Dissecting the center of Centaurus A and NGC 4151

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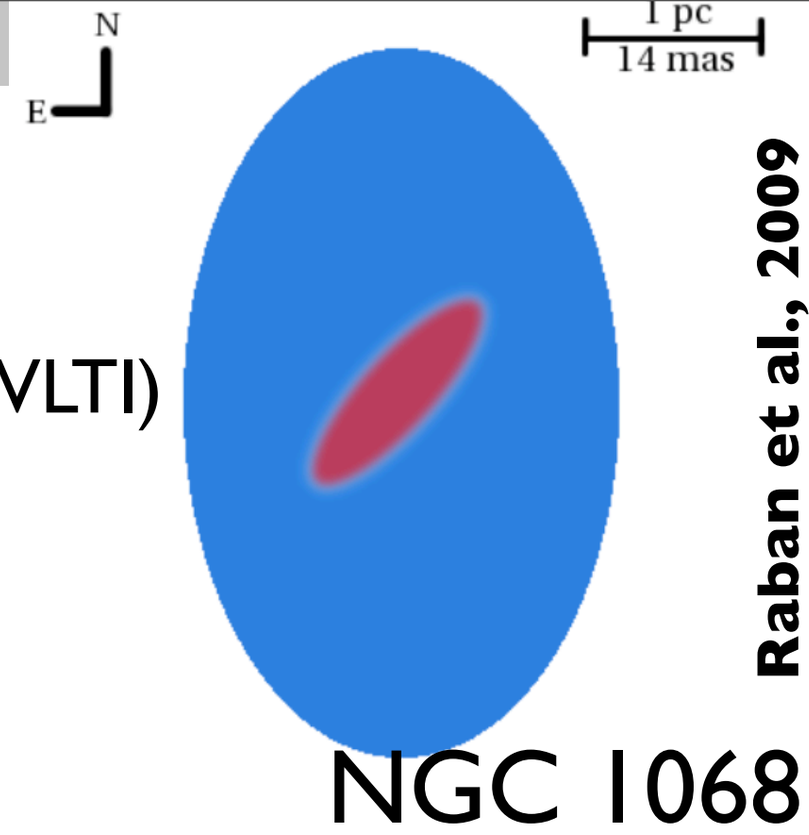
and with K. Tristram, W. Jaffe

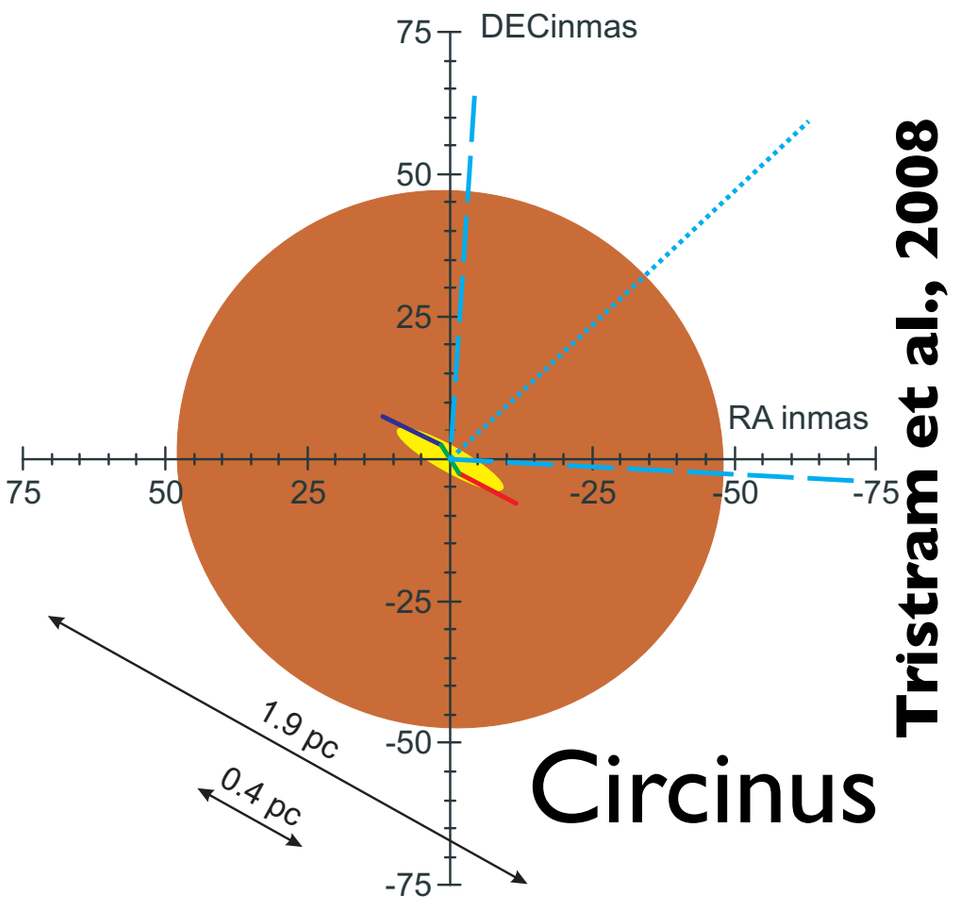
Image credit: Marc Schartmann

MIDI AGN programme

MIDI is the MID-infrared Interferometric Instrument (VLTI)

- **Detailed studies**
  - NGC 1068 (Sy 2), Raban et al. 2009
  - Circinus (Sy 2), Tristram et al. 2008
  - Cen A (Radio Gal.), Meisenheimer et al. 2007
- **Snapshot survey** of 7 other, weaker galaxies, Tristram et al. 2009
- **Results**: torus exists, very different [temperature, chemical comp., orientation] in the three well-studied galaxies



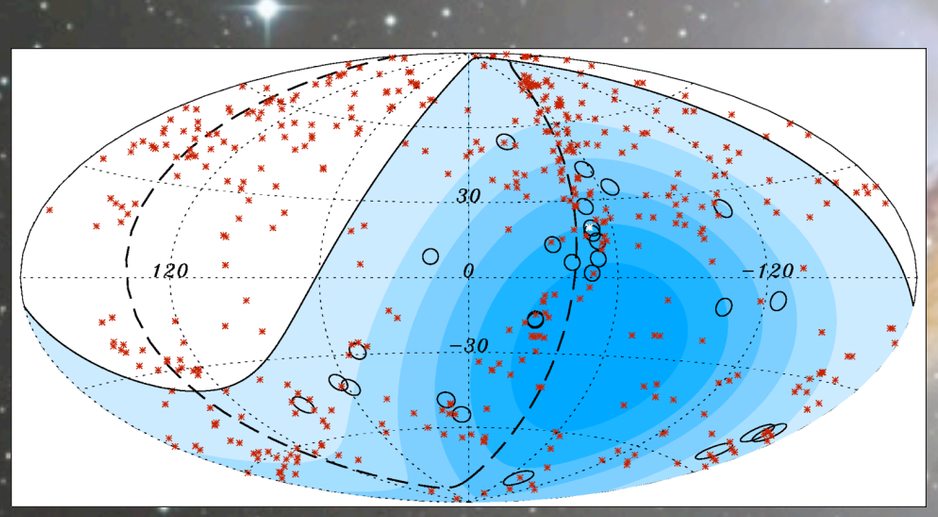


Centaurus A

sub-mm
X-Ray
Optical

Credit: ESO/WFI (Optical); MPIfR/ESO/APEX/A.Weiss et al. (Submillimetre); NASA/CXC/CfA/R.Kraft et al. (X-ray)

Centaurus A

- closest major merger / radio galaxy / AGN at ~ 3.8 Mpc (54 mas / pc)
- dust lane from interaction with other gal 500 Myrs ago
- 

possible source of UHE cosmic rays
- warped molecular gas disk 110 pc x 280 pc / P.A. = 140° at the center

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X-Ray
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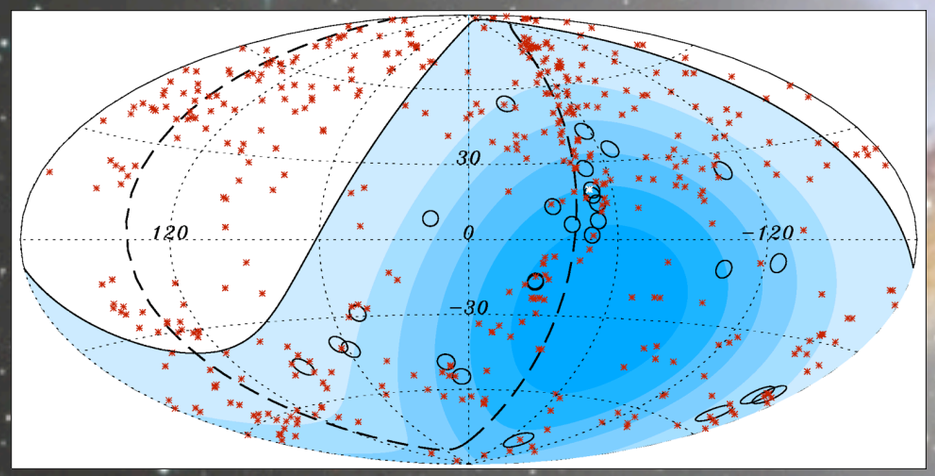
- 

