METIS am E-ELT

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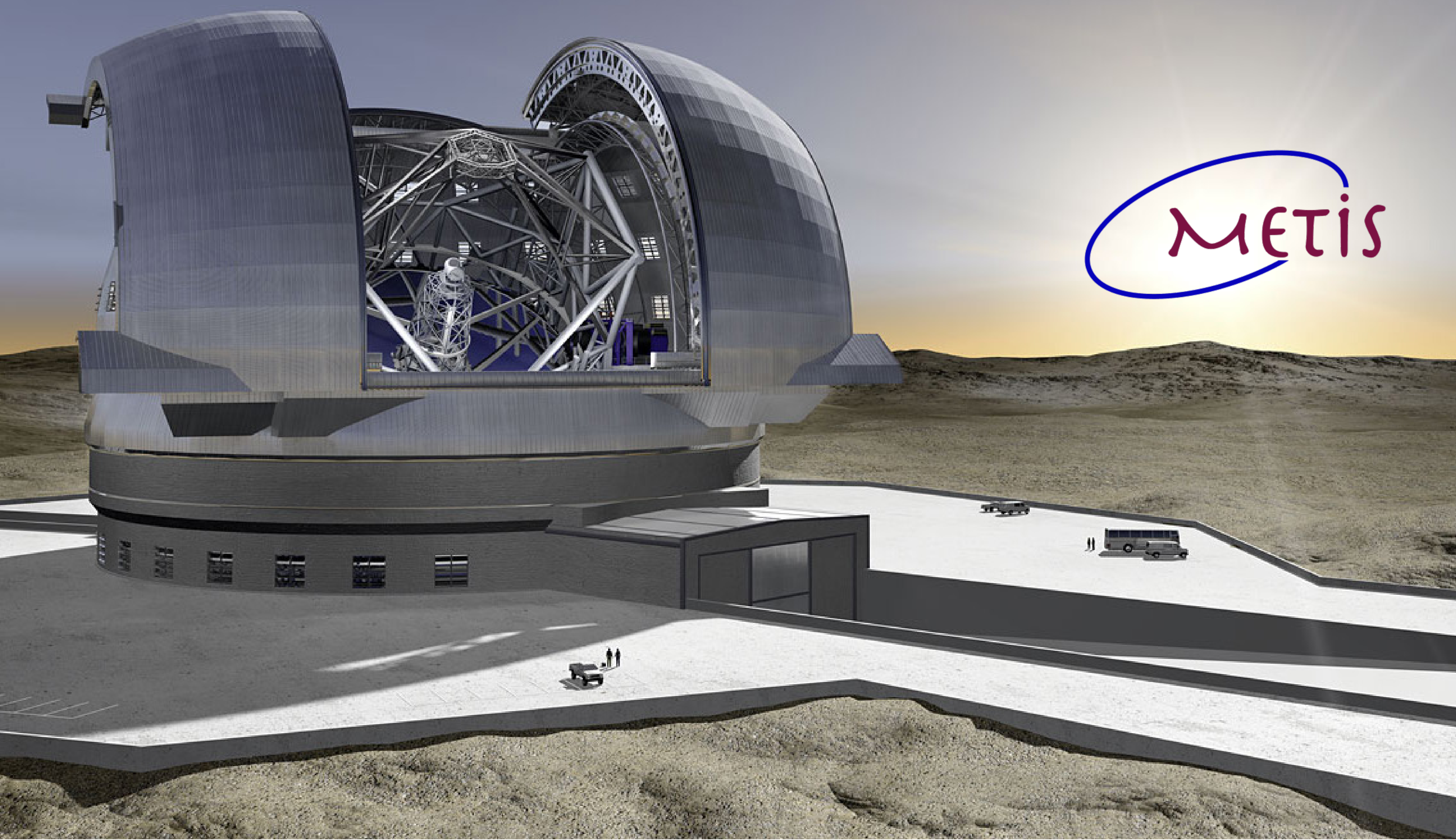
Leiden University

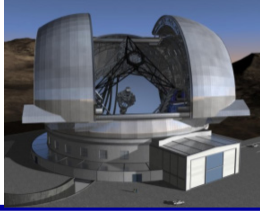
12. Juni 2015

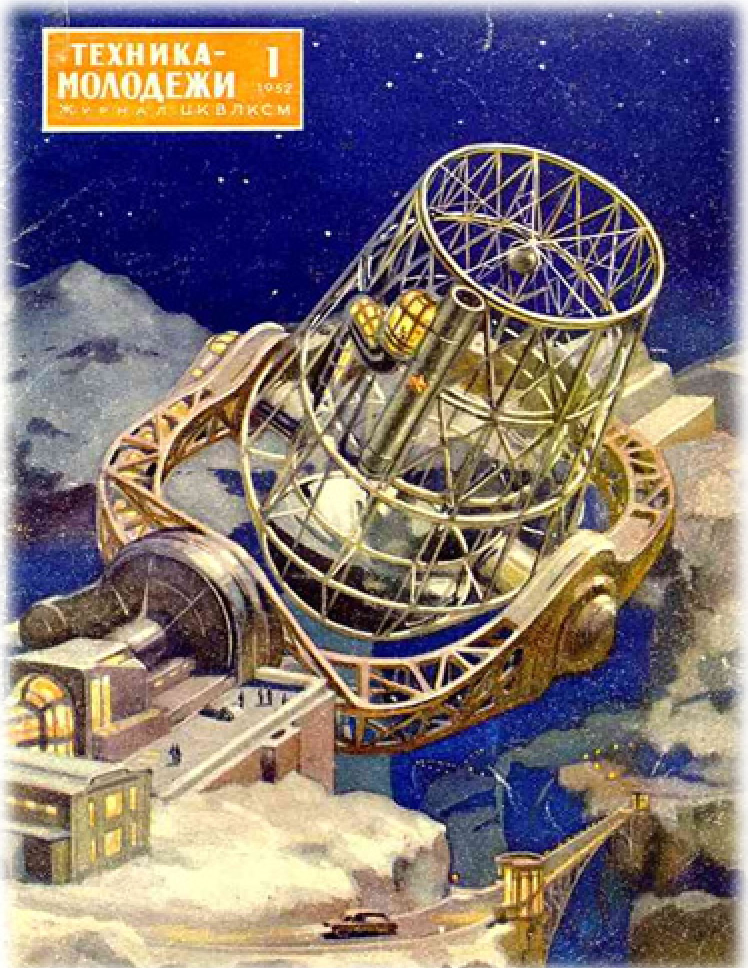
1. Das E-ELT
2. Überblick: METIS
3. Astronomische Ziele
4. Technologie

1. THE E-ELT



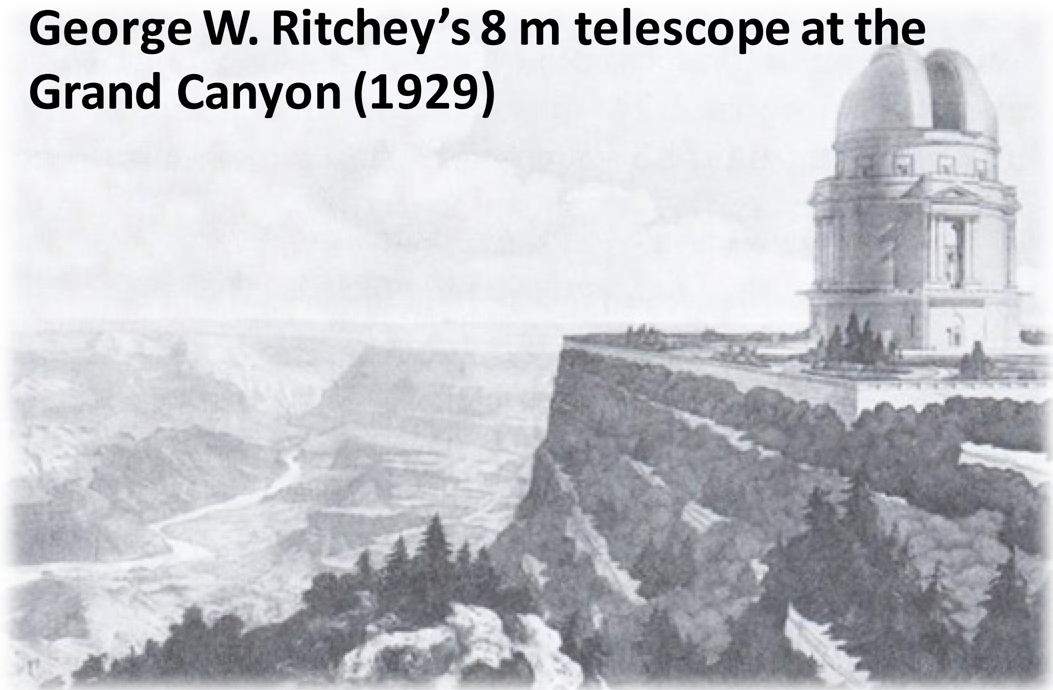
Big Telescope Dreams

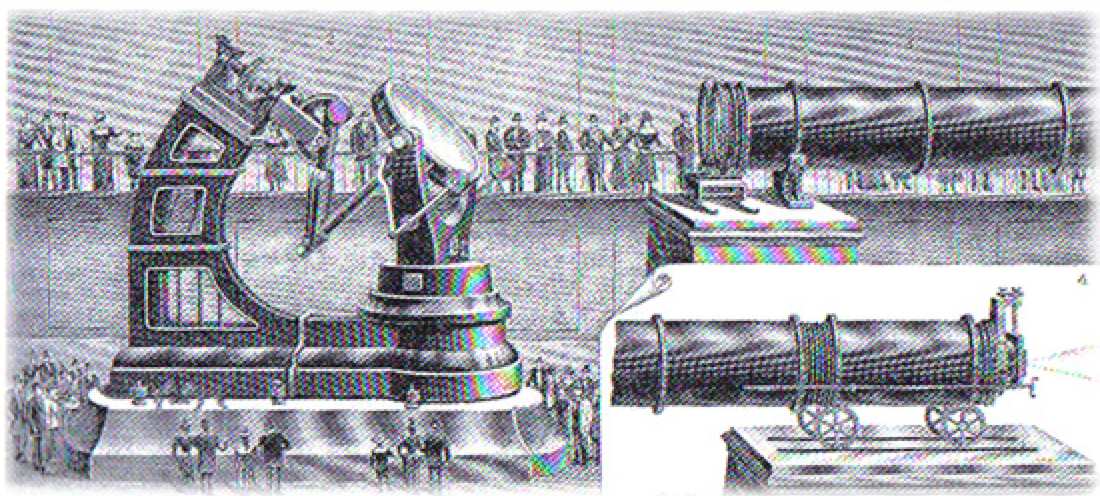




Russian Telescope (1952)

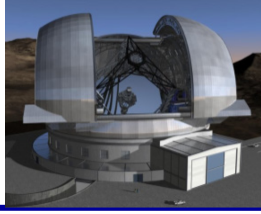
George W. Ritchey's 8 m telescope at the Grand Canyon (1929)





2m horizontal refractor of the Paris Universal Exhibition (1900)

Why bigger Telescopes?

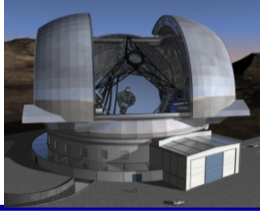


1. larger collecting area → higher sensitivity

$$S/N \sim D^2 \quad \text{and} \quad S/N \sim \sqrt{t_{\text{int}}} \quad \Rightarrow t_{\text{int}} \sim D^{-4}$$

One hour with a 39m telescope ⇔ 500 years with a 1m telescope

Why bigger Telescopes?



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One hour with a 39m telescope ⇔ 500 years with a 1m telescope

2. better angular resolution → sharper images

$$\theta_{\min} = 1.22 \frac{\lambda}{D}$$

← wavelength

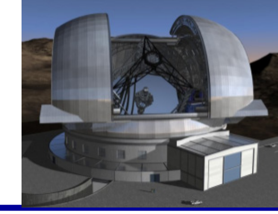
← diameter

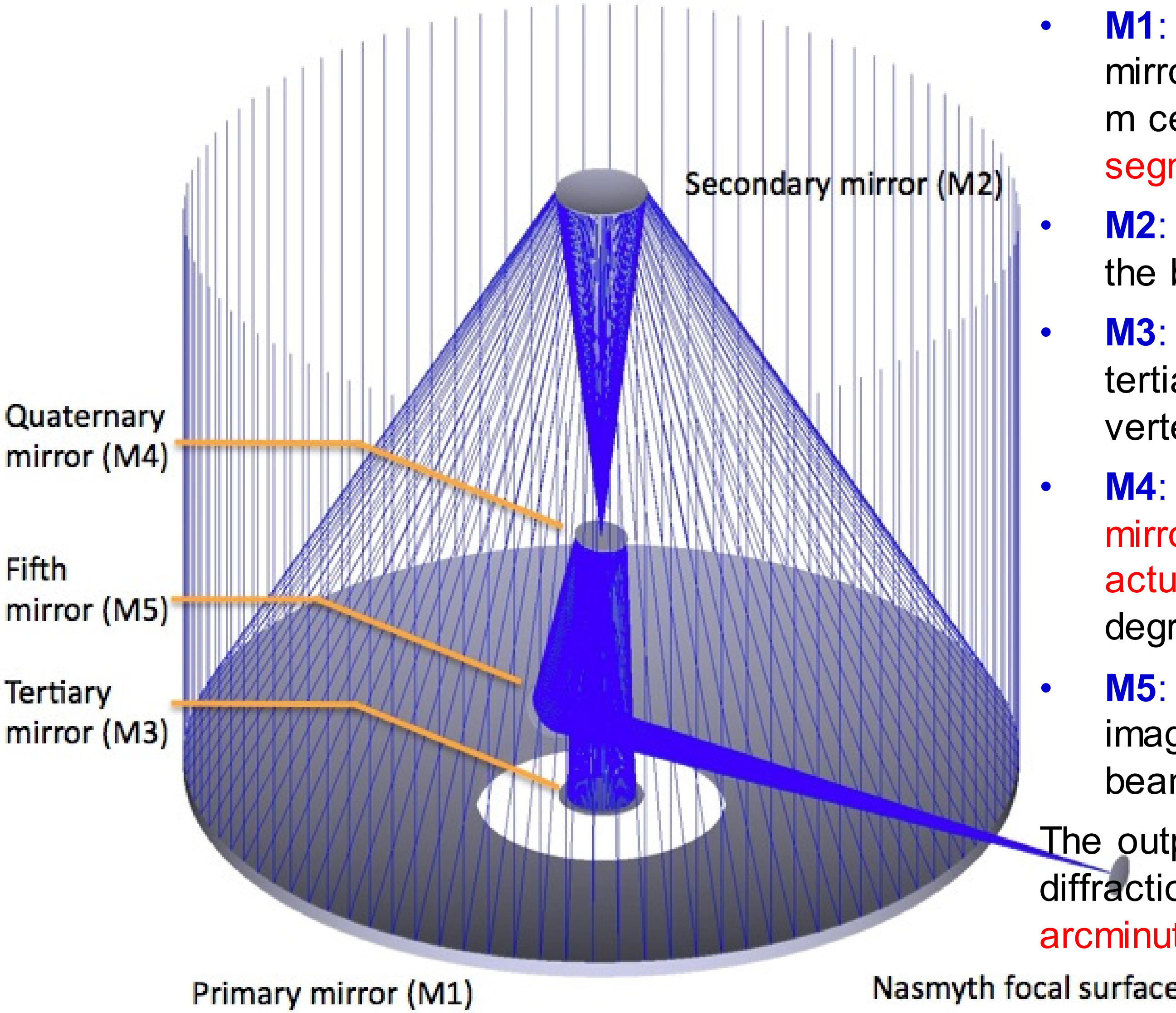
39m optical telescope → angular resolution of 0.003 arcsec.

