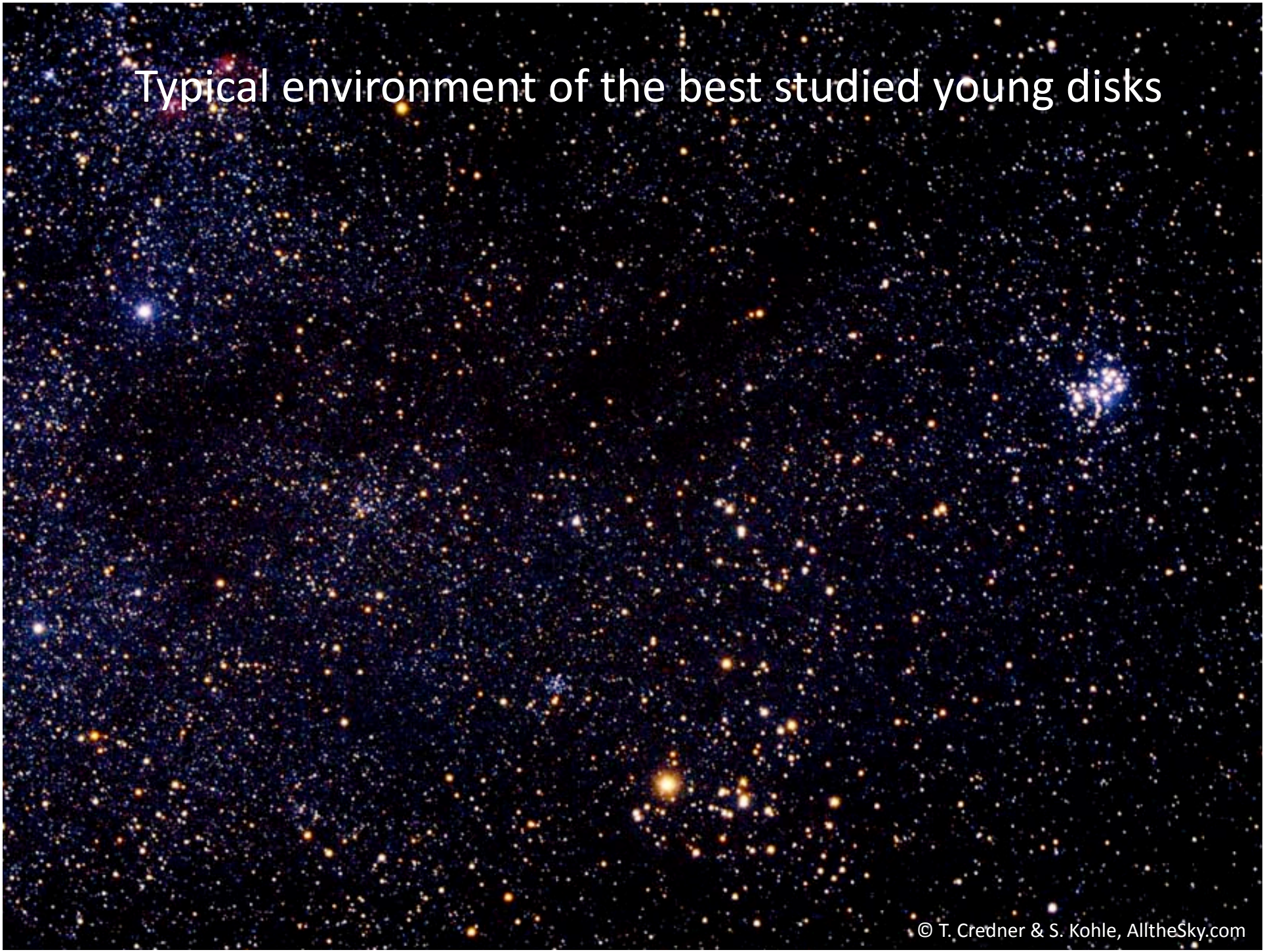
Disk masses in the Orion Trapezium Cluster

Jonathan Williams and Rita Mann

jpw,rmann@ifa.hawaii.edu

Institute for Astronomy
University of Hawaii
2680 Woodlawn Dr.
Honolulu, HI 96822, USA


