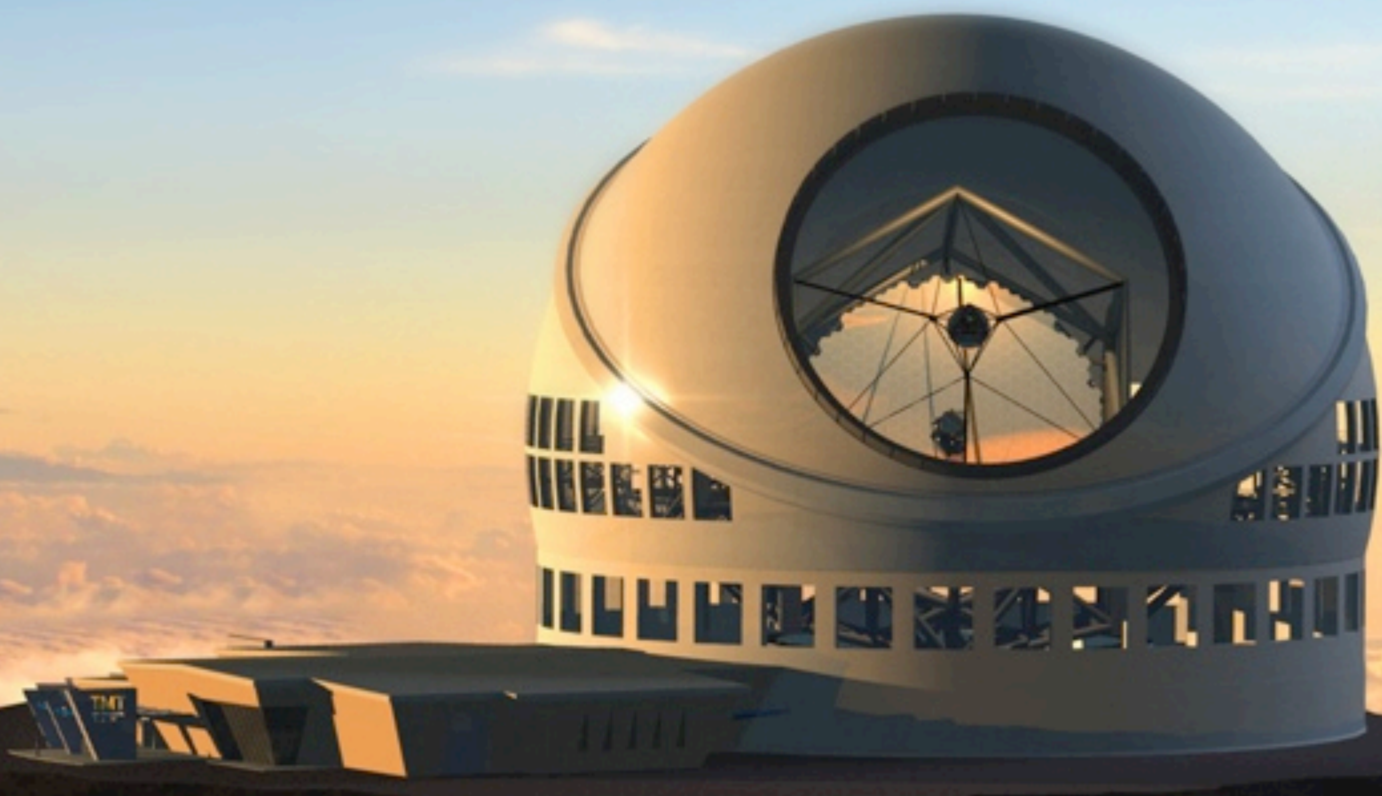
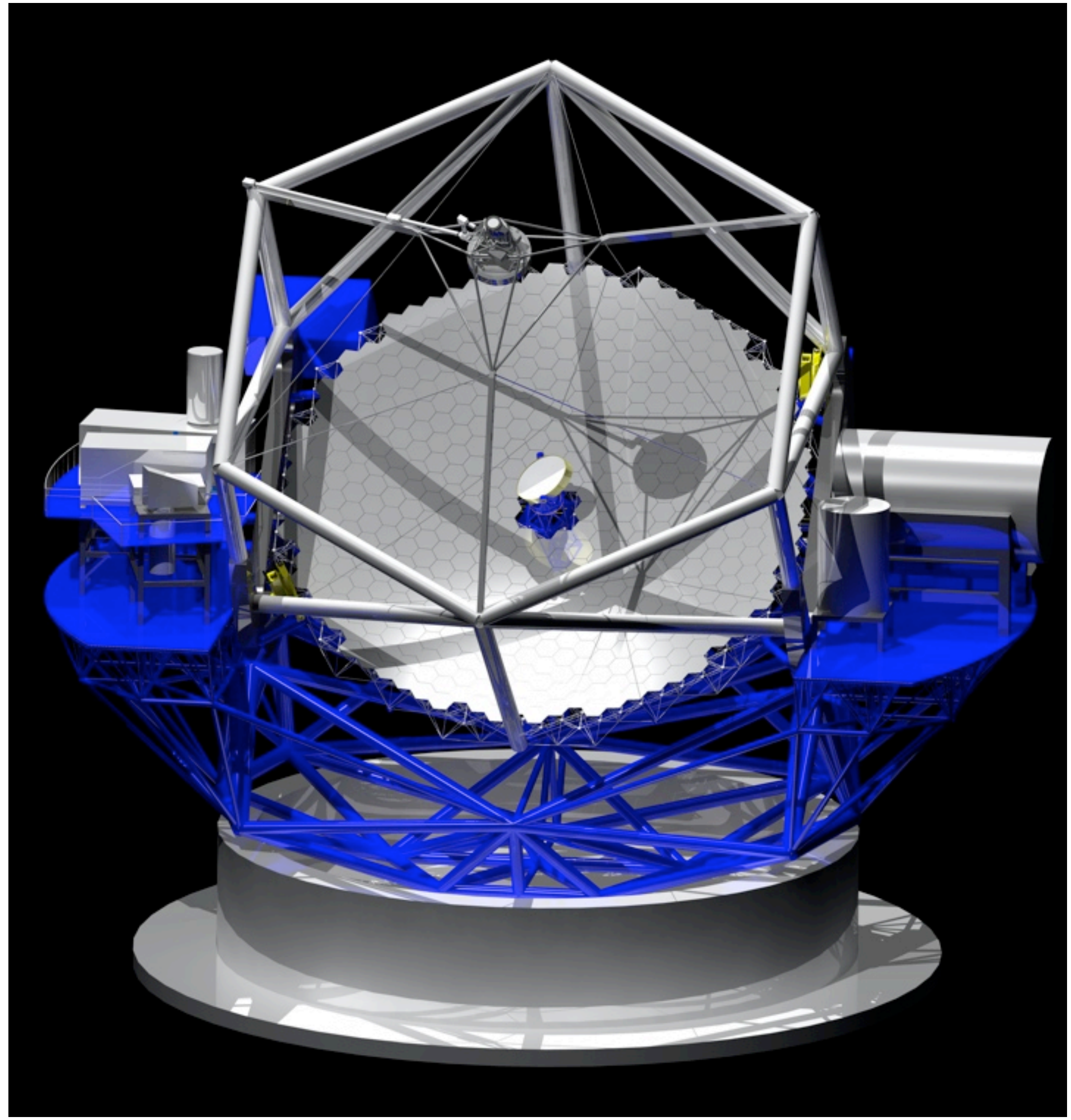
The Thirty Meter Telescope



Paul Hickson, UBC
ALMA and ELTs 2009-03-24

What is TMT?

- Thirty-meter aperture
- Filled, segmented primary
- Active and adaptive optics
- UV to thermal IR
- Broad range of instruments
- Caltech, Univ. of California, Canada
- Project Scientist: Jerry Nelson
- First light 2018



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TMT features

- 14 - 200 times the sensitivity of 8 m telescopes (D^2 - D^4 gain)
- 3 - 5 times the resolution of 8 m telescopes and JWST
- 20 arcmin field of view
- 5 AO modes
- Pointing in < 3 min
- Instrument change in < 10 min
- Calotte enclosure

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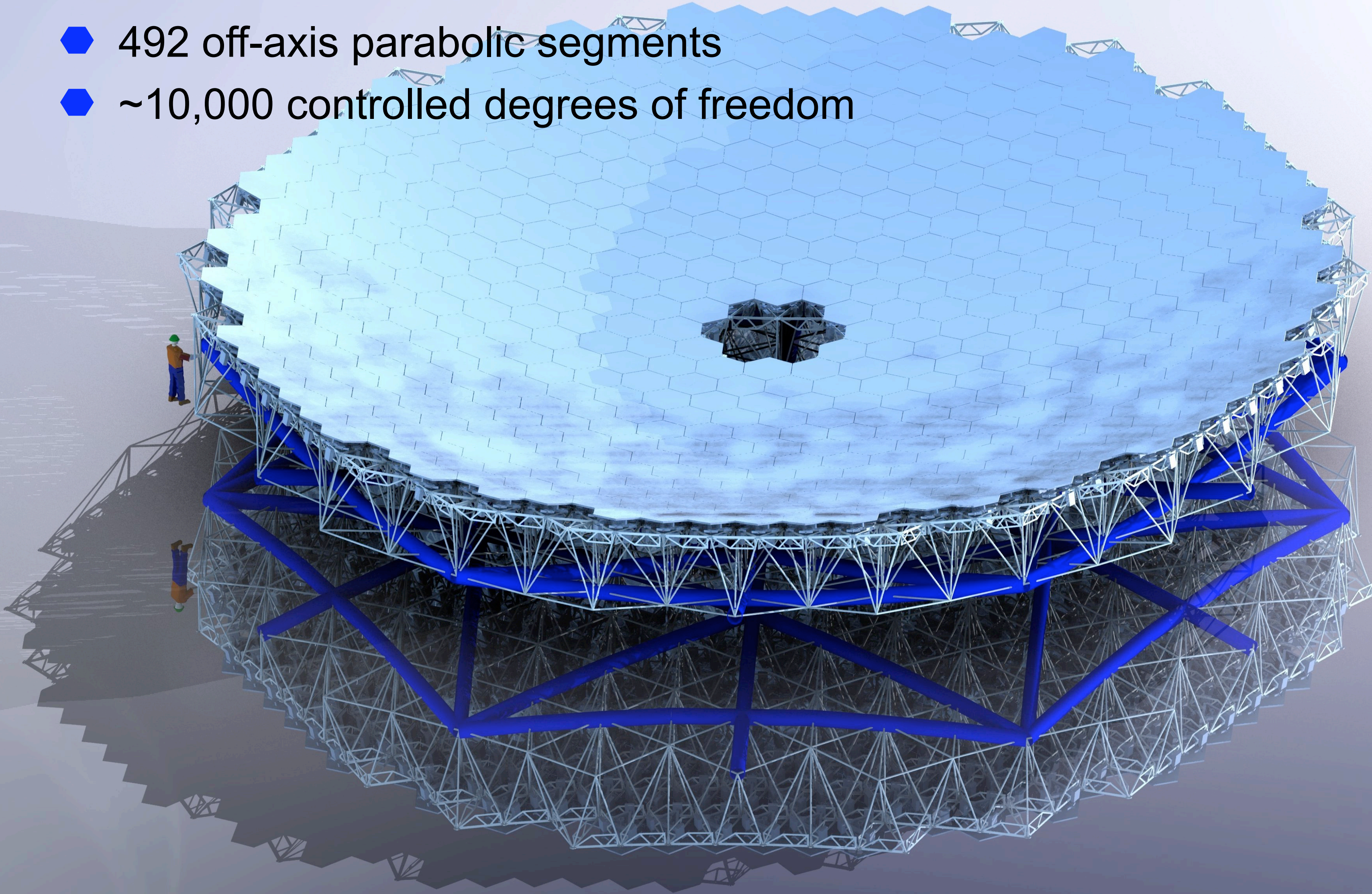
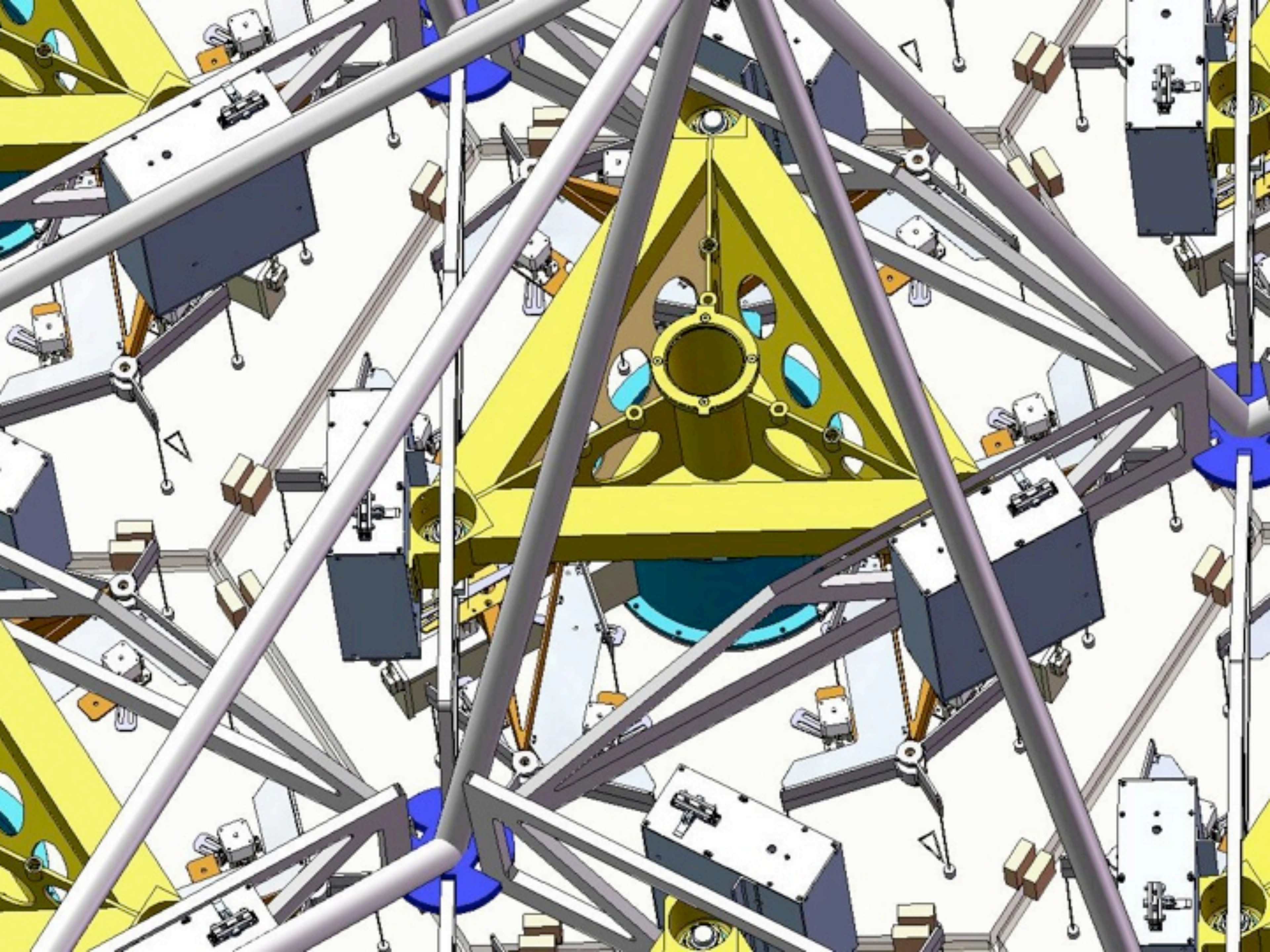
TMT primary mirror

