The IRAIT Telescope

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IRAIT (historical) Teams

Telescope
M. Busso, G. Tosti, G. Nucciarelli, M. Bagaglia, A. Piluso, J.–M. Christille, A. Mancini (Univ. PG), R. Briguglio, D. Romano (Univ. La Sapienza), I. Di Varano (INAF-OATe), C. Abia (Univ. Gr) + others...

AMICA
O. Straniero, M. Dolci, G. Di Rico, G. Valentini, A. Valentini, A. Di Cianno, C. Giuliani, M. Ragni (INAF – OATe), F. Bortoletto, M. D’Alessandro, D. Magrin (INAF – OAPd), L. Corcione (INAF – OATo), A. Riva (INAF – OABr), D. Romano (Univ. La Sapienza) + others...

CAMISTIC
G. Durand, P.–O. Lagage, V. Minier, P. Tremblin, Y. Reinert (CEA – Saclay) + others...

(Logistics)
PNRA, IPEV...
The concept of an infrared telescope operating from antarctic sites was developed in the early 1990s by Paolo Maffei (1926 – 2009), who considered Antarctica “the best site on Earth to observe the sky at infrared wavelengths”.

Only in 2000 the International Robotic Antarctic Infrared Telescope (IRAIT) project was finally started.

After his death, the telescope has been renamed ITM (Infrared Telescope «Maffei»).
IRAIT – Concept and design history

Antarctica’s advantages...

- Low T
  - High atmospheric stability
    - Low instrumental background
    - Low atmospheric background
    - Excellent seeing
    - Transparency windows stability

- Low P, RU
  - Low water vapour content
    - High atmospheric transmission
    - Broader “classical” atm. windows
    - New atmospheric windows

- Polar site
  - Continuity of observations
  - High duty-cycle
    - (100% beyond 4 \(\mu\)m)

- Clear sky
IRAIT – Concept and design history

... and challenges

- **Low T**
  - **people** → Very limited human activities
  - **devices** → Unsafe storage at very low T
  - **devices** → Unreliable operation at very low T

- **Low P, RU**
  - **people** → Slow-rate human activities
  - **devices** → Low heat dissipation
  - **devices** → Static charge problems

- **Polar site**
  - **people** → Accessible for 3 months only
  - **devices** → Static charge problems
IRAITH – Concept and design history

Cassegrain optical configuration with two Nasmyth stations alternatively fed by a folding tertiary mirror

Primary mirror diameter: 800 mm
Primary focal ratio: 3
Total focal ratio: 21.65
Wobbling secondary mirror for object/sky chopping observations

Alt–azimuth mount
2007–2008: sIRAIt

Precursor of IRAIT

25-cm aperture, EQ mount

Cassegrain configuration, f/12

Instrumentation:

MaxCAM CCD camera by FLI:
  Size: 768 x 512 (9 μm pix)
  Scale: 0.65 arcsec/pix
  FOV: 8 x 5.3 arcmin² FOV

Classical UBVRI optical filters
2007–2008: sIRAIT

sIRAIT time-series of the RS CVn binary star V841 Cen and the δ-Scuti star V1034 Cen

Two targets on the same field. Observed 6–16 July 2007 in BVR bands. 243 continuous and consecutive hours (10.15 days).

2008–2010: installation at Dome C
IRAIT instruments: *AMICA project* (2005)

Two-arms camera for imaging between 2 and 25 μm

Fully-reflective optical system, diffraction limited performance

Broad-band filters K, L, M, N, Q

Very fast readout electronics

Designed and built for Antarctica
IRAIT instruments: *AMICA project* (2005)

**DETECTORS**

NIR (2-5 \( \mu \)m): InSb 256 x 256, \( T_{op} \sim 30 \) K (cryocooler 1\(^{st}\) stage)

MIR (5-28 \( \mu \)m): Si:As 128 x 128, \( T_{op} \sim 6 \) K (cryocooler 2\(^{nd}\) stage)

**OPTICS**

Four gold-coated mirrors, two planar + two off-axis parabolae

Scale: NIR: 0.538 arcsec/pix, MIR: 1.345 arcsec/pix

FOV: NIR: 2.29 x 2.29 arcmin\(^2\), MIR: 2.89 x 2.89 arcmin\(^2\)

