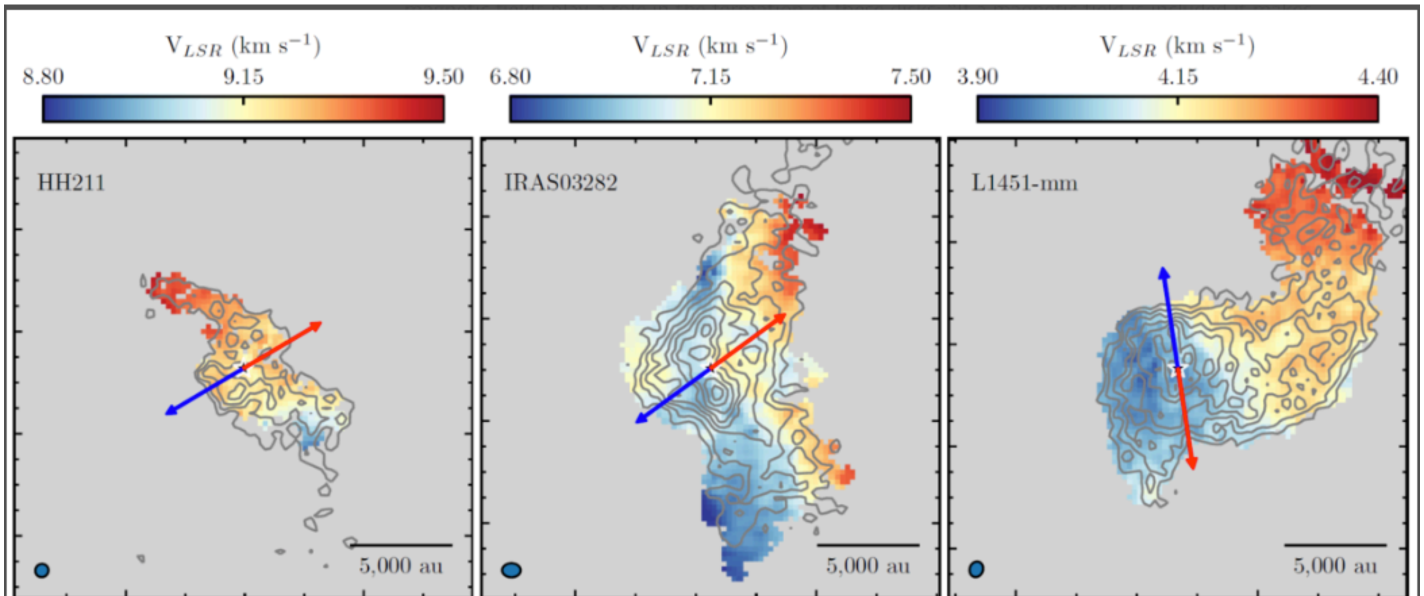
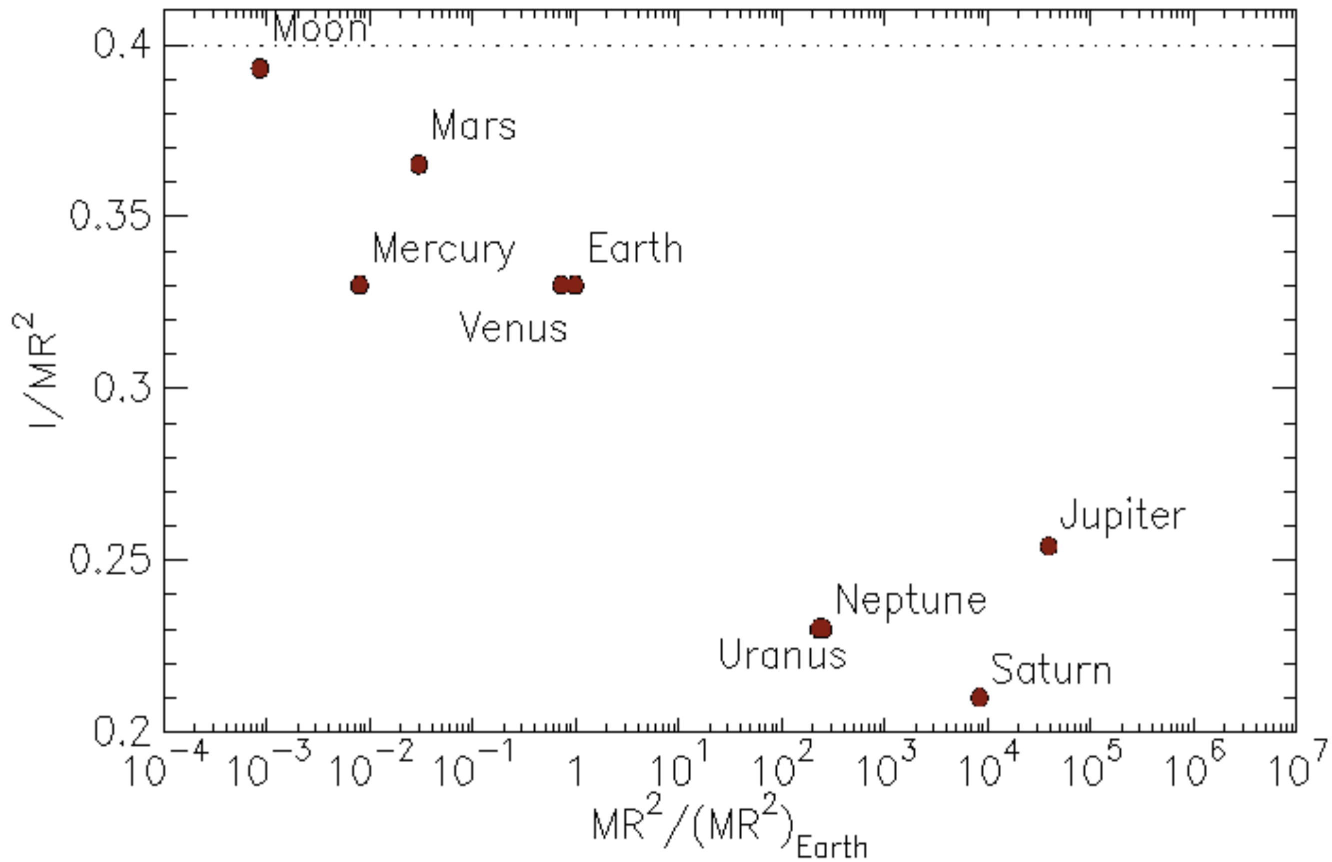
Radial Velocities – Solid body rotation



