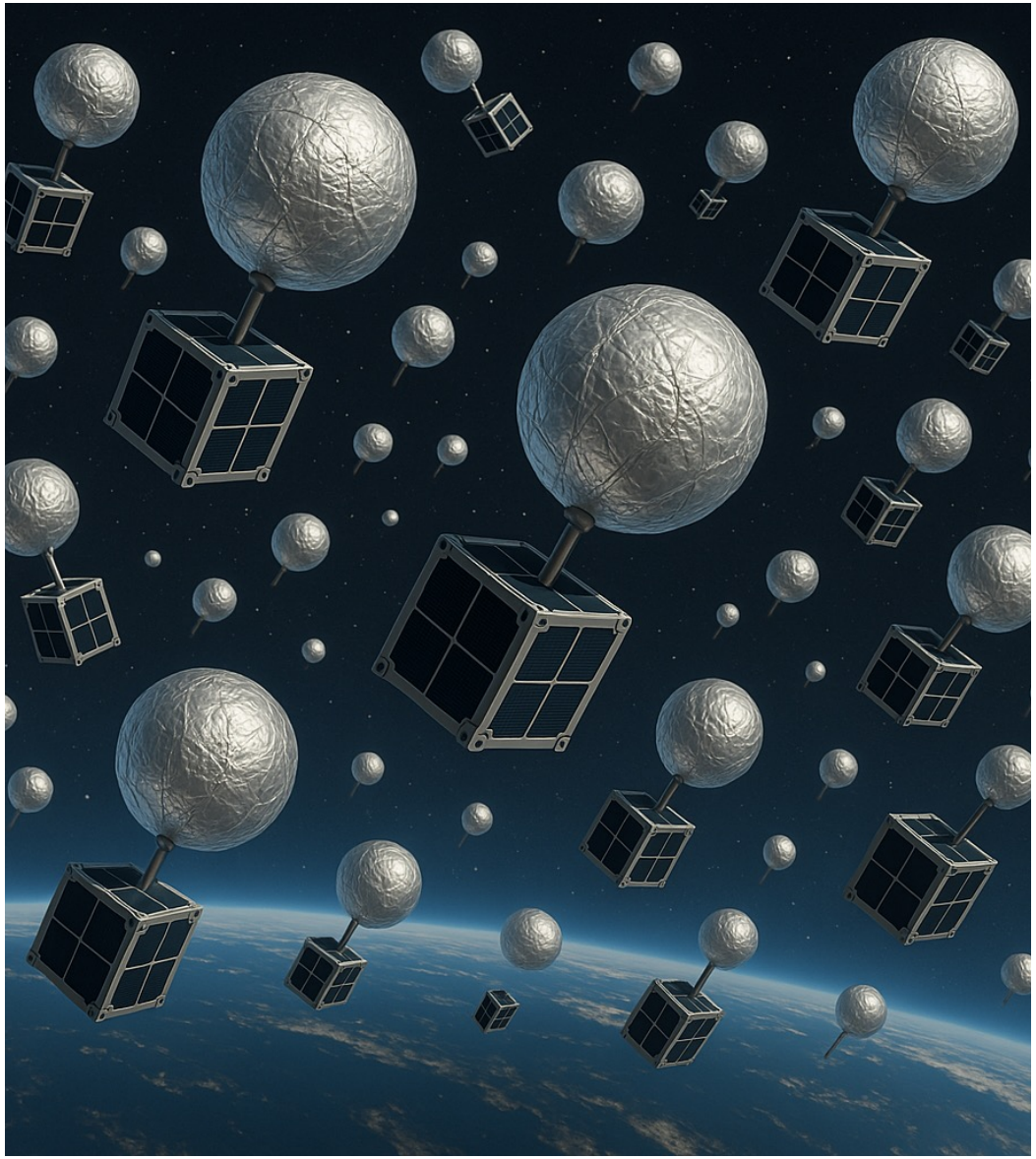
# The Case for a Space Array

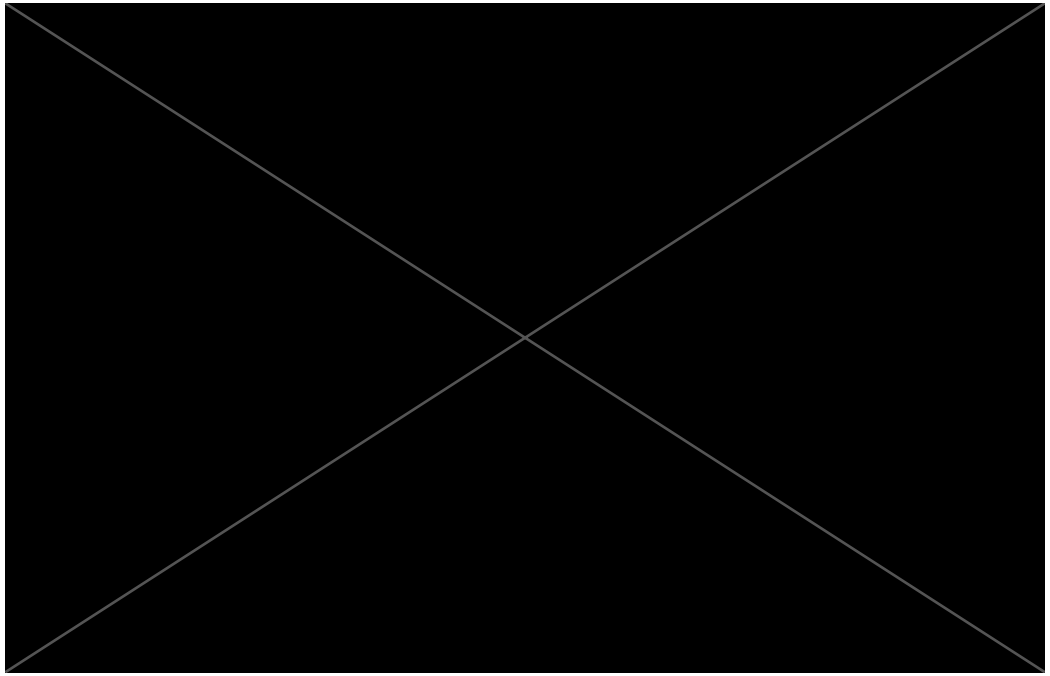
E. Villard

# Summary

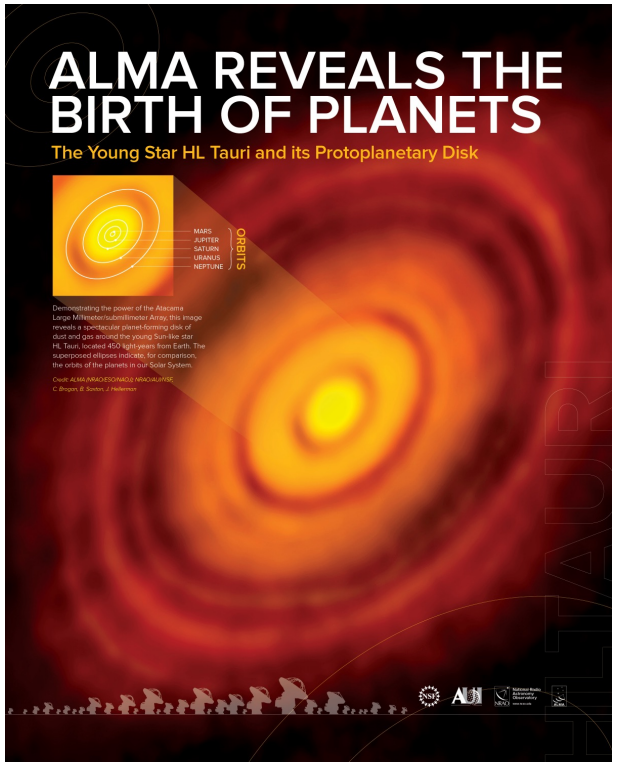
- We all want a space-based radio interferometer.
- Most of the required technology is mature.
- It can be done. (If we find the money.)

