

PAH chemistry and IR emission from circumstellar disks

Ruud Visser, Leiden Observatory

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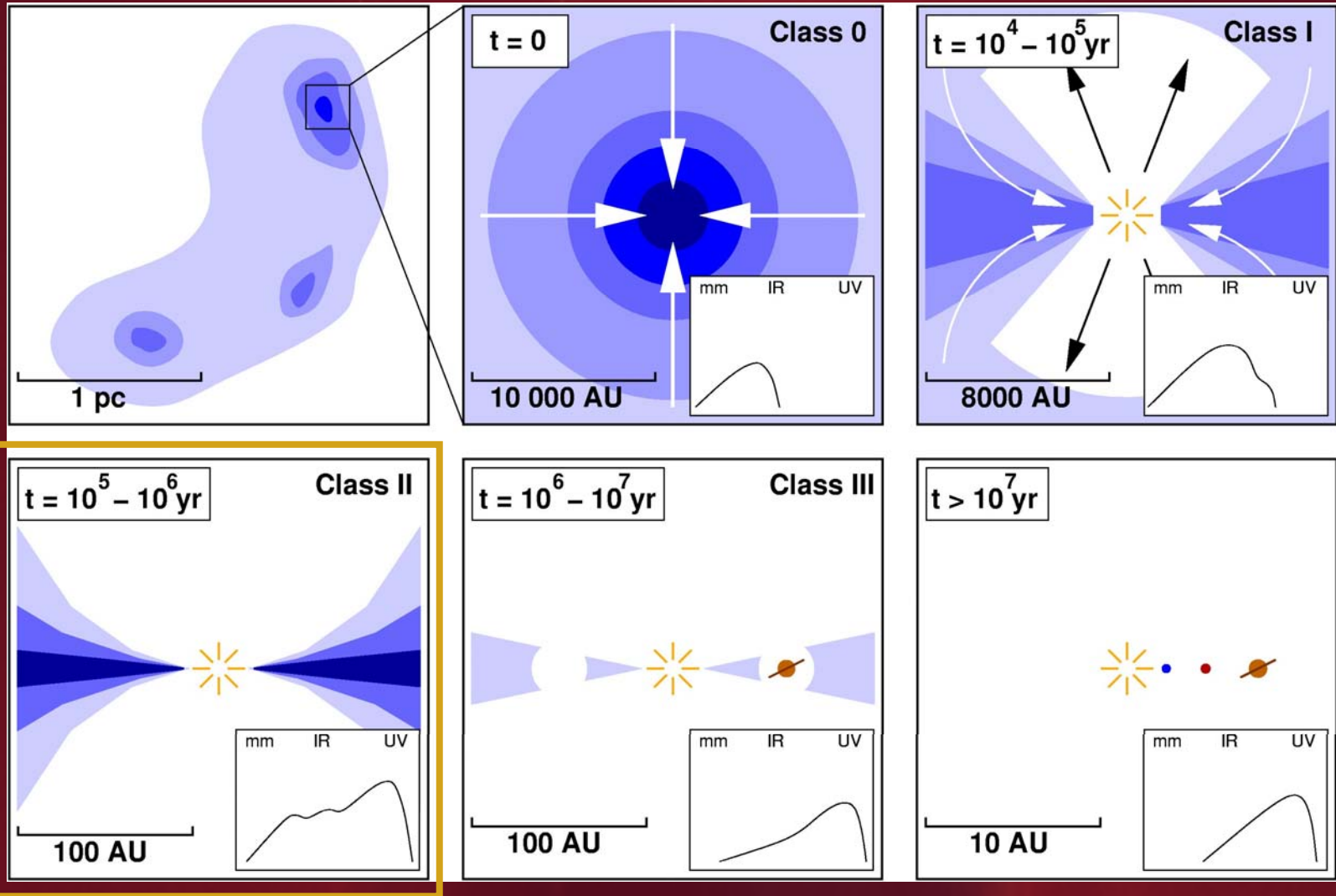


Vincent Geers, Kees Dullemond,
Jean-Charles Augereau,
Klaus Pontoppidan, Ewine van Dishoeck

To appear soon in A&A and on astro-ph

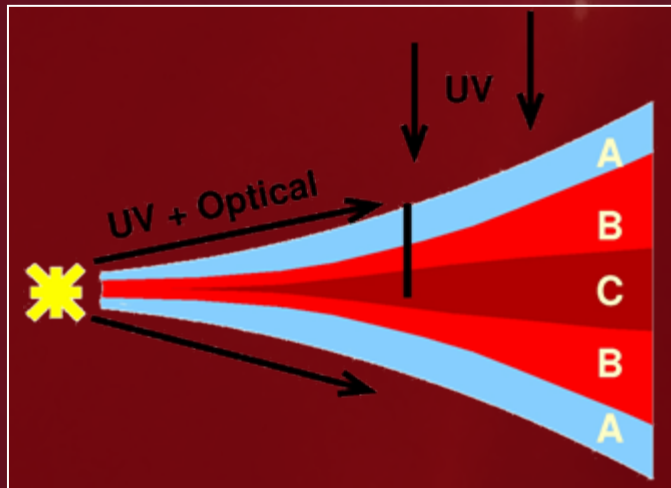
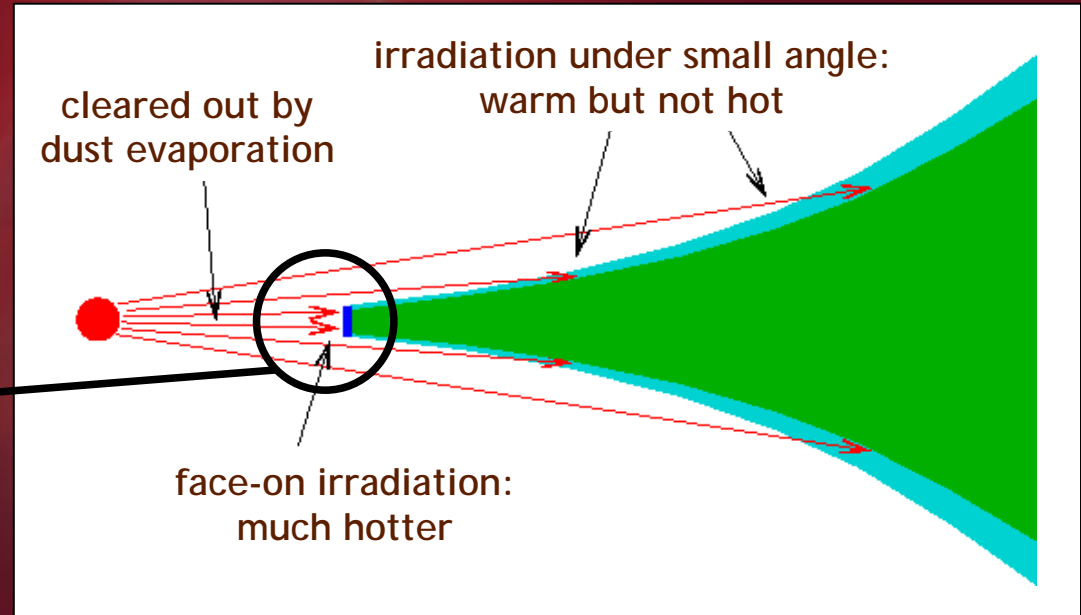
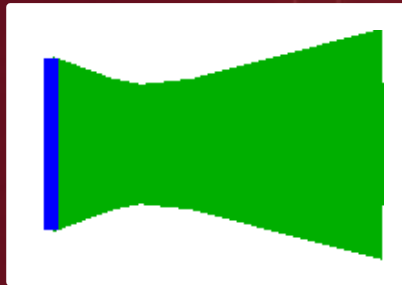


