

CDIM—ASTRA

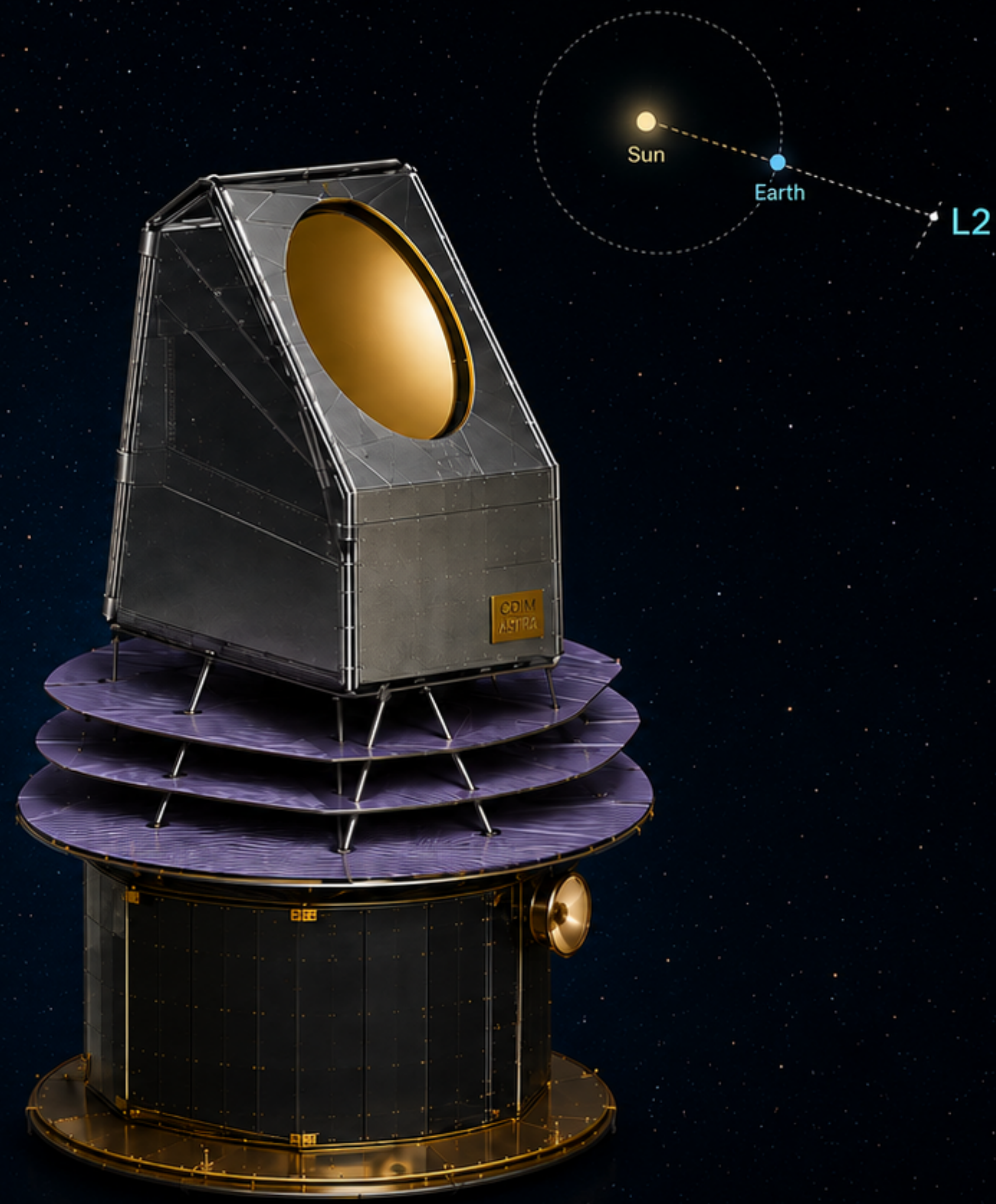
Cosmic Dawn Intensity Mapper

Wide-field spectro-imaging for cosmic dawn, reionization, and galaxy formation

 0.75–12 μm

 $R \approx 300$

 Wide-field spectro-imaging



NASA ASTRA Workshop
Asantha Cooray • University of California, Irvine



Why **CDIM-ASTRA** now?

The landscape has advanced, but the missing measurement remains wide-field spectral mapping of the reionization era

OBSERVATORY
LANDSCAPE

2020

2025

2030

2035

2040

HUBBLE

Legacy imaging & spectroscopy

JWST

Deep spectroscopy

ROMAN

Wide-field imaging

HERA / SKA-Low

21-cm intensity mapping

SPHEREx

All-sky spectroscopy

CDIM-ASTRA

Wide-field spectro-imaging of the reionization era

CDIM-ASTRA bridges galaxies and the intergalactic medium

1

JWST

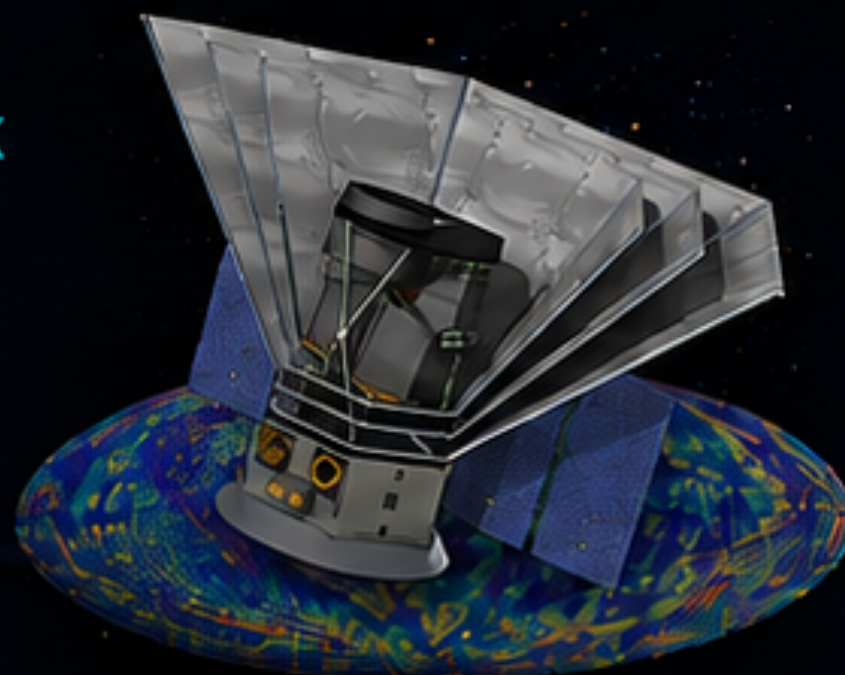
Deep spectroscopy is transforming our view of early galaxies and black holes, but in pencil-beam fields.



2

**Roman +
SPHEREx**

Wide-field imaging and all-sky LVF heritage create the source catalogs, calibration path, and survey context.



3

**21-cm
experiments**

HERA, SKA-Low, and successors trace neutral hydrogen and the growth of ionized structure.



CDIM-ASTRA connects galaxies, black holes, and the intergalactic medium in a single **3D spectroscopic** survey.