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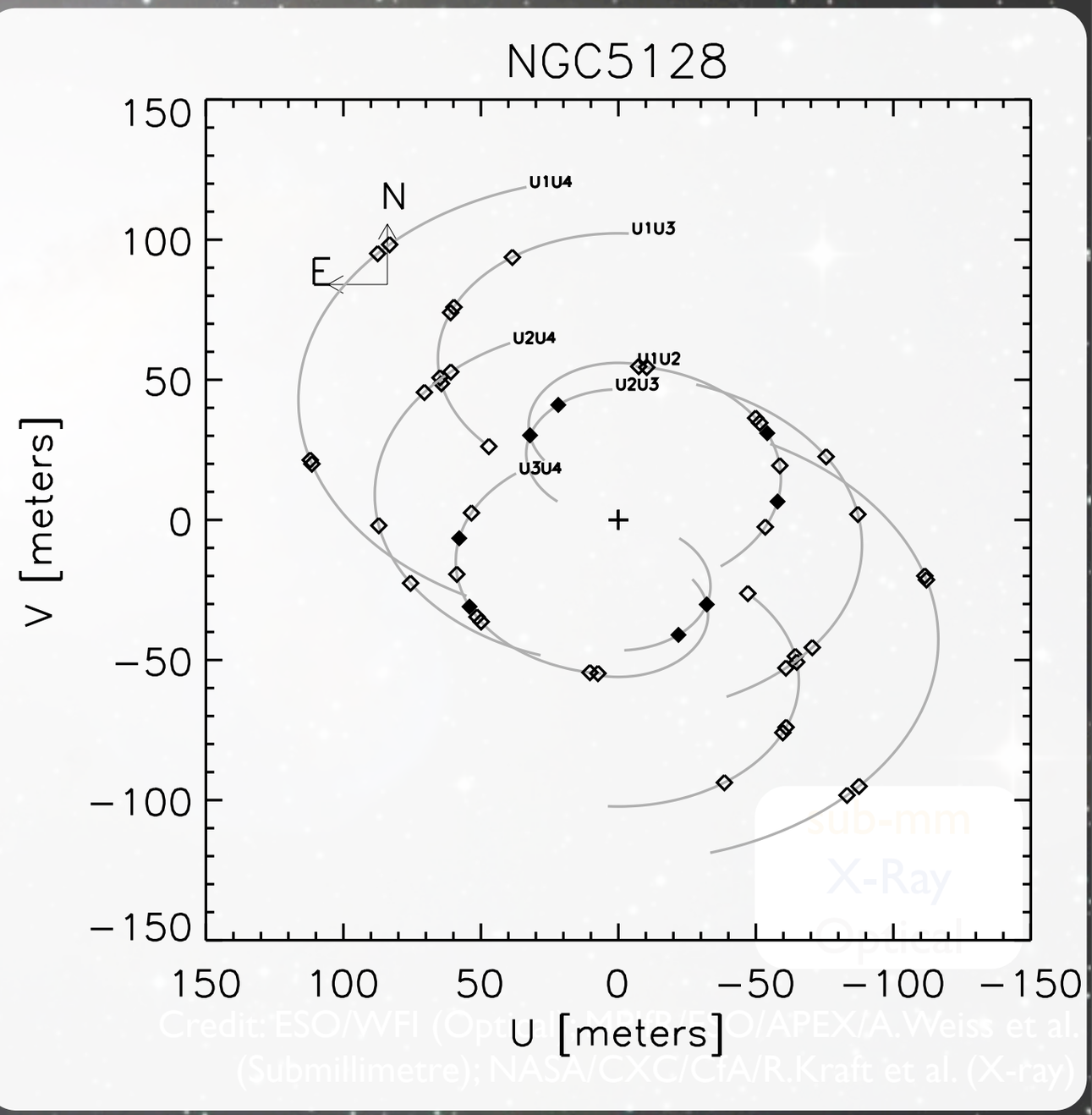
(u,v) coverage with MIDI



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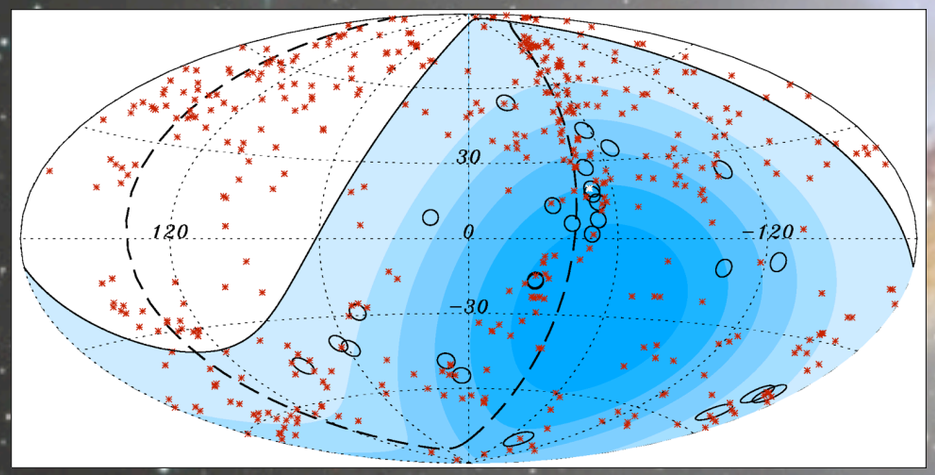
- 

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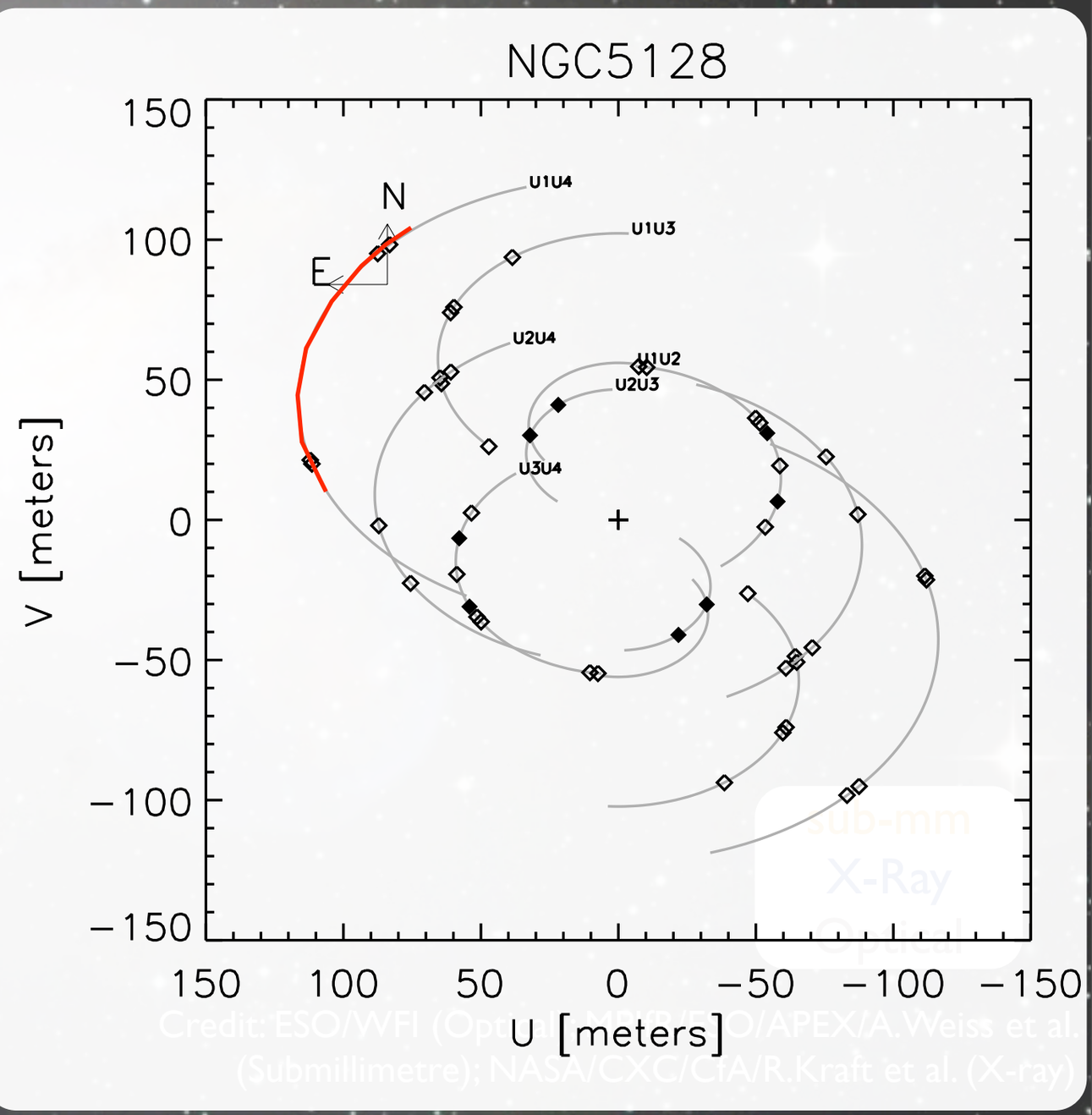
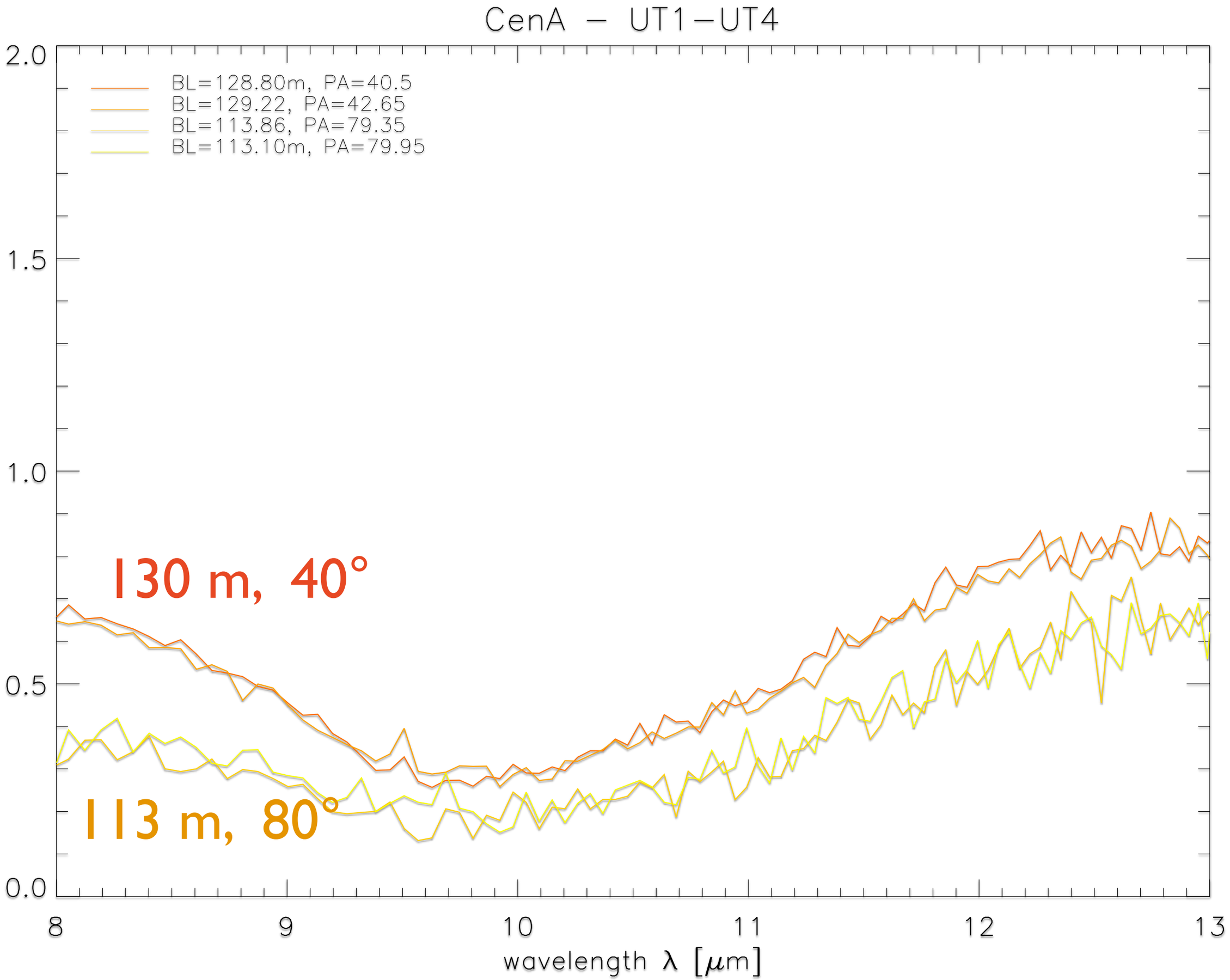
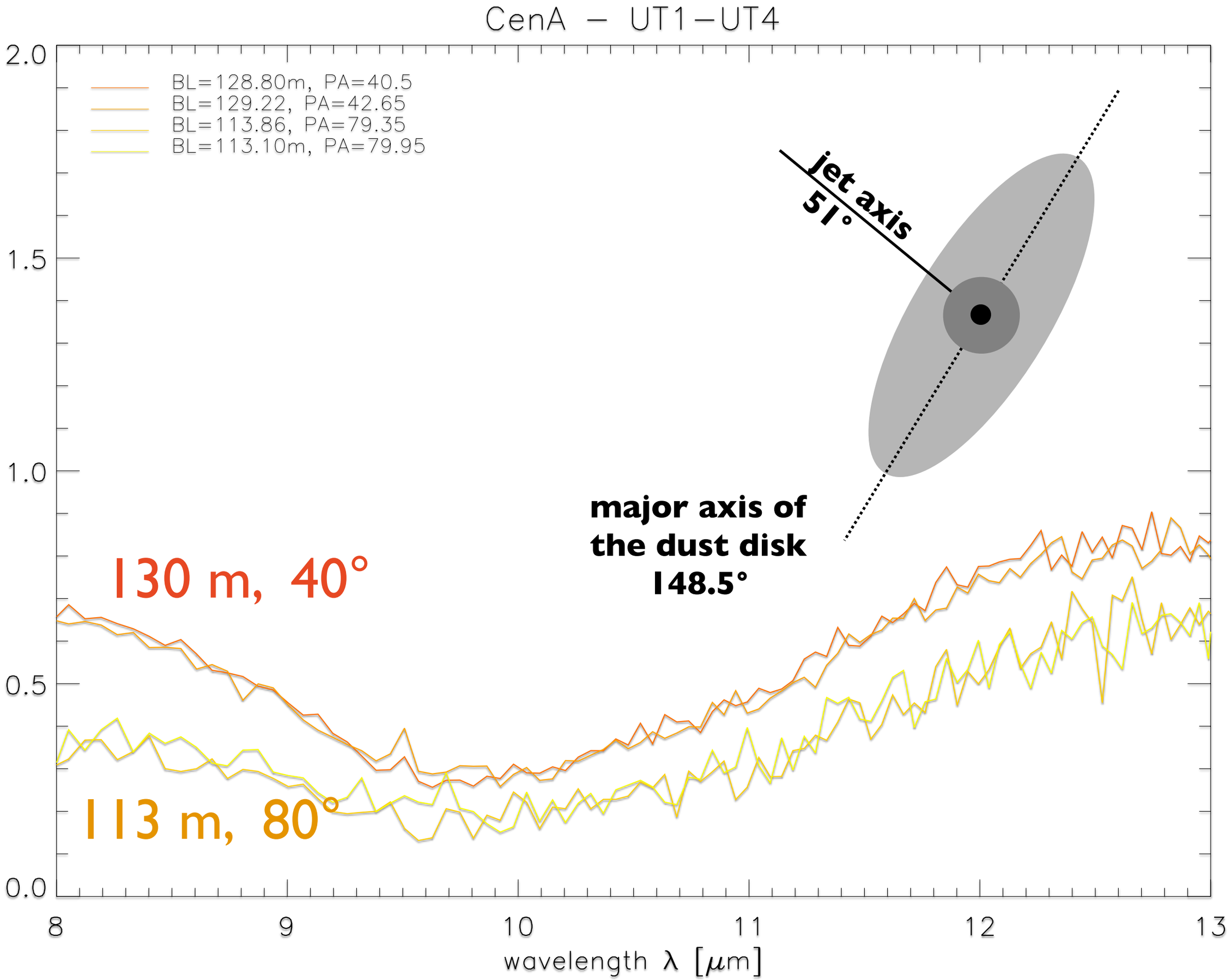



