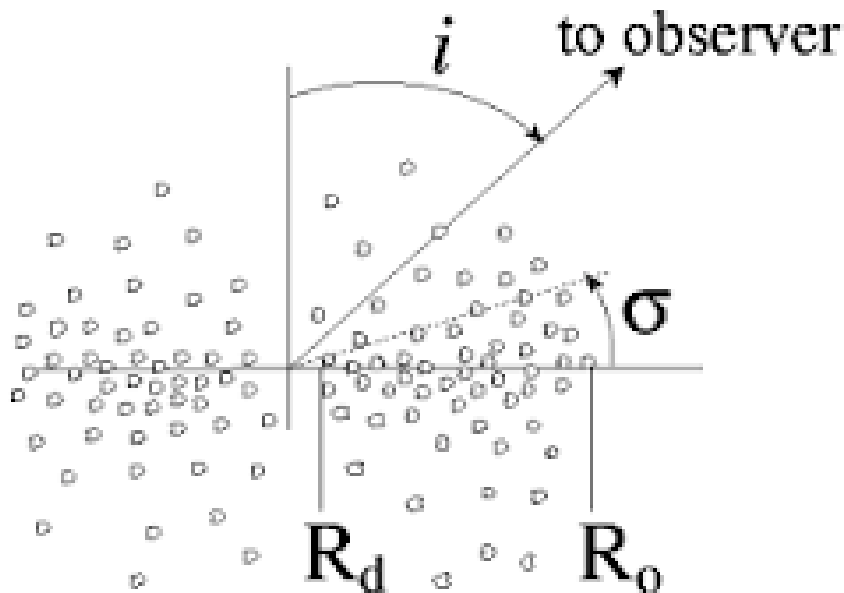


Two-phase AGN clumpy torus model and SED library

Torus structure :	clump+disk+envelope
Dust properties :	fluffy grains
SED library :	5 parameters
Examples:	low starburst contribution "pure" AGN

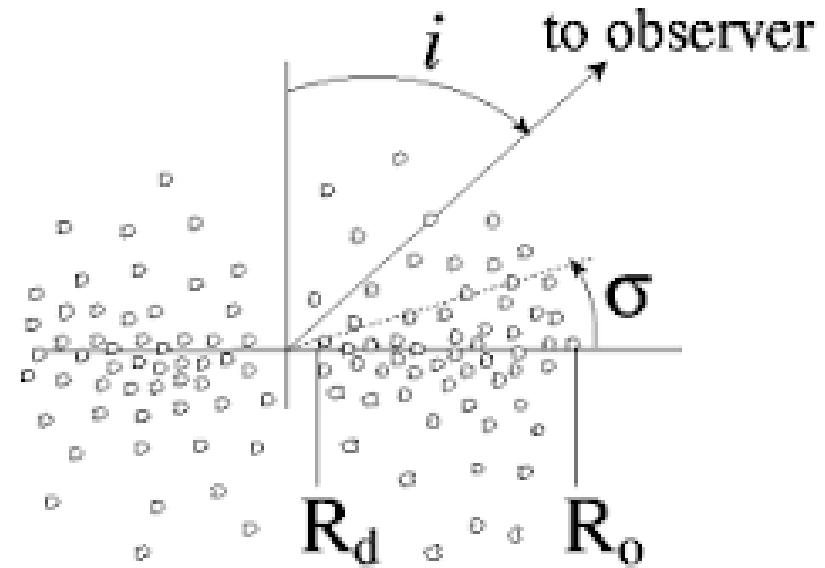
Homogenous \leftrightarrow clumpy AGN tours models

Homogenous disks because of challenges in RT
Pier & Krolik 1992, Efstathiou & Rowan-Robinson 1993, ...



Elitzur et al. 2001,
Nenkova et al. 2008,
Hönig & Kishimoto 2010,

Caveats on clumpy AGN torus models



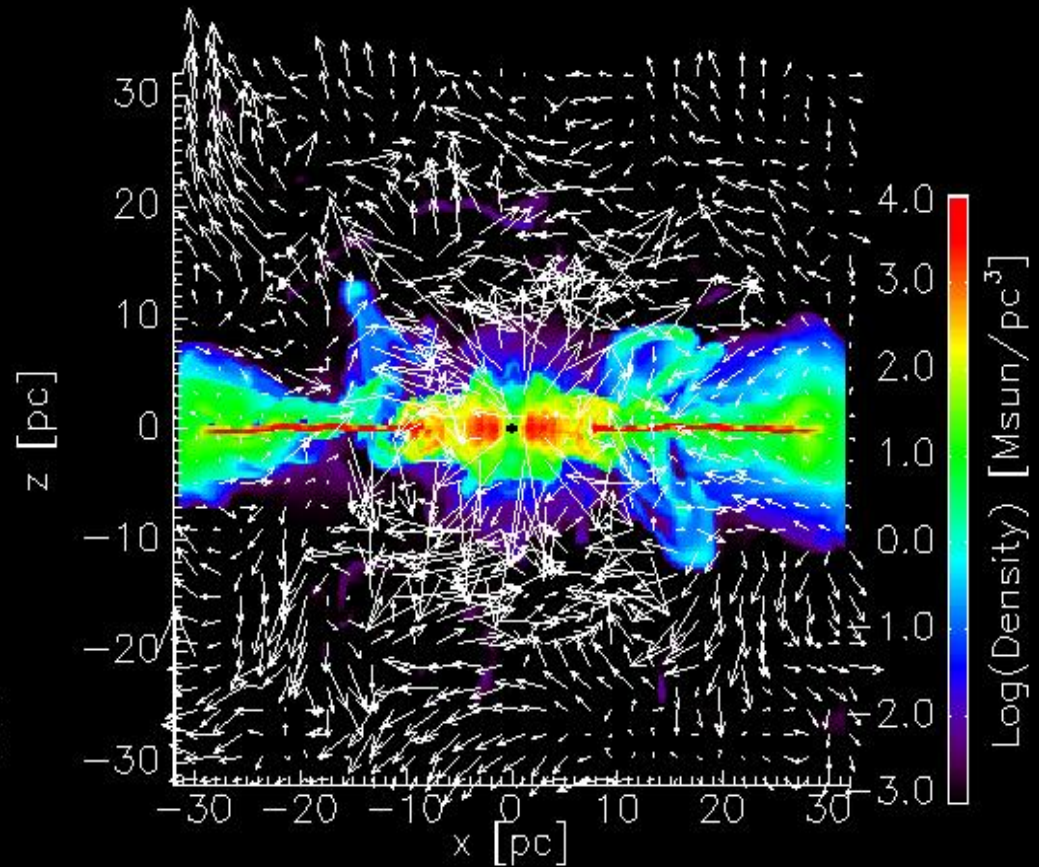
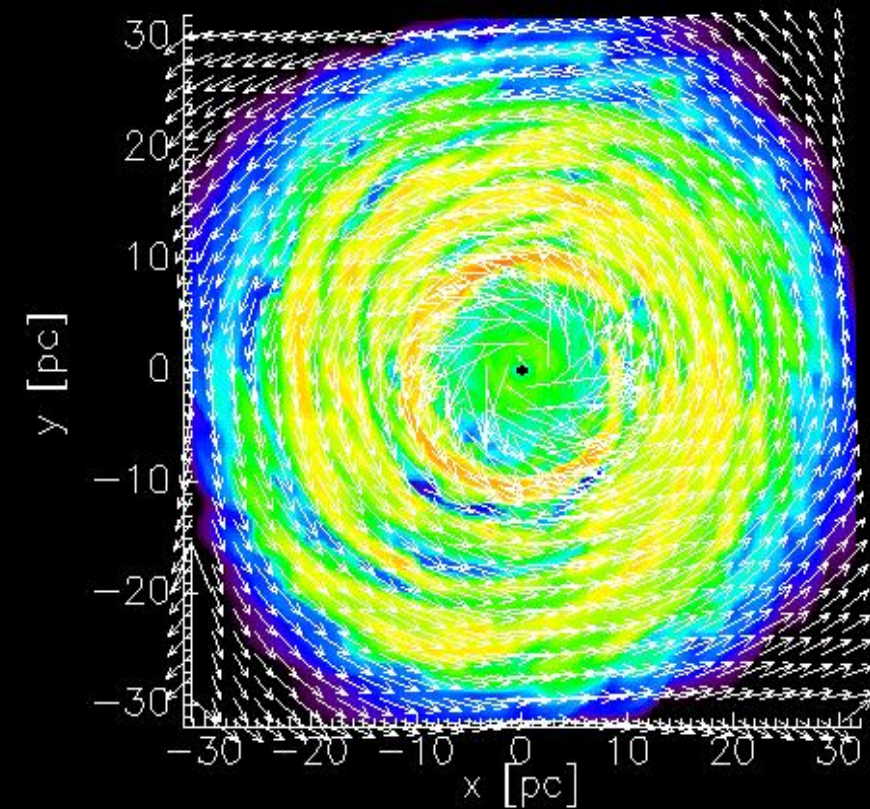
Challenges in RT:

- Statistical arguments
- Energy balance $\sim 5\%$
- No clump heating from disk
- Shadowing effects
- 9-11 free parameters

Hydro-dynamical simulation of AGN torus structure (Wada 2012)

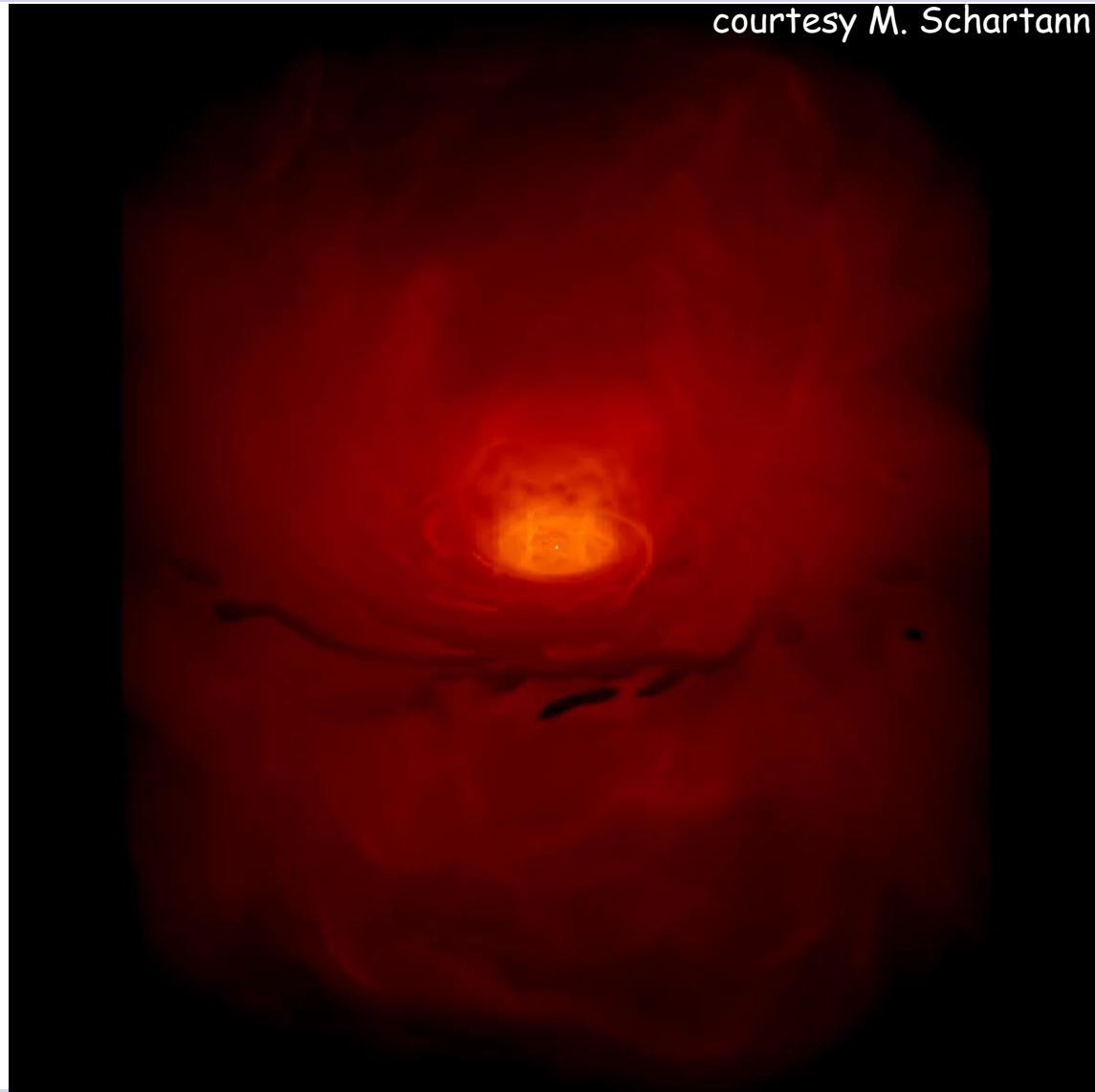
0.49405

courtesy K.Wada



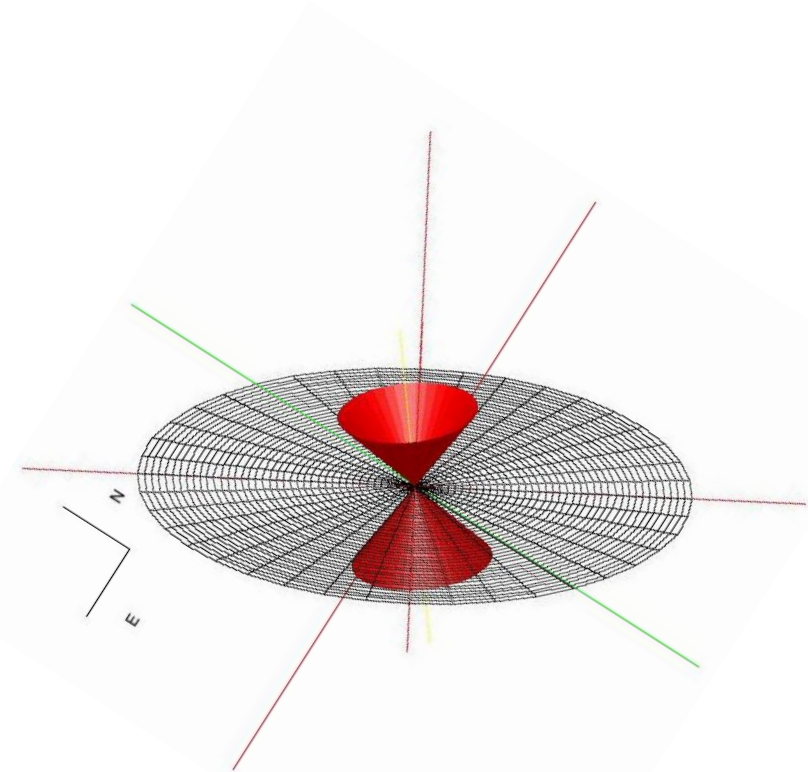
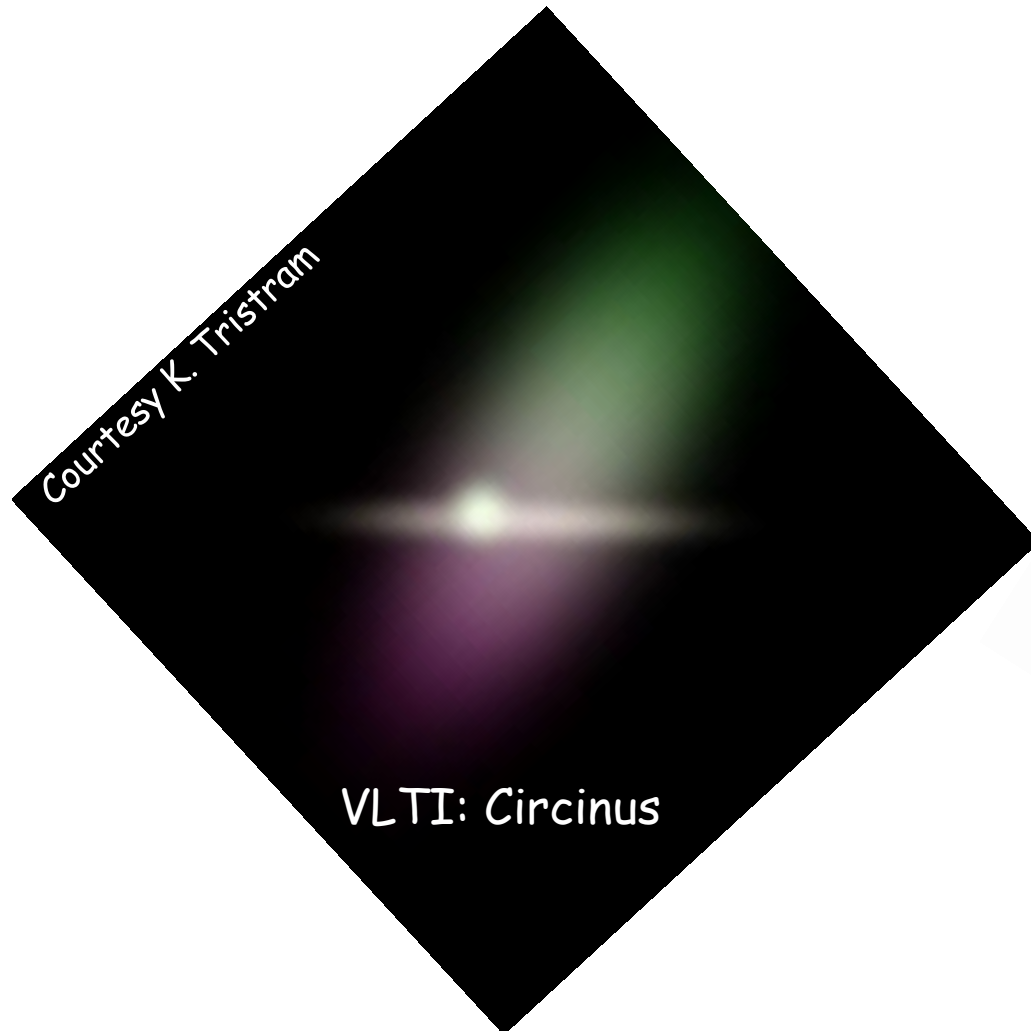
MIR view of the AGN torus

