

PAH chemistry and IR emission from circumstellar disks

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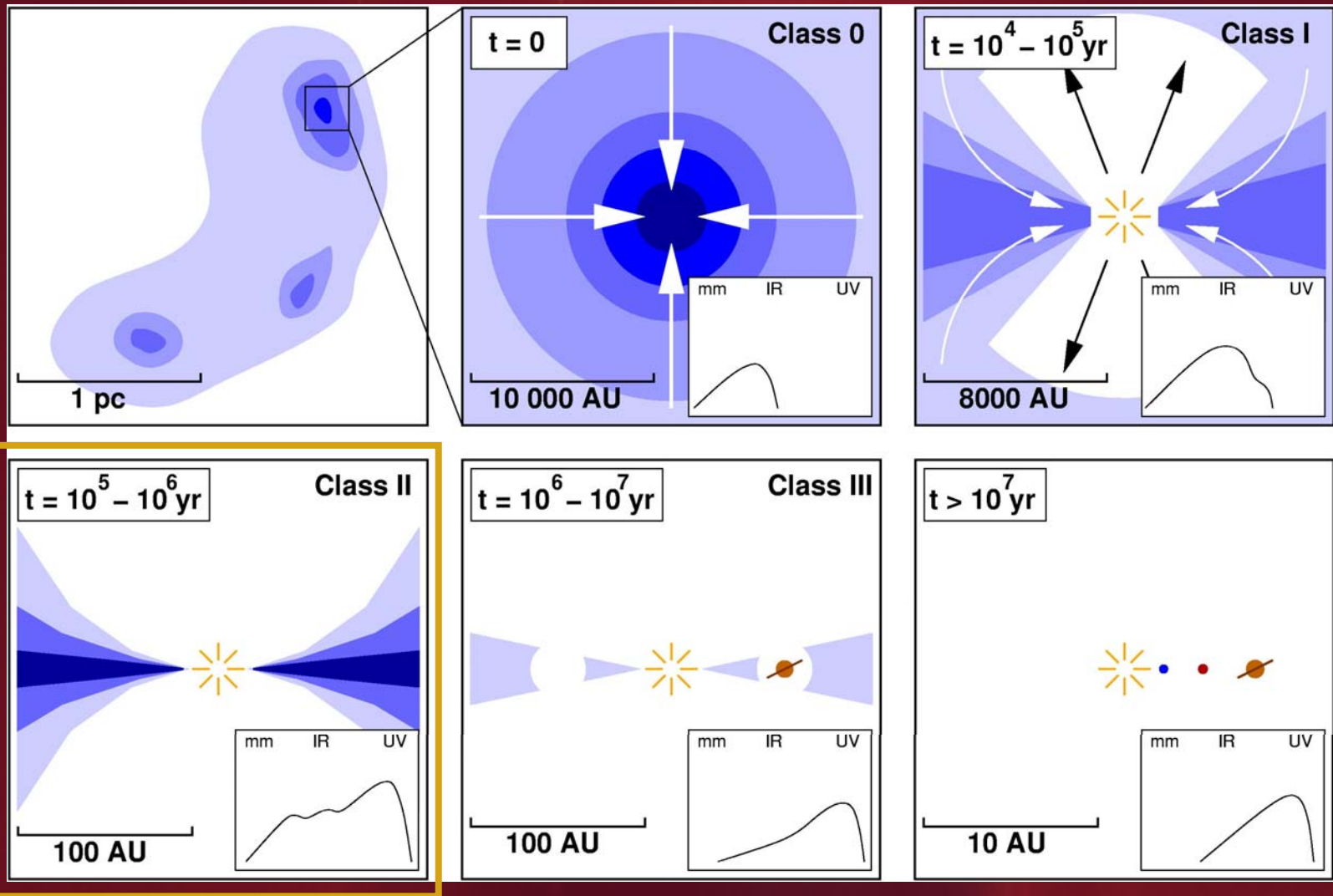


In a nutshell

- Put PAHs in static circumstellar disk
- Compute their chemistry
 - charge, hydrogen coverage, size
- Compute their IR emission
- Analyze effects of chemistry and disk parameters on emission

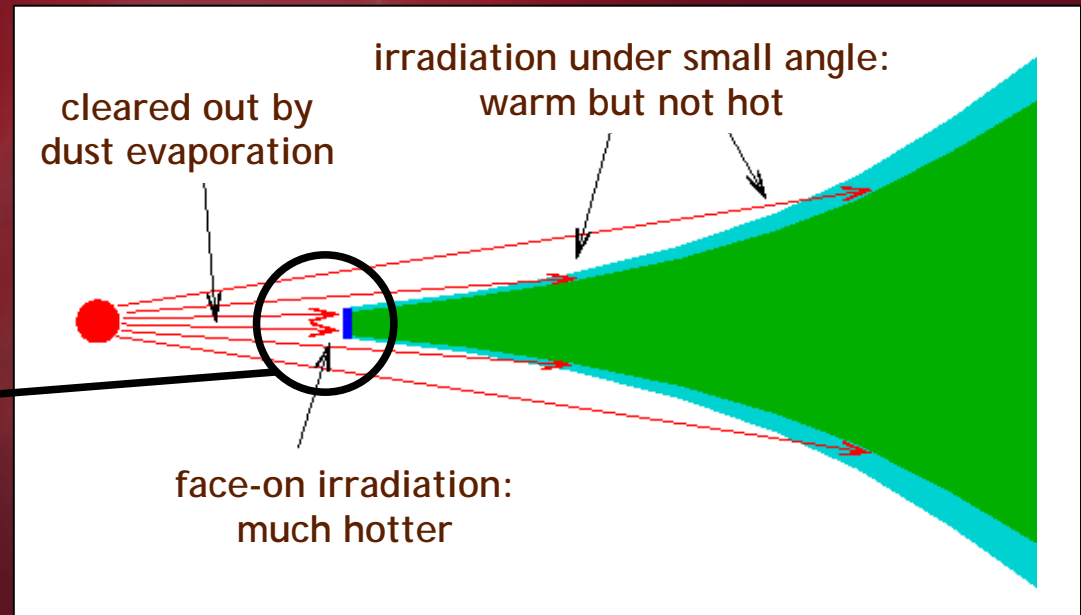
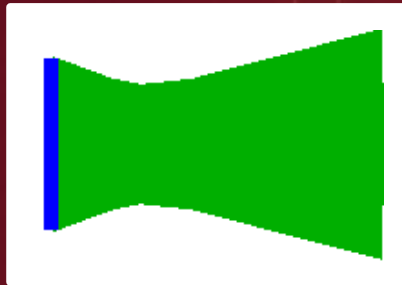
Star and planet formation

(low-mass stars)



