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Twenty years of TIRGO telescope

F. Mannucci

CNR, Istituto di Radioastronomia, sezione di Firenze, largo E. Fermi 5, I-50125, Firenze

Abstract. We present the characteristics and the current status of the *Telescopio Infrarosso del Gornergrat (Tirgo)*, the national infrared facility operating from the beginning of the 80s over the swiss alps. We describe its current instrumentation and resume its activities during its 20 years of life.

Key words. infrared telescope – infrared astronomy

1. Introduction

The Tirgo telescope has been operating for more than 20 years at 3150 m of altitude on the Gornergrat mountain in the Swiss alps. It has a 1.5m primary mirror and is optimized for infrared astronomy, making it one of the first 5 telescopes in the world to be capable of far-IR observations.

2. The site

The top of the Gornergrat mountain (see Fig. 1) 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^o and -20^o) and low precipitable water vapor (PWV, see Fig. 2). 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 drawback is that the fraction of clear nights is usually around 35% in winter and even below during summer. For this reason the telescope in usually closed during the 6 summer months and the total number of observing nights is around 70 per year. The seeing in the near-infrared bands is usually between 2 and 3 arcsec FHWM, probably dominated by the local environment. These values of the seeing and the low fraction of clear nights make Tirgo no longer competitive with other national or international facilities for near-infrared observations.

3. The telescope

Tirgo has a classical equatorial Cassegrain configuration, with a 1.5m primary. It is 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 allows the use of four instruments and an optical camera: a set

Send offprint requests to: F. Mannucci
Correspondence to: largo E. Fermi 5, I-50125, Firenze

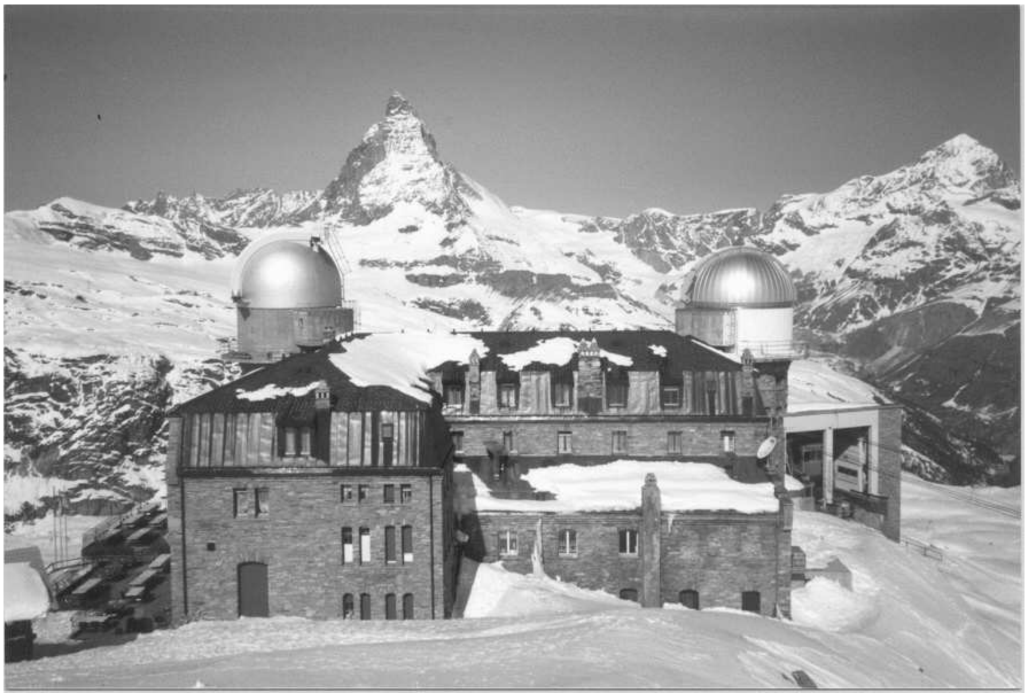

Fig. 1. The domes of the Tirgo telescope (right) and the submillimeter KOSMA telescope (left) as seen from the Gornergrat top. On the background, the Mattelhorn and the Wieshorn. The sky is not always like this.

of four dicroics bend the infrared light to one of the four scientific instruments while the optical light is collected by a camera for pointing and tracking. Its is possible to switch from one instrument to the other in just a few seconds. Large efforts were spend in making the control of the telescope as friendly as possible to reduce the assistance needed by the astronomers. Telescope and dome set-up, pointing, tracking, focusing and offsetting are controlled by a single program with an intuitive graphical user interface. The same program can also handle target catalogs and is interfaced with the acquisition software (specific to the detector in use) to pass all the relevant informations as target name and telescope position. By experience, any "average" astronomer can drive the telescope by himself after half an hour of introduction.

