

# The Thirty Meter Telescope

## Primary Mirror:

30m hyperboloidal mirror with 492 segments

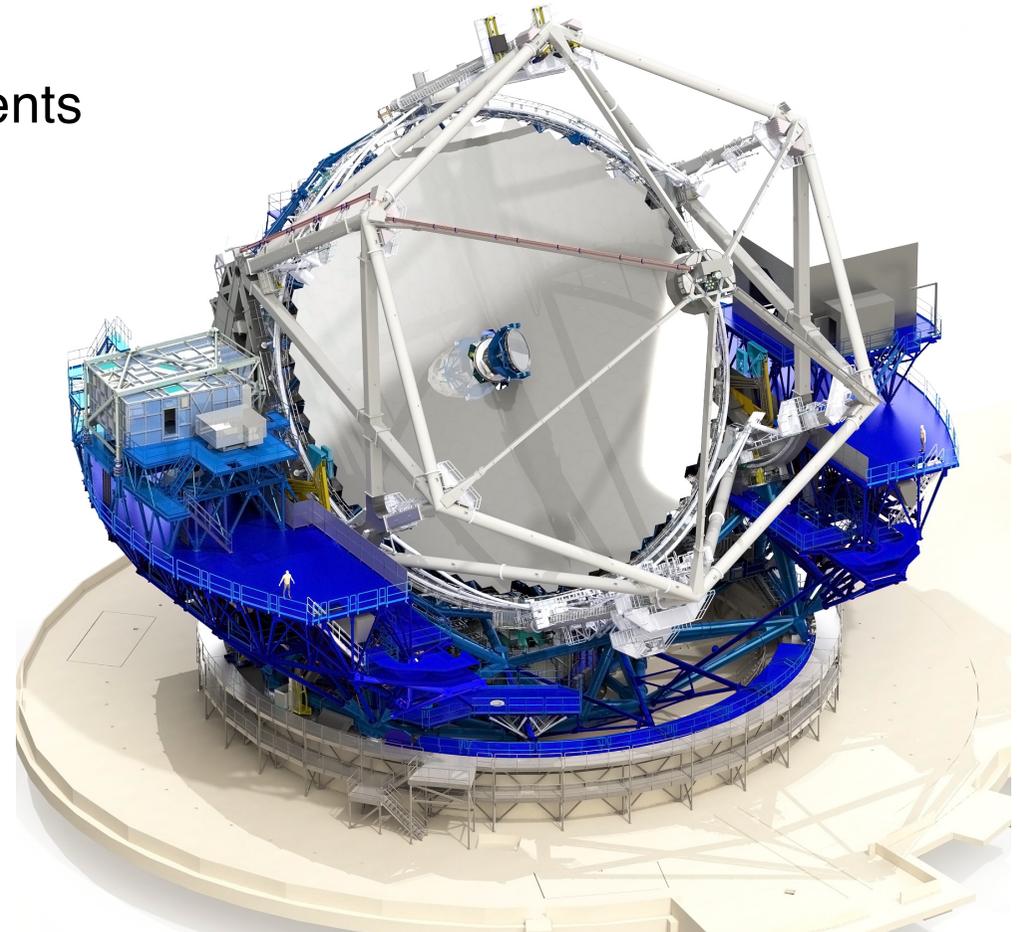
## Secondary Mirror:

3.1m convex hyperboloidal mirror

## Tertiary Mirror:

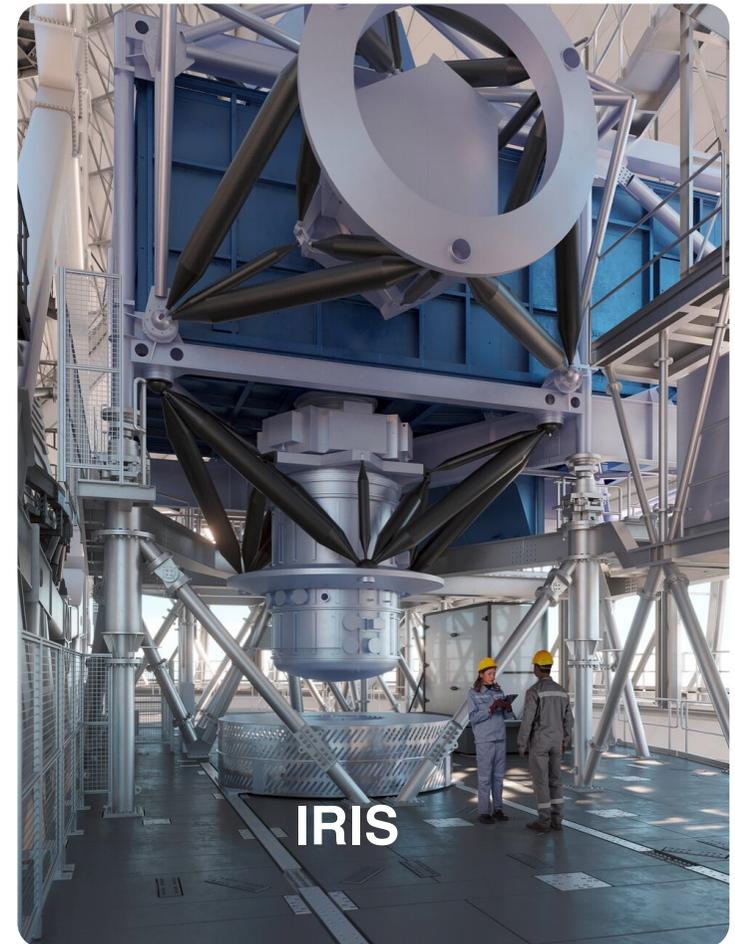
2.5m x 3.5m mirror

- ▶ FOV: 20 arcmin (15 arcmin unvignetted)
- ▶ f/15 (Primary mirror: f/1)
- ▶ Focal length: 450m
- ▶ Operating  $\lambda$ : 0.31~28 $\mu$ m
- ▶ Laser guide star system
- ▶ Diffraction limit: 0.008 arcsec at 1 $\mu$ m



# First Light Instruments

|                            | <b>IRIS</b><br>InfraRed Imaging Spectrograph  | <b>WFOS</b><br>Wide Field Optical Spectrometer  | <b>MODHIS</b><br>Multi-Objective Diffraction-limited High-Resolution Infrared Spectrograph |
|----------------------------|---|---|--|
| <b>Adaptive Optics</b>     | MCAO  | <i>Seeing limited (GLAO)</i>  | MCAO   |
| <b>Spectral Resolution</b> | 4,000 ~ 8,000   | 1,500 ~ 3,500   | 100,000  |
| <b>Wavelength Coverage</b> | 0.84~2.4  | 0.31~1.0  | 0.31~1.0   |
| <b>Functionalities</b>     | Imaging:<br>FOV 34"x34",<br>0.004"/pix<br><br>IFS:<br>0.45"x0.51"<br>@0.004"/pix<br>2.25"x4.4"<br>@0.050"/pix | FOV:<br>8.3'x3', 0.05"/pix<br><br>Spec:<br>58 objects,<br>0.75"x8"slits,<br>0.5" gaps | FOV:<br>5"Φ,<br>vel precision<br>30cm/s<br><br>Fiber:<br>0.1"x0.1" (0.02" sampling)        |

