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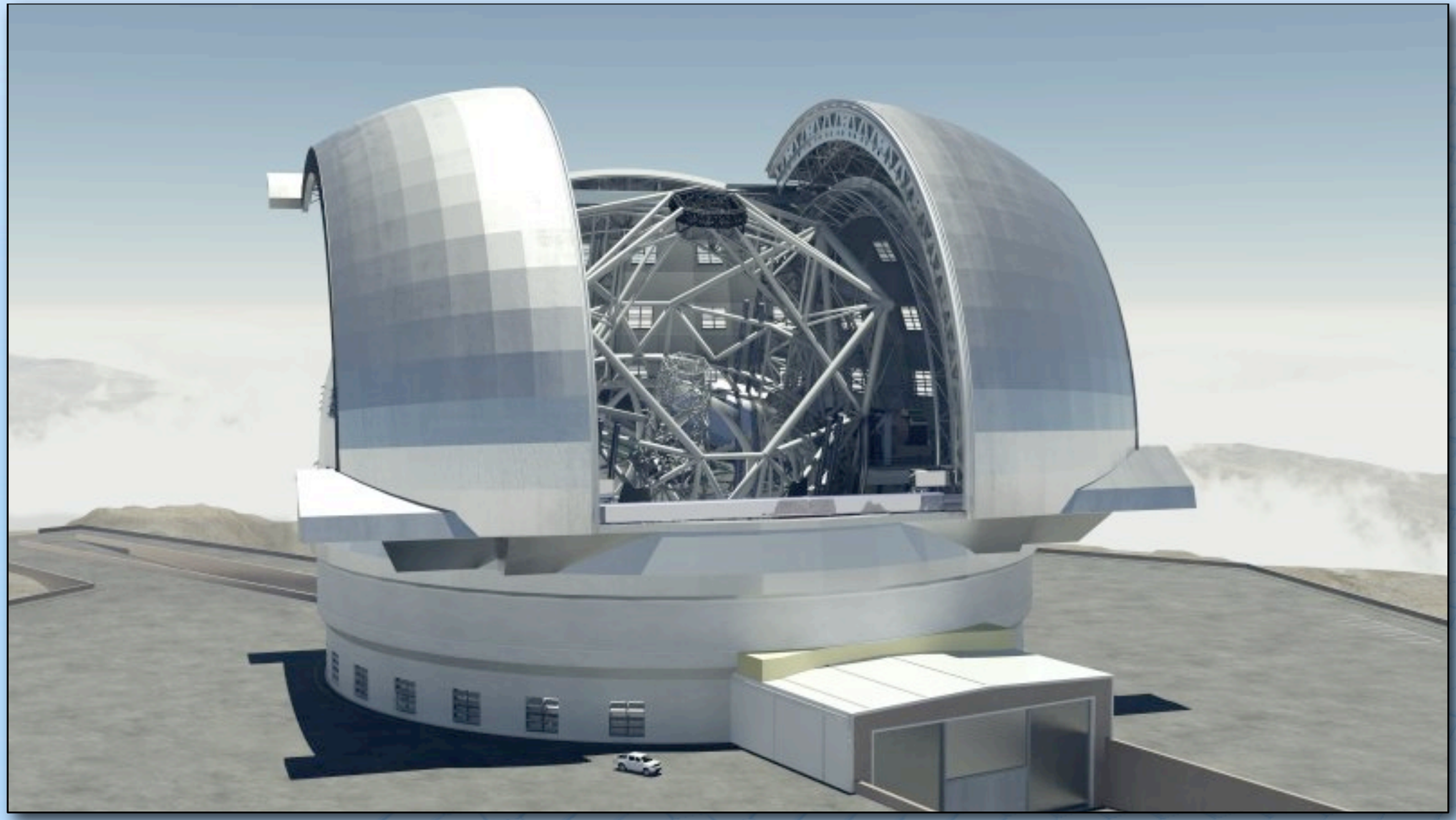
Adaptive Optics Science in the E-ELT Era

Markus Kissler-Patig



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Project overview

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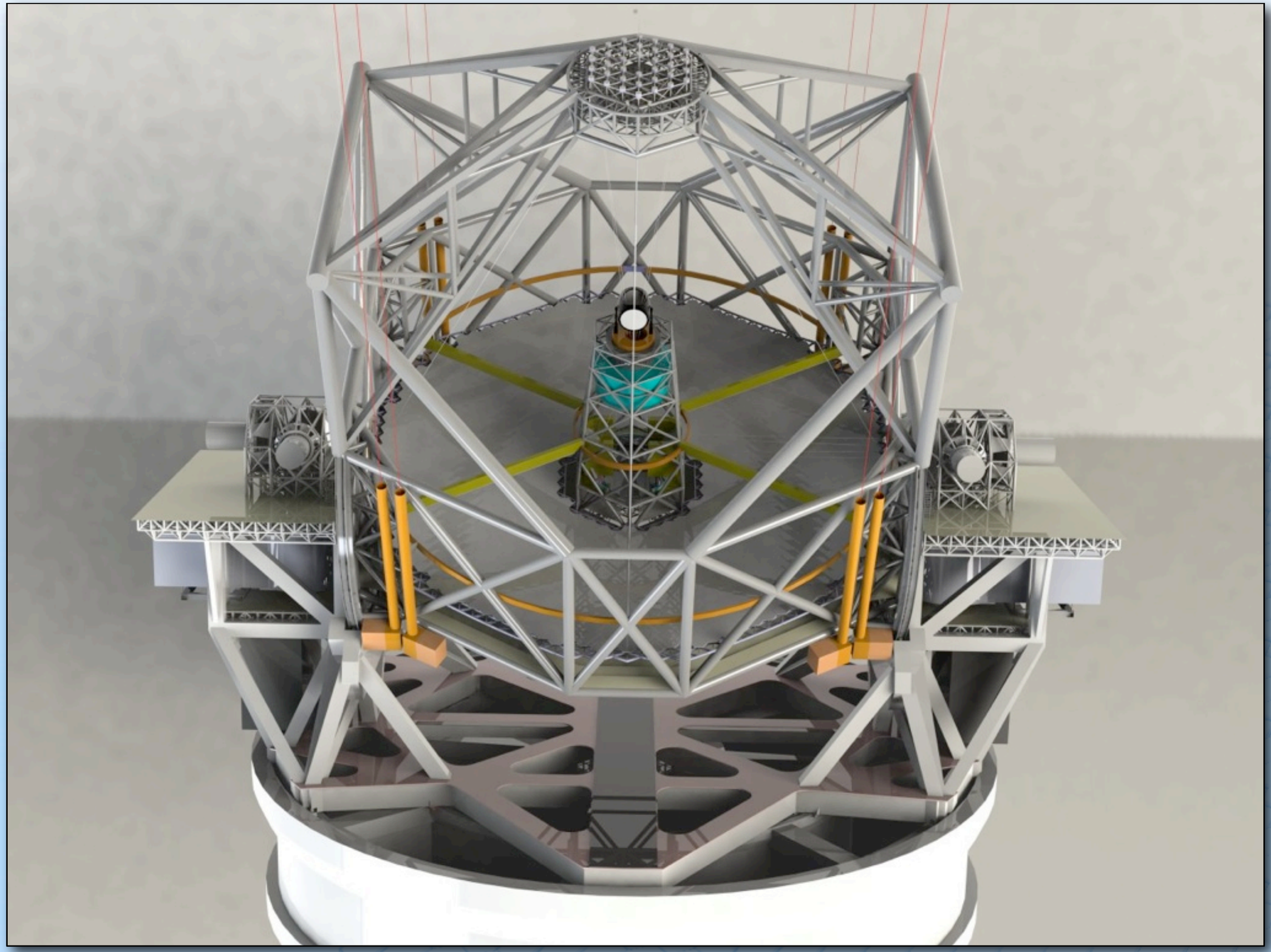
Telescope overview



