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## Circular polarimetry of magnetic cataclysmic variables

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**Abstract.** Magnetic cataclysmic variables are complex accreting binary systems with short orbital periods. Here we present circular polarimetry of five magnetic cataclysmic variable candidates. 1RXS J161008.0+035222, V1432 Aql, and 1RXS J231603.9–052713 have cyclotron emission, which confirms them as AM Her systems. Our data are consistent with zero values for the circular polarization of 1RXS J042555.8–194534 and FIRST J102347.6+003841 imposing some constraints to the polar classification of these objects.

### 1. Introduction

Cataclysmic variables (CV) are short period binaries composed by a white dwarf (primary) and a late-type main-sequence star. The secondary star fills its Roche lobe, losing material to the primary by the inner Lagrangian point, L1. Due to its angular momentum, this material forms an accretion disk around the white dwarf. Polars (or AM Her systems) are CV in which the primary has a magnetic field in the range from 10 to 100 MG. Such a high magnetic field prevents disk formation. Therefore, the material from the secondary goes to the primary magnetic pole(s) via an accretion stream. Another consequence of the magnetic field is the synchronization of the white dwarf rotation with the orbital revolution.

In the accretion region, near the white dwarf surface, the material is fully ionized producing highly polarized cyclotron emission due to the presence of the strong magnetic field. As a large fraction of the optical flux in polars comes from such region, they have large values of polarization, mainly circular. Consequently, polarimetry is a fundamental tool to classify an object as an AM Her system.

Stokes parameters are also a powerful accreting region diagnosis because they depend strongly on the angle by which that region is observed as well as on its physical properties. The orbital behavior of the linear polarization position angle depends only on the inclination of the system,  $i$ , and the colatitude of

the axis of the magnetic field,  $\beta$ . Besides, the phase interval during which no cyclotron emission is observed also constrains  $i$  and  $\beta$ . Estimates of the value of the magnetic field as well as of some other plasma properties can also be obtained through the modelling of flux and polarization variation with orbital phase (see Wickramasinghe & Meggitt 1985, for accreting column cyclotron models).

In this work we present polarimetric observations of candidates to AM Her systems for which no polarization measurement is reported in the literature. A more detailed description of the observations and data reduction, as well as a deeper analysis of the results, will be presented elsewhere.

## 2. Observations

The observations have been done with the 1.6-m Perkin-Elmer telescope at *Observatório do Pico dos Dias*, operated by the *Laboratório Nacional de Astrofísica*, Brazil, using a CCD camera modified by the polarimetric module described in Magalhães et al. (1996). The CCD arrays used were back-illuminated SITe with  $1024 \times 1024$  pixels. The observations were done in three runs during 2003.

The polarimetric modulus consists of a fixed analyzer (calcite prism), a  $\lambda/4$  retarder waveplate and a filter wheel. The use of a calcite block, which separates the extraordinary and ordinary beams, eliminates any sky polarization (Piirola 1973; Magalhães et al. 1996). The retarder plate is rotated with  $22^\circ 5$  steps. Therefore, a polarization measurement consists of eight integrations in consecutive retarder orientations. The  $\lambda/4$  retarder allows us to measure the circular and linear polarization simultaneously.

The images have been reduced following the standard steps of differential photometry using the IRAF<sup>1</sup> facility. Counts were used to calculate the polarization using the method described in Magalhães, Benedetti, & Roland (1984) and Rodrigues, Cieslinski, & Steiner (1998). The polarimetric reduction was greatly facilitated by the use of the package *pcddpack* (Pereyra 2000). Photometry can be done summing the counts in the two beams.

## 3. Results

In the following sections, we present a short review of the objects and some qualitative results.

### 3.1. 1RXS J042555.8–194534

The ROSAT X-ray spectrum of 1RXS J042555.8–194534 is typical of a polar (Schwope et al. 2000). Its optical spectrum and photometry are also consistent with this classification (Schwope et al. 2002). However, no circular polarization was detected at a level of 2%. More observations - using time resolved optical spectroscopy, for instance - are necessary to understand the nature of this object.

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<sup>1</sup>IRAF is distributed by National Optical Astronomy Observatories, which is operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

### 3.2. FIRST J102347.6+003841

This object was discovered by its radio emission and subsequent optical observations revealed the spectrum of a magnetic CV (Bond et al. 2002). Its optical light curve is compatible with a polar in which most of the flux originates from the reflection of a hot white dwarf on the secondary surface (Would, Warner, & Pretorius 2004). The circular polarization measured was less than 1.5% (Figure 1). This may be interpreted as a negligible contribution from any cyclotron emission to the flux in the R band: less than  $\approx 1\%$ .