Star and planet formation



Disk structure

- Flaring disk
- Dust evaporation



Puffed-up inner rim

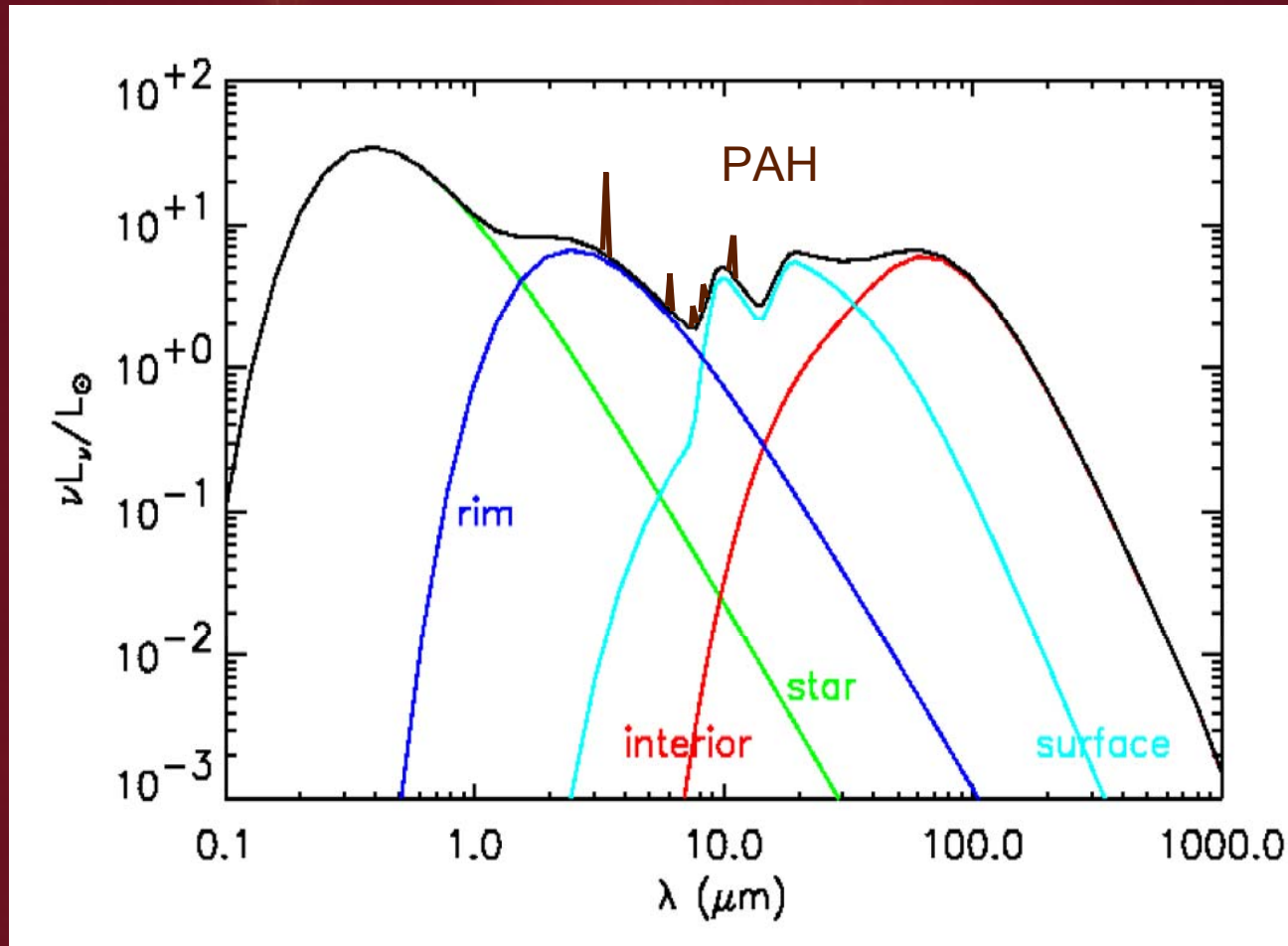
Natta et al. 2001

Dullemond, Dominik & Natta 2001

Spectral energy distribution (SED)

Natta et al. 2001

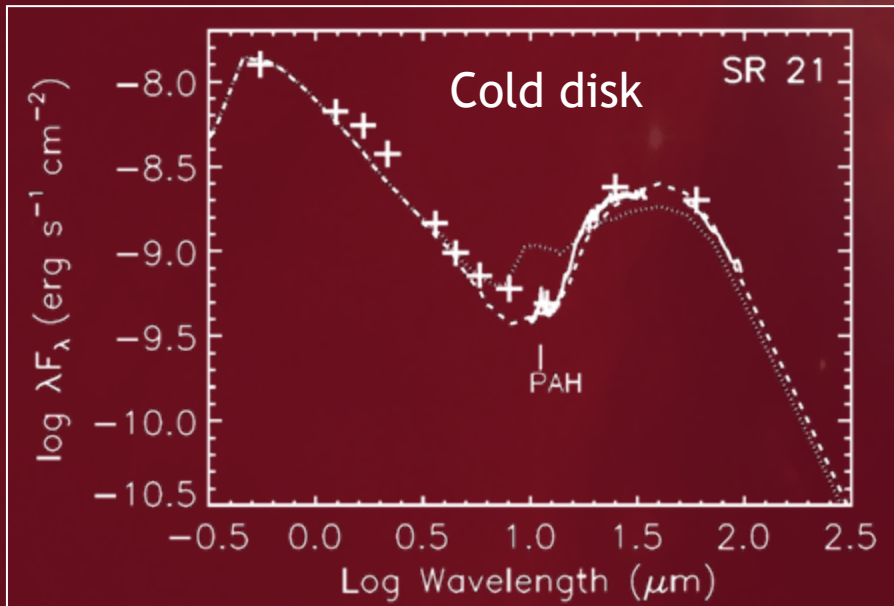
Dullemond, Dominik & Natta 2001



Each wavelength regime traces different part of star+disk system

PAHs observed in disks

- Herbig Ae/Be disks: 60%
- T Tauri disks: 8% (lower limit)
- Cold disks (inner gap): 100% (4 out of 4)