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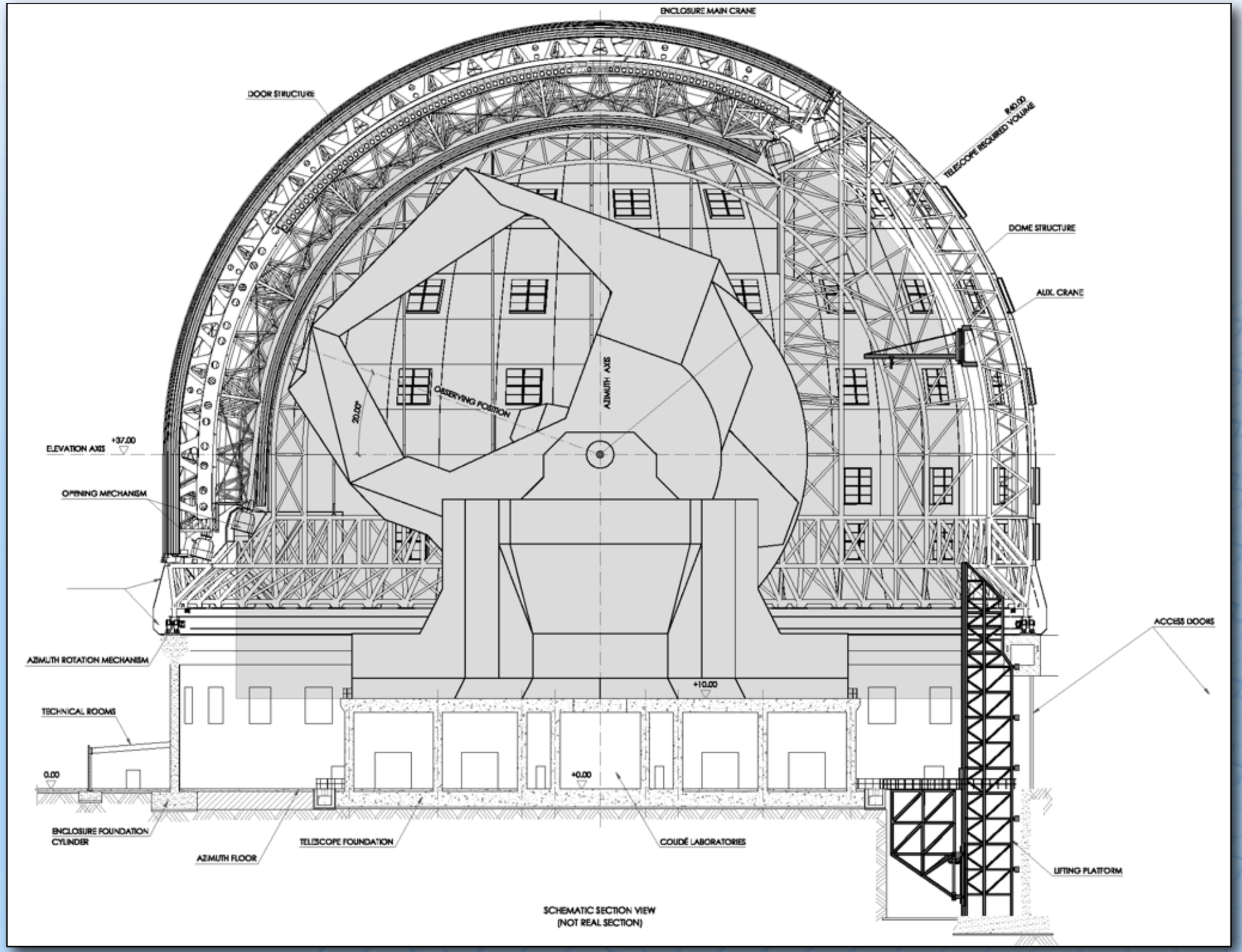
Telescope overview



