PAH evolution from clouds to disks around low mass YSOs

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Spitzer & VLT survey of disks and embedded sources

We present a sensitive mid-infrared spectroscopic survey of PAH features toward a sample of low-mass T Tauri stars and embedded young stellar objects, observed both as part of our Spitzer Legacy program "From Molecular Cores to Planet-Forming Disks" (c2d) and through programs with VLT-ISAAC, VISIR, NACO. The features are discussed in the context of the disk structure, envelope mass, stellar radiation field and PAH abundances.

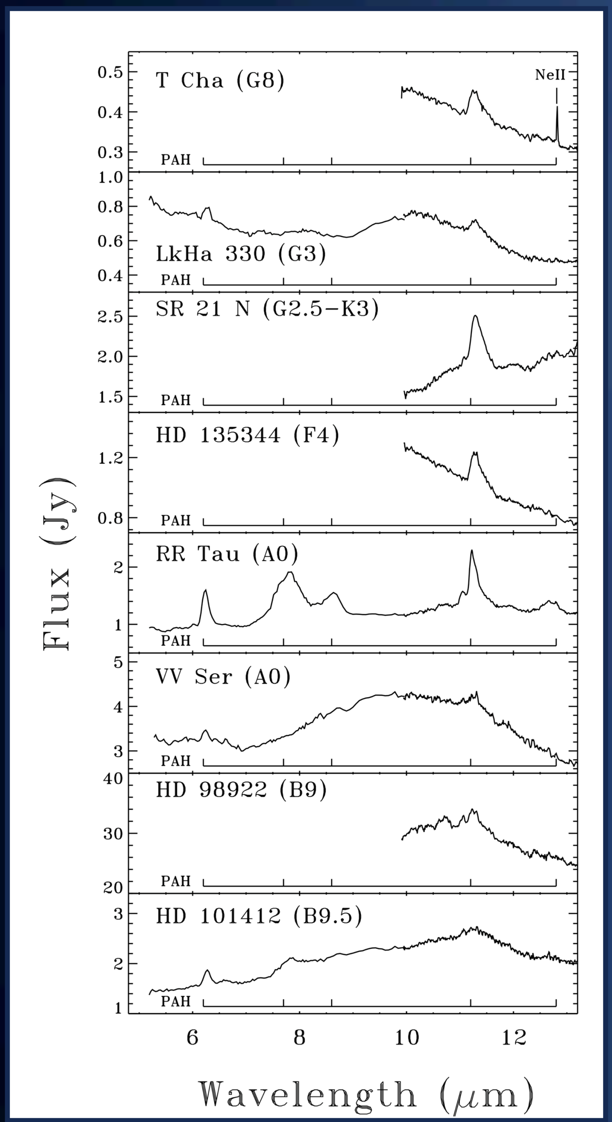


FIGURE 1 Spitzer mid-IR spectra of intermediate and low mass young stars in the c2d sample with clear PAH features.

