Examining structure in stellar winds of early B type supergiant stars

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Importance of wind structure for stellar mass-loss

Mass-loss rates are critical for understanding the evolution of hot, massive stars and their feedback into the interstellar medium.

Stellar winds of these stars, and consequently UV wind diagnostic lines are structured and variable.

The HST ULLYSES UV data sets provide the opportunity to probe wind structure at sub-solar metallicity.

Earlier studies[1] have sought to identify observational signatures of structures within the stellar winds of OB type stars, based on individual UV spectra.

We focus here on wind structure in B type supergiant stars within the Large and Small Magellanic Clouds (LMC, SMC).

Technique

The effect of wind clumping on doublet line ratios has previously been demonstrated[2]. In smooth winds, the ratios of the optical depths of the doublet components will be the ratios of the doublet oscillator strengths (*f*).

In structured winds, the component optical depths are determined by the coverage fraction, describing the fraction of the wind structure that is optically thick. In this case, the doublet component optical depth ratio therefore departs from the *f*-value ratio and approaches unity.

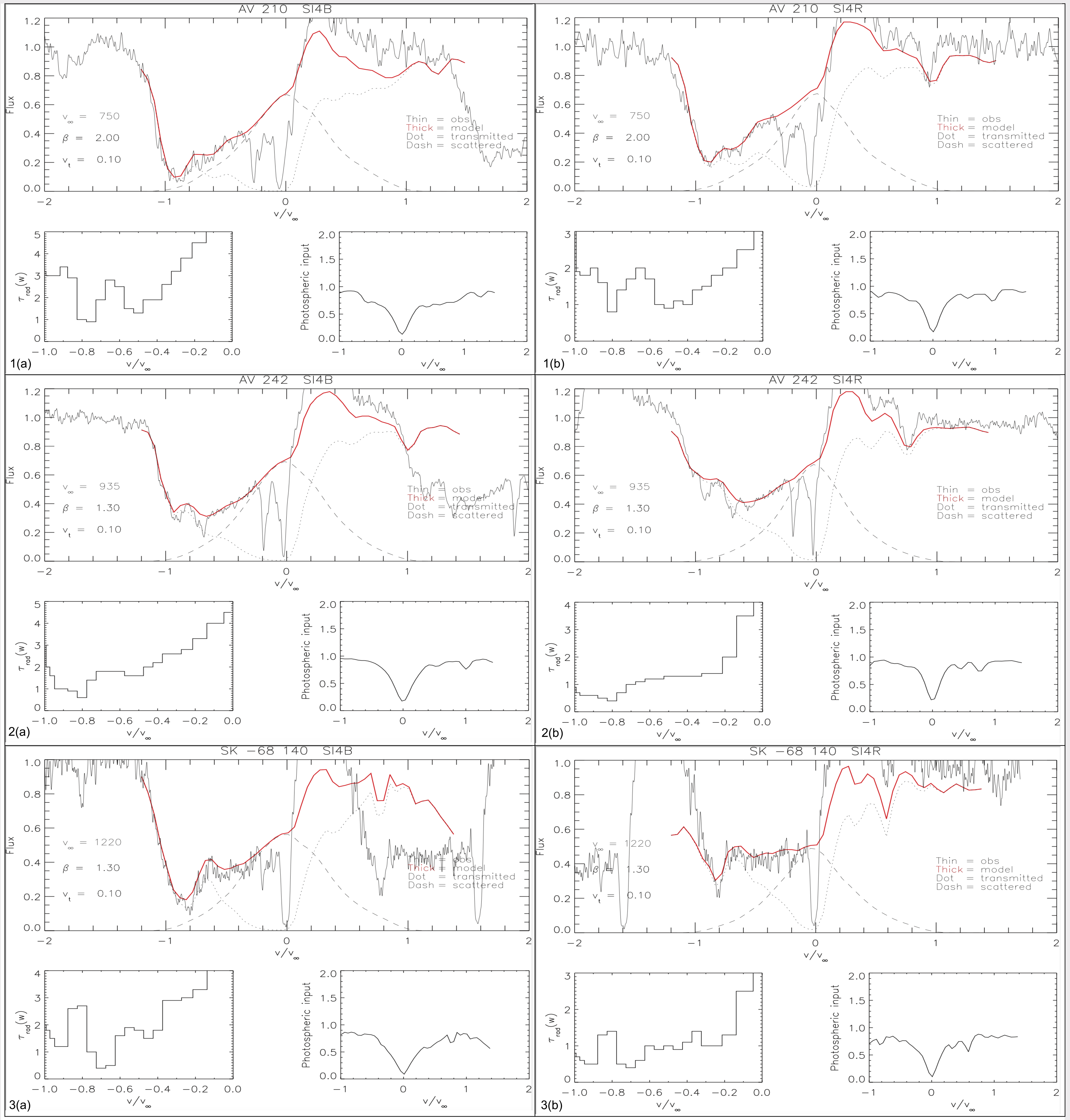
We here consider evidence for such departure by examining each element of the Si IV 1394, 1403 Å feature in the UV spectrum of target stars. This doublet's components are well-separated, so can be treated as radiatively decoupled and separately fitted using an SEI-derived[3] model.

