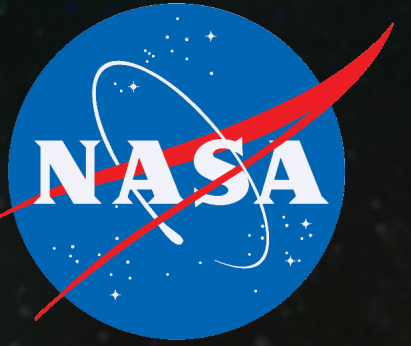




CDIM = “see-dim”



Cosmic Dawn Intensity Mapper

A Probe Class Spectro-Imaging Astrophysics
Mission for Reionization

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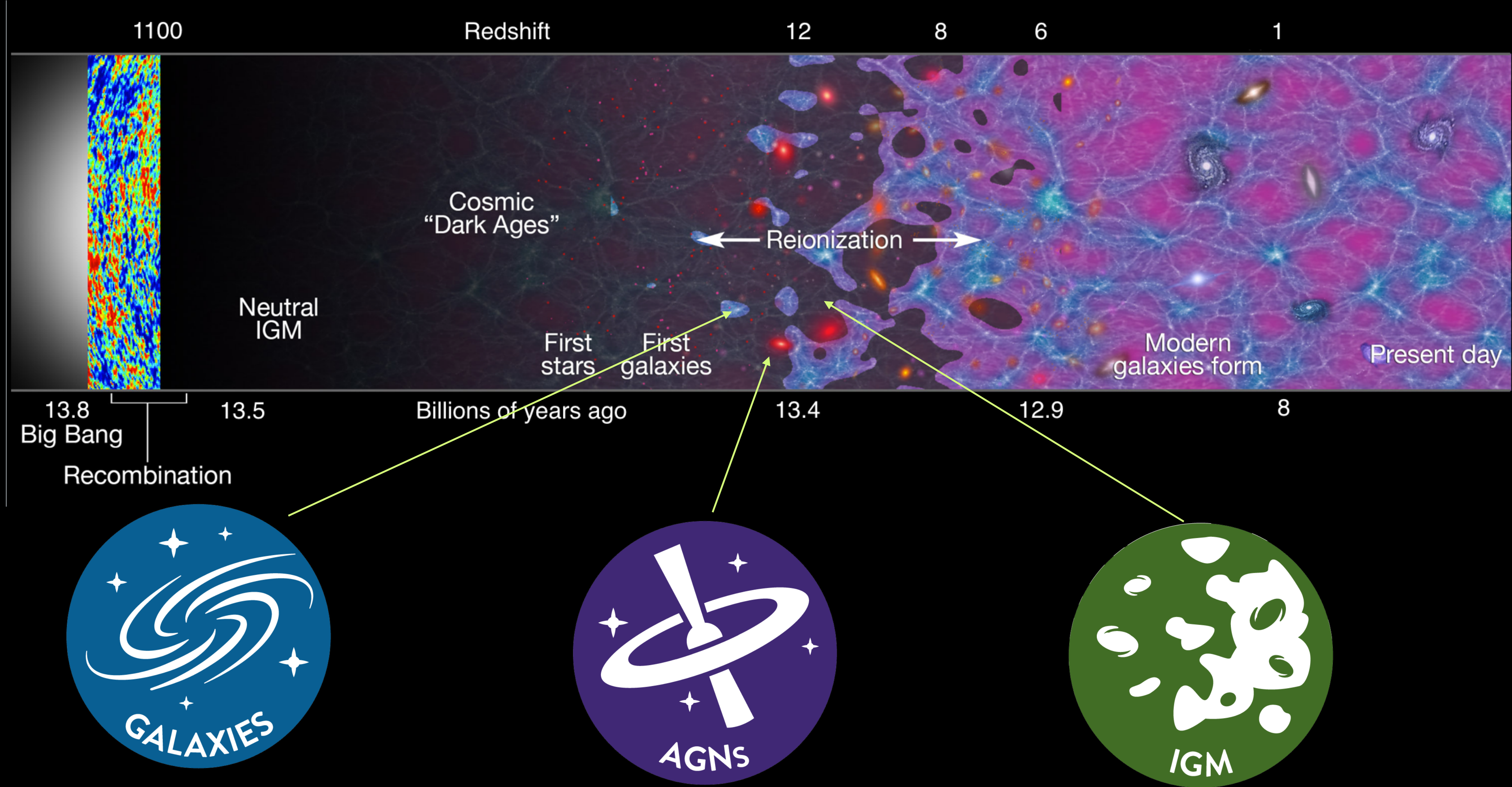
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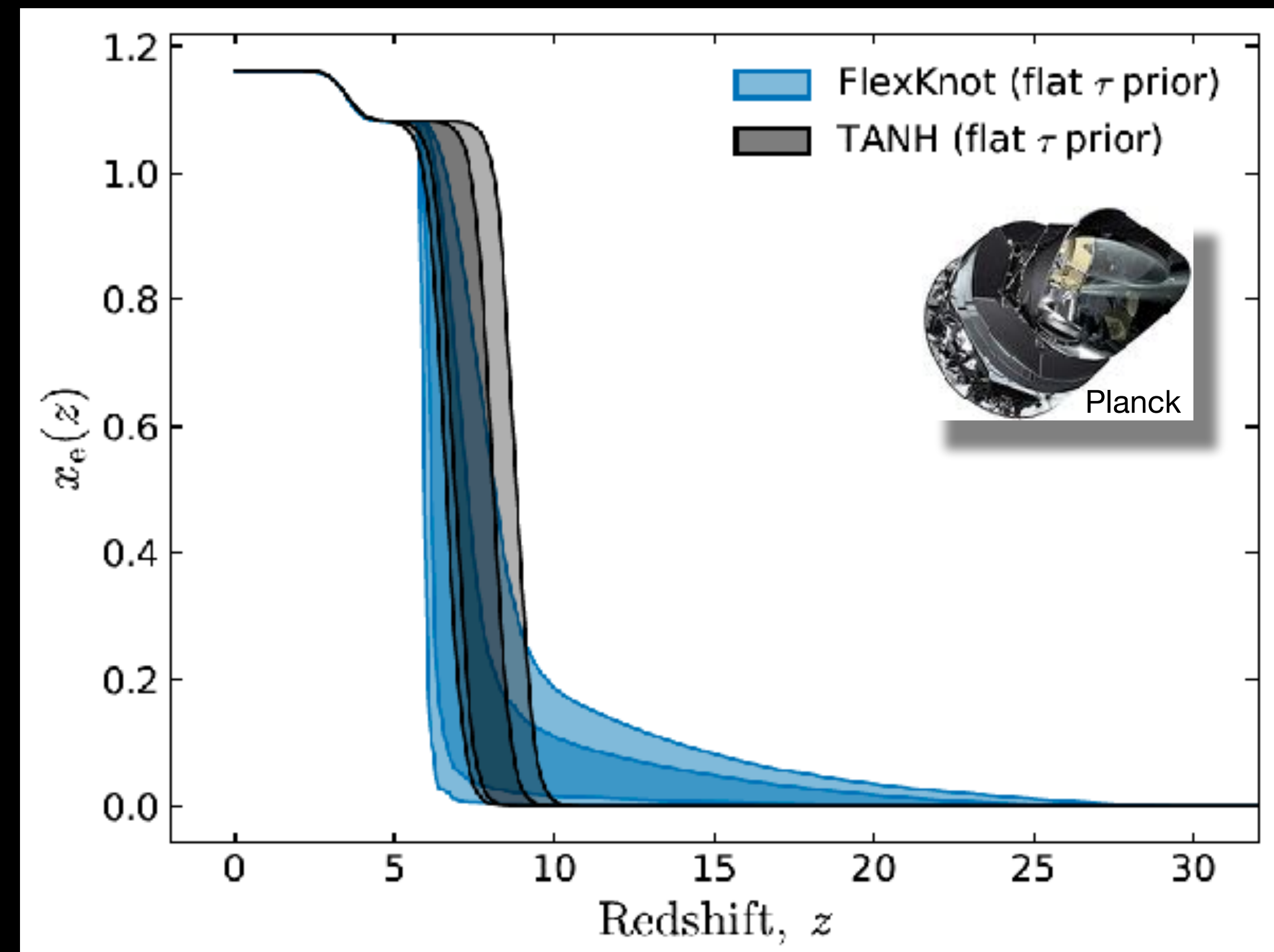
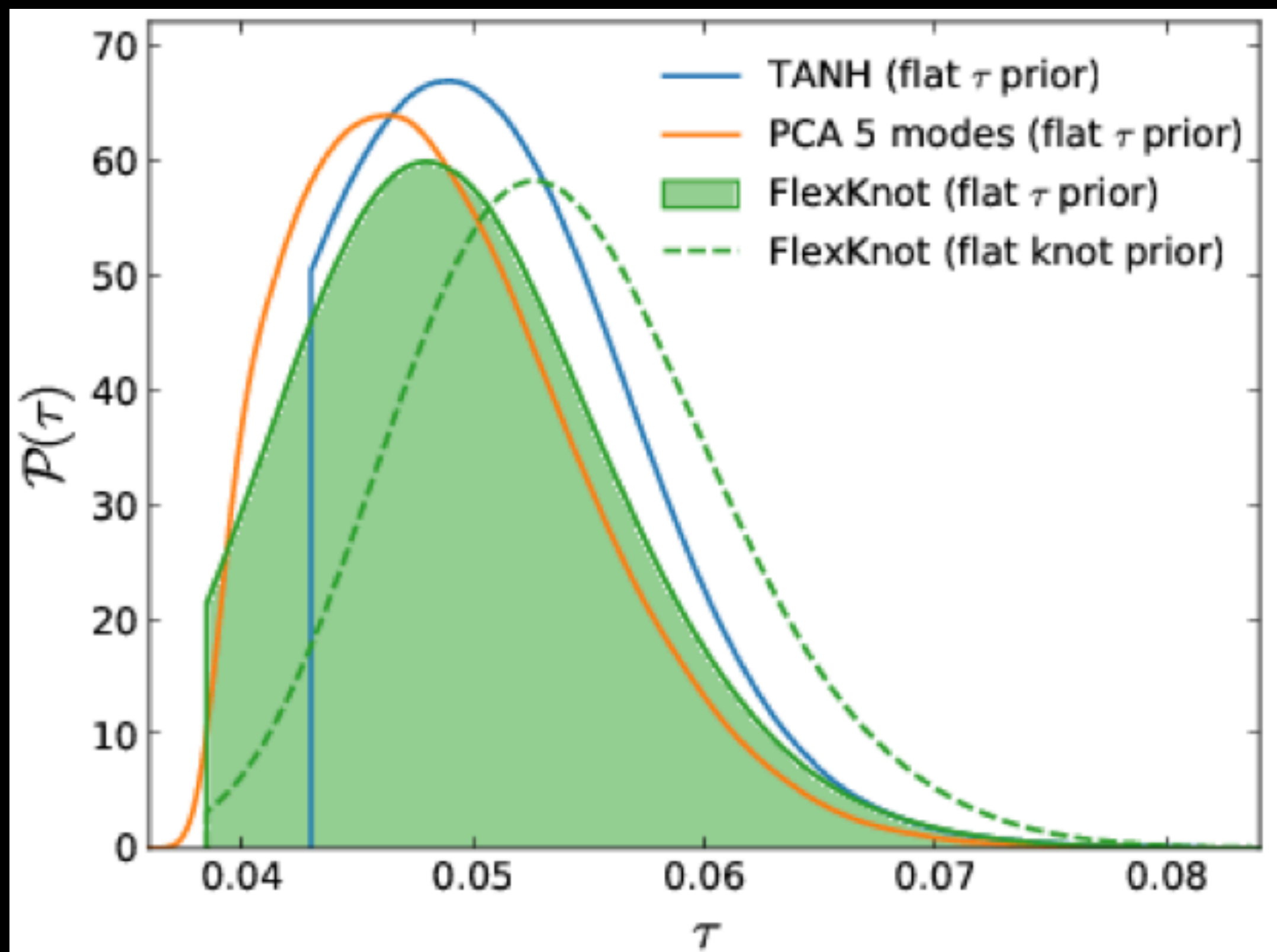
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Cosmic Dawn and Reionization



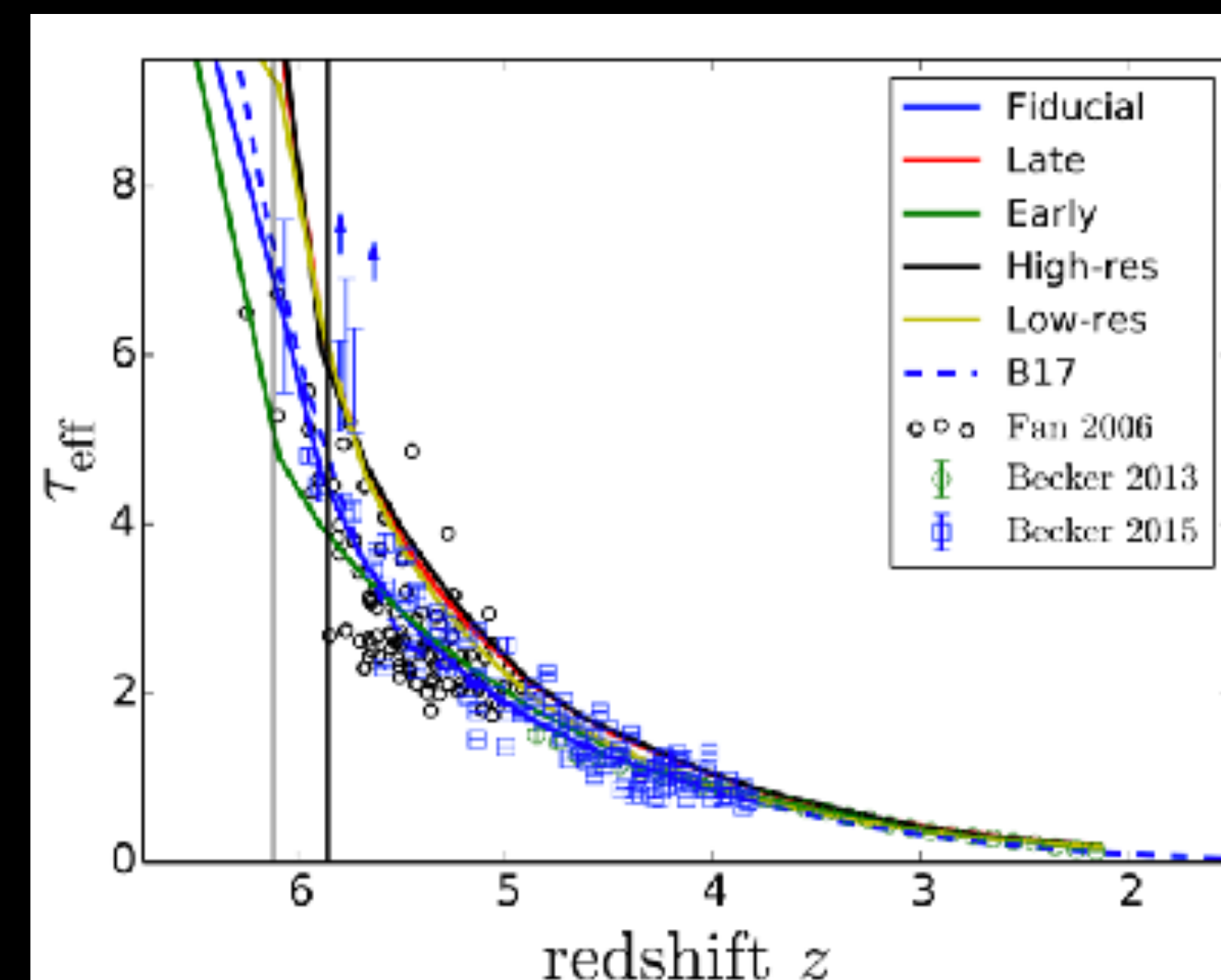
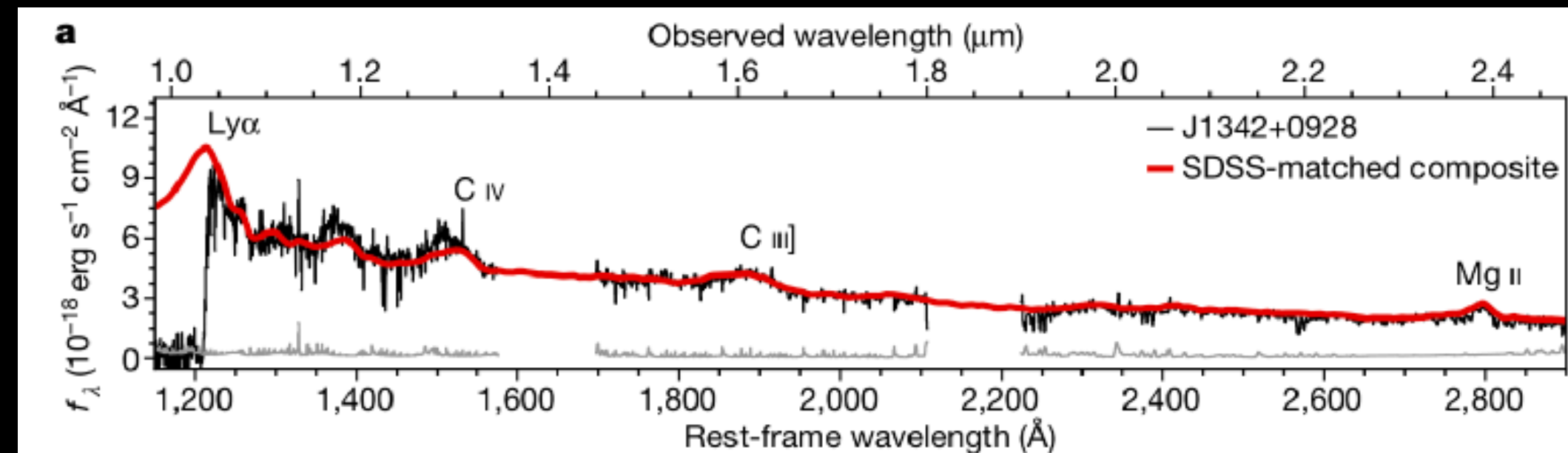
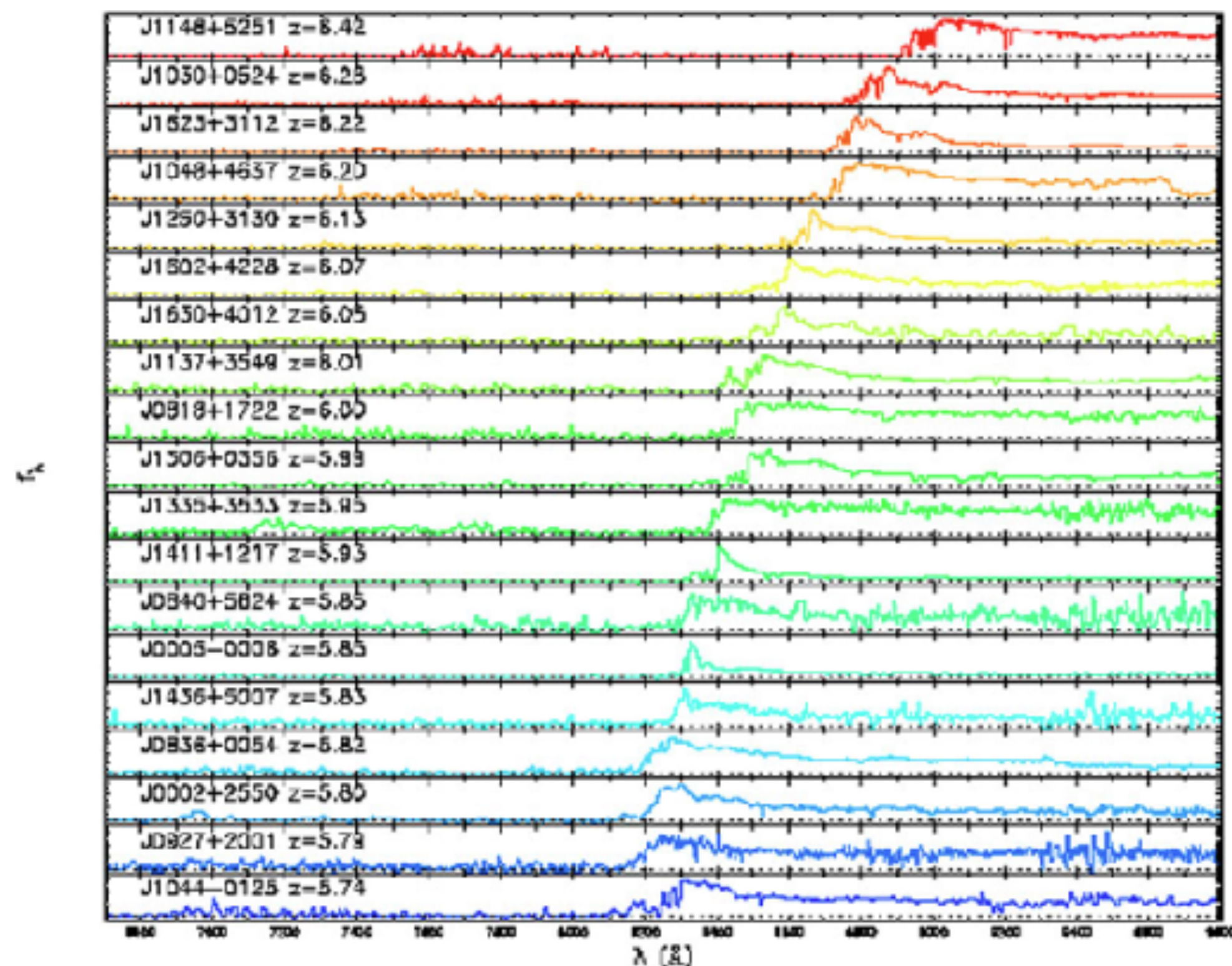
What do we know about reionization?



