National Aeronautics and Space Administration

Astrophysics




Astrophysics Division Update

NAC Astrophysics Subcommittee
NASA Headquarters
July 20, 2016

Paul Hertz
Director, Astrophysics Division
Science Mission Directorate
@PHertzNASA

This presentation will be posted at
http://science.nasa.gov/science-committee/subcommittees/nac-astrophysics-subcommittee/

SMD Leadership Change

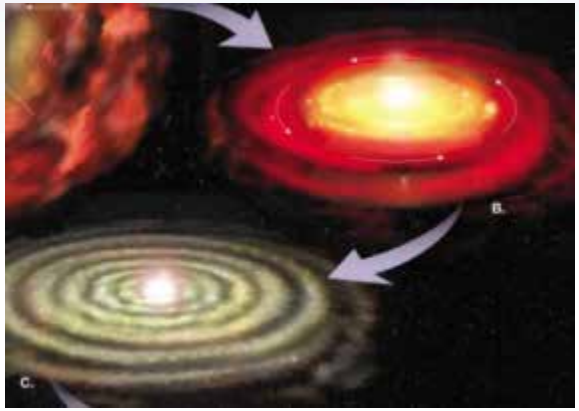
- John Grunsfeld has retired from NASA as of May 31.
- Geoffrey Yoder, previously the Deputy Associate Administrator for SMD, is now the Acting Associate Administrator for SMD.

- Mr. Yoder has spent 16 years in industry and 16 years at NASA, and his prior assignments include Deputy Director for Astrophysics, Acting Director for Astrophysics, JWST Program Director, SMD Deputy AA for Programs, and SMD Deputy AA.
- Mr. Yoder's priorities for SMD are:
  - Continuing to advance the SMD missions in formulation, development, and operations.
  - Integrating strategic planning across all Divisions to further advance NASA objectives and Decadal Surveys.
  - Making NASA's technical and capability management more efficient to free up resources for missions and science.
  - Basing NASA's decisions firmly on community input and peer review.

Why Astrophysics?

Astrophysics is humankind's scientific endeavor to understand the universe and our place in it.

1. How did our universe begin and evolve?

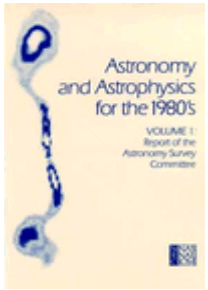


2. How did galaxies, stars, and planets come to be?

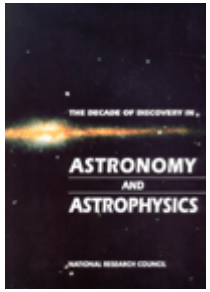
3. Are We Alone?

These national strategic drivers are enduring

1972



1982

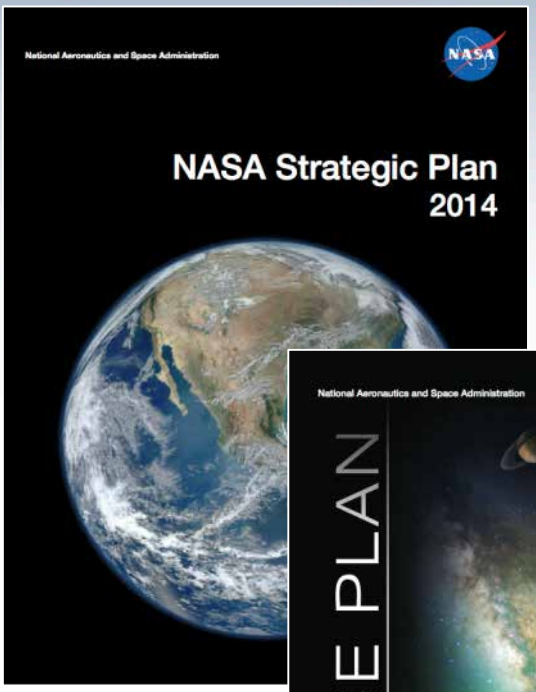


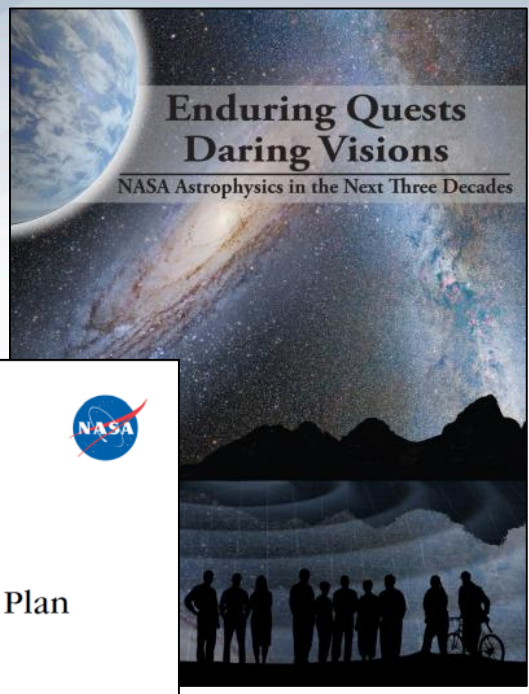
1991

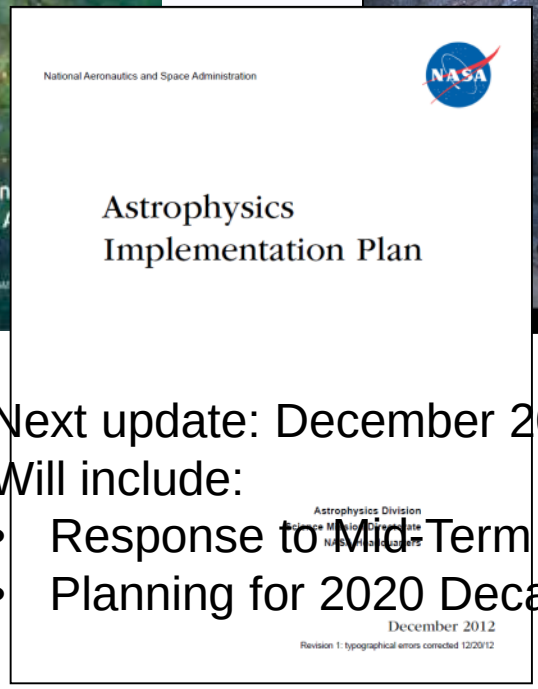
2001

2010

Astrophysics Driving Documents





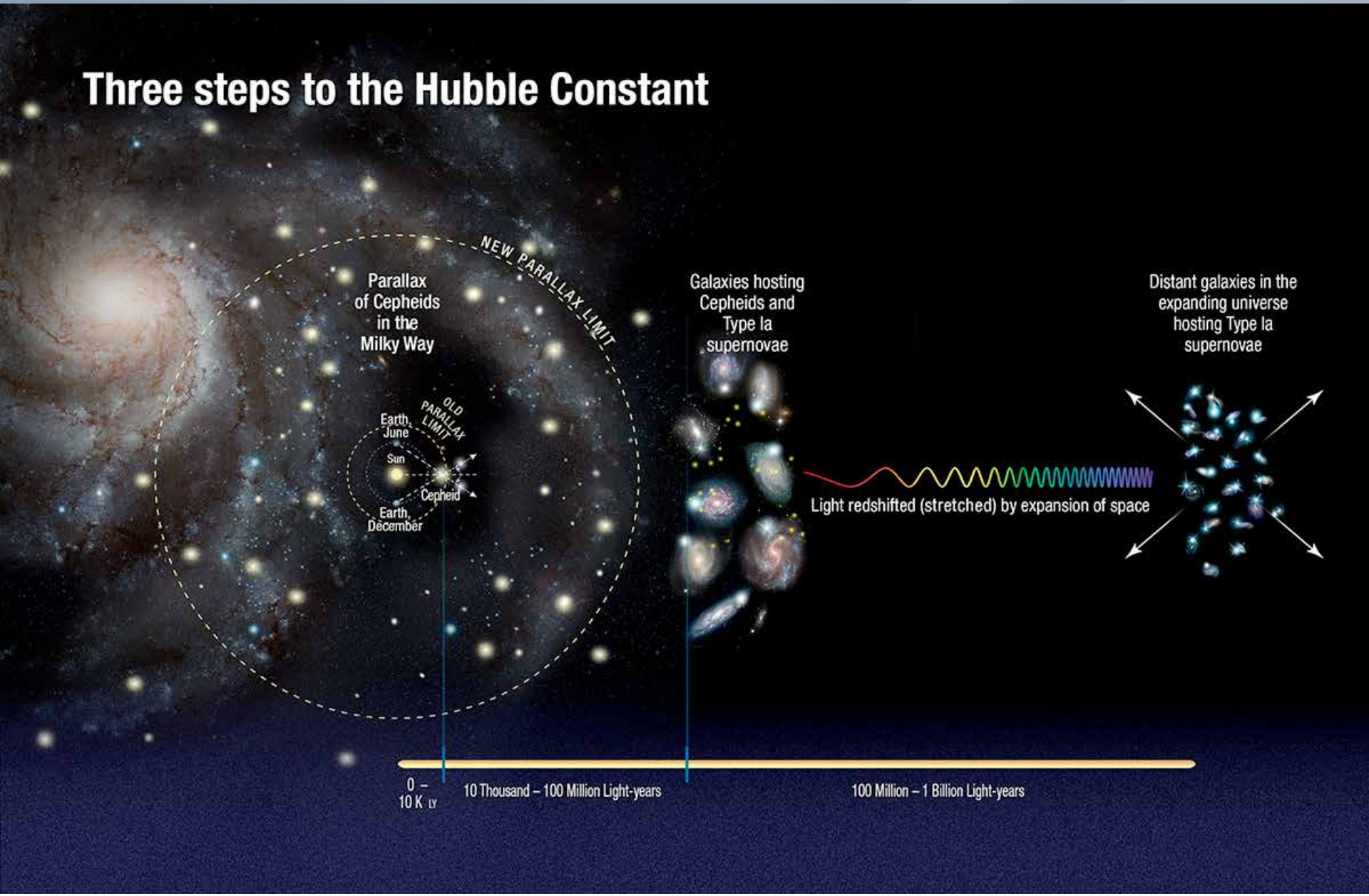


Next update: December 2016

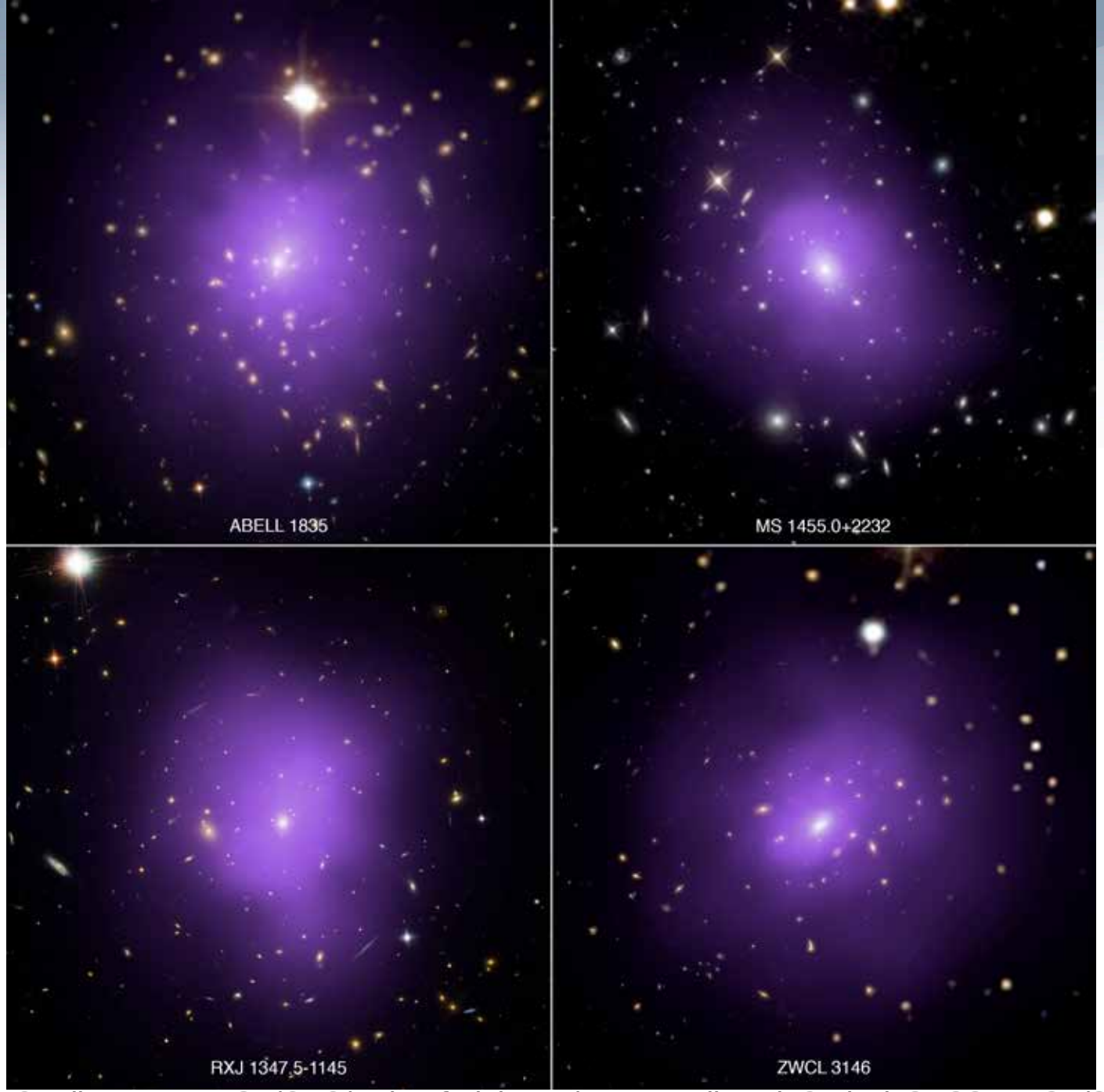
Will include:

- Response to Mid-Term Report
- Planning for 2020 Decadal Survey

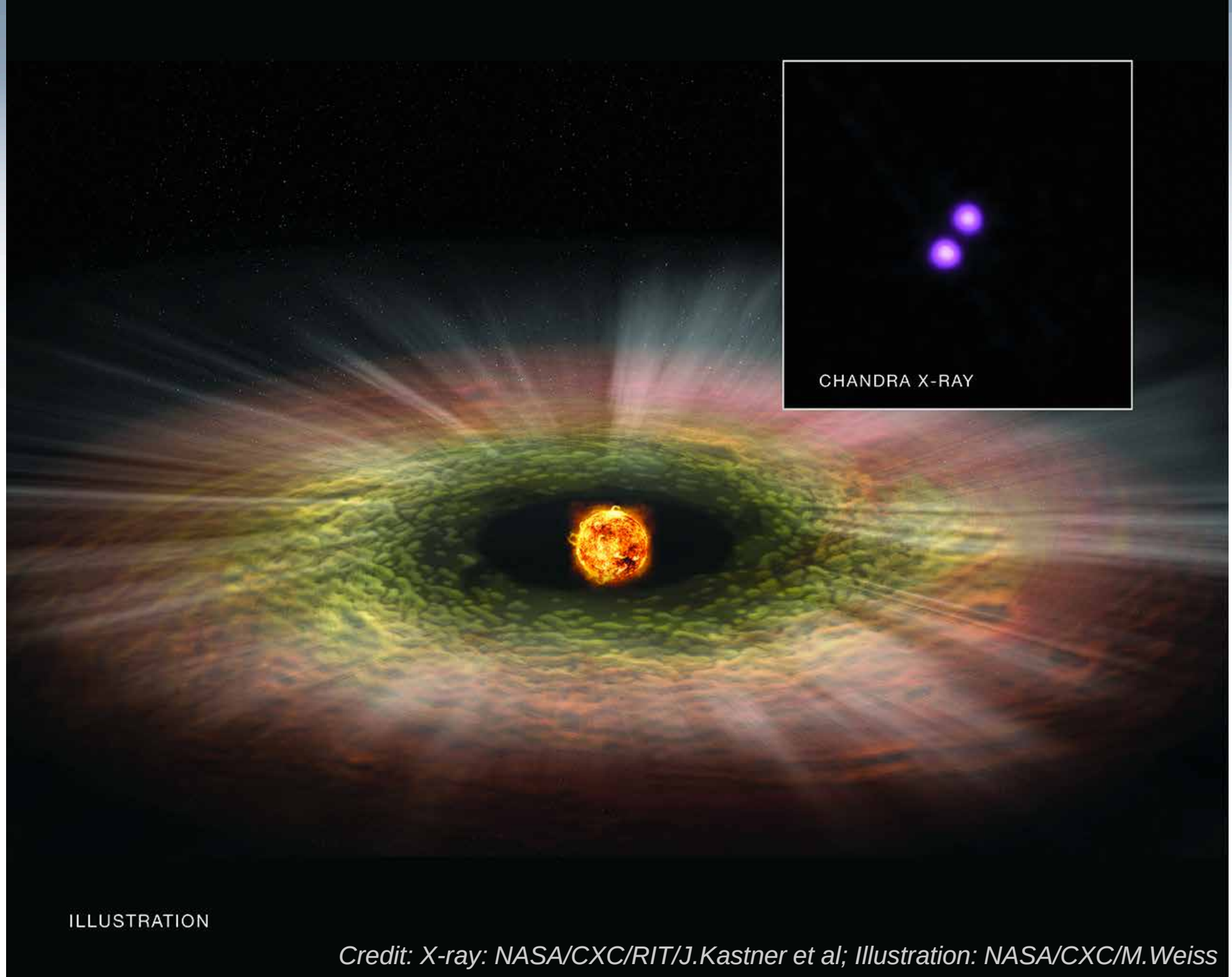
http://science.nasa.gov/astrophysics/documents



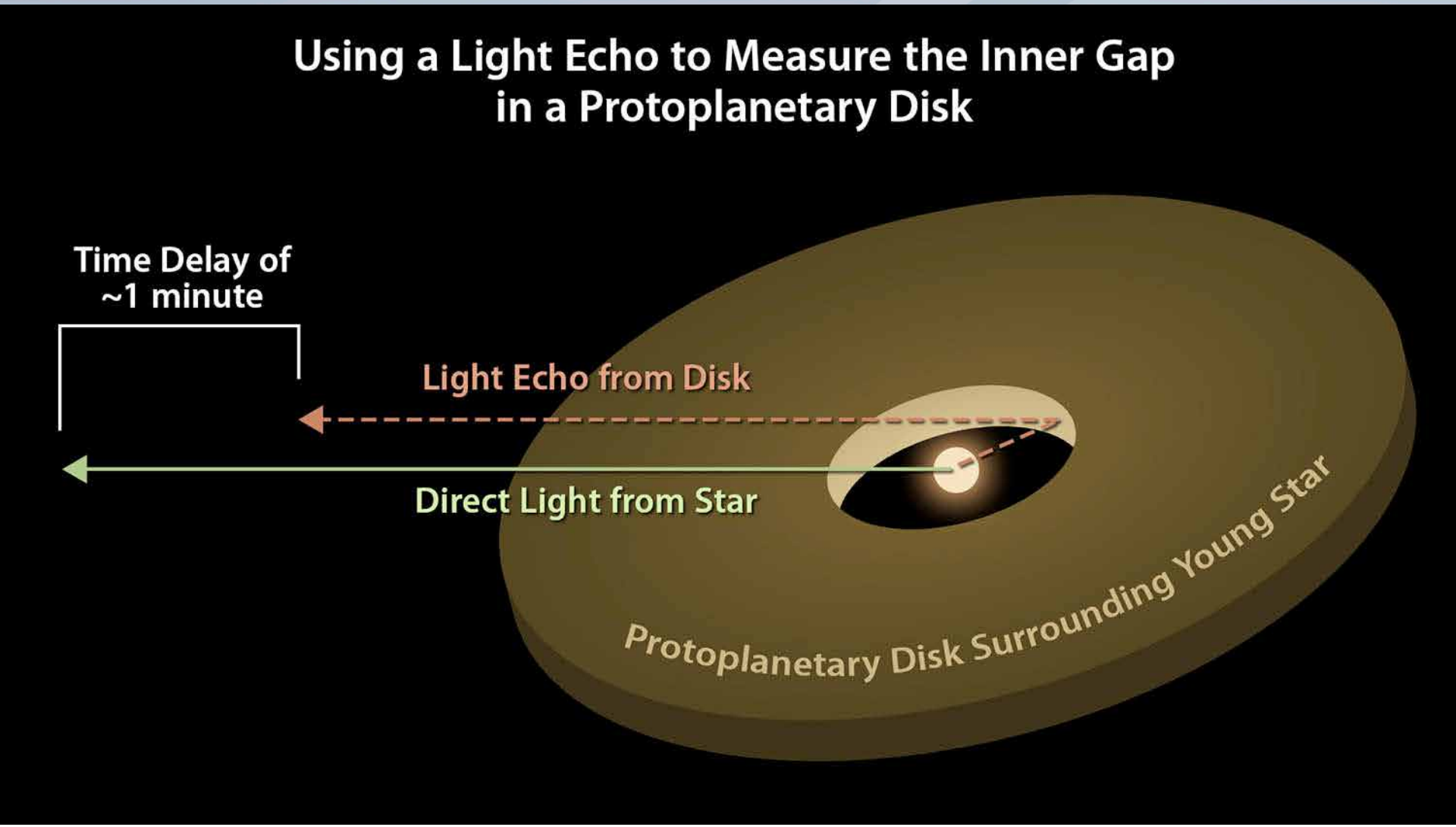
Credit: NASA, ESA, A. Feild (STScI), and A. Riess (STScI/JHU)



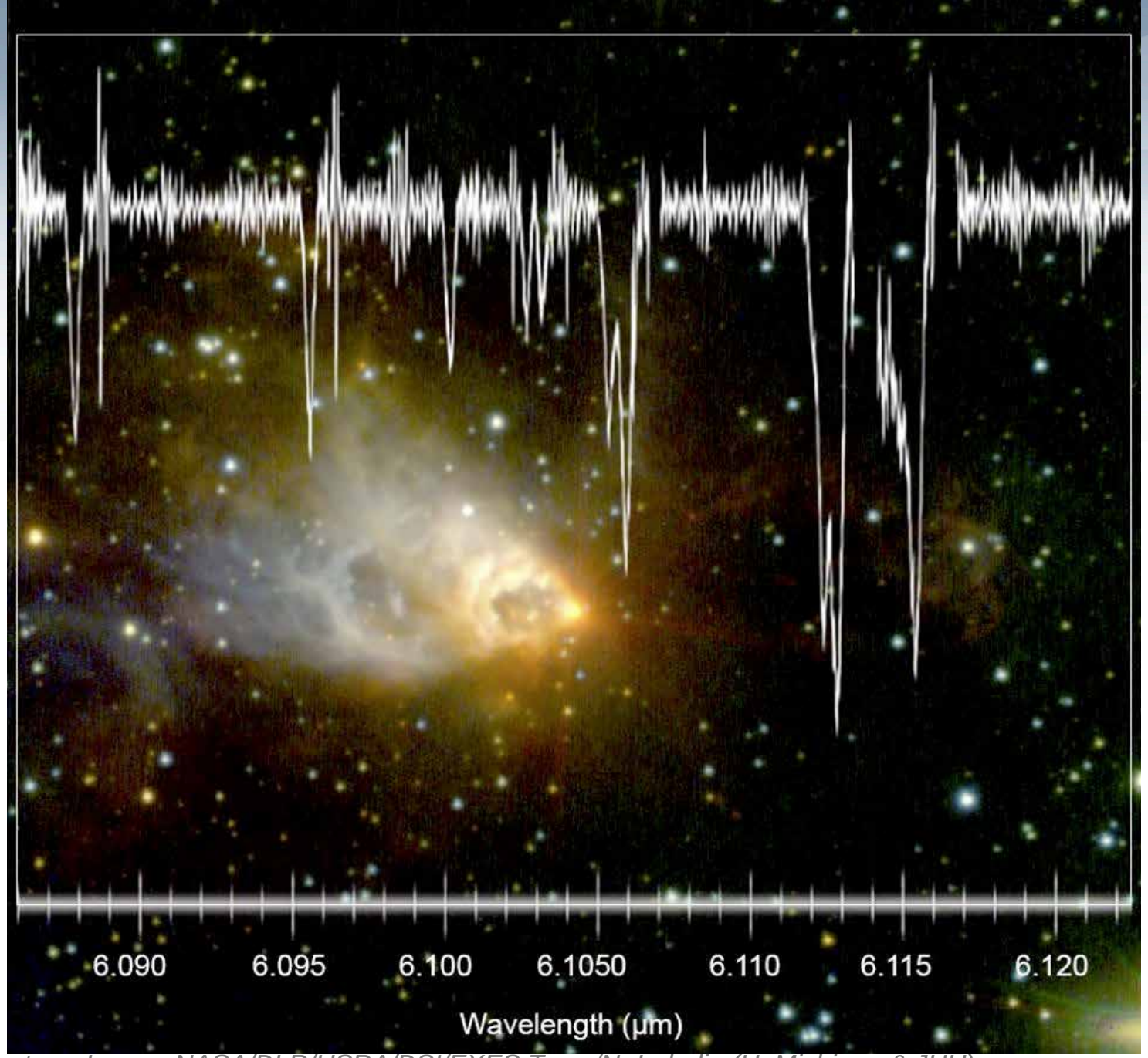
Credit: X-ray: NASA/CXC/Univ. of Alabama/A. Morandi et al; Optical: SDSS, NASA/STScI