Observations

Figures 1-3 in the centre panel show the separate SEI model fits for each element of the Si IV doublet (the thick line on each large plot).

The lower left plot in each group show the radial optical depths across normalised velocities (v/v_∞) for three of the five initial target stars.

The lower right plot in each group illustrates the photospheric contribution which is derived from a suitably normalised TLUSTY[4] model fit for each star.



Figs. 1(a),(b), 2(a),(b), 3(a),(b) (Left to right, top to bottom) show SEI model fits for blue (left) and red (right) components of the Si IV doublet. 1 and 2 are SMC stars, 3 is an LMC star. Smaller plots show radial optical depths and photospheric contribution. Plots for AV 266; NGC 2004 ELS 3 (used in Table 1) not shown.

Results: radial optical depth ratios

Table 1, below, shows the optical depth ratios observed between the blue and red elements of the Si IV doublet for each star (*f*-value ratio = 2).

Note that we consider for this purpose the optical depth ratios over a restricted velocity range (0.35 – 0.7 v/v_∞) to avoid complications from narrow absorption components (NACs) and from the very low velocity regime.

One later-type star has been included as a comparator.

Star	Spectral type	Mean rad. opt. depth ratio	Std dev.	Std error
AV 210	B1.5 Ia	1.55	0.27	0.10
AV 242	B0.7 Iaw	1.59	0.25	0.09
AV 266	B1 I	1.68	0.57	0.20
Sk-68 140	B0.7 Ib-Iab Nwk	1.59	0.46	0.16
NGC2004 ELS 3	B5 Ia	1.92	0.20	0.07

Table 1: Tabulation of spectral types of initial target stars and average radial optical depth ratios for blue/red components of the Si IV doublet feature. The final two columns show the standard deviation and standard error for each average optical depth ratio calculation.

Summary of findings

AV 210, AV 242: data indicate that wind structure is present.

NGC 2004 ELS 3: data indicate that no significant wind structure is present.

AV 266, Sk -68 140: inconclusive results.

Conclusion

Our initial results show how single-epoch ULLYSES spectra can be used to detect wind structure in early B type supergiants.

Among our sample of five stars, two show statistically significant evidence of structure.

Future work: expand the sample to study how metallicity, spectral type, wind speed and opacity is correlated with wind structuring.

References

1. e.g. Prinja, RK; Massa, DL *A&A* **521**, L55 (2010)
2. Massa, DL; et al *ApJ* **586**, 996 (2003)
3. Lamers, HJGLM; Cerruti-Sola, M; Perinotto, M *ApJ* **314**, 726 (1987)
4. Hubeny, I *Comp Phys Comm* **52**, 103 (1988) and later guides

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