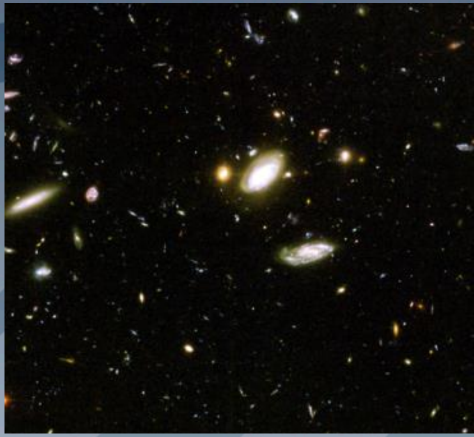
National Aeronautics and Space Administration

Astrophysics



Big Data Task Force of the NAC Science Committee

Washington DC

February 16, 2016

Paul Hertz

Director, Astrophysics Division

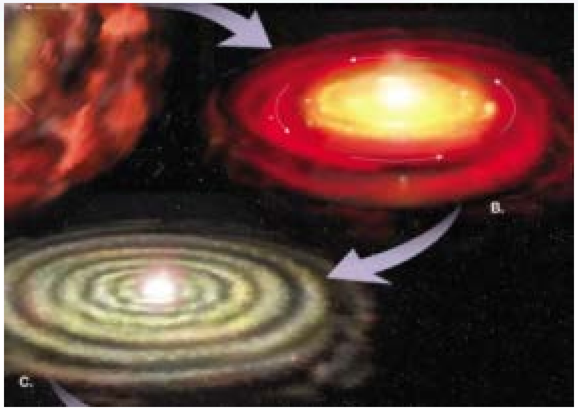
Science Mission Directorate

@PHertzNASA

Why Astrophysics?

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

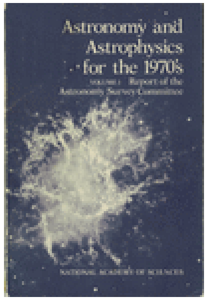
1. How did our universe begin and evolve?



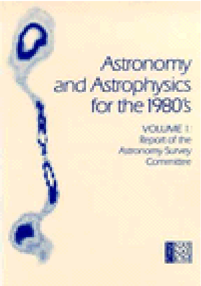
2. How did galaxies, stars, and planets come to be?

3. Are We Alone?

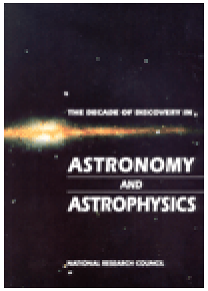
These national strategic drivers are enduring



