TMTの観測装置開発

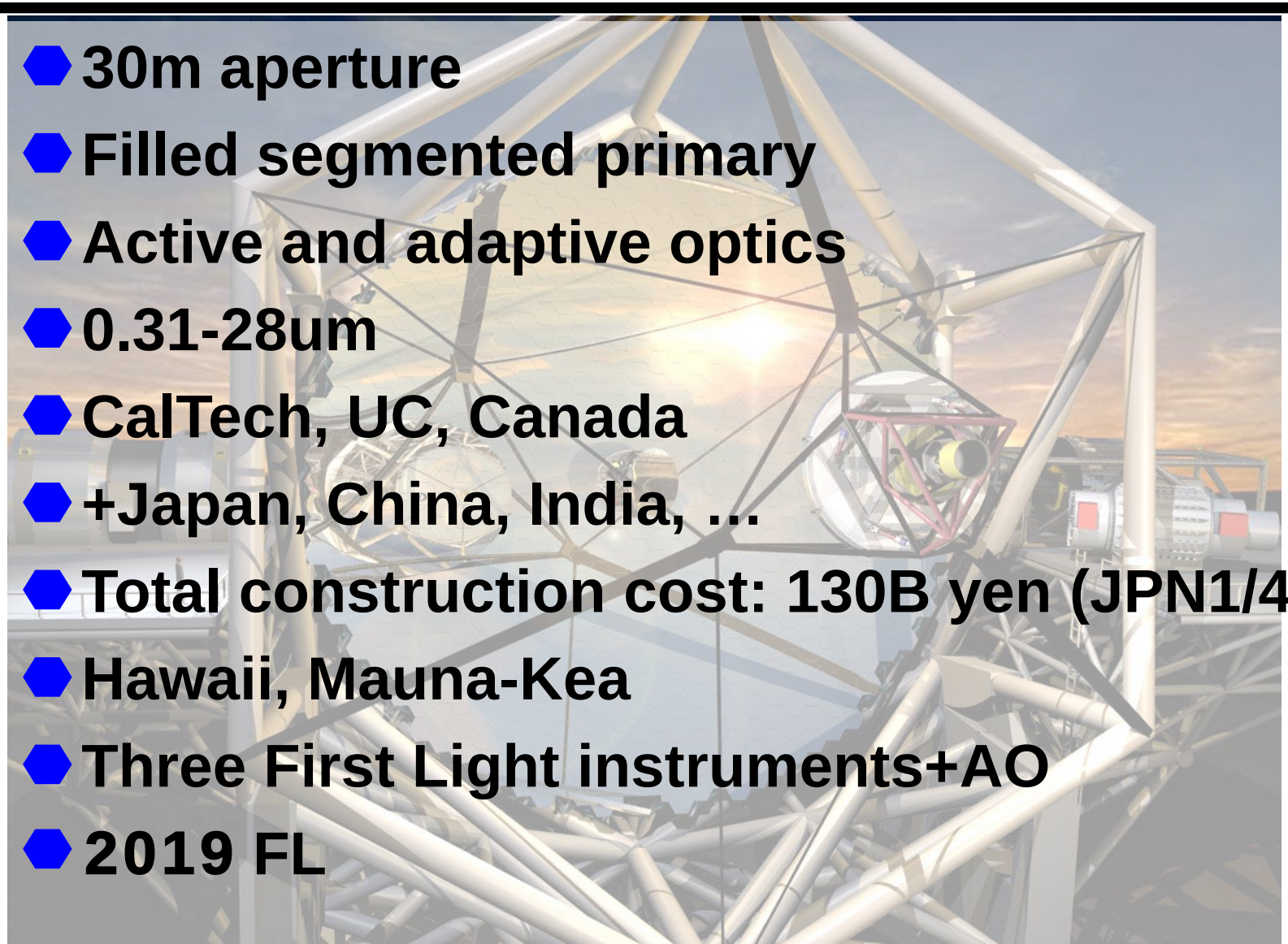
- Project Overview
- TMT FL instruments
- Japanese instruments

柏川伸成
(NAOJ/TMT project)
Jan. 2011

Overview

TMT
THIRTY METER TELESCOPE

TMT Fast Facts



- 30m aperture
- Filled segmented primary
- Active and adaptive optics
- 0.31-28um
- CalTech, UC, Canada
- +Japan, China, India, …
- Total construction cost: 130B yen (JPN1/4)
- Hawaii, Mauna-Kea
- Three First Light instruments+AO
- 2019 FL

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vs. Subaru
x13 sensitivity, x4 resolution

sensitivity $\propto D^2$

resolution $\propto \lambda/D$

Why we want larger telescope?

- To see more distant objects
- To see more detailed structure
- To see in shorter time
- To see more objects

