低散乱軸外し望遠鏡の高コントラスト観測と近赤外高分散分光器ESPRIT開発の現状

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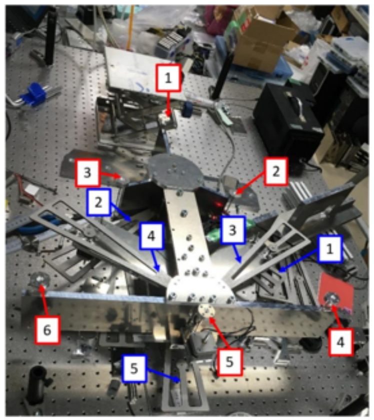
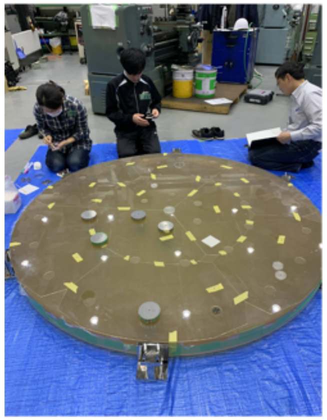
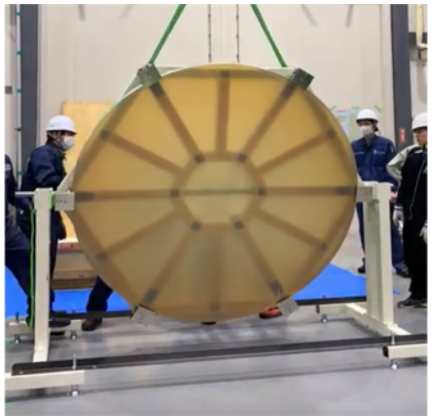
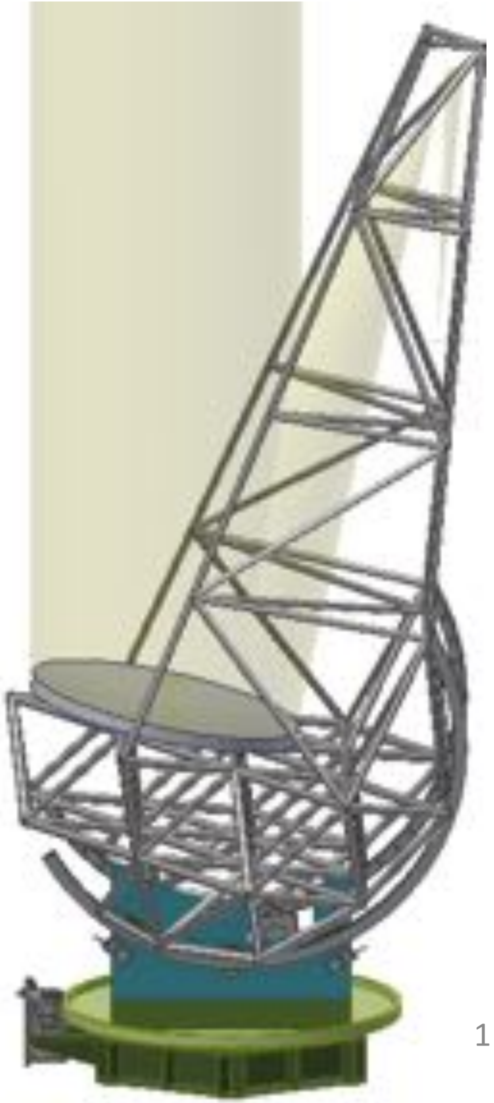
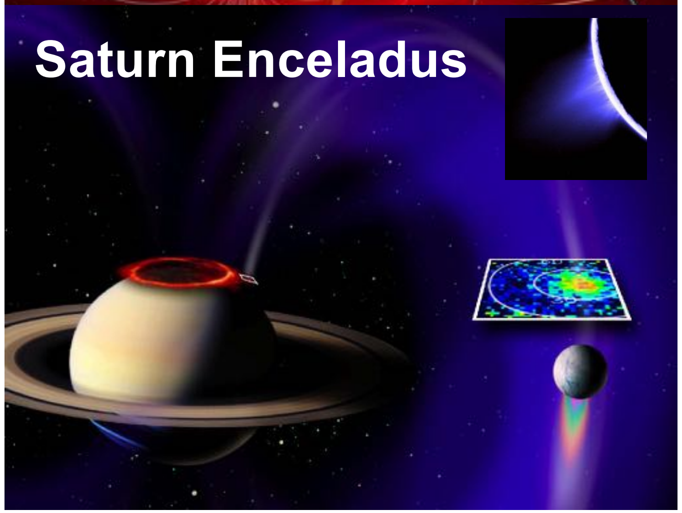








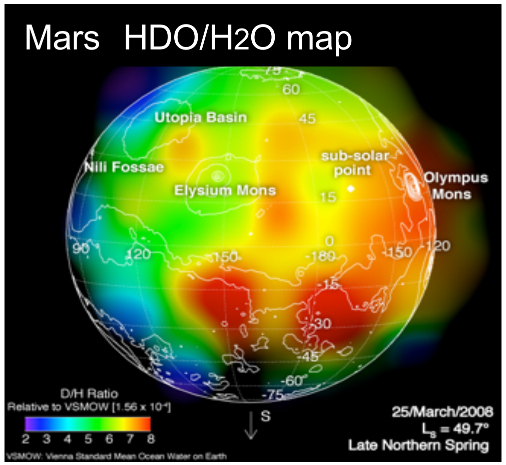
Introduction: Aim and targets

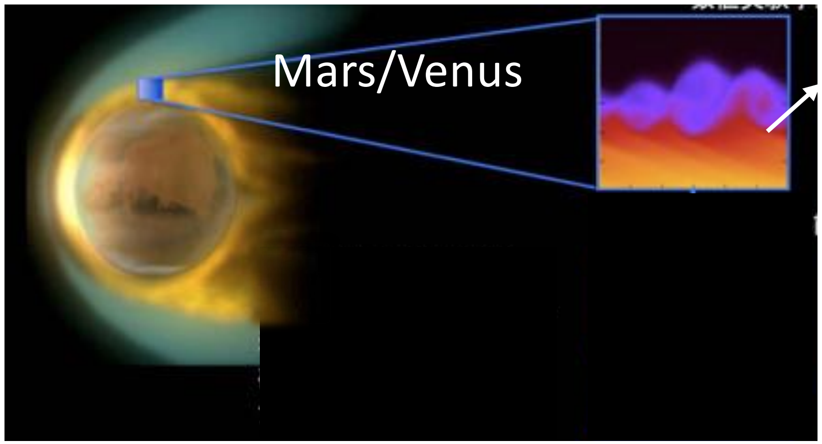


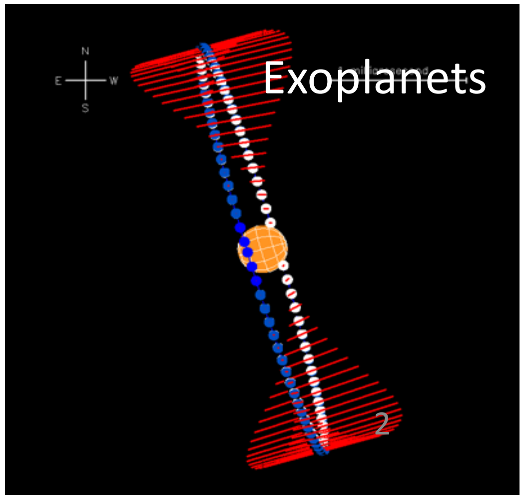
Why is high-contrast observation with high-resolution spectroscopy necessary?

