Tomographic Separation of Composite Spectra of O-Type Stars

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ABSTRACT: We have analyzed UV photospheric lines of three O-type binaries (AO Cas, Plaskett's Star, and 29 UW CMa) by means of tomographic and cross-correlation analyses, with the goal of estimating the physical properties of the individual stars. The tomographic techniques allowed us to estimate T_{eff} and $\log g$, the luminosity ratio, and rotational velocities. The mass ratios were obtained from a cross-correlation technique, applied to spectral regions in which preliminary tomography shows the secondary has strong photospheric line features.

1.   ALGORITHMS AND DATA REDUCTION

Ultraviolet spectra with good orbital phase coverage were gathered from the IUE Regional Data Analysis Facility in Boulder. Although these data were used initially to investigate the stellar winds, they do cover about 80% of the spectrum from 1340 – 1780 Å. We used 16, 17, and 28 data sets for AO Cas, Plaskett's Star, and 29 UW CMa respectively.

The tomography algorithm used was a version of the ILST (Iterative Least–Squares Technique). For a binary star, we can imagine a luminous 'object' two pixels thick by n pixels long, where n is the number of pixels per spectrum. The radial velocity differences of the stars at different epochs correspond to different view angles for tomography. See Bagnuolo & Gies 1991 (BG) for details.

2.   AO CASSIOPEIAE

AO Cas is a 3.52d double-lined spectroscopic binary (O9 III, Walborn 1973). Historically, mass ratios have been derived ranging from 1.0 to 1.4, mainly by modelling of the ellipsoidal light curve. The temperatures are relatively pooly determined, but it was thought that the primary is slightly hotter.

Our results for this star have been presented elsewhere (BG). Table 1 summarizes the physical parameters found for both components of this star, as well as for the other two stars; one basic result is that the secondary is slightly hotter. Figures 1a and 1b show that the secondary (lower spectra, both spectra rectified to unit continuum) has stronger Fe V lines than the primary (upper spectra), but weaker Fe IV lines.

3.   PLASKETT'S STAR

Plaskett's Star (HD 47129) has generally been considered the most massive binary since its discovery in 1922. The spectral type of the primary was estimated variously as O7.5 III(f) by Garmany *et al.* (1980) and O7 I by Hutchings & Cowley (1976). The secondary has been an enigma and secondary lines had not been previously found in IUE data. Because of the poor quality of secondary

TABLE 1. Derived Stellar Properties

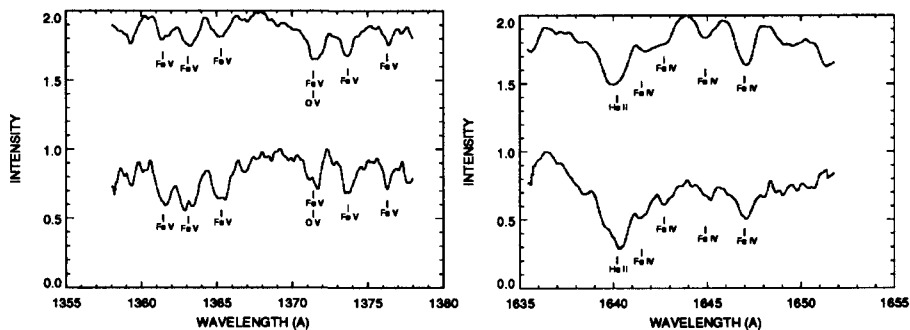| Parameter	AO Cas		Plaskett's Star		29 UW CMa	
	Primary	Secondary	Primary	Secondary	Primary	Secondary
$M/\mathcal{M}_\odot$	12.4	18.3	42.5	51.0	20.0	22.4
Int. Sp. Class	O9.5 I	O8.1 V	O7.3 I	O6.2 I	O8 I	B0 I
T_{eff}	32000	36000	35100	38400	33000	26000
log $L/L_\odot$	5.06	4.82	5.80	5.57-5.94	5.98	5.41
$R/R_\odot$	10.9	6.3	21.5	13.8-21.1	30	25
log g	3.29	4.00	3.4	3.5-3.9	2.8	3.0
$V \sin i$ (km s^{-1})	120	130	75	310	—	—

