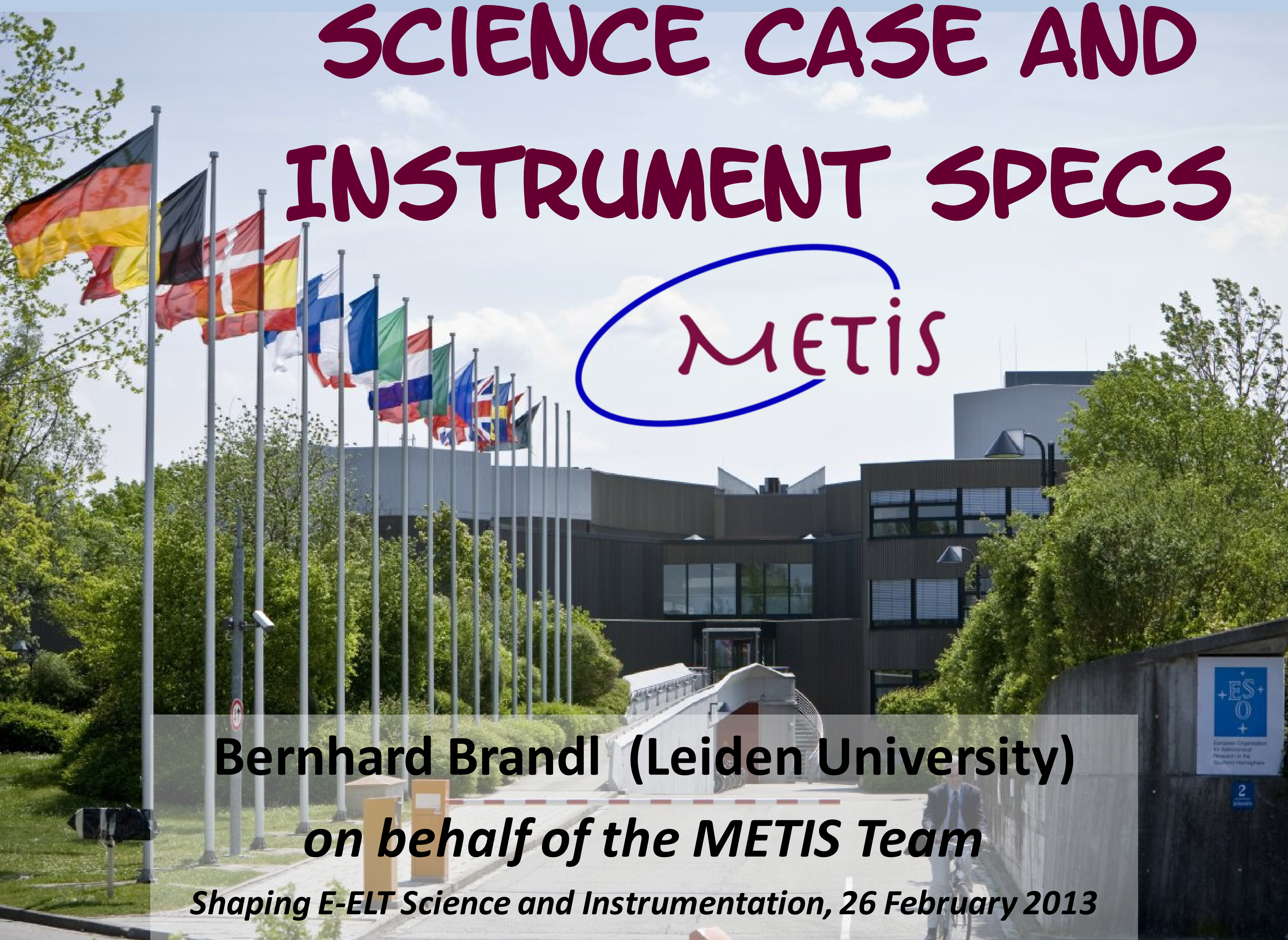
SCIENCE CASE AND INSTRUMENT SPECS

METIS



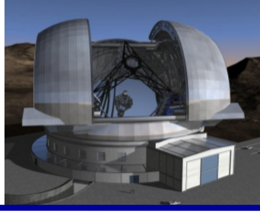
Bernhard Brandl (Leiden University)

on behalf of the METIS Team

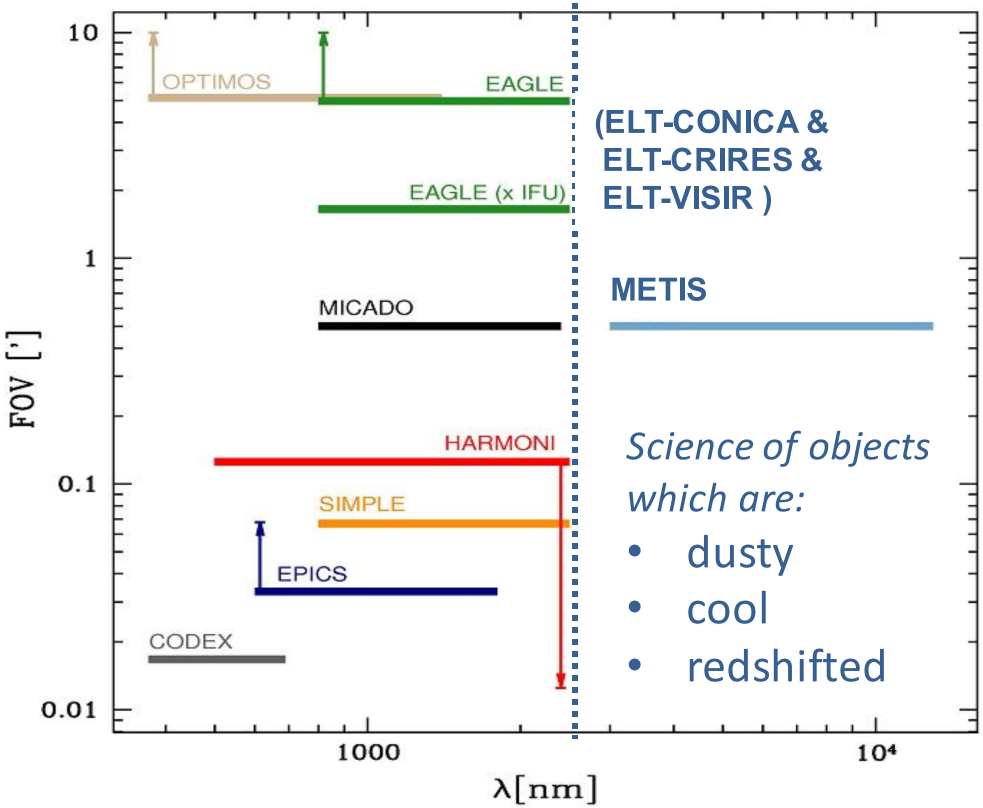
Shaping E-ELT Science and Instrumentation, 26 February 2013

Introduction

What is METIS?

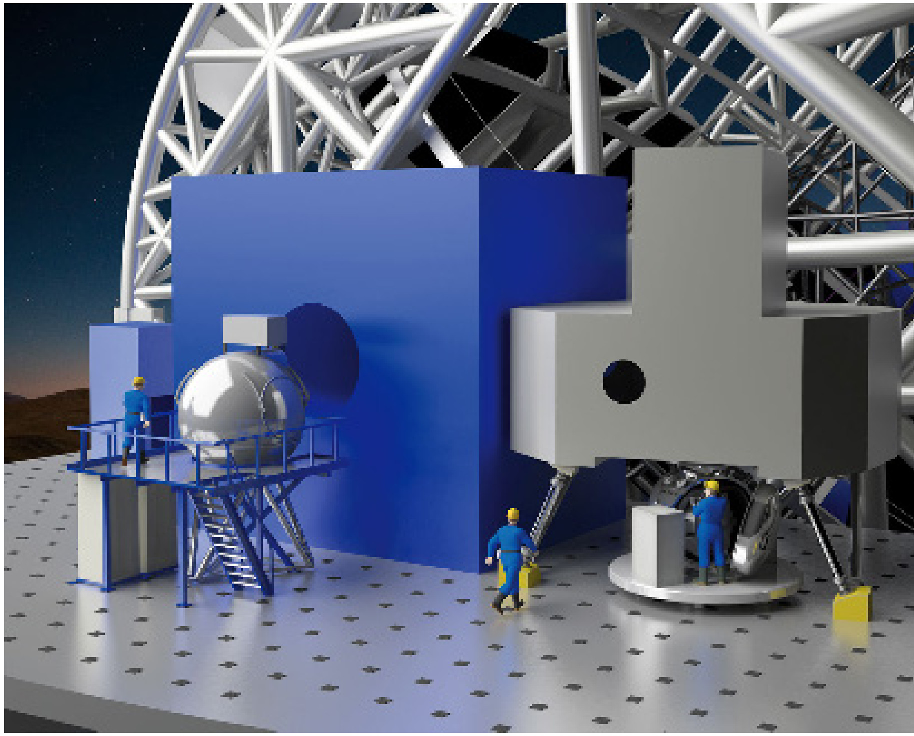


The '**M**id-infrared **ELT** **I**mager and **S**pectrograph' METIS is *the* instrument for the thermal infrared (λ > 3 µm)

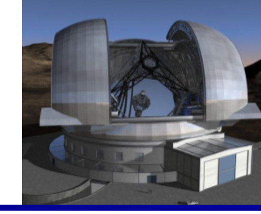


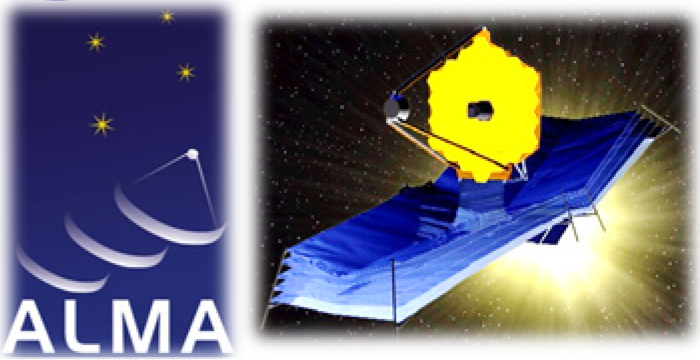
Science of objects which are:

- dusty
- cool
- redshifted



Considerations

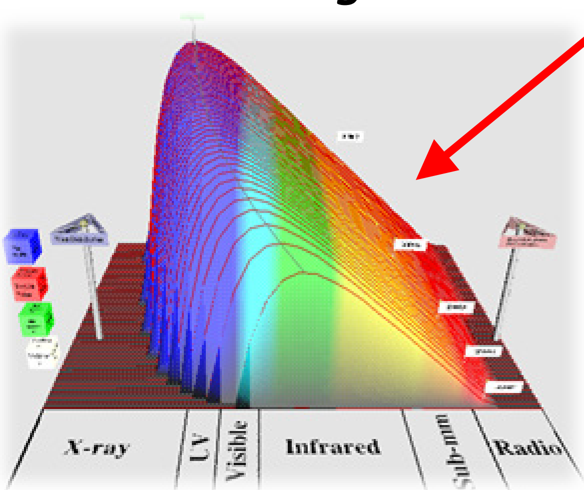




Complementarity

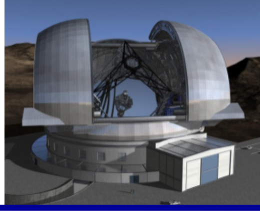
Resolution & Sensitivity

Thermal Background



Cost & Complexity

Instrument Baseline

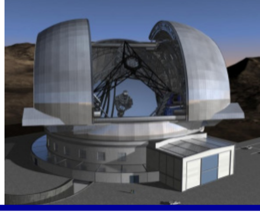


1. An **imager** at **L/M & N** band with an 18″×18″ wide FOV. The imager includes:
   - **coronagraphy** at L/M and N-band
   - **long slit,** low-resolution (R ~ 5000) **spectroscopy** at L/M & N
   - **polarimetry** at N-band [TBC]

2. An **IFU** fed, **high resolution spectrograph** at **L/M** band [2.9 – 5.3µm] with a FoV of ≈0.4″×1.5″ and a spectral resolution of R≈100,000.

