MATISSE AGN PROGRAM

What’s the Science?

Examine warm dusty “torus” at pc scales around AGNs and related in- and out-flows.

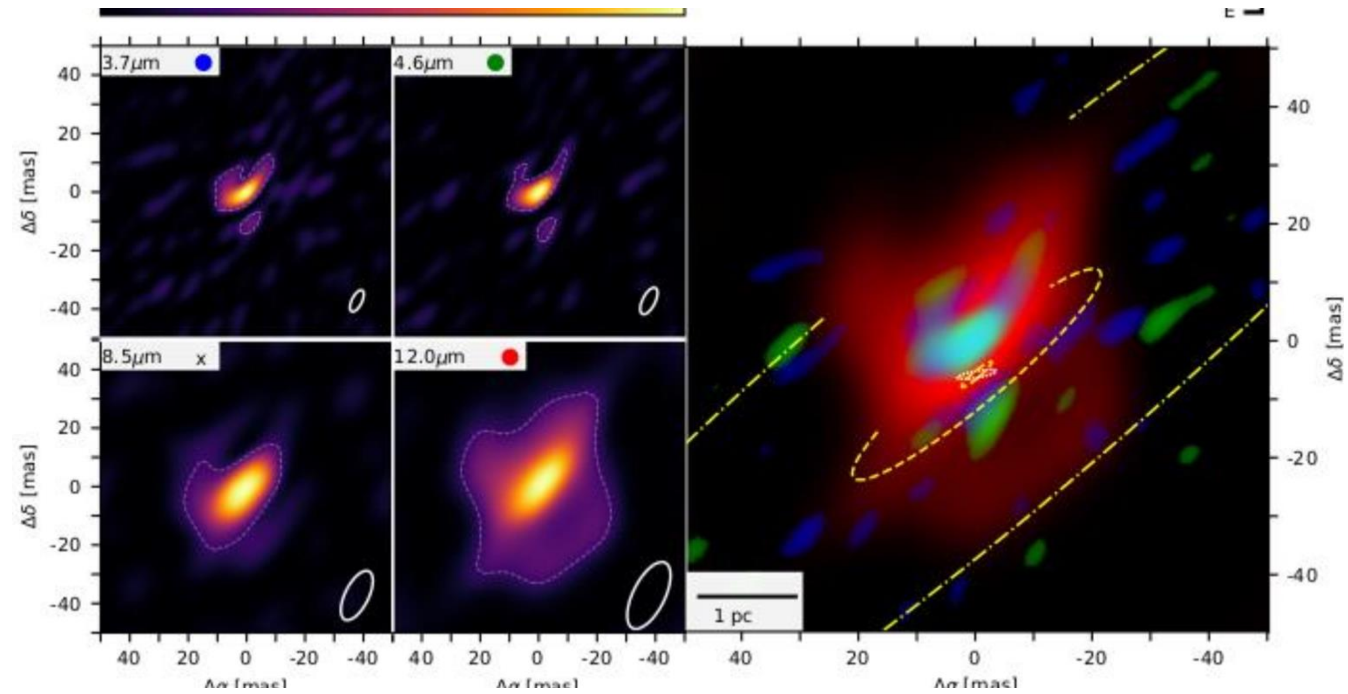
- Determines appearance of AGN (Sy ½)
- Absorbs much of AGN luminosity; converts to IR
- IR area/mass can halt accretion and drives winds
- Polarization may reveal magnetic field morphology
- This is where the AGN decides how much fuel to consume

“Inner torus”==Broad Line Region is visible to high redshifts. Comparison of IR morphology to Reverberation morphology -> redshift independent cosmological parameters

