National Aeronautics and Space Administration

Astrophysics Division Update

Astronomy and Astrophysics Advisory Committee

June 1, 2015

Astrophysics

Paul Hertz

Director, Astrophysics Division
Science Mission Directorate

@PHertzNASA

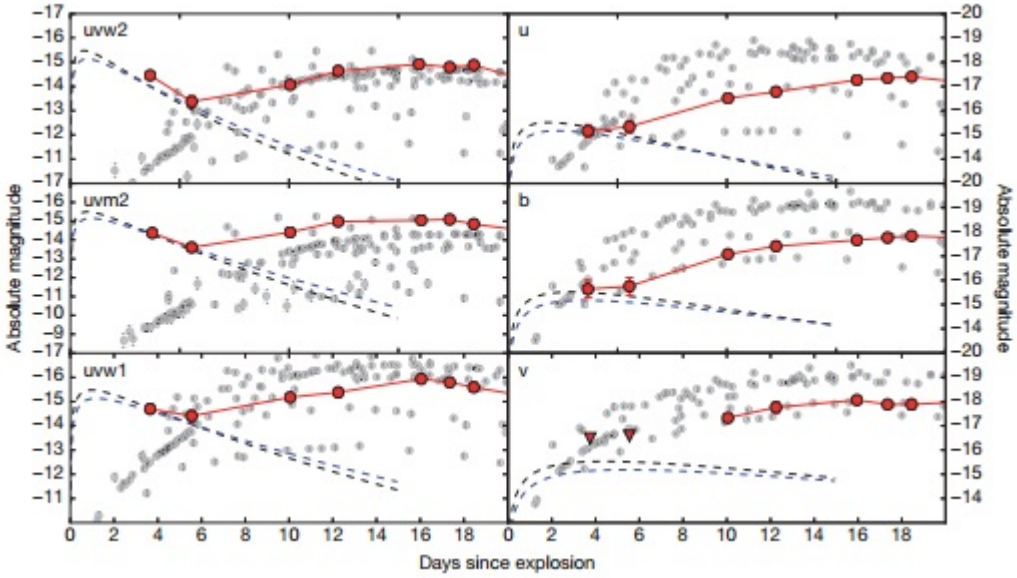
Outline

- Science Highlights
- Budget Status: FY15 Execution, FY16 Request, FY16 Markups
- Program/Project Updates
- R&A Update
- 2020 Decadal Survey Planning
- Response to 2015 AAC Report Recommendations

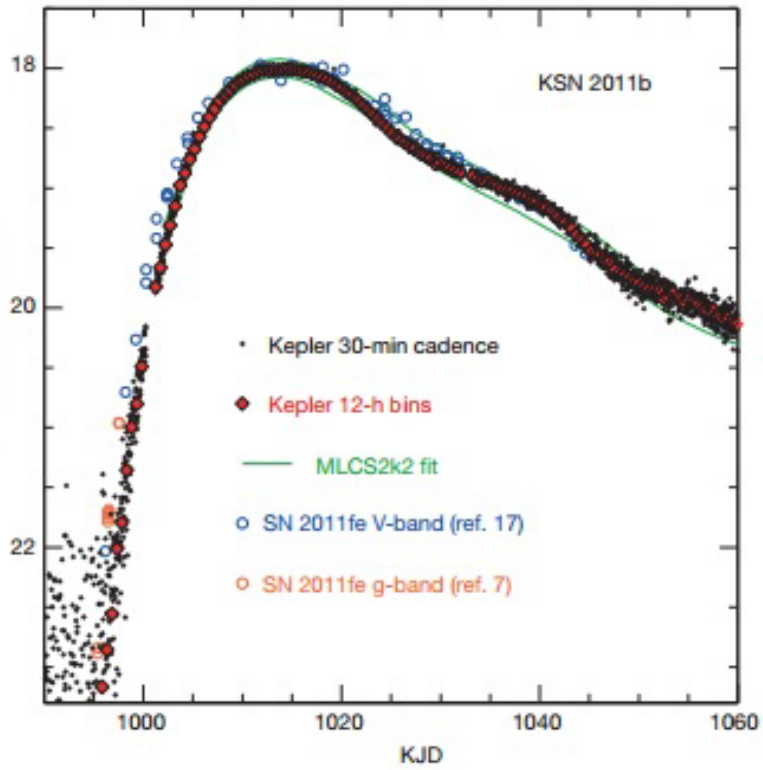
NASA Spacecraft Capture Early Moments of Baby Supernovae

Published in the May 21, 2015 edition of Nature.

- Type Ia supernovae: Cosmic probes from exploding white dwarf
- Two origin models: single WD collapse, binary WD merger

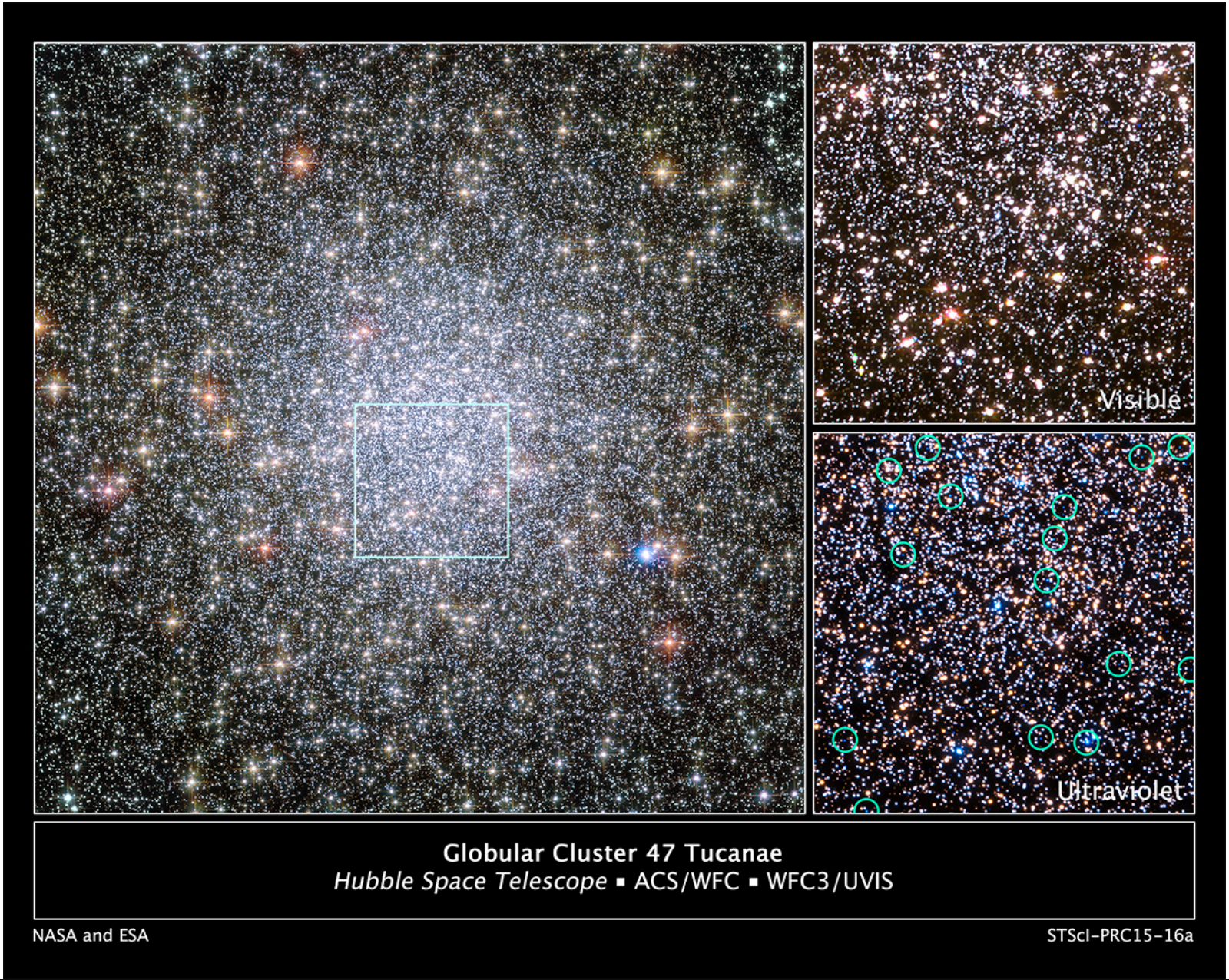


iPTF14atg (Swift): UV brightening after initial decay implies single star collapse

