Preliminary Spitzer Results on Weak-line T Tauri Star Disks from the Cores to Disks (c2d) Legacy Project

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c2d Team

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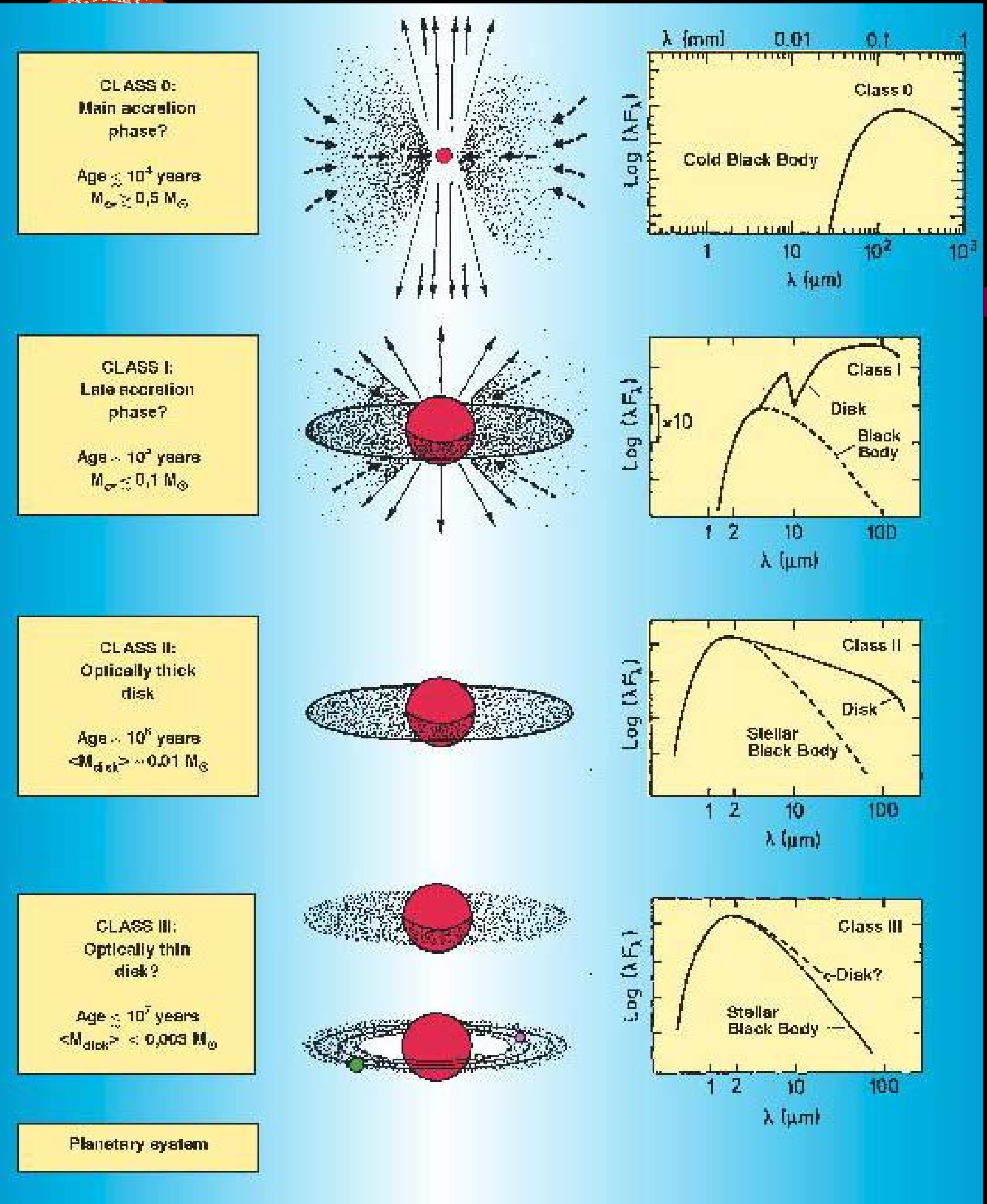
- Many associates

