



# Giant Magellan Telescope

## Current Status & Perspectives

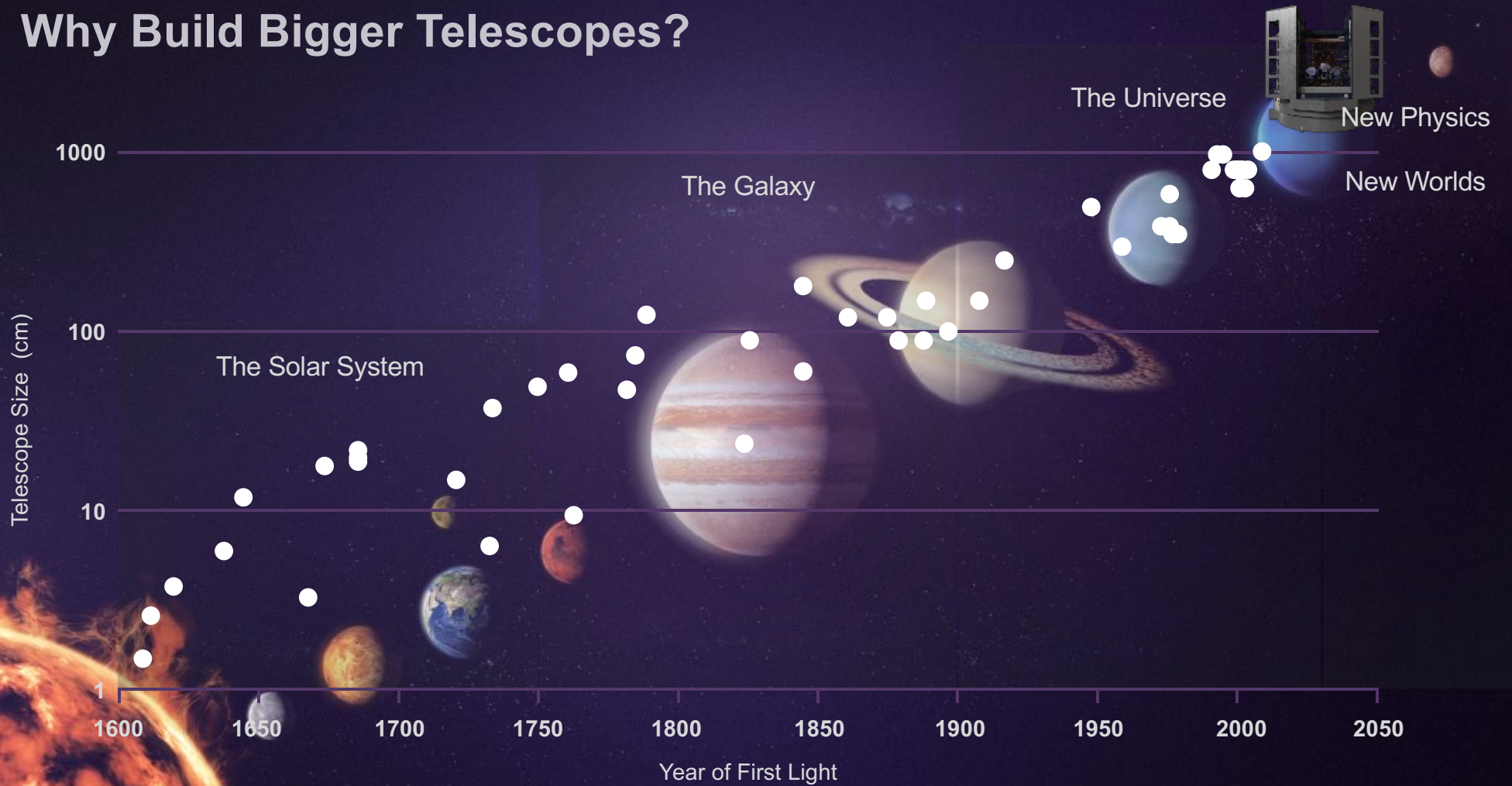
Presented by

**Alex Cavaliéri Carciofi**

**GMT Brazilian Office SAC Representative**

Slides prepared with assistance from: **R. Bernstein** (Chief Scientist, GMTO) & **Cláudia Oliveira** (IAG)

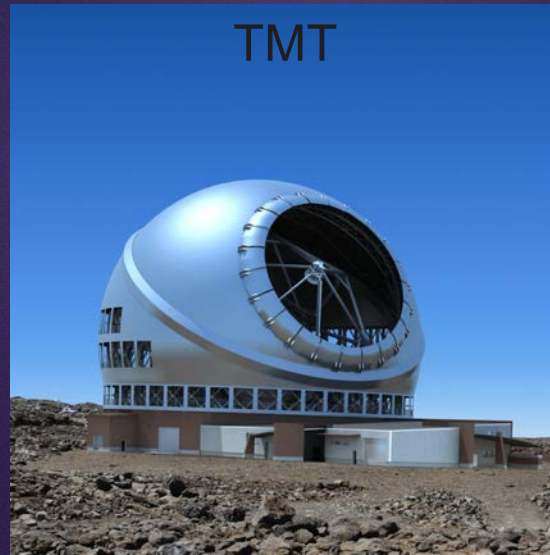
# Why Build Bigger Telescopes?



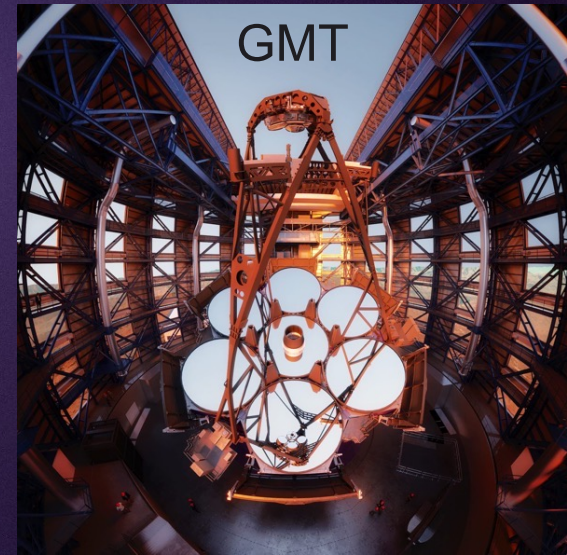
# The Megatelescopes of the Next Generation



2028-2029 (?)



?



2032-2035 (?)

An architectural rendering of the Gemini Multi-Object Spectrograph (GMT) telescope building at night. The building is a large, modern structure with a prominent cylindrical base and two tall, narrow towers. The sky is dark and filled with stars, with the Milky Way visible. The building's interior is illuminated, showing the complex structure of the telescope. In the foreground, there are smaller buildings and a road with a few cars.

## TALK OUTLINE

1. GMT Overview
2. Science Goals
3. Current Status
4. Brazilian participation

## • The GMT design:

- Optical to IR (0.3 – 25 $\mu$ m)
- 25.4 m (effective) diameter  
(compare with ~39 m of ELT)



