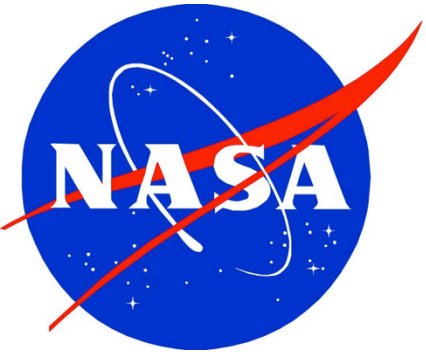
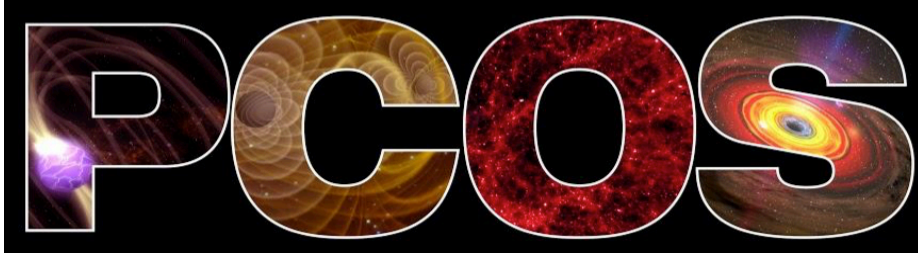




NASA's Physics of the Cosmos Program

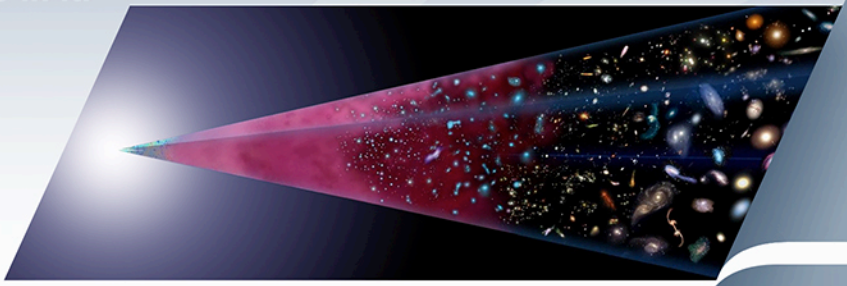
Terri Brandt
PCOS Chief Scientist

AAS
4 Jan 2020

Why Astrophysics?

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

How did our universe begin and evolve?



Physics of the Cosmos (PCOS)

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

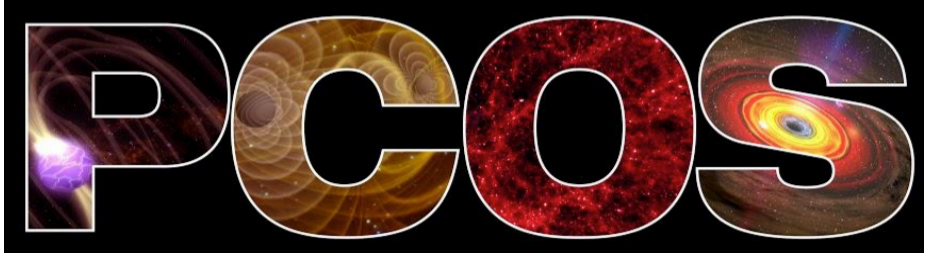
Cosmic Origins (COR)

Are we alone?

Exoplanet Exploration (ExEP)

Program Office Themes

Enduring National Strategic Drivers



Physics of the Cosmos Program Office Purpose:

to explore some of the most fundamental questions regarding the physical forces and laws of the universe:

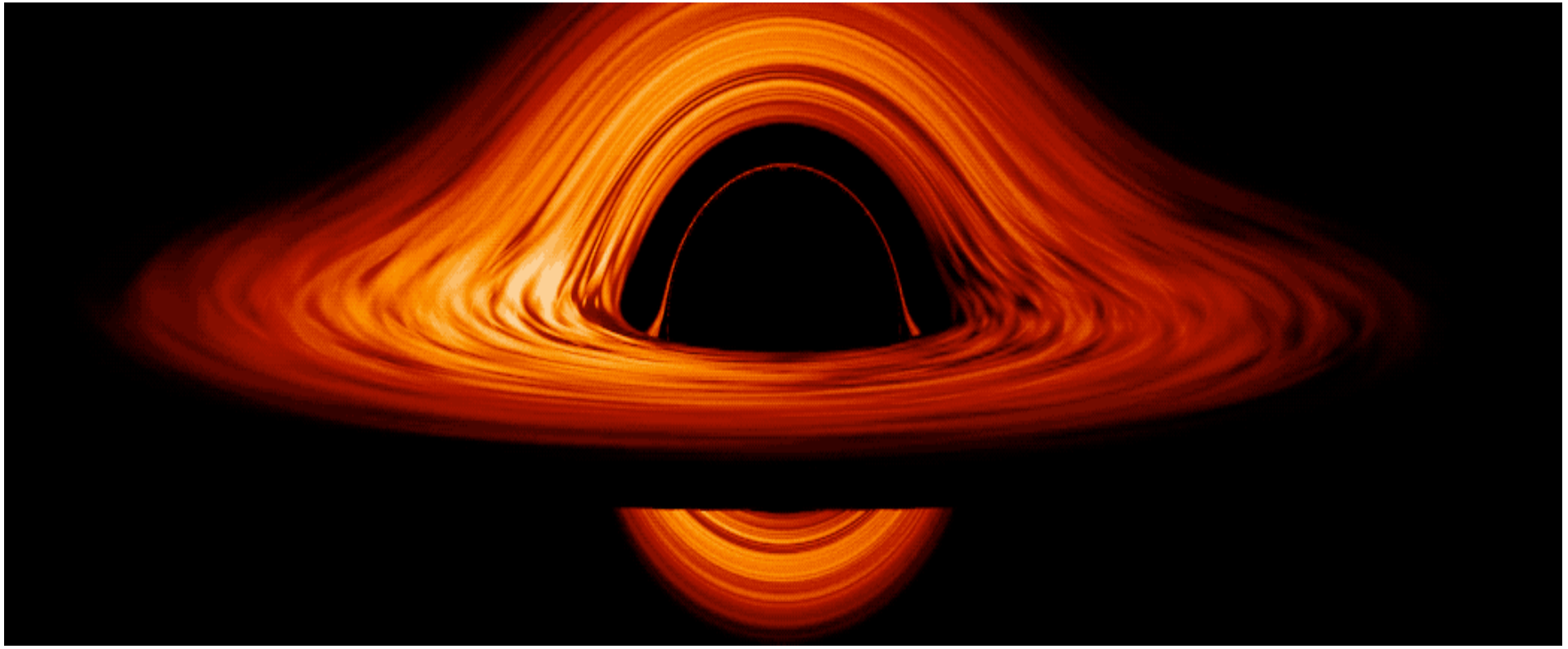
- the validity of Einstein's General Theory of Relativity and the nature of spacetime;
- the behavior of matter and energy in extreme environments;
- the cosmological parameters governing inflation and the evolution of the universe; and
- the nature of dark matter and dark energy.

