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The scientific use of the 1.2-m Galileo telescope of the Asiago Astrophysical Observatory after its recent refurbishment

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Abstract. During the last 10 years the Galileo 1.2-m telescope has been completely refurbished in its optical, mechanical and electronic parts. This successful result opened suddenly the way to new scientific programs involving observations of Galactic and extragalactic sources. It gave the chance to participate efficiently in international campaigns of spectroscopic monitoring of variable sources like AGNs, supernovae, novae, dwarf novae, etc.

Key words: telescopes – spectroscopy – active nuclei

1. Introduction

The Asiago Astrophysical Observatory of the University of Padua and its 1.2-m telescope, dedicated to Galileo Galilei, were commissioned in 1942. At that time the Galileo telescope was the largest mirror telescope in Europe. In 1973 after the construction of the Copernico 1.82-m telescope at Cima Ekar (Padova Astronomical Observatory - INAF), still now the largest telescope in Italy, the equipment of the Galileo telescope and its control system were not more sufficiently improved to profitably obtain the most out of the optical capabilities of the instrument. The strong and rapid development of electronics, in terms of detectors, controllers, computers, and network facilities opened up a new horizon to the scientific performances of meter-class telescopes, often already doomed to be definitely scraped or to be left in a lethal disuse (Fig. 1).

The current Cassegrain optical configuration of the Galileo telescope consists of a parabolic primary mirror with a diameter of 122 cm and a focal length of 600 cm, and a recently changed hyperbolic secondary mirror with a diameter of 52 cm and a focal length of 456 cm. The equivalent focal length of the telescope is 1200 cm and the focal ratio is f/10. The spatial scale in the focal plane is about 17″/mm. A Perkin Elmer Boller & Chivens spectrograph is mounted at the Cassegrain focus. It is equipped with four gratings having 150, 300, 600 and 1200 grooves/mm, and an Andor iDus 512×2048 px CCD camera. The maximum reachable resolution is R=600, 1250, 2400 and 4600, respectively, at the Nyquist limit.

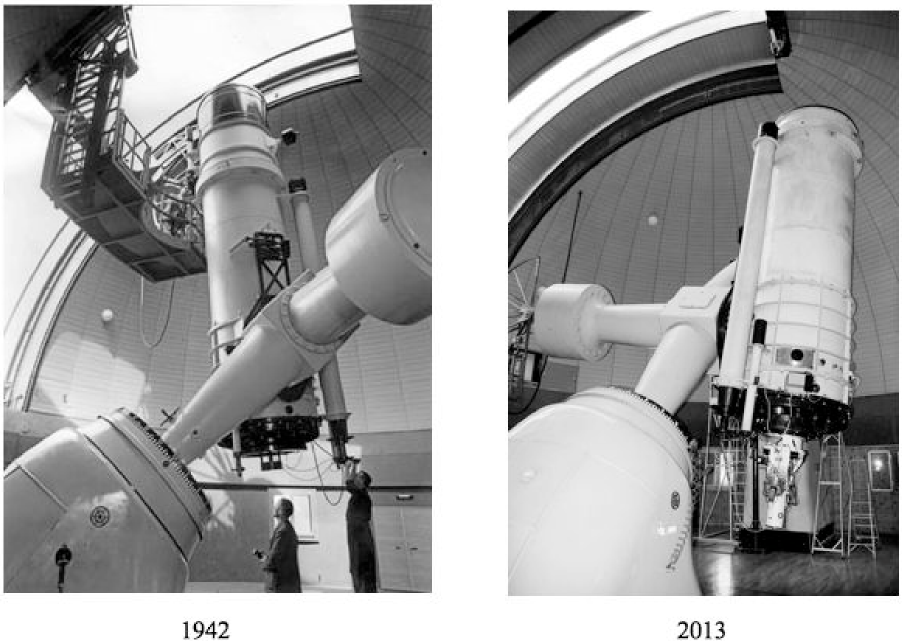

Figure 1. The 1.2-m Galileo telescope after its commissioning in 1942 (left) and after its refurbishment in 2013 (right).

2. The refurbishment

After a period of scientific testing to prove the capabilities of the instrumentation and disclose the points of weakness which could be improved, a group of technical and scientific staff members of the Department of Astronomy in Padova started the refurbishment of the Galileo telescope, in close collaboration with two private firms: MFC Elettronica and Marcon Premium Italian Telescopes.

In January 2006 the old Wright 512×512 px CCD camera was replaced by the already mentioned Andor iDus 512×2048 px, having a much higher quantum efficiency, especially at shorter wavelengths (60% at 4000 Å), and a smaller pixel size (13.5 μm). Then, the Andor iXon EMCCD 1024×1024 px with a pixel size of 8 μm was purchased to change the old Proxitronic intensified guiding camera. This was a crucial step to increase the potentiality of the telescope since the Peltier cooling system of iXon allowed to easily guide with stars up to magnitudes 15–16, instead of the previous 12–13, and also to detect and spectroscopically observe sources as faint as magnitude 17–18, absolutely not reachable in the past.

