



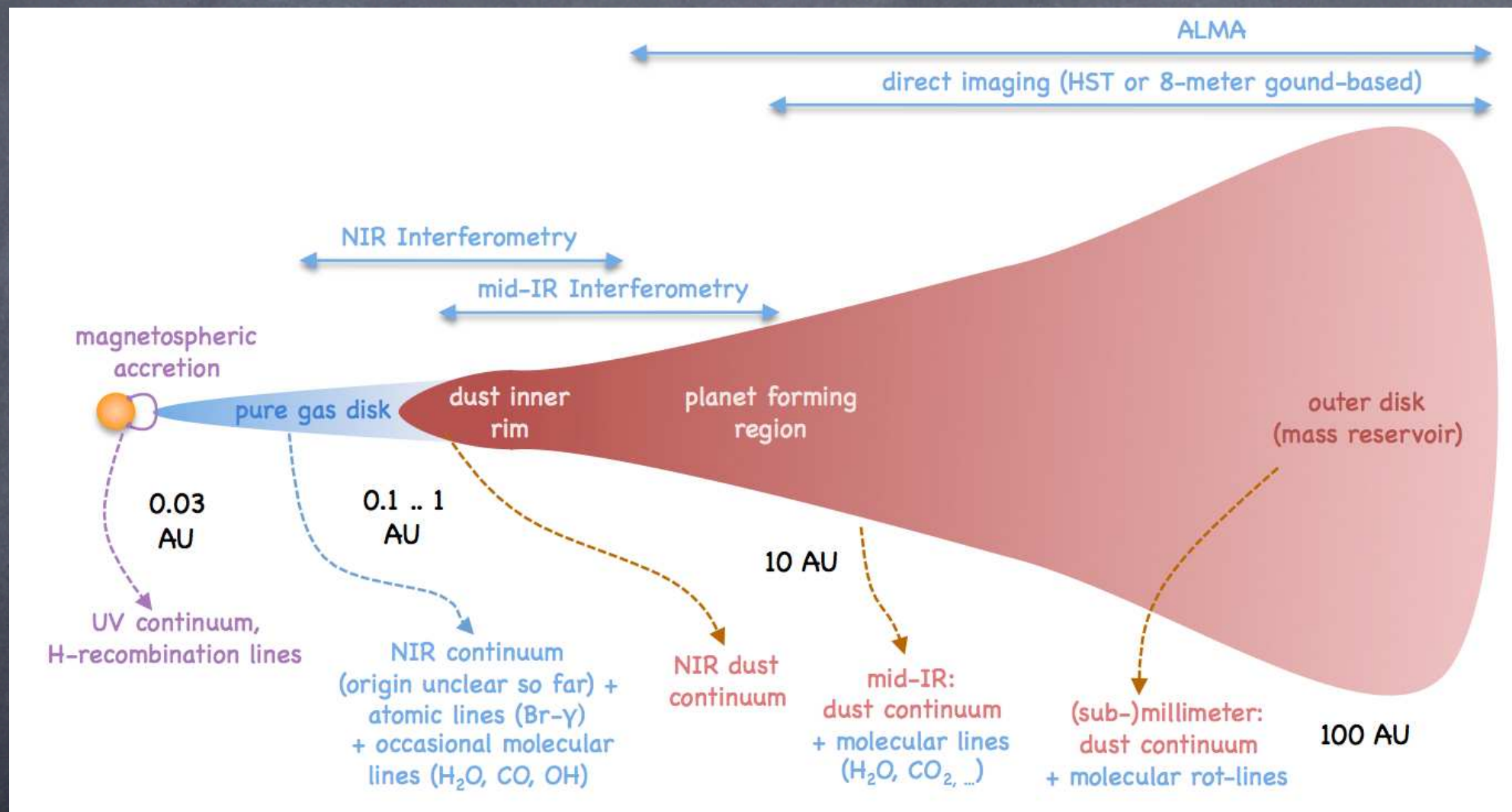
# Protoplanetary disks at the astronomical Unit Scale

The contribution of PIONIER and future VLTI second  
generation instruments

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CRISTAL-IPAG team  
VLTI System Engineering group and ESO Sciops department



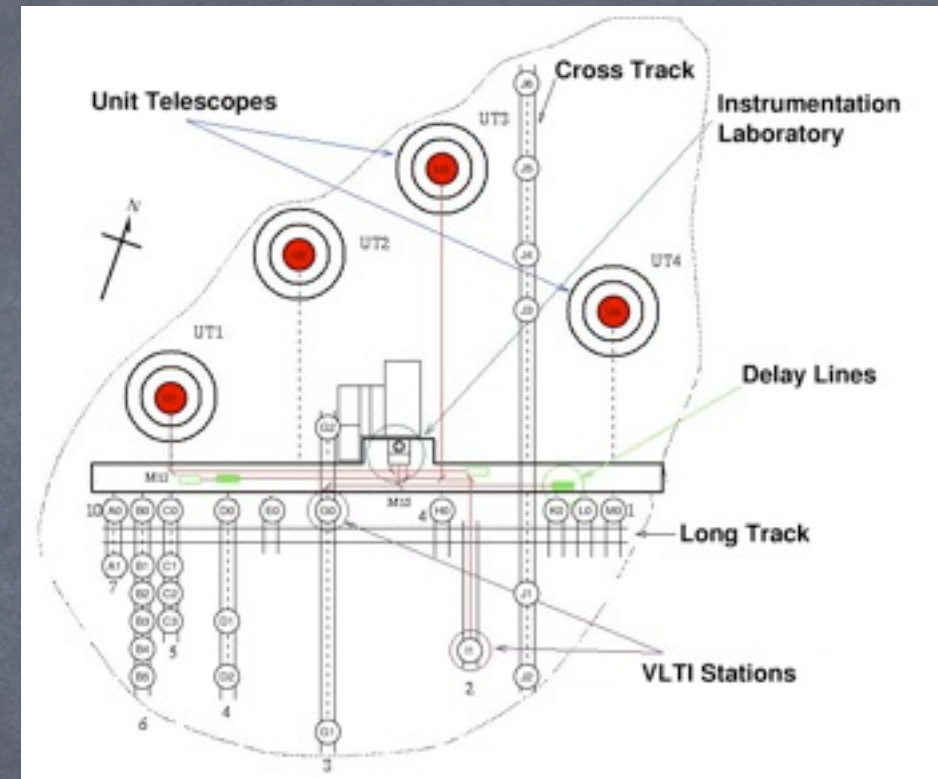
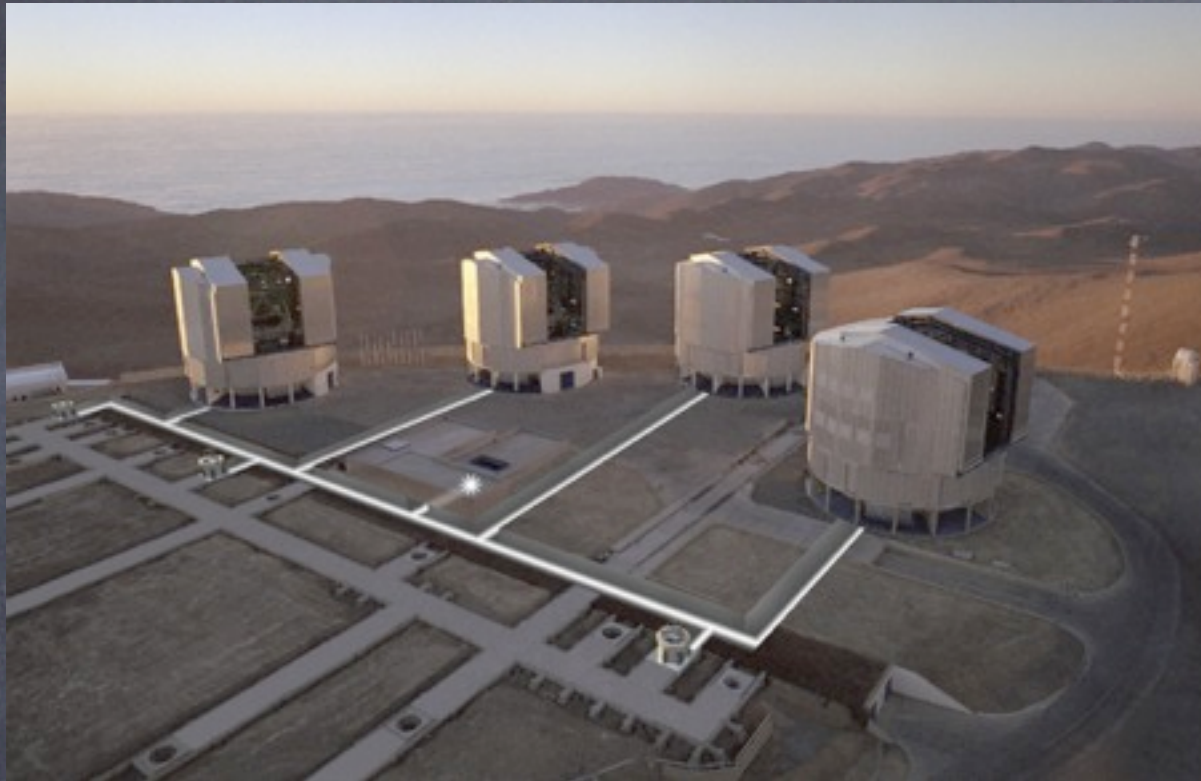
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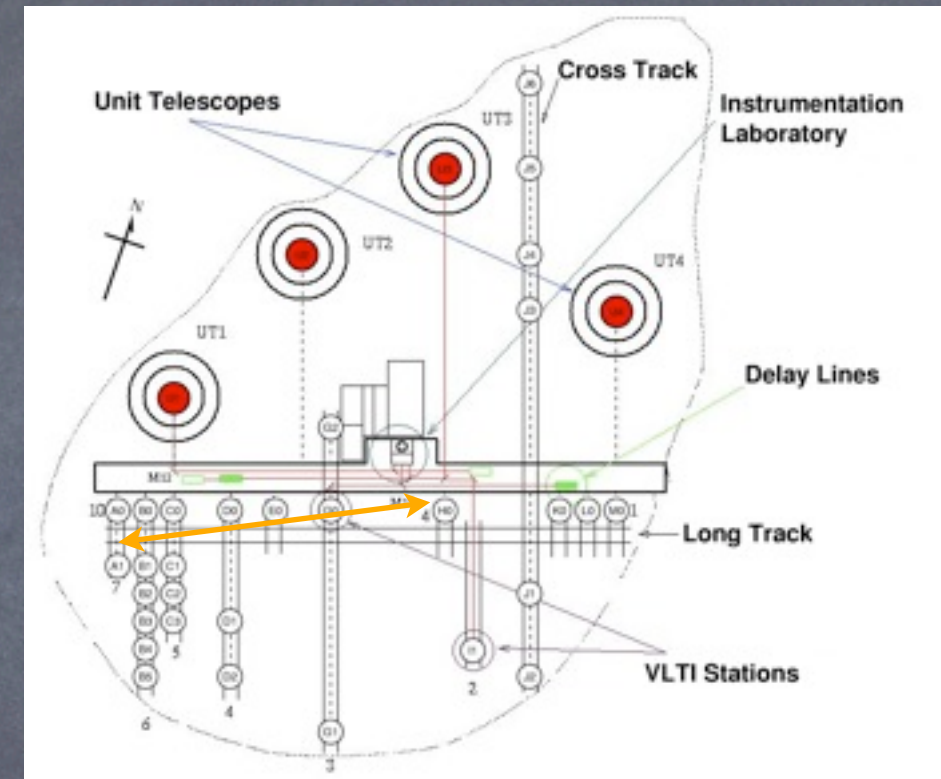
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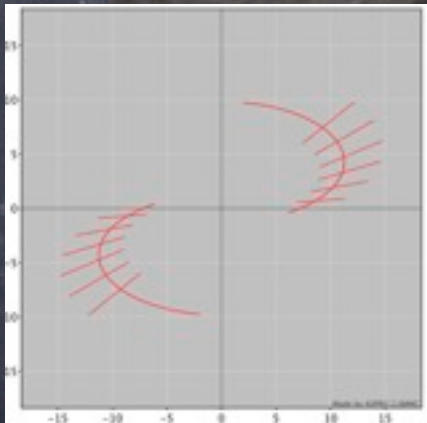