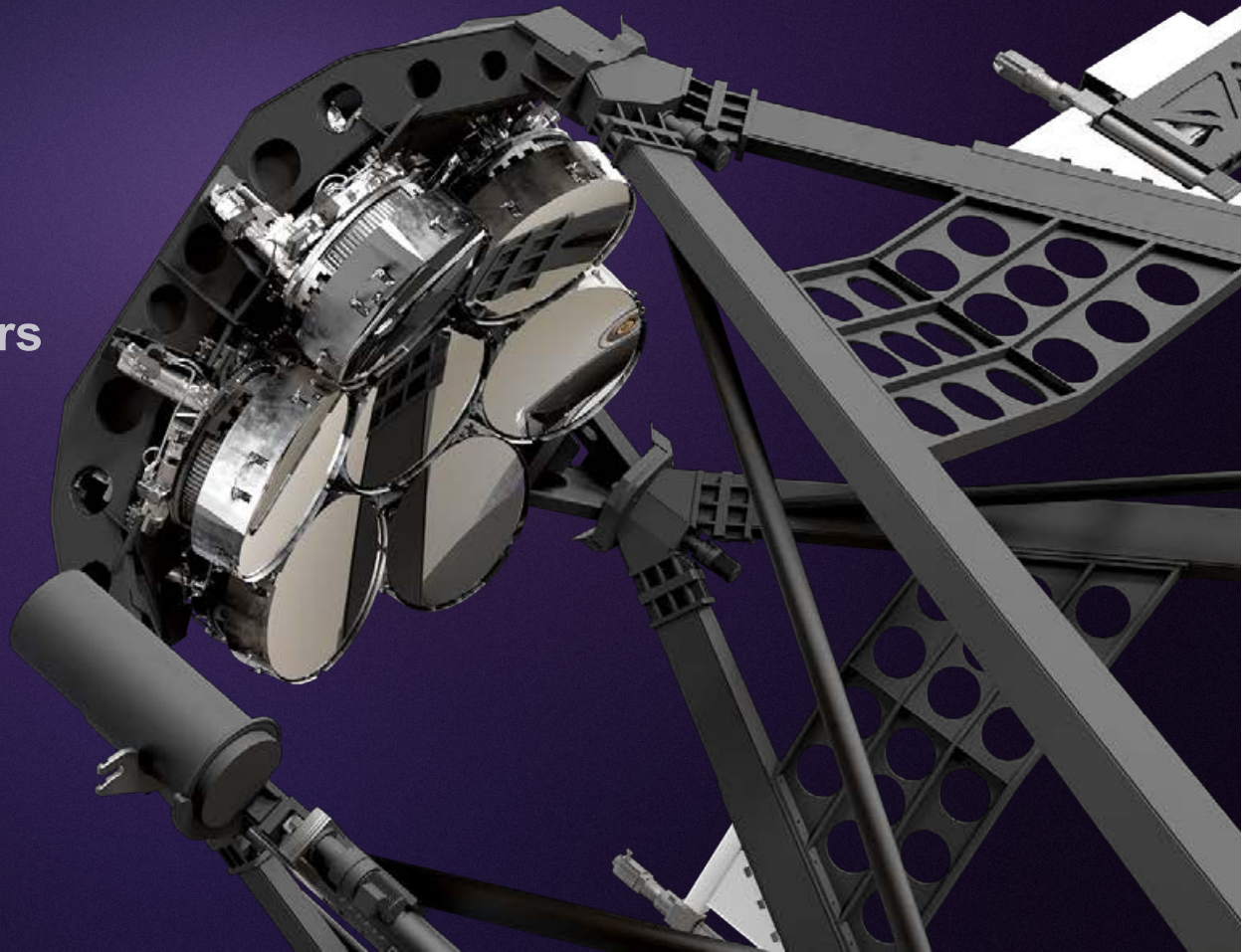
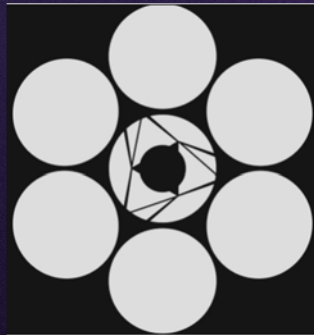
## • Key Design Features:

- **Double-segmented (paired 1:1)**
  - M1: 7 x 8.4m segments
  - M2: 7 x 1.1m segments
- **Aplanatic Gregorian (concave M2)**  
delivers a sharp, **wide field** of view  
without significant distortion
- **Fast beam: F/8**
  - **Largest FoV among the ELTs**



## • Key Design Features:

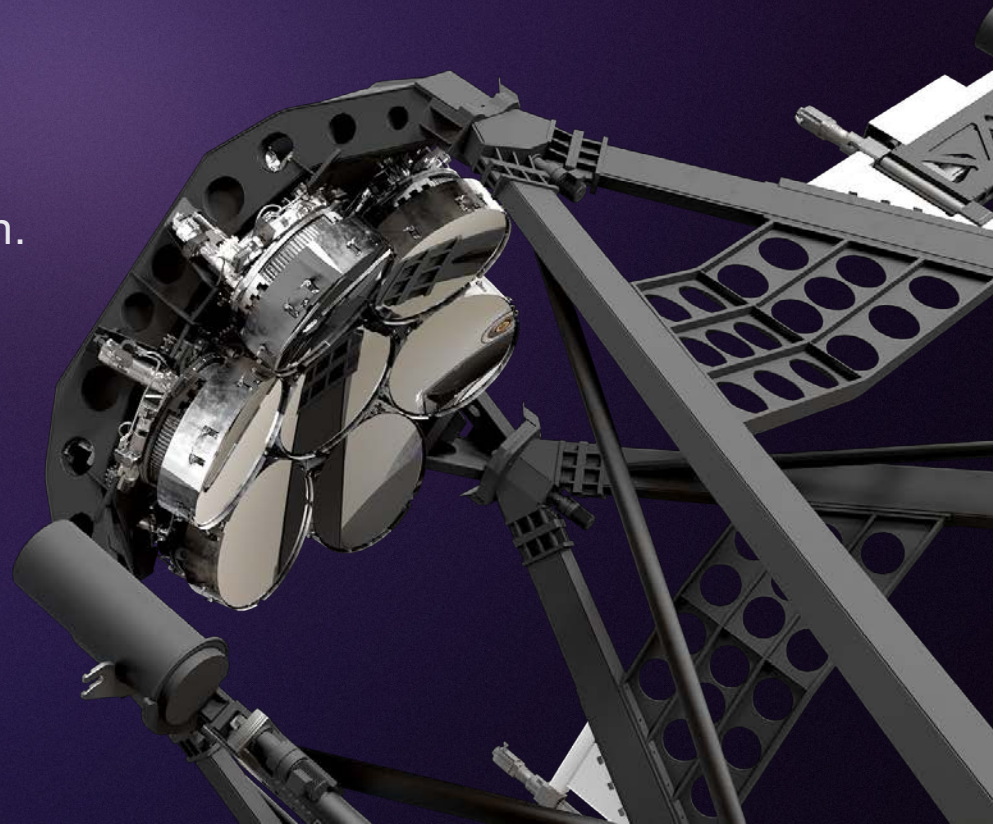
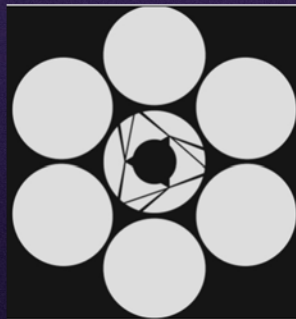
- Tripod upper truss
  - cleaner diffraction patterns
- Adaptive Secondary Mirrors
- Clean pupil
  - Minimal obscurations



## • Key performance:

Optimized for **diffraction limited imaging**

- Full time adaptive optics (M2)
  - AO is always in the beam!
- **Real prime focus** – efficient AO calibration.
- Fine alignment and phasing uses M2
- High efficiency (2 reflections), low thermal background



• Revolutionary capabilities: **diffraction limited using any instrument**

**Angular resolution ( $\sim \lambda/D$ ):**

- 10-15x better than HST
- 4-6x better than JWST (1-10 $\mu$ m)

**Sensitivity ( $\sim D^2/\theta^2 \sim D^4$ ):**

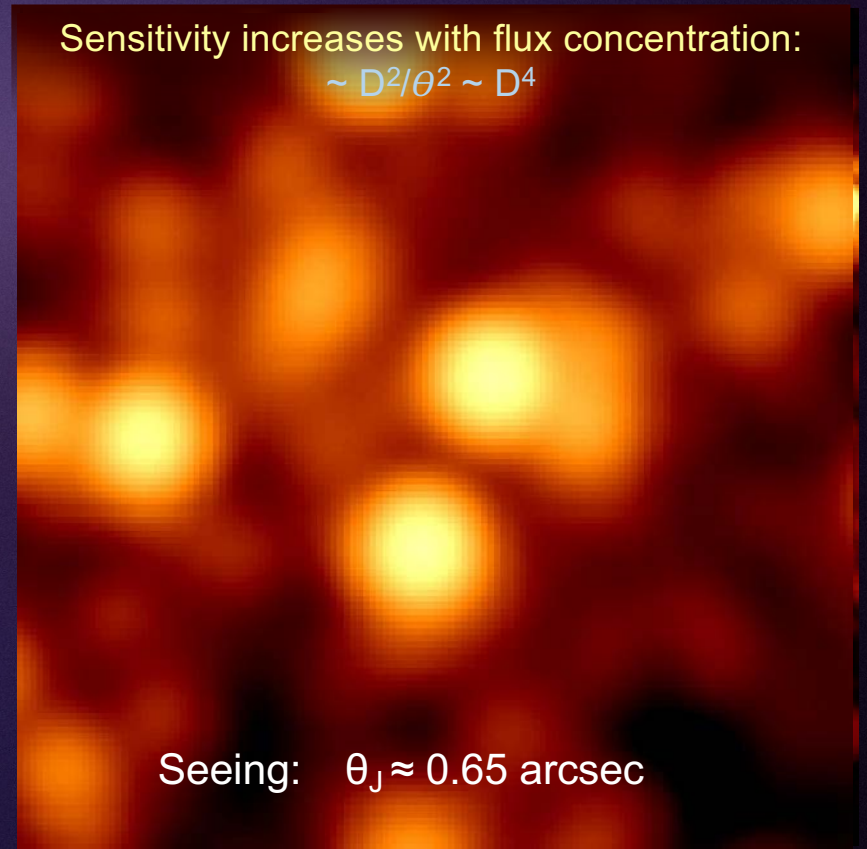
- $\theta$ : angular resolution element
- Ability of the telescope to detect faint sources
- 14-200 x better than 8m class telescopes

