

NASA Astrophysics Division (APD) Technology Gap List

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The Astrophysics Technology Gap List

- APD technologists maintain a prioritized Technology Gap List to help guide NASA's technology investments to enable or enhance future astrophysics missions in Decadal report
- Gap List addresses technology for all three APD thematic programs: PhysCOS, COR, ExEP
- ExEP's technology focus has been on the technology program towards a future exoplanet direct imaging mission which became Habitable Worlds Observatory (HWO) as recommended in the 2020 Decadal report

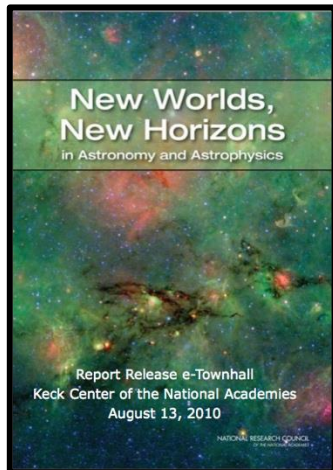
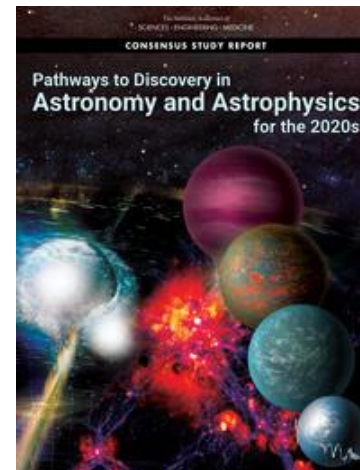


TABLE ES.4 Space: Recommended Activities—Medium-Scale (Priority Order)

Recommendation	Science	Appraisal of Costs ^d
1. New Worlds Technology Development Program	Preparation for a planet-imaging mission beyond 2020, including precursor science activities	\$100M to \$200M
2. Inflation Probe Technology Development Program	Cosmic microwave background (CMB)/inflation technology development and preparation for a possible mission beyond 2020	\$60M to \$200M



Recommendation: NASA should embark on a program to realize a mission to search for biosignatures from a robust number of about ~25 habitable zone planets and to be a transformative facility for general astrophysics.

Technology Gaps

- <https://science.nasa.gov/astrophysics/programs/astrophysics-division-technology/technology-gaps/>
- The science objectives define technology Performance Objectives
- The “Gap” is between Current State of the Art and Performance Objectives
- Multiple technologies could be candidates to close the gap



ASTROPHYSICS
TECHNOLOGY DEVELOPMENT

Overview

Technology

Outreach



Astrophysics Program Offices

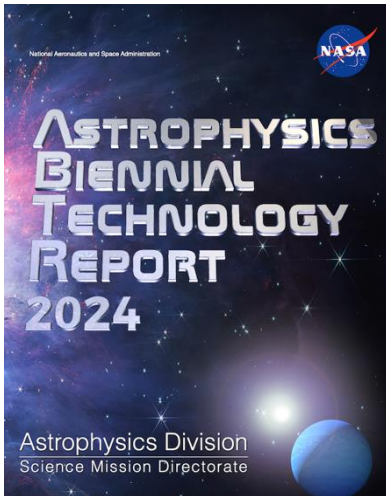
2019 Astrophysics Strategic Technology Gaps

[View/download as PDF](#)

Jump to : [Tier 1](#) | [Tier 2](#) | [Tier 3](#) | [Tier 4](#) | [Tier 5](#)

Gap Name	Description	Current State-of-the-Art	TRL SOTA Solution		Performance Goals and Objectives	Scientific, Engineering, and/or Programmatic Benefits	Applications and Potential Relevant Astrophysics Missions	Urgency
Angular Resolution (UV/Vis/NIR)	The capability to resolve the habitable zones of nearby star systems in the UV/Vis/NIR band, with a large space telescope.	Monolith: 3.5-m sintered SiC with < 3 μ m SFE (Herschel); 2.4-m ULE with ~10 nm SFE (HST); Depth: Waterjet cutting is TRL 9 to 14; but TRL 3 to >18; Fused core is TRL 3; slumped fused core is TRL 3 (AMTD). Segmented: (no flight SOA): 6.5 m Be with 25 nm SFE (JWST); Non-NASA: 6 DOF, 1-m class SiC and ULE, < 20 nm SFE, and < 5 nm wavefront stability over 4 hr with thermal control	3	3	Large (4–16 m) monolith and multi-segmented mirrors for space that meet SFE < 10 nm rms (wavelength coverage 400–2500 nm); Wavefront stability better than 10 pm rms per wavefront control time step; CTE uniformity characterized at the ppb level for a large monolith; Segmented apertures leverage 6 DOF or higher control authority meter-class segments for wavefront control.	This gap is likely to be closed by development of large monolithic or segmented telescopes. Aside from angular resolution, large primary mirrors enhance planet sensitivity due to reduction in science integration time with greater collecting areas and throughput enabling probing of a larger number of more distant stars' habitable zones and improved spectral resolution.	LUVOR, HabEx, or any other large UV/Vis/NIR space observatory.	Demonstration of feasibility and as much risk reduction as possible prior to completion of Astro2020. Per LUVOR and HabEx Final Reports, TRL 6 in the mid-2020's would be needed.