CenA – UT1–UT4
BL=128.80m, PA=40.5
BL=129.22, PA=42.65
BL=113.86, PA=79.35
BL=113.10m, PA=79.95
130 m, 40°
113 m, 80°
2.0
1.5
1.0
0.5
0.0
8
9
10
11
12
13
wavelength λ [μm]


CenA – UT1–UT4
BL=128.80m, PA=40.5
BL=129.22, PA=42.65
BL=113.86, PA=79.35
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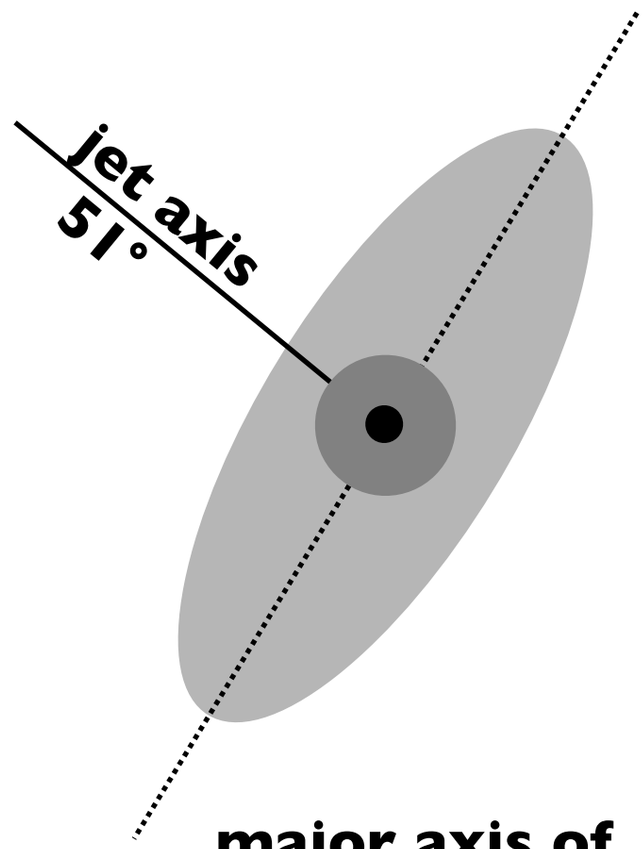
jet axis
51°
major axis of
the dust disk
148.5°
130 m, 40°
113 m, 80°
2.0
1.5
1.0
0.5
0.0
8
9
10
11
12
13
wavelength λ [μm]

Centaurus A

- only weakly emitting dust disk (L_{dust} ~ 0.1 $L_{dust,\ Circinus}$), no optically thick torus
- disk ⊥ VLBI jet axis
- disk size: ~ 0.6 pc x 0.2 pc (68° inclined thin disk?)
- point source flux ratio ~ 50% (synchrotron core)

