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Introduction

GW Librae is one of the few Cataclysmic Variable systems in which the white dwarf primary shows ZZ Ceti-like pulsations. The binary also exhibits rare and large amplitude dwarf nova outbursts. The system was first discovered in 1983 during a super-outburst and in mid-April 2007 entered its second recorded period of outburst activity with a magnitude change of ~ 9 . We present time-resolved optical spectroscopy of the system during and after the 2007 outburst and discuss the dynamics and evolution of the optical lines. High-resolution spectroscopy near the Call IR triplet lines illustrates their superior sensitivity relative to the more commonly analysed Balmer lines.

Evolution of the outburst

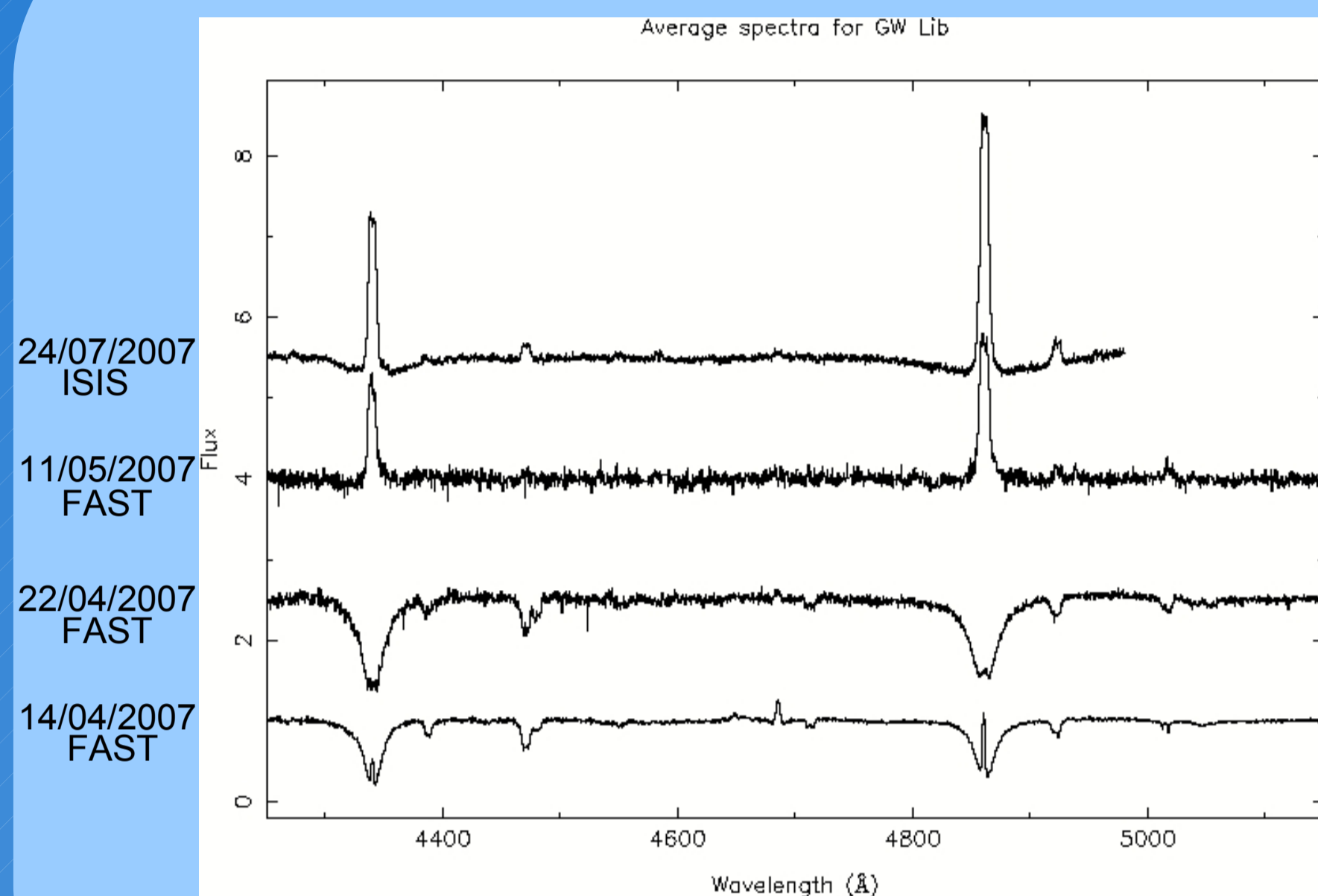


Figure 1: Normalised average spectra of GW Lib during different stages of the outburst. The bottom two spectra have been multiplied by a constant to increase the line strengths compared to the strong emission in the top two spectra.

We monitored the first month of outburst activity with 9 epochs of time-resolved data obtained with the FAST spectrograph on the FLWO 1.5m. In addition, spectra were obtained with Magellan during quiescence in 2004 and 2 months into the 2007 outburst. Finally, in July 2007 the WHT used its two armed spectrograph ISIS to simultaneously look at the blue and red part of GW Lib's spectrum

During outburst, the Balmer lines are dominated by deep absorption troughs with sharp emission lines, giving a negative EW. The emission lines decrease over a few nights therefore decreasing the equivalent even further. A month later, the lines are dominated by shallow double peaked emission lines. The EW has undergone the same drastic change and has a high positive value. In July, the double peaked profile is flanked by shallow absorption troughs, decreasing the EW slightly.

