

INSTRUMENTATION FROM SPACE AND GROUND BEYOND 2030

ADRIANO FONTANA
INAF





INSTRUMENTATION FROM SPACE AND GROUND BEYOND 2030

ADRIANO FONTANA
INAF

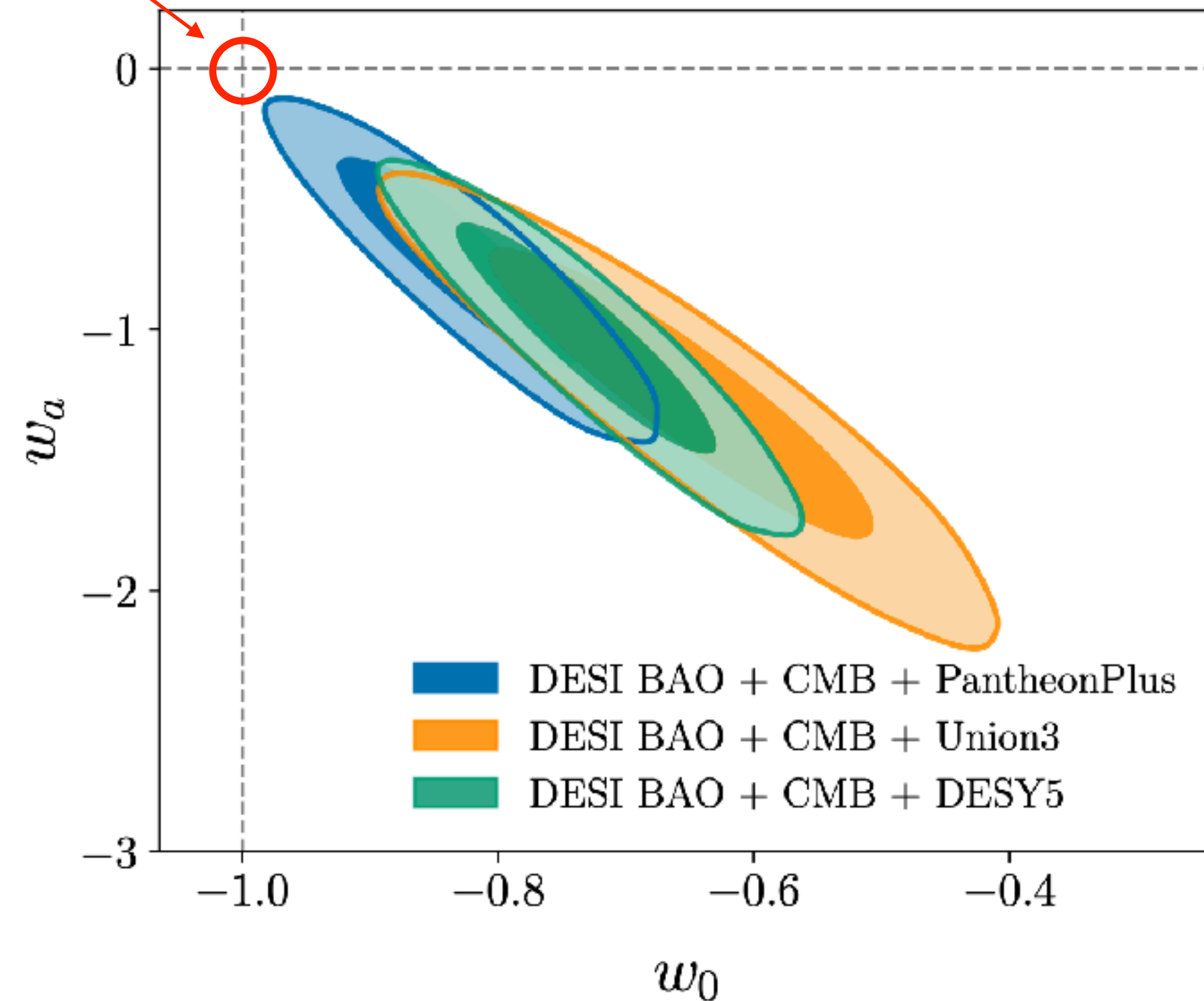
- 1) Provide a science-driven view on main facilities active in the 30s
- 2) Provide a sort of general-view landscape
- 3) Both aimed at introducing the discussion: how to maximise the impact of GTO
- 4) My recipe: invest on scientific exploitation of most competitive current instrumentation to be ready for the '30s

IS Λ -CDM COSMOLOGY CHALLENGED?

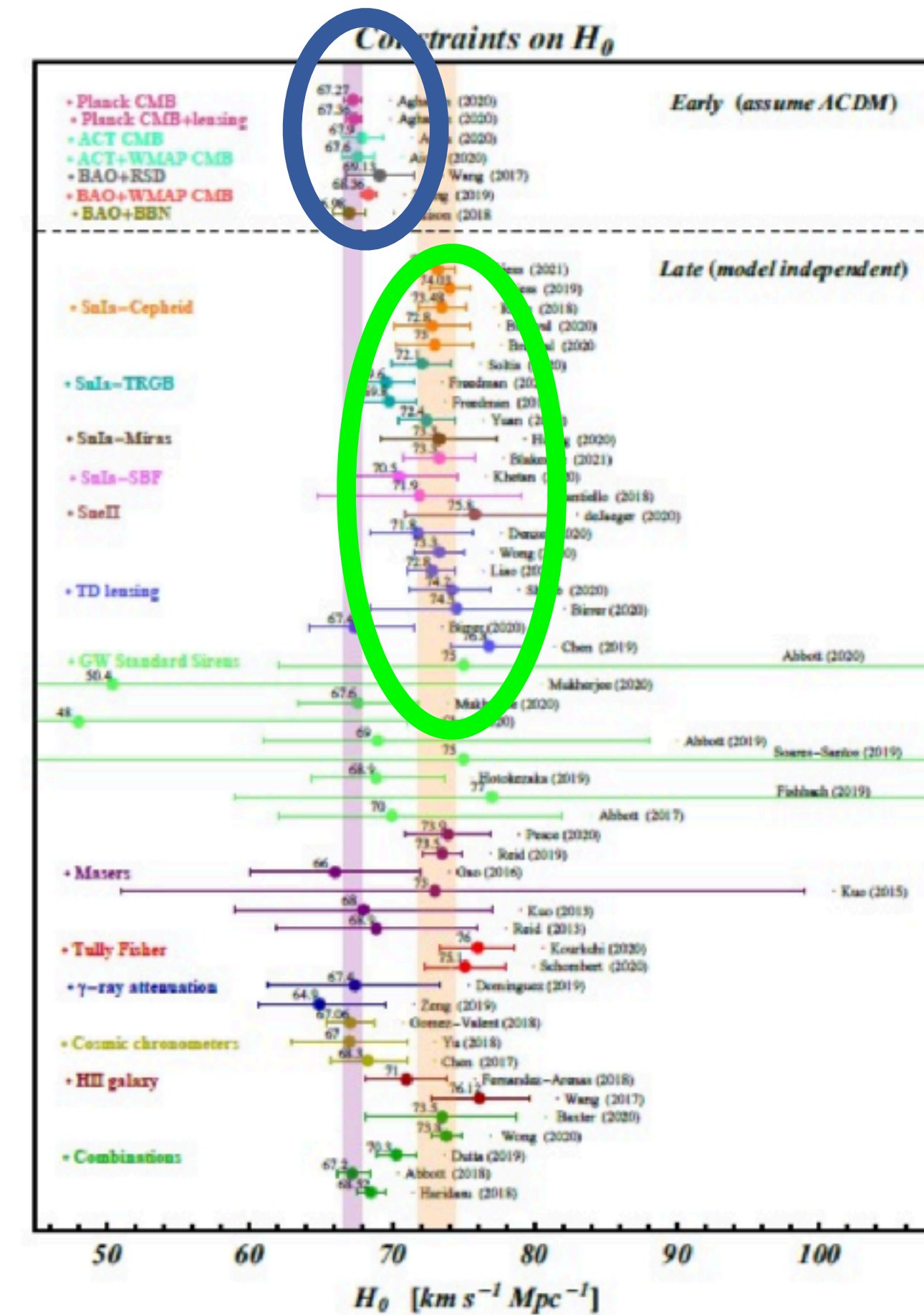
However, Λ -CDM **is** challenged by other measurements.

Λ -CDM

CMB+ DESI-BAO + SN

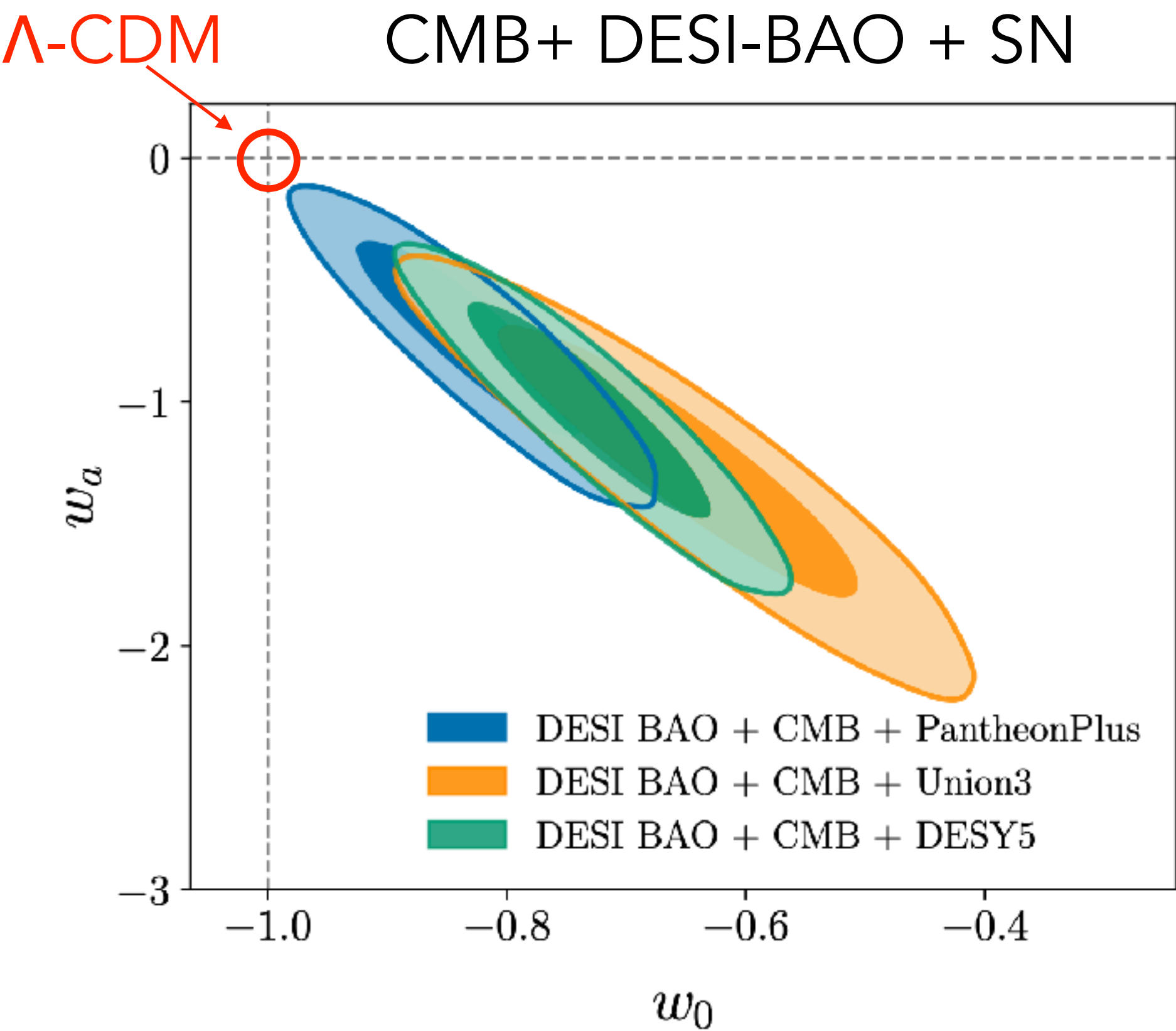


Hubble constant tension



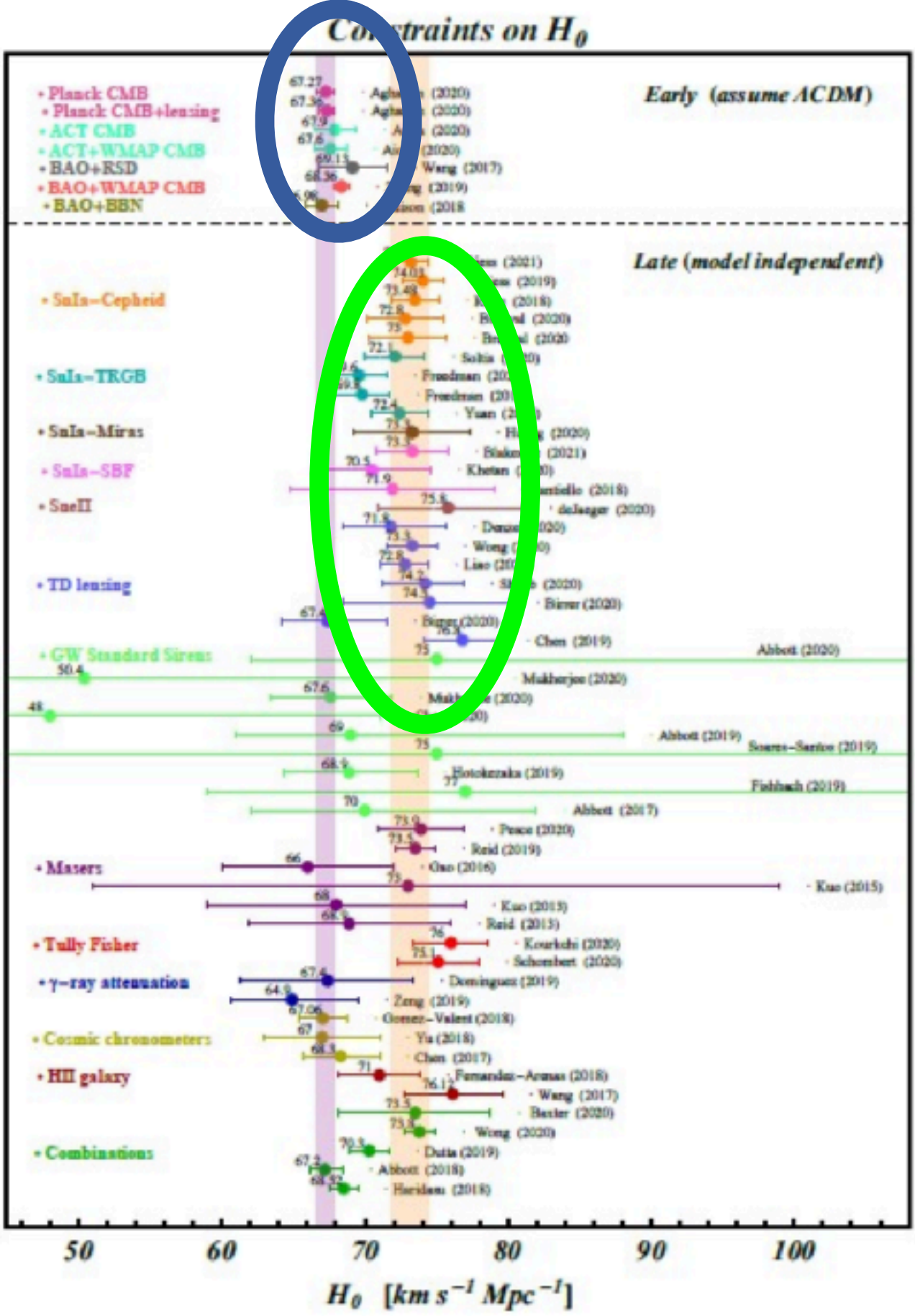
IS Λ -CDM COSMOLOGY CHALLENGED?

However, Λ -CDM **is** challenged by other measurements.

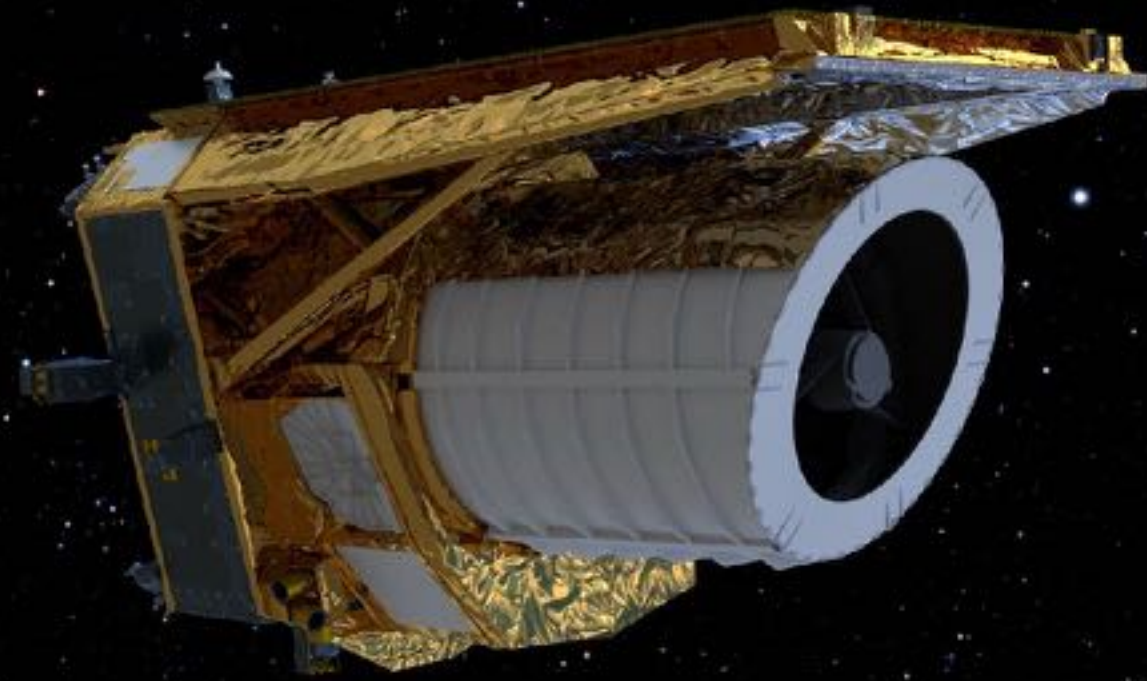


Desi Collaboration, 2024

Hubble constant tension



EUCLID



1.2m telescope

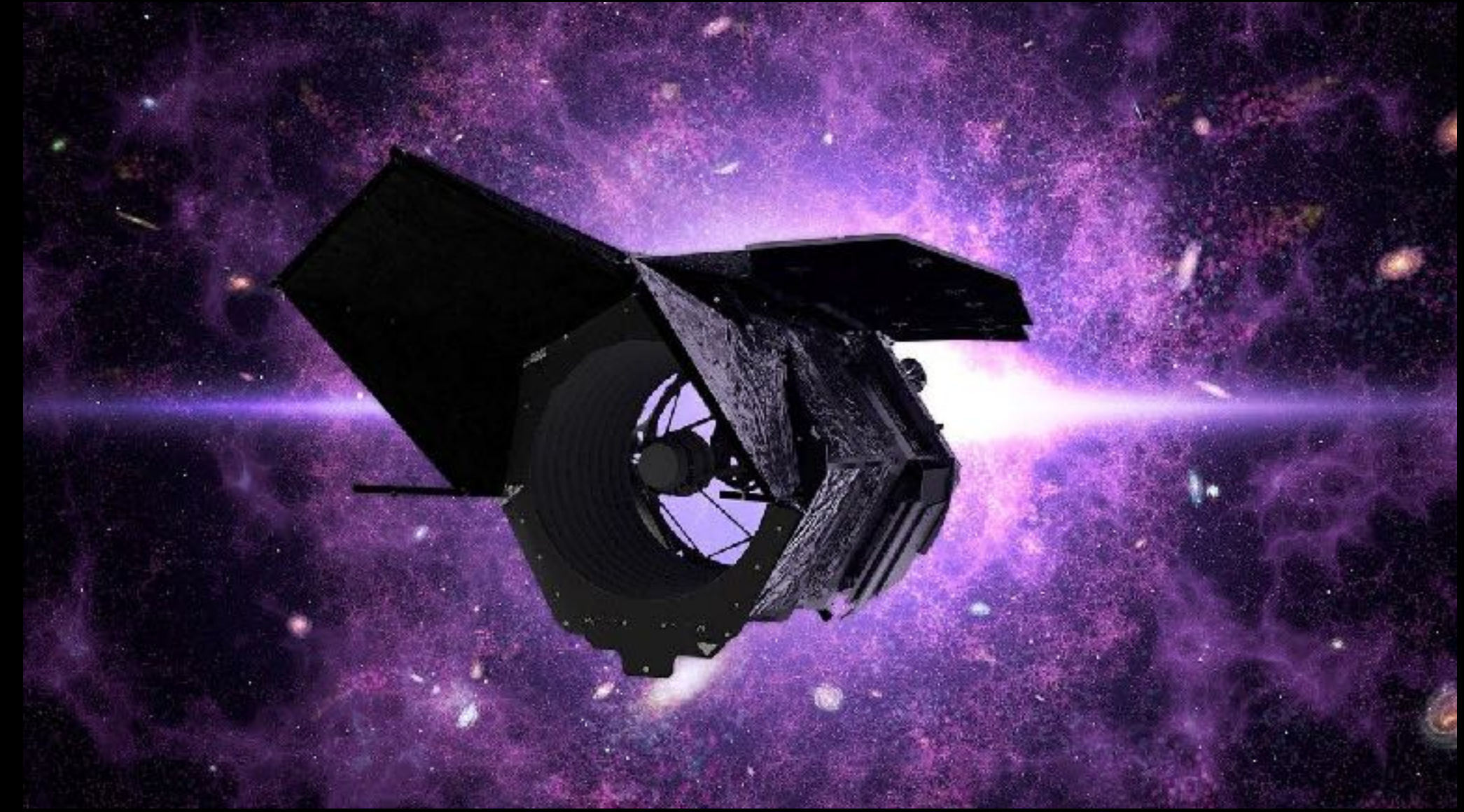
**Wide field: 0.5sqdeg/
pointing**

0.6-1.8 μm

Exquisite PSF in the visible

Wider/Shallower/survey telescope

Gracy Roman



2.4m telescope

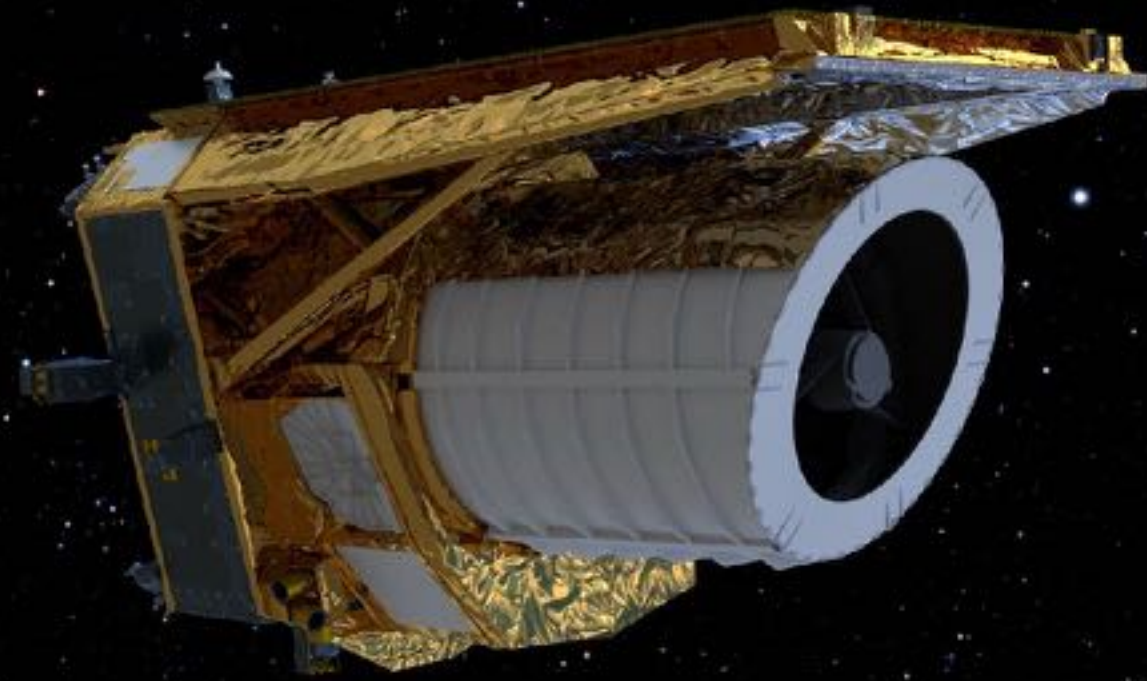
**Wide field: 0.28sqdeg/
pointing**

0.5-2.3 μm

Better PSF in the near IR

Smaller/Deeper/Observatory-kind

EUCLID



Gracy Roman



8m telescope

Wide field: 9sqdeg/pointing

0.4-1. μm

Ground-based PSF...

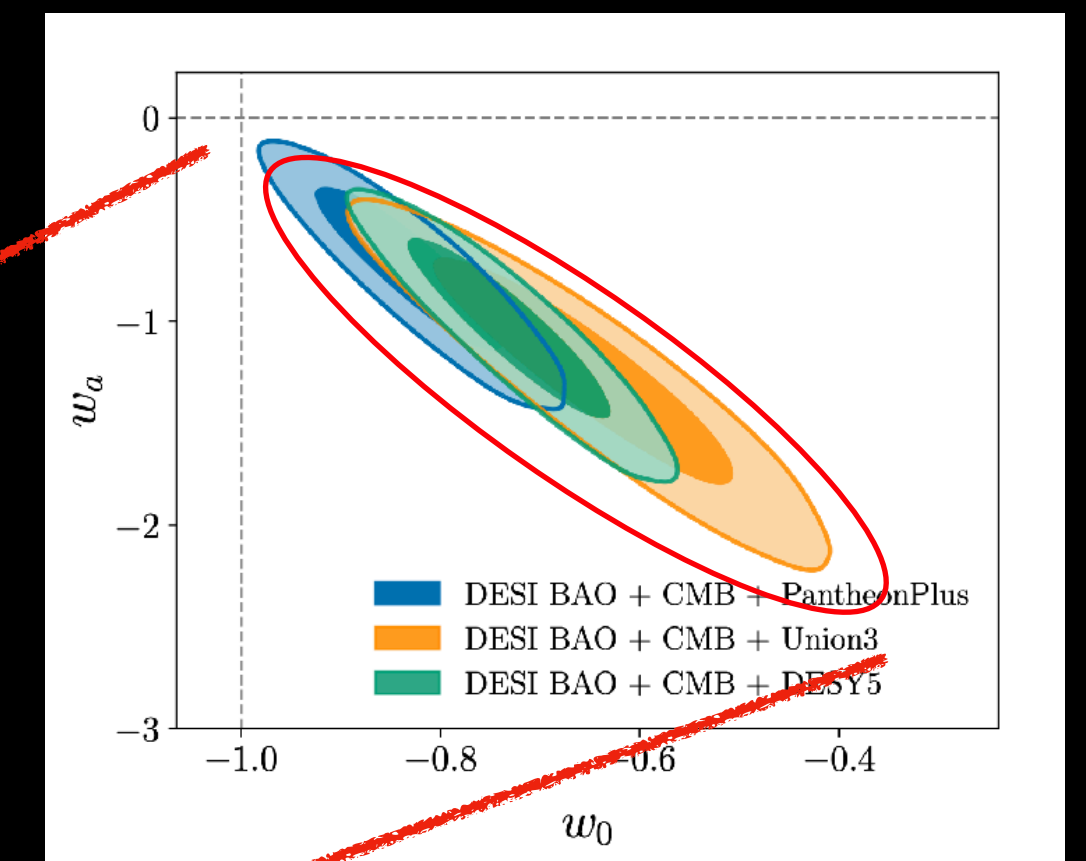
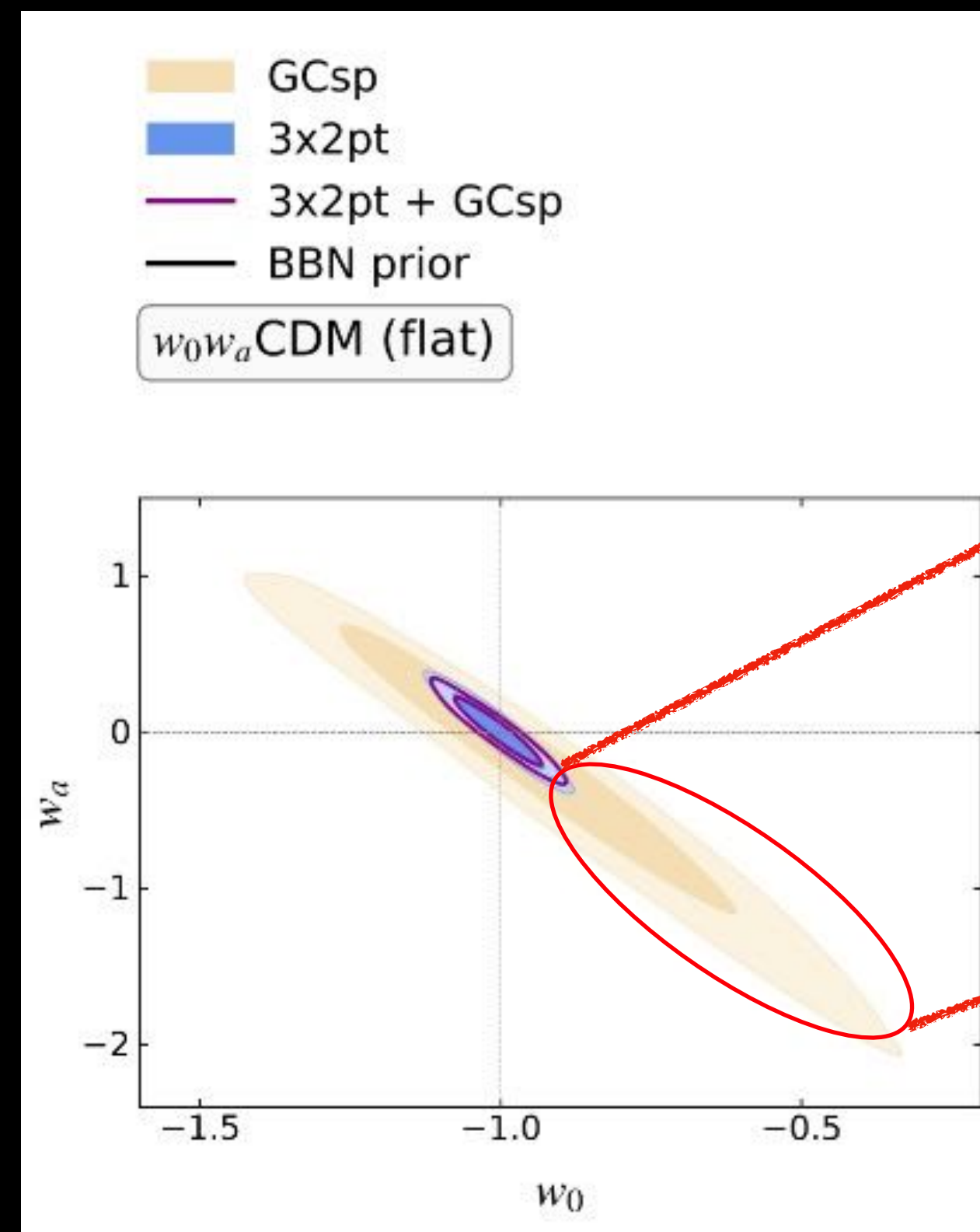


**Vera Rubin
Observatory**

Euclid is a physics experiment.