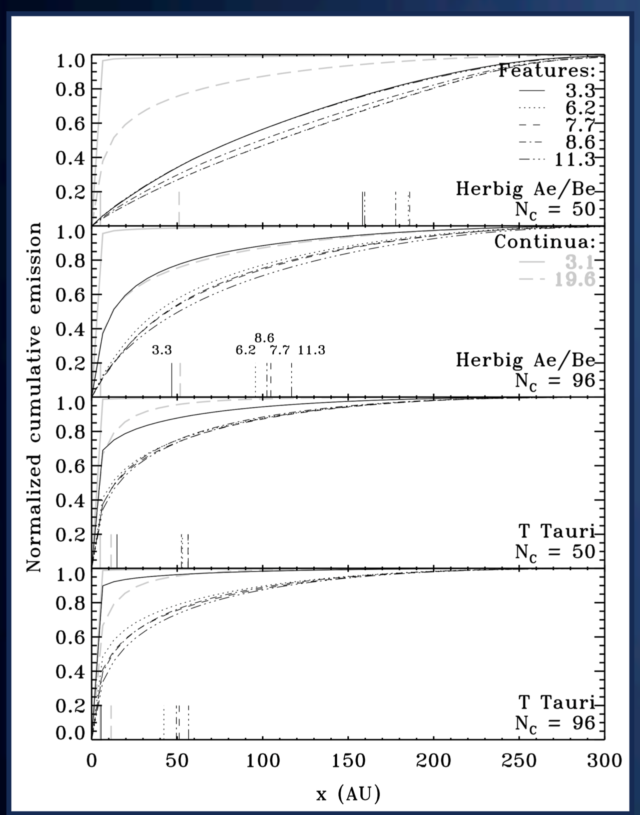


FIGURE 3 (above) Normalized cumulative intensity of 5 main PAH features (black) and continua at 3.1 and 19.6 μm, for two PAH sizes (50 and 96 C atoms), from Visser et al. 2007.

The measured spatial extent of PAH features in disks around TT and HAeBe stars is consistent with larger PAHs.

PAHs in T Tauri disks : statistics and spatial extent

- PAH emission detected towards:
  - 4 out of 37 TT stars (T Cha, LkHα 330, SR21N, EC82) + 1 tentative TT detection (SY Cha) => 11-14% detection rate; significantly lower than 54% for Herbig Ae/Be disks
- 11.2 μm and 6.2 μm features always detected; 7.7 and 8.6 μm often "masked" by silicate / continuum emission
- 11.2 μm line fluxes from TT disks typically an order of magnitude smaller compared to HAeBe disks, consistent with 10-100x lower PAH abundances (Fig. 2, Geers et al. 2006)
- All 4 (low mass) sources in the entire sample with evidence for dust holes in inner disk show clear PAH features.
- Spatial extent of PAH features found to be 12-60 AU (radial), constraining PAH emission to originate from the disk, and not a tenuous remnant envelope (Geers et al. 2007)
- Spatial extent consistent with larger ($N_C \geq 100$) PAHs (Fig 3)

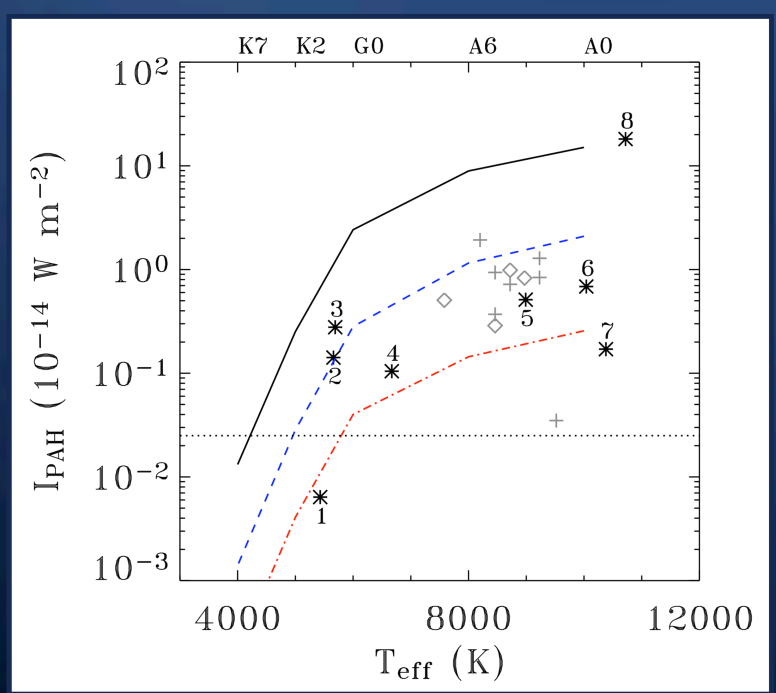
Modeling PAHs in a disk

We use 2D Monte Carlo radiative transfer models of circumstellar disks (Dullemond et al. 2001), which include a PAH emission model, to study the relation between disk structure and PAH feature strength (Geers et al. 2006), model the PAH chemistry and IR emission in disks (Visser et al. 2007), including their spatial extent (Geers et al. 2007).

FIGURE 2 (below) 11.2 μm line strength (normalized to d = 150 pc) vs. T_{eff} and PAH abundance. *: c2d detection +: ISO detection ◊: ISO upper limit (Acke et al. 2004, A&A 426, 151).