Where to Find More Details



Astrophysics Division
Technology Website

- **Astrophysics Biennial Technology Report (ABTR)**
 - Technology gaps for all three NASA Astrophysics Division programs
 - 2026 ABTR is in progress, release expected ~Mar 2027
- **Technology Gap Website**
 - <https://science.nasa.gov/astrophysics/programs/astrophysics-division-technology/technology-gaps/>
- **Astrophysics Division Technology Website**
 - <https://science.nasa.gov/astrophysics/programs/astrophysics-division-technology/>
- **Database of technology investments:**
 - <https://esto.nasa.gov/Astrophysics/>

Where does the Gap List come from?



- **APD's Biennial Technology Selection and Prioritization Process:**
 - **Identify Technology Gaps** applicable to Astrophysics strategic objectives as described in the Decadal Survey (2021)
 - **Rank Technology Gaps** to prioritize them for investment via competed and directed means
 - **Inform the community** of NASA's technology needs for Astrophysics
- **Candidate Gaps are submitted by the community of scientists, technologists and engineers; also generated by Program Office technologists**
 - Gap solicitations will open in January after the Ad ASTRA study selections are announced
 - The submission 2024 form with instructions can be found on the APD website (the form may be updated for 2027)
https://assets.science.nasa.gov/content/dam/science/astro/technology/Tech_gap_form_2024-09-27.docx
- **The APD program offices consolidate and/or edit gap submissions with advice from PAGs (PhysCOS/COR) or ExoTAC (ExEP), and loop back with originators**

Technology Gap Submission Form



Astrophysics Strategic Technology Gap Input Form	
<u>Technology Capability Gap Name:</u>	<u>Date Submitted:</u>
<u>Submitter Name:</u>	<u>Organization:</u>
<u>Telephone:</u>	<u>Email Address:</u>
Prioritization Information (see accompanying instructions)	
<u>Identify Strategic Missions Enhanced or Enabled by Closing this Technology Gap:</u> ☐ HWO ☐ Far-IR Flagship ☐ X-ray Flagship ☐ CMB Probe ☐ Far-IR Probe ☐ X-ray Probe ☐ Other (write in below the mission name or activity and reference where it is mentioned in Astro2020):	
<u>Brief Description of the Technology Capability Needed (100 – 150 words):</u> 	
<u>Technical Goals and Objectives (Key Performance Parameters) to Fill the Capability Gap (150-300 words):</u> 	
<u>Assessment of the current TRL of full solution addressing all the above key performance parameters and requirements and references (integer between 1 and 9 per NPR 7123.1D, Appendix E):</u>	
<u>References justifying the above TRL (if any):</u> 	
<u>Scientific, Engineering and/or Programmatic Benefits (100 – 150 words):</u> 	
<u>Applications and Potential Relevant Missions for Astrophysics Division (100-200 words):</u> 	
<u>Urgency:</u> Years to estimated launch or other schedule driver: Level of complexity (single tech, system of techs, or system of tech systems): Level of difficulty (straightforward, stretch, or major stretch):	

Gap List Prioritization

- **Each Gap receives a prioritization score in each of four criteria:**
 - Strategic Alignment with APD objectives
 - Benefits and Impacts
 - Urgency
 - Scope of Applicability
- **Draft prioritization scores assigned by ExEP/PhysCOS/COR program office technologists and scientists**
- **Final prioritization done with ExoTAC (ExEP), Technology Management Board (PhysCOS/COR)**
- **Based on prioritization scores, Gaps are divided into priority tiers**

