# The dusty torus surrounding NGC 1068's active nucleus observed with GRAVITY/VLTi

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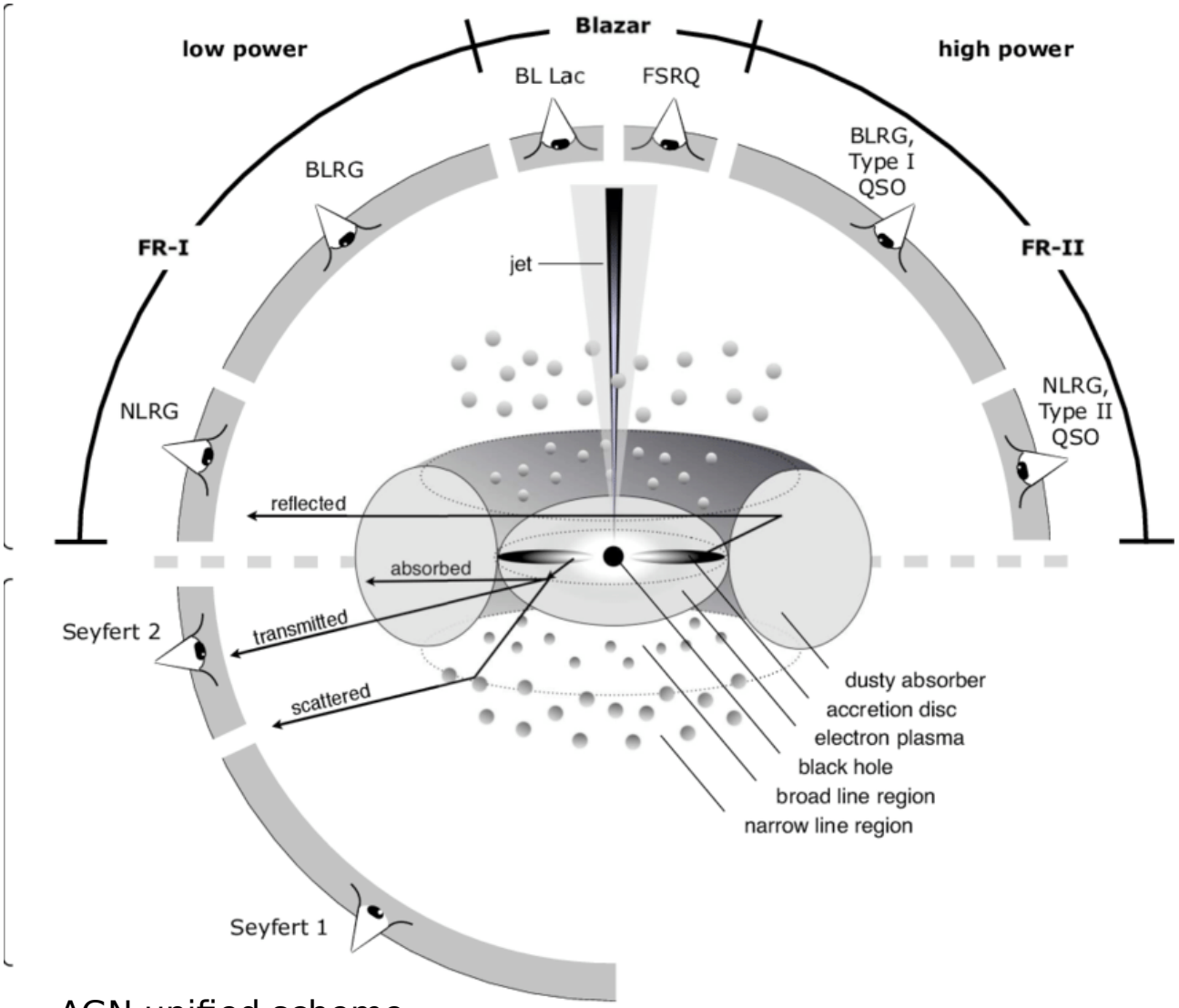
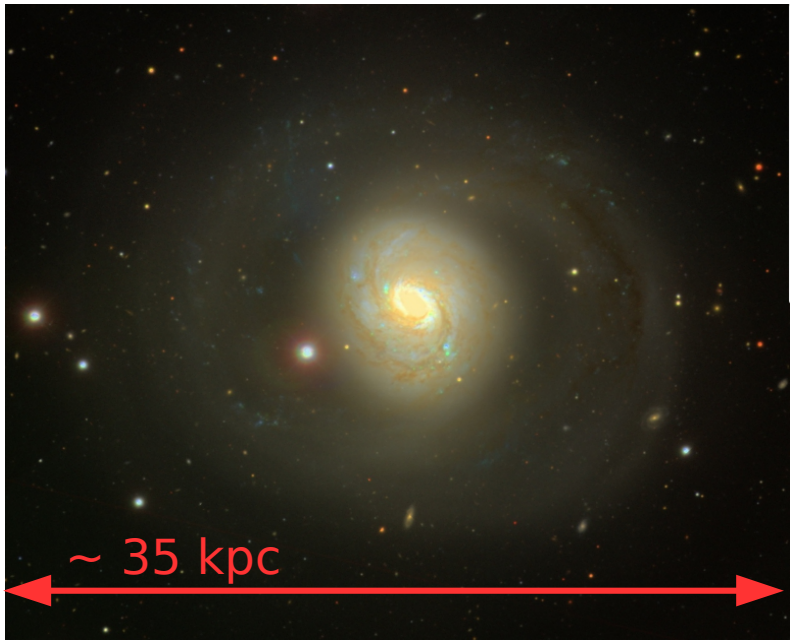
# Active Galactic Nuclei



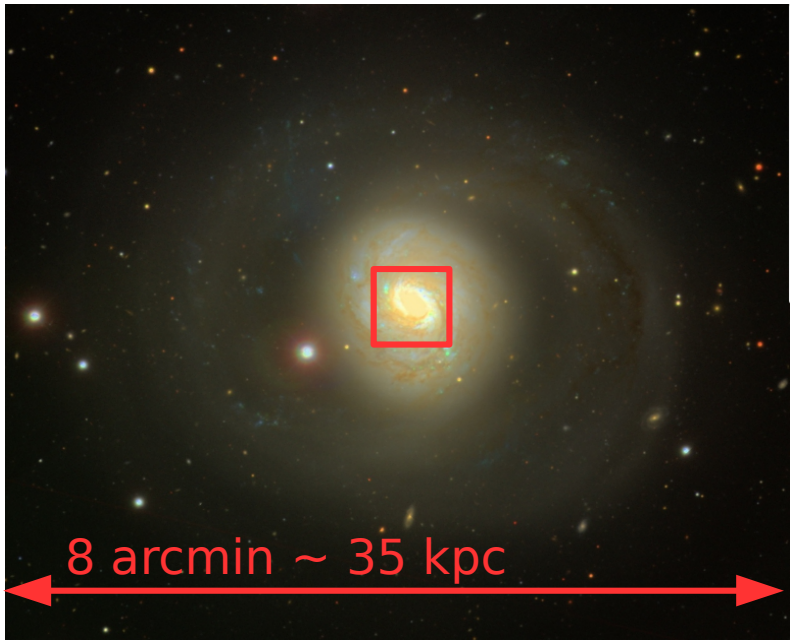

AGN unified scheme
Graphic courtesy of Marie-Luise Menzel (MPE)

- Many different observational features depending on the target
- All those difference explained by the unified model
- One kind of object, different positions of the observer
- A supermassive black hole and its accretion disk surrounded by an obscuring structure: ***the dusty torus***