# The VLTI



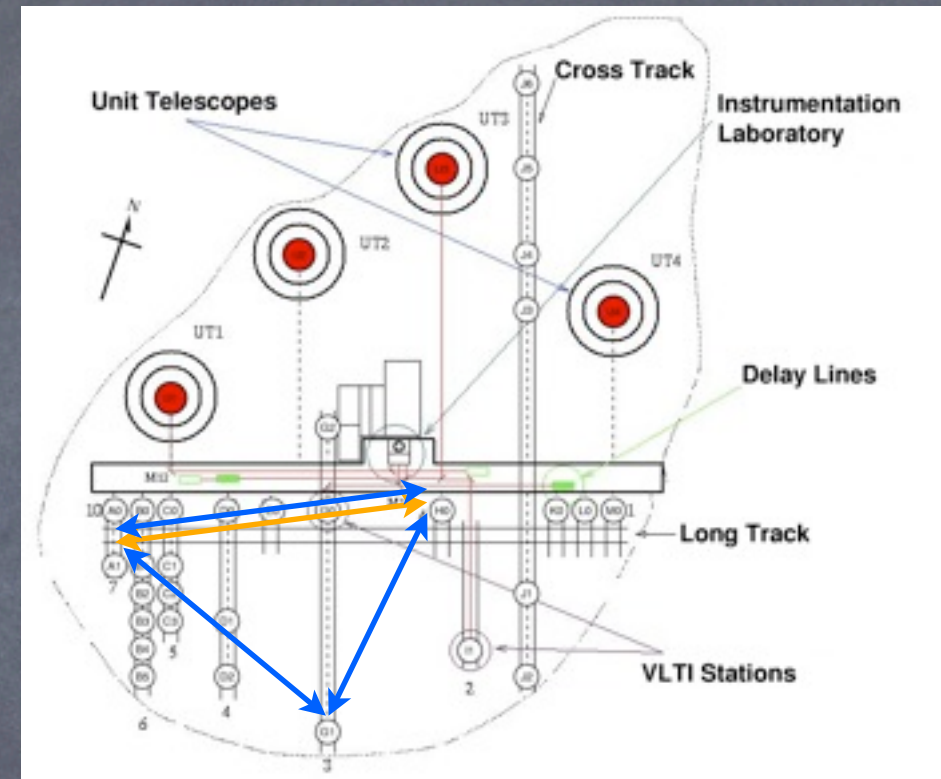
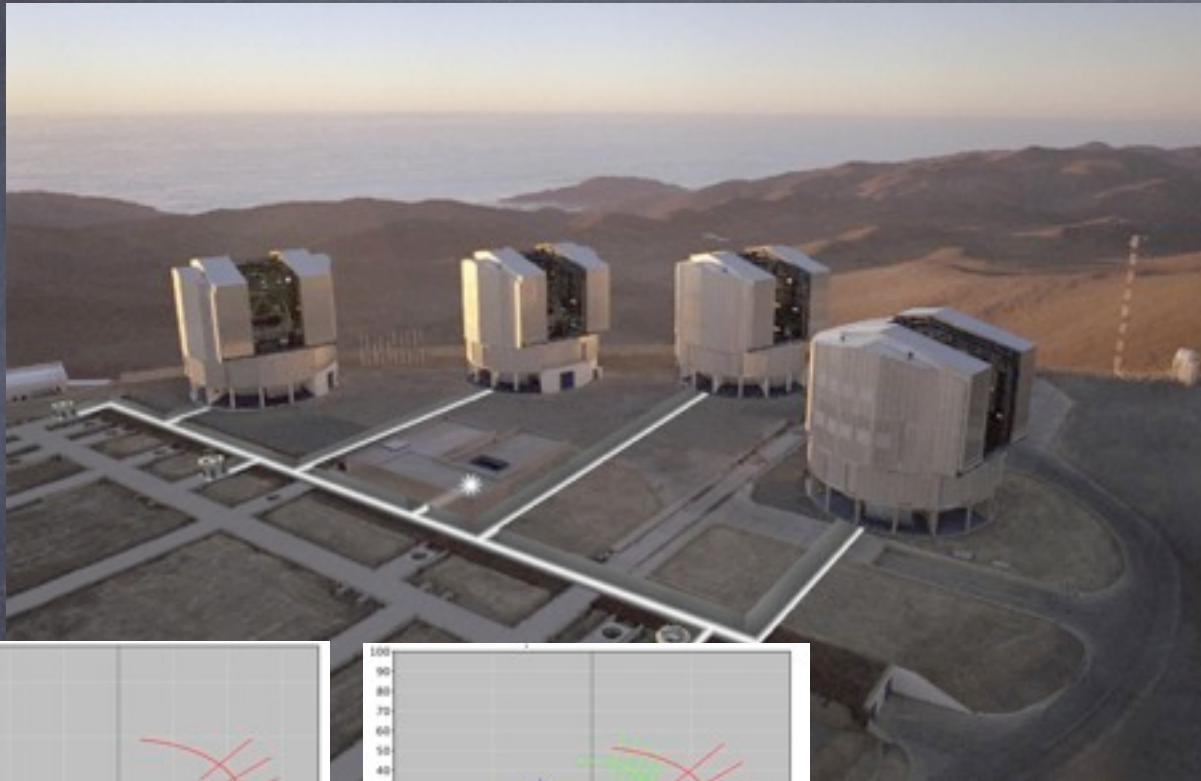
MIDI