Disk structure

- Flaring disk
- Dust evaporation



Puffed-up inner rim

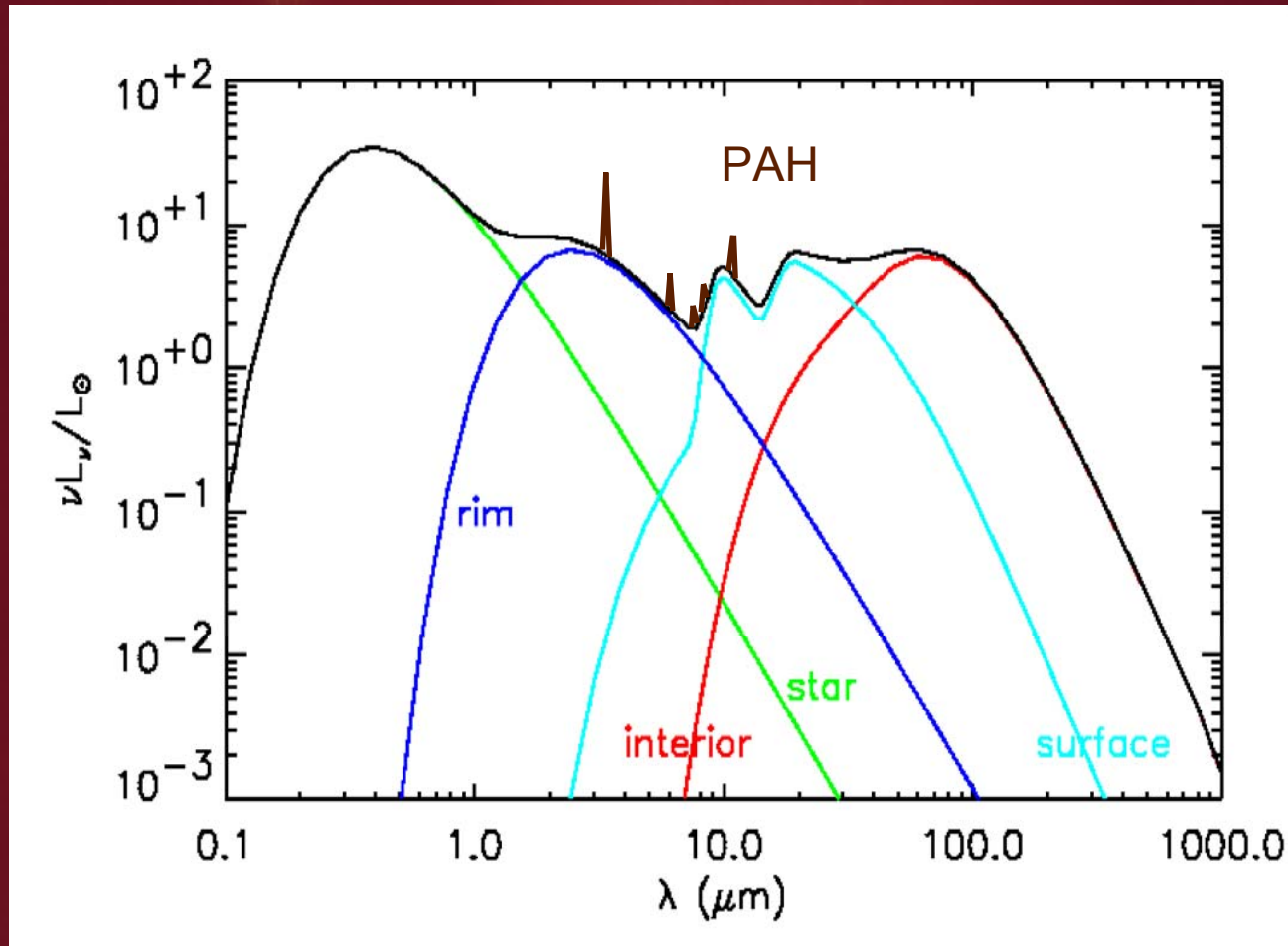
Natta et al. 2001

Dullemond, Dominik & Natta 2001

Spectral energy distribution (SED)

Natta et al. 2001

Dullemond, Dominik & Natta 2001



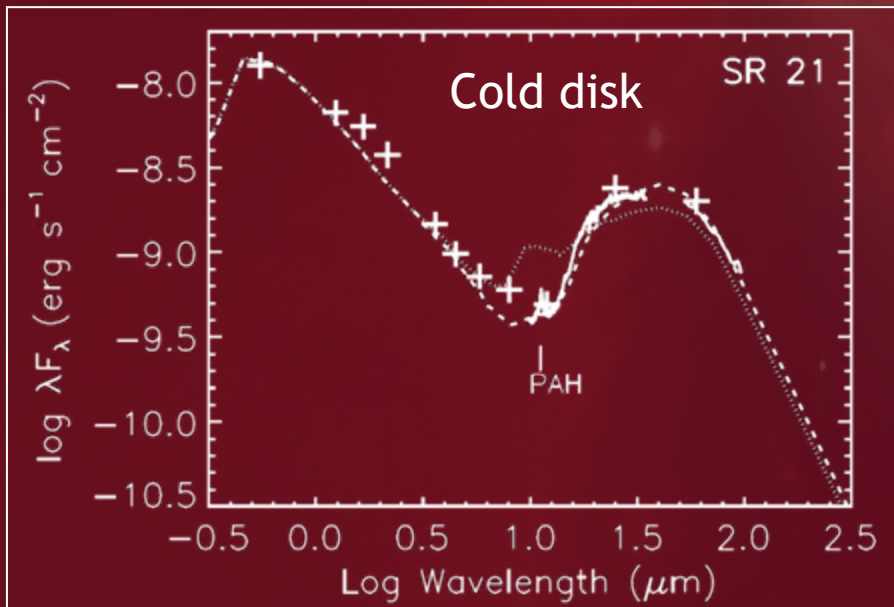
Each wavelength regime traces a different part of star+disk system

PAHs observed in disks

- Spitzer is the first telescope to probe PAHs around solar-mass stars
- Detections:
 - Herbig Ae/Be: 60%
 - T Tauri: 8% (lower limit)
 - Cold disks (inner gap): almost all sources



PAHs in gap!

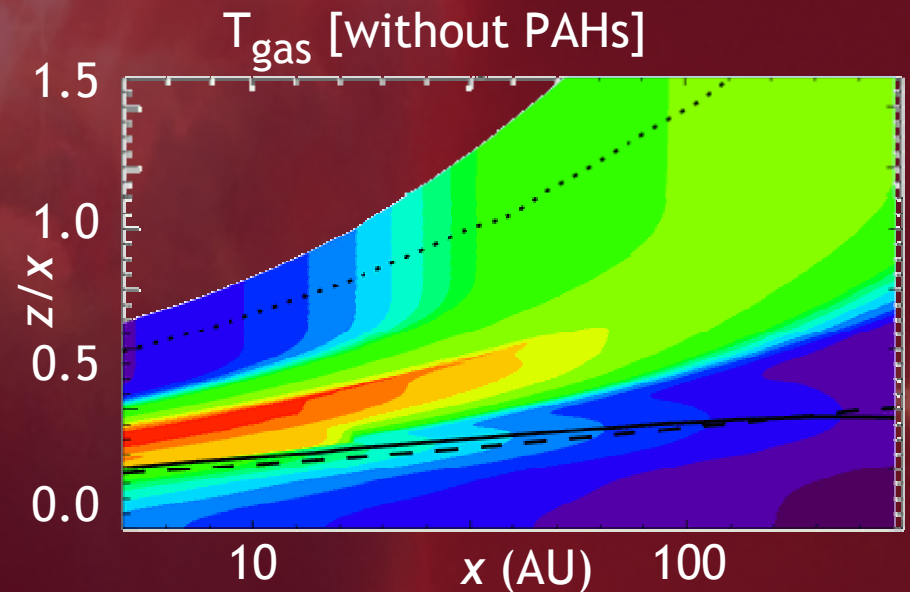
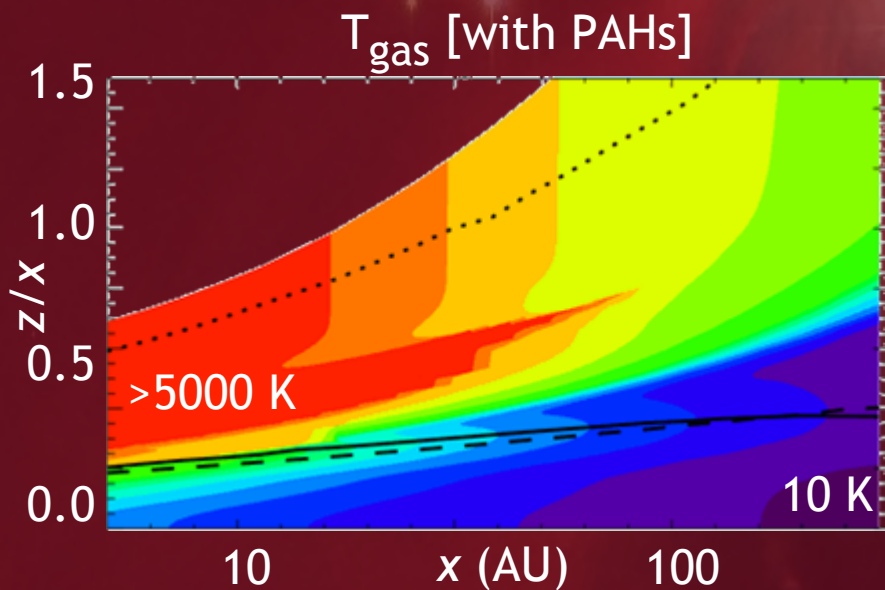


Abundances in disks are
10-100x lower than in ISM

Acke & van den Ancker 2004
Geers et al. 2006
Brown et al. submitted

Why study PAHs in disks?