→ <u>To detect faint emission surrounding a bright object</u>

- ✓ Emissions of volcanic-origin gases from satellites of Jupiter and Saturn
  - e.g., Io, Europa, Enceladus
- ✓ Exosphere and escaping neutrals and ions
  - e.g., Martian and Venusian exosphere
- ✓ Exoplanetary atmosphere

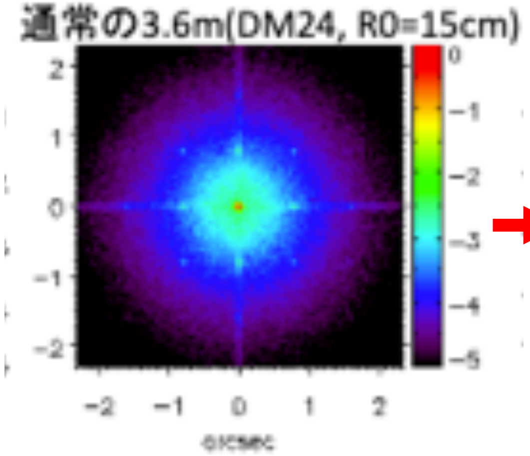




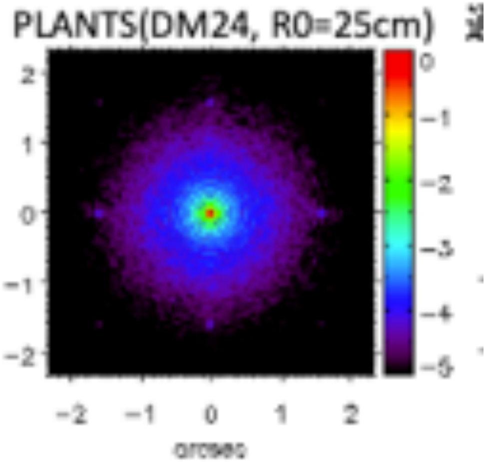


High-contrast performance by the PLANETS telescope

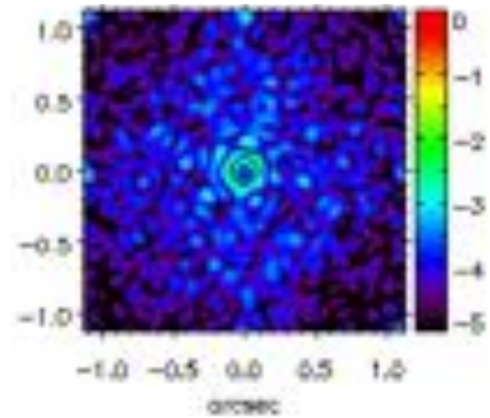
A. Conventional telescope(Φ3.6m)



B. PLANETS（Φ1.8m)



C. PLANETS（Φ1.8m)
+ Coronagraph



Low-scattering system with an off-axis 1.8m primary

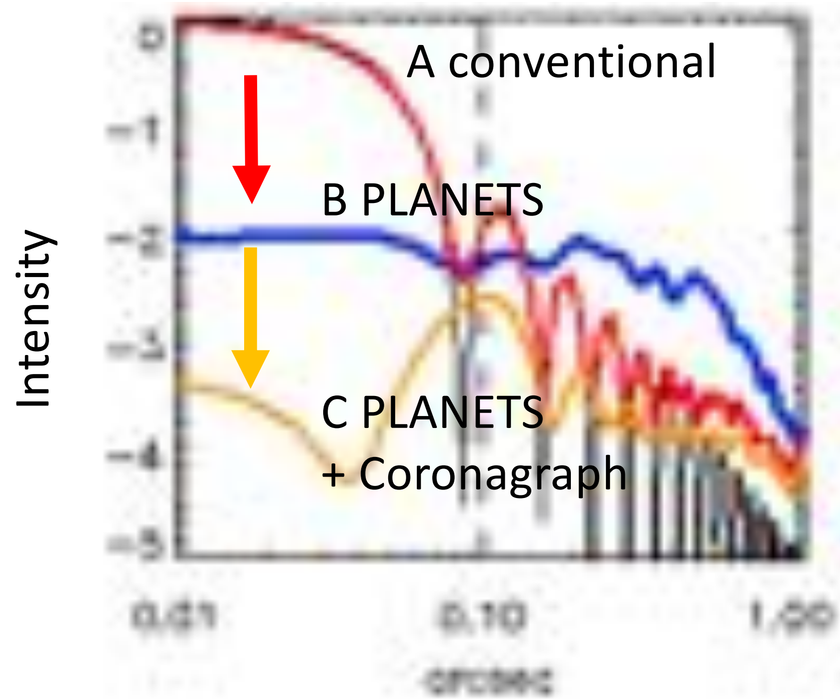
+

Adoptive optics by a deformable secondary mirror to compensate atmospheric turbulence

