Constraining the Dust Distribution in AGN Dust Tori

implications from high-spatial resolution VLT/VISIR spectro-photometry

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(BASED ON HÖNIG ET AL., IN PREPARATION)

OVERVIEW

- ☐ BRIEF STATUS OF MID-IR TORUS OBSERVATIONS
- ☐ GROUND-BASED VISIR OBSERVATIONS OF NEARBY AGN
- ☐ INTERPRETATION WITH 3D CLUMPY TORUS MODELS:
  THE DUST STRUCTURE REVEALED

MOTIVATION

- Spitzer has done extensive mid-IR observations of AGN

- however: compromised spatial resolution (3" at 10 μm)

  → a lot of host galactic flux included (e.g. PAH features)

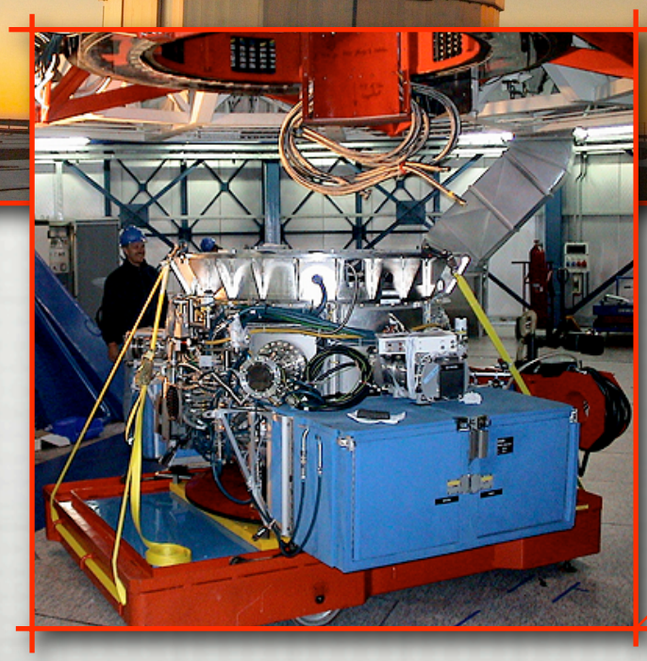
- Solutions:
  - Interferometry (but limited number of objects)
  - ground-based observations with 8m-class telescopes

- Our objects:
  - nearby type 1 and 2 Seyfert galaxies
  - radio quiet
  - flux limit ~100 mJy (execution constraint)
  - luminosity range log L_X = 42.3 ... 44.0
  - hydrogen column densities $<10^{20}$ ... $>10^{24}$ cm^{-2}

