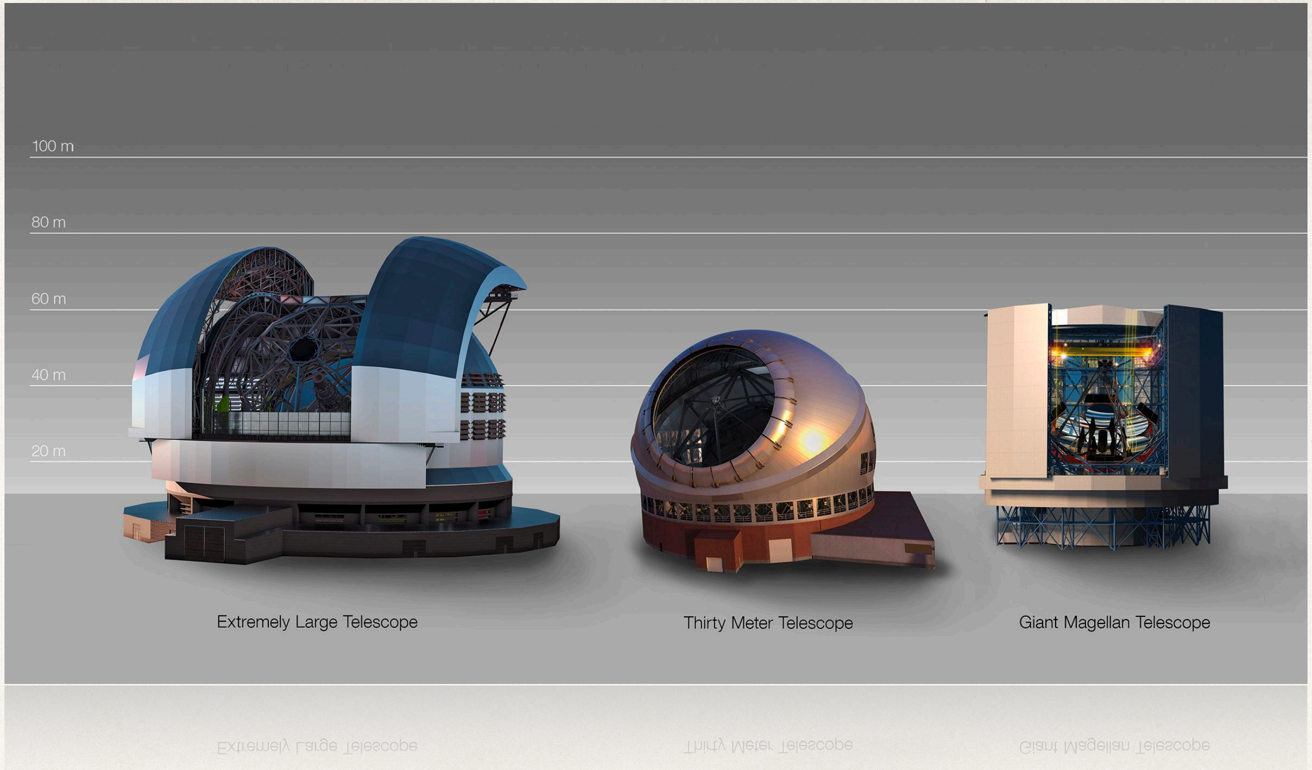
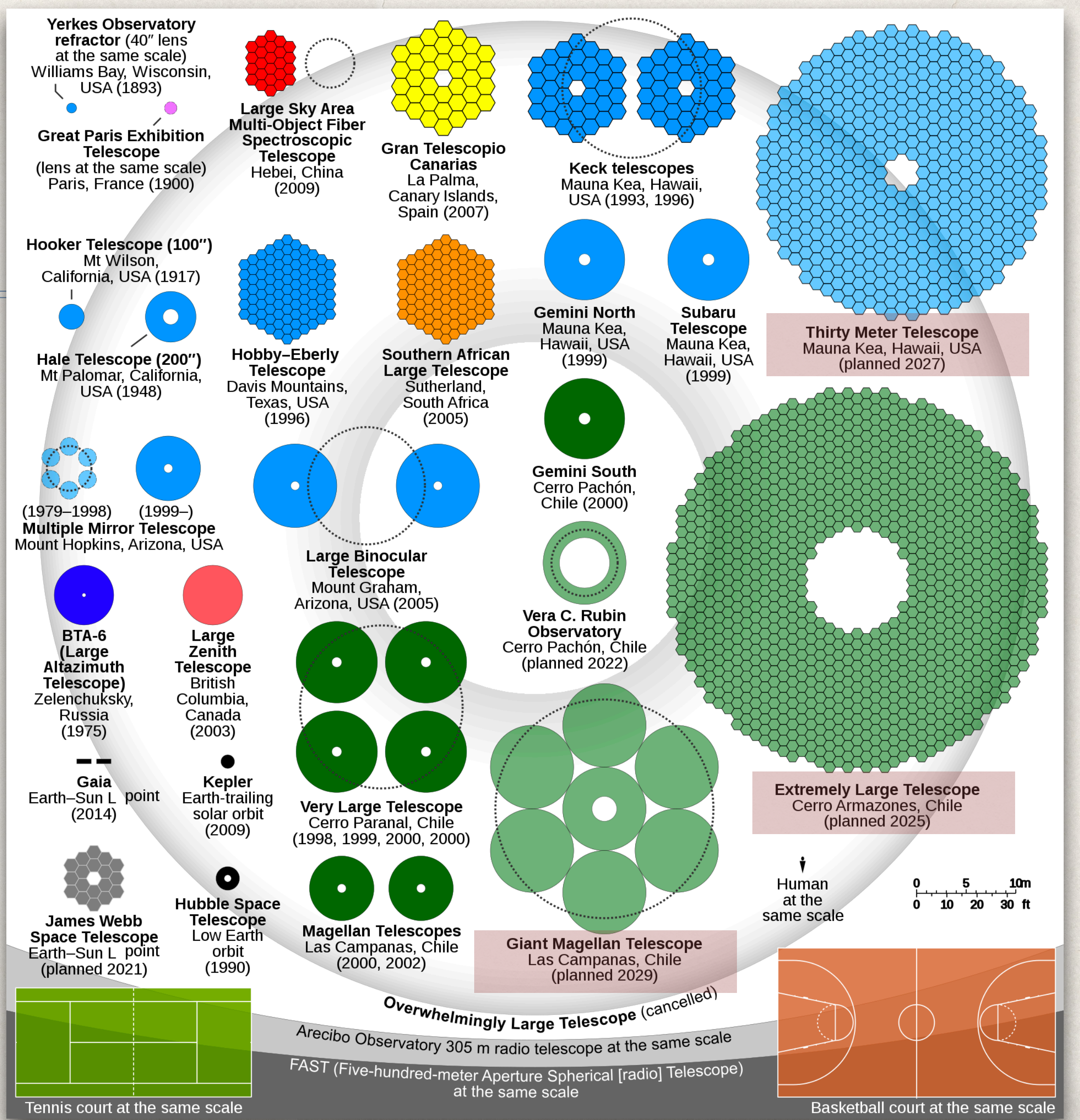


