THE BRITE SPECTROPOLARIMETRIC SURVEY

C. Neiner[1] and A. Lèbre[2]

Abstract. The BRITE constellation of nanosatellites observes very bright stars to perform seismology. We have set up a spectropolarimetric survey of all BRITE targets, i.e. all ∼600 stars brighter than V=4, with Narval at TBL, ESPaDOnS at CFHT and HarpsPol at ESO. We plan to reach a magnetic detection threshold of $B_{pol} = 50$ G for stars hotter than F5 and $B_{pol} = 5$ G for cooler stars. This program will allow us to combine magnetic information with the BRITE seismic information and obtain a better interpretation and modelling of the internal structure of the stars. It will also lead to new discoveries of very bright magnetic stars, which are unique targets for follow-up and multi-technique studies.

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1 BRITE

The BRITE (BRIght Target Explorer) constellation of nano-satellites monitors photometrically, in 2 colours, the brightness and temperature variations of stars with V≤4, with high precision and cadence, in order to perform asteroseismology (Weiss et al. 2014). The mission consists of 3 pairs of nano-satellites, built by Austria, Canada and Poland, carrying 3-cm aperture telescopes. One instrument per pair is equipped with a blue filter; the other with a red filter. Each BRITE instrument has a wide field of view (∼24°), so up to 25 bright stars can be observed simultaneously, as well as additional fainter targets with reduced precision. Each field will be observed during several months. As of September 2014, 6 nano-satellites are already flying and 5 are observing. Each pair of nano-satellites can (but does not have to) observe the same field and thus increase the duty cycle of observations.

BRITE primarily measures pressure and gravity modes of pulsations to probe the interiors and evolution of stars through asteroseismology. Since the BRITE sample consists of the brightest stars, it is dominated by the most intrinsically luminous stars: massive stars at all evolutionary stages, and evolved cooler stars at the very end of their nuclear burning phases (cool giants and AGB stars). Analysis of OB star variability will help solve two outstanding problems: the sizes of convective (mixed) cores in massive stars and the influence of rapid rotation on their structure and evolution. In addition, measurements of the timescales involved in surface granulation and differential rotation in AGB stars, cool giants and cool supergiants will constrain turbulent convection models.

2 Combining asteroseismology and spectropolarimetry

The study of the magnetic properties of pulsating stars is particularly interesting since, when combined with the study of their pulsational properties, it provides (1) a unique way to probe the impact of magnetism on the physics of non-standard mixing processes inside these stars and (2) strong constraints on seismic models thanks to the impact of the field on mode splittings and amplitudes.

The combination of an asteroseismic study with a spectropolarimetric study has been accomplished for only a couple of massive stars so far, e.g. for the β Cep star V2052 Oph (Briquet et al. 2012). This star

[1] LESIA, Observatoire de Paris, CNRS UMR 8109, UPMC, Université Paris Diderot, 5 place Jules Janssen, 92190 Meudon, France
[2] LUPM - UMR 5299 - CNRS and Université Montpellier II - place E. Bataillon, 34090 Montpellier, France
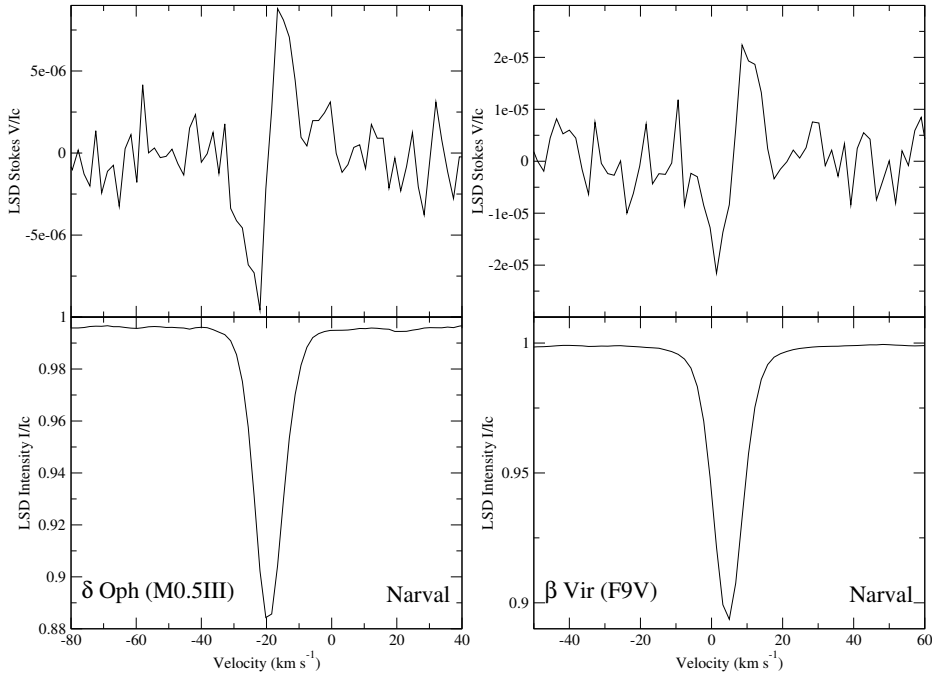
Fig. 1. Examples of magnetic field detections in the single cool stars δ Oph and β Vir. Shown are the LSD Stokes V magnetic signatures (top panels) and LSD intensity profiles (bottom panels).