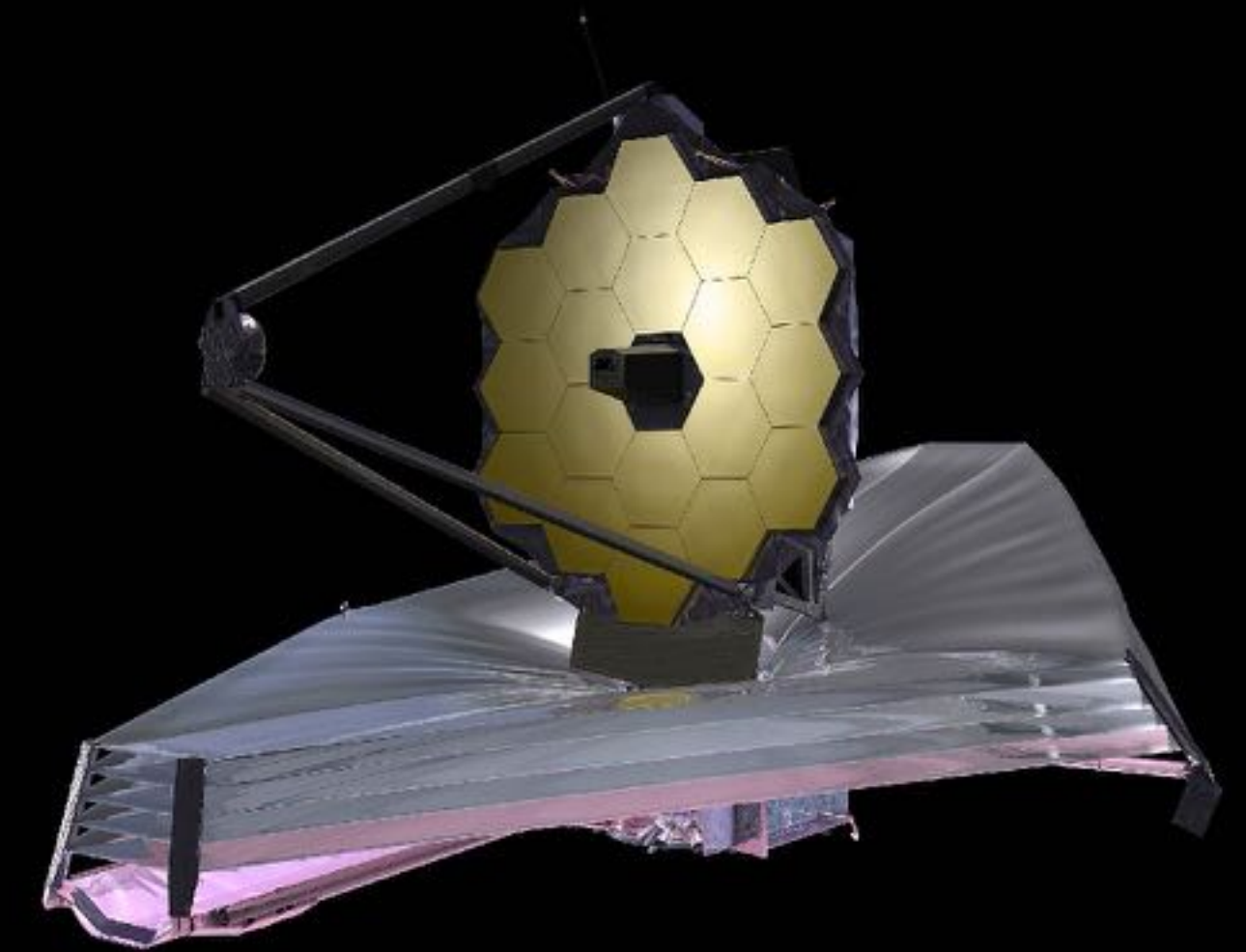
Main goal: dark matter / dark energy

**Wide field (~15000sq deg) survey of
the extragalactic sky**



**We need independent avenues to constraint
cosmological parameters**

JWST



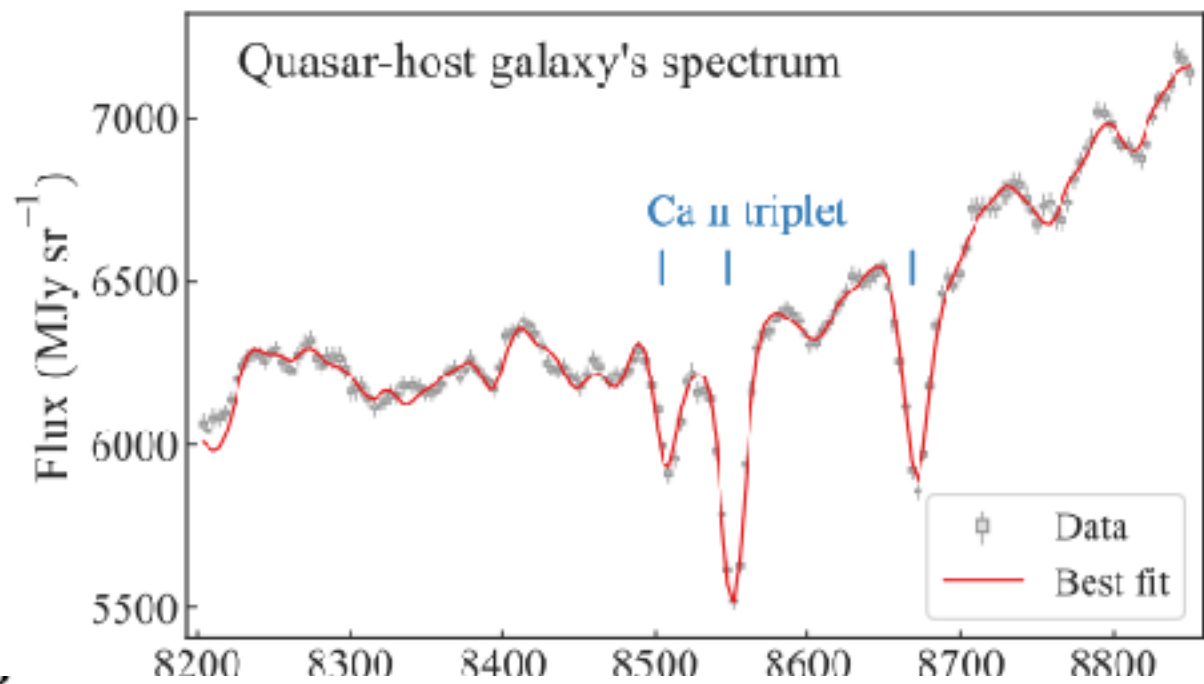
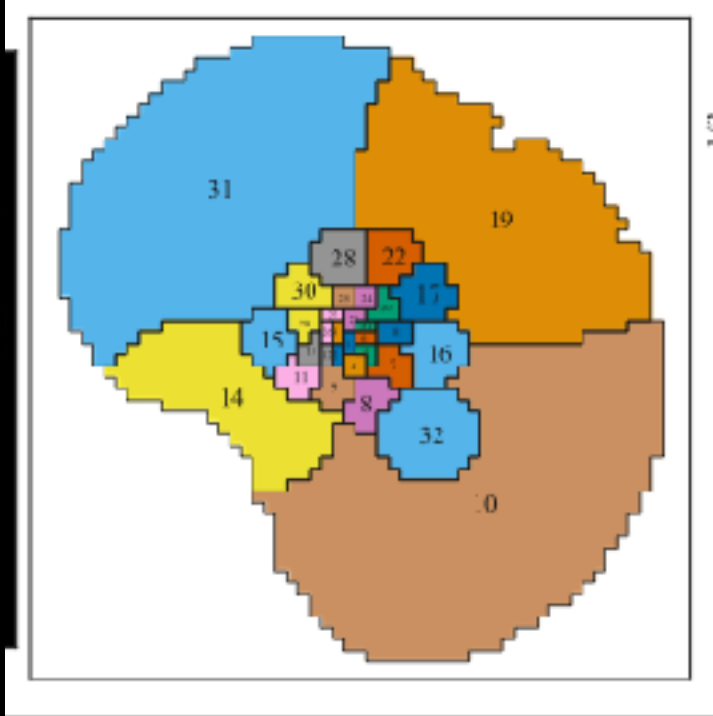
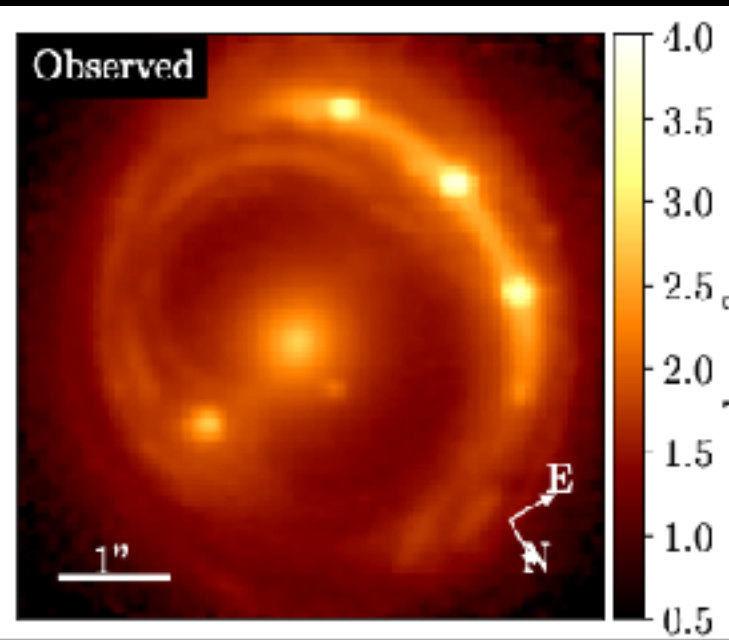
6.5m cooled telescope

**Small field of view
($<2\text{arcmin}$)**

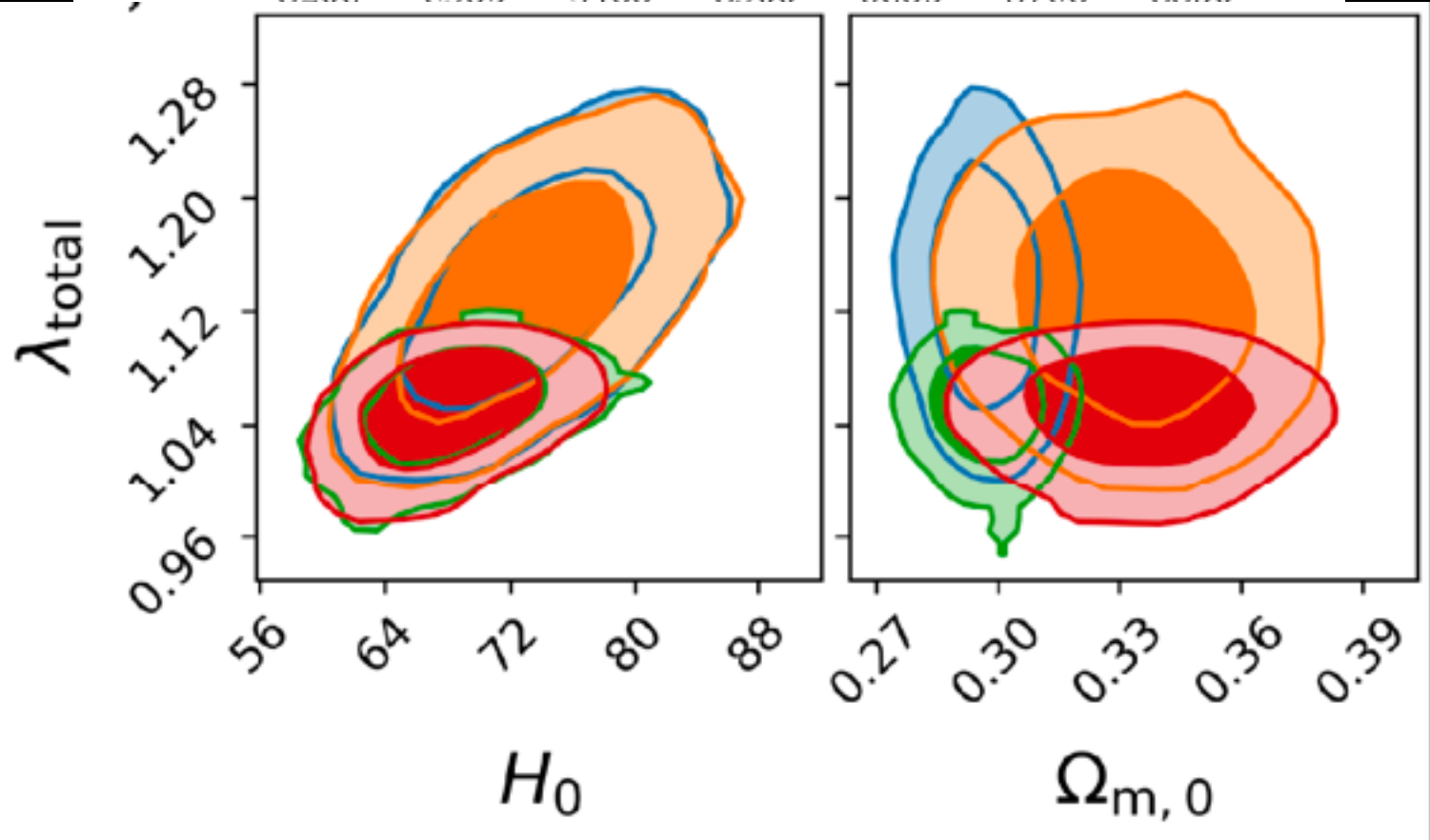
1-25 μm

JWST can do cosmology....

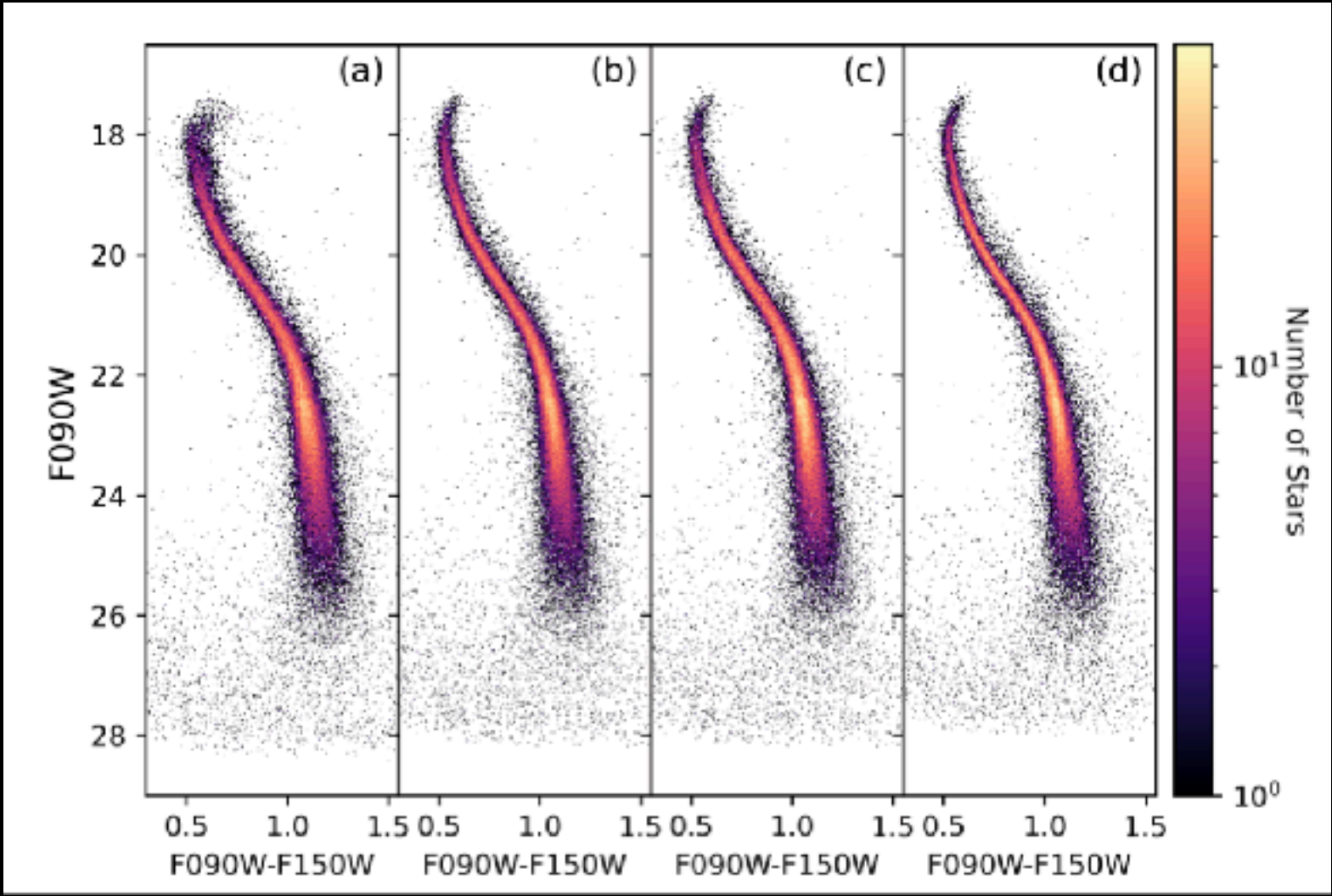
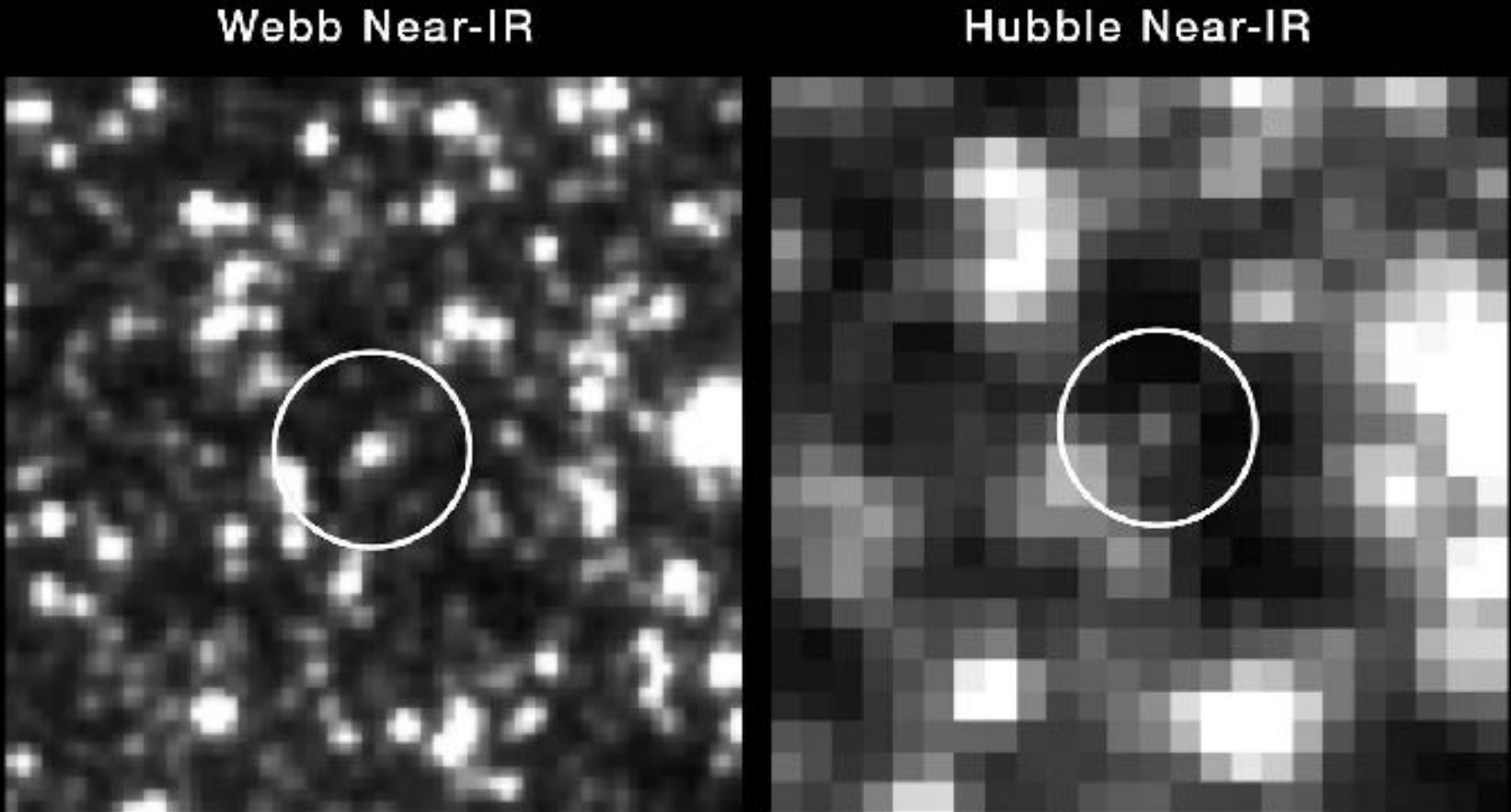
Time Delay in multiply lensed QSO $\rightarrow H_0$



Shajib, Treu+25,
Sheu, Treu +, 26
TDCOSMO



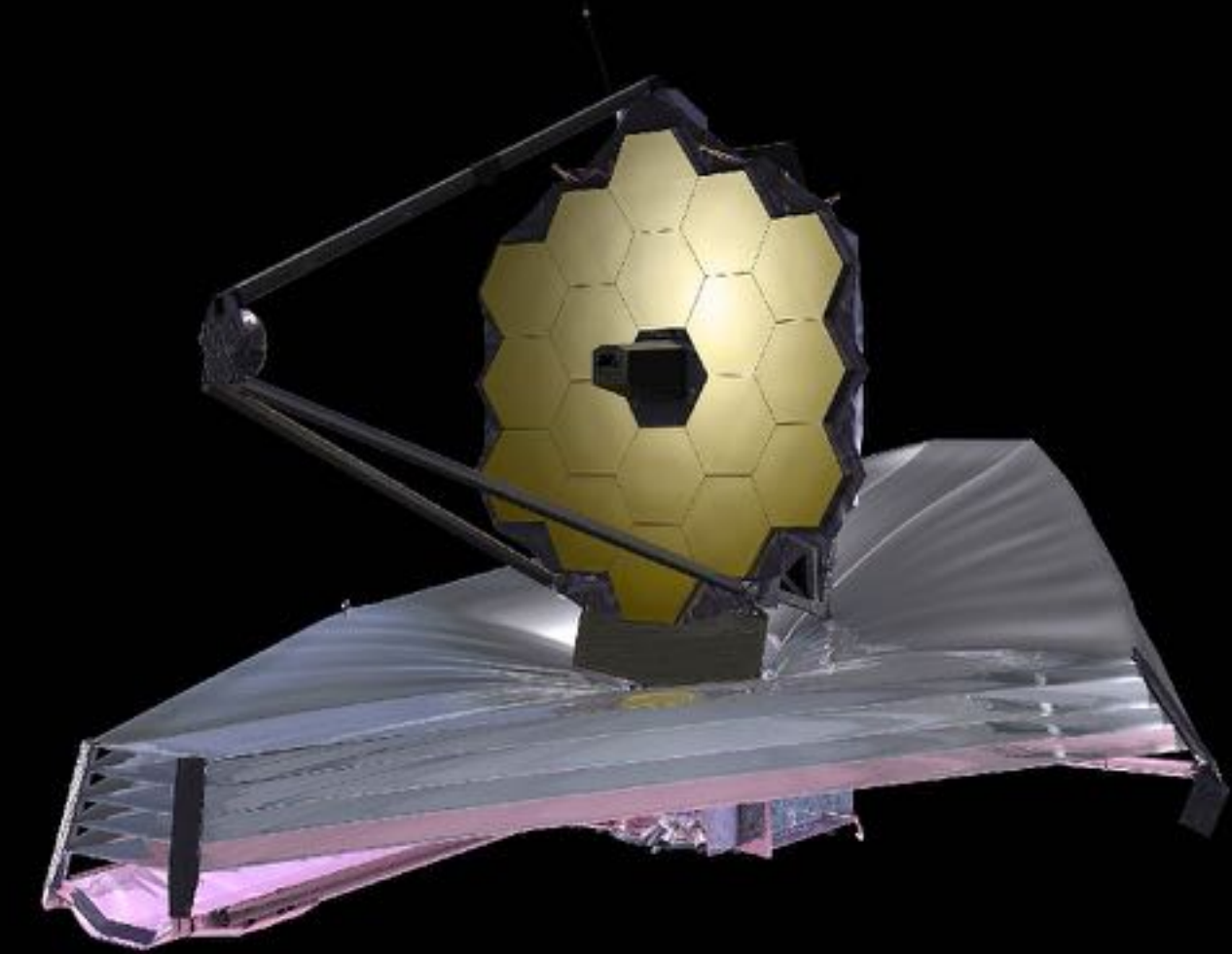
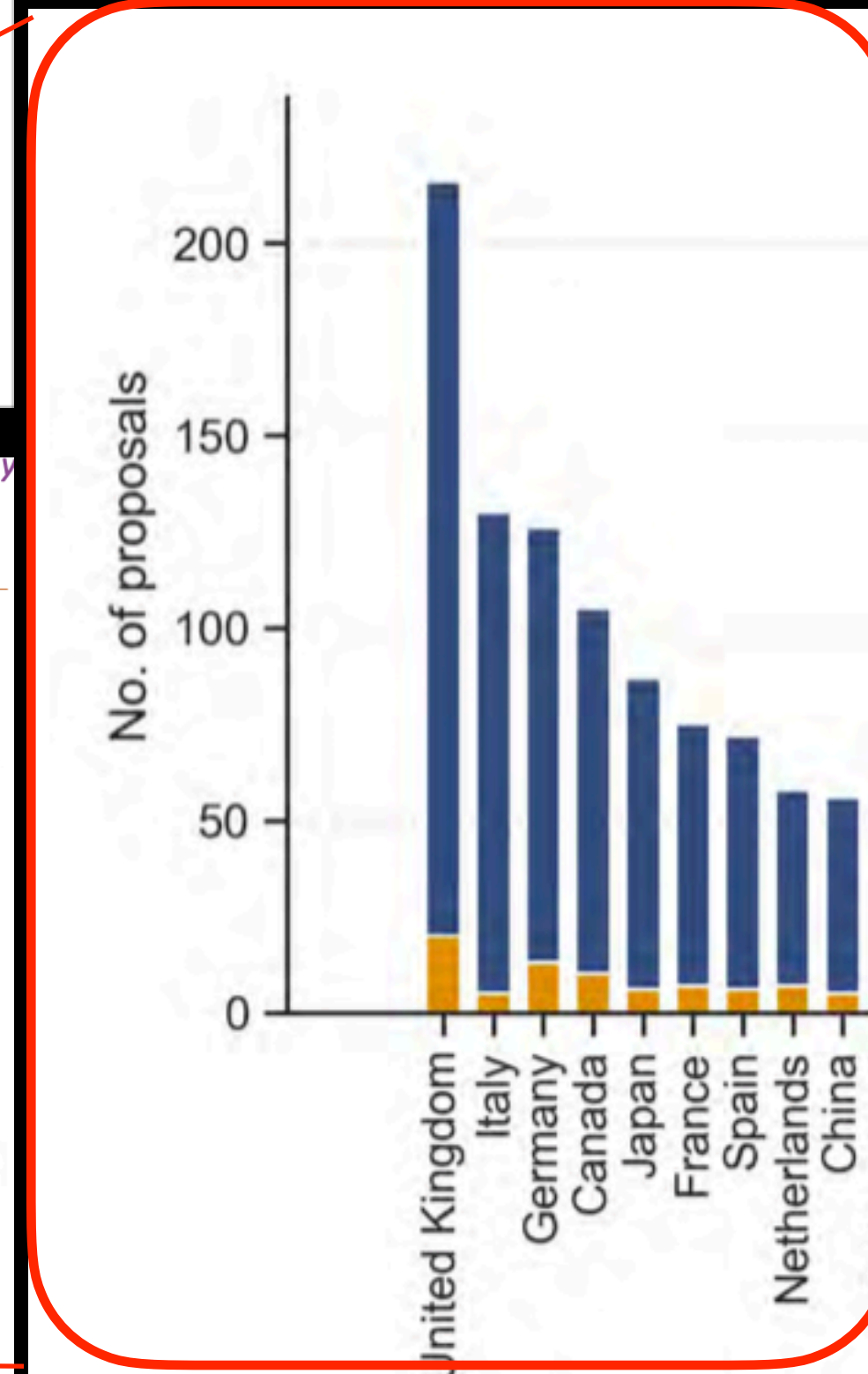
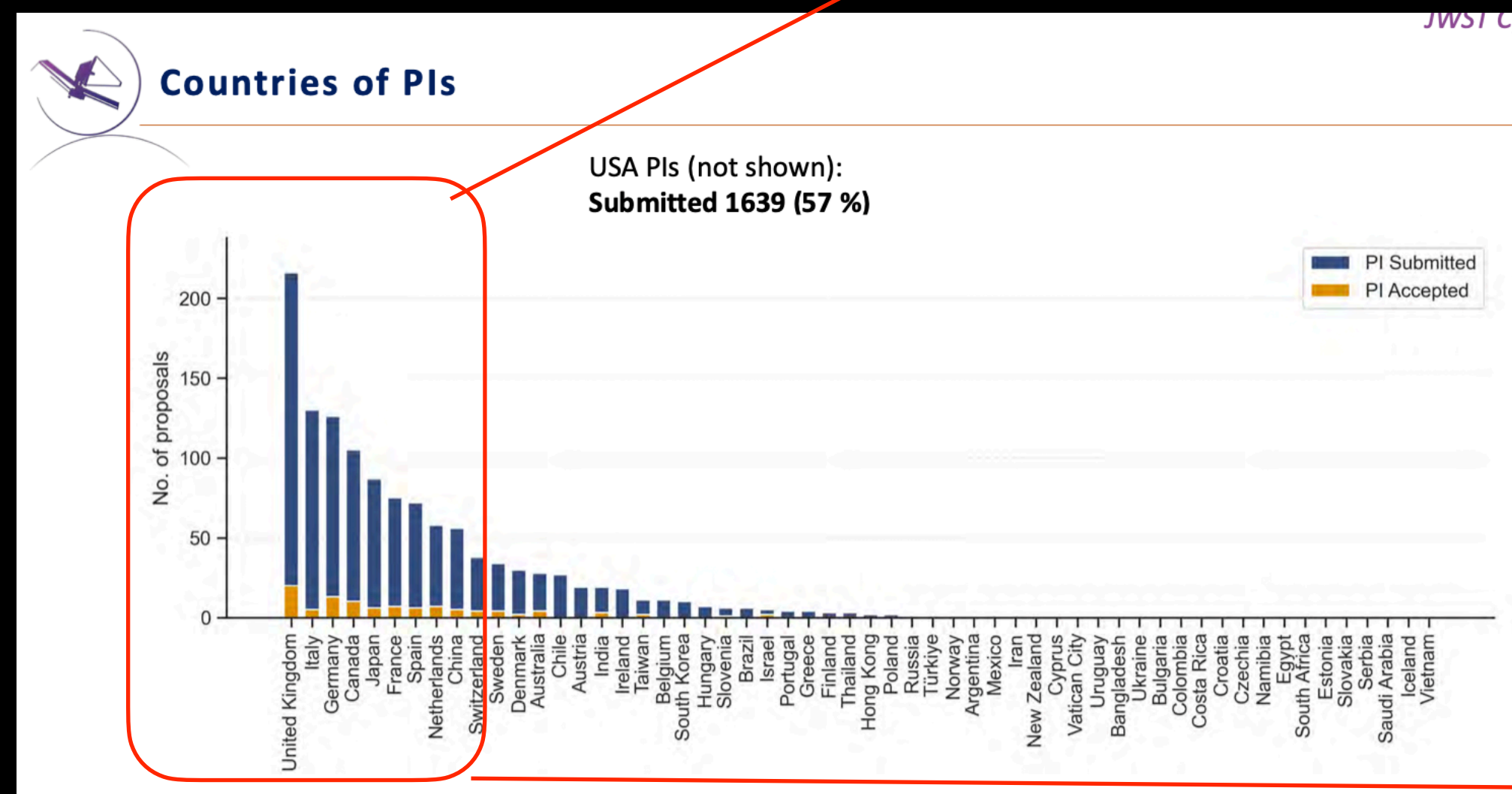
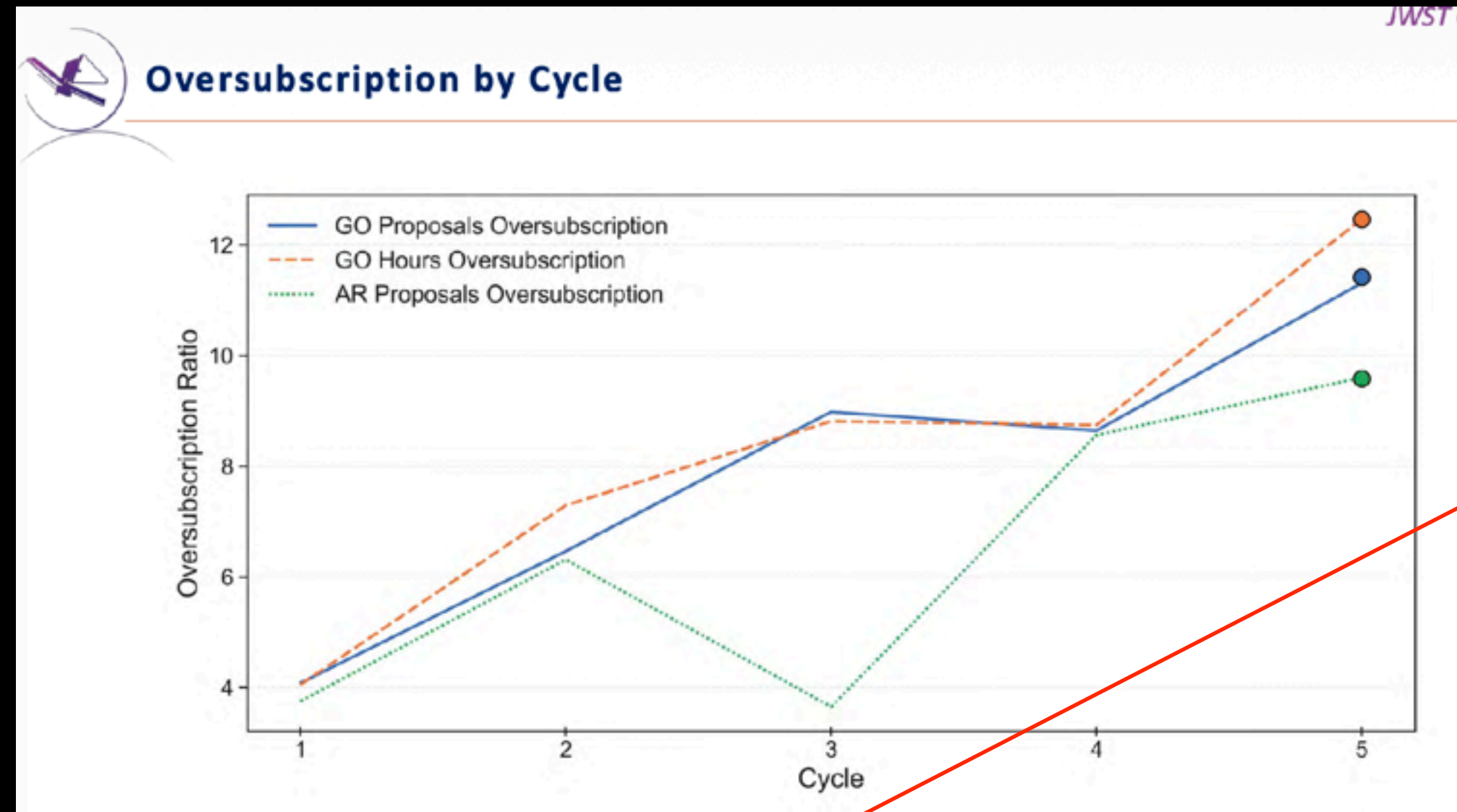
Confirms distance ladder based on Cepheids