- human hair seen from 460m distance

39 Meter is Big!

Novel 5-Mirror Concept

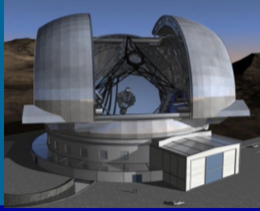


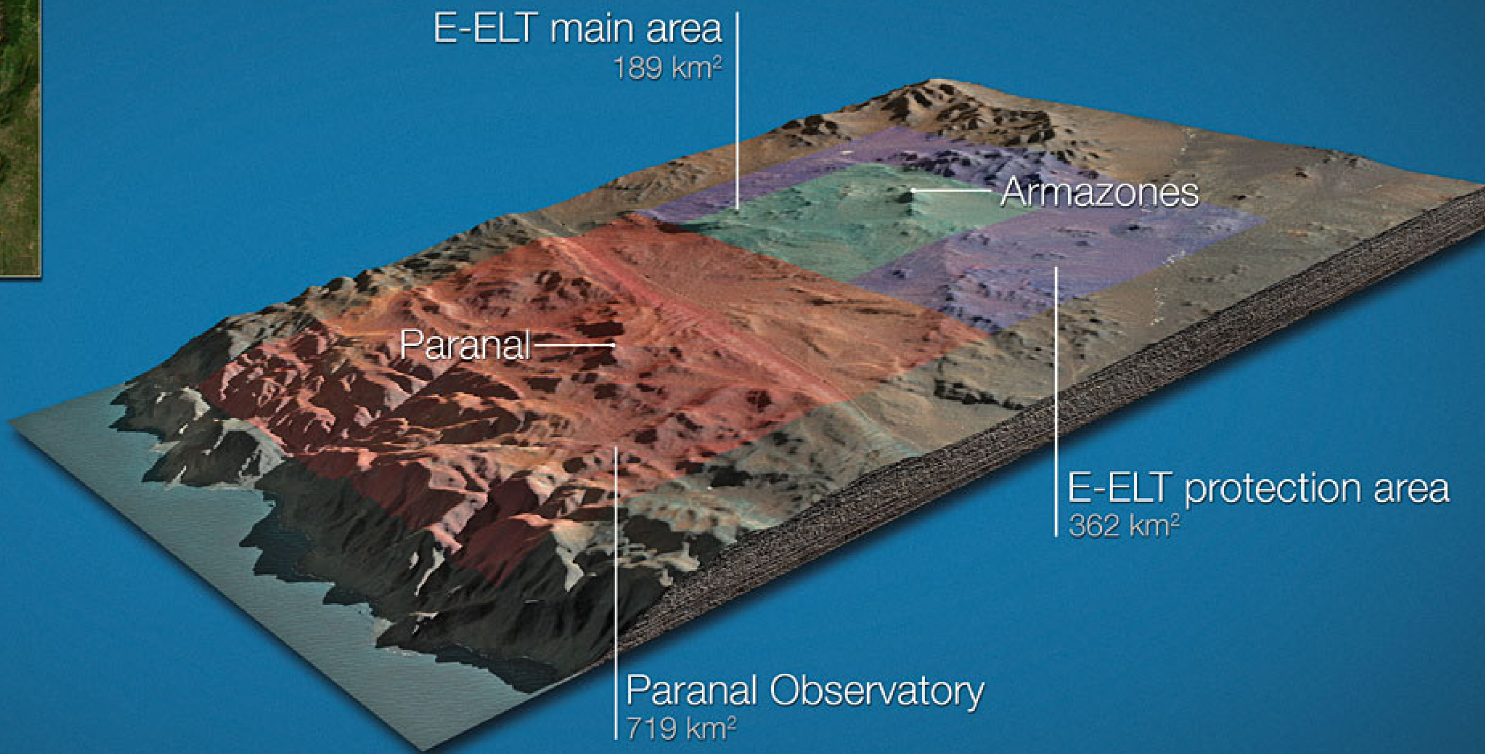


- **M1**: elliptical f/0.93 segmented mirror of 39-m diameter and 11.1-m central obstruction; 798 segments, 1.45m each
- **M2**: 4.2-m mirror, convex, returns the beam through a hole in M4
- **M3**: 3.8m mildly aspheric concave tertiary mirror, located at the vertex of the primary.
- **M4**: 2380×2340mm flat adaptive mirror, supported by up to 8000 actuators; inclined at 7.75 degrees
- **M5**: flat tip-tilt mirror for the final image correction. M4 is to the beam direction.

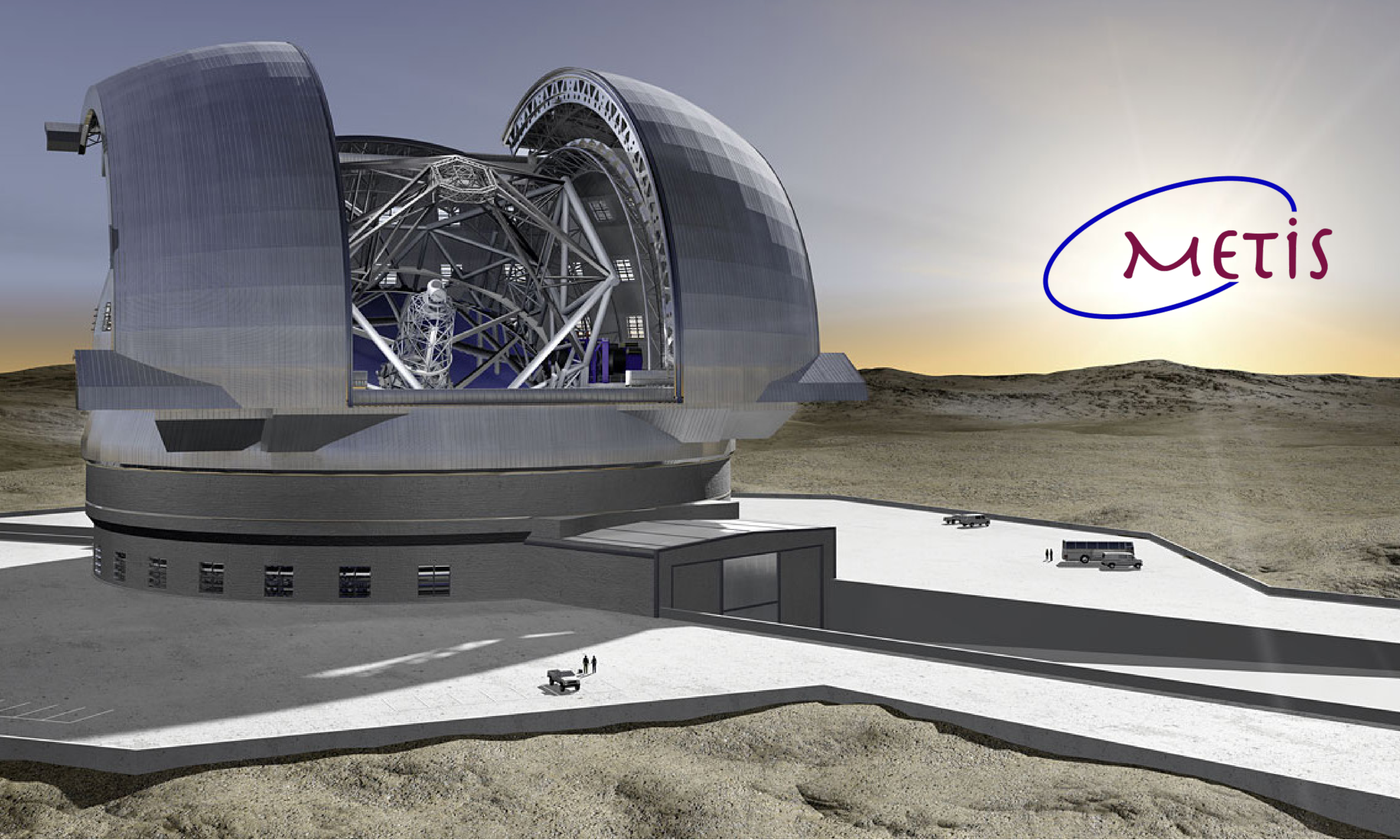
The output beam at f/17.48 is nearly diffraction limited over the entire 10-arcminute field of view.

Site: Cerro Armazones

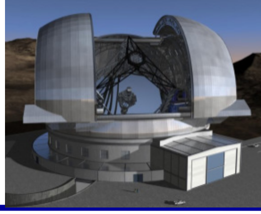




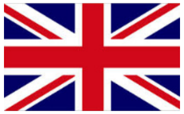
2. METIS OVERVIEW

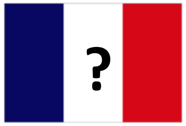


E-ELT Instrument Suite



PI country:

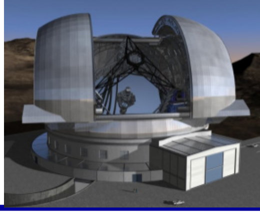


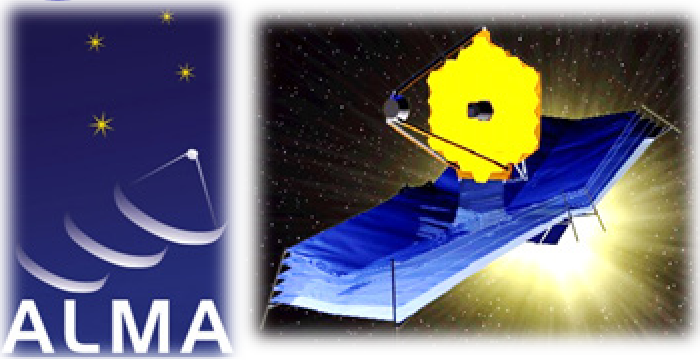
???

	MICADO	HARMONI	METIS	HIRES	MOS	#6
Call phase A	–	–	–	Q3 /2015	Q3 /2015	2016 ?
End phase A	2009	2009	2009	Q4 / 2016?	Q4 / 2016?	
Construction proposal → STC	4/2015	4/2015	4/2015			
Phase B kick-off	Q3 / 2015	Q3 / 2015	Q3/ 2015			
First light	~2024	~2024	~2025	202?	202?	20??

… plus **EPICS/PCS**, a high contrast exoplanet imager

METIS Fundamental Considerations



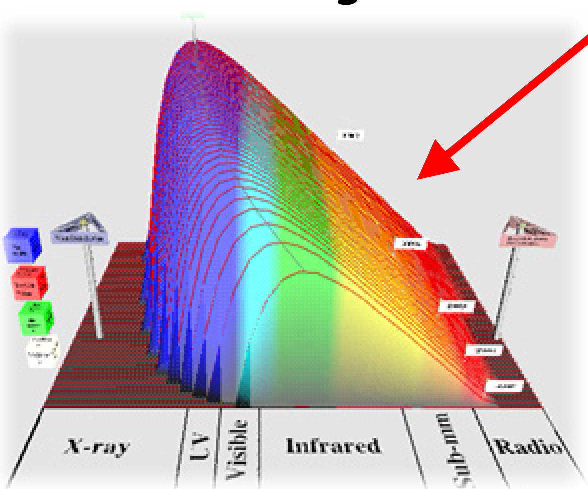


Complementarity

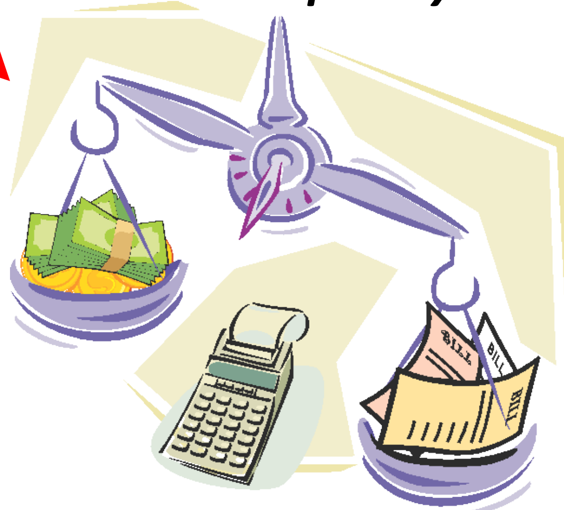
Resolution & Sensitivity

METIS

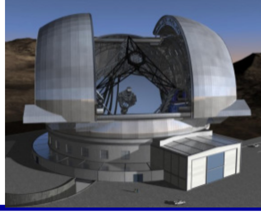
Thermal Background



Cost & Complexity



METIS New Instrument Baseline



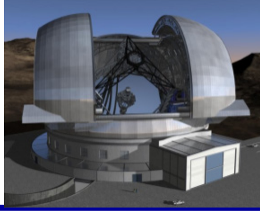
…as refined by ESO/PST on 10 Feb 2015, confirmed by STC on 23 April 2015

METIS shall include the following observing capabilities:

- **Imaging at 3 – 19 µm.** The imager shall include low/medium resolution slit spectroscopy as well as coronagraphy for high contrast imaging.
- **High resolution (R ~ 100,000) IFU spectroscopy at 3 – 5 µm**, including a mode with extended instantaneous wavelength coverage.