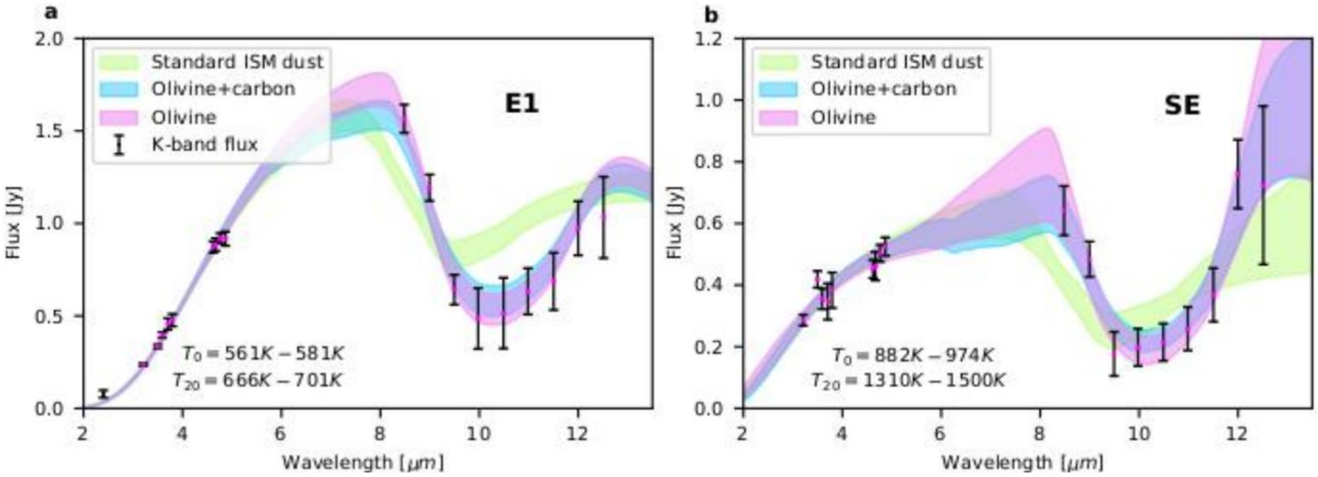
PAST:

- Thermal Imaging of dust hiding the Black Hole NGC1068 Gamez Rosas et al., 2022 [57]
- Dusty Heart of Circinus I,II Isbell et al. 2022, 2023 [32,2]
- Carbonaceous Dust in the nucleus of NGC1068 Gamez Rosas et al, 2023
- Chromatic Modelling of Dust in nucleus of NGC1068 Leftley et al, 2024 [1]