Weisz+24
Riess+24

Observatory

Highly over-subscribed (8% chances!)



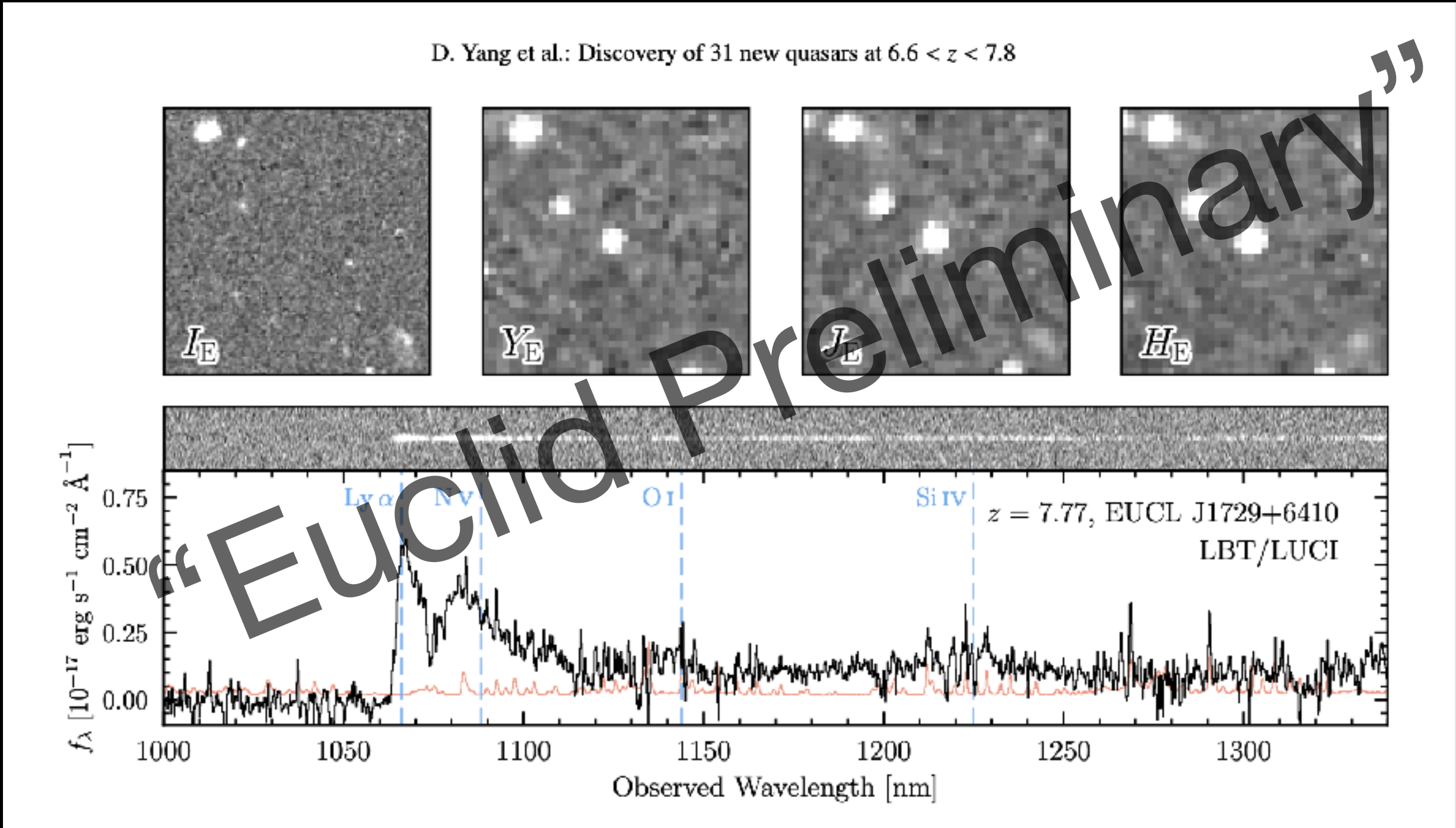
Will (hopefully!!!) remain operative until ~2040.

Combination of JWST and ELT can be ground-breaking

EUCLID Wide field (15000sq deg) survey of the extragalactic sky

Secondary goal: legacy science

Highest redshift QSO (z=7.77): Euclid + LBT



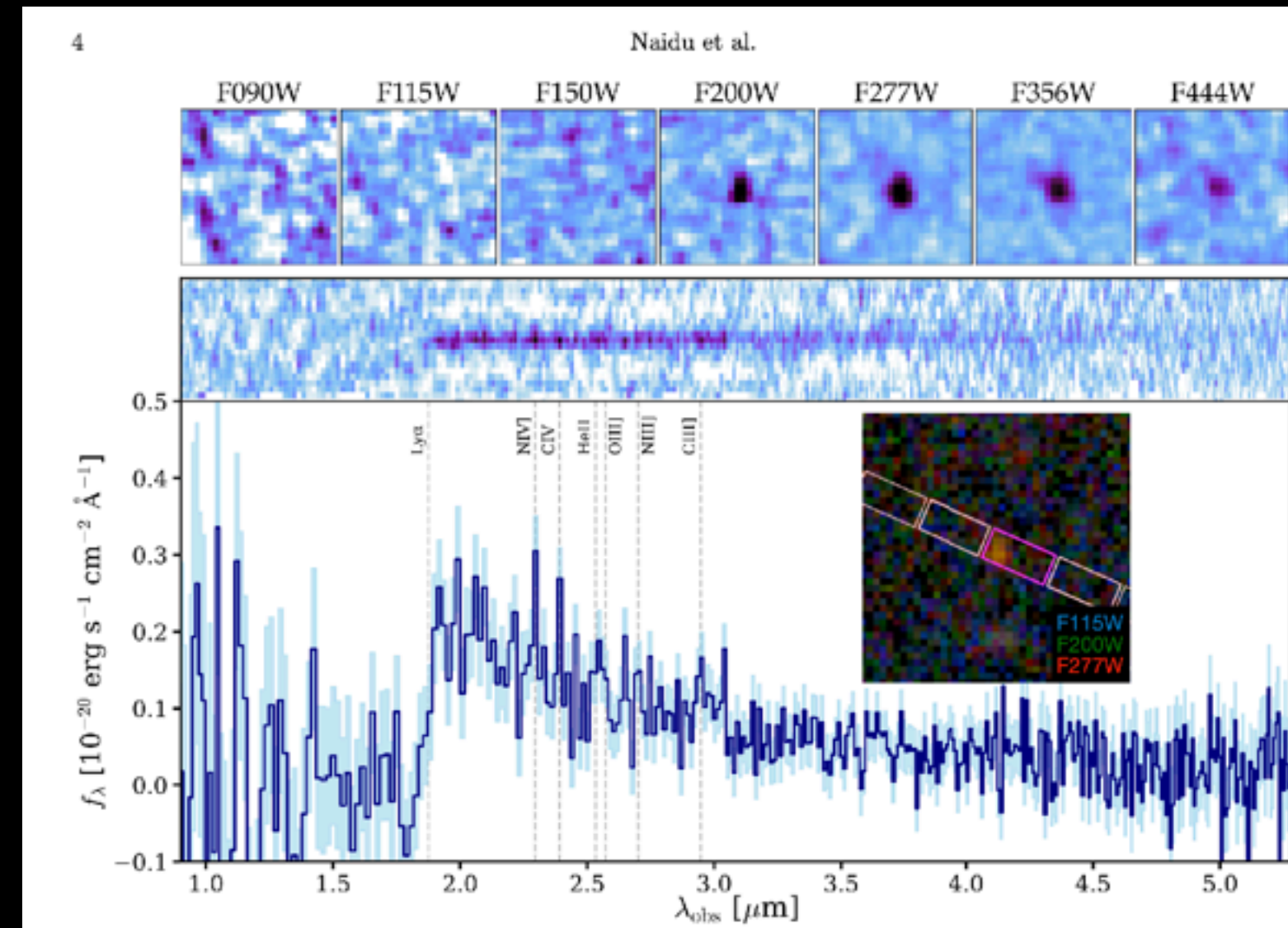
Yang et al, subm.

NOMINAL MISSION – 6 years – ends 31/12/2029											POST-OPS – 2 years		
iQ1	Q1	iDR1	iQ2	Q2	DR1	iQ3	iDR2	Q3	DR2	iQ4	Q4	iDR3	DR3
NOV 2024	MAR 2025	OCT 2025	MAR 2026	JUN 2026	OCT 2026	JAN 2028	MAR 2028	MAY 2028	MAR 2029	JAN 2030	MAY 2030	OCT 2030	OCT 2031

JWST is a unique machine to study the birth of galaxies...

1) An unexpected number of galaxies at $z > 10$

Naidu+25



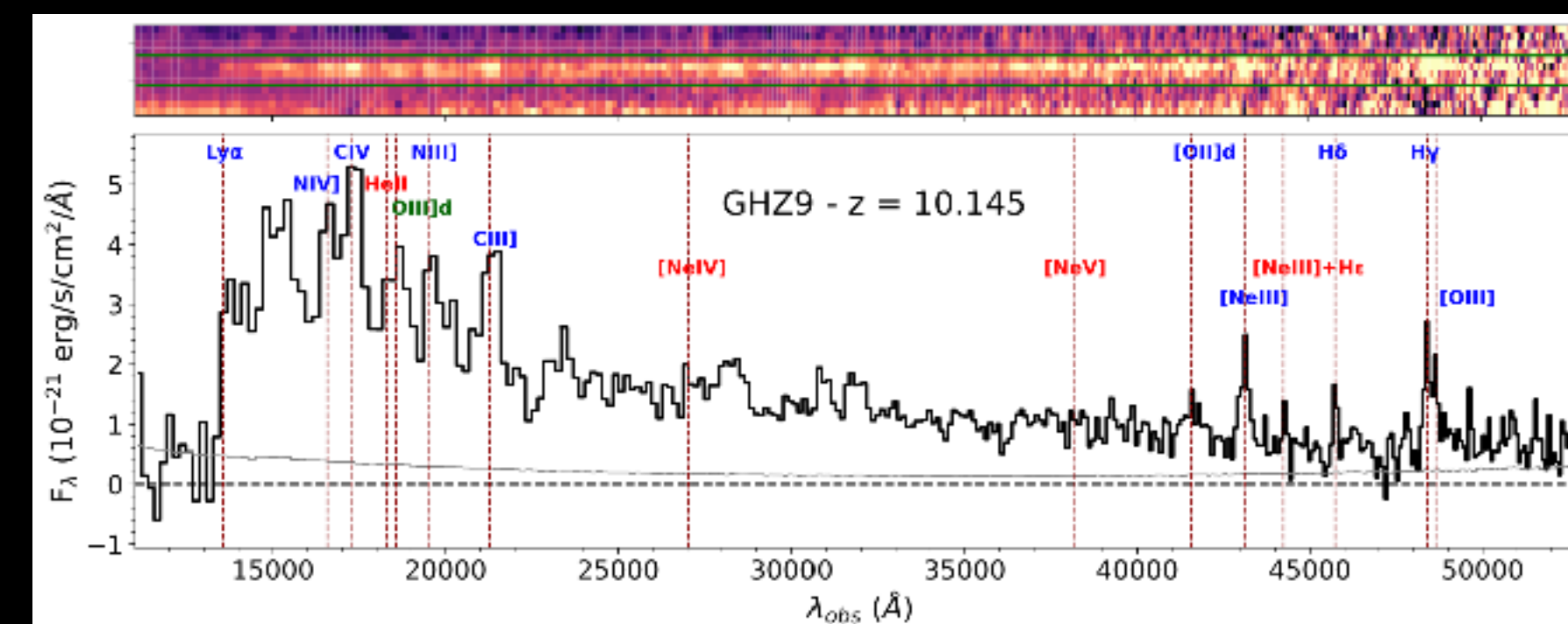
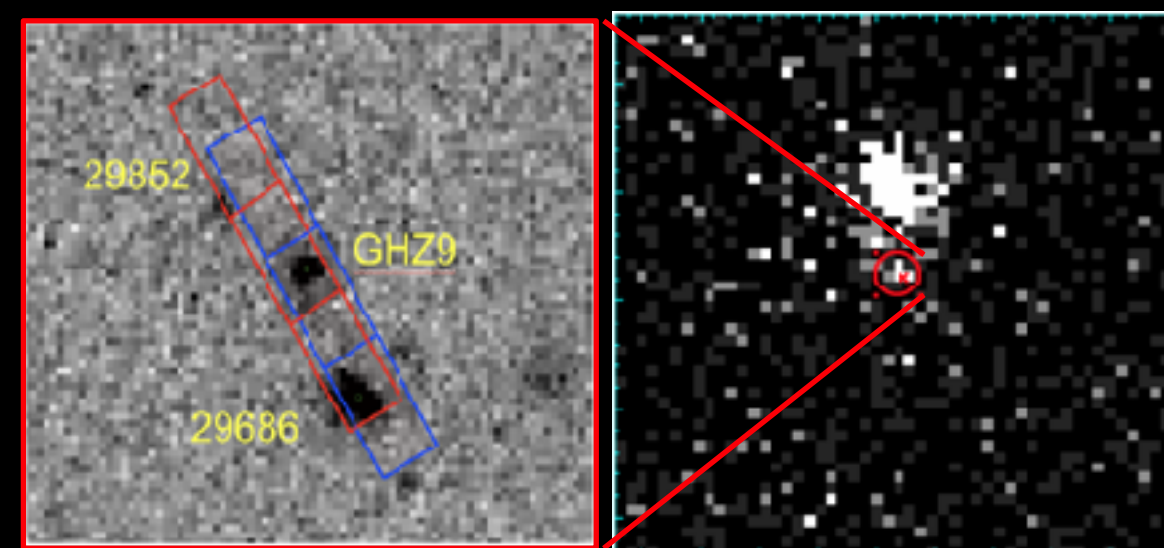
Highest
redshift galaxy
($z=14.44$)

2) An unexpected number of AGNs at $z > 7$

The dual nature of GHZ9: coexisting AGN and star formation activity in a remote X-ray source at $z=10.145$

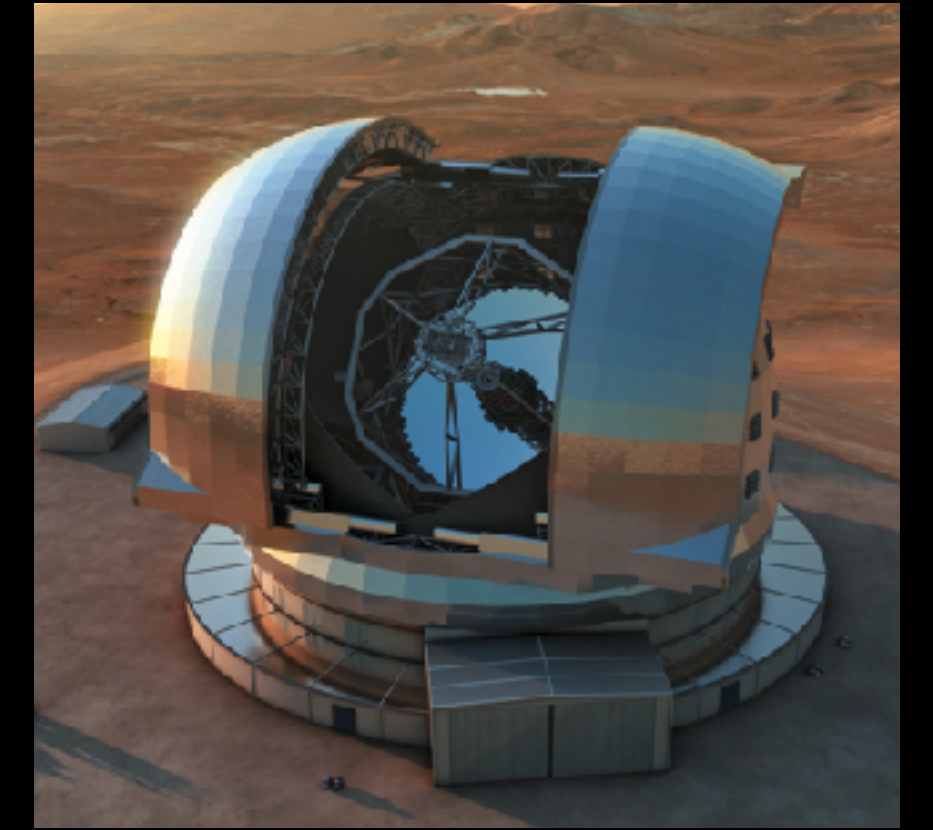
LORENZO NAPOLITANO ,^{1,2} MARCO CASTELLANO ,¹ LAURA PENTERICCI ,¹ CRISTIAN VIGNALI ,^{3,4} ROBERTO GILLI ,⁴ ADRIANO FONTANA ,¹

Napolitano+25

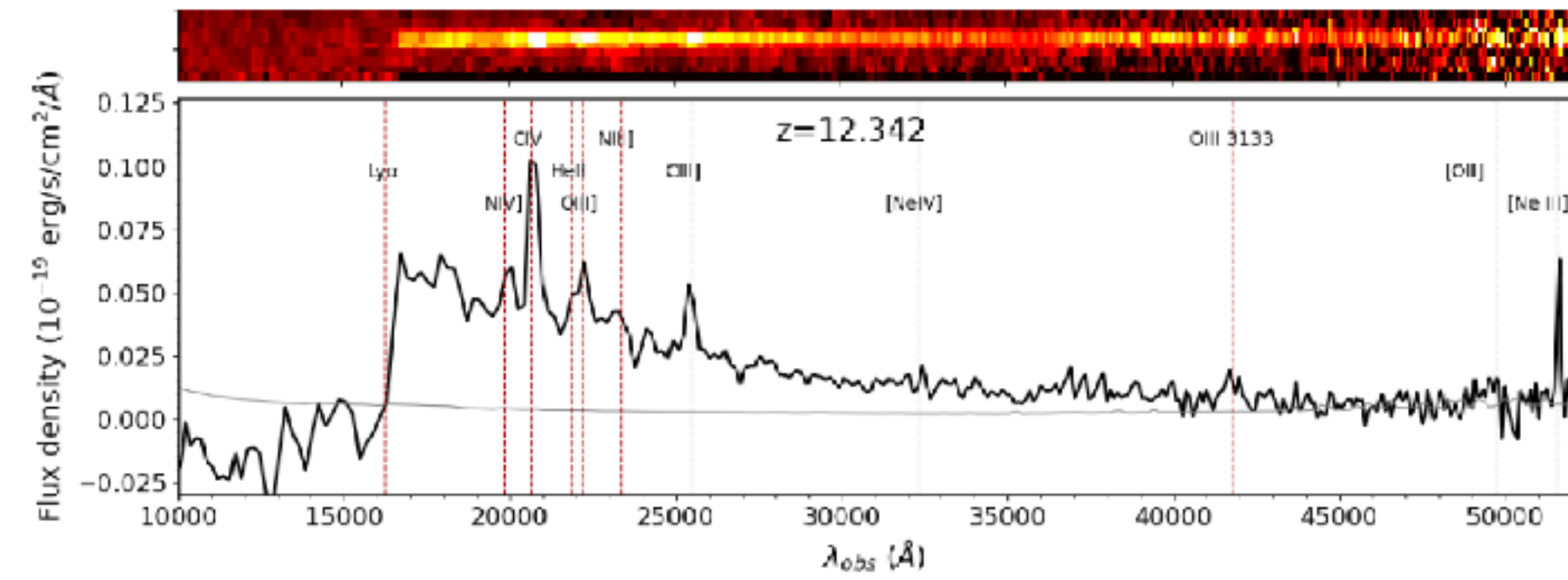




James Webb

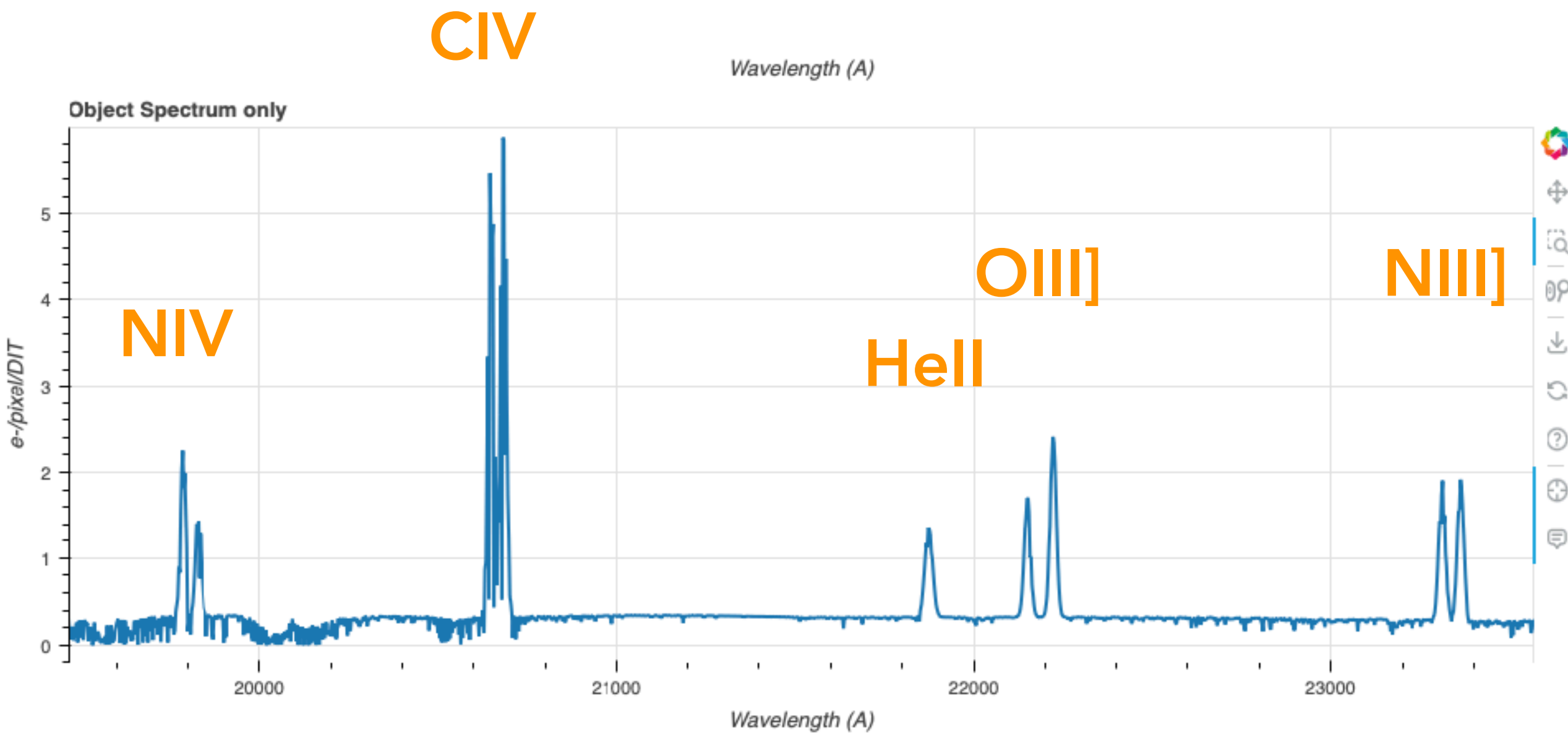


Extremely
Large
Telescope



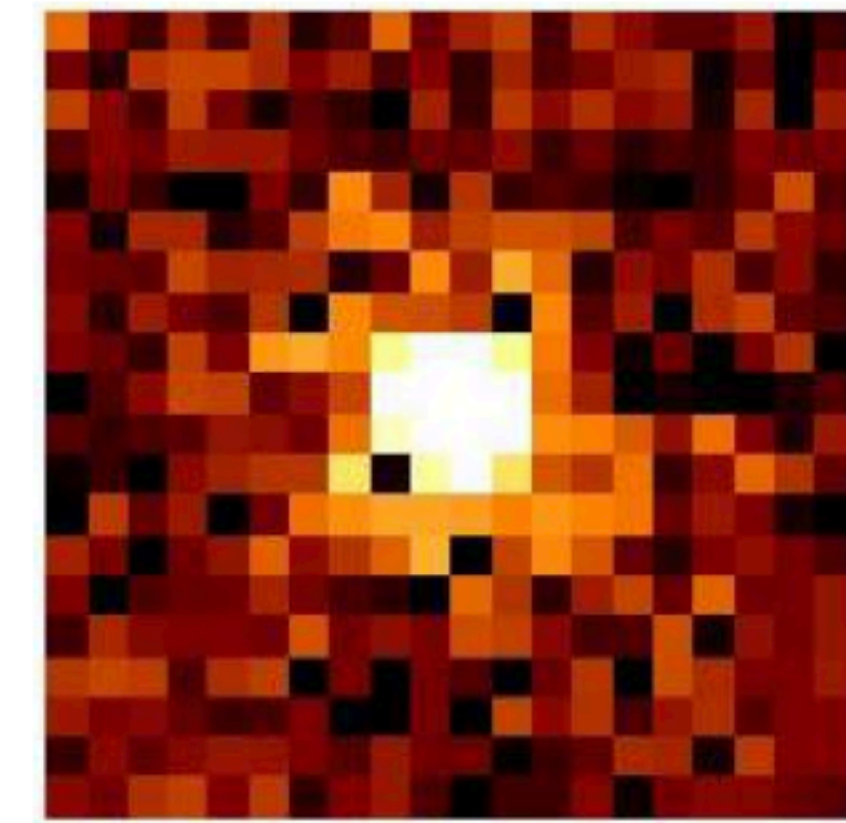
GHZ12 @ ELT

How many galaxies host a BH? What is the BH mass?