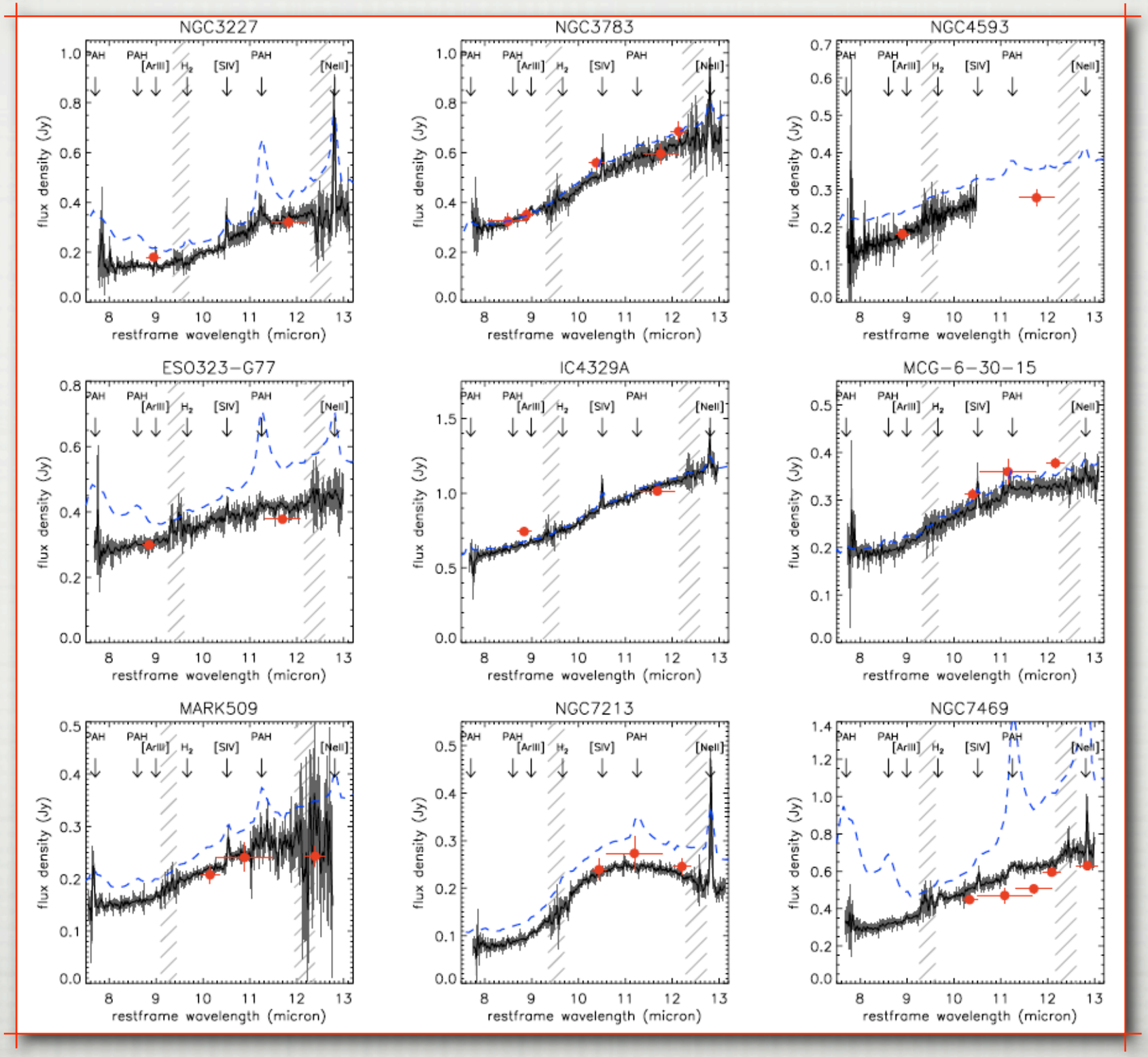
VISIR AT THE VLT

- VISIR = VLT Imager and Spectrograph in the mid-IR
- Wavelength range: N-band: 7.7-13.2 μm; Q-band: 16.5 - 27.4 μm
- Spatial resolution in the N-band: 0.25" - 0.40"

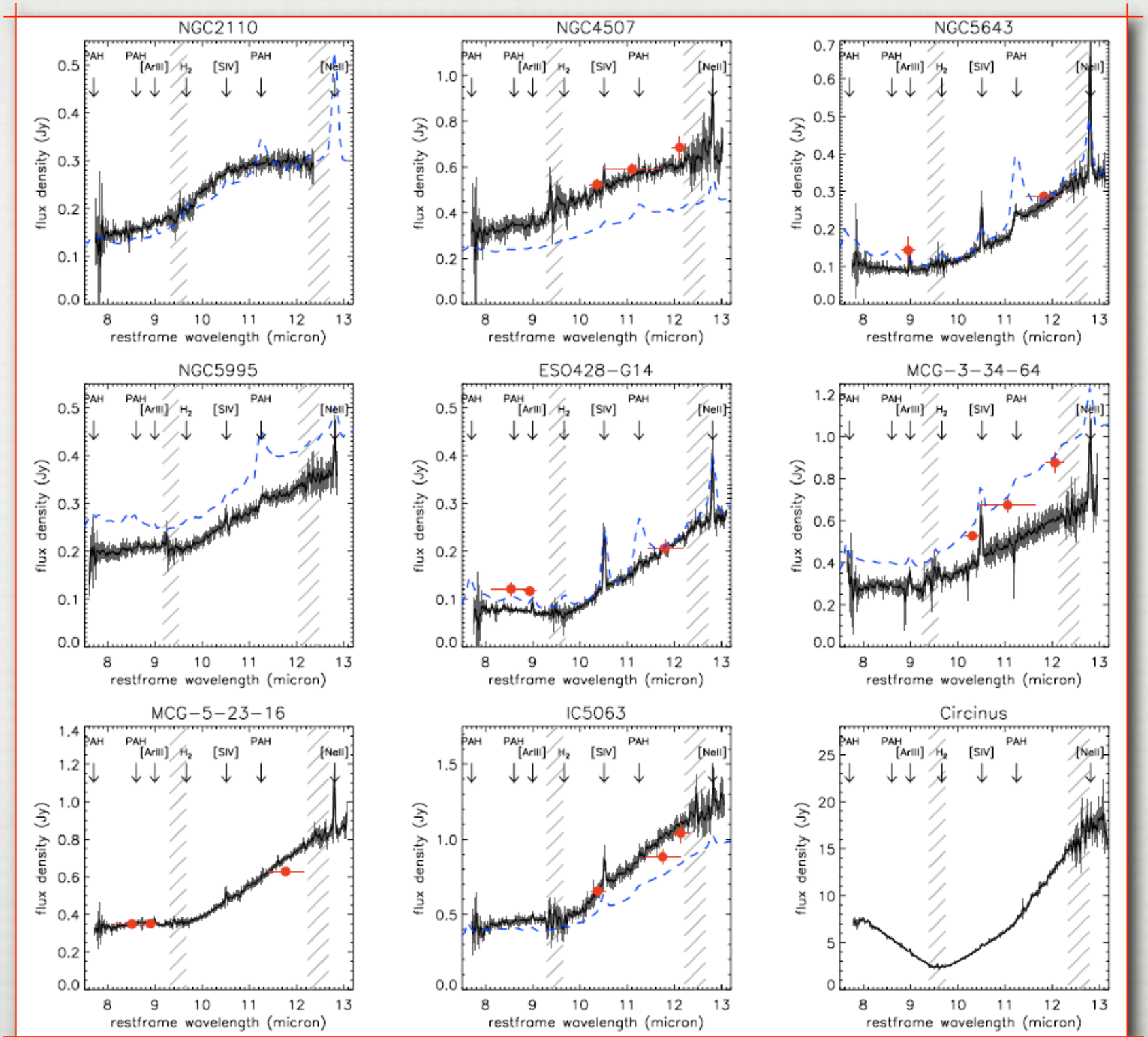
  → 10x better than Spitzer!