Weak-line T Tauri Stars

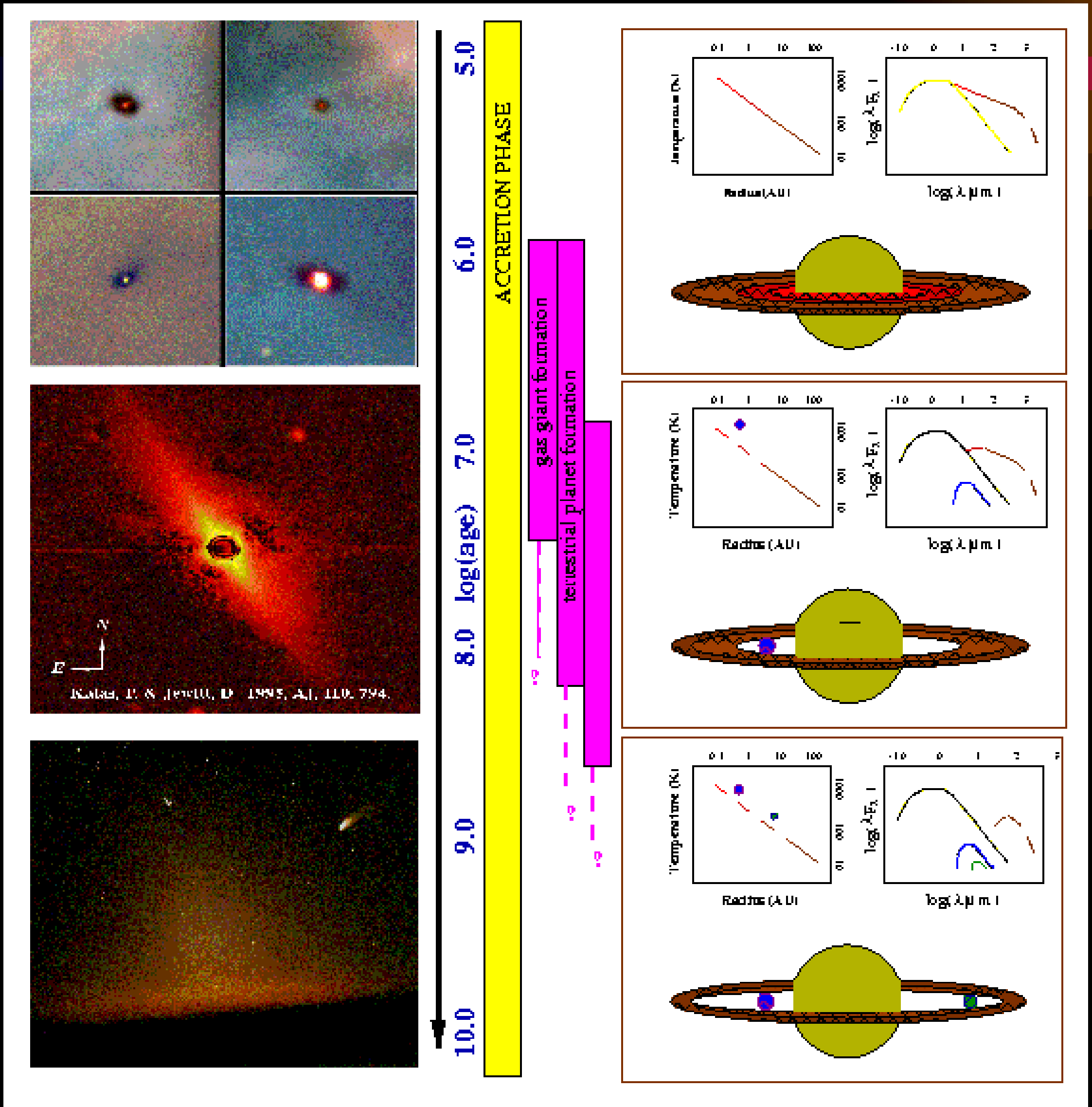
- "Classical" T Tauri stars (CTTS) have spectroscopic signatures of accretion and/or outflow
- "Weak-line" T Tauri stars (WTTS) are defined as having Hα equivalent width of < 10 Å (K0 star)
- Most have been discovered by X-ray surveys of star-forming clouds
- Confirmation usually consists of demonstrating presence of abundant lithium with high resolution spectroscopy; ages are not precise, but range from < 10^6 to > 10^7 yr
- Some controversy continues regarding the age and distance of these objects; we have chosen sources within 6 deg of cloud centers to minimize interlopers of Pleiades age; SIM could settle this



Disk Evolution

- Class III sources thought to correspond to weak-line T Tauri stars
- From IRAS, ISO, and ground-based studies, know disks become mostly invisible by 10^7 yr
- Is this due to total dissipation, inside-out clearing, or flux limit of surveys?

