Mid-infrared interferometry of AGNs:

A statistical view into the dusty nuclear environment of the Seyfert Galaxies

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General idea of the method

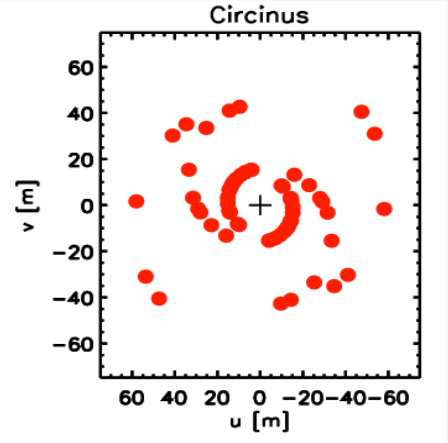
- **We try to find a reasonable description of an interferometric dataset using the Standard model idea** (line of sight effect + stochastic nature of torus models)

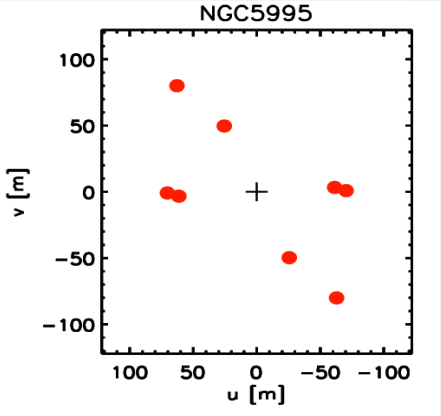
- **A direct comparisson** between the observed distribution of interferometric points with the model distribution (we characterize the distributions by their mean and variance)

- Aim of our work is to learn more about **general properties** than individual cases. **No individual fits**.

Why statistical approach?

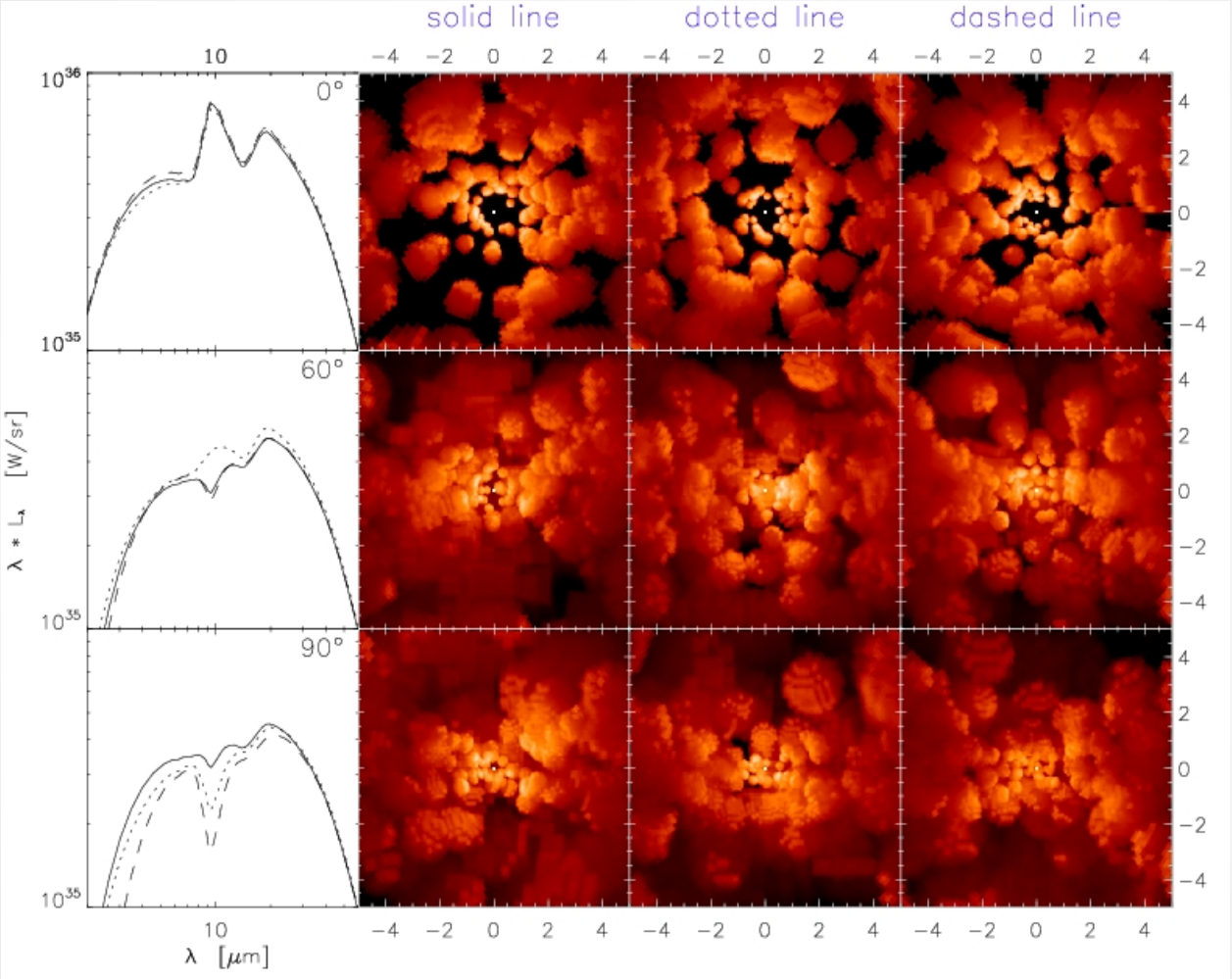
- **Uncertainty on the true position angle and inclination** produce additional degeneracy on individual fits.