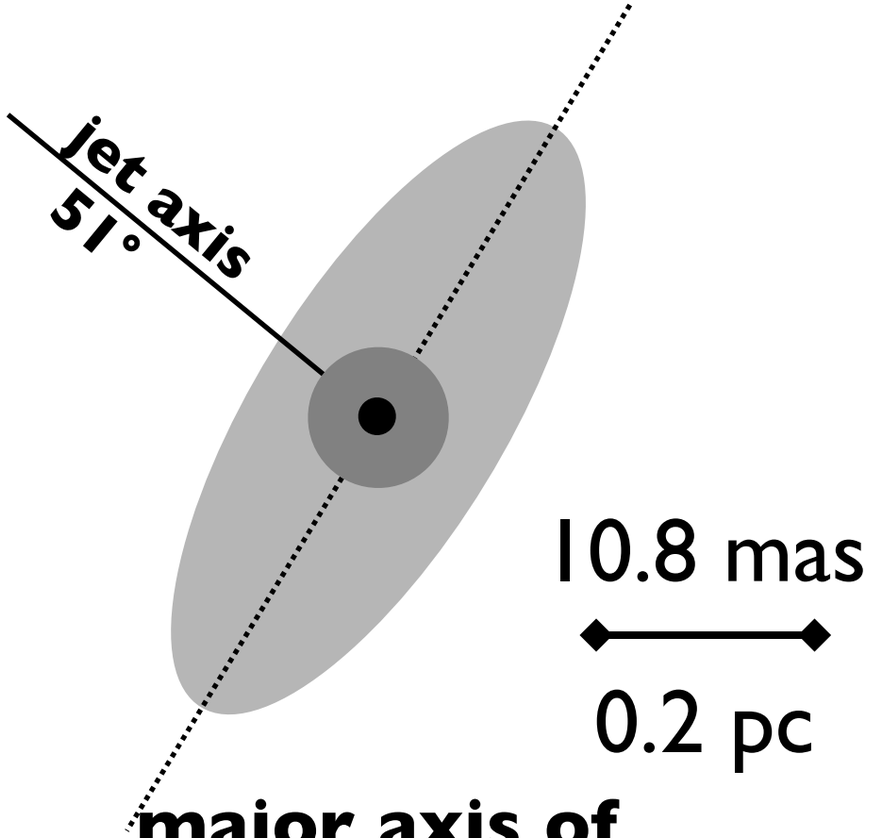


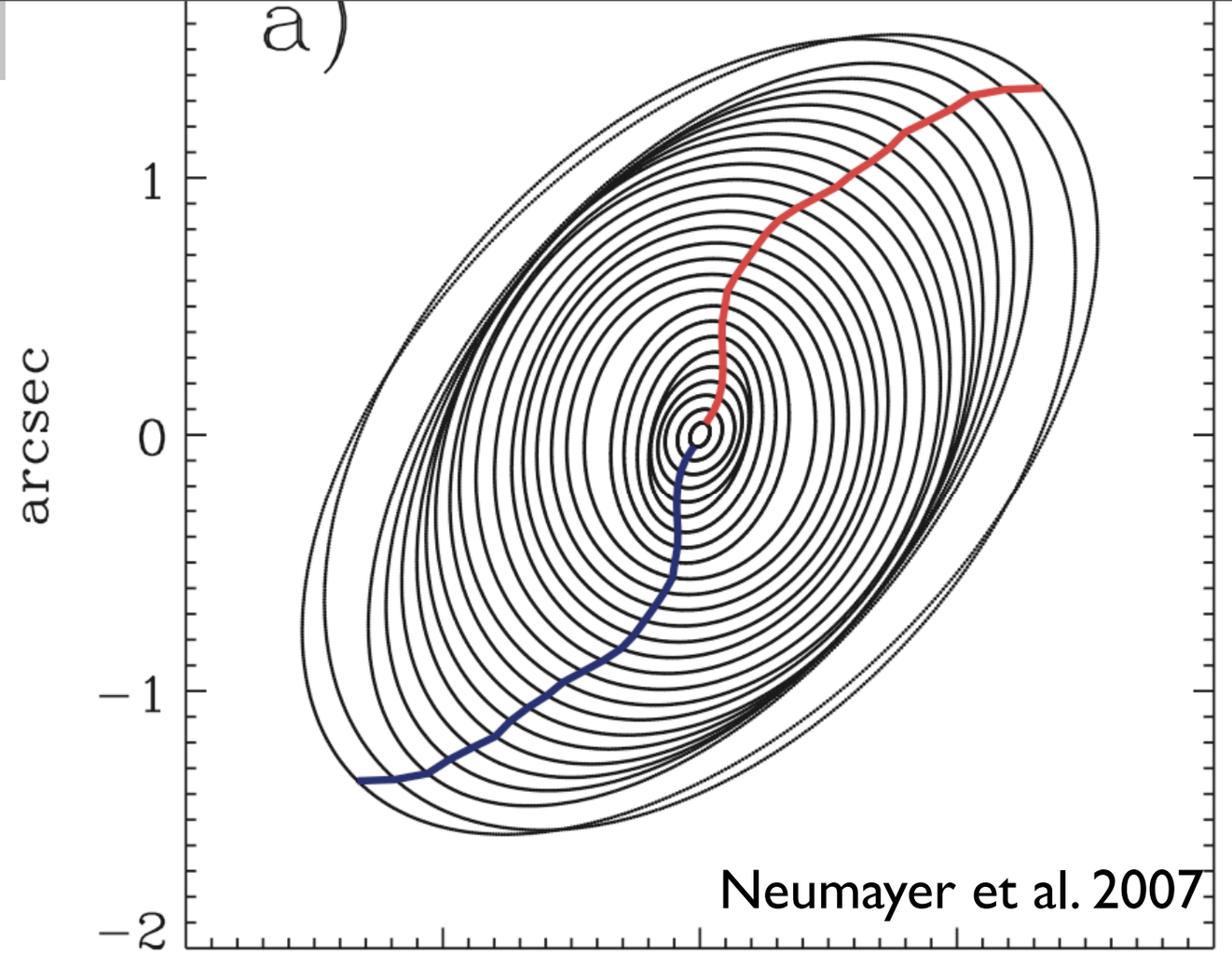
Meisenheimer et al. 2007

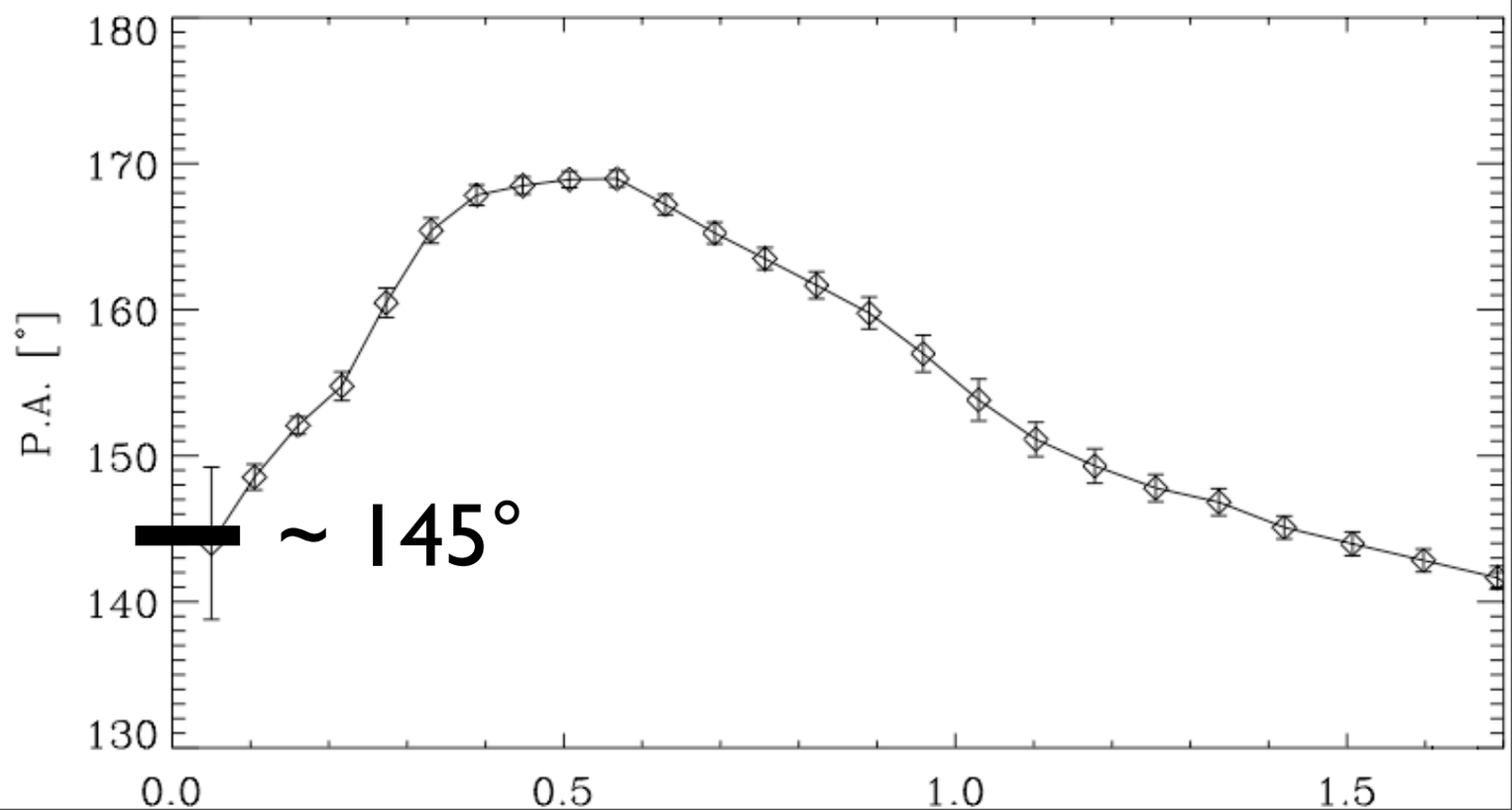
Burtscher et al. 2009
(in preparation)

Centaurus A

Connection to larger scales?





