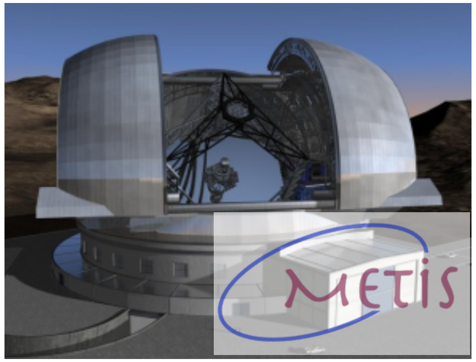
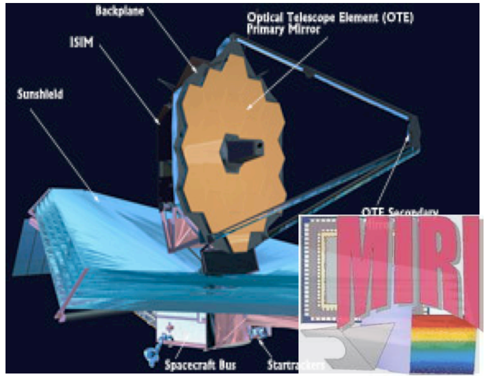
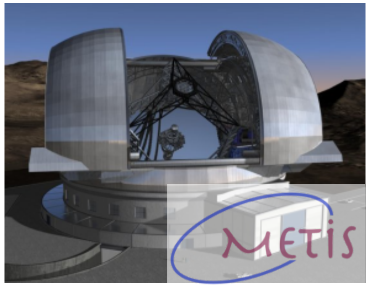


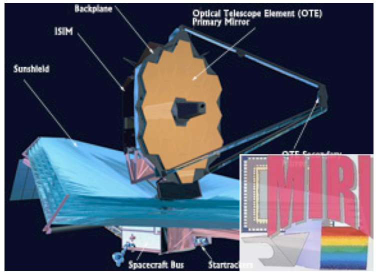


Observations of proto-planetary disks with the JWST/MIRI and the E-ELT/METIS instruments; witnessing the birth of planetary systems.

E. Pantin, I. Kamp, T. Henning, L.B.F.M. Waters,
E. van Dishoek, D. Barrado, P.O. Lagage,
B. Brandl, A. Boccaletti, H. Walker, J. Surdej,
and O. Absil



Compared performances



ELT/METIS

(see M.Kissler-Patig presentation, B.Brandl poster)

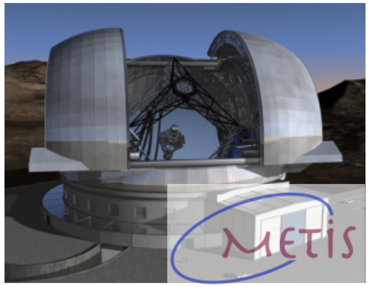
- good sensitivity to point sources and peaky structures (~25 μJy at 10 μm)
- excellent angular resolution (0.05"/ 10 μm), direct imaging of planetary regions (r<30 AU) in closest disks (d<150 pc) will be achievable
- very limited sensitivity (~10 mJy/"^{2}, nul in some cases !) to extended emission

JWST/MIRI

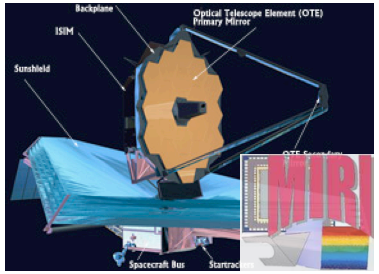
(see A.Glasse presentation)

- very good sensitivity to point sources (~1 μJy at 10 μm)
- angular resolution (0.3" at 10 μm) comparable to that of current 8m-class telescopes instruments (e.g. VISIR)
- awesome sensitivity to extended emission (~1 μJy/"^{2} at 10 μm)

Same wavelength coverage, high level of complementary between extended source sensitivity/angular resolution



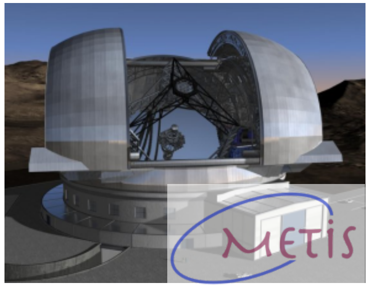
(Some) open questions



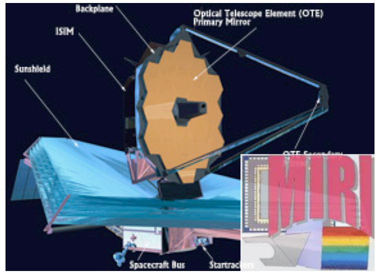
- **Does observed exoplanets diversity reflects different initial conditions in the disks ?**

  - physical sizes of disks (formation, truncation) ?
  - vertical structure, dust settling
  - dust composition vs distance
  - gaps created by forming protoplanets, sizes ?
  - Disks evolution process ? Gas dissipation:how, when ? Dustâ planetesimals timescale ?
  - exoplanets formation mechanism(s) :
    - core-accretion (inner regions) vs
    - gravitational collapse (outer regions, minimum surface density)

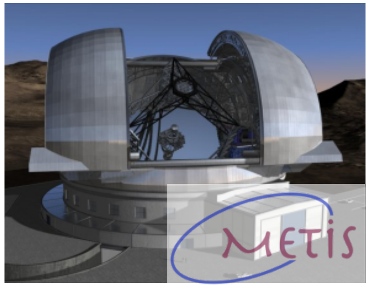
Necessary/favorable physical conditions for planet formation ?



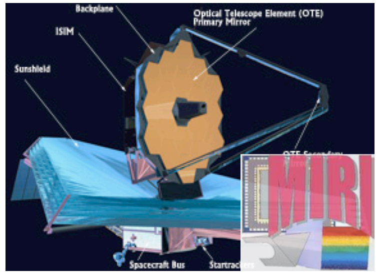
Why making imaging in the mid-IR ?



- The contrast between the star and the disk is largely reduced (~1 vs several 10^3 in NIR).
- As disks evolves in time, gas photoevaporates, flaring ↘, dust coagulates and settles. Mid-infrared imaging traces the dusty disk structure.
- Direct imaging allows to break degeneracies of SEDs-based interpretations.
- Direct signatures (solid state features) of different materials : spectro-imaging can trace the radial distribution of dust species (amorphous vs crystalline silicates, ices, clays, calcium carbonates, ...

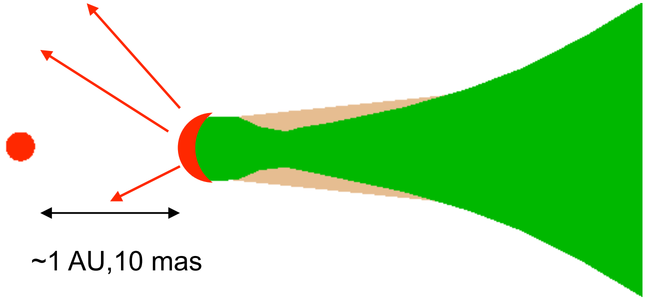


What do we observe in the mid-IR range ?

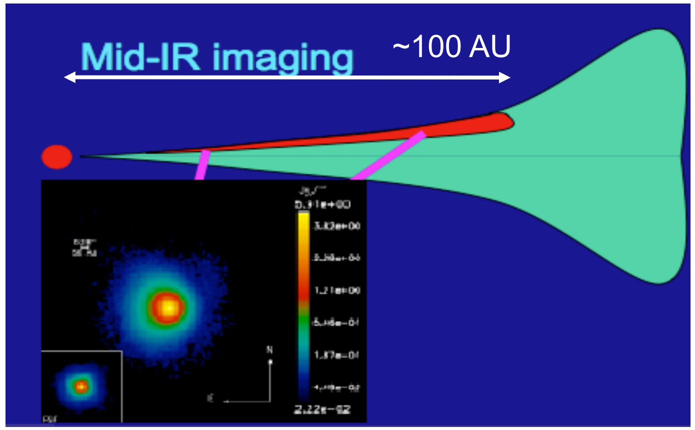


- Mainly the thermal emission from heated dust grains

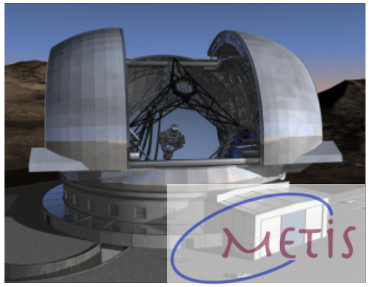
- Mainly the inner rim (1500 K) that produces >90% of the total 10 μm flux (continuum)



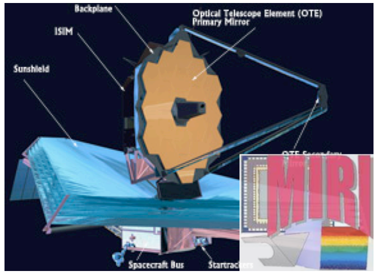
- Once, the inner rim masked/subtracted, the thermal emission produced at the disks' surface (τ=1), on intermediate distance scales (3-100 AU)



- PAH emission (7.7, 8.6, 11.3 μm) on larger scales (➔ R_{out})



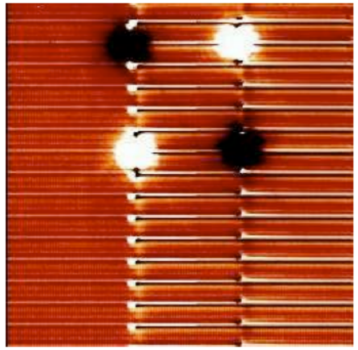
How do we observe the disks in the mid-IR ?