Protostellar Disks to Planetary Systems



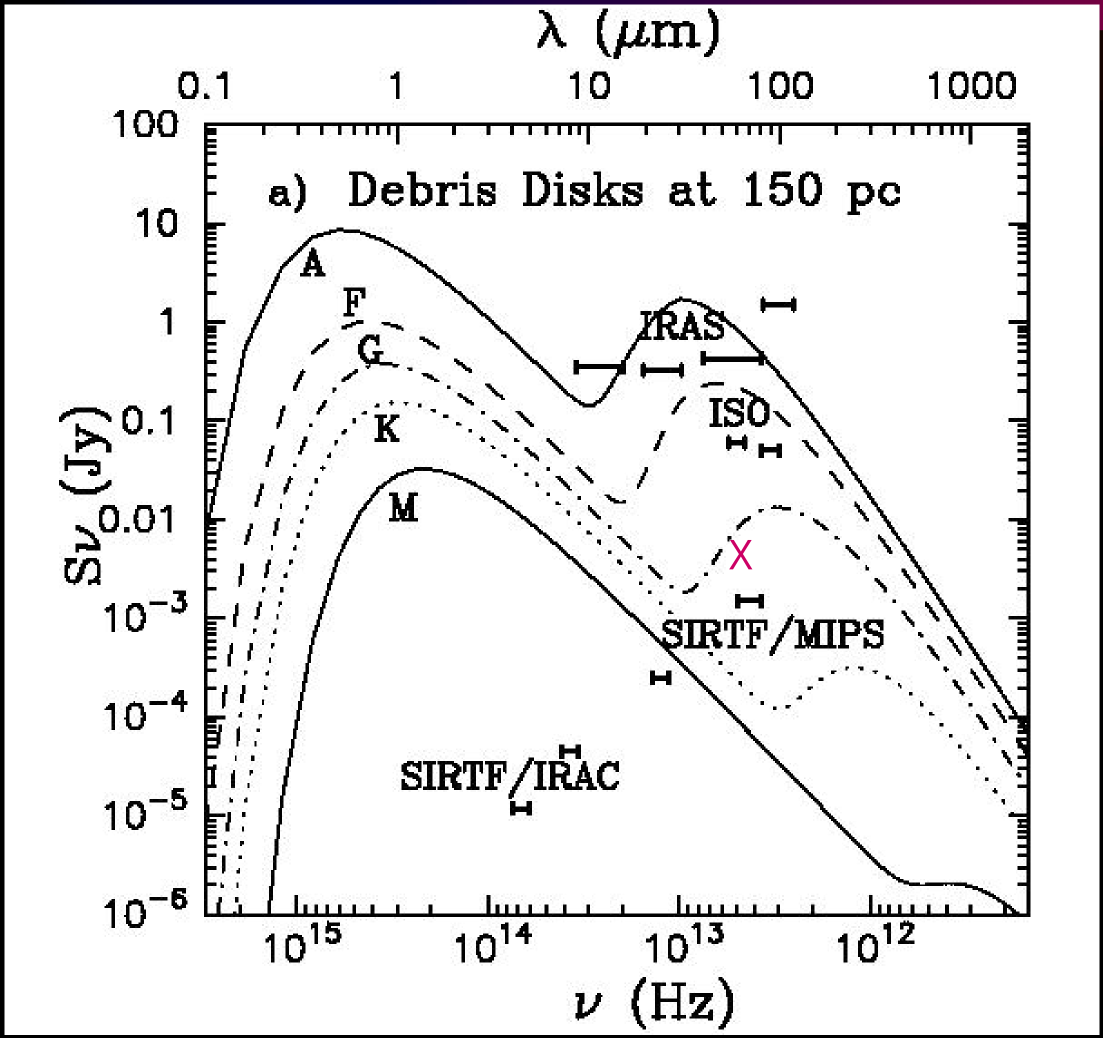
Cores to Disks
0 – 3 Myr

WTTS?

FEPS Team
3 Myr – 3 Gyr

FEPS results on 5 – 10 Myr star disks will be coming this fall

Spitzer Can Detect Debris Disks to few x 0.1 M_{moon}



- Model has 0.1 M_{moon} of 30 μm size dust grains in a disk from 30–60 AU
- Bars are 3 σ
- Model based on disks around A stars
- Unfortunately, MIPS-70 is a factor of 3-4 less sensitive than prelaunch predictions
- Can detect debris disks around solar type stars in nearby clouds

Importance of WTTS

- Are all stars in cloud born with disks?
- Do disks evolve at different rates for coeval stars in the same environment?
- How fast does the disk material in the planet forming zone (few AU) dissipate?
- Is the WTTS phenomena related to planet formation? (a job for SIM…)

