AGN interferometric observations to measure cosmological distances

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Atelier API “Ondes gravitationnelles et objets compacts”

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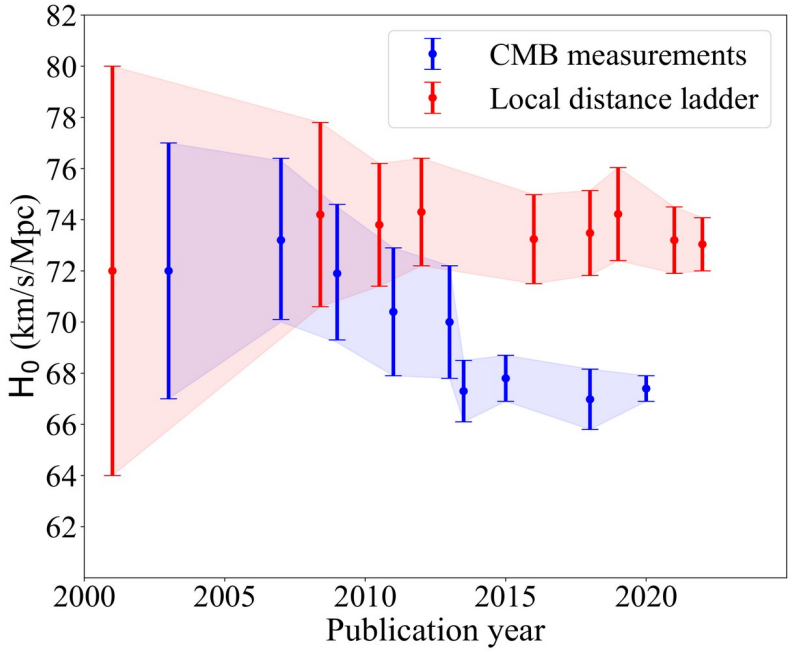
Context: Hubble tension

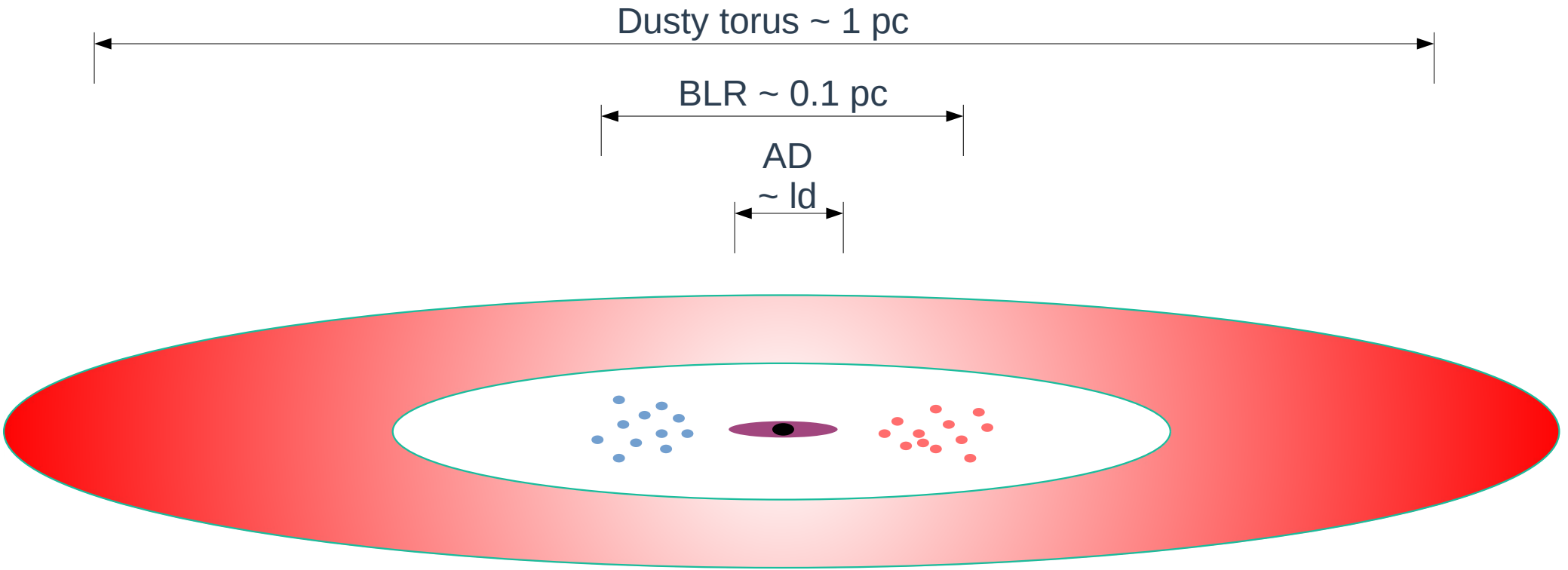
~5σ difference between H_0 measurements:

- **Local Universe:**
  $H_0 = 73.04 \pm 1.04$ Km.s^{-1}.Mpc^{-1}
- **CMB:**
  $H_0 = 67.27 \pm 0.60$ Km.s^{-1}.Mpc^{-1}



Hu et al (2023)

Solution: Active Galactic Nuclei as independent distance measurements

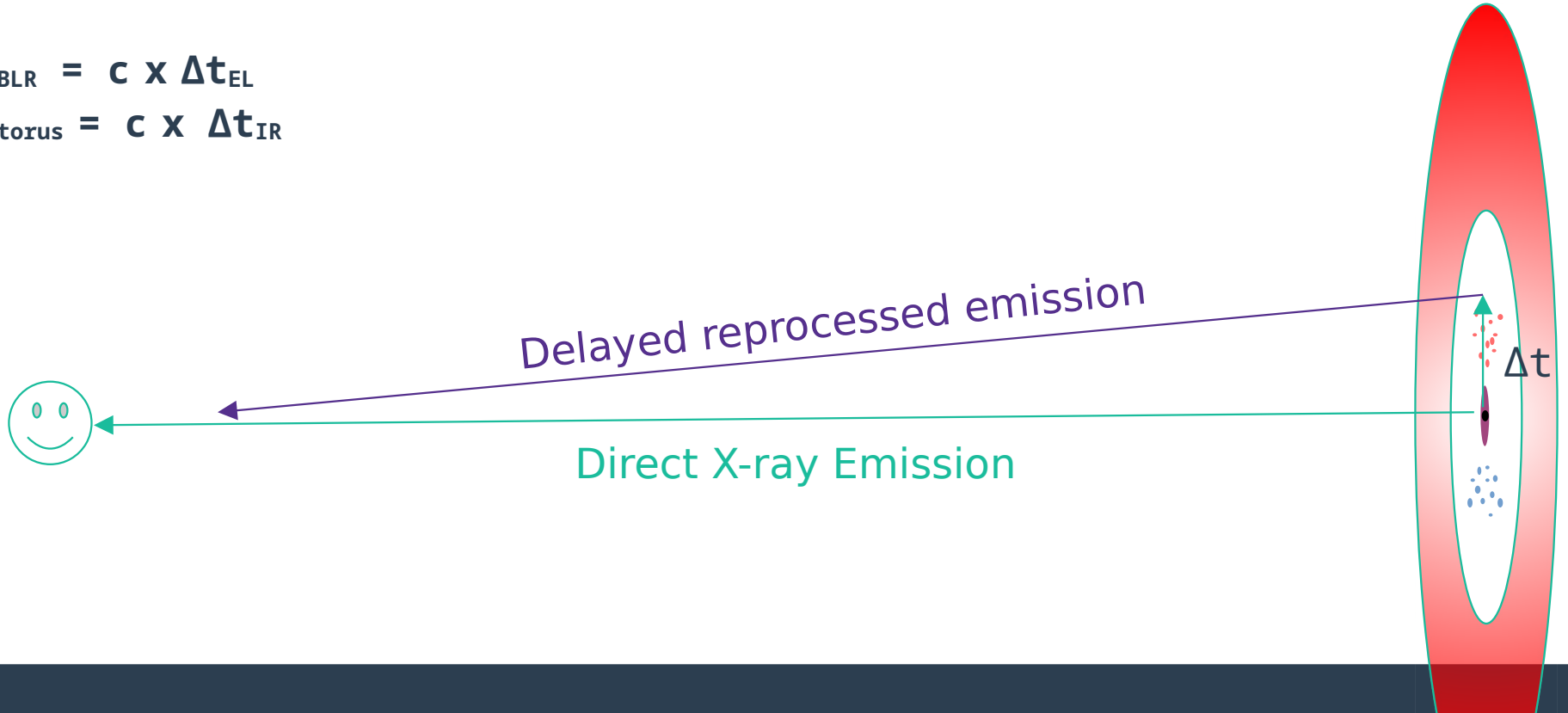