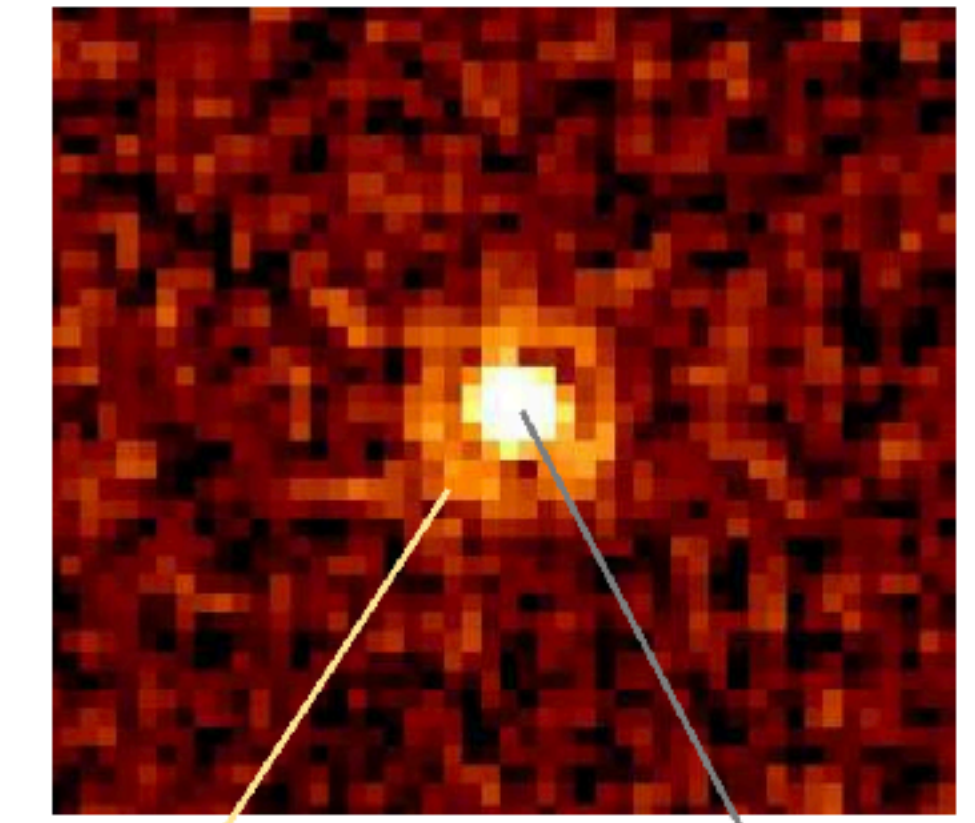
SHARP/ELT

NIRCam F200W



0.6"

MICADO+SCAO Ks



0.2"

extended host galaxy

central AGN

Composite AGN???

High AGN are one example of science case where we clearly lack an efficient X-ray satellite

New-Athena (FUTURE).

Expected Launch 2037 (Adoption 2027)

Single Mirror (HEW=8'', 1.4 m²)

X-IFU (microcalorimeter array res. 2.5 eV-measured 2.01+/-0.31 eV)

Wide Field Imager (DEPFET FoV = 40''x 40'', 170 eV resolution)

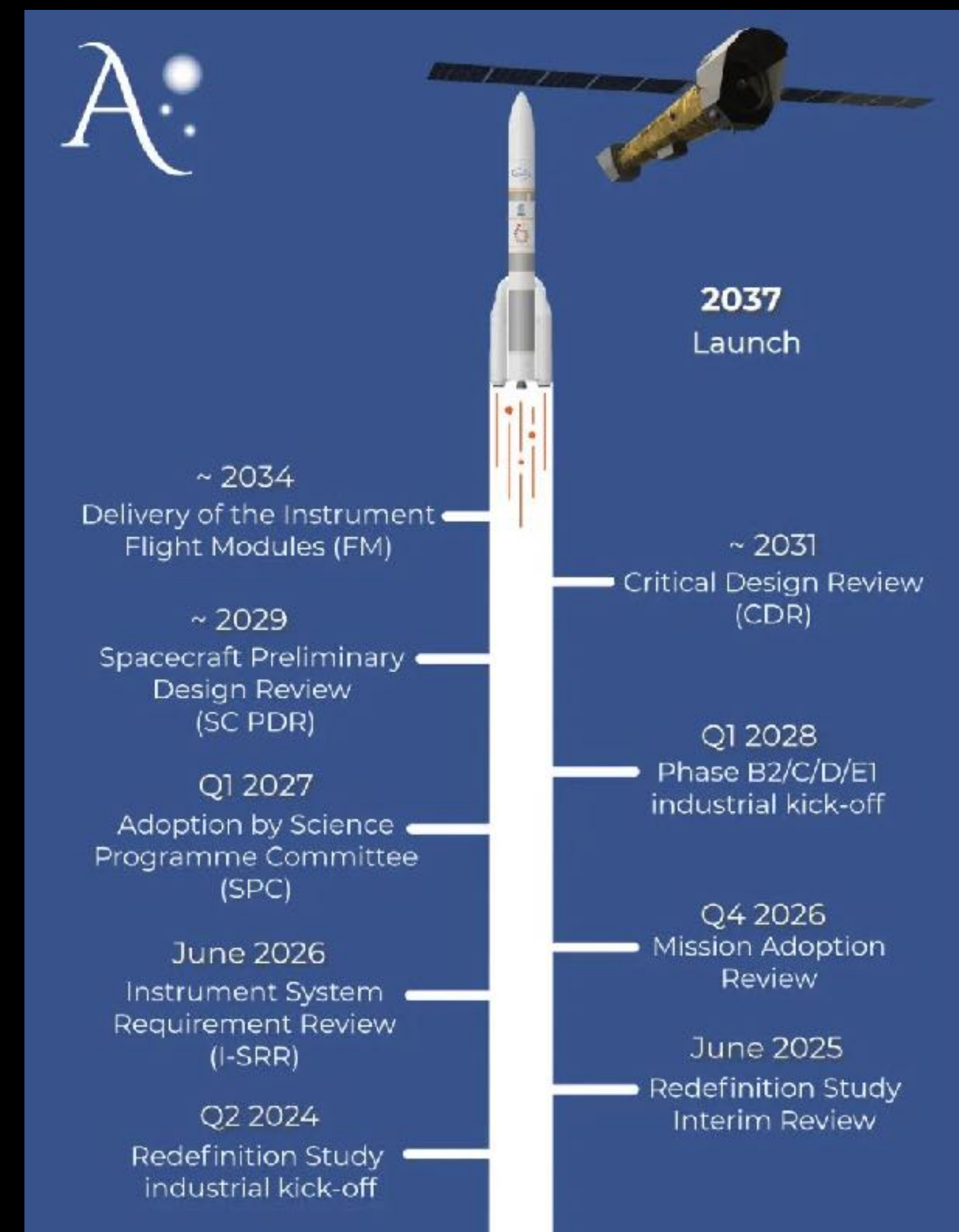
Italian Contribution

Anticoincidence X-IFU

Co-PiShip X-IFU

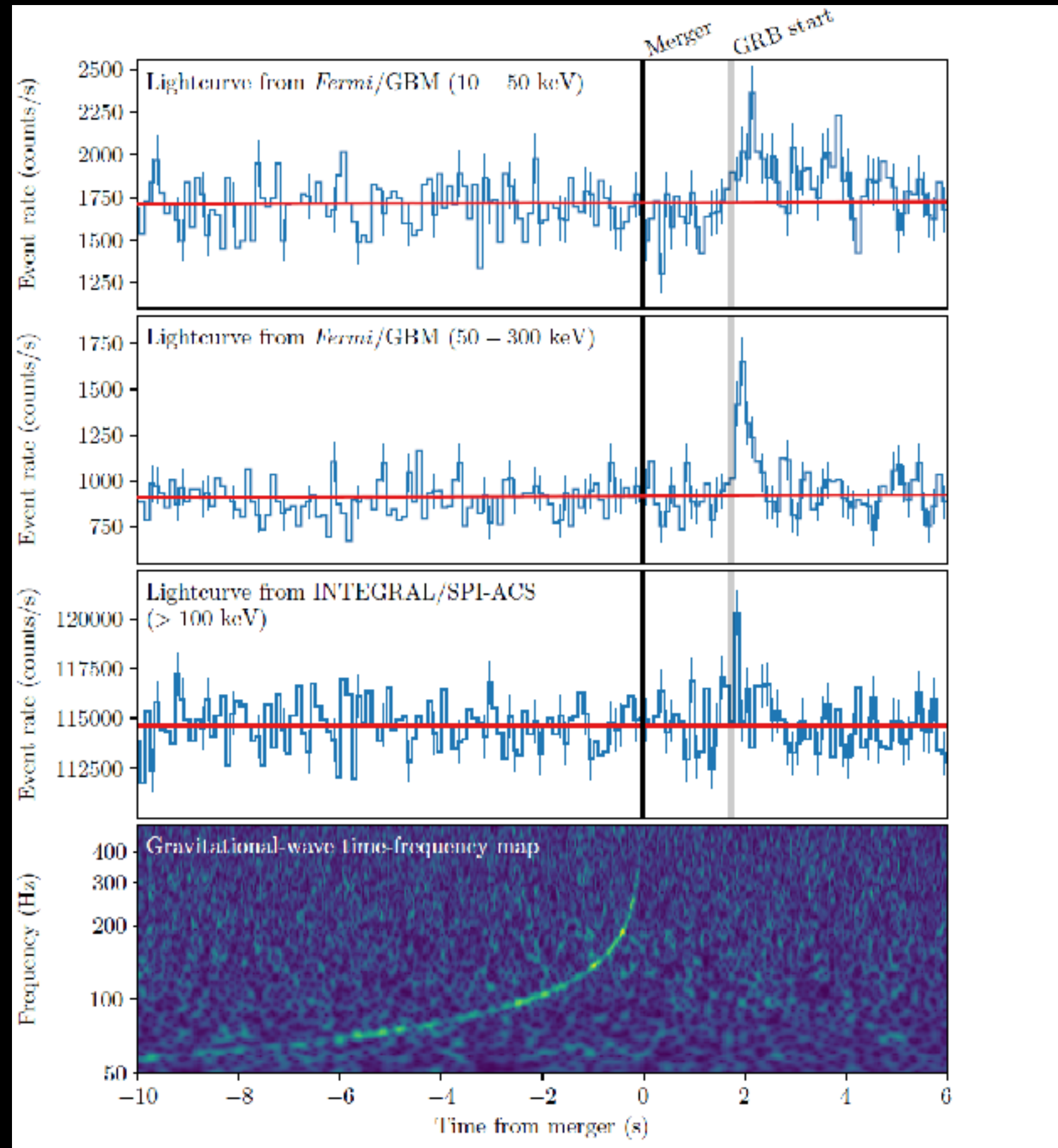
X-IFU → detailed physics of hot gas (spectroscopy)

WFI → census of the X-ray Universe (surveys & variability)



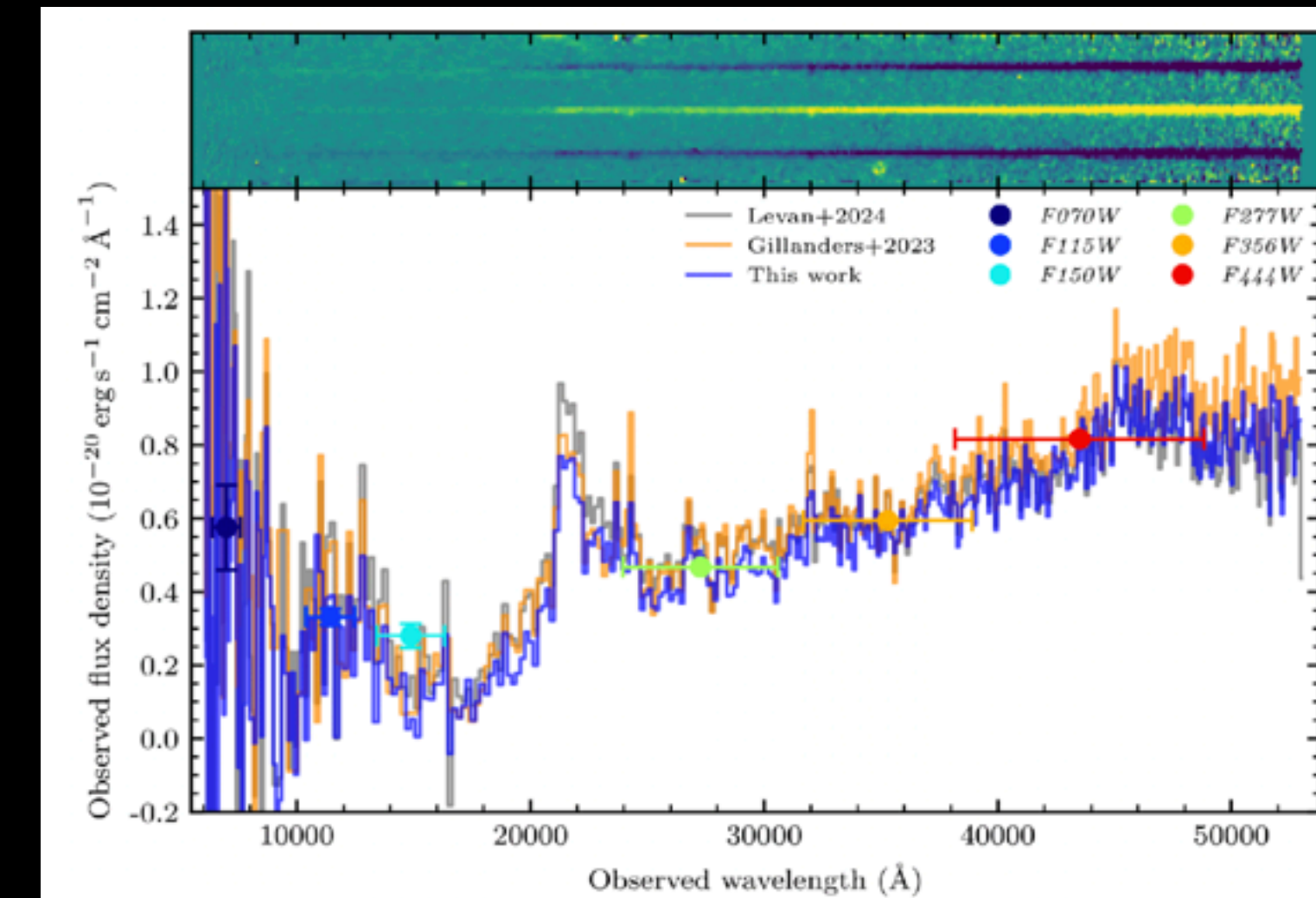
Multimessenger astronomy

New multi-messenger astrophysics:
i) search for GRB/e.m. counterparts of GW events (NS-NS merging)



Abbott et al., '17, ApJL

Kilonova: tellurium detection in GRB 230307A



Gillanders and Smart 24

LISA - LASER INTERFEROMETER SPACE ANTENNA

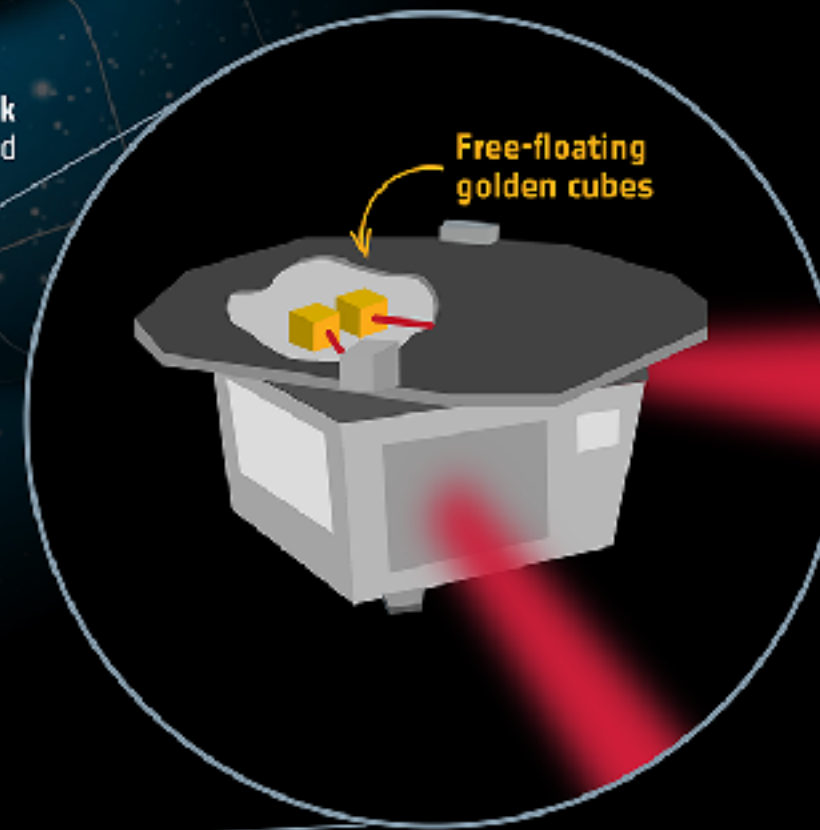
Gravitational waves are ripples in spacetime that alter the distances between objects. LISA will detect them by measuring subtle changes in the distances between **free-floating cubes** nestled within its three spacecraft.

3 identical spacecraft exchange **laser beams**. Gravitational waves change the distance between the **free-floating cubes** in the different spacecraft. This tiny change will be measured by the laser beams.



* Changes in distances travelled by the laser beams are not to scale and extremely exaggerated

Powerful events such as **colliding black holes** shake the fabric of spacetime and cause gravitational waves



LISA will detect:

- WD merging in the MW
- IMBH ($10^5 - 10^7 M_{\odot}$) merging
- spiralling BH pairs (alerts)
- primordial GW?

Thousands of detections/yr

Launch date: 2035

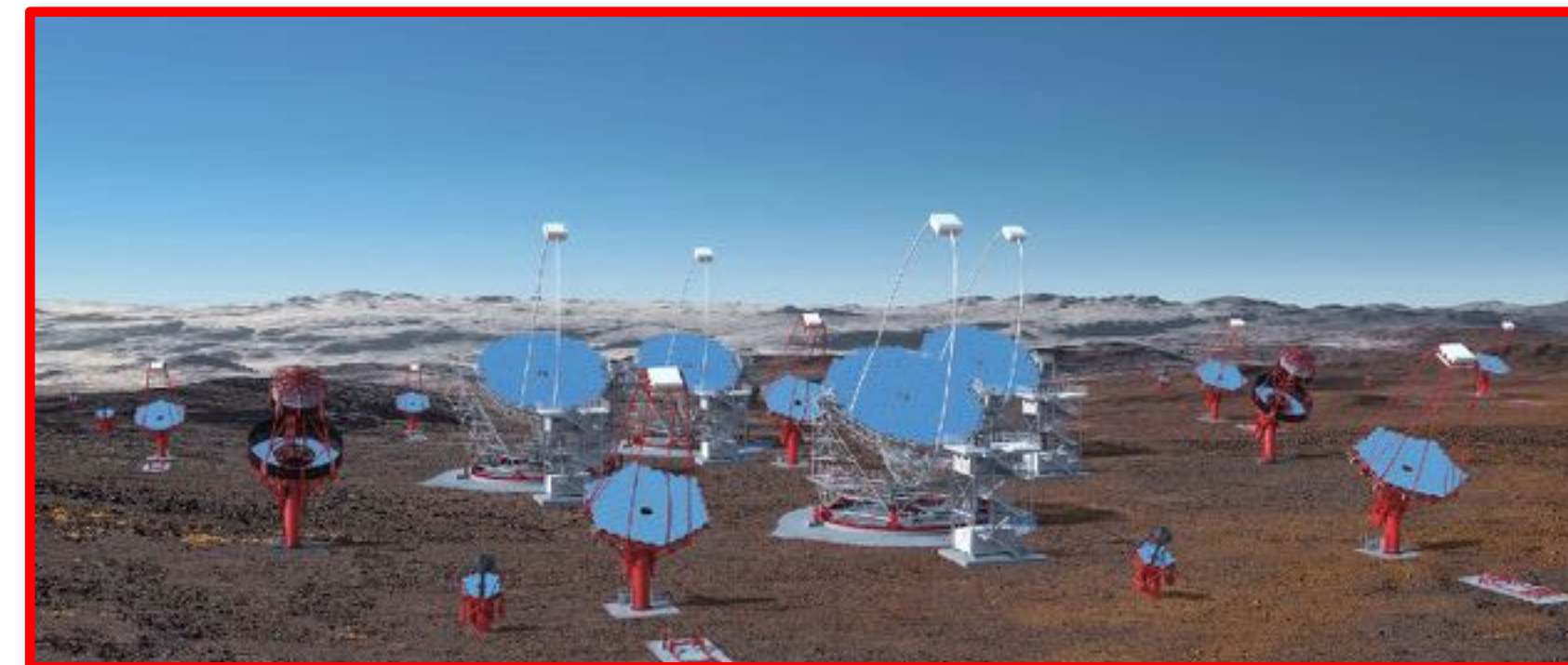
The CTAO Observatory (+ CTA+) in a nutshell:

- ERIC Infrastructure (one of the biggest in EU) started in January '25
- Italy's contribution second only to DE, first ERIC with HQ in Italy
- 2 observing sites (North and South hemispheres):
 - a) CTAO-N (La Palma, Canary Islands): 4 LSTs + 9 MSTs (NB: ASTRI MA in nearby Tenerife with 9 ASTRI-tel (~SSTs))
 - b) CTAO-S (Chile, Paranal): 14 MSTs + 37 SSTs

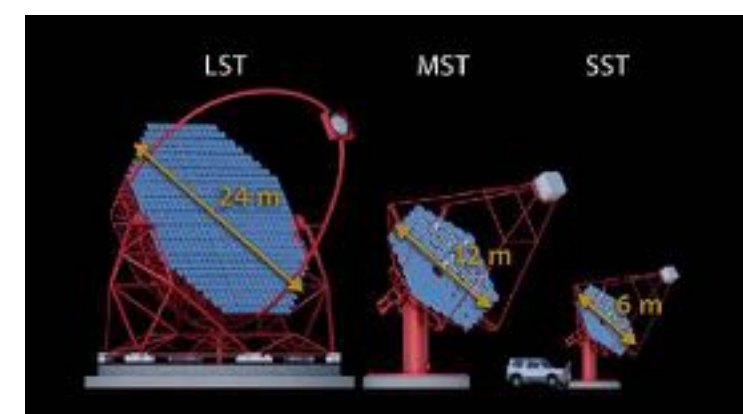
CTAO-N (La Palma)



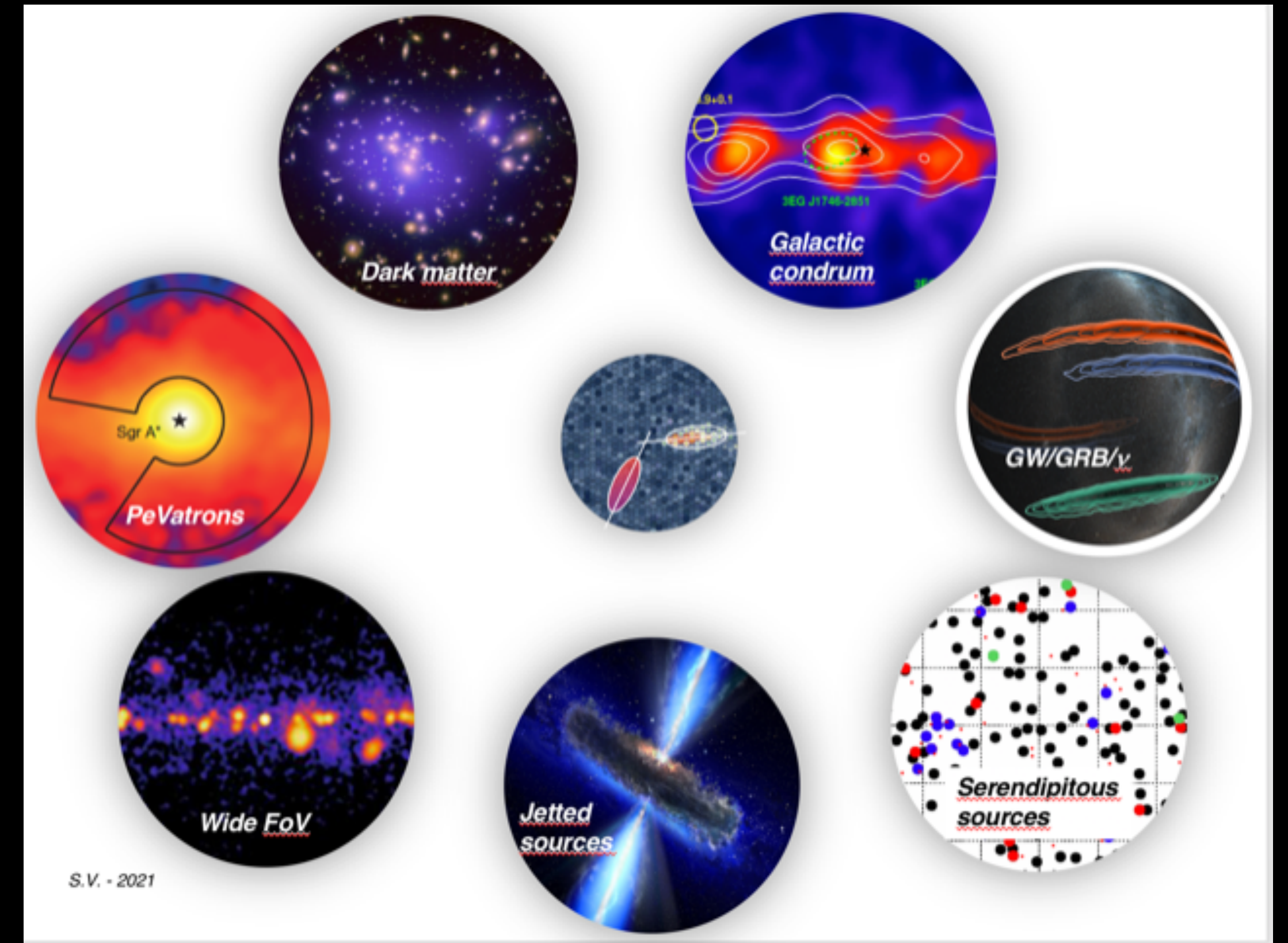
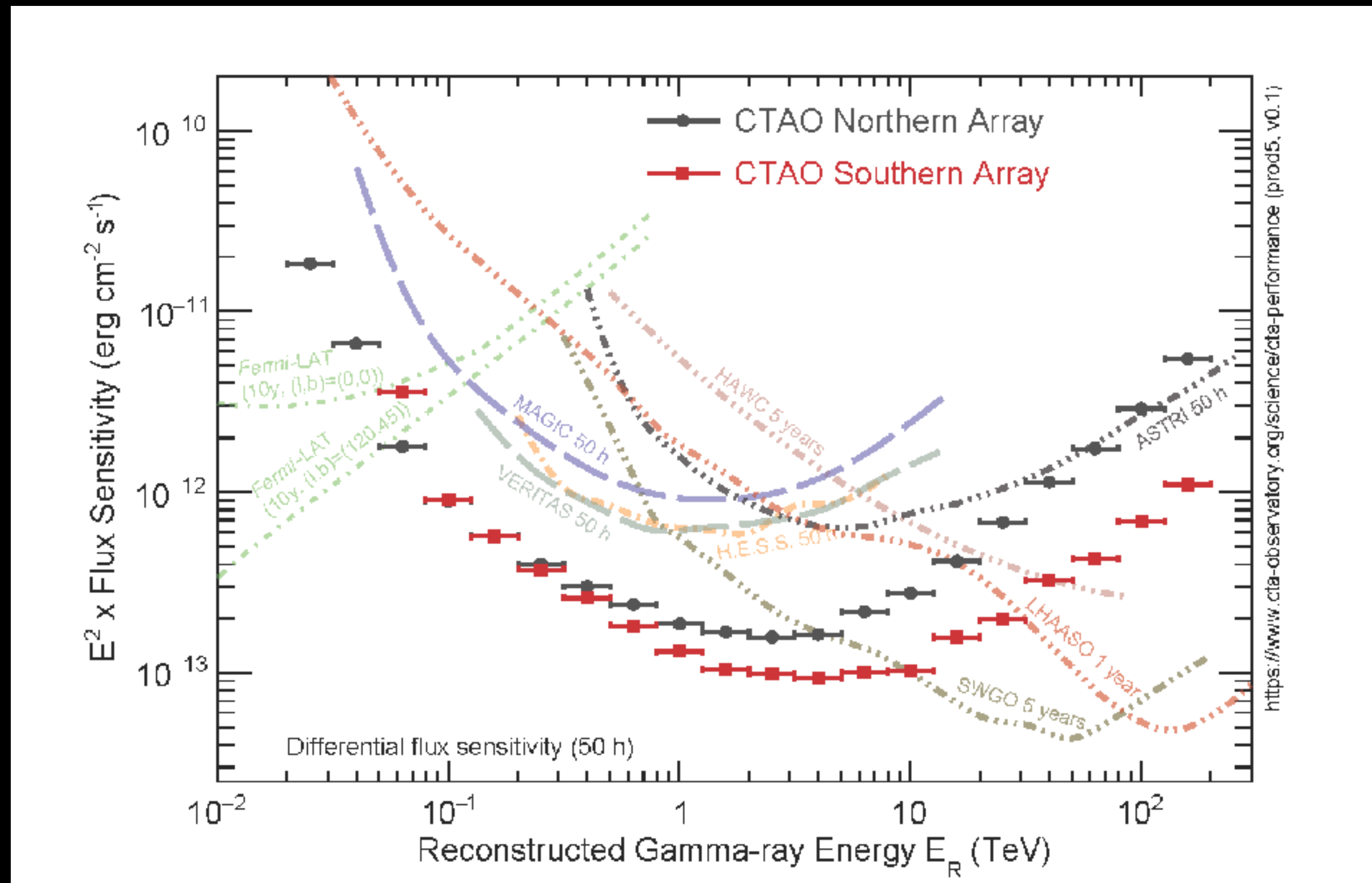
CTAO-S (Cile)



+ 2LST-S and 5 SST with CTA+!! (PNRR project)



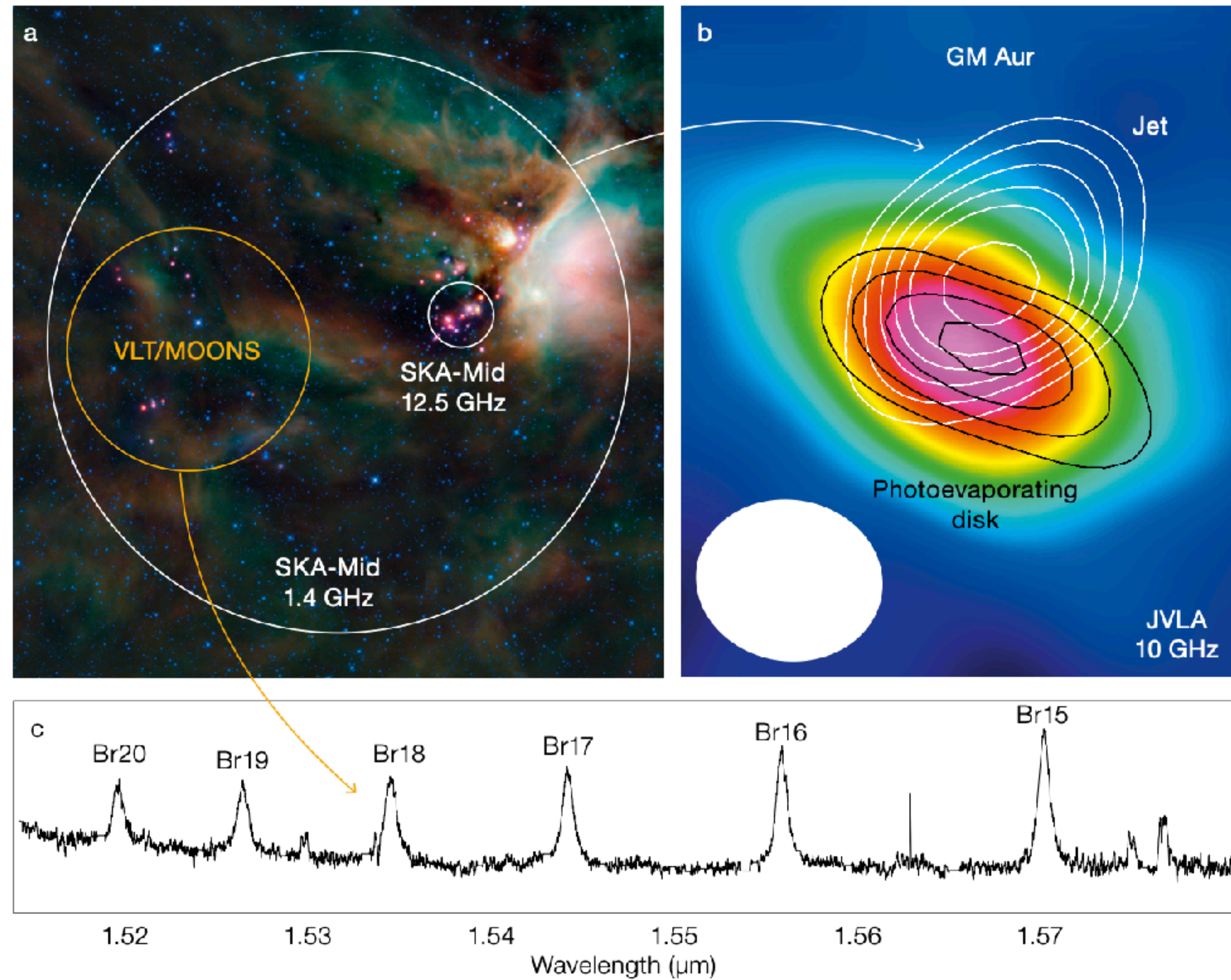
The ASTRI-MA/CTAO Projects: The New Italian/Open Observatories in the TeV energy range



ASTRI-MA and CTAO will revolutionise the TeV science and community,
and expect the unexpected!