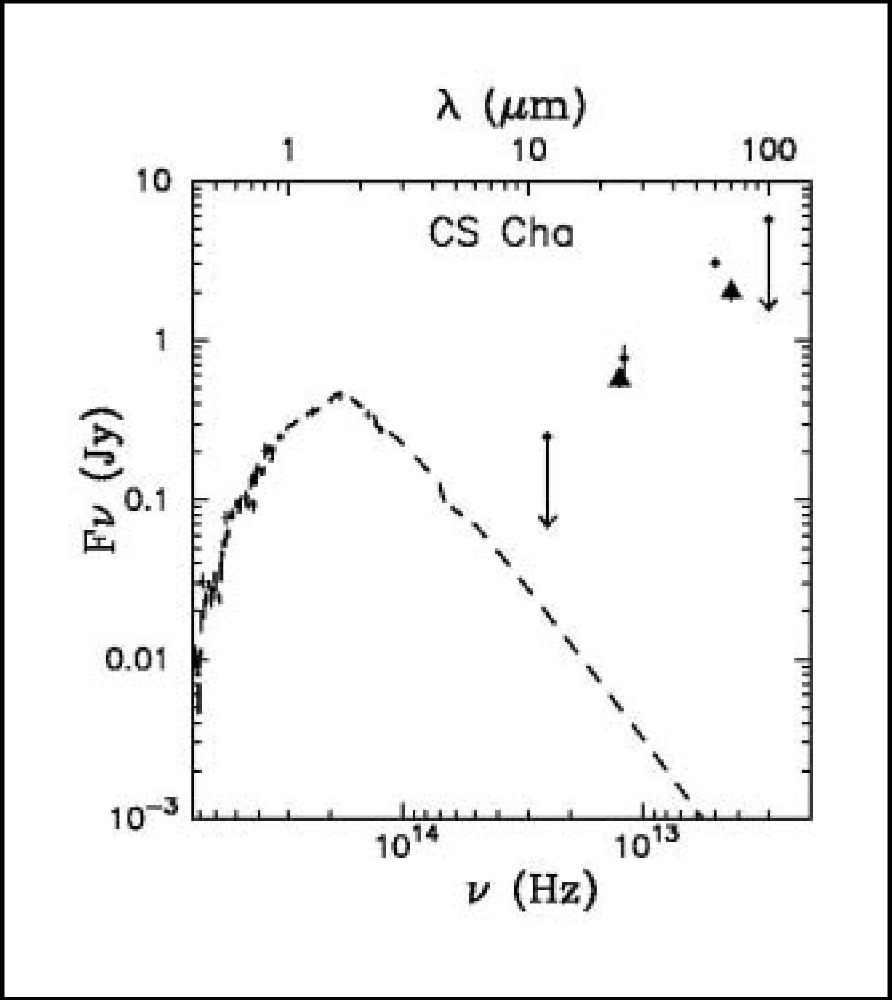
Previous Work on WTTS Disks

- Strom et al. (1989) – ½ of young stars in nearby clouds do not show disk excesses in NIR/IRAS survey
- Beckwith et al. (1990) – ½ of young stars do not show millimeter disk continuum emission
- Skrutskie et al (1990) – few disks in transition out to 10 microns
- Osterloh & Beckwith (1995) – WTTS have lower mm detection rate than CTTS
- ISO results – many new sources in cloud with 8 & 15 μm excesses; disks largely gone by 10 Myr

Cores to Disks WTTS Photometry

- Sample ~180 stars individually targeted within 6 deg of Taurus, Cha, Lupus, Oph clouds (Serpens and Perseus excluded due to greater distance) + known WTTS within large cloud maps
- High resolution optical spectroscopy taken by c2d team for entire sample
- IRAC 12 sec HDR observations; see departure from photosphere; bridge to 2MASS
- MIPS few cycles 24 & 70 um photometry (5 sigma sensitivities of ~200 μJy and 7 mJy); material at a few AU in planet-forming zone
- Status – 11 stars in Chamaeleon observed with MIPS reported here; similar number observed with IRAC, but not the same stars; awaiting full SEDs