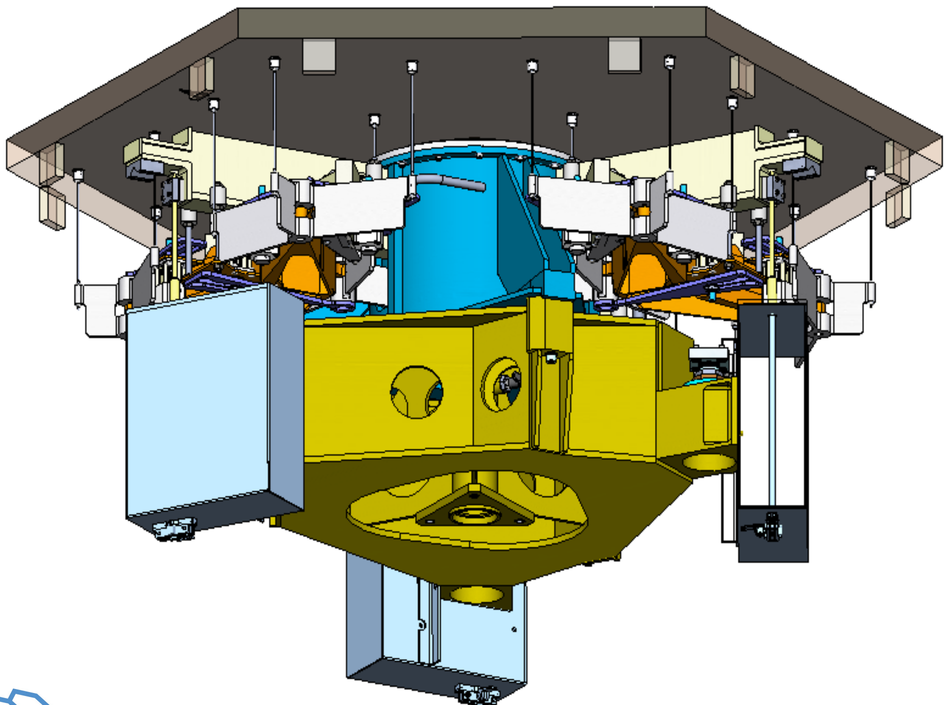
- 492 off-axis parabolic segments
- ~10,000 controlled degrees of freedom

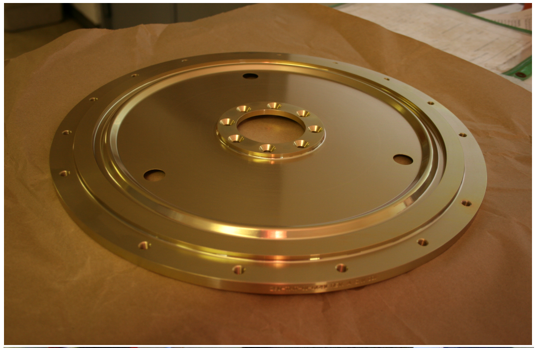


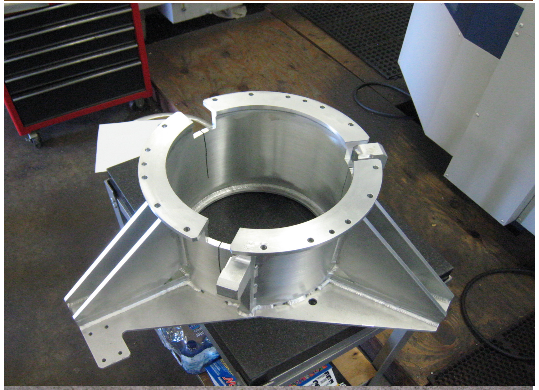


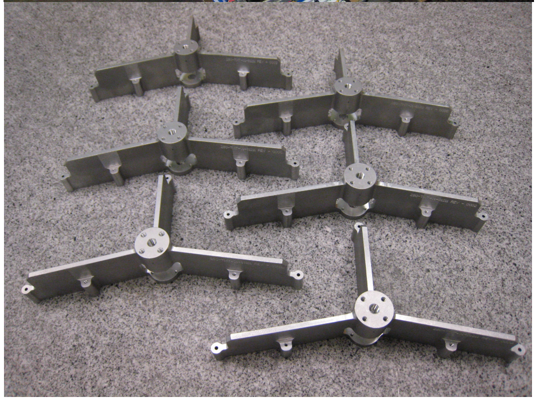
Segment support assembly

- Edge sensors, actuators and warping harness
- Prototyping underway









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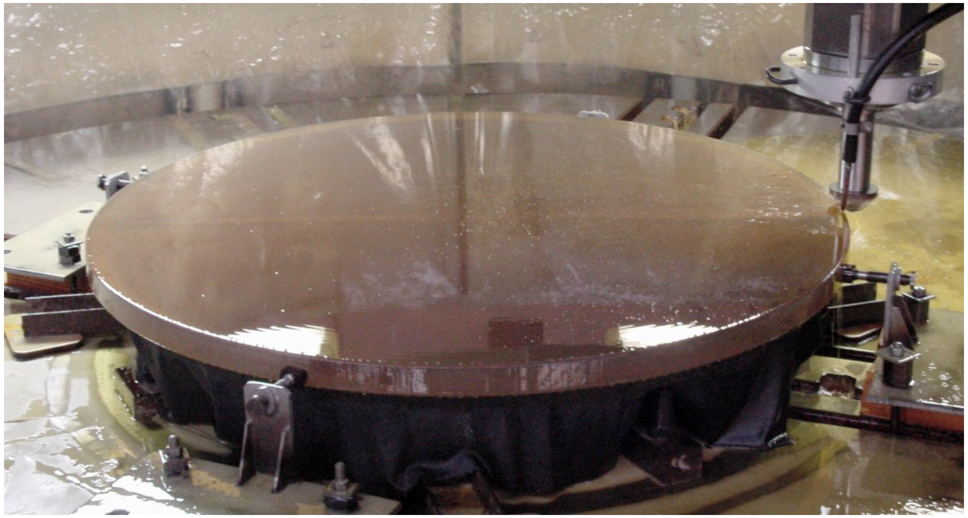
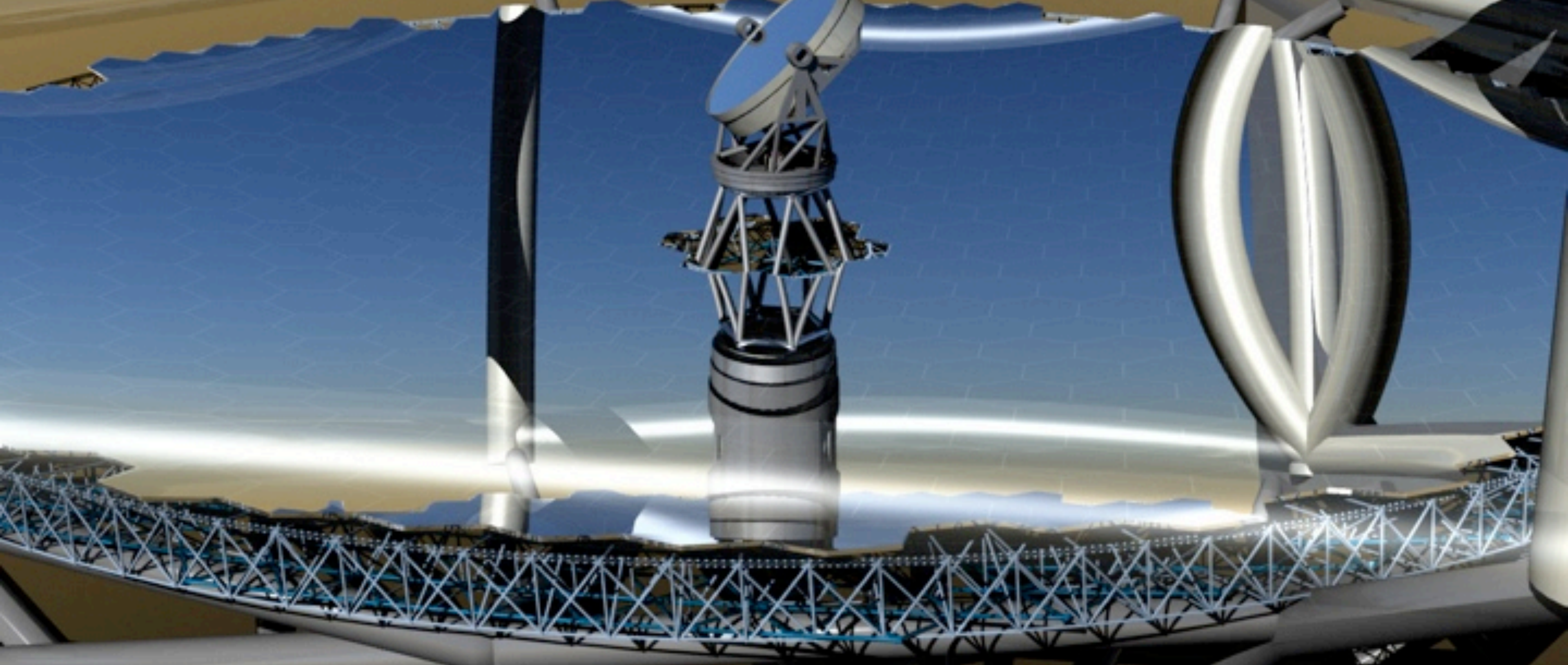
Primary mirror blank fabrication and testing



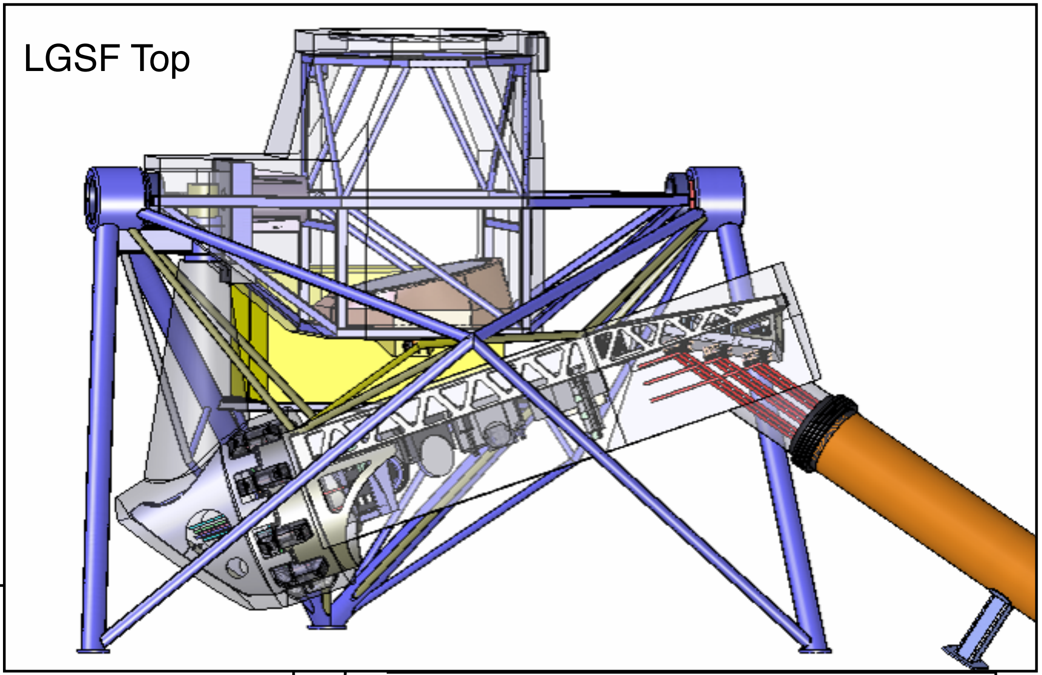
Classical Richey-Chretien optics

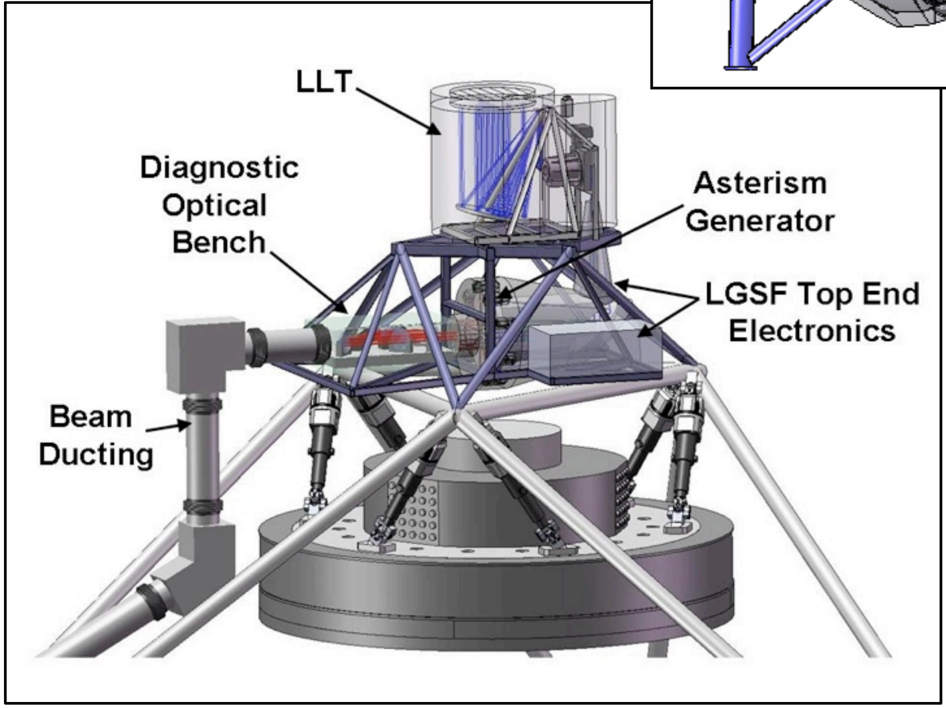
- fully articulating tertiary mirror to select and track Nasmyth instruments