Synergy of THESEUS with ELT, TMT and large optical/NIR facilities of the future

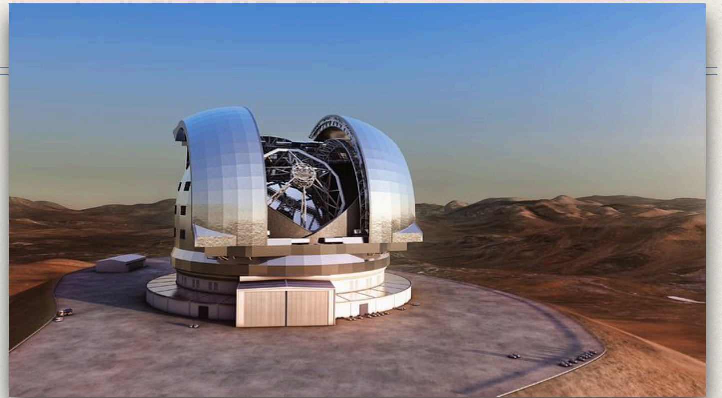
S. BASA (Aix Marseille Univ, CNRS, CNES, LAM, Marseille, France)

25th of March, 2021

The extra large telescopes are coming



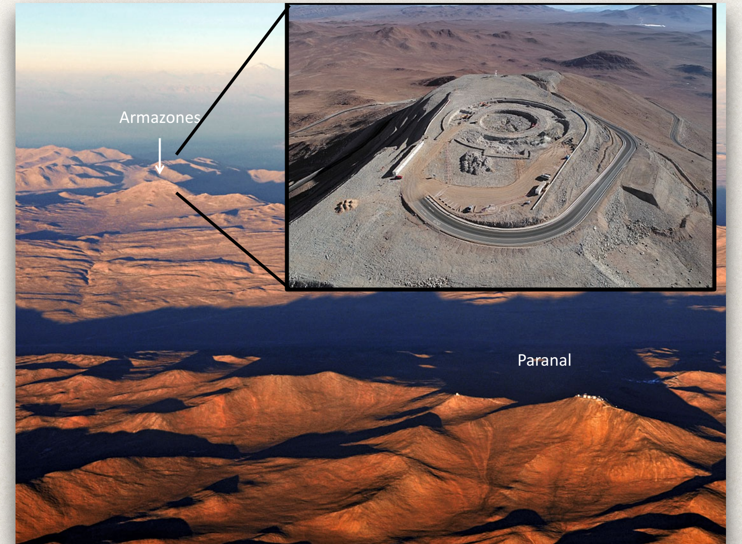
ELT: European Extremely Large Telescope



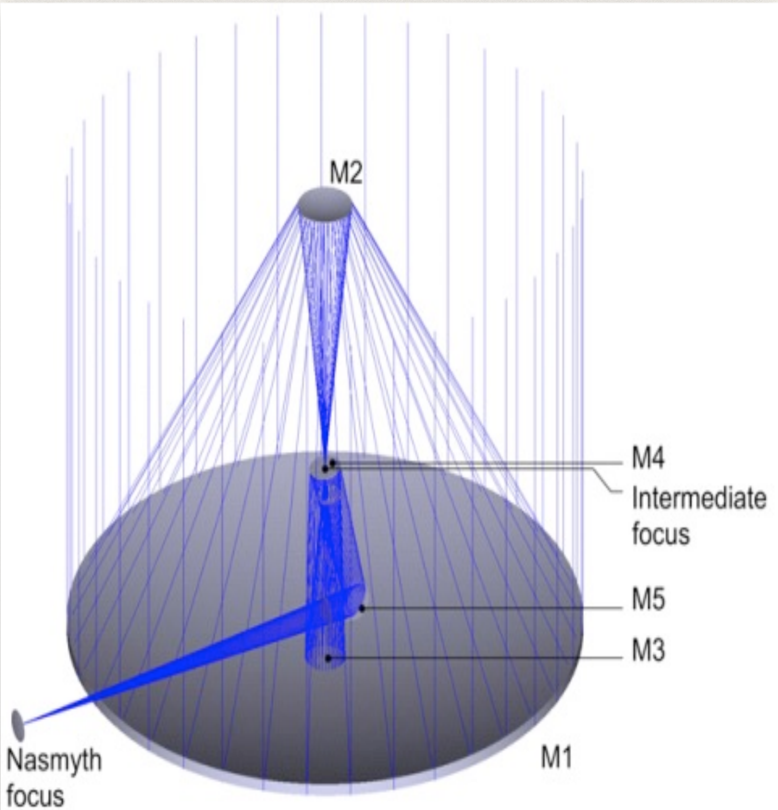
Project under ESO leadership:

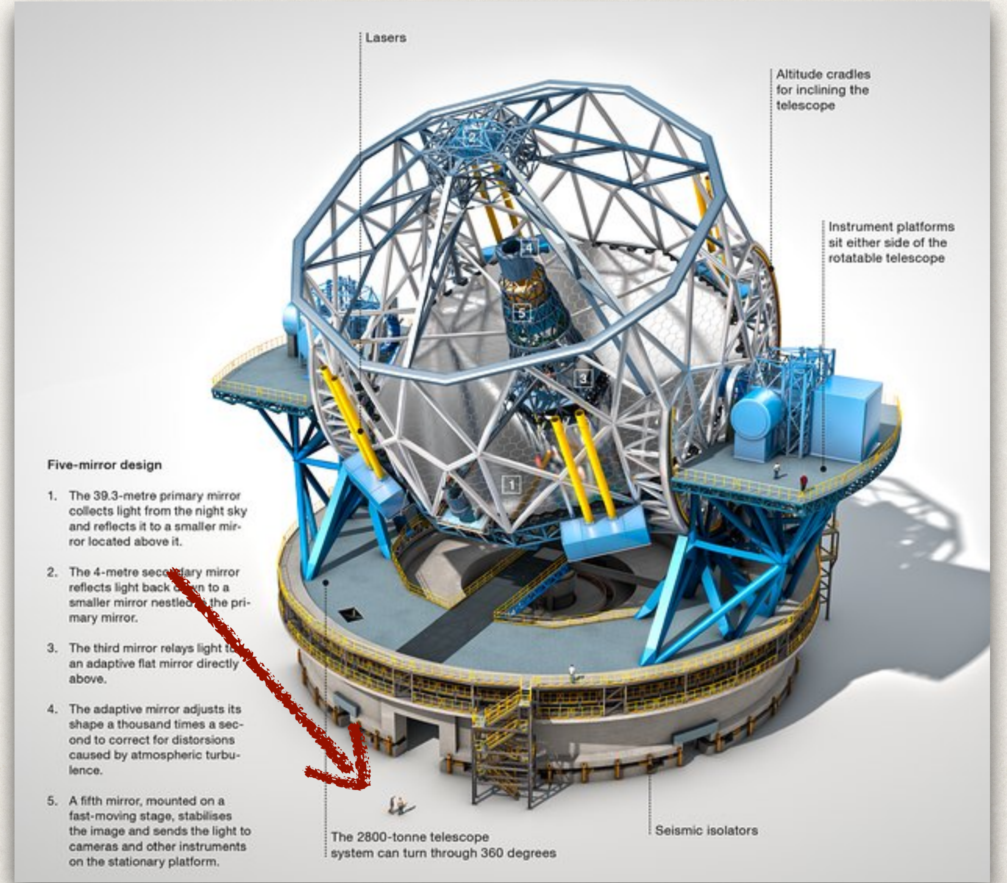
- 39-m segmented M1 (1300 m^2 !).
- 4.2-m monolithic & active M2 mirror.
- 2.5-m adaptive M4 & M5 .

- Site: Cerro Armazones, Chile.
- Completion: 2026 (2027?).
- Cost: ~ 1200 M€



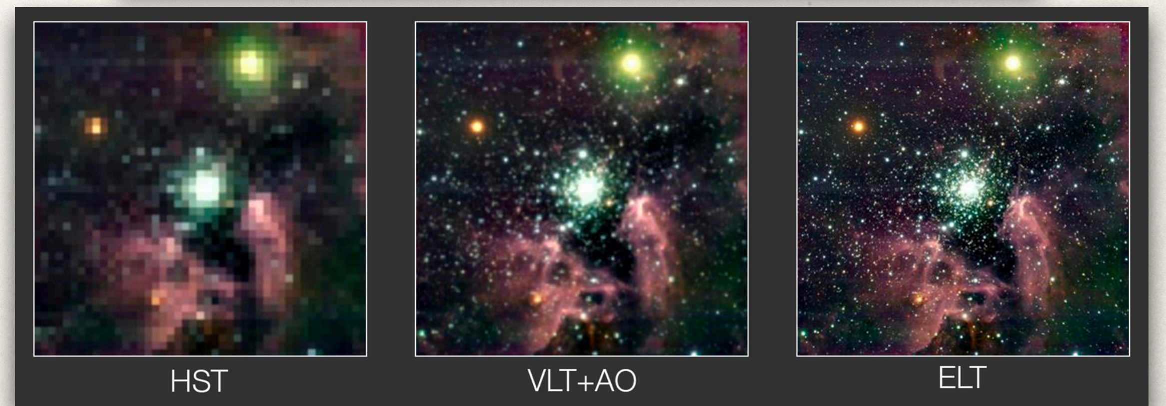
ELT: European Extremely Large Telescope





The coming of age of Laser guide Star

- Lasers generate artificial stars in the upper atmosphere through backscattering of the laser photons.



