C/O or not C/O? Chemical fingerprinting of the birthplaces of exoplanets and brown dwarf companions

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Planet formation in disks

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Planet formation in disks

Core accretion
Gravitational instability

Bill Saxton, NRAO/AUI/NSF
C/O ratio

Öberg et al. 2011
HR 8799c

- Planets at 15-70 AU between H₂O and CO snowlines
- Measured C/O=0.65
- Excluded: gas-only CA (C/O<0.6)

Konopacky et al. 2013
HR 8799c

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Solar abundances for HR 8799?

Konopacky et al. 2013
Why forgetting host stars?

C/O in nearby solar-like stars, Fortney (2012)
Motivation

- Analyze host stars and companions in complex
- Feasibility: can we confidently measure C/O in principle?
1. Host star survey

- FEROS at the 2.2m telescope in La Silla
- $R = 48\ 000$
- Spectral coverage: 330-920 nm
- 20 host stars with directly imaged exoplanets
2. Companion survey

- SINONI/VLT at Paranal
- JHK spectroscopy
- $R = 1500, 2000$ or $4000$
- 10 planet/BD companions
AB Pic A+B

- **Host:** K2V, $T_{\text{eff}}=4800-5000\text{K}$
- **Companion:** $T_{\text{eff}}=1600-1900\text{K}$, $15M_{\text{Jup}}$ at 275 AU

Chauvin et al. (2005)
Metallicity determination

$T_{\text{eff}}$ from color-T relations

Line synthesis

Fe abundance

C/O ratios

**Oxygen**
- Forbidden [O] at 6300 angstrom
- O triplet at 7772, 7774, 7775 angstrom

**Carbon**
- Various C lines at: 5052, 5380, 6587, 7087, 7111, 7113, 7837 angstrom
AB Pic A

- $T_{\text{eff}}=5200\pm100K$
- $[\text{Fe/H}]=-0.11\pm0.15$
- $[\text{C/O}]=-0.03\pm0.10$

Chauvin et al. (2005)
AB Pic B: chi-square minimization

- BTSettl (courtesy of D. Homeier)
- [Fe/H]: 0.0 and +0.3
- [C/O]: 0.0 and +0.2

Chauvin et al. (2005)
AB Pic B: chi-square minimization

**Best fits**

All bands combined and H, K separately:
Teff = 1500K, logg = 3.5, [C/O] = +0.2

**J band:**
Teff = 1700K, logg = 5.5, [C/O] = 0.0
Problem diagnosis

"Fitting function": $f_{\text{obs}}(\text{wavelength}) = g(\text{wavelength}) \times f_{\text{model}}(\text{wavelength})$
AB Pic B [C/O] = +0.2 (0.85 in linear scale)

Öberg et al. 2011
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AB Pic A+B: **TENTATIVE** conclusions!

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$[\text{C/O}] = +0.2$ - formed by core accretion?

Chauvin et al. (2005)
Summary

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- Try different models (Molliere’s and Helling’s model grids)
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Thank you!