HD 306414, the optical counterpart to the Peculiar X-Ray Transient IGR J11215-5952

Conference or Workshop Item

FULL TITLE
ASP Conference Series, Vol. **VOLUME**, **YEAR OF PUBLICATION**
NAMES OF EDITORS

HD 306414, the optical counterpart to the peculiar X-ray transient IGR J11215-5952

J. Lorenzo and I. Negueruela

Alicante University, Spain

A.J. Norton

Open University, United Kingdom

Abstract. HD 306414 is the optical counterpart to the transient X-ray source IGR J11215−5952, characterised by short flares occurring every 165 days. In order to improve our understanding of this source, we obtained high-resolution spectroscopy of HD 306414 around the time of the February 2007 X-ray outburst. Large variations in the shape of the Hα emission feature and the radial velocities of metallic lines are seen around the time of the X-ray emission.

1. Introduction and Observations

The hard X-ray source IGR J11215−5952 is a peculiar transient displaying very short X-ray outbursts every 165 days (Sidoli et al 2007). The outbursts last only a few days, and strong emission ($L_{\rm X} > 10^{35}{\rm erg\,s^{-1}}$) is only seen for 2–3 days each cycle. The source is associated with the luminous supergiant HD 306414 (Steeghs et al 2006) and shows characteristics typical of wind accretors. Some authors have considered IGR J11215-5952 an example (even a paradigm) of a Supergiant Fast X-ray Transient, while others doubt this association. Here we present the first study of the optical counterpart in order to shed light on its properties.

Spectra of HD 306414 were obtained with FEROS at the ESO/MPG 2.2-m telescope, located at the European Southern Observatory in La Silla. The observations were conducted between December 2006 and February 2007. The resolving power of the spectra is $R \sim 48000$. The spectra cover a wide spectral range, from $\sim$ 3500Å to $\sim$ 9200Å spread over 39 échelle orders. A total of eleven spectra were bias subtracted, flat-field corrected, optimally extracted and wavelength calibrated using the MIDAS data reduction package.

The extracted spectrum is typical of a luminous supergiant. The spectral type is between B0.5 and B0.7, while all luminosity criteria support a very luminous supergiant of class Ia. The spectrum contains several emission lines, most notably Hα, which presents a P-Cygni-type profile in emission. We also note several Fe III emission lines between 5920 and 6032Å. Wolf & Stahl (1985) proposed that the Fe III lines of multiplets 115 and 117 in emission discriminate between normal B supergiants and B hypergiants. This is actually not the case. We have checked that several early-B Ia supergiants show these lines in emission. HD 306414 is a B0.5 Ia supergiant.

We display the evolution of Hα in Figure 1. We notice a very strong variation in radial velocity around the time of the X-ray outburst, which started on February 6^{th} and peaked on February 8^{th}. A blue absorption feature is clearly seen on the February 5^{th} spectrum, suggesting enhanced mass loss. Unfortunately, our coverage of the outburst is not complete. We note, however, that a big excursion in radial velocity was also seen on December 22^{nd}, far away from periastron, though no absorption feature was seen then.

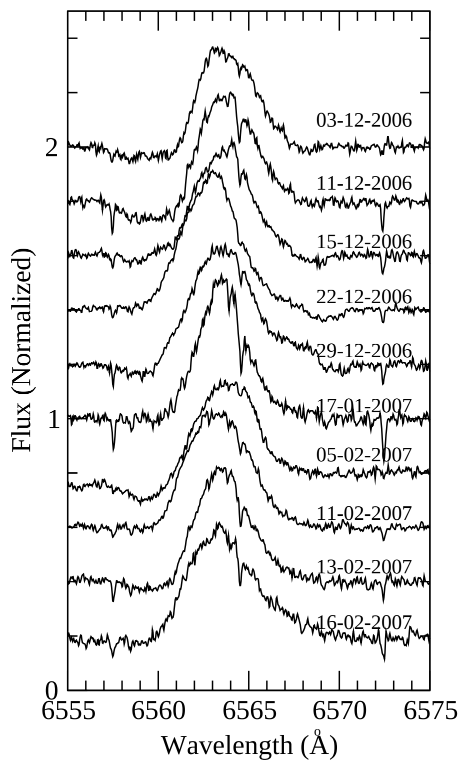

Figure 1. Hα profiles normalized and displayed in temporal order (day-month-year).

2. Radial Velocities (RVs)

First, we calculate radial velocities by estimating by hand the shift with respect to the position of the spectral lines at rest, in order to decide which set of spectral lines would be more suitable for deriving a radial velocity curve. We tried the following lines: Si III triplet ($\lambda\lambda$4552.66, 4567.87, 4574.77), O II ($\lambda\lambda$4590.97, 4596.17) and N II ($\lambda\lambda$4601.48, 4607.15, 4613.87, 4621.39). We conclude that the best behavior corresponds to the Si III triplet. This multiplet has three well-resolved lines covering a substantial range in line strength. When we display the radial velocity as a function of time for the three components of the Si III triplet, we estimate a maximum dispersion of 11.7 km s^{-1}. For the other lines used, we find that the dispersion is 2.5 times larger than the O II lines and 3.3 times larger for the N II lines.