5 Meter
Hale 200-inch
Mirror

10 Meter
Keck
Mirror

30 Meter
TMT
Mirror

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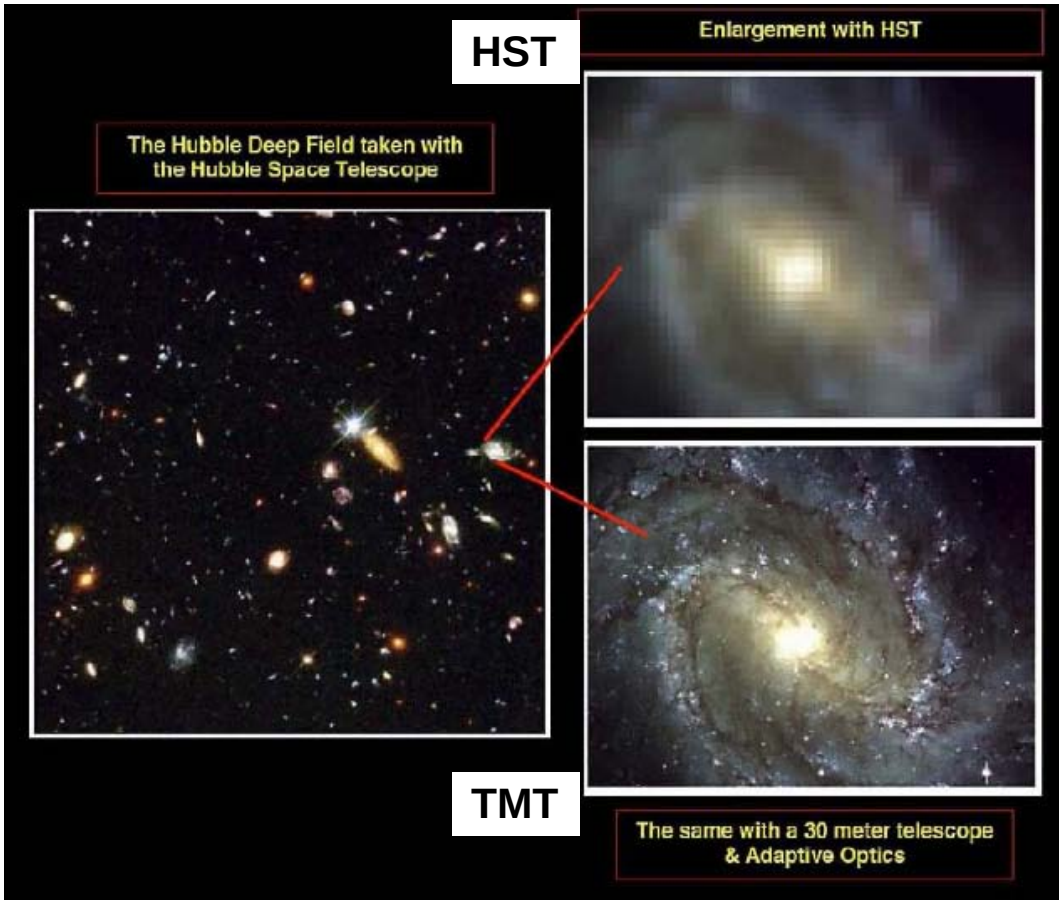
Adaptive Optics(AO)

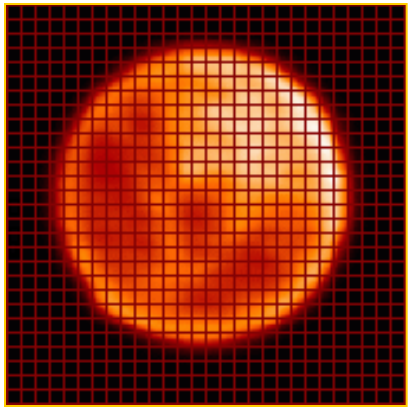


- Angular resolution 0.6→0.015arcsec (2.2μm)
- sensitivity upgrades by 1order
- Several thousand elements
- Much higher resolution than HST
- 5 times higher resolution than JWST
- Almost all the TMT NIR observation will use AO in TMT.

High spatial resolution w/TMT/AO

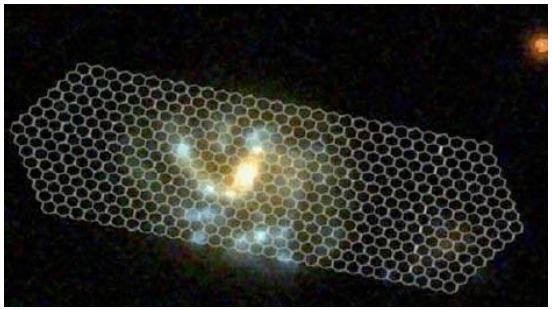
- AO on TMT provides unprecedented ability to investigate objects on small scales. Essentially no images exist on these scales for direct comparison.

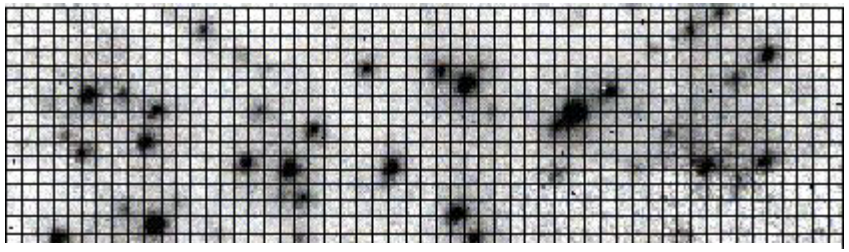
0.01” @5 AU	= 36 km	(Jovian’s and moons)
5 pc	= 0.05 AU	(Nearby stars – companions)
100 pc	= 1 AU	(Nearest star forming regions)
1 kpc	= 10 AU	(Typical Galactic Objects)
8.5 kpc	= 85 AU	(Galactic Center or Bulge)
1 Mpc	= 0.05 pc	(Nearest galaxies)
20 Mpc	= 1 pc	(Virgo Cluster)
z=0.5	= 0.07 kpc	(galaxies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