# NGC 1068



# NGC 1068



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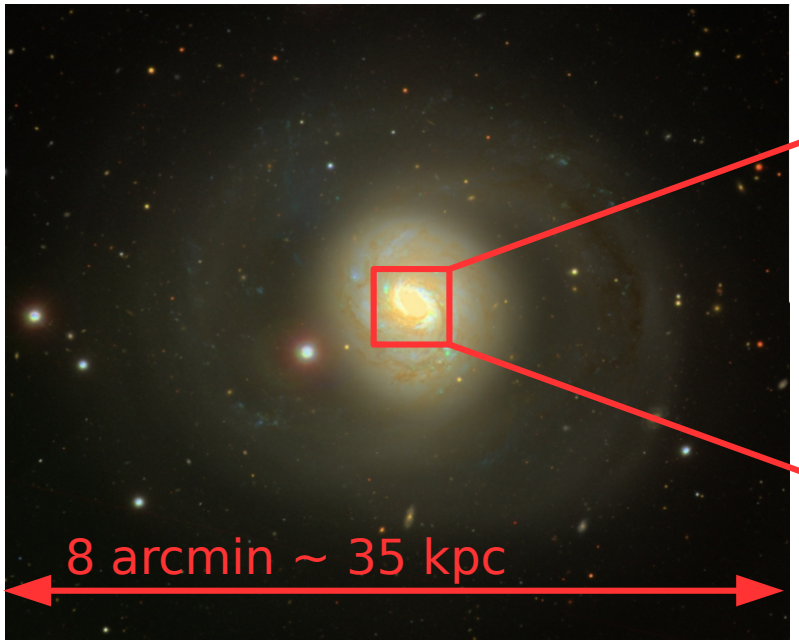
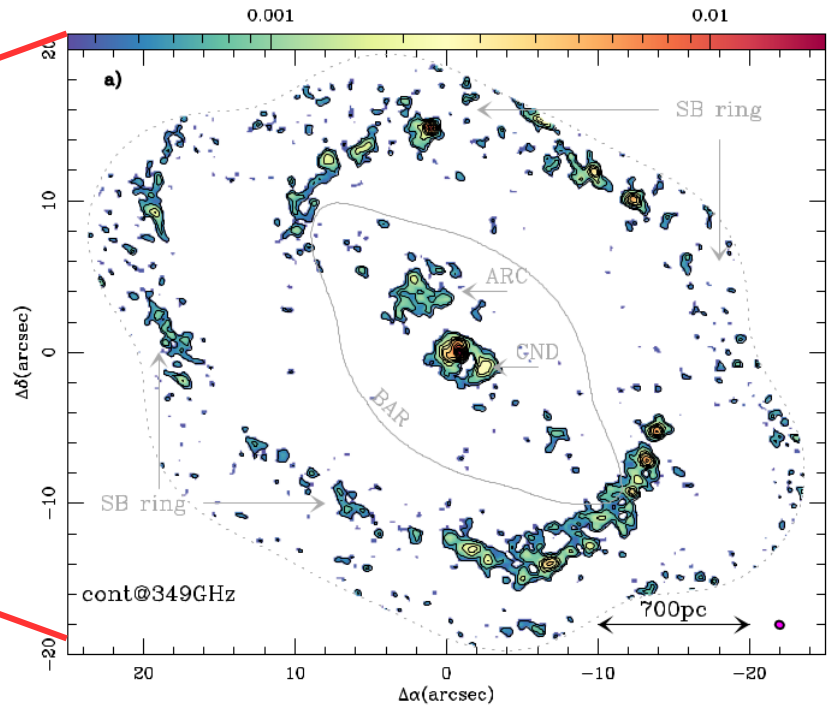



FoV / 10



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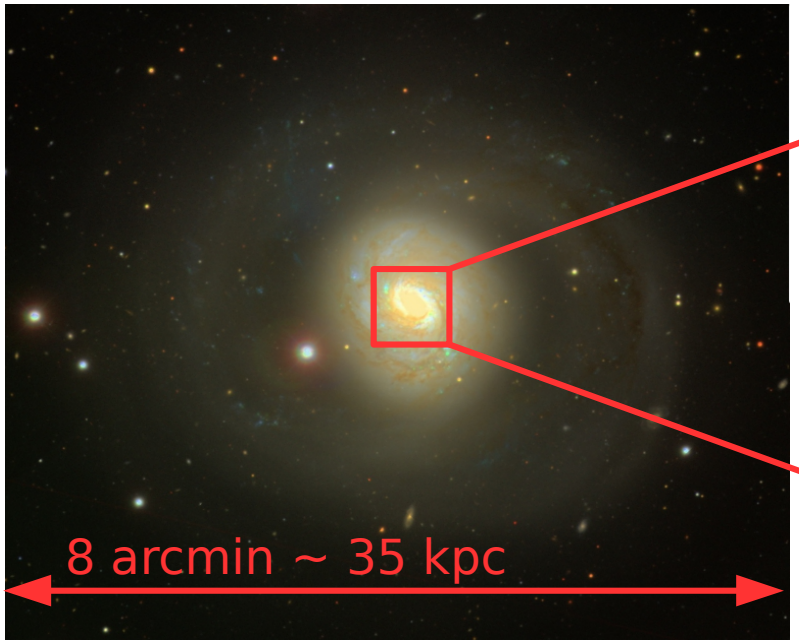
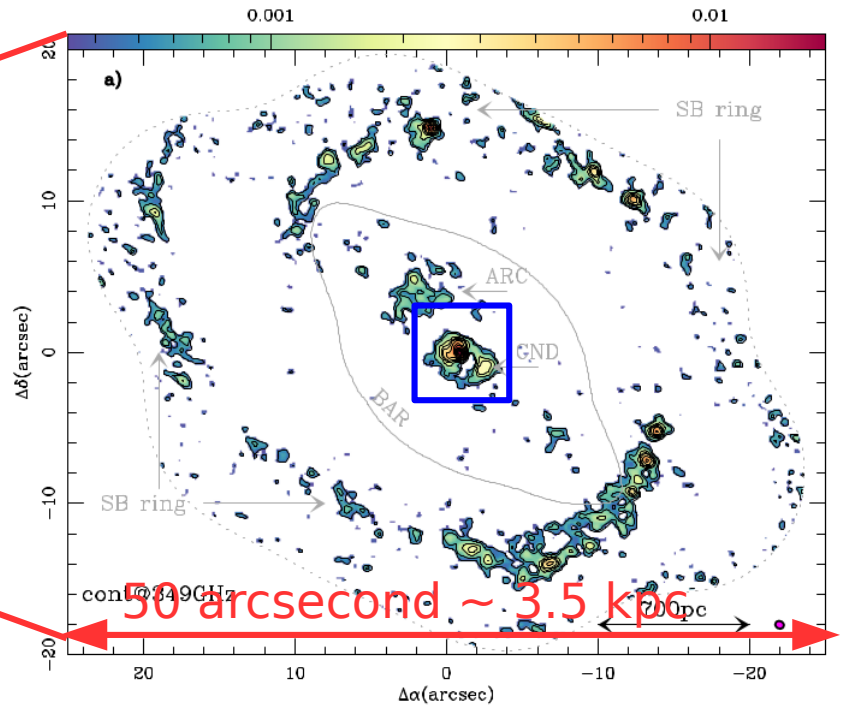



FoV / 10



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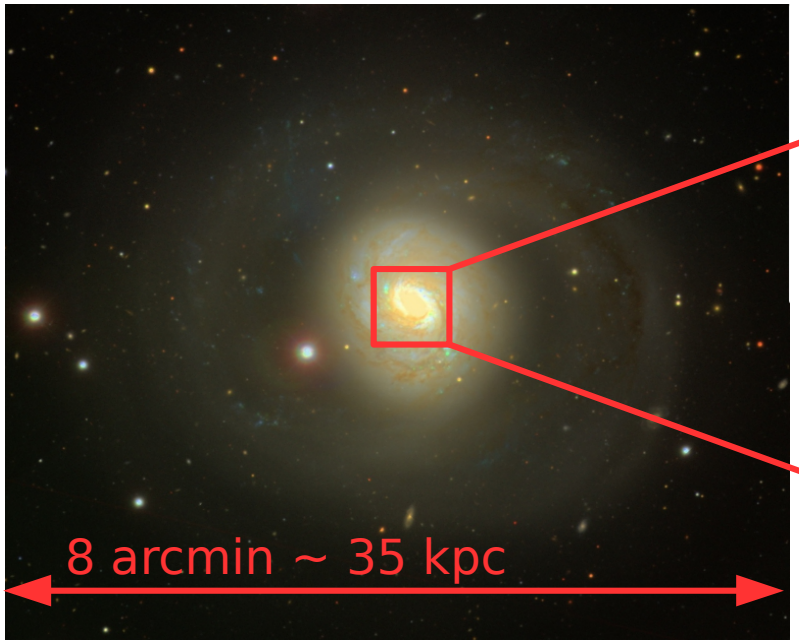
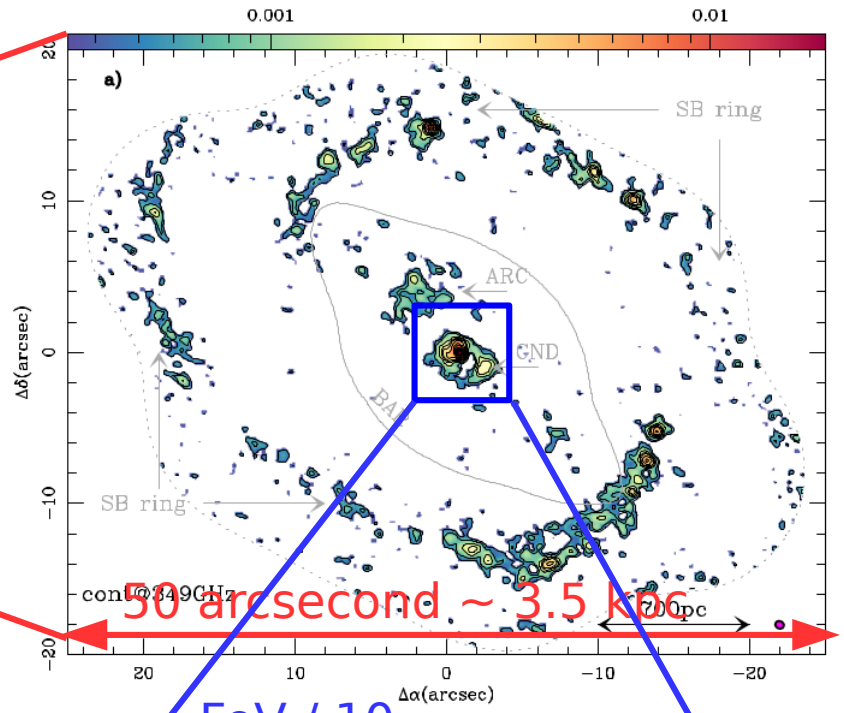
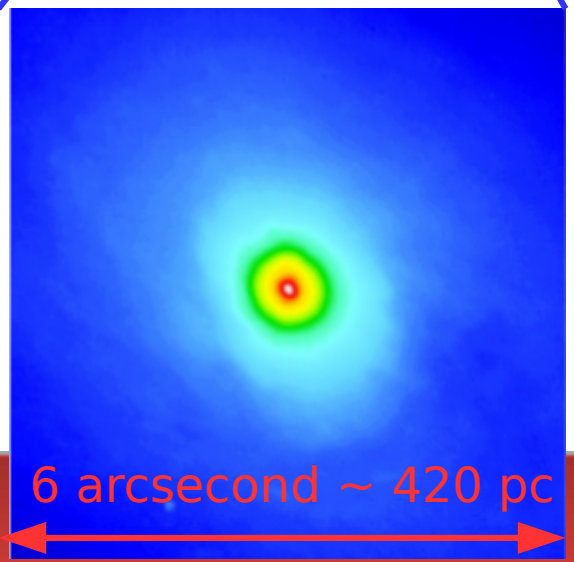