MFC Elettronica provided us with a completely new control system: programmable electronic plates with modern components and RAM on-board, integrated servo motors by JVL for the right ascension and declination motions, the on/off switching of the spectral lamps for calibrations, the slit-width motorization and the automatic dome tracking, which did not exist in the past. Moreover, MFC Elettronica made a new software for the telescope pointing, the autoguiding system, and the acquisition of scientific data.

The last fundamental step took place in 2011. In the past, the 1.2-m telescope had two foci: a Newton focus and a Cassegrain one, which could be used by changing the secondary mirrors. The length of the telescope made dangerous its use in a blind automatic way or even interactively from the underlying control–room, because of the presence of the platform, visible in Fig. 1 (on the left panel), used to reach the Newton focus during the observations or in general to reach the top of the telescope for technical operations. Moreover, the focal ratio of the telescope in Cassegrain configuration, f/16, made it not well suited for the spectrograph, which is f/9. Therefore, it was decided to reduce the length of the telescope by modifying its optical configuration from f/16 to f/10, and by removing the light shield at the top and the ring of the Newton focus, which is now decomissioned. This task was given to the firm Marcon Premium Italian Telescopes, which has a long experience and a well-proven expertise in making telescopes. This firm provided us with a new high quality hyperbolic mirror made in Astrosital and its full mechanical support. In addition, they polished again the surface of the primary mirror in order to get a better quality of the point spread function of the optical combination (primary plus secondary mirror).

Thanks to the new optical configuration, the new CCD cameras with a Peltier cooling system, and the new electronics, the telescope could be remotely controlled. Now it is possible to observe from the control–room which is inside the dome, from any other room of the observatory, and virtually from any other place having a sufficiently fast internet connection. At the end of this refurbishment process, we obtained an improvement of 5 mag in limit magnitude for stellar sources. Spectra of stars of magnitude 17 with resolution R=700 and typical signal-to-noise S/N=3 on the continuum at 5500 Å can be obtained with an exposure time of one hour.

The night sky pollution, but mostly the bad seeing are still the main limitations of this observatory. While for the first one not much can be done, we discovered that the second one is mainly caused by the temperature gradient inside the telescope between the primary mirror and the surrounding air. Some successful tests were carried out in collaboration with MFC Elettronica to implement a cooling system for the primary mirror, with the aim to keep its temperature at values very close to those expected during the night, therefore reducing the temperature gradient and decreasing significantly the seeing during the observations.

3. Scientific programs

In the following we report some of scientific programs carried out by us with the 1.2-m telescope. Other programs are described in the contribution "Science with the refurbished Asiago 1.22m telescope" by Alessandro Siviero.

3.1. AGNs monitoring

Active Galactic Nuclei (AGNs) are among the most powerful and variable sources in the Universe. In particular, the fluxes of both continuum and broad emission lines in type 1 AGNs, like Seyfert 1s and quasars, show similar temporal variations on scales of days and weeks, but their light curves are not coincident. A time delay is observed in the light curves of emission lines with respect to the continuum, and it is explained by the time necessary to the ionizing continuum to reach the gaseous clouds emitting the broad lines, the so-called Broad Line Region (BLR). The well-known Reverberation Mapping technique (Peterson, 1993) aims to measure this time delay. By assuming that the ionized gas of the BLR is in virial motion around the supermassive black-hole (SMBH) and its accretion disk, this technique allows to estimate the mass of the SMBH, but it is extremely time consuming and requires spectroscopic observations every two or three days for several weeks. Thanks to the high flexibility of their schedules, small telescopes have a great potential in contributing to such a research. At the beginning of 2012, the 1.2-m Galileo telescope was involved for the first time in an international monitoring program: some nearby Seyfert 1 galaxies were successfully monitored for a couple of months, definitely proving the new capabilities of the telescope in extragalactic observations after its refurbishment.

3.2. ENLR in nearby Seyfert galaxies

According to the Unified Model of the AGNs, we should expect to detect kpc-scale extended regions of ionized gas emitting narrow lines, the so-called Extended Narrow Line Region (ENLR), in virtually all Seyfert 2 galaxies and many intermediate-type Seyfert. Unfortunately, until now they have been visible only in a few cases. At least two key questions are still open: 1) how much is the ENLR really extended? 2) what is the origin of the kpc-scale ionized gas? This kind of research requires observations with multiple techniques, like narrow-band photometry, integral-field and long-slit spectroscopy. A first paper on these issues was published by Cracco *et al.* (2011) about NGC 7212, and new very promising results are coming from the current study of Mrk 6. In addition to the data already at our disposal, several long-slit spectra of the galaxy at different position angles were obtained with the 1.2-m telescope. Typical exposure times of 3-3.5 hours allowed to detect [O III]λ5007 up to a brightness of some 10^{-18} erg cm^{-2} s^{-1} $arcsec^{-2}$ and discover an ENLR 2-3 times more extended than previously known (Fig. 2). These results confirm that the lack of a strong pressure permits to use small telescopes to test challenging ideas which are believed too risky for large telescopes and also to improve studies already in progress with additional data.