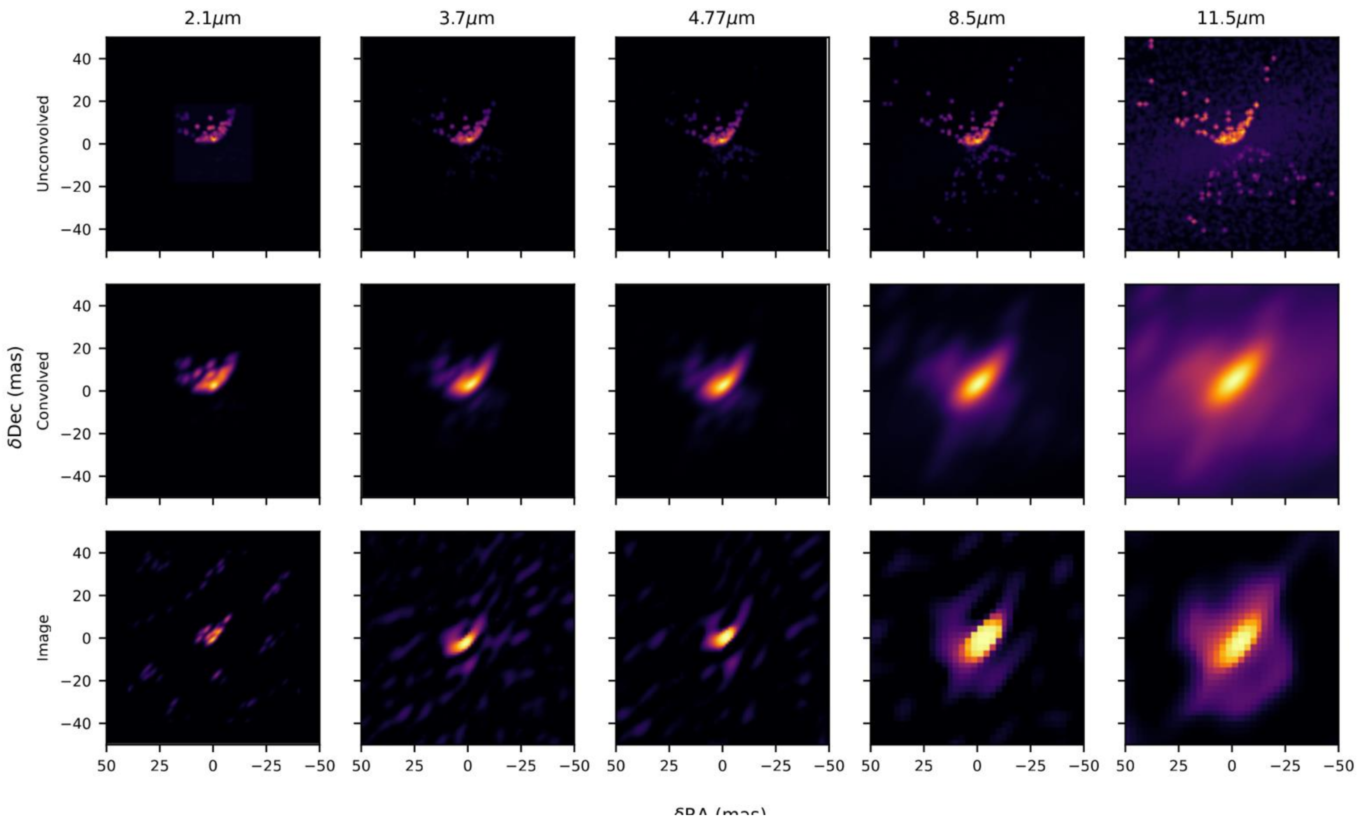
Gamez Rosas et al. Nature 2022



Gamez Rosas et al. Nature 2022

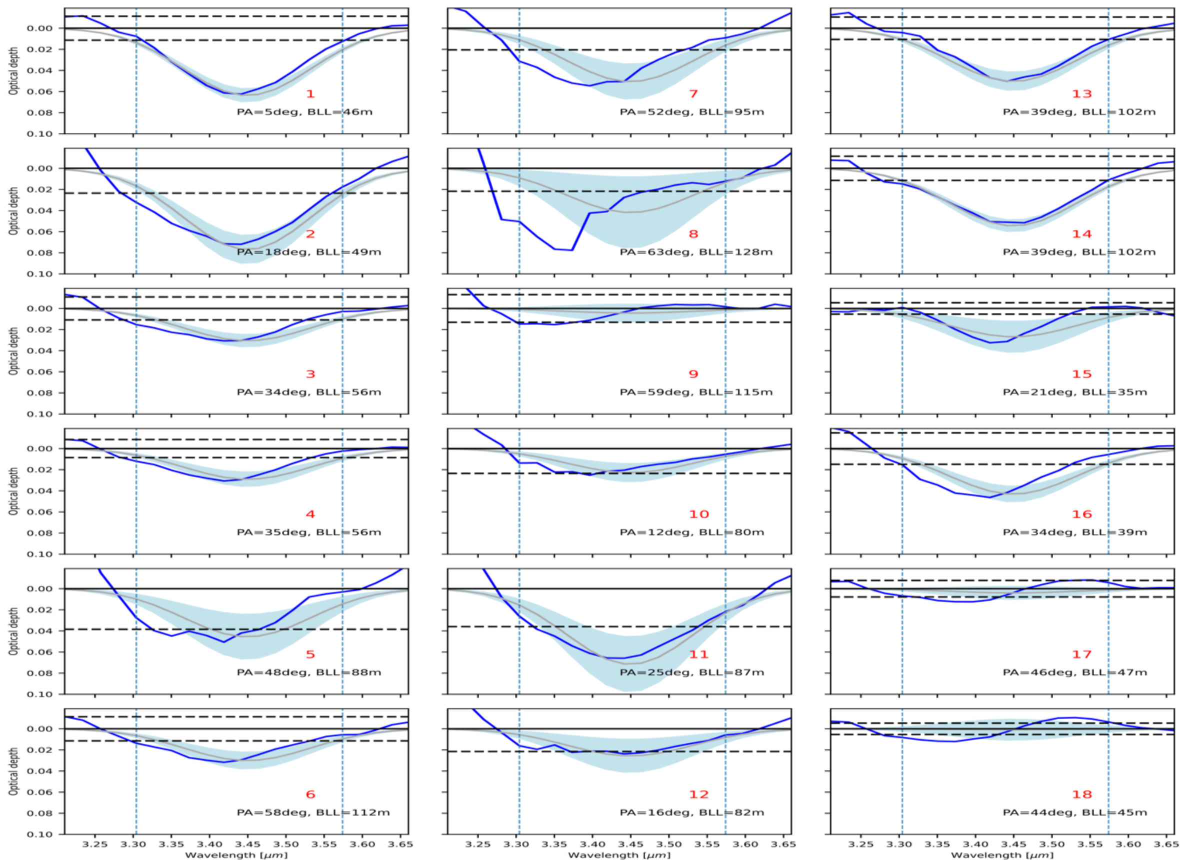


Leftley et al., 2024



Gamez Rosas et al. 2023

NGC1068 Amorphous Carbon Absorption per Baseline



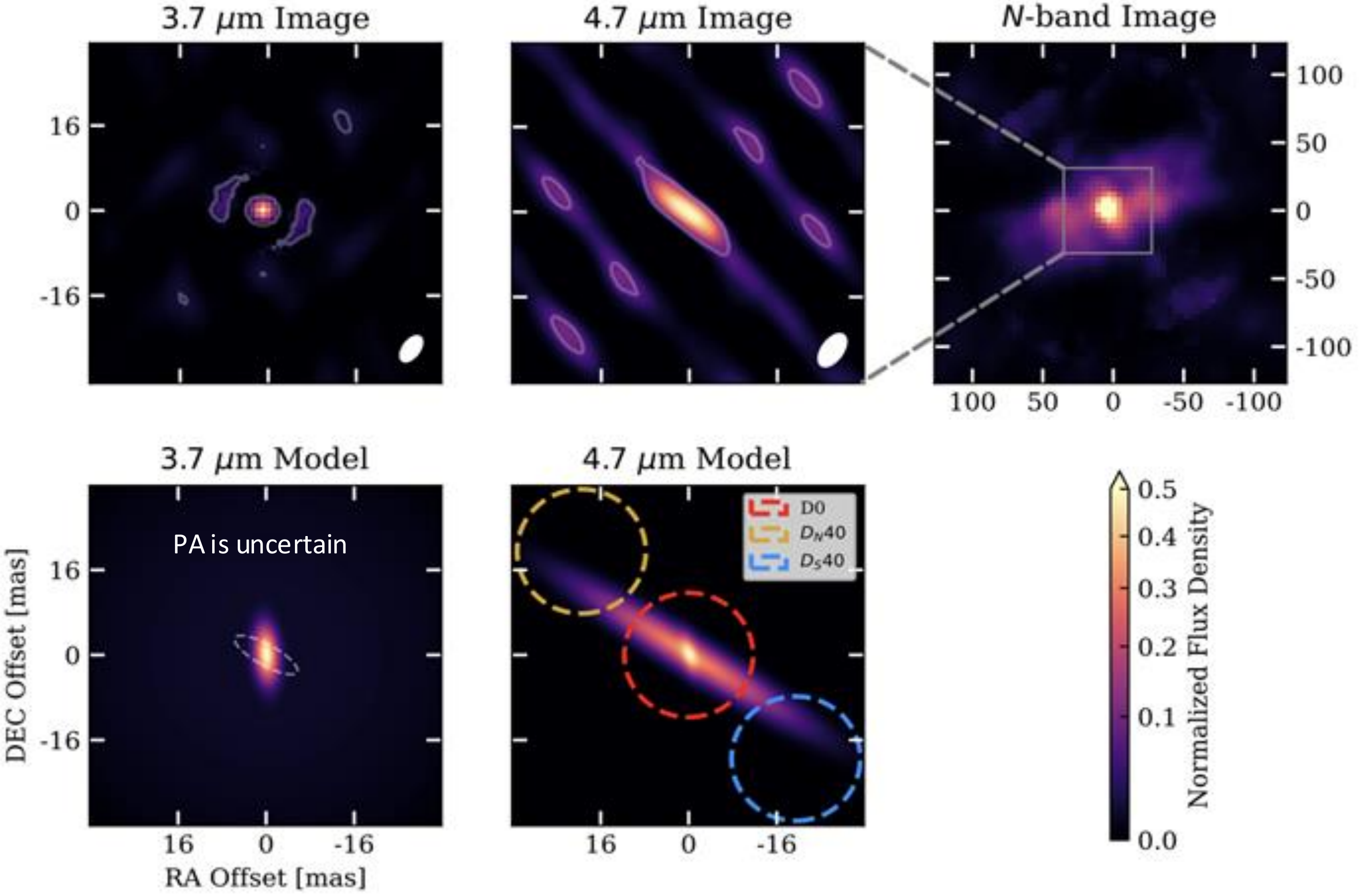
Circinus

LMN-bands published (Isbell et al. 2022, 2023)

Central flux higher than RT models predict

Spatially resolved temperatures agree with clumpy dust

Supports **clumpy** *radiation fountain* models of AGN



PRESENT

- Imaging of Cen A — In Progess
- AT Imaging of large structures in NGC1068 — L-band:good, N-band: needs bias correction
- Survey of AGNs (GO, GTO, Archive) with goals similar to Burtscher MIDI paper but with LM-band and closure phases
    - Data already acquired for ~20 sources: need to create reliable QC estimates
- ADD table of overall GTO results time, sources, successful, failed

AGN Large Survey Main Science Goals

- Allow a statistical study of AGN dust properties beyond ~6 very bright nearby targets
