TMT
Thirty Meter Telescope

JWST/TMT synergy/complementarity for solar system observations

ELT Science in Light of JWST

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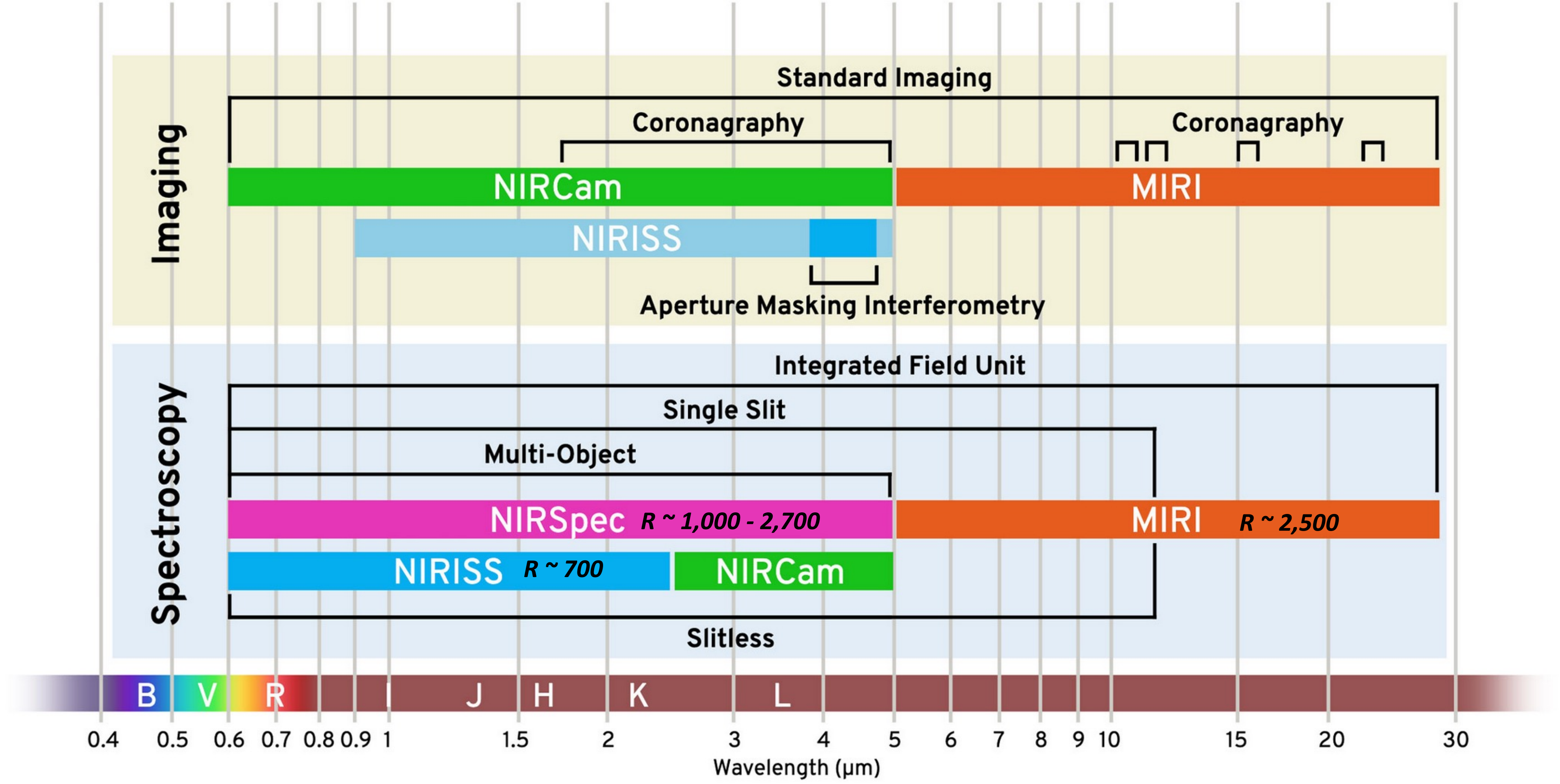
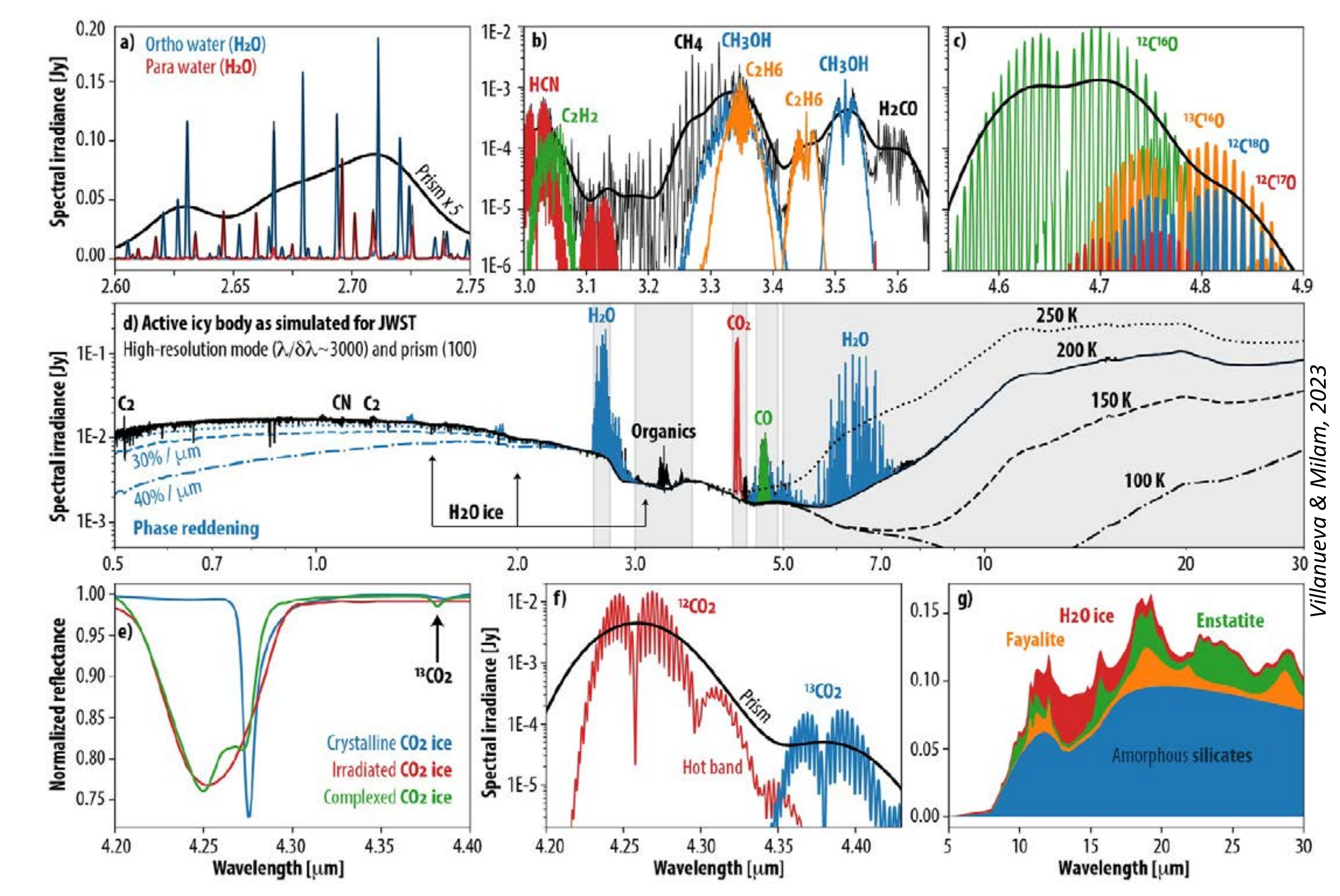
Dec. 12, 2023