TYPE I VISIR SPECTRO-PHOTOMETRY



TYPE 2 VISIR SPECTRO-PHOTOMETRY

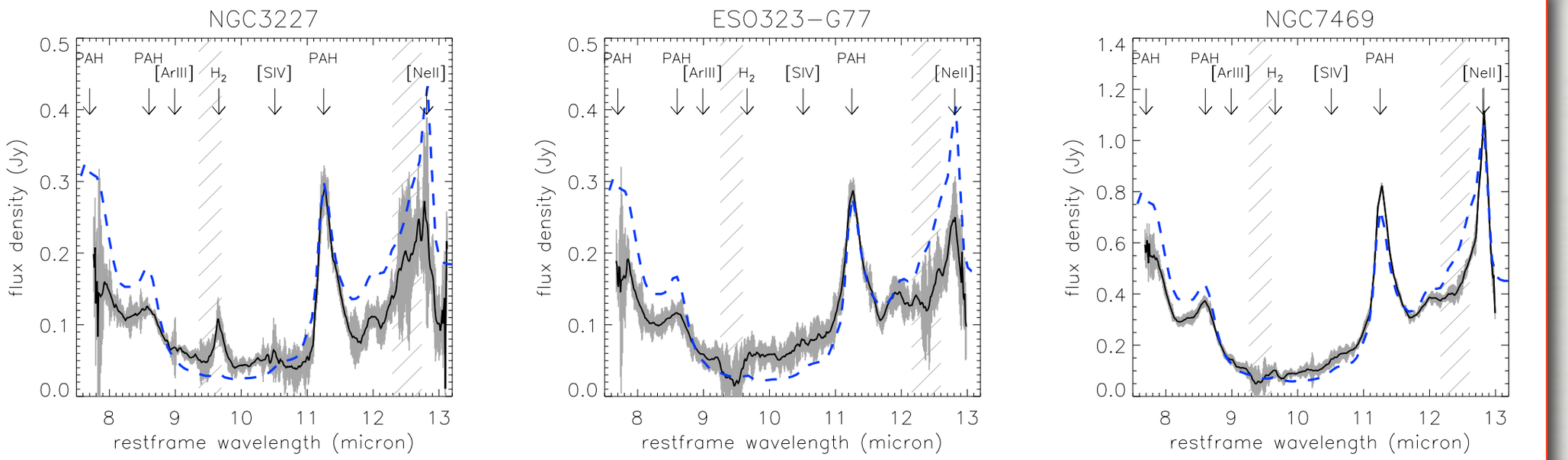


VISIR VS. SPITZER

- star-formation confused with the nucleus in Spitzer is resolved out

  → improved spatial resolution (compact sources)

  → chopping/nodding (extended/screen emission)



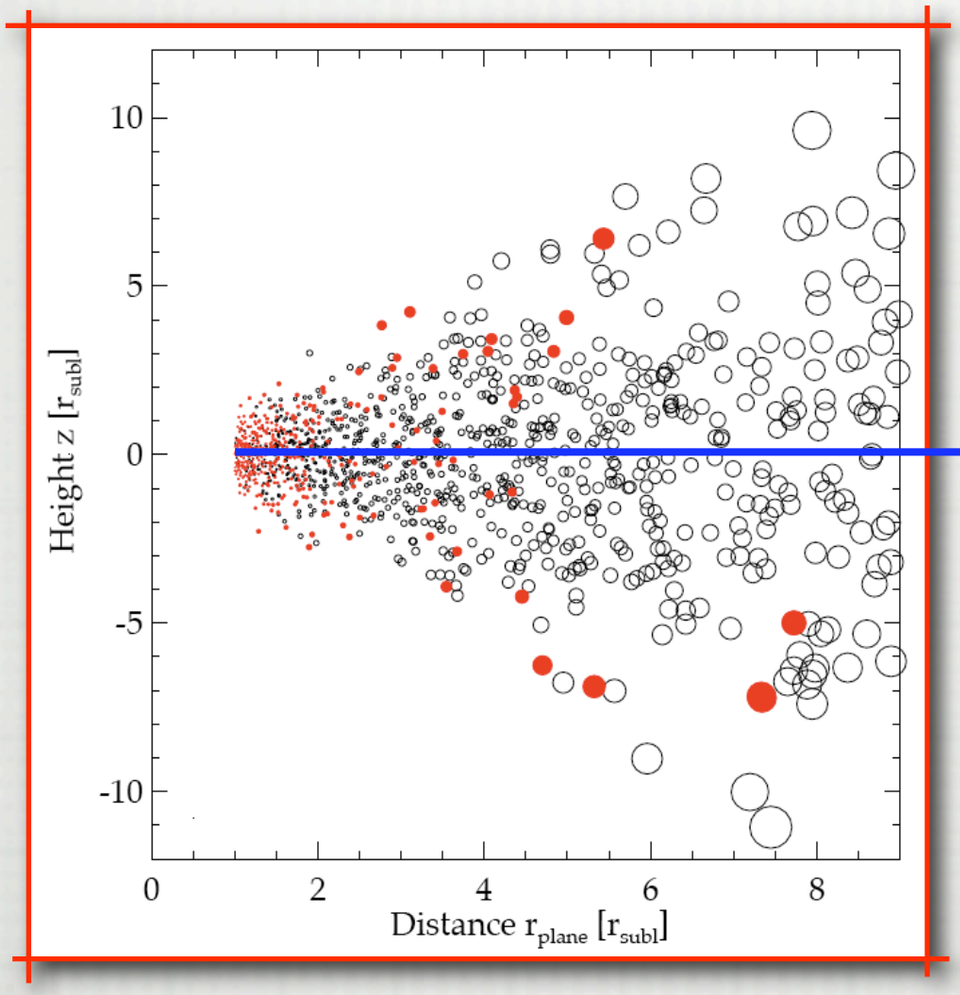
- sources (mostly) unresolved in VISIR aperture