Typical environment of the best studied young disks
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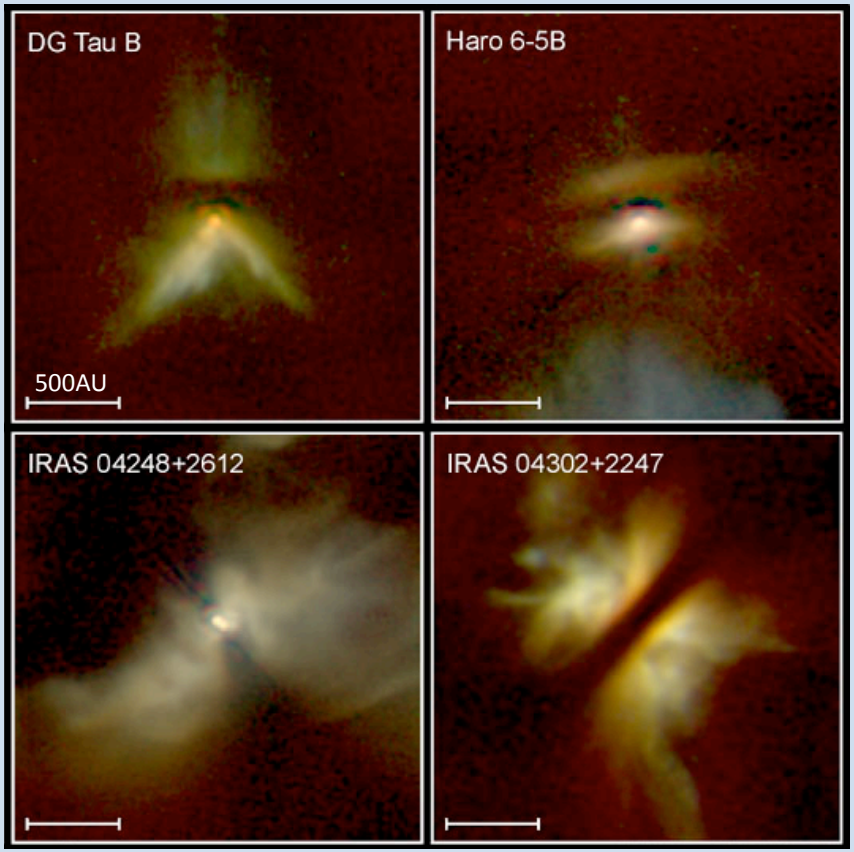
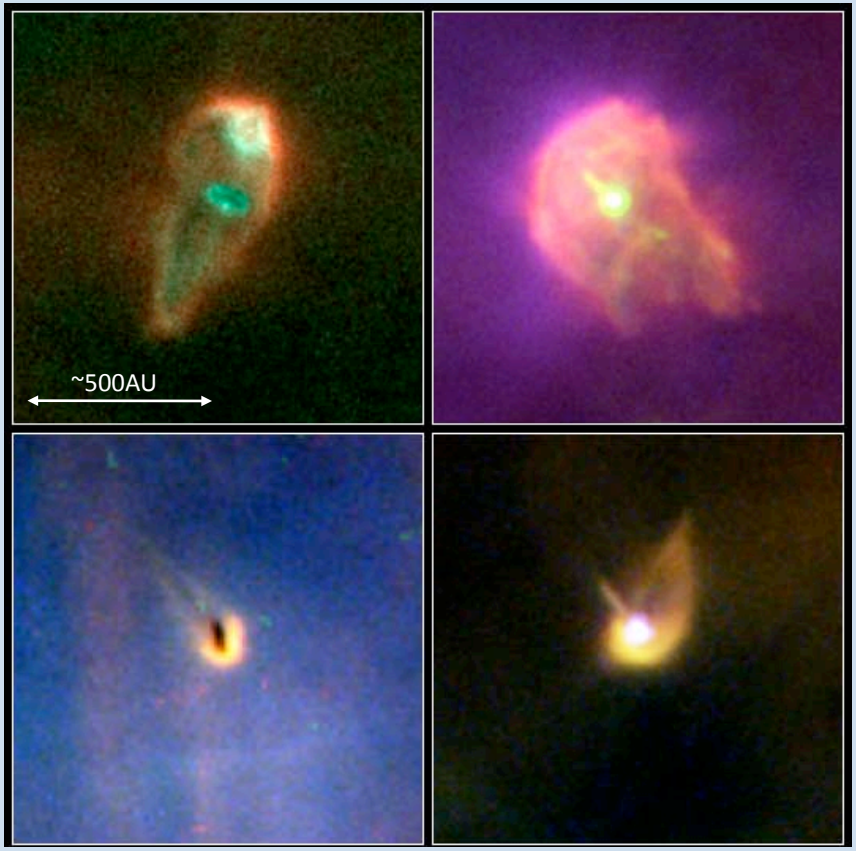
Typical environment where most stars form
http://www.eso.org/public/outreach/press-rel/pr-2001/phot-03-01.html

Disks in Taurus and Orion





hubblesite.org

Observational requirements

- High sensitivity as Orion is 3x further than Taurus
- High resolution as the disks are clustered
- λ large enough for $\tau_{dust} < 1$
- λ short enough for $F_{dust} > F_{free\text{-}free}$

