Extensive Spectroscopic and Photometric Study of HD 25558, a Long Orbital-Period Double-Lined Binary with Two SPB Components*

Koninklijke Sterrenwacht van België

Á. Sódor [1,2],

P. De Cat [1], *D. Wright* [1,3], *C. Neiner* [4], *M. Briquet* [5,6], *R.J. Dukes* [7], *F.C. Fekel* [8], *G.W. Henry* [8,9], *M.H. Williamson* [8], *M.W. Muterspaugh* [8], *E. Brunsden* [10], *K. Pollard* [10], *P.L. Cottrell* [10], *F. Maisonneuve* [10], *P. Kilmartin* [10], *J. Matthews* [11], *T. Kallinger* [12], *E. Kambe* [13], *C.A. Engelbrecht* [14], *R.J. Czanik* [15], *S. Yang* [16], *O. Hashimoto* [17], *S. Honda* [17,18], *J.N. Fu* [19], *B. Castanheira* [20], *H. Lehmann* [21], *P. Beck* [6], *N. Behara* [22], *H. Van Winckel* [6], *S. Scaringi* [6], *J. Menu* [6], *A. Lobel* [1], *P. Lampens* [1], *P. Mathias* [23]

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[1] Koninklijke Sterrenwacht van België • [2] Konkoly Observatory, Budapest • [3] University of New South Wales • [4] Observatoire de Paris • [5] Université de Liège • [6] K. U. Leuven • [7] The College of Charleston • [8] Tennessee State University • [9] Kitt Peak National Observatory • [10] University of Canterbury • [11] University of British Columbia • [12] University of Vienna • [13] Okayama Astrophysical Observatory • [14] University of Johannesburg • [15] North-West University, South Africa • [16] University of Victoria • [17] Gunma Astronomical Observatory • [18] Kwasan Observatory • [19] Beijing Normal University • [20] The University of Texas at Austin • [21] Thüringer Landessternwarte Tautenburg • [22] Université Libre de Bruxelles • [23] Université de Toulouse

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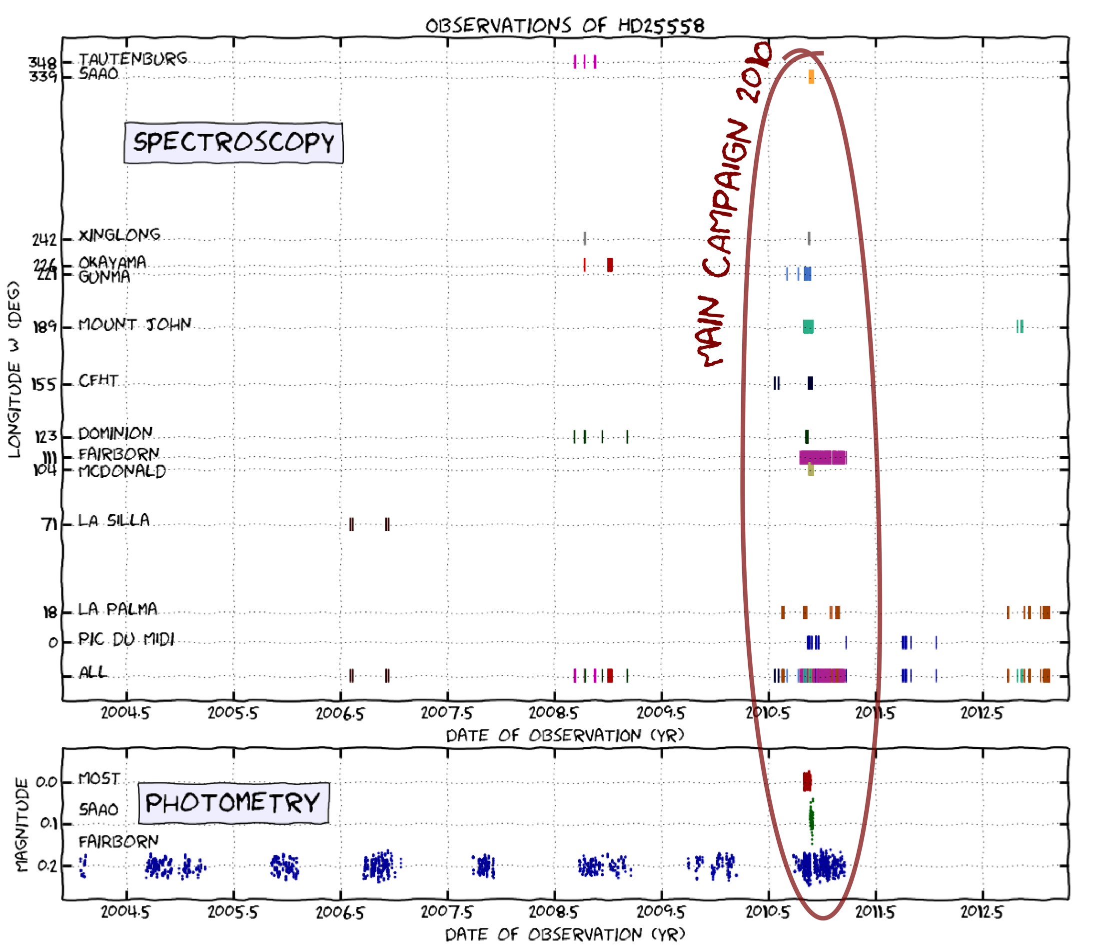
1. The Project and the Target