  → mid-IR emisison region <24-160 pc or <625-1800 x r_{sub}

TORUS MODEL PARAMETERS

- **Basic model parameters** of our 3D clumpy torus model

  Hönig et al. 2006; Hönig & Kishimoto 2009, submitted



$$\eta_z \propto \exp\left(\frac{z^2}{2h^2}\right)$$

$$\eta_\theta \propto \exp\left(\frac{\theta^2}{2\theta_0^2}\right)$$

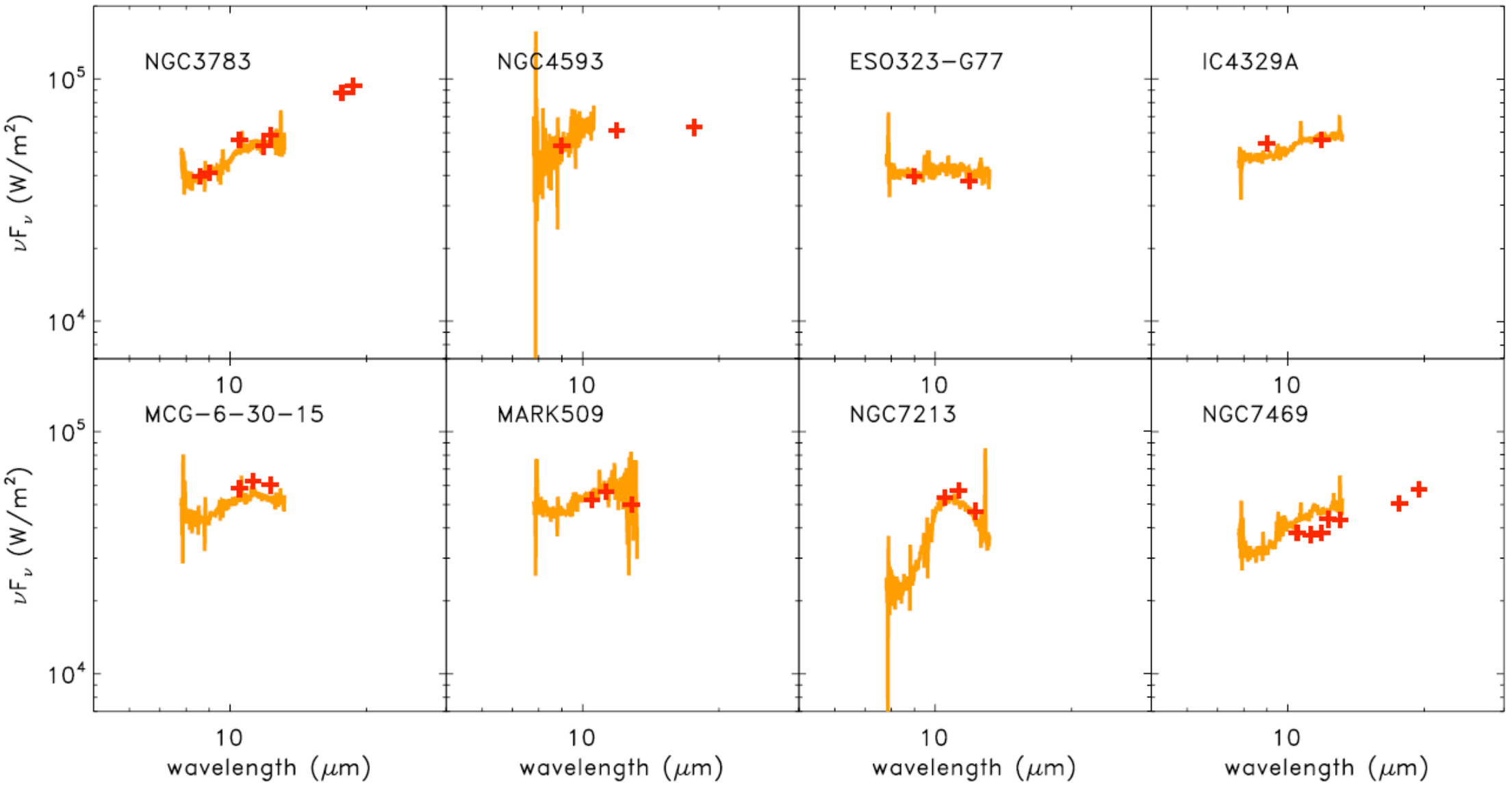
$$\eta_r(r) \propto r^a$$

N_0

$$\tau_\lambda = \tau_V \times Q_{\rm ext}$$

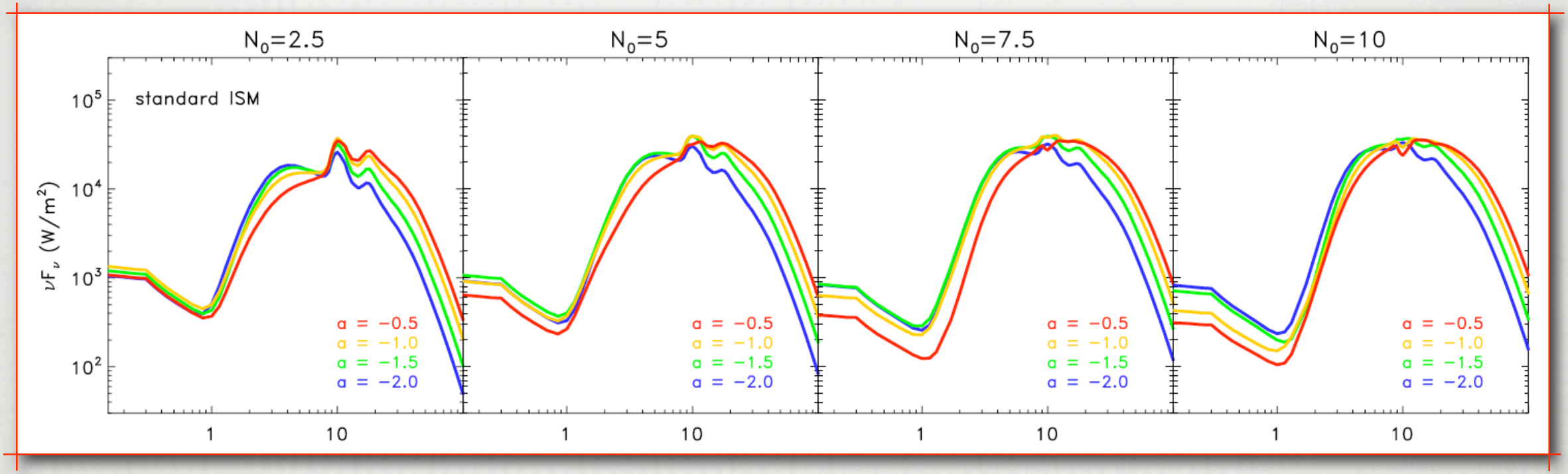
- Note: Rout has to be set appropriately to avoid cut-off!