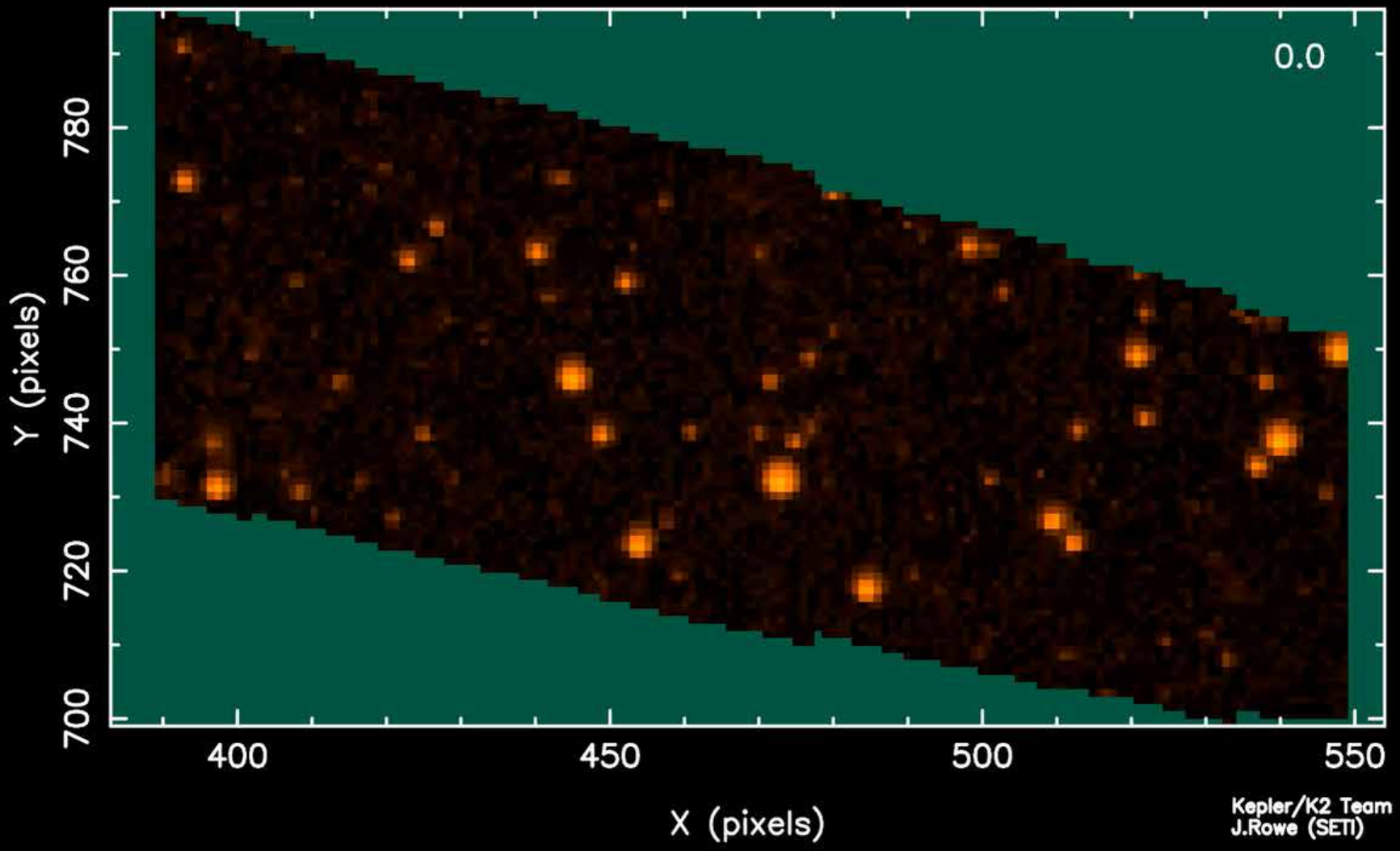


KSN 2011b (Kepler): No disruption in light curve implies binary merger

Hubble Captures Stellar Exodus in Action



Kepler/K2 Campaign 3 Observes Neptune



Movie available at: http://www.nasa.gov/feature/kepler/ames/kepler-observes-neptune-dance-with-its-moons

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 ISS-CREAM (TBD), 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
- Update to the Astrophysics Implementation Plan released in December 2014
- Progress being made against recommendations of the 2010 Decadal Survey
  - NRC Mid Decade Review (with NSF, DOE) to begin in mid 2015
  - NASA identifying 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
- Includes $42M for Education SMD-wide as a separate budget line (so E/PO is no longer budgeted as 1% of every mission)
- 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