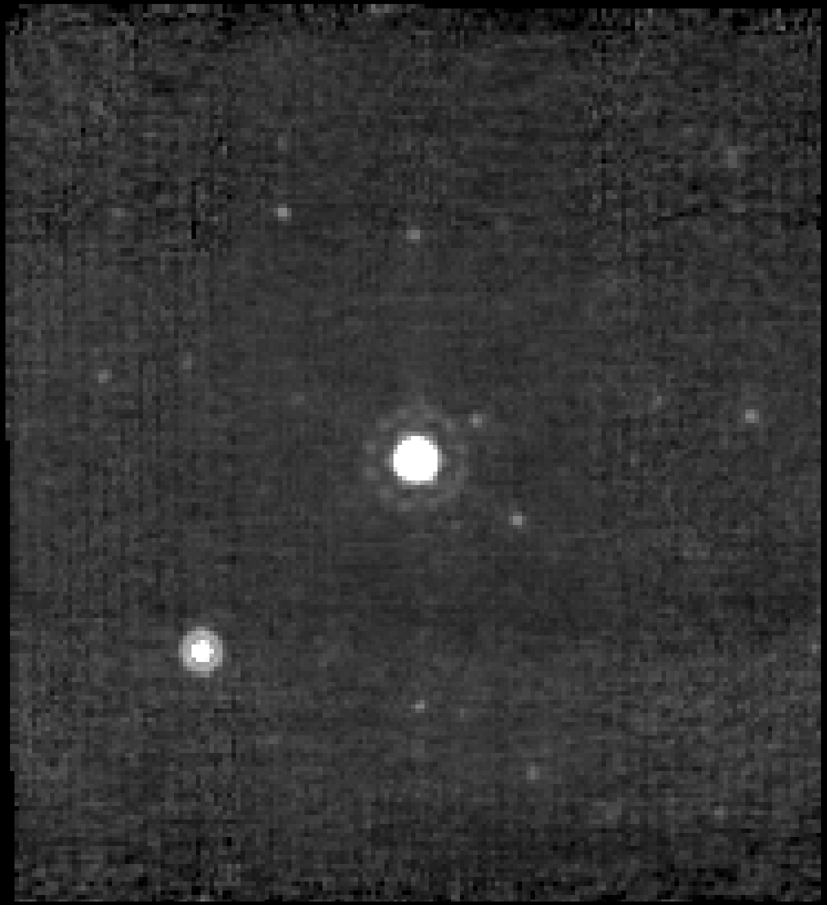
CS Cha



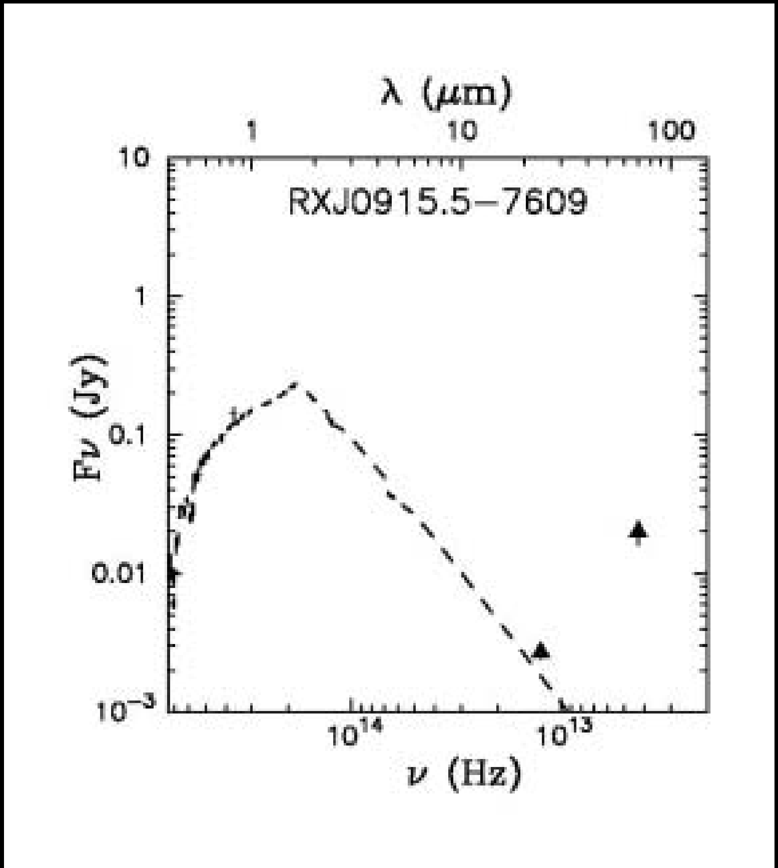
- M0 star
- Variable Halpha emission star with strong IR excess out to millimeter; occasional "weak" CTTS
- Preliminary MIPS fluxes close to previously measured IRAS 25 & 60 micron values
- IRAC points may confirm presence of inner hole suggested by IRAS 12 micron upper limit
- Similar to CoKu Tau 4?

