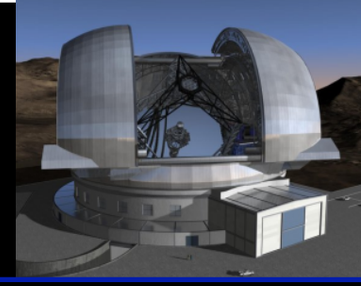
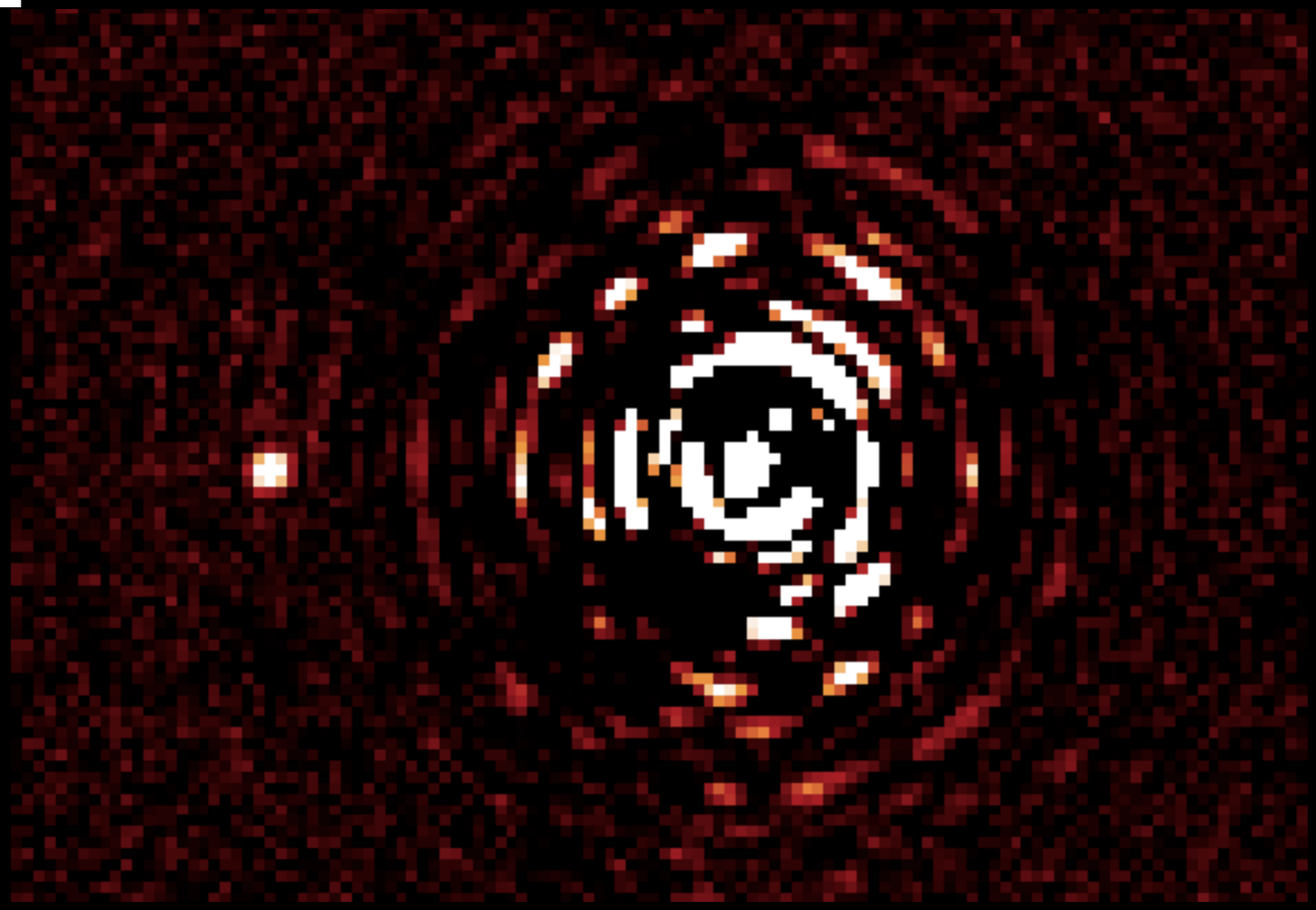
METIS

Mid-infrared
E-ELT Imager and
Spectrograph

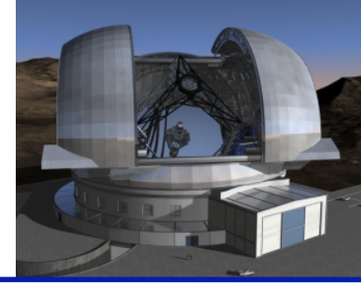
Exoplanets in the mid-IR with E-ELT & METIS

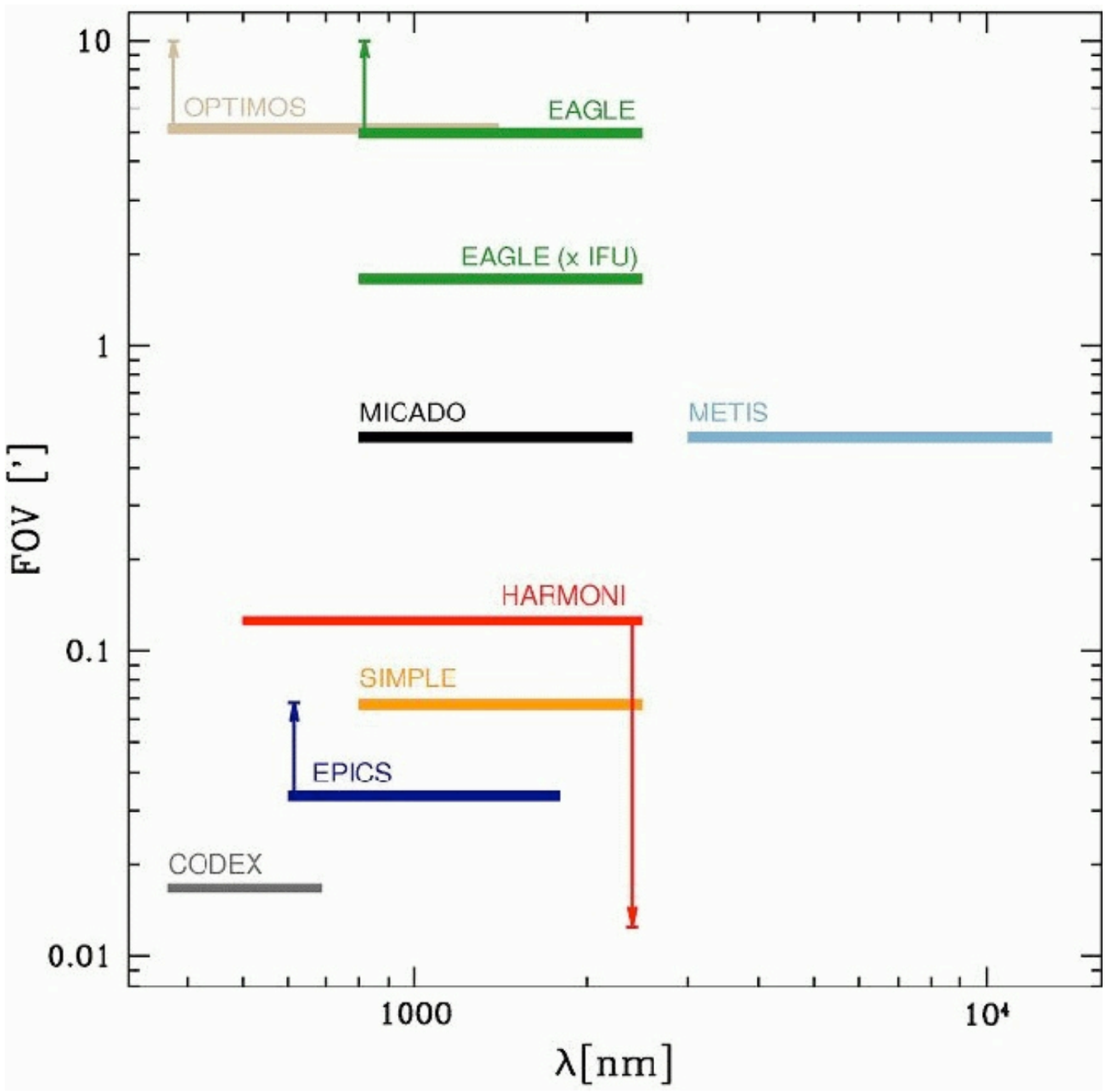




Wolfgang Brandner (MPIA), Eric Pantin (CEA Saclay), Ralf Siebenmorgen (ESO), Sebastian Daemgen (MPIA/ESO), Kerstin Geißler (MPIA/ESO), Markus Janson (MPIA/Univ. of Toronto)

METIS wavelength range of E-ELT instruments





see also talks by Andreas Eckart, Bernhard Brandl, ...

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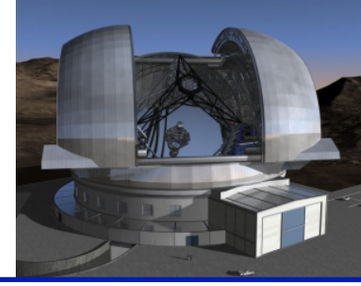
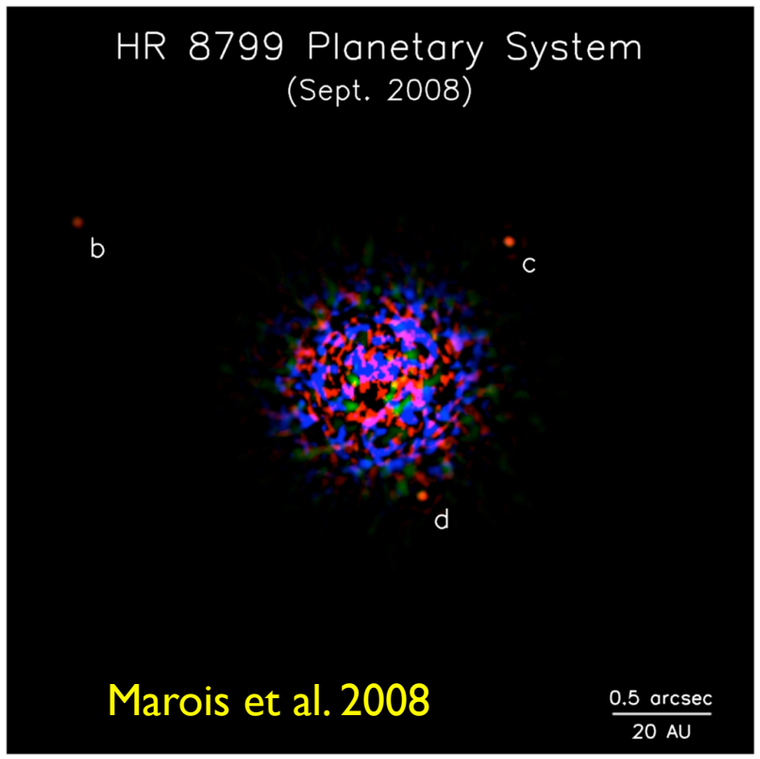
Science Goals



Scientific topics addressed by direct detection of giant exoplanets in the mid-IR:



* Exoplanet orbital parameters (astrometry)
* Atmospheric composition and chemistry
* Temperature profile of atmosphere
* Internal structure (radius, mass)
* Weather and seasons
* Formation of giant planets (core accretion, disk instability)