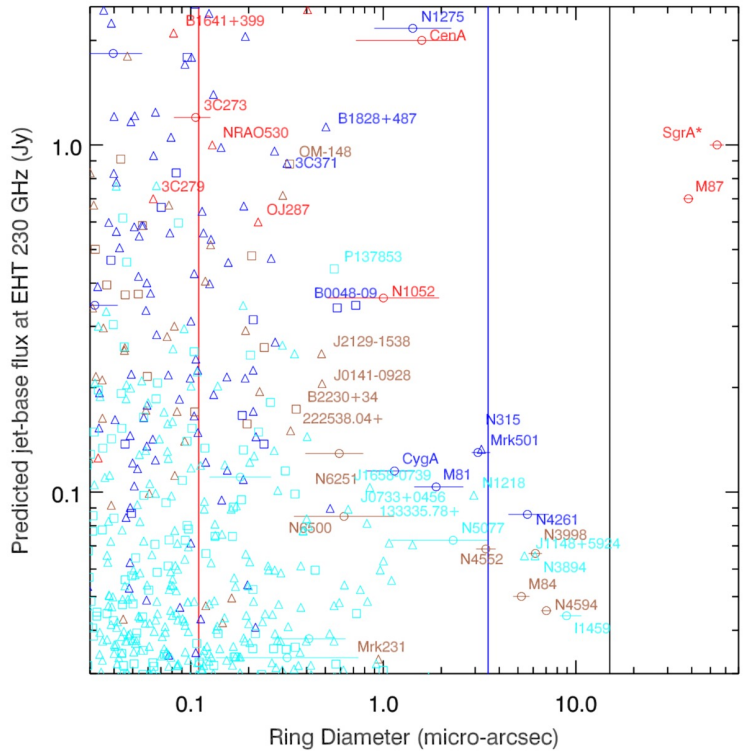


# The idea of a Space Array



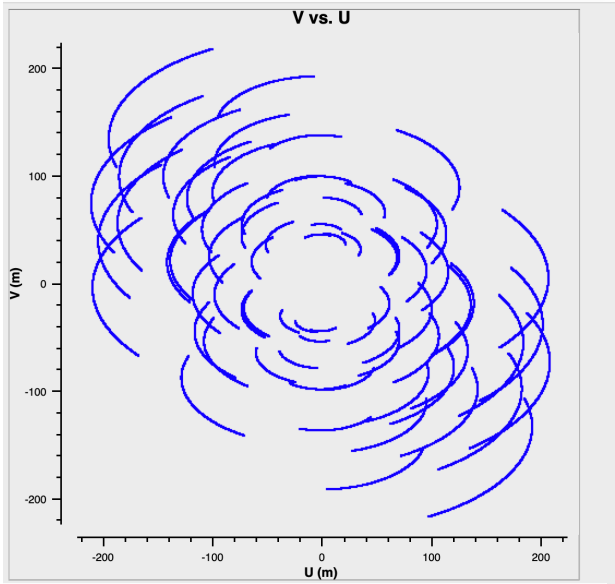
# Initial science interest

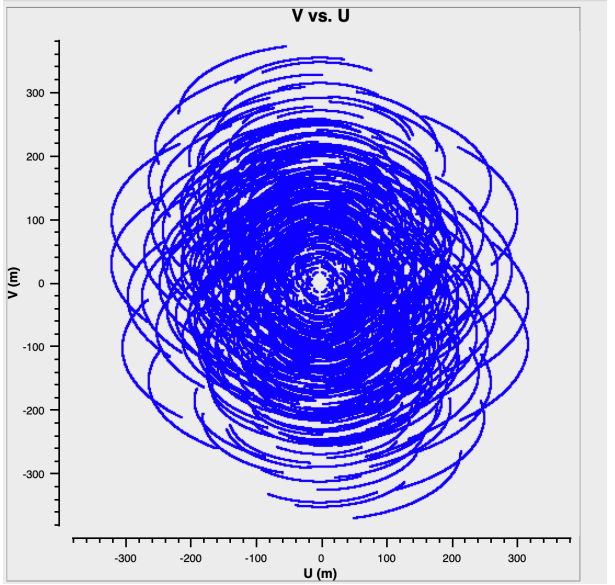


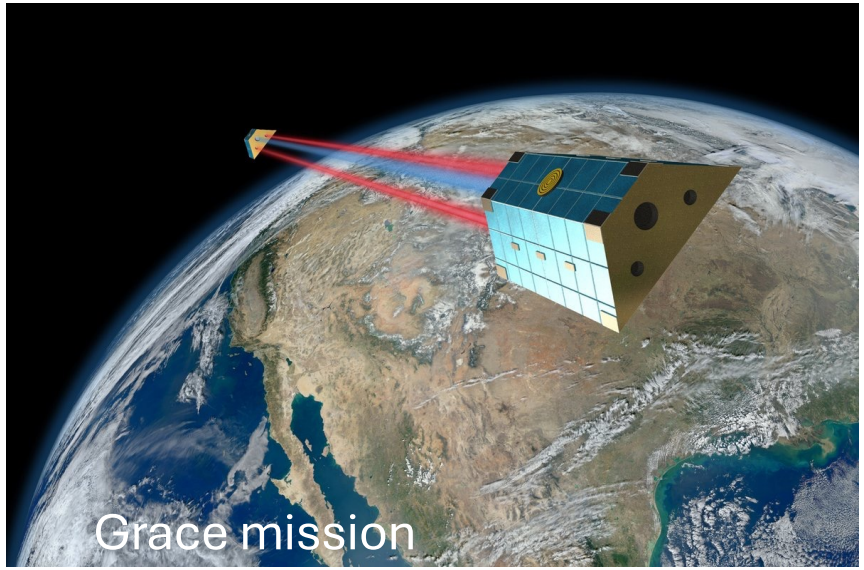



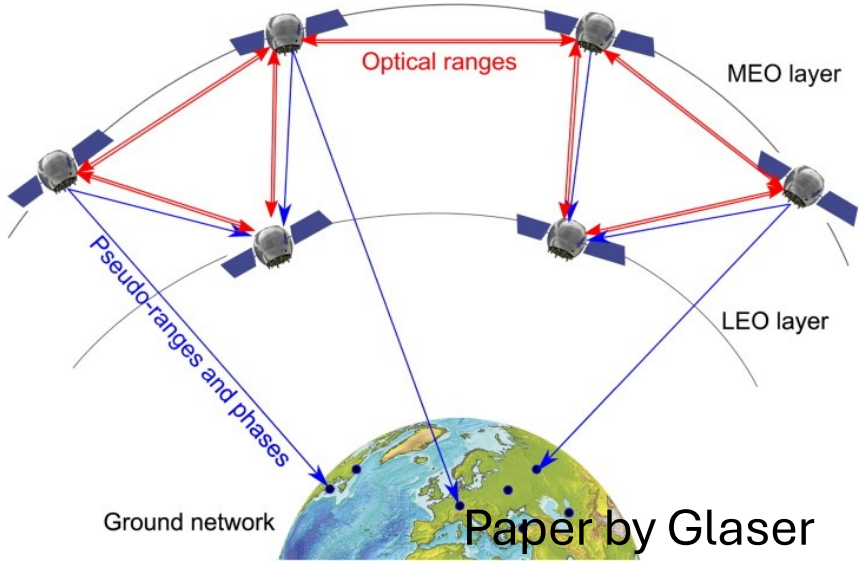
# Unique capabilities

1. HIGH FREQUENCY observatory
   - From 300 GHz up to FIR (mainly limited by antenna quality)
2. HIGH IMAGING QUALITY
   - Fantastic uv coverage, thanks to (large) number of satellites and rapid orbital rotation
   - *“It cannot be overstated how crucial the UV-coverage is to the successful imaging of the complex structure of HL Tau.” (ALMA Partnership et al 2015)*
3. Large range of HIGH ANGULAR RESOLUTIONS
   - MEO altitude provides highest angular resolution.
   - SLOW DRIFT of array provides varying angular resolution over time (e.g. ALMA configurations)






