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Stellar Wind Parameter Determination through Modeling IR Line Profiles in B-type Supergiants

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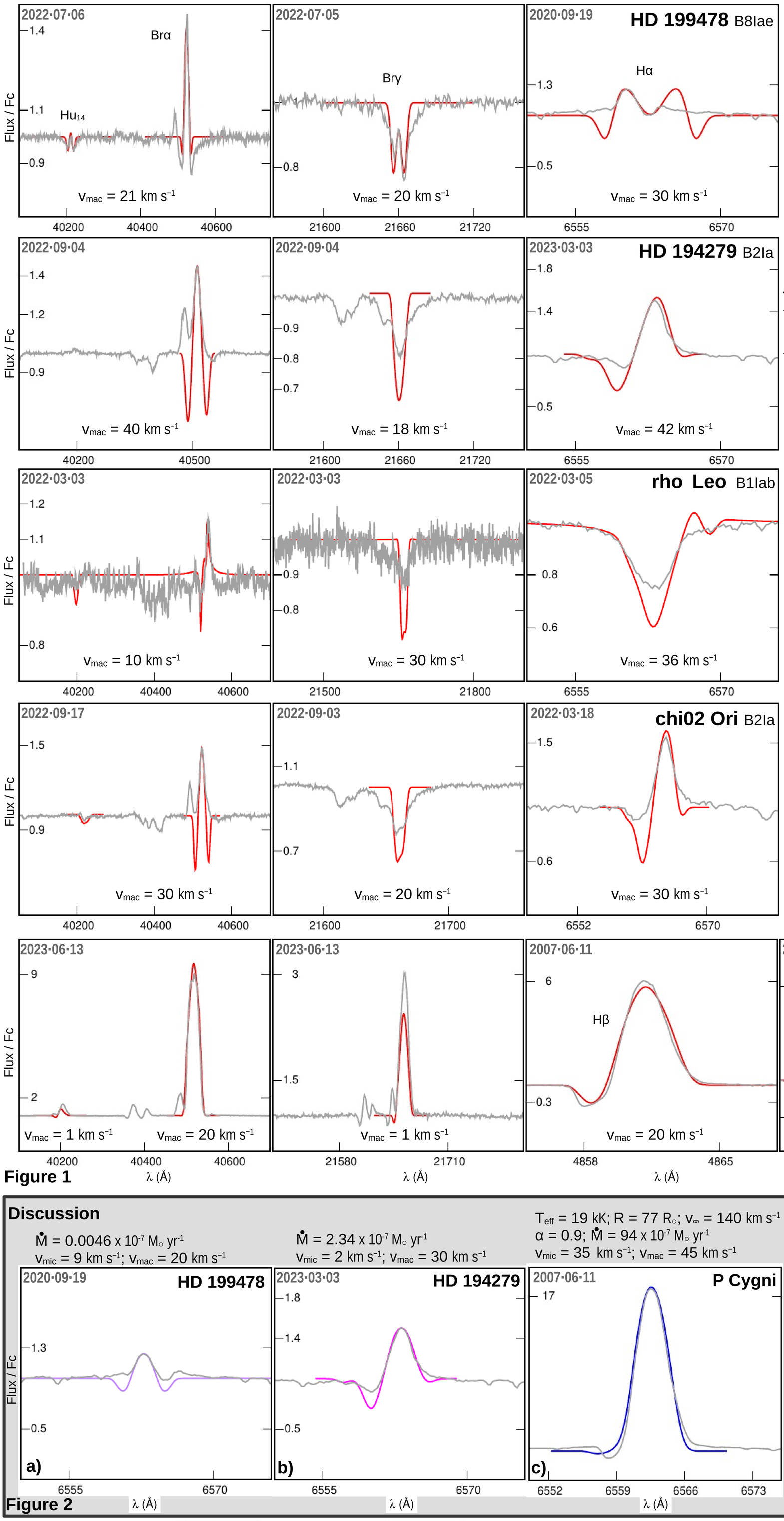