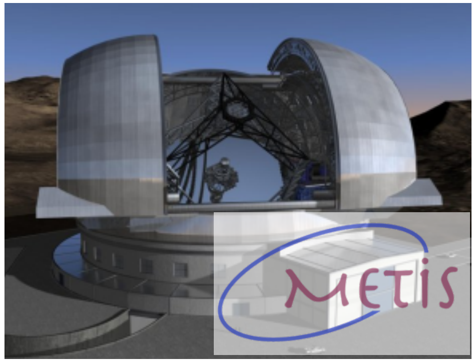
- **Ground-based 8m telescopes (VLT/VISIR) :**
  - direct imaging +
  - PSF subtraction (strong limitations if PSF variable !)

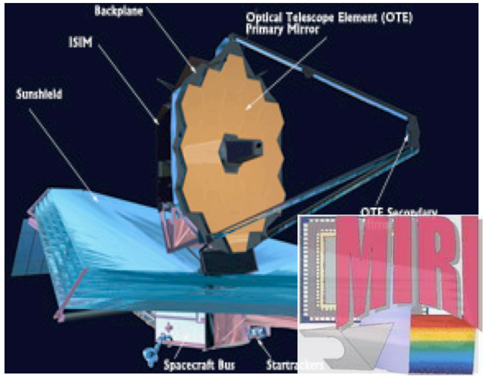
- **JWST/MIRI :**
  - coronagraphic mode is compulsory to avoid detector saturation (F<20 mJy) and decrease photon noise

- **ELT/METIS :**
  - photon noise is irrelevant, detector artifacts (~saturation) are !
  - contrast performances strongly enhanced in coronagraphic mode

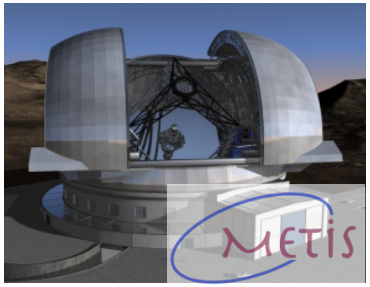


⇨ **pathfinder VISIR upgrade project (proposed implementation of a MIRI-like 4QPM coronagraph)**

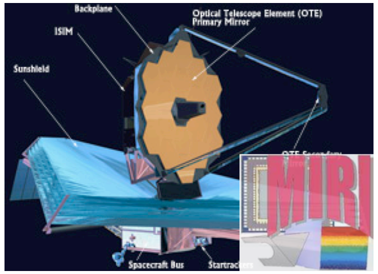




THE MIRI GTO imaging proposal/program

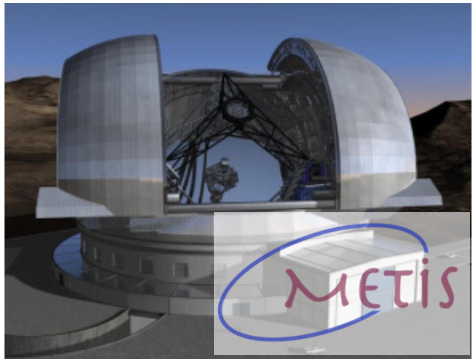


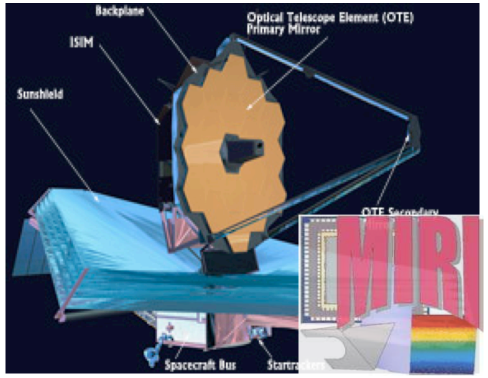
Goals



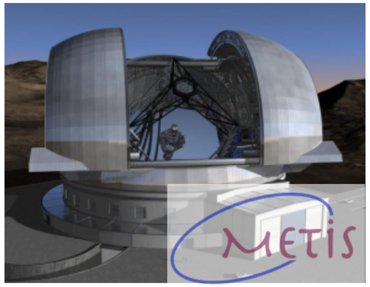
study:

- **large-scale geometry of the disks:**
  - MIRI tremendous sensitivity allows to observe the disks up to very large distances from the star
  - for the first time, a large sample of T-Tauri disks are observable/resolvable in the mid-IR
- **disks (dust) vertical structure** (complementarity with spectroscopic program, (I.Kamp pres.)):
  - dust settling
  - dust coagulation
  - disks stratification
- **search for forming/formed planets signature:**
  - direct detection of forming protoplanet is highly unlikely (brightness peak@accreting phase ?)
  - embedded massive bodies produce structures in disks:
    - gaps
    - bright rims
    - asymmetries

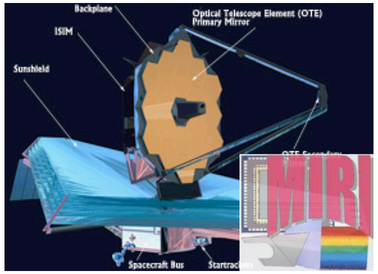




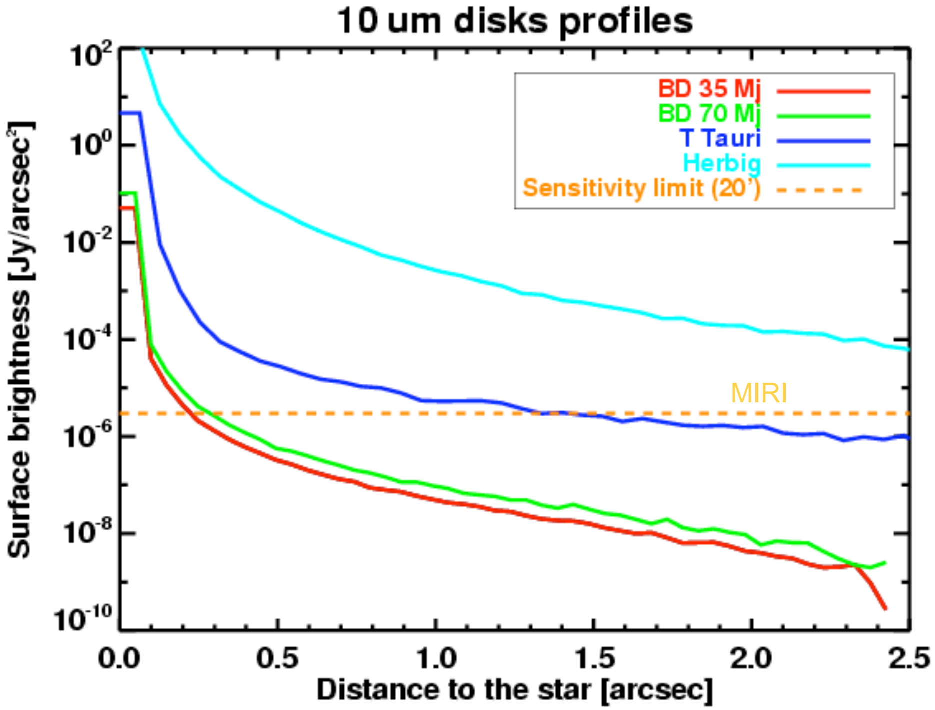
MIRI study of Large Scale Structure of Protoplanetary Disks

