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THE IRAIT PROJECT INFRARED ASTRONOMY FROM ANTARCTICA

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Abstract. The Concordia Station (Candidi 2003), on the Antarctica Plateau, will soon become one of the best observatories to perform infrared observations in the 2–20 μm atmospheric windows and beyond, thanks to its low sky background, low temperature and high atmospheric transparency. The possibility of passively cooling the telescope is a further advantage. We describe here the first permanent Antarctic infrared telescope, under development for the Dome C base. It is the *International Robotic Antarctic Infrared Telescope (IRAIT).* We briefly outline a few scientific motivations for it, then we review the technical characteristics and the status of its development. The infrared camera for IRAIT is described in another dedicated paper in this volume.

1 Introduction

IRAIT (International Robotic Antarctic Infrared Telescope) is a reflecting telescope with a diameter of 80 cm, which will be the first European Infrared telescope operating on the Antarctica Plateau (Toti 2003). It is planned to start its work at Dome C during Summer 2006–2007 and be possibly ready for winter operations in 2007. It will offer a unique opportunity to test, through real long-wavelength imaging, the quality of a site that has been long believed to be the best on Earth for near and mid infrared astronomy (Storey *et al.* 2003). We sketch here a number of fields suitable to be afforded efficiently within the limits of a robotic 80-cm telescope; this inevitably leads to foresee survey-mode operations, which are more

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suitable to be implemented as pre-packed sets of instructions to be transferred to the Antarctic base periodically. Such kind of work requires the repetition of the same procedures several times, thus making the management of the equipment easier and the dimension of the control software more compact; moreover, a small telescope, with limited resolution but with an appreciably large field of view (several arcmin squared) is in itself an ideal tool for surveys. We can also notice that this opportunity of a large field of view will coexist with 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 places (Chamberlain *et al.* 2000), so that an 80 cm telescope may reach flux limits normally possible only with instruments of much larger size (2.5–3 m). (See also the presentation of the mid-infrared camera AMICA in this volume.)

In general, many exciting scientific targets easily come to an astronomer's mind, when thinking of an infrared observatory in Antarctica; but obviously only a limited part of them can be achieved with simple operation modes and with IRAIT's expected performances (Busso *et al.* 2002). 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 256×256 pixels) is near 0.6. Having a Pixel Field of View of 1.6 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 (winter). At 20 μm this number should be doubled.

With the above estimate for the background, the actual flux measurable will be typically a factor of 3 larger than the backgroud, *i.e.* around 10 mJy at 10 μm. With these possibilities in mind, we are confident that even a moderate-size telescope like ours will provide significant results in many fields, and we briefly summarize here below a few topics that can be addressed.

1.1 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, from observation of the features of their mid-IR emission from silicates and SiC and we can also implement simple surveys of ionic line emissions in the infrared (*e.g.* from noble gases) to understand the ionization conditions and the kinematics of Planetary Nebulae. But perhaps the most important result expected from IRAIT is the systematic observation of AGB stars longward of 10 μm, and possibly beyond 20 μm.

The energy distribution of the reddest AGB sources, which are stars at the termination of their evolution, on their way to lose the envelope and produce a planetary nebula, show that the bolometric magnitudes are strongly contributed by radiation from cold dust in mid-far infrared, so that criteria used so far for determining their luminosity from observations up to the N photometric band (10 μm) are clearly insufficient, both to establish when the star terminates its

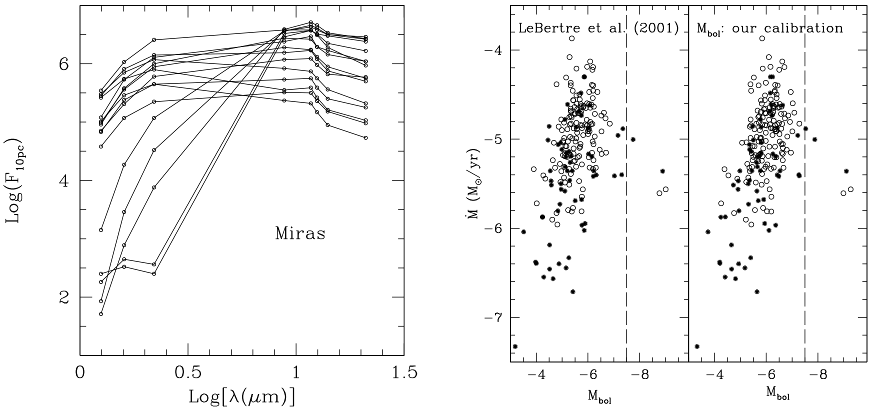

Fig. 1. (Panel **a)** left): energy distribution of a few Mira-type stars showing that the IR excess extends beyond 20 μm. (Panel **b)** right): correlation between mass loss and bolometric magnitudes for a sample of AGB stars, either deriving the magnitude from colors up to 10 μm (LeBertre's criterion) or including data up to 25 μm (Our calibration). The figure shows that including the 20 μm window significantly modifies the magnitude for several stars.

evolution, and to find correlations between the radiative properties and mass loss (see Figs. 1a and b).

