



NASA Astrophysics Division Update

NAC Science Committee

April 8, 2015

Astrophysics

Paul Hertz

**Director, Astrophysics Division
Science Mission Directorate**

@PHertzNASA

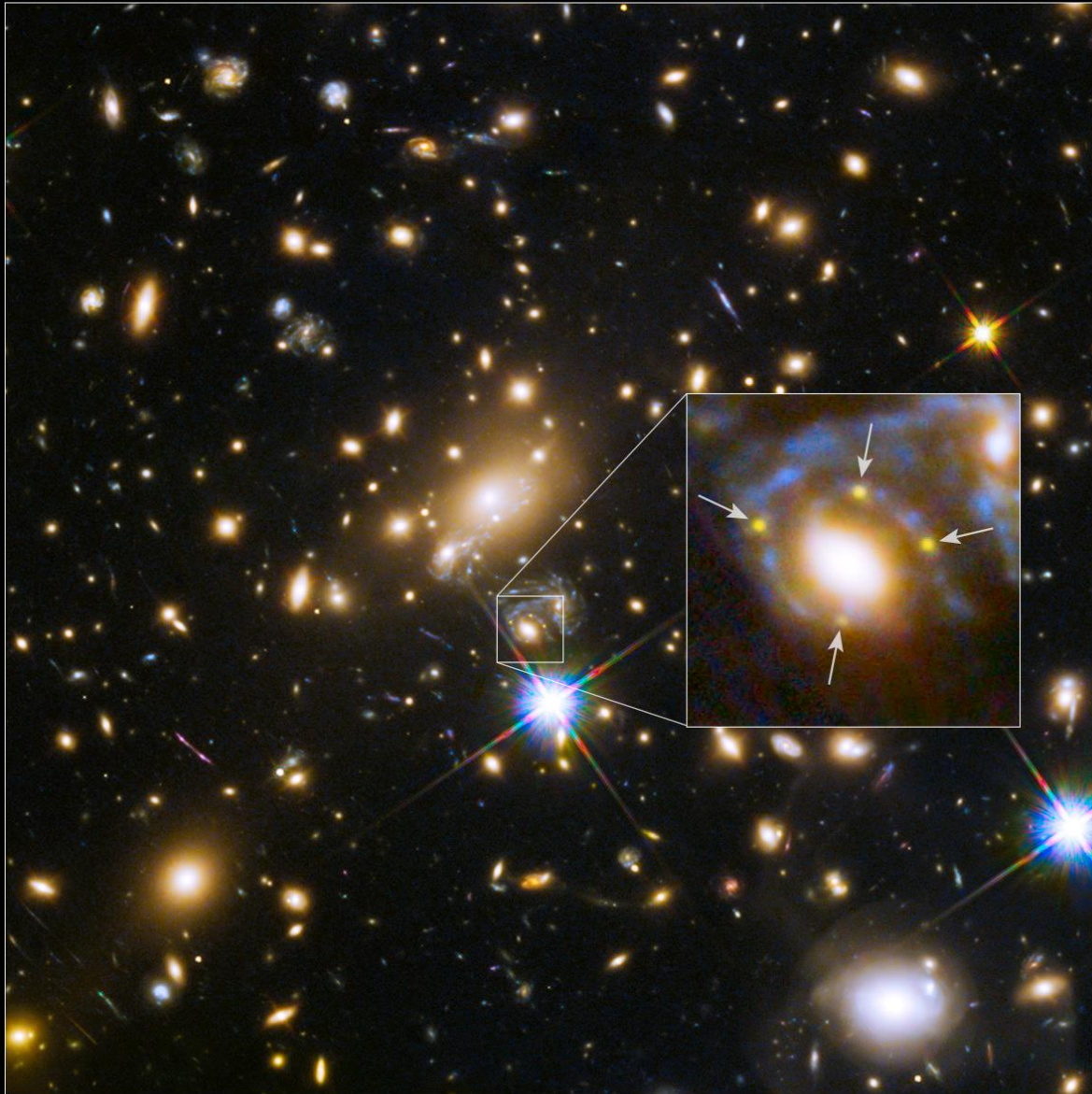
Astrophysics Division Overview

- **Strategic Objective:** Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars.
- **Major activities:**
 - Building, launching, and operating space observatories, many with international partners.
 - Developing technologies to enable future observatories.
 - Basic R&D as well as focused technology development.
 - Conducting and sponsoring cutting-edge research, enabling research, technology, and workforce development.
 - Suborbital-class projects using scientific balloons, sounding rockets, International Space Station, and other platforms.
 - Analysis of data from NASA and international partner space observatories.
 - Theoretical and computational investigations.
 - Laboratory experiments in support of astrophysical understanding.

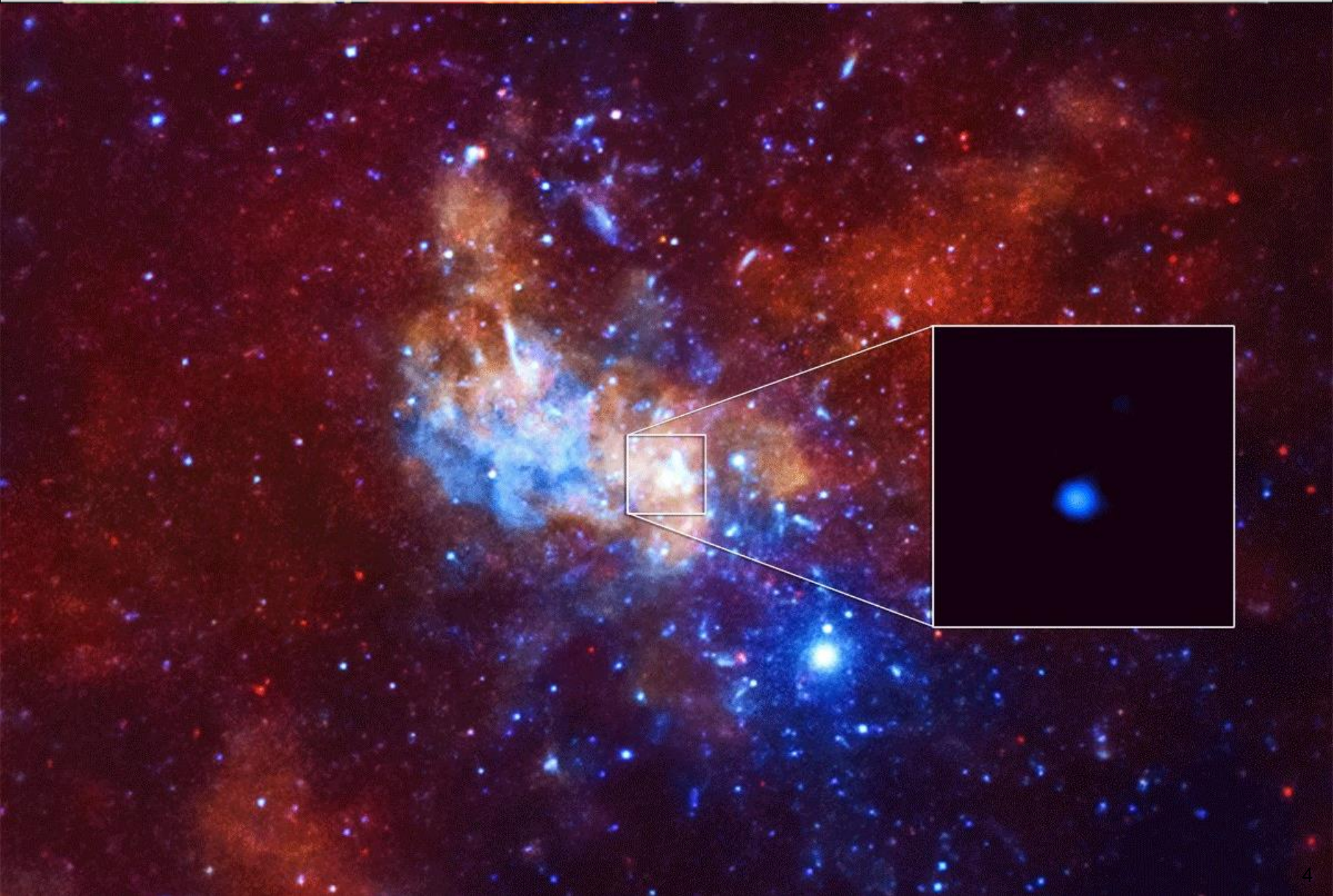
Hubble Sees Supernova Split into Four Images by Cosmic Lens

