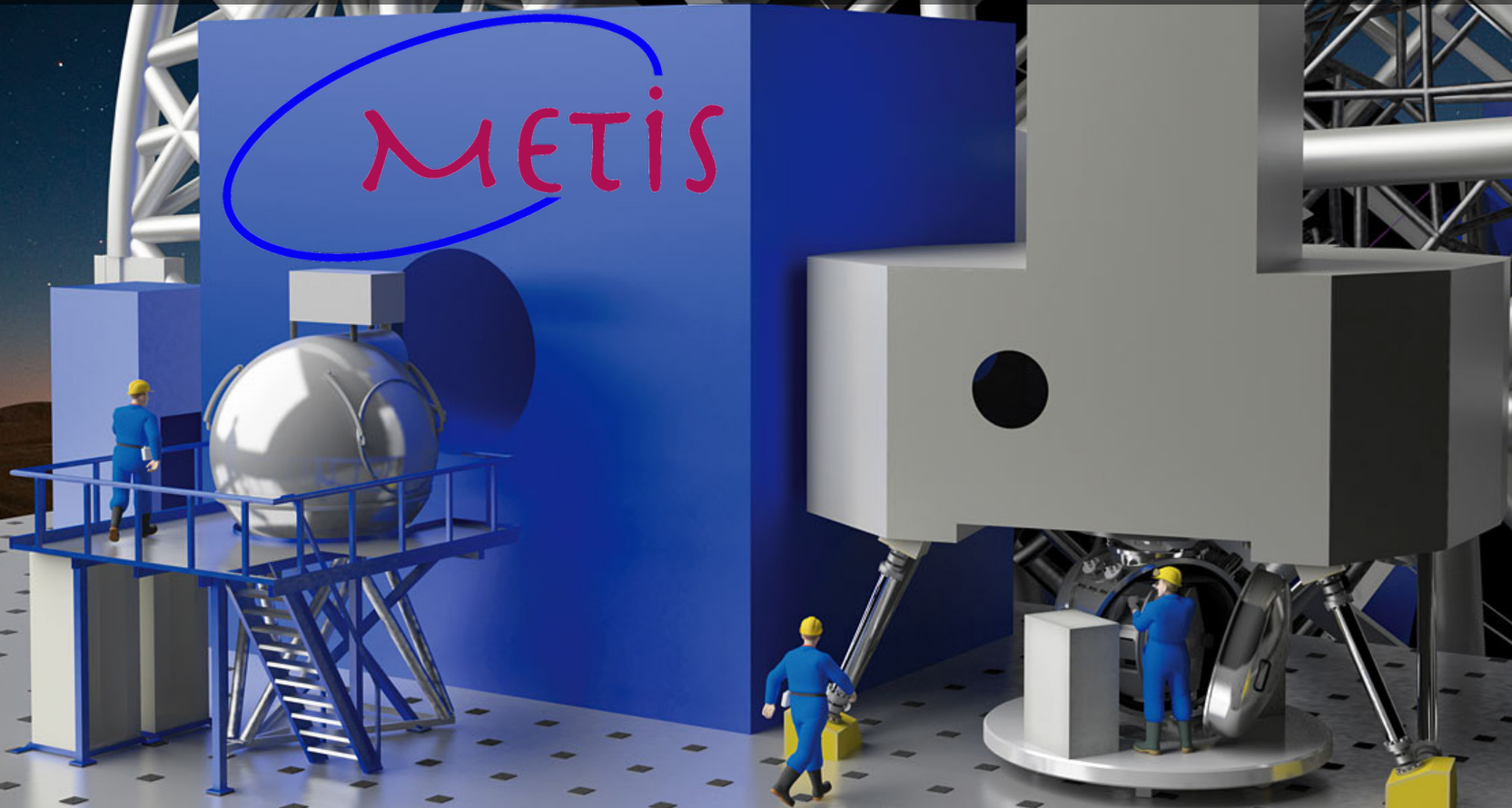


# PERFORMANCE AND EXOPLANET DISCOVERY SPACE OF METIS

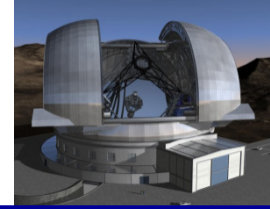


**Bernhard Brandl (Leiden University)**

*Exoplanet Observations with the E-ELT, 5 February 2014*



# Instrument Baseline



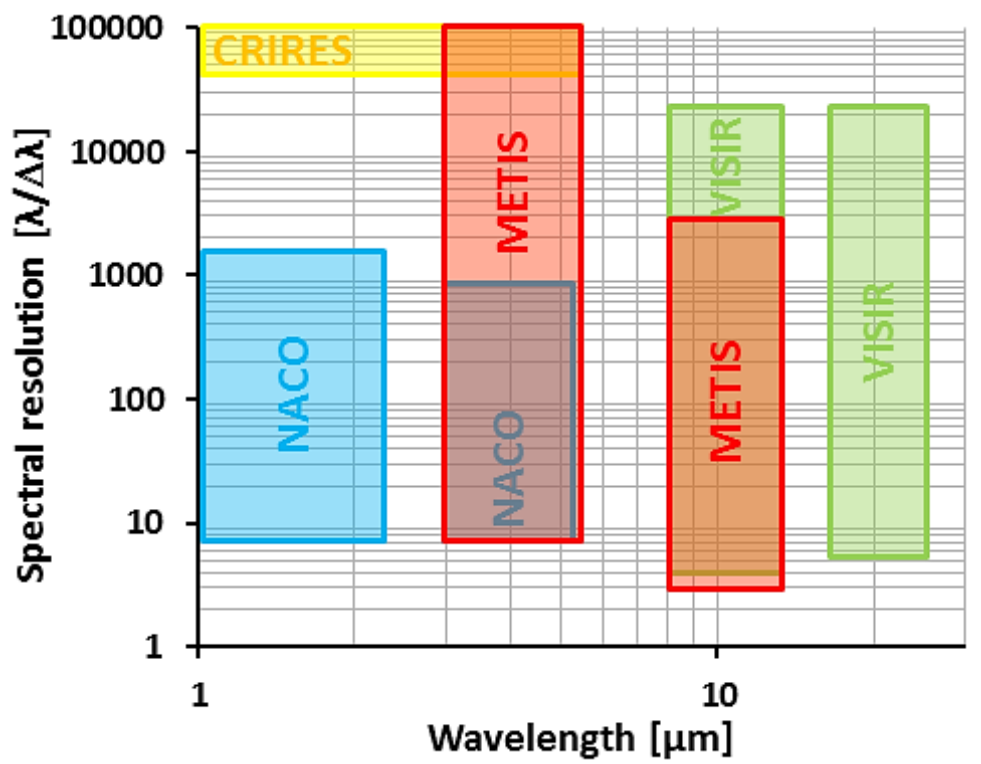
The 'Mid-infrared ELT Imager and Spectrograph' METIS is ...:

