

CHROMOS Implementation

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Presenting for the CHROMOS Science Team

NASA Ad ASTRA Community Science Workshop
September 2, 2026

Credit: ESA/Euclid/Euclid Consortium/NASA

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CHROMOS aims to complete four surveys addressing key Astro2020 topics

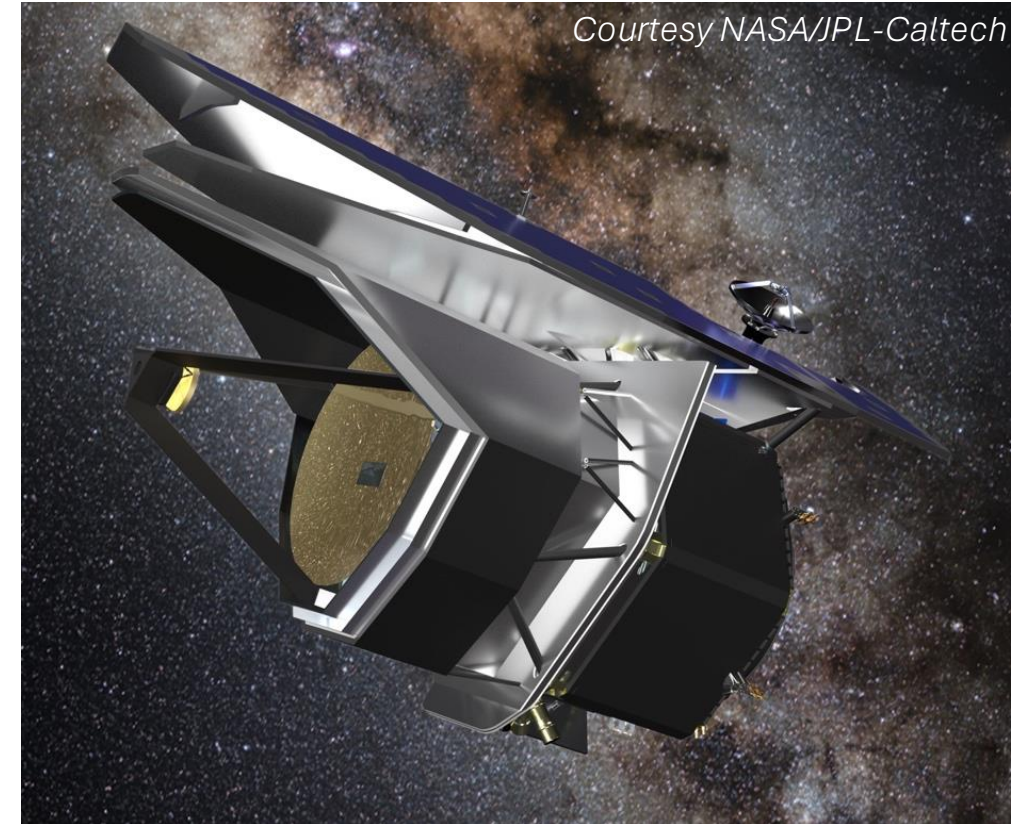
Survey Theme	Survey Presenter	Survey Region	Survey duration	Number of targets
Cosmology	Yun Wang (Talk)	Roman Medium & Euclid Wide (1/3 of sky)	3 years*	> 1 billion galaxies
Galaxy Evolution	Andreas Faisst (Talk)	Roman Medium & Euclid Wide (1/3 of sky)	3 years*	> 1 billion galaxies
Galactic Science	Lynne Hillenbrand (Poster)	Roman Galactic Plane Survey (GPS) – 700 deg ²	6 months	> 1 billion stars
Exoplanets	Tom Greene (Talk)	Selected stars across the sky	18 months	> 500 transiting ice and gas giant planets

**The Cosmology and Galaxy Evolution surveys occur in parallel with the same data set*

All four surveys require a massively multiplexed multi-object spectrograph in space

Cosmic Higher-Resolution Origins Multi-Object Spectroscopy (CHROMOS) Mission Concept

Parameter	Value
Telescope aperture	2 m primary diameter
Field of view	0.7 deg ²
Wavelength range	1.25–5 μ m
Instruments	4 identical two-channel spectrographs - blue channel: 1.25–2.5 μm - red channel: 2.5–5 μm 1 imager for guiding, slitmask alignment, and calibration
Resolving power	$R = 1000$ (cleanly separate H α & [N II])
Spectral multiplex	$\leq 24,000$ simultaneous targets
Orbit	Earth-Sun L2 halo
Mission lifetime	5 years on orbit
Projected cost	~\$1.2B (scaling 1.5 m ATLAS Probe to 2 m)



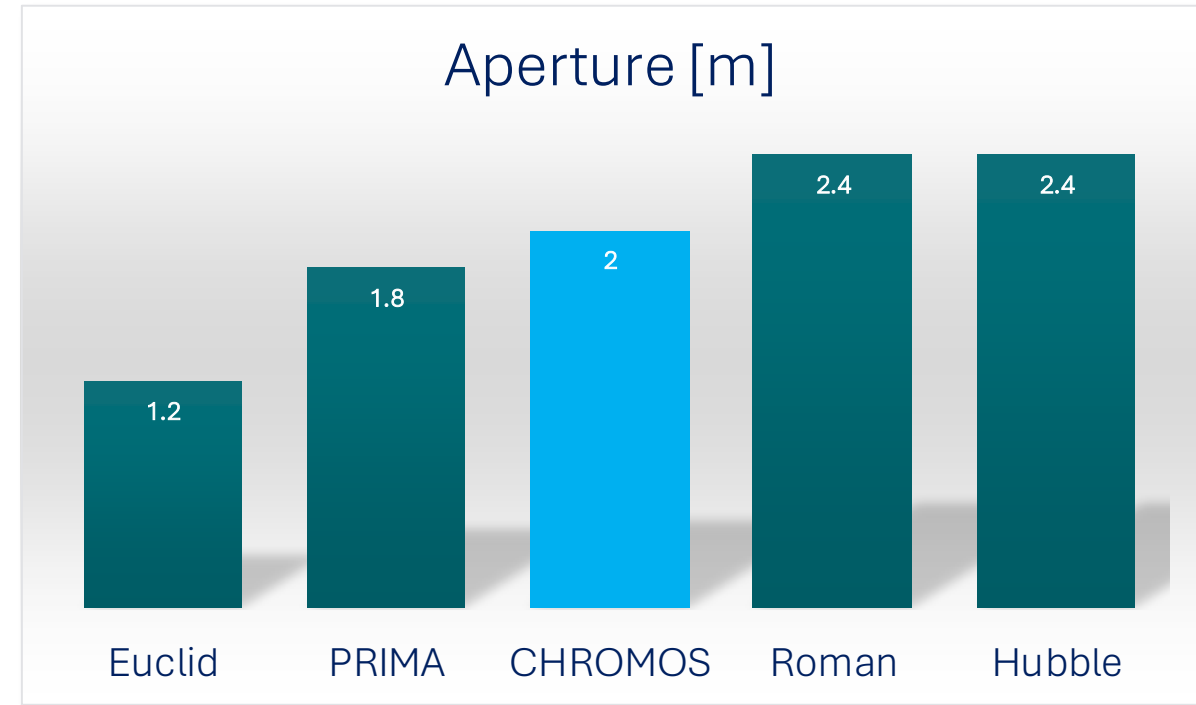
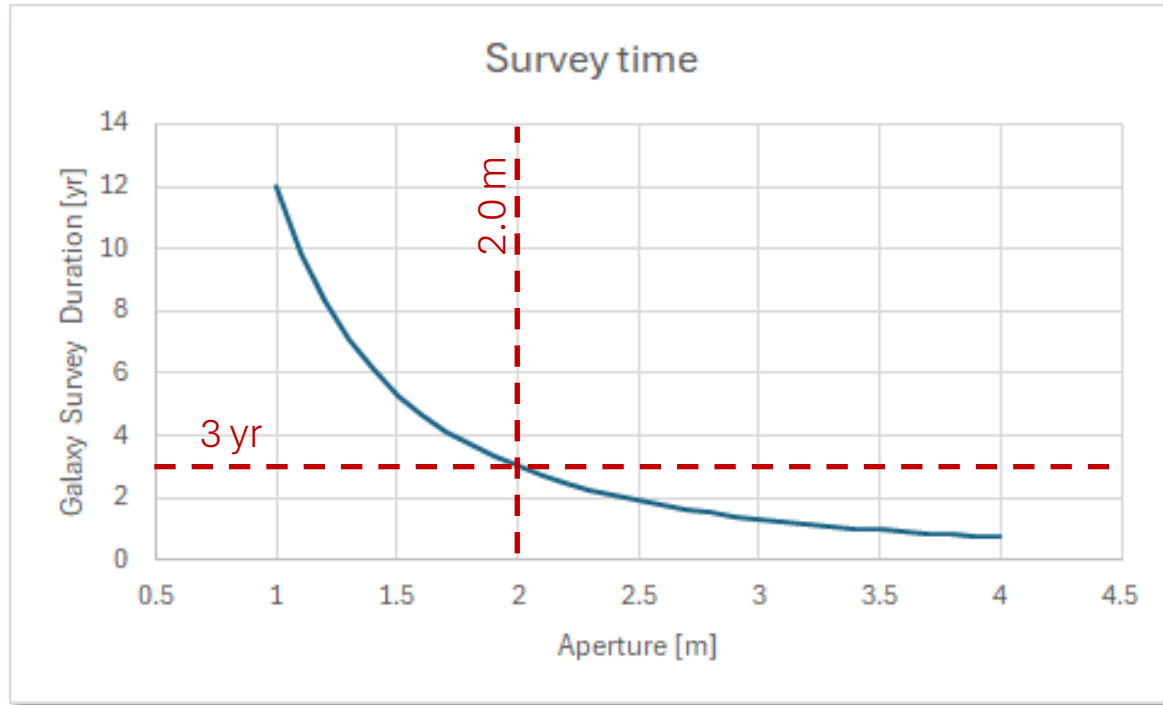
PRIMA observatory is the best CHROMOS analog