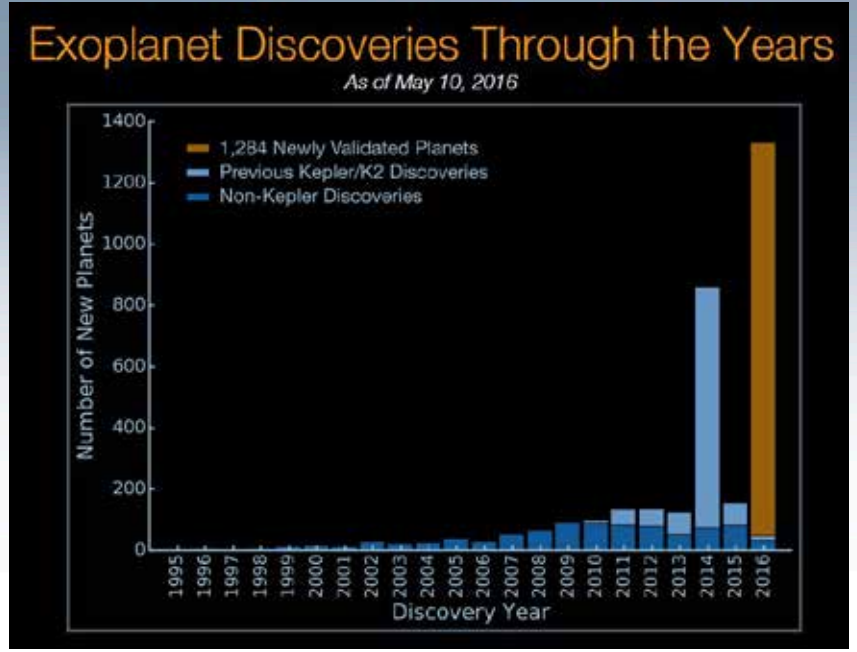
Credit: X-ray: NASA/CXC/RIT/J.Kastner et al; Illustration: NASA/CXC/M.Weiss

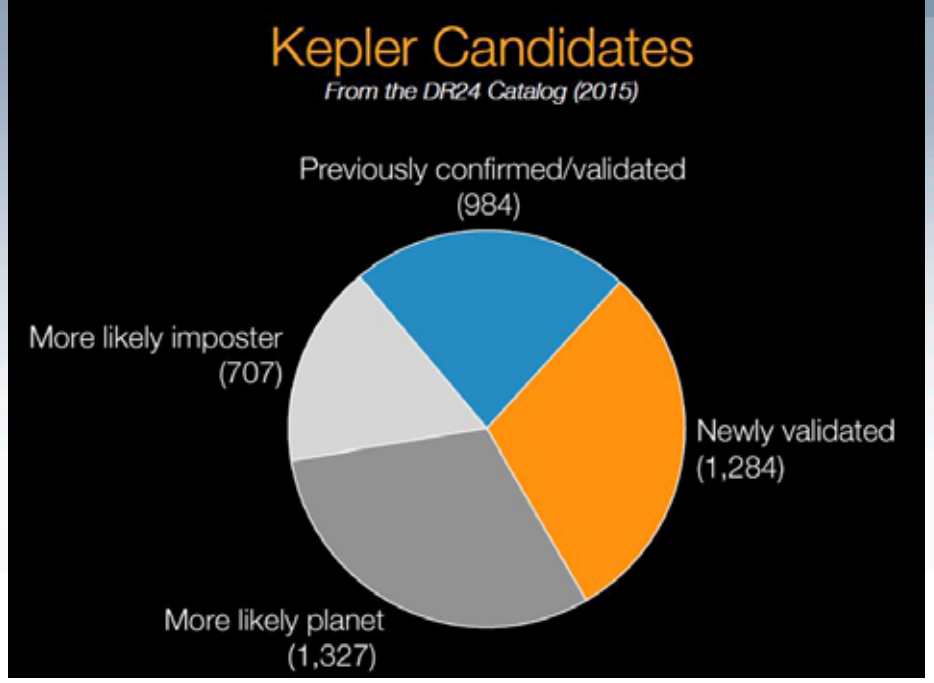


Credit: NASA/JPL-Caltech

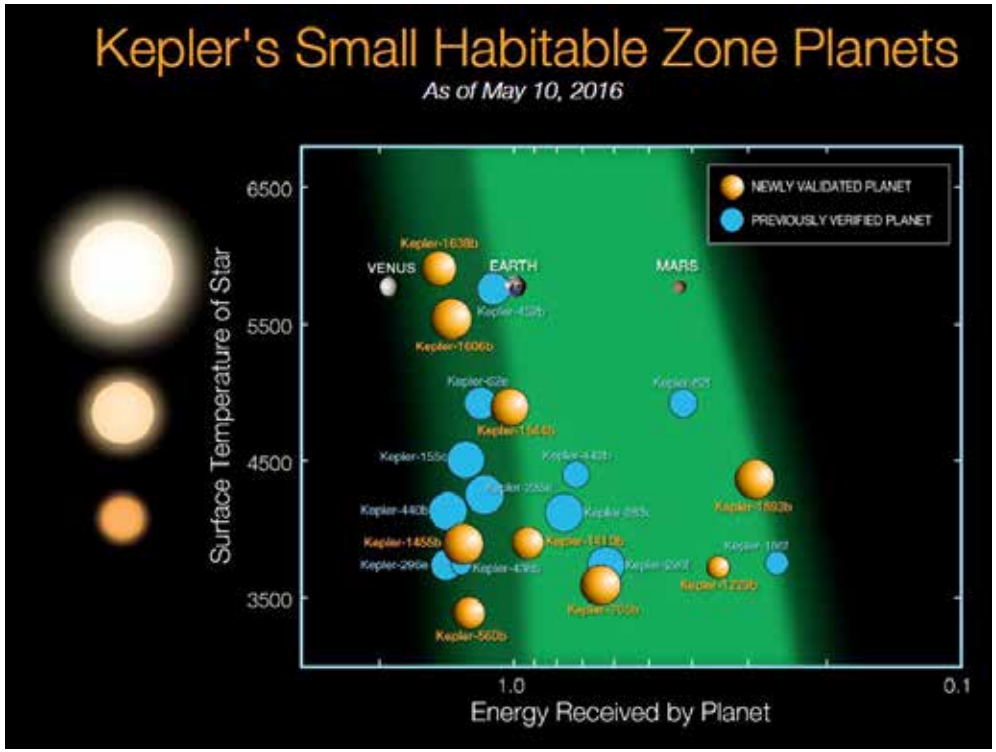


Credits: Spectrum Image: NASA/DLR/USRA/DSI/EXES Team/N. Indrolio (U. Michigan & JHU); Background Image: C. Aspin et al. / NIRI / Gemini Observatory / NSF.





Credits: NASA Ames/W. Stenzel; Princeton University/T. Morton



Credits: NASA Ames/N. Batalha and W. Stenzel


Dwarf Planet Makemake and Moon
HST WFC3/UVIS
NASA, ESA, and A. Parker (SwRI)
STScI-PRC16-18a

Evolution of the Astrophysics Subcommittee

- NASA is proposing that the NAC Science Committee's four subcommittees associated with SMD divisions become stand-alone Federal Advisory Committee Act (FACA) committees.
  - Earth Science Subcommittee
  - Planetary Science Subcommittee
  - Astrophysics Subcommittee
  - Heliophysics Subcommittee
- Committees will advise the respective Division Director within SMD
  - Advice to be delivered and acted upon at the right organizational level
  - Many community-based studies (e.g., Senior Reviews, Science and Technology Definition Teams) will now have a chartered Federal advisory committee to report to
- Committees will have
  - Charters (rather than a Terms of Reference)
  - Membership balance plans
- Next steps
  - Approval of charters and membership balance plans by the NASA Administrator
  - Review by the General Services Administration
  - Filing with Congress

Evolution of the Astrophysics Subcommittee

- NASA has decided to apply for FACA charters for the four science advisory subcommittees, including the Astrophysics Subcommittee.
  - Many community-based studies (e.g., Senior Reviews, Science and Technology Definition Teams) will now have a chartered Federal Advisory Committee to report to.
- Once chartered, this Astrophysics Subcommittee (APS) will be replaced by the Astrophysics Advisory Committee (APAC).
  - All current APS members will be appointed to the APAC.
  - Meeting schedule and member expectations will be unchanged.
- The Astrophysics Advisory Committee will report to the Director of the Astrophysics Division.
  - The APAC Chair will continue to serve as a member of the NAC Science Committee.
- Once the Astrophysics Advisory Committee is chartered, then the Director of the Astrophysics Division will establish subordinate groups.
  - Three Program Analysis Groups (COPAG, ExoPAG, PhysPAG)
  - Four STDTs for large mission studies (FIRS, HabEx, LUVOIR, XRS)
  - L3 Study Team

Astrophysics - Big Picture

- **The FY16 appropriation and FY17 President's budget request provide funding for NASA astrophysics to continue its programs, missions, projects, and supporting research and technology.**
  - The total funding (Astrophysics including Webb excluding STEM) remains at ~$1.35B.
  - Fully funds Webb to remain on plan for an October 2018 launch.
  - Funds WFIRST formulation (new start) starting in February 2016.
  - Maintains increased level of funding for R&A and new suborbital capabilities.
  - Funds SMD STEM education activities across astrophysics and other disciplines.
- **The operating missions continue to generate important and compelling science results, and new missions are under development for the future.**
  - Chandra, Fermi, Hubble, Kepler/K2, NuSTAR, Spitzer, Swift, ESA's XMM-Newton all operating well; Senior Review in Spring 2016 recommended continued operation.
  - SOFIA is in 5-year prime operations as of May 2014; HAWC+ 2nd generation instrument commissioning in Spring 2016; 3rd generation instrument studies underway.
  - ESA's LISA Pathfinder successfully launched on December 3, 2015; performing well.
  - JAXA's Hitomi (née ASTRO-H) launched on February 17, 2016; communication was lost with spacecraft on March 26, 2016, and JAXA has ceased recovery efforts.
  - Missions under development for launch include NICER (2017), ISS-CREAM (2017), TESS (2017), Webb (2018), ESA's Euclid (2020), WFIRST (mid-2020s).
  - 5 SMEX and MO concept studies selected in 2015; MIDEX AO in 2016; NASA joining ESA's Athena X-ray observatory (2028) and ESA's L3 gravitational wave obs (2034).
- **Progress being made toward recommendations of the 2010 Decadal Survey.**
  - NRC Mid Decade Review (with NSF, DOE) underway; report expected in Jul/Aug 2016.
  - NASA initiating large and medium mission concept studies as input for 2020 Decadal Survey.

