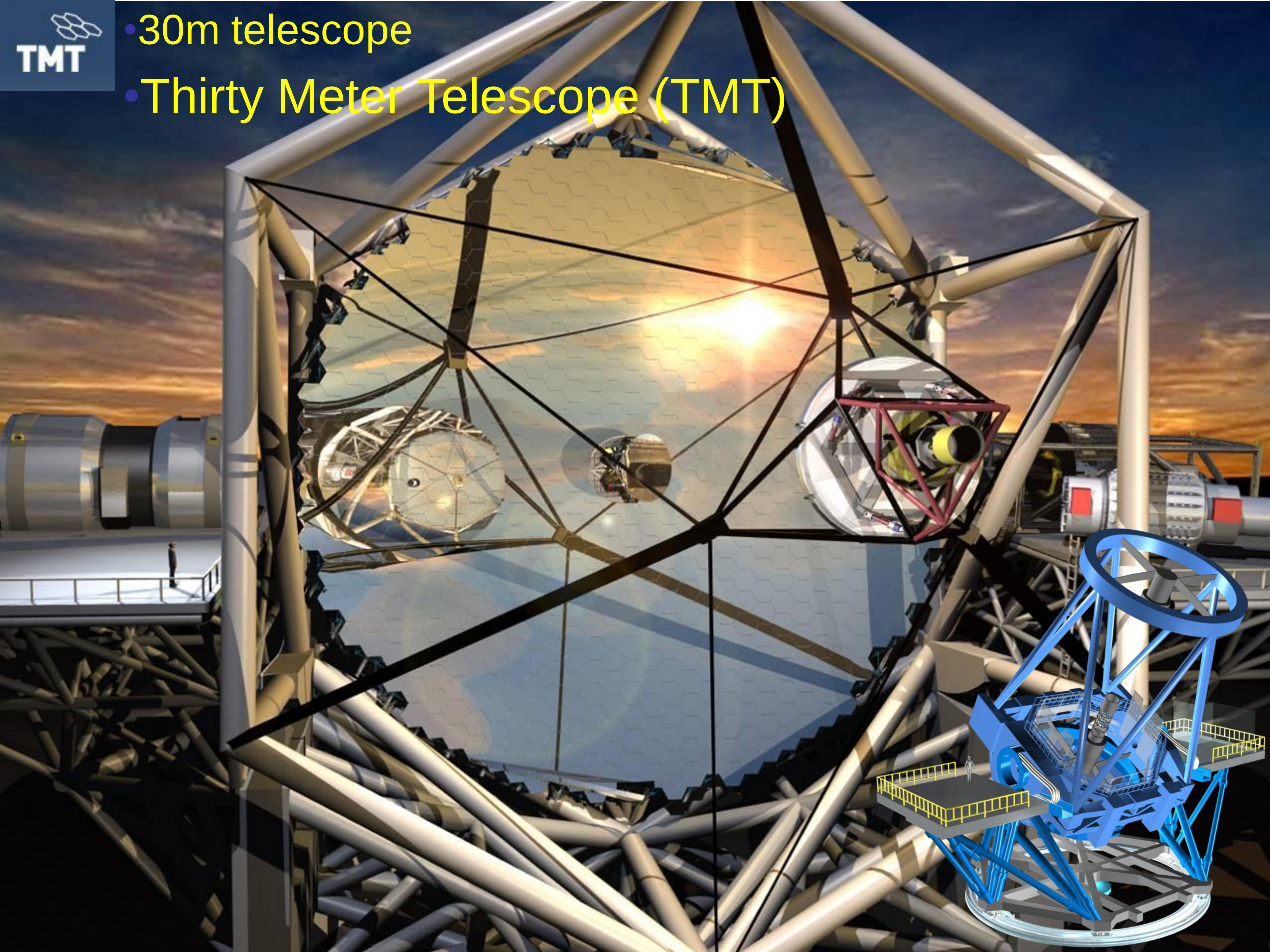
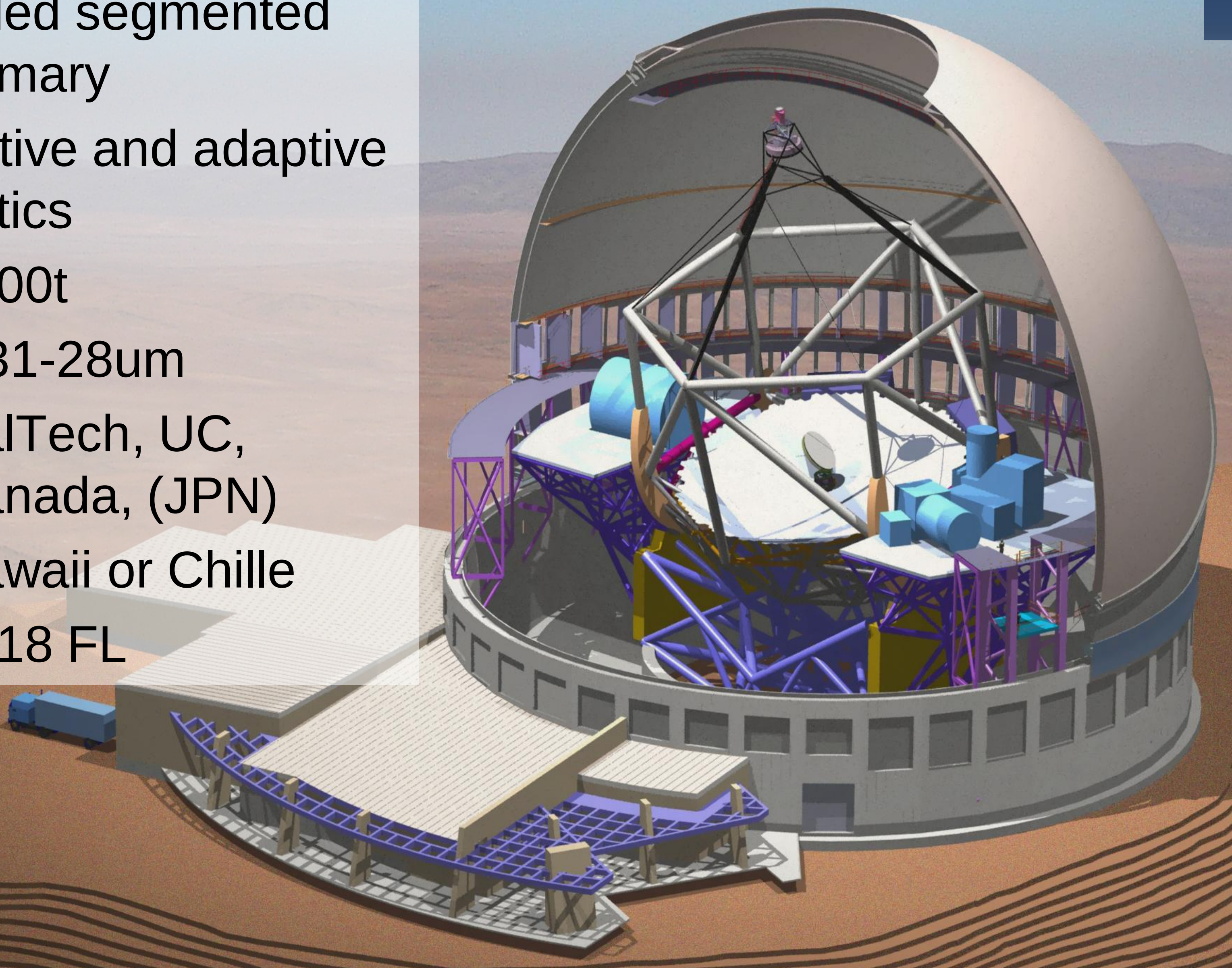
TMTからSPICAへの期待

Nobunari Kashikawa
(NAOJ/TMT project)
June 2009

- 30m telescope
- Thirty Meter Telescope (TMT)



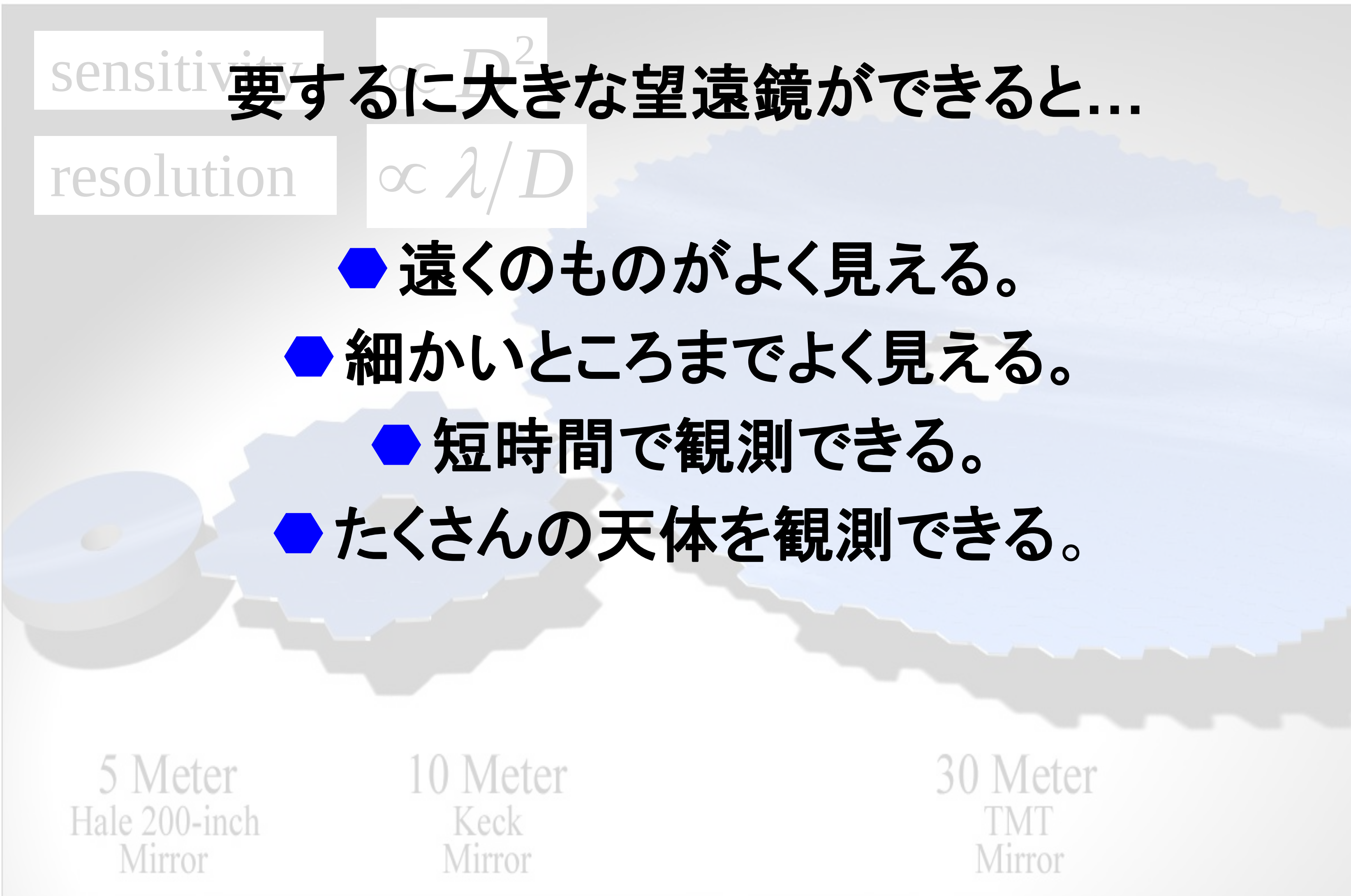
- 30m aperture
- Filled segmented primary
- Active and adaptive optics
- 1400t
- 0.31-28um
- CalTech, UC, Canada, (JPN)
- Hawaii or Chille
- 2018 FL



TMT

TMT
THIRTY METER TELESCOPE

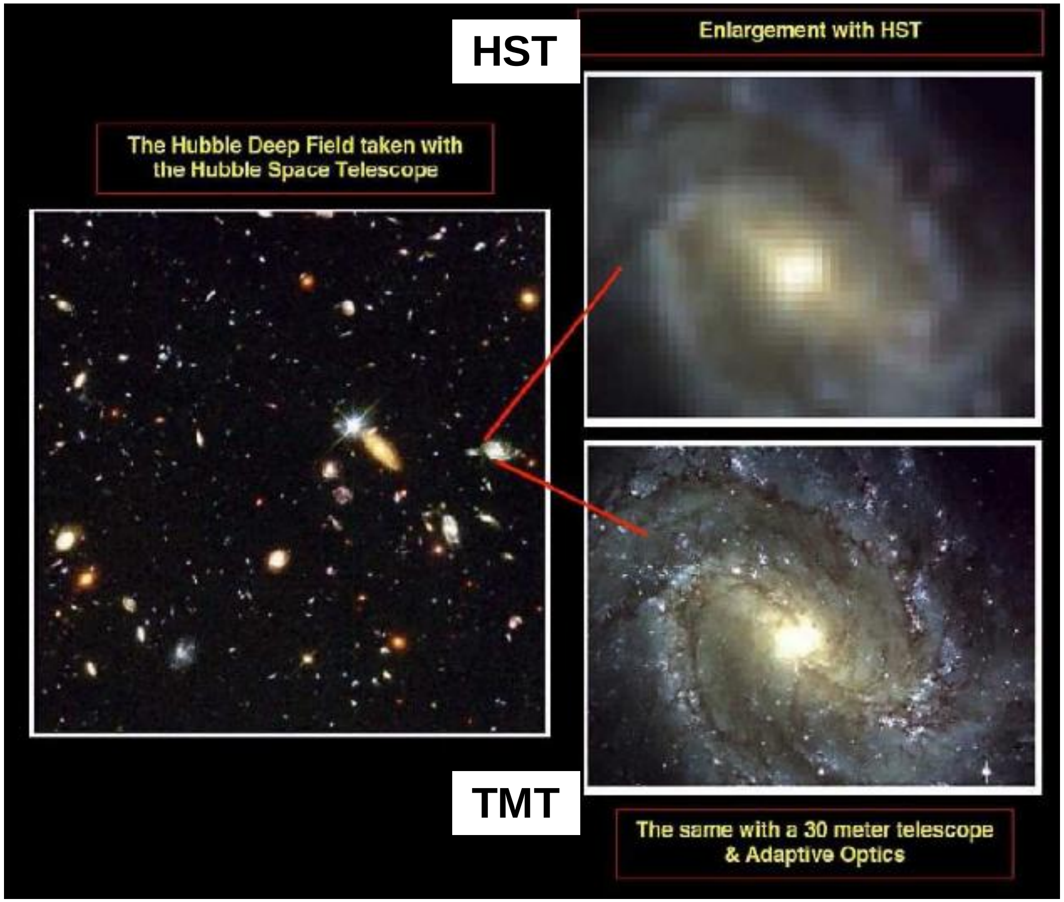
vs. Subaru
x13 sensitivity, x4 resolution



要するに大きな望遠鏡ができると...

- 遠くのものがよく見える。
- 細かいところまでよく見える。
- 短時間で観測できる。
- たくさんの天体を観測できる。

Adaptive Optics(AO)

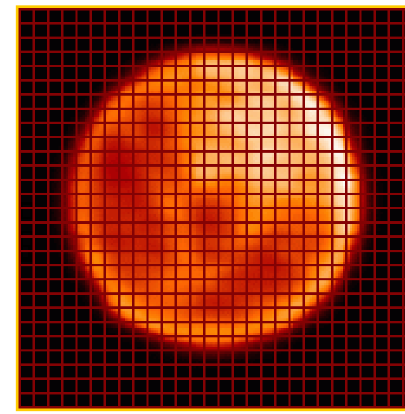


- Angular resolution 0.6→0.015arcsec (2.2μm)
- sensitivity upgrades by 1order
- Several thousand elements
- Much higher resolution than HST
- 5 times higher resolution than JWST
- Almost all the TMT NIR observation will use AO in TMT.