+

Coronagraphy

High-contrast observation



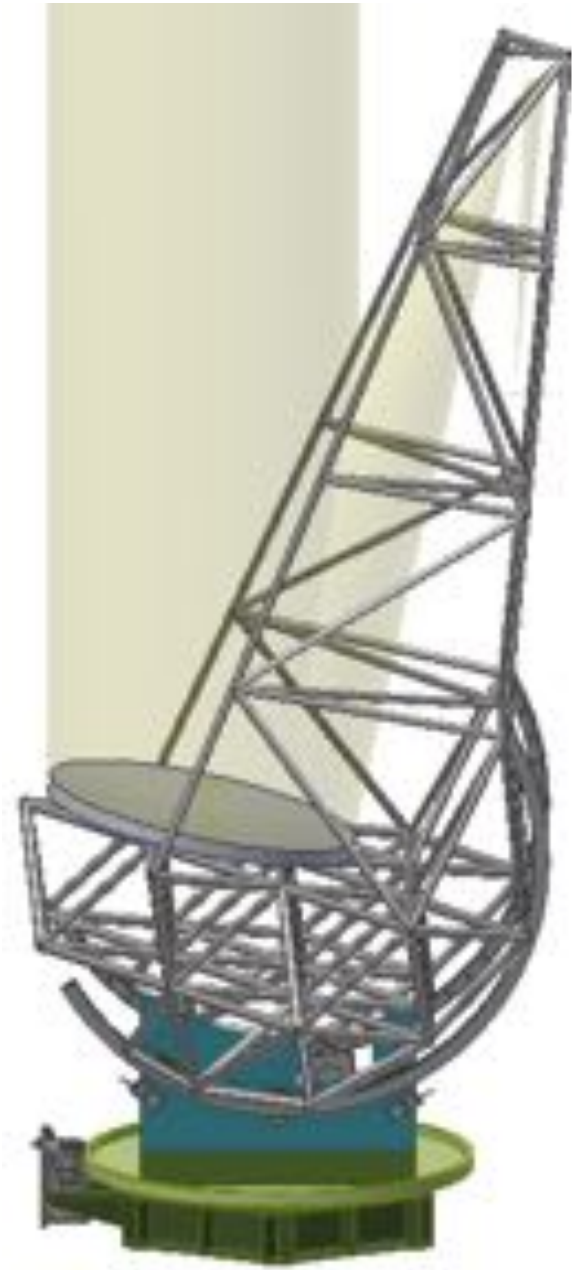
Distance from main object surface

Key technologies of the PLANETS telescope

- ✓ Low-scattering and high-contrast optical system
- ✓ Coronagraphy
- ✓ Adoptive optics
- ✓ High-resolution spectroscopy in visible to mid-infrared range
- ✓ Fiber imaging/spectroscopy
- ✓ Monitoring capability
- ✓ Flexibility for TOO

↓

PLAENTS makes possible to observe faint emission near the bright main body (which is fainter by 10^{-5} to 10^{-7} than the main body) with sufficient SNR.



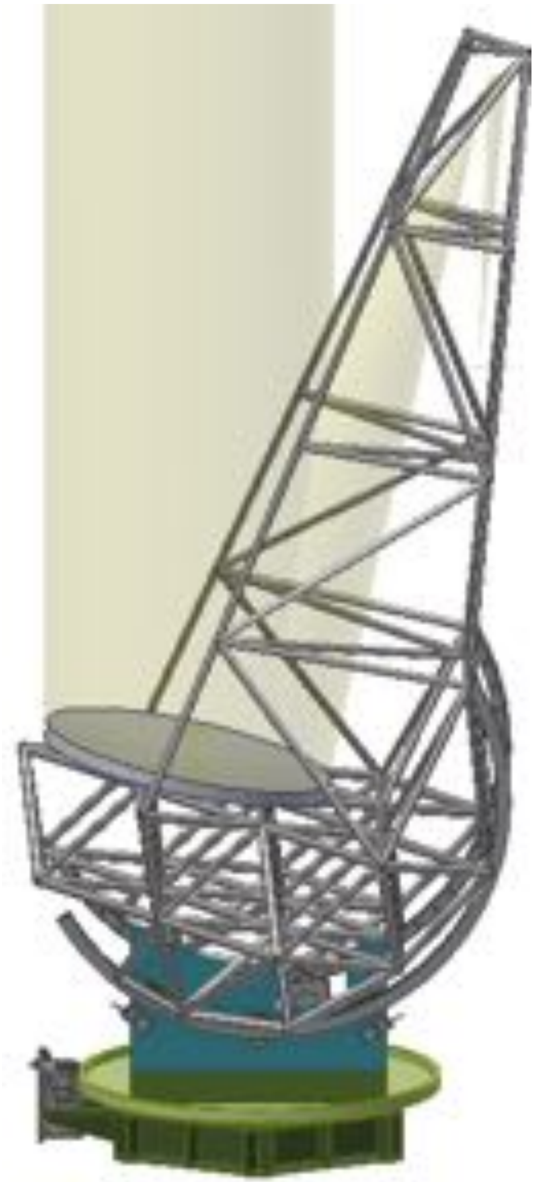
Specification of PLANETS

- Gregorian focus (50-100kg)
  - Fiber bundle (Vis. NIR)
  - Hollow cone fiber (MIR)

  FOV(TBR):　6 arc min (Gregorian)

  1 arc min (def. limted image)）
- (Nasmyth or Coude focus)
  - Cryogenic near and mid-infrared Echelle spectrometers
  - Guest instrument

M1: parabola, 1.86m
4.333m fl
M2: ellipse, 12cm
0.26m fl



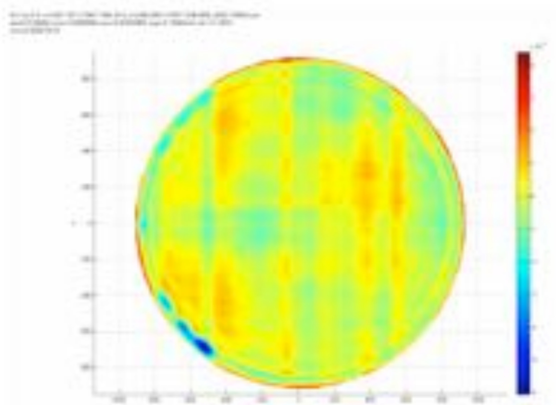
1.85m primary mirror
Ohara Clearceram Z-HS

Melting (Dec. 2010)

Φ = 1850mm, t=100mm

Shipping to Los Angels (May 2011)

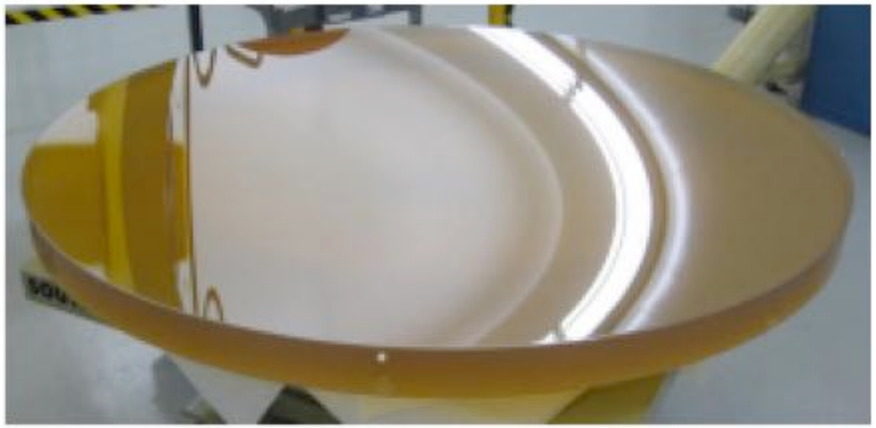
Rough polishing at Harris/EXELIS (July 2012)



10.9µm P-V
1.51µm RMS

Down-sampled data solutions
Average of 10 data collects
Zernike terms 1-11 subtracted.