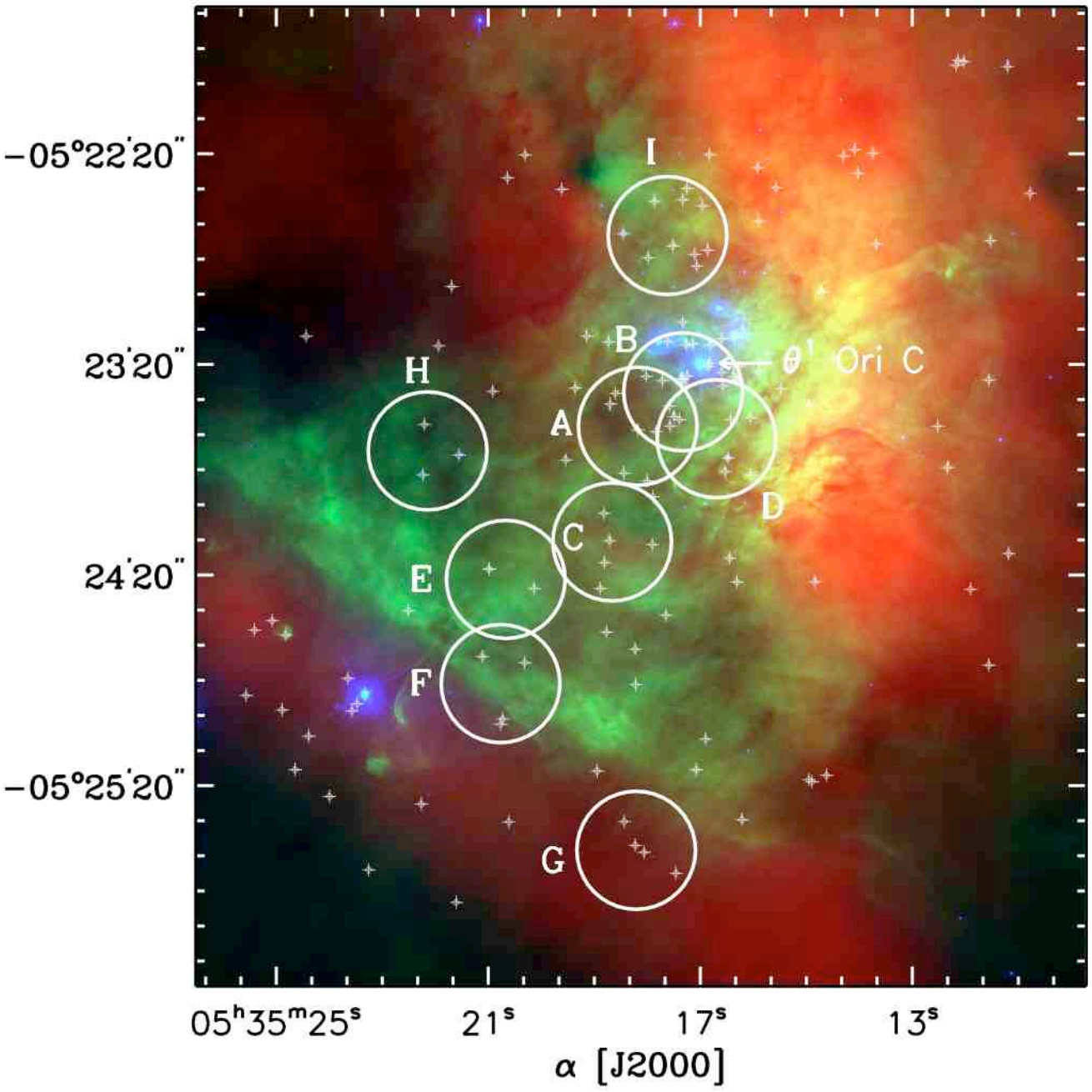
-> interferometry at 850μm with the Submillimeter Array

An SMA survey of disks in the Trapezium Cluster

Red = SCUBA 450μm
Green = HST Hα
Blue = HST V

9 fields chosen to lie in regions of low cloud background;
38'' diameter fov,
~2'' resolution,
~1-2 mJy rms

Extends previous work by:
Williams et al. 2005
Eisner & Carpenter 2006
Eisner et al. 2008