CHROMOS Instrument Key Capabilities

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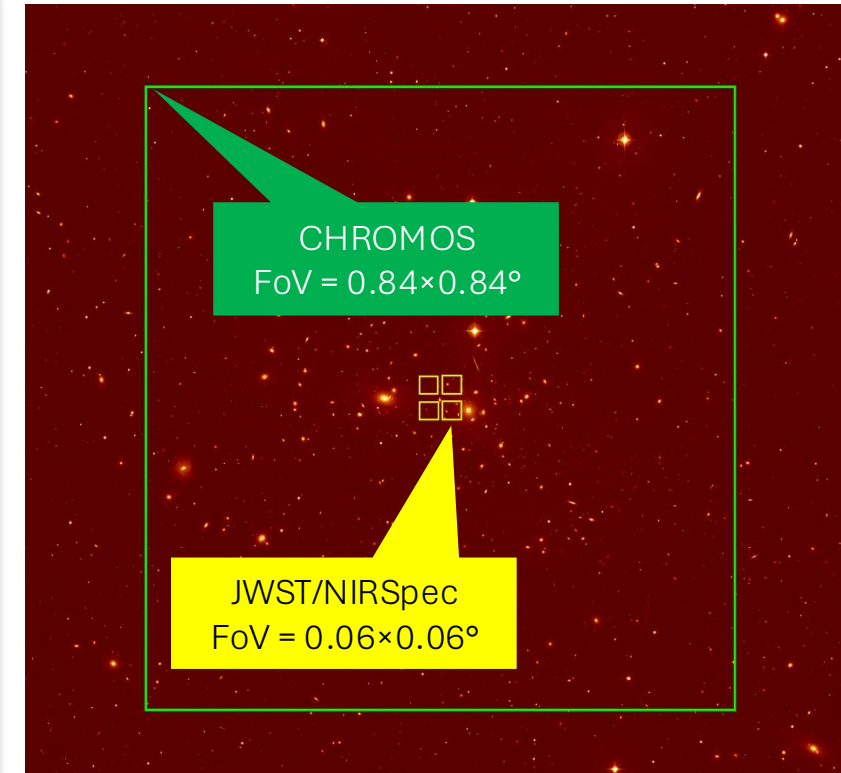
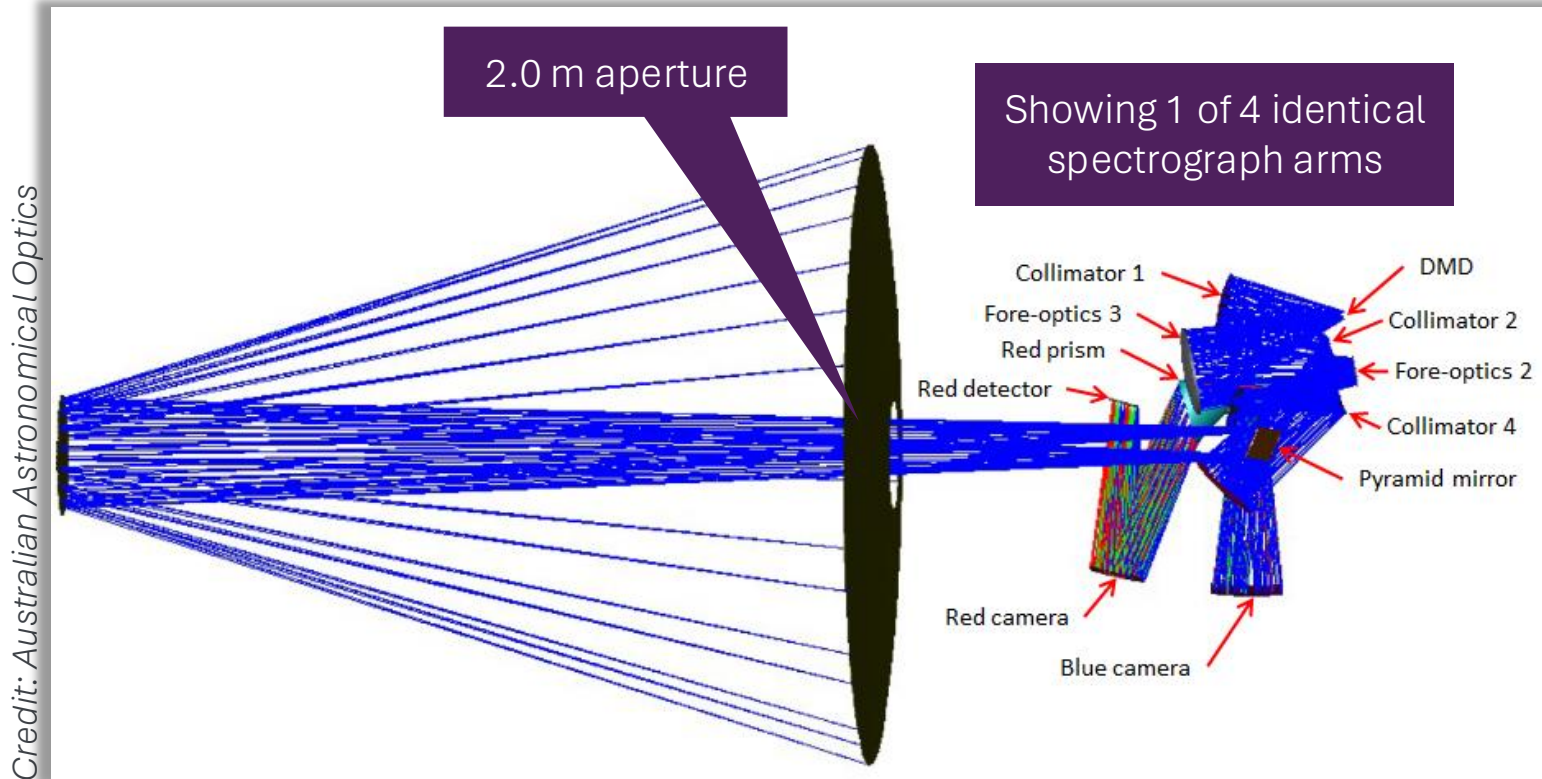
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CHROMOS uses a sizable telescope to collect enough light for measuring redshifts of distant galaxies



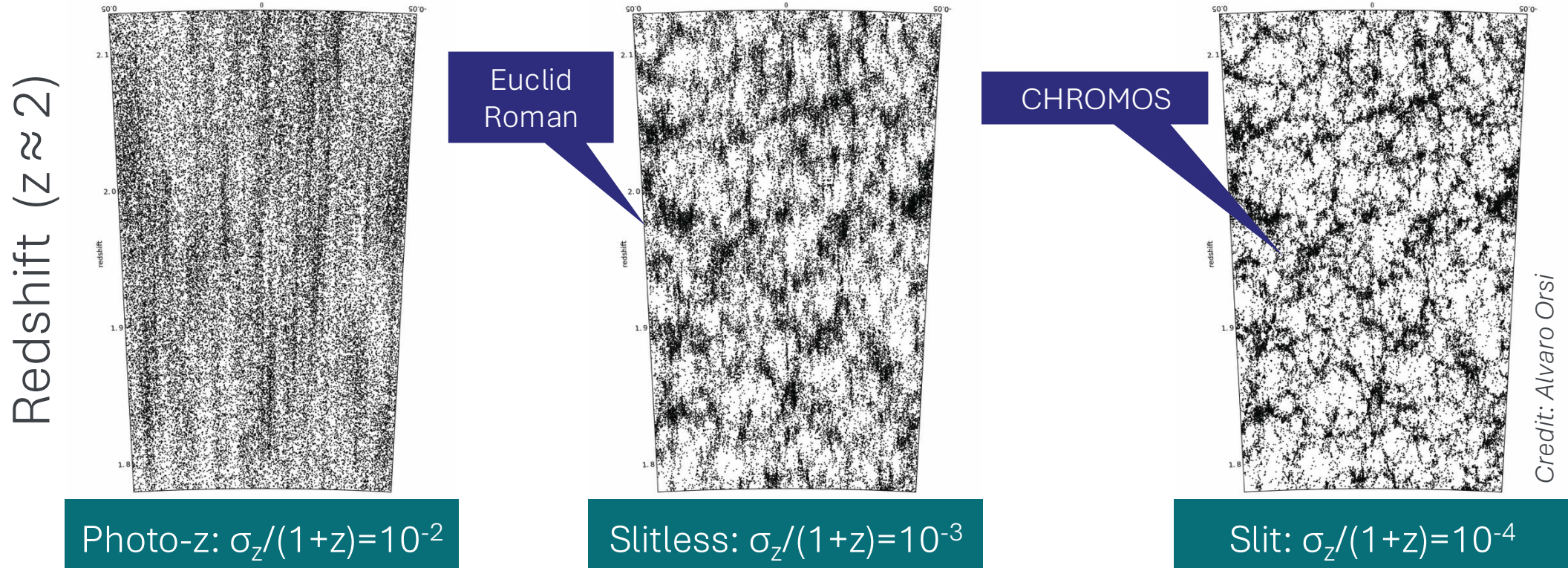
The CHROMOS telescope size is well within current manufacturing and launch capabilities

CHROMOS needs an expansive field of view to survey wide regions of sky



CHROMOS preliminary optical design provides the desired 0.7 deg^2 field of view ($270 \times$ JWST/NIRSpec)