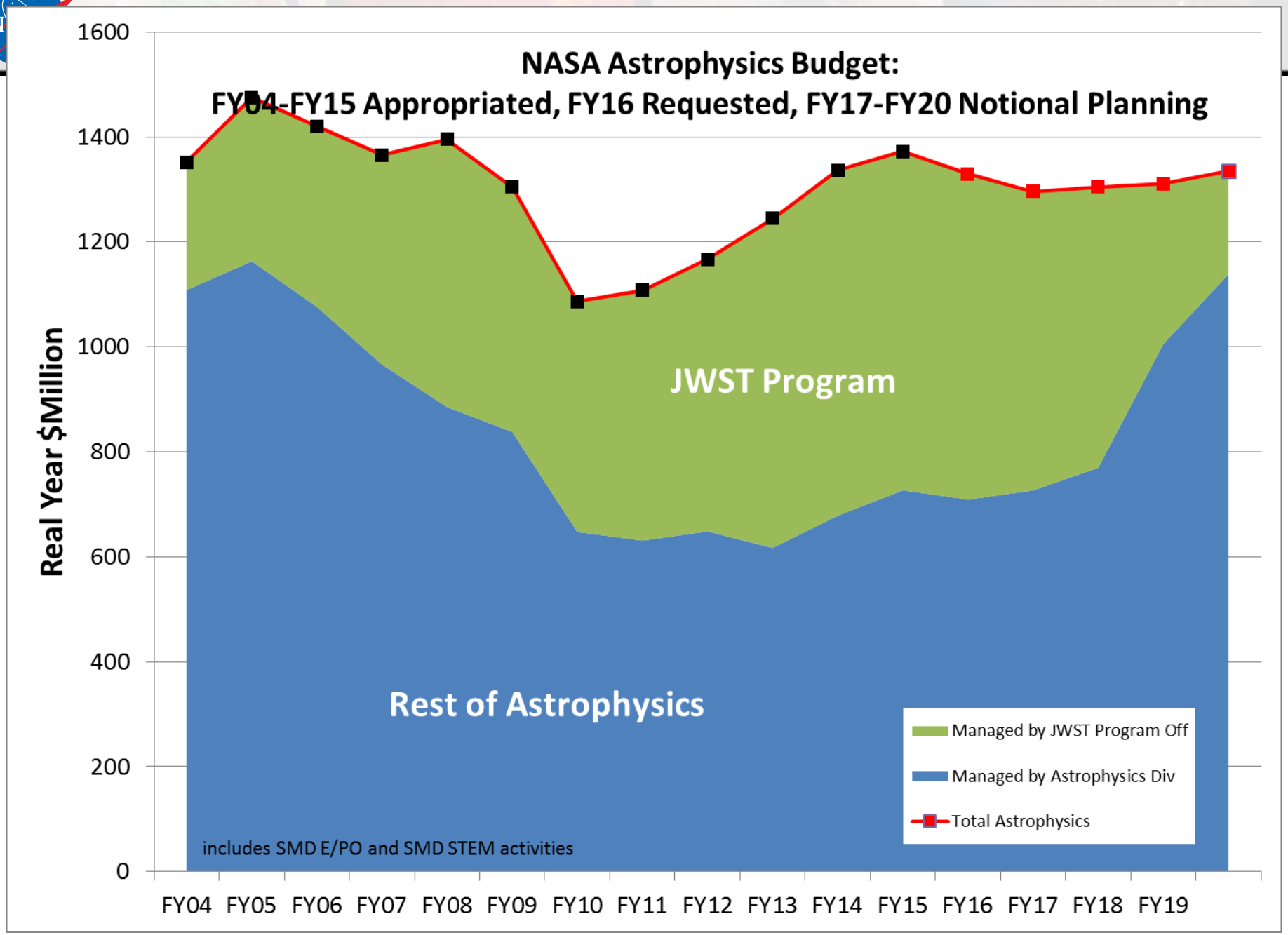
FY16 President's Budget Request

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

- Ø Continues preformulation of WFIRST/AFTA as the "Astrophysics Decadal Strategic Mission."
- Ø Grows Astrophysics Research and Analysis (including Astrophysics Data Analysis Program) from ~$80M/yr to ~$90M/yr in FY16.
- Ø Supports completion of missions under development, including LPF/ST7, ASTRO-H, NICER, TESS, and Euclid.
- Ø 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.
- Ø Provides full funding for SOFIA operations and places SOFIA into the 2016 Astrophysics Senior Review.
- Ø Plans for the 2016 Astrophysics Senior Review.
- Ø Plans for continued Hubble operations through FY20 providing overlap with JWST.
- Ø 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
1600
1400
1200
1000
800
600
400
200
0
JWST Program
Rest of Astrophysics
includes SMD E/PO and SMD STEM activities
Managed by JWST Program Off
Managed by Astrophysics Div
Total Astrophysics
FY04 FY05 FY06 FY07 FY08 FY09 FY10 FY11 FY12 FY13 FY14 FY15 FY16 FY17 FY18 FY19

FY16 House Appropriations Committee Markup

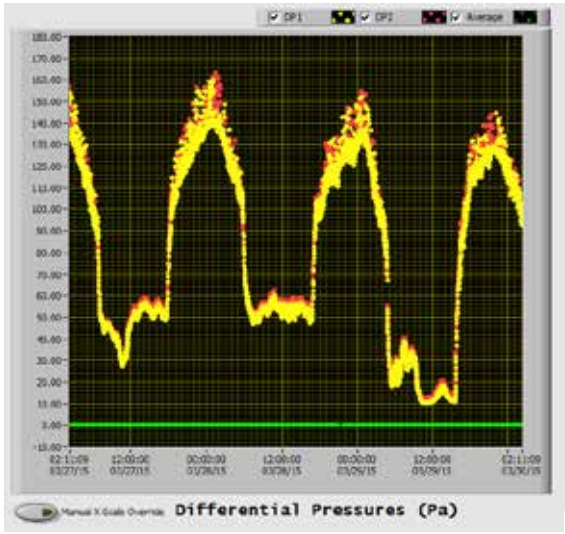
- On May 20, 2015, the House Appropriations Committee marked up the NASA FY16 budget request and sent it forward to the full House for consideration

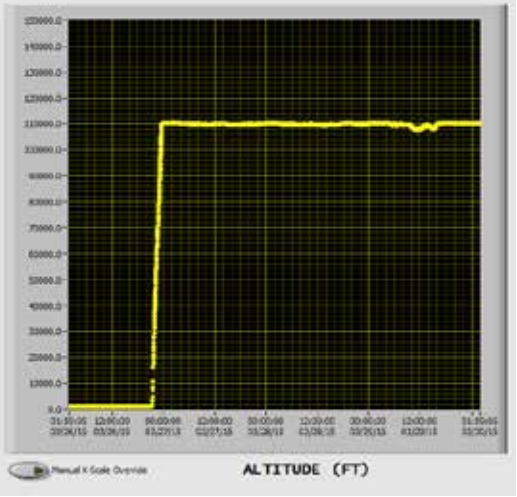
$M	FY15 Appropriation	FY16 President's Request	FY16 House Mark-up	FY16 Delta House vs Request
NASA	18,010.2	18,529.1	18,529.1	0
SMD	5,244.7	5,288.6	5,237.5	-51.1
JWST	645.4	620.0	620.0	0
Astrophysics	726.8	709.1	735.6	+26.5
WFIRST	50.0	14.0	49.8	+35.8
SMD Education	42.0	20.0	32.0	+12.0
Rest of Astroph	634.8	675.1	653.8	-21.3

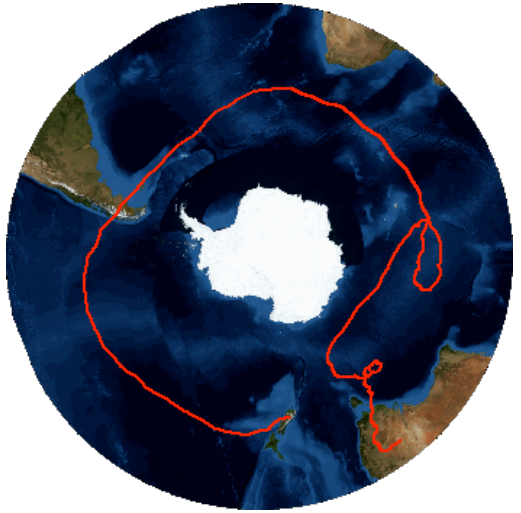
- Follow Decadal Surveys
- Fully fund JWST
- Include coronagraph on WFIRST
- Prohibit SOFIA from Senior Review until meets traditional criteria
- Reallocate Education funds proportionally to Divisions for management

Hubble 25th Anniversary

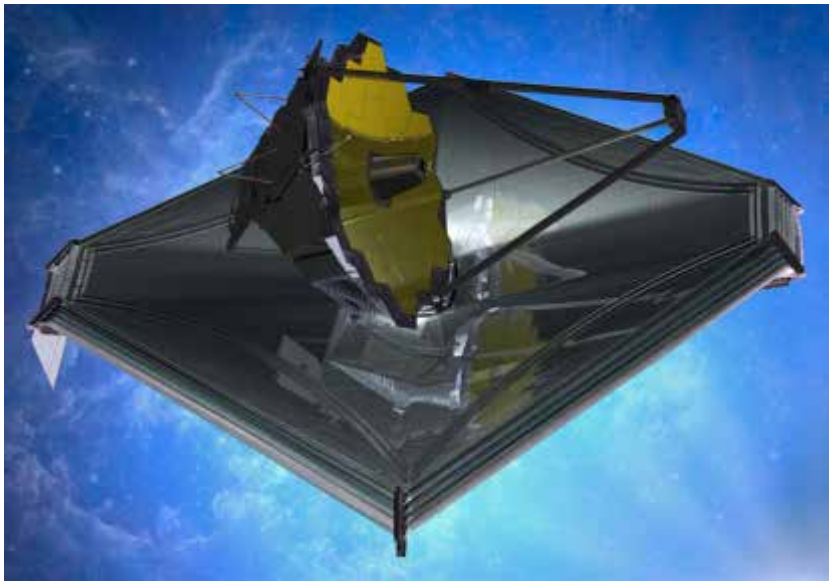
New Zealand Superpressure Balloon Test Flight







JWST
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 Accomplishments

- All instruments re-integrated into ISIM after planned cryovacuum 2 rework (near-IR detector replacement, microshutter unit replacement)
- First pathfinder telescope cryo testing at JSC underway
- Flight Telescope Backplane assembly completed
- 1st Flight sunshield layer delivered, 3 more in manufacturing