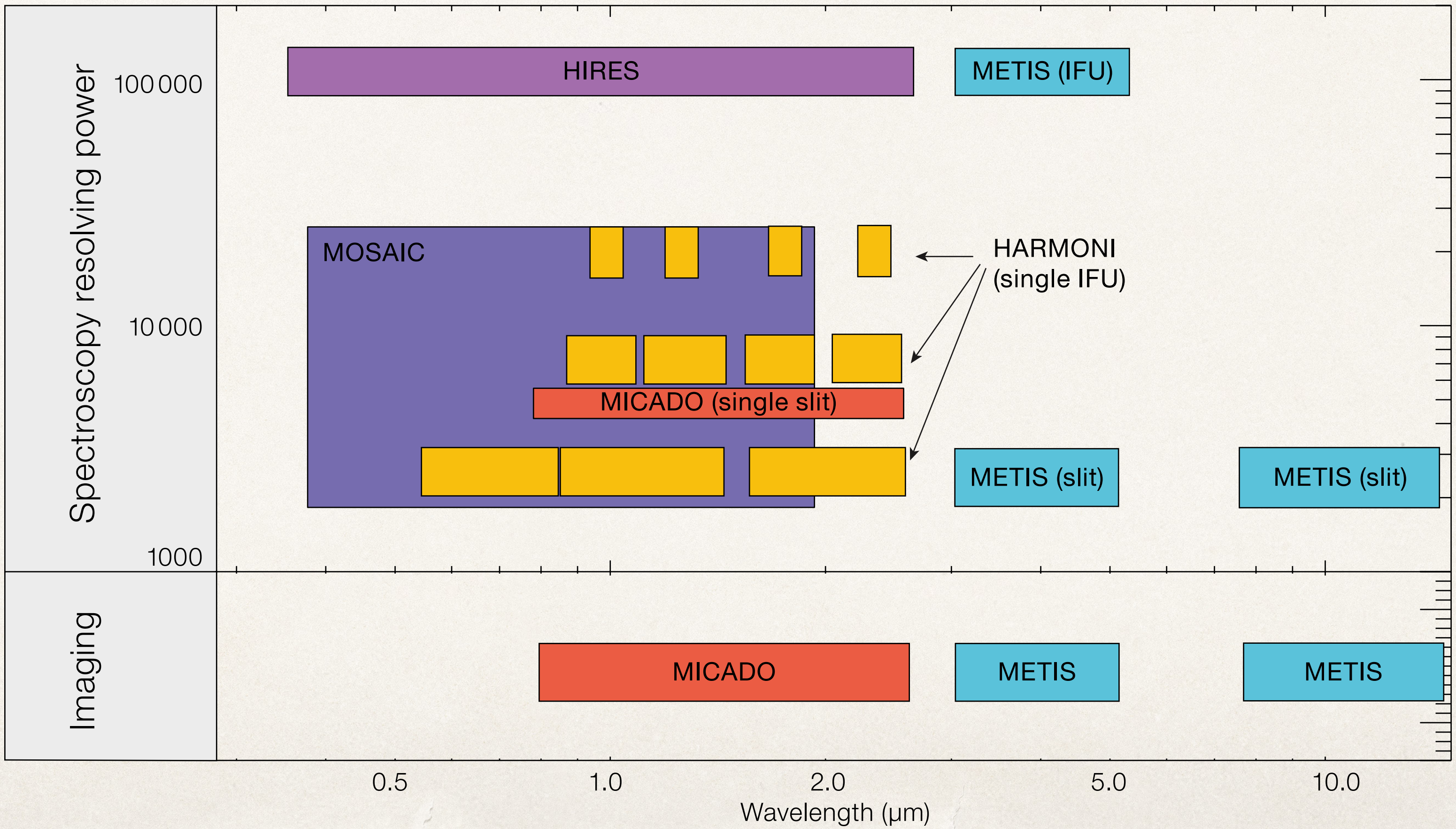
A very complete instrumentation

Even if the dates are a "little" optimistic, by the time of Theseus, ELT observations will have begun:

- 2027-2028 for MICADO, HARMONI & METIS.
- > 2030 for HIRES & MOSAIC

Instrument	Main specifications			Schedule				
	Field of view/slit length/ pixel scale	Spectral resolution	Wavelength coverage (μm)	Phase A	Project start	PDR	FDR	First light
MICADO	Imager (with coronagraph) 50.5′ × 50.5′ at 4 mas/pix 19′ × 19′ at 1.5 mas/pix	*I*, *Z*, *Y*, *J*, *H*, *K* + narrowbands	0.8–2.45	2010	2015	2019		
	Single slit	*R* ~ 20 000						
MAORY	AO Module SCAO – MCAO		0.8–2.45	2010	2015			
HARMONI + LTAO	IFU 4 spaxel scales from: 0.8″ × 0.6″ at 4 mas/pix to 6.1″ × 9.1″ at 30 × 60 mas/pix (with coronagraph)	*R* ~ 3200 *R* ~ 7100 *R* ~ 17 000	0.47–2.45	2010	2015	2018		
METIS	Imager (with coronagraph) 10.5″ × 10.5″ at 5 mas/pix in *L*, *M* 13.5″ × 13.5″ at 7 mas/pix in *N*	*L*, *M*, *N* + narrowbands	3–13	2010	2015	2019		
	Single slit	*R* ~ 1400 in *L* *R* ~ 1900 in *M* *R* ~ 400 in *N*						
	IFU 0.6″ × 0.9″ at 8 mas/pix (with coronagraph)	*L*, *M* bands *R* ~ 100 000						
HIRES	Single object	*R* ~ 100 000	0.4–1.8 simultaneously	2018				
	IFU (SCAO)							
	Multi object (TBC)	*R* ~ 10 000						
MOSAIC	~ 7-arcminute FoV ~ 200 objects (TBC)	*R* ~ 5000–20 000	0.45–1.8 (TBC)	2018				
	~ 8 IFUs (TBC)	*R* ~ 5000–20 000	0.8–1.8 (TBC)					
PCS	Extreme AO camera and spectrograph	TBC	TBC					