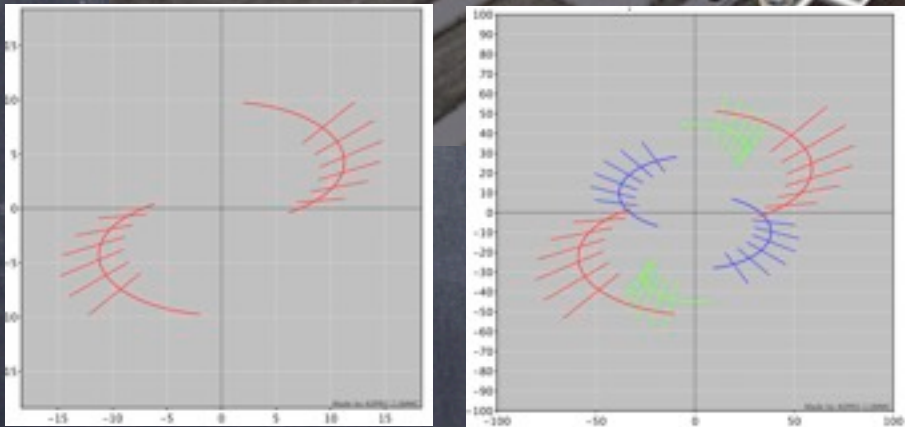




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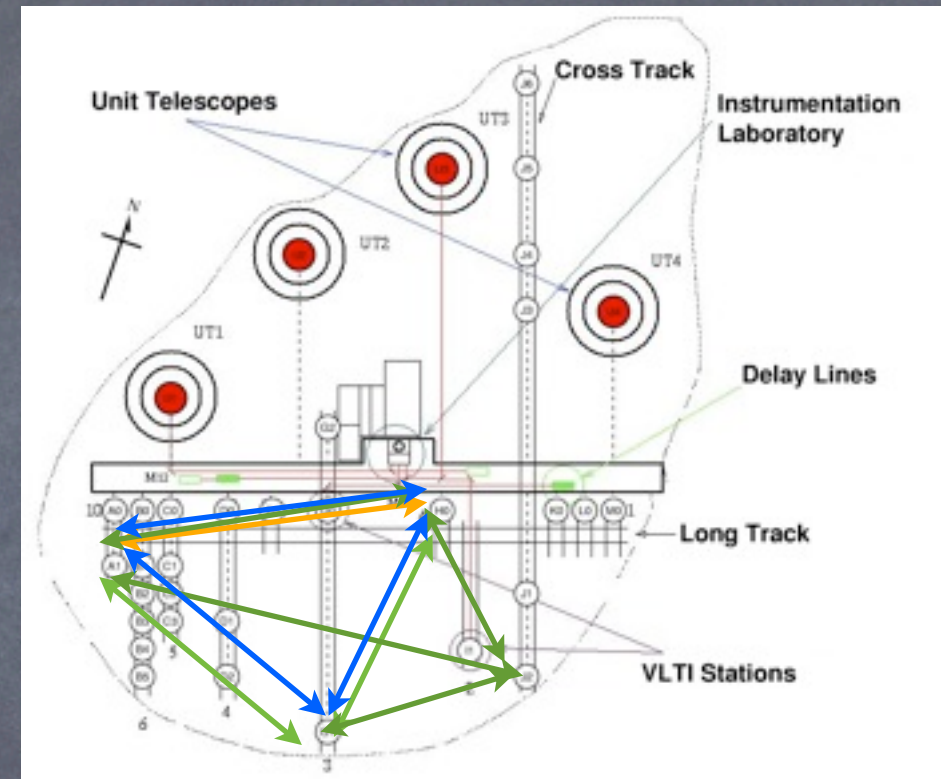
MIDI  
AMBER



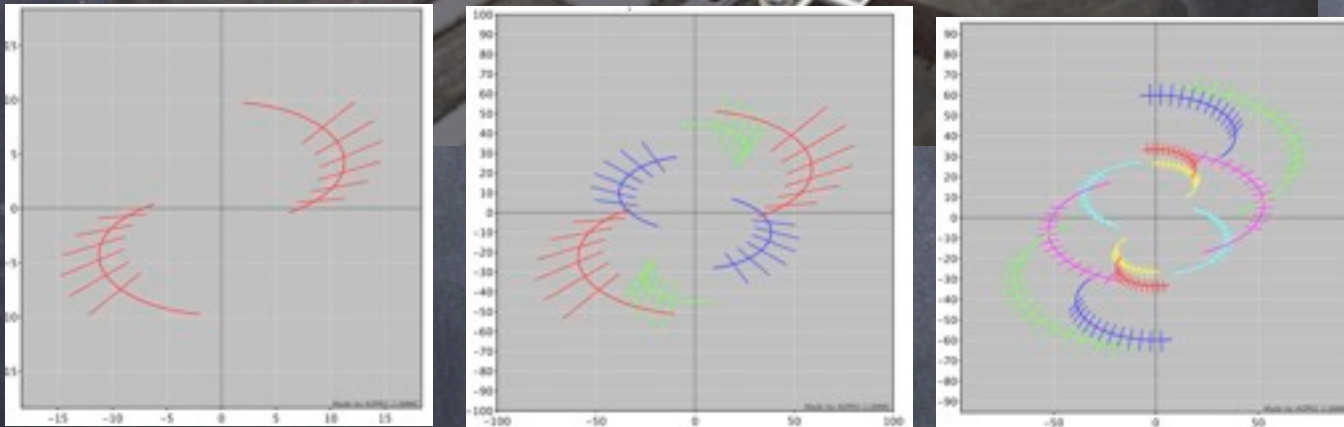




# The VLTI



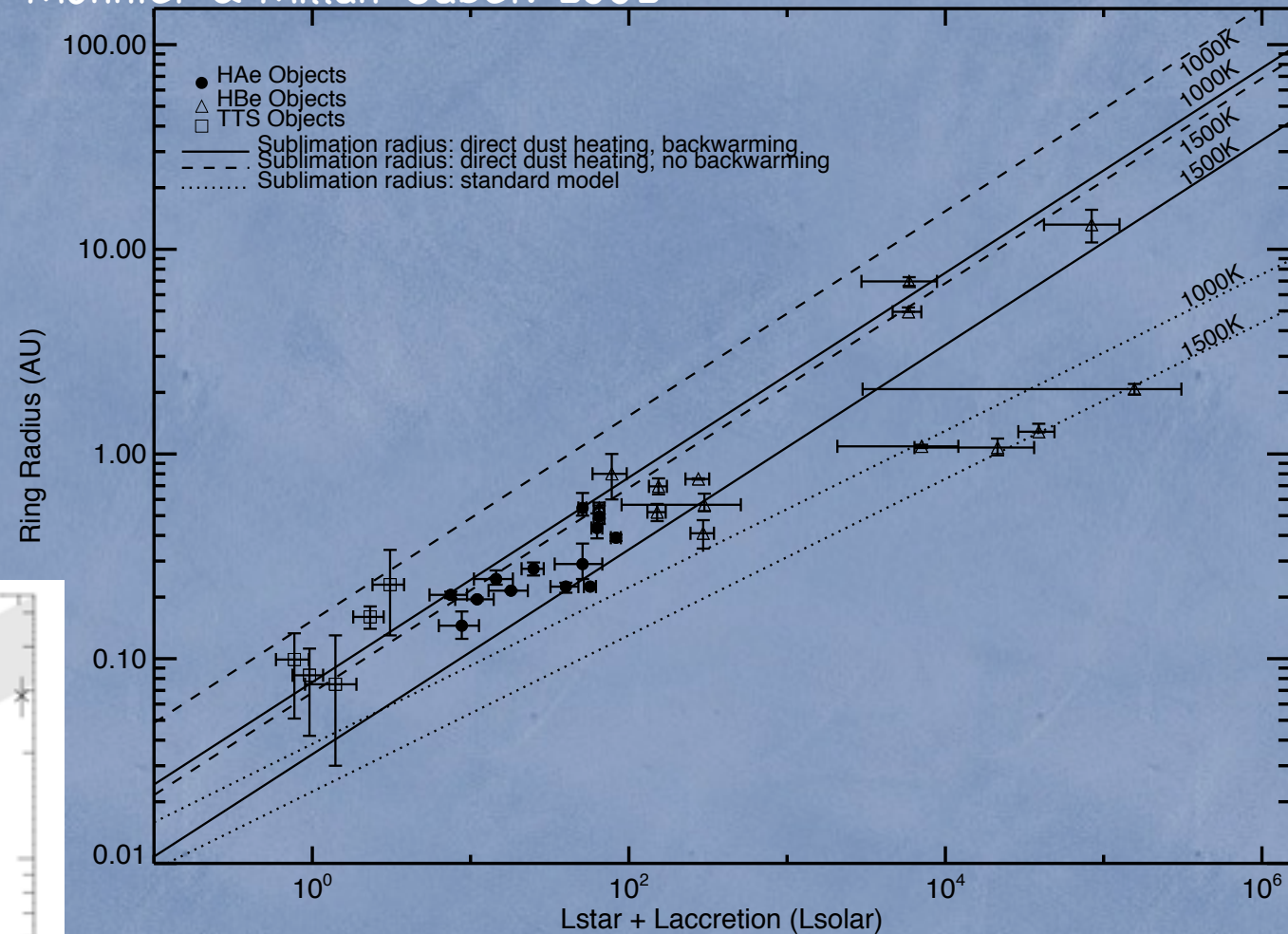
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AMBER  
PIONIER