Courtesy of M. Cappi

Star formation



Square Kilometer Array



SKA-Low

→ 131,072 low-frequency antennas in Western Australia

512 stations

0.05-0.35Ghz



SKA-Mid

→ 197 mid-frequency dishes in South Africa

197 dishes (80 from Meerkat)

Band1 (0.35-1.05Ghz)

Band2 (0.95-1.75Ghz)

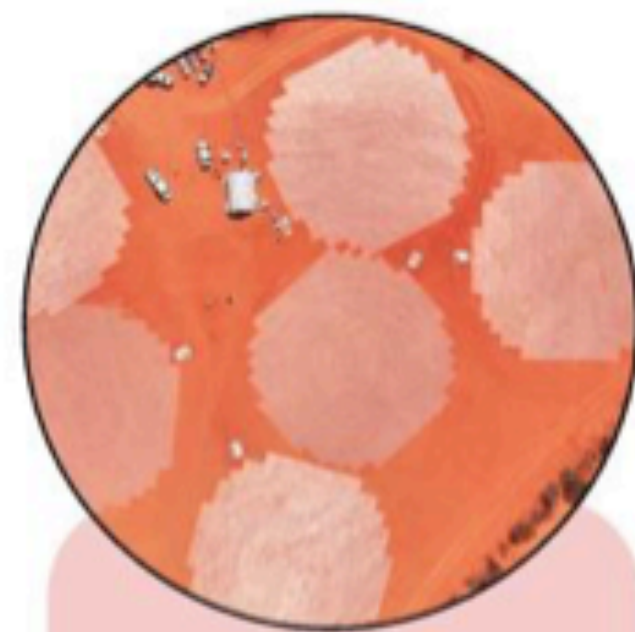
Band5 (5.6-15.4Ghz)

Evolution of SKAO operational modes

SKAO milestones

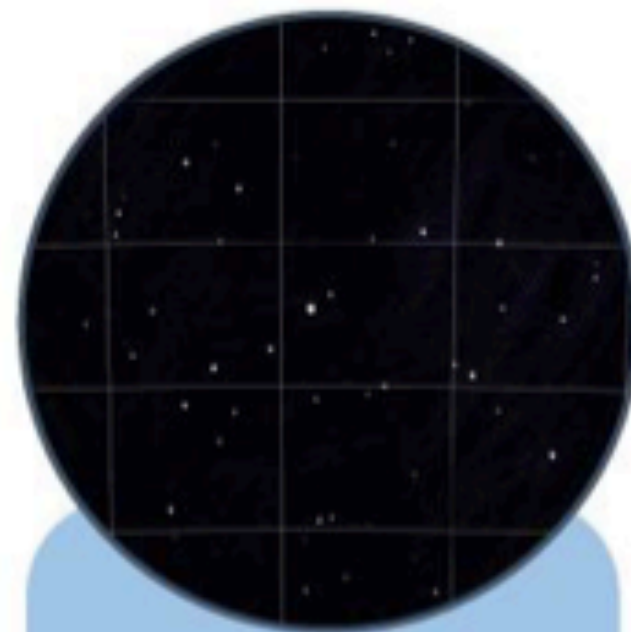
Community involvement starts

Credit: I. Heywood, SARAO



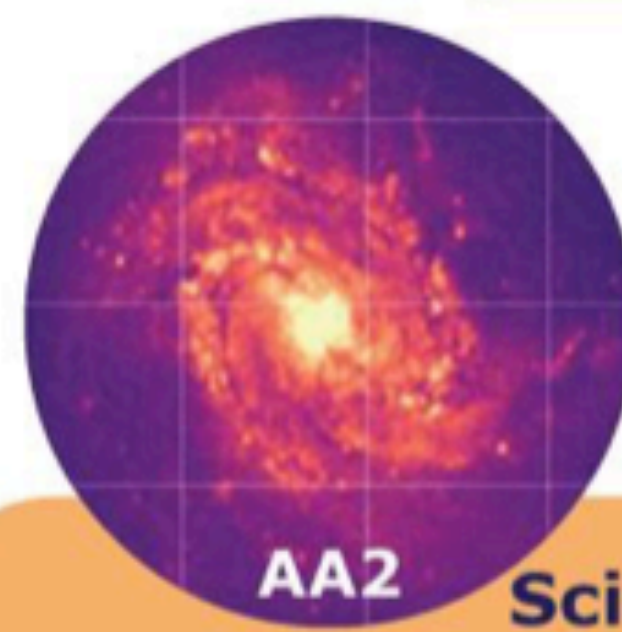
Construction

- Building antennas, dishes, roads...
- Followed by Assembly, Integration and Verification



Commissioning

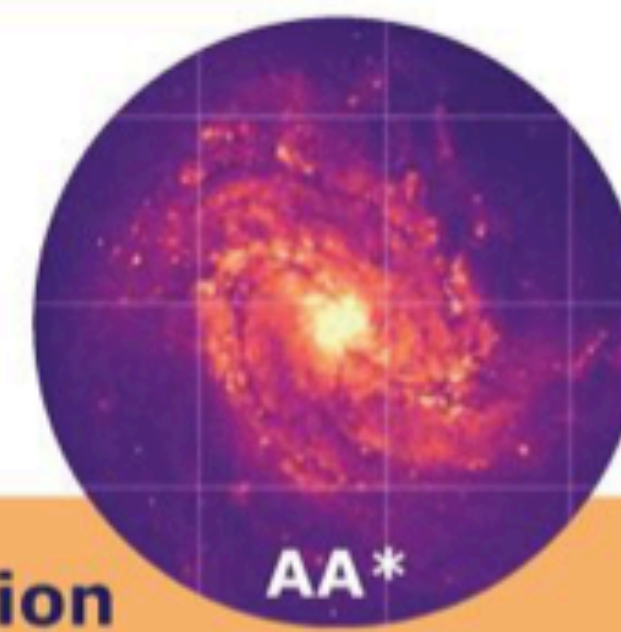
- SKAO activity
- Collaborative across system verification and science commissioning



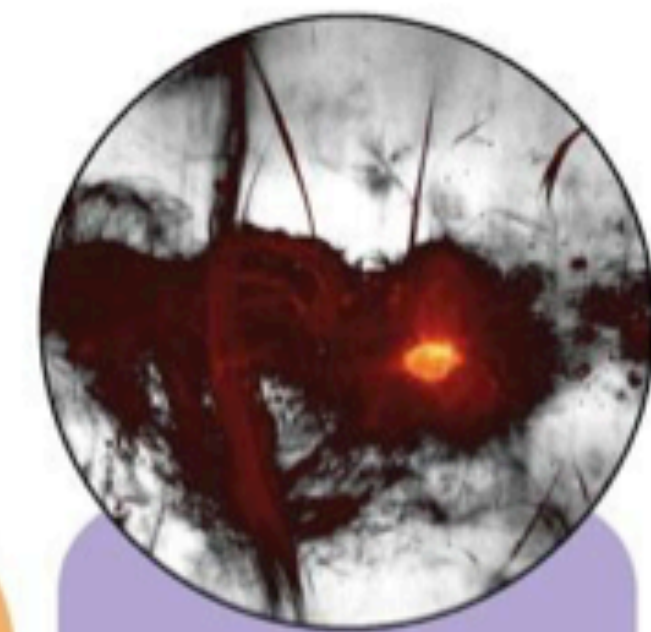
AA2

Science Verification

- **Primary purpose of SV is verification of the scientific capability, overall workflow and usability of the system** → science is a bonus, not guaranteed.
- Provide an end-to-end test of the system for each mode/ODP
- Must not place unnecessary burden on the SKA user community
- Build trust in operational model and excitement on our way to science



AA*



Cycle 0

- Shared-risk PI projects
- SRCNet resources ready for user
- proprietary periods



Now

Now

Mid 2027

First half 2029

2030



Now

Now

First half 2029

First half 2031

2032



Last Update: 31 March 2026



Finanziato
dall'Unione europea
NextGenerationEU



Ministero
dell'Università
e della Ricerca



Italiadomani
PIANO NAZIONALE
DI RIPRESA E RESILIENZA



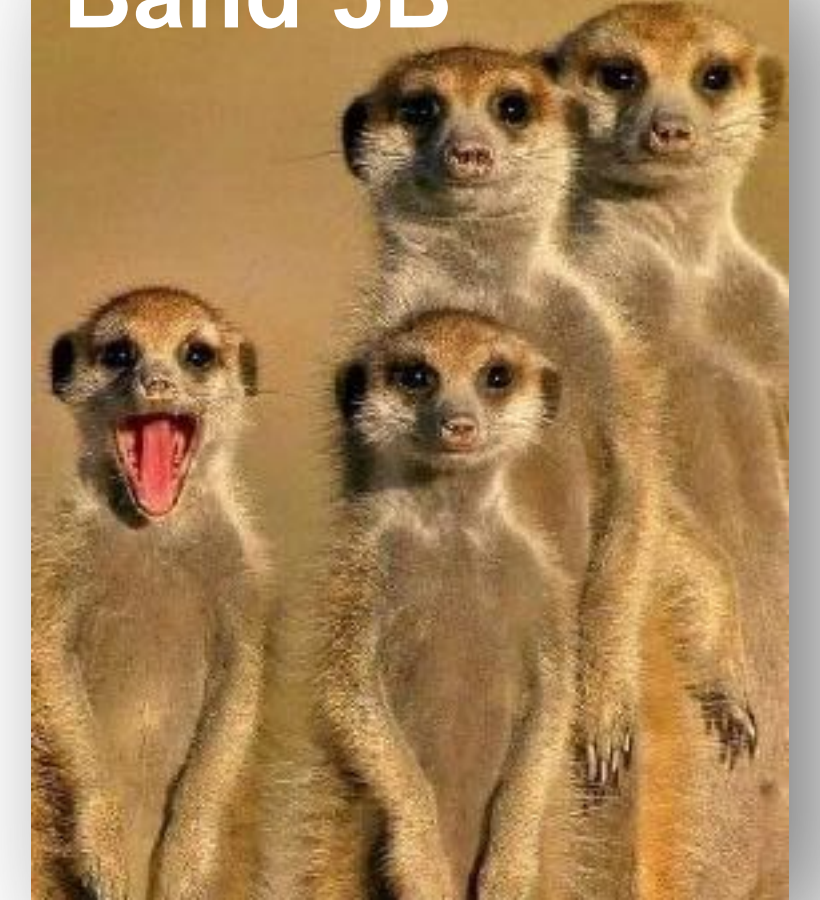
INAF
ISTITUTO NAZIONALE
DI ASTRONOMIA

MeerKAT is the pathfinder of SKA-mid

INAF will provide **64 Band 5B** (8.3-15.4 GHz) receivers on MeerKAT dishes.

Upgrading MeerKAT's 64 dishes with **Band 5B receivers** will establish the array as the **most sensitive instrument** in the **8.3–15.4 GHz** range in the Southern Hemisphere until full SKA-MID operation.

Band 5B



A fully capable MeerKAT has two main benefits for SKA

- The 64 extra receivers will significantly increase the sensitivity of SKA in Band 5 (Area +30%).
- The additional short spacings provided by MeerKAT will substantially enhance the image fidelity of extended emission.

Technical capabilities



Angular
resolution
0.5"-2.3"



Sensitivity
4.8-8 uJy/beam
(10 minutes)



Bandwidth
2500 MHz



Instantaneous
FOV
6.9 arcmin



Mosaic time
16 hours
(1 deg² / 10 uJy/beam)



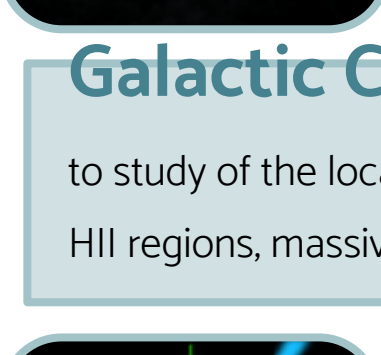
Band 5B @MeerKAT

Will unlock **unprecedented capabilities** to address the **most fundamental astrophysical questions...**



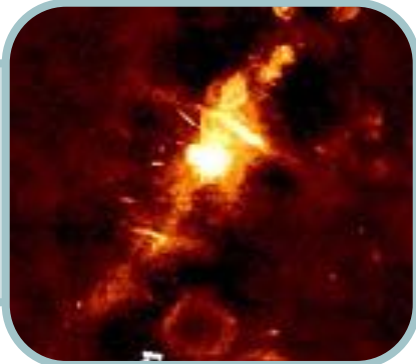
Complex Organic Molecules

in nearby star forming regions, allowing to trace carbon chemistry and dust lifecycle



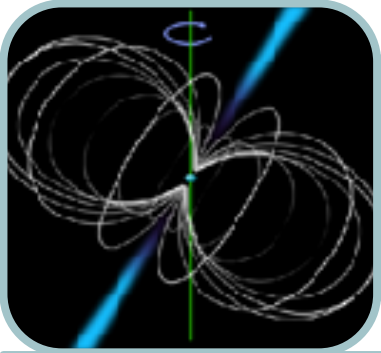
Galactic Centre

to study of the local populations and extreme phenomena (Sgr A*, SNRs, HII regions, massive stars, non-thermal filaments)



Pulsars in the Galactic Centre

are the “timing solution” to test General Relativity, BH properties, nuclear forces



Star formation and HII regions

to investigate feedback mechanisms in (massive) star formation at sub-arcsec resolution and sensitivity in a key observational window



Molecules at high redshift

to better trace molecular formation at early cosmological epochs



Nearby galaxies

to study star formation and better understand galactic evolution, study of super star clusters.



Transient science

to monitor dwarf novae, novae, X-ray binaries (spatially resolved ejecta & spectral evolution) and GRBs.



Synergies with high energy facilities

to search for radio counterparts of high-energy/neutrino events



Radio galaxies

resolving jets & lobes to map B-fields and investigate the role of turbulence and particle re-acceleration.

VLBI with MeerKAT

to search for radio-loud AGNs in gas-rich mergers, detection strongly lensed AGNs, study of dark matter

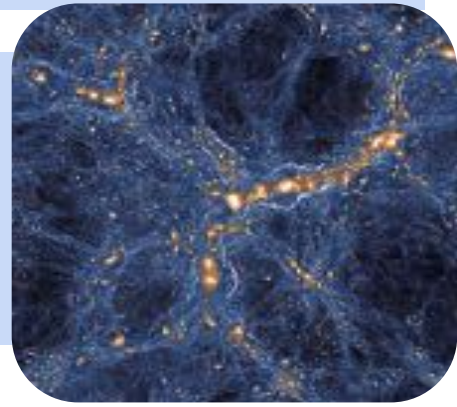


Extragalactic spectro-polarimetry

for a legacy band 5b survey to investigate radio galaxies, AGN variability, clusters and extragalactic transients

Galaxy clusters

studies of intracluster medium (ICM), radio relics and central cluster regions/AGN (polarization and RM)



Star formation and HII regions

to investigate feedback mechanisms in (massive) star formation at sub-arcsec resolution and sensitivity in a key observational window



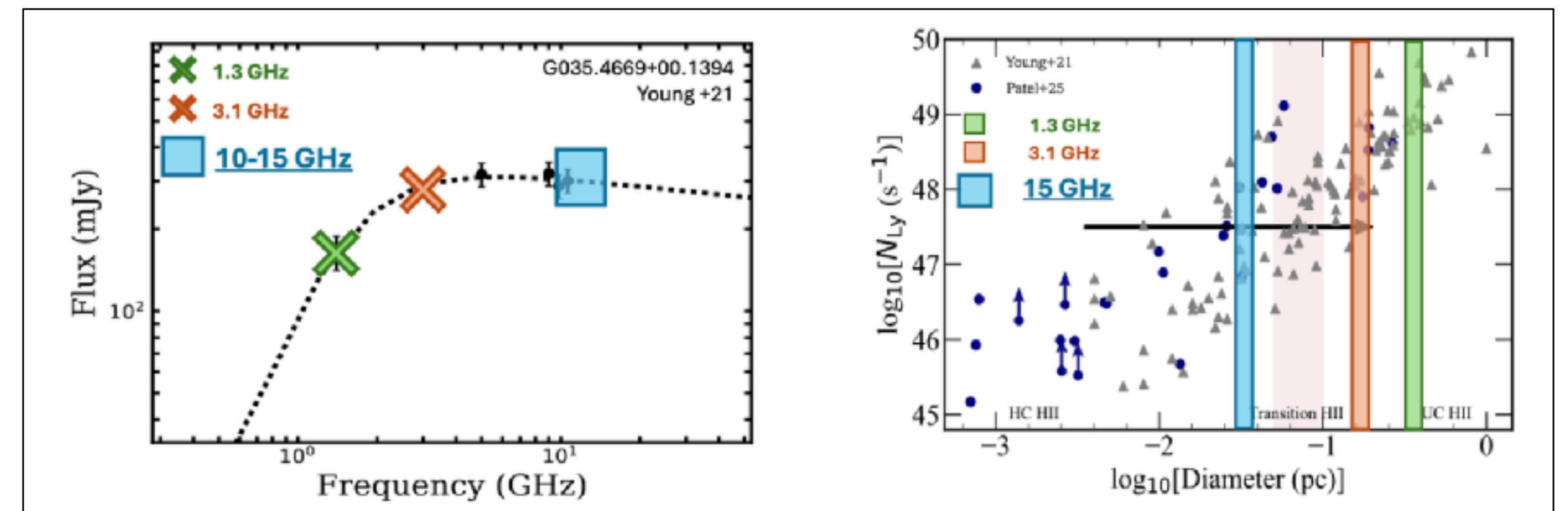
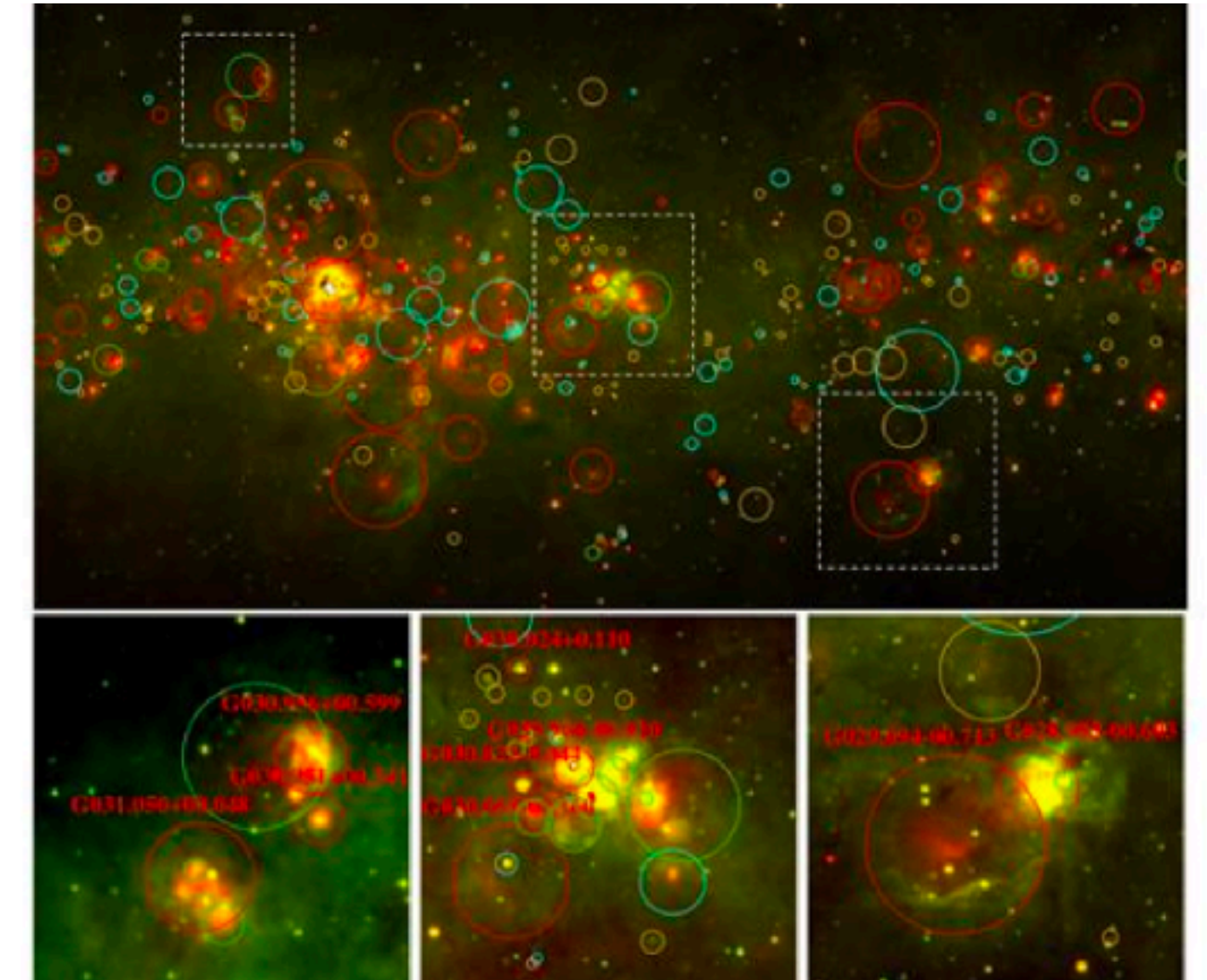
- Need to disentangle the complex interplay between gravity, turbulence & feedback in the star forming processes
- Focus on HII clumps in the Galactic Plane, to complement existing surveys
- Hyper-compact (HC) and Ultra-compact (UC) HII regions become optically thin at GHz frequencies (1-5 GHz & 5-50 GHz respectively)

MeerKAT @~10-15 GHz

Diameter ~0.05-0.03 pc (~1.0''– 0.7'') @d=10 kpc

**Flux $\gtrsim 30 \mu\text{Jy/beam}$
($N_{\text{Ly}} \gtrsim 10^{44.5} \text{ s}^{-1}$)**

The Band 5b frequency range allows the determination of the SED for the HII regions, which coupled with the angular resolution allows to study their evolution out to ~10 kpc away from us



Courtesy of A. Traficante/T. Venturi

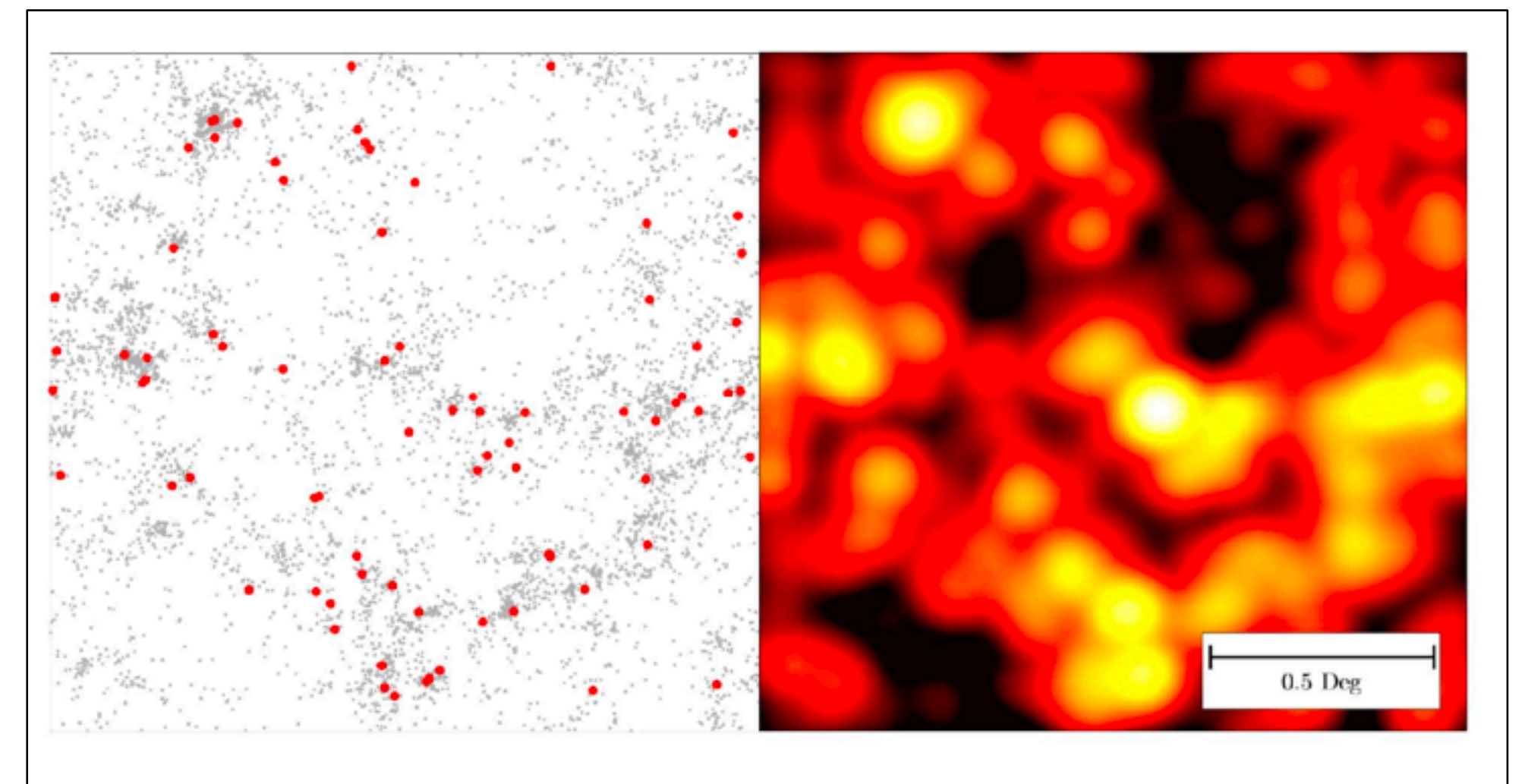
Molecules at high redshift

to better trace molecular formation at early cosmological epochs

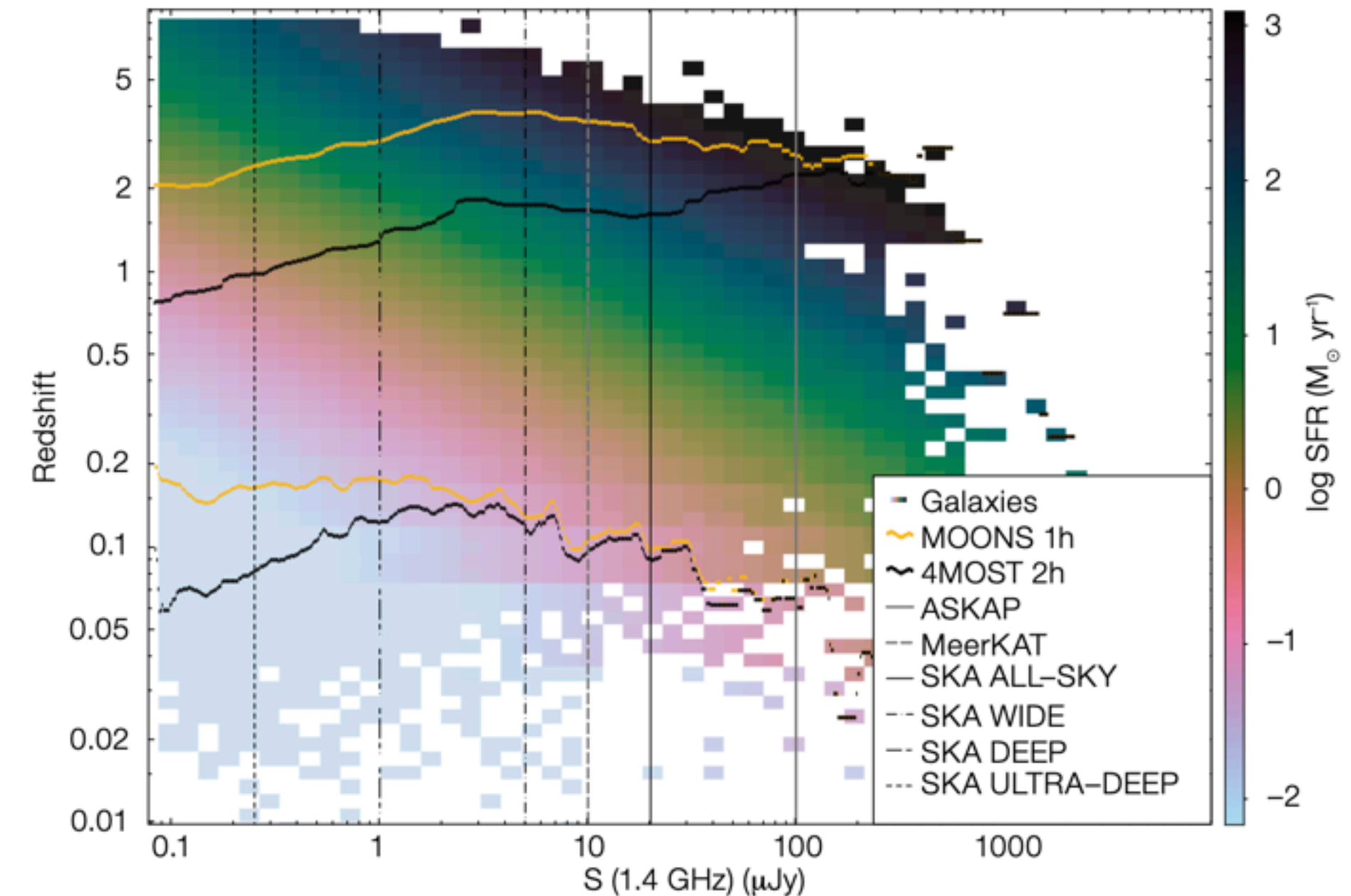
Observations of molecular gas in galaxies at all redshifts are critical for measuring the cosmic evolution in molecular gas density and understanding the star-formation history of the Universe.

