

# MPIA Project Overview



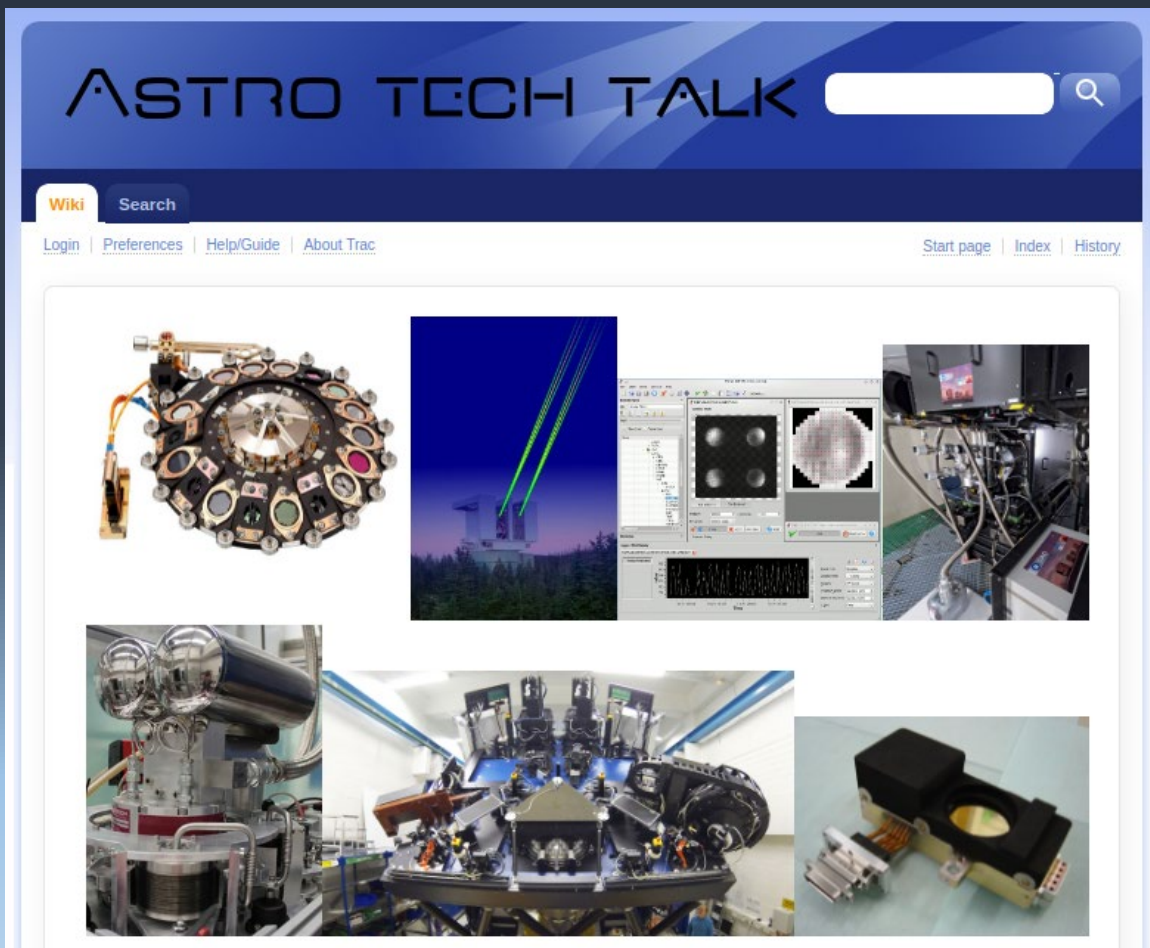
Martin Kürster

Head of the technical departments

Project coordinator

# AstroTechTalk

## – now Mondays at 3 p.m.

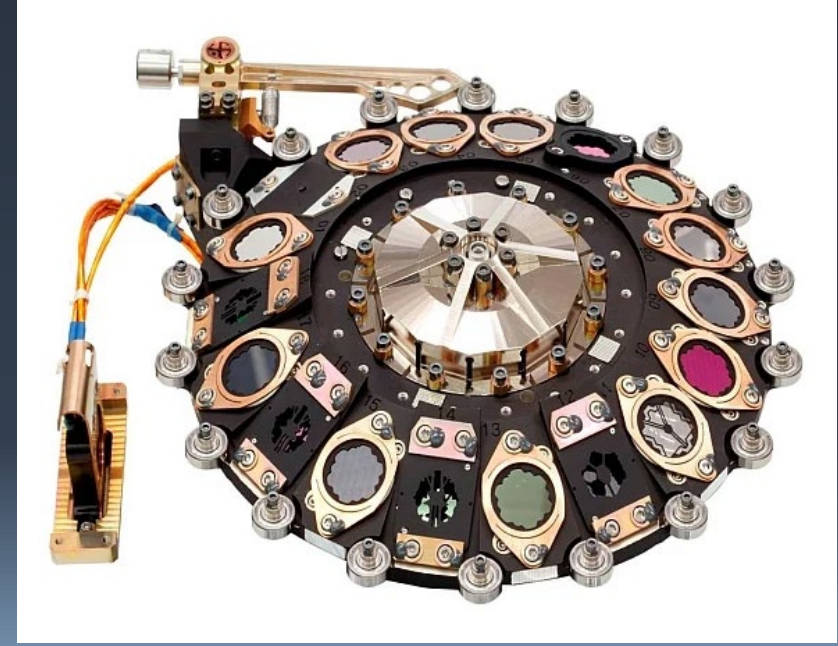


Date	Speaker	Topic
		<b>MPIA Project Overview</b>  This talk will provide an overview of the ongoing astronomical instrumentation projects of the MPIA.  It presents  * which work packages the MPIA has taken over within the respective consortium which collaborates in development and construction,  * the current phase of each project and the overall schedule,  * the main characteristics of the instruments, such as type, wavelength, resolution, field-of-view, etc.  A brief look at the science planned with each instrument rounds off the presentation.  Presentation: German Slides: English Questions: German, English
21.02.2022	Martin Kürster	
28.02.2022	--	--
07.03.2022	Wolfgang Brandner & Wolfgang Gässler	Project ELT/ANDES
14.03.2022	--	--
21.03.2022	Markus Feldt	Project VLT/SPHERE+
28.03.2022	--	--
04.04.2022	Vianak Naranjo	HAWAII-4K Detector for PANIC
11.04.2022	--	--
18.04.2022	<i>Holiday</i>	<i>Easter Monday</i>
25.04.2022	André Boné	Tolerance studies for the Relay Optics of MICADO
02.05.2022	--	--
09.05.2022	Aline Dinkelaker (AIP)	Astrophotonics
16.05.2022	--	--
23.05.2022	Armin Böhm	The new fine mechanical Workshop (with guided tour)
30.05.2022	--	--
06.06.2022	<i>Holiday</i>	<i>Whit Monday</i>
13.06.2022	Caroline Kulcsar (Institut d'Optique Graduate School)	TBD
20.06.2022	--	--
27.06.2022	--	<i>Institute meeting</i>
04.07.2022	Natalie Fischer	Workshop program at the HdA
11.07.2022	--	--
18.07.2022	... open ...	
25.07.2022	--	--

# Prologue JWST “Webb”



JWST in the integration hall of the Goddard Space Flight Center

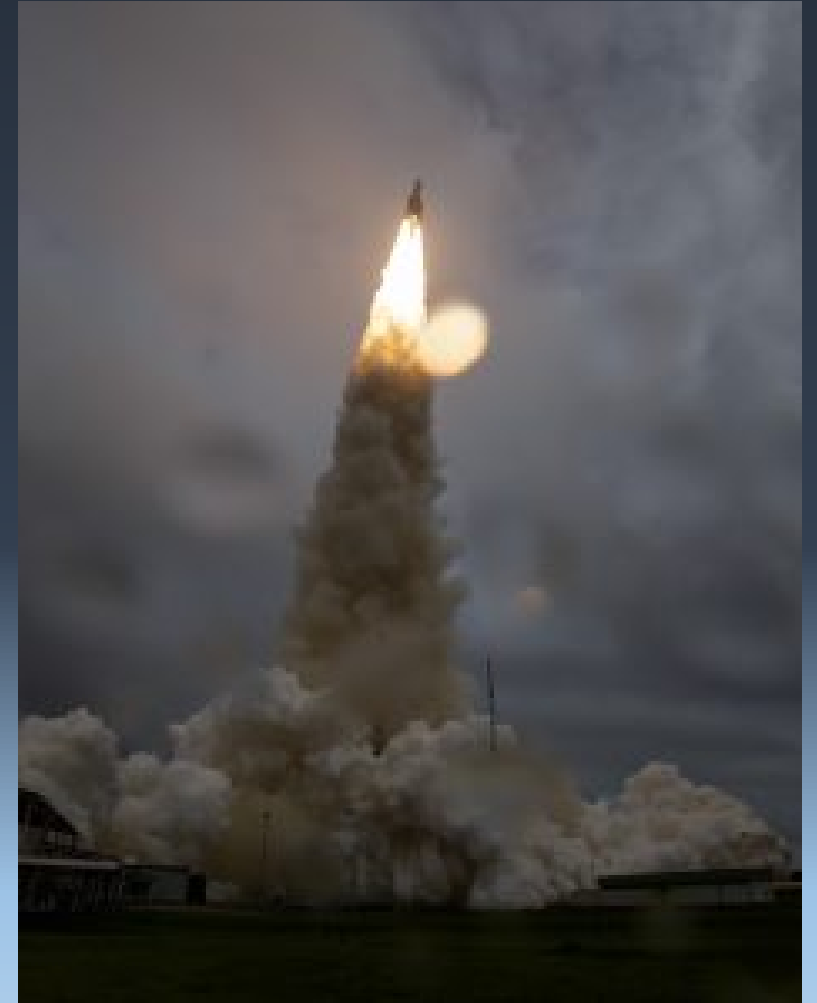


The famous MIRI filter wheel

MPIA ended its projects related to our contributions to JWST in Oct 2010 (NIRSPEC) and Dec 2010 (MIRI)