CMB (with Planck) finds a low optical depth to electron scattering;
bulk of the reionization at $z \sim 8$

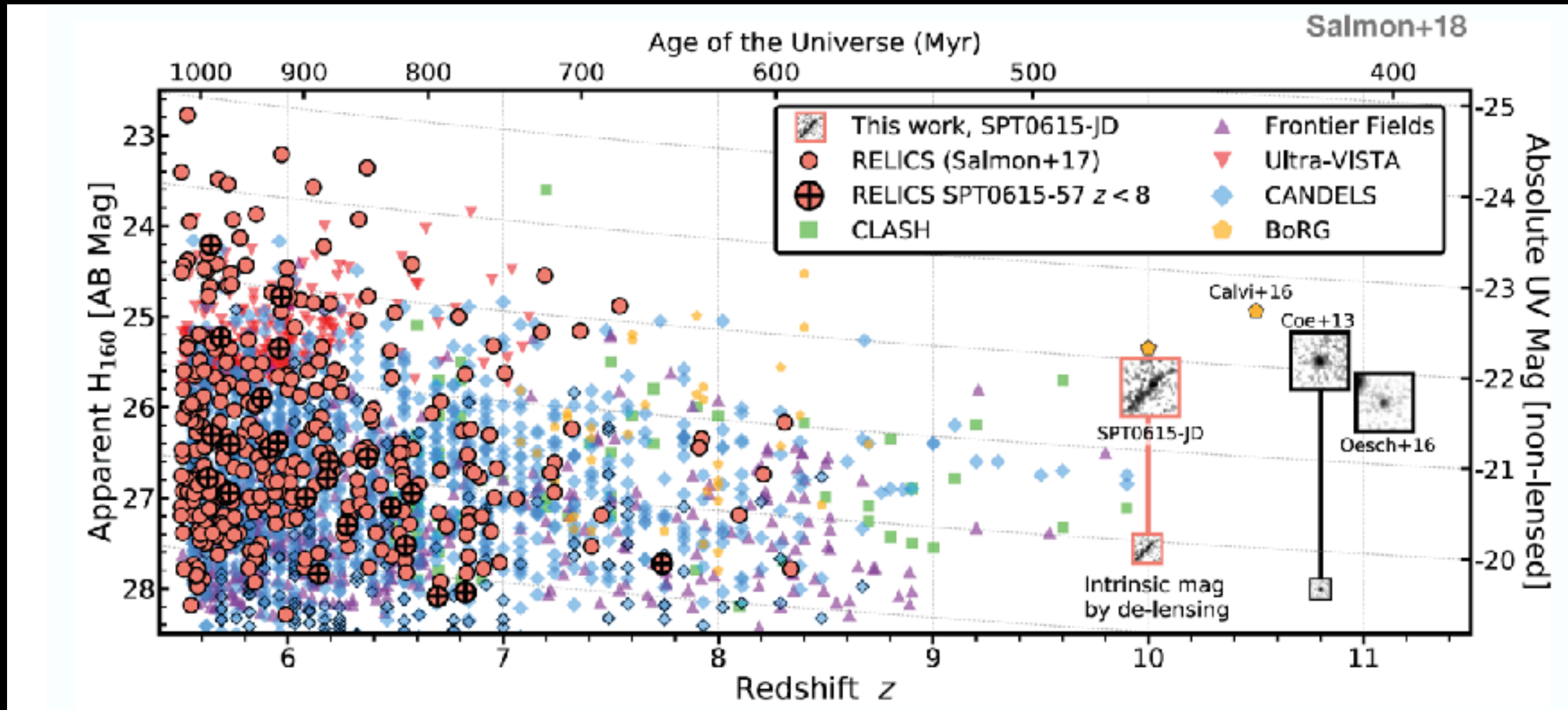
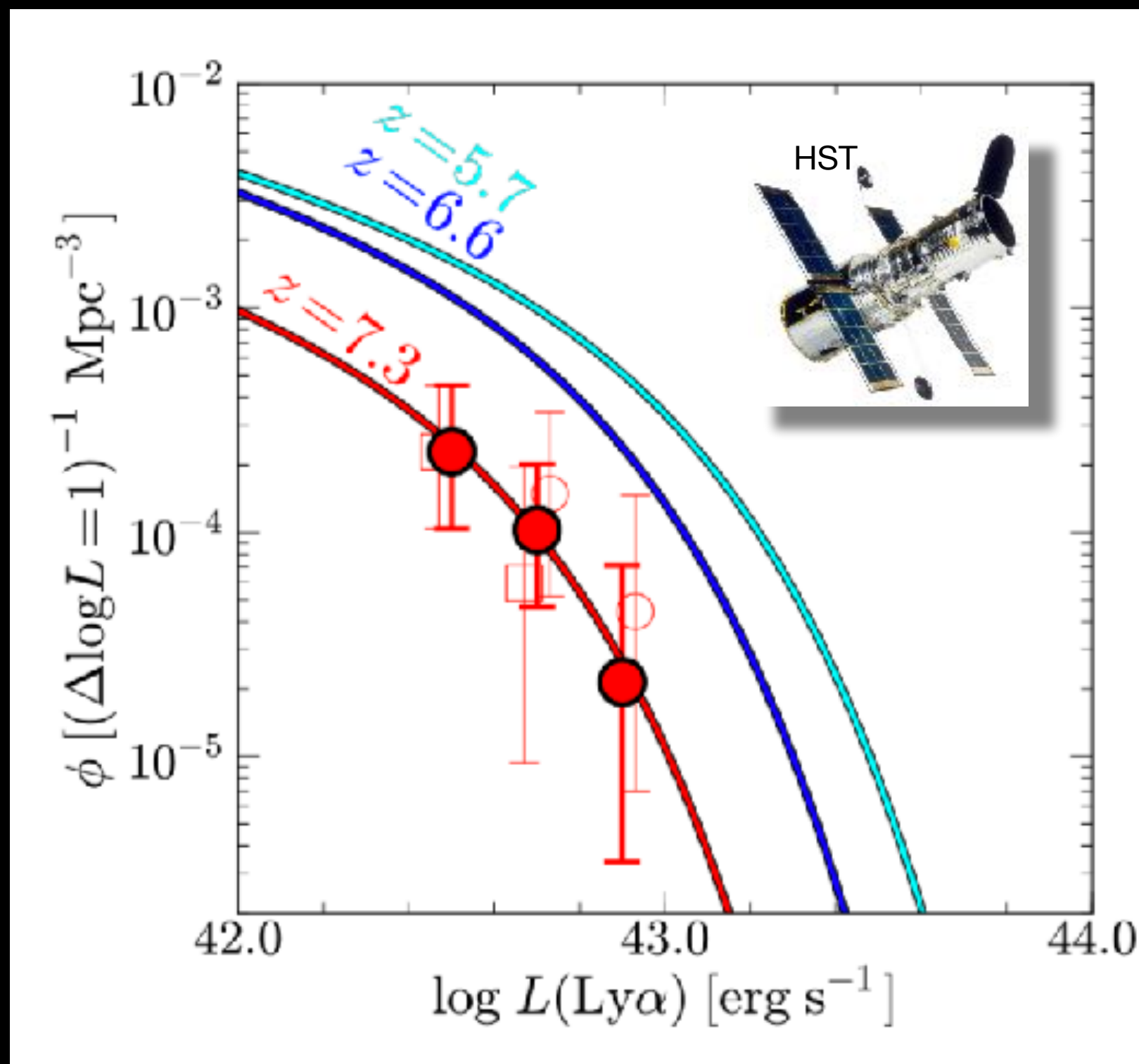
What do we know about reionization?

Around $z \sim 6$ large dark gaps appear in the spectrum



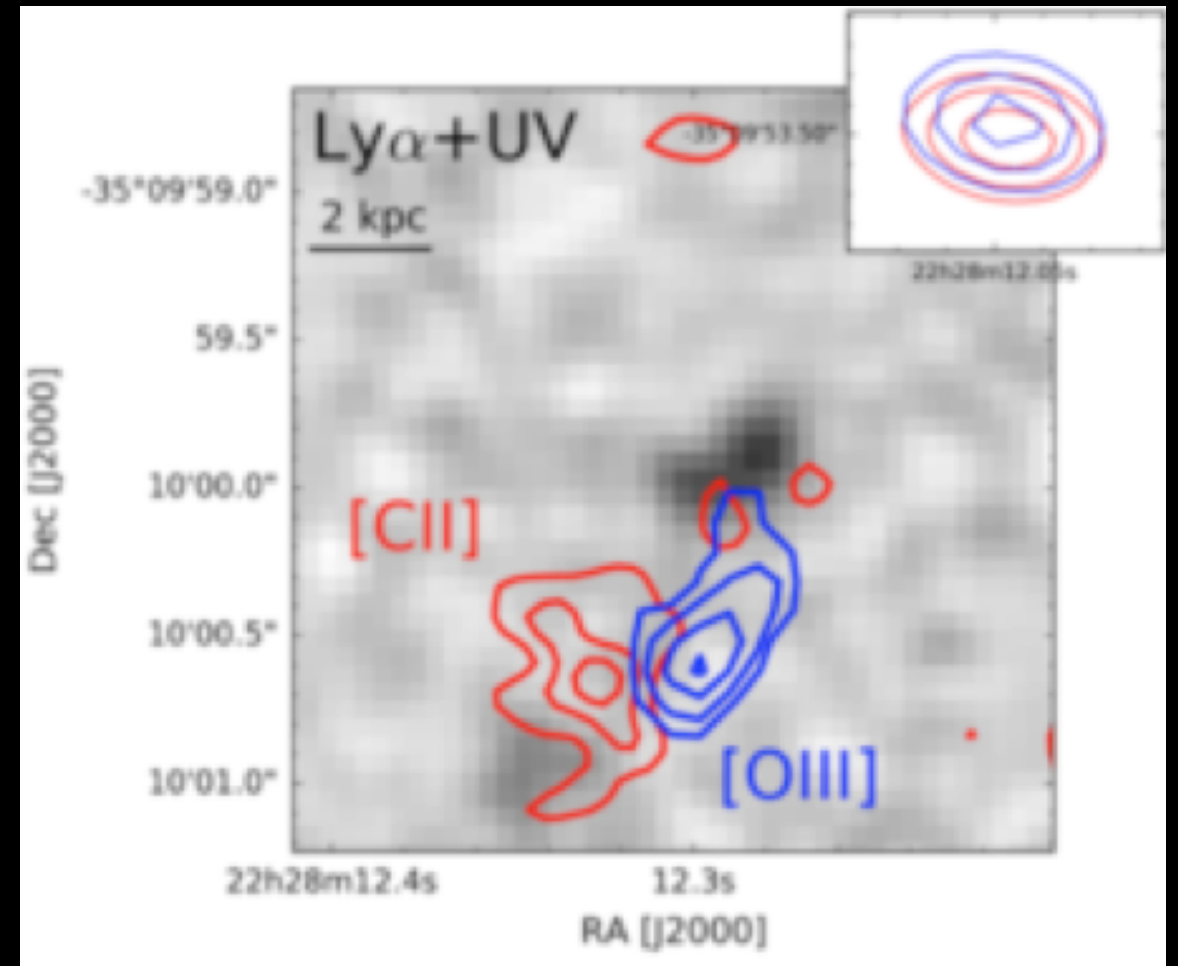
Observations of $z > 6$ quasars from SDSS/UKIDSS etc show clear Gunn-Peterson troughs; **reionization ended at $z \sim 6$ with a rapid increase in the optical depth at $z > 6$**

What do we know about reionization?

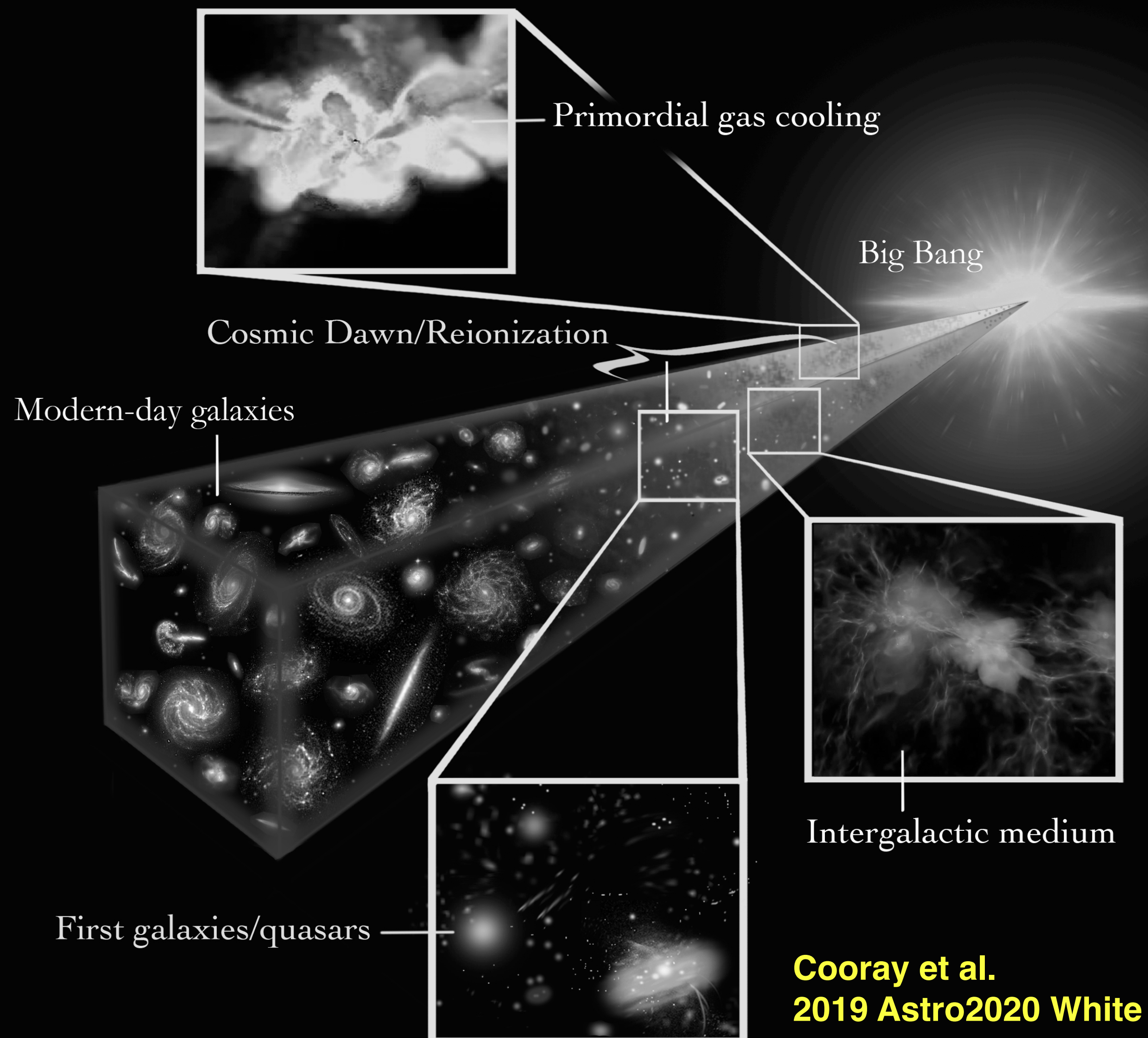


HST/Ground: **Ly α emitters exist at $z > 7$** and Ly-break drop-out **galaxies exist out to $z \sim 11$** in the optical.