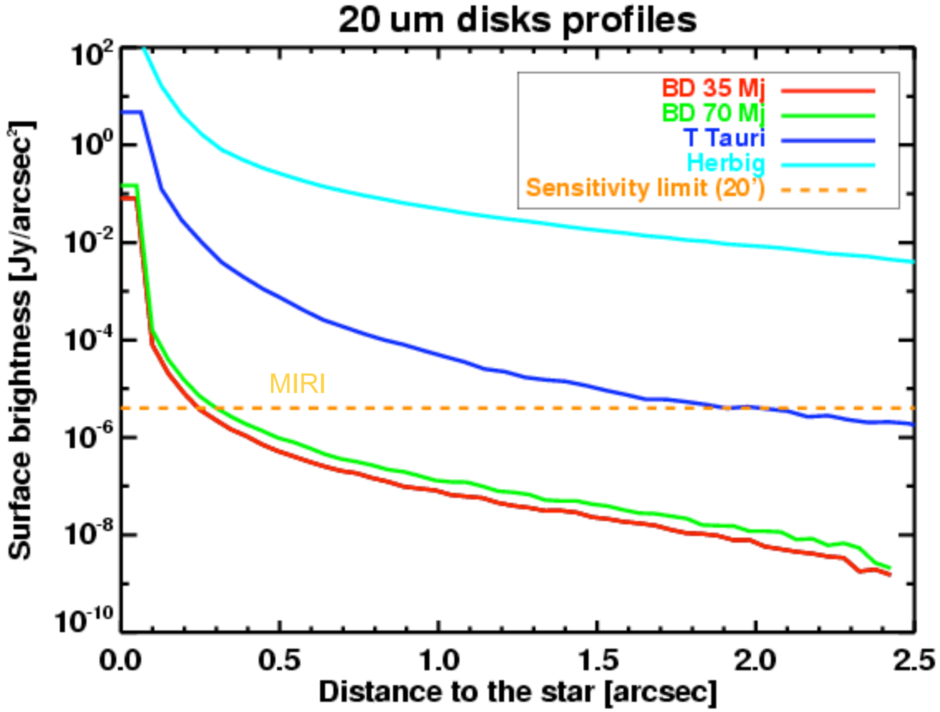


Continuum profiles

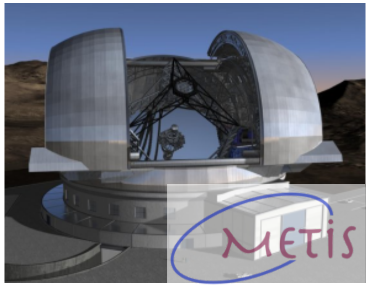


Herbig stars : $M>M_o$
T-Tauri stars : $M<= M_o$

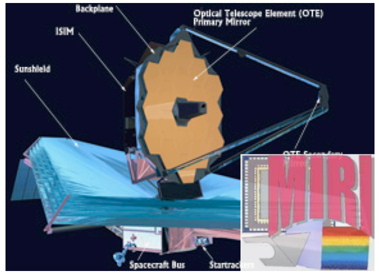


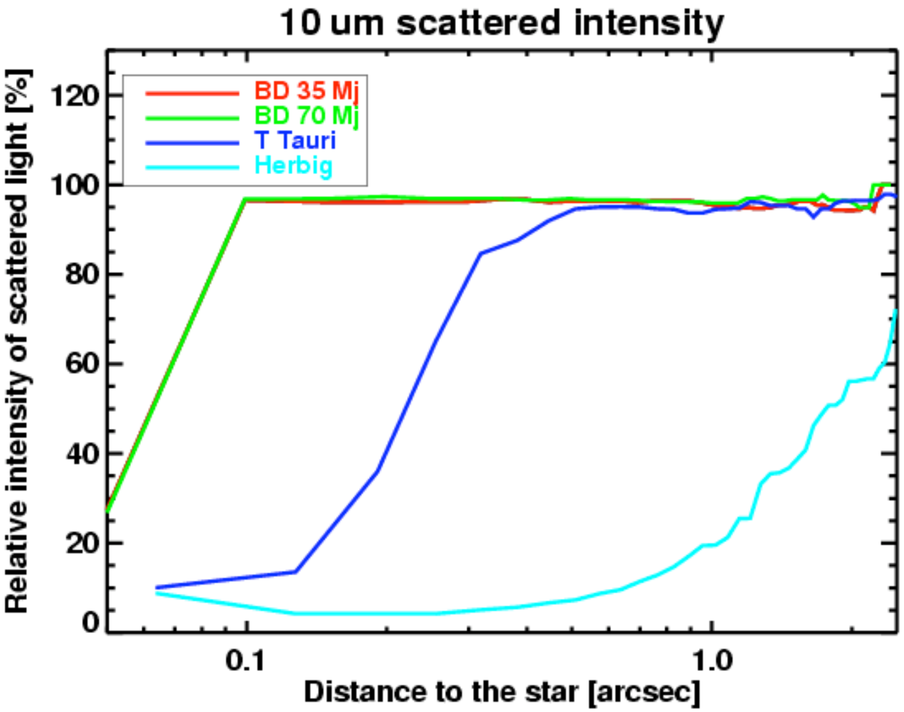


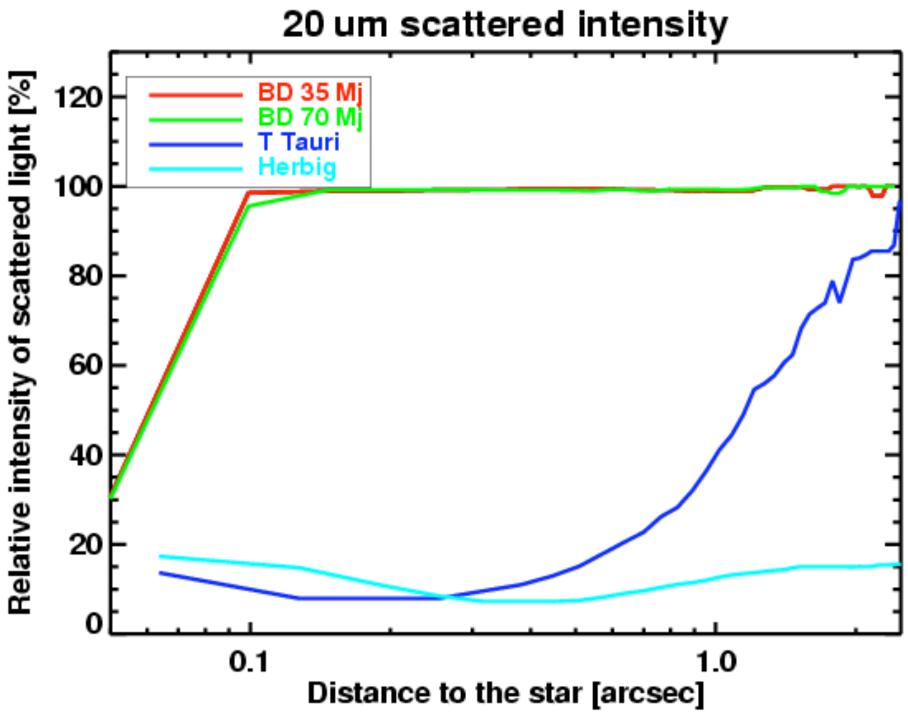
In the case of Herbig disks, the PAH emission (8.6, 11.3 μm) is brighter and more extended than continuum emission

