NASA Astrophysics Update

Space Studies Board | March 27-31, 2023

Dr. Mark Clampin
Director, Astrophysics Division
Science Mission Directorate

Science Mission Directorate

ASTROPHYSICS

Organizational Chart

DIVISION MANAGEMENT

Dr. Mark Clampin
Director

Sandra Cauffman
Deputy Director

ADMINISTRATIVE SUPPORT
Kelly Johnson, Jennifer Baker (C), Pamela King-Williams (C)

DIVISION LIAISONS

Resource Management
Erik Edwardson (Lead)
Danielle Gervallis
Jennifer Holt

Policy
Peter Meister (Lead)
Enida Santiago-Arce

Communications
Alise Fisher (Lead)

Program Support Specialist
Sara Schwartzman

CROSS CUTTING

Technologist
Mario Perez (Chief)
Omid Noroozian (Deputy)

APD Communications
Hashima Hasan (Lead)
Doris Daou (Deputy)
Liz Landau (C - OCOMM Liaison)
Natasha Pinol (C - Public Engagement Liaison)

Inclusion, Diversity, Equity, and Accessibility
Kartik Sheth (Lead)
Antonino Cucchiara (Deputy)

GOMAP Program
Julie Crooke (Executive)
Shawn Domagal-Goldman (Scientist)

APD Information Manager
Rhiannon Roberts (C)

FLIGHT PROGRAMS

Associate Director
Joseph Smith

PROGRAM EXECUTIVES

Rachele Cocks
Lucien Cox
Shahid Habib
Janet Letchworth
Mark Sistilli

RESEARCH & ANALYSIS

Associate Director
Eric Smith

R&A Lead
Stefan Immler

PROGRAM SCIENTISTS

Manuel Bautista
Dominic Benford
Valerie Connaughton
Antonino Cucchiara (C)
Doris Daou
Michael Garcia
Thomas Hams (C)
Hashima Hasan
Doug Hudgins
Stefan Immler
Hannah Jang-Condell
Patricia Knezek
Bill Latter
Sangeeta Malhortra
Roopesh Ojha
Joshua Pepper
Mario Perez
Kartik Sheth
Eric Smith
Linda Sparke
Sanaz Vahidinia

PROGRAM SUPPORT SPECIALIST
Ingrid Farrell (C)

ASTROPHYSICS STRATEGIC MISSIONS

Program Director
Sandra Cauffman

Program Manager (Acting)
Garth Henning

PROGRAM EXECUTIVES

Ed Griego
Lucas Paganini
Miles Skow

PROGRAM SUPPORT
Tony Comberiate (C), Andre Davis (C)

Legend
C - Contractor

Astrophysics by the NUMBERS

RESEARCH

~400 U.S. Science PIs Funded
~128 Individual Institutions Selected
~$135M Awarded Annually

TECHNOLOGY DEVELOPMENT

~$220M Invested Annually

SMALLSATS/ CUBESATS

2 Science Missions Launched
8 Science Missions in Development
1 ISS-attached Science Mission

REFEREED PUBLICATIONS

20,122 Total Publications
4,857 Hubble Publications (2017-2021)
101 JWST Publications (First 6 months)

SOUNDING ROCKETS

14 Science Missions Launched (Suborbital)
4 In Development

MISSIONS

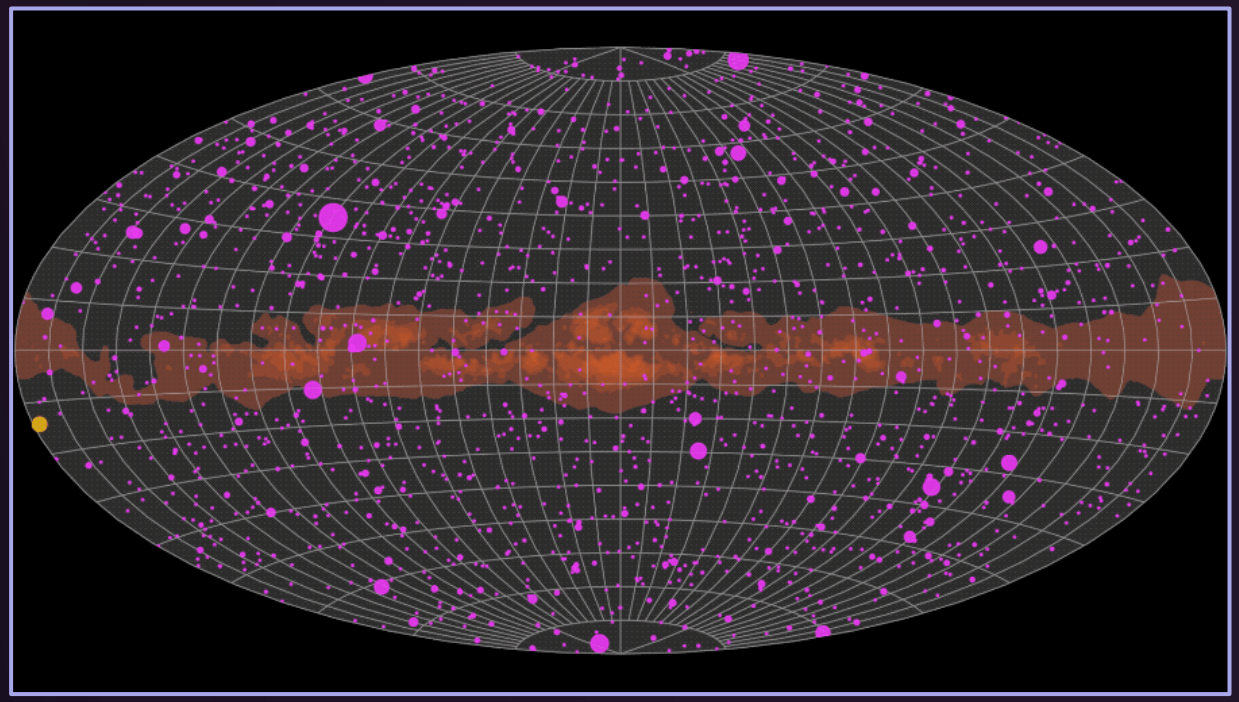
11 Missions Operating
11 Missions in Development

BALLOONS

14 Suborbital Balloons Launched
20 Missions in Development

NASA’s Fermi Captures Dynamic Gamma-Ray Sky

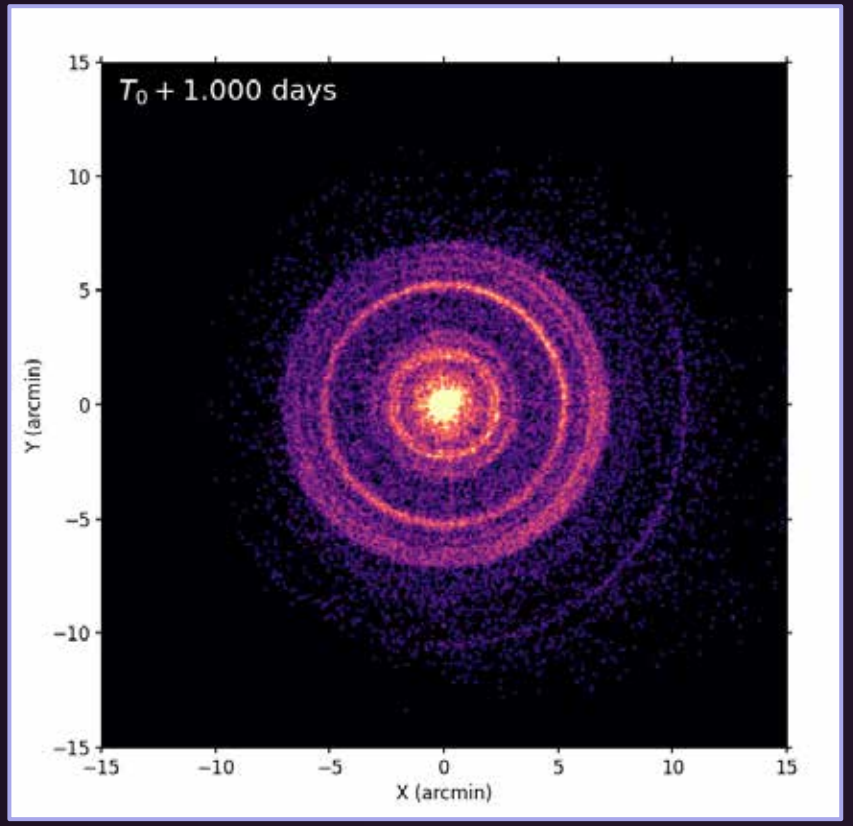
- This animation shows a year of observations from February 2022 to February 2023 taken with the Large Area Telescope (LAT) aboard NASA’s Fermi Gamma-ray Space Telescope
- The pulsing circles represent just a subset of more than 1,500 light curves that were collected by the LAT over nearly 15 years in space.
- Over 90% of the sources in the dataset are blazars, central regions of galaxies hosting active supermassive black holes that produce powerful particle jets pointed almost directly at Earth.
- This database could lead to new multimessenger insights into past events.



Credits: *NASA's Marshall Space Flight Center/Daniel Kocevski*
Caption: *The animation shows a subset of the LAT gamma-ray records now available for more than 1,500 objects in a new, continually updated repository. Each frame represents three days of observations. Each object’s magenta circle grows as it brightens and shrinks as it dims. The yellow circle represents the Sun following its apparent annual path across the sky.*

NASA’s Swift, Fermi Missions Detect Exceptional Cosmic Blast

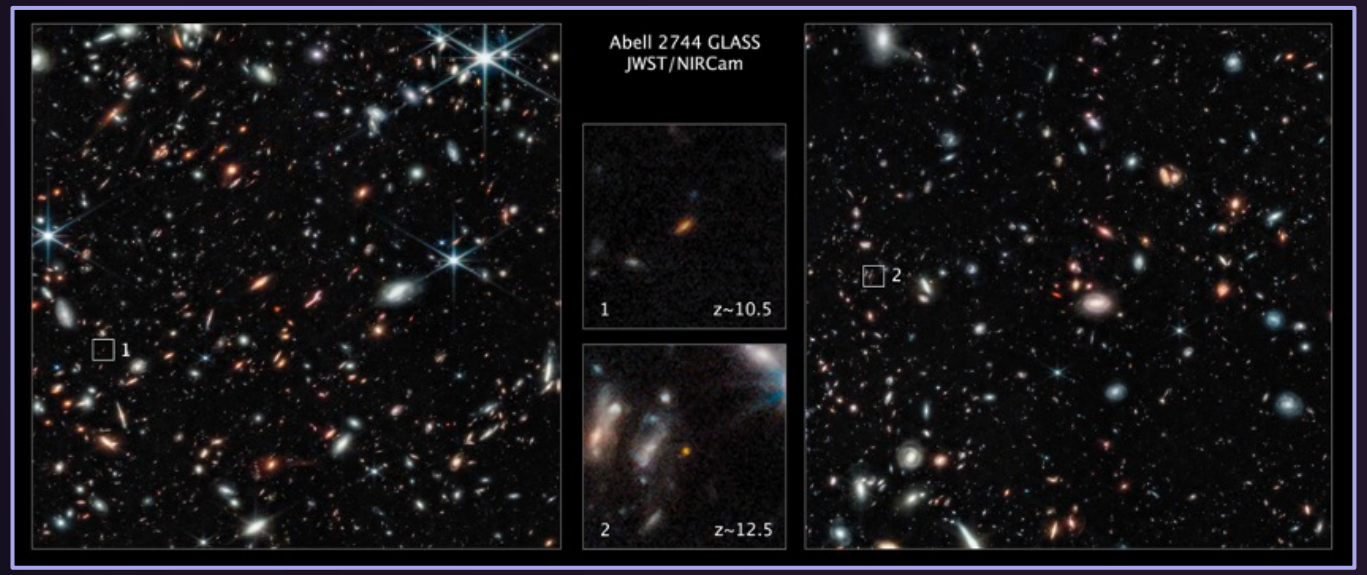
- An unusually bright and long-lasting pulse of high-energy radiation that swept over Earth Sunday, October 9, 2022.
- The emission came from a gamma-ray burst (GRB) – the most powerful class of explosions in the universe – that ranks among the most luminous events known.
- Called GRB 221009A, the wave of X-rays and gamma rays triggered detectors aboard NASA’s Fermi Gamma-ray Space Telescope , Neil Gehrels Swift Observatory, and Wind spacecraft, as well as others.
- This signal had traveled an estimated 1.9 billion years to reach Earth and provides new insights into stellar collapse, the birth of a black hole.



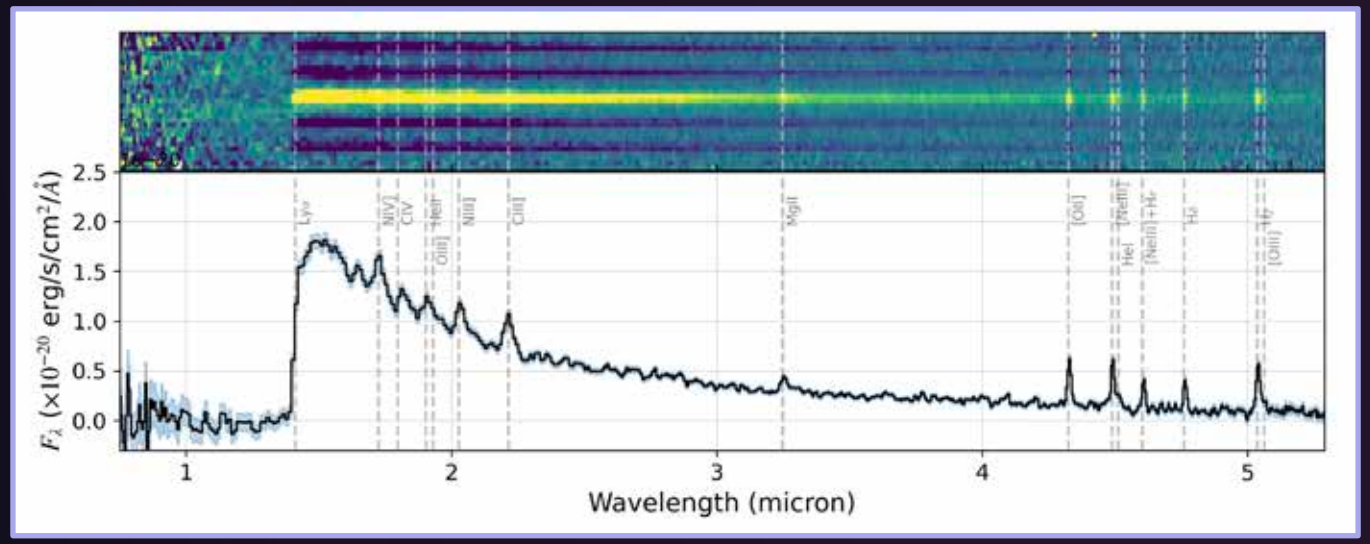
Swift’s X-Ray Telescope captured the afterglow of GRB 221009A about an hour after it was first detected. The bright rings form as a result of X-rays scattered from otherwise unobservable dust layers within our galaxy that lie in the direction of the burst and expand over time as we observe scattering from larger and larger angles.