OBSERVED VISIR TYPE 1 MID-IR SED



- mid-IR SEDs are comparably red, i.e. rise with λ

WHAT THE MODELS TELL US



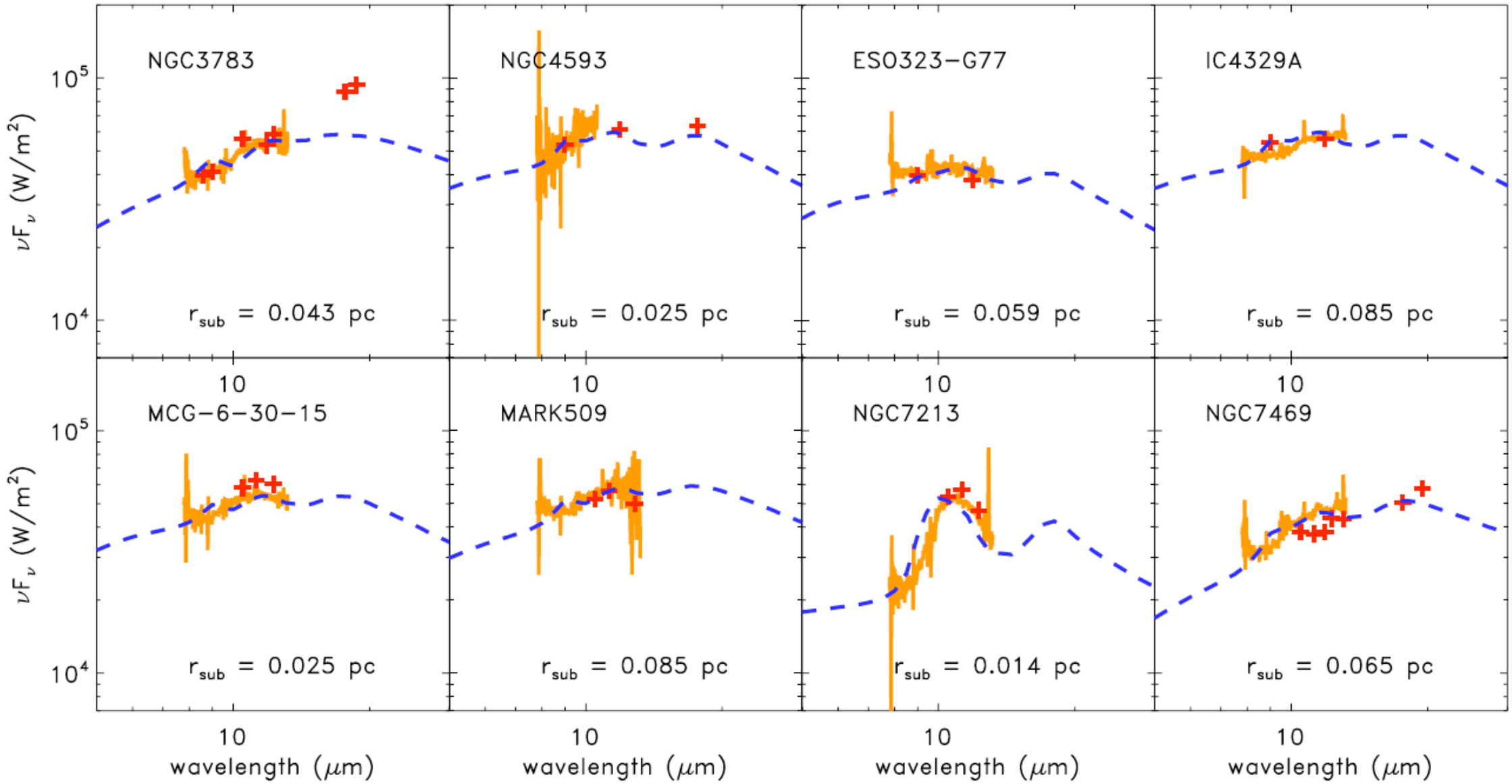
Hönig & Kishimoto 2009, submitted

dust distribution profile steep
a=-1.5 … -2.0

dust distribution profile flat
