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Scientific results after the first year of operation of the Toppo di Castelgrande telescope (TT1)

V. Ripepi[1], D. Mancini[1], F. Cortecchia[1], F. Cusano[1], M. Dall'Ora[1], S. Leccia[1], R. Molinaro[1], N. Penninpede[1], G. Clementini[2], C. M. Raiteri[3], and R. Silvotti[3]

[1] Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Capodimonte, Via Moiariello 16, I-80131 Napoli, Italy
[2] Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Bologna, Via Ranzani 1, I-40127 Bologna, Italy
[3] Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Torino, Via Osservatorio 20, I-10025 Pino Torinese (TO),Italy e-mail: ripepi@oacn.inaf.it

Abstract. In this paper we present preliminary results obtained during the first year of activity of the Toppo Telescope (TT1). We briefly outline the main characteristics of the system (telescope+instrument). Preliminary results from a few projects carried out with the TT1 are described, with particular emphasis on the exploitation of the TT1 observatory capabilities.

Key words. Stars: variables: general – Galaxy: halo – quasars: individual

1. Introduction

Scope of this paper is to present preliminary results obtained during the first year of operation of the Toppo di Castelgrande telescope (TT1). Over the period Oct. 2008-Nov. 2009, a total of 117 observing nights were offered for observation (periods AOT1, AOT2, and AOT3) with an actual observing efficiency of 20%, being down-time due to bad weather and technical failures ∼70% and ∼10%, respectively. In the following we describe results obtained by a number of different projects during the 24 nights of effective observations, with the main aim of outlining the instrument capabilities.

Send offprint requests to: V. Ripepi

2. The telescope and the instrument.

TT1 is an altazimuthal telescope of 1.57 m in size in Ritchey-Chretien optical configuration. It is placed at 1250 meters a.s.l. on a peak of the Appennini Mountains in the Basilicata Region (South Italy). It is about 10 km away from the Castelgrande town (Pz). Detailed information on telescope and site can be found on the web page: http://www.tt1obs.org.

The telescope is equipped with the Toppo Telescope Scientific Camera (TTSC), a nitrogen-cooled CCD camera mounted at the Cassegrain focus. The CCD detector presently installed is a SITe SI-424a grade 2 with 24 μm wide pixels. The CCD is back-illuminated and thinned to reach a better quantum efficiency in the UV. It is also characterized by an anti-reflection coating in the visible and by the

MPP technology that allows to have low dark current even at high temperatures. The CCD is read out by means of four different amplifiers (OUTPUTS 1 to 4), so that in output we have four independent 1024x1024 subimages. The read out time requires about 22 s. The four sub-images are then joined in a few seconds after the read-out into a unique 2Kx2K image by means of a dedicated software. The read out noise (r.m.s.) and the gain are 7 e^- and 1.6 e^-/ADU, respectively. With this setup the linearity is reached at about 50000 ADU. The projected pixel size on the sky is 0.385 arcsec, for a total field of view of 12.8$'$x12.8$'$. More detailed information on the camera can be found in Ripepi et al. (2008).

3. Results

In the following we describe briefly a few programs that have been carried out with TT1. Results of a program devoted to the study of the young, distant open cluster Dolidze 25 are presented in a separate paper (see F. Cusano et al., this book).

3.1. EXOplanet search with the TIming MEthod (EXOTIME, P.I. R. Silvotti)

The main drivers of the project are: i) Late-stage evolution of planetary systems: detection of new planets orbiting evolved stars, in particular hot subdwarf B stars (sdBs), through the timing method using the stellar pulsation as a clock (O-C diagram). ii) Secular variation of the pulsation periods: measuring dP/dt from the O-C plot allows to determine the precise evolutionary status of a star and helps the mode identification. iii) Asteroseismology: determination of the basic stellar parameters. iv) Investigation of the mechanisms that can explain the formation of single sdB stars. More details on the EXOTIME project can be found at the home page of the project (www.na.astro.it/ silvotti/exotime, see also Silvotti et al. 2007; Schuh et al. 2010).

Observations with TT1: more than 30 nights were awarded to this project in periods AOT1 and AOT2. Data have been collected along about 10 nights (several only partially observed). Data reduction is in progress. We show in Fig. 1 one night of data for star PG 1325+101 (Feb. 27 2009). The figure shows how the TT1 data are adequate for this kind of research.