Supernova Refsdal
Galaxy Cluster MACS J1149.6+2223

Hubble Space Telescope
ACS/WFC ■ WFC3/IR

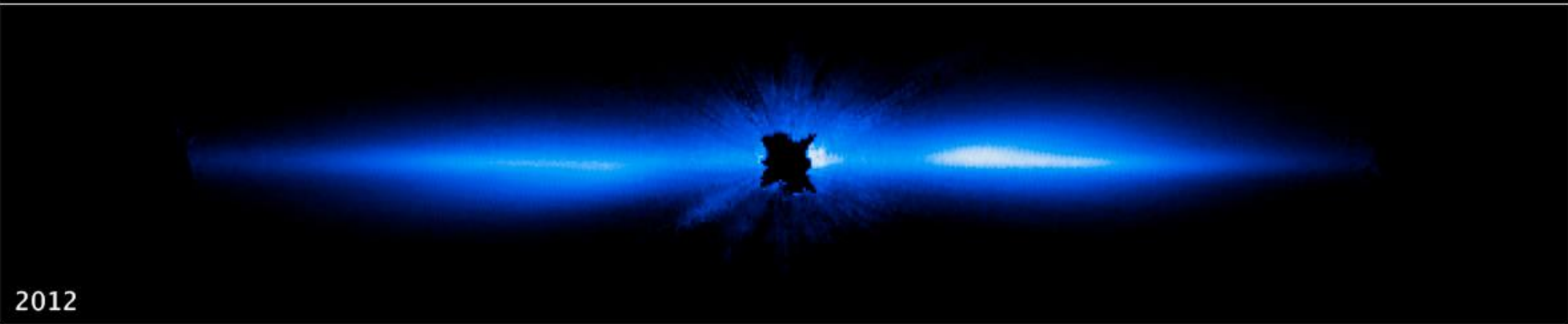
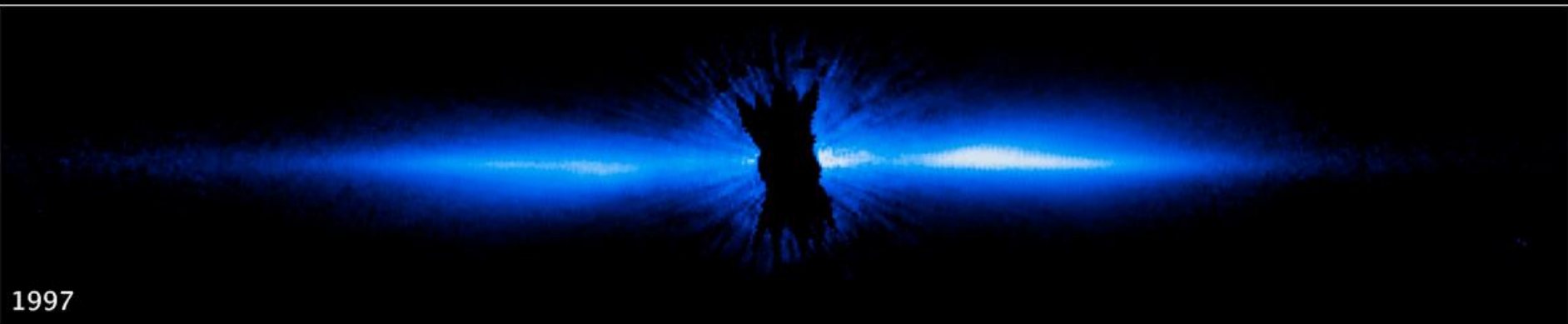