CDIM-ASTRA

COSMIC DAWN INTENSITY MAPPER – ADVANCED SPECTROSCOPIC TELESCOPE FOR REIONIZATION AND ASTROPHYSICS



JWST changed the problem

The first galaxies and black holes are accessible; the next step requires volume, spectra, and context.

1 Galaxies to $z \geq 14$

Confirmed systems now reach the first few hundred million years after the Big Bang. The next question is how representative they are.

2 Early chemical growth

JWST spectra show strong nebular lines and chemical enrichment in some very early systems, making rest-frame optical diagnostics essential.

3 Compact red sources

Little red dots and broad-line sources may be dense starbursts, obscured accretion, or both. Wide-field spectroscopy is needed to measure the population.

JWST opened the window; CDIM-ASTRA turns it into a wide-field, 3D spectroscopic census.

Context: NASA Webb Early Universe, JADES, and Little Red Dot results



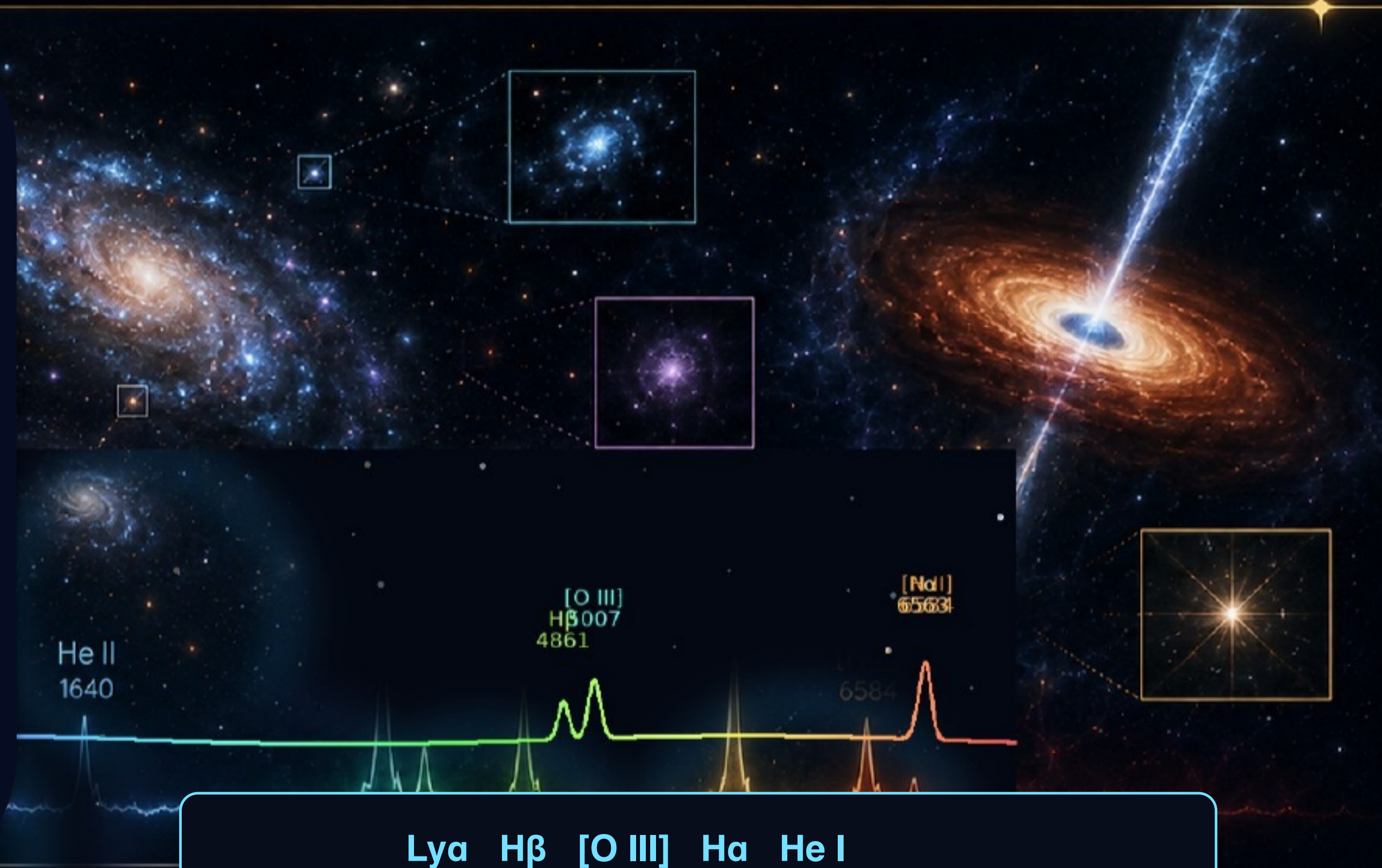
Science I | Galaxies, black holes, and the first stars

Rest-frame UV and optical spectroscopy across large cosmic volumes during reionization and cosmic dawn

Recover stellar masses, metallicity, dust, nebular excitation, and ionizing spectra for entire populations rather than isolated JWST fields.

Constrain high-redshift AGN, little-red-dot populations, and the black-hole contribution to reionization with H α , [O III], H β , and Ly α .

Search for Population III candidates, pristine systems, and rare luminous transients across the wide-area sky.