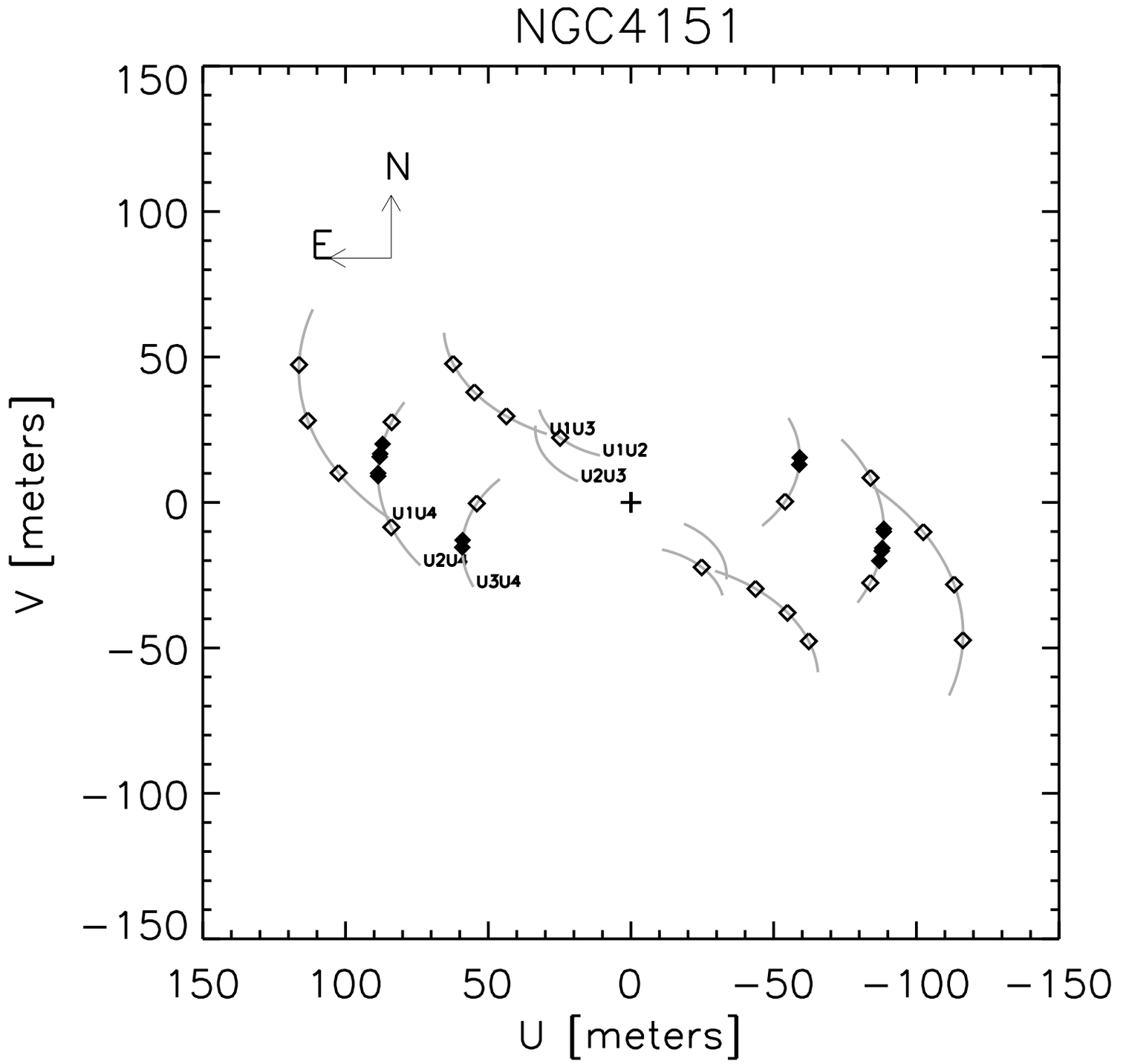


NGC 4151

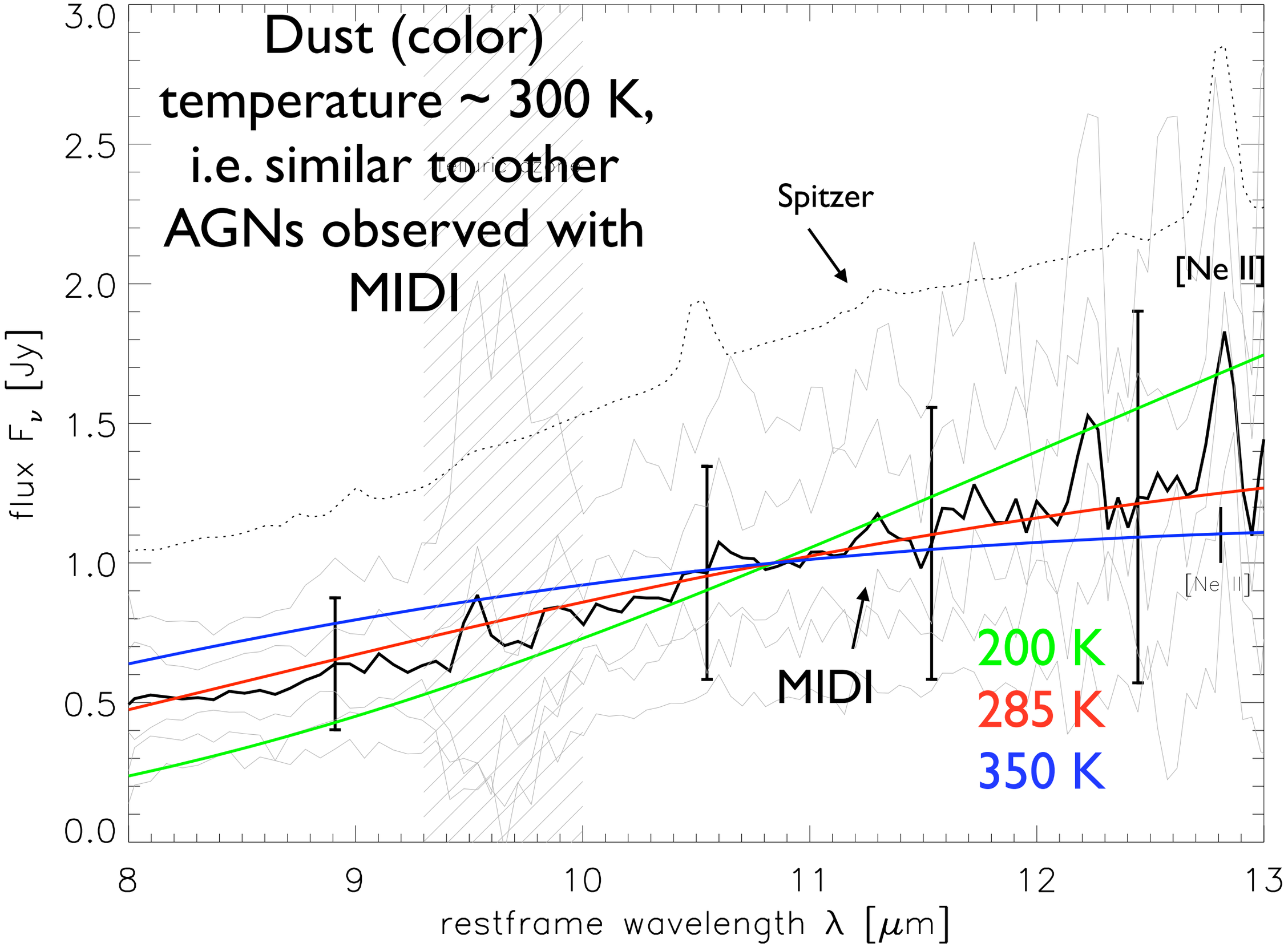
gri image – Hogg, Blanton and SDSS

NGC 4151

- Brightest (N ~ 1 Jy) and nearest (D ~ 14 Mpc) Sy 1 galaxy
- Difficult to observe (mag. limit for VLTI, very northern DEC)
- Successfully observed in April 2008 with fringes on two different baselines (60m, 90m, at similar P.A.s)



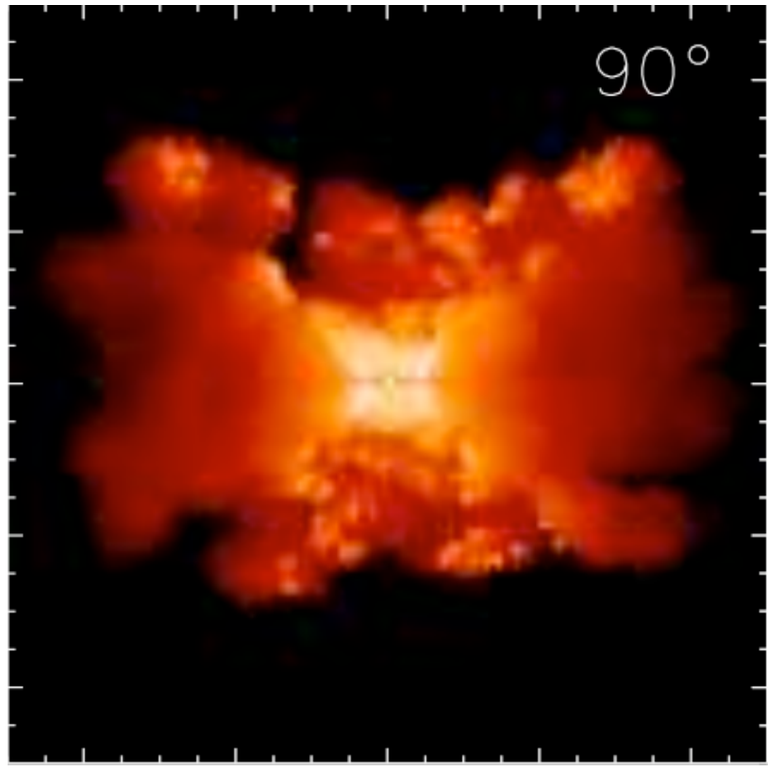
NGC 4151

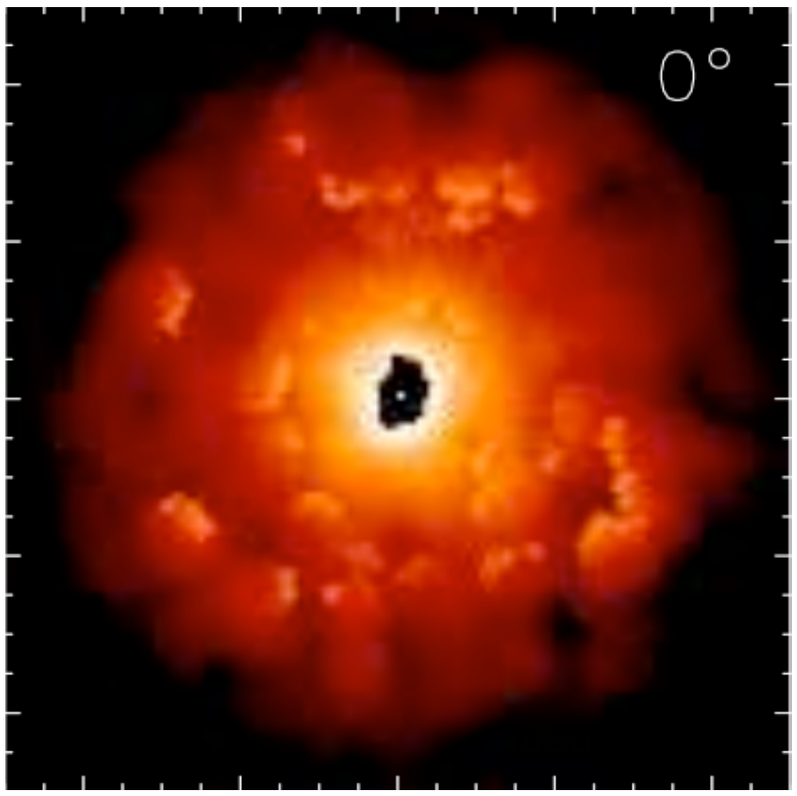

Dust (color)
temperature ~ 300 K,
i.e. similar to other
AGNs observed with
MIDI
Spitzer
[Ne II]
MIDI
200 K
285 K
350 K
[Ne II]
telluric ozone
flux F_ν [Jy]
restframe wavelength λ [μm]
3.0
2.5
2.0
1.5
1.0
0.5
0.0
8
9
10
11
12
13

