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High-Speed Photo-Polarimetry of Magnetic Cataclysmic Variables

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Abstract

I review recent highlights of the SAAO High-speed Photo-POlarimeter (HIPPO) on the study of magnetic Cataclysmic Variables. Its high-speed capabilities are demonstrated with example observations made of the intermediate polar NY Lup and the polar IGRJ14536-5522.

Keywords: cataclysmic variables - polars - intermediate polars - optical - polarimetry - photometry - X-rays - individual: NY Lup, IGRJ14536-5522.

1 Introduction

SAAOs HIPPO was designed and built in order to replace its highly successful but aging single channel equivalent, namely the UCT (University of Cape Town) photo-polarimeter (Cropper 1985). Its purpose is to obtain simultaneous all-Stokes parameters, of unresolved astronomical sources. In addition, it is capable of high speed, simultaneous 2 filtered, photo-polarimetry in order to permit investigations of rapidly varying polarized astronomical sources. Of particular interest are magnetic Cataclysmic Variables (mCVs).

In the following two sections we demonstrate its capabilities.

2 Photo-Polarimetry the Intermediate Polar NY Lup

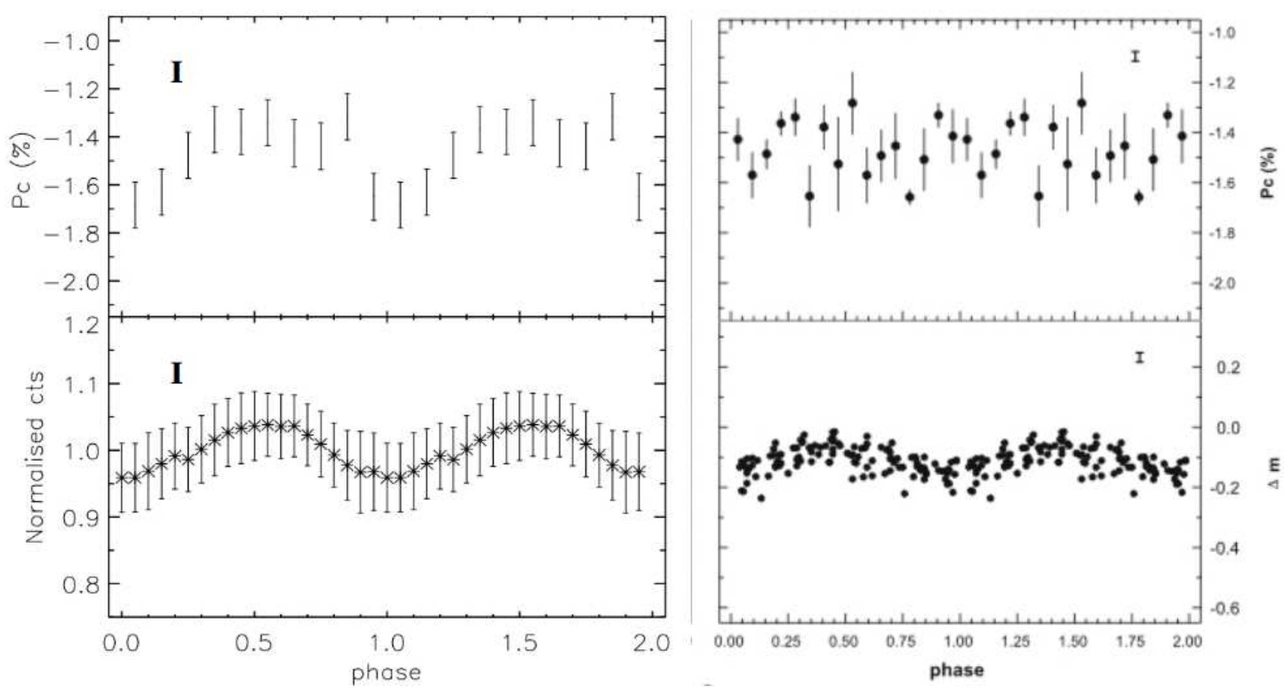

Figure 1: I-band photo-polarimetric observations of the intermediate polar NY Lup. Bottom and top panels are the phase-spin-folded photometry and circular polarization respectively. Left and right panels were made with the 1.9m of the SAAO and the VLT respectively. Figure reproduced from Potter et al. (2012).

Fig. 1 shows two sets of I-band observations of the intermediate polar NY Lup, phase-folded on its white dwarf spin period of 693s. The data in the left hand panels were made with the 1.9m telescope of the SAAO (taken from Potter et al 2012) and the right hand panels were made with the 27 times larger VLT of the ESO (taken from Katajainen et al 2010). The SAAO polarimeter (HIPPO; Potter et al 2010) is equiped with photo-multiplier tubes whereas the VLT polarimeter used a superior, 4 times more quantum efficient, CCD camera.