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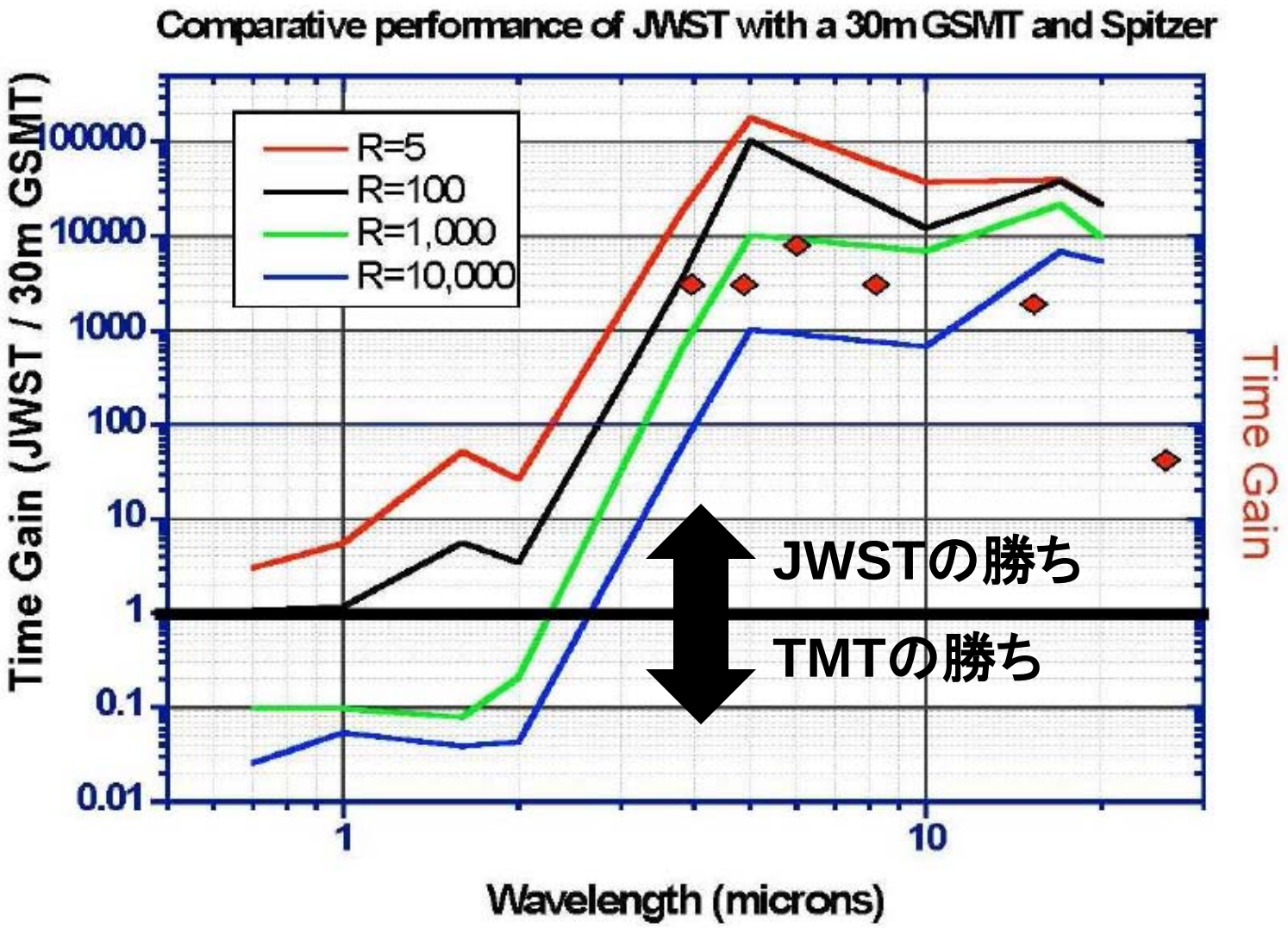
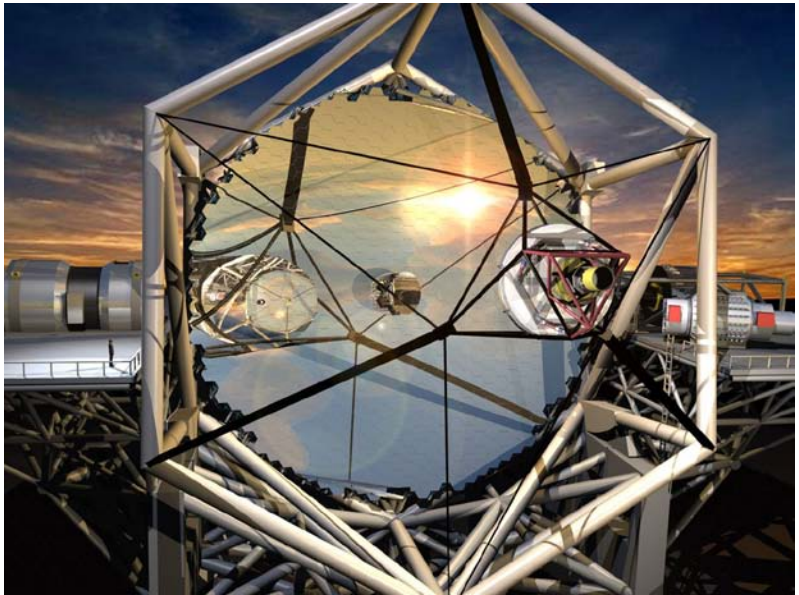
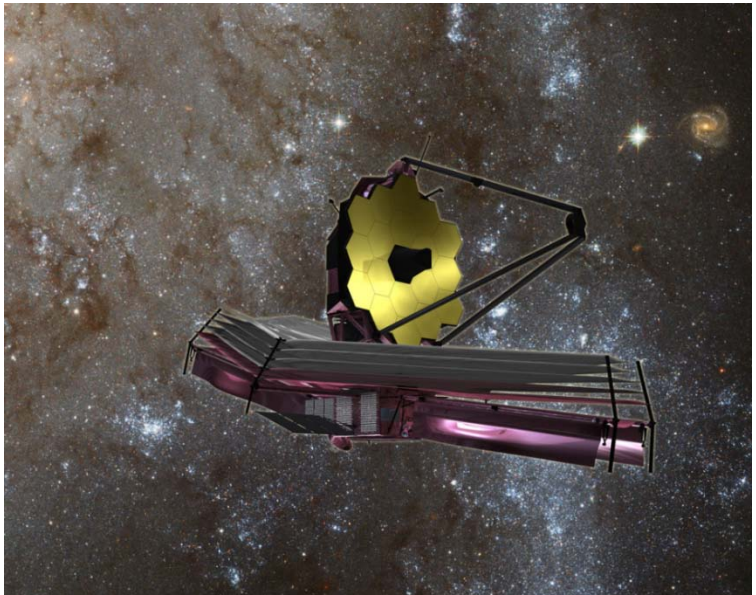
vs. JWST



TMT advantages

- **High spatial resolution** 0.015arcsec
  → more detailed structure
- **High spectral resolution** R~100,000
  → more accurate physical measurements
- High sensitivity in optical (0.3-1um) over wide FOV(>10')
- Short response times for ToO
- Flexible and upgradable