NASA Astrophysics

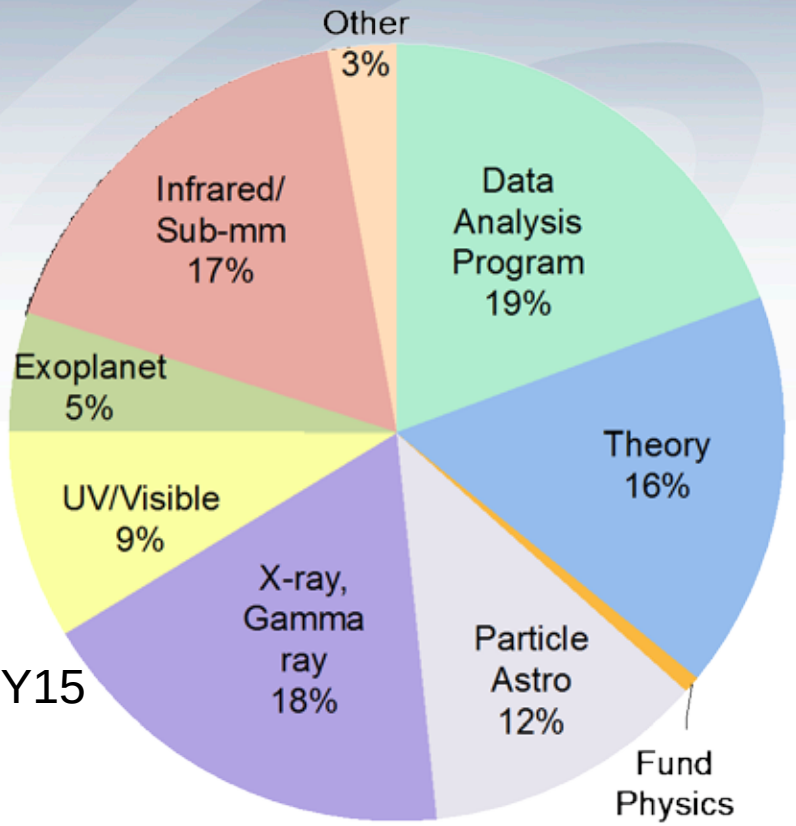
Program Update

Research and analysis
Missions in extended operation
Missions in prime operation
Suborbital missions
Missions in development

Astrophysics Research Program Funding

Most recent year:

	Proposals Rec'd	selected	Success Rate	Year-1 $M
RTF-15	5	3	60%	0.3
APRA-14	149	42	28%	12.7
SAT-14	27	11	41%	6.6
ADAP-15	249	51	20%	6.2
XRP-15	43	7	16%	1.2
ATP-14	214	32	15%	4.7



Split of $88M in FY15

Growth from $65M (FY07) to $74M (FY10) to $88M (FY15) to $90M (FY17 req)

Funding for Astrophysics Research Award Programs: $M

Planned Changes in Astrophysics Research

Rebalance of funding between Postdoctoral Fellowships and R&A.

- Presentation by Linda Sparke (Astrophysics Research Program Manager)

Restructure the Nancy Grace Roman Technology Fellowship program.

- Presentation by Billy Lightsey (RTF Program Officer)

The Astrophysics Subcommittee is tasked with considering these planned changes and providing a response to the Director of Astrophysics at its October 2016 meeting.

- The response may include comments, findings, and/or recommendations,
- The Subcommittee may create a working group to collect further information, as appropriate, to inform the Subcommittee's discussions and response.

Explorers MIDEX and MO AO in 2016

- Draft solicitations: Draft MIDEX AO released on July 14, 2016. Draft SALMON-2 Appendix for Explorers MO to be released on July 22, 2016.
- Target dates: AO release late Summer 2016, proposals due 90 days later, Selection Summer 2017, final downselect late 2018.
- MIDEX: standard launch services on an ELV provided at no charge against the mission cost cap; no MIDEX ISS attached payloads
  - PI-managed Cost Cap for the MIDEX is $250M (FY2017 dollars)
  - MIDEX launch readiness date no later than December 2023
- MO may be Partner MO, Small Complete Missions (SCM) or NMES.
  - SCM that are suborbital class (ULDB, CubeSat, SRLV) or on ISS: access to space provided by NASA at no charge to PI-managed Mission Cost
  - NASA-provided ELV launch for $20M charge to PI-managed Mission Cost
  - PI-managed Cost Cap for the MO is $70M, $35M for suborbital class MO
  - SCM launch readiness date no later than December 2022
  - PMO or NMES endorsement need date before January 2022
- Selected missions execute a nine-month Phase A study funded at $2M for MIDEX, $500K for MO
  - Science Enhancement Options (SEOs) are allowed
  - Student Collaborations are allowed (incentive of 1% of the PI-Managed Mission Cost Cap)


Formulation
Implementation
Primary Ops
Extended Ops
Spitzer
8/25/2003
Kepler
3/7/2009
WFIRST
Mid 2020s
LISA Pathfinder (ESA)
12/3/2015
Webb
2018
Euclid (ESA)
2020
Chandra
7/23/1999
XMM-Newton (ESA)
12/10/1999
TESS
2017
Swift
11/20/2004
NuSTAR
6/13/2012
Fermi
6/11/2008
Hubble
4/24/1990
CREAM (on ISS)
2017
NICER (on ISS)
2017
SOFIA
Full Ops 5/2014

2016 Astrophysics Senior Review

Chandra X-ray Observatory Panel

Hubble Space Telescope Panel

Budgets already recognized in the notional run-out of the President's FY 2016 budget request. Mature and stable missions with no operational changes.

Main Panel:

Fermi
Kepler/K2
NuSTAR
Spitzer
Swift
XMM-Newton

Main panel.

2016 Astrophysics Senior Review
Main Panel Findings – Overall

Mission	Panel Rating	Panel Ranking
Swift	E	1
Kepler/K2	E	2
NuSTAR	E/VG	3
XMM-Newton	E/VG	4
Fermi	E/VG	5
Spitzer	E/VG	6

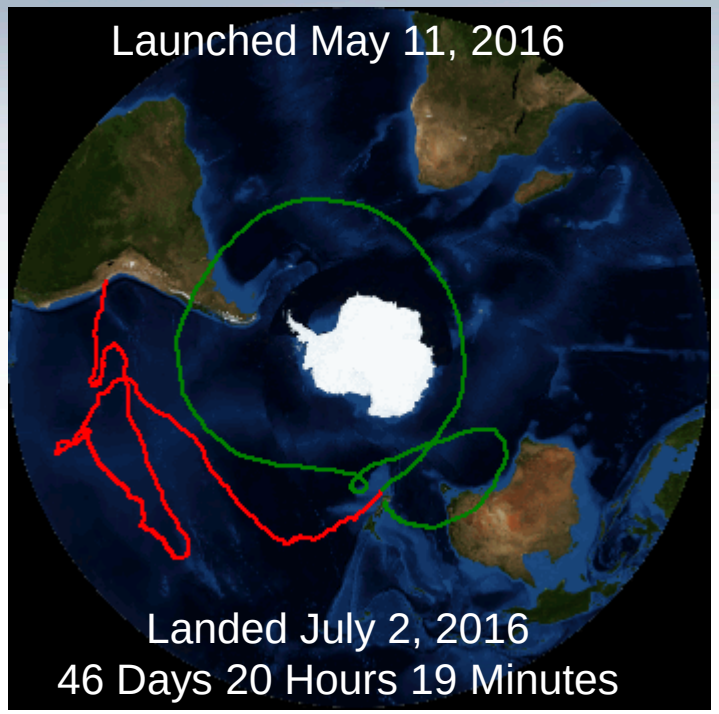
- “The SR2016 panel finds no scientific reason to discontinue or significantly reduce any of the six missions under this review.”
- “We strongly encourage NASA to find a way to continue all of these missions at their full funding level.”
- “The scientific value of the complete Astrophysics Senior Review 2016 portfolio is greater than the sum of its parts.”

2016 Astrophysics Senior Review
NASA Implementation Decisions

Mission	Extend?	SR2018?	Comments
Hubble	Yes	Yes	
Chandra	Yes	Yes	
Fermi	Yes	Yes	Reduced budget
Kepler/K2	Yes	No	End-of-mission plan
NuSTAR	Yes	Yes	
Spitzer	Yes	No	Reduced budget; end-of-mission plan
Swift	Yes	Yes	Augmentation for automation
XMM	Yes	Yes	Augmentation for GO program

- Maintain all 8 missions in operation, with K2 and Spitzer ending.
  - Spitzer ending in mid-FY19 after providing significant precursor work for JWST and after JWST commissioned.
  - Kepler/K2 ending in FY19 when fuel is exhausted.
- Maintaining all 8 missions will require some reductions in mission funding in order allow the overarching finding (the continuation of all missions) to be implemented.

2016 New Zealand SPB Campaign



Compton Spectrometer and Imager (COSI)

PI: Steven Boggs, UC Berkeley

Superpressure Balloon and COSI payload on the Ground in Peru

http://www.csbf.nasa.gov/newzealand/wanaka.htm

Recent & Upcoming Suborbital Missions

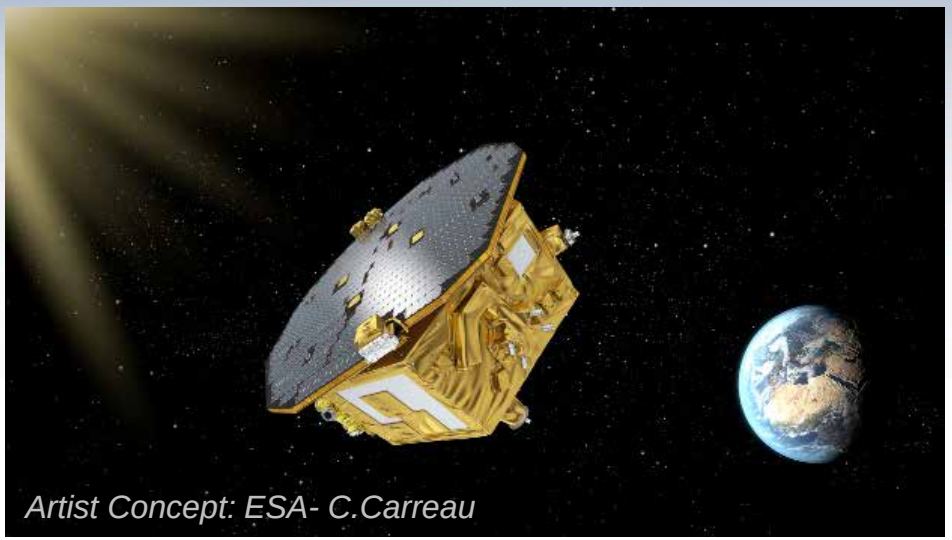
Sounding Rockets

- FY16-FY17 Sounding Rocket Launches @ White Sands NM
  - **PICTURE-B** – S. Chakrabarti, U Mass Lowell (Nov 24, 2015)
  - **DXL** – M. Galeazzi, U Miami (Dec 5, 2015)
  - **FORTIS** – S. McCandliss, JHU (Dec 18, 2015)
  - **CHESS** – K. France, Colorado U (Feb 22, 2016)
  - **Micro-X** – E. Figueroa, MIT (~Nov 2016)
  - **CIBER-2** – J. Bock, Caltech (~Dec 2016)

Stratospheric Balloons

- Winter FY16 Conventional Balloon Campaign @ McMurdo Station Antarctica
  - **GRIPS** – P. Saint-Hilaire, UC Berkeley (Jan 19-30, 2016)
- Spring FY16 Super Pressure Balloon Campaign @ Wanaka New Zealand
  - **COSI** – S. Boggs, UC Berkeley (May 16 – Jul 2, 2016)
- Summer FY16 Conventional Balloon Campaign @ Palestine TX
  - **SuperBIT** – W. Jones, Princeton U (July 1, 2016)
- Fall FY16 Conventional Balloon Campaign @ Ft Sumner NM
  - **BETTII** – S. Rinehart, NASA GSFC (Aug/Sep 2016)
  - **FIREBALL-2** – C. Martin, Caltech (Aug/Sep 2016)
  - **PIPER** – A. Kogut, NASA GSFC (Aug/Sep 2016)
  - **X-Calibur** – H. Krawczynski, Washington U (Aug/Sep 2016)
- Winter FY17 Conventional Balloon Campaign @ McMurdo Station Antarctica
  - **ANITA-4** – P. Gorham, U Hawaii (Dec 2016/Jan 2017)
  - **BACCUS** – E.S. Seo, U Maryland (Dec 2016/Jan 2017)
  - **STO-2** – C. Walker, U Arizona (Dec 2016/Jan 2017)

ST-7/LISA Pathfinder
ST-7/Disturbance Reduction System (DRS)



CURRENT STATUS:

- ESA's LISA Test Package has been operating for 90 days using ESA's cold gas thrusters.
- LISA test package performance exceeds requirements.
- NASA's Disturbance Reduction System (DRS) completed commissioning July 8.
- The DRS had an anomaly on July 9, just prior to the start of science operations. Thruster cluster 2 has shut down and the event is being investigated.