Our project aims detailed investigations of main-sequence g-mode pulsators by collecting and analysing time series of photometric and high-resolution spectroscopic measurements to get an observational hint on mode-selection mechanisms in these objects.

HD 25558 is an SPB star, discovered by Waelkens et al. (1998). It is a multiperiodic pulsator, but the light variations are dominated by one frequency of 0.653 d^{-1} (Waelkens et al. 1998, Mathias et al. 2001, De Cat et al. 2007).

2. Observations

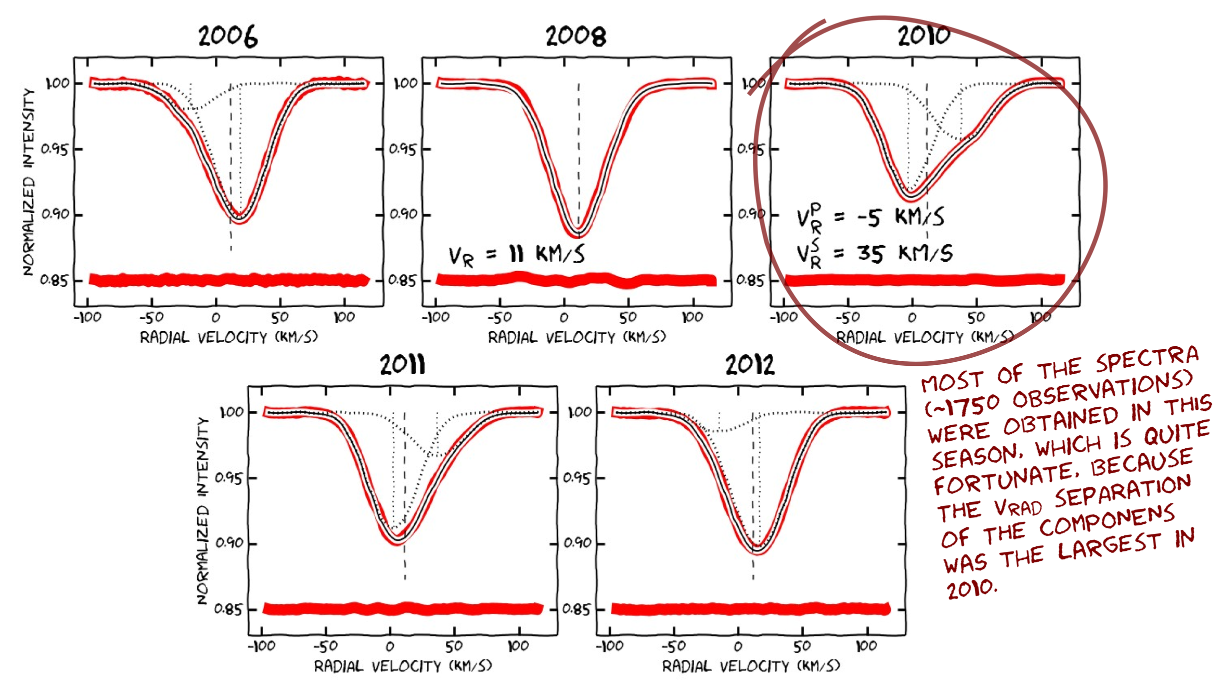
We analysed ~2000 high-resolution spectroscopic observations, obtained during 5 seasons with 13 instruments. Most of the data (~1750 spectra) were obtained in the 2010 season. Ground-based and space photometry (*MOST*) were also used.