NASA's Chandra Detects Record-Breaking Outburst from Milky Way's Black Hole

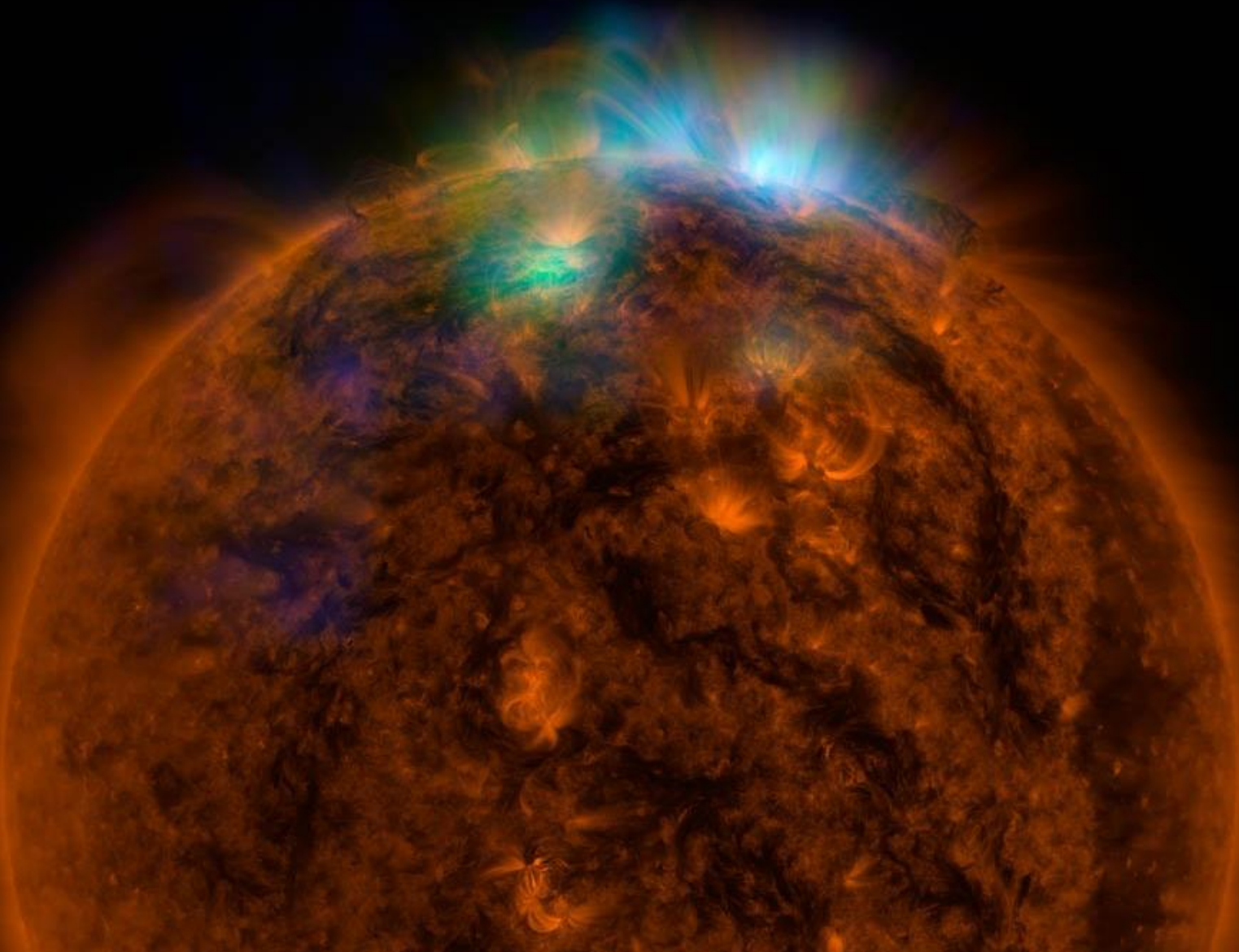


NASA's Hubble detects Distortion of Circumstellar Disk by a Planet

Beta Pictoris ■ *Hubble Space Telescope* ■ STIS



Sun Dazzles In First-Ever NuSTAR High-Energy X-Ray Portrait



SOFIA Finds Missing Link Between Supernovae and Planet Formation

Sagittarius A East Supernova Remnant

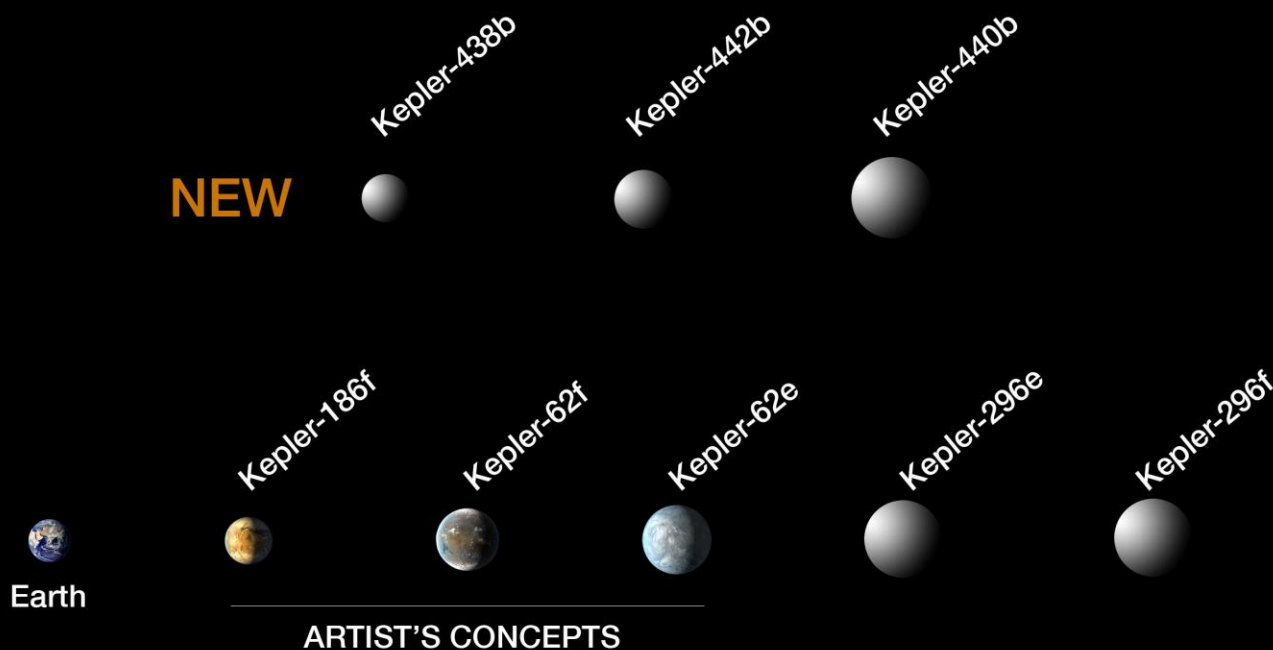
- Warm dust
- Cold dust
- Radio
- X-Ray

5 Light Years

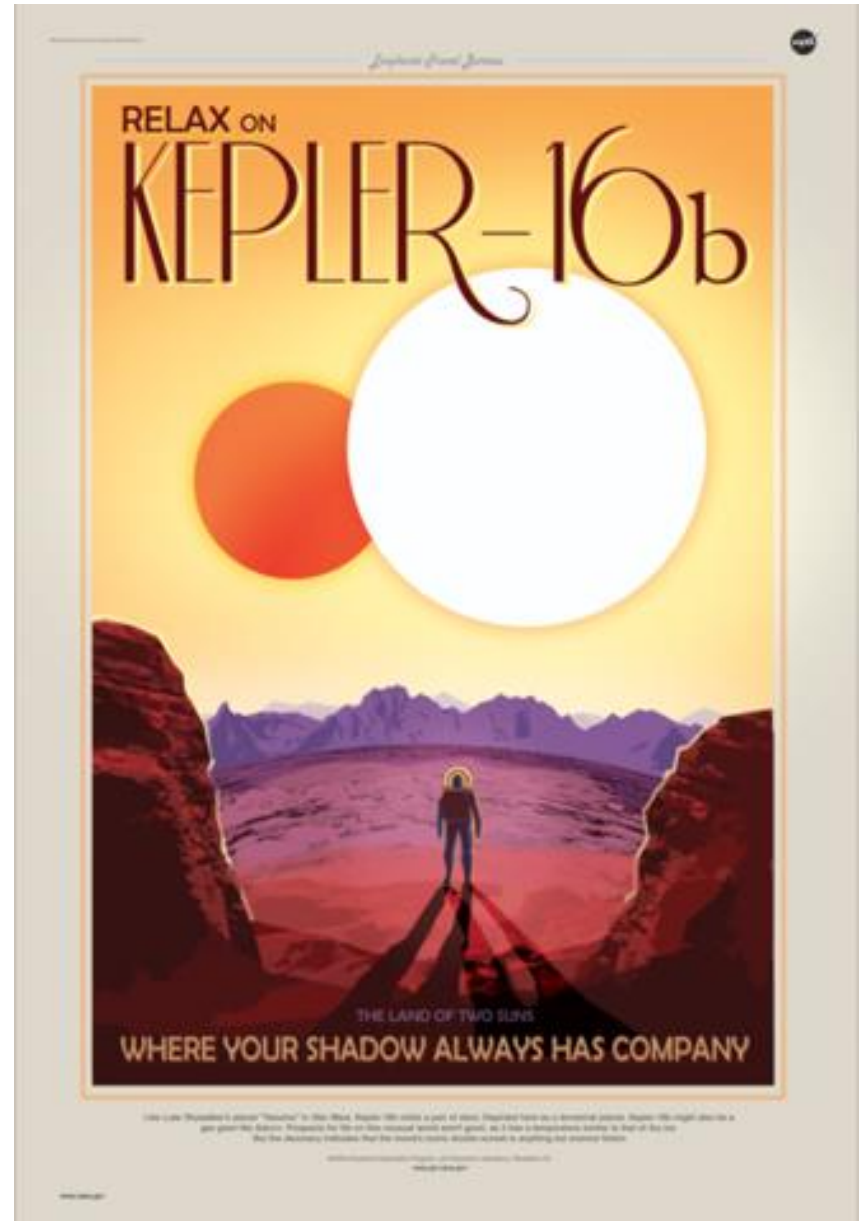
Image Credit: NASA/CXO/Herschel/VLA/Lau et al

NASA's Kepler Marks 1,000th Exoplanet Discovery, Uncovers More Small Worlds in Habitable Zones