4. The instruments

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. The instruments currently available for public use are four:

- FIRT: near-IR single-element fast photometer. It is sensitive between 1 and 5 micron using apertures between 7 and 40 arcsec. Its fast electronics makes it possible a data rate up to 1 KHz. For this reason FIRT is currently used mostly for lunar occultations (see below).
- ARNICA: near-IR array camera. This is currently the most used instrument. Its 256×256 NICMOS3 detector is sen-

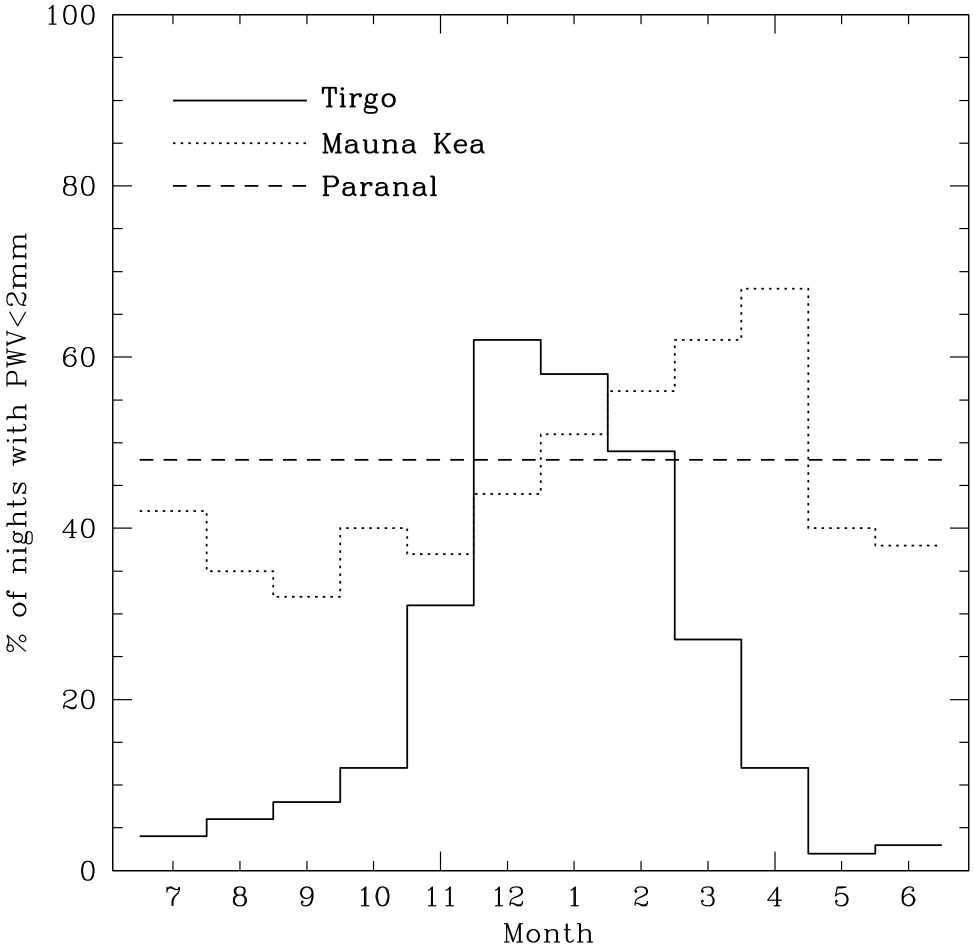

Fig. 2. Average number of nights with precipitable water vapor (PWV) below 2mm at Gornergrat, Mouna Kea and Paranal. The value of 2mm was chosen as representative of a "good" night. The Gornergrat data were taken from the KOSMA staff during 5 years between January 1989 and September 1993 (Kramer & Stutzki 1997). Mouna Kea and Paranal data are taken from the relative web pages. Only an average over the year is available for Paranal.

sitive between 1 and 2.5 micron over a field-of-view of 4×4 arcmin. The camera is equipped with the standard JHKK′ broad-band filters, a set of narrow-band filters for line study and a set of low-resolution grisms for spectra with R∼300. The detection limits (5σ in 1 hour) are around 20.1 in J, 19.2 in H and 19.0 in K. It was also mounted at several other telescopes: as WHT, SFOR, VATT, NOT and TNG.