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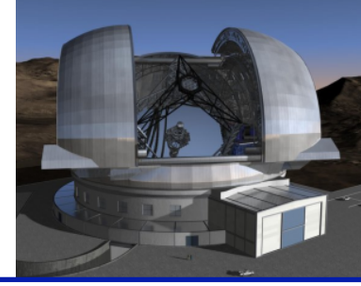
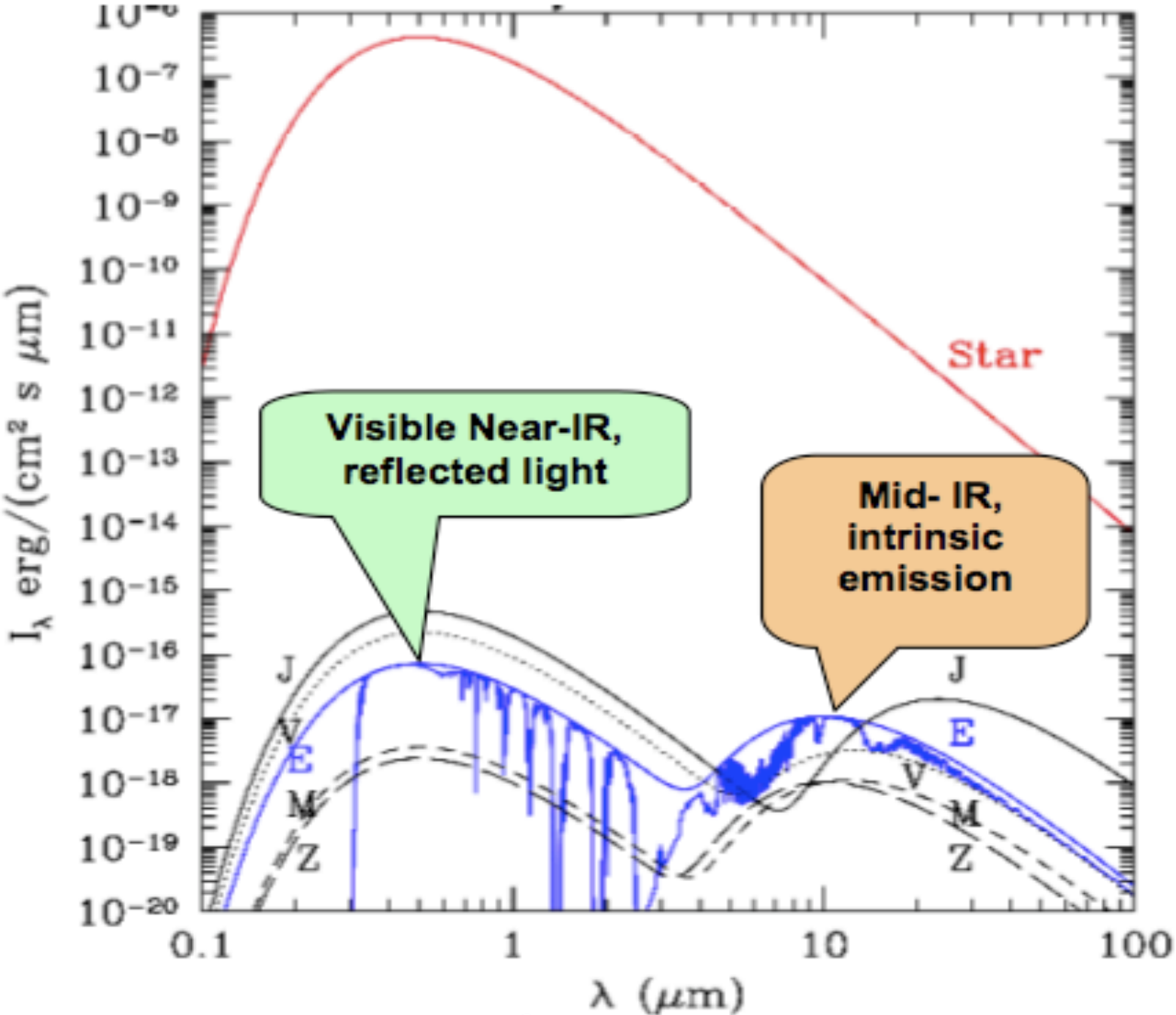
Exoplanets in the mid-IR - why?





=> Detection of intrinsic emission

(rather than reflected star light)

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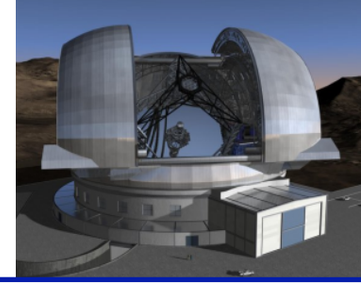
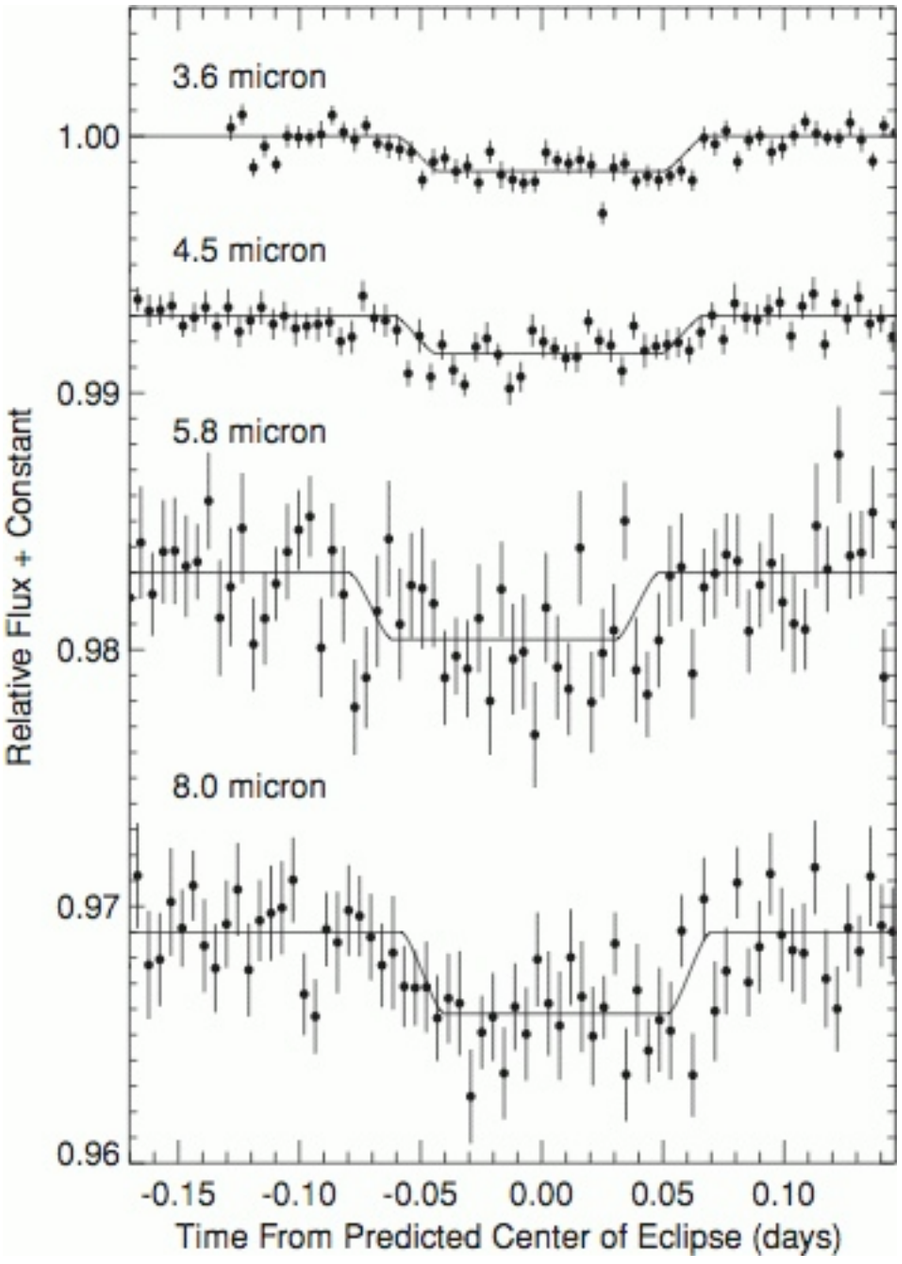
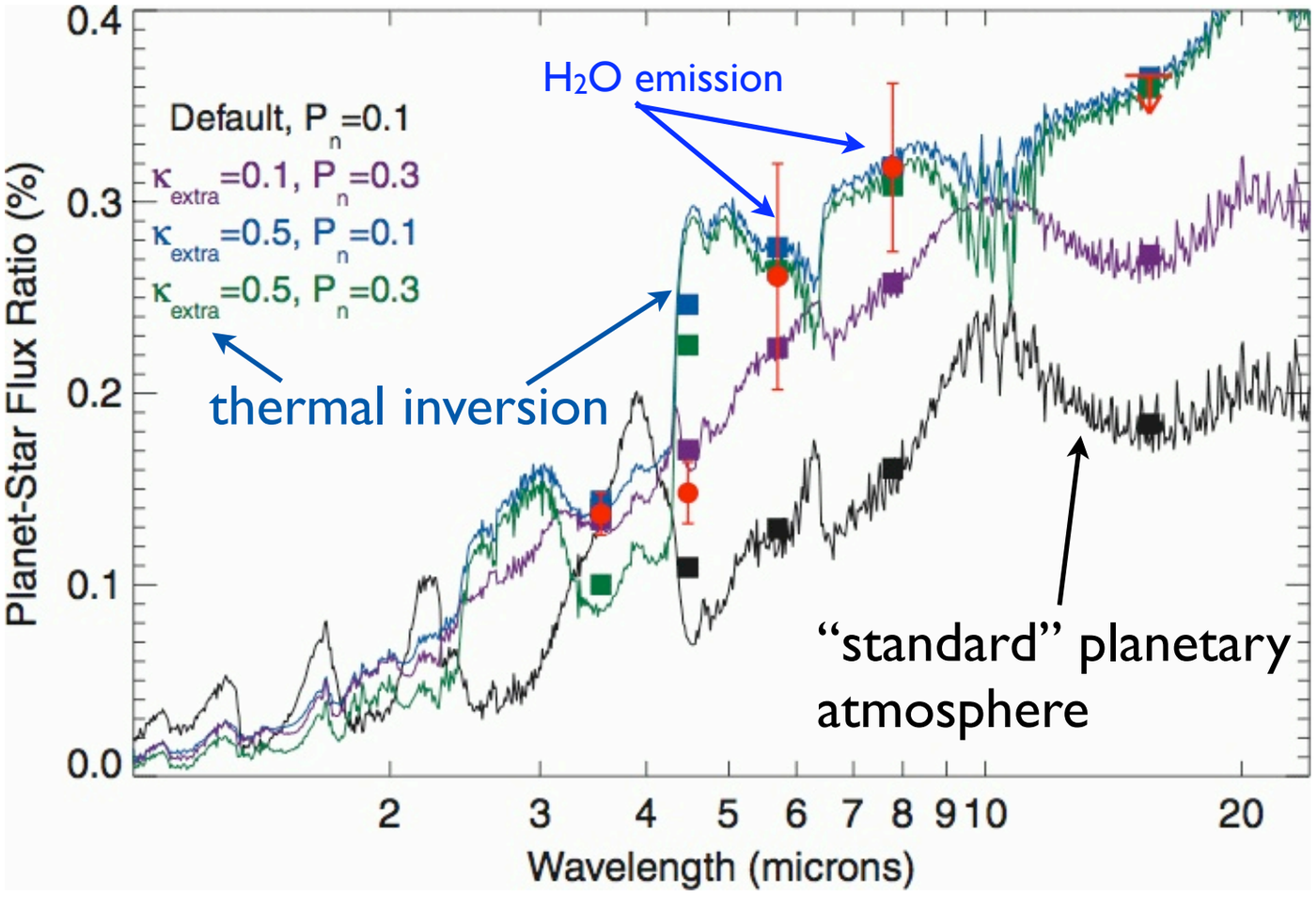
Exoplanets in the mid-IR