*All subsystems work at the diffraction limit (**SCAO & LTAO**)*

The METIS Consortium



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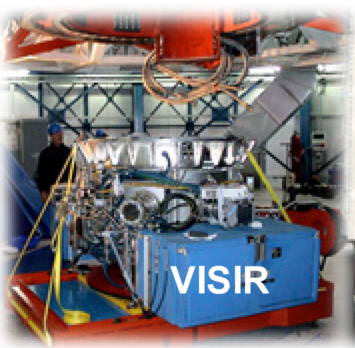
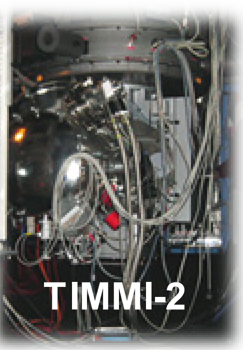
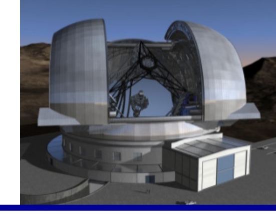
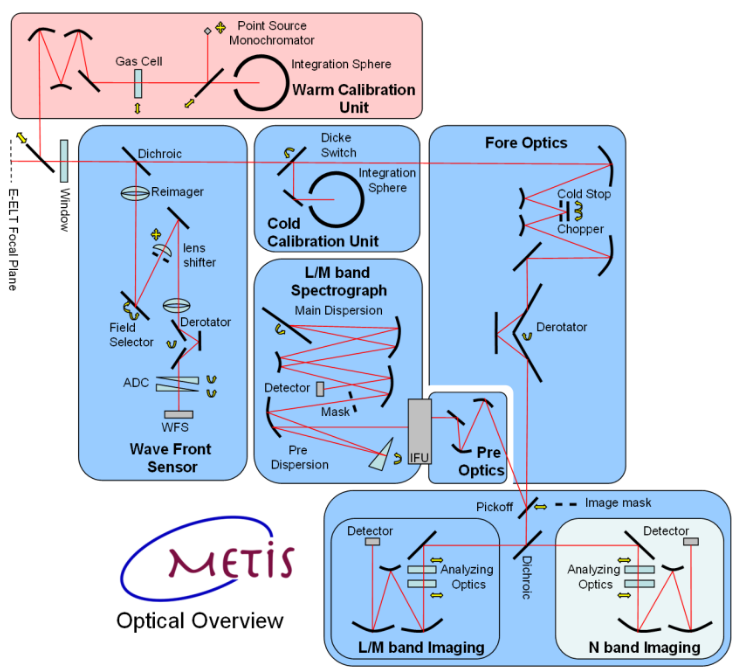




Partners and WPs



- Backbone structure
- Imager
- Mecha-nisms
- HR/IFU spectrogr.
- Operation & calibrat.
- Cryo-vac system
- Data-red. software
- Common fore-optic
- Adaptive Optics
- Calibrat. units
- Windows/ dichroics
- Control electronic
- GSE/hexa pod
- AIT (@sys lev)
- PI / Mana-gement