- Tracers of warm upper layer
- Effects on chemistry
 - e.g. charge exchange, H_2 formation
- Heating via photoionization



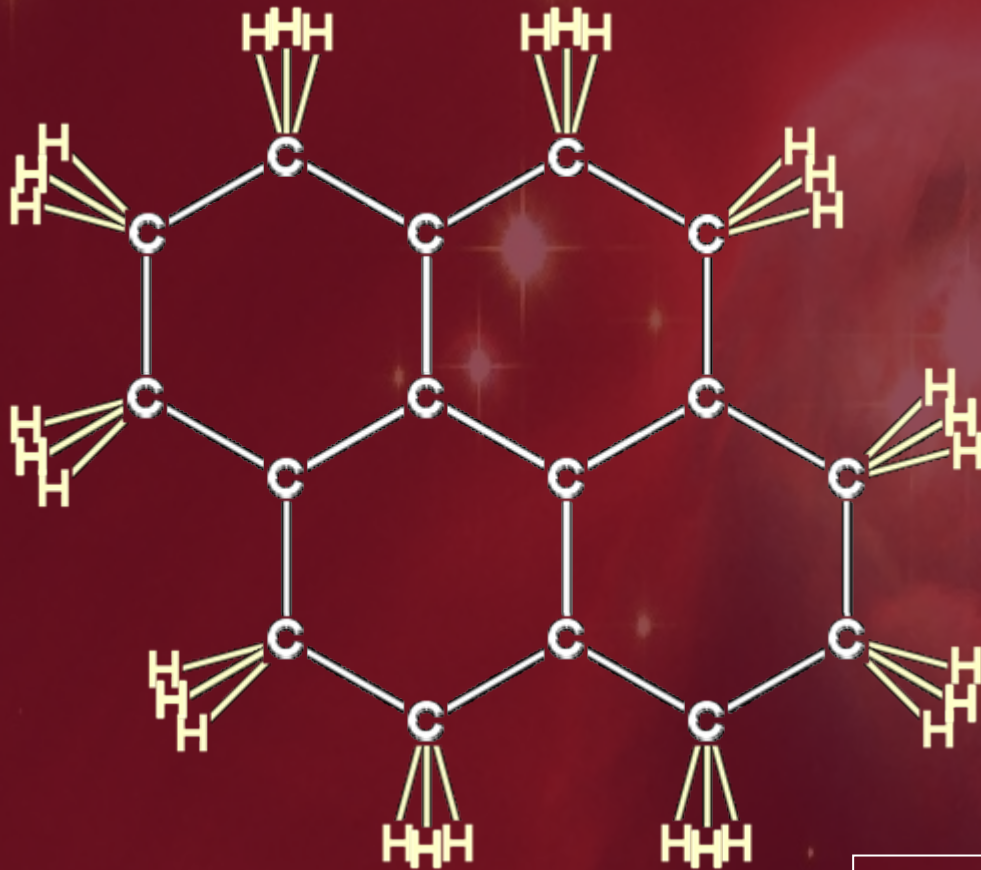
Modelling PAHs in disks

1. Standard static disk model creates density, temperature, radiation field

Dullemond, Dominik & Natta 2001

2. Calculate PAH chemical equilibrium for a given N_C ; multiple sizes possible
3. Calculate PAH excitation (including multi-photon) and IR emission
4. Optional reiteration steps 1–3
5. Create spectrum (SED) or image

PAH: Carbon and hydrogen

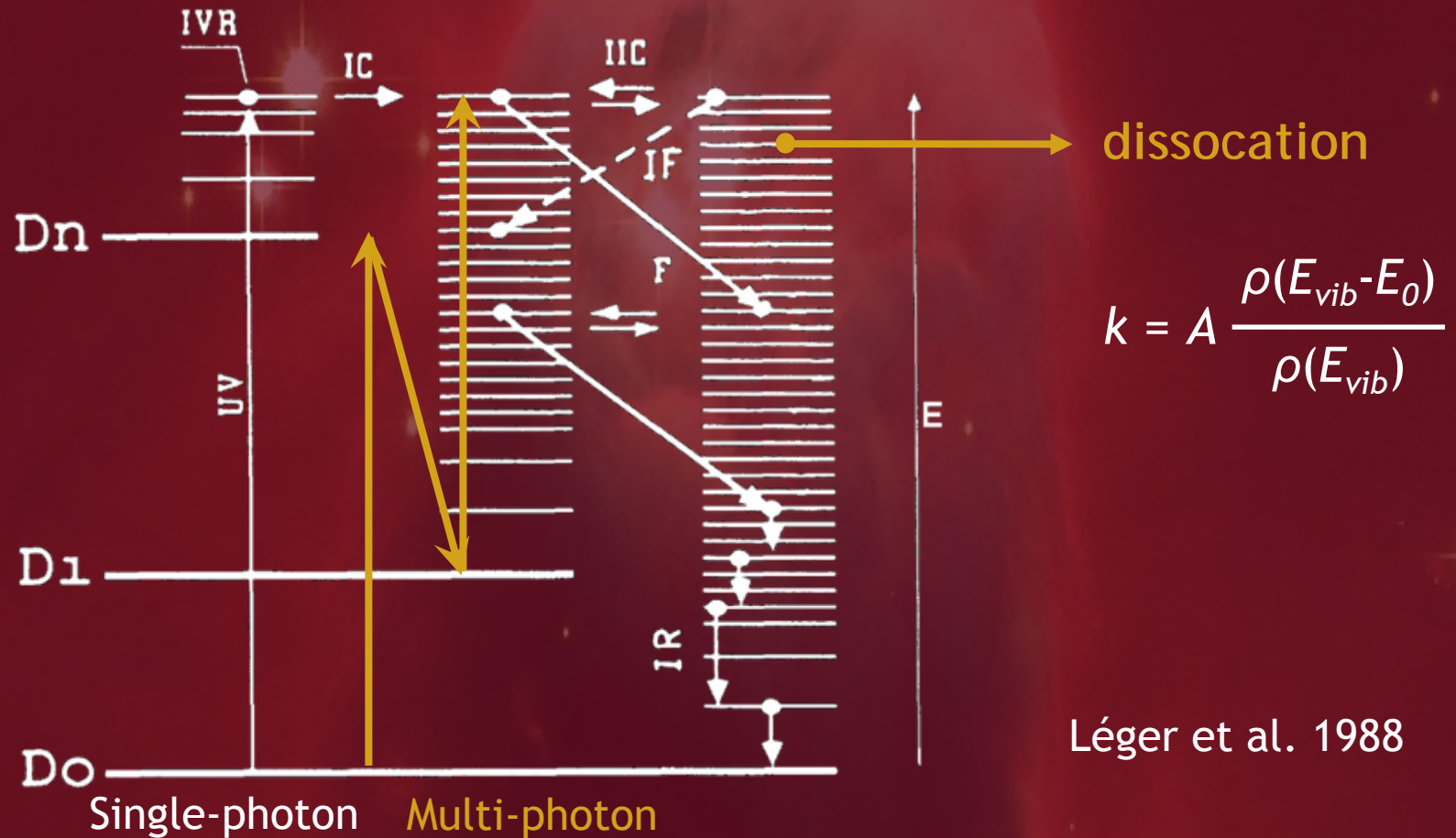


- Carbon skeleton
- Hydrogen at edge
- Extreme: double hydrogen coverage
- Loss of hydrogen
- Extreme: no hydrogen coverage
- Loss of carbon

Hydrogen coverage is primarily governed by density (n_H) and UV intensity

Photodestruction (1)