ALMA: **detectors of [OIII]/[OI]/[CII] lines at $z \sim 6-9.1$** suggest rapid metal build-up during reionization.



Cosmic Dawn Goals for 2020s



Cooray et al.
2019 Astro2020 White Paper

Anticipated breakthroughs (2020-2030)

- *Cosmic star-formation rate density (ground-based mm-wave and JWST deep surveys)
- *Validation of existing Planck CMB optical depth to reionization (initial 21-cm surveys)
- *Stellar mass function (JWST, Euclid/WFIRST)
- *Supermassive blackhole mass function (Euclid/WFIRST, JWST, ground)

Proposed Scientific Goals for 2030+

- *Precise measurement of reionization history (21-cm surveys combined with 3D tracer fields)
- *Cosmic molecular gas mass density during reionization
- *Cosmic dust and metal abundances during reionization
- *Initial mass function PopIII stars during cosmic dawn and reionization
- *Molecular mass function of primordial star-forming clouds
- *Minimum halo mass of first galaxies

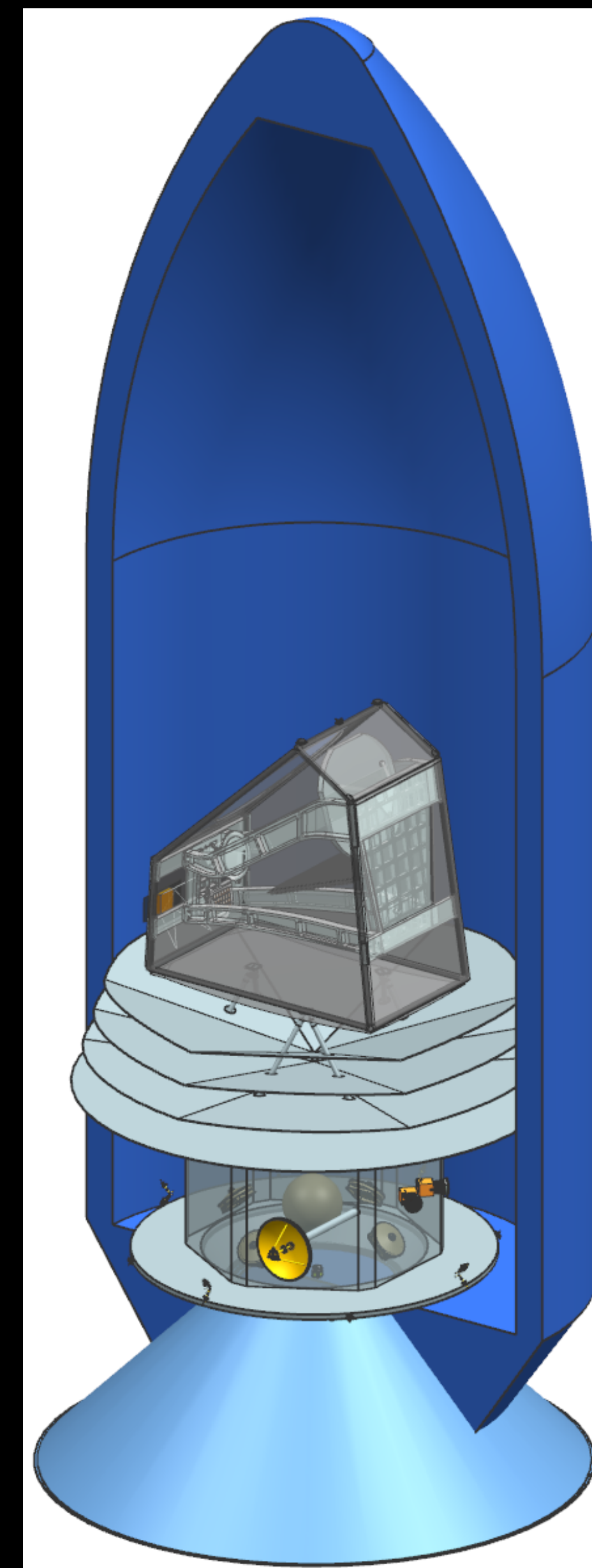
CDIM in a (Falcon-9) Nutshell

Cosmic Dawn and Reionization Sciences

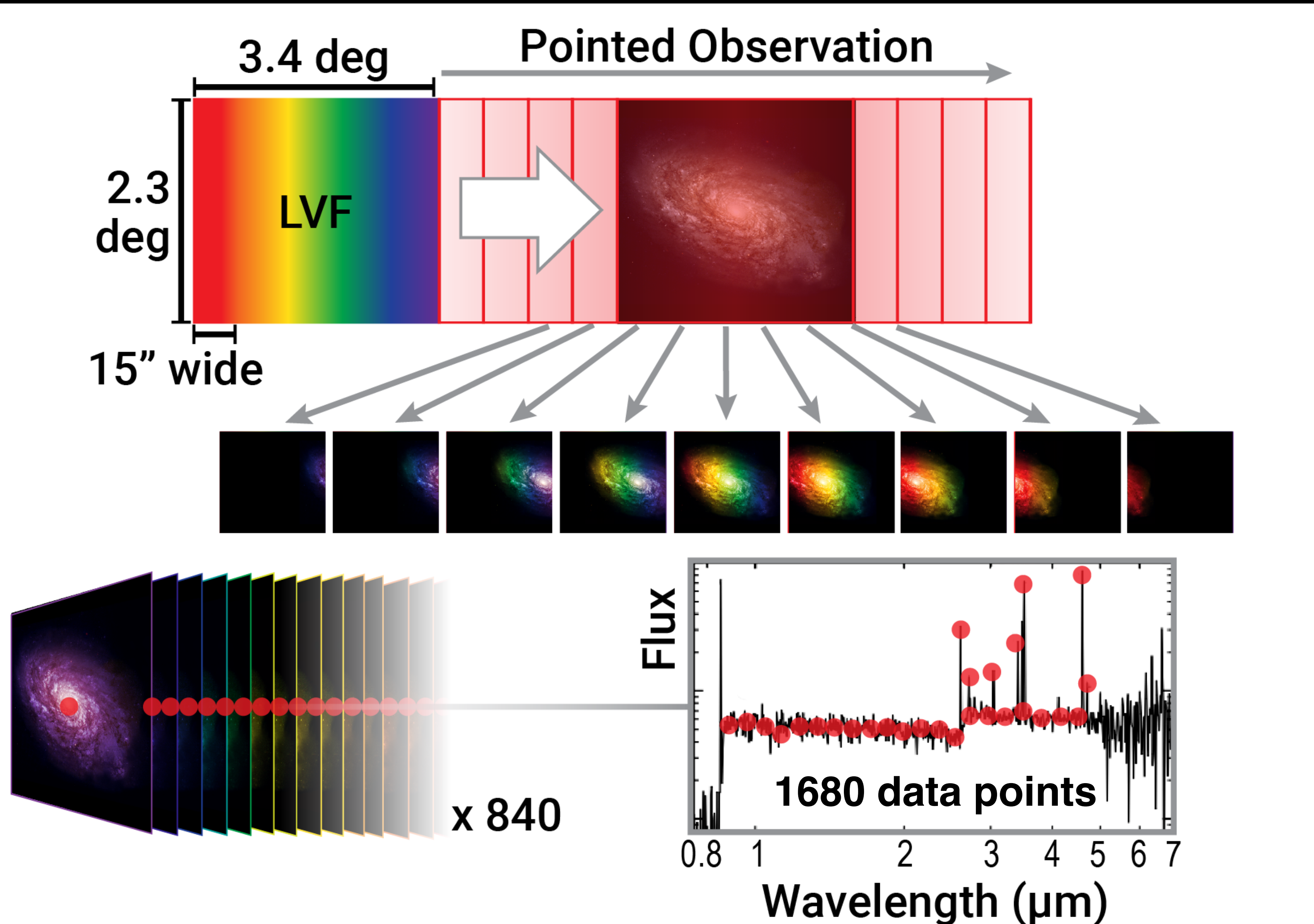
- First Galaxies: tracing H α during reionization to $z=8$, Ly α to $z > 15$
- First Blackholes: finding AGNs at $z=8$
- Reionization Tomography: Ly α , H α intensity mapping during reionization

CDIM: Near-IR Wide-field Spectro-Imaging Survey Telescope

- 0.75 μm – 7.5 μm spectro-imaging in 840 narrow bands at $R=300$
- 0.83 m effective aperture (1.1 m physical)
- 2" PSF, 1" pixels, ~ 9 sq. degree focal plane
- Three-tiered (15-300 deg 2) survey in 4 years
- Substantial heritage: linear variable filters (e.g., SPHEREx), H2RGs to 7.5 μm (NEO-Surveyor), V-groove passive thermal cooling (e.g., Planck)
- Costed at JPL to be about \$920M (incl. 30% margin)

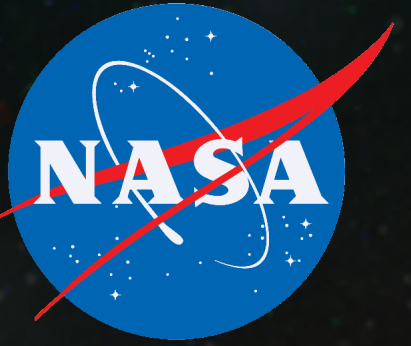


Spectroscopy with Linear Variable Filters (LVF)



CDIM

CDIM = “see-dim”

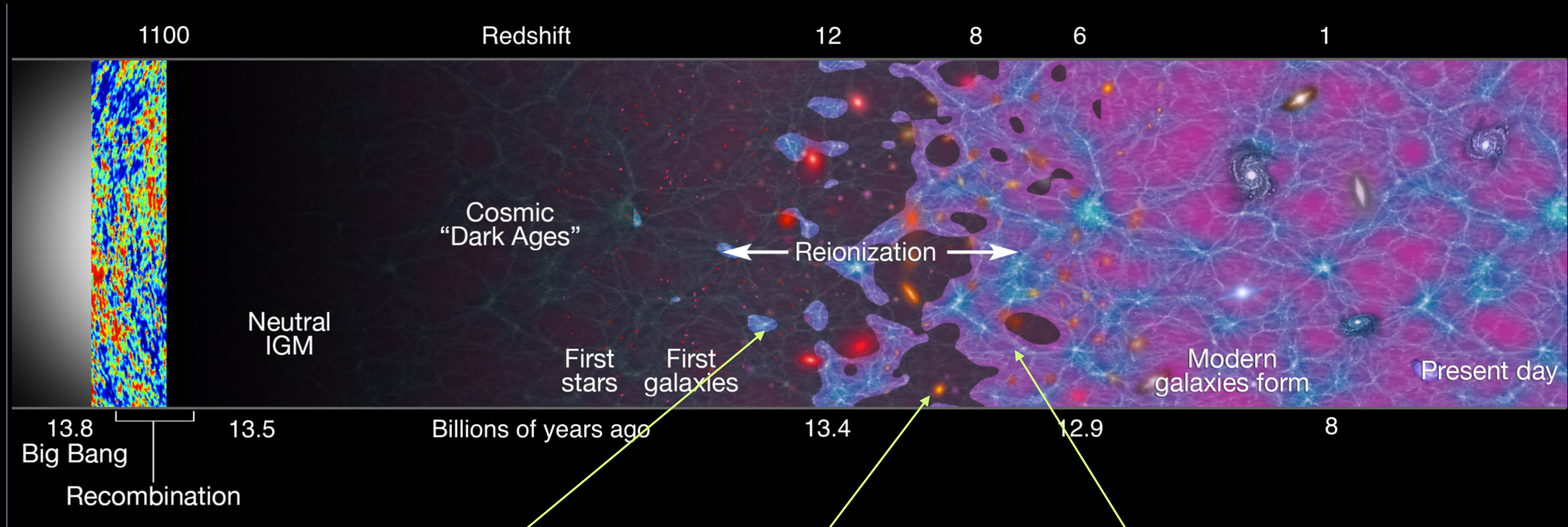


Cosmic Dawn Intensity Mapper

A Probe Class Spectro-Imaging Astrophysics
Mission for Reionization

CDIM Science Case
Tzu-Ching Chang, JPL
(Study Scientist)

Cosmic Dawn and Reionization



Measuring $H\alpha$
up to z of 8

- $R \geq 300$ to separate $[NII]$ from $H\alpha$
- Line flux sensitivity



Finding black
holes to z of 8

- Large survey area
- Point source sensitivity



Mapping reionization
topology and history
with $H\alpha$ and $Ly\alpha$ at
 z of 5-10

- Wavelength 0.75-7.5 microns
- Large field of view
- Surface brightness sensitivity

CDIM Three-tiered Survey



- Detecting faint, high-redshift galaxies
- Deep survey; 15 deg² to overlap with WFIRST/Euclid deep fields
- Detecting bright, rare AGNs



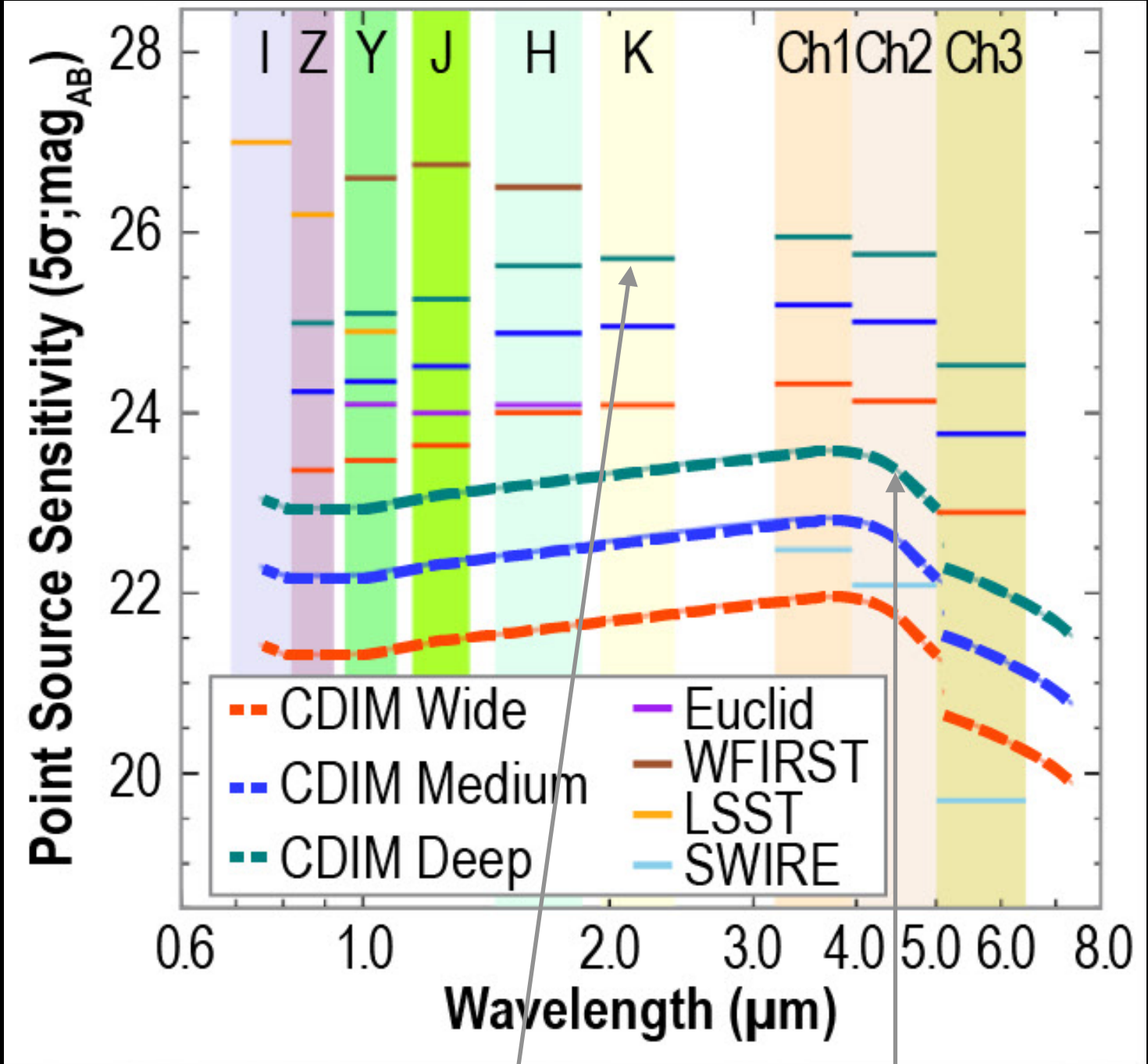
- Wide survey; 300 deg² to catch $z=8$ AGNs.
- At either SEP or NEP, visible all-year round from L2, surrounding the Deep survey field



- Reionization tomography in synergy with 21 cm intensity maps
- Medium survey; 30 deg² to match a SKA 21 cm EoR deep field likely overlapping with the ECDF-S and HERA
- Four-year survey. Observing efficiency at $> 90\%$, ($\sim 7\%$ of time for slewing).