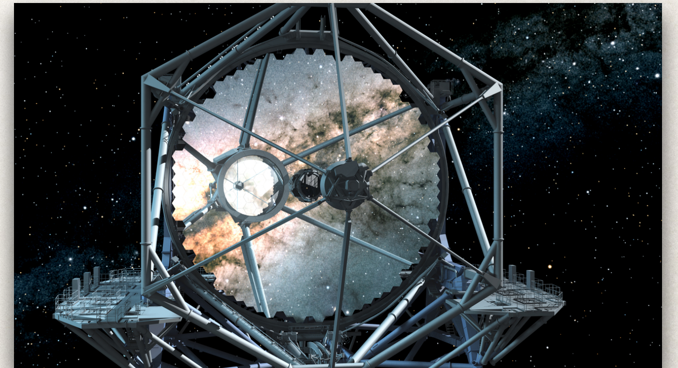
A very complete instrumentation



TMT: Thirty Meters Telescope

Project led by Caltech + Univ. California + Canada + China + India + Japan:

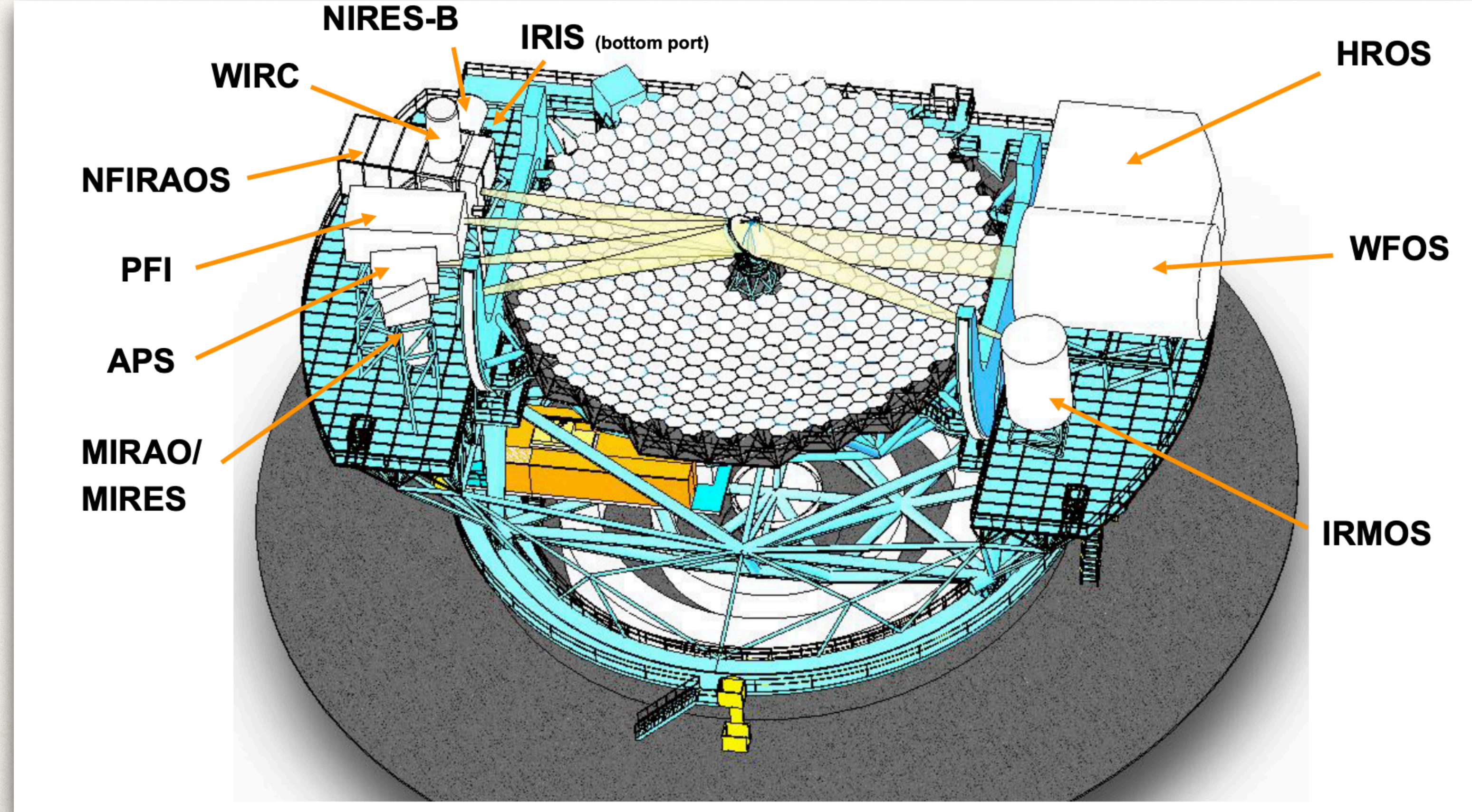
- 30-m diameter.
- Site Hawaii (alternate site: Canary Is. / La Palma).
- Construction halted in 2015.
- Completion: TBD.
- Cost: ~ 1500 M$



