Using MagAO and GPI to obtain complete SEDs and empirical bolometric luminosities of young giant exoplanets
Beta Pictoris – First star known to host bodies analogous to those seen in the Solar System

Using MagAO

Smith & Terrile 1984

Infrared view of the planetary system around the young star β Pictoris

β Pictoris

position of the star (artificially subtracted)

β Pictoris

giant planet β Pic b
seen in L' band (3.8 μm)
in November 2009

dust disk
in J band (1.3 μm)

size of Saturn’s orbit around the Sun

0.5 arcsec
10 au

25 arcsec
500 AU

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Lagrange et al 2009

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Gemini Planet Imager
Using MagAO & GPI to obtain complete SEDs & Lbol's of young EGPs

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Macintosh et al 2014
Males et al 2014
Morzinski et al 2015
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GPI H spectrum: Teff 1600-1700 K; logg 3-5

Chilcote et al. 2015
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Spectrum of Beta Pic A

\[ F_\lambda \text{ [ergs sec}^{-1} \text{ cm}^{-2} \mu m^{-1}] \]

- 13 Color
- Cousins
- Glass
- ESO

\[ \lambda \text{ [\mu m]} \]
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Beta Pic b Spectral Energy Distribution 0.9-5um

Lagrange+ 2009
Quanz+ 2010
Bonnefoy+ 2011/2013
Currie+ 2011/2013
Absil+ 2013
Males+ 2014
This Work

MagAO ★
GPI +
NaCo ●
NICI ●
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Teff 1500-1700 K; logg 3-5

BT-Settl 11
1700 K
log(g)=5.0
R=1.59 Rjup
log(Lbol/LSun)=-3.79
[Fe/H]=0.5
$\chi^2=1.28$

BT-Settl 11bc
1500 K
log(g)=3.0
R=1.87 Rjup
log(Lbol/LSun)=-3.82
$\chi^2=1.29$
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Blackbody fit: Teff 1800 K

1800 K
log(g)= N/A
R=1.28 Rjup
log(LBol/LSun)=-3.78

$\chi^2_v=1.53$
Using MagAO & GPI to obtain complete SEDs & Lbol of young EGPs

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Blackbody families

$F_{\lambda}$ [ergs sec$^{-1}$ cm$^{-2}$ $\mu$m$^{-1}$]

$\lambda$ [\(\mu\)m]

1850 K
1750 K
1650 K
1550 K

1.23 R_Jup
1.37 R_Jup
1.55 R_Jup
1.78 R_Jup
VisAO constrains Teff while Clio constrains $R$.

Using MagAO & GPI to obtain complete SEDs & Lbol of young EGPs.

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<table>
<thead>
<tr>
<th>Teff/K</th>
<th>R/R_Jup</th>
<th>log(LBol/LSun)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1850</td>
<td>1.23</td>
<td>-3.78</td>
<td>(84.3%)</td>
</tr>
<tr>
<td>1750</td>
<td>1.37</td>
<td>-3.77</td>
<td>(83.8%)</td>
</tr>
<tr>
<td>1650</td>
<td>1.55</td>
<td>-3.77</td>
<td>(82.9%)</td>
</tr>
<tr>
<td>1550</td>
<td>1.78</td>
<td>-3.76</td>
<td>(81.5%)</td>
</tr>
</tbody>
</table>
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Beta Pic b fits the hot-start evolutionary models

Spiegel & Burrows 2012
Using MagAO & GPI to obtain complete SEDs & Lbol's of young EGPs

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Measuring $L_{\text{Bol}}$ for tens more planets with GPI & MagAO will fill in the formation picture

McBride et al 2011

Hot start
Cold start
Using MagAO & GPI to obtain complete SEDs & Lbol of young EGPs

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Energy budget: to model cooling evolution

- Insolation/irradiation
- Gravitationally contracting
- Differentiation

Fortney 2011
Using MagAO & GPI to obtain complete SEDs & Lbols

- Insolation/irradiation
- Gravitationally contracting
- Differentiation

Cooling evolution: Interior models

- Insolation/irradiation
- Gravitationally contracting
- Differentiation

Fortney 2007

Fortney 2011

MagAO

magao.as.arizona.edu
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- Fundamental parameters describing formation & evolution remain to be measured
- Broad spectral coverage of the full O/IR SED with MagAO, plus spectra with GPI, is a powerful tool to measure $L_{\text{Bol}}$ and atmospheric properties
- Fully characterizing tens of Jupiter analogs with MagAO+GPI will give a better picture of the formation mechanisms
- This is still a data-starved field with a lot of exciting developments to come with cutting-edge instruments like MagAO, GPI, & JWST!
Thanks: Michelson Sagan NExScI Dawn et al!