- an imager at L/M & N band, and
- an IFU spectrograph at L/M band with  $R \approx 100,000$
- working at the diffraction limit.

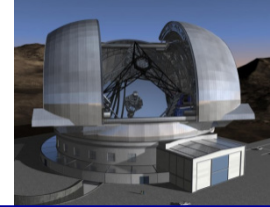
METIS with respect to the VLT instrument suite →

PS Sensitivities (1hr, 10σ)

$\lambda$	F	mag
L	1 $\mu\text{Jy}$	21.2
M	10 $\mu\text{Jy}$	18
N	100 $\mu\text{Jy}$	14

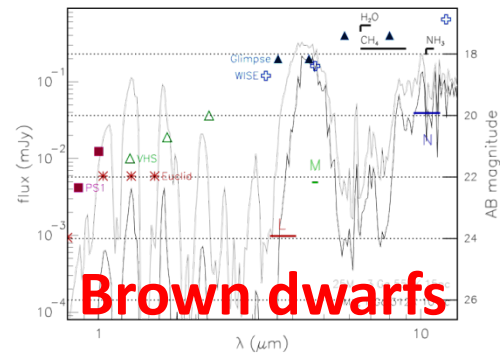
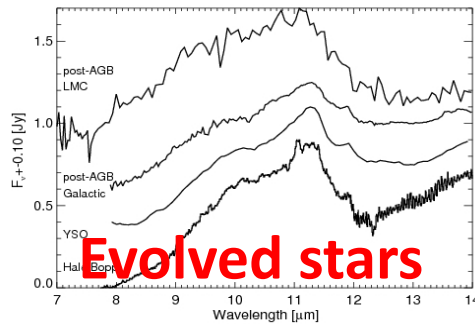