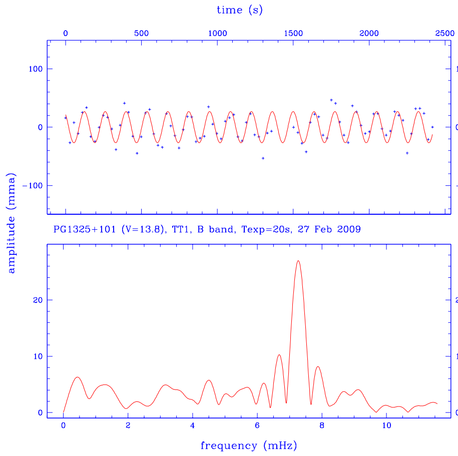

Fig. 1. Top and bottom panels show the light curves (plus symbols) and the periodograms, respectively, for the sdB star PG 1325+101.

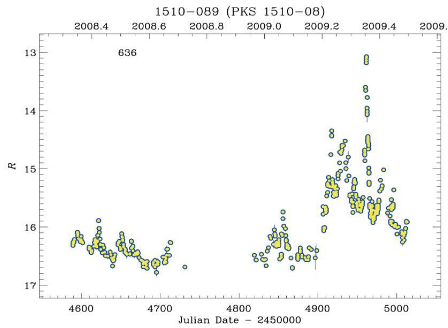

Fig. 2. Light curve for the blazar PKS 1510-089

3.2. Observing gamma-ray loud blazars in the AGILE and Fermi era (P.I. C. Raiteri

The GLAST-AGILE Support Program (GASP), born in 2007 from the international collaboration Whole

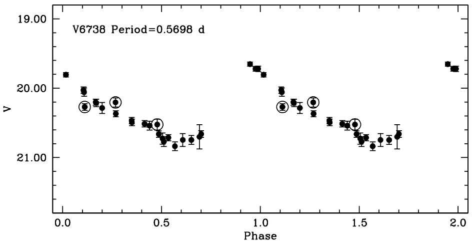

Fig. 3. Light curve of one of the three RR Lyrae stars we have identified in UMa I. Phase points obtained at the TT1 are encircled

Earth Blazar Telescope (WEBT, http://www.oato.inaf.it/blazars/webt/), aims at monitoring a sample of 28 blazars gamma-loud in the optical, near-infrared and radio domains. Several exposures of selected blazars, were collected with TT1 during the nights March, 25 and 27, 2009. In particular, we observed the source PKS 1510-089, in coincidence with its outburst in the optical as well as strong gamma ray activity, as derived from AGILE and Fermi satellite observations. TT1 observations are shown in Fig. 2 together with data collected at other telescopes of the GASP collaboration. GASP data on PKS 1510-089, including TT1 observations have been published by Abdo et al. (2010) and D'Ammando et al. (2011) for the Fermi-LAT and AGILE teams, respectively. As for the other sources, data collected with TT1 for 0716+714, OJ 287, and Mkn 421 were already included in the GASP light curves and will be used for future publications. In particular, data for Mkn 421 (with the aim of studying the multifrequency behaviour of this source), have been published by Abdo et al. (2011) for the Fermi-LAT collaboration.

3.3. Near Field Cosmology: the variable star population of the UFDs UMa I and Segue2 (P.I. V. Ripepi)

3.3.1. The project

This project is devoted to the observation of two possible relicts of the Milky Way

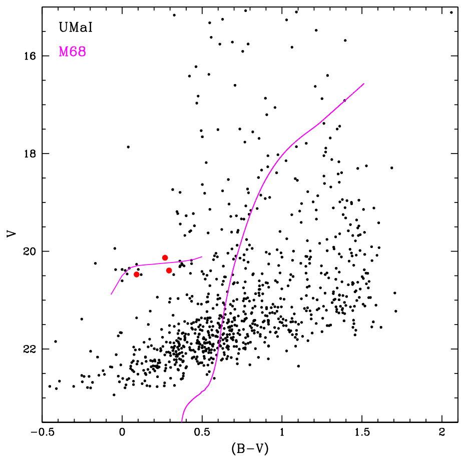

Fig. 4. Color-magnitude diagram of UMa I: red dots show the three RR Lyrae stars we have found in the galaxy; the magenta solid line show the mean riudgeline of the Galactic globular cluster M68.

(MW) formation process: the "ultra-faint" dwarf spheroidal galaxies (UFDs) Ursa Major I (UMaI) and Segue2. The Λ-Cold-Dark-Matter (Λ-CDM) theory of galaxy formation predicts that several hundred small dark halo satellites should surround the halos of large galaxies like the MW and M31 (Moore et al. 1999). Dwarf Spheoridal galaxies (dSphs) are also deemed to be best candidates for the "building blocks" from which the MW and M31 halos were assembled (Searle & Zinn 1978). The dSph galaxies surrounding the MW can be divided into two groups: "bright" dSphs, mainly discovered before 2005, and "faint" dSphs, discovered in the last few years primarily from analysis of images obtained by the Sloan Digital Sky Survey (SDSS; York et al. (2000)).