JWST Early Universe: First Results

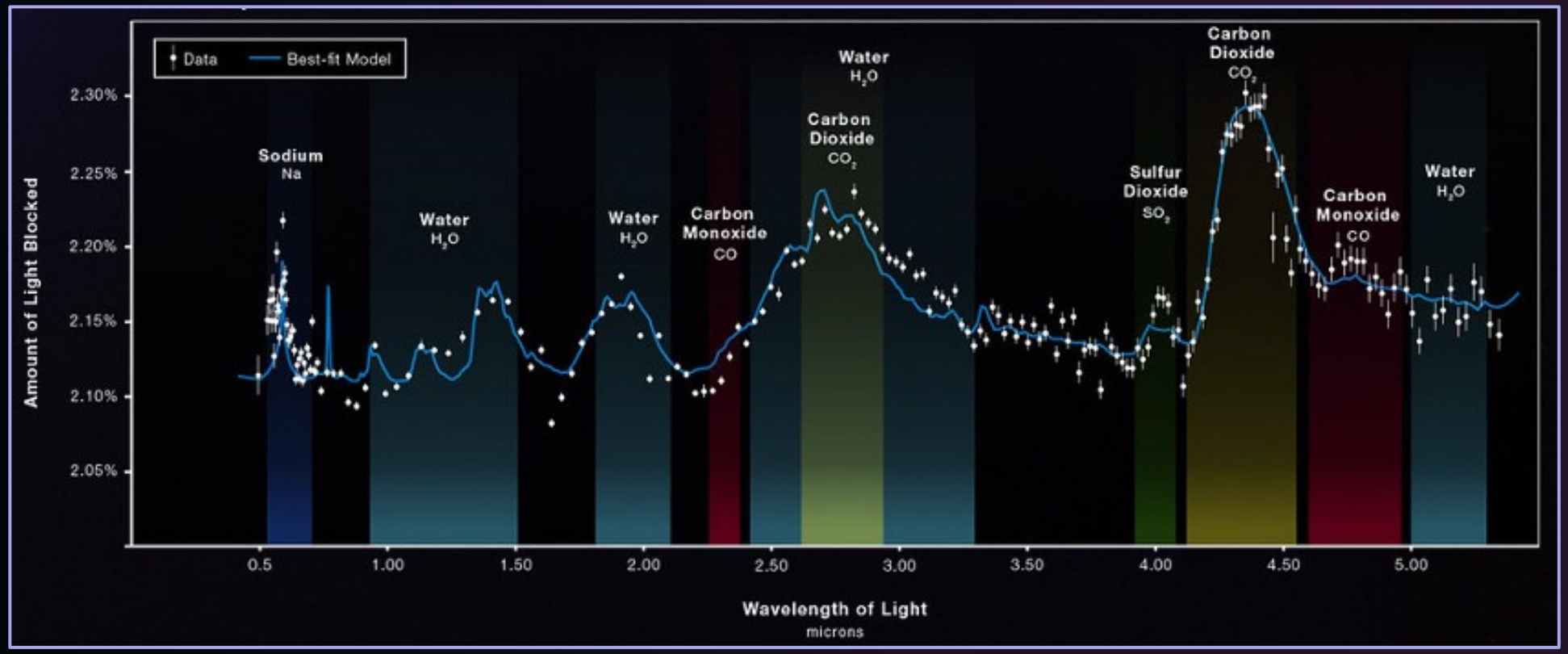
- Abell 2744 with insets showing galaxies that existed 350 and 450 million years after the big bang.
- Webb's findings suggest that the galaxies would have had to begin coming together about 100 million years after the big bang. Credit: NASA, ESA, CSA, T. Treu (UCLA)



- JADES NIRSpec Spectroscopy of GN-z11: a unlensed z = 10.60 luminous galaxy
- Bunker et al. 2023 (arXiv:2302.07256v1)

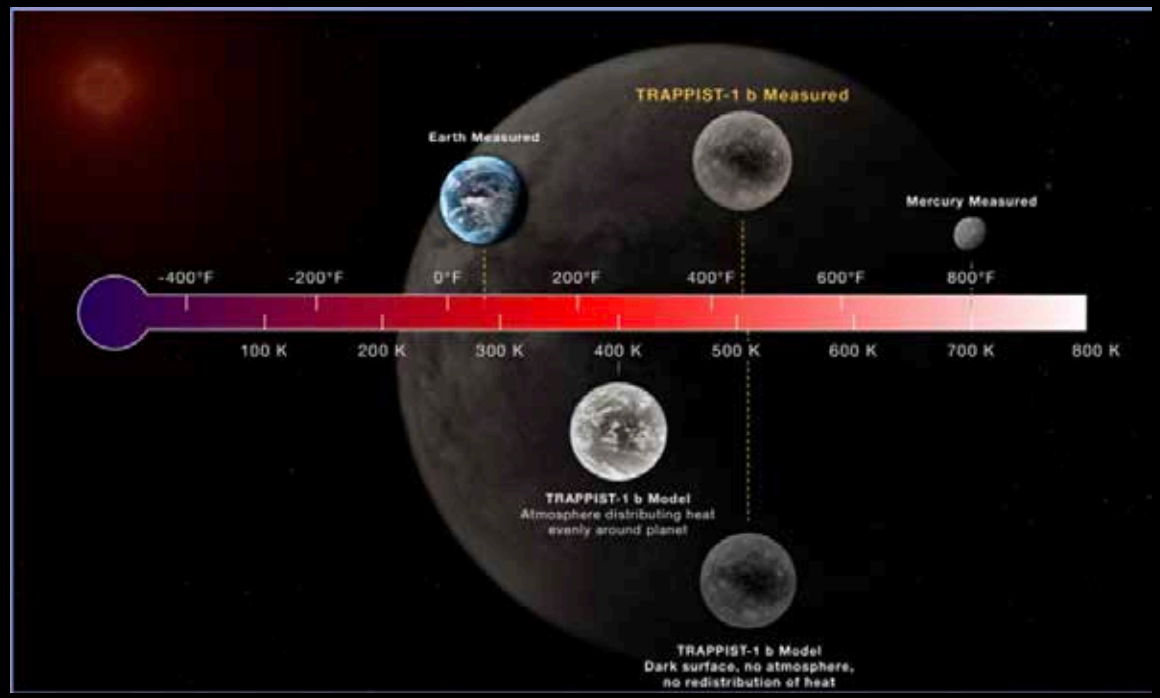


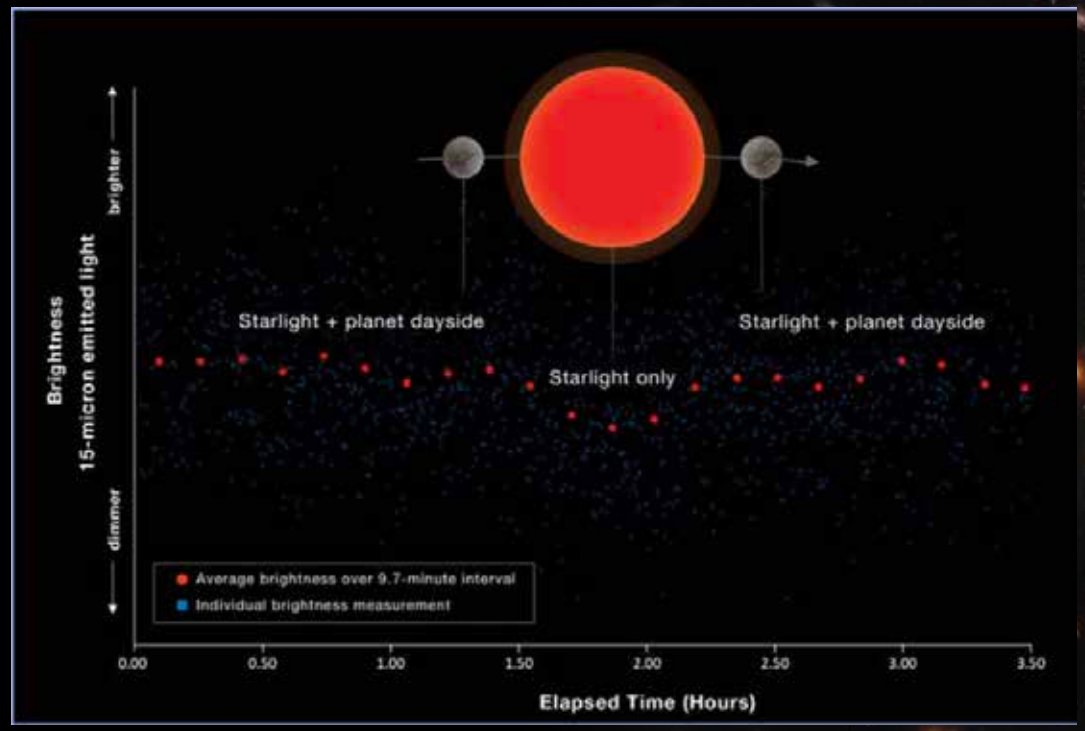
JWST Exoplanet First Science Results

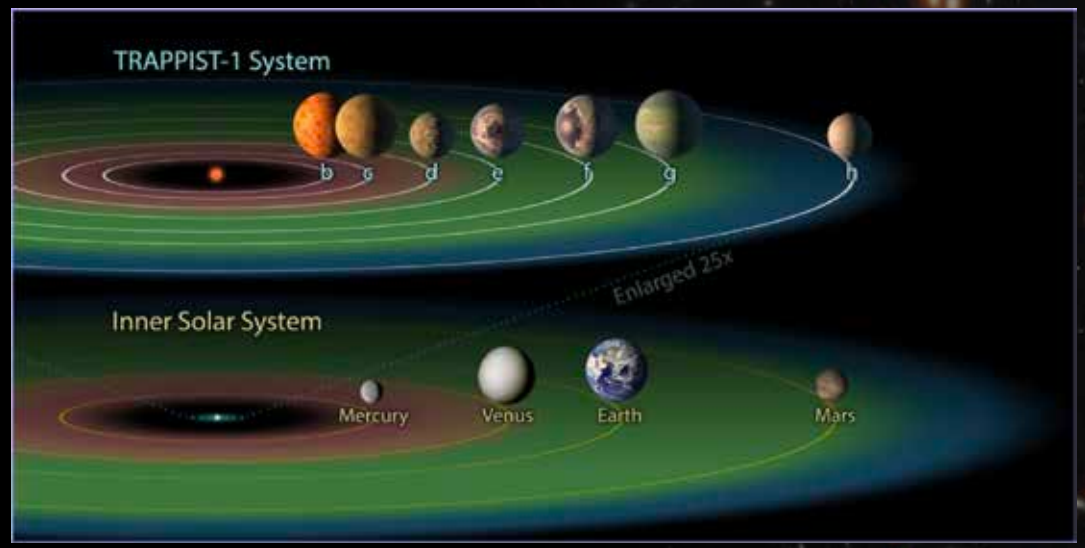


- JWST spectrum of the gas giant exoplanet WASP-39b showing the first molecular and chemical profile of an exoplanet's atmosphere, revealing the presence of H_2O, SO_2, CO, Na and K, as well as signs of clouds, and the first clear evidence of carbon dioxide in a planet outside our solar system. This planet is what is known as a "hot Saturn". The data shown here provide the first concrete evidence of photochemistry.
  Credits: NASA, ESA, CSA, J. Olmsted (STScI)

Trappist 1b


TRAPPIST-1 b Measured
Earth Measured
Mercury Measured
-400°F
-200°F
0°F
200°F
400°F
600°F
800°F
100 K
200 K
300 K
400 K
500 K
600 K
700 K
800 K
TRAPPIST-1 b Model
Atmosphere distributing heat evenly around planet
TRAPPIST-1 b Model
Dark surface, no atmosphere, no redistribution of heat


Brightness
15-micron emitted light
brighter
dimmer
Starlight + planet dayside
Starlight only
Starlight + planet dayside
Average brightness over 9.7-minute interval
Individual brightness measurement
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
Elapsed Time (Hours)


TRAPPIST-1 System
b
c
d
e
f
g
h
Enlarged 25x
Inner Solar System
Mercury
Venus
Earth
Mars