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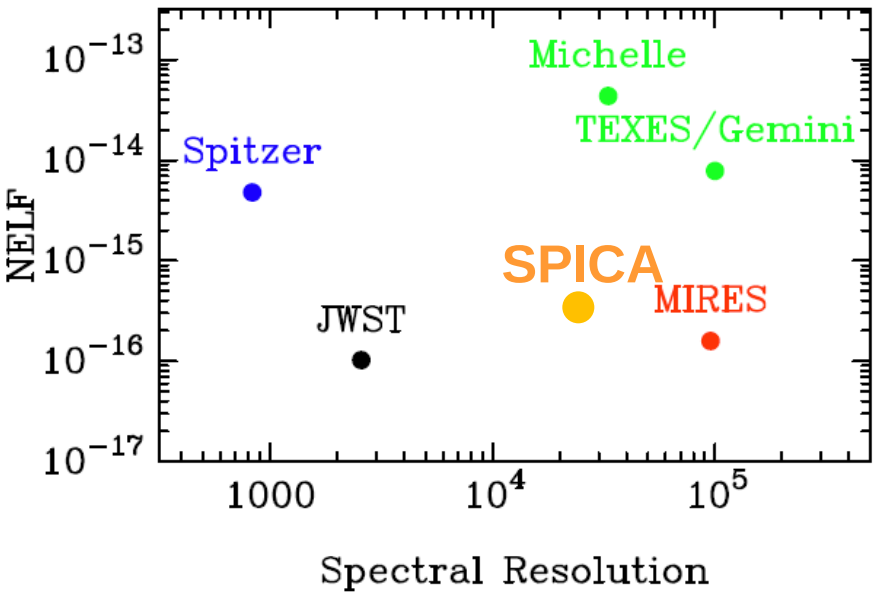
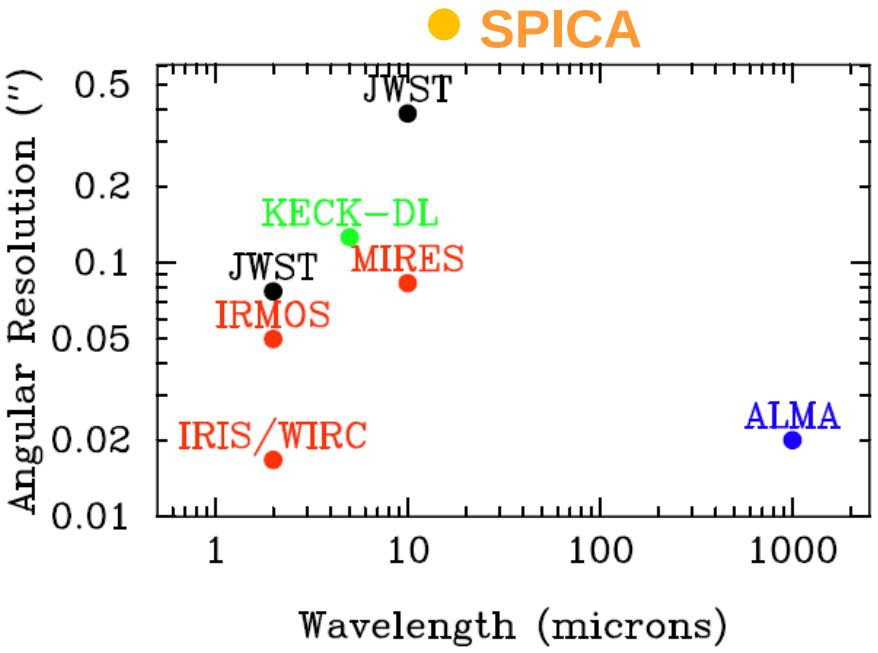
Synergy w/Space-IR and ALMA