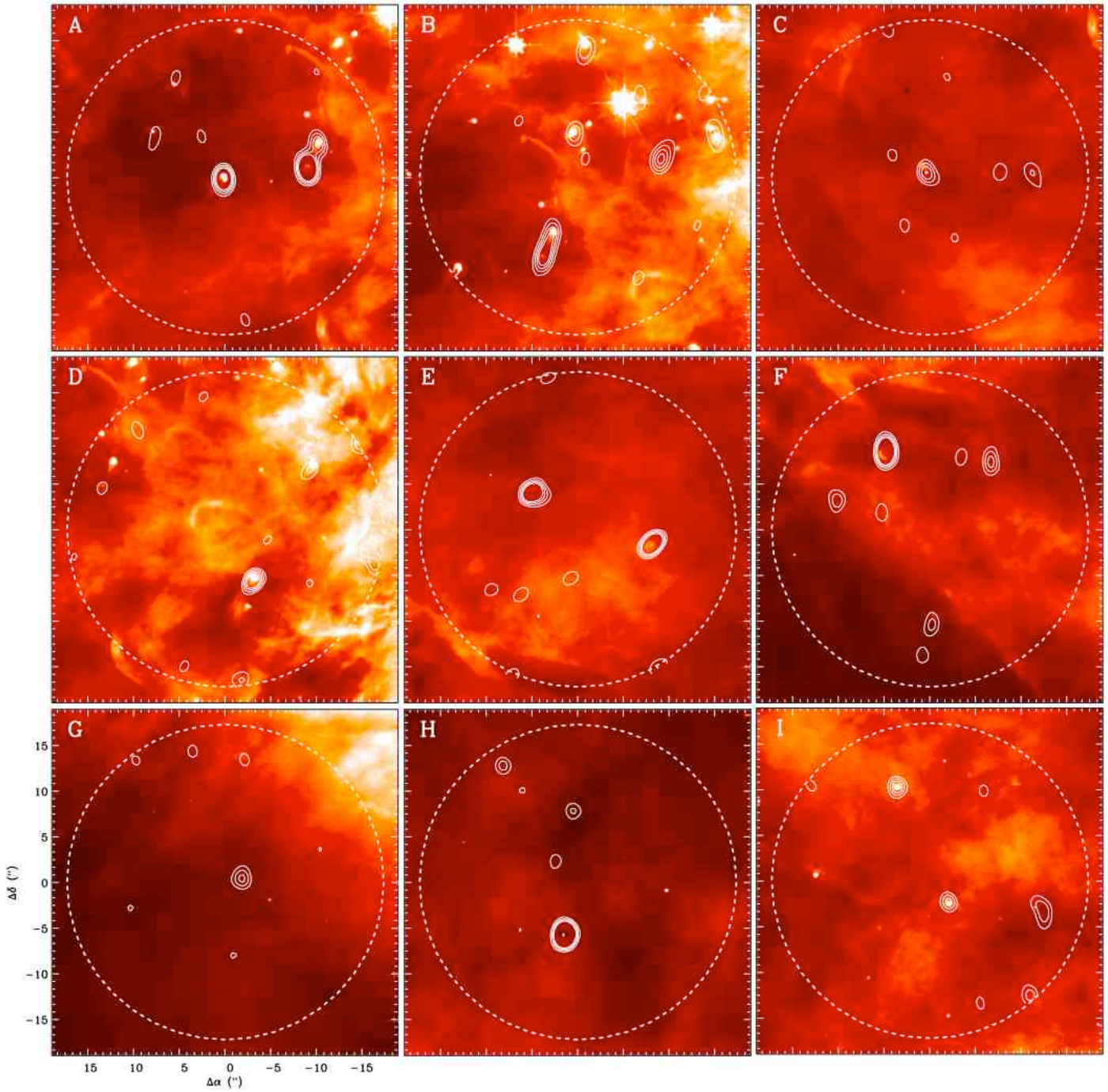
Individual fields

Image = HST Hα
Contours = 850μm
Levels at 3,5,7,9σ

55 disks lie in 9 fields
26 detected at >3σ
(typically ~ $4M_{Jup}$)

Only HST identified disks (proplyds) are detected – no new objects found.

Limits on θ^1C *show* $M_d/M_* < 10^{-4}$
(if massive stars form with disks, they disappear within 1Myr)

