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A NEW WAY TO STUDY THE STELLAR PULSATION FIRST POLAR MISSION PAIX

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Abstract. In the context of long and continuous timeseries photometry and after the MOST, CoRoT, KEPLER space missions and large geographic longitude ground–based networks, a new way is offered by the polar location helping to cope with the problem associated with the Earth day–night cycle. In this paper, we present the first long timeseries photometry from the heart of Antarctica -Dome Charlie- and we discuss briefly our new results and perspectives on the pulsating stars from Antarctica, especially the connection between temporal hydrodynamic phenomena and cyclic modulations. Finally, we highlight the impact of PAIX -the robotic Antarctica photometer- on the stellar pulsation study.

Keywords: Polar mission, robotic Antarctica photometer -PAIX-, stellar pulsation, Asteroseismology, observation, oscillations, hydrodynamics, space missions.

1 Introduction

Stellar oscillations and Asteroseismogy are currently one of the fundamental techniques to improve our understanding of the internal structure of stars. On the observational side, progress is limited by the data accuracy needed to detect numerous modes of oscillations with small amplitudes and by the discontinuous nature of typical ground-based data strings which often introduces ambiguities in the determination of oscillation frequencies. Space missions such as MOST (Matthews 1998), CoRoT (Chadid et al. 2010a) and KEPLER (Borucki et al. 2007) enable to overcome both difficulties, and indeed have considerably enhanced the scope of asteroseismological methods. However, the outcome of the space missions (MOST, COROT and KEPLER) on the stellar oscillation fields shows large gaps in terms of the flexibility during the observing runs, the choice of targets, the repair of failures and the inexorable high costs. Now the time has came to implement a new way to study the stellar oscillations with long uninterrupted and continuous observations over 150 days from the ground, south polar site –Dome Charlie– the great image quality and the high time coverage with PAIX. This photometer is made of the low–cost commercial components, and achieves astrophysical measurement time-series of stellar pulsation fields, challenging photometry from space. In this talk, we briefly describe the polar mission PAIX and the first outcome of the stellar pulsation from the heart Antarctica during 1 polar night.

2 Getting the PAIX Science for the Least Money

2.1 PAIX Mission, Polarcraft, Concept and Description

PAIX –Photometer AntarctIca eXtinction– gives new insight to cope with unresolved stellar enigma and stellar oscillation challenges and is a great opportunity to benefit from an access to one of the best astronomical site on Earth –Dome Charlie– at a height of 3300 m on $75^{deg}06^{min}04^{s}S, 123^{deg}20^{min}52^{s}$ E of Antarctica plateau, where the seeing reaches a median value of 1 arcsec during the polar night (Vernin et al. (2009) and Giordano et al. (2012)). PAIX is attached to the Cassegrain focus of a 40-cm Ritchey-Chretien optical telescope, with a F/D ratio of 10, located at Dome C in the open field, without any shelter, installed at ice level. The set–up of PAIX was improved by the use of a new camera SBIG ST10–XME, yielding images of 728 x 490 pixels with 3 x 3 binning across a 12.4 x 8.3 arcmn field of view. The camera is cooled with a Peltier assembly, with temperature

*Based on observations collected from Antarctica at Dome C, by use of PAIX telescope, during the polar night 2009

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regulation. The quantum efficiency is 60%, 85%, 80% and 55% at respectively 400, 550, 700 and 800 nm. PAIX challenges space telescopes and even has more advantages than CoRoT and KEPLER in observing in UBVRI bands and then collecting multicolor light curves simultaneously of several targets in the same field of view 12.4 arcmin x 8.3 arcmin.
PAIX has been antarctized to run under extreme conditions at temperatures as low as -80 deg.C, and has been designed and built by PaixTeam where the operating headquarters and the Principal Invistigator M. Chadid are located at Université de Nice Sophia–Antipolis and Observatoire de la Côte d'Azur.

2.2 PAIX Robotisation and Observations

The observations are collected under the extreme conditions of the climate, humain survival and isolation that prevail in the heart of Antarctica, by the use of PAIX.
A continuous, uninterrupted series of multi-color photometric observations is collected all along one polar night – 150 nights — from April to October, with Earth's day–night duty cycle of 80 % with 40–60 s of integration times and a high optical photometric accuracy of 0.025 mag for a 12 mag V–magnitude (Chadid et al. 2010b).
PAIX shows a tremendous increase of the productivity with the development of a new remote control software PACS –PAIX Acquisition and Control Software– and then is automatically operated without any human on-site intervention (except under extreme weather conditions or major power failure). For the first time, remote polar observations is finally possible from anywhere in the world towards the heart of Antarctica, Dome Charlie. Remote observing sequences are scripted and data series are automatically transferred through VPN tunnel to a server located in Nice (Figure. 1).

