Name of research institute or organization:

INAF - Istituto di Radioastronomia

Title of project:

TIRGO – Telescopio Infrarosso del Gornergrat

Project leader and team:

Prof. Gianni Tofani, directorof the institute
Prof. Enzo Natale, director of the department
Dott. Filippo Mannucci, telescope supervisor

Project description:

The TIRGO telescope use to be an Italian national facility for infrared observations. Founded in the late '70, its scientific operation ended in March 2005 and during the following summer the telescope was dismounted. The decision of closing the telescope was due to the fact that several other larger telescopes with infrared capabilities are now available to Italian astronomers, and the budget limitations allows no duplications.

The telescope had a great impact on Italian astronomy as, in the late '70s, it was one of the first 5 telescopes in the world capable of infrared observations. The development of this telescope and of its instrumentation had the consequence of creating a competitive group of infrared astronomers and technicians.

The site

The top of the Gornergrat mountain is one of the highest location in Europe than can be reached in every period of the year because of the presence of a rack-railway. It was chosen as an astronomical site because during winter it has low temperatures (between -10 and -20 deg) and low precipitable water vapor. During a few tens of nights a year the conditions at Gornergrat are excellent to allow for far-IR observations, and during this short time Gornergrat is one of the best sites in the world.

The telescope

Tirgo had a classical equatorial Cassegrain configuration, with a 1.5m primary. It was optimized for infrared observations, with no buffles and a small (20 cm) secondary mirror that can oscillate up to 30 Hz with a throw up to 5 arcmin. A "cube" mounted below the primary mirror at the position of the secondary focus allowed for the use of four instruments and an optical camera: a set of four dicroics bent the infrared light to one of the four scientific instruments while the optical light was collected by a camera for pointing and tracking. It was possible to switch from one instrument to the other in just a few seconds.

Many instruments were used at Tirgo (see Table 1), most of them developed specifically for that telescope. Several Italian institutions were involved in this effort, in particular those in Arcetri (Observatory, CNR and university), the CNR institutes of IAS, IFSI, TESRE and IROE, and the Observatory of Turin.

Table 1 **Instruments used at TIRGO**
near-IR InSb photometer
mm GaGe photometer
Optical photometer
mid-IR spectrometer
mid-IR camera TIRCAM
mid-IR camera CAMIRAS
mid-IR bolometer
mid-IR camera TCMIRC
far-IR bolometer
near-IR InSb photometer FIRT
near-IR spectrometer GOSPEC
near-IR camera ARNICA
near-IR spectrometer LONGSP
mid-IR camera TIRCAM2
optical intensified camera
optical CCD camera
800Ghz heterodine

Tirgo was an Italian national facility open also to foreign astronomers. A national time allocation committee was in charge of reviewing the proposals twice a year and assigning observing time. Tirgo produced about 340 (known) papers, including over 160 refereed papers.

Data Archive

All the data taken after 1992 by ARNICA and LONGSP are publicly available in the web site html://tirgo.arcetri.astro.it/. A web form allows the selection of the data from object name, target position, night of observation, filter or file name. A total of about 330.000 images are available, 45GB of data.

