MATISSE
Multi AperTure mid-Infrared SpectroScopic Experiment

Spatially resolving the chemical composition of the planet building blocks

Alexis Matter\textsuperscript{1}, F. Pignatale\textsuperscript{2}, B. Lopez\textsuperscript{1}\textsuperscript{1}\textsuperscript{Laboratoire J.L. Lagrange - Observatoire de la Côte d'Azur}\textsuperscript{2}\textsuperscript{Institut de Physique du Globe de Paris}
The observed planetary systems

- ✔ Diversity of mass and size
- ✔ Diversity of location
- ✔ (very likely) Diversity of composition → planet-hosting stars = $0.2 < \text{C/O} < 0.8$

(e.g., Brewer & Fischer 2016; Suarez-Andres et al., 2018)
The building blocks of planets

10um silicate feature is ubiquitous in disks

What about the other solid species? Which condensates can we expect in the planet-forming regions?

Juhasz et al. (2010)
Cloud collapse and material injection into the forming disk
Modeling of condensation sequences

Models of dust condensation  

Pignatale et al. (2016)

2D disk structure (D’Alessio et al., 1999)  
+  
Initial gas composition

Thermodynamical equilibrium  

Distribution of condensates

⚠️  
Valid at high temperatures (T > 500 K)
Models of dust condensation

Pignatale et al. (2016)

2D disk structure (D’Alessio et al., 1999)
+ Initial gas composition

Thermodynamical equilibrium

Distribution of condensates

Valid at high temperatures (T > 500 K)

Example:
Initial bulk composition with Solar C/O

- Refractories
- Enstatite
- Iron
- Nickel
Models of dust condensation

*Matter et al.* (2020)

|          | 0.4   | 0.4   | Solar | Solar | 1     | 1     |
|----------|-------|-------|-------|-------|-------|-------|
| C/O      | high  | low   | high  | low   | high  | low   |
| forsterite (Mg$_2$SiO$_4$) | 13.06 | 21.14 | 25.57 | 39.13 | 4.12  | 50.21 |
| enstatite (MgSiO$_3$)       | 23.74 | 15.97 | 38.32 | 20    | x     | 14.33 |
| metal (Fe)                    | 1.35  | 0.86  | 36.11 | 27.71 | 7.3   | 29.9  |
| troilite (FeS)                | x     | x     | 0     | 10.72 | x     | x     |
| fayalite (Fe$_2$SiO$_4$)     | x     | x     | ~0    | 2.44  | x     | 4.85  |
| FeSi                             | x     | x     | x     | x     | 87.28 | x     |
| graphite (C)                   | x     | x     | x     | x     | 1.23  | 0.71  |
| FeO                                | 43.8  | 53.91 | x     | x     | x     | x     |
| MgO                                | 8.56  | 5.59  | x     | x     | x     | x     |
| SiO$_2$                        | 9.25  | 1.58  | x     | x     | x     | x     |
| spinel MgAl$_2$O$_4$            | 0.24  | 0.94  | x     | x     | x     | x     |
MATISSE – how to produce the synthetic spectra

**Disk Model**

- Disk emission
- Radiative transfer
- Emission of stellar photon packets
- Scattering
- Absorption/reemission

**Input**

0.1-1 au
Dust condensation zone (C/O=0.4, 0.54, 1)

**MATISSE simulator**

Astro silicates + carbon

8 um

13 um

Synthetic 'spatially resolved' spectra
(< 1.5 au, < 0.8 au, < 0.6 au)

Matter et al. (2020)
MATISSE – Synthetic spatially resolved spectra

High-resolution spectra (R=220)
Grain size distribution = 0.1 um - 1mm

Matter et al. (2020)
Comparison with observed inner disk spectra

Herbig star HD142527

Avenhaus et al. (2017)

Matter et al. (2020)
Comparison with observed inner disk spectra

Herbig star HD142527

Inner disk probed by MIR interferometry

Matter et al. (2020)

MIDI and synthetic correlated fluxes (HD142527)

Low-resolution (R=30) 'C-rich' synthetic spectrum

Avenhaus et al. (2017)
Comparison with observed inner disk spectra

Herbig star HD144432

Garufi et al. (2017)

Inner disk probed by MIR interferometry

Matter et al. (2020)
Comparison with observed inner disk spectra

Herbig star HD144432

Inner disk probed by MIR interferometry

Garufi et al. (2017)

MIDI and synthetic correlated fluxes (HD 144432)

Matter et al. (2020)

Low-resolution (R=30) 'solar' synthetic spectrum
Summary

- Dust condensation sequences at LTE → Specific inner-disc compositions (C/O=0.4, solar C/O, C/O=1)
- RT disc model → synthetic MATISSE N-band spectra → specific shape and amplitude for ≠ C/O
- Qualitative interpretation of N-band inner-disc spectra → HD142527 (C-rich) and HD144432 (Solar)

Take-home message

- Inner disc mineralogy can be very specific
- Proper interpretation of solid-state spectroscopy of discs → need for ‘physically consistent’ dust chemistry models
- Mid-IR instrumental context is very favourable