High spatial resolution w/TMT/AO

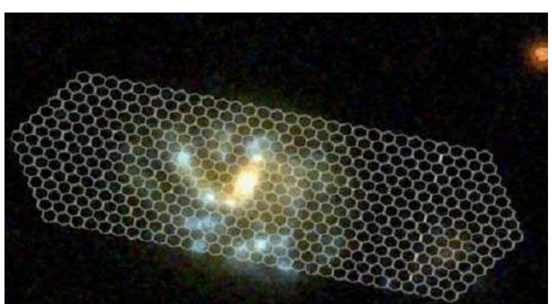
- AO on TMT provides unprecedented ability to investigate objects on small scales. Essentially no images exist on these scales for direct comparison.

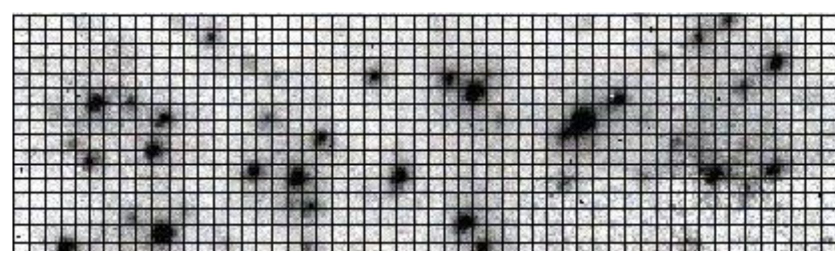
0.01” @	5 AU	= 36 km	(Jovian’s and moons)
	5 pc	= 0.05 AU	(Nearby stars – companions)
	100 pc	= 1 AU	(Nearest star forming regions)
	1 kpc	= 10 AU	(Typical Galactic Objects)
	8.5 kpc	= 85 AU	(Galactic Center or Bulge)
	1 Mpc	= 0.05 pc	(Nearest galaxies)
	20 Mpc	= 1 pc	(Virgo Cluster)
	z=0.5	= 0.07 kpc	(galaxies at solar formation epoch)
	z=1.0	= 0.09 kpc	(disk evolution, drop in SFR)
	z=2.5	= 0.09 kpc	(QSO epoch, $H\alpha$ in K band)
	z=5.0	= 0.07 kpc	(protogalaxies, QSOs, reionization)



Keck AO image of Titan with an overlayed 0.05” grid (~300 km)

High-z galaxy image superimposed on a TMT IFU with 50-100pc spatial resolution





Keck AO image of M31 Bulge with 0.1” grid

TMT
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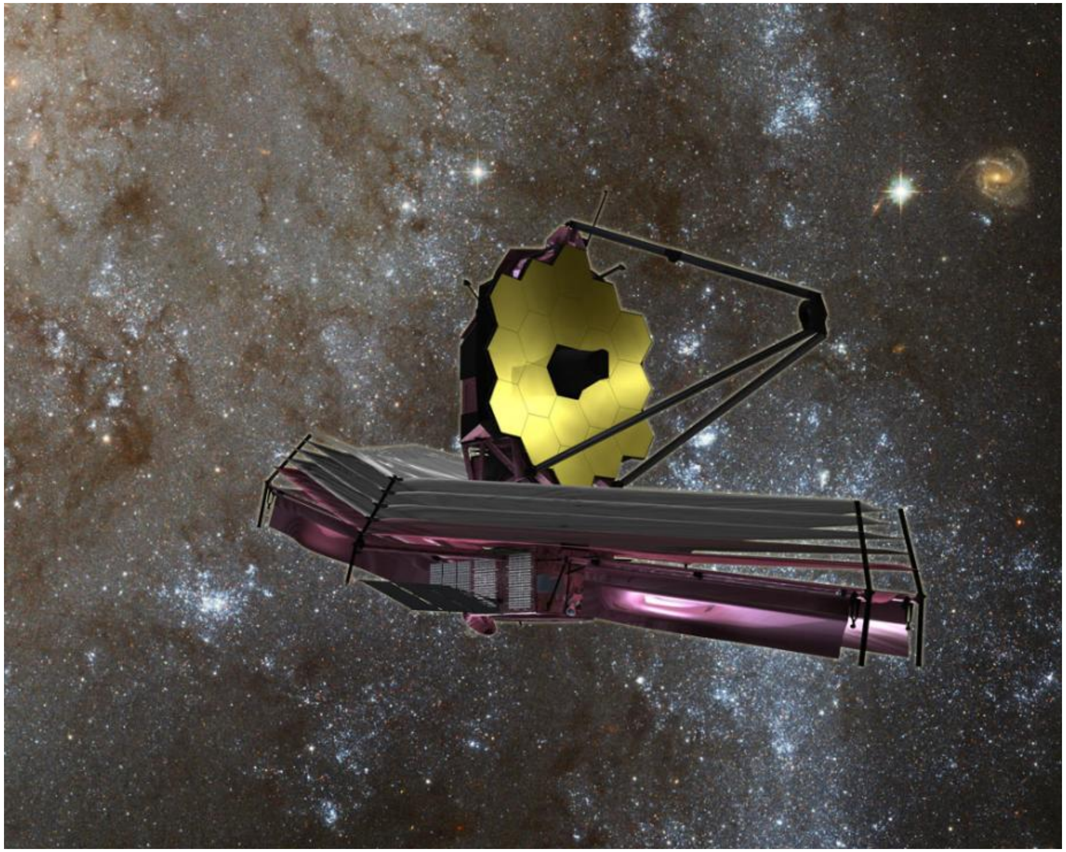
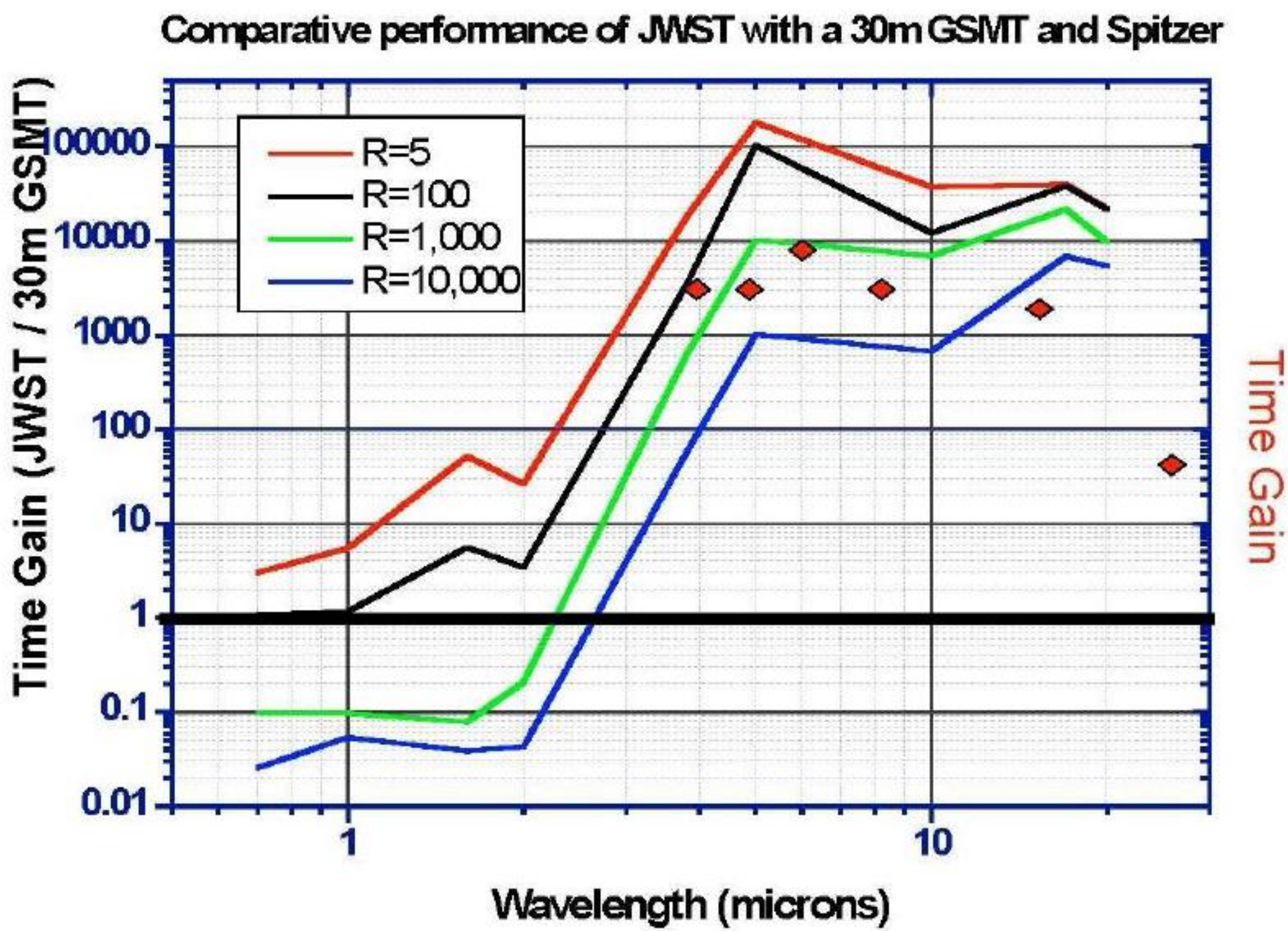
Synergy w/JWST



vs. JWST



Comparative performance of JWST with a 30m GSMT and Spitzer
Time Gain (JWST / 30m GSMT)
100000
10000
1000
100
10
1
0.1
0.01
R=5
R=100
R=1,000
R=10,000
Time Gain
1
10
Wavelength (microns)

Synergy w/JWST

- JWST advantages
  - Full sky coverage & high observing efficiency
  - 0.6-28.5um
  - High sensitivity for BB IR photometry
  - Stable PSF with time and FOV
- TMT advantages
  - High sensitivity in optical (0.3-1um) over wide FOV(>10')
  - High sensitivity in high-angular/spectral resolution spectroscopy
  - Short response times for ToO
  - Flexible and upgradable

THIRTY METER TELESCOPE

vs. SPICA in MIR

- 感度と分解能

	空間分解能 @ λ=10μm	撮像点源感度 5σ 1時間 @ λ=10μm	分光波長分解能 R
30m望遠鏡 + MIR	0.09"	150μJy	数百、数千、100,000
8.2mすばる + COMICS	0.32"	2,000μJy	250 2,500 10,000
3.5mSPICA + 中間赤外装置	0.75"	1μJy	1,500 3.000 (30,000)
6.5mJWST + MIRI	0.4"	0.1μJy	3,000