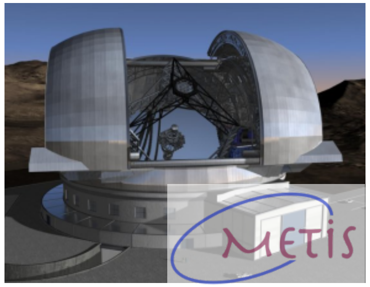


Scattered mid-IR emission

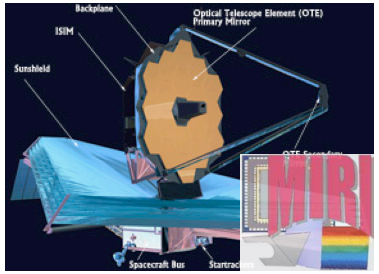


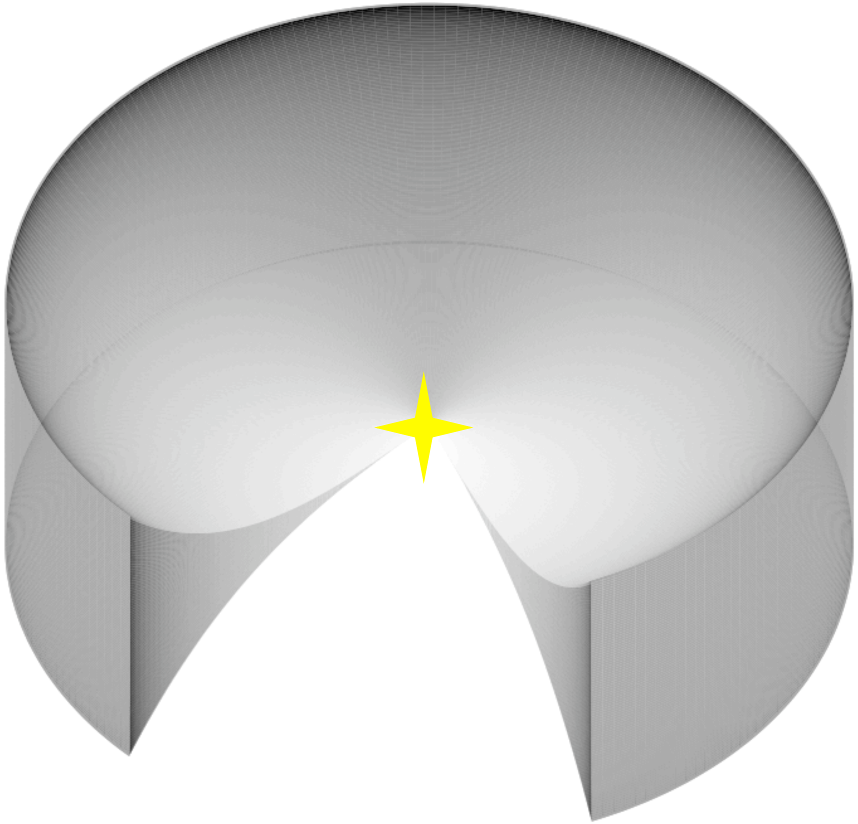


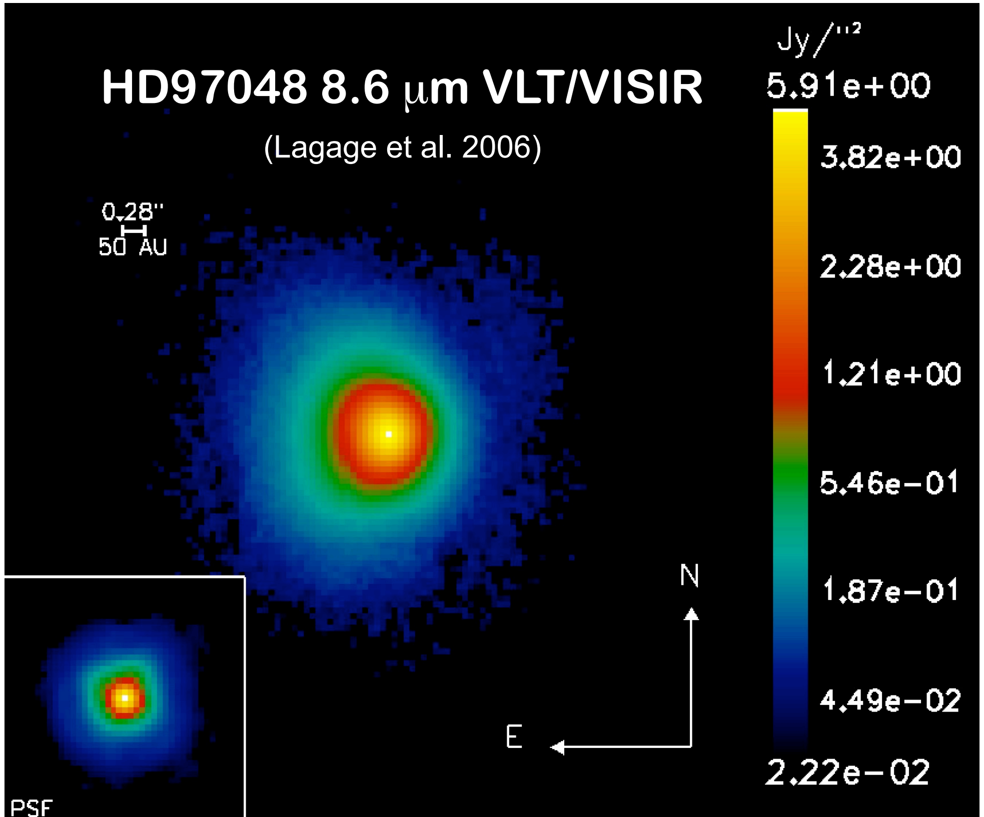


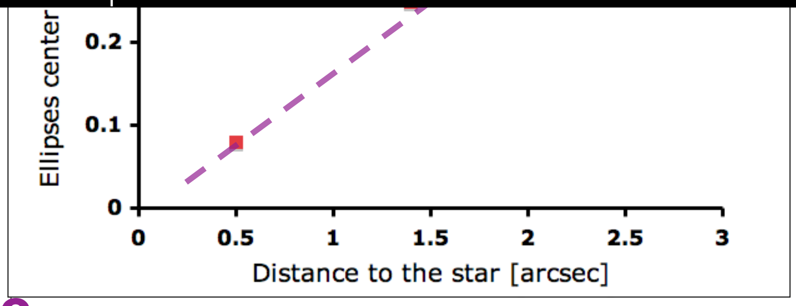


Large Scale Parameters



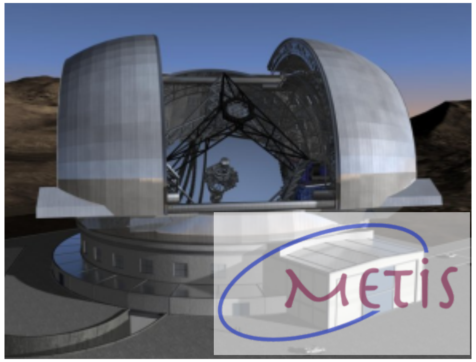


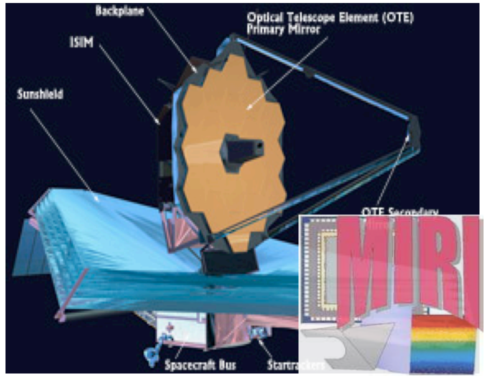




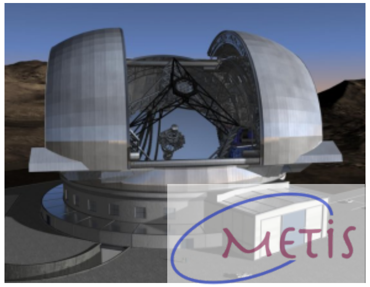
- scale height at a given distance
- flaring parameter