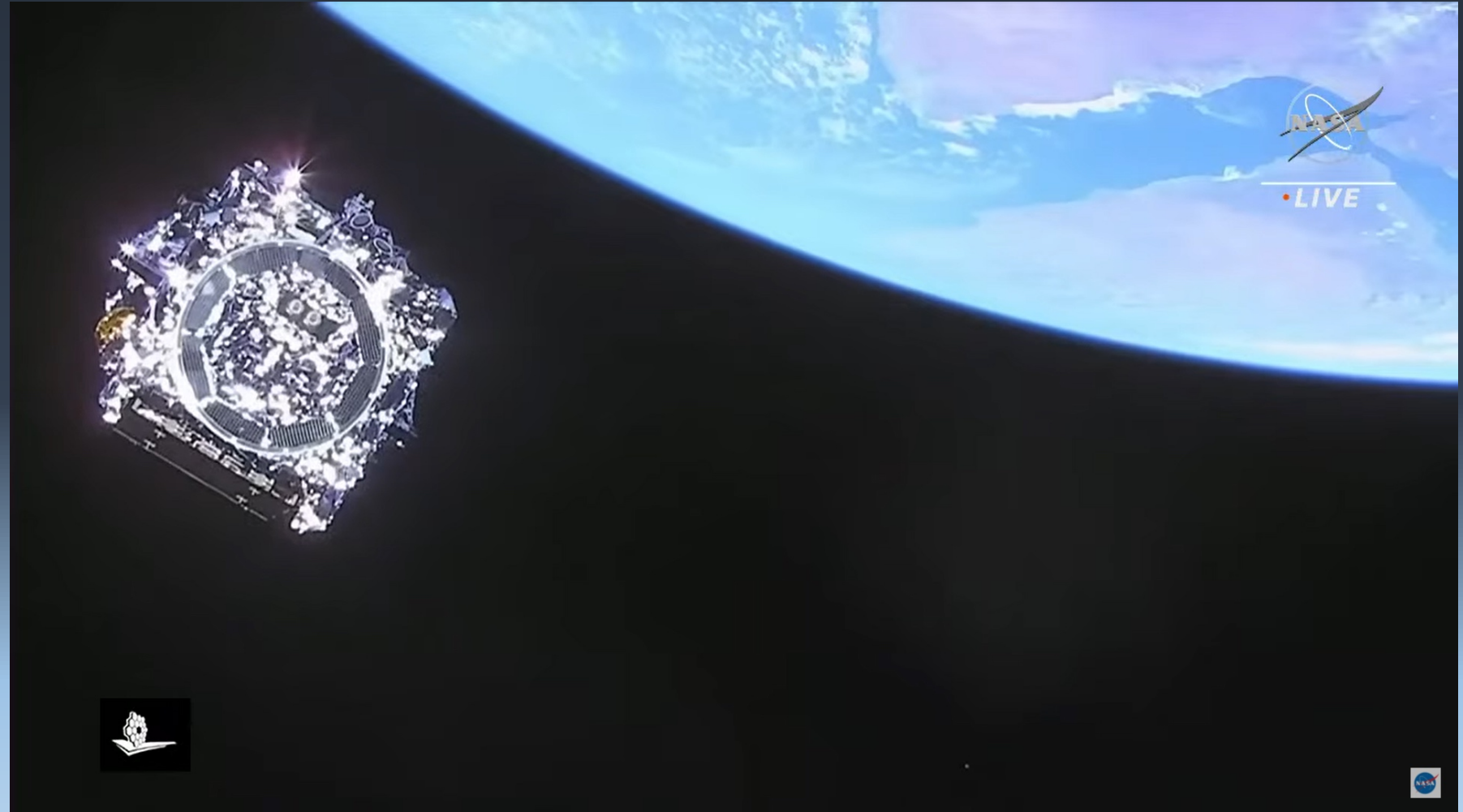


# Prologue

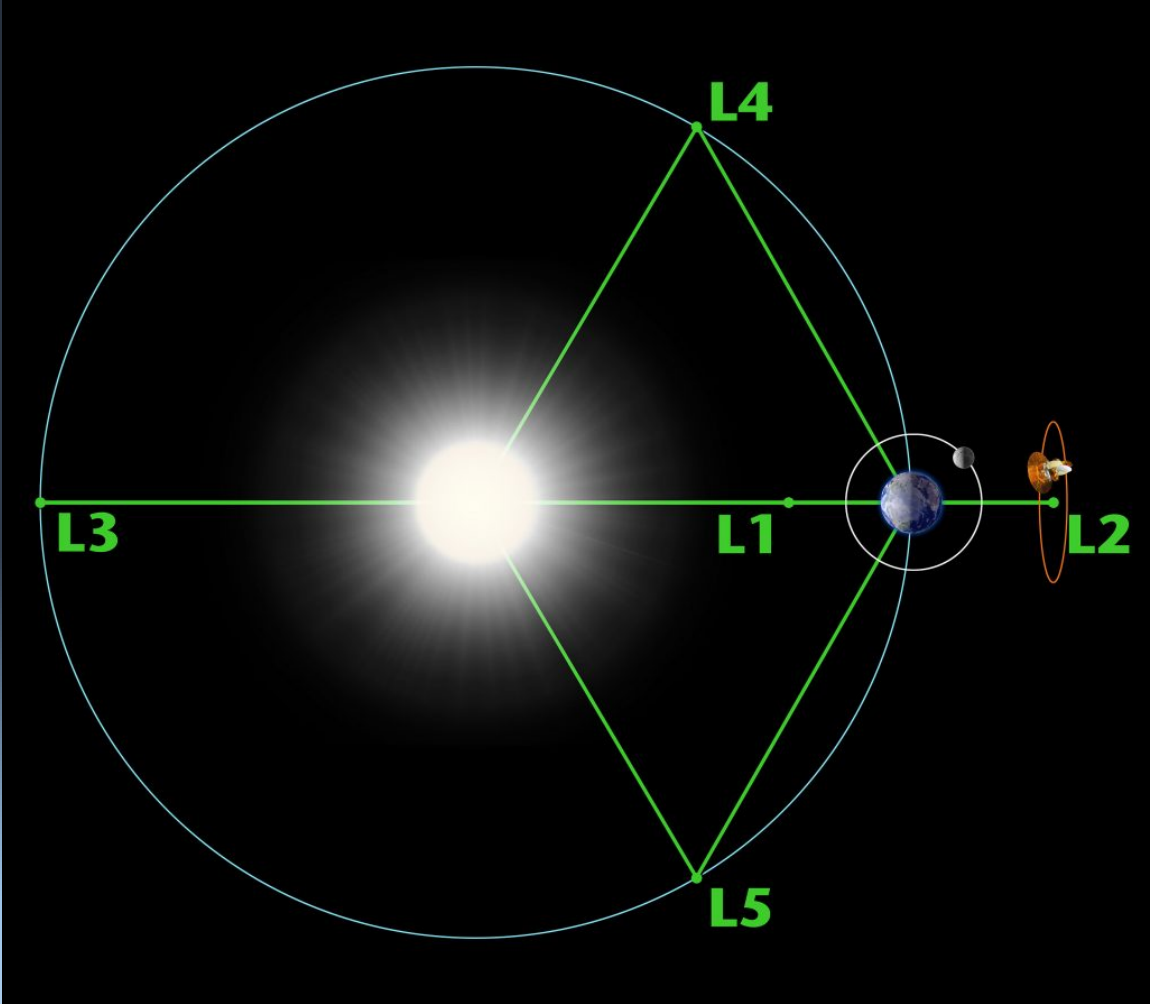




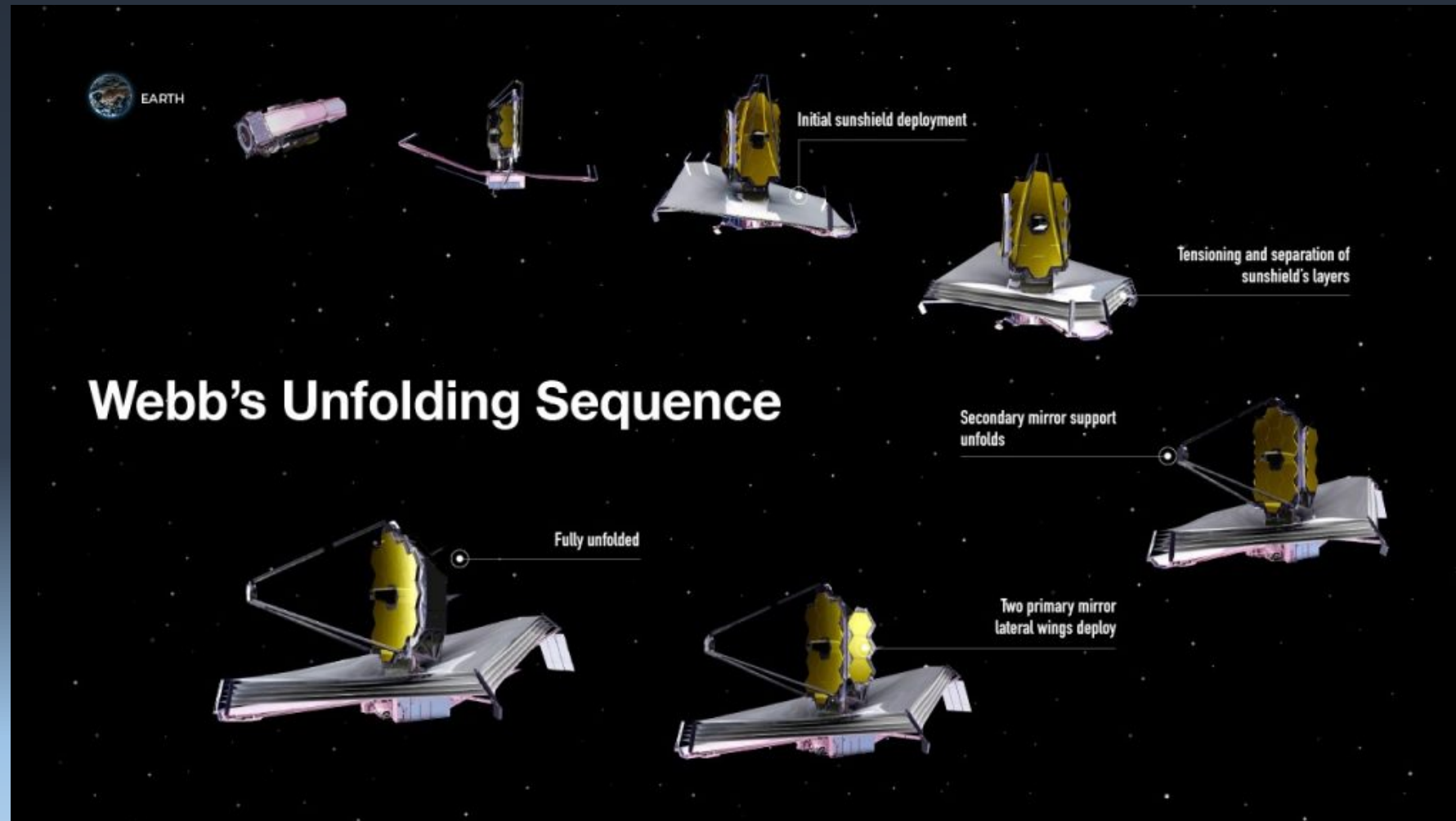
# Prologue



# Prologue



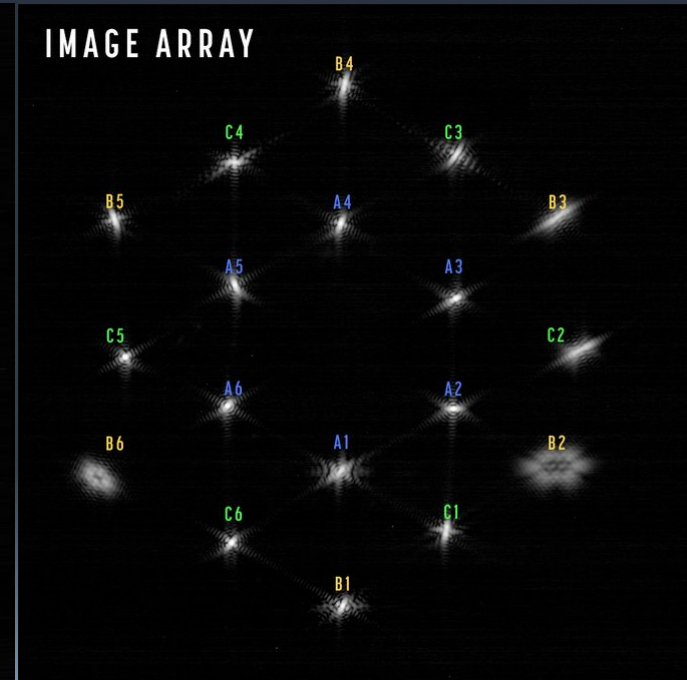
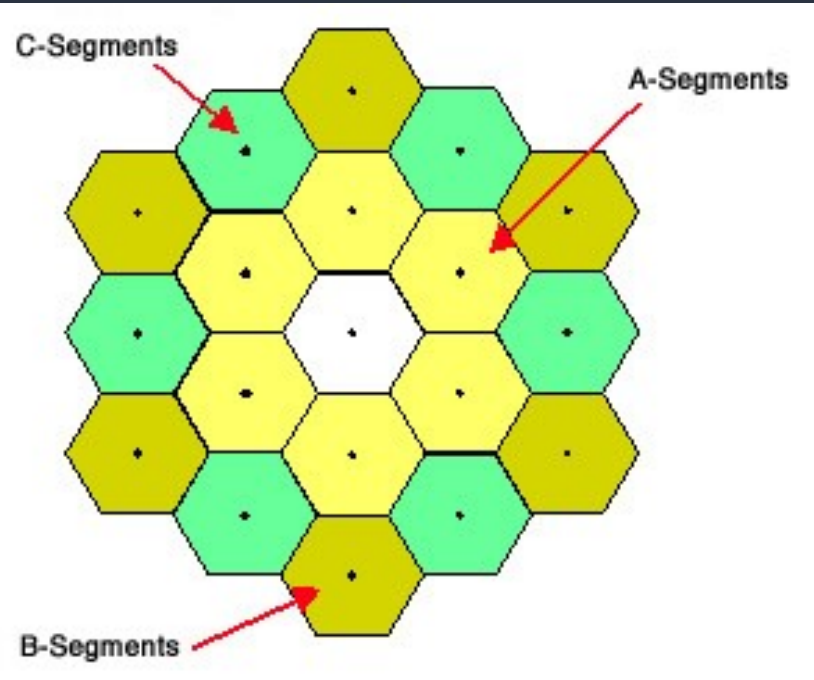
# Prologue



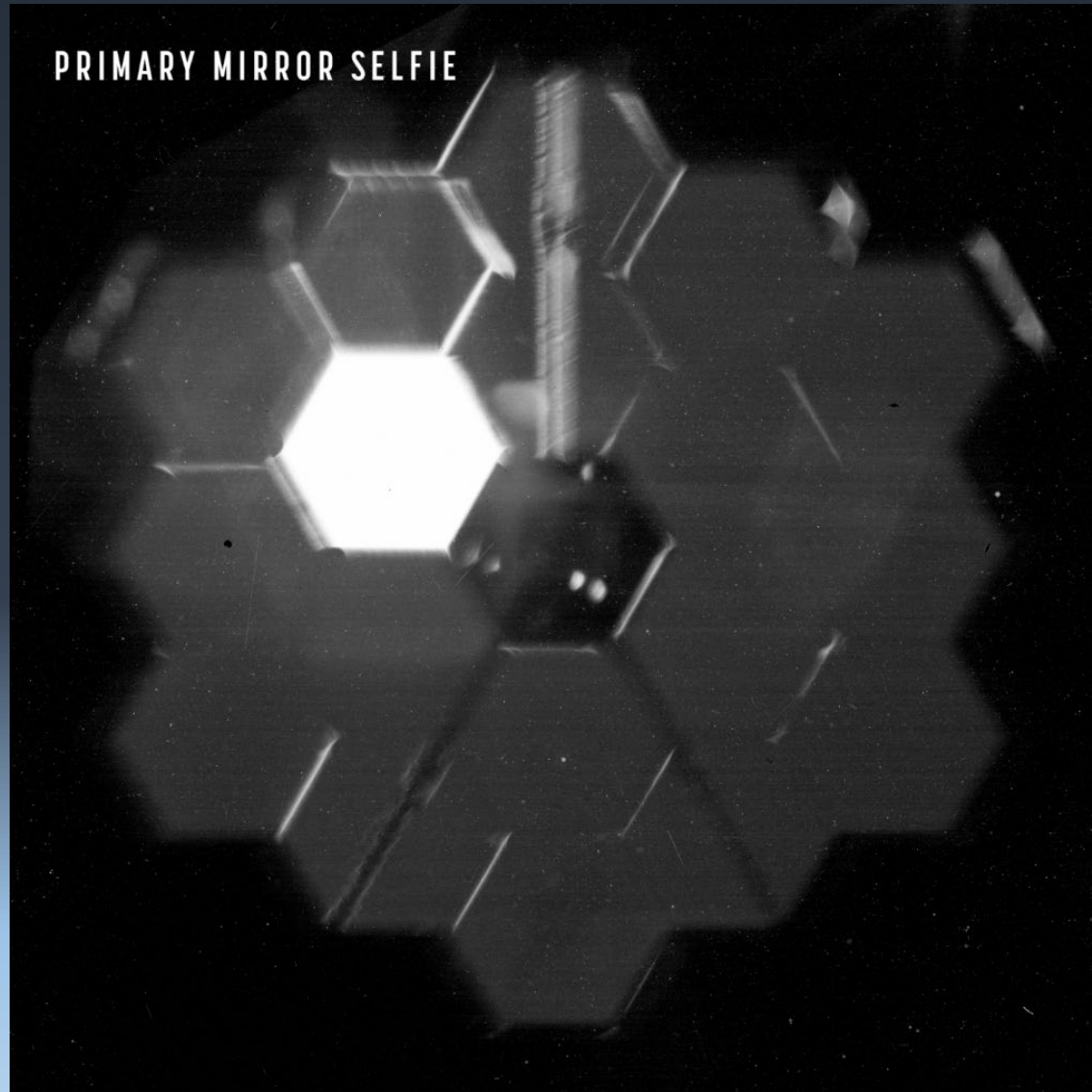
→ Movie



# Prologue



# Prologue



# MPIA Project Overview

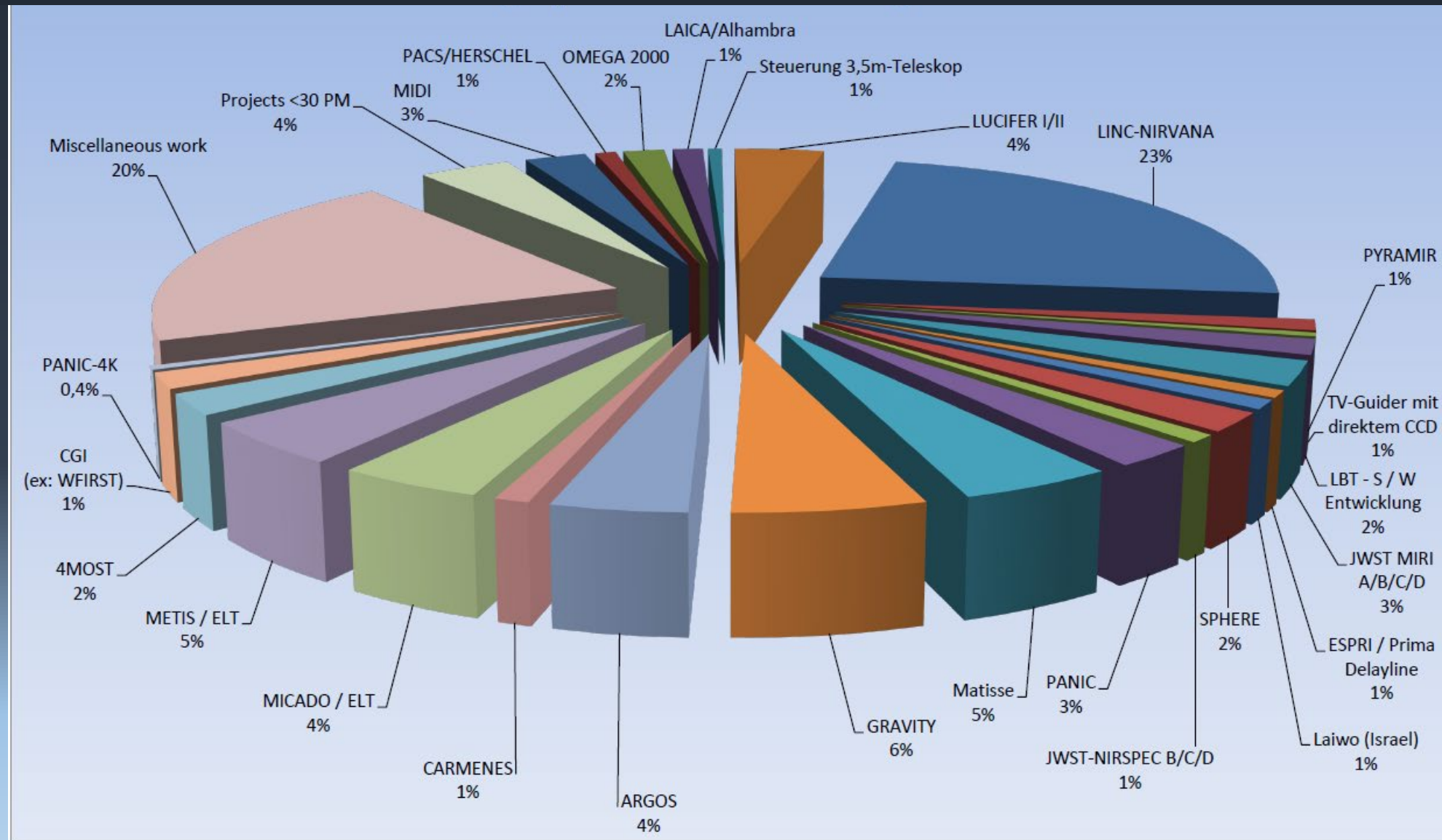
**What has happened in the past 20 years ...**

**... a look back**



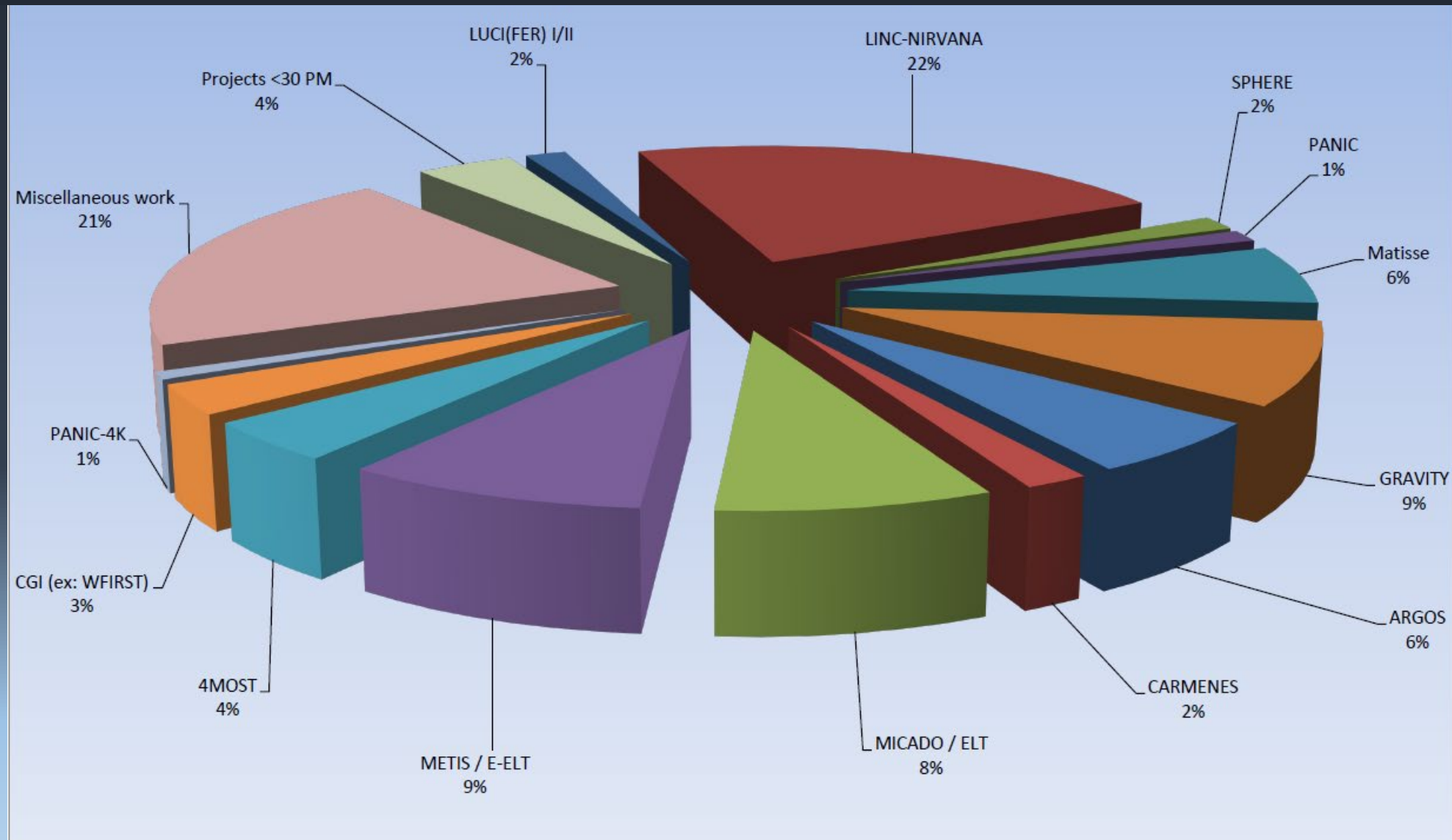
# MPIA instrumentation projects from S1/2001 to S1/2021