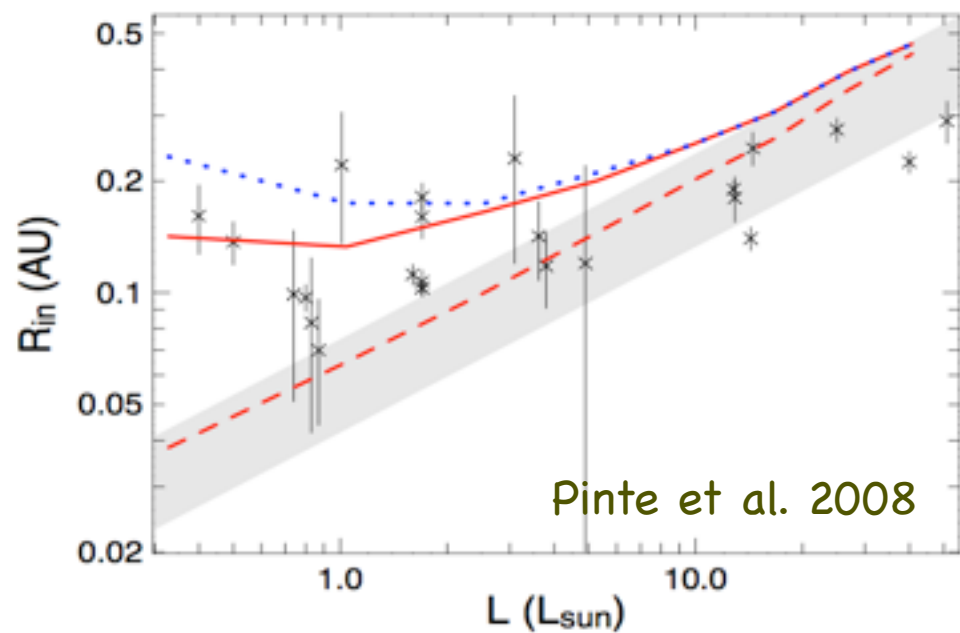


# Size luminosity relation

Monnier & Millan-Gabet: 2002



Pinte et al. 2008

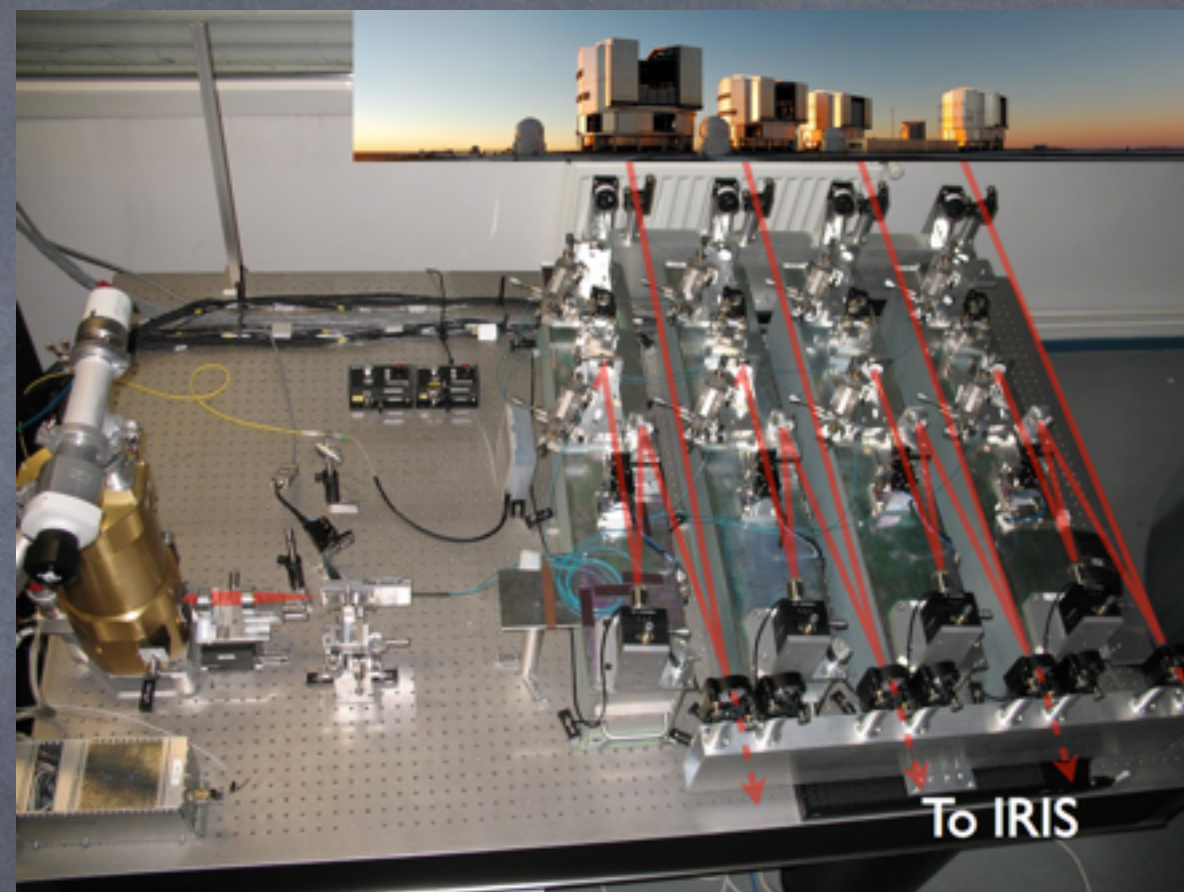






# PIONIER

- 4 T Visitor instrument
- H/(K) band low resolution (40)
- Fast track – Short life (2011–2013)
- Designed to fill the sensitivity/imaging gap until Gravity/Matisse arrive
- 30 stars observed so far (4 AT) from Herbig Ae Be Stars to T Tauri and counting