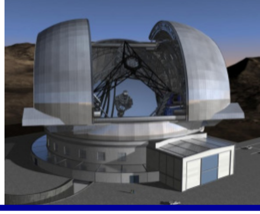


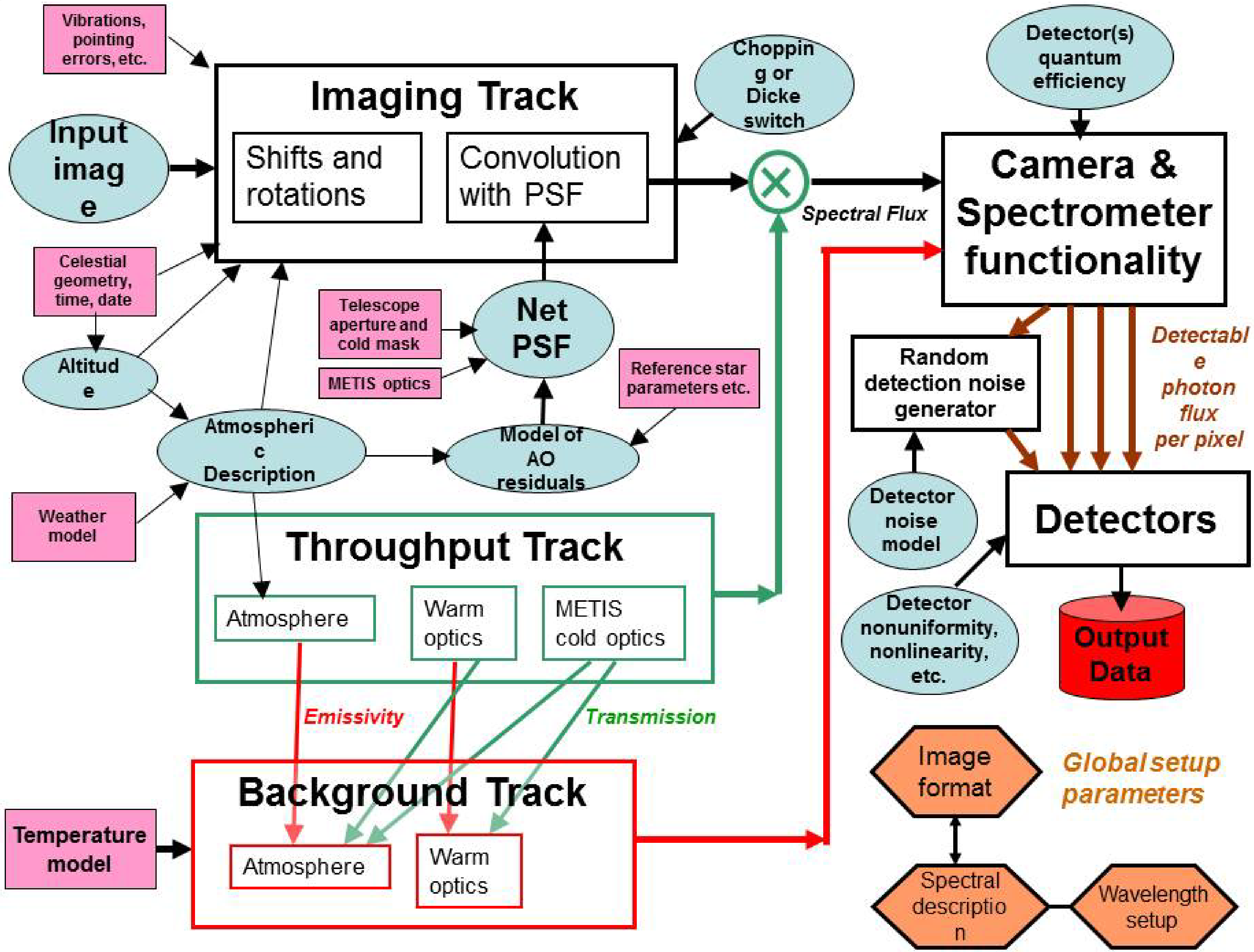
SE - Lars Venema

PM - Frank Molster

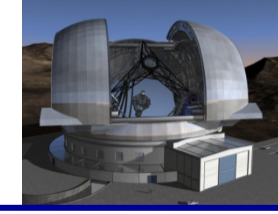
26/02/2013

Instrument Simulator



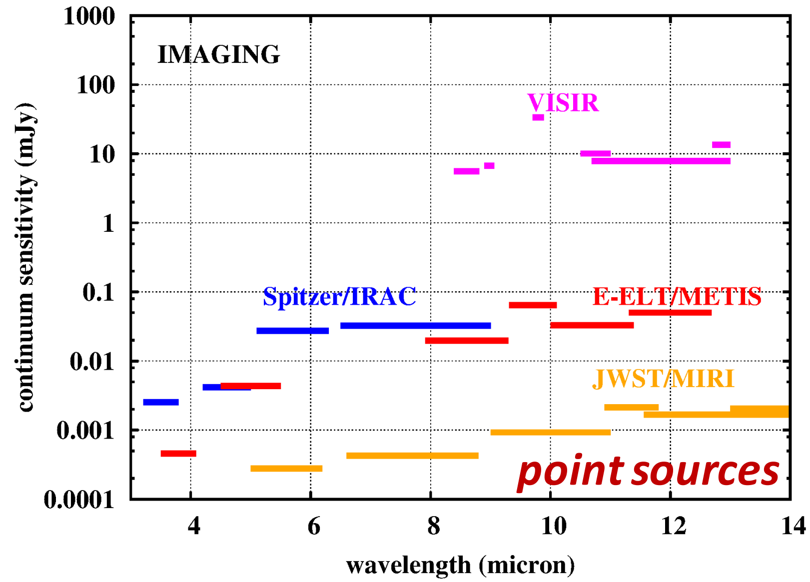


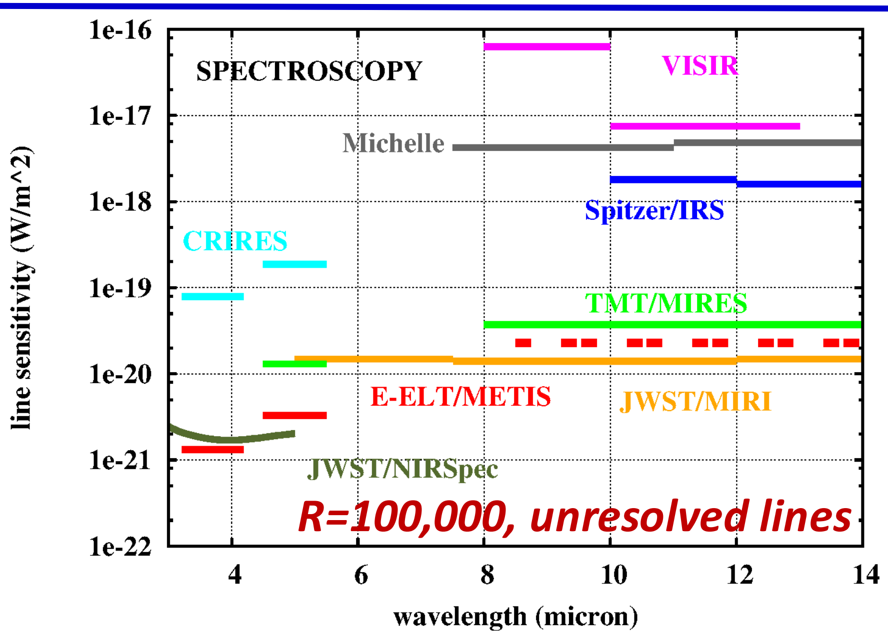
Sensitivity

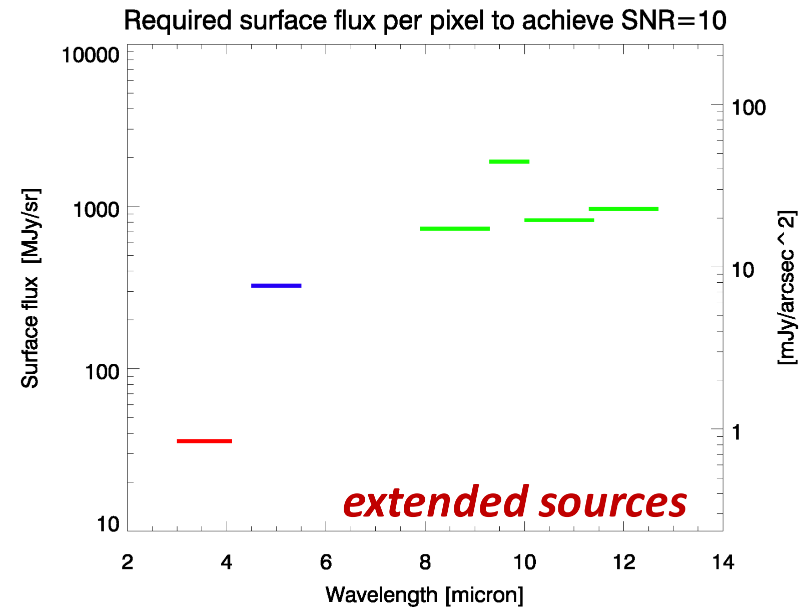


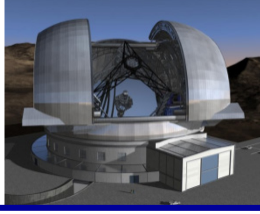
Assumptions:

- 37m E-ELT
- 11.1m obscuration
- 15% emissivity + spiders
- t_{int} = 1hr
- S/N = 10σ









METIS Take-away Message:

METIS will provide:

HST-like resolution but at mid-IR wavelengths

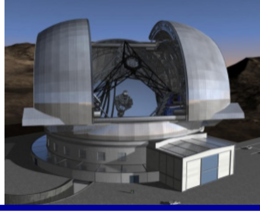
Spitzer/IRAC-like imaging sensitivity (point sources)

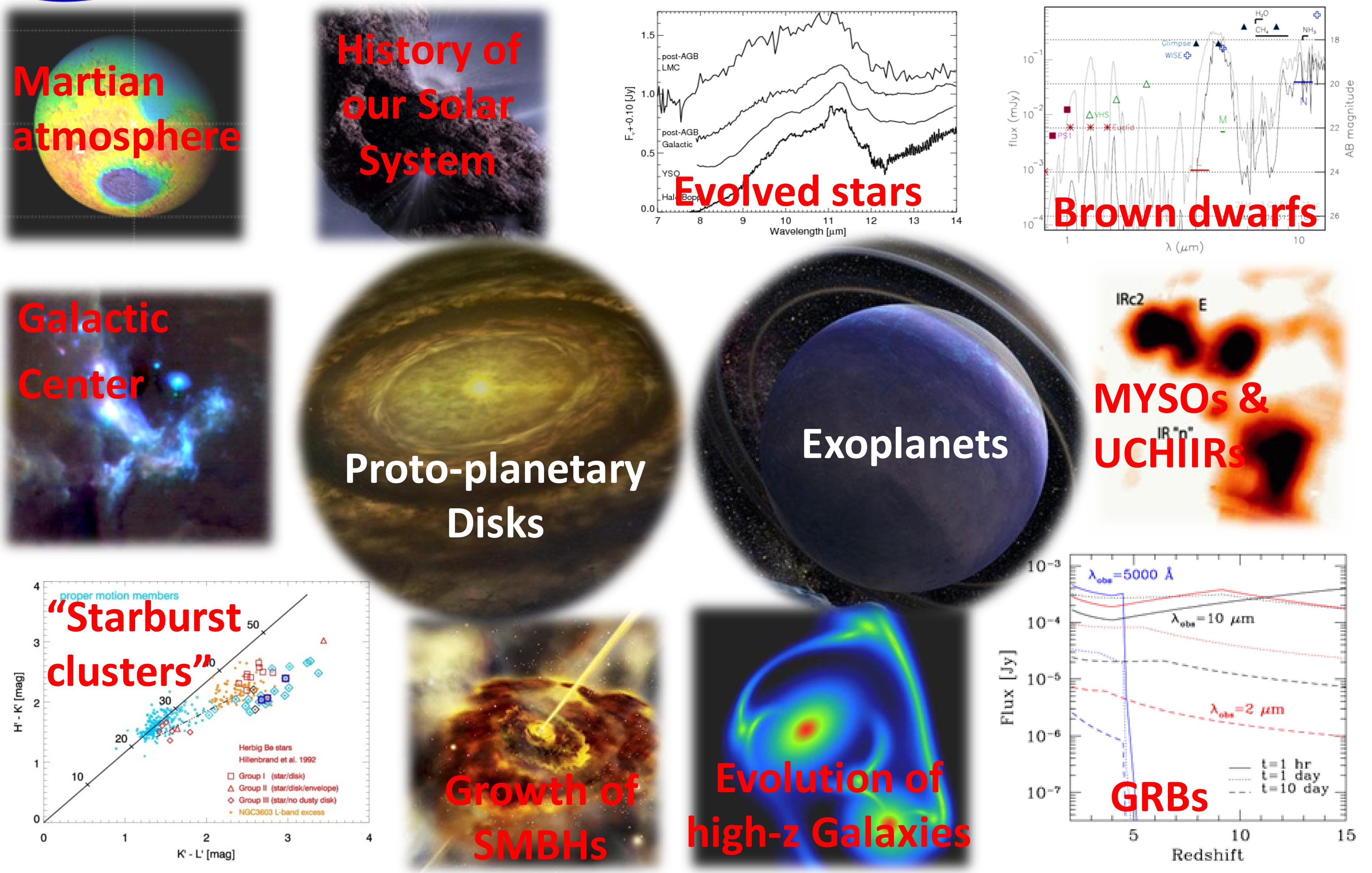
JWST/NIRSPEC-like line sensitivity @ 3-5µm (unresolved lines)