Template model:
- Kurucz spectrum with PMS stellar parameters, T_{eff} = 10,000K
- $M_{disk} = 10^{-2}\ M_\odot$, R_{disk} = 300AU
- $C_{100}H_{24}$, 50% neutral, 50% singly ionized
- PAH abundance: 5×10^{-7} w.r.t. H_2 (ISM), and 10, 100x lower (black, blue, red)

PAH detections consistent with 10-100x lower PAH abundance w.r.t. ISM.



Lack of PAHs around embedded YSOs

- Obtained VLT-ISAAC spectra for 39 and Spitzer IRS spectra for 53 embedded YSOs (12 overlapping)
- PAH detected toward 1 out of 63 embedded YSOs (~2%)
  - 3.3 μm PAH feature undetected in majority of sample (97%) (Fig 4, Geers et al. 2008); 1 detection for IRS 48, now confirmed as a disk source (Geers et al. 2007b)
  - Line flux typical upper limits of 5×10^{-16} W m^{-2}
  - Compact 11.2 μm PAH emission seen for 1 out of 53 Spitzer sources: GY 23, borderline embedded source

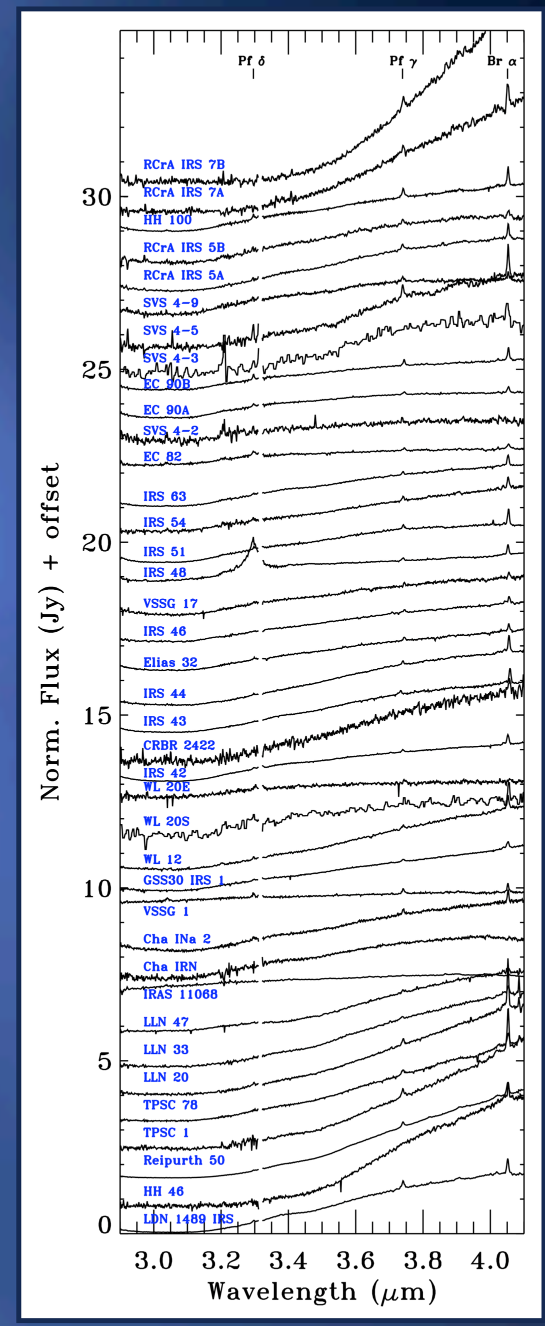


FIGURE 4 (right) VLT-ISAAC L-band spectra of sample of candidate embedded YSOs.