Built by: IPAG/CRISTAL-team

Funding: IPAG, UJFourier, CNRS, INSU-PNP/PNPS, ANR Exozodi





# The difficulties of image reconstruction

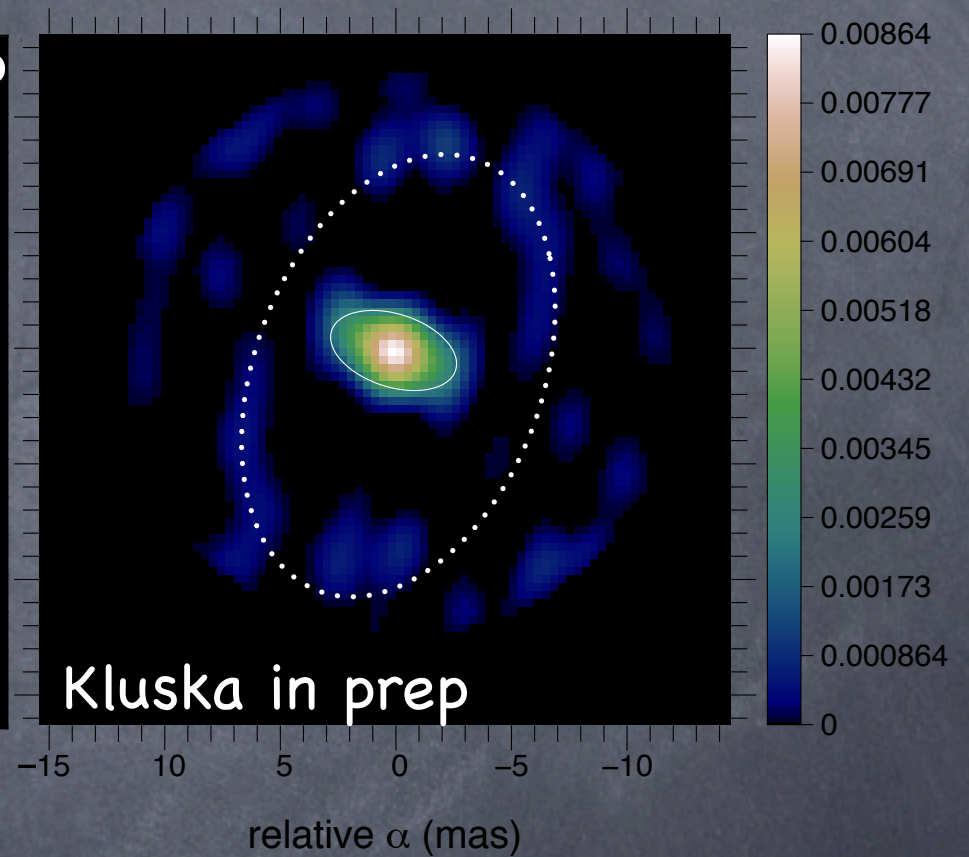
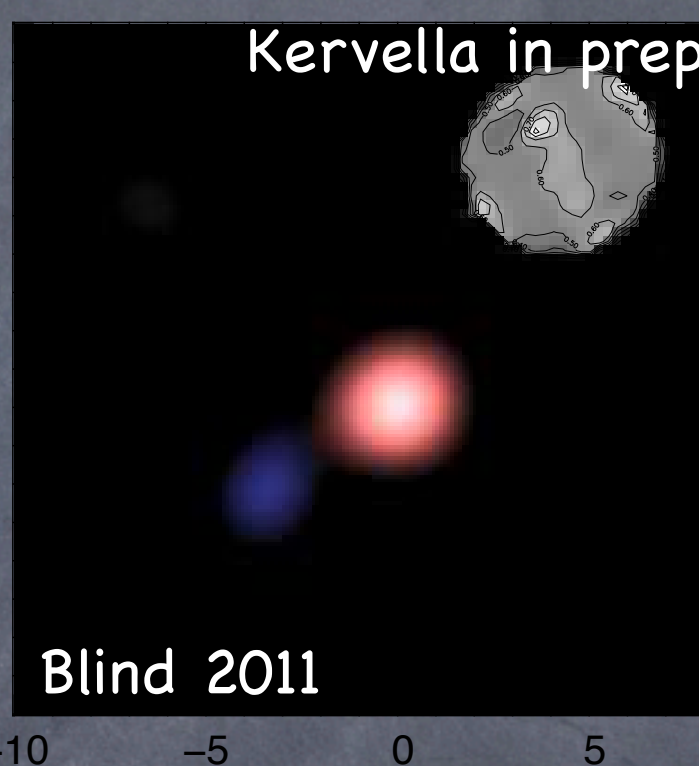
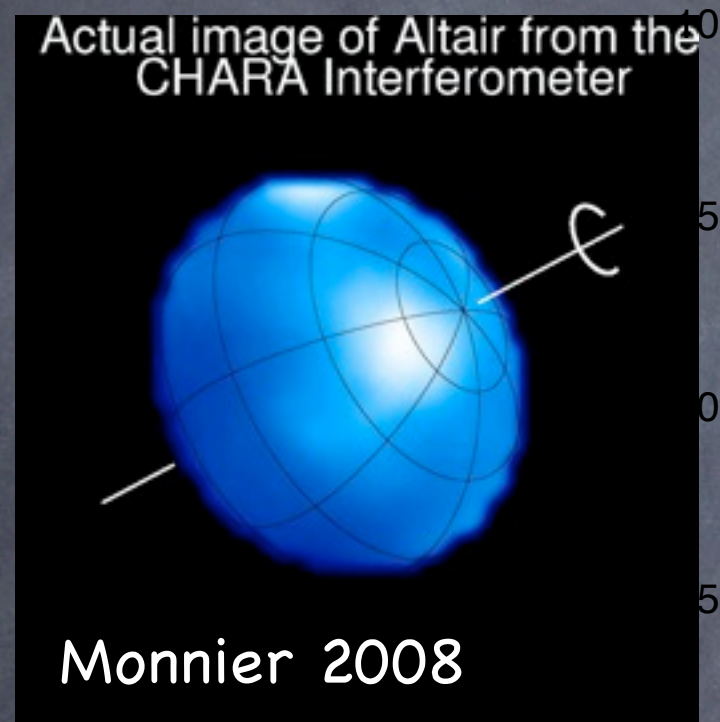


Constraints:  
Emission is located within  
an ellipse





# The difficulties of image reconstruction

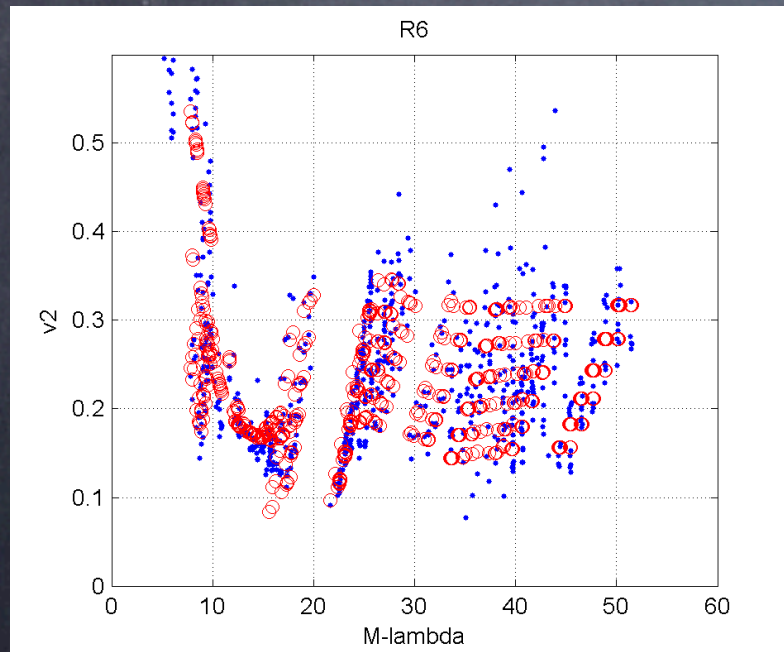
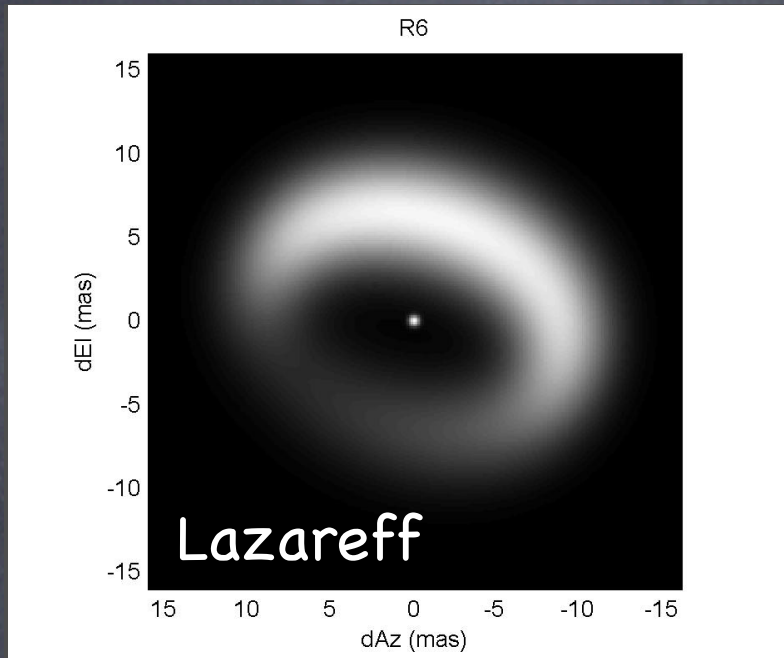