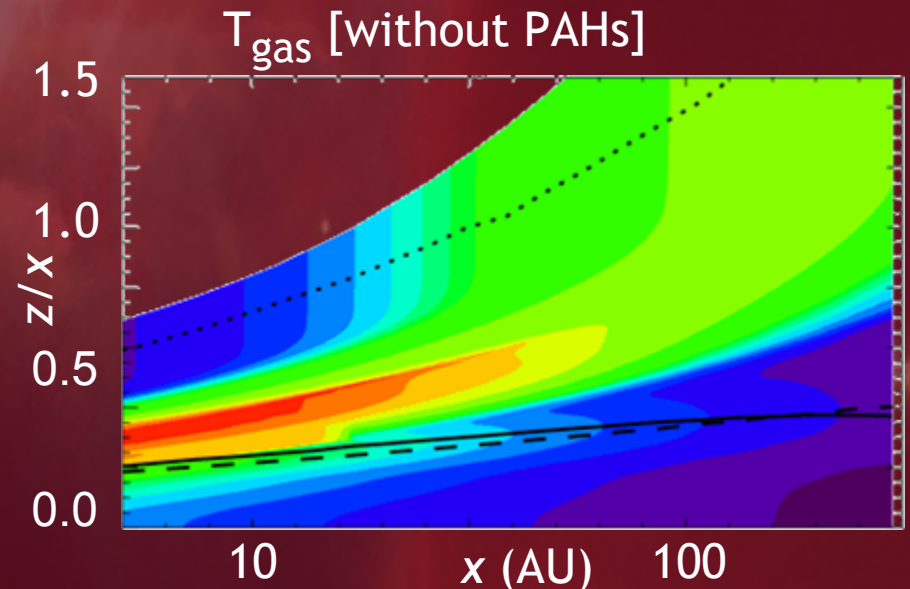
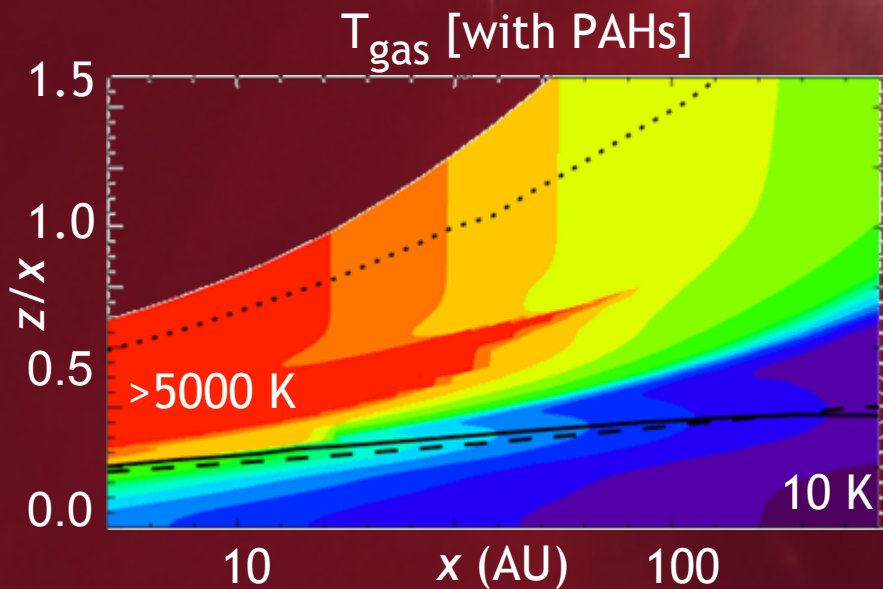


Abundances in disks factor
10-100 lower than in ISM

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)
- 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

Chemistry and IR emission

- Reactions:

- $\text{PAH} + \text{UV} \rightarrow \text{PAH}^+ + \text{electron}$
- $\text{PAH} + \text{electron} \rightarrow \text{PAH}^- + \text{IR}$
- $\text{PAH} + \text{UV} \rightarrow \text{PAH}_{-1} + \text{H}$
- $\text{PAH} + \text{H} \rightarrow \text{PAH}_{+1} + \text{IR}$
- $\text{PAH} + \text{UV} \rightarrow \text{PAH}_{-C_n} + \text{C}_n$ [carbon loss a.k.a. destruction]

Le Page et al. 2001, 2003
Weingartner & Draine 2001
Draine & Li 2001

- PAH formation and growth?

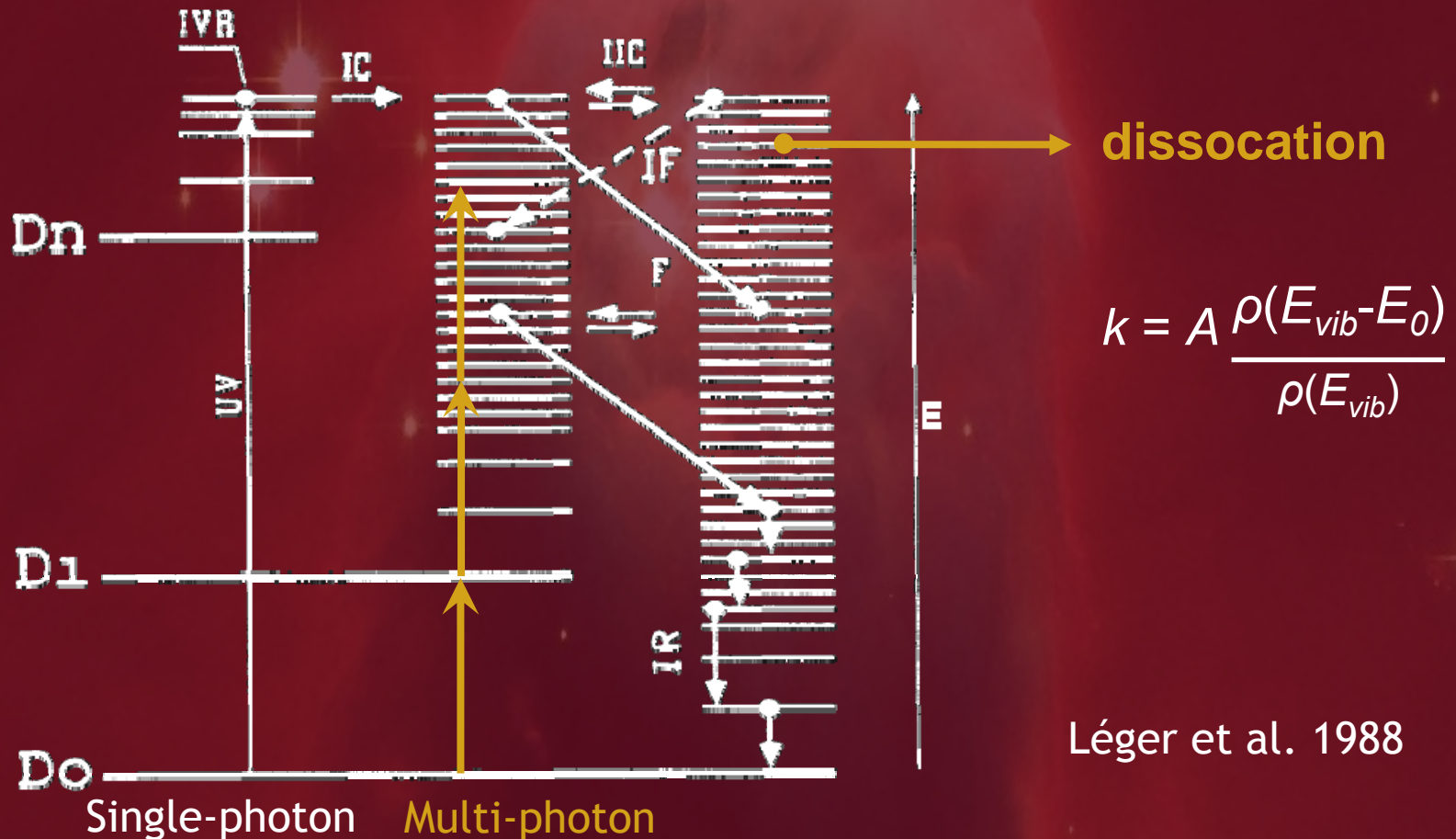
- PAHs enter disk from parent cloud
- *In situ* formation is assumed unimportant
- Possibilities for *in situ* formation:

- Hot, dense inner region
- Accretion shocks

Cherchneff et al. 1992
Frenklach & Feigelson 1989
Desch & Connolly 2002
Woods & Willacy 2006

Photodestruction (1)

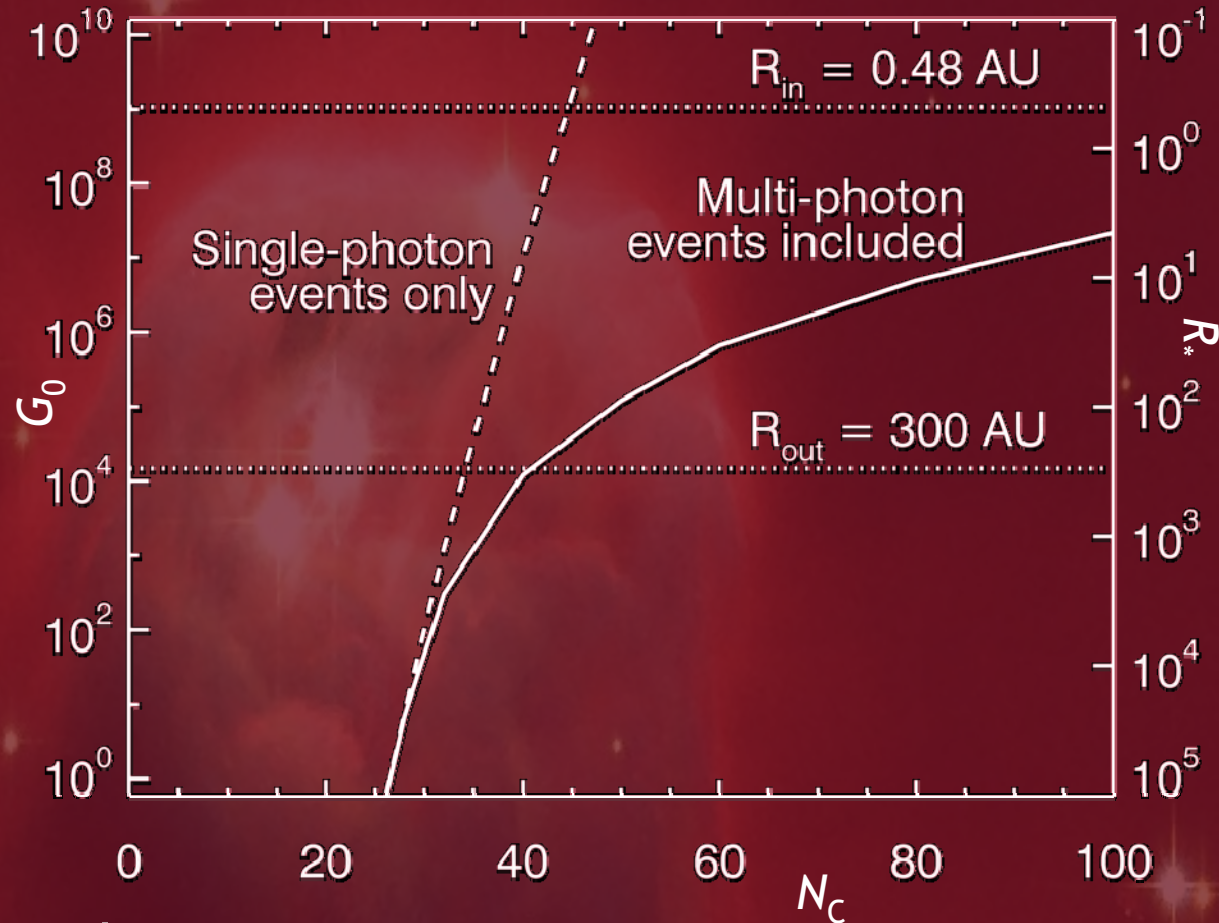
- UV absorption → hydrogen loss followed by carbon loss



Photodestruction (2)

- 10,000 K star
- Disk lifetime: 3×10^6 yr
- R_* (right axis): radius along $\tau_{\text{vis}}=1$ surface for which PAH is destroyed in disk lifetime

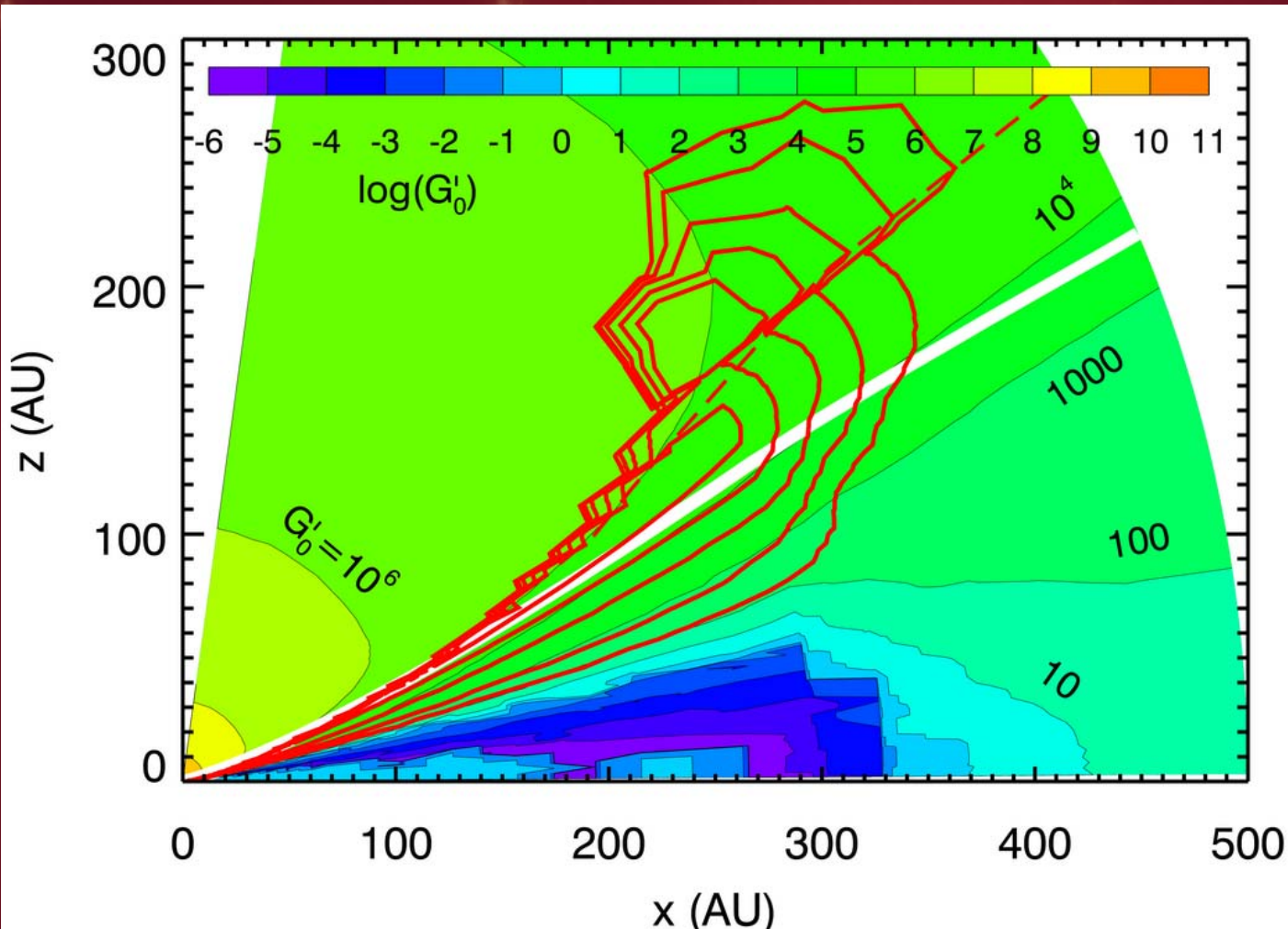
Multi-photon events are important



Destruction in surface layers:

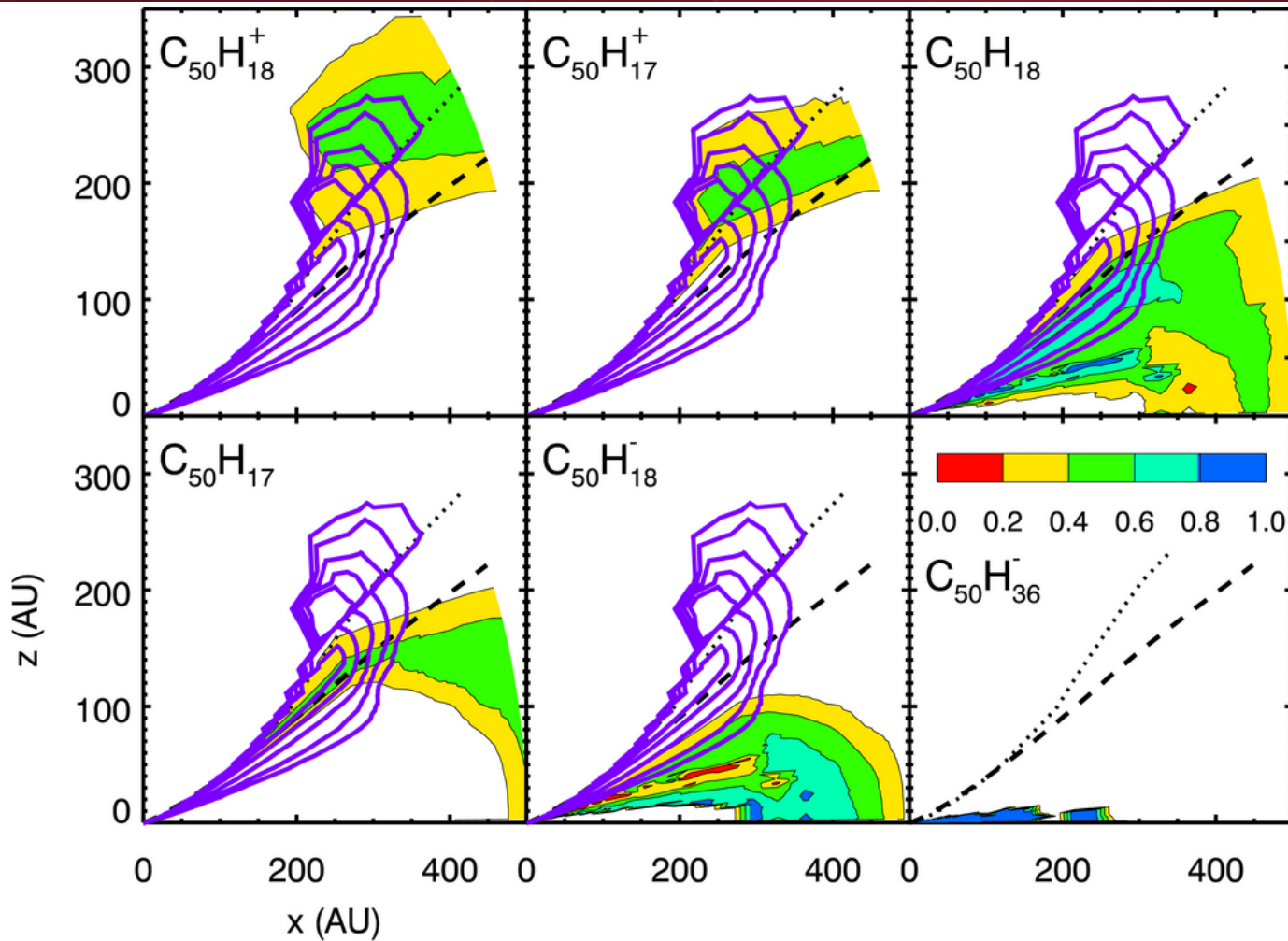
- $N_C < 40$: entire disk
- $N_C > 40$: part of disk \rightarrow $N_C = 100$ survives as close as few AU from the star

Radiation field and PAH emission



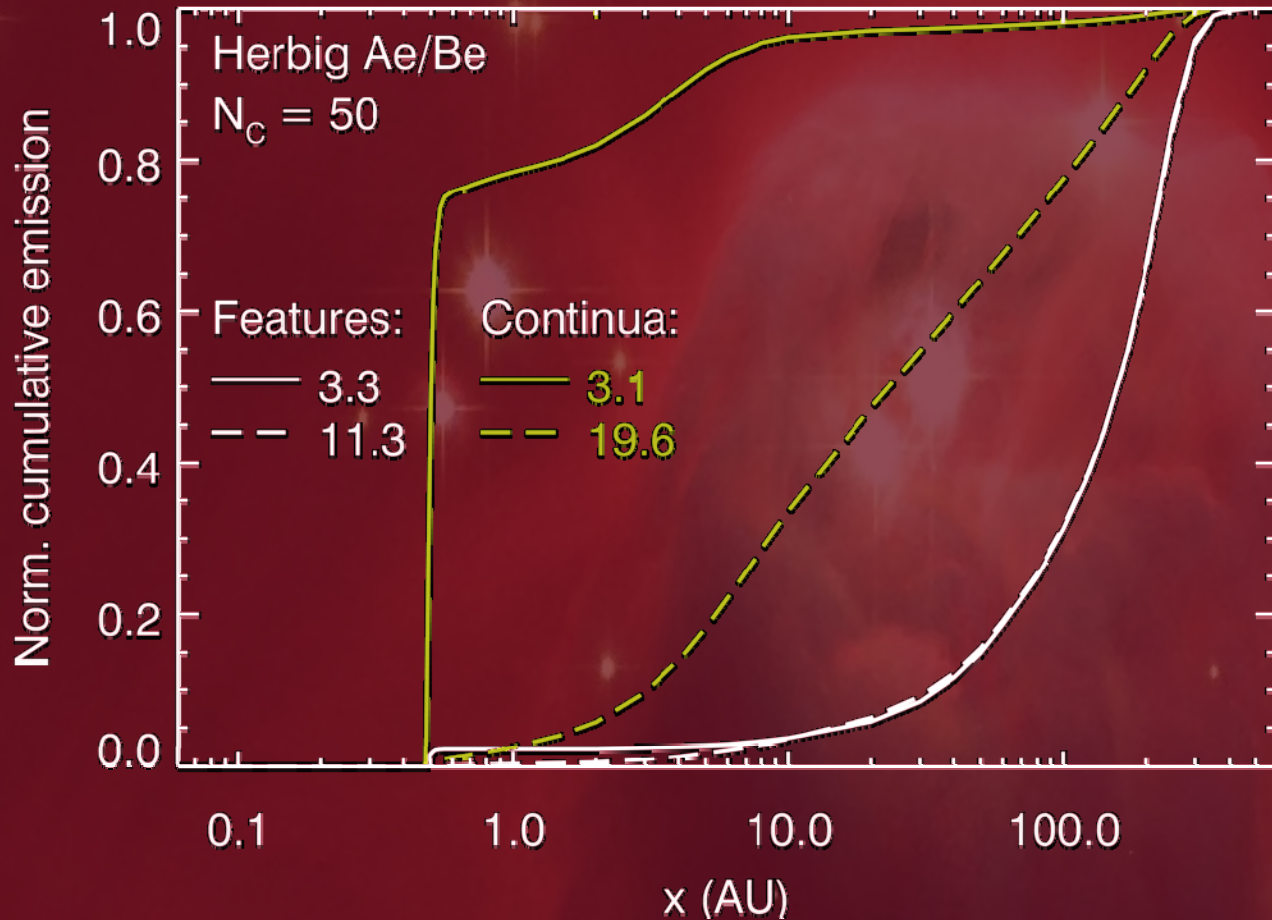
- $N_C = 50$ in H_{Ae}Be disk
- Destruction for $G_0 \gtrsim 10^5$
- Emission mostly from surface layers