**Natural Guidestar AO:**

*K*-band Strehl ratio  $\sim 80\%$

Astrometry  $\sim 0.01$  mas

Sensitivity increases with flux concentration:  
 $\sim D^2/\theta^2 \sim D^4$



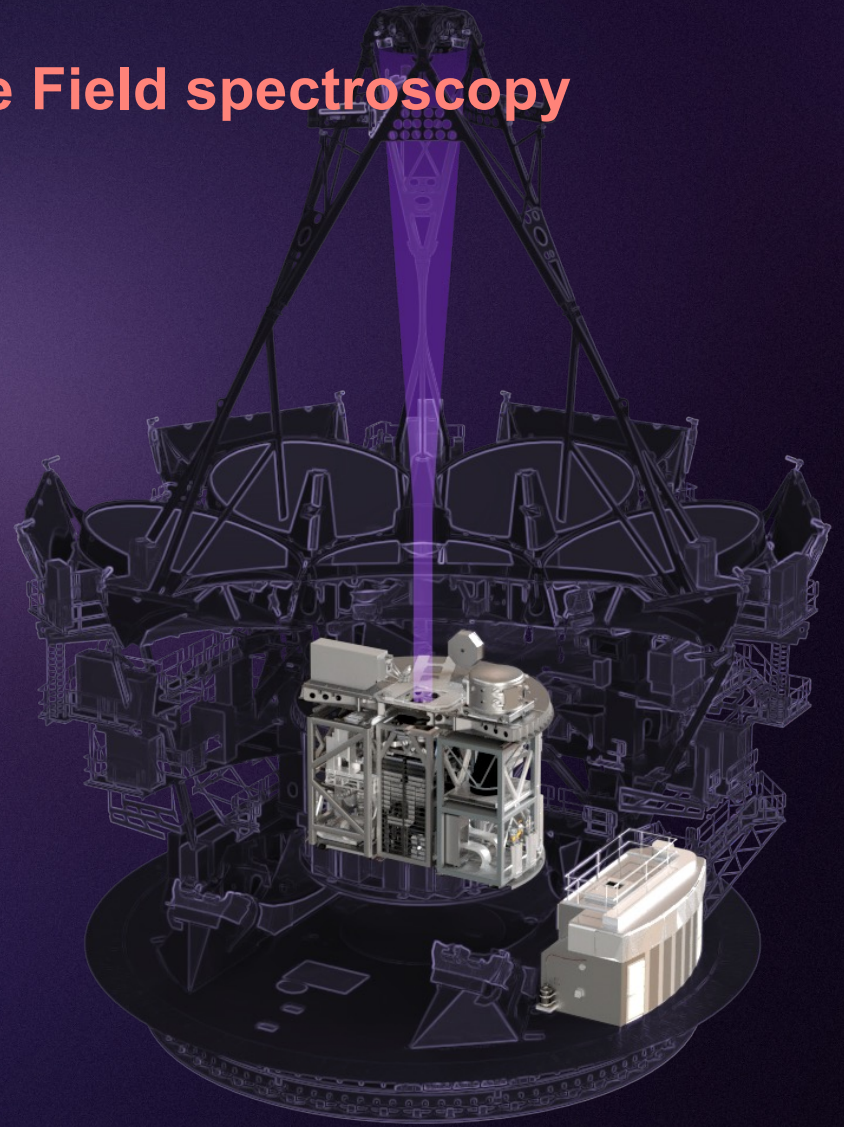
Seeing:  $\theta_J \approx 0.65$  arcsec

• Key performance: **Optimized for Wide Field spectroscopy**

- 20' field of view
- Stations with no M3 (ideal for polarimetry)
- GLAO over >10' field

GLAO = **Ground Layer Adaptive Optics**

Essential for large FoV because a large fraction of the turbulence is close to the ground



## Wide Field performance: Étendue

Planned instruments: field of view

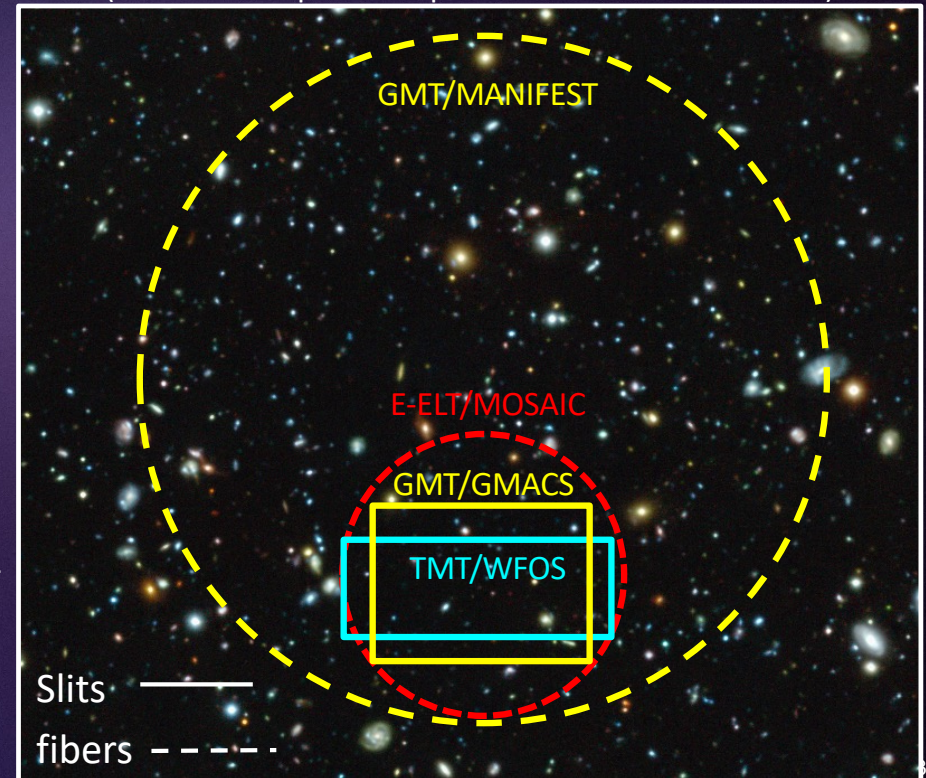
- GMT/MANIFEST = 20 arcmin diameter
- GMT/ GMACS = 6x7 arcmin<sup>2</sup>
- TMT/WFOS = 3x8 arcmin<sup>2</sup>
- EELT/MOSAIC = 7 arcmin diameter

Efficiency for wide field observations:

$$\text{Etendue} = [\text{collecting area}] \times [\text{field of view}] / [\text{resolution}]$$

Etendue is a measure of how much light a telescope can gather from an extended region of the sky and how efficiently it can transfer that light through its optical system

Practical limit: ~1 meter in telescope focal plane  
(due to atmospheric disp. correctors and field lenses)



GMT's etendue is unmatched, especial for faint sources.

## Scientific Instruments: 10 stations, rapid switching

### Gravity invariant station

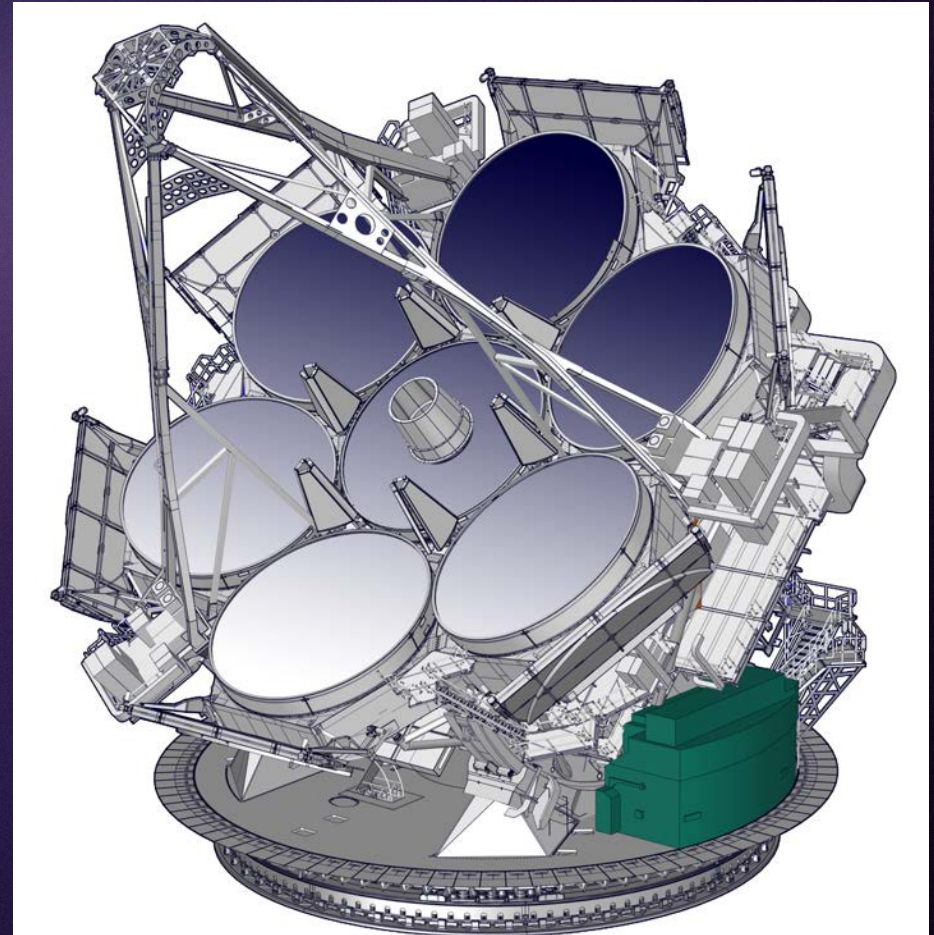
- Optical echelle + precision radial velocity (G-CLEF)