Constraints:  
Emission is located within  
an ellipse



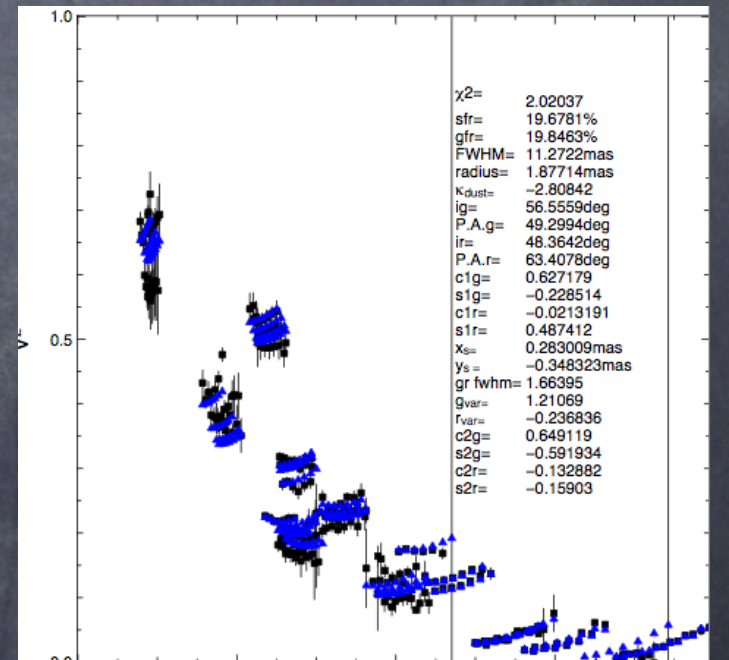
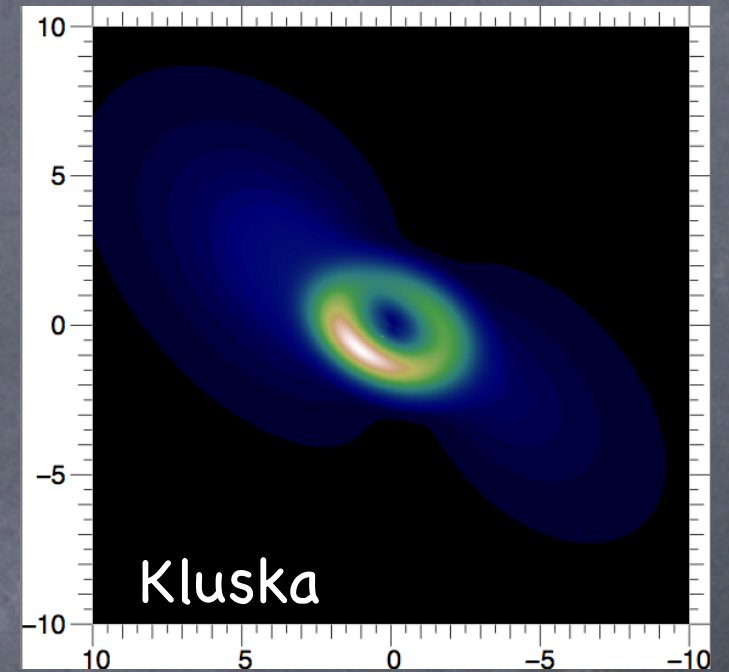


# Parametric “imaging”



## Constraints:

- There is a star
- Emission has an inner/outer boundary
- It is contained in an ellipse
- It can have various components
- It is allowed to show azimuthal asymmetry of  $m=1,2$

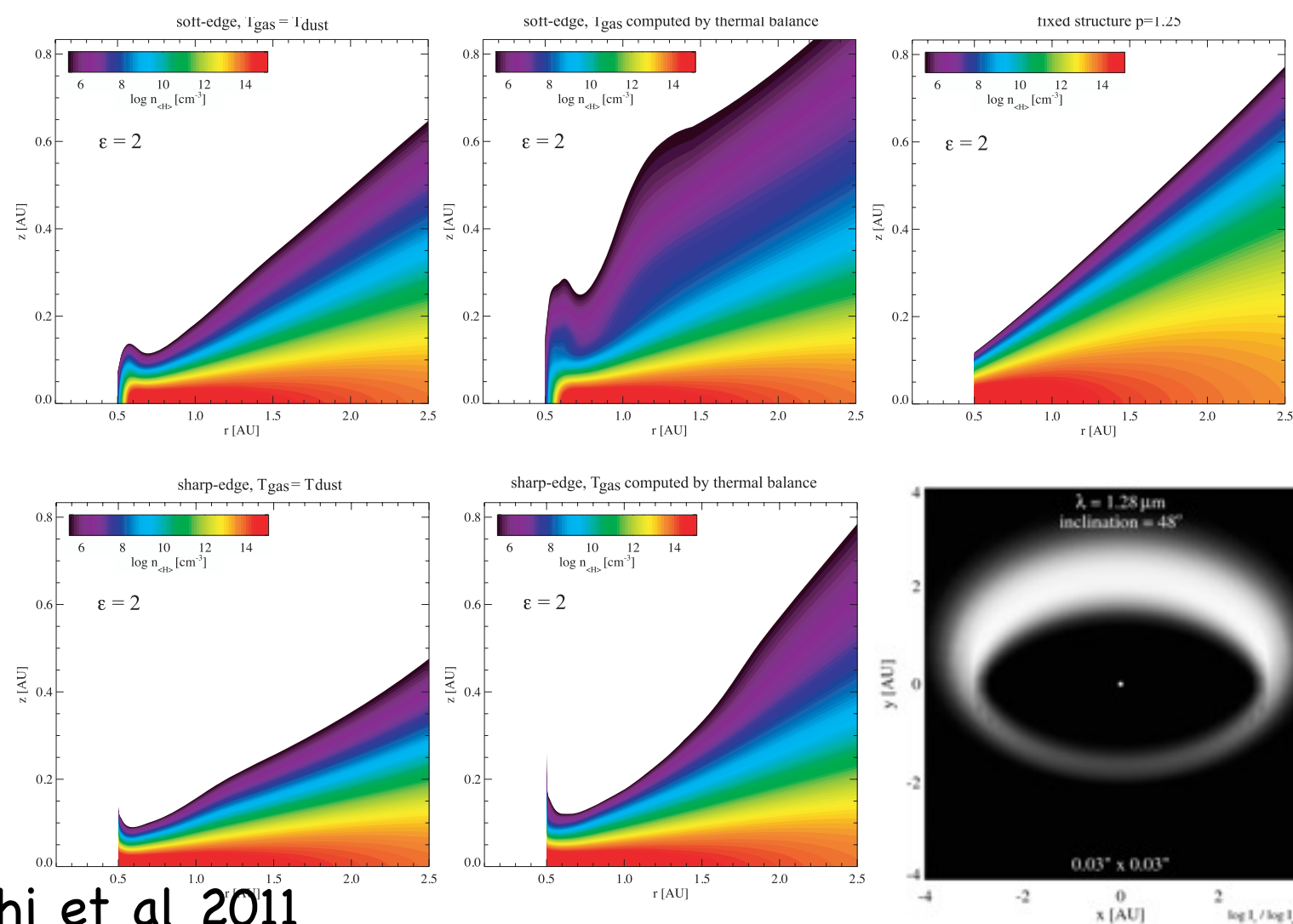






# PIONIER images bring strong constraints

- Dust sublimation
- Dust/Gas coupling
- Dust settling
- Inner gas screening
- Accretion flow
- Disk/Mass loss relation

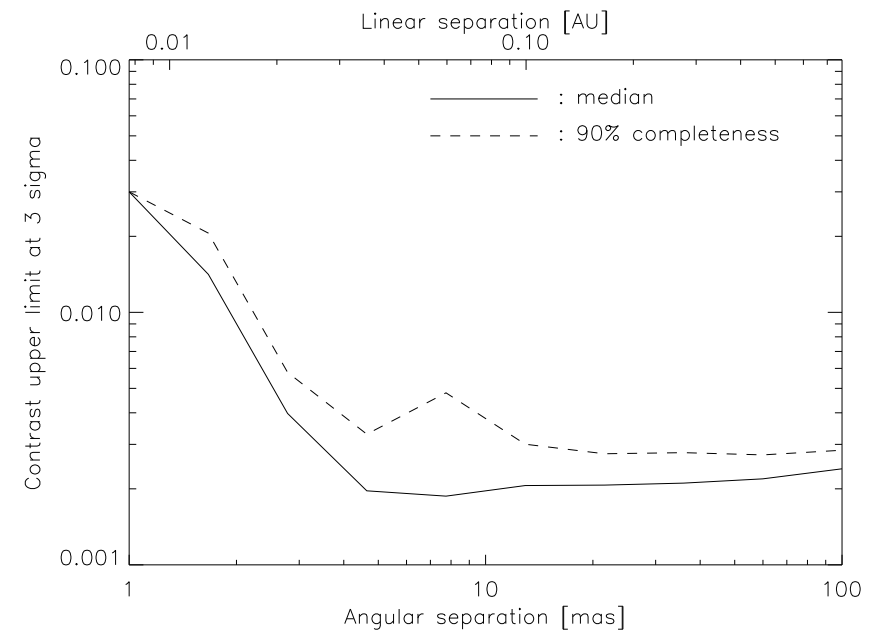
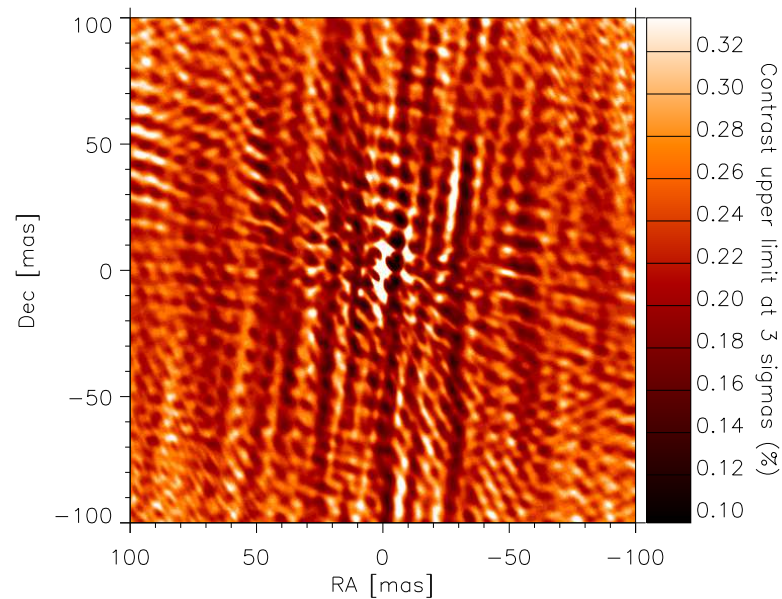
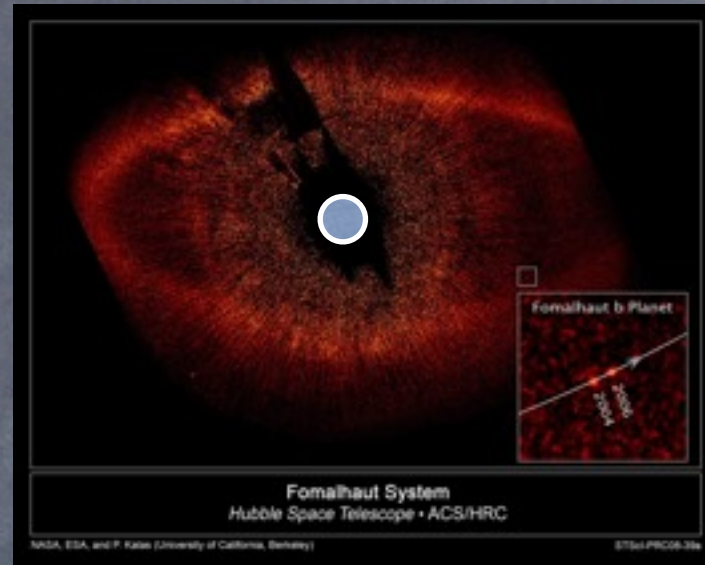