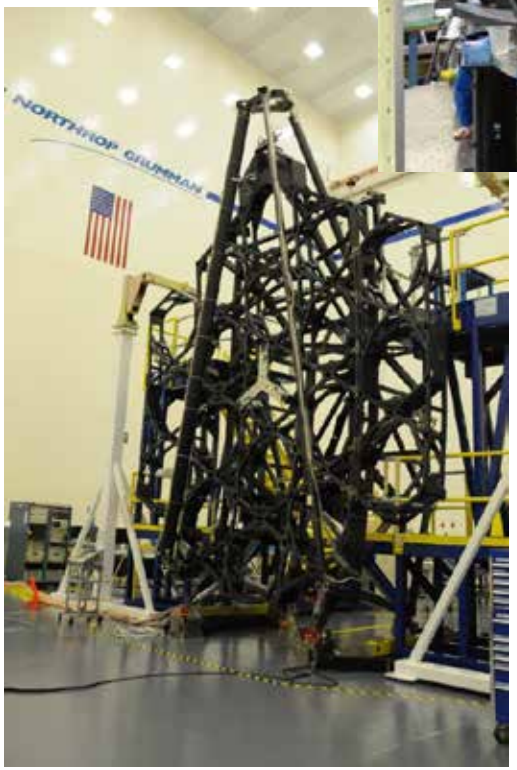
Remaining 2015 Plans

- Complete MIRI cryocooler
- Start Assembly of the Primary mirror segments onto the Flight Backplane
- Start 3rd and final cryovacuum test of science instrument suite (ISIM)
- Deliver spacecraft bus to testing

http://jwst.nasa.gov/

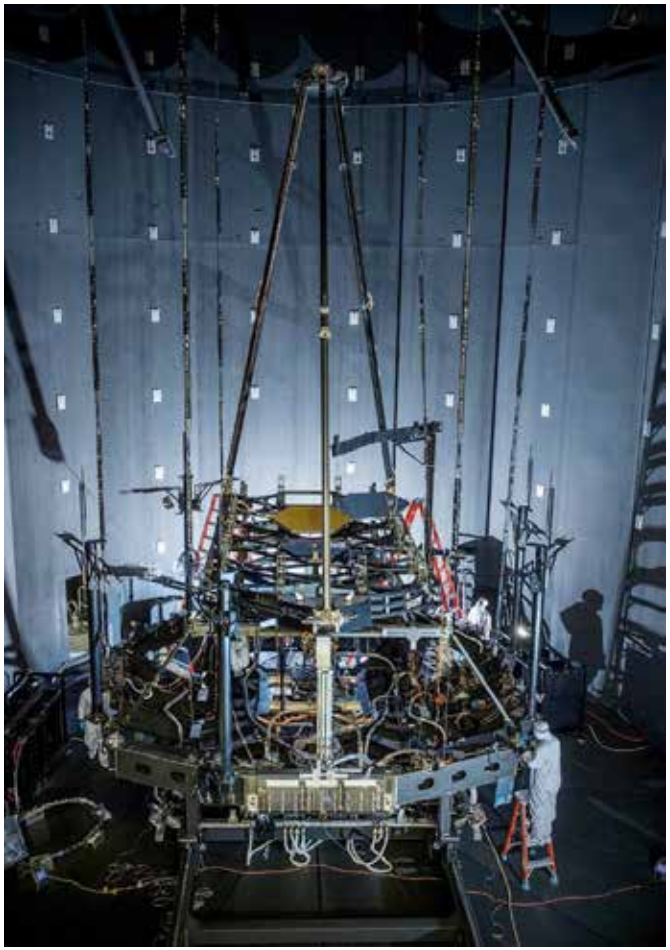
JWST Hardware Progress

Spacecraft Bus



Flight Backplane

All instruments back in ISIM



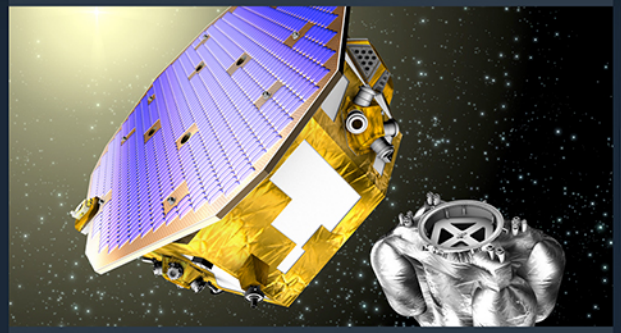
Pathfinder Telescope in JSC Chamber A

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

Astrophysics Missions in Development

LISA Pathfinder
9/2015

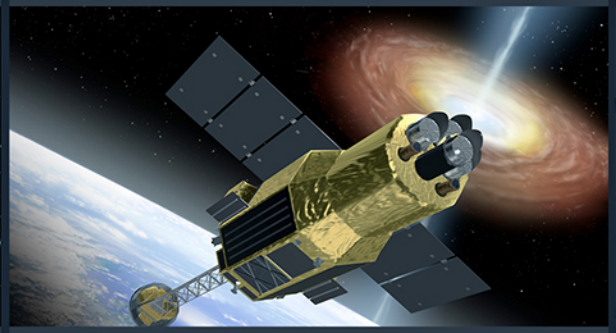
ESA-led Mission



NASA supplied the ST7/Disturbance Reduction System (DRS)