- ESA Mission with NASA Collaborating
- Project Category: 3 Risk Class: C
- DRS flies on the ESA LISA Pathfinder spacecraft
- Sun-Earth L1 halo orbit
- Drag-free satellite to offset solar pressure
- Payload delivery: July 2009
- Launched: December 3, 2015 GMT
- LPF prime mission: 7 months
- Data Analysis: 12 months

http://sci.esa.int/lisa-pathfinder/

- DRS will operate for 90 days in science operations mode.
- ESA discussing potential (2-3 months) mission extension if all goes well.

SOFIA
Stratospheric Observatory for Infrared Astronomy

- **World's Largest Airborne Observatory**
- 2.5-meter telescope
- 80/20 Partnership between NASA and the German Aerospace Center (DLR)
- Science Center and Program Management at NASA-Ames Research Center
- Science Flight Operations at NASA-Armstrong Flight Research Center
- Four US and Two German science instruments commissioned
  - Provide imaging, spectroscopy and photometry ranging from visible to far infrared
  - Advanced science instruments under development for future operation

https://www.sofia.usra.edu/

CURRENT STATUS:

- In prime mission operation since May 2014
- Observing status:
  - Mapping D/H ratio on Mars with the EXES spectrometer (Encrenaz et al. 2016)
  - Calibrated data from Horsehead nebula released in February 2016 with no proprietary restrictions
  - Study of ISM tracers in low-metallicity Small Magellanic Cloud (Requena-Torres et al. 2016); Bulk of molecular hydrogen is traced by [C II] and not by CO.
  - Completed final science flight of a seven-week, three-instrument deployment to Christchurch, New Zealand (June 4-July 25, 2016)
  - Received over 200 proposals in response to the Cycle 5 Call for Proposals with selections to be announced in October; Significant interest in new SOFIA instruments.
- Science instruments:
  - Conducted first part of HAWC+ commissioning in April 2016; Part II commissioning series is scheduled for September 2016
  - Commissioning of upGREAT High Frequency Array, operating at 4.7 THz, is planned for November 2016
  - Concept Study Reports have been submitted for the SOFIA 3rd Generation Instrument; selection to be announced this Fall
- SOFIA Science Symposium: "The Local Truth, Star Formation and Feedback in the SOFIA Era" (Asilomar Conference Center; October 17- 20, 2016)
- Recompeting contract for science mission operations

Astrophysics Missions in Development

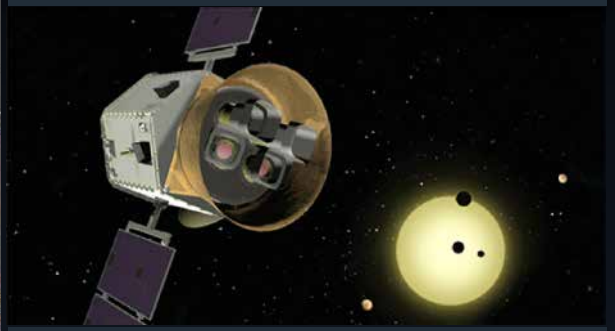
NICER
NASA Mission

Neutron Star Interior Composition Explorer

CREAM
NASA Mission

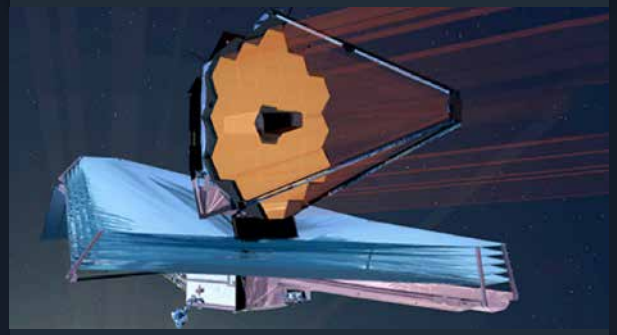
Cosmic Ray Energetics And Mass

TESS
NASA Mission



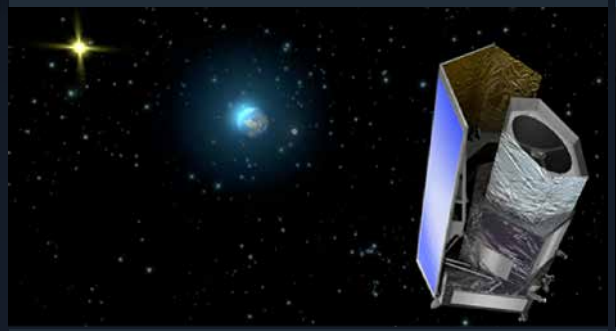
Transiting Exoplanet Survey Satellite

Webb
NASA Mission



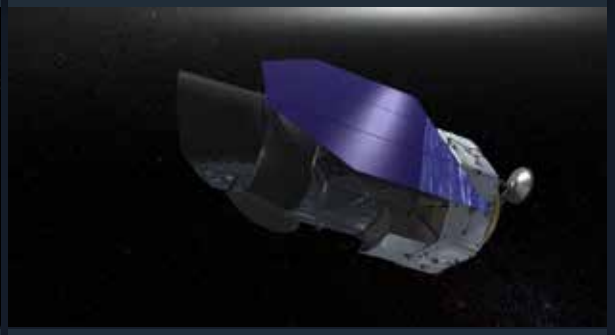
James Webb Space Telescope

Euclid
ESA-led Mission



NASA is supplying the NISP Sensor Chip System (SCS)

WFIRST
NASA Mission



Wide-Field Infrared Survey Telescope

NICER
Neutron star Interior Composition Explorer

Removal of shipping container cover from NICER payload at Kennedy Space Center

NICER being prepared for storage at KSC

- All subsystems/sub-assemblies have completed fabrication and environmental testing
- The NICER payload completed final integration and test
- December 2015: Pre-environmental Review
- January 2016: Start Phase D
- February 2016: Start of payload environmental testing
- April 2016: Completion of payload environmental testing
- June 2016: Payload delivered to KSC and completed ISS interface testing. Now stored at KSC until launch
- February 2017 (TBC): Launch on SpaceX-11 commercial resupply service (CRS) flight to ISS

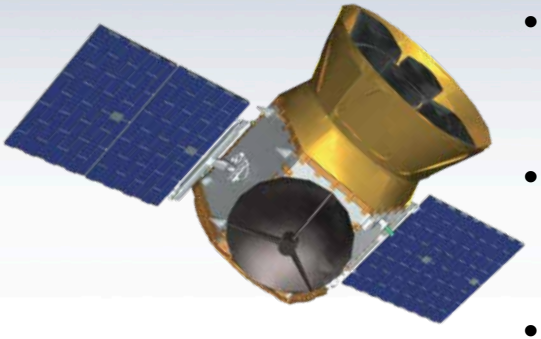
https://heasarc.gsfc.nasa.gov/docs/nicer/

CREAM
Cosmic Ray Energy and Mass

- July 2015: CREAM delivered to KSC and stored at KSC until launch
- June 2017 (TBC): Launch on SpaceX-12 commercial resupply service (CRS) flight to ISS

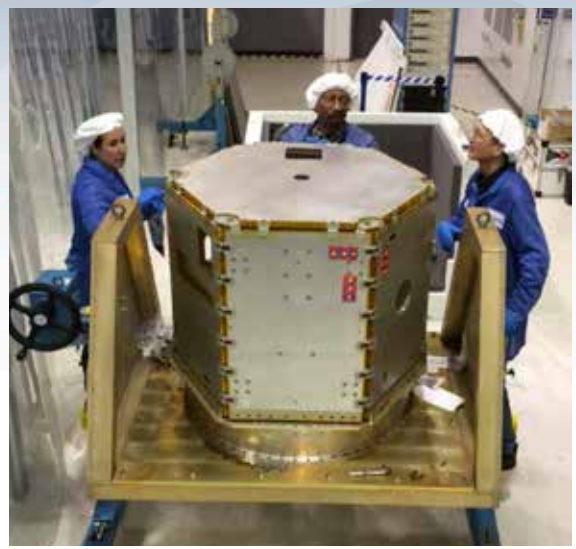
http://cosmicray.umd.edu/iss-cream/

TESS
Transiting Exoplanet Survey Satellite



CURRENT STATUS:

- Most spacecraft bus components have been delivered and s/c bus is being assembled
- Flight instrument build underway; first lots of flight CCDs have been produced
- Flight camera optics in assembly



Medium Explorer (MIDEX) Mission

PI: G. Ricker (MIT)

Mission: All-Sky photometric exoplanet mapping mission.

Science goal: Search for transiting exoplanets around the nearby, bright stars.

Instruments: Four wide field of view (24x24 degrees) CCD cameras with overlapping field of view, operating in the Visible-IR spectrum (0.6-1 micron).

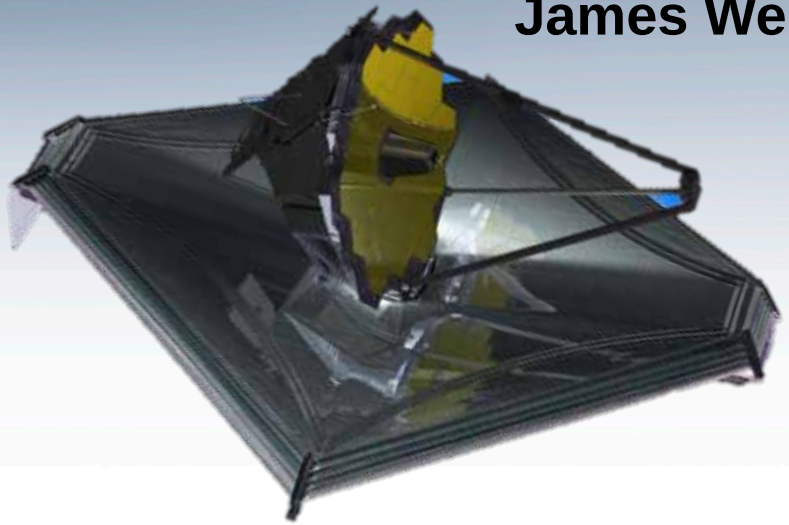
Operations: NLT June 2018 launch with a 3-year prime mission including 2 years of spacecraft operations and an additional 1 year ground-based observations and analysis. High-Earth elliptical orbit (17 x 58.7 Earth radii).

UPCOMING EVENTS:

- Spring-Fall 2016 – TESS bus integration and instrument integration ongoing
- Winter-Summer 2017 – TESS Observatory integration and test
- Spring 2017 – System Integration Review (SIR) and KDP-D
- Fall 2017 – TESS delivery to KSC launch site.
- Dec 2017 – Launch readiness date from Canaveral FL

http://tess.gsfc.nasa.gov/

Webb
James Webb Space Telescope



Large Infrared Space Observatory

Top priority of 2000 Decadal Survey

Science themes: First Light; Assembly of Galaxies; Birth of Stars and Planetary Systems; Planetary Systems and the Origins of Life

Mission: 6.5m deployable, segmented telescope at L2, passively cooled to <50K behind a large, deployable sunshield

Instruments: Near IR Camera, Near IR Spectrograph, Mid IR Instrument, Near IR Imager and Slitless Spectrograph

Operations: 2018 launch for a 5-year prime mission

Partners: ESA, CSA

2015-2016 Accomplishments

- Telescope mirrors installed
- Science instruments integrated with Telescope
- MIRI cryocooler completed
- Spacecraft bus powered on for first time
- Completed 2nd test of Pathfinder Telescope and ground support equipment at JSC in support of 2017 test of flight hardware

