Determining the orbital parameters of gamma-ray binary HESSJ0632+057

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Introduction

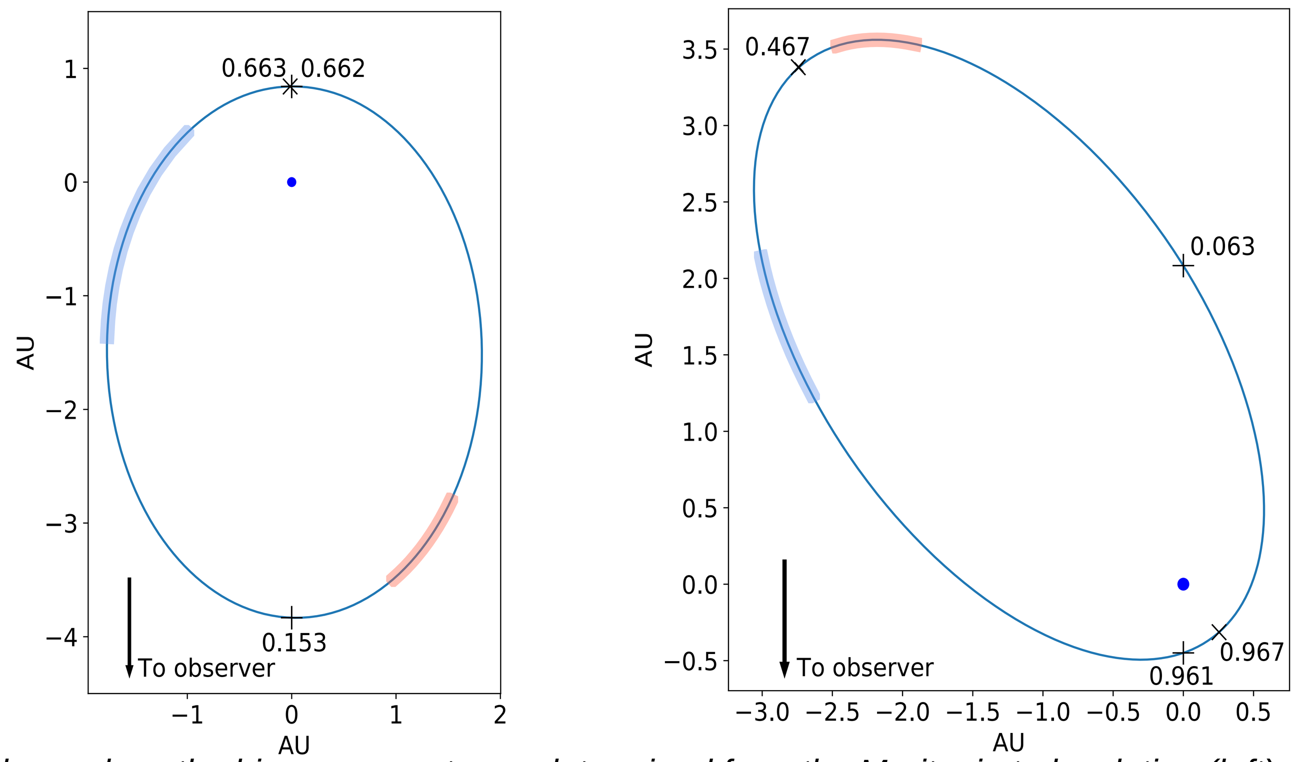
Gamma-ray binaries are a subclass of high mass binaries that emit most of their non-thermal emission in the gamma-ray regime (>1MeV). All known sources are composed of a massive O or B/Be type star and a compact object within the mass range of a neutron star or black hole. The origin of the non-thermal emission, which extends from radio up to very high energy (VHE) gamma-rays, has been interpreted through two different models, the so-called pulsar-wind and microquasar scenarios. In the pulsar-wind scenario, the non-thermal emission originates from the shock that forms between the stellar and pulsar winds. Alternatively, the microquasar scenario suggests the emission originates from an accretion powered relativistic jet, see eg. [1,2]. In order to interpret and model the non-thermal emission in these systems, it is necessary to understand the nature of the compact object and the orbital parameters of the binary system.