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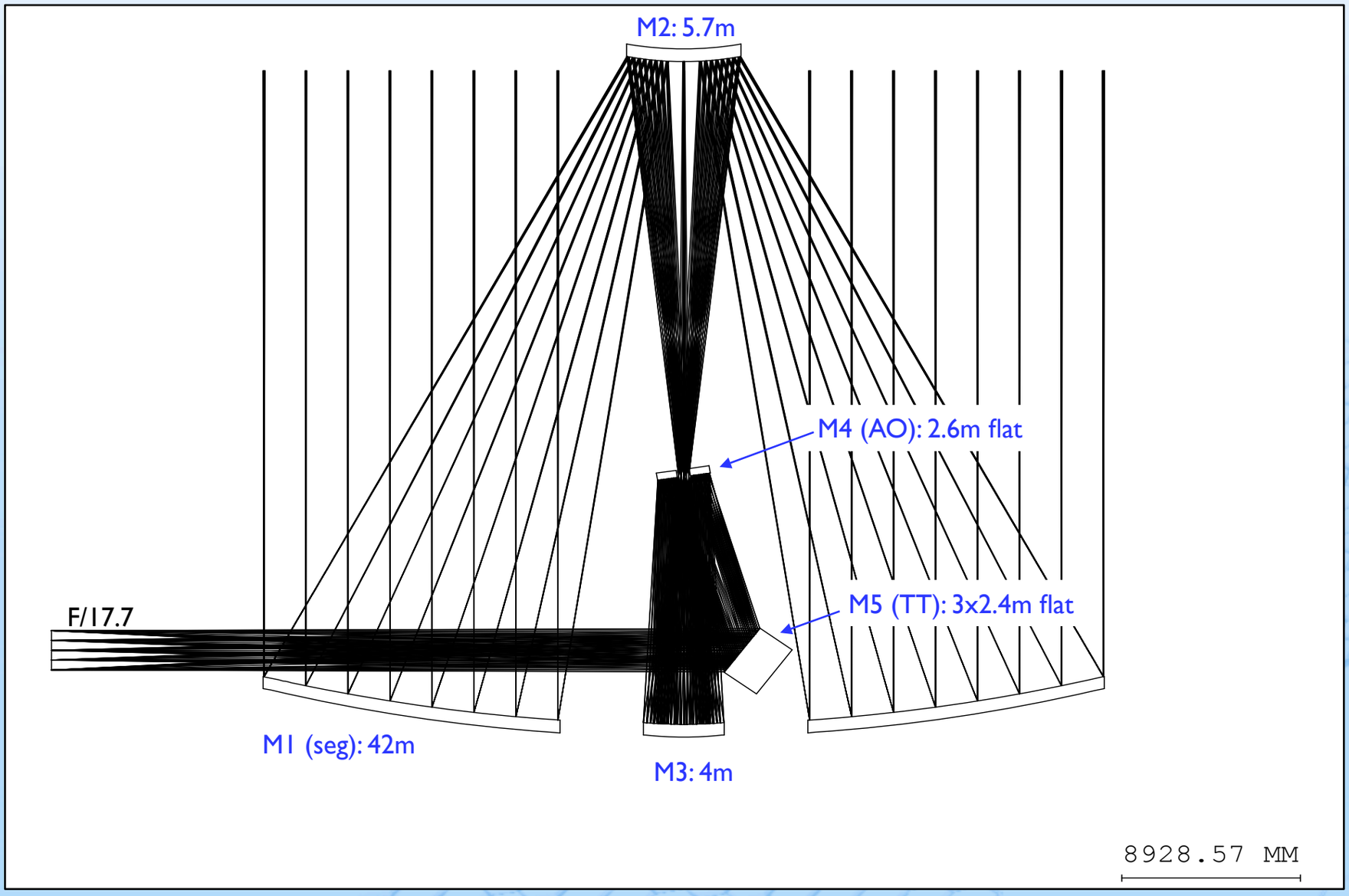
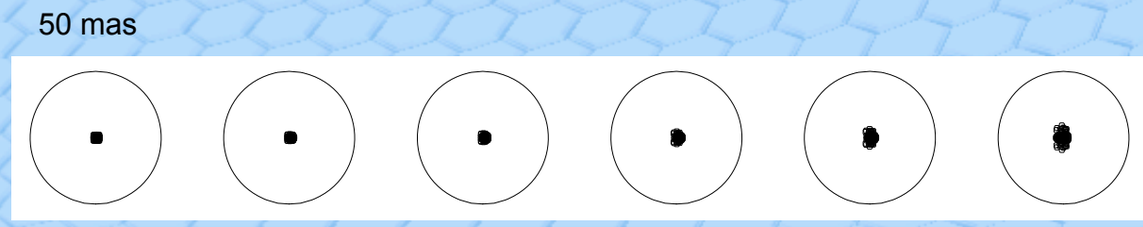
Telescope overview



Field of view (radius)	RMS Wavefront Error (nm)	Strehl ratio at wavelength 500 nm	Strehl ratio at wavelength 2000 nm
axis	4	1.00	1.00
1 arc min	4	1.00	1.00
2 arc min	5	1.00	1.00
3 arc min	7	0.99	1.00
4 arc min	9	0.99	1.00
5 arc min	13	0.97	1.00



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Science Case

Science case

- Today's great ideas

  Design Reference Mission, Design Reference Science Plan, Science Cases of the Instrument Teams, ...

- Synergies with other major ground- and space-based facilities

  (8m class telescopes, ALMA, JWST, surveys, SKA, ...)

- Enable Discoveries - expect the unexpected

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Today's Science

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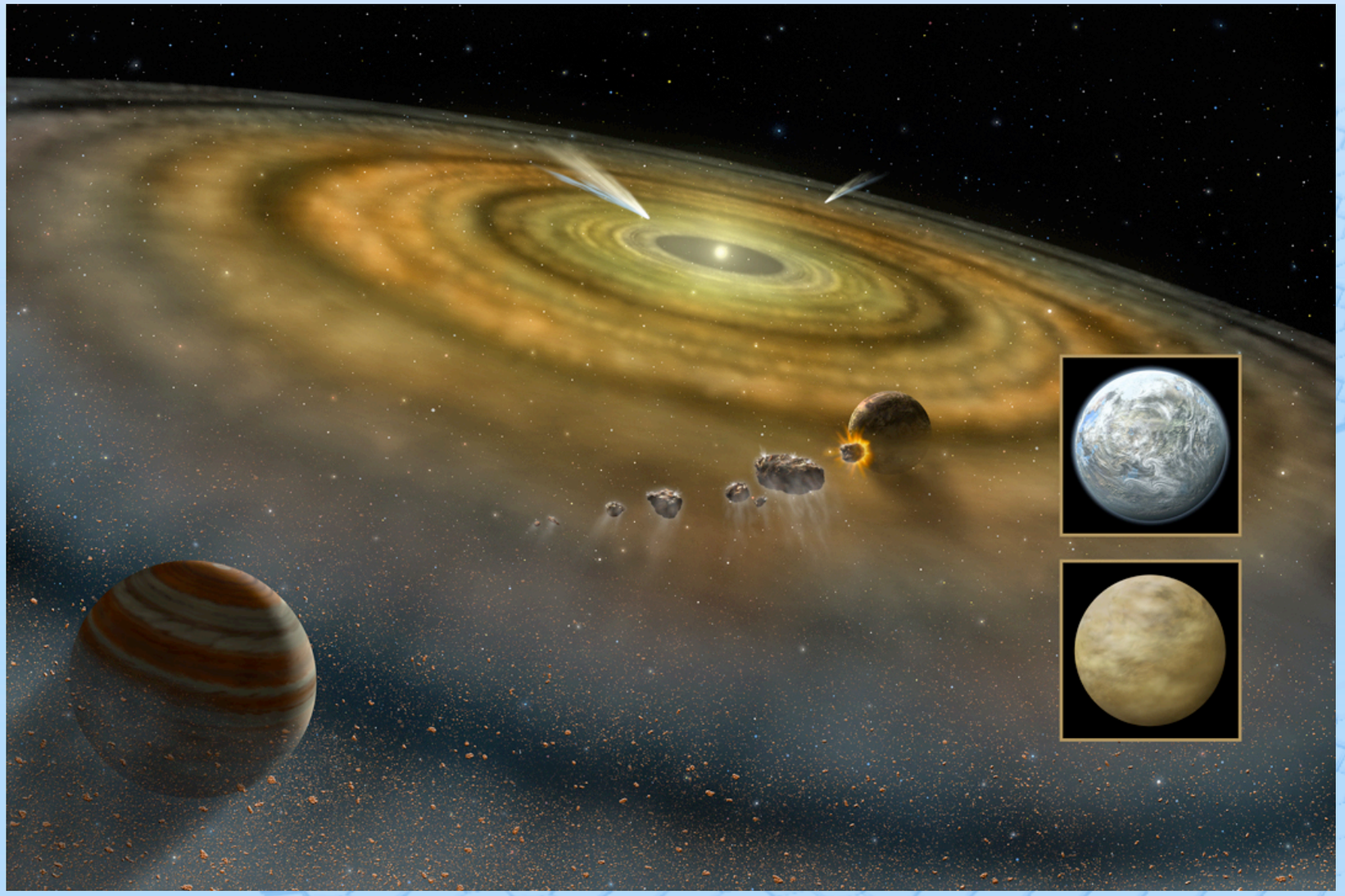
Planets & Stars