- **Randomness of the cloud distribution** produce different images or SEDs for models with same parameters and inclination.

Why probabilistic?



Schartmann et al (2008)

Seyfert sample

Source	D [Mpc]	z	Type
I Zw 1	222	0.0589	Sy 1
NGC 424	44.7	0.0110	Sy 2
NGC 1068	14.4	0.0038	Sy 2
NGC 1365	18.1	0.0055	Sy 1
IRAS 05189-2524	167	0.0426	Sy 2
H 0557-385	135	0.0339	Sy 1
IRAS 09149-6206	222	0.0579	Sy 1
MCG-05-23-16	38.8	0.0085	Sy 2
Mrk 1239	84.5	0.0200	Sy 1
NGC 3281	47.6	0.0107	Sy 2
NGC 3783	43.8	0.0097	Sy 1
NGC 4151	16.9	0.0033	Sy 1
NGC 4507	51.7	0.0118	Sy 2
NGC 4593	41.2	0.0090	Sy 1
ESO 323-77	64.2	0.0150	Sy 1
IRAS 13349+2438	393	0.1076	Sy 1
IC 4329 A	68.3	0.0161	Sy 1
Circinus	4.2	0.0014	Sy 2
NGC 5506	28.7	0.0062	Sy 2
NGC 5995	102	0.0252	Sy 2
NGC 7469	60.9	0.0163	Sy 1

- Data collected from MIDI Large Program (Burtscher et al. 2013). **Inhomogeneous flux-limited sample**.
- **Only Seyfert Galaxies**, we exclude Cen A and 3C 273
- **21 sources** with observations from at least 3 different baselines.
- Average measurements at 8.5, 10. , 12.5 um.

Torus setup

INPUT PARAMETERS	
Parameter	Values
Bolometric luminosity accretion disk (L_{disk})	$1.2 \times 10^{11} L_{\odot}$
Inner radius of the torus (R_{in})	0.4 pc
Constant of clump size distribution (a_0)	0.2 pc
Radial profile density exponent (α)	$-2, -1.5, -1, -0.5, 0$
Radial extension	25, 50, 75, 100 R_{in}
Half opening angle (θ_{open})	30°, 45°, 60°
Total average $\tau_{9.7}$ along the equator ($\langle\tau_{9.7}\rangle_{\phi}$)	1, 2, 4, 8, 16
Filling factor at inner rim	0.4, 1.4, 5.3, 20, 40 %
Number of realizations	10
Lines of sight per realization	
Type I:	10
Type II:	10
Distribution of inclination angles	Uniform in a sphere

We follow a similar approach as Schartmann, et al.(2008). **Wedge-like torus filled with clouds**

Clouds randomly distributed following a powerlaw distribution $\rho_r = \rho_0 (r/1\ \mathrm{pc})^{\alpha}$

Cloud radius grow linearly with distance $a_{cl} = a_0 (r/1\ \mathrm{pc})$

Clouds are homogeneously filled with dust.