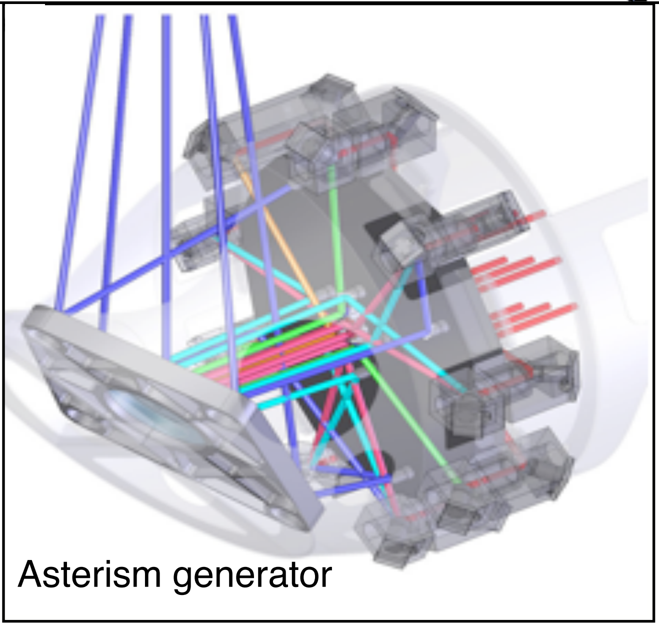


TMT AO systems

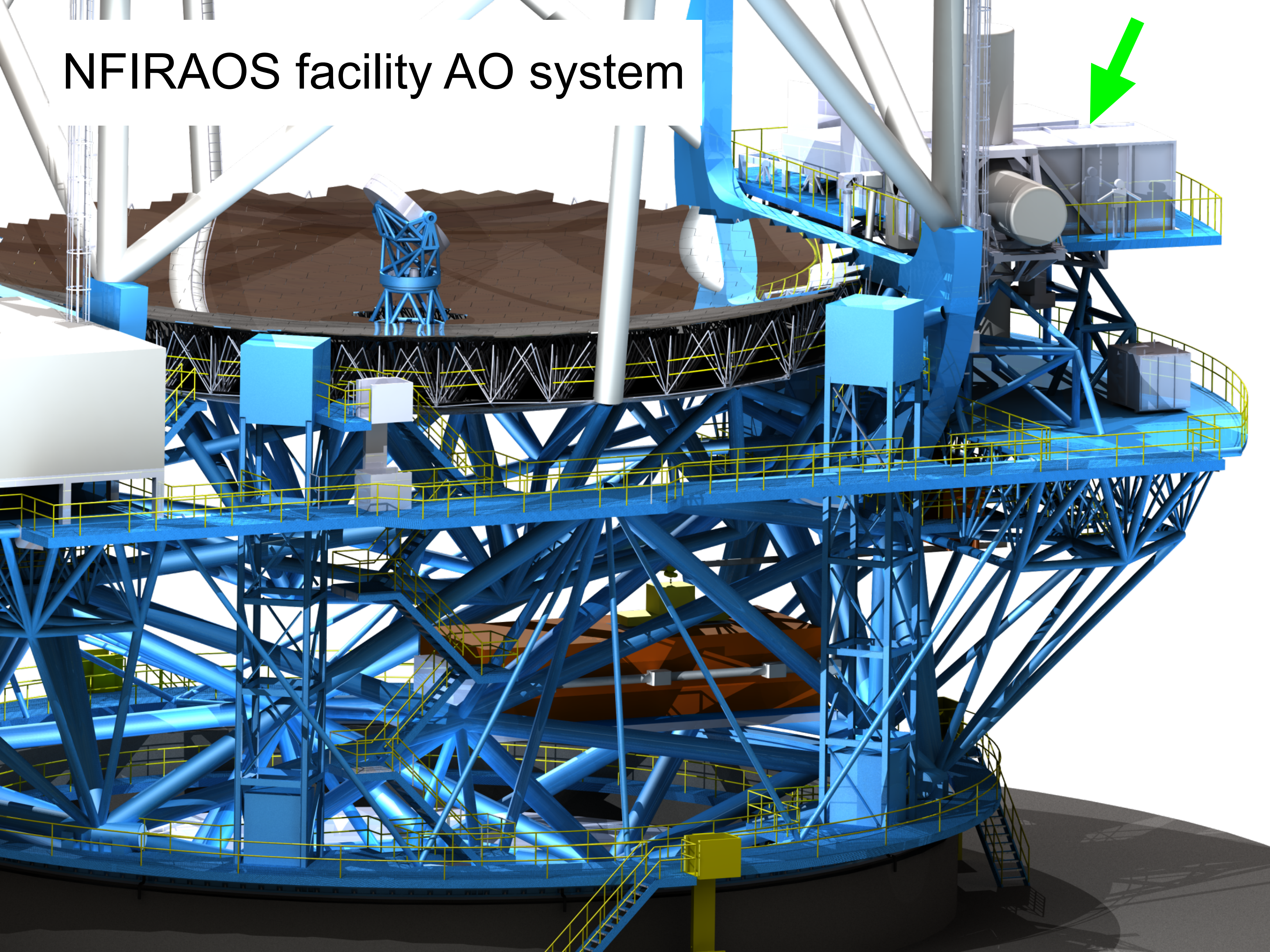
- MCAO (NFIRAOS)
- MOAO (IRMOS)
- MIRAO (MIRES)
- GLAO (WFOS)
- EXAO (PFI)





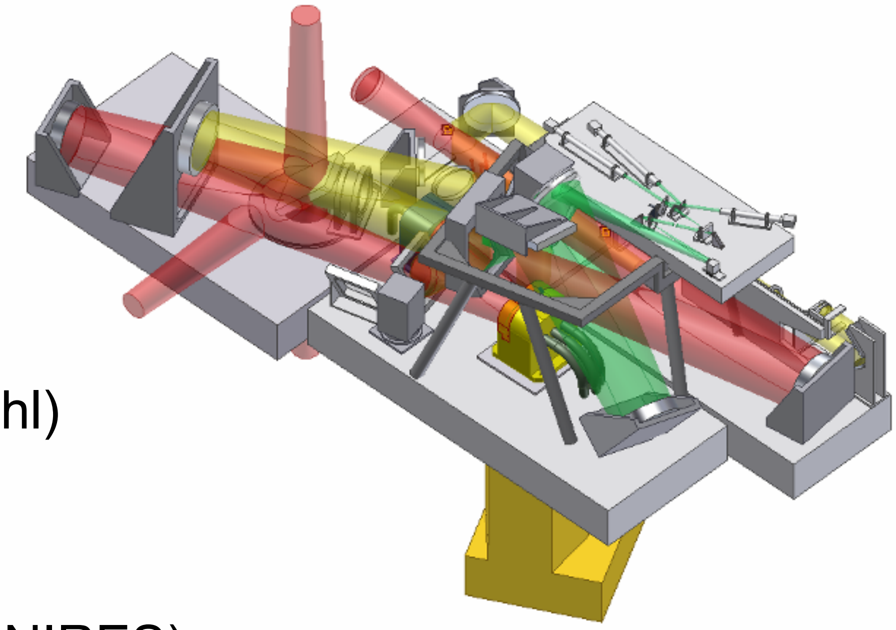


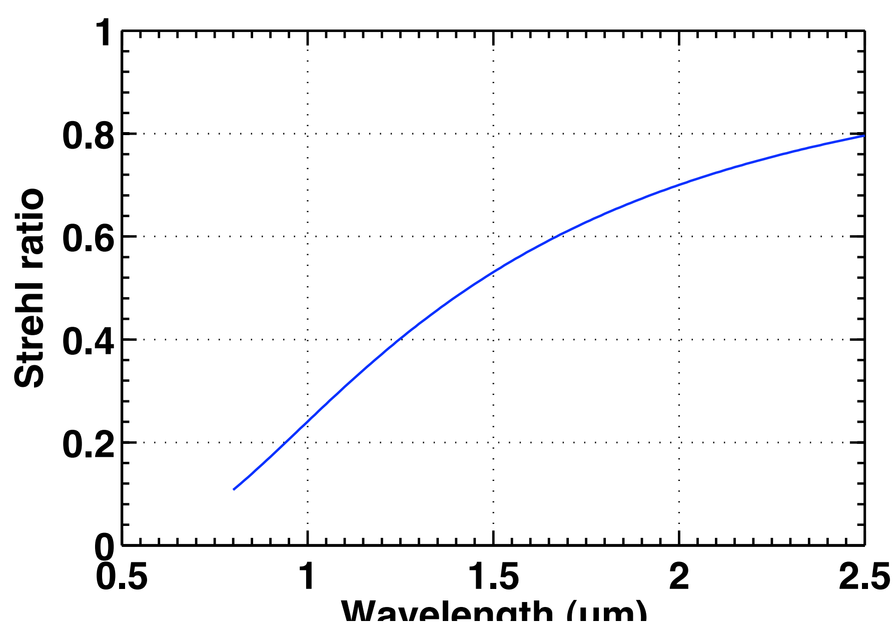
NFIRAOS facility AO system

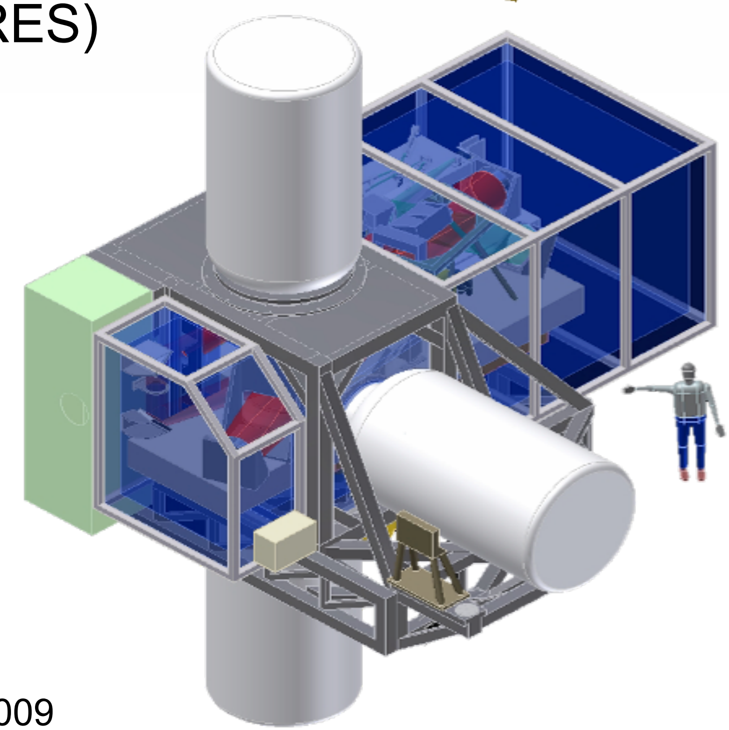


NFIRAOS

- MCAO system with 2 deformable mirrors (~10,000 DOF)
- 0.8 - 2.5 um
- 2.3 arcmin field (30” with high Strehl)
- Cooled to -30C
- 50% sky coverage at galactic pole
- Feeds 3 instruments (IRIS, IRMS, NIRES)

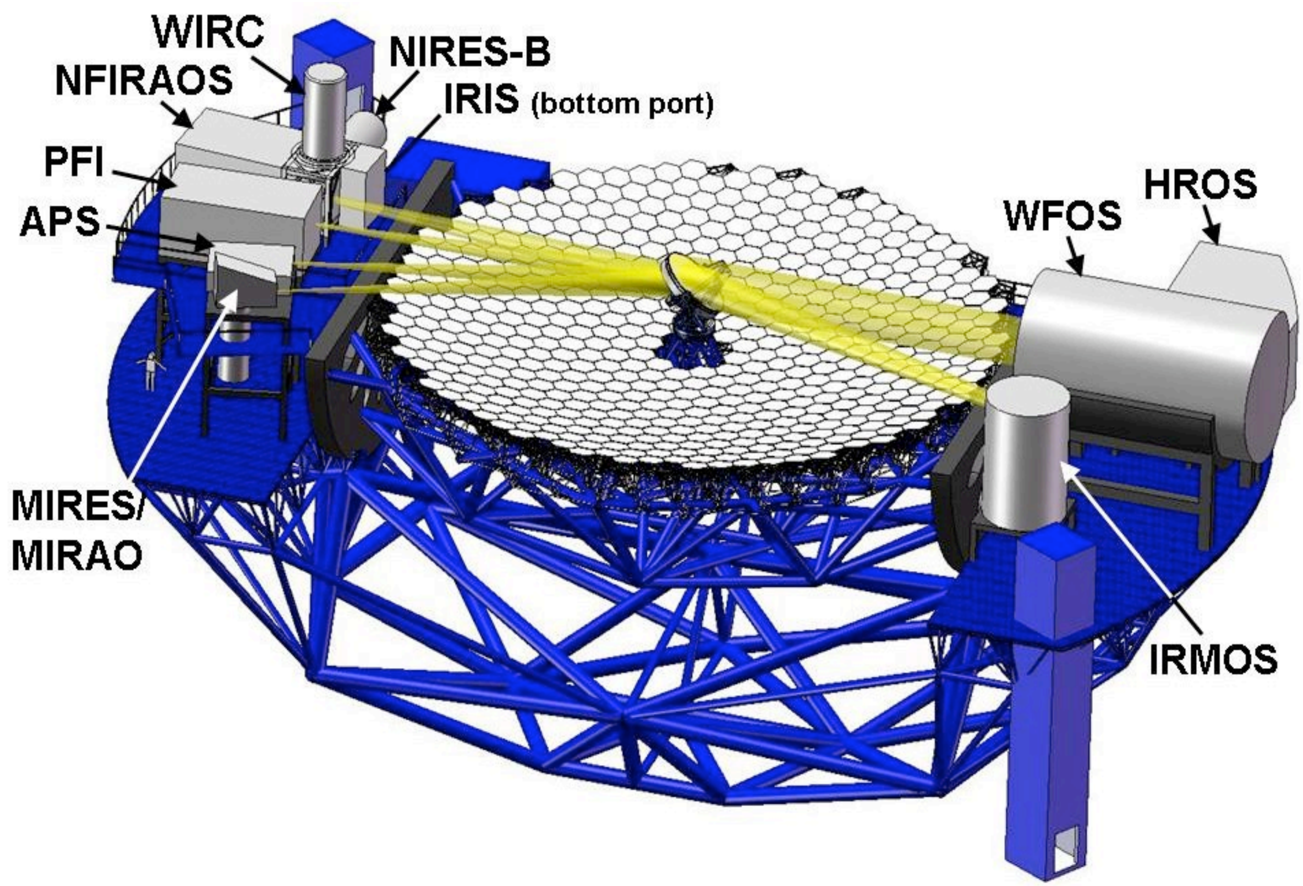






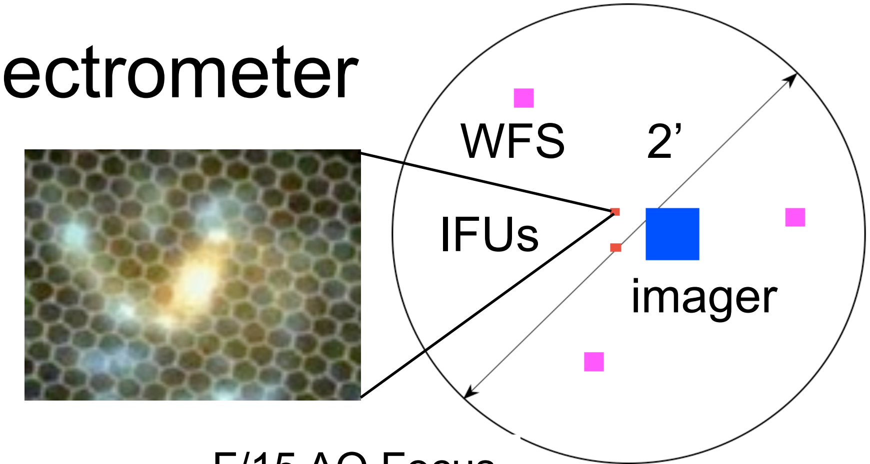
Science instruments

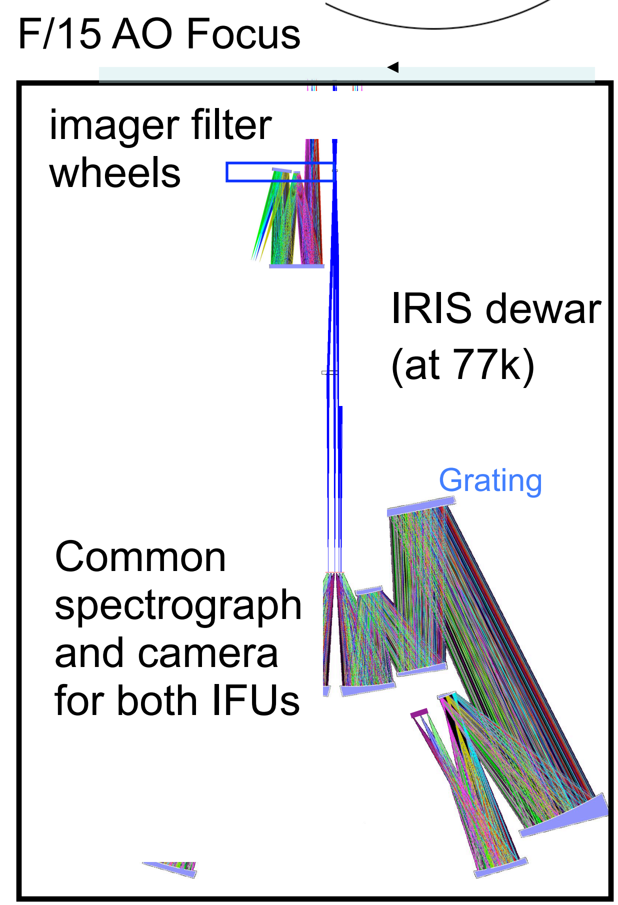
- Initial complement:
  - IRIS
  - IRMS
  - WFOS
- First decade:
  - NIRES
  - MIRES
  - PFI
  - HROS
  - WIRC
  - IRMOS