The gamma-ray binary HESSJ0632+057 is associated with Be star MWC 148 and some unknown compact object. Previous studies by Cesares et al. 2012 [3] and Moritani et al. 2018 [4] were undertaken to determine orbital parameter solutions. However, they obtained two different and incompatible solutions. The source shows two maxima in the X-ray and TeV light curve, at orbital phase 0.3-0.4 and 0.7-0.8. [5] Moritani et al. proposed that this corresponds to the pulsar entering and exiting the circumstellar disc. The Cesares et al. solution would place these maxima around apastron, where we expect the emission to be at a minimum. This project has undertaken to provide clarity to the binary solution for this system. Here we present the initial results.

Observations & Analysis

Spectoscopic observations were obtained with the High Resolution Spectrograph [6] in HR mode on the Southern African Large Telescope [7]. Three 600s exposures were taken per observation. The observations took place between December 2020 and February 2021. The spectra were reduced through the HRS pipeline [8]. The reduced spectra were all continuum corrected and adjusted to the heliocentre.

The radial velocity was measured by fitting Voigt profiles to the Balmer emission lines, which originate from the Be star's circumstellar disc. The fits were made to the wings of the emission lines, since this originates from the inner region of the disc.



The figures above show the binary geometry as determined from the Moritani et al. solution (left) and the Cesares et al. solution (right) for orbital periods of 313 and 321 days respectively. Superior- and inferior-conjunction as well as apastron and periastron are indicated on the orbital paths. The phases for the maxima in the X-ray and TeV light curves are indicated by the broad red (phases 0.3-0.4) and blue (phases 0.7-0.8) lines. The observer views both systems from the bottom of the page as indicated by the arrow.

Discussion & Conclusions

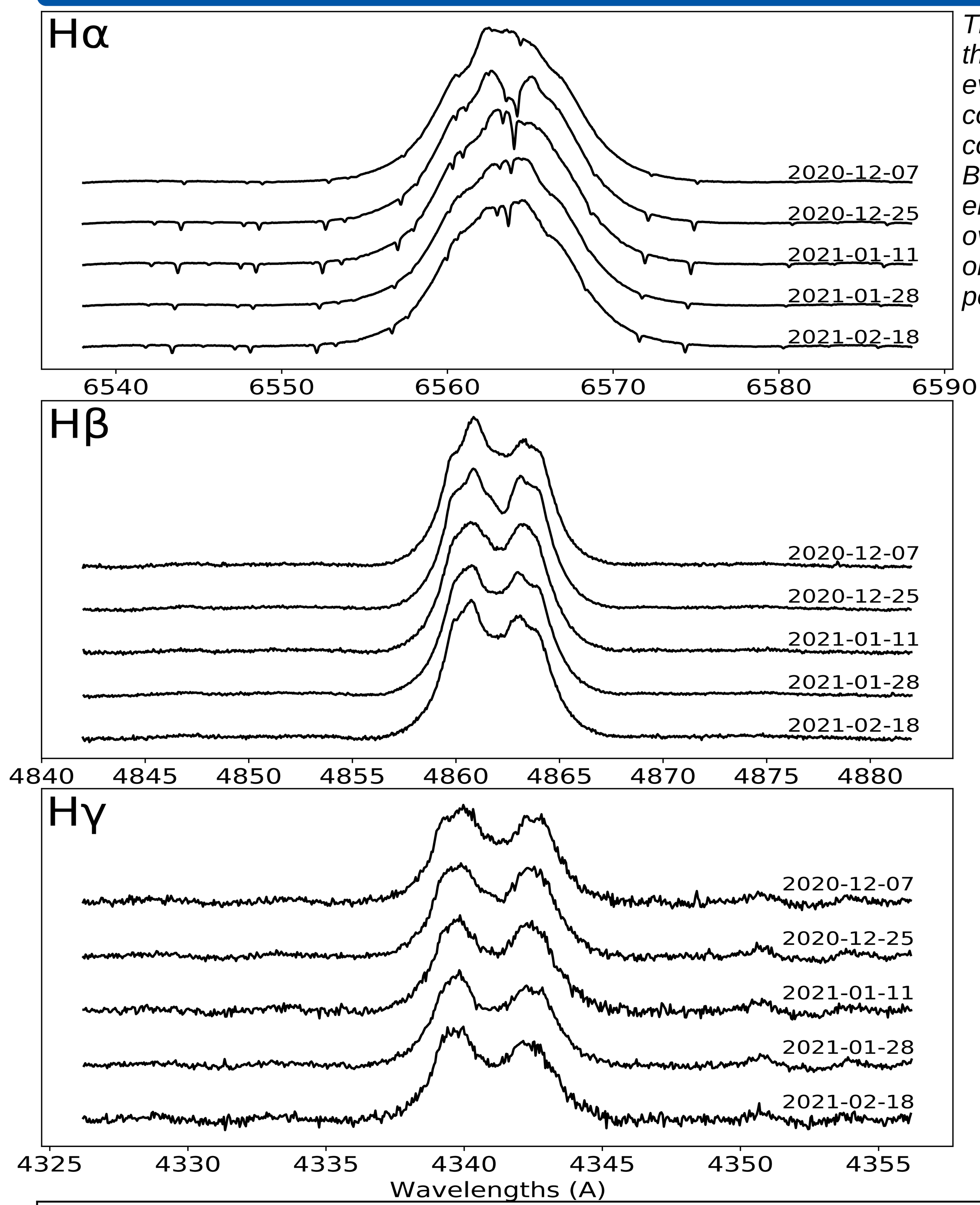
Initial results from spectroscopic observations obtained from the HRS on the Southern African Large Telescope illustrate how the line profiles change over the observation period and shows a general trend of decreasing radial velocity with time for all the Balmer emission line fits. The error in the radial velocities are purely statistical, derived from the goodness of the Voigt profile fits. These results are more consistent with the Moritani et al. solution. The cause for the offset between the radial velocities of the different Balmer lines still needs to be investigated, and we will further look at measuring the radial velocities from the weaker absorption lines originating from the Be star.