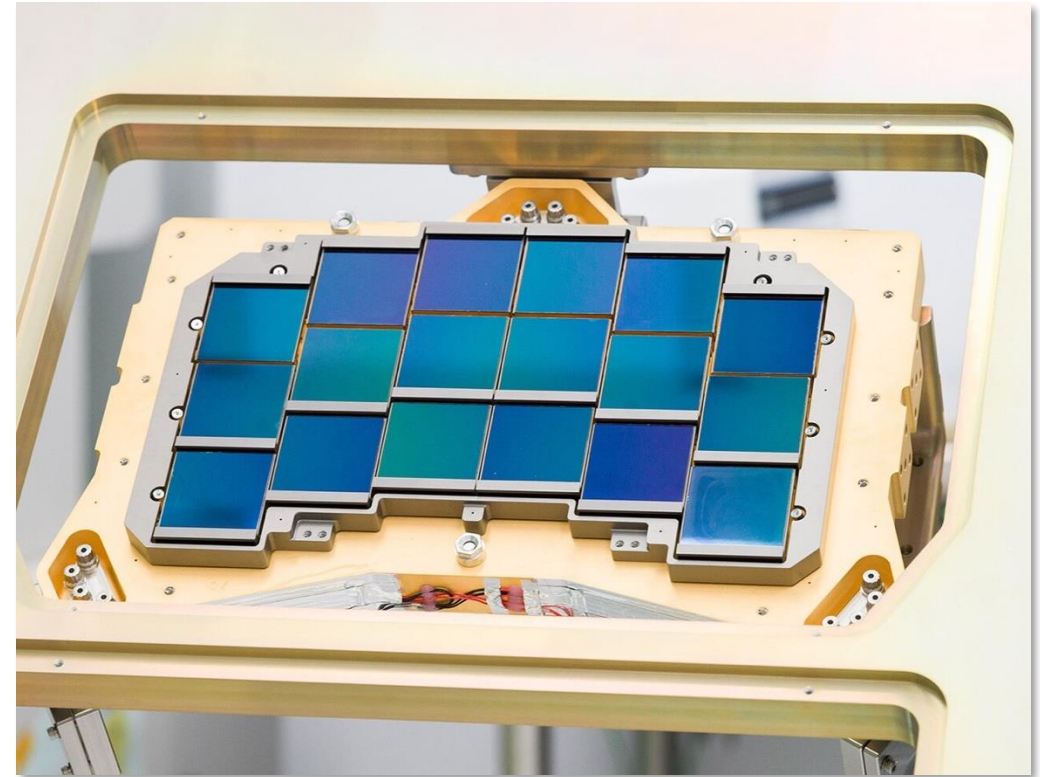
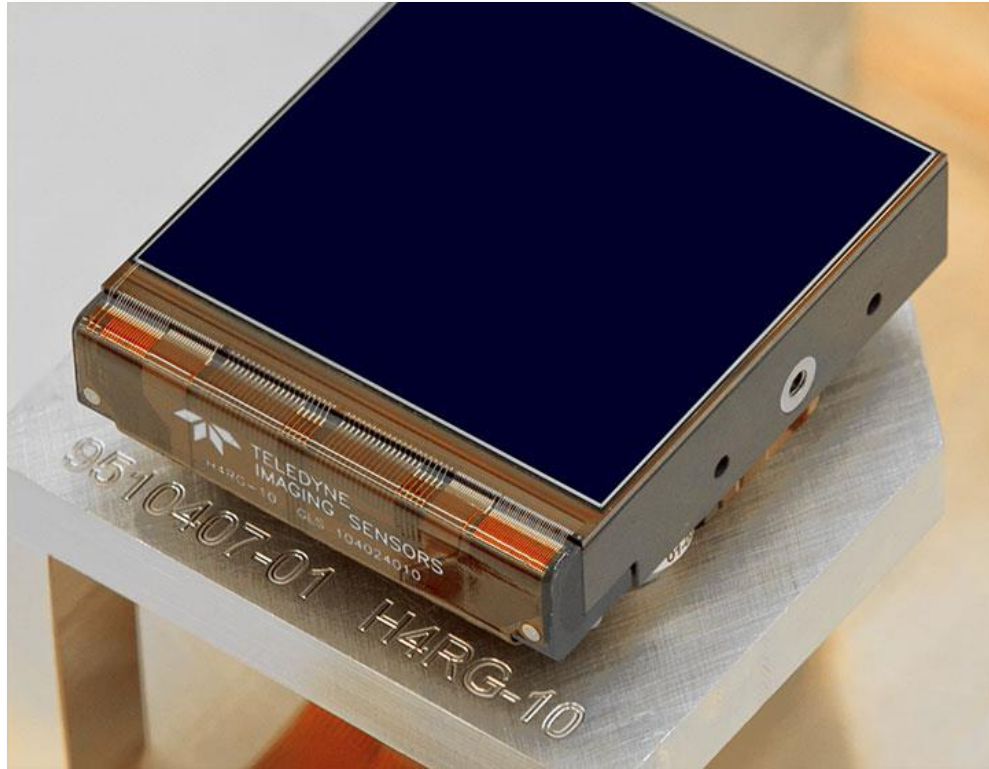
CHROMOS needs true slit spectra with reasonable resolving power ($R \sim 1000$)



CHROMOS true slit spectra **vastly reduce background contamination** and source confusion while resolving large-scale structures in the galaxy distribution

CHROMOS needs exceptionally low-noise focal planes to observe faint galaxies and targets

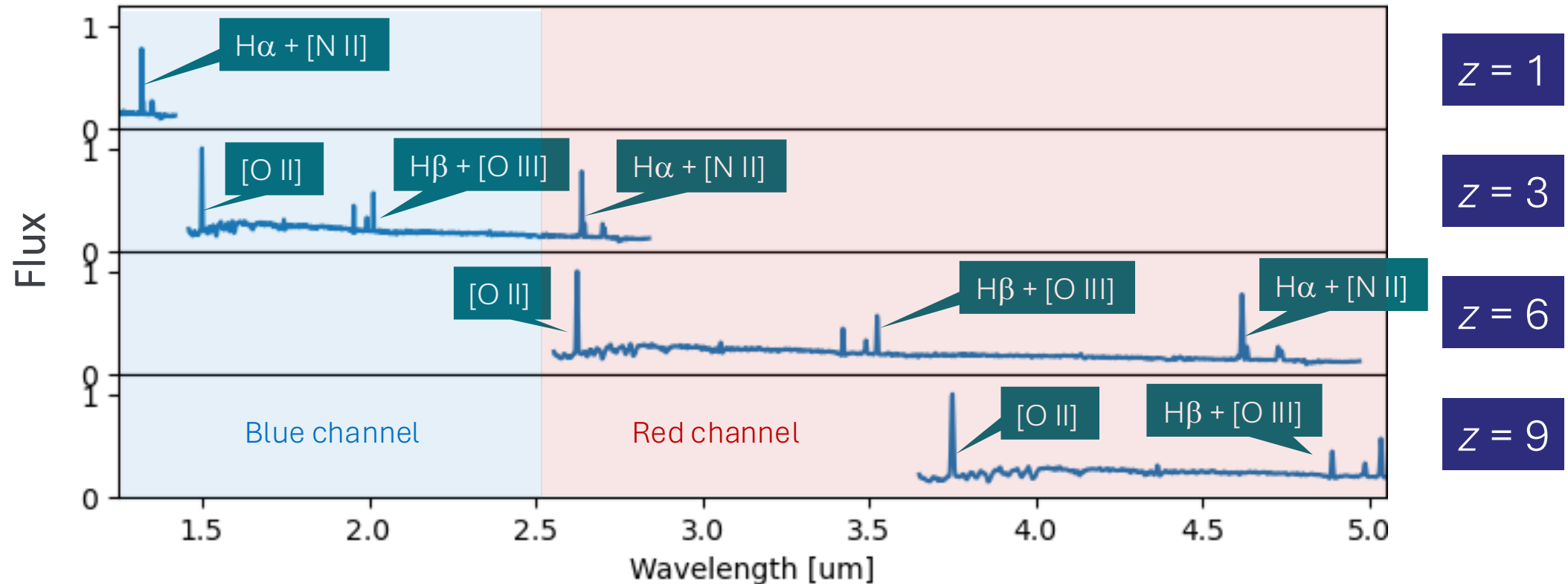
Credit: Teledyne Technologies Incorporated



Credit: NASA/GSFC

Teledyne HAWAII-4RG™ HgCdTe detectors provide low-read-noise capability for CHROMOS

CHROMOS observes the full 1.25–5 μm near infrared wavelength range to capture key emission lines for galaxies in the redshift range $1 < z < 9$



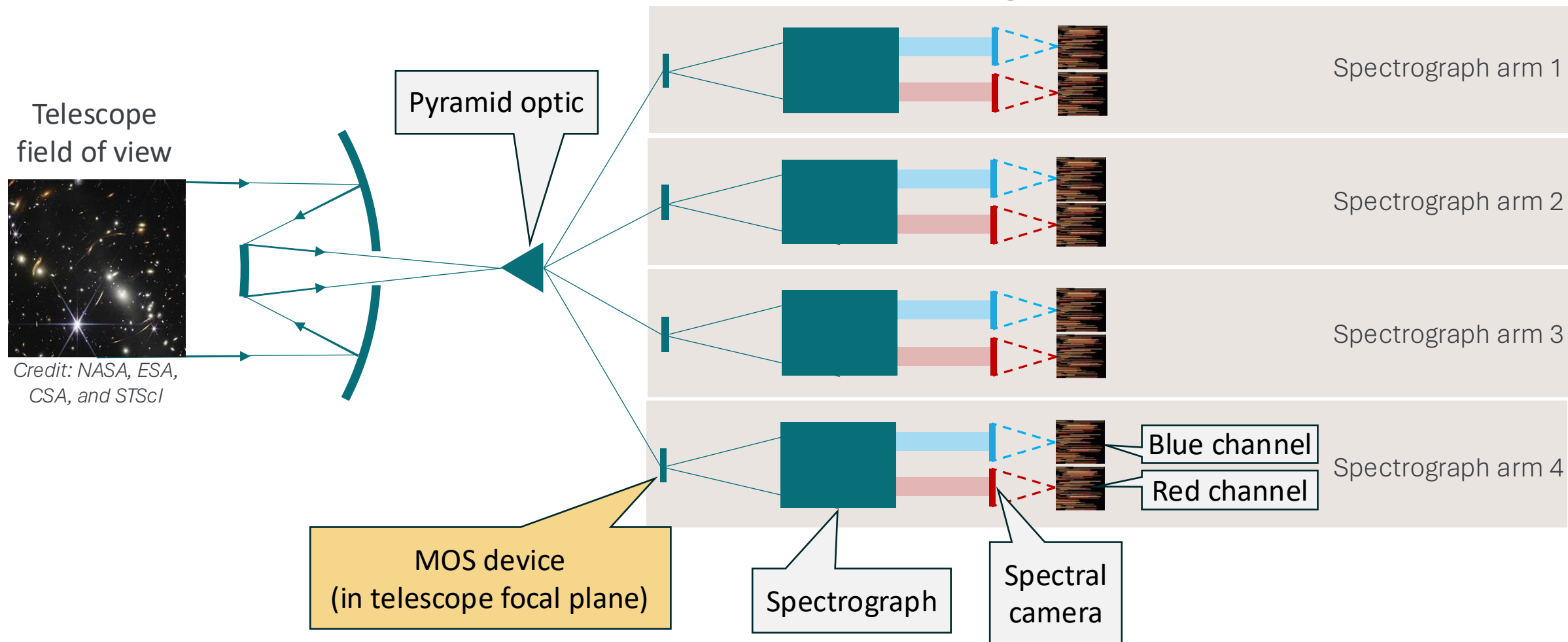
CHROMOS employs separate blue and red channels in each spectrograph arm to capture the full wavelength range