indicators of disks evolutionary state

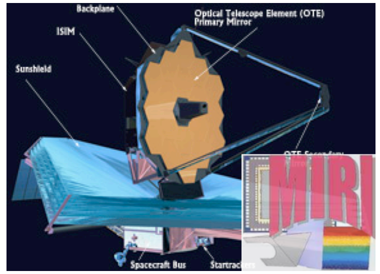


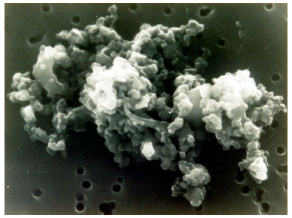


MIRI study of Disks Vertical Structure



Dust evolution

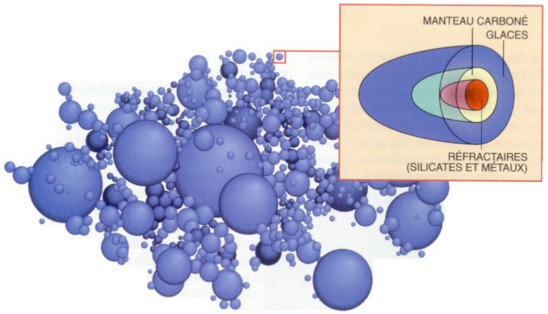


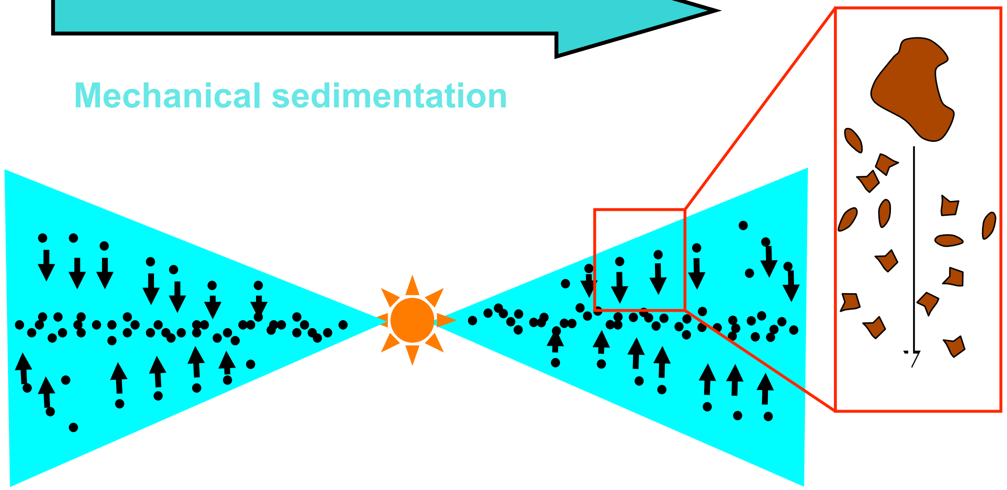


0.1 μm | 1 μm | 1cm | 1m

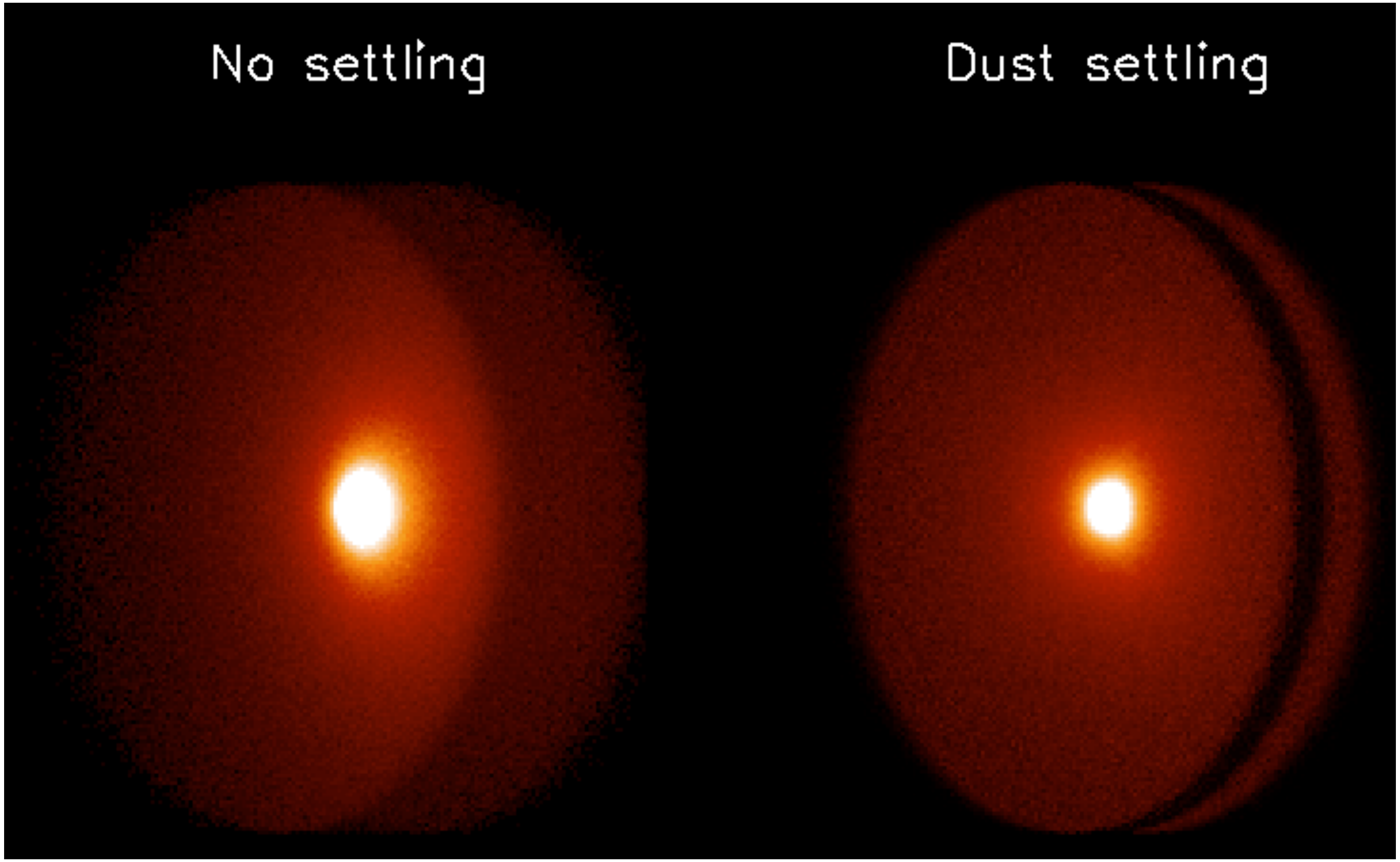
Electromagnetic sticking

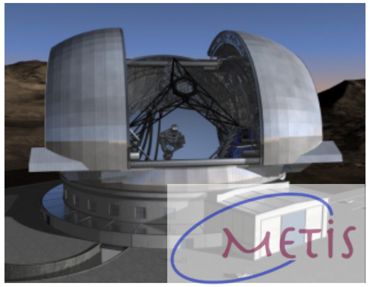
Mechanical sedimentation



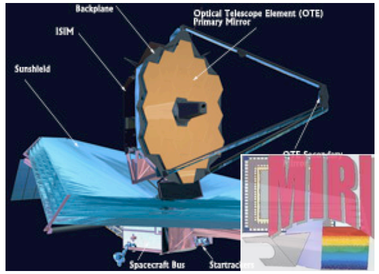


Disks appareance



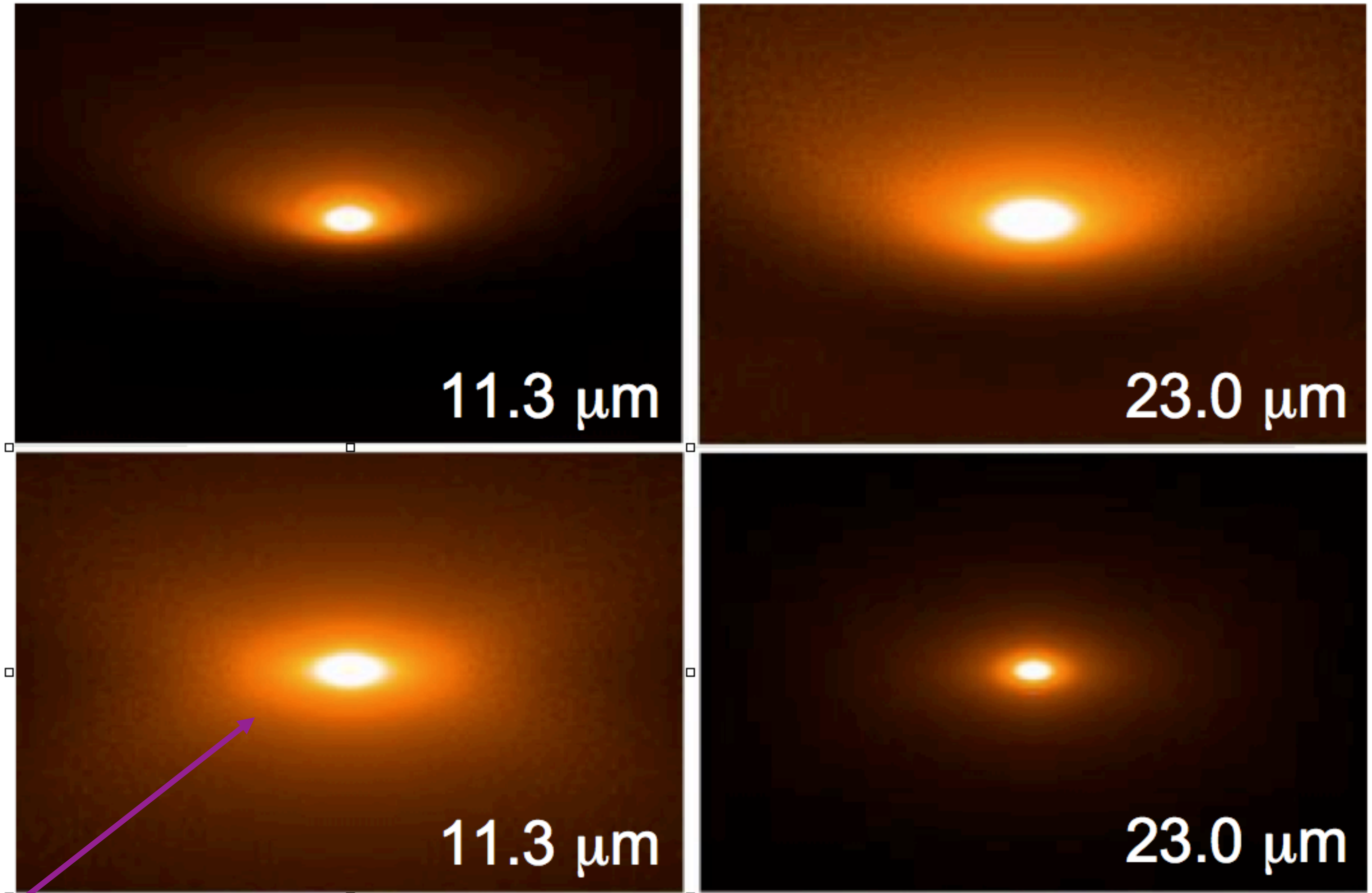