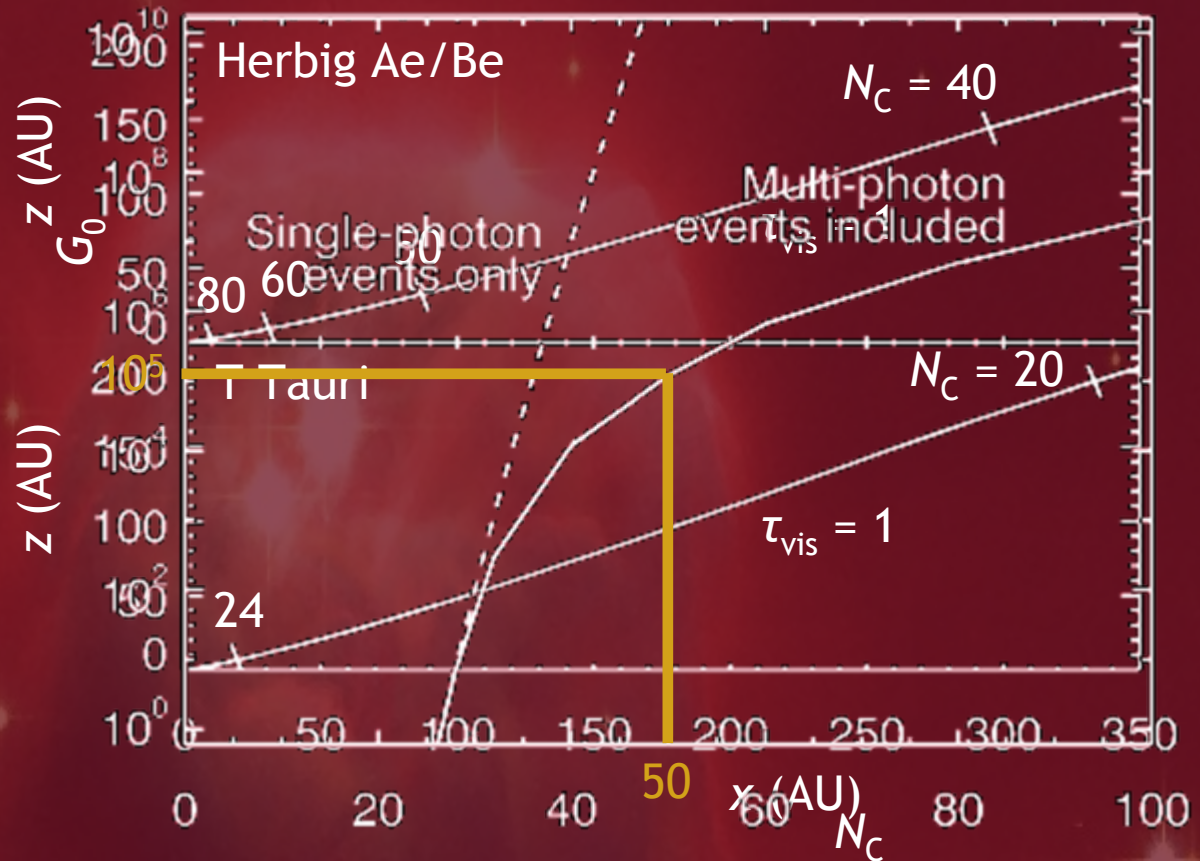
- UV absorption → hydrogen loss followed by carbon loss



Léger et al. 1988

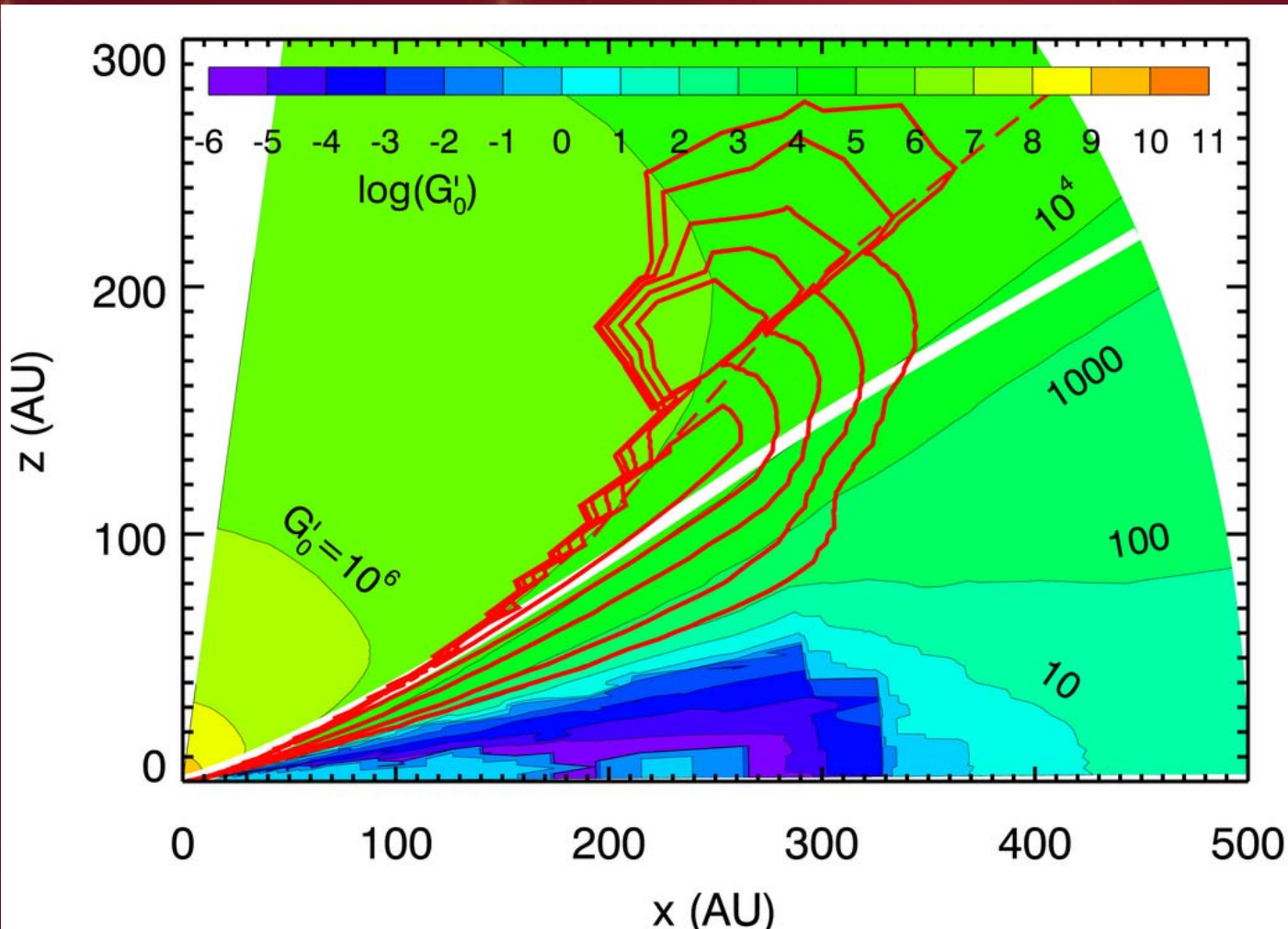
Photodestruction (2)

- G_0 : UV intensity
- Assume disk lifetime: 3 Myr
- Multi-photon events are important for $N_C > 30$
- $N_C = 50$ destroyed in 3 Myr at $G_0 = 10^5$,
 $N_C = 100$ destroyed in 3 Myr at $G_0 = 2 \cdot 10^7$