Thi et al 2011





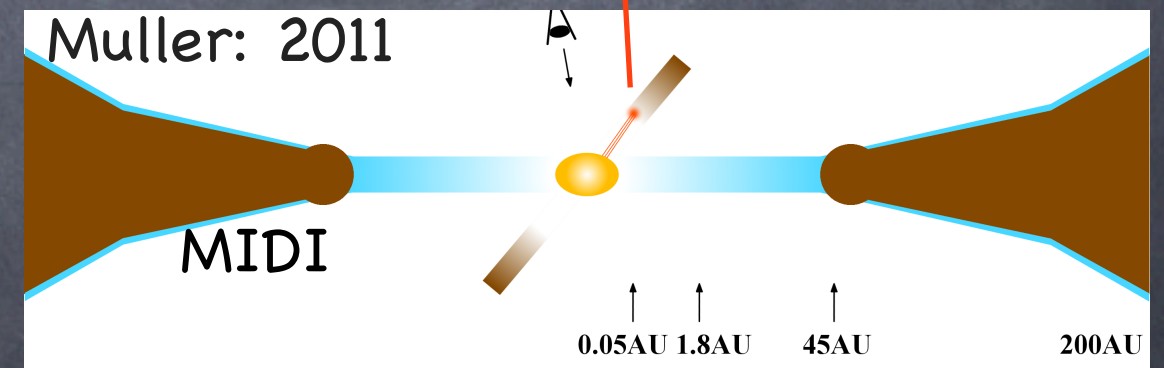
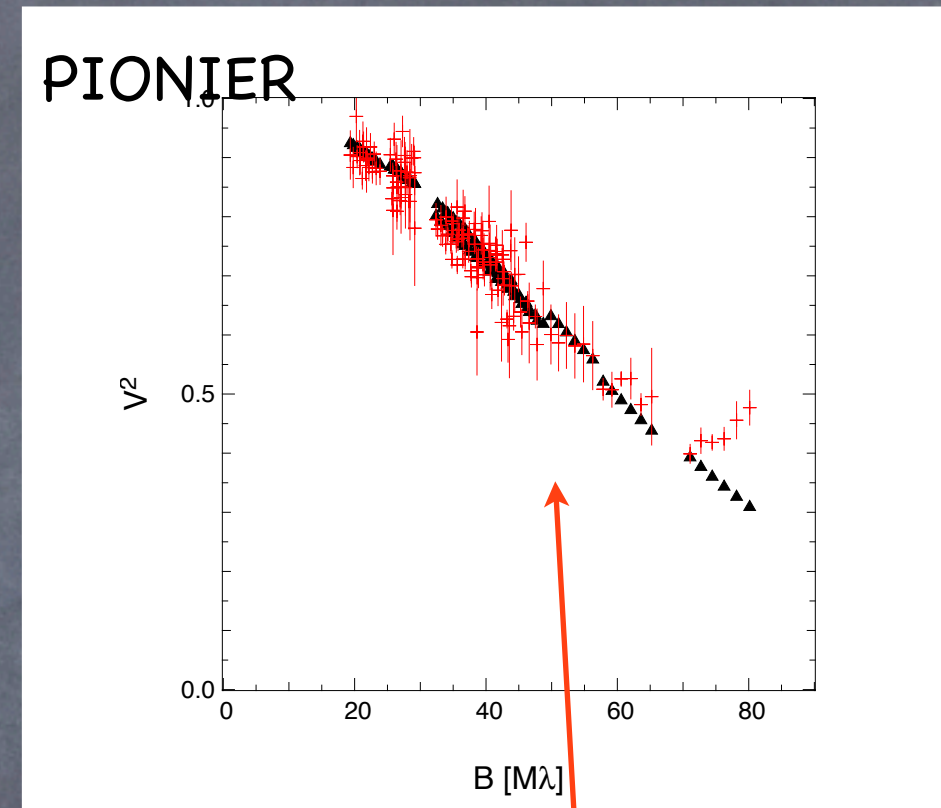
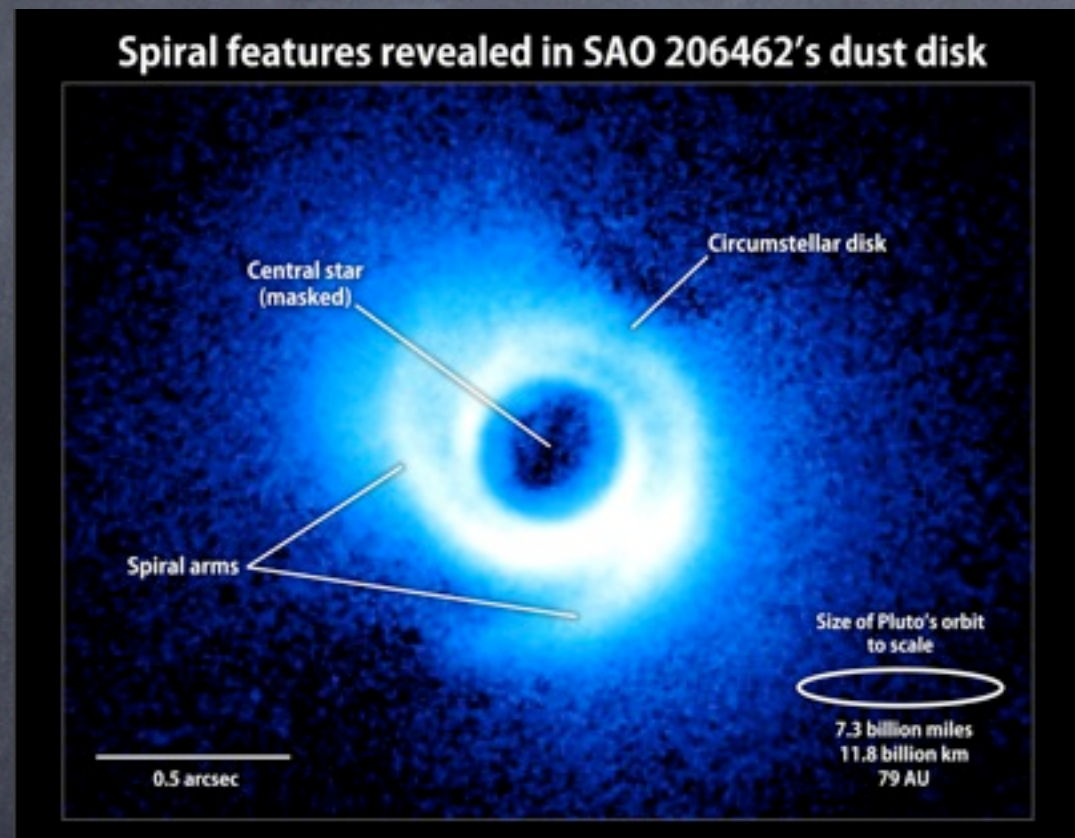
# Planets ?







