Large inner holes and narrow outer disks from Herschel's observations of transitional disks in Lupus

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Ph. André - CEA, Saclay

Lupus III region - ESO/Digitized Sky Survey 2. Acknowledgement: Davide De Martin
http://www.space.com/19286-dark-space-cloud-stars-photo.html
Main characteristics

Young stars with disks

Little or no excess at 10μm

Significant one at longer wavelengths

Inner disk clearing - gap

Due to ¿planet formation?
Main characteristics

Young stars with disks

Little or no excess at 10μm

Significant one at longer wavelengths

Inner disk clearing - gap

Due to ¿planet formation?
Main characteristics

- Young stars with disks
- Little or no excess at 10\,\mu m
- Significant one at longer wavelengths
- Inner disk clearing - gap

Due to ¿planet formation?
Herschel data

Lupus III - Optical
- Nearby region
- Young: 1.5 – 3 Myr
- Star formation

ESO/Digitized Sky Survey 2.
Acknowledgement: Davide De Martin
Herschel data

Lupus III - far IR

<table>
<thead>
<tr>
<th>Herschel imaging instruments</th>
<th>PACS</th>
<th>SPIRE</th>
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<td>Wavelengths (μm)</td>
<td>70, 100, 160</td>
<td>250, 350, 500</td>
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Herschel Gould’s Belt Survey (PI: Ph. André)
Herschel data

Lupus III - far IR

217 known YSO

114 detected in Herschel's maps

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Herschel Gould's Belt Survey (PI: Ph. André)
A combination of K, WISE-12 and PACS-70 fluxes allows the identification of transitional disks with Herschel data (Ribas et al. [2013])

\[ \alpha_{[\text{K-12}]} < 0 \]

\[ \alpha_{[12-70]} > 0 \]
Our 2MASS + WISE + Herschel selection criteria finds two already known transitional disks in Lupus

Herschel Gould's Belt Survey (PI: Ph. André)
## Herschel detections in Lupus

### Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sz 91</th>
<th>Sz 111</th>
</tr>
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<tbody>
<tr>
<td>RA</td>
<td>16:07:11.59</td>
<td>16:08:54.69</td>
</tr>
<tr>
<td>Dec</td>
<td>-39:03:47.54</td>
<td>-39:37:43.11</td>
</tr>
<tr>
<td>Sp Type</td>
<td>M 1.0</td>
<td>M 1.5</td>
</tr>
<tr>
<td>Temperature (K)</td>
<td>3785</td>
<td>3650</td>
</tr>
<tr>
<td>Mass (M_\ast)</td>
<td>0.75</td>
<td>0.66</td>
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### Images

- **Sz 91**: 70\textmu m
- **Sz 111**: 70\textmu m
Physical interpretation

Sz 91

Sz 111

Ancillary Data – Optical, 2Mass, WISE, Spitzer

New Herschel Data – PACS, SPIRE
Physical interpretation

Sz 91

Sz 111

$\lambda F_{\lambda}$ [ergs/cm$^2$/s/Å]

$\lambda$ [Å]

M1 Star Photosphere

Literature Photometry

Herschel Photometry

optically thin disk

optically thick disk
### Disk models

**Parameters**

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<tr>
<td>$M_{\text{dust}} (M_\odot)$</td>
<td>[0.001 - 0.009]</td>
<td>undetermined</td>
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<tr>
<td>$R_{\text{in}}$ (AU)</td>
<td>[20 - 100]</td>
<td>[40 - 80]</td>
<td>[35 - 60]</td>
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<td>$R_{\text{out}}$ (AU)</td>
<td>[25 - 100]</td>
<td>[≤ 70]</td>
<td>[40 - 70]</td>
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<tr>
<td>Surface density profile</td>
<td>[-0.5 - -1.75]</td>
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<td>undetermined</td>
</tr>
<tr>
<td>Inclination (°)</td>
<td>[0 - 90]</td>
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*Hyperion - radiative dust transfer code – Robitaille et al. (2011)*
Disk models

Hyperion - radiative dust transfer code – Robitaille et al. (2011)

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Two parameters constrained
Constraining the outer disk

Goodnes of fit probability maps:
- Inner radius constrained for both objects → large inner hole
- Outer disk constrained for Sz 111

Ongoing process
Hyperion - radiative dust transfer code – Robitaille et al. (2011)
Constraining the outer disk

Motivation: Cieza et al. (2011) on another transitional disk (T Cha)

Outer disk very small

Outer disk very tenous

Hyperion - radiative dust transfer code – Robitaille et al. (2011)
Overall interpretation of the system

**Facts**
- Large inner holes

Artist's rendition of the protoplanetary disk around J 1604

http://subarutelescope.org/Pressrelease/2013/02/07/index.html

Solar System

~50 AU
Overall interpretation of the system

**Facts**

- Large inner holes
- Small outer disk (Sz 111)

Artist's rendition of the protoplanetary disk around J 1604
http://subarutelescope.org/Pressrelease/2013/02/07/index.html
Overall interpretation of the system

**Facts**

- Large inner holes
- Small outer disk (Sz 111)
- Gas accretion to the star (Hughes et al., 1994)

**Ongoing formation of giant planets**

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Image: Artist's rendition of the protoplanetary disk around J 1604. (http://subarutelescope.org/Pressrelease/2013/02/07/index.html)
Conclusions and Future Work

**Results**

- Transitional disk detection method tested

- Two objects confirmed in Lupus cloud – Sz 91 and Sz 111

- SED modelling allows to constrain sizes of circumstellar disks → they present **large inner holes** and, in one case, narrow outer rings

- Large inner holes and accretion to the stars hint at **ongoing giant planet formation** on these systems

**Future work**

- Finalize analysis

- Submit A&A letter

- **ALMA** follow-up observation and preparation to **JWST**