1972

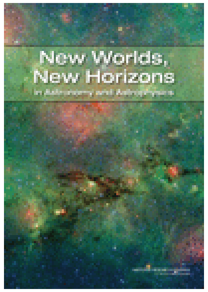


1982



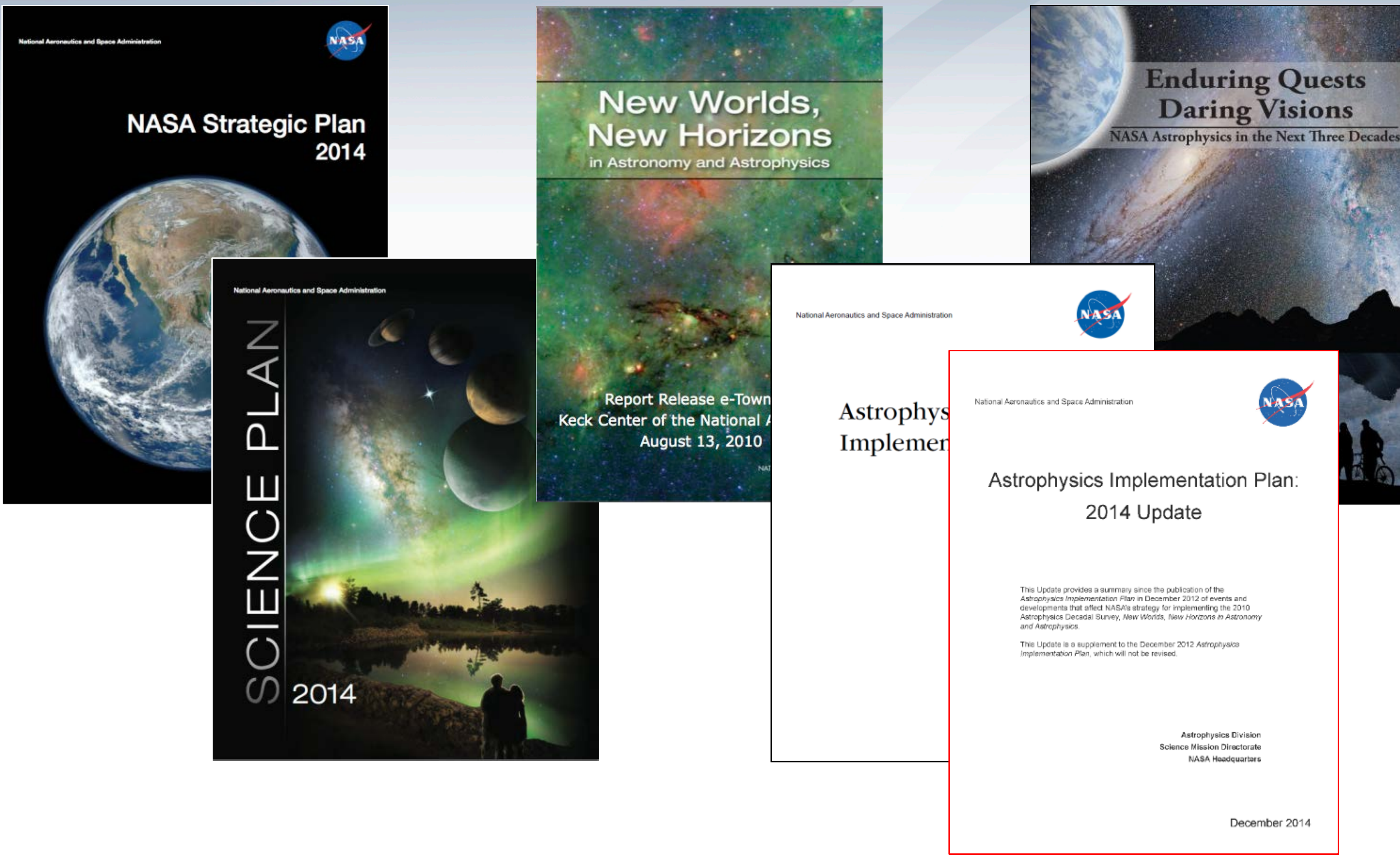
1991

2001



2010

Astrophysics Driving Documents

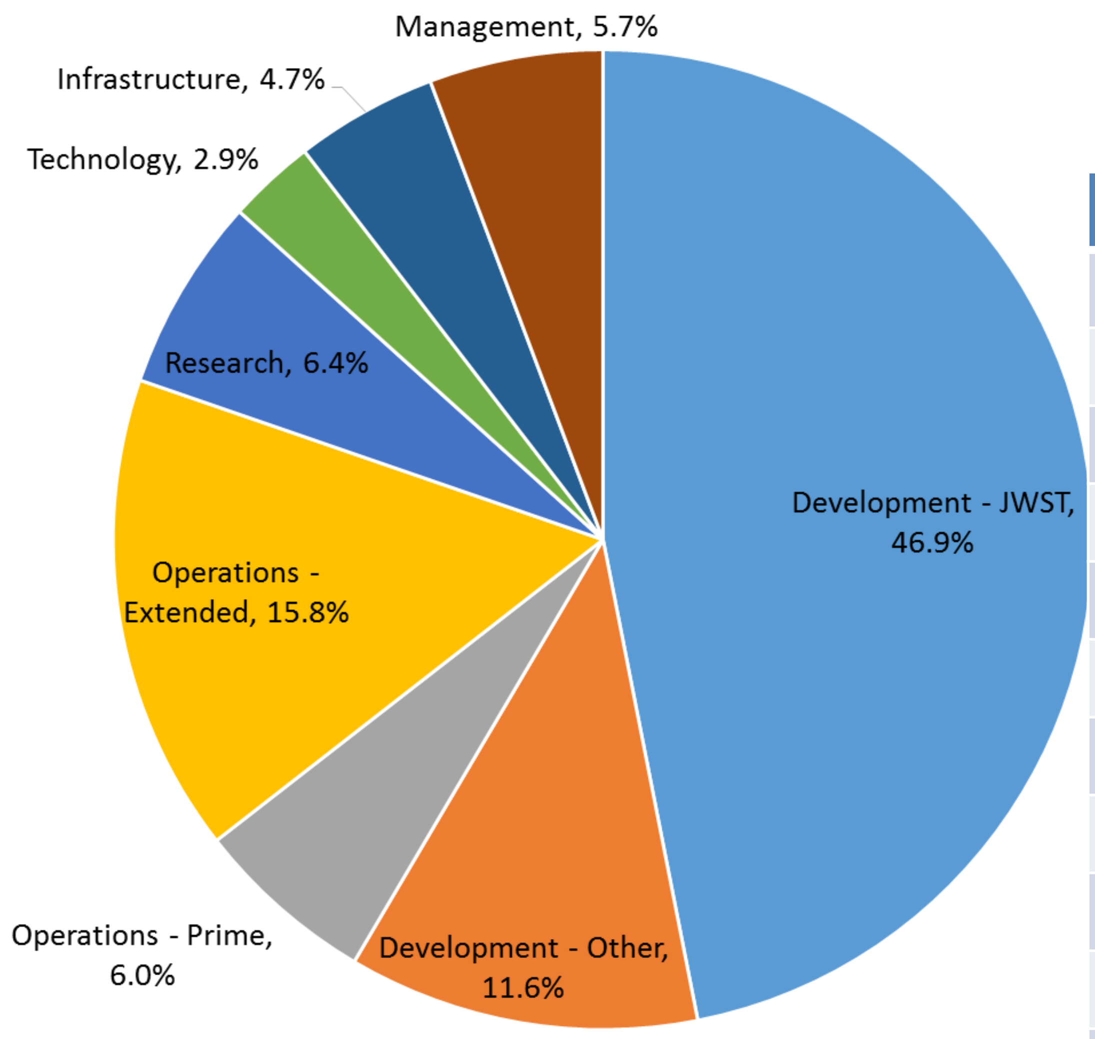


http://science.nasa.gov/astrophysics/documents

Astrophysics Overview

- Strategic Objective: Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars.
- In addition to space missions, the NASA Astrophysics portfolio includes basic research and technology development, development and stewardship of national capabilities for conducting space astrophysics, and suborbital investigations.
- Investment choices are informed by the Decadal Surveys, other NRC studies, and other science community input especially advisory committees and peer reviews.
- 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, mission enabling studies, technology demonstrations, and workforce development.
  - Suborbital-class projects using scientific balloons, sounding rockets, International Space Station, and other platforms.
  - Analysis of data from NASA and partner space observatories.
  - Theoretical and computational investigations.
  - Laboratory experiments in support of astrophysical understanding.

FY15 Astrophysics Budget Fractions



FY15 Budget	100.0%	$1,376M
Dev - JWST	46.9%	645M
Dev - Other	11.6%	159M
Ops - Prime	6.0%	82M
Ops - Ext	15.8%	217M
Research	6.4%	88M
Technology	2.9%	40M
Infrastructure	4.7%	65M
Management	5.7%	79M
GO - Prime		1.6M
GO - Ext		59.7M


Formulation
Implementation
Primary Ops
Extended Ops
XMM-Newton (ESA)
12/10/1999
Swift
11/20/2004
CREAM (on ISS)
12/2016