Physics of the Cosmos spans the fields of high-energy astrophysics, cosmology, and fundamental physics, with a wide range of science goals. These include the following:

- General Relativity and the Nature of Spacetime
- Massive Black Holes and the Evolution of Galaxies
- Matter and Energy in the Most Extreme Environments
- Dark Energy
- Big Bang and the Evolution of the Universe

More resources: https://pcos.gsfc.nasa.gov

Science Highlight:
Black Hole Visualization



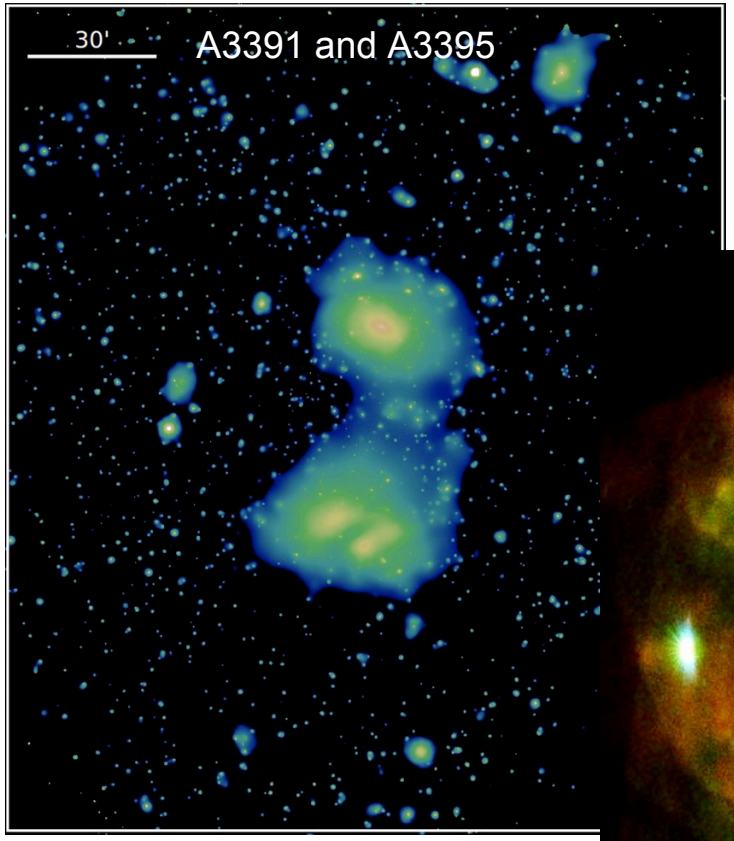
Black hole visualization related to BH modeling for LISA by Jeremy Schnittman featured for Black Hole week, picked up by NPR and other news outlets.

https://www.nasa.gov/feature/goddard/2019/nasa-visualization-shows-a-black-hole-s-warped-world

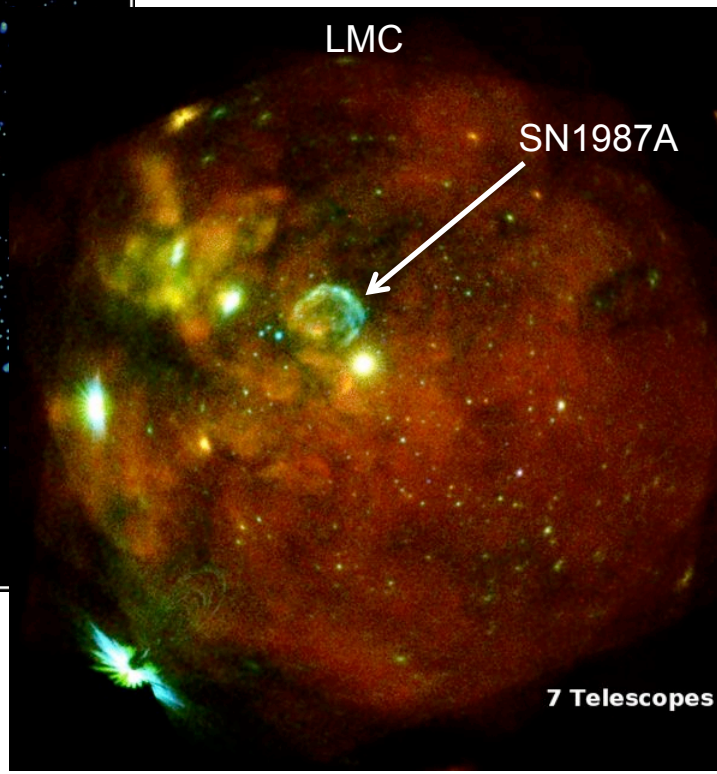
Science News Highlight: First Images from eROSITA!

Two interacting galaxy clusters:
- A3391 and A3395
- hot gas in a bridge between two galaxies shows that they are interacting dynamically

Large Magellanic Cloud (LMC):
- Hot gas and many supernova remnants
- SN1987A, growing fainter

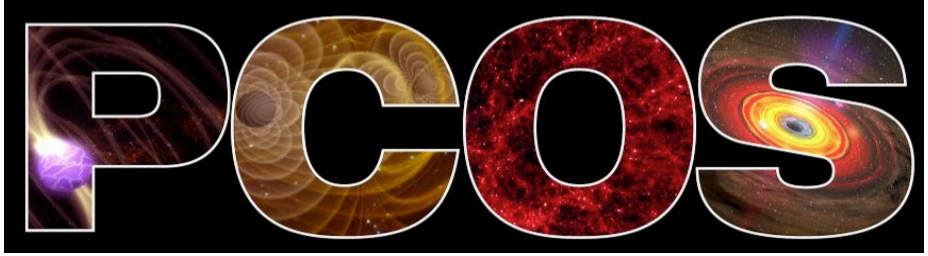


T. Reiprich (Univ. Bonn), M. Ramos-Ceja (MPE), F. Pacaud (Univ. Bonn), D. Eckert (Univ. Geneva), J. Sanders (MPE), N. Ota (Univ. Bonn), E. Bulbul (MPE), V. Ghirardini (MPE), MPE/IKI