2016 Plans

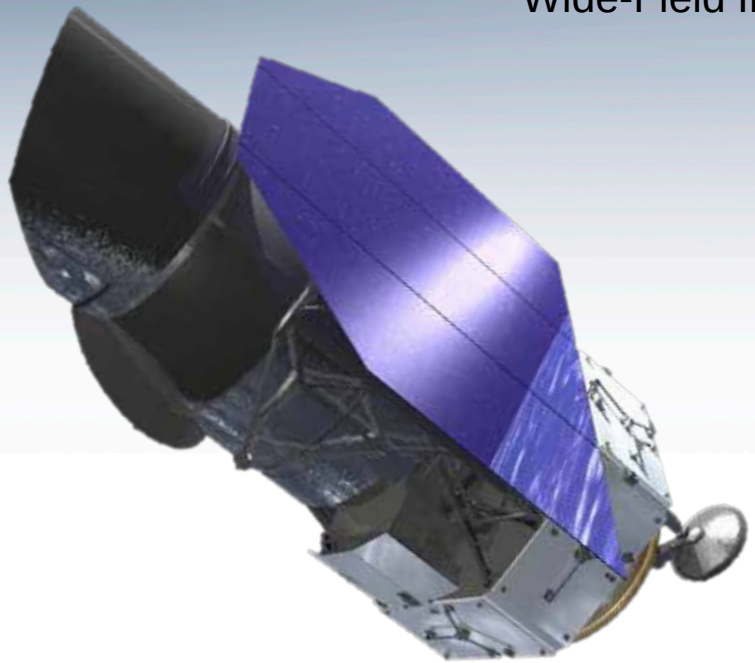
- Complete ambient testing of combined Telescope and instruments
- Complete spacecraft bus
- Complete sunshield membrane fabrication
- Cryovacuum testing of combined Telescope and instruments at JSC
- Integrate Sunshield and Spacecraft

http://www.jwst.nasa.gov/

JWST remains on track for an October 2018 launch within its replan budget guidelines

WFIRST

Wide-Field Infrared Survey Telescope



Wide-Field Infrared Survey Telescope

Top priority of 2010 Decadal Survey

Science themes: Dark Energy, Exoplanets, Large Area Near Infrared Surveys

Mission: 2.4m widefield telescope at L2; using existing hardware, images 0.28deg^2 at 0.8-2μm

Instruments (design reference mission): Wide Field Instrument (camera plus IFU), Coronagraph Instrument (imaging/IFS)

Phase: Currently in Formulation (Phase A)

CURRENT STATUS:

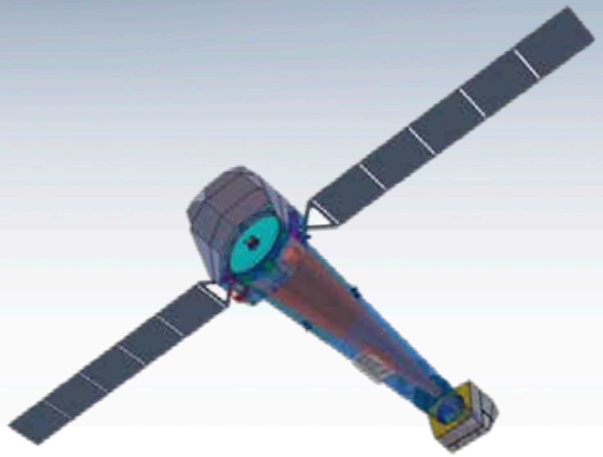
- Completed Mission Concept Review (MCR) held in December 2015
- Formulation Science Investigation Teams selected in December 2015; first meeting held February 2016.
- Ball and Lockheed Martin selected in February 2016 to support Wide-field Instrument Concept Studies
- Passed Key Decision Point A (KDP-A) in Feb 2016
  - Official start of formulation phase
  - Successful KDP-A held February 17, 2016
  - Established management agreement for total mission cost to govern formulation trades
  - Next major milestone is acquisition strategy meeting (ASM) in August 2016
- On track for TRL-6 of new technologies in 2017
- Working toward System Requirements Review (SRR) in June 2017 and KDP-B in October 2017
- FY17 budget request matches FY16 appropriation of $90M. In-guide budget supports launch in mid-2020s.

WFIRST has begun Formulation

http://wfirst.gsfc.nasa.gov/

Athena

Advanced **T**elescope for **H**igh **En**ergy **A**strophysics



- **Second ESA Cosmic Vision Large mission**
  - L-class with NASA/JAXA participation
  - Decadal Survey recommendation
  - Large X-ray mirror, X-IFU and WFI instruments
- **Launch Date:** 2028
- **Breakthrough Technologies**:
  - High Throughput, Wide FOV, High spectral resolution X-ray Astronomy
  - 10x Chandra area, 100x improved non-dispersive spectral resolution, 5x FOV.
- **Science Objectives**: The Hot and Energetic Universe: How does ordinary matter assemble into the large scale structures that we see today? How do black holes grow and shape the Universe?

CURRENT STATUS:

- Selected as 2nd Large mission in ESA Cosmic Visions Program.
- Currently in 2 year Study Phase.
- NASA and US community involved in Study Phase via membership on ESA-chartered Athena Science Study Team and SWGs
- NASA budgeting for a $100M-$150M hardware contribution, plus a U.S. GO program and a U.S. data center.
- NASA will provide the sensor array for the X-ray Integral Field Unit (calorimeter).
- NASA will provide optical bench and ASIC design, and is studying a Science Processing Module, for Wide Field Imager.
- NASA and ESA are discussing other possible NASA contributions.
- NASA continues to invest in Athena technologies via SAT and directed investigations.

http://sci.esa.int/cosmic-vision/54517-athena/

NASA's L3 Study Team (L3ST)

- Following the successful launch of the LISA Pathfinder, NASA has formed an L3 Study Team (L3ST) with membership drawn the US astrophysics community.
- The goals of the L3ST are:
  1. Analyze the options for NASA participation in the L3 mission and work with the European L3 consortium on proposals to ESA; and
  2. Prepare a report to the 2020 Decadal Survey on NASA's participation, including possible options, in the L3 mission as a minority partner.
- The membership of the L3 Study Group and its Charter can be found at **http://pcos.gsfc.nasa.gov/studies/L3/**
- A draft report for Goal 1 has been delivered to Astrophysics Division Director on June 20, 2016.

The draft report identifies the major areas of interest for the US for gravitational wave technology development and provides an analysis of their respective benefits and limitations.

- The draft report will assist NASA in its negotiations with ESA and will guide future SAT investments in gravitational wave technology.
- The draft report will be available soon at **http://pcos.gsfc.nasa.gov**

NASA Astrophysics

Budget Update

FY16 Appropriation

Outyears are notional planning from FY16 President's budget request

($M)	2014	2015	2016	2017	2018	2019	2020
Astrophysics*	$678	$685	$731	$707	$750	$986	$1118
JWST	$658	$645	$620	$569	$535	$305	$198
Total	$1336	$1330	$1351	$1273	$1285	$1291	$1316

*** Excludes "SMD STEM Activities" in all years.**

- Provides $90M for WFIRST and directs NASA to start Formulation.
- Provides full funding ($85M) for SOFIA operations and places SOFIA into the 2018 Astrophysics Senior Review.
- Provides full funding ($98M) for continued Hubble operations.
- Provides $37M for SMD STEM education activities.
- Requires reduction of $36M in rest of Astrophysics portfolio.

($M)	FY16 Request	FY16 Approps	Delta
JWST	$620	$620	--
WFIRST	$14	$90	+$76
SOFIA	$85	$85	--
Hubble	$97	$98	+$1
Rest of Astrophysics*	$493	$457	-$36 (-7%)
Total	$1309	$1351	+$42

* Excludes "SMD STEM Activities."

FY16 Appropriation

- Addressing the $36M reduction across the rest of Astrophysics

Project	$ FY16	Impact
Explorers Futures	$11M	Two month delay in development of future Explorers missions
TESS	$11M	Use of reserves not needed by the TESS project in FY16, with payback to the TESS project in FY17 and FY18 (rephasing of reserves)
ASTRO-H	$7M	Use of reserves held by the ASTRO-H project in case of problems in I&T or a launch delay; not needed by ASTRO-H project because ASTRO-H launched on time
R&A	$3M	One year reduction; fewer selections spread over FY16-FY17
Spitzer	$3M	Additional support from SMD makes up for reduction

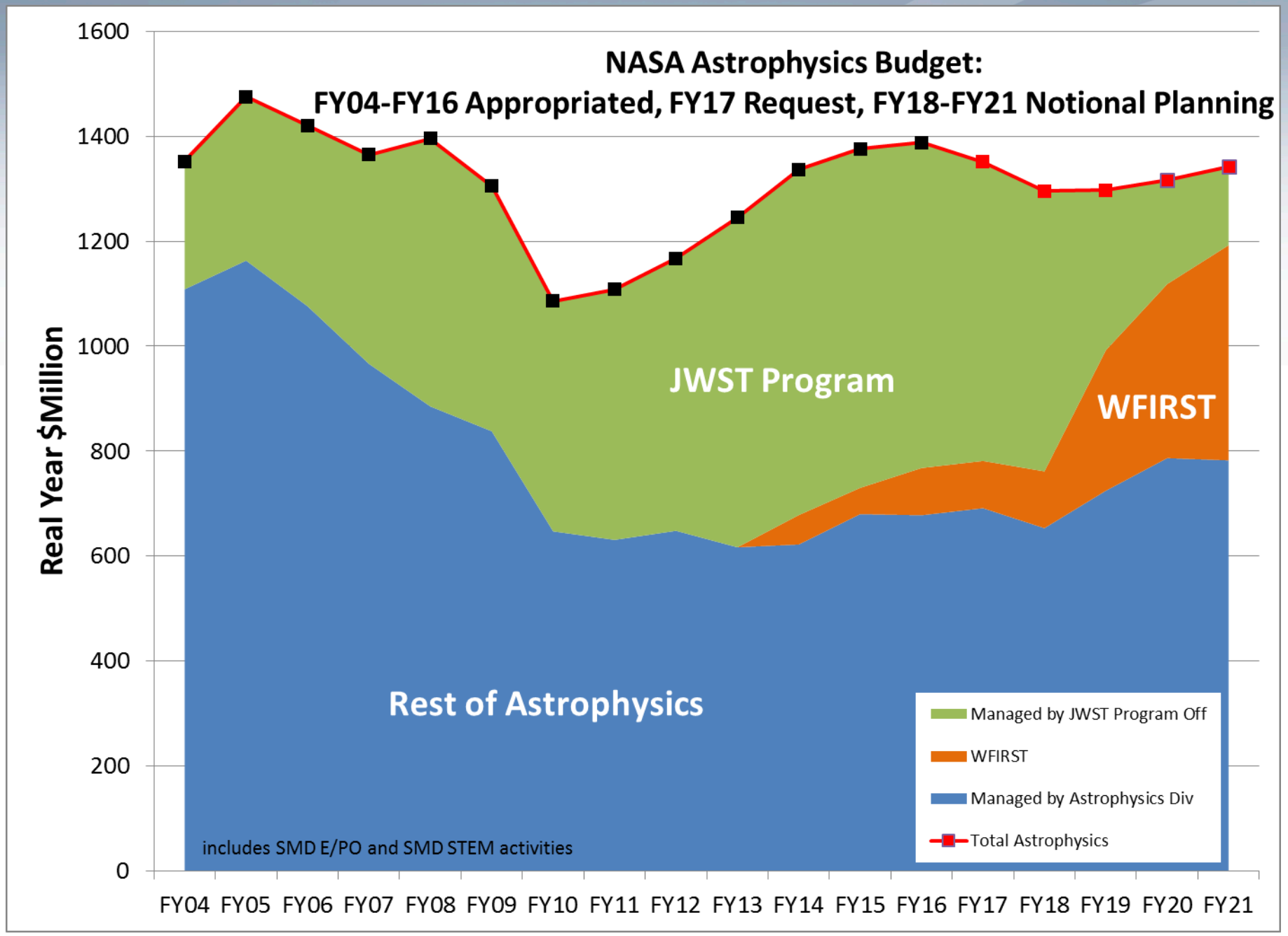
FY17 Budget Request

Outyears are notional planning from FY17 budget request

($M)	2015	2016	2017	2018	2019	2020	2021
Astrophysics*	$685	$731	$757	$737	$967	$1094	$1168
JWST	$645	$620	$569	$534	$305	$197	$150
Total*	$1330	$1351	$1326	$1271	$1272	$1291	$1318

*** Excludes "SMD STEM Activities" in all years.**

- This budget request is an excellent budget request for NASA Astrophysics ($1,326M excluding STEM).
- It compares well with the FY16 Appropriation ($1,351M excluding STEM) and significantly exceeds the FY17 notional runout in the President's FY16 request for NASA Astrophysics including JWST ($1,276M excluding STEM).
- This budget request and the notional runout allows WFIRST to be executed without additional funding.
- This budget request and the notional runout support other Decadal Survey priorities.
  - Continued Explorer AOs at the cadence of 4 per decade.
  - Partnerships on ESA's Athena X-ray observatory and L3 gravitational wave observatory.
  - Precursor exoplanet science and technology including Large Binocular Telescope Interferometer, Extreme Precision Doppler Spectrometer, and WFIRST Coronagraph.
  - Retains prior growth in R&A and suborbital programs.
- Senior Review funding is inadequate to continue all currently operating missions in FY17-FY18 without reductions in mission and GO funding.