Disks appareance

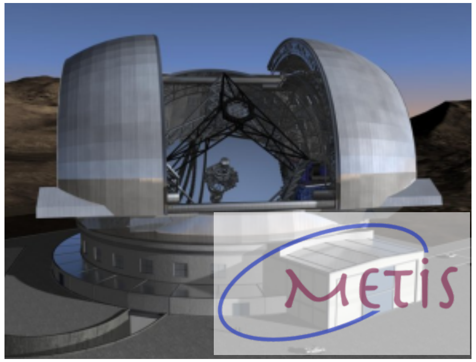


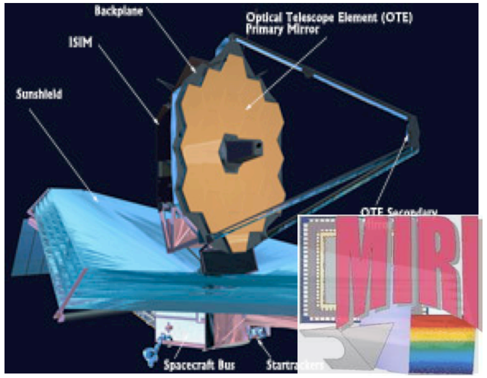
no dust settling

dust settling

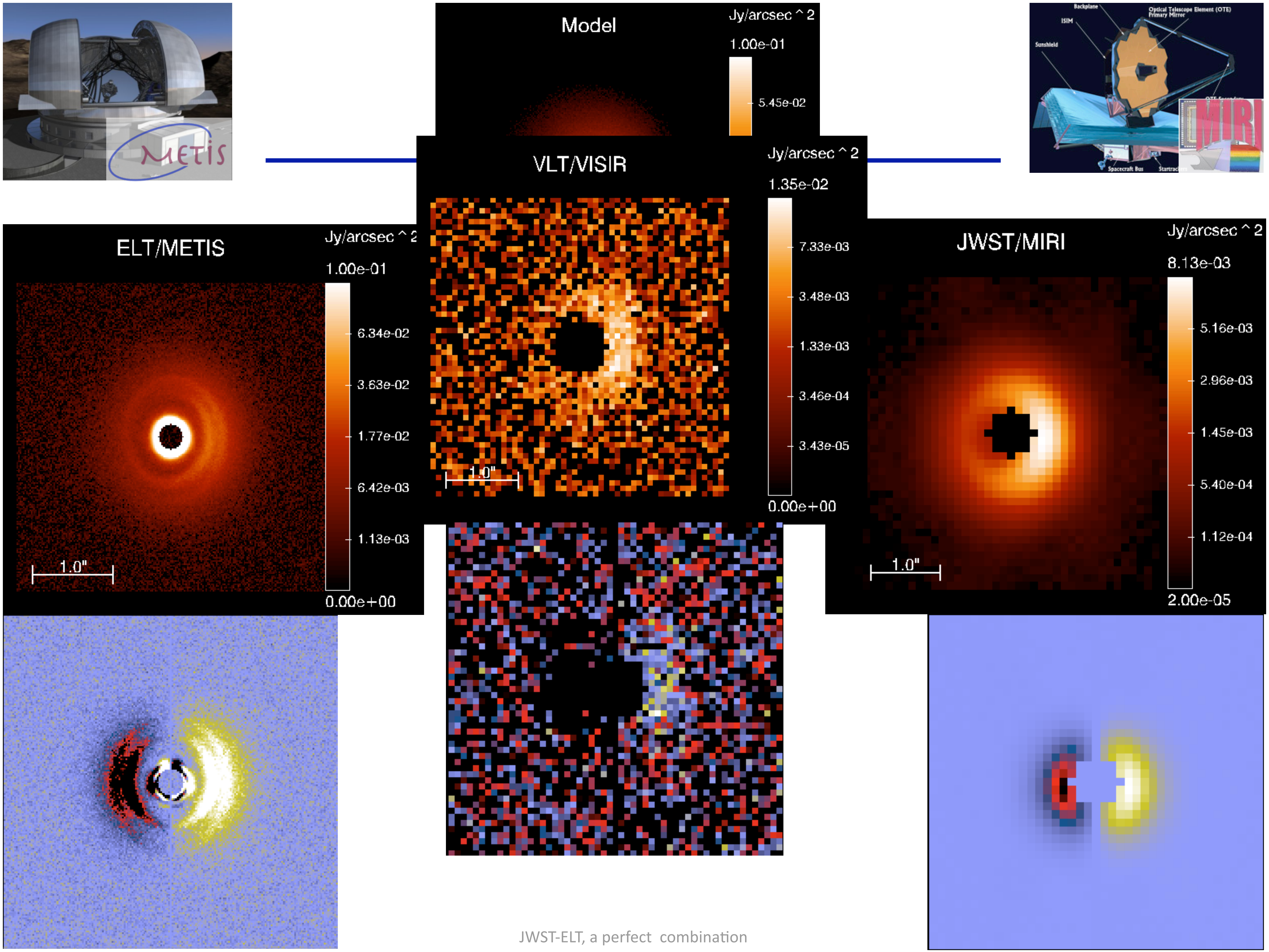


PAH dominated spectrum

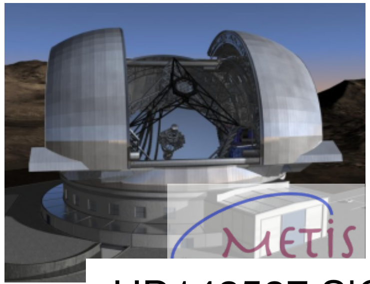




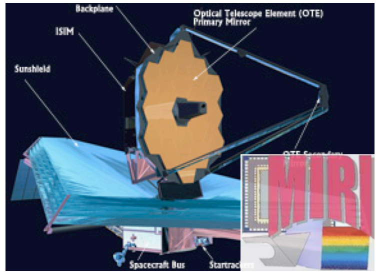
Signatures of planets and planetary formation



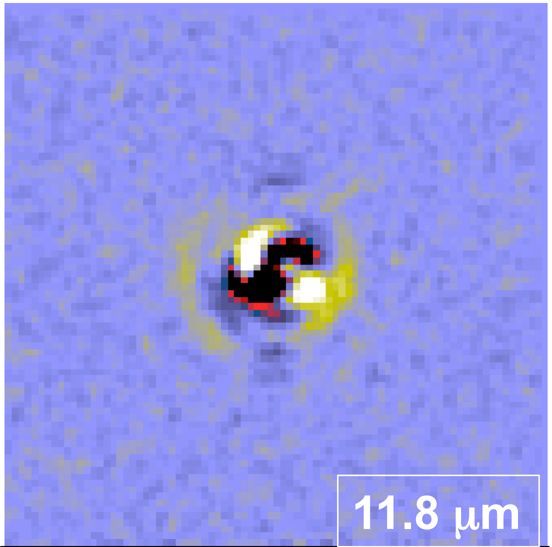
JWST-ELT, a perfect combination



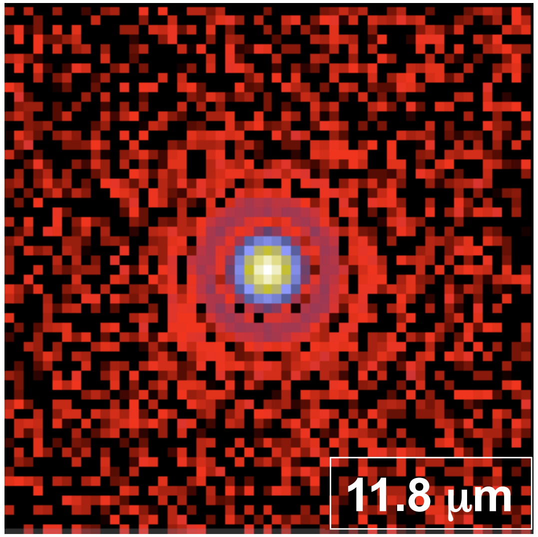
Why "long-wavelength" data (λ>20 μm) are also very important ?