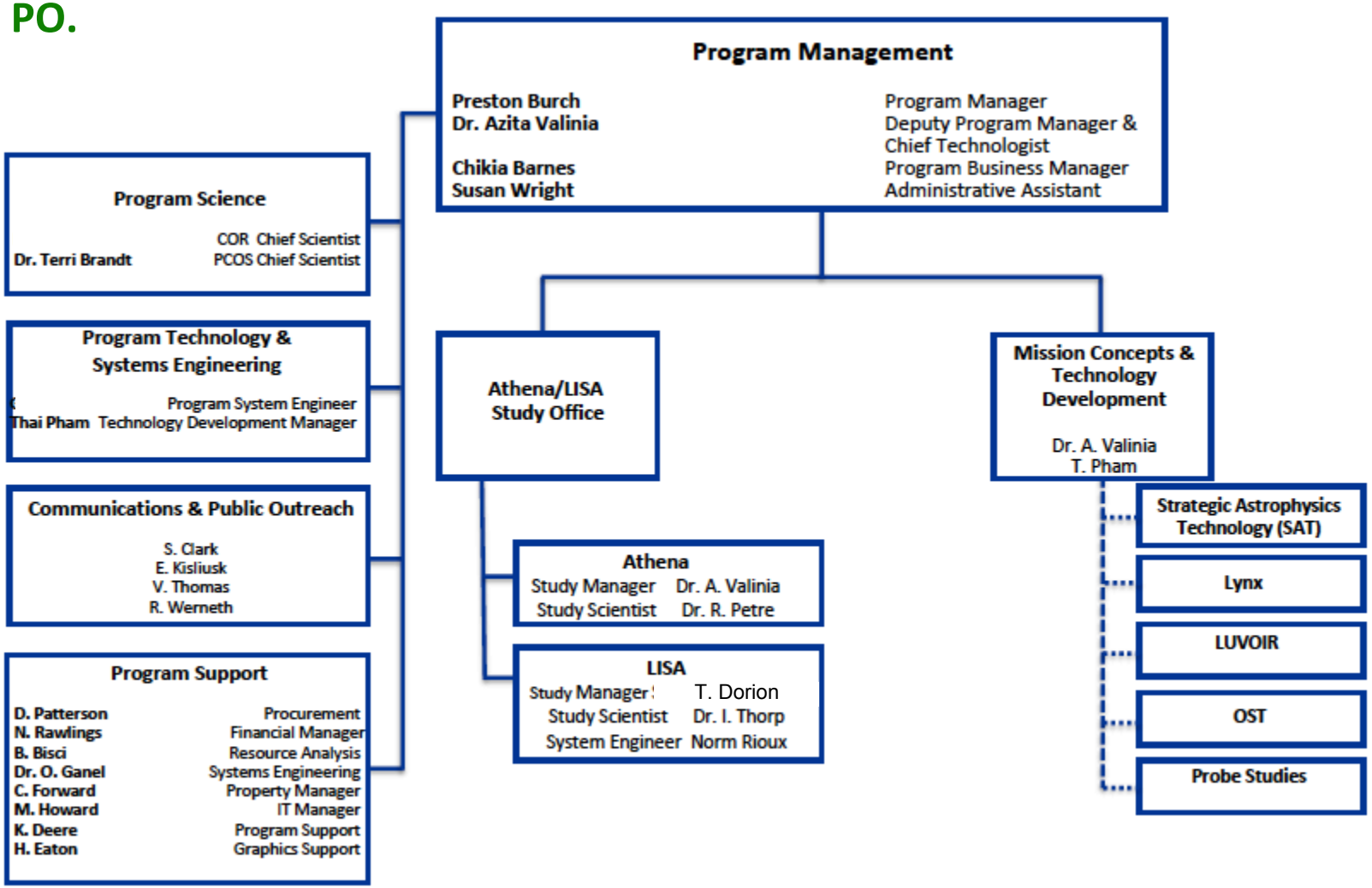


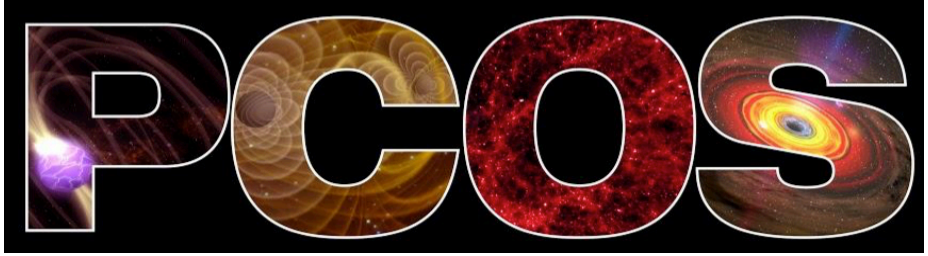
F. Haberl, M. Freyberg and C. Maitra, MPE/IKI

https://www.mpg.de/14056201/first-light-erosita



PCOS/COR Program Office (PO) authority flows from Astrophysics Division Director Paul Hertz to his HQ staff, Shahid Habib & Dan Evans, and to the PCOS/ COR PO.





Activities supporting PCOS goals and priorities:

- Managed by the PCOS/COR Program Office at NASA's Goddard Space Flight Center and reported to NASA Headquarters.
- Include:
  - **Mission studies** and pre-project mission oversight, insight, and support
  - **Strategic technology** (SAT) maturation oversight, insight, and support
  - **Community engagement**, including via the Physics of the Cosmos Program Analysis Group (PhysPAG)
  - Maintaining **science cognizance** to enable more successful NASA strategic planning

The PCOS Program Office hosts
- Athena Study Office
- LISA Study Office

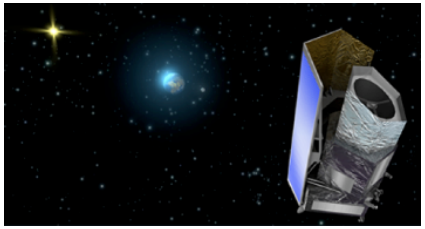
and oversees
- science and
- technology activities

for NASA's contribution to these ESA-led and other strategic missions.

Missions

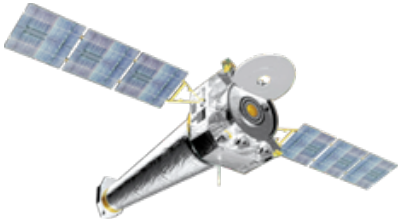
Operating Missions:

Euclid ~2022
ESA-led Mission



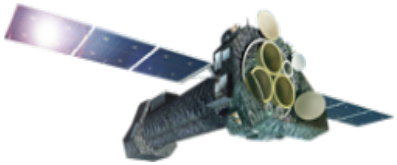
NASA supplying the NISP Sensor Chip System (SCS)

Chandra 1999
NASA Strategic Mission



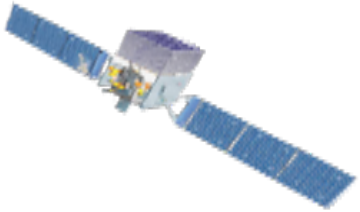
Chandra X-ray Observatory

XMM-Newton 1999
ESA-led Mission



X-ray Multi Mirror - Newton

Fermi 2008
NASA Strategic Mission



Fermi Gamma-ray Space Telescope

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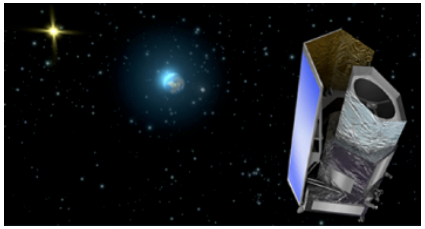

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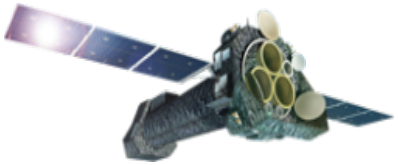

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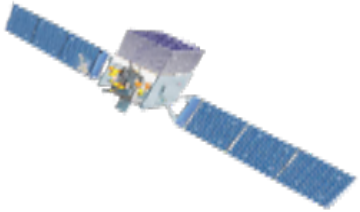

Fermi Gamma-ray Space Telescope

And,

- Particle astrophysics
- Gamma-ray (MeV+)
- X-ray
- Inflation probe
- Cosmic Structure
- Gravitational waves

From all platforms!

- Satellites,
- the ISS,
- Balloons,
- Sounding rockets, …

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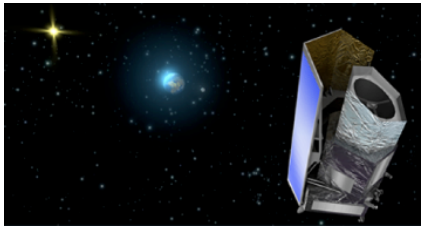

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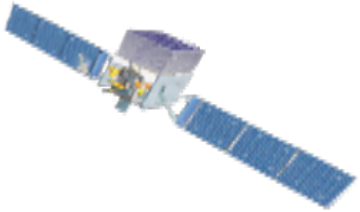

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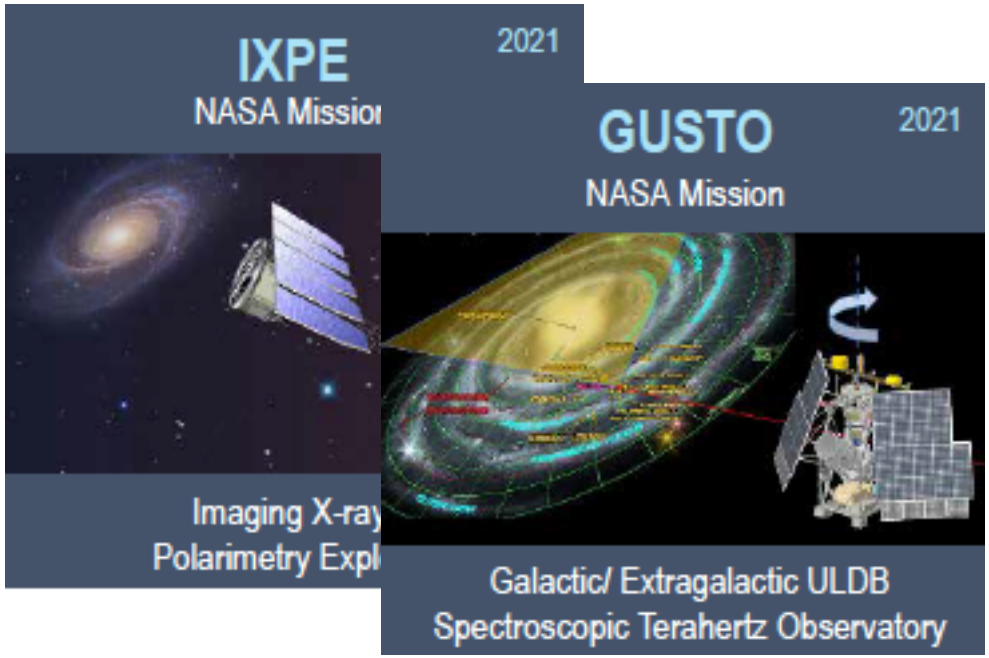