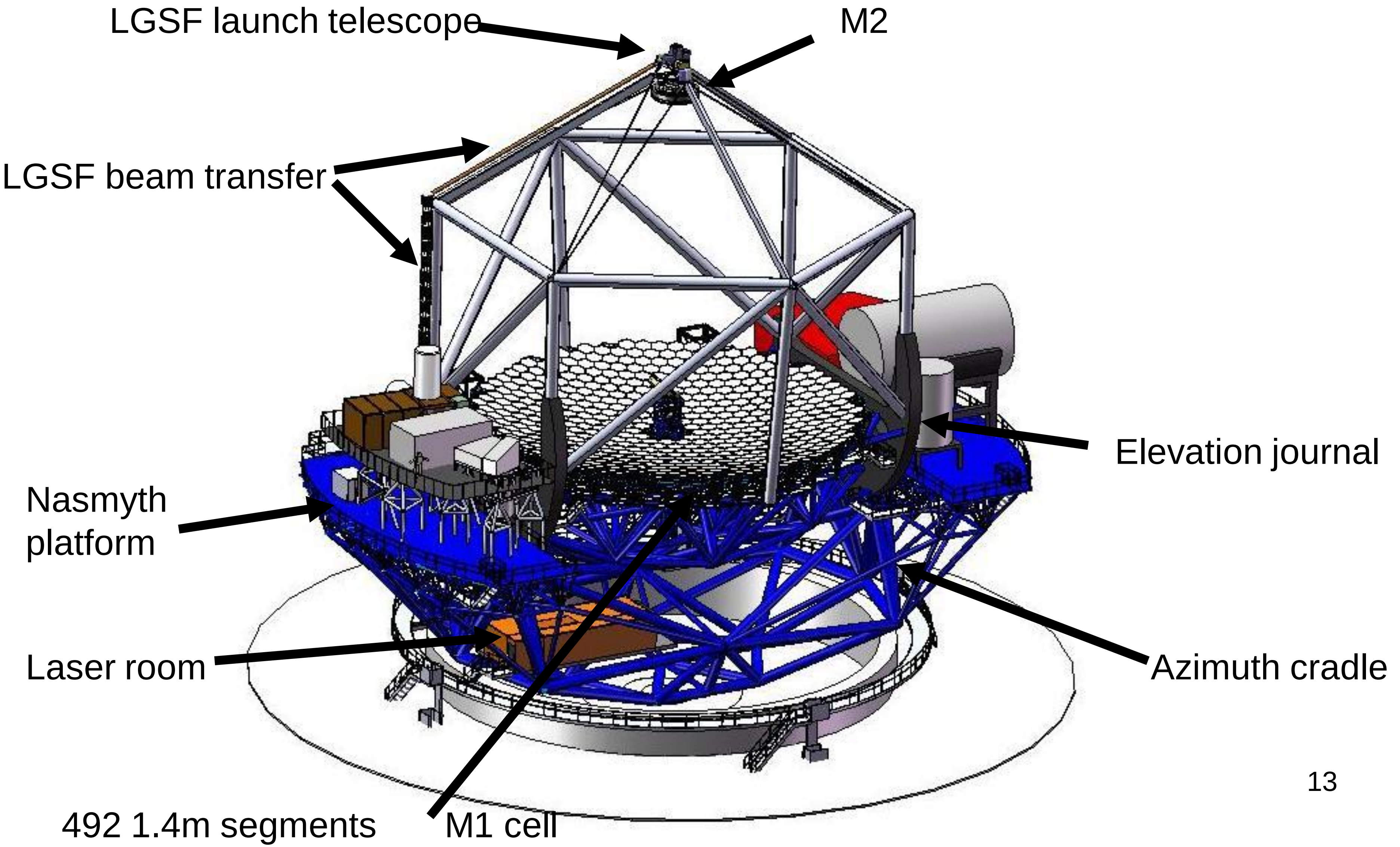
- 宇宙望遠鏡の１桁上をいく空間分解能
- ２桁上をいく波長分解能

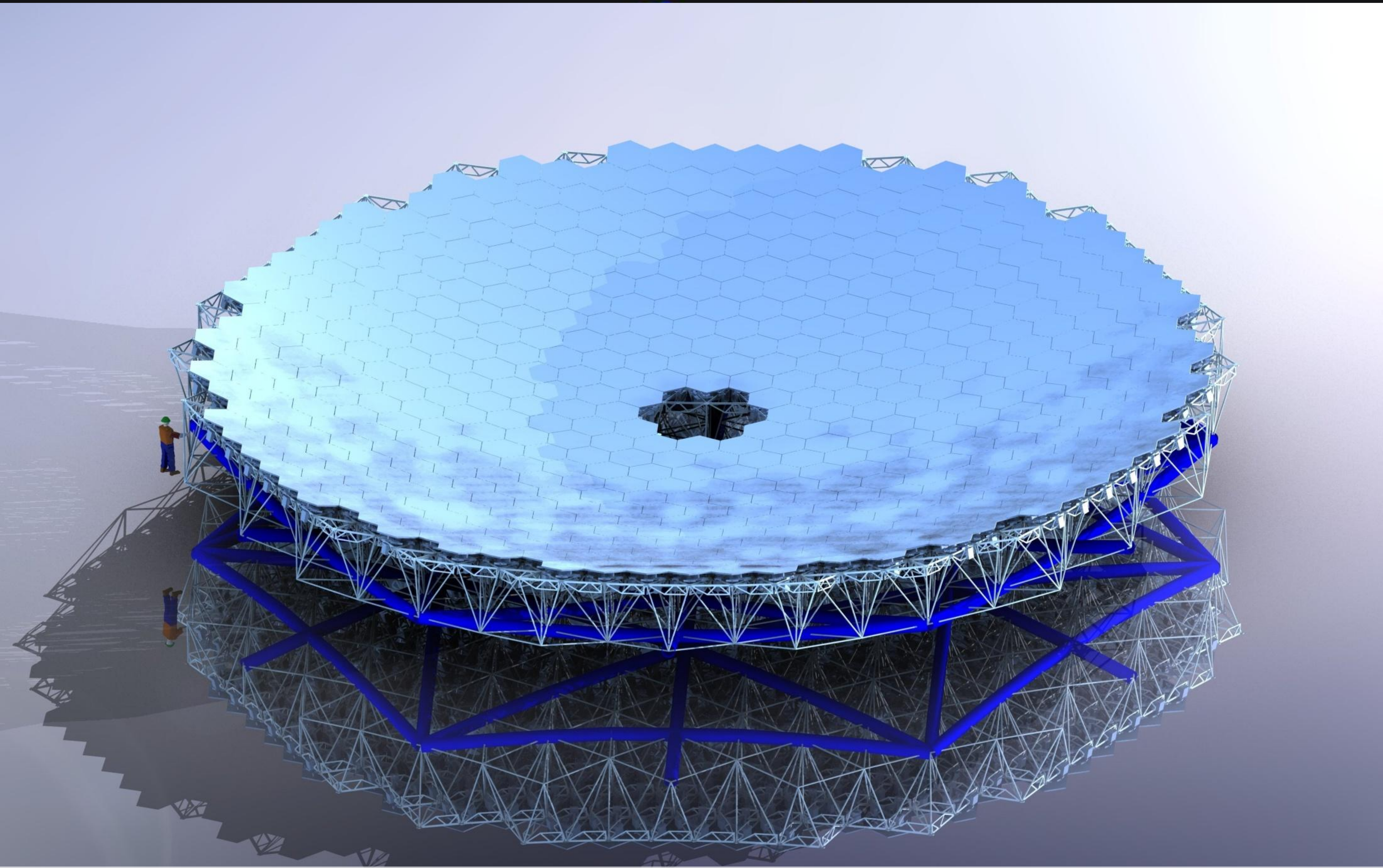
©岡本さんのトラペ

TMT THIRTY METER TELESCOPE

Telescope

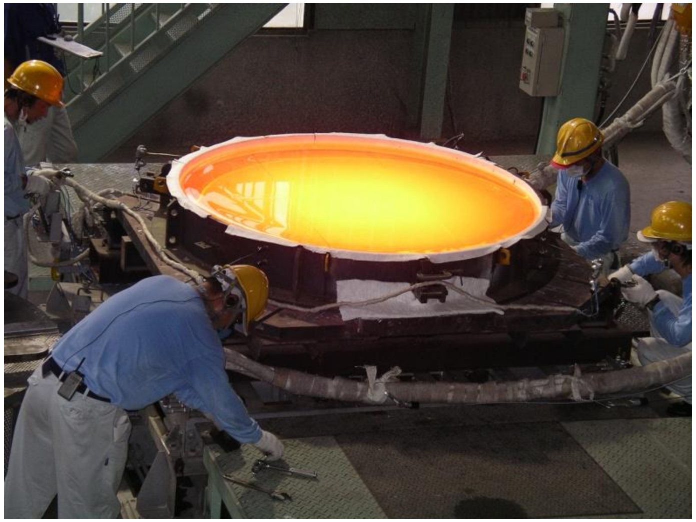
30m RC Telescope (CAD drawings)