METIS Science

Overview

Science Drivers

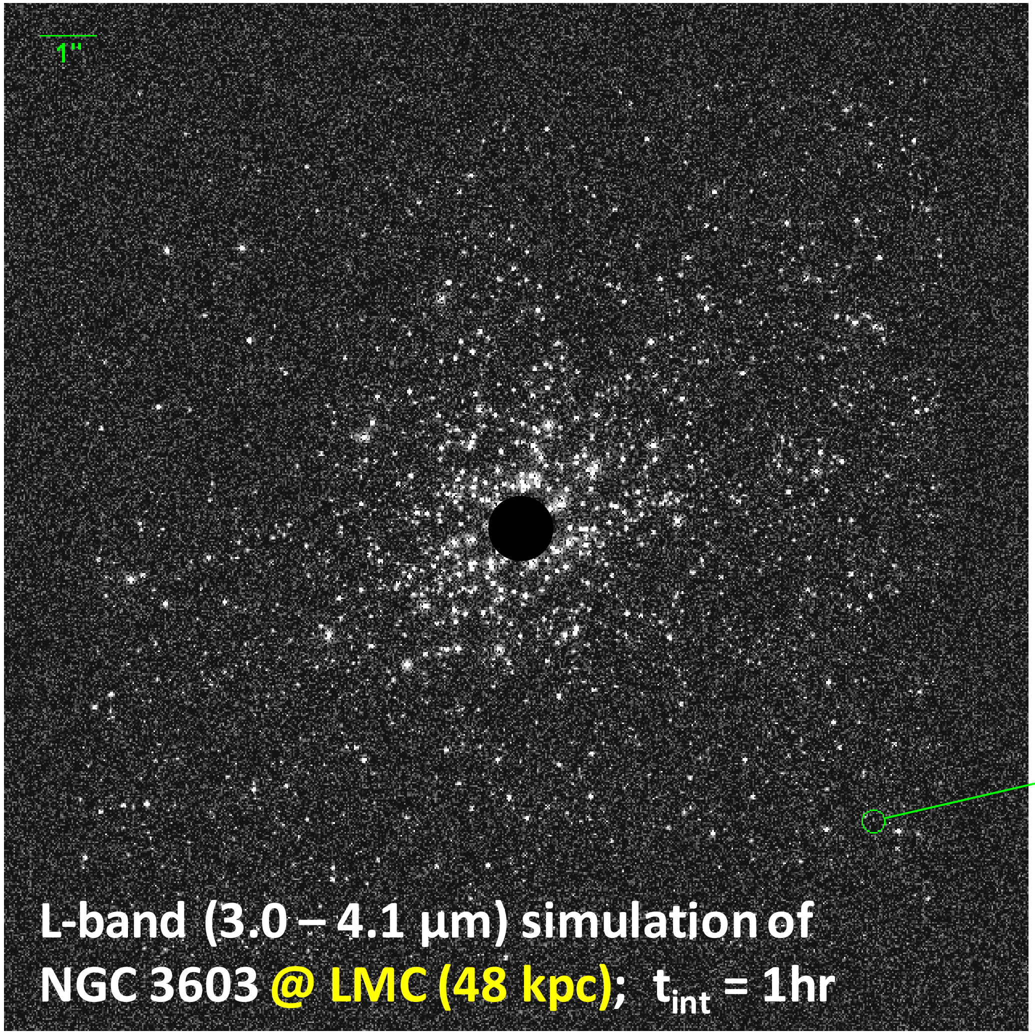


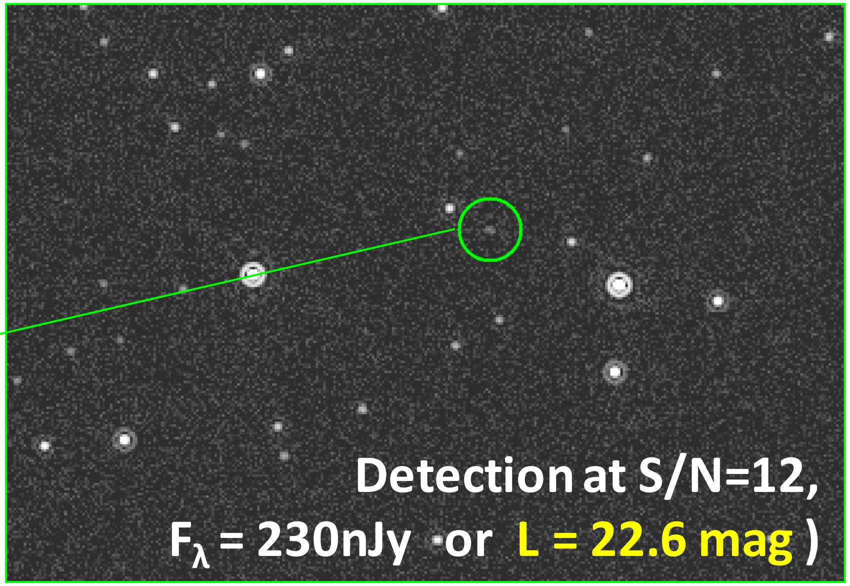


"Starburst Clusters"

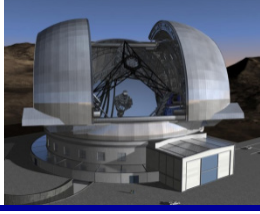
Mass segregation & IMF ← cluster membership

Evolution of disks in extreme environments

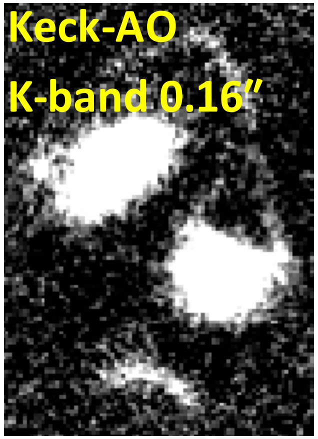


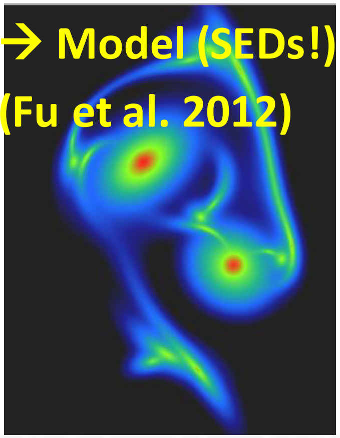


Morphology & Evolution of IR Luminous Galaxies

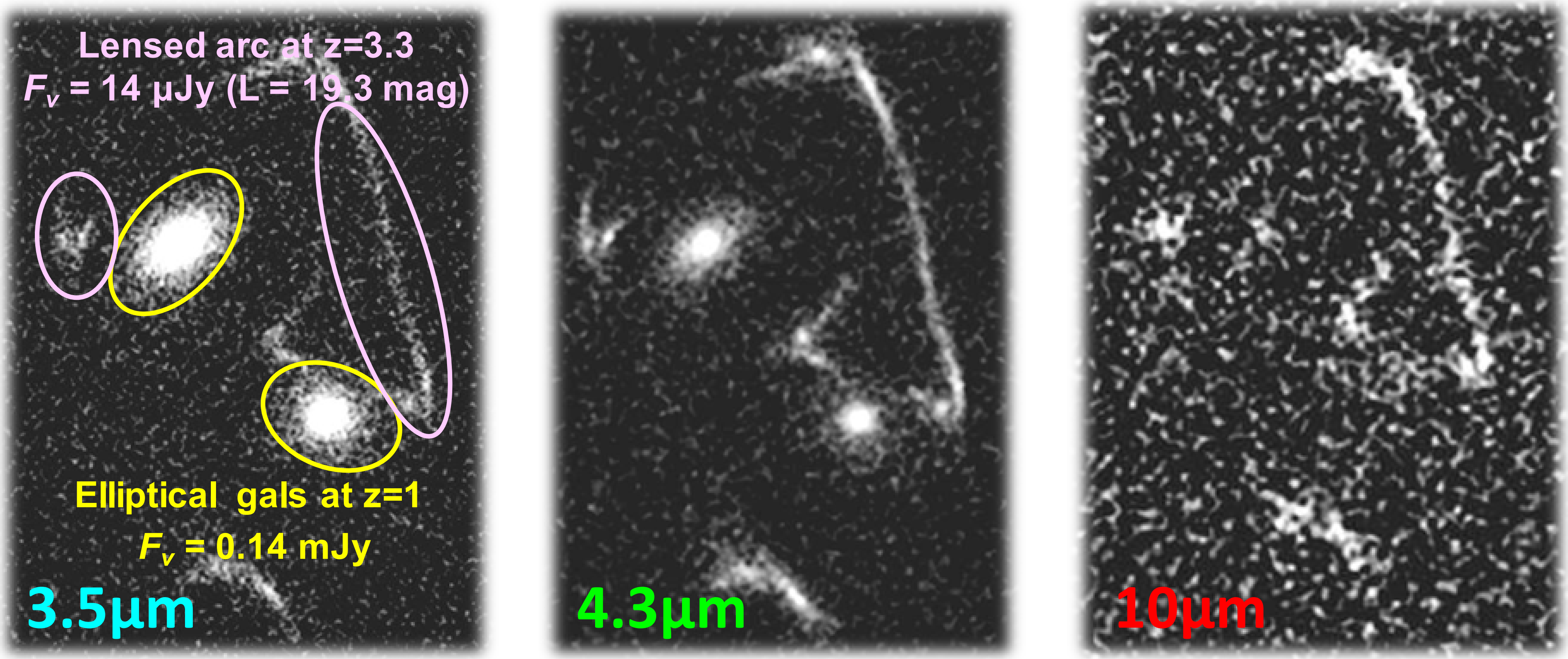


Feasibility study: Two ellipticals at z = 1 and a lensed sub-mm galaxy at z = 3.3



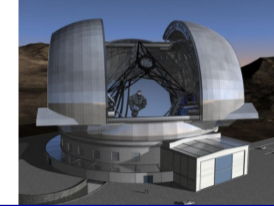


METIS simulator → t_{int} = 5 hours



METIS Science

Exoplanets

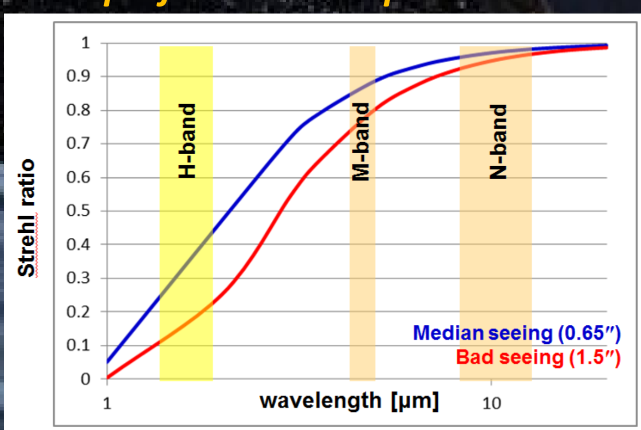


Key Questions

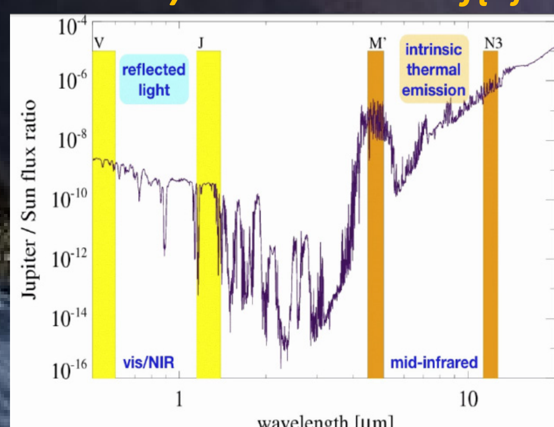
- **Which stars have planetary systems?** → **D**etection
- **What are their physical properties?** → Characterization

METIS is particularly suited for these studies because:

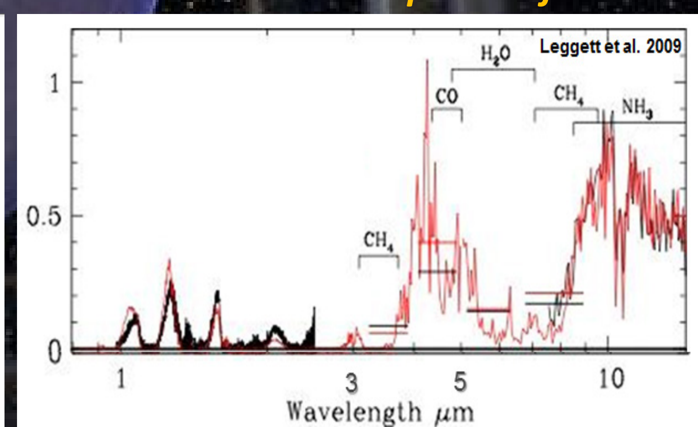
AO performance improves with λ

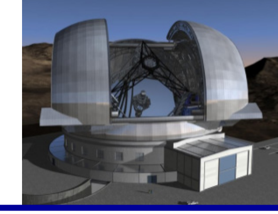


Planet/Star contrast = f{λ}



Thermal-IR is rich in spectral features

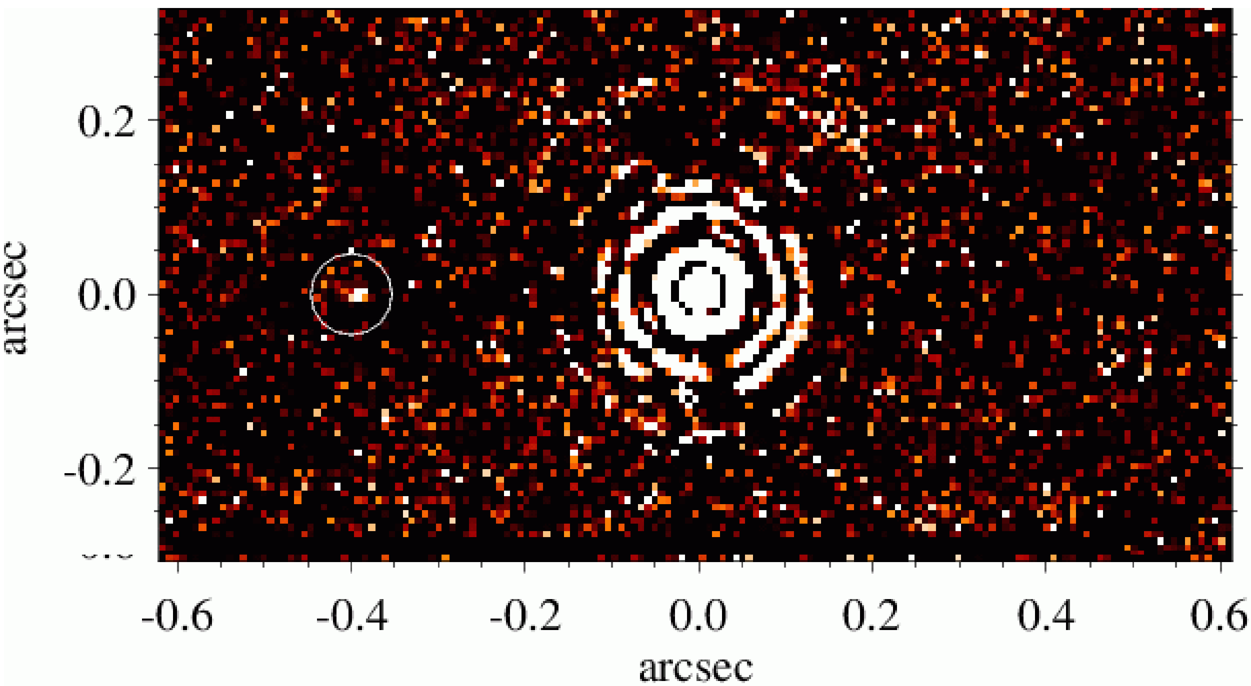




Example Detection @M

Simulated:

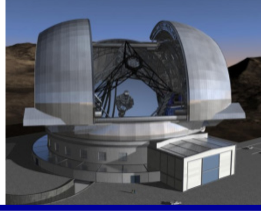
- Star: **M5V @ 10 pc** (50 Myr old)
- Planet: **1 M_{Jup} @ 4AU** **(Spiegel & Burrows 2012)**



"Observed" with METIS @ 4.7µm in **5 hours**

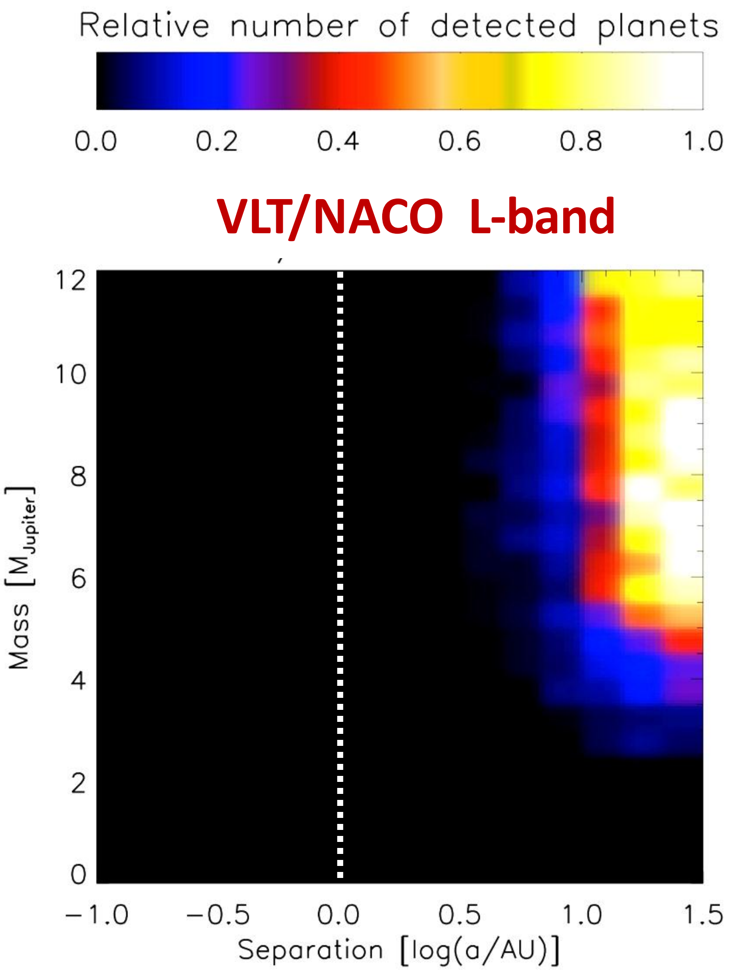
using ADI techniques and AO (seeing ~0.67" - 0.75")

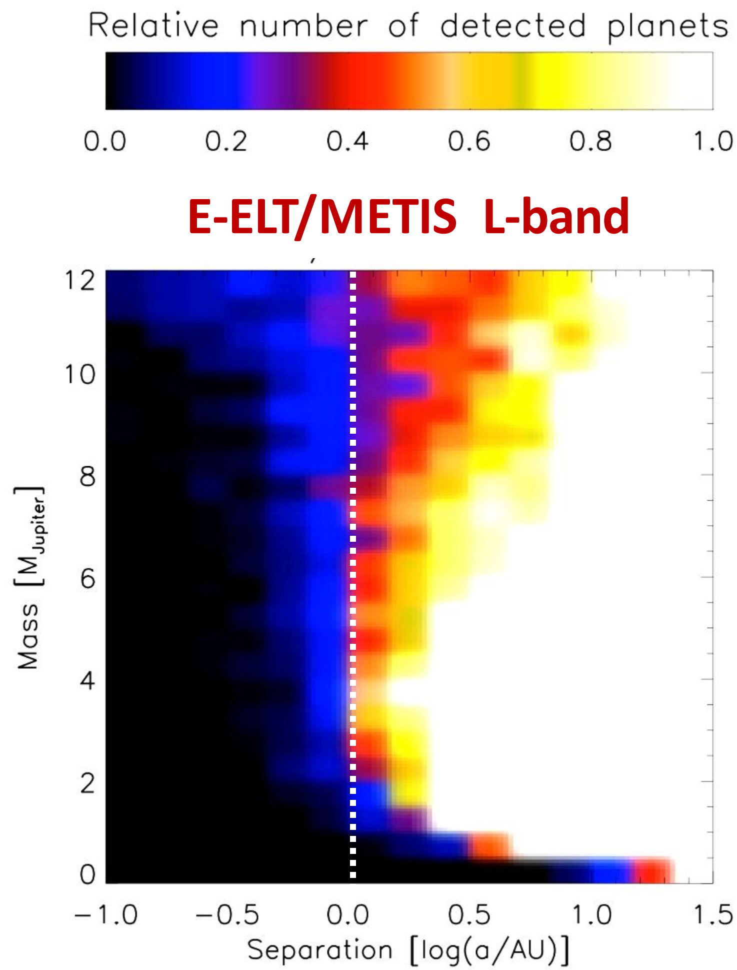
Discovery Space @ 4µm



Simulations of …:

1. Planet population (M,P – extrapolation from RV)
2. METIS contrast curve
3. Random orbital location of the planets

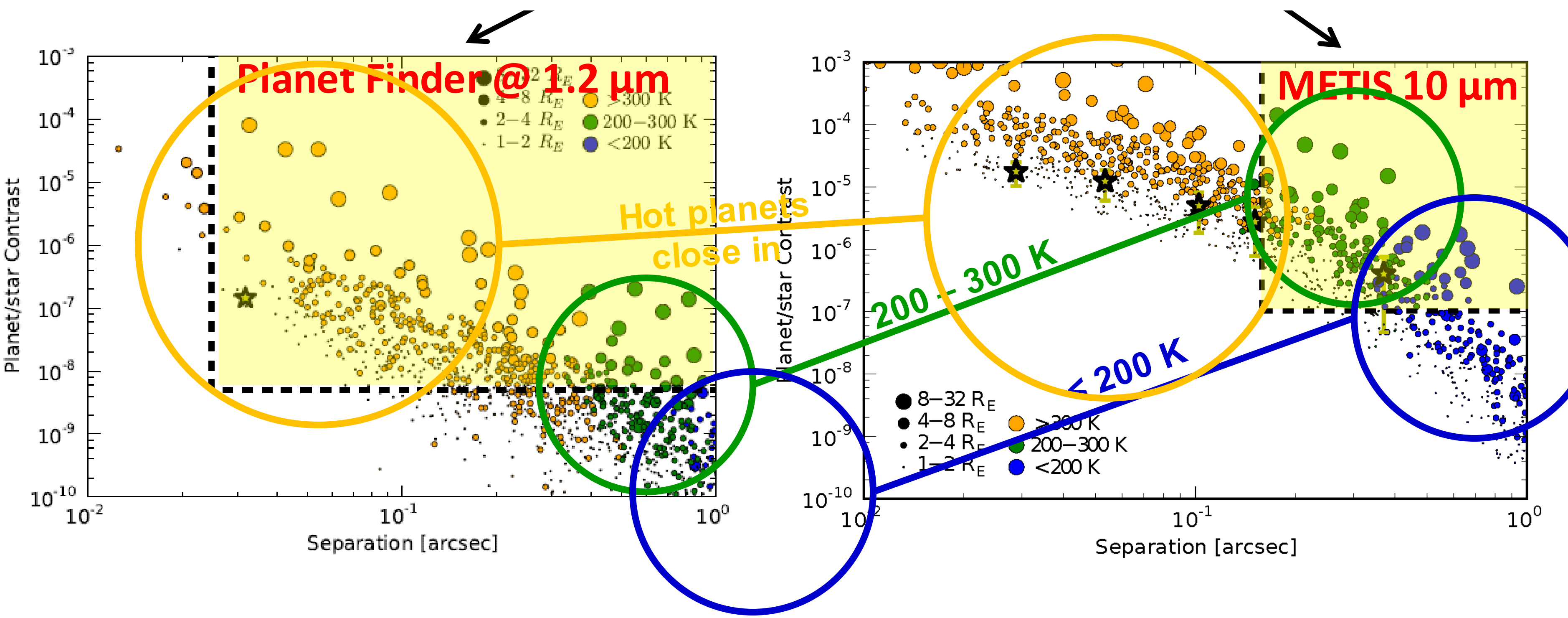




METIS Discovery Space @ 10µm

Wavelength comparison: **reflected light** versus **thermal emission**

(based on sample of stars within 8pc, Kepler statistics with P<50 days)