The velocity field in the three youngest proto-stellar sources in the Perseus molecular cloud. Blue denotes regions moving towards us, red denotes regions moving away from us. All systems show a systematic rotation around the axis indicated. Please note the different velocity scales indicated at the top.

(LSR=Local Standard of Rest)

Inertia moment – deviations from homogeneity (*$I = 0.4\ MR^2$*)



Distribution of β (rotational support)

DENSE CORES IN DARK CLOUDS. VIII. VELOCITY GRADIENTS

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ABSTRACT

We present an analysis of motions consistent with uniform rotation in dense cores (density $\gtrsim 10^4$ cm^{-3}; size $\sim$0.1 pc). Twenty-nine of the 43 cores studied have a statistically significant gradient. The detected gradients range in magnitude from 0.3 to 4 km s^{-1} pc^{-1}, corresponding to $2 \times 10^{-3} < \beta < 1.4$, with typical values $\beta \sim 0.02$, where β is the ratio of rotational to gravitational energy.

Some gradients are spatially continuous and are consistent with uniform rotation, but other apparent gradients are caused by clump-clump motion, or sharp localized gradients, within a map. The motions in L1495, B217, L1251, L43, B361, and L1551 are discussed in detail. In L1551, the residuals of the fit to the NH_3 velocity field indicate an outflow from IRS 5 in the same direction as the CO outflow.