Paper by Glaser

# Investigating the feasibility

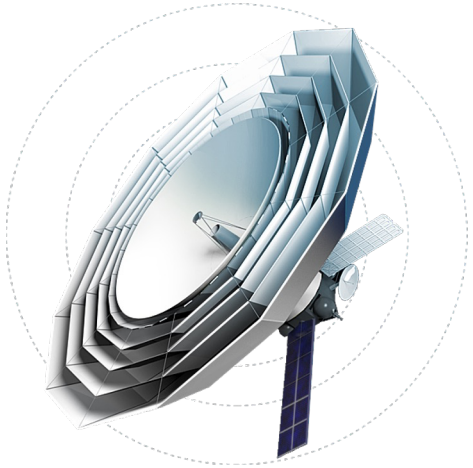
[redacted]

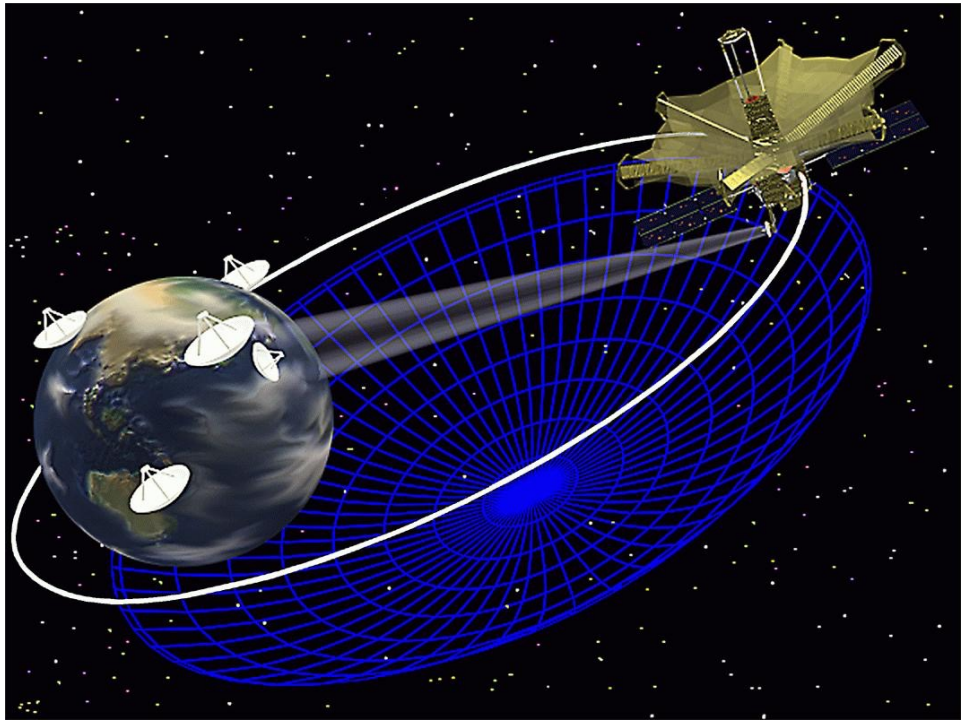
- We decided to focus on two topics:
  - Investigating the feasibility of measuring baseline vectors to better than a millimeter
  - Development of an observing simulator
- Our idea was to keep it simple as much as possible, and use only GNSS.

[redacted]

# A very active Space-VLBI community

- VSOP
- RadioAstron
- ESPRIT (Thijs)
- Event Horizon Imager
- THEZA
- Black Hole Explorer
- Capella





# The Space Array team

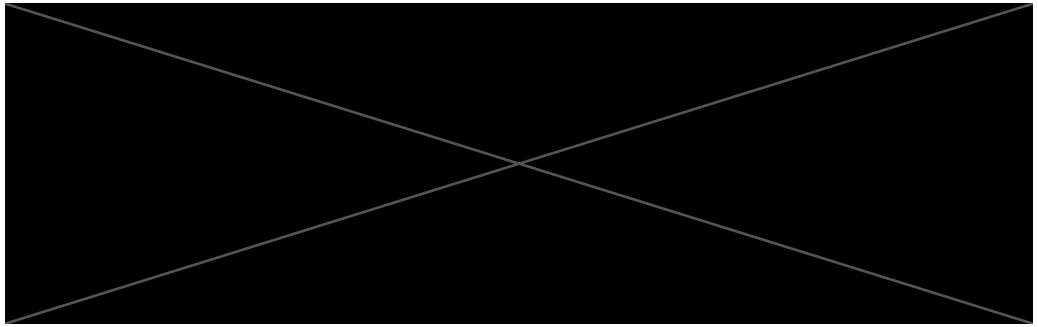
- Kick-off meeting in December in Gothenburg (funded by Chalmers)
- Large range of expertise:
  - Space VLBI, sub-mm interferometry, receivers, antennas, correlators, satellite navigation, laser communication
- Private companies: Space Tech, Airbus
- Space agencies: ESA, CNES, SRON