Distribution in disk



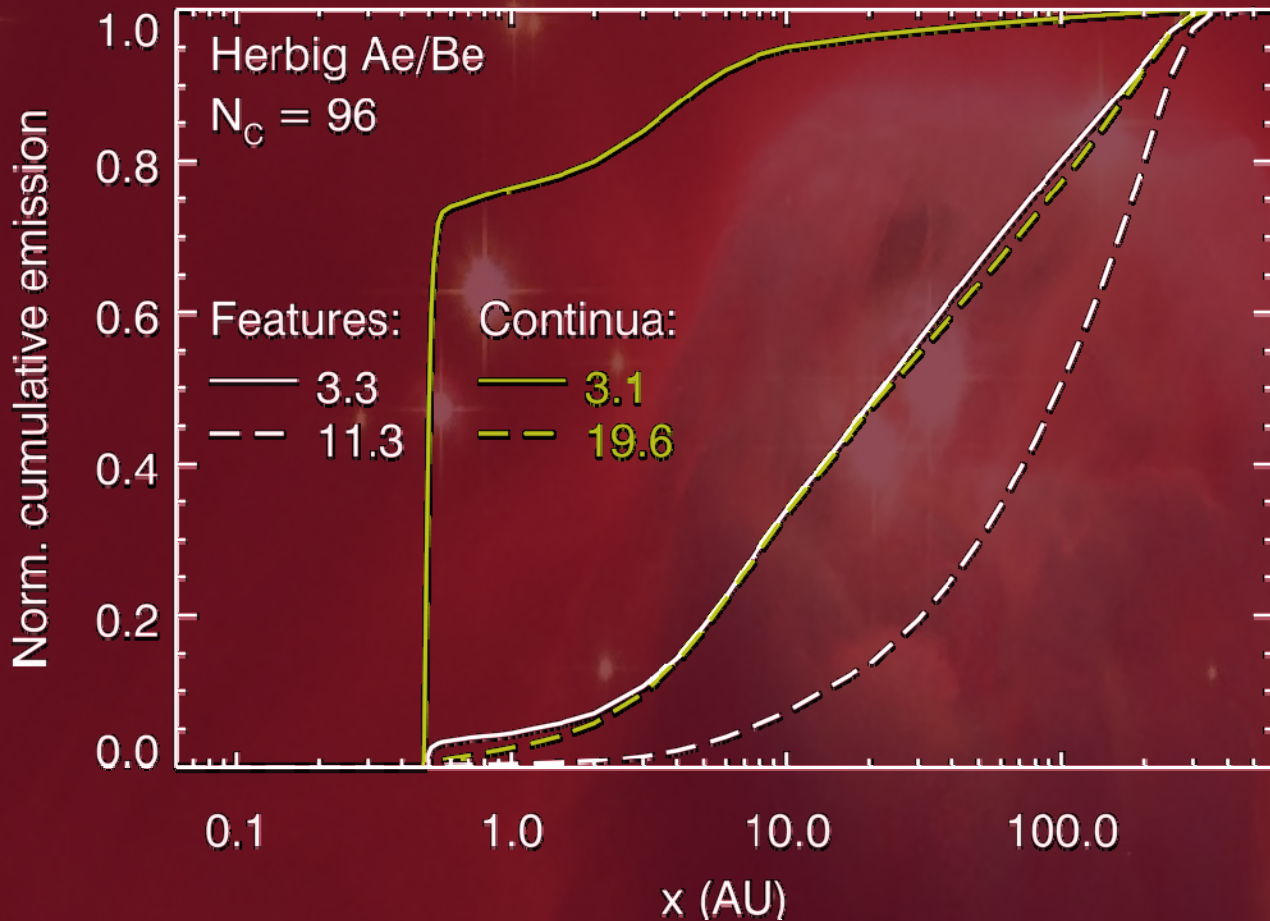
- $N_C = 50$ in HAeBe disk
- Disk surface: positive ions
- Main disk: neutral
- Midplane: negative ions
- Preference for $N_H = 17, 18$ or 36