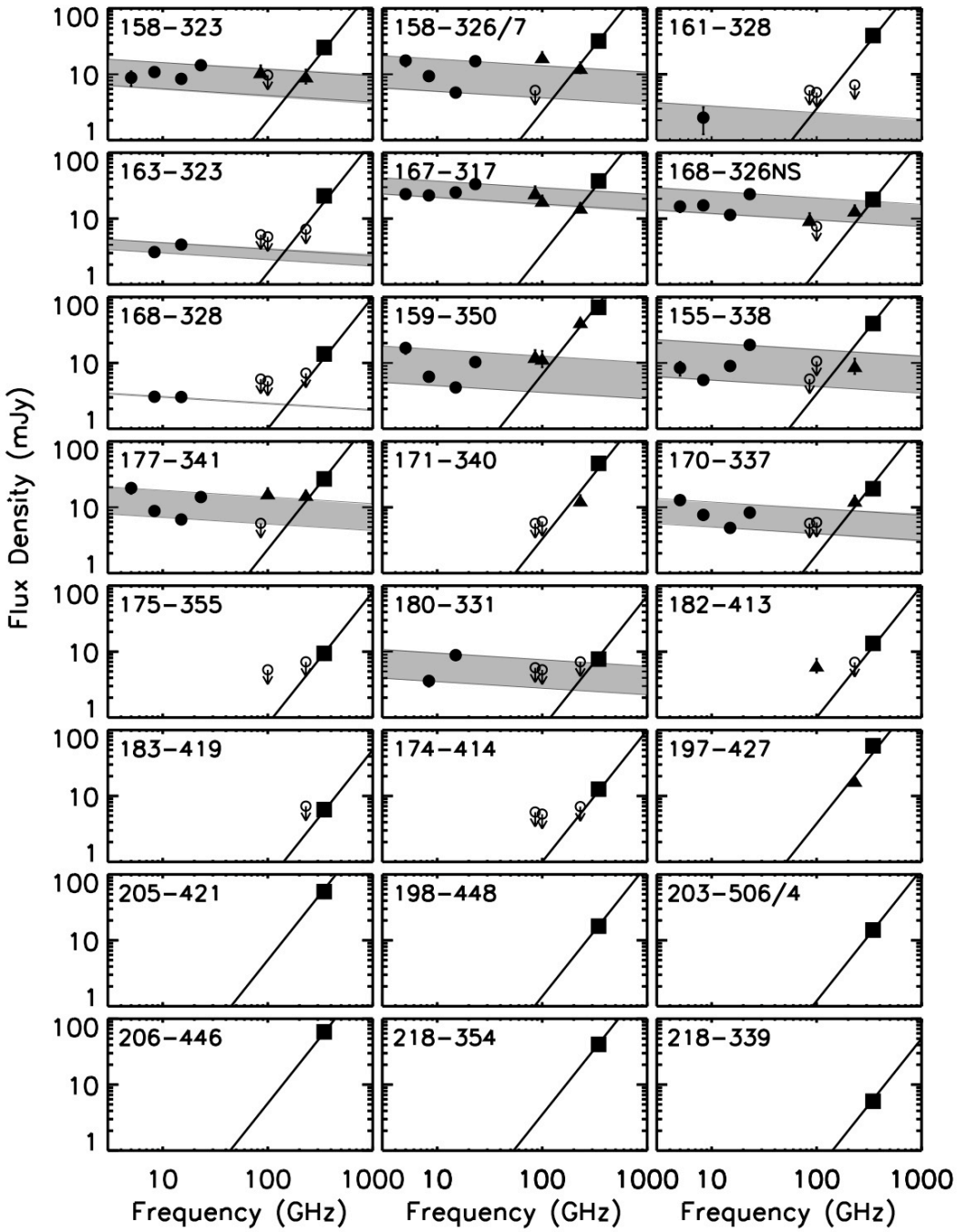


6cm-850µm disk SEDs

VLA cm (Felli et al. 1993, Zapata et al. 2004)
BIMA 3mm (Mundy et al. 1995)
OVRO 3mm (Eisner & Carpenter 2006)
CARMA+SMA 1mm (Eisner et al. 2008)

Squares show SMA 850µm fluxes corrected for background emission
Grey represents range of free-free emission $F_\nu \sim \nu^{-0.1}$
Dust shown schematically as $F_\nu \sim \nu^2$

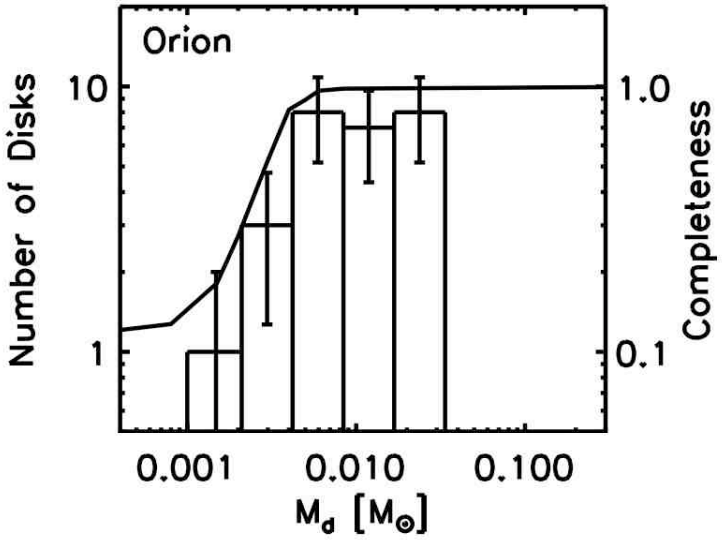
24 have significant dust emission
-> can determine disk masses



Differential disk mass distribution

The completeness is a function of map location, free-free contribution, and cloud background. We estimated it for each proplyd by simulations with fake sources.

(Note it does not reach zero since several disks could have negligible dust mass and still be detectable in free-free emission at 850μm!)