Filling factor defined as the fraction of the total volume that is filled with dust

Sublimation of dust grains implemented.

Main results

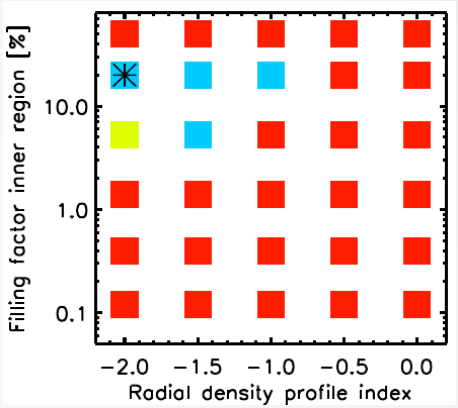
- **Full set** (including Type I and Type II) **could not be explained** by using a fixed parameter set.

- **Good agreement between subsets** (divided by Seyfert Type) **and models**.

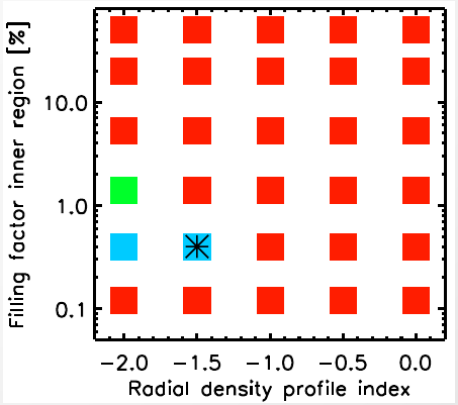
- Main difference: the fraction of space filled with clouds

BEST FIT VALUES		
Type I parameters	Acceptable area	Best fit
Radial profile density exponent	≤ -1.5	-1.5
Radial extension [r_s]	Unconstrained	50
Opening angle [Deg]	Unconstrained	45
Total average $\tau_{9.7}$	≥ 8	16
Filling factor at inner rim [%]	[0.4 - 1.4]	0.4
Type II parameters	Acceptable area	Best fit
Radial profile density exponent	≤ -1	-2
Radial extension [r_s]	Unconstrained	100
Opening angle [Deg]	[45 - 60]	60
Total average $\tau_{9.7}$	≥ 8	16
Filling factor at inner rim [%]	≥ 5	20

Seyfert Type II



Seyfert Type I

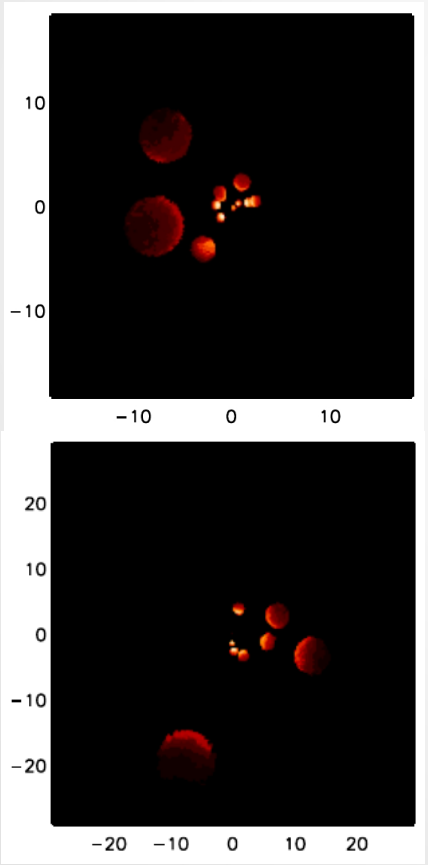


Confidence regions

What do the best fits look like?