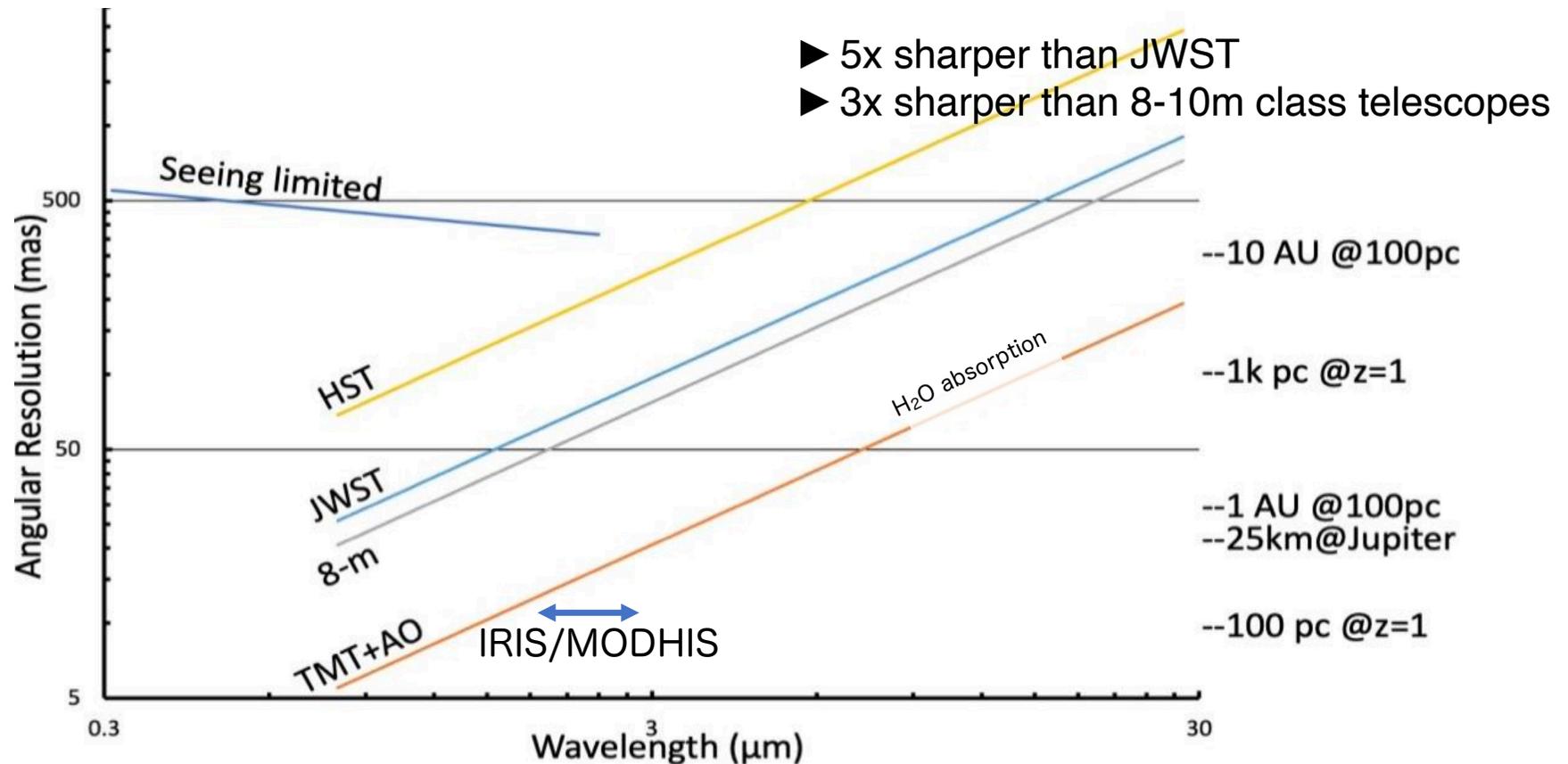


# Second Generation Instruments

| Instrument   | AO                     | Spec Resolution                   | $\lambda$ [ $\mu\text{m}$ ] | Functionalities  |
|--|------------------------|-----------------------------------|-----------------------------|--|
| PSI<br>Planetary Systems Imager                                    | <i>ExAO</i>            | 100, 5,000                        | 1~5                         | Constrast: 10E-8 @2I/D (max 10E-9)<br>IFU: working angle 0.01"~1"                                  |
| MICHI<br>Mid-Infrared Camera High-Disperser & IFU-Spectrograph     | MIR-AO                 | 10~100, 600, 120,000<br>1000(IFU) | 3.4~14<br>(16~25 tbd)       | Imager:<br>24.4x24.4" (0.011"/pix)<br>28.1x28.1" (0.028"/pix)<br>IFU(5"x2") & Echelle spectroscopy |
| HROS<br>Moderate-to-High Resolution Spectrometer                   | <i>no-AO</i><br>(GLAO) | 50,000 ~ >90,000                  | 0.31~1.1<br>(1.3 goal)      | 5" slit  |
| IRMOS<br>near-InfraRed Multi-Object Spectrograph                   | <i>MOAO</i>            | 2,000 ~ 10,000                    | 0.8~2.5                     | IFU: 3", 10-object 5' $\Phi$<br>or<br>50-object Slit 2' $\Phi$                                     |
| NIRES<br>Near-IR AO-fed Echelle Spectrometer                       | <i>MCAO</i>            | 20,000 ~ 100,000                  | 1~5                         | 2"スリット   |
| ARISE<br>Astronomical Rapid Imager and Spectropolarimetric Explore | <i>no-AO</i><br>(GLAO) | >15,000<br>(tbd)                  | 0.31~4.8                    | Imager: 5'x5' (0.1"/pix)<br>IFU: 0.1"/pix<br>10Hz (全画面)<br>100Hz (部分)                              |