presents a magnetic field with a strength at the poles of about 400 G that has been modelled thanks to Narval spectropolarimetry (Neiner et al. 2012). Moreover our asteroseismic investigations of this object showed that the stellar models explaining the observed pulsational behaviour do not have any convective core overshooting (Briquet et al. 2012). This outcome is opposite to other results of dedicated asteroseismic studies of non-magnetic β Cep stars (e.g. Briquet et al. 2007). Indeed, it is usually found that convective core overshooting needs to be included in the stellar models in order to account for the observations (Aerts et al. 2010). The most plausible explanation is that the magnetic field inhibits non-standard mixing processes inside V2052 Oph. Indeed the field strength observed in V2052 Oph is above the critical field limit needed to inhibit mixing determined from theory (e.g. Zahn 2011). These findings opened the way to a reliable exploration of the effects of magnetism on the physics of mixing inside stellar interiors of main-sequence B-type pulsators.

Conversely, the deformation of line profiles by pulsations is usually neglected when modelling the magnetic field present in pulsating stars. However, these deformations directly impact the shape of the Stokes V signatures and thus our ability to derive correct magnetic parameters. We recently developed a version of the Phoebe 2.0 code that allows us to model both the line and Stokes V profiles at the same time, taking pulsations into account, thus presenting for the first time coherent spectropolarimetric models including magnetism and pulsations (see Neiner et al. 2014). Thanks to this work, and the combination of seismic and spectropolarimetric data, much more reliable magnetic parameters can be derived for pulsators.

3   The BRITE spectropolarimetric survey

There are $\sim$600 stars brighter than V=4, which are the prime targets of BRITE. We started a systematic survey of all these BRITE targets with spectropolarimetry. Narval at TBL is used for all targets with declination above -20°, ESPaDOnS at CFHT for stars with declination between -45 and -20°, and HarpsPol at ESO for stars with declination below -45°.

From the results of the MiMeS project (Wade et al. 2014), we know that $\sim$10% of all O and B stars have detectable magnetic fields. A similar occurrence is found for A stars and down to F5. The magnetic fields observed in these stars are stable oblique dipoles of fossil origin, with surface strength at the poles from $B_{\mathrm{pol}} \simeq 100$ G to several kG. Therefore we aim at detecting all fields above 50 G. For stars cooler than F5, the magnetic fields have a dynamo origin and $\sim$50% of them are found to be magnetic on average (see Konstantinova-Antova et al. 2014). The cool giants and supergiants, however, have very weak fields with B_{pol}
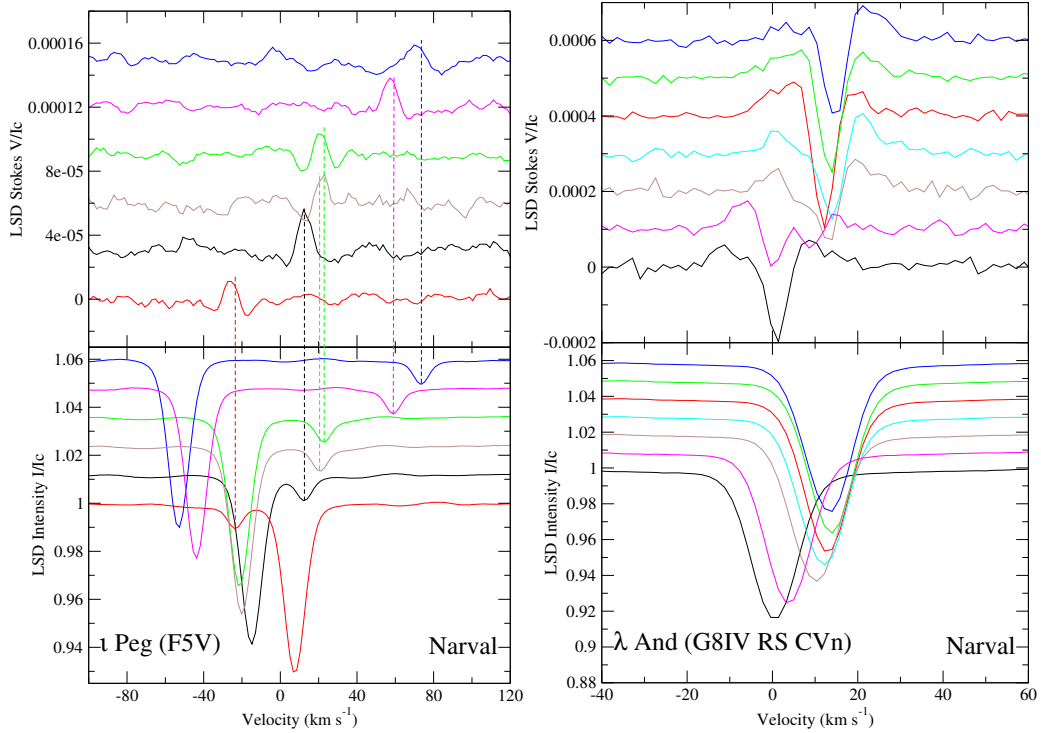
Fig. 2. Examples of magnetic field detections in the cool stars ι Peg and λ And, that have been followed-up with several observations. ι Peg is a binary star: the magnetic signature follows the radial velocity of the magnetic component. The panels are the same as in Figs. 1.