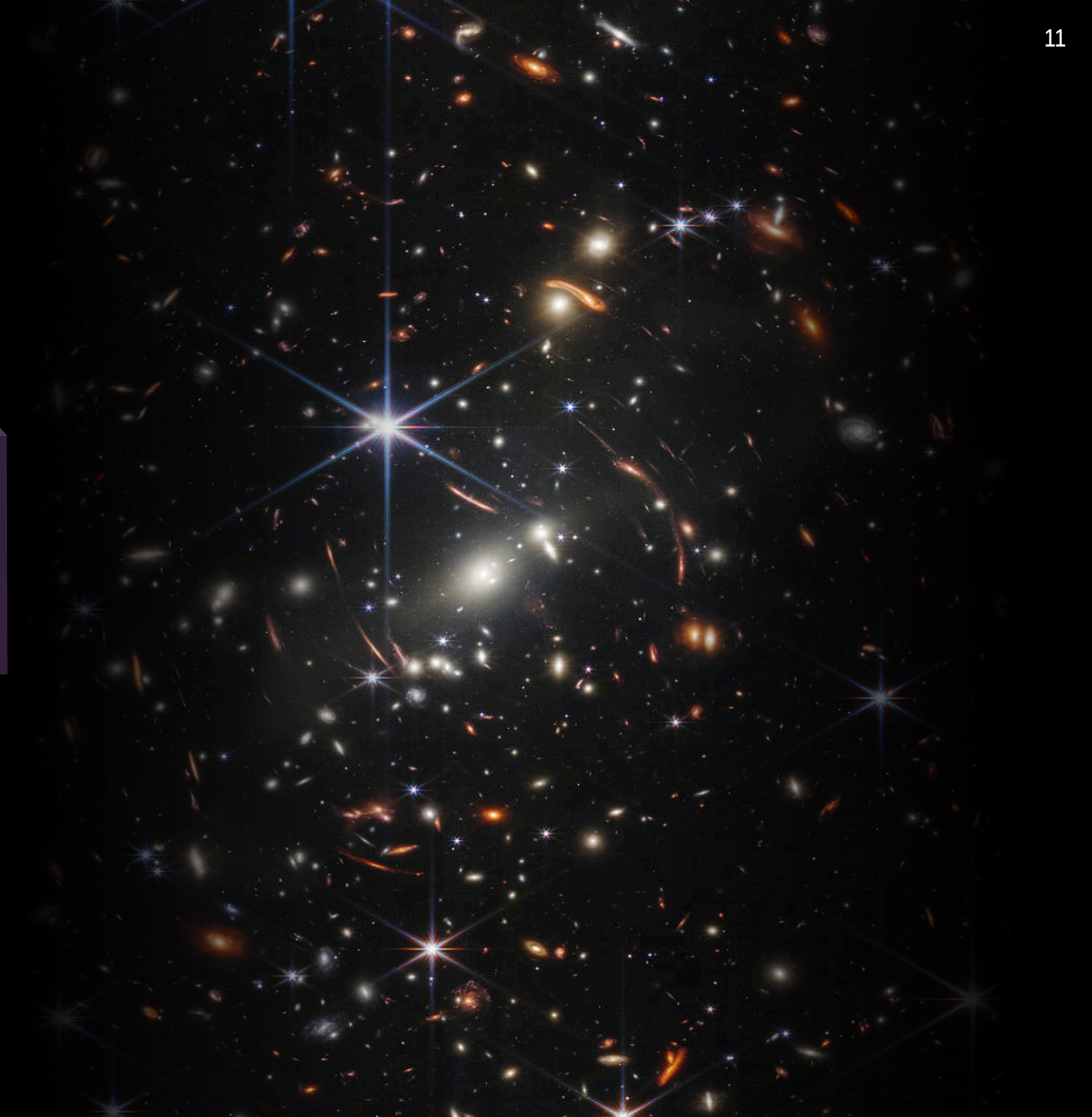
Budget

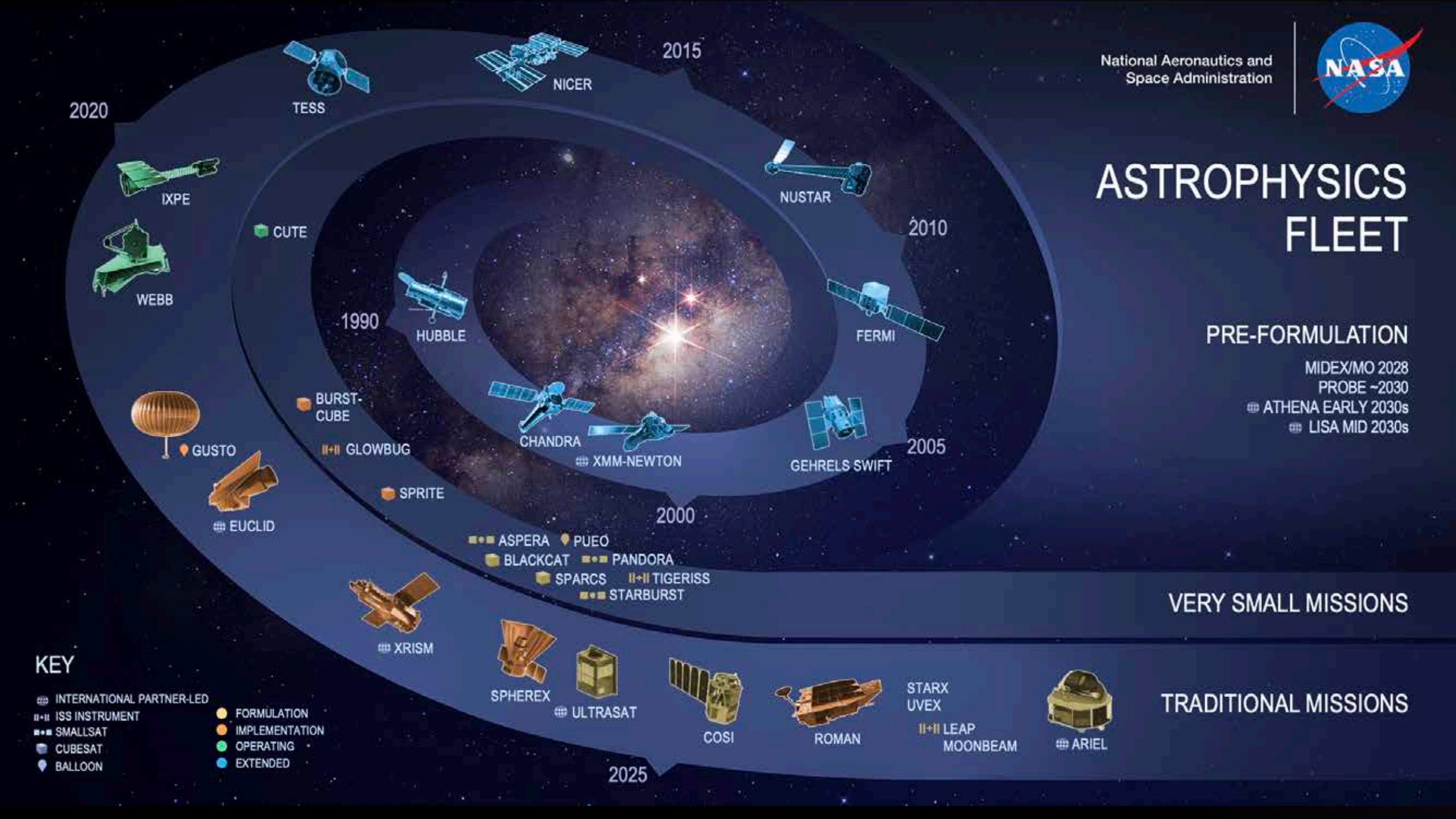
Astrophysics Budget

- FY23 appropriation $1510M, versus FY22 appropriation of $1589M.

- FY24 President's Budget:
  - FY24 request $1557M (FY23 PBR $1556M)
  - Modest decadal wedge begins in FY24 for technology maturation in support of Decadal Survey-recommended GOMAP for Habitable Worlds Observatory
  - Extend operating missions per Senior Review recommendations, including Hubble, Chandra and the Transiting Exoplanet Survey Satellite (TESS)
  - SOFIA close out budget FY23-25 permits responsible closeout, dispositioning of assets, data reprocessing and archiving, and career transition for early careers
  - Delays in Explorers program up to one year
  - Reduction in ATHENA funding pending ESA re-formulation activities

Mission Status




National Aeronautics and Space Administration
NASA
ASTROPHYSICS FLEET
2020
2015
2010
2005
2000
1990
2025
TESS
NICER
IXPE
NUSTAR
CUTE
WEBB
HUBBLE
FERMI
BURST-CUBE
GUSTO
GLOWBUG
CHANDRA
XMM-NEWTON
GEHRELS SWIFT
EUCLID
SPRITE
ASPERA
PUEO
BLACKCAT
PANDORA
SPARCS
TIGERISS
STARBURST
XRISM
SPHEREX
ULTRASAT
COSI
ROMAN
STARX
UVEX
LEAP
MOONBEAM
ARIEL
PRE-FORMULATION
MIDEX/MO 2028
PROBE ~2030
ATHENA EARLY 2030s
LISA MID 2030s
VERY SMALL MISSIONS
TRADITIONAL MISSIONS
KEY
INTERNATIONAL PARTNER-LED
ISS INSTRUMENT
SMALLSAT
CUBESAT
BALLOON
FORMULATION
IMPLEMENTATION
OPERATING
EXTENDED

Astrophysics Mission Classes

DECADAL SURVEY

>$1B $1B

>$2B
LARGE CLASS
Great Observatory or Flagship

~$1.5B
MEDIUM CLASS
Probe
PICC $1B*

EXPLORER AO

$450M $225M

~$450M
SMALL CLASS
Medium Explorer (MIDEX)
PICC $300M*

~$225M
SMALL CLASS
Small Explorer (SMEX)
PICC $145M*

SALMON AO

$80M $40M

$80M
SMALL CLASS
Standard Mission of Opportunity
**

$40M
SMALL CLASS
SmallSat Mission of Opportunity
**

ROSES

$20M $5M

$20M
SMALL CLASS
Pioneers SmallSat
**

$5M
SMALL CLASS
APRA CubeSat

$20M
SUBORBITAL
Pioneers Balloon

$10M
SUBORBITAL
APRA Balloon

$5M
SUBORBITAL
APRA Sounding Rocket

Updated December 11, 2021

*PI Cost Cap **Includes ISS-attached Experiments

Roman Space Telescope

Features

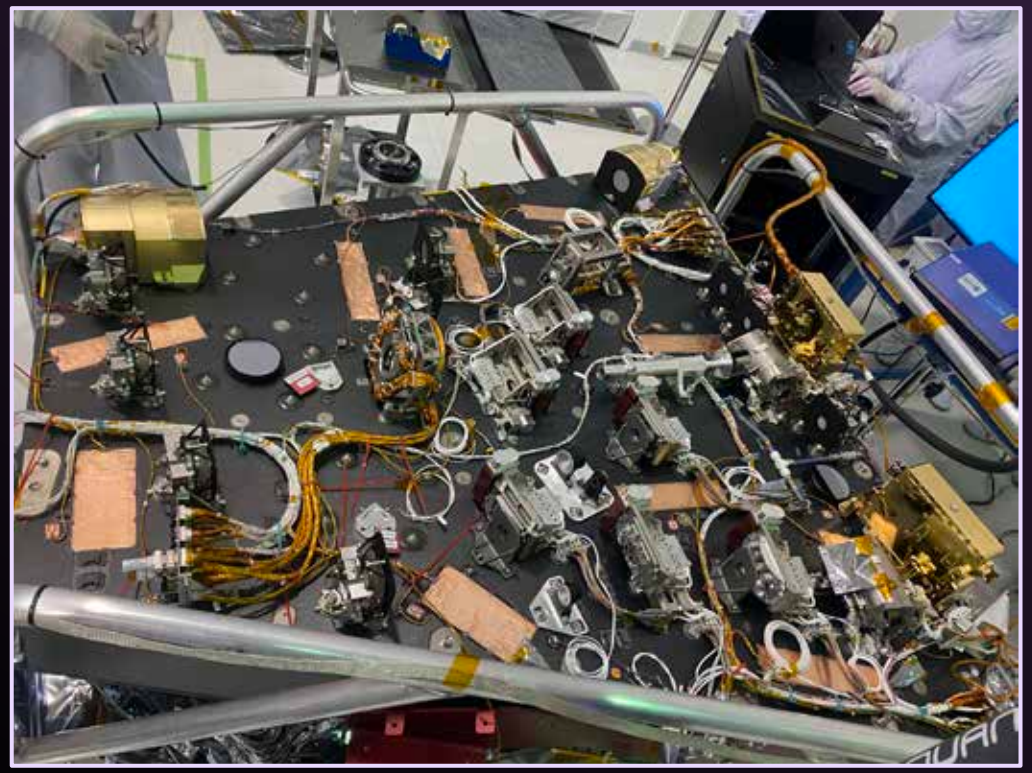
- Determine the nature of the dark energy that is driving the current accelerating expansion of the universe
- Perform statistical census of exoplanetary systems through microlensing survey
- Survey the NIR sky with unprecedented sensitivity, scale, and efficiency

Important Milestones

Roman Coronagraph Instrument

Features

- Able to directly image gas giant exoplanets; pathfinder for future exo-Earth characterization
- Employs active optics to achieve 1000× better planet to host-star flux ratio
- < 1 year to instrument delivery
- All flight hardware @ JPL
- Optics bench fully populated
- Predicted performance:
  ~80% margin on our L1 requirement



Important Milestones

LISA

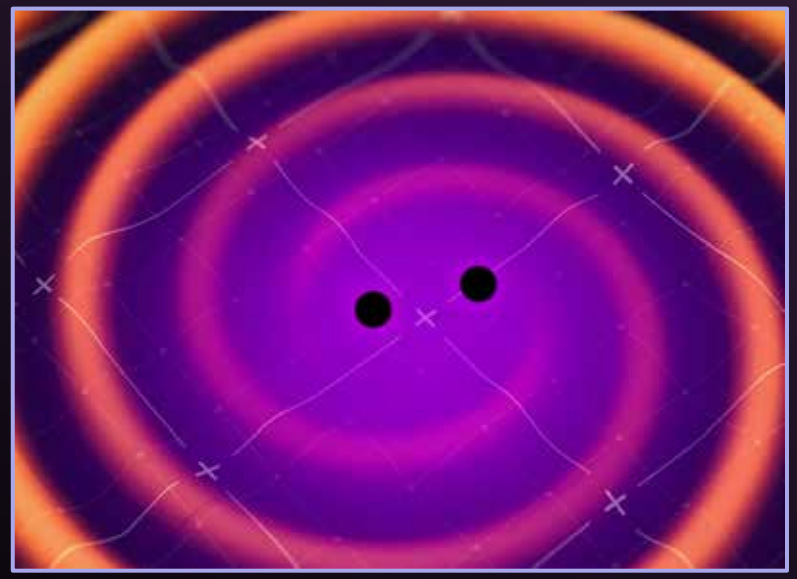
Laser Interferometer Space Antenna

ESA and NASA Partnership

- LISA will be the first space-based gravitational wave observatory (LRD~2037)
- Sources in LISA's milliHertz band range from white dwarf binaries in our galaxy to merging massive black holes at extreme redshift

NASA Contributions:

- Stable telescopes to facilitate inter-spacecraft interferometry
- Laser Systems for interferometer light source
- Charge Management Device for test mass charge control
- Data analysis pipelines and support for science investigations



Merging black holes produce gravitational waves that distort the fabric of spacetime.
Credit: NASA/GSFC Conceptual Image Lab

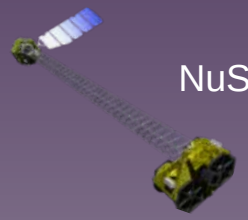
Status:

- NASA in pre-Phase A Study and technology development managed by Physics of the Cosmos Program Office at GSFC. Systems engineering & science support from JPL & MSFC.
- ESA approaching end of Phase B1, Mission Adoption milestone planned for Nov. 2023 (TBC)
- The LISA Preparatory Science Program (LPS) accepted proposals as part of ROSES-22. Closed on March 16, 2023.