JWST Instruments Capabilities



Instrument capabilities for solar system

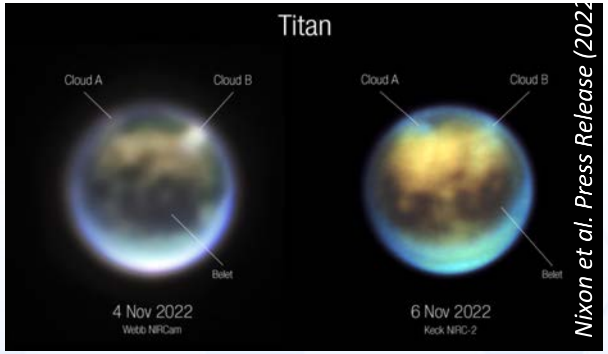
- JWST wavelength coverage, sensitivity, and spatial resolution (+ stable PSF), enables breakthrough investigations about:
  - Conditions for life/habitability within solar system
  - Evolution of primitive planetesimals (building blocks of larger bodies)
  - Water and organics transport to inner regions of solar nebulae
- Gases, minerals, ices, have strong absorption features at these wavelengths

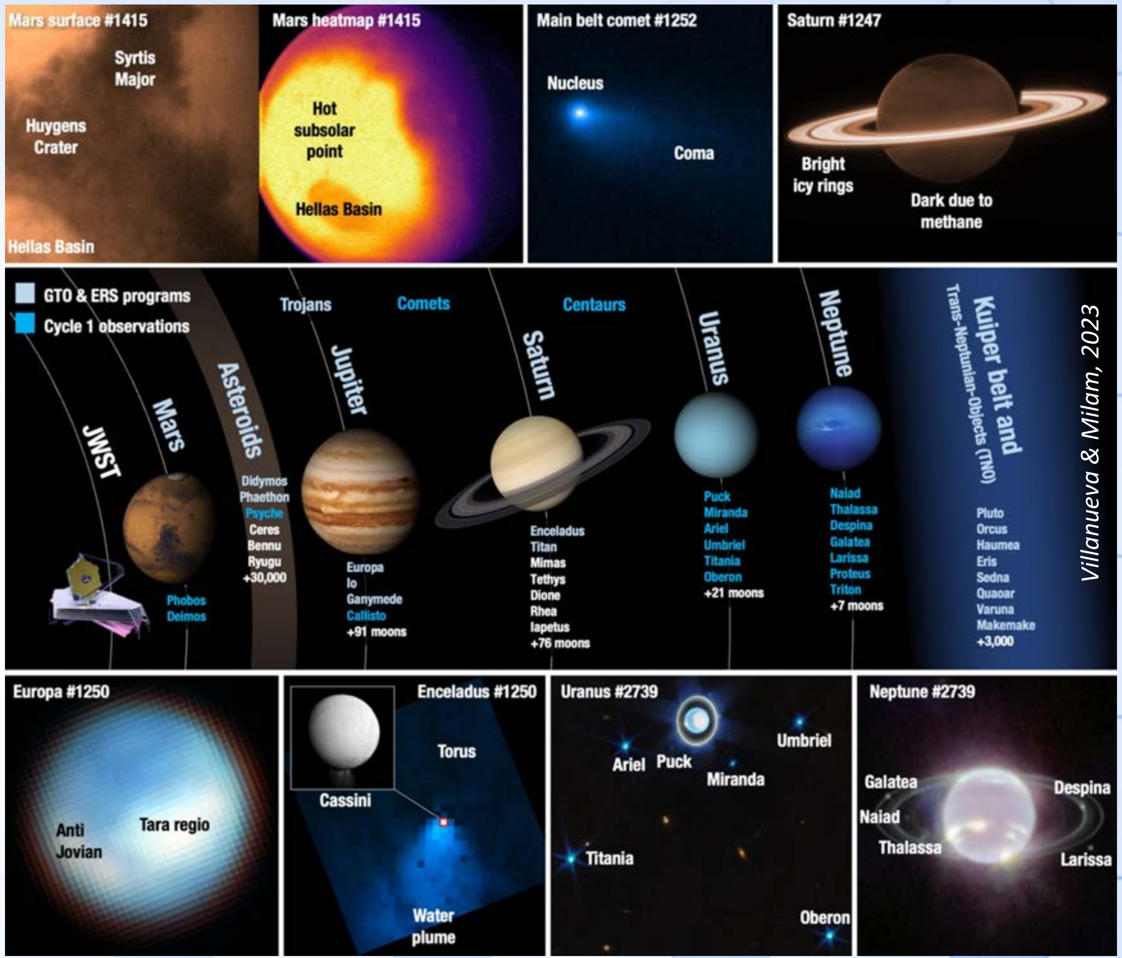


Villanueva & Milam, 2023

Highlights of early JWST results