Gradient orientation appears to be preserved over a range of density, as evidenced by comparing results for NH_3 to fits of $C^{18}O$ and CS maps. There appears to be no correlation between the inferred rotation axis and the orientation of elongated cores, a result consistent with the relatively small energy of rotation in these regions. The magnitude of the velocity gradient in a core has no relation to the absence or presence of an associated young stellar object.

We find that the specific angular momentum, J/M, scales roughly as $R^{3/2}$, where R represents the diameter of the FWHM intensity contour in a map. This relationship between specific angular momentum and cloud size can be understood if (*a*) cores are in approximate virial equilibrium, (*b*) line width scales as cloud size roughly according to $\Delta v \propto R^{1/2}$, and (*c*) β is roughly constant (i.e., independent of R) over the range of scales studied.

Subject headings: ISM: clouds — ISM: kinematics and dynamics — ISM: molecules — stars: formation

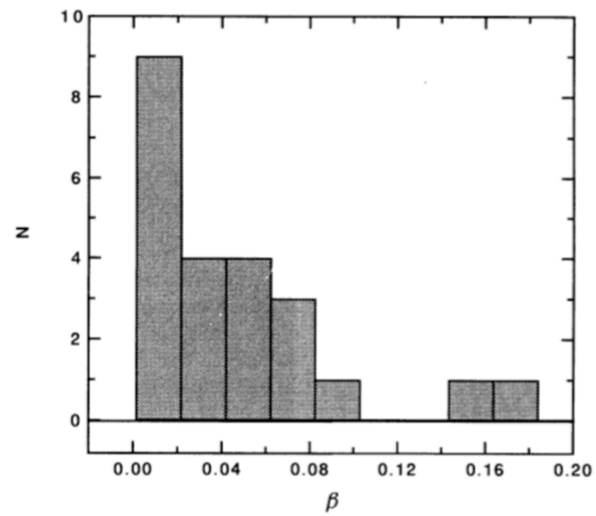
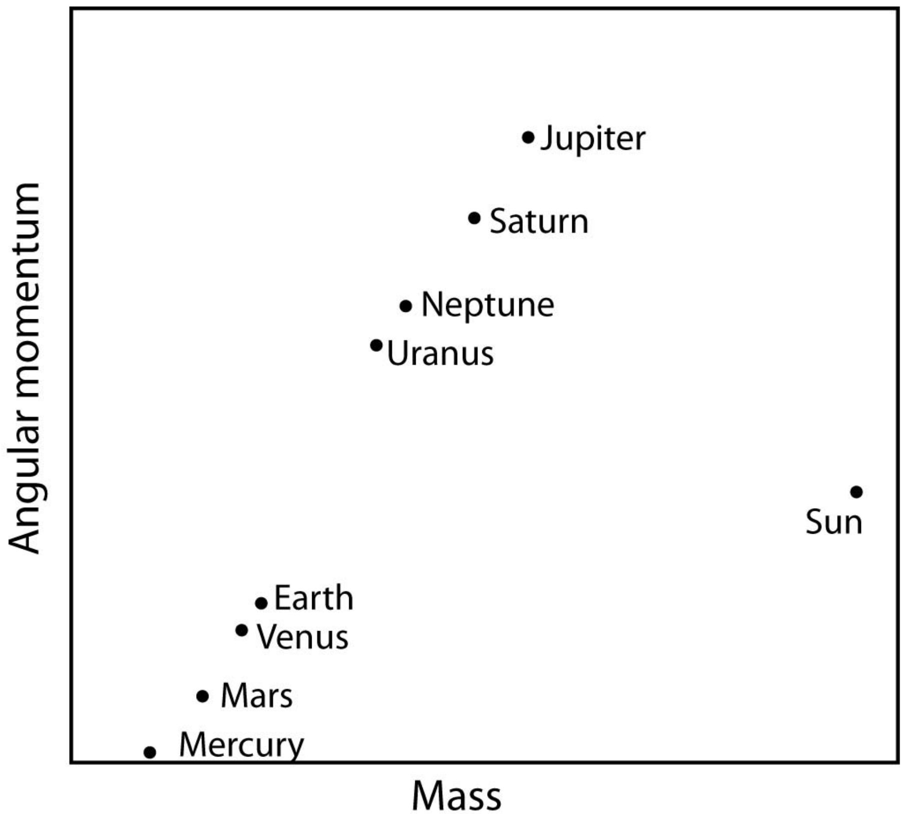