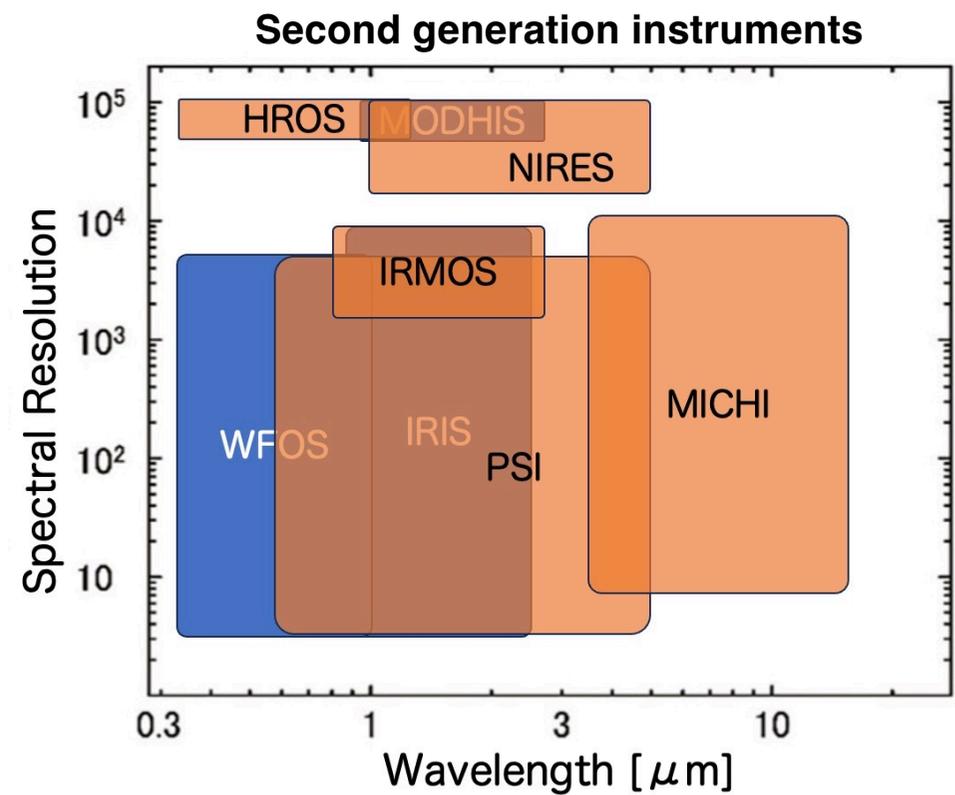
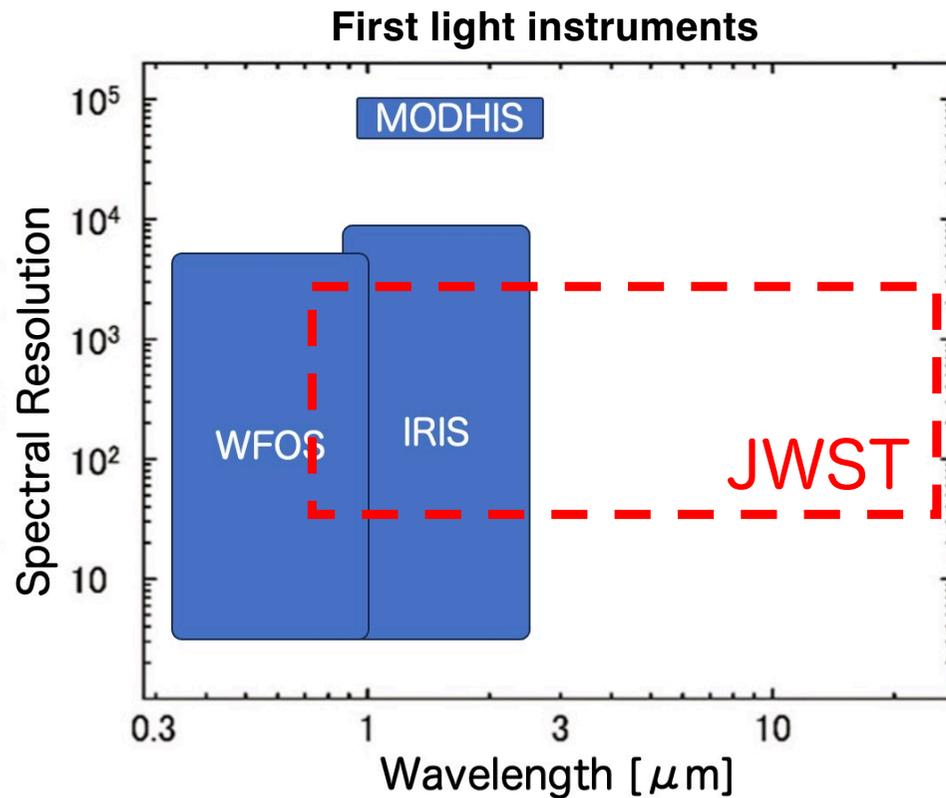
# TMT Provides Diffraction Limited Images in NIR

AO-assisted observations achieve  $\sim 0.01''$  resolution in the NIR, surpassing all space and ground-based telescopes currently in operation.



# TMT Provides High Spectral Resolution

TMT's instruments are equipped with a wide range of spectral resolution, as high as  $R \sim 10^5$ , allowing observations of a wide range of astronomical targets.



# TMT's Uniqueness over E-ELT/GMT

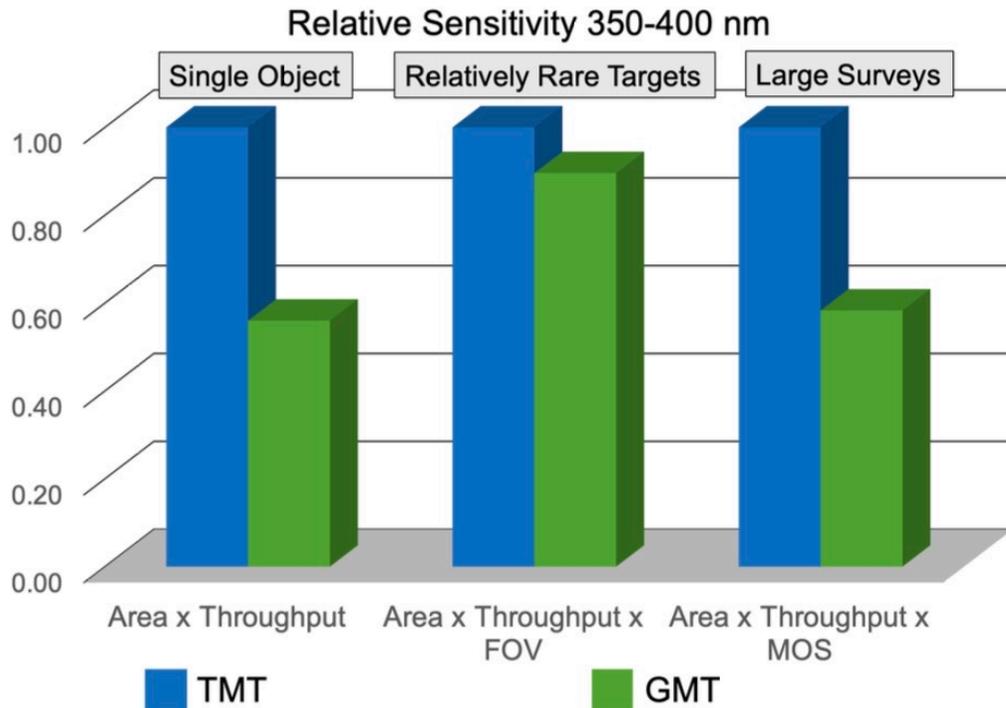
- ▶ **The only ELT in the northern hemisphere**
  - ▶ Critical for follow-up observations of transients discovered by Subaru wide-field imaging
  - ▶ TMT with E-ELT/GMT can follow a target for many hours because they are at different longitudes
  - ▶ Local group, Virgo cluster, and the Andromeda galaxy are in the North
- ▶ **Widest FOV** (9x than E-ELT) and **highest efficiency** (~1.2x than E-ELT), wide-field MCAO system, and wide-field visible MOS.
- ▶ **Quick instrument switching time (<10 min)**, which is a **significant advantage** for rapidly decaying **ToO sources such as neutron star mergers, initial phases of supernovae explosion**
- ▶ AO-assisted at 1<sup>st</sup> light, providing diffraction limited resolution from early science