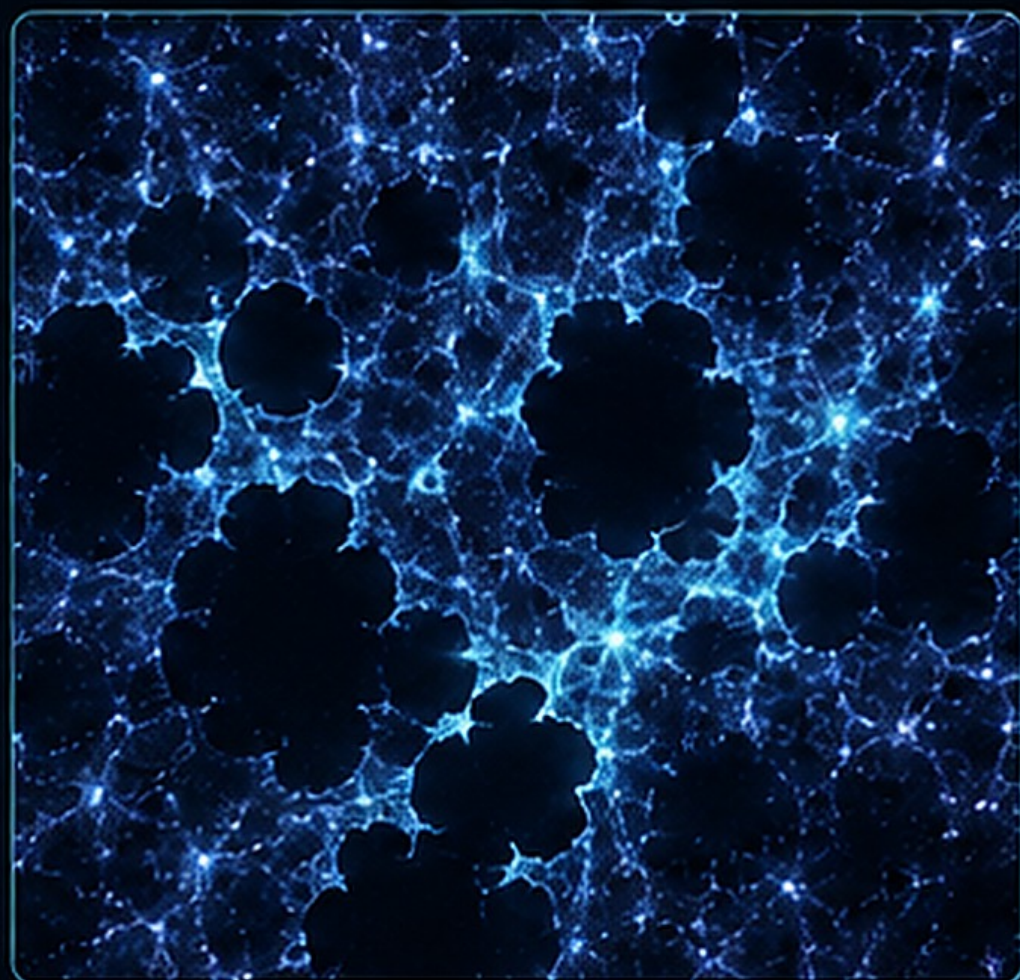




Science II | Reionization tomography and intensity mapping

Map the aggregate line-emission field and cross-correlate it with 21-cm measurements to reveal bubble growth and IGM physics

21-cm



Low High

Ly α



Low High

H α



Low High

- ★ Recover aggregate Ly α and H α emission from sources too faint to detect individually
- ★ Cross-correlate with 21-cm surveys to measure bubble sizes, topology, and reionization history
- ★ Compare Ly α and H α to isolate radiative-transfer effects and the physical state of the IGM
- ★ Provide wide-area 3D spectral cubes matched to reionization-era science