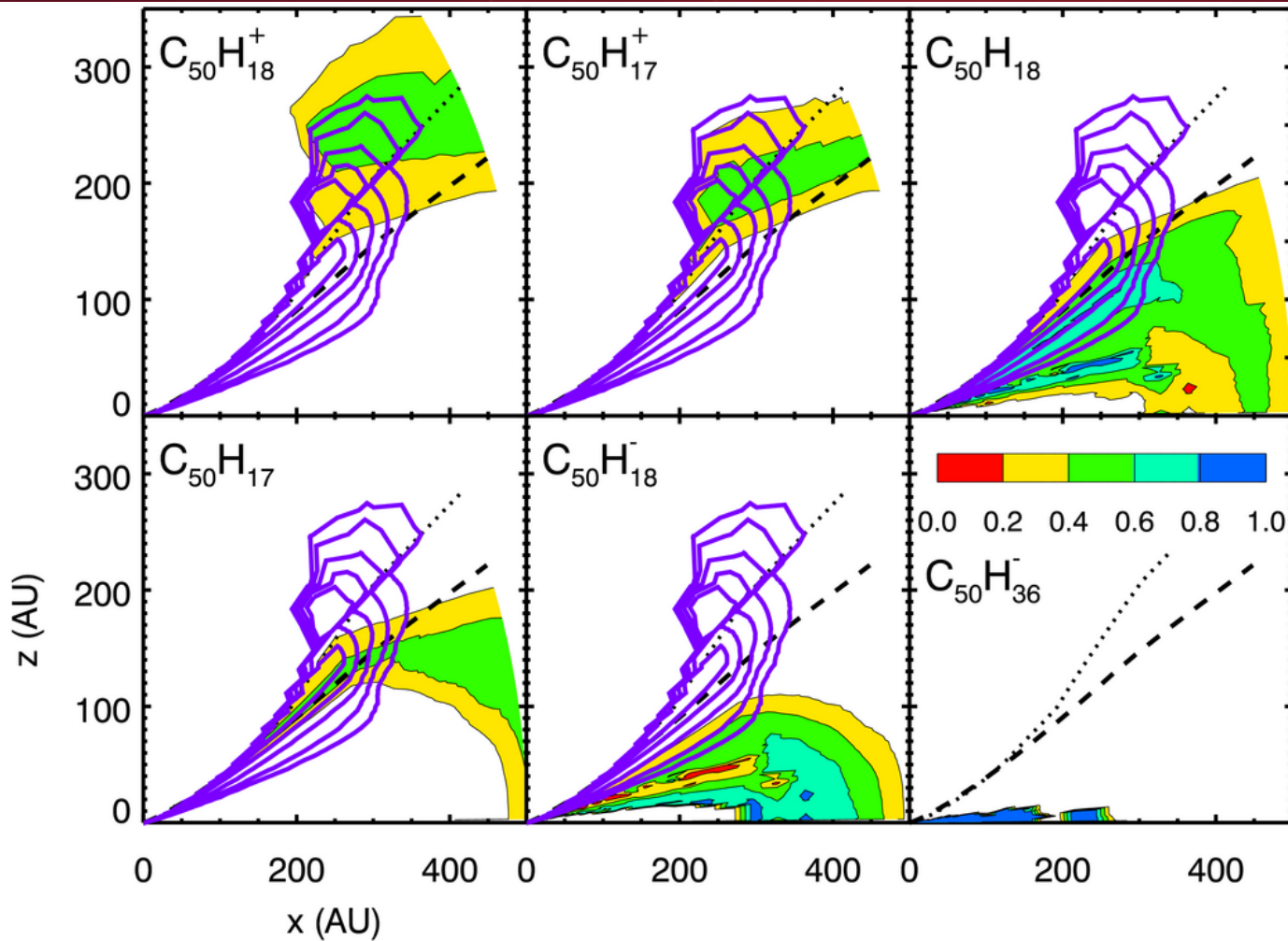
- Destruction occurs mostly in or above surface layers
- Smaller PAHs can survive in T Tauri disk

Radiation field and PAH emission



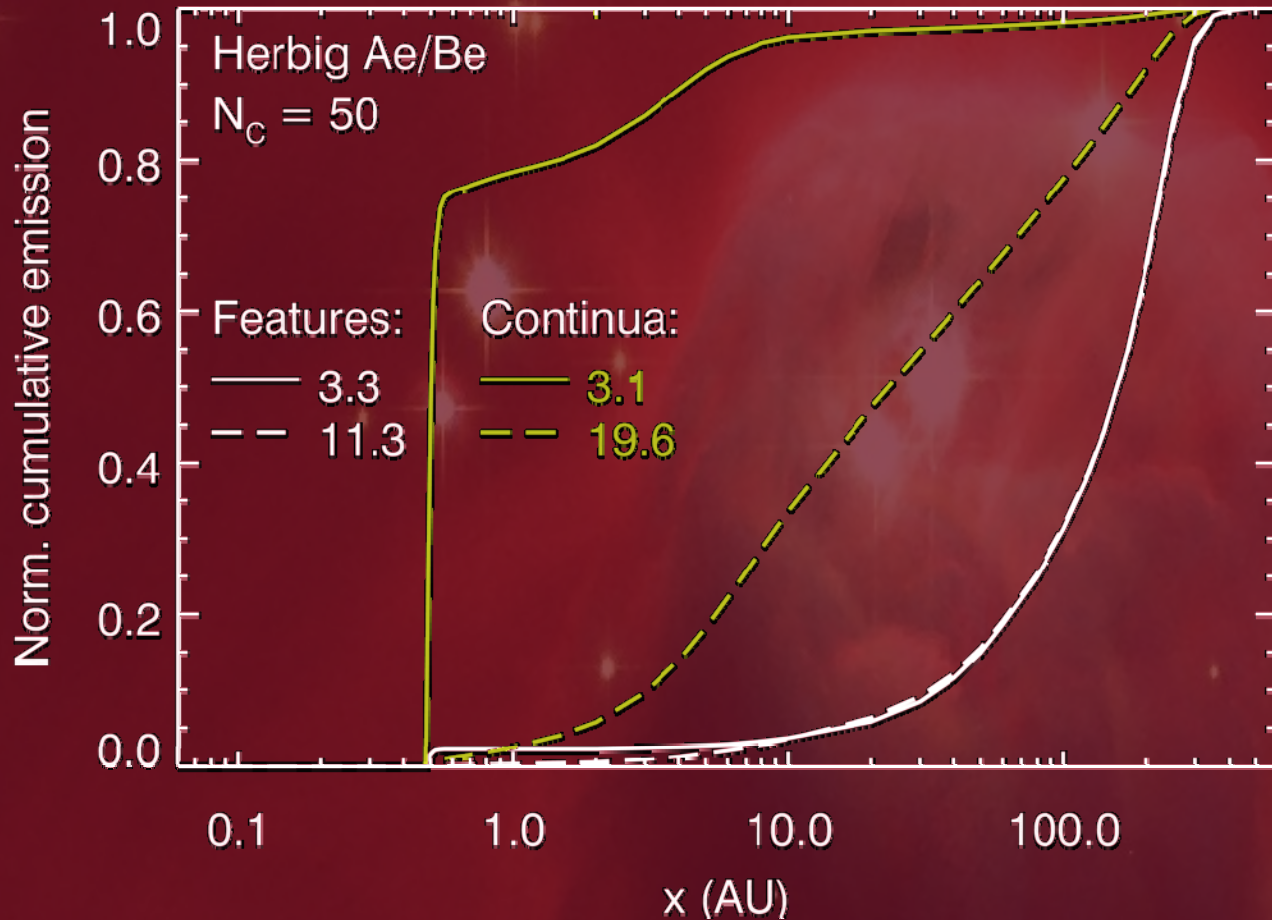
- $N_C = 50$ in Herbig disk, $R_{\text{disk}} = 300$ AU
- Destruction for $G_0 \gtrsim 10^5$
- Emission mostly from surface layers