IRIS - Infrared imaging spectrometer

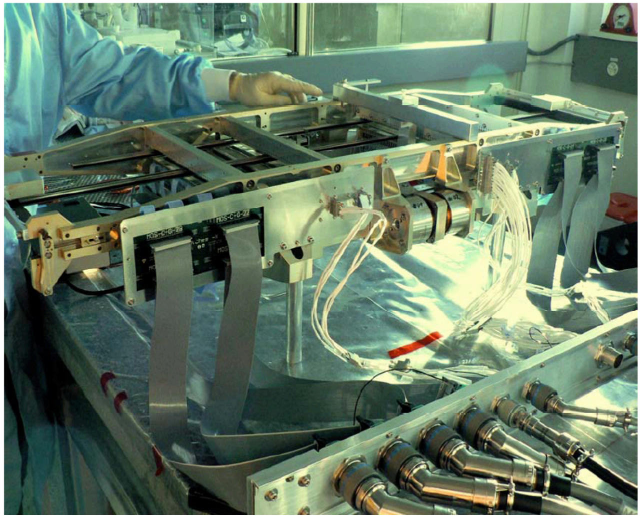
- 0.8 - 2.5 um wavelength range
- 15” x 15” imager with 4 mas pixels
- Spectrometer overs entire J, H or K band at *R* = 4000
- Lenslet integral-field spectrometer
  - 128x128 spatial pixels
  - 5% bandpass at highest spatial resolution
  - 4 and 10 mas scales
- Image slicer
  - 90 slices; 2:1 aspect ratio
  - 25 and 50 mas scales (1.1’’ and 2.2’’ field of view)

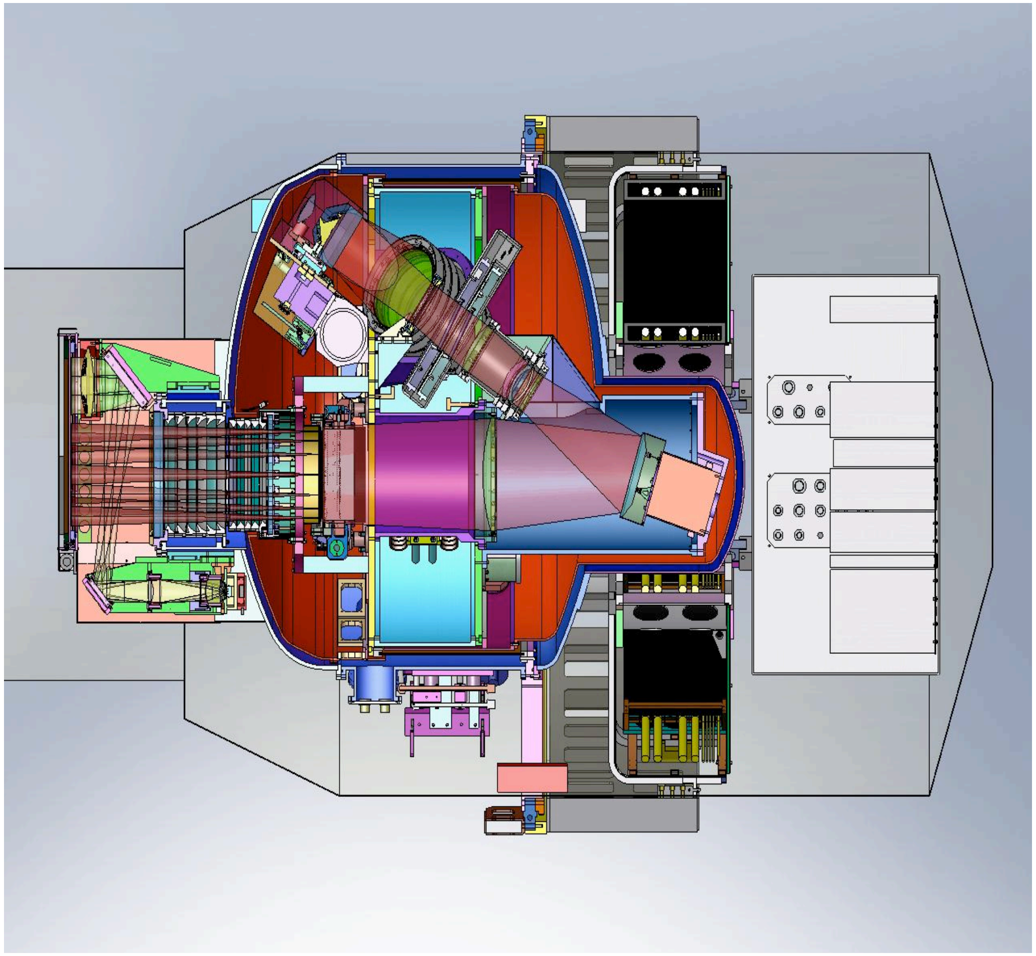




IRMS - Infrared multislit spectrometer

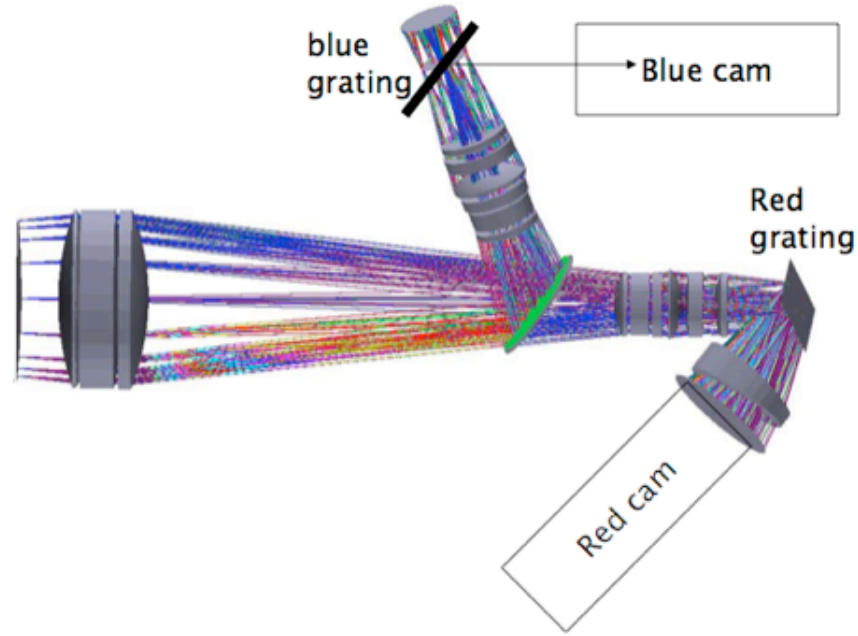
- 0.8 - 2.5 um cryogenic multi-slit spectrometer
- 2.3 arcmin field of view
- 0.06 arcsec sampling
- 46 moveable slits 2.4” long
- Covers entire Y, J, H or K band at *R* = 4660

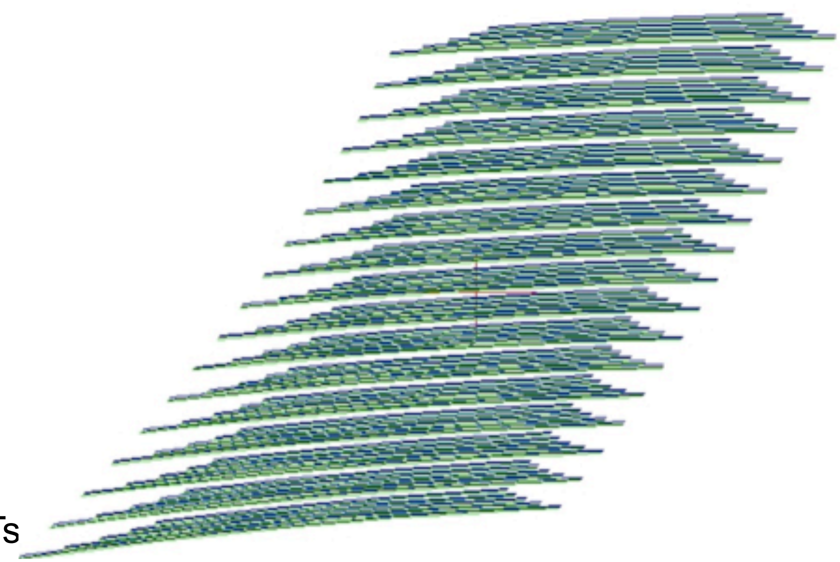




WFOS - Wide-field optical spectrograph

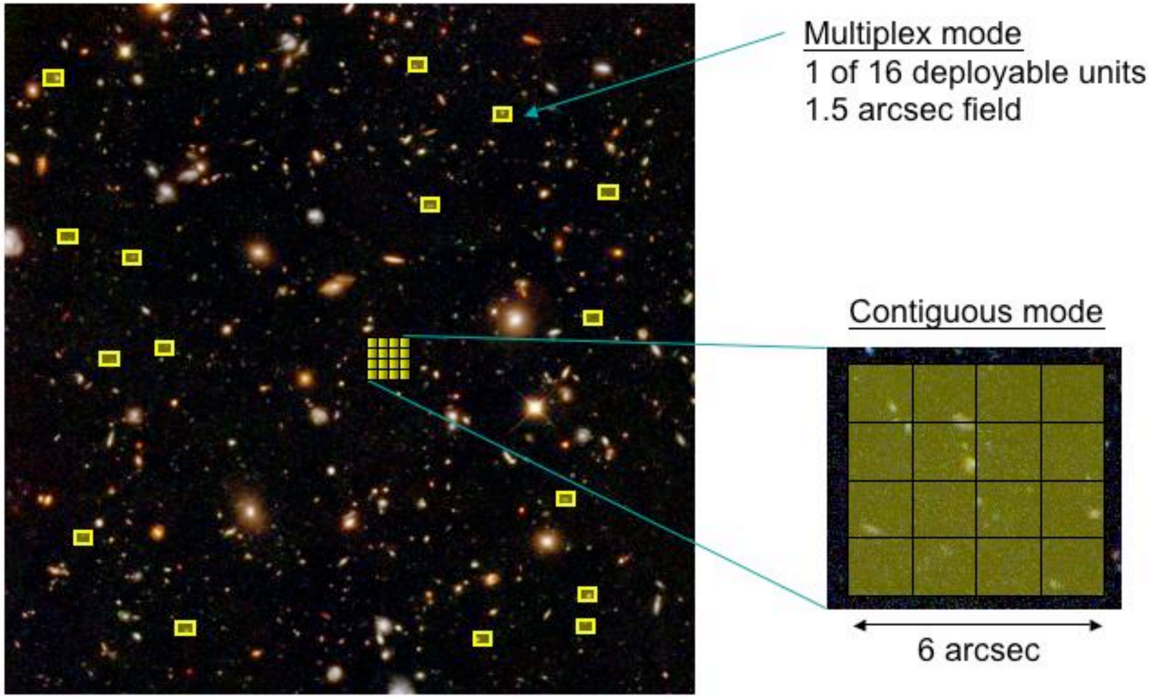
- 0.31 - 1.1 um wavelength range
- Observe up to 1500 objects over a 40.5 sq. arcmin FOV
- Spectral resolution 300 - 7500
- Reflecting gratings / prism cross-dispersion, and fixed dichroic beamsplitter at 550nm
- "Echellette" design provides up to 5 orders
- Full wavelength coverage, even at highest resolution, for "discovery science"
- Low resolution mode (single order) for maximum multiplex advantage





IRMOS - Infrared multiobject spectrometer

- Infrared multi-object spectrometer
- 20 IFUs accessing a 5 arcmin FOV
- 0.8 - 2.5 um
- R ~ 2000 - 10000
- Employs MOAO to give diffraction-limited resolution



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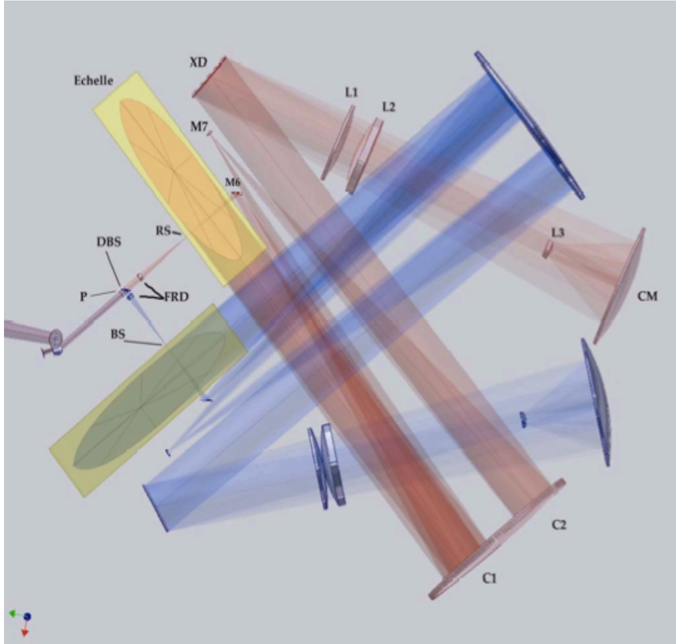
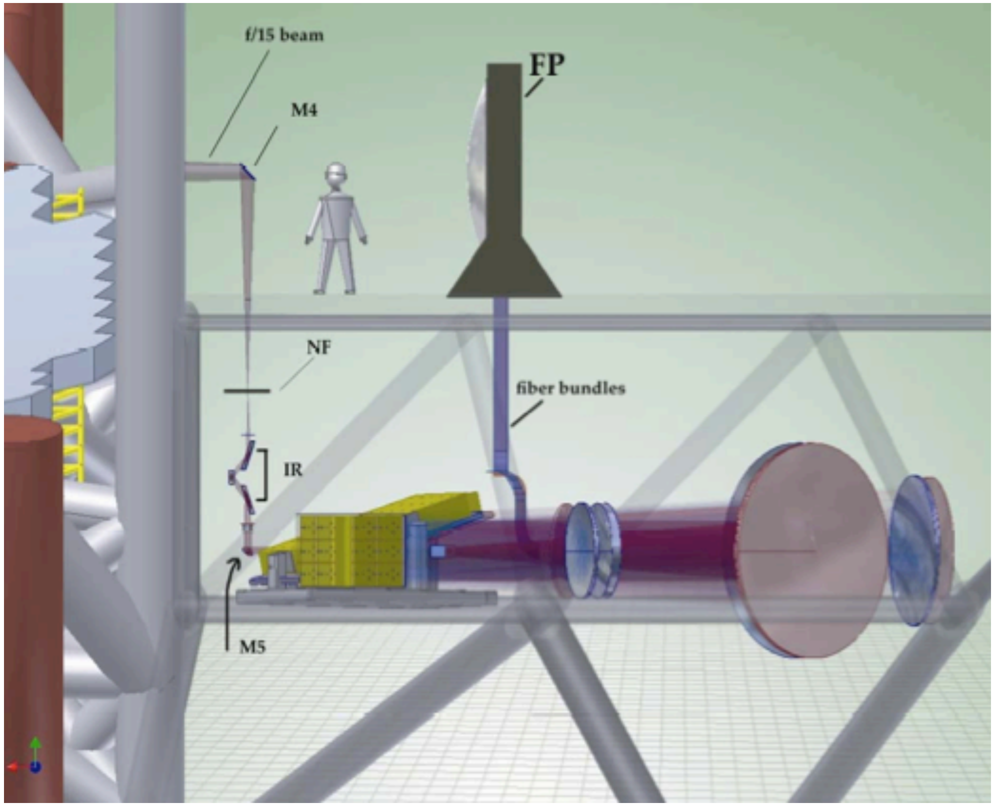
HROS - High-resolution optical spectrometer

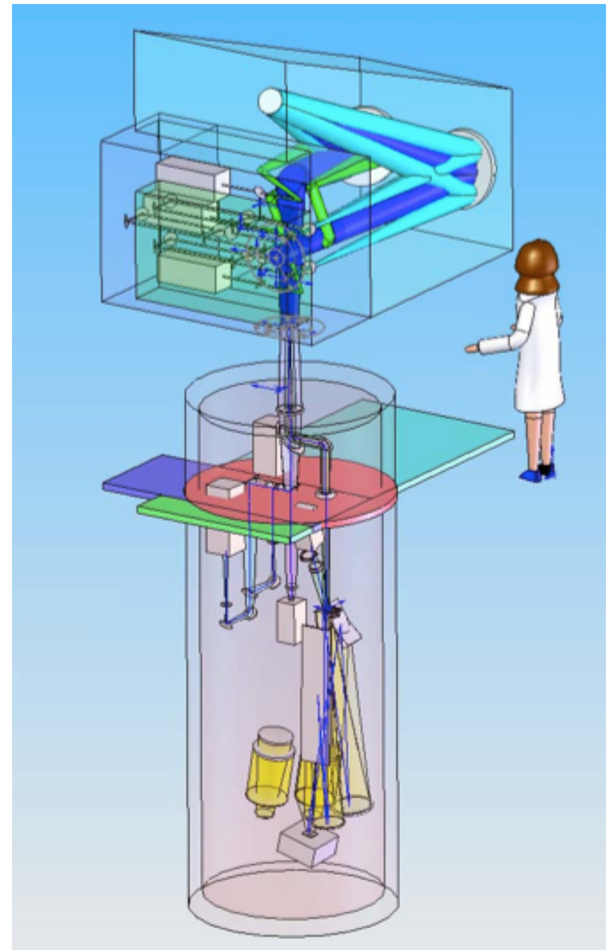
- 0.3 - 1 um Echelle spectrometer
- R ~ 20,000 - 100,000
- Fiber feed MOS option



