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SPECTRO-POLARIMETRY AT TELESCOPE B. LYOT

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Abstract. We report here on the current capabilities of the 2-m telescope B. Lyot located in the French Pyrénées, and offered to the National and European observers community. This telescope is largely specialized on high resolution spectro-polarimetry. A number of actions in the latest years has been coordinated to reinforce its competitivity in this domain, wrt international standards: improvement of the telescope operations performance and efficiency, internal re-organisation, and development of a new generation spectro-polarimeter. With this new instrument, Narval, open to science observation in December 06, TBL is ready to play a major role in the emerging observational study of stellar magnetism.

1 The telescope Bernard Lyot

The telescope Bernard Lyot (TBL) is a 2-m telescope located in the French Pyrénées. The high altitude ($\sim$ 3000 m) and specific situation of the Pic du Midi provide interesting sky properties in terms of transparency (down to near UV) and in terms of seeing (routinely in the 1" - 1.5" range). The niche and interest for this medium-sized infrastructure in the context of the international panel of observation tools is strongly supported by the following characteristics, as identified in the late 90s, and either improved or consolidated since then:

- strong and specific science cases, taking benefit from the possibility to carry large surveys and/or long timescale monitoring, and specialized instrumentation. Stellar magnetism drives the primary science case with breakthrough results for various classes of stars, even if TBL also provides NIR imaging capability and makes possible to set-up visitor instruments. This science case, addressed though high accuracy and high resolution spectro-polarimetry, is discussed in the following sections.
- site access and management: a safe access to summit and much improved lodging infrastructure have been obtained in 2000 with reduced astronomical staff through a convention with the touristic valorisation of the Pic du Midi;
- reduced team and costs: in the same period, the technical team dedicated to TBL has been significantly reduced down to 15 people (mostly technicians) and focussed on operations (rather than development) of a reduced number of instruments (even though the latest instrumentation, Narval, was finally still developed dominantly by this team);
- high operation quality and efficiency has still been achieved with significantly improved performance since 2000 (photon efficiency in fiber-fed spectropolarimetry improved by $\sim$ 20% ; low technical down-time). This was possible thanks to some critical upgrades and a wide maintenance review and pluri-annual plan concerning the telescope itself and the accompanying equipments such as mechanics (telescope declination fine tracking, dome motorization), electronics (EMC, various control-command and servo loops characterization), pointing and guiding (camera and software), telescope optical alignment characterization and optimisation, operation procedures, etc.

On this basis, TBL observation time has been open to the National community (as a National observation tool and with program selection and support by the thematic National Committees) and to the European community through FP6-Opticon/Access program (supporting the corresponding full operation costs). Some results obtained sofar in the domain of spectro-polarimetry are reminded in the following section whereas the status of the new instrument Narval and its science perspective are described later on.

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2 Achievements with Musicos spectro-polarimeter

The Musicos instrument (Baudrand et al,. 1992, Donati et al. 1997) has demonstrated how powerful the high resolution spectro-polarimetry is for the study of stellar magnetism. Emerging observational results on this topic reveal a number of surprises or discrepancies wrt current models of stellar internal structures, dynamics, and evolution in relation to the magnetic field.

First, the large scale magnetic field can be investigated around an extended sample of stellar classes. Initial detections of magnetism in the case of active low mass stars have been extended to slower rotators (less active) targets, closer to the solar case, such as ξ Boo (Petit et al. 2005). The discussion of detectable magnetic field in more massive A stars (with a radiative envelope) also directly address the origin and evolution of magnetism, as a function of the apparent peculiar chemical abundances to which it appears strongly correlated (Wade et al. 2006, Aurière et al. 2006). Magnetism in younger and even more massive stars was also evidenced (for instance Neiner et al. 2003), providing new direct inputs for further studies of its specific structure and the impact on stellar formation processes (accretion, wind, angular momentum ejection, etc.)

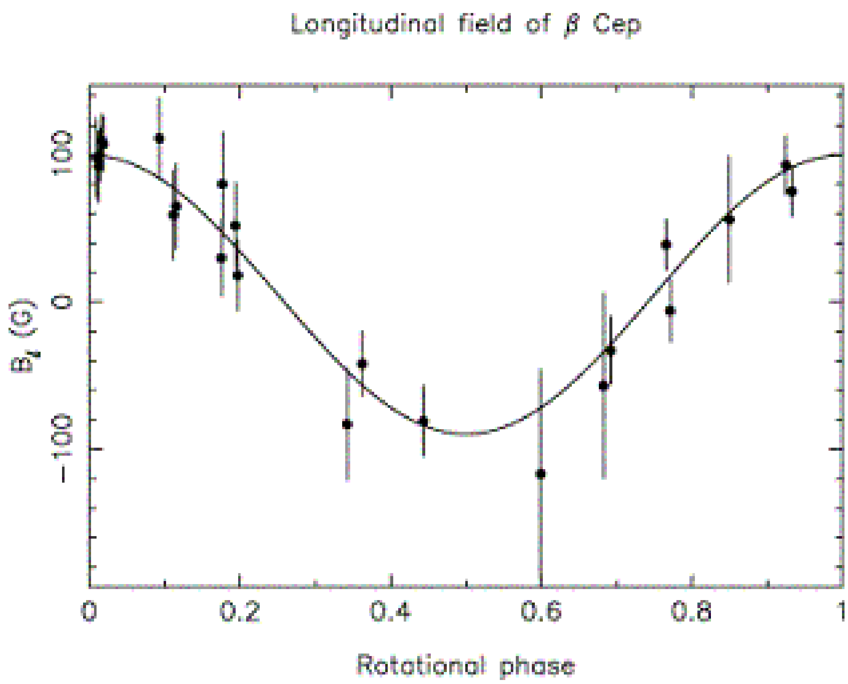

Fig. 1. Detection of the large scale longitudinal magnetic field of a young hot star, βCep, modulated zith the stellar rotation

On top of surveys of large target samples scanning the whole HR diagram, monitoring of some specific targets shows the variation of apparent magnetic signatures along with the stellar rotation. Dense observational phase coverage makes then possible to inverse these signatures into the mapping of the 3D magnetic field vector at the stellar surface.