2024 APD Technology Gap List in priority tiers



Tier-1 Technology Gaps

Coronagraph Contrast and Efficiency in the Near IR
Coronagraph Contrast and Efficiency in the Near UV
Coronagraph Stability

Cryogenic Readouts for Large-Format Far-IR Detectors
Fast, Low-Noise, Megapixel X-ray Imaging Arrays with Moderate Spectral Resolution
High-Bandwidth Cryogenic Readout Technologies for Compact and Large-Format Calorimeter Arrays
High-Efficiency, Low-Scatter, High- and Low-Ruling-Density, High- and Low-Blazed-Angle UV Gratings
High-Efficiency X-ray Grating Arrays for High-Resolution Spectroscopy
High-Performance Sub-Kelvin Coolers
High-Reflectivity Broadband Far-UV-to-Near-IR Mirror Coatings
High-Resolution, Lightweight X-ray Optics

High-Throughput, Large-Format Object-Selection Technologies for Multi-Object and Integral-Field Spectroscopy

Integrated Modeling for HWO: Multi-Physics Systems Modeling, Uncertainty Quantification, and Model Validation

Large-Format, High-Resolution Far-UV (100 - 200 nm) Detectors
Large-Format, High-Resolution Near-UV (200 - 400 nm) Detectors
Low-Stress, Low-Roughness, High-Stability X-ray Reflective Coatings
Mirror Technologies for High Angular Resolution (UV/Visible/Near IR)
Optical Blocking Filters for X-ray Instruments
Scaling and Metrology for Advanced Broadband Mirror Coatings for HWO
Segmented-Pupil Coronagraph Contrast and Efficiency in the Visible Band
UV Multi-Object Spectrograph Calibration Technologies
UV Single-Photon Detection Sensitivity
Visible/Near-IR Single-Photon Detection Sensitivity

Technology Gaps transitioned to HWO

Tier-2 Technology Gaps

Advanced Cryocoolers
Broadband X-ray Detectors
Compact, Integrated Spectrometers for 100 to 1000 μm
Cryogenic Far-IR to mm-Wave Focal-Plane Detectors
Far-IR Imaging Interferometer for High-Resolution Spectroscopy
Far-IR Spatio-Spectral Interferometry
Heterodyne Far-IR Detector Systems
High-Performance Computing for Event Reconstruction
High-Resolution, Direct-Detection Spectrometers for Far-IR Wavelengths
High-Throughput Focusing Optics for 0.1-1 MeV Photons
High-Throughput UV Bandpass Standalone and Detector-Integrated Filters and Bandpass Selection

Improving the Calibration of Far-IR Heterodyne Measurements
Large-Format, High-Spectral-Resolution, Small-Pixel X-ray Focal-Plane Arrays
Large-Format, Low-Noise and Ultralow-Noise, Far-IR Direct Detectors
Low-Power Readout and Multiplexing for CMB Detectors
Millimeter-Wave Focal-Plane Arrays for CMB Polarimetry
Optical Elements for a CMB Space Mission
Starshade Deployment and Shape Stability
Starshade Starlight Suppression and Model Validation
Stellar Reflex Motion Sensitivity: Astrometry
Stellar Reflex Motion Sensitivity: Extreme Precision Radial Velocity
Warm Readout Electronics for Large-Format Far-IR Detectors

ExEP Technology Gaps

Tier-3 Technology Gaps

Broadband X-ray Polarimeter
Charged-Particle-Discriminating X-ray/Gamma-Ray Detectors
Dynamic Switching for Ultra-Low-Power, High-Resolution Charge Readout
High-Energy-Resolution Gamma-Ray Detectors
Large-Aperture Deployable Antennas for Far-IR/THz/sub-mm Astronomy for Frequencies Above 100 GHz
Large Cryogenic Optics for the Mid IR to Far IR
Large Field-of-View and Effective-Area Gamma-Ray Detectors

Low-Power, Low-Cost Semiconductor Detectors
Low-Power Readout for Silicon Photomultipliers
Photometric and Spectro-Photometric Precision of Time-Domain and Time-Series Measurements
Precision Timing Measurement Technology
Radiation-Tolerant, Photon-Counting Light Detectors
Sensitive Spectrometer for CMB Spectrum Measurement
UV/Optical/Near-IR Tunable Narrowband Imaging Capability