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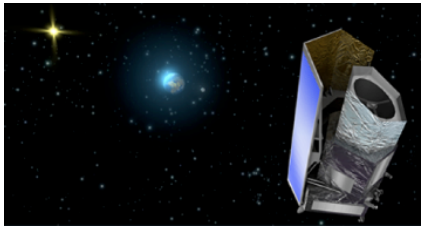

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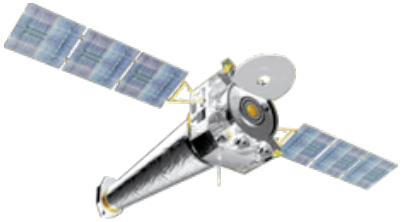

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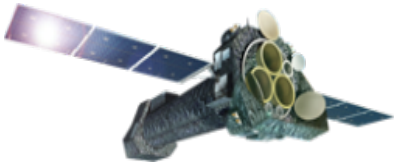

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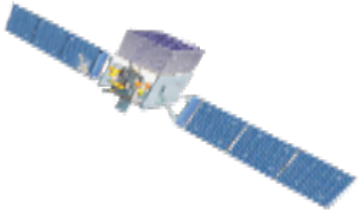

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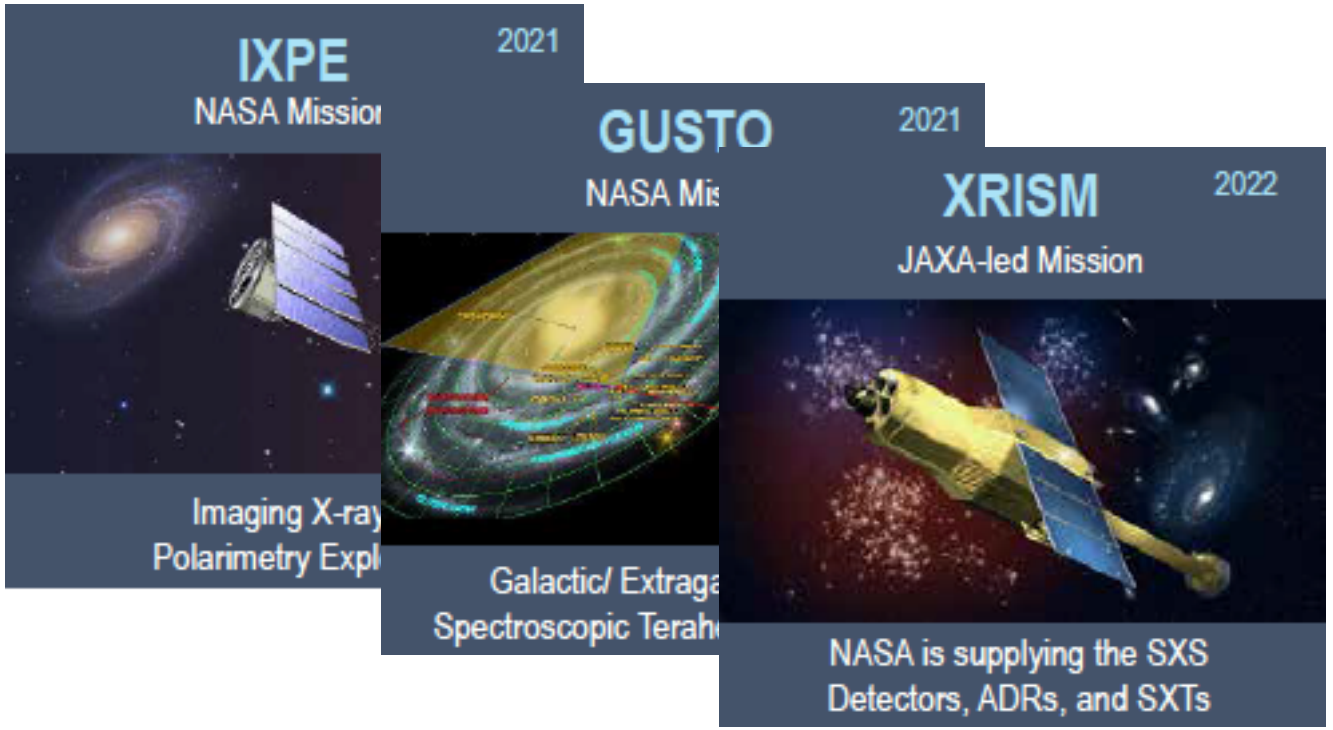

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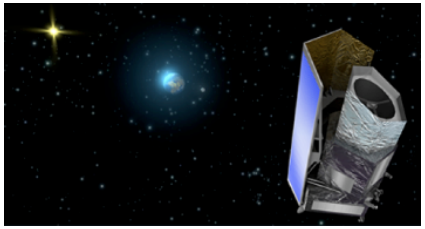

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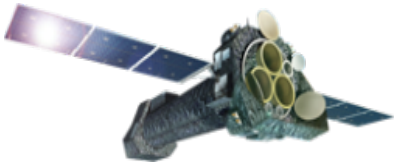

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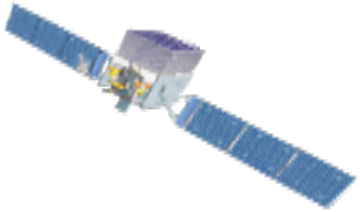

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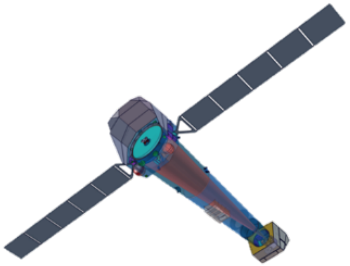
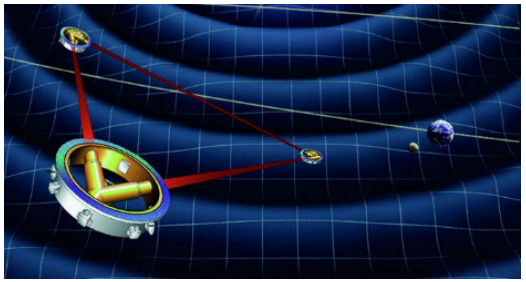
Missions in Pre-formulation:

Athena 2030s
ESA-led Mission



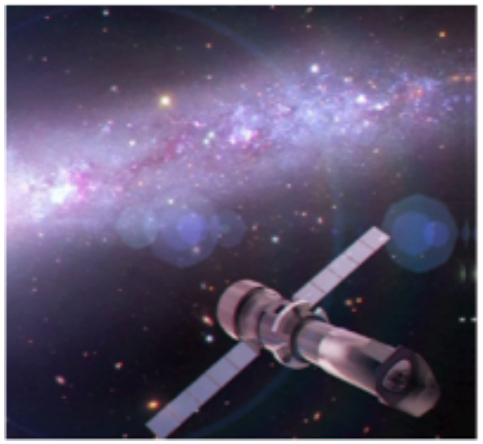
NASA is supplying elements for both instruments
Science team members

LISA 2030s
ESA-led Mission



NASA is developing technology for both the payload and the mission
NASA LISA Study Team

Athena



Athena is an ESA flagship X-ray mission slated for launch in early 2030s

Two instruments provided by member states:

- calorimeter (X-IFU) and
- wide-field imager (WFI)

NASA is planning hardware contributions, with options for both X-IFU and WFI, and is discussing observatory contributions.

Current status: in (ESA) Phase B

- Nov 2019: Athena passed Mission Formulation Review (MFR)!
- Anticipate Adoption by ESA's Science Programme Committee in 2021

Get involved! Join an Athena Science Working Group, organized by theme: Hot Universe, Energetic Universe, and Observatory

For more info:

Tues 7 Jan 9-10.30a: *Athena* X-ray Mission: Multi-wavelength and Multi-messenger Opportunities organized by Jon Miller, NASA Athena Study Team Chair

http://www.the-athena-x-ray-observatory.eu/

LISA

LISA is an ESA-led space gravitational wave observatory.