ASTRO-H
11/2015

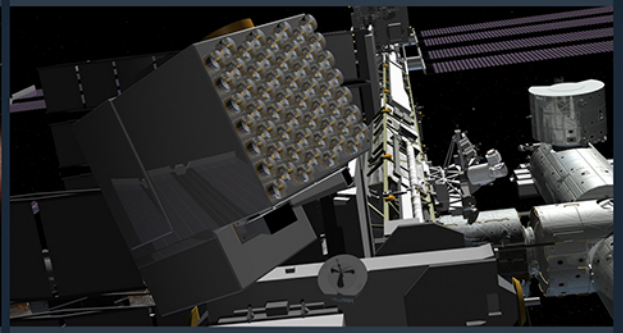
JAXA-led Mission



NASA supplied the Soft X-ray Spectrometer (SXS) instrument

NICER
8/2016

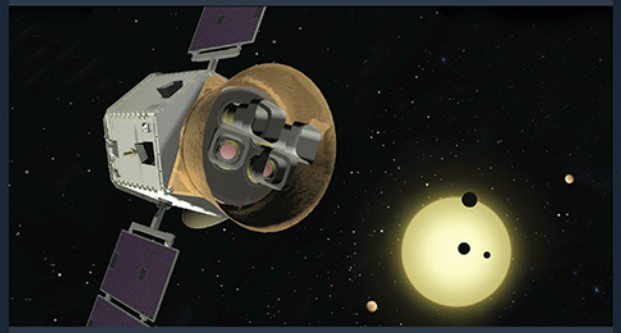
NASA Mission



Neutron Star Interior Composition Explorer

TESS
8/2017

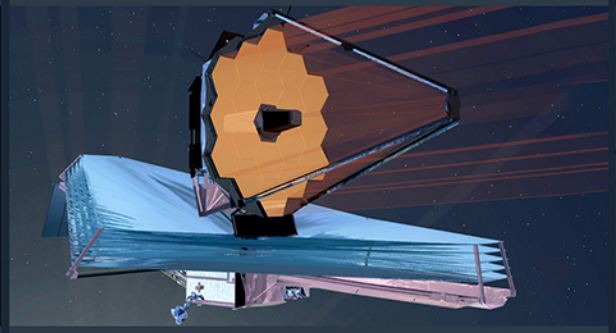
NASA Mission



Transiting Exoplanet Survey Satellite

JWST
10/2018

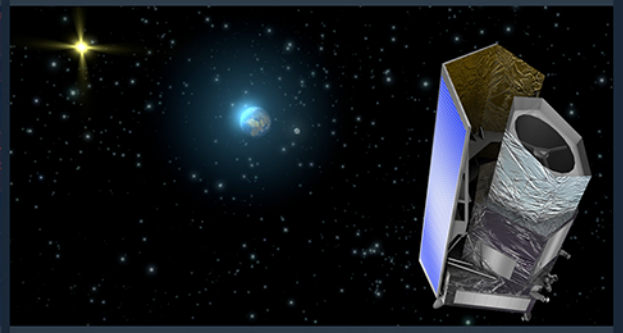
NASA Mission



James Webb Space Telescope

Euclid
2020

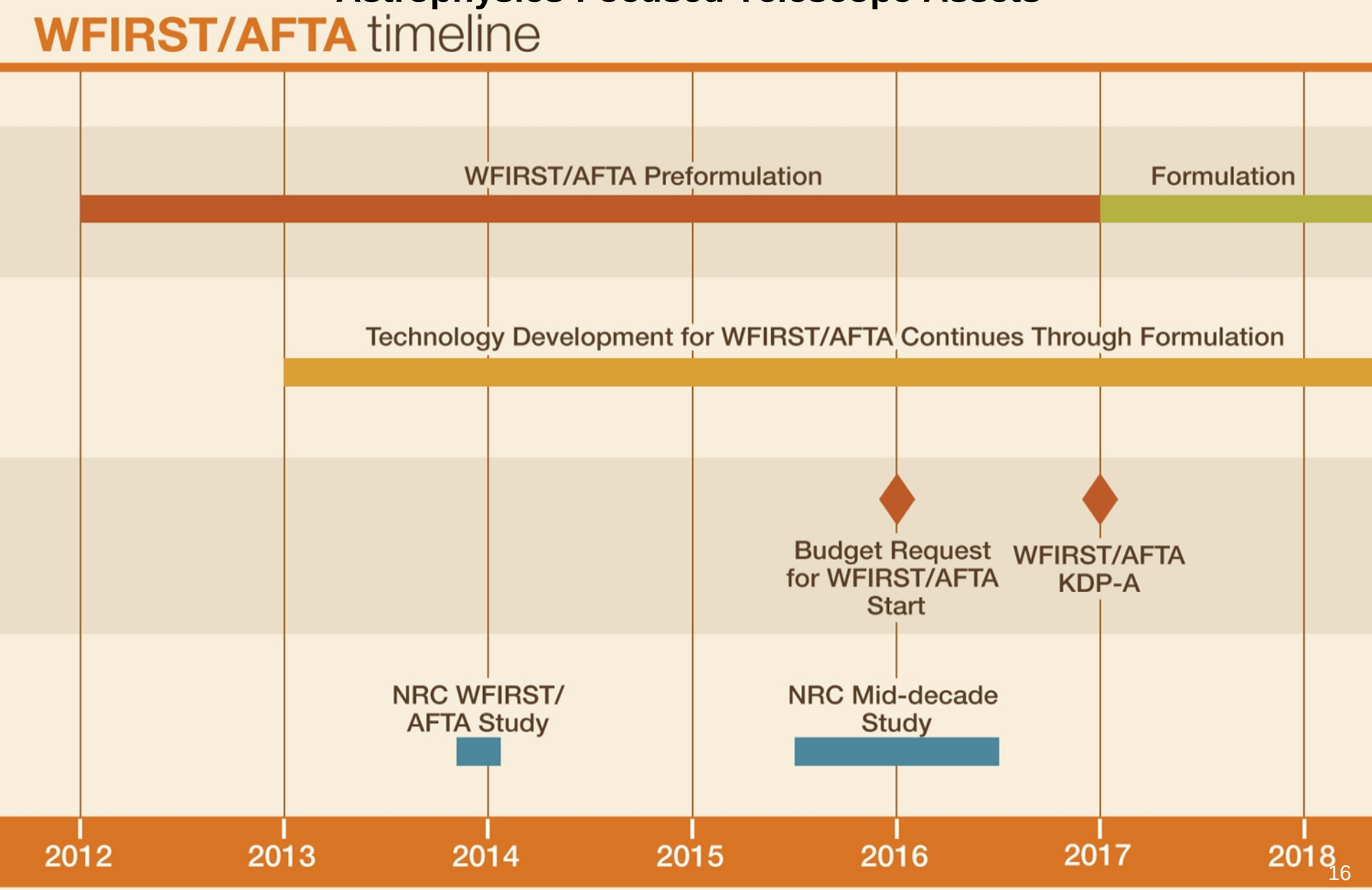
ESA-led Mission



NASA is supplying the NISP Sensor Chip System (SCS)

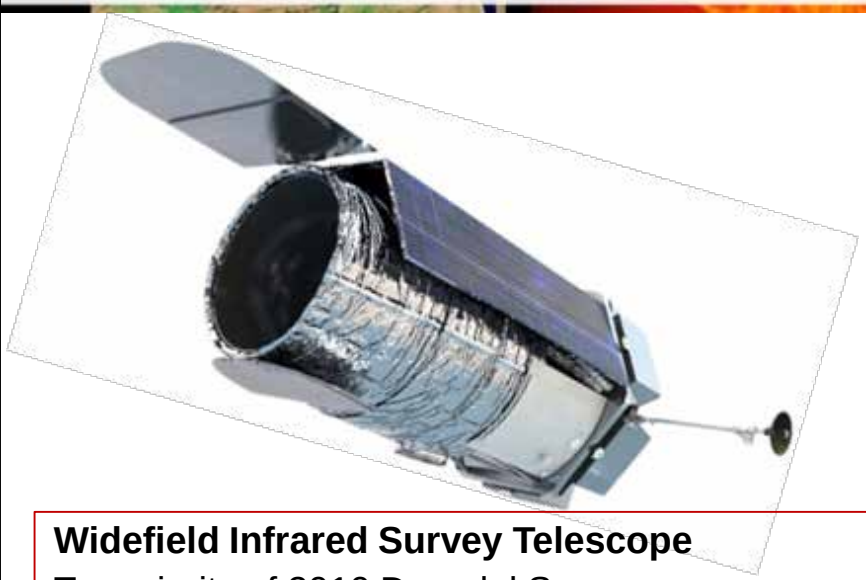
Plan for WFIRST/AFTA Preformulation

Widefield Infrared Survey Telescope using Astrophysics Focused Telescope Assets



WFIRST / AFTA

Widefield Infrared Survey Telescope with Astrophysics Focused Telescope Assets



Widefield 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 GEO, uses existing AFTA hardware to image 0.28 deg^2 at 0.8-2.0 µm

Instruments (design reference mission): Wide Field Instrument, Coronagraph Instrument