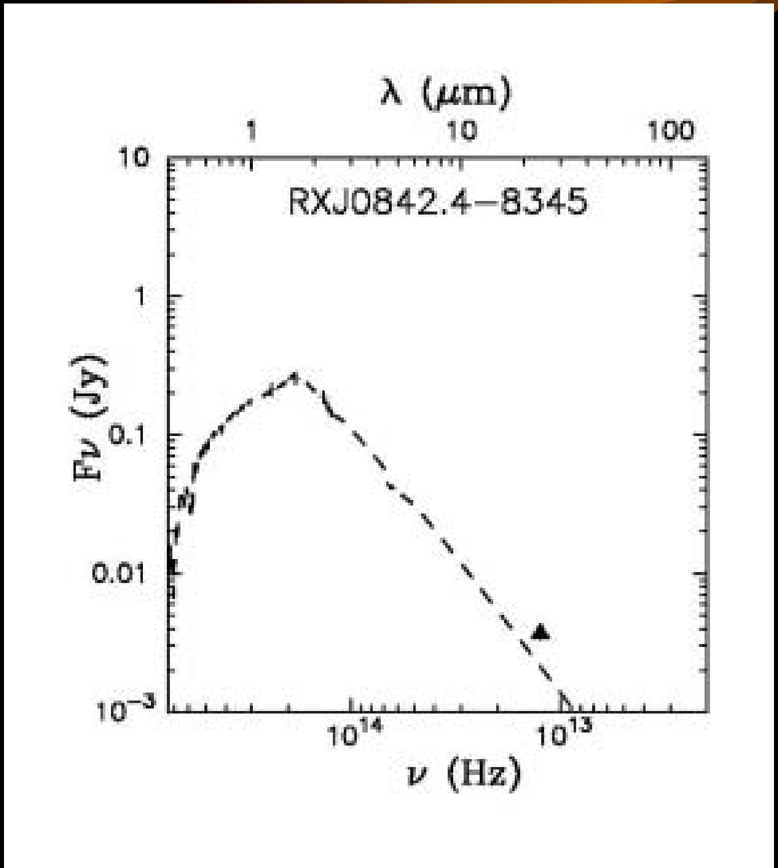
Schwartz 41

- K0 star
- 1.9″ binary
- Subject to Halpha flaring with equivalent width varying from absorption to 20 Å emission
- Seen at 12 & 25 μm by IRAS, not 60 μm
- Spitzer detects at 70 μm ~ 150 mJy



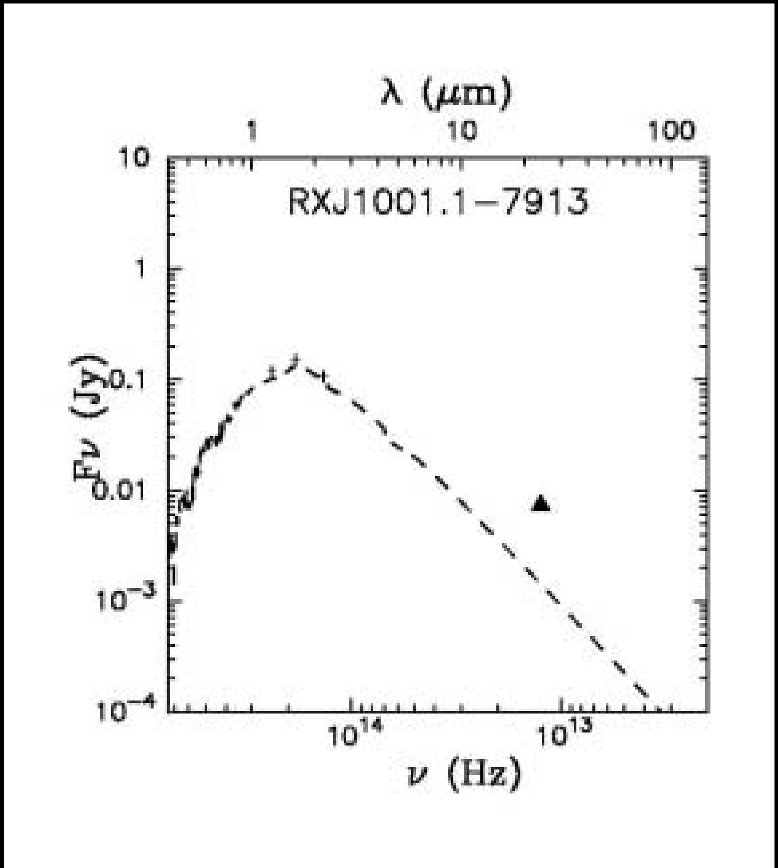
Other WTTS Possibly Detected at 70 microns

