 

# The preliminary orbit of the new massive binary HD 93249

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**Resumen** / El OWN Survey es un monitoreo espectroscópico de alta resolución de estrellas tipo O y WN visibles desde el hemisferio Sur y cuya multiplicidad es desconocida. El proyecto empezó hace más de diez años y ha descubierto un importante número de nuevas binarias y otros sistemas múltiples. En este contexto, presentamos la primera órbita espectroscópica de la estrella HD 93249, el miembro más brillante del cúmulo abierto Trumpler 15, y demostramos que se trata de un sistema de corto período compuesto por una estrella primaria de tipo O9 III y una secundaria de tipo espectral B temprano.

**Abstract** / The OWN Survey is a high-resolution spectroscopic monitoring of Southern O and WN-type stars, whose multiplicity status is unknown. This project started more than ten years ago and it has discovered an important number of new binaries and other multiple systems. In this context, we present the first spectroscopic orbit of HD 93249, the brightest member of the Trumpler 15 open cluster, demonstrating that this is a short period binary system composed of a primary star of type O9 III and an early B-type secondary star.

*Keywords* / stars: massive — binaries: spectroscopic — stars: individual (HD93249)

## 1. Introduction

The OWN survey is a high resolution optical spectroscopy monitoring of Southern O and WN stars for which the multiplicity status was not known at the time the project started in 2006 (Gamen et al., 2007; Barbá et al., 2014, 2017).

HD 93249 ($\alpha = 10^{\rm h}\ 44^{\rm m}\ 43.9^{\rm s}$, $\delta = -59^\circ\ 21'\ 25''$, J2000.0; $V = 8.48$) is the brightest star in the Trumpler 15 (Tr 15) open cluster. It was first classified as O9 III by Walborn (1973). This classification was confirmed in other works, and most recently by Sota et al. (2014), who also pointed out to the double-lined binary nature (SB2) of this system, based on information provided by the OWN survey.

There are many determinations of the distance to Tr 15 in the literature, which are not always in agreement. However, there is consensus about the open clusters Tr 14, Tr 15, Tr 16 and Collinder 228 (Co 228) being part of the Carina Nebula complex.

Mel'Nik & Dambis (2009) calculated the Hipparcos trigonometric parallax as the median value of the parallaxes of individual stars in Tr 15 finding a distance $d = 3$ kpc. They also calculated distances to Tr 14, Tr 16, and Co 228 obtaining 2.8, 2.1, and 2.0 kpc, respectively.

The individual distance to HD 93249 was recently estimated in $d = 3097^{376}_{305}$ pc by Bailer-Jones et al. (2018) based in the *Gaia* parallax (DR2). A similar value, namely $d = 3162$ pc, was determined by Maíz Apellániz & Barbá (2018) through the spectrophotometric method.

Shull & Danforth (2019) made an analysis of 29 O stars located in the Carina Nebula Region star clusters (the only Tr 15 star included in the study is HD 93249). They found a common distance of $2.87 \pm 0.73$ kpc based on the Gaia parallax and spectrophotometric distances of $2.42 \pm 0.29$ kpc or $d = 2.60 \pm 0.28$ kpc (distances to HD 93249 resulted between 2.52 and 2.76 kpc). The spectrophotometric distances depend on the adopted absolute magnitudes.

HD 93249 and the second brightest star in Tr 15, Tr 15 2 (CPD –58 2659B), were identified as the possible driving stars of an Extended Red Object (ERO) towards the direction of Tr 14, which would be an indication of the interaction among the massive stellar winds of both open clusters, thus supporting the idea that they are at a similar distance (Sexton et al., 2015). These authors also proposed that HD 93249 is a runaway star that produces the bowshock located at 7.8 arcsec, almost coincident in direction with the proper motion of HD 93249 (see also Kobulnicky et al., 2016).

Here, we present the first radial-velocity orbit of HD 93249. The paper is organized as follows: the spectroscopic data is described in Sec. 2.; the radial velocity measurements are explained in Sec. 3.; the preliminary orbital solution is shown in Sec. 4.; the fundamental parameters of the system components are discussed in Sec. 5.; and our conclusions are presented in Sec. 6.

## 2. Observations

Thirty-four high-resolution spectra were collected during several observing runs between 2008 and 2019. We employed the échelle spectrographs attached to the 2-m

Table 1: Details of the instrumental configurations used in this work.

| Observatory + Spectrograph | $\Delta\lambda$ [Å] | $R$ | $n$ |
|---|---|---|---|
| CASLEO + échelle/REOSC | 3600–6100 | 15 000 | 18 |
| La Silla/ESO + FEROS | 3570–9210 | 46 000 | 11 |
| Las Campanas + échelle | 3500–9850 | 40 000 | 5 |

class telescopes in Argentina and Chile, i.e. Jorge Sahade, CASLEO, Argentina; Irenée du Pont, Las Campanas (LCO), Chile; and MPG/ESO 2.2-m, La Silla (LS/ESO), Chile.