- Detection of $J=1 \Rightarrow 0$ line of ^{12}CO molecule (rest frequency= 115.27 GHz) in hundreds of Galaxies in the range $6.95 < z < 9.98$, during the cosmic Epoch of Reionization- CO is best tracer of molecular gas content
- Parallel spectral line surveys HCN (rest frequency=88.63 GHz) , HCO+ (rest frequency= 88.19 GHz)
range. $5.1 < z < 7.5$
H₂O maser (rest frequency= 22 GHz)
range $0.5 < z < 1.2$
- Deep 12 GHz continuum maps for AGN/starburst studies.

Courtesy of G. Bernardi



+ continuum from SKA



Prandoni+24

Resolution Θ scales like $\Theta = 1.22 \frac{\lambda}{D} \dots$

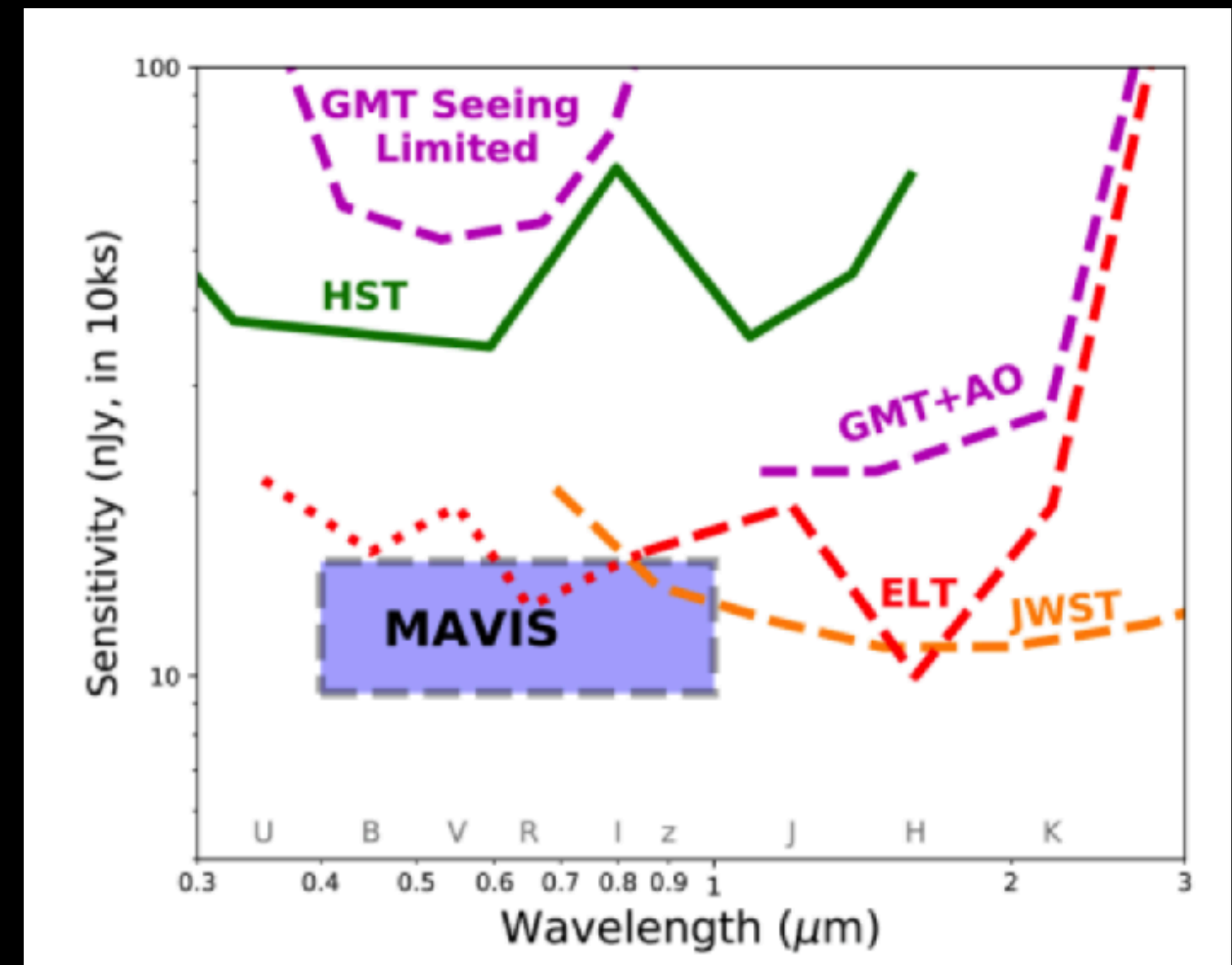
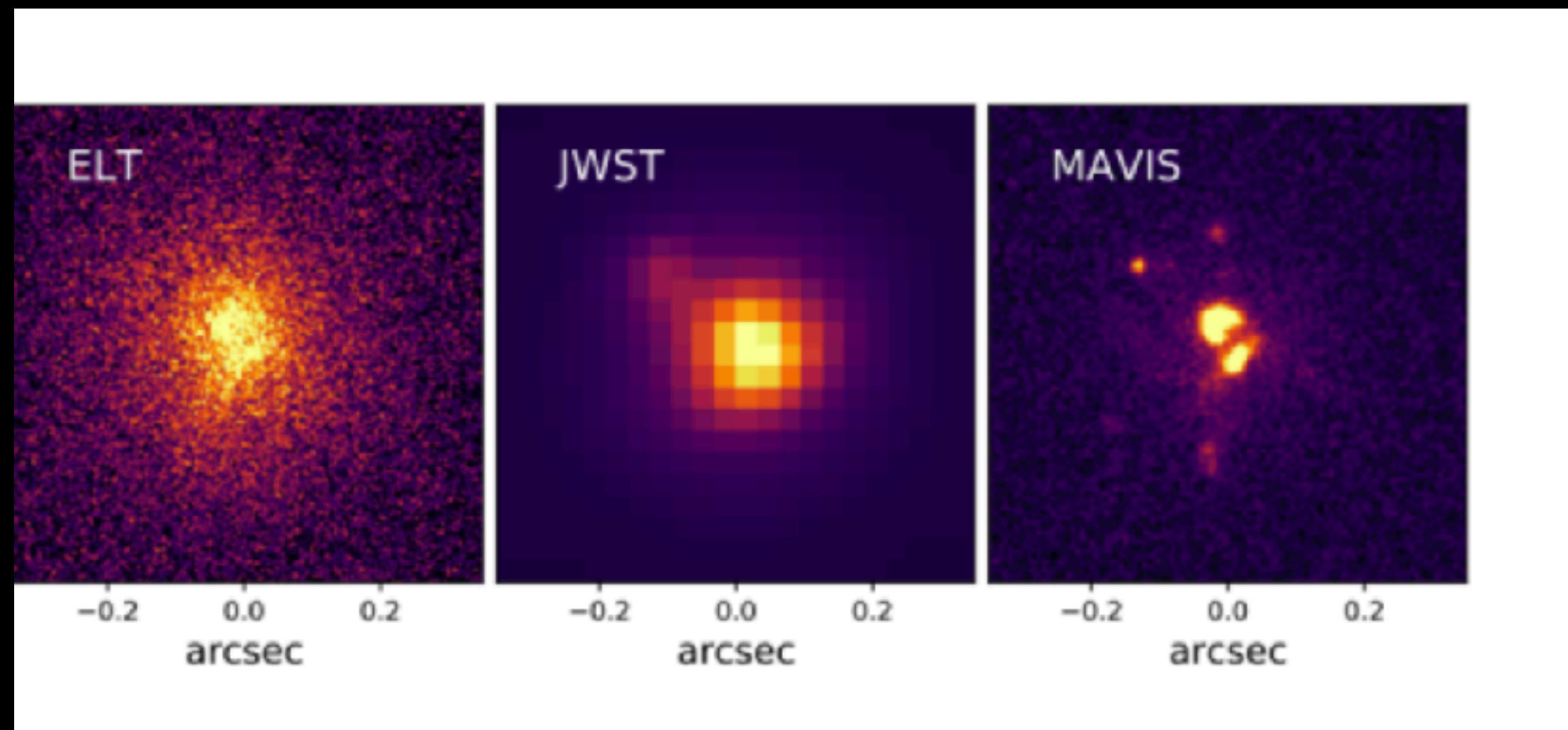
Resolution Θ scales like $\Theta = 1.22 \frac{\lambda}{D} \dots$

....making a 8m in the V band equivalent to a 40m in K...

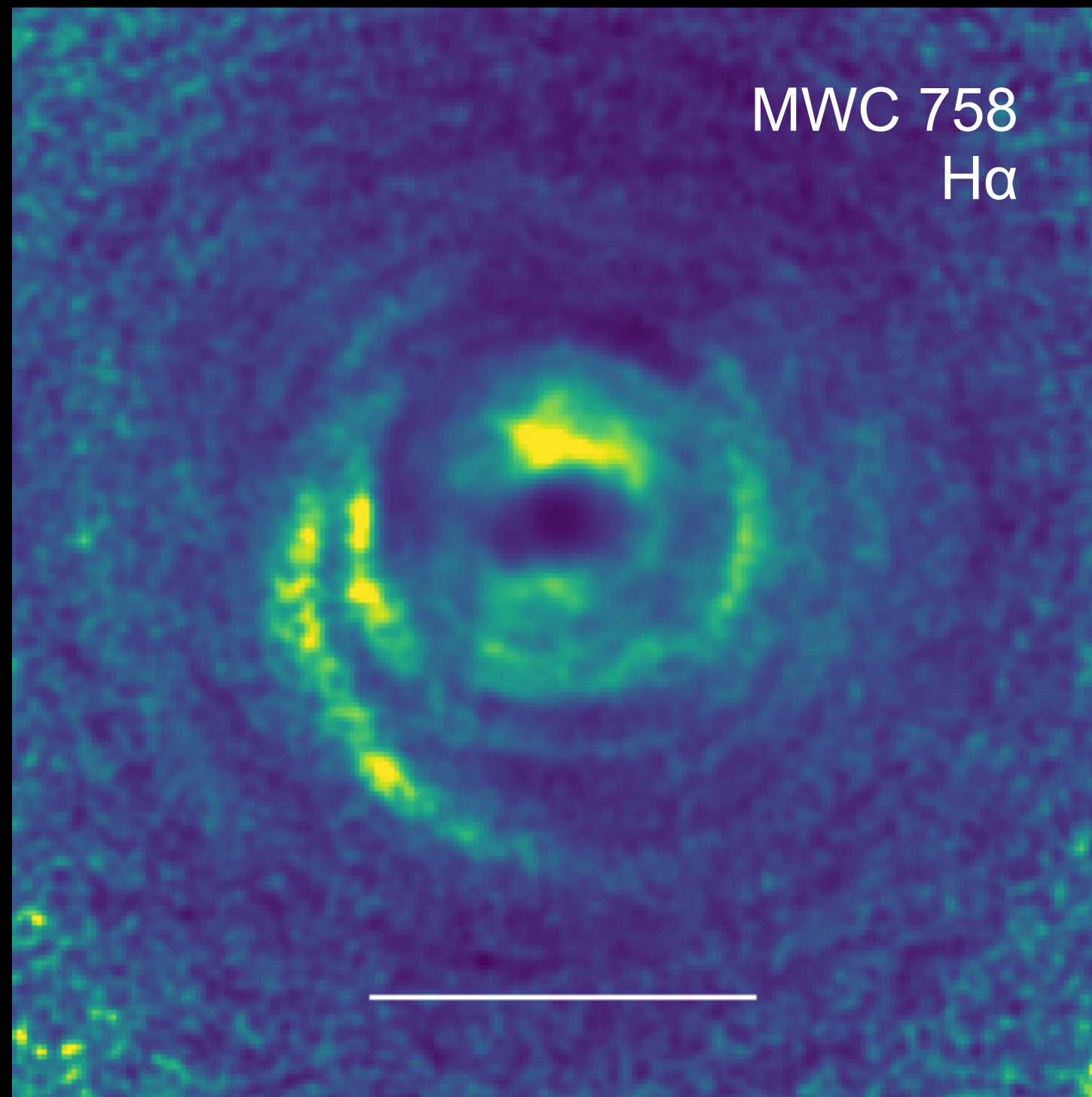
Resolution Θ scales like $\Theta = 1.22 \frac{\lambda}{D} \dots$

....making a 8m in the V band equivalent to a 40m in K...

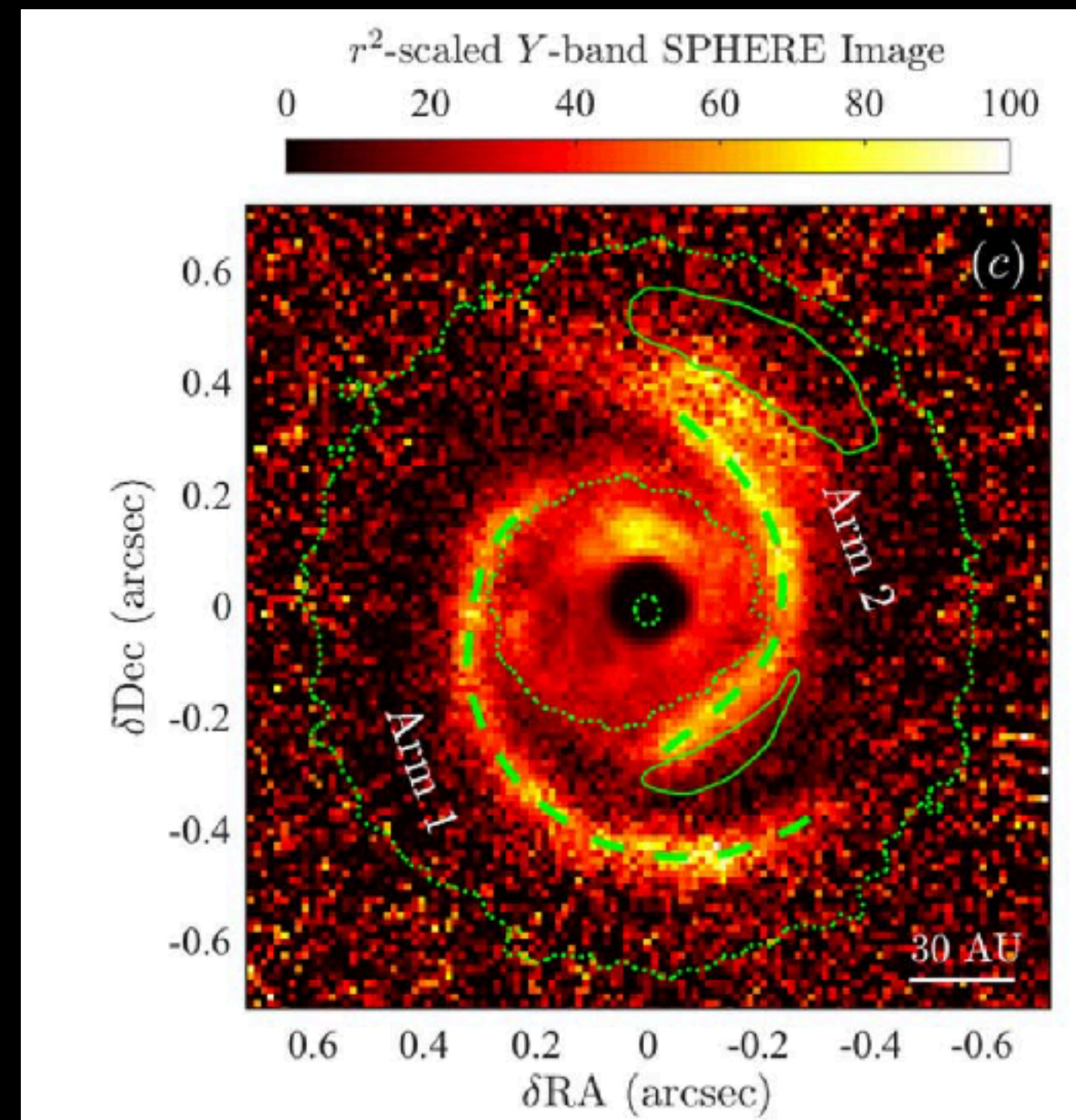
MAVIS @ VLT (2030s)



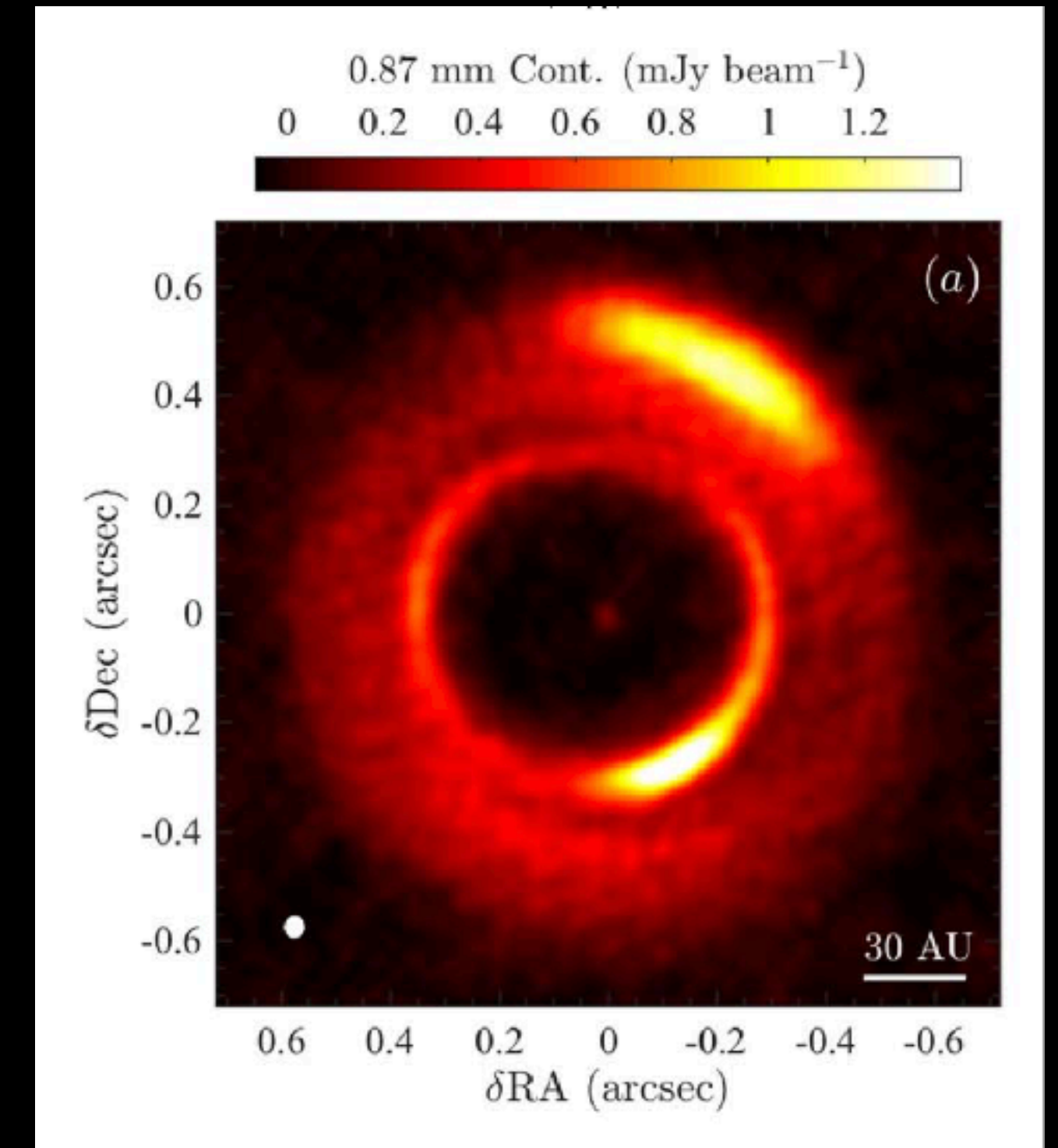
SHARK-VIS@LBT



Y-band Sphere

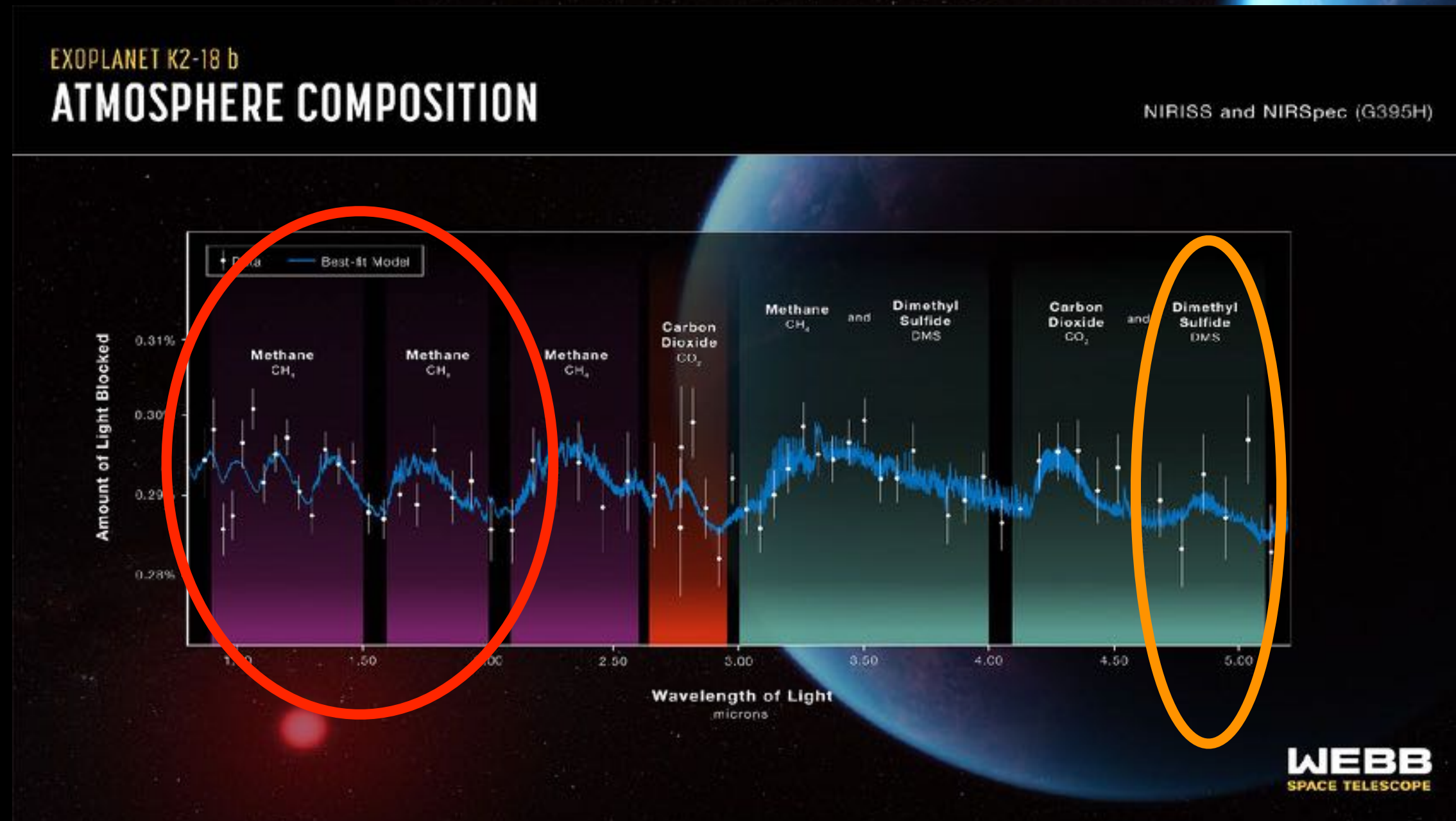


0.85mm ALMA

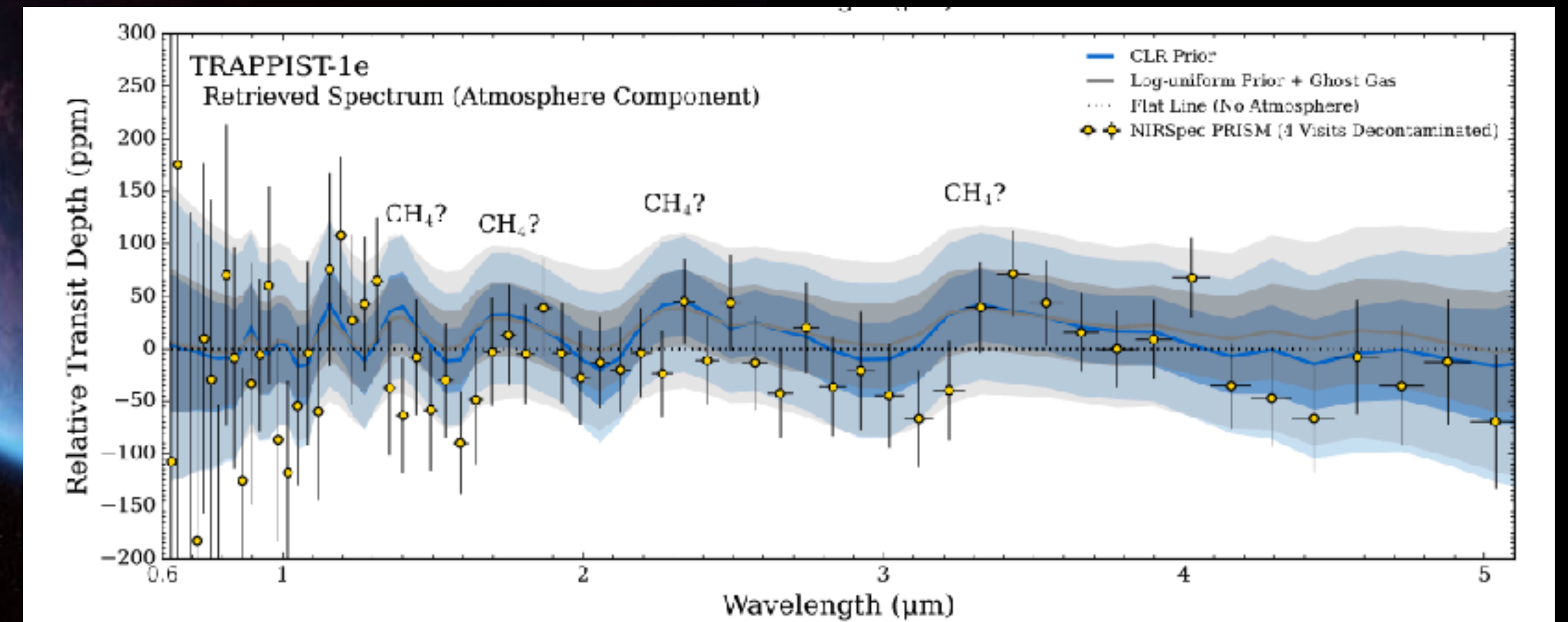


Deng+18

Exoplanet: atmosphere characterisation



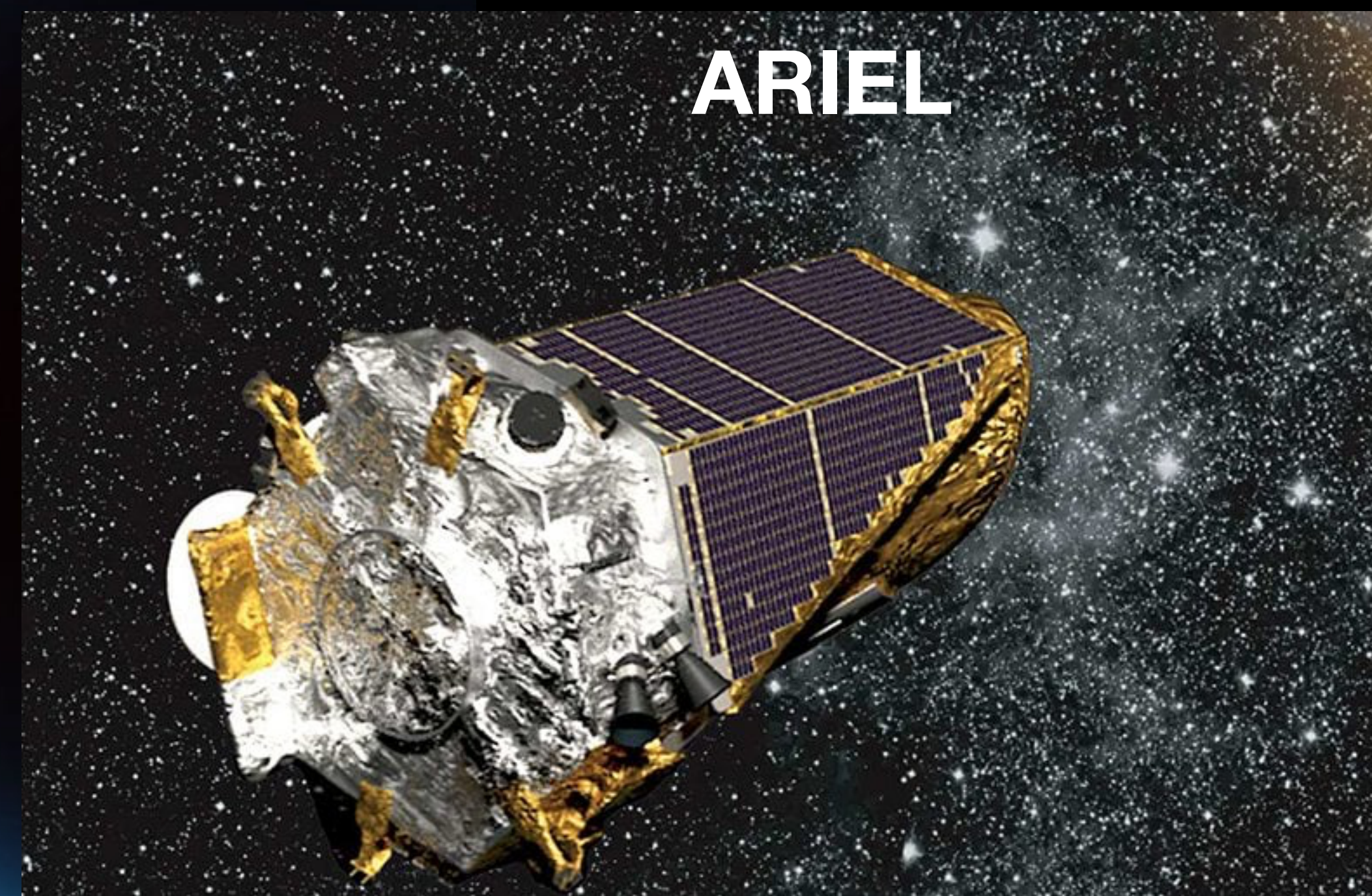
Madhusudhan+25



Glidden+25



**Imaging for transit detection
of long period earth like
exoplanets**



**IR Spectroscopy for
atmosphere
characterisation**

Italy is a **major** (2nd) contributor to both missions

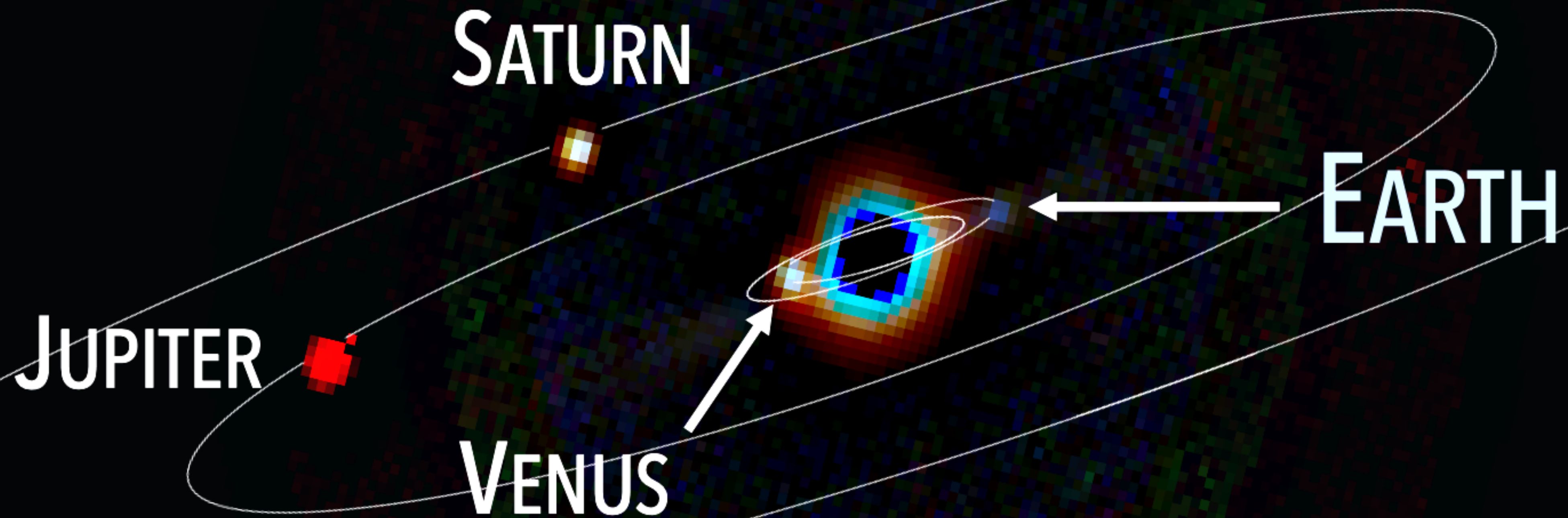
HABITABLE WORLDS OBSERVATORY

TELLING THE STORY OF LIFE IN THE UNIVERSE

A super-Hubble to search for
life in the universe and
perform transformative
astrophysics