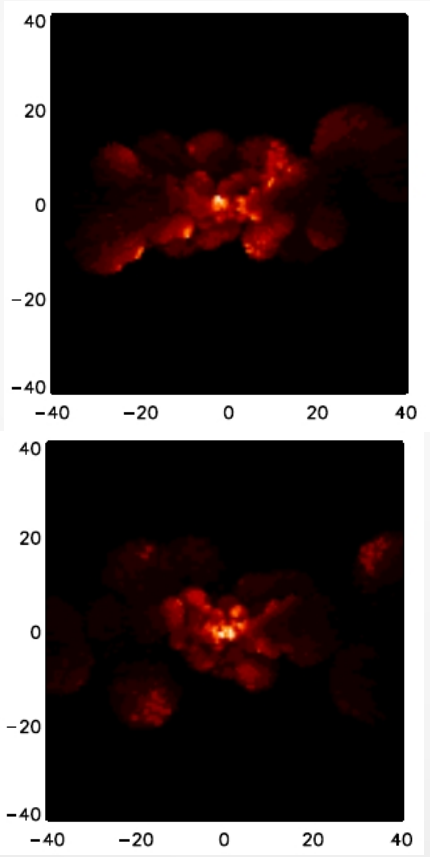
Best fit Type I

Model A

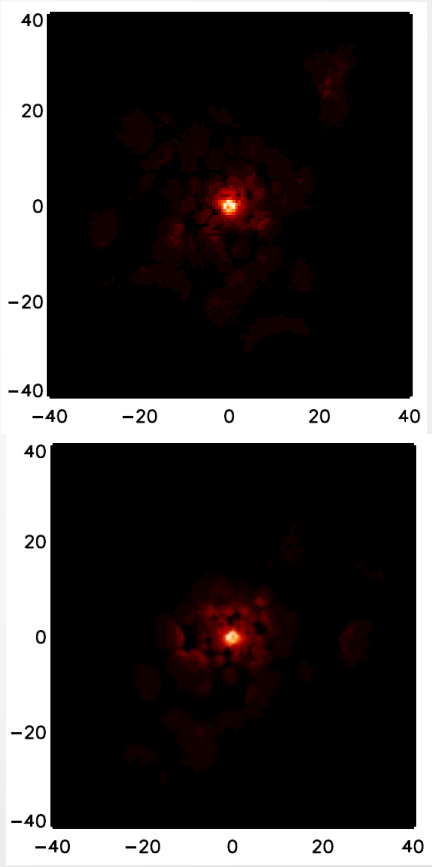


Best fit Type II

Model B



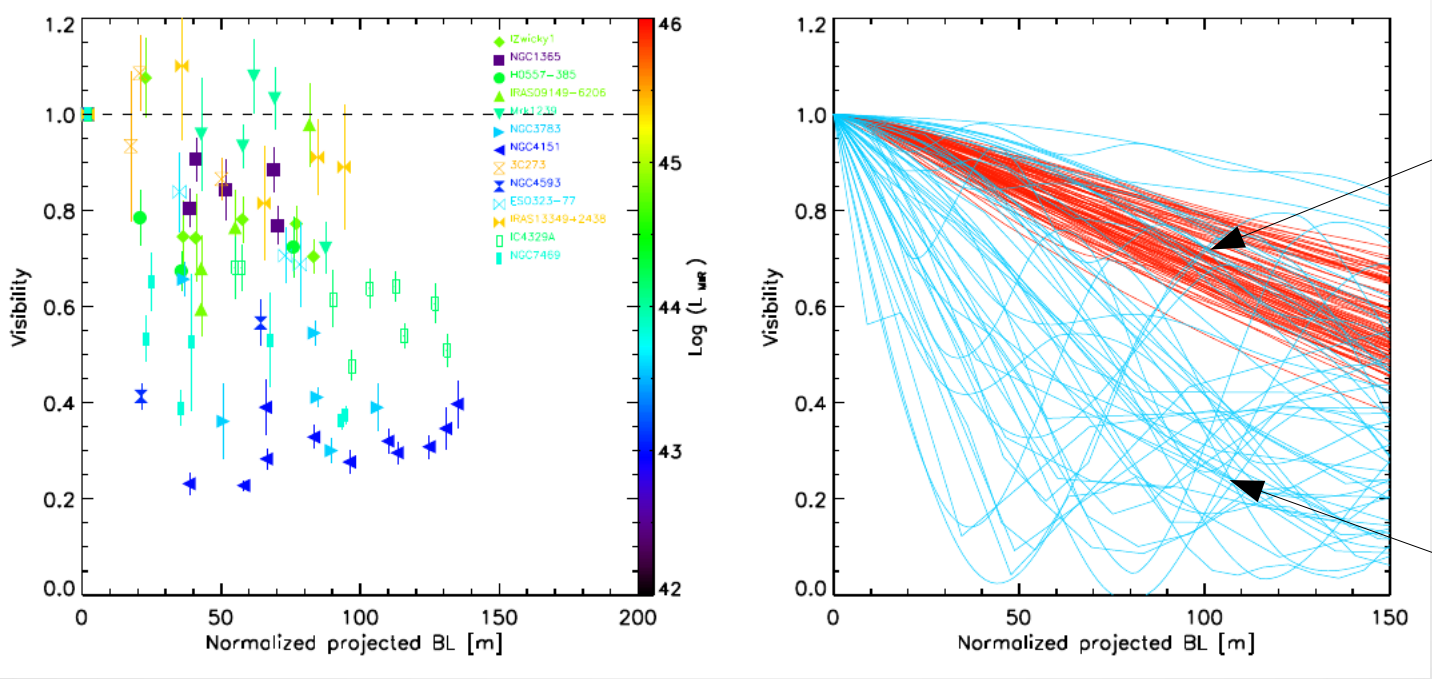
Unobscured line of sights from Model B



Type I's show a large dispersion on how well resolved they are (no clear