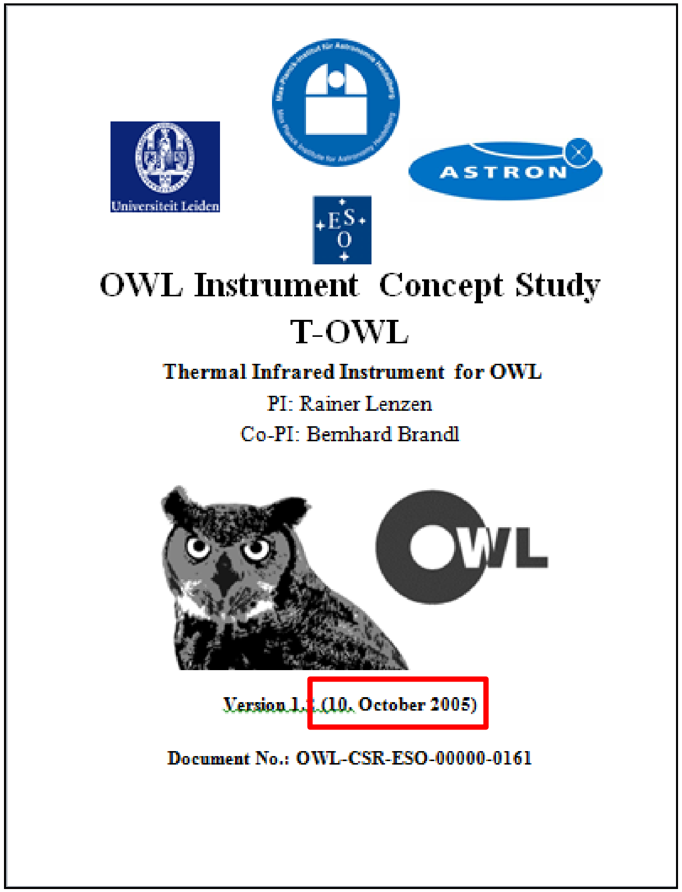
➢ All observing modes work at the **diffraction limit** with single conjugate (SC) and eventually assisted by a laser tomography adaptive optics (LTAO) system.

METIS It all started with T-OWL



T-OWL = **T**hermal-infrared instrument for the **OWL** telescope.

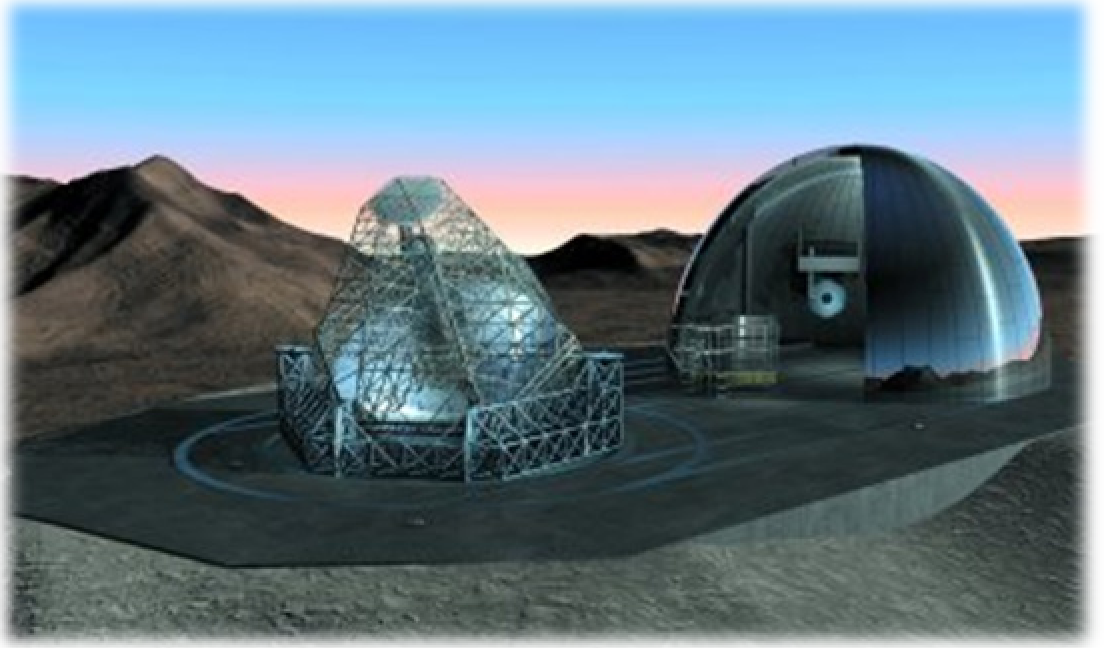
This was 10 years ago!



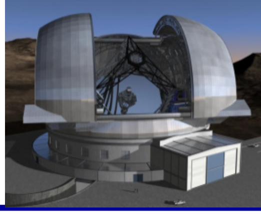
OWL Instrument Concept Study
T-OWL
Thermal Infrared Instrument for OWL
PI: Rainer Lenzen
Co-PI: Bernhard Brandl

Version 1.1 (10. October 2005)

Document No.: OWL-CSR-ESO-00000-0161



METIS Consortium Partners



T-OWL | **Phase A** | **METIS**

NOVA — **B. Brandl (PI)**

Max-Planck-Institut für Astronomie Heidelberg — **M. Feldt (R. Lenzen)**

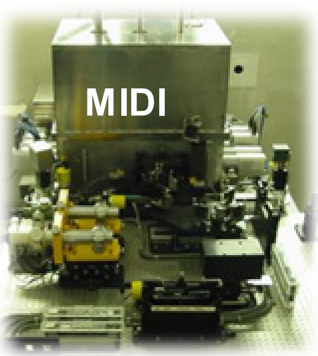
cea — **E. Pantin**

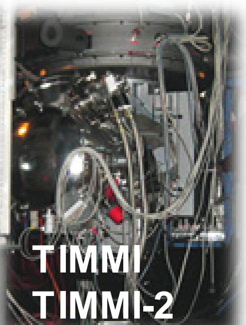
Science & Technology Facilities Council UK Astronomy Technology Centre — **A. Glasse**

KATHOLIEKE UNIVERSITEIT LEUVEN — **C. Waelkens**

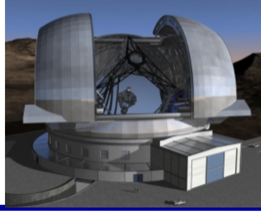
ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich — **M. Meyer**

universität wien — **M. Guedel**

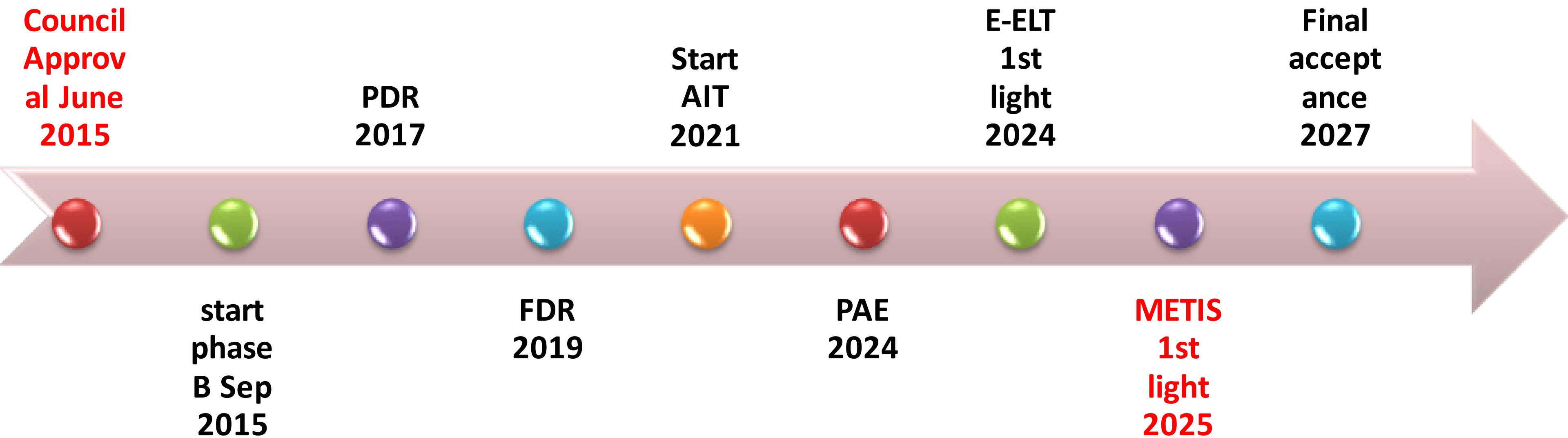




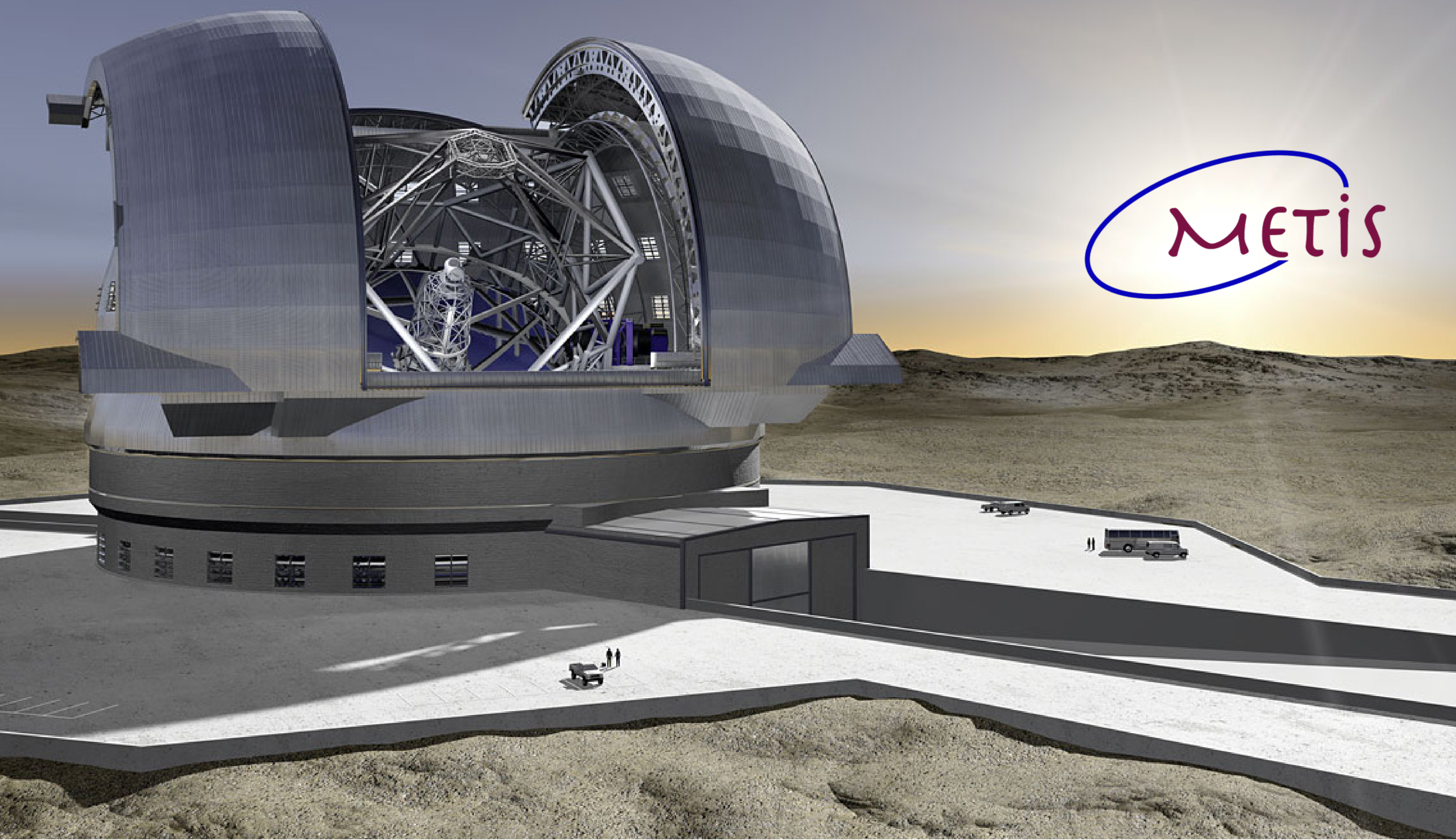
PROJECT TIMELINE



February 2015: Project Science Team → TLRs
April 2015: STC approved Tech. Specs.
May 2015: FC approved budget
June 2015: Council approved GTO allocation