Relative amount of labor from the technical departments



# MPIA instrumentation projects from S1/2011 to S1/2021

Relative amount of labor from the technical departments



# MPIA Project Overview

**What is happening now ...**

**... the present**



# Ongoing projects at MPIA

Project No	Project name	Observatory	Project leader / Project manager
<i>Regular ongoing projects</i>			
<del>#0102</del>	<del>LINC NIRVANA</del>	<del>LBT</del>	<del>Herbst / Kürster</del>
#1501	MICADO	E-ELT	Pott / Hofferbert
#1502	METIS	E-ELT	Feldt / Scheithauer
#1503	4MOST	VISTA	Bergemann / Gässler
#1901	NTE	NOT	Kürster
#1902	CGI	Roman ST	Krause
#2001	LVM Telescopes	LCO	Herbst / Gässler
#2002	PANIC-4K	CAHA	Bizenberger
<i>Technology development projects</i>			
s/n	GeoSnap Detector	—	Bizenberger/Scheithauer
<i>Order projects</i>			
s/n	METImage	Co.	Krause ← soon to end

# Milestone overview

Status: 06 December 2021 M. Kürster				PROJECT - MILESTONES																							
Project №	Project name	Observatory	Project leader / Project manager	1 / 2021						2 / 2021						1 / 2022						2 / 2022					
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Regular ongoing projects									1									1									
#0102	LINC-NIRVANA	LBT	Herbst / Kürster															1									
#1501	MICADO	E-ELT	Pott / Hofferbert							1											2	3				4	
#1502	METIS	E-ELT	Feldt / Scheithauer				1									2		3							4		4
#1503	4MOST	VISTA	Bergemann / Gässler																								
#1901	NTE	NOT	Kürster				1											3							4		
#1902	CGI	Roman ST	Krause									2	3					4	5	6	7						
#2001	LVM Telescopes	LCO	Herbst / Gässler	1																			8				
#2002	PANIC-4K	CAHA	Bizenberger									1			2										4		
Technology development projects																											
s/n	GeoSnap Detector	–	Bizenberger/Scheithauer		1																			2			
Order projects																											
s/n	METImage	Co.	Krause						1						2	3	4										
Regular ongoing projects																											
#1501	MICADO	E-ELT	Pott / Hofferbert								2																
#1502	METIS	E-ELT	Feldt / Scheithauer																								
#1503	4MOST	VISTA	Bergemann / Gässler								6																
#1901	NTE	NOT	Kürster		9	10			11	12																	
#1902	CGI	Roman ST	Krause			4																					
Technology development projects																											
s/n	GeoSnap Detector	–	Bizenberger/Scheithauer			3														4							
Regular ongoing projects																											
#1501	MICADO	E-ELT	Pott / Hofferbert	3				4						5						←	6	→				7	
#1502	METIS	E-ELT	Feldt / Scheithauer												5	6							7	8			
Technology development projects																											
s/n	GeoSnap Detector	–	Bizenberger/Scheithauer															5									

# MPIA telescopes all over the world



MPIA has contributed to several instruments for ESO's Very Large Telescope (VLT), and its astronomers frequently use the VLT for their research.

Credit: ESO / J. E. Salgado (josefrancisco.org)



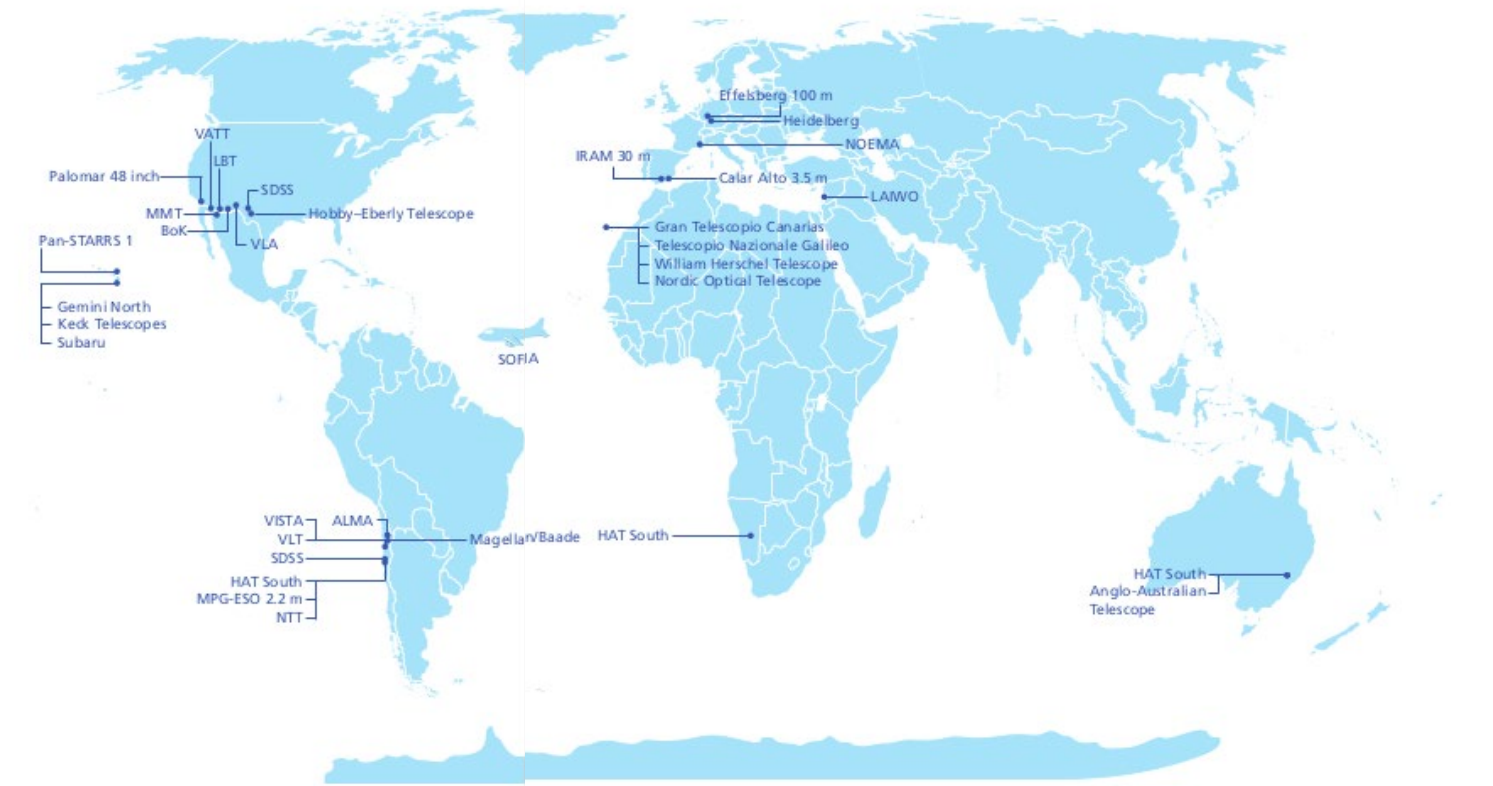
MPIA researchers regularly use the ALMA observatory on the Chajnantor plateau in the Atacama desert to study the coldest and most distant objects in the cosmos. ALMA is an interferometer for observations at millimeter and submillimeter wavelengths, located at an elevation of 5000 km.

Credit: ESO / C. Malin



The 100 m radio telescope in Effelsberg is operated by the Max Planck Institute for Radio Astronomy. MPIA astronomers have made use of it e.g. to study star formation in nearby galaxies.

Credit: M. Pössel / HdA



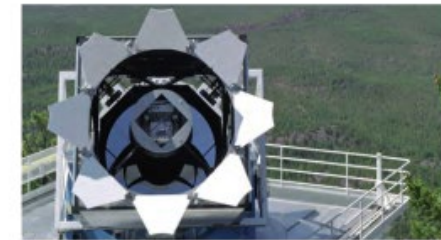
With access to large parts of Earth's airspace, the flying NASA/DLR observatory SOFIA is flexible in its choice of observing location. MPIA astronomers (and others) use SOFIA for observations in near-, mid- and far-infrared.

Credit: NASA / J. Ross



The Nordic Optical Telescope (NOT) on La Palma is a 2.56 m mirror telescope. MPIA is involved in constructing the instrument NTE, the "NOT Transient Explorer".

Credit: B. Tubbis



MPIA is a member of the Sloan Digital Sky Survey (SDSS), a spectroscopic survey using a 2.5 meter telescope in New Mexico. The survey gathers high-quality spectra of a large number of astronomical objects.

Credit: SDSS



# An MPIA instrumentation project ``almost`` finished – LINC-NIRVANA



PI and (also local) project leader: Tom Herbst (MPIA)  
PM: Martin Kürster w/ Ralph Hofferbert  
SE: Thomas Bertram  
PS: Eva Schinnerer → Glenn van de Venn ...

# An MPIA instrumentation project ‘almost’ finished – LINC-NIRVANA



## LINC-NIRVANA

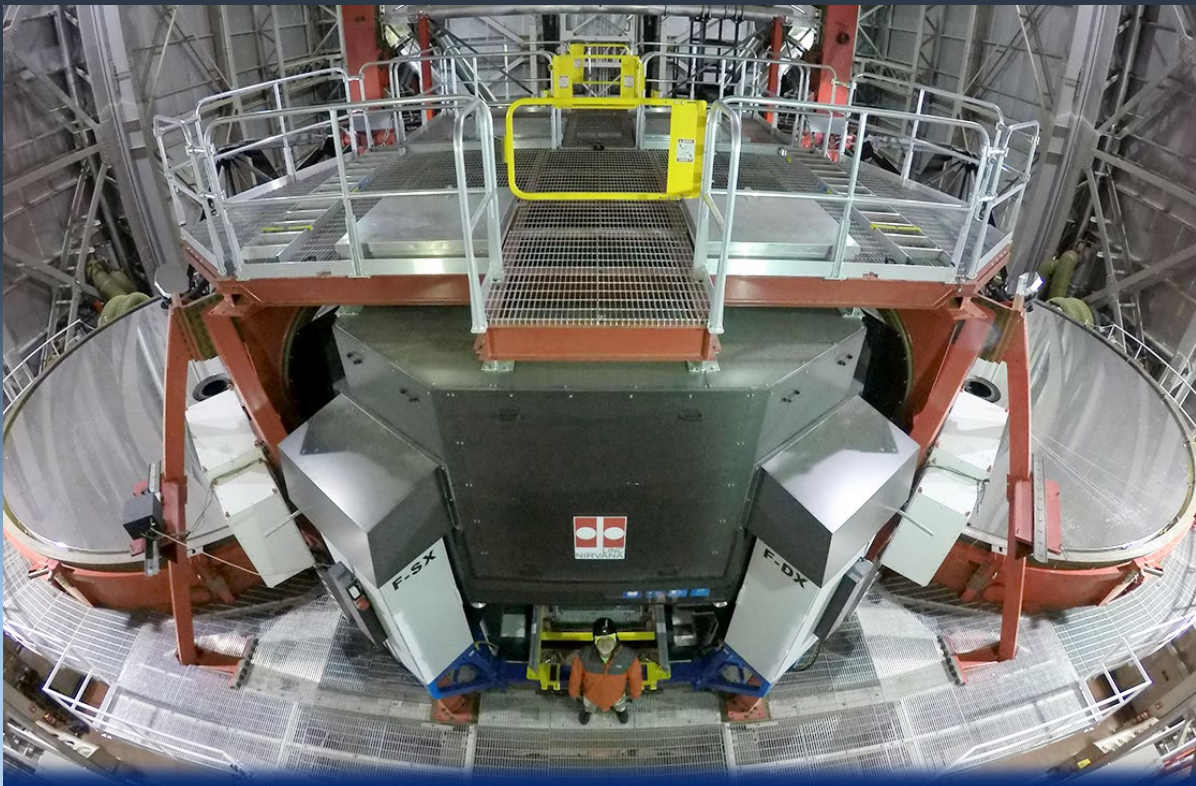
LBT Interferometric Camera –  
Near-InfraRed Visual Adaptive interferometer for Astronomy

Telescope	Large Binocular Telescope, Mt. Graham
Wavelength range	Near-infrared, 1.1 – 2.4 $\mu\text{m}$
Targets	Star clusters, black holes, protoplanetary disks
Resolution	30–90mas (wavelength-dependent); interferometric: 10–30mas
Special features	Particularly wide-field adaptive optics
MPIA contribution	PI inst., optics, electronics, SW, cryogenics, mechanics
Status	Advanced commissioning phase



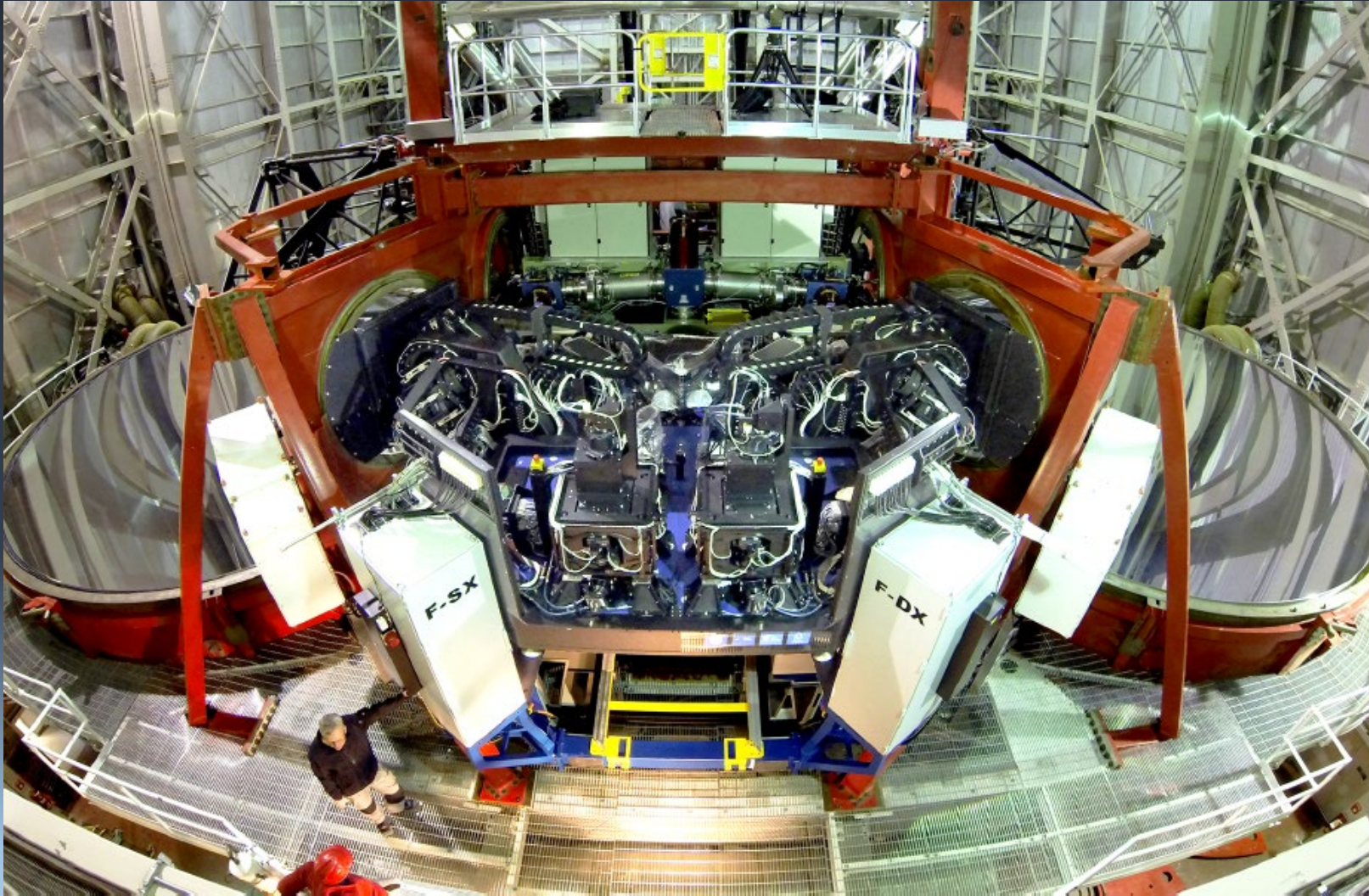
LBT

Large Binocular Telescope  
Mt. Graham (3221 m)  
Arizona, USA



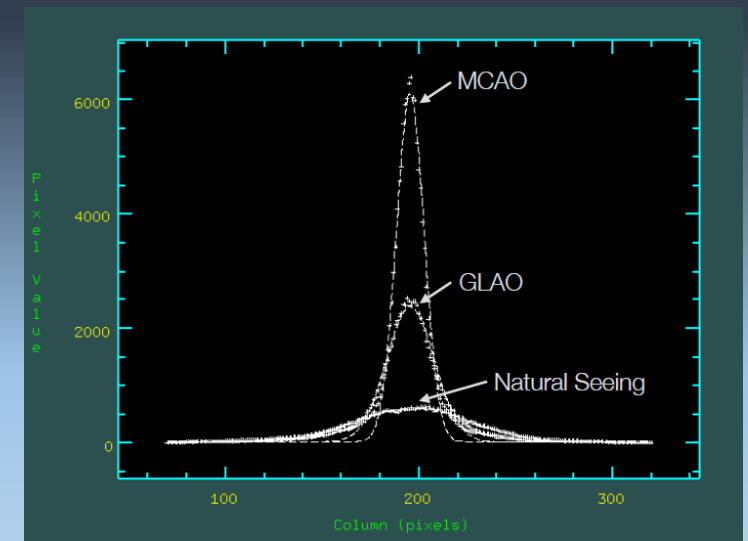


# An MPIA instrumentation project ``almost'' finished – LINC-NIRVANA



Ground + High Layer = MCAO !