- Similar to MIDI "diversity" survey (Burtscher, 2013, 34 sources, 212 citations) but with greater wavelength coverage and with closure phases
- Needed for accurate modelling of AGN physics; MATISSE allows modelling of temperatures, geometries, and compositions and disk/wind decomposition
- Correlate dust properties with accretion rate, black hole mass, galaxy properties
- Provide tighter constraints on the use of dust for local cosmological distance measurements in combination with GRAVITY gas phase BLR measurements:
- Note also: Sublimation region (extended BLR) redshifted to L band at z~0.5 and we can get entire 2-3.3 micron rest-frame on one detector (complements GRAVITY low-redshift results)

Limits and counts

We definitely need good AO, and a good Fringe Tracker with off-axis tracking (promised ten years ago) to go much beyond current sample. Here are approximate number of N-band observable targets with "high-quality" structural information (visibilities, closure phases, differential phases) for given Fringe Tracker performance. We assume top quality GPAO with LGS

FT limit (K mag)	**(Stand Alone)**	**12.5**	**13.5**	**16**
On-axis	10	17 if not resolved(better S/N)	50	+170
Off-axis	0	+46 (good S/N)	+50	+30

Near Future Developments

- GPAO Short term: using official limit, emasculation of AGN program for the next few years until LGS are available; a few targets available with off-axis bright AO stars
- MATISSE WIDE
  - Extends statistical sample from ~15 to ~60
  - Not currently supported by ESO
  - Almost all necessary work can be done by MATISSE consortium
- Upgrade GRA4MAT to K=13.5 (with reduced Strehl ratio)
  - Extends statistical sample from ~15 to ~50
  - Not supported by ESO/GRAVITY team
  - Requires testing and deeper analysis of GRA4MAT algorithms
- Polarization GRAVITY also interested; Software and Calibration only
- Better atmospheric models Allow longer (software) coherent integration. To 1 hour?

Fainter versus smaller

For sources heated by nuclear UV, there is an approximate scaling law relatinging apparent size

apparent flux and wavelength: $\theta \propto \sqrt{f}\lambda^2$ or of size to resolution at baseline B: $\frac{\theta}{r} \propto \sqrt{f}\lambda B$