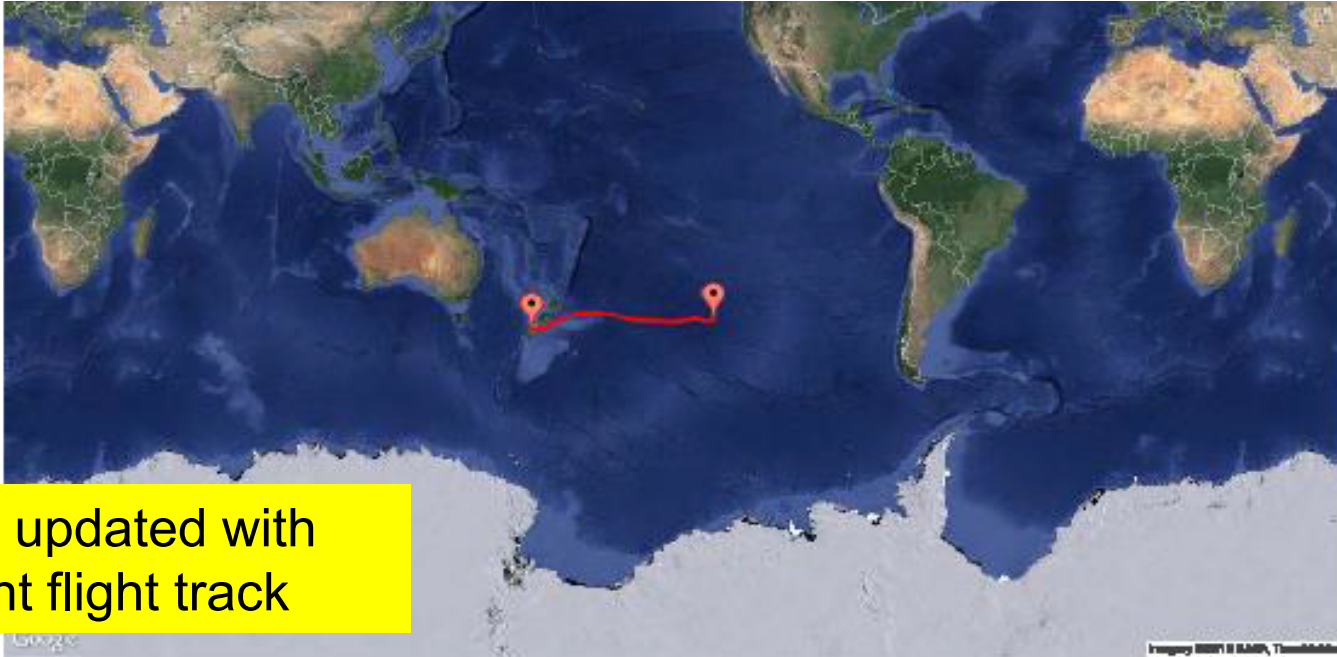
NASA Kepler's Hall of Fame: Small Habitable Zone Planets *As of January 2015*



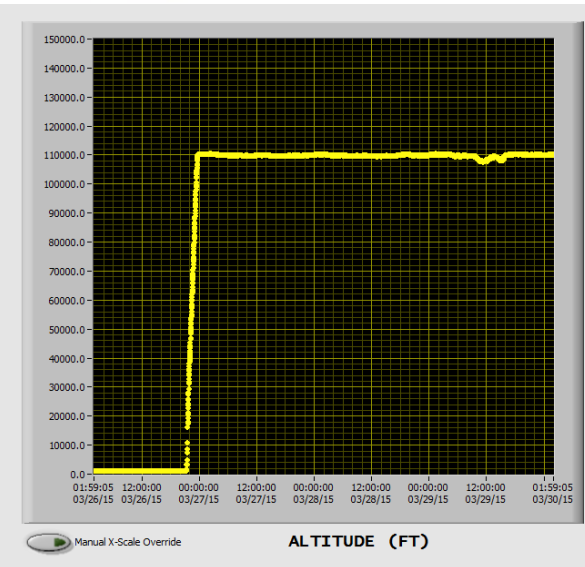
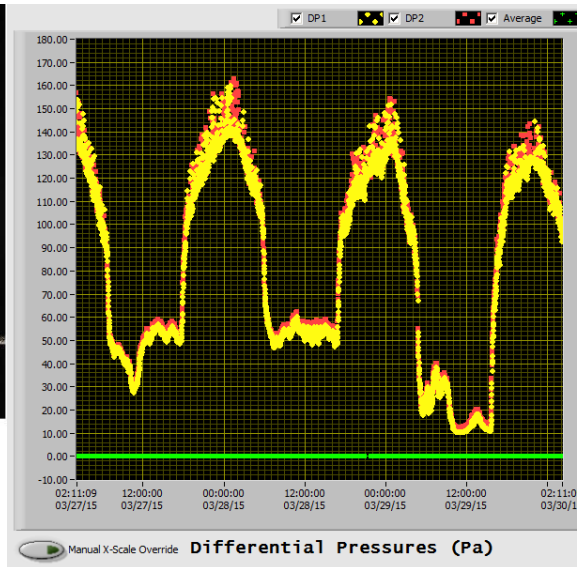
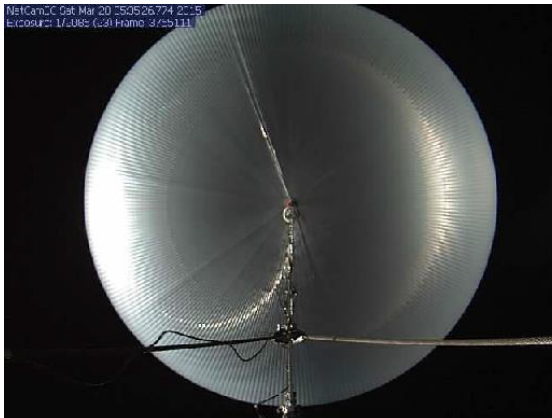
The Exoplanet Travel Bureau



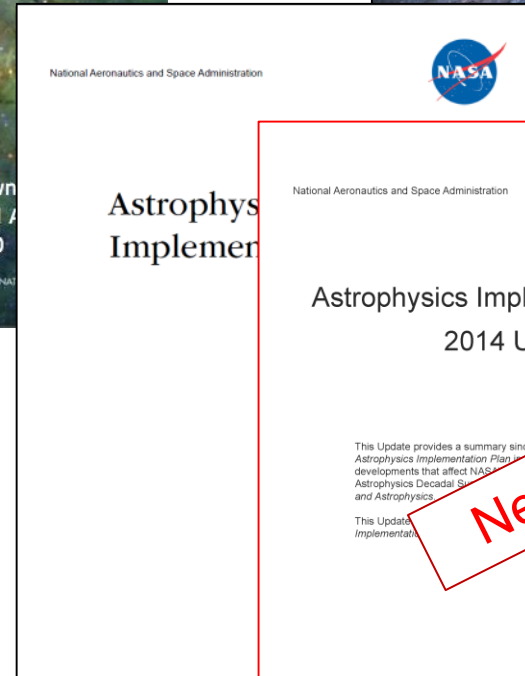
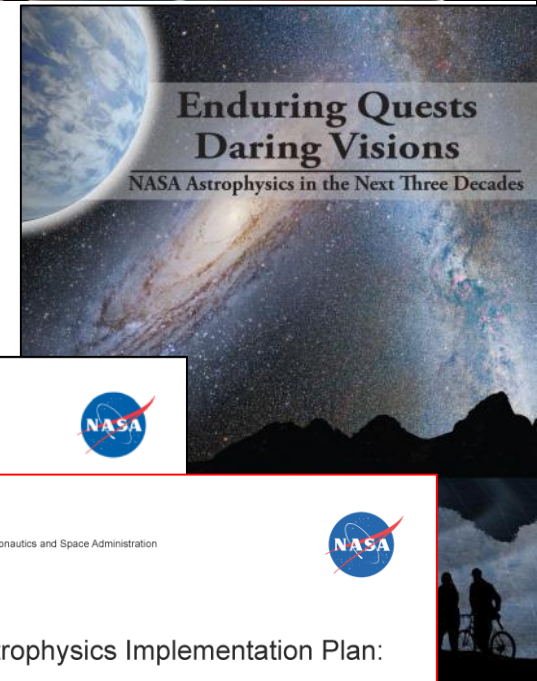
ULDB Test Flight – March 30