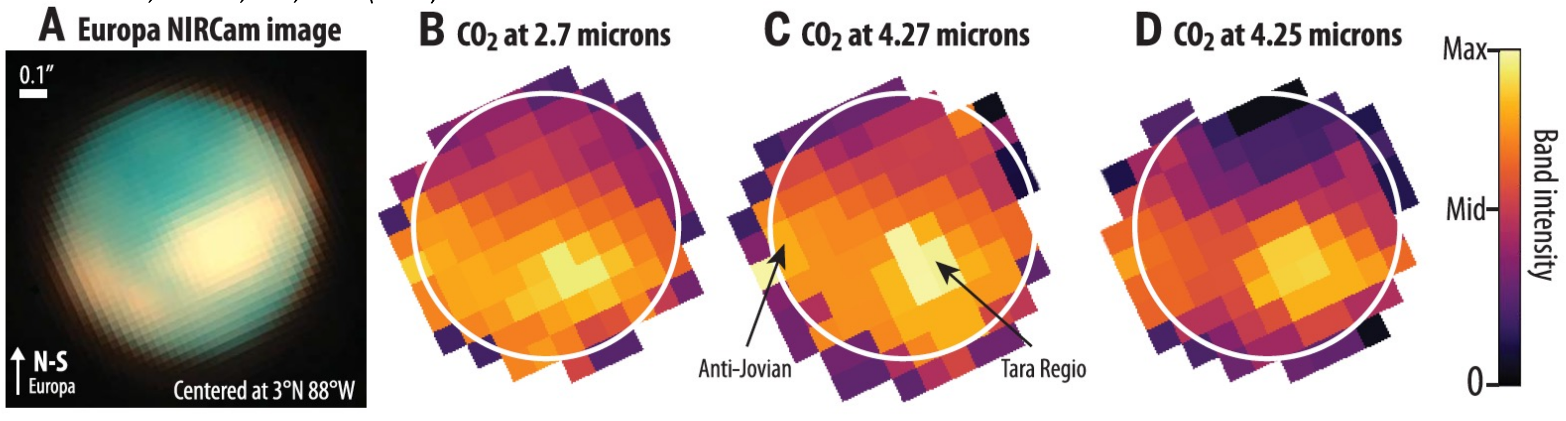
- The first ~1.5 years were prolific!
  - Many programs already started or completed, and myriad of targets observed: Saturn, Enceladus, Titan, comets, asteroids, KBOs, Centaurs, Mars, Jupiter, Saturn, Neptune, Uranus, etc
  - Follow-up of the DART target during impact showed capability for large tracking rates > 360”/hr (=100mas/sec, *current limit is set to 75mas/sec*).

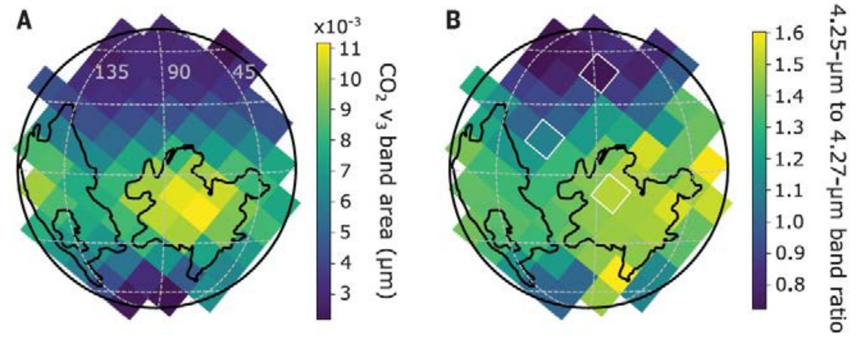




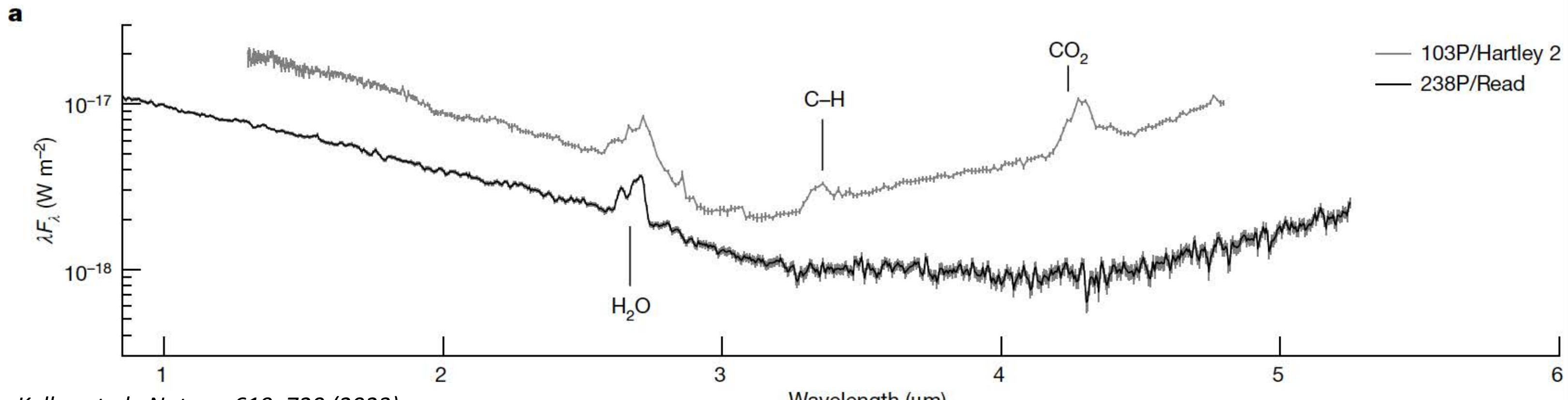
Selected results (i)

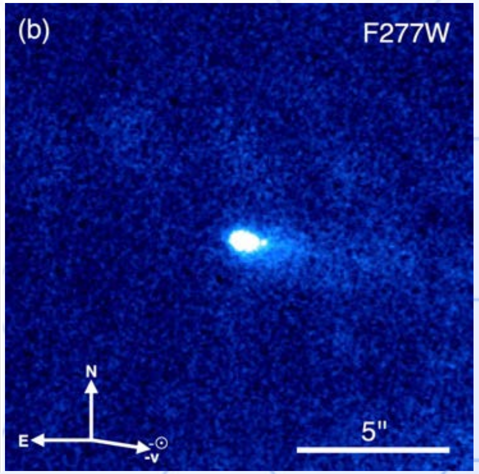
Villanueva et al., Science, 381, 1305 (2023)