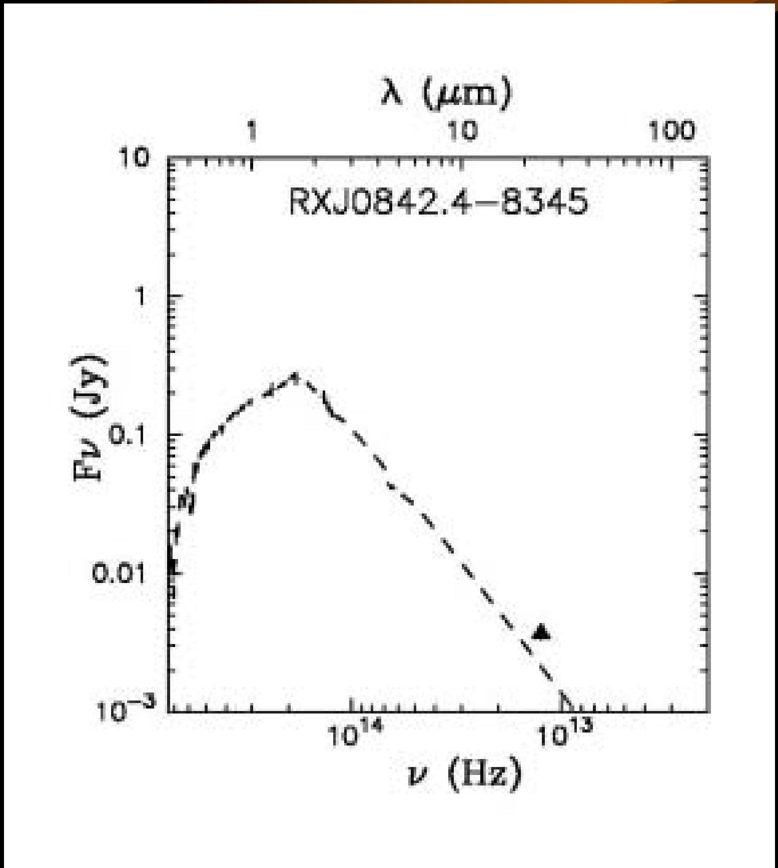




Both have possible small excesses at 24 microns

WTTS with Possible 24 Micron Excesses





Comparison of Optical and MIPS-24

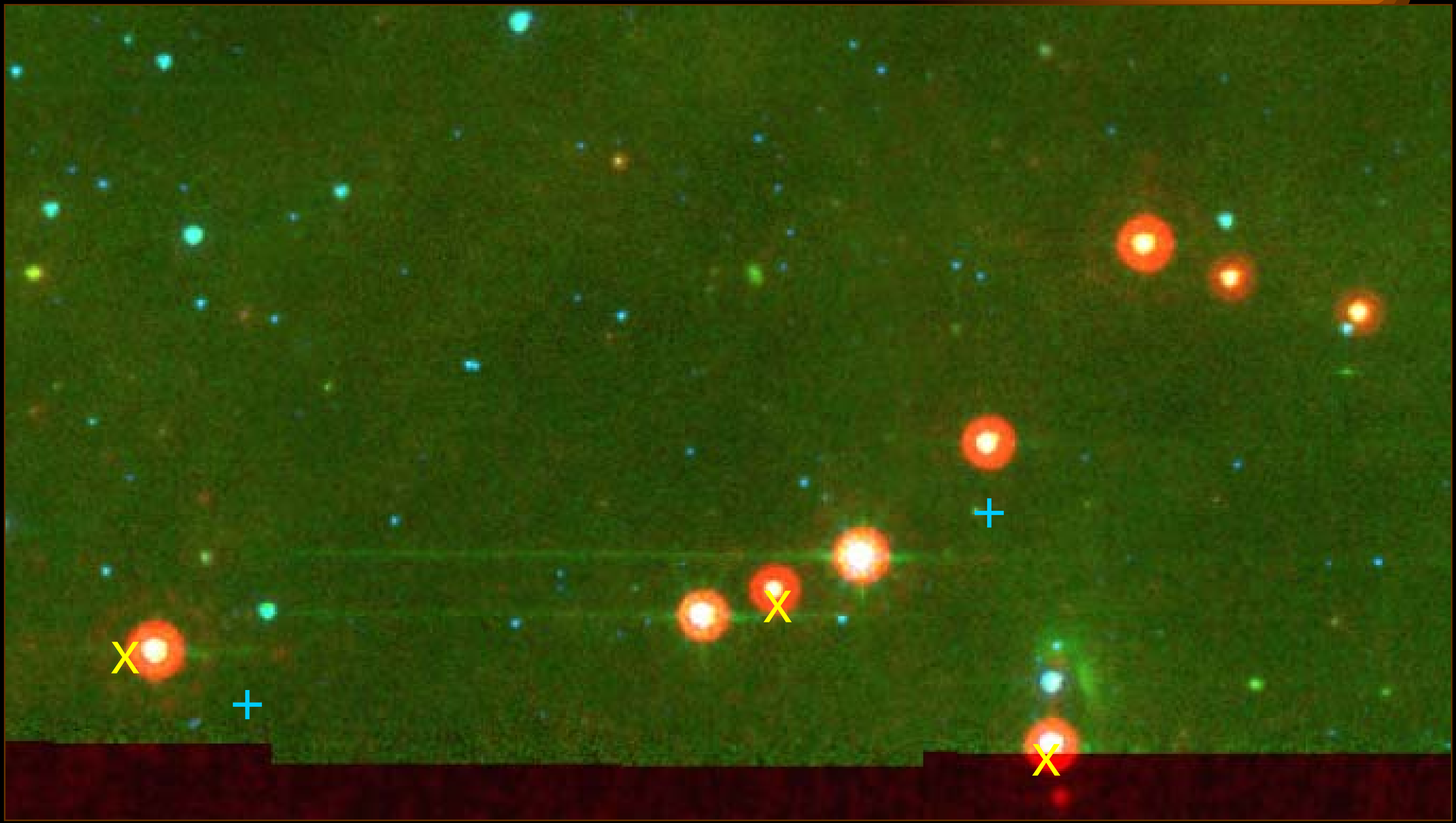
Summary of Current c2d WTTS Results

- We have MIPS photometry for 11 WTTS
- 2 were previous IRAS sources; both have 24/70 excess
- Of the others (all ROSAT stars), 2/9 are probable 70 μm detections
- Most of the ROSAT stars have suggestions of slight 24 um excesses; need to check calibration more thoroughly to confirm

