Protoplanetary Disks in the Orion Nebula Cluster (ONC):
Gas-Disk Morphologies and Kinematics as seen with ALMA

Ryan Boyden
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Orion Molecular Cloud

- Nearest example of massive star formation: ~400 pc

- The Orion A Filament contains multiple Rich Clusters, such as the ONC, NGC 1977 and NGC 1980

Figure: Meingast+2016
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Orion Nebula Cluster

- Contains:
  - >100 disk-bearing, low mass stars
  - Massive Trapezium (OB) Stars

- Important properties of the ONC
  - High Stellar Density
  - Intense UV irradiation from the Trapezium Stars
  - “proplyds"

Credit: NASA
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ALMA Program
Probing Planet-forming Zones in ONC Disks

• Cycle 4, #2015.1.00534.S
  • PI: Eisner
  • Central 1.5’ x 1.5’ ONC region
  • Sensitivity: 0.1 mJy / beam
  • Resolution: 0.08” (~35 AU)

• Scientific Goals
  • Detect the disks in dust, CO (3-2), and HCO\(^+\) (4-3)
  • Measure dust and gas properties and compare with other regions

Credit: NASA
Example Detections

Gas: Boyden & Eisner in review
Gas Size Distribution
Gas Size Distribution

- ONC
- Lupus
- Taurus

$P \geq R_{gas}$

$R_{gas}$ (AU)

$10^2$ $10^3$
Gas Size Distribution

ONC gas disks are compact

ONC, Lupus, and Taurus gas disks are compared, showing that ONC gas disks are more compact than those in Lupus and Taurus.
$R_{\text{gas}}$ Correlations

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**$R_{\text{gas}, CO}$ vs. $d_{\text{toc}}$**

- **CO (3-2)**
- **HCO$^+$ (4-3)**

Distance from $\Theta^1$ Ori C (pc)

Boyden & Eisner in review
Gas-disk sizes are sensitive to changes in UV field strength

\[ R_{\text{gas}} \text{ Correlations} \]
Takeaways

1. Disks (gas+dust) in the ONC are impacted by the rich cluster environment
   • e.g., they are compact, and their properties correlate with the distance from $\theta^1$ Ori C

2. Observed kinematics of the ONC gas disks are consistent with Keplerian rotation

3. Future Work: follow-up ALMA observations, radiative transfer modeling, etc.

4. Discuss further? Contact me at rboyden@email.arizona.edu
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Ricci et al. (2008)
Keplerian Modeling

“181-247”; HCO\(^+\) (4-3)

Boyden & Eisner in review
Keplerian Modeling

“181-247”; HCO\(^+\) (4-3)

Blue-Shifted Emission
~Rest Emission
Red-Shifted Emission

Boyden & Eisner in review
Continuum Mosaic

\[ \theta^1 \text{ Ori C} \]

\( 0.02 \text{ pc} \)
Continuum Mosaic

Dust Detections (Blue)

Eisner+2018
Dust-Disk Sizes

![Graph showing the probability of dust disk sizes versus disk radius in au for different regions (Lupus, UpSco, Oph, Taurus, Cham I, ONC)].

Eisner et al. 2018
$R_{\text{gas}}$ Correlations

- $R_{\text{gas}, CO}$ vs. $d_{toc}$
- $R_{\text{dust}}$ vs. $d_{toc}$

Boyden & Eisner in review
$R_{gas}$ Correlations

$R_g = R_d$

Boyden & Eisner in review
**R_{gas} Correlations**

![Graph showing correlations between R_{gas} and R_{dust} with data points for HCO^+ (4-3) and CO (3-2).]

Taurus fit

Lupus fit

R_{g} \sim 2R_{d}

Boyden & Eisner in review
Large scale emission near most CO kinematic disk detections: "Cloud Contamination"