Distribution in disk



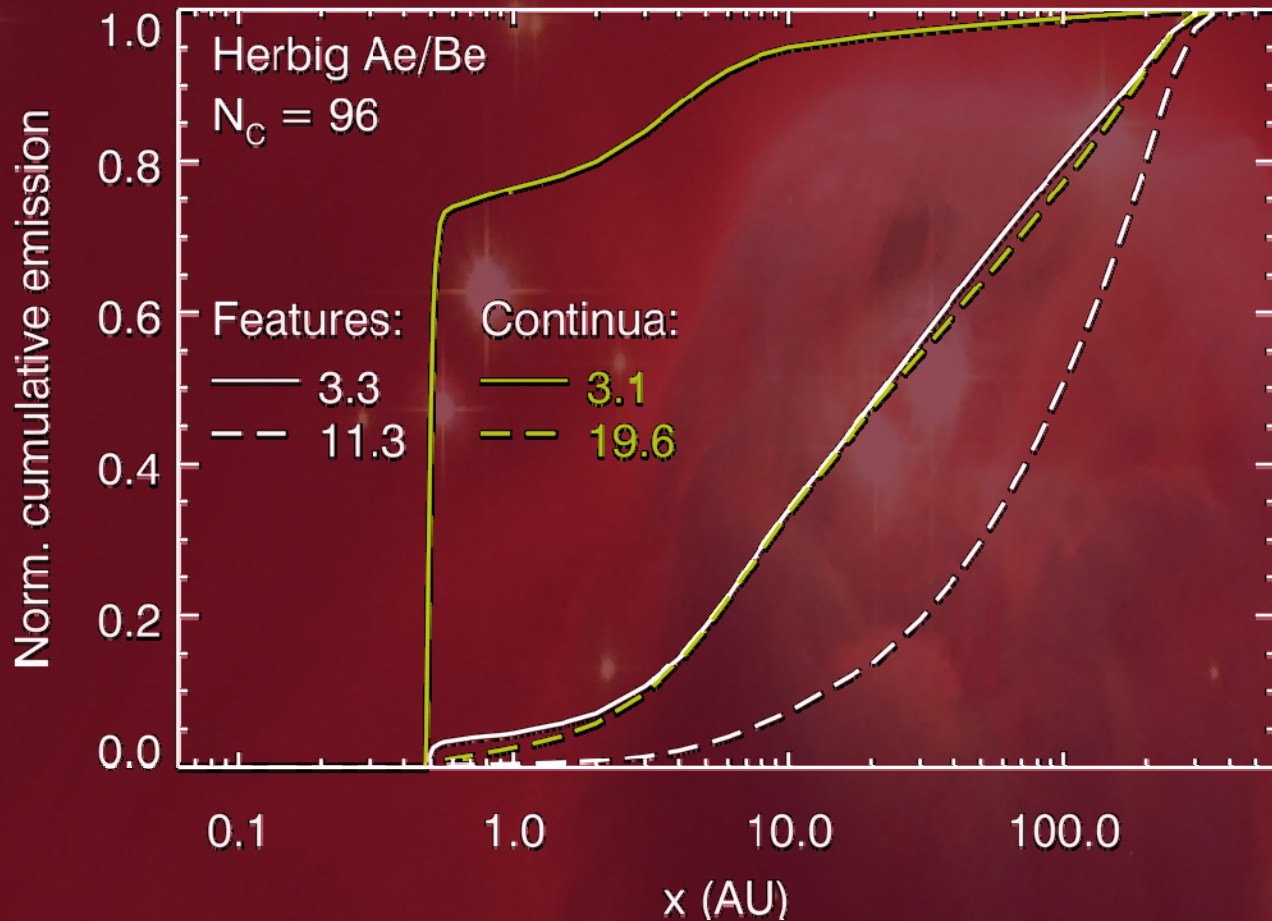
- $N_C = 50$ in Herbig disk
- Disk surface: positive ions
- Main disk: neutral
- Midplane: negative ions
- Preference for $N_H = 17, 18$ or 36

Spatial extent of features (1)



- $N_C = 50$ in HAeBe disk
- PAHs destroyed out to 100 AU (surface layers): features very extended with respect to continuum

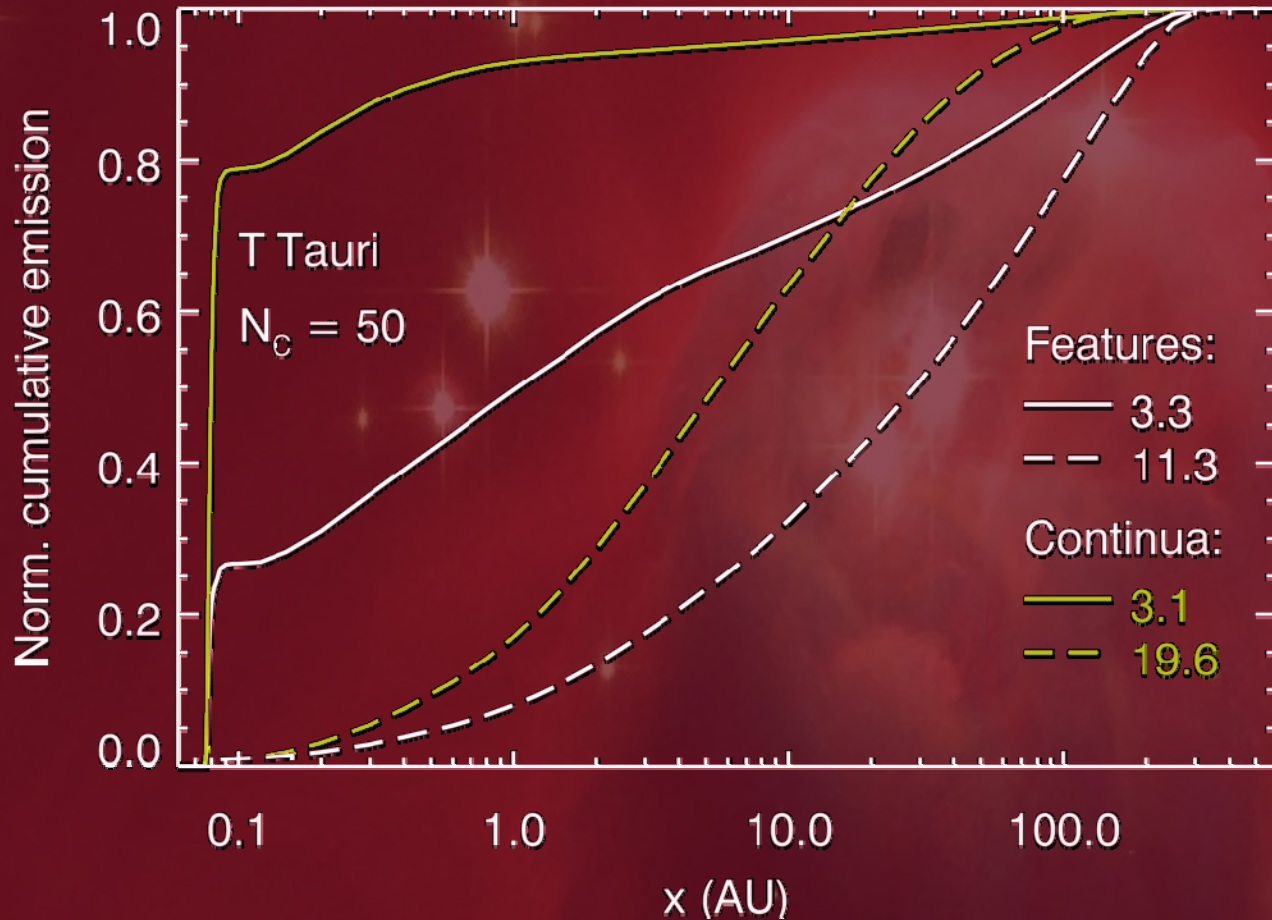
Spatial extent of features (2)



- $N_C = 96$ in HAeBe disk
- PAHs destroyed out to 5 AU (surface layers): features less extended than for $N_C = 50$
- Features more extended than adjacent continuum