Both data sets show a spin modulation in the photometry and agree on the average value of circular polarization of $\sim$ -1.5 percent. However, contrary to expectations, the HIPPO observations are by far the superior dataset for the following reasons: The VLT photometry appears to have a residual repeating pattern of about 8 cycles per spin period, probably arising as a result of the different waveplate position angles. The HIPPO circular polarization shows a clear spin modulation whereas the VLT polarimetry displays a more random scatter about the mean. In addition the HIPPO also obtained simulatenously B-band observations. These observations (not shown) clearly show the presence of a circularly polarised spin modulation. The VLT B-band were not only not simultaneous, but also did not detect a spin modulation. Furthermore the HIPPO simultaneously measured linear polarization (not shown) albiet a non-detection.

The superior performance of the HIPPO is because it is optimised to measure polarization variability. Specifically the exposure readout times of the photomultiplier tubes are very fast (sub-second) thus enabling polarization measurements to be made on a timescale much shorter than the intrinsic variability of the polarization. The CCD readout times on the VLT were too slow leading to the smearing of the polarimetric variability and systematic residuals in the photometry.

3 Photo-Polarimetry the Polar IGRJ14536-5522

IGRJ14536-5522 (=Swift J453.4-5524) was discovered as a hard X-ray source by INTEGRAL (Kuiper, Keek, Hermsen, Jonker & Steeghs 2006) and by Swift/BAT (Mukai et al. 2006). A pointed Swift/XRT observation led to the identification with a ROSAT all-sky survey (RASS) source 1 RXS J145341.1-552146, and hence to its optical identification (Masetti et al. 2006). Based on these observations and the presence of short period optical and X-ray periodic modulations, Revnivtsev et al. (2008) classified it as an IP.

Followup photo-polarimetric observations with the HIPPO (Potter et al. 2010) however clearly shows orbitaly modulated photometry and circularly polarization from ~ 0 to ~ 18 per cent, unambiguously identifying IGRJ14536-5522 as a polar (Fig.2, left and right upper panels respectively: from Potter et al. 2010). In addition to the orbital modulation, a close inspection of the photometry and polarimetry reveals short period modulations throughout the orbit which, in addition to being a hard INTEGRAL source, contributed to its initial mis-identification as an IP. The short period modulations are mostly consistent with being due to noise or flickering. However, detailed Fourier analysis of all of the data reveals that some of the data sets show significant singularly persistent peaks that are consistent with QPOs.

The results are shown as a trailed amplitude spectrum in the second row of Fig.2. Between phases 0.2-1.0 the amplitude spectra do not show any significant peaks which indicates that the variations are mostly flickering or noise. However, there is a significant dominating signal centered on 0.0032(1) Hz (5.2 minutes, indicated by the dashed line) between phases 1.0 and 1.3 in both the photometry and the polarimetry. This is clear evidence of a QPO.

In the third row of Fig. 2 we show the normalised photometry and polarimetry during the phase range that is dominated by the QPO. Over plotted are the least squares fit of the QPO frequencies. As one can see, the QPO is very well described by the single dominant frequency as found in the trailed amplitude spectra. The plots in the bottom row of Fig. 2 show the corresponding amplitude spectra for the QPO dominated phase range.

Our polarimetric results unambigously demonstrate that the QPO emissions (photometric and polarimetric) originate from the accretion shock. Ultimately, these are caused by variations in the accretion flow. The most natural place to modulate the accretion flow would be at the threading region, perhaps caused by instabilities as a result of the interaction of the accretion flow with the magnetic field. We are now using MHD modelling to investigate this possibility.

