Peculiarities in the ($\theta^1$) Orion Trapezium Components A and B (V1016 and BM Ori)

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$\theta^1$ Ori B = HD 37021 = BM Ori

V = 8.0          B1-3 V

Eclipsing and spectroscopic binary P = 6.47053 d

- Primary eclipse: Color dependent; depth $\sim 0.7$ mag in V. Total duration WAS $\sim 16$ hours (8h of flat bottom), but it shortened to less than 12 hours (Windemuth, 2013)

- Shallow secondary eclipse; better detected at NIR $\lambda$s

- Spectroscopic observations have shown the eclipse is NOT an occultation. A pre-main-sequence, early-F secondary star + circumsecondary disk are required to explain the observations.
$\theta^1$ Ori B = HD 37021 = BM Ori

Spectroscopic orbital parameters lack precision because:

1. The primary component has very wide spectral lines (mostly H and He) that are contaminated by strong nebular lines.

2. Vitrichenko & Klochkova (2004) propose a variable systemic velocity due to a third component with mass $\sim 2$ Mo in a very eccentric orbit ($e = 0.92$), $P \sim 1302$ d and $K(1+2) \sim 20$ km/s (only the primary was used).

3. There is probably circumstellar matter flowing around and between both components. (The MgII $\lambda 4481$ strong line shows no correlation with the orbital phase)
$0^i$ Ori B = HD 37021 = BM Ori

The secondary spectrum is clearly show when cross-correlating BM Ori spectrum with an early-F type template (except during secondary eclipses).

We propose to obtain the orbital parameters of the eclipsing binary using the secondary component, in order to check for the existence of a third, putative CLOSE component.

A progress report is here presented.
The only observed complete cycle: 2010 Jan. Orbital parameters (P=6.47053 d fixed) e=0.05 \( \omega=82^\circ \) K=170 km/s \( \gamma=4.9 \) km/s
All the data (2010 Jan through 2014 Dec) $P = 6.47053\ d$
O-C grouped by epochs; orbital parameters are those obtained for the 2010 Jan run (one whole cycle)
O-C folded by the photometric phase; orbital parameters are those obtained for the 2010 Jan run (one whole cycle)
Setting orbital parameters equal to those of the 2010 Jan run, except for the systemic velocity, we obtain values for this parameter in five epochs, and a velocity curve for the eclipsing binary due to its motion about the center of mass of the system.
$0^i$ Ori B = HD 37021 = BM Ori

CONCLUDING REMARKS

With only 5 data points it is, of course, impossible to find a solution to the orbit of the binary+third component. But such triple system appears to be real.

Lower values of the eccentricity are compatible with our data (0.27 +/- 0.07 for the previously shown “must likely” solution). Shorter period values (512 d) are also possible!!!

“Complete cycle” observations are needed in order to minimize the effect of (circumstellar-induced?) variations in the radial velocities throughout each cycle. Past observations of “complete cycles” must be incorporated (there is at least one; search is in progress).
Multiplicity in the Orion Trapezium
(Preibisch et al. 1999; Schertl et al. 2003; Weigelt et al. 1999; Kraus et al. 2009)

\[ \text{B2 - B3: } \rho = 0.117'' \]
\[ \text{A1 - A2: } \rho = 0.215'' \]

\[ \text{D1 - D2: } \rho = 0.0184'' \]
\[ \text{C1 - C2: } \rho = 0.024'' \]

Orbital motion of \( \theta^1 \) C 1-2

HST image: Bally et al. (1998)

Herbig & Griffin 2006

IOTA
\( \theta^1 \text{ Ori A} = \text{HD 37020} = \text{V1016 Ori} \)

\[ V = 6.73 \quad B0.5 \ V \]
\[ v \ \text{sen} \ i = 55 \text{ km/s} \quad (\text{Simón-Díaz et al 2007}) \]

Eclipsing and spectroscopic binary \( P = 65.433 \text{ d} \)
Eclipse discovered by Lohsen (1975)
Aprox. depth: 1.0 mag. Aprox. Duration: 21 hours

Its delayed discovery as an eclipsing variable suggest:

— recent perturbation
— capture of the secondary component
(\text{Dolgachev et al, 1989 ; Poveda 1999})

\( \text{NO SECONDARY ECLIPSE HAS BEEN OBSERVED} \)
Compilation of photometric and radial velocity data (+ 5 IUE spectra) yield photometric period and orbital parameters. They (wrongly) conclude that the secondary is a late B or an early A pre-main-sequence star.
Orbital parameters not very well determined

Orbit eccentricity:

0.73 ± 0.03 (Bossi et al. 1989)
0.50 ± 0.11 (Abt et al. 1991)
0.66 ± 0.03 (Vitrichenko et al. 1998)
0.626 ± 0.031 (Stickland & Lloyd, 2000)
0.66 ± 0.02 (This work)
Light curve obtained simultaneously with the first spectroscopically observed eclipse
Velocity curve of V1016 Ori with both components
Orbital parameters obtained

<table>
<thead>
<tr>
<th>Both components</th>
<th>Primary</th>
<th>Secondary</th>
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</thead>
<tbody>
<tr>
<td>e</td>
<td>0.685</td>
<td>0.649</td>
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<tr>
<td>$\omega$</td>
<td>183°8</td>
<td>179°7</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>37.1</td>
<td>38.15</td>
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<tr>
<td>$a_1 \sin i$</td>
<td>27.9 Ro</td>
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</tr>
<tr>
<td>$a_2 \sin i$</td>
<td>139.5 Ro</td>
<td></td>
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</tbody>
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$q = \frac{M_2}{M_1} = 0.200$
The Rossitter-MacLaughlin (R-M) effect in V1016 Ori = $\theta^1$ Ori A
Simulation of the R-M effect as produced by HD209458b in transit, with $\lambda$ (the orbital obliquity) as free parameter.
Normalized (O-C) curve: RM effect in 7 eclipses
Simulated R-M effect as a function of \( R = R_1/R_2 \), the ratio of the components' radii.

\[ \lambda = 70^\circ \]
$R = R_1/R_2 = 0.75$ and $\lambda$ as the free parameter
CONCLUSIONS for V1016 Ori

• The secondary is almost as large as the primary but much cooler (about 5800 K).

• Orbital parameters are consistent with those previously calculated (except for the systemic velocity?).

• The orbital obliquity (spin-orbit angle) is very large ($\approx 70^\circ$) suggesting strong perturbations during multiple star formation processes.

THANKS FOR YOUR KIND ATTENTION