Constraining stellar CMEs

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Abstract

A lot has been done on an observational basis in the past with respect to stellar coronal mass ejections. Using the method of Doppler-shifted emission/absorption, still, only fast events can be unambiguously identified with erupting filaments/prominences. These often form the cores of CMEs on the Sun. From dM stars we know that there are numerous observations of Doppler-shifted emission events with projected velocities of 100-300km/s. Constraints are needed to better interpret those signatures which are potential CME candidates. We have chosen cloud modeling to constrain what might produce such signatures. We focus on one known event from the literature, found on the fast rotating dMe star V374 Peg, and find that both a filament and a prominence scenario reproduces the peak flux of the Doppler-shifted emission signatures, contrary to the solar case where filaments produce an absorption signature in the Balmer lines. The deduced parameters from modeling show values in the upper range of solar prominence parameters, except for temperature and area, which are larger. A prominence/filament eruption scenario is therefore very likely for the event found on V374 Peg.

The event on V374 Peg and modeling:

Vida et al. (2016) presented a complex flare event with several blue wing asymmetries in the Hα spectral line, which were detected on the young dMe star V374Peg. The fastest sequence of asymmetries (see Fig. 1) was interpreted to be an eruptive event reminiscent to an erupting filament/ prominence on the Sun. The fast part of the sequence lasted for 4 spectra (corresponding to 20 minutes), those are the ones we reproduce (normalized peak flux) with a cloud model formalism (Eq. 1 for the prominence case and Eq. 2 for the filament case, adapted from Odert et al., 2020; Odert et al., 2022), to constrain their nature and deduce parameters of the eruptive event.

$$F = \frac{S}{I_*}\frac{A_P}{A_*}(1-e^{-\tau})+1 \qquad \text{... Eq. 1}$$

$$F = (\frac{S}{I_*}-1)\frac{A_P}{A_*}(1-e^{-\tau})+1 \qquad \text{... Eq. 2}$$

The unknowns in the cloud model formalism are the source function, the area, and the optical thickness. The source function and the optical thickness are delivered by an NLTE code.

