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The massive binary HD 152218 revisited: A new colliding wind system in NGC 6231 ☆

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Abstract

We present the results of an optical and X-ray monitoring campaign on the short-period massive SB2 binary HD 152218. Combining our HiRes spectroscopic data with previous observations, we unveil the contradictions between the published orbital solutions. In particular, we solve the aliasing on the period and derive a value close to 5.604 d. Our eccentricity $e = 0.259 \pm 0.006$ is slightly lower than previously admitted. We show that HD 152218 is probably undergoing a relatively rapid apsidal motion of about $3° \text{ yr}^{-1}$ and we confirm the O9IV + O9.7V classification. We derive minimal masses of $15.82 \pm 0.26\ M_\odot$ and $12.00 \pm 0.19\ M_\odot$ and constrain the radius of the components to $R_1 = 10.3 \pm 1.3\ R_\odot$ and $R_2 = 7.8 \pm 1.7\ R_\odot$. We also report the results of an XMM-*Newton* monitoring of the HD 152218 X-ray emission throughout its orbital motion. The averaged X-ray spectrum is relatively soft and it is well reproduced by a 2-T optically thin thermal plasma model with component temperatures about 0.3 and 0.7 keV. The system presents an increase of its X-ray flux by about 30% near apastron compared to periastron, which is interpreted as the signature of an ongoing wind–wind interaction process occurring within the wind acceleration region.

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1. Introduction

Early-type stars of spectral type O are characterized by strong stellar winds. Though not as extreme as those of their evolved descendants, the Wolf–Rayet stars, these winds combine terminal velocities of a few thousand km s^{-1} and important mass-loss rates (about $10^{-7} - 10^{-5}\ M_\odot \text{ yr}^{-1}$) that significantly affect both the surroundings of the star and its evolution. In a binary system, it is expected that the winds from the two stars collide, producing a density enhanced region known as the wind interaction zone. The shock-heated plasma within this zone is expected to produce an additional contribution to the X-ray emission from the early-type system and, indeed, the early-type binaries are known to be statistically X-ray overluminous compared

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to single stars of the same spectral type (Chlebowski and Garmany, 1991). This extra X-ray emission might display phase-locked modulations, either due to a change of the absorption properties along the line of sight, or to a modulation of the shock strength due e.g. to a varying separation between the components in an eccentric binary. The properties of the shock thus strongly depend both on the geometry of the binary system and on the characteristics of the individual winds. However, these properties often cruelly lack accurate constraints. In this framework, our team is involved in a long-standing effort to study early-type stars in a number of open clusters.

The present work focuses on the short-period binary HD152218, located in NGC 6231 at the core of the Sco OB 1 association. This star is a long known SB2 system (Struve, 1944). Previous papers (Hill et al., 1974; Levato and Morrell, 1983; Stickland et al., 1997; García and Mermilliod, 2001), however, reported conflicting results and we thus decided to re-appraise the orbital properties of this apparently well-studied system. The aim is to bring its orbital and physical parameters on firm ground. As mentioned above, accurate ephemeris and a detailed knowledge of the orbital and physical properties of a system are indeed crucial ingredients for interpreting the X-ray data and for uncovering the possible signature of a wind interaction.

The remaining of this paper is organised as follows. The next section describes the observational material and the data reduction processes. Section 3 aims at unveiling the discrepancies of the previously published orbital solutions. Section 4 discusses the physical properties and evolutionary status of HD 152218 and, in Section 5, we analyse the X-ray observations in the light of the upgraded orbital solution. Finally, Section 6 provides a summary of the present work.

2. Observations and data reduction

2.1. Optical spectroscopy

The present work is based on 42 high-resolution spectra of HD 152218 obtained at the European Southern Observatory (ESO, La Silla, Chile) and at the Cerro Tololo Inter-American Observatory (CTIO). These were acquired during 35 different nights distributed over eight runs between May 1997 and May 2004. The journal of the observations is presented in Table 1.