FoV / 10




FoV / 10



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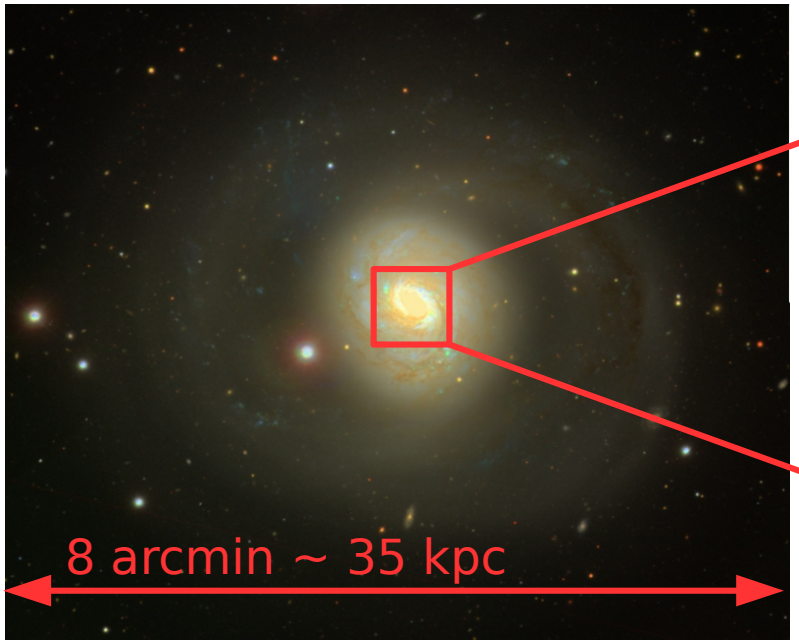
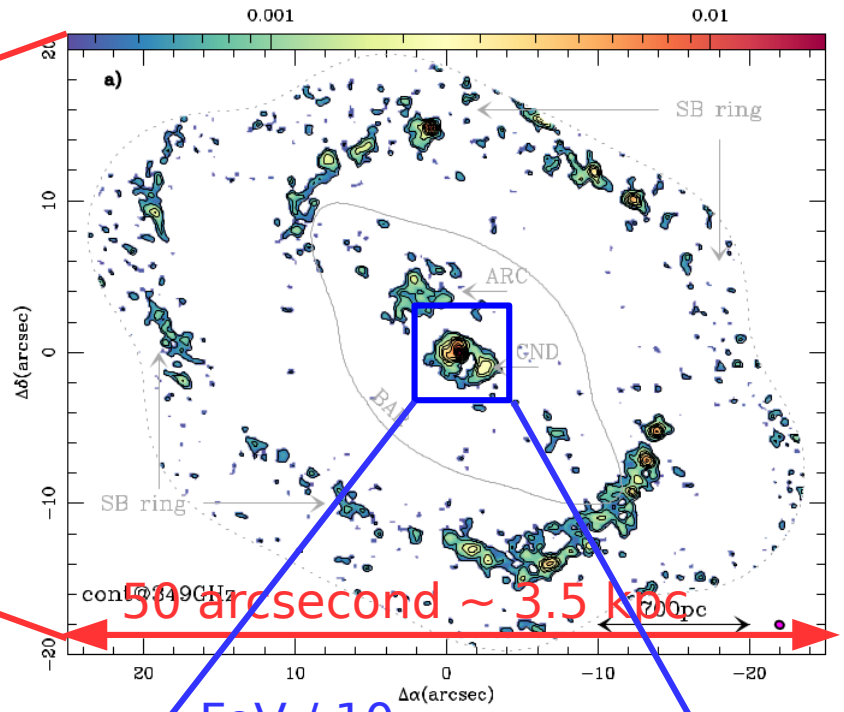
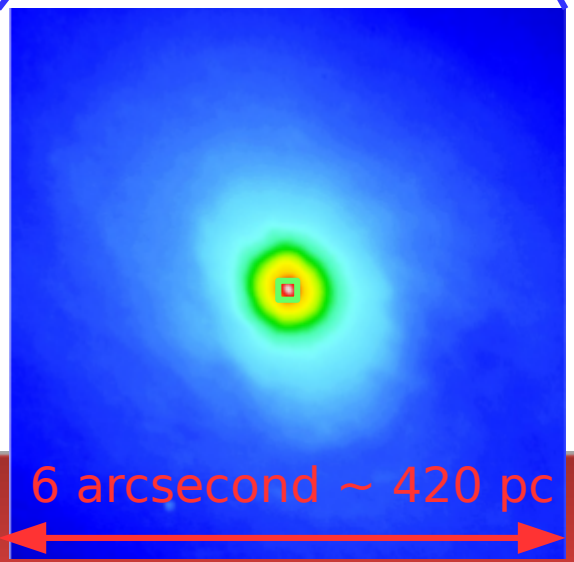



FoV / 10




FoV / 10



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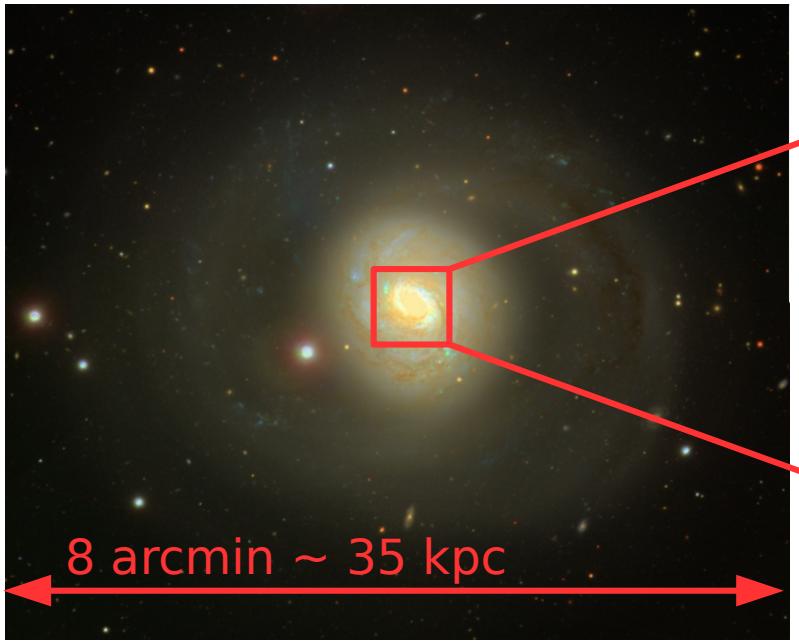
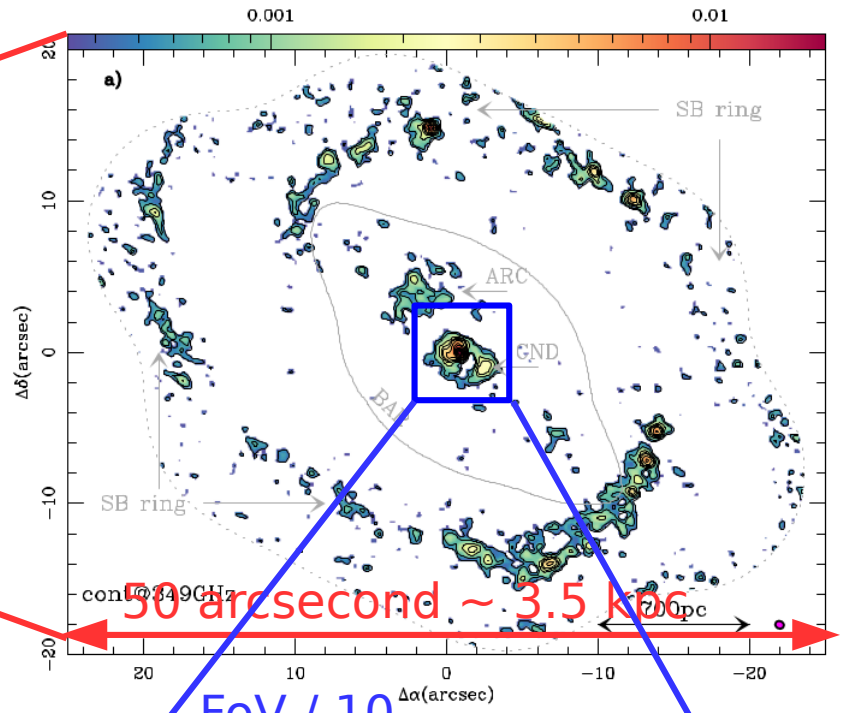