# METIS A Multi-Purpose Instrument



**Martian atmosphere**

**History of our Solar System**

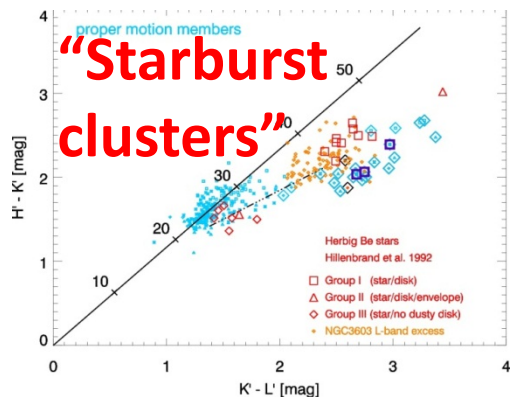


**Galactic Center**

**Proto-planetary Disks**

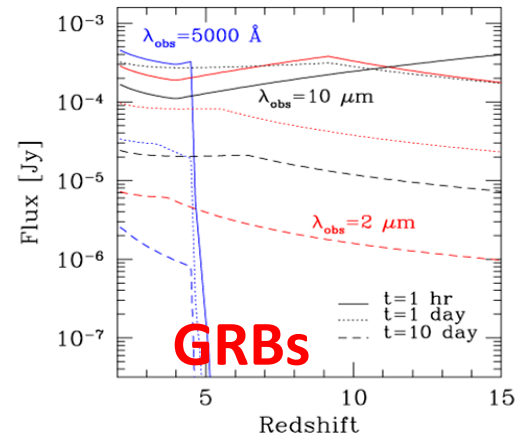
**Exoplanets**

**MYSOs & UCHIIRs**

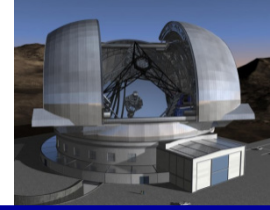


**Growth of SMBHs**

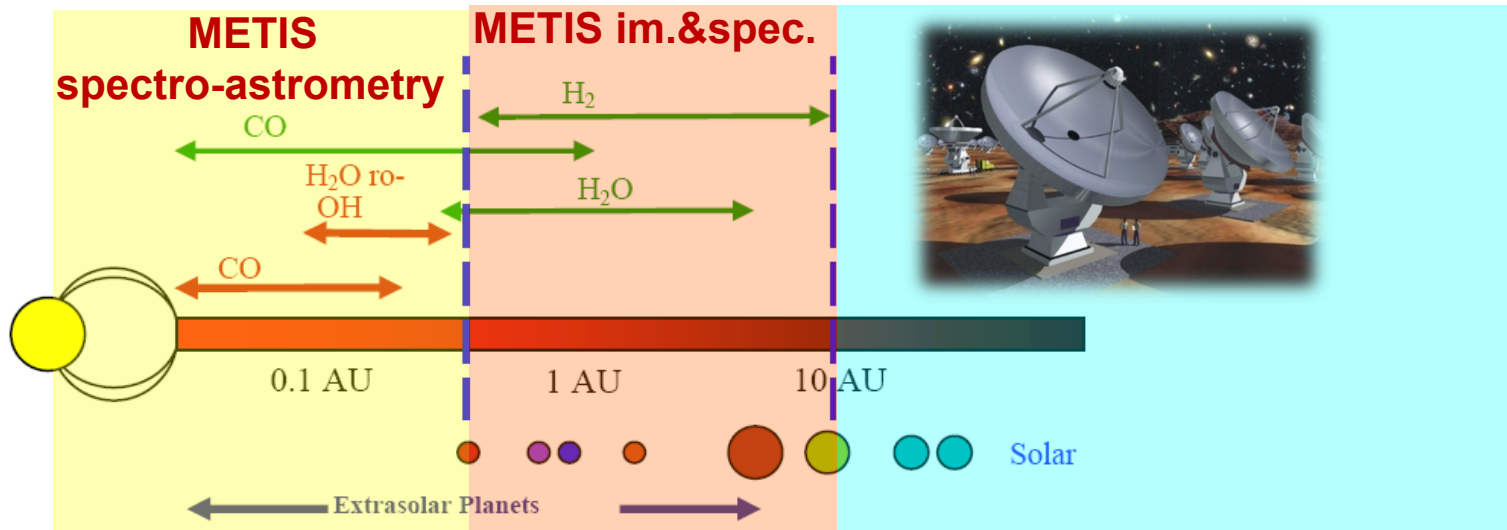
**Evolution of high-z Galaxies**



# METIS probes the *inner* PP Disk



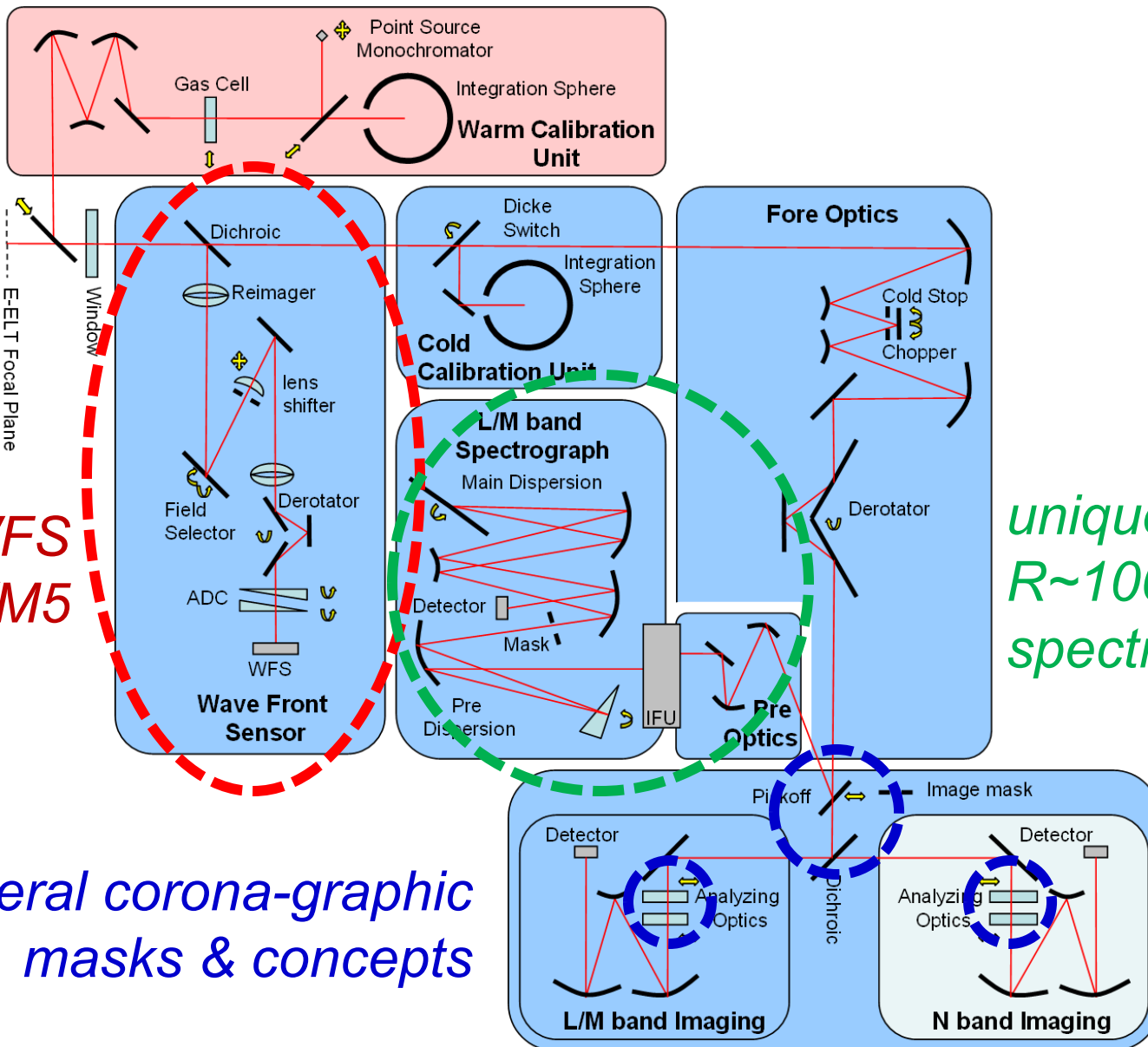
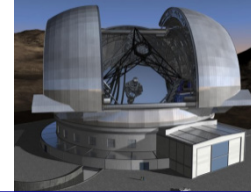
For nearby young systems:



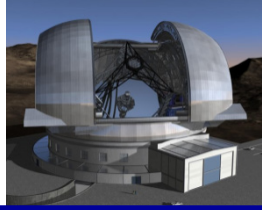
	METIS	ALMA
Target	inner disk – hot gas	outer disk – cool gas
Spectroscopy beam	0.03" @ 4.7μm	≈0.10"
Detail reconstruction	full aperture	synthesized aperture