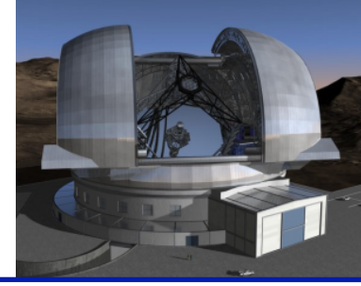


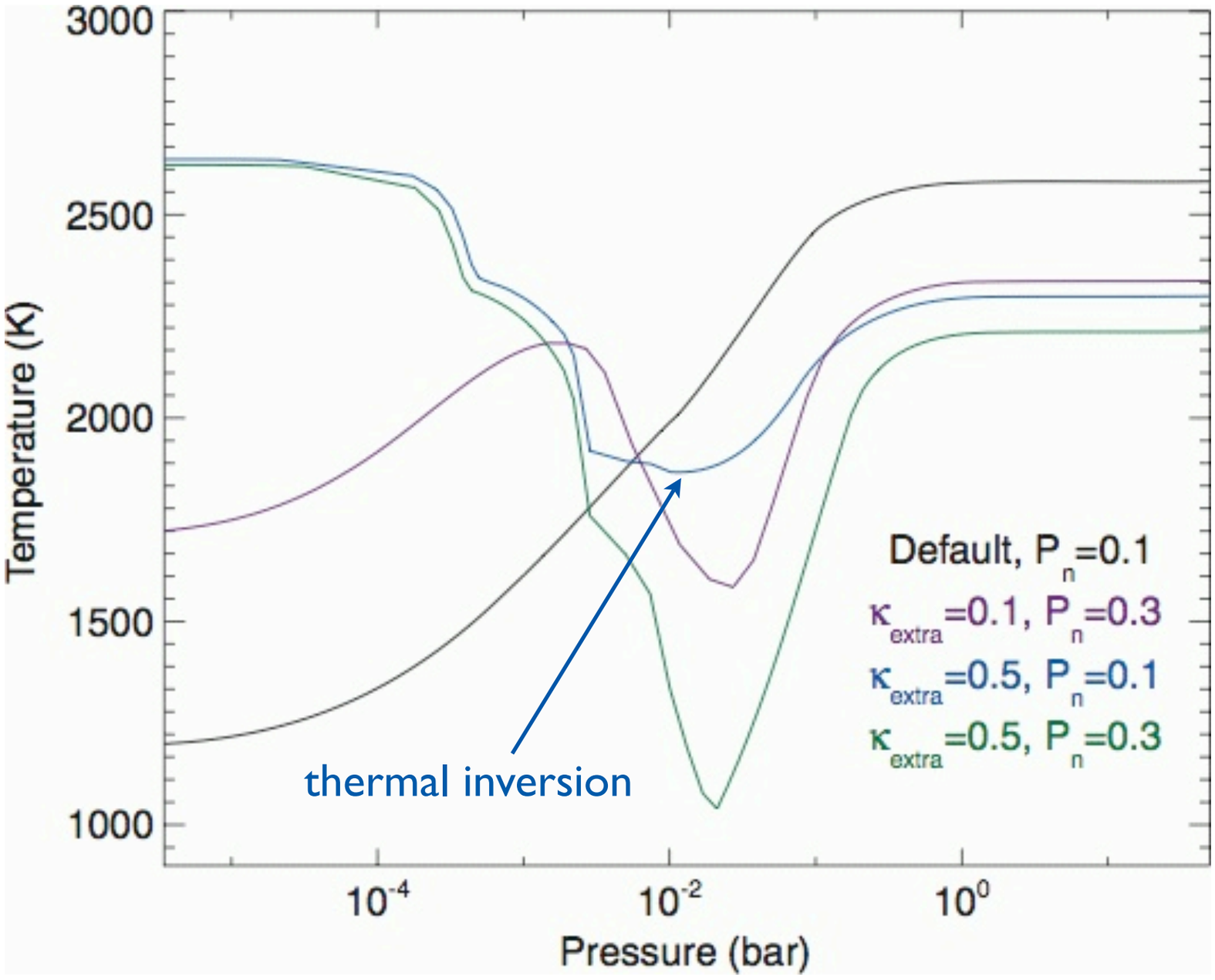
Observations of the secondary eclipse of the transiting exoplanet TrES-4 with SPITZER/IRAC (Knutson et al. 2009):





Exoplanets in the mid-IR





3.6 to 8.0 μm observations of TrES-4 reveal temperature inversion in exoplanet atmosphere (Knutson et al. 2009)!

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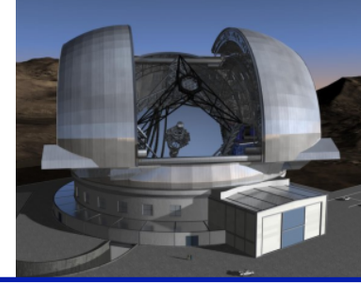
Sample

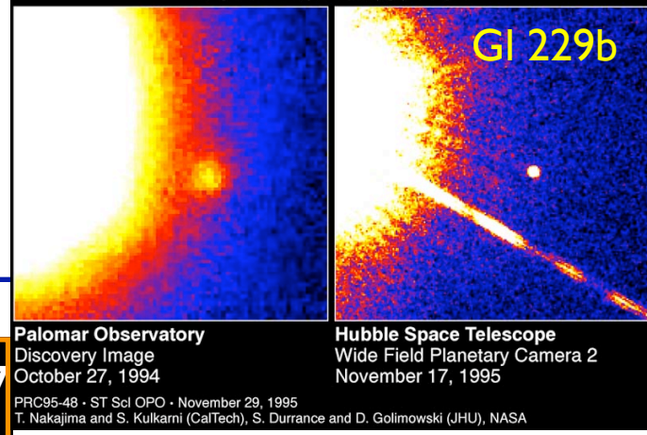


Focus on nearby stars ->

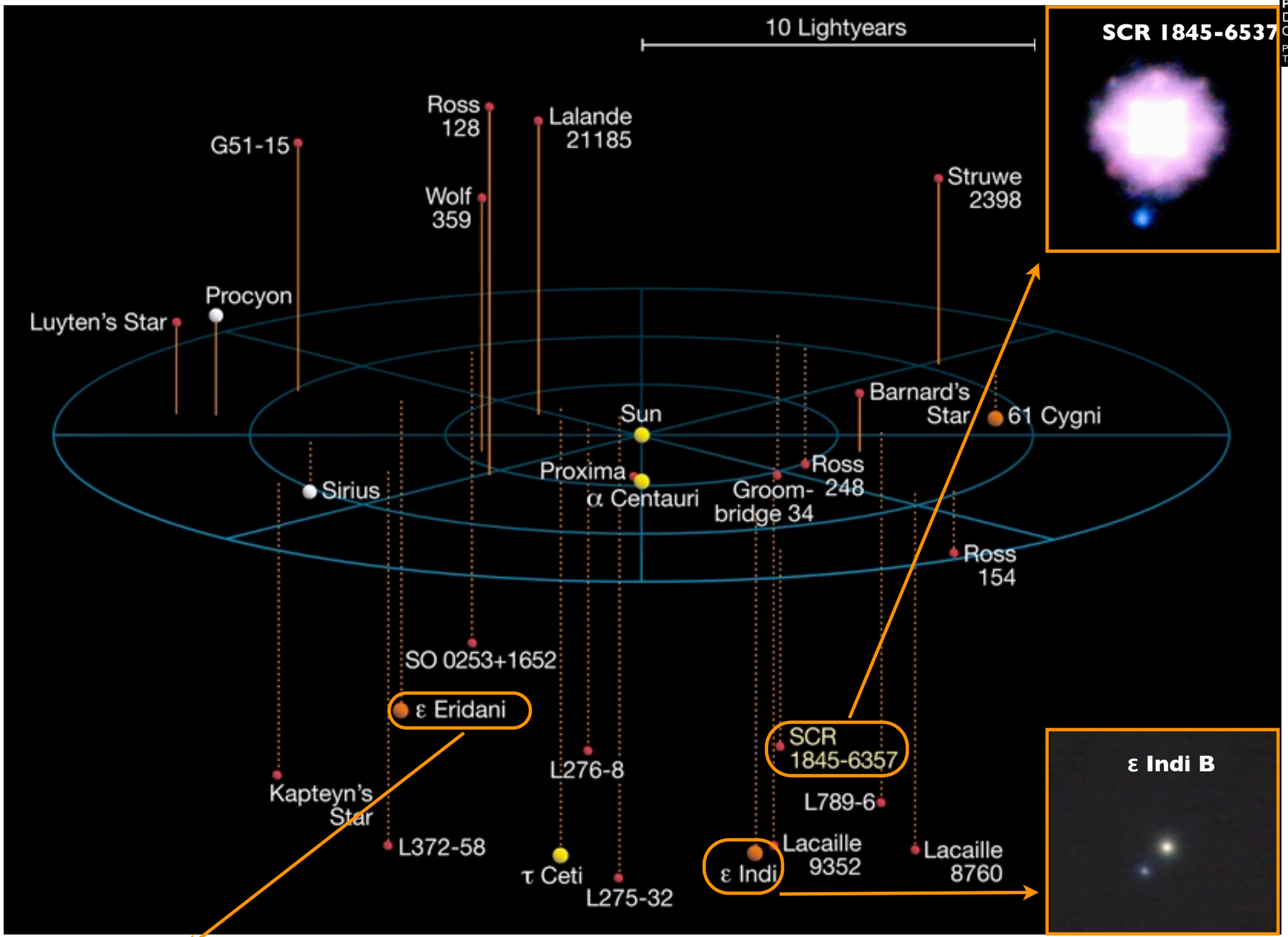
optimize detection limits with respect to planet brightness, and angular separation between star and exoplanet:
42m E-ELT PSF: FWHM = 20 mas @4μm, 50mas @10μm

distance of 5pc: 20 mas = 0.1 A.U.

Substellar companions to stars in the 6pc sample



SCR 1845-6537b has ~40 to 50 M_{Jup} (Kasper et al. 2007)



Eps Indi A has a binary brown dwarf as companion with a system mass ~120 M_{Jup} (Cardoso et al. 2009)