Time and geographic distribution of the observations on HD 25558

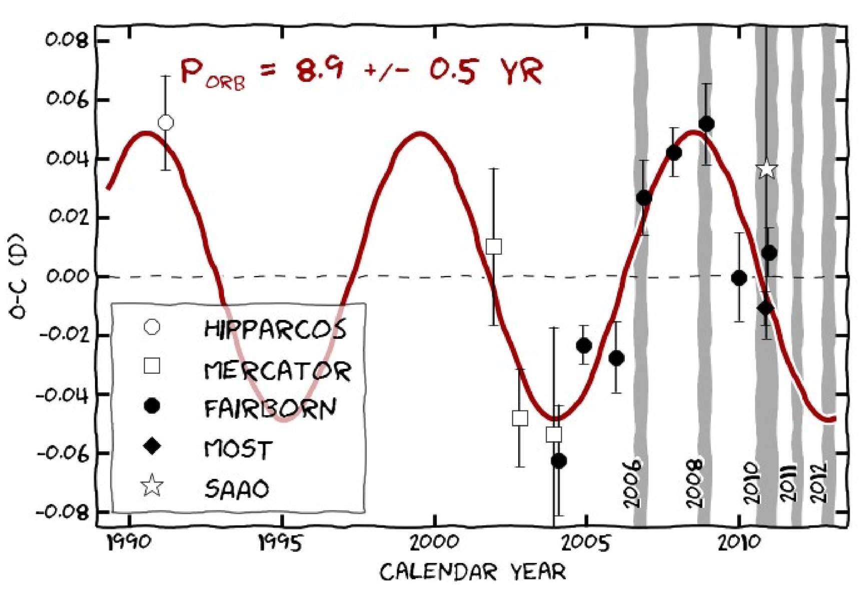
3. Binarity

Season-by-season variations in the time-averaged cross-correlated line profiles show binarity and indicate a long (>6 yr) orbital period.

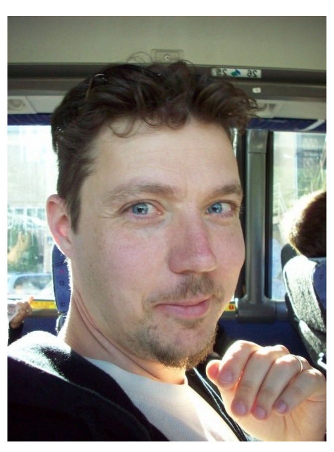


Season-by-season line-profile variations due to binarity

O-C analysis of the dominant frequency in the photometric data indicates an orbital period of ~9 yr. The dominant frequency originates from the primary component.

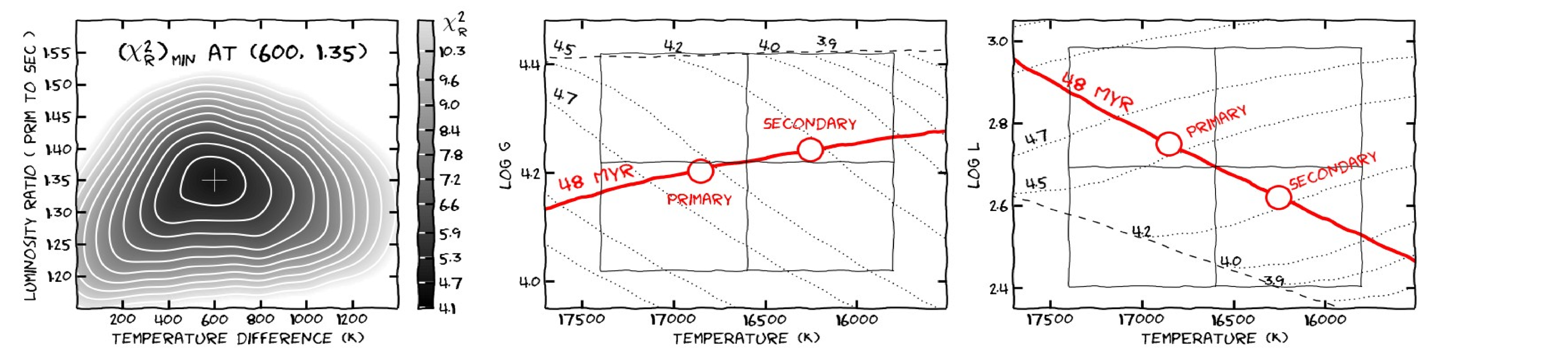


O-C diagram of the dominant frequency of HD25558. The variations can be explained with the light delays caused by the orbital motion. The intervals of the spectroscopic observations are marked with gray bands.