A) Reverberation Mapping

Time delay between X-ray variations vs BLR and torus IR variations

$R_{BLR} = c \times \Delta t_{EL}$

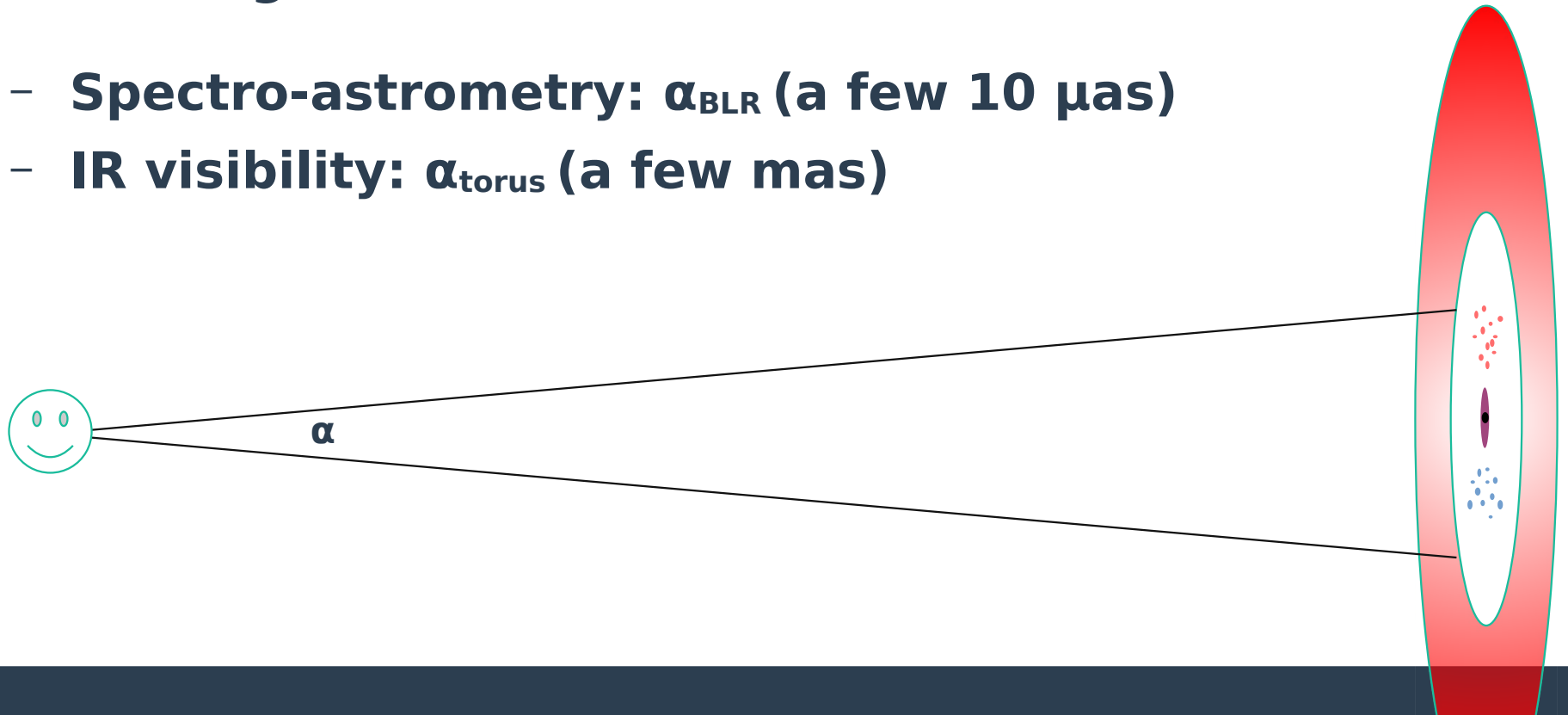
$R_{torus} = c \times \Delta t_{IR}$



A) Interferometry

Direct angular sizes with GRAVITY/VLTI:

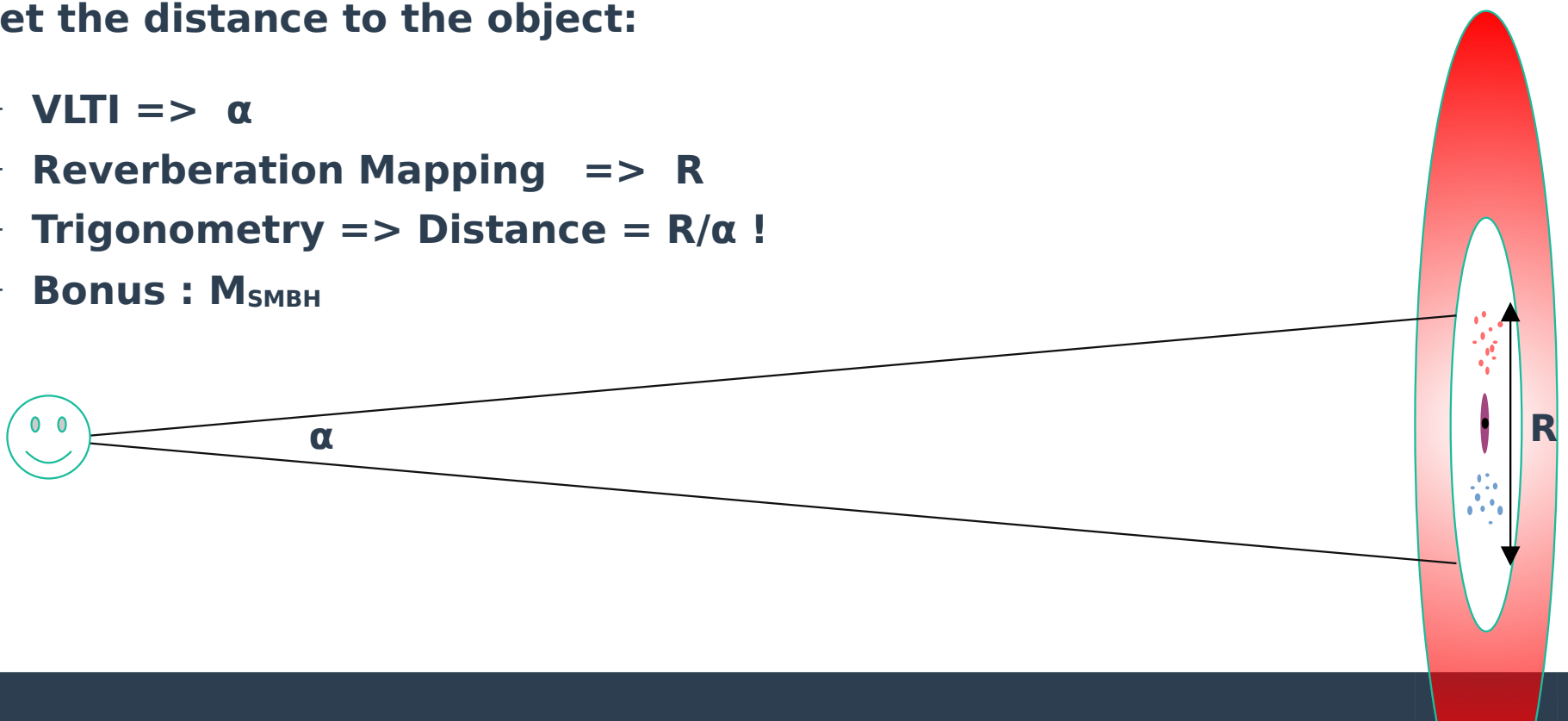
- **Spectro-astrometry: α_{BLR} (a few 10 µas)**
- **IR visibility: α_{torus} (a few mas)**



Interferometry + Reverberation mapping

Knowing the angular size and the physical size we can get the distance to the object:

- **VLTI => α**
- **Reverberation Mapping => R**
- **Trigonometry => Distance = R/α !**
- **Bonus : M_{SMBH}**