- LONGSP: near-IR long slit spectrometer. It is based on the same array as ARNICA and provides spectra with resolution between 1000 and 3000 along a 70 arcsec slit.
- TIRCAM2: mid-IR array camera (see Persi, this volume). Based on a

Rockwell Si:As 128×128 array, it is optimized for observations around 10μm and contains several filters between 8 and 14μm. Its sensitivity (5σ, 1 hour) at 12.5μm is about 0.5 Jy.

The nitrogen needed for most of the infrared instruments is produces at the telescope.

5. Management, costs and publications

Tirgo is an Italian national facility but is is open also to foreign astronomers. A national time allocation committee is in charge of reviewing the proposals twice a year and assigning observing time.

The institution in charge of the telescope is the *Istituto di Radioastronomia, sezione di Firenze* of the CNR, in collaboration with the *Osservatorio di Arcetri* and with the *Università di Firenze*. *INAF* provides part of the founding. No one is working for the Tirgo telescope full-time, observations are usually performed by a guest astronomer and one assistant from Arcetri, rotating among a dozen astronomers and technicians. The total amount of work needed for the observations and the maintenance can be estimated in about 20 month/man per year, including visiting astronomers. The cost of the operations are around 150 K-euro.

Tirgo produced about 330 (known) papers, including 150 refereed papers (see Fig. 3). The rate of refereed publications was about 5 per year until the introduction of ARNICA (1993), and increased up to 14 afterward. In the last few years the rate is decreasing because of the use of ARNICA at the TNG for two years (1998 and 1999) and the availability of many near-IR cameras on larger telescopes and in better sites.

6. Data Archive

After one year of proprietary period, all the data taken from 1993 by ARNICA and LONGSP becomes 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.

Table 1. Instruments used at TIRGO (the list is probably incomplete).

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

7. Some representative results

Many scientific problems were addressed by Tirgo in 20 years of observations. Here I list some of them to resume the scientific activity at the telescope. The listed works are not necessary the most important in their fields: the choice didn't follow any objective rule but is mostly based of personal taste. This is also a sub-sample of the results presented at the conference

7.1. 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

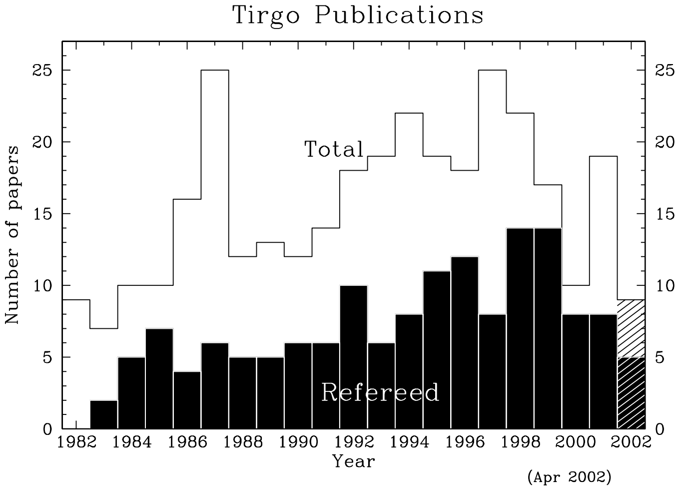

Fig. 3. Number of Tirgo publications from 1982. In black the publications with a referee.

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 (see e.g. Richichi et al. 2002) and the measured of the temperature scale of the cold stars Richichi et al. (1999), (see Fig. 4).

7.2. 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 these wavelength and therefore in this filter the planet appears dark, with some emission only from the polar caps (see Fig. 5). 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 informations on the composition.

7.3. 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. To my knowledge this is the longest wavelength ever reached at Tirgo.

The second-longest wavelength published measures were obtained at 34 mum 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.