### Narrow field — Folded port (M3 fed)

- IR echelle (GMTNIRS)
- IR integral field spectrograph (GMTIFS)
- High contrast AO imager (GMagAO-X)

### Wide field — Direct Gregorian (No M3)

- Commissioning camera (ComCam) imager, polarimeter ?)
- Wide field optical spec (GMACS)
- Wide Field fiber feeding system (MANIFEST)



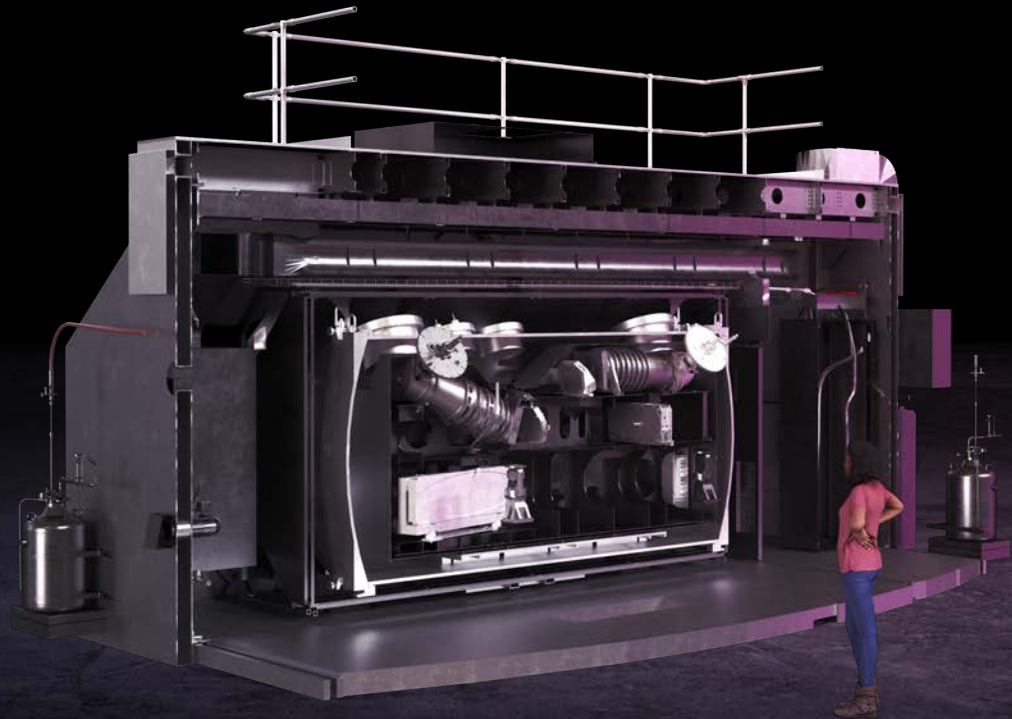
## G-CLEF

PI: A. Szentgyorgyi, SAO

GMT-Consortium Large Earth Finder

Optical Echelle

- $\lambda = 0.35\text{-}0.95\mu\text{m}$  (red & blue arms)
- $R = 20,000\text{--}150,000$
- FOV~1.5' for 1-7 Objects
- Modes: Natural seeing, GLAO, fed by MANIFEST, fed by GMagAO-X
- **PRV performance:**
  - < 50 cm/s per exposure
  - < 10 cm/s over time
- **Stage: In construction**  
To be used on Magellan prior to GMT commissioning.



## GMACS:

PI: D. Fabricant, SAO

**GMT Multi-object Astronomical and  
Cosmological Spectrograph**

**Wide Field Optical Spectrograph**

- $\lambda = 0.32\text{-}1.0\mu\text{m}$ , red & blue arms
- $R = 1,000\text{--}6,000$
- FOV = 6'x7'
- Modes: Natural seeing, GLAO
- Can be fed by MANIFEST for up to a 20' FOV (diameter)
- **Stage: PDR in march 2025.**
- **FDR: march/2027**



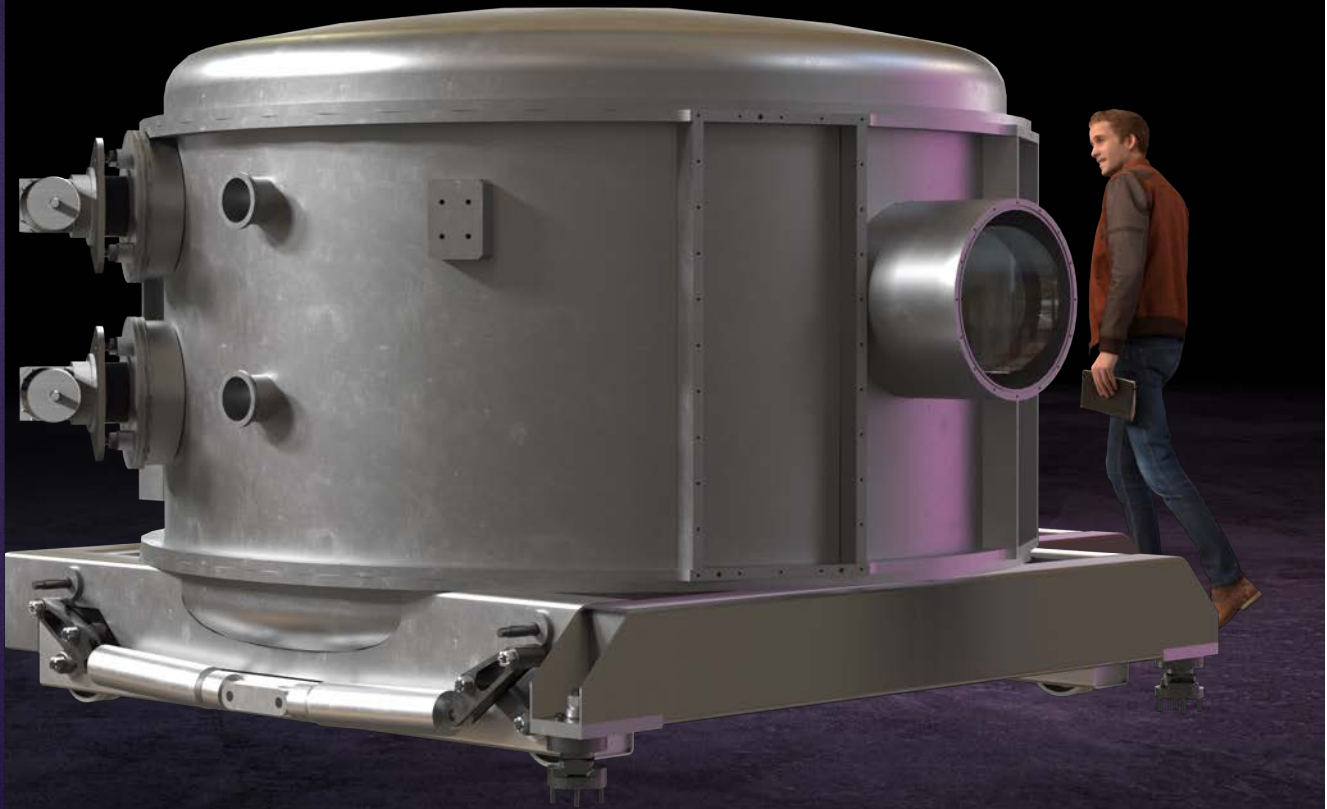
## GMTIFS

PI: R. Sharp (ANU)

### IR integral field spec & imager

- $\lambda = 0.32\text{--}1.0\mu\text{m}$ , red & blue arms
- $R = 1,000\text{--}6,000$
- $\text{FOV} = 6'\times 7'$
- Natural seeing, GLAO
- Can be fed by MANIFEST for up to a 20 arcmin FOV (diameter)

In Final Design



## GMTNIRS

GMT Near-IR Spectrograph

### Infrared Echelle

- $\lambda=1-5.4\mu\text{m}$
- $R=50,000-100,000$
- 1 obj, 1.3" long slit
- NGAO, LTAO
- 0.008" pix
- Exceptional efficiency:
  - Silicon immersion gratings
  - J to L-band in one exposure

### In Final Design

To be used on Magellan prior to GMT commissioning.