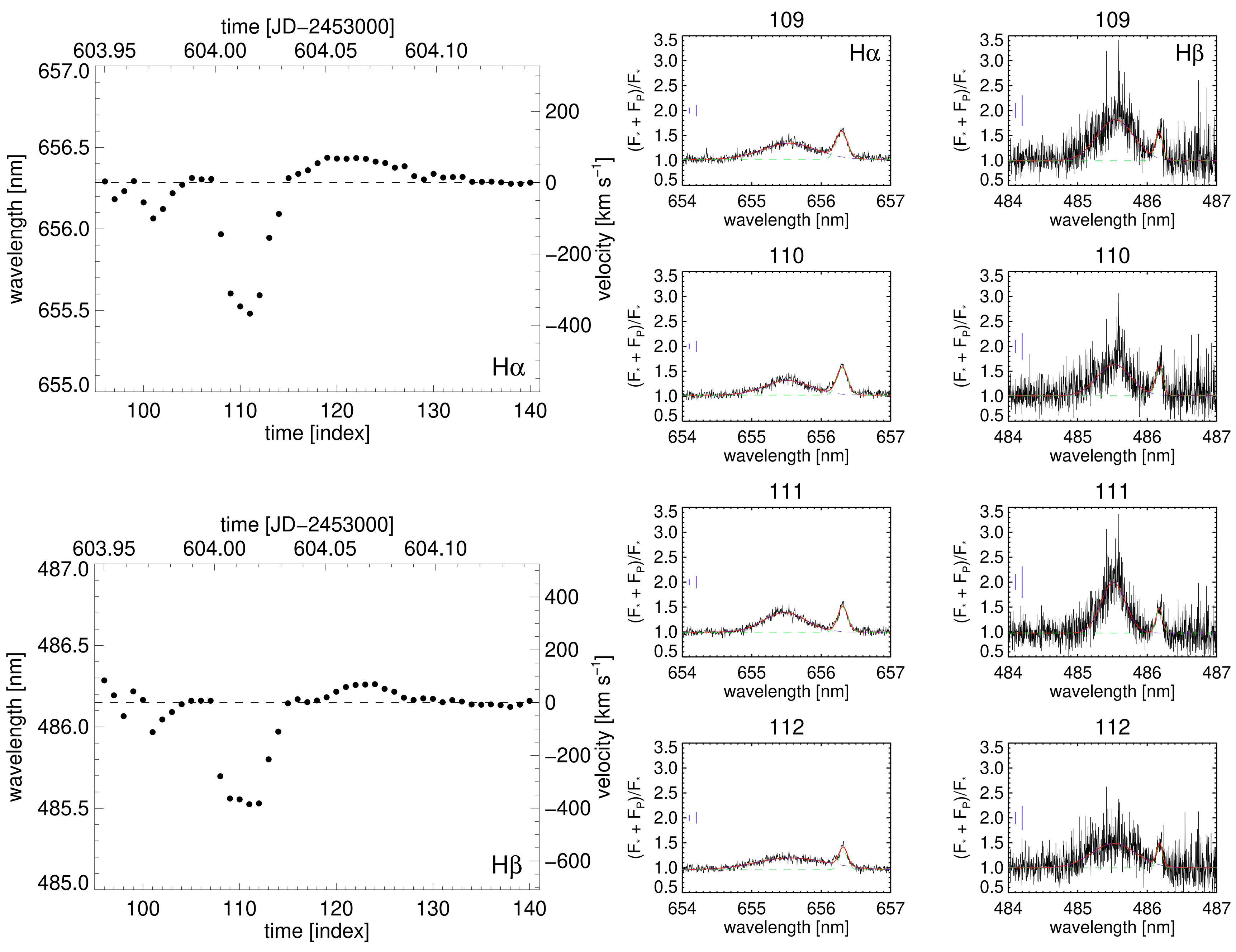

Fig. 1: *Left panels: Bulk velocities of the Hα and Hβ asymmetries of the event on V374 Peg. Right panels: Residual spectra in Hα and Hβ of the event on V374 Peg. One can clearly see the asymmetry and the line core enhancement.*

The NLTE code (Heinzel et al., 1995; Heinzel et al., 1999) is and was successfully applied a number of times to solar quiescent and eruptive filaments and prominences (see e.g. Heinzel et al., 2014, 2016). The prominence/filament is represented in the NLTE model by a 1-D slab. The NLTE model demands input grids for temperature, prominence height, prominence thickness, area, and gas pressure. From the results, we run several ten thousand runs, we finally generate histograms of the parameters shown in Fig. 2 (for parameter dependencies see Leitzinger et al., 2022).