NASA is a junior partner w possible technology contributions, including:

- Laser
- Telescope
- Charge management system
- Phasemeter
- Microthrusters

Current status: in (ESA) Phase A

- Dec 2019: LISA passed ESA Mission Consolidation Review!
- Mission Adoption currently anticipated in early 2020s.

NASA LISA Study Team (Kelly Holley-Bockelmann, Chair) highlights:

- Science Support Taskforce Report: Maximizing US Participation in LISA Science
- Currently preparing a report on the "science value" of data products and outlining community needs/desires for US ground segment contributions and science participation

Broader astrophysics community involvement is welcome!

NLST community survey link:
https://forms.gle/s8MmCan8neAKqD186

For more info:

Tues 7 Jan 2-3.30p: LISA Preparatory Science Program

https://sci.esa.int/web/lisa/ and *https://lisa.nasa.gov/*

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- Laser
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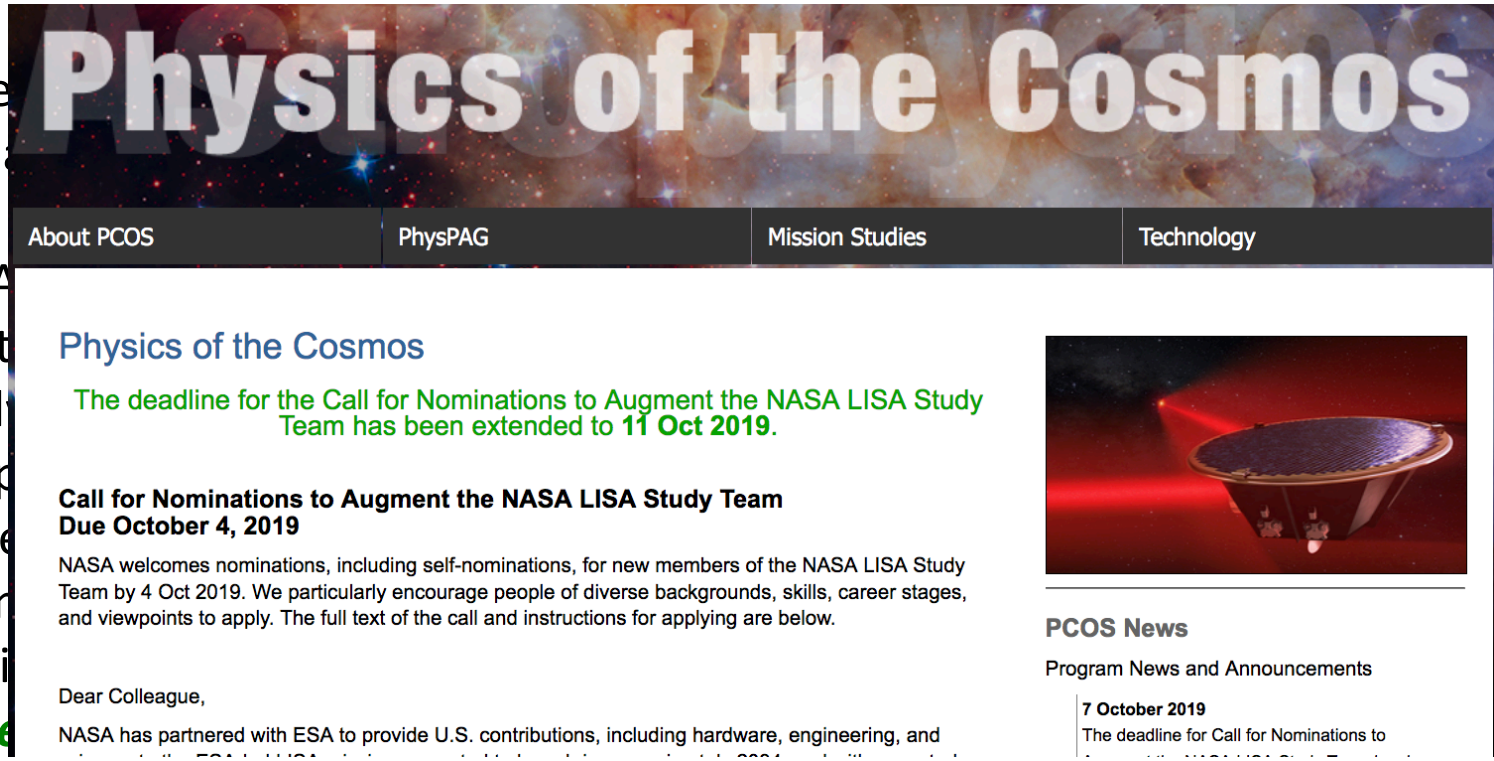
Current status:

- Dec 2019: LISA
- Mission Adopt

NASA LISA Stud

- Science Supp
- Currently pre
  outlining cor
  science parti

Broade



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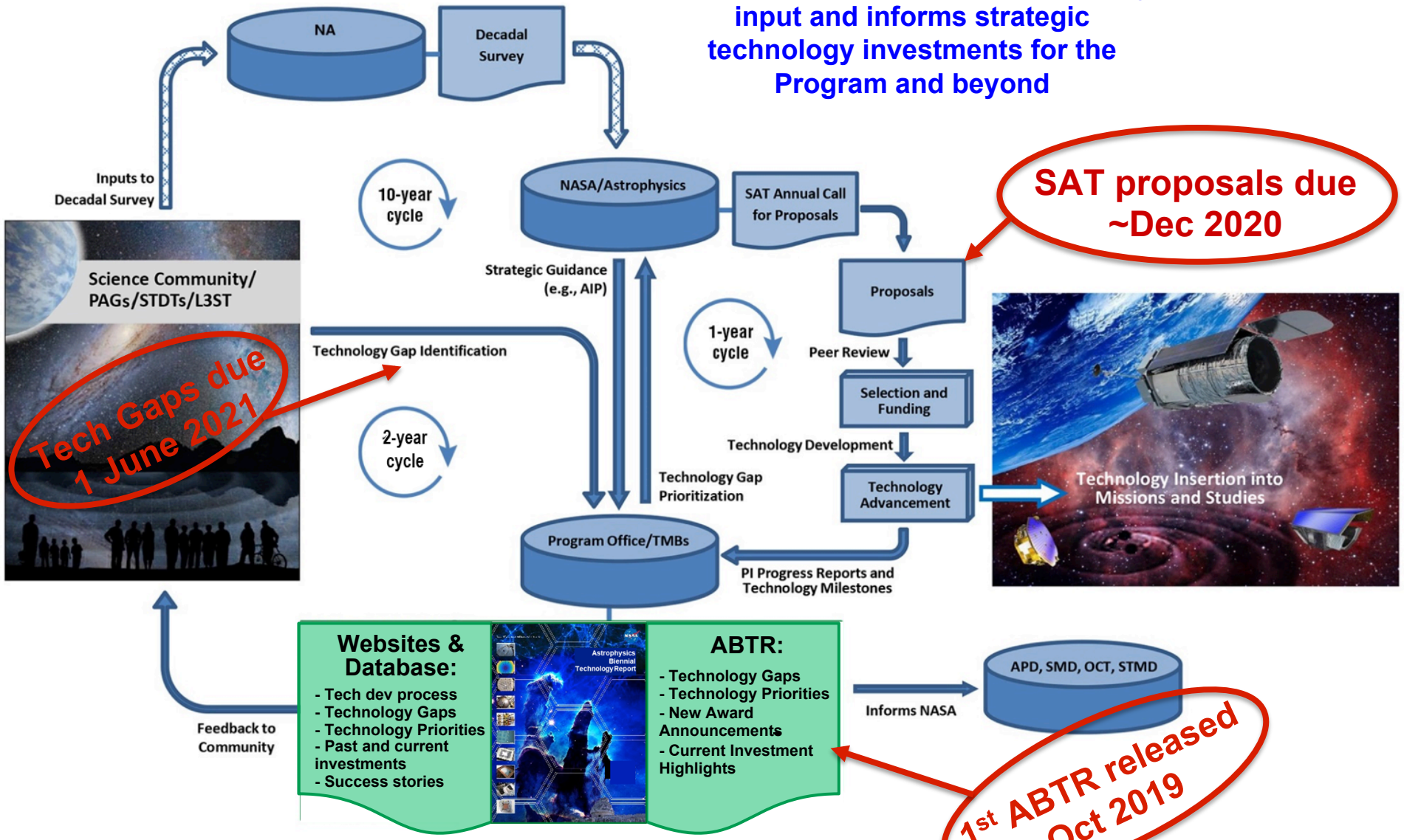
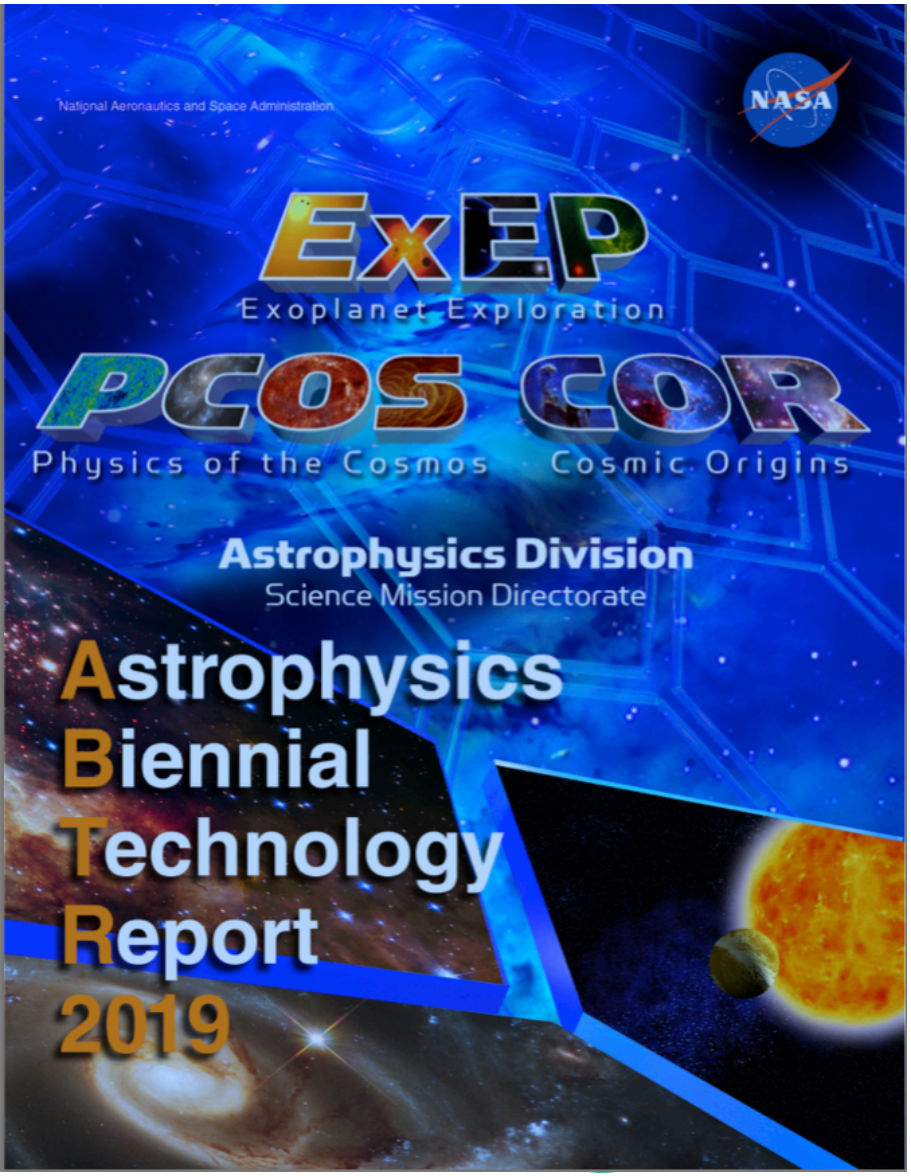
Strategic Technology Development Process

Process is responsive to community input and informs strategic technology investments for the Program and beyond



https://apd440.gsfc.nasa.gov/technology.html

First Astrophysics Biennial Technology Report!



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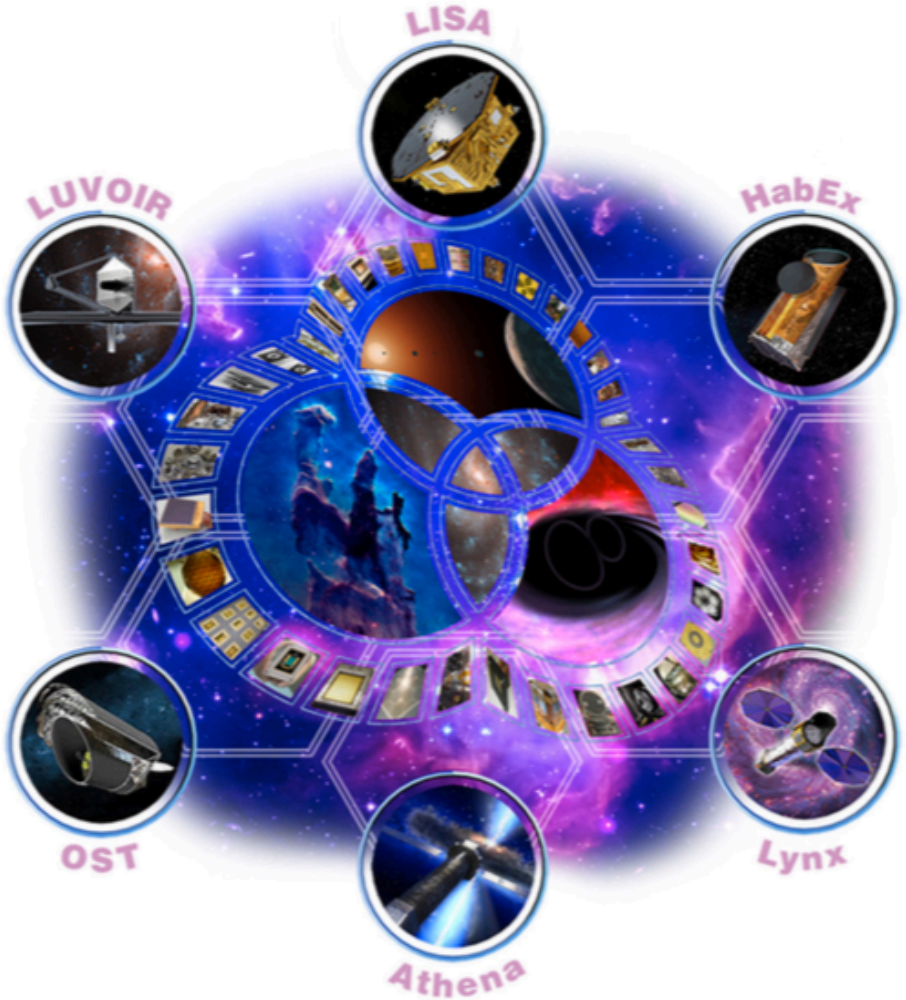

https://apd440.gsfc.nasa.gov/technology.html)