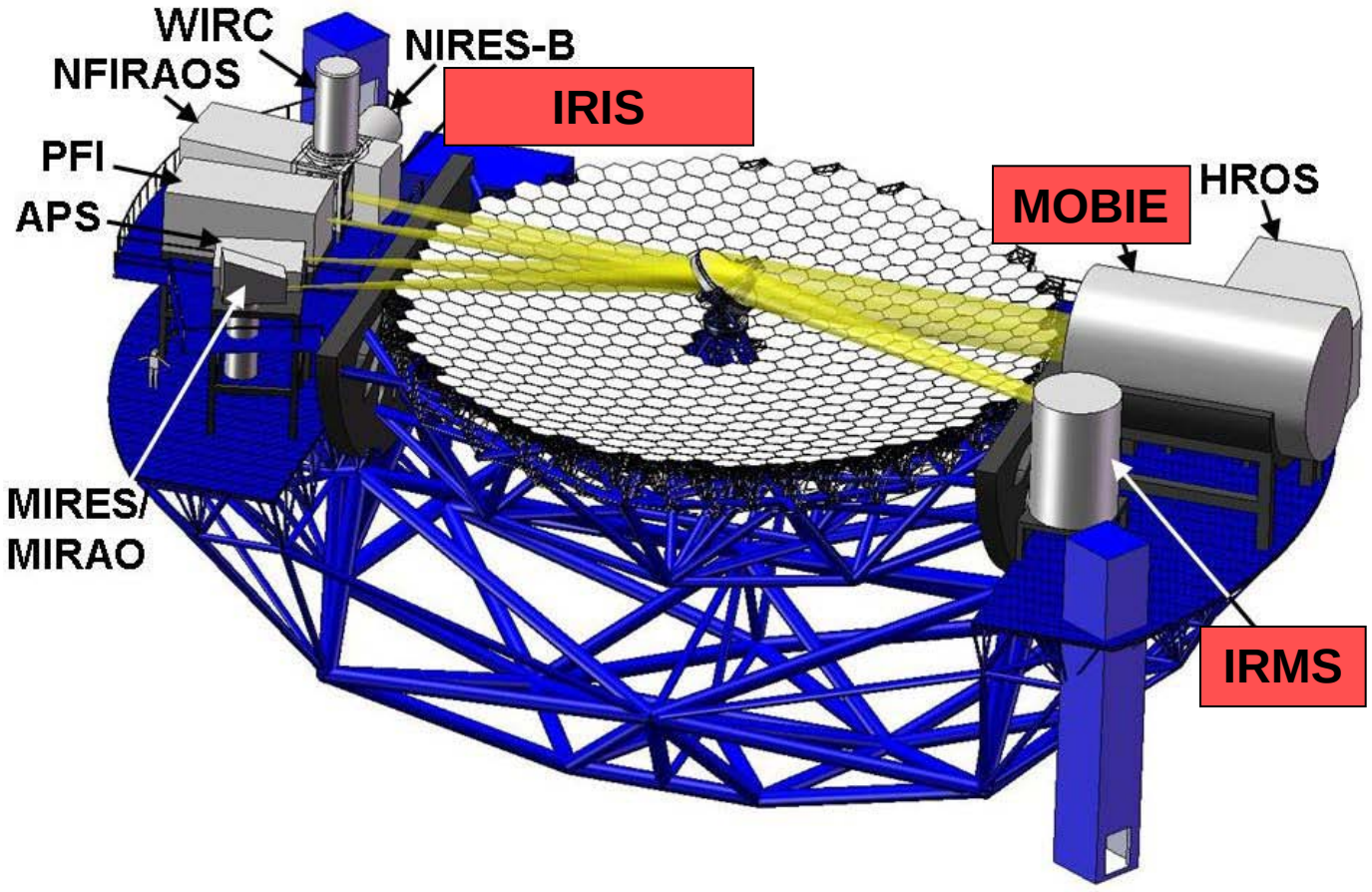




- MIR域でJWSTより2ケタ程度高い波長分解能
- MIR域でSPICAより1ケタ高い空間分解能
- NIR域でALMAとほぼ同じ空間分解能

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 (MOBIE)	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

TMT Instrument Lineup Summary

- **First Light Instruments** (FL前後までに必ず製作する。建設費から予算がつく)
  - **IRIS** ----- Keck/OSIRISの後継
  - **WFOS** ----- Keck/DEIMOSの後継
  - **IRMS** ----- Keck/MOSFIREそのまま

(以下はFL以降順次立ち上げられていくいわゆる2nd gen.装置。予算は運営費から。)

- **First Decade Instruments** (06年時にTMT装置候補として検討されたもの)
  - (NIRES) → J-NIRESとmerge
  - (MIRES) → J-MIRESとmergeしてMICHI
  - IRMOS
  - HROS
  - **PFI**
  - **WIRC**
  - …
- **J-TMT Instruments**
  - **(J-NIRES)** ----- Subaru/IRCSの後継
  - **MICHI** ----- Subaru/COMICSの後継
  - **(J-IRMOS)** ----- Subaru/MOIRCSの後継
  - **(J-HROS)** ----- Subaru/HDSの後継

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FL instrumentation

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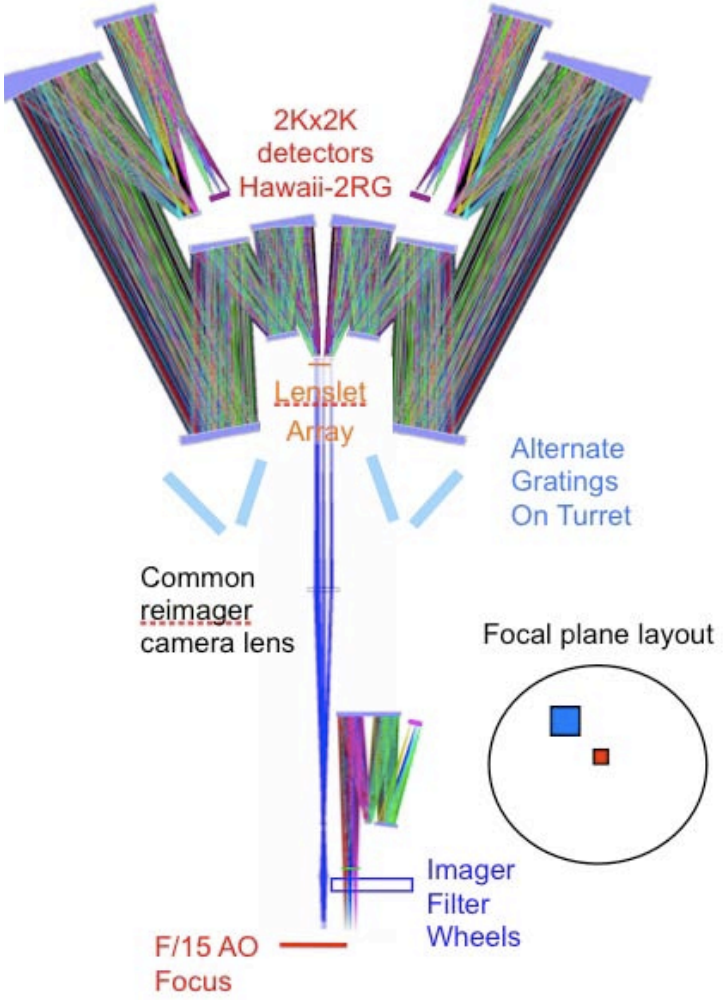
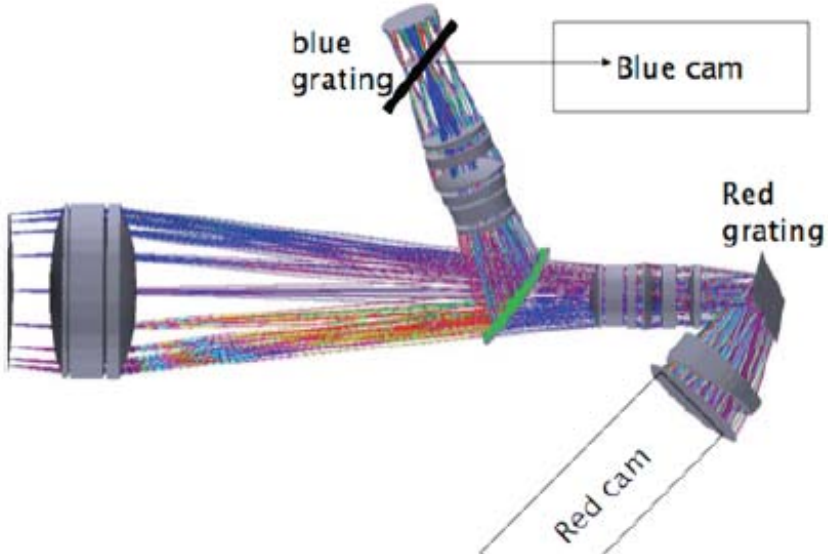
IRIS
Infrared imaging spectrometer