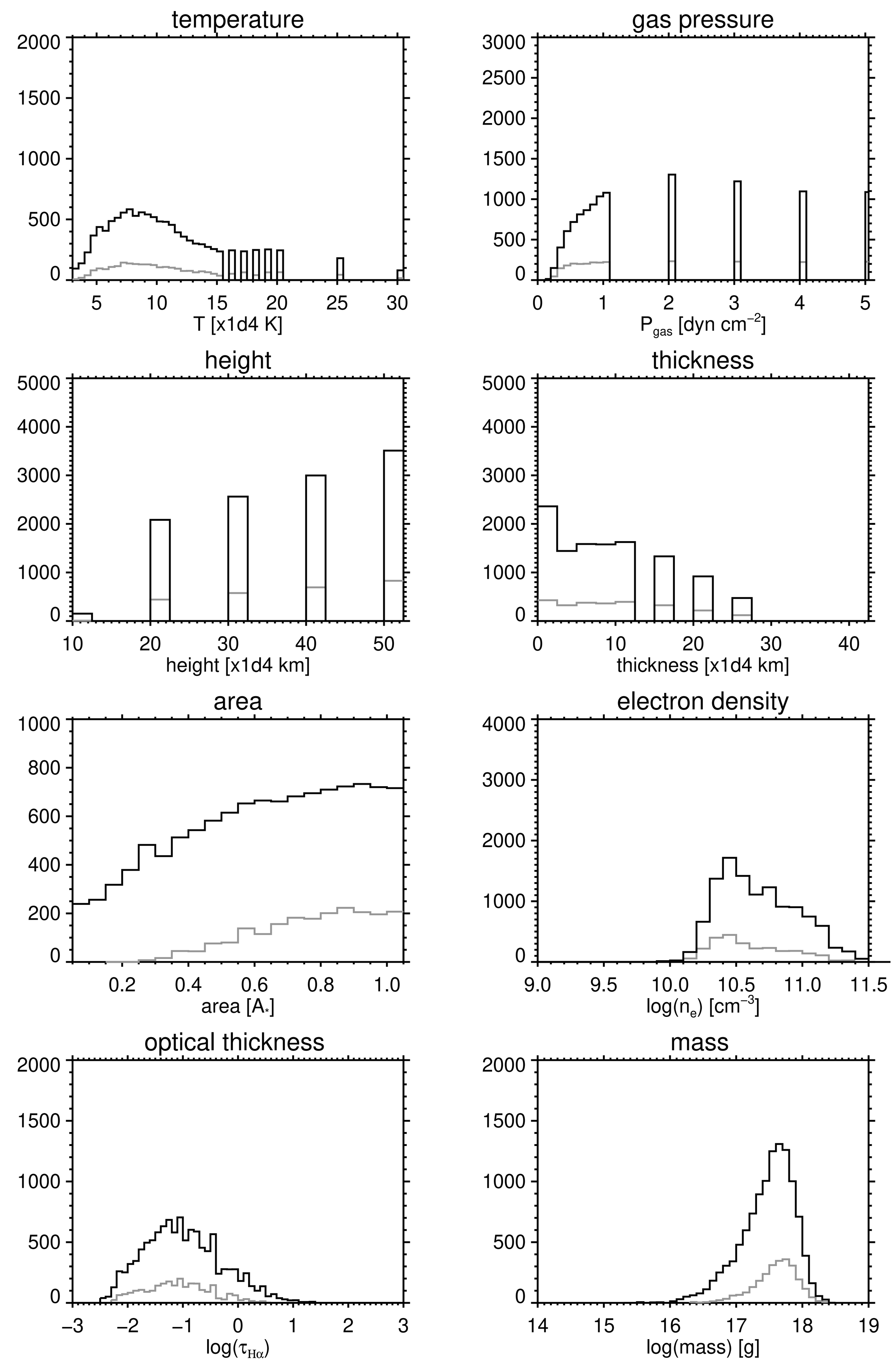

Fig. 2: *Histograms of filament parameters for spectrum 109 (first fast asymmetry) including also filament mass.*

Results:

The median value of height is 400000 km (1.77 R_*), of thickness 50000-75000 km (0.22-0.33 R_*), of temperature 95000-115000 K, of $\log(n_e)$ 10.6-10.7, of gas pressure 1-2 dyn cm^{-2}, of τ(Hα) 0.03-0.1, and of area 0.55-0.7 A_*. Thickness, electron density, mass, and gas pressure are at the upper range of parameter distributions of solar filaments/prominences. Temperature and area are much larger than for solar filaments/prominences. For prominence geometry we find less cases but the parameter distributions are comparable.

Conclusion:

The event presented in Vida et al. (2016) is very likely an erupting filament, although we can not exlude a prominence geometry. This moreover cleary says that on dM stars filaments can also occur in emission (thermal emission dominates over scattering, see also Odert et al., 2022), contrary to the solar case, and this sheds new light on the numerous detections of Balmer line asymmetries found on dM stars (e.g. Fuhrmeister et al., 2018; Vida et al., 2019).

References: Furhmeister et al., 2018, A&A, **615**, 14; Heinzel, 1995, A&A, **299**, 563; Heinzel et al., 1999, A&A, **346**, 322; Heinzel et al., 2014, A&A, **564**, A132; Heinzel et al., 2016,A&A, **589**, A128; Leitzinger et al., 2022, MNRAS, **513**, 6058; Odert et al., 2020, MNRAS, **494**, 3766; Odert, Leitzinger, Heinzel, 2022, Poster at Cool Stars 2021; Vida et al., 2016, A&A, **590**, A11, Vida et al., 2019, A&A, 623, 49

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