The instrumental configurations are described in Table 1, where in successive columns we give the observatory and spectrograph identification, the wavelength coverage ($\Delta\lambda$), the spectral resolving power ($R$), and the number of spectra collected ($n$).

Data from CASLEO and LCO were processed and calibrated using standard IRAF* routines contained in the CCDPROC and ECHELLE packages; while La Silla observations were reduced via the FEROS pipeline supported by ESO.

## 3. Radial velocity measurements

This preliminary work is based on radial velocities (RVs) of the He I $\lambda$5876 absorption line. We choose this particular spectral line for the first orbital analysis because it presents a high signal-to-noise ratio in most of our data and its wavelength is long enough to allow distinguishing both binary components at quadrature phases. Fig. 1 shows spectra obtained during two opposite quadratures in the regions containing the He I $\lambda$4471 and Mg II $\lambda$4481 lines, and He I $\lambda$5876 lines, respectively. The arrows indicate the positions of the faint lines corresponding to the secondary component.

Radial velocities were measured using the NGAUSS task within the IRAF-STSDAS package. The profiles of the He I $\lambda$5876 line in several spectra obtained at quadrature phases were first fitted with two different Gaussian functions. We soon noted that the Gaussian amplitudes and widths obtained for each component were very similar from spectrum to spectrum. Next, we decided to adopt for each binary component the average Gaussian amplitude and width from those individual fits, and leave them as fixed parameters to then fit the central wavelengths and thus determine the corresponding RVs.

## 4. Orbital solution

We searched for periodicities in the 34 RV measurements of the primary component using the online tool provided by the NASA Exoplanets Archive**, determining a most probable period $P$=2.98 d.

*IRAF is distributed by the National Optical Astronomy Observatories which are operated by the Association of Universities for Research in Astronomy, under collaborative agreement with the US National Science Fundation.

**https://exoplanetarchive.ipac.caltech.edu

Table 2: Preliminary orbital parameters of the SB2 system HD 93249.

| Parameter | Unit | Primary | Secondary |
|---|---|---|---|
| $P$ | [d] | $2.97968 \pm 0.00001$ | |
| $T_{\rm periastron}$ | [HJD] | $2454985.393 \pm 0.005$ | |
| $V_0$ | [km s$^{-1}$] | $-5.0 \pm 0.4$ | |
| $e$ | | $0.0121 \pm 0.0085$ | |
| $\omega$ | [°] | $347 \pm 44$ | |
| $K_i$ | [km s$^{-1}$] | $42.5 \pm 0.6$ | $92.6 \pm 0.9$ |
| $a_i \sin i$ | [R$_\odot$] | $2.48 \pm 0.04$ | $5.42 \pm 0.04$ |
| $M_i \sin^3 i$ | [M$_\odot$] | $0.52 \pm 0.03$ | $0.24 \pm 0.02$ |
| $q$ [M$_2$/M$_1$] | | $0.46 \pm 0.01$ | |
| $r.m.s.$ | [km s$^{-1}$] | 1.5 | |

This period was fed as initial value into the orbital parameter fitting code GBART, adapted from Bertiau & Grobben (1969). According to the spectral resolution, we gave weights of 1 (LCO and LS/ESO) or 0.5 (CASLEO) to the measured RVs. The orbital parameters resulting from our best fit are presented in Table 2 and illustrated in Fig. 2.

## 5. Discussion

A quick inspection to the RV orbital solution presented in Table 2 shows that the derived minimum masses are small, which points to a low orbital inclination. If we assume for the primary O9 III a mass of $M_1 \sim 22$ M$_\odot$ (Martins et al., 2005), the orbital inclination would be as low as $i \sim 17°$ and the mass of the secondary component would be $M_2 \sim 10$ M$_\odot$, suggesting a B1–3 V star (see e.g. Hohle et al., 2010), in good agreement with the detection of faint He I and Mg II features in its spectrum (see Fig. 1). In a future stage of this investigation, we plan to disentangle the primary and secondary spectra, which will allow a more robust determination of their spectral types.

Our preliminary characterization of the secondary component can be used to refine the spectro-photometric distance to HD 93249. If we assume for the secondary star a B1 or B2 spectral type, and a luminosity class V, its flux would amount from 14 % to 4 % of the flux of the primary O9 III component, and thus the observed composite $V$ magnitude (adopting $E(B-V) = 0.39$ and $R_V = 3.82$ from Maíz Apellániz & Barbá, 2018), would correspond to a distance of 3.0 or 3.1 kpc, suggesting a negligible influence of the secondary companion on the spectro-photometric distance.

Assuming an orbital inclination close to 17° and radii for the O9 III and early-B V components from Martins et al. (2005), i.e., $R_{\rm O9III} = 13.4$ R$_\odot$ and $R_{\rm B} = 6.3$ R$_\odot$, respectively, the separation between components would be only $a \sim 27$ R$_\odot$. The geometrical configuration of the system can then be modeled by means of the PHOEBE code (Prša, 2018) (see Fig. 3). This model predicts ellipsoidal light variations for the system, which should be searched through precise photometric observations.