Figure 1

Motivation

Blue supergiants (BSGs) are massive and rapidly evolving stars, characterized by strong winds. Analyzing these objects, particularly their stellar winds, is crucial for understanding the evolution of massive stars and their host galaxies. However, observed BSG properties differ from predictions based on the theory of line-driven winds. For example, the standard theory predicts too high values for the mass-loss rates of B supergiants [19,20]. Najarro et al. [14] showed that the hydrogen lines in the near-infrared domain (Brα, Brγ, Pfγ) provide more reliable information about the wind properties than those of the optical spectral region. As the near-infrared lines trace the intermediate and inner parts of the wind [10,14], they could bring additional information about the velocity field and density structure of their line-forming regions [2,9,16]. These authors demonstrated that the Brα line is a more sensitive indicator of mass loss than the Hα line.

Table 1: Parameters of the selected stars according to the literature.

Star	T_{eff} [kK]	log(g) [dex]	R [$R_\odot$]	v sin i [km s^{-1}]	v_∞ [km s^{-1}]	β	$\dot{M}$ [10^{-7} $M_\odot$ yr^{-1}]
HD 199478[11,15]	13	1.7	68	41	230	0.8...1.5	1.86...6.61
HD 194279[8,18]	19	2.3	44.7	53	550	2.5	10.5
rho Leo[1,6]	22	2.55	37.4	50	1110	1.0	3.5
chi02 Ori[7]	19	2.3	23	40	510	2.0	1.7
P Cygni[17]	18.7	2.25	75	35	185	2.3	400.0

Results

We compare high-resolution spectroscopic observations of BSGs, acquired with the Gemini Near-Infrared Spectrograph (GNIRS, Programs ID GN-2022A-Q-322, GN-2022A-Q-234, GN-2022B-Q-226, GN-2023A-Q-132) in the K- and L-bands, complemented with Hα line profiles obtained at Ondřejov Observatory, with synthetic hydrogen spectral line profiles (Fig. 1, Table 2). For the line profile modeling, we use an adapted version of the APPEL code [3,4,12] in order to describe the structure of the wind of these stars and to estimate accurate mass loss rates. This code solves the NLTE radiative transfer equation in the comoving frame with spherical geometry, using a β law for describing the wind velocity field.

Table 2: Wind and stellar parameters derived by our model fit.

Star	T_{eff} [kK]	log(g) [dex]	R [$R_\odot$]	v_∞ [km s^{-1}]	α = T_w / T_{eff}	β	v_{mic} [km s^{-1}]	$\dot{M}$ [10^{-7} $M_\odot$ yr^{-1}]
HD 199478	13	2.0	68	280	0.34	0.8	6	0.009
HD 194279	20	2.25	45	115	0.6	2.3	13	2.88
rho Leo	22.5	3.0	35	1100	0.4	2.0	15	4.30
chi02 Ori	20	2.5	23	120	0.6	2.5	10	0.90
P Cygni	18	2.25	75	160	0.7	1.1	15	96.0

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Discussion

Figure 2

Our model parameters for **HD 199478** provide a good fit and identify the star as a "weak-wind" BSG (Table 2). However, with an even smaller mass-loss rate (Fig. 2a), we can improve the fit of the Hα emission line, just like for **HD 194279** (Fig. 2b).

For **rho Leo**, our derived mass-loss rate (Table 2) is larger than the published value (Table 1), while for **chi02 Ori** we obtain a lower rate.

The Hα line modeling of the LBV **P Cygni** (Fig. 2c) requires a parameter set slightly different from that of the other spectral lines shown above. The wind does not seem to follow an isothermic behaviour, and the Hα line may be affected by the deceleration of the wind or clumping.

Part of the discrepancies between previously published and our $\dot{M}$ estimates can be attributed to the different observation dates, as all the selected stars are very variable. The models show some discrepancies in the wings, since our line profile modeling approach does, at present, neither account for the effect of the free electron redistribution profile nor the Stark effect. We estimate that the uncertainty of the derived parameter values is on the order of 5 to 10% according to [5].

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