Non-Strategic

Advancement of X-ray Polarimeter Sensitivity
Detection Stability in Mid-IR

- **Technology Gap List update for 2027 will be responsive to ASTRA Initiative**
 - Possibly new capabilities needed to implement ASTRA Initiative studies → new technology gaps
 - Strategic Alignment criterion will be adjusted to reflect selections of ASTRA studies and ASTRA roadmap
 - The gaps inform APDs strategy and planning, and the process will be responsive to ASTRA.
- **Gap List Update schedule is driven by plans for Astrophysics Research Technology (ART, which subsumes SAT and APRA) 2027 (may change):**
 - Amendment for ART released in ~May, late summer deadline
 - Gap List planned for delivery to public in ~May
 - Note that HWO will manage and fund their own technology development
- **Based on decadal recommendations, APD may choose to direct some technology funding, or create more focused competitions, adjusting SAT call accordingly**

Next Steps



- **Think about technology needed for ASTRA Concepts**
- **Submit new Technology Gaps**
 - Technology Gaps (new and updated) can be submitted starting January 12, 2027 through Feb 12, 2027
- **New Gap List will be released to coincide with SAT amendment**
 - On current schedule, this is ~May 2027 (subject to change)

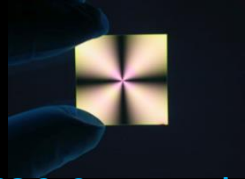
BACKUP

Prioritization Scoring Guidelines from 2019

Criterion	Weight	Max Score	Max Weighted Score	General Description/ Question	4	3	2	1	0
Strategic Alignment	10	4	40	How well does the technology align with Astrophysics science and programmatic priorities of current programmatic guidance (i.e., AIP, Roadmap, Decadal Survey)?	Technology enables science with in mission concept receiving highest current programmatic consideration in AIP or Roadmap (4 for approved APD missions/contributions (LISA, Athena), SOFIA, and 3.5 for STDTs)	Technology enables science with in mission concept receiving medium current programmatic consideration in AIP or Roadmap (non-STDT surveyors (CMB Polarization Surveyor or IP)	Technology enables science within mission concept receiving low current programmatic consideration in AIP or Roadmap (Mappers)	Technology enables science within mission concept not considered in AIP or Roadmap, but positively addressed in Decadal Survey	Technology does not enable science within any mission concept considered by current Astrophysics programmatic guidance
Benefits and Impacts	8	4	32	How much impact does the technology have on applicable mission(s)? To what degree does the technology enable and/or enhance achievable science objectives, reduce cost, and/or reduce mission risks?	Critical and key enabling technology; required to meet mission concept objectives; without this technology mission would not launch or science return would be significantly impaired	Highly desirable; not mission-critical to mission objectives, but significantly enhances science capability, reduces critical resources needed, and/or reduces mission risks; without it, missions may launch, but science return would be compromised	Desirable - not required for mission success, but offers moderate science or implementation benefits; if technology is available, would almost certainly be implemented in mission	Minor science impact or implementation improvements; if technology is available would be considered for implementation in mission	No science impact or implementation improvement; even if available, technology would not be implemented in mission
Urgency	5	4	20	Given anticipated complexity and "length" of gap (informed by relevant ongoing efforts), assessed against the time available until anticipated launch and/or other schedule drivers, how urgently does the gap need to be addressed?	Estimated schedule margin of 0% or less (i.e., negative)	Estimated schedule margin is greater than 0% and less than or equal to 20%	Estimated schedule margin is greater than 20% and less than or equal to 40% (SOFIA)	Estimated schedule margin is greater than 40% and less than or equal to 60%	Estimated schedule margin is greater than 60%
Scope of Applicability	2	4	8	How cross-cutting is the technology? How many Astrophysics programs and/or mission concepts (including Explorers and Probes) could it benefit?	Applies to more than one high-priority strategic Astrophysics mission concepts (High priority means SA >3)	Applies to one high-priority strategic Astrophysics mission concept and one or more other strategic mission concepts	Applies to more than one strategic Astrophysics mission concept	Applies to just one strategic Astrophysics mission concept and at least one non-strategic Astrophysics mission (e.g., Explorers, Probes, etc.)	Applies to only one strategic Astrophysics mission, or one or more non-strategic missions