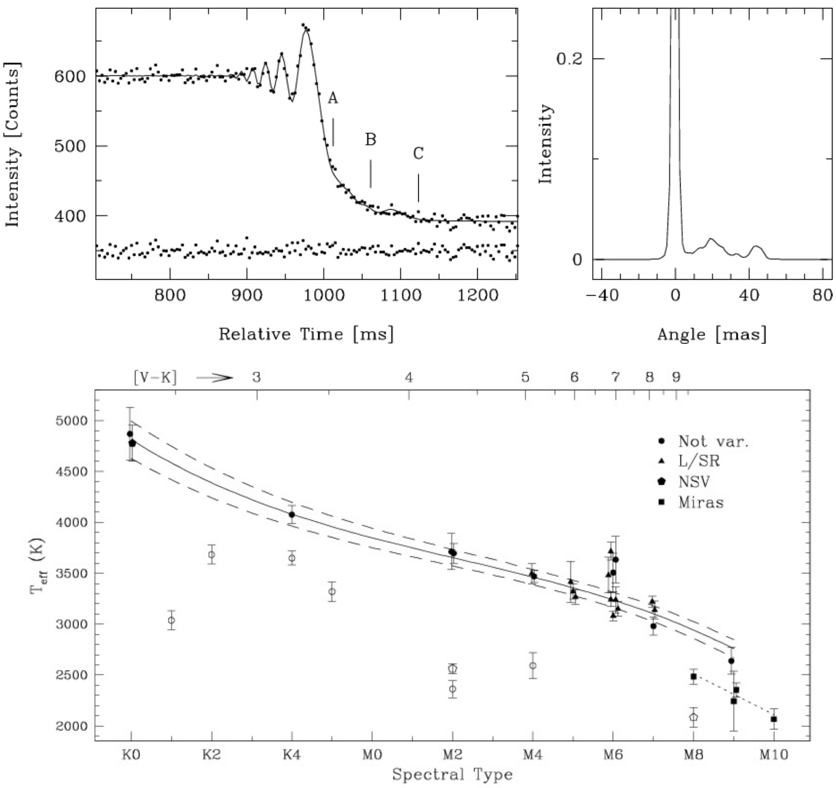

Figure 1: *Upper panel*: lunar occultation of SAO77810. The dots are the observation, the solid line a model it. The residuals are also shown. The source turns out to be a riple star with the intensities shown in the right panel (Richichi et al., 2000}. *Lower panel*: Temperature scale of the cold stars between classes K0 and M10 (Richichi et al., 1999} as measured using mostly radii and photometry obtained at Tirgo. The solid line is the obtained mean calibration, the dashed lines represent the range of associated error.

Some representative results

Many scientific problems were addressed by Tirgo in 20 years of observations. Here some of them are listed to resume the scientific activity at the telescope. The listed works are not necessary the most important in their fields, as the choice didn't follow any objective rule.

Lunar Occultations

When a source is covered by the edge of the moon during its motion, the diffraction pattern produced is a function of the shape and the dimension of the source. Using sophisticated deconvolution algorithms, stellar diameters as small as a few milli-arcsec (mas) can be measured with precision of about 1 mas, and the stellar multiplicity can be accurately tested. Lunar occultations is one of the oldest Tirgo projects, started in December 1985 and recorded more than 400 lunar occultations by using both FIRT and ARNICA. The main scientific targets are the measure of the frequency of binary stars, constraining models of star formation, and the measure of the star diameter, a very important parameter to study the stellar structure. Among the results, the discovery of several tens of new binary and multiple stars (Richichi et al.,

2002) and the measured of the temperature scale of the cold stars (Richichi et al., 1999, see Fig. 1)