0.073 arcsec

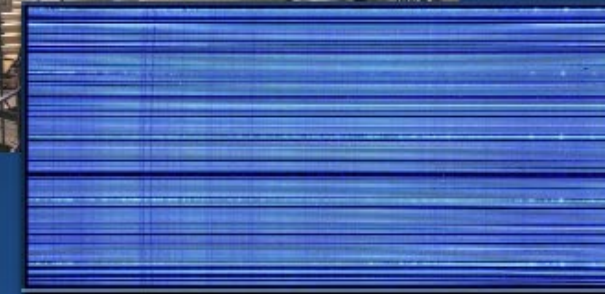




# The current MPIA instrumentation projects – 4MOST



## 4MOST – 4m Multi-Object Spectroscopic Telescope



*Roelof de Jong – AIP (PI)*

*Wolfgang Gaessler (Local Project Manager)*

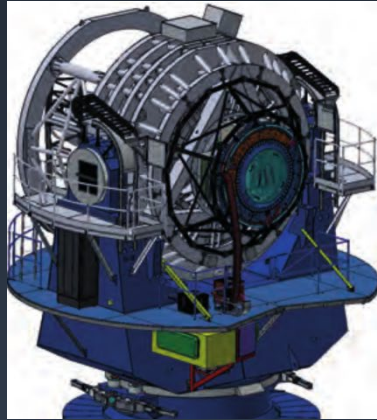
*Maria Bergemann (Local Project Scientist)*

[www.4MOST.eu](http://www.4MOST.eu)





# The current MPIA instrumentation projects – 4MOST



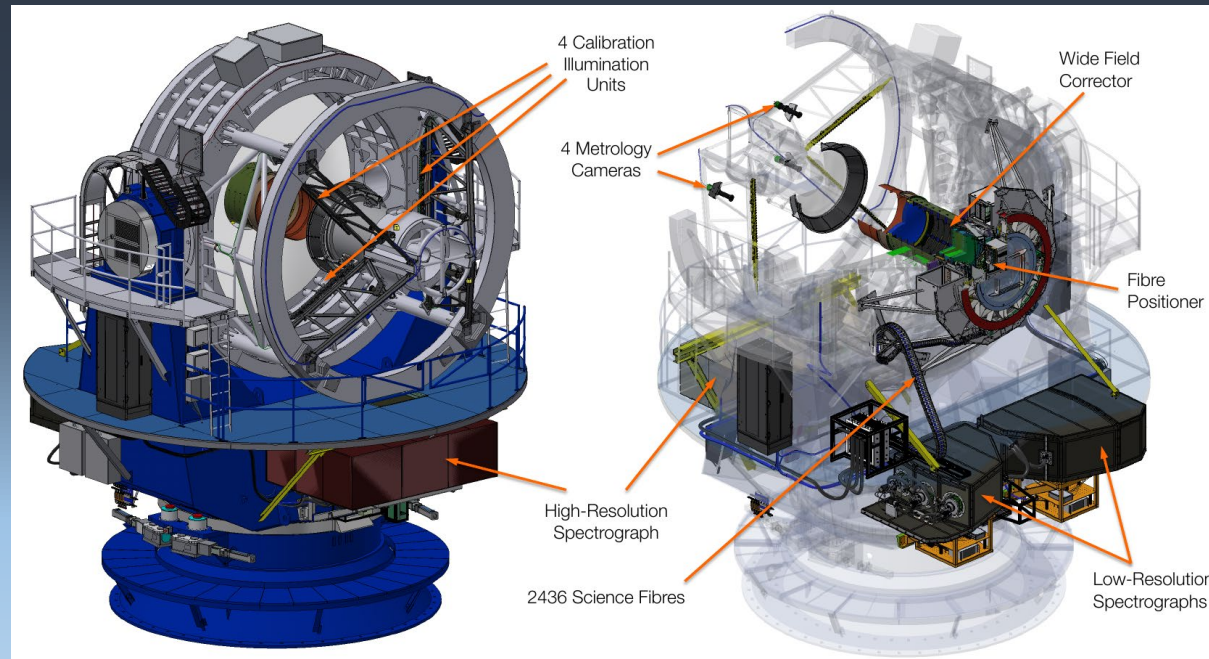
## 4MOST

4 meter Multi-Object Spectroscopic Telescope

Telescope	VISTA Telescope, Paranal, Chile
Wavelength range	420 – 900 nm
Targets	Milky Way and galaxies, structure of the cosmos
Resolution	Spectral resolving power of 5000 – 20,000 (spatial resolution n/a)
Special features	2400 fibres over a field-of-view of 4 square degrees
MPIA contribution	Instrument control electronics
Status	Manufacturing phase

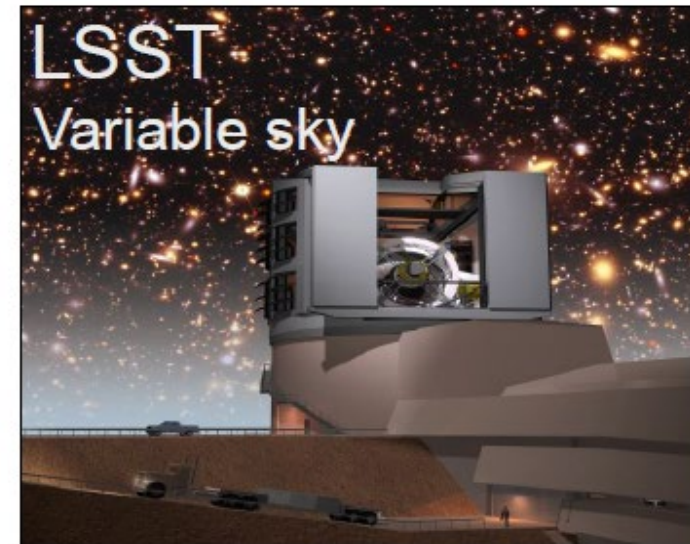
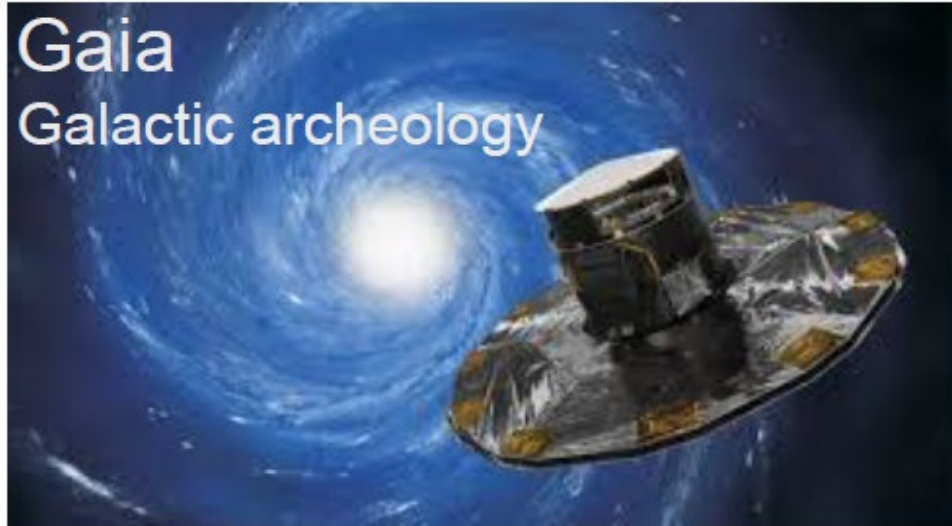


ESO VLT/VLT + VISTA  
European Southern Observatory  
Very Large Telescope / Interferometer  
+ VLT Survey Telescope  
Cerro Paranal (2635 m)  
Chile



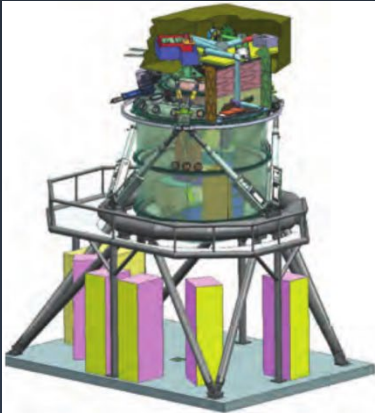
# The current MPIA instrumentation projects – 4MOST

Complements three space-based european observatories plus a ground-based one





# The current MPIA instrumentation projects – METIS and MICADO for the ESO/ELT – our largest projects



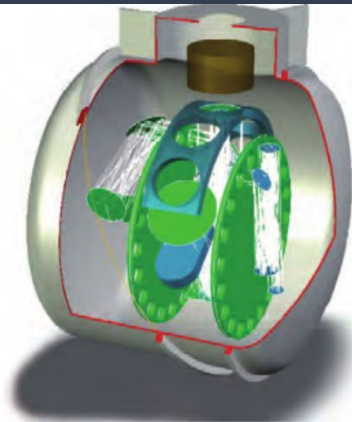
## METIS

Mid-infrared ELT Imager and Spectrograph

Telescope	Extremely Large Telescope
Wavelength range	Mid-infrared (3 – 9 $\mu\text{m}$ = L/M, N, Q bands)
Targets	Disks, exoplanets, supermassive black holes, high- <i>z</i> galaxies
Resolution	16 – 74 mas depending on wavelength
Special features	Can do coronagraphy and polarimetry
MPIA contribution	Imager and single-conjugate adaptive optics
Status	Final design phase, FDR in (June) November 2022

Co-PI and local project leader:  
Local PM:  
Local SE:  
Local PS:

Markus Feldt  
Silvia Scheithauer  
Thomas Bertram  
Roy van Boekel



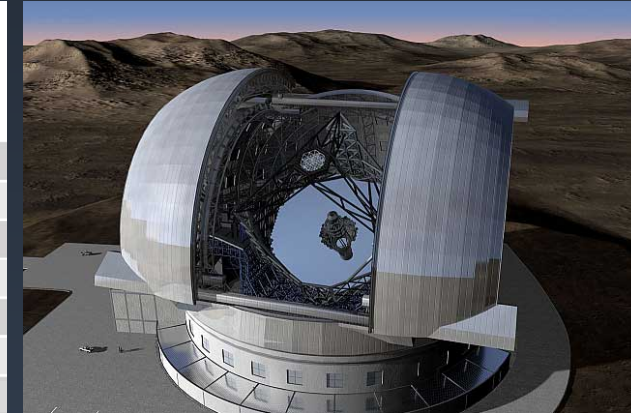
## MICADO

Multi-AO Imaging Camera for Deep Observations

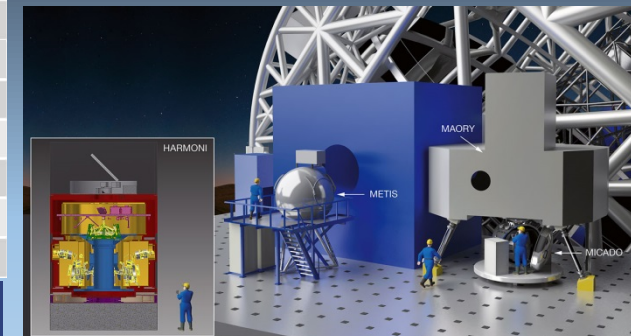
Telescope	Extremely Large Telescope
Wavelength range	Near-infrared 0.8 – 2.45 $\mu\text{m}$
Targets	Stellar motions in galaxies, dwarf galaxies, first supernovae
Resolution	6 – 13 mas depending on wavelength
Special features	High sensitivity, precise astrometry
MPIA contribution	instrument derotator bearing, astrometric calibration
Status	Final design phase, FDR in March 2022

Local project leader and scientist:  
Local PM:  
Local SE:

Jörg-Uwe Pott  
Ralph Hofferbert  
Friedrich Müller

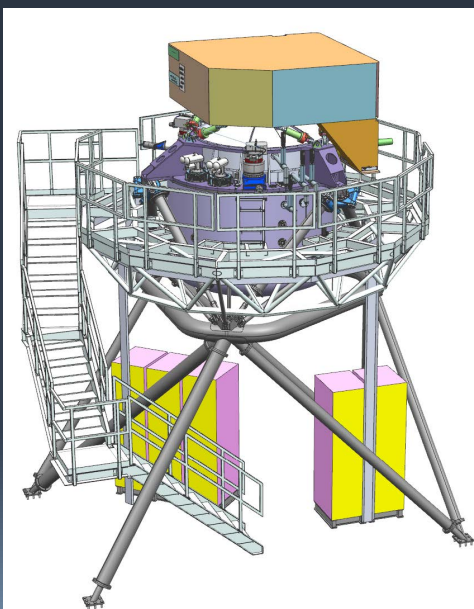


ESO ELT  
European Southern Observatory  
Extremely Large Telescope  
Cerro Armazones (3060 m)  
Chile

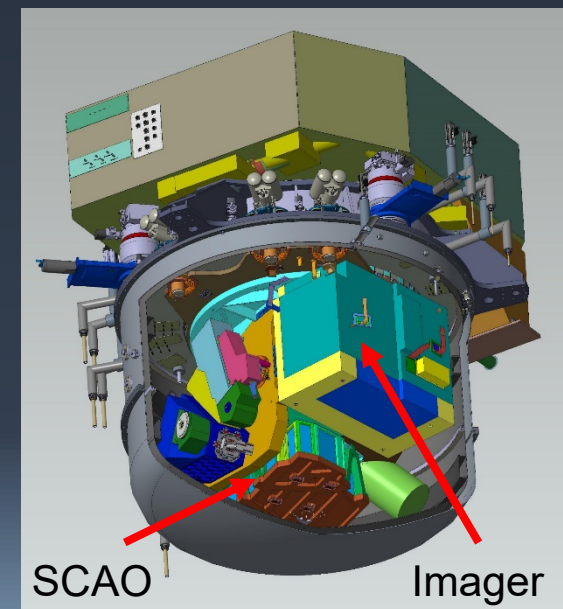
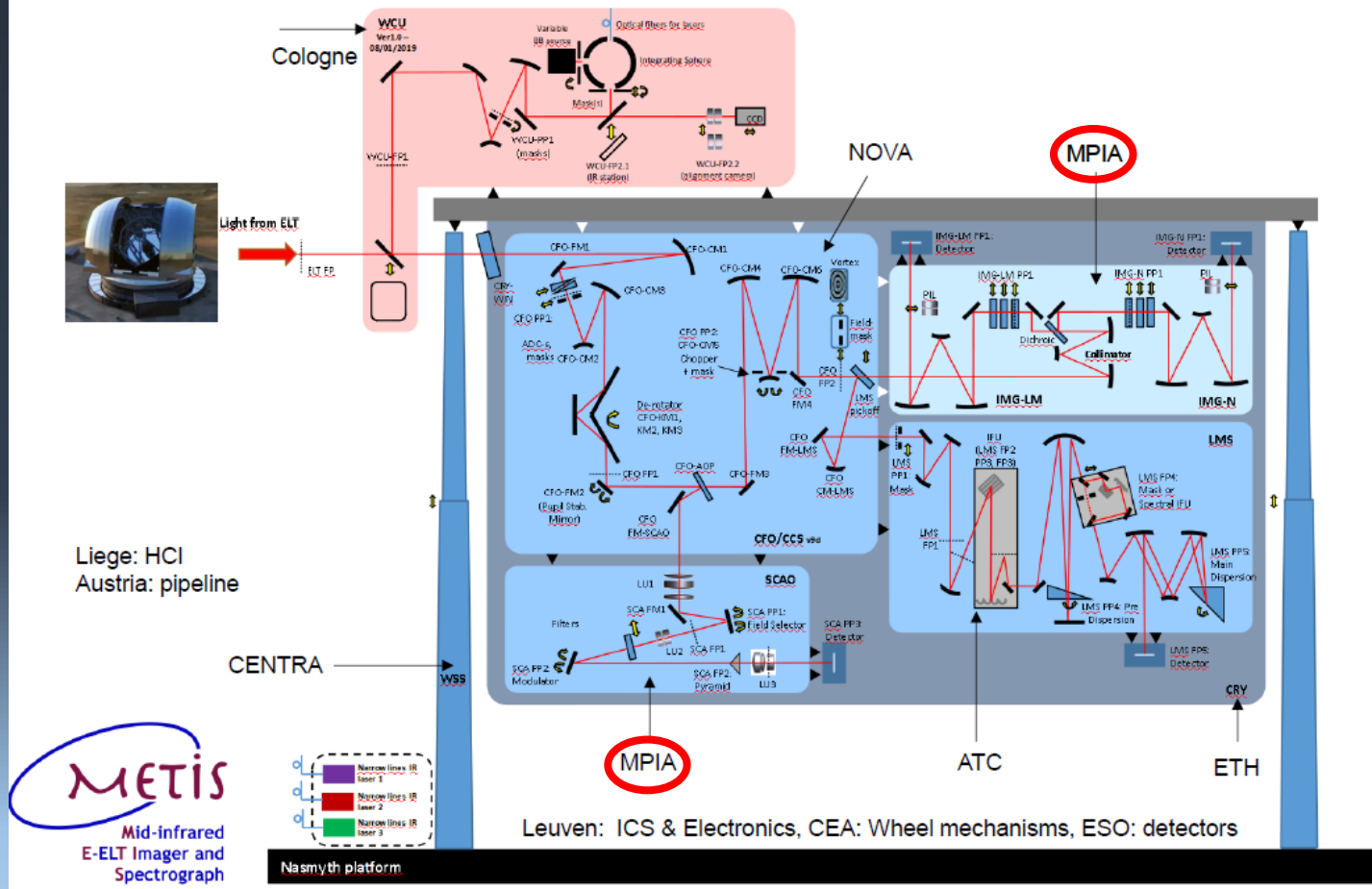


