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DogsHeaven Observatory international cooperation – Wind structure : The cases of ζ Puppis and γ^2 Velorum

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Abstract. We show in this paper some results of DogsHeaven Observatory, a private observatory in Brasília, Brazil. From supernova discoveries to stellar occultations of solar system bodies, from millisecond pulsar optical detection to support with spectroscopic data on stellar research, the observatory operates in several distinct fields. In this paper we highlight two works that will have an impact on stellar astrophysics field. In the first work, headed by Noel D. Richardson, we report on the first multi-color precision light curve of the bright Wolf-Rayet binary γ^2 Velorum, obtained over six months with the nanosatellites in the BRITE-Constellation fleet. In parallel, we obtained 488 high-resolution optical spectra of the system. The second work, headed by Tahina Ramiaramanantsoa, was a study of the early-O-type supergiant ζ Puppis and it was based on 5.5 months of dual-band optical photometric monitoring at the 1 mmag level and ground-based multi-site spectroscopic monitoring in eight observatories.

Resumo. Nós mostramos nesse trabalho alguns resultados do Observatório DogsHeaven, instituição privada, situado em Brasília, Brasil. De descoberta de supernovas até ocultações estelares de corpos do Sistema Solar, de detecção óptica de pulsares de milisegundos ao suporte com dados espectroscópicos em pesquisa estelar, o observatório opera em campos diversos. Nesse trabalho nós destacamos dois trabalhos, os quais terão impacto no campo de astrofísica estelar. No primeiro trabalho, liderado por Noel D. Richardson, apresentamos a primeira curva multiespectral de precisão da binária Wolf-Rayet γ^2 Velorum, obtida com dados de seis meses da constelação de nanosatélites BRITE. Em paralelo foram obtidos 488 espectros de alta resolução do sistema. O segundo trabalho, liderado por Tahina Ramiaramanantsoa, foi um estudo da estrela supergigante ζ Puppis, e foi baseado em monitoramento fotométrico em duas bandas por 5.5 meses com resolução de 1 mmag e com monitoramento espectroscópico feito em oito observatórios.

Keywords. Stars:winds, outflows – Stars:Wolf-Rayet – Stars:supergiants

1. Introduction

DogsHeaven Observatory is a private observatory located in Brasília, Brazil. The observatory has activities in several astronomical and astrophysical fields. From TNO's occultations, as in Braga-Ribas et al.(2013) and Ortiz et al.(2012), to supernovae and novae search, from stellar low and medium resolution spectra to software development, the observatory has been participating in several current researches with worldwide active specialists.

The observatory has a set of telescopes up to a diameter of 50cm and several science appliances, from spectroscopes to ugriz and johnson photometric filters. The site has clear nights usually from April to September with the rainy season between October and March and, as a consequence few available nights. However, during the season is frequent daily availability, what is a very important asset when we are doing research that needs worldwide or timely coverage.

The first discovery of a supernova in Brazil happened at DogsHeaven Observatory in 2002 by Cacella et al. (2002). It was a nearby Ia supernova in Leo called 2002bo. It was located in NGC3190, some 80 millions light years away. This supernova was discovered 13 days prior to maximum and had a very extensive coverage. Due to a very detailed study in visual and infrared wavelenghts this supernova is one of reference stars used today in supernova reasearch.

More recently, the observatory discovered a more distant, 800 millions light years away, supernova type Ic in Antlia. This supernova is called 2017dgk, Cacella (2017) and spectroscopic confirmation was done by ePESSTO ESO-NTT. This supernova is currently object of a study as is located in a dwarf galaxy.

The observatory also was an important player in the discovery of the optical counterpart of the millissecond pulsar XTE J0929-314, reported by Cacella (2002), after RXTE ASM Team reported the discovery of a faint x-ray transient in Antlia. Data from Very Large Array showed that the astrometry of the observatory were favorably compared with a much larger professional facility.

DogsHeaven Observatory is currently particpating in several programs and international cooperations. The main research currently at the observatory is the search of transient objects, solar system objects, photometric imaging and spectroscopy.

The observatory is currently cooperating with ASAS-SN in confirming transients, as reported in Holoien (2017), mainly supernovae.

With SASER, the the Southern Astro Spectroscopy Email Ring, we participate in a worldwide coverage of spectroscopic research of some specific targets, mainly visible in southern hemisphere, as in Molnár et al. (2016). This cooperation with professional astronomers allowed the observatory to participate actively in the two papers shown in this paper.