3 Stellar pulsation study

3.1 Antarctica RR Lyrae survey

We present the first optical photometric data collected by the use of PAIX from Dome Charlie. A continuous and uninterrupted series of photometric observations, of the Blazhko* RR Lyrae star S Arae, was collected during one polar night – 150 nights — from 18 April to 20 Septembre 2009. Figure. 2 shows the PAIX light curve of S Arae. The V-magnitude varies between 10 and 11.5 mag, with an accuracy of 0.025 mag, in a period of 0.452 d and a Blazhko period of 48.544±0.045 d. A total of 89736 CCD frames, during 323 pulsation cycles and 3 Blazhko cycles, were acquired with 40 to 60 s integration times, allowing an average time resolution T/P around 0.15 % of the pulsation period, where T is the exposure time and P is the period of the pulsation. The PAIX data were analyzed using the software PDM13 (Zalian et al. 2014). Besides the main pulsation period of 0.452 d and the Blazhko period of 47.264 d, the frequency analysis shows three new significant frequencies that we interpreted as a first radial overtone (0.319 d) and two non–radial modes (0.338 d and 0.263 d) never detected so far in an RR ab type (Chadid et al. 2014).

3.2 Possible explanation of the Blazhko effect

Figure. 3 presents the light curve of S Arae, showing the *lump*, *bump* and *hump* (Chadid & Preston 2013). The most striking feature is that the descending branch of the light curve demonstrates the existence of new bumps at phases $\varphi = 0.10$ and $\varphi = 0.70$. We call them *jump* and *rump*. The *jump* occurs just after maximum light and the *rump* appears very close to the *bump*. They might be a consequence of a multi–shock structure, the atmosphere of the Blazhko star S Arae is crossed by several shock waves with different amplitudes and physical origins. In this condition, the shocks develop a stationary coronal structure and drive an outflowing wind. The latter minimize gradually the overall compression of the atmosphere and then the strength of κ–γ mechanisms. Perhaps, the outflowing wind plays a major role of a trigger mechanism acting on the κ and γ mechanisms. We suggest that the Blazhko effect is a consequence of a dynamical interaction between a multi–shock structure and the outflowing wind of a coronal structure (Chadid et al. 2014).

*Chadid (2011)