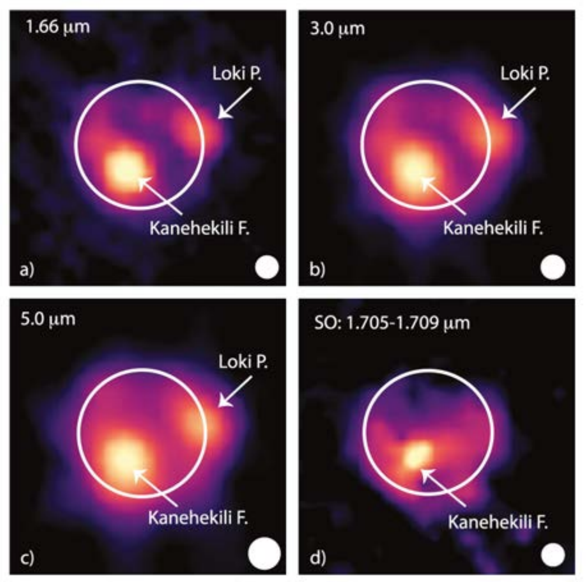
Trumbo et al., Science 381, 1308 (2023)



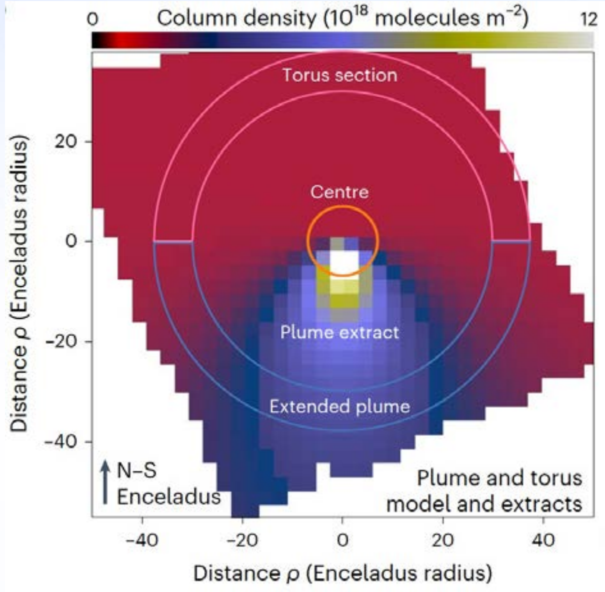


Kelley et al., Nature, 619, 720 (2023)

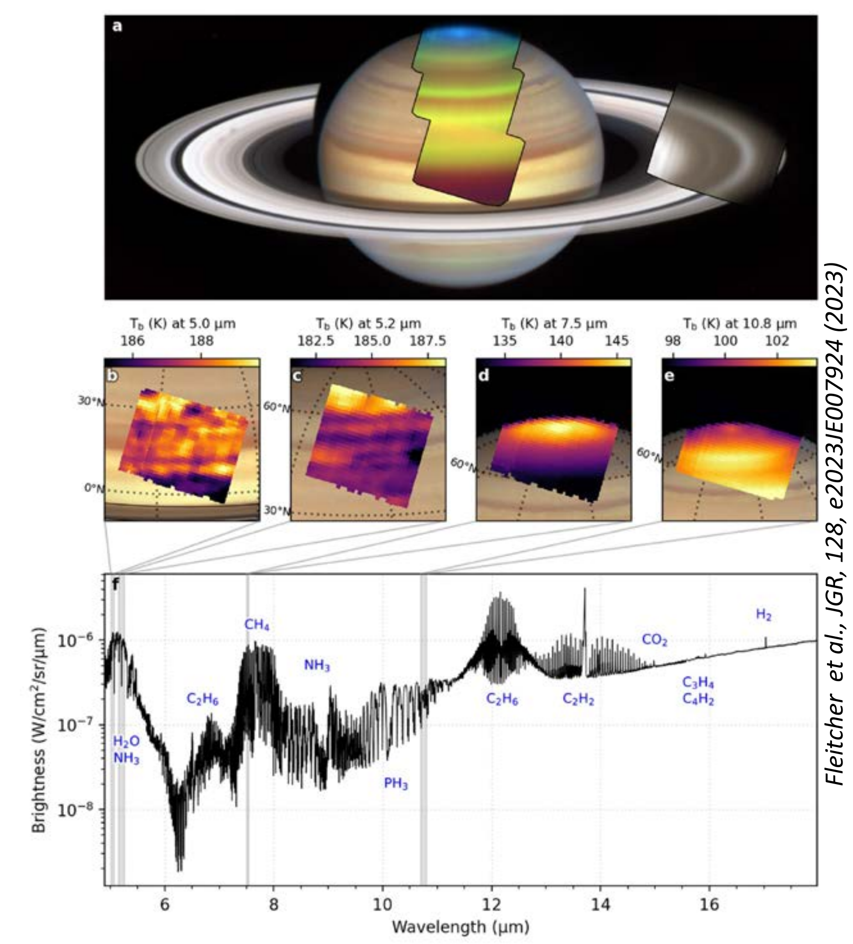
Selected results (ii)



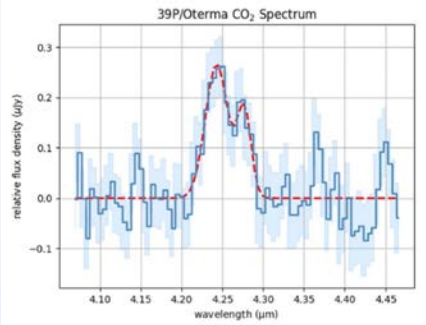
dePater et al., JGR, 128, e2023JE007872 (2023)

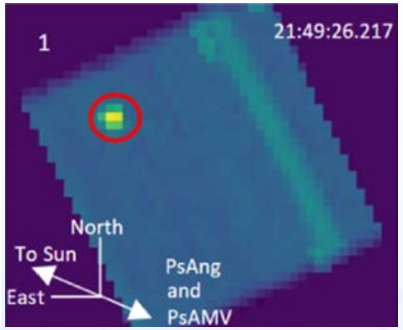


Villanueva et al., Nature, 7, 1056 (2023)



Fleitcher et al., JGR, 128, e2023JE007924 (2023)