# METIS

## METIS Optical Overview



Cryostat height 2.8m,  
diameter 2.7m

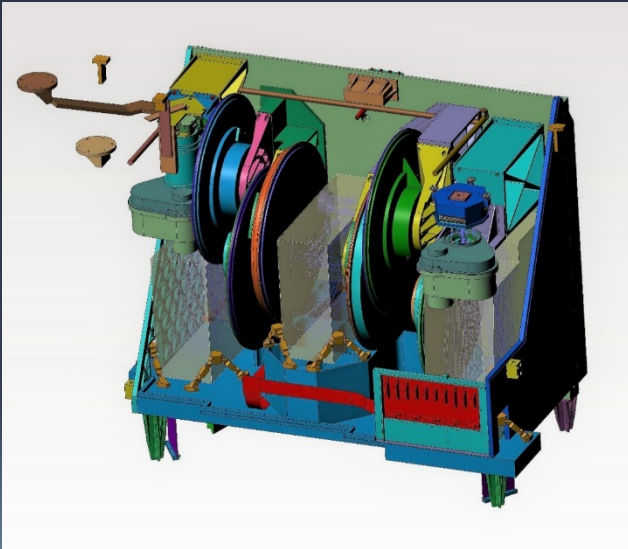


SCAO Imager  
MPIA's work packages

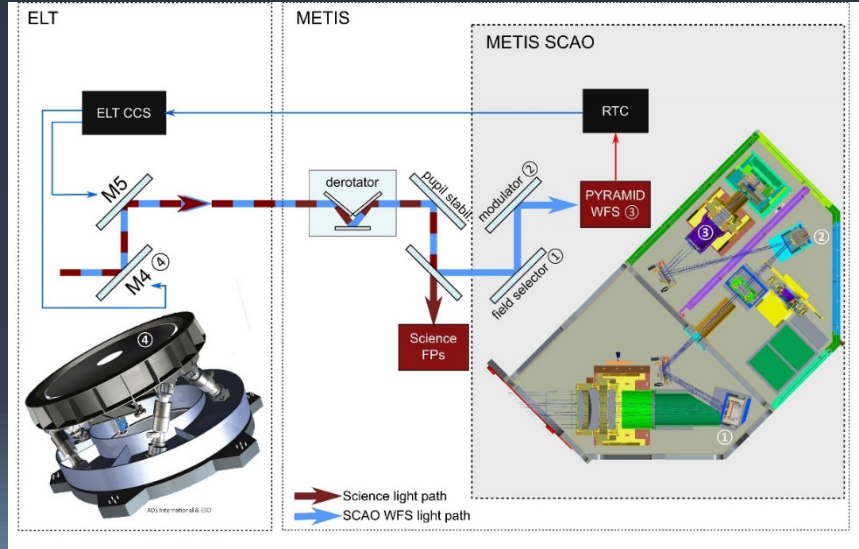


# METIS

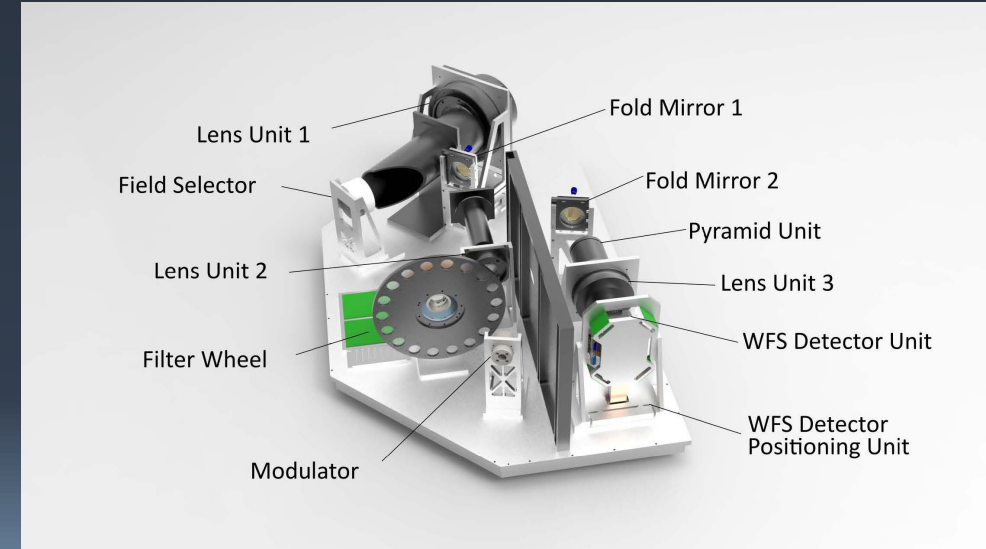
Imager



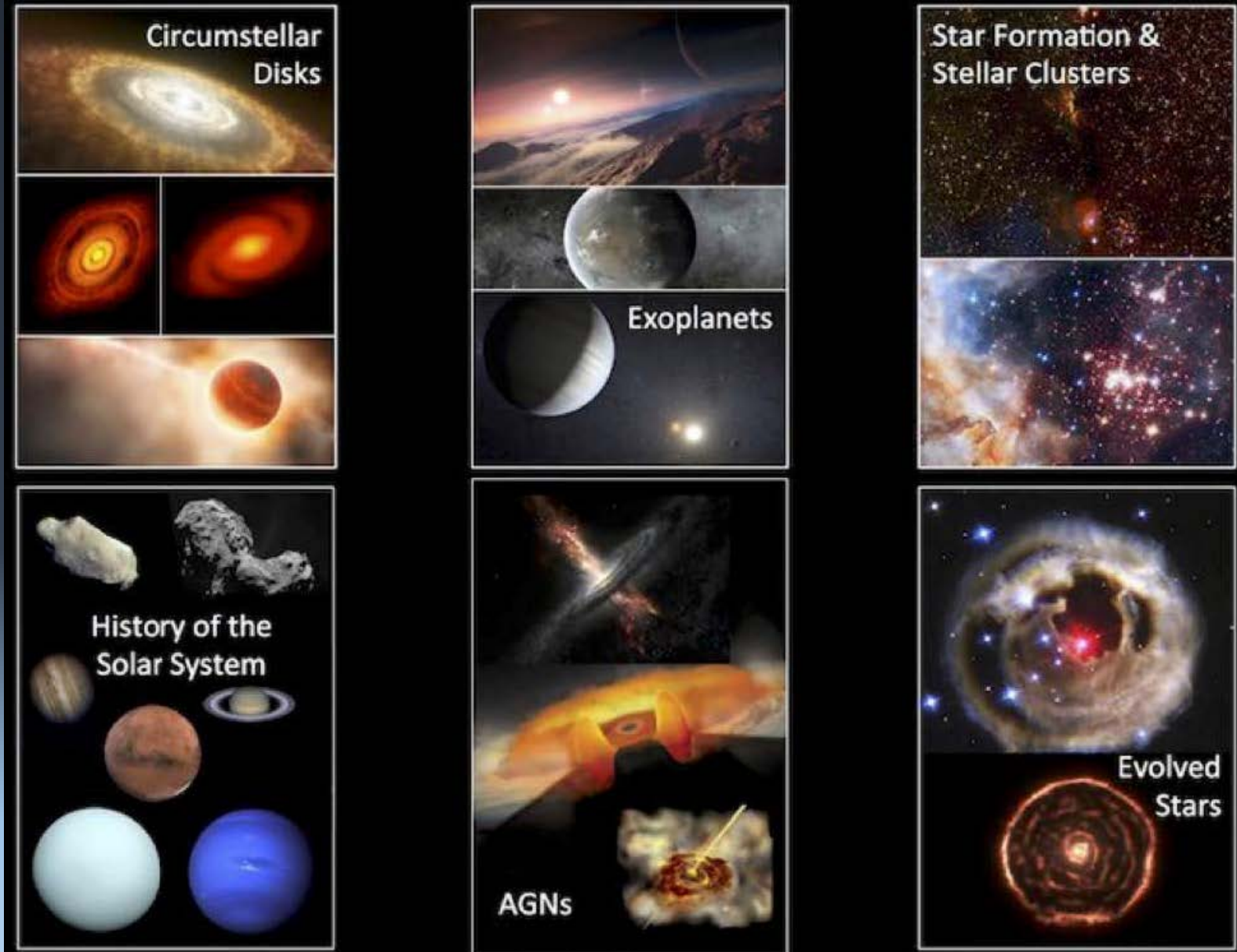
SCAO system



SCAO WFS



# METIS



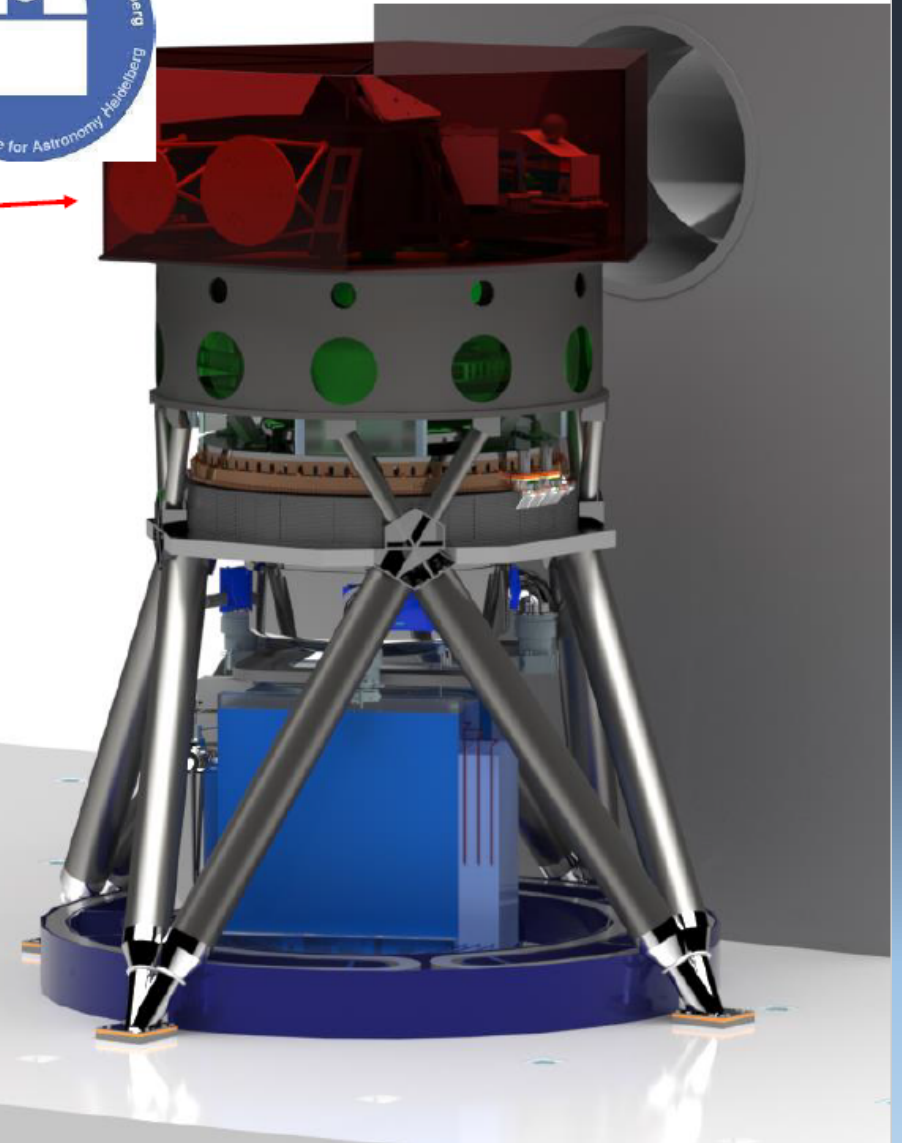
## Main science topics:

- Protoplanetary disks
- Planet formation
- Solar system formation history
- Massive stars and cluster formation
- Evolved stars and their circumstellar environment
- Galactic center
- Physics of galaxies
- Active galactic nuclei

# MICADO

## Global Architecture

- Relay optics – transfers ELT focal plane downwards into MICADO
- Calibration assembly, mounted next to relay optics, replicates ELT focal plane (later moves to MAORY bench).
- NGS WFS module (Green Doughnut) – contains SCAO on a top bench & MAORY NGS WFS on a lower bench.
- Cryostat (not visible, hidden inside GD support).
- Derotator.
- Support Structure – for fixed upper platform & central ring (which supports rotating mass)
- Co-rotating platform with electronics cabinets (due to cable length limitations).





# MICADO

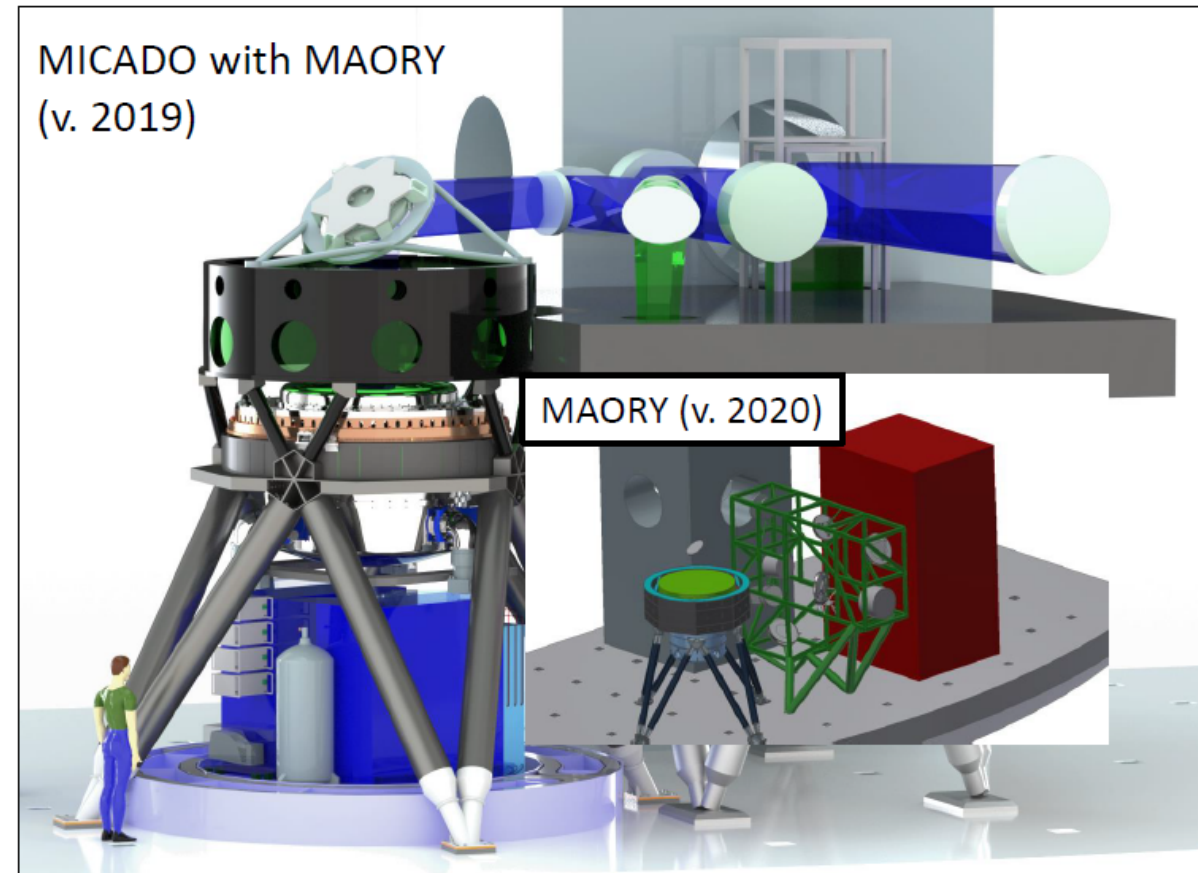
## MICADO & MAORY

Stand-alone phase with just SCAO during initial operations.



Long term operation with MAORY (LGS-MCAO, & keeping SCAO).

MAORY: project led by INAF, uses 4-6 LGS and up to 3 NGS to provide uniform AO correction over full MICADO field.