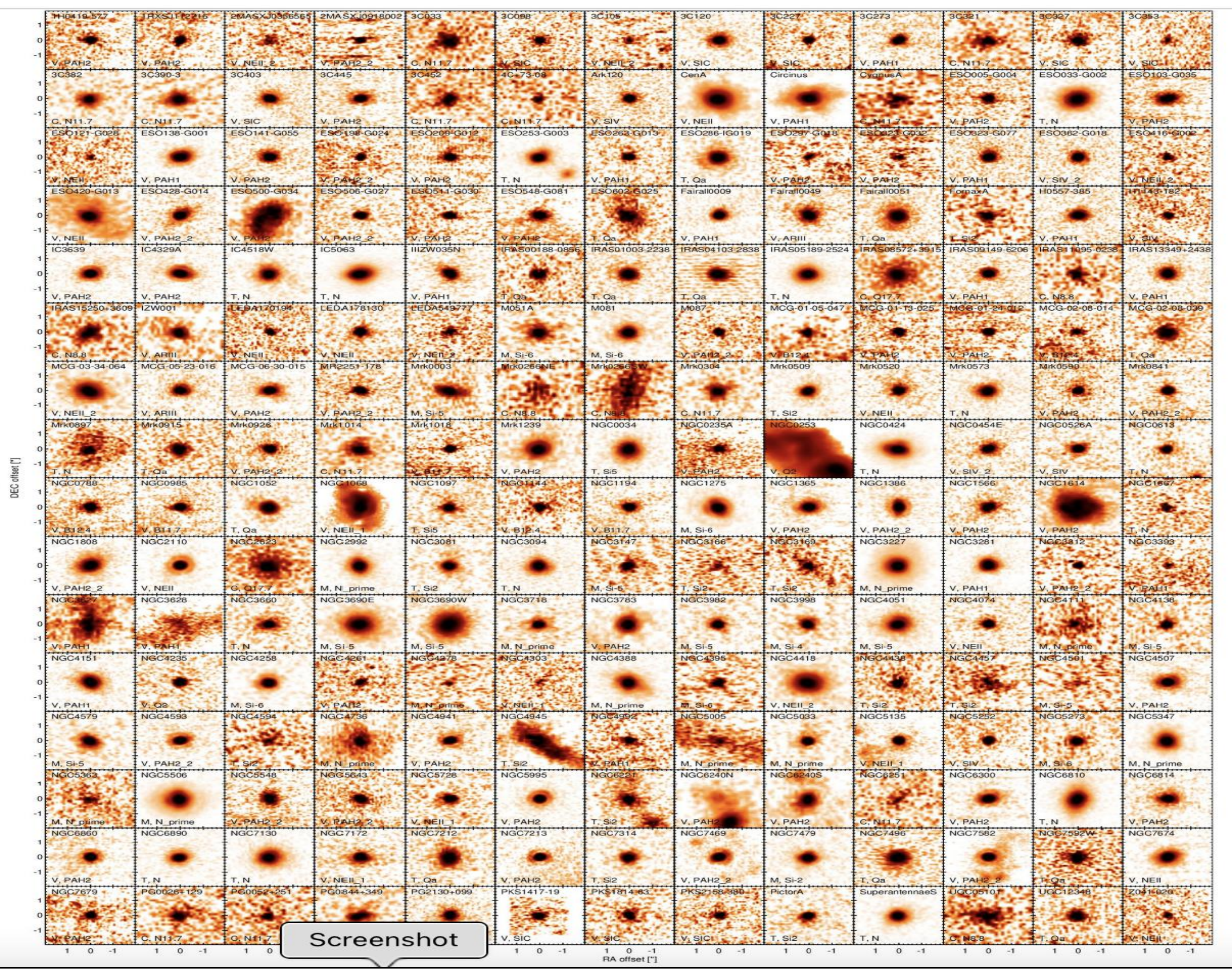
So fainter sources are smaller.

There are perhaps 6-8 very bright well resolved sources that can be mapped with VLTI/MATISSE

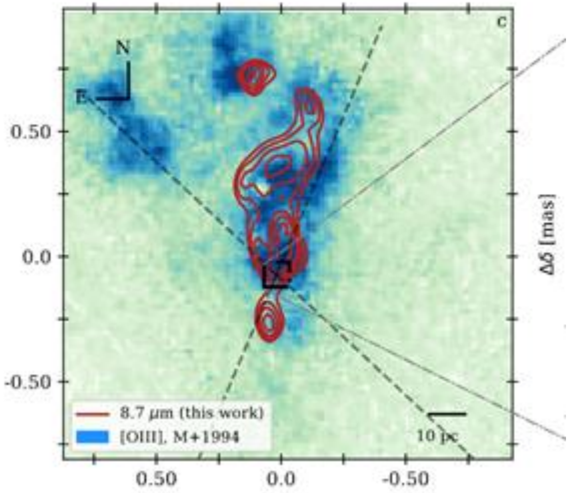
Beyond that there are a dozen or so that have measurable extension (e.g. gaussian fit) under pre-GPAO conditions (almost none with official GPAO limits) and many dozens that can be done with GPAO+LGS+MATISSE-WIDE

Is there a point in going fainter?