Eps Eps is suspected to house multiple giant planets

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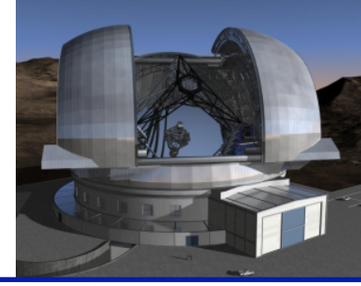
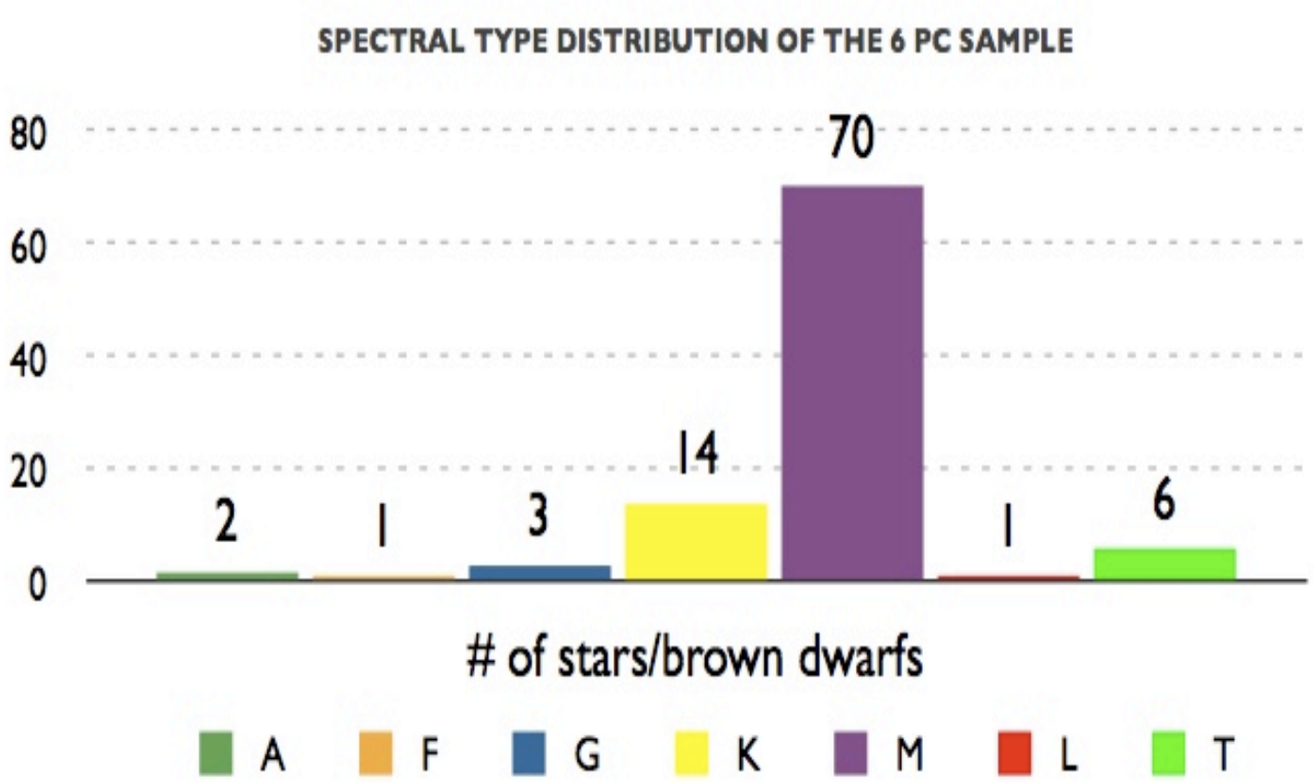
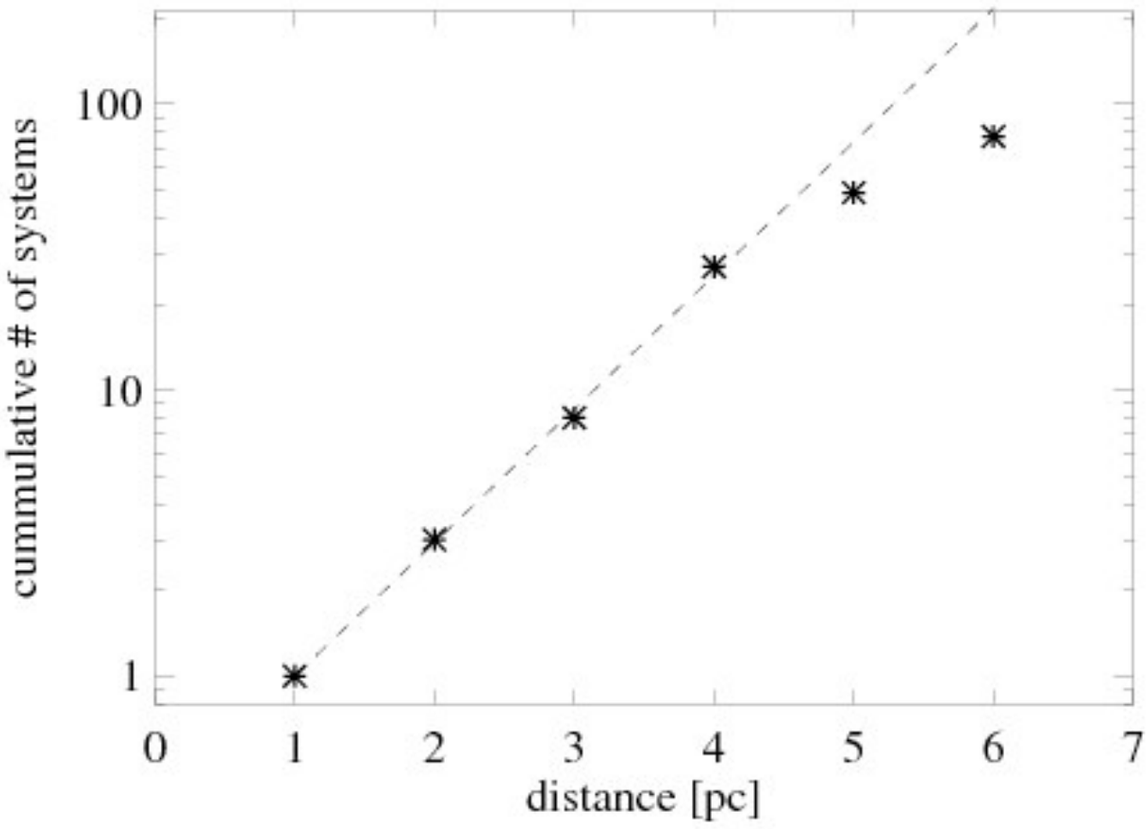
The 6 pc sample

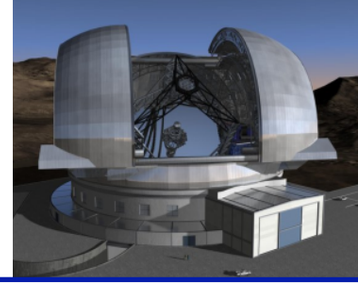


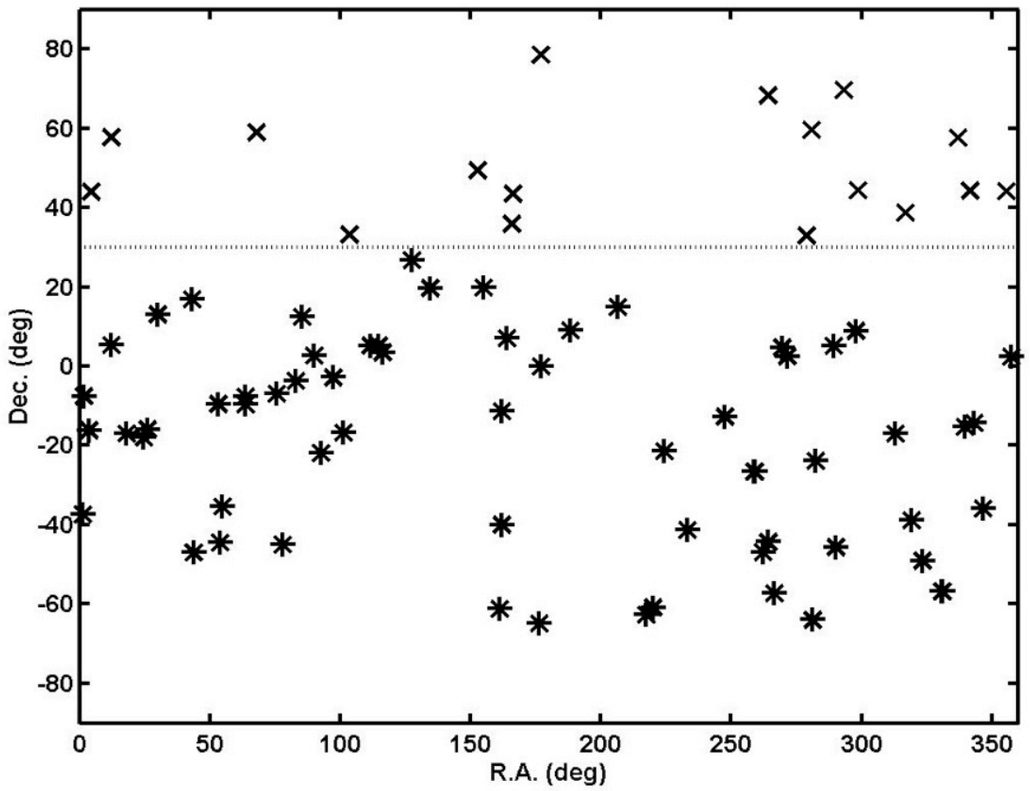




* 90 stars, dominated by K- and M-dwarfs
* L- and T-dwarfs are preferentially companions to stars
* number of systems vs. distance indicates incompleteness for dist ≥ 4 pc => up to 100(!) ultra-cool dwarfs missing?

The 6pc sample





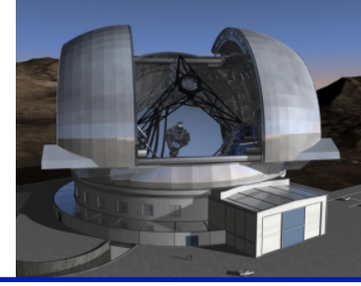
Assumption: E-ELT in the southern hemisphere:

80% of sample at declination < +30° (> -30°)

up to 70 stars to be surveyed from the southern hemisphere

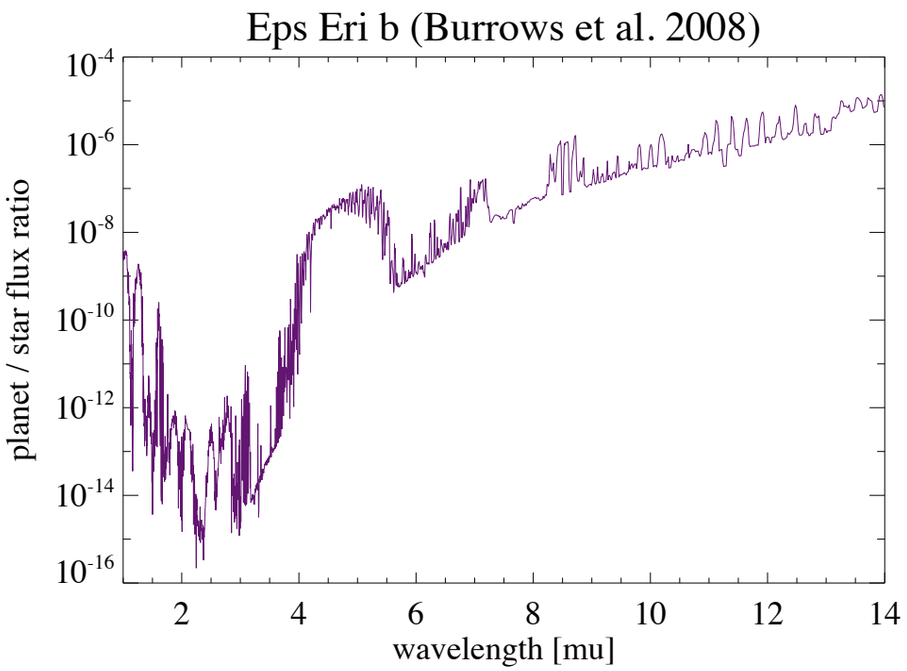
Primary targets: follow-up on exoplanets detected by VLT/SPHERE, VLTI/PRIMA & GRAVITY

METIS Instrument Science requirements

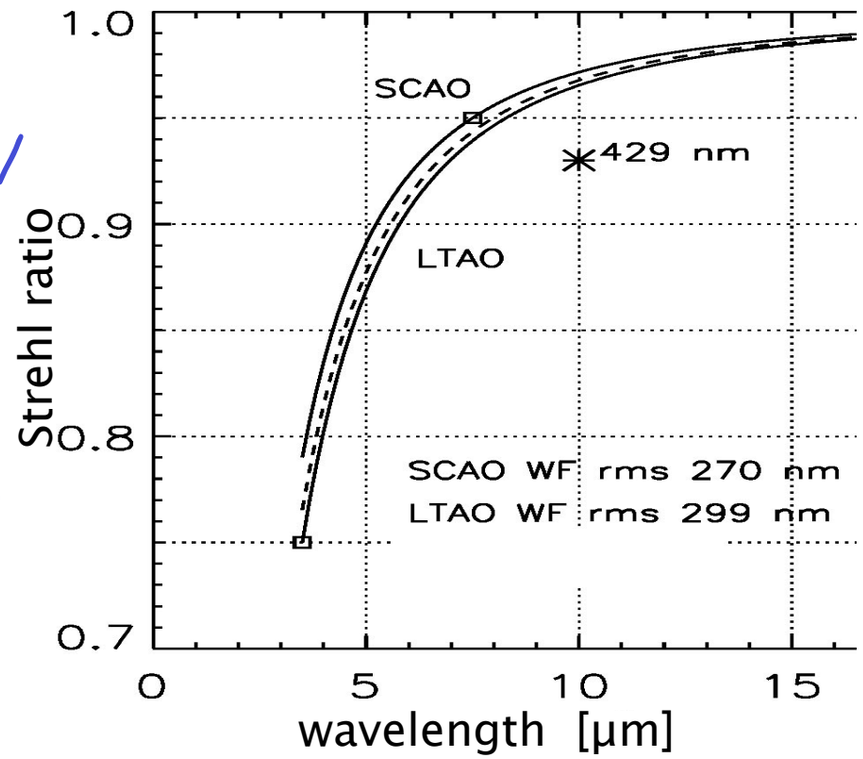


- Wavelength range: 3 to 14 µm
- Imager:
  - diffraction limited (Nyquist sampling) at 3.5 and 7 µm
  - coronagraph (4-quadrant phase mask?!)
- Spectrograph: low-resolution (R≤3000), long slit (LMN)
- visual NGS wavefront sensor, aim: Strehl ratio ≥90% in N-band on bright sources (V≤13mag)