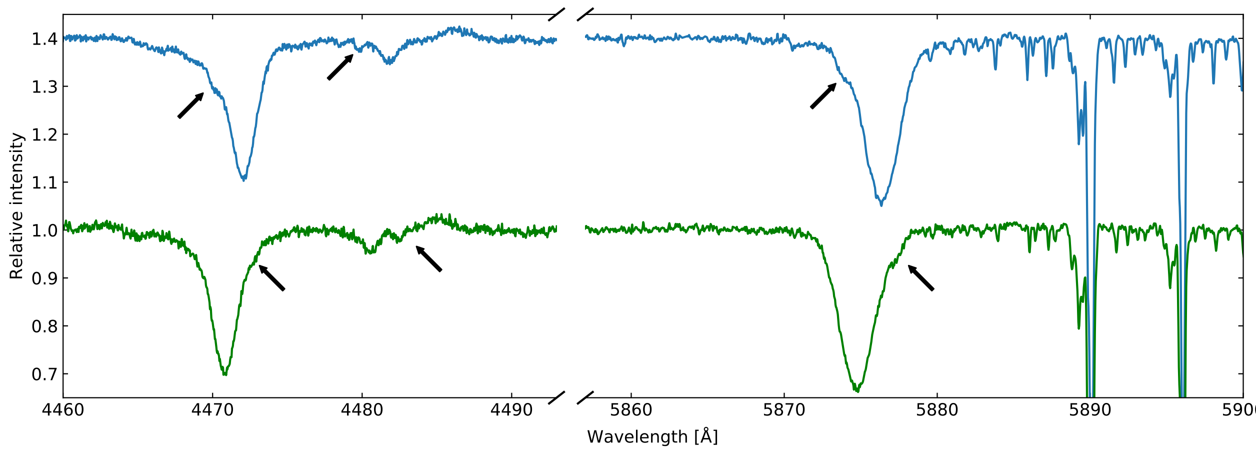


Figure 1: Spectra of HD 93249 observed at quadratures. Left: the wavelength region containing He I λ4471 and Mg II λ4481. Right: the wavelength region around He I λ5876. The arrows indicate the position of the secondary component.

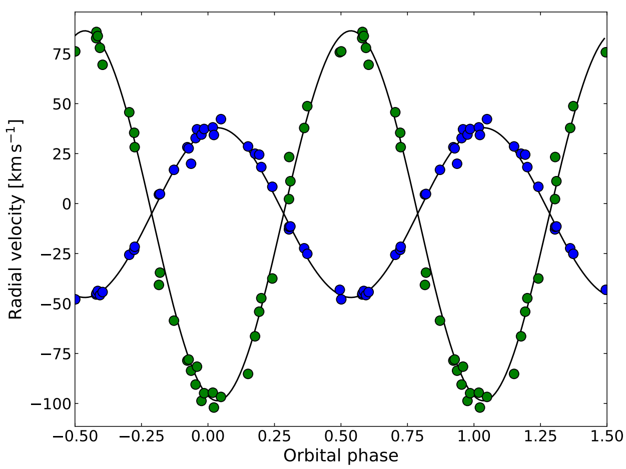


Figure 2: RV orbit of the SB2 system HD 93249. Blue and green circles represent the RVs of He I λ5876 of the primary and secondary components, respectively. Error bars are smaller than the symbols size.

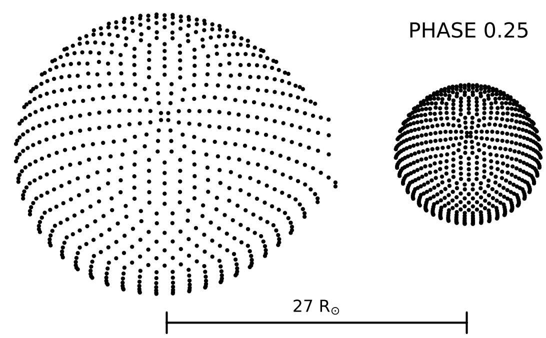


Figure 3: Geometrical configuration of the system HD 93249, modeled by the PHOEBE code, if the radius of the giant star were the calibrated by Martins et al. (2005).

## 6. Conclusions

We have demonstrated that HD 93249 is a short period ($P \sim 3$ d) SB2, composed of a primary star of spectral type O9 III and an early-B secondary star. We have presented the first RV orbit for this system, which shows negligible eccentricity. The small minimum masses observed in Table 2 point to a low orbital inclination. If we assume a “normal” mass for the primary component, the mass of the secondary and the orbital inclination can be estimated. Moreover, if typical radii are assumed for the O III and early-B binary components, the separation between them results relatively small, and the system would probably present ellipsoidal light variations, a possibility worth exploring in future follow-up observations.

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