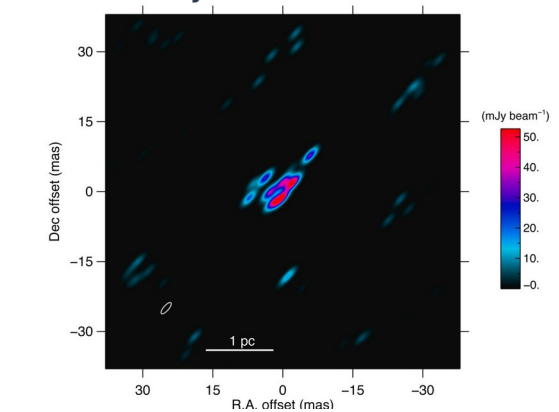
Problems

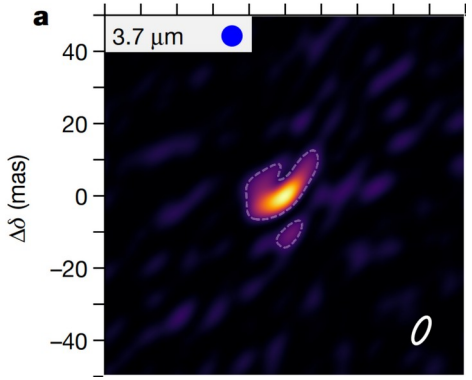
- **While independent from the distance ladder and the ΛCDM model, there are some problems:**
  - Dependent on the model of the torus/BLR
  - Degeneracy between parameters, in particular *i* and M_{SMBH}
  - Low number of targets
- **Projet AGN_MELBA**
- **My contribution:**
  - Improve the model of the dusty torus
  - Improve interferometric image reconstructions

Interferometric image reconstruction

- **Problem:**
  - Interferometers give access to very high angular resolution, but do not provide images
  - They provide an incomplete and irregular sampling of the Fourier Transform of the images
  - Reconstructing the images is a highly degenerate inverse problem with an infinite number of solution
- **Solution:**
  - Include *a priori* knowledge about the geometry of the source, i.e. regularization
    - Find the best compromise between fit to the data and adequation to this regularization term
    - My new method :)

Gravity Collab (2020)