In May 1997, five (respectively six) high-resolution spectra of the He I λ4471 (respectively He II λ4686) line were obtained with ESO's 1.4 m Coudé Auxiliary Telescope (CAT) at La Silla, using the Coudé Echelle Spectrometer (CES) equipped with the Long Camera (LC). The detector used was ESO CCD#38, a Loral 2688 × 512 pixel CCD with a pixel size of 15 × 15 μm. The slit width was chosen to achieve a nominal resolving power of 70,000–80,000. The effective resolving power as derived from the FWHM of the lines of the ThAr calibration exposures is 65,000–75,000. Typical exposure times were of the order of 30 min and the average signal-to-noise ratio (SNR) is about 140. The observed wavelength domain is centered on the He I λ4471 or He II λ4686 line and is ~45 Å wide.

Another set of three echelle spectra over the range 3850–5790 Å was obtained with the Bench-Mounted Echelle Spectrograph (BME) attached to the 1.5 m CTIO Ritchey–Chrétien Telescope, during a 5-night run in June 1999. Forty-nine orders were observed using the KPGL2 316 lines mm^{-1} grating as a cross-disperser. The detector

Table 1
Journal of the spectroscopic observations of HD 152218

HJD (days)	$\phi_{\rm HeI}$	$\overline{\rm RV_{\lambda,1}-\gamma_{\lambda,1}}$ (km s^{-1})	$\overline{\rm RV_{\lambda,2}-\gamma_{\lambda,2}}$ (km s^{-1})
621.673[a]	0.406	−25.00	−29.31
622.642[a]	0.579	63.69	−133.73
622.755[a]	0.599	80.30	−123.20
623.648[a]	0.759	151.20	−200.79
623.762[a]	0.779	163.30	−188.40
624.590[a]	0.927	74.35	−116.83
624.722[a]	0.950	13.36	9.05
625.626[a]	0.112	−158.93	209.21
625.734[a]	0.131	−171.70	233.10
626.591[a]	0.284	−104.57	166.73
626.716[a]	0.306	−85.00	141.40
1299.883[c]	0.430	−7.56	−5.01
1300.882[c]	0.608	94.15	−107.22
1301.883[c]	0.787	152.44	−201.56
1302.901[c]	0.968	−2.09	0.46
1304.902[c]	0.325	−82.39	134.85
1323.853[c]	0.707	132.51	−175.86
1327.796[c]	0.411	−11.80	−9.25
1328.905[b]	0.609	82.27	−124.90
1329.855[b]	0.778	147.17	−199.78
1331.882[b]	0.140	−182.39	213.02
1669.812[c]	0.442	−6.42	−3.87
1670.804[c]	0.619	96.65	−114.87
1670.918[c]	0.639	108.37	−132.91
1671.828[c]	0.802	153.10	−200.44
1672.865[c]	0.987	−12.61	−10.06
1673.878[c]	0.168	−168.93	211.74
2037.812[c]	0.110	−172.15	221.33
2037.903[c]	0.126	−174.37	222.99
2039.800[c]	0.465	−3.87	−1.32
2040.859[c]	0.654	111.51	−142.01
2381.695[c]	0.474	−2.42	0.13
2382.692[c]	0.652	109.41	−147.06
2383.691[c]	0.831	149.50	−193.52
2782.709[d]	0.033	−98.31	129.27
2783.748[d]	0.219	−148.99	194.69
2784.699[d]	0.389	−17.66	−15.11
3130.843[d]	0.156	−173.97	223.41
3131.716[d]	0.312	−85.25	133.87
3132.730[d]	0.493	4.66	3.89
3133.760[d]	0.677	115.83	−163.34
3134.723[d]	0.849	141.10	−189.24

Column 1 lists the Heliocentric Julian Date (in format HJD – 2,450,000) at mid-exposure. The next three columns present the phases (calculated from the He I-line SB2 orbital solution of Table 4) and the averaged primary and secondary radial velocities computed in the respective systemic velocity frames (see Section 3.3). Superscripts in Column 1 indicate the instrument setup: [a] CES + ESO – CAT, [b] BME + CTIO 1.5 m, [c] FEROS + ESO 1.5 m, [d] FEROS + ESO/MPG 2.2 m.