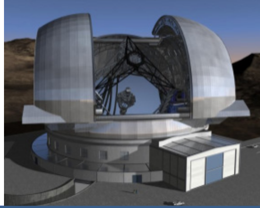


3. METIS SCIENCE

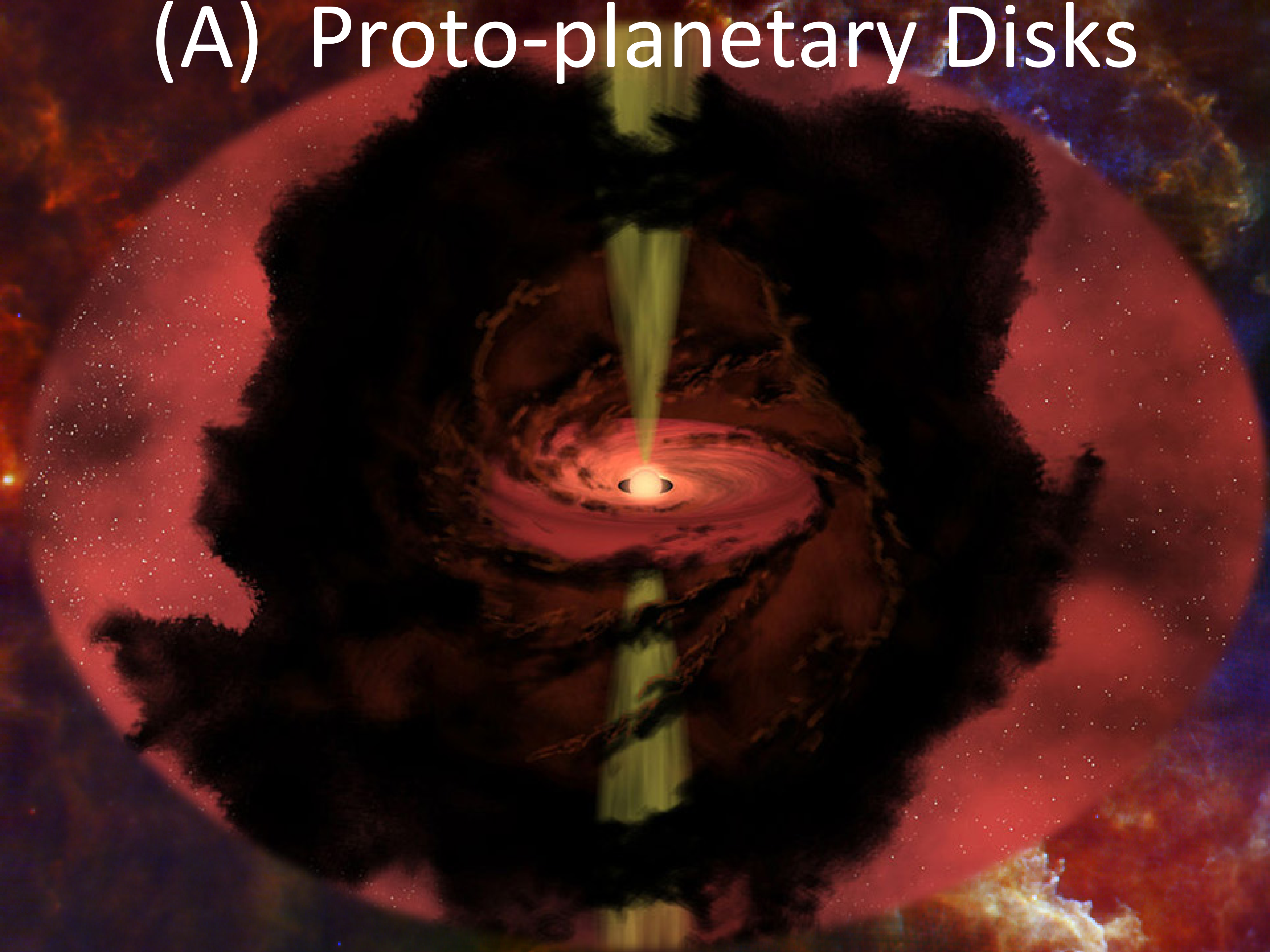


METIS

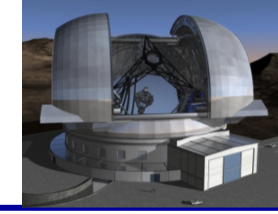
Science: Broad Range



(A) Proto-planetary Disks

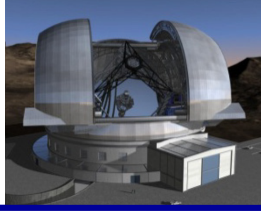


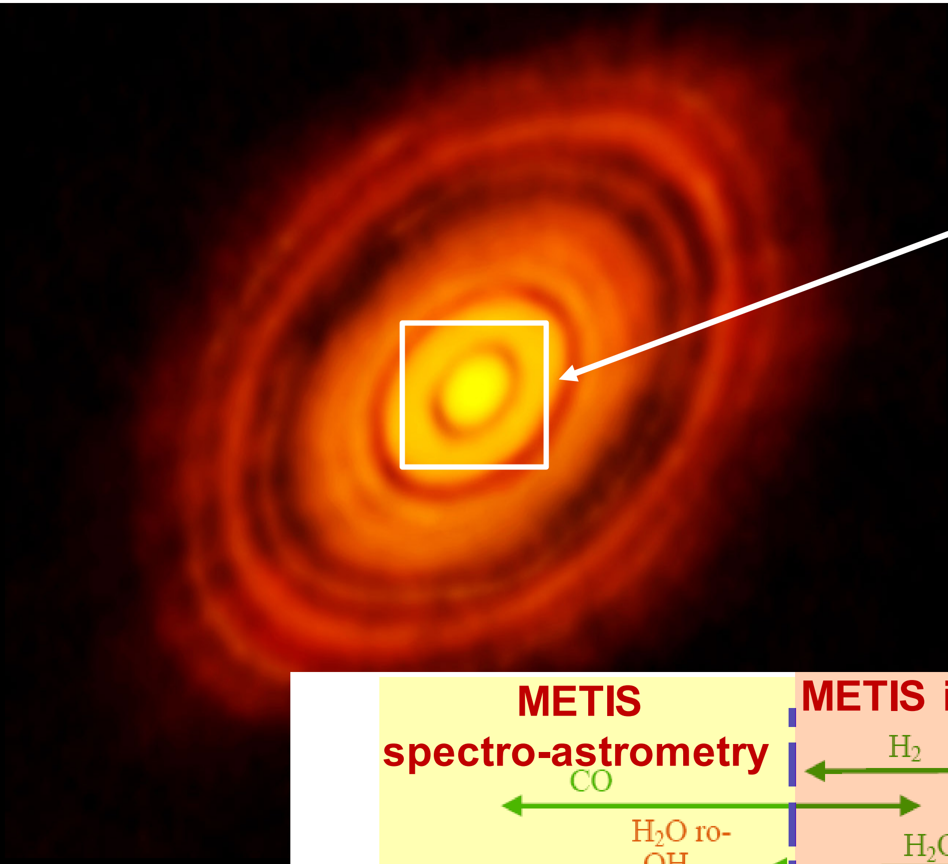
Key Questions



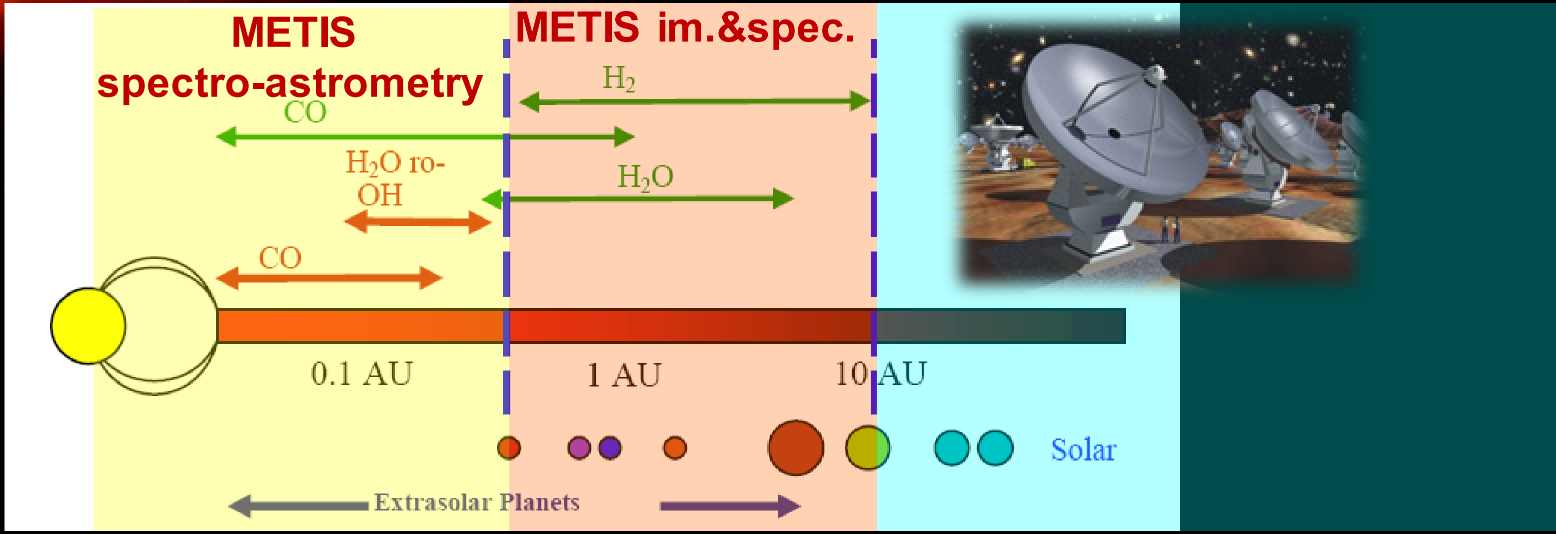
- **Protoplanet – disk interaction:** Is there evidence for the presence of proto-planets?
- **Proto-planetary disk evolution:** What is the dominant mechanism that disperses the primordial gaseous disk? On what timescales (← planet formation)?
- **Chemical processes in disks:** ISM → disks → planets

METIS ...probes the *inner* Disk





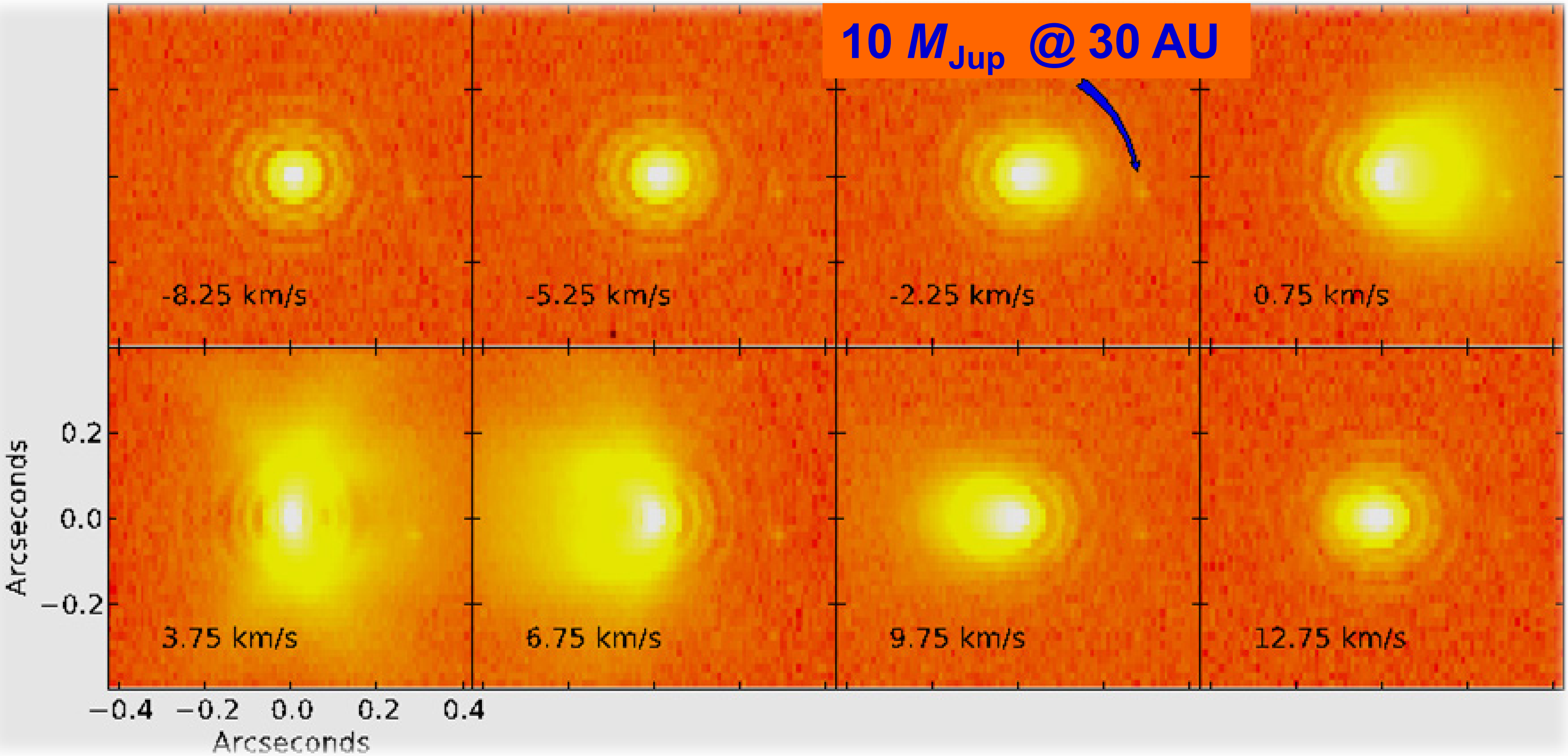
HL Tau
ALMA press release
eso1436



Circum-*Planetary* Disks

Observation of a proto-planetary disk with an embedded protoplanet

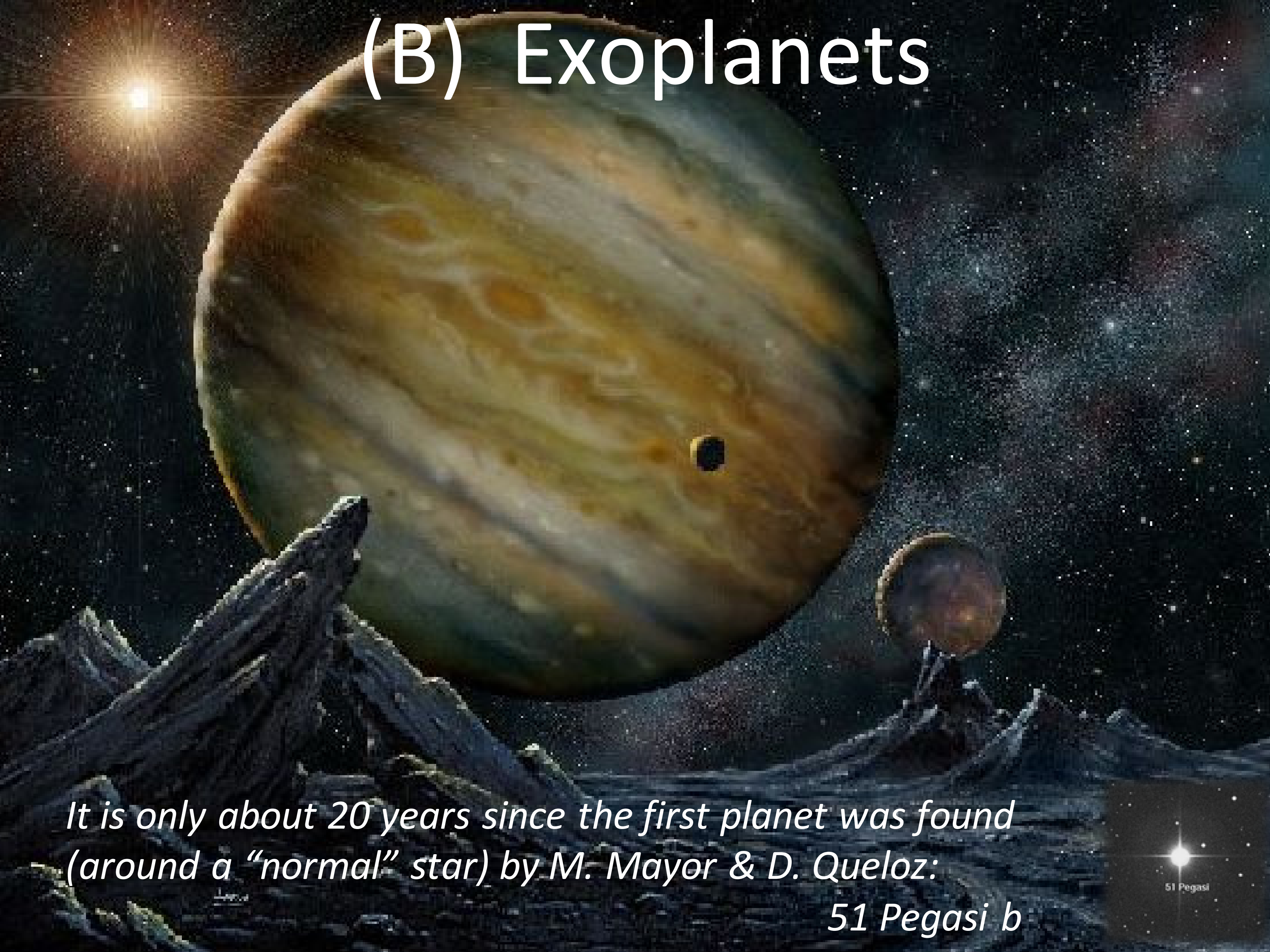
1 hour METIS-IFU @ 4.7 µm CO ro-vibrational band (Pontoppidan et al. 2013)