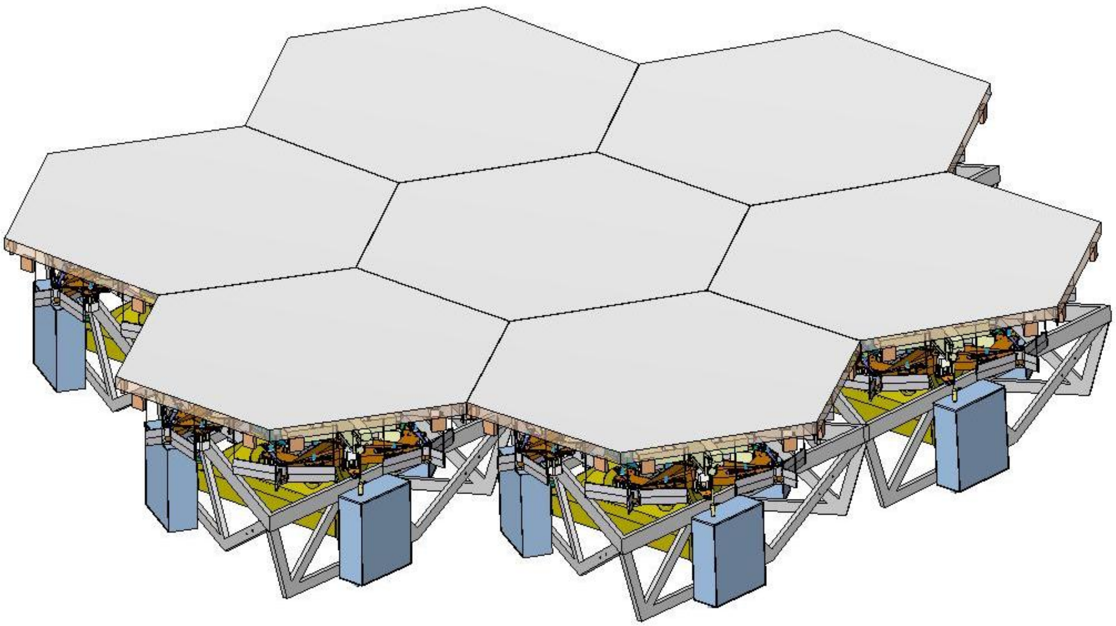


- 492 parabolic off-axis segment mirrors, D=1.44m

日本の寄与：鏡材製作
オハラガラスでの主鏡材試作

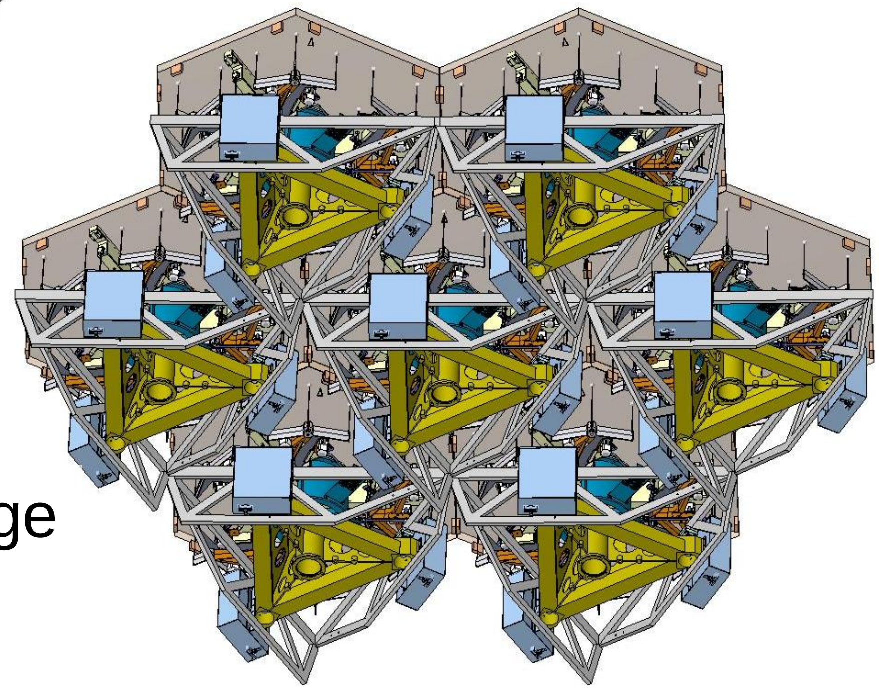


Segment Support Assembly (SSA) Design

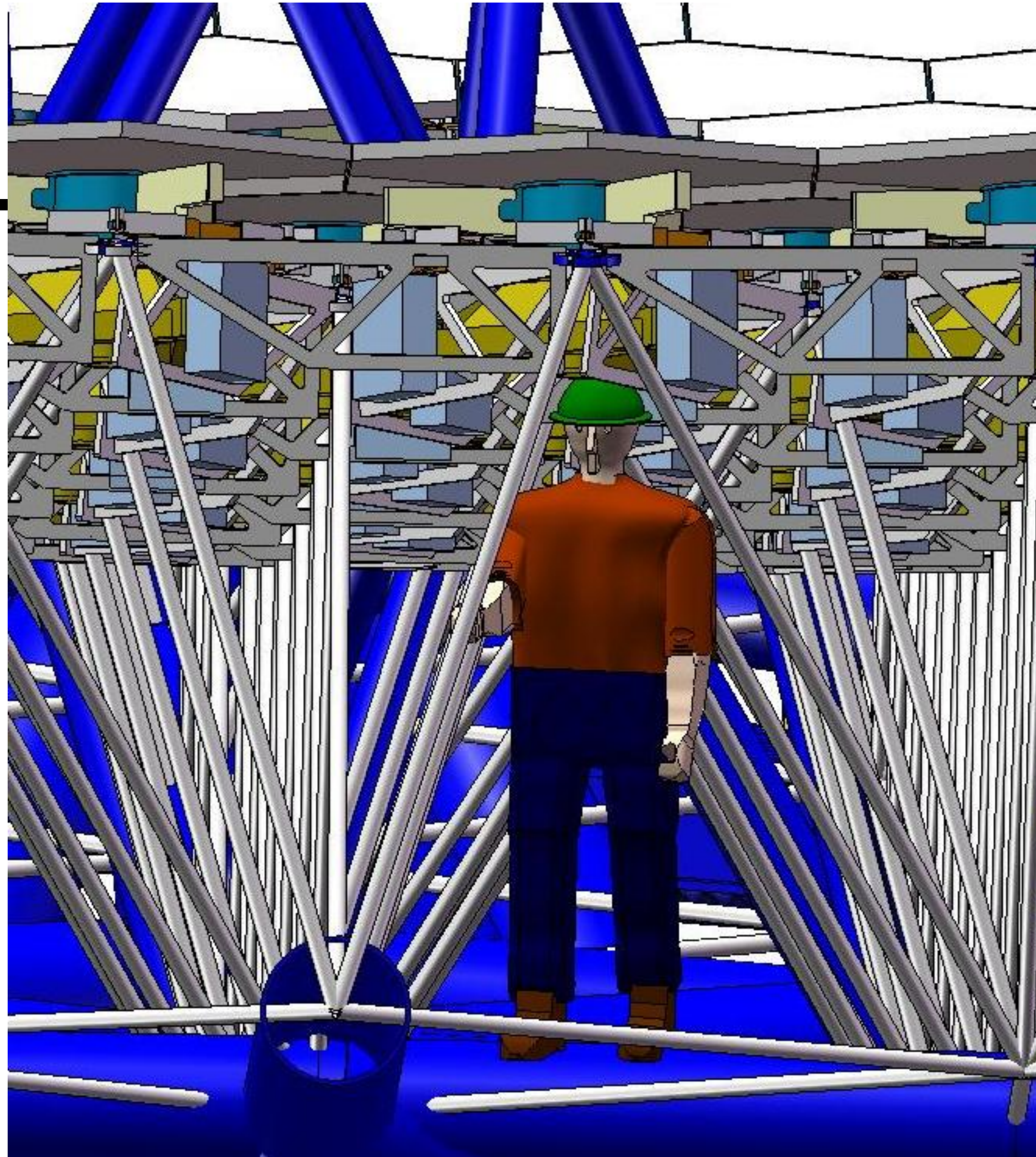


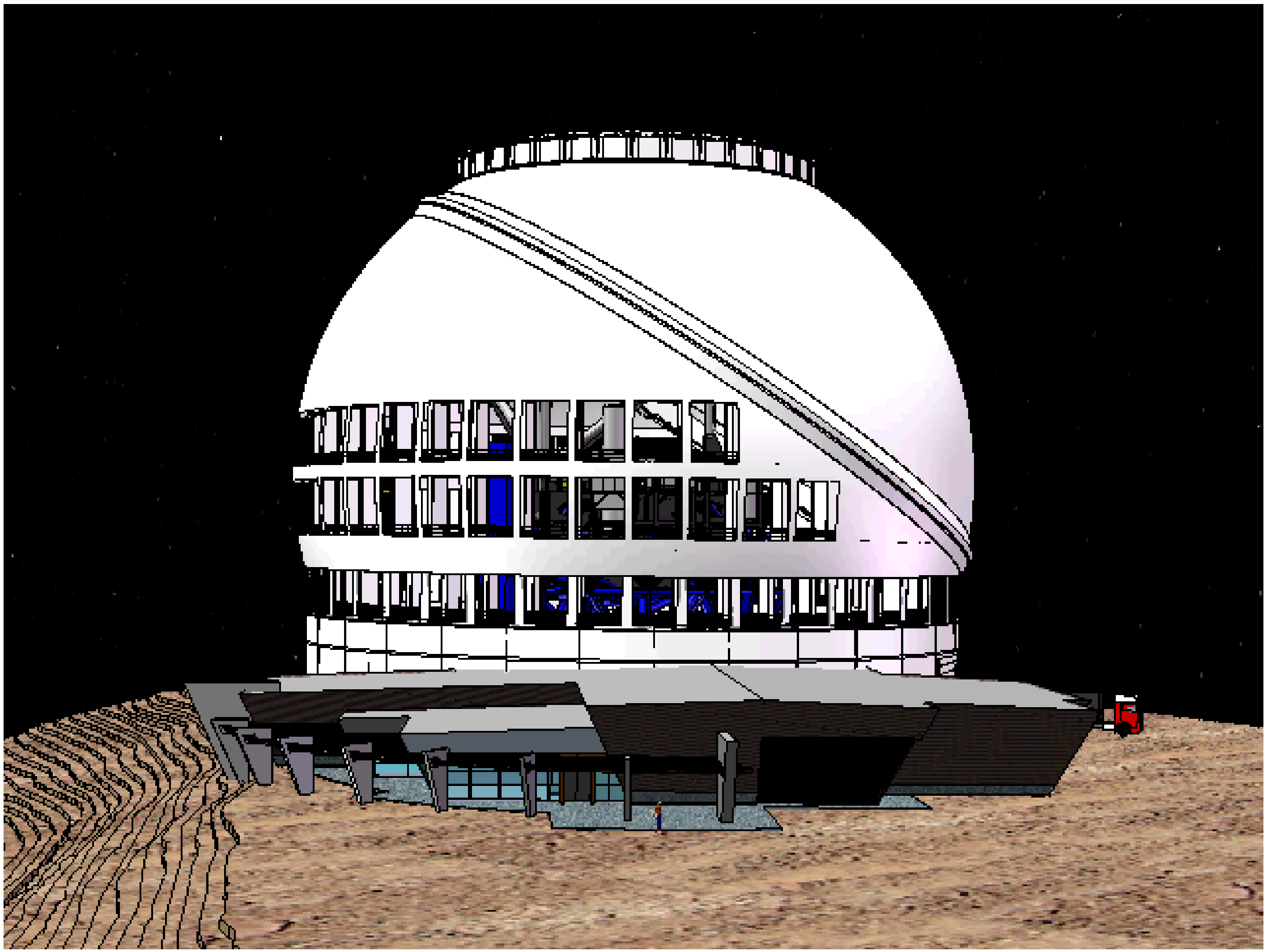
- Seven Segment Assembly – Top View

- Seven Segment Assembly – Bottom View

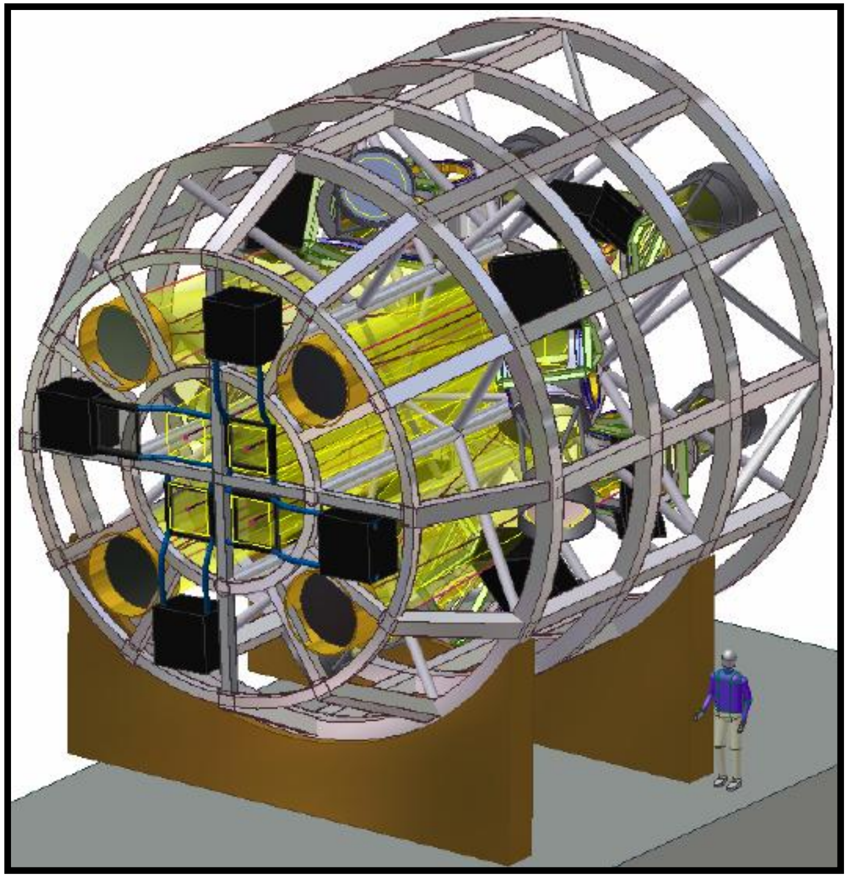


- Real time control of flexure change
- 10000 degrees of freedom



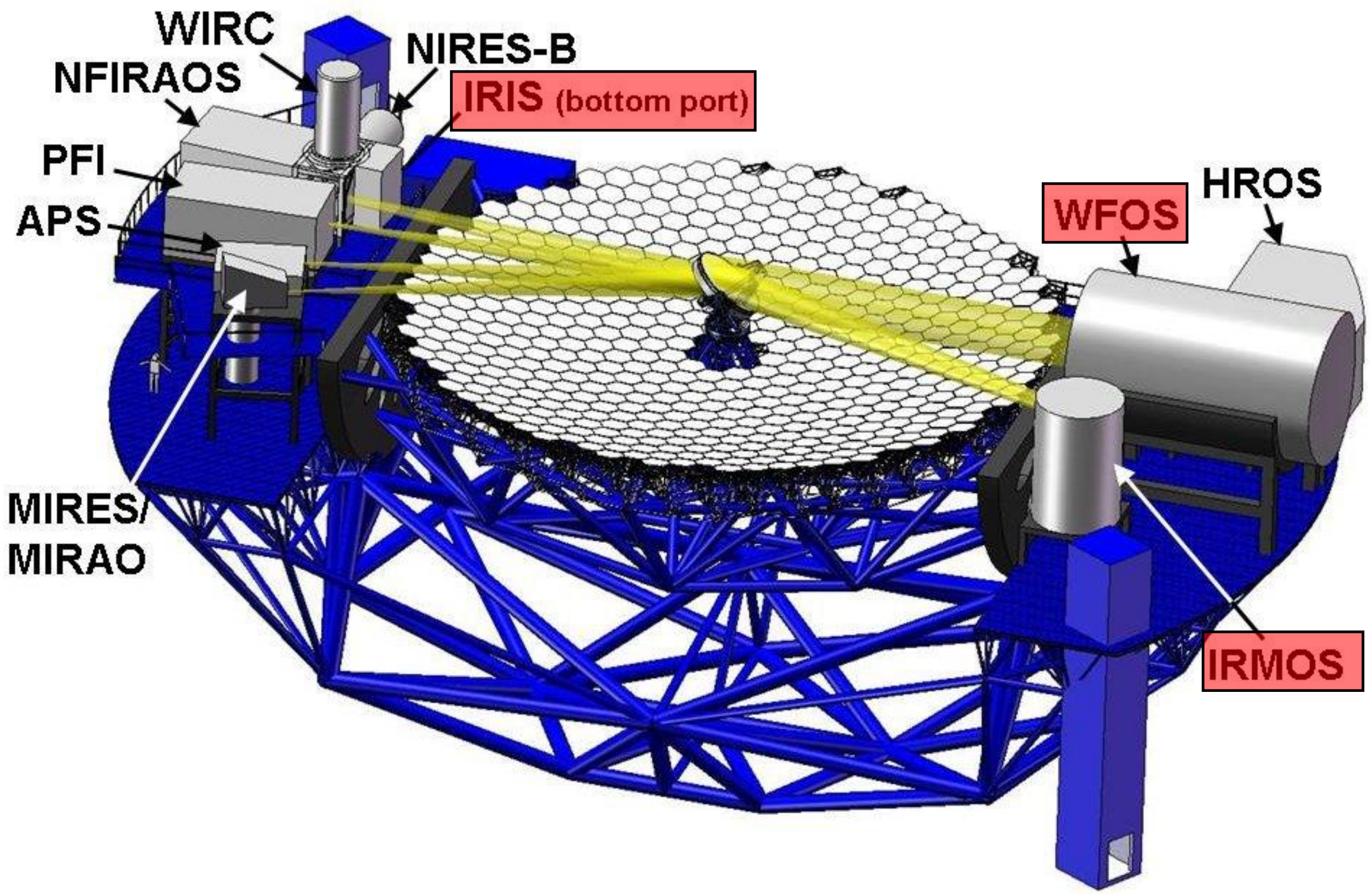


Instruments



Nasmyth Configuration: First Decade Instrument Suite

- Platform 7 m below elevation axis
- Articulated M3 – facilitates quick instrument change
- Addressable regions: -28° to 6° and 174° to 208° for small FOV

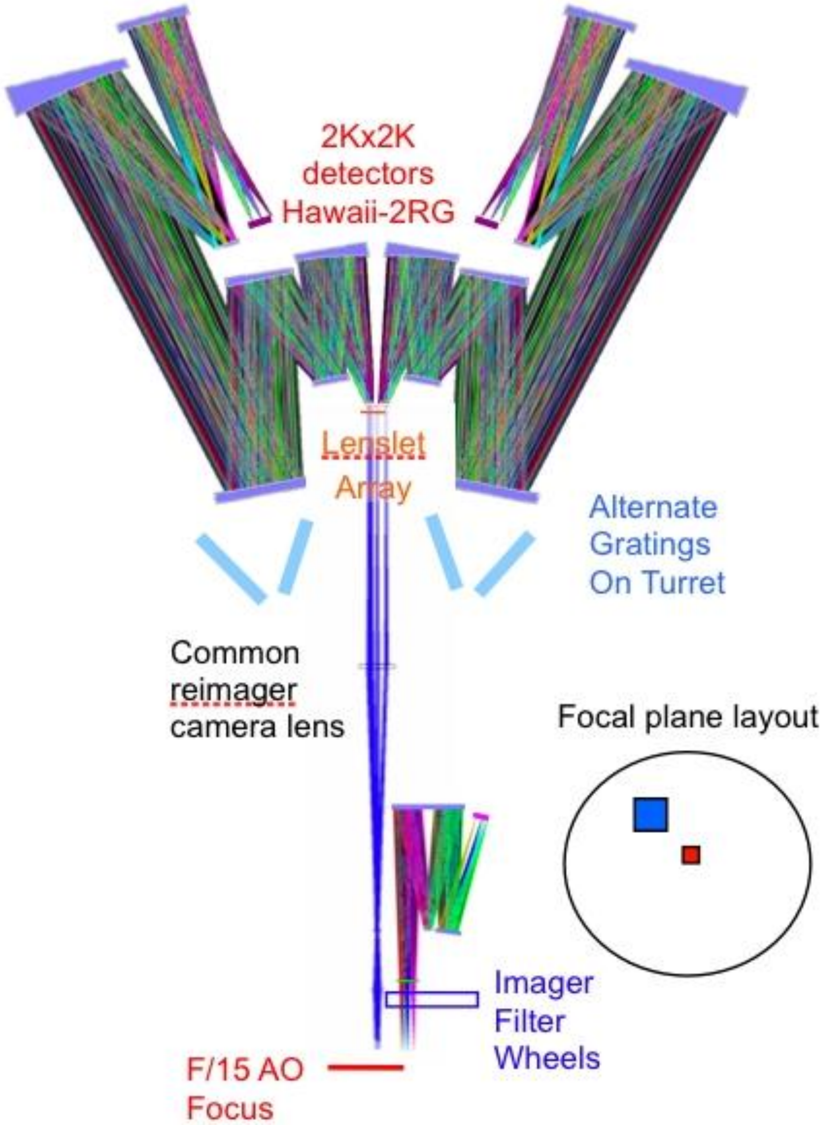


TMT Early Light Instrument Suite

Instrument	Spec.Res.	Science Case
Near-IR DL Spectrometer & Imager (IRIS)	≤4000	Assembly of galaxies at large redshift; Black holes/AGN/Galactic Center; Resolved stellar populations in crowded fields
Wide-field Optical Spectrometer (WFOS)	300 - 5000	IGM structure and composition 2<z<6; High-quality spectra of z>1.5 galaxies suitable for measuring stellar pops, chemistry, energetics
Multi-slit near-DL near-IR Spectrometer (IRMS)	2000 - 10000	Near-IR spectroscopic diagnostics of the faintest objects; JWST followup
Mid-IR Echelle Spectrometer & Imager (MIRES)	5000 - 100000	Physical structure and kinematics of protostellar envelopes; Physical diagnostics of circumstellar/protoplanetary disks: where and when planets form during the accretion phase
ExAO I (PFI)	50 - 300	Direct detection and spectroscopic characterization of extra-solar planets
High Resolution Optical Spectrograph (HROS)	30000 - 50000	Stellar abundance studies throughout the Local Group; ISM abundances/kinematics, IGM characterization to z~6; Extra-solar planets!
MCAO imager (WIRC)	5 - 100	Galactic center astrometry; Stellar populations to 10Mpc
Near-IR, DL Echelle (NIRES)	5000 - 30000	Precision radial velocities of M-stars and detection of low-mass planets; IGM characterizations for z>5.5

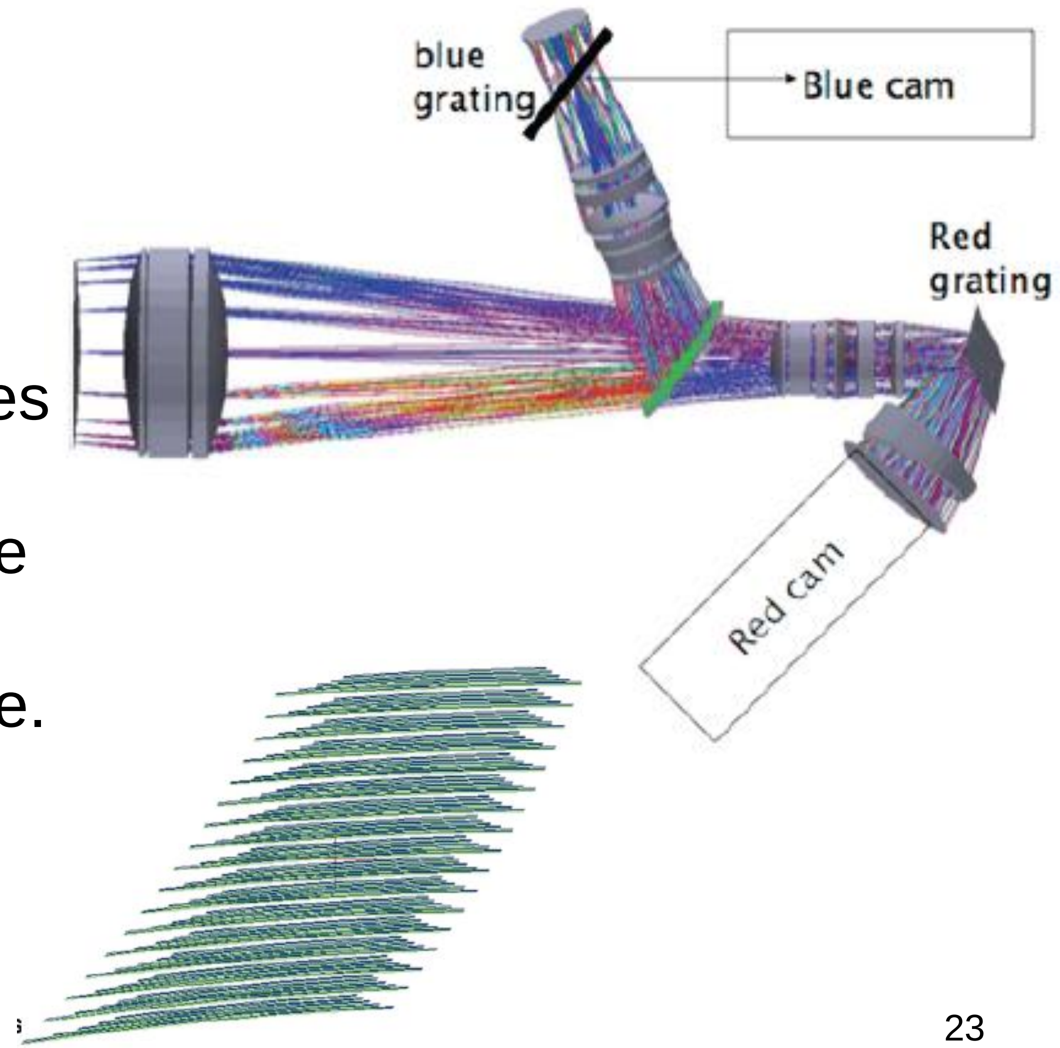
IRIS
Infrared imaging spectrometer

- 0.8 - 2.5 microns
- FOV
  - < 2” IFU
  - DL imaging 30” x 30” w/4mas
- Spec. R: 4000 over entire J, H and K bands, one band at a time
- Lenslet IFU
  - 128x128pix
  - 4 and 10mas scale
- Image slicer
  - 90 slices
  - 25 and 50mas



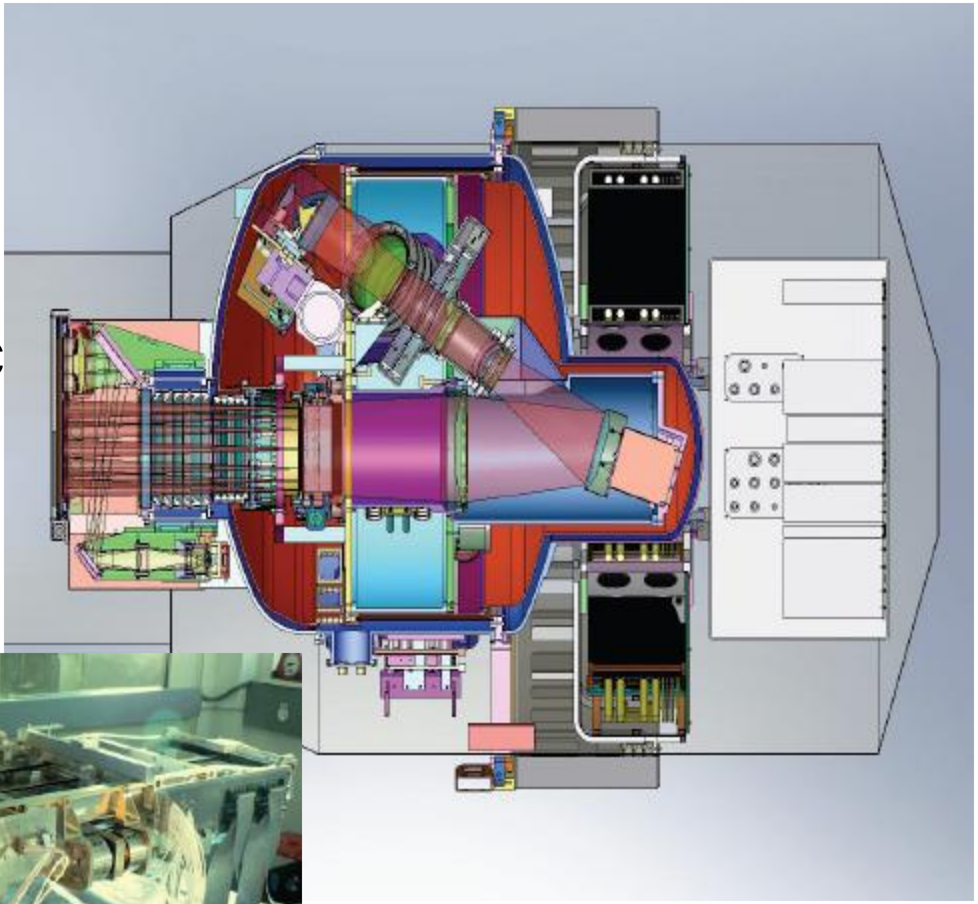
MOBIE
Infrared imaging spectrometer

- 0.31 - 1.1 microns
- 1500 objects over 40.5sqmin FOV
- R=300-7500
- Echellette design provides up to 5 orders
- Full wavelength coverage
- Low resolution mode for max. multiplex advantage.