ANTI-CORRELATION ON IONIZED BUBBLE SCALES



3D tomography

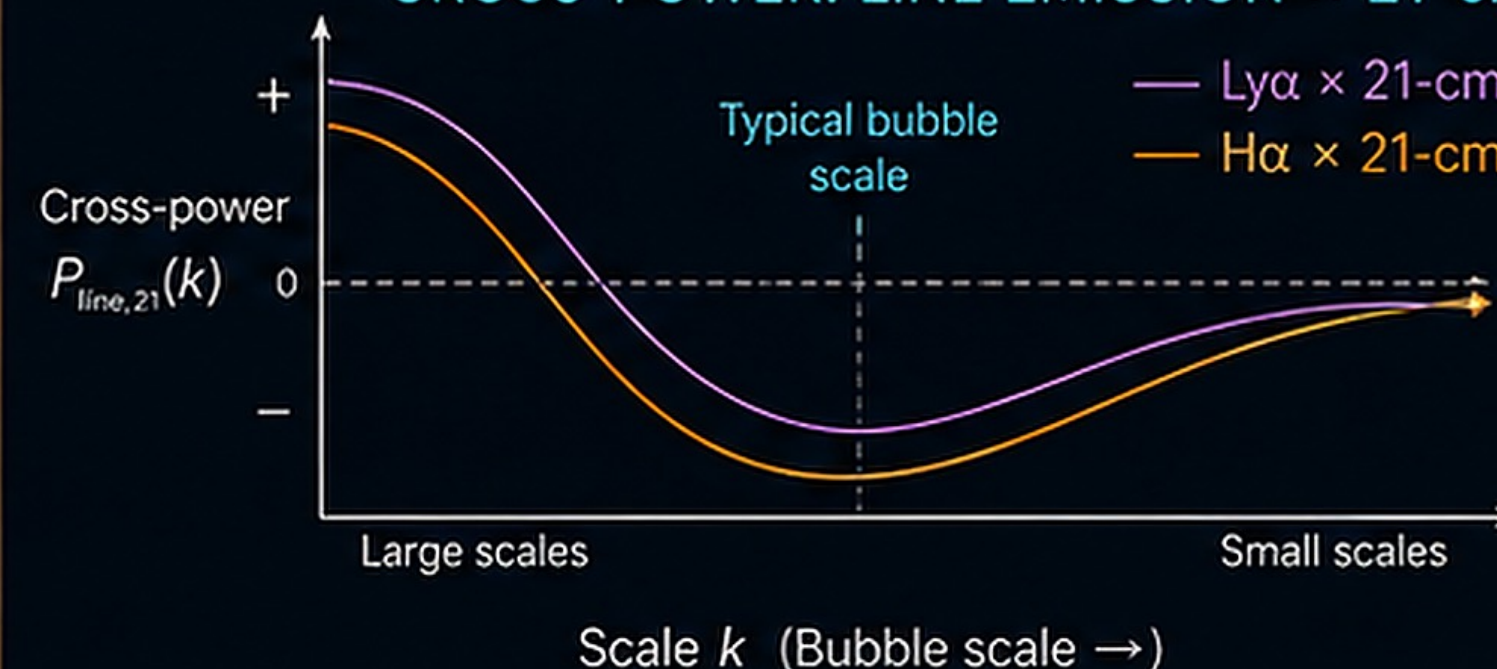


Ly α $\times$ 21-cm

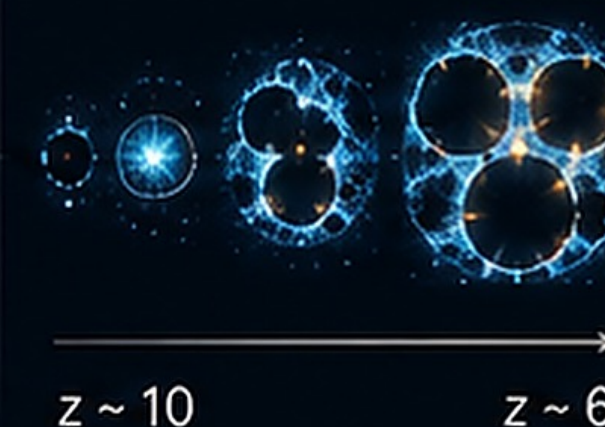


Bubble growth

CROSS-POWER: LINE EMISSION $\times$ 21-cm

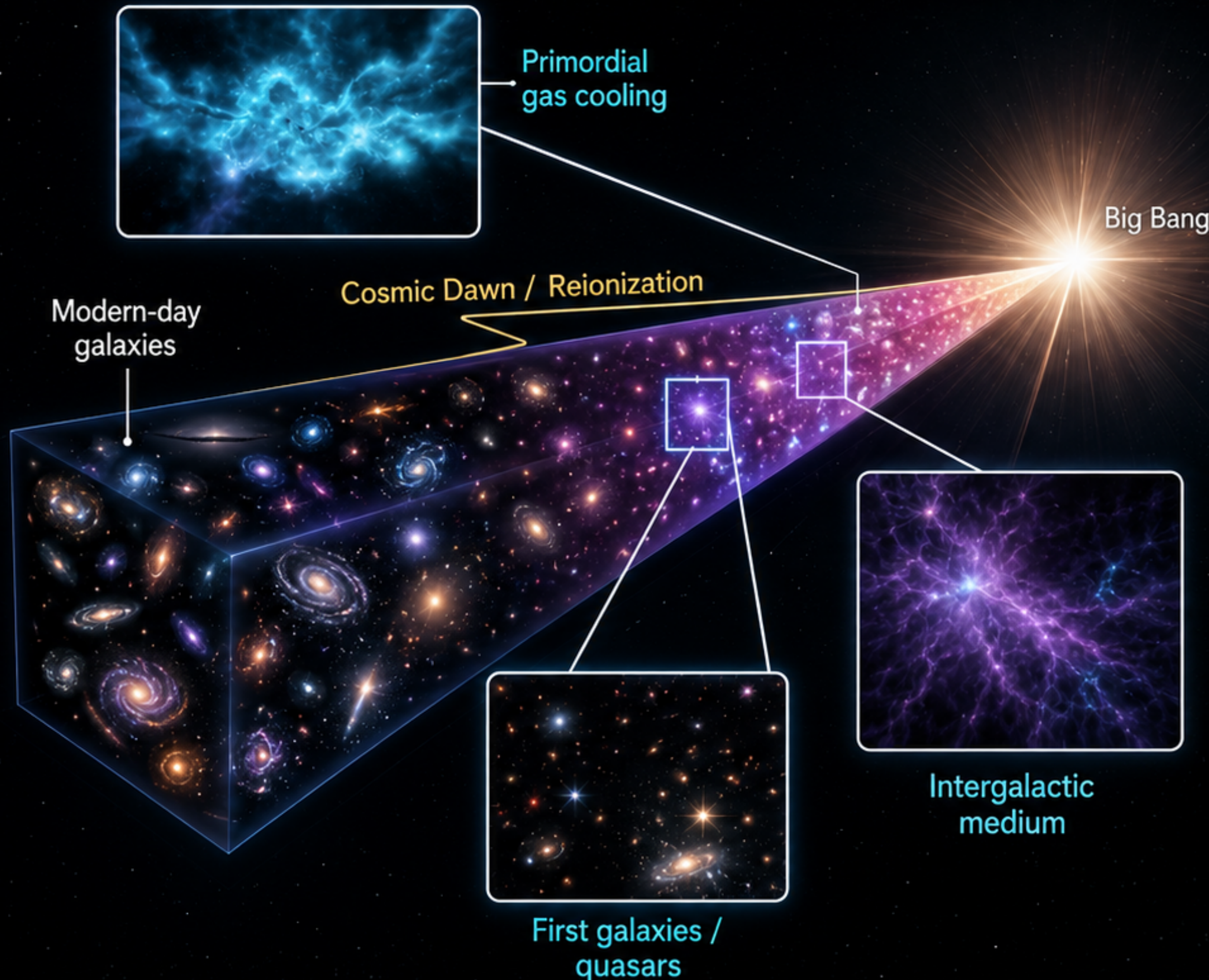


Bubble growth (redshift $\downarrow$)



CDIM-ASTRA Cosmic Dawn Goals

What JWST has already revealed, and what a 2035+ wide-field spectroscopic survey must still measure



Anticipated breakthroughs (2027–2035)

- ✓ Cosmic star-formation rate density at high redshift from JWST deep surveys
- ✓ Abundant luminous galaxies in the first 500 Myr
- ✓ Stellar mass function of early galaxies
- ✓ Early accreting black holes and AGN demographics
- Initial constraints on reionization from 21-cm pathfinders

CDIM-ASTRA science goals for 2035+

- 3D spectroscopic maps of H-alpha, [O III], and Ly-alpha through reionization
- 21 cm Precise history and topology of reionization via cross-correlation with 21-cm surveys
- Cosmic molecular gas, dust, and metal enrichment in the first galaxies
- Minimum halo mass and clustering of the sources that ionized the IGM
- Growth of the first black holes in their large-scale environments
- Galaxies and the intergalactic medium in one tomographic survey

CDIM–ASTRA Design in a Nutshell

Mission concept, observatory architecture, and cosmic dawn science goals



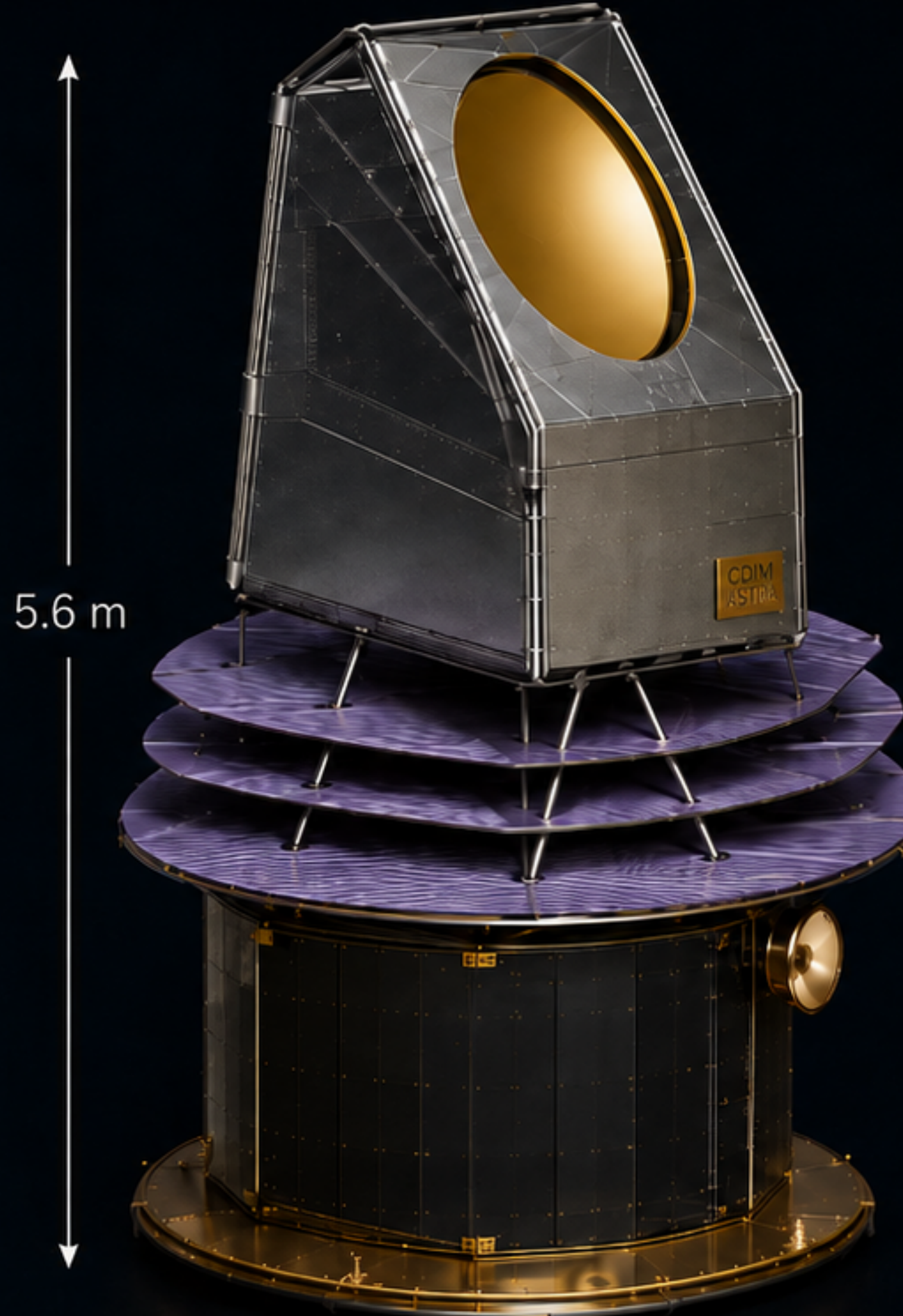
NASA Probe-class mission concept for the 2020 Decadal Survey