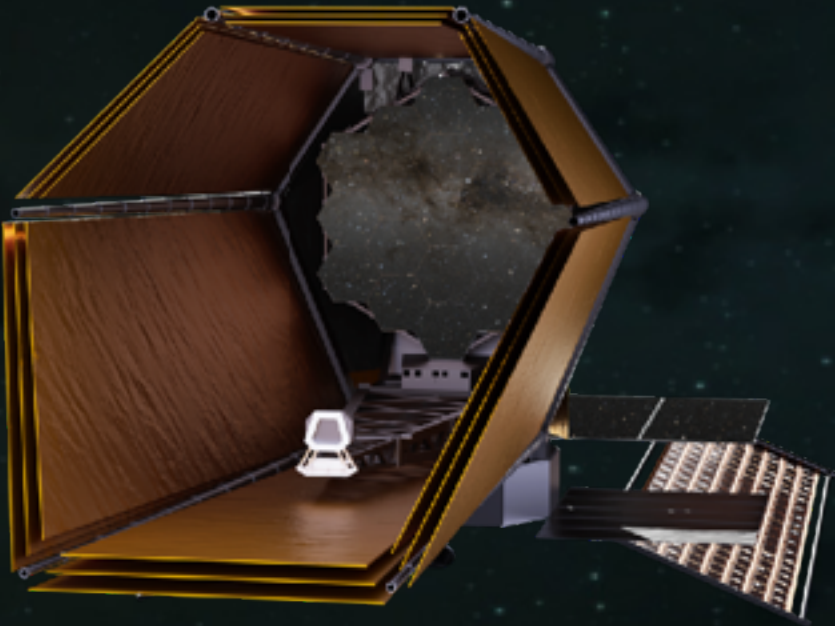
H A B I T A B L E
W R L D S
O B S E R V A T O R Y

ANOTHER EARTH



Preliminary simulated high-contrast image of the
Solar System with a coronagraph on HWO

PRELIMINARY SPECS & CANDIDATE INSTRUMENTS

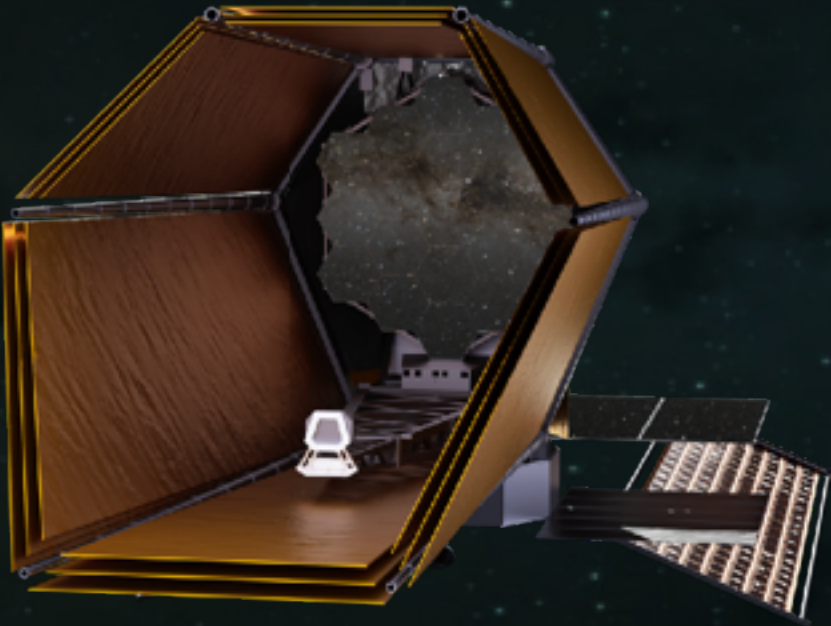
Telescope	
Diameter	≥6.0 m
Bandpass	~100–2500 nm
Diff. Limit @	~500 nm
	

Fourth Instrument
To be defined
<i>Candidates include NUV Coronagraph, FUV IFS, UV Spectropolarimeter</i>

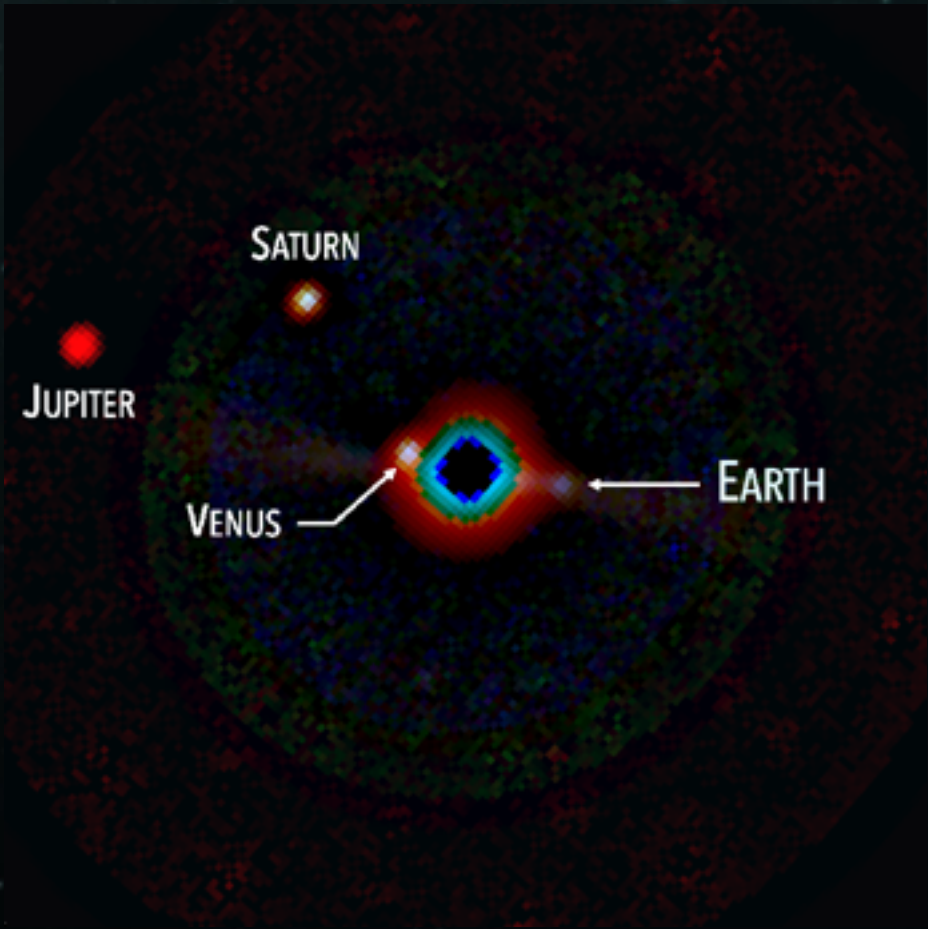
Coronagraph	
High-contrast imaging and imaging spectroscopy	
Bandpass	~350–1700 nm
Contrast	
	Vis: ~140 NIR: ~70, 200

High-Resolution Imager	UV Multi-Object Spectrograph
Bandpass	
Field-of-View	
60+ science filters & grism	
High-precision astrometry?	

PRELIMINARY SPECS & CANDIDATE INSTRUMENTS

Telescope	
Diameter	≥6.0 m
Bandpass	~100-2500 nm
Diff. Limit @	~500 nm
	

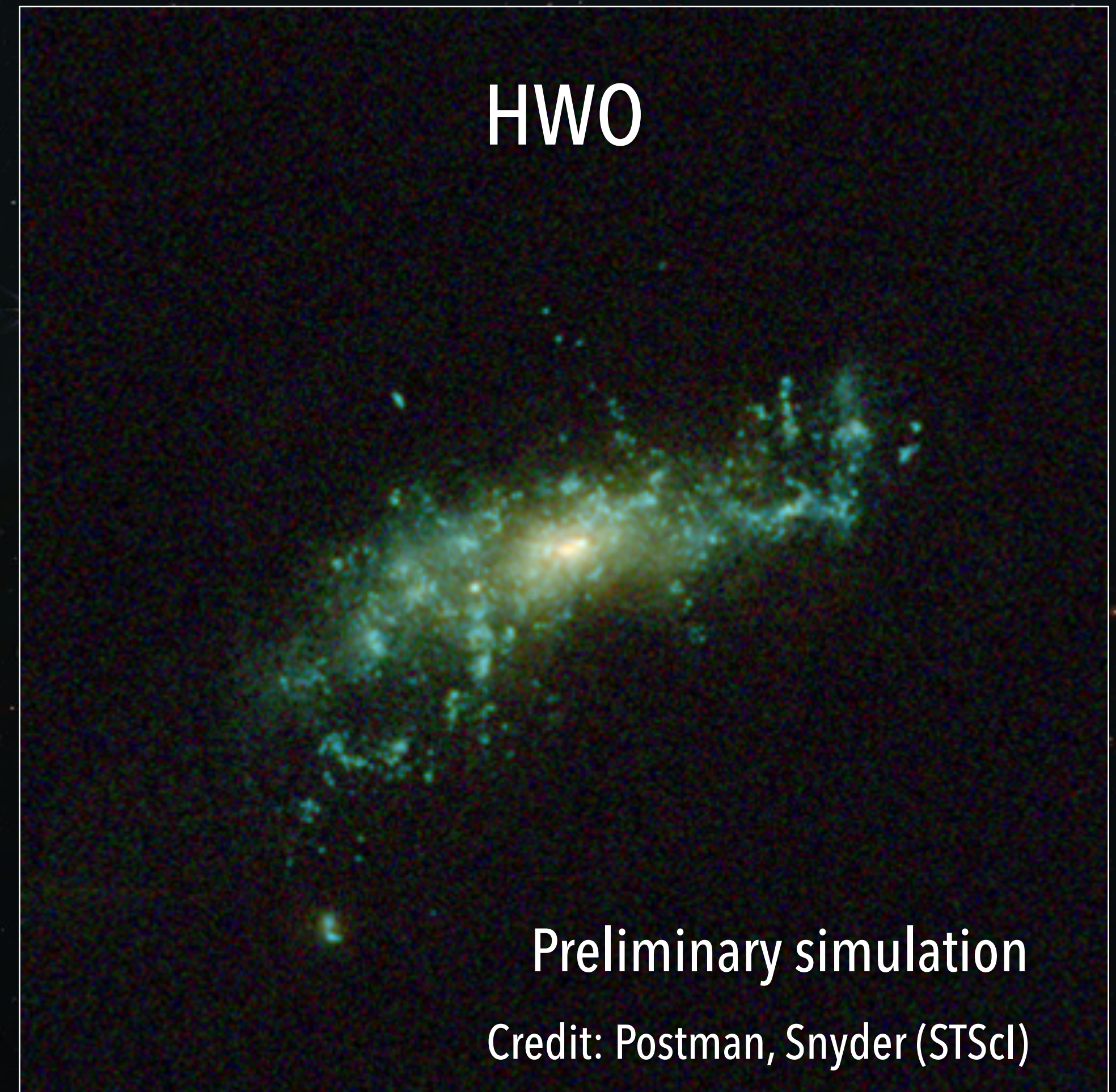
Fourth Instrument
To be defined
Candidates include NUV Coronagraph, FUV IFS, UV Spectropolarimeter

Coronagraph	
High-contrast imaging and imaging spectroscopy	
Bandpass	~350-1700 nm
Contrast	
	Vis: ~140 NIR: ~70, 200
	

High-Resolution Imager	
Bandpass	
Field-of-View	
60+	
High	Ceres

UV Multi-Object Spectrograph	
UV/Vis multi-object spectroscopy and FUV imaging	
Bandpass	~100-1000 nm
Field-of-View	~
Apertures	~
	~500-50,000
	

THE BUILDING BLOCKS OF GALAXIES



Low-mass dwarf galaxy at redshift = 2

SHAPING THE ITALIAN CONTRIBUTION TO HWO

FONTANA¹, A.¹, ANNIBALI, F.², BRIGUGLIO, R.³, BROGI, M.^{4,5}, BUSONERO, D.⁵, CRESCI, G.², D'INCECCO, P.⁶, D'ODORICO, V.⁷, DI MARCANTONIO, P.⁷, FINESCHI, S.⁵, GUILLUY, G.⁵, IVANOVSKI, S.⁷, IZZO, L.⁸, LA RUCCA, N.⁹, LANDONI, M.¹⁰, LIUSTRO, E.⁹, MANCINI, L.²⁰, MARCELLINO, M.^{11,13}, MARCONI, A.^{12,3}, MASSARI, D.², MICELA, G.¹³, MORESCO, M.^{14,2}, NASCIMBENI, V.¹⁵, PARESCHI, G.⁹, PEDICHINI, F.¹, PENTERICCI, L.¹, PINO, L.³, PIOTTO, G.^{15,16}, PIRANOMONTE, S.¹, POLYCHIRONI, D.⁵, RIGLIACO, E.¹⁵, SACCO, G.³, SARACCO, P.¹⁷, SIMONETTI, P. M.⁷, SOZZETTI, A.⁵, TESTI, L.¹⁴, TOZZI, A.³, TRAFICANTE, A.¹⁸, TSANTAKI, M.³, USLENGHI, M.¹⁹, VASSALLO, D.¹⁵, AND ZINGALES, T.^{15,16}

¹INAF Osservatorio Astronomico di Roma, Via Frascati 33, 00078 Monteporzio Catone, Rome, Italy

²INAF Osservatorio di Astrofisica e Scienza dello Spazio di Bologna, via Gobetti 93/3, Bologna, 40129, Italy

³INAF – Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, 50125, Firenze, Italy

⁴Dipartimento di Fisica, Università degli Studi di Torino, via Pietro Giuria 1, I-10125, Torino, Italy

⁵INAF Osservatorio Astrofisico di Torino, Via Osservatorio, 20, Pino Torinese, 10025, Italy

⁶INAF – Osservatorio Astronomico d'Abruzzo, Via Mentore Maggini, 64100 Teramo, Italy

⁷INAF - Osservatorio Astronomico di Trieste, Via Tiepolo, 11, Trieste, 34131, Italy

⁸INAF - Osservatorio Astronomico di Capodimonte, Salita Moiaricello 16, 80131 Naples, Italy

⁹Dipartimento di Biologia, Università di Padova, via U. Bassi 58b, 35131 Padova, Italy

¹⁰INAF-Osservatorio Astronomico di Brera, via Emilio Bianchi 46, 23807 Merate, Italy

¹¹Università degli Studi di Palermo, Dipartimento di Fisica e Chimica, Via Archirafi 36, Palermo (Italy)

¹²Dipartimento di Fisica e Astronomia, Università degli Studi di Firenze, Via G. Sansone 1, Sesto Fiorentino, 50019, Italy

¹³INAF – Osservatorio Astronomico di Palermo, Piazza del Parlamento, 1, 90134 Palermo, Italy.

¹⁴Dipartimento di Fisica e Astronomia "Augusto Righi", Università di Bologna, Via Piero Gobetti 93/2, I-40129 Bologna, Italy

¹⁵INAF – Osservatorio Astronomico di Padova, Vicolo dell'Osservatorio 5, 35122 Padova, Italy

¹⁶Dipartimento di Fisica e Astronomia "Galileo Galilei", Università degli Studi di Padova, Vicolo dell'Osservatorio 3, 35122, Padova, Italy

¹⁷INAF-Osservatorio Astronomico di Brera, via Brera 28, 20121 Milano, Italy

¹⁸INAF - Istituto di Astrofisica e Planetologia Spaziali, Via Fosso del Cavaliere 100, Rome, 00133, , Italy

¹⁹INAF – Istituto di Astrofisica Spaziale e Fisica Cosmica, Milan, Italy and

²⁰Department of Physics, University of Rome "Tor Vergata", Via della Ricerca Scientifica 1, 00133 – Rome, Italy

Version April 30, 2026

ABSTRACT

This paper summarizes the interest of the Italian astronomical community toward the possible participation to the development of the Habitable World Observatory (HWO). It is largely based on the outcome of a dedicated meeting held in Rome in the July 2025, and it includes further revisions and new suggestions arisen in these months. It includes a succinct description of the main scientific interests and of the key technologies that the Italian community can contribute with to the development of the mission. It also include a short section dedicated to the instrument concepts that we deem important to develop for potential adoption on HWO, and that the Italian community is interested to. Last but not least, it includes a concise presentation of the main instruments for ground-based telescope (VLT and ELT) and space mission that will be operative before HWO and in which the Italian community has leading positions. They will be invaluable to settle the scientific landscape for the mission and to prepare the Italian scientists make optimal use of HWO. This paper is primarily aimed at paving the way to discussions and collaborations with worldwide scientists and agencies interested in the development of the mission.

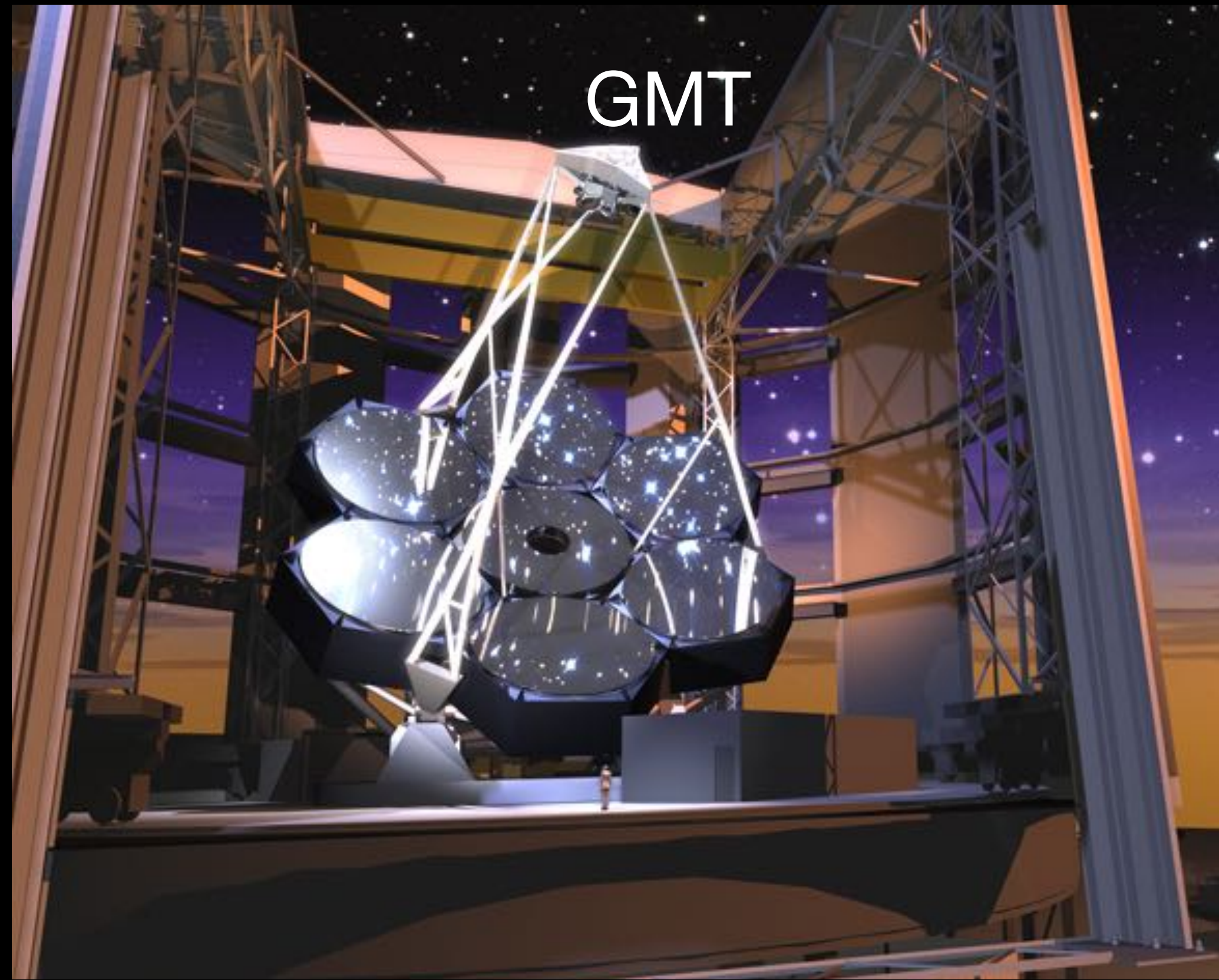
Subject headings: Instrumentation

A White Paper for the Italian participation is in preparation.

Ample space for adding YOUR contribution.

A mailing list (270 participants) is active, send me an e-mail to contribute.

ELT Competitors (are there any?)

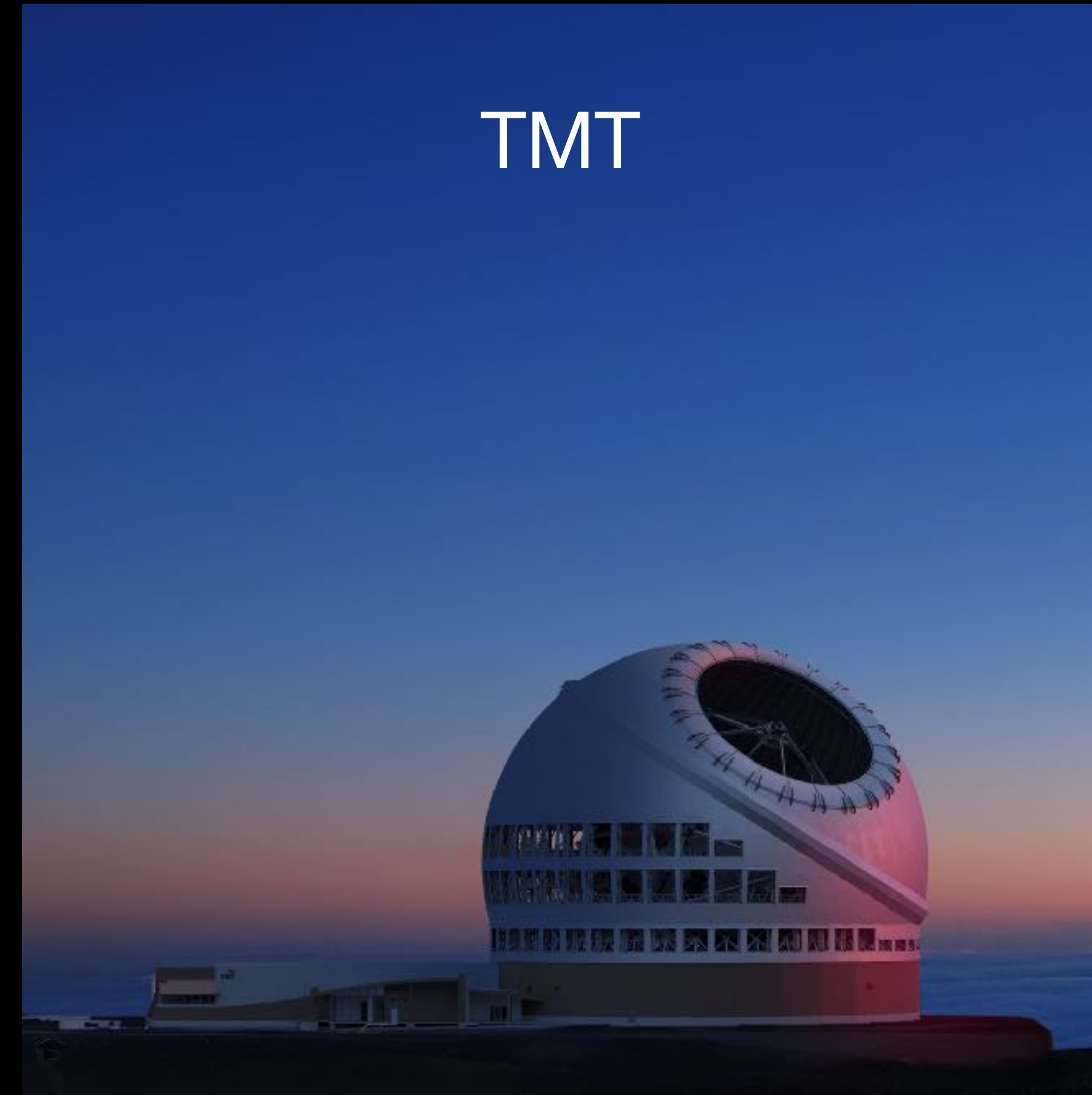
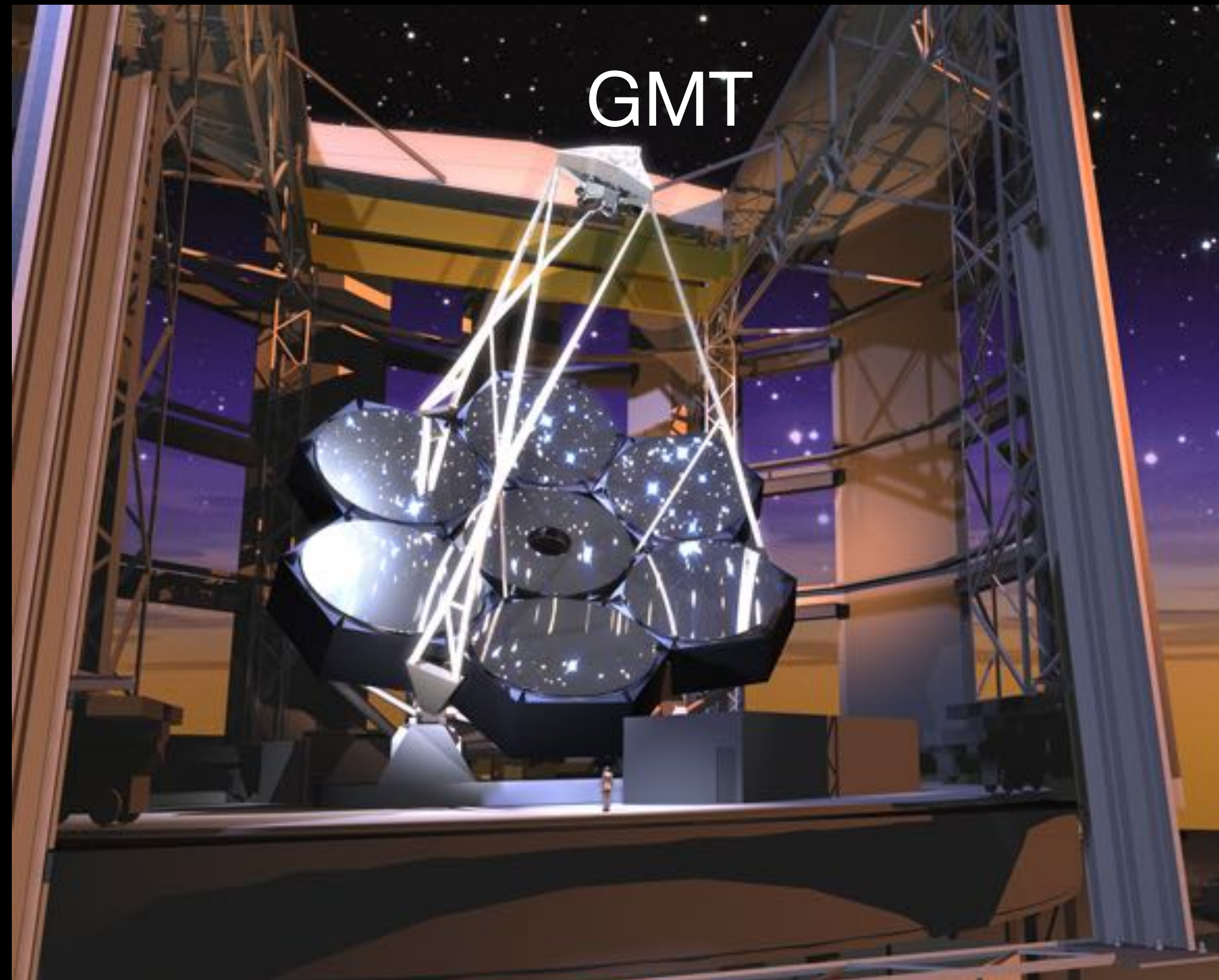


24m-equivalent tel to be located in Chile



30m tel to be located in ...? Canary?