JWST
2018
Euclid (ESA)
2020
Fermi
6/11/2008
Spitzer
8/25/2003
Hubble
4/24/1990
Kepler
3/7/2009
ASTRO-H (JAXA)
2016
WFIRST
Mid 2020s
NICER (on ISS)
8/2016
Chandra
7/23/1999
TESS
2017
NuSTAR
6/13/2012
LISA Pathfinder (ESA)
12/3/2015
SOFIA
Full Ops 2014

Astrophysics Missions

	LRD	Prime	Phase	Provenance	Next SR
Hubble	1990	5 yrs	E-ext	Strategic – large (1972 DS)	2016
Chandra	1999	5 yrs	E-ext	Strategic – large (1982 DS)	2016
XMM-Newton (ESA)	1999	5 yrs	E-ext	Strategic - partnership	2016
Spitzer	2003	5 yrs	E-ext	Strategic – large (1991 DS)	2016
Swift	2004	2 yrs	E-ext	PI-led competed - MIDEX	2016
Suzaku (JAXA)	2005	2 yrs	F (closeout)	PI-led competed – MO	
Fermi	2008	5 yrs	E-ext	Strategic – medium (2000 DS)	2016
Kepler/K2	2009	4 yrs	F/E-ext	PI-led competed - Discovery	2016
Herschel (ESA)	2009	4 yrs	F (closeout)	Strategic - partnership	
Planck (ESA)	2009	4 yrs	F (closeout)	Strategic - partnership	
NuSTAR	2012	2 yrs	E-ext	PI-led competed - SMEX	2016
SOFIA	2014	5 yrs	E-prime	Strategic – medium (1991 DS)	2018
LISA Pathfinder (ESA)	2015	9 mos	E-prime	PI-led competed – New Millennium	Ad Hoc
ASTRO-H (JAXA)	2016	3 yrs	C/D	PI-led competed - MO	NET 2018
NICER	2016	18 mos	C/D	PI-led competed - MO	NET 2018
TESS	2017	2 yrs	C/D	PI-led competed - MIDEX	NET 2018
Webb	2018	5 yrs	C/D	Strategic – large (2000 DS)	NET 2022
SMEX/MO	~2020		A/B	PI-led competed – SMEX and MO	
Euclid (ESA)	2020		C/D	Strategic - partnership	
Athena (ESA)	2028		Pre-A	Strategic - partnership	
WFIRST	Mid-2020s	6 yrs	A/B	Strategic – large (2010 DS)	
L3 GW Obs (ESA)	2034		Pre-A	Strategic - partnership	

