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University of Colorado, Boulder

Henry Throop

A Hazardous Process?

Planetary Formation Near Bright Stars:

Collaborators:

Terry Esposito (CU) •
Mark McCaughrean (AIP)
John Bally (CU) •
Conclusions & Predictions

Physical Processes in Externally-Illuminated Environments

Evolutionary Modeling of Young Disks

OVO

HST

Observations of Young Disks: Evidence for Grain Growth

Where Do Most Stars Form?
Orion Nebula

HST Cycle 4
Circumstellar Disk Observer

Transmitted Light

(Tauus, Pic, Rings)

Reflected Light

Observations

Orion Proplyds
Disks dominated by large particles?

\[ \text{vs. } R = 3 - 5 \text{ for ISM.} \]

Disks consistent with \( R = \sqrt{1 - (L - B)/E} \geq 1.5 \).

Radial extinction profiles show no measurable reddening?

Apparent disk size is independent of wavelength?

\[ \text{HST Observations of Orion Disks} \]

\[ 50 \text{ dark disks seen in silhouette, } \alpha = 0.2 - 1.9 \mu \text{m} \]
Large particles at center; small particles at poles
Polar halos do change with wavelength
Translucent NE aura nearly identical at 0.65 \mu m, 1.87 \mu m

WFC2 Hα

114-426 Disk Images
cross-correlations

Determine best-fit $\chi^2$ > 1 parameter ranges and
of randomly-generated disks

Use Monte Carlo approach: minimize $\chi^2$ over large number

Consider all wavelets simultaneously

model images

9-parameter 3D disk model, forward-convolve to create

Determine particle sizes, disk properties using BASS model

Translucent outer edge is PSF scale – need to be careful!

HST Observations of Orion Disks
Best Fit Model Results

Data

Model

Residuals

HST16 Ha

HST10 Ha

SW OIII
Depth

Observational limitations are spatial resolution, optica.

Edge-on, face-on disk structure, parameters constrained.

Disks are consistent with large particles at outer edges.

Disks have sharply terminated outer edges.

Results of 3D Monte Carlo disk modeling:

HST Observations of Orion Disks
I. 3 mm continuum, line emission not detected, $P > 21$ mJy

Observations of Bally et al. 1998 of two Orion fields, 1.8'' beam
Requires \( k' \) inconsistent with modeling results

Alternative explanation: Disk masses very low \( M > 0.02M_\odot \)

Non-detection is difficult to explain without large particles.

- Non-detection is removed by evaporative flow?
- Orion small particles removed by evaporative flow?
- Orion disks slightly older, more evolved than Taurus?
- Continuum (Beckwith et al. 1990)
  
  HL Tau: At 450 pc, would detect 100 my at 1.3 mm

  \( \lesssim 3 \) few cm

- Low \( \rho \) requires low mass opacity \( k' \), i.e., large particles
- Non-detection at 21 my implies disk is optically thick

- Optically thick \( f_0K \) disk would be visible

Modeled ORAO Disk Observations
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<th>Disk Scaling Regimes</th>
<th>Galaxy</th>
<th>Protoplanets' Initial Conditions</th>
<th>Mass Disks</th>
<th>Collisionsally Active?</th>
<th>Dynamically Young?</th>
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Photoevaporation of Orion Disks

(Johnstone et al. 1998; Stierlin et Hollenbach 1999, Henney  O'Dell 1999)
Prospects for planetary formation: insight into our own SS

- Predict disks’ past and future states in addition to present-day environment to probe disks deeper than by data alone
- Use physical, evolutionary model and knowledge of existing Solar Nebula models are not valid for Orion environment
- Disk evolution cannot be modeled in isolation from Trapezium stars → violent place

Orion nebula environment:
Evolutionary Modeling of Orion Disks
$\Sigma \sim R^{-3}$, $t_{uv} = 0$ yr

Particle Size Evolution, Steep Case
\[ \gamma \eta = 10^4 \ \text{yr} \]

Orbital Distance [Å]

Normal Optical Depth

Optical Depth Profiles, Shallow Case
\[ \forall \mathcal{Y}^0 = \mathcal{Y} \cap \mathcal{H}^{-3} \cap \mathcal{X} \]

Disk Composition Evolution, Steep Case
Large EKR difficult

Jovian planets difficult

Terrestrial planets unaffected

Formation of planets:

Gas, all small particles lost in ~ 10^7 yr

Disk outer edge is sharp, populated with large particles

Disk is removed outward of ~ 100 AU

Ctram growth is rapid: meter-sized particles in 10^7 yr at 10 AU

Results:

Evolutionary Modeling of Orion Disks
Likely:

- Planetary formation is hazardous, but possible and
  sticking properties, \( \Delta \) ignition time
  Results sensitive to initial mass distribution, mass loss rate,

Terrestrial planet formation only minimally affected

- Difficult to form Jupiters before disks are destroyed
  (i).

We are witnessing very earliest stages of planetary formation (i)

\[ \text{disks} \]

Numerical modeling shows grains grow quickly throughout

\[ \text{particles} < \text{mm} \]

Non-detection at mm implies low optical depth,

\[ \text{Lack of color in disks implies particles} < \text{mm} \]

Orion disks:

Three lines of evidence support large particles in the

Conclusions
beat out photovaporation.
If disks have even a small headstart, grain growth will
orbit the Trapezium

Many disks are temporarily shielded from radiation as they
1 tbsp. Oiri turned on recently

Solutions:
We see large particles in the midst of many hazards

\[ 10^6 \text{ yr} \]
(10^6 yr) but we see old disks

A quandrum:

But...
should not expect an extra-solar cometary visit soon.

Our Solar System has an anomalously large cometary reservoir, and we

metalllicity and the existence of planets surrounding a star.

Photoevaporation causes a positive correlation between stellar

which can be detected by infalling planetesimals (vsy. Pic).

Stars in Orion with no visible disks have already formed Giant Planets

Growth followed by photoevaporation.

ISM is populated with large, aggregate particles caused by grain

association; therefore, Kuiper Belt may extend to 100’s of AU

association indicates our Solar System did not form in OB

Jovian planets are rare in OB associations unless they form rapidly.

organics also makes them ideal places for life.

Terrestrial planets are common in OB associations, UV production of

Predictions