# Organization

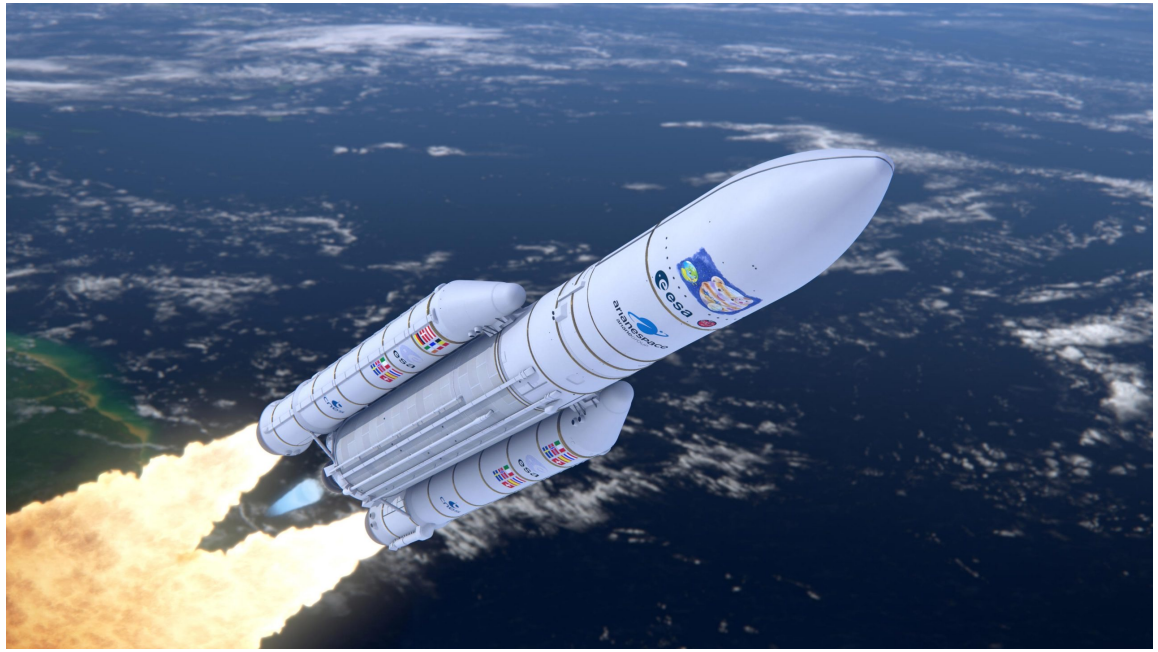
- Three WGs: Science, Technical and Observing simulator
- WGs are meeting every week. Team meeting every Friday.
- You’re most welcome to join us!

# ESA call for science missions

- Different classes: M, F and mini-F
- We considered all options and concluded we had a case for an M-class proposal.