CHROMOS Critical Enabling Technology: MOS device

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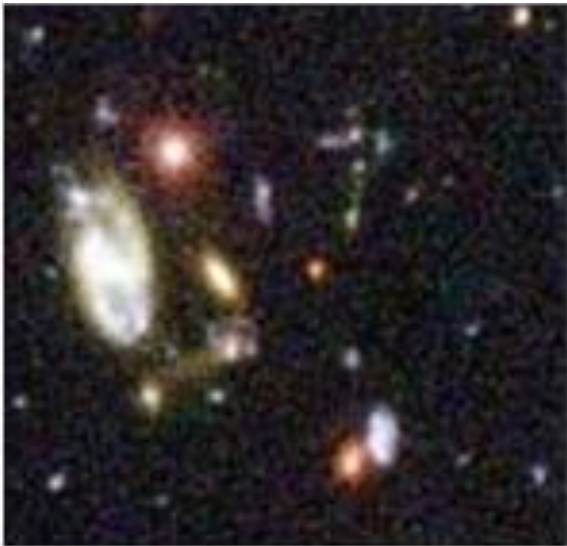
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SIRMOS features 4 MOS devices (one per spectrograph arm)



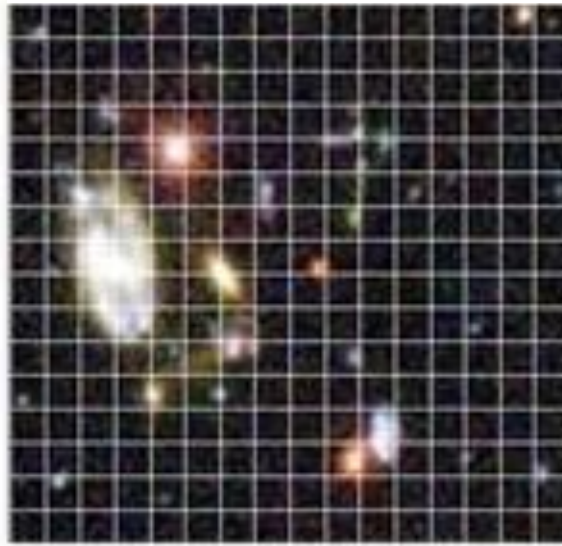
MOS devices enable simultaneous spectroscopy of multiple targets

Scene on the sky

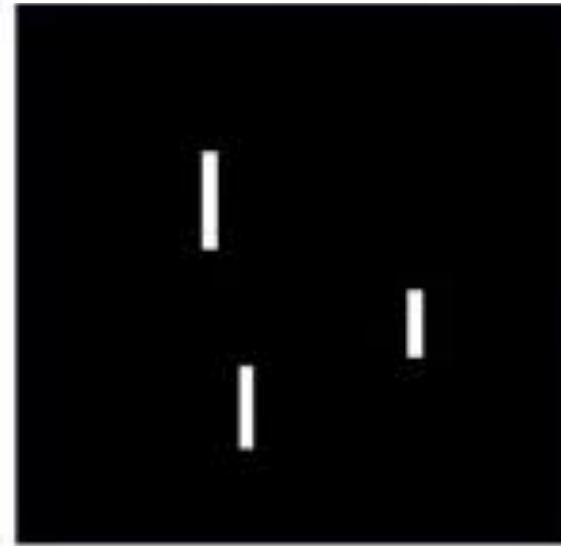


Credit: NASA/GSFC

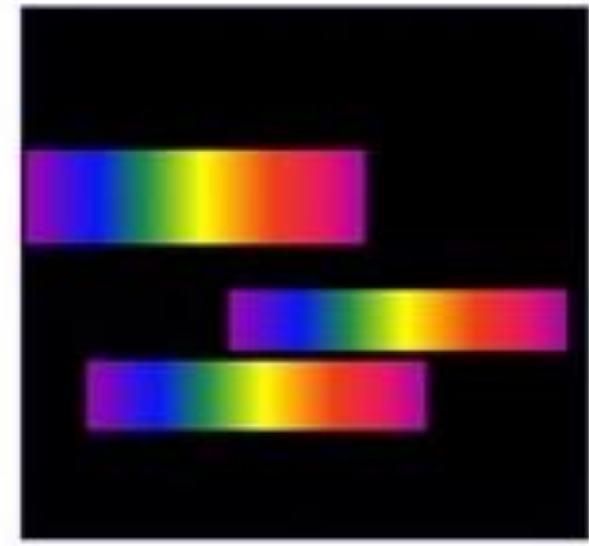
Scene on the shutter mask



Selection of targets



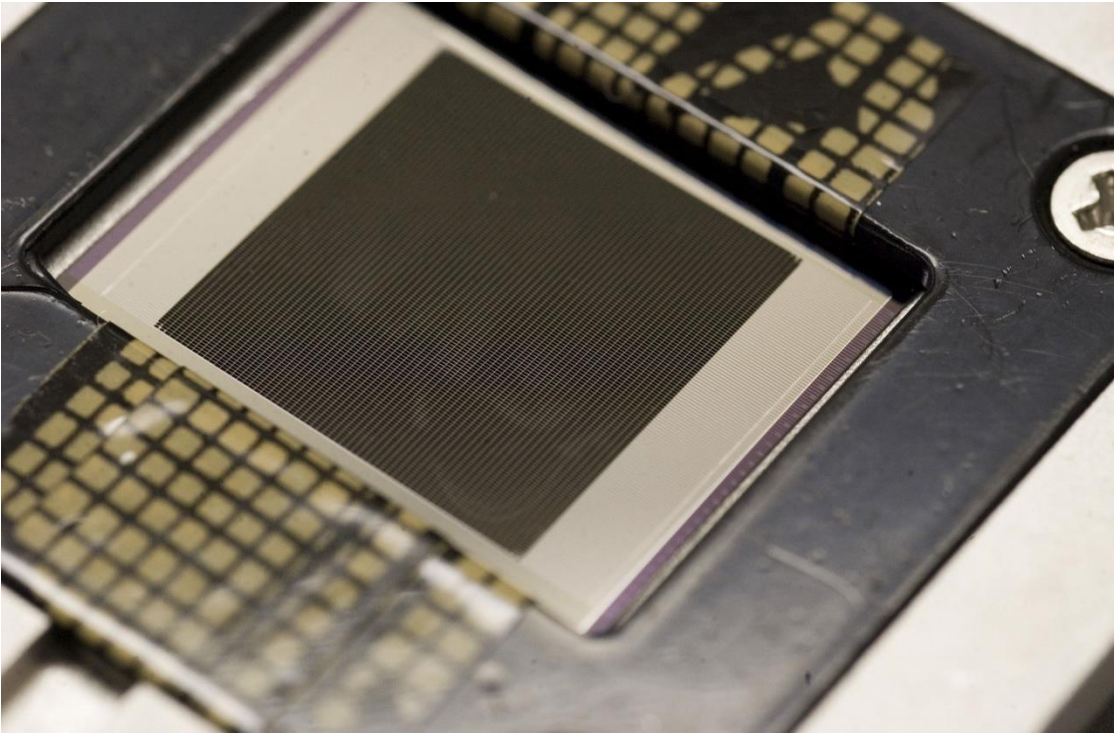
Spectra on the detector



CHROMOS collects $\leq 24,000$ spectra at once using four identical spectrometer channels operating in parallel

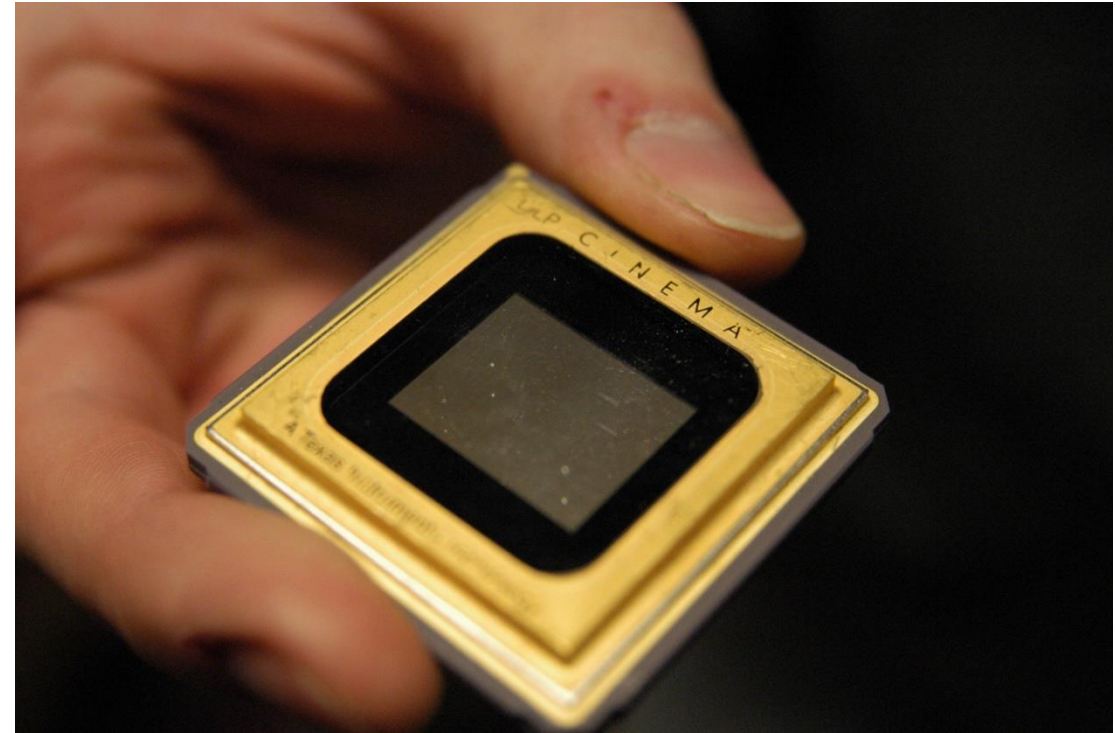
Highly-Multiplexed Slit Spectroscopy - Options

Micro-Shutter Array (MSA)