- Protoplanet (warm circum-planetary gas): *broad* line emission;
- Proto-planetary disk: Doppler shifted, *narrow* line emission

→ Planet is separated from cooler disk in planes of the IFU cube

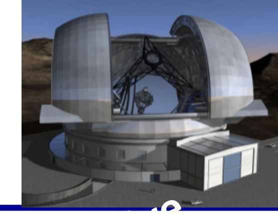
(B) Exoplanets



It is only about 20 years since the first planet was found (around a "normal" star) by M. Mayor & D. Queloz:

51 Pegasi b

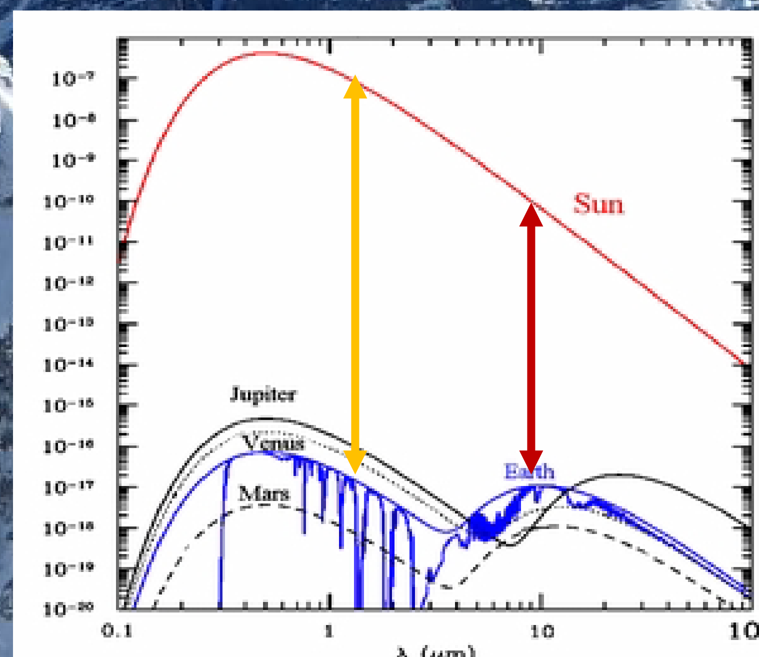
The Contrast Problem



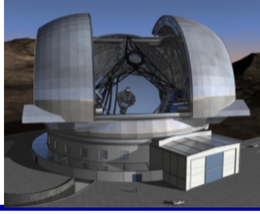
The flux ratio ("contrast") between Jupiter and the Sun is ~10^9!

Finding a Jupiter next to the Sun is like finding a red blood cell with GPS on the slope of Mount Everest

An Earth would correspond to small part of red blood cell



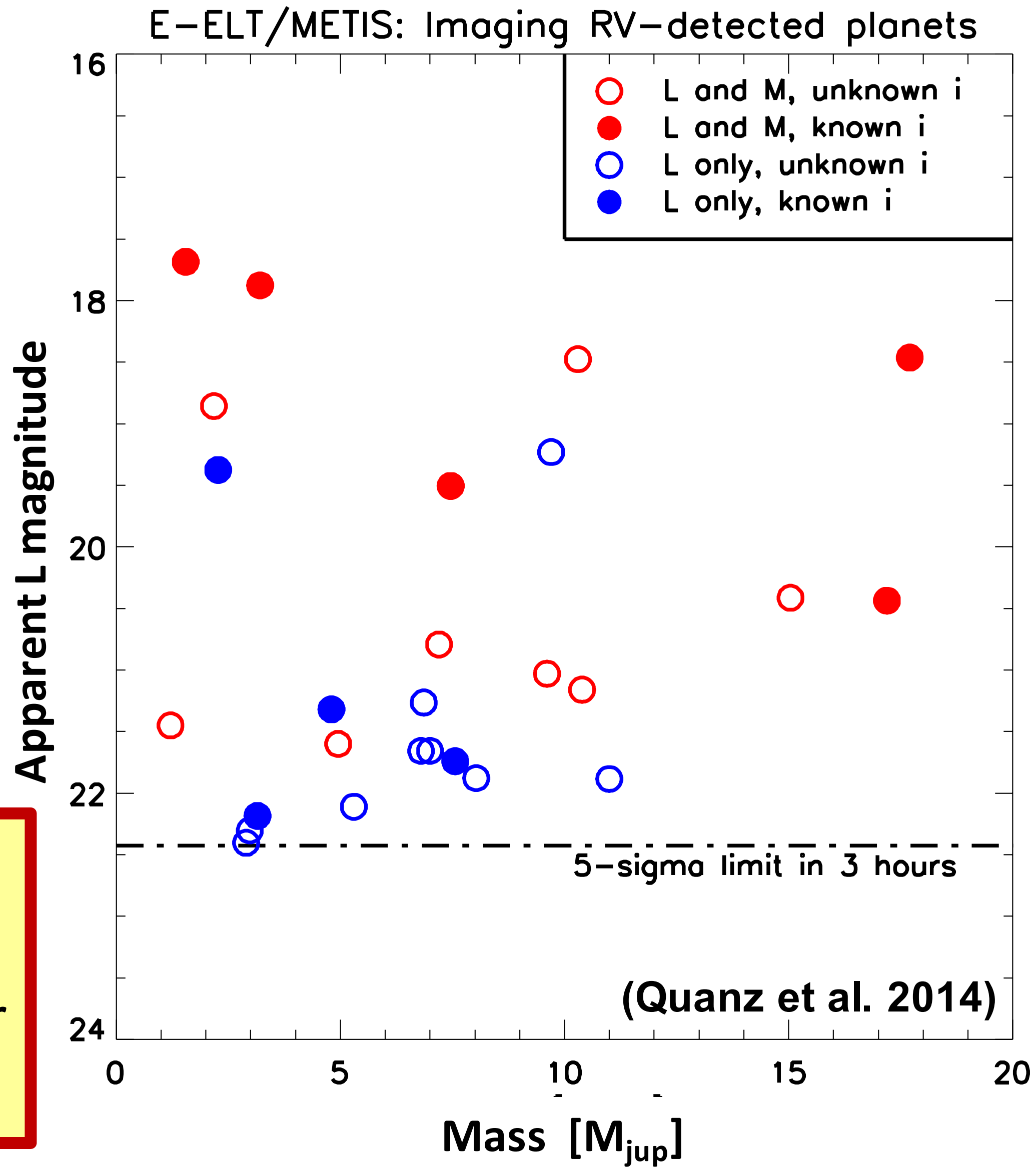
METIS Direct Detection@3-5µm



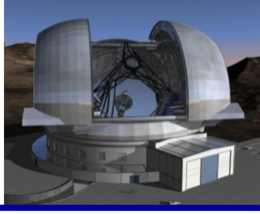
- Simulated detections of currently *known* gas giants detected by RV surveys
- 14 of these can be detected with METIS in ≤ 3 hours (per target)

This assumes that a contrast of 10^{-6} (background limit) can be reached @ 3 λ/D.

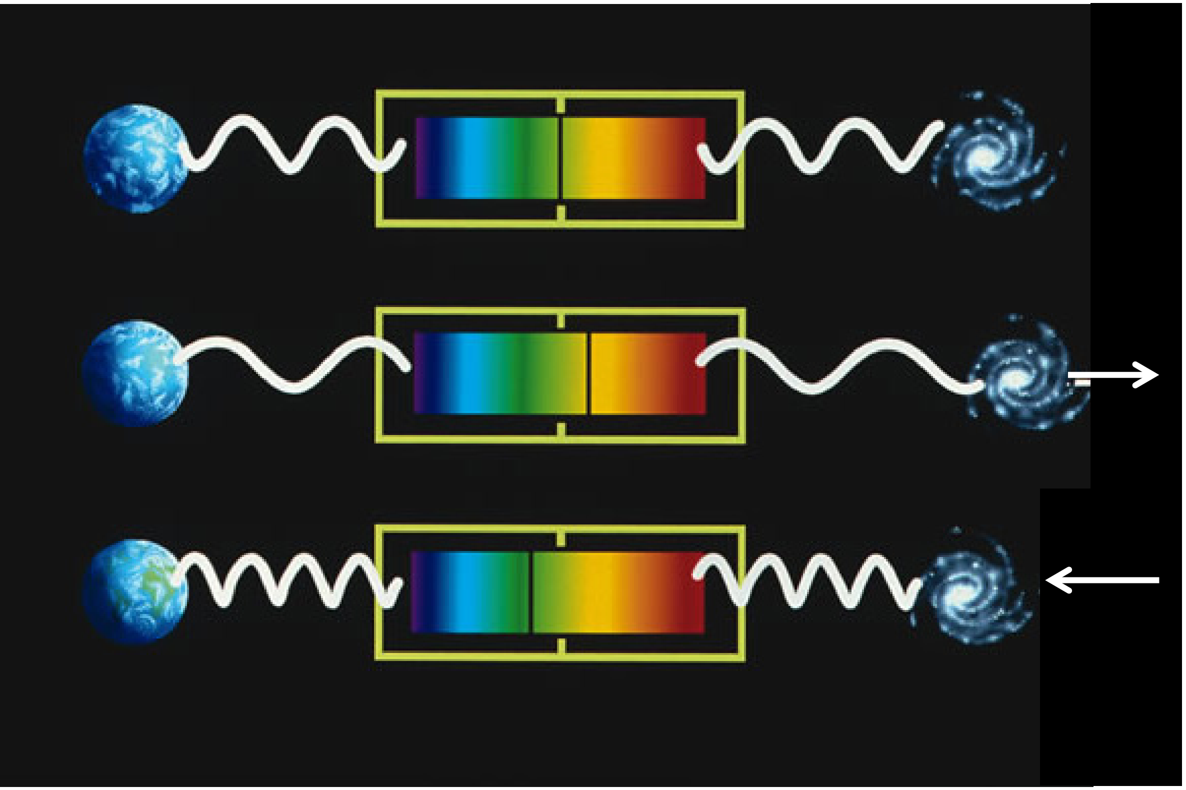
(RV + Kepler + GAIA + JWST + Plato) – planets ➔ sample of hundred detectable systems for study with METIS

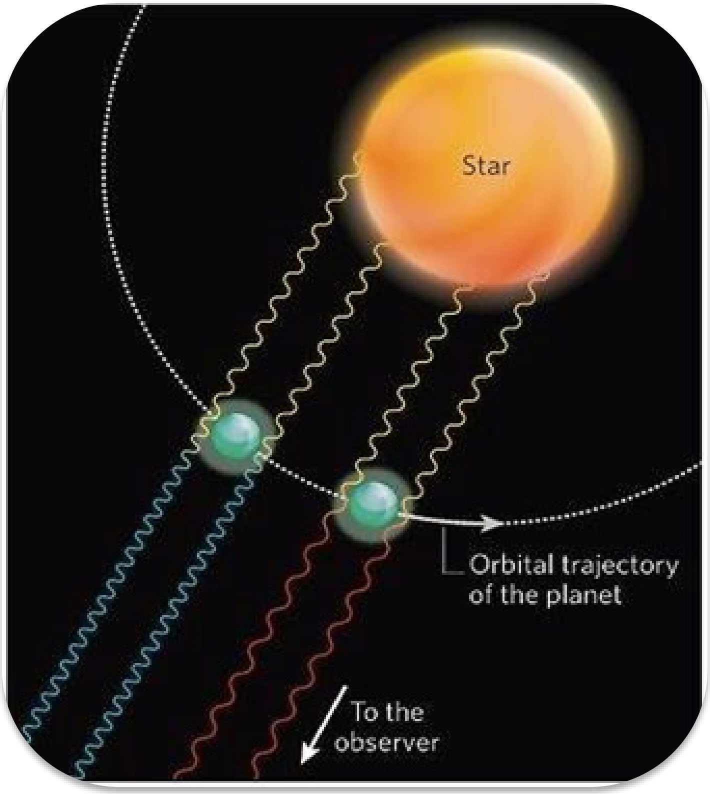


High Resolution Spectroscopy



The unique high dispersion mode of METIS uses the Doppler shift to study planets.