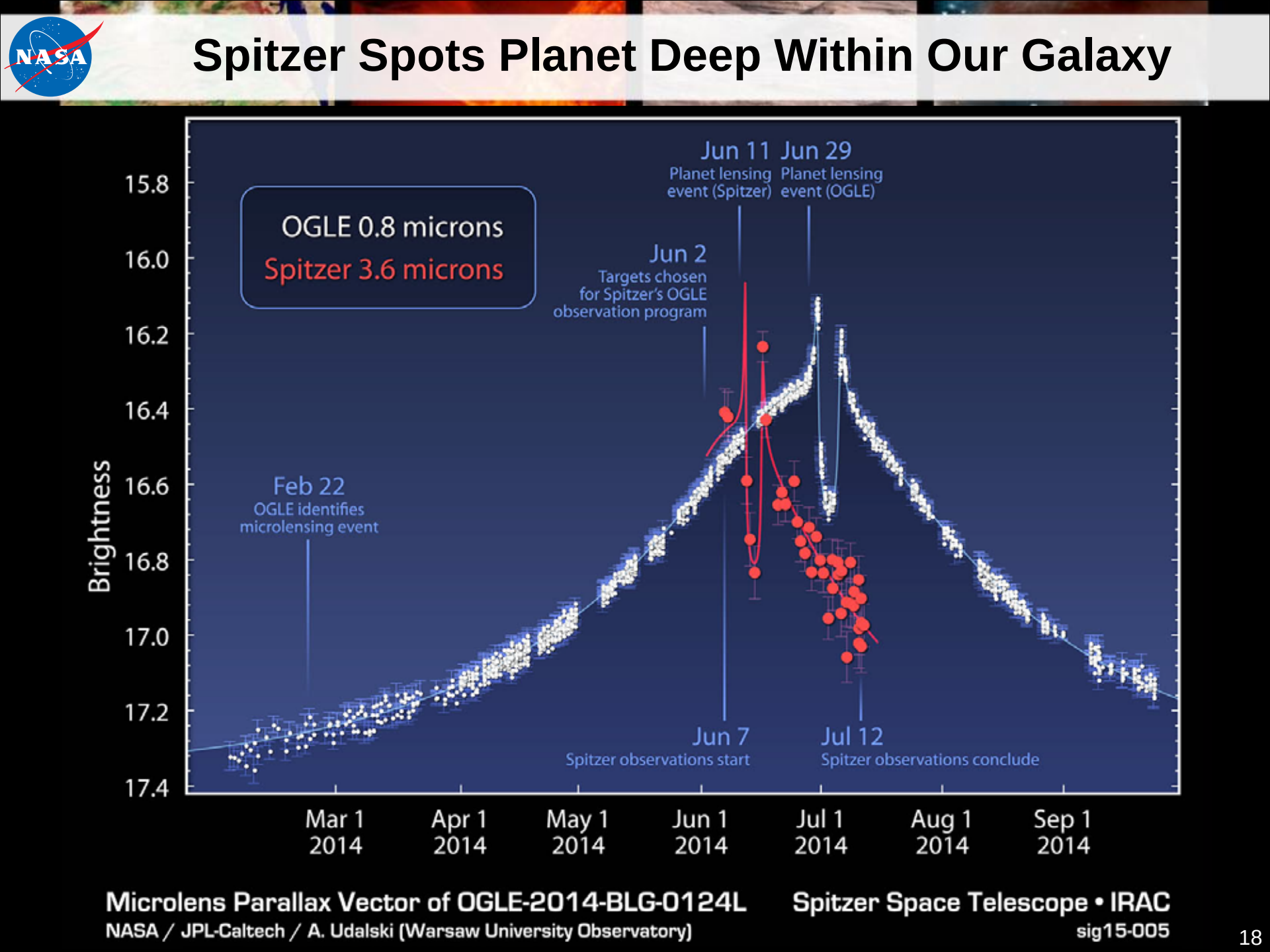
- FY15 Budget Request and FY15 Appropriation support pre-formulation of WFIRST/AFTA
- Plans support Agency/Administration decision for formulation to begin NET FY 2017, should funding be available.

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

CURRENT STATUS:

- May 2013, NASA Administrator Bolden directed study of WFIRST/AFTA and preserve option for FY17 new start if budget is available.
  - No decision expected before early CY 2016.
- Currently in pre-formulation phase.
  - Activities include technology development for detectors and coronagraph (with STMD), assessment of the 2.4m telescopes including risk mitigation, mission design trades, payload accommodation studies, and observatory performance simulations.
- Maturing key technologies by FY19.
  - H4RG infrared detectors for widefield imager.
  - Internal coronagraph for exoplanet characterization.
- March 2014 NRC study on WFIRST/AFTA offers positive view of AFTA, with concerns about technology and cost risks.
- WFIRST Preparatory Science (WPS) funds ROSES proposals that are relevant to WFIRST's goals and WFIRST-specific simulations and models.
- SDT final report submitted January 31, 2015, and available online at wfirst.gsfc.nasa.gov.
- Solicitation for members of Formulation Science Working Group (F-SWG) to be released soon

Spitzer Spots Planet Deep Within Our Galaxy



Microlens Parallax Vector of OGLE-2014-BLG-0124L

NASA / JPL-Caltech / A. Udalski (Warsaw University Observatory)

Spitzer Space Telescope • IRAC

sig15-005

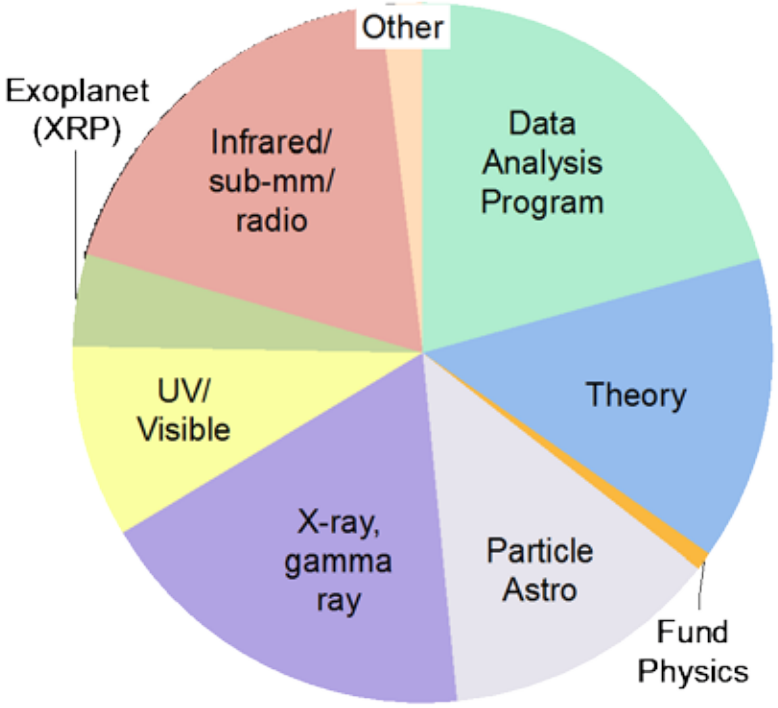
Kepler
Kepler Space Telescope

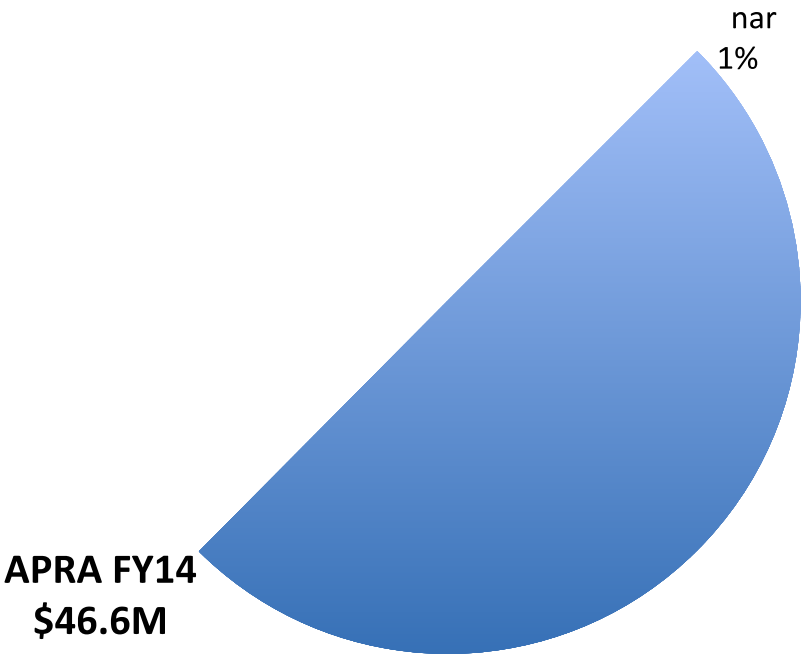
- **NASA's first space mission dedicated to the search for extrasolar planets, or exoplanets**
- **PI:** W. Borucki, NASA Ames Research Center
- **Launch Date:** March 6, 2009
- **Payload:** 0.95-meter diameter telescope designed to measure the tiny dimming that occurs when an orbiting planet passes in front of ('transits') a star
- **Scientific objectives:**
  - conduct census of exoplanet systems
  - explore the structure and diversity of extrasolar planetary systems
  - determine the frequency of habitable, Earth-sized planets in our galaxy