Exoplanet characterization  
Pre-main Sequence  
Proto-stellar Disks  
Debris Disks

## ComCam

Commissioning Camera

### Wide Field Re-imaging Camera

- $\lambda = 0.35-1\mu\text{m}$
- FoV= 6 amin
- Spatial resolution: 0.1asec/pix
- Powerful for:
  - Polarization (no folds in beam!)
  - Narrow band img. (Fabry-Perot)
  - Wide field, high stability imaging

In Prelim Design



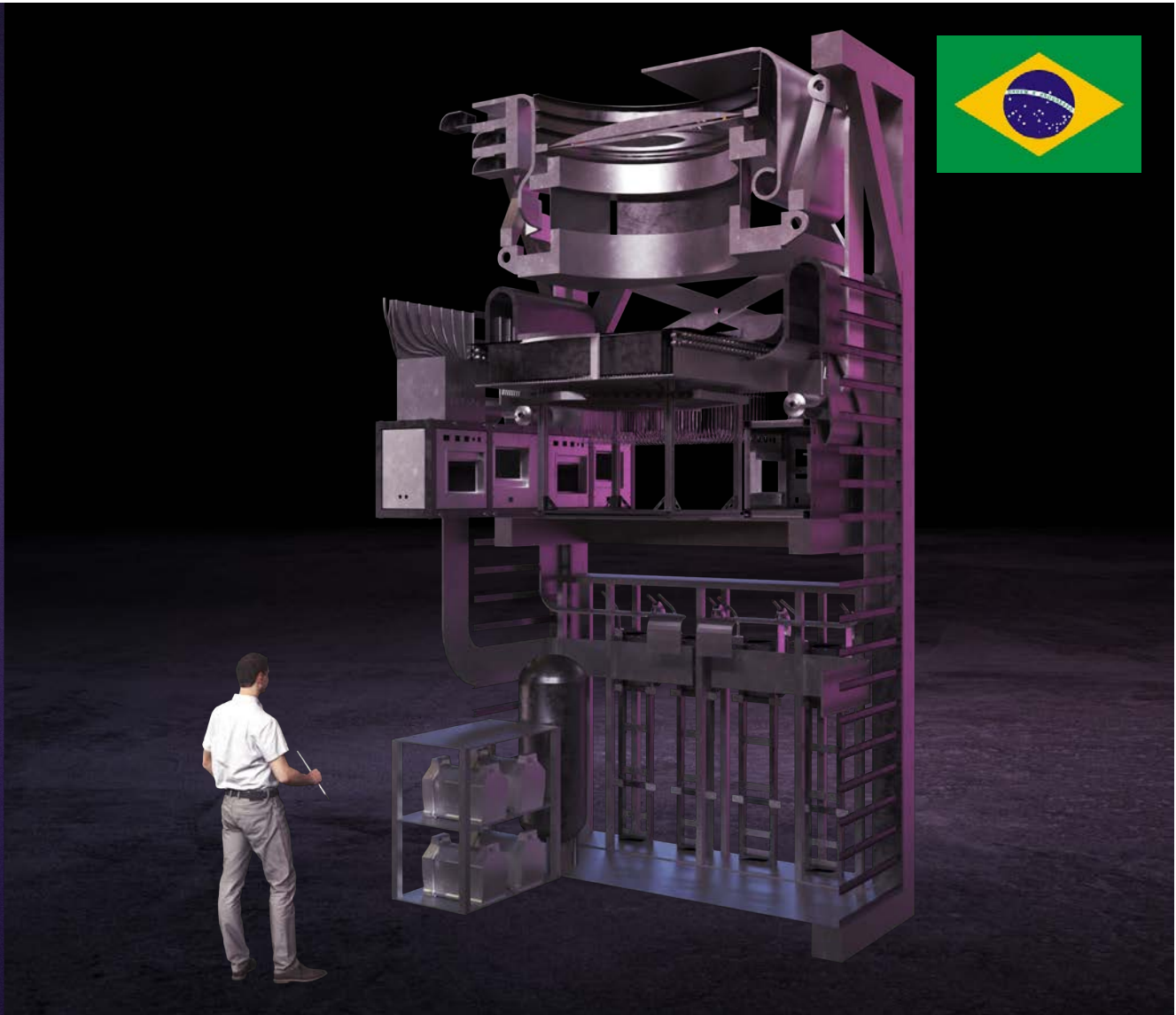
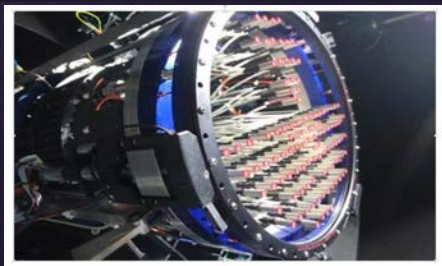
## MANIFEST

Many-Instrument Fiber System

### Fiber-fed system for O/IR

- Fiber sets optimized for each inst.
- “Starbug” auto-configuring positioner
- 20 arcmin FOV: 0.4-1.1  $\mu\text{m}$
- 14 arcmin FoV: 0.32-1  $\mu\text{m}$

In conceptual design



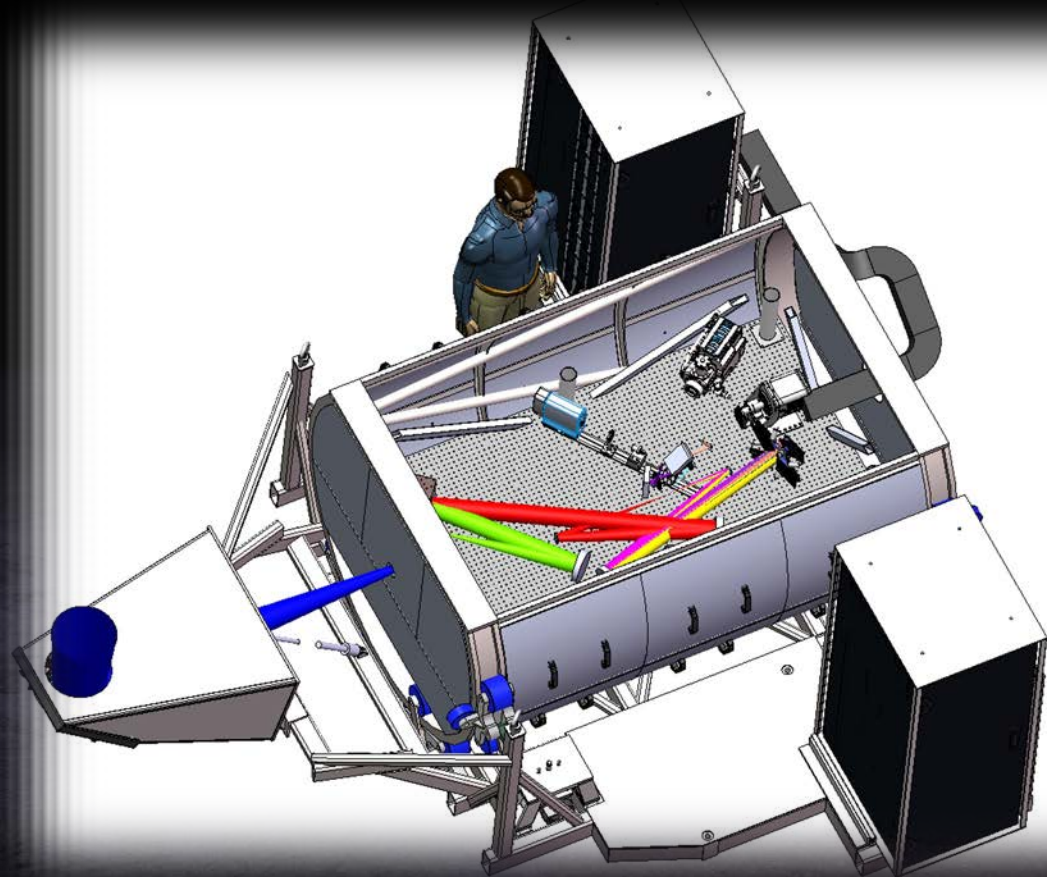
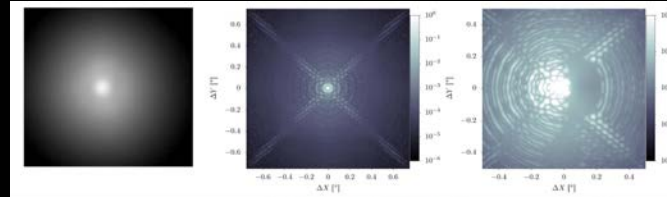
# GmagAO-X

Extreme-AO, high-contrast imager

J. Males, L. Close (UA)

- $\lambda=0.6\text{--}5\mu\text{m}$
- High Strehl ratios ( $\sim 90\%$ )
- Exoplanet imaging

In Final Design Stage!