CDIM Sensitivity and Spectrum

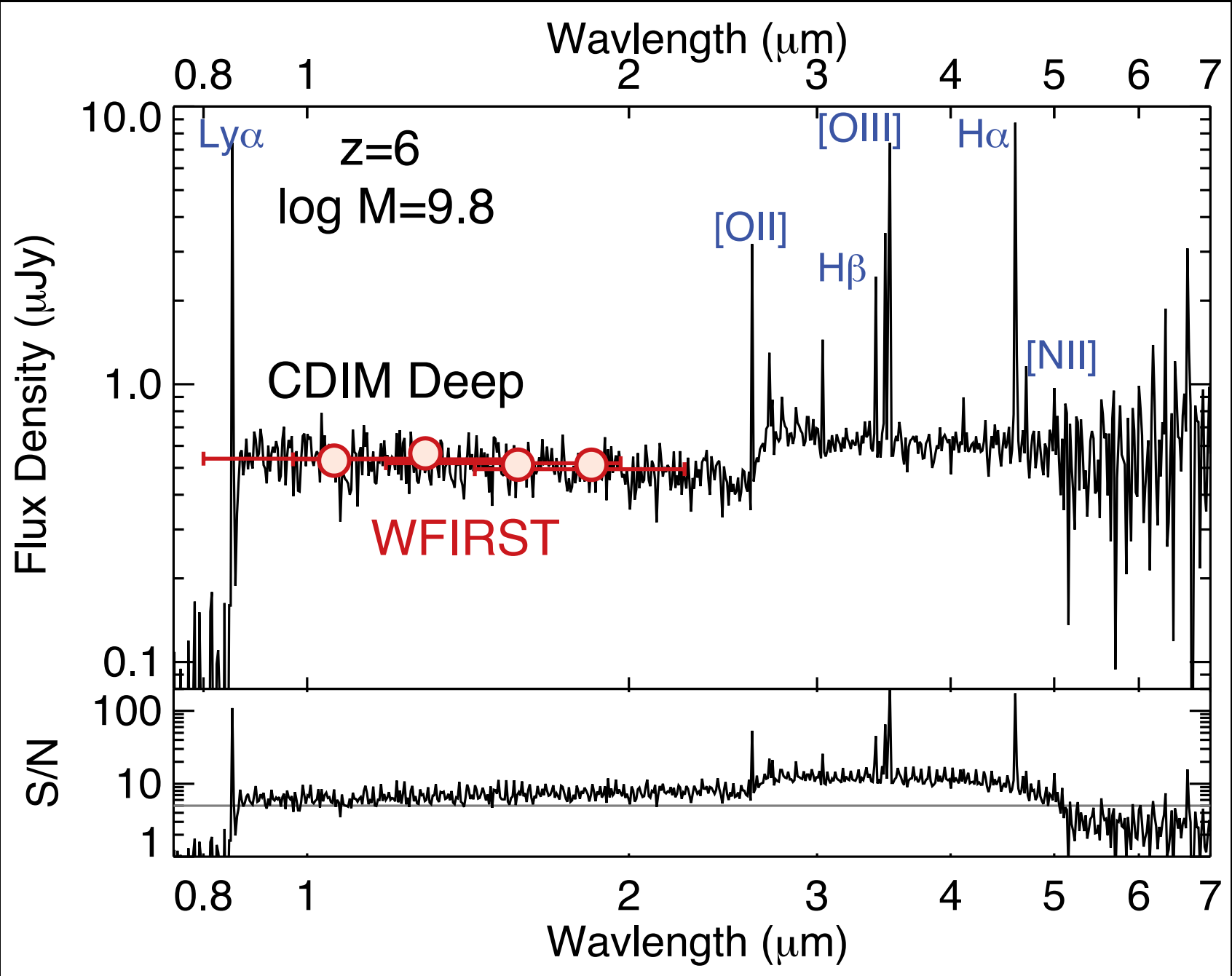
CDIM Point Source Sensitivity



CDIM R=5
Broad
bands

CDIM R=300
840 bands

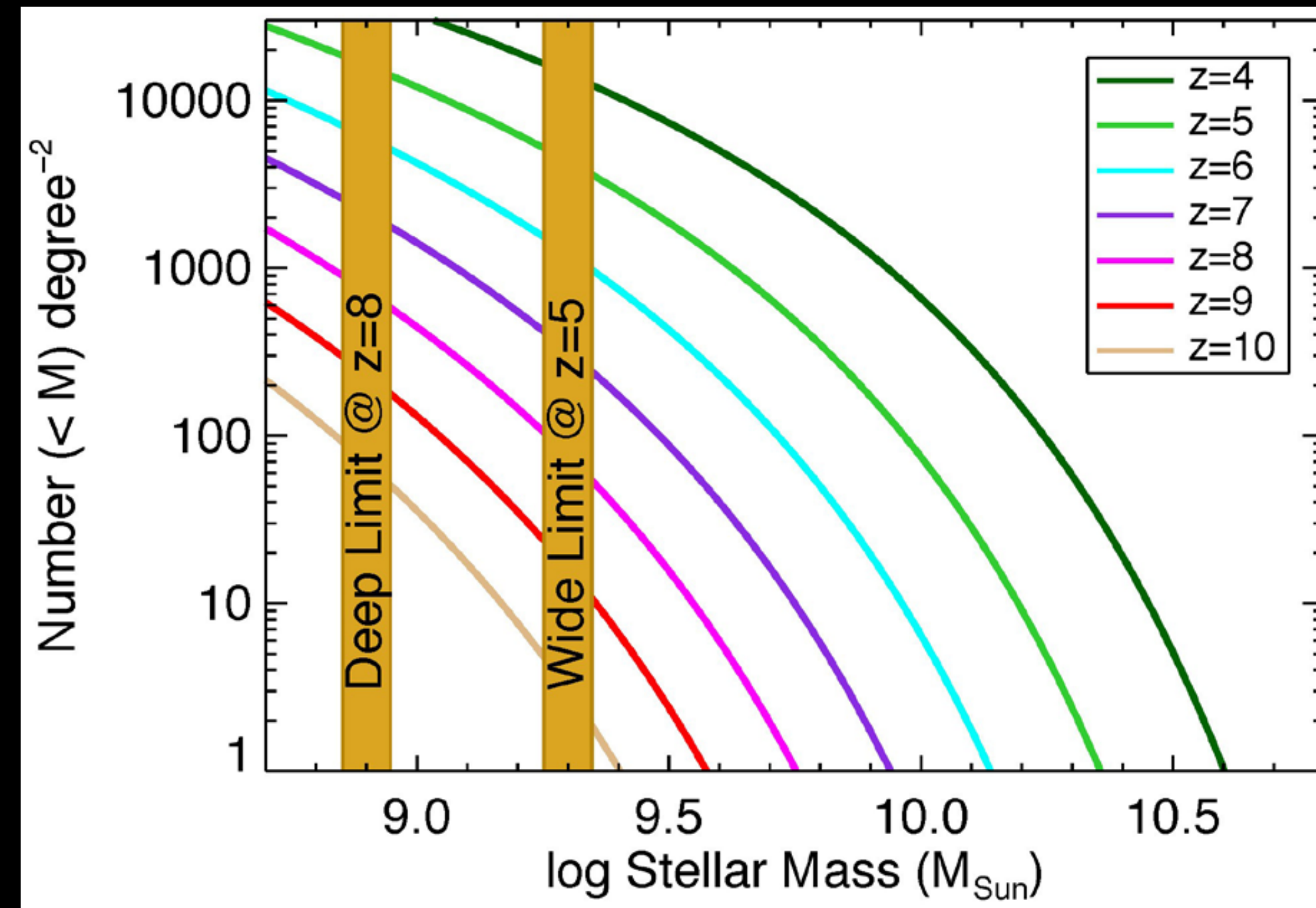
Simulated z=6 CDIM observed galaxy spectrum



CDIM measures redshifts of
galaxies and quasars
And provides spectral lines



CDIM Detects Faint Galaxies

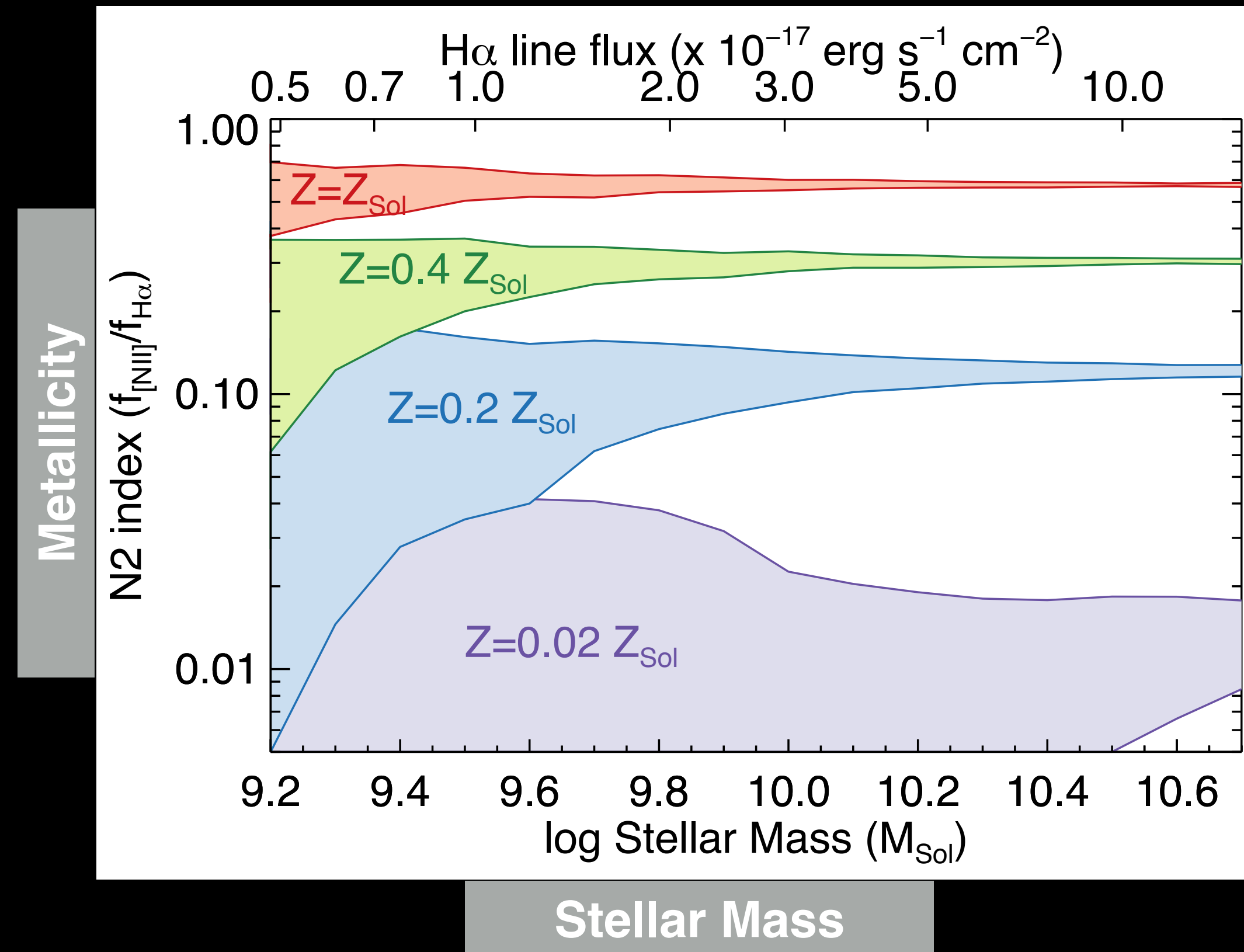


- Measure redshifts for most WFIRST-HLS detected galaxies at $z=5-8$

CDIM Measures Stellar Mass and Metal production



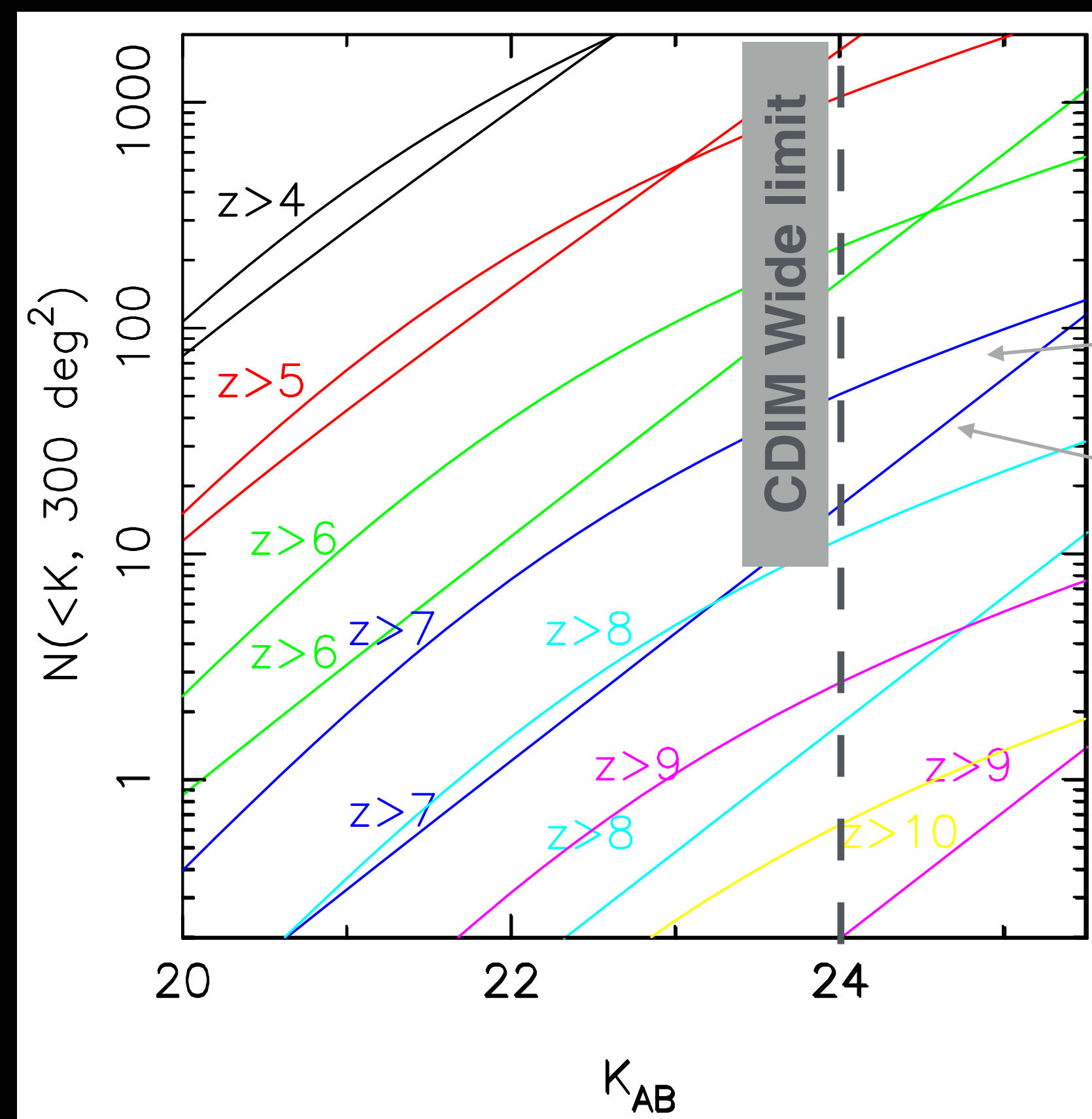
$z=6$



- Measure stellar mass from rest-frame optical, and metallicity from $[NII]/H\alpha$.
- CDIM traces stellar mass and metal build up across redshift



CDIM measures growth of blackhole masses



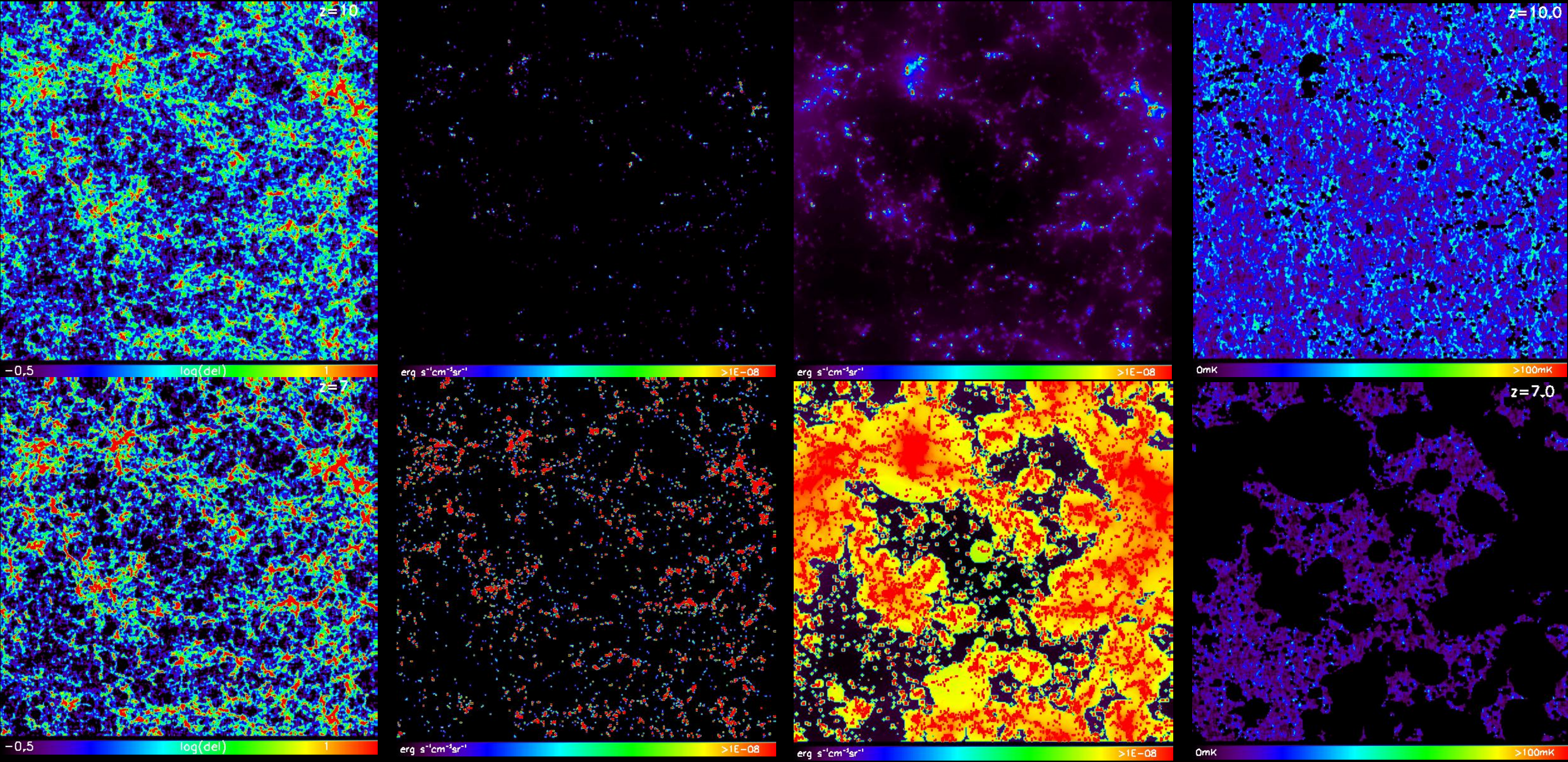
- Two quasar luminosity functions, Willott+15 and Kulkarni+18 and Wang+18 which has a steeper faint-end slope, both forecast more than 100 quasar detections at $z=6$.
- CDIM measures >100 quasars with spectra at $z>6$, inferring blackhole masses down to $10^7 M_{\text{sun}}$ using MgII line. CDIM measures blackhole mass growth across redshift.