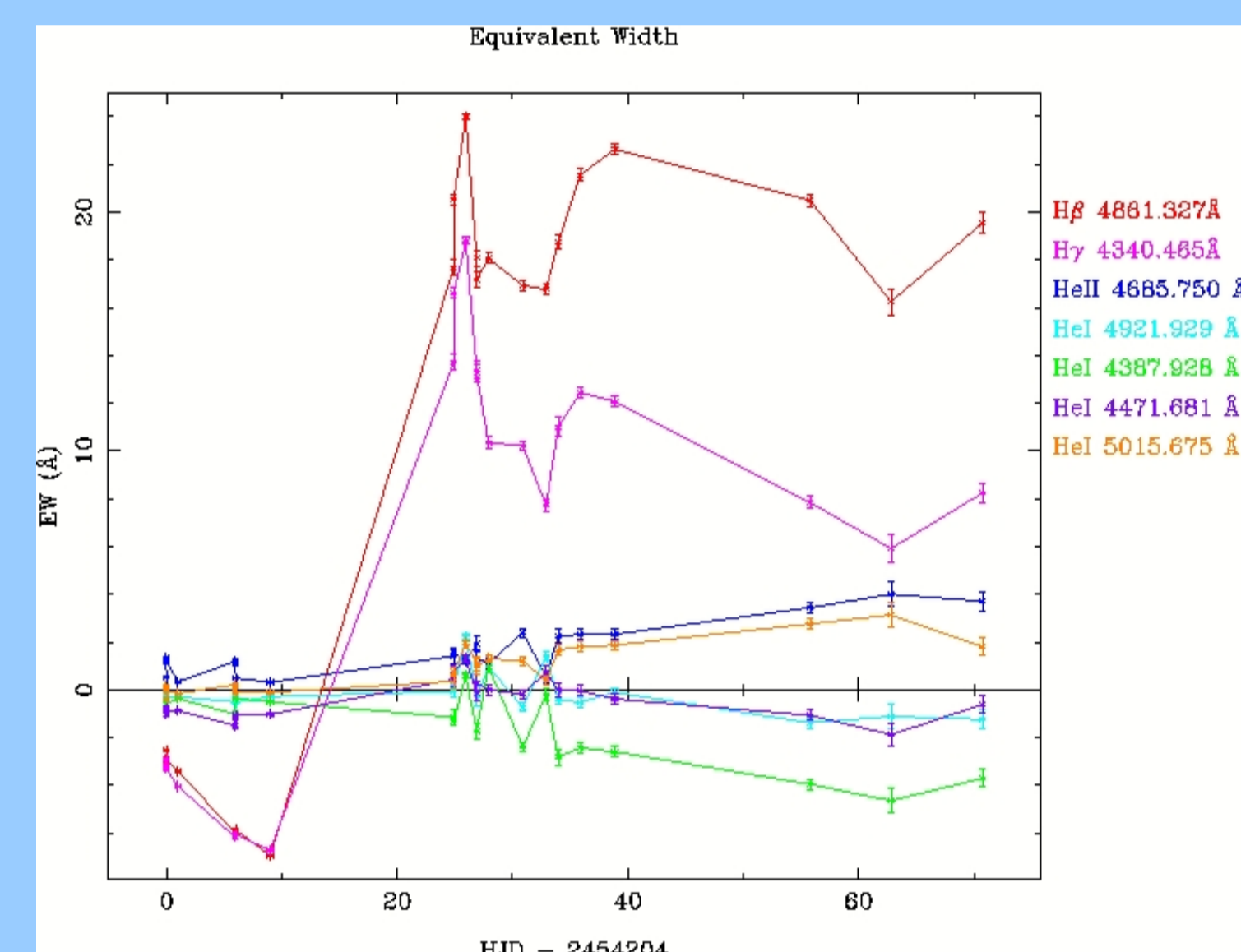


Figure 2: Equivalent width of the different elements as a function of outburst. Lines with negative values are dominated by absorption, and those dominated by emission have a positive value.