METIS

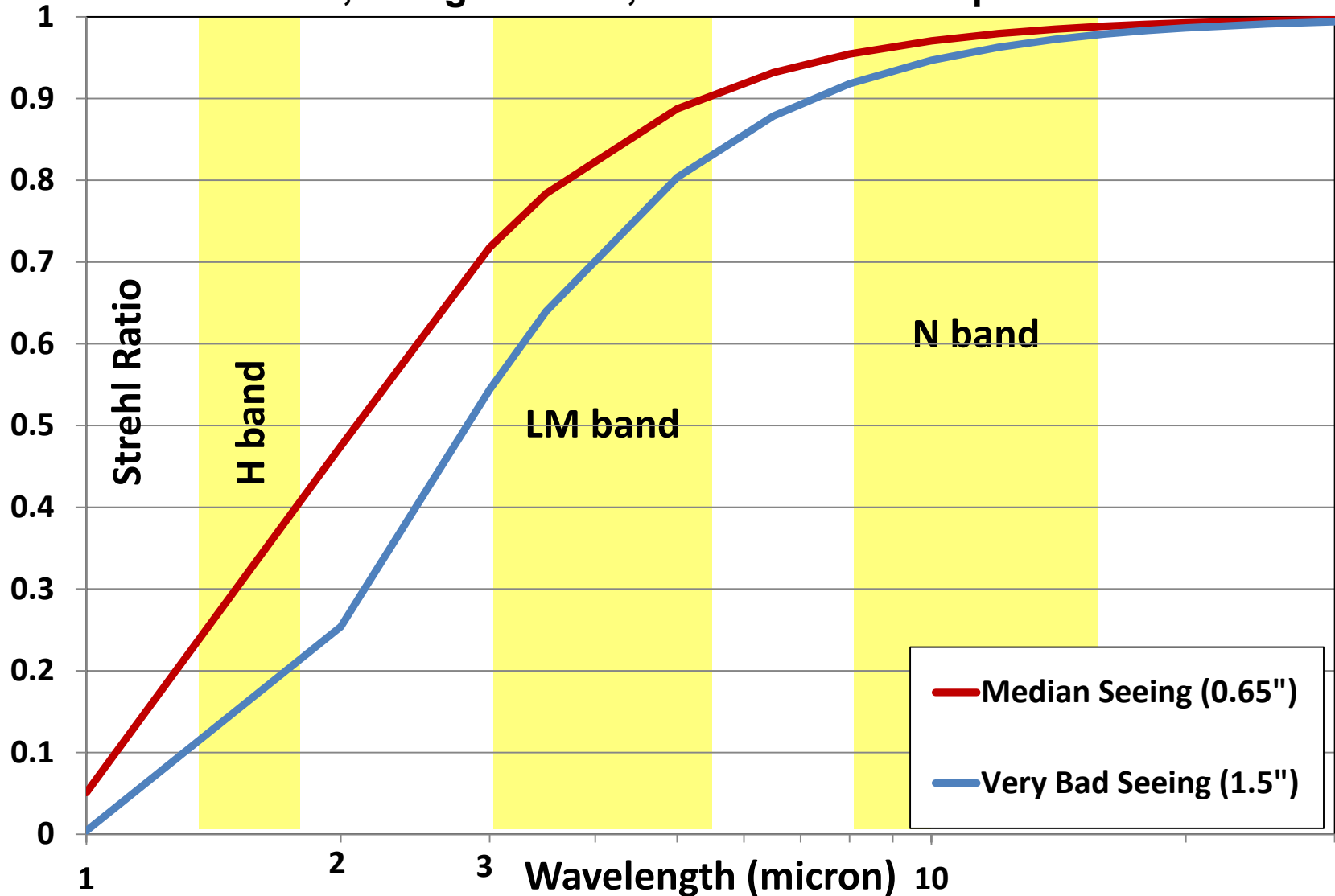
# METIS ↔ Exoplanets !



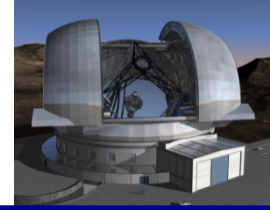
# METIS E-ELT SCAO Performance



D=39m, V=6 guide star, 100 Hz closed loop



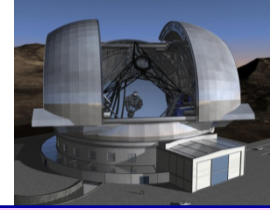
# METIS AO & Quasi-static Speckles



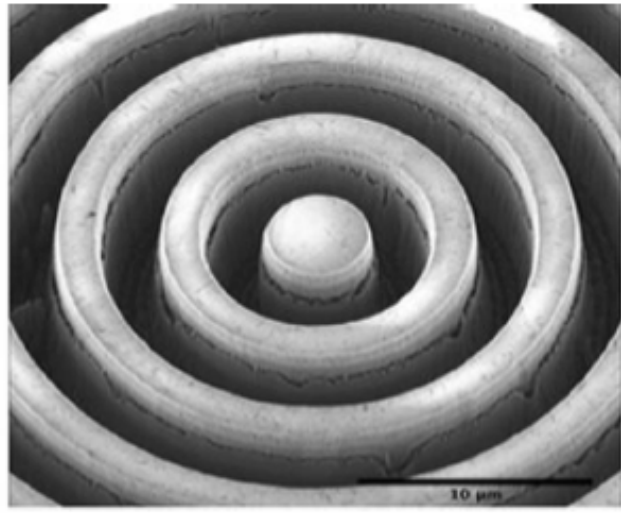
HD 95086b – first detection at K-band by Perrin, Marois, & the GPI team (2014)

- So far no direct detections at  $<5\lambda/D$  due to quasi-static speckles
- Removal of persistent speckles (ADI, SDI, LOCI, PCA) requires stable PSF over  $\geq 1$  minute
- Need high Strehl ratios to get a stable PSF and coronagraph to work well  $\rightarrow$  PSI
- METIS will routinely deliver SR  $\geq 80\%$

# METIS Coronagraphic Concepts



Focal plane: **AGPM**



Considerations:

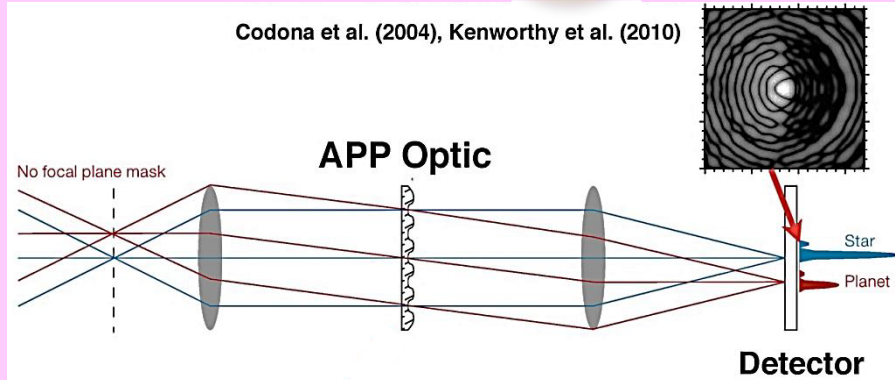
- *Highest contrast*
- *Residual vibrations*
- *Calibration (e.g., drift scanning)*
- *Source morphology*