IRMS
Infrared multislit spectrometer

- 0.8 - 2.5 microns
- 2.3 arcmin FOV
- 0.06arcsec sampling
- 46 movable slits, 2.”4 arcsec
- Adjustable plate scale:
  4, 9, 22 and 50 mas
- R=4600 over entire Y, J, H and K bands
- Copy of Keck/MOSFIRE

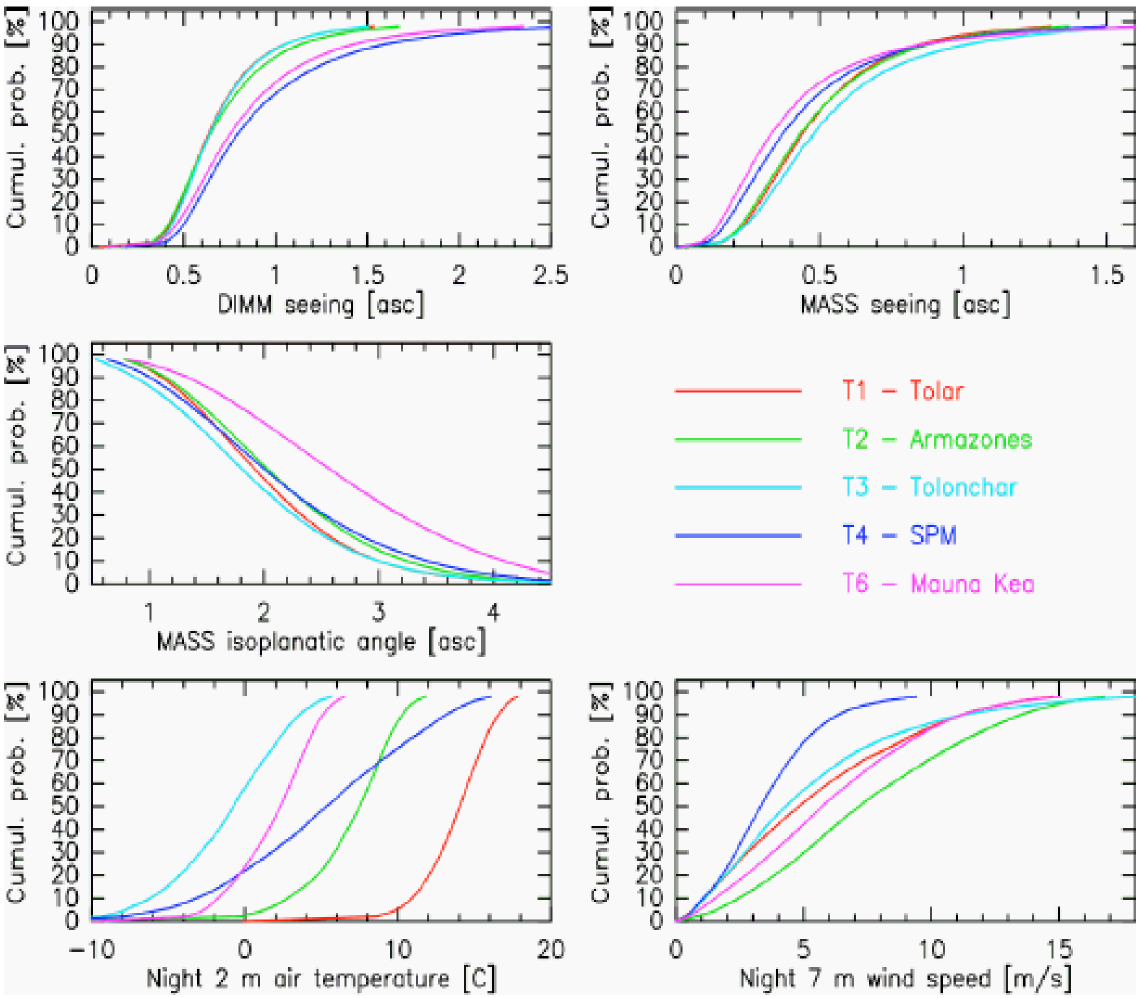


THIRTY METER TELESCOPE

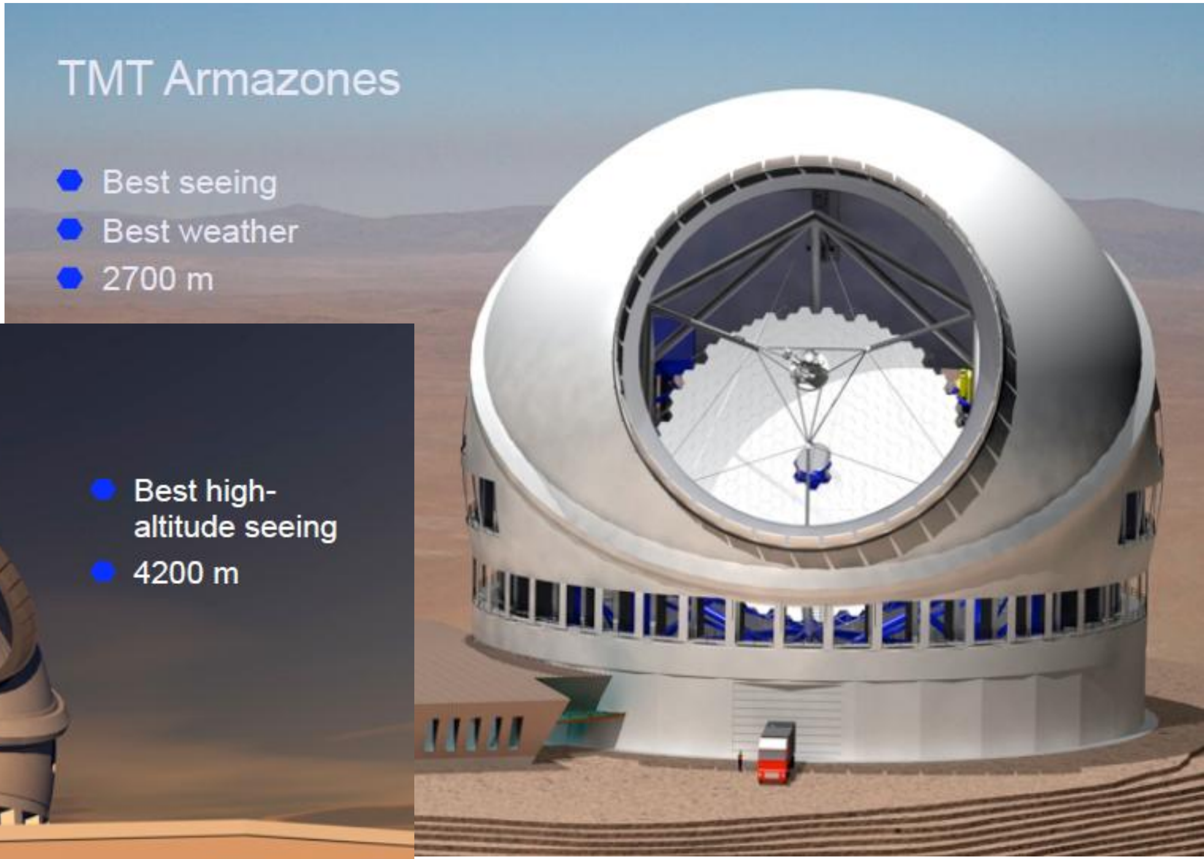
Site

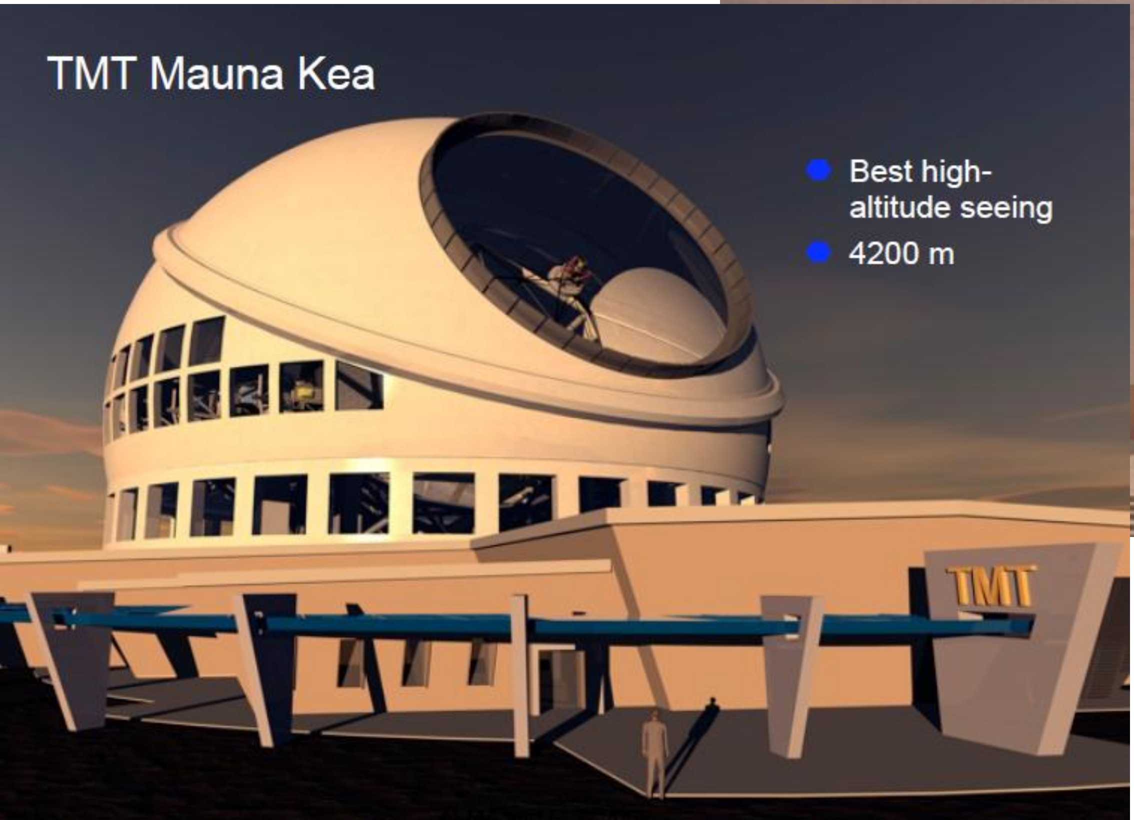
Site testing

- Armazones (Chile) and MaunaKea (Hawaii) are selected as best sites.
- Site decision expected July 2009
- Schoeck et al. PASP, April, 2009



Mauna Kea vs. Armazones





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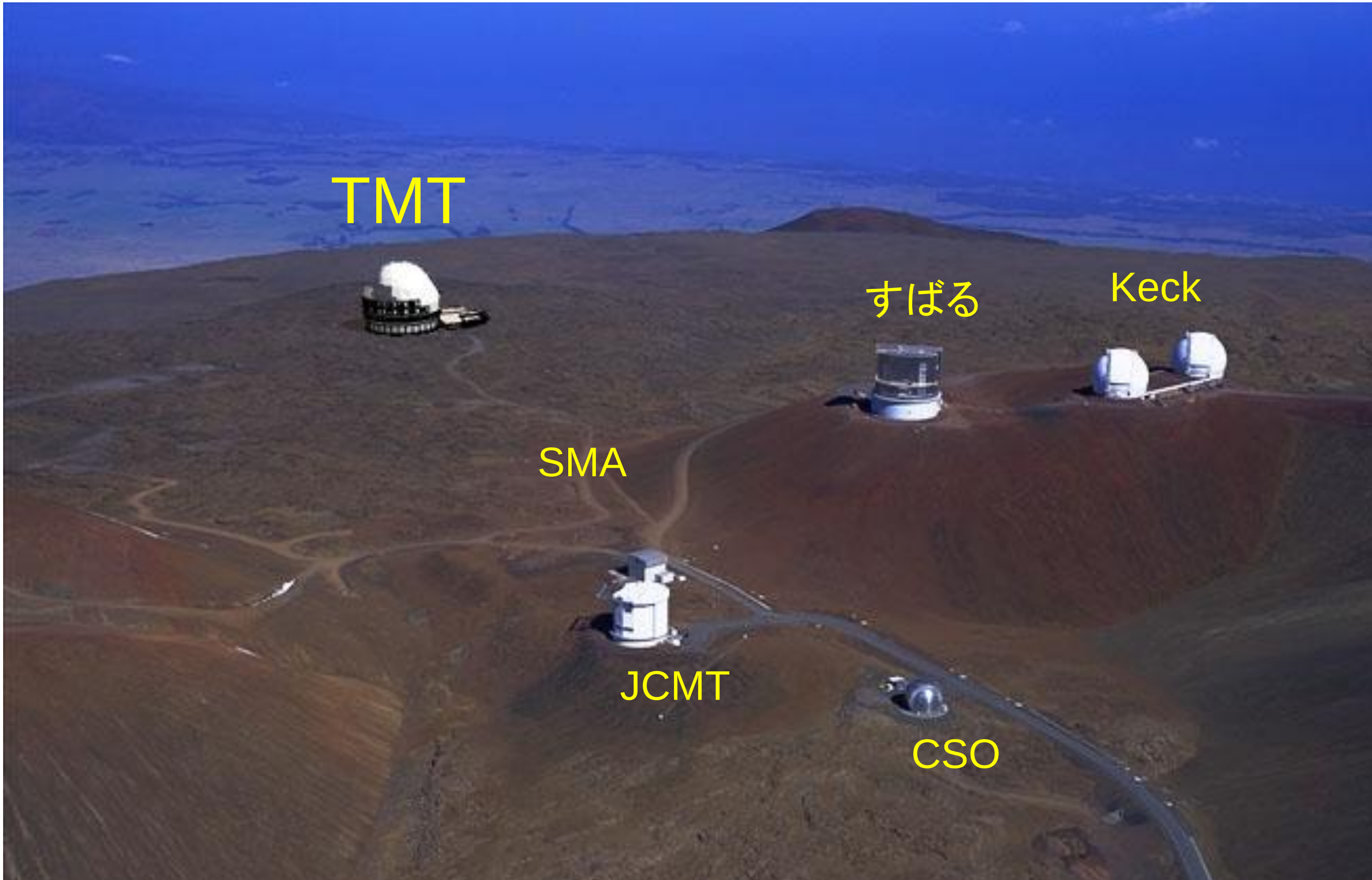
In the case of Mauna Kea



Japanese Contribution

- ELT準備室開室！on April 2009

Current activities

- TMT has been authorized as one of two future large projects (cf. SPICA) by Japanese community
- Agreement between TMT and NAOJ
- Goals & Contributions
    - Equal partner (25 %)
    - Operations
    - M1 segments: Glas Blanck: OK (OHARA)
    - M1 segments: Polishing: R&D phase
    - Instrumentation: IRIS & WFOS, 2nd instruments
    - Infrastructure
    - Others (e.g., Adaptive M2, Data archive)