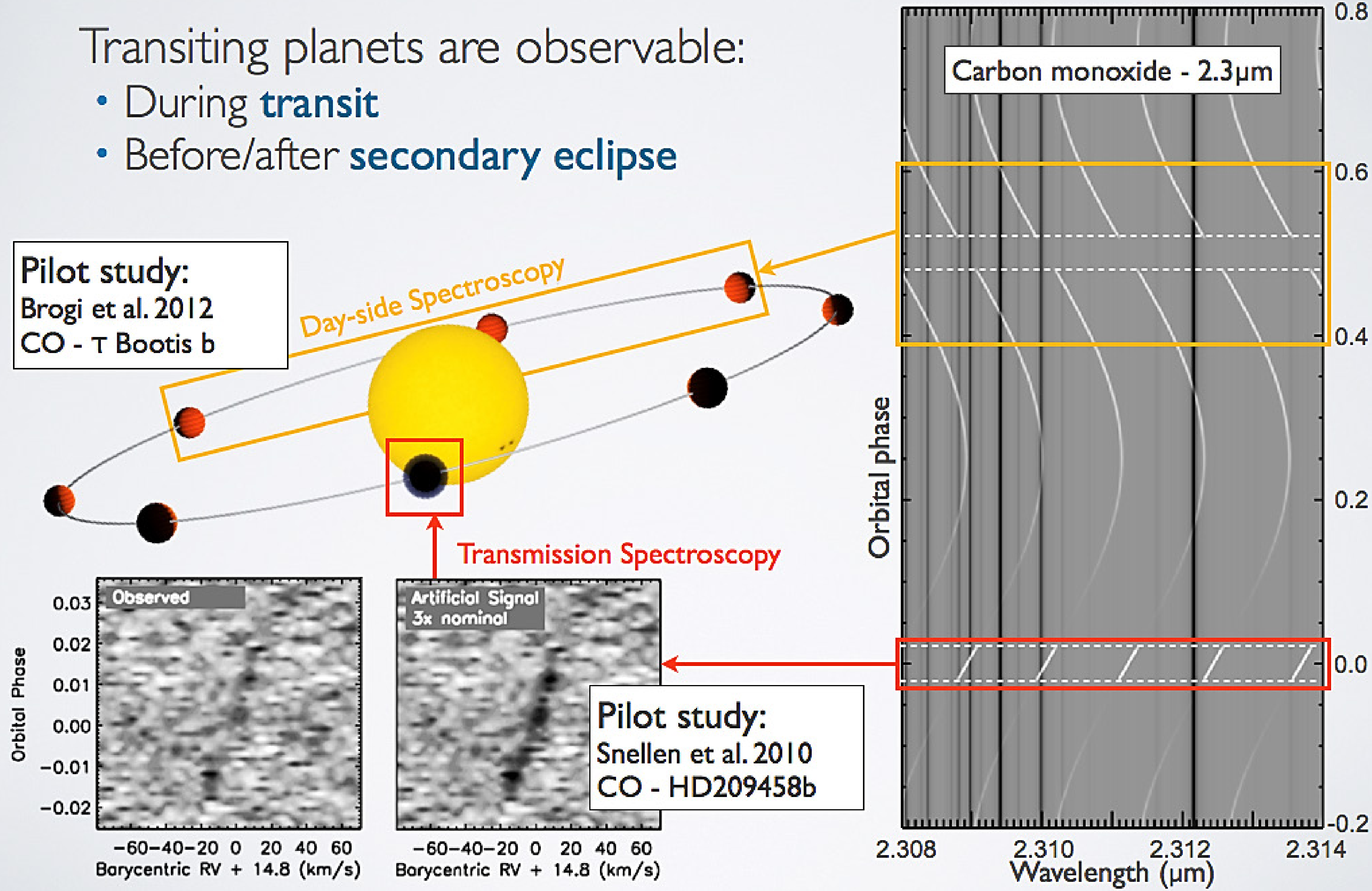




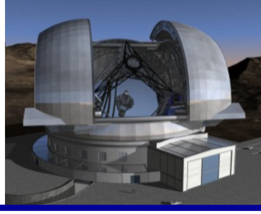
METIS Spectral Characterization

Transiting planets are observable:

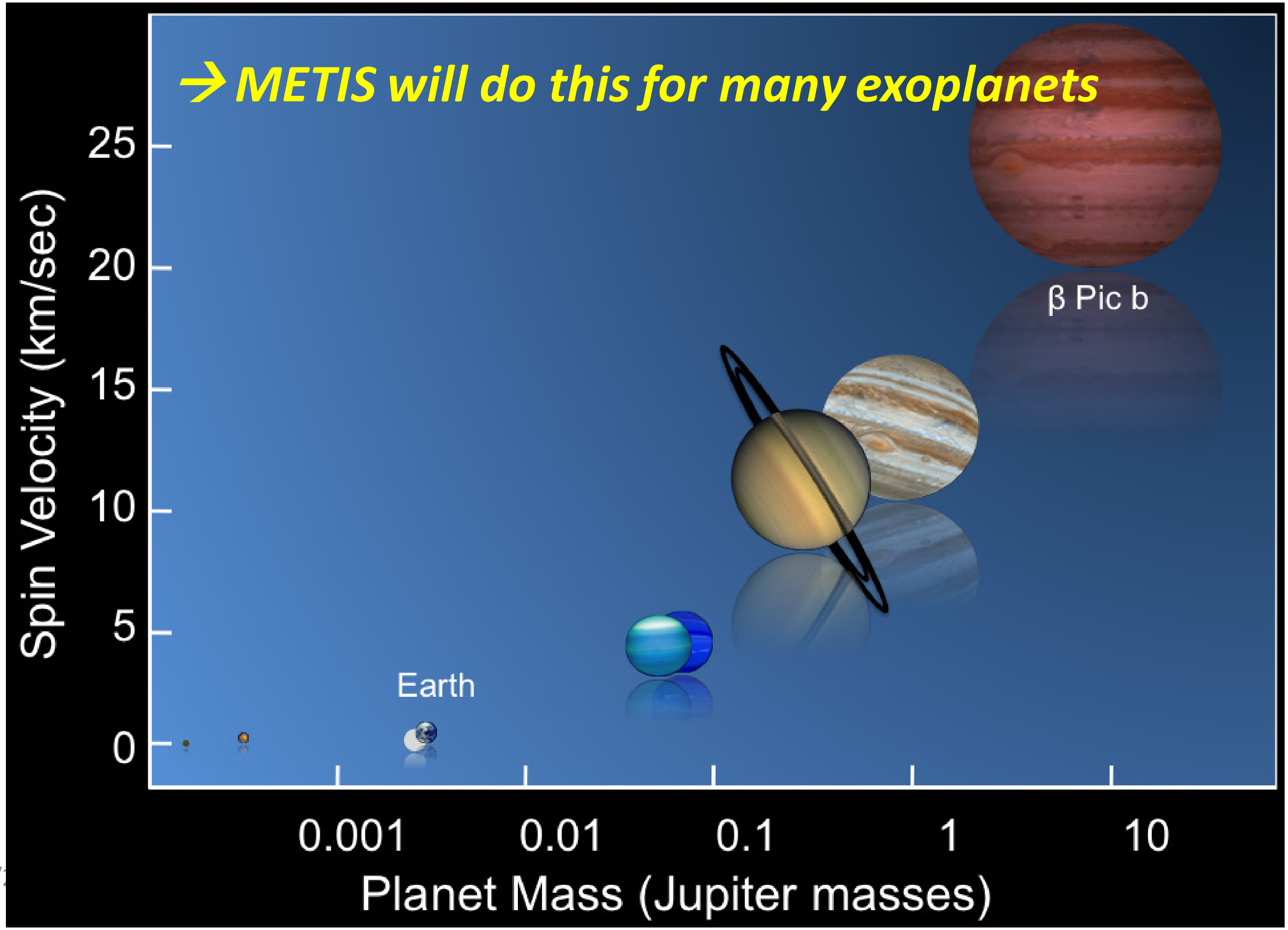
- During **transit**
- Before/after **secondary eclipse**



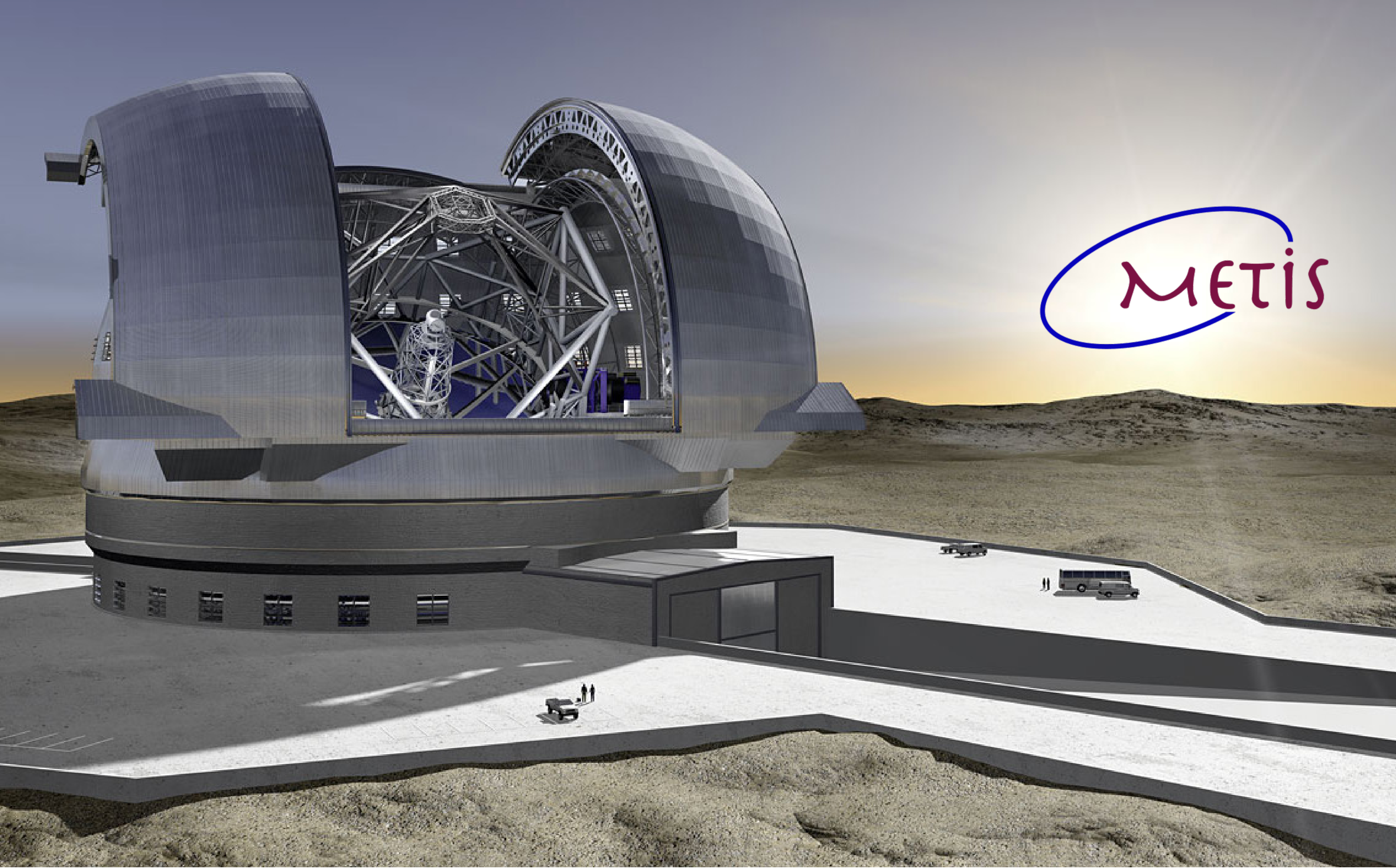
Planet Spin Rotation



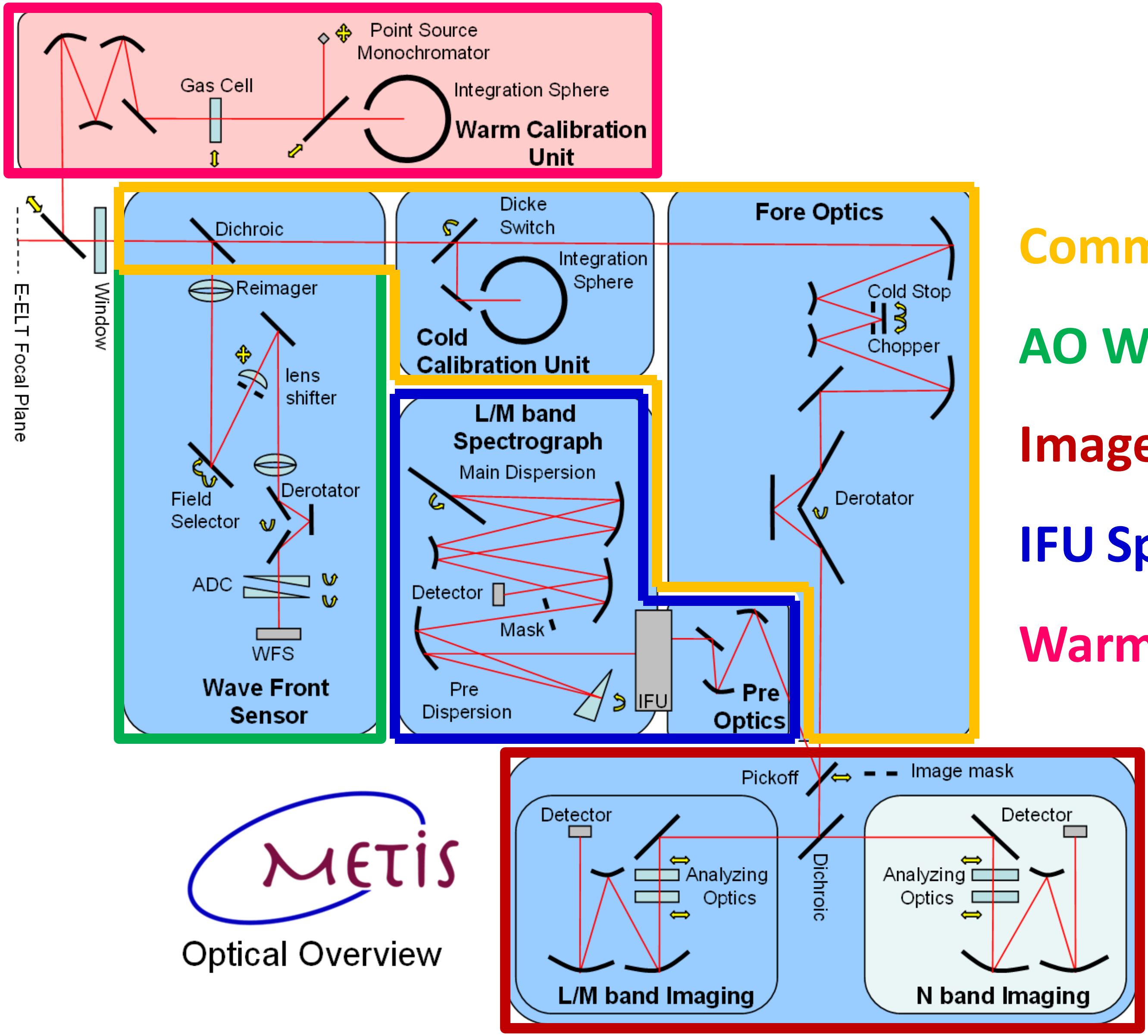
First detection of exoplanet spin-rotation ***(Snellen, Brandl, et al., Nature 2014)***