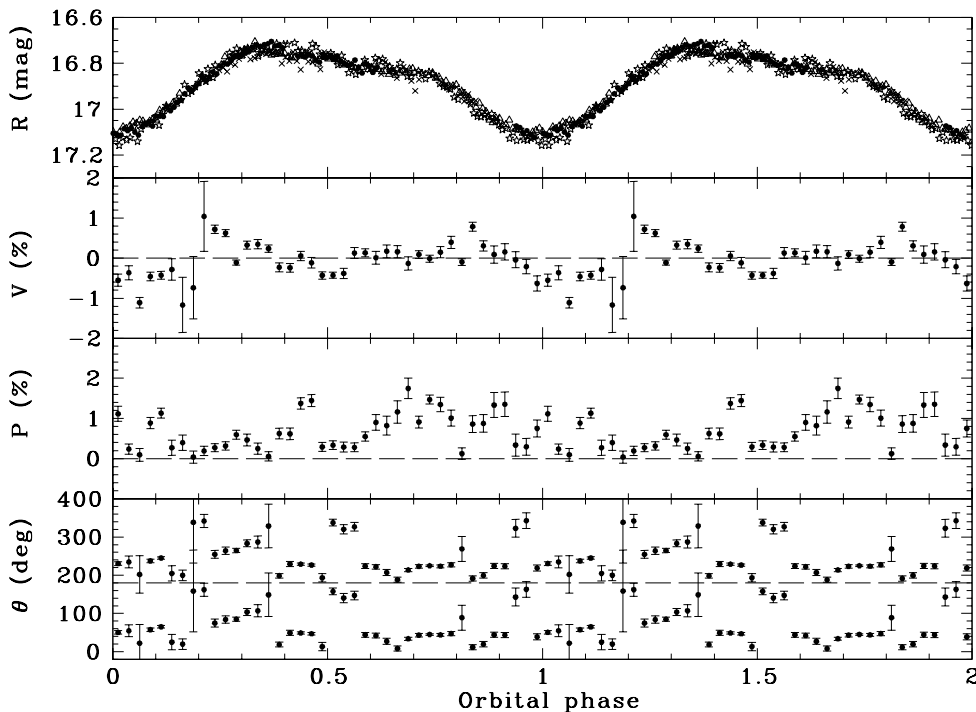


Figure 1. Photometry, circular and linear polarimetry of FIRST J102347.6+003841 in R band from data taken in April 2003.

### 3.3. 1RXS J161008.0+035222

This source is another polar candidate from the ROSAT satellite (Schwope et al. 2000). Optical identification and spectral classification have been done by Jiang et al. (2000) and Schwope et al. (2002). The high values of the measured circular polarization (Figure 2) show that this object is a polar. There was no evidence of occultation of the accretion region in the light curve, indicating that the system may have an one-pole accretion geometry. The small variation of the position angle is consistent with small values of  $\beta$ . Another possible solution is  $i \approx \beta \approx 90^\circ$ , but in this case the accretion region should be out of sight approximately half the orbital period.