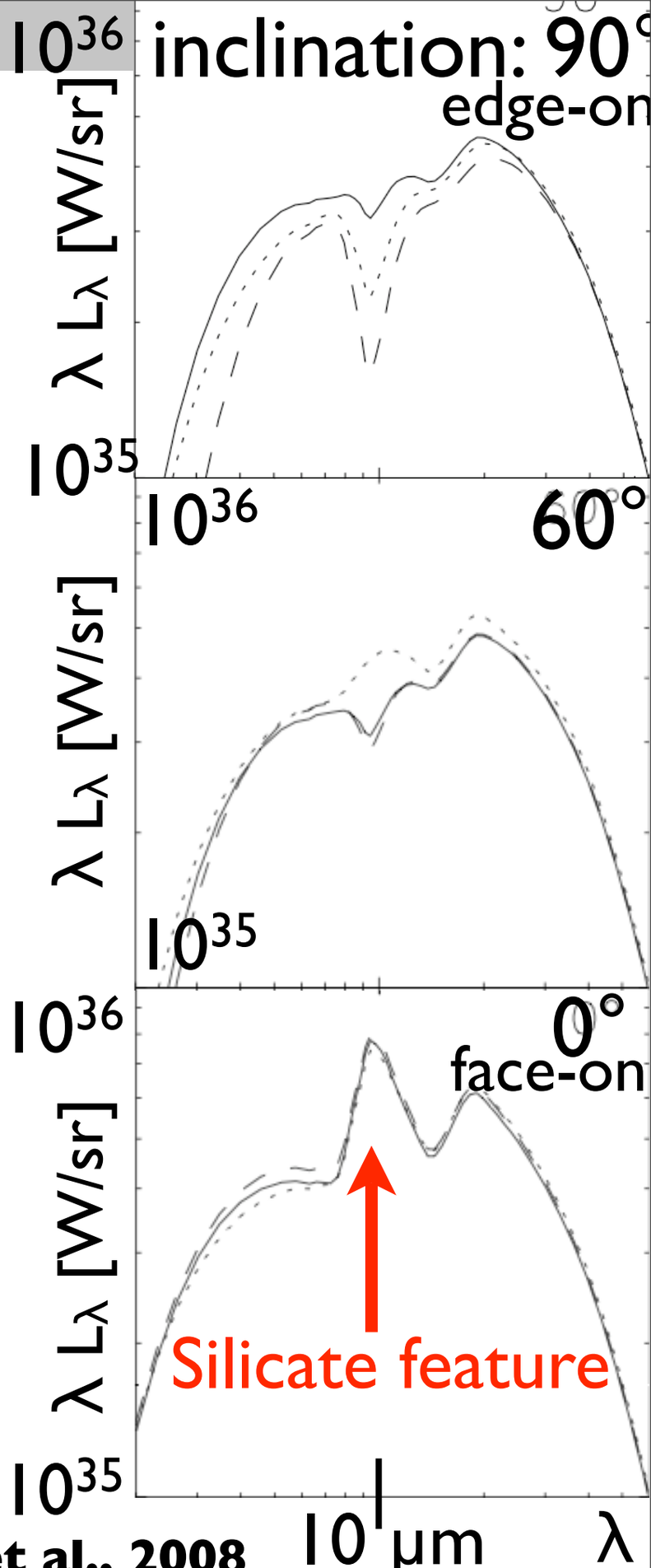
Type 2 galaxies:
NGC 1068, Circinus, ...

Radiative transfer models of dusty tori

Type 1 galaxies:
now for the first time torus in **NGC 4151** resolved

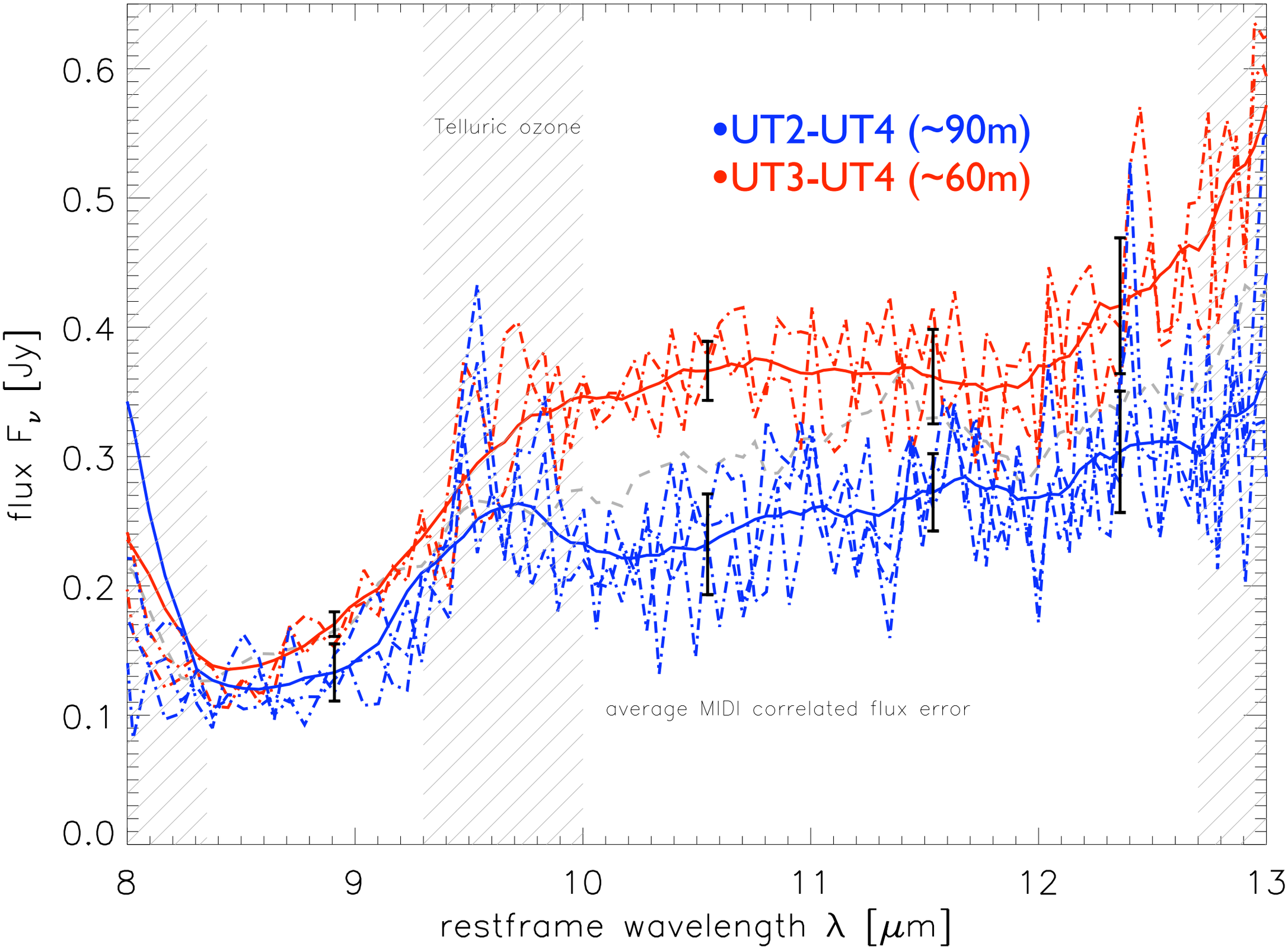






Schartmann et al., 2008

NGC 4151 – correlated flux



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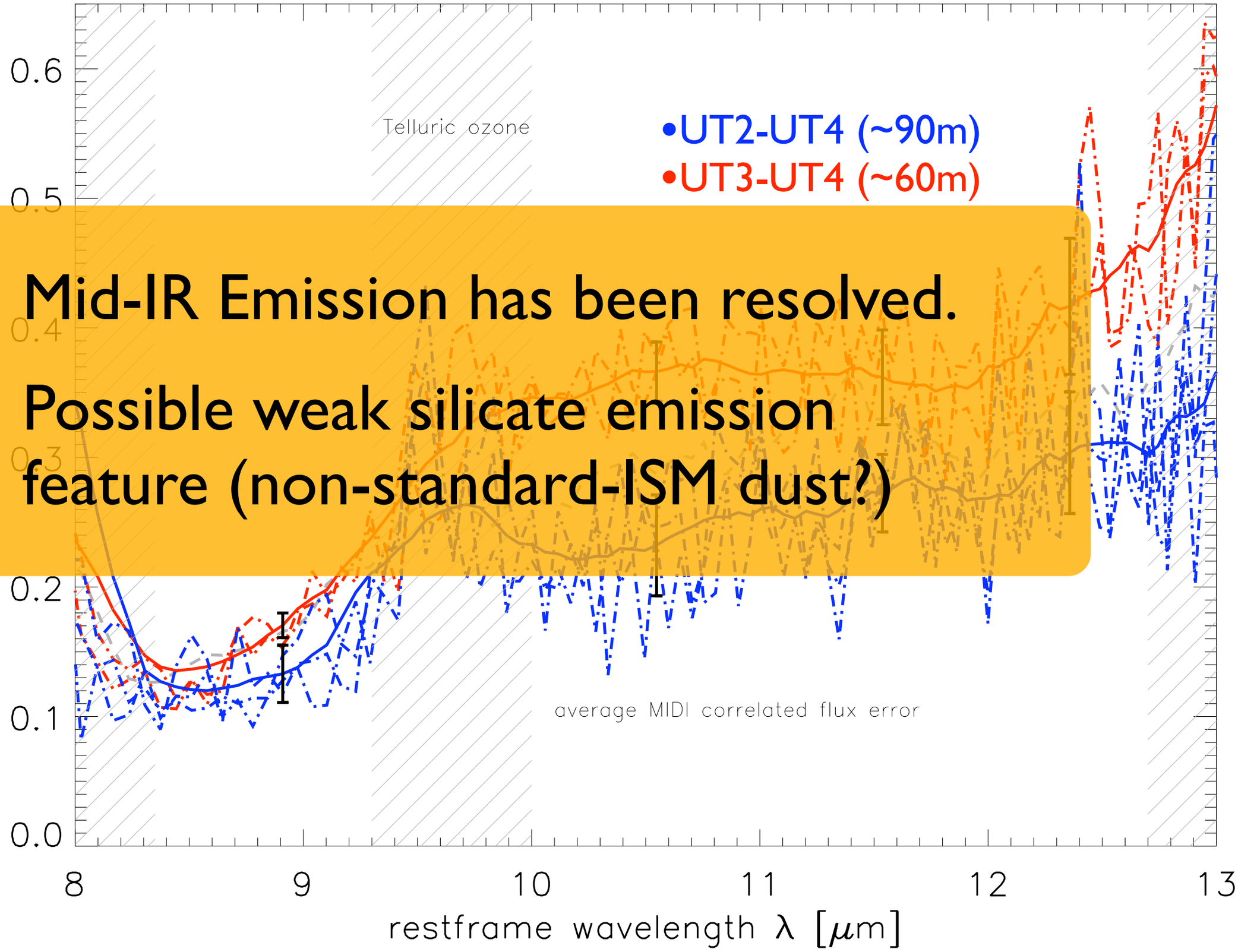
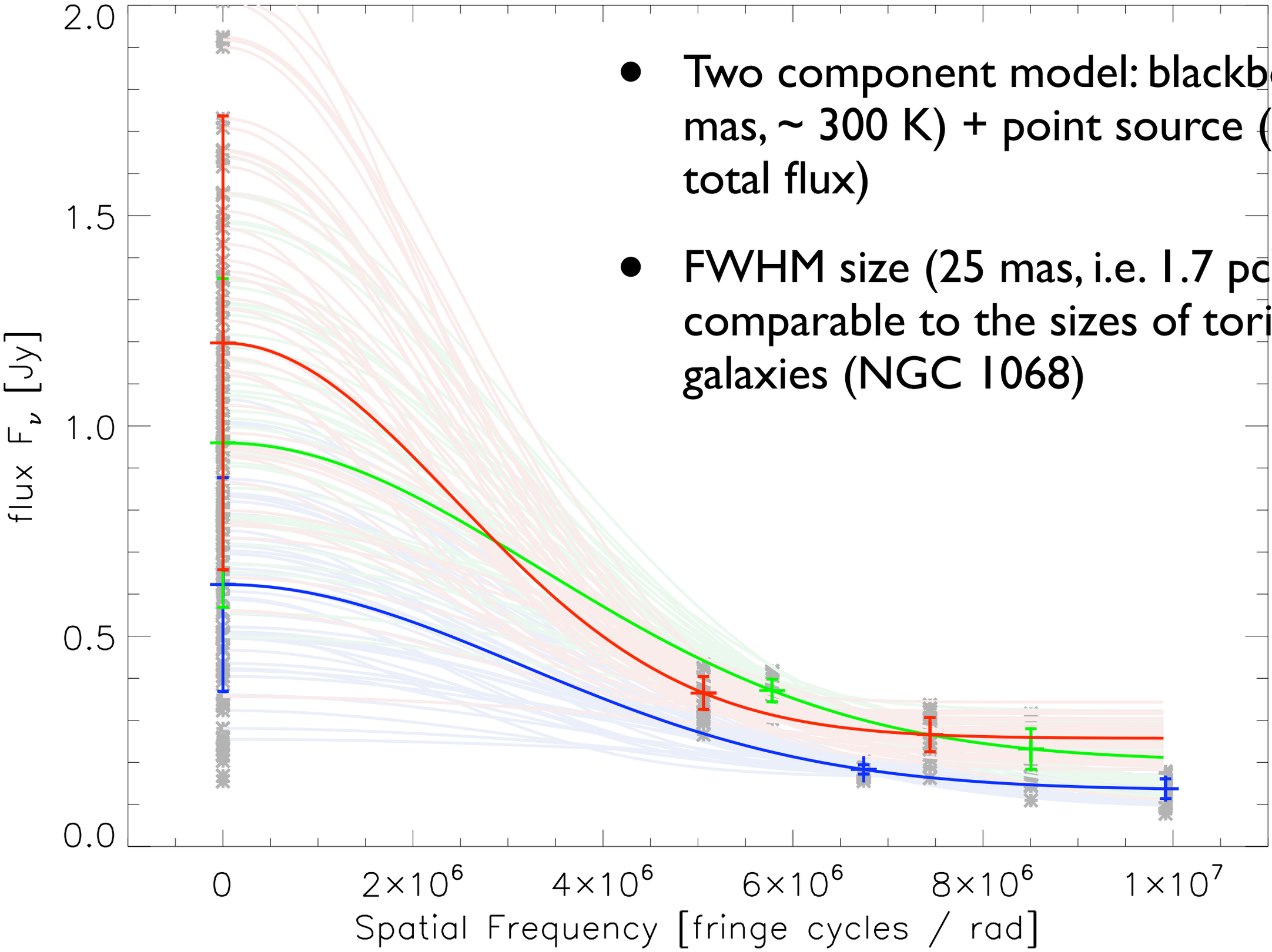