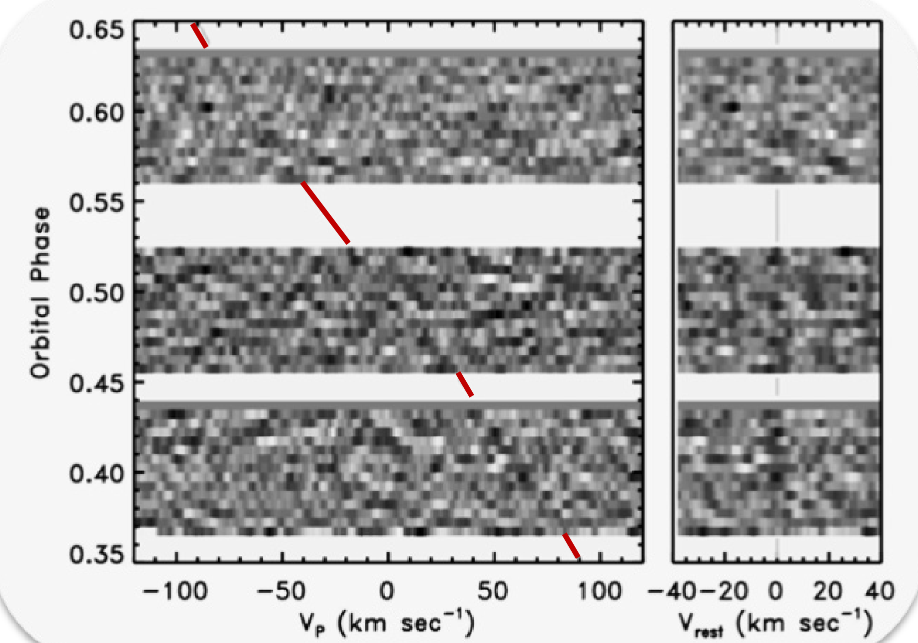


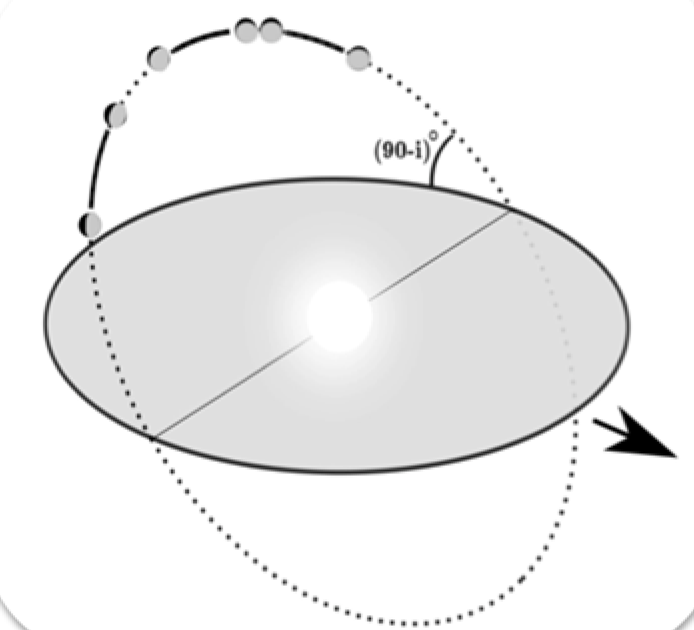
Thermal-IR imaging shifts the distribution of sampled planets to substantially cooler T_{eq} (~200 K) planets at somewhat larger distances

→ highly complementary to EPICS!

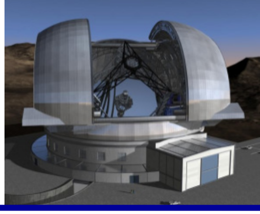
Transit Spectroscopy

First atmosphere detection of a non-transiting planet, *τ-Bootis b*
(Brogi et al. , *Nature 2012)*
15 hours CO absorption@K-band with CRIRES/VLT for this K=3.4 star





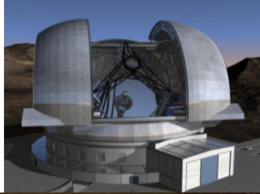
- L-band: stronger features, better contrast esp. for cooler planets
- with the E-ELT/METIS dozens of systems can be characterized
- *Individual* spectral lines will be detected → planet rotation, seasons



METIS Science

Protoplanetary Disks

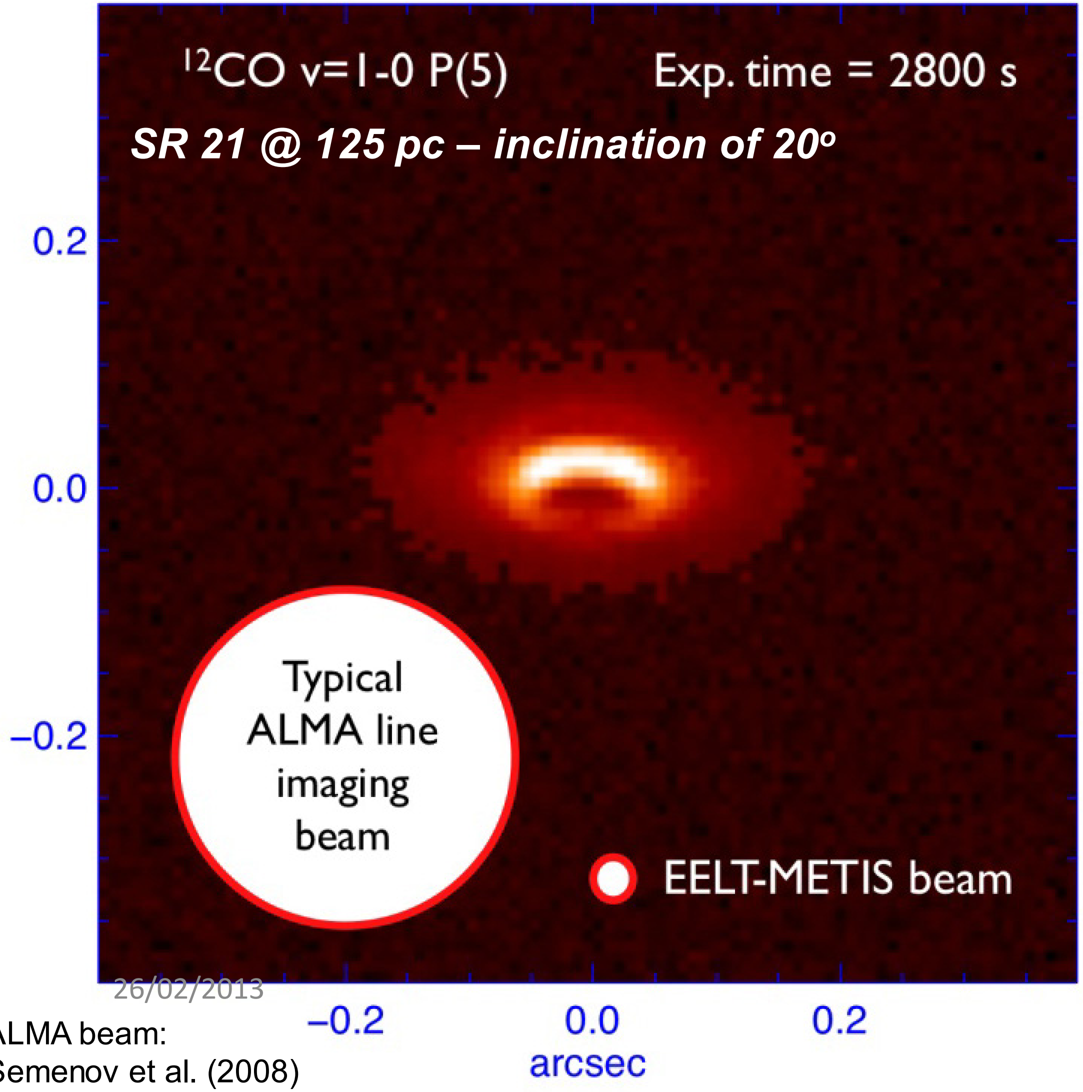
Key Questions



- **Protoplanet – disk interaction:** continuum imaging may suggest presence of p-planets, but only resolved (non-Keplerian) dynamics can prove it
- **PP disk evolution:** what is the dominant mechanism that disperses the primordial gaseous disk? Protoplanets? Photoevaporation? → *What is the likelihood that the inner disk is cleared by a forming planetary system before photo-evaporation?*
- **Chemical processes in disks:** disk composition ⇔ planets
  E.g., 3.3 µm PAH emission: strong in early type stars but not in low-mass stars.

Line Imaging of PP-Disks

Line imaging reduces emission from star <u>and</u> background!



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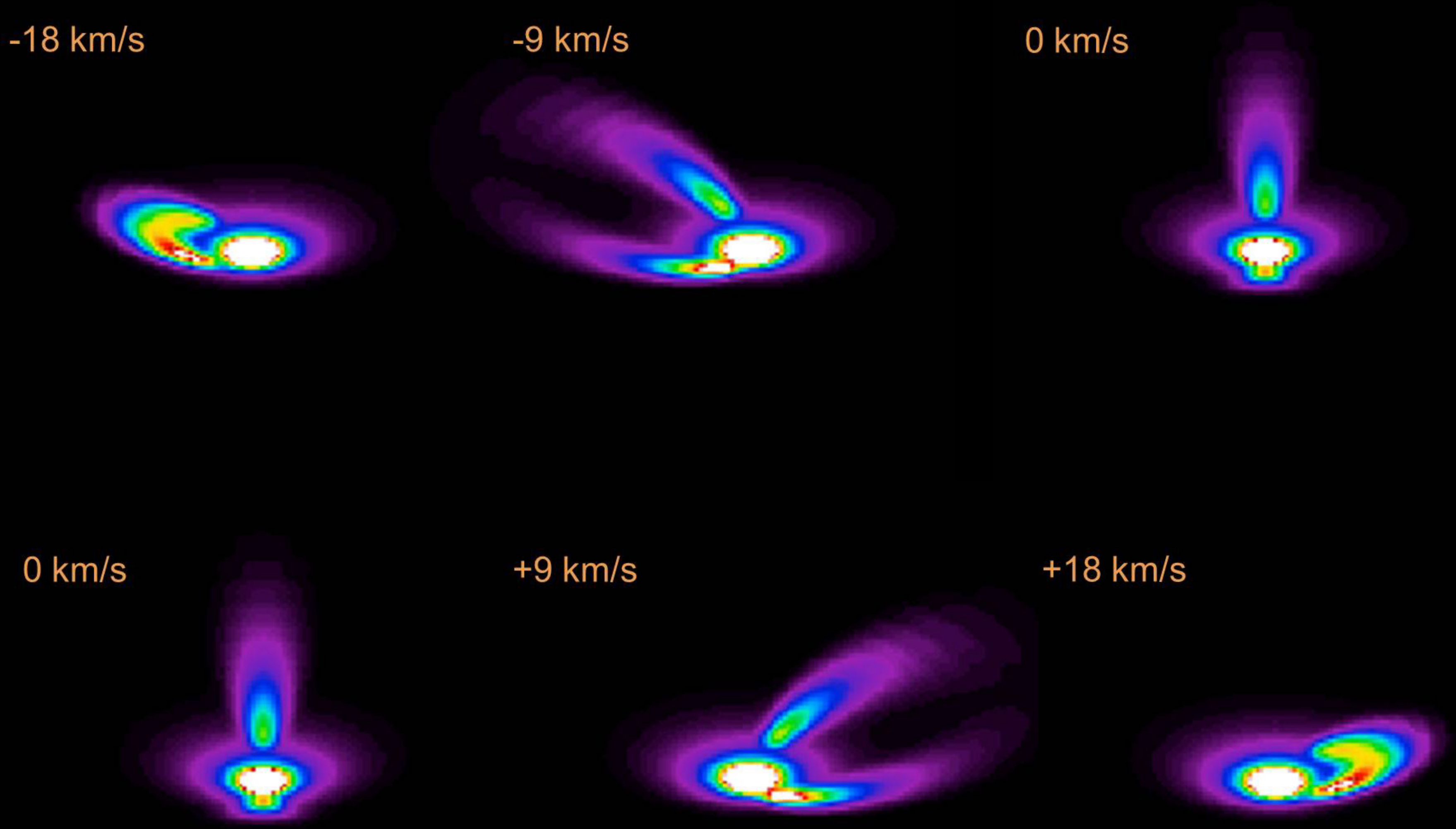
ALMA beam: Semenov et al. (2008)