21cm, H α , Ly α Reionization Tomography

Density fluctuation Ionizing sources (traced by galactic H α) Partially ionized IGM (traced by scattering Ly α) Neutral IGM (traced by 21cm)

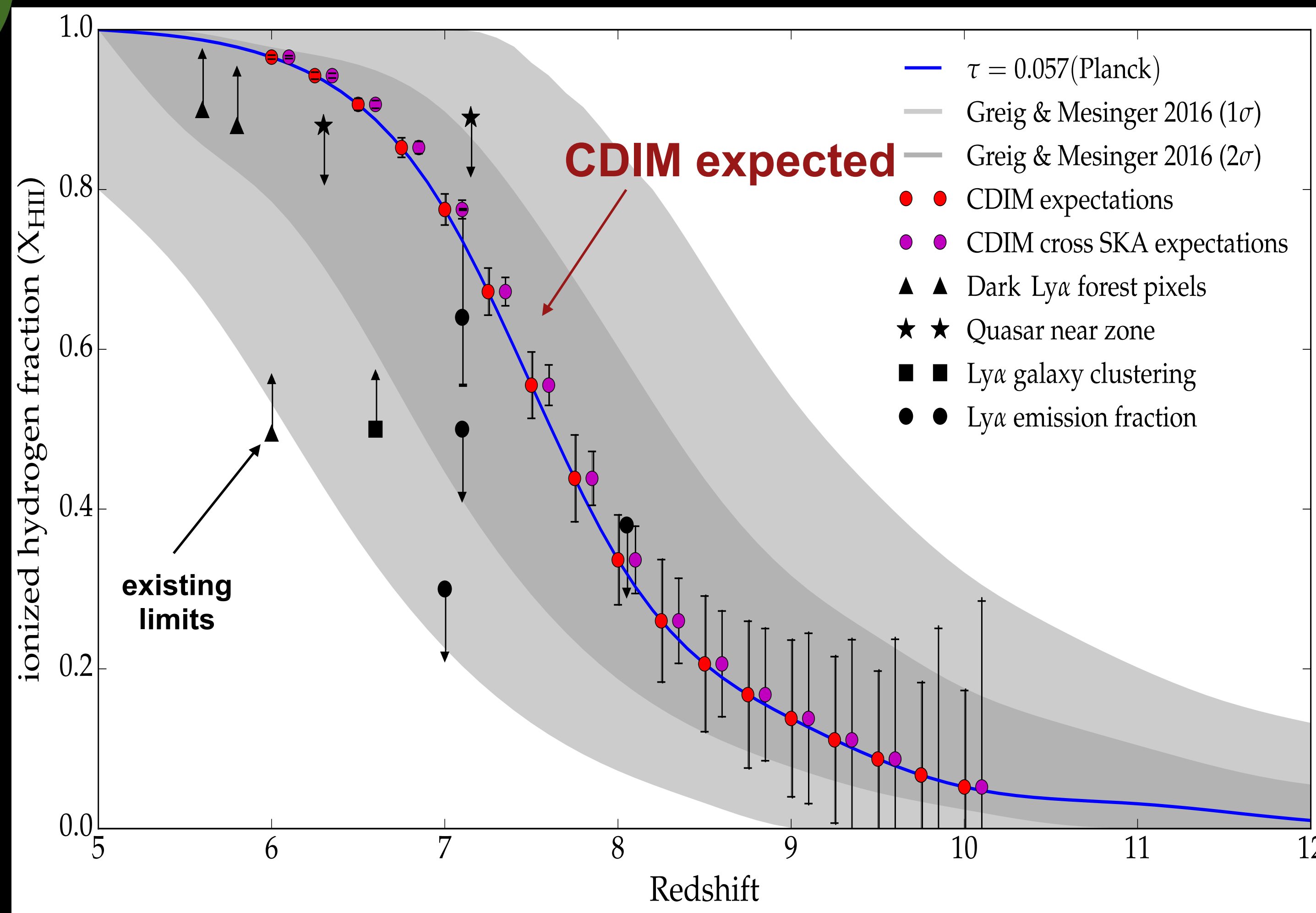
z=10
↓
z=7



200 Mpc CDIM CDIM SKA/HERA



Reionization History



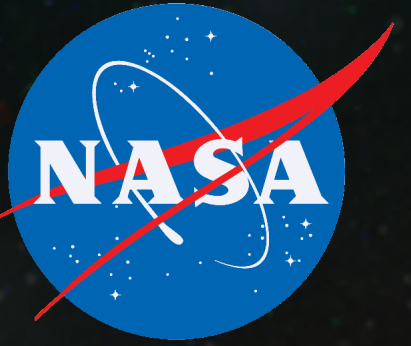
- Ionization fraction can be inferred from multiple measurements: evolution of LAEs, $\text{H}\alpha$ and $\text{Ly}\alpha$ intensity evolution, and amplitudes of ($21\text{cm} \times \text{Ly}\alpha$) cross-power spectra.

Science Requirements

NASA Science Goals	CDIM Science Goals	CDIM Science Objectives	Science Requirements			Instrument Requirements			Mission Requirements	
			Physical Parameters	Observables	Measurement Requirement	Instrument Parameter	Science Requirement	Capability	Driver	Parameter
Explore the origin and evolution of the galaxies, stars and planets that make up our universe [NASA Science Plan] How does the Universe work? How did we get here? [NASA 2014 Science Mission Directorate Strategy Document]	Trace the stellar mass buildup, dust production history, and metal enrichment history during cosmic reionization.	Determine if the rate of growth of metals and dust corresponds to the growth of stellar mass at $5 < z < 8$. 	Metallicity of galaxies via the oxygen abundance, stellar mass, and dust attenuation (extinction rate, dust density)	[OIII], [OII], [NII]/H α , H α /H β @ $5 < z < 8$	(i) Wavelength coverage to detect H α out to z of 10. (ii) Spectral resolving power to resolve [NII] and H α . (iii) Sensitivity to detect galaxies $< 10^9 M_{\text{sun}}$ in a deep survey.	Wavelength range	$2.2 \leq \lambda \leq 6.0 \mu\text{m}$	$0.75 \leq \lambda \leq 7.5 \mu\text{m}$	Data Reliability and Systematic Error Control	Deep, medium and wide surveys each with $\geq 90\%$ voxel completeness for internal reliability. Spatial resolution: Effective PSF FWHM $\leq 2''$ at $1 \mu\text{m}$ (from science requirements). Stable cooling to $< 35 \text{ K}$ to control $> 5 \mu\text{m}$ array dark current.
						Spatial resolution (pixel scale)	$\Theta_{\text{pix}} = 1''\text{--}2''$	$\Theta_{\text{pix}} = 1''$		
						Spectral resolving power	$\lambda/\Delta\lambda \geq 300$	$\lambda/\Delta\lambda = 300$		
						Point source broadband photometric sensitivity (R=5, 5 σ ; deep survey)	24.5 AB mag at J band	25.2 AB mag at J band		
	Establish the role of active galactic nuclei (AGN) in cosmic reionization.	Determine the fractional contribution of super-massive black hole/AGNs to reionization photon budget. 	Unbiased UV photon spectral density; black-hole masses via line widths of optical lines.	Rest-frame UV continuum @ $z = 5\text{--}8$. [MgII] and other metal lines.	(i) Sensitivity to detect faint quasars in a wide survey. (ii) Spectral resolving power to detect equivalent width of broad metal lines.	Spectral line flux sensitivity (3.5 σ ; deep survey)	$5.0 \times 10^{-18} \text{ erg s}^{-1} \text{ cm}^{-2}$ at $4.6 \mu\text{m}$	$2.7 \times 10^{-18} \text{ erg s}^{-1} \text{ cm}^{-2}$ at $4.6 \mu\text{m}$		
						Wavelength range	$2.9 \leq \lambda \leq 6.0 \mu\text{m}$	Same as above		
						Spatial resolution (PSF; FWHM)	$\Theta_{\text{FWHM}} = 2''$ at K band	$\Theta_{\text{FWHM}} < 2''$ at K band		Deep survey: 15 deg^2, imbedded in the Wide survey.
						Spectral resolving power	$\lambda/\Delta\lambda \geq 300$	Same as above		
	Establish the progression and topology of reionization from cosmic dawn at $z = 10$ to the end of reionization at $z < 6$.	Determine the progress of reionization by measuring the ionization fraction in at least 10 redshift bins at $5 < z < 10$, with accuracy better than 10%. 	Ly α luminosity function, escape fraction, and the spatial distribution.	Ly α	(i) Wavelength coverage to detect Ly α out to z of 10. (ii) Sensitivity to detect faint galaxies.	Point source broadband photometric sensitivity (R=5, 5 σ ; wide survey)	23.5 AB mag at K band	24.0 AB mag at K band	Survey Strategy	Medium survey: 30 deg^2, to overlap with 21-cm fields from HERA and SKA1-LOW.
						Wavelength range	$0.75 \leq \lambda_{\text{Ly}\alpha} \leq 0.98 \mu\text{m}$	$0.75 \leq \lambda \leq 7.5 \mu\text{m}$		
						Spectral resolving power	$\lambda/\Delta\lambda \geq 100$	Same as above		
			Reionization history of the universe.	Ly α and H α	(i) Ability to perform cross-correlations, including Ly α and H α , and 21-cm radio measurements.	Spectral line flux sensitivity (3.5 σ ; deep survey)	$2.9 \times 10^{-17} \text{ erg s}^{-1} \text{ cm}^{-2}$ at $0.85 \mu\text{m}$	$2.0 \times 10^{-17} \text{ erg s}^{-1} \text{ cm}^{-2}$ at $0.85 \mu\text{m}$		Wide survey: 300 deg^2, driven by number of AGN detections.
						Wavelength range	$0.75 \leq \lambda_{\text{Ly}\alpha} \leq 1.4 \mu\text{m}$ $3.9 \leq \lambda_{\text{H}\alpha} \leq 7.2 \mu\text{m}$	$0.75 \leq \lambda \leq 7.5 \mu\text{m}$		
						Spectral resolving power	$\lambda/\Delta\lambda \geq 100$	Same as above		Read, reduce, and telemetry spectral imaging data.
						Surface brightness sensitivity (1 σ ; medium survey)	$1.3 \times 10^{-18} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ Hz}^{-1} \text{ sr}^{-1}$ at $1.1 \mu\text{m}$	$1.5 \times 10^{-19} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ Hz}^{-1} \text{ sr}^{-1}$ at $1.1 \mu\text{m}$		

CDIM

CDIM = “see-dim”



Cosmic Dawn Intensity Mapper

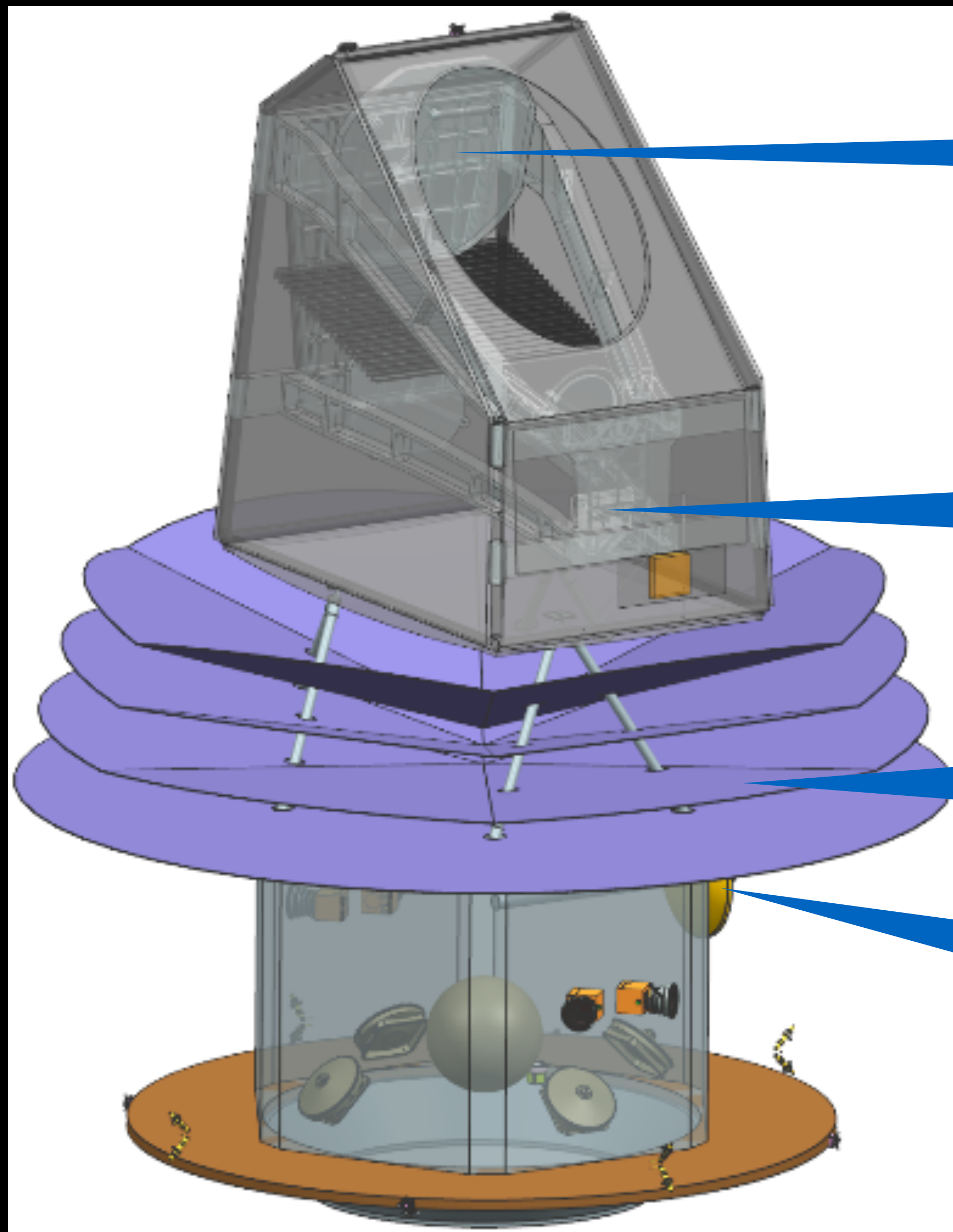
A Probe Class Spectro-Imaging Astrophysics
Mission for Reionization

CDIM Design

Asantha Cooray (UC Irvine)

CDIM Design

5.6m



Three-mirror all-reflective design
with 1.1m physical aperture/
0.83m effective aperture

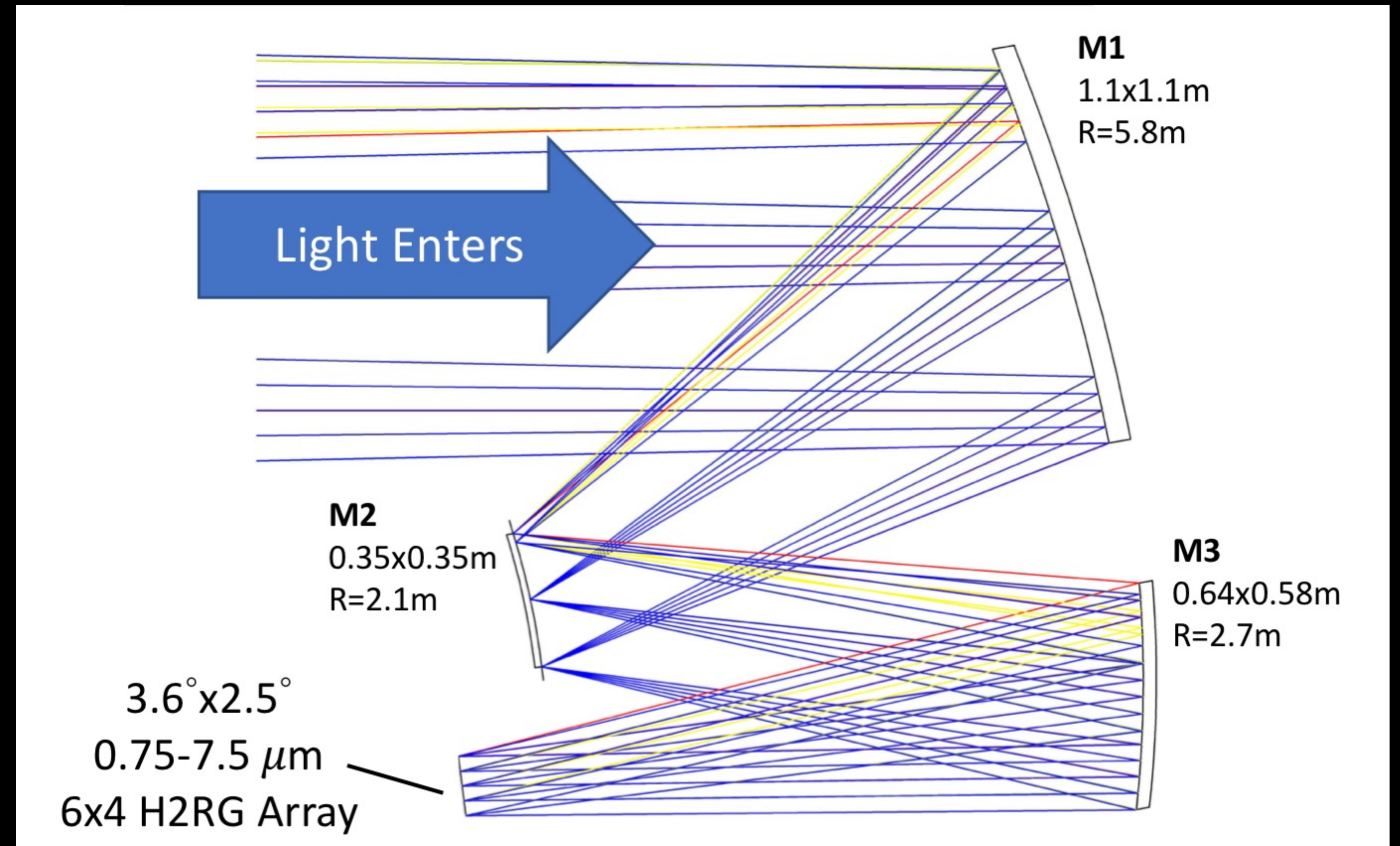
Linear Variable Filters (LVF) at
 $R=300$, 4x6 H2RG detectors