# MICADO

## Key Capabilities

MICADO will provide:

### ☐ Imaging

- 0.8-2.4 $\mu$ m with >30 broad/narrow filters
- 1.5 & 4mas pixels for 19 & 51" FoV at 6-12mas
- Similar sensitivity to JWST, and 6 $\times$  better resolution

### ☐ Astrometric imaging

- 10-50 $\mu$ as precision anywhere in the field
- 10 $\mu$ as/yr = 5km/s at 100k pc after only a few years

### ☐ High Contrast imaging

- focal & pupil plane coronagraphs
- angular differential imaging
- small inner working angle

### ☐ Spectroscopy

- for compact sources
- fixed configuration for 0.8-1.45 $\mu$ m & 1.21-2.45 $\mu$ m
- $R \sim 20000$  for point sources ( $R \sim 10000$  across slit)

# The current MPIA instrumentation projects – (CARMENES and) PANIC-4K for Calar Alto Observatory



## CARMENES

Calar Alto high-Resolution search for M dwarfs with Exoearths with Near-infrared and optical Echelle Spectrographs

Telescope	3.5 meter Telescope, Calar Alto
Wavelength range	Near-infrared and visible light, 0.5 – 1.7 $\mu\text{m}$
Targets	Planets around 300 M dwarf stars including Earth-like planets
Resolution	High spectral resolving power of 82,000 (spatial resolution n/a)
Special features	Two high-precision spectrographs for radial velocity measurements
MPIA contribution	NIR detector/cryostat, electronics, software, integration facility
Status	Operational, survey underway, instrumentation project ended



Calar Alto-Observatorium  
Calar Alto (2168 m)  
Spanien



## PANIC-4K

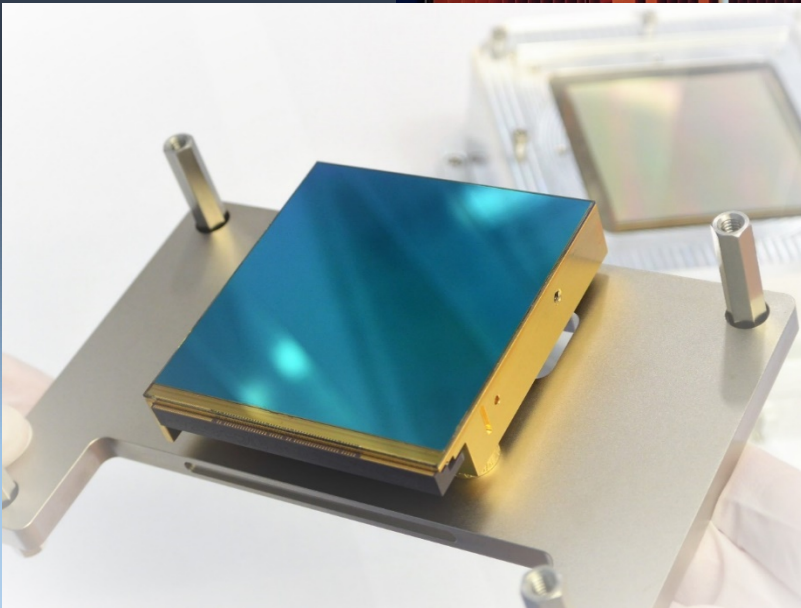
PANoramic Near-Infrared Camera with a 4K detector

Telescope	2.2 meter Telescope, Calar Alto
Wavelength range	Near-infrared, 0.9 – 2.15 $\mu\text{m}$
Targets	Multipurpose wide-field survey imager
Resolution	Seeing limited
Special features	Large field-of-view – size of the full Moon
MPIA contribution	Integration and characterization of new HAWAII-4-RG detector
Status	Refurbishment with new detector underway

Project leader:

Peter Bizenberger

# The current MPIA instrumentation projects –PANIC-4K

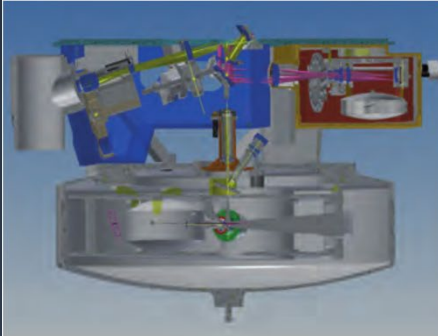




# The current MPIA instrumentation projects – NTE and LVM Telescopes ... for `other` observatories

## NTE

NOT Transient Explorer



Telescope	2.5 meter Nordic Optical Telescope (NOT), La Palma
Wavelength range	UV, visible, near-infrared, 334 – 2200 nm
Targets	Transient phenomena, gamma-ray bursts, gravitational wave sources, kilo- and supernovae
Resolution	Imaging: 0.18"/pixel, field-of-view 6'; spectroscopy: $R \sim 5000$ ; 20" long slit
Special features	Rapid response mode (< 2 minutes) under development
MPIA contribution	Read-out systems for the NIR cameras
Status	FDR passed. MPIA contributions ready to be delivered. Applying for GTO time

Project leader (PI):  
PM:  
Local project leader:

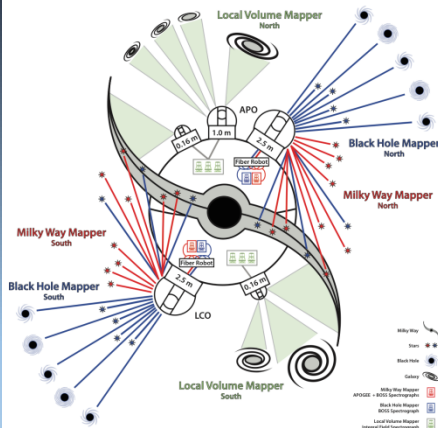
Johan Fynbo (NBI)  
Jacob Clasen (NOT)  
Martin Kürster



Roque-de-los-Muchachos-Observatorium  
Nordic Optical Telescope  
Roque de los Muchachos (2350 – 2400 m)  
La Palma, Kanarische Inseln, Spanien

## LVM Telescopes (SDSS V)

Focal planes Large Volume Mapper project (Sloan Digital Sky Survey V)



Telescope	Four 16 cm telescopes each for LCO (and APO ???)
Wavelength range	360 nm – 1000 nm
Targets	Spectroscopy: $R = 2000 - 22000$
Resolution	Milky way and local volume galaxies
Special features	Multi-epoch optical & IR spectroscopy, integral field
MPIA contribution	Telescopes and K-mirrors
Status	Commissioning Chile to start in August 2022

Project leader:  
PM:

Tom Herbst  
Wolfgang Gässler



Las-Campanas-Observatorium (LCO)  
Cerro Las Campanas (2380 m)  
Chile (+)



Apache-Point-Observatorium (APO)  
Apache Point (2788 m)  
New Mexico, USA



# The current MPIA instrumentation projects – NTE for NOT

NOT

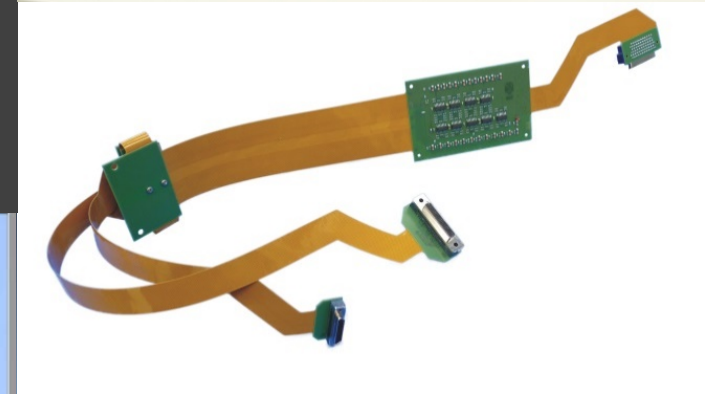


MPIA contributions – all ready for delivery:

- three ROE units with cabling
  - our in-house development !
- the R/O software
  - ditto !
- the characterization of the HAWAII-2-RG detectors
  - we have the expert !

Plus:

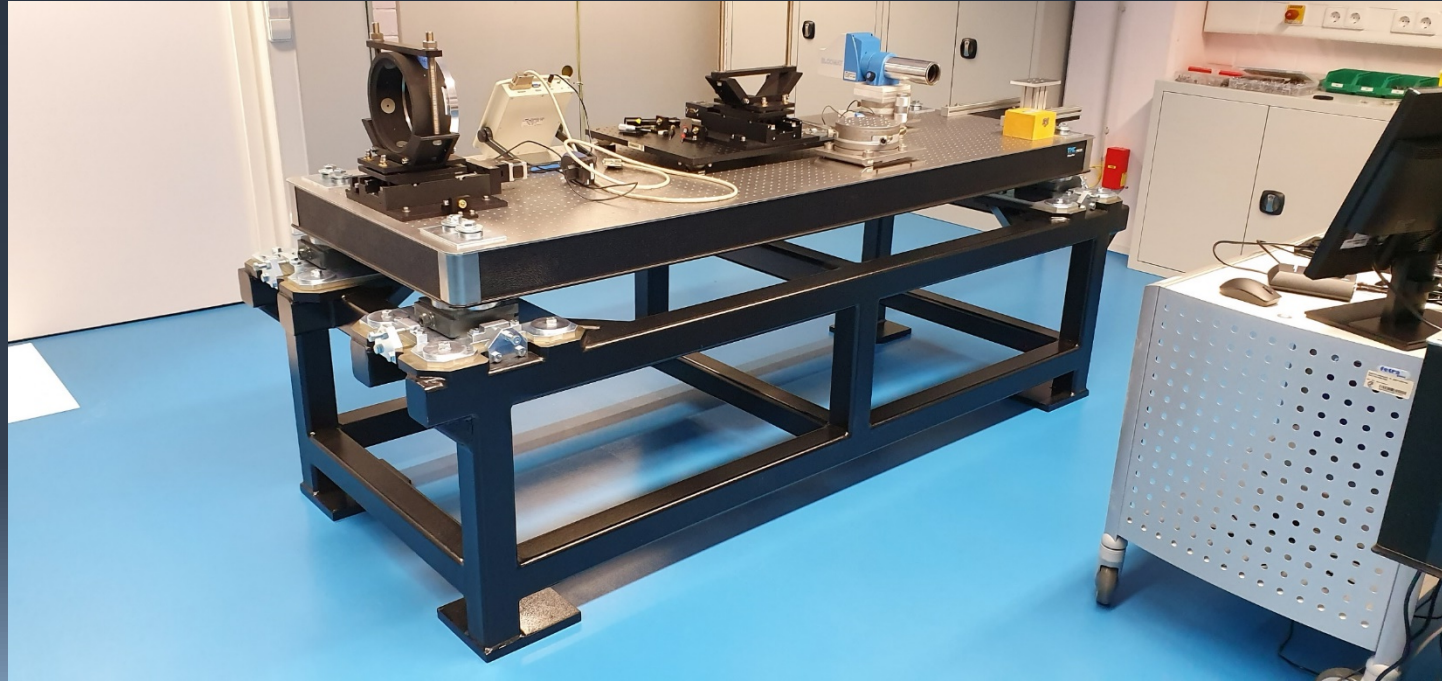
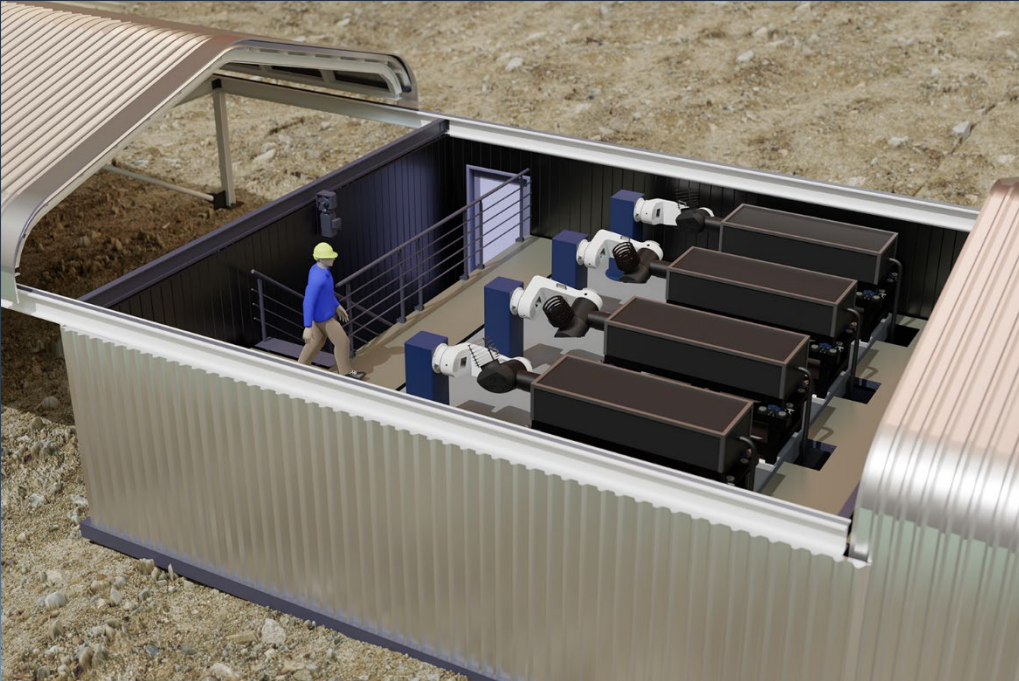
- fabrication of the detector mounts
  - again we have the expert for detector handling !
- design and fabrication of the transport boxes



## CANARY ISLANDS

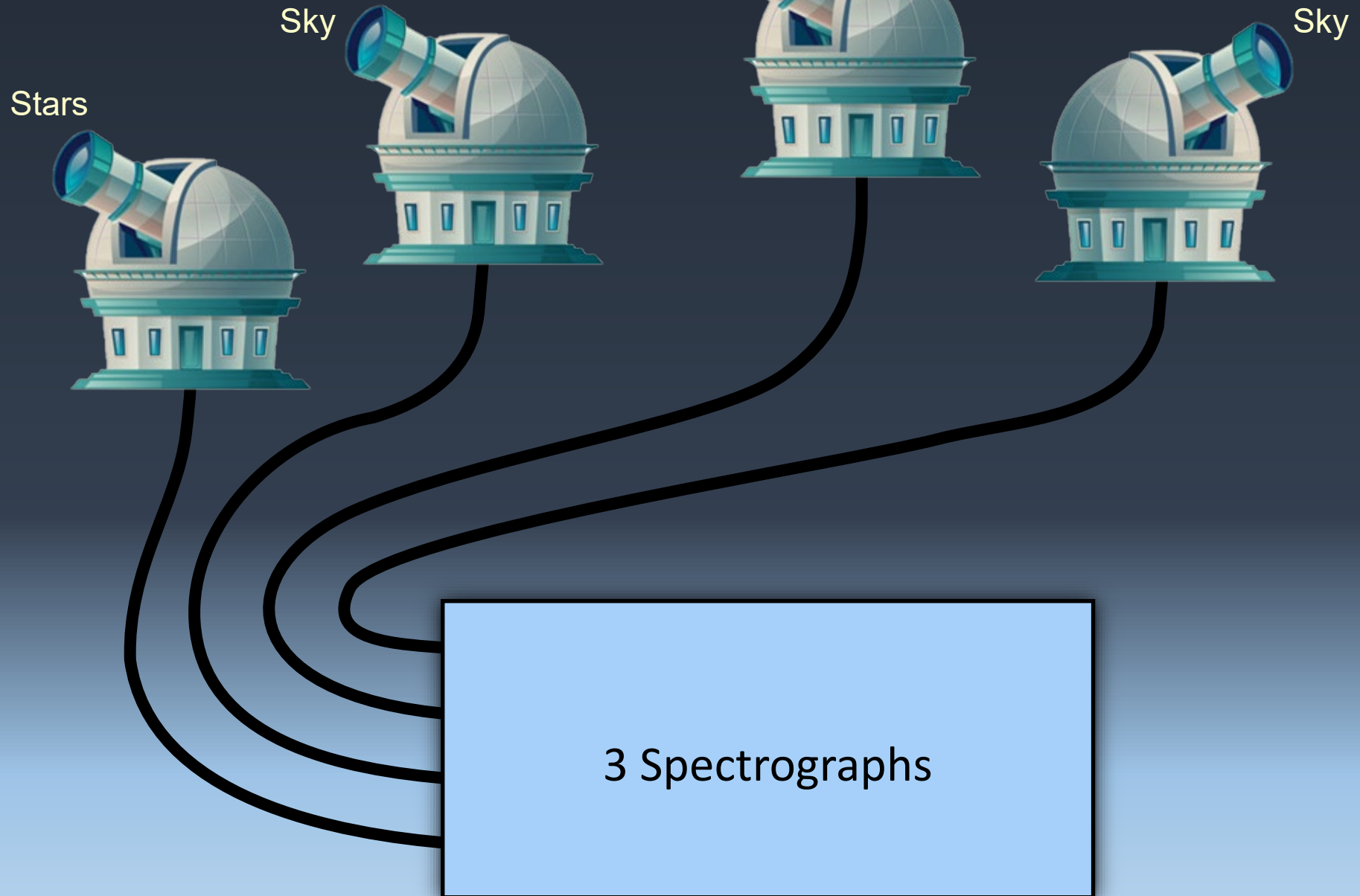


# The current MPIA instrumentation – LVM Telescopes for LCO



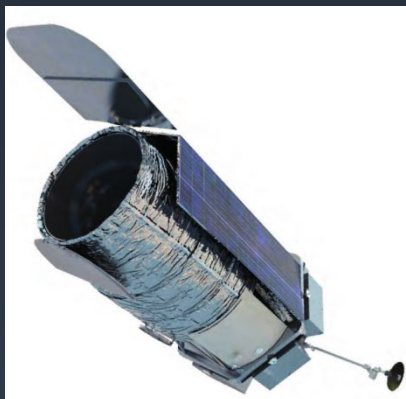


# How Does LVM Work?





# The current MPIA instrumentation projects – CGI / Roman Space Telescope (ex: WFIRST)



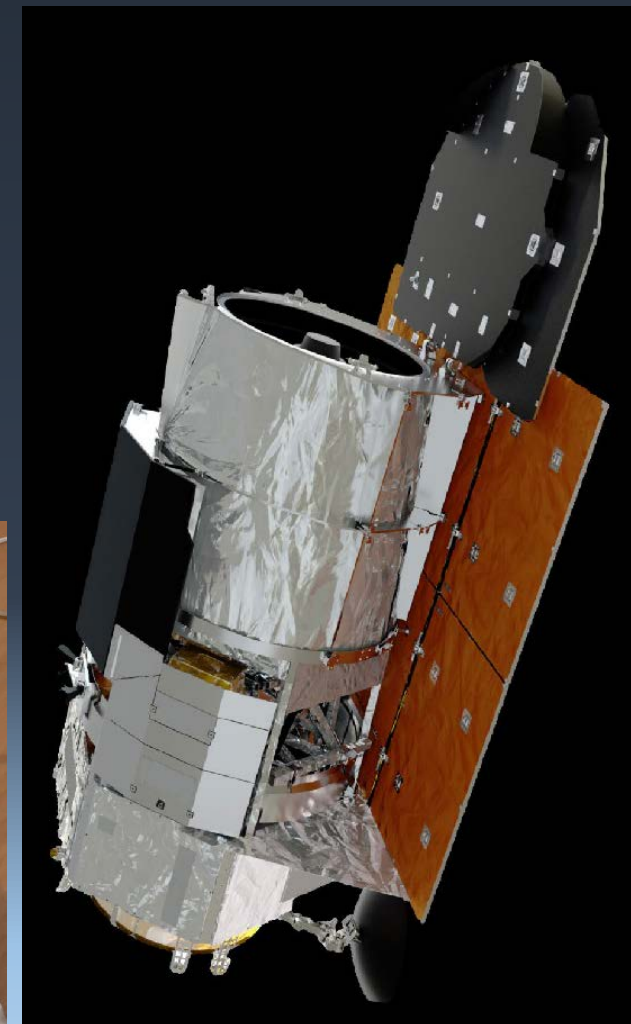
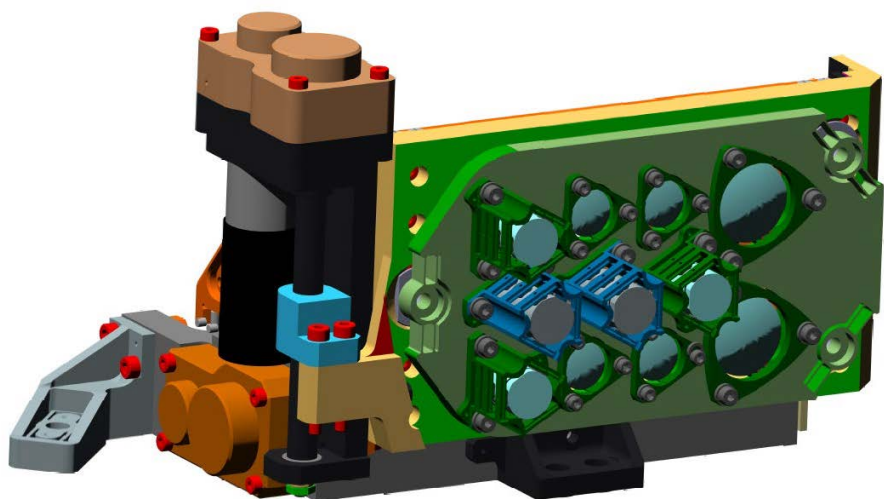
## CGI / Roman Space Telescope (ex: WFIRST)