Trails during outburst

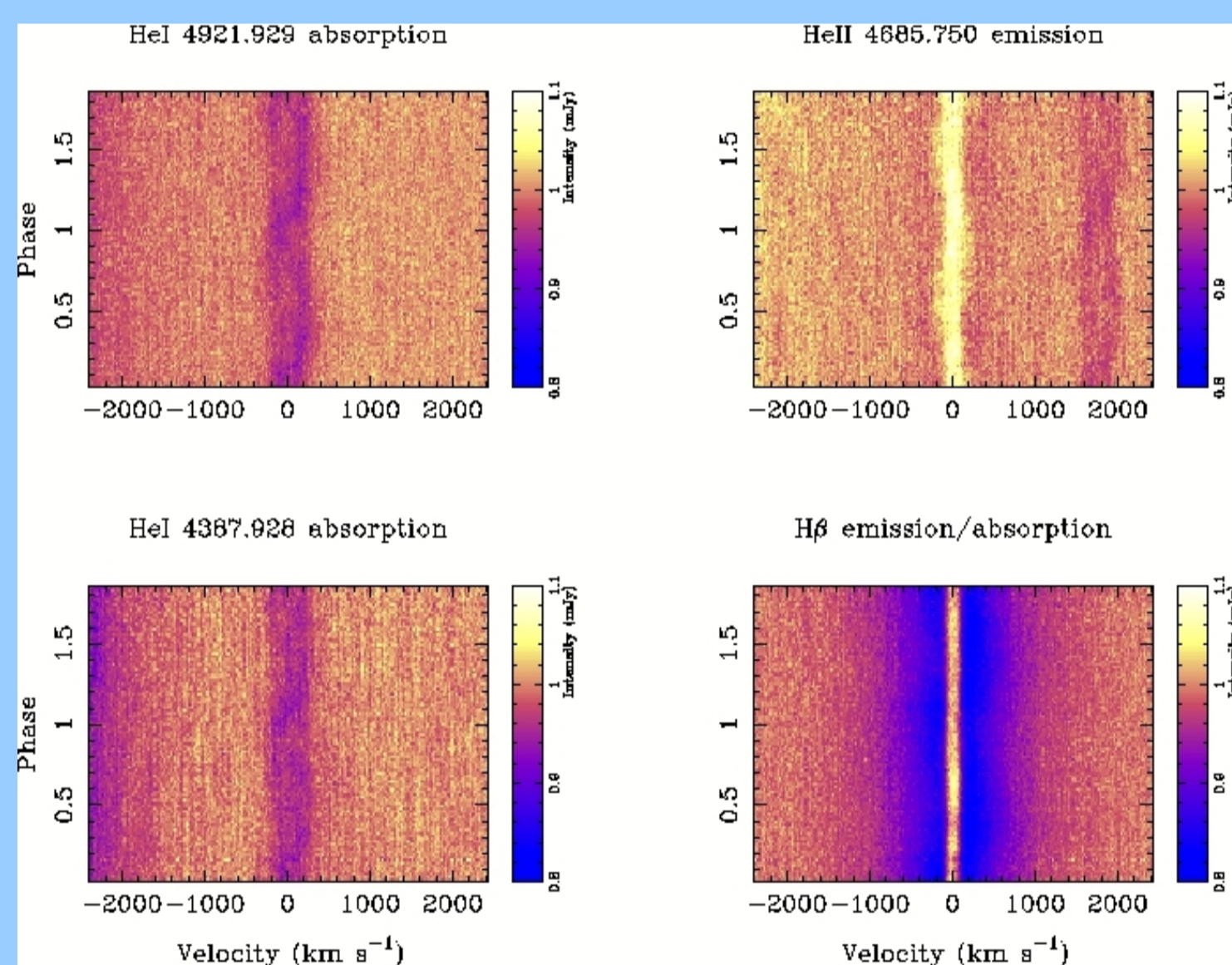


Figure 3: Trailed spectra for several elements in the spectrum of GW Lib on 14 April 2007.

Two nights after initial outburst the trailed spectra of GW Lib show a strong, steady and sharply peaked emission line for H β together with a deep absorption with a much larger amplitude and a different offset.

The HeII emission is in anti-phase with the H β absorption. The HeI absorption lines have not enough S/N to fit their structure.

A multiple Gaussian fit to H β in different epochs has been done giving a different velocity amplitude and velocity offset for each.

We suggest the large amplitude absorption line on 14 April 2007 originates from the accretion disc, but does not trace the orbital velocity of the white dwarf, as its amplitude is too large. We also detected a narrow emission component offset from the absorption with no significant orbital velocity amplitude. The emission line on 24 July 2007 can be associated with the orbital velocity of the white dwarf.

