

# Simultaneous modelling of X-ray emission and optical polarization of intermediate polars: the case of V405 Aur

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**Abstract.** We present a simultaneous modelling of X-ray and optical (UBVRI) emission of V405 Aurigae, the intermediate polar with the highest magnetic field, using the CYCLOPS code. Our preliminary fit to V405 Aur suggests that is possible to model its data using only one post-shock region, differently from literature results.

**Resumo.** Apresentamos a simultânea modelagem da emissão em raios-X e no óptico (UBVRI) de V405 Aurigae, a polar intermediária de maior campo magnético, usando o código CYCLOPS. Nosso resultado preliminar sugere que é possível modelar os dados usando apenas uma região pós-choque, diferentemente dos resultados na literatura.

**Keywords.** magnetic fields — polarization — radiative transfer — methods: numerical — novae, cataclysmic variables.

## 1. Introduction

Intermediate polars (IPs) are a subset of magnetic cataclysmic variables in which the white-dwarf (WD) spin period is much shorter than the orbital period. The material flows along the magnetic field lines forming columns or curtains. The compressed material — the post-shock region — near the WD is responsible by most of the system emission in high energies: Bremsstrahlung and lines emission dominate in X-rays. In optical and IR spectral region, other components are the main emitters, as the disk, when present. Some IPs present optical polarization that comes from cyclotron emission from the post-shock region.

In this study, we present our modelling of the optical polarization and X-ray emission of V405 Aurigae, the intermediate polar that has the highest magnetic field. The observational characteristics of V405 Aur (Evans & Hellier 2004; Pirola et al. 2008) are: flux presents a double-peaked modulation in optical and X-rays; optical circular polarization is variable and alternates between positive and negative values; XMM-Newton spectra show two components with a strong soft X-rays excess. The optical polarization indicates a magnetic field of  $\sim 30$  MG and two post-shock regions. X-rays data were also modelled using two regions, however the geometry is not the same in terms of inclination and colatitude:  $i = 65^\circ$  and  $\beta = 60^\circ$  from X-rays data and  $i = 30 - 50^\circ$  and  $\beta = 90^\circ$  from optical data.

The cyclotron emission of polars (CYCLOPS) code calculates the radiative transport in the magnetic accretion columns considering free-free and cyclotron as emission processes and photoelectric absorption and electron scattering as extinction processes. CYCLOPS permits the fitting of multiband data (Costa & Rodrigues 2009; Silva et al. 2013). This code adopts a 3D-representation treatment and non-homogeneous post-shock region in terms of density, temperature and magnetic field. Hence auto-eclipse, projection effects, and absorptions internal to the binary system are consistently considered. The code also considers the interstellar extinction in X-ray and optical wavelengths. Up to the present time the cyclops is a unique tool.

**Table 1.** Parameters of v405 Aur model.

cyCLOPS input parameters	Fitted values
$i$	$52.0^\circ$
$\beta$	$52.0^\circ$
$\Delta_{long}$	$2.0^\circ$
$h$	$0.11 R_{WD}$
$B_{pole}$	45 MG
$B_{lat}$	$78.0^\circ$
$B_{long}$	$288.0^\circ$
$T_{max}$	128 keV
$\log(N_{max})$	$12.5 \text{ cm}^{-3}$
$\delta_{phase}$	0.194
Model results	Values
$B_{reg}$	24 – 34 MG
$\langle T \rangle$	52.4 keV
$T_{pond}$	26.2 keV
$T_{range}$	10 – 128 keV
$Att(MI)$	0.158
$\chi_{norm}^2$	0.068