a=-0.5 … -1.0

- a can be constrained by the mid-IR SED slope

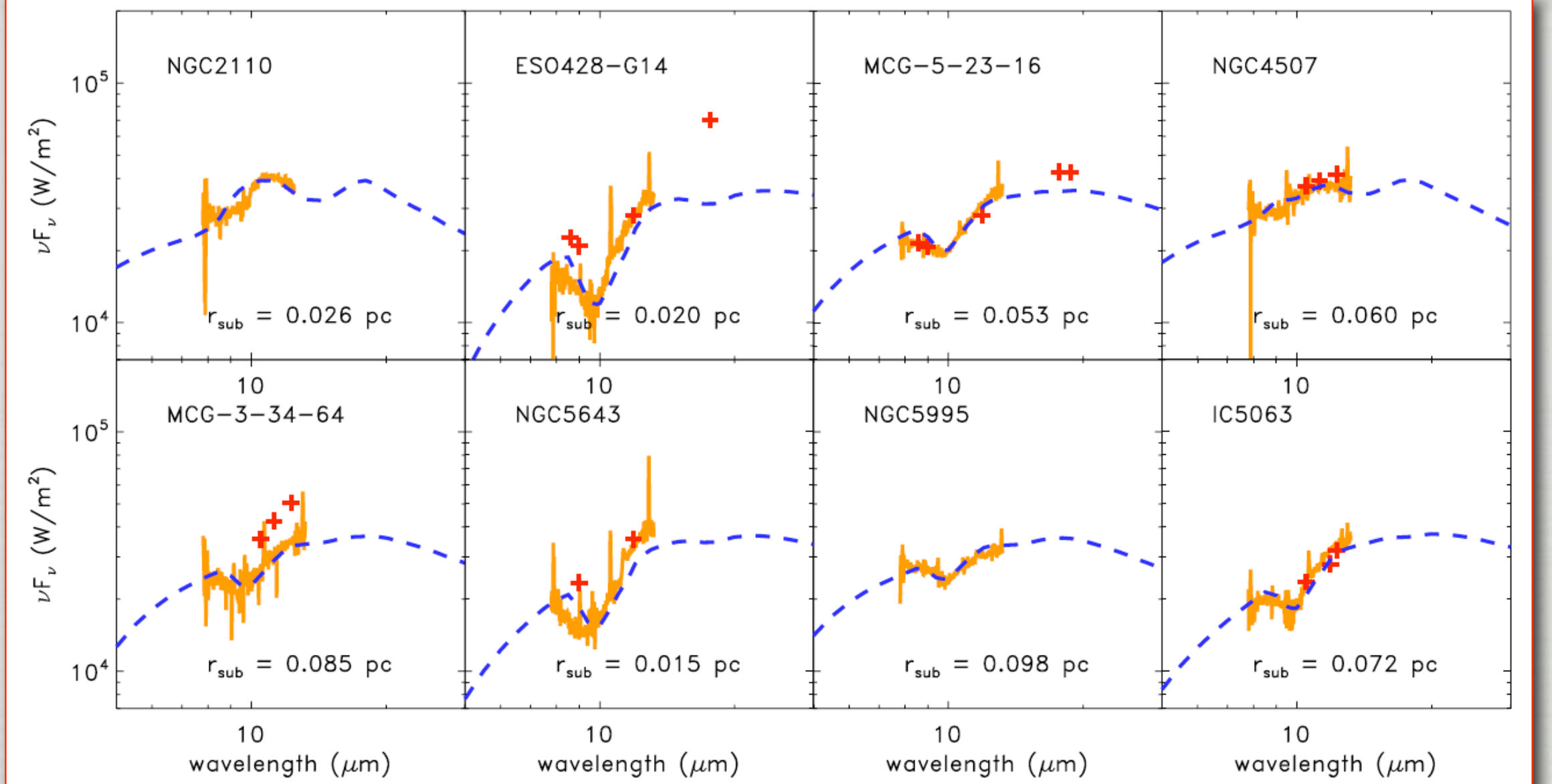
MODELING MID-IR TYPE I DATA



$$
\begin{aligned}
a &= -0.859 \pm 0.269 \\
i &= 20^\circ \pm 15^\circ \\
N_0 &= 6.5 \pm 1.9
\end{aligned}
$$