V-NIR Coronagraph/Telescope Technology Gaps

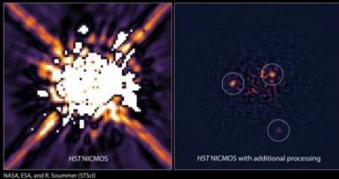
Contrast



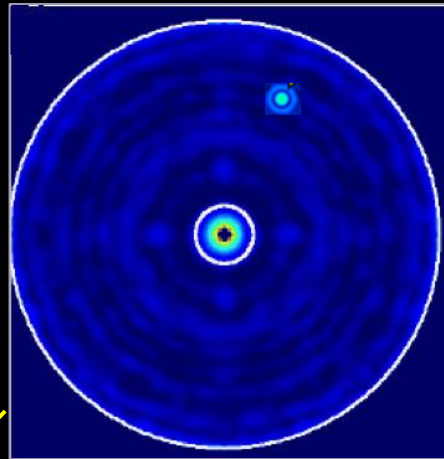
CG-2: Coronagraph Architecture



CG-3: Deformable Mirrors



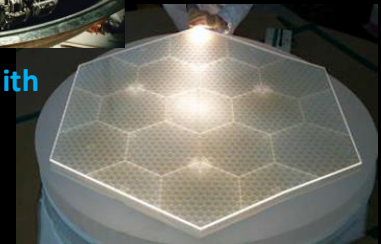
CG-4: Data Post-Processing



Angular Resolution

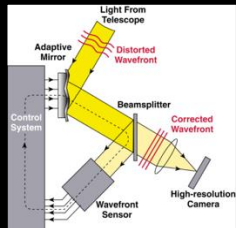


CG-1: Large Monolith Mirrors



CG-1: Segmented Mirrors

Contrast Stability



CG-5: Wavefront Sensing and Control

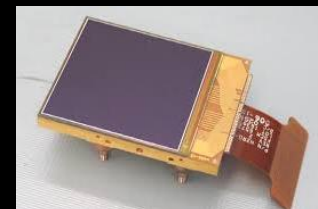
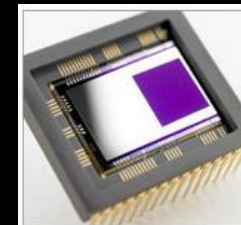


CG-6: Mirror Segment Phasing



CG-7: Telescope Vibration Sensing and Control or Reduction

Detection Sensitivity



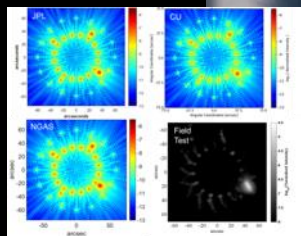
Ultra-low Noise Visible (CG-8) and Infrared (CG-9) Detectors

Starshade Technology Gaps

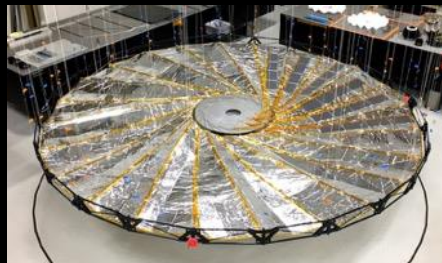
(1) Starlight Suppression



Suppressing scattered light off petal edges from off-axis Sunlight (S-1)

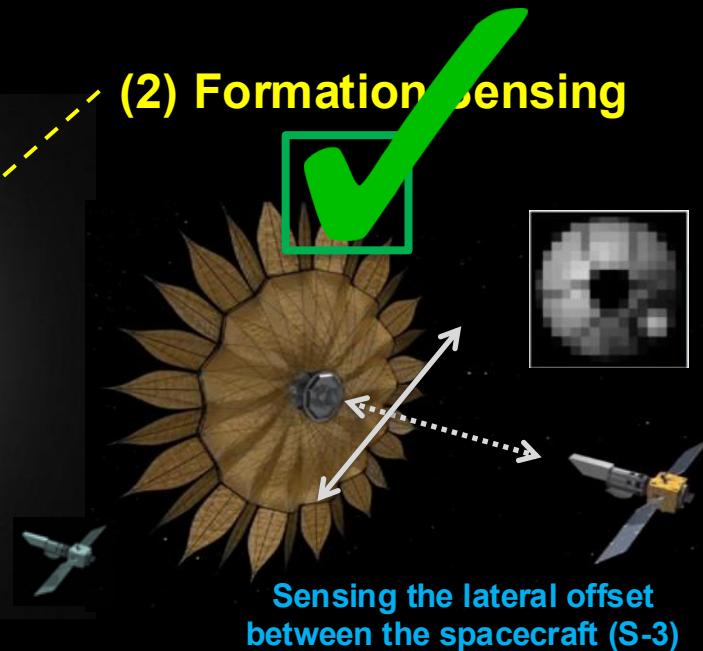


Suppressing diffracted light from on-axis starlight and optical modeling (S-2)