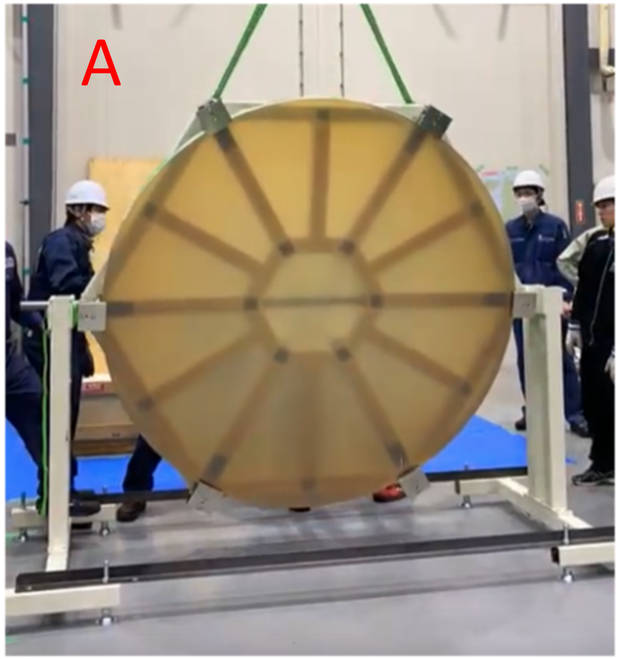
Arrived in Maui (June 2017)



Now at Tohoku Univ., Japan (Jan. 2020)

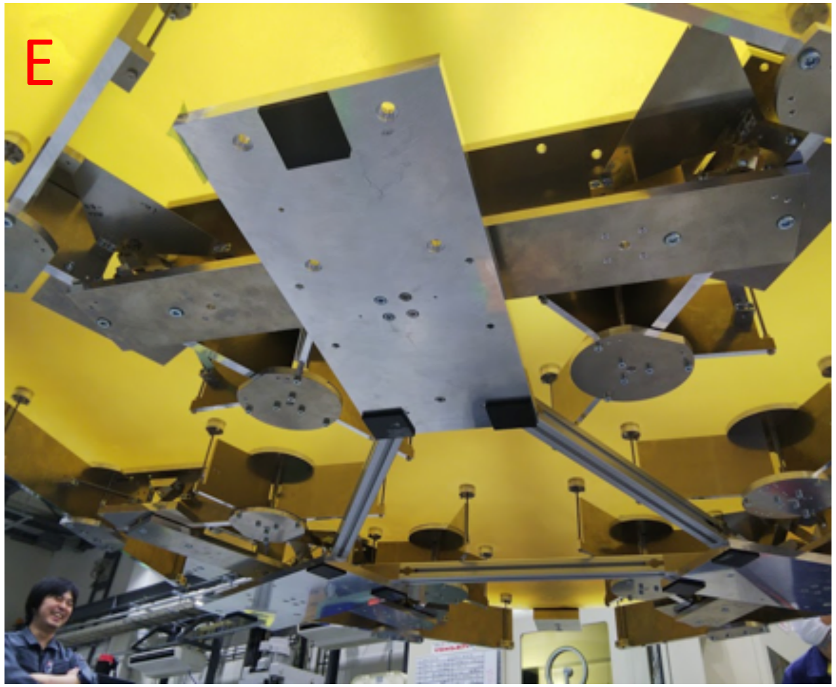
Primary mirror: current status

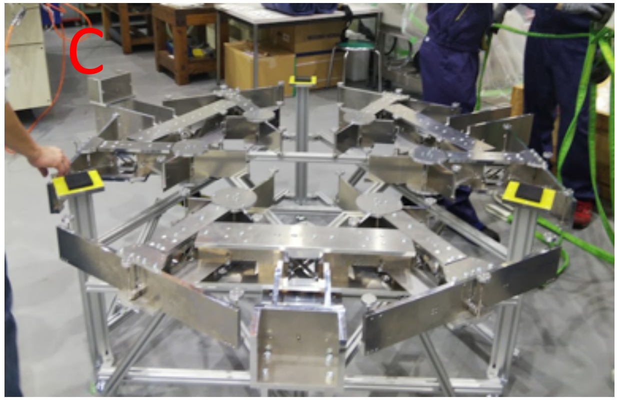
Jan. 2020　Transferred from Hawaii to Tohoku Univ.
Feb. 2020　Metal adopters for the mirror support were glued in the backside(A,B)
Feb. 2020-　Now developing the mirror support with whiffle-tree system（C, D, E）

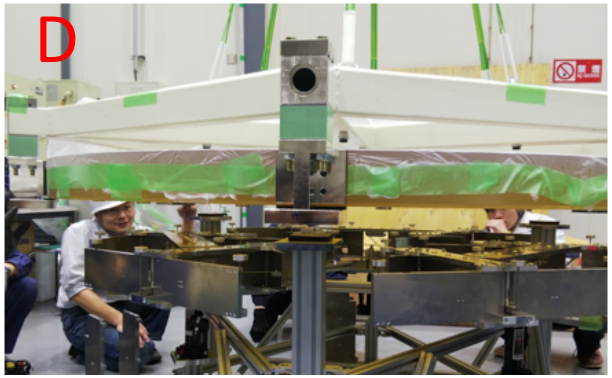


- We adopted the whiffle-tree support system and warping harnesses that is similar to TMT and 3.8m Kyoto Seimei telescope.