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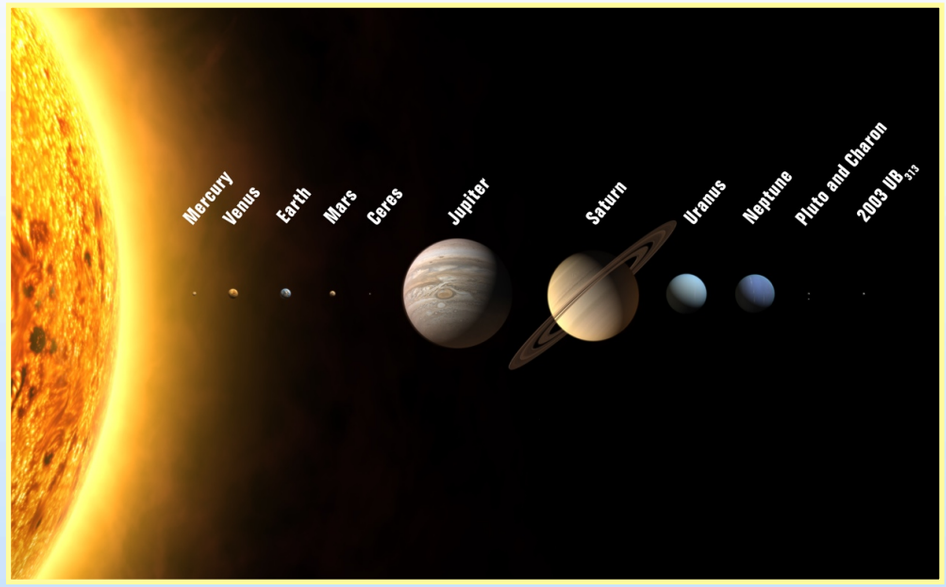
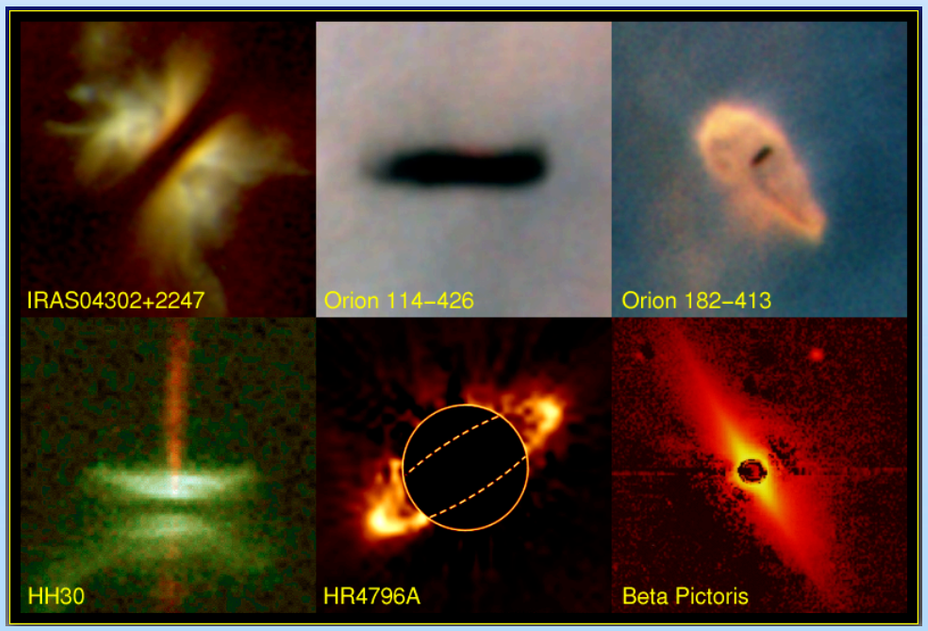
- From giant to terrestrial exo-planets: detection, characterisation and evolution





