THE PECULIAR OF?P STARS HD 108 AND HD 191612: THE X-RAY VIEW

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ABSTRACT

The peculiar Of?p spectral category notably contains two stars, HD 108 and HD 191612, that were found to display spectacular line profile variations in the visible domain: these stars apparently alternate between two different spectral states. To discover the origin of this intriguing behaviour, we undertook a multiwavelength campaign, with a special emphasis on X-ray observations. The analysis of the X-ray emission provides crucial information for constraining the nature of these peculiar objects and testing conflicting models. We have obtained high-quality XMM-*Newton* observations of these objects and we present here a preliminary analysis of these data.

Key words: X-rays: stars – Stars: early-type – Stars: peculiar – Stars: individual: HD 108, HD 191612.

1. INTRODUCTION

The Of?p category was introduced by Nolan Walborn in 1972 to describe two stars, HD 108 and HD 148937, with spectra that were slightly different from those of normal Of supergiants. Notably, they exhibit C III lines around 4650Å with an intensity comparable to that of the neighbouring N III lines. In addition, their spectra show sharp emission lines and some P Cygni profiles. A third star was added afterwards to this new class, HD 191612.
Of all Of?p stars, HD 108 is the best studied, but also the most controversial one. Some authors found radial velocity (RV) variations reminiscent of a binary motion, usually with a relatively short period (Hutchings 1975) although Barannikov (1999) derived a much longer period. However, other papers (e.g. Vreux & Conti 1979, Underhill 1994) reported no sign of orbital motion and rather attributed the RV and line profile variations to wind instabilities. To settle the conflicting situation, a new campaign for observing the Of?p stars was thus needed.

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2. OBSERVATIONS OF OF?P STARS

After an intense monitoring at the Haute-Provence Observatory, the visible spectrum of HD 108 revealed an unexpected behaviour (Nazé et al. 2001). The carefully measured RVs do not show any signature of orbital motion, but the star clearly undergoes long-term line profile variations: the Hydrogen and the He I lines pass from emission or P Cygni profiles to absorptions. This behaviour doesd not affect the whole spectrum of HD 108, since some lines remain unchanged, like He II λ 5412. As He I λ 4471 varies while He II λ 4542 does not change, the star then apparently displays spectral type variations, from O6 (in the high emission state) to O8 (in the low emission state). Such a transition already happened in the past (Nazé et al. 2001), and the recurrence timescale is approximately 50-60 years. More recently, Walborn et al. (2003) reported a very similar phenomenon in the spectrum of another Of?p star, HD 191612 (see Fig. 1), but with a much shorter timescale (∼540 days). However, the last member of the Of?p class, HD 148937, does not seem to show significant spectral variations. Note however that the data are rather scarce for this star, and that very long (tens of years) or very short (a few months) variation timescales could have been missed (Nazé 2004).

Barannikov (1999) detected magnitude and color variations for HD 108 and the analysis of recent Hipparcos observations can not exclude a variability for HD 108 and HD 148937. Moreover, a clear modulation (with a period of approximately 540 days) was detected in the Hipparcos photometry of HD 191612 (Nazé 2004, Walborn et al. 2004). These photometric changes and the spectral variations appear correlated (see Fig. 1).

To better understand these peculiar stars, we have requested and obtained XMM-*Newton* observations. The XMM-*Newton* data of HD 108 were taken during Rev. 0494 and revealed a thermal X-ray spectrum, well fitted by a two temperature optically thin plasma (with kT_1 ∼0.2 keV and kT_2 ∼ 1 keV), and a slight overluminosity compared to the classical $L_X - L_{BOL}$ rela-