4. METIS TECHNOLOGY



Instrument Concept



Common Fore-Optics

AO Wavefront Sensor

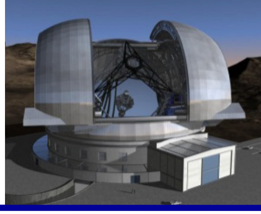
Imager

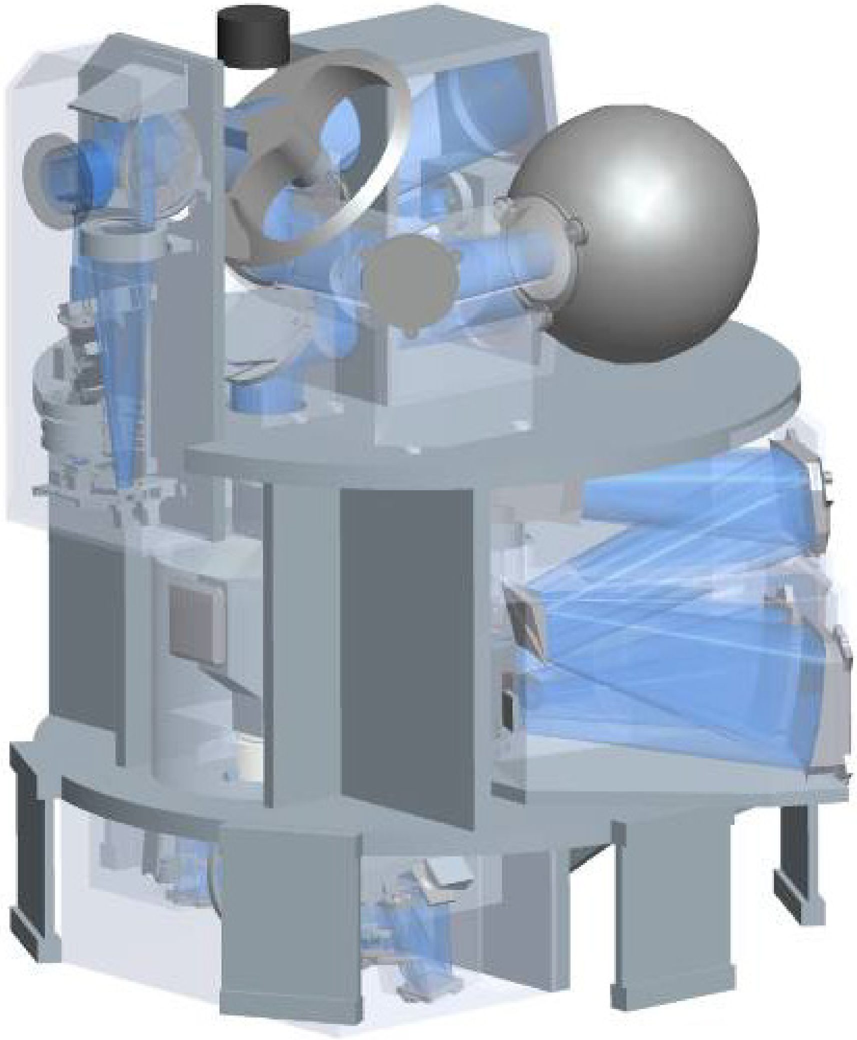
IFU Spectrograph

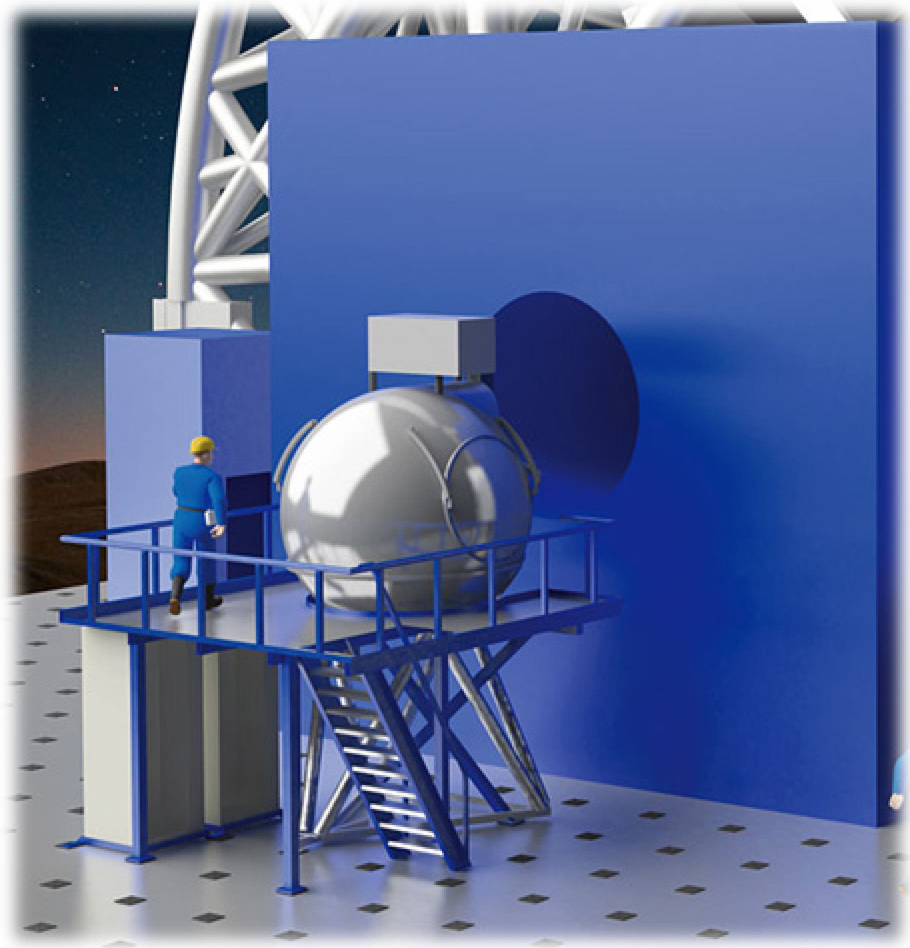
Warm Calibration Unit

Optical Overview

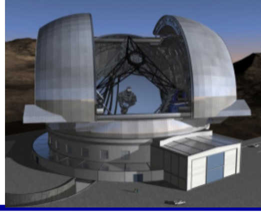
Instrument Concept







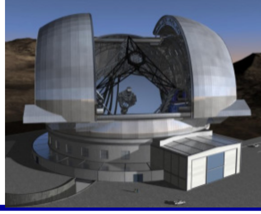
Detectors



METIS has relatively moderate detector needs

Module	Type	Pixels
AO WFS (NIR)	SELEX SAPHIRA	600 x 600
L/M band imaging	HAWAII-2 RG	2048 x 2048
N band imaging	AQUARIUS	1024 x 1024
L/M IFU spectroscopy	HAWAII-4 RG	4096 x 4096

Imager (MPIA WP)



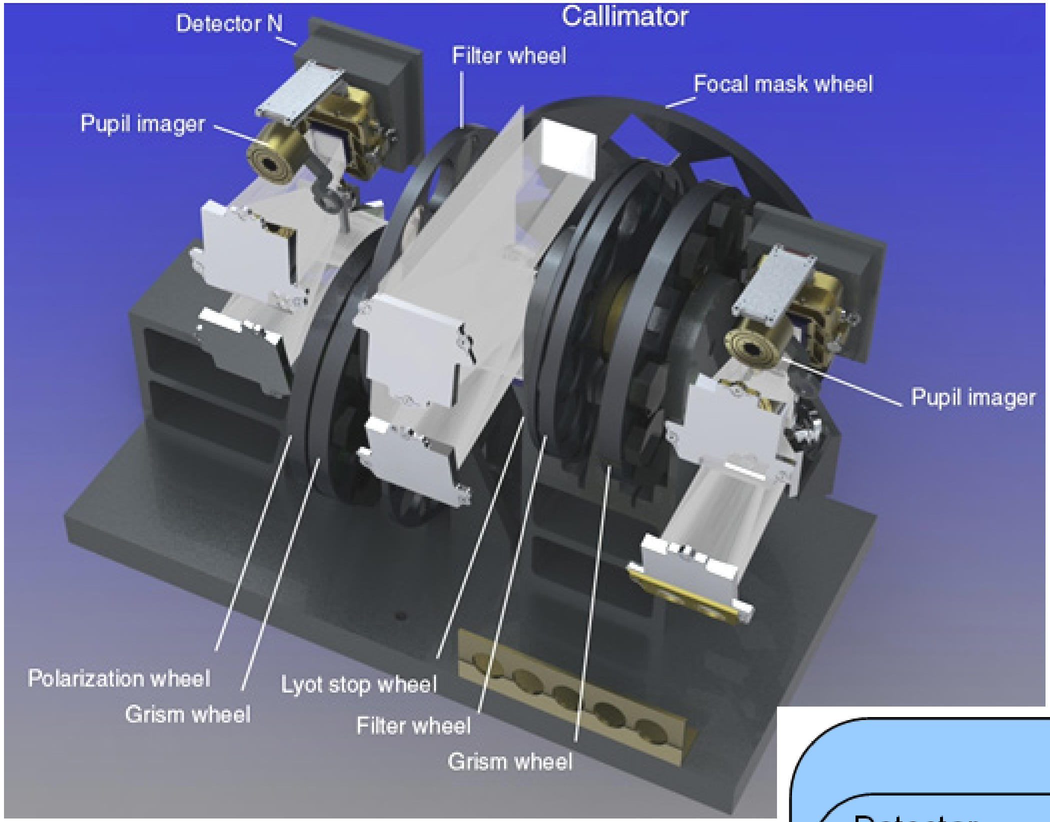
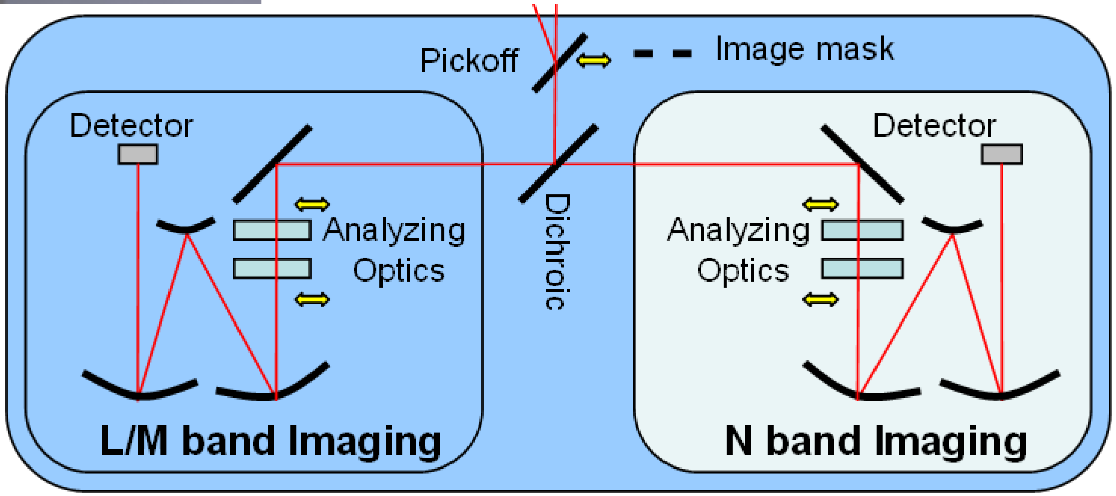


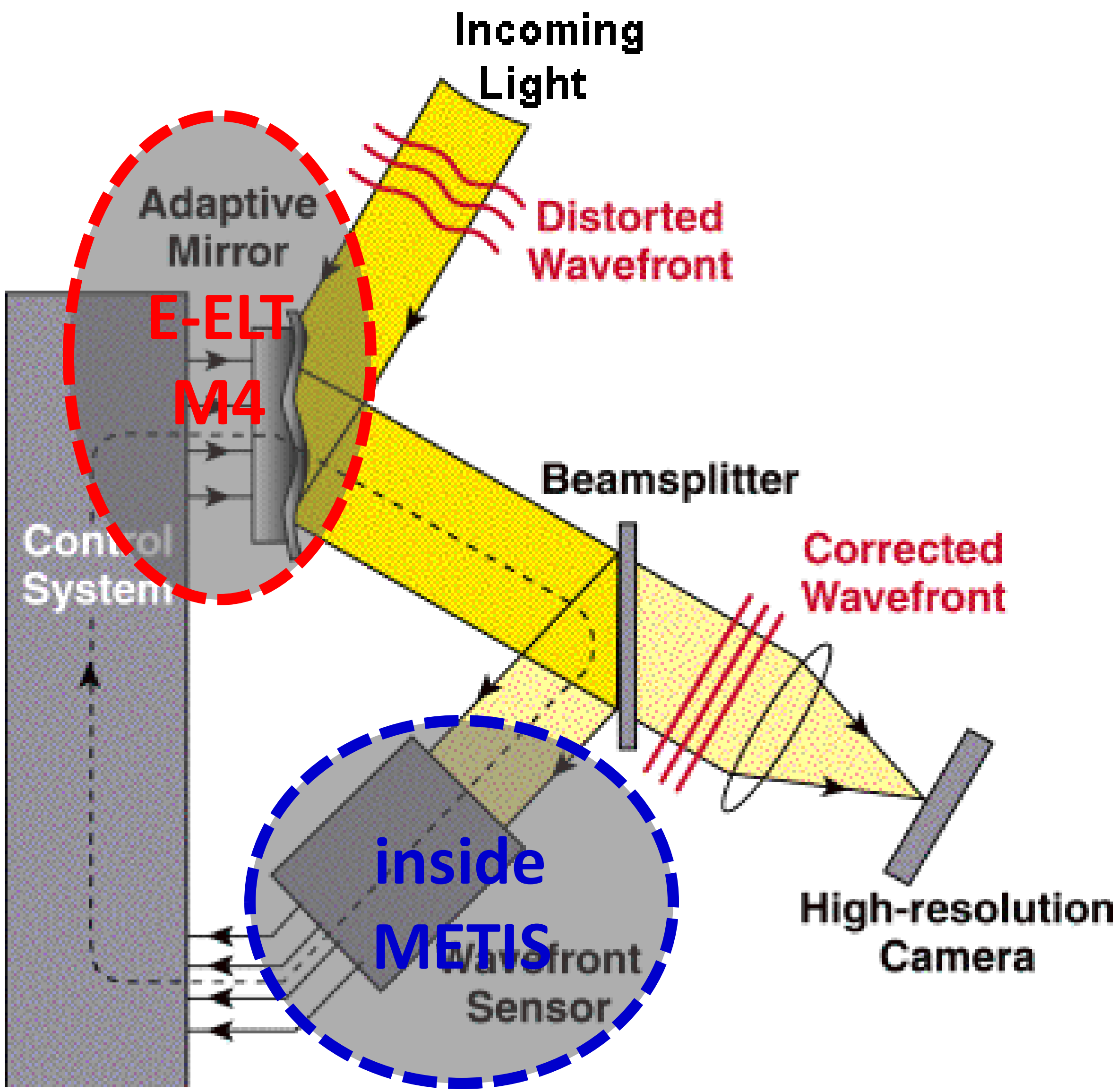
Image includes:

- **Imaging 3 – 19 µm**
- **Slit spectroscopy (medium R)**
- **Coronagraphy**

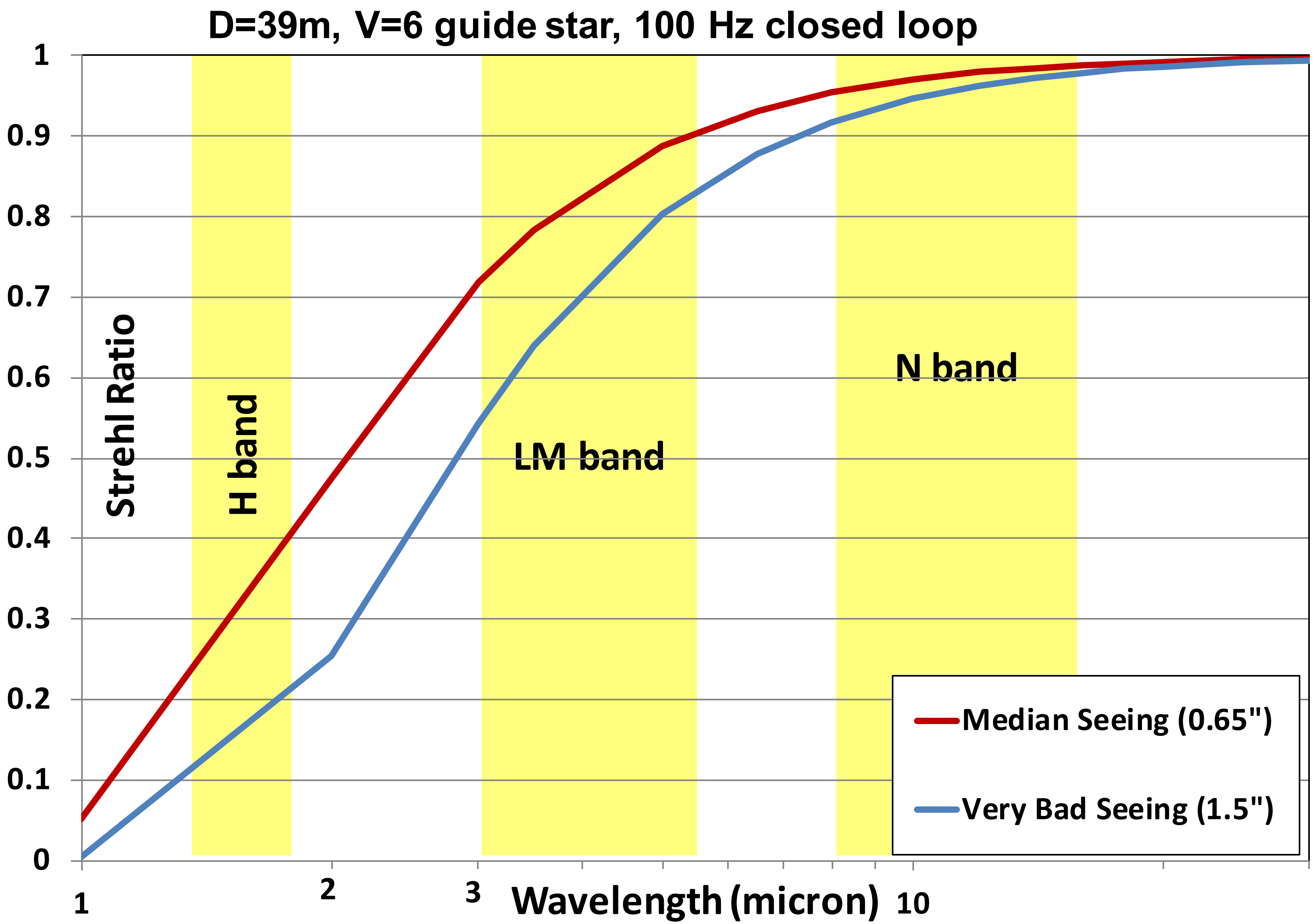
Design: Rainer Lenzen



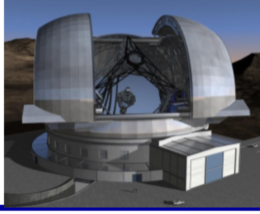
METIS needs AO

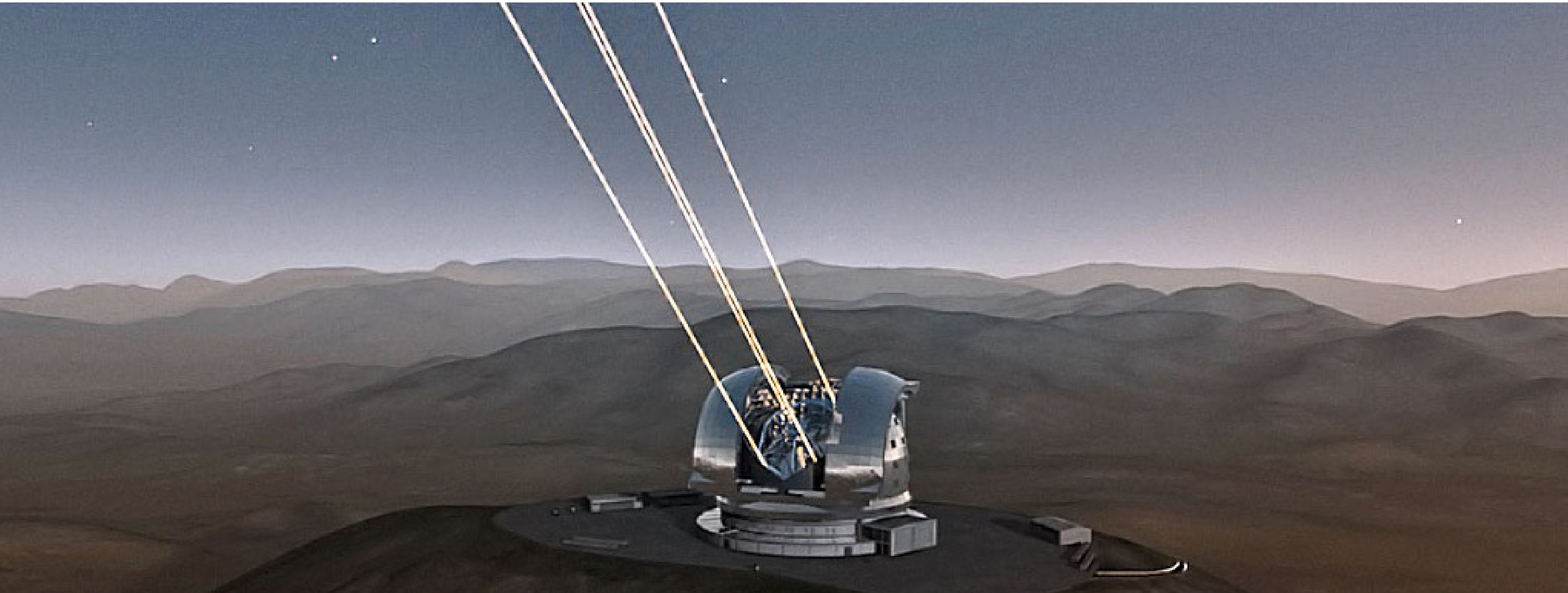


(SC)AO Performance



METIS Adaptive Optics (MPIA WP)



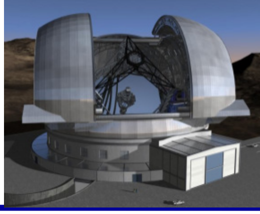


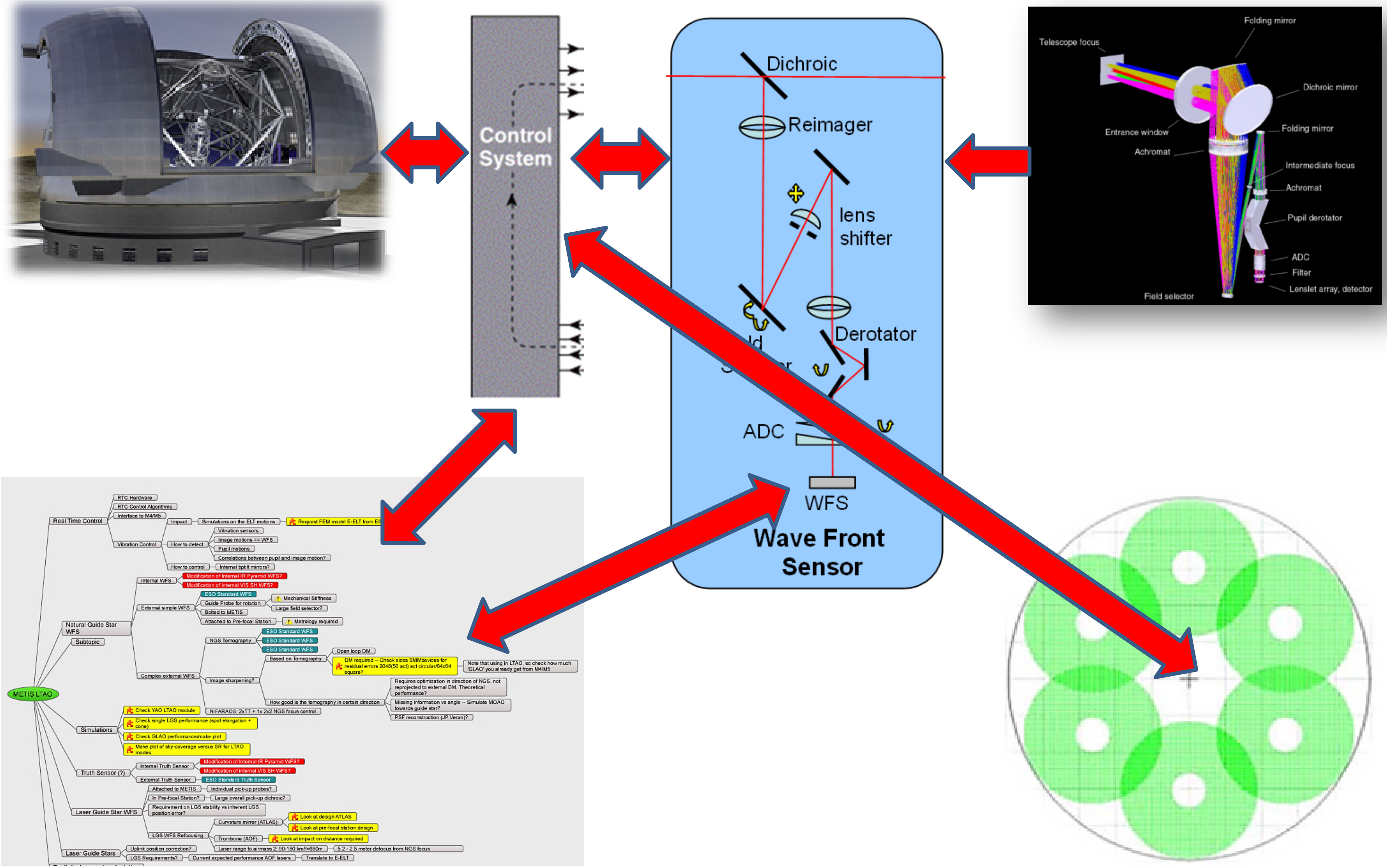
METIS needs two flavors of AO:

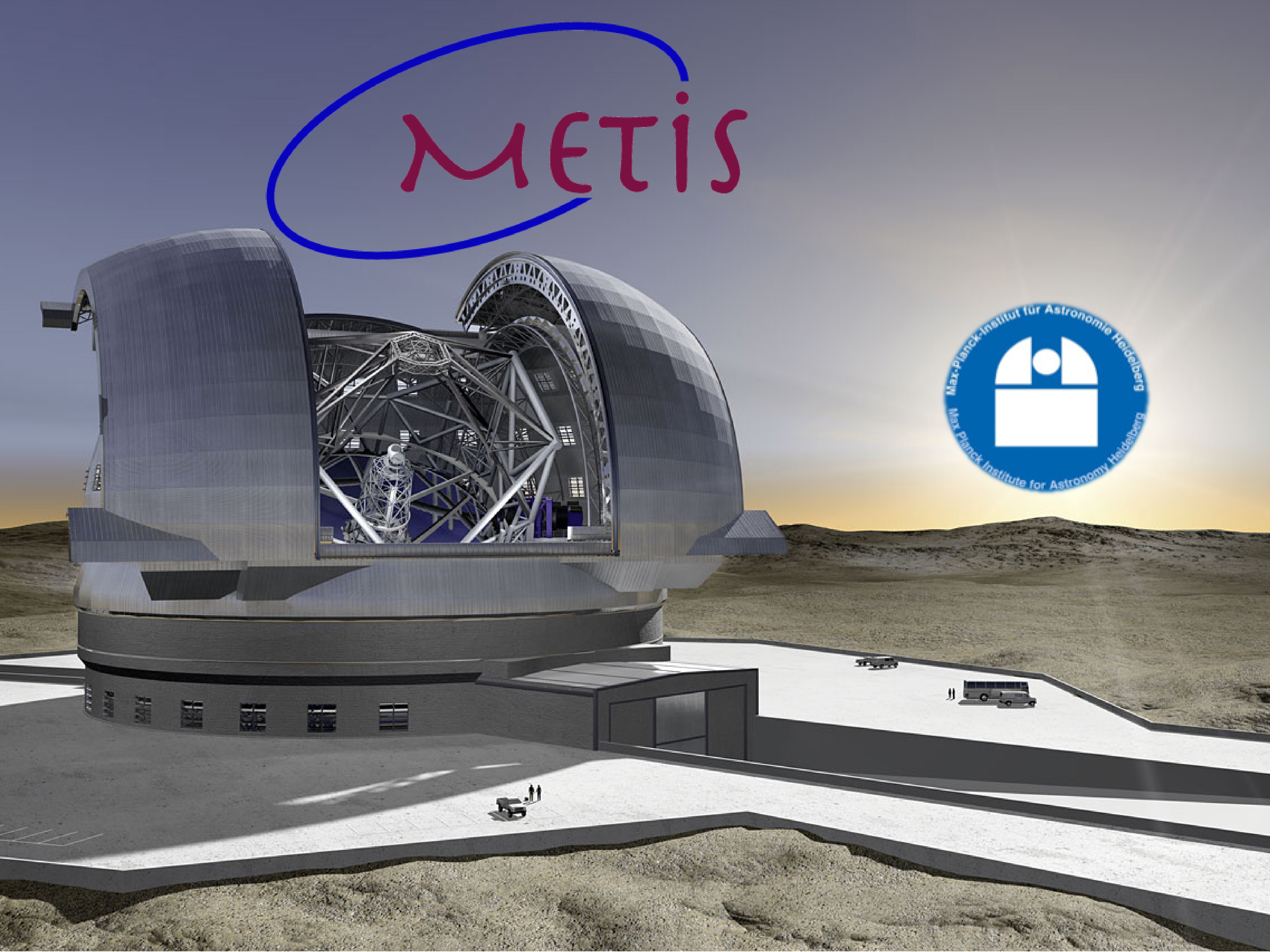
A. SCAO: internal WFS & E-ELT M4/5 → large fraction of Galactic science

B. LTAO: laser guide stars → extragalactic science & faint Galactic targets

AO System Complexity






METIS
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