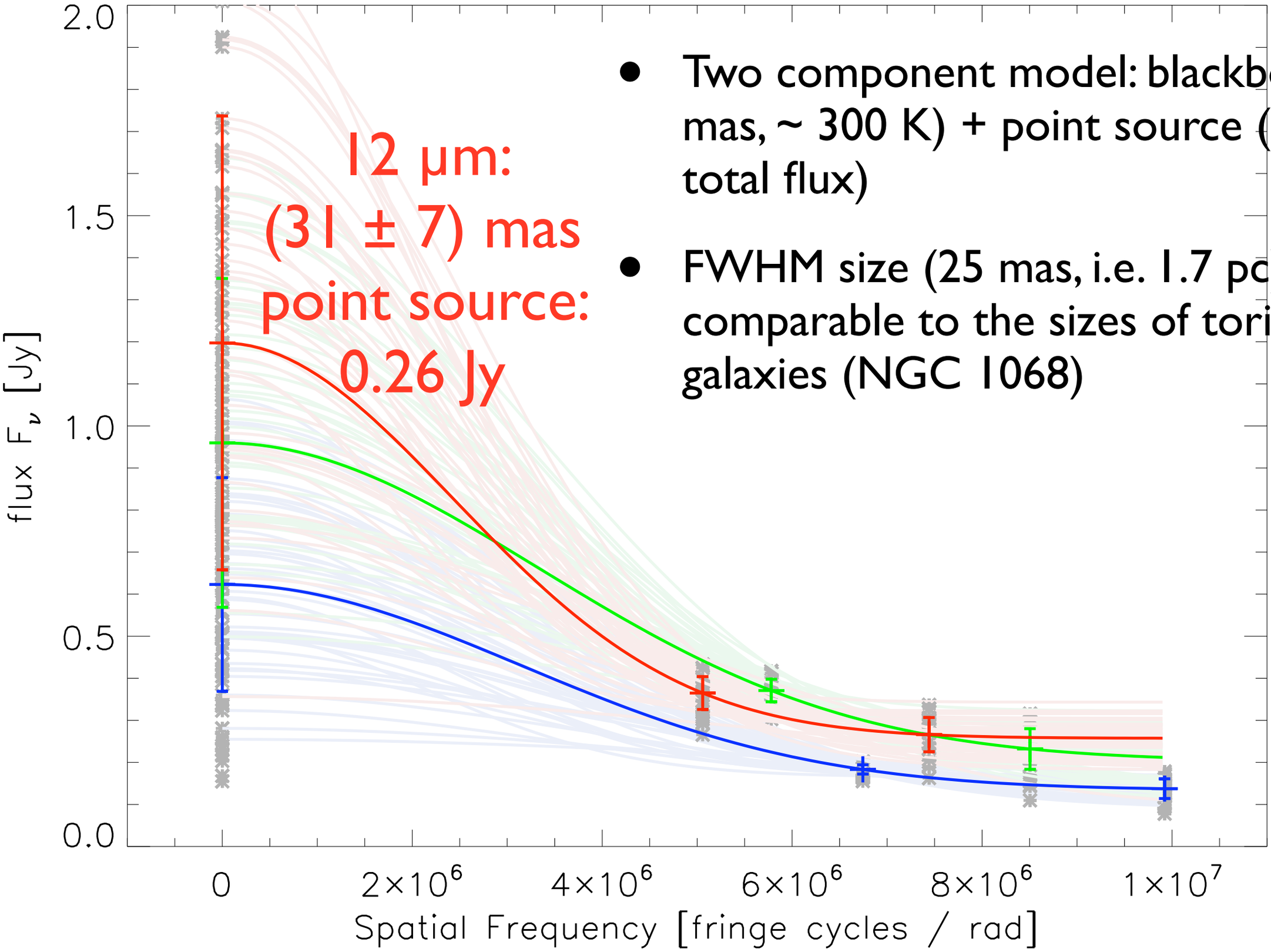
- Mid-IR Emission has been resolved.
- Possible weak silicate emission feature (non-standard-ISM dust?)

NGC 4151 – Size of the Mid-IR emitter



- Two component model: blackbody (25 mas, ~ 300 K) + point source (< 15% of total flux)
- FWHM size (25 mas, i.e. 1.7 pc) is comparable to the sizes of tori in type 2 galaxies (NGC 1068)

NGC 4151 – Size of the Mid-IR emitter



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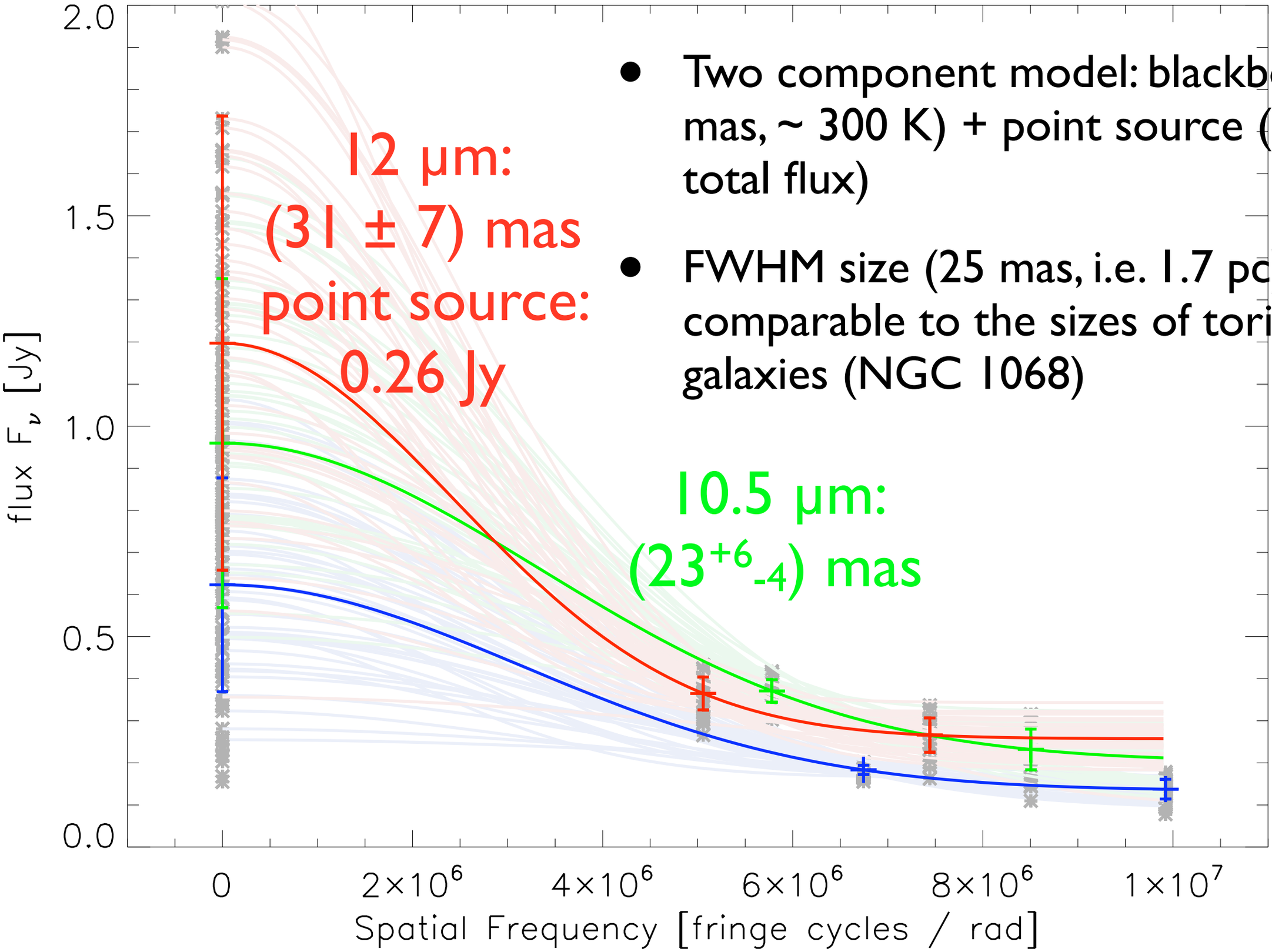