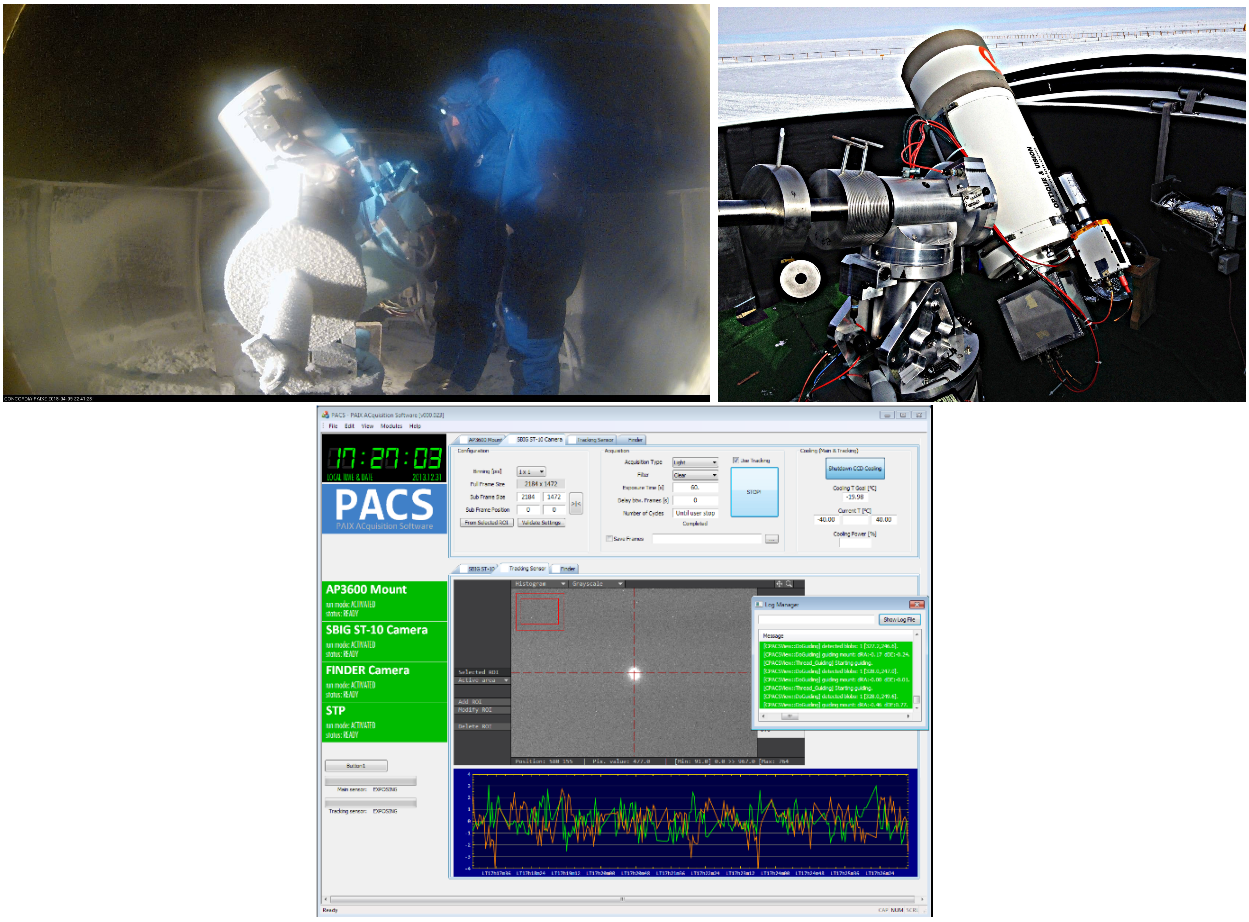

Fig. 1. Top*:* The robotic Antarctica photometer –PAIX– during the polar night (on the left) and during the polar day (on the right) in the heart of Antarctica at Dome Charlie. Remote observing sequences are scripted and data series are automatically transferred through a VPN tunnel to a server located in Nice. PAIX is antarctized to run under extreme conditions at temperatures as low as -80 deg.C. **Bottom:** Screen capture of the remote PAIX Acquisition and Control Software PACS.

4 Conclusions

PAIX – robotic Antarctica photometer – polar mission is a great opportunity for monitoring stars with excellent time-sampling and unprecedented photometric precision over up to 150 days, and could even challenge the photometry from space for less Money. As an important benefit, high-quality RR Lyrae polar light curves are obtained with a quasi-uninterrupted coverage over several pulsation and Blazhko cycles. The PAIX polar data, are the most accurate and continuous data set of oscillating and pulsating stars ever obtained from the ground-based observation networks. Due to the proper data sampling and high precision we got new results towards understanding of the atmospheric dynamics and the pulsation behaviour in the pulsating stars type RR Lyrae. We describe the still puzzling Blazhko phenomenon on a higher level and we suggest a new explanation of the Blazhko effect.

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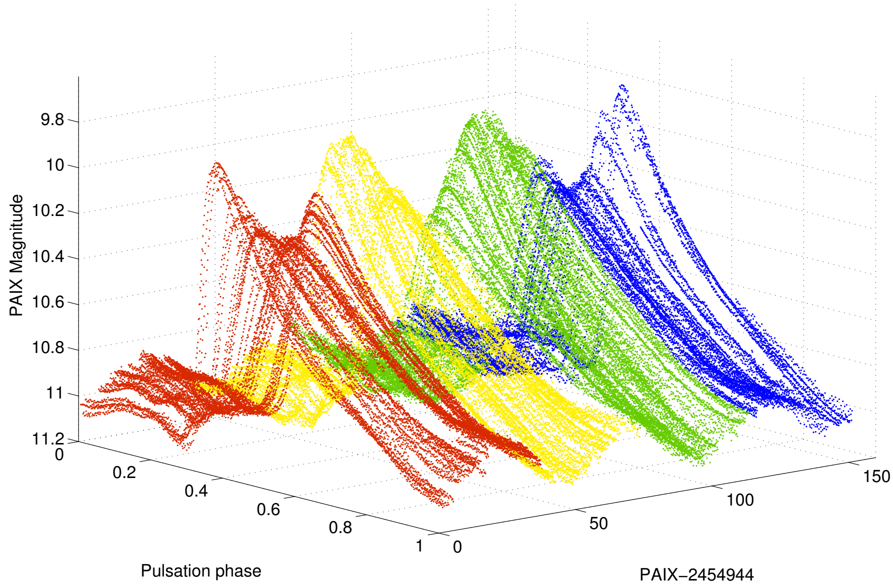

Fig. 2. Three–dimensional PAIX light curve of S Arae over 150 days –one polar night– folded with the pulsation period (0.452) over 3 Blazhko cycles and showing a strong Blazhko strength.

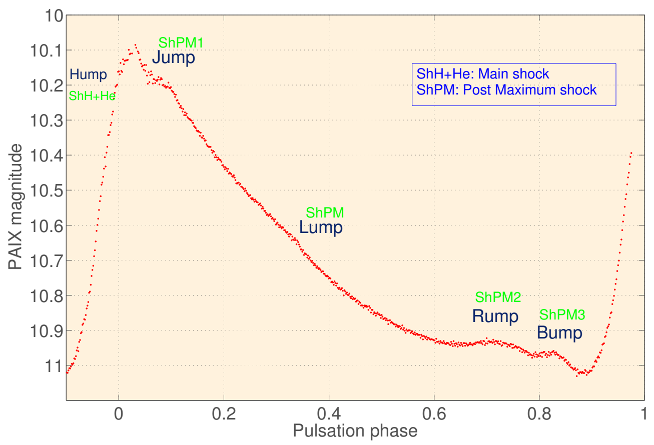

Fig. 3. PAIX light curve of S Arae showing the hump, jump, lump, rump and bump

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