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 pre-formulation

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

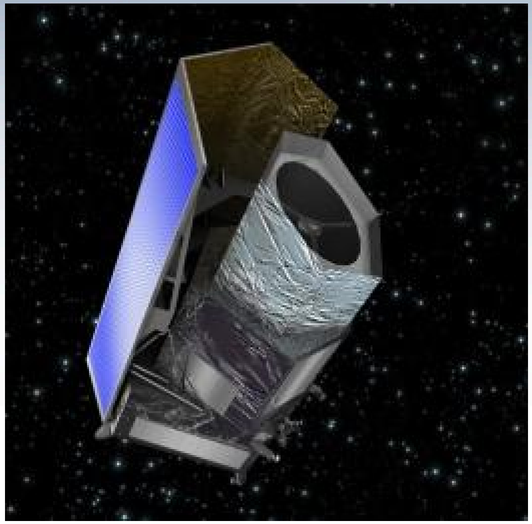
CURRENT STATUS:

- Completed Mission Concept Review (MCR) held in December 2015
- Formulation Science Investigation Teams selected in December 2015; first Formulation Science Working Group meeting in February 2016
- Planning for Key Decision Point A (KDP-A) in Feb 2016
  - Official start of formulation phase
  - Supported by FY16 appropriations
  - SMD Program Management Council January 26, 2016
  - Agency Program Management Council on February 17, 2016
- Industry RFI released July 2015; RFP for industry studies released in January 2016
- Other activities include:
  - Technology development for detectors and coronagraph (with STMD); prototyping key parts
  - Assessment of telescopes + risk mitigation
  - Mission design trades; performance simulations
- Maturing key technologies by FY19
  - H4RG infrared detectors for widefield imager
  - Internal coronagraph for exoplanet characterization
  - Milestones on road to achieve TRL-5 by end of CY16, TRL-6 by end of CY18; reports made public

WFIRST starts Formulation in February 2016

Euclid

A visible and near-infrared telescope to explore cosmic evolution



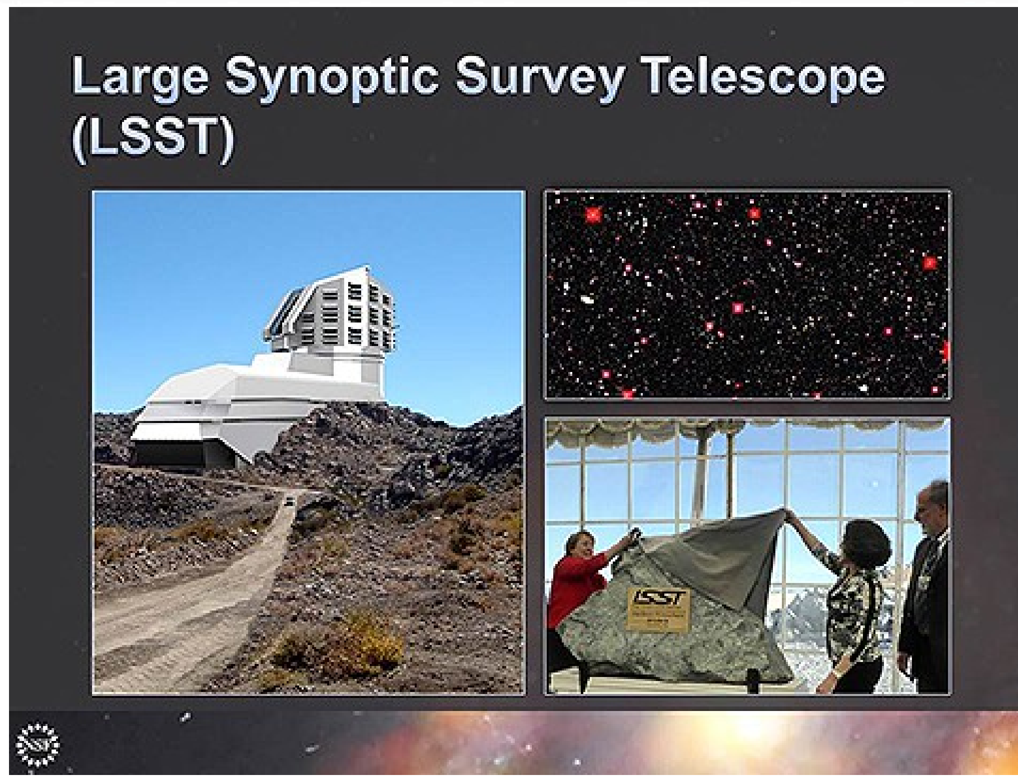
- **ESA Cosmic Vision 2015-2025 Mission**, M-Class with NASA participation.
- 1.2-m mirror, visible & near-IR images, spectra
- **Launch Date**: Dec 2020
- **Science Objectives**:
  - Euclid will look back 10 billion years into cosmic history.
  - Probe the history of cosmic expansion (influenced by dark energy and dark matter) and how gravity pulls galaxies together to form the largest structures.
  - The shapes of distant galaxies appear distorted because the gravity of dark matter bends their light (gravitational lensing). Measuring this distortion tells us how the largest structures were built up over cosmic time.
  - Measuring how strongly galaxies are clumped together tells us how gravity influences their motions, and how dark energy has affected the cosmic expansion.