Fig. 11.—Distribution of β, shown for the 23 cores where enough information is available to calculate β *without* assuming virial equilibrium (i.e., the estimate of gravitational energy is based on the measured cloud size and a derived volume *density*, not on line width). Note that the value of $\beta = 1.4$ for L1495NW is not included in this distribution; this seemingly discrepant value is discussed in the text (§ 6.2).

β ~ 0.02 (<<1)

The Angular Momentum Problem



Angular Momentum of the Solar System:

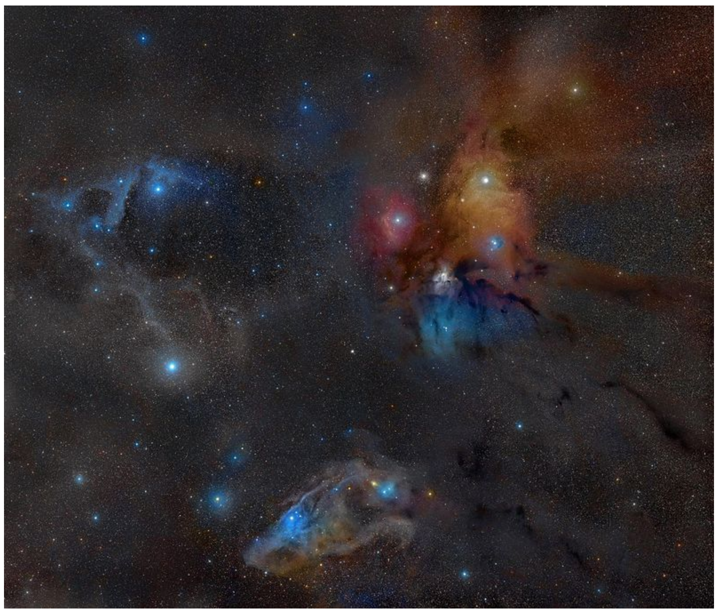
Dominated by Jupiter's orbital angular momentum

100x larger than the ***Sun***'s spin angular momentum

10,000x smaller than the angular momentum of a typical *molecular cloud core*.

Star forming regions

ρ Oph complex (120 pc)

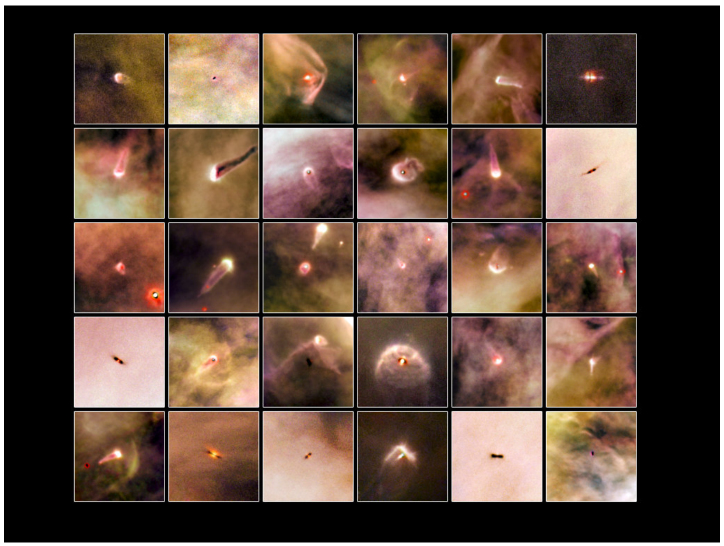


Taurus molecular cloud (140 pc)