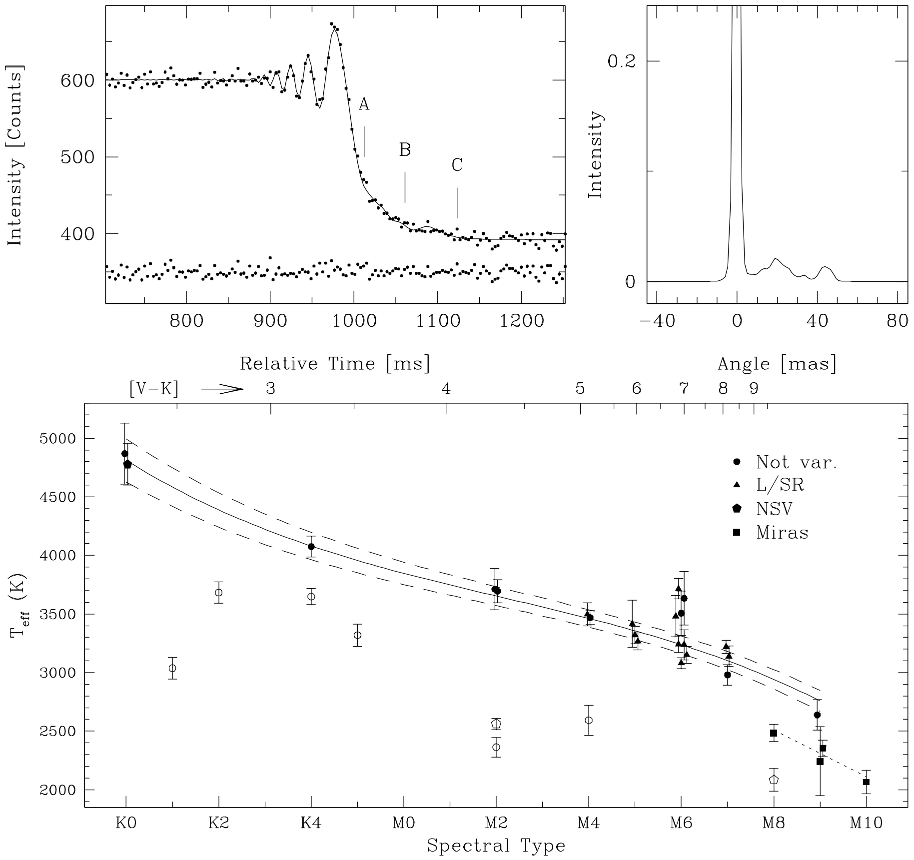

Fig. 4. *Upper panel*: lunar occultation of SAO77810. The dots are the observation, the solid line a model fit. The residuals are also shown. The source turns out to be a triple star with the intensities shown in the right panel (Richichi et al. 2000). *Lower panel*: Temperature scale of the cold stars 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.

7.4. Imaging and spectroscopy of the Orion bar

The Orion bar is one of the favorite target 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. 7) .

7.5. 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. 6).

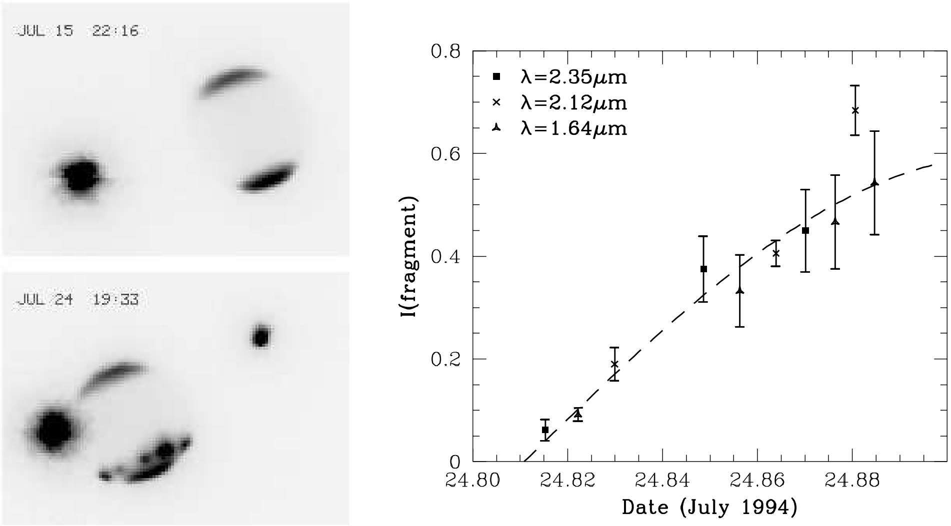

Fig. 5. *Left panel*: Jupiter before and after the collisions with the fragments of the comet Shoemaker-Levy 9 in July 1994. Before the impacts only the polar caps of the planet are visible because of the use of a filter centered on a methane band. The bright spots outside the planet circle are the satellite 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 1μm grains.