日本の寄与：主鏡非球面加工

- 主鏡研削(+研磨)
  - 超精密大型研削盤 (ナガセインテグレックス社製)
  - 他国内大手光学メーカー：研磨

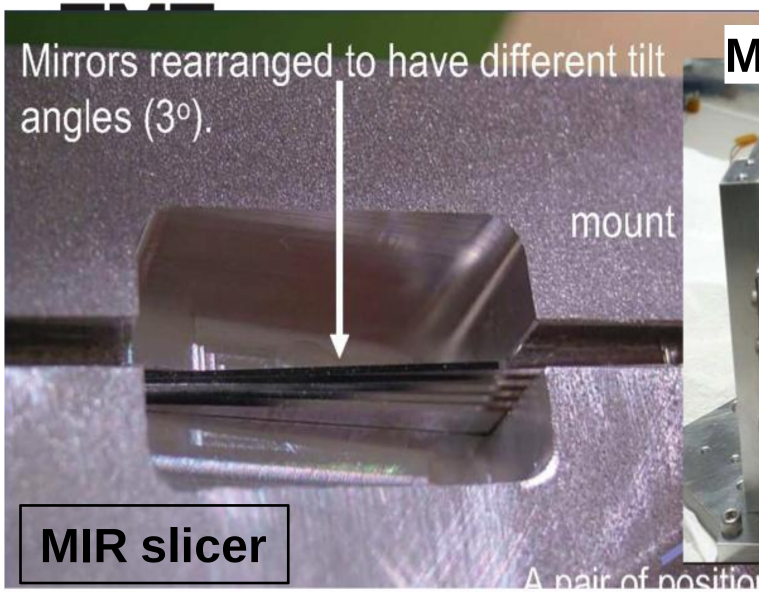
2008-2009年

TMT用ブランク材で試験研削・技術実証

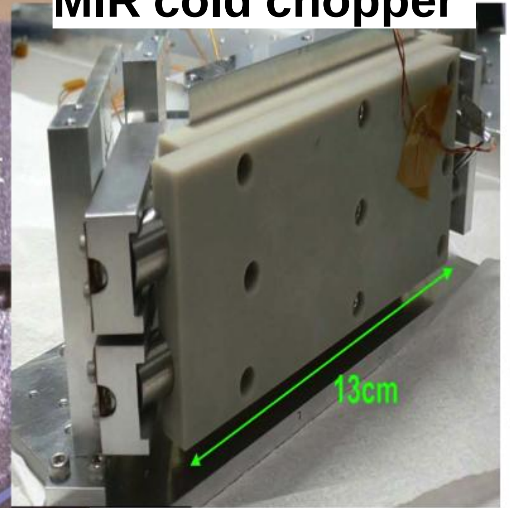
Current Activities: Instrumentation

- IRIS: Imager Design & Science. Promotion is still on going.
- WFOS: Possibilities to join the team (e.g., optics)
- Four 2nd Instruments design works are on going:
  - Optical High Dispersion Spectrograph (W.Aoki+) R=60,000 w/ 0.2" slit, Image slicer, etc. ← HROS
  - Mid-IR Low-resolution Spectrometer (Y.Okamoto+) R=several 100~1000, additional option of MIRES
  - NIR High Dispersion Spectrograph (N.Kobayashi+) R~100,000 w/ Immersion Gr. (ZnSe & Si) ← NIRES
  - NIR Multi IFU spectrograph with MOAO (M.Akiyama+) R~3000, FOV=4~15', >20 objects ← IRMOS

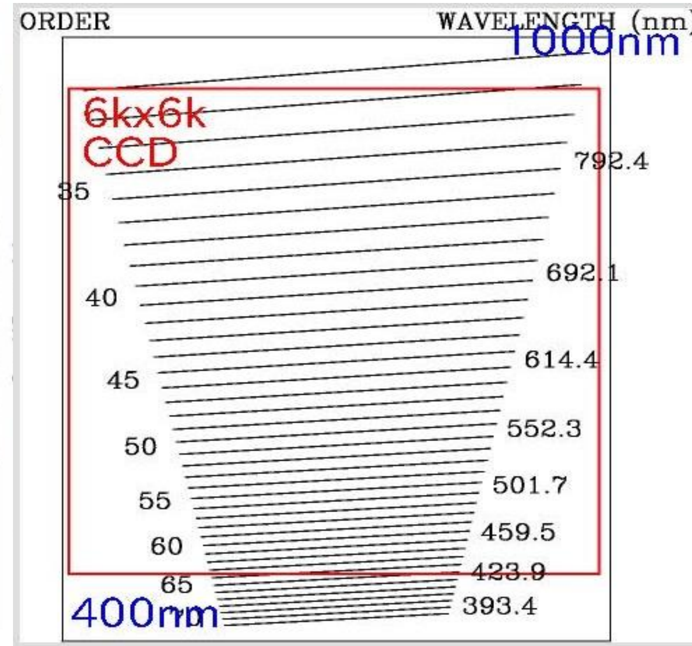
Current Activities: Instrumentation



MIR cold chopper

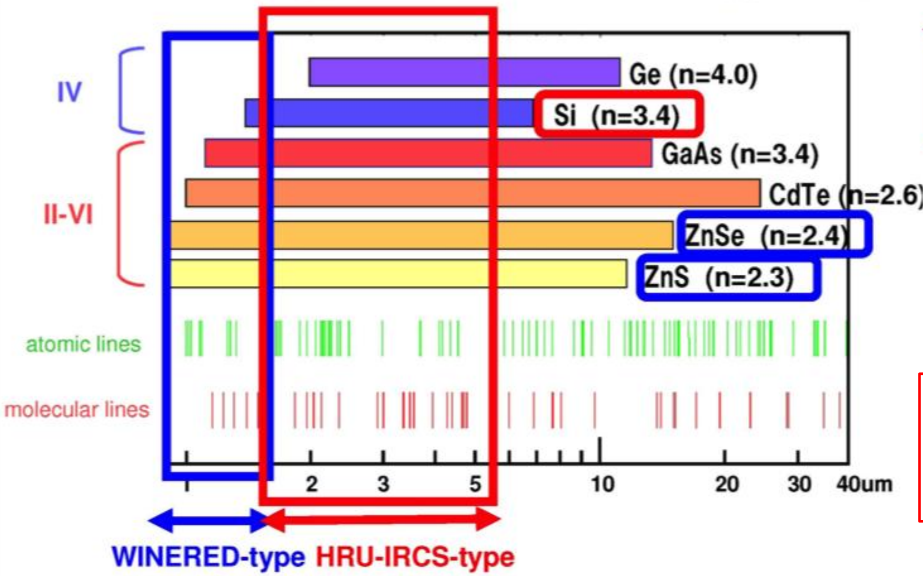


Opt HDS: Echelle format

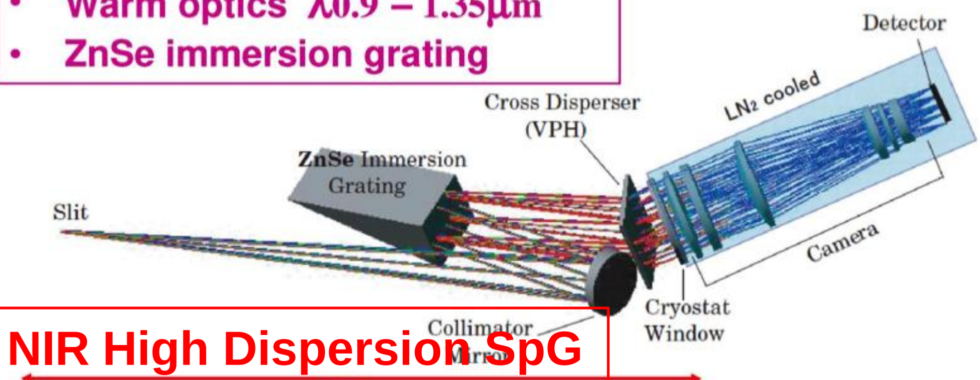


5. 要素開発(イマージョングレーティング)

Material Candidates for NIR Immersion



- Warm optics λ0.9 – 1.35μm
- ZnSe immersion grating



NIR High Dispersion SpG Optical Design

Ikeda et al. 2006, SPIE

2008/3/25

TMT
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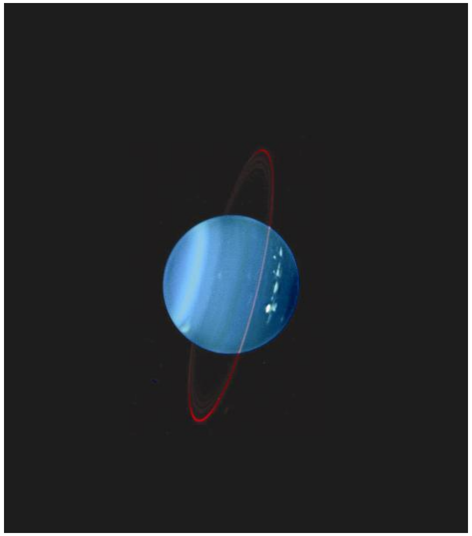
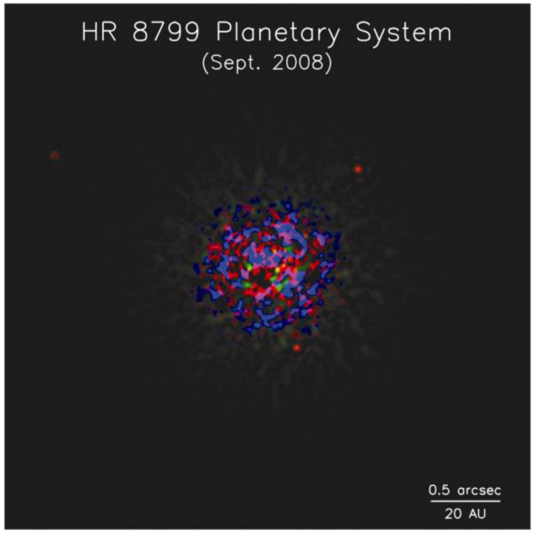
Science Cases





Expand current frontiers
— deeper, finer, and much more —

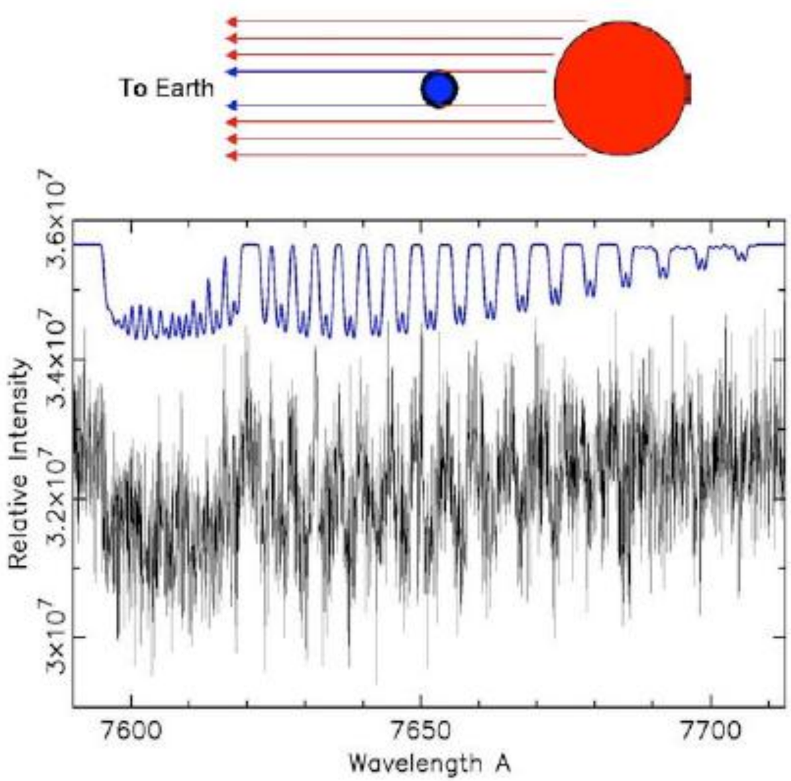
- Direct imaging of exoplanets:
  separation 0.2arcsec→0.02, contrast $10^{-5} \rightarrow 10^{-8}$
- Search for metal poor stars:
  Galactic halo→local group
- Star formation history of nearby galaxies:
  Red giants→MS, 5mag fainter
- Distant SNe:
  z=1.5→z=2-4
- Kinematics and chemical structure of galaxies:
  z=2,3→z=6
- Chemical evolution, IGM metallicity:
  $10^{-2} \rightarrow 2\times10^{-4} Z_\odot$ accuracy
- Co-evolution of BH and galaxy:
  20→100Mpc or $M_{BH}=10^7 \rightarrow 10^6 M_\odot$

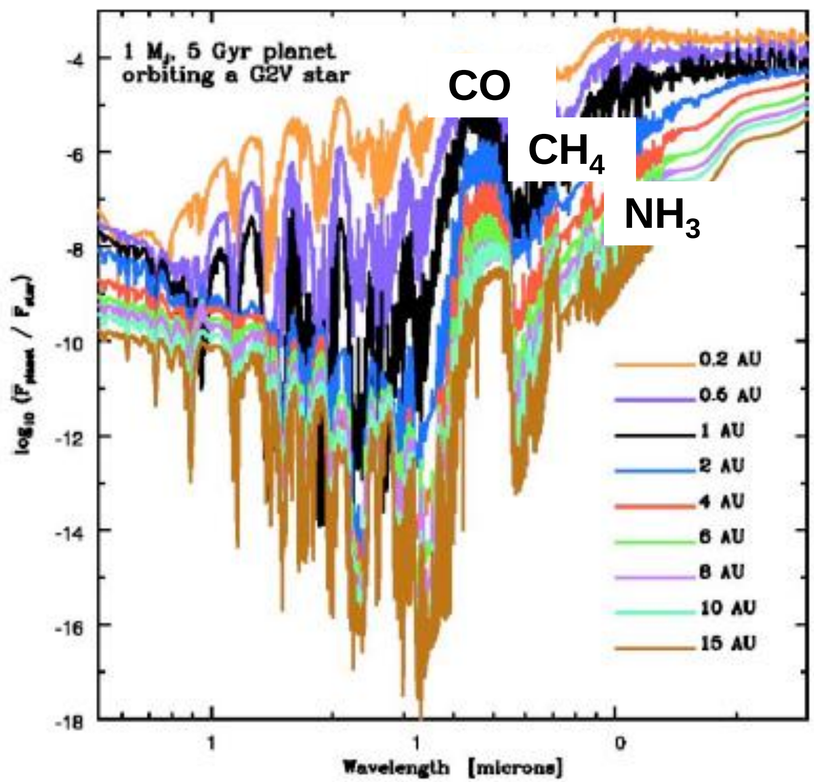
Open new frontiers
— Next Astronomy —

- Structure and composition of atmosphere, weather, volcanic activity, crustal activity in the solar system.
- Detection of organic molecules of H_2O, O_2, O_3 in exoplanets.
- IMF dependence of mass and environment by MIR obs. for young stars in dense molecular clouds.
- Direct observation for the shape of protostar core and inflow/outflow from PP-disk.
- Measurement of stellar orbits around the BH in Galactic center.
- 3D mapping of IGM evolution.
- The first star/galaxy/QSO.
- Redshift drift/ time evolution of physical constants.
- Miscellaneous

Planetary atmosphere

- Absorptions due to molecules in the transiting planetary atmosphere are superimposed on the spectrum of the host star.
- 3hrs integ. (snr=30000, 6km/s)of TMT/HROS for O_2 of Mstar
- MIR high. res. Spec. for organic hydrocarbon molecules