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

Ka-band HGA. Data rate ~ 400
Gbit/day, 1hr/day downlink

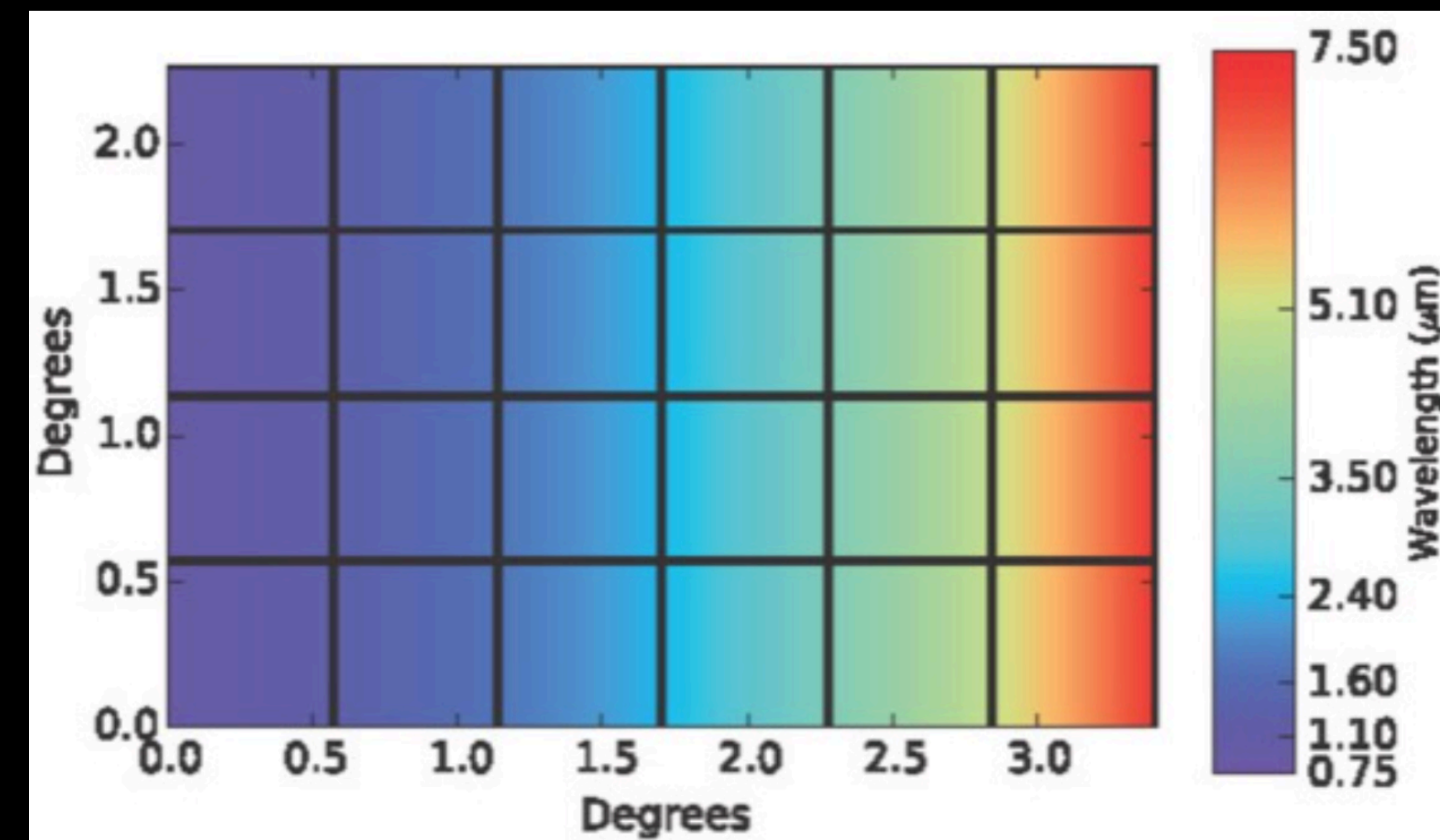
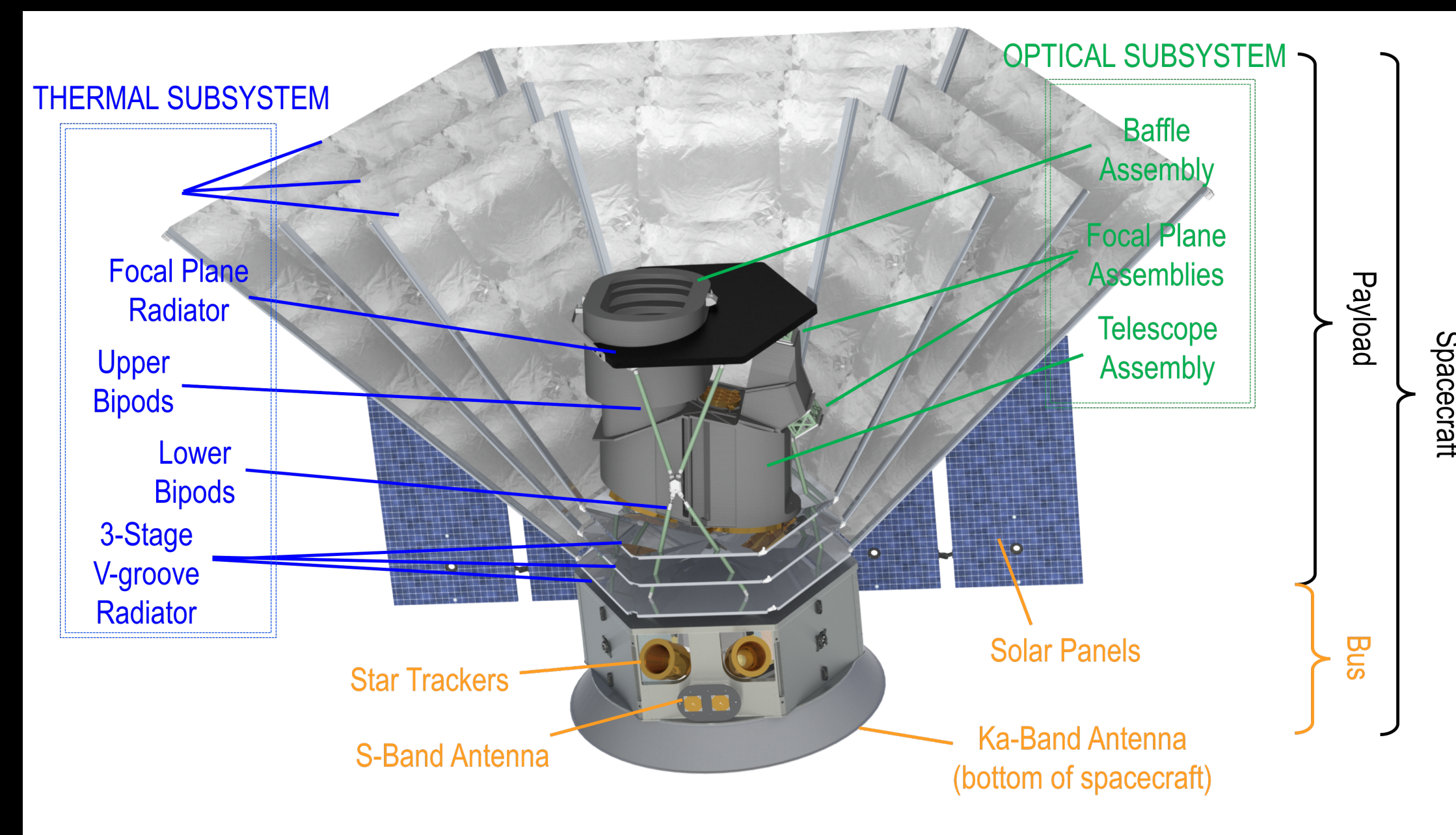
CDIM Telescope

- CDIM telescope is a wide-field three-mirror anastigmat design with 1.1m largest optic and 0.83m entrance pupil
- **Beryllium mirrors** and structure provide passive athermalization in a lightweight design that simplifies integration and test, and substantial heritage (Spitzer, JWST)
- **9 deg² field of view** design < 0.6" RMS image PSF, low distortion and a flat focal plane well matched to **1" H2RG pixels**



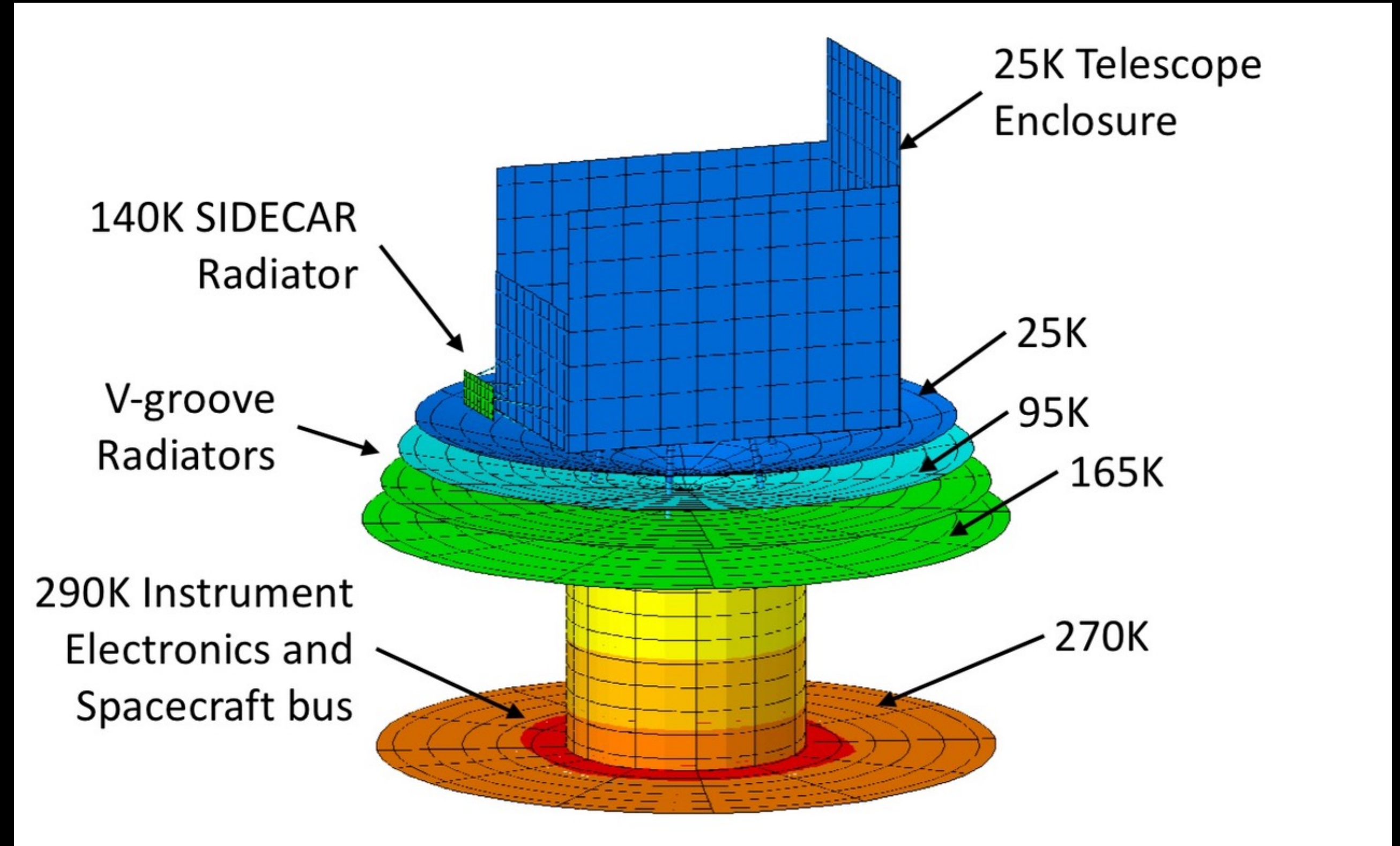
Spectroscopy with CDIM

- There is **no spectrometer!**
 - No re-imaging, no prisms or gratings
 - No moving parts
- Imaging spectroscopy with linear variable filters (LVFs)
 - CDIM spectral coverage: 0.75 – 7.5 μm
 - Spectral resolving power: $R = 300$
 - 6 filter bandpasses x 4 identical rows
 - 24 H2RG detectors (4 types)
- LVFs have flight heritage:
 - New Horizons – Pluto
 - OSIRIS-REx – asteroid Bennu:
- SPHEREx (MIDEX) mission also uses wide-field imaging and LVFs



Thermal design

- Thermal design based on successful Planck v-groove passive cooling
- Telescope enclosure reaches 25 K
 - Requirement 70 K
- Focal plane array has small heaters for stability
 - Meet requirement of 35 K
- Separate radiator for SIDECARs
 - Meets 140-200 K allowed range
- Overall design has substantial thermal margin

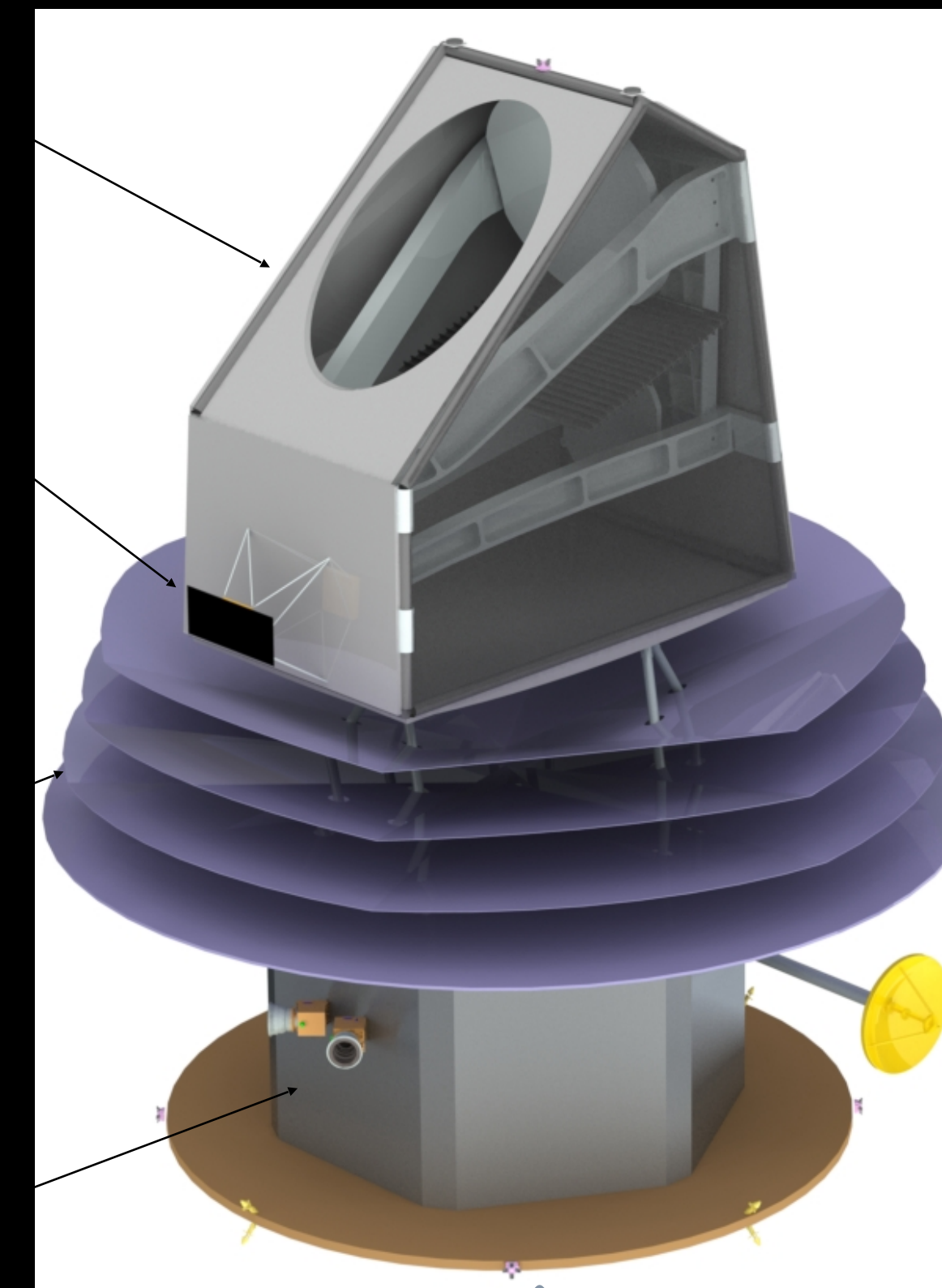


Payload Architecture

- CDIM payload supported by bipods on spacecraft bus
- Solar panels and telecommunication high-gain antenna on lower surface of the bus