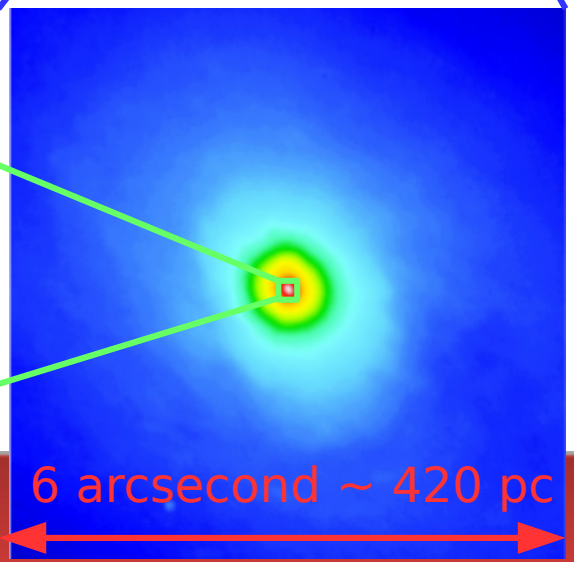

FoV / 10



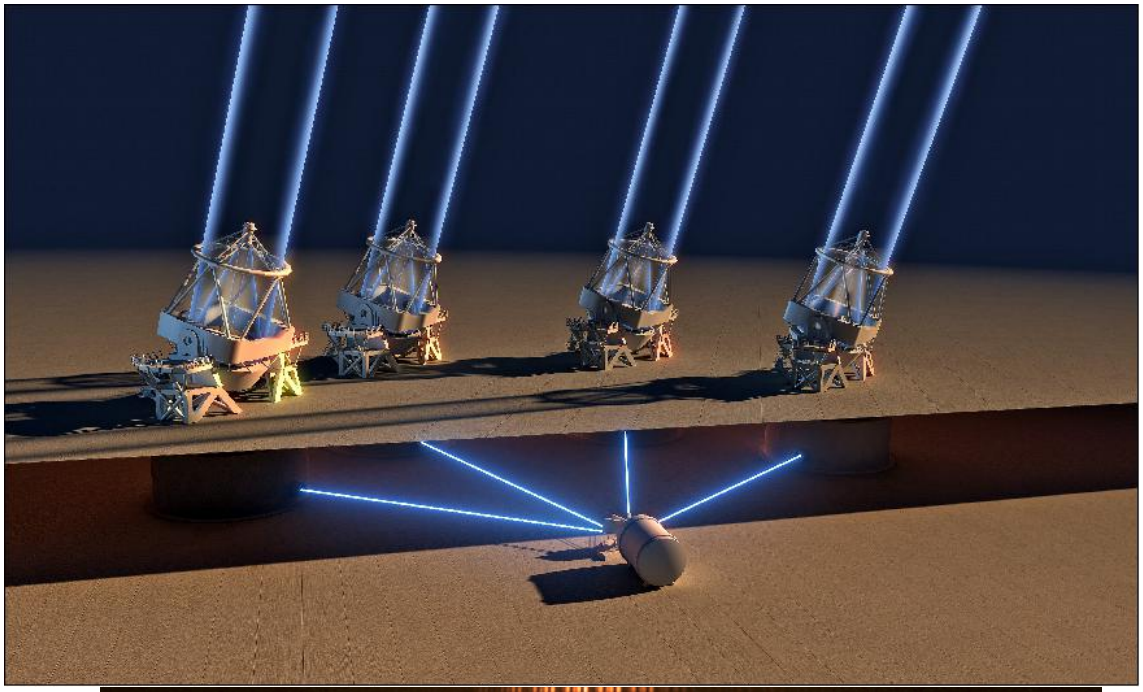

FoV / 10

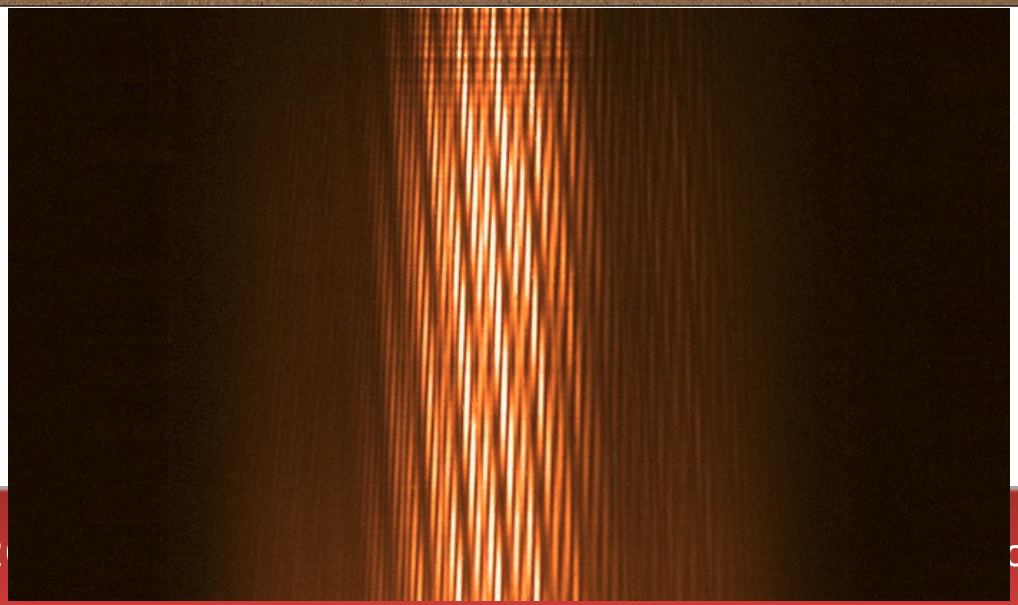
**THIS TALK**

FoV / 100



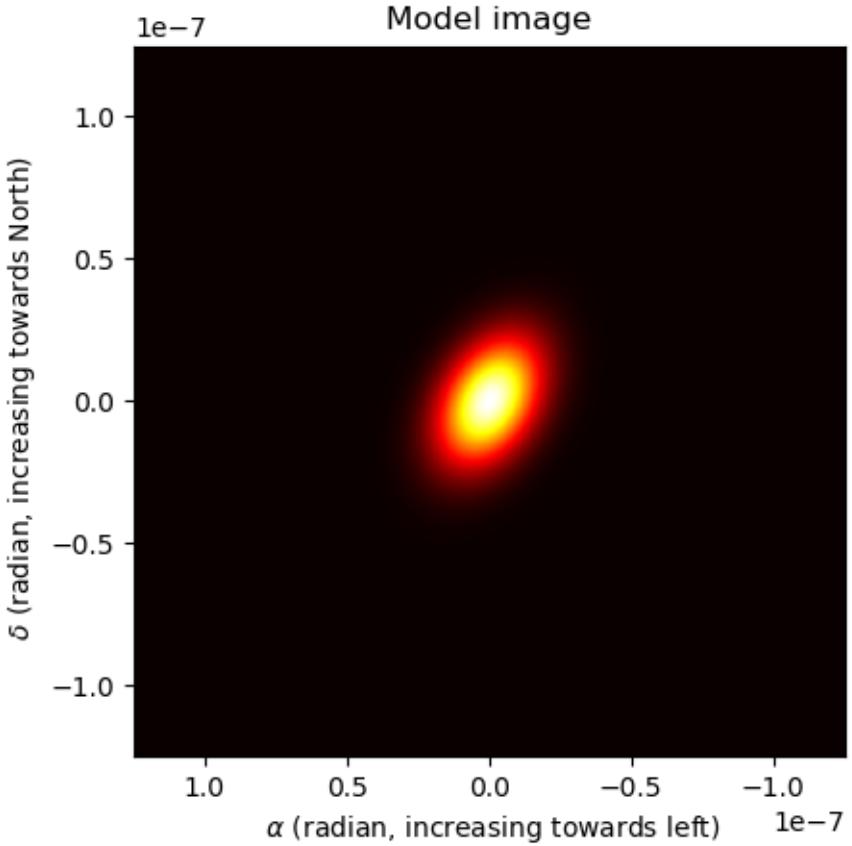
# GRAVITY/VLTi



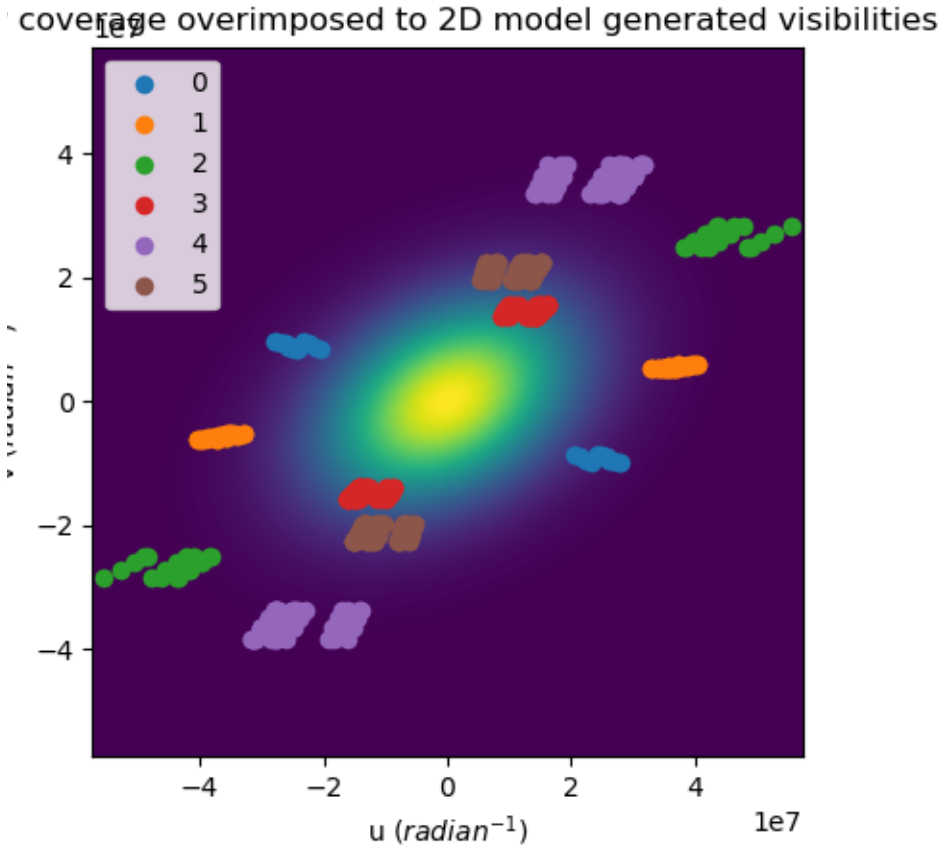


- Interferometer at the VLTi
- Combines the beams of the four 8m telescopes