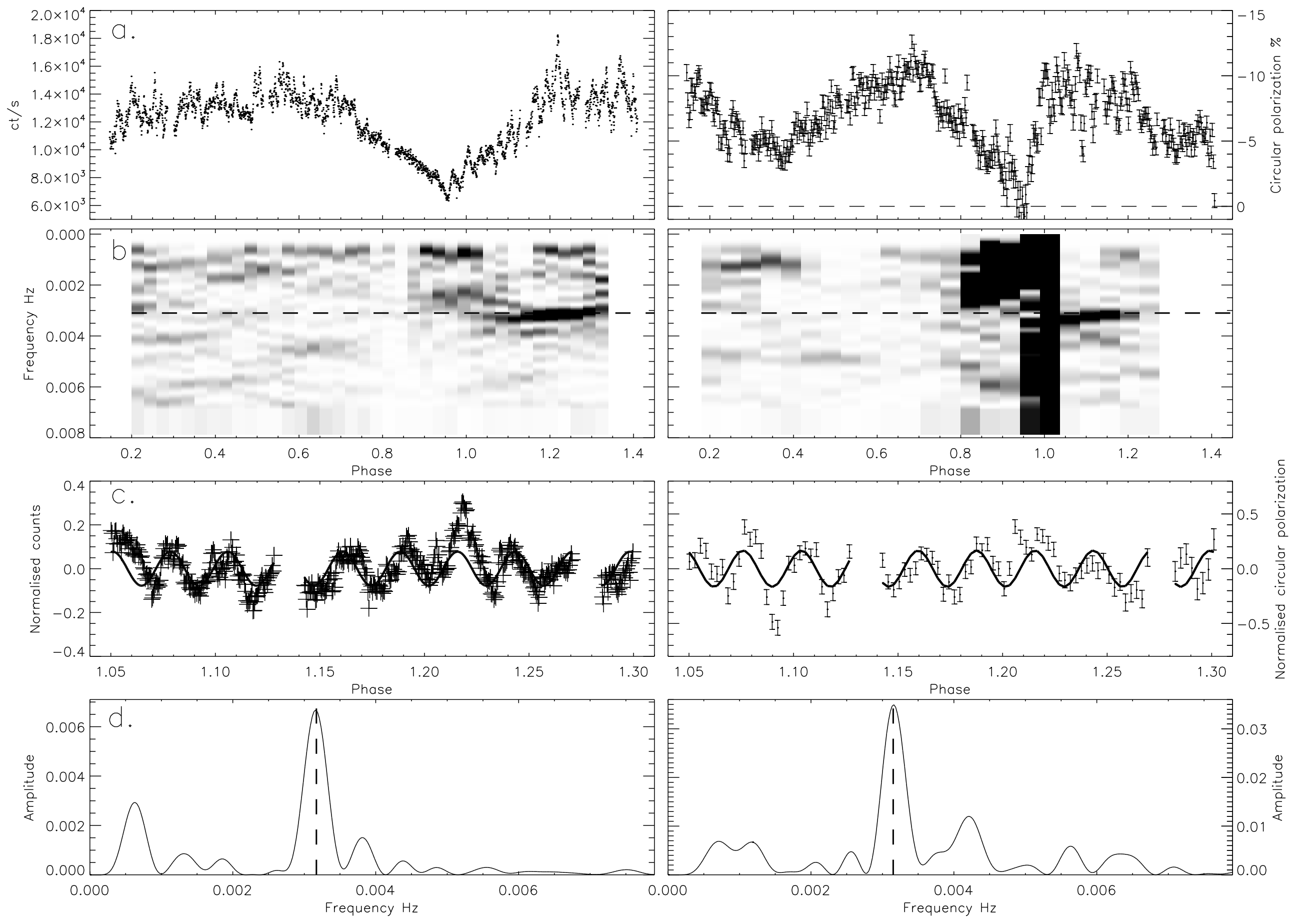

Figure 2: Left plots, a-d: The photometry, the corresponding trailed amplitude spectra, the normalised photometry for the phase range 1.0-1.3 and its corresponding amplitude spectra respectively. The solid curve is the least squares fit using the frequency derived from the trailed spectra (dashed line). Right plots: as in the left plots but for the circular polarization. Figure reproduced from Potter et al. (2010).

4 Conclusions

We have shown that the SAAO HIgh-speed Photo-POlarimeter (HIPPO) is capable of high-speed, multi-filtered, simultaneous all-Stokes observations. It is therefore ideal for investigating rapidly varying astronomical sources such as magnetic Cataclysmic Variables. In particular white dwarf spin modulations and Quasi-Periodic-Oscillations (QPOs).

Acknowledgement

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References

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DISCUSSION

CHRISTIAN KNIGGE: Do you have any speculative ideas already for the origin of the ∼ 6 minute QPOs?

STEPHEN POTTER: Since the QPO is seen in polarized light then it must be associated with the accretion shock region. So best guess is that the QPO may represent an instability in the threading region causing quasi-modulated accretion onto the white dwarf.

PIETER MEINTJES: In one of your slides you showed distinct QPO features with periods of ∼ few seconds. Any idea what may have caused that and is that associated with high or low states in accretion? In other words, are they sometimes more prominent than other times (depending on accretion) and is the polarization level also fluctuating depending on accretion?

STEPHEN POTTER: Photometric QPOs of the order of a few seconds are thought to arise from oscillations in the shock itself. There is not yet a sufficient amount of observational data to see if there is any correlation with e.g. accretion rate and/or magnetic field strengths etc. We detect polarized QPOs at ∼ minute timescales but not ∼ second timescales.