Will be updated with current flight track



Astrophysics Driving Documents



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

Major Mission Accomplishments Past 12 Months

- The **Astrophysics Senior Review** for operating missions was held in March 2014. The “K2” mission for the **Kepler** spacecraft was approved for two years. Two year extensions were also approved for **Fermi, NuSTAR, Spitzer, Suzaku, Swift, and XMM-Newton. Hubble and Chandra** were extended.
- The **Stratospheric Observatory for Infrared Astronomy (SOFIA)** passed KDP-E and was declared operational on May 29, 2014.
- The **Neutron-star Interior Composition Explorer (NICER)** experiment for the International Space Station completed its Critical Design Review (CDR) on July 31, 2014.
- July 31, 2014, the **Nuclear Spectroscopic Telescope Array (NuSTAR)** successfully completed its prime mission and, as a result of the 2014 Senior Review, begun its extended mission.
- On September 9, 2014, the **Hubble Space Telescope** successfully completed the 5-year prime mission that began with Servicing Mission 4 (SM-4) in 2009.
- The **Transiting Exoplanet Survey Satellite (TESS)** passed KDP-C and was confirmed into the implementation phase on October 31, 2014.
- In December 2014, **SOFIA** returned to the U.S. following a successful Heavy Maintenance Visit in Germany; resumed science flights in January 2015.
- On December 18, 2014, ~25 proposals were received for **Astrophysics Explorers** small missions or missions of opportunity; the selection of one of each is anticipated for summer 2015.
- By January 2015, NASA completed delivery to Japan of all NASA-provided flight hardware for the JAXA **ASTRO-H** mission for integration into the spacecraft and system-level environmental testing.
- **Two Balloon campaigns comprising nine payloads** were completed in FY14.
- **Three Sounding Rocket payloads** were flown in FY14.



Hubble Space Telescope 25th Anniversary

Sample of Events & Programs:

- Hubble 2020 STScI symposium Apr 23
- Webcast event at National Air & Space Museum April 24
- Coordinated events worldwide April 24
- Family Day at Udvar-Hazy April 25
- Exhibits at museums around the world
- Exhibits at multiple airports
- Nationwide University lecture series
- Education programs in all 50 states
- Comprehensive traditional & social media outreach plans
- 'Ode to Hubble' video contest
- New Planetaria clips
- Re-release of IMAX 'Hubble 3D'



Find out more: hubble25th.org

Join the celebration: [#Hubble25](https://twitter.com/Hubble25)

Astrophysics - Big Picture

- **The FY15 appropriation and FY16 budget request provide funding for NASA astrophysics to continue its programs, missions, and projects as planned**
 - The total funding (Astrophysics including JWST) is flat at ~\$1.3B through FY20
 - Fully fund JWST to remain on plan for an October 2018 launch
 - Fund continued pre-formulation and technology work leading toward WFIRST
 - Restore SOFIA to the budget with a reduction in FY15 and full funding beyond
 - Provide funding for SMD's education programs
- **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, Suzaku, Swift, XMM-Newton continued following the 2014 Senior Review
 - SOFIA is in prime operations as of May 2014
 - Missions on track for launch include LISA Pathfinder (2015), ASTRO-H (2015), NICER (2016), TESS (2017), JWST (2018), Euclid (2020)
 - New Explorers being selected (SMEX in 2015, MIDEX in 2017), WFIRST being studied, NASA joining ESA's Athena and ESA's L3 gravitational wave observatory
- **Progress being made against recommendations of the 2010 Decadal Survey**
 - Update to the Astrophysics Implementation Plan has been released
 - NRC Mid Decade Review (with NSF, DOE) to begin in early 2015
 - NASA initiating large mission concept studies for 2020 Decadal Survey

FY15 Appropriation

(\$M)	2013	2014	2015	2016	2017	2018	2019
Astrophysics			\$685				
JWST			\$645				

- Provides \$77M more than the President's Budget Request for FY15
- Supports the commitment to an October 2018 launch date for JWST
- Includes \$50M for continued preformulation of WFIRST, an increase of \$36M over the Administration request and comparable to FY14
- Includes \$70M for continued SOFIA operations, a reduction of \$14M (17%) from FY14
 - Directs NASA to (a) seek partners to restore SOFIA to its full level, and (b) not terminate missions without a Senior Review
- Includes \$98M for Hubble operations, the same as FY14
- Includes \$38M for scientific ballooning, an increase of \$5M (15%) from FY14
- Does not specify the distribution of funding for the rest of Astrophysics, but the funding is adequate for Astrophysics to execute its program as planned in FY15.
 - Includes support as planned in FY15 for missions under development, operating missions, SMEX AO, R&A, etc.
 - Final budget numbers available when NASA operating plan approved

FY16 President's Budget Request

What's changed

- Continued operations for SOFIA are provided, including assessment as part of the 2016 Astrophysics Senior Review
- Following the 2014 Astrophysics Senior Review, mission operations extensions are approved for Kepler, NuSTAR, Spitzer, Suzaku, and XMM
- Funding for the Hubble Fellows has been moved from COR SR&T to the Hubble project
- TESS budget reduced due to selection of lower cost Falcon 9 launch vehicle
- To support ESA schedule, Euclid development is delayed and budget is rephased
- To support JAXA schedule, ASTRO-H budget is rephased
- Astrophysics Future Missions adjusted to match planned AO schedule; budget supports Decadal Survey cadence of 4 AOs per decade

What's the same

- R&A, Data Analysis, Archives, Program management
- Scientific Balloon project
- Closeout budgets for Herschel and Planck
- Following the 2014 Astrophysics Senior Review, previously budgeted mission operations extensions are approved for Chandra, Fermi, Hubble, and Swift
- Senior Review budget maintained for mission extensions beyond FY17
- Astrophysics Decadal Strategic Mission for development of the mission that follows JWST

FY16 President's Budget Request

Outyears are notional planning from FY16 President's budget request

(\$M)	2014	2015	2016	2017	2018	2019	2020
Astrophysics*	\$678	\$685	\$689	\$707	\$750	\$986	\$1,118
JWST	\$658	\$645	\$620	\$569	\$535	\$305	\$198

- Supports operating missions: Chandra, Fermi, Hubble, Kepler, NuSTAR, SOFIA, Spitzer, and Swift.
- Funds development of Explorer missions TESS and NICER. TESS will continue the search for exoplanets, scanning all of the sky for Exoplanets closer to Earth than those found by Kepler.
- Supports pre-formulation studies for WFIRST/AFTA.
- Maintains a competed astrophysics research program and support of the balloon program.
- Supports the commitment of an October 2018 launch date for JWST.
 - Will deliver the Integrated Science Instrument Module for integration;
 - Completes integration of flight primary mirror subassemblies onto the flight primary mirror backplane;
 - Completes acceptance testing of the cryocooler compressor assembly;
 - Completes spacecraft bus structure; and
 - Completes the sunshield structure manufacture and test.

* Excludes "SMD STEM Activities" in all years.