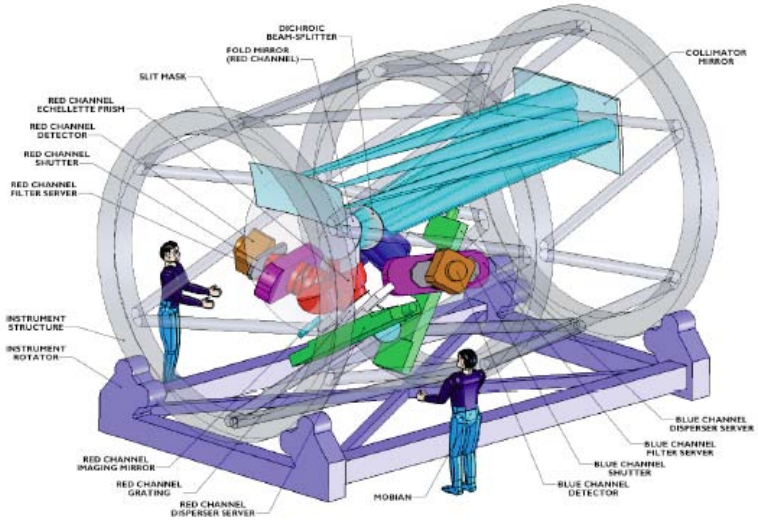
- 0.8 - 2.5μm
- R<4000
- Lenslet IFU
  - 128x128pix
  - 4 plate scales(4-50mas)
- Image slicer
  - 90 slices w/25 and 50mas
- FOV
  - < 2” IFU
  - DL imaging 17” w/4mas
- Imager: designed by Japan
- PI: James Larkin (UCLA)
  - Co-I: Anna Moore (Caltech), PS: Betsy Barton (UCI), Others: UCS , Japan,U.Tolonto



MOBIE
Optical MOS Spectrograph

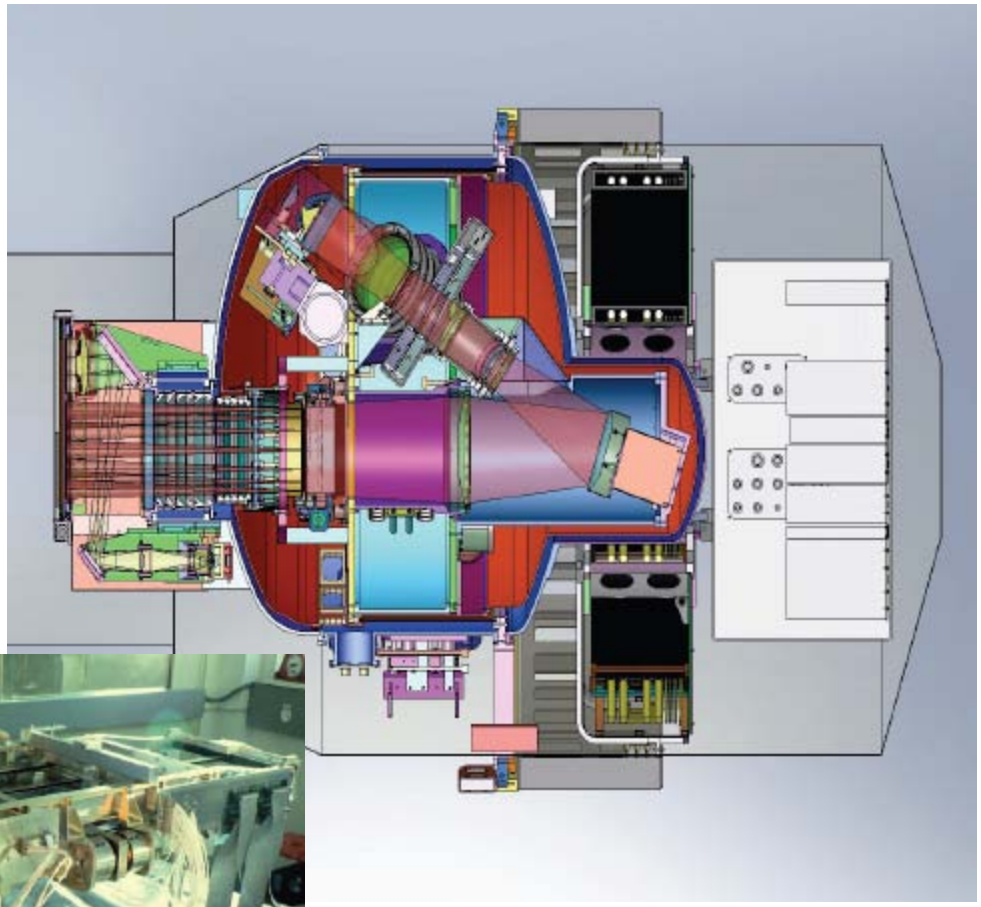
- 0.31 - 1.1 μm
- ~140 multiplicity over 9.6’
- R=300-8000
- 5 order Echellette
- Full wavelength coverage
- Low resolution mode for max. multiplex advantage.
- PI: Rebecca Bernstein (UCSC)
  - PM: Bruce Bigelow (UCSC),PS: Chuck Steidel (Caltech)