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

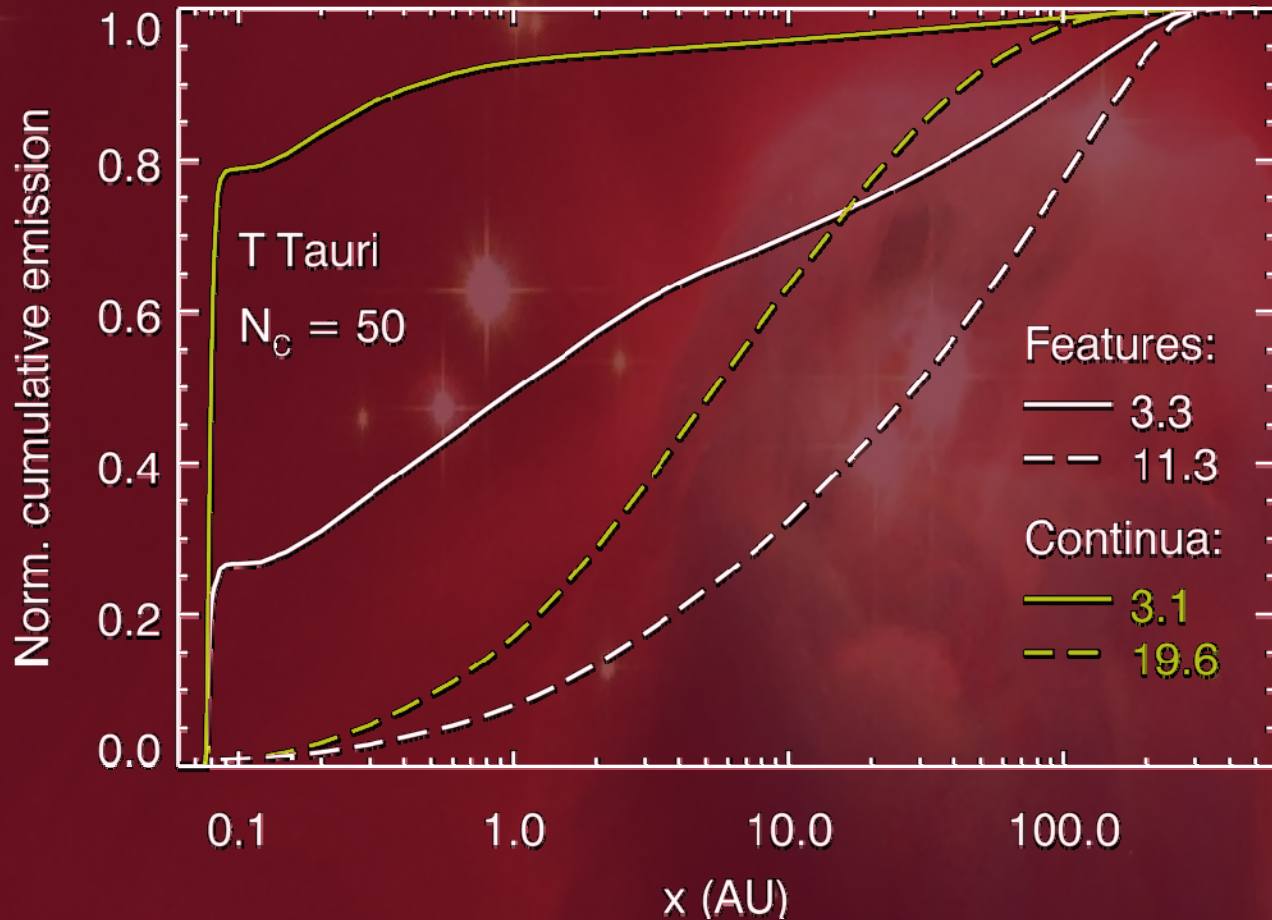
Spatial extent of features (2)



- $N_C = 96$ 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

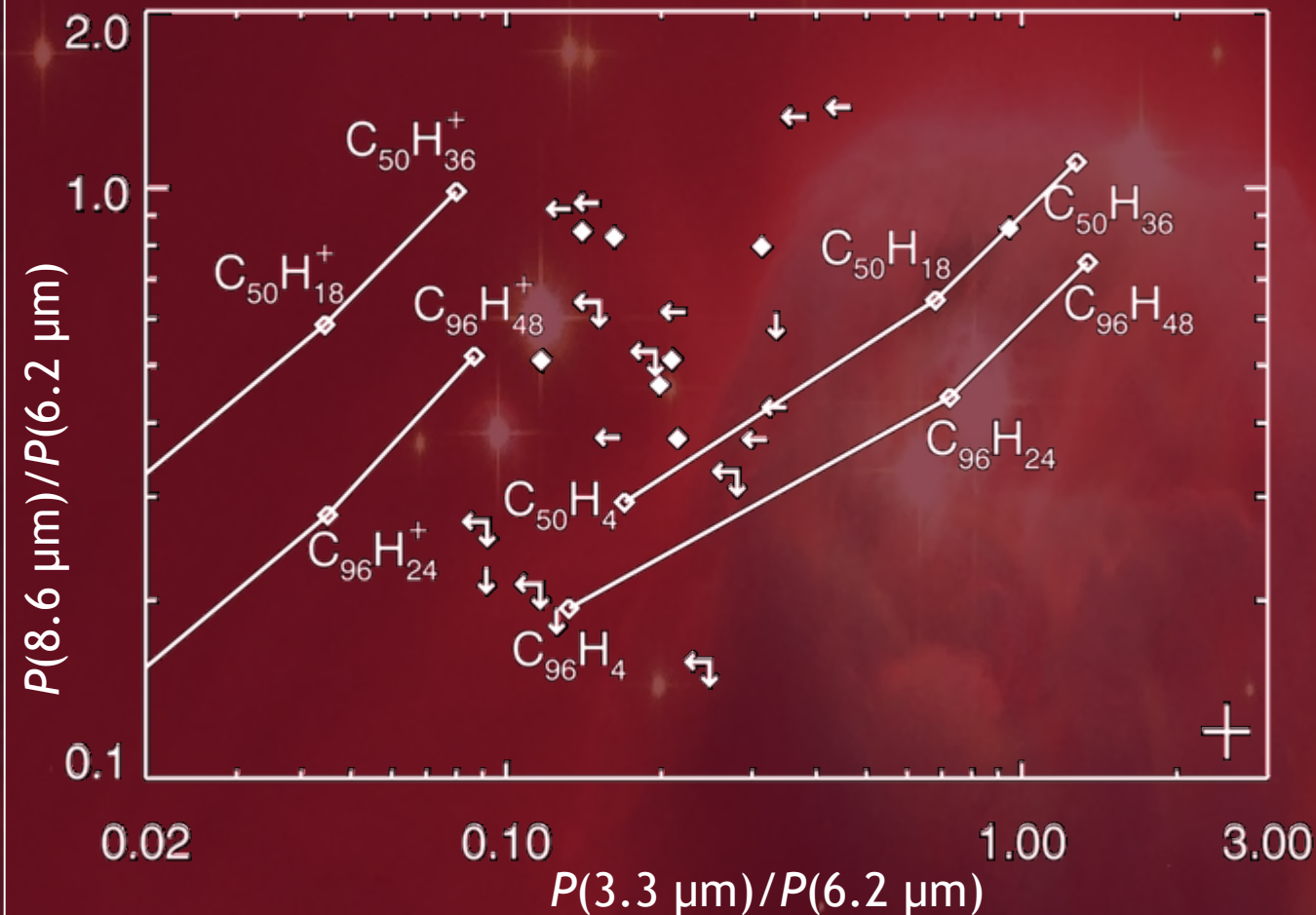
Observed spatial profiles show better match with $N_C = 96$ than with $N_C = 50$

Spatial extent of features (3)



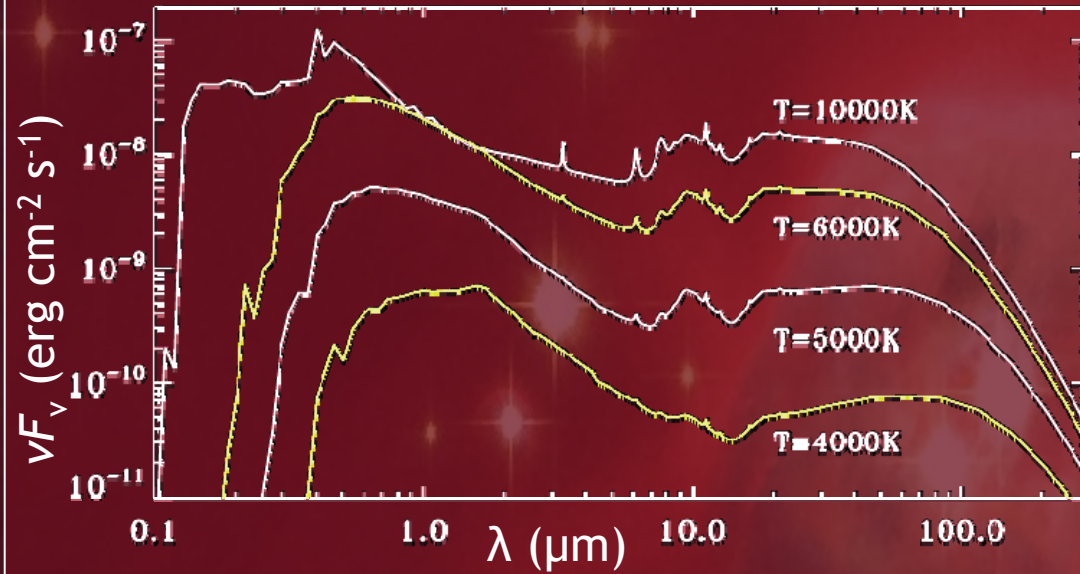
- $N_c = 50$ in T Tau disk
- PAHs survive almost everywhere: features less extended than for HAeBe
- Features more extended than adjacent continuum