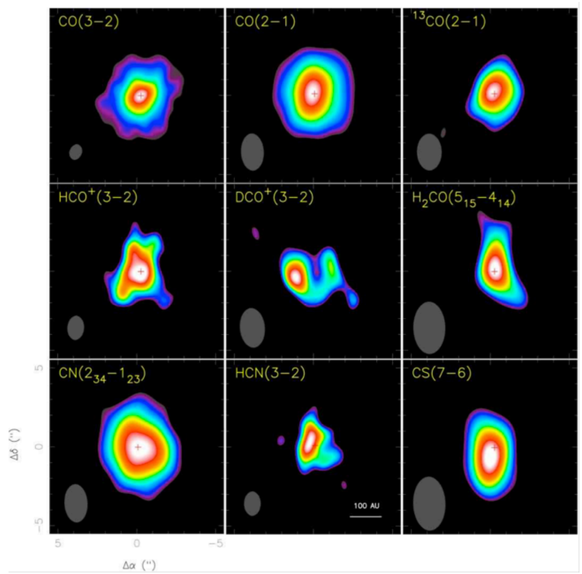
HST view of disks in Orion

HST vs SMA vs ALMA

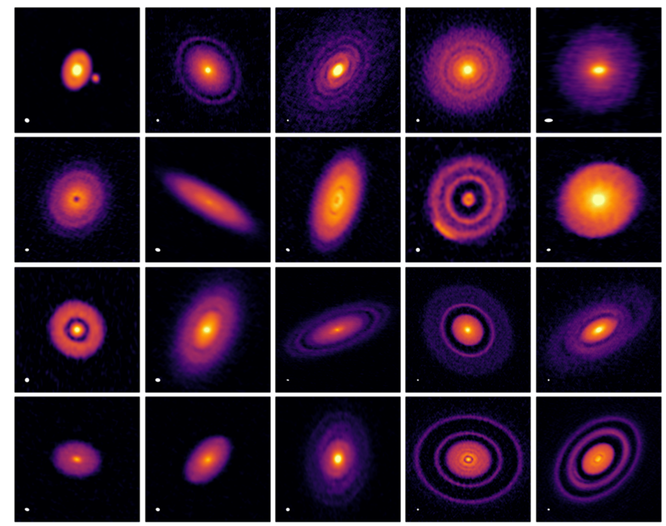
HST



SMA



ALMA



Distribution of Disk Sizes

Draft version January 16, 2020
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The evolution of dust-disk sizes from a homogeneous analysis of 1-10 Myr-old stars

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ABSTRACT

We utilize ALMA archival data to estimate the dust disk size of 152 protoplanetary disks in Lupus (1-3 Myr), Chamaeleon I (2-3 Myr), and Upper-Sco (5-11 Myr). We combine our sample with 47 disks from Tau/Aur and Oph whose dust disk radii were estimated, as here, through fitting radial profile models to visibility data. We use these 199 homogeneously derived disk sizes to identify empirical disk-disk and disk-host property relations as well as to search for evolutionary trends. In agreement with previous studies, we find that dust disk sizes and millimeter luminosities are correlated, but show for the first time that the relationship is not universal between regions. We find that disks in the 2-3 Myr-old Cha I are not smaller than disks in other regions of similar age, and confirm the Barenfeld et al. (2017) finding that the 5-10 Myr USco disks are smaller than disks belonging to younger regions. Finally, we find that the outer edge of the Solar System, as defined by the Kuiper Belt, is consistent with a population of dust disk sizes which have not experienced significant truncation.

Keywords: protoplanetary disks, stars: pre-main sequence, submillimeter: planetary systems