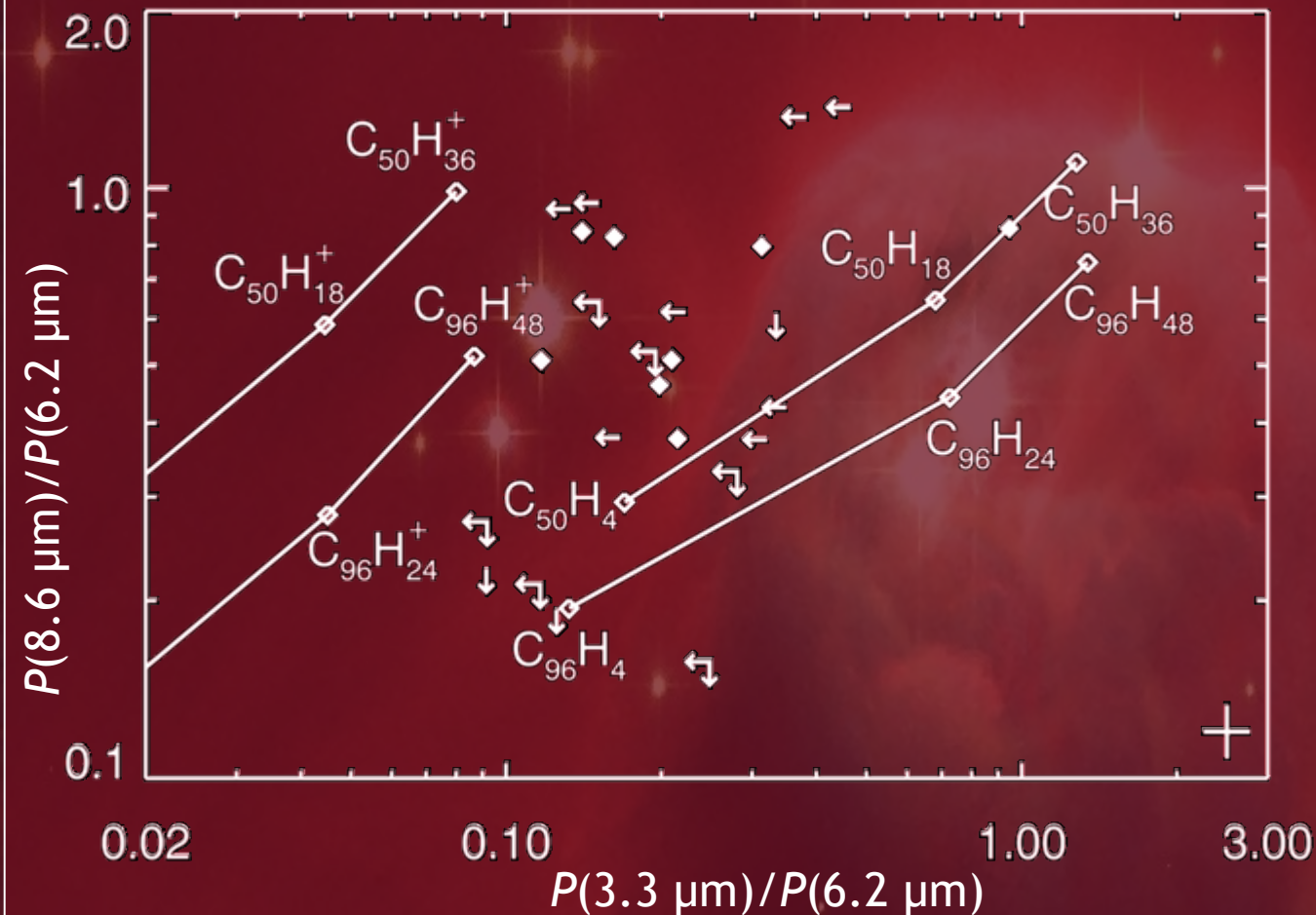
Observed spatial profiles show PAH emission on a scale of tens of AU: better match with $N_C = 96$ than with $N_C = 50$

Spatial extent of features (3)



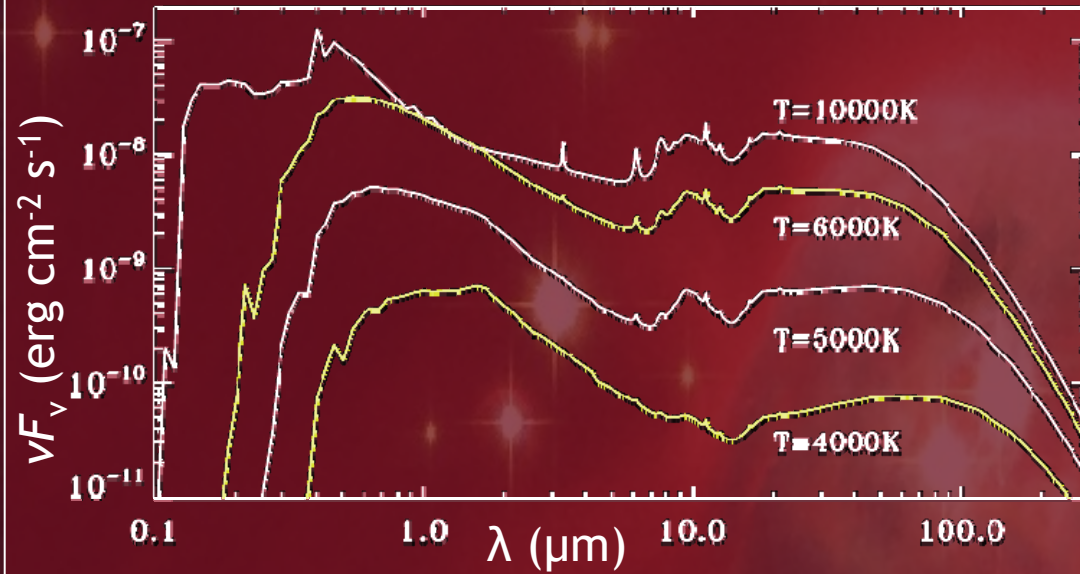
- $N_c = 50$ in T Tau disk
- PAHs survive almost everywhere: features less extended than for HAeBe
- Features more extended than adjacent continuum

Peak flux ratios in HAeBe disks

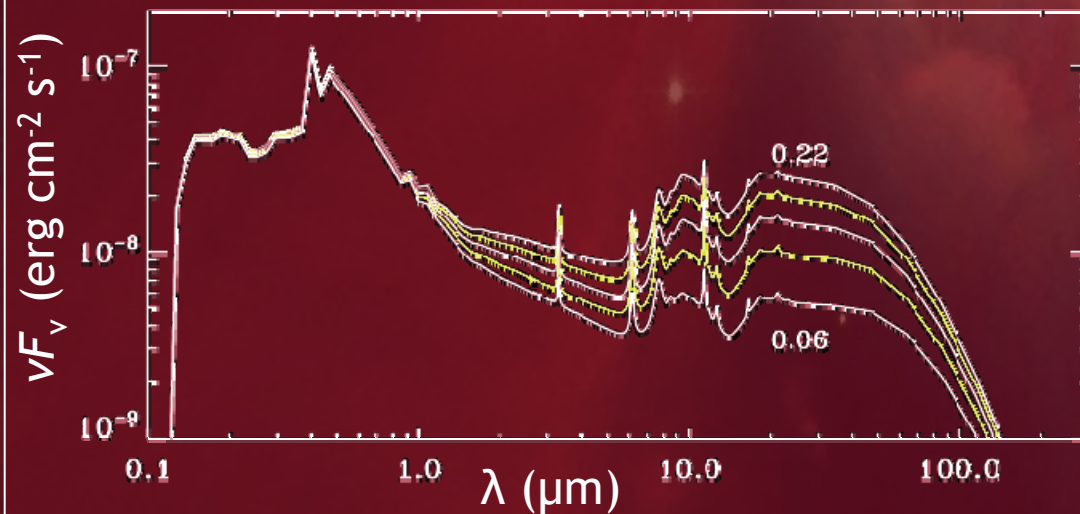


Observations consistent with mix of neutral and ionized, as well as normal to double hydrogenation