Astrophysics Explorers Program

Selected before 2011

Gehrels Swift



NuSTAR

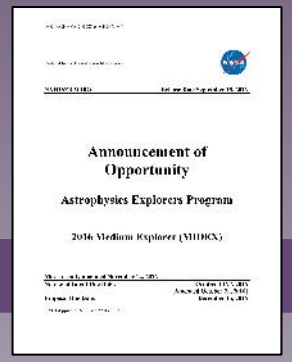
PROBE 2023

SMEX ~~2024~~ 2025

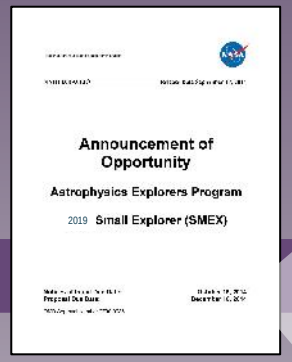
4 AOs per decade

MIDEX 2011

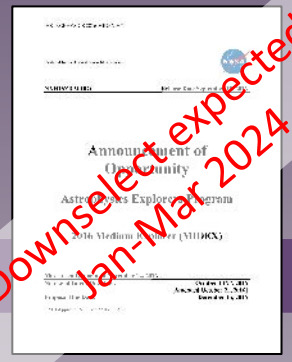
SMEX 2014



MIDEX 2016

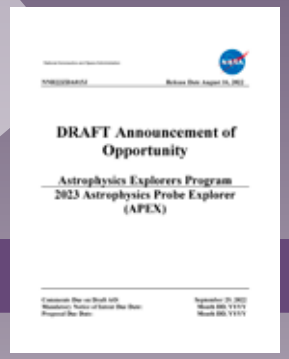


SMEX 2019



Downselect expected Jan-Mar 2024

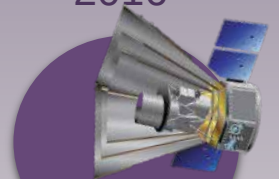
MIDEX 2021



Small and Mid-Size Missions

TESS

IXPE

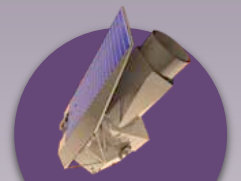


SPHEREx

COSI

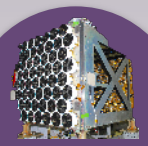
STAR-X
UVEX

Directed 2013



Euclid

Missions of Opportunity



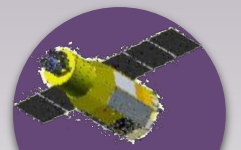
NICER

GUSTO

ARIEL

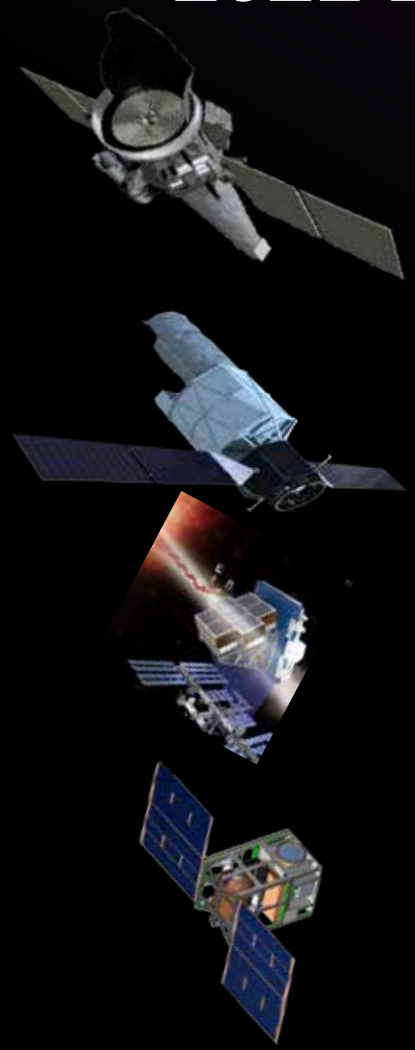
LEAP
MoonBEAM

Directed 2017



XRISM

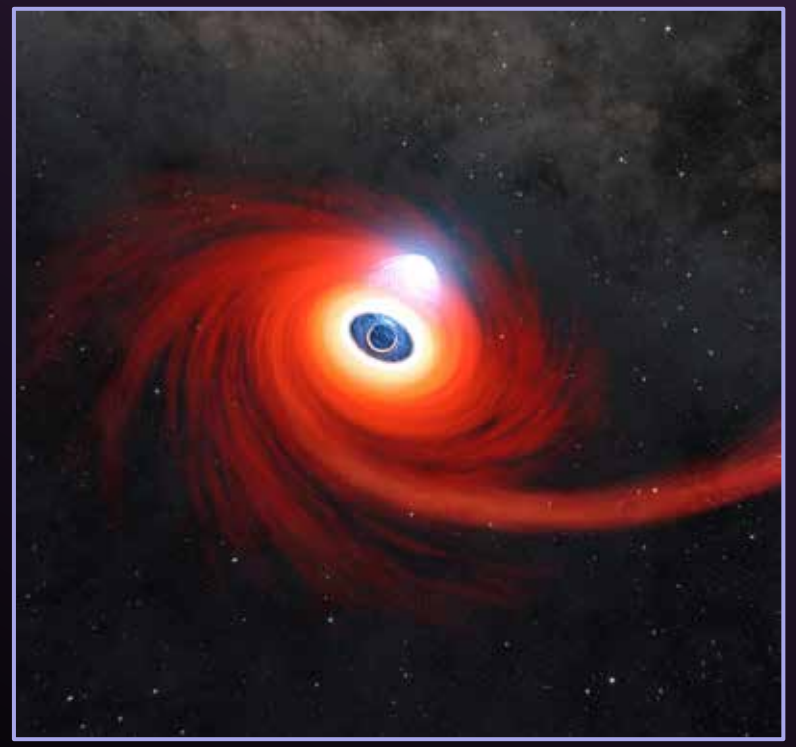
2021 Explorer Competitive Step-2 Studies



- MIDEX: Survey and Time-domain Astrophysical Research Explorer (STAR-X): Sensitive widefield X-ray surveys with < 5 arcsec imaging. STAR-X can respond within 2 hours to point X-ray and UV telescopes at transient cosmic sources. STAR-X Principal investigator: William Zhang (GSFC)
- MIDEX: UltraViolet EXplorer (UVEX): Deep imaging survey in two bands of ultraviolet light, plus R~1000 spectroscopy – new insights into galaxy evolution and the lifecycle of stars. Distributes alerts for transient sources within 1 hour of data receipt, follows up alerts within 3 hours. UVEX Principal investigator: Fiona Harrison (Caltech)
- MO: LargE Area burst Polarimeter (LEAP): Mounted on the ISS, LEAP studies gamma-ray bursts from the energetic jets launched during the formation of a black hole after the explosive death of a massive star, or in the merger of compact objects. MO Principal investigator: Mark McConnell (University of New Hampshire)
- MO: Moon Burst Energetics All-sky Monitor (MoonBEAM): From its lunar-resonant orbit, MoonBEAM sees almost the whole sky at any time, watching for bursts of gamma rays from distant cosmic explosions and providing rapid alerts. MoonBEAM Principal investigator: Chuimun Michelle Hui (MSFC).

NuSTAR
Nuclear Spectroscopic Telescope Array

- In 2022, NASA's NuSTAR mission celebrated 10 years studying the X-ray universe.
- NuSTAR was the first to focus high-energy (>10 keV) X-ray light.
- NuSTAR's made the first unambiguous measurement of a black hole's spin, which it did in collaboration with the ESA (European Space Agency) XMM-Newton low-energy X-ray mission.
- NuSTAR also discovered pulsations from the mysterious Ultraluminous X-ray (ULX) population, which are bright, off-nuclear X-ray sources seen in some nearby galaxies.
    - ULX pulsations imply that at least some ULXs are extreme neutron stars, accreting at 100's of times the limit for stable accretion (i.e., the Eddington limit).

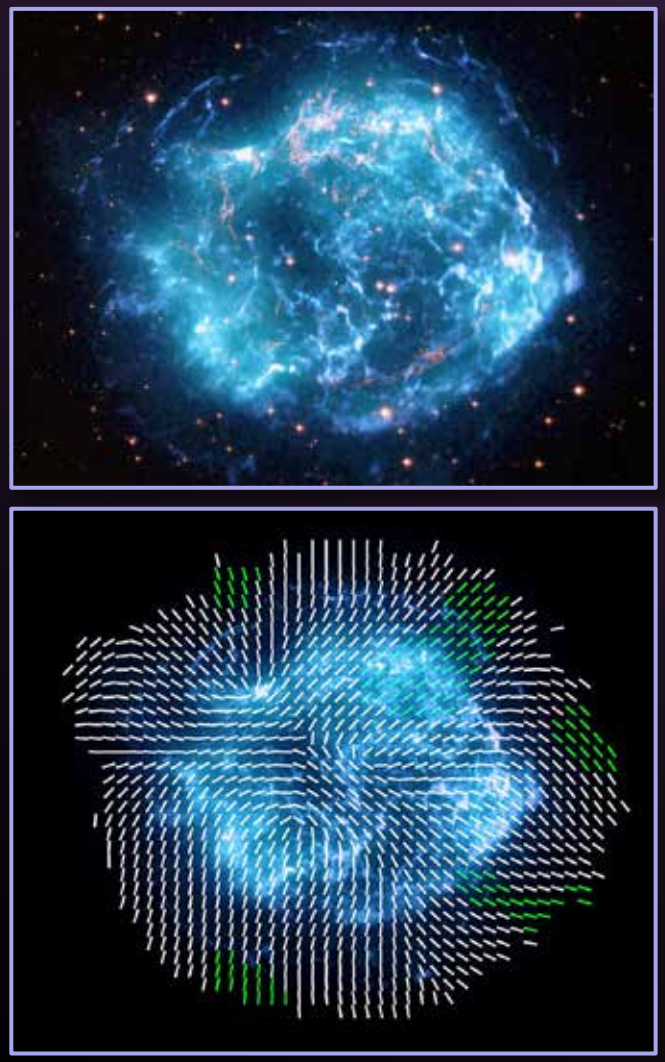


When a star comes too close to a supermassive black hole, tidal forces tear the star apart in a violent and luminous transient phenomenon known as a Tidal Disruption Event. This artist's conception is from a recent news release that reported on NuSTAR observations of an unusually nearby – and thus bright – event, which enabled unprecedented studies of X-ray emission from the newly formed accretion disk and corona.
Credits: NASA/JPL-Caltech

IXPE

Imaging X-ray Polarimetry Explorer

- IXPE (collaboration between NASA and the Italian Space Agency) launched on December 9, 2021.
- IXPE is NASA's first mission to study the polarization of X-rays from many different types of celestial objects.
    - Source classes with robust detections of polarization include magnetars, accreting neutron stars, blazars, accreting stellar mass black holes, and supernova remnants.
- As IXPE approaches the end of its prime mission, APD will make a decision on whether to extend until the 2025 Senior Review
    - Requires an independent assessment of the progress the mission has achieved toward:
        - Meeting its science objectives
        - Fulfilling its technical success criteria
        - Potential for the General Observer



IXPE observation showing the direction of the magnetic field across regions of the remnant Cas A
Credits: X-ray: Chandra: NASA/CXC/SAO; IXPE: NASA/MSFC/J. Vink et al.

ARIEL/CASE

Atmospheric Remote-sensing Infrared Exoplanet Large survey
Contribution to ARIEL Spectroscopy of Exoplanets

ESA and NASA Partnership

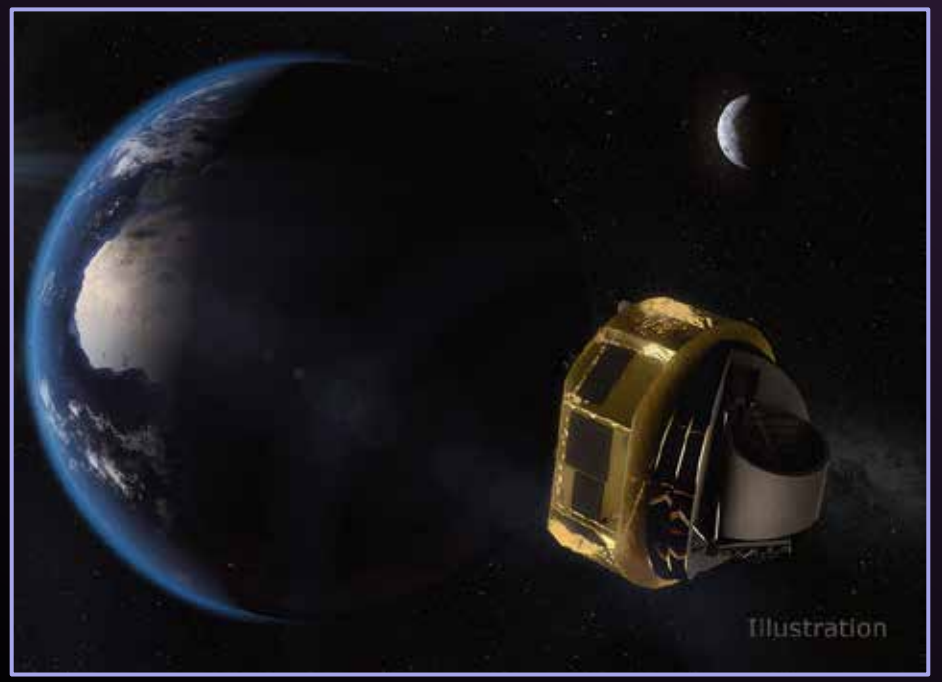
- ARIEL with the CASE, which provides the optical and near-infrared science capabilities and fine guidance sensors will survey and characterize the atmospheres of ~1000 exoplanets.

NASA Contributions:

- Detectors, cold front-end electronics & packaging
- Thermal Management
- Cryoflex cables for ARIEL Fine Guidance System
- Providing US participation in science team, mission survey design, and scientific discoveries

Status:

- Project entered Phase C in February 2023

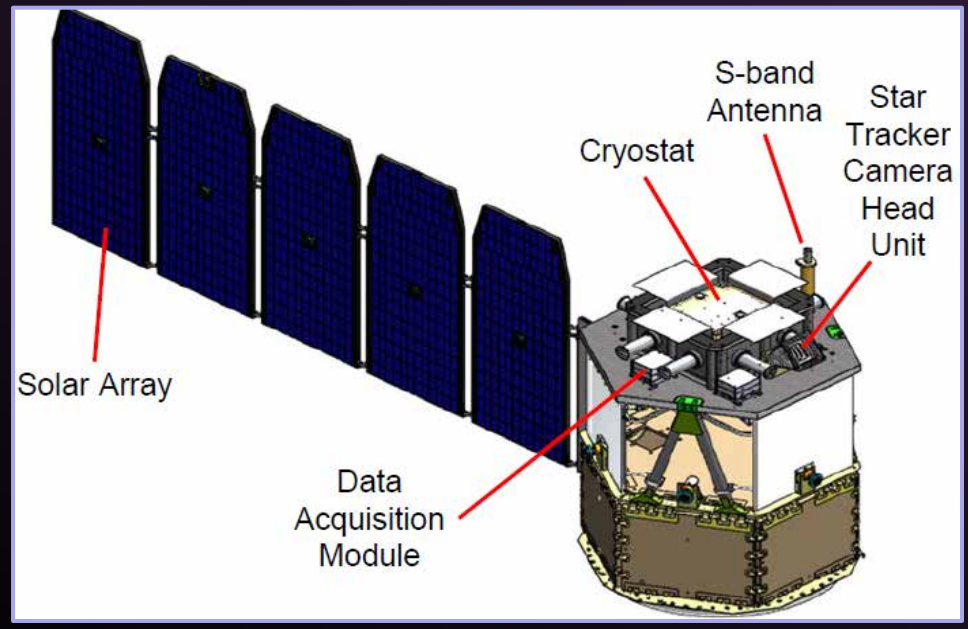


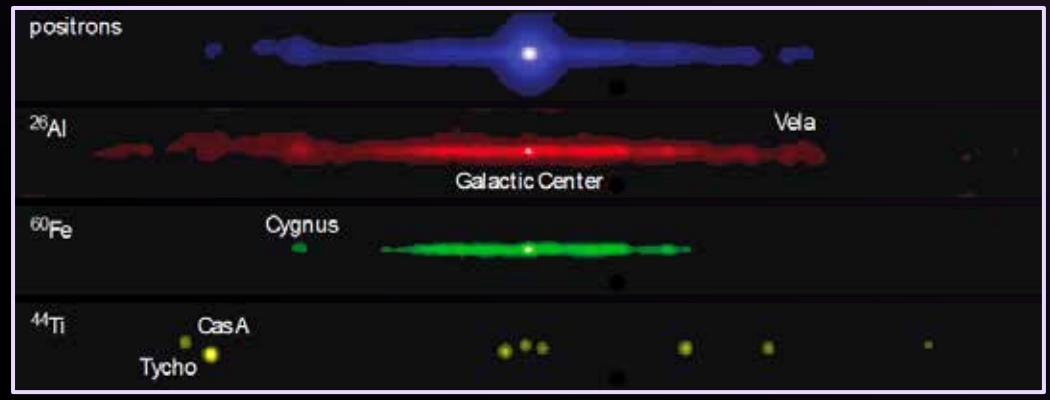
An artist's concept showing ARIEL in orbit.
Credit: ESA/STFC RAL Space/UCL/Europlanet Science Office

Compton Spectrometer and Imager (COSI)

- **PI: John Tomsick, UC Berkeley**
- COSI is Compton imaging spectrometer with cryogenic Ge detectors for 0.1-5 MeV gamma-rays
- COSI will provide an understanding of the positron excess; map ^{26}Al (half-life 60yr) to study element formation; make the first map of ^{60}Fe (half-life 2.6Myr, only source is core-collapsed SN) to trace past core collapse supernovae; and discover new young supernovae in ^{44}Ti (half-life 0.7Myr).
- COSI will use polarization to gain insight into extreme environments, such as accreting black holes (AGN and Galactic) and γ-ray bursts (GRBs).
- COSI will localize the γ-ray counterparts to GW events (short GRBs) and detect high-energy neutrino counterparts.
- System Requirements Review January 2023; Preliminary Design Review February 2023