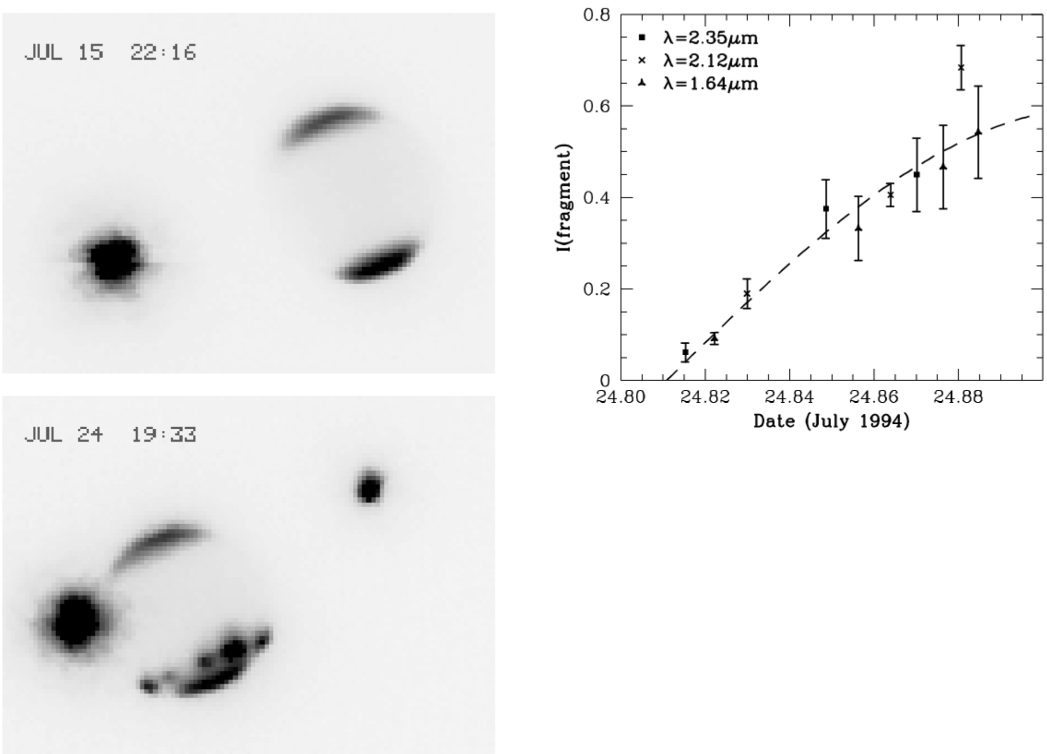

Figure 2: *Left panel*: Jupiter before and after the collisions with the fragments of the comet Shoemaker-Levy 9 in July 1994. Before the impacts only the polar caps of the planet are visible because of the use of a filter centered on a methane band. The bright spots outside the planet circle are the satellite Io and Europa. The loci of the impacts are visible near the southern cap in the second image. *Right panel*: the variation with rotation phase of the brightness of the K+W fragment. This evolution is well fitted by a simple sin function with the expected values of phase and period, indicating that the dust is geometrically thin and optically thick. The albedo of the dust can also be measured and the results support the hypothesis of the presence of silicate dust of 1 micron grains.

Comets

Many comets, including SL9, Hyakutake and Hale-Bopp, were observed at Tirgo with several instruments. The collision between Jupiter and the comet Shoemaker-Levy 9 was observed in July 1994 using ARNICA. A custom narrow-band filter centered on a methane absorption band was used for this project. The atmosphere of the planet is opaque at this wavelength and therefore in this filter the planet appears dark, with some emission only from the polar caps (see Fig. 2). The fragments of the comet deposited dust on the outer layers of the atmosphere and therefore after the impacts these region appear bright due to the reflected solar light. By using ARNICA observations (Tozzi et al., 1994) measured the geometrical distribution of the dust and its albedo, giving information on the composition.

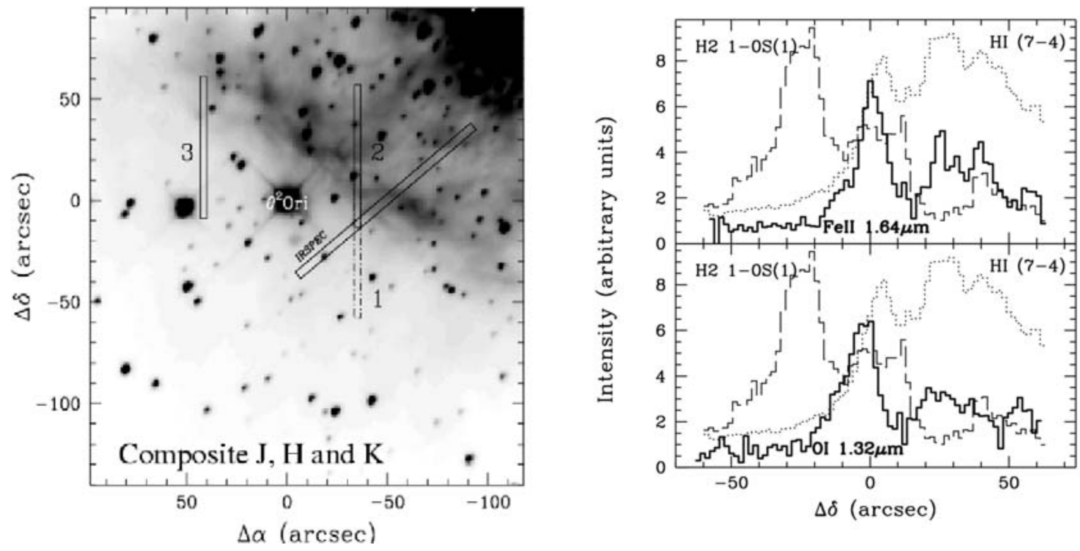

Figure 3: ARNICA and LONGSP observations of the Orion bar from Marconi et al., 1998. *Left panel*: composite ARNICA J, H and K image of the Orion bar. The positions of the LONGSP and IRSPEC slits are indicated. *Right panel*: variation of the brightness of various emission lines along the slit, tracing the gas and radiation conditions across the region. Dotted line: H(7-4); dashed line: H2 1-0S(1); solid line: FeII 1.64µm in the upper panel, OI 1.317µm in the lower panel.