TMT
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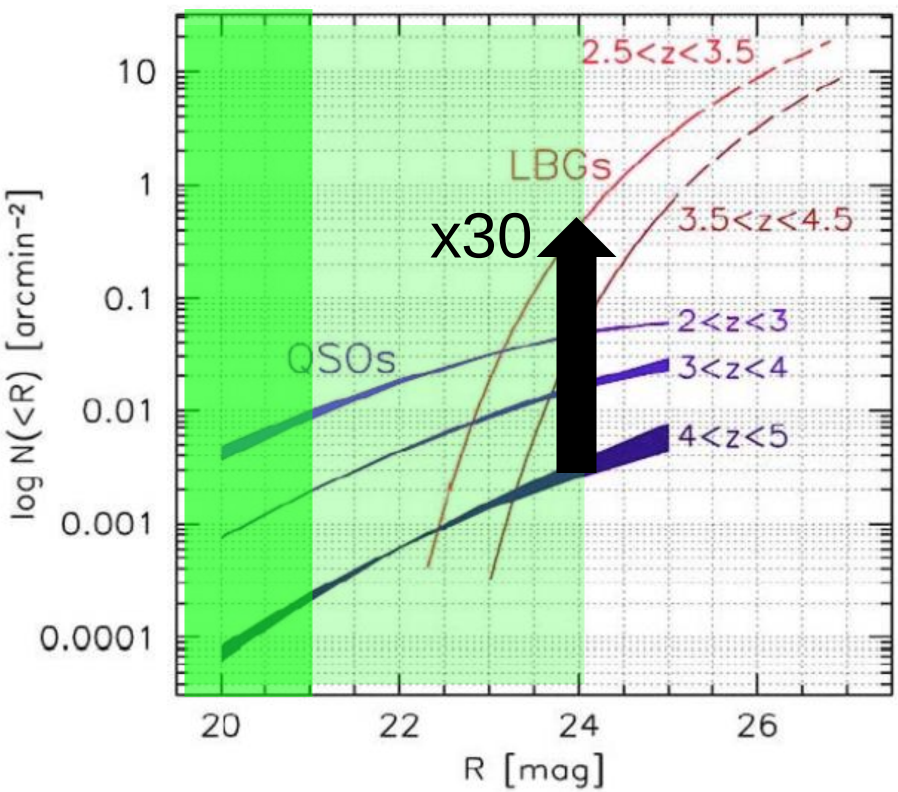
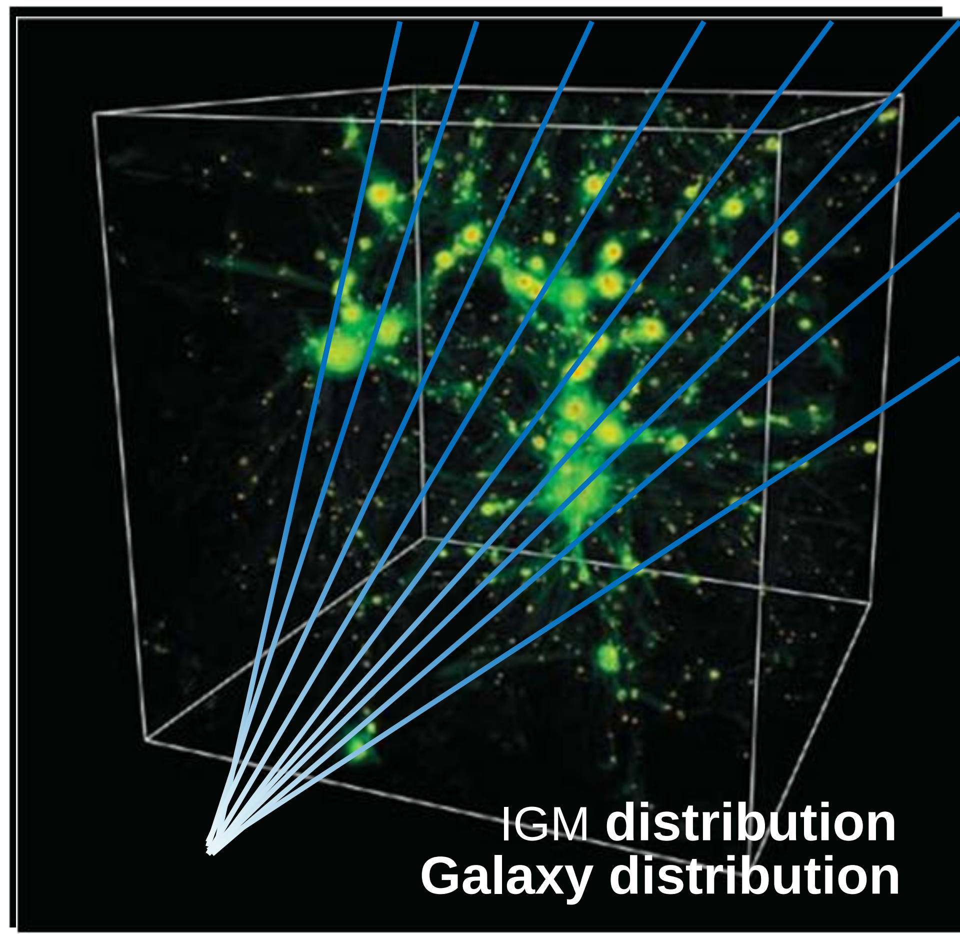
IGM tomography

- TMT R=10,000 mode: lim.mag.=24mag
- Not QSO but Galaxies are dominant in number density (2/arcmin^2)
- Space correlation <300kpc scale
- 3Dmap of HI･metal･star･DM



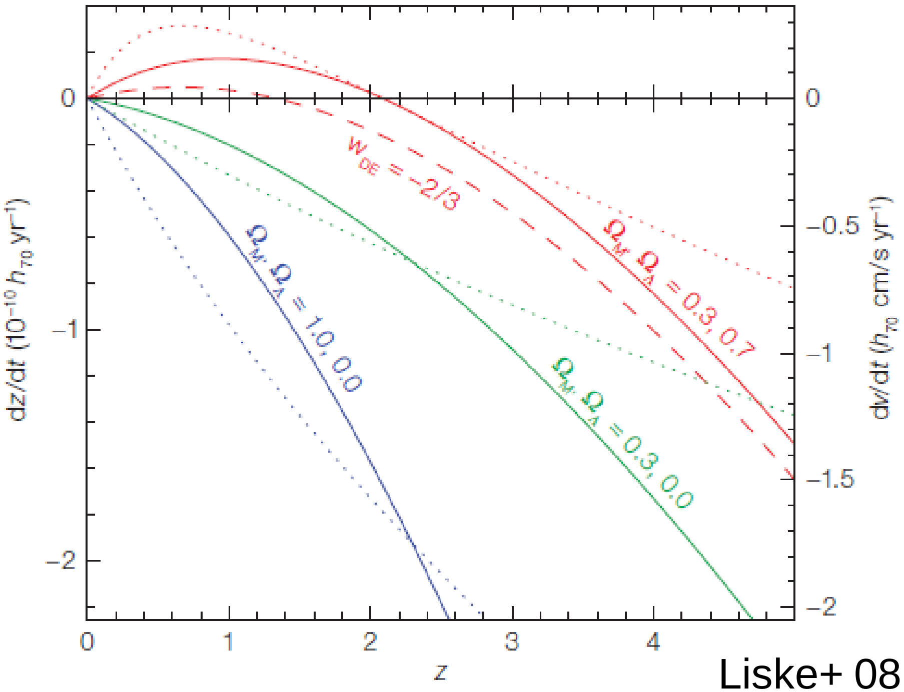


Redshift drift

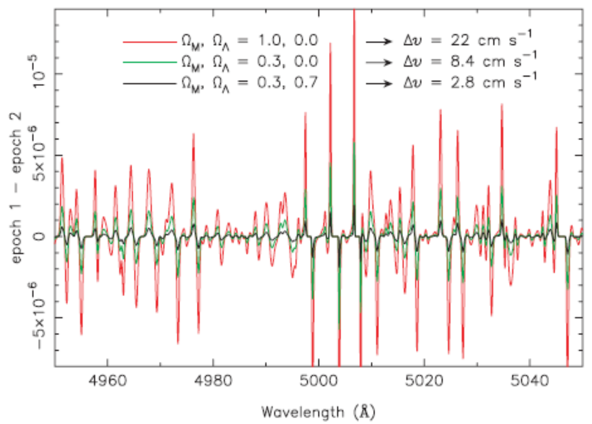
- Acceleration / Deceleration of the universe causes observed redshift as a function of time.

$$\dot{z} = (1+z)H_0 - H(z)$$

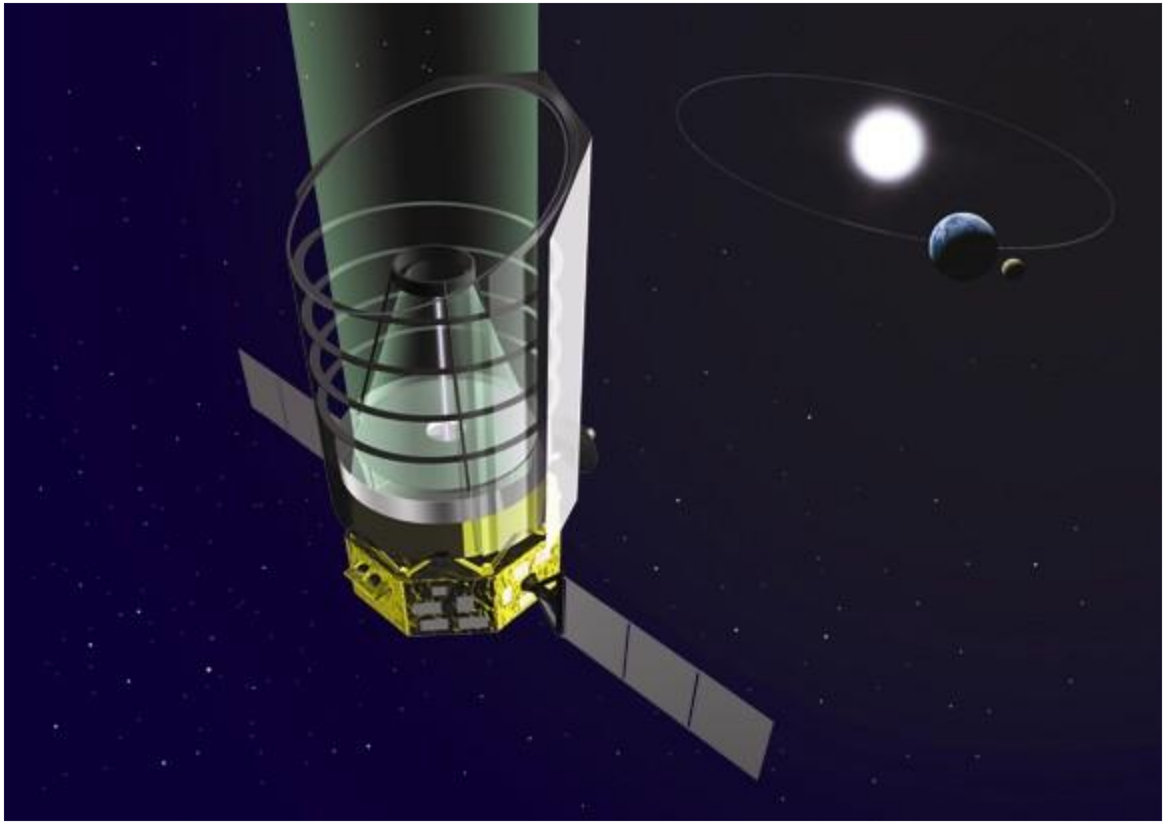
- 6cm/s per 10yrs @z=4
- High S/N and R obs. for ~20 Lyα forests with 4000hrs of TMT over 20yrs
- Direct and model-independent measure of the expansion history.