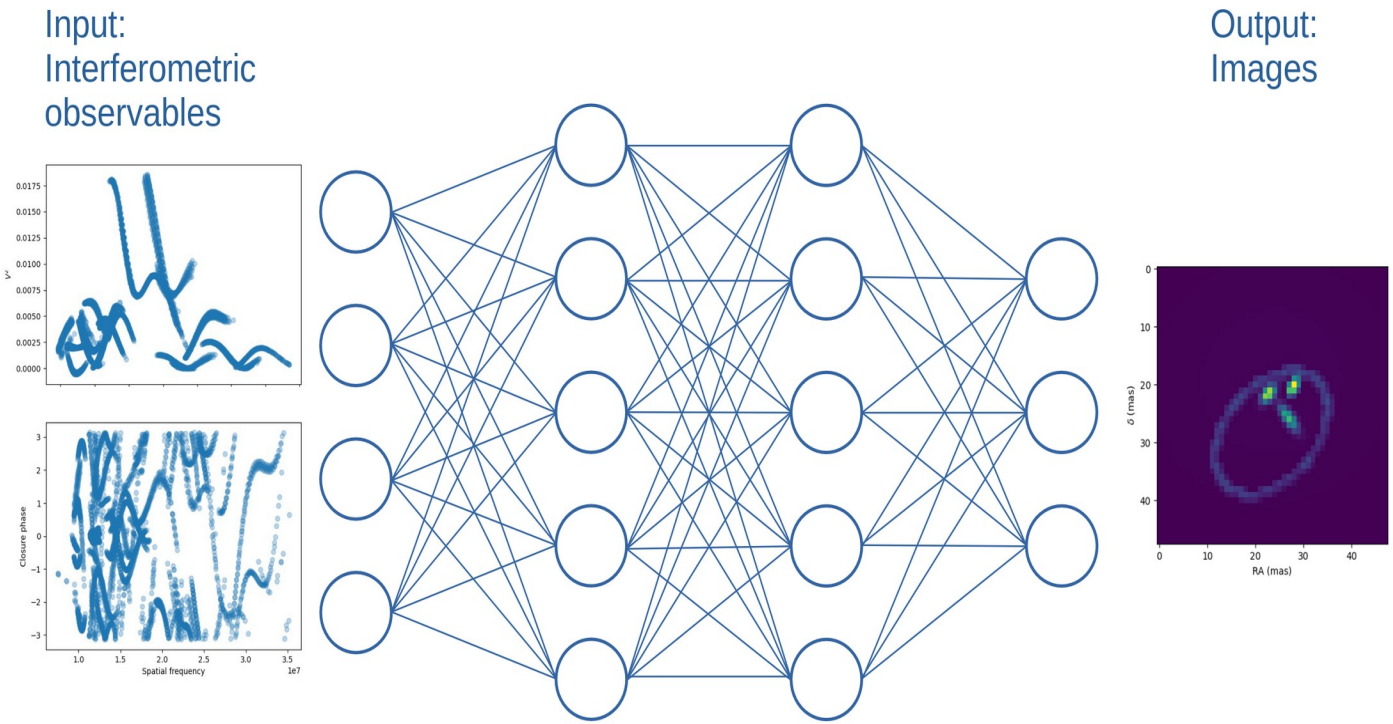




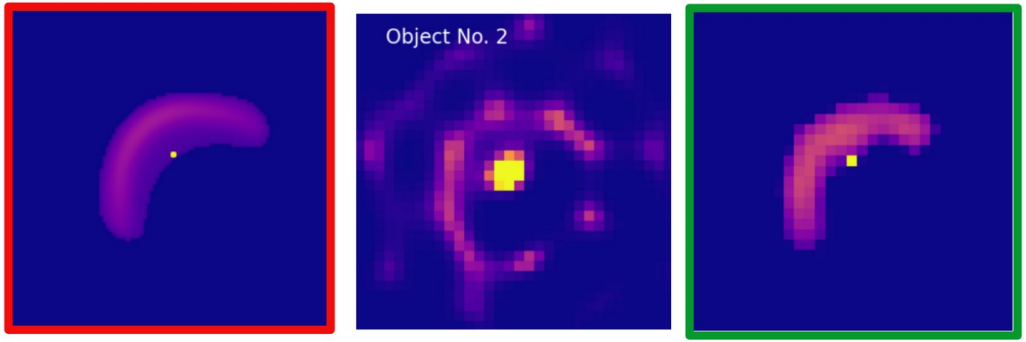
Gamez-Rosas et al (2022)

Neural network based image reconstructions

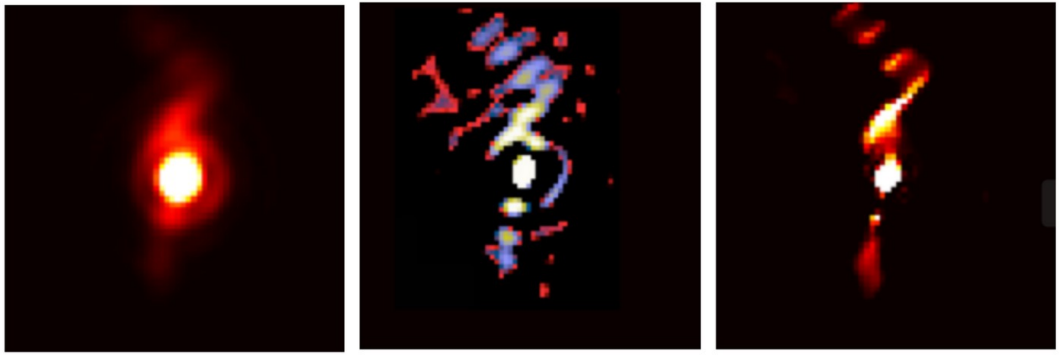
1) **Create fake astronomical images**
2) **Compute synthetic interferometric observations for each**
3) **Relentlessly train a neural network to reconstruct the original image based on the mock observation**
4) **Apply to the real observation**



Promising results



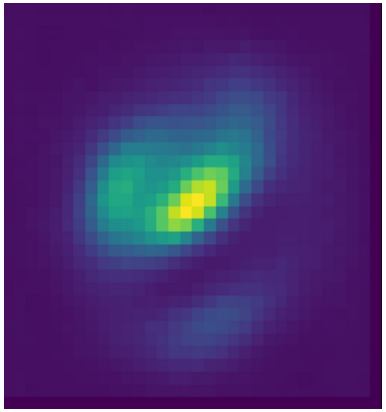
Optical interferometry imaging contest IX, Sanchez et al (2022)



Bonus: Deconvolution of Adaptive Optics images

MATISSE/VLTI image of NGC 1068 (nearby AGN)

Classical image reconstruction Gamez-Rosas et al (2022)



Neural Network based image reconstruction

Conclusions

1) Improve interferometric image reconstructions
2) Use it to improve our knowledge of AGN torii
3) Use it to improve SARM measurements of cosmological distances (and SMBH masses)
4) Get a precise new H_0 estimate, independent from distance ladder and ΛCDM model