Long wavelength observations

In 1982 a GaGe bolometer was used at Tirgo to obtain observations at 1mm of wavelength (Mandolesi et al., 1984) observed the giant molecular cloud W49 and detected it at the level of 1300 Jy. This is the longest wavelength ever reached at Tirgo.

The second-longest wavelength published measures were obtained at 34µm between 1983 and 1988 by using a Ge bolometer (Persi et al., 1990}. The target was a sample of OH/IR stars observed to derive the stellar mass loss rate and test the origin of the pumping of the OH maser. The Tirgo observations between 2 and 34µm nicely fit the IRAS data.

Imaging and spectroscopy of the Orion bar

The Orion bar is one of the favorite targets for infrared astronomy, and Tirgo gave its contribution to the study of this region of active star formation. Marconi et al., (1998) used LONGSP to observe this region and study the stratification of the emission to derive density, temperature, geometric distribution and radiation field in the various emitting regions (see Fig. 3)

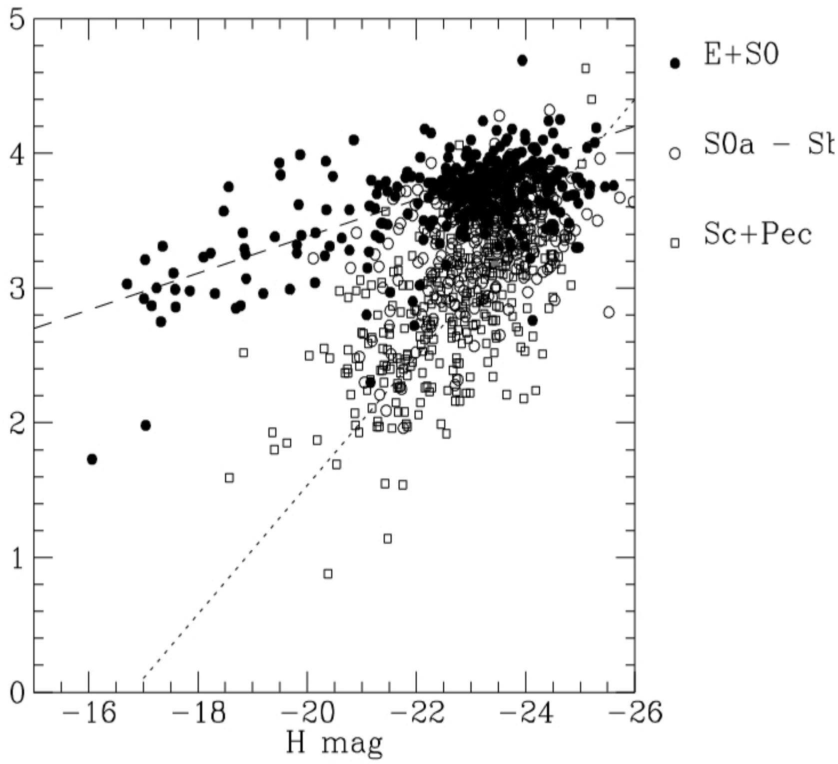

Figure 4: Color magnitude relation for the galaxy in the sample by Gavazzi et al. (1996, 2000), Black dots are ellipticals and S0s, circles and squares are later type galaxies. The two different behaviours are related to different formation histories and star populations.

Surface brightness of galaxies

Gavazzi and co-workers have used ARNICA to observe over 900 galaxies of various morphological types in the H band. Observations spanned three years from 1995 and 1997 and produced the largest homogeneous sample on near-IR data of galaxies before 2MASS. The aim of this work was to measure the surface photometry of a large number of galaxies to study several issues related to the process of galaxy formation, as the color-magnitude relation (see Fig. 4, Gavazzi et al., 1996). As the mass-to-light ratio (M/L) in H and K does not depend on galaxy luminosity, the near-IR bands are in fact good tracer of the stellar mass.

The near-IR camera ARNICA had quite a large field-of-view among the cameras based on the 256x256 arrays. This allowed for the observations of large, nearby galaxies to study their detail properties. A large sample of galaxies (about 200) were observed in J, H and K by Hunt, Giovanardi, Moriondo and coworkers to deconvolve bulges and disks, extract a nuclear point-like component, study the color gradients due to both the stellar populations and to extinction effects, study the global scaling relations for disks and bulges, investigate the properties of the bars (Moriondo et al., 1998, 1999).