- K band (2.0 – 2.4 um)
- Very high angular resolution : up to 4 mas
- Does not provide images
- Provides fringes
- Fortunately, ***fringes provide a measurement of the Fourier Transform of the image***

# Interferometry 101

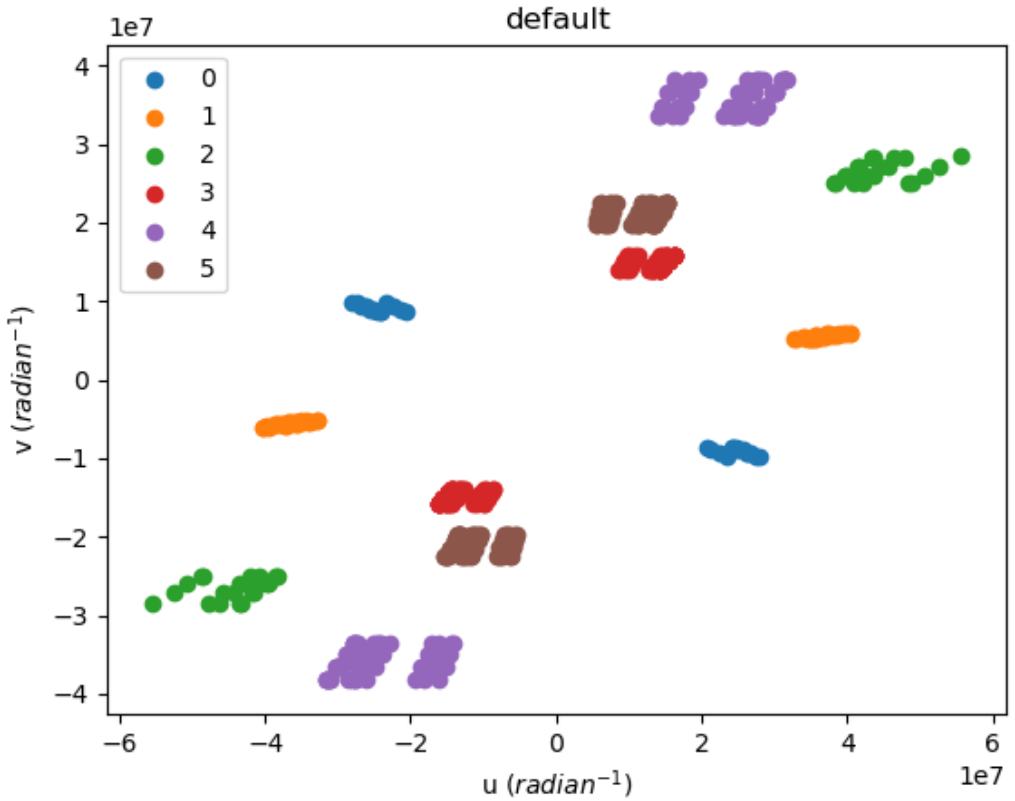



Hypothetical image of an astronomical object (elongated gaussian)