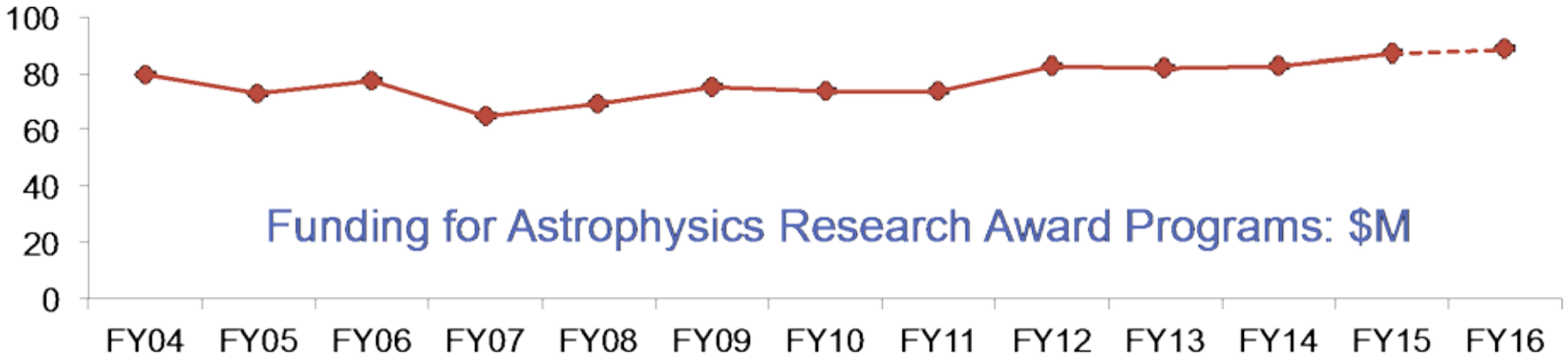
CURRENT STATUS:

- Kepler "K2" observation method was approved for operations through FY2016 after completion of the 2014 Senior Review.
  - Kepler is conducting observations along the ecliptic, changing its orientation four times per year.
  - The fifth 75-day Campaign started in April 2015 and runs until July 2015.
  - Targets are selected via proposals from the community. Step 1 cycle 3 proposals (covering Campaigns 8-10) are due June 2, 2015 and Step 2 proposals are due on July 1, 2015.
- K2 Campaign 9 will target the Galactic bulge in a focused Microlensing.
  - Campaign will measure parallaxes and obtain distances and masses for a significant number of microlensing events including those caused by bound and free-floating planets.
  - Efforts are underway to maximize scientific value by partnering with a ground-based, southern telescope to obtain multi-color photometry of the K2 field.
- December 18, 2014: First confirmed planet discovery using K2 observation method
- From 2009-13, Kepler continuously monitored 100 sq. deg. field in constellations of Cygnus and Lyra for 4+ years.
  - These observations ended after failure of 2nd reaction wheel.
- Analysis of first 4 years of Kepler data has revealed:
  - Approximately 4600 exoplanet candidates
  - Over 1000 candidates confirmed as planets to date
  - More than 100 planets discovered in their star's "habitable zone".
- Analysis of the full (4+ year) Kepler data set ongoing.

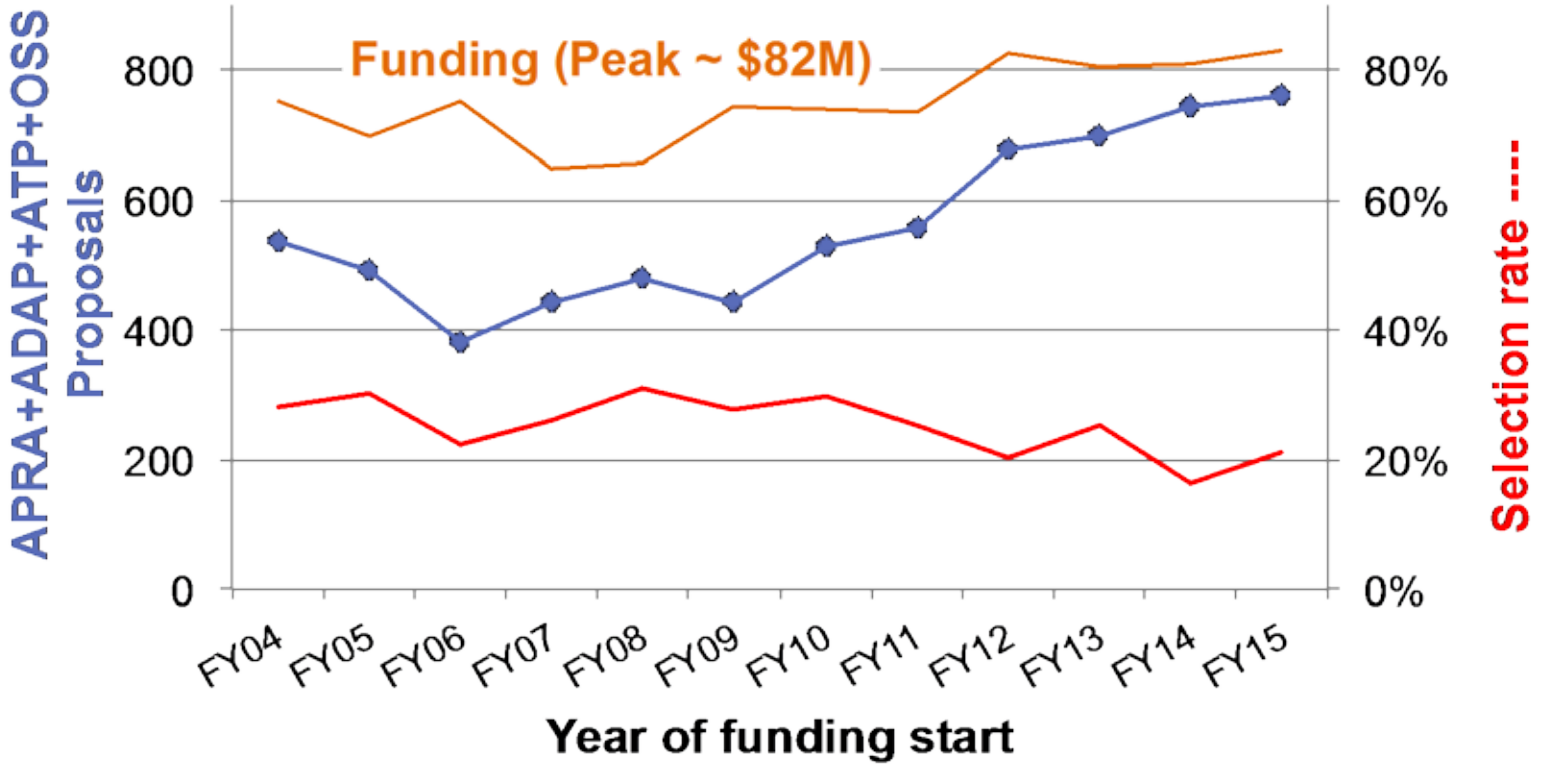
FY14 Research Program Budget and Spending







…but proposal numbers grow faster than $$



In 2014 the Astrophysics Research Program received twice as many proposals as in 2006.

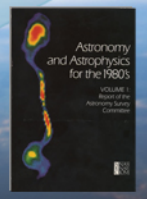
Funding for the program has risen 25% since 2006, but it has not doubled; so the success rate has fallen.

Total funding per successful proposal has been steady at $500k-$600k – this is an average over theory investigations, flight payloads, etc.