- Circumstellar disks: probing the inner AU

- Young clusters and the Initial Mass Function: down to Jupiter masses

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Stars & Galaxies

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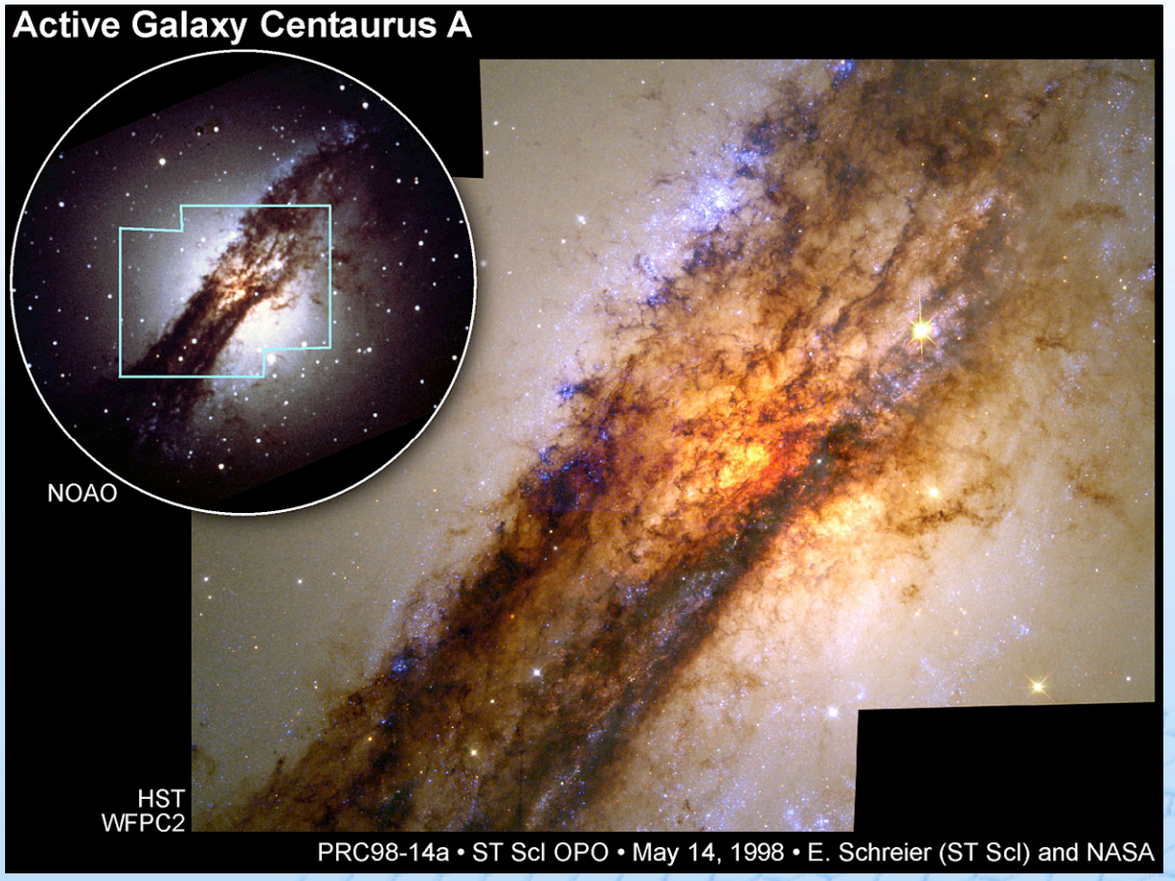
Imaging and spectroscopy of resolved stellar populations in nearby giant galaxies



- Black holes and AGN: from the Galactic Centre to z~0.5

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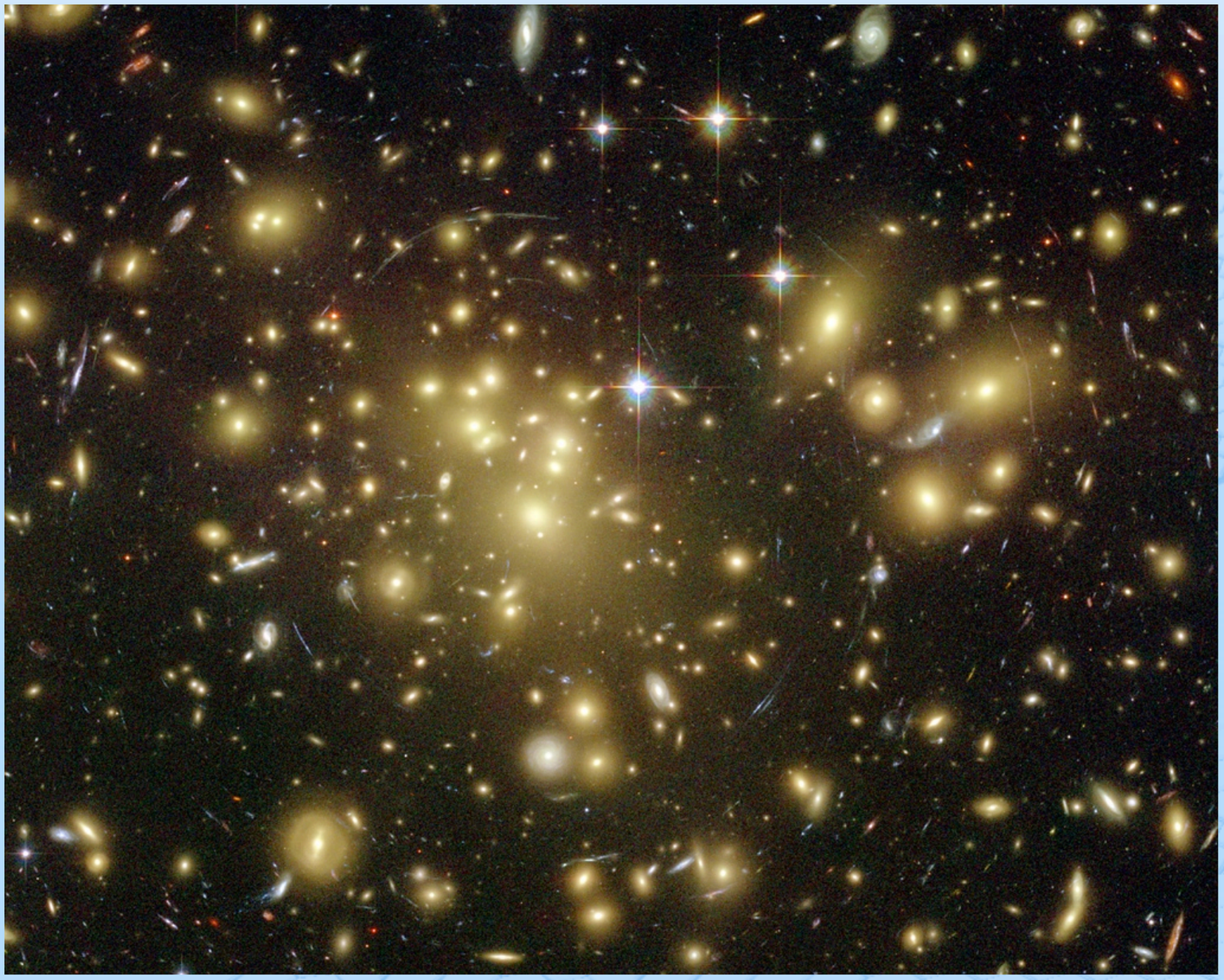
Galaxies & Cosmology