CURRENT STATUS:

- Currently in implementation phase.
- NASA providing Sensor Chip Systems for Near Infrared Spectrometer and Photometer (NISP) instrument
- ~80 U.S. scientists are members of the Euclid Science Team that will analyze the data, and make maps of the sky.
- NASA has initiated the buy for the flight infrared detectors. NASA will test and characterize the near-IR flight detectors.
  - .Flight elements have begun fabrication
  - First sensor chip assemblies have completed screening, remaining are in assembly
  - Remaining hardware elements are beginning production
  - NASA on track for delivery on schedule
- NASA is developing the ENSCI (Euclid NASA Science Center at IPAC). ENSCI will:
  - Support all segments of US community on Euclid to enhance science utilization
  - Integrate into Euclid Science Ground System provided by the Euclid consortium to gain/contribute expertise in pipelines

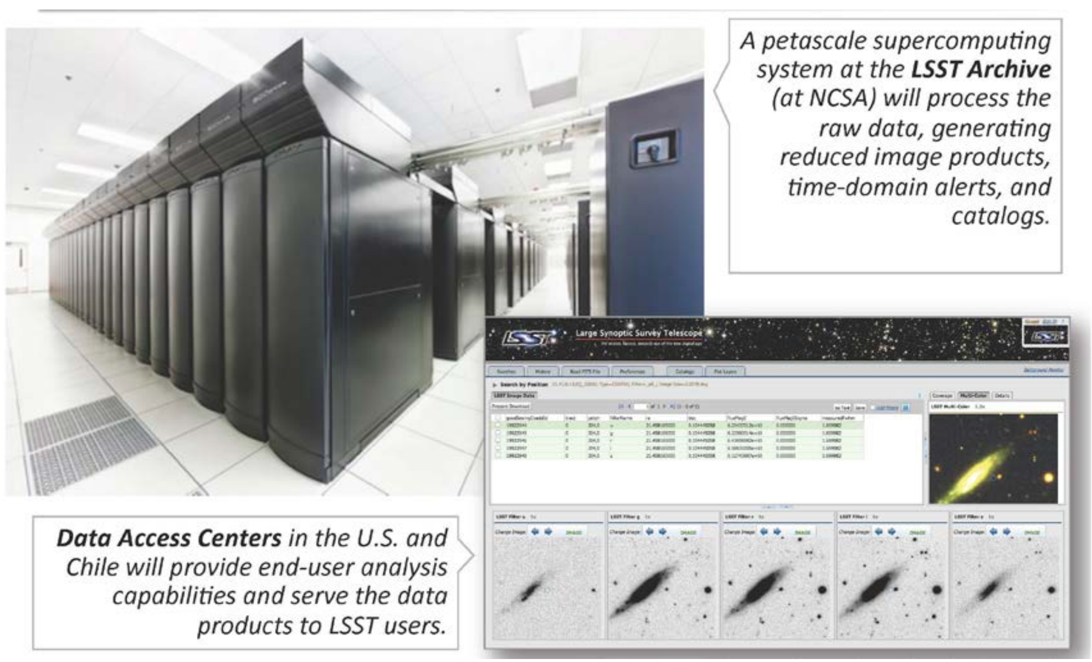
Large Synoptic Survey Telescope

- NSF construction award made in August 2014
- Strong NSF/DOE partnership in construction and operations
- NRC committee studied OIR system in LSST era (more later)



Large Synoptic Survey Telescope

- The LSST is an integrated survey system designed to conduct a decade-long, deep, wide, fast time-domain survey of the optical sky. It consists of an 8-meter class wide-field ground based telescope, a 3.2 Gpix camera, and an automated data processing system.
- Over a decade of operations the LSST survey will acquire, process, and make available a collection of over 5 million images and catalogs with more than 37 billion objects and 7 trillion sources. Tens of billions of time-domain events will be detect and alerted on in real-time.



Astrophysics: WFIRST, Euclid, and LSST

- LSST, Euclid, and WFIRST are all wide, deep imaging survey missions operating in the optical/IR.

- A combined analysis of the data from all three will provide a significant enhancement in scientific return for cosmological studies. For reduction of systematics, this will probably require joint processing at the pixel level.