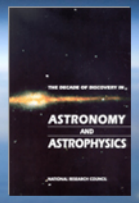
ASTROPHYSICS

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 Decadal Survey
Large Mission Concepts

- Study 3-4 large mission concepts as candidate prioritized large missions
  - Science case
  - Technology assessment
  - Design reference mission with strawman payload
  - Cost assessment
- Community Plan
  - 2015: PAGs gather community input on selecting concepts for study
  - 2016: Appoint STDTs and Center study office, STDT assess technology
  - 2017: Fund technology development through SAT, STDT works
  - 2018: STDT submits DRM for cost assessment
  - 2019: STDT issues report, input to Decadal Survey
- Community workshops (incomplete list)
  - Mar 19, Joint PAG EC meeting, Baltimore
  - Jun 3-5, Far-IR workshop, Pasadena
  - Jun 13-14, ExoPAG meeting, Chicago
  - Jun 25-26, UV-Vis SIG meeting, Greenbelt
  - Jun 29-Jul 1, HEAD & PhysPAG meeting, Chicago
  - Aug 1, Joint PAG session @ IAU General Assembly, Honolulu

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Preparing for the 2020 Decadal Survey
Large Mission Concepts

The initial short list (in alphabetical order):

- **FAR IR Surveyor** – The Astrophysics Visionary Roadmap identifies a Far IR Surveyor as contributing through improvements in sensitivity, spectroscopy, and angular resolution.
- **Habitable-Exoplanet Imaging Mission** – The 2010 Decadal Survey recommends that a habitable-exoplanet imaging mission be studied in time for consideration by the 2020 decadal survey.
- **UV/Optical/IR Surveyor** –The Astrophysics Visionary Roadmap identifies a UV/Optical/IR Surveyor as contributing through improvements in sensitivity, spectroscopy, high contrast imaging, astrometry, angular resolution and/or wavelength coverage. The 2010 Decadal Survey recommends that NASA prepare for a UV mission to be considered by the 2020 Decadal Survey.
- **X-ray Surveyor** – The Astrophysics Visionary Roadmap identifies an X-ray Surveyor as contributing through improvements in sensitivity, spectroscopy, and angular resolution.

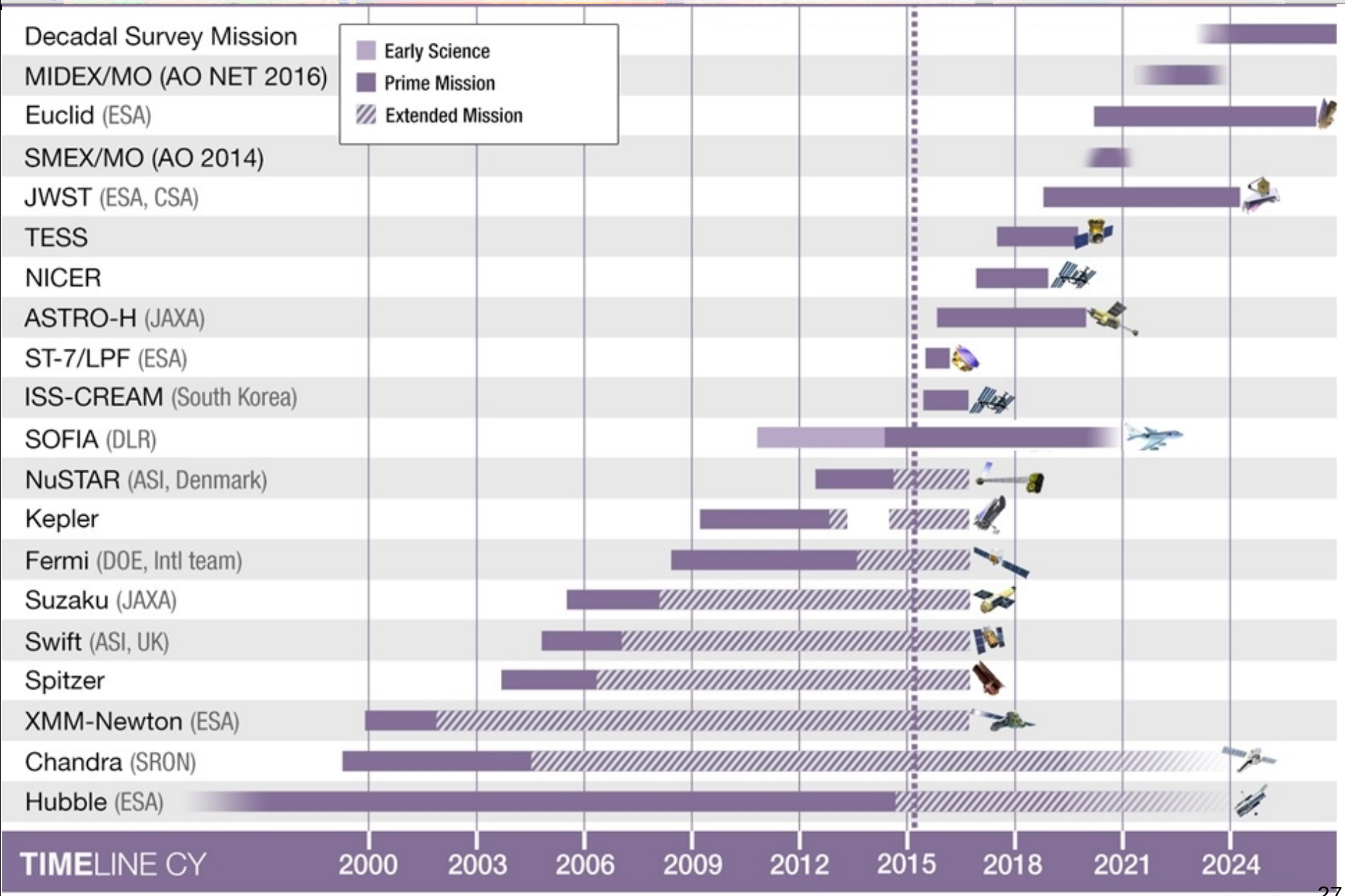
Preparing for the 2020 Decadal Survey
Thinking about Probes

- What was done 10 years ago?
  - Origins Probes Mission Concepts (2004)
    - ROSES call for quick (~9 month) paper concept studies
    - ~9 concepts selected in 2004; total funding ~$1M ($100K average)
  - Astrophysics Mission Concepts Study (AMCS; 2007)
    - ROSES call for ~1 year paper concept studies
    - Nineteen (+1) ASMC concepts selected in 2007; total funding $13M ($700K average)
  - Was this effective? Efficient? Appropriately impactful?
- Possibilities this time
  - Real mission concept studies
    - Just like we are doing for large mission concepts
    - How would we select them? Where does funding come from?
  - Paper mission concept studies
    - Just like AMCS, but limited to Probes
  - Self selected, self funded
    - Anybody can submit a white paper to the 2020 Decadal Survey
- Awaiting input from the PAG reports

AAAC 2015 Recommendations

- “The agencies should continue to pursue international partnerships in order to further accomplish the goals of NWNH. The Principles for Access1 should guide the process.”
  - NASA agrees;
    - Principles explicit in NASA/NSF MOU on NN-EXPLORE
    - Principles being applied in discussions with ESA regarding Athena
    - Principles being applied in formulating WFIRST policies
- “We urge the agencies and Congress to recognize the important role of basic research to the future of our country, including the special contributions that astronomy and astrophysics can offer.”
  - NASA agrees; Astrophysics continues to receive support from both the Administration and the Congress in budget process
- “The agencies should continue to work with the astronomy and astrophysics community to clarify and quantify the underlying factors contributing to the declining success rate seen at NASA and NSF, and develop data-driven ideas for managing the problem.”
  - NASA agrees; multiple science divisions at NASA providing data to AAAC working group

Astrophysics Timeline



Dates beyond 2016 are contingent upon the results of the 2016 Senior Review