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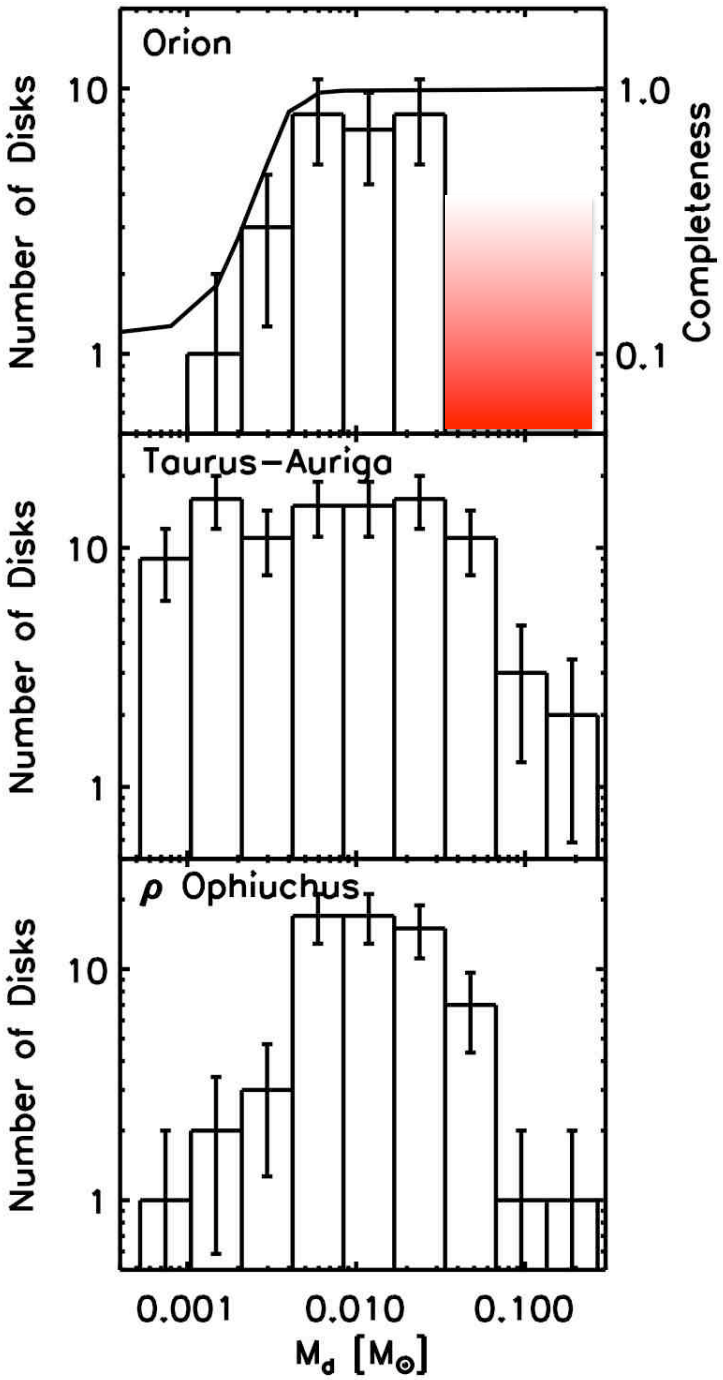
Compared to Class II disks from Taurus and ρ Ophiuchus SCUBA surveys (Andrews & Williams 2005, 2007)

