CANADA-FRANCE-HAWAII TELESCOPE

Wade

No code

An all-sky high-resolution Stokes I+V spectropolarimetric survey of bright stars complete to V=4

Semester : 2015A

Science Cat. : Stars and stellar population

Abstract

We propose to continue an all-sky high resolution spectropolarimetric survey of all stars brighter than V=4, in support of the BRITE-Constellation mission. With ESPaDOnS, we will acquire a single R=65,000, SNR>1000 spectrum of approximately 100 previously unobserved targets. Observations will be acquired in spectropolarimetric mode, providing a high-precision diagnosis of the stellar magnetic field with each spectrum, sufficient to detect weak dynamo and fossil magnetic fields in cool and hot stars, respectively. The data will be used for the determination of fundamental physical parameters, rotational velocities, and chemical abundances, along with stellar magnetic characteristics, which will synergise with BRITE's primary asteroseismological mission. The unprecedented quality of the dataset will result in enormous legacy value, and in serendipitous discoveries, including the detection of faint binary companions, spectroscopically peculiar systems and new intensely magnetic stars.

Telescopes

Telescope	Observing mode	Instruments
CFHT	QSO Regular	ESPaDOnS

Applicants

Name	Affiliation	Email	Country		Potential observer
Gregg Wade	Queen's University / Royal Military College of Canada (Physics)	Gregg.Wade@rmc.ca	Canada	Pi	
A.F.J. Moffat	Université de Montréal	moffat@astro.umontreal.ca	Canada		
S. Rucinski	University of Toronto	rucinski@astro.utoronto.ca	Canada		
S. Mochnacki	University of Toronto	stefan@lepus.astro.utoronto.ca	Canada		
J. Matthews	University of British Columbia	matthews@astro.ubc.ca	Canada		
Alexandre David-Uraz	Queen's University	adavid-uraz@astro.queensu.ca	Canada		
Dr. Herbert Pablo	University of Montreal (Physics)	hpablo@astro.umontreal.ca	Canada		
Tahina RAMIARAMANANTSOA	Université de Montréal (Département de Physique)	tahina@astro.umontreal.ca	Canada		
Gemma Whittaker	University of Toronto	whittaker@astro.utoronto.ca	Canada		
Aleksander Schwarzenberg-Czerny	Copernicus Astronomical Center	alex@camk.edu.pl	Poland		
Rainer Kuschnig	University of Vienna	rainer.kuschnig@univie.ac.at	Austria		
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Dr Veronique Petit	University of Delaware (Dept. of Physics and Astronomy)	vpetit@udel.edu	United States		

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State	Ontario
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Applicants are continued on the last page

Requested Time (exposure + overheads) in hours (in nights for Classical)

18.0

Overall scheduling requirements

None

Observing runs

Run	Instrument	Seeing	Config	Details
A	ESPaDOnS	1.00 - 1.50" (ESPaDOnS)	Observing mode: Polarimetry Read-out mode : Normal	(None) None

Targets

Field	RA	Dec	Epoch		Runs	Moon	Seeing Lower	Seeing Upper	S/N	Magnitude	Diameter	Comments

Scientific Justification

Context

BRITE-Constellation (where BRITE stands for BRIght Target Explorer) is a Canadian idea that has attracted interest world-wide.This nanosatellite mission will monitor photometrically, in two colours, the brightness and temperature variations primarily of stars brighter than V ≈ 4, with precision and time coverage not possible from the ground. The mission design consists of three pairs of 7 kg nanosats (hence "Constellation") from Austria, Canada and Poland carrying 3 cm aperture optical telescopes and CCDs. One instrument in each pair is equipped with a blue filter; the other, a red one. Each BRITE instrument has a wide field of view (≈ 24 degrees), so up to 15 bright stars can be observed simultaneously in 32 x 32 sub-rasters. Photometry of additional fainter targets (with reduced precision but thorough time sampling) is possible through on-board data processing. **Five BRITE nanosats are current operational, in low-Earth dusk-dawn polar orbits.**

BRITE-Constellation primarily measures p- and g-mode pulsations to probe the interiors and ages of luminous stars through asteroseismology. The BRITE sample of many of the brightest stars (illustrated in Fig. 1) in the night sky is dominated by the most intrinsically luminous stars, comprising two basic classes: **Hot luminous H-burning stars** (O to F stars), for which analyses of their variability have the potential to help solve two outstanding problems: the sizes of convective cores in massive stars and the influence of rapid rotation on their structure and evolution; and **cool luminous stars** (AGB stars, cool giants and cool supergiants), for which measurements of the time scales involved in surface granulation and differential rotation will constrain turbulent convection models. Mass loss from these stars (especially the massive supernova progenitors) is a major contributor to the evolution of the interstellar medium, so in a sense this sample dominates cosmic "ecology" in terms of future generations of star formation. Moreover, the massive stars are believed to share many characteristics of the lower mass range of the first generation of stars ever formed (although the original examples are long gone).

