An unprecedented view of hot-star atmospheres from ASTRAL-II UV spectra: the early-types sample

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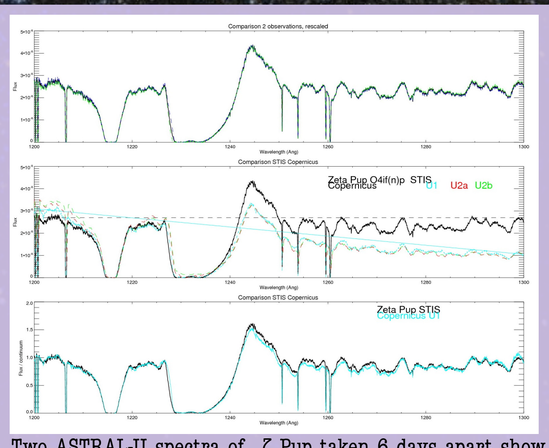
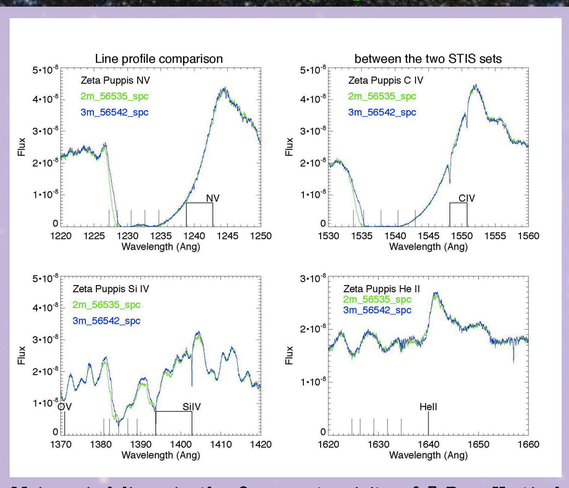
Comparison of ζ Pup with early Copernicus data



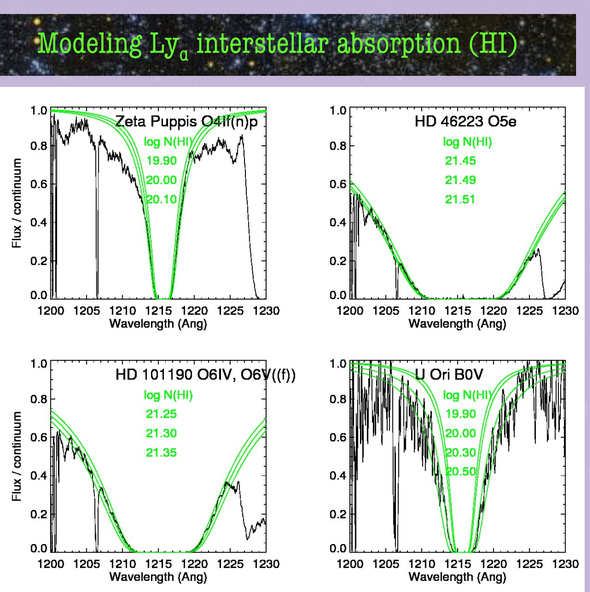
Two ASTRAL-II spectra of ζ Pup taken 6 days apart show subtle differences in the wind lines (see below). We compared the average ASTRAL-II spectrum with Copernicus data, the only data available at very high resolution. We normalize the (uncalibrated) Copernicus spectra and ASTRAL spectra to the local continuum: the broad line profiles generally compare very well, validating the reduction procedure (see Ayres et al. for details of the STIS echelle data reduction)

Short-term variation of ζ Pup wind lines



Major wind lines in the 2 separate visits of ζ Pup. Vertical bars indicate the rest-frame positions of the doublets, as well as wind velocities of 1000, 1500, 2000, 2500, 2800 km/s for the blue component of the doublet. The high S/N of ASTRAL-II data allows us to appreciate subtle variations in the wind velocity and/or optical depth structure of the outer wind layers. This star is known to show variability in wind line profiles with recurrent Discrete Absorption Components ("DACSs") on time-scales of 1-5 days (Howarth et al. 1995 ApJ, 452, L65). In the NV and CIV lines, any variation would only be visible in the non-saturated portion of the profiles, such as the short-wavelength edge, reflecting changes in the outermost layers of the expanding wind.