An architectural rendering of the Gemini Multi-Object Spectrograph (GMT) telescope building at night. The building is a large, modern structure with a prominent cylindrical section and two tall, narrow towers. The sky is dark and filled with stars, including the Milky Way. In the foreground, there are smaller buildings and a road with a few cars.

## TALK OUTLINE

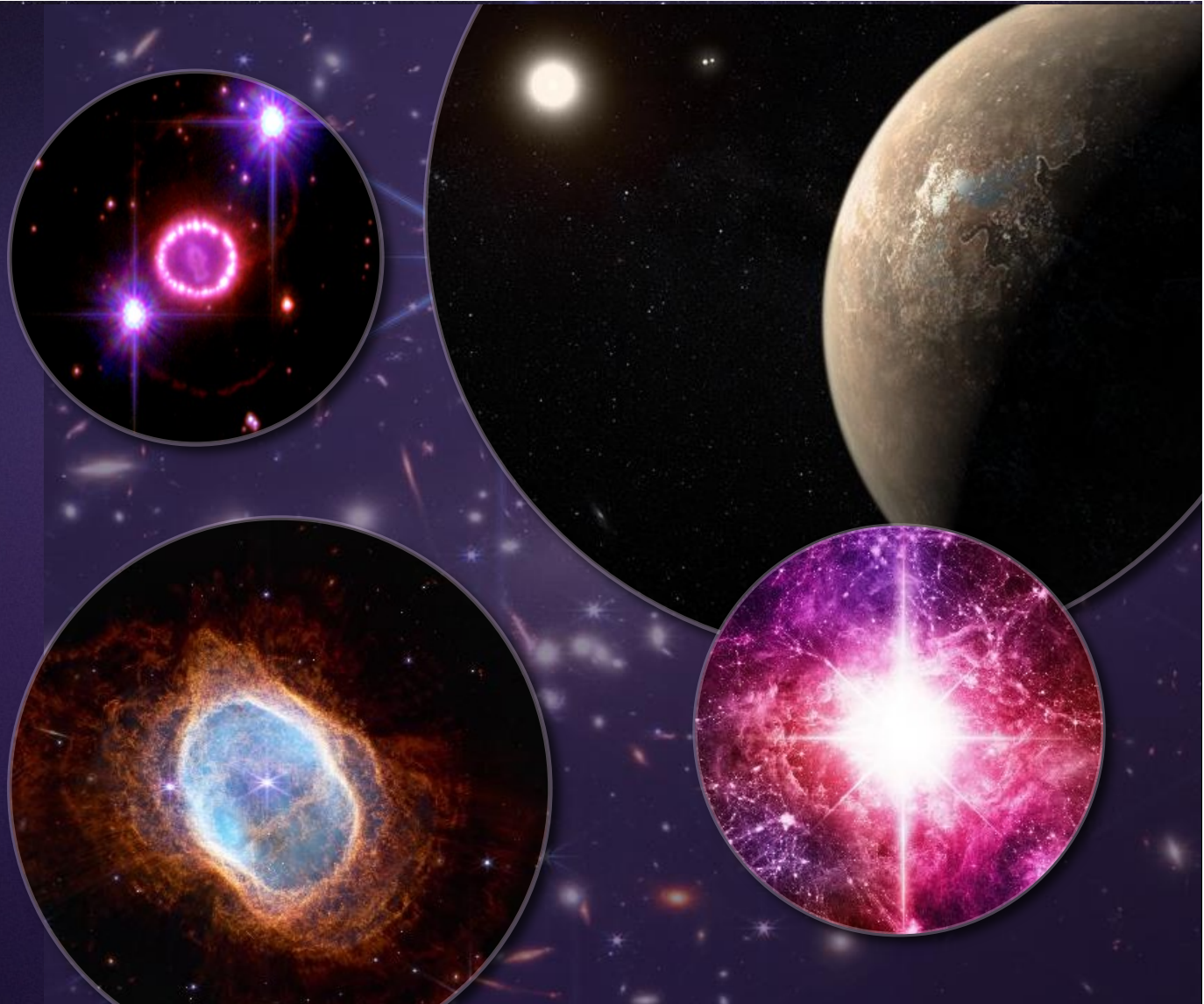
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## Advancing Science

The 3 mega-telescopes will revolutionize humanity's view and understanding of the Universe.

In particular, the GMT (see the GMT science book) is after:

- ❁ Are we (life) alone in the Universe?
- ❁ How are stars born and how do they die?
- ❁ How do galaxies grow and evolve?
- ❁ How did the Universe form and grow?



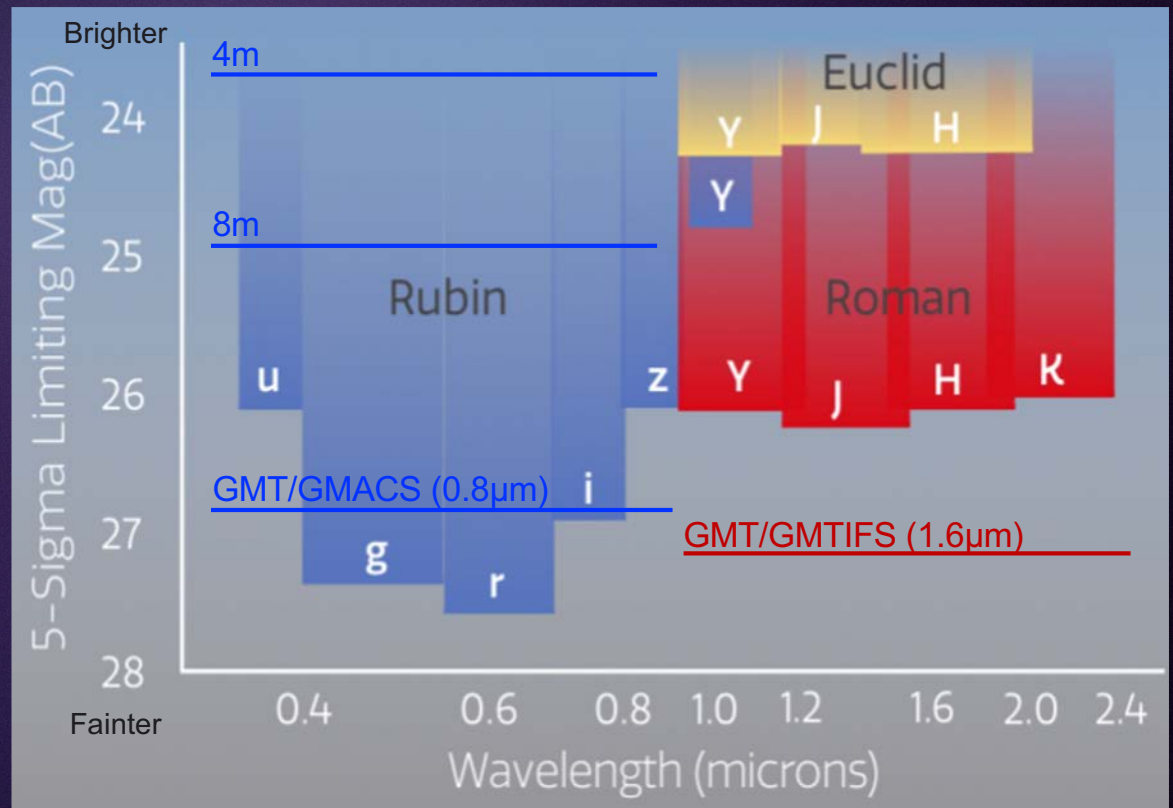
## Priority science: Optical spectra of large surveys

- **Galaxy evolution:**  
assembly over cosmic time  
baryon cycle into/out of galaxies
- **The nature of Dark Matter:**  
ultra-faint dwarf galaxies
- **The nature of Dark Energy:**  
spectroscopy of lensed arcs
- **Black holes:**  
general relativity, galaxy co-evolution

GMT ~ TMT per exposure for slit spec.

GMT is fastest (x2-20) for largest surveys!

GMT can take spectra of any object in these surveys



\* Lines show 5-sigma spectroscopic detection limits, 20 hour integrations. 8 hr integration limits are 1 mag brighter.

Amplifying the scientific impact of contemporary observatories:

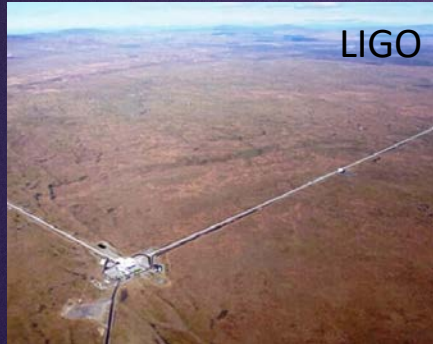
Efficient, multi-object spectroscopy at all spectral resolutions (0.3-10 $\mu$ m)

= physics, chemistry, & evolution of the sources discovered by new observatories.