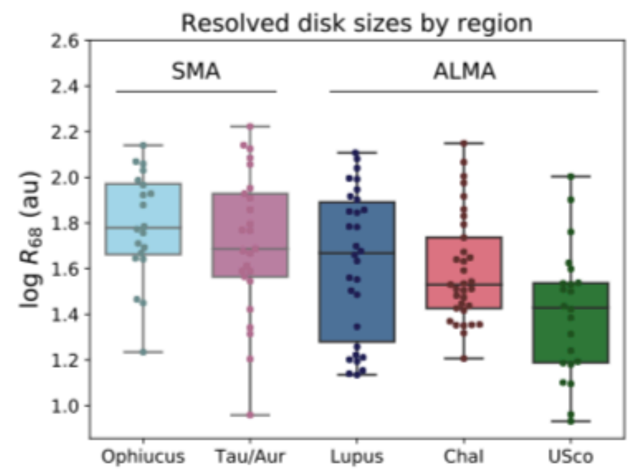

Figure 4. Swarmplots for resolved disks in different regions, ordered by age. The boxplots include a shaded region surrounding the R_{68} 25-75% quartiles, the horizontal line denotes the median disk size, while whiskers define the 0-25% and 75-100% quartiles. The regions observed with the SMA are greyed out because they are biased to the brightest millimeter disks, hence their size distributions should not be directly compared to the regions observed by ALMA.