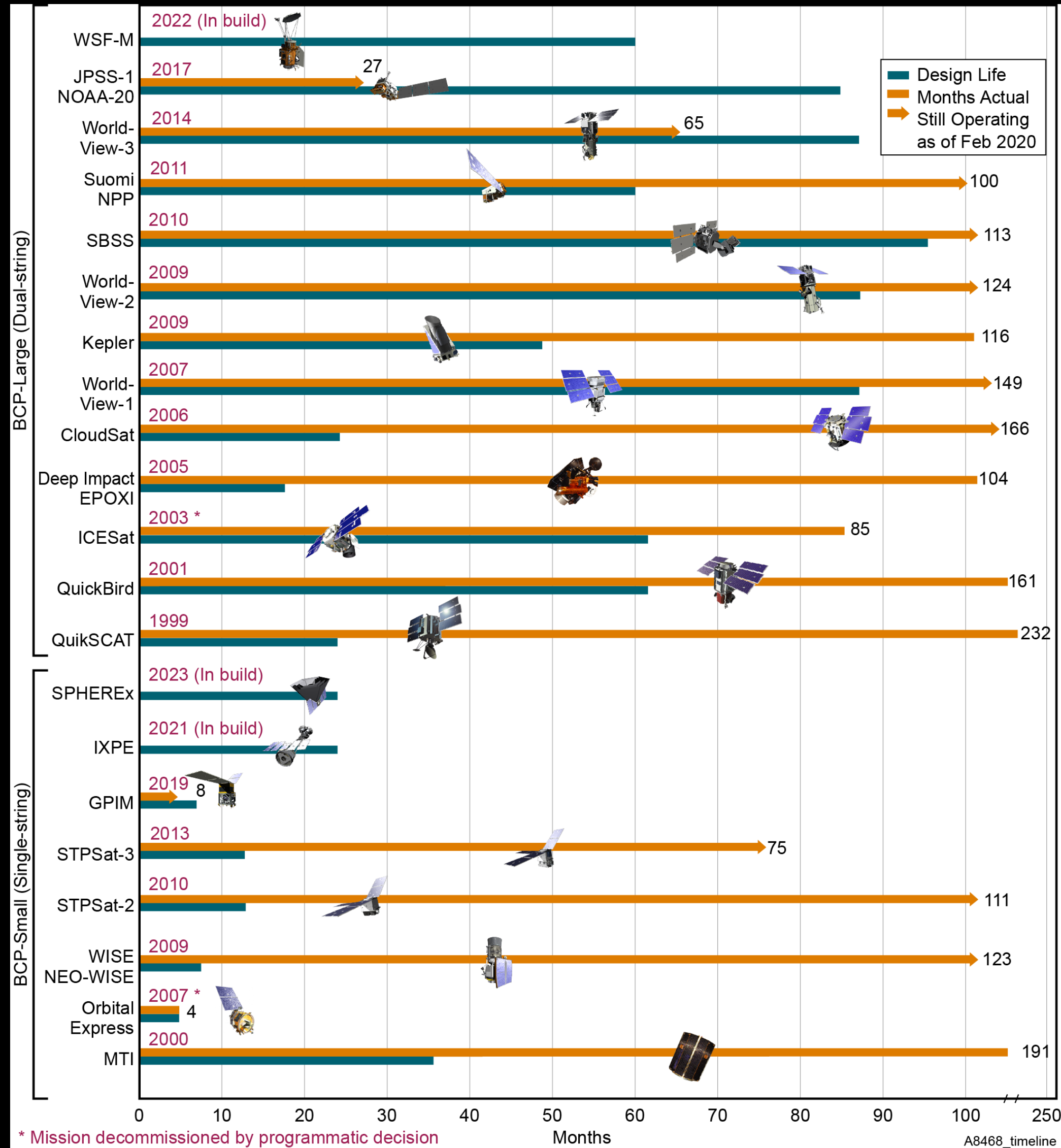
Accommodation	Requirement	Capability
Power (W)	50	125*
Data Rate (Mb/s)	5	10
Data Storage (Gb)	413	1536
Pointing Control (arcsec)	1	< 1
Pointing Stability (arcsec / 250 sec)	0.5	0.5
Thermal	Payload and S/C thermally decoupled	

Telescope boresight



Sunlight (up to 18° off-axis)

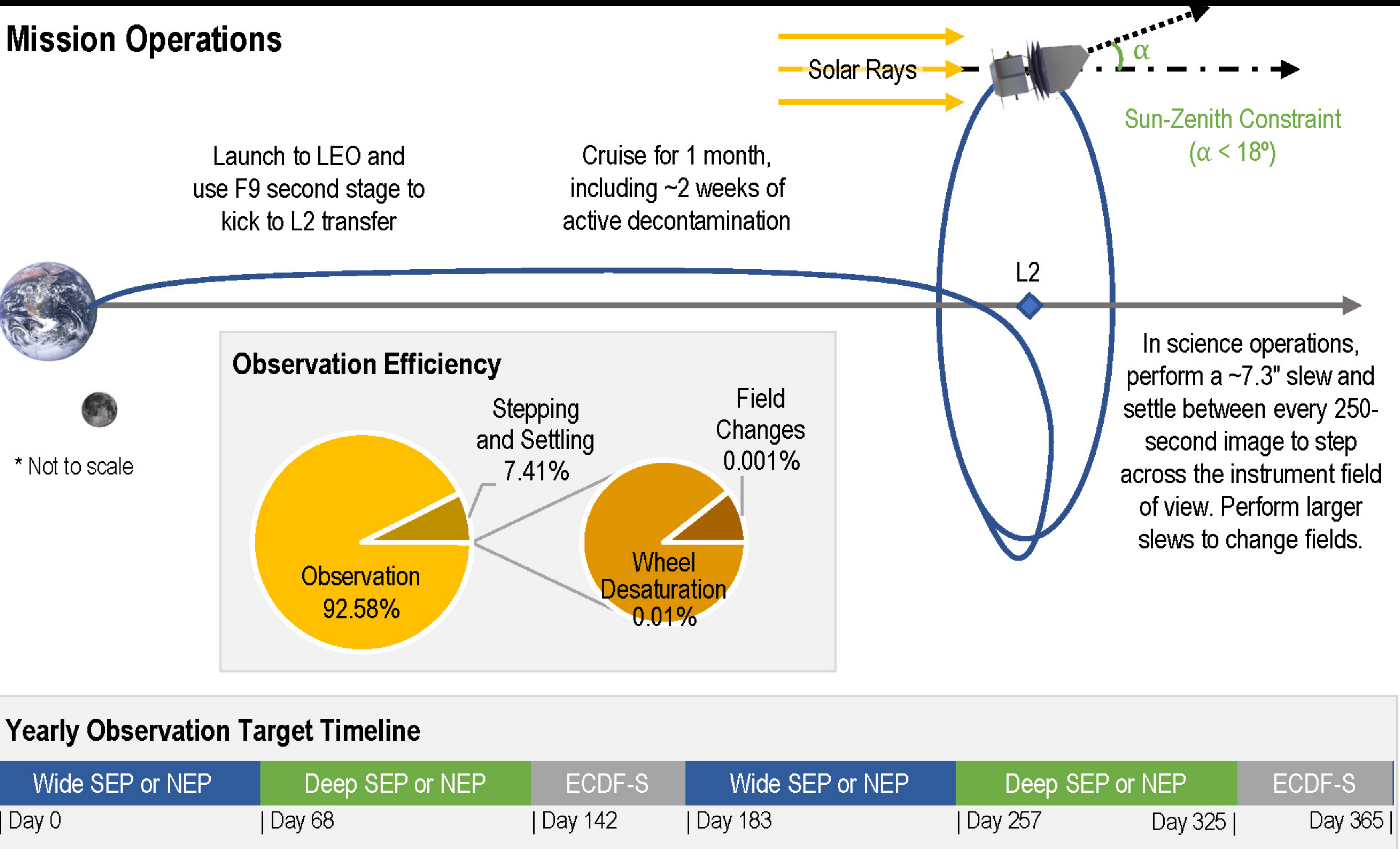
CDIM Spacecraft



- CDIM team worked closely with Ball; study team includes a Ball spacecraft engineer and a Ball systems engineer
- Ball has experience integrating passively cooled telescopes onto their Ball Commercial Platform (BCP) spacecraft line
 - Deep space heritage with Kepler and Deep Impact missions
 - Precision pointing heritage with Kepler
 - Cryo-payload interface heritage with WISE and SPHEREx (now in Phase B)
 - Autonomous rapid slew and settle heritage WorldView-1,2,3
- Ball buses meet lifetime expectations
- BCP platform has successfully supported 12 missions on orbit with over 70 years of cumulative on-orbit time

CDIM Survey Strategy

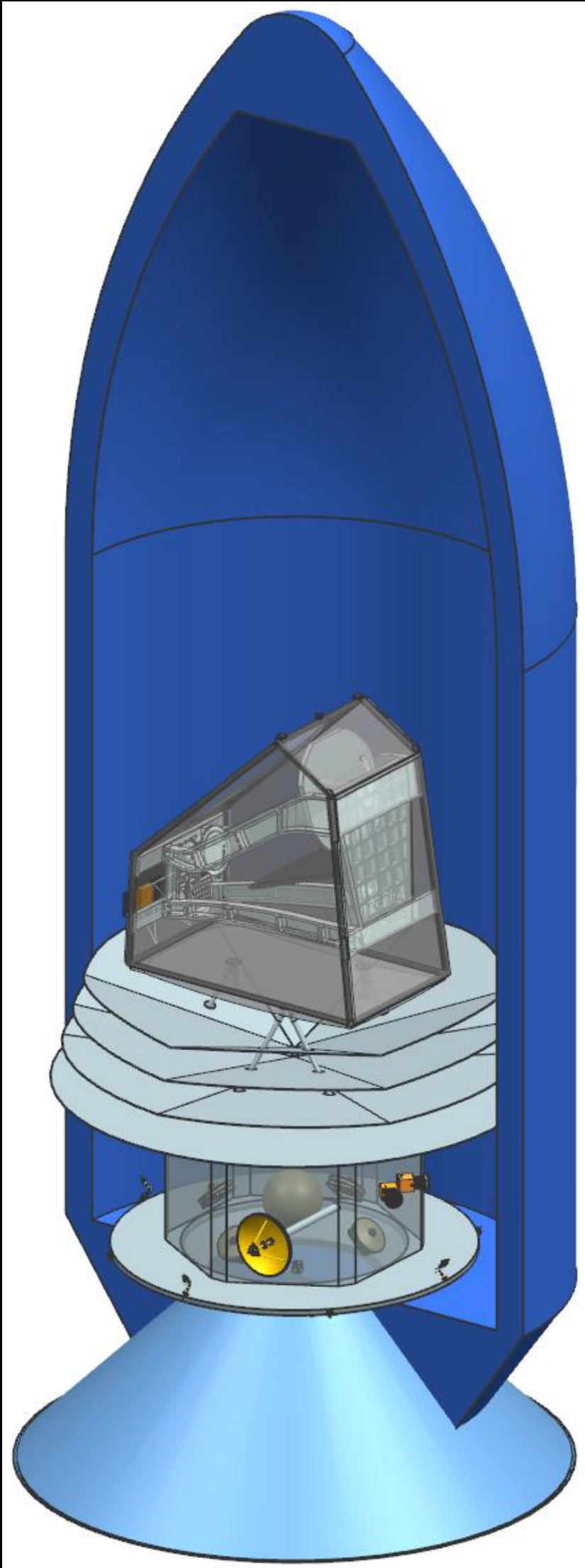
Mission Operations



Two other IR “Probe” class and higher missions > 90% efficient: Spitzer/Herschel

CDIM Flight System

- Designed to maximize observing efficiency
 - Large solid angle accessible for pointing
 - Steerable HGA
 - Agile telescope
- No telescope and spacecraft bus deployments
- Compatible with all EELV 5m fairings



Subsystem	Mass (kg)	CAP (W)
Attitude Control	66.1	156
Command & Data	16.8	38
Power	46.4	60.5
Propulsion	13.1	8
Propellant	24.5	0
Structures & Mechanisms	224.2	0
S/C-Side LV Adapter	8.6	0
Cabling	48.5	0
Telecom	27.7	60
Thermal	22.3	61
Spacecraft Bus Total	489.6	383.5
Instrument	694.0	50.0
Dry Total, CBE	1183.6	433.5
Dry Total, MEV	1429.0	
Wet Total, MEV	1453.5	621.5
Maximum Possible Value	3428.5	820.0
Margin (%)	136%	32%

Technology Development

- CDIM team identified two technology developments
 - 7.5 μ m cutoff H2RG detectors
 - Linear Variable Filters (LVFs)
- These are described in the APC White Paper and 50-page report
- Summaries next

7.5 μ m cutoff H2RG detectors

- 7.5 μ m cutoff H2RG detectors leverage 10 μ m NEOCAM/NEO-Surveyor detector development.
 - 7.5 μ m fabrication is easier (alloy is harder at the shorter wavelength; easier to remove substrate)
 - Detectors have already demonstrated the required dark current performance at <35K
 - Substrate-thinning to minimize cosmic ray degradation
 - \$8M and 3 years

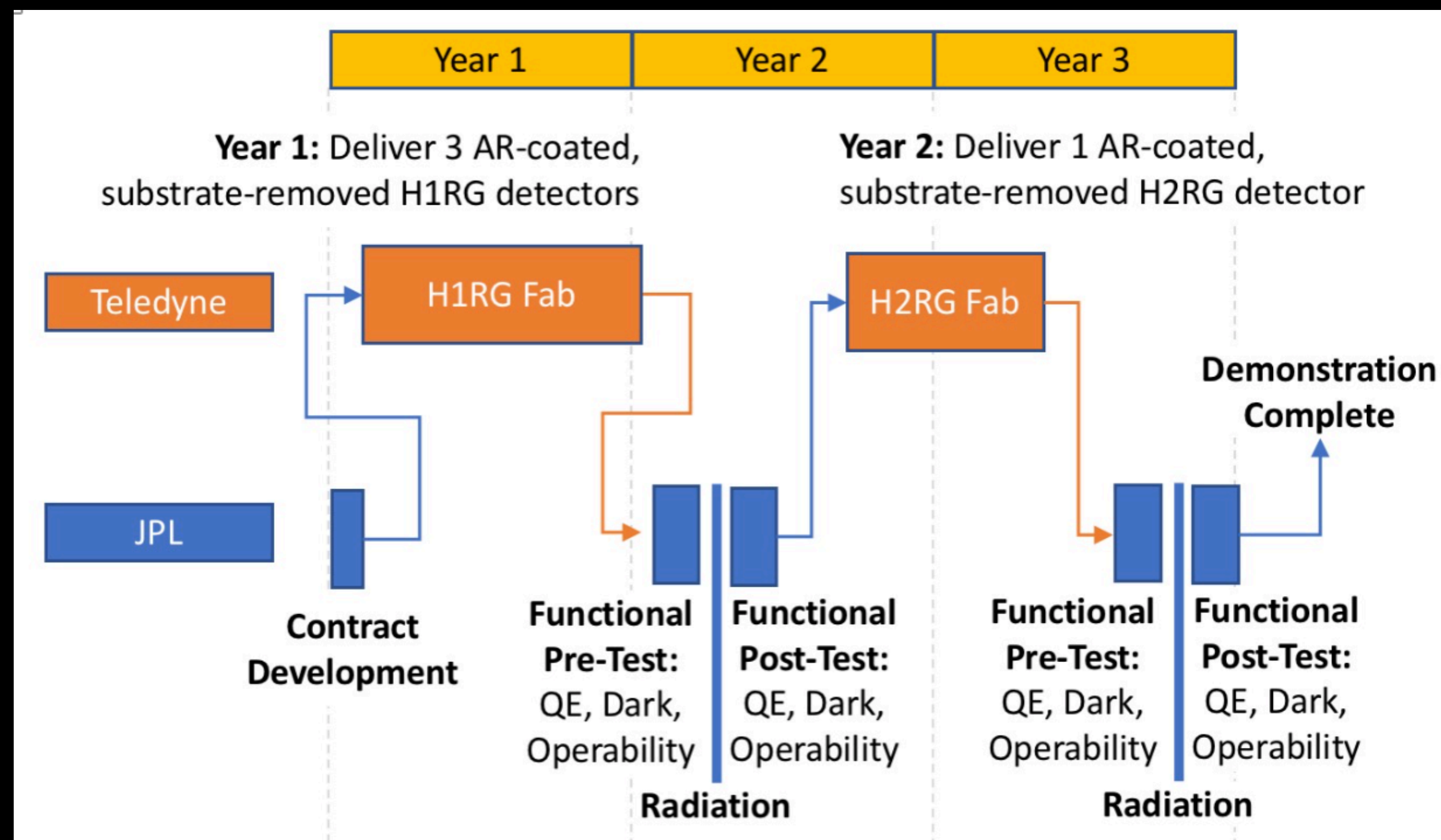


Figure 5-1. The planned technology development program for long wavelength detectors includes process development using the H1RG format and final delivery of a flight-like H2RG.

