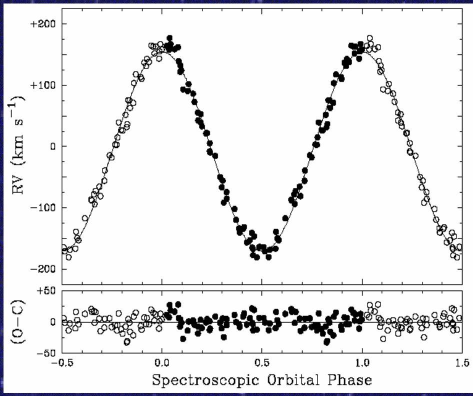
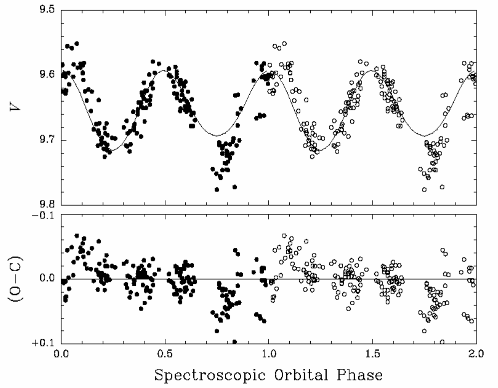
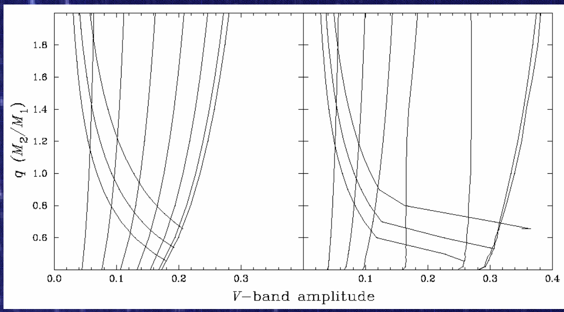
# The Bothersome Binary BD+36 4063

ON supergiants represent the most surface-enriched objects in the sequence OC : O normal : ON. We also know that there is an exceptionally high incidence of binaries among the ON stars; possibly *all* ON stars are in binary systems, which would imply that they are products of binary evolution. Case studies (and particularly mass determinations) should inform us in respect of these objects' evolution, but unfortunately we have not had any 'well-behaved' ON systems amenable to analysis – until now.




***THE BINARY***: BD+36 4063 was classified ON9.7Iab by Walborn & Howarth (2000), who showed it to be a further example of a binary ON system. The orbit is now well established, with period P=4.8d and mass function f(m)=2.2 $M_\odot$; furthermore, small-amplitude photometric variations are present, indicative of 'ellipsoidal' variations.

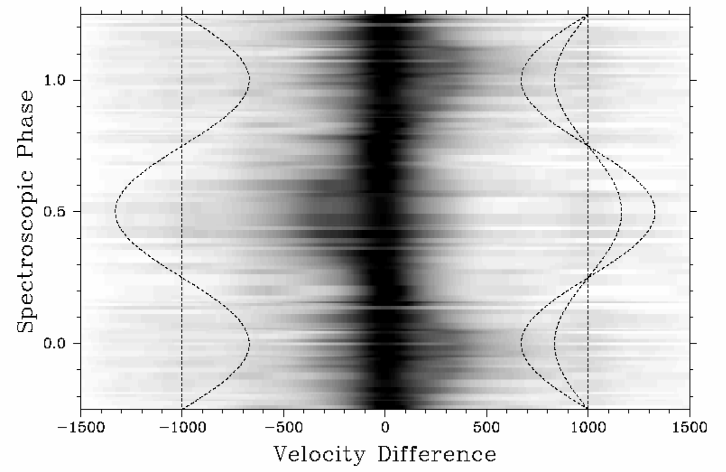



BD+36 is very probably a Cyg OB1 member, so we have an estimate of *M(V)*, and we can estimate *T*(eff) from a spectroscopic analysis, whence we can determine the primary's radius (~20$R_\odot$). This radius cannot be larger than the Roche-lobe size $R_L$, which scales with orbital semi-major axis *a*, and is a function of the mass ratio, *q*, and the rotational rotation rate, ω: $R_L = a\,f(q, \omega)$. We also have $a = a_1 \sin i\,(1+q)/(q \sin i)$; eliminating *i* between these two equations provides a constraint between mass ratio and inclination. The photometric variations provide a separate constraint between *q* and *i* (see model fit above), so the system can be fully solved (subject to reasonable assumptions about the degree of lobe filling).

