ALMA Observations of Circumstellar Disks in the Upper Scorpius OB Association

Based on Barenfeld et al. (2016)

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Image Credit: ESO/L. Calçada
Outline

I. Introduction

II. Our Survey

III. Disk Fluxes and Masses

IV. Disk Evolution

V. Summary
Upper Sco: the end of primordial disk evolution

Hernandez et al. (2008)
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Upper Sco
(age = 5-11 Myr,
d = 145 pc)
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Upper Sco Disk Sample

- Debris/Evolved Transitional
- Primordial

Bar chart showing the number of disks in different spectral types:
- G-K: 10 disks
- M0: 5 disks
- M1: 3 disks
- M2: 4 disks
- M3: 5 disks
- M4: 30 disks
- M5: 4 disks
Our ALMA Upper Sco Survey

106 disks in Upper Sco (Luhman & Mamajek 2012)
341 GHz (0.88 mm) continuum and CO J = 3-2
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50 AU resolution
0.1 $M_\oplus$ of dust
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Detections

| Disk Type              | Continuum | CO    |
|------------------------|-----------|-------|
| Primordial             | 53/75     | 26/75 |
| Debris/Evolved         | 5/31      | 0/31  |
| Transitional           |           |       |
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0.88 mm continuum images, 0.34” resolution
Disk fluxes are correlated with spectral type.

![Graph showing correlation between 0.88 mm Flux Density (mJy) and Spectral Type (G5 to M5).]
Faint continuum disks are also faint in CO.
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< 40 AU or depleted
Conversion of continuum flux density to dust mass

\[ M_{dust} = \frac{S_\nu d^2}{\kappa_\nu B_\nu(T)} \]
Conversion of continuum flux density to dust mass

\[ M_{dust} = \frac{S_v d^2}{\kappa_v B_v(T)} \]

145 pc

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Conversion of continuum flux density to dust mass

\[ M_{\text{dust}} = \frac{S_{\nu} d^2}{\kappa_{\nu} B_{\nu}(T)} \]

\[ \kappa_{341 \, \text{GHz}} = 2.7 \, \text{cm}^2/\text{g} \]

145 pc
Conversion of continuum flux density to dust mass

\[ M_{\text{dust}} = \frac{S_{\nu}d^2}{\kappa_{\nu}B_{\nu}(T)} \]

\[ \kappa_{341 \, \text{GHz}} = 2.7 \, \text{cm}^2/\text{g} \quad T_{\text{dust}} = 25 \, K \times \left( \frac{L_*}{L_{\odot}} \right)^{0.25} \]
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Dust mass correlates with stellar mass.
Dust mass to stellar mass ratio declines with age.

Upper Sco (age 5-11 Myr)
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Dust mass to stellar mass ratio declines with age.

\[
\frac{M_{\text{dust}}}{M_*} \quad \text{vs. Stellar Host Mass (M_\odot)}
\]

Taurus (age 1-2 Myr)
Upper Sco (age 5-11 Myr)
Dust mass to stellar mass ratio declines with age.

Lupus Data: Andrews et al. (2013)
Taurus Data: Ansdell et al. (2016), Alcalá et al. (2014, 2016)
Upper Sco Data: Barenfeld et al. (2016)
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Dust mass to stellar mass ratio declines with age.

**Graph:**
- Upper Sco (age 5-11 Myr)
- Taurus (age 1-2 Myr)
- Lupus (age 1-3 Myr)
Dust mass to stellar mass ratio declines with age.

\[ P\left(\frac{M_{dust}}{M_*} \geq M\right) \]

- **Lupus** (age 1-3 Myr)
- **Taurus** (age 1-2 Myr)
- **Upper Sco** (age 5-11 Myr)
Dust Mass Evolution Summary

• Disk dust mass is correlated with stellar mass in Upper Sco, consistent with younger systems.
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  - Disk dissipation?
  - Grain growth?
  - Planet formation?
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  • Grain growth?
  • Planet formation?

See Barenfeld et al. (2016) for more details.