- $0.75\ \mu\text{m} - 12.5\ \mu\text{m}$ spectro-imaging in $\sim 1,025$ narrow bands at $R = 300$
- 1.4 m effective aperture (1.8 m physical aperture)
- 11.6 sq. degree focal plane (1" pixels, 6×6 H2RG detectors)
- Diffraction-limited at $12.5\ \mu\text{m}$, $\sim 2.2''$ PSF
- Three-tiered survey in 4 years
- Astro2020 Probe Concept: 0.85 m, $0.75 - 7.5\ \mu\text{m}$, costed under \$1B FY20 dollars



Cosmic Dawn and Reionization Science

- First Galaxies: tracing $\text{H}\alpha$ to $z = 17$
- First Black Holes: finding AGNs to $z = 17$
- Reionization / Cosmic Dawn Tomography: $\text{Ly}\alpha$ and $\text{H}\alpha$ intensity mapping to $z = 17$



Three-mirror all-reflective design with 1.4 m effective aperture



Linear Variable Filters (LVF) at $R = 300$, 6×6 H2RG detectors



V-groove radiators, passive cooling at $T < 35\ \text{K}$ in L2 halo orbit

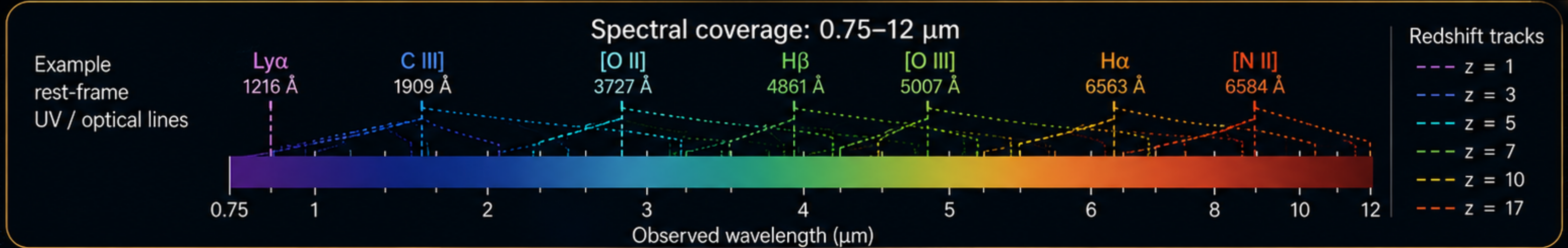


Ka-band HGA, data rate $\sim 400\ \text{Gbit/day}$, 1 hr/day downlink

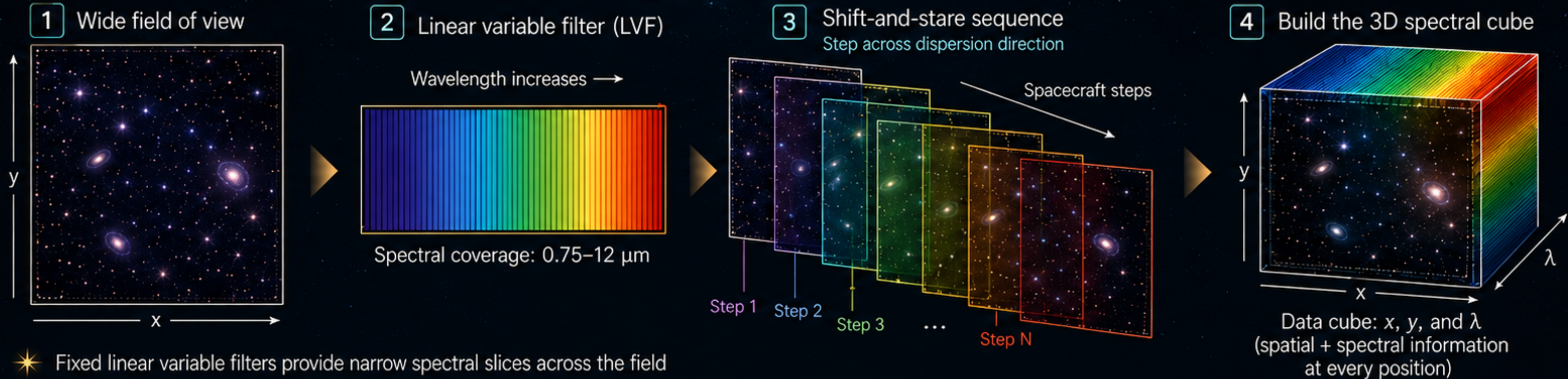


LVF spectro-imaging | Shift-and-stare spectral cube building

Linear variable filters enable wide-field spectroscopy without a grism or moving focal-plane mechanism



0.75–12 μm coverage enables H α mapping to $z \approx 17$.



- Fixed linear variable filters provide narrow spectral slices across the field
- Successive small spacecraft steps build a Nyquist-sampled spectrum at each sky position
- No slit or grism is required for the science survey mode
- The output is a calibrated 3D cube: x, y, and wavelength