Importance of Study

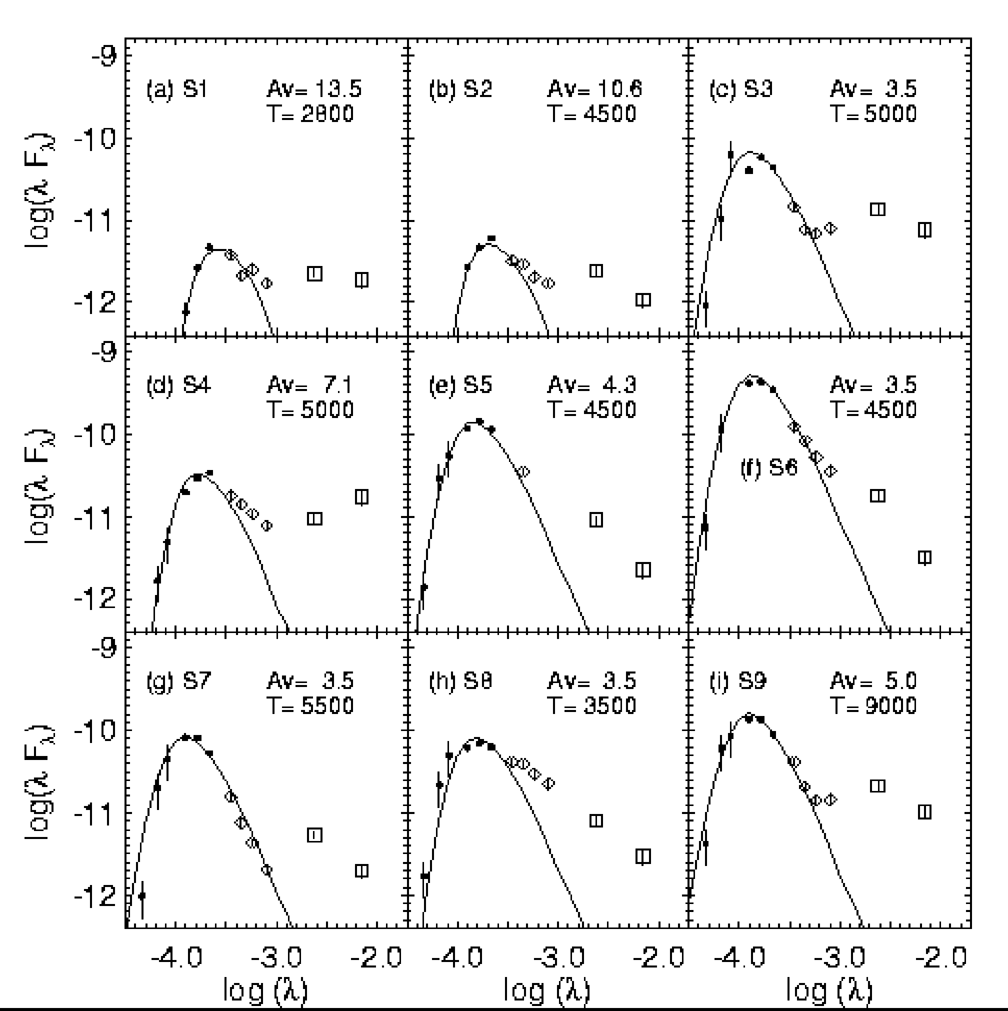
- If majority of WTTS lack any evidence for remnant disks
  - Stars born diskless or very rapid disk dissipation in substantial percentage of cloud population
  - WTTS population older than or unrelated to CTTS population
- If many WTTS show remnant disks
  - Identification of previously rare transitional disks
  - Potential of planet formation as disk clearing mechanism
  - Validation of current paradigm of disk SED evolution

Spitzer First Look Survey
Observations of L1228 South
13 arcmin by 7 arcmin (300 pc)



L 1228 South SEDs + Fits

- 9 YSOs in close proximity; presumably coeval
- Wide variety of SEDs
- S7 has no excess shortward of 24 μm – transitional disk?
- Note also S3 and S9 with short wavelength SED gaps



Conclusions

- The c2d team has observed 11 WTTS in Chamaeleon using MIPS 24 & 70 μm
- Of the 9 sources undetected by IRAS, 2/9 have 70 μm excesses and most may have small 24 μm excesses
- Presuming that all these sources are young stars associated with the clouds, our results suggest that disk clearing out to several AU takes place on a < 3 Myr time scale for at least some objects
- Similar results are found for PMS clusters observed by Spitzer; transitional disks are found around stars which are apparently coeval with classical T Tauri stars

HST WFPC2 Image of CoKu Tau 4

- 1400 AU filamentary circumstellar nebula
- Remnant envelope?
- Not typical of WTTS
- Need to add envelope component to disk models?