The Whole is Greater than the Sum of the Parts: Optimizing the Joint Science Return from LSST, Euclid and WFIRST (Jain et al., http://arxiv.org/abs/1501.07897)

Astrophysics: Science and Data Archives

NASA Astrophysics supports an integrated system of science data archives

- Astrophysics Data System (ADS)/SAO
- High Energy Astrophysics Science Archive Research Center (HEASARC)/GSFC
- Infrared Science Archive (IRSA) at Infrared Processing and Analysis Center (IPAC)/Caltech
- Mikulski Archive for Space Telescopes (MAST)/STScI
- NASA Exoplanet Archive (NEA) at NASA Exoplanet Science Institute (NExScI)/Caltech
- NASA Extragalactic Database (NED) at IPAC/Caltech
- NASA Astrophysics Virtual Observatory (NAVO)

http://science.nasa.gov/astrophysics/astrophysics-data-centers/

Astrophysics: Science and Data Archives

Challenges identified by 2015 Senior Review:

- The infrastructure and the technological approaches that are being used will certainly be obsolete at the end of the next 4-5 year review cycle.
- Network bandwidths available to the data centers will soon be two generations behind the current standard for research internet.
- Data centers need to raise concerns about sustainability where they exist, regardless of budgetary constraint

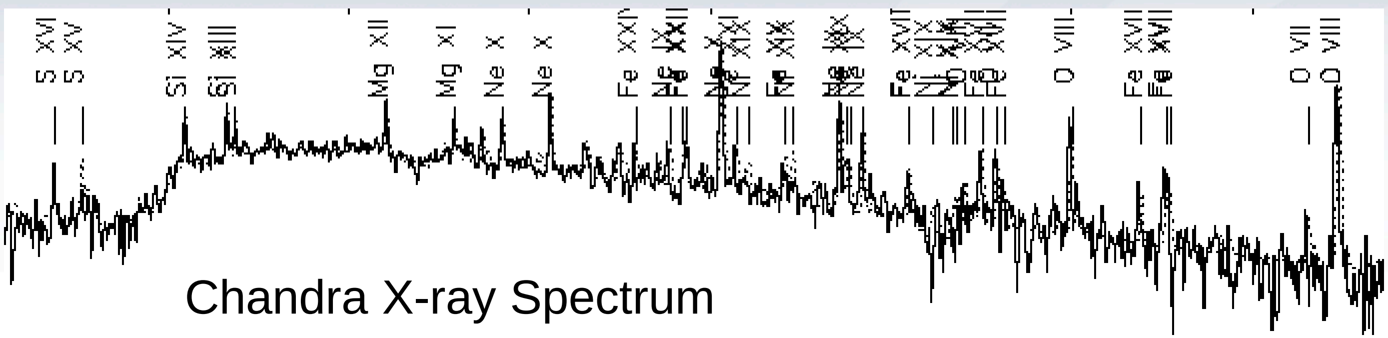
http://science.nasa.gov/media/medialibrary/2015/07/08/NASA-AAPR2015-FINAL.pdf

- Cloud computing and associated commercial services.
  - It is clear that some of our services cannot be migrated yet, while we do utilize clouds for some services.
  - It may well be that cloud computing is a good fit for creating the huge simulations we need (for Euclid and WFIRST, and incidentally also LSST), and also for running joint processing.
  - It is a matter of how well matched the science requirements are to the commercial services, first their technical services but also their charging model (it may be cheaper to work with DOE supercomputers).

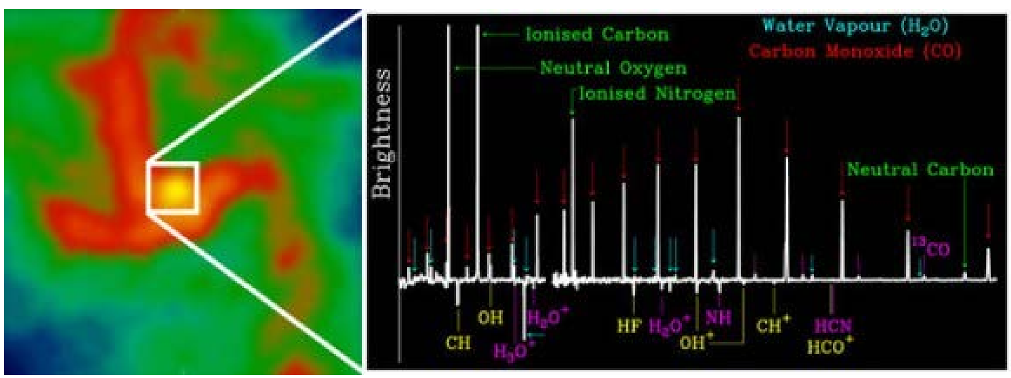
Astrophysics: Theoretical and Computational Astrophysics Networks