FY16 President's Budget Request

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Astrophysics*	\$678	\$685	\$689	\$707	\$750	\$986	\$1,118
JWST	\$658	\$645	\$620	\$569	\$535	\$305	\$198

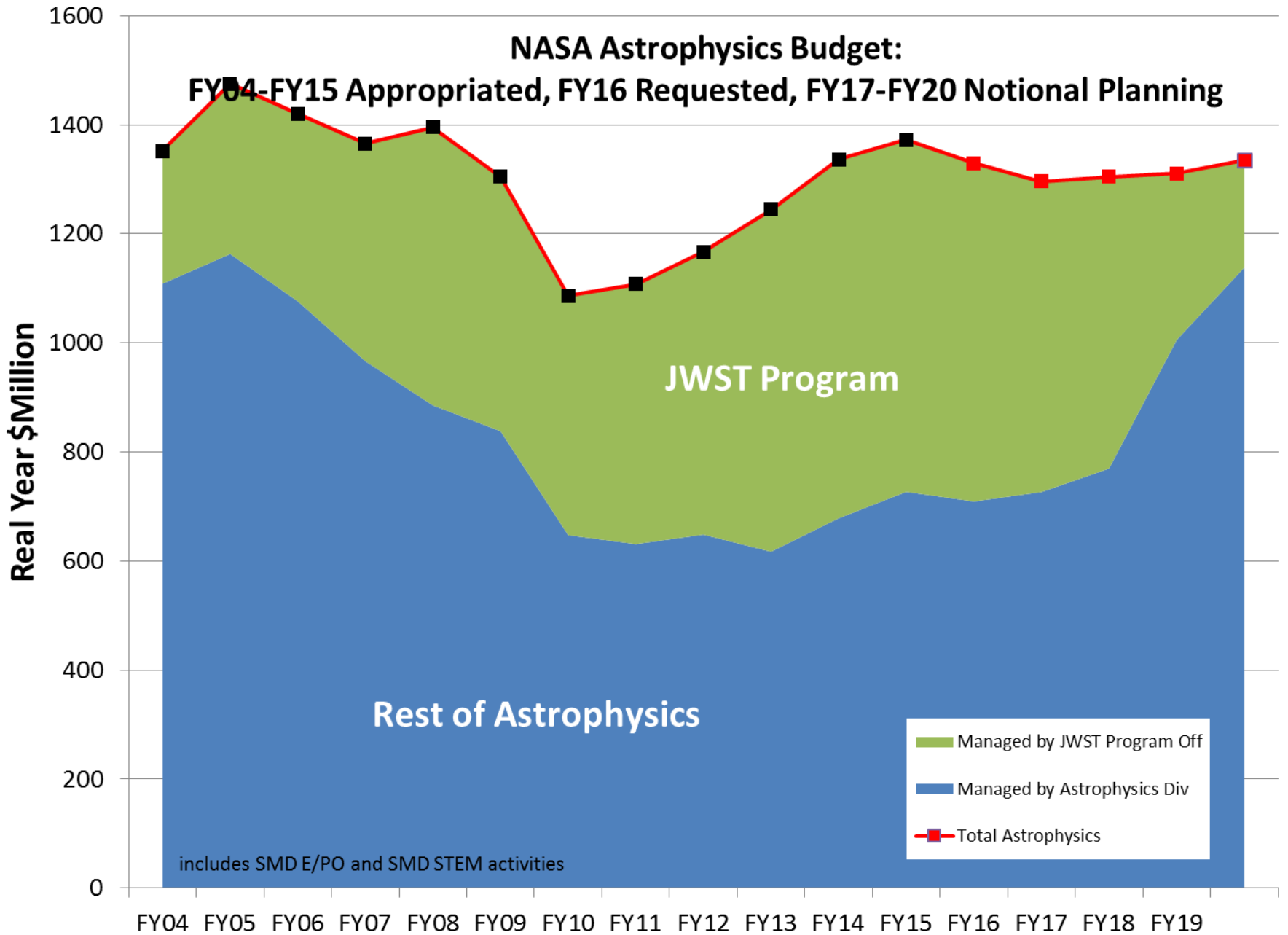
- Continues preformulation of WFIRST/AFTA as the “Astrophysics Decadal Strategic Mission.”
- Grows Astrophysics Research and Analysis (including Astrophysics Data Analysis Program) from ~\$80M/yr to ~\$90M/yr in FY16.
- Supports completion of missions under development, including LPF/ST7, ASTRO-H, NICER, TESS, and Euclid.
- Enables selection of a SMEX mission and an Explorer Mission of Opportunity from the 2014 AO, and notional release of a MIDEX AO in late CY16/early FY17.
- Provides full funding for SOFIA operations and places SOFIA into the 2016 Astrophysics Senior Review.
- Plans for the 2016 Astrophysics Senior Review.
- Plans for continued Hubble operations through FY20 providing overlap with JWST.
- Plans for mission concept studies and technology development (within the three Program SR&T budgets) leading up to the 2020 Decadal Survey.

* Excludes “SMD STEM Activities” in all years.

NASA Astrophysics Budget:

FY04-FY15 Appropriated, FY16 Requested, FY17-FY20 Notional Planning

Real Year \$Million



Rest of Astrophysics

JWST Program

includes SMD E/PO and SMD STEM activities

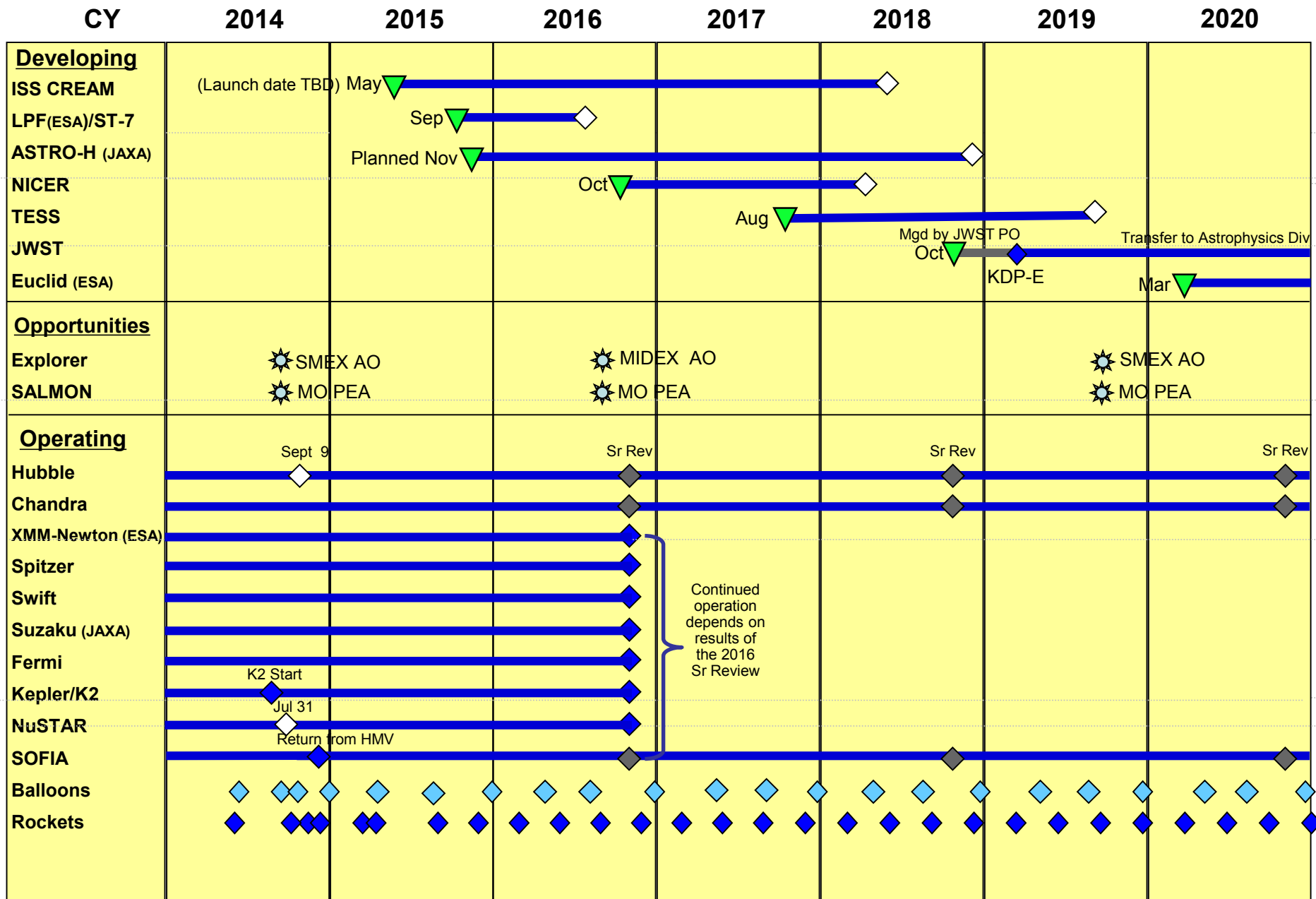
- Managed by JWST Program Off
- Managed by Astrophysics Div
- Total Astrophysics