Pupil plane: **APP**

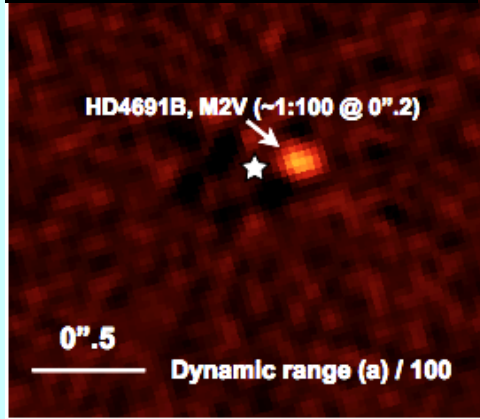
APP coronagraphs are insensitive to pointing errors, drifts and vibrations!



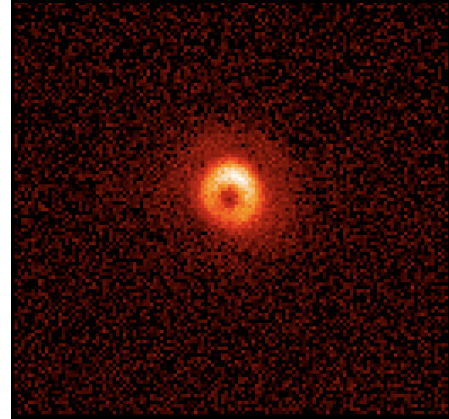
Codona et al. (2004), Kenworthy et al. (2010)



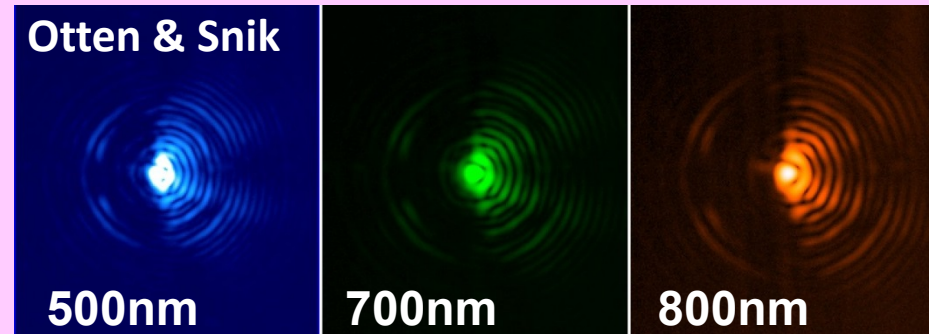
L-band (NACO)



N-band (VISIR)