Solving the binary solution for this system is essential for understanding how the non-thermal emission could be produced. This is impotant as it addresses the long standing question of which scenarios of binary systems are able to produce very high energy emission.

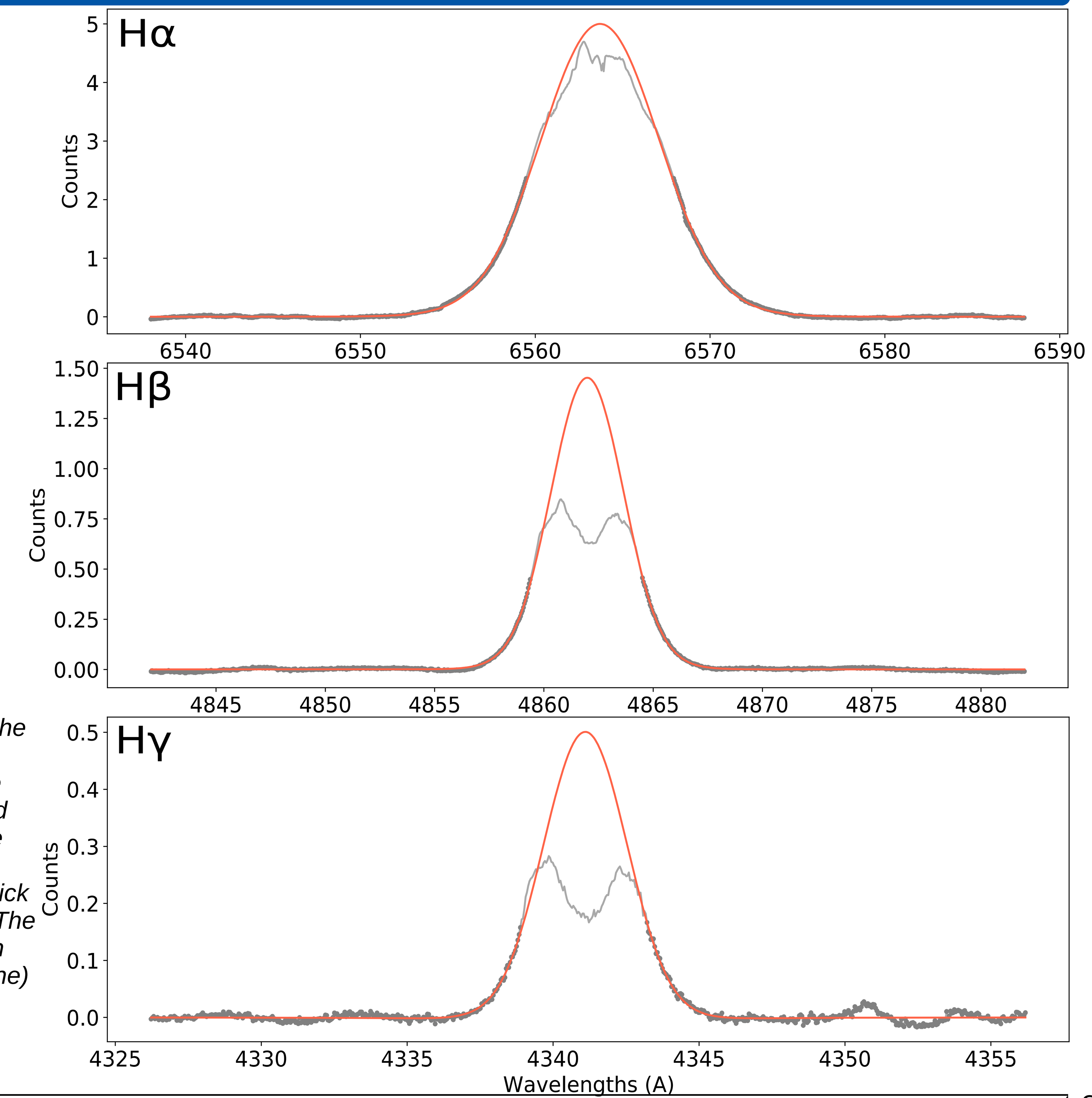
References

1 Dubus, 2013, arXiv:1307.7083
2 Chernyakova et. Al, 2019, arXiv:1909.11018
3 Cesares et al, 2012, arXiv:1201.1726v2
4 Moritani et. Al, 2018, arXiv:1804.03831v1
5 The Astrophysical Journal, 780:168 (14pp), 2014 January 10
6 Crause, Sharples, Bramall et al. 2014, SPIE, 9147, 6 [ADS]
7 Buckley, Swart & Meiring 2006, SPIE, 6267,32 [ADS]
8 Kniazev A. Y., Gvaramadze V. V., Berdnikov L. N., 2016, MNRAS, 459, 3068

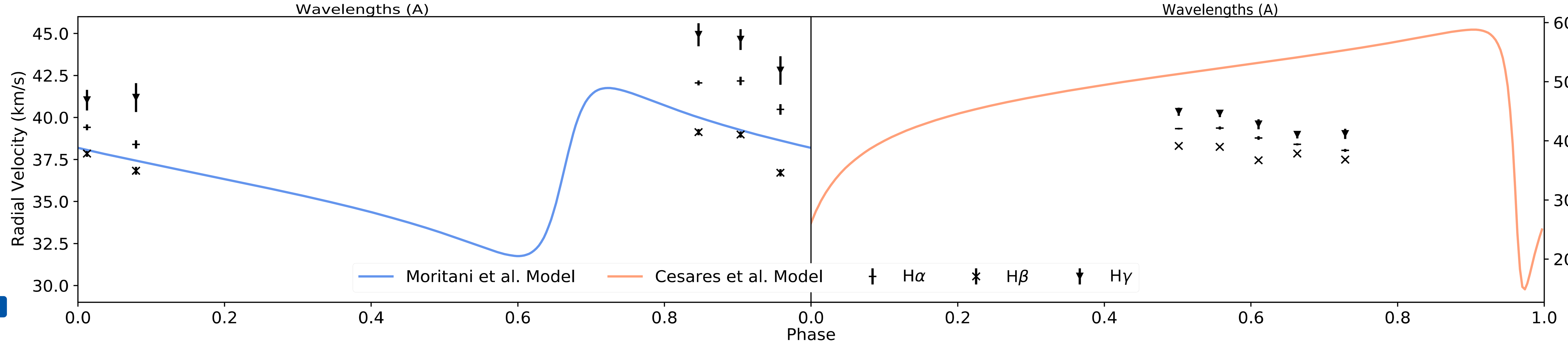
Results



The figures on the left show the evolution of the continuum corrected Balmer emission lines over the observation period.



The figures on the right show examples of the Voigt profile (red line) fitted to the wings of the Balmer lines (thick dotted region). The average of each line (thin gray line) is shown for illustration.



The figure above shows the radial veolcity measurements of the Balmer emission lines in this work (black data points), plotted against the phase relative to the Moritani et al. (blue) and Cesares et al. (orange) models of their orbital solutions. The error shown in the radial velocities are purely statistical, derived from the goodness of fit from the Voigt profile fits to the wings of the Balmer emission lines.