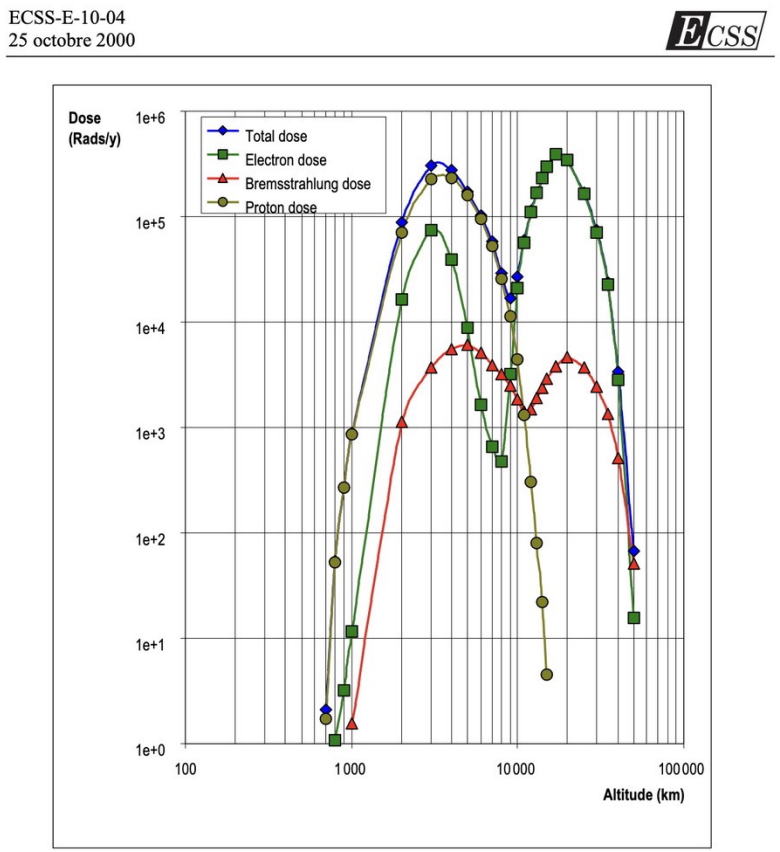


- Science cases: BH imaging, photon ring, AGNs, transients, masers, disks



# Science requirements

- Orbit orientation: inertial, optimized for M87 and SgrA* (minimum), all-sky coverage (goal)
- Observing frequency range: 230-650 GHz (minimum), 70-900 GHz (goal)
  - The higher frequency gives access to optically thin emission and highest angular resolution.
  - The lower frequency allows observing quasars for phase referencing.
- Angular resolution: 6 μas (minimum), 2 μas (goal, 10x better than EHT)
- Point-source sensitivity:
  - Minimum: 8 mJy in 1h (EHI: 2x4m antennas, 500GHz, 5GHz BW, 150K, 2bits)
  - Goal: 1.5 mJy in 1h (4x4m antennas, 500GHz, 20GHz BW, 150K, 3bits)
- Observing mode: space-to-space (minimum), space-to-space and space-to-ground (goal)



# Technical requirements

- Number of satellites: 2 (minimum), 4 (goal)
- Antenna diameter: >= 4m
  - Surface accuracy (rms): 10 microns (minimum)
- Receivers
  - IF Bandwidth: 5GHz (minimum), 20 GHz (goal)
  - Number of polarizations: 2
  - Frequency bands:
    - Minimum: ALMA Bands 6 and 8
    - Goal: ALMA Bands 3, 6, 7, 8 and 10
- Peak data rate (continuum): 40 Gbps (minimum), 240 Gbps (goal)

- Correlation: in-orbit (minimum), in-orbit and on the ground (goal)
- Baselines
  - Real-time (in-orbit correlation)
    - Residual error (statistical): 10 cm (minimum)
    - Stability: lambda/15 over 1s (minimum)
  - After orbit reconstruction (all cases, including in-orbit correlation)
    - Residual error: lambda over 10 min (minimum), lambda over 30mn (goal)
  - Final (after offline calibration)
    - Residual error: lambda/15
- We are working with Airbus experts on the antenna design and the overall cost estimate.

# Summary

- The Space Array team is an active collaboration between sub-mm/FIR scientists and experts in many technical areas, in academia and private companies.
- Our long-term goal is a large constellation of sub-mm/FIR satellites in Earth's orbit.
- Our current assessment is that a sub-mm long-baseline interferometer is technically possible.
  - We need to study more the FIR case. It might be feasible, but it will be pushing the envelope in terms of antenna, baseline determination and cost-effectiveness.
- The ESA call is a fantastic opportunity, but there is so much we can do.
- Our goal is to focus on the highest angular resolution.
  - Sensitivity and uv coverage will need integration.
- You're most welcome to join us!