- points towards *flat dust distribution*

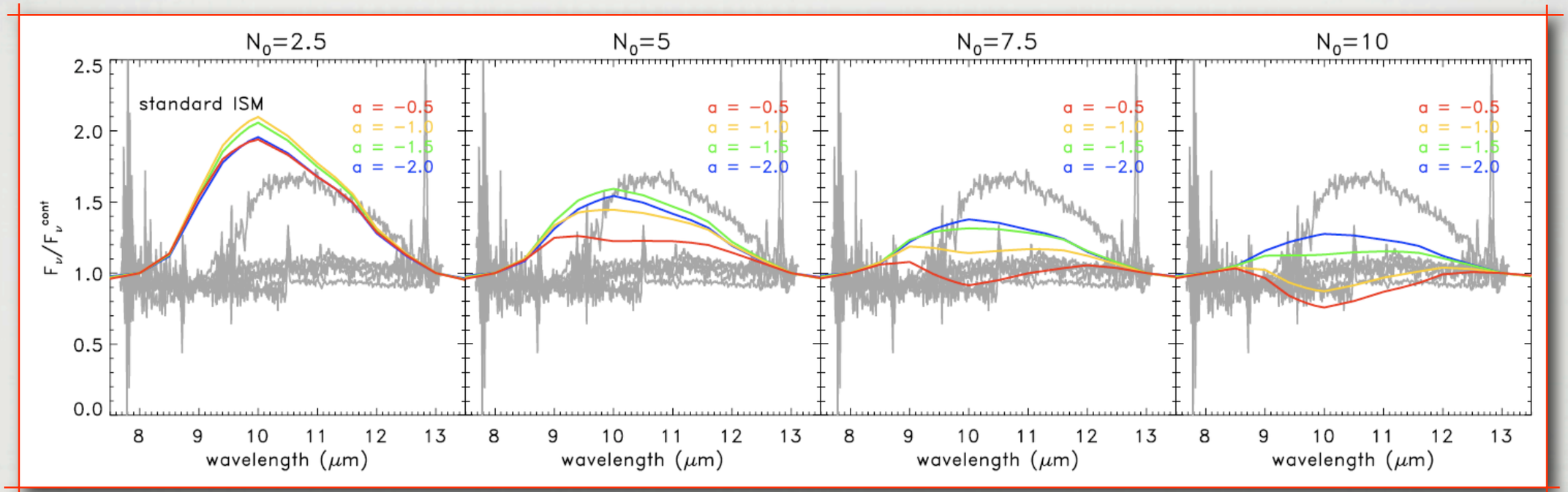
MODELING MID-IR TYPE 2 DATA

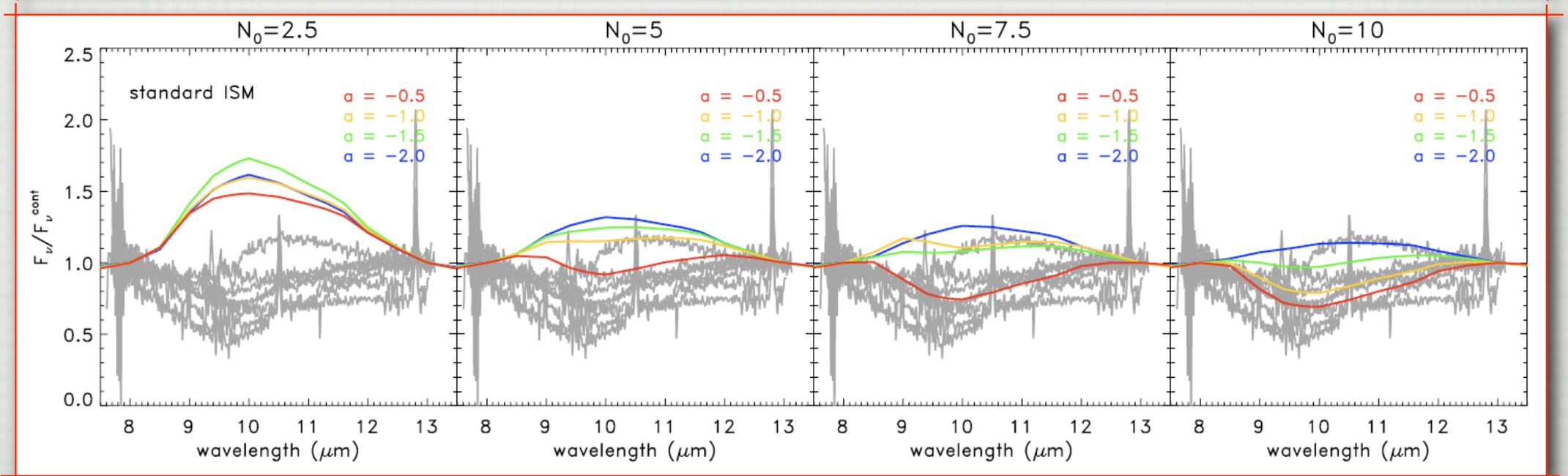


$$
\begin{aligned}
a &= -0.825 \pm 0.220 \\
i &= 75^\circ \pm 15^\circ \\
N_0 &= 6.9 \pm 1.7
\end{aligned}
$$