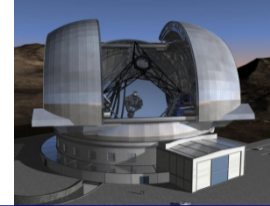


Otten & Snik



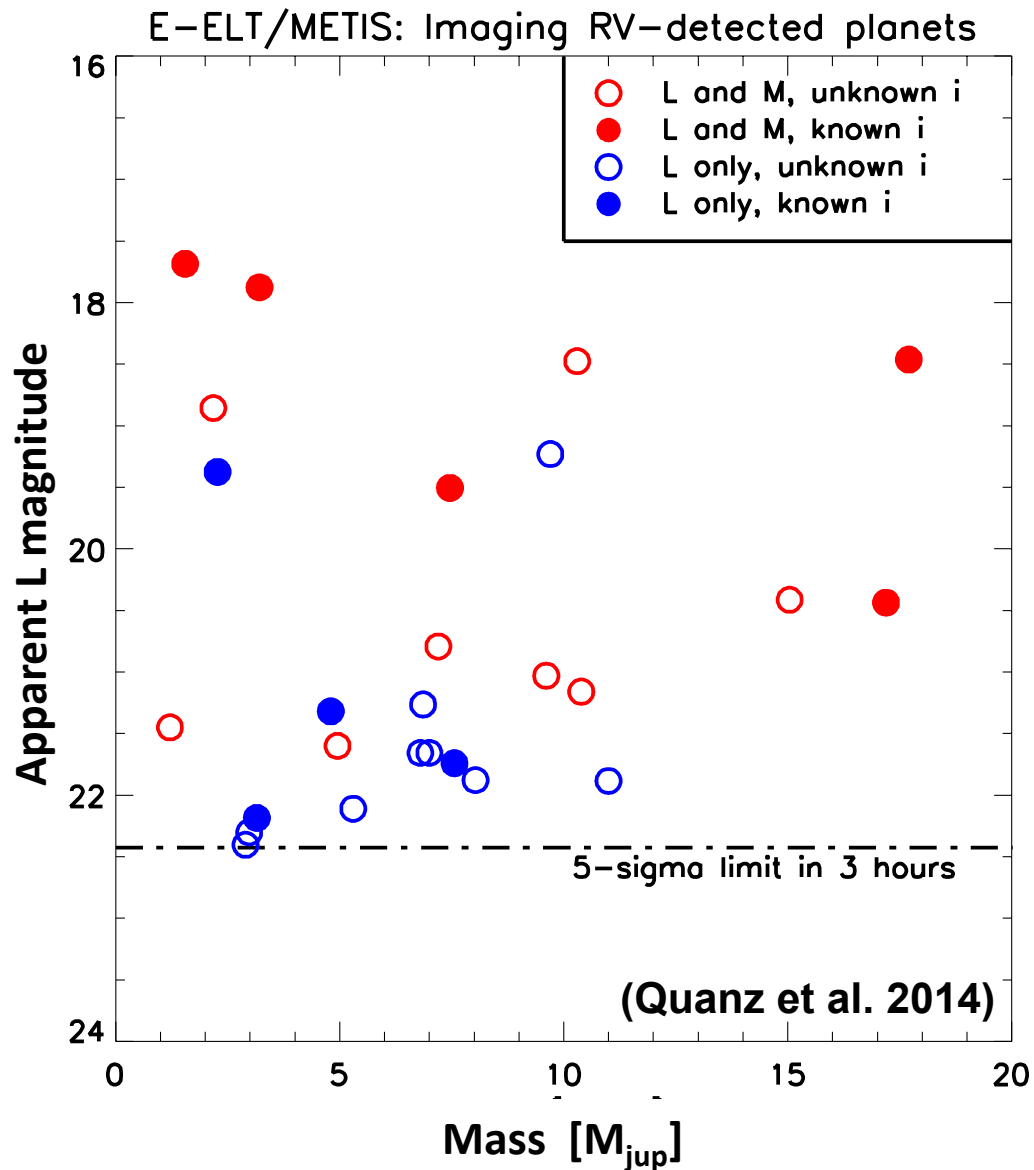


# METIS Example Detections @ 3-5 $\mu\text{m}$

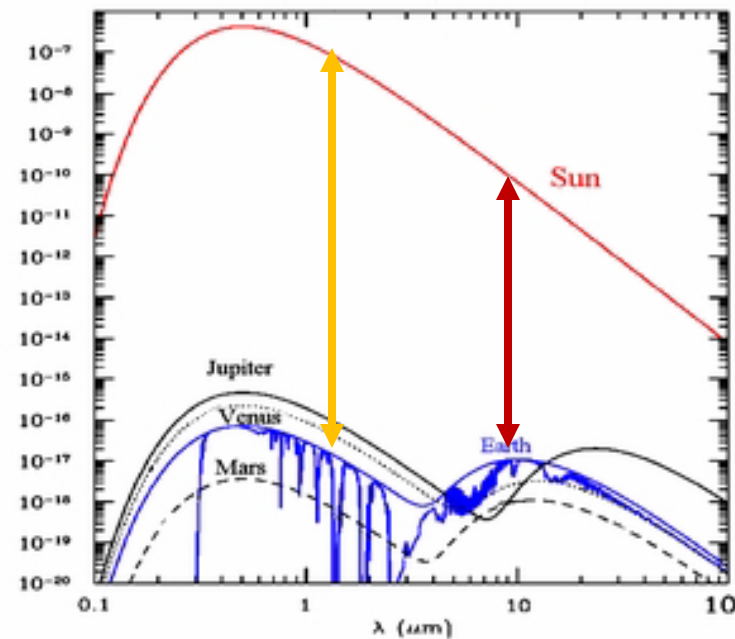
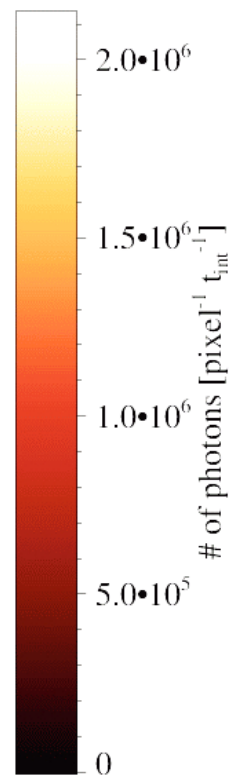
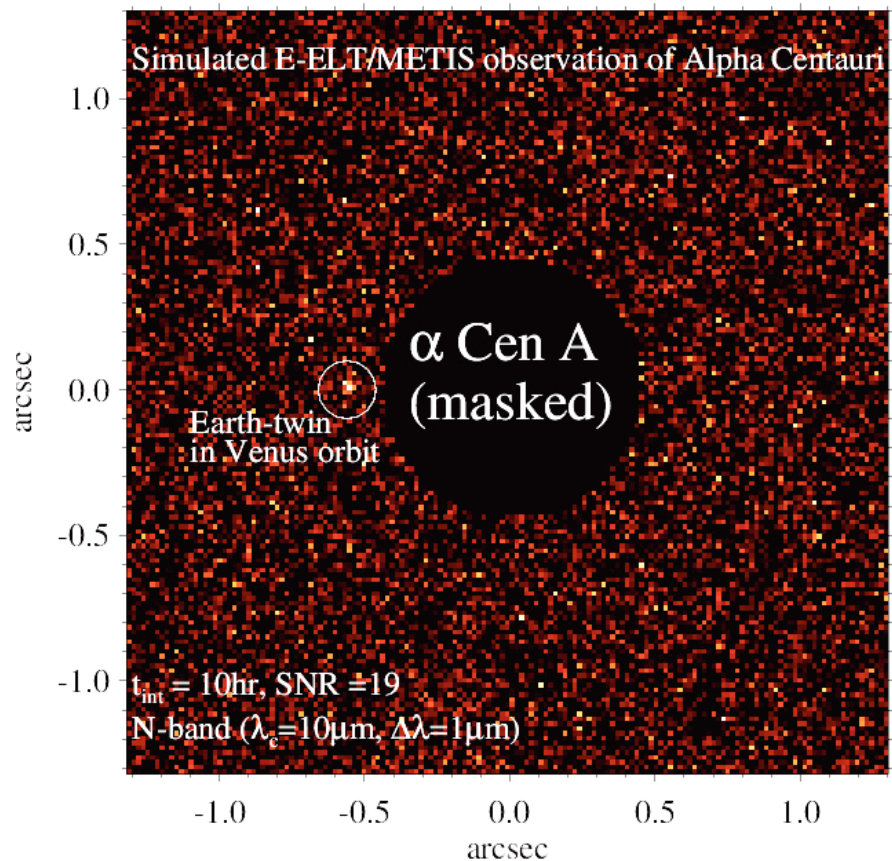
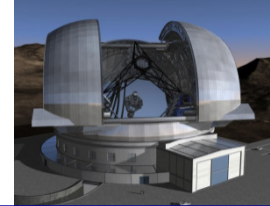


- Simulated detections of currently *known* gas giants detected by RV surveys
- 14 of these can be detected with METIS in  $\leq 3\text{hr}$  (per target)
- This assumes that a contrast of  $10^{-6}$  (background limit) can be reached at  $3 \lambda/D$

Many RV planets will be beyond reach of METIS but several will be directly imaged



# METIS Example Detections @10 $\mu$ m



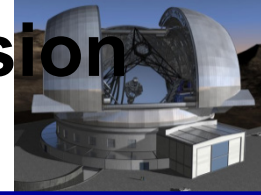
Simulated 10hr **N-band** coronagraphic observation of **Alpha Centauri A**. An **Earth-twin** (same radius and atmospheric composition, but with an average temperature of about **330K**) in a Venus-like orbit would be detectable (**10hr, S/N=19**).