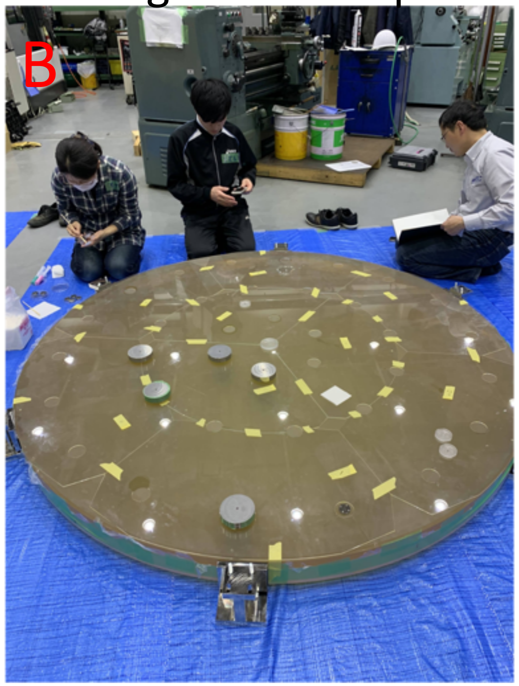
Whiffle-tree mirror support







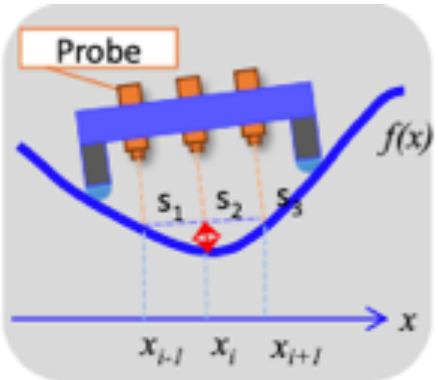
Gluing metal adopters



Final polishing of primary mirror

Dec. 2020 -

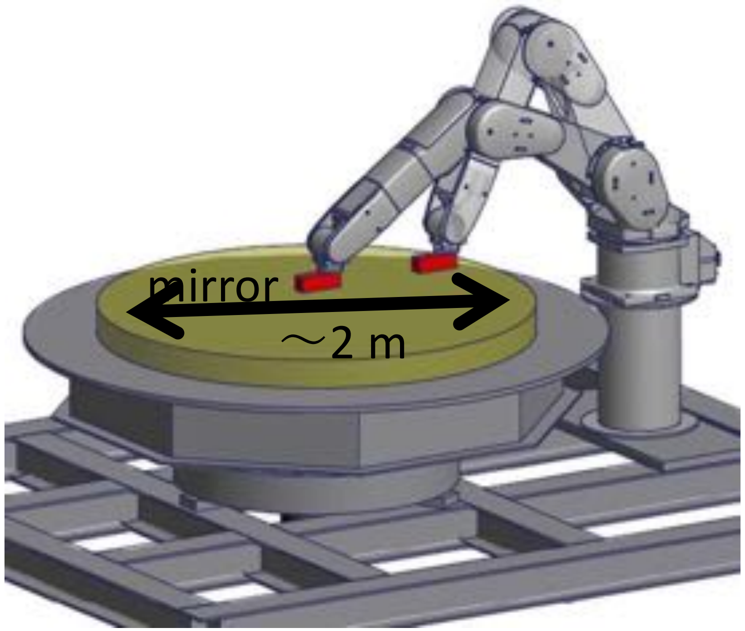
- Collaboration with Nagoya Univ. Kyoto Univ., and Logist-Laboratory (Astro-Aerospace)
- Polishing by a robot arm
- Metrology by 3-point drag probe



By the only robot-arm, polishing and measuring are executed on large and free form optics

(including flat and convex shapes).

- Dragging 3-point probe method
- Data stitching algorithm
- Flow of data processing
- Sample result

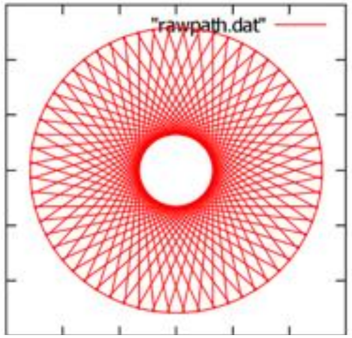


Metrology and polishing by robot arm

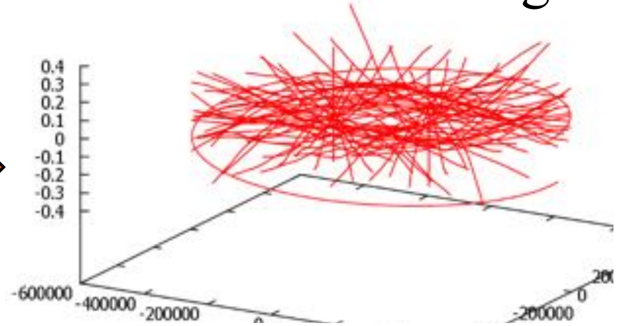
Achieved RMS<10nm for the secondary mirror of Seimei(Φ1m)
We require RMS<20nm for PLANETS primary mirror (Φ1.8m)