Modeling PAHs in a disk with an envelope

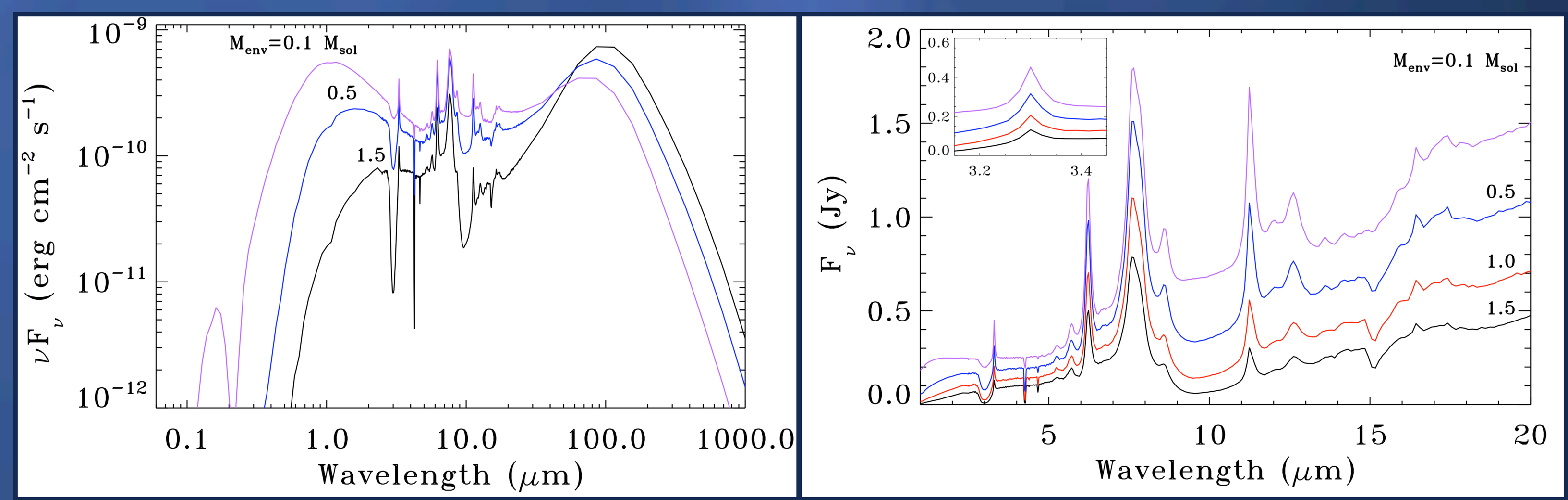
We use the same model as for disks but with an envelope and outflow cone added (Geers et al. 2008) to study the effects of :

- luminosity of central star, UV excess
- inclination
- mass of the envelope (Fig 5)
- PAH abundance
- Location of PAHs (disk, envelope, or both)

FIGURE 5 (below) Model SEDs and blow-up of spectra with M_{env} = 1.5 (black), 1.0 (red), 0.5 (blue) and 0.1 (purple) $M_\odot$ at i = 45°.

Template model:
- Blackbody spectrum with L = 1 $L_\odot$ and T_{eff} = 4,000K
- $M_{disk} = 5\times10^{-2}\ M_\odot$, R_{disk} = 300 AU
- $C_{100}H_{24}$, 50% neutral, 50% singly ionized, template abundance 5×10^{-7} w.r.t. H_2 (ISM value)
- M_{env} = 1.0 $M_\odot$, $R_{env-outer}$ = 10000 AU, R_{rot} = 300 AU

At standard ISM PAH abundances, for typical class I stellar and envelope parameters, PAH features are clearly present in all models, in contrast with observations.



Conclusions

- Spitzer survey T Tauri disks
  - PAH emission from T Tauri disks is rare (11-14%)
  - Explained by PAH abundance 10-100x lower than interstellar abundance (T_{eff} > 4200K)
  - Typical radial spatial extent of 12-60 AU, consistent with larger PAHs ($N_C \geq 100$)
- Embedded sources
  - PAHs detected toward at most 1 out of 63 (candidate) embedded protostars (2%)
  - Low detection not explained by inclination, envelope mass, luminosity of central source
  - Absence of PAHs emission most likely explained by much lower PAH abundance in the gas, e.g., due to freeze-out of PAHs on icy layers on dust grains and/or coagulation. Thus, most PAHs likely enter the protoplanetary disks frozen out on grains.

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