Statistical view of Protoplanetary Disks Evolution

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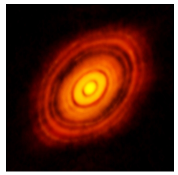
Introduction

◆Planet-Forming Disks: Key Insights

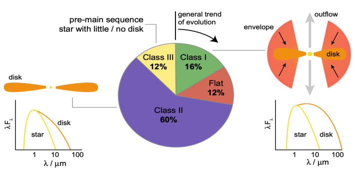


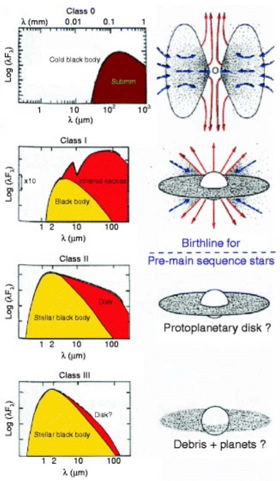
Protoplanetary disc around HL Tauri by ALMA

- •**Role**:
  - •Disks of gas and dust around young stars are the birthplace of planets.
- •**Structures**:
  - Rings, spirals, arcs, shadows.
  - Substructures differ in dust and gas components.
- •**Formation Drivers**:
  - Host star and disk properties.
  - Disk-planet interactions.

◆Evolution of the Disk:

- Pre-main sequence
- Measuring the disk fraction in SED through infrared survey for different star-forming regions.





Empirical sequence for the formation and circumstellar evolution of a single star, based on the shape of the SED. [1][2]

Reference

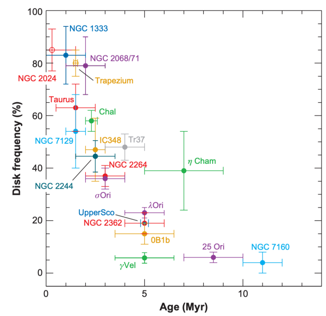
[1] Andr´e, P., 2002, EAS Publications Series, 3, pp 1-38.
[2] Armitage, P. J., & Kley, W. 2019, From Protoplanetary Disks to Planet Formation
[3] Mark C. Wyatt. Annu. Rev. Astron. Astrophys. 2008. 46:339–83
[4] M. Ansdell et al 2016 ApJ 828 46
[5] L. Testi et al. A&A 663, A98 (2022)
[6] Gijs D. Mulders et al 2021 ApJ 920 66

Features

Choosing the simplest model for disks: accretion disk

◆ Disk Lifetime

The typical disk lifetime is 1-3 Myr (40-80%):
Disk fraction sharply decrease from young to old star-forming regions with age of a few million years.



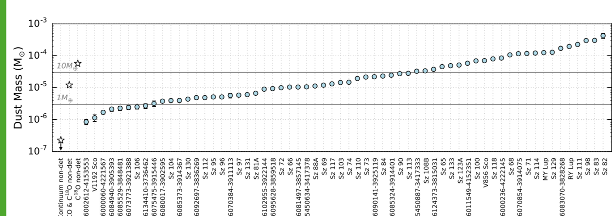
Evolution of protoplanetary disks with detectable near-IR excess as a function of time. [3]

◆ Disk Dust Masses

→**How massive are the dust grains?**

- Dust disk masses have been surveyed at millimeter wavelengths.
- The disk mass is estimated with a simple relation (Hildebrand 1983):

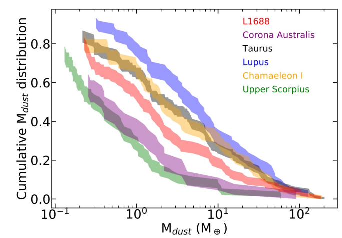
$$M_{\rm dust} = \frac{F_\nu d^2}{\kappa_\nu B_\nu(T_{\rm dust})} \approx 7.06 \times 10^{-7} \left(\frac{d}{150}\right)^2 F_{890\mu m} M_\odot$$



Dust masses for all the continuum-detected disks.[4]

→ **Comparison between different regions**

- Young star-forming regions statistically have more massive disk than older regions: generally, the disk masses decrease with time.
- The median disk masses are ~10 Earth masses with huge dispersion.



Name	Median age (Myr)	25% (Myr)	75% (Myr)
Corona Australis	0.6	0.5	2.1
L1688	1.0	0.5	2
Taurus	0.9	0.5	1.7
Lupus	2.0	1.3	3.6
Chamaeleon I	2.8	1.4	6.6
Upper Scorpius	4.3	2.7	7.6

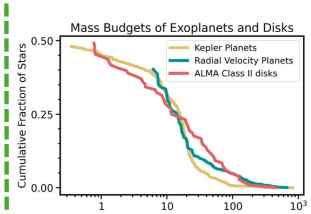
Comparison of the dust masses cumulative distributions in the various regions.[5]

❓ Mass budget problem:

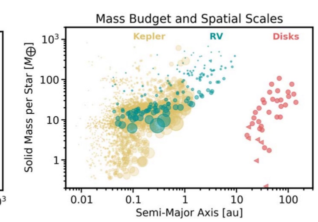
Disk mass vs. planet mass

- All three distributions peak near ≈10 Earth Mass.
- Theoretically, planet formation involves steps like dust growth and gas accretion, each with mass loss, needing a higher initial disk mass.

→ The mass budget may not be enough for forming extrasolar planets.



Solid mass budget of exoplanet systems and protoplanetary disks around solar-mass stars.[6]



Estimated solid system mass vs. spatial scale for exoplanets systems and protoplanetary disks around solar-mass stars.[6]