(Schartmann et al. 2014)

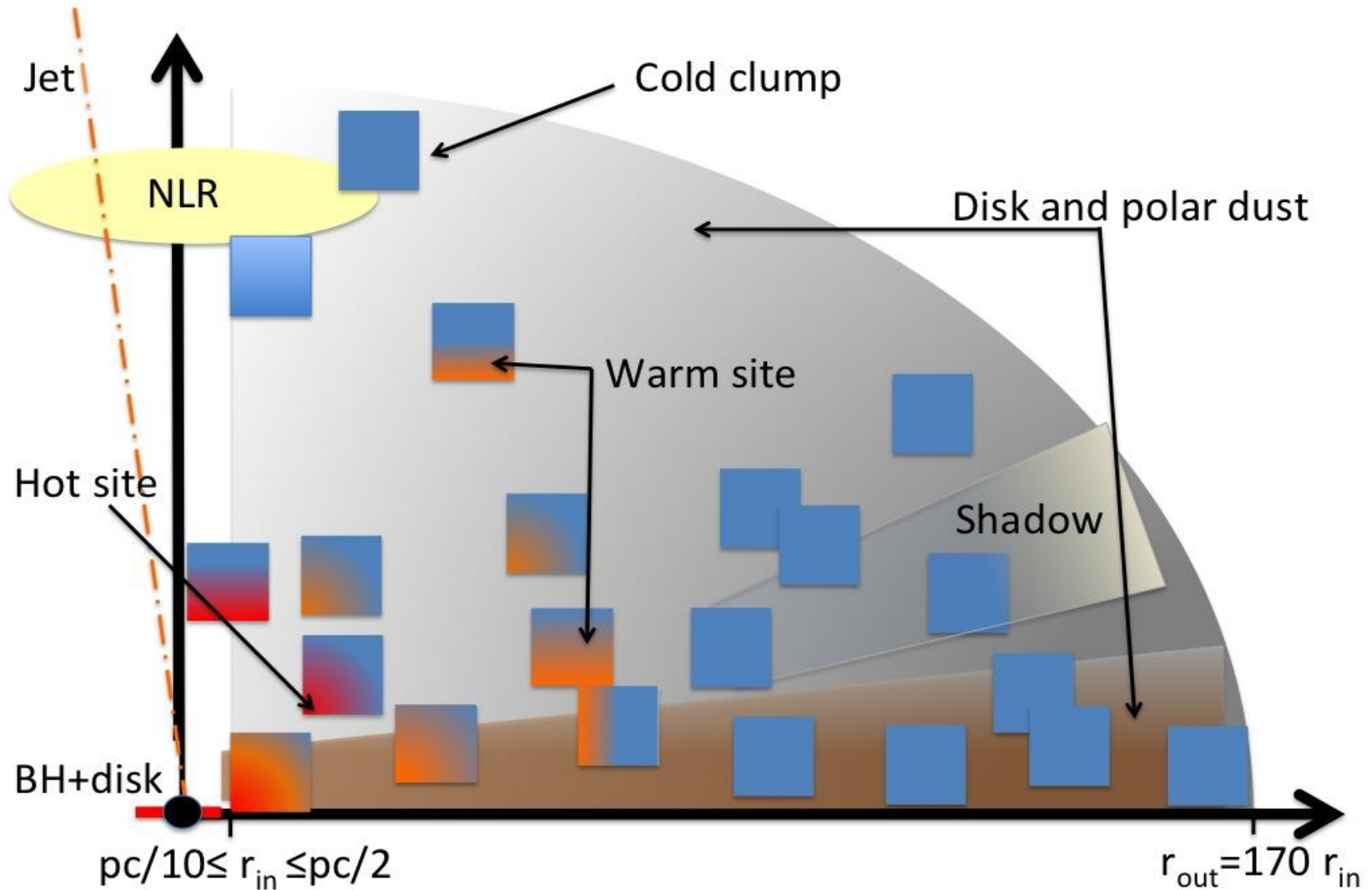


Dust in polar region of AGN tours

V L T I: Burtscher et al. 2013, Hönig et al. 2013, Tristram et al. 2014,
Review by Netzer 2015

