Polarimetric Instrumentation at the DAO

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Observations of stellar magnetic fields have been carried out with the Dominion Astrophysical Observatory's (DAO) 1.8-m Plaskett Telescope for more than 10 years using the in-house built spectropolarimeter, *dimaPol*. This instrument was inspired by John Landstreet's Balmer line polarimeter. I'll briefly describe the instrument and how it has generated interest in polarimetric instrumentation development at HAA. As a result HAA is now involved in an effort to refurbish the Gemini Facility Polarization Modulator (GPOL). I'll provide an outline of this project as well.

1 The DAO Spectropolarimeter: *dimaPol*

Polarimetry is an important tool in studying the Universe. But measuring the polarization of celestial objects can be tricky. The signal is usually quite weak. Various instrumental effects can easily make it nearly undetectable or hard to interpret. The DAO has in-house expertise in this area. In the early 2000s it was decided that polarimetry should become one of DAO's niches. A spectropolarimetric module called *dimaPol* was built for the DAO 1.8-m Plaskett Telescope (Monin et al., 2012). The module was put in service in 2007 and has been extensively used ever since. It was greatly inspired by John Landstreet's Balmer polarimeter (Angel & Landstreet, 1970). *dimaPol* measures circular polarization in Hβ and nearby metallic lines. It uses fast, low-voltage electronic modulation and has no moving parts. This makes it very inexpensive to maintain. It is also very easy to operate. *dimaPol* employs a ferro-electric liquid crystal (FLC) for fast modulation. FLCs are voltage controlled waveplates. This is a first ever use of FLCs in night time astronomy. Since then FLCs have been employed in instruments such as SPHERE/ZIMPOL and HIPPI for extremely high precision polarimetry.

dimaPol has several important advantages. It allows simultaneous detection of polarization signals in the hydrogen Hβ line as well as metallic lines with similar precision. In some stars hydrogen and metals agree well throughout most of the magnetic cycle, while in others a huge discrepancy is observed (Fig. 1). Another advantage is that stars with a wide range of rotational velocities can be studied because the contrast is less affected by rotational broadening. A higher polarimetric precision can be reached thanks to *dimaPol*'s fast switching capabilities. On telescopes that show significant tracking errors fast switching capabilities could be a game changer.

2 GPOL Upgrade

In 2014 an instrument called GRACES connected the Gemini North Telescope to ESPaDOnS, a popular spectropolarimeter on the Canada-France-Hawaii Telescope (CFHT), with the longest astronomical optical fiber employed to date. The

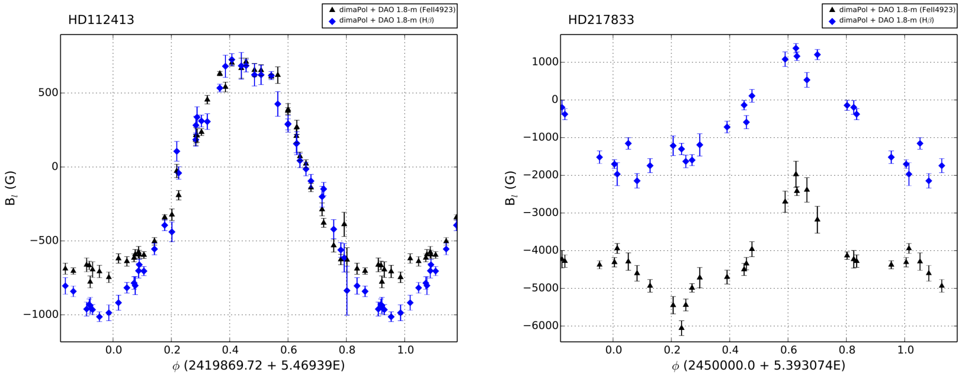

Fig. 1: *dimaPol* longitudinal magnetic field curves (Bohlender, private communication). For each object the magnetic field measurements are phased on the rotation period indicated at the bottom of each figure. (left) HD 112413: the hydrogen Hβ and metallic line measurements agree very well throughout the cycle except near phase 0.0. (right) HD 217833: for this star a very large 4 kG offset exists between the two curves. If the dipole field strength was derived from the metallic lines only it would be overestimated by a factor of four.

GRACES receiver unit is a cassette in GMOS, the Gemini Multi-Object Spectrograph. We explored a possibility of adding a FLC modulator to the GRACES cassette, but the idea was rejected. GMOS is usually mounted on a side port, after the science fold mirror in the Instrument Support Structure. Such a silver-coated mirror placed in the light path at a 45° angle introduces an almost 40 % cross-talk between the Stokes U and V signals (based on an internal study by the Gemini team in 2008). Any polarization modulator has to be placed before such a folding mirror.

There are, in fact, polarimetric modulators called GPOL to be installed before the Gemini telescopes' science fold mirrors. Two identical units were built, one for each of the Gemini North and South telescopes. Each unit employs two waveplates: one for VIS-NIR ($0.34 - 2.5\,\mu$m) and the other for the L-band, centered at $3.5\,\mu$m. Either plate can be independently inserted into the beam and mechanically rotated in order to create polarimetric modulation. A GPOL unit was deployed at Gemini North in 2002, but unfortunately never commissioned.

An instrument upgrade proposal to commission GPOL was submitted by an international team that includes staff from the DAO. The proposal has been accepted and work has begun. Unfortunately, GPOL has now been inactive for almost two decades. A series of verifications are first going to be performed in a lab at the DAO in order to assess the instrument's current condition and the best path forward to upgrade and commission it.

The goal is to commission GPOL with the Gemini Near InfraRed Imager and spectrograph (NIRI). NIRI is equipped with a polarimetric analyzer. The analyzer, however, is behind three oblique reflections so this might affect the polarization properties of the beam. A study of the polarization properties of the coatings used at Gemini is planned as part of the proposed work package. A dual rotating polarimeter is being built for this purpose. The results of the study will help us to better understand possible instrumental polarization effects of the Gemini telescopes.

References

Angel, J. R. P., Landstreet, J. D., *ApJ* **160**, L147 (1970)

Monin, D., et al., *PASP* **124**, 914, 329 (2012)

Clockwise from top left: Dmitry Monin, John Landstreet, Luca Fossati, Claude Catala.