Peak flux ratios in HAeBe disks

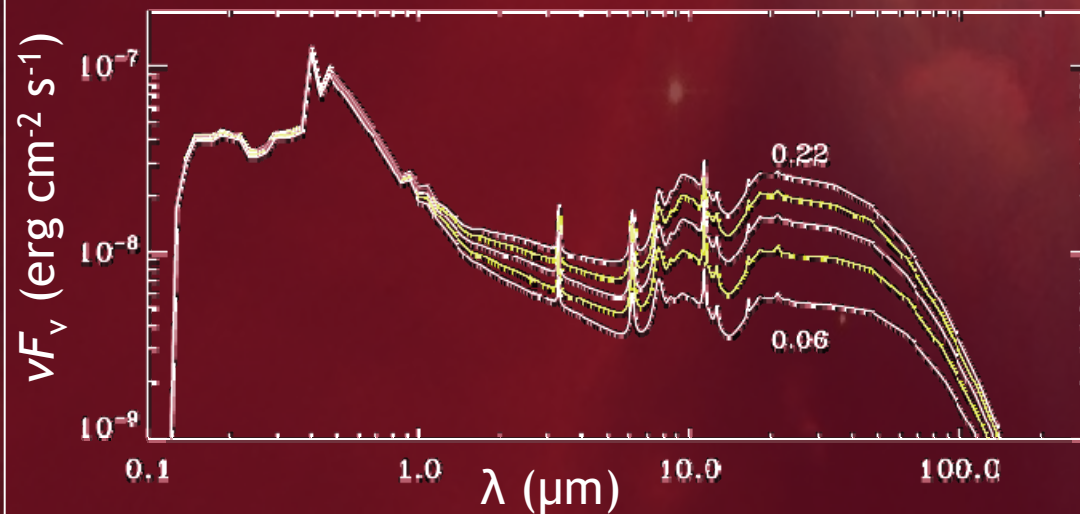


Observations consistent with mix of neutral and ionized, as well as normal to double hydrogenation

Stellar temperature & Disk flaring

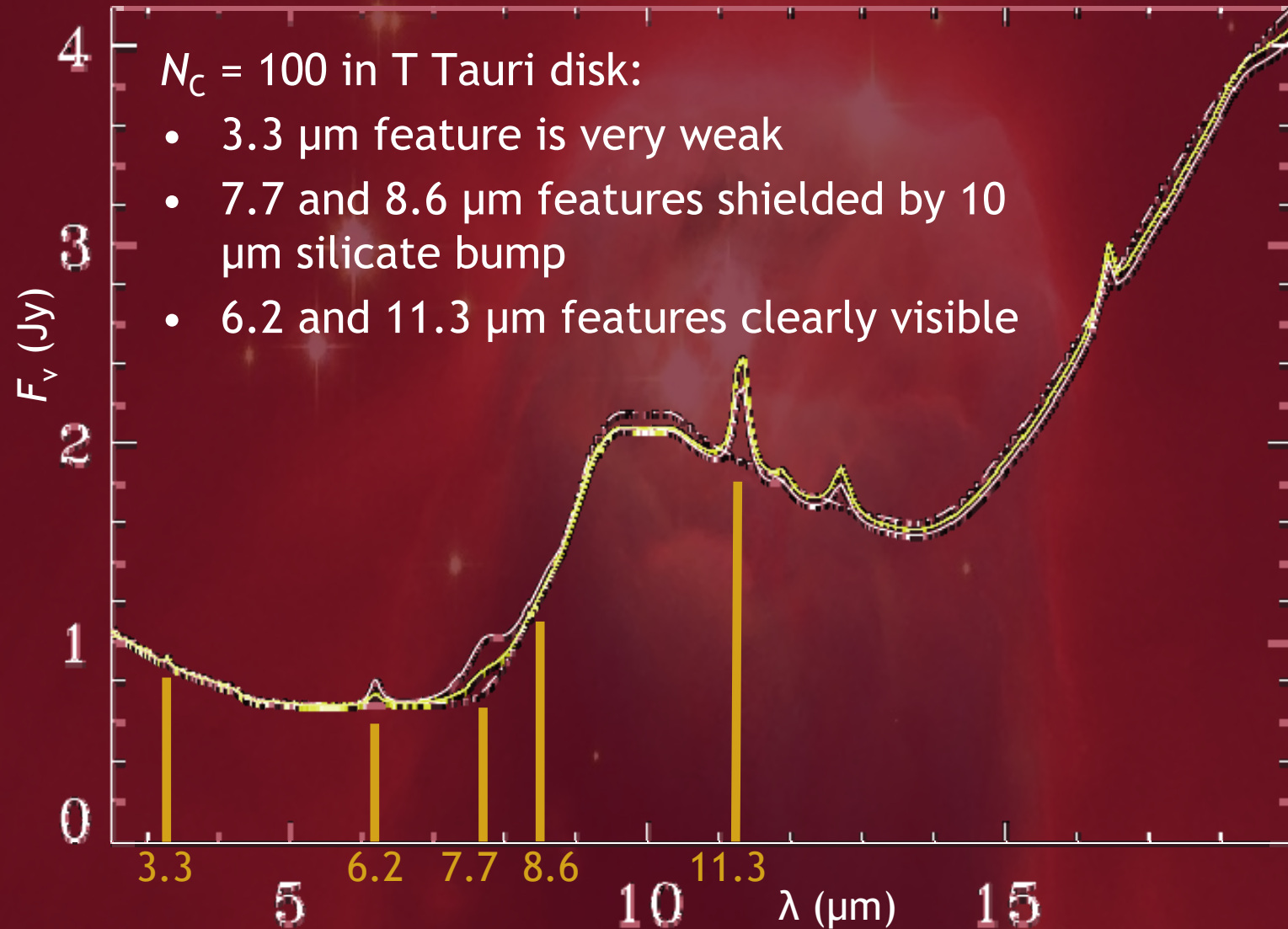


- Total flux increases with T_* , as do features



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

Feature masking in T Tau spectra



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), Ressler & Barsony (2003)
 - multiple charge and hydrogenation states
 - abundances 10-100x lower than in ISM
- Future work:
 - Spatially resolved observations
Geers et al. in prep.
 - Dust and PAH settling
Dullemond et al. in prep.
 - Study PAH evolution/“trail” from ISM to disk

Thank you!

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