ELT Competitors (are there any?)



24m-equivalent tel to be located in Chile

30m tel to be located in ...? Canary?

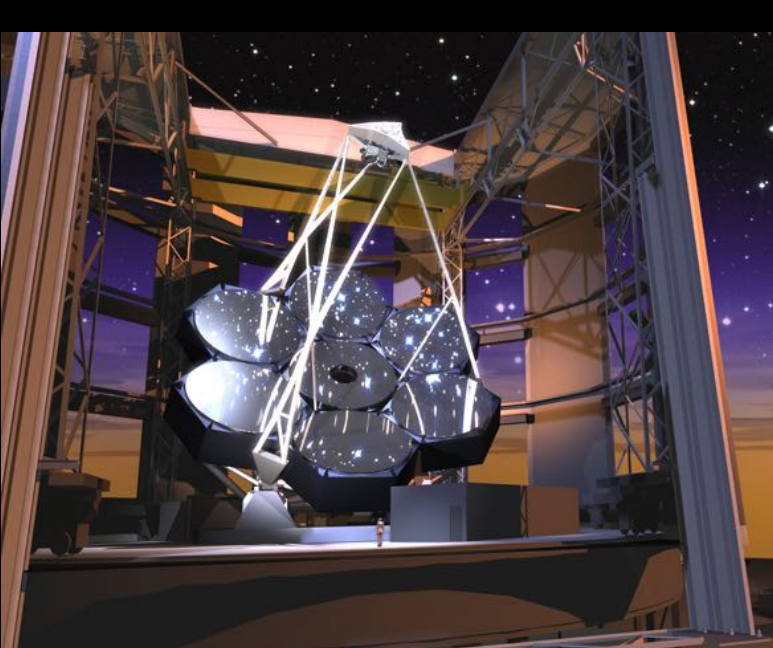
Allowed to proceed to phase B with NSF funds.

NOT funded by NSF

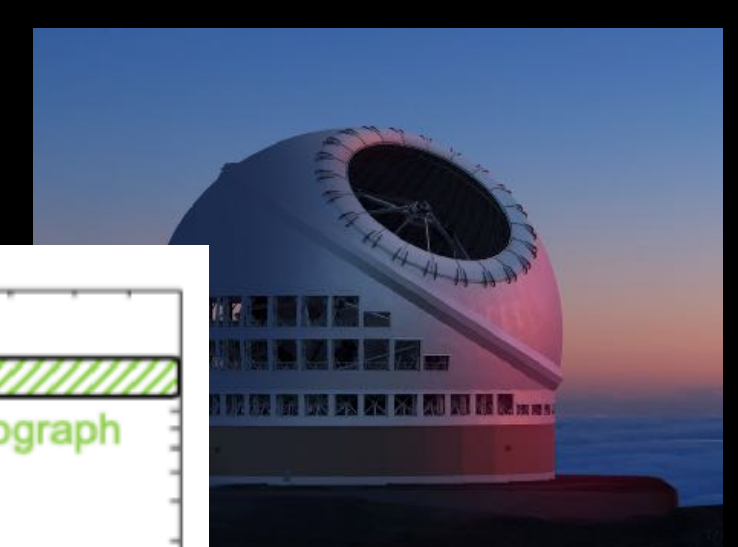
Construction **not** granted so far.

GMT mirrors are being cast in Tucson (4/7 done, 5th in progress)

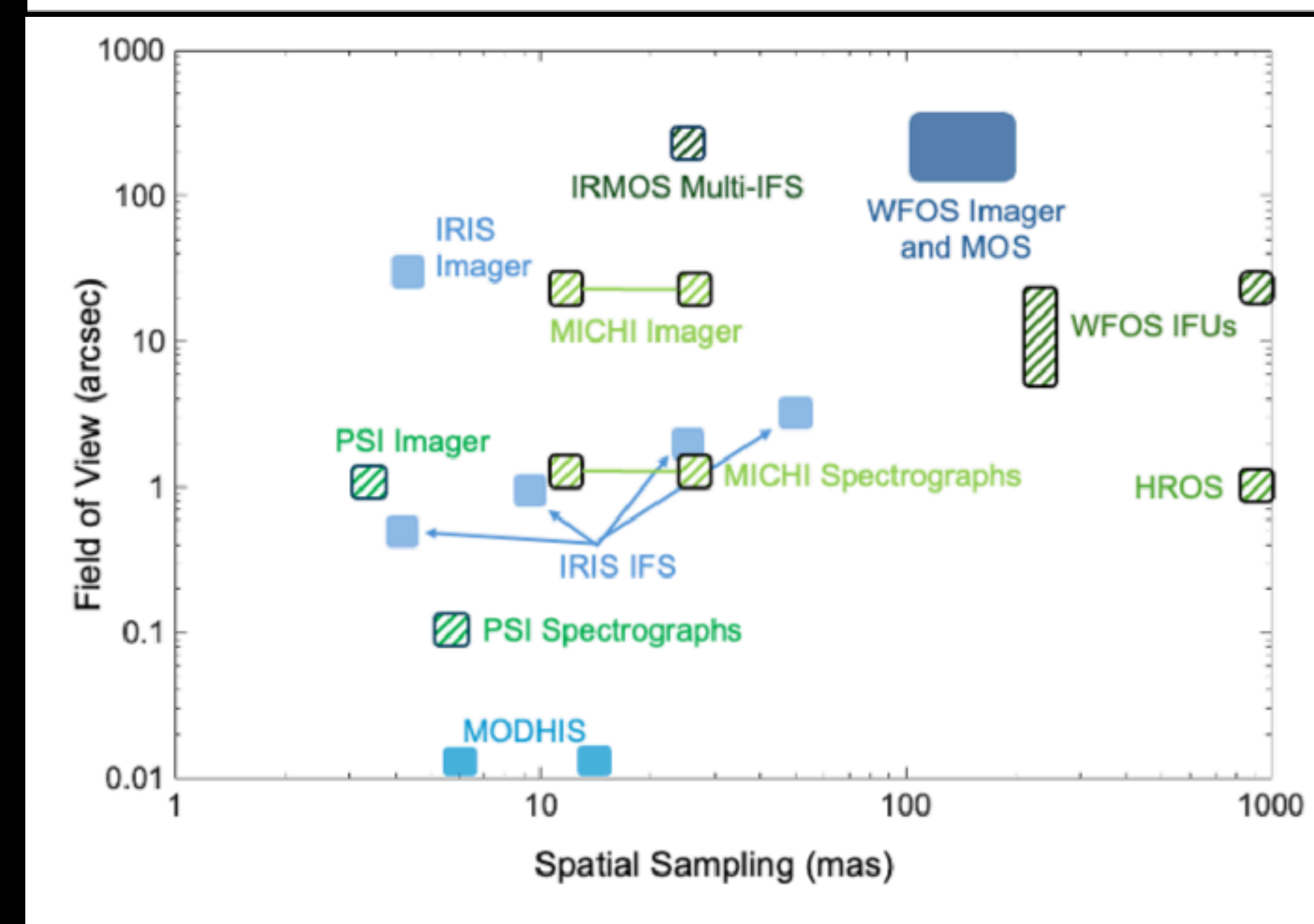
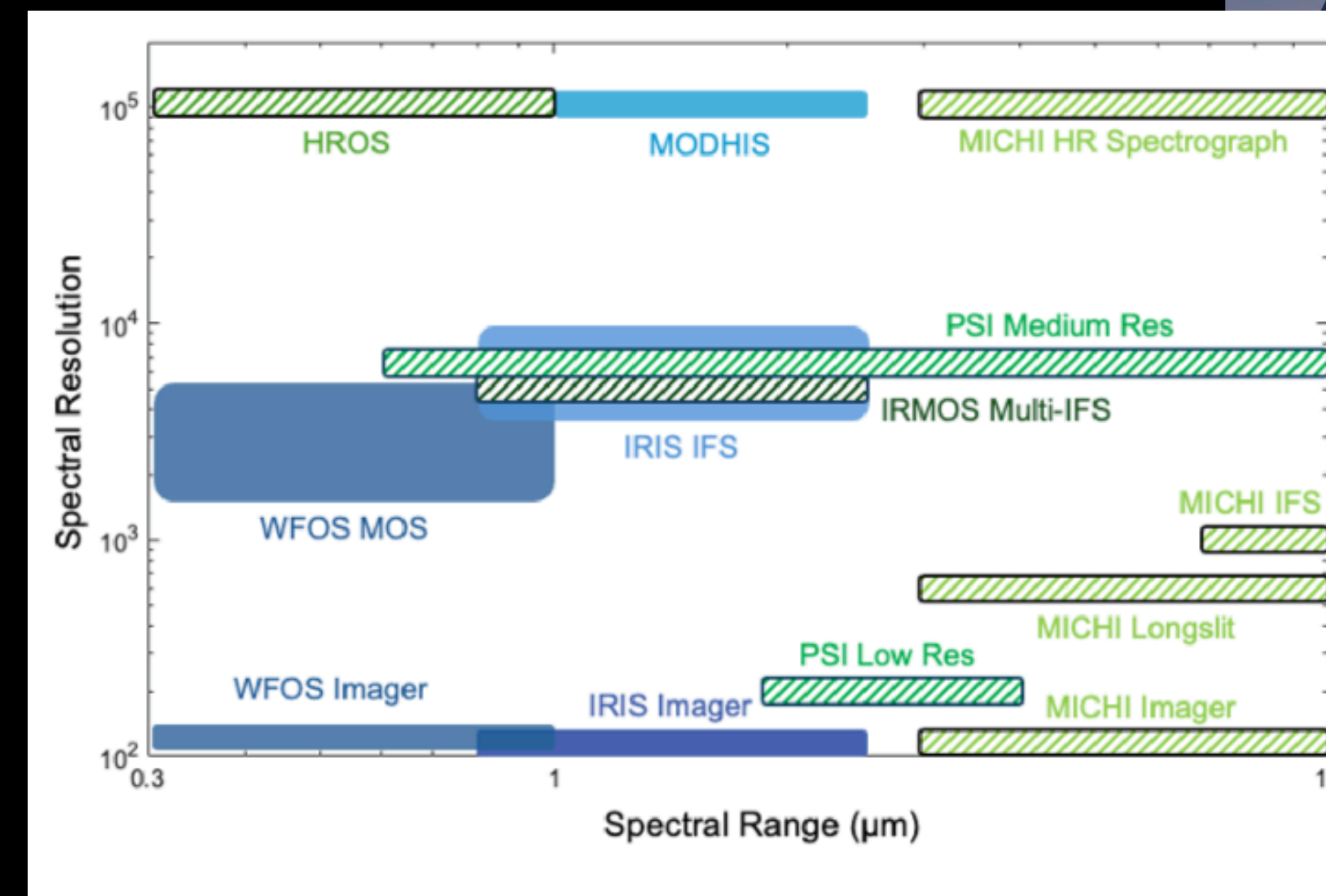




GMT/TMT(?) Instruments are somewhat simpler by design...



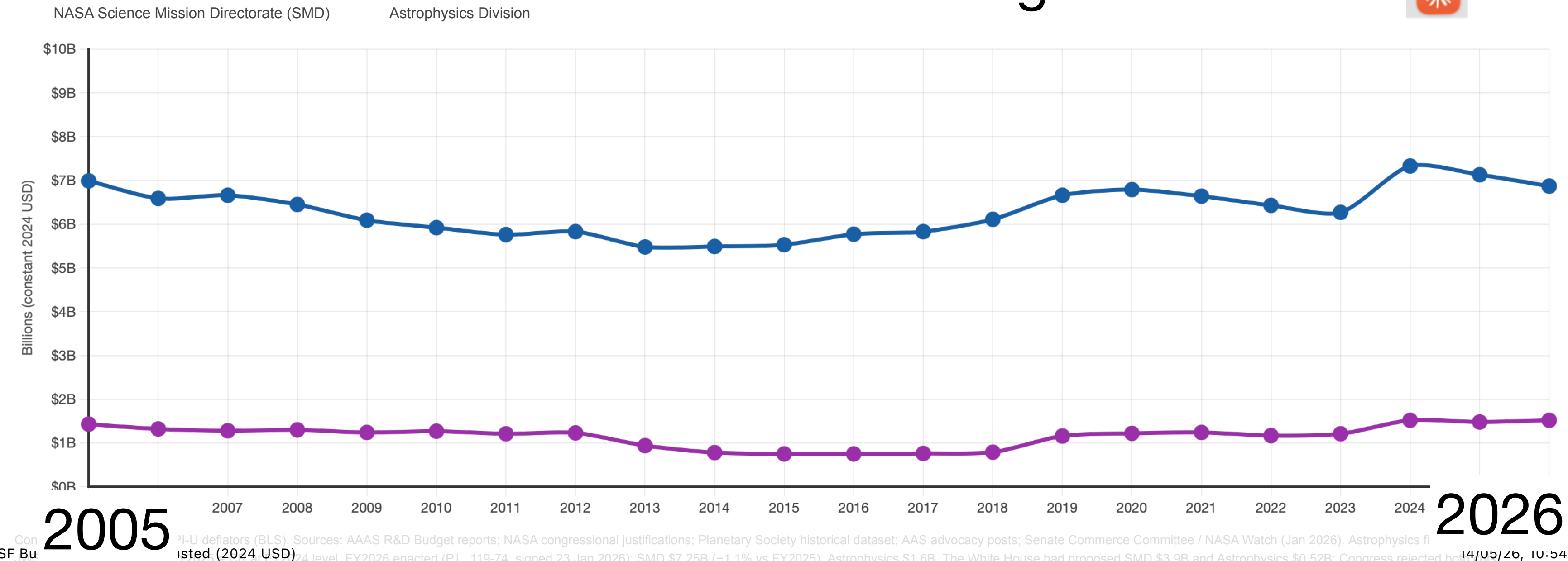
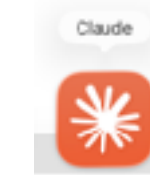
Instrument	Function	λ range (microns)	Resolution	FOV
GMACS	Optical Multi-Object Spectrometer	0.35-1.0	250-4000	64-200 arcmin ²
NIRMOS	Near-IR Multi-Object Spectrometer	1.0-2.5	Up to ~4000	49 arcmin ²
QSpec	Optical High Resolution Spectrometer	0.3-1.05	30K 1" slit	3" + fiber mode
SHARPS	Optical High Resolution (Doppler) Spectrometer	0.4-0.7	150K	7 x 1" fibers
GMTNIRS	Near-IR High-Resolution Spectrometer	1.2- 5.0	25K-100K	Single object
MIISE	Mid-IR Imaging Spectrometer	3.0-25.0	1500	30"
HRCam	Near-IR AO Imager	0.9-5.0	5-5000	30"
GMTIFS	NIR AO-fed IFU	0.9-2.5	3000-5000	3"



GMT/TMT(?) have 10-15 years of lag wrt ELT.

NASA astronomy budget — constant 2024 USD
Science Mission Directorate (SMD) and Astrophysics Division, FY2005–FY2026

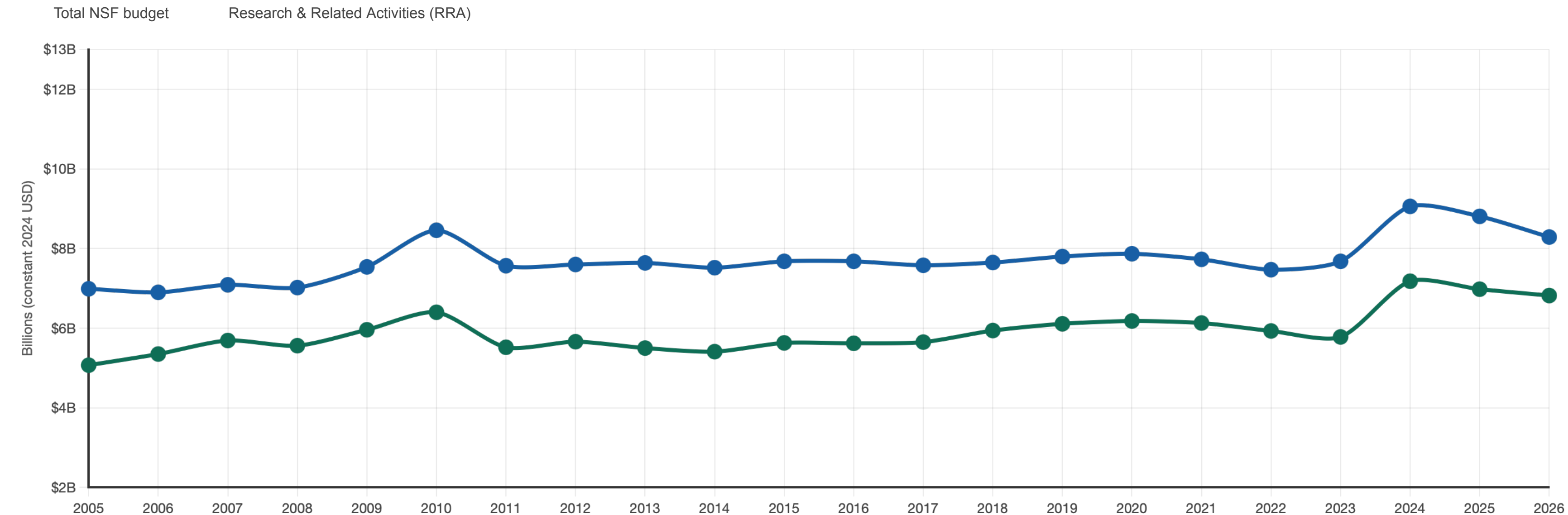
NASA budget



Constant 2024 USD using CPI-U deflators (BLS). Sources: AAAS R&D Budget reports; NASA congressional justifications; Planetary Society historical dataset; AAS advocacy posts; Senate Commerce Committee / NASA Watch (Jan 2026). Astrophysics figures include one-time stimulus from 2009. FY2026 enacted (P.L. 119-74, signed 23 Jan 2026): SMD \$7.25B (−1.1% vs FY2025), Astrophysics \$1.6B. The White House had proposed SMD \$3.9B and Astrophysics \$0.52B; Congress rejected both.

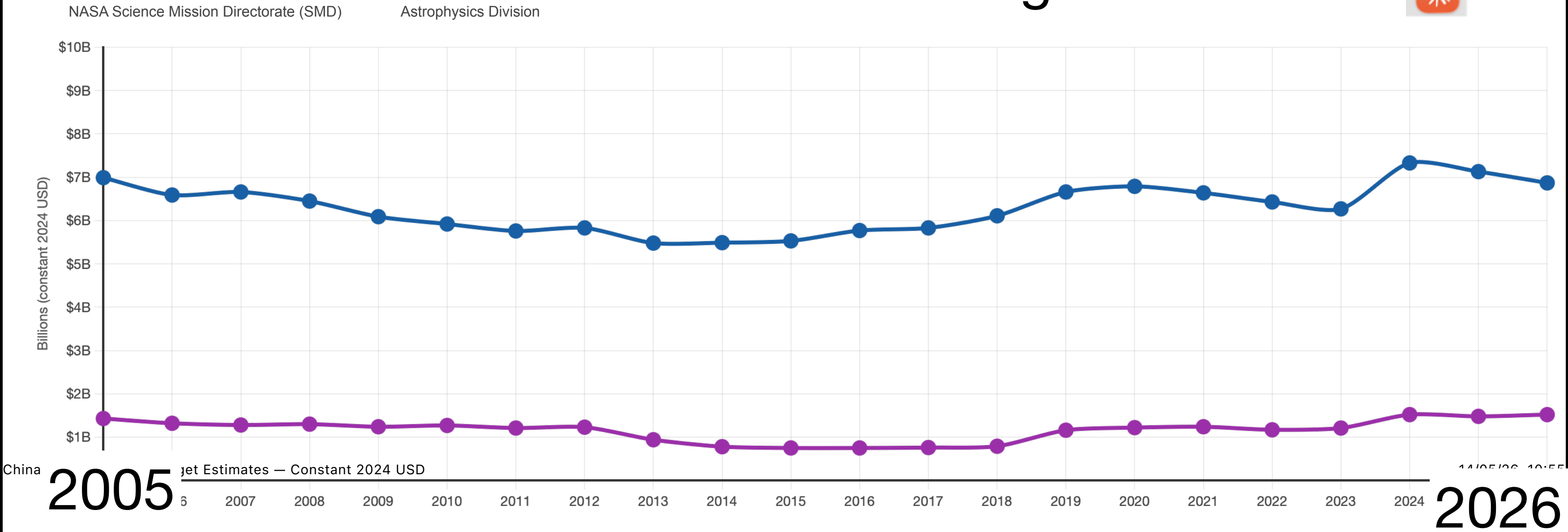
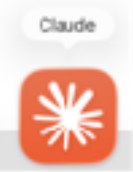
NSF budget — constant 2024 USD
Total appropriation and Research & Related Activities (RRA) account, FY2005–FY2026

NSF budget



Constant 2024 USD using CPI-U deflators (BLS). Sources: NSF Budget Requests & Appropriations (nsf.gov); CBS P48783 (2025); AAS/Senate Commerce Committee (Jan 2026). ARPA one-time stimulus included in 2009–2010. FY2025 = continuing resolution at FY2024 level.

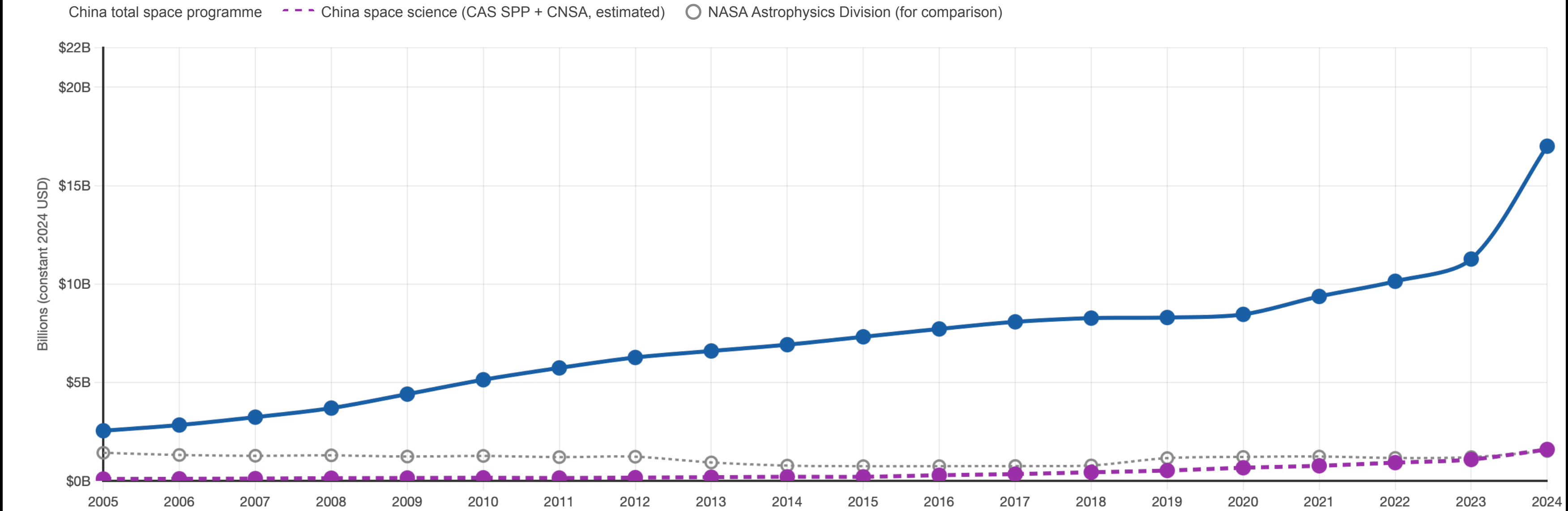
NASA budget



China space science budget — constant 2024 USD (estimates)
Total space programme and space science component, FY2005–FY2024, with NASA Astrophysics for comparison

Important caveat: China does not publish itemised space science budgets. All figures are estimates derived from Euroconsult programme line is more reliable.

China space science budget



Constant 2024 USD using CPI-U deflators (BLS). Sources: Euroconsult Government Space Programs reports (2020, 2022, 2024); CRS reports; Bloomberg/CAS (2016) re: 4.7B yuan for 2011–2015 SPP; Planetary Society CNSA overview (2023–2024); CAS Bulletin (2024).

Chinese investments in ground based astronomy are ramping up

+ SKA... but out of TMT

COMPLETED FACILITIES

- 1997–2008** ● **LAMOST / Guoshoujing Telescope** ~¥235M (~\$35M)
optical
4m effective aperture, 5° field of view, 4,000 fibres simultaneously. Located at Xinglong, Hebei. Began science survey 2012. World-leading spectroscopic throughput — over 20 million stellar spectra by 2023, the largest such catalogue ever assembled. Key science: Milky Way structure, stellar populations, radial velocity surveys.
- 2008–2012** ● **Tianma 65m Radio Telescope (TMRT)** ~¥200M (~\$30M)
radio
Fully steerable 65m dish at Shanghai Astronomical Observatory, operational 2012. Covers L through Q bands (1–50 GHz). Key instrument for VLBI and lunar/deep space tracking. Participated in imaging the M87 black hole shadow alongside EHT (2019).
- 2009–2016** ● **MUSER / Mingantu Spectral Radioheliograph** undisclosed
solar
100 antennas (two arrays) at Mingantu, Inner Mongolia. Covers 400 MHz–15 GHz, designed for solar radio imaging of the full solar disk with high temporal and spectral resolution. World's most capable solar radio interferometer at its completion. Key science: solar flares, CME initiation, radio bursts.
- 2011–2016** ● **FAST — Five-hundred-metre Aperture Spherical Telescope** ¥1.2B (~\$180M)
radio
500m reflector in a karst depression in Guizhou province. Effective aperture ~300m. Frequency 70 MHz–3 GHz. Fully operational January 2020; opened to international proposals 2021. World's largest single-dish radio telescope, ~2.5× more sensitive than Arecibo was. Key science: pulsar census and timing, FRB detection, HI surveys, SETI, gravitational wave PTA.
- 2018–present** ● **Lenghu Astronomical Observation Base** ¥~2B (~\$290M) total site
optical
High-altitude site (4,200m) on Saishiteng Mountain, Qinghai. Confirmed world-class seeing (median ~0.75 arcsec) in a 2021 Nature paper. Planned to host at least 9 projects and ~30 telescopes. Operational instruments include a 2.5m telescope (USTC, 2021). China's answer to Mauna Kea or La Palma as a premier optical site.
- 2021–2023** ● **DSRT — Daocheng Solar Radio Telescope** ¥100M (~\$14M)
solar
313 dishes of 6m diameter in a 1km-diameter ring at 3,820m altitude in Sichuan. Completed and passed key tests September 2023. Part of the Meridian Project phase 2. World's largest synthesis aperture solar radio array. Covers 150–450 MHz for CME tracking. Key science: coronal mass ejections, space weather forecasting.

UNDER CONSTRUCTION / PLANNED

- ~2026** ● **JUST — Jiao Tong University Spectroscopic Telescope** ~¥1.3B (~\$180M)
planned optical
4.4m aperture, multi-object spectrograph (2,000 fibres, R~4,000–5,000) plus high-resolution mode (R~100,000). Sited at Lenghu. Targets: large-scale structure surveys, exoplanet atmospheres, multi-messenger follow-up of transients. Effectively LAMOST-II at a better site.
- 2024–~2032** ● **EAST — Expanding Aperture Segmented Telescope** undisclosed
planned optical
Peking University project at Lenghu (4,200m). Stage 1 (2024–2028): 6m segmented mirror in 18 hexagonal segments, JWST-like design. Stage 2 (~2030–2032): expansion to ~12m. Would become China's largest optical telescope and Asia's most powerful. Science focus: dark energy, dark matter, galaxy evolution, exoplanets.
- ~2030+** ● **MST — Multiplexed Survey Telescope (Tsinghua)** ¥1.3B (~\$180M)
planned optical
6.5m wide-field multi-object telescope at Lenghu. ~7 years to completion from approval. Science priorities: dark matter, dark energy, gravitational wave counterparts, stellar streams. Competing for a similar niche to the MSE (Canada-led) and DESI follow-on in Europe.

Lenghu site is comparable to Mauna Kea:
4200m, 75% time seeing <0.75”
(Deng+, Nature 2021)

Conclusions

Conclusions

1) We have an unique opportunity:

ELT (+SKA+CTA) will be the major *discovery machine(s)* in the 30s.

Europe - **we** - can lead the field.

Conclusions

1) We have an unique opportunity:

ELT (+SKA+CTA) will be the major *discovery machine(s)* in the 30s.

Europe - **we** - can lead the field.

2) “Go big or go home”: Be bold, be ambitious.

We need to aim at *transformational discoveries*.

ELT has the latitude and power to be what JWST has been in the 20s.

Conclusions

1) We have an unique opportunity:

ELT (+SKA+CTA) will be the major *discovery machine(s)* in the 30s.

Europe - **we** - can lead the field.

2) “Go big or go home”: Be bold, be ambitious.

We need to aim at *transformational discoveries*.

ELT has the latitude and power to be what JWST has been in the 20s.

3) How to get there?

Invest in *frontier science with pathfinders*: JWST, VLT, LBT, MeerKAT, etc

Conclusions

1) We have an unique opportunity:

ELT (+SKA+CTA) will be the major *discovery machine(s)* in the 30s.

Europe - **we** - can lead the field.

2) “Go big or go home”: Be bold, be ambitious.

We need to aim at *transformational discoveries*.

ELT has the latitude and power to be what JWST has been in the 20s.

3) How to get there?

Invest in *frontier science with pathfinders*: JWST, VLT, LBT, MeerKAT, etc

4) Italy is uniquely placed to *exploit synergies*: Euclid, SKA, CTA, LSST, etc