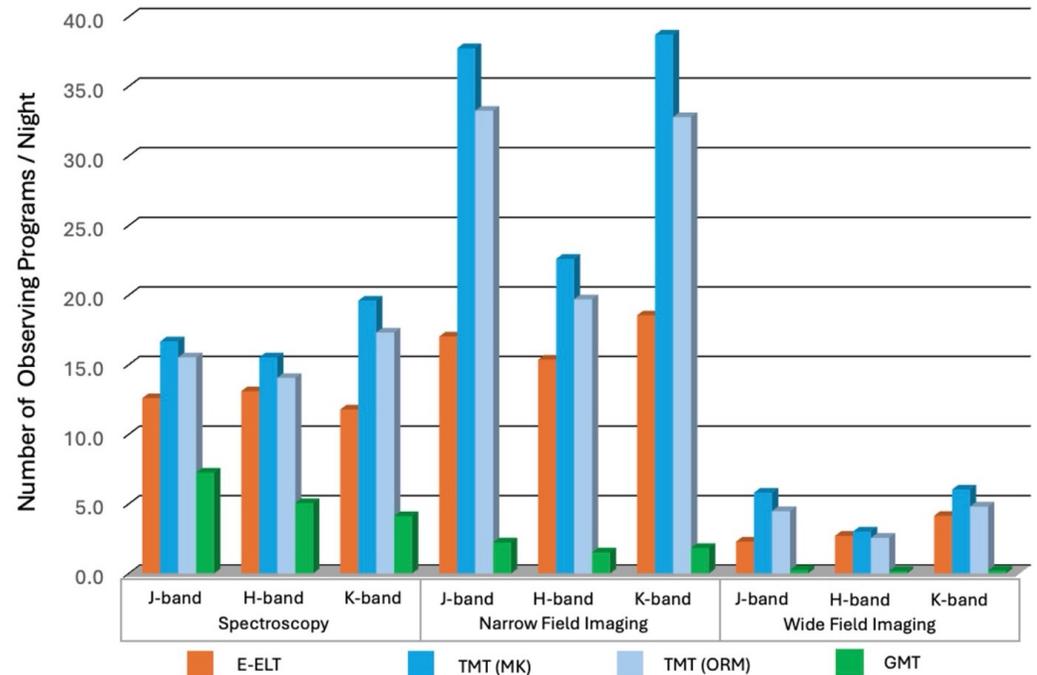
|              | TMT                      | GMT       | E-ELT                   |
|--------------|--------------------------|-----------|-------------------------|
| M1           | 30m f/1                  | 24.5m     | 39m f/0.87              |
| M2           | 3.1m                     | 1.1m x 7  | 4.1m                    |
| # of mirrors | 3                        | 2-3       | 5                       |
| Efficiency   | 0.92                     | 0.92-0.95 | 0.79                    |
| FOV          | 20'<br>(15' unvignetted) | 20'       | 10'<br>(5' unvignetted) |

GMT : Giant Magellan Telescope, E-ELT : European Extremely Large Telescope

- ▶ **TMT is sensitive below 450nm (ultraviolet)**
- ▶ TMT uses UV-enhanced coating for mirrors
- ▶ E-ELT's visible MOS does not observe < 450 nm
- ▶ Unique science (e.g., OH in comets, <sup>9</sup>Be line)