No moving
focal-plane parts



High
throughput



Survey-
optimized

Focused technology maturation | two enabling areas

CRYOGENIC HgCdTe INFRARED DETECTOR MOSAIC

High performance, low noise sensing at cryogenic temperatures



DARK
CURRENT



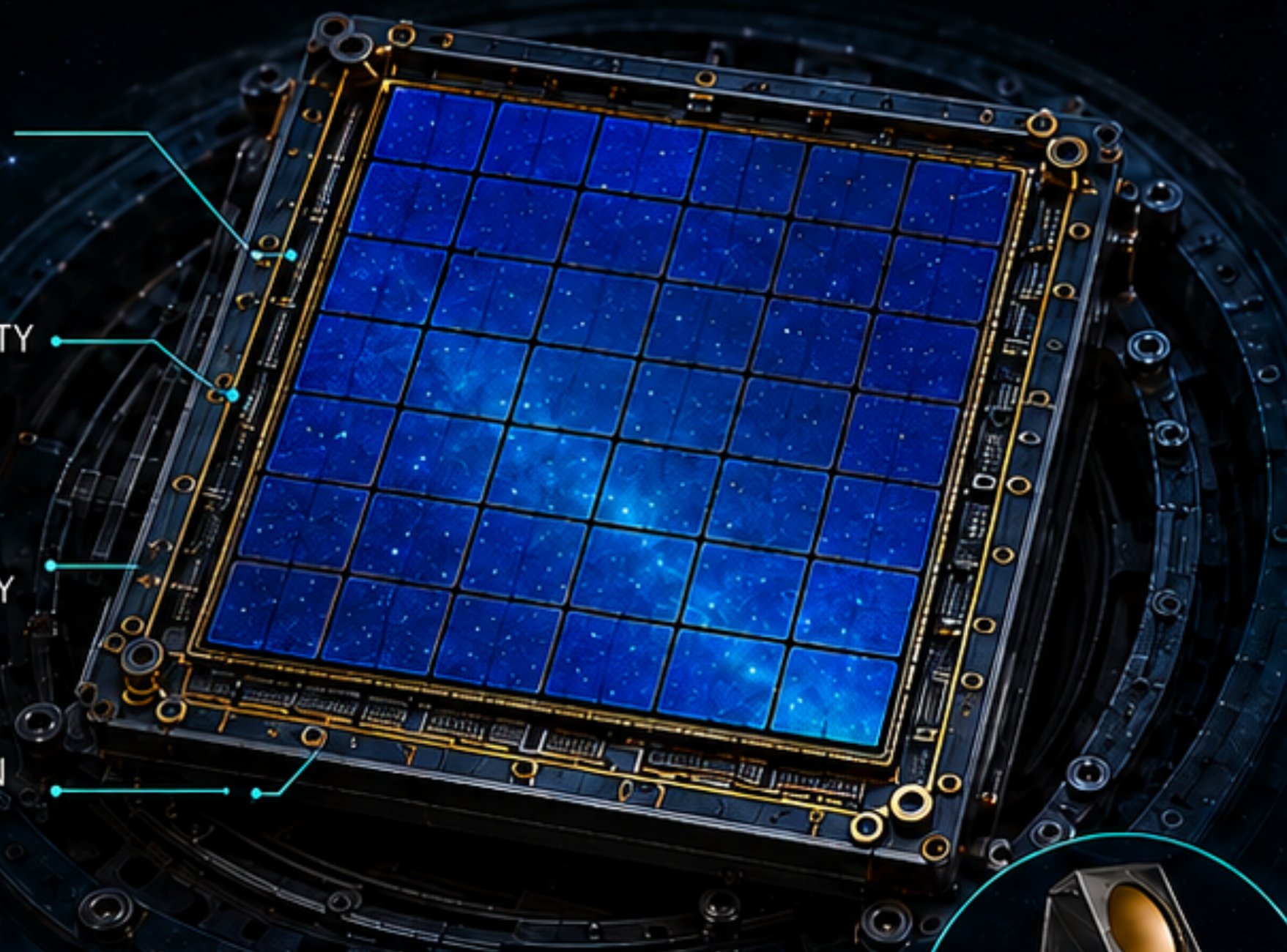
OPERABILITY



QUANTUM
EFFICIENCY



RADIATION
TESTING

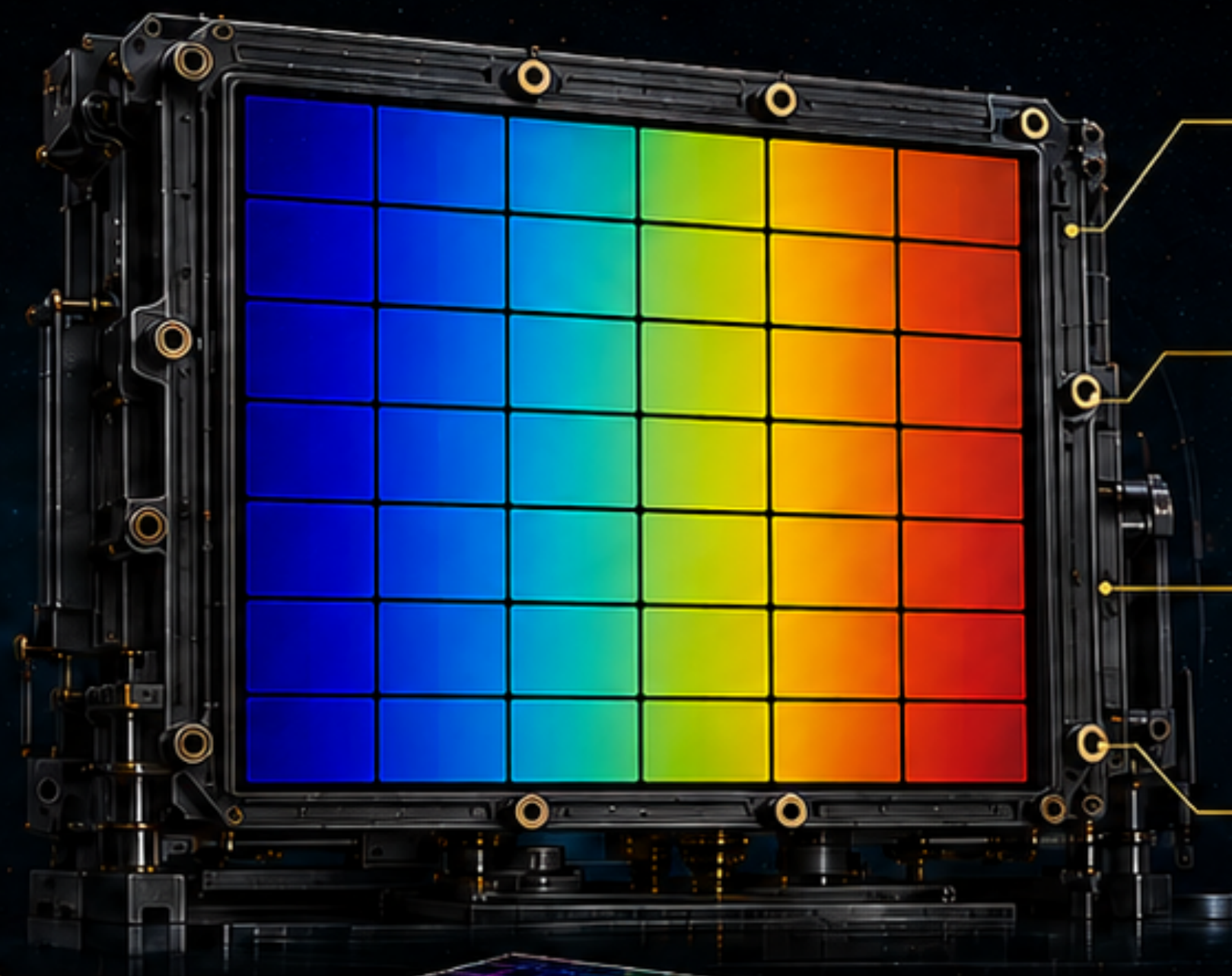


Pre-formulation focus: detectors + linear variable
filters

CDIM-ASTRA

LARGE-FORMAT LINEAR VARIABLE FILTER (LVF)