Credit: NASA

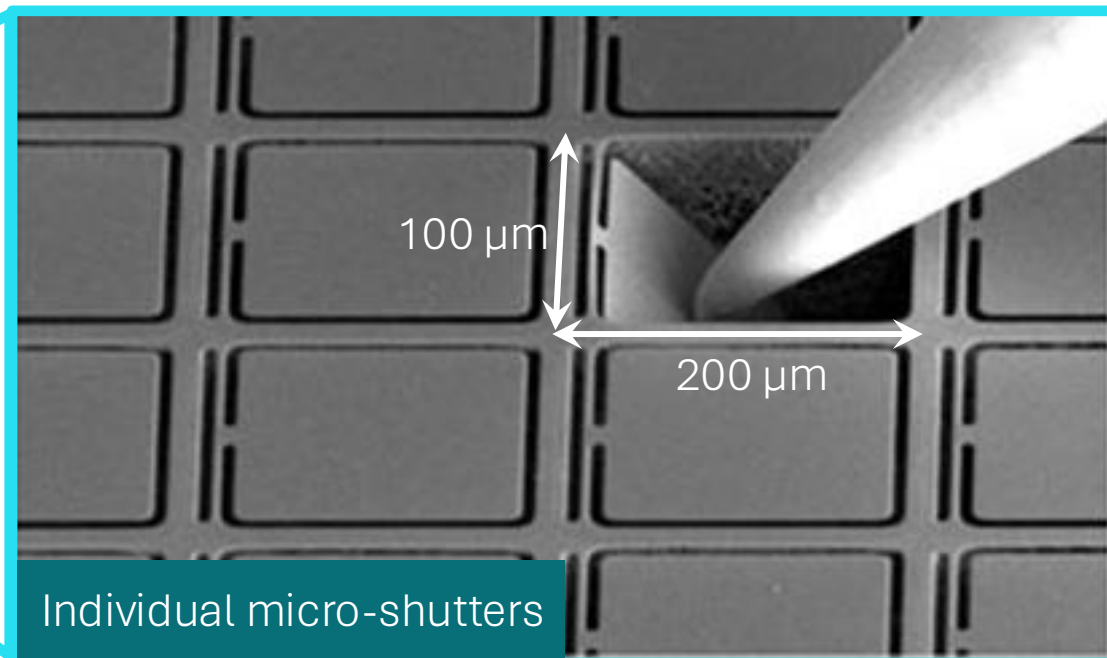
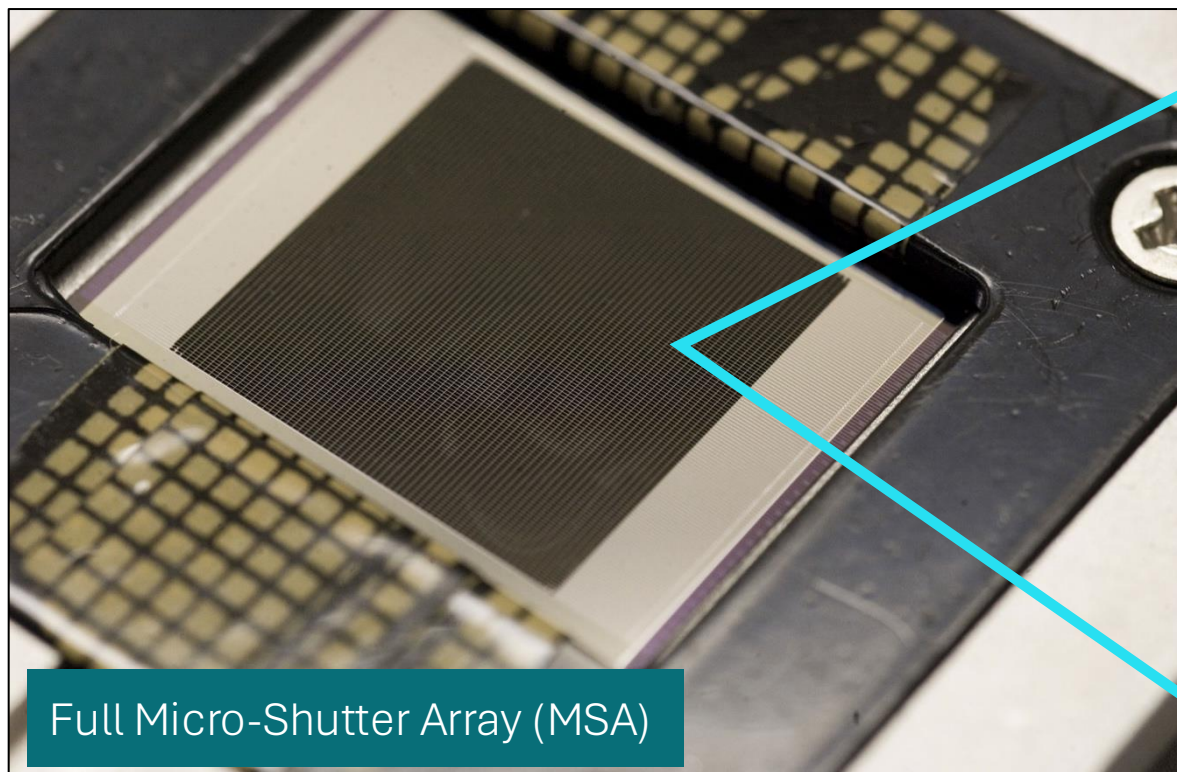
Digital Micromirror Device (DMD)



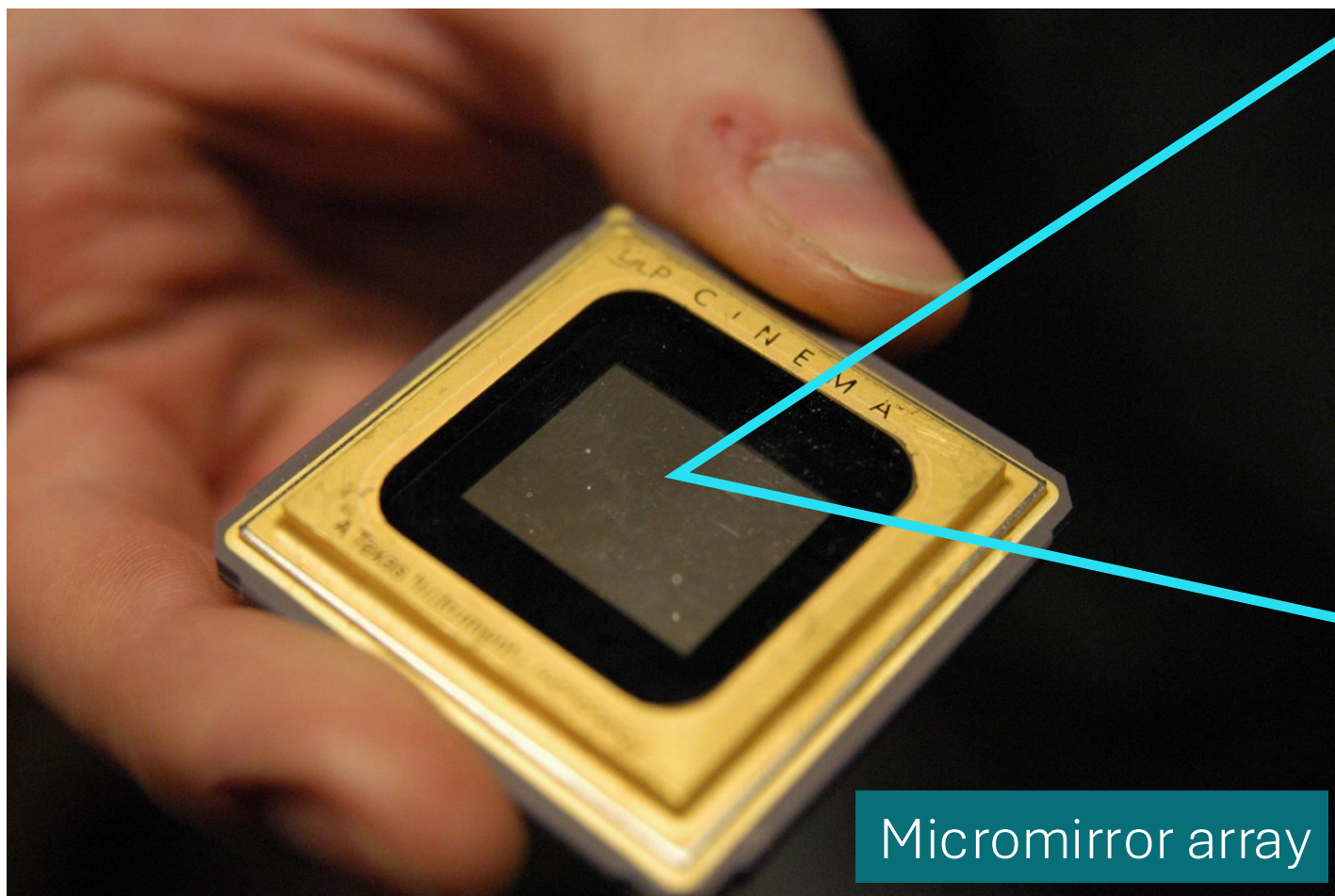
Credit: Andrew Hitchcock

MSA and DMD are both feasible multi-slit options for CHROMOS

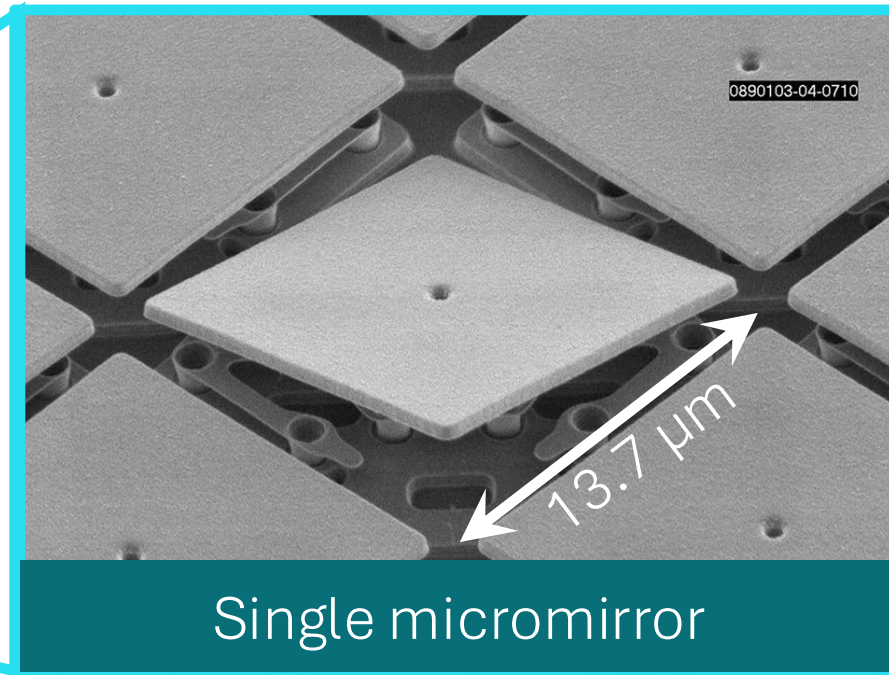
MSA features an array of individual “windows” that swing open on command