With Akira Karai, from Koyama Astronomical Observatory at Kyoto Sangyo University, we are conducting a research looking for detection of C2 and CN lines in Novae, as reported in Akira & Cacella (2016).

With RIO group we are collaborating with observations of stellar occultations of TNOs and Centaurs.

Currently we are following early B supergiant μ Sgr at lines C II $\lambda\lambda$6578/6583 , Si II $\lambda\lambda$6347/6371, Hα and He I λ6678.

Beyond that, the Observatory developed a software that is helping to automatically detect new transients, moving objects or variable stars. 2017dgk supernova was discovered with this tool.

2. The variability of the BRITE-est Wolf-Rayet binary, γ^2 Velorum I. Photometric and spectroscopic evidence for colliding winds

In the first work, headed by Richardson (2017), the observatory generated 56 spectra for the research. We report on the first multi-color precision light curve of the bright Wolf-Rayet binary γ^2 Velorum, obtained over six months with the nanosatellites in the BRITE Constellation fleet. In parallel, we obtained 488 high-resolution optical spectra of the system. In this first report on the datasets, we revise the spectroscopic orbit and report on the bulk properties of the colliding winds. We find a dependence of both the light curve and excess emission properties that scales with the inverse of the binary separation. When analyzing the spectroscopic properties in combination with the photometry, we find that the phase dependence is caused only by excess emission in the lines, and not from a changing continuum. We also detect a narrow, high-velocity absorption component from the He I λ5876 transition, which appears twice in the orbit. We calculate smoothed-particle hydrodynamical simulations of the colliding winds and can accurately associate the absorption from He I to the leading and trailing arms of the wind shock cone passing tangentially through our line of sight. The simulations also explain the general strength and kinematics of the emission excess observed in wind lines such as C III λ5696 of the system. These results represent the first in a series of investigations into the winds and properties of γ^2 Velorum through multi-technique and multi-wavelength observational campaigns.

3. BRITE-Constellation high-precision time-dependent photometry of the early-O-type supergiant ζ Puppis unveils the photospheric drivers of its small- and large-scale wind structures.

The second work, headed by Ramiaramanantsoa (2017), and which the Observatory contributed with 164 spectra, was based on 5.5 months of dual-band optical photometric monitoring at the 1 mmag level, BRITE-Constellation has revealed two simultaneous types of variability in the O4I(n)fp star ζ Puppis: one single periodic non-sinusoidal component superimposed on a stochastic component. The monoperiodic component is the 1.78 d signal previously detected by Coriolis/SMEI, but this time along with a prominent first harmonic. The shape of this signal changes over time, a behaviour that is incompatible with stellar oscillations but consistent with rotational modulation arising from evolving bright surface inhomogeneities. By means of a constrained non-linear light curve inversion algorithm we mapped the locations of the bright surface spots and traced their evolution. Our simultaneous ground-based multi-site spectroscopic monitoring of the star unveiled cyclical modulation of its He II λ4686 wind emission line with the 1.78-day rotation period, showing signatures of Corotating Interaction Regions (CIRs) that turn out to be driven by the bright photospheric spots observed by BRITE. Traces of wind clumps are also observed in the He II λ4686 line and are correlated with the amplitudes of the stochastic component of the light variations probed by BRITE at the photosphere, suggesting that the BRITE observations additionally unveiled the photospheric drivers of wind clumps in ζ Pup and that the clumping phenomenon starts at the very base of the wind. The origins of both the bright surface inhomogeneities and the stochastic light variations remain unknown, but a subsurface convective zone might play an important role in the generation of these two types of photospheric variability.

4. Final Remarks

In this work we show how a private observatory can contribute with research data and discoveries to the astronomical community. DogsHeaven Observatory is open to cooperation on diverse astronomical fields with capabilities ranging from imaging to spectroscopy.

References

Arai Akira, Cacella P. 2016, ATEL, 9359
Braga-Ribas, F. et al. 2013, ApJ, 773, 26
Cacella, P. et al. 2002, IAUC, 7847
Cacella, P. 2002, IAUC, 7893
Cacella, P. 2017, TNS, 2017dgk, 2017-464
Holoien, T. W.-S. et al. 2016, MNRAS, 471, 4966
Molnár, L. et al. 2016, MNRAS, 466, 4009
Ortiz J. L. et al. 2012, Nature, 491, 566
Ramiaramanantsoa T. et al. 2017, MNRAS, Accepted
Richardson, N. et al. 2017, MNRAS, 471, 2715