Note on contrast and image quality

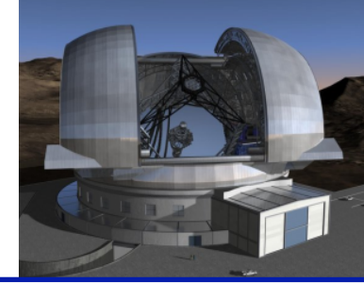


* brightness ratio star / planet better in the thermal IR: 10^9 @1µm-> 10^7 @10µm
* Strehl ratio increases with observing wavelength

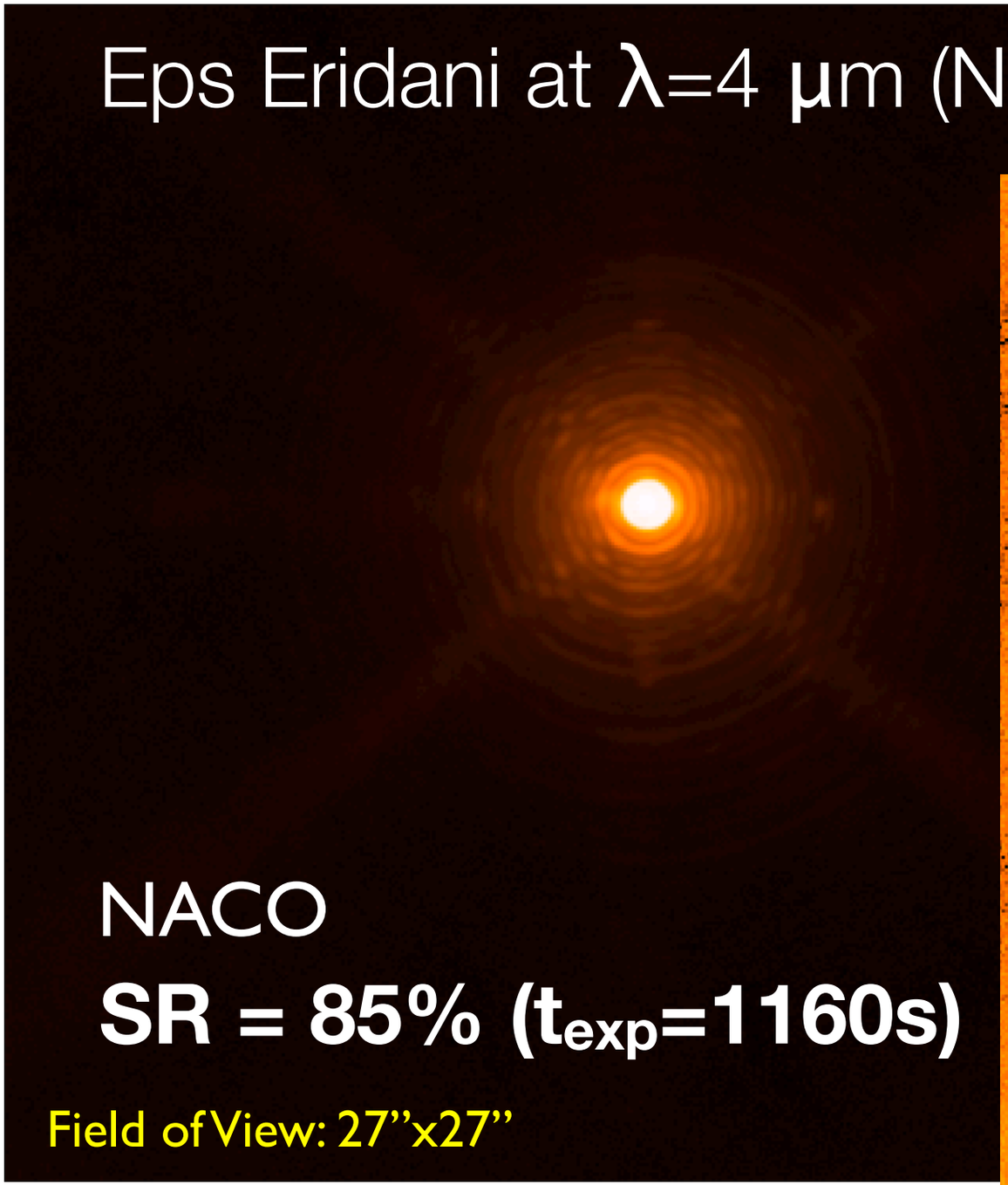


METIS

"Extreme AO" at the VLT



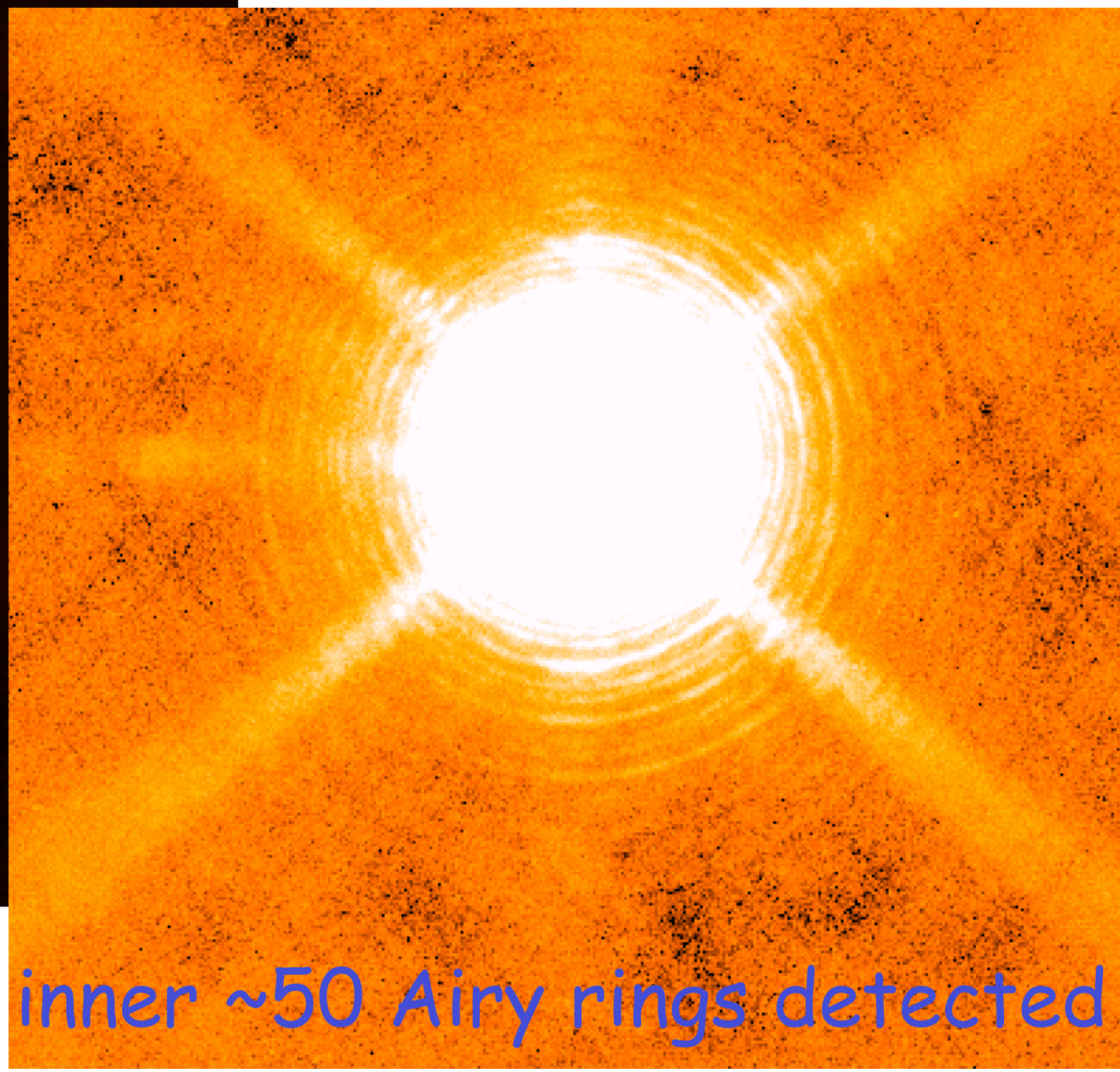
Eps Eridani at λ=4 μm (NB4.05)



NACO

SR = 85% (t_{exp}=1160s)

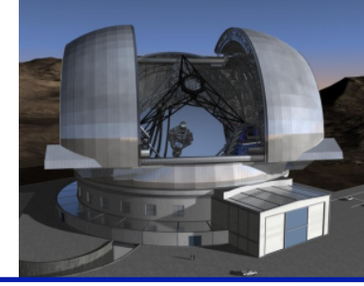
Field of View: 27"x27"