DMD features an array of individual “mirrors” that tilt on command



Micromirror array



Single micromirror

Top: Texas Instruments
Left: Andrew Hitchcock

Key characteristics of existing MOS candidates for CHROMOS

Capability	Fulfilling Feature	Current MSA	Current DMD
High multiplexing capability	Large array format	★	★★★★★
High throughput	High NIR transmission or reflection	★★★★★	★
Low diffraction	Optic size >> 5 μm	★★★★★	★
Space compatibility	Rad-hard electronics	★★★★★	★
Cryogenic operation	Demonstrated operation at low temps	★★★★★	★★★★
Longevity	Exceptional mechanical and electronic reliability	★★	★★★★★
Low mass	Small form factor, lightweight	★★★★	★★★★★
Low power	Customized low-power electronics	★★★★★	★★★★

Both existing MOS devices would require development for CHROMOS

NASA's GSFC is developing improved "Next-Gen" Micro-Shutter Arrays

Kutyrev et al. 2025 JATIS



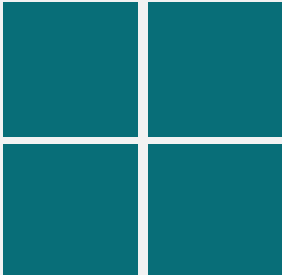
Credit: NASA/GSFC

Increase reliability

- Eliminate magnetic actuation
- Eliminate life-limited mechanical components

Enhance multiplexing

- 4x larger array format
- 2-side buttable

$$2 \times 284 = 768$$


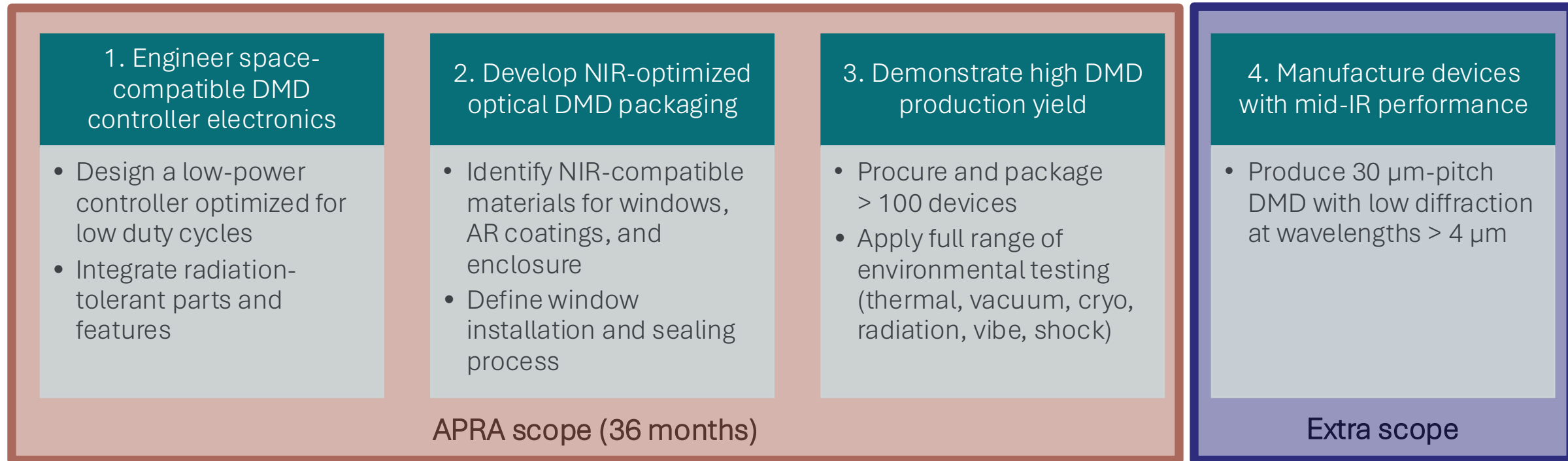
$$2 \times 768 = 1536$$

Mature technology

- Smaller-format MSA now at TRL-9
- Larger-format MSA targeting TRL-5 in 2028
- Control electronics will follow in HWO Phase A

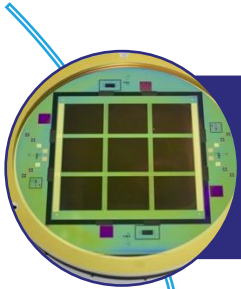
Current Next-Gen MSA devices are not designed for cryogenic operation but can be modified for CHROMOS

The CHROMOS team has a well-defined DMD technology development plan

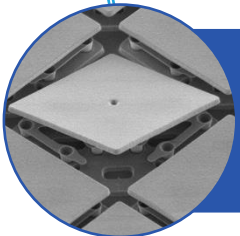


If CHROMOS is funded, the team will pursue expanding the APRA scope to develop a mid-IR DMD

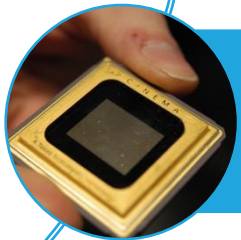
CHROMOS has multiple paths to achieving a high-quality MOS device



Adapt NASA's Next-Generation Micro-Shutter Array (MSA)



Develop Enhanced Digital Micromirror Device (DMD)



Modify existing DMD design for IR operation

CHROMOS instrument driving capabilities summarized

Capability	Solution	Relative degree of difficulty
Large telescope aperture	2 m	Low
Wide wavelength coverage	1.25 – 5.0 μm	Low
High-quality low-res spectroscopy	$R \sim 1000$	Low
Exceptionally low-noise focal planes	Teledyne HAWAII-4RG™ HgCdTe detectors	Low
Wide on-sky field of view	0.7 deg ²	Moderate
True slit spectroscopy	Next-Gen Micro-Shutter Array (MSA) or Enhanced Digital Micromirror Device (DMD)	High
Highly-multiplexed spectroscopy mode	Simultaneous spectra of $\leq 24,000$ targets	High

All necessary CHROMOS capabilities are achievable within 3 years

CHROMOS spacecraft bus design drivers

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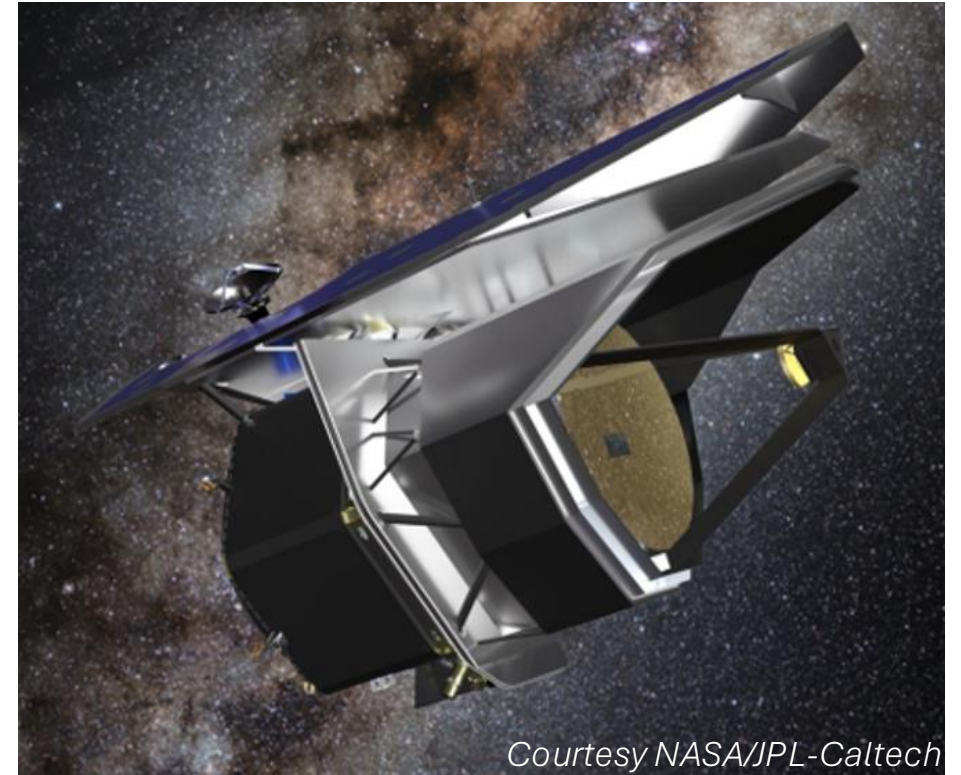
CHROMOS spacecraft bus design drivers

Capability	Performance Needed	Solution	Relative degree of difficulty
Cryogenic operation - optics	< 80 K	Passive sunshade, open telescope	Low
Cryogenic operation – detector	< 55 K	Cryo radiator	Low
Pointing accuracy (absolute)	< 0.75 arcsec	Star trackers, gyros	Moderate
Pointing stability (jitter)	< 20 mas over 6 hr	FGS	Moderate
Repointing	< 60 sec (for moves of < 1°)	Reaction wheels, etc.	Moderate
Stable thermal environment	< 0.2 K variation	L2 halo orbit, sunshield, active thermal control	Moderate
Data bandwidth to ground	< 30 Gb/day	On-board Up-the-Ramp processing, On-board data compression	Low

All CHROMOS bus design drivers are within current capabilities

CHROMOS turns ambition into reality by coupling transformative science to mission-ready technologies

- Two different MOS device options are on track to meet the required reliability and multiplex capability
- All other key instrument capabilities are achievable
- All bus design drivers remain manageable
- The mission serves as a pathfinder for critical MOS technologies on HWO



CHROMOS is a high-impact, low-risk mission that merits full-scale study and investment