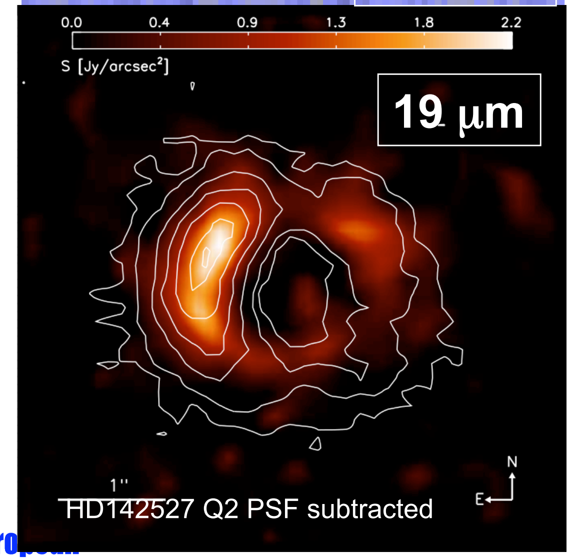


HD142527 SiC PSF subtracted

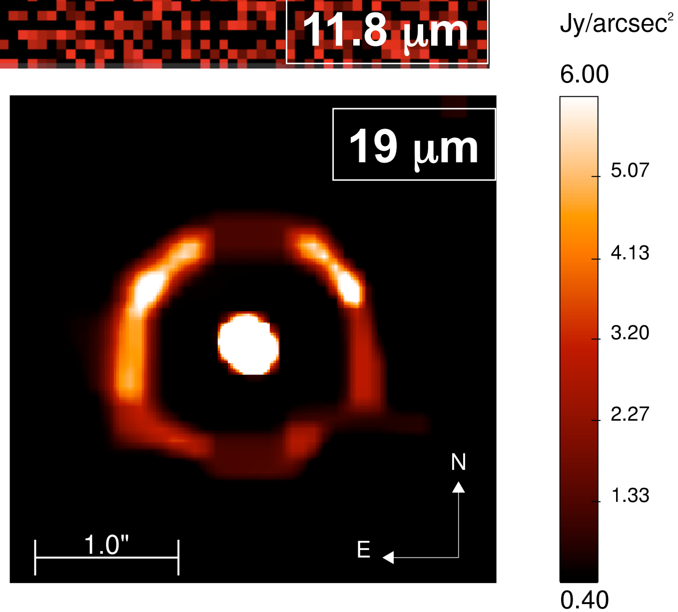


PSF subtraction

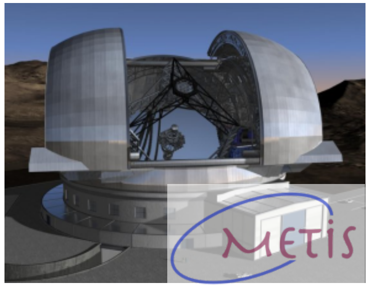




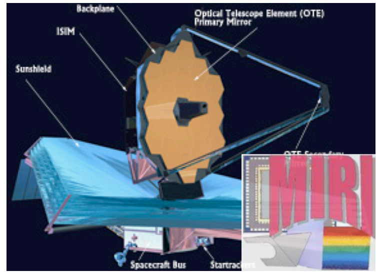
deconvolution

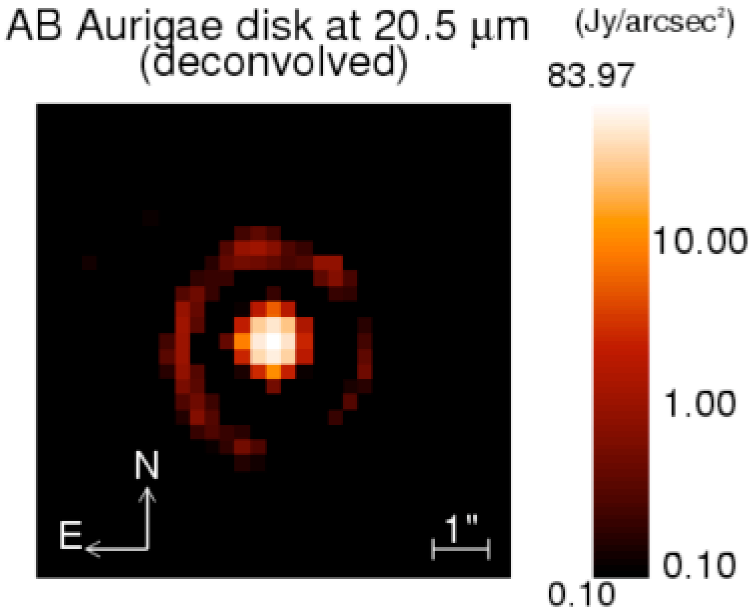


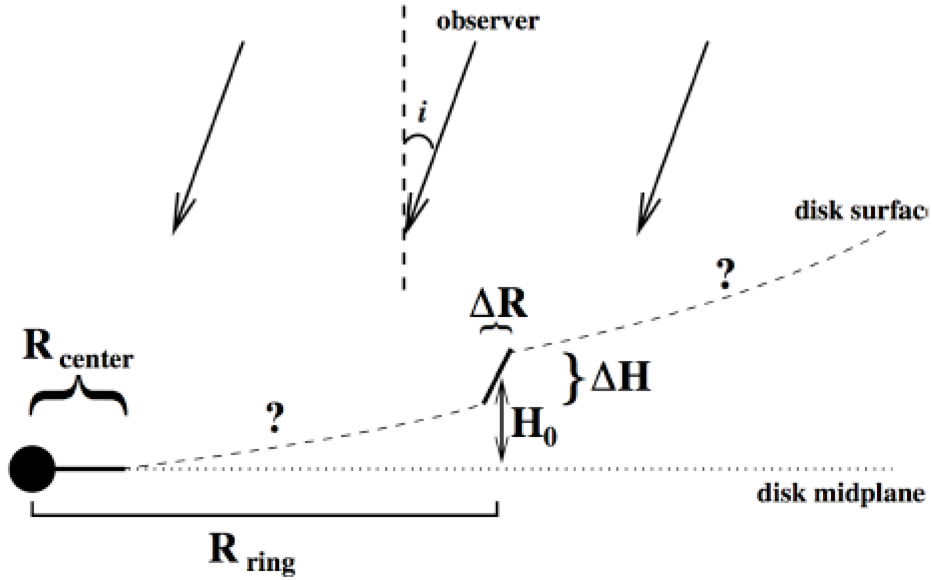
Verhoeff et al., 2010, submitted



Why long-wavelength data are also very important ?

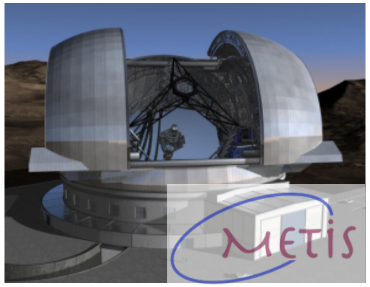




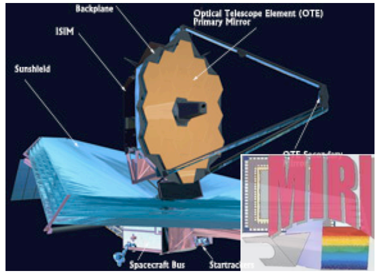


Pantin, E. et al., 2005

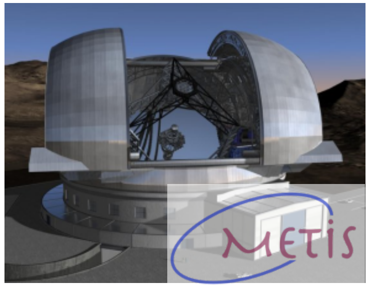
No structures detected at shorter wavelengths !



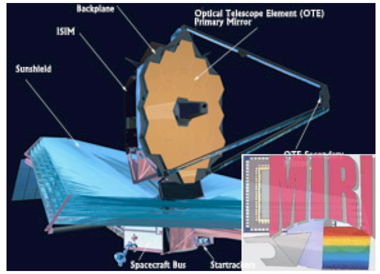
The MIRI disks imaging GTO sample



- 10 Herbig ✭ / 14 T-Tauri ✭ / 2 brown dwarves
- A large sample of moderately inclined disks
- A handful of almost edge-on disks ("*disk tomography*")
- Selection of "transition disks" (last stages of planet formation ???)
- Several star forming regions represented (Chameleon, Taurus-Aurigae, Scorpus, Ophiuchi
- Good overlap/complementarity with the spectroscopic program (see I.Kamp's presentation)



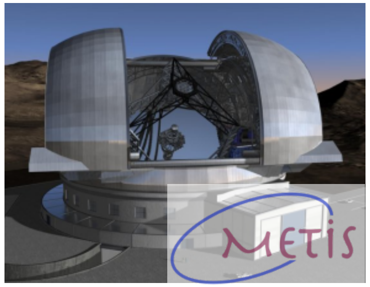
Conclusions

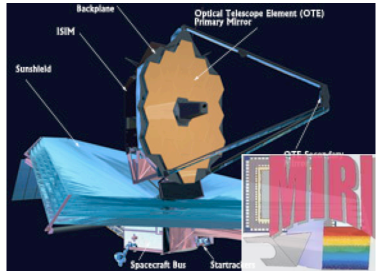


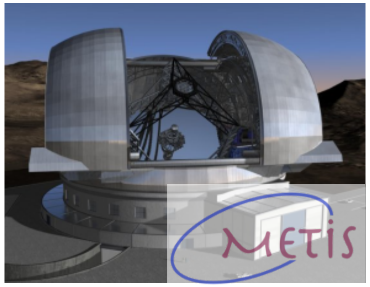
- **8m-class intruments** have probed so far only the emerged part of the iceberg:
  - mostly 11.3 μm emission PAH-rich disks
  - only Herbig disks

