From Interacting Binaries to Exoplanets: Essential Modeling Tools
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An Unexpected Outcome from Disentangling

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1. A surprising result...

During our recent spectroscopic study of ϵ Aur (Chadima *et al.* 2011), we made an attempt to detect weak spectral lines of the secondary, hidden in a dark disk, using the spectral disentangling technique of Simon & Sturm (1994) and Hadrava (1995, 1997, 2004). We used the Dominion Astrophysical Observatory (DAO) and Ondřejov (OND) red electronic spectra, which cover more than one half of the orbital period. To our surprise, two different programs that disentangled the spectrum in Fourier space, KOREL (Hadrava 1995, 2004) and FDBINARY (Ilijić *et al.* 2001), both yielded apparently good, similar reconstructions of *two* well-defined spectra for mass ratios near unity. The results (Solution 1) are shown in Fig. 1 (left panels) and Table 1 (left column). This result is hard to accept as real given the existing knowledge about the system: ϵ Aur is an F-type star with an unseen companion embedded in a cool, dark disk (temperature $\sim$ 500–600 K). A detailed search for any trace of spectral signatures of the secondary in the spectra was carried out (see Bennett *et al.*, these proceedings). Although they found line profile variations that were correlated with orbital phase, these variations were not consistent with the presence of a secondary.

2. ...its verification...

To shed more light on the whole problem, we carried out two further tests. First, we attempted to disentangle the spectra for an arbitrarily-chosen, fictitious orbital period of 700 days. All six orbital elements were allowed to converge freely in KOREL. The disentangling procedure was then repeated using the alternate program FDBINARY, for the same orbital elements found by KOREL. Comparable disentangled profiles were obtained, this time with a strong secondary spectrum (Solution 2), shown in Fig. 1 (middle panels) and Table 1 (middle column). Next, we fixed the period at the value found for the physical variations (66.21 d: Chadima *et al.* 2011) and allowed the remaining five elements in KOREL to converge freely. An even stronger secondary spectrum was found (Solution 3), presented in Fig. 1 (right panels) and Table 1 (right column).

3. ... and a possible explanation

What can be the reason for such unusual behaviour from a technique that usually returns excellent results? Our application violates one of the basic principles of disentangling: the assumption that the line profiles of both binary components vary in intensity but not in shape. The line profiles of ϵ Aur do exhibit changes on a timescale of weeks. However, disentangling has been successfully applied to several binaries with components

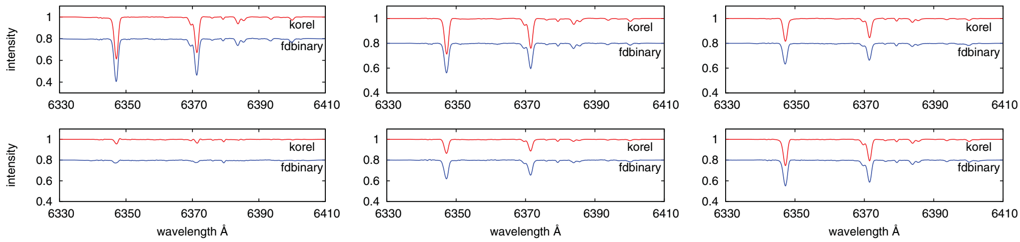

Figure 1. Disentangled spectra of ϵ Aur from KOREL and FDBINARY solutions. Spectra of the primary appear in the top panels; those of the secondary in the bottom panels. Solution 1 is shown on the left, solution 2 is in the middle and solution 3 is on the right.

also exhibiting line profile changes on timescales shorter than their orbital periods, so this is probably not the only reason. We believe that the problem occurs because the amplitude of the ϵ Aur radial velocity changes is small compared to the width of the spectral lines. Therefore, in the model, spectral lines of the primary as well as of the putative secondary remain heavily blended at all orbital phases, and the line width changes are misinterpreted by both programs as arising from the lines of two binary components.

Our result represents a methodological warning that one should not accept even a very satisfactory result from the disentangling procedure without carrying out additional tests to see how realistic the result is. We suggest first mapping the space of the key orbital elements and checking the run of the sum of squares of the residuals.

Table 1. The resulting orbital elements obtained in the three trials discussed in the text. Elements freely converged in a given solution are denoted by asterisks.

element	solution 1	solution 2	solution 3
$T_{\mathrm{per.}}$ (HJD-2454000)	609.0	577.6*	639.5*
P (d)	9890.62	796.7*	66.21
e	0.252	0.295*	0.305*
ω (°)	42.3	114.8*	49.97*
K_1 (km s^{-1})	14.35	14.23*	15.00*
$q = M_2/M_1$	0.994*	0.998*	0.900*

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