Telescope	Roman Space Telescope
Wavelength range	Near-infrared, large region imaging
Targets	Exoplanet detection and dark energy research
Resolution	Wide field near-infrared imaging with an angular resolution of $\sim 0.2$ arcsec
Special features	Field-of-view 100 times that of the HST; coronagraphs
MPIA contribution	Mechanisms and their control for ground support equipment
Status	CDR passed. End of MPIA project March 2022



*Project leader:*

*Oliver Krause*

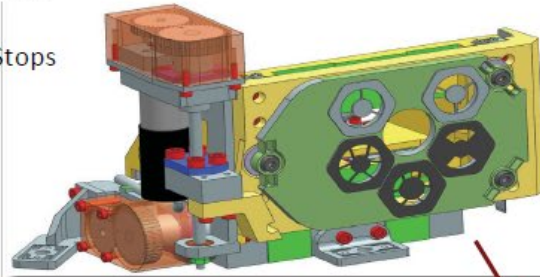


# The current MPIA instrumentation projects – CGI / Roman Space Telescope (ex: WFIRST)

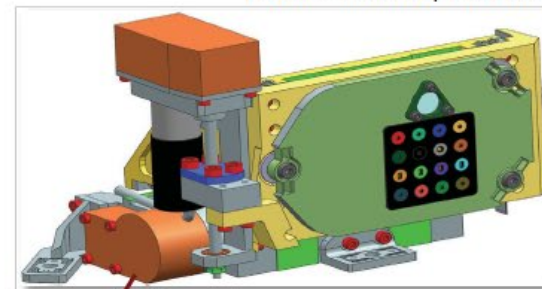
## CGI precision Alignment Mechanisms

6 feedback-controlled electro-mechanical units for highly stable, sub-micrometer positioning of optical elements

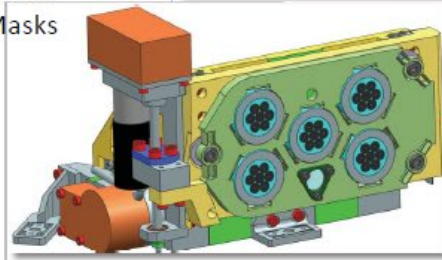
**LSAM:** Lyot Stops



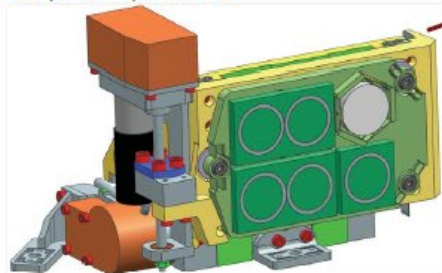
**FSAM:** Field Stops & Slits



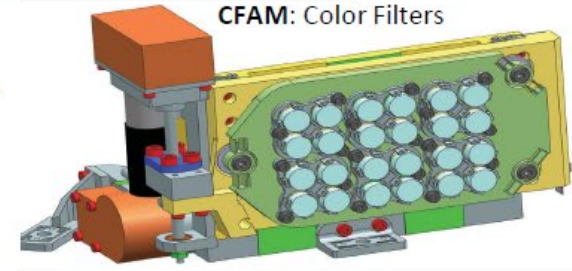
**FPAM:** Focal  
Plane Masks



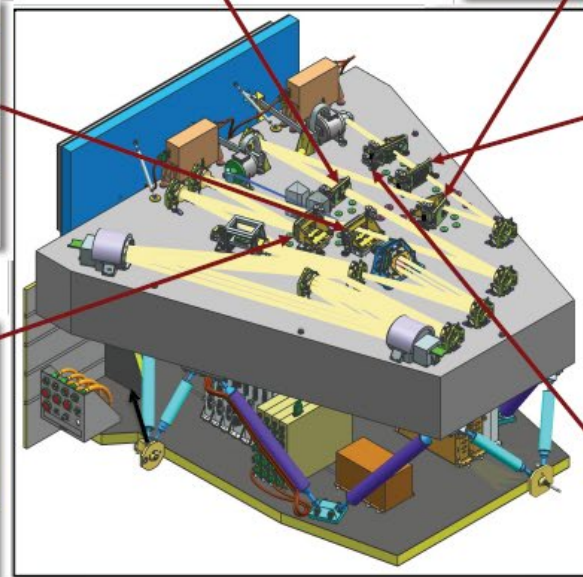
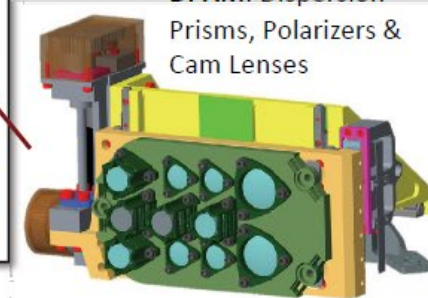
**SPAM:** Shaped Pupil Masks



**CFAM:** Color Filters



**DPAM:** Dispersion  
Prisms, Polarizers &  
Cam Lenses



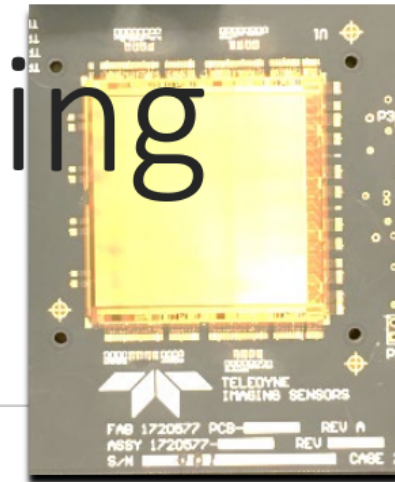


# The current MPIA instrumentation projects – Technology development project: GeoSnap Detector

Project leader:  
PM:

Peter Bizenberger  
Silvia Scheithauer

## GeoSnap: A 1024x1024 HgCdTe array covering 3-13 $\mu$ m



DANI ATKINSON, MICHAEL MEYER, & RORY BOWENS (UM)

JARRON LEISENRING, BILL HOFFMAN, DENNIS HART, & KATE MORZINSKI (UA)

16 OCTOBER 2020



TELEDYNE  
SCIENTIFIC & IMAGING  
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# The current MPIA instrumentation projects – Technology development project: GeoSnap Detector



THE UNIVERSITY  
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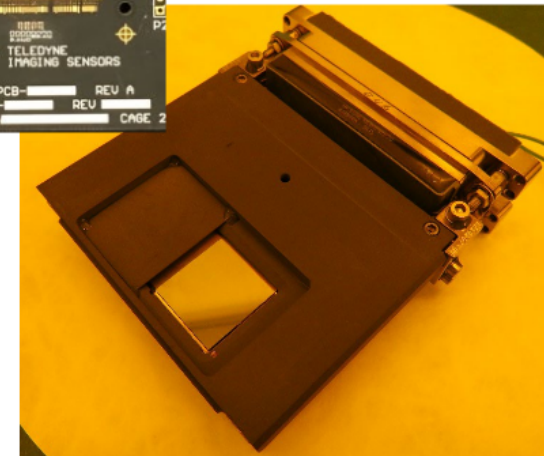
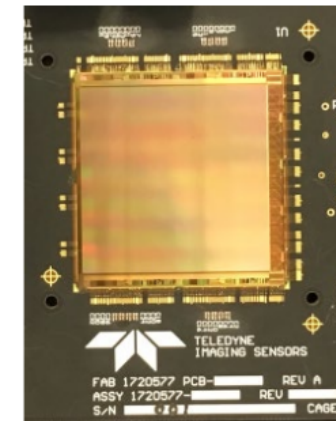


UNIVERSITY of  
ROCHESTER



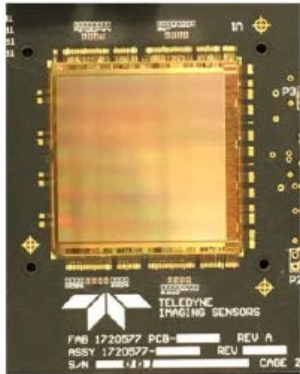
## The GeoSnap!

- A detector for an underdeveloped spectral range!
- $<100 \text{ ke-}/\text{s}$  dark!
- Enables potential direct imaging of exo-Earths
- $\frac{1}{f}$  <sup>noise</sup> to be suppressed by chopping and influx level
- Upcoming deployment!

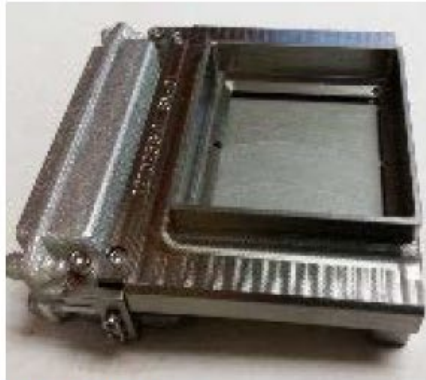


# The current MPIA instrumentation projects – Technology development project: GeoSnap Detector

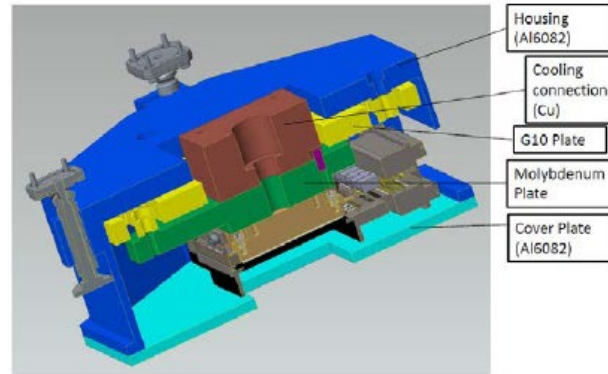
The Detector -- its career



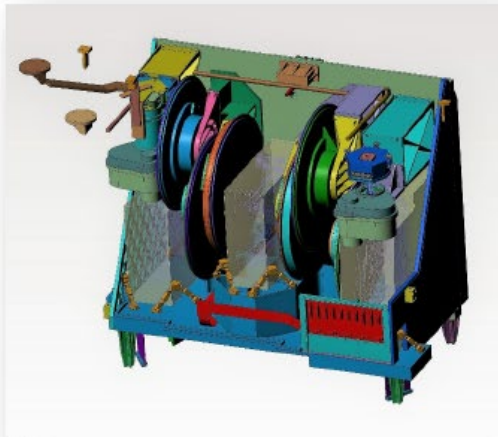
GeoSnap



Detector Package



Detector Mount



METIS Imager



METIS Instrument

## Schedule:

- |            |   |
|------------|---|
| 2021 Feb.  | Internal detector mount design review               |
| .....      |   |
| 2022 Sept. | Delivery of GeoSnap R/O circuit                     |
| 2022 Nov.  | <i>METIS FDR</i>                                    |
| 2023 March | Delivery of GeoSnap science grade array             |
| 2024 May   | Verification of detector system within METIS imager |
| 2026 March | Delivery to METIS system                            |

# The current MPIA instrumentation projects – Order project for company Hensoldt: METImage / DLR

*Project leader:*

*Oliver Krause*





# The current MPIA instrumentation projects – Order project for company Hensoldt: METImage / DLR

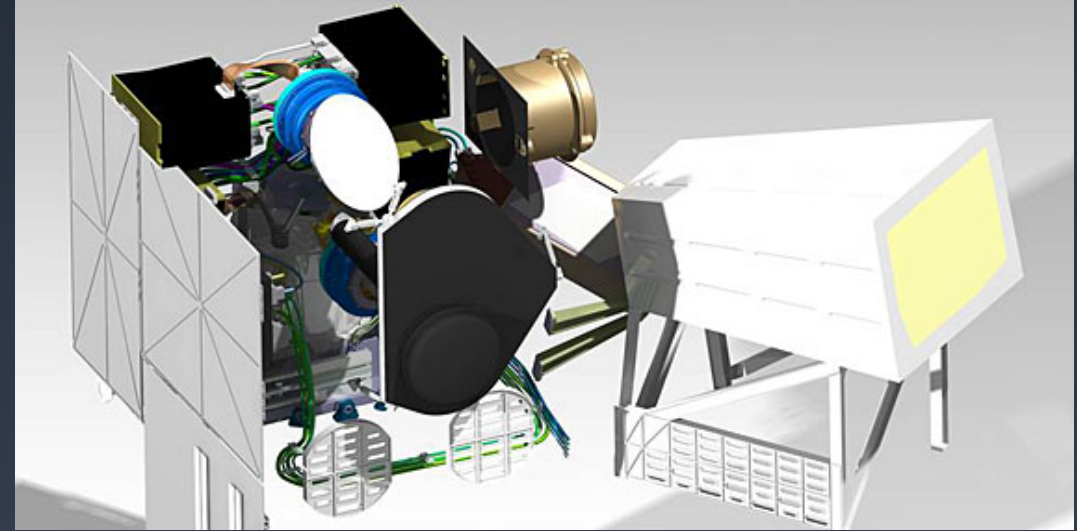
Order project for company Hensoldt: METImage

Status: About to end ...

Task: Component characterization in one of our test cryostats, more specifically, performance tests of the cryogenic relay optics

- The DLR<sup>\*)</sup> project METImage is a multi-spectral imaging radiometer for meteorologic applications
- It will fly on the satellites of the EUMESAT Polar System – Second Generation as of 2024
- It will collect information about clouds, cloud coverage, land surfaces, and ocean, aerosols, ice, and surface temperatures incl. fires
- It will thus contribute to predicting weather and climatic conditions

<sup>\*)</sup> DLR = Deutsches Zentrum für Luft- und Raumfahrt



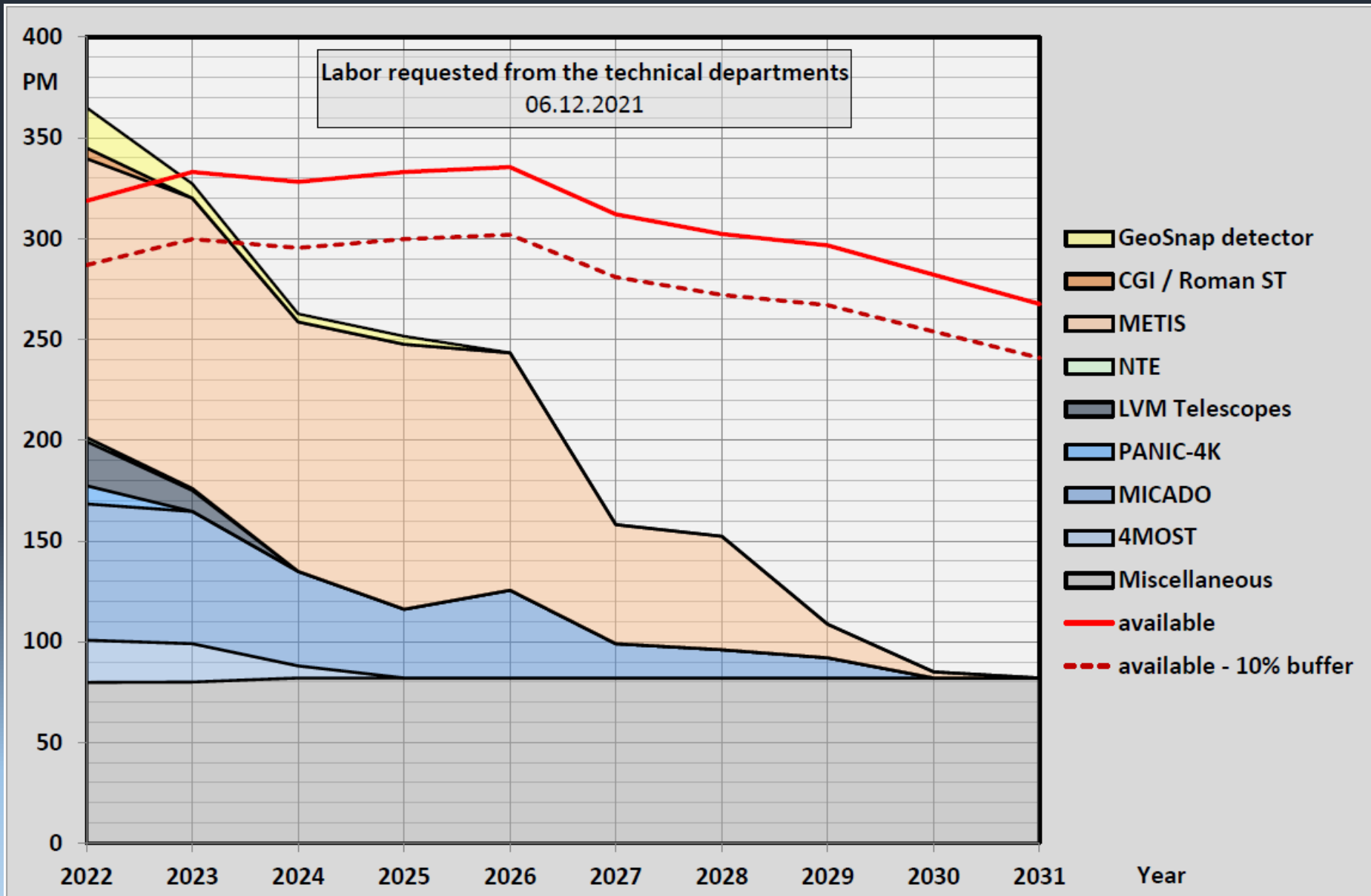
# MPIA Project Overview

What is going to happen ...