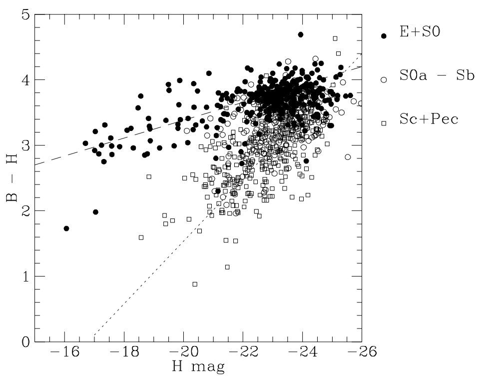

Fig. 6. Color magnitude relation for the galaxy in the sample by Gavazzi et al. (2000, 1996). Black dots are ellipticals and S0s, circles and squares are later type galaxies. The two different behaviours are related to different formation histories and star populations.

7.6. Spectra of normal galaxies

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.

ARNICA has quite a large field-of-view among the cameras based on the 256×256 arrays. This allows 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). LONGSP was used to observe a sample

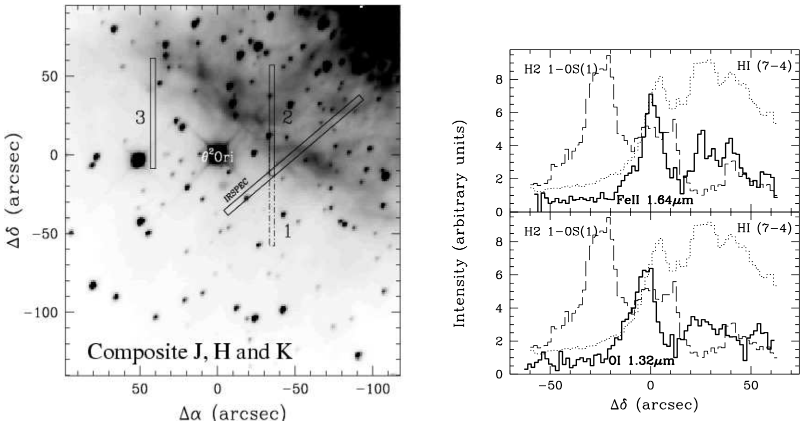

Fig. 7. ARNICA and LONGSP observations of the Orion bar from Marconi et al. (1998). *Left panel*: composite ARNICA J, H and K image of the Orion bar. The positions of the LONGSP and IRSPEC slits are indicated. *Right panel*: variation of the brightness of various emission lines along the slit, tracing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

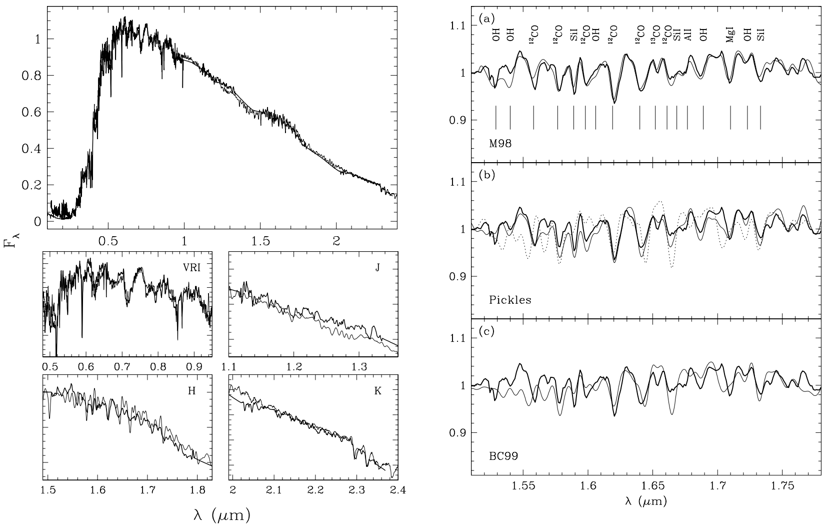

Fig. 8. *Left panel*: comparison between the observed average spectrum of the elliptical galaxies (thick line) with the prediction by Bruzual & Charlot (1999, ,BC99) model for a simple stellar population 12 Gyr old. The overall spectral shape is very well fitted, while many absorption lines are not correctly reproduced. *Right panel*: Detail spectrum of the early-type galaxies in the H band (thick line) compared with various libraries of stellar spectra, Meyer et al. (1998, M98), Pickles (1998) and with the Bruzual & Charlot spectrum in the left panel.

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. 2001). 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.

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