Evolution of Disks Surrounding Intermediate Mass Stars

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Goals

- Determine the fraction of accretion disks among young, intermediate mass stars
- Search for evidence of disk evolution over the age range t << 1 Myr to t ~ 2 Myr

Approach

- Study a sample of stars in the rich, young cluster IC 1805 (d ~2kpc; t ~ 1-2 Myr)
- Use SEDs to diagnose the presence and structure of disks

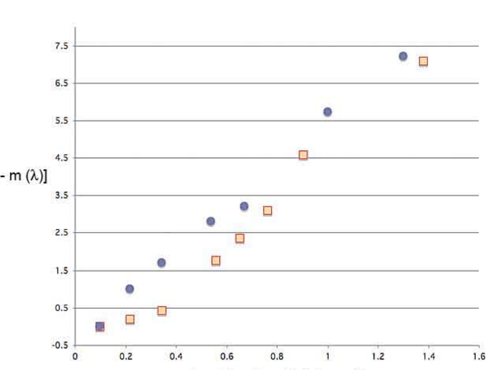
Observations

- Extant optical (Massey et al. 1995) & near-IR (2MASS) photometry
- IRAC and MIPS photometry
- Classification spectra (WIYN Hydra)

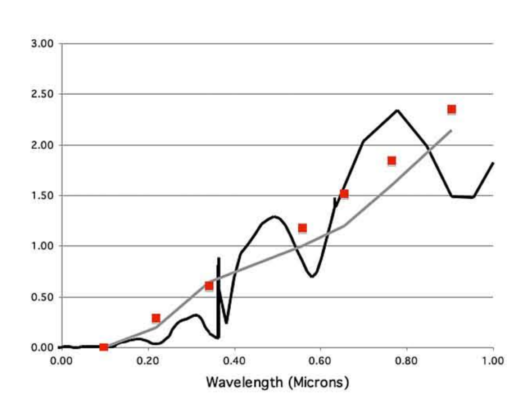
Classification of Disk Candidates

Reddening-corrected SEDs provide basis for identifying 3 disk types

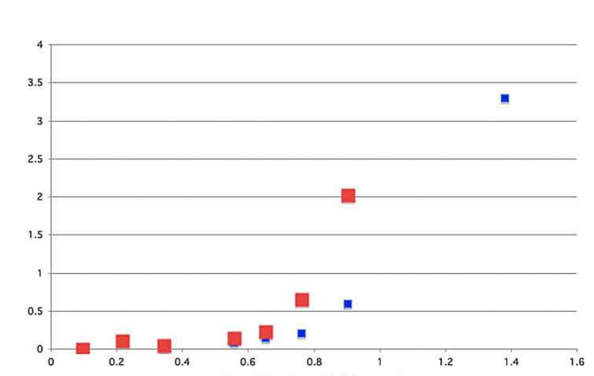
1. Optically thick disks extending inward to near the stellar surface
2. Disks with IR excesses consistent with optically thin gas emission
3. Disks with large inner holes (r > 20 AU)
   - Manifest by significant excesses at 8, 24 μm; none at shorter λ



(1) SEDs for the Ae/Be star AB Aur (blue circles) compared with an optically thick disk in IC 1805 (Massey et al. # 682).



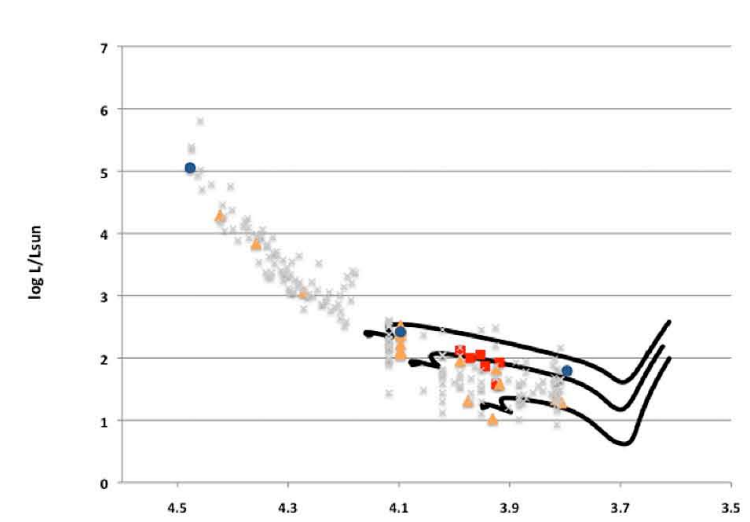
(2) SED (red squares) for star # 271 in IC 1805 which shows excess emission consistent with optically thin gas emission. The solid grey line is the SED predicted from a model of a Be star excretion disk with an excretion rate of $5x10^{-11} M_{sun}$/yr (Sigut & Jones 2007); the black line is that predicted for an accretion disk with an accretion rate of $10^{-9} M_{sun}$/yr (Muzerolle et al. 2004).