Linear Variable Filters (LVFs)

Linear Variable Filters (LVFs) have substantial flight heritage:

- New Horizons – LVFs in the near IR (up to $R \sim 200$) on
 - LEISA instrument with $R=240$ and 560 (Reuter et al. 2008).
 - LVF full-color image of Jupiter using LEISA on the cover of Science ([Baker, 2007](#))
- OSIRIS-REx at asteroid Bennu:
 - OVIRS instrument ([Reuter et al., 2018](#)) covers $0.4\text{--}4.3\mu\text{m}$ in 3 bands with $R = 125\text{--}200$
- SPHEREx in NASA Astrophysics MidEX 2023 launch ($R=40\text{--}135$; $0.75\text{--}5.0\mu\text{m}$)
- Simulations (multi-layer interference filter) of LVF performance for CDIM have achieved the required $R=300$ spectral resolving power
- Develop to meet the out-of-band rejection (OD-5) needed to minimize backgrounds
- Environmental tests to show 35K operations
- \$4M and 3 years

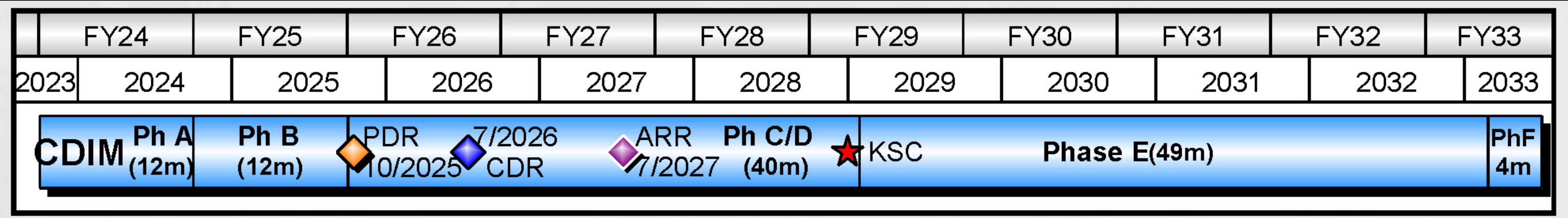
Table 5–1. LVF Technology Development budget

Task	LVF Technology development	Cost	Schedule
1	Development of $4\mu\text{m}$ to $8\mu\text{m}$ materials and improve out-of-band blocking	\$1.0M	12 months
2	LVF coating stress	\$1.0M	8 months
3	Software optimization	\$0.25M	6 months
4	Fabricate prototype and performance/environmental testing to TRL 6	\$1.5M	12 months
TOTAL		\$3.75M	38 months



Table 7-2. CDIM mission costs estimated by Team X and CDIM Team		
Work Breakdown Structure (WBS) Elements	Team X Cost Estimate (\$FY18)	CDIM Team Cost Estimate (\$FY18)
Development Cost (Phases A-D)	\$690.1M	\$666.4M
1.0, 2.0, & 3.0 Management, Systems Engineering, and Mission Assurance	\$51.5M	\$50.8M
4.0 Science	\$25.0M	\$25.0M
5.0 Payload System	\$170.5M	\$170.5M
5.01 Payload Management	\$1.8M	\$1.8M
5.02 Payload Engineering	\$1.4M	\$1.4M
5.04 Telescope (incl. II&T)	\$167.3M	\$167.3M
5.04.01 Instrument (IR Spectrometer)	\$152.0M	\$152.0M
5.04.02 Optical Telescope Assembly	\$15.2M	\$15.2M
6.0 Flight System	\$220.1M	\$189.0M
7.0 Mission Operations Preparation	\$16.3M	\$16.3M
9.0 Ground Data Systems	\$23.0M	\$23.0M
10.0 Assembly, Test, and Launch Operations (ATLO)	\$24.6M	\$34.0M
12.0 Mission and Navigation Design	\$0.0M	\$4.2M
Development Reserves (30%)	\$159.2M	\$153.7M
Operations Cost (Phase E)	\$89.0M	\$89.0M
1.0 Management	\$4.5M	\$4.5M
4.0 Science	\$40.0M	\$40.0M
7.0 Mission Operations	\$23.6M	\$23.6M
9.0 Ground Data Systems	\$9.7M	\$9.7M
Operations Reserves (15%)	\$11.1M	\$11.1M
Launch Vehicle	\$150.0M	\$150.0M
Total Cost (including Launch Vehicle)	\$929.0M	\$905.4M
Note: See §7.1 for explanation of cost differences		

Schedule



CDIM Study/Design Trades to meet “Probe” Cost

- De-scopes (cost-driven trades):
 - Studied telescope sizes from 1.5m to 1.0m largest optic → 1.1m physical aperture (0.83m effective aperture)
 - 6x6 H2RGs → 6x4 H2RGs
 - Other ways to do spectroscopy including deformable micro mirrors (DMMs; cost for 1.5m telescope + 36 H2RGs + DMMs for IFU = ~\$2B estimate).
 - \$1B cost limit leads to an approach like LVFs
- Science impact from 1.5m → 1.1m physical/0.83m effective + 24 H2RGs:
 - 10% reduction in estimated number of detected galaxies, and 10% reduction in quasars
 - Impacts point source (galaxy/AGN science) at $z > 8$, but preserves intensity mapping out to $z > 10$
 - Science reduction mitigated by
 - 3 year → 4 year survey plan
 - Smaller deep field, and wider shallow field (wider-shallow is better for rare sources like bright AGNs)
- How cost trades were done during the study:
 - Initial Team X ‘rule of thumb’ used to scope initial telescope size
 - Only the final adopted design (presented here) was fully costed by Team-X at JPL

H2RG vs H4RG detectors

- H4RG was studied in the Team X Instrument Follow-Up session
- Smaller pixels implies re-design of telescope and re-optimization of aperture size, field of view etc.
- Conclusions:
 - After a trade study, concluded H4RG offers no obvious benefit
 - H2RG detector array is well-matched to the science objectives, PSF and required pixel-scale for source detection and intensity mapping measurements
 - H4RGs carries an extra cost and a risk; not necessary for a Probe mission.



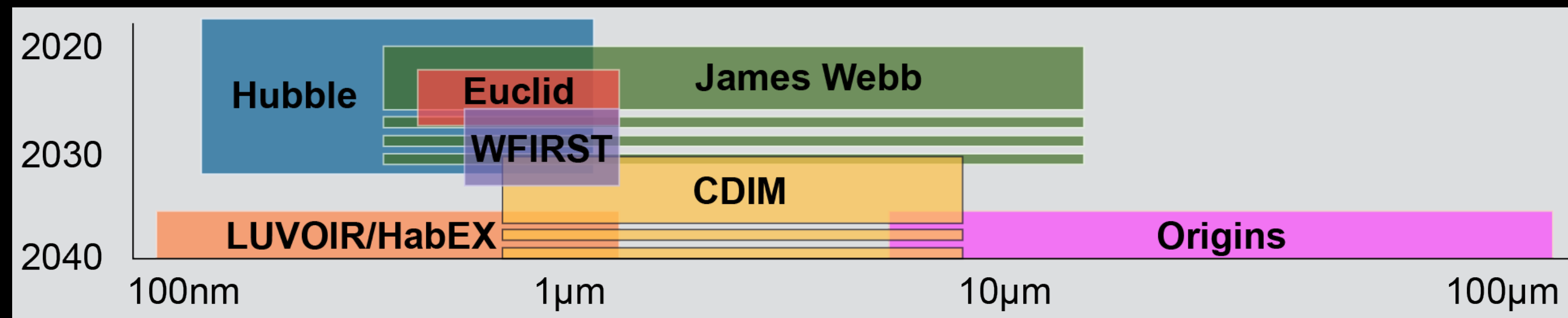
CDIM Concept Summary Slide

Team Grassroot	Team-X or Program Office	RAO or CE&P	PCAT Parametric
905	929	943	962

- Comments on Team Costing : Team estimate of \$905M is \$5M below WBS 1-3 of previous mission averages. Spacecraft appears low by \$25-35M (we agree with Team-X). These cost increases are consistent with both Team-X and CE&P estimates.
- Comments on Schedule: The CDIM schedule appears low risk.
- Concept Maturity: Advanced for this stage.
- Science Implementation: CDIM performs a 4 year all-sky survey from L2 and is an instrument for multi-object spectroscopy from 0.75 to 7.5 μm . It comprises a wide field, cryogenic telescope that forms an image of the sky on a 2-dimensional array of infrared detectors, each with an associated linear variable filter (LVF,). A mosaic of 24 Teledyne H2RG detectors. Science should be achievable.
- Mission: The 1.1-m beryllium telescope is readily available as are the detectors and Liner Variable Filters with some modifications. System is passively cooled to 35k with margin at L2. Spacecraft is based on slightly modified existing Ball spacecraft. Has a single deployment, the aperture cover. No moving parts in the payload. Dry mass is 1184kg
- Enabling Technologies: The technology development required is modest and currently at TRL 4. Five of six bands of the detectors are TRL 9. Current HgCdTe detectors with 5.5 μm cutoff are off the shelf. Requires extension for band 6 to 7.7 μm . The linear variable filters likewise require extension from >4 μm to 7.5 μm cutoff. Omega Optical, the filter supplier has already retired much of the design risk during the probe study.
- Challenges: No significant ones identified. The design concept is based on considerable amount of commercially available technology.

The PCAT assessment is that this mission can LIKELY be accomplished within a \$1B cost cap.

Summary

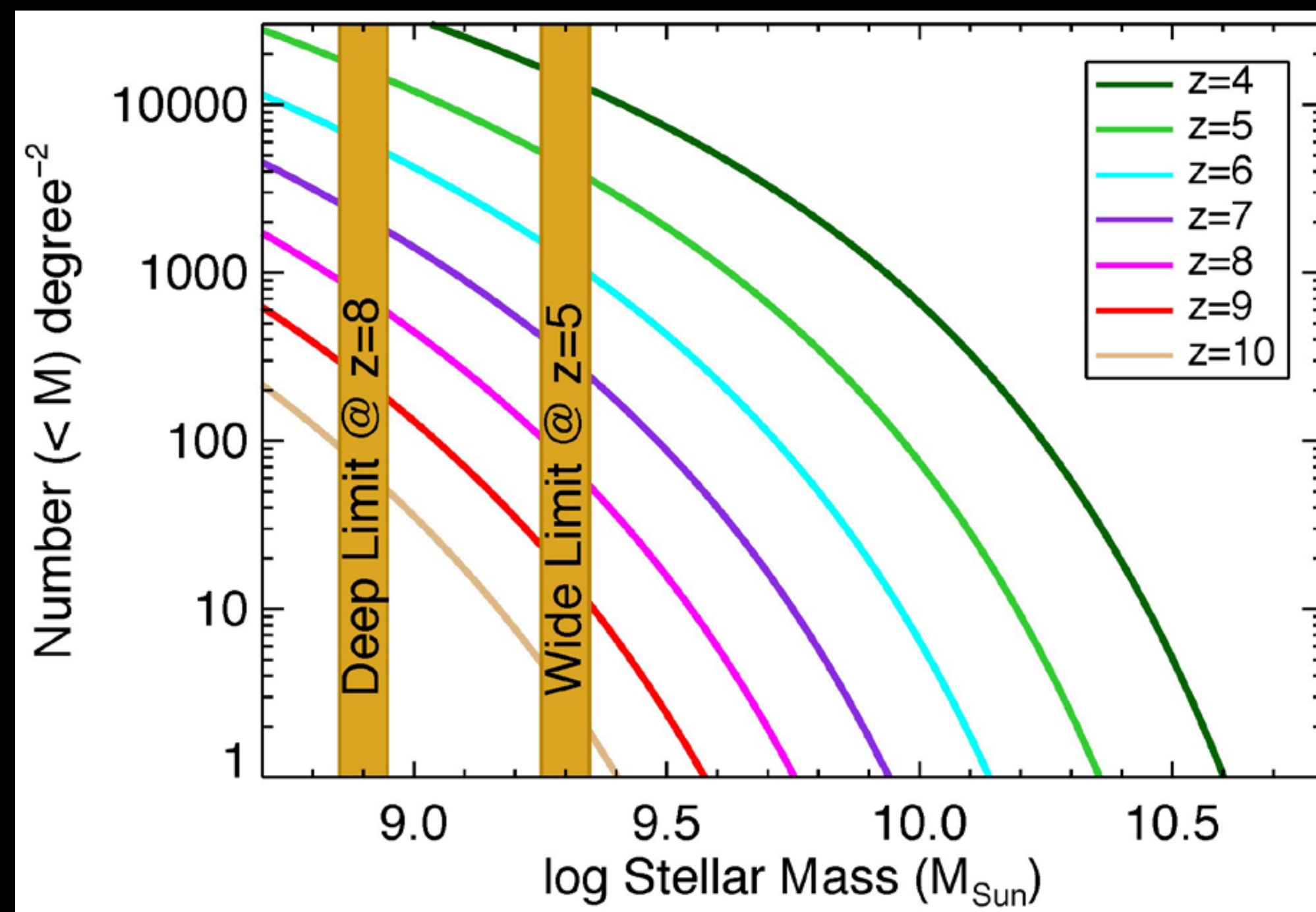
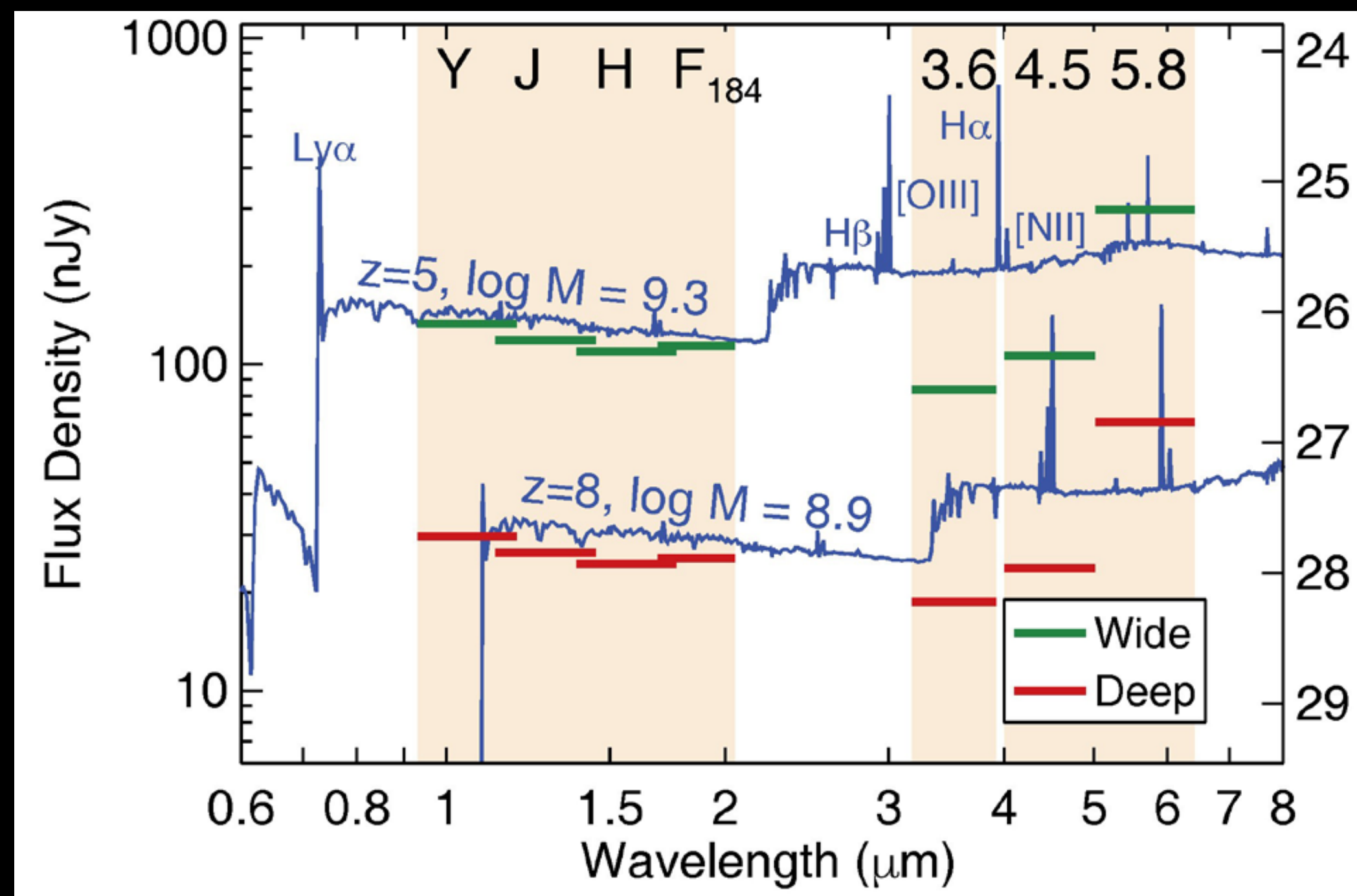


- **CDIM probe design developed:**
 - 0.75 μm – 7.5 μm wide-field spectro-imaging at $R=300$
 - 0.83 m effective aperture, 2" PSF, 1" pixel, 9 sq. degree focal plane
 - Efficient three-tiered survey design
- **Designed to probe Cosmic Dawn and Reionization in novel and powerful ways:**
 - First Galaxies: tracing $\text{H}\alpha$ to $z=10$, studying stellar mass and metal build up
 - First Blackholes: finding AGNs at $z=8$, constraining blackhole mass growth
 - Reionization Tomography: $\text{Ly}\alpha$, $\text{H}\alpha$ Intensity Mapping to measure bubble growth and reionization history
- **Simple, robust design, Low risk, High readiness level, with Science margin**
 - Fully costed to be <\$1B with Class-B margin
 - Could be extended for GO program; cost is for 4-years of science operations for CDIM science case

Downlink Rates / Data Volume / Analogies

- CDIM can store > 3.5 days of science data before requiring downlink
 - ~400 Gbit/day science data generation
 - ~1500 Gbit onboard storage (192 Gbyte)
- Ball designed a 150 Mbit/s Ka-band telecom system for science data
 - 0.65m gimbaled high-gain antenna
 - 60 W amplifier
 - 10.5 dB link margin
- All daily science data can be downlinked to 34m DSN antennae in < 1 hour
 - Current design can support either daily 1-hour downlinks (or 2-hour downlinks every other day)
 - Total of < 6 hours DSN contact required per week for science data, split between 7 or 3-4 passes
 - Both designs fit within existing New Frontiers spacecraft DSN utilization
 - Mission 1 : 3-4 DSN passes per week, 4 hours per pass
 - Mission 2: 1 DSN pass per week, 8 hours per pass

CDIM Detects Faint Galaxies



- Measure redshifts for most WFIRST-HLS detected galaxies at $z=5-8$