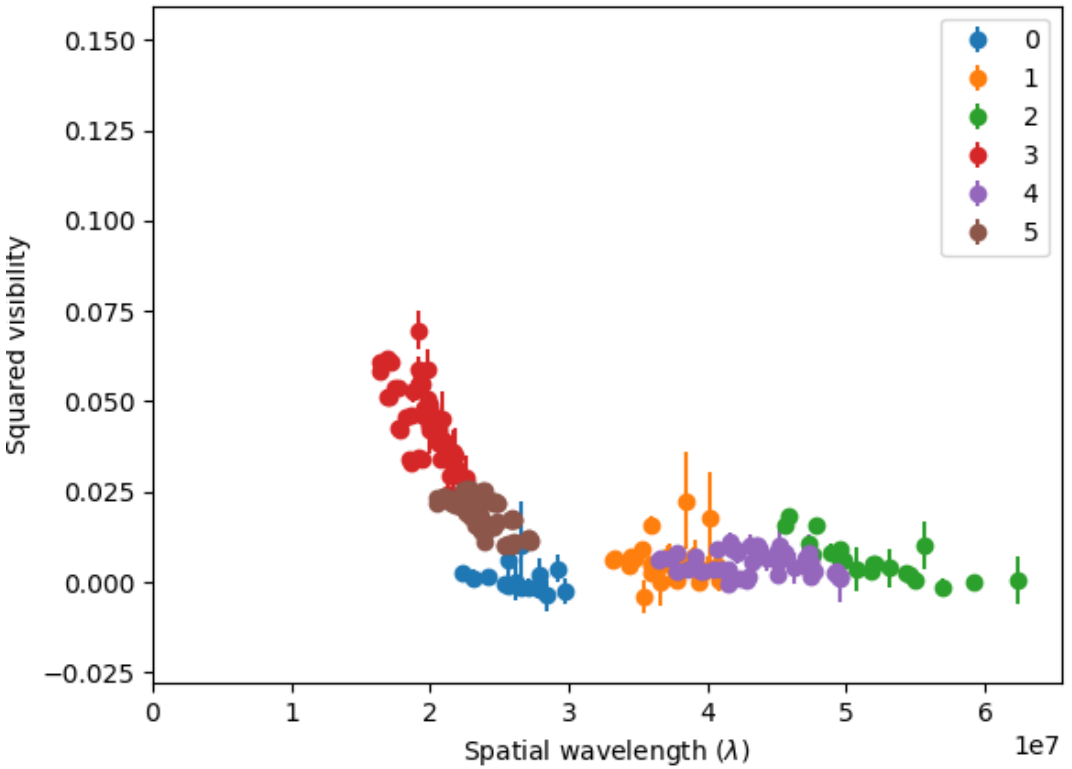



Fourier transform of the image and GRAVITY sampling : uv plane

# The observation

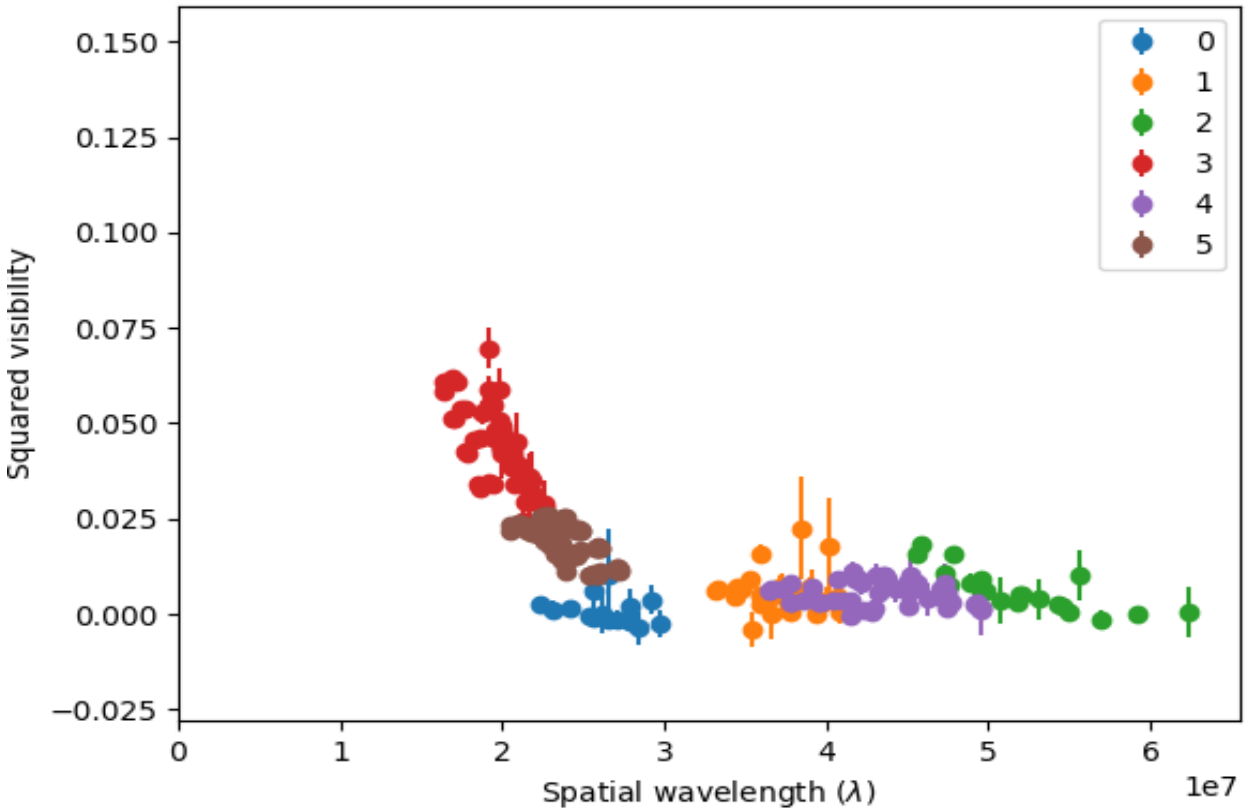



UV plane of our observation




Visibility points of our observation (i.e. norm of the FT)

# How to deal with visibility points?




Visibility points of our observation
(i.e. norm of the Fourier Transform)

- Directly attempt to reconstruct an image from the visibility points (Pfuhl+2020)
- Fit simple geometrical model to the visibility points (Raban+2009)
- Generate images from an AGN simulation to be compared with the visibility (this work)

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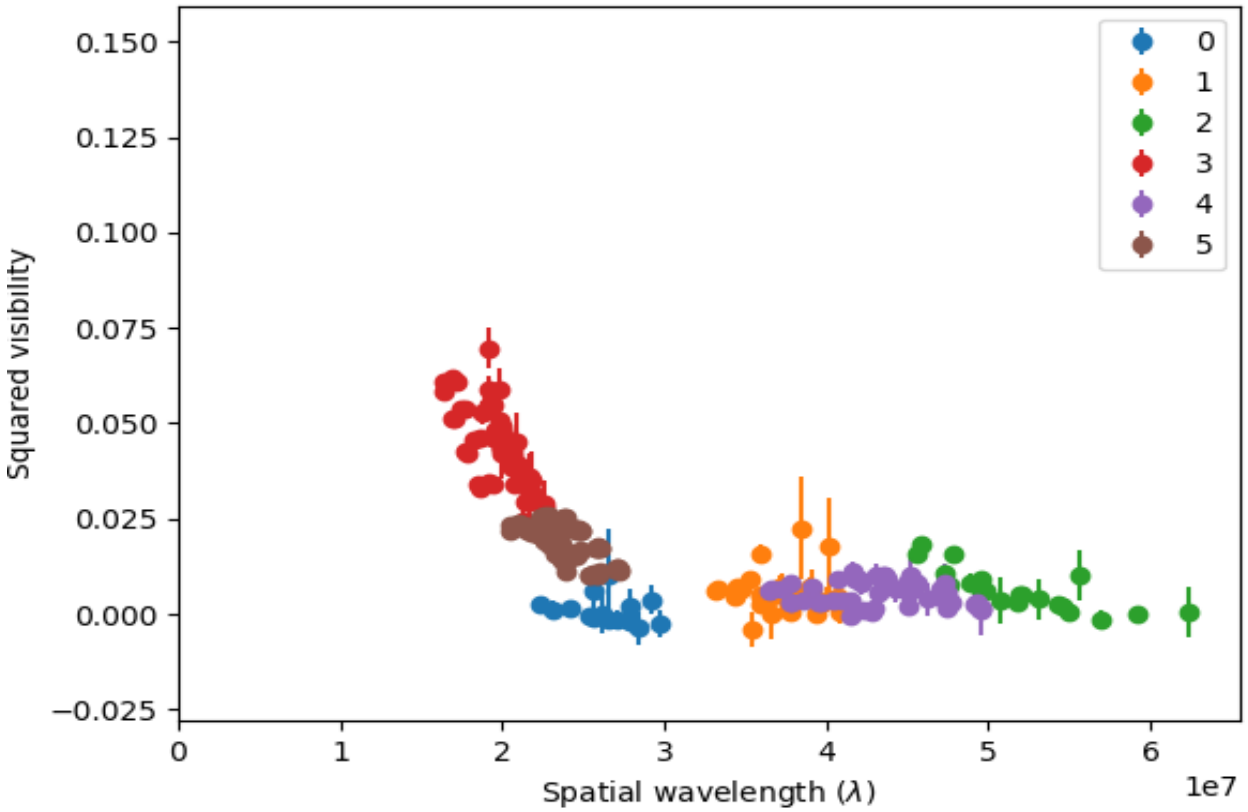