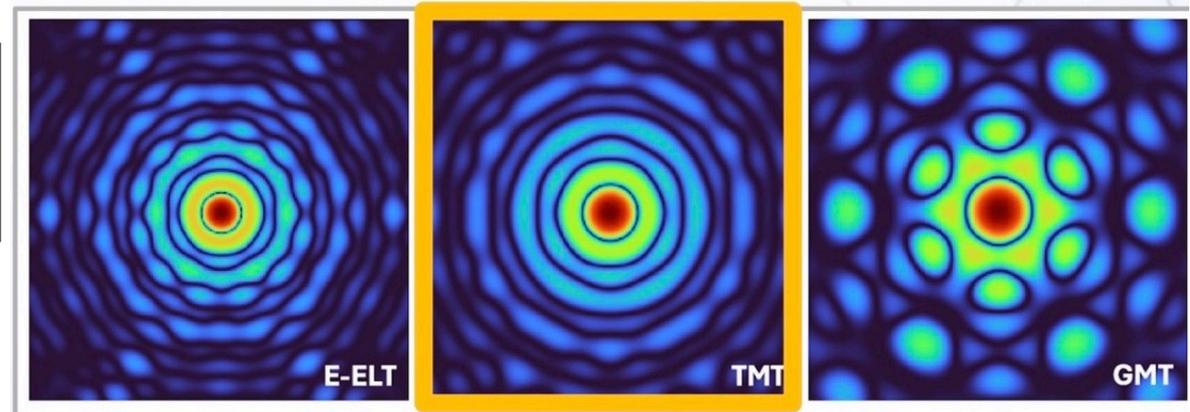
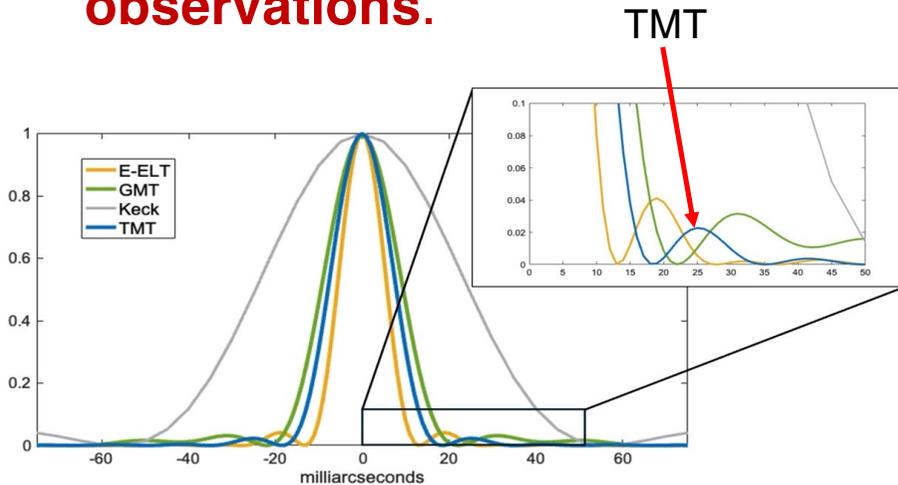
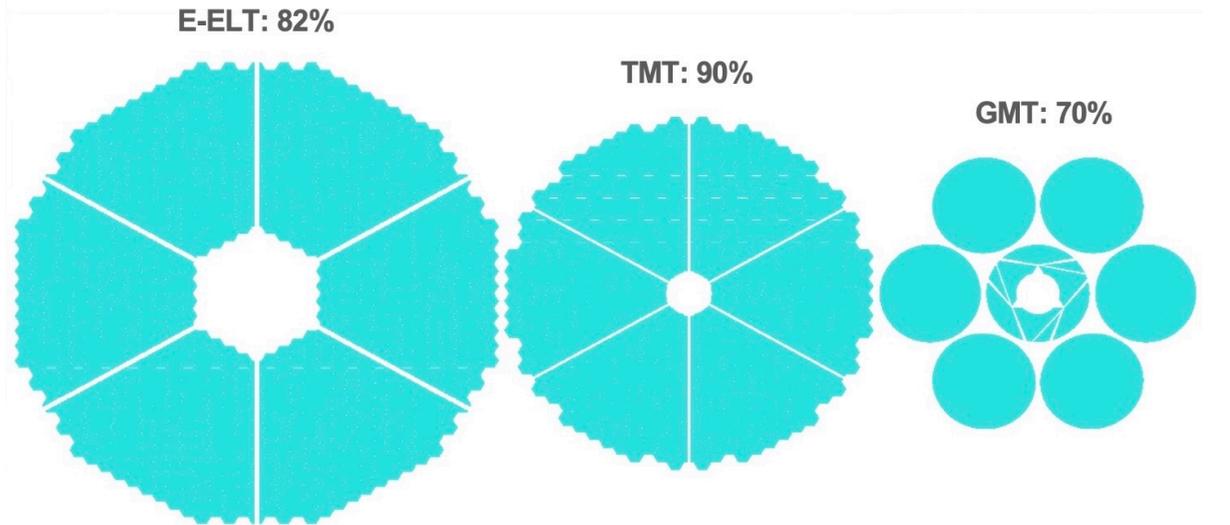


- ▶ TMT/NFIRAOS is the AO system temperature controlled to -30 deg
- ▶ **TMT outperforms E-ELT and GMT in NIR spectroscopy, narrow and wide field imaging**



