Addressing the Question Posed by the Of?p Stars: HD191612

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There are three known Of?p stars in our galaxy, they are the well known peculiar stars HD108, HD148937 and HD191612. The question mark in their spectral classification was introduced by Walborn (1972) to indicate doubt that these stars are normal Of supergiants. They are characterised by their CIII λλ 4647, 4650, 4651 emission lines being comparable in strength to their NIII λλ 4634, 4640, 4642 emission lines, unlike normal Of supergiants where the CIII lines are always much weaker (Figure 1). In addition the ultra-violet spectra of Of?p stars also exhibit a stellar wind morphology more akin to O-type giants than to Of supergiants. HD108 has been extensively studied (Nazé et al., 2001) and is subject to large and so far unexplained spectroscopic variations, though with a variability timescale of approximately 56 years systematic study is difficult. HD148937 on the other hand, though relatively little studied does exhibit an impressive nitrogen rich ejection nebula, NGC6164 and NGC6165 (Figure 2). Apparently HD148937 has undergone a previous catastrophic mass loosing event, perhaps similar to those of Luminous Blue Variables such as P Cygni and Eta Carinae. Therefore, despite their rarity, the Of?p stars are well worth detailed study as they may represent an important phase in the short, and spectacular, career of a massive star approaching the end of its lifetime.

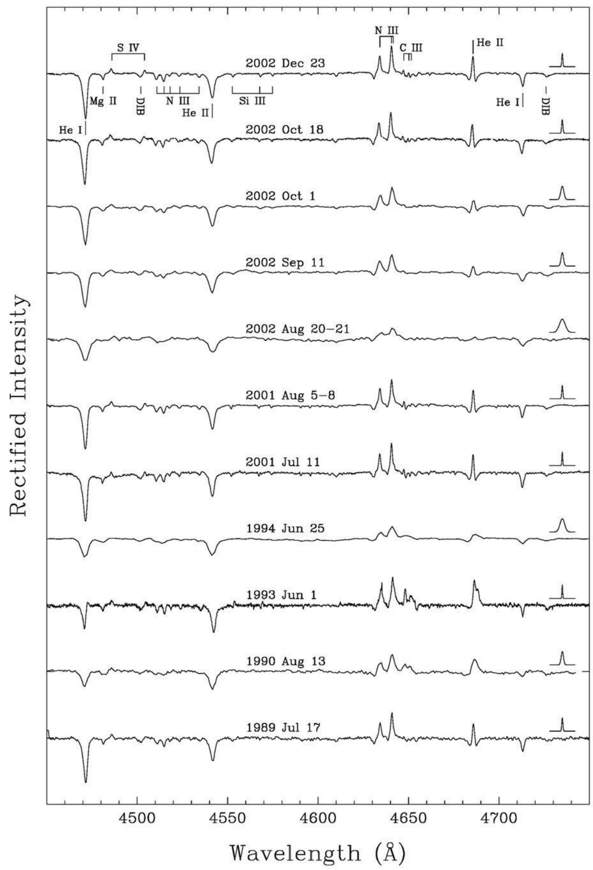

Figure 1. Montage of green region spectral data for HD191612. The June 1st 1993 spectrum of HD191612 was taken during its O6 like Of?p phase and illustrates a typical characteristic of these peculiar stars, namely the CIII λλ 4647, 4650, 4651 lines are comparable in strength to the NIII λλ 4634, 4640, 4642 lines. Note also the strong emission present in HeII λ 4686. Compare with December 2002.

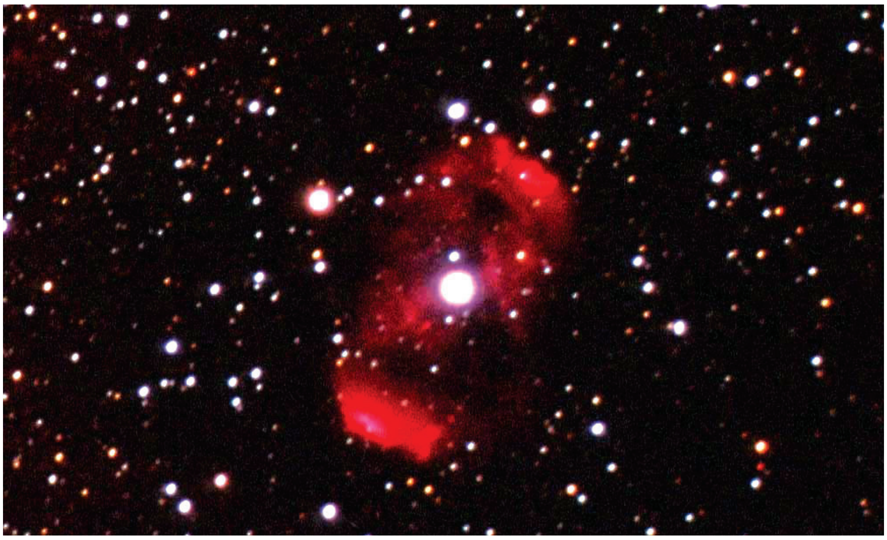

Figure 2. The ejection nebulae NGC 6164 and NGC 6165 surrounding the Of?p star HD148937. This image is courtesy of Mischa Schirmer (ING) from `http://aida.astroinfo.org/`. Note the point-symmetric nature of the nebulae around the central star.