- as well: points towards flat dust distribution

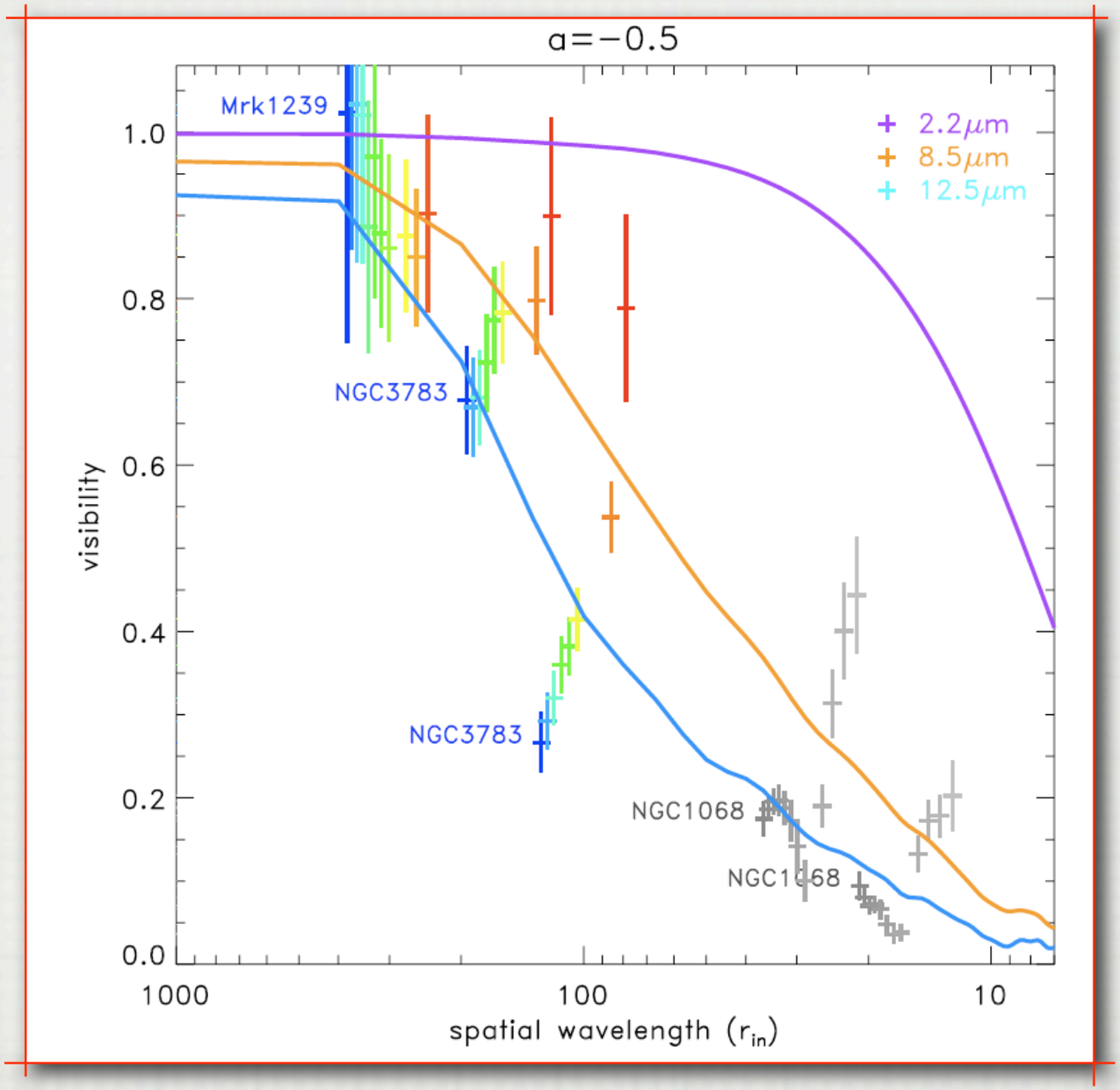
A LOOK AT THE SI FEATURES





- again: points towards flat dust distribution

MODELING MID-IR TYPE 1 INTERFEROMETRY



$a = -0.5 \ldots -1.0$

Kishimoto et al. 2008;
Hönig et al., in prep.

- scaling type 1 interferometry of different objects to the same spatial scale
- modeling the radial visibility curves with 3D clumpy torus model

SUMMARY AND CONCLUSIONS

- ☐ GROUND-BASED HIGH-SPATIAL RESOLUTION MID-IR SPECTRO-PHOTOMETRY

- ☐ VISIR ISOLATES THE EMISSION FROM THE TORUS

- ☐ FROM MODELS:

  - SEDs can constrain the radial dust distribution in the torus

- ☐ MODELING OBSERVATIONS:

  - flat radial dust distribution of $a = -0.5 \ldots -1.0$

  - corollary: surface number density approximately $\sim r^{-0.5 \ldots -1.0}$

- ☐ PHYSICAL INTERPRETATION: TBD...

  - disk-like? see Marc's talk