This proposal requests time to continue a systematic survey of the BRITE primary targets to acquire high-quality reference spectra and accompanying magnetic field measurements using ESPaDOnS. This program was initiated in 14A.

Progress report

We **are performing a complete high resolution magnitude-limited spectropolarimetric survey of potential BRITE-Constellation targets, obtaining observations for all V<4 stars in the sky.** This corresponds to ~600 stars, about half of which are hot stars (F5 or hotter), the other half are mostly cool giants and supergiants. The survey will be accomplished using high resolution spectropolarimeters located on 3 continents, in order to access bright stars at all declinations. The ESPaDOnS component of the survey focuses on stars with intermediate declinations from -20 to -45 deg. This corresponds to approximately 120 stars.

To date we have acquired validated observations of 60 targets, from a total time allocation of 28 hours in 14A/B. For semester 14B we were allocated 17h in A queue (must do). During the first ESPaDOnS runs in August and September we acquired validated observations of 29 targets. The data quality was generally good, but with a few poorer observations acquired during cloudy night. The median SNR was 1850 per pixel. Magnetic fields were detected in 2 of the targets observed this semester. Example line profiles acquired during the first two ESPaDOnS runs of this semester are illustrated in Figs. 2 and 3.

The technical details are described in the following section.

Scientific Justification

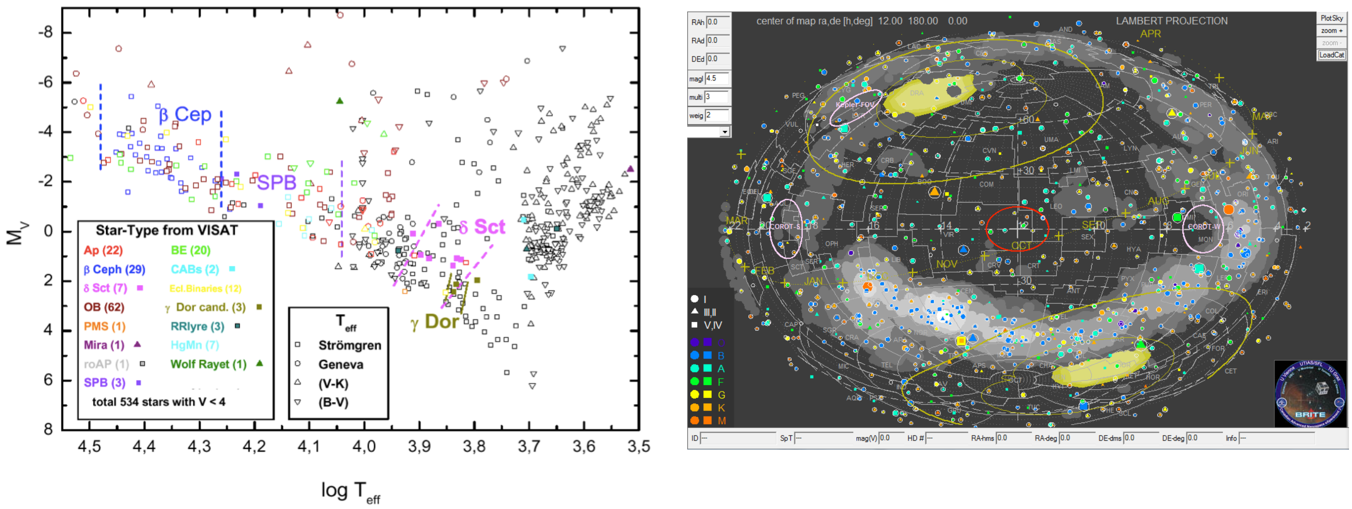

Fig. 1: Left: HR diagram of the brightest BRITE-Constellation targets. Right: Distribution of these targets on the sky, with encoding of spectral type and luminosity class. The BRITE targets span the entire HR diagram of massive and evolved stars, and are distributed across the entire sky.