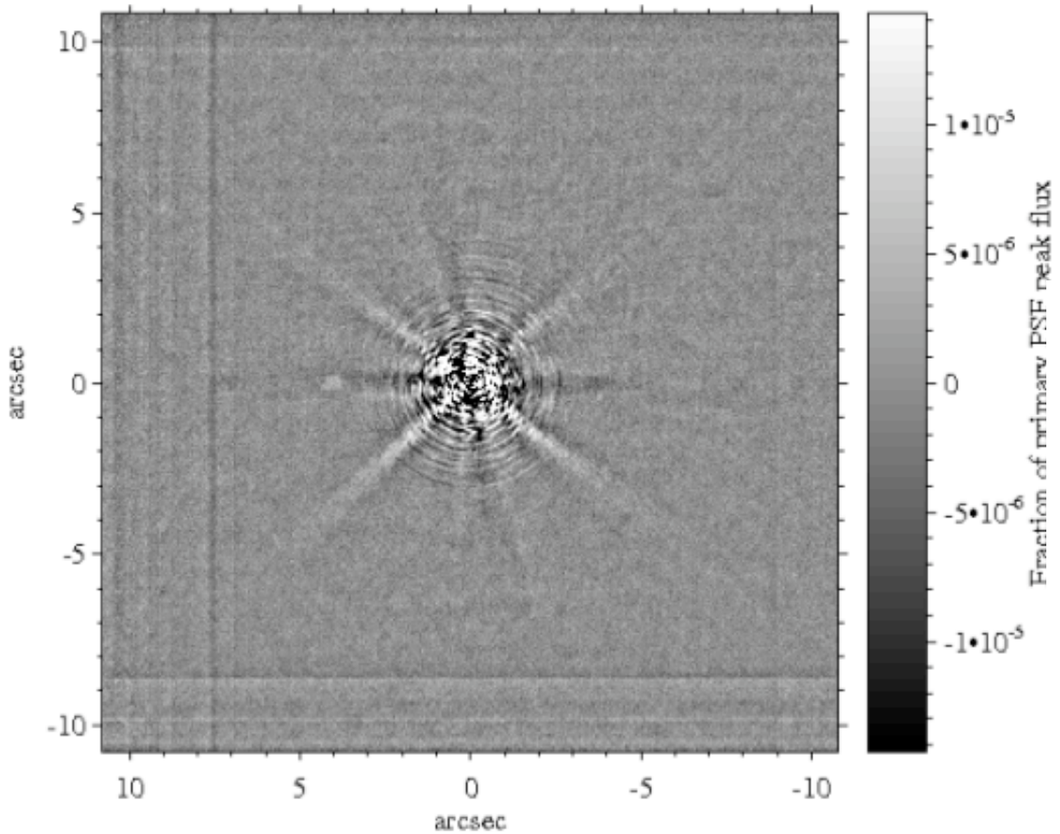


inner ~50 Airy rings detected

Janson et al. 2008, A&A 488, 771

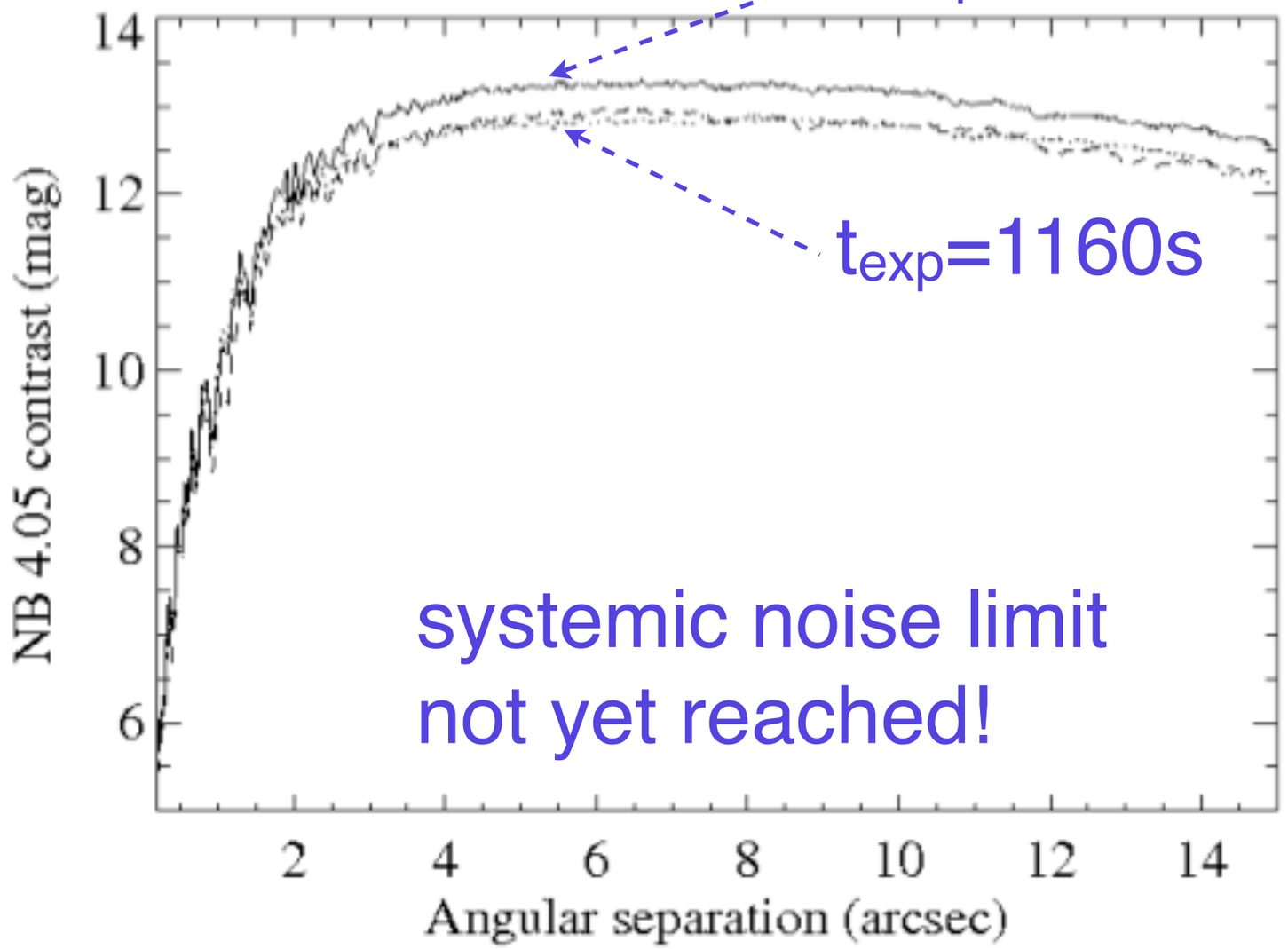
METIS "Extreme AO" with VLT/NACO





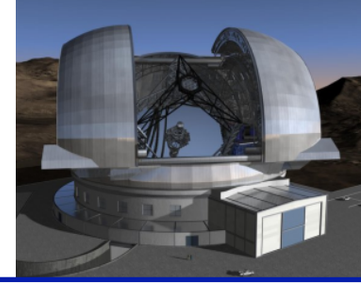
Difference image

ADI contrast: ≤ 2*10^5



Janson et al. 2008, A&A 488, 771

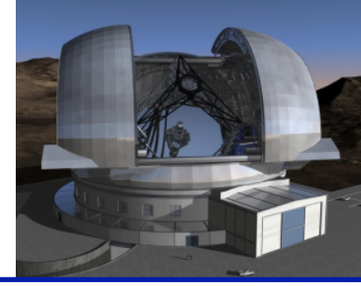
Simulations

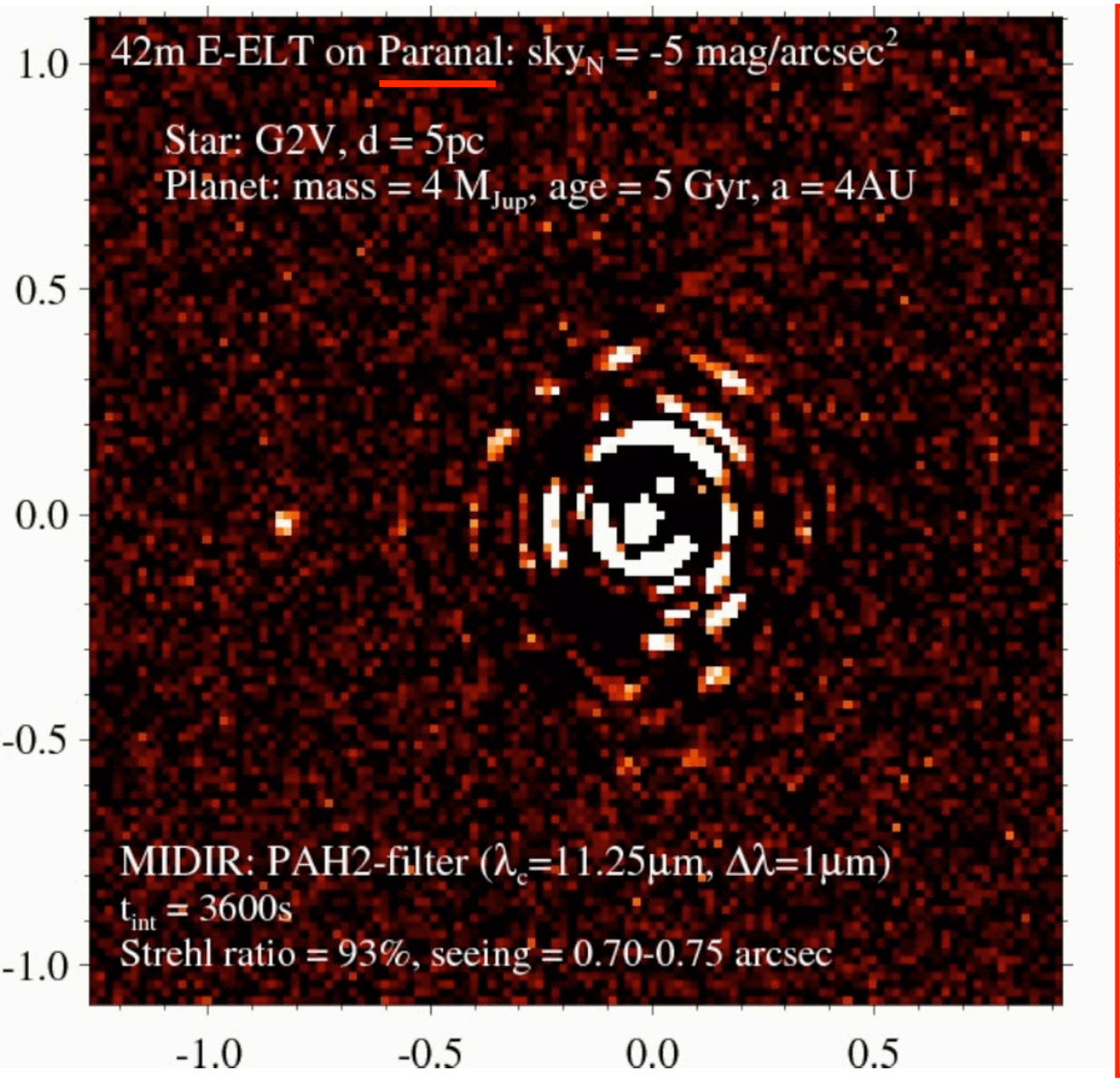


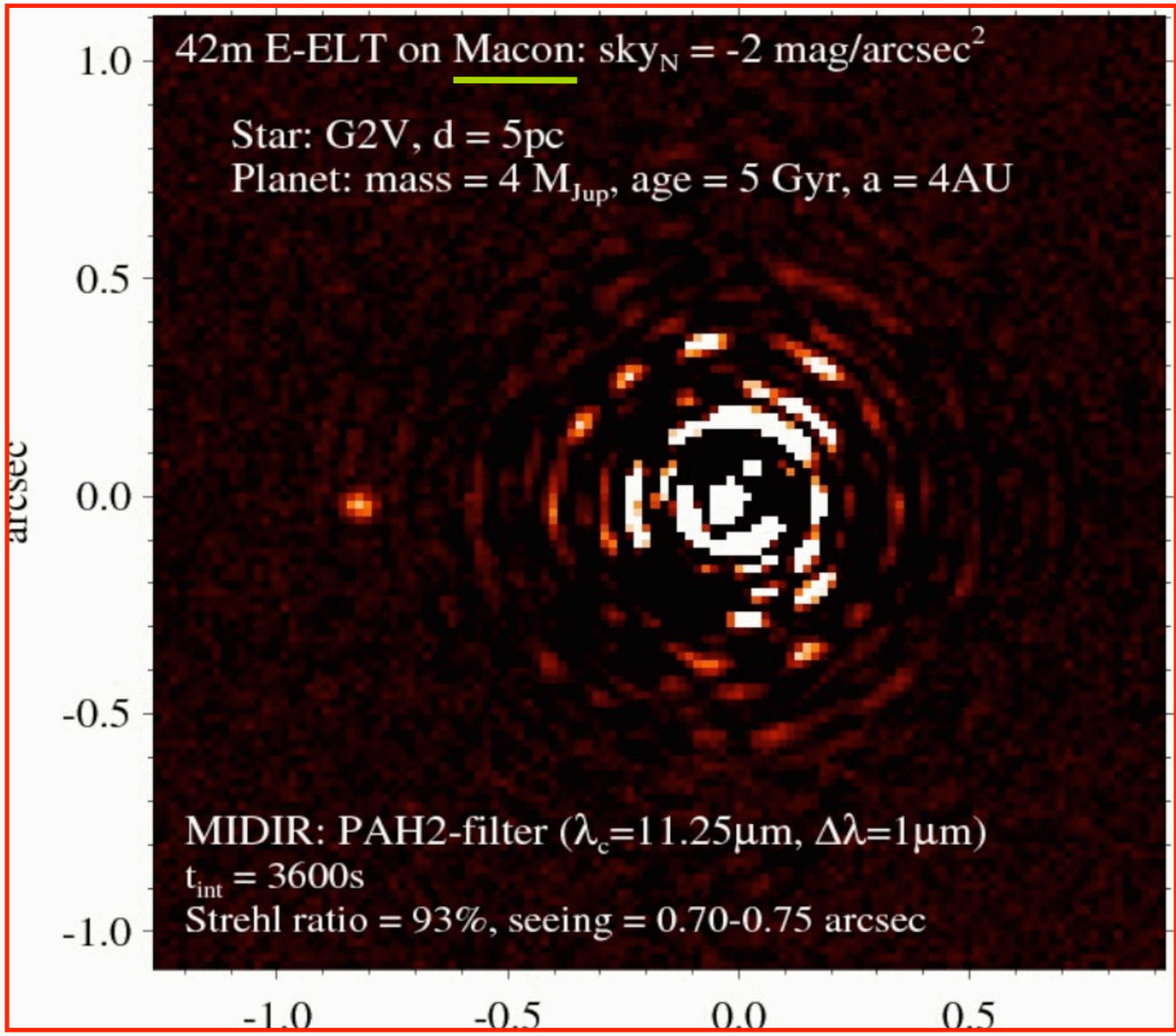
- Photon statistics: background noise limit
- Based on AO-corrected E-ELT PSF provided by ESO Adaptive Optics group
- PSF variations due to seeing (0.70" to 0.75")