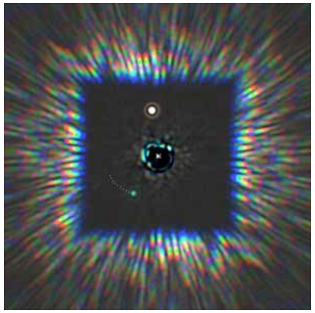


MIRES and NIRES - Infrared echelle spectrometers

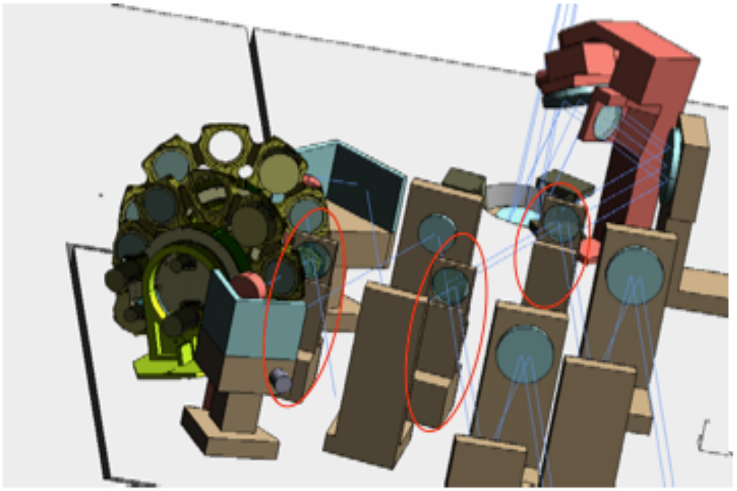
- Hi-resolution echelle spectrometers (3)
- 1-2.5, 2.5-5, 5-28 um
- R ~ 5000 - 100,000
- MIR science imager
- Employ NFIRAOS and MIRAO AO systems

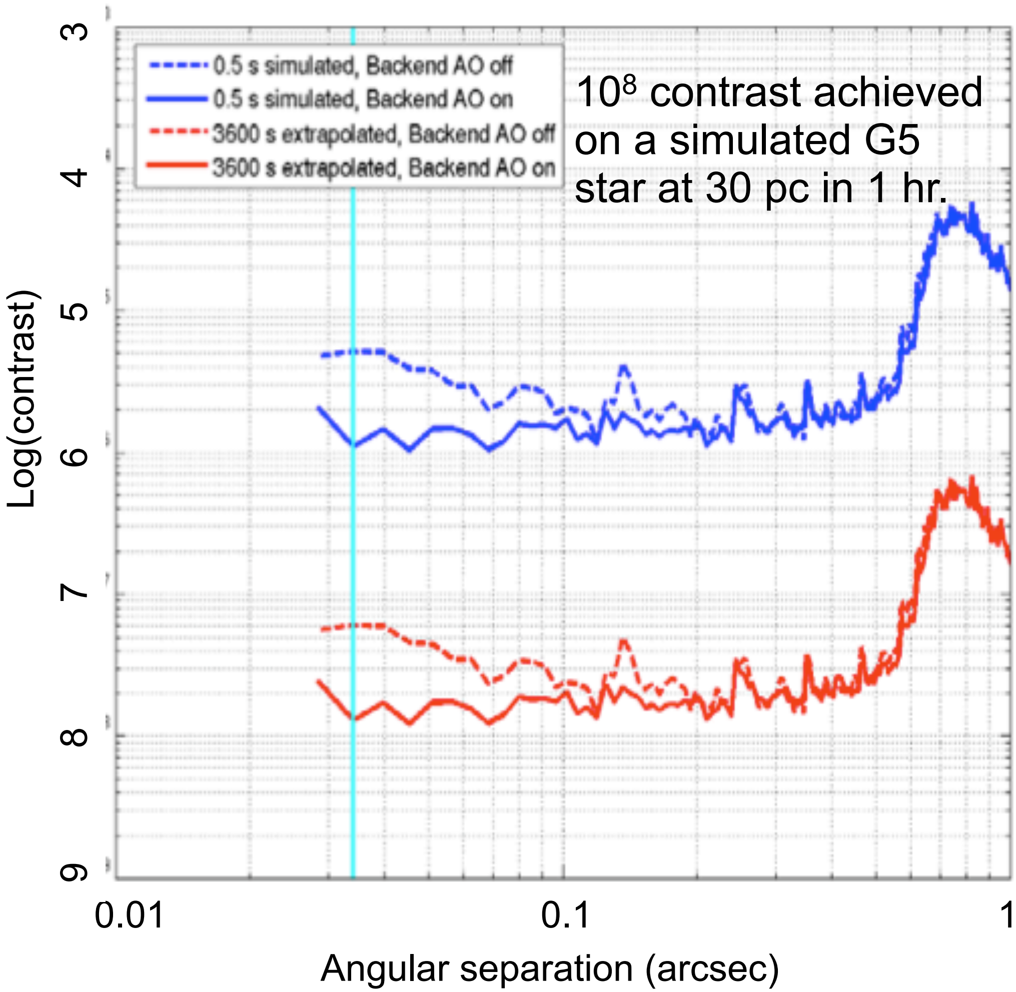


PFI - Planet formation instrument



- high-contrast ExAO system
- 1 - 5 um 2” x 2” imager and IFU spectrometer (R ~ 70 - 700)
- 2-stage nulling interferometer
- Speckle suppression system

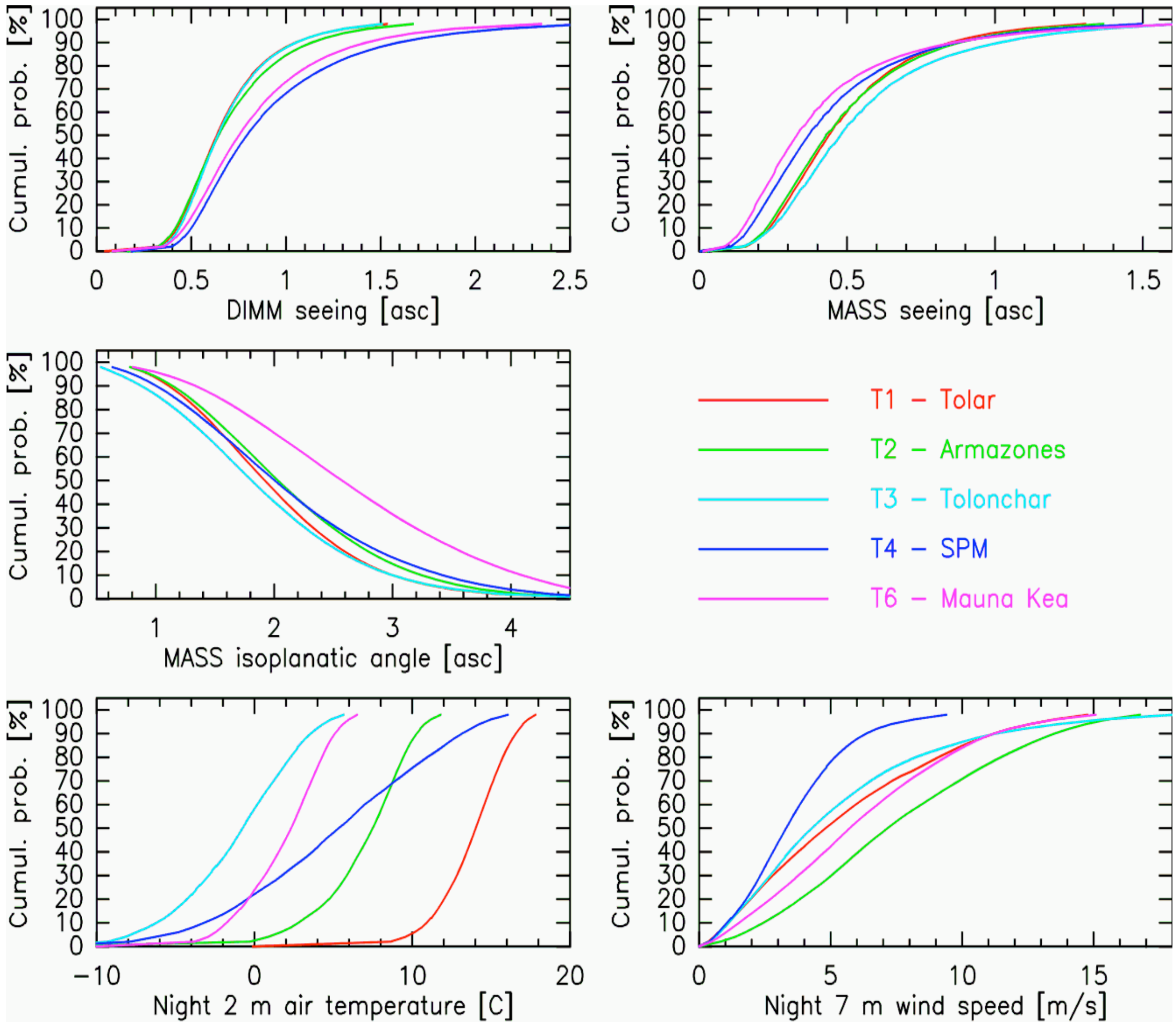




TMT site testing

- All potential TMT sites are excellent
- Armazones & Mauna Kea selected as best southern and northern hemisphere sites.
- Site decision expected June 2009

Schoeck et al., "Thirty Meter Telescope Site Testing I: Overview," to appear in PASP, April 2009