Spectra of normal galaxies

The spectrometer LONGSP was used to observe a sample of large, nearby galaxies of morphological type between E and Sc to define the first set of template spectra on normal galaxies at near-IR wavelengths (Mannucci et al., 2000). 28 galaxies were observed in J, H and K using apertures similar to those used by Kinney et al., (1996) in the optical to define their catalog of template spectra, allowing a reliable matching of the two sets. The final uncertainties of the spectra are between 1 and 3%. These spectra are very useful to test the galaxy spectrophotometric models which are usually calibrated by using optical spectra only. The dominant stellar populations can also be studied by the ratio between the equivalent widths of several lines in the H and K bands (see Figure 5)

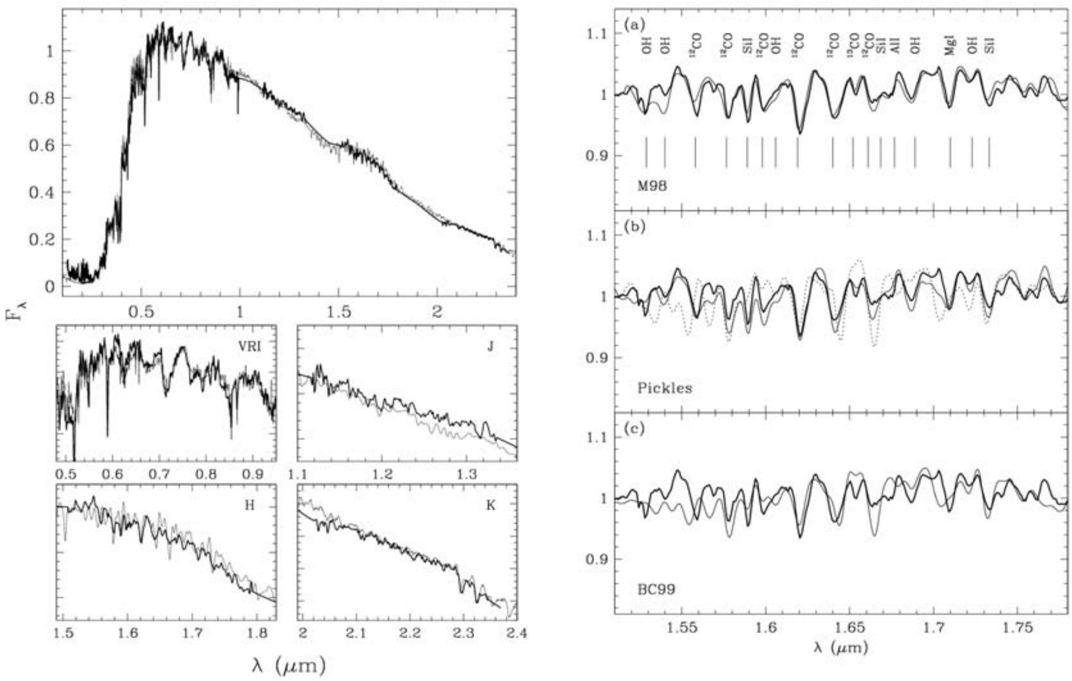

Figure 5. *Left panel:* comparison between the observed average spectrum of the elliptical galaxies (thick line) with the prediction by Bruzual & Charlot (2003) model for a simple stellar population 12 Gyr old. The overall spectral shape is very well fitted, while many absorption lines are not correctly reproduced. *Right panel*: Detail spectrum of the early-type galaxies in the H band (thick line) compared with various libraries of stellar spectra (Meyerset al., 1998, Pickles 1998) and with the Bruzual \& Charlot spectrum in the left panel.

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Key words:

Infrared astronomy, infrared instrumentation

Internet data bases:

http://arcetri.astro.it/irlab/tirgo (Telescope site)
http://tirgo.arcetri.astro.it (Public Data archive)

Collaborating partners/networks:

Several italian institutions have collaborated with IRA in the development of new instruments: among the others, the Turin Astronomical Observatory and two institutes of the CNR located in Rome, IAS and IFSI.

Scientific publications and public outreach 2005:

Refereed journal articles

Richichi, A.; Roccatagliata, V., Aldebaran's angular diameter: How well do we know it? 2005, A&A , 433 305.

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