1.2 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.

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

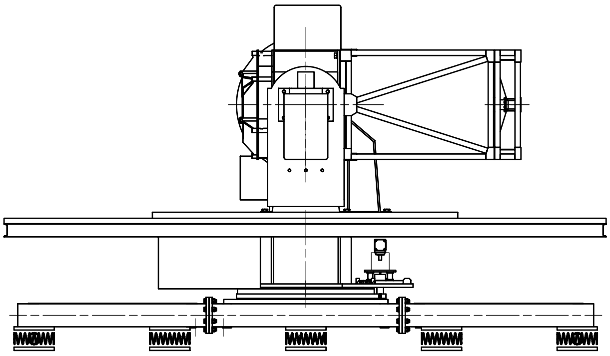

Fig. 2. Assonometric view of the IRAIT telescope on its platform connecting it to the container-observatory.

1.4 *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 The Telescope

2.1 *Mechanics*

An assonometric view of the telescope mechanical layout is shown in Figure 2. The box-like center section of the optical support structure is coupled to the fork *via* bearings in the two fork arms. The primary mirror cell is attached at the bottom of the center section. The altitude drive gear wheel stays on the centerline of the central section. 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 slew 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, $v \leq 16\,\mathrm{m\,s^{-1}}$). A finite element analysis of the optical support's 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 thermal gradients 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 the corresponding pinion allow the elevation axis to move. A cable de-rotation system from STENDALTO is adopted.

2.2 Thermal Propagation

All subsystems of the telescope will be subject to strong thermal stresses in the extreme Antarctic environment. This is especially critical for the sophisticated electronic readout system designed for the camera (Corcione *et al.* 2003), and for the telescope controls. These subsystems will therefore be included in dedicated boxes with individual climatization. The thermal conditioning has been designed for an operation temperature of 0 degrees Celsius, and is obtained through open cell insulating materials, with thermal conductivity below 0.01 W/mK. One has to consider that the electronic parts to be enclosed have a production of thermal energy variable between 10W to a few KW; this heating must be used and partially eliminated to maintain the required constant internal temperature. A PID control thermostat (now under test in a climatic room) has been devised for this scope, using thermo-couple sensing devices. Humidity will also be monitored and compensated, despite the dry environment. Also the thermal emission from the telescope, especially under the temperature gradient due to the sun in summer has to be maintained at minimum, to avoid perturbations of the perfect environmental conditions for IR observations. To this purpose a numerical model of the full system and of thermal fluxes through its parts is under development, to correct for any critical situation.

2.3 Optics

The M1 mirror is mounted on a 18-point floating waffle-tree structure, and has 8 lateral supports. Instruments will be mounted at Nasmyth foci, which fact implies the existence of a tertiary mirror (M3) deviating the beam from the secondary mirror (M2). One of the Nasmith stations will host the AMICA camera (see below), while the other is free for instruments to be tested for Antarctic operations, thus making IRAIT also a test bench for future projects.

The construction of M2 and M3 requires a lot of care, as they will operate in extreme ambient conditions. The focusing and chopping operations will be made by M2; due to the main scientific goals of IRAIT (wide field mid-infrared surveys and imaging of extended sources), M2 should have a tilt amplitude of about $4' \times 4'$ on the sky, which is adequate to our maximum 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.

2.4 The Container

The IRAIT telescope is integrated into a modified ISO20 container (3.5 × 3.5 × 6.05 m). In order to avoid the transmission of dangerous vibrations and shocks to the components of the telescope (*e.g.* optics and electronics) during transportation we adopted a solution consisting of 12 steel rope insulators mounted at the interface between the base of the telescope and the container floor. The container can be opened and closed *via* hydraulic systems. Also, it can be heated, and this option will be useful during the installation and test phase of the telescope and of its instrumentation at Dome C. Once there, 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 of a few hundred meters from the Concordia Station.

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