With also a very complete instrumentation

Instrument	λ (μm)	Field of view/ Slit length	Spectral resolution	Science Cases
InfraRed Imager and Spectrometer (IRIS)	0.8 – 2.5 0.6 – 5 (goal)	<3″ IFU >15″imaging	> 3500 5-100 (imaging)	• Assembly of galaxies at high z • Black holes/AGNs/Galactic Center • Resolved stellar populations in crowded fields
Wide-field Optical spectrometer and imager (WFOS)	0.31 – 1.0	>40 arcmin^2 >100 arcmin^2 (goal) Slit length>500″	1000-5000@0.75″ slit >7500 @0.75″ (goal)	• IGM structure and composition at 2 < z < 6 • Stellar populations, chemistry and energetics of z > 1.5 galaxies
InfraRed Multislit Spectrometer (IRMS)	0.95 – 2.45	2 arcmin field, up to 120″ total slit length with 46 deployable slits	R=4660 @ 0.16 arcsec slit	• Early Light • Epoch of peak galaxy building • JWST follow-ups
Deployable, multi-IFU, near-IR spectrometer (IRMOS)	0.8 – 2.5	3″ IFUs over >5′ diameter field	2000-10000	• Early Light • Epoch of peak galaxy building • JWST follow-ups
Mid-IR AO-fed Echelle spectrometer (MIRES)	8 – 18 4.5 – 28 (goal)	3″ slit length 10″ imaging	5000-100000	• Origin of stellar masses • Accretion and outflows around protostars • Evolution of gas in protoplanetary disks
Planet Formation Instrument (PFI)	1 – 2.5 1 – 5 (goal)	1″ outer working angle, 0″.05 inner working angle	R≤100	• 10^8 contrast ratio (10^9 goal) • Direct detection and spectroscopic characterization of exoplanets
Near-IR AO-fed echelle spectrometer (NIRES)	1 - 5	2″ slit length	20000-100000	• IGM at z > 7, gamma-ray bursts • Local Group abundances • Abundances, chemistry and kinematics of stars and planet-forming disks • Doppler detection of terrestrial planets around low-mass stars
High-Resolution Optical Spectrometer (HROS)	0.31 – 1.1	5″ slit length	50000	• Doppler searches for exoplanets • Stellar abundance studies in Local Group • ISM abundance/kinematics • IGM characteristics to z~6
"Wide"-field AO imager (WIRC)	0.8 – 5.0	30″ imaging field	5-100	• Precision astrometry (e.g., Galactic Center) • Resolved stellar populations out to 10 Mpc

With also a very complete instrumentation

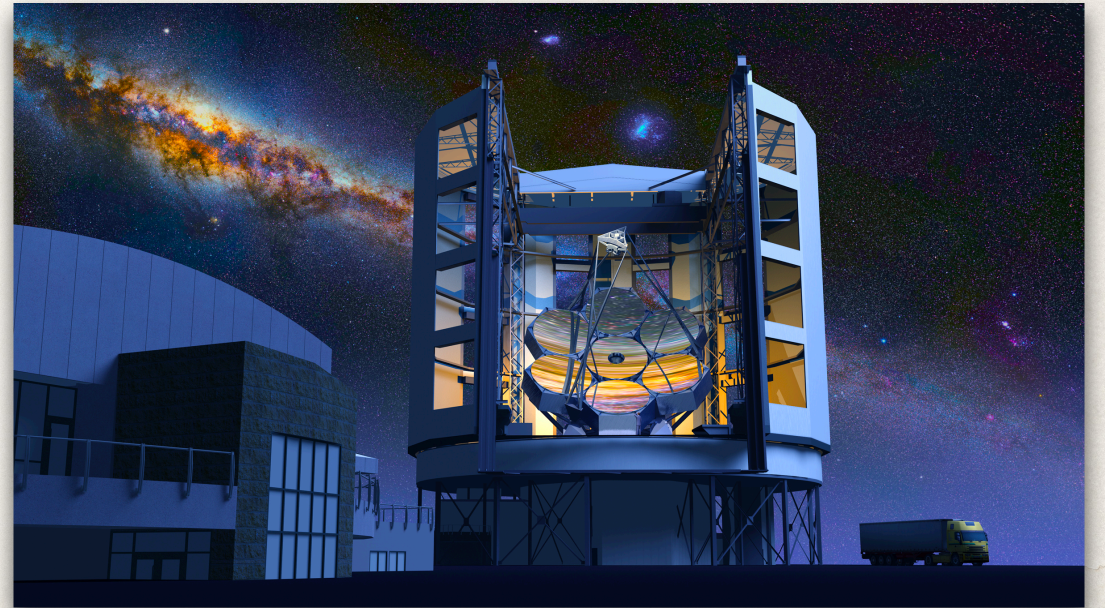


GMT: Giant Magellan Telescope

Consortium of US universities + foreign partners:

- Carnegie, Chicago, Harvard, Smithsonian, Texas, Arizona.
- Australia (ANU and AAL), Korea (KASI), Brazil, Chile.

- 7 x 8-m mirrors on the same structure: 21-m diameter (equivalent).
- Site: Las Campanas, Chile.
- Completion: 2029.
- Cost: ~ 1000 M$