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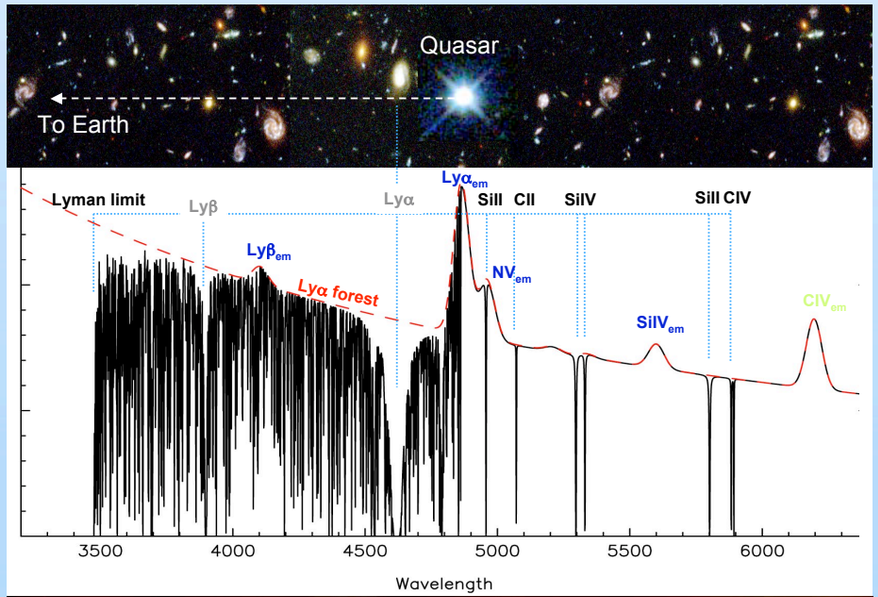
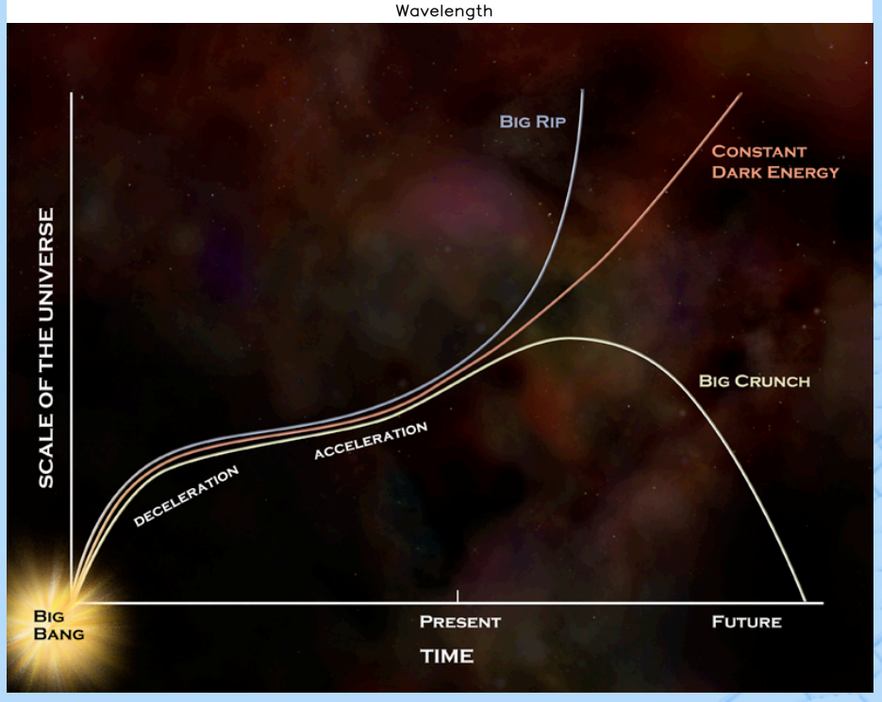
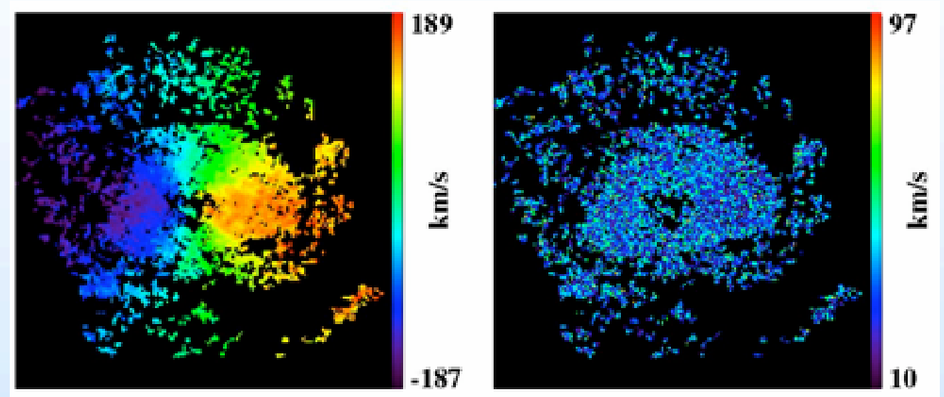
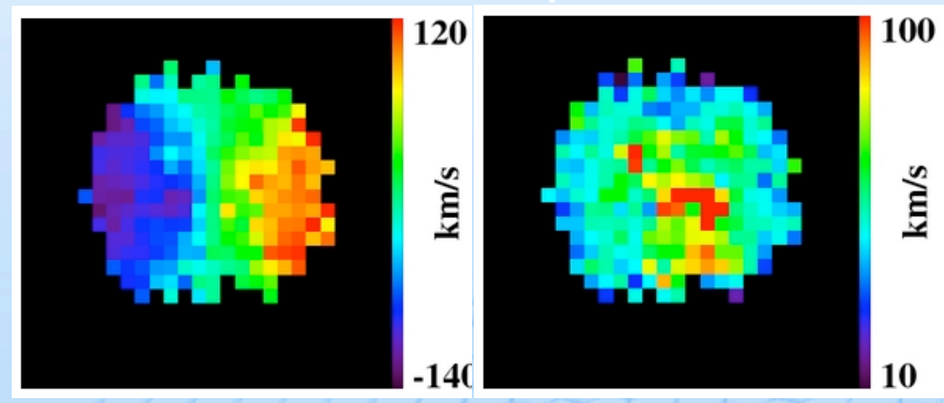
First light: the physics of highest-redshift galaxies







z ~ 4 50 mas pixels



z=0 rotating disk simulations (M. Puech)
42-m, 10-hr integration, MOAO (MCAO)

- IGM, metal enrichment
- A dynamical measurement of the expansion history of the universe