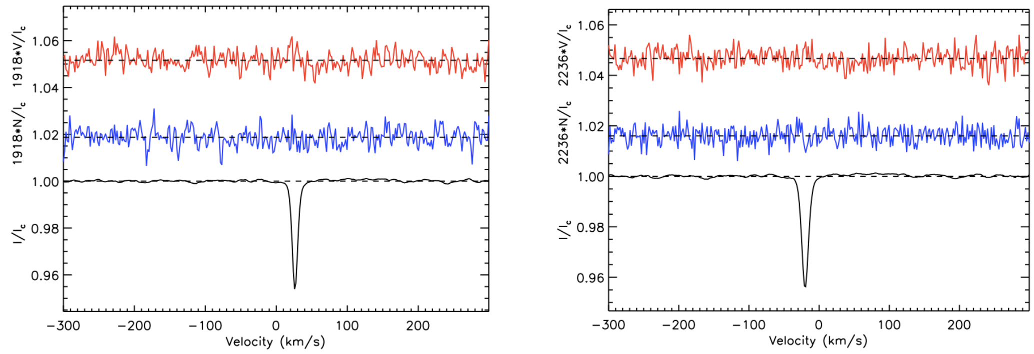

Fig. 2: HD 177241 (K0III) and HD 175775 (G9II/III), two giants for which the best precision was obtained during the first part of the 14B run. Magnetic precision of 0.25 G was obtained in both cases, without any Zeeman detection. This is indicative of the *very low magnetic activity* of some cool giants.

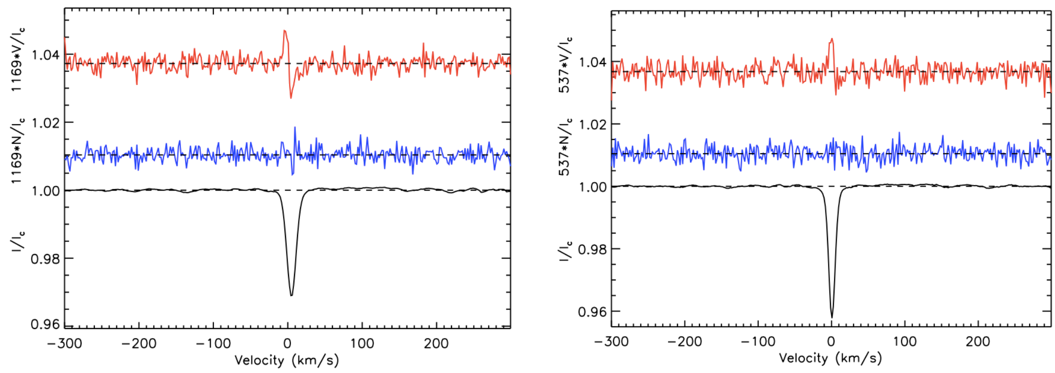

Fig. 3: New magnetic detections obtained in 14B: HD 213009 (G7III) and HD 218670 (K1III). In contrast to HD177241 and HD 175775, magnetic fields are detected in both of these cool giants with an average strength of 1-2 G. These stars represent two of 6 stars for which magnetic detections have been achieved.

Technical Justification

The aim of our program is to acquire high precision spectroscopy and Stokes V spectropolarimetry for the ~600 stars with apparent magnitudes V<4 using 3 spectropolarimeters:

- **Espadons@CFHT:** This program concentrates on stars with -45 < dec < -20 deg. 11h were allocated in 14A and 17h in 14B.
- **Narval@TBL:** This program will concentrate on stars with dec > -20 deg. C. Neiner is the PI. Time already executed is 45h. 28h have been allocated for 14B. 97 targets observed, 11 confirmed magnetic detections.
- **HarpsPol@ESO:** C. Neiner is the PI. Time has not yet been allocated. A proposal is in preparation for resubmission at the next deadline. This program will concentrate on stars with dec < -45 deg.

For each of the ~600 stars we will obtain 1 spectropolarimetric observation in Stokes V with a high S/N. The SNR (and thus exposure time) are derived to reach an upper limit of 50 G for the strength of the surface dipole field (5 G for the longitudinal field) for all stars F5 or earlier, and 5 G (0.5 G for the longitudinal field) for all stars cooler than F5. In any case all spectra will have a minimum S/N of 1000 to obtain the best-quality Stokes I spectrum possible (higher SNRs yield better magnetic precision, but yield little improvement in Stokes I). These data will be used to infer whether the star is detected to be magnetic, as well as to characterise the star and provide stellar fundamental parameters for the BRITE seismology project. For detected stars, we propose conservative follow-up observations to obtain a basic characterization of the magnetic field properties. Our primary aims are to acquire state-of-the-art reference spectra for each star, as well as a high-precision diagnosis of their magnetic fields. Our quality target is a resolving power of at least 65,000, full spectral coverage from 360-1000 nm, and a peak signal-to-noise ratio per 1.8 km/s pixel of over 1,000. At the completion of the survey, we will have obtained one top quality spectrum for the 600 brightest stars - for the first time in a homogeneous way - with significance well beyond a magnetic field survey.

