The VLTi/PIONIER survey of TTauri disks of the southern hemisphere

Why such a survey?

- NIR Interferometry is able to resolve young stars' inner rim thus providing us information on its shape.

- Herbig stars are bright and resolved enough to be well observed, either in number or in uv coverage (see Jacques Kluska poster, No 2.14)

![Graph](image)

**HD98922**
- F.: 37%
- T.: 1650K

1 NACO pixel
Why such a survey?

- Observation of TTauri are more sparse: 1-2 baselines (80m) and few points, often averaged (Ex: Akeson et al.2005)

### TABLE 3
**KI VISIBILITY DATA**

<table>
<thead>
<tr>
<th>Source</th>
<th>Number of Integrations$^a$</th>
<th>Average $\nu^2$</th>
<th>$\sigma_{\text{statistical}}$</th>
<th>$\sigma_{\text{statistical+systematic}}$</th>
<th>$u$ (m)</th>
<th>$v$ (m)</th>
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<tbody>
<tr>
<td>BP Tau</td>
<td>3</td>
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<td>0.050</td>
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$^a$ An integration includes 125 s of fringe data and all necessary internal calibrations.
Why such a survey?

• Observation of TTauri are more sparse: 1-2 baselines (80m) and few points, often averaged (Ex: Akeson et al.2005)

=> Simple models for disks:
  - Gaussian for unresolved inner rim
  - Ring model for resolved inner rim

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Calculated inner rim coherent with the sublimation radius for the luminous Haebes stars...

But not for the faint TTauri stars!

New physics added to the thermal ring model, sometime exotic, to explain such discrepancy.
A bit of history:
Scattering

- Full radiative transfert model: scattered emission dominant for low luminosity star

- Scattering: disk illuminated further, so the ring model overestimates the inner radius

From Pinte & al. 2008
With this model, the emission can be roughly splitted into the star, the thermal inner rim and the scattered/extended emission:

\[ V \approx \frac{V_{\text{star}} F_{\text{star}} + V_{\text{therm}} F_{\text{therm}} + V_{\text{ext}} F_{\text{ext}}}{F_{\text{ext}} + F_{\text{star}} + F_{\text{therm}}} \]

Scattered light is emitted in large regions of the disk emission, so \( V_{\text{ext}} \) falls to 0 at short baselines.

We didn't have data to prove/rule out that model up to date.
The Survey

- The visitor instrument PIONIER:
  - 4 telescope combiner
  - 6 Baselines, from 40 to 130m
  - 3 Independant Closure Phases

- 20 night awarded over 2 years (autumn 2011- spring 2013)
  - 5 nights lost due to weather, average for the remaining nights.

- 22 southern TTauri stars
  - Several observations with turning UV plan => we can constrain the geometry of the disk (Inclination, P.A.)
Simple fitting

The visibility of our sample shows often straight data with small dispersion

=> A linear fit can help estimate the extended component
The visibility of our sample shows often straight data with small dispersion.

=> A linear fit can help estimate the extended component.

\[ V^2(0) = 0.8 \Rightarrow \text{There is scattering emission from an extended component.} \]
Fitting the sample:

Conclusions

- $V^2(0) < 1$ for nearly all the resolved systems

$=>$ Scattering is common for low luminosity YSOs.

- Qualitative tool:
  - Doesn't work for binaries, edge-on disks or bad dataset.
  - Doesn't say much thing about the structure of the disk
Fine modelling : HT Lup

- K3 star
- Small amorphous silicates features
- 2 companions, 1 inside the disk
- Parametric model with inner disk, gap, outer disk

![HT Lup’s SED](image)
Fine modelling : HT Lup

HT Lup inner disk
Last minute!

- 2 weeks ago:
  - 7 nights with short baselines (11 to 36 m)
Last minute!

- 2 weeks ago:
  - 7 nights with short baselines (11 to 36 m)
  - 75% of the nights lost (weather), mean conditions for the rest.