# TMT has the best Point Spread Function

- ▶ TMT has a simple optical layout with 90% of diameter filled with mirrors.
- ▶ TMT has the **cleanest PSF with lowest side-lobes.**
- ▶ **Extremely important for high-contrast exoplanet observations.**



GMT : Giant Magellan Telescope, E-ELT : European Extremely Large Telescope

# TMT's Sites

| Site Characteristics<br>(Median values, unless<br>stated)                       | (Units)      | TMT MK<br>(USA) | TMT ORM<br>(Spain) | E-ELT<br>Armazones<br>(Chile) | GMT<br>Las<br>Campanas<br>(Chile) |
|---|--------------|-----------------|--------------------|-------------------------------|-----------------------------------|
| Altitude of site  | meters       | 4050            | 2250               | 3060                          | 2415                              |
| Fraction of yearly usable time<br>considering all adverse weather<br>conditions | %            | 72              | 72                 | 86                            | 75                                |
| Seeing at 60 m above ground   | arcsec       | 0.50            | 0.58               | 0.50                          | 0.50                              |
| Isoplanatic angle   | arcsec       | 2.55            | 2.31               | 2.05                          | 2.05                              |
| Atmospheric coherence time  | ms           | 7.3             | 6.0                | 5.0                           | 5.0                               |
| Precipitable water vapor  | % time < 2mm | 54              | 20                 | 50                            | 23                                |
| Mean nighttime temperature  | °C           | 2.3             | 7.6                | 7.5                           | 13                                |

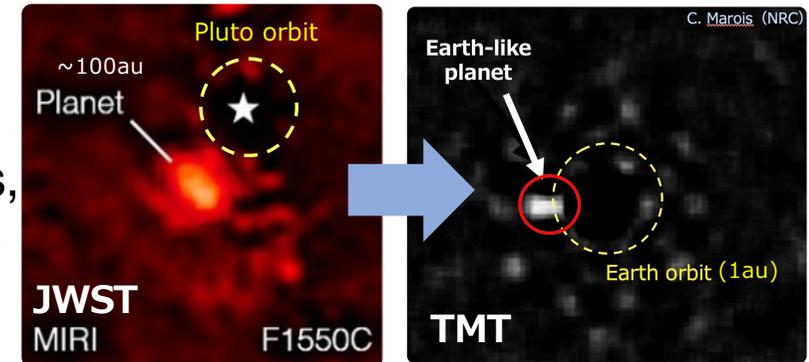


Extremely Well Suited  
for Adaptive Optics

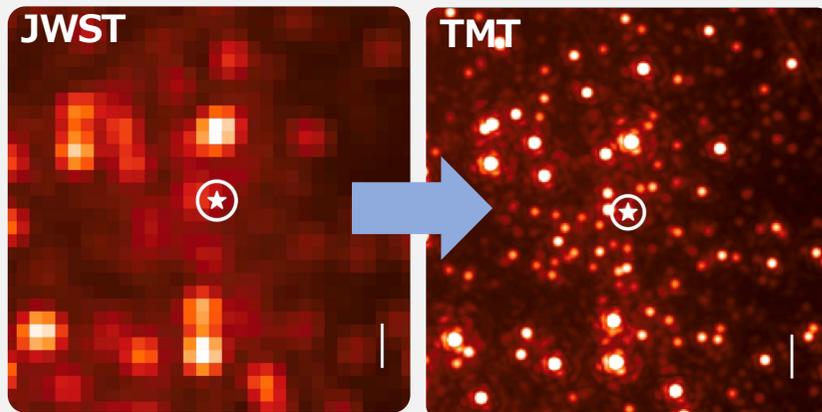


# Comparison with JWST

- ▶ **JWST** will continue to play an important role in capturing gaseous planets relatively far from the central star.
- ▶ **TMT**, with its high spatial & spectral resolution capabilities, will directly image and study the atmospheric composition of rocky earth-orbit planets close to the central star.