The CFHT component of the survey comprises 121 stars identified using the SIMBAD database. Of these, 17 have been previously observed by other programs with sufficient SNR using Espadons or Narval. Due to the large number of targets, we have summarised their observational properties and total I-times in a PDF file that can be accessed at the following link: https://dl.dropboxusercontent.com/u/7869678/CFHT14B_BRITE.pdf

We have computed exposure times based on the extensively tested exposure time model developed for the MiMeS and Binamics Large Programs. The calculation employs the ESPaDOnS/Olapa ETC, but takes into account spectral type and vsini in order to estimate the exposure time required to reach a particular precision of the surface magnetic field. We have validated our exposure time calculations using the data acquired in semesters 14A/B. Overheads assume fast readout.

Following acquisition, reduction, careful merging and normalisation, the magnetic field measurements and the spectral database (to be reported in dedicated publications) will be made available publicly. Additional time may be requested for follow-up of stars discovered to be of particular interest (e.g. spectroscopically peculiar objects, magnetic stars). Magnetic diagnosis will be performed using Least Squares Deconvolution (e.g. Donati et al. 1997, Kochukhov et al. 2010) using tuned line masks. This procedure has been demonstrated to be the most sensitive approach to detecting and modeling stellar magnetic fields.

This project has excellent legacy value, and is superbly suited to filling RA gaps in the CFHT queue, as it consists of many short OGs with targets distributed more-or-less uniformly on the sky. **The total time required for the survey is 62 hours. 28 hours were allocated in 14A and 14B. We aim to complete the program in 2 additional semesters. We are therefore requesting 17 hours + 1 hour follow-up during semester 15A.**

RA (h): 0-4	4-8	8-12	12-16	16-20	20-24
4.1	10.6	5.8	20.6	17.2	3.5

Table 1: Table of survey time distribution (in hours) as a function of RA. Note that this distribution includes all survey targets to be observed during the entire program.

Students involved

Student	Level	Applicant	Supervisor	Applicant	Expected completion date	Data required
Tahina RAMIARAMANANTSOA	Doctor	Yes	A.F.J. Moffat	Yes	2016/09	Yes
Alexandre David-Uraz	Doctor	Yes	Gregg Wade	Yes	2015/09	Yes
James Sikora	Master	Yes	Gregg Wade	Yes	2015/09	Yes

Linked proposal submitted to this TAC: No

Linked proposal submitted to other TACs: No

Any other expenditure

Relevant previous Allocations: Yes

14A: 11 hours allocated. 38 targets observed. Data are reduced and preliminary analysis carried out. Nearly all spectra meet quality criteria. 3 magnetic field detections.
14B: 17 hours allocated. After completion of 40% of Espadons nights, 29 observations have been obtained. Nearly all spectra meet quality criteria. 2 magnetic field detections so far this semester.

One paper (Shultz et al. 2014, MNRAS) taking advantage of survey observations of a previously-known magnetic star will soon be submitted. An additional half-dozen papers reporting and analysing the new detections are at various stages of preparation.

Related Publications

MOST detects rotating bright spots on the O7.5III star xi Per, Ramiaramanantsao et al. 2014
Search for a Magnetic Field via Circular Polarization in the Wolf-Rayet Star EZ CMa, de la Chevrotière et al. (with Moffat), 2013
The Magnetic Properties of Galactic OB Stars from the Magnetism in Massive Stars Project, Wade et al., 2013
A magnetic confinement versus rotation classification of massive-star magnetospheres, Petit et al. 2013
Discovery of a magnetic field in the rapidly rotating O-type secondary of the colliding-wind binary HD 47129 (Plaskett's star), Grunhut et al. 2013
Precision photometry and variability of massive stars from space, Moffat et al. 2013
Investigating the spectroscopic, magnetic and circumstellar variability of the O9 subgiant star HD 57682, Grunhut et al. 2012
NGC 1624-2: a slowly rotating, X-ray luminous Of?cp star with an extraordinarily strong magnetic field, Wade et al. 2012
Using MOST to reveal the secrets of the mischievous Wolf-Rayet binary CV Ser, David-Uraz et al. 2012
Systematic detection of magnetic fields in massive, late-type supergiants, Grunhut et al., 2010
Discovery of a weak magnetic field in the photosphere of the single giant Pollux, Aurière et al. (with Wade), 2009

Observing run info :

Applicants

Name	Affiliation	Email	Country		Potential observer
David Bohlender	NRC-Herzberg	david.bohlender@nrc-cnrc.gc.ca	Canada		
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Werner Weiss	University of Vienna (Institute of Astronomy)	werner.weiss@univie.ac.at	Austria		
Dr Coralie Neiner	Observatoire de Meudon (LESIA)	coralie.neiner@obspm.fr	France		