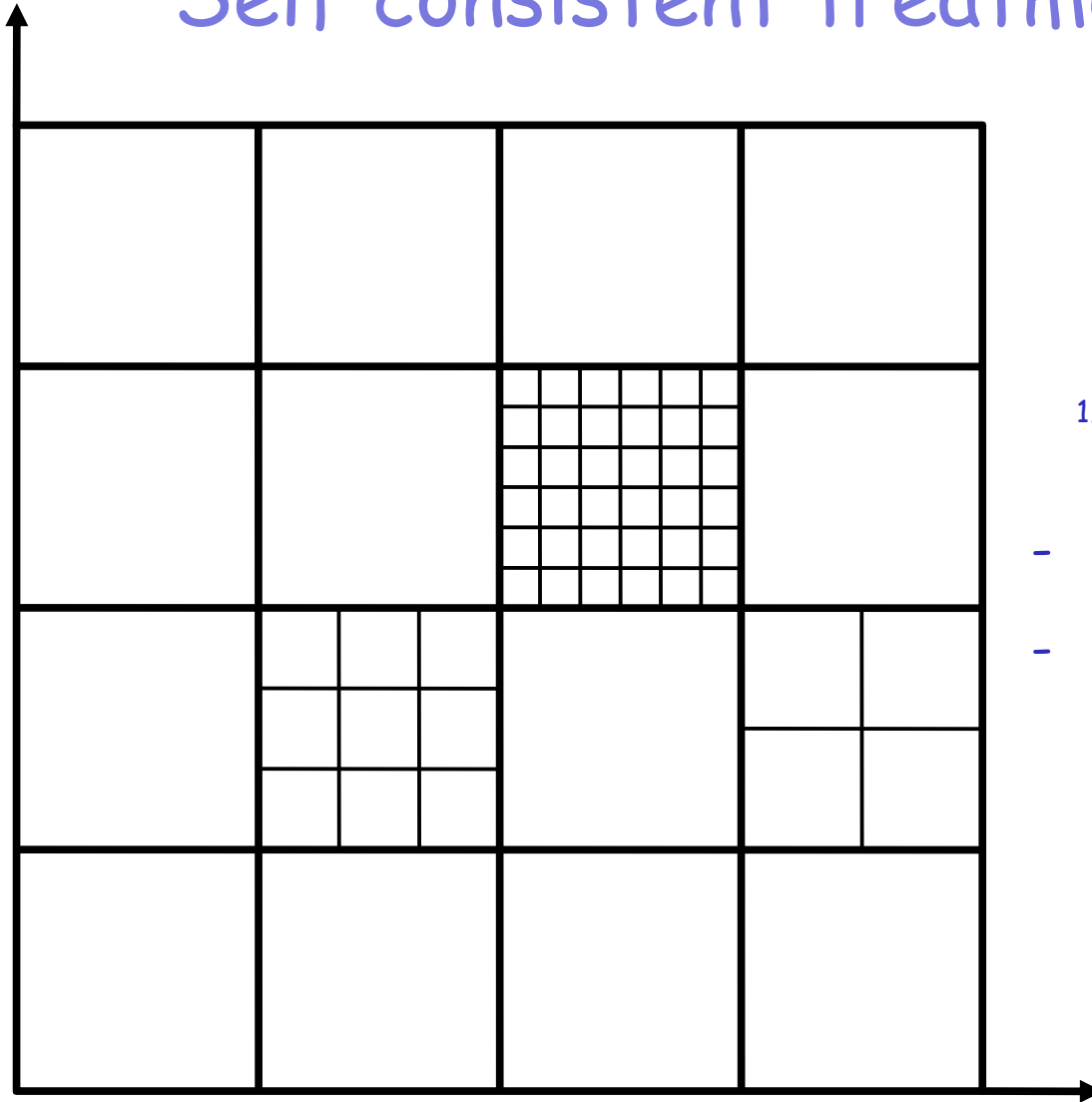


Phenomenological AGN torus structure



3D Monte Carlo radiative transfer

Self consistent treatment

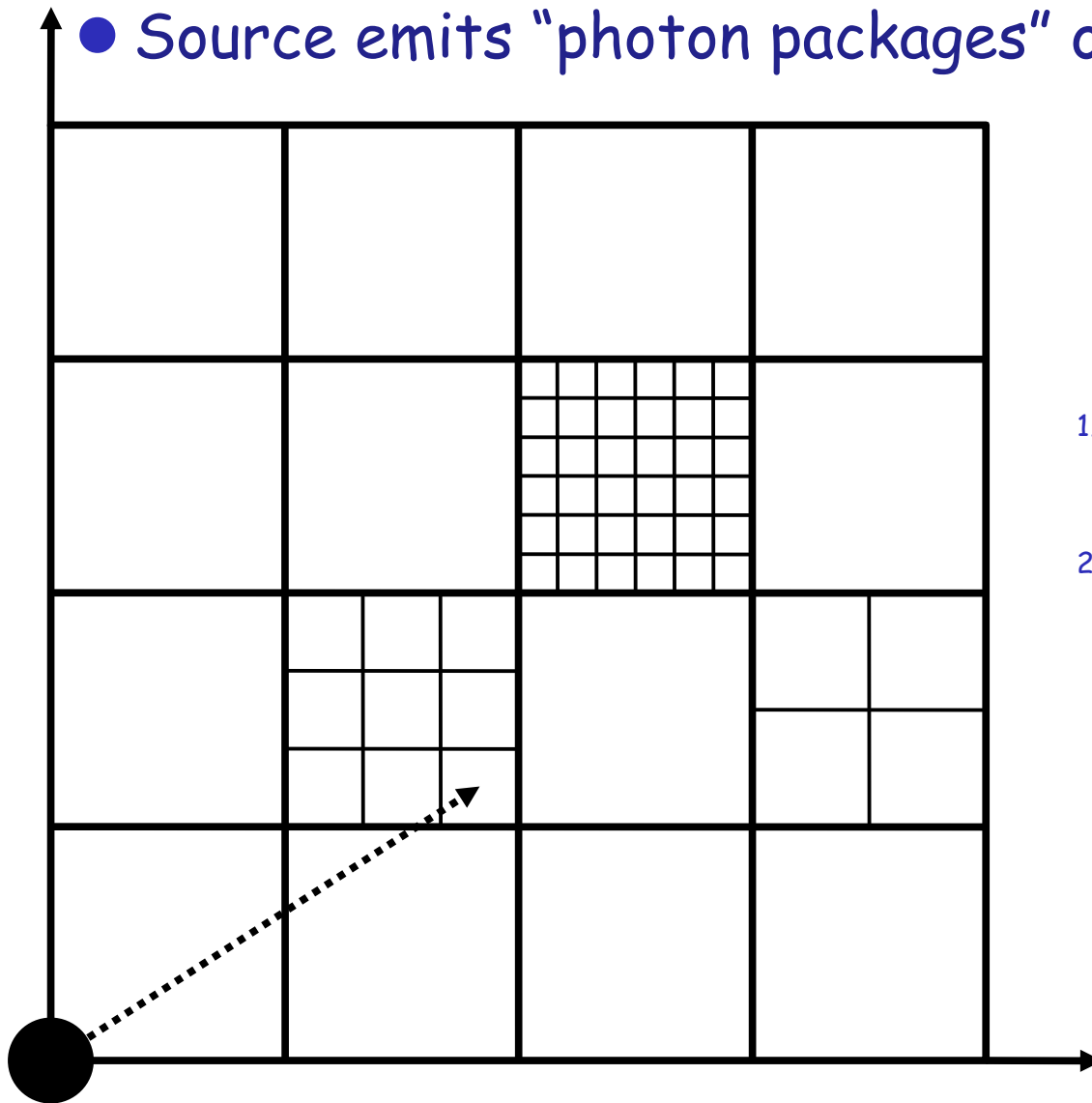


1. Geometry:

- Arbitrary dust distribution
- Pseudo adaptive mesh important for clumps

3D Monte Carlo radiative transfer

- Source emits "photon packages" of equal energy



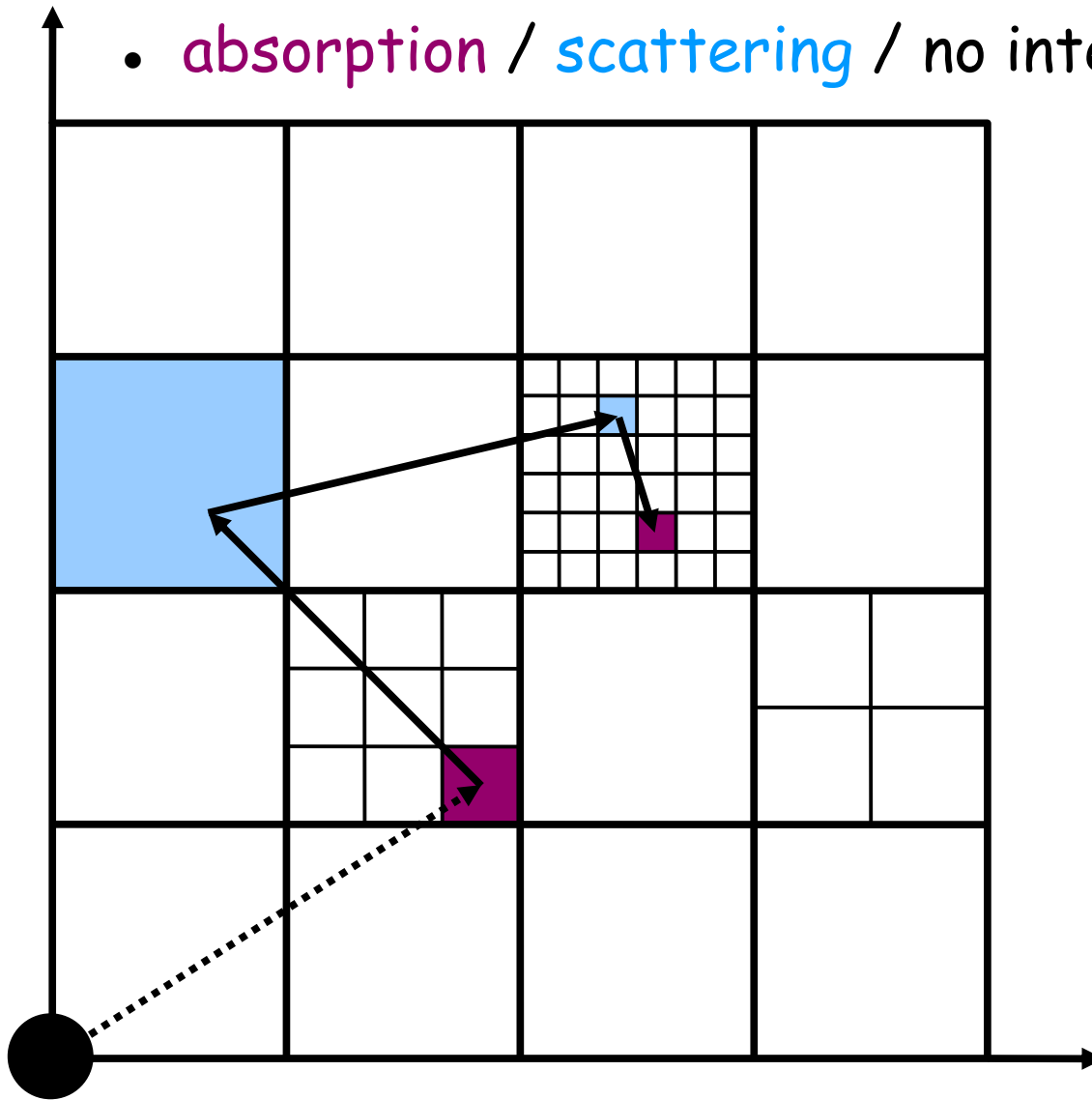
1. Geometry

2. Source

3D Monte Carlo radiative transfer

- absorption / scattering / no interaction

$$\tau = -\ln(\zeta)$$



1. Geometry
2. Source
3. Inter-action
4. Dust temperature

3D Monte Carlo radiative transfer

- Photons escape model cloud

1. Geometry

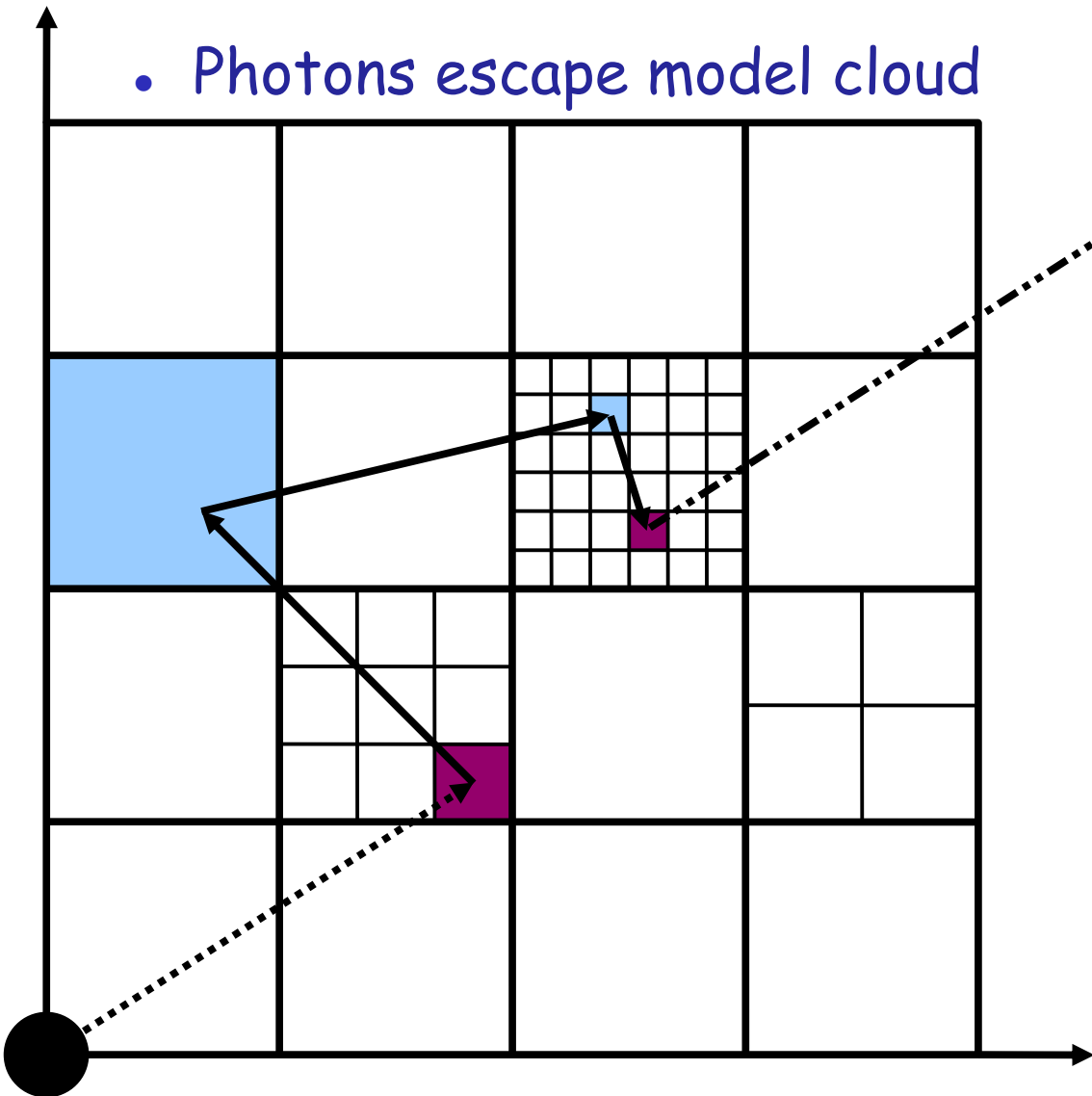
2. Source

3. Inter-action

4. Dust temperature

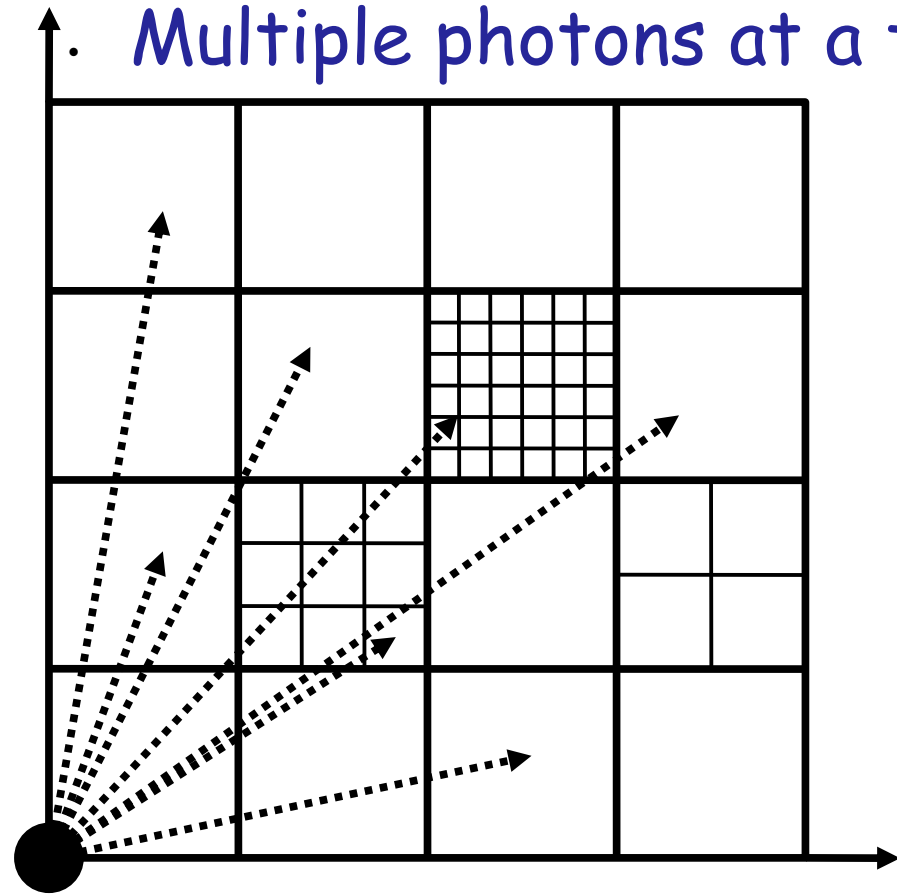
5. Detection

Time as 4th dimension
(Light echo's)



Vectorised 3D Monte Carlo

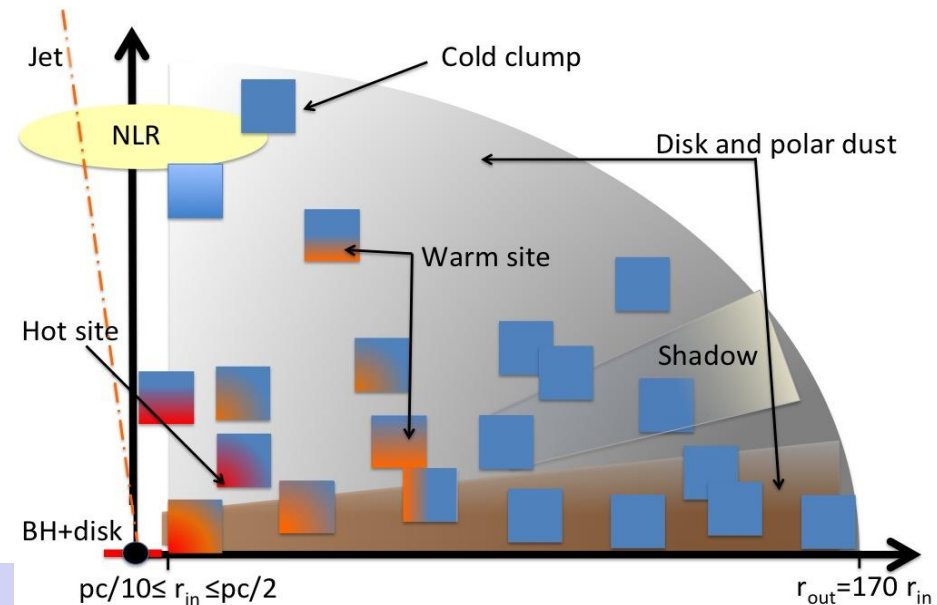
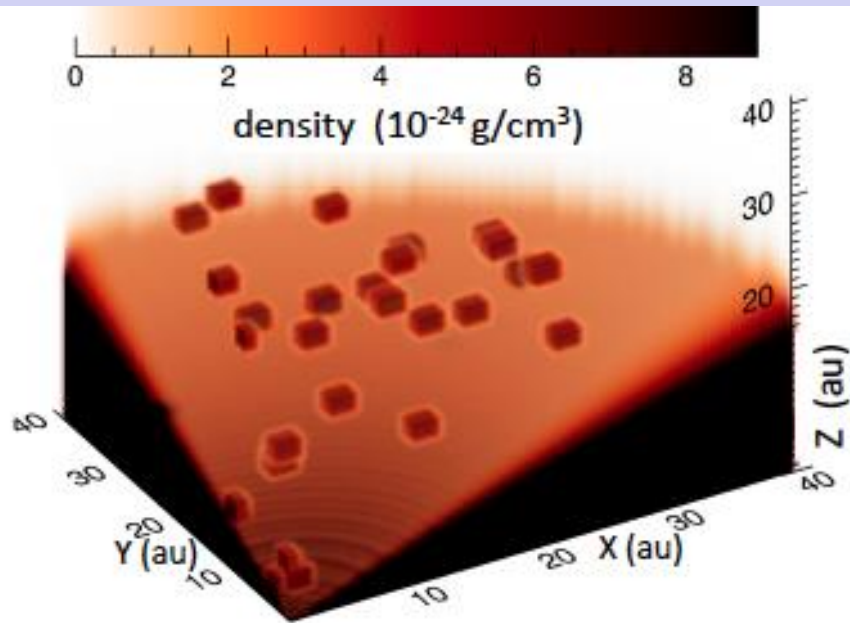
• Multiple photons at a time → faster !



Challenges:

- ❖ Cell locked when hit by photon
- ❖ Parallel random number generator (Mersene Twister)
- ❖ Graphical Processing Units (CUDA)