Launch Readiness Date: 2027





Simulated Radioactive Milky Way

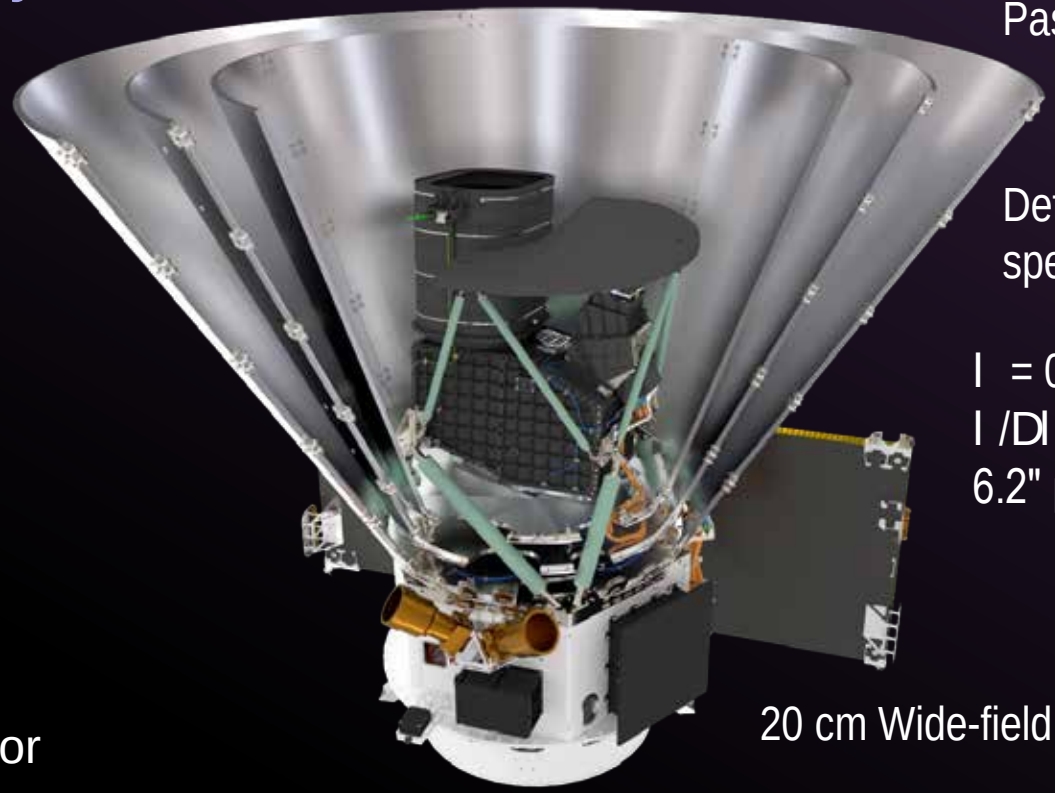
Sphere-X

An All-Sky Infrared Spectral Sky Survey

Small Mission, Big Science

- Origin of the Universe
- Origin and History of Galaxies
- Origin of Water in Planetary Systems
- First All-sky Infrared Spectral Survey

- Critical Design Review (CDR) successfully completed Jan 2022
- Systems Integration Review (SIR) planned for December 2023
- Current Agency launch readiness date is April 2025



GUSTO

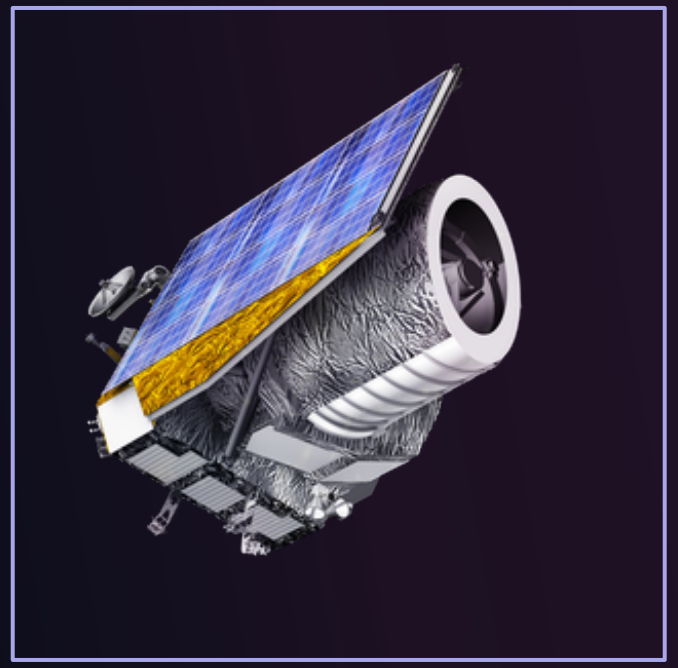
An All-Sky Infrared Spectral Sky Survey

Science Description	Project Description	Key Information
GUSTO will provide the first complete study of all phases of the stellar life cycle, from the formation of molecular clouds, through star birth and evolution, to the formation of gas clouds and the re-initiation of the cycle. GUSTO provides 500 times the angular and 1,000 times the velocity resolution of previous surveys of the Galaxy in [CII], [OI], and [NII].	Sub-orbital Balloon-borne 0.9 m Cassegrain telescope launched from Antarctica to study the Milky Way and the Large Magellanic Cloud.	**Mission Phase:** C **Launch Date:** 12/2023 **Mission Life:** 75 days **Category:** 3 **Class:** D Streamlined **Launch Vehicle:** Zero Pressure Balloon

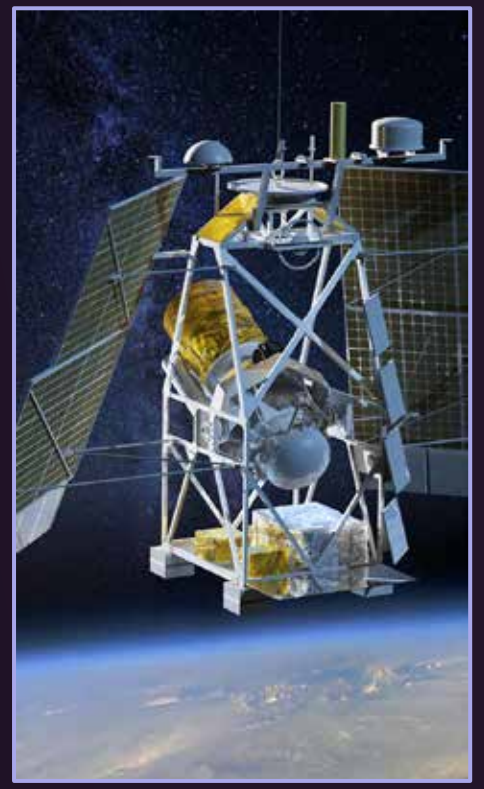
- GUSTO is scheduled to fly from Antarctica in December 2023

Astrophysics Division Launches: CY2024

XRISM:
Tanegeshima, Japan 2023



Euclid
Kennedy Space Center, July 2023



GUSTO (SMEX Balloon)
Antarctica December 2023

ATHENA

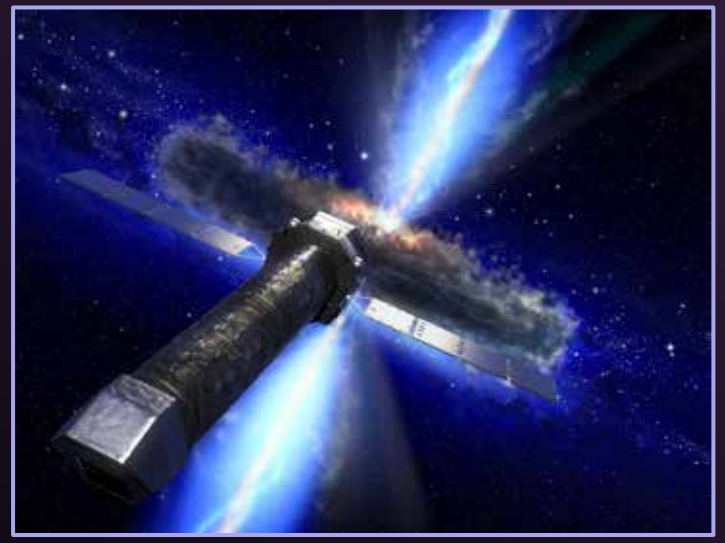
Advanced Telescope for High Energy Astrophysics

ESA and NASA Partnership

- ATHENA will look deep into the X-ray Universe, studying the evolution of super-massive black holes and hot gas in and out of galaxies over the life of the Universe.

Status:

- Mission is being reformulated by ESA, whilst retaining flagship-level science. NASA has reiterated support for Athena and willingness to reprioritize its contributions.
- Rachel Osten (STScI) and Lía Corrales (U. Michigan) selected as the NASA representatives to the Athena Science Redefinition Team (SRDT). Andy Ptak (NASA Athena PS) selected as Mission Redefinition Team (MRT) point-of-contact.



Artist's concept of ATHENA.
Credit: ESA

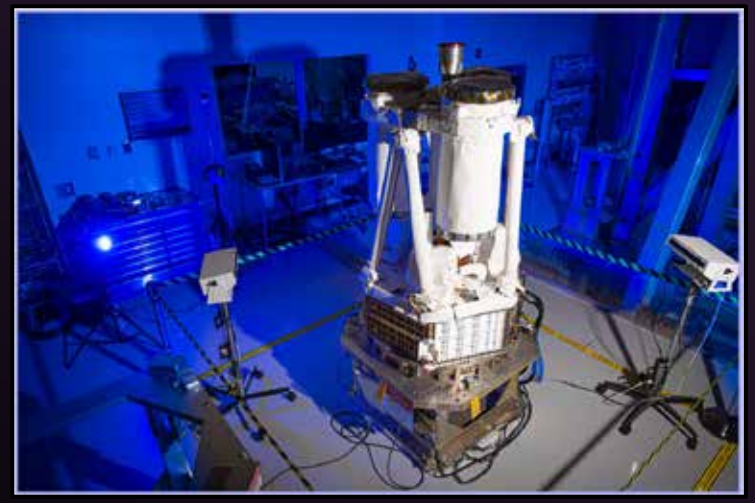
Current "NewAthena" mission concept

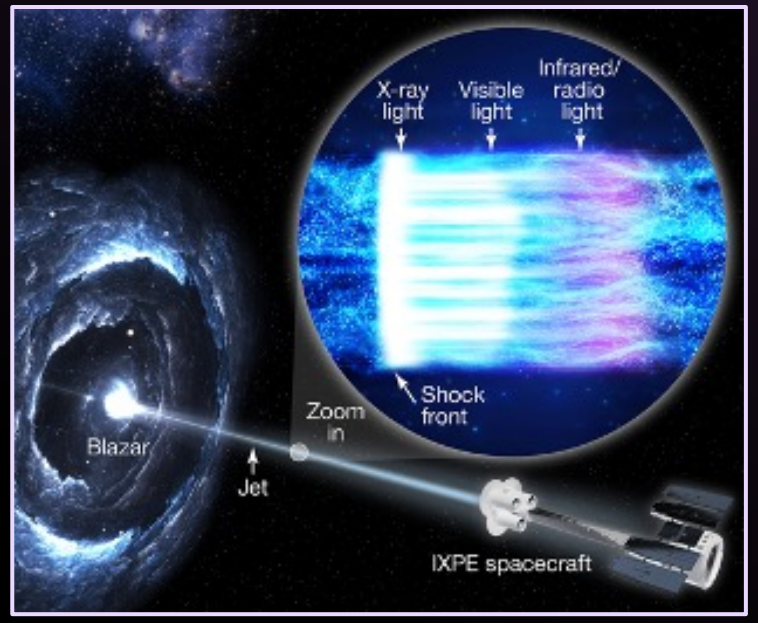
- Effectively dependent on the US contribution of a 50K -> 4K cryocooler to the X-IFU
- Mission profile results in reductions to performance relative to original Athena, but retains a large X-ray mirror, the X-IFU calorimeter with at least 4 eV energy resolution, and the Wide-Field Imager (WFI)

- Budget Impacts
  - In light of deferred Adoption date ~(2027) , FY24 PBR contains significant slowdown to Athena.
  - With planned switch to a crycooler as a NASA contribution, the FY24PBR Athena budget withdraws support for the XRCF testing element (FY25 onwards), with a significant reduction in FY24 for XRCF testing.

IXPE shows that many high-energy sources are polarized

- IXPE (Imaging X-ray Polarimetry Explorer, a collaboration between NASA and the Italian Space Agency) launched on December 9, 2021 – it is NASA's first mission to study the polarization of X-rays.
- Mission operations began on January 11, 2022. IXPE is now in the second year of its two-year baseline mission.
- As of January 11, 2023, 39 sources were observed; 20 of these have secure detections of X-ray polarization: e.g.
  - Blazars Mrk 421 and Mrk 501 are 10%-15% polarized in X-rays, 2-5x more than in visible light: X-rays likely from a magnetized shock (lower picture)
  - Accreting stellar-mass black hole Cyg X-3 shows 25% polarization: X-rays likely reflected from a thick dusty torus.
- If IXPE passes review at the end of its two-year mission, a general observer program will begin in February 2024.

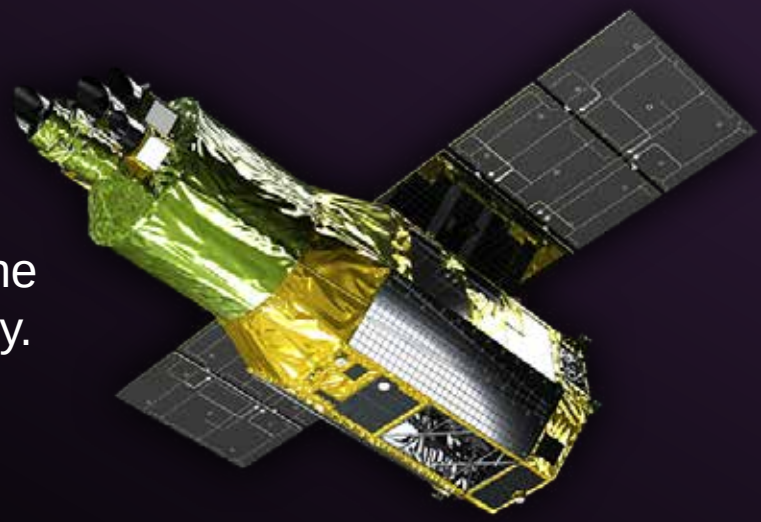




XRISM

X-Ray Imaging and Spectroscopy Mission

- XRISM, formerly known as XARM, is a JAXA/NASA collaborative mission with ESA participation and is expected to launch May 2023.
- The objective of the mission is to investigate celestial X-ray objects in the Universe with high-throughput imaging and high-resolution spectroscopy.
- The XRISM payload consisted of two instruments:
  - Resolve - a soft X-ray spectrometer
  - Xtend – a soft X-ray imager
- The first XRISM Data Analysis Workshop was held on February 22 & 23, 2023.
  - The objective of this workshop was to prepare the astronomical community for the upcoming Cycle 1 General Observer Call for Proposals for XRISM.