[Sky brightness -4.5 mag/arcsec<sup>2</sup>, system throughput ~10%].

# METIS

# IFU Spectroscopy

Transmission  
Day side



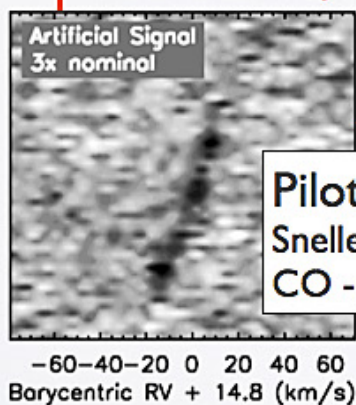
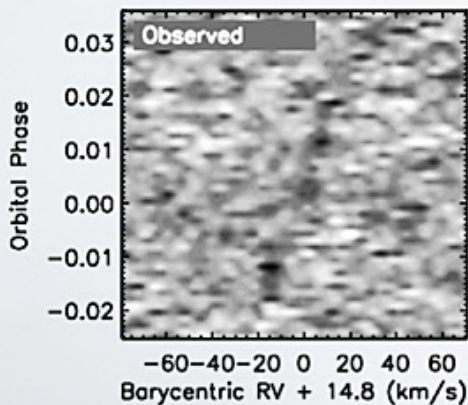
Transiting planets are observable:

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

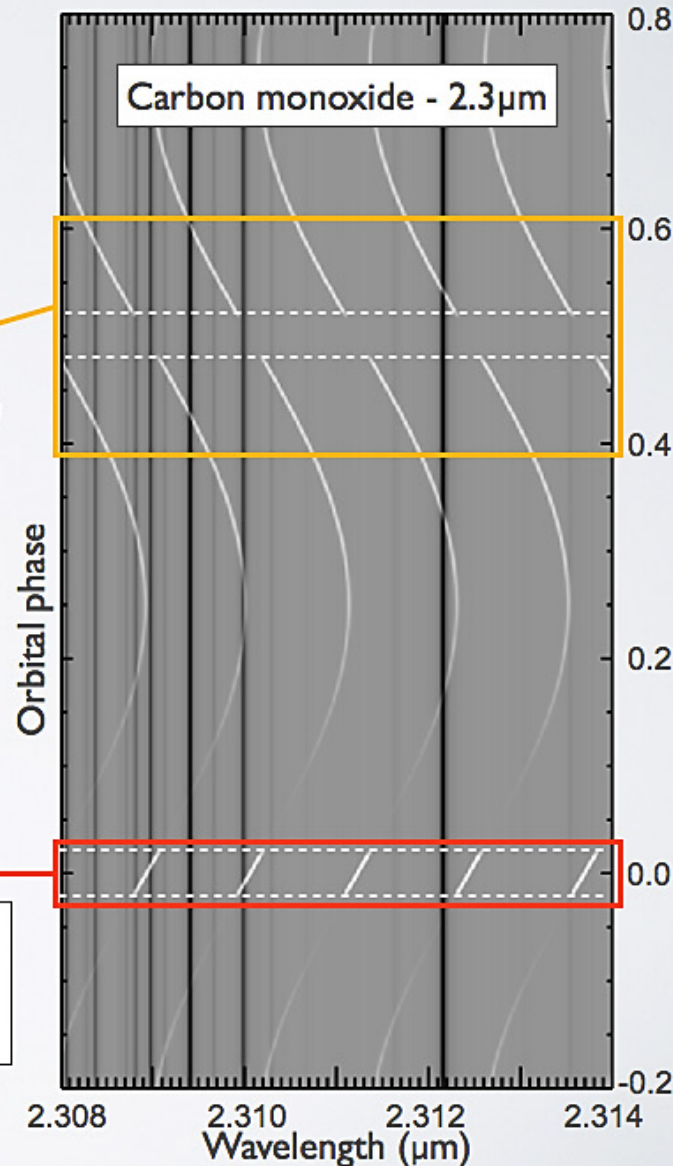
Pilot study:  
Brogi et al. 2012  
CO -  $\tau$  Bootis b