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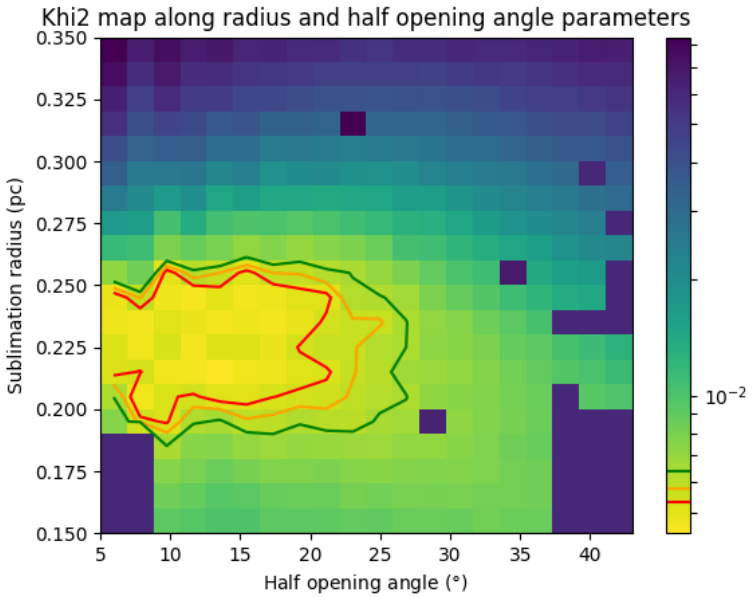
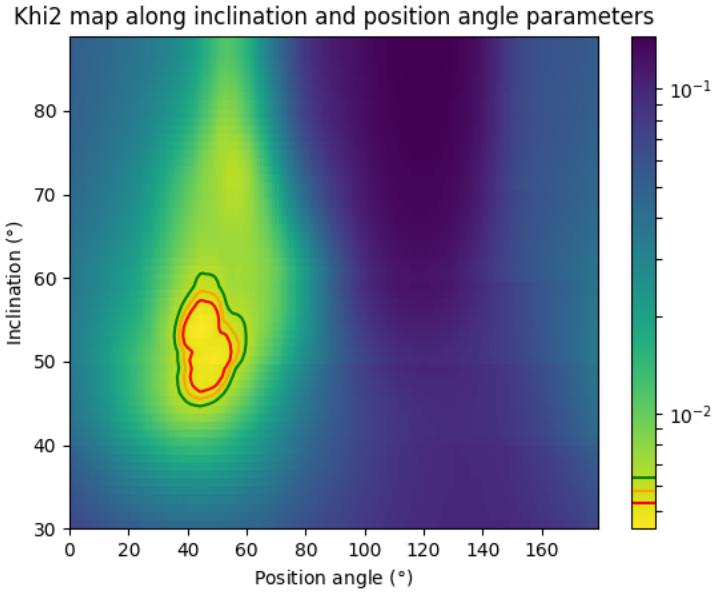
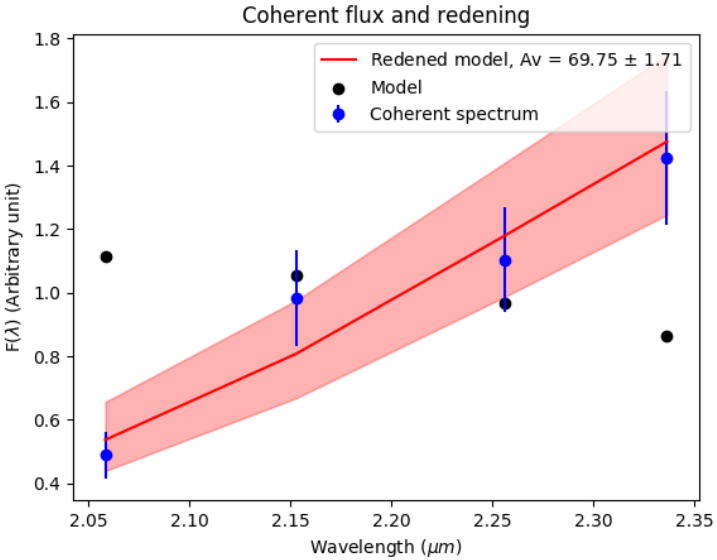
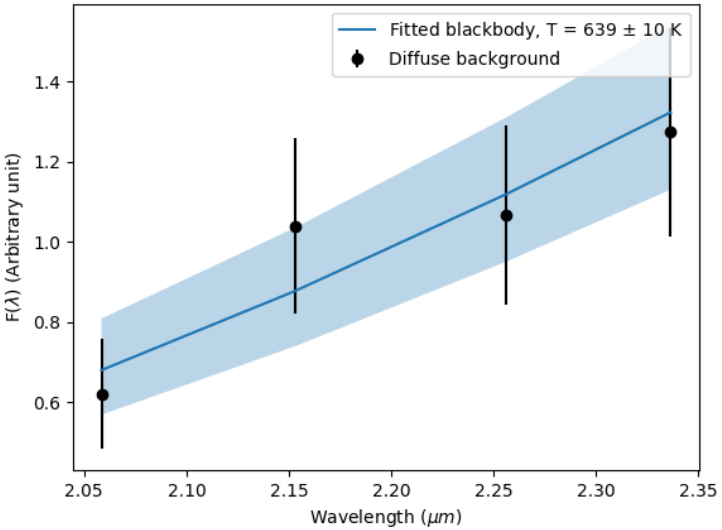
# What can be constrained?



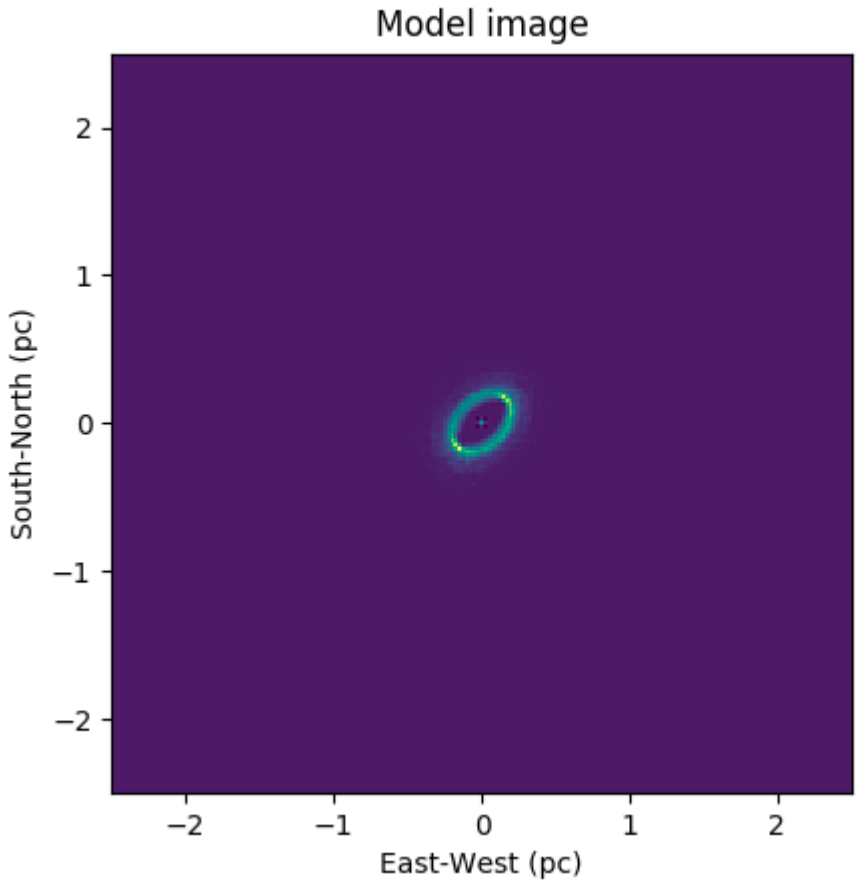



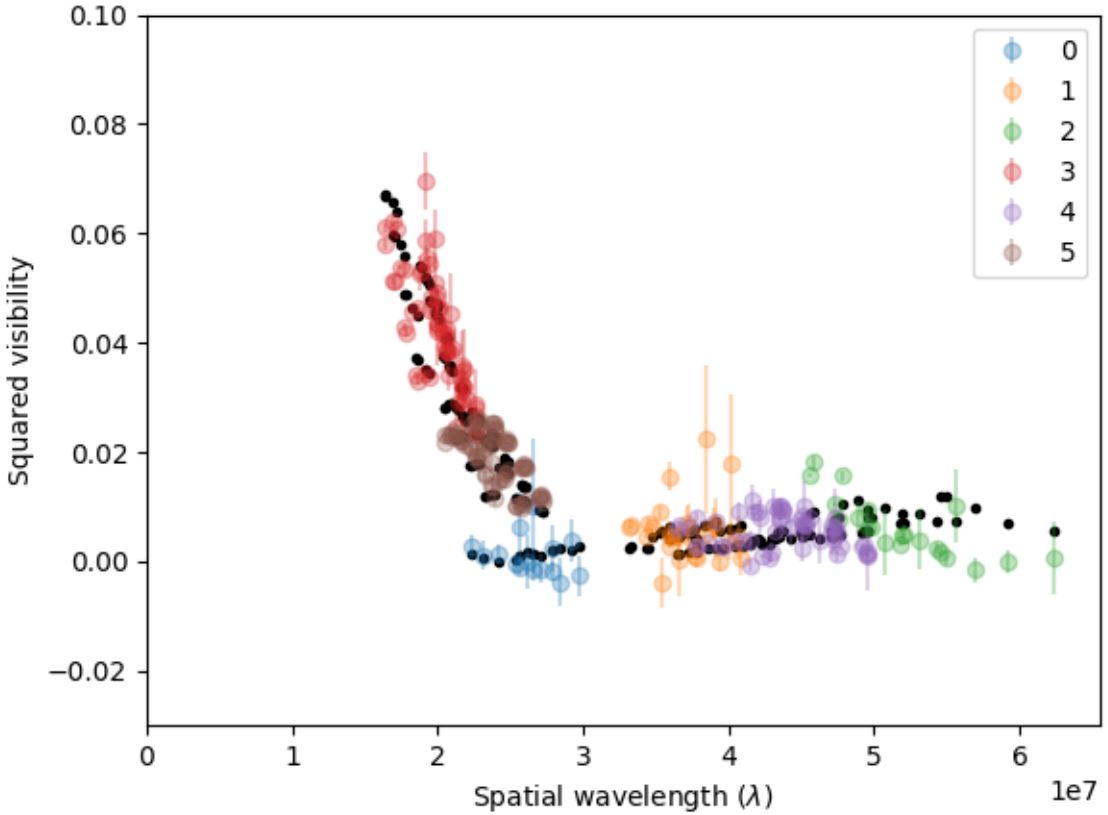

- Geometrical parameters:
  - Sublimation radius
  - Opening angle
  - Inclination
  - Position Angle
- Foreground extinction
- Incoherent background