4. Physical parameters

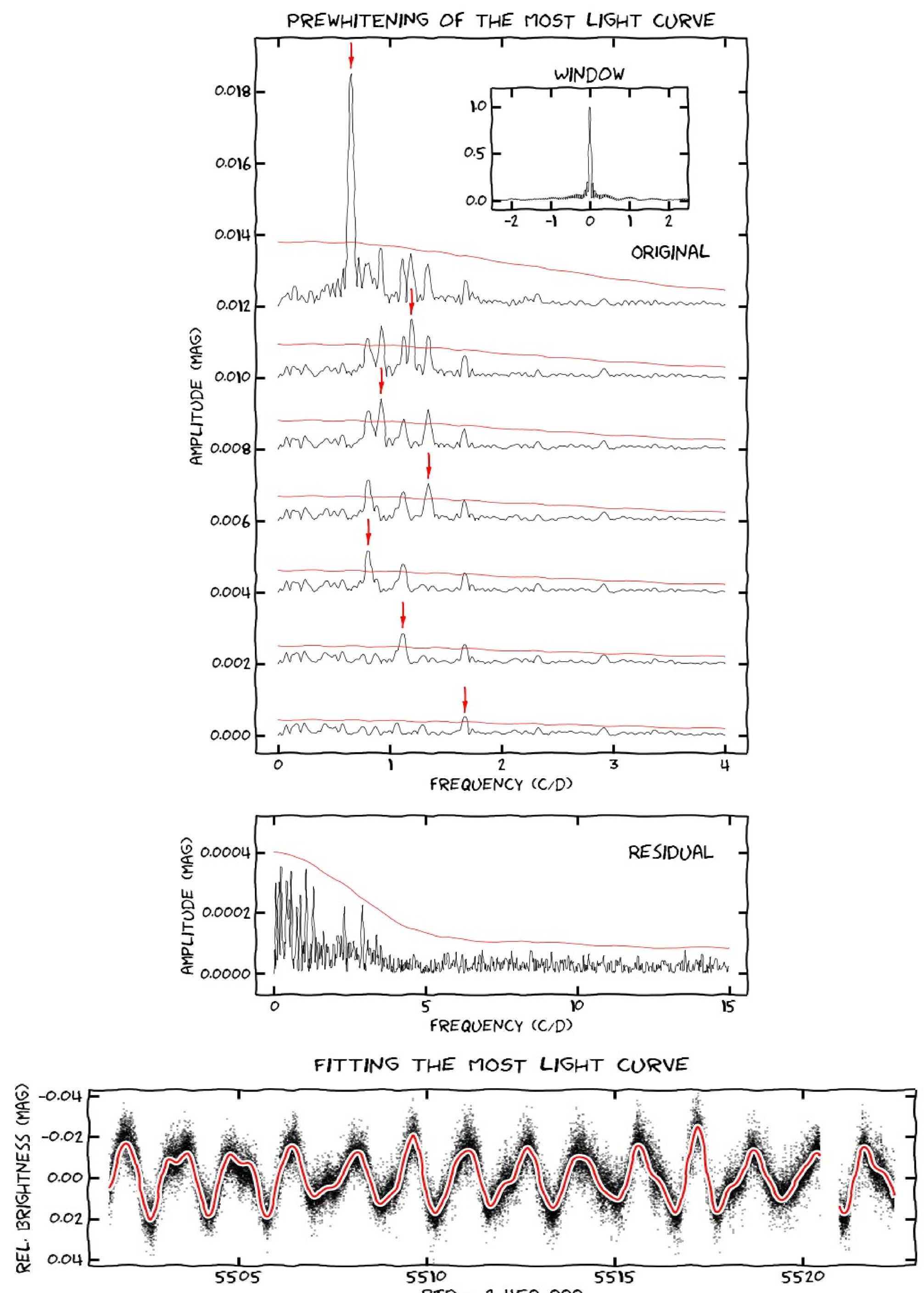
Mean (luminosity weighted) $T_{\rm eff}$, $\log g$ and $\log L$ values were determined for the system from Geneva photometry. Relative values of the two components were calculated by modelling their equivalent width (EW) ratios in 21 selected metallic lines in a good-quality time-averaged spectrogram from 2010. **Both components lie within the SPB instability strip.** Our spectropolarimetric measurements indicate the presence of a magnetic field in the secondary, but not in the primary component.