HD191612 came to our attention when N. R. Walborn noticed that the spectrum discussed by Herrero et al. (1992) was different from the discovery spectrum of Walborn (1973). This realisation prompted a thorough check of the historical publication record and the ING archive at Cambridge, as well as a drive to obtain new spectra through ING's service programme. As a result the spectrum was found to be highly variable, appearing to switch between an O6–7 spectral type with the Of?p characteristics and an O8 spectral type in which the CIII emission lines are absent (Figure1). While the data precluded determining any periodic behaviour of the spectrum, Walborn et al. (2003, Paper I) suggested that spectroscopic states might persist for a decade, although one transition occurred on a time scale of only 13 months.

We continued to monitor HD191612 through 2003 and the first half of 2004 using the Isaac Newton and William Herschel Telescopes, as well as several other northern hemisphere telescopes; WIYN, OMM, MMT, OHP, Skinakas, and Loiano. While Paper I had left HD191612 in its O8 state at the end of 2002, May 2003 saw a return to the O6 state, where it remained until a possible transition in December of that year. After a gap of five months the star was recovered in its O8 state implying that stable spectral states last approximately 7–9 months. However an important breakthrough came with the discovery of a periodic behaviour of HD191612 in the Hipparcos photometric survey (Nazé, 2004), with a period of approximately 540±13 days. Combining this with the spectroscopic variability enabled us to refine this period to 538±3 days which is also consistent with Walborn's initial classification in 1973. Indeed all of the data from Paper I, plus data from the 2003/04 campaign, perfectly match this period, with the hotter O6 phase occurring during maximum brightness, accompanied by strong Hα emission and reduced HeI line strengths. This led us to predict that a transition should occur in October 2004 (Walborn et al., 2004, and Figure 3), a prediction subsequently confirmed by our on-going multi-site spectroscopic monitoring campaign which by now had expanded to include the NOT and TNG on La Palma. The blue points in Figure 3 show the onset of transition occurring as predicted with the very smooth change in Hα as it switches from absorption to emission, accompanied by a weakening of the HeI lines.

Despite the wealth of observational data now accumulated for HD191612, this star, like the others in its class, remains enigmatic. Its characteristics cannot be explained by known mechanisms linked to rotation or pulsation. Perhaps the most tempting explanation lies in the regime of binary evolution; a compact companion in an eccentric orbit and small periastron separation is one possible model. Unfortunately, while we can rule out radial velocity variations of HD191612 greater than 10–20 km/s this is not a strong constraint for this scenario, improved observations around a supposed periastron (Hα maximum) are clearly desirable and ongoing.

The relatively short period of HD191612 and wealth of spectroscopic material make it an ideal candidate for detailed study. In the coming year we will continue to monitor HD191612 and look forward to complementing the optical coverage with the acquisition of X-ray data using XMM-Newton (P. I. Nazé). The expectation is that we will obtain X-ray spectra at three phases representing typical O6, O8 and transition states of this star, along with contemporaneous optical spectroscopy.

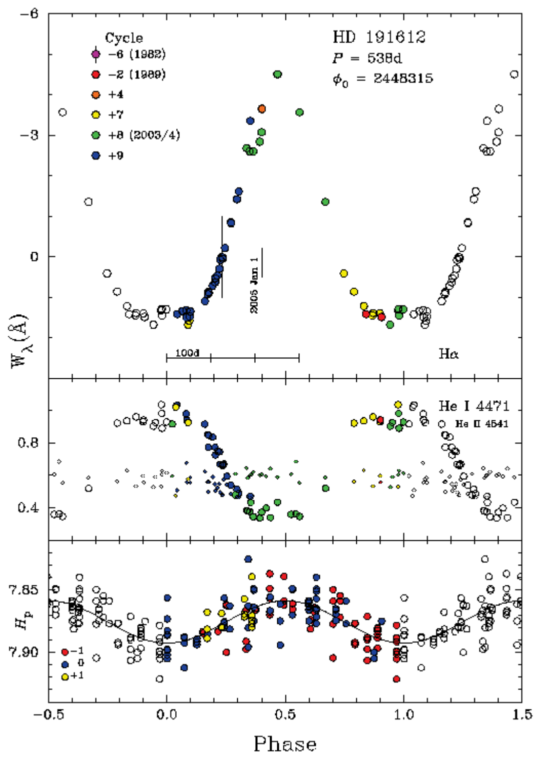

Figure.3 Illustration of spectral and photometric variability of HD191612. The upper panel shows how the Hα line switches from absorption (positive equivalent width) to emission (negative equivalent width). Note the good agreement between the data points covering 22 years, or 16 cycles. The central panel highlights the change in spectral type between the star's O8 type (large He I equivalent width) to its O6 type (small He I equivalent width). The bottom panel shows the light curve obtained from the Hipparcos data.

We would like to thank the many observers and telescope groups who took part in this campaign (see Papers I and II), including Chris benn, Roy Østensen and Gloria Andreuzzi on La Palma. ¤

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