After this preliminary analysis, we used the cross-correlation technique, as implemented in the Starlink/FIGARO HCROSS command, on the Si III triplet lines. A spectrum of the B0.7 Iab supergiant HR 4806 was used as a template. We cross-correlate every individual spectrum using the region of the Si III triplet. The resulting velocities corrected for heliocentric motion are displayed in Figure 2.

2.1. Radial Velocity Curve

In Fig. 2, we fold the radial velocities using the period of 165 days from Sidoli et al (2007). We have tried to match their distribution with a model radial velocity curve. The model assumes $M_{\rm x} = 1.44\ M_{\odot}$ and $M_{*} = 35\ M_{\odot}$, typical of the spectral type. Even though the model does not reproduce well the distribution of the radial velocities, we favour the set of orbital parameters shown in Table 1.

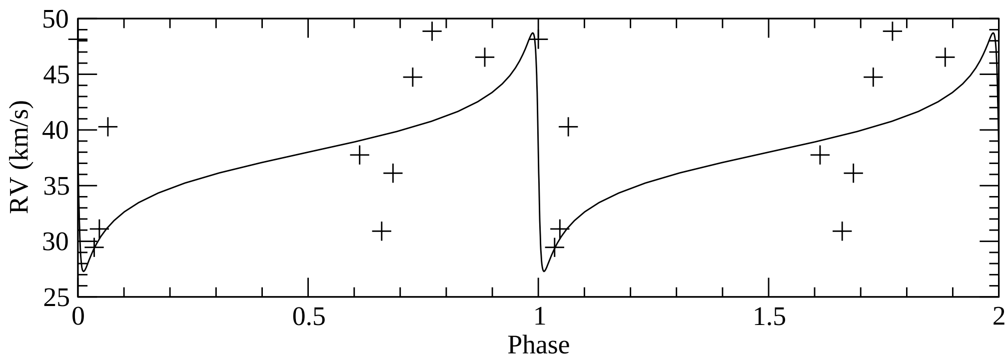

Figure 2. Measured radial velocities (crosses) and model radial velocity curve for the optical component. Two whole periods are displayed.

Table 1. Possible orbital solutions. The semi-amplitude of the velocity curve and the major semi-axes for both components are calculated only for the maximum values of eccentricity, inclination and systemic velocity allowed.

Parameter	Value
Eccentricity	$0.5 < e < 0.88$
Inclination	$60° < i < 90°$
Systemic velocity [km s^{-1}]	$36 < \gamma < 42$
Optical component mass [$M_{\odot}$]	35 (assumed)
K_x [km s^{-1}]	260.25
K_o [km s^{-1}]	10.70
$a_{\rm X}$ [$R_{\odot}$]	403
a_{*} [$R_{\odot}$]	16.6

The measured errors on the radial velocities are negligible on this scale and much smaller than the excursions seen. These excursions are also observed in other systems containing very luminous supergiants, such as GX 301−2 (Kaper et al 2006), and their origin is yet unknown.

3. Conclusions

- Our 11 high resolution spectra cover $\sim$ 75 days. This is less than half the 165-d orbital period and therefore we cannot derive a true orbital solution. We have only checked that the observed radial velocities seem compatible with the expected curve for a high-eccentricity system. We need further spectroscopy of HD 306414 to improve on these results, as the large excursions seen in the radial velocity curve are preventing us from finding an orbital solution.

- We are working on an atmosphere model fit for HD 306414, using the FASTWIND code. This will be used to derive stellar parameters and abundances. The synthetic spectrum will also be used as a template for more accurate RV measurements, expanding our set of spectral lines.

- Two models have been proposed to explain the behaviour of IGR J11215−5952. Sidoli et al. (2007) speculate on the presence of an equatorial disk around the supergiant. The optical spectra do not seem to present evidence for a sizable disk. A very thin disk is still a possibility, but parameters need to be finely tuned for the model to work. Negueruela et al. (2008) have suggested that the wind is clumpy and accretion becomes inefficient when the neutron star is more than $\sim 3R_*$ away from the supergiant. Our simulations show that this scenario is viable if the eccentricity is very high. For an assumed $R_* = 30\ R_\odot$, we must have $e < 0.89$ (otherwise the neutron star hits the supergiant). For eccentricities $0.85 < e < 0.88$, the neutron star is at a distance $r < 3R_*$ for $\sim$ 5 days. For eccentricities smaller than 0.73, the neutron star is never at $r < 3R_*$ (note that this result depends fundamentally on the assumed R_*).

References

Kaper, L., van der Meer, A.& Najarro, F.(2006) A&A 457, 595-610.
Negueruela, I., Torrejón, J.M., Reig, P., Ribó, M. & Smith, D.M. (2008) AIP Conf. Proc., vol.1010, p.252.
Sidoli, L., Romano, P., Mereghetti, S., Paizis, A., Vercellone, S., Mangano, V. & Götz. (2007) A&A 476, 1307.
Steeghs, D., Torres, M.A.P, Jonker, P.G. (2006) A TEL 768.
Wolf, B. & Stahl, O. (1985) A&A 148, 412.