luminosity-size relation, *Burtscher et al 2013*)

Size distribution for unobscured line of sights:

Model B much more narrow than Model A



Intrinsic luminosity

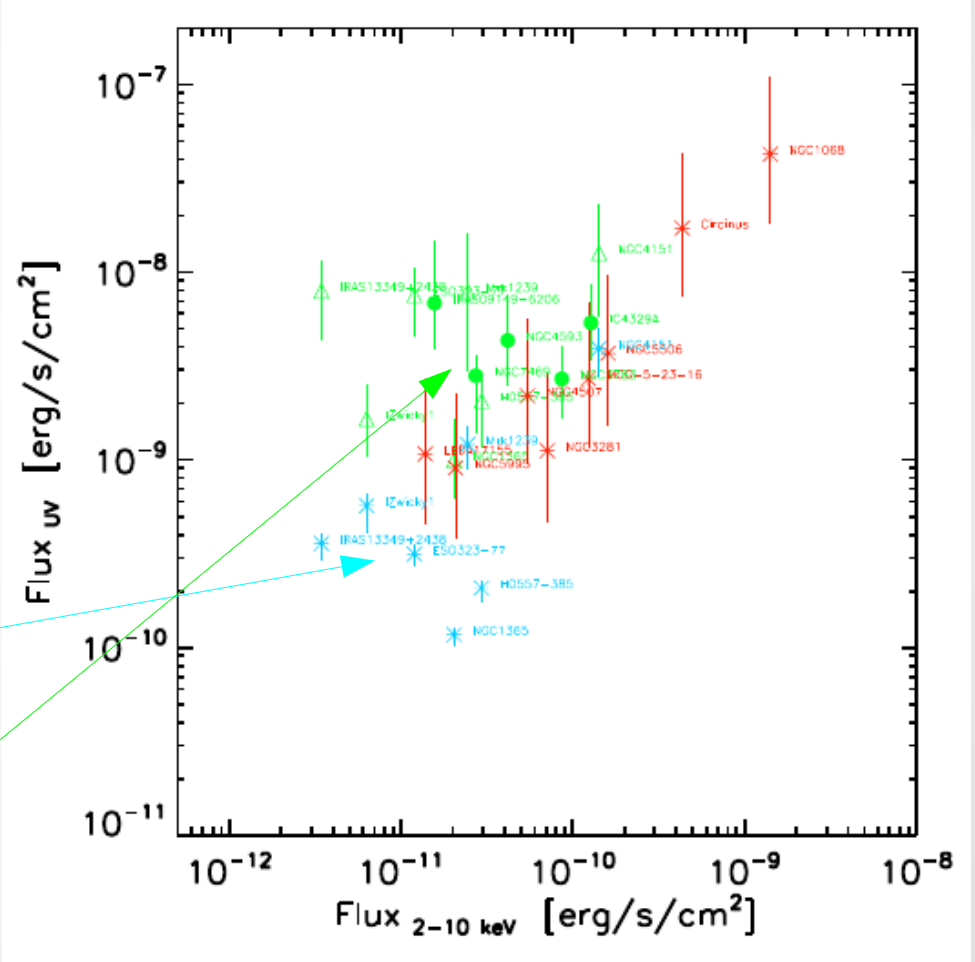
Assuming 2-10 KeV emission as a tracer for the intrinsic UV emission of the accretion disc.