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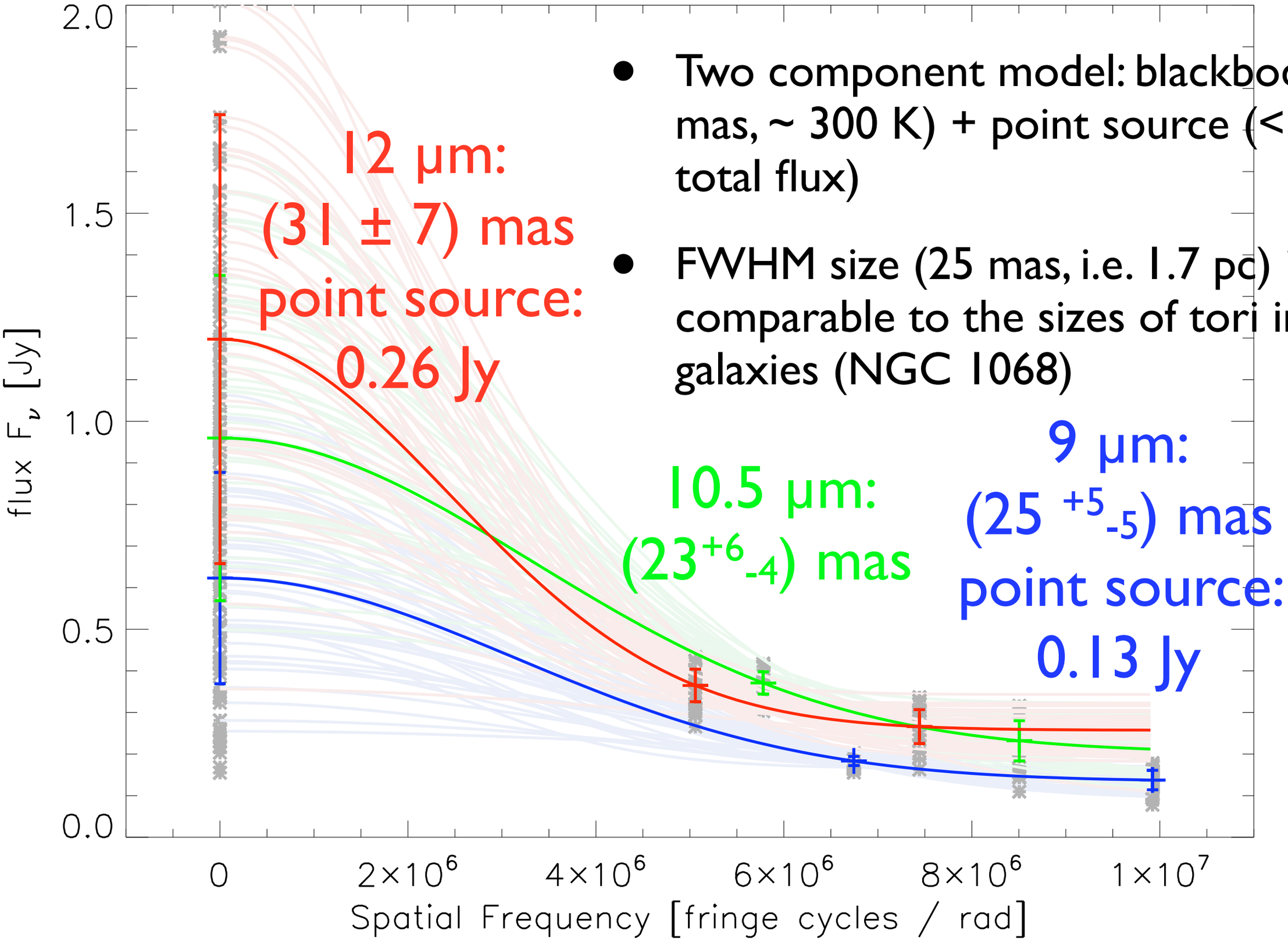

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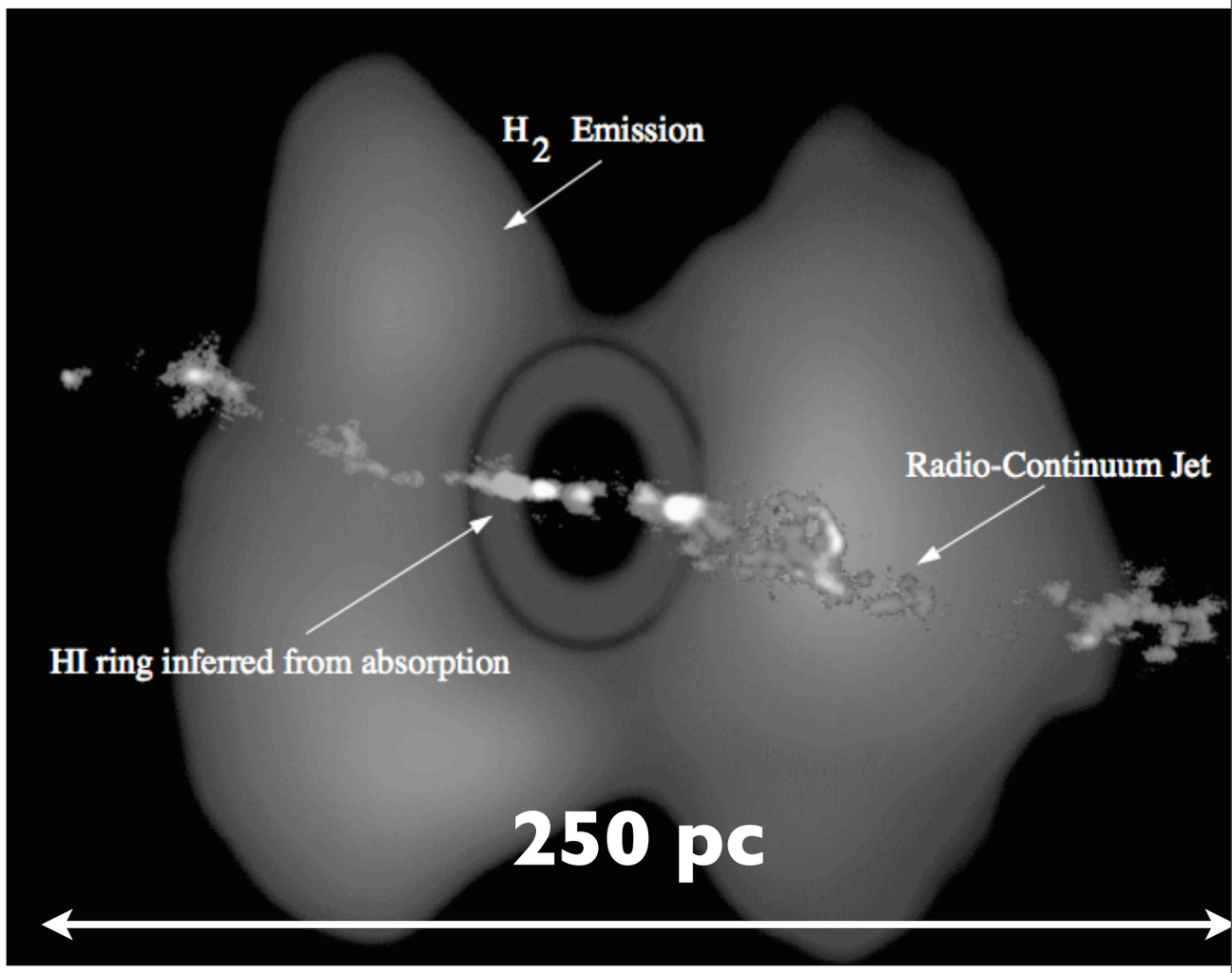
Compared to...

- *K* band interferometry from Keck: majority of *K* band emission comes from r < 0.05 pc (Swain et al. 2003)
- lag time between *K* and *V* band flares: $r_{reverberation} \sim 0.04$ pc ~ $r_{sublimation}$ (Minezaki et al. 2004)
- Radio observations: H I absorption seen against background by Mundell et al. 2003



Mundell et al. 2003

NGC 4151 – Open questions

- **Silicate emission** feature? Spitzer data inconclusive... (Buchanan et al. 2006)
- Warm vs. hot dust: We see ~ 300 K warm dust – **where is the hot dust** that should be seen face on in a type 1 (1.5) Seyfert?
- **Cool point source** spectrum (0.13 Jy @ 9 μm, 0.26 Jy @ 12 μm). This is not what one would expect to see from the hot unresolved dust...

Summary

- To test the unified model we observe the dusty torus of nearby Active Galactic Nuclei with mid-infrared interferometry
- Detailed observations of the nearest radio galaxy Centaurus A have revealed a thin disk ⊥ VLBI jet axis
- For the first time, a torus is now resolved in a „type 1“ (unobscured) galaxy, NGC 4151
- Outlook: Studies of more AGNs will allow us to get statistical information, further modelling (hydro + rad. transfer) will give more physical insight