FIGURE 1 (above). Separated spectra of AO Cassiopeiae
FIGURE 2 (below). RV curve and separated spectra of Plaskett's Star
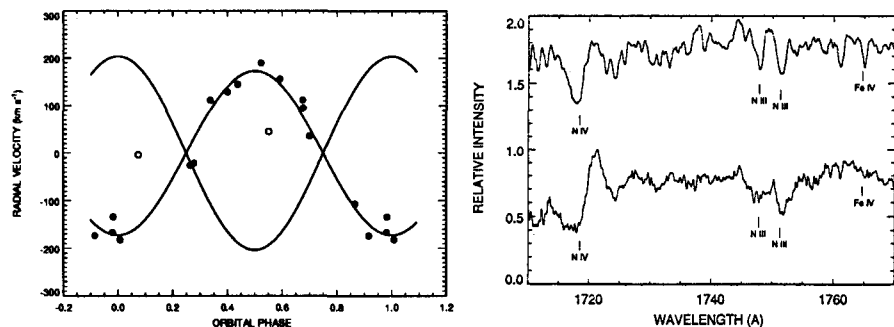
orbital data, the mass ratio and masses are uncertain.

We performed a preliminary tomographic analysis (using the primary orbit by Stickland 1987) and identified the three regions of the strongest secondary lines. We then did a cross-correlation analysis of these regions, producing the radial velocity curve for the secondary shown in Figure 2a, allowing estimates of the masses. (See also Bagnoulo *et al.* 1992) The final tomographic analysis produced sets of reconstructed spectra of which an example is shown in Figure 2b. Note the rotationally broadened lines of the secondary (bottom spectra) and the relative weakness of the secondary Fe IV lines. The secondary has a

characteristic P Cygni profile for the N IV λ1718 line compared to the primary, indicating that the former has a somewhat stronger wind.

The most unexpected results of these analyses (see Table 1) were the earlier type and rapid rotation of the secondary. Two evolutionary scenarios suggest themselves. In the first, both primary and secondary are core hydrogen burning objects evolving off the main sequence. The evolution of the more massive secondary has been retarded by its rapid rotation. The second is an Algol–type system. The primary was initially more massive, but evolved to "red point" on the evolutionary track, filling its Roche lobe and transferring mass and angular momentum to the secondary. The secondary was spun up the large rotational velocity we currently observe. We favor the second scenario for several reasons. If so, there should be a number of 'Plaskett-type' systems, in which the initial separation is close enough to allow a Roche lobe overflow, but far enough to allow the secondary to remain 'spun up' without complete tidal braking.

4. 29 UW CMA

Finally, the secondary of 29 UW CMa had not been seen in the UV, and estimated mass ratios range from $q = 0.75$ (Leung & Schneider 1978) to $q = 1.30$ (Hutchings 1977). We determined the mass ratio to be $q = 1.12$, using techniques as in BG. The secondary is clearly later in type (Fe V lines are weak), but also has several spectral pecularities including the unusually strong λ1723 blend. The primary wind appears to completely dominate, unlike for the other two stars. Figures 3a and 3b show two separated spectra for this star.
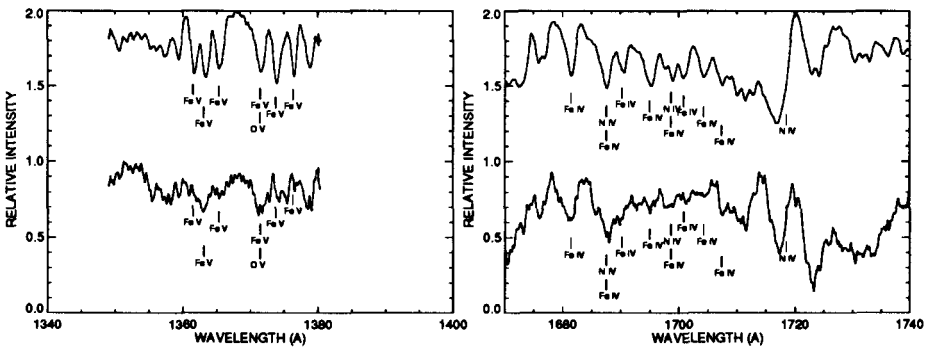

FIGURE 3. Separated spectra of UW CMa

5. REFERENCES

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