UV estimation from our infrared modeling.

→ **Probably a combination of**

1) **Type Is according to Standard Model**, sharing similar properties with Type Iis.

2) **Inefficient Type I's**, with a lower fraction of sky covered by dust.



Summary

- Within our parameter space and models we conclude that Type I and Type II sources, cannot be described by a single stochastic model, assuming differences are due to inclination or line of sight effects

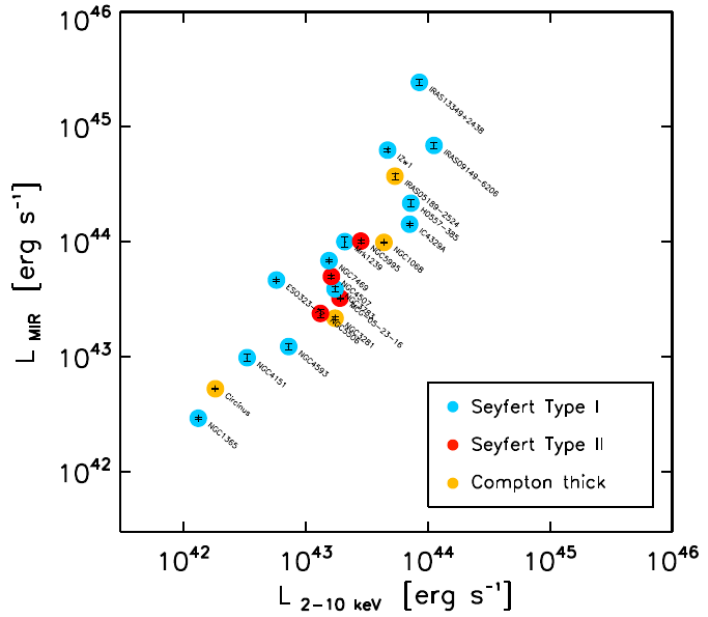
- Instead, we find a reasonable description for Type I and Type II sources taken as separate subsets with different models.

- The large apparent fluctuations in interferometric measurements of Type I sources could be caused by a limited number of clouds and their stochastic nature.

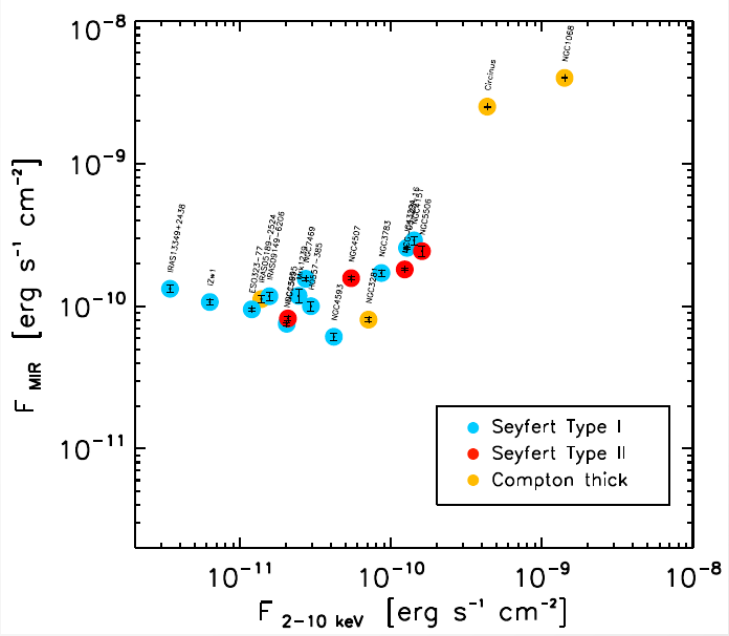
- A more plausible scenario is a combination of Type Is and Type II s in agreement with the Standard model (and a high number of clouds) and Type Is with a low fraction of the sky covered by the dust.