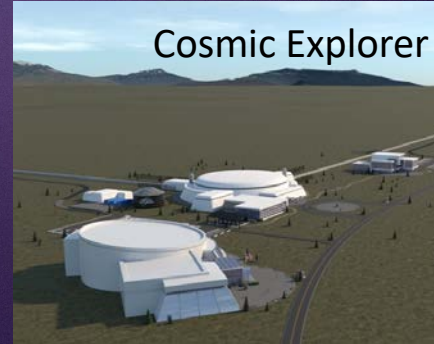
Rubin



LIGO



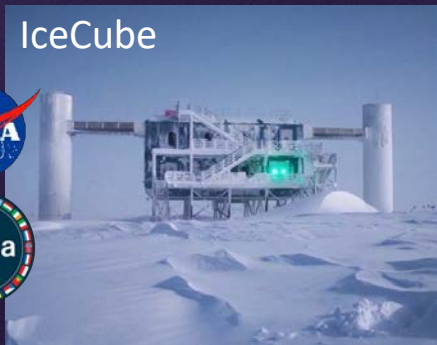
Cosmic Explorer



SKA



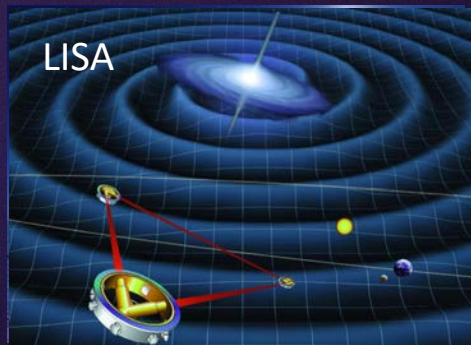
IceCube



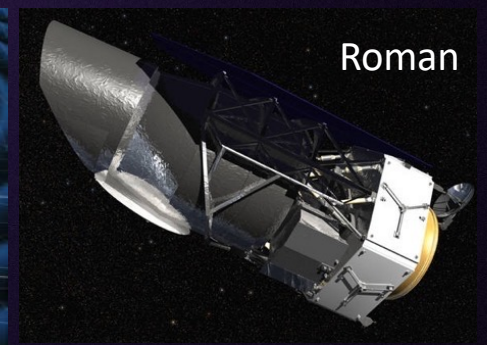
JWST



LISA



Roman



## GMT Science Book 2018

2026: Science Book is being revised.  
Stay Tunned!

When GMT was conceived:

- JWST didn't exist
- Rubin was not operational
- AI-assisted surveys in astronomy was immature

NOW:

- Rubin will dominate transient discovery,
- JWST already transformed infrared astronomy,
- Roman is approaching launch,
- SKA is coming,





## TALK OUTLINE

1. GMT Overview
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4. Brazilian participation: a window of opportunity

# GMT Corporation

- Became a Non-profit Corporation in 2006
- Site is within Las Campanas property — owned by Carnegie, leased to GMTO Corp.
- 16 institutions + Chile



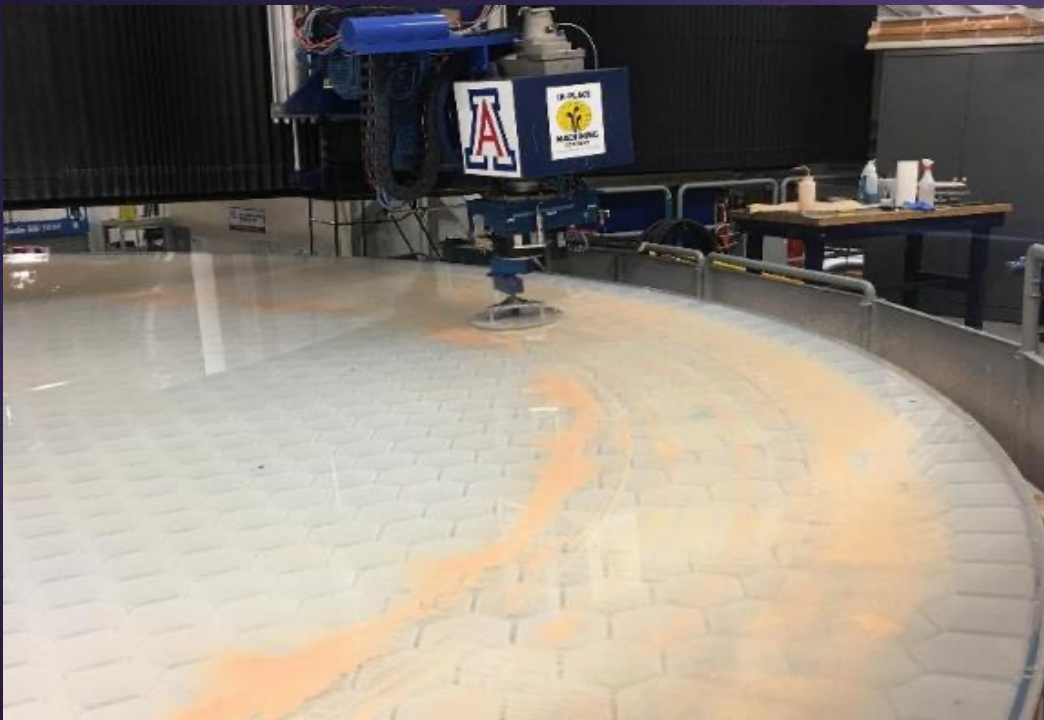
# Primary Mirror Segments

Segments S1, S2, and S3 are complete!



# Primary Mirror Segments

S4, S5, S6 in various stages of fabrication.



# Primary Mirror Segments

Segment 7 — glass placement in Sept 2023



... furnace open in Jan 2024.

“Best ever!”