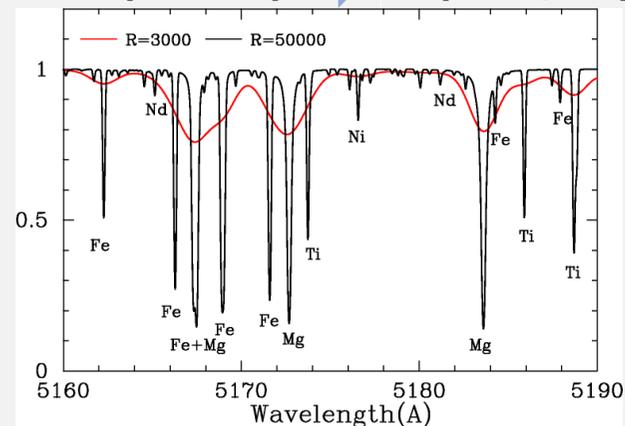


## ▶ Higher Angular Resolution

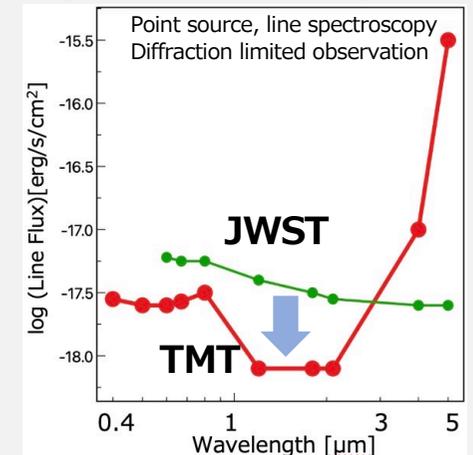


## ▶ Higher Spectral Resolution

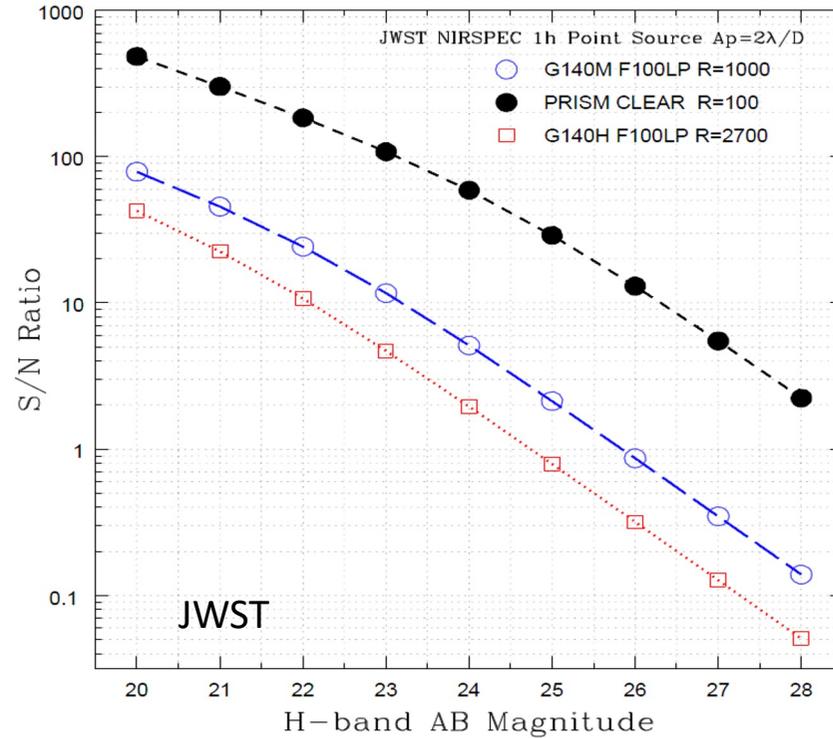
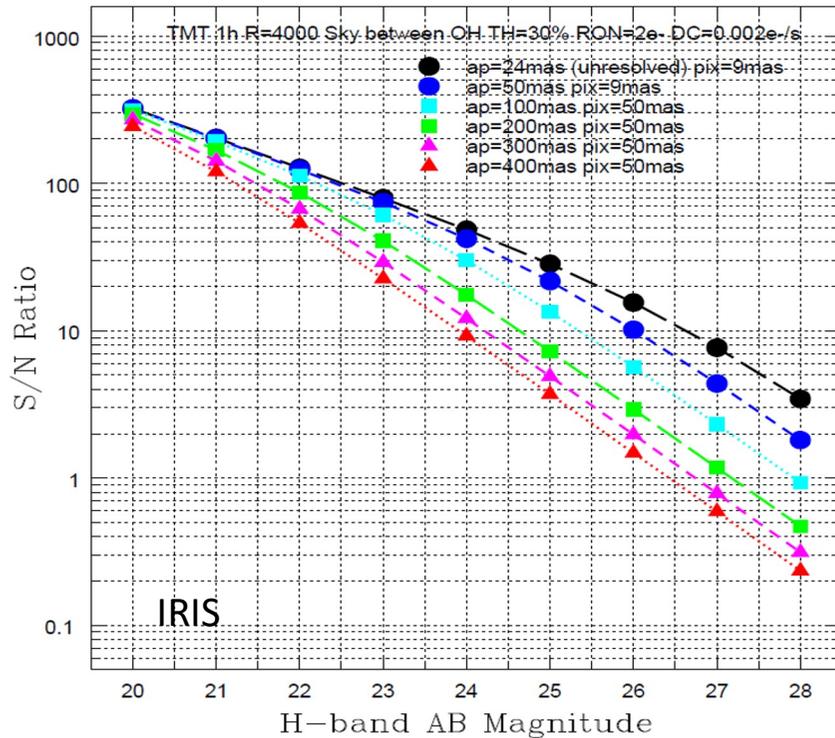
JWST(R=3000) → TMT(R>50,000)



## ▶ Higher Sensitivity in NIR



# Comparison of IRIS and JWST



IRIS will be able to observe fainter objects at higher resolution than JWST

8 hr with IRIS achieve SNR>20 for  $z \sim 8$  Ly $\alpha$  luminosity of  $L > 5 \times 10^{41}$  erg/s (SFR < 10 M/yr)