Bright and faint dSphs lie in two separate regions of the absolute magnitude versus half-light radius plane (see Figure 8 of Belokurov et al. (2007)). The bright dSphs include 10 galaxies that are found to contain stars having different chemical composition than the stars in the Galactic halo. Furthermore, they generally host RR Lyrae stars with pulsation properties that differ from the properties of the variables in the MW Galactic Globular Clusters (GCs), being "Oosterhoff-intermediate" (Oosterhoff 1939). It is thus unlikely that the halo of the MW formed from objects with properties similar to those of the bright dSphs that are observed today. Since 2005, 17 new faint satellites of the MW were discovered, primarily from SDSS imaging (see, e.g. Belokurov et al. 2007, and references therein). They all host an ancient stellar population with chemical properties similar to that of external Galactic halo stars (see e.g. Helmi et al. 2006). The new objects are therefore good candidates for the "building blocks" of the Galactic Halo. To further test this hypothesis, it is important to check whether the new dSphs contain RR Lyrae stars with pulsation properties (i.e. Oosterhoff type) consistent with the properties observed for the variables in the MW halo. To this purpose, our group is carrying out a systematic study of the variable stars (in particular of RR Lyrae type) in the newly discovered faint dSphs. Time series data are being collected with a large variety of telescopes: the 1.3m LCO-Polish, the 1.5m Loiano, the 1.8m Lowell, the 2.2m ESO, the 2.3m WIRO, the 2.5m INT, the 3.5m TNG, the 4.1m SOAR, the 4.2m WHT. We have already published results for 5 of the SDSS dSphs, namely, Bootes I, (Dall'Ora et al. 2006); CVn I, (Greco et al. 2008); CVn II, (Kuehn et al. 2008); Coma, (Musella et al. 2009) and Leo IV (Moretti et al. 2009), and have observed with TT1 two new SDSS faint dSphs, namely: UMaI and Segue2. .

3.3.2. Ursa Major I (UMaI)

We have an extended dataset for this galaxy coming from three different telescopes: the Tautenburg 2.0m, the Loiano 1.5m, and the Subaru 8m (archive data). We observed UMaI with TT1 on May 2009, obtaining only a few epochs in V (with exp. times of 1800 sec.) due to bad weather. Data pre-reduction was performed with IRAF, whereas for the PSF photometry we adopted DAOPHOT/ALLSTAR (Stetson 1987). We have detected three RR Lyrae variables in this galaxy. In Fig. 3 we show the light curve for one of them: the encircled dots mark the phase points obtained with the TT1. Note the very small errors at this relatively faint magnitudes. Fig. 4 shows the color-magnitude diagram for the galaxy where the red dots mark the RR Lyrae found in UMa

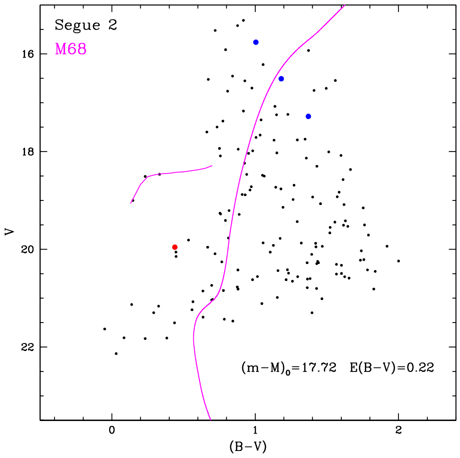

Fig. 5. CMD of Segue 2 based on TT1 data. A blue dot shows a candidate SX Phe star and a red dot marks a red variable we have identified in the system. The magenta line is the ridgeline of the metal poor globular cluster M68. The values used to fit M68 ridgeline are labeled.

I (two of them are likely contaminated by companion stars). In the figure, the magenta solid line shows the mean ridgeline of the Galactic globular cluster M68. Adopting [Fe/H]∼-2.2, E(B-V)∼ 0.02 mag, and <V(RR)>=20.43 mag, we obtain for the galaxy a distance modulus of $(m-M)_0=19.95\pm0.10$ mag, in perfect agreement with previous estimates in the literature. The average period of the three RR Lyrae stars we have found in UMaI is <P(RRab)>=0.64 d, hence this galaxy has Oosterhoff type II properties. Thus in terms of the pulsation properties of the RR Lyrae stars UMaI, as the vast majority of the SDSS dSphs we have studied so far, could resemble the plausible building blocks of the Galactic halo.

