Linking planets to disks with elemental ratios

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Planets can move…

…but can we relate their composition to their origin?
Most known planets: 0-10 Myr

- Jet
- Accretion
- Sublimation
- Snowlines
- Snowlines
- Ices
- Radial drift
- Disk wind
- Gas, small dust
- Mix, diffusion
- Freeze-out
- Dust

A protoplanetary disk

0-10 Myr

Midplane temperature

r (au)

0.1  1  10  100
A planet-disk C/Onnection hypothesis

Öberg et al. (2011)
Adding physics, chemistry complicates the picture

Pebble drift

Chemistry & evolving disk

Booth et al. (2017); Eistrup et al. (2017)
## Measured gas-phase ratios in disks

<table>
<thead>
<tr>
<th>Object</th>
<th>C/H $(\times 10^{-4})$</th>
<th>C/O</th>
<th>N/O</th>
<th>S/H $(\times 10^{-5})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>2.69</td>
<td>0.55</td>
<td>0.16</td>
<td>1.32</td>
</tr>
<tr>
<td>DM Tau</td>
<td>0.2…1.0</td>
<td>&gt;1</td>
<td></td>
<td>&lt; $10^{-2}$</td>
</tr>
<tr>
<td>GM Aur</td>
<td>$10^{-2}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GO Tau</td>
<td>&gt;1</td>
<td></td>
<td></td>
<td>&lt; $10^{-2}$</td>
</tr>
<tr>
<td>HD 100546</td>
<td>1.35</td>
<td>&lt;0.9</td>
<td></td>
<td>$\sim 10^{-4}$</td>
</tr>
<tr>
<td></td>
<td>0.135</td>
<td>&lt;0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IM Lup</td>
<td>0.8</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LkCa 15</td>
<td>&gt;1</td>
<td></td>
<td></td>
<td>&lt; $10^{-2}$</td>
</tr>
<tr>
<td>TW Hya</td>
<td>0.01</td>
<td>&gt;1.1</td>
<td></td>
<td>$\sim 10^{-4}$</td>
</tr>
</tbody>
</table>

**Jupiter**

2.37  <0.48  <1.36  8.9

*Kama et al. (2016); unpublished results; full references in ARIEL Planet Formation WG review note*
Spatially resolved CO abundance

Zhang et al. (2019); Krijt et al. (2018)
Spatially resolved CO abundance

work in progress
see also Kama et al. (2015, inner disk); Bergner et al. (2019, outer disk)
A-type stars: where we link planets to disks

Kama et al. (2019 arXiv; accepted in A&A)
A-type stars: where we link planets to disks

Kama et al. (2019 arXiv; accepted in A&A)
Predicted TESS yield

- **FFIs**
- **2-min**

### Number of Planets

**Spectral Type**
- M: 496
  - FFIs: 371
  - 2-min: 125
- K: 695
  - FFIs: 216
  - 2-min: 479
- G: 1218
  - FFIs: 351
  - 2-min: 867
- F: 1524
  - FFIs: 299
  - 2-min: 1225

### Look here to investigate planet formation

TESS yields from
Barclay et al. (2018)
Unlocking the science:
Outlook on disks leading up to ARIEL

• Characterisation of CHNOPS reservoirs in disks
  see Kama et al. (2019, ApJ) for S

• Spatially resolved elemental ratio measurements + models
  work in progress

• Planets, disks of A-stars can constrain formation, migration:
  include A-type star HJs in space missions
  Kama et al. (2019, arXiv) and in prep

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