Host stars investigations with VEGA/CHARA

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Outline

• Context: observing host stars.

• Observations of three chosen host stars:
  – 14 And
  – u And
  – 42 Dra

• The case of indomitable θ Cygni.
  – Results
  – Variations of the diameter

• Conclusions.
CONTEXT
Why observing host stars?

• To understand better the link between stars and the presence of exoplanets.

• Need of missing stellar parameters (radii....) and of the influence of perturbating elements (spots, LD, …) to study stellar evolution.

• Study of the sample

Exoplanets host stars observable by VEGA/CHARA, ≈ 40 stars (ANR «100 Stars»):
F, G or K stellar type
Diameter < 2mas
Mag V < 6
OBSERVATIONS OF HOST STARS
14 And

HD_221345 1.267±0.147 mas

$\theta_{\text{LD}} = 1.51 \pm 0.02$ mas
$\chi^2_{\text{reduced}} = 2.769$
$\theta_{\text{UD}} = 1.40 \pm 0.02$ mas

$\theta_{\text{UD}} = 1.27 \pm 0.15$ mas
$\chi^2_{\text{reduced}} = 9.13$

Spatial frequency in 1/rad
**u And**

- **HD9826, HIP7513, HR458**
  - Hosts four exoplanets
  - **RA:** 01:36:47.8
  - **Decl:** +41° 24' 20"
  - **V mag:** 4.10
  - **K mag:** 2.86 (Furhmann et al., 1998)

**Observations:**
- Ø**E2E1W2, W2W1**
- Ø**3 observations in October and November 2011**

**Results:**
- \(\theta_{LD} = 1.18 \pm 0.01\) mas
- \(X^2_{\text{reduced}} = 6.9\)
- \(\theta_{UD} = 1.12 \pm 0.01\) mas

**Graphs:**
- \(\theta_{UD} = 1.00 \pm 0.20\) mas
- \(X^2_{\text{reduced}} = 3.29\)
42 Dra

\[ \theta_{UD} = 2.08 \pm 0.21 \text{ mas} \]

\[ \chi^2_{\text{reduced}} = 1.69 \]

\[ \theta_{LD} = 2.12 \pm 0.02 \text{ mas} \]

\[ \chi^2_{\text{reduced}} = 0.199 \]

\[ \theta_{LD} = 1.97 \pm 0.02 \text{ mas} \]
Fundamental parameters of stars

- **Radius:** \[ R \pm \delta R = \frac{\theta_{LD} \pm \delta \theta_{LD}}{9.305 \times (\pi \pm \delta \pi)} \]
- **Mass:** \[ g = -\frac{GM}{R^2} \]
- **Effective temperature:** \[ L = 4\pi R^2 \sigma T_{eff}^4 \]

<table>
<thead>
<tr>
<th>Star</th>
<th>( \theta_{LD} ) [mas]</th>
<th>( \chi^2_{reduced} )</th>
<th>( \pi )</th>
<th>Radius [( R_\odot )]</th>
<th>Mass [( M_\odot )]</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 And</td>
<td>1.51( \pm )0.02(1.3)</td>
<td>2.769</td>
<td>12.63( \pm )0.27(2.1)</td>
<td>12.82( \pm )0.32(2.5)</td>
<td>2.60( \pm )0.42(16)</td>
</tr>
<tr>
<td>( \nu ) And</td>
<td>1.18( \pm )0.01(0.9)</td>
<td>6.9</td>
<td>74.12( \pm )0.19(0.3)</td>
<td>1.70( \pm )0.02(0.9)</td>
<td>1.12( \pm )0.25(22)</td>
</tr>
<tr>
<td>42 Dra</td>
<td>2.12( \pm )0.02(0.9)</td>
<td>0.199</td>
<td>10.36( \pm )0.20(1.9)</td>
<td>22.04( \pm )0.48(2.2)</td>
<td>0.92( \pm )0.11(12)</td>
</tr>
</tbody>
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Errors dominated by the parallax!