ABTR: PCOS SAT Portfolio

PCOS Technology Development Title	PI Name	Institution	Technology Area
High-Speed, Low-Noise, Rad-Tolerant CCD Image Sensors for Strategic High-Energy Missions	Bautz, Mark	MIT	Detector
Superconducting Antenna-Coupled Detectors for CMB Polarimetry with the Inflation Probe	Bock, James	JPL	Detector
Development of Adjustable X-Ray Optics with 0.5 Arcsec Resolution for the Lynx Mission Concept	Reid, Paul	SAO	Optics
Microwave SQUID Readout Technology to Enable Lynx and Other Future Great Observatories	Bennett, Douglas	NIST	Electronics
High-Resolution and High-Efficiency X-Ray Transmission Grating Spectrometer	Schattenburg, Mark	MIT	Optics
Space-Based Gravitational-Wave Laser Technology Development Project for LISA	Yu, Anthony	GSFC	Laser
Telescopes for Space-Based Gravitational-Wave Observatories	Livas, Jeffrey	GSFC	Telescope
Phase-Measurement System Development for Interferometric Gravitational-Wave Detectors	Klipstein, William	JPL	Electronics
LISA Colloid Microthruster Technology Development	Ziemer, John	JPL	Micropropulsion
UV LED-Based Charge Management System	Conklin, John	U of FL	Electronics
Advancing the Focal Plane TRL for LiteBIRD and Other Next-Generation CMB Space Missions	Lee, Adrian	UCB	Detector
Next-Generation X-Ray Optics	Zhang, William	GSFC	Optics
Differential Deposition for Figure Correction in X-Ray Optics	Kilaru, Kiran	MSFC	Optics
Direct Fabrication of Full-Shell X-Ray Optics	Bongiorno, Stephen	MSFC	Optics
Computer-Controlled Polishing of High-Quality X-Ray Optics Mandrels	Davis, Jacqueline	MSFC	Optics
Low-Stress Mirror Coatings for X-Ray Optics	Broadway, David	MSFC	Coatings
X-Ray Testing and Calibration	Ramsey, Brian	MSFC	Optics
Hybrid X-Ray Optics by Additive Manufacturing	Broadway, David	MSFC	Optics
Advanced TES Microcalorimeters	Kilbourne, Caroline	GSFC	Detector
Laboratory Spectroscopy for Space Atomic Physics	Porter, Scott	GSFC	Detector
Magnetically Coupled Calorimeters	Bandler, Simon	GSFC	Detector
Providing Enabling and Enhancing Technologies for a Demonstration Model of the Athena X-IFU	Kilbourne, Caroline	GSFC	Detector
US Contribution to the Athena Wide Field Imager	Burrows, David	PSU	Electronics

ABTR: New SAT (FY20) Awards

SAT Project Title	PI Name	Institution	Technology Area
Toward Fast, Low-Noise, Radiation-Tolerant X-Ray Imaging Arrays for Lynx: Raising Technology Readiness Levels Further	Bautz, Mark	MIT	Detectors
Laboratory Demonstration of Multi-Star Wavefront Control in Vacuum	Belikov, Ruslan	ARC	Coronagraph
A Single-Photon-Sensing and Photon-Number-Resolving Detector for NASA Missions	Figer, Donald	RIT	Detectors
Microwave Multiplexing Readout Development	Frisch, Josef	Stanford	Electronics
Photon-Counting NIR LmAPD Arrays for Ultra-Low-Background Space Observations	Hall, Don	U Hawaii	Detectors
High-Performance, Stable, and Scalable UV Aluminum Mirror Coatings Using ALD	Hennessy, John	JPL	Coatings
A Novel Optical Etalon for Precision Radial Velocity Measurements	Leifer, Stephanie	JPL	EPRV
Development of Low-Power FPGA-Based Readout Electronics for Superconducting Detector Arrays	Mauskopf, Philip	ASU	Electronics
Optimal Spectrograph and Wavefront Control Architectures for High-Contrast Exoplanet Characterization	Mawet, Dimitri	Caltech	Coronagraph
Superconducting Antenna-Coupled Detectors and Readouts for PICO CMB Polarimetry	O'Brient, Roger	JPL	Detectors
Development of an Ultra-Stable Mid-Infrared Detector Array for Space-Based Exoplanet Transit Spectroscopy	Staguhn, Johannes	JHU	Detectors
Large-Format, High-Dynamic-Range UV Detector Using MCPs and Timepix Readouts	Vallerga, John	UCB	Detectors
System-Level Segmented Telescope Design Project Title	**PI Name**	**Institution**	**Technology Area**
Ultra-Stable Telescope Research and Analysis – Technology Maturation	Coyle, Laura	Ball Aerospace	Telescopes
Technology Maturation for Astrophysics Space Telescopes	Nordt, Alison	Lockheed Martin	Telescopes

ABTR: Tech Gaps

Tier 1 Technology Gaps
Angular Resolution (UV/Vis/NIR)
Coronagraph Contrast
Coronagraph Contrast Stability
Cryogenic Readouts for Large-Format Far-IR Detectors
Fast, Low-Noise, Megapixel X-Ray Imaging Arrays with Moderate Spectral Resolution
High-Efficiency X-Ray Grating Arrays for High-Resolution Spectroscopy
High-Resolution, Large-Area, Lightweight X-Ray Optics
Large-Format, High-Resolution, UV/Vis Focal Plane Arrays
Large-Format, High-Spectral-Resolution, Small-Pixel X-Ray Focal-Plane Arrays
Large-Format, Low-Noise and Ultralow-Noise Far-IR Direct Detectors
Large-Format, Low-Noise, High-QE Far-UV Detectors
Next-Generation, Large-Format, Object Selection Technology for Multi-Object Spectrometers for LUVOIR
Vis/NIR Detection Sensitivity

ABTR: Tech Gaps

Tier 1 Technology Gaps
Angular Resolution (UV/Vis/NIR)
Coronagraph
Coronagraph
Cryogenic Rea
Fast, Low-Noi
Spectral Reso
High-Efficienc
High-Resoluti
Large-Format,
Large-Format,
Large-Format,
Large-Format,
Next-Generati
Spectrometers
Vis/NIR Detec

Tier 2 Technology Gaps
Advanced Millimeter-Wave Focal-Plane Arrays for CMB Polarimetry
Detection Stability in Mid-IR
Heterodyne FIR Detector Arrays and Related Technologies
High-Efficiency Object Selection Technology for UV Multi-Object Spectrometers
High-Performance Spectral Dispersion Component/Device
High-Reflectivity Broadband FUV-to-NIR Mirror Coatings
High-Throughput Bandpass Selection for UV/Vis
Large-Format Object Selection Technology for Multi-Object Spectrometers for HabEx
Starshade Deployment and Shape Stability
Starshade Starlight Suppression and Model Validation
Stellar Reflex Motion Sensitivity – Astrometry
Stellar Reflex Motion Sensitivity – Extreme Precision Radial Velocity