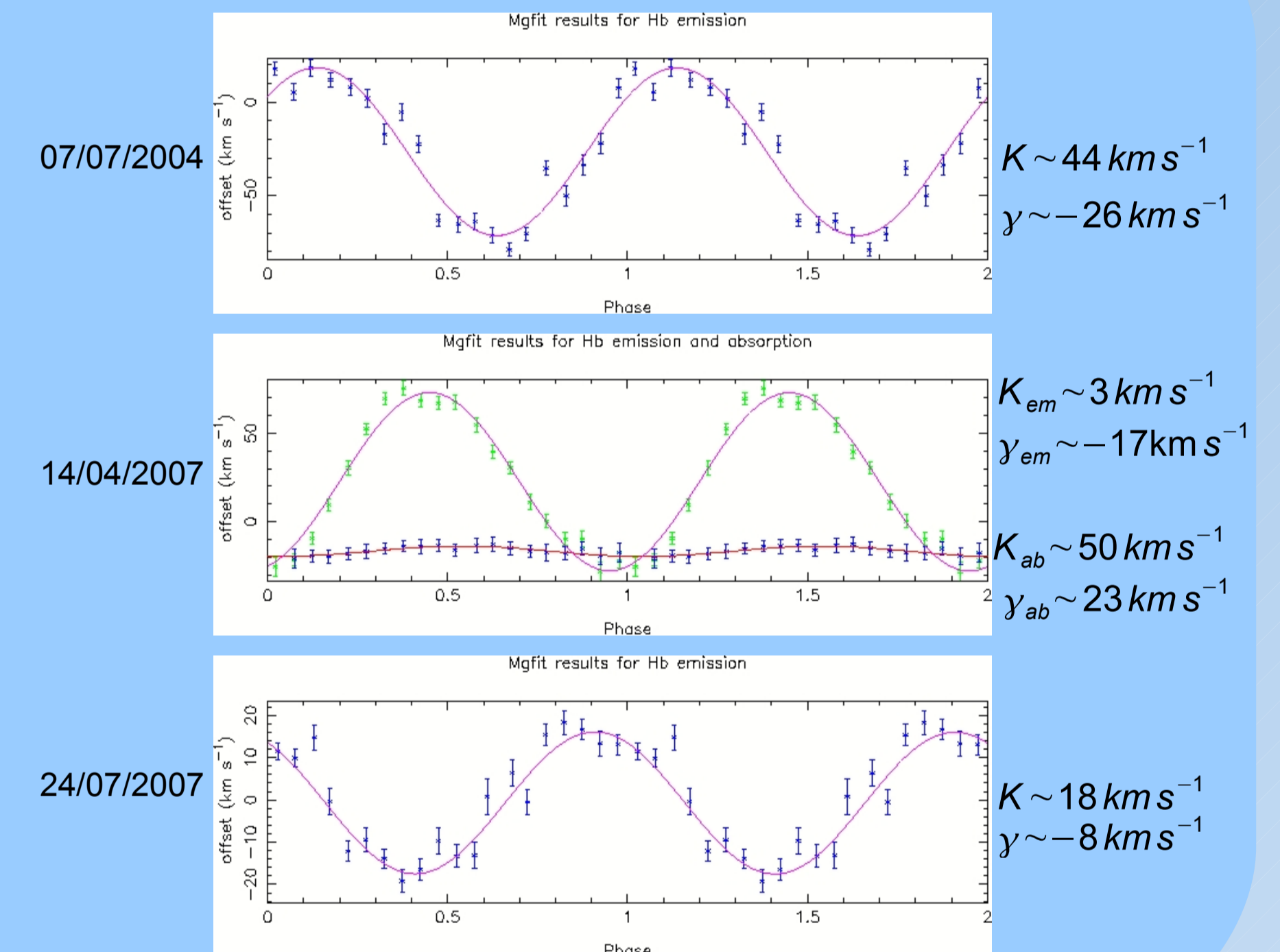


Figure 4: Velocity profiles of H β elements during different epochs.

Detection of the mass donor in quiescence

In July 2007 the WHT observed GW Lib covering both the Balmer regime and the Call triplet around 8500Å. While H β only shows a shallow double peaked profile, Call 8662Å also shows a sharp S-wave component in the trailed spectra which we associate with the irradiated mass donor star, as predicted by [1].

The Maximum Entropy Method for Doppler tomography has been used to project the time-resolved spectra into velocity space. The H β profiles maps an accretion disc, while the narrower Call 8662Å profiles maps a more detailed accretion disc and the mass donor star.

The plotted model estimates $K_2 \sim 85 \text{ km s}^{-1}$, $K_1 \sim 15 \text{ km s}^{-1}$ and therefore $q \sim 0.18$.