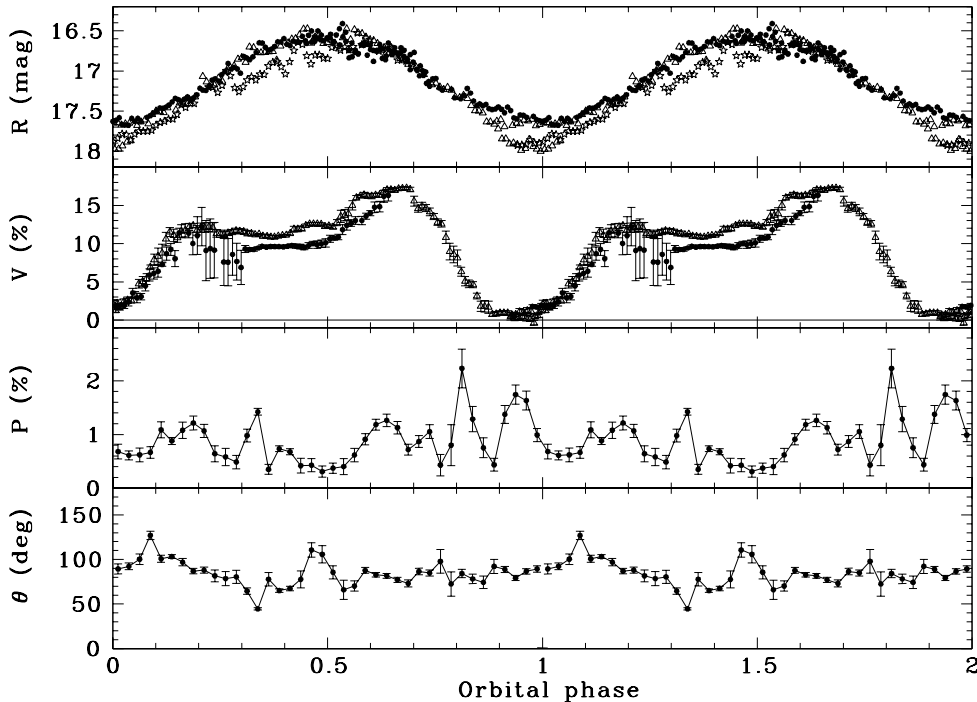


Figure 2. Photometry, circular and linear polarimetry of 1RXS J161008.0+035222 in R band from data taken in April 2003.

### 3.4. V1432 Aql

In contrast with the other objects from this work, V1432 Aql is a well studied CV. Even so, its classification is still controversial: an asynchronous polar (Mukai et al. 2003) or an intermediate polar (Singh & Rana 2003)? Previous attempts to detect circular polarization have only managed to put upper limits to its value: 7% (Watson et al. 1995) and 2% (Friedrich et al. 1996).

We obtained measurements of V1432 Aql in two epochs: August and September 2003. In both epochs, circular polarization of up to 4% was measured. If one considers the classification as an asynchronous polar and uses the ephemerides for the orbital and white dwarf motions from Mukai et al. (2003), the two epochs are separated by approximately half the beat period. The polarization curves displayed different shapes in each observed epoch even if phased with the white dwarf rotation.

### 3.5. 1RXS J231603.9–052713

It is also a polar candidate from ROSAT (Beuermann & Thomas 1993; Thomas et al. 1998; Schwobe et al. 2000). In spite of the partial orbital period coverage, it is evident a large circular polarization variable in phase confirming this object as a polar (Figure 3).

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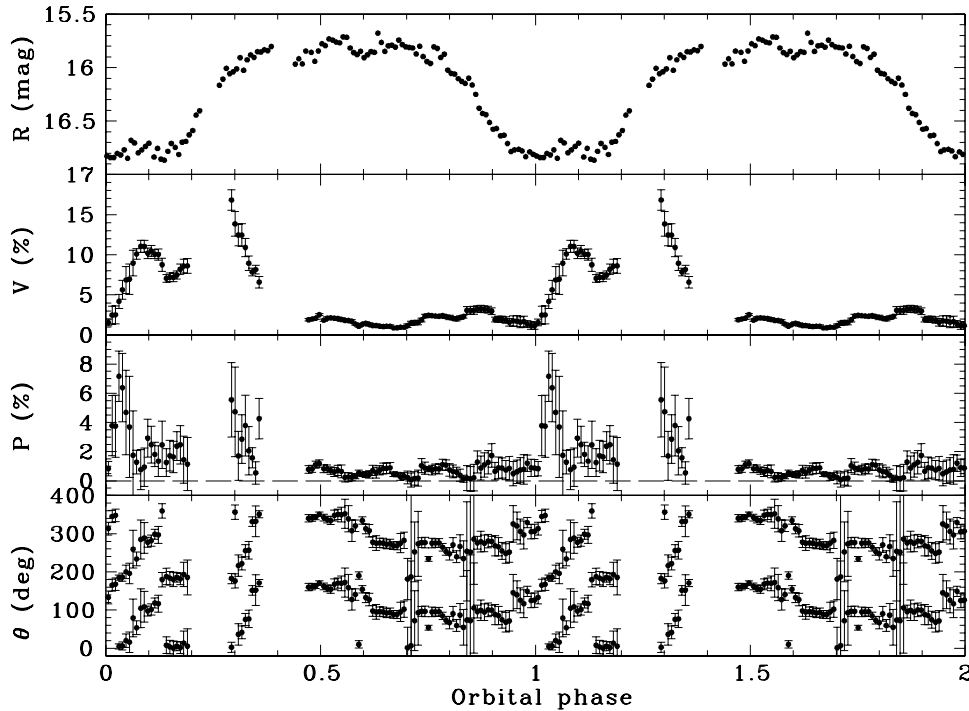


Figure 3. Photometry, circular and linear polarimetry of 1RXS J231603.9–052713 in R band from data taken in September 2003.

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