Orion lacks massive disks, $M_d > 0.04\ M_\odot$

Expect 8 disks if like Taurus

$P(0) = e^{-8} = 0.03\%$

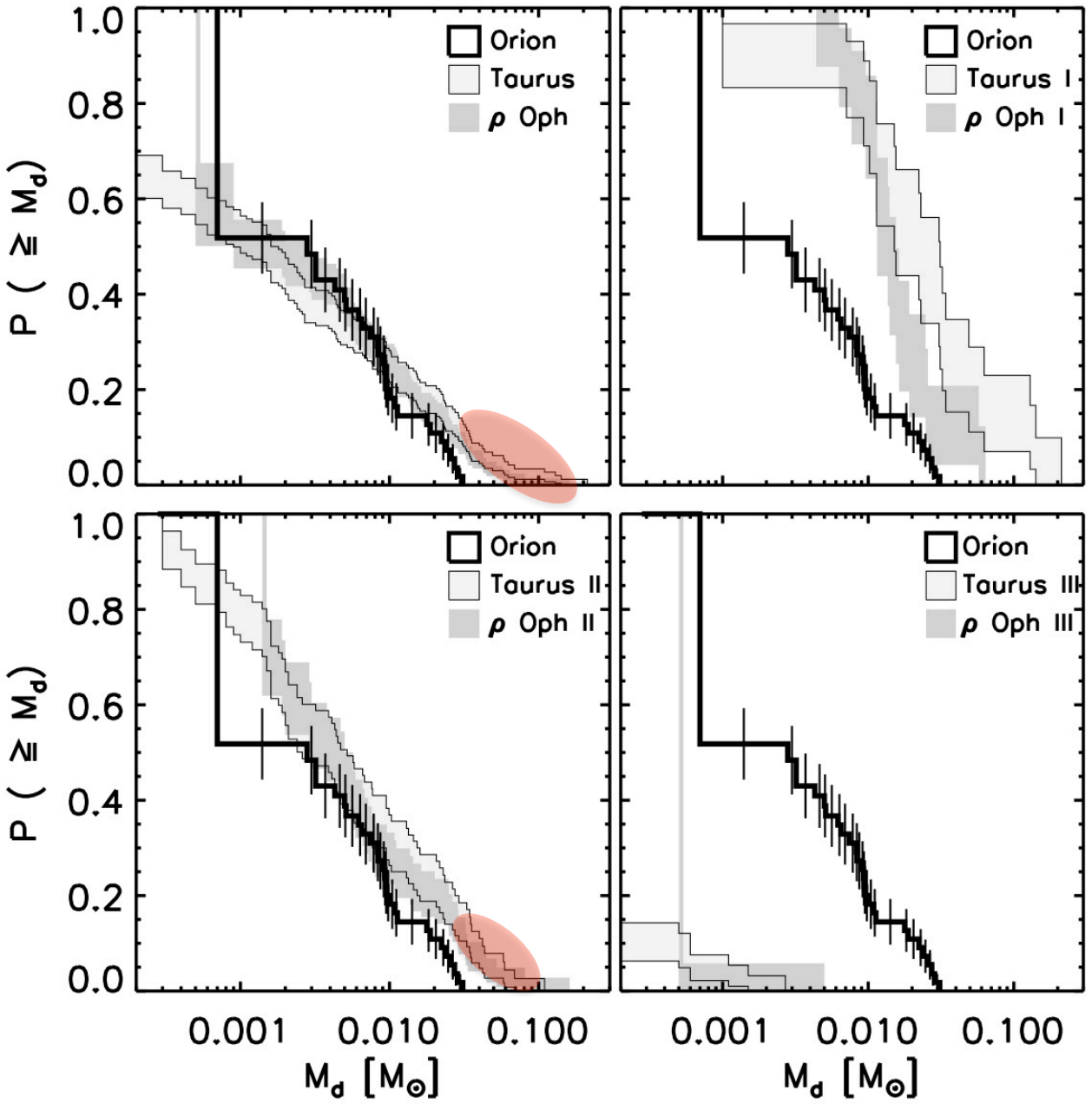
(but only 4 if like ρ Oph -> P(0)=1.8%)



Cumulative disk mass distribution

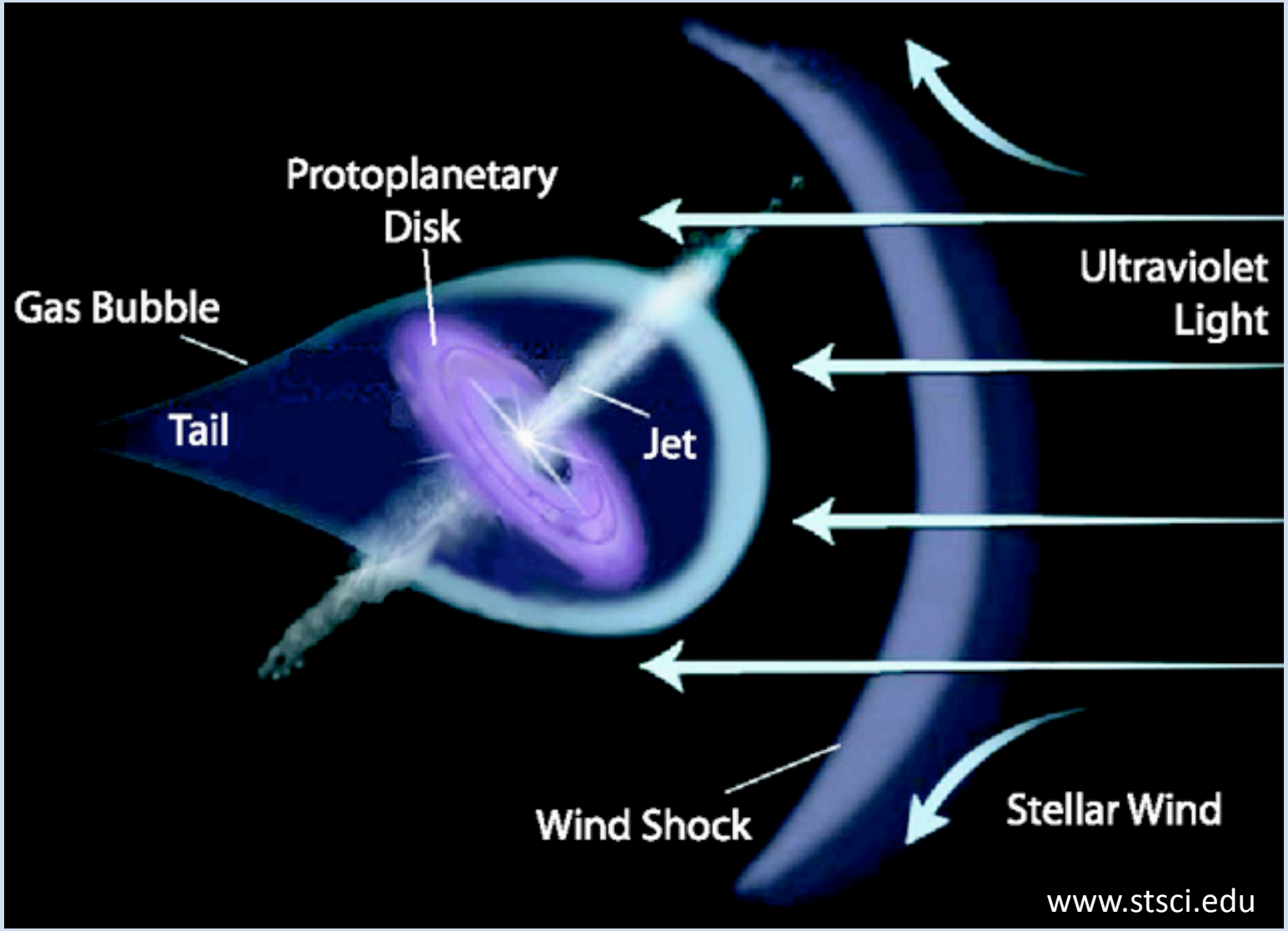
Orion proplyd masses are most similar to those of Taurus and ρ Ophiuchus Class II.