METIS

Direct Imaging - "wide field"



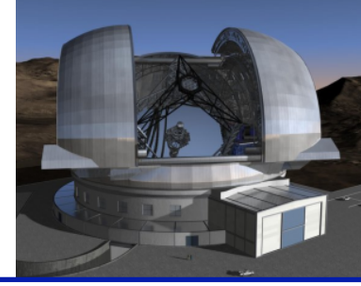


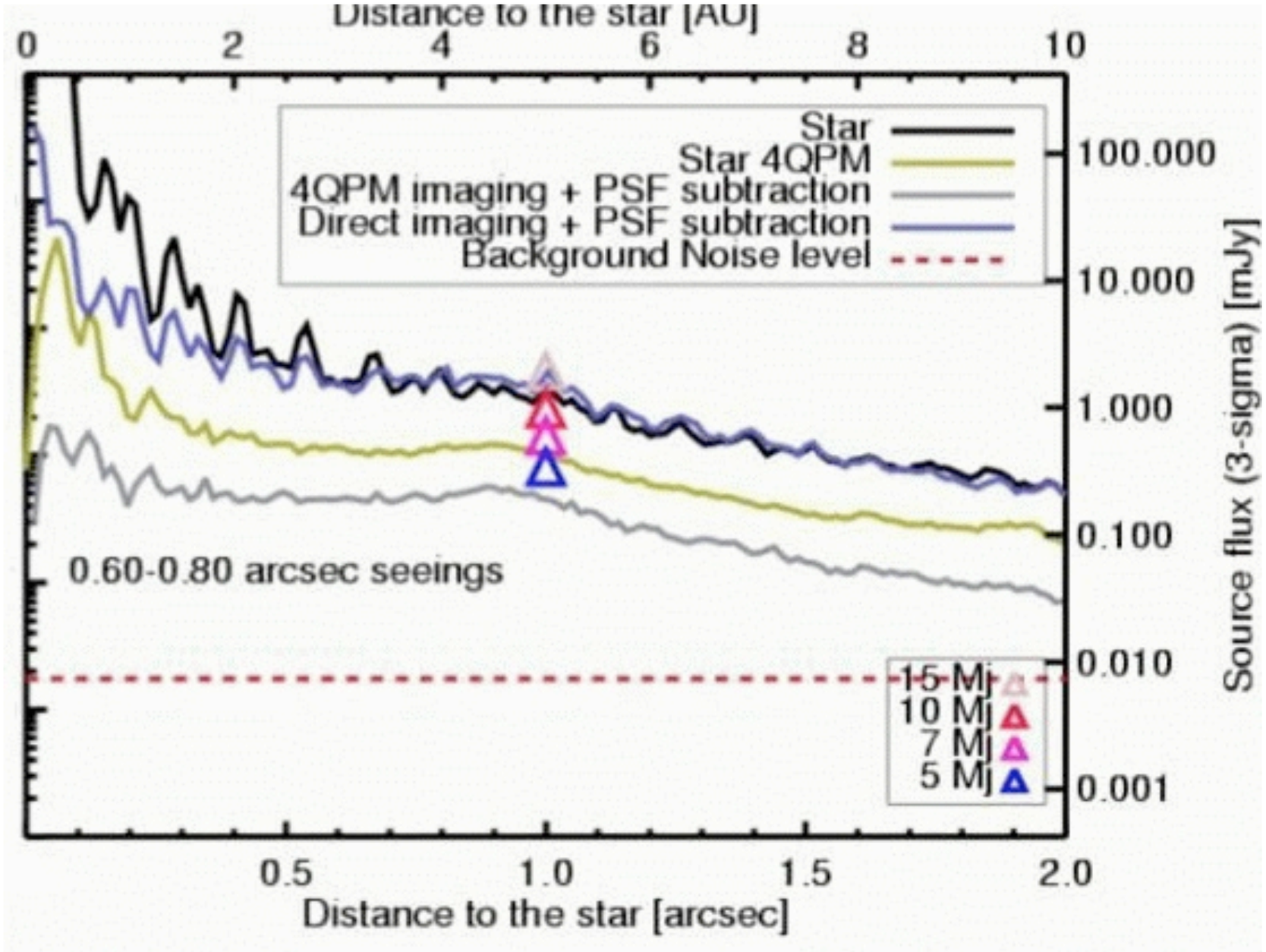


Complementary to EPICS detections of Giant Planets in reflected light

Residuals of PSF subtraction limits close-in contrast-> **coronagraph**

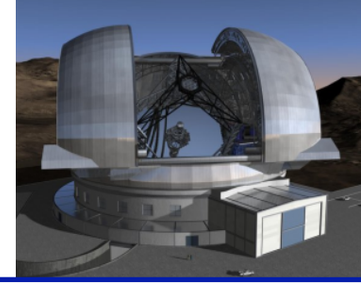
METIS Coronagraphic imaging: "narrow" field



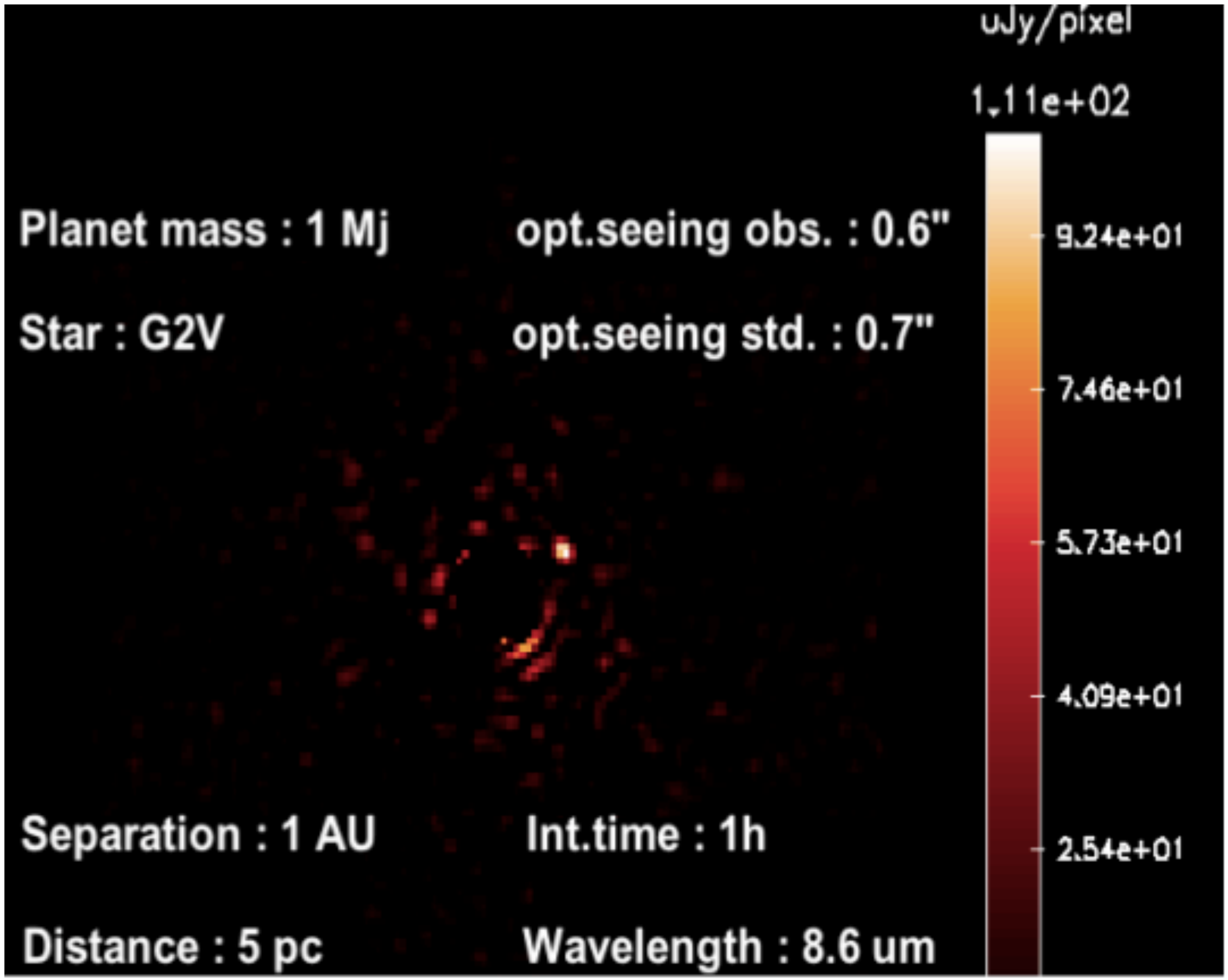


4QPM: contrast improvement by 10 (wide field) to ~100 (@0.2")