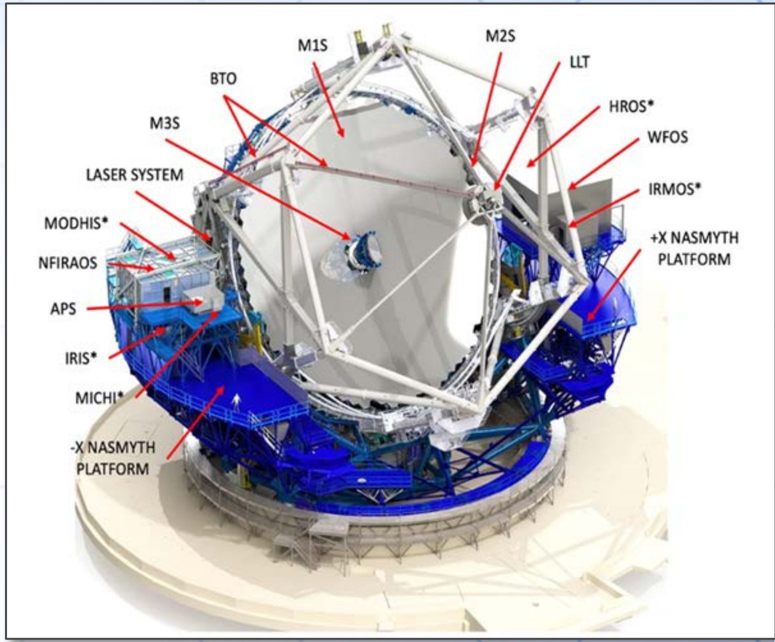
Harrington Pinto et al., PSJ, 4:208 (2023)

JWST < ---- > TMT: complementarity

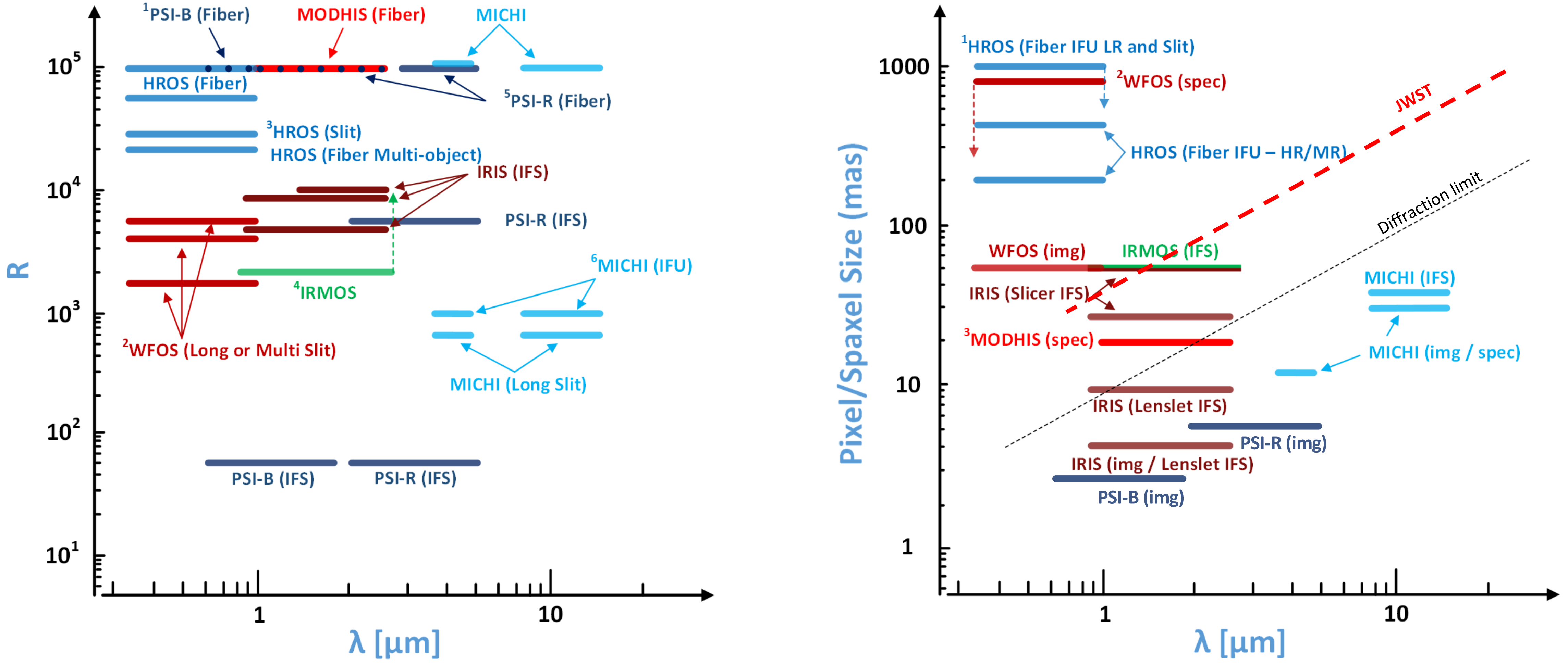
TMT
Thirty Meter Telescope

Instrument Capabilities (first-light + first-decade)

	Instrument and Description	λ Range (µm)	Spectral Resolution	Modes	Field of View
(Final design)	**IRIS**/Diffraction-Limited NIR Imager and IFS	0.84–2.4	Z, Y, J, H, K, bandpass filters and multiple narrower in band filters. 4,000 and 8,000 (some modes to 10,000)	NGSAO, LGS MCAO	Imager: 34" x 34" @ 0.004"/pix IFU with two slicing techniques Lenslet: 0.512" x 0.512" @ 0.004"/spaxel Slicer: 2.25" x 4.4" @ 0.050"/spaxel
(Preliminary design)	**WFOS**/Wide Field Optical Spectrometer	0.31–1.0	1,500 and 3,500 using 0.75" slits. Goal of 5,000 currently achieved and higher R available with narrower slits.	SL*	25 (8.3 x 3)-arcmin^2 500" total slit length (up to 60 targets with 8" slits) Imaging: full field @ 0.05"/pixel
(Conceptual design)	**MODHIS**/Multi-Objective Diffraction-Limited High-Resolution Infrared Spectrograph	0.95–2.4	> 100,000 with 30 cm/s (goal 10 cm/s) Doppler velocity precision	NGSAO, LGS MCAO	4" diameter field of regard (possible that this will be slightly larger)
	PSI/Planetary System Instrument	0.6–5.3	(fiber fed) High resolution R > 100K (IFS) Medium resolution R > 5,000 (IFS) Low resolution R > 50	ExAO	2–5.3 µm only: 1.2" x1.2" (low resolution) 0.15" x 0.15" (medium resolution)
	MICHI/mid-IR Imager, IFU and Spectrometer	3.4–13.8	Imager < 100, IFS 600–1,000, Spectrometer 120,000	MIRAO	Imager: 28.1" x 28.1" @ 0.027.5" mas/pix N band IFU: 0.175" x 0.07" (35 mas/spaxel)
	HROS/High-Resolution Optical Spectrograph	0.31–1	Single Object: 100,000 & 50,000 (fibers) 40,000 & 20,000 (slits) Multi-Object: 25,000	SL, GLAO	> 10" in diameter (single object mode) 10'–20' diameter (multi-object mode)
	IRMOS/IR Multi-Object Spectrograph	0.8–2.5	2,000–10,000	MOAO	> ten 3" IFUs deployable within a 5' diameter field