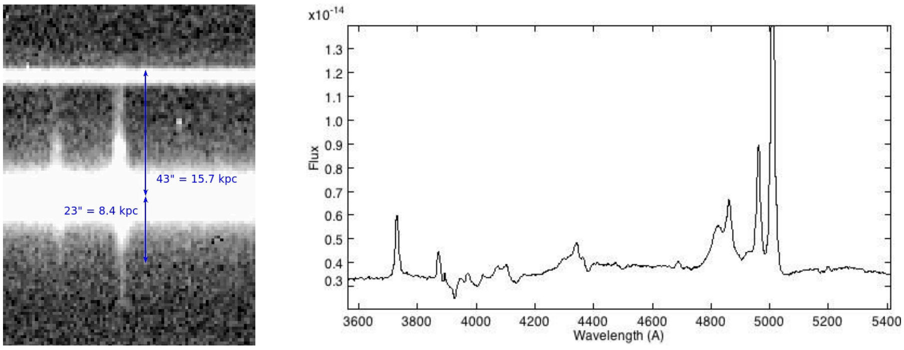

Figure 2. The spectrum of Mrk 6 at position angle PA=0° (left), showing the emission lines [O III]$\lambda\lambda$4959,5007 extended up to several kpc from the nucleus, and the blue part of the nuclear spectrum of Mrk 6 (right).

3.3. Optical spectroscopy of γ-ray sources

In collaboration with the high energy physicists of our department, we started a new research with the aim to spectroscopically observe γ–ray sources with the 1.2-m telescope. The project consists of: 1) obtaining spectra of candidate γ–ray Narrow Line Seyfert 1 galaxies to confirm their spectral classification and derive the mass of their SMBHs and their accretion rates; 2) obtaining the spectra of the optical counterparts of unidentified FERMI-LAT sources; 3) monitoring MAGIC sources. A first promising result was obtained very recently: the optical spectrum of the FERMI source SBS 1646+499 shows the presence of [O III]λ5007, Hα, and [N II]λ6583 emission lines (Fig. 3). Catalogued as a flat radio spectrum source (Healey *et al.*, 2007), this galaxy is very likely a Flat Spectrum Radio Quasar.

3.4. Education and training

Small telescopes are also ideal to train young astronomers, that is undergraduate students, PhD students and post-docs, who should never have the feeling that observations consist only in filling electronic forms and then wait for the data

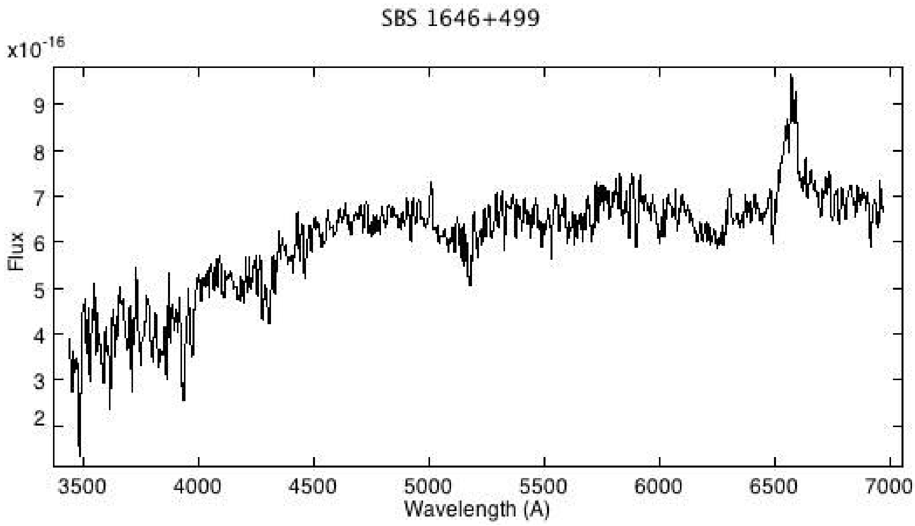

Figure 3. The optical spectrum of the FERMI source SBS 1646+499.

taken by someone else. On the contrary, they have the chance to learn how to organize an observing night, how to evaluate the quality of their data and possibly how to improve them. To this aim it was decided to offer the 1.2-m Galileo telescope to the students of the Master Degree and PhD in Astronomy of the University of Padova, who can use it to get experience with observations and also carry on scientific researches. In addition, the telescope is available for projects with students of secondary schools (Ciroi *et al.*, 2011).

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