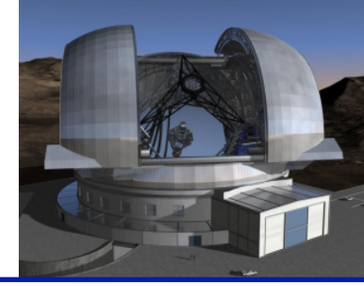
Coronagraphic imaging: "narrow" field



Young Solar System with E-ELT/METIS from 5 pc distance

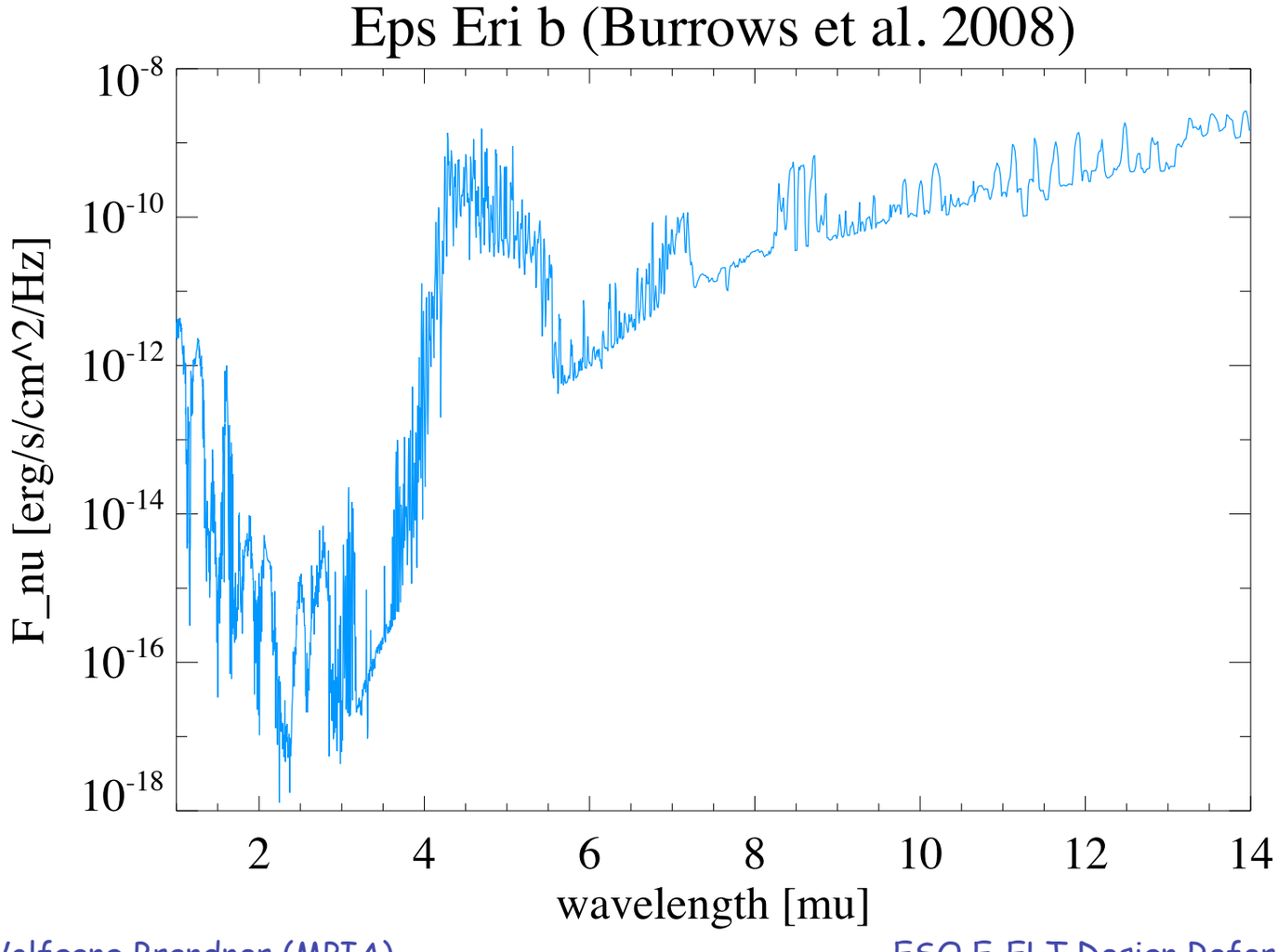


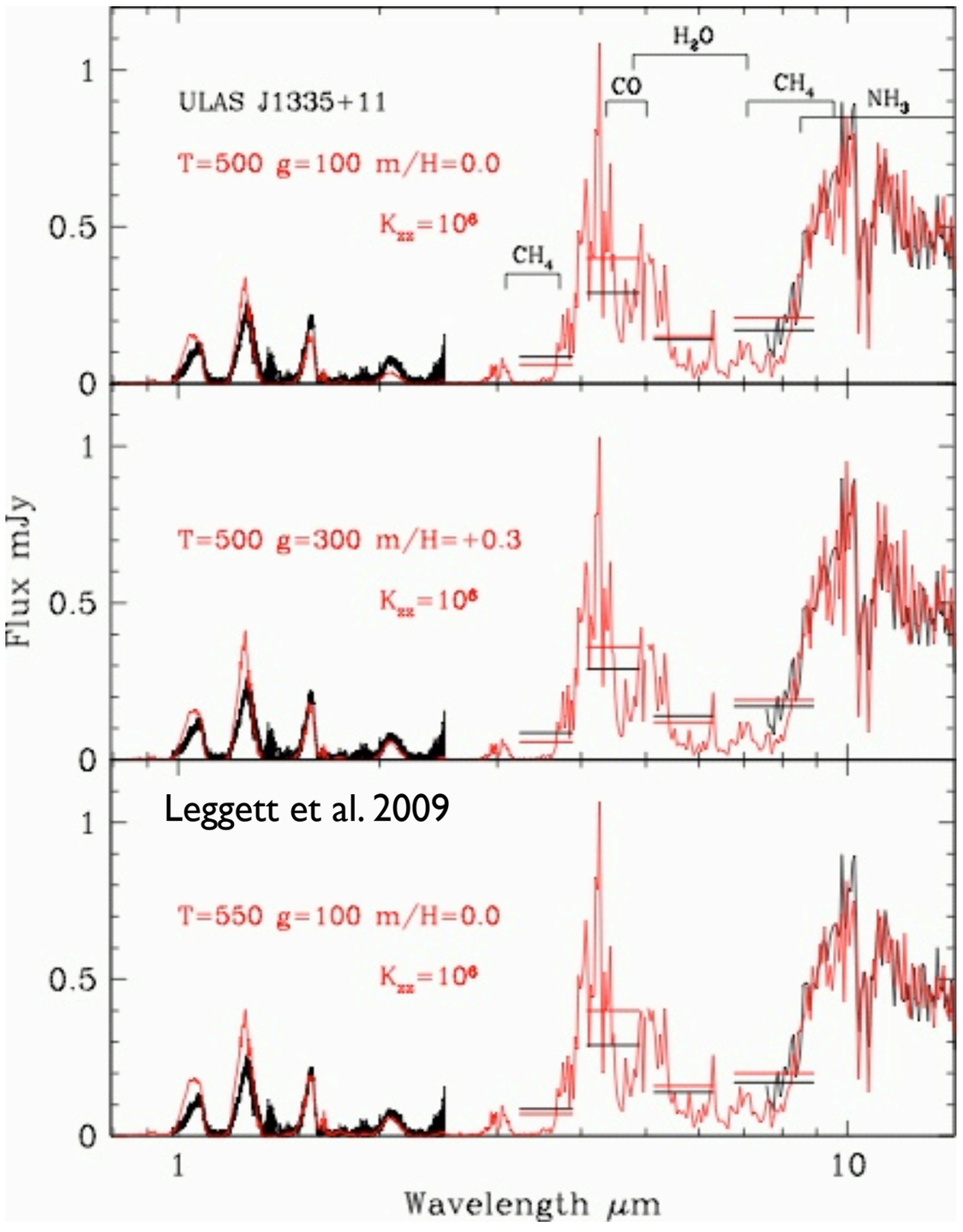
Spectroscopic follow-up



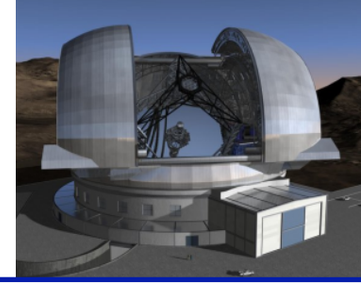
L-M-N band low-res spectra:

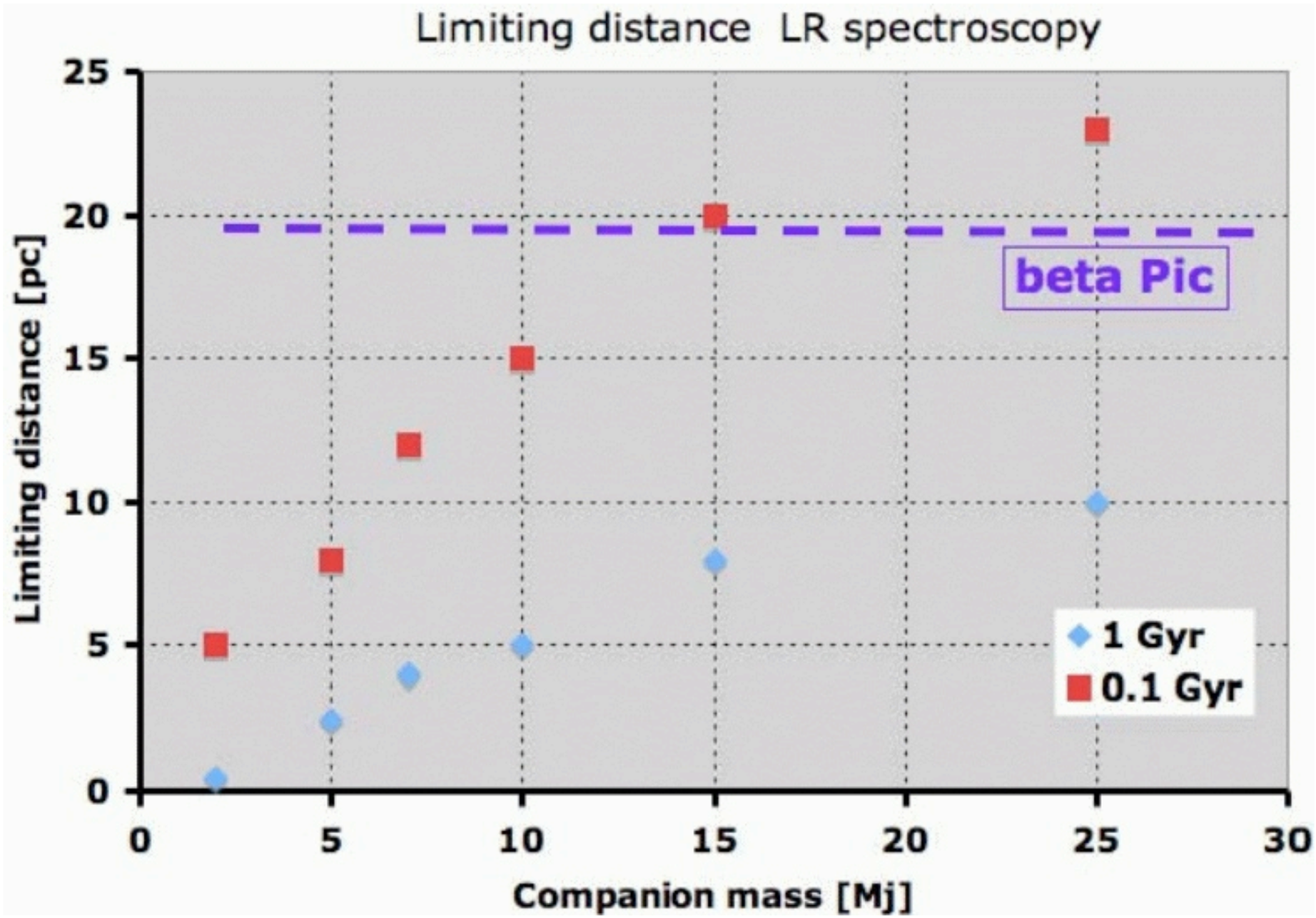
CH_4 , CO, NH_3, C_2H_4, H_2O …





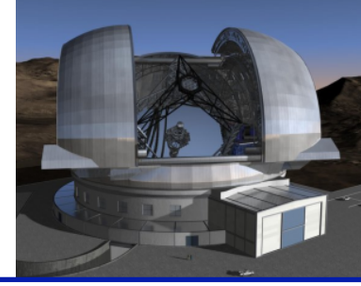
METIS N band low-resolution spectroscopy





detection limits have to be re-evaluated assuming non-equilibrium chemistry!

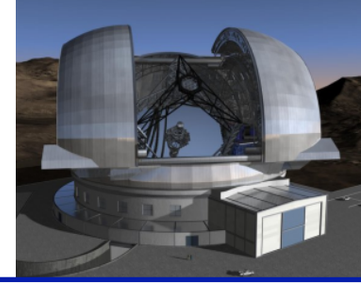
METIS discovery space



Aka "The co-optition"

* E-ELT/METIS: diffraction-limited resolution 6.5 times better than JWST/MIRI
* Follow-up on exoplanets detected by VLT/SPHERE and VLTI/PRIMA & GRAVITY
* Complementary to E-ELT/EPICS, which detects exoplanets primarily in reflected light, while METIS studies intrinsic thermal emission from exoplanets

Summary: Science Goals



Scientific topics addressed by direct detections of giant exoplanets in the mid-IR:

* Exoplanet orbital parameters (astrometry)
* Atmospheric composition and chemistry
* Temperature profile
* Internal structure (radius, mass)
* Weather and seasons
* Formation of giant planets (core accretion, disk instability)