Science Capabilities

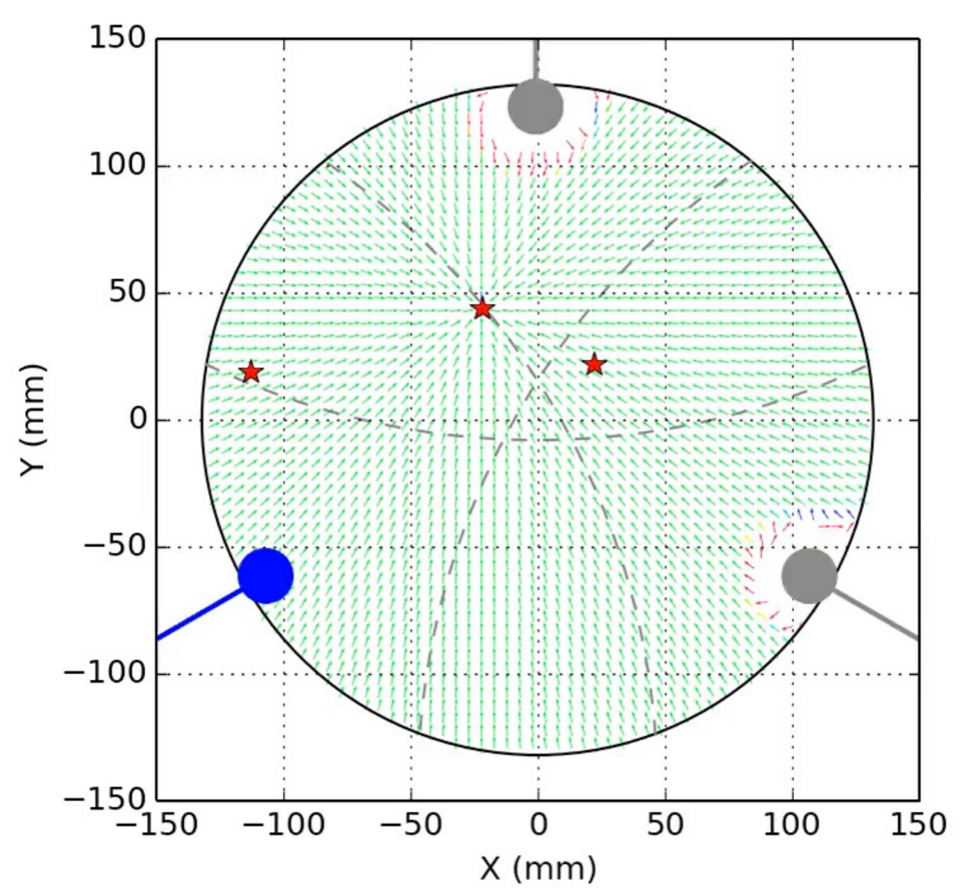


TMT Spatial Resolution for Selected Solar System Bodies

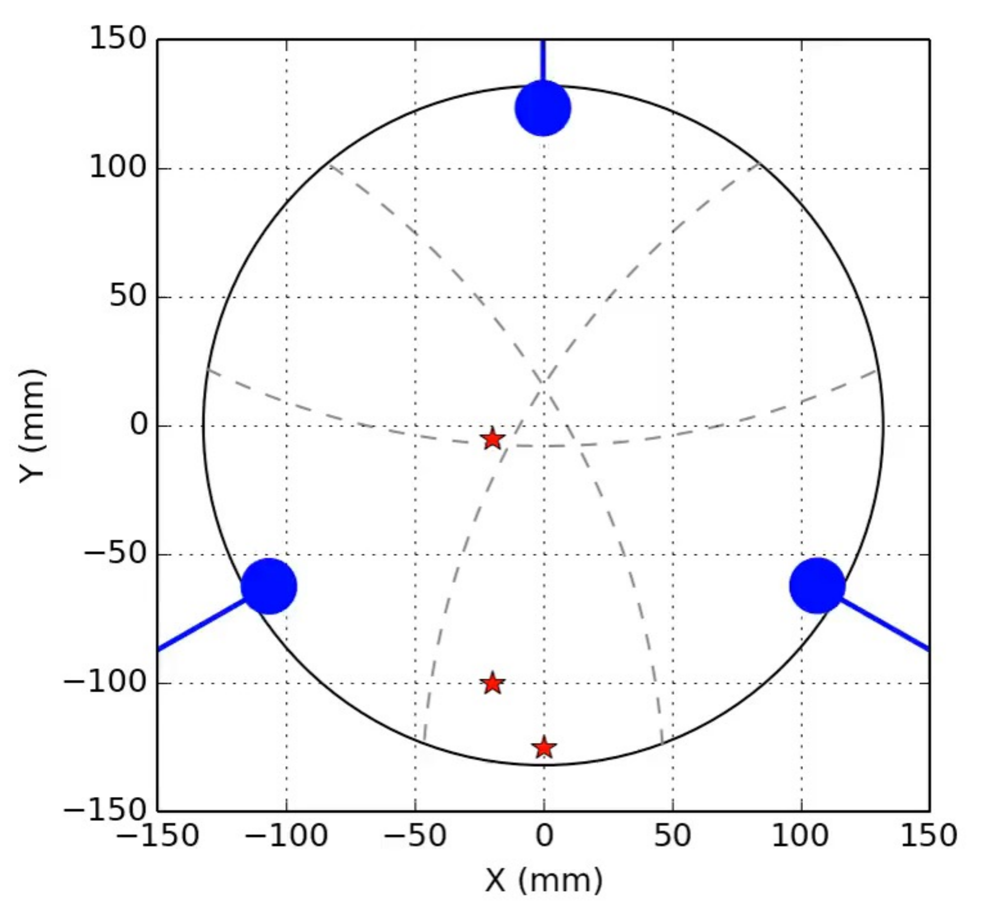
TMT spatial resolution at 1μm and at opposition for selected solar system bodies						
Target	Diameter (km)	Distance (in AU)	Angular diam. (")	Nb resolution elements across apparent diam.	Nb resolution elements across apparent surf.	Spatial resolution (km)
Ceres	952	1.63	0.81	130	17012	7
Pallas	545	1.29	0.58	94	8920	6
Io	3644	4.09	1.23	199	39442	18
Europa	3122	4.09	1.05	170	28951	18
Titan	5152	8.09	0.88	142	20156	36
Triton	2706	28.87	0.13	21	436	130
Chiron	220	15.96	0.02	3	9	72
Pluto	2390	34.05	0.10	16	245	153
Charon	1210	34.05	0.05	8	63	153
Mars	6780	0.64	14.55	2352	5531644	3
Jupiter	143000	4.09	48.23	7794	60740203	18
Saturn	120500	8.09	20.55	3321	11026150	36
Uranus	51120	18.24	3.86	624	389997	82
Neptune	49530	28.87	2.37	382	146085	130

