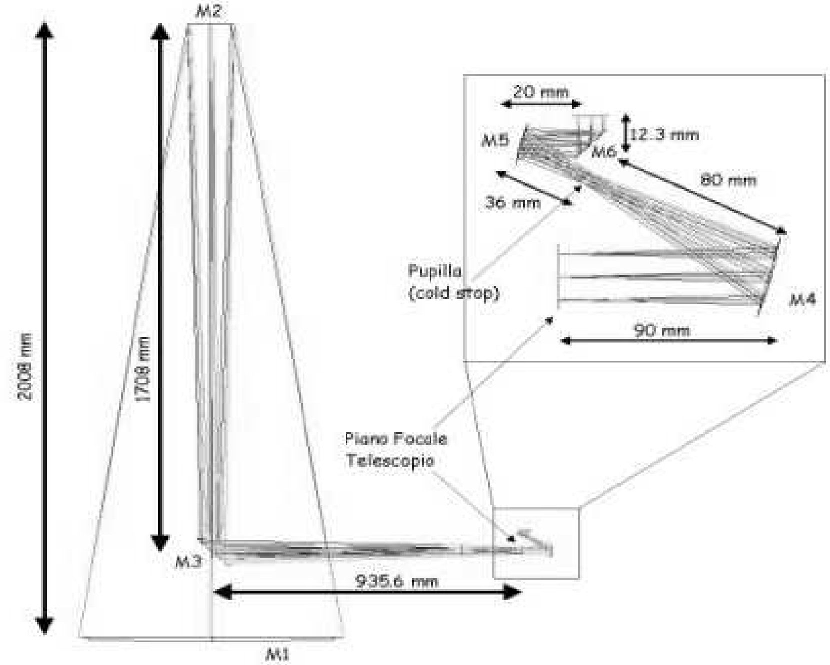

Fig. 3. The optical layout of the AMICA camera at the Nasmith focus of IRAIT

4. The mid-Infrared Camera

Though at Dome C the sky background is expected to be much lower than in all other sites (Storey et al. 2003), direct measurements in IR bands are available only for the South Pole (Chamberlain et al. 2000).

We shall fill this gap with our Antarctic Mid-Infrared Camera AMICA, aimed at performing 10- and 20-μm photometry and imaging. The camera is presently under construction at INAF-Osservatorio di Teramo. It is based on a reflective optical layout (see Figure 3) and uses gold-coated, diamond-turned aluminum mirrors and a KRS-5 entrance window. This provides achromatic imaging over our spectral range. AMICA will profit of the low telescope emission, due to passive cooling in the low temperature environment.

The observing conditions should allow us to use a moderate-flux type of array, providing a lower noise level and a better linearity than for high-flux versions. We adopt the 2-28 μm Si:As BIB 128x128 FPA of DRS Technologies, whose response is shown in Figure 4. The well capacity is 10^7 electrons/pixel: readout is performed by 4 parallel lines, with a maximum frame rate of 500 Hz.

The operating temperature (5 K) will be maintained by a closed-loop cryocooler, thus minimizing maintenance of the cryogenic system and allowing the unmanned operations of the camera in winter. With a de-magnification of a factor 2, and for 75 μm pixel pitch, we shall have adequate sampling of the PSF at 10 and 20 μm and a field of view of more than 4 x 4 arcmin. The photometric system will include the N and Q filters. together with a CVF and standard narrow-band filters in the 10 μm window.

The readout and control electronics derive from those of the TIRCAM camera (Corcione

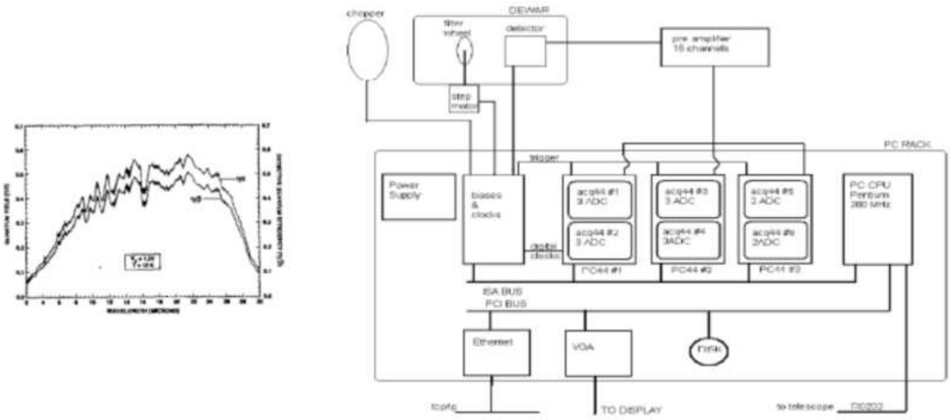

Fig. 4. The response curve of the Si:As detector array and the scheme of the electronic system designed for its readout

et al. 2003), with improvements in the remote control of the bias levels and of the clocks.

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