Dec. 2020 -

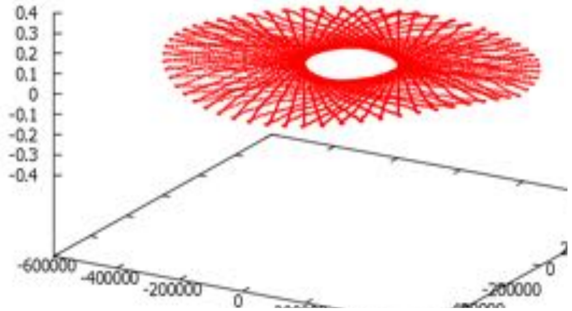
Measuring



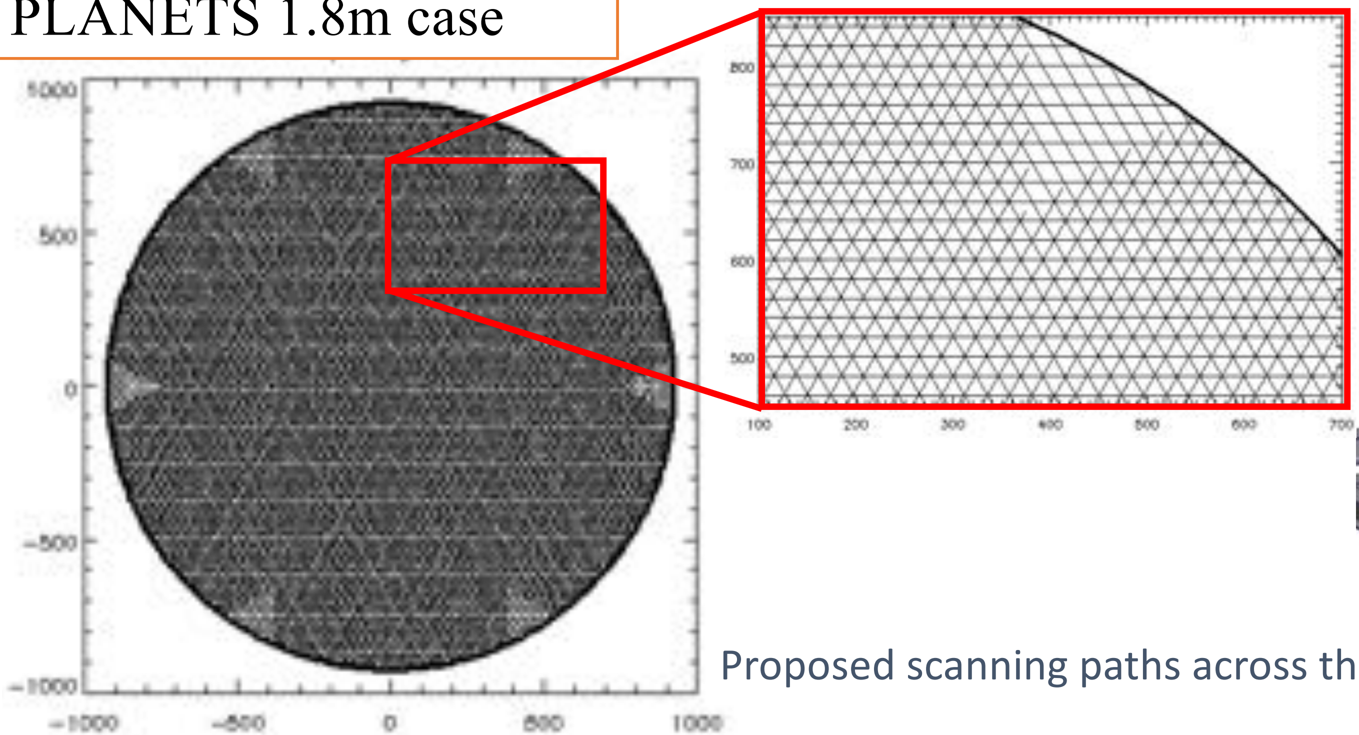
Data stitching



Stitching and Evaluation

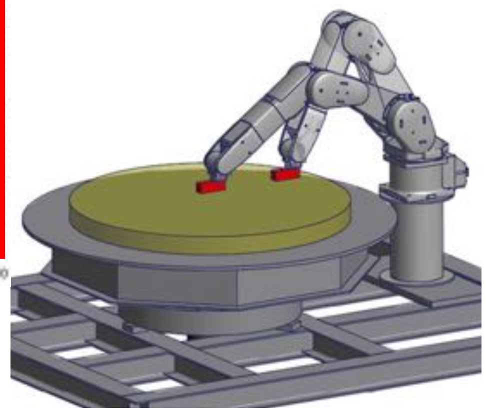


PLANETS 1.8m case



Proposed scanning paths across the PALENTS M1

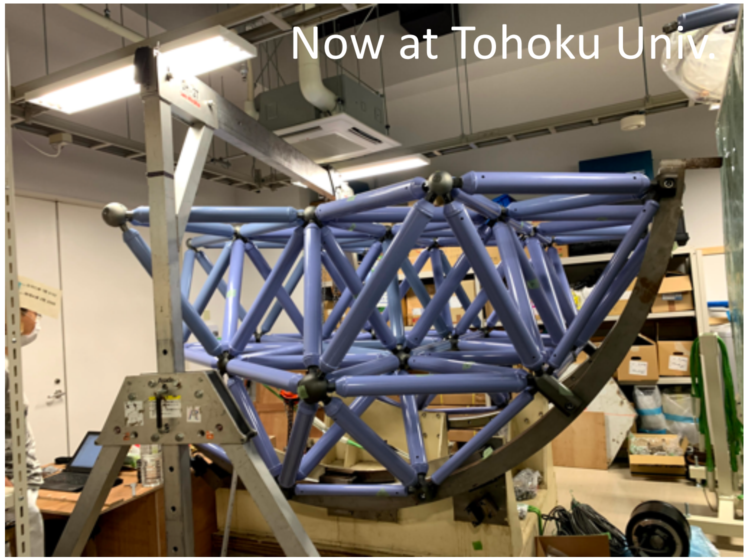
Correcting polish

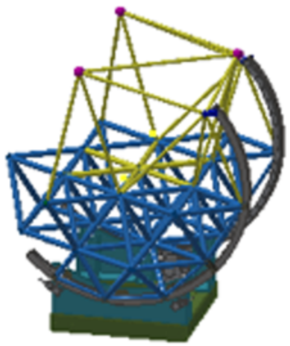


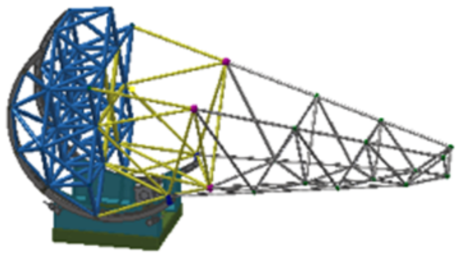
Telescope mount

March 2020 -

- Reuse of the technical demonstration model of the 3.8m Seimei telescope stored at Nagoya University
Lightweight and robust pedestal
Some parts (R-guides, encoder, servo motor, etc.) and upper truss are newly procured.
Fabrication has been started, and will be completed within a year.







Observation targets suitable for high-contrast capability of PLANETS

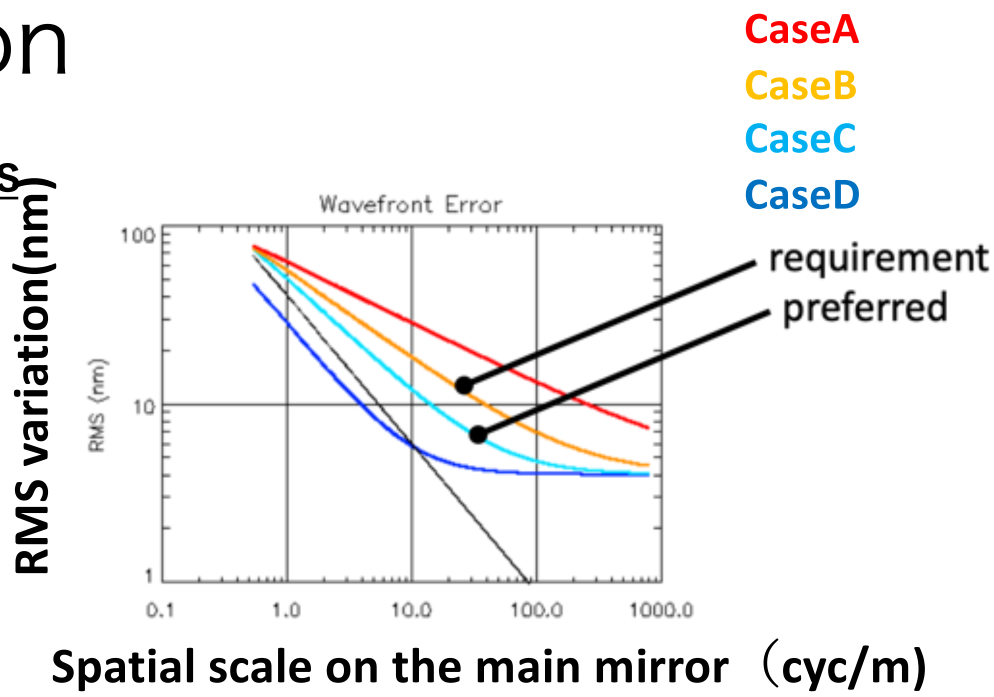
- Volcano on Jupiter’s satellite Io and Europa [Collaboration with Hisaki/Juno/JUICE]
- Martian ionosphere/exosphere and escaping gases [Collaboration with MAVEN/MMX/MACO]
- Mercury Na, Ca, K atmosphere [Collaboration with Beppi Colombo/Mio]
- Exoplanetary atmosphere
- Active small bodies like comets and asteroids