Dust density distribution

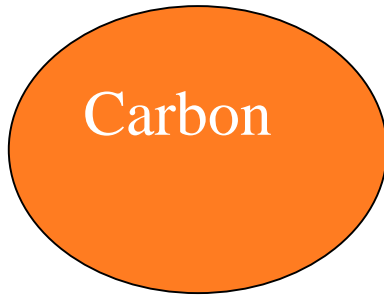


ISM dust \longleftrightarrow fluffy grains



Draine 2011, Feltre et al 2012, Jones et al. 2014, Siebenmorgen et al. 2014

ISM dust \longleftrightarrow fluffy grains

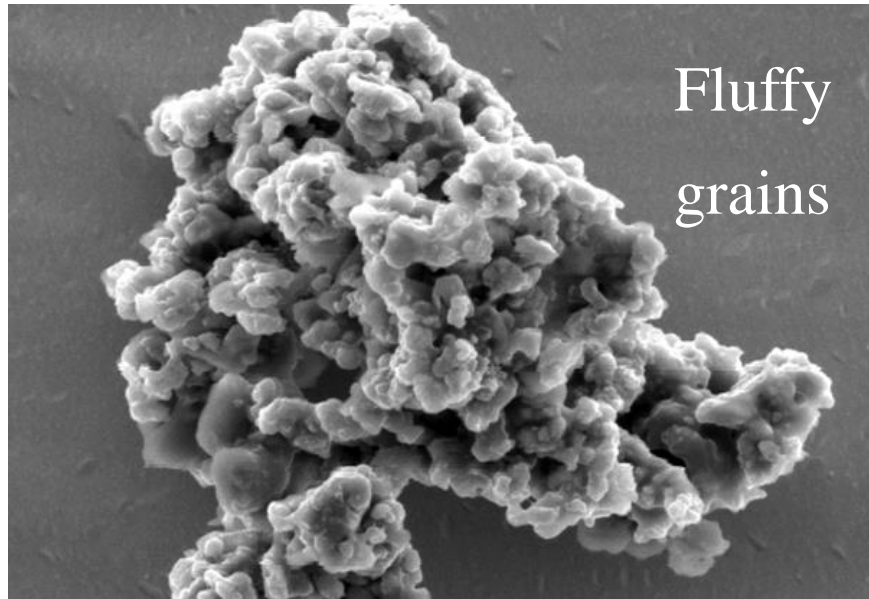


+



diffuse ISM
 $n \sim 1 \text{ atom/cm}^3$

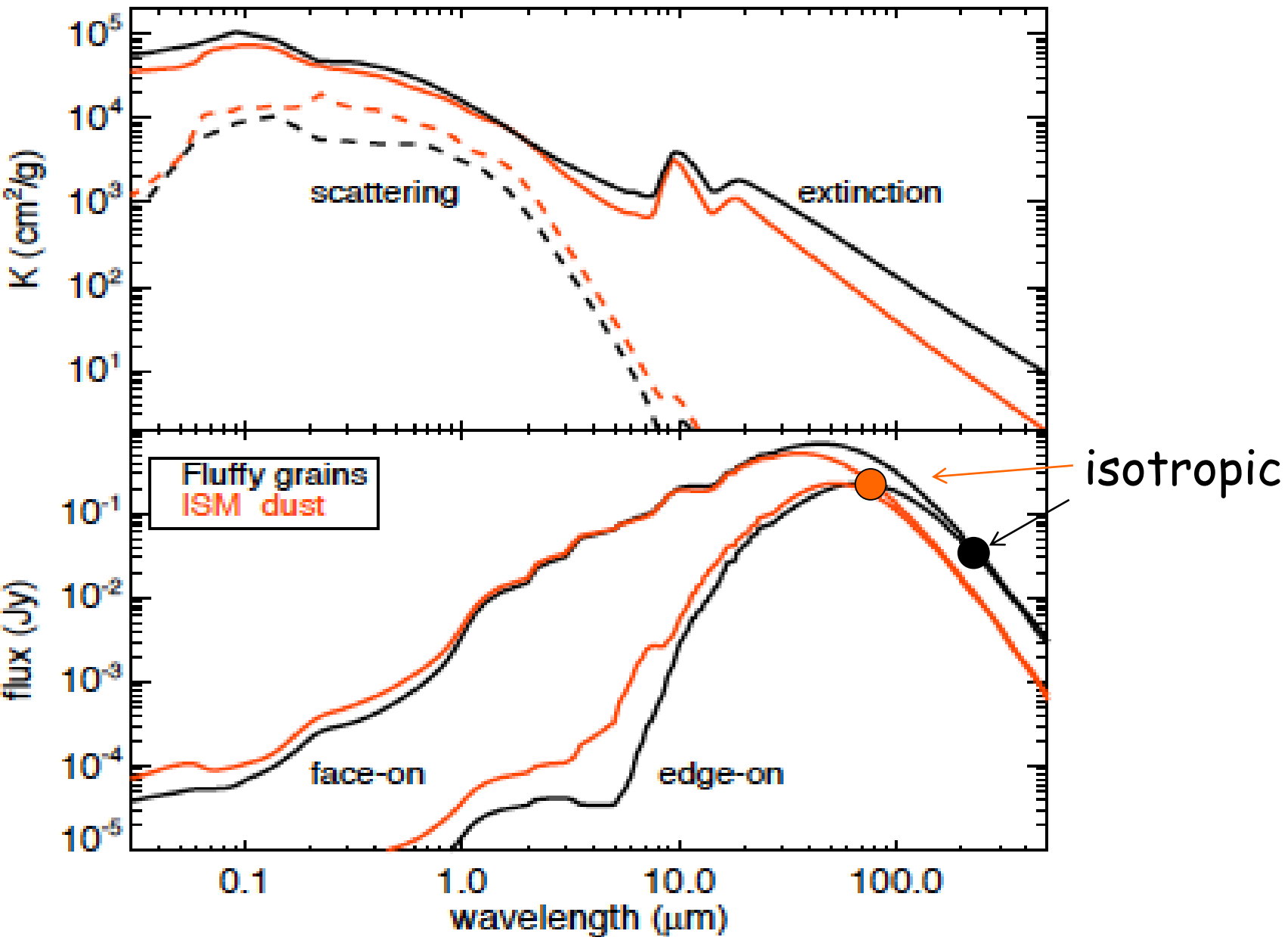
Draine 2011, Feltre et al 2012, Jones et al. 2014, Siebenmorgen et al. 2014



AGN dust
 $n \sim 10^{2...6} \text{ atom/cm}^3$

Krügel & Siebenmorgen 1994

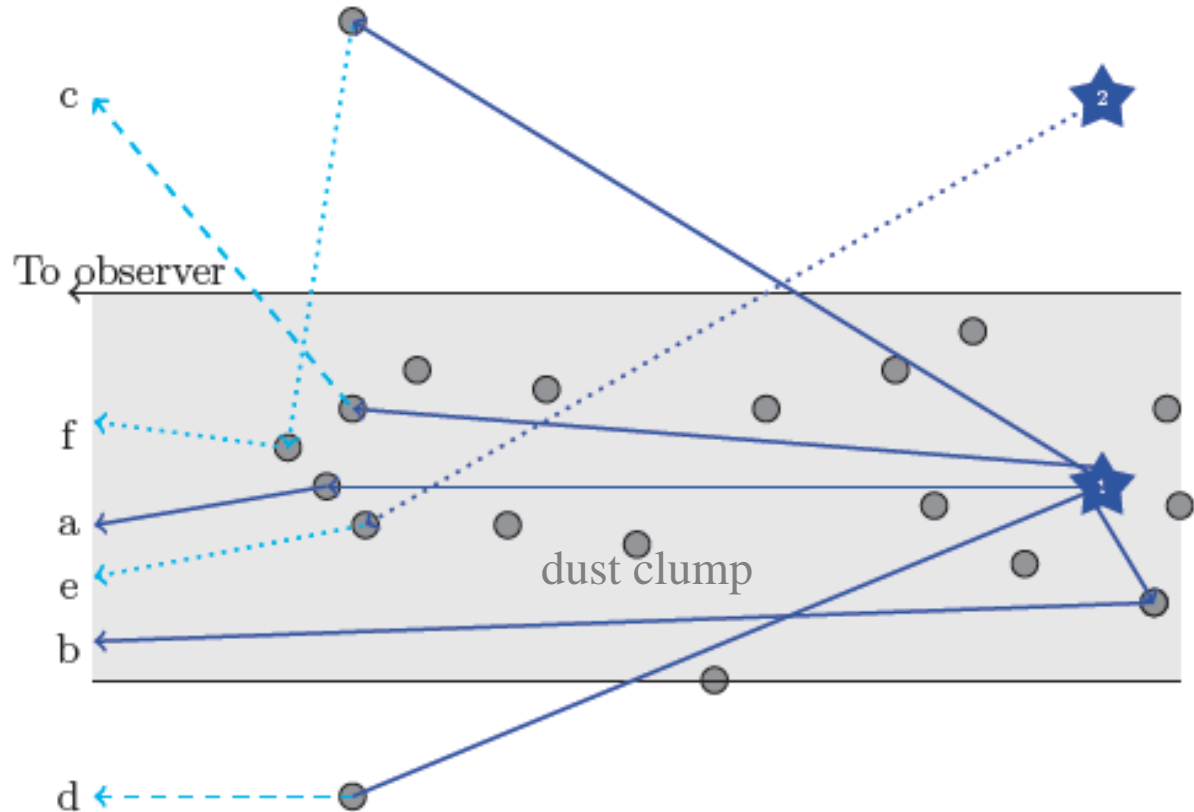
ISM dust \longleftrightarrow fluffy grains



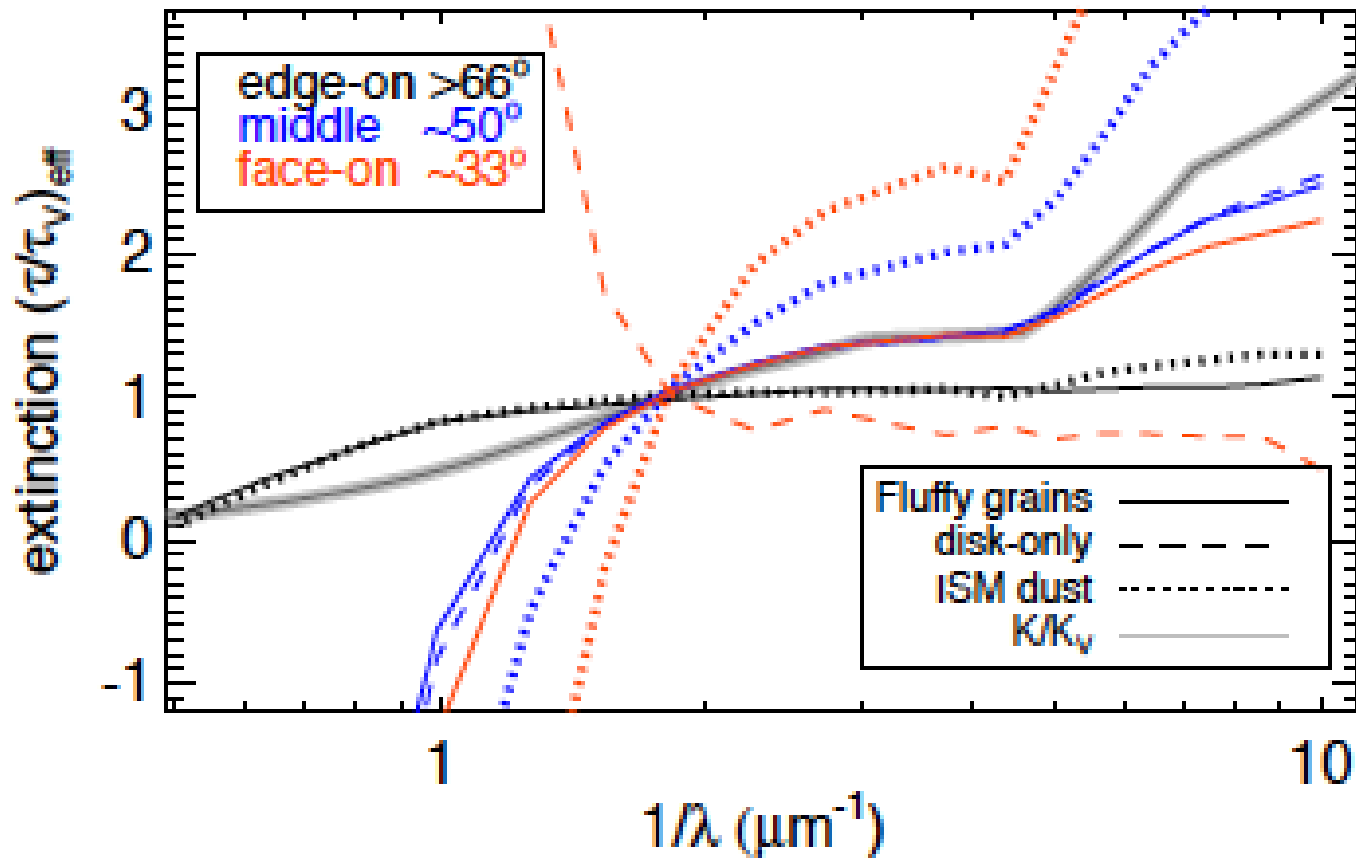
Caveat on extinction measurements

Scattering in or out-of-the beam

$$\tau_{\text{eff}} = - \ln \frac{F_{\text{obs}}}{F_{\text{nd}}}$$



AGN torus extinction \longleftrightarrow viewing angle



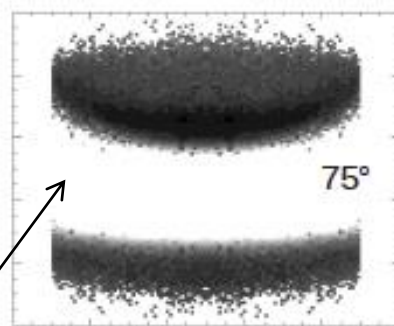
-> No 1:1 link to dust properties !

AGN imaging

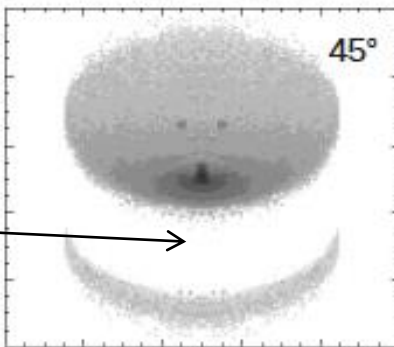
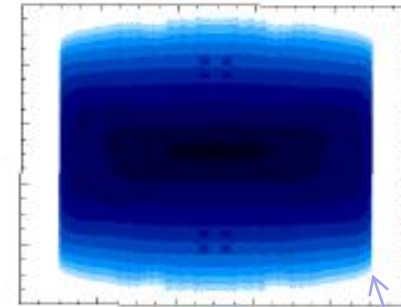
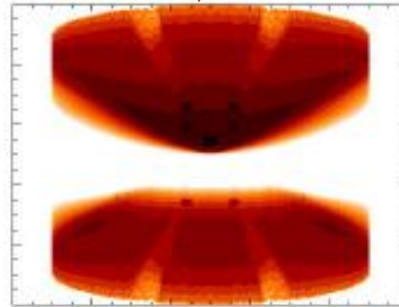
polar dust