NASA Astrophysics Budget:
FY04-FY16 Appropriated, FY17 Request, FY18-FY21 Notional Planning
Real Year $Million
1600
1400
1200
1000
800
600
400
200
0
JWST Program
WFIRST
Rest of Astrophysics
includes SMD E/PO and SMD STEM activities
Managed by JWST Program Off
WFIRST
Managed by Astrophysics Div
Total Astrophysics
FY04 FY05 FY06 FY07 FY08 FY09 FY10 FY11 FY12 FY13 FY14 FY15 FY16 FY17 FY18 FY19 FY20 FY21

FY17 Appropriations

- Both the House and the Senate appropriation subcommittees for NASA have marked up the President's budget request for NASA.
- Neither chamber has had a full vote on the NASA appropriation.
- Both chambers made changes to the President's budget request for NASA. The differences must be resolved before the FY17 NASA appropriation can be signed into law.

($M)	FY17 Request	Senate Mark	Senate Delta	House Mark	House Delta
Total Astrophysics	1350.9	1376.4	+25.5	1362.3	+11.4
JWST	569.4	569.4		569.4	
Hubble	97.3	98.3	+1.0		
SOFIA	83.8	83.8		85.2	+1.4
WFIRST	90.0	120.0	+30.0		
Mirror Tech		5.0	+5.0		
Starshade Tech				10.0	+10.0
STEM	25.0	42.0	+17.0	37.0	+12.0
Rest of Astrophysics		457.9	-27.5	660.7	-12.0

NASA Astrophysics

Planning for the 2020 Decadal Survey

Responding to the 2010 Decadal Survey

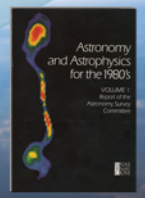
Prioritized Recommendation	NASA plans (partial list)
LARGE ACTIVITIES	
WFIRST	In Phase A, launch in mid-2020s
Explorers	Executing 4 AOs per deca
LISA	Partnering on ESA ased gravitational wave observ
IXO	Partn SA's Athena x-ray observatory
MEDIUM ACTIVITIES	
Exoplanet technology	FIRST coronagraph, starshade and coronagraph technology development
Inflation Prob gy	3 balloon-borne technology experiments
SMALL ES	
R&A aug entations	R&A up 20% since FY10
Mid-TRL technology	Initiated Strategic Astrophysics Technology program
Suborbital missions	Initiated super pressure balloon capability

Waiting for the Mid Term Review report

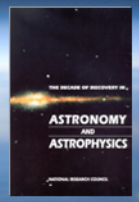
ASTROPHYSICS

Decadal Survey Missions

1972
Decadal Survey
Hubble



1982
Decadal Survey
Chandra



1991
Decadal Survey
Spitzer, SOFIA

2001
Decadal Survey
JWST

2010
Decadal Survey
WFIRST

Preparing for the 2020 Astrophysics Decadal Survey

- NASA has begun to study large mission concepts as input to the 2020 Decadal Survey
  - A well informed Decadal Survey makes better recommendations
- NASA has appointed Science and Technology Development Teams and initiated four large mission concept studies
  - X-ray Surveyor
  - Far Infrared Surveyor
  - Large Ultraviolet/Optical/Infrared Surveyor
  - Habitable Exoplanet Imaging Mission
- Science and Technology Definition Teams have a significant role and responsibility
  - Develop science case
  - Flow science case into mission parameters
  - Vet technology gap list
  - Direct trades of science vs cost/capability
- NASA is also planning to issue a call for medium-size mission concept studies (Astrophysics Probes)

http://science.nasa.gov/astrophysics/2020-decadal-survey-planning/

Preparing for the 2020 Decadal Survey
Large Mission Concepts

NASA has assembled Science and Technology Definition Teams (STDTs) for each of the four large mission candidates to enable Mission Concept Studies as input to the 2020 Decadal Survey.

	Community STDT Chairs	Center Study Scientist	Study Lead Center	HQ Program Scientist
Far IR Surveyor asd.gsfc.nasa.gov/firs	Asantha Cooray* Margaret Meixner	David Leisawitz	GSFC	Kartik Sheth
Habitable Exoplanet Imaging Mission www.jpl.nasa.gov/habex	Scott Gaudi* Sara Seager	Bertrand Mennesson	JPL	Martin Still
Large UV/Optical/IR Surveyor asd.gsfc.nasa.gov/luvoir	Debra Fischer* Bradley Peterson	Aki Roberge	GSFC	Mario Perez
X-ray Surveyor wwwastro.msfc.nasa.gov/xrs	Feryal Ozel* Alexey Vikhlinin	Jessica Gaskin	MSFC	Dan Evans

http://science.nasa.gov/astrophysics/2020-decadal-survey-planning/

Medium (Astrophysics Probes) Mission Concept Studies

In March 2016:

- The three PAGs issued a joint statement regarding NASA's plans for studying Astrophysics Probe mission concept studies.
  - NASA should support the development of a probe class of competed missions for the Decadal Survey.
  - There exists a wide range of community science goals that are both consistent with current National Academy priorities and that can be enabled with medium-class missions.
  - The work of preparing high quality white paper proposals to the 2020 Decadal Survey, for missions of this class, cannot be performed absent funding.
  - NASA HQ funds should allow at least 10 concepts for probe-class missions to be studied in some depth.
  - APD consider apportioning sufficient funds to carry out multiple CATE analyses that would apply to the general category of probe missions in advance of the Decadal Survey.
- The Astrophysics Subcommittee discussed the PAG analyses and provided findings to the NAC Science Committee.
  - A probe-class mission line should be considered by the Decadal Survey.
  - [NASA should] issue a solicitation through ROSES for Astrophysics Probe mission concept study proposals, with the expectation that roughly 10 will be selected for one-year studies supported at the level of roughly $100K each.

Medium (Astrophysics Probes) Mission Concept Studies

- NASA will solicit competitively selected, peer-reviewed, funded mission concept studies for Astrophysics Probes.
- NASA anticipates issuing a solicitation for Astrophysics Probe mission concept studies as a ROSES program element. NASA would issue this solicitation in August 2016 with proposals due approximately 90 days later. Following a peer review, NASA expects to make selections for 1-year funded studies beginning in March 2017.
- The solicitation will include the following guidelines.
  - Mission concept studies must be for missions that arguably can be realized for a life cycle cost between that of a MIDEX mission (~$400 million) and $1 billion.
  - The evaluation criteria will include the science merit in advancing NASA astrophysics science objectives, the value of a new study given any previous studies of similar mission concepts, and the feasibility of the mission concept being realizable with a new start in the 2020s for no more than $1 billion.
  - In addition to the funding provided to the mission concept study team, NASA will provide each study with an architecture design lab session at a NASA Center and a NASA cost assessment at the conclusion of the study; these services will be provided by NASA outside of the funding provided to the study team.
  - The total funding available to be awarded for selected proposals is $1M. NASA envisions selecting ~5-8 studies each funded at a level of $100K.

Medium (Astrophysics Probes) Mission Concept Studies

- The final deliverable of the mission concept studies will be a written report by the study team, which, along with the NASA cost assessment, will be presented to the Decadal Survey Committee.
- NASA acknowledges that the Decadal Survey Committee will receive additional mission concepts studies that were not funded by NASA.
- NASA plans to ask the Decadal Survey Committee to consider the following possible paths toward realizing Astrophysics Probes as part of a balanced portfolio of missions and activities in the 2020s and 2030s.
  a) Recommend a line of Astrophysics Probes, with the specific probes selected through a competitive process. Optionally the Decadal Survey Committee could recommend specific mission objectives to be included in an Astrophysics Probe line similar to the New Frontiers program of the Planetary Science Division.
  b) Request NASA to conduct a more detailed mission concept study of a small number (~2-3) of Astrophysics Probe mission concepts, with the objective to develop a mission concept that has sufficient detail to be subject to the Decadal Survey's independent cost assessment. The Decadal Survey Committee could then prioritize among these well-costed options and recommend that NASA pursue one or more of them.

Medium (Astrophysics Probes) Mission Concept Studies

Schedule for Astrophysics Probes Mission Concept Studies

Release solicitation	August 2016
Receive NOIs	September 2016
Proposal due date	November 2016
Selection & Study initiation	March 2017
Study completion	September 2018

NASA seeks feedback from the Subcommittee on this plan

NASA Astrophysics

Considering ASTRO-H2

Hitomi

(formerly ASTRO-H)

Soft X-ray Spectrometer and Soft X-ray Telescope Mirrors

- **Explorer Mission of Opportunity**
- **PI**: R. Kelley, Goddard Space Flight Center
- **Launch Date**: Feb 17, 2016 on JAXA H-IIA
- **Science Objectives**: Study the physics of cosmic sources via high-resolution X-ray spectroscopy. The SXS will enable a wide range of physical measurements of sources ranging from stellar coronae to clusters of galaxies.

CURRENT STATUS

The U.S. provided key instrument contributions to the JAXA Hitomi mission, including:

- Soft X-ray telescope mirrors (SXT-S and SXT-I)
- X-ray Calorimeter Spectrometer Insert (CSI), including Adiabatic Demagnetization Refrigerator (ADR) and ADR Controller
- Aperture Assembly

- Following successful activation of the observatory and instruments, Hitomi suffered a mission-ending spacecraft anomaly on March 26, 2016
- Prior to mission failure, the SXS demonstrated a spectral resolution of ~4.7 eV, significantly exceeding the pre-launch requirement
- The SXS completed several science observations, including a scientifically significant observation of the Perseus Cluster

UPCOMING EVENTS:

- Finalization of JAXA mishap investigation
- PI-led team complete analysis and archiving of available data

Hitomi (formerly ASTRO-H) Anomaly

JAXA Hitomi Experience Report (May 24, 2016)

Presumed Mechanism (Summary)

(From “Normal situation” to the “Attitude anomaly Event” and “Objects separation”)

- On March 26th, attitude maneuver to orient toward an active galactic nucleus was completed as planned.
- After the maneuver, unexpected behavior of the attitude control system caused incorrect determination of its attitude as rotating, although the satellite was not rotating actually. In the result, the reaction wheel to stop the rotation was activated and lead to the rotation of satellite.
- In addition, unloading of angular velocity by Magnetic Torquer operated by attitude control system did not work properly because of the attitude anomaly. The angular momentum kept accumulating in reaction wheel.
- Judging the satellite is in the critical situation, ACS switched to Safe Hold mode, and the thrusters were used. At this time ACS provided atypical command to the thrusters by the inappropriate thruster control parameters. As a result, it thrusted in an unexpected manner, and it is estimated that the satellite rotation was accelerated.
- Since the rotation speed of the satellite exceeded the designed speed, parts of the satellite that are vulnerable to the rotation such as solar array paddles, Extensible Optical Bench and others separated off from the satellite. There is high possibility that the both Solar Array Paddles had broken off at their bases and were separated.

http://http://global.jaxa.jp/projects/sat/astro_h/

Considering ASTRO-H2

Background

- The capability of spatially resolved, high spectral resolution x-ray images has been a key science objective of NASA since the 1985 selection of a GSFC microcalorimeter for the original AXAF payload.
- This capability has not yet been realized on an orbital mission, and the potential science return remains unrealized.
  - Placed on AXAF-S when AXAF descoped, then cancelled.
  - JAXA included a microcalorimeter built by GSFC on the ASTRO-E, ASTRO-E2 (Suzaku), and ASTRO-H (Hitomi) missions. None of these missions reached normal operations.
- The successful demonstration of the Soft X-ray Spectrometer (SXS), along with its cooling chain, on ASTRO-H (Hitomi) demonstrated TRL-9 for this technology and retired the technology maturation risk.
- On June 1 & June 14, JAXA President Okumura announced JAXA's intent to study a rebuild of Hitomi ("ASTRO-H2") and JAXA has asked NASA to consider participating in the mission.
  - NASA has agreed to consider a build-to-print of the instrument demonstrated on ASTRO-H (Hitomi).
  - JAXA has indicated a desire to begin development of ASTRO-H2, if approved, in FY2017.