## 2. V405 Aur modelling

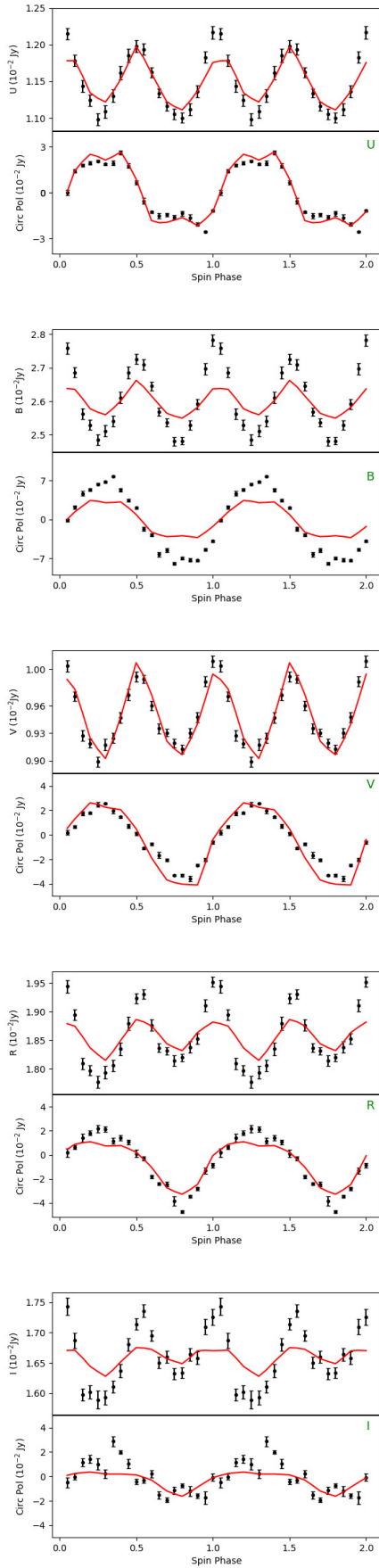
Our goal is to find a model that explains both optical and X-rays V405 Aur data. We show the Table 1 a set of parameter a preliminary fit of V405 Aur data. The fitting was performed using the PIKAIA genetic algorithm and AMOEBA (Charbonneau 1995; Press et al. 1992).

Figures 1 and 2 show a good model obtained by a simultaneous fitting of U, B, V, R, and I light and polarization curves and X-ray spectra.

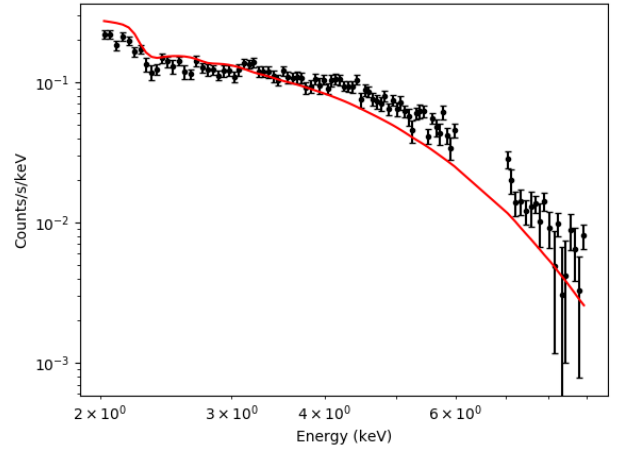
## 3. Conclusions and Prospects

A preliminary fit to V405 Aur suggests that is possible to model its data using only one post-shock region, unlike previous studies.

The present models consider each band represented by only one wavelength. Multiwavelength correction may be the key to



**FIGURE 1.** A good model obtained by a simultaneous fitting of UBVRI light and polarization curves of V405 Aur.



**FIGURE 2.** Our best model fit for the X-rays spectra of V405 Aur.

better fit some bands such as B and I. We also intend to fit simultaneously the light curves in X-rays.

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## References

- Charbonneau, P., 1995, *ApJS*, 101, 309
- Costa, J. E. R., Rodrigues, C. V. 2009, *MNRAS*, 398, 240
- Evans, P. A. & Hellier, C. 2004, *MNRAS*, 353, 447
- Piirola, V., Vornanen, T., Berdyugin, A., & Coyne, G. V. 2008, *ApJ*, 684, 558
- Press, W. H., Teukolsky, S. A., Vetterling, W. T., Flannery, B. P., 1992, *Numerical recipes in FORTRAN. The art of scientific computing*, 29, 32
- Silva, K. M. G. et al., 2013, *MNRAS*, 432, 1587