On Instrument WaveFront Sensor (OIWFS) guide probe acquisitions

Sidereal tracking mode
acquiring on different constellations

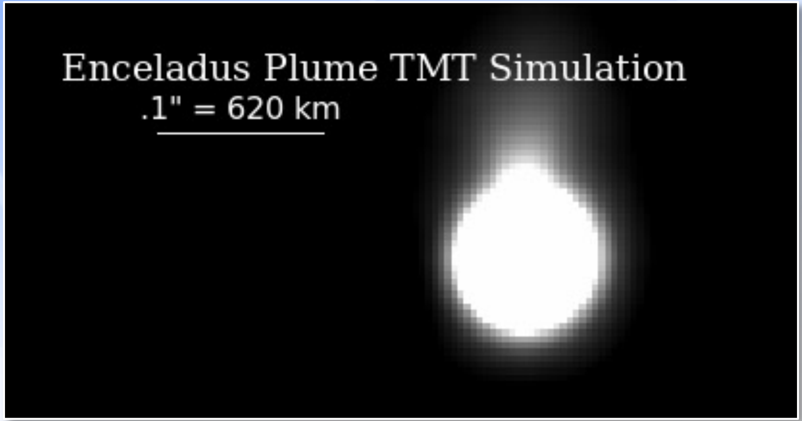


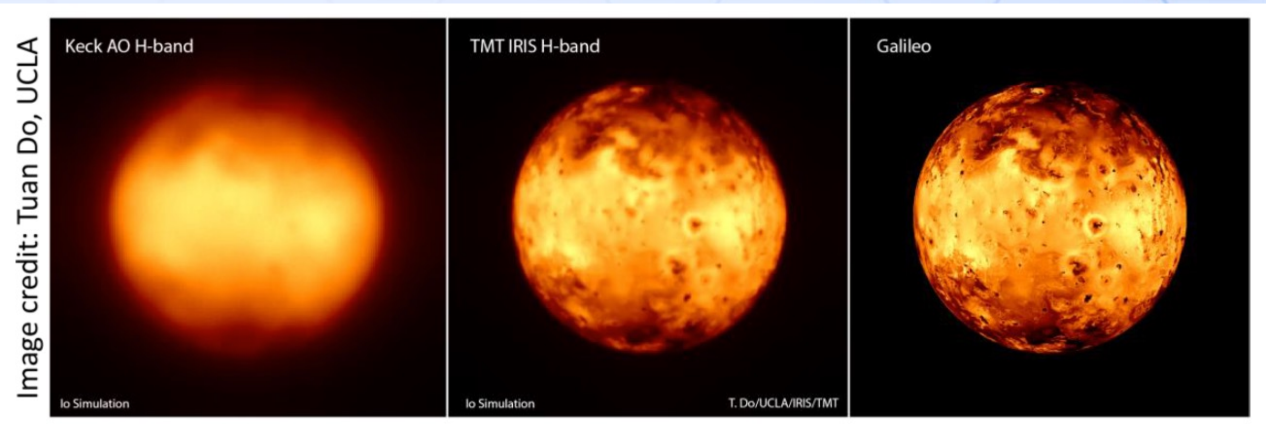
Non-Sidereal tracking mode
for a single target