# Signposts of planets ?







# The VLTI Family

MATISSE

GRAVITY

PIONIER

MIDI

AMBER







# Gravity

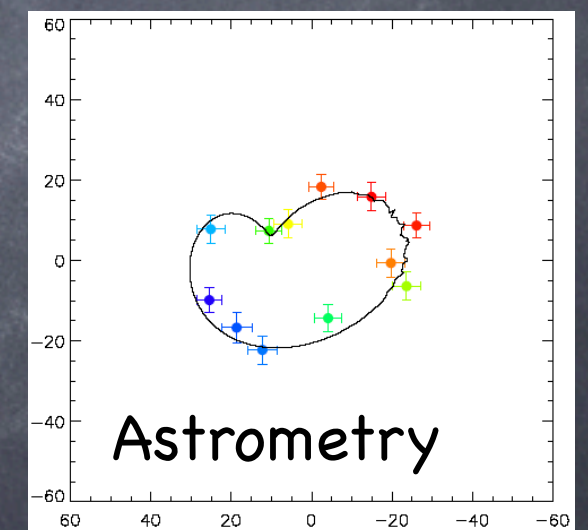
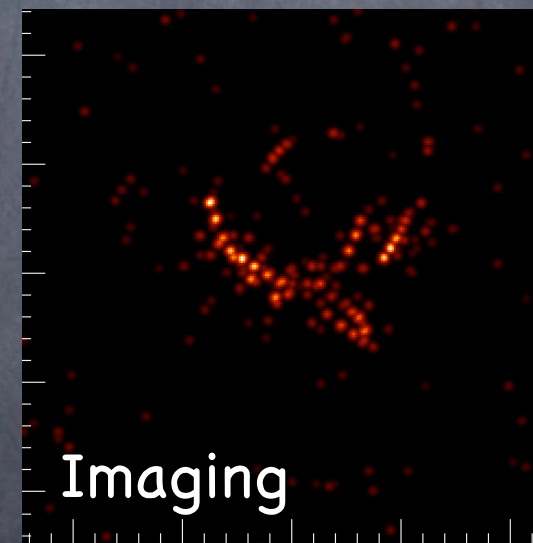
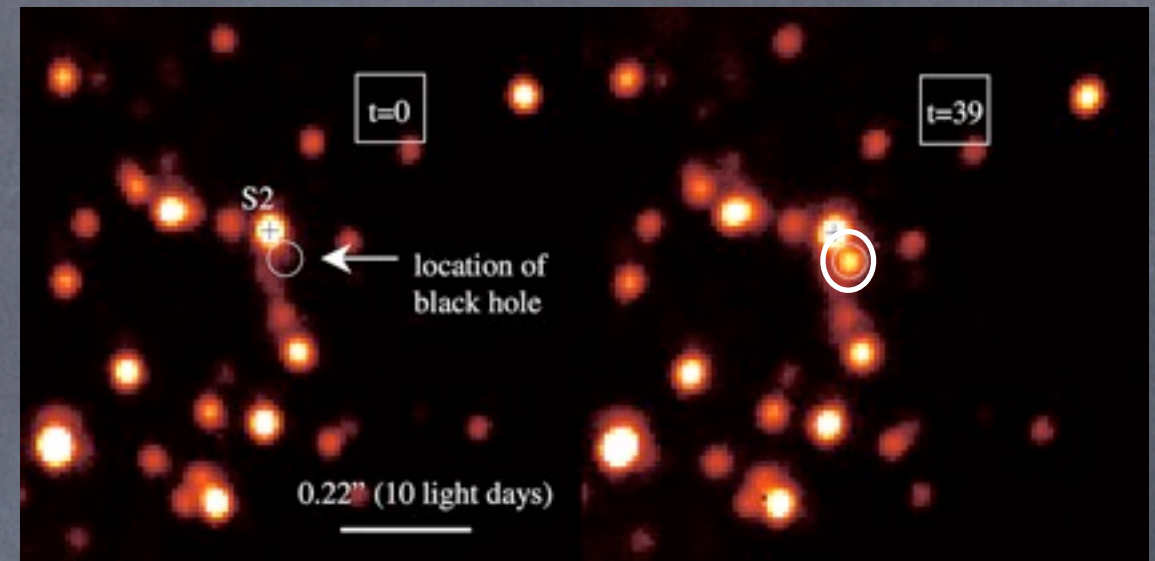


## Description

- 4 Telescope Astrometry and Imaging
- K band
- 3 Resolutions (22  $\rightarrow$  4000)
- Astrometry: 10  $\mu$ as in 5 min on K $\sim$ 15

## Goal

- Imaging of gas distribution in inner RIM (wind vs. disk), kinematics
- Morphology of inner RIM
- Planets in binary systems (astrometry)
- Planets in clusters (astrometry)



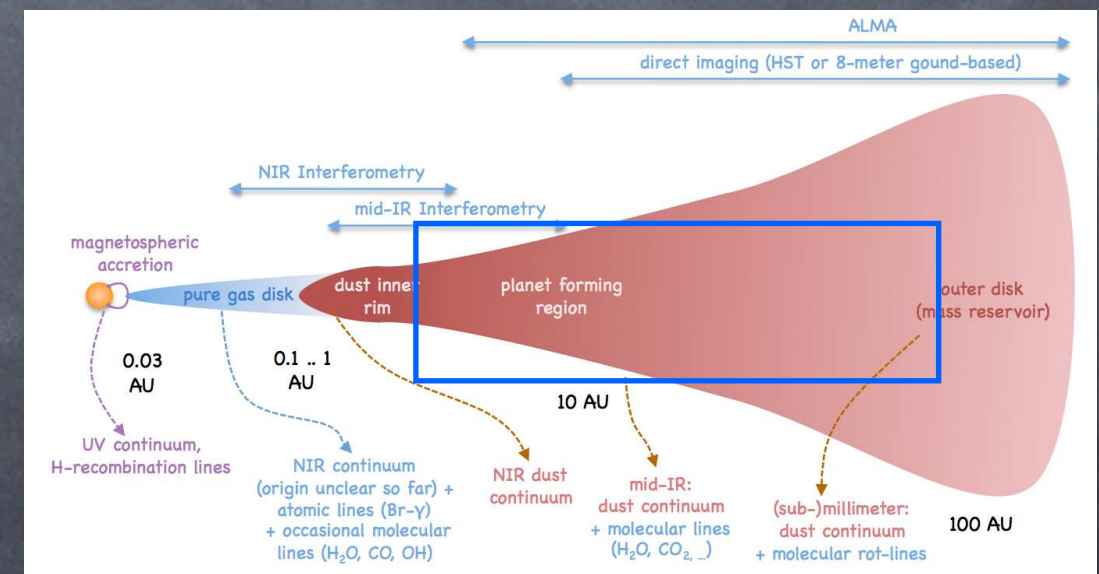
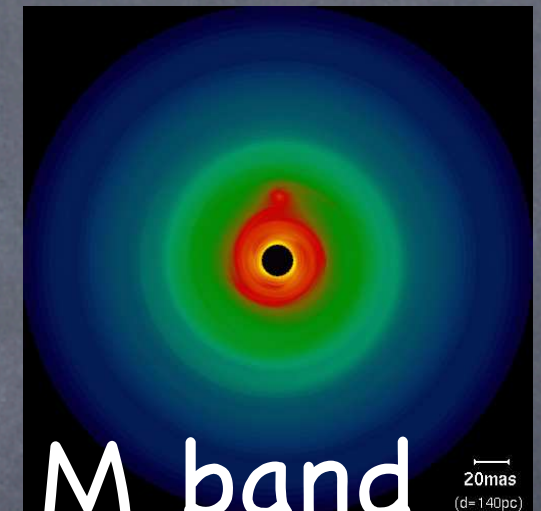




# MATISSE



- 4 Telescope Imager
- L,M,N bands (simultaneous)
- 3 Resolutions (30  $\rightarrow$  1000) depending on bands
- Surface brightness profiles
- Gaps, transitions, high accretion spots







# Concluding remarks



- Optical interferometry has become a key observational tool for protoplanetary disks studies
- Brings severe constraints on the inner disk boundary → physical conditions up to 10/20 AUs
- Aperture synthesis is in its infancy but likely to reveal unknown structures but takes telescope time (or more telescopes)
- The first systematic survey of protoplanetary disks inner rim from high mass stars to solar analogs is underway with PIONIER
- Signposts of planets ...yes, planets ... probably very hard
- MATISSE and GRAVITY are well tailored to enhance the sample of observed stars and bring unique astronomical unit scale constraints on the planet formation scenarios
- check Wolf et al. (2012) AAR for a review