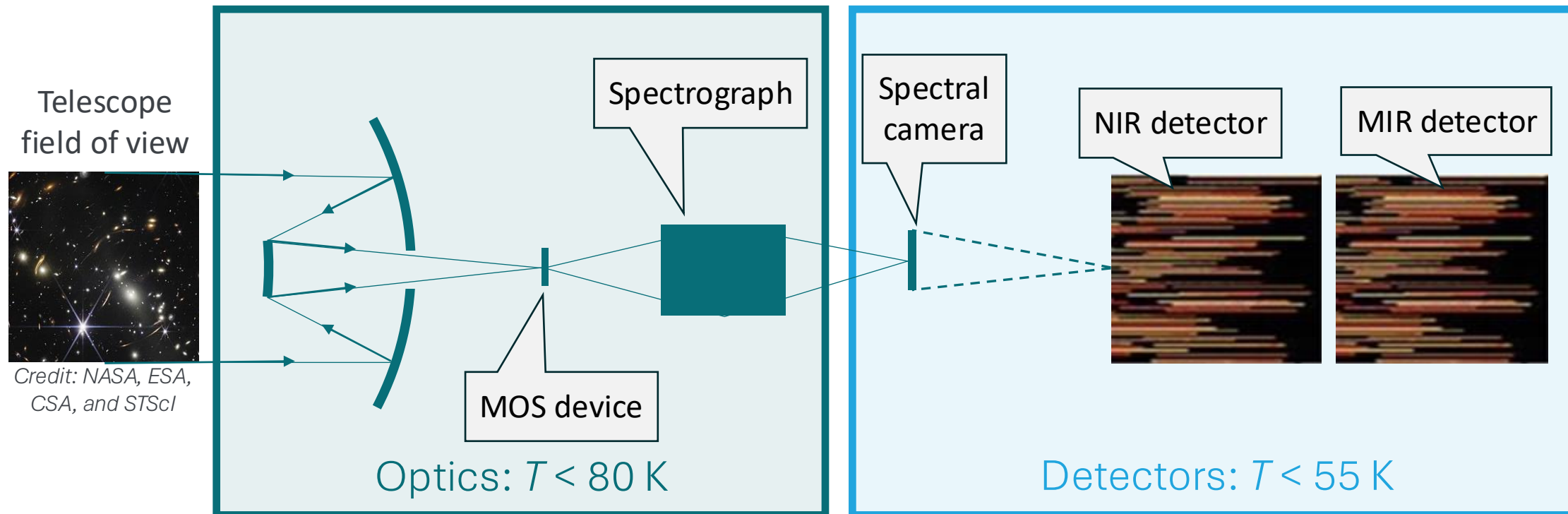
CHROMOS spacecraft bus design drivers - backup

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CHROMOS optics and focal plane require cooling to operate efficiently out to $5.0\text{ }\mu\text{m}$

Credit: Robberto et al. 2025



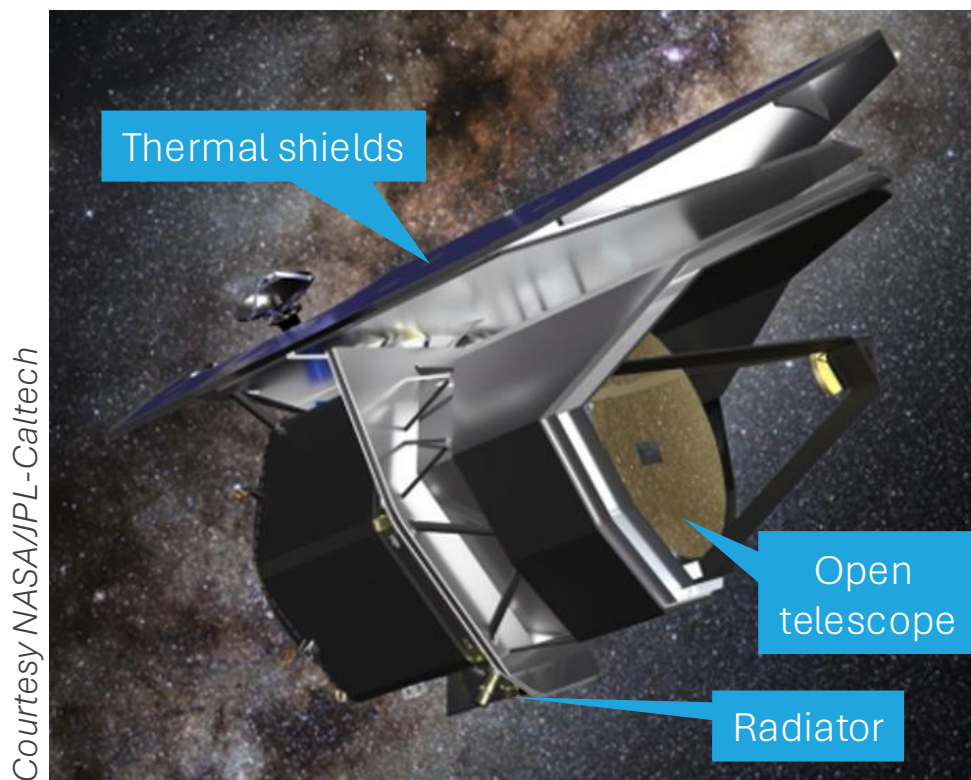
To limit thermal background, CHROMOS optics must operate at 80 K and the detector system at 55 K

CHROMOS cryogenic needs are comparable to other space telescopes

Mission	Red limit [μm]	Optics Temp [K]	Detector Temp [K]
Euclid	2.0	130	95
Roman	2.3	120	95
SPHEREx	5.0	80	55
CHROMOS	5.0	80	55
JWST	28	50	< 6
PRIMA	200	4.5	<1

CHROMOS covers the same wavelength range as SPHEREx and thus has similar thermal requirements

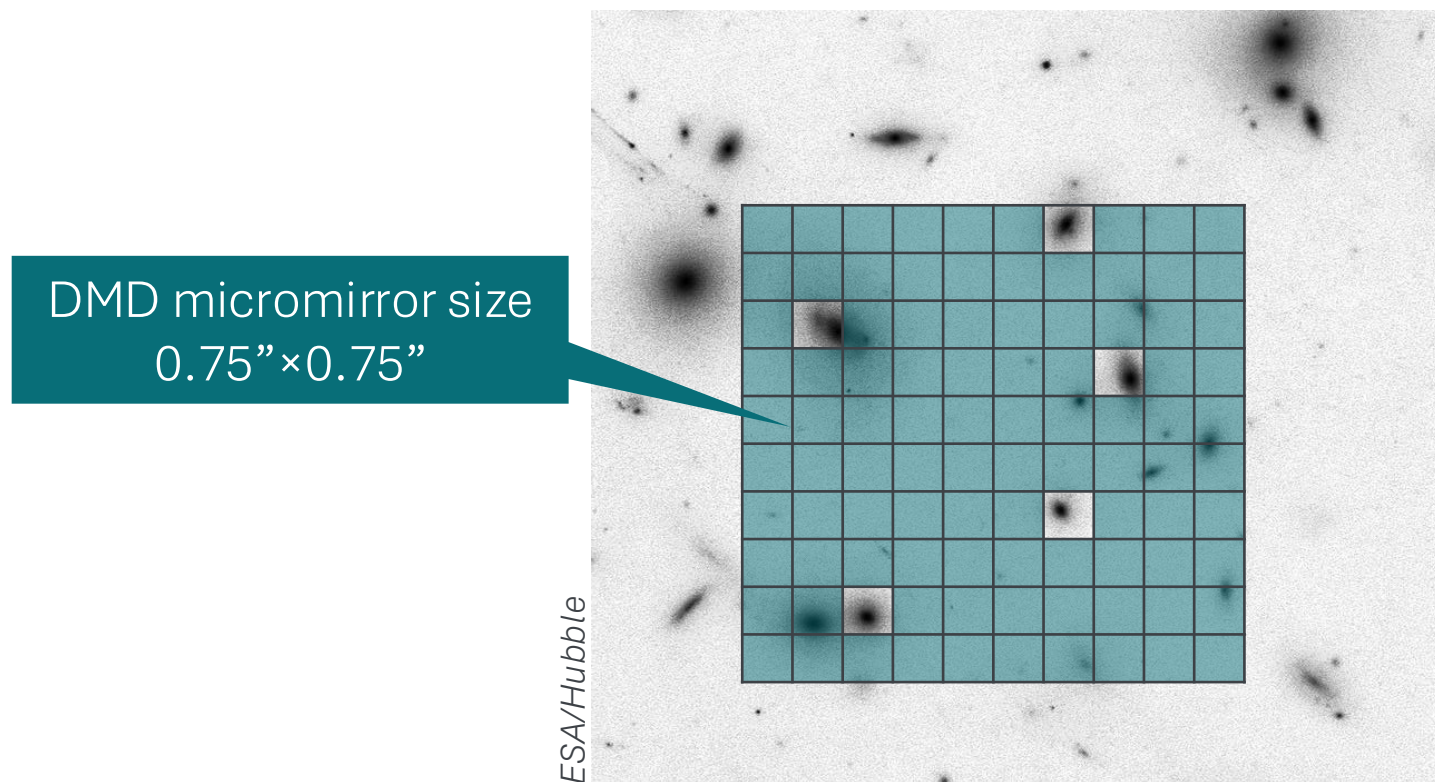
PRIMA far-IR mission thermal design serves as a model for CHROMOS



Attribute	PRIMA	CHROMOS
Primary aperture	1.8 m	2.0 m
Orbit	Earth-Sun L2	Earth-Sun L2
Optics temperature	< 5 K	< 80 K
Detector temperature	< 1 K	< 55 K

PRIMA's purely passive cryogenic features achieve 45 K payload temperature, more than sufficient for CHROMOS

CHROMOS pointing accuracy needs are reasonable

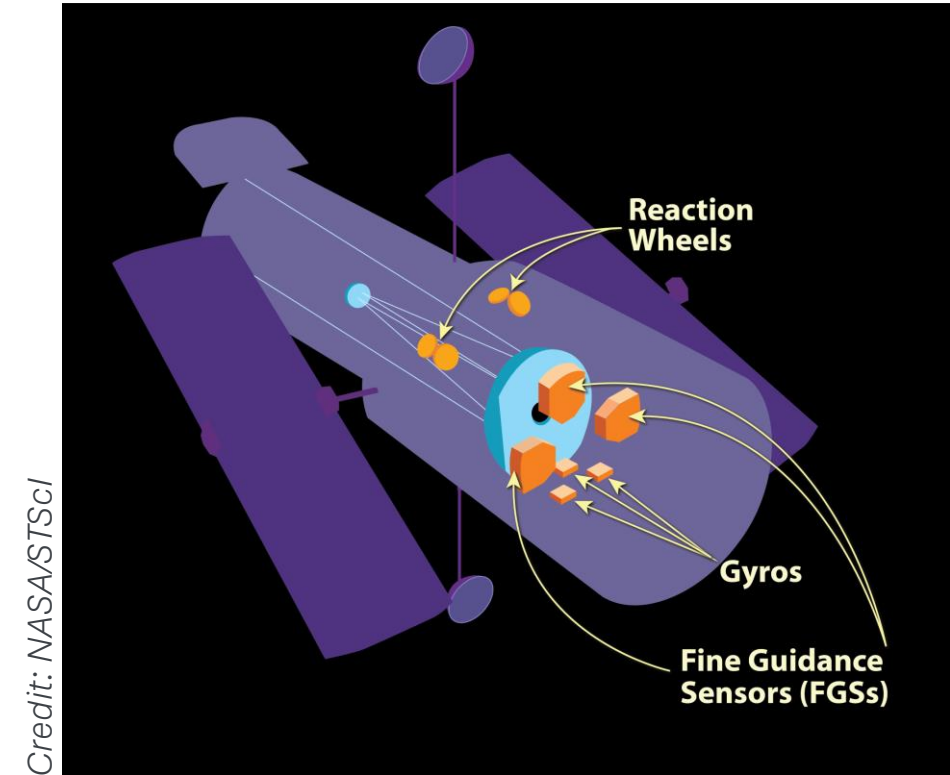


Mission	Pointing accuracy [arcsec, 1 σ]
JWST	< 0.067
Roman	<< 0.10
PRIMA	< 1.0
CHROMOS	Requirement: < 10 Goal: < 0.5