ASURV tests (Kaplan-Meier estimator) show Orion is statistically different from Class I and III Tau/ρOph and from the high mass end of Class II and the full distribution.



Comparison with theory

(Johnstone et al. 1998; Adams et al 2004; Clarke 2007)



Comparison with theory

• Within 0.03pc (15’’) of θ^1C, EUV dominates; ionizing photons penetrate outward flow, disk surface heated to 10^4K, only the inner few AU remain bound

- The SMA detection rate is lower in the central field
- *BUT the numbers are too small to be significant*

Comparison with theory

• Beyond 0.03pc, FUV dominates; thick PDR develops, disk surface is heated to ~10^3K, inner ~50 AU survive for many Myr

- Most Orion proplyds are unresolved by HST; r < 60 AU
- The disk mass distribution is truncated; M < 0.04 $M_\odot$
- The largest disks *tend* to be the most massive
- *BUT there is no clear trend of disk size or mass with distance from* θ^1C *or stellar mass*

NOTE: our conclusions are similar to Eisner et al. (2008) but some of our disk ids and mass determinations are different

Comparison with Taurus

We find $\frac{M_{\max}(Taurus)}{M_{\max}(Orion)} \approx 3$

$\Rightarrow \frac{R_{\max}(Taurus)}{R_{\max}(Orion)} \approx 3-9$ for $\Sigma(r) \alpha r^{-n}$ where n=1-1.5

SMA imaging -> median R(Taurus)=200 AU but range over 100-700 AU

Most Orion proplyds in our sample are unresolved by HST -> R < 60 AU
but ~10% are resolved with R~70-150 AU

The masses and sizes of the Orion proplyds are consistent with photoevaporation from an initial distribution similar to Taurus

Planet formation capability

12/55 (22%) proplyds have $M_{disk} > 0.01 M_{\odot}$
6 of which are unresolved by HST so have solar system scales (R<60AU) and are long-lived

30% of Class II disks in Taurus and ρ Ophiuchus have $M_{disk} > 0.01 M_{\odot}$ but have much larger sizes, R~200 AU
13% have $M_{disk} > 0.03 M_{\odot}$ and should have > $0.01 M_{\odot}$ within 60AU

The percentage of Orion disks with a MMSN in their inner 60AU appears to be similar (~10%) to that of similar age disks in Taurus and ρ Ophiuchus

Summary

- SMA imaging of 9 fields in the Trapezium Cluster; 850 μm photometry toward 55 HST proplyds
- 24 disks have clear dust excesses above free-free emission
- disk mass function is similar to Taurus and ρ Ophiuchus Class II but is truncated at $M \sim 0.04\ M_{\odot}$
- lack of massive disks due to external photoevaporation; inferred initial sizes and masses similar to Taurus
- disks with the potential to form Solar System analogs are no less likely in Orion than in low mass star forming regions

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