MIR rescaling vs X-ray rescaling

- Artificially move our models closer or further away to match 12 um single-dish flux of every source. **Rescaling of the syntetic observations.**



Moderate correlation

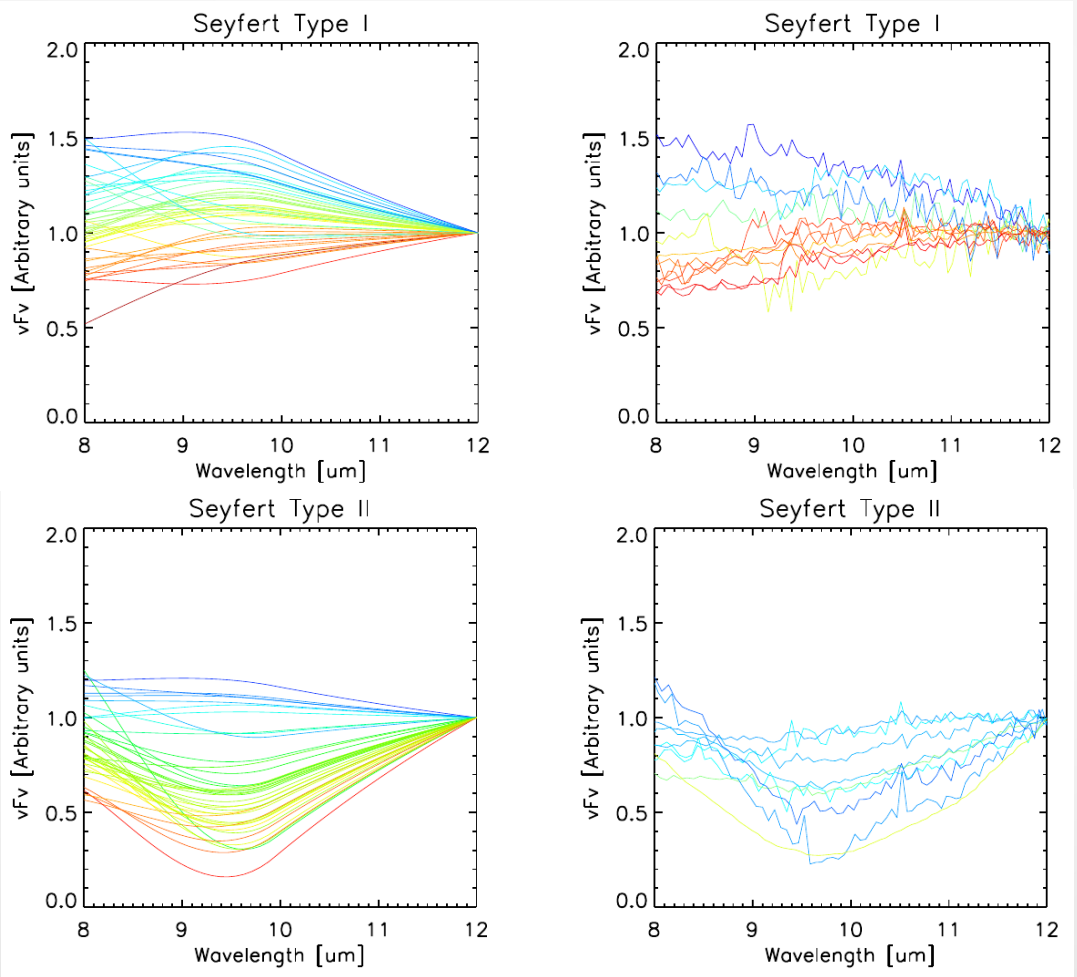


Correlation not so clear

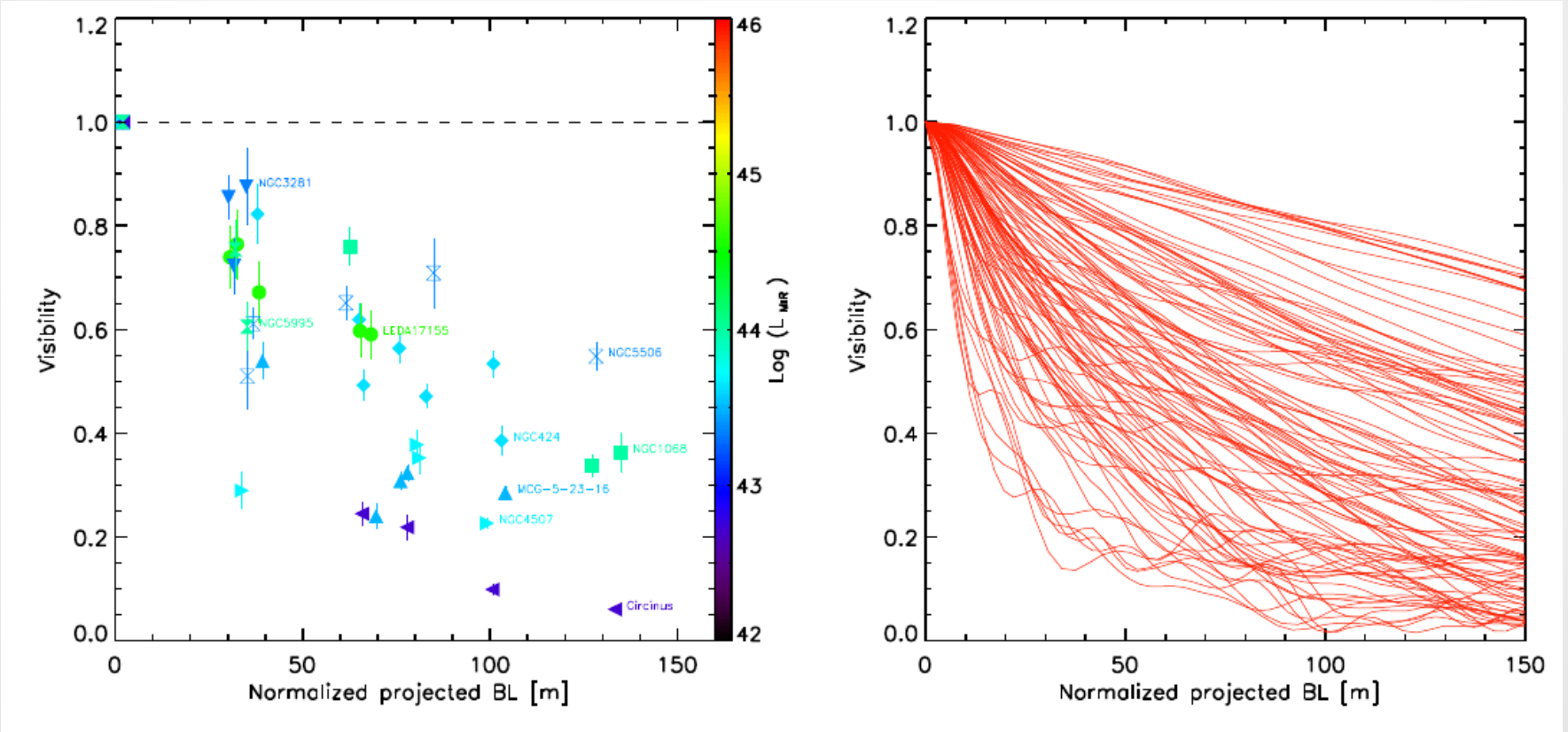
The mid-infrared single dish spectra

Models

Observed



Type II s


Visibility
Normalized projected BL [m]
Log (L MIR)
NGC3281
NGC5995
LEDA17155
NGC5506
NGC424
NGC1068
MCG-5-23-16
NGC4507
Circinus
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
50
100
150
42
43
44
45
46