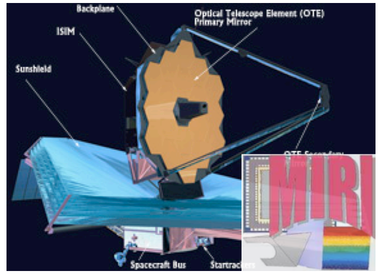
- JWST/MIRI (2014-) will allow to:
  - the underlying continuum disks emission
  - push the stellar mass limit down to the T-Tauri regime (BD in some favorable cases ?)
  - make the first steps to infer the presence of gaps/planets by direct imaging

- ELT/METIS (2018-) will:
  - angularly resolve the "planetary regions" of closests disks (d<150 pc)
  - allow to study the fine structure of the disks : gaps, spirals, walls, ... produced by forming protoplanets


METIS


Backplane
ISIM
Optical Telescope Element (OTE)
Primary Mirror
Sunshield
Spacecraft Bus
MIRI


METIS


Backplane
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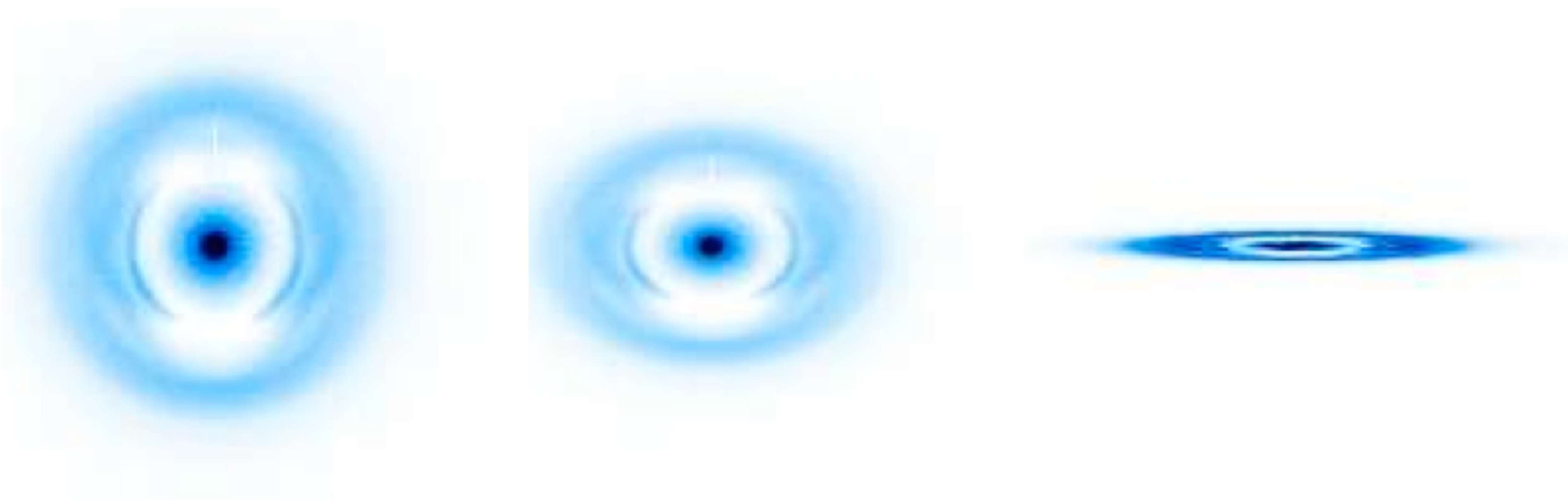

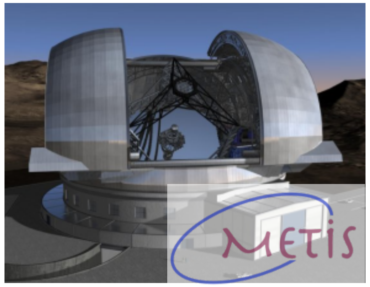

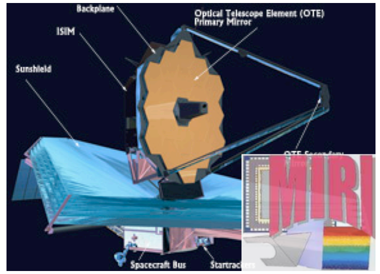

Backplane
Optical Telescope Element (OTE) Primary Mirror
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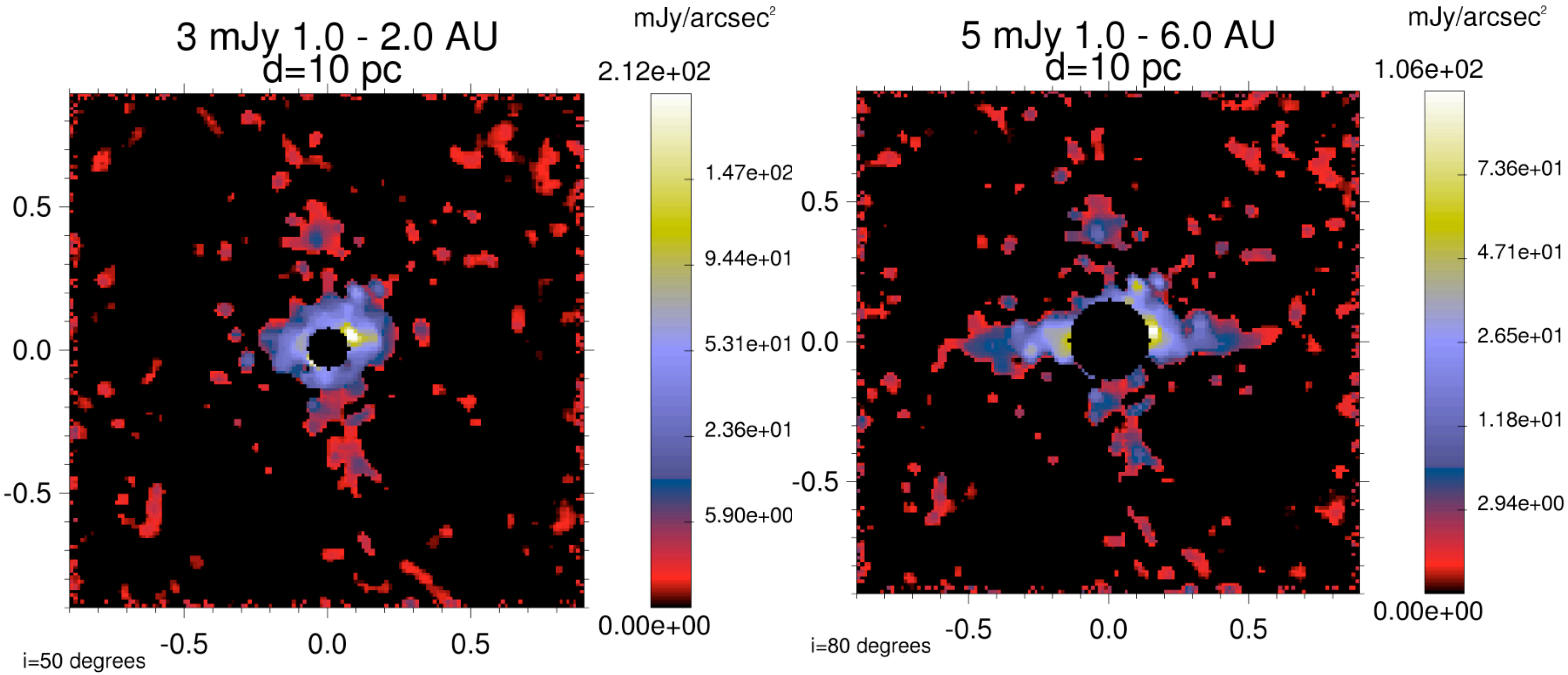

3 mJy 1.0 - 2.0 AU
d=10 pc
mJy/arcsec²
2.12e+02
1.47e+02
9.44e+01
5.31e+01
2.36e+01
5.90e+00
0.00e+00
0.5
0.0
-0.5
-0.5
0.0
0.5
i=50 degrees
5 mJy 1.0 - 6.0 AU
d=10 pc
mJy/arcsec²
1.06e+02
7.36e+01
4.71e+01
2.65e+01
1.18e+01
2.94e+00
0.00e+00
0.5
0.0
-0.5
-0.5
0.0
0.5
i=80 degrees