(3) SEDs for two stars in IC 1805 (red squares #13; blue circles #9), which show excesses consistent with inner holes of size ~ 20 AU.

HR Diagram

Spectra + reddening corrected photometry enable placing 300 stars in an HRD



HR Diagram for those stars in IC 1805 that show either (1) Ae/Be-like SEDs (red squares); (2) SEDs consistent with optically thin gas emission (blue circles); or (3) SEDs consistent with inner holes (orange triangles). Stars with no evidence of excess emission over the range $1 < \lambda < 24\mu m$ are plotted as light grey crosses.

Disk Statistics:

Mass	Sample Size	% Ae/Be	% Opt Thin	% Inner Holes
< 4 M_{sun}	115	5	2	14
> 4 M_{sun}	78	0	1	4

At a similar age, the percentage of stars with M < 1 Msun that are surrounded by accretion disks is 50-70%. The age at which that fraction drops to ~5% is 5-7 Myr. We conclude that the typical disk lifetime for intermediate mass stars is t << 0.5 Myr.

A Possible Evolutionary Path: An Hypothesis

All intermediate mass stars are surrounded initially by optically thick accretion disks that extend inward to near the stellar surface (Type 1 disks; Ae/Be-like)

Subsequent evolution is driven by:

- Disk accretion (draining and spreading) and photoevaporation
- Planet building

Type 2 disks (optically thin gaseous disks) may be analogous to many 'transition disks' surrounding solar-like stars (optically thin inner disk; continued accretion of dust-poor gas). Najita et al. (2007) have proposed that the properties of such disks can be explained by:

- Formation of an EGP
- Accretion onto the EGP (90% of inflowing material) and onto the central star (10%)
- Filtering of small dust grains or acceleration of grain growth in the vicinity of the EGP

Such disks would be the evolutionary descendents of type 1 disks, following formation of an EGP.

Type 3 disks (disks with large inner holes; r ~ 20 AU) could result from:

- The combined effects of accretion and photoevaporation via the 'uv switch' model initially proposed by Clarke et al. (2002). An inner hole of size comparable to the photoevaporatiion radius (r ~20 AU for stars of this type) is created when the accretion rate through the disk drops to a level below the photoevaporation rate.
- Formation of a massive EGP, with mass sufficient to tidally isolate the inner and outer disk. Such a planet would need to form near the ice condensation radius (also at r ~ 20 AU for stars of this type) and, perhaps implausibly, suffer no inward migration.

Such disks could be produced either during the later evolutionary stages of initially low mass disks (when the disk accretion rates drop to low values), or the early evolutionary stages of initially high mass disks in which massive EGPs could form rapidly.

Key Tests:

Obtain high resolution optical and NIR spectra of Type 2 disks to

- Confirm that they exhibit accretion (inverse P Cyg profiles) and gas emission signatures
- Rule out Be-star analogs (EX-cretion disks) by measuring stellar rotation speeds

Refine theoretical and observational estimates of photoevaporation and accretion rates for Intermediate mass stars to check the applicability of 'uv switch' model for 2-10 M_{sun} stars.

Carry out AO and/or interferometric observations of Type 3 disks to check for evidence of high mass EGPs.

References

Clarke et al. 2002, MNRAS 328, 485

Massey et al., 1995, ApJ 454, 151

Muzerolle et al., 2004, ApJ 617, 406

Najita et al. 2007, MNRAS 378, 369

Sigut & Jones 2007, ApJ 668, 481