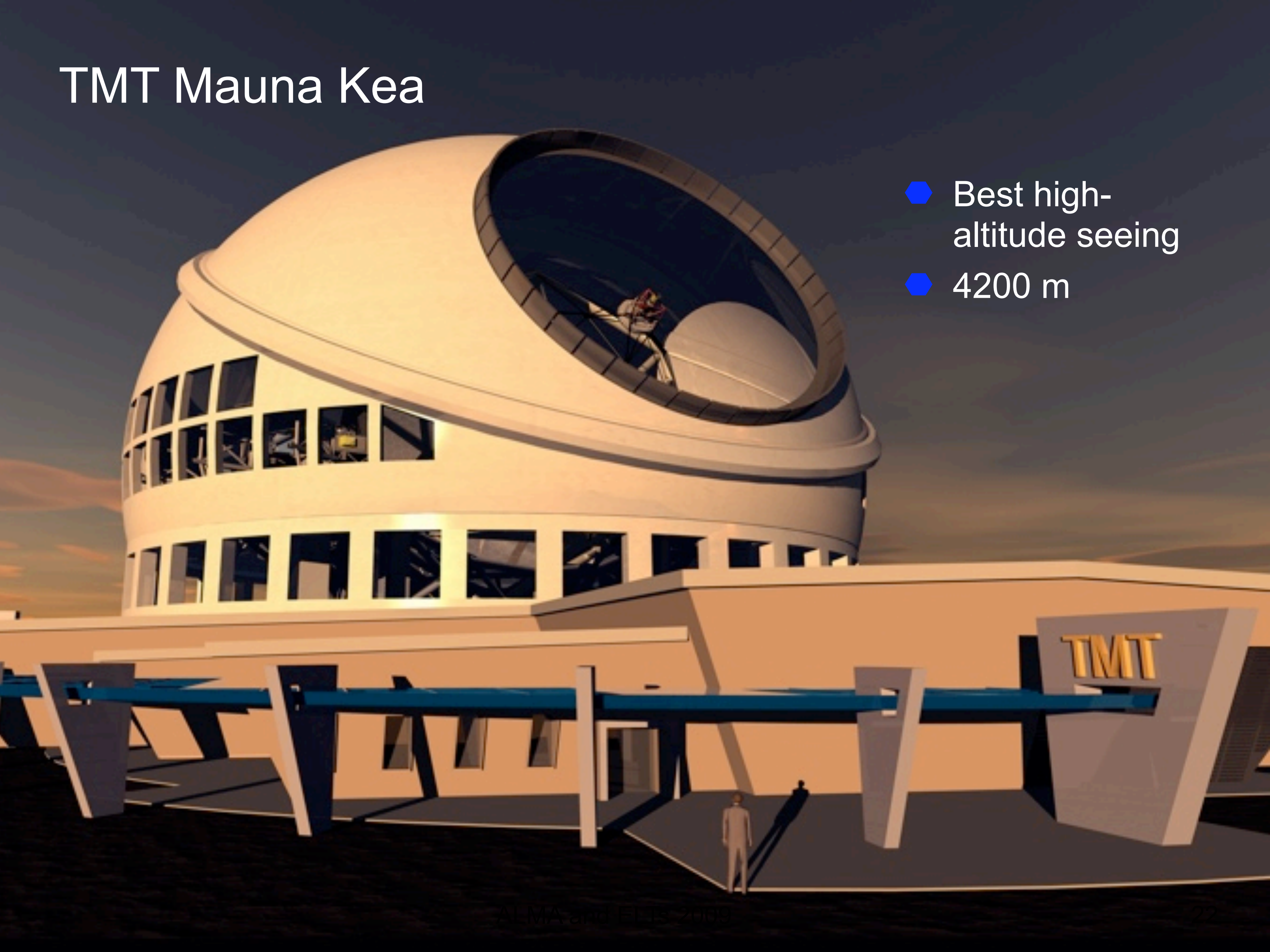


TMT Armazones

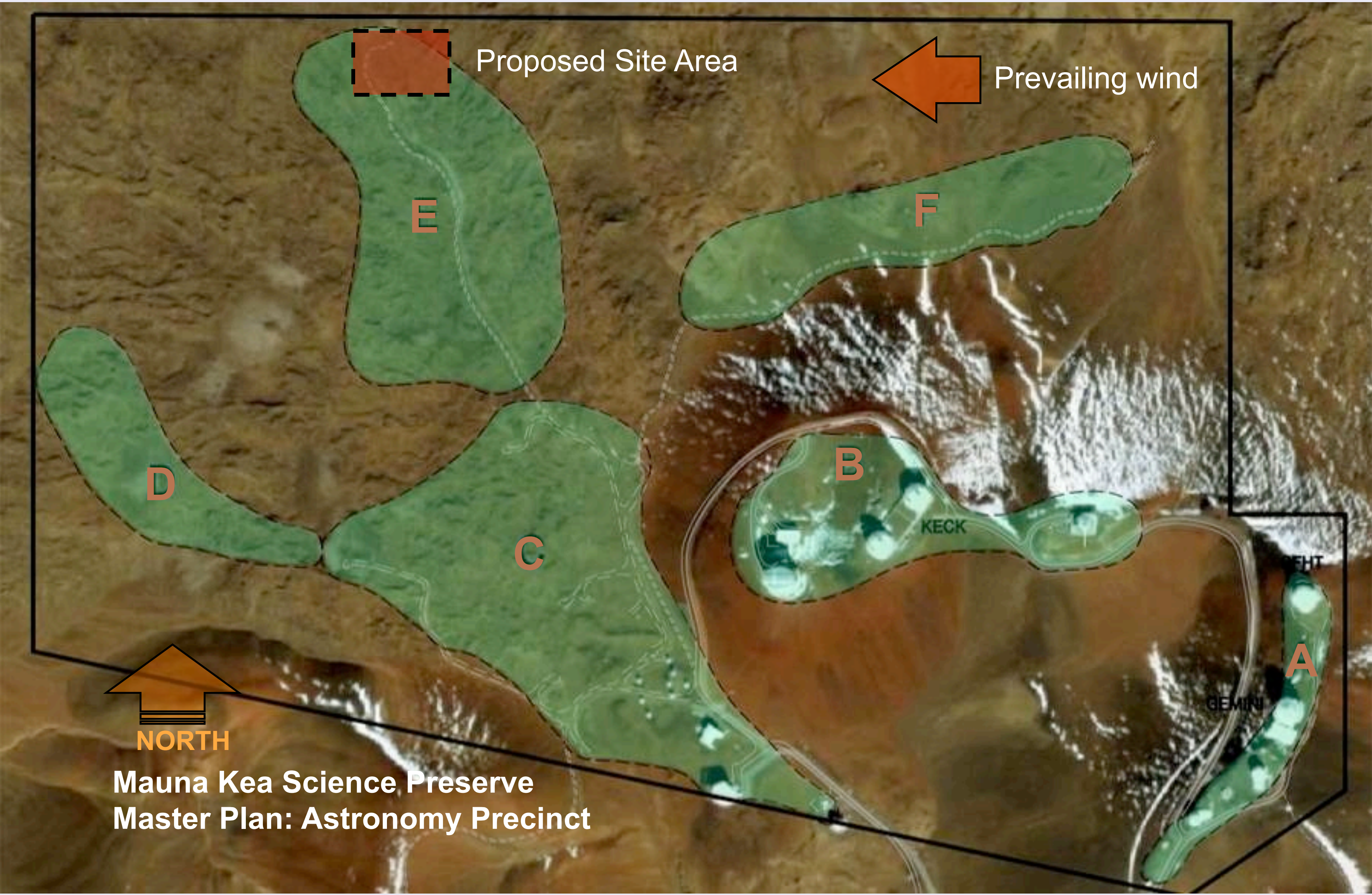
- Best seeing
- Best weather
- 2700 m

TMT Mauna Kea

- Best high-altitude seeing
- 4200 m

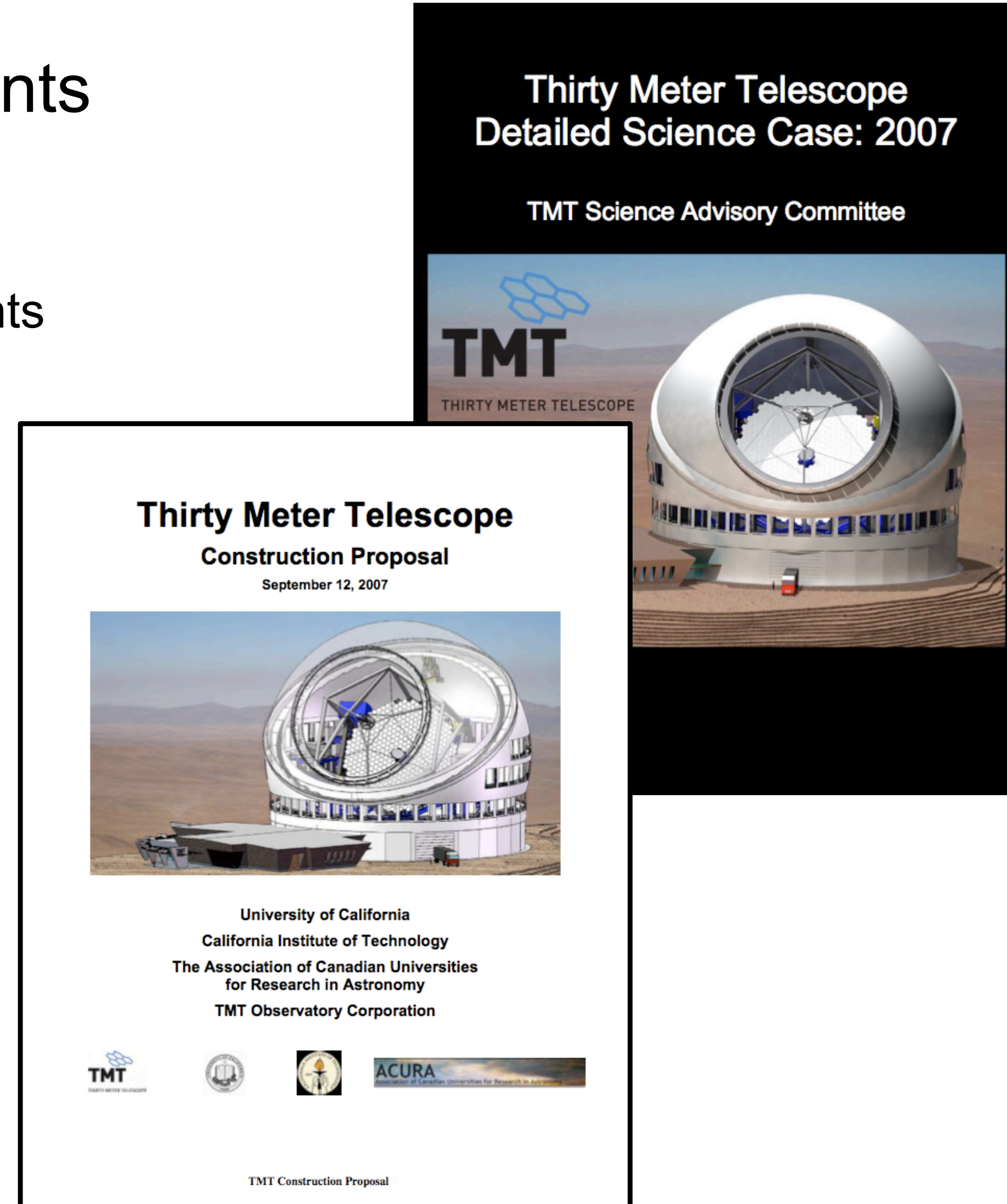


Mauna Kea 13N site



Foundation documents

- Detailed Science Case
- Observatory Requirements Document
- Observatory Architecture Document
- Operations Concept Document
- TMT Construction Proposal
- www.tmt.org



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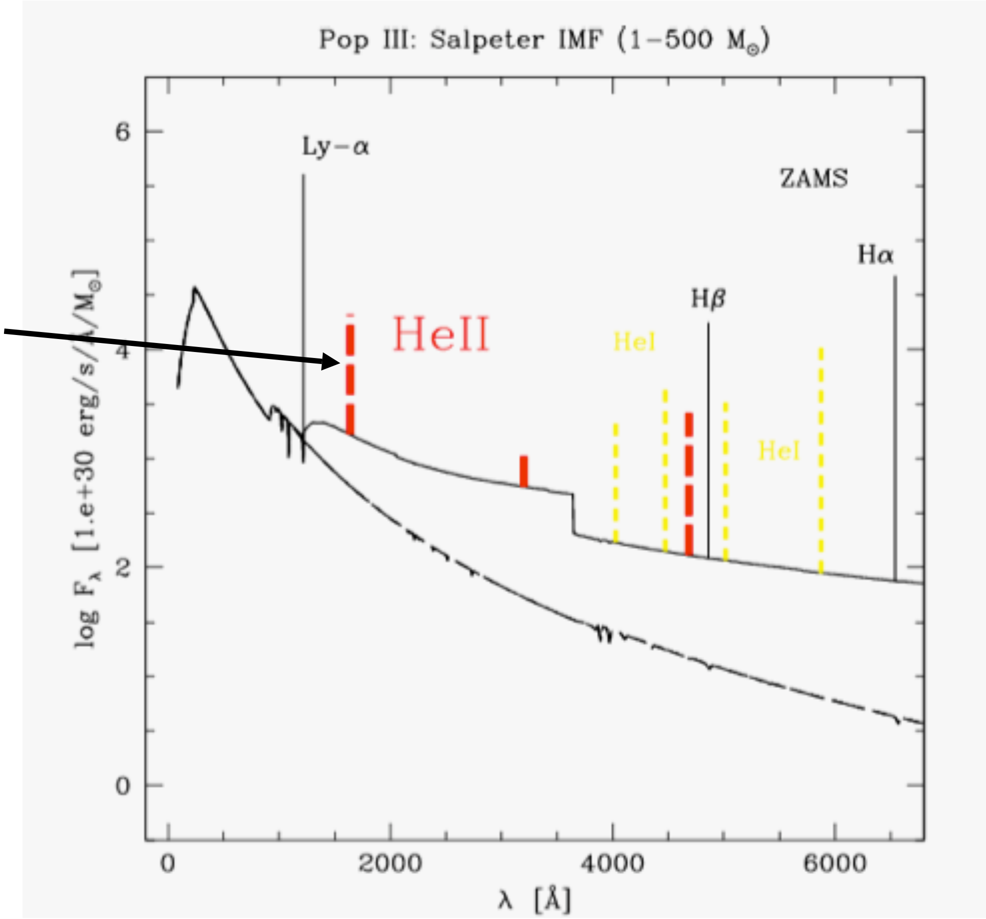
The first luminous objects

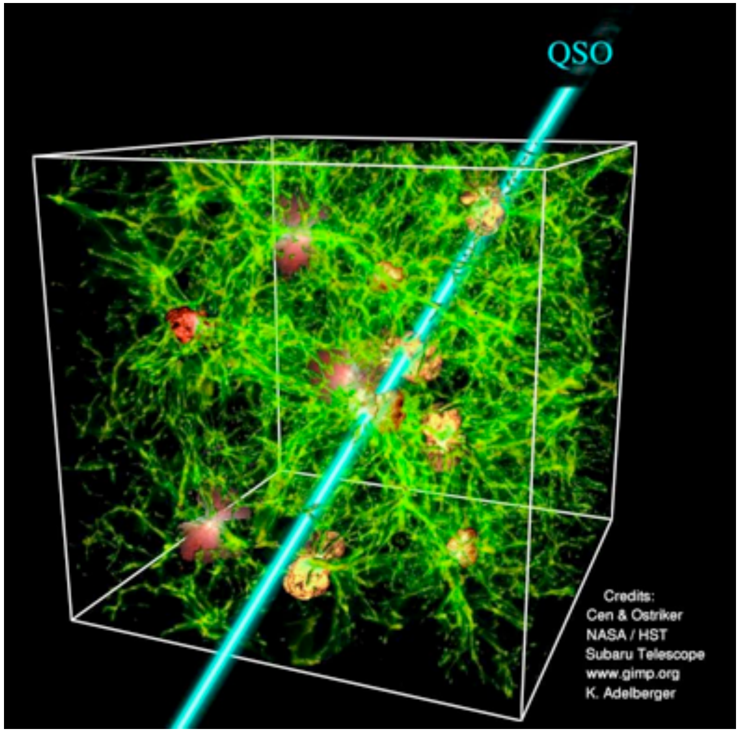
- TMT should detect the first luminous objects - and will study the physics of objects found with JWST:
  - Detection of He II emission would confirm the primordial nature of these objects.
  - With IRIS and IRMOS, TMT will be able to study the flux distribution of sources, and the size and topology of the ionization region.
  - IRMOS will reach ~ 2×10^{-20} erg s^{-1} cm^{-2} for 25 mas sources in 4 hrs (an order of magnitude fainter than JWST)

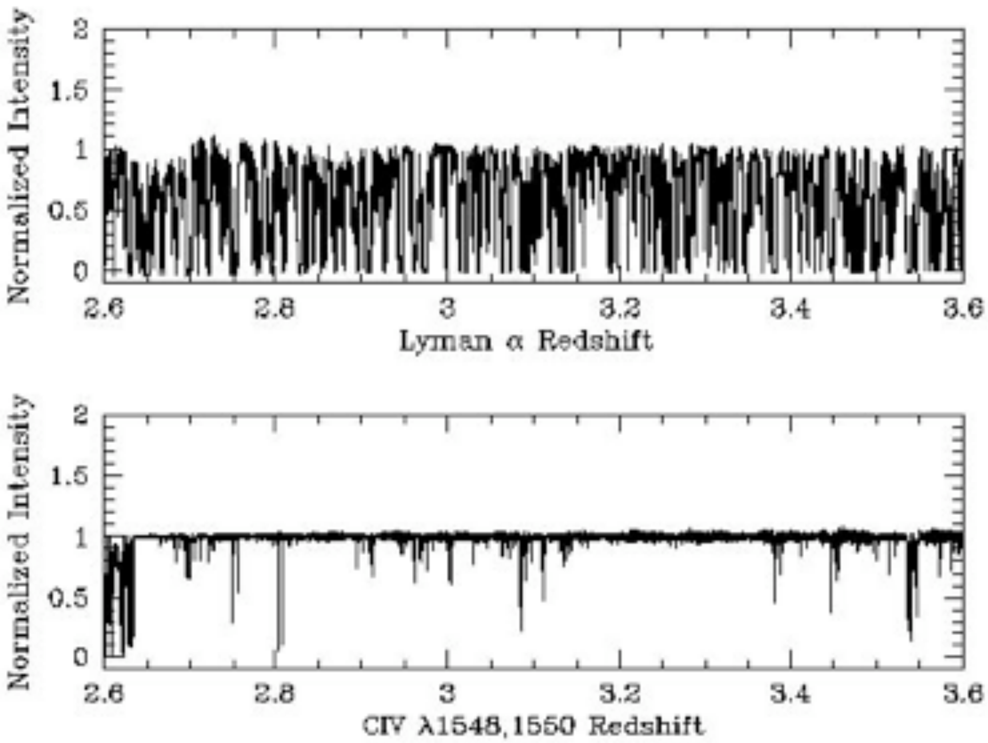


Schaerer 2002

High-redshift Universe

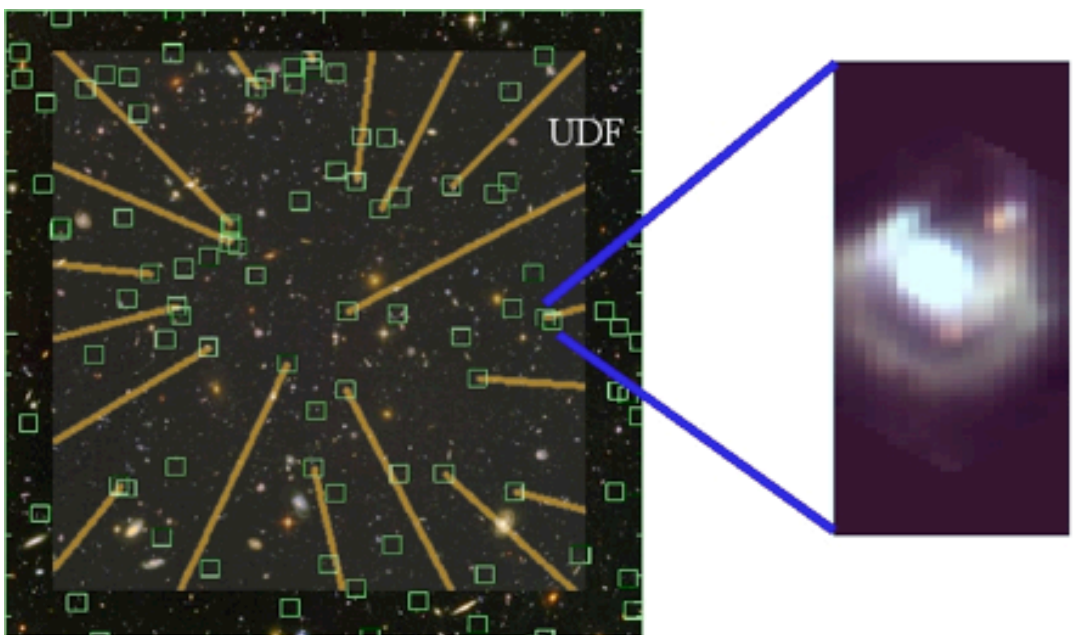
- WFOS will map the 3-d distribution of baryons and study galaxy-IGM interactions using background galaxies as probes
- Dark matter power spectrum on small scales from Ly-α forest