Project title	PI	Institution	Topic / Agency
Multi-Scale Plasma Flows Around Black Holes	J. McKinney	U Maryland	black hole accretion
	R. Narayan	Harvard	
	D. Psaltis	U Arizona	NASA
From the ISM to the IMF: Multi-Scale, Multi-Physics Modelling of Star Formation	E. Ostriker	Princeton	star formation
	M. Krumholz	UC Santa Cruz	
	C. McKee	UC Berkeley	NASA
The SPIDER Network: Supernova Progenitor, Internal Dynamics & Evolution Research	L. Bildsten	UC Santa Barbara	supernovae
	F. Timmes	Arizona State U	
	R. Townsend	U Wisconsin-Madison	NASA
	J. Toomre	U Colorado at Boulder	
Extracting Astrophysics and Fundamental Physics from Multi-Messenger Observations of Compact Objects	C. Ott	Caltech	mergers of black holes and neutron stars
	D. Brown	Syracuse U	
	S. Teukolsky	Cornell U	
	S. Reddy	U Washington	NSF
The multi-scale physics of massive black hole formation, fueling, and feedback	C. Reynolds	U Maryland	black holes in galaxies
	P. Natarajan	Yale U	
	P. Laguna	Georgia Inst Tech	NSF
Black Hole Accretion Theory and Computation Network	C. F. Gammie	U Illinois	black hole accretion
	E. Quataert	UC Berkeley	
	J. M. Stone	Princeton U	NSF

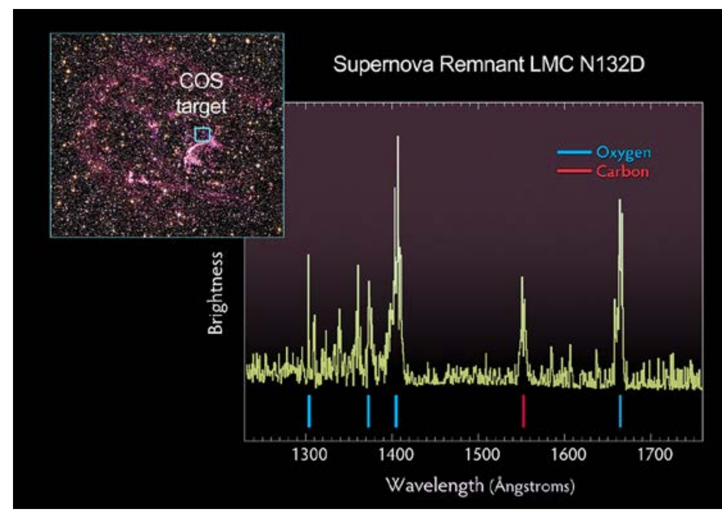
Astrophysics: Laboratory Astrophysics Investigations