Credit: JAXA

Astrophysics Explorers: Future AOs

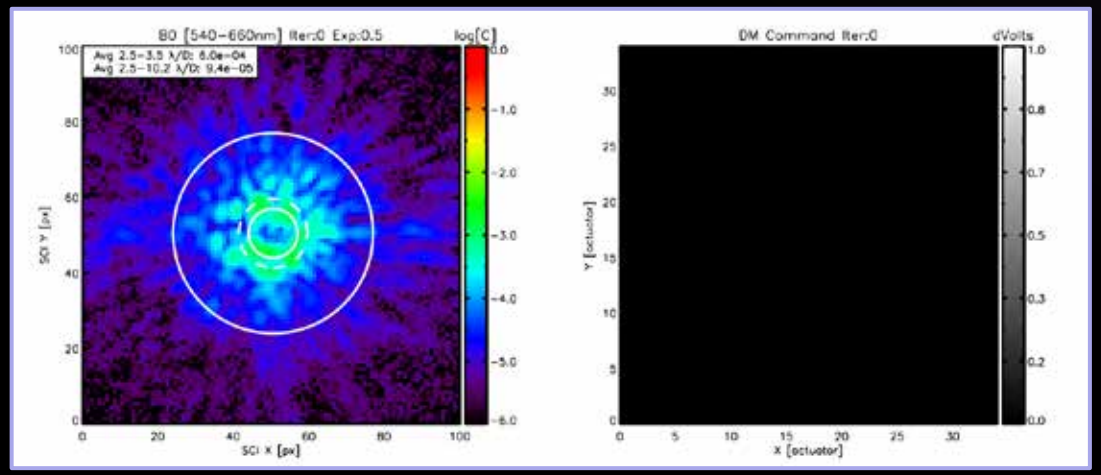
- Since the release of the Astro2010 report, Astrophysics has been able to maintain a cadence of 4 Explorers opportunities per decade, each offering a Mission and a Mission of Opportunity.
- The FY24 budget request does not allow the release of the next SMEX/MO AO in Spring 2024; instead, it is deferred by a year to Spring 2025.
- At this point there is no change to the timing of the 2026 MIDEX/MO.

Balloon Program

- During 2022, NASA successfully implemented a scientifically productive Balloon Campaign.

PICTURE-C: Balloon-Borne Coronagraphy

- The first on-sky coronagraph dark hole created in a space-like environment



Chakrabarti et al. - U Mass Lowell

SPIDER: Balloon-borne CMB experiment

- **SPIDER** studies the Cosmic Microwave Background (CMB) and its polarization for indications of gravitational waves associated with the Big Bang.

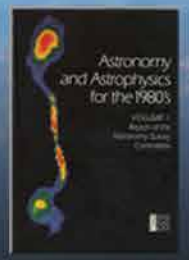
SPIDER’s balloon flight track over Antarctica

ASTRO2020 Forward Plan

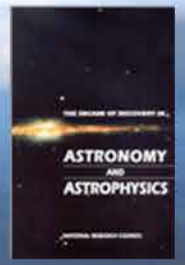
Astrophysics

Decadal Survey Missions

1972
Decadal Survey
Hubble



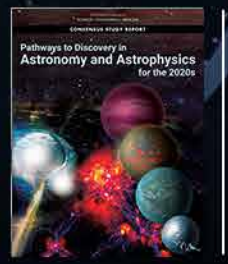
1982
Decadal Survey
Chandra



1991
Decadal Survey
Spitzer

2001
Decadal Survey
Webb

2010
Decadal Survey
Roman



2021
Decadal Survey

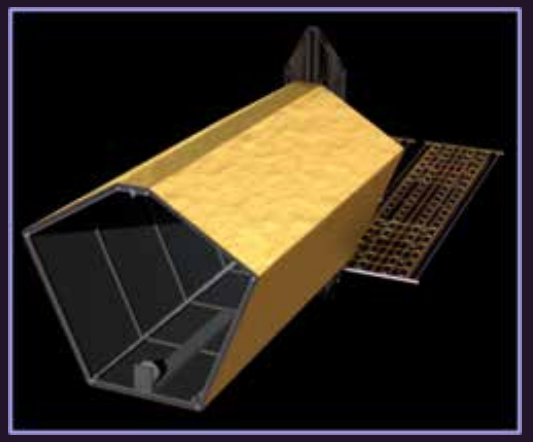
Status of Astro2020 Key Recommendations

Key Mission Recommendations	Latest Action	Next Planned Action
Near-Infrared/Optical/Ultraviolet 6-m telescope with high-contrast imaging capability (part of GOMAP program)	Technology strategy	
Great Observatory Mission and Technology Maturation Program (GOMAP)	GOMAP discussions underway within NASA, Precursor Science workshops held April, October 2022	APAC Spring Meeting, March 29-30, 2023
Space-based time-domain and multi-messenger counterparts program (TDAMM)	APD conducted a 8/22-24/2022 Workshop	APAC Spring Meeting, March 29-30, 2023
Astrophysics Probe Mission	8/16/2022 Draft Call for Proposals	APAC Spring Meeting, March 29-30, 2023
End SOFIA operations by 2023	SOFIA operations ended. NASA's Press Release 9/30/2022	Action complete

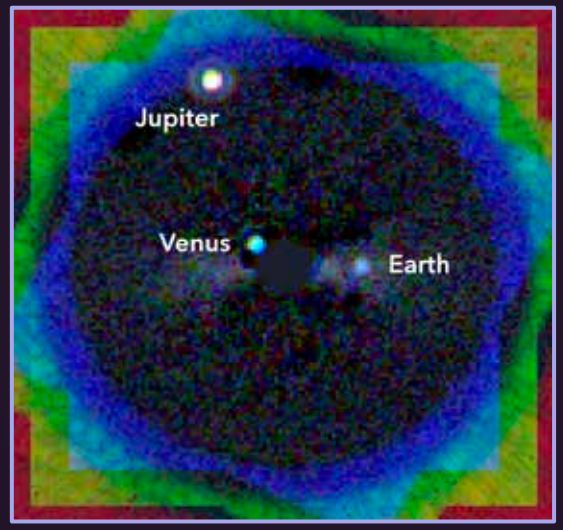
APD Responses to Decadal

Pathways to Habitable Worlds: Astro2020

- **Are there habitable planets harboring life elsewhere in the universe?**



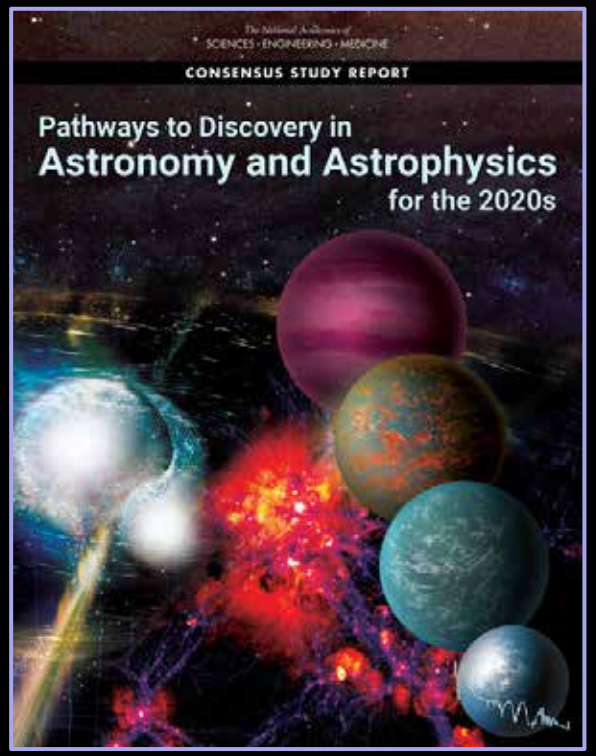
- **Primary recommendation:**
  - Space telescope, with ~6 meter aperture and coronagraphic imaging capability
  - Observe ~100 nearby sun-like stars, and detect potentially habitable planets
    - Survey habitable planet candidates for evidence of life
  - Conduct program of general astrophysics

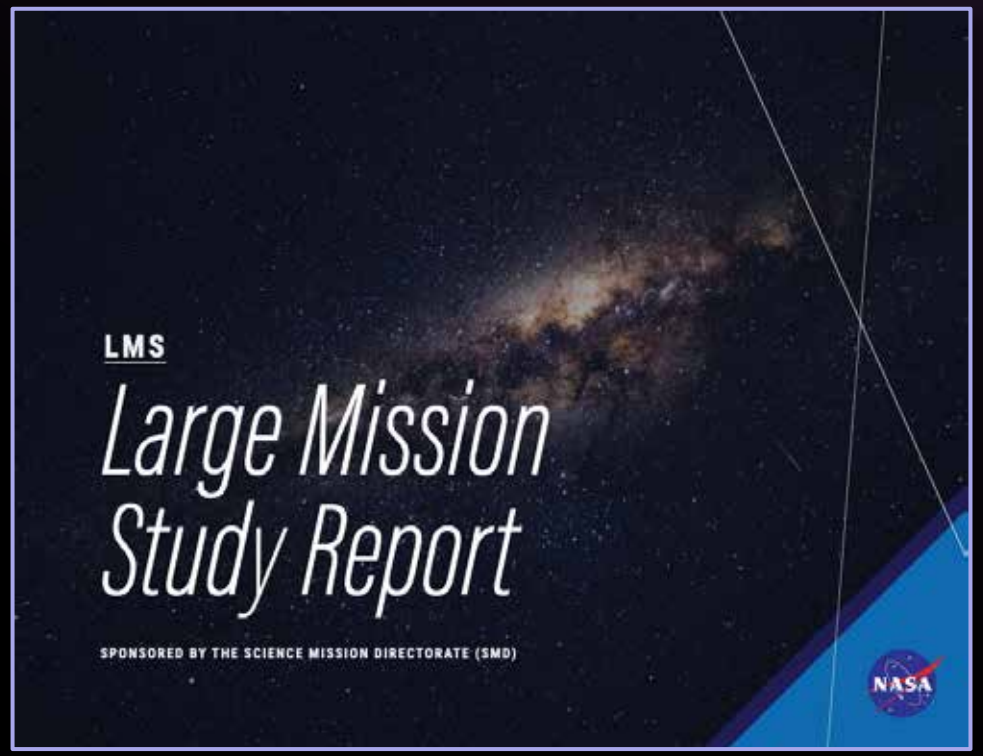


- Primary Technical requirements
  - Segmented mirror telescope w/active control of WFE achieving ~10s pm stability
  - Coronagraph achieving contrast levels of 10^{-10}

- **Habitable Worlds Observatory**

The Habitable Worlds Observatory:
Big Picture Strategy





The Habitable Worlds Observatory:
Big Picture Strategy

- **Build to schedule**: Mission Level 1 Requirement e.g. Planetary mission strategy
- **Evolve technology**:
  - Build upon current NASA investments and TRL-9 technology
  - Segmented optical telescope system from JWST
  - Coronagraph from Roman ‘s coronagraphic imager program
- **Next Generation Rockets**:
  - Larger telescope aperture sizes
  - Leverage opportunities offered by large fairings to facilitate mass & volume trades
- **Planned Servicing**: Robotic servicing at L2
- **Robust Margins**: Design with large scientific, technical, and programmatic margins
- **Mature technologies first**: Reduce risk by fully maturing the technologies prior to development phase.

The Habitable Worlds Observatory
Big Picture Strategy

ASTRO2020 recommendation and timescale drives a focused technology program

Telescope

- Large segmented mirror investments with ongoing technology development program
- Scalable to launcher fairing options & next 5 years of science metrics outcomes
- Legacy of JWST technology investments (TRL-9) and infrastructure
- JWST as an on-orbit testbed
- Industry capabilities
- Focus investments on technology tall-poles rather than investing in infrastructure

- **Coronagraph**
  - Significant investment in Roman coronagraph (future on-orbit testbed)
  - Significant investments through SAT & APRA coronagraph programs

The Habitable Worlds Observatory

Habitable Worlds: Primary Science Goal

- Survey nearby stars for habitable planets, and spectroscopically characterize them for evidence of life (biosignatures)

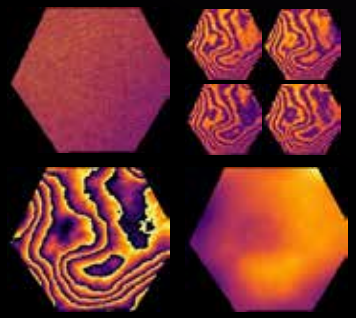
Observatory: General Astrophysics Program

Future Great Observatories

- Decadal Survey recommends future X-Ray and Far-IR future great observatories
  - Note that investments would begin towards the end of the decade per the Survey's recommendations
  - APD will maintain X-Ray/Far-IR technical capabilities this decade via:
    - SAT and APRA program investments
    - 2023 Probe solicitation for X-Ray and Far-IR mission concepts
    - Explorers program

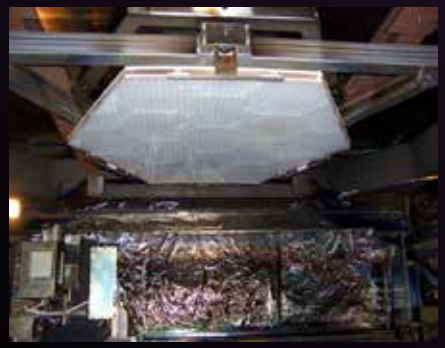
Astrophysics Technology Investments

Big Picture Strategy



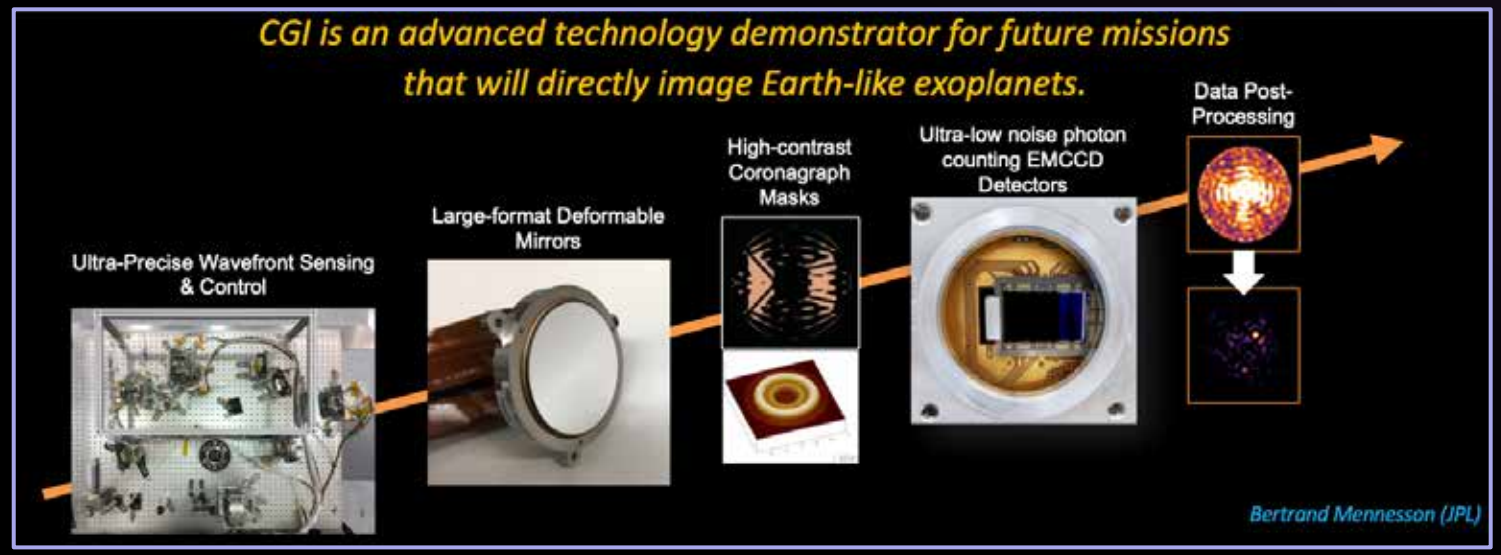
Credit: NASA GSFC

Picometer-scale dynamics measured with high-speed interferometry



Credit: L3/Harris

Lightweight ULE mirror segment



Astrophysics Probe

- On August 16, 2022 NASA issued a draft AO for a PI-led Astrophysics Probe for comment.
- The PI cost cap is $1B; AO requires a General Observer/Guest Investigator (GO/GI) Program during the 5-year prime mission. For a pointed observatory, 70% of observing time is allocated for GO. A survey observatory will make data available as soon as practicable.
- The target date for the final Probe AO remains July 2023
- This is a two-step AO: because the Probes are more complex than previous Explorers, and this is the first one, the competitive Phase A studies will last 12 months
- In response to the recommendation of Astro2020, Astrophysics will accept proposals for:
  - A far-infrared imaging and/or spectroscopy mission
  - An X-ray probe
- Proposing teams should check the Q&As frequently at https://explorers.larc.nasa.gov/2023APPROBE/