of the order of a few to 10 G. Therefore for these stars, we aim at detecting all fields above $B_{\rm pol} = 5$ G. For each star, we thus acquire one observation with a very high signal-to-noise, to reach the desired detection level.

Thanks to this very high signal-to-noise spectropolarimetric observation of each target, we will:

(1) discover new magnetic stars. This is particularly crucial for massive stars, since only ∼65 magnetic OB stars are known as of today, including only a handful of pulsating massive stars (see Petit et al. 2013). Note that one measurement is enough to detect a field as magnetic signatures appear in Stokes V profiles even for cross-over phases (i.e. when the longitudinal field is null).

(2) help select the best high priority targets for BRITE, i.e. the magnetic massive ones and the most interesting cool ones. BRITE can observe all ∼600 stars in 6 years if each field is observed 3 months on average, but it is useful to observe the most interesting targets first or longer. In particular the BRITE sample includes 11 O stars, 160 B stars (including 29 known β Cep stars, 20 known classical Be stars, and 22 chemically peculiar B stars), 106 A stars (including 6 known Ap stars), 12 eclipsing binaries, 7 known δ Scuti stars, 7 HgMn stars, 3 RR Lyrae stars, 1 known roAp, 22 cool sub-giant stars, several dozens red giants,... Magnetic stars among them will be prime targets for asteroseismology.

(3) determine the fundamental parameters of all targets for the BRITE seismic modelling: effective temperature, gravity, projected rotation velocity (vsini), as well as abundances in particular for magnetic and chemically peculiar stars (HgMn, Ap, Am...). See e.g. Fossati et al. (2014).

(4) provide a complete spectropolarimetric census of bright (V≤4) stars, by combining the Narval, ESPaDOnS and HarpsPol data, as well as archival data.

4 First results

The first Narval and ESPaDOnS observations already led to the discovery of 14 new magnetic stars. All of them are cool stars and several are binary objects. Examples of new detections obtained with Narval are shown in Figs. 1, 2 and 3.
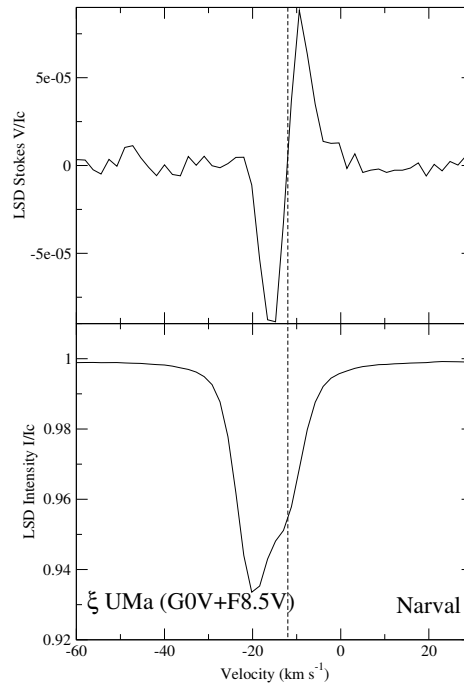
Fig. 3. Example of a magnetic field detection in the cool binary ξ UMa observed only one time. The field can still be attributed to the red-shifted component. The panels are the same as in Figs. 1.

5   Conclusions

By combining the data acquired with Narval, ESPaDOnS and HarpsPol, a complete spectropolarimetric census of bright (V≤4) stars will be available. We will use this database to perform detailed unbiased statistics on the presence of detectable magnetic fields in stars. The data will also be made available to the community as a legacy, through the PolarBase database (Petit et al. 2014).

All the spectra (whether the star is magnetic or not) will also serve to determine the fundamental parameters of the BRITE stars, needed for seismic modelling. For magnetic stars, chemical peculiarities may appear in the spectra and will be studied as well. The best targets will be followed-up to characterise their magnetic fields in details and provide crucial inputs for seismic modelling.

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