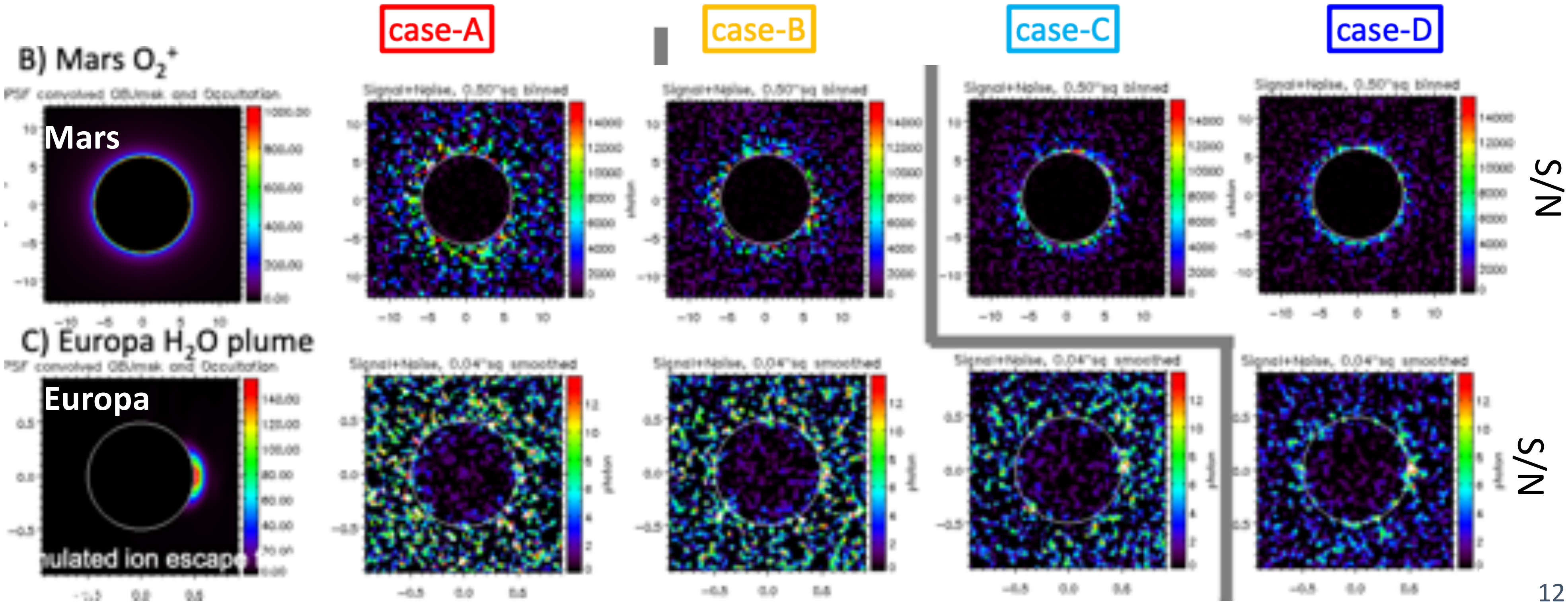
What are the required time and spatial resolutions?

Observation simulation

Four cases in polished mirror roughness

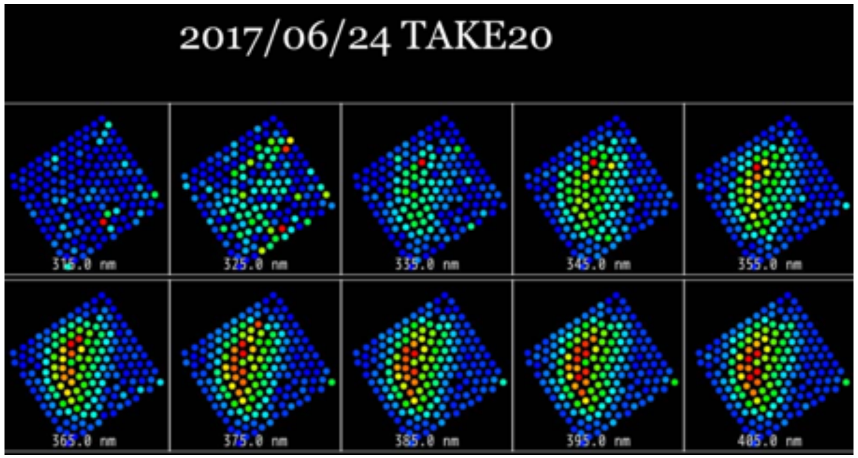
- Black: diffraction limit
- Orange: required （20 nm for 10- cm scale, 6 nm for 1-cm scale),
- Light blue：best case
- Micro-roughness < 4 nm （best case < 2 nm ）

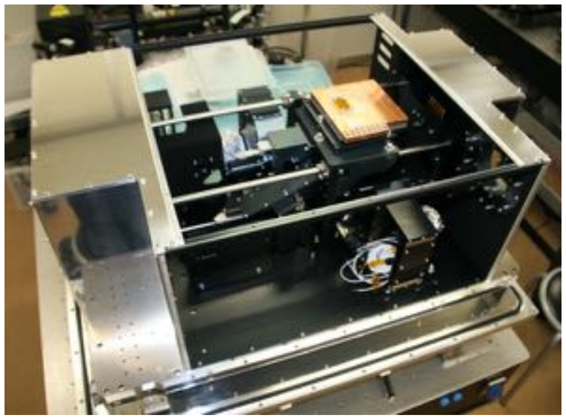
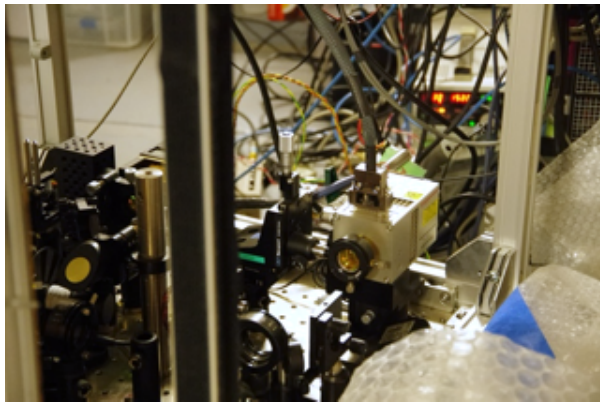




Instruments

Instrument	Spec.
Fiber : Visible Imager and Spectrograph with Coronagraphy (Vispec)	0.4-0.9µm, FOV~1' / R~70,000
Fiber : Mid-IR laser heterodyne spectrometer (MILAHI)	7-11µm, R ~ 10^{6-7}
Gregorian: DiPOL-2 (Polarization imager) (KIS)	B, V, R polarimetry (DoLP ~ $10^{-5\sim6}$)
Nas: NIR Echelle spectrograph (ESPRIT)	1-4µm, R ~ 20,000
Nas: Mid-IR GIGMICS (Nagoya U.)	7-12µm, R ~ 40,000

