

K2 Asteroseismology of hot magnetic stars

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Current scientific status and science objectives

About ten percent of all hot stars host a magnetic field at their stellar surface, detectable with current ground-based spectropolarimeters (Wade et al. 2014, IAUS, 302, 265). How these magnetic fields interact with certain layers deep inside the star and how they influence internal physical processes is poorly understood. They can for example alter the efficiency of the internal mixing of chemical species or play a crucial role in the transport of angular momentum. It is therefore assumed that these magnetic fields are important for the stellar structure and evolution of a large number of hot stars.

As it is not possible to look inside a star and study its interior, we resort to asteroseismology to probe the stellar interior by studying their non-radial stellar pulsations. Tremendous progress in asteroseismology has been made over the last decade, since the space-based missions such as the nominal *Kepler* mission provided a vast amount of data and the asteroseismic techniques improved significantly. However, the number of hot magnetic pulsators studied in detail with high precision space-based photometry is very limited.

With this work, we aim to better understand how the stellar magnetic field influences the non-standard mixing processes governing the interior of hot stars. Through this DDT proposal, we intend to reach this goal by monitoring a significant number of magnetic Ap/Bp stars during Campaign 9 of the K2 mission, pointed towards the Galactic Plane. Moreover, by combining this study with previous K2 monitoring campaigns, we reach a statistically significant number of hot magnetic stars.

From a theoretical point of view, magnetic Ap/Bp stars have various pulsational behaviours (see Aerts et al. 2010, Springer, for a detailed overview). Bp and late A stars host heat-driven gravity modes, respectively being SPB and γ Dor pulsators, probing the core region of the star. Pulsating early A stars are either classified as roAp stars or as δ Sct pulsators, which are more sensitive to the stellar envelope. The former exhibit high-order stochastic magneto-acoustic modes, while the latter as low-order pressure modes. Those heat-driven modes, observed with a high precision thanks to the long timebase, are necessary to perform successful seismic and stellar modelling, inferring the connection between stellar magnetic fields and their internal properties.

The magnetic fields observed in 10% hot stars, and in particular in all Ap/Bp stars, are of fossil origin, *i.e.* remnants from the magnetic field of the original molecular cloud from which the star formed, possibly enhanced by a dynamo during the very early stages of stellar evolution. These fossil fields have a simple configuration, most of the time a simple dipole inclined compared to the rotation axis. Magnetic fields also produce the peculiar chemical surface abundances, giving rise to the 'p' spectral classification. Combining the magnetic information with a seismic study enables us to put strong constraints on the stellar modelling, since it provides information of the stellar surface, through the magnetic study, and the deep interior, probed by asteroseismology. Moreover, comparing the amount of mixing obtained by asteroseismic investigation for a sample of magnetic hot stars with that of a sample of non-magnetic objects would already allow us to corroborate or disprove the theoretical prediction that magnetic fields inhibit mixing in stellar interiors.

At present, only two magnetic pulsating stars have been studied in such detailed manner, namely β Cep (Shibahasi & Aerts 2002, ApJ, 531, L143) and V2052 Oph (Briquet et al. 2012, MNRAS, 427, 483). Although magnetic fields have been detected in a number of other pulsating

stars, there is no detailed seismic modelling available for them. The reason being the current lack of either asteroseismic data for those stars or modelling of their magnetic field. We try to remedy the situation in the framework of this proposal.

Methodology

Target selection To reach our science objectives, we cross-matched all known Ap/Bp stars on SIMBAD with the boresight pointing of Campaign 9. In addition, we also checked the CATALOGUE OF AP, HGMN AND AM STAR (Renson & Manfroid 2009, A&A, 498, 961) for known Ap and Bp stars. In total, 17 Ap/Bp-stars with $8 \text{ mag} \leq V \leq 11 \text{ mag}$ fall on silicon in this observing field.

Long cadence observations are proposed for all targets in our sample, since we aim to study the p - and g -modes and not the roAp pulsations. These frequencies are expected to stay well below the Nyquist frequency ($\nu_{\text{Nyq}} \approx 24 \text{ c/d}$) of the *Kepler* long cadence data (30 min sampling). Previous studies have shown that the pulsations expected have amplitudes of a few millimagnitudes, which are difficult to study with ground-based observations.

General strategy for data interpretation We are expecting data with similar quality as the initial K2 fields and have already developed tools to construct lightcurves from the provided pixel data. In addition, in-house routines are available to correct for any remaining effects of the roll of the satellite (Vanderburg & Johnson 2014, PASP, 126, 948; Buysschaert et al. 2015, MNRAS, 453, 89).

The detrended lightcurves will undergo a detailed frequency analysis to determine whether periodic brightness variations are present. We will use a traditional iterative prewhitening procedure (e.g. Degroote et al. 2009, A&A, 506, 471) to retrieve their significant frequencies. Mode identification for each significant frequency will either be performed by searching for characteristic patterns in the frequencies (or their periods) or by investigating the line-profile variations in timeseries of high-resolution high signal-to-noise spectroscopy.

A high-resolution grid of MESA (Paxton et al. 2011, ApJS, 192, 3) evolutionary tracks has been computed in advance. These include different internal mixing processes with varying efficiency. Seismic models for each stellar model computed with GYRE (Townsend & Teitler 2013, MNRAS, 435, 3406) allow a direct comparison with the observed seismic information for each star.

Ground-based observations We will take high-resolution spectroscopy for the proposed targets who still lack well-defined stellar parameters, using the HERMES spectrograph mounted on the 1.2m telescope in La Palma, Spain (Raskin et al. 2011, A&A 526, A69). Our team owns and hence has guaranteed access to the telescope and its instruments.

Legacy

A limited number of hot magnetic stars have been monitored with high precision space-based photometry for an extended amount of time. Individually studied targets have already hinted towards some effects, but the full scope in a statistical sense remains still unknown. Therefore, the K2 mission provides an unique opportunity to study the intricate interplay between magnetism and stellar structure and evolution in hot stars.