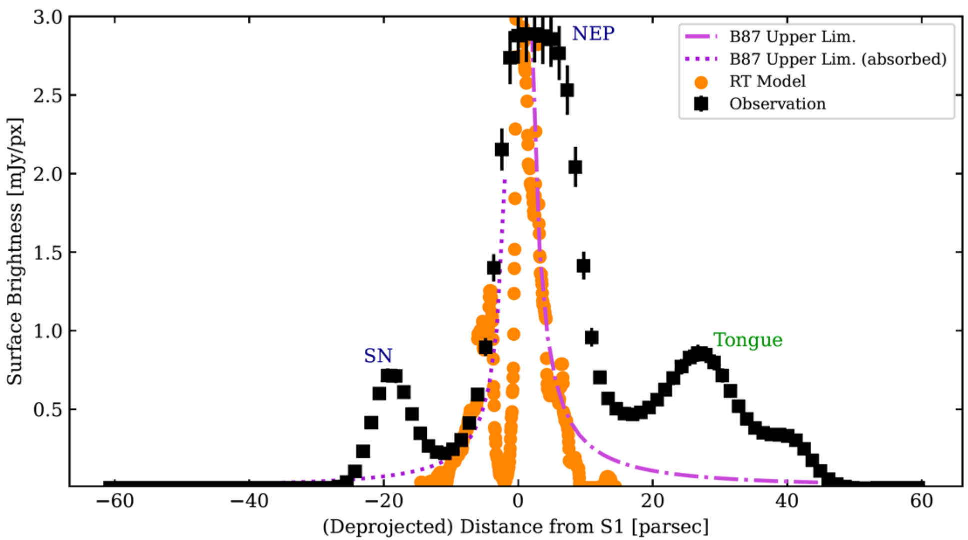
- With parameterized sizes we can start doing statistics of dust structures versus AGN properties such as Luminosity, Eddington ratio, Seyfert type to better understand the physics of the tori and winds
- At redshifts >= 1, the size/flux/luminosity relation breaks down (sources are bigger)
- For very luminous quasars the characteristic size starts bumping into the host galaxy and other physics plays a role
- There are non-radiative heating mechanisms that do not obey the scaling law: for example the well known “Cloud C” in NGC 1068 represents the jet bumping into and heating a molecular cloud (proposed by us in open time, but rejected) . These mechanisms are important in the AGN->galaxy feedback scenarios and should be picked up more often if we can go fainter
- Higher sensitivity allows more information-rich observing modes: higher spectral resolution (crystallinity) and polarization (B fields, scattering)


DEC offset ["]
RA offset ["]
Screenshot

LBTI midIR Image on top of HST OIII



midIR brightness (black) on top of centrally heated RT model



MATISSE Polarization

- Science vision:
  - Morphology, and maybe strength of magnetic field: vital in MHD driven flow
  - Distinguish scattered from emitted light
- Expect ~>5% polarization in AGNs based on single dish data
- Expect accuracy of ~< 1% from MATISSE polarizers
- Support for outside MATISSE group for calibration and reduction:
  - E.Lopez-Rodriguez (South Carolina)
  - C. Packham (Texas)
  - D. Sluse (Liege)
- No hardware changes necessary
- Need new OB definitions
- No new DRS routines (but probably new recipes)
- Most software work in postprocessing reduction and calibration
- GRAVITY has already begun a similar effort, including modelling of VLTI polarization behavior, we should co-ordinate with them

Far Future

- 5^{th} UT? Not very interesting for faint sources 1.3km adds resolution
- Better Fringe Trackers c.f. Romain’s talk. OR:Extreme high spectral resolution for fiber beam transport
- LIDAR Laser Fringe Tracker