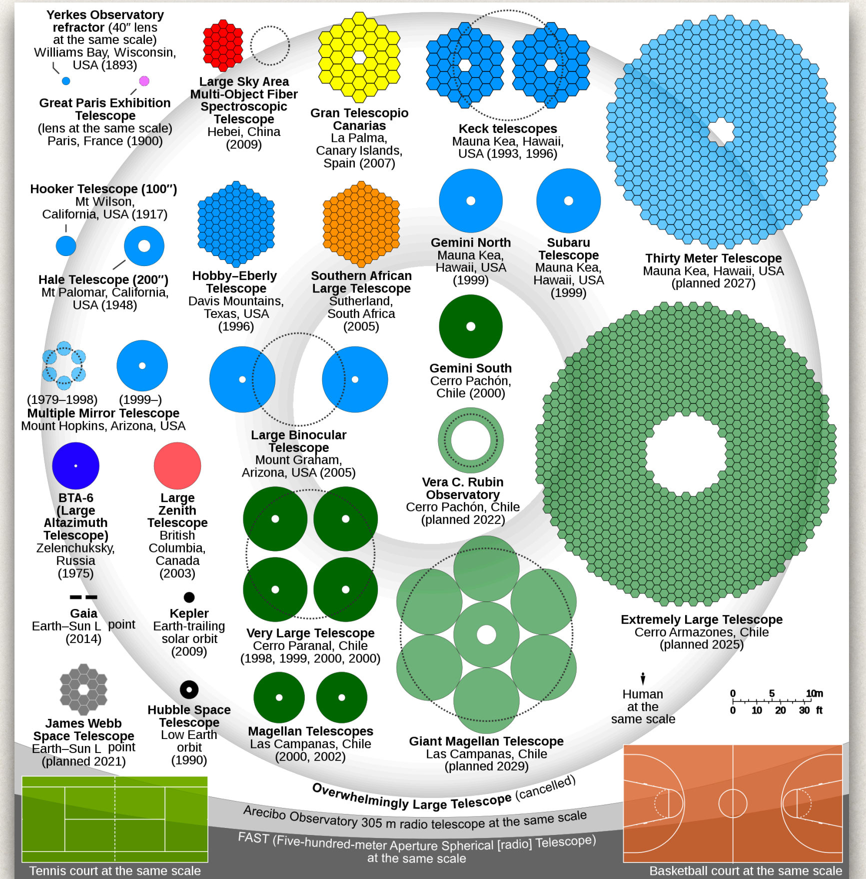


With also an attractive instrumentation

Instrument	Function	λ range (microns)	Resolution	FOV
GMACS	Optical Multi-Object Spectrometer	0.35-1.0	250-4000	64-200 arcmin^2
NIRMOS	Near-IR Multi-Object Spectrometer	1.0-2.5	Up to ~4000	49 arcmin^2
QSpec	Optical High Resolution Spectrometer	0.3-1.05	30K 1" slit	3" + fiber mode
SHARPS	Optical High Resolution (Doppler) Spectrometer	0.4-0.7	150K	7 x 1" fibers
GMTNIRS	Near-IR High-Resolution Spectrometer	1.2- 5.0	25K-100K	Single object
MIISE	Mid-IR Imaging Spectrometer	3.0-25.0	1500	30"
HRCam	Near-IR AO Imager	0.9-5.0	5-5000	30"
GMTIFS	NIR AO-fed IFU	0.9-2.5	3000-5000	3"

In a nutshell

Type of Instrument	GMT	TMT	E-ELT
Near-IR, AO-assisted Imager + IFU	GMTIFS	IRIS	HARMONI
Wide-Field, Optical Multi-Object Spectrometer	GMACS	WFOS	MOSAIC-HMM
Near-IR Multislit Spectrometer	NIRMOS	IRMS	MOSAIC-HMM
Deployable, Multi-IFU Imaging Spectrometer		IRMOS	MOSAIC-HDM
Mid-IR, AO-assisted Echelle Spectrometer		MICHI	METIS
High-Contrast Exoplanet Imager	TIGER	PFI	ELT-PCS
Near-IR, AO-assisted Echelle Spectrometer	GMTNIRS	NIRES	HIRES
High-Resolution Optical Spectrometer	G-CLEF	HROS	HIRES
"Wide"-Field AO-assisted Imager		WIRC	MICADO



The transient sky

All these facilities have identified the study of the transient sky in their scientific cases.

Understanding and Using the Gamma-Ray Bursts of course:

- Understanding Progenitors of the GRBs.
- Probing the High-z Universe with the GRBs.
- Measuring the galaxy luminosity function.
- Etc.

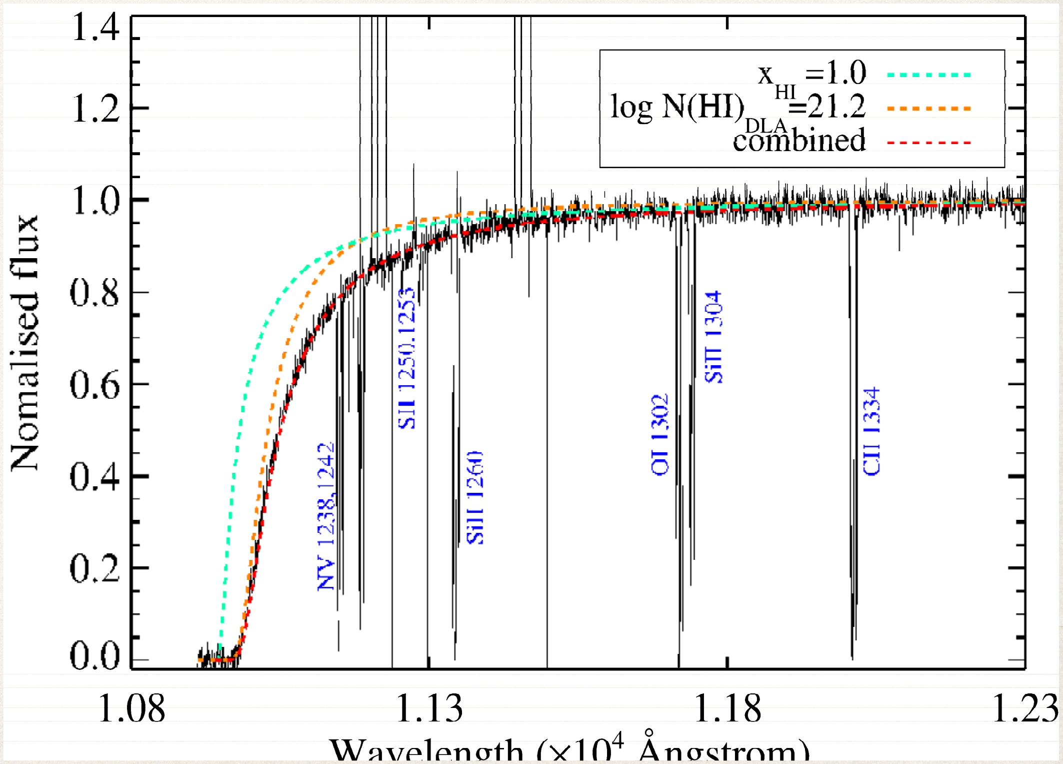
But also:

- Studying Tidal Disruption Events.
- Identifying the Gravitational-Wave Sources.
- Etc.

Probing the High-z Universe with the GRBs.