Sato et al., 2008: \( M = 2.2 \ M_\odot \)

Furhmann et al., 1998: \( M = 1.27 \pm 0.06 \ M_\odot \)

Döllinger et al., 2009: \( M = 0.98 \pm 0.05 \)
Exoplanets parameters

\[
\frac{(m_p \sin i)^3}{(m_\star + m_p)^2} = \frac{P}{2\pi G} K^3 (1 - e^2)^{3/2}
\]

Eggengerger, A. et Udry, S., 2009

<table>
<thead>
<tr>
<th>Star</th>
<th>Planet</th>
<th>$P_{\text{orb}}$ [d]</th>
<th>e</th>
<th>$M_{\text{pl} sini}$ [$M_{\text{Jup}}$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 And</td>
<td>14 And b</td>
<td>185.84±0.23</td>
<td>0</td>
<td>5.31</td>
</tr>
<tr>
<td>$\nu$ And</td>
<td>$\nu$ And b</td>
<td>4.6±0.2</td>
<td>0.02±0.01</td>
<td>0.62</td>
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<tr>
<td></td>
<td>$\nu$ And d</td>
<td>1276.5±0.6</td>
<td>0.30±0.07</td>
<td>3.74</td>
</tr>
<tr>
<td></td>
<td>$\nu$ And e</td>
<td>3848.9±0.7</td>
<td>0.01±0.00</td>
<td>0.96</td>
</tr>
<tr>
<td>42 Dra</td>
<td>42 Dra b</td>
<td>479.1±6.2</td>
<td>0</td>
<td>3.78</td>
</tr>
</tbody>
</table>

Results in good agreements with previous results!

*Sato et al., 2008: $M_{\text{pl} sini} = 4.8 \, M_{\text{Jup}}$
*Curiel et al., 2011: $M_{\text{pl} sini} = 0.69, 1.98, 4.13$ and $1.1 \, M_{\text{Jup}}$ for $u$ And b, $u$ And c, $u$ And d and $u$ And e respectively.
*Döllinger et al., 2009: $M_{\text{pl} sini} = 3.9 \, M_{\text{Jup}}$
THE CASE OF INDOMITABLE $\theta$ CYGNI
θ Cygni

- M dwarf companion orbiting at 46 AU of angular separation, contrast of 7.9 in the V band) (Desort et al., 2009).

- Kepler target \(\rightarrow\) photometric observations led to the detection of solar-like oscillations.

- Spectroscopic observations with \(\rightarrow\) and SOPHIE (OHP) \(\rightarrow\) quasi-per RV of \(\approx\)150 days.

\(\rightarrow\) More than 3 exoplanets? Co-orbiting planets in resonance? (Desort et al., 2009).

\[\text{RV by Anne-Marie Lagrange with SOPHIE (OHP)}\]

\(\text{Julian Day – 2454000}\)
Observations

- From June 2010 to November 2011
- E2E1W2, W2W1E1 and W2W1E2
- 3 different calibrators
- Sequence of observations: cal – target – cal

⇒ Dispersed results!
Results

<table>
<thead>
<tr>
<th>Stellar parameters</th>
<th>Value±Error</th>
</tr>
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<tbody>
<tr>
<td>LD diameter [mas]</td>
<td>0.760±0.002(0.3)</td>
</tr>
<tr>
<td>Radius [R⊙]</td>
<td>1.490±0.006(0.4)</td>
</tr>
<tr>
<td>Mass [M⊙]</td>
<td>1.30±0.14(11)</td>
</tr>
</tbody>
</table>

Radius =1.70 ± 0.03  
(Boyajian et al. 2012) 
Radius =1.50 ± 0.04  
(van Belle et al., 2008)

\[ \theta_{LD} = 0.861 \pm 0.015 \]  
(Boyajian et al. 2012) 

Mass=1.34 ± 0.01  
(Boyajian et al. 2012) 
Mass =1.38 ± 0.05  
(Desort et al., 2009)
Variations of $\theta$ Cygni’s diameter

$0.667 \text{ mas} < \text{LDD} < 0.813 \text{ mas}$

Phase = (RJD mod 150)/150
Variations of θ Cygni’s diameter

• Periodical radial velocity of 150 days: link with the variation of the diameter?

• Waiting for closure phases…

• Other possible causes:
  – A second unknown companion, which would exchange flux with the host star?
CONCLUSIONS
Conclusion (1/2)

• Perspectives:
  • Direct determination of LD coefficients,
  • Need to improve the calculation of error bars.

• Improved modeling (Cesam2K):
  • $T_{\text{eff}}$ and metallicity,
  • Mass and age.

• Good method to derive $M_{\text{pl}}sini$.
• To be applied to transiting exoplanets to directly deduce planets radii.
Conclusion (2/2)

- Validity of the measurements with the observations of 14 And, u And and 42 Dra.

- θ Cygni shows dispersed results, but the other measurements prove that VEGA provide good quality data.
  ➔ Intrinsic variations from the star?

- We know that this star has been showing interesting but not understood patterns since it has been observed.
  ➔ Star not fully understood yet, the investigations continues…
Thank you for your attention