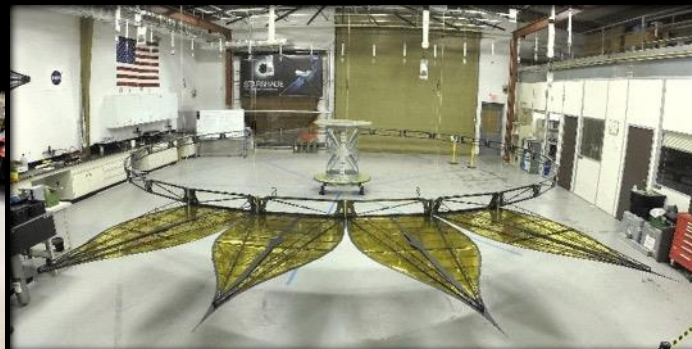
Positioning the petals to high accuracy, blocking on-axis starlight, maintaining overall shape on a highly stable structure (S-5)

(2) Formation Sensing



Sensing the lateral offset between the spacecraft (S-3)

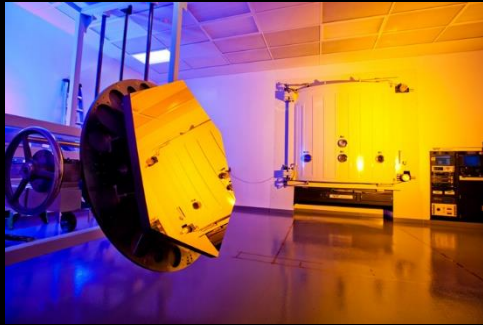
(3) Deployment Accuracy and Shape Stability



Fabricating the petals to high accuracy (S-4)

Other Technology Gaps

UV Contrast

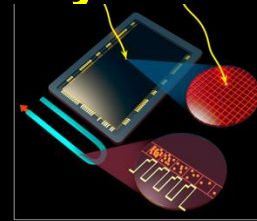


CG-10 UV/V/NIR Mirror Coatings

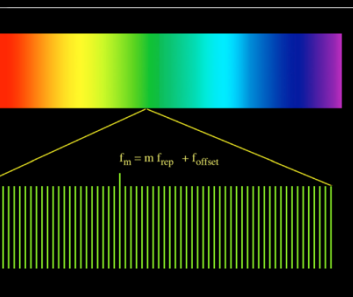
UV Detection Sensitivity



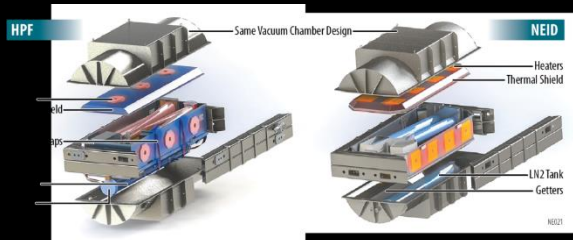
CG-12: Ultra-low Noise UV Detectors



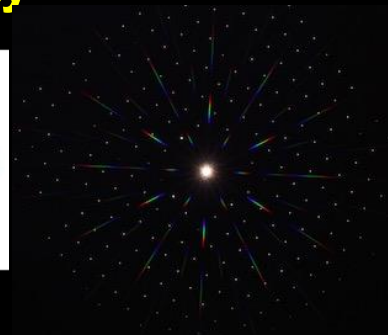
Stellar Reflex Motion Sensitivity



M-2: Laser Frequency Combs for Space-based EPRV

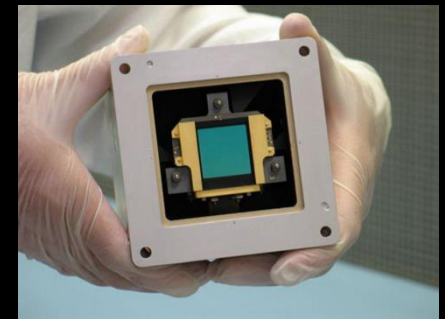


M-1: Ground-based Ultra-high Precision Radial Velocity



M-3: Astrometry

Transit Spectroscopy Sensitivity



M-4: Ultra-stable Mid-IR Detectors for Transit Spectroscopy