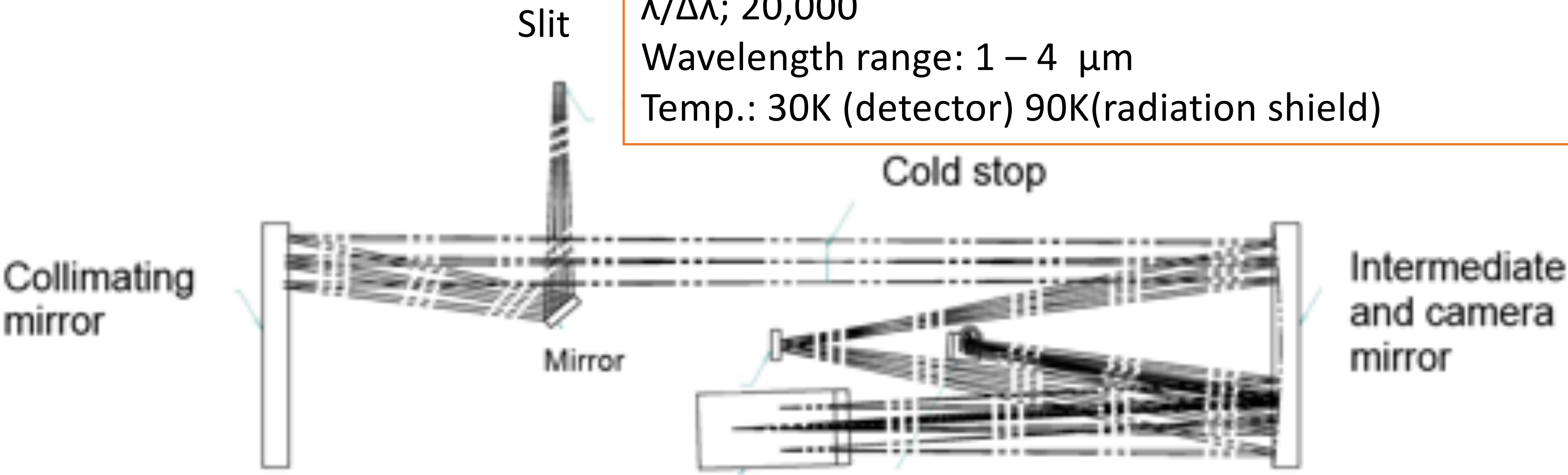


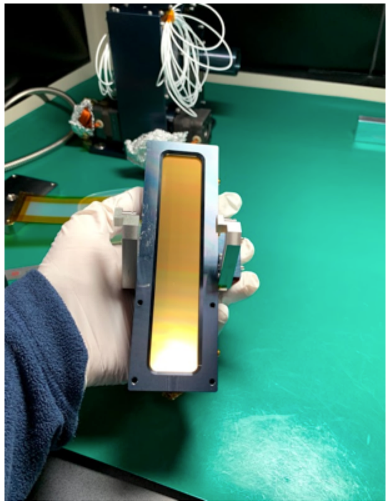



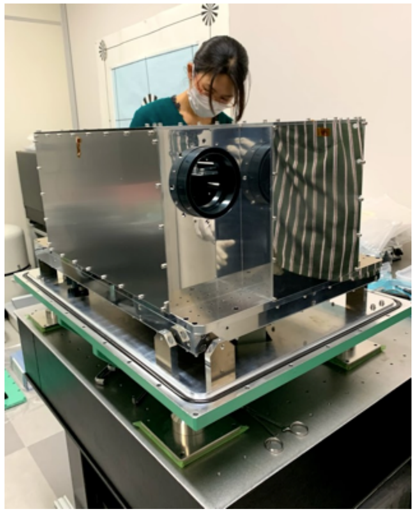
e.g., Near-infrared Ecelle spectrograph(ESPRIT)

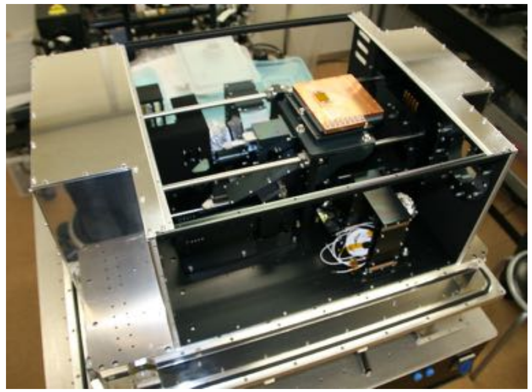
[on-going]

Detector; Raytheon InSb 256x256 array
Imaging and Echelle spectrograph
λ/Δλ; 20,000
Wavelength range: 1 – 4 μm
Temp.: 30K (detector) 90K(radiation shield)







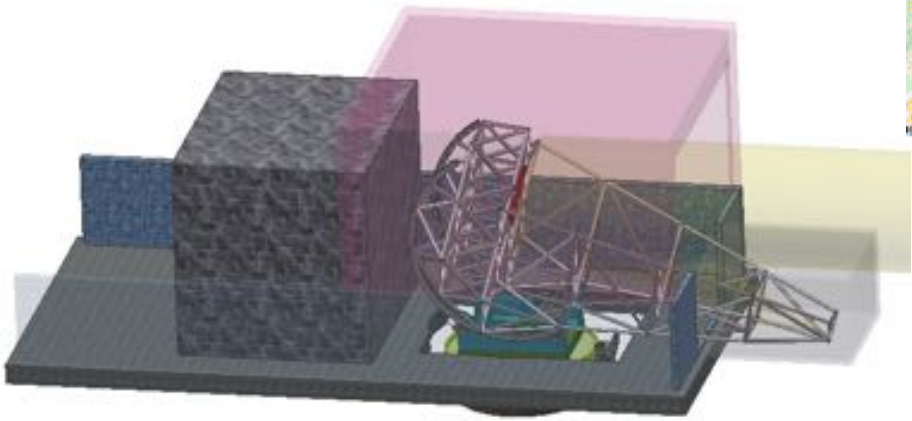


First light in Japan

2021 -

Fortunately, our Iitate observatory (37.6^{o}N, 2-hour drive from Sendai) is suitable to enclose the telescope structure and carry out the first light detection of stars.

Roll-off roof building in the Iitate observatory



Future plan at Haleakala

2021(TBR) -

- Haleakala High-Altitude Observatory, Maui, Hawaii(3040m, GLAT=20º 42.5' N, GLON=203º 44.5' W)
- Got permission (CDUP) for the renovation of Chicago building, University of Hawaii.
- In addition, alternative (and cheaper) renovation of old Ashra house is now under discussion.