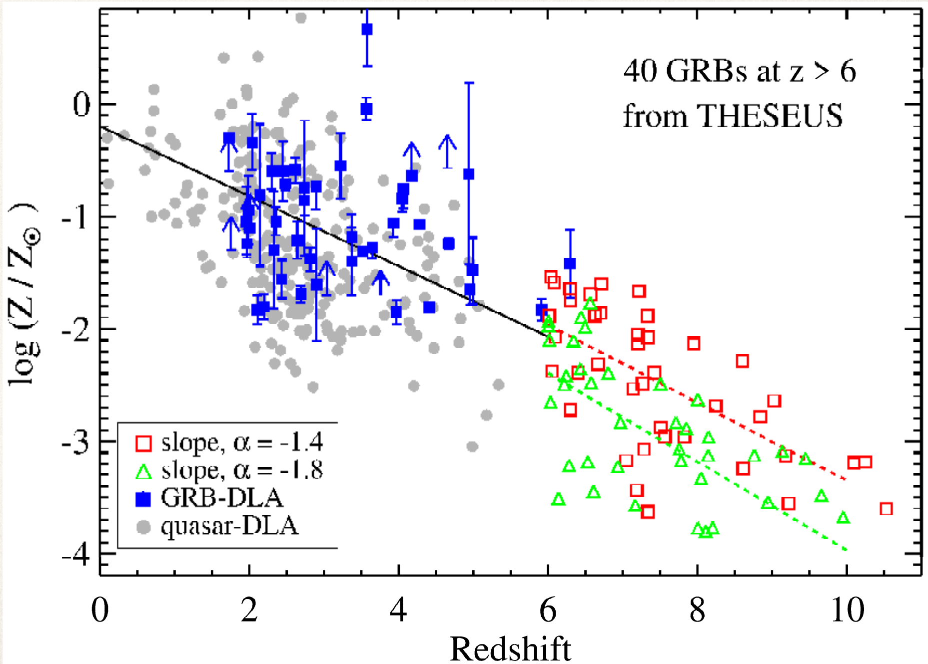
- Possible to quantify the ionization gas content through simultaneous measurement of metal absorption lines and modelling the red-wing of Ly-α to determine host HI column density.
- Potentially possible even several days post-burst.

Simulated ELT 30-minute spectrum of a z=8.0 GRB afterglow with J(AB)=20 (after ~0.5 day) and R=10 000.



The build-up of metals, molecules and dust

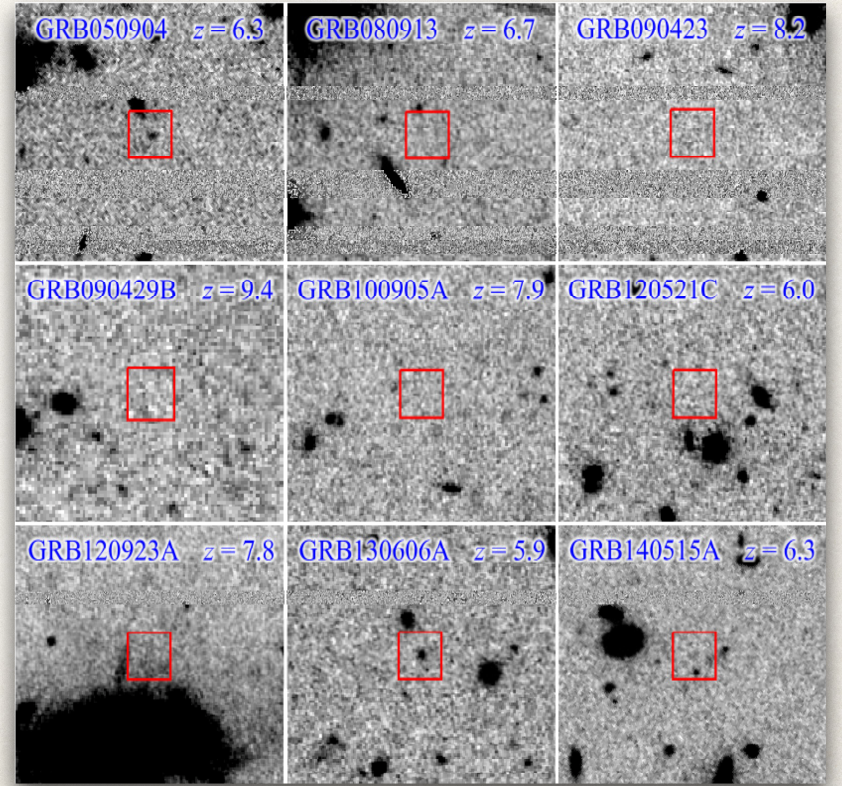
- An efficient way to map metallicities and abundance patterns across the whole range of star forming galaxies in the early Universe, including those at the very faint end of the LF



Detecting undetectable galaxies

- The faint-end of the galaxy luminosity function is a key issue for understanding the reionization era.
- But the faint-end of the LF steepens with redshift: $\alpha \sim 2$ at $z > 6$.
- Expected magnitudes fainter than $m_{AB} \sim 30$: at the limit of what is reachable with the 30-m class telescopes.

HST very deep imaging illustrating the difficulty to detect the host galaxies.



In summary

Theseus will be in operation when the largest telescopes, ELT, TMT and GMT, are fully operational:

- The first generation of instruments (imagery&spectroscopy) is well adapted to the Theseus scientific motivation.

The unique combination of these observations will allow us to better understand the earliest days of the Universe:

- Measuring the galaxy luminosity function.
- Monitoring the cosmic metal enrichment and the chemical evolution to early times.
- Identifying the reionisation cosmic origin.
- Etc.

But beware, we must not forget that many telescopes, even if they are « smaller » (VLT, Keck, etc.), will always be in operation and probably easier to access.