Modeling Ly_α interstellar absorption (HI)

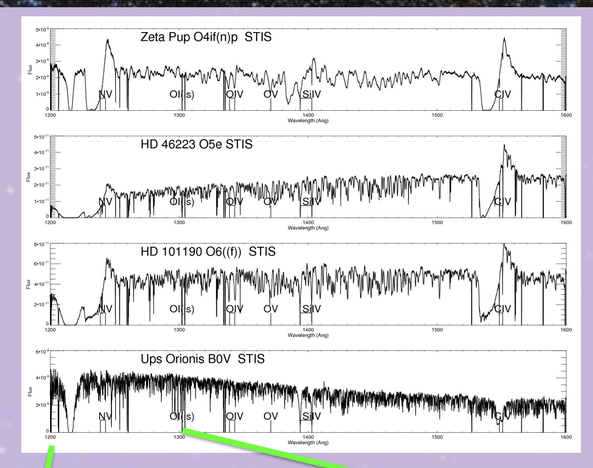


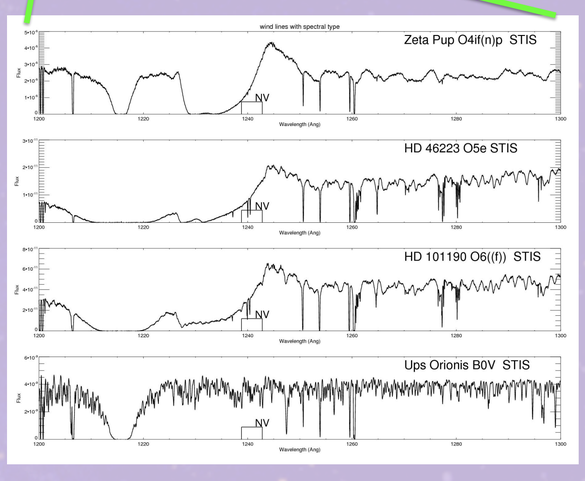
The region of the broad interstellar Ly_α absorption, with model calculations of foreground HI absorption for different column densities (green). The spectra (black) are normalized relative to the local continuum; some stellar lines are seen in the wings of Ly_α

The ASTRAL-II hot stars treasury program (P.I. T. Ayres) is constructing a library of UV spectra (1150-3100Å), with signal-to-noise > 100 and the highest resolution feasible (30,000 – 100,000), of prototypical hot stars representing major types. The sample includes also emission line ('e') and 'peculiar' types. Such high quality spectra will remain a benchmark reference for stellar atmosphere modeling for years to come. The overall program is described by Ayres et al. in this symposium.

We present a first look at the spectra of the hottest stars in the sample, including variations in the wind of ζ Puppis between two observations taken 6-days apart, and preliminary results from line analysis with expanding atmosphere models computed with CMFGEN.

Major wind lines in the short wavelength range





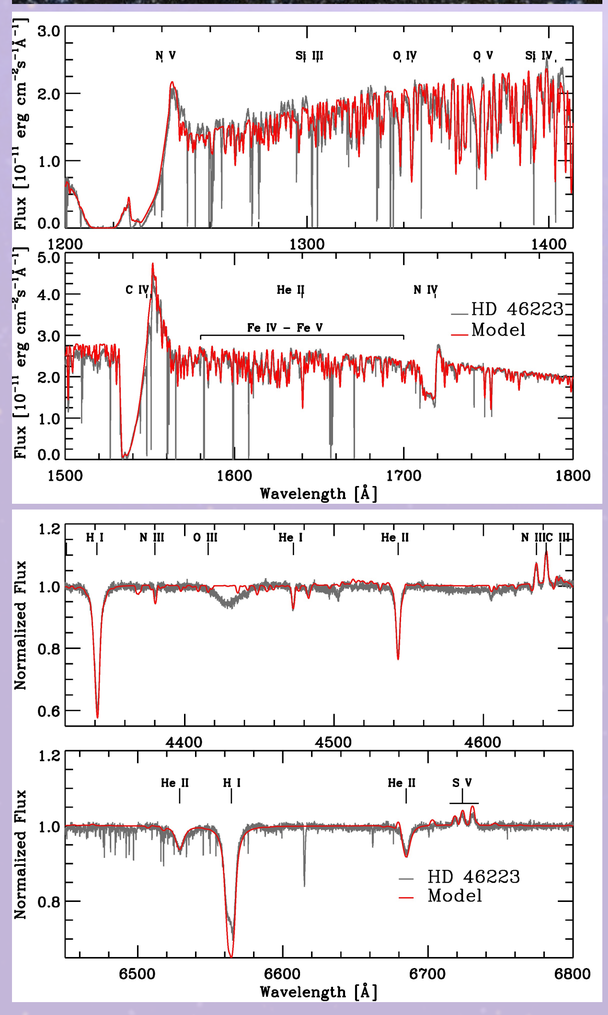
The hottest stars in the ASTRAL-II sample:

HD Number	Proper Name	α_{2000}	δ_{2000}	V	B-V	Type	π	Notes
		(°)	(°)	(mag)	(mag)		(")	
93129A	HD-93129A	160.989	-59.547	7.31	0.17	O2If*	0.000	double: 0.05" sep
66811	**ZET-PUP**	120.896	-40.003	2.25	-0.28	O4If(n)p	0.003	classic P-Cygni wind
46223	**HD-46223**	98.038	+04.823	7.32	0.13	O5e	0.000	MK standard
101190	**HD-101190**	174.541	-63.196	7.33	0.04	O6V((f))	0.000	
46202	HD-46202	98.043	+04.966	8.20	0.16	O9V	0.000	MK standard
36512	**UPS-ORI**	82.982	-07.301	4.62	-0.26	B0V	0.001	sharp-lined
36959	HR-1886	83.754	-06.009	5.67	-0.23	B1Vv	0.001	sharp-lined, `normal' B
37479	SIG-ORI-E	84.696	-02.594	6.66	-0.18	B2Vp	0.007	broad-lined, magnetic star
36285	**HR-1840**	82.586	-07.434	6.32	-0.19	B2IV-V	0.001	sharp-lined
52089	EPS-CMA	104.656	-28.972	1.51	-0.13	B2Iab	0.008	low ISM
160762	IOT-HER	264.866	+46.006	3.80	-0.17	B3IV	0.007	sharp-lined, abundance standard
120709	**3-CEN-A**	207.956	-32.994	4.52	-0.14	B5IIIp	0.009	HgMn
215573	XI-OCT	342.595	-80.123	5.31	-0.12	B6IV	0.007	sharp-lined, `normal' B

(see Ayres et al. for complete table)

Spectral modeling with the CMFGEN atmosphere code, from Puebla, Hillier et al. in prep. Sample results for 2 stars

HD 46223 (top panel: ASTRAL UV spectra)

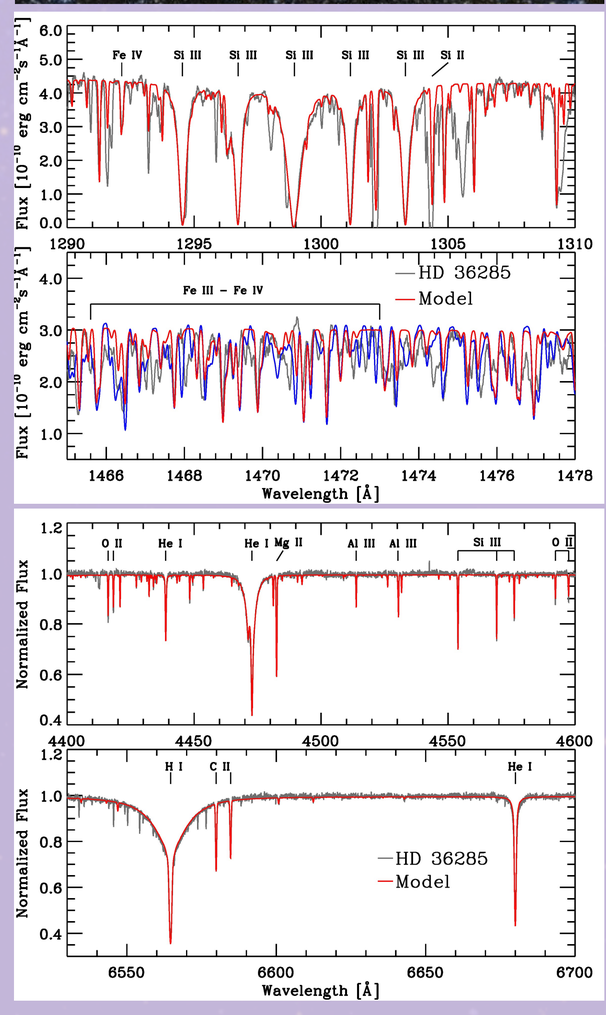


←LEFT Best-fit CMFGEN model (red) of HD 46223 (05e) with T_{eff}=4.25E4, log g=3.9, dM/dt=4E-8 $M_\odot$/yr. Mass-loss rate is about 40% lower than previously derived (Martins et al. 2012 A&A 538, 39), due to the lower filling factor (which describes the amount of clumping in the wind) constrained by OV and NIV lines. T_{eff} and log g are also refined. The high S/N of the STIS UV data has allowed us to improve the fit wrt previous analysis, especially for iron transitions and for features long-wards of 1700Å. The narrow, deep absorption features (UV and optical) are interstellar absorptions, the broad feature around 4440Å is a diffuse interstellar band. The optical spectra (R~46000) were taken with the FIES echelle spectrograph at the Nordic Optical Telescope (Simón-Díaz et al. 2011 Bull. Soc. Roy.Liege 80, 514, Simón-Díaz & Herrero 2014 A&A, 562, 135)

RIGHT →

Best-fit (T_{eff}=2.1E4K, logg=4.1) CMFGEN model (red) of the B2IV-V star HD 36285. The fit in the optical range is superb; the high S/N of the STIS UV spectrum, and the star's low rotation rate, allow us to investigate the inadequacies of present atomic data. In the top panel, the red model includes only transitions of known wavelength. However, many additional lines of Fe III and Fe IV are expected in some wavelength regions. The blue model shows the same CMFGEN model computed including also transitions with uncertain wavelengths. These additional lines strongly affect some UV spectral regions.

HD 36285 (top panel: ASTRAL UV spectra)



References:

Ayres, T. & ASTRAL science teams, 2014 , AAS, 223. 25437
Ayres, T. et al. 2014, arXiv 1411.1419
Ayres, T. et al. 2015, this symposium
Puebla, R. E., Hillier, C.J., et al. 2015, in preparation

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