Considering ASTRO-H2

Benefit

- Cited in the 2010 Decadal Survey as a “truly revolutionary technology,” an X-ray microcalorimeter will provide a major leap forward in our understanding of the universe.
- The science community has communicated the importance of this science and the impact of the loss of ASTRO-H (Hitomi) directly to NASA.
- Achieving the science possible with a relatively modest observatory (e.g., ASTRO-H2 with SXS) in advance of a large observatory with a next generation microcalorimeter instrument (Athena with the X-ray Integral Field Unit (XIFU) microcalorimeter) would significantly enhance the science return and mitigate the technical risk of the Athena mission.
- The report from the X-ray Science Interest Group (XRSIG) of the Physics of the Cosmos Program Analysis Group (PhysPAG), dated July 5, 2016, offers more details.

Considering ASTRO-H2

Cost

- Assuming a build-to-print SXS instrument (detector system including cooling chain and associated electronics plus two mirror systems), and taking into account lessons learned and available flight spare parts, the estimated cost for the U.S. (4.5 year Phase A-D, not including operations and GO program) would be $70-90M (FY2017-FY2021).
- At this time, it is not known whether any additional funding would be made available to supplement the planned NASA astrophysics budget to undertake a NASA contribution to ASTRO-H2.
- The approximately $20M per year required for a NASA contribution to ASTRO-H2 is smaller than the challenges to the planned astrophysics program in recent appropriations that have been accommodated with modest acceptable impact.
- The funding required for a NASA contribution to ASTRO-H2 would need to start in FY2017, so delaying future Astrophysics Explorers AOs (like the 2016 MIDEX AO) would not free up funding in the appropriate year; NASA therefore does not intend to delay the 2016 MIDEX AO even if a decision is made to proceed with ASTRO-H2.

Considering ASTRO-H2

Plan

- NASA is studying the possibility of contributing for ASTRO-H2 a build-to-print copy of the flight hardware provided for Hitomi.
- NASA will work with JAXA to address the root causes that JAXA has identified as being responsible for the Hitomi mishap and loss of mission. NASA and JAXA will address these issues to assure that any future JAXA/NASA partnership missions will be successful.
- Should NASA agree to participate in ASTRO-H2, the development of the ASTRO-H2 hardware and guest observer facility would be directed to GSFC rather than competed through a competitive proposal opportunity, such as an Explorers MO AO. Only the GSFC team can execute a build-to-print project, on a rapid schedule and at the lowest cost.
- Should NASA agree to participate in ASTRO-H2, NASA will work with JAXA to make the ASTRO-H2 observatory available to the general observer (GO) community at a level equal to or greater than was planned for Hitomi.
- NASA will continue discussions with JAXA in August 2016 regarding a possible ASTRO-H2 mission.

Considering ASTRO-H2

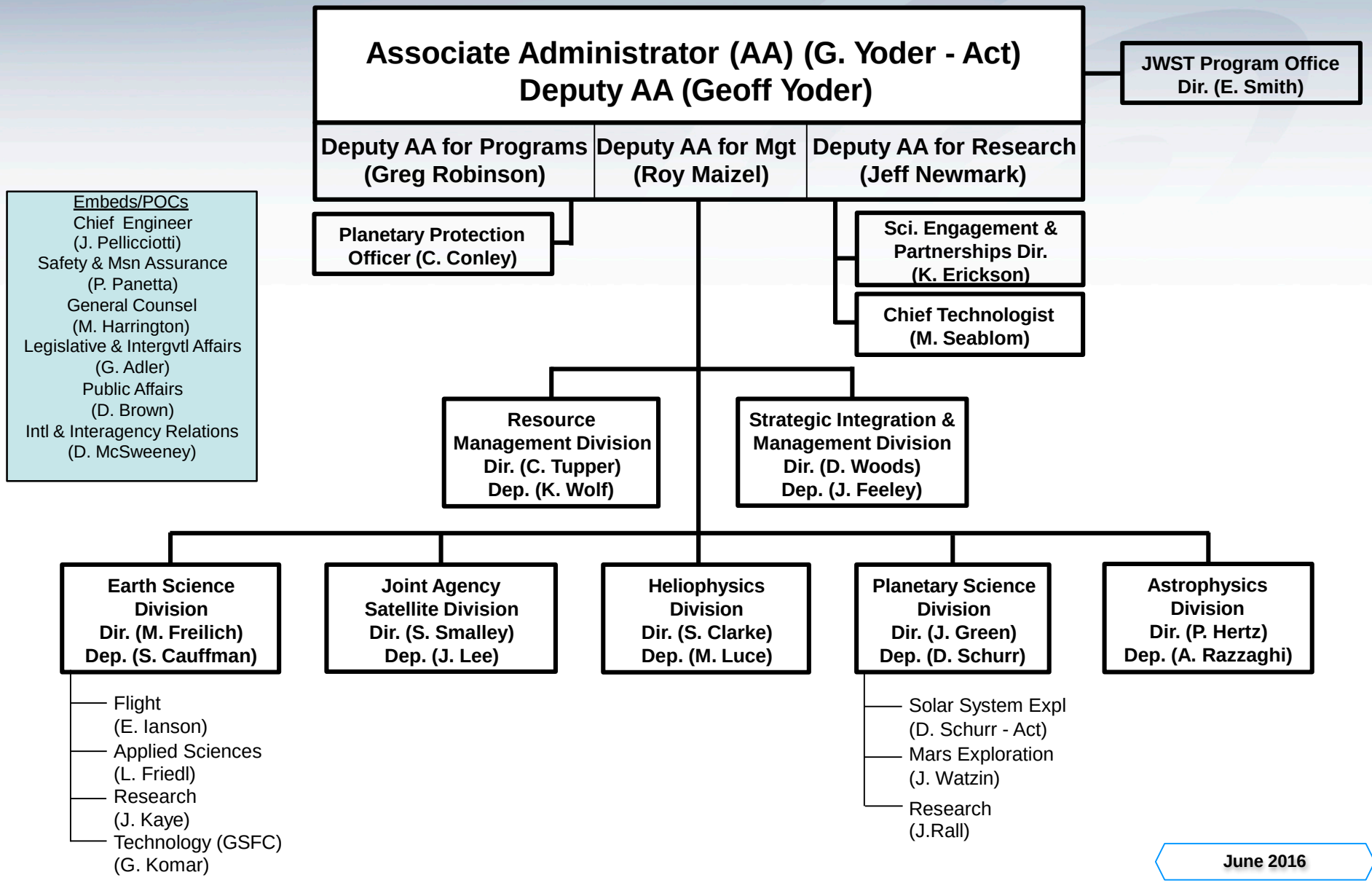
The Astrophysics Subcommittee is asked to consider NASA's plans to continue discussing a potential ASTRO-H2 with JAXA and to provide a response to these plans.

- The response may include comments, findings, and/or recommendations.


Formulation
Implementation
Primary Ops
Extended Ops
Spitzer
8/25/2003
Kepler
3/7/2009
WFIRST
Mid 2020s
LISA Pathfinder (ESA)
12/3/2015
Webb
2018
Euclid (ESA)
2020
Chandra
7/23/1999
XMM-Newton (ESA)
12/10/1999
TESS
2017
Swift
11/20/2004
NuSTAR
6/13/2012
Fermi
6/11/2008
Hubble
4/24/1990
CREAM (on ISS)
2017
NICER (on ISS)
2017
SOFIA
Full Ops 5/2014

BACKUP

SMD Organization



Astrophysics Division, NASA Science Mission Directorate

Resource Management
Omana Cawthon+
Clemencia Gallegos-Kelly+

Director
Paul Hertz
Deputy Director
Andrea Razzaghi

Lead Secretary: Kelly Johnson
Secretary: Leslie Allen
Program Support Specialist: Jackie Mackall

Cross Cutting
Technology Lead: Billy Lightsey*
Education POC: Hashima Hasan (Lead Comm Team)
Public Affairs Lead: Kartik Sheth
Information Manager: Lisa Wainio*

Astrophysics Research

Program Manager:	Linda Sparke
Program Support:	Pam Terrell*
Astrophysics Data Analysis:	Doug Hudgins
Astrophysics Theory:	Keith MacGregor*, Theresa Brandt*
Exoplanet Research:	Martin Still*
APRA lead:	Michael Garcia*
Cosmic Ray, Fund Physics:	Thomas Hams*, Vernon Jones, Keith MacGregor*, Rita Sambruna
Gamma Ray/X-ray:	Dan Evans, Michael Garcia*, Stefan Immler*, Lou Kaluzienski, Rita Sambruna, Wilt Sanders
Optical/Ultraviolet:	Michael Garcia*, Hashima Hasan, Mario Perez*, Martin Still*
IR/Submillimeter/Radio:	Dominic Benford*, Doug Hudgins, Kartik Sheth, Erin Smith*
Lab Astro:	Doug Hudgins
Theory & Comp Astro Net:	Keith MacGregor*
Roman Tech Fellows:	Billy Lightsey*
Data Archives:	Hashima Hasan
Astrophys Sounding Rockets:	Wilt Sanders
Balloons Program:	Vernon Jones(PS), Mark Sistilli (PE)

Programs / Missions & Projects

Exoplanet Exploration (EXEP)

Program	**Doug Hudgins**	**John Gagosian**
Keck	Hashima Hasan	Mario Perez*
Kepler/K2	Mario Perez*	K. Chamberlin*/Jeff Hayes
LBTI	Doug Hudgins	Mario Perez*
NN-EXPLORE	Doug Hudgins	John Gagosian
WFIRST	Dominic Benford*	John Gagosian

Cosmic Origins (COR)

Program	**Mario Perez***	**Shahid Habib***
Herschel	Dominic Benford*	Jeff Hayes
Hubble	Michael Garcia*	Jeff Hayes
James Webb^	Hashima Hasan	Ray Taylor^
SOFIA	Hashima Hasan	Shahid Habib*
Spitzer	Erin Smith*	Jeff Hayes

Physics of the Cosmos (PCOS)

Program	**Rita Sambruna**	**Shahid Habib***
Athena	Michael Garcia*	Jeanne Davis
Chandra	Stefan Immler*	Jeff Hayes
Euclid	Linda Sparke	Keith Chamberlin*
Fermi	Stefan Immler*	Jeff Hayes
Planck	Rita Sambruna	Jeff Hayes
ST-7/LPF	Rita Sambruna	Keith Chamberlin*
XMM-Newton	Stefan Immler*	Jeff Hayes

Astrophysics Explorers (APEX)

Program	**Wilt Sanders**	**Jeanne Davis**
Hitomi	Lou Kaluzienski	Jeanne Davis
NICER	Rita Sambruna	Jeanne Davis
NuSTAR	Lou Kaluzienski	Jeff Hayes
Suzaku	Stefan Immler*	Jeff Hayes
Swift	Martin Still*	Jeff Hayes
TESS	Doug Hudgins	Mark Sistilli

+ Member of the Resources Management Division
** Detailee, IPA, or contractor*
^ James Webb is part of the JWST Program Office.

July 13, 2016

SMD Education Cooperative Agreements dedicated to astrophysics

Universe of Learning (PI: Denise Smith, STScI; co-I institutions: CXC/SAO, IPAC/JPL, ExEP/JPL, Sonoma State U.; Evaluation: Goodman Research Group, Cornerstone Evaluation Associates.)

- Combines science and technology from across NASA Astrophysics with proven education infrastructure to address audience needs and SMD education objectives.
- Program Status: Start-Up Phase Underway
  Year 1 funded effective 3/21/16; full team kick-off in June; Needs assessments, literature reviews, evaluation plan in progress; User benchmarking of website infrastructure initiating in May; Definition of collaborations with other CAN awardees in progress.

SOFIA Airborne Astronomy Ambassadors (PI: Dana Backman; Evaluation: WestEd)

- Scheduled Cycle 4 cohort of 22 educators for SOFIA flights between August 2016 and January 2017.
- Met with Santa Clara County (N. California) school district science coordinators for assessment of needs, aimed at eventual selection of Cycle 5 (2017) teacher cohort and baseline measurements of student performance; Scheduled meetings with Los Angeles county school officials for assessment of needs.

Girl Scouts: Reaching for the Stars (PI: Edna DeVore, SETI)

- Held two Space Science Badge design workshops.
- Drafted Badges for Daisies, Brownies, and Junior Girl Scouts (grades K-5).
- Collaborated with the GS Volunteer Tool Kit team to develop online materials for leaders.
- Supported Bridging Day for 6,500 Junior Girl Scouts at Golden Gate Bridge, San Francisco.
- Held 3-day Volunteer Leader Astronomy Camp at University of Arizona.
- Planning Girl Scout Destinations program for solar eclipse in 2017.