Left: chi-square map of the temperature difference and luminosity ratio by modelling EW ratios of 21 spectral lines; **middle and right:** evolutionary tracks (dotted), the ZAMS (dashed), the isochrone crossing the mean parameters (48 Myr, red), and the location of the two components on this isochrone.

5. Frequency analysis

Fourier analysis of the light curves and of the moments of the cross-correlated line profiles, and pixel-by-pixel (PbP) Fourier analysis of the line-profile variations revealed 11 independent frequencies and a harmonic of the dominant frequency.



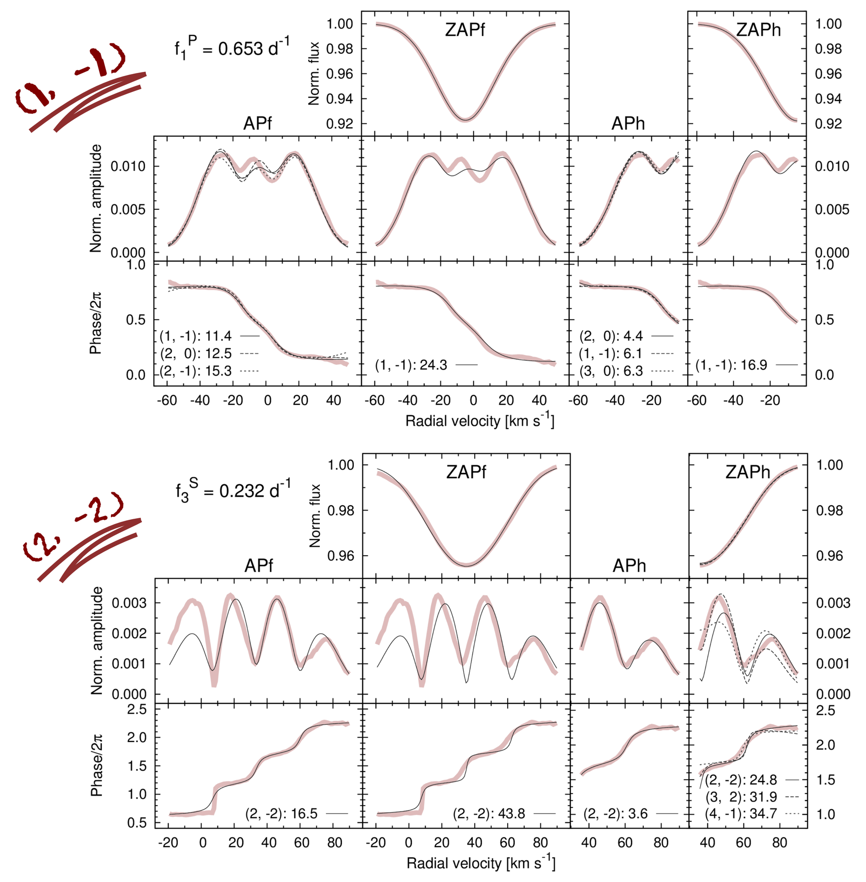
An example of analysing and fitting the most light curve.

Both components show line-profile variations consistent with g-mode pulsations. We are able to attribute each of the 11 frequencies to one of the components, based on the morphology (axis of symmetry) of their Fourier-parameter profiles.

6. Mode identification

Photometric mode identification (ℓ): multicolour amplitude ratios and phase differences based on the 8-season Strömgren ($uvby$) photometry from Fairborn Observatory.