CHROMOS pointing accuracy **requirement** of 10 arcsec is well within current capability;
goal of < 0.5 arcsec allows more efficient operations

CHROMOS pointing stability (jitter) needs are challenging but attainable

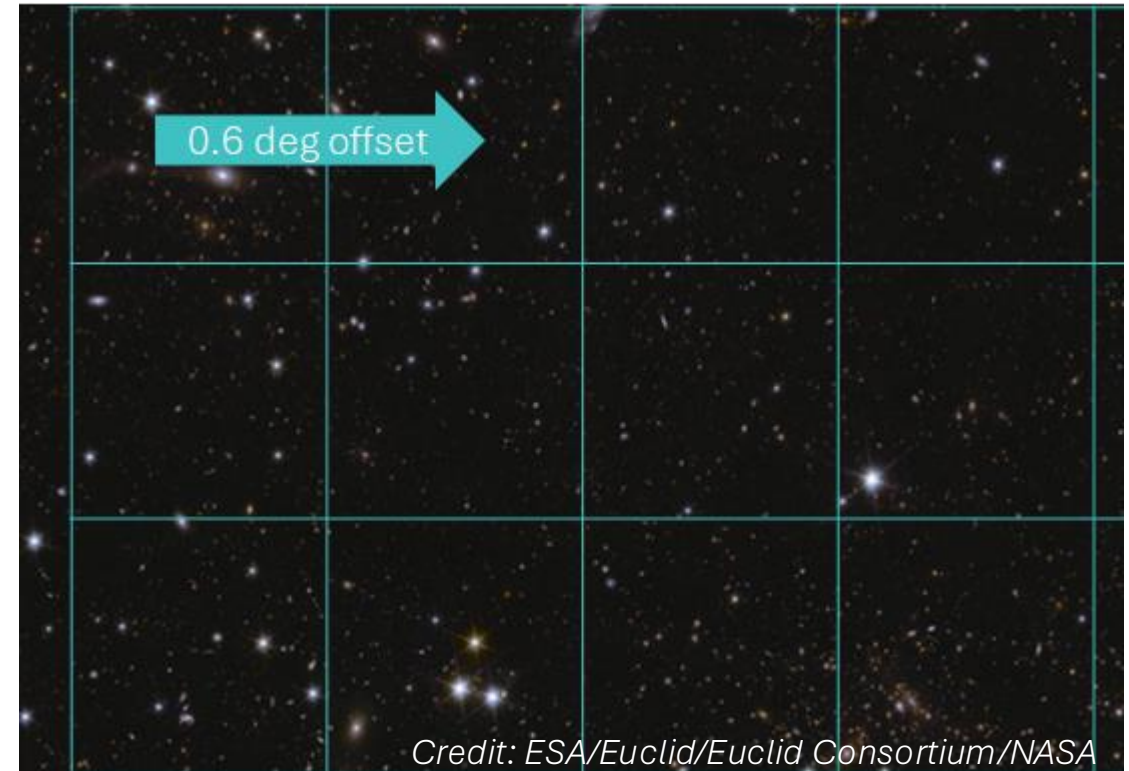
- CHROMOS requirement: 20 mas (RMS) over 6 hr
 - Driven by exoplanet transit observation timescale
- Euclid on-orbit performance: 25 mas (RMS)
- Roman expectation: < 6 mas (RMS)
- JWST on-orbit performance: 1 mas (RMS)
- Disturbance mitigation strategies:
 - Avoid cryocooler
- Control strategies:
 - Star trackers
 - Reaction wheels
 - FGS + FSM (if needed – Roman meets CHROMOS target without a FSM)



Exoplanet spectroscopy drives CHROMOS pointing stability requirement

CHROMOS bus agility (repointing) needs are within current capabilities

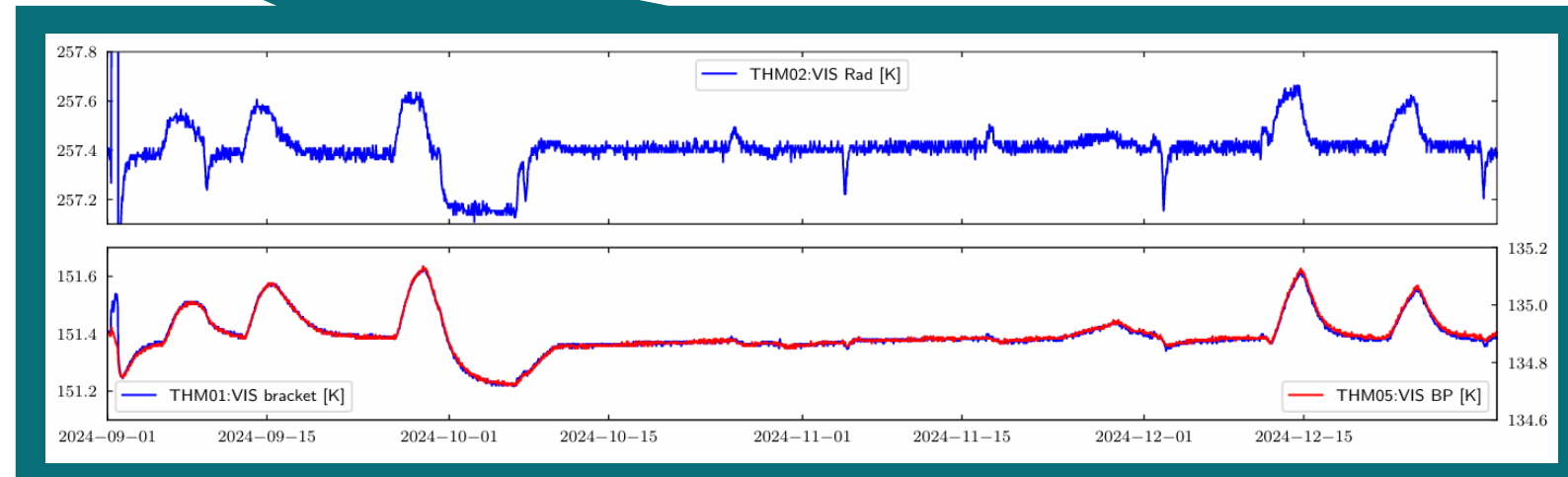
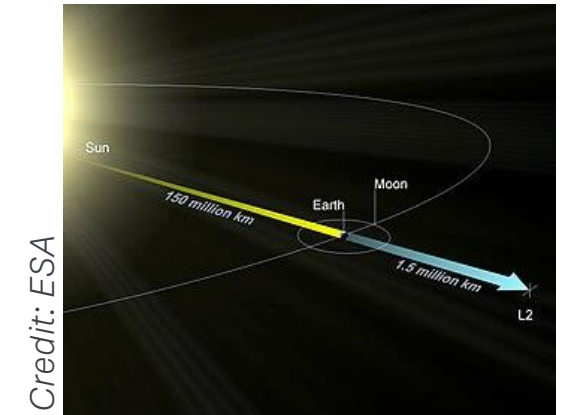
Mission	Required Agility
Euclid	complete 1° repoint in 65 s
Roman	complete 1° repoint in 60 s
CHROMOS	complete 1° repoint in 60 s



1° repoint and settle within 60 seconds is within the heritage envelope of large space telescopes

CHROMOS thermal stability is within current capability

- CHROMOS requirement: ± 0.2 K
- Euclid performance: ± 0.2 K
- Implementation via
 - Stable L2 halo orbit
 - Small slews during observing
 - Passive sunshield
 - Active temperature control



Euclid Collaboration: Anselmi et al. 2026

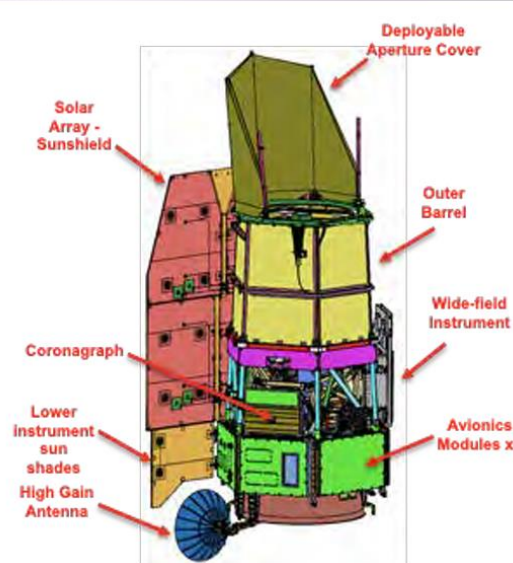
Euclid sees on-orbit thermal variation of ± 0.2 K peak to peak

CHROMOS daily data volume is order of magnitude below Roman

- Estimate **30 Gb/day** under normal galaxy survey mode
- Assume
 - On-board Up-the-Ramp processing (100x savings)
 - On-board data compression (2x savings)

ROMAN SPACE TELESCOPE

Roman Observatory and Instruments



Telescope: 2.4m aperture

Two Instruments:

Wide Field Imager / Slitless Spectrometer

- Vis/Near IR bandpasses (0.48 – 2.3 micron)
- Field of view 0.281 deg² (~200× HST WFC3-IR)
- 18 4k × 4k detectors (288 Mpixels)

Coronagraph

- Visible bandpass
- Contrast 10⁻⁸-10⁻⁹

Data Volume: 11 Tb/day

Orbit: Sun-Earth L2

Mission Duration: 5 yr, 10yr goal

https://roman.gsfc.nasa.gov/science/technical_resources.html

Credit: NASA

CHROMOS generates 30 Gb of data daily vs. 11,000 Gb for Roman/WFI