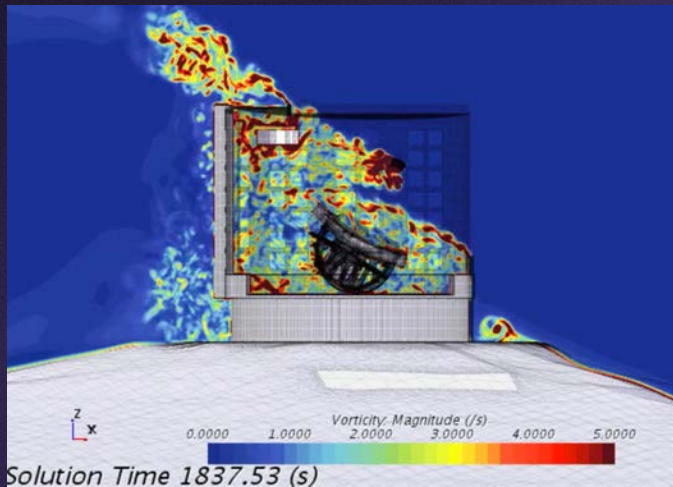
**OHARA**  
E6 Low Expansion Glass

Photo credit:  NATIONAL GEOGRAPHIC



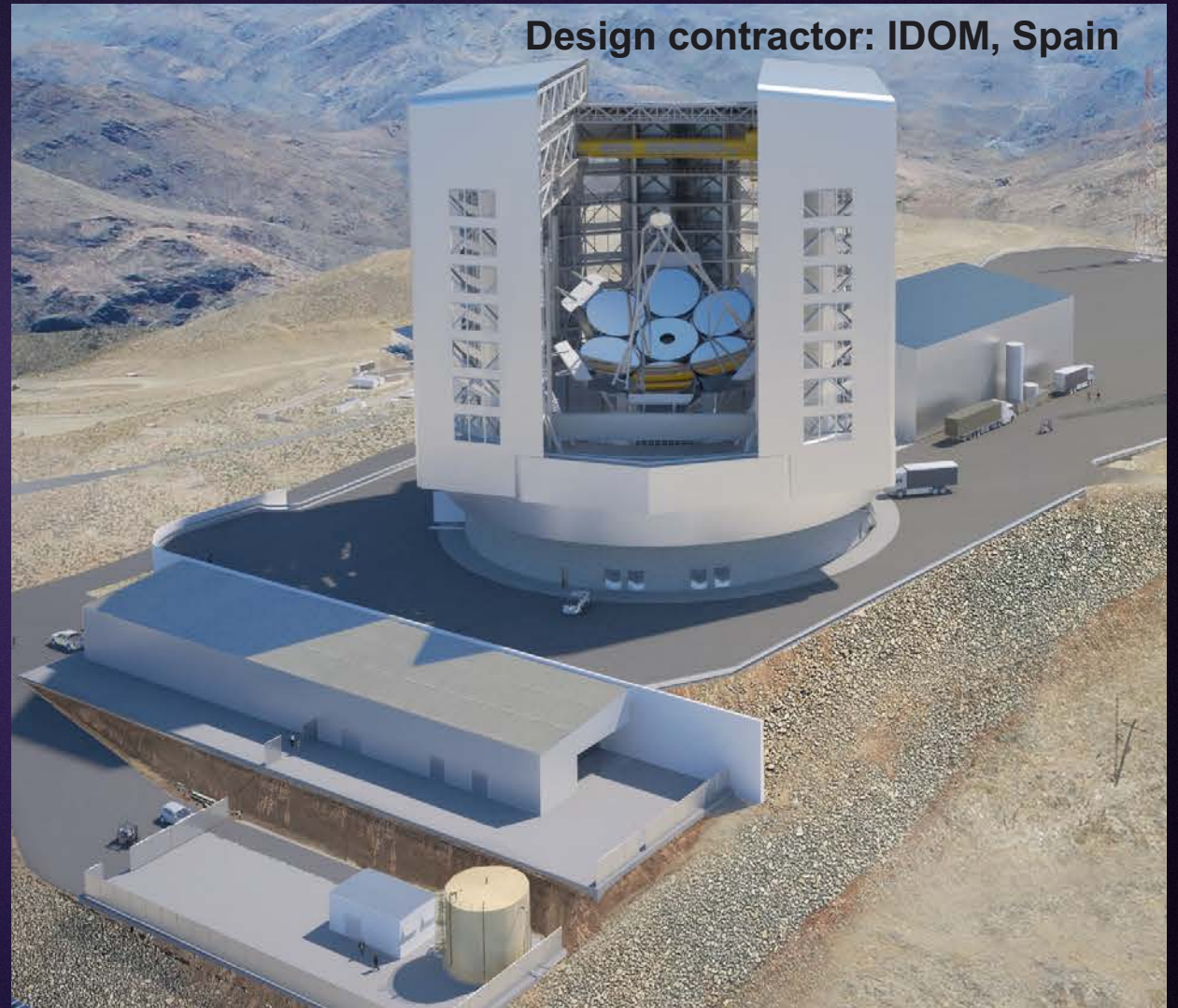
# Enclosure

In construction  
(Final Design Review  
passed in May 2024)



CFD modeling and water/wind-tunnel  
testing  
(using enclosure and site topology data)

Work by Boeing Corp, GMTO team,  
structure & seismology experts.



# Recent Progress and Looking Ahead

**2019:** Hard rock excavations completed

**2022:** Telescope mount manufacturing begins

**2023:** Casting the seventh (final) primary mirror

Pouring GMT's concrete foundation

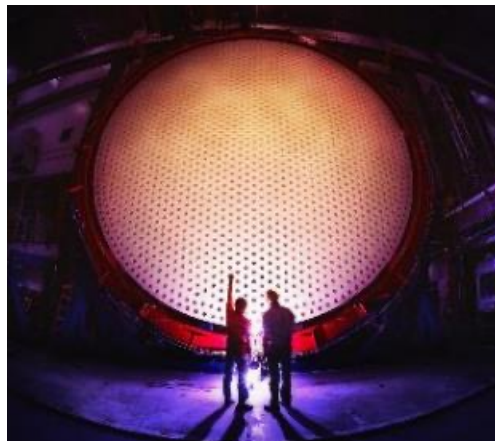
**2025:** NSF green light to PDR. FDR ~2027

**Finalize manufacturing of the telescope mount**

**Building GMT's enclosure**

**Shipping the 7 primary mirrors, mount to Chile**

**Installing GMT's scientific instruments**



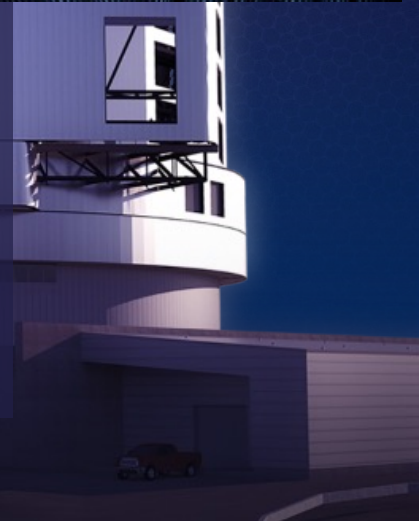


## TALK OUTLINE

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# GMTBrO

- Brazil joins as founder in 2014
- GMT Brazil Office (GMTBrO) was created in 2015 to organize, plan and execute GMT-related instrumentation and IT projects.
- The GMTBrO is composed of a multidisciplinary team of astronomers, physicists, engineers, and computer scientists from different institutions, including USP, Unicamp, Univap, and Instituto Mauá
- Approximately 60 people involved in different levels
- Currently funded by a Special FAPESP project (P.I. Laerte Sodré Jr.)



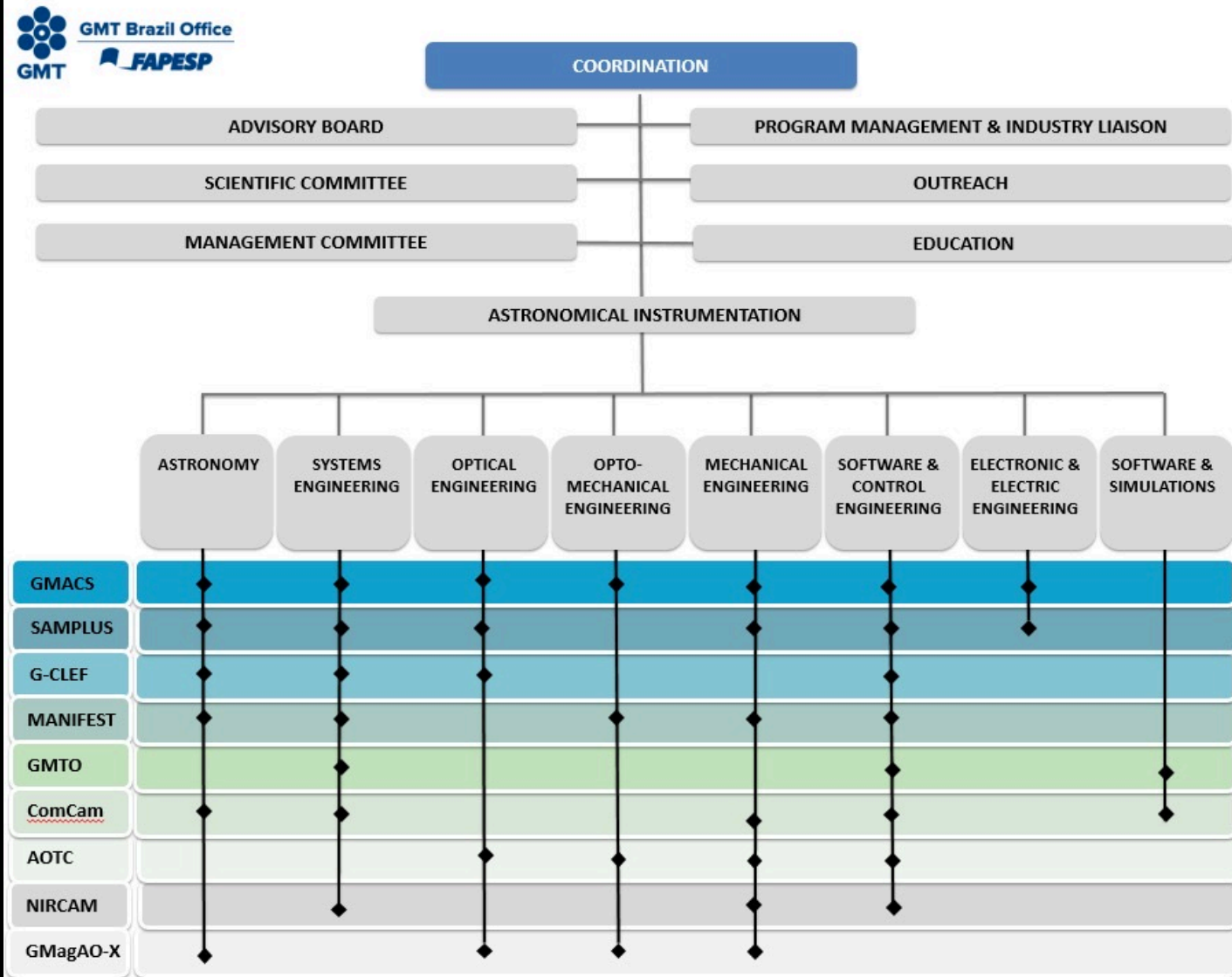
# Current Status (Brazil)

- FAPESP has already paid **50 million dollars** in 10 payments of 5 million (the last one was in June 2023) for the telescope and instruments
- Currently, FAPESP has a **<5% share**, which will drop to around 3% at first light (based on the estimated value of the telescope).
- The GMT Brazil office has a **leading role in the development of two instruments, GMACS and MANIFEST**.



# GMTBrO Project Structure

GMT was the main driving force behind the formation of a new astronomical instrumentation group established in the state of São Paulo, coordinated both by GMTBrO and Instituto Steiner.



Thank you!