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Discoveries

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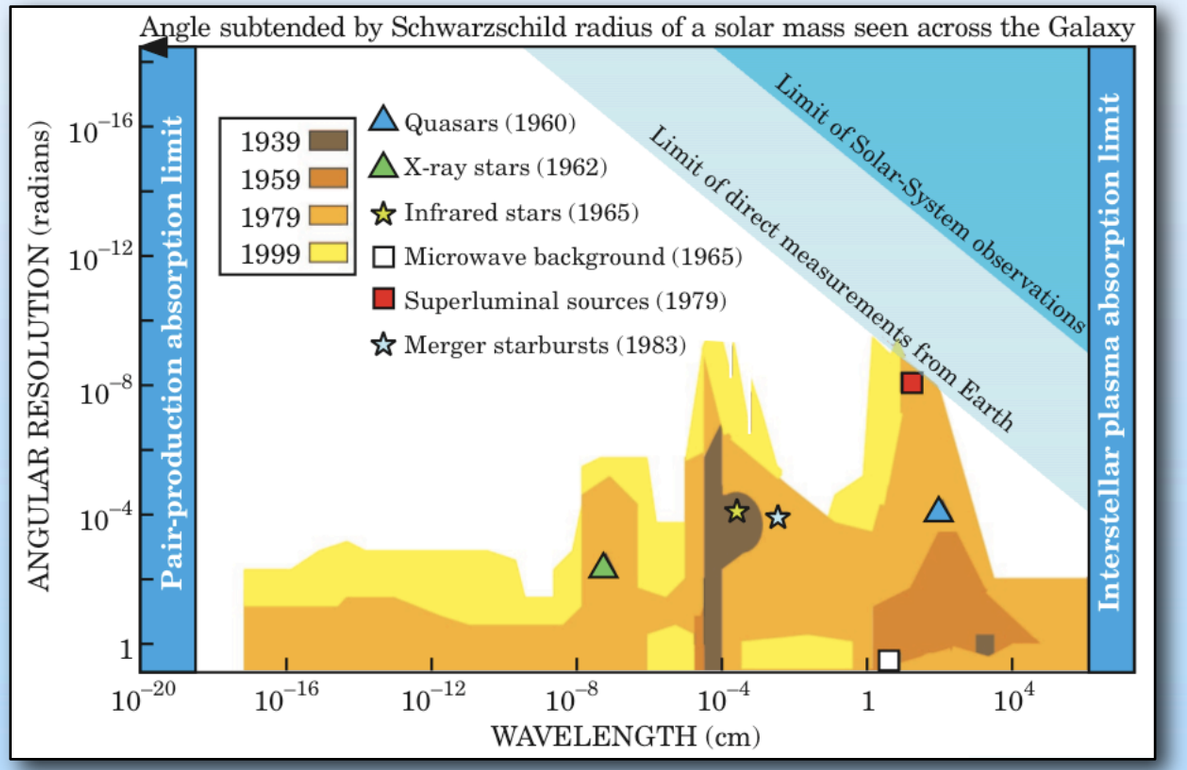
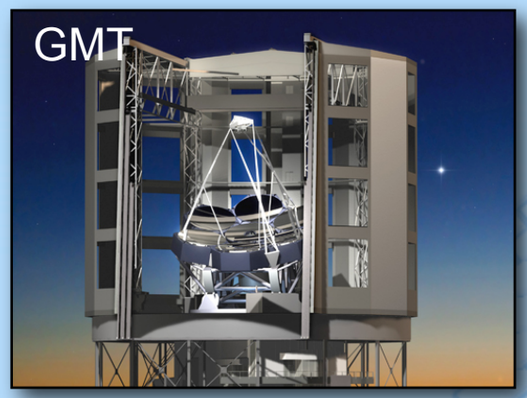
Discovery potential

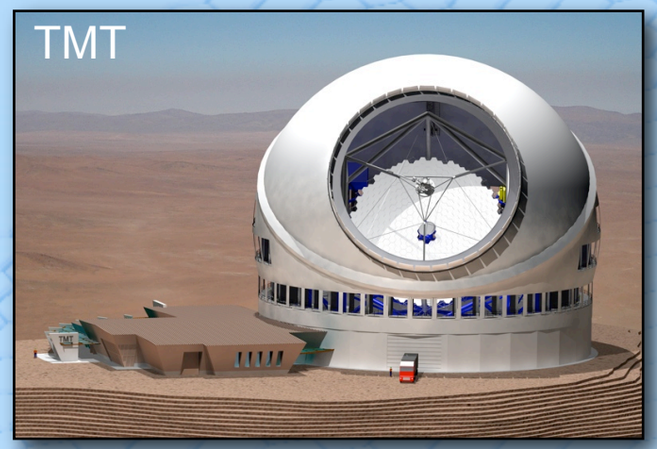


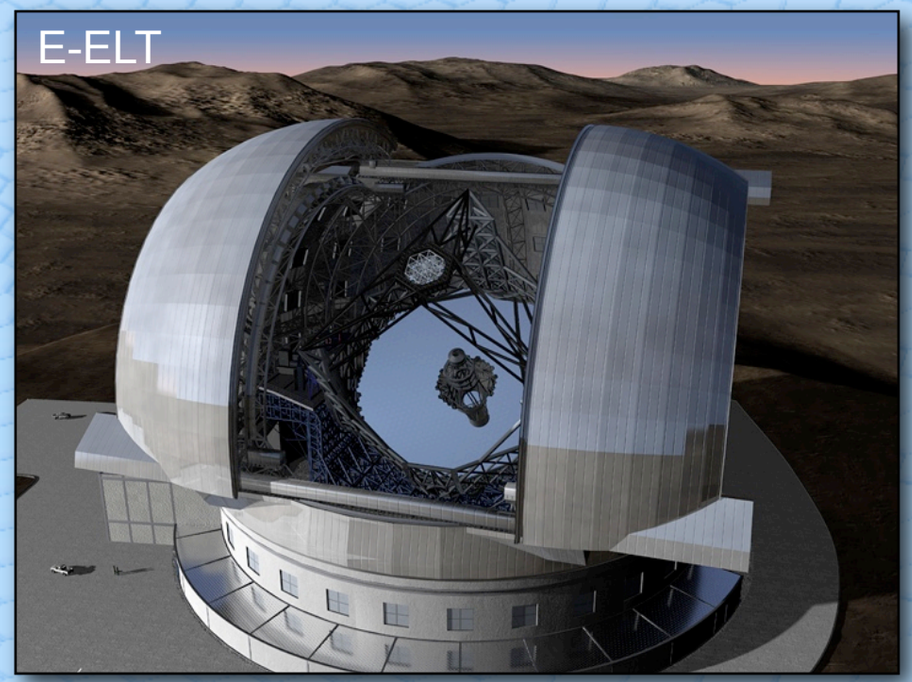
M.Harwit, Physics Today, Nov. 2003

Discoveries by opening new parameter space

- Spatial resolution
- Photon sensitivity







	~50 m^2	~400 m^2	~600 m^2	~1200m^2 (JWST: 25 m^2)
1µm:	25 mas	9 mas	7 mas	5 mas (JWST: 34 mas)

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Requirements on AO

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Fundamentals on Adaptive optics

- The Seeing scales as λ/r_0 with r_0~1m/15cm at 2.5/0.5 μm
- The Diffraction limit scales as λ/D