Dispersion across the field with precise, stable spectral control



OUT-OF-BAND
BLOCKING



WAVELENGTH
STABILITY



COATING
STRESS



CALIBRATION

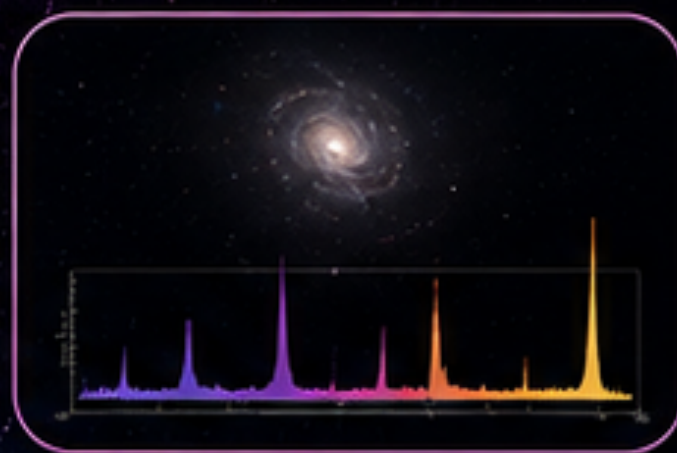


3D SPECTRAL CUBE



Survey strategy | A three-tier legacy survey

Depth, area, and repeated cadence are matched to galaxies, reionization tomography, and rare-source discovery



DEEP

100 deg²

Very deep legacy fields,
faint galaxies, rest-frame
optical diagnostics,
Population III / rare-source
discovery



MEDIUM

1000 deg²

Ly α / H α intensity
mapping and Roman
HLWAS mid-tier survey



WIDE

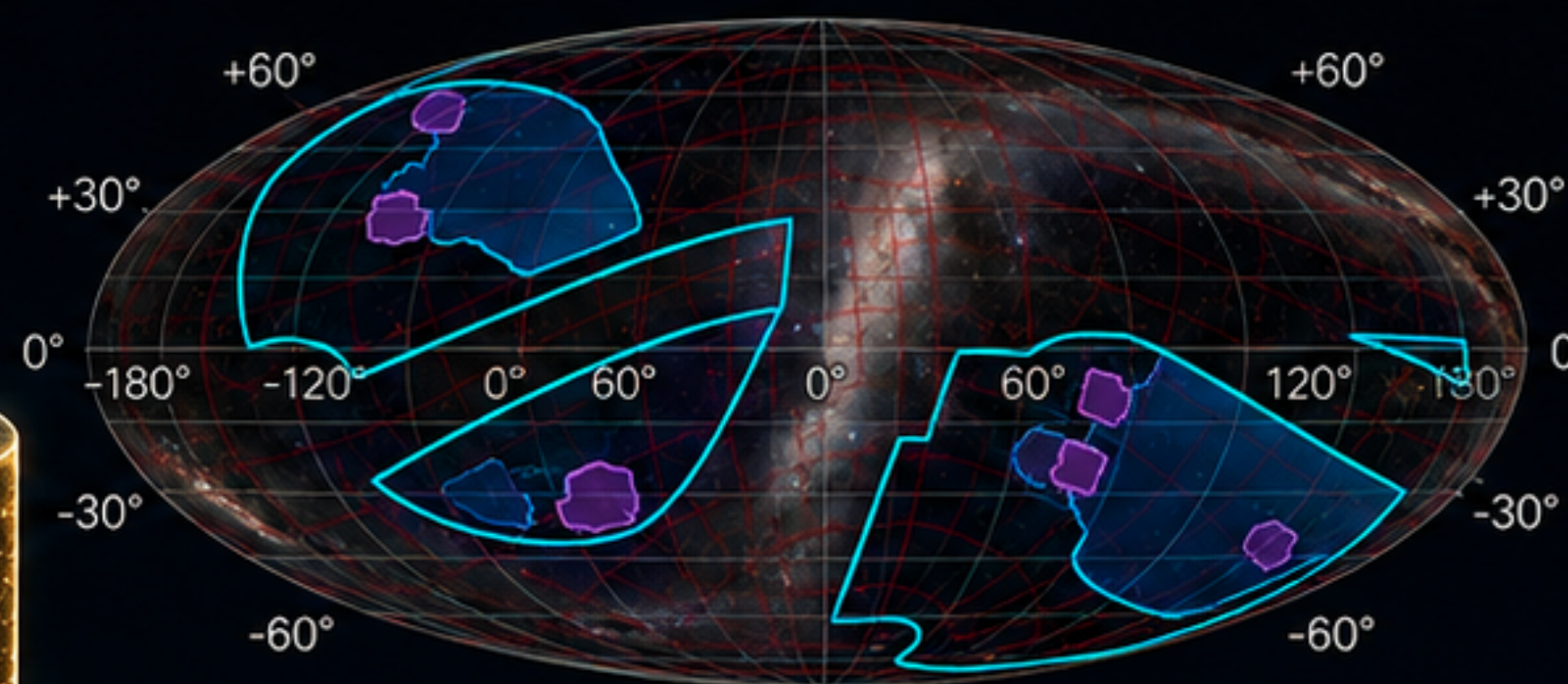
4000 deg²

Rare quasars, bright sources,
cosmic variance control,
and legacy science



Repeated visits support
transient discovery,
zodiacal-light mitigation,
and systematic control.

Sky coverage & overlap



- WIDE survey (~4000 deg²)
- MEDIUM survey (~1000 deg²)
- DEEP fields (~100 deg² total)





Summary | Broader science, legacy value, and the ASTRA study

One spectral survey flagship mission can enable a broad community program while pursuing the cosmic-dawn flagship case

A Broader science enabled

- ★ Low-redshift H α and galaxy-evolution surveys across cosmic time
- ★ Nearby galaxies, AGN, and spectral diagnostics in the infrared
- ★ Time-domain discovery, including rare high-redshift transients
- ★ Galactic and stellar science, including cool objects and spectral variability
- ★ Community-led legacy surveys and archival spectral-cube science

B What ASTRA should deliver

- ★ Re-optimize the science case for the post-JWST, Roman, SPHEREx, and 21-cm era
- ★ Mature the mission architecture, cost, and survey plan for a strategic-class concept
- ★ Retire risk for long-wavelength HgCdTe arrays and large-format LVFs
- ★ Define a compelling flagship path to map galaxies and the IGM together during reionization and cosmic dawn



CDIM-ASTRA would deliver the first wide-field 3D spectral view of the sources and structure of cosmic reionization.





CDIM-LITE: LIFE-TRACE

A 30-cm all-sky mid-IR SMEX concept

Legacy Infrared Finder and Explorer — Tracing the Role of Aromatic Chemistry in Ecosystems



MISSION CONCEPT

- 30-cm three-mirror cryogenic telescope
- 5.0–11.4 μm LVF spectro-imaging at $R \approx 100$
- Uniform all-sky survey with 83 spectral channels
- $2.28^\circ \times 2.28^\circ$ field of view, 4 arcsec pixels, 2048×2048 H2RG
- 500-km dawn–dusk Sun-synchronous orbit, 24-month survey
- Under \$190M (FY26)