Window: CdTe, 1” OD

Filters: K (2.2 \( \mu \)m), L (3.8 \( \mu \)m), M (4.7 \( \mu \)m), N (10.5 \( \mu \)m), Q (20.0 \( \mu \)m)

**ELECTRONICS**

Readout: 4 output channels on both NIR and MIR

Speed: Frame time down to 2.7 msec (~350 frames / sec)

**SOFTWARE**

Custom made, object-oriented (C++)
The management strategy adopted for AMICA

Rather than developing special technologies for Antarctic conditions, it has been chosen to reproduce temperate conditions inside a given volume, hosting (almost) all the AMICA subsystems.

AMICA is therefore built from commercial (OTF) devices.

In order to carefully produce and keep the temperate conditions, a Local Monitoring and Control system has been developed, called Environmental Control System (ECS).

ECS is a PLC/PC based system which continuously collects more than 200 telemetries (temperatures, RH, electrical data, status of components and devices…) from AMICA subsystems and automatically controls their operating conditions.

ECS is a special Health Monitoring and Management System (HMMS) designed for Antarctica.
The management strategy adopted for AMICA
The management strategy adopted for AMICA

- upper cabinet
- lower cabinet
- cryostat
The management strategy adopted for AMICA

Even the components managed by ECS, and therefore usually operating under normal conditions, have been preliminary tested in (antarctic) climatic chamber.
The management strategy adopted for AMICA

Tests under the worst Antarctic conditions have been performed for the AMICA subsystems that had to work *outside* ECS.
2010: beginning installation of AMICA
Test campaign in Antarctica

ECS was installed at Dome C during the SC 2010-2011, with the aim to be tested under real antarctic conditions.
2010: beginning installation of AMICA
Test campaign in Antarctica

ECS was tested by D. Romano for 120 days during winter 2011. The tests (more than 250,000 samplings, for a total of more than 55 millions telemetries recorded) revealed an excellent performance of the system, which showed only minor problems.
IRAiT instruments: **CAMISTIC project (2008)**

Array of 16 x 16 bolometers

Scale: 26 arcsec/pixel (with Nyquist sampling)

FOV: 6.8 arcmin, 63 arcsec beam

Op. temperature: 0.3 K

Bands: 200 µm + 350 µm

Goals: Measure of the atmosphere emission (and WVC) at FIR and Sub-mm wavelengths
2012: completing and operating the IRAIT facility

Important refurbishment of the telescope

Completing installation of AMICA (Jan 18, 2013)

Completing installation of CAMISTIC (Jan 23, 2013)

Starting commissioning for the telescope and the two instruments (early March, 2013)
The IRAIT refurbishment: *highlights*

Integration of control and management options on-board the telescope. This eliminated the problems frequently occurring as a consequence of loss of communication between the telescope and the Shelter.

Reduction of telescope subunits with the integration of functionalities previously distributed. Simplification of the system and its management. E.g. the so-called box4, originally devoted to control the secondary and tertiary mirrors, now includes also the telescope motion control, the guiding CCD control and their interface.

Replacement of heaters- and coolers-based thermal control of telescope subunits with a glycol-based circulation system. Together with the reduction of telescope subunits, this severely reduced the power consumption (from 9 to 4 kW).
AMICA installation
AMICA installation
The (new) Astronomy Shelter

A fundamental role in the completion of the IRAIT facility has been the construction of a new Astronomy Shelter, which should be devoted to all astronomical instruments running at Dome C.
The evolution of IRAIT

*From the past to the future*

The availability of a crucial logistical infrastructure like the Astronomy Shelter has triggered a change in the philosophy of IRAIT.

Thanks to the presence of human operators during the whole year, the telescope and the two instruments, originally designed to be robotic, can now operate only automatically.

In the near future, thanks to the rapid development of fast and reliable satellite links between Concordia and the rest of the World, it will be possible to furtherly reduce the local human effort and to remotely use the telescope and its instruments.
IRAIT Commissioning: what are we learning?

Since the start of commissioning, AMICA and CAMISTIC have been operating for almost 2 (antarctic) months each.

No astronomical data have been gathered at the current date.