- 18 stars observed, 50% exploitable...
Extended emission at short baselines

Preliminary data, same linear fitting.

$V^2(0)$ still below 1 at short baselines
Extended emission at short baselines

Preliminary data, same linear fitting.

$V^2(0)$ still below 1 at short baselines

Extended emission resolved for Baselines $\sim 10m$ for RU Lup

$=>$ bright component $> 5$ AU for RU Lupi
Our HT Lup model has to be refined: the extended component is brighter than we thought.

We have new constraints on large scales structures: great!

Fine modelling: What about HT Lup?
In Conclusion

- Scattering appears to be one of the main emission processes in TTauri disks, and it varies greatly from one disk to another.

- Simple « thermal » models cannot reproduce the drop-off caused by this extended emission.

- To have good models, we need:
  - Observations at long baselines to constrain the inner rim
  - Observations at short baselines to constrain scattering emission.
  - Full radiative transfert models to reproduce correctly the SED and interferometric data.
Thank you!
Why such a survey: The ring model

Hypothesis: In the Near InfraRed, all the emission come from the thermal inner rim.
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Why such a survey:
The ring model

=> provide the inner rim of the disk
### Fine modelling: HT Lup

- **K3 star**
- **Small amorphous silicates features**
- **2 companions, 1 inside the disk**
- **Parametric model with inner disk, gap, outer disk**

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<td>Teff</td>
</tr>
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<td>Radius</td>
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<table>
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<th>Inner disk</th>
<th>Outer disk</th>
</tr>
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<tr>
<td>$M_{\text{dust}}$</td>
<td>$8 \times 10^{-6}M_{\text{sol}}$</td>
</tr>
<tr>
<td>$R_{\text{in}}$</td>
<td>0.25 AU</td>
</tr>
<tr>
<td>$R_{\text{out}}$</td>
<td>7 AU</td>
</tr>
<tr>
<td>$H_{100}$</td>
<td>12 AU</td>
</tr>
<tr>
<td>$\beta$</td>
<td>1.2</td>
</tr>
<tr>
<td>Inclination</td>
<td></td>
</tr>
<tr>
<td>P.A.</td>
<td></td>
</tr>
<tr>
<td>Compo.</td>
<td>Astrosilicates</td>
</tr>
<tr>
<td>$a_{\text{min}}$</td>
<td>0.5 μm</td>
</tr>
<tr>
<td>$a_{\text{max}}$</td>
<td>2 μm</td>
</tr>
</tbody>
</table>
Fine modelling : RU Lup

RU LUP’s SED

Intensity (W/m²)

Wavelength (μm)

V²

CP

Baselines (Mλ)
Studying the inner regions of protoplanetary disks (1-10 AU) is of utmost importance to understand the formation of planets and the accretion process feeding the forming central star. Herbig AeBe stars are bright enough and they have been observed previously by interferometers. The data for the fainter T Tauri stars is much more sparse. Also, previous observations of T Tauri stars were generally limited to a single baseline. In this contribution we will present the results of our ongoing survey at the VLTI. We have used the PIONIER combiner that allows the simultaneous use of 4 telescopes at ESO/VLTI, yielding 6 baselines and 3 independent closure phases at once. PIONIER’s integrated optics technology makes it a very sensitive instrument and we have observed 22 T Tauri stars to this date, the largest such survey so far for T Tauri stars.

Our results clearly show the very significant contribution of an extended component to the interferometric signal. We will show that the extended component is different from source to source and that the data with several baselines offer a way to improve our knowledge of the disk geometry and/or composition.

We will present a more detailed case study to show how the extended component can be associated convincingly to scattered light. These results validate an earlier study by Pinte et al. (2008). These results show that the dust inner radii of T Tauri disks now appear to be in better agreement with the expected position of the dust sublimation radius, contrarily to previously claims.

We will conclude this contribution by presenting plans for extending the current survey with both wavelength and baseline coverage to further study the disk geometry.