Day-side Spectroscopy

Transmission Spectroscopy

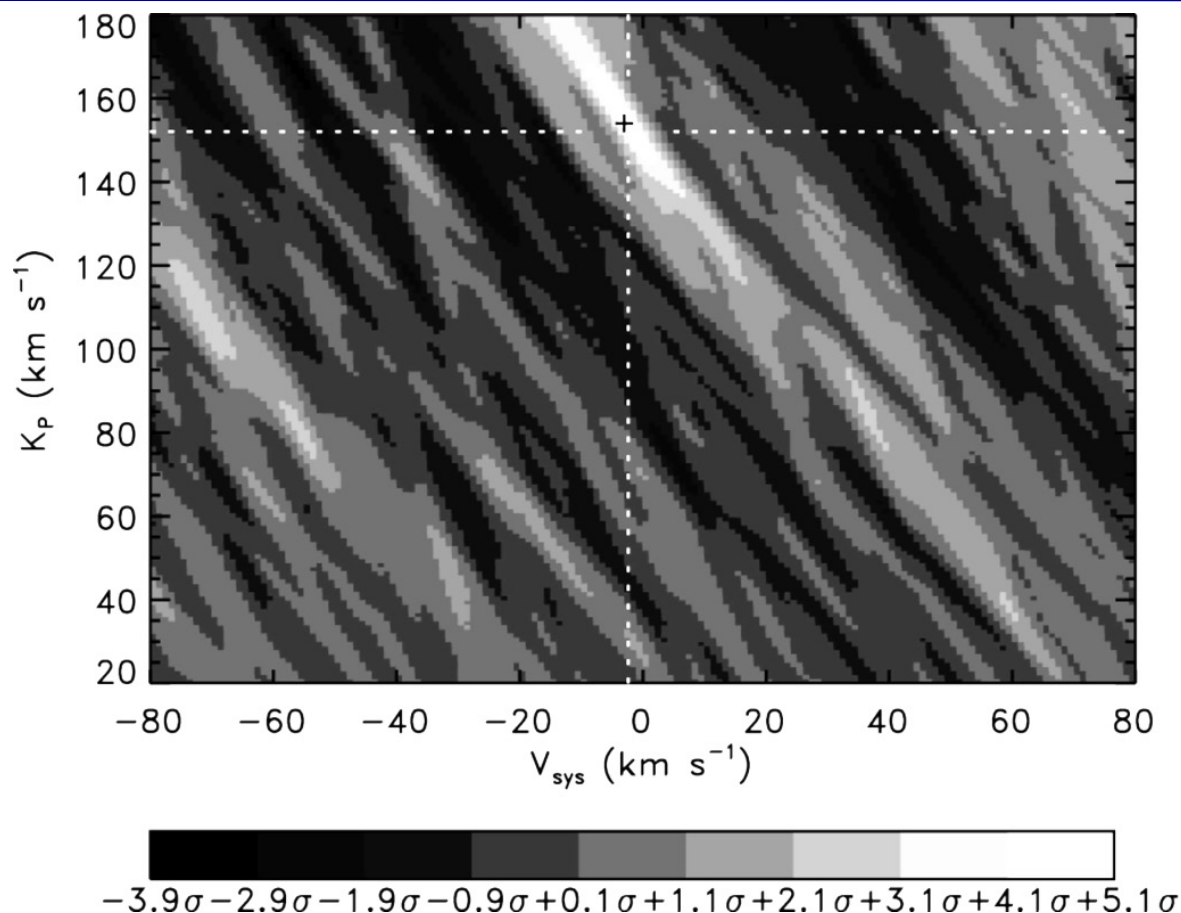
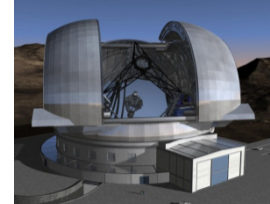


Pilot study:  
Snellen et al. 2010  
CO - HD209458b

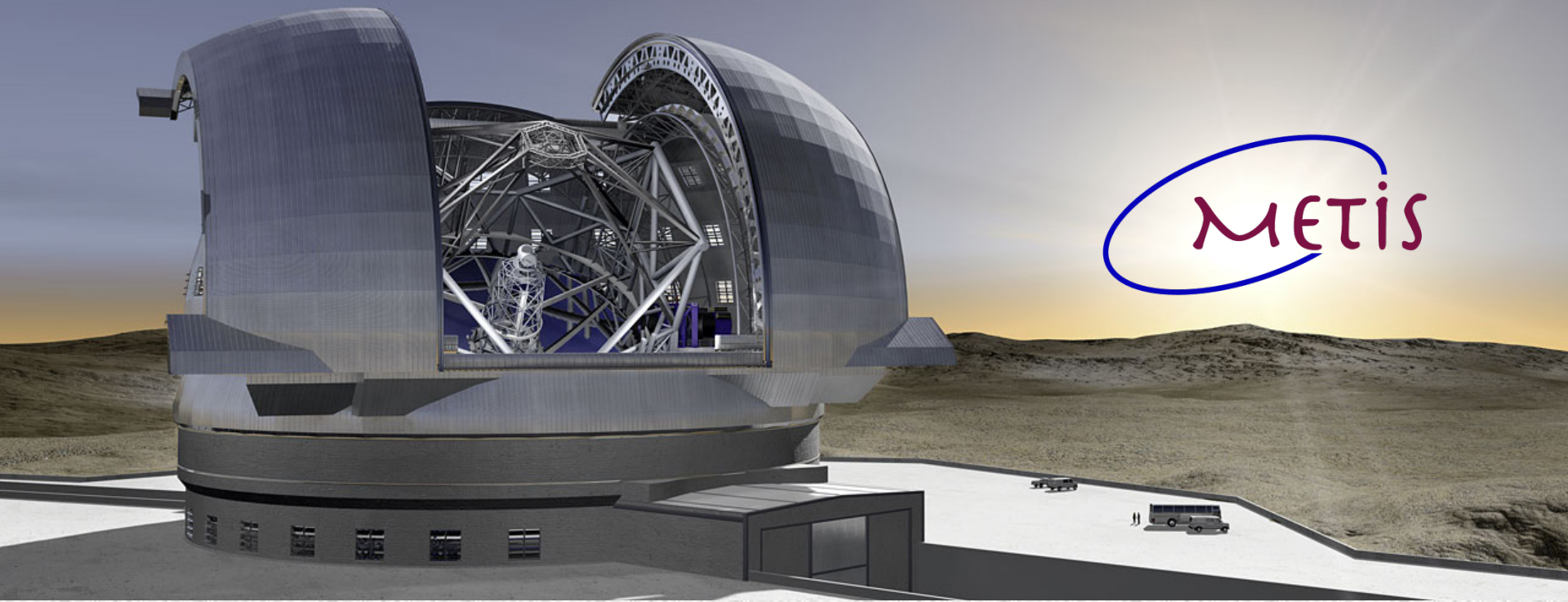


METIS

CRIRES showed "It works"



Detection of **water vapor absorption @  $3.2 \mu\text{m}$**  in the thermal dayside spectrum of **HD189733 b**, using CRISP at  $R=100,000$  (Birkby et al. 2013). *A 5-sigma signal is seen in the cross-correlation values at the system velocity and expected orbital velocity of the planet.*



- *METIS is a general science instrument, particularly suited for the study of proto-planets and exoplanets.*
- *METIS will make significant contributions by direct imaging & spectroscopic characterizations.*
- *METIS has the potential for many more techniques, e.g., Doppler imaging of exoplanetary atmospheres.*