→ ^{12}CO line detectable out to ≥ 15 AU (1.5 R_{jup}) in t_{int} ≤ 1hr.

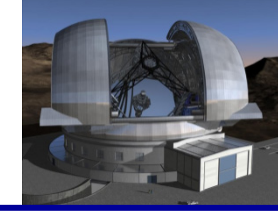
Discovery space:

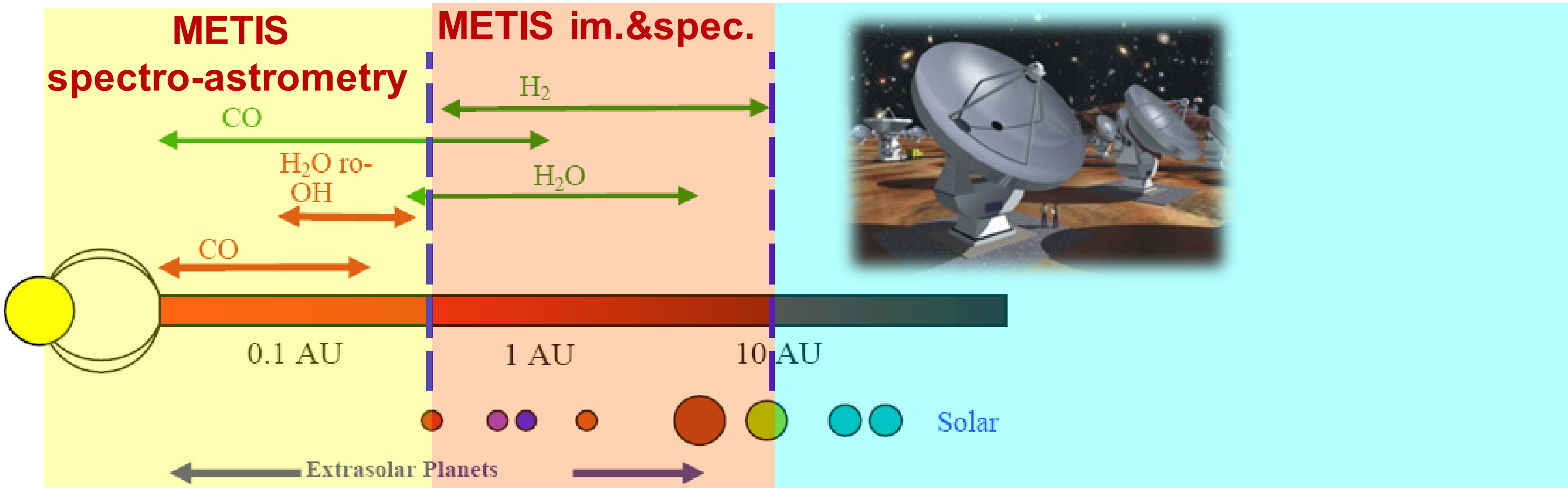
- *CRIRES (~20 min) spatially resolved CO lines (~10 targets)*
- *METIS: surveys of hundreds of targets*

IFU high resolution spectroscopy provides dynamical info!



Disks: METIS ⇔ ALMA

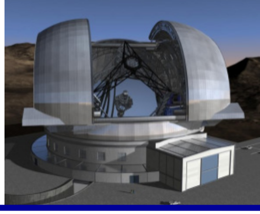




	METIS	ALMA
Target	inner disk – hot gas	outer disk – cool gas
Spectroscopy beam	0.03“ @ 4.7µm	≈0.10“
Detail reconstruction	full aperture	synthesized aperture

The near-term Future

Science Case Updates



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Science Case

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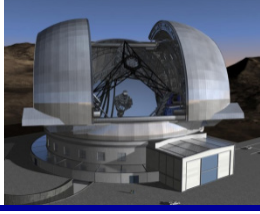
METIS Project Management



Instrument	Procurement Plan
ELT-CAM ELT-IFU	As first-light instruments, and considering their necessary integration with adaptive optics, discussions regarding instrument-architecture and specifications must be started in 2012. Due to the revised telescope design and depending on the AO approach adopted, some Phase A design may also need to be repeated. ESO will therefore plan to contract instrument construction with the existing MICADO and HARMONI consortia, subject to successful negotiation.
ELT-PCS	Competitive tendering for enabling technology development and instrument construction will be applied.
ELT-MIR	Provided technology readiness can be demonstrated in 2013, a mid-IR imager/spectrometer will be delivered as ELT-3. Since the METIS consortium contains most member-state institutes with mid-IR instrument experience (it is essentially the JWST-MIRI team) ESO will plan to contract directly with that consortium.
ELT-4	Competitive tendering for enabling technology development and instrument construction will be applied.
ELT-5	Competitive tendering for enabling technology development and instrument construction will be applied.
ELT-6	Competitive tendering for enabling technology development and instrument construction will be applied.

	ELT-IFU	ELT-CAM	ELT-MIR	ELT-4	ELT-5	ELT-6	ELT-PCS
Commissioning	2022	2022	2023	2024	2026	2028	2025–30

Solid funding situation:

NOVA, MPIA, CEA: √ secured

KATHOLIEKE UNIVERSITEIT LEUVEN: √ secured first phase

METIS
Mid-infrared E-ELT Imager and Spectrograph

METIS

Project Management Plan

Doc. No.: E-PLA-MET-503-1001

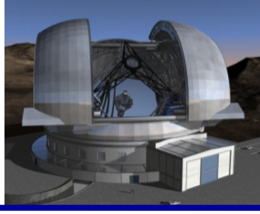
Issue: 1.1

Date: 01.02.2013

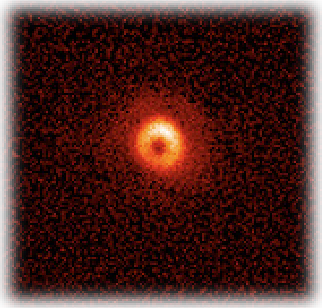
[8/9/2012] ***ESO sees the overall consortium (…) to be a solid one with sufficient experience to bring the instrument to successful conclusion.***

ESO, Karl-Schwarzschild-Str. 2, D-85748 Garching bei München

Detectors

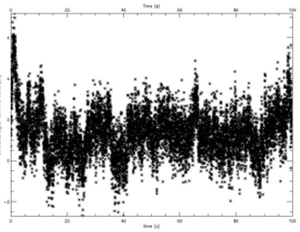


Module	Type	Pixels
AO WFS (NIR)	SELEX SAPHIRA	600 x 600
L/M band imaging	HAWAII-2 RG	2048 x 2048
N band imaging	AQUARIUS	1024 x 1024
L/M IFU spectroscopy	HAWAII-4 RG	4096 x 4096

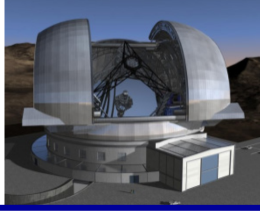


Side note on the recent performance issues with the AQUARIUS:

- The AQUARIUS detector works – albeit with higher 1/f noise
- The METIS chopper can calibrate the 1/f noise
- Less than 1-in-20 “METIS-pixels” is an AQUARIUS pixel
- Sufficient time to develop calibration strategies and even alternatives (HgCdTe)

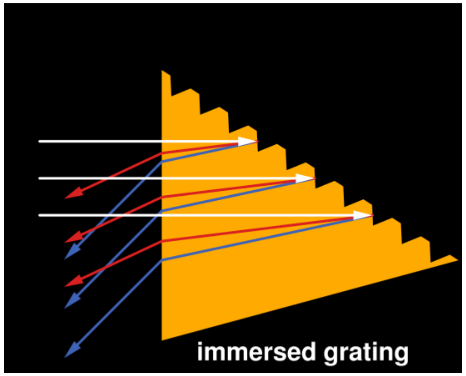


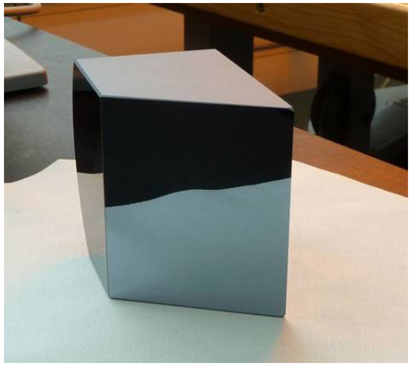
METIS Technology Developments



Immersed Grating

Netherlands Institute for Space Research

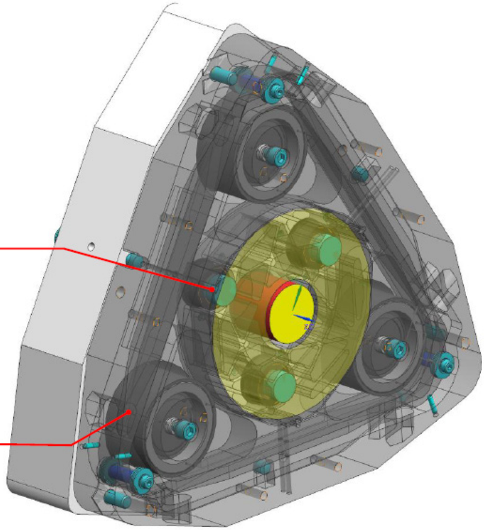




- Wavelengths 2.9 – 5.3 µm
- Silicon, size: 150mm × 90mm
- Groove density: 50 mm^{-1} (20th – 42nd)
- WFE < 100 nm RMS