ABTR: Tech Gaps

Tier 1 Technology Gaps
Angular Resolution (UV/Vis/NIR)
Coronagraph
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Tier 2 Technology Gaps
Advanced Millimeter-Wave Focal-Plane Arrays for CMB Polarimetry
Detection Stabil
Heterodyne FIR
High-Efficiency
High-Performan
High-Reflectivity
High-Throughpu
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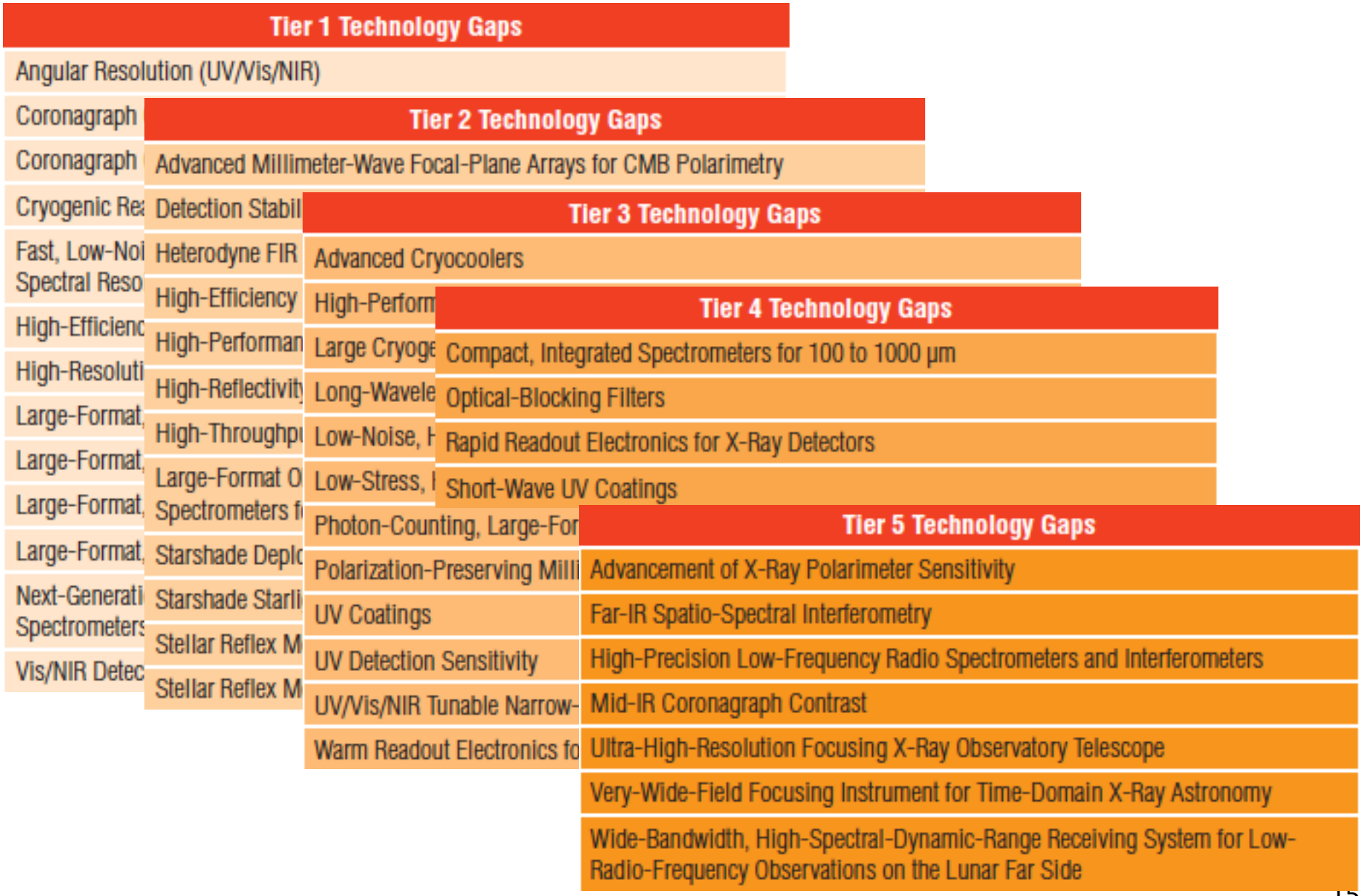
Spectrometers f
Starshade Deplo
Starshade Starli
Stellar Reflex M
Stellar Reflex M

Tier 3 Technology Gaps
Advanced Cryocoolers
High-Performance, Sub-Kelvin Coolers
Large Cryogenic Optics for the Mid-IR to Far-IR
Long-Wavelength-Blocking Filters for X-Ray Micro-Calorimeters
Low-Noise, High-QE UV Detectors
Low-Stress, Highly Stable X-Ray Reflective Coatings
Photon-Counting, Large-Format UV Detectors
Polarization-Preserving Millimeter-Wave Optical Elements
UV Coatings
UV Detection Sensitivity
UV/Vis/NIR Tunable Narrow-Band Imaging Capability
Warm Readout Electronics for Large-Format Far-IR Detectors

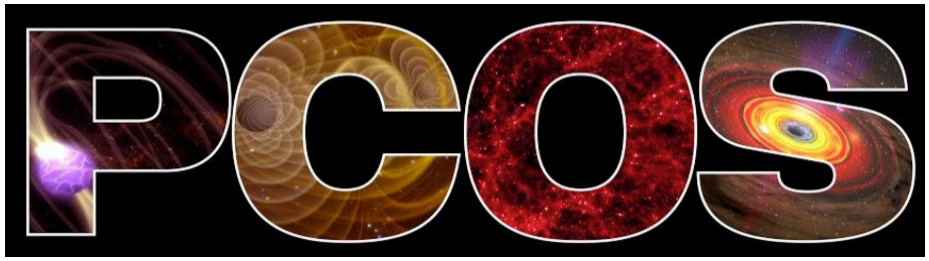
ABTR: Tech Gaps



PCOS Chief Scientist enables ground-breaking science from space by working at the interfaces between missions and studies, technology, the community, and NASA HQ.

Current PCOS Science Goals and Priorities:

- Ensure a more successful **Decadal survey** by supporting community preparations and HQ activities, spanning the range of inputs: from science to missions, technology, and state of the profession, which all impact our ability to do ground-breaking science
- Ensure more **successful missions** by
  - supporting on-going mission studies and pre-projects, eg LISA, Lynx, Athena;
  - through technology efforts, eg SAT;
  - by coordinating with current missions; and
  - by preparing for studies for mission recommended by the Astro2020 Decadal
- **Engage the community** to support a successful APD portfolio.



Keep up with the latest PCOS-related NASA News!

- PCOS-News emails
- Website: News & announcements

PCOS News

Program News and Announcements

19 December 2019
We would like to welcome our four new **PhysPAG EC members**, starting in Dec 2019. We extend our thanks to the three **departing EC members**.

22 November 2019
Assessments of cost and technical credibility of the Large Mission Concept Studies and for the Probe studies are public this month. » **Details**

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NASA Headquarters seeks PhD scientists to serve as Program Scientists » **Details**

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The deadline to **submit abstracts** to give a **lightning talk** at the Jan AAS **PCOS & PhysPAG session** on a **revolutionary multimessenger / multimission astrophysics discovery** that involves at least one NASA mission is extended to **Wed 27 Nov 2019**.

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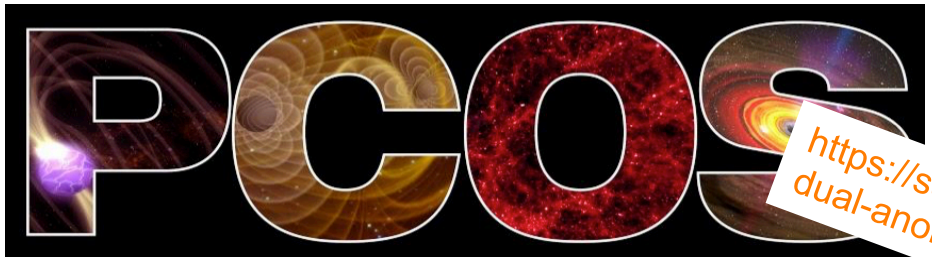

https://science.nasa.gov/researchers/dual-anonymous-peer-review

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+ GW-EM Taskforce Survey, and many more!

HEAD Newsletter

- PCOS News article
- GW, CR, GR, X-ray SIG articles
- MMA SAG article

The Gravitational Wave Science Interest Group

NICOLAS YUNES (UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN), JOHN W. CONKLIN (UNIVERSITY OF FLORIDA), KELLY HOLLEY-BOCKELMANN (VANDERBILT UNIVERSITY)

The GW SIG organized a Focus Session at the April APS Meeting 2019, which was held in Denver, Colorado. The speakers of the focus session were Nicolas Yunes from Montana State University (now at the University of Illinois Urbana-Champaign), Shane Larson (Northwestern University) and John Conklin (University of Florida). Dr. Yunes spoke about the science we expect to be able to extract with *LISA* in the future, with a focus on modified gravity and tests of General Relativity. Dr. Larson talked about "Adding *LISA* to your Toolbox", a summary of the broad *LISA* science case and tools to help interested researchers begin adding *LISA*-related calculations

Physics of the Cosmos News

T. J. BRANDT (NASA GSFC, PCOS CHIEF SCIENTIST), PANAYIOTIS TZANAVARIS (NASA/GSFC & CRESST), BERNARD KELLY (NASA/GSFC & CRESST)

NASA's Physics of the Cosmos (PCOS) program explores some of the most fundamental questions regarding the physical forces and laws of the universe: from testing General Relativity to better understanding the behavior of matter and energy in extreme environments; the cosmological parameters governing inflation and the evolution of the universe; and the nature