SCIENCE ENABLED



1. Trace aromatic carbon:

PAH bands at 6.2, 7.7, 8.6, and 11.3 μm plus candidate C_{60}



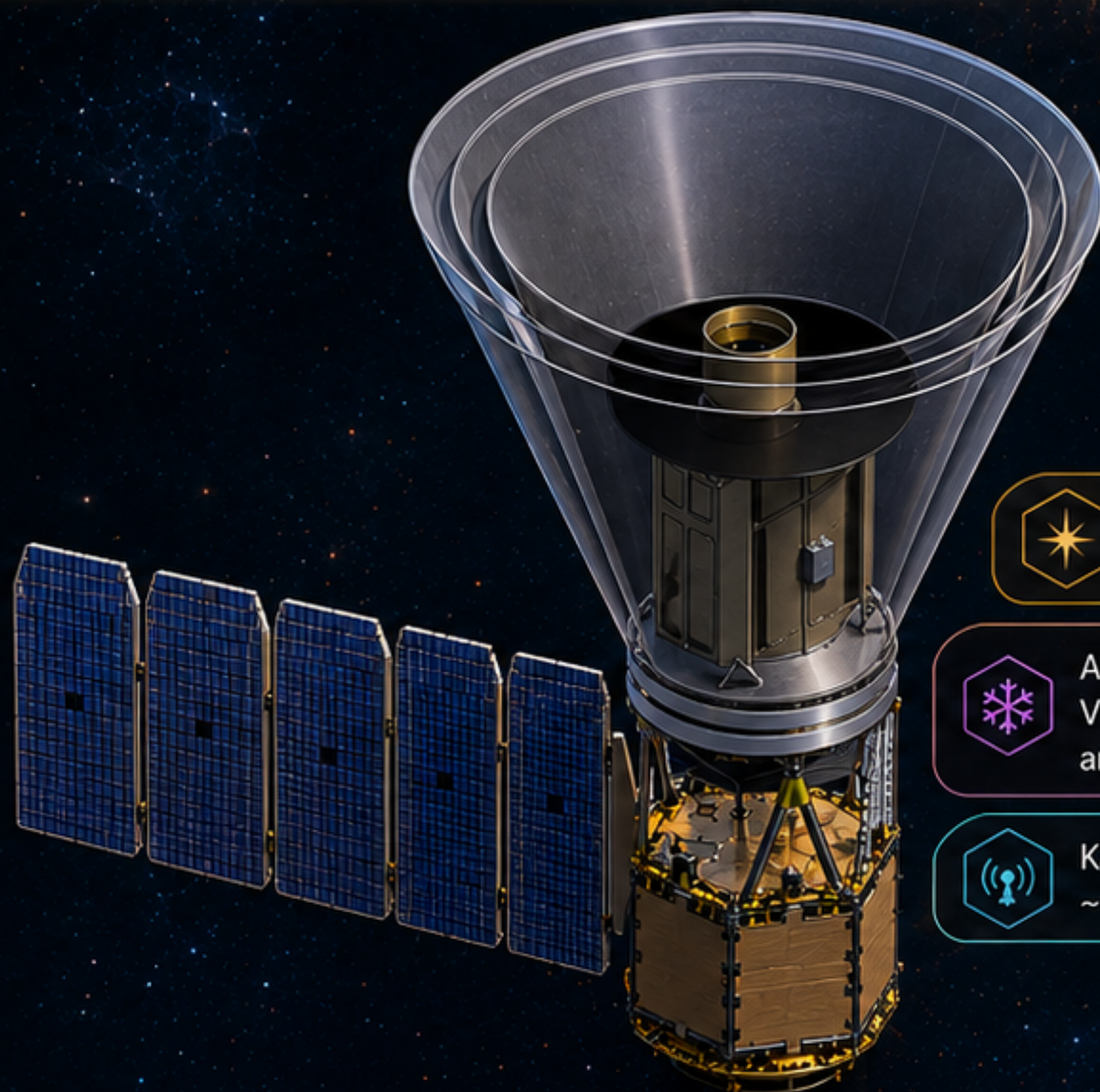
2. Measure warm gas and feedback:

H_2 S(3)–S(7), [Fe II], [Ar II], [Ar III], $\text{P}\alpha$, [S IV]



3. Find buried black holes and dusty nuclei:

silicate absorption, continuum shape, PAH equivalent width



No moving optical parts

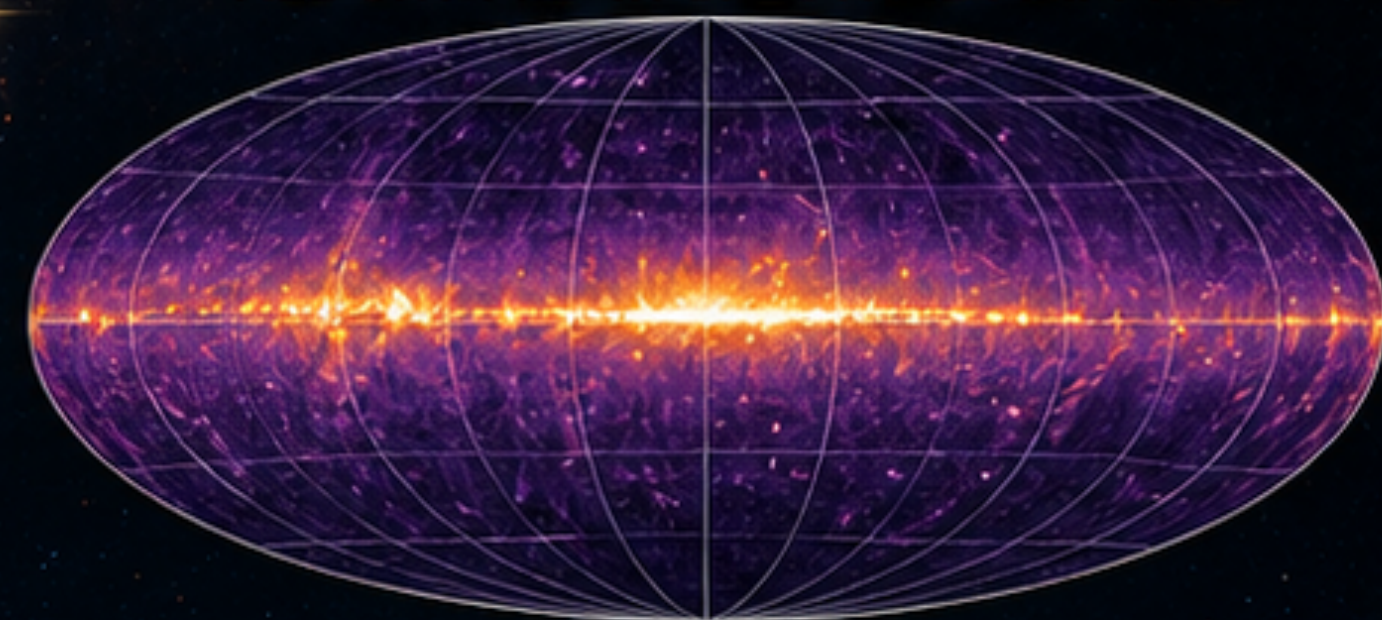


Active cryocooler + V-groove thermal architecture



Ka-band downlink, ~5.3 GB/day

ALL-SKY MID-IR SPECTRAL MAPPING



PARTNERSHIP

- UCI — PI and science leadership
- Berkeley / SSL — project management, systems engineering, mission ops
- Northrop Grumman — LEOStar-2 spacecraft bus
- Quartus Engineering — 30-cm cryogenic telescope
- UCLA, U. Arizona, RIT, Vertex, IPAC / IRSA — focal plane, instrument science, cryocooler, and archive



LIFE-TRACE would deliver the first uniform all-sky 5–11.4 μm spectral map of carbon-rich dust, warm gas, and obscured activity.