- For 8m-class telescopes:
  - in K: Seeing ~ 0.5” vs. ~0.05” DL (factor 10)
  - in V: Seeing ~1.0” vs. ~0.01” DL (factor 100)
- For the E-ELT:
  - in K: Seeing ~ 0.5” vs. ~0.01” DL (factor 50)
  - in V: Seeing ~1.0” vs. ~0.002” DL (factor 500)

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Key requirements for Adaptive optics

- Seeing improved imaging over the full field of view
- Narrow-field, diffraction-limited imaging and spectroscopy in the wavelength range 1 to 20 μm.
- Wide-field (1'-2') diffraction limited imaging in the wavelength range 0.6 - 2.5 μm.
- Extreme contrast (up to 10^{-10} at few λ/D) imaging/ spectroscopy
- Full patrol field, seeing improved multi-object spectroscopy

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Instrument Concepts

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Study Plan

Name	Instrument type	Wavelength range	FoV and sampling	Spectral resolution	AO support envisaged	Notes
MICADO	Diffraction limited NIR Imager (slit spectroscopy?)	0.8-2.4 µm	30” 3-5 mas/pix		SCAO/MCAO	
HARMONI	Single-field NIR spectrograph	0.8-2.4 µm	~1”-10” 4-40 mas/pix	~4000 (~20.000)	SCAO/LTAO	
EAGLE	Wide-field multi-object NIR spectrograph	0.8-2.4 µm	patrol field ≥5' 10-50 mas/pix	~5000 (>10.000?)	MOAO	multiplex >20
CODEX	High-resolution visual spectrograph	0.35-0.72 µm	point source	>120.000	Tip-Tilt?	stability < 2 cm/s over 30 years
METIS	Mid-IR imager and spectrograph	3.5-20 µm	30” 15-30 mas/pix	5-200 ~100.000	SCAO/LTAO	Polarimetry
EPICS	Planet finder	0.6-1.8 µm	~2”-4”	>50	XAO	Polarimetry
OPTIMOS	Optical MOS (+ imaging?)	0.3-1.8 µm	5’-10’ FoV	1000 or 10.000	GLAO	multiplex >100
SIMPLE	NIR high-resolution spectrograph	0.8-2.4 µm	slit	>100.000	SCAO/LTAO	
MAORY	Multi-conjugated AO module	0.6-2.4 µm	2’ FoV			2 DMs + M4, 6 LGS
ATLAS	Laser tomography AO module	0.6-2.4 µm	1’ FoV			M4, 6 LGS

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Adaptive Optics

- The Telescope delivers:
  - seeing limited mode
  - Ground Layer AO (w/ and w/o LGS) [GLAO]

- Post-Focal AO facilities:
  - Single Conjugated AO (no LGS) [SCAO]
  - Laser Tomography AO (1 DM, 6 LGS) [LTAO]
  - Multi-conjugated AO (3 DMs, 6 LGS) [MCAO]

- AO included in instruments:
  - Extreme AO [XAO]
  - Single Conjugated AO in the mid-IR [SCAO]
  - Multi-Object AO [MOAO]

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Conclusions

The main power of the E-ELT will reside in achieving, with the help of AO, a spatial resolution never achieved at optical/infrared wavelength to this depth before.

Adaptive Optics in all its forms will play a crucial role in enabling the science case of the E-ELT (much more than it did for 8m-class telescopes).

Scientific breakthroughs in many areas, as well as unexpected discoveries are unavoidable.

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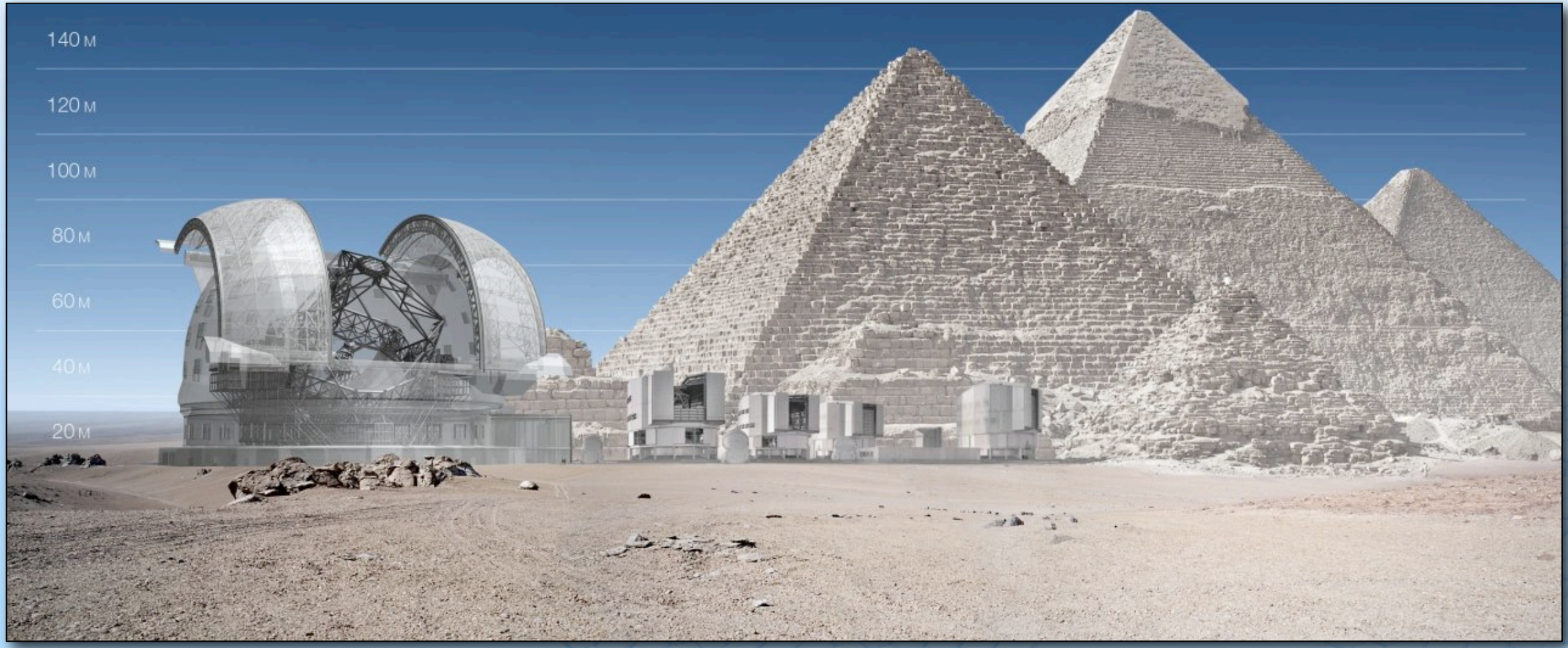

Looking forward to the next 20 years of AO at ESO!