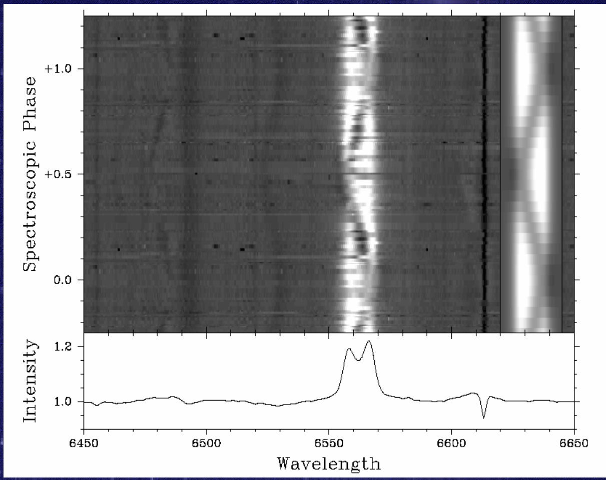
(Left) Constraints on the BD+36 system; near-vertical lines show photometric amplitudes as a function of mass ratio for *i* =30-90° at 10° steps (left to right), for a point-source secondary (left panel) or for a B0V-like secondary (right panel). Lines running down from top left towards bottom right show loci of models which reproduce the observed $a1 \sin i$ for a primary radius of 17.4, 20.4, and 23.4 $R_\odot$ (top to bottom).

**A 'best guess' model has $R_1 = 20.4 \pm 3 R_\odot$, $q = M_2/M_1 = 0.74 \pm 0.15$, $i = 52 \pm 3°$,**
**$M_1 = 36 \pm 15\,M_\odot$ – an unexceptional (if imprecise) mass for a late-O supergiant.**

***THE BOTHER***: The preferred system solution would fit in very nicely with a late-O/early-B, main-sequence secondary. A star like this would be around 2m fainter than the primary, and should have a fairly clear absorption-line signature (even if a rapid rotator); but there's no sign of it spectroscopically, and the photometry suggests it may have the higher surface brightness. Secondly, Hα orbital variability is surprisingly simple: it can be accounted for almost entirely by a constant, strong, symmetrical, optically thin emission component with $\Delta v \approx 300$ km s$^{-1}$ (HWHM); where does this emission come from, and why doesn't it respond to the stars' motion? Could previous mass transfer from an evolved secondary be a factor?




A rather complicated figure!
(1) Cross-correlation functions were obtained by cross-correlating a spectrum of υ Ori (B0V) against all blue spectra, then shifting to the rest frame of the primary. They are greyscaled here, where the zero-velocity dark band is the signature of the primary's ccf.
(2) A spectrum of 10 Lac (O9V) was added to the spectra, with Δm=2m and velocity shifts *in antiphase* to the actual secondary; maximum positive velocity is at phase 0.0 (as shown by the left-hand sine wave). This 'fake secondary' is easily visible in the greyscaled data.
(3) The lower-amplitude sine wave to the right shows heliocentric zero velocity in this rest frame; there's a weak matching feature evident in the data, which probably arises from inadequate corrections for interstellar, or circumstellar, features.
(4) The larger-amplitude right-hand sine wave shows the secondary's expected behaviour for a mass ratio of 1 (amplitude increases with decreasing secondary mass); there is no trace of the real secondary's spectrum.




Hα spectra (with the mean spectrum shown in the bottom panel). The data are shown in a heliocentric rest frame, and orbital motion can be seen in the photospheric lines (e.g., He II λ6527; constant-wavelength features are diffuse interstellar bands). Variability is largely accounted for by a simple constant emission component plus a constant-strength, variable-velocity photospheric absorption profile; the inset shows a simple model constructed on this basis.