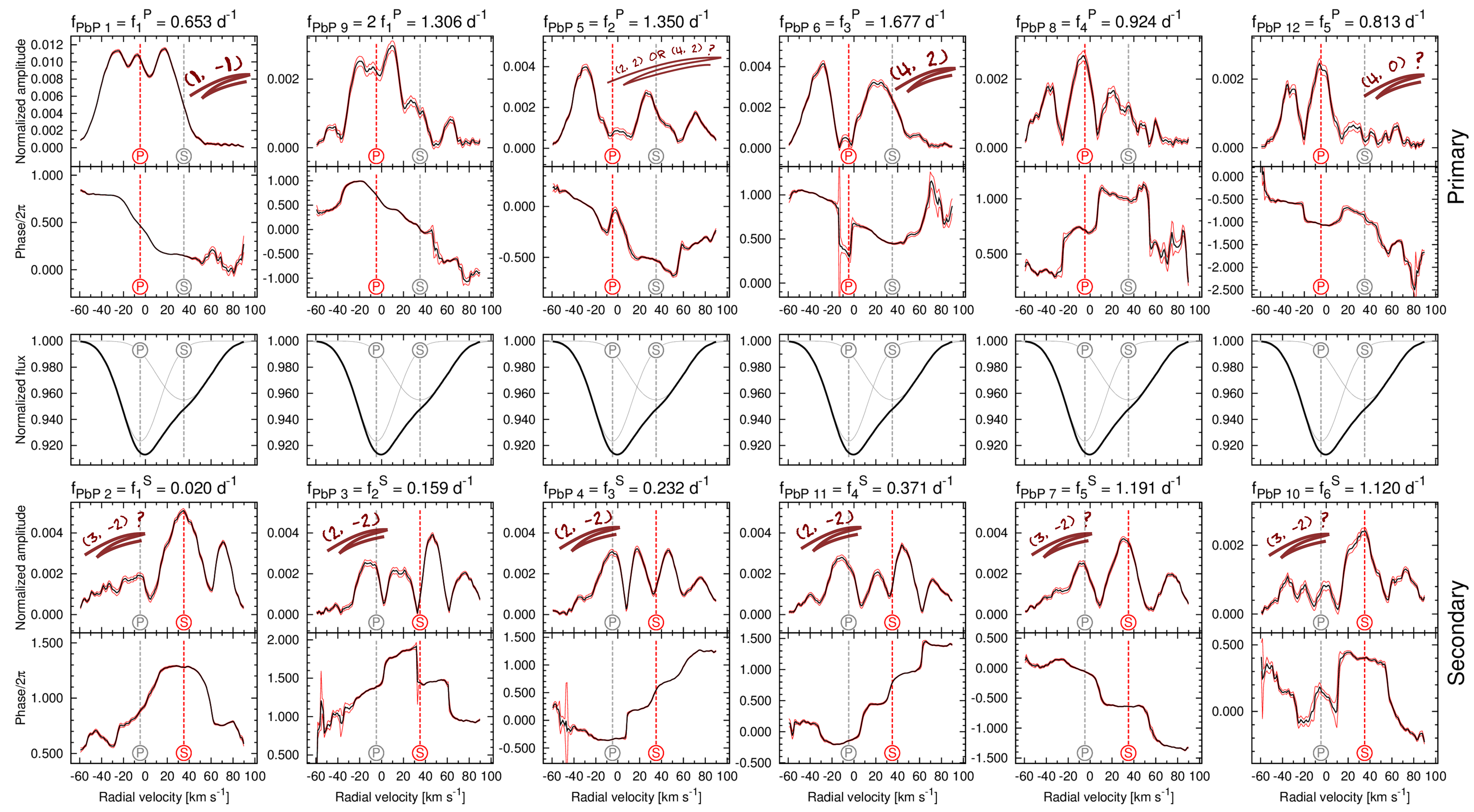
Spectroscopic mode identification (ℓ, m): Fourier parameter fit (FPF) of the line-profile variations determined with the PbP method using famias (Zima 2008). This method also yields the inclination and $v \sin i$ of the star.



Two example fits of spectroscopic mode identification using the FPF method. **Top:** the dominant frequency (primary). **Bottom:** a successfully identified (2, -2) mode of the secondary. Four different fitting methods were used: **AP/ZAP:** only the amplitude and phase profiles, or also the zero-point profile was fitted. **F/H:** the full profile or only one half (which is unaffected by the companion) was fitted.

Most important mode-identification results:

- The results are indicated in the large figure below.
- The dominant mode ($f_1^{\rm P}$) is identified as (ℓ, m) = (1, -1).
- There are three (ℓ, m) = (2, -2) modes excited in the secondary: $f_2^{\rm S}$, $f_3^{\rm S}$ and $f_4^{\rm S}$.
- The primary is a relatively slow rotator: $i^{\rm P}$ = 60°, $(v \sin i)^{\rm P}$ = 21.5 km/s, $P^{\rm P}_{\rm rot}$ ~ 6 d.
- The secondary is a fast rotator: $i^{\rm S}$ = 20°, $(v \sin i)^{\rm S}$ = 35 km/s, $P^{\rm S}_{\rm rot}$ ~ 1.2 d.



Fourier-parameter profiles of the identified frequencies in the 2010 spectroscopc data. Mode-identification results are also indicated in the panels. **Middle row:** zero-point profiles (identical for each frequency). **Upper 2 rows:** amplitude and phase profiles of the primary. **Bottom 2 rows:** the same for the secondary.

References

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