Finally, monitoring such stellar maps over weeks gives direct indications of the stellar differential rotation which is a key ingredient of the dynamo process in convective envelopes (Petit et al. 2004)

On even longer timescales, the stability of the magnetic structures can be addressed: either the erratic evolution on yearly timescales or the organisation according to a magnetic cycle is about to be discussed for various stellar parameters and compared to the unique (and still not well understood) case of the Sun (Petit et al. 2006).

This rapid and non exhaustive overview illustrates some of the unique results and the strong impact on fundamental stellar physics that high resolution spectro-polarimetry can provide. A large fraction of these results are obviously quite consuming in terms of telescope time, either due to the required size of target samples or due to the need for target monitoring on various timescales. The combination of a very accurate

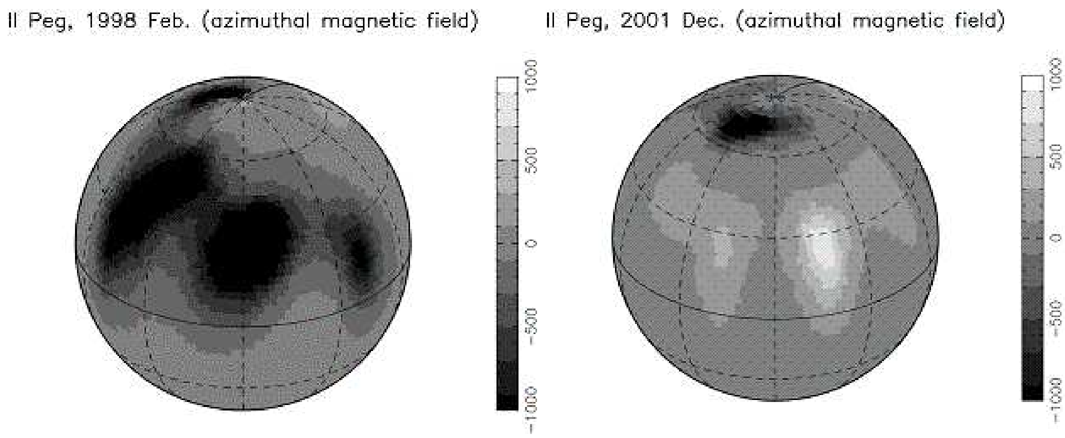

Fig. 2. The structure of azimuthal magnetic field at the surface of iiPeg shows a large modification and polarity inversion on long timescales (between 1998, left, and 2001, right) as in the case of the solar magnetic cycle.

spectro-polarimeter to a medium-sized telescope makes it very appropriate for such purposes.

3 Status and perspective of the new instrument Narval

The new instrument Narval is, as Musicos, a fiber-fed visible spetro-polarimeter. However, the increase of performance will dramatically open-up the potential science impact initiated with Musicos, with sensitivity improved by a factor 30, enlarged spectral domain ($\times$ 3) from 390 to 1000 nm simultaneously, and finer spectral resolution ($\times$ 2) R $\sim$ 65000. Narval shares the same opto-mechanical design as Espadons at CFHT, and detailed instrument description can be found in `http://www.ast.obs-mip.fr/projets/espandons/espadons.html` (also Donati et al., in prep) These instrumental capabilities directly translate into much more efficient observations for large target samples, but also access to new interesting but faint target classes (such as younger (and more distant) stars, very low mass, entirely convective, stars, etc.) and finally detectivity to smaller magnetic fields.

Some outstanding results in these fields have already been obtained with CFHT/Espadons on specific targets. Narval will be very complementary to Espadons: on top of some possible coordinated observations on complementary longitudes for continuous monitoring of some targets, Narval will be available for a much larger number of observing nights as required for most of the in-depth investigations of stellar magnetism. A dedicated working group mandated by PNPS (see `http://www-laog.obs.ujf-grenoble.fr/heberges/pnps/PLAIN/spol/`) identifies high interest and need for typically more than 2000 nights with such an instrumentation, in which TBL/Narval has definitely a primary role to play. The corresponding science case covers the characterization of magnetic structure and the corresponding discussion of dynamo processes over an extended range of stellar parameters, from very hot stars to convective M dwarfs, but also the stellar surface dynamics, influence of binarity, and the interaction with the stellar environments such as winds or disks in the case of young stars.

Following the re-structuration in the late 90s, TBL manpower resource is not dimensioned for new instrument design and development. The development of Narval (PI: M. Aurière) could be performed on the basis of the already existing design for opto-mechanics from Espadons, support and expertise from Espadons team (LATT) and from OMP. Still, most of the effort ($\sim$ 80%) relied on TBL team for electronics control-command and software design, and overall assembly, integration and tests. This challenge comes now to a very positive end since this involvement makes sure the required instrument expertise is well transferred to TBL, as an excellent basis for further good maintenance and follow-up of the instrument in operation.

Narval has now been integrated and fully tested in laboratory in Tarbes. The overall schedule has been reasonably controlled (taking into account a slightly delayed starting point to take full benefit from the experience gained during Espadons integration, and including a few months delay associated with resolving connection issues around cryostat and detector) and costs well estimated. The main properties of the instrument (transmission, polarimetric separation, resolving power, stability) have been satisfactorily checked. It is now being transported to the telescope, for final on-sky tests in November. It is open to first science observation in December 2006.

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