Distribution of Disk Sizes


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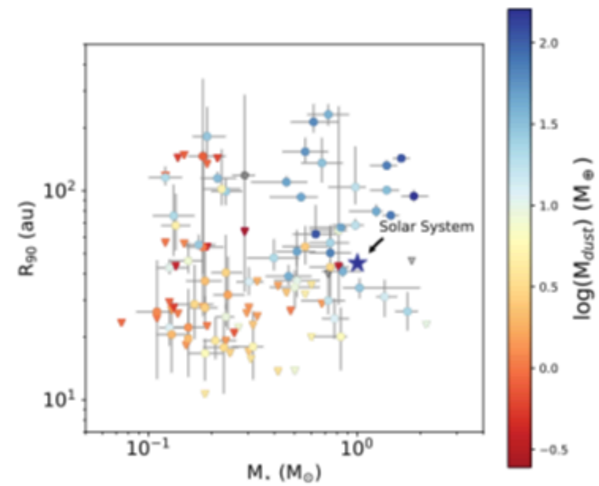
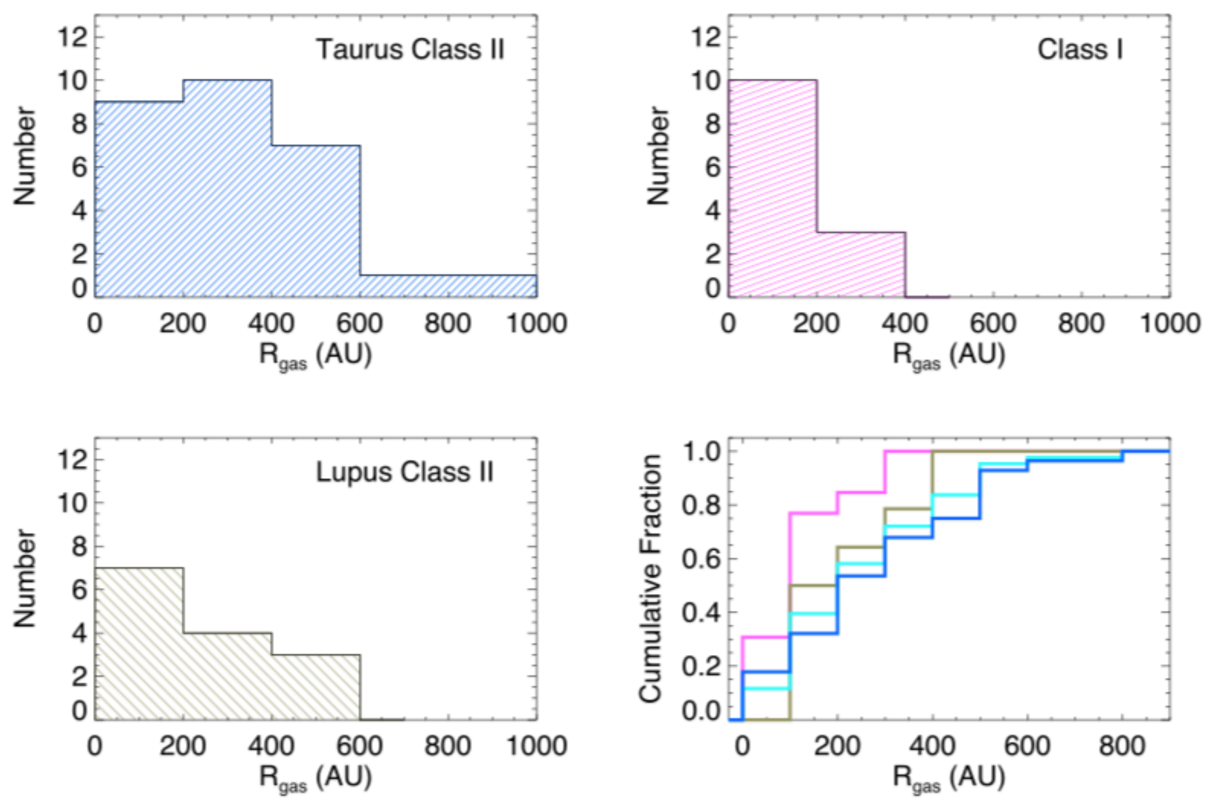
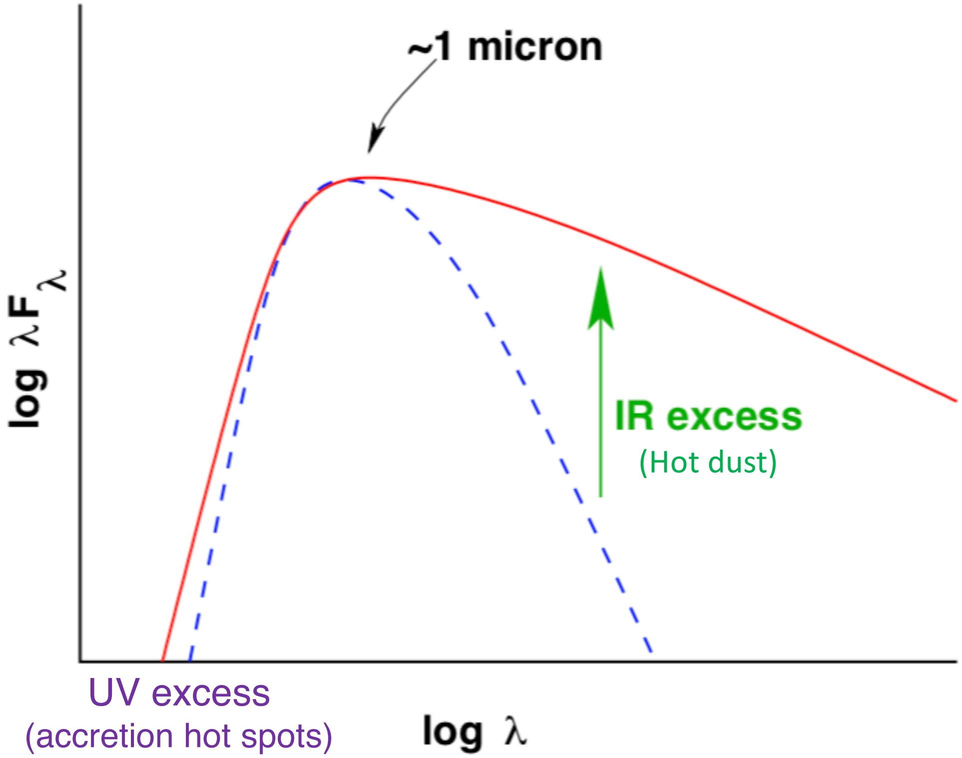


Figure 9. The R_{90} sizes and dust masses for disks in the 1-3 and 2-3 Myr old Lupus and Cha I star-forming regions are plotted along with the Solar System in order to determine if the Solar System (denoted in the figure with a star) should be considered *typical*, or a statistical outlier. Disks with constrained size estimates are shown as circles, and upper limits with triangles. The color of each symbol (including the Solar System) corresponds to the dust mass.

Distribution of Disk Sizes



T Tauri


~1 micron
log λF$_\lambda$
IR excess
(Hot dust)
UV excess
(accretion hot spots)
log λ