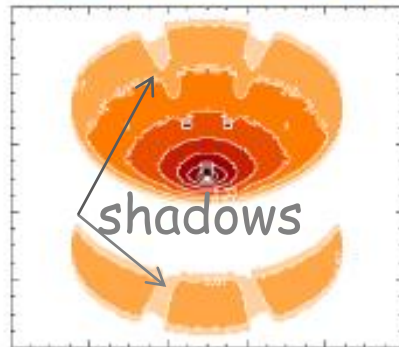
edge-on



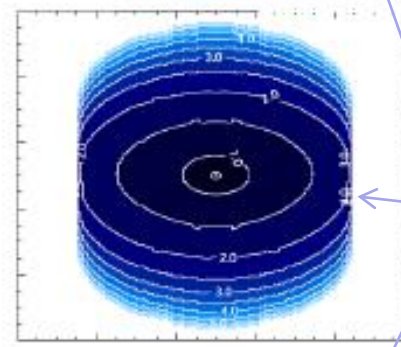
75°



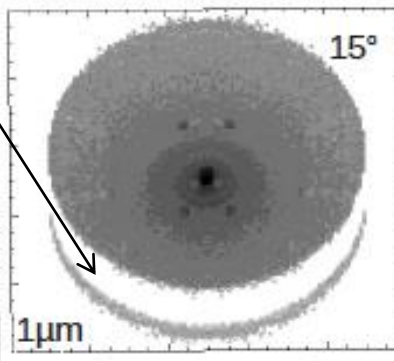
45°



shadows

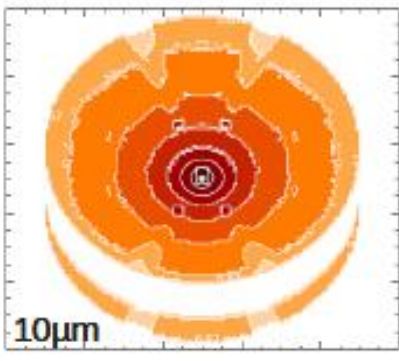


isotropic

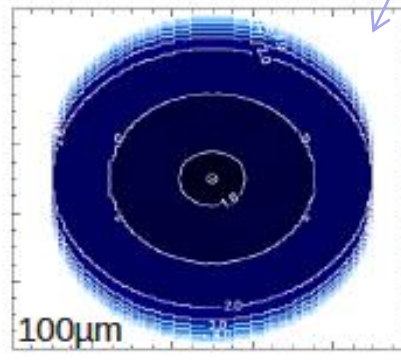


15°

1μm



10μm



100μm

face-on

SED library of AGN

Minumum set of 5 free parameters

1) Viewing angle

2) Inner radius

3) Cloud filling factor

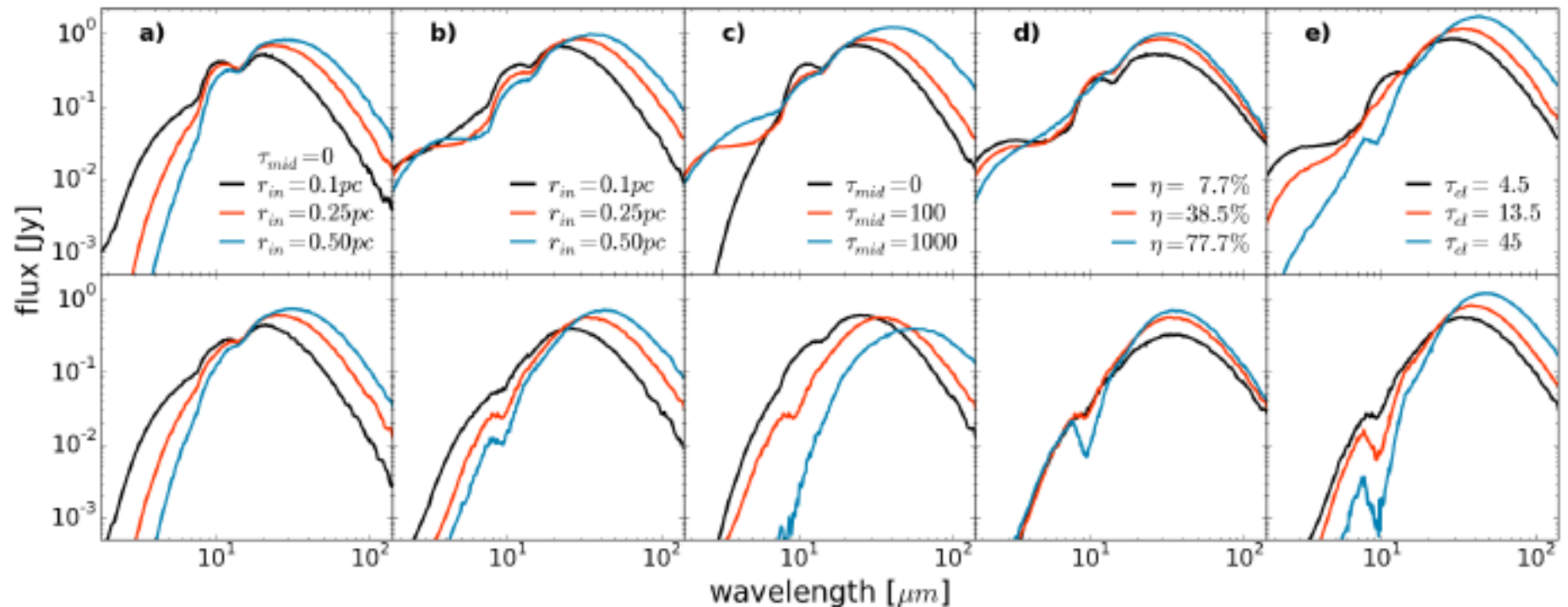
4) Optical depth of clouds

5) Optical depth of disk midplane

Library includes ~3600 SEDs

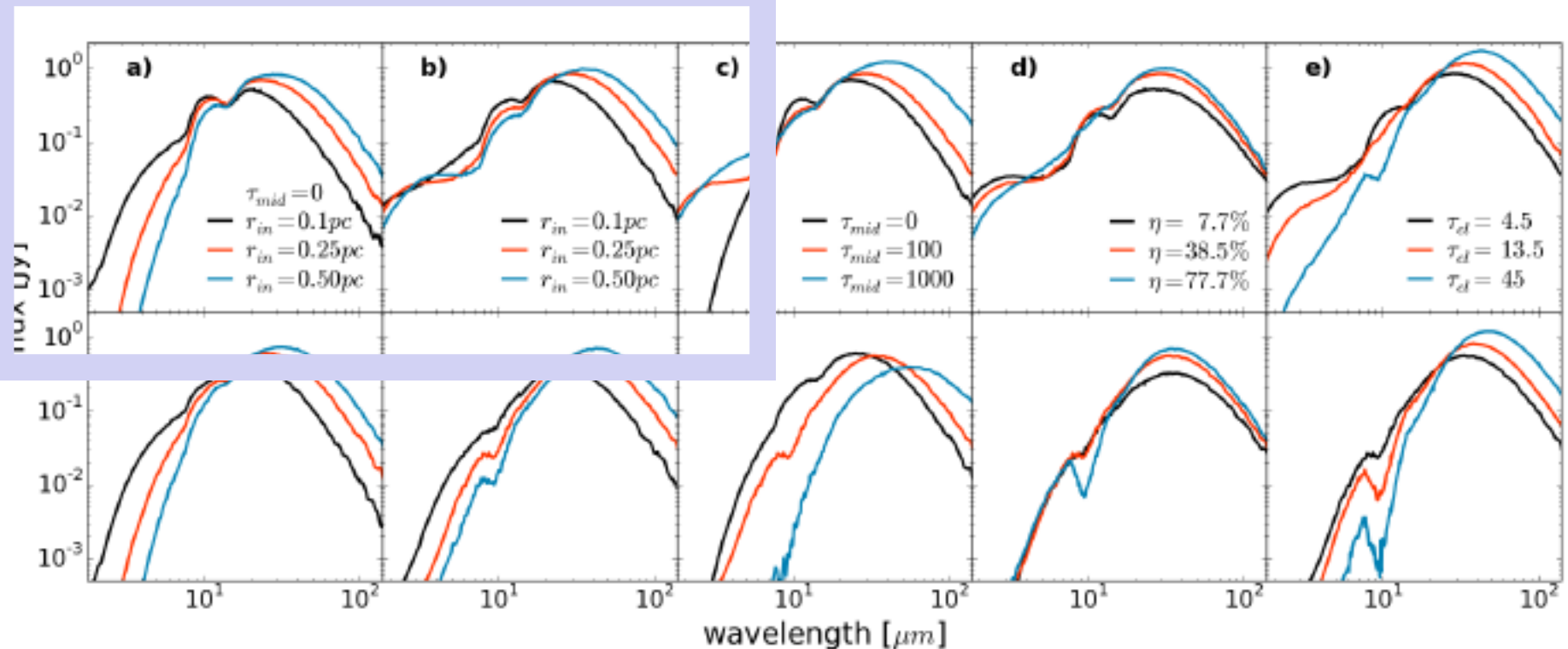
Impact of AGN parameters on SED

Ralf Siebenmorgen et al.: Self-consistent clumpy AGN torus models: SED library for observers

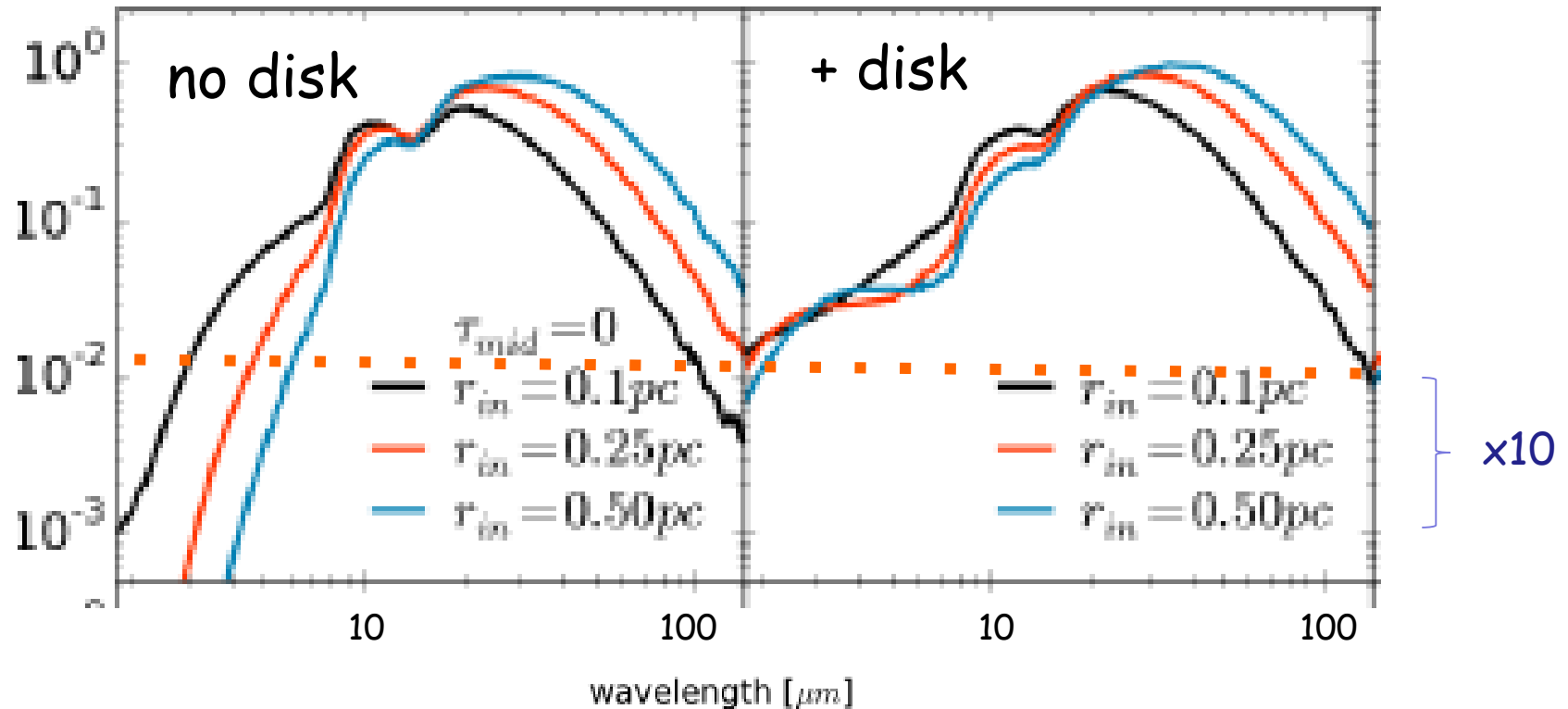


Impact of AGN parameters on SED

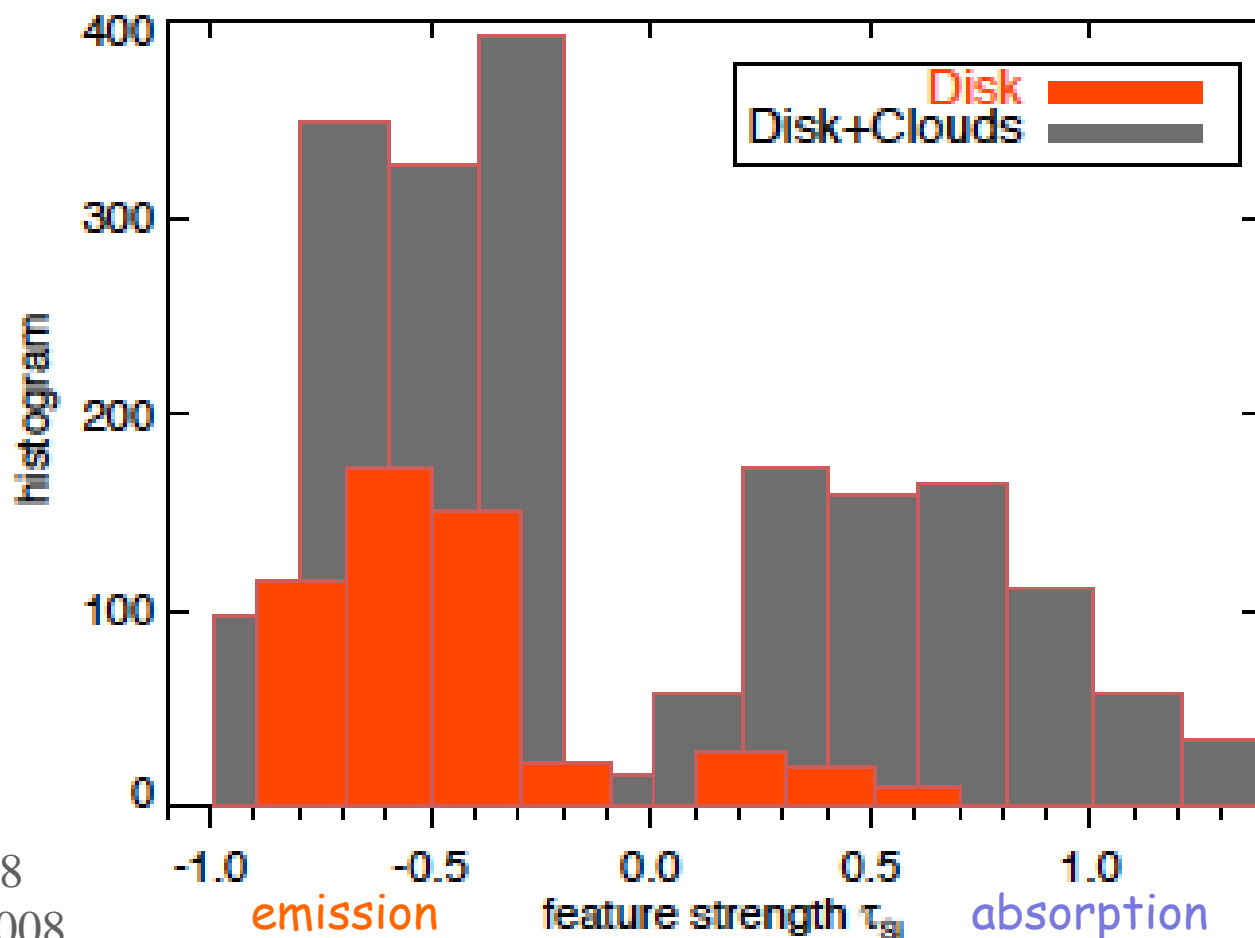
Ralf Siebenmorgen et al.: Self-consistent clumpy AGN torus models: SED library for observers



NIR flux enhanced by disk



Strength of the 10 μ m silicate band

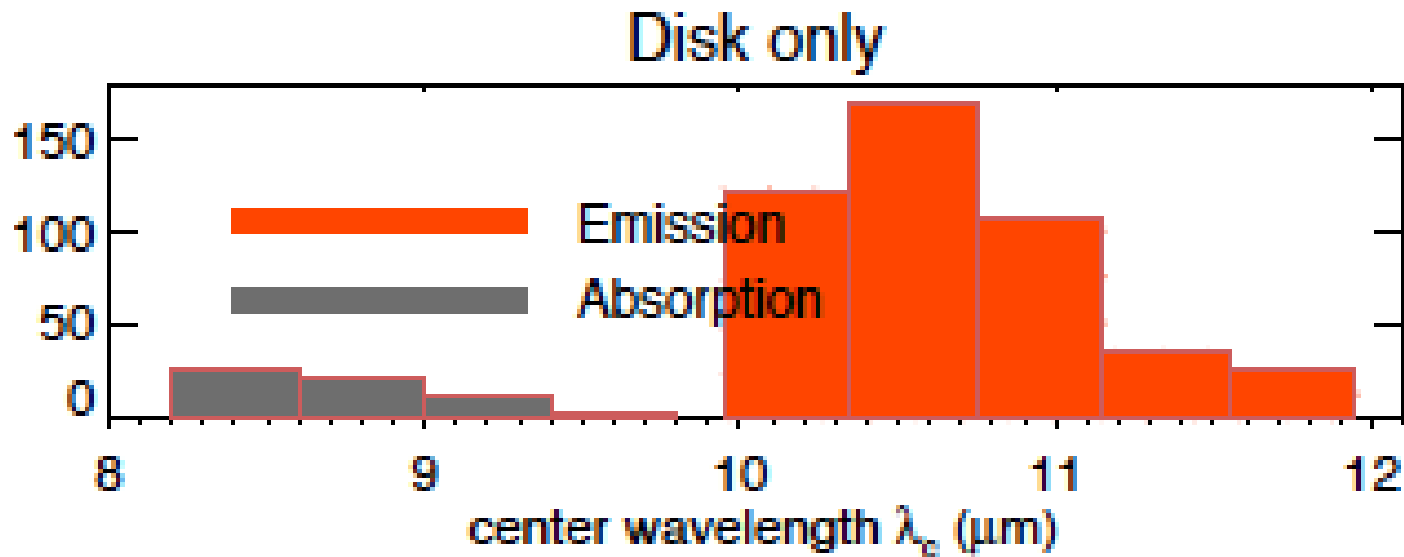
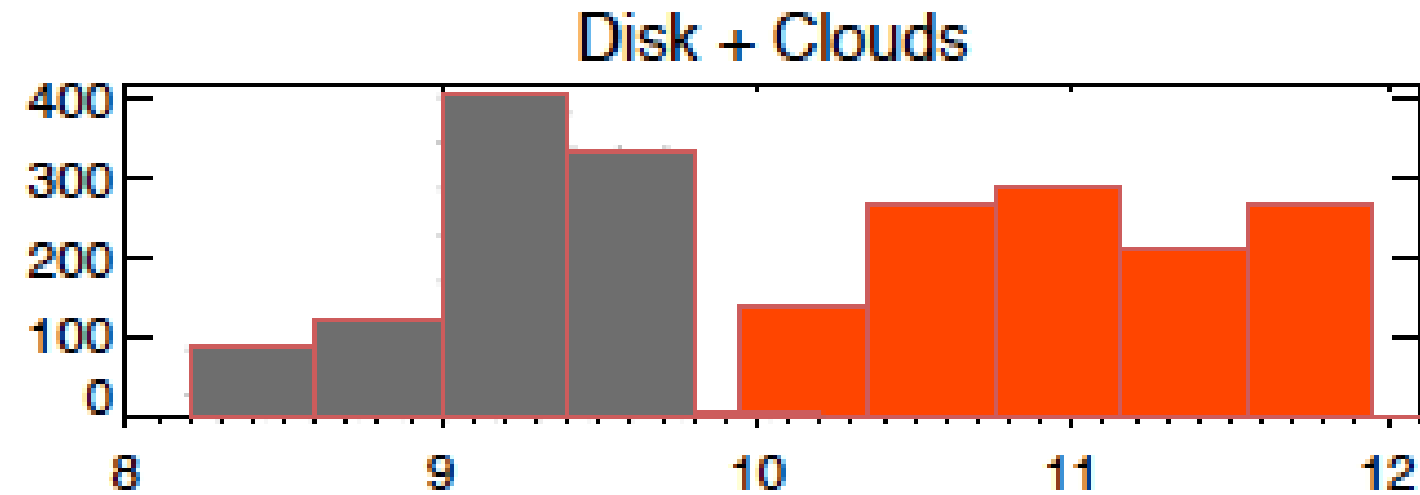