FY15 and FY16 Planned Accomplishments

- The **TESS** Explorer Mission was confirmed to begin implementation (KDP-C) in Oct 2014
- SOFIA completed its Heavy Maintenance Visit in Dec 2014; resumed science flights in Jan 2015
- The **WFIRST/AFTA** science definition team final report completed Jan 30.
- JAXA's **ASTRO-H** mission to begin spacecraft system level test (KDP-D) in FY15 [~April 2015]
- The Astrophysics **Data Archives Senior Review** will be held in FY15 [spring 2015]
- The NRC **Mid-Decade Review** will begin in FY15 [spring 2015]
- A Critical Design Review (CDR) for NASA's contribution to ESA's **Euclid** will be held in FY15 [~Mar 2015]
- **Hubble** has achieved 25 years of operation in FY15 [Apr 2015]
- **TESS** will complete its Critical Design Review (CDR) in FY15
- The **ISS-CREAM** experiment will be launched to the International Space Station (KDP-E) in FY15/FY16 [LRD under review]
- **SOFIA** program management will transition from Armstrong Flight Research Center (AFRC) to Ames Research Center (ARC) in FY15 [NLT summer 2015]
- The Step 1 selection (KDP-A) will be made for the next Small Astrophysics **Explorer** and Explorer Mission of Opportunity in FY15 [summer 2015]
- ESA's **LISA Pathfinder** with NASA's ST-7 experiment will launch (KDP-E) in FY15/FY16 [NET Jul 2015]
- **NICER** will begin system level test (KDP-D) in FY15/FY16 [~Sep 2015]
- JAXA's **ASTRO-H** mission will launch (KDP-E) in FY16 [NET Nov 2015]
- NASA will select its contribution to ESA's L2 **Athena** mission study in FY16 [ESA AO in spring 2016]
- The Astrophysics **Operating Missions Senior Review** will be held in FY16 [spring 2016]
- Four **Balloon** campaigns are planned in FY15, and four campaigns are planned in FY16
- Five Astrophysics **Sounding Rocket** payloads are planned in FY15, and several are planned in FY16

Astrophysics Science Mission Events

Last updated March 24, 2015



▼ Launch Date (mission 'working to' date)
 ◆ Event Date
 End of Prime Mission
 ◆ Balloon Campaigns
 ☀ Notional AO Release Date

Progress Toward Decadal Survey Priorities

The NASA FY15 Appropriation, the President's FY16 Budget Request, and the notional out year budget planning guidance in the President's FY16 Budget Request, support:

Large-scale 1. WFIRST	Preformulation and focused technology development for WFIRST/AFTA (a 2.4m version of WFIRST with a coronagraph) are underway to enable a new start NET FY2017. Budget line established for an Astrophysics Decadal Strategic Mission.
Large-scale 2. Augmentation to Explorer Program	Astrophysics Explorers planned budget increased to support decadal cadence of AOs including SMEX AO in Fall 2014 and MIDEX AO in late 2016/early 2017.
Large-scale 3. LISA	Discussing partnership on ESA's L3 gravitational wave observatory and participating in ESA-led assessments in 2014-2015. Strategic astrophysics technology (SAT) investments plus support of LISA Pathfinder.
Large-scale 4. IXO	NASA is pursuing a partnership on ESA's L2 Athena X-ray observatory; the Athena study phase, with U.S. participation, is underway. Strategic astrophysics technology (SAT) investments.
Medium-scale 1. New Worlds Technology Development Program	Focused technology development for a coronagraph on WFIRST, strategic astrophysics technology (SAT) investments, and exoplanet probe mission concept studies. Established partnership with NSF to develop extreme precision Doppler spectrometer as facility instrument. Exozodi survey using LBTI.

Progress Toward Decadal Survey Priorities

The NASA FY15 Appropriation, the President's FY16 Budget Request, and the notional out year budget planning guidance in the President's FY16 Budget Request, support:

Medium-scale 2. Inflation Probe Technology Development Program

Balloon-borne investigations plus strategic astrophysics technology (SAT) investments.

Small-scale. Research Program Augmentations

Increased annual R&A budget by 10% from FY10 to FY12 and another 10% from FY14 to FY16. Within R&A: established Theoretical and Computational Astrophysics Networks (TCAN) program with NSF; funding available for astrophysics theory; funding available for lab astrophysics; funding available for suborbital payloads.

Small-scale. Intermediate Technology development Augmentation

Established competed Strategic Astrophysics Technology (SAT) program element; directed technology funding for WFIRST and other large-scale decadal priorities.

Small-scale. Future Ultraviolet-Visible Space Capability

Strategic Astrophysics Technology (SAT) investments.

Small-scale. SPICA (U.S. contribution to JAXA-led)

Not supported as a strategic contribution; candidate for Explorer Mission of Opportunity.

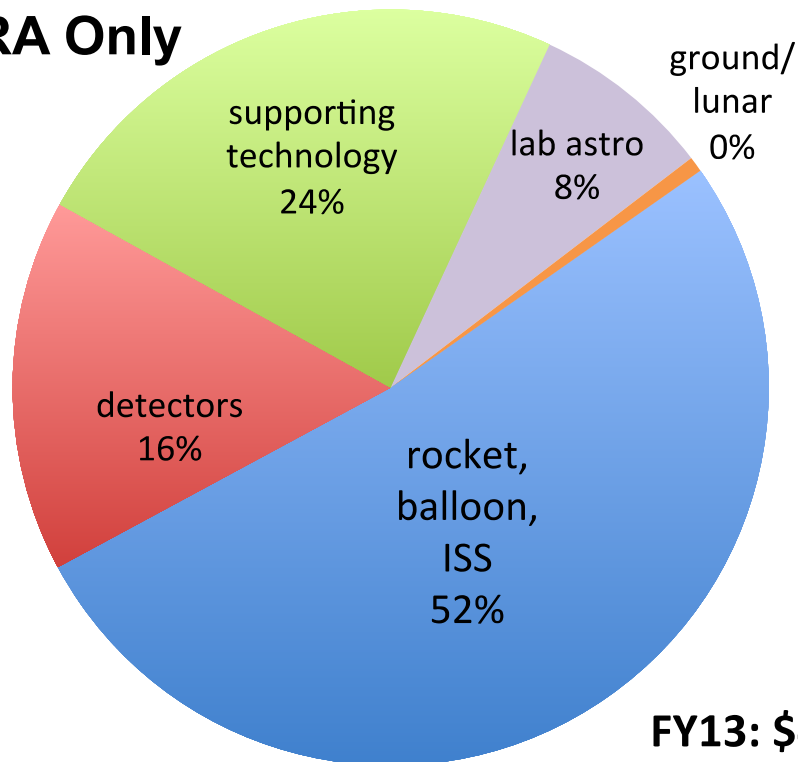
Astrophysics Research Program Funding

Snapshot: Most Recent Year

	Proposals Rec'd	Year-1 \$M	Proposals selected	Success Rate	Proposals Rec'd 2015
APRA-13	179	10.0	43	24%	151
SAT-13	18	5.4	10	56%	28
ADAP-14	300	7.5	62	21%	
XRP-14	62	1.3	11	18%	
ATP-14	214	4.7	31	14%	
TOTAL	773	28.9	157	20%	