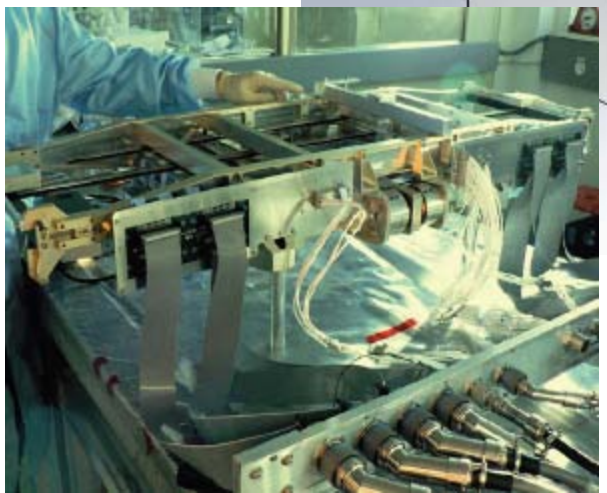




IRMS
Infrared multislit spectrometer

- 0.8 - 2.5 μm
- 2.3 arcmin FOV
- 0.06arcsec sampling
- 46 slits
- plate scale: 60 mas
- R=4600 over entire Y, J, H and K bands
- Clone of Keck/MOSFIRE
- Step 0 towards IRMOS





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J-TMT instrumentation

日本における活動: 装置開発

日本のTMT装置開発2本の柱

- **第一期観測装置の開発・製作に日本から参加**
  - IRIS: 装置デザインとサイエンスの検討
  - MOBIE/IRMS: 装置・サイエンスグループへの加入を検討中
- **第二期観測装置を日本主導で開発・製作・供給**
  - 可視高分散分光器(青木ほか) — HDS
  - 中間赤外低分散分光器 (岡本ほか) — COMICS
  - 近赤外高分散分光器 (小林ほか) — IRCS
  - 近赤外多天体分光器 w/IFU+MOAO (秋山ほか) — MOIRCS
  - 系外惑星直接撮像装置（松尾ほか） — IRD

Subaru instruments

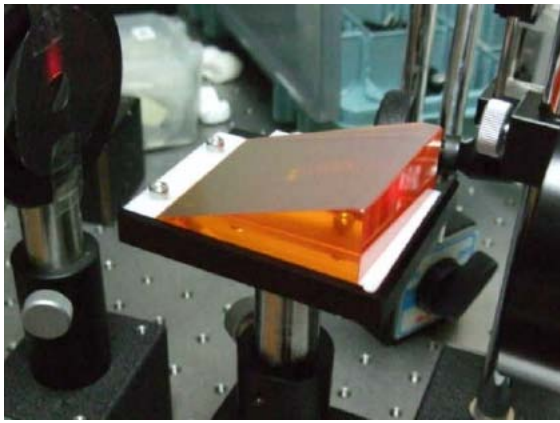
TMT用観測装置検討会

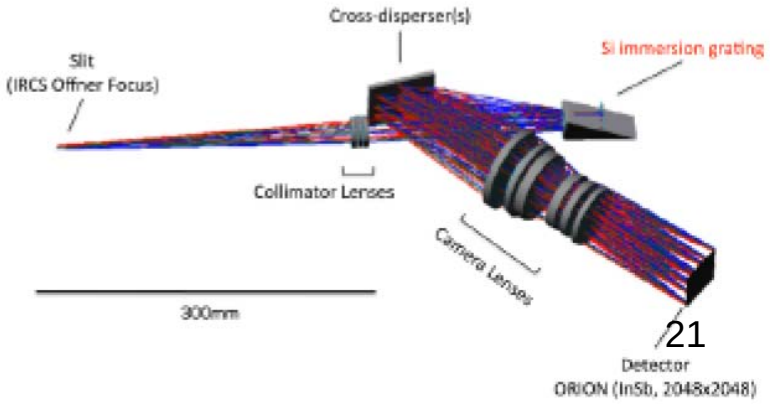
日本における活動: 装置開発

- 第2期装置開発スケジュール(TBD 予算獲得状況による):
  - 2008 May: TMT-J 装置提案募集（４装置の応募）
  - 2008-2011 :各提案の具体化とR&D。装置検討会
    http://jelt.mtk.nao.ac.jp/tmtinst/
  - TMTのCfPに対していくつかの概念設計をTMTへ提案
  - 2012-2014: TMT Design Review process
  - 2020-: コミッショニング、テスト開発開始

NIR High Dispersion Spectrograph

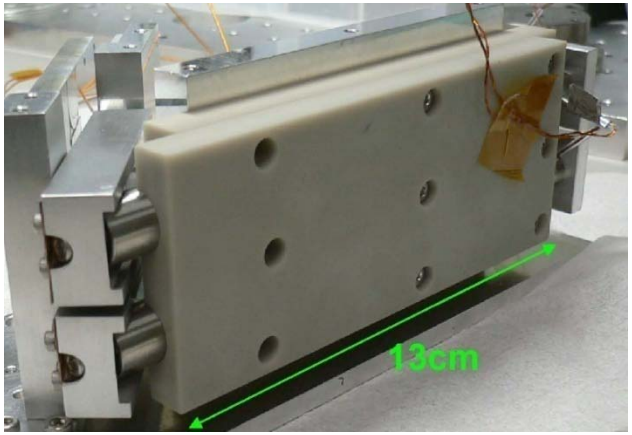
- R=40,000 (80,000max)
- Short arm (0.9-2.5um) [& long arm (1.9-5.5um)]
- Slit: 0.”02 x 0.5-1” (option: long slit ~30”, MOS?)
- J~20, H~20, K~19.5 (10σ) R~50,000, 1hr
- Key sciences
  - IGM at 2.5<z<6(metallicity), and z>6(reionization)
  - Atmosphere of exoplanets
- collaborations with UH NIRES team (Rayner/Tokunaga)
- Prototype WINERED and IRCS-HDU
  - ZnSe immersion grating
  - Molecular gas cell, Laser comb.
  - …