Release of final AO:	**July 2023 (target)**
Proposals due:	NET mid-November 2023

Time Domain and Multi-Messenger Astrophysics (TDAMM)

- Astro2020 Decadal Survey recommended Time-Domain and Multi-Messenger Astrophysics (TDAMM) as highest priority sustaining activity for NASA Astrophysics.
  - TDAMM contributions of current NASA fleet highlight the need to maintain and replace the workhorse missions.
  - Recommended strategic approach is to add space-based capabilities based on science priorities and status of complementary facilities.
    - e.g. gravitational-wave, neutrino, international e/m missions
  - Roman Space Telescope is a game changer for TDAMM: Opportunities for TDAM astrophysics in recent Roses call
  - New NASA missions address need for continuous monitoring for transients (X-Ray, Gamma-ray)
    - Smallsat missions (BurstCube, GlowBug,BlackCat, StarBurst)
    - Explorers: COSI (in development)
      - Star-X, UVEX, LEAP and MoonBeam (in Step-2 competitive downselect)
    - NASA partnership with Israel (ULTRASAT) adds sensitive wide-field UV monitoring
    - Planetary Mission NEO-Surveyor adds IR transient monitoring capability

Time Domain and Multi-Messenger Astrophysics (TDAMM)

- Conducting a study of coordinating TDAMM observations among NASA spacecraft using centralized proposal, and ToO initiation to make more efficient use of fleet
- NASA transient alert system
  - Modernizing in preparation for the Rubin era of ~10^6 alerts per night
  - Funding multi-mission and mission-design software tools for community use
  - Initiating discussions across Agencies e.g. LIGO w/NSF
- PhysCOS/COR hosted TDAMM workshop in Annapolis, MD. on August 22-24, 2022
  - White Paper recently delivered and posted
  - International agency meeting identified areas of collaboration
    - 2nd meeting International working group held 3/2023 to discuss coordination
- Through PhysCOS community groups, supporting new and upcoming Science Analysis Groups in the areas of Gamma-ray Transient Networks and Space Communications

TDAMM Report

TDAMM Workshop

2023 Astrophysics Research Solicitations

Supporting Research and Technologies			
Astrophysics Research & Analysis	APRA	IP	
Strategic Astrophysics Technology	SAT	IP	
Astrophysics Theory Program	ATP	IP	DAPR
Nancy Grace Roman Technology Fellowships	RTF		
Astrophysics Decadal Survey Precursor Science	ADSPS		DAPR
Data Analysis			
Astrophysics Data Analysis	ADAP		DAPR
Fermi, Swift, NuSTAR, NICER, TESS, **IXPE** New	GO/GI		DAPR
Mission Science and Instrumentation			
Astrophysics Pioneers (suborbital science)	Pioneers		DAPR
Suborbital payloads solicited through APRA	APRA	IP	DAPR
Roman Research and Opportunities	Roman	IP	DAPR
Cross Divisional			
Exoplanets Research Program	XRP		DAPR
Topical Workshops, Symposia and Conferences	TWSC		
Citizen Science Seed Funding Program	CSSFP		
Graduate Student Research Awards	FINESST		

Solicited Separately			
JWST, Hubble, Chandra GO/GI/Archive/Theory programs	GO/GI		DAPR
NASA Hubble Fellowship Program	NHFP		
NASA Postdoctoral Program	NPP		
Support for XMM-Newton U.S. PIs (selected by ESA)	XMM GO		
Not Solicited in ROSES-23			
Theoretical and Computational Astrophysics Networks, every other year	TCAN	IP	DAPR

IP: Proposals require an Inclusion Plan for creating and sustaining a positive and inclusive working environment.

Assessment of IP not part of adjectival rating / does not inform selection of proposals. However, funding only released after a satisfactory Inclusion Plan is accepted.

Inclusion Plan pilot program will continue in 2023 but likely not expand until later.

DAPR: Proposals evaluated using dual-anonymous peer reviews where panelists do not know the identities of the proposing teams and institutions.

On-going & Planned IDEA Initiatives in APD

- Inclusion Plans in ROSES22:
  - Piloting continues - APRA, LISA, SAT, TCAN, Roman, Precursor Science
  - IP assessment criteria are not part of evaluation criteria but if IP is inadequate, funding released only after IPs are judged to be adequate
  - ROSES 23 has new standardized language and various programs across SMD will continue to pilot this effort
  - SMD held a community workshop and a resources page available as of January 2023 under SMD Inclusion webpage
- APD Community Days have begin
  - APD Virtual visit (Clampin, Eric Smith, Cucchiara, Sheth) visited Puerto Rico on March 7th.
  - Stakeholders on the island engaged in planning
  - Faculty and graduate students across island invited
  - Follow up visits planned to further engage on specific areas (i.e. engineering / technology as well as undergraduate research etc.)

On-going & Planned IDEA Initiatives in APD

Continued

- Statement of Principles by APD developed and shared across NASA Astrophysics ecosystem

Statement of Principles

- Regular attendance at National Society of Black Physicists (NSBP) and Society for Advancement of Chicanos and Native Americans in Science (SACNAS) meetings

- Other previous APD pioneering efforts:
  - Code of Conduct for review panels developed by APD, now adopted SMD-wide!
  - Changes in language to Senior Review (SR) aligned with NASA's core value of Inclusion – our changes to SR adopted SMD-wide!
  - Changes to AO language

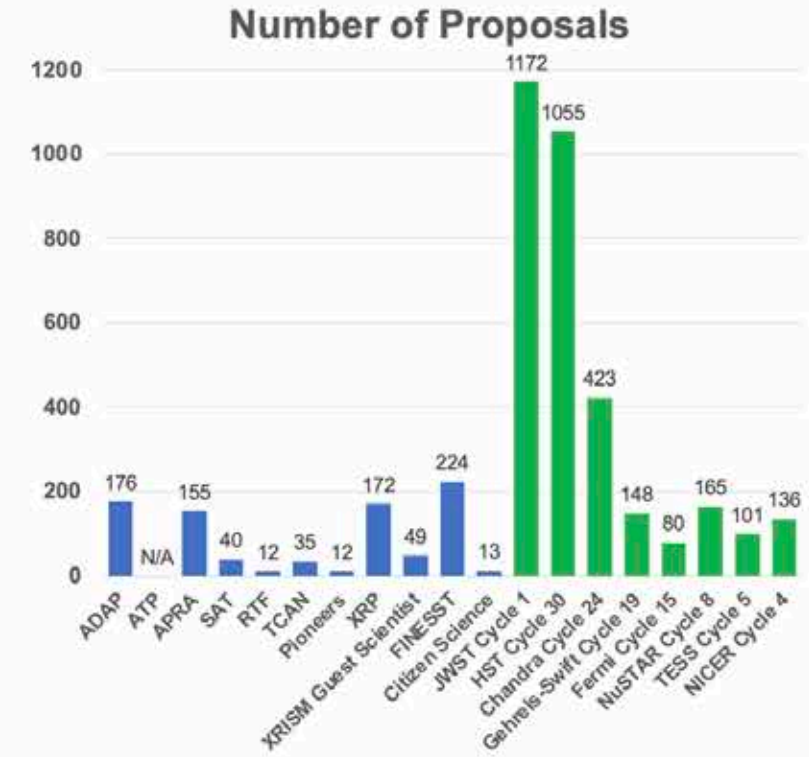
Code of Conduct

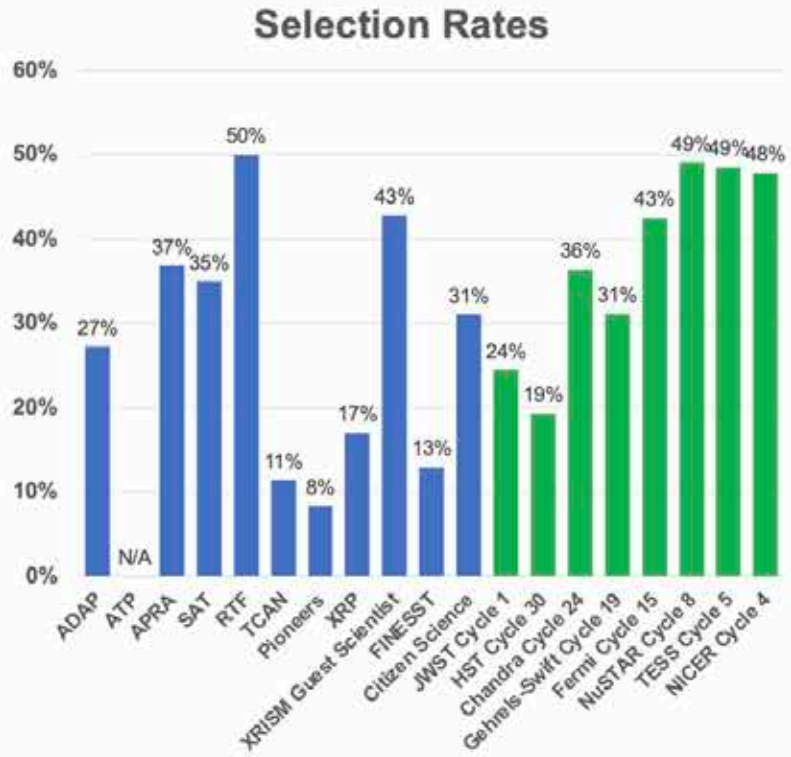
SMD Inclusion Plan Resource Page

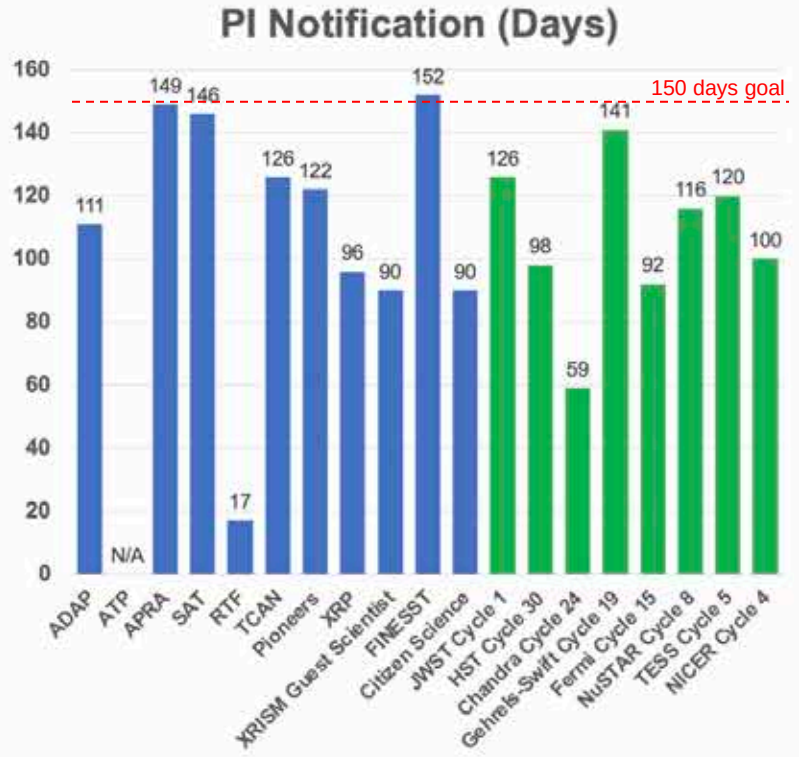
THANK YOU

Astrophysics R&A Selection Rates

March 2022-2023







R&A: 888 proposals
GO/GI: 3,280 proposals
Total: 4,168 proposals

R&A: 24% (19% last year)
GO/GI: 28%
Average: 27%

80% of PI notification:
R&A: 110 days
GO/GI: 107 days

* Only programs with selections made and PIs notified

Status of Science Data Policy

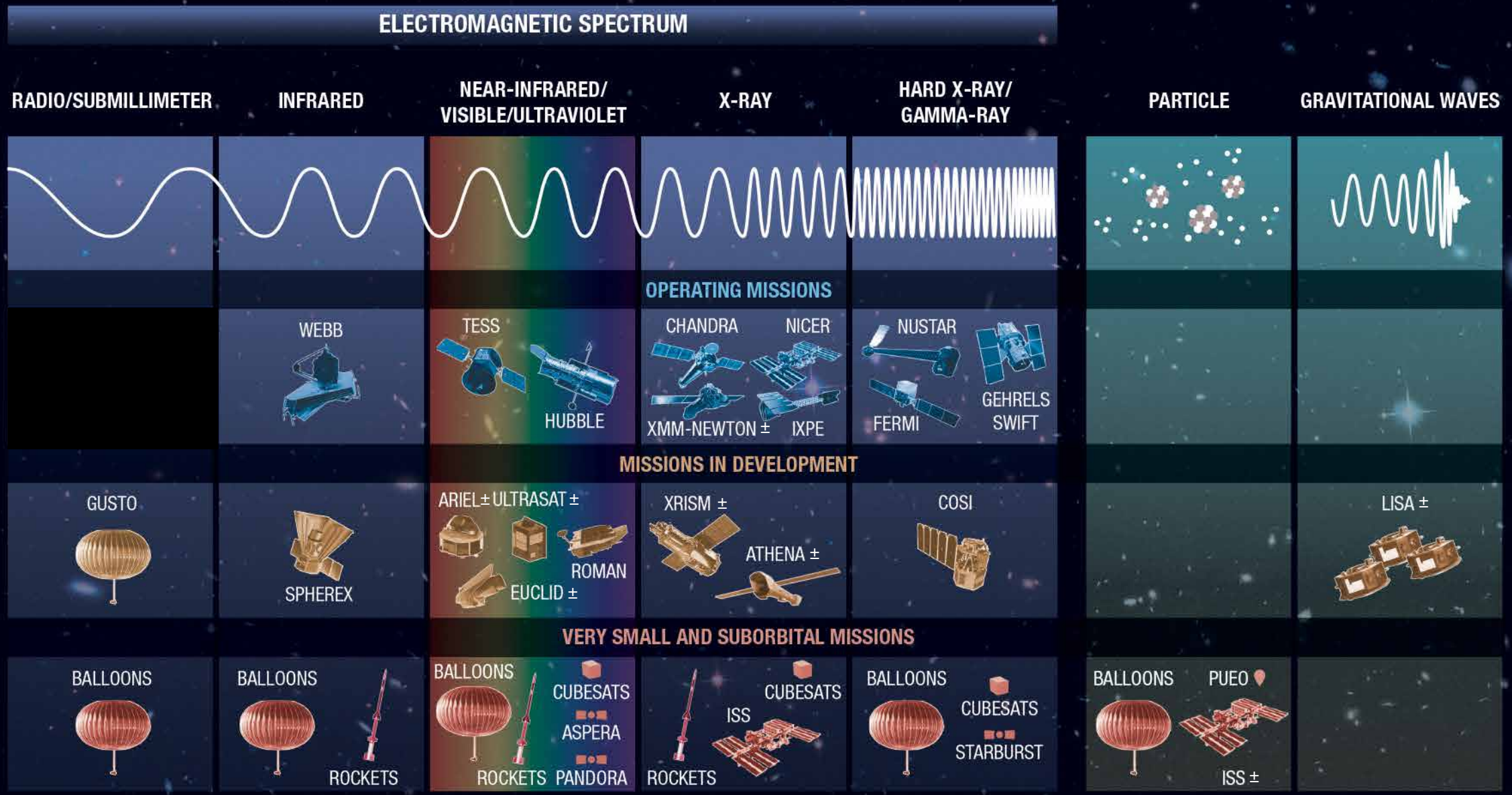
Year of Open Science

Science Data Policy and a Year of Open Science

- SMD has released SPD-41a: Scientific Information Policy for the Science Mission Directorate to provide guidance on the open sharing of publications, data, and software created in the pursuit of scientific knowledge.