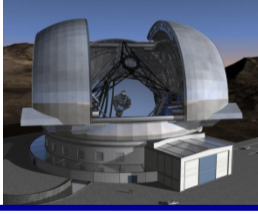
2-D Cryo-Chopper

Netherlands Institute

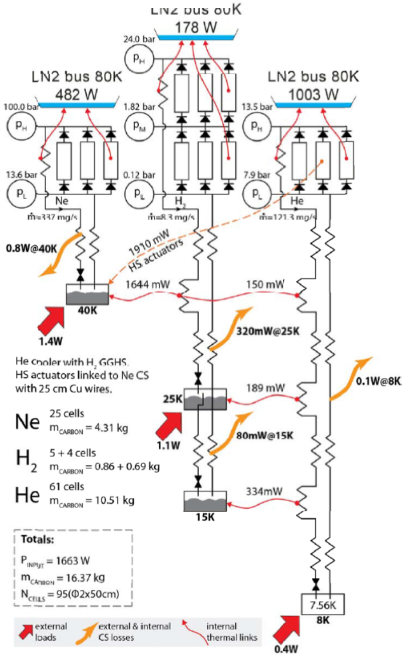


- Operating temperature 80K
- 1.7 µrad stability and repeatability
- 5 msec chopping time
- any position within 8.5 mrad

Technology Developments

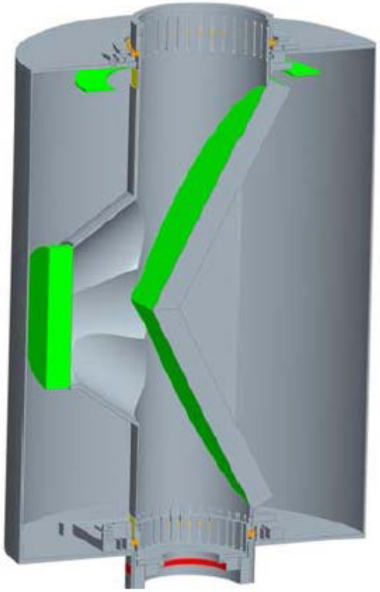


Sorption Cooler



- reversible adsorption and JT expansion
- vibration+maintenance-free operation
- T = 7 - 40K with <<10 mK/mth stability

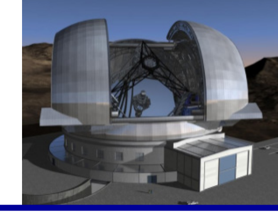
Active Cryo-Derotator



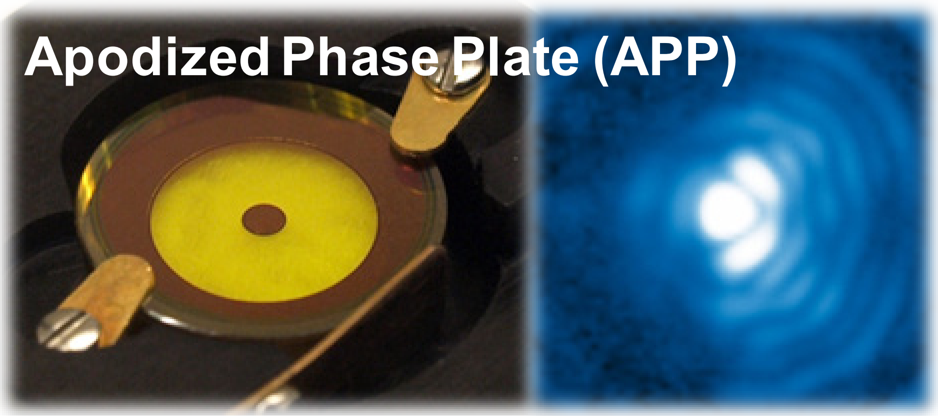
- ultra-stable optical derotator
- length ~ 0.5 m
- cryo-compatible (T ~ 70K)
- active control of 1 axis

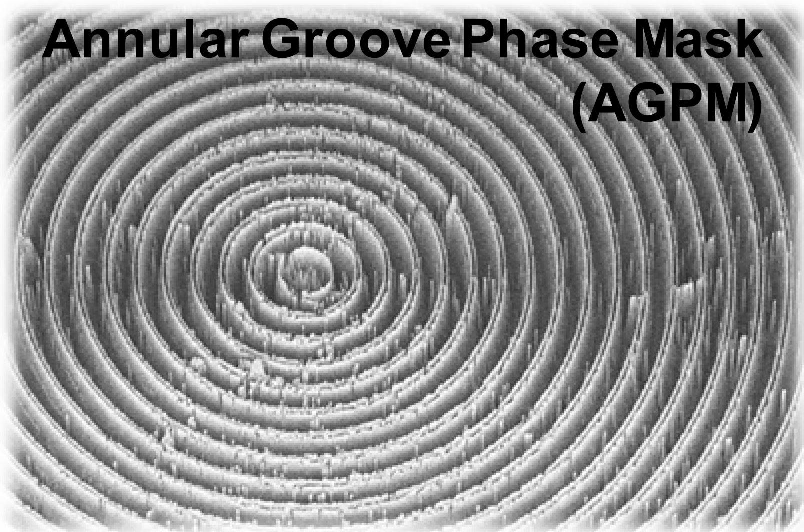
METIS

Technology Developments



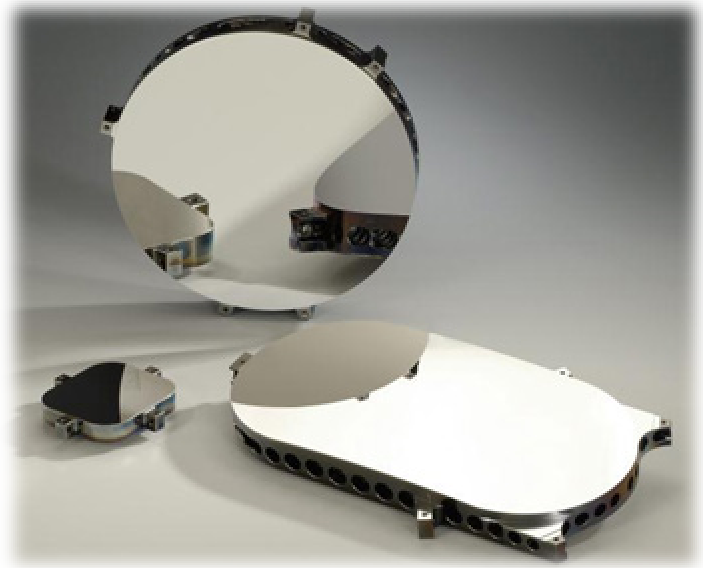
Novel Coronagraphs at 3 & 10 µm





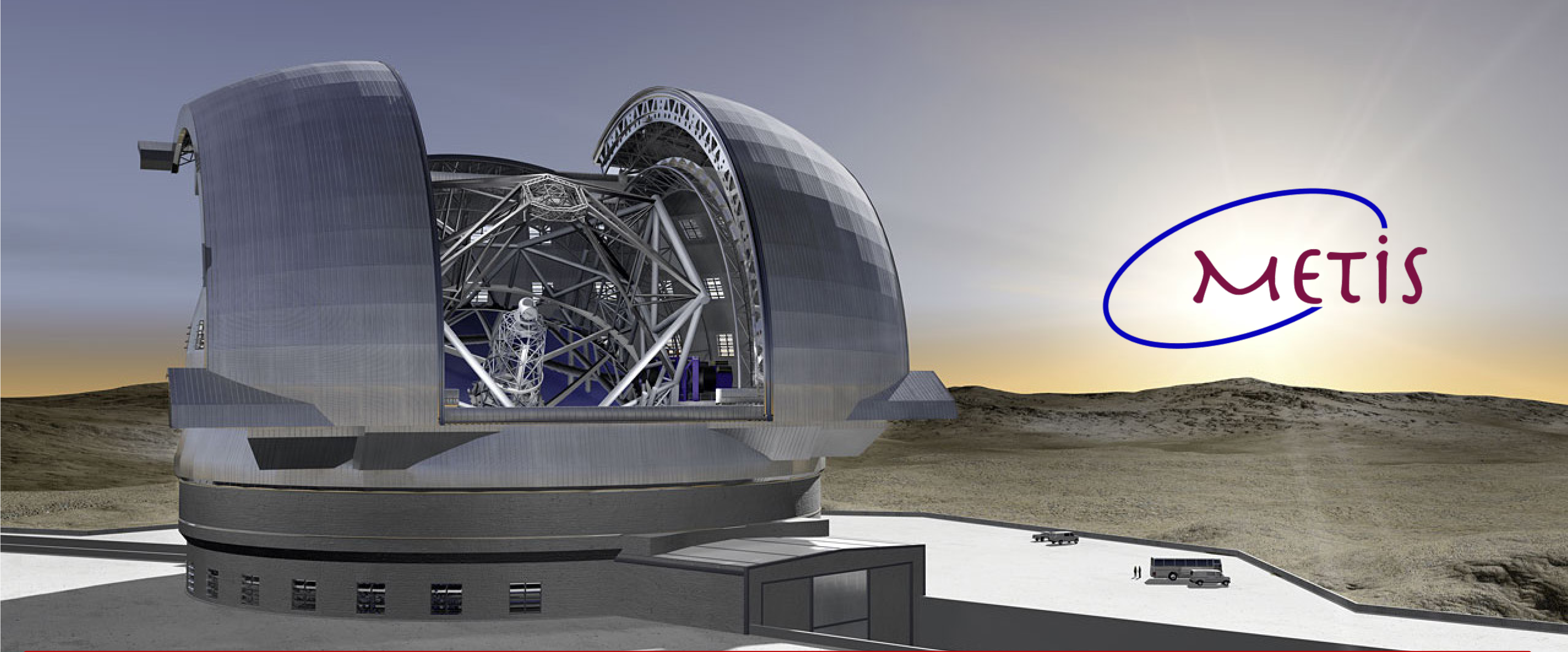
High Performance Metal Optics

Fraunhofer IOF



- Excellent surface figure & micro-roughness
- matches CTE of Al alloy with high silicon content to electroless nickel NiP
- Prototype mirror manufactured

Summary



- ***METIS will deliver unique and outstanding science in many areas – from the Solar System to high-z galaxies.***
- ***Arguably the biggest discovery space will be in the areas of exoplanets and protoplanetary disks.***
- ***The METIS project is in great shape:***
  scientifically, technically & financially.