This period has had to be devoted to refine the telescope pointing and tracking, to align the guiding CCD and the instruments, to face problems with the chopping secondary mirror (which suffers low temperatures), to fix electrical and software instabilities of AMICA, to optimize the glycol-based refrigeration of the CAMISTIC compressor and to solve logistical problems.

A first important consideration is the following: if Antarctica is almost like the Space from the scientific point of view, this is even more true from the technological point of view. This is because, in spite of the tests performed and the technological solutions adopted for facing the antarctic conditions, no instrument can be considered «plug and play».
IRAIT Commissioning: what are we learning?

However, it has to be noticed that no serious problem arose with the instruments.

A second important consideration is therefore the following: if a technological project for Antarctica is properly developed, only minor problems are expected to occur and ordinary maintenance should be performed every summer campaign.

«Modularity» is the magic word. However, modularity alone is not enough: it is also necessary to ensure fast, easy and safe replacement of components and subsystems.

The third consideration is finally the following: systems have to be modular, and their single components must be «plug and play».

Antarctica ↔ Space
Expected science with IRAIT / AMICA / CAMISTIC

Site testing

Computed atmospheric emission between 2 and 25 \( \mu \text{m} \) at Mauna Kea (top curves) and Dome C (bottom curves)

(from Lawrence et al., 2004)
Expected science with IRAIT / AMICA / CAMISTIC

Site testing

Computed Atmospheric transmission between 2 and 25 μm at Mauna Kea (top) and Dome C (bottom) (from Lawrence et al., 2004)
Astronomy with IRAIT / AMICA

N-band SNR=10 performances at different environmental temperatures

- Exposure time (sec)
- Magnitude

Temperature:
- 270
- 240
- 210
- 180
Astronomy with IRAIT / AMICA

Figure 4. On the left, the diffraction pattern of a random distributions of point sources (after the “Source Generation” process). The final output image for this case is shown on the right. The random distributions both in sources position and fluxes is used to estimate crowding effects.

(from Di Rico et al., SPIE 2012)
Astronomy with IRAIT / AMICA

(from Di Rico et al., SPIE 2012)
IRAS Catalog @ 12 $\mu$m \quad N < 5.5 \text{ mag}

IRAIT+AMICA
$S/N > 5$

Up to 140,000 point sources
(1200 in LMC)
IRAI+AMICA

$S/N > 5$

IRAS Catalog @ 25 $\mu$m $Q < 2.0$ mag

Up to 40,000 point sources

(200 in LMC)
Astronomical programs with IRAIT / AMICA

- AGB stars in the Milky Way, in LMCs and nearby galaxies
- Star Formation Regions in the Milky Way and nearby galaxies
- Red SuperGiants in the Milky Way and nearby galaxies
- Obscured Supernovae
- Extinction in our and in nearby galaxies
- Stellar Variability (P-L relations in L & M)
- ...
AGB Stars

Reflected V light

Irradiated IR light @ 10 μm
AGB Stars variability
The PL relation for Mira Variables

Mira-type AGB variable stars: large amplitudes ($\Delta K > 0.4$ mag)
long periods (100 ~ $P$ ~ 1000 days)

PL(K) relation for O-rich (solid circles) and C-rich (open circles) Mira variables in the Large Magellanic Cloud (Whitelock et al., 2008)
AGB Stars variability

The PL relation for Mira Variables

Mira-type AGB variable stars: large amplitudes ($\Delta K > 0.4$ mag)
long periods ($100 \sim P \sim 1000$ days)

Computed spectra of IZ Peg (left) and V829 Cas (right),
two C-rich AGB variable stars of Mira type
Conclusions

1) The development phase of IRAIT and its instruments has been completed during the 2012 – 2013 summer campaign.

2) The facility is currently under commissioning at Dome C.

3) Even if the commissioning could request more effort than originally thought, the science operations phase is expected to start soon with the first scientific data.

4) IRAIT will provide primarily site testing data at wavelengths still unexplored.

5) IRAIT/AMICA are expected also to carry on simple but interesting astronomical programs.

6) The technological experience gained during the design, construction, installation and operation phases will be very useful (integrated with other similar experiences) for the development of future, larger, astronomical facilities.
...thank you!