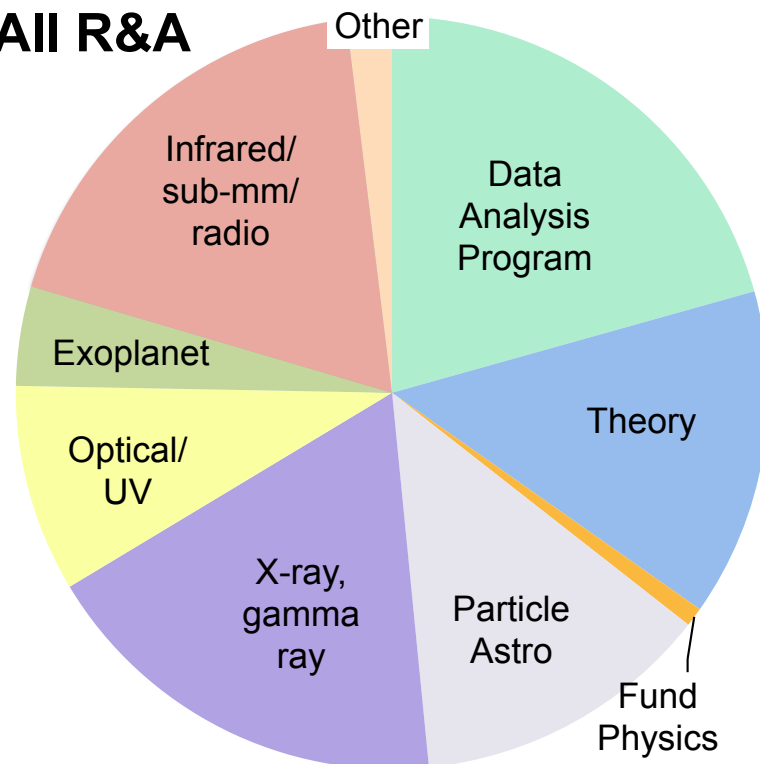
Does not include
RTF, TCAN, WPS,
GO programs

APRA Only

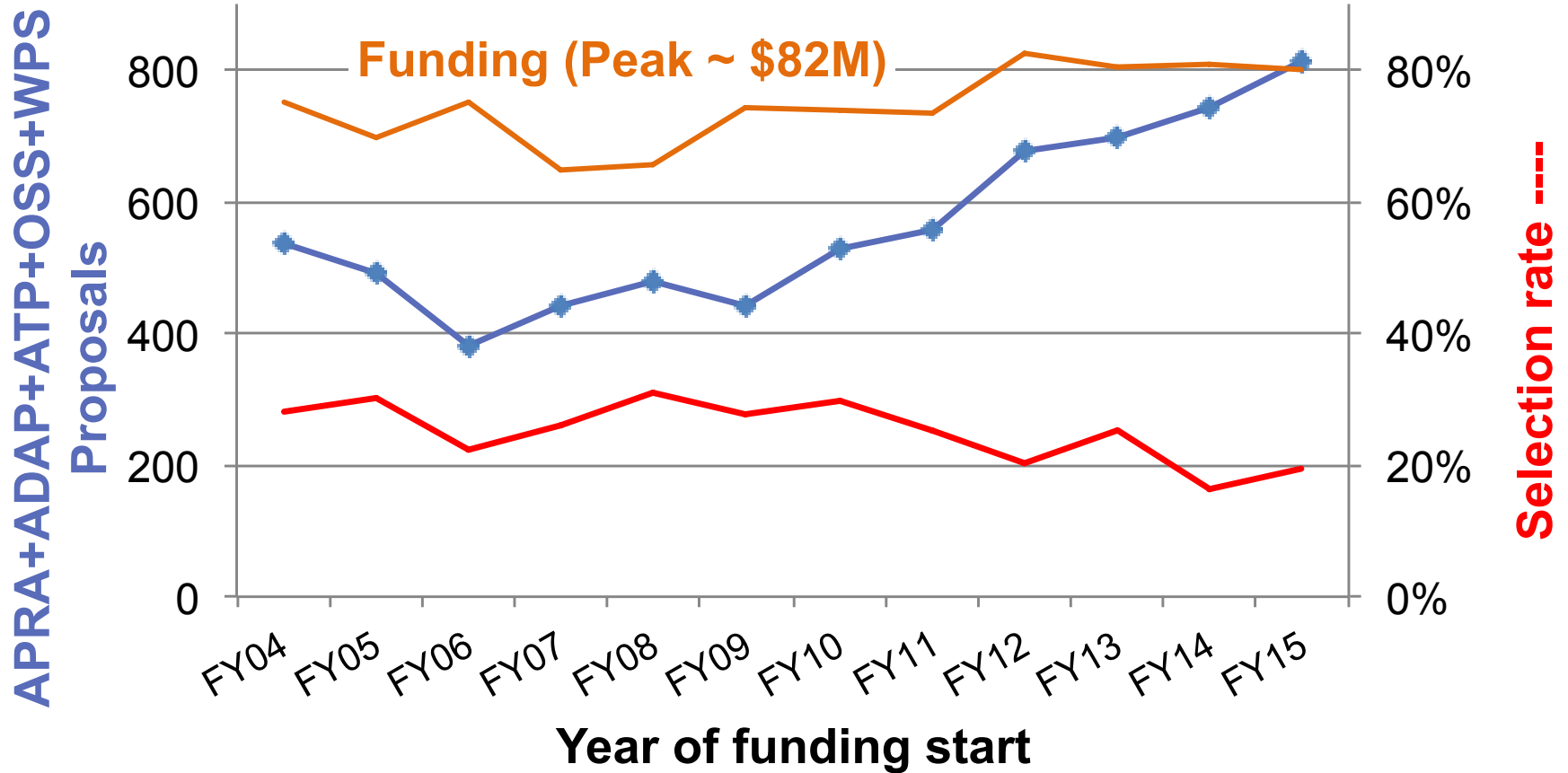


FY13: \$47.7M

All R&A



Astrophysics ROSES selection rates

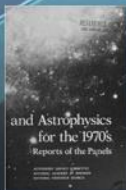


AAAC task force on R&A and demographics being led by Prisca Cushman (U. Minn)

ASTROPHYSICS

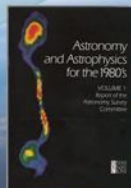
Decadal Survey Missions

1990



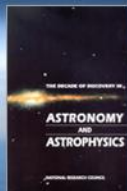
1972
Decadal Survey
Hubble

1999



1982
Decadal Survey
Chandra

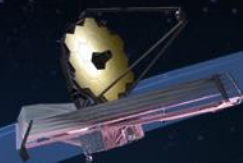
2003



1991
Decadal Survey
Spitzer, SOFIA



LRD: 2018



2001
Decadal Survey
JWST

LRD: 2020s



2010
Decadal Survey
WFIRST

Preparing for the 2020 Decadal Survey

Large Mission Concepts

- The 2020 Decadal Survey will prioritize large space missions to follow JWST and WFIRST.
 - To enable this prioritization, NASA needs to provide information on several candidate large space mission concepts for consideration by the 2020 Decadal Survey Committee.
- What information needs to be provided to the Decadal Survey committee to enable prioritization of large missions
 - Science case
 - Strawman design reference mission with strawman payload
 - Technology development needs
 - Cost requirements assessment
- NASA needs to initiate technology development for candidate large missions so that technology will be ready when needed.
 - Technology needs to be sufficiently mature when it is time to start the highest priority large mission in the 2020 Decadal Survey.
 - The next large mission after WFIRST could be started when funding becomes available as WFIRST approaches launch in the early or mid-2020s.

Astrophysics Timeline