Levenson et al. 2008
Schartmann et al. 2008
Sirocky et al. 2008
Thompson et al. 2009
Hatziminaoglou et al. 2015

$$\tau_{Si} = - \ln \left(\frac{F_{\text{peak}}}{F_{\text{cont}}} \right)$$

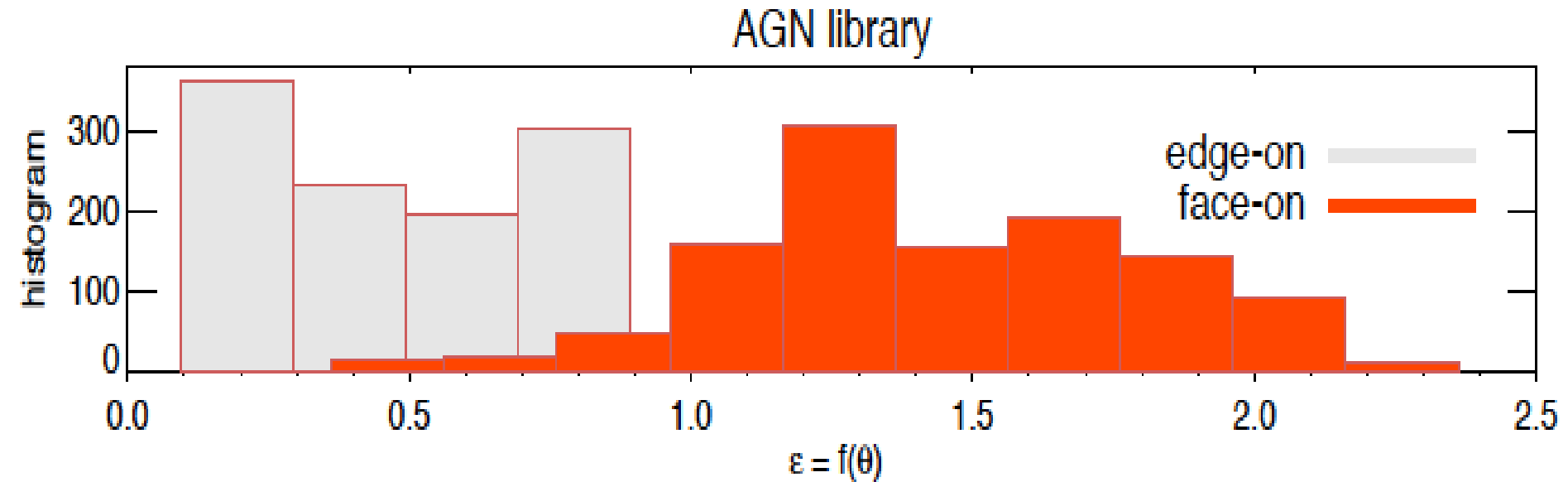
Siebenmorgen et al. (2015)

Center wavelength of the 10 μ m feature



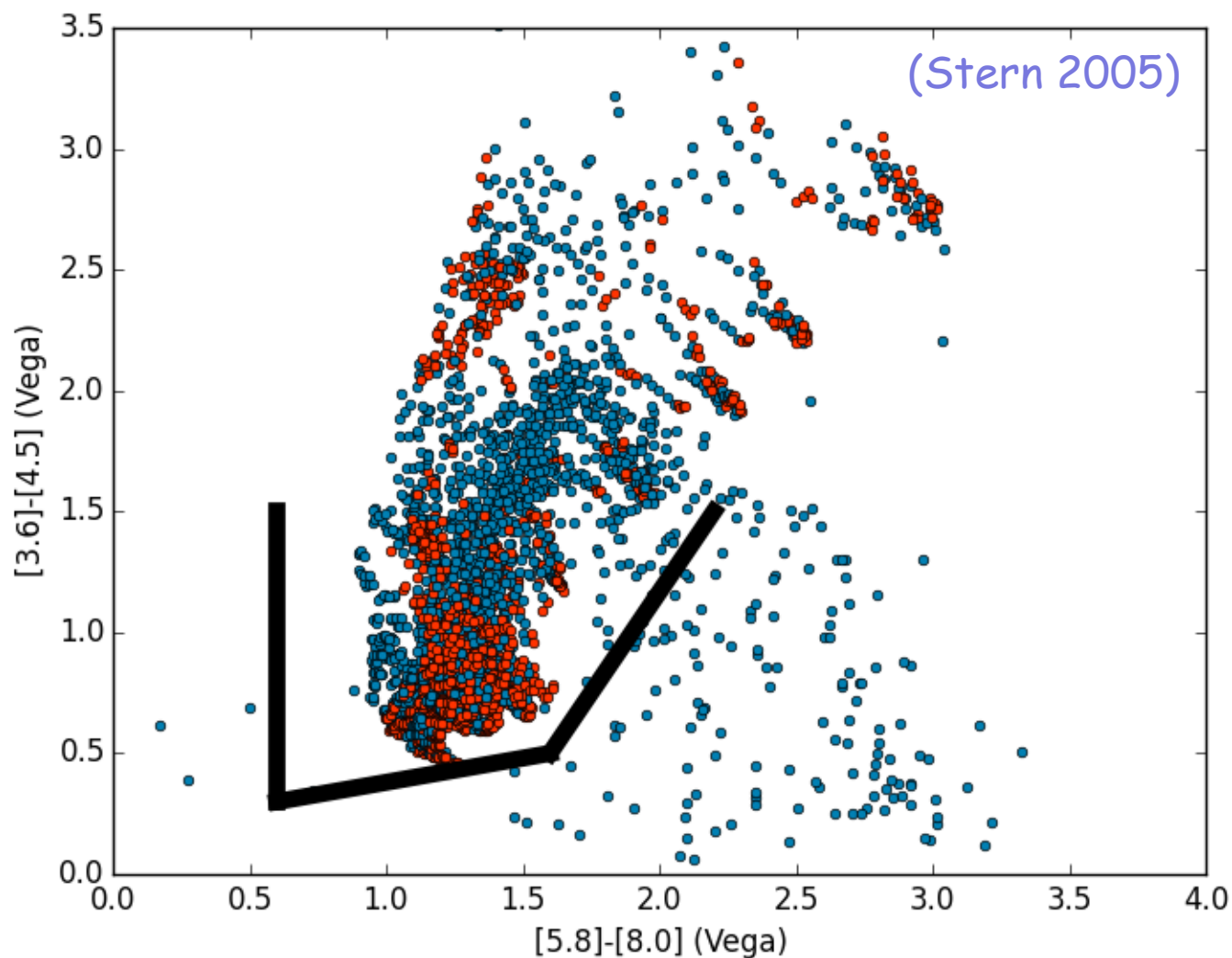
Intrinsic AGN luminosity L_{AGN}

$$\epsilon = \frac{F(\theta)}{F_{\text{nd}}} = \frac{L_{\text{obs}}(\theta)}{L_{\text{AGN}}/9}$$

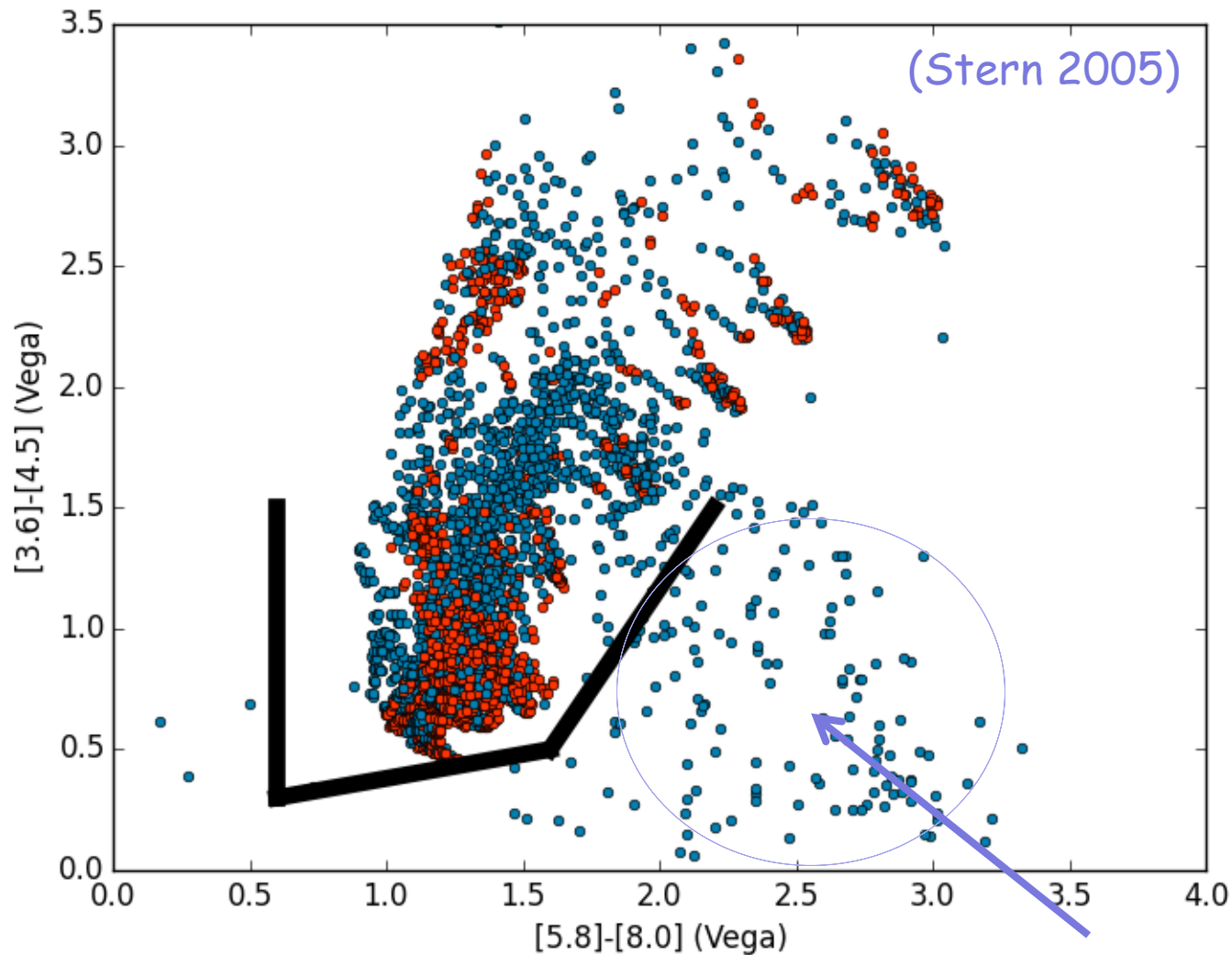


Assuming isotropic AGN emission (Stalevski et al. 2012)

SED Library \leftrightarrow IRAC colors of AGN

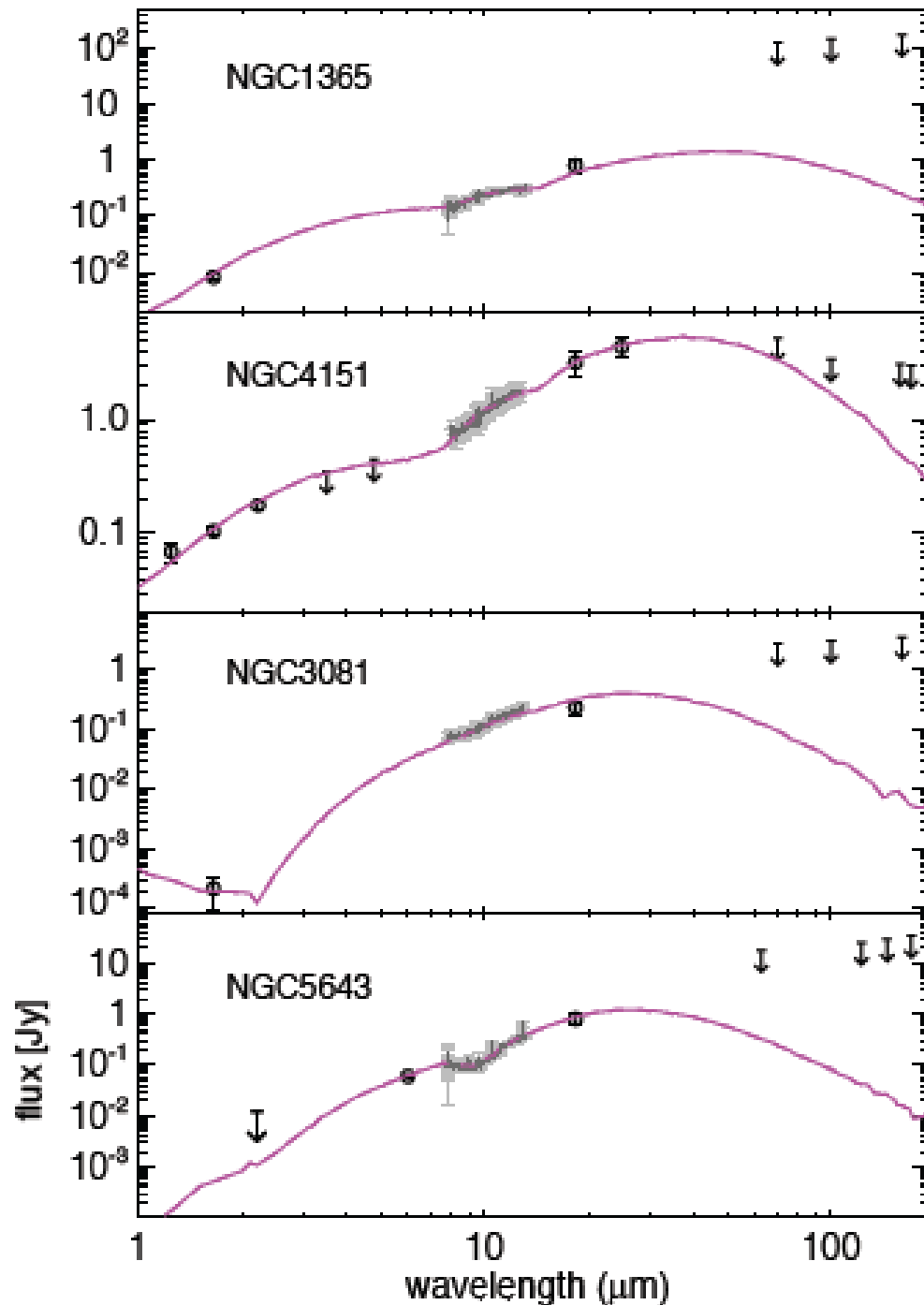


SED Library \leftrightarrow IRAC colors of AGN



edge-on, high extinction AGN

Seyferts



Ground based MIR:

Alonso Herrero et al 2011

Gonzales- Martin et al 2013

Esquej et al. 2014

Ruschel-Dutra et al 2014

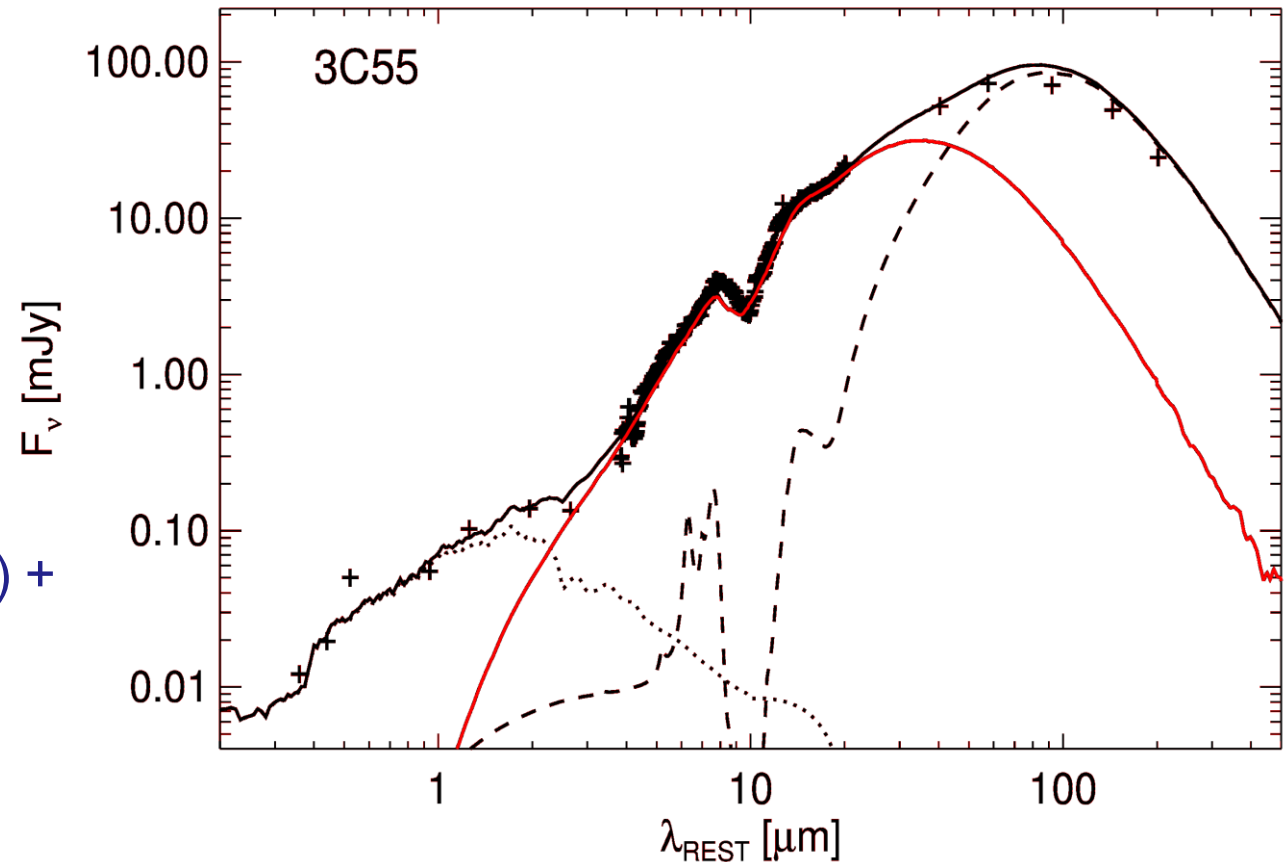
Ichikawa et al 2015, ...

Herschel+Spitzer sample of 3C (z<1)

- 87 detection (Westhues '16)
- **Silicate absorption**
6 with $\tau_{\text{Si}} > 1$

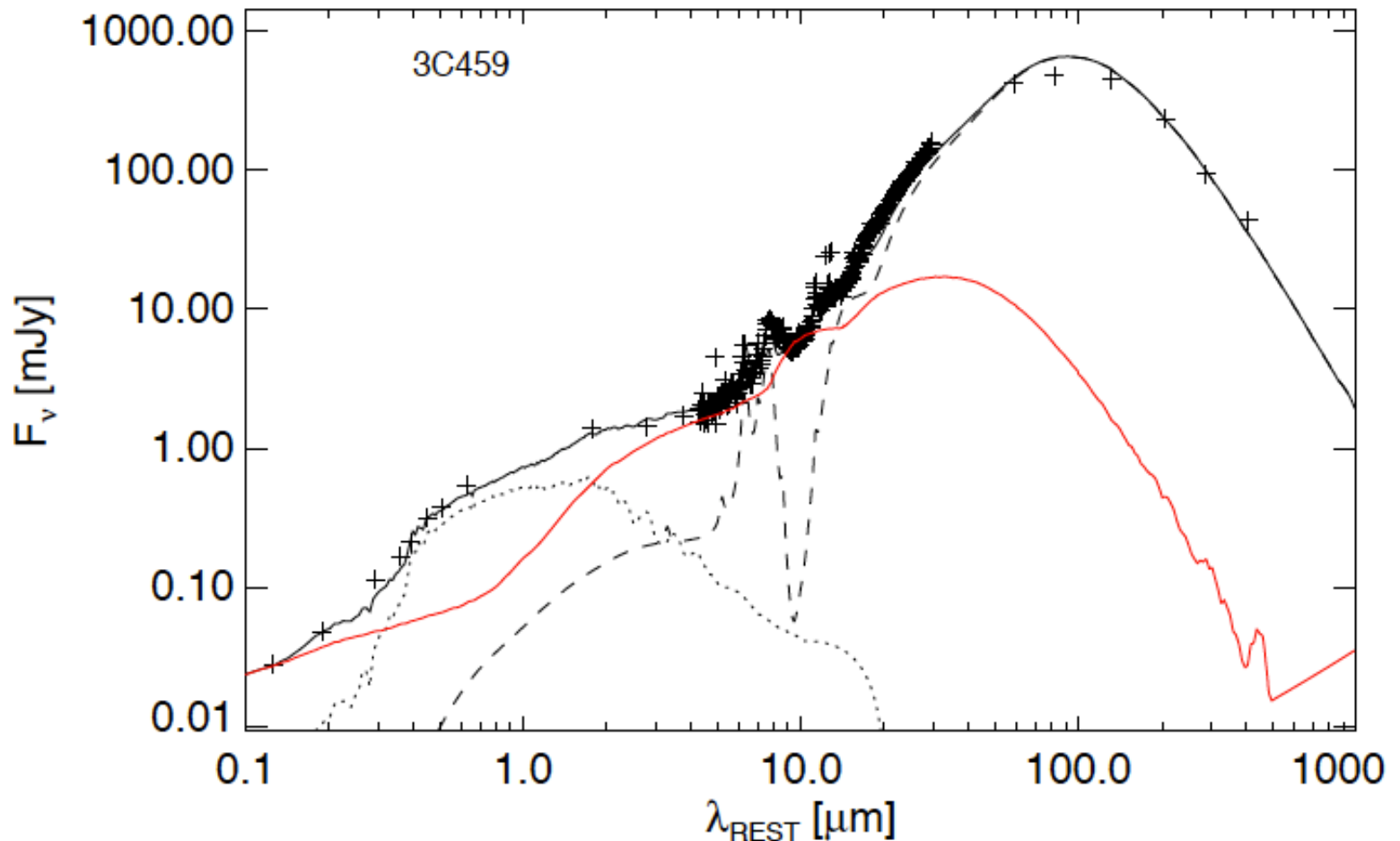
Bayesian fit:

- Host (Bruzal'03) +
- AGN +
- Starburst



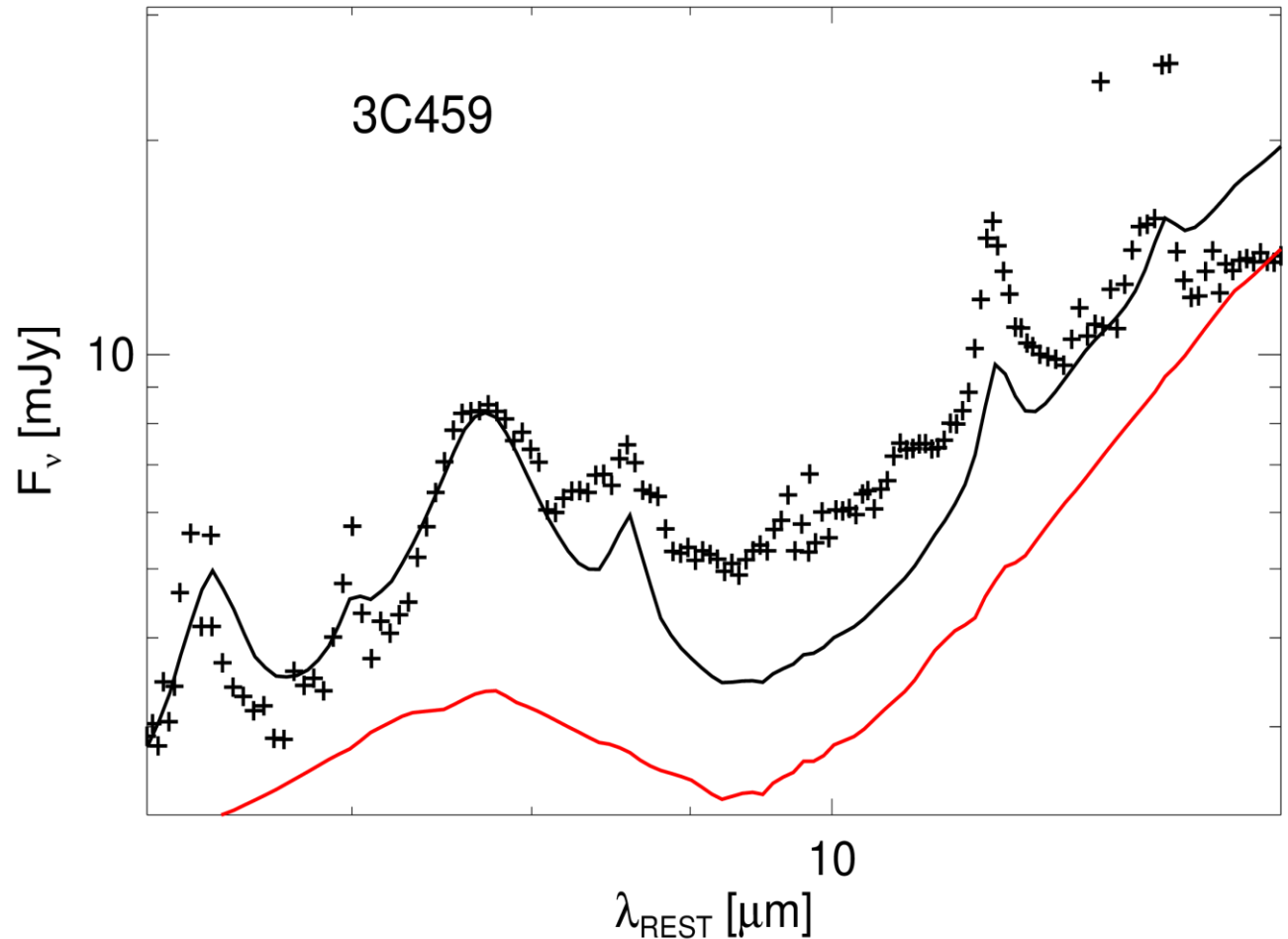
Herschel+Spitzer sample of 3C ($z < 1$)