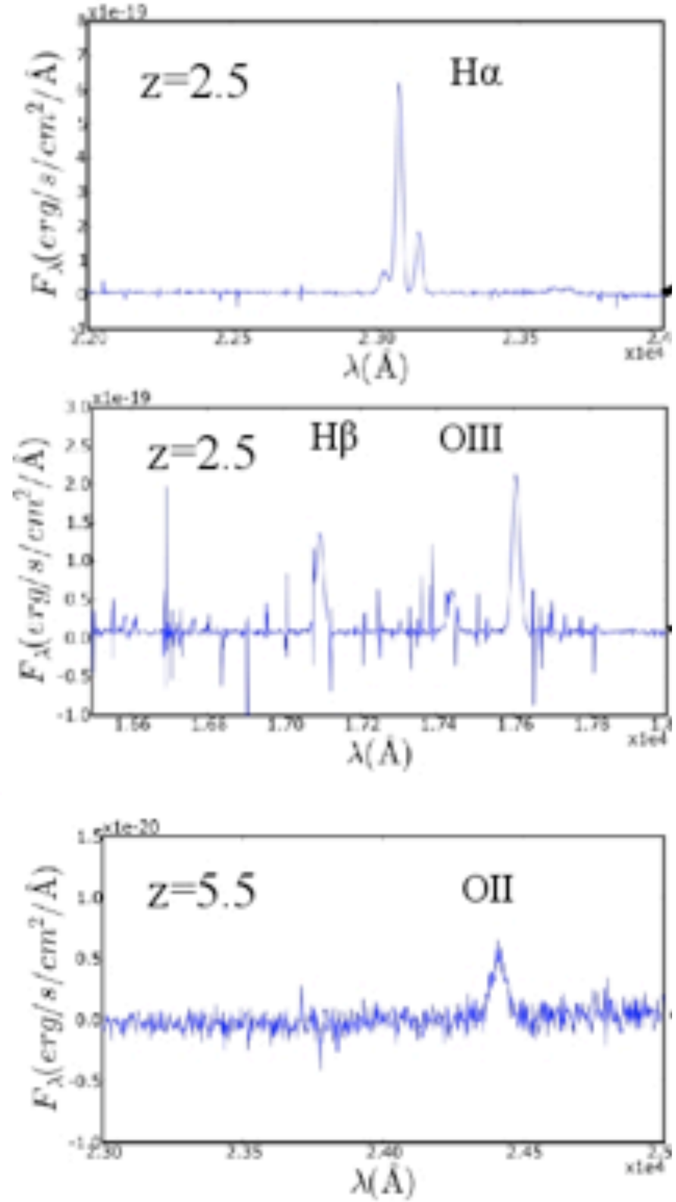




Dissecting galaxies

- IRIS and IRMOS will provide spectra at at 50 - 100 pc spatial resolution using integral-field spectroscopy
- Map kinematics, chemistry, star-formation, to z ~ 6





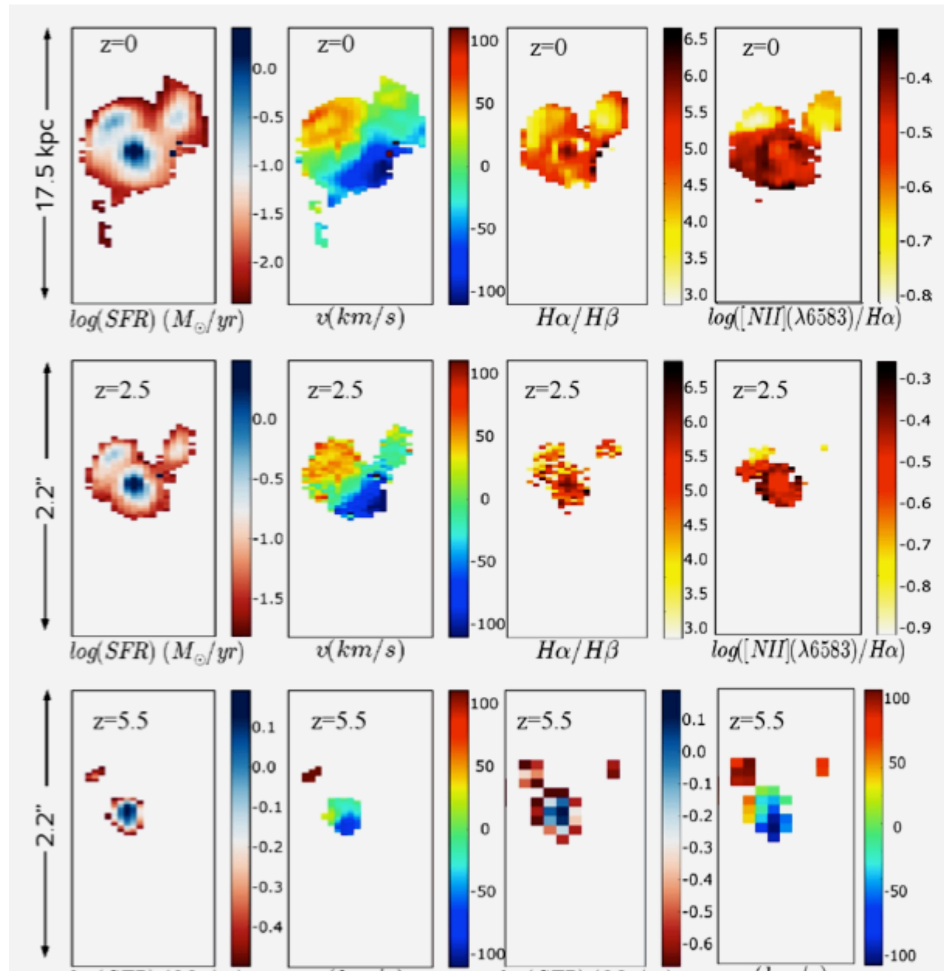
The physics of galaxy formation and evolution

- Mapping the physical state of galaxies over the redshift range where the bulk of galaxy assembly occurs:
  - Star formation rate
  - Metallicity maps
  - Extinction maps
  - Dynamical Masses
  - Gas kinematics
- Synergy with ALMA:
  - Molecular emission

z = 0

z = 2.5

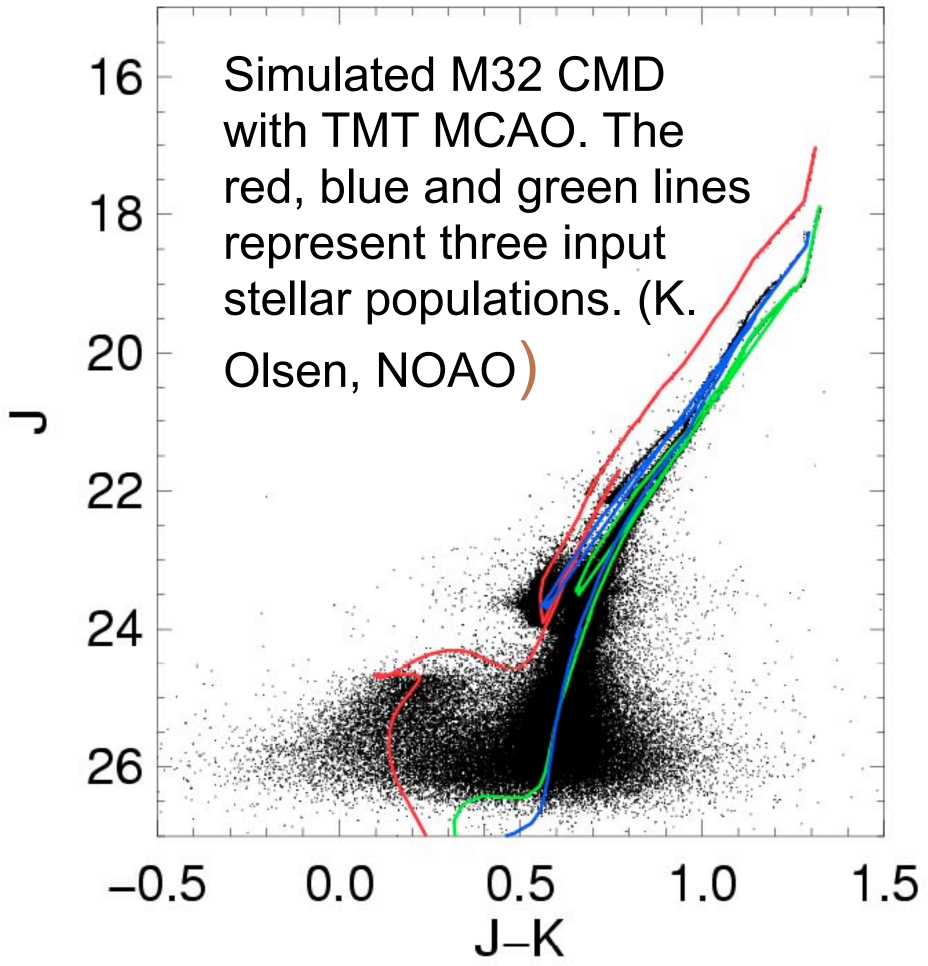
z = 5.5



TMT IRMOS-UFHIA team

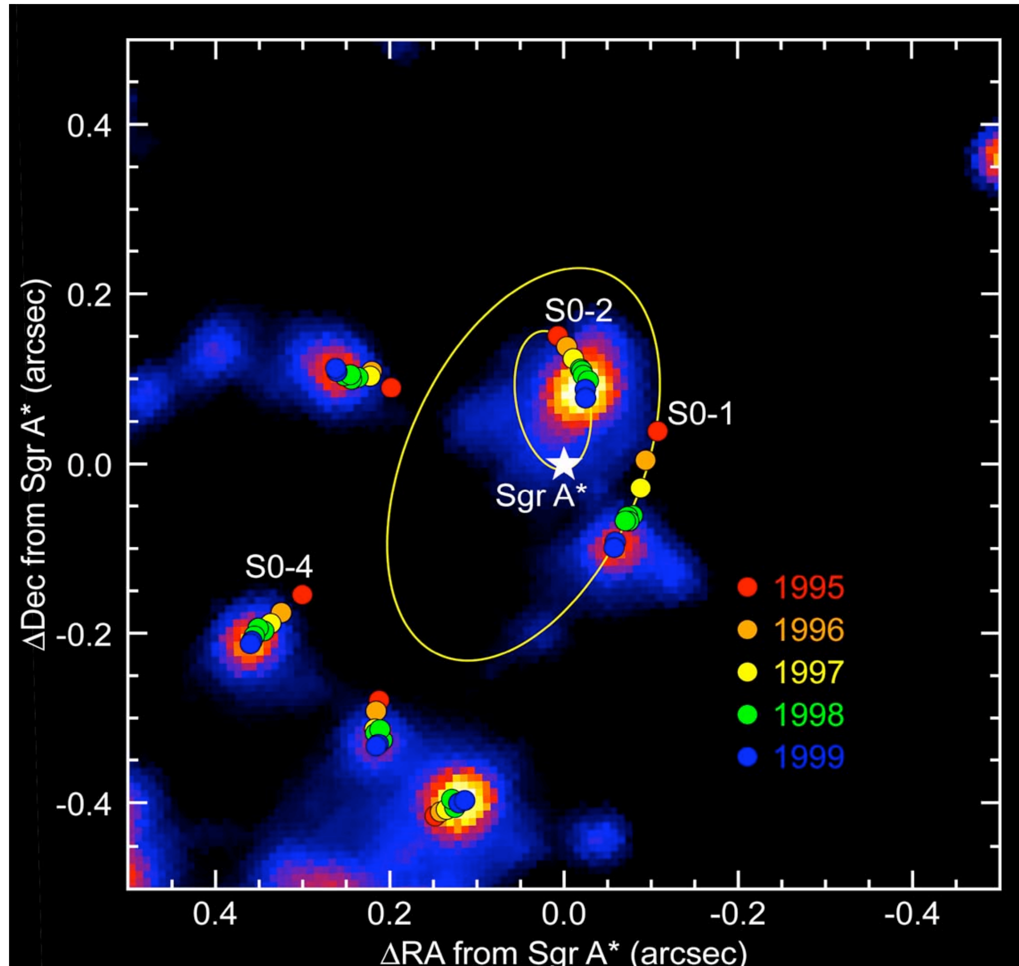
Stellar Populations in the Local Universe

- IRIS, WFOS and HROS will determine the star formation history in galaxies out to the Virgo cluster.
- Adaptive optics will allow photometry of resolved stellar populations in crowded fields.
- Study star-formation history and metallicity in a wide range of environments.
- Moderate and high-resolution spectroscopy will provide element abundances.
- Complimentary to high-z galaxy studies.



Black holes and active galactic nuclei

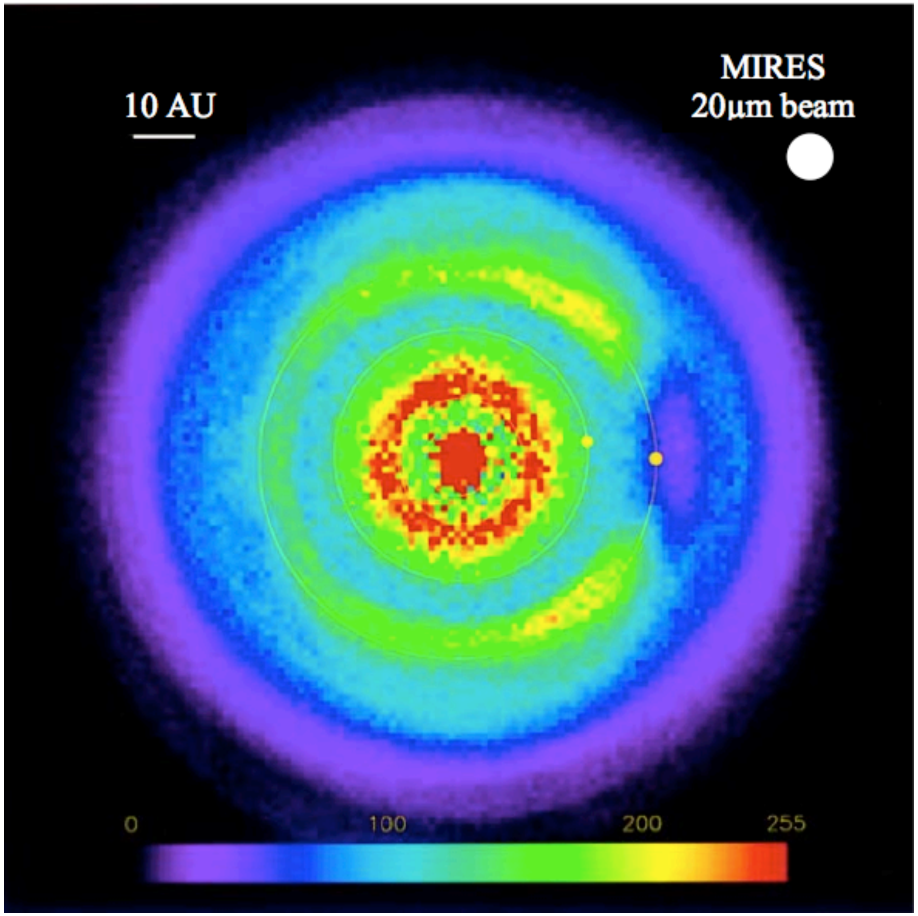
- IRIS will map stellar orbits in the galactic center with precision ~30 uas to probe the gravitational potential, study the nature of dark matter on small scales, and measure general-relativistic effects.
- TMT will detect and spatially resolve accretion disks and the spheres of influence of massive black holes to z ~ 1, and study AGN mass and metallicity at all redshifts.



A. Ghez, UCLA

Physics of Star and Planet Formation

- MIRES will be able to image protoplanetary disks and detect features produced by planets:
  - TMT will have 5x the resolution of JWST.



