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Ground-based observations for the BRITE-Constellation Satellites

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Abstract. BRITE (BRIght Target Explorer) Constellation is a network of five nano-satellites to investigate stellar structure and evolution of the brightest stars in the sky and their interaction with the local environment. Micropulsation, wind phenomena, and other forms of stellar variability are recorded via high precision photometry in two wavelength regions (red and blue). The success of this mission is also very much depending on supportive ground-based observations, especially spectroscopy. We review the variety of such needed observations together with already published results. Furthermore, we describe the aims and tasks of the BRITE-Constellation Ground-Based Observing Team.

Key words: Space vehicles – Stars: variables: general – Astronomical data bases

1. Introduction

BRITE-Constellation is a group of five nano-satellites, launched in 2013 and 2014, aimed at obtaining continuous time-series high precision photometry in the blue and red wavelength regime for the brightest (typically $V < 6$ mag) stars in the sky (Weiss et al., 2014).

The scientific goals of the mission are mainly related to the investigation of the variability of upper main sequence stars, i.e. hot massive stars. These stars show a variety of variability types which are caused by pulsations, mass loss, rotation, stellar winds, and interactions in binary and multiple systems (Aerts & Sterken, 2006).

However, for a comprehensive study, often, further ground-based observations are needed. The advantage of studying bright stars is, for example, that spectroscopic observations either exist in archives or can be easily obtained even with a small or medium-size telescope.

The BRITE-Constellation Ground-Based Observing Team (GBOT) was founded in 2012 to support collaborations between BRITE-Constellation PIs

Table 1. BRITE-Constellation satellites in orbit.

Country	Satellite Name	ID	Launch	P_{orb} (min)	Filter
AUT	UniBRITE	UBr	2013-02-25	100.37	red
AUT	BRITE-Austria "TUG-SAT-1"	BAb	2013-02-25	100.36	blue
CAN	BRITE-CA1 "Toronto"	BTr	2014-06-19	98.24	red
POL	BRITE-PL2 "Heweliusz"	BHr	2014-08-19	97.10	red
POL	BRITE-PL1 "Lem"	BHr	2013-11-21	99.57	blue

and ground-based observers worldwide. Its mission is to maximize the scientific output of the BRITE-Constellation project.

In this article we will give a few examples of how such additional observations helped to significantly improve the analysis. Furthermore, we will describe the GBOT in more detail.

2. The BRITE-Constellation Satellites

Here, we will give a short overview of the BRITE-Constellation satellites. A much more detailed description can be found in Pablo et al. (2016).

The origin of BRITE-Constellation can be traced directly to two developments: the Canadian micro-satellite project Microvariability and Oscillation of Stars (MOST, Matthews, 2004) and the beginning of the nano-satellite program at the Space Flight Laboratory (SFL) of the University of Toronto in the early 2000s. The MOST mission, proposed in 1997 and launched on 30 June 2003, is still delivering photometric data of the highest quality (Mikulášek et al., 2016). Based on the experience accumulated during this mission, a consortium of researchers from Austria, Canada and Poland was formed. Finally, in the years 2013 and 2014, six satellites were launched from which five are fully functioning. An overview of these satellites are listed in Table 1. In the following, we itemise the basic relevant properties of the mission and its instrument:

- Aperture: 3 cm.
- Size: 20x20x20 cm.
- Bright stars with $V < 4$ mag.
- Two wavelength regions: 400 - 450 nm (blue filter) and 550 - 700 nm (red filter).
- Nearly all-sky coverage.
- One field observed up to half a year.
- Field-of-view has a diameter of about 24° x 24°.

From 2013 to October 2018, 520 stars in 34 campaigns were successfully observed (Pigulski, 2018). The scientific output is manifold (Baade, 2018) and extends from Luminous Blue Variables at the hot and red supergiants at the cool luminous end, both with mostly slow variations, to δ Scuti, γ Doradus, and rapidly oscillating Ap stars at the low-luminosity/rapid-variability end. Furthermore, rotational induced variability and eclipsing binaries have been successfully investigated with BRITE-Constellation data (Paunzen & Rode-Paunzen, 2017; Ratajczak & Pigulski, 2018). The whole project is a major success and it can be hoped that the overlap with targets from the TESS mission (Ricker et al., 2014), will further result in several additional scientific investigations.

3. Some results from ground based support observations

In this section, a short overview of selected results of joint efforts using BRITE-Constellation and additional ground-based data is given. In principle, all types of supportive observations, for example, photometric (Stachowski et al., 2015), polarimetric (Neiner et al., 2017), and spectroscopic (Richardson et al., 2017) data strengthen the individual scientific cases. In the following, we have selected five different star groups showing the success of the GBOT.

β Cephei stars: A simultaneous ground and space-based photometric study of ν Eridani was presented by Handler et al. (2017). In this scientific case, ground-based Strömgren *uvy* photometry allowed a mode identification using the amplitude ratios and phase shifts of the different filters. Although this is also, in principle, possible with the two wavelength regions covered by the BRITE-Constellation data, light curves in additional filters help to put tight constraints on the pulsational models.

Be stars: The variability of this star group caused by mass-loss and circumstellar material can be investigated using BRITE-Constellation and other space-based photometric data (Baade et al., 2018). Additional spectroscopic observations, for example of the Hα profiles, help characterizing the disk around these stars. Especially studying the emission line and radial velocity changes are crucial for modelling the close stellar environment.

γ Doradus stars: Zwintz et al. (2017) presented a detailed analysis of 43 Cygni. High-resolution and high signal-to-noise ratio spectroscopic data obtained at the 1.2 m Mercator telescope with the HERMES spectrograph were used to determine the fundamental atmospheric parameters and chemical composition of this object. With these astrophysical parameters and the 156-days long data set obtained with the BRITE-Toronto satellite, they derived the mode identification, asymptotic period spacing, and near-core rotation rate on the basis of a suite of MESA/GYRE models. Only with the combination of photometry and spectroscopy it was possible to determine the near-core rotation rate and find indications of the presence of a significant chemical gradient in the stellar interior.

O-type supergiants: Stochastically-triggered photospheric light variations were detected in V973 Scorpii (Ramiaramanantsoa et al., 2018) on the basis of BRITE-Constellation observations. The variations on a time scale between 5 and 10 days can be best traced by continuous photometric data over many cycles. To connect this phenomenon to the amount of stellar wind and mass-loss, additional low as well as medium-resolution spectra are needed.

Rapidly oscillating Ap stars: This object class is very demanding in terms of photometric accuracy because the amplitudes of variability hardly reach a few mmags. Weiss et al. (2016) analysed α Circini, one of the prototypes of this variability class. Only with the combined BRITE-Constellation and archival long-term ground-based data, it was possible to study the pulsational and rotational period of this object.

4. The BRITE-Constellation Ground-Based Observing Team

In the following, we give an overview of the main tasks and information which can be found at the website http://www.brite-constellation.at:

- Overview of ground-based observations for completed, ongoing, and future BRITE-Constellation observations.
- Ground-based observing proposals for BRITE-Constellation targets.
- Sub-teams of GBOT and their PIs.
- List of ground-based facilities that already contributed with ground-based observations.
- Information from archives, databases, and the literature.
- Other relevant information (e.g. publications).
- List of GBOT members.

The collaboration with GBOT is open for the whole community. The contact person for any inquiries is Konstanze Zwintz (konstanze.zwintz@uibk.ac.at).

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