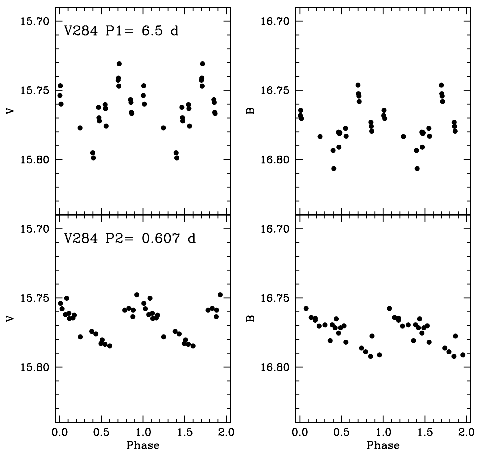

Fig. 6. Light curves for the puzzling red variable V284. This star shows two pulsation modes with periods as labelled in the figure

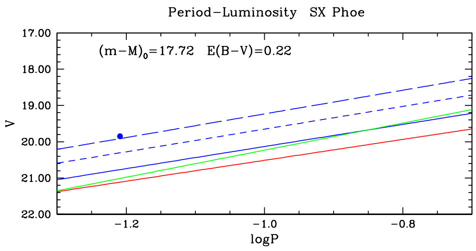

Fig. 8. Period-Luminosity diagram for the candidate SX Phe star V2396. Red and green lines show the empirical PL relations by McNamara et al. (2004) and Poretti et al. (2008), respectively. The solid, short-dashed and long-dashed lines show the theoretical PL relations for fundamental, first and second overtone modes, respectively; after Santolamazza et al. (2001)

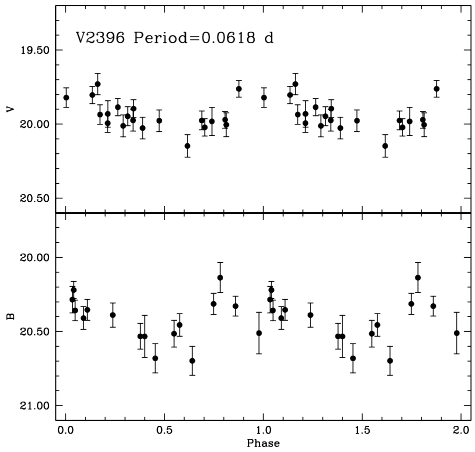

Fig. 7. Light curve for the SX Phe candidate V2396

3.3.3. Segue 2

Segue 2 is an extremely faint system discovered by Belokurov et al. (2009) and is considered as the possible transition between a dwarf galaxy and a globular cluster. We observed Segue 2 in the B,V bands during 8 nights in Nov, 2009. Standard pre-reduction was performed with IRAF, whereas aperture photometry (the field is not crowded) was carried out with DAOPHOT (Stetson 1987). Landolt's standard stars were used for the absolute photometric calibration. The color-magnitude diagram (CMD) we have obtained for Segue2 is shown in Fig. 5. We compared the CMD with the mean ridgeline of M68 to estimate the distance modulus and reddening of Segue 2. As a result we find $(m\text{-}M)_0$=17.72±0.15 mag and E(B-V)=0.22±0.02 mag, in excellent agreement with the literature values.

We did not find any RR Lyrae star in Segue 2, this is not surprising as the horizontal branch is very poorly populated, however we were able to discover a few interesting variable sources. In particular we detected three "red" variables with small amplitudes and a candidate SX Phoenicis (SX Phe) star. In Fig. 6 we plot the light curves of the most interesting red variable (V284) that shows two clear modes of pulsations with periods of 6.5 d and 0.607 d, respectively. The period ratio does not correspond to any known multimode variable type. The classification of this star is difficult due to the lack of spectroscopic information, that we plan to obtain in the future. Star V2396 (Fig. 7)) is also very interesting because it is a SX Phe candidate (SX Phe are the δ Scuti counterpart at low metallicities). SX Phe stars obey a Period-Luminosity (PL) relation. If we use the distance and reddening estimated from the CMD, we can verify if the position of

V2396 is consistent with that expected for a SX Phe variable. This is shown in Fig. 8, that suggests the star could indeed be a second overtone SX Phe. We plan to collect additional data to confirm the variable candidates we have detected in Segue 2.

4. Conclusions

The first year of observations with TT1 was hampered by bad weather. Nevertheless, a number of scientific programs were carried out, and results will be published soon. The introduction of the TFOSC instrument (*Toppo Faint Object Spectrograph Camera*), planned for the beginning of 2011, will greatly enhance the capabilities of the TT1 telescope. In particular, the increased field of view (squared unvignetted area $\sim 17' x 17'$) coupled with the wide choice of filters (UBVRI, ugriz, uvbyHβ, Hα + other narrow filters) will make TFOSC at TT1 an attractive instrument for a variety of photometric programs. As for spectroscopy, low (up to V$\sim$16-17) and mid resolution (up to V$\sim$13) will become possible, allowing to carry out different programs both in the galactic and extragalactic fields of research.

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