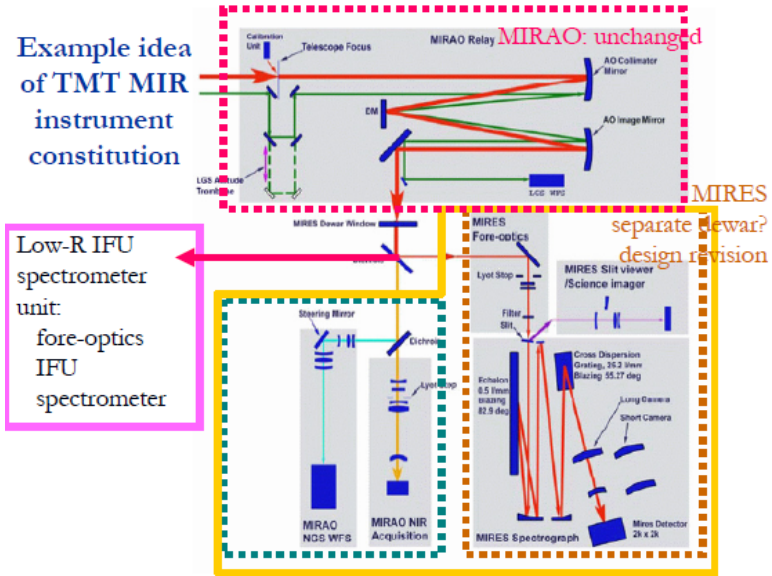




Mid-IR Imager & Spectrometer(MICHI)

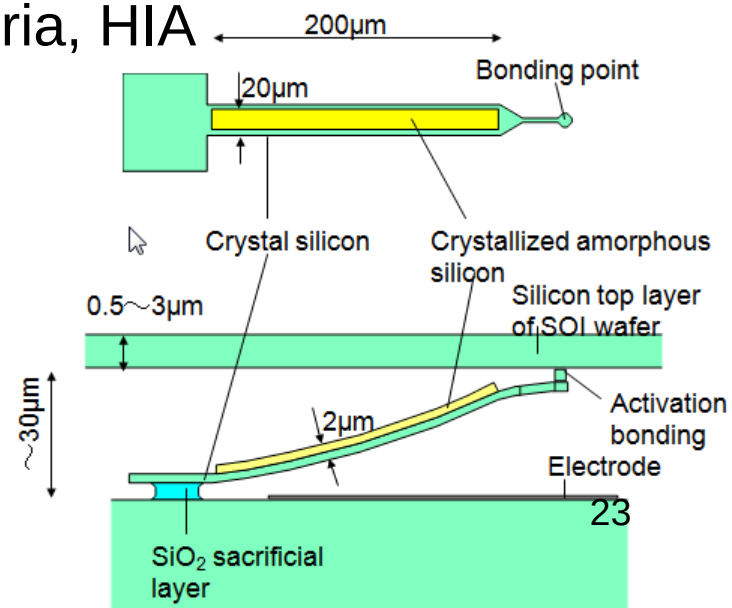
- Imaging & Spectroscopy in N- and Q- bands, FOV=30”-1’
- 0.”08@10um, 0.”16@20um w MIR AO
- R=100-100,000 @7.5-13.5um & 16-25um
- Options: IFU, polarimetry
- Key sciences
  - Dynamics and chemistry of PP disk
  - High-R spec. for bio-markers
- collaborations w/ UH & Florida MIRES (Tokunaga/Packham)
- R&Ds
  - Image slicer
  - Internal cold chopper
  - …





Wide field NIR IFU spectrograph

- NIR IFU spectroscopy of 10-20 objects simultaneously (cf. IRMOS)
- FOV 5arcmin w/MOAO, spatial resolution 0.”02@2um
- 20 IFU units, R=1,000-20,000
- Key sciences
  - Search for galaxies in formation-phase at 7<z
  - Physical properties of galaxies in growing-phase at 2<z<7
- collaborations w/ MOAO team of U.Victoria, HIA
- R&Ds
  - large stroke MEMS-DM
  - tomography algorithm
  - Fiber IFU
  - …



Optical High Dispersion Spectrograph

- They used to study an “all-purpose” spectrograph (e.g. HIRES/Keck, HDS/Subaru), but now they turned to investigate an “ultimate” spectrograph focusing on the accuracy and stability (e.g. CODEX, ESPRESSO)
- Key sciences
  - Detection of terrestrial exoplanets around solar-type stars
  - Direct measurement of cosmic expansion
- Required accuracy of radial velocity ～10cm/s (e.g. 1m/s accuracy is attained with ESO/HARPS)
- AIs (experiments with 1.8m telescope and Subaru)
  - Stabilities of inst. Temperature, air pressure, opt. alignment
  - Laser comb.
  - …

Second-Earth Imager for TMT (SEIT)

- Contrast requirements：10^{-8} @0”.01, 10^{-9} @0”.03
- Inner working area: 0”.01 (2l/D at 0.08μm)
- Pupil densified coronagraph(瞳関数変換レンズコロナグラフ)+ High-contrast visible imaging by pupil remapping (可視高コントラスト撮像装置)
- 0.8-1.2μm
- FOV 0.”1
- Key science: Direct detection of earth-like exoplanets
- Requires ExAO

TMT第２期観測装置候補

- 第２期観測装置をどう実現していくか具体的方針については未決定であるが、これまでの経緯を踏まえると将来的に海外の装置検討と競争しなければならない。
- そのためにも今から十分競争力のある検討・要素開発をする必要がある。
- First Decade Instruments （06年時にFLI同様TMT装置候補として検討されたもの。）
  - (NIRES) → J-NIRESとmerge
  - (MIRES) → J-MIRESとmergeしてMICHI
  - J-IRMOS vs. IRMOS (Caltech, U.Florida)
  - J-HROS vs. HROS (UC Santa Cruz, U.Colorado)
  - J-PFI vs. PFI
  - WIRC
  - …
- 天文台と大学が連携して実現へ。

Summary

- 30m TMTの特徴を活かした高空間・高分散観測。
- 3つの第1世代観測装置は既に決定。
- 第1・2期観測装置の開発・製作に日本から参加
- 日本独自のサイエンスケースは？
- みなさまのご支援お願いいたします。

- 現時点での装置サマリー
- http://optik2.mtk.nao.ac.jp/~kashik/tmt/inst_summary_07262010.pdf
- http://optik2.mtk.nao.ac.jp/~kashik/tmt/TMTinst_NK_07262010.pdf

www.tmt.org

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