- 87 detection (Westhues '16)
- **2 with PAH emission**

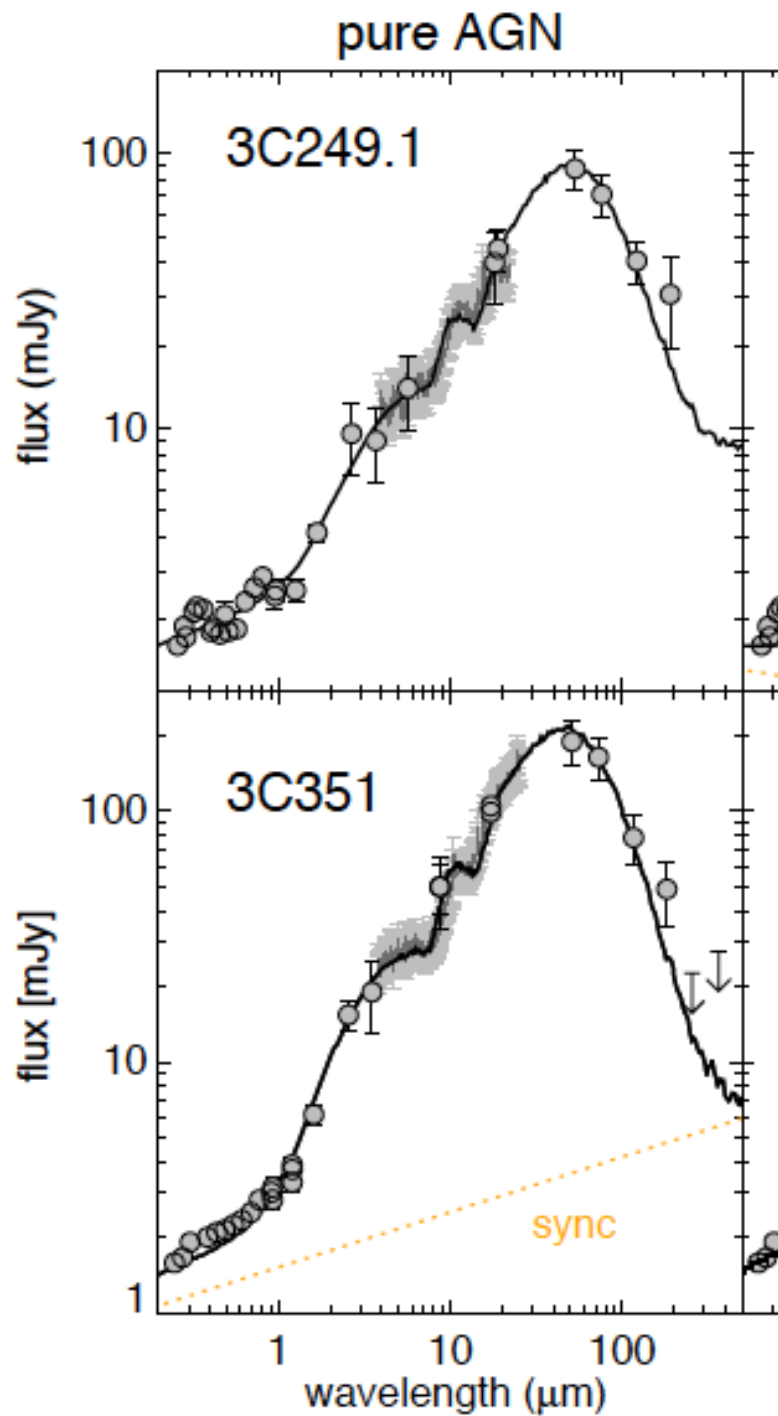


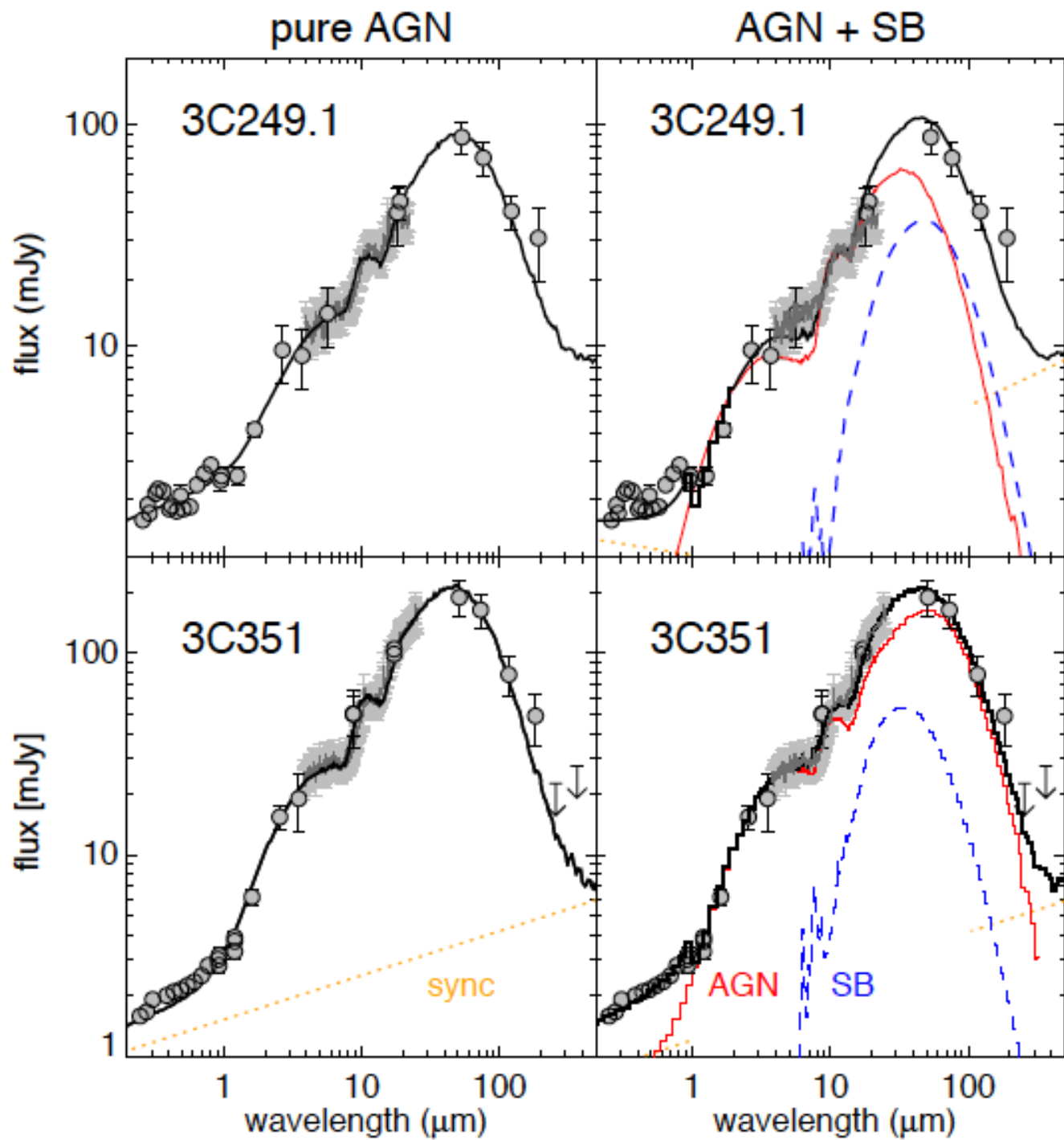
Herschel+Spitzer sample of 3C ($z < 1$)

- 87 detection (Westhues '16)
- **2 with PAH emission**

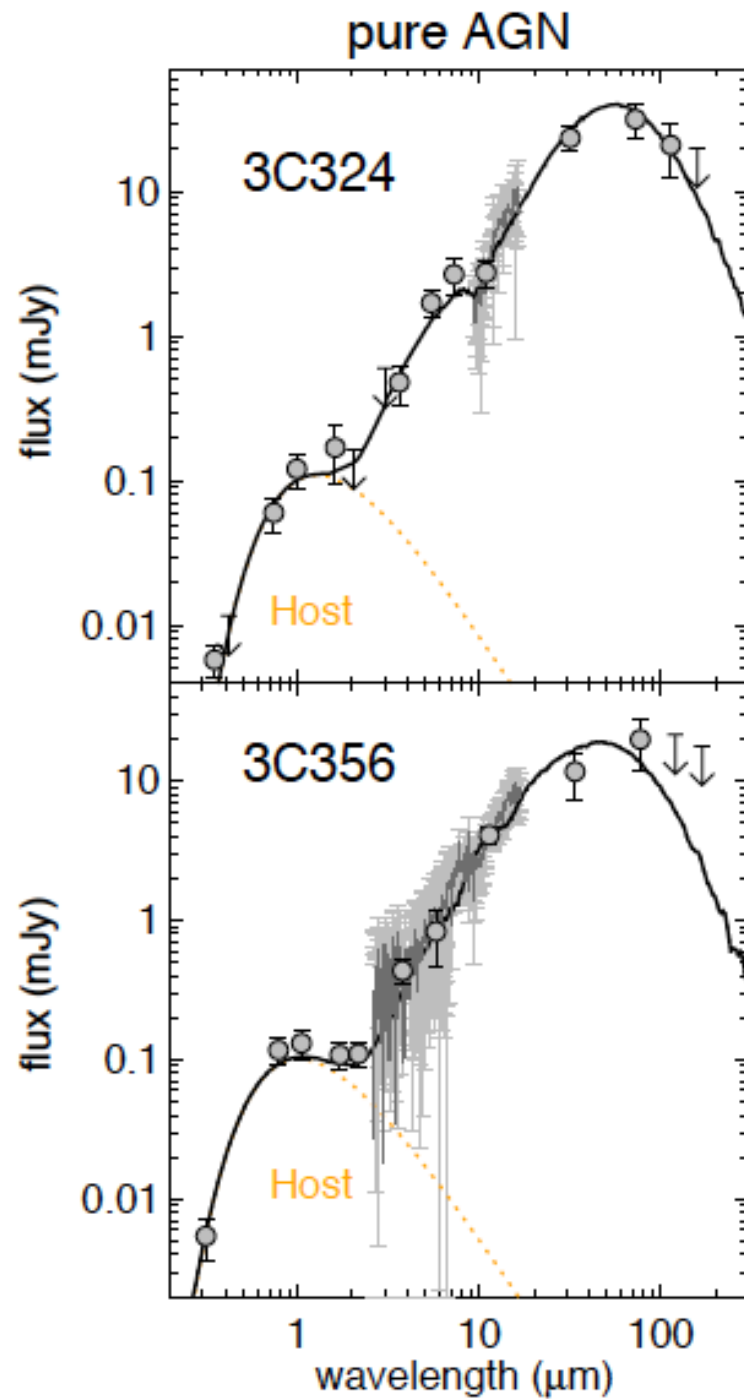


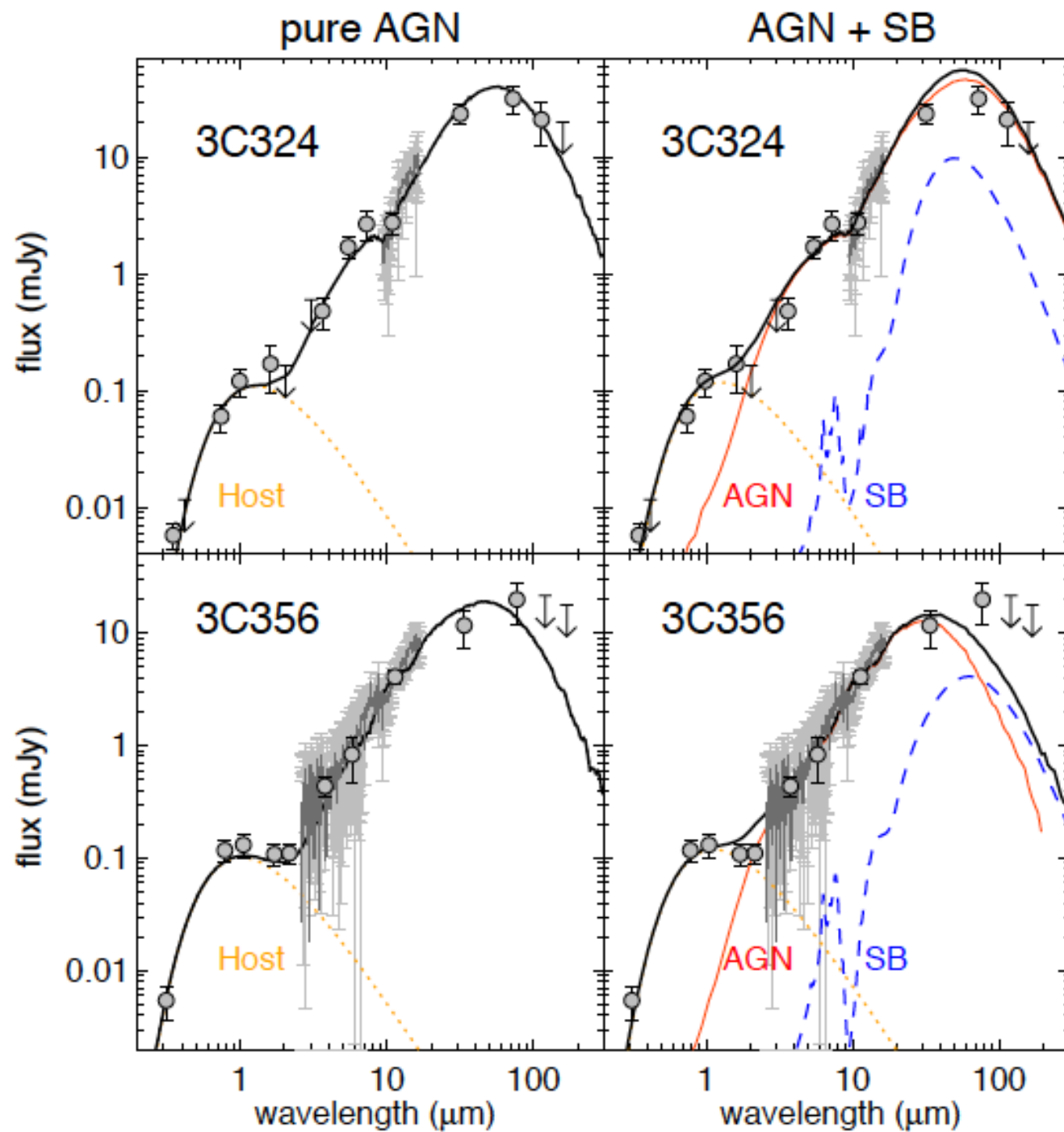
Type I



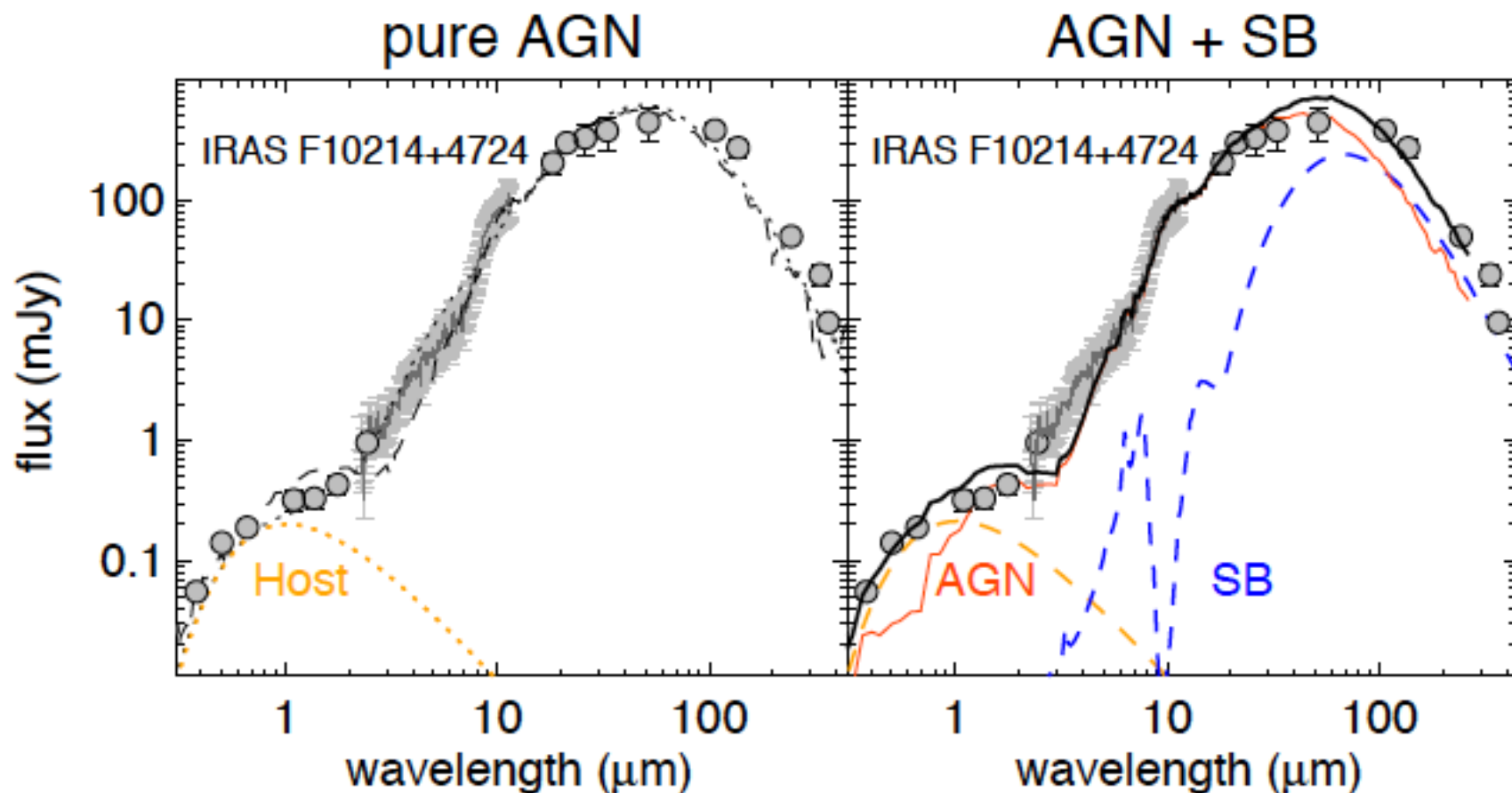


Type II





Hyper-luminous galaxy

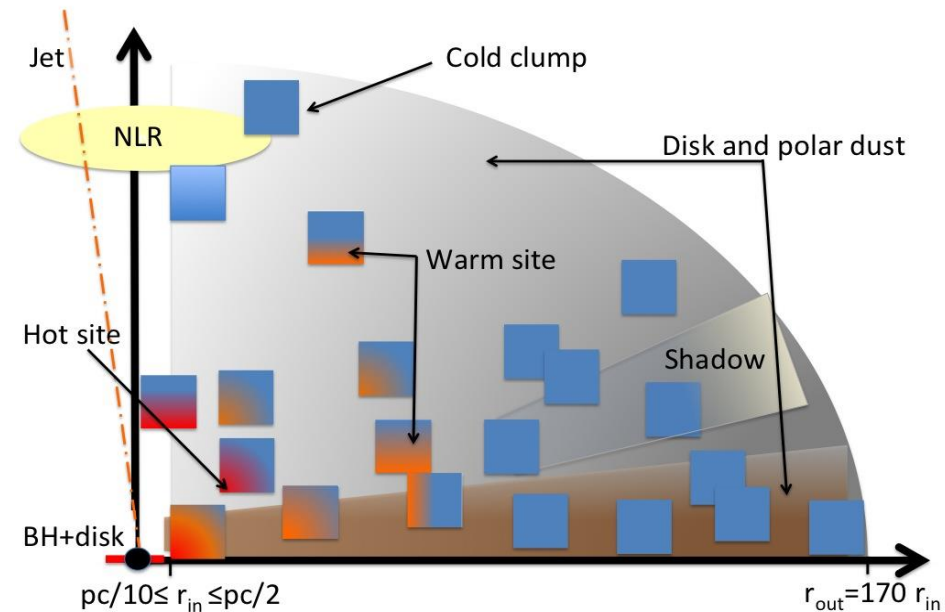


SED fitting methods: $\text{MCMC} \sim \chi^2$

Two-phase AGN tours model

SED library:

- 5 parameters
 - Fluffy grains
 - Estimate intrinsic L_{AGN}
 - $10\mu\text{m}$ silicate band
 - NIR: disk \leftrightarrow no disk
-
- Seyferts $\sim\rightarrow$ AGN + host
 - Type I+II $\sim\rightarrow$ pure AGN (SB $<10\%$)



www.eso.org/~rsiebenm/agn_models/