Chandra X-ray Spectrum

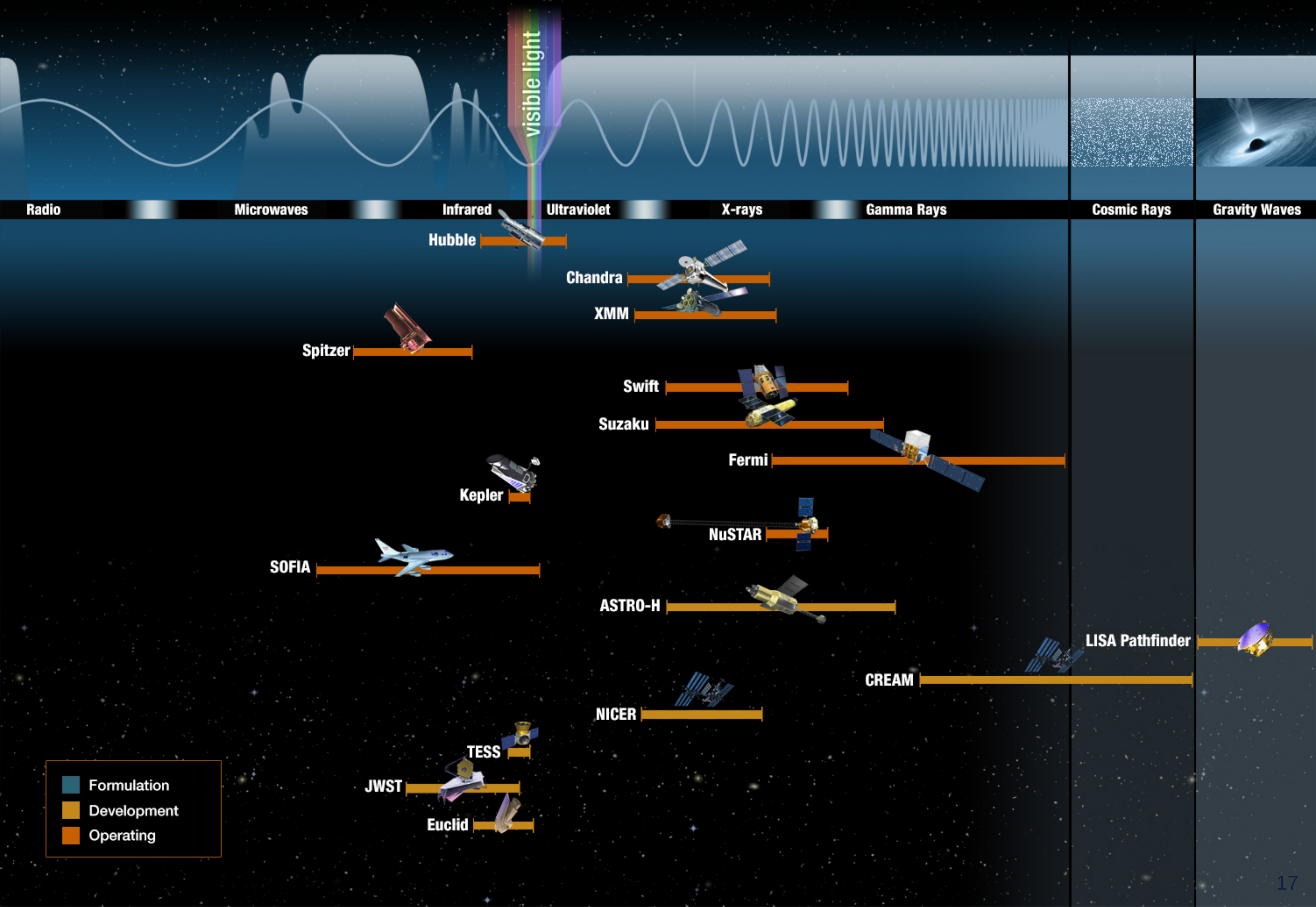


Herschel Far Infrared Spectrum



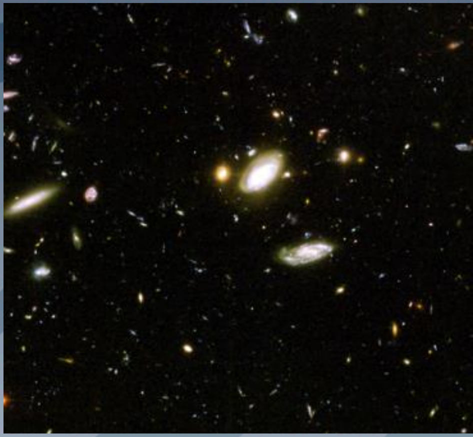
Hubble Visible/Ultraviolet Spectrum

Astrophysics Mission Portfolio 2015



Astrophysics



BACKUP

Astrophysics Division - SMD

December 3, 2015

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*
Division E/PO POC: Hashima Hasan (Lead Comm Team)
Division Public Affairs POC: Kartik Sheth
Information Manager: Lisa Wainio*

Astrophysics Research

Program Manager: Linda Sparke
Astrophysics Data Analysis: Doug Hudgins
Astrophysics Theory: Keith MacGregor*
Exoplanet Research: Martin Still*
APRA lead: Michael Garcia*
Cosmic Rays, Fund Physics: Vernon Jones, Keith MacGregor*
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: Vacant
Theory & Comp Astro Net: Keith MacGregor*
Roman Tech Fellows: Billy Lightsey*
Data Archives: Hashima Hasan
Astrophysics Sounding Rockets: Wilt Sanders*
Balloons Program: Vernon Jones(PS), Mark Sistilli (PE)

Programs / Missions

	Program Scientist	*Program Executive*
Exoplanet Exploration (EXEP)		
Program	**Doug Hudgins**	**John Gagosian**
Keck	Hashima Hasan	Mario Perez*
Kepler/K2	Mario Perez*	Jeff Hayes
LBTI	Hashima Hasan	Mario Perez*
NExScI	Hashima Hasan	Mario Perez*
Cosmic Origins (COR)		
Program	**Mario Perez***	**Shahid Habib***
Herschel	Dominic Benford*	Jeff Hayes
Hubble	Michael Garcia*	Jeff Hayes
JWST	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	Keith MacGregor*	Jeff Hayes
Planck	Rita Sambruna	Jeff Hayes
ST-7/LPF	Wilt Sanders*	Keith Chamberlin*
XMM-Newton	Stefan Immler*	Jeff Hayes
Astrophysics Explorers (APEX)		
Program	**Wilt Sanders***	**Mark Sistilli**
ASTRO-H	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
WFIRST-AFTA	Dominic Benford*	John Gagosian

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