- SMD has developed Open Science Guidelines that provide further guidance to the community on general implementation of SPD-41a.

- The Astrophysics Scientific Information Management Policy provides further clarification on the application of SPD-41a to the Astrophysics Division.



5 balloon payloads
2 sounding rocket payloads

2 Pioneers smallsats
6 balloon payloads
2 rocket payloads
3 cubesats

1 Pioneers smallsat
4 balloon payloads
4 sounding rocket payloads
2 cubesats 1 ISS experiment

1 Pioneers balloon
4 balloon payloads
1 ISS experiment

March 2022

± Partner-led mission

JWST Awards To Date

- Public
  - Space Symposium
  - National Air and Space Museum
  - National Space Club and Foundation
  - Aviation Week
  - Bloomberg Businessweek
  - Popular Science
  - American Institute of Aeronautics and Astronautics
  - TIME
  - Explorers Club

- NASA/Science
  - George Rieke
  - Marcia Rieke
  - Charles Bowers
  - Randy Kimble
  - Gillian Wright
  - Pierre Ferruit
  - René Doyon
  - Jane Rigby
  - Michael McElwain
  - Massimo Stiavelli
  - JWST Project Science Team
  - JWST Science & Ops Center Development Team
  - JWST Science Operations Team

Cleanroom workers pose for a quick group photo with the James Webb Space Telescope mirrors on May 4th, 2016. Credit: NASA/Chris Gunn

Three Paths for Community Engagement with Roman

- Help define and shape core community surveys
  - Submit science pitch and/or white paper for Core Community Survey definition
    - Science pitch – few paragraphs describing science case for one of the community surveys, short questionnaire on survey parameters
      - Deadline 17 Feb 2023, low bar to entry to encourage high participation
    - White papers – several page document with details on science case, sketch of survey design and methods/metrics on how to evaluate science metric against survey parameters
      - Deadline summer, detail enables more meaningful evaluation

- Actively engage with mission partners and science community
  - Join Roman Technical Working Groups
    - Groups pursing topics of interest across many science areas
      - Two groups currently (calibration, software) but will add more after ROSES proposal selection
    - Simple web sign up page, rolling deadline, open to all
  - Plan to form community-led science collaborations later this year

- Obtain funding to prepare for and enhance Roman Science
  - Submit proposal to Roman ROSES solicitation
    - Funding to work on Roman science preparation (including engagement in technical working groups and survey definition)
    - Proposal deadline March 21 2023; another opportunity in 2025

Response to CAA report on Roman Observations

- **Committee of Astronomy and Astrophysics Report on Roman Space Telescope Observations**
  - Provided a set of 10 principles to guide NASA and Roman on the process for assigning mission observing time allocations

- **Some takeaways include**
  - Endorses community led approach to setting Roman observation program
  - Emphasizes importance of competitively balancing/awarding time between each of the three CCS and GA Surveys

- **We agree with the findings and conclusions in the CAA report**
  - The Roman mission (science centers + project) have developed and started implementing a plan to define the core community surveys that builds upon the principles laid out in the CAA report

Astrophysics Technology Program - FY23

Technology Inception & Experimentation APRA & RTF

- *44 new technology projects awarded*
- *13 additional non-technology awards*
- *Average selection rate: 28%*
- *Portfolio:*
  - *Supporting Balloons, Sounding Rockets & CubeSats*
  - *Detectors across wavelengths*
  - *Mirrors, coatings and gratings*

Total: $55M

Technology Maturation SAT & ISFM

- *Portfolio has 36 active SAT & 10 ISFM projects*
- *14 new SAT projects awarded in FY23*
- *10 new ISFM projects (FY23-FY25)*
- *Next SAT solicitation planned in FY24 (ROSES-2023).*
- *Average SAT award: $1.8M (3 years)*
- *Average SAT selection rate: 32% (historically is ~30%)*

Total: $26M

Directed Technologies

- *Roman CGI ($42.5M)*
- *LISA ($29.6M)*
- *Athena ($16.2M)*
- *Euclid ($9.9M)*
- *NN-Explore – NEID ($3.3M)*

Total: $100M

Post-Decadal Initiatives

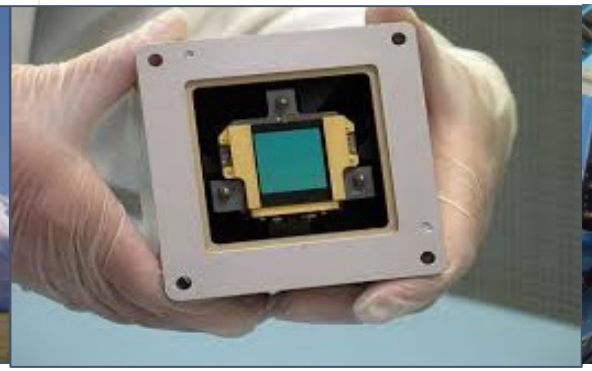
- *Coronagraph Testbed*
- *Ultra-stable Testbed*
- *Segmented Mirror Telescope Program (SMTP) – Industry Contract*

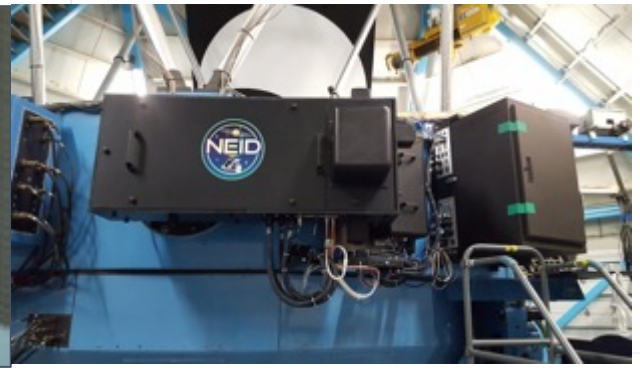
Total: $15M

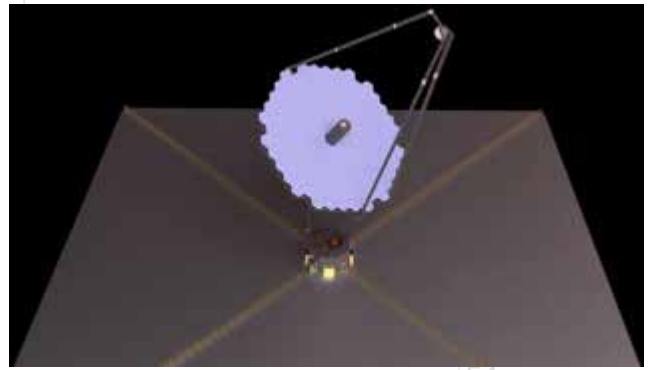
Not technology elements:

- *TDAMM – $2M*
- *Precursor Science - $3M*

Total: $5M



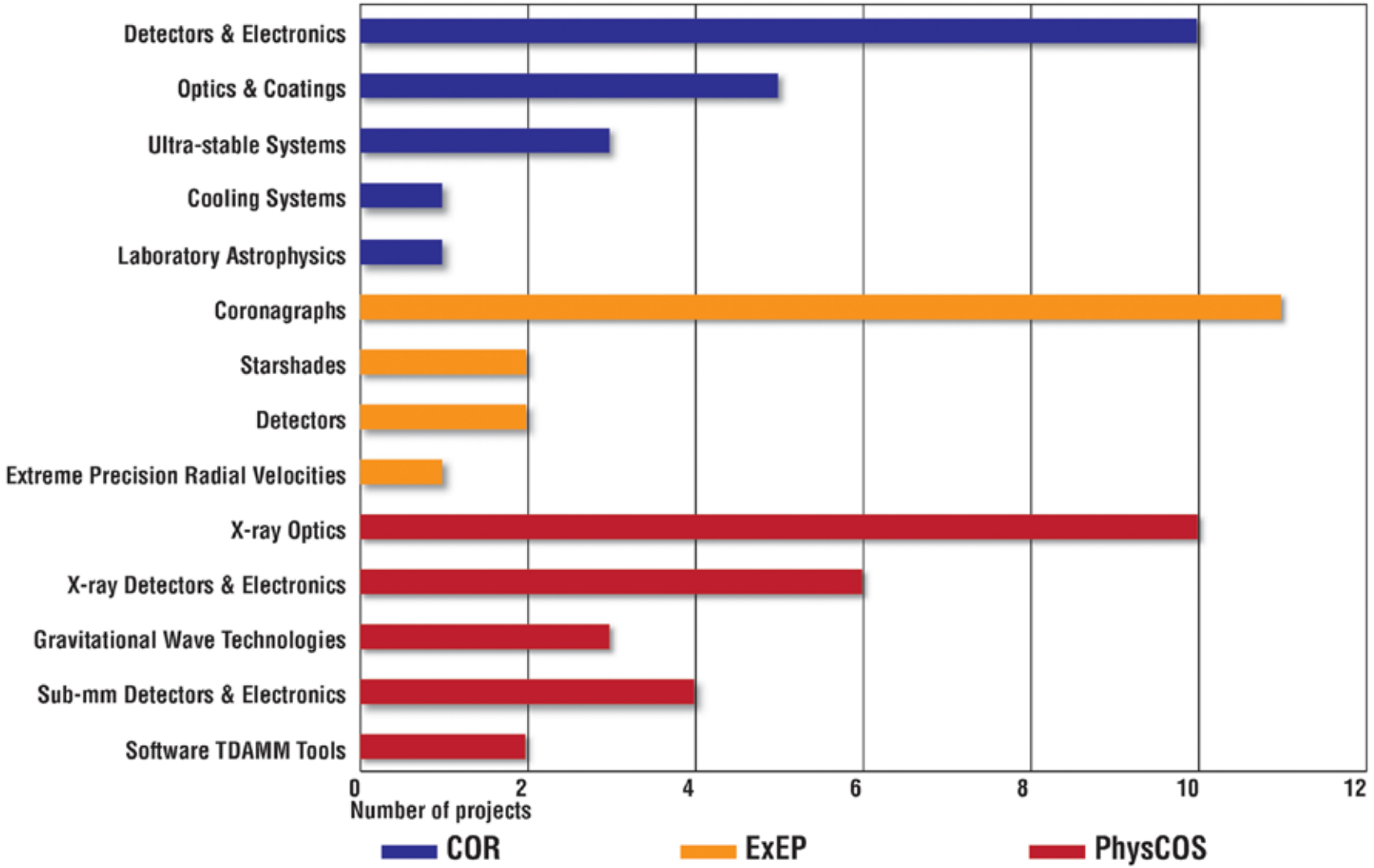




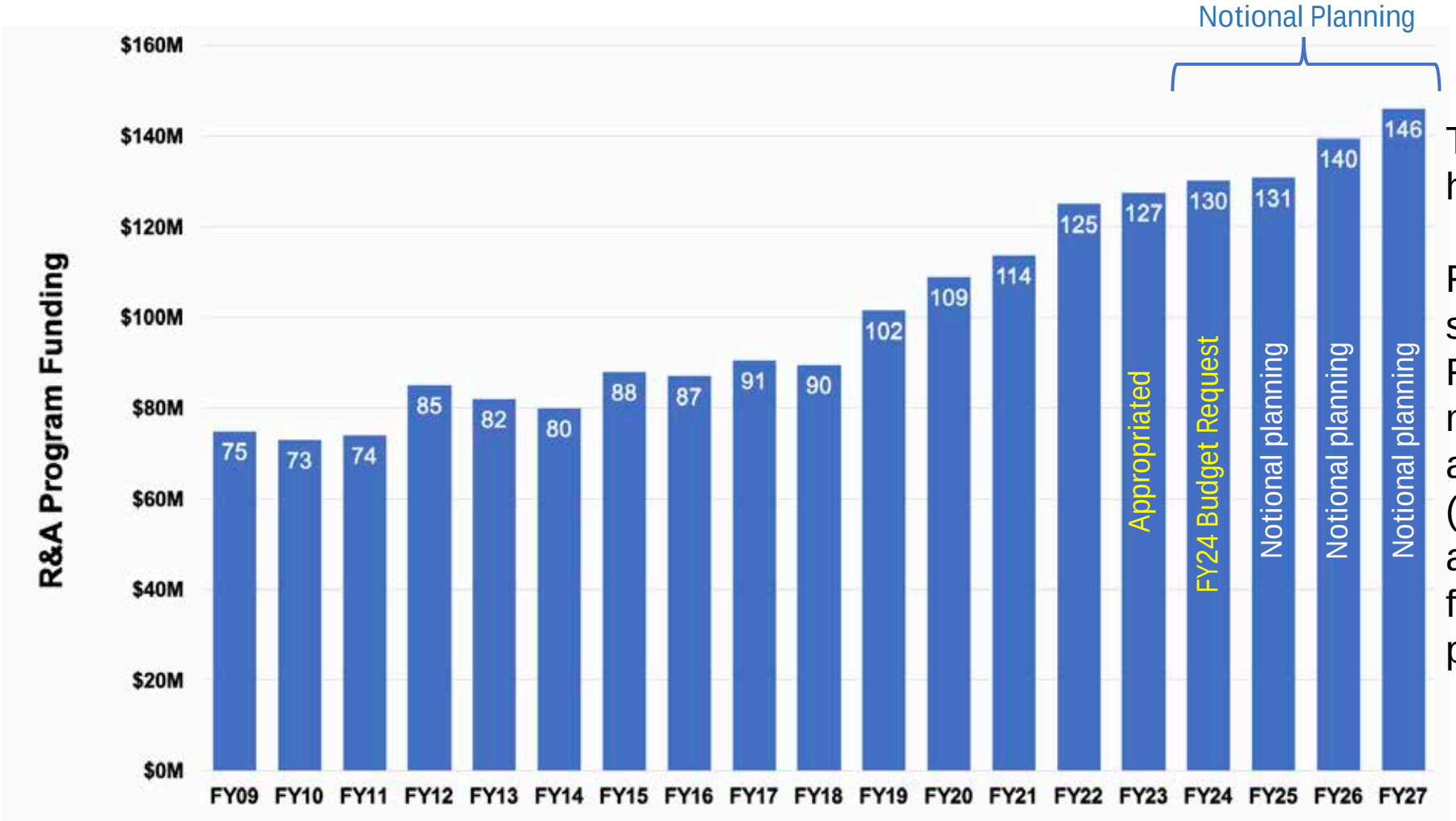
Current Strategic Technology Projects

- (SAT + ISFM - **building blocks)**

For more information see
http://www.astrostrategictech.us/



Research & Analysis Funding



The Astrophysics R&A Program has seen a sustained growth.

For the last 12 months, the selection rates were 24% for R&A programs and 28% for mission's General Observer and General Investigator (GO/GI) programs, with a total average selection rate of 27% for all Astrophysics ROSES programs.