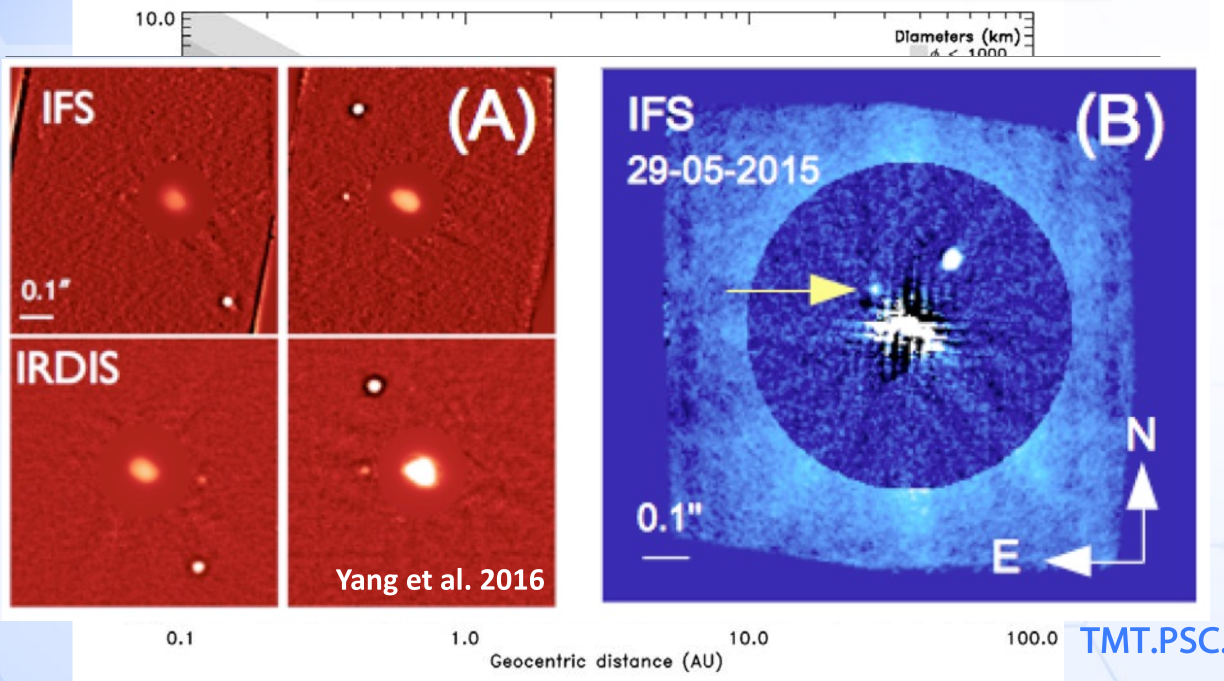


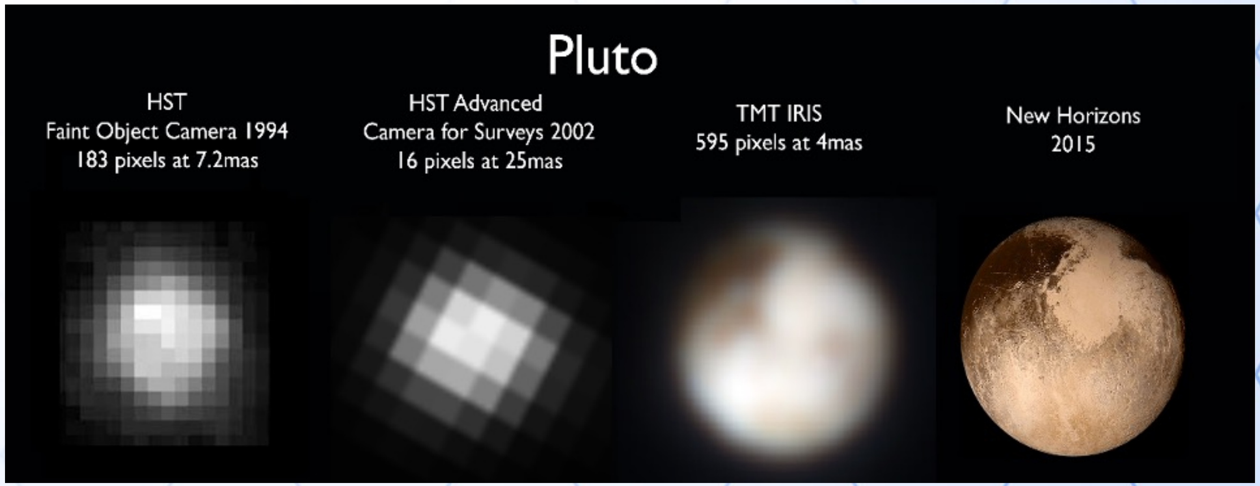
TMT: Solar System Applications

IRIS
PSI

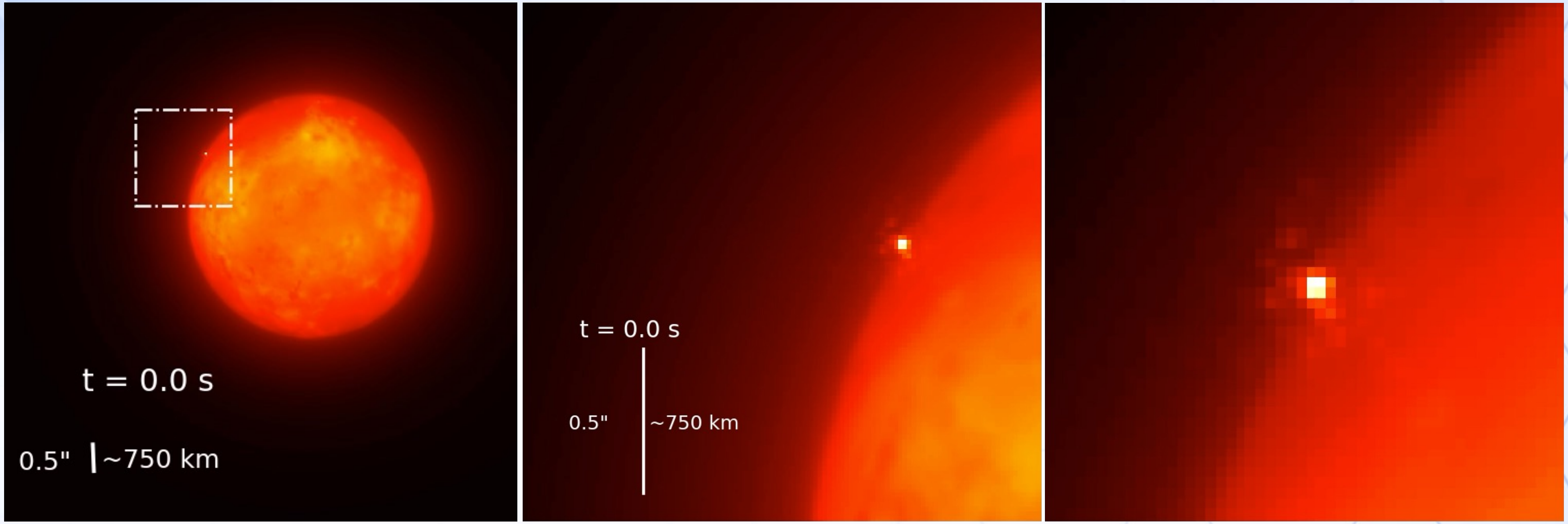








Studying Active Volcanic Plumes



IO. IRIS/TMT – N. Rundquist

TMT prospects *vs* JWST

- Higher-spatial resolution will enable **detailed geological studies** of solar system objects, including **monitoring of their activities** (e.g. Enceladus, Triton, satellites of the giant planets, planetary rings, etc)
- Higher-spectral resolution, combined with high-spatial resolution, will enable measurements of the **temperature and distribution of atmospheric trace species** on Mars, Venus, gas giants and their moons, tracking spatial and temporal evolution
- Visible spectroscopy will extend studies of small solar system bodies to include **spectral slope** measurements and effect of space weathering, but also detection of strong spectral lines, **like CN in comets**, etc.

Acknowledgments

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