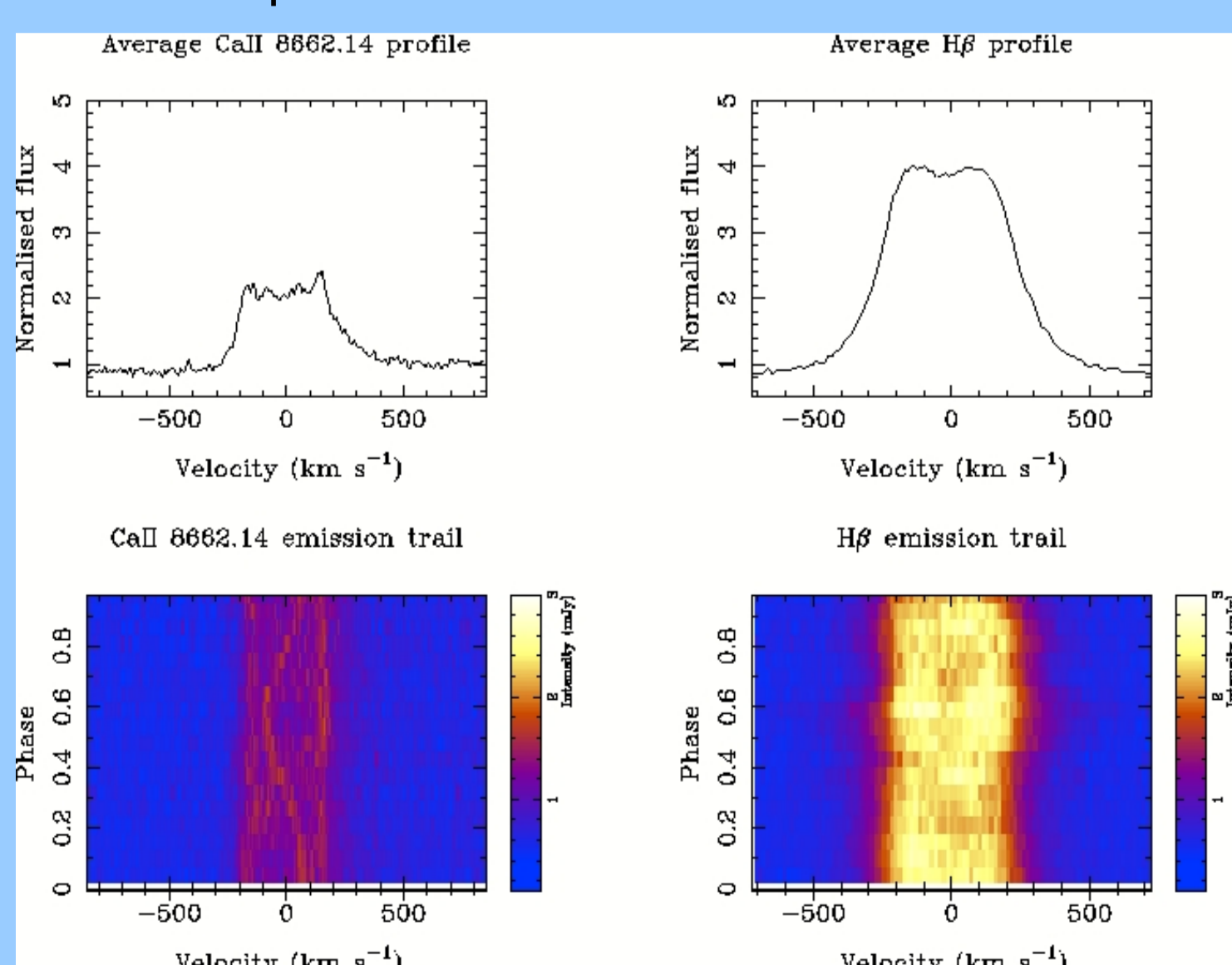


Figure 5: Average profiles for Call and H β and trailed spectra on 24 July 2007

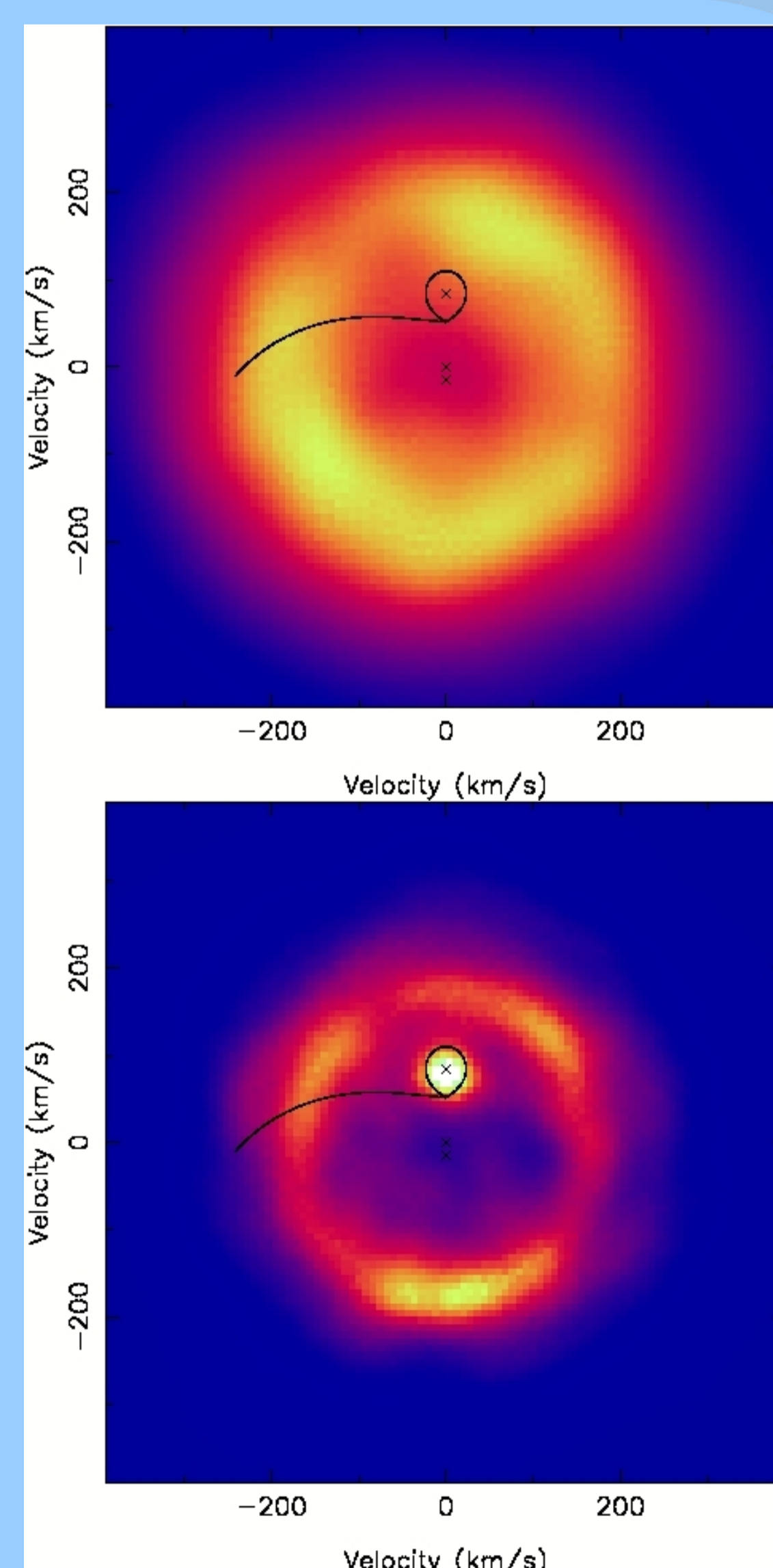


Figure 6: Doppler maps for H β (top) and Call (bottom). The Balmer map shows an accretion disc due to the shallow double peaked profile. The Call map shows structure in the disc and the donor star.

Conclusions and Implications

The optical lines in GW Lib evolved significantly across its 2007 outburst. Their complex and changing dynamics challenge a straightforward associated of the components with either the white dwarf or traditional disc features. A breakthrough is provided by the detection of the mass donor star in the Call triplet lines, illustrating the powerful diagnostic of these often ignored features. This allows us to derive initial estimates for the binary parameters of GW Lib.

Assuming a primary mass of $1.0M_{\odot}$, from [3] and the period $P_{\text{orb}} = 76.79 \text{ m}$, from [2], the found mass ratio from the Call Doppler map implies binary parameters estimations of

- $M_2 \sim 0.18M_{\odot}$
- $a \sim 0.63R_{\odot}$, $a_1 \sim 0.10R_{\odot}$, $a_2 \sim 0.53R_{\odot}$
- $v_1 \sim 96 \text{ km s}^{-1}$, $v_2 \sim 509 \text{ km s}^{-1}$
- $i \sim 10^{\circ}$

References

- [1] Marsh, T.R., Dhillon, V.S., 1997, MNRAS, 292, 385
- [2] Thorstensen, J.R., et al., 2002, PASP, 114, 1108
- [3] Townsley, D.M., Arras, P., Bildsten, L., 2004, AJ, 608, 105