Liske+ 08

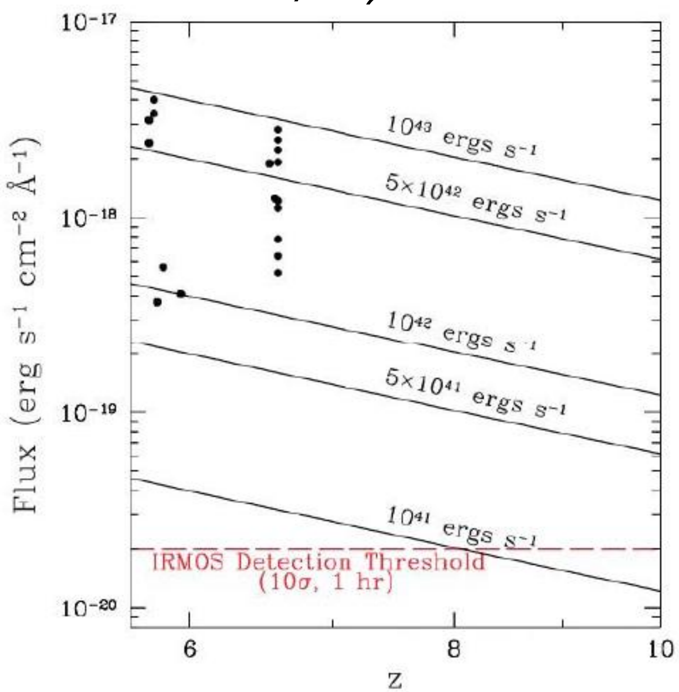


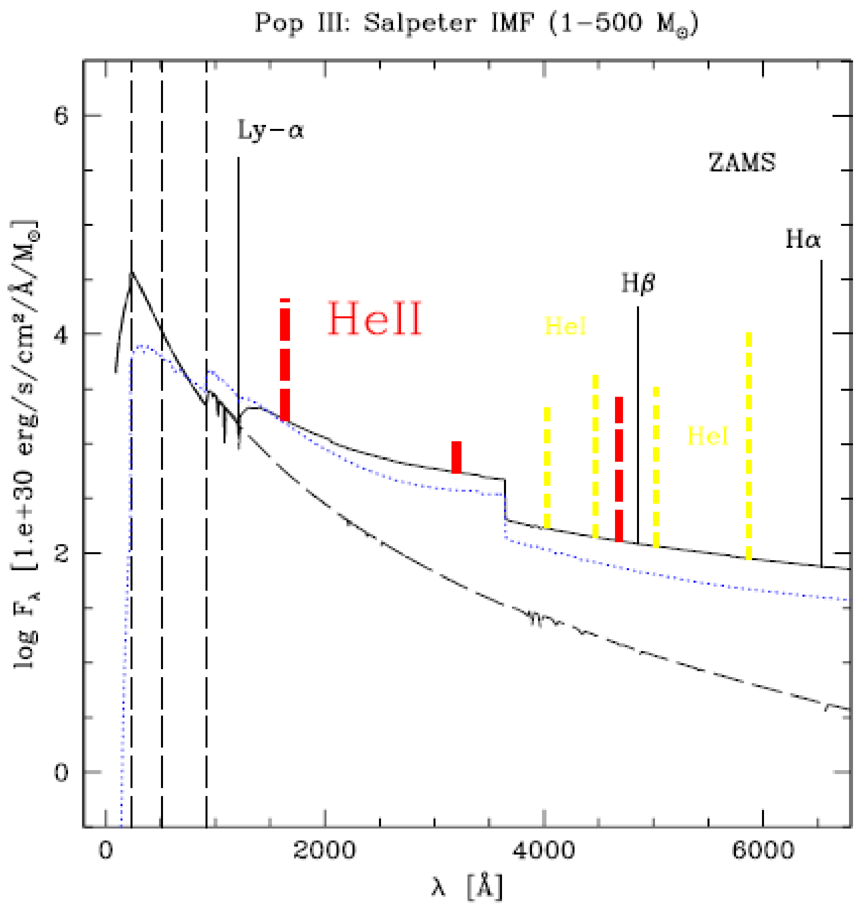
Synergy w/SPICA



PopIII detection

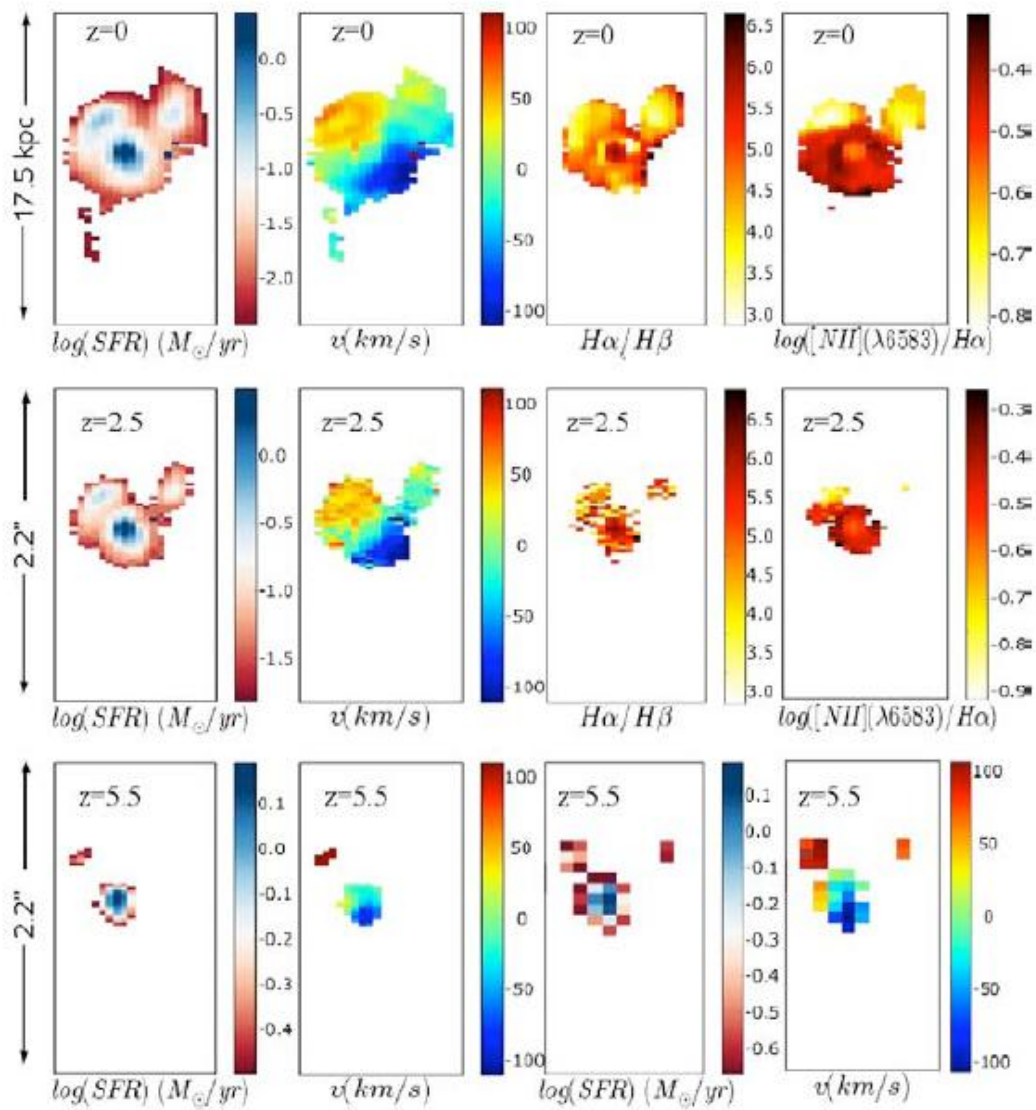
- HeII 1640A is a characteristic signature of popIII.
- Tiny (<30mas) & faint sources
- TMT can detect HeII at z<14.
- JWST: detection of sources
- SPICA: Hα, H_2 detection





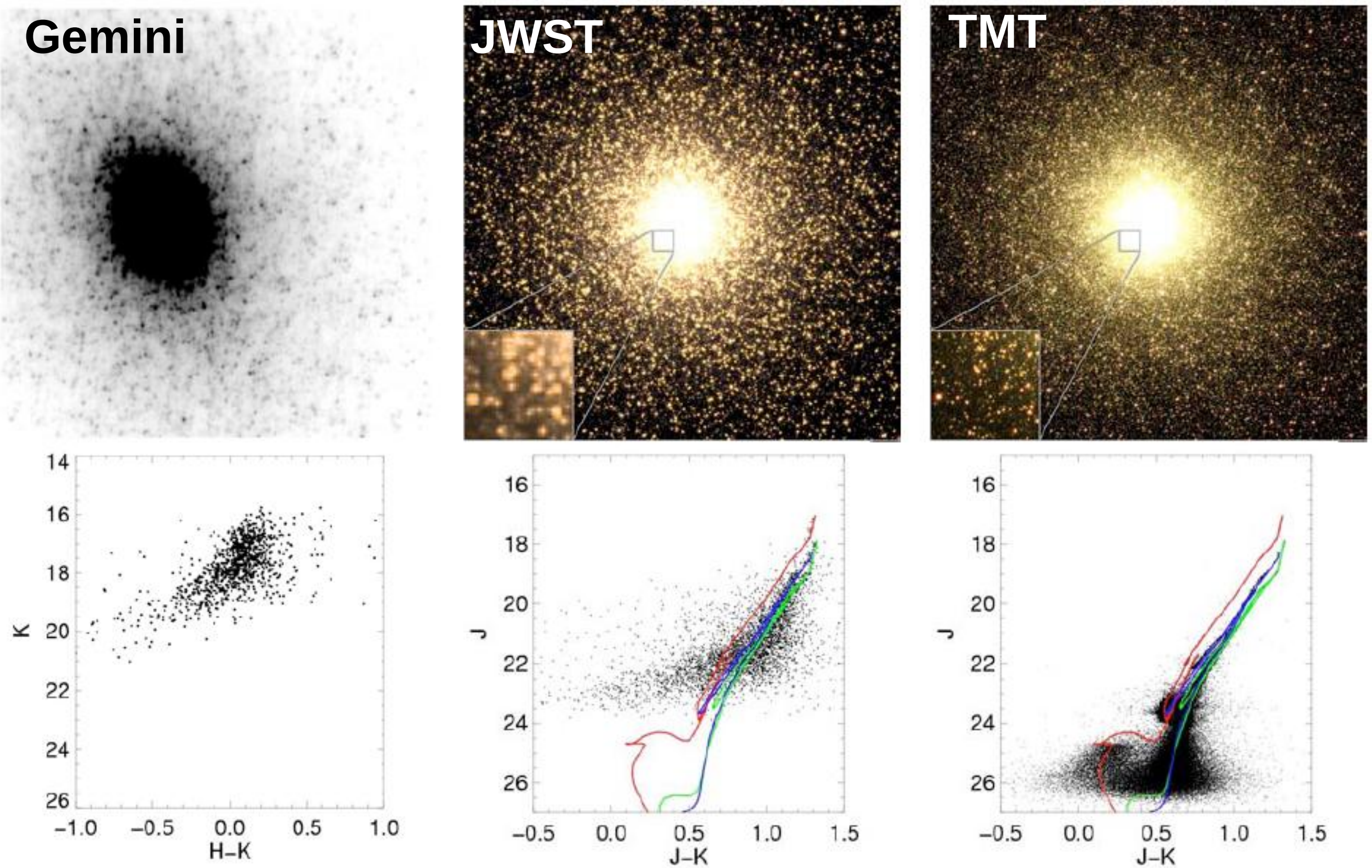
Mapping of kinematic/chemical evolutions

- 2D mapping of SFR, velocity, extinction, and metallicity.
- TMT will gain 10-100 in sensitivity and >3-5 in angular resolution over current facilities.
- Understand the Internal dynamics and complex baryonic processes within a DM halo.
- SPICA: dust, obscured AGN@z<3
- ALMA: molecular gas



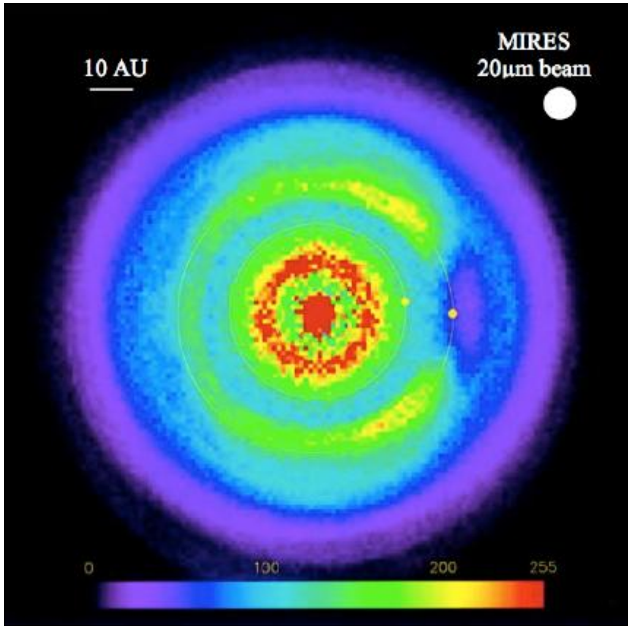
SFH of nearby galaxies

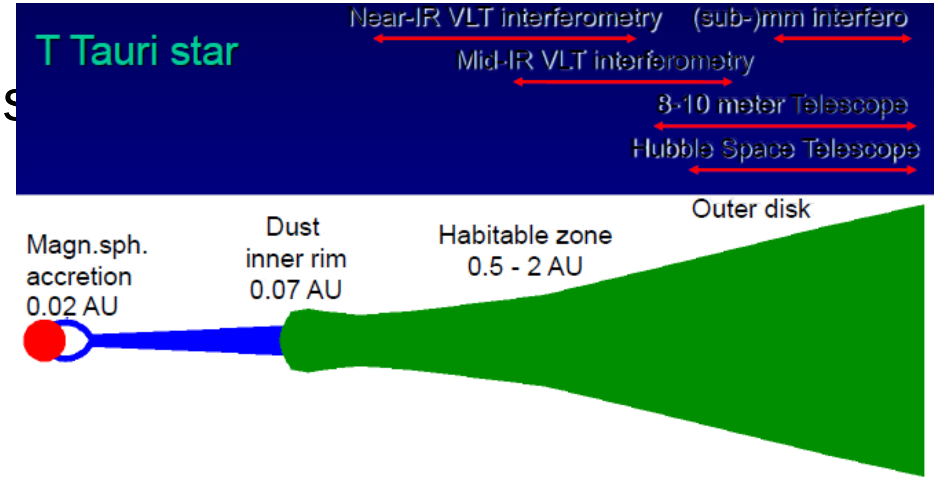
- Deep CMD for nearby galaxies can be drawn even in crowded regions. In the case of M32, TMT will reach to the MS turnoff.
- TMT R~4000 spec. for RGB stars will constrain SFH.
- SPICA: dust distribution, feedback from activity, merging



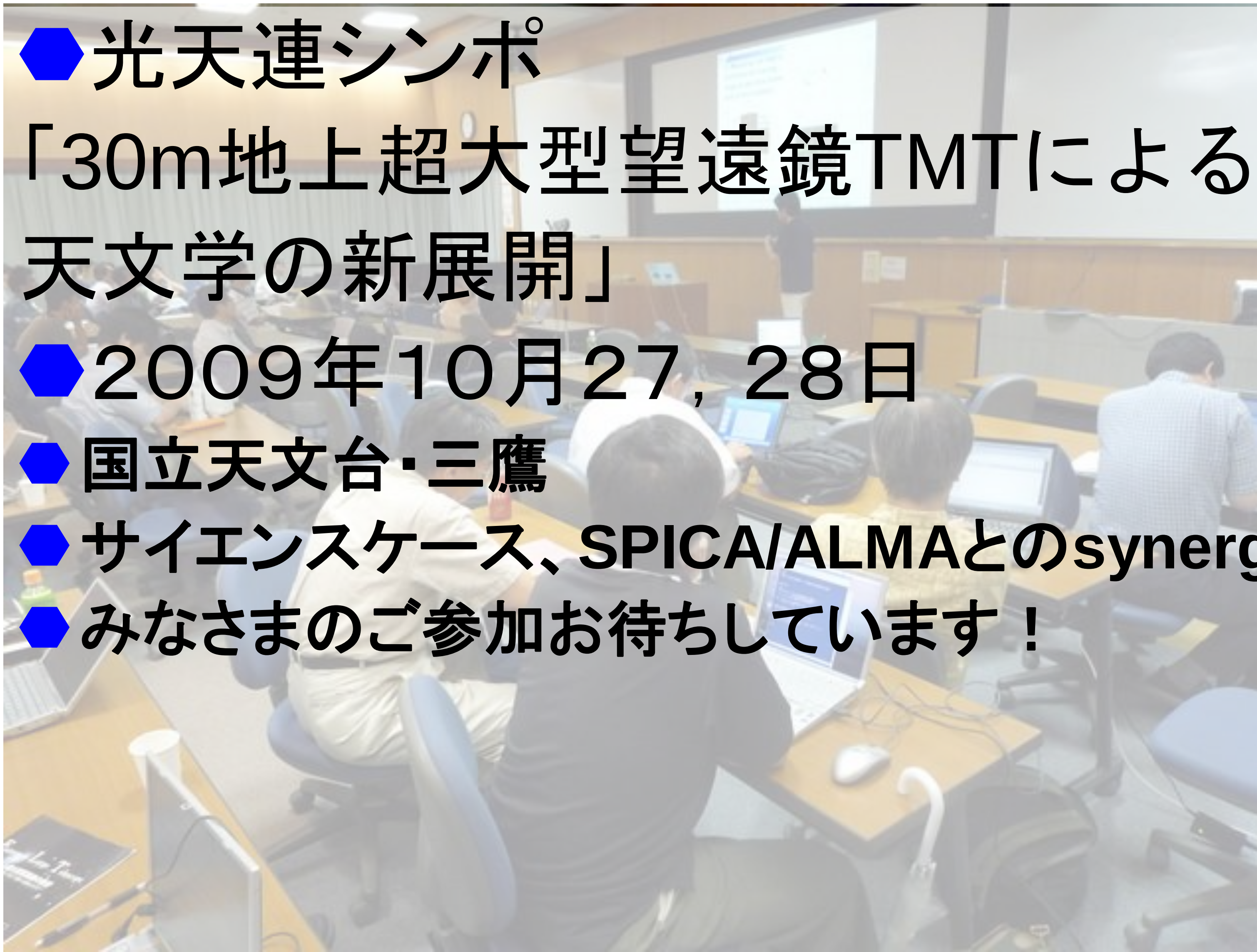
Protoplanetary disk

- TMT MIR R~100000 spec. for protostellar cores to reveal structure and kinematics of infalling envelopes /jets/winds.
- H_2O, CO as diagnostics to map T/ρ/v at <1AU
- MIRES will be able to image protoplanetray disks at <1au
- SPICA: H_2 flux, H_2Oice
- ALMA: outer molecular clouds





光天連シンポのお知らせ



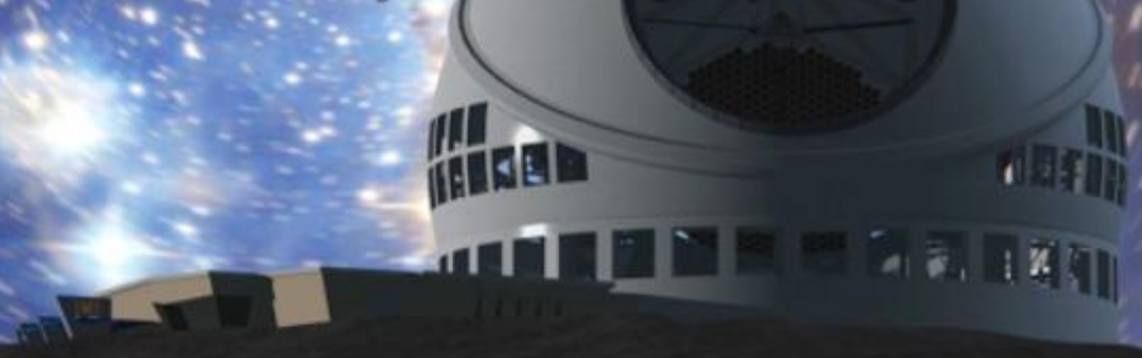
- 光天連シンポ

「30m地上超大型望遠鏡TMTによる天文学の新展開」

- 2009年10月27，28日
- 国立天文台･三鷹
- サイエンスケース、SPICA/ALMAとのsynergy
- みなさまのご参加お待ちしています！

Summary

- 30m aperture, Filled segmented primary.
- High sensitivity, High angular/spectral resolution.
- Broad science cases: expand current frontiers & new frontiers.
- 2018 FL: Many exciting synergies w/SPICA.



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