... the crystal ball

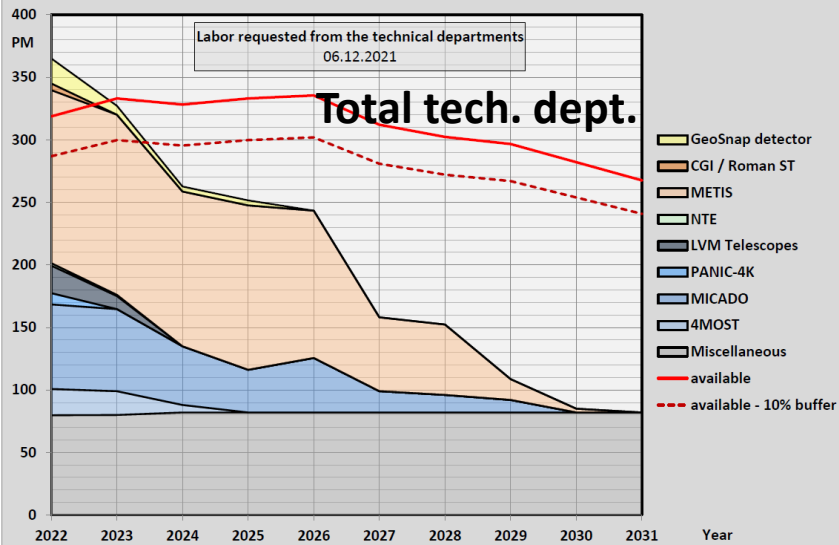


# The 10-year preview

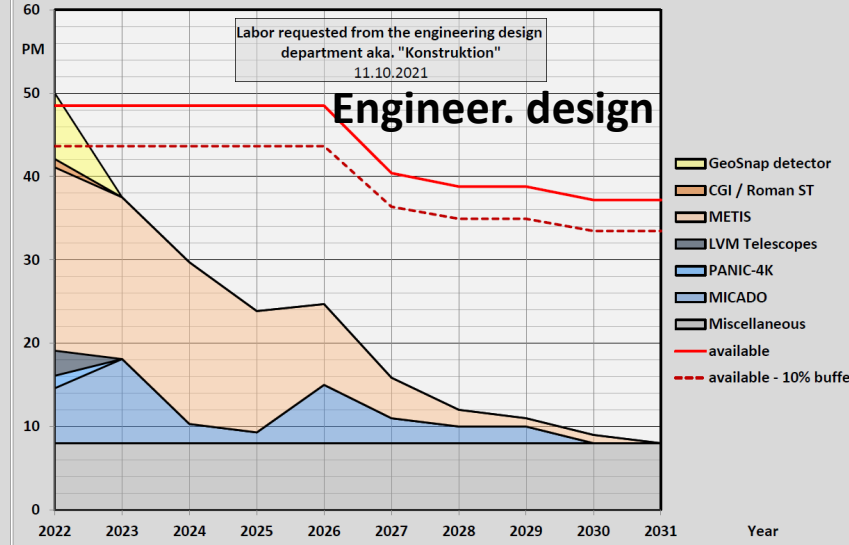




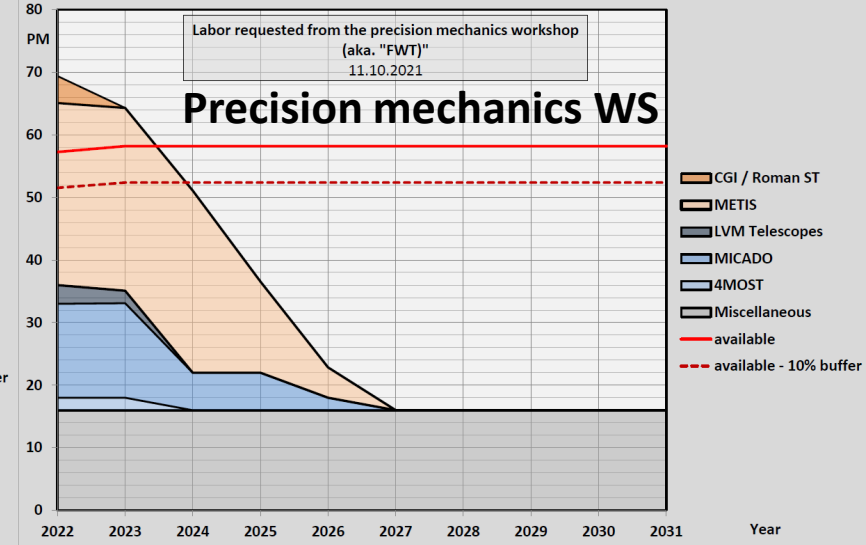
# The 10-year preview



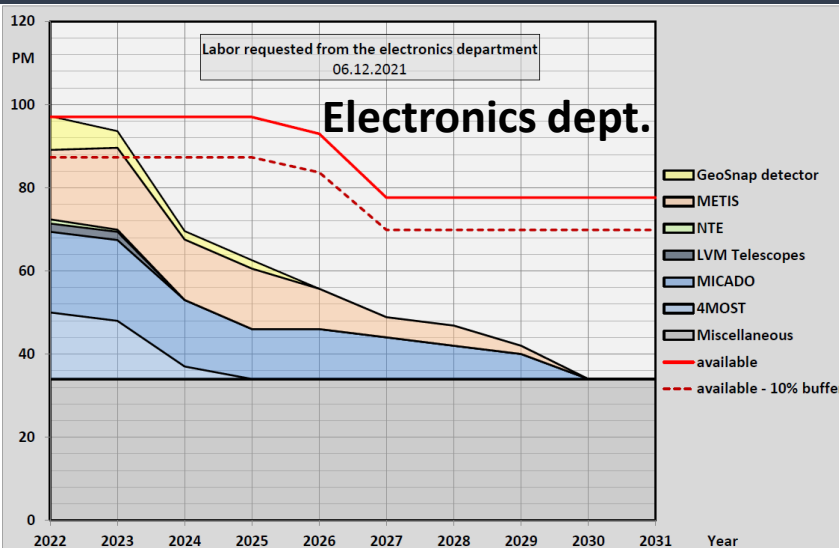
2022 — 2031



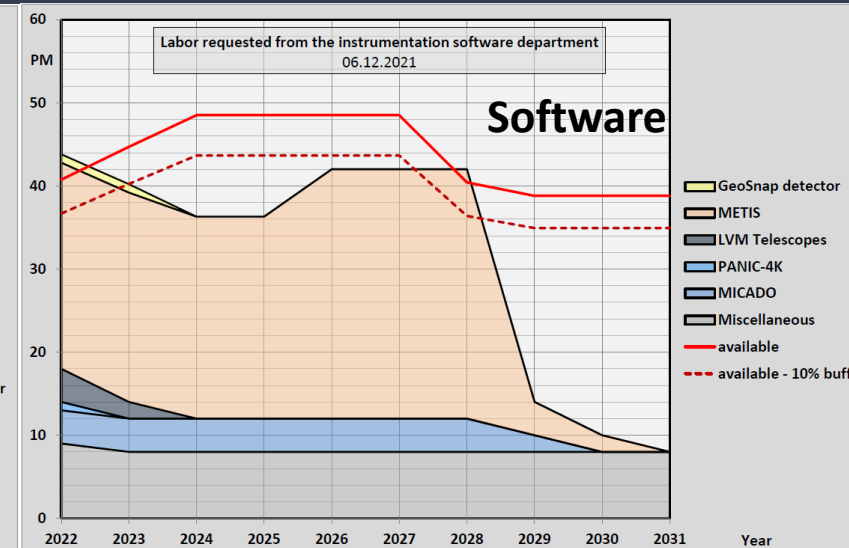
2022 — 2031



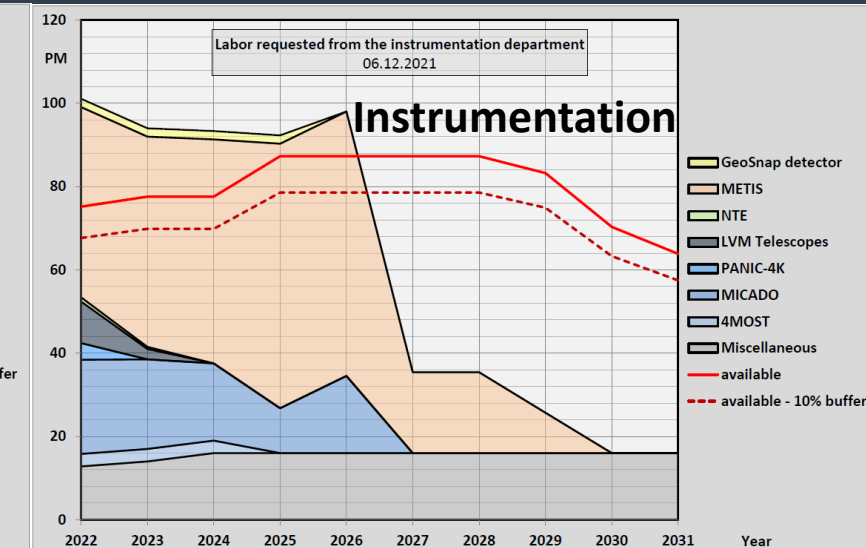
2022 — 2031



2022 — 2031



2022 — 2031



2022 — 2031

# Future MPIA instrumentation projects

- VLT /SPHERE+
  - Larger AO bandwidth
  - NIR WFS
  - Higher spectral resolution

*Project leader:*

*Markus Feldt*

- ELT / ANDES (ex: HIRES)
  - MPIA work packages under discussion:
    - Electronics for the K-band and UV spectrographs and for the calibration unit
    - The ``complete'' K-band spectrograph

*Project leader (PI):*

*Alessandro Marconi (U-Florence, INAF Arcetri)*

*Local project leader:*

*Wolfgang Brandner*

*Local PM:*

*Wolfgang Gässler*

# New MPIA instrumentation projects – SPHERE+ for ESO VLT

## Scientific and technical requirements

- **sci.req 1: Acces the bulk of the young giant planet population down to the snow line**
  - **tech.req 1: increase bandwidth of AO system**
- **sci.req 2: Observe a large number of fainter (lower mass) stars**
  - **tech.req 2: operate WFS in NIR**
- **sci.req 3: Improve the level of characterization of exoplanetary atmospheres**
  - **tech.req 3: increase resolution of spectroscopic facilities**



# New MPIA instrumentation projects – SPHERE+ for ESO VLT

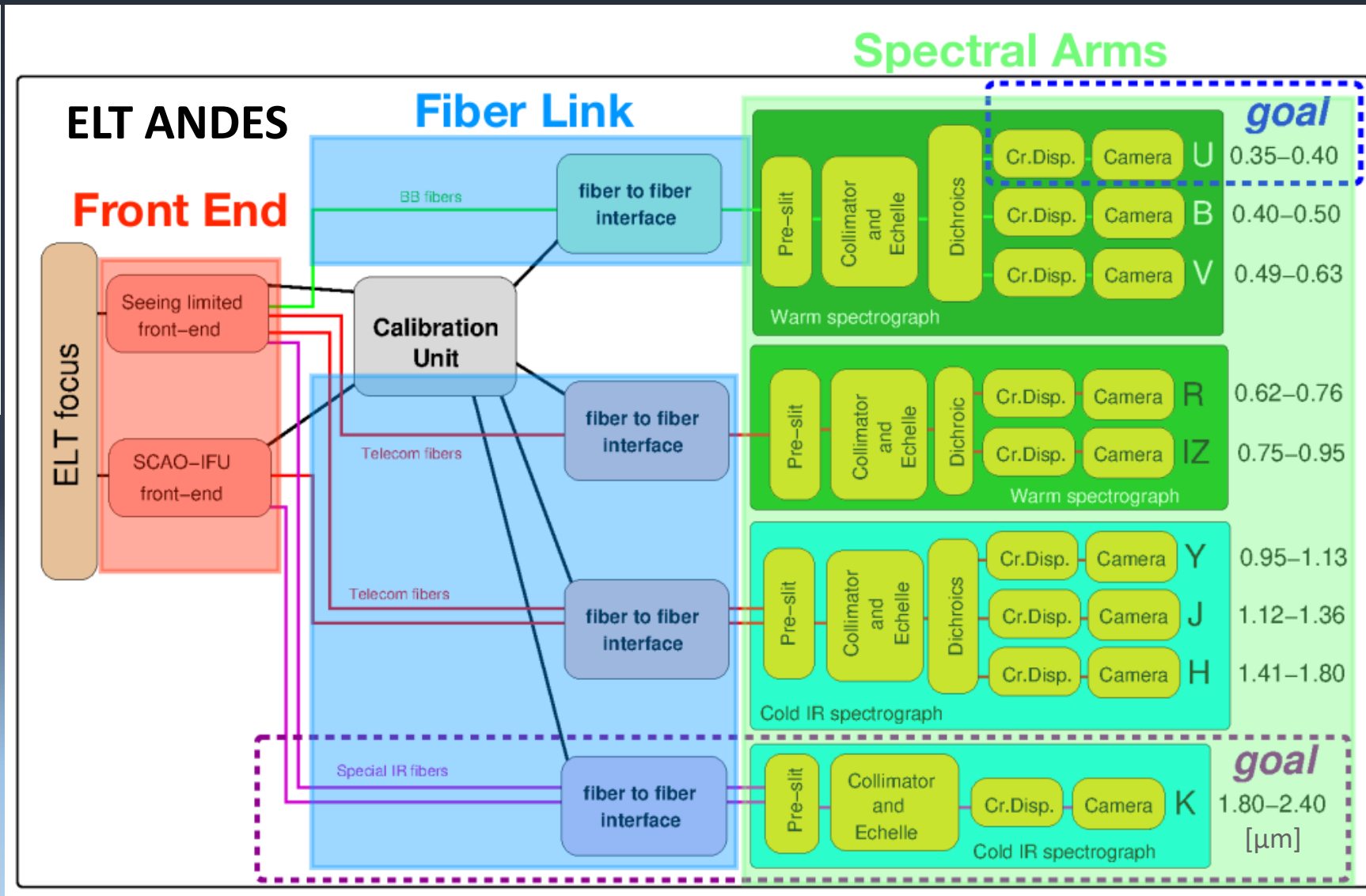
## Proposed MPIA contribution

Task	Description	Responsible	Time	Units
AO Simulations	<ul style="list-style-type: none"> <li>• Prerequisite: Existing COMPASS config for SPHERE+ (tbc LESIA)</li> <li>• Introduce METIS reconstructor (Zonal VDM)</li> <li>• Comparative case study wrt               <ul style="list-style-type: none"> <li>▫ Standard performance</li> <li>▫ Impact of LW</li> <li>▫ Impact of TBD</li> </ul> </li> </ul>	M. Feldt H. Steuer	2022-2023	1.0 FTE
Pyramid Prism	<ul style="list-style-type: none"> <li>• Review procurement specs</li> <li>• handle contact with WZW (attempt others again if necessary)</li> <li>• Receive prism</li> <li>• handle characterization / verification of pyramid</li> </ul>	TBD	2023	50k€ 0.5FTE
Control Electronics	TBD	L. Mohr	2024-2025	1.0 FTE
Fibre coupling study for IFU	<ul style="list-style-type: none"> <li>• Study of optimal design of IFU fibre link               <ul style="list-style-type: none"> <li>▫ Evaluating technologies, throughput, Field of View etc</li> <li>▫ New novel concepts (printed reformatters, dithered lenslets)</li> </ul> </li> <li>• Possibly: Full design of Sphere+ link</li> <li>• With money, could build link</li> </ul>	R. J. Harris	2022-2023	R.J.H. gets 20% his time for own research. I would suggest 10% max goes on this

# New MPIA instrumentation projects – ANDES for ESO ELT (ex: HIRES)

## Schedule

- ★ Phase A: 2016-2018 **Completed!**
- ★ Phase B (PDR): 2022-2023
- ★ Phase C (FDR): 2024-2025
- ★ Integration (PAE): 2026-2029
- ★ Commissioning & PAC: 2029/2030



**Thank you !**