Simulation of Solar System protoplanetary disk (Liou & Zook 1999)

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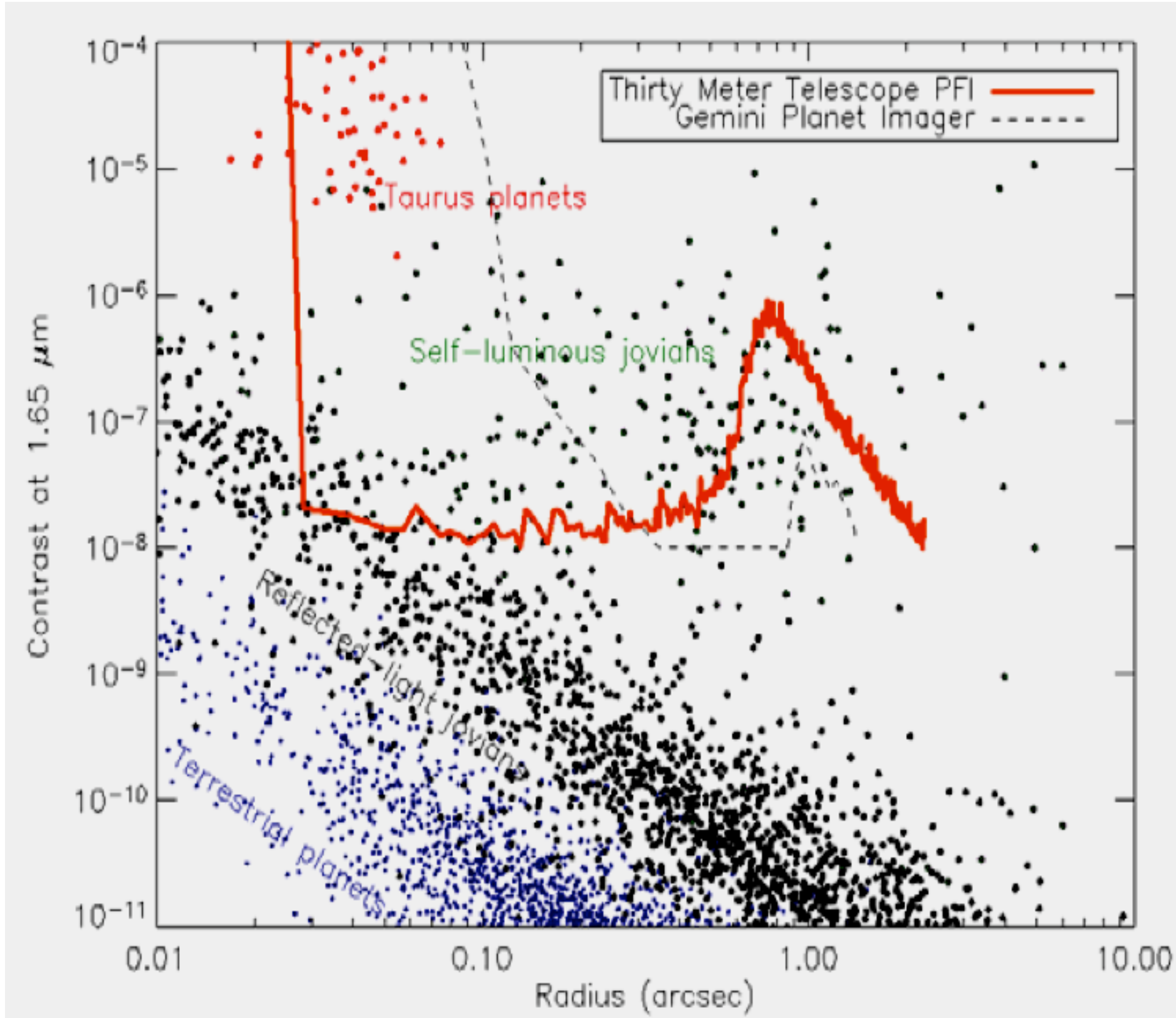
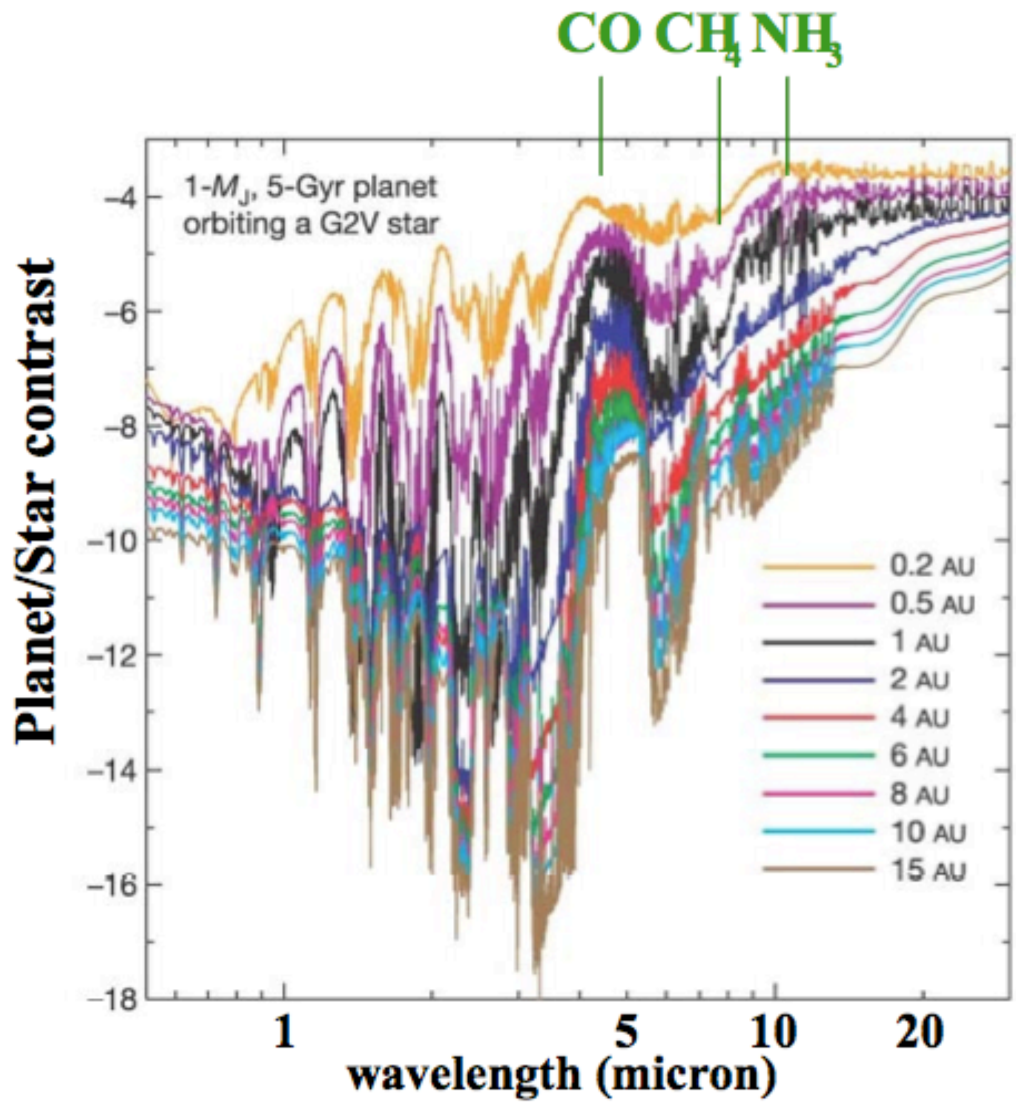
Characterizing exoplanets

- Self-luminous planets in nearby star-forming regions
- Detect jovian planets by reflected light
- Probe scales comparable to inner solar system
- Detect planets forming in circumstellar disks.



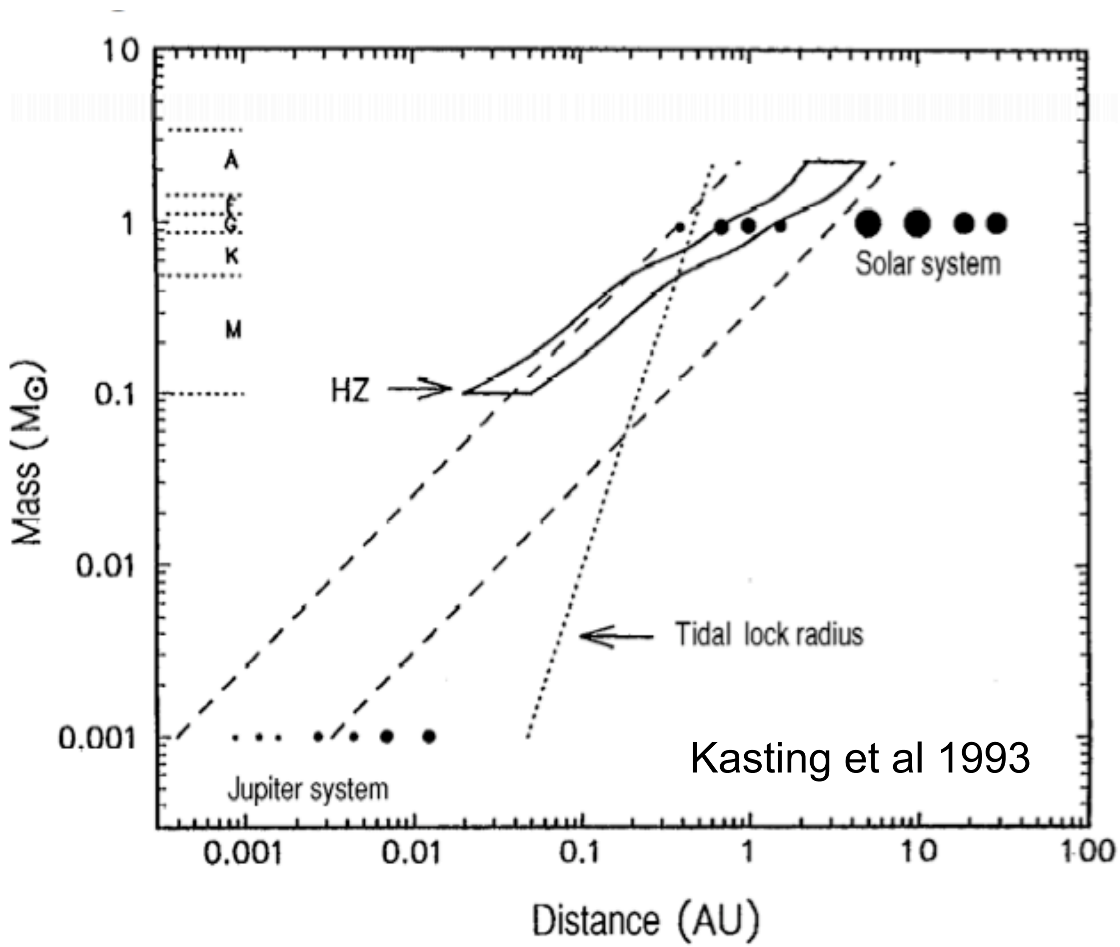
Spectroscopy of exoplanet atmospheres

- Direct spectroscopy in the mid-infrared with MIRES
- Contrast is more favorable in the mid-infrared.
- Strong molecular lines characterize the atmospheric composition.
- Near-infrared spectroscopy with PFI
- Absorption spectroscopy of transiting planets with HROS



Doppler detection of terrestrial planets

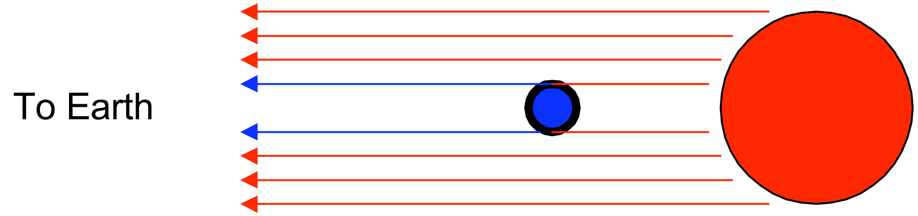
- HROS will expand the number of host stars accessible to Doppler spectroscopy by a factor of ~ 30,
- It will be possible to detect Earth-mass planets in habitable zones around nearby M stars (0.01 - 0.3 AU).

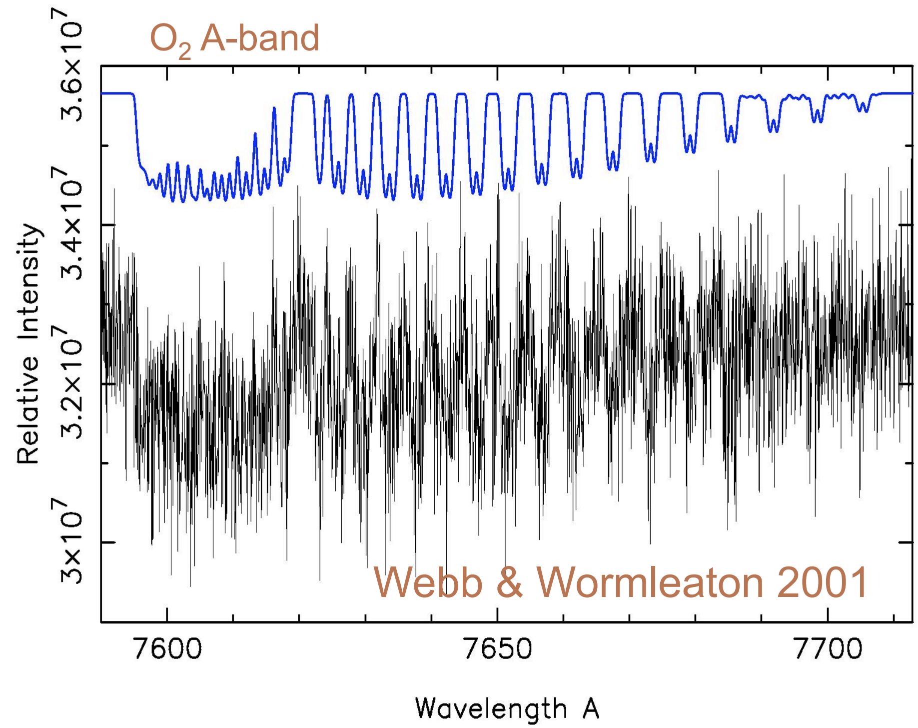


Kasting et al 1993

Atmospheres of terrestrial planets

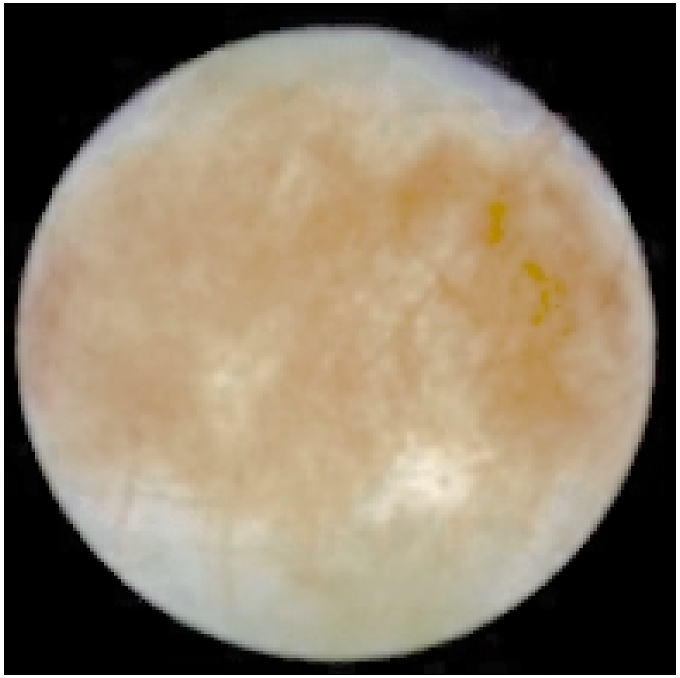
- Absorption signatures of gases in the atmosphere in transiting planets can be detected by high-resolution spectroscopy
  - Na, K, He, will be easily detectable
- HROS should be able to detect O_2 in the atmosphere of an Earth-like planet orbiting in the habitable zone of an M star
  - s/n ~ 30,000 per 6 km/s resolution element - achievable by TMT in ~ 3 hrs.





Solar system studies

- IRIS will be able to detect a 1 km TNO at 50 AU in 15 min.
- IRIS and MIRES will provide a capability for high-spatial resolution imaging and spectroscopy of planets and satellites of the solar system:
  - high-resolution spectra of features on outer Solar System bodies will allow studies of atmospheric physics and atmospheric and surface chemistry
  - Regular monitoring will allow TMT to study transient phenomena, weather, volcanic activity, etc.



Europa at the resolution of TMT adaptive optics (M. Brown, CIT)

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