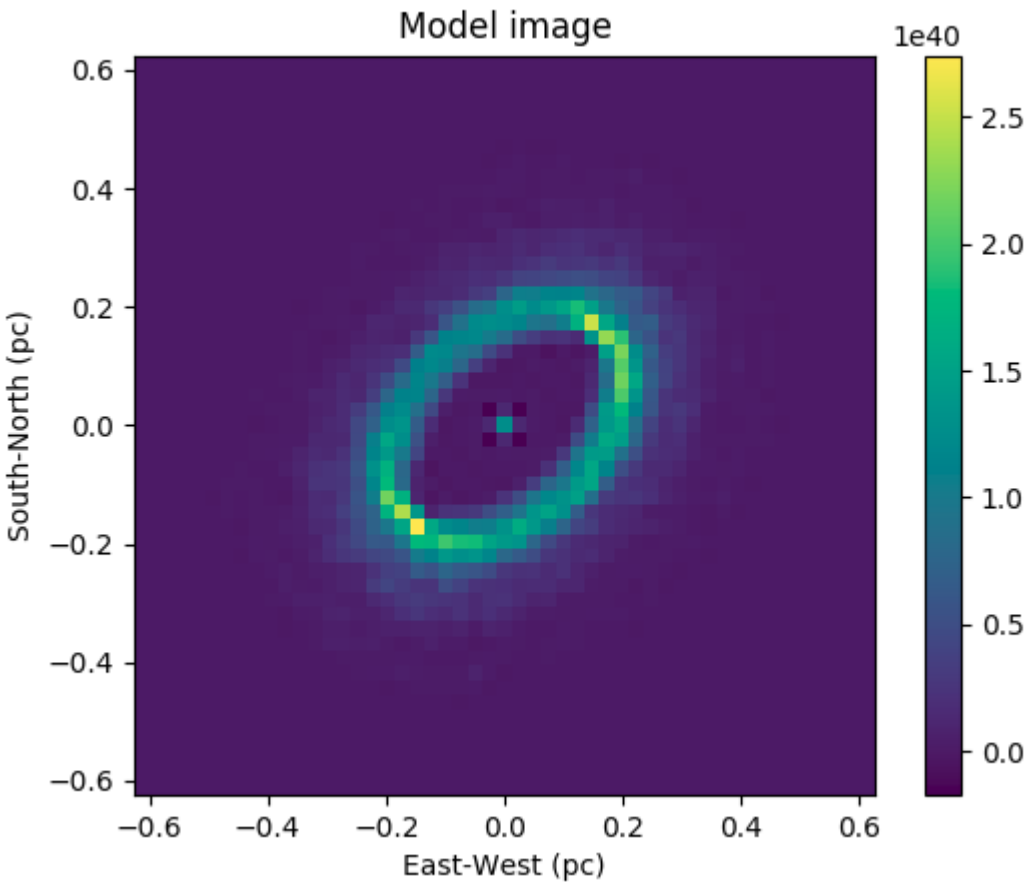



# Best model


Model image
South-North (pc)
East-West (pc)
2
1
0
−1
−2
−2
−1
0
1
2


Squared visibility
Spatial wavelength (λ)
1e7
0.10
0.08
0.06
0.04
0.02
0.00
−0.02
0
1
2
3
4
5
6
0
1
2
3
4
5

# Best model

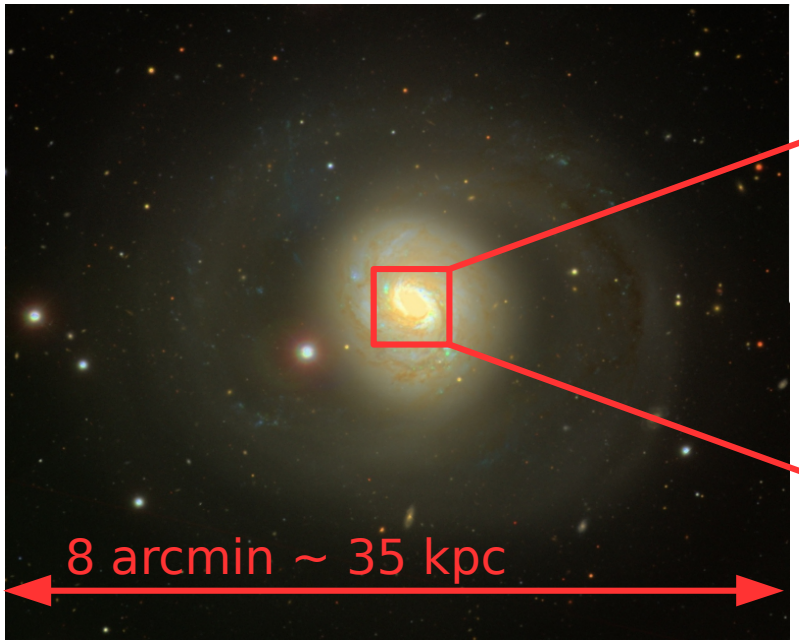



- Sublimation radius:
  R = 0.22 +/- 0.02 pc
- Inclination:
  I =52 +/- 6°
- Position Angle:
  PA = -46 +/- 7°
- Opening angle:
  $A_{1/2}$ = 13 +/- 8°
- Foreground extinction:
  $A_v$ = 70
- Background:
  Blackbody at T ~ 640 K

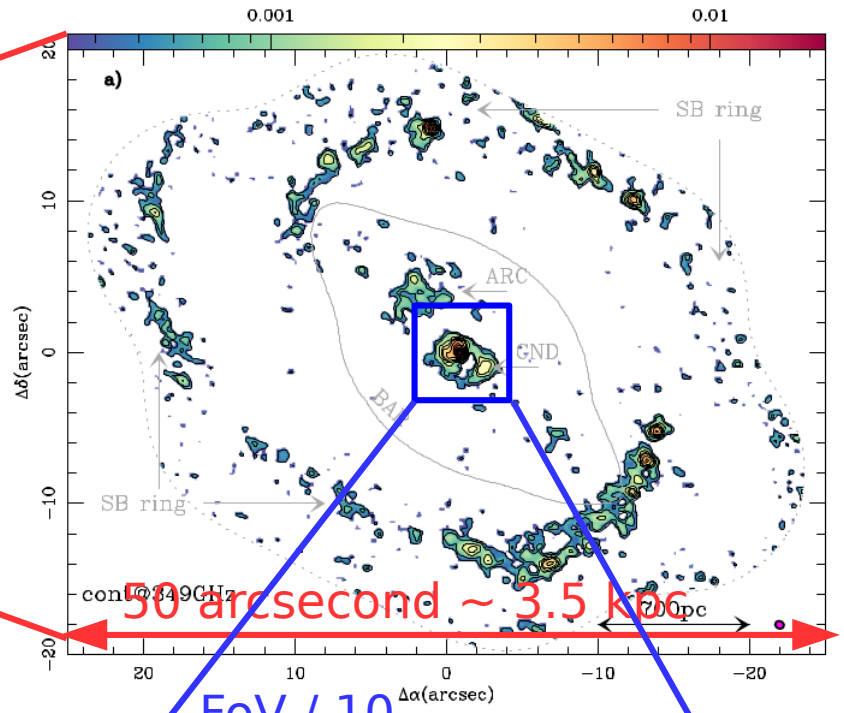
# Conclusions

- GRAVITY/VLTi is able to fully resolve the hot dust in NGC 1068’s nucleus
- We have good constraints on the geometrical properties of the structure
- The hot dust is not responsible for the obscuration of the nucleus
- There is a misalignement with the observed maser disk:
  - Either both are part of a *warped* parsec scale disk
  - Either we are looking at two embedded rings

# Thank you for your attention




FoV / 10

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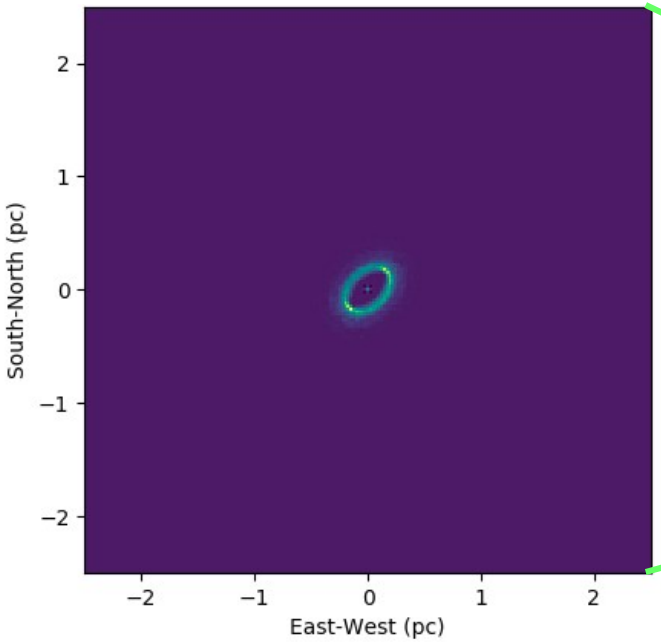


FoV / 100