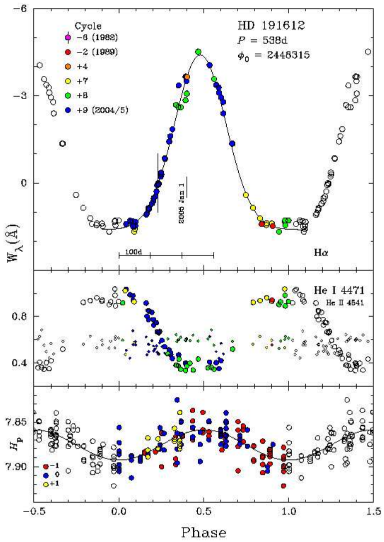

Figure 1. Variations of the EW of the Hα line (top), of the He I *λ 4471 and He* II *λ 4542 lines (middle) and the Hipparcos photometry of HD 191612 (bottom).*

tion (Nazé et al. 2004). In addition, three observations of HD 191612 (Revs 0975, 0981, and 1004) are already available and a last one will be taken in October 2005. These data sample the descending branch of the EW variations (see Fig. 1). A preliminary analysis shows that the X-ray spectrum of HD 191612 is very comparable to that of HD 108, with similar absorbing columns and temperatures (see Fig. 2). No significant changes of the spectral parameters were found when comparing the XMM-*Newton* observations between one another, but the data clearly indicate a small decrease of the X-ray flux, of the order of 15%. Such a small variation in flux could not have been detected before because of the large errors bars on the $ROSAT$ and $Einstein$ data of these stars. Finally, we may note that the $ROSAT$ spectrum of HD 148937 suggests similar spectral parameters, compared to those of HD 108 and HD 191612 (Nazé 2004).

3. DISCUSSION AND CONCLUSIONS

Our multiwavelength observational campaign has revealed many new aspects of the Of?p stars HD 108 and HD 191612. First, we have uncovered spectacular long-term variations of many line profiles that appear correlated with broad-band photometric changes. The recurrence timescale of these variations is ∼540 days for HD 191612 and ∼50-60 years for HD 108, but we note that no sign of orbital motion was detected during the analysis of the RVs of these stars.

To explain this peculiar behaviour, we first postulated the existence of a compact companion that would accrete matter near periastron and emit then X-rays capable of altering the wind ionization structure (Nazé et al. 2001). However, the XMM-*Newton* observations have now shown that the X-ray luminosities of these stars are too low for X-ray binaries (Nazé et al. 2004). In addition, the X-ray flux apparently decreases simultaneously with the visible emission lines, contrary to what could be expected for the compact companion model.

The variations of these peculiar stars could then result from a particular type of wind variability (like e.g. in the case of a variable magnetic field, of stellar pulsations, or of a peculiar, pre-LBV evolutionary stage). On the other hand, the strict, long-term recurrence of the variations, the rather high value of the second temperature fitted to the X-ray spectra and the slight X-ray overluminosity is rather reminiscent of the presence of a colliding wind phenomenon in an eccentric binary composed of two 'normal' stars. A thorough analysis of the latest XMM-*Newton* data of HD 191612 (especially the RGS ones) will certainly help us to distinguish between those models. Note that a last challenge might also be mentioned: the similarity between HD 148937 and the other Of?p stars.

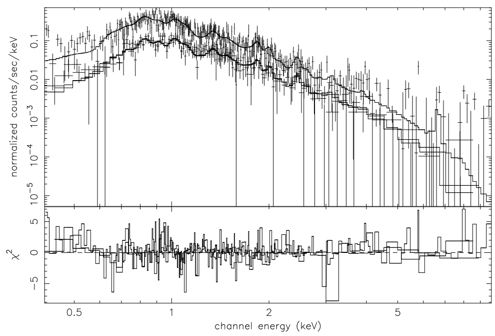

Figure 2. The EPIC spectra of HD 191612 taken during Rev. 1004, superimposed on the best-fit mekal model.

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REFERENCES

Barannikov A.A., 1999, Astron. Let. 25, 169

Hutchings J.B., 1975, ApJ 200, 122

Nazé Y., 2004, PhD thesis, Université de Liège

Nazé Y., Vreux J.-M., Rauw G., 2001, A&A 372, 195

Nazé Y. et al., 2004, A&A 417, 667

Underhill A.B., 1994, ApJ 420, 869

Vreux J.-M., Conti P.S., 1979, ApJ 228, 220

Walborn N.R. et al., 2003, ApJ 588, 1025

Walborn N.R. et al., 2004, ApJ 617, L61