Stellar temperature & Disk flaring

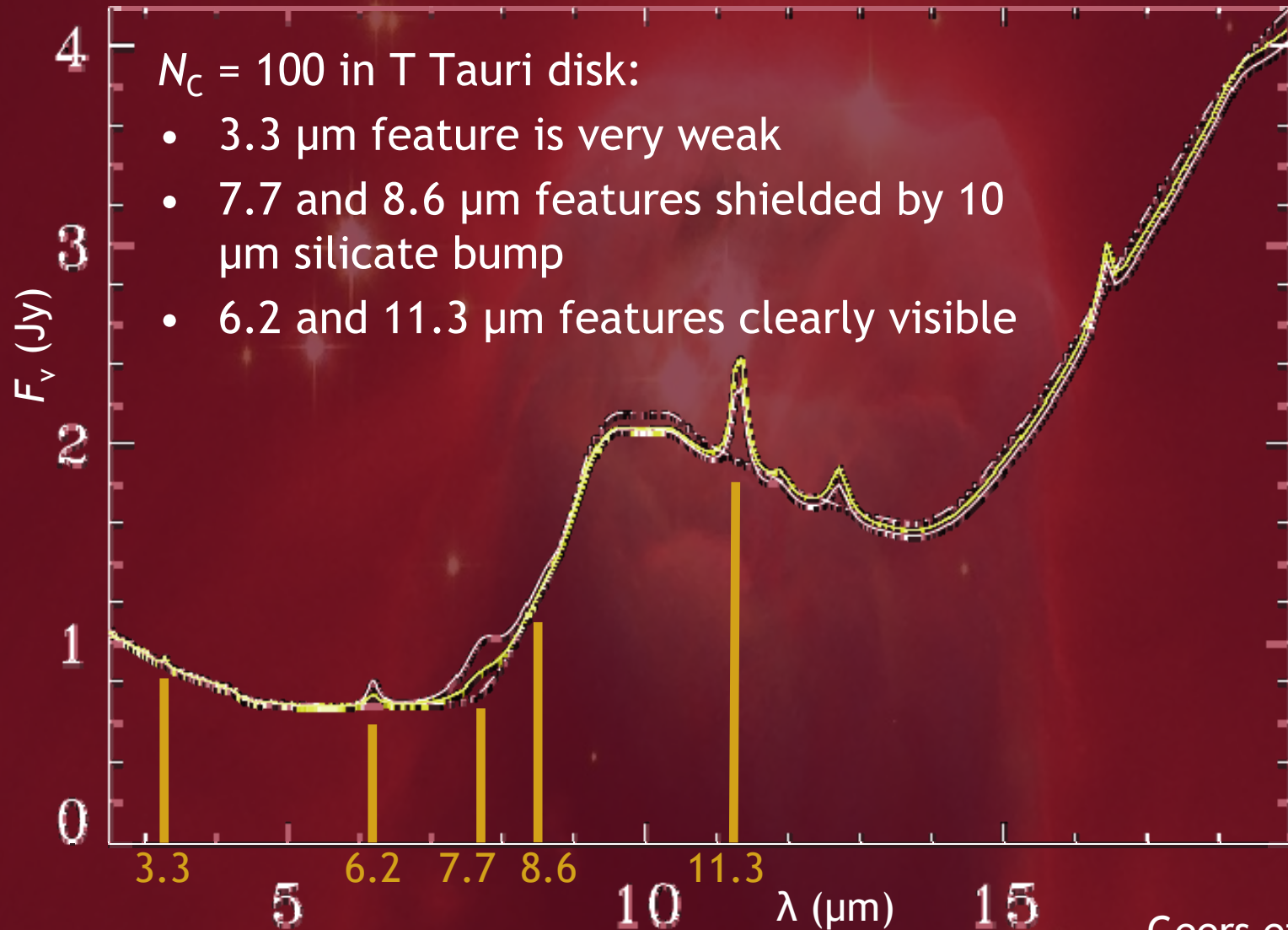


- Total flux increases with T_* , as do features



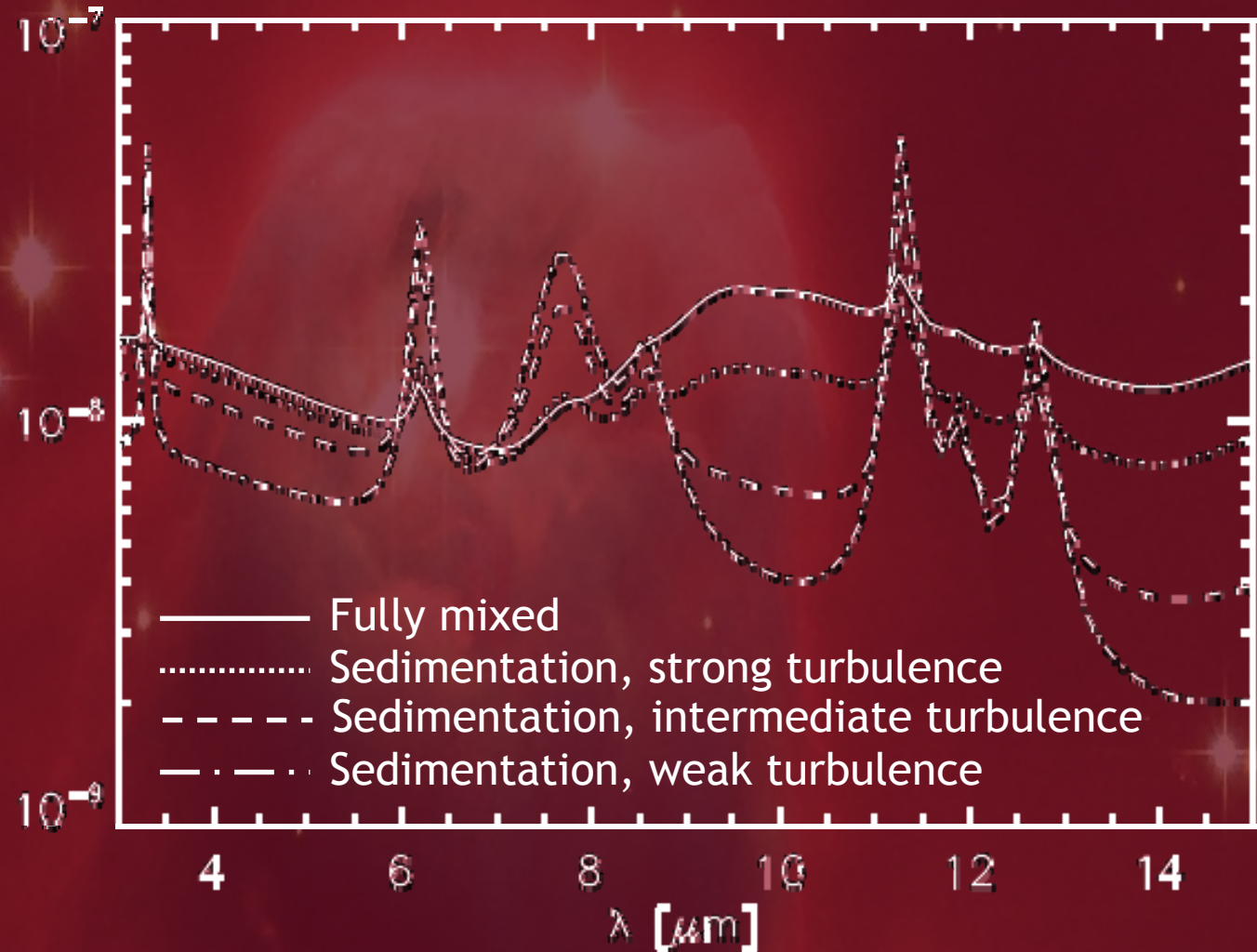
- Mid-IR flux increases with flaring angle; features almost constant

Feature masking in T Tau spectra



Sedimentation and turbulence

- Sedimentation (vertical settling) of PAHs is slower than that of larger grains
- Sedimentation enhances PAH features (as long as turbulence is not too high)



Conclusions and outlook

- PAH emission from circumstellar disks:
 - not from very small PAHs ($N_C < 50$)
 - from surface layers, spatially extended
cf. van Boekel et al. (2004), Geers et al. (2005), Habart et al. (2006)
 - multiple charge and hydrogenation states
 - abundances 10-100x lower than in ISM
 - sedimentation can enhance PAH features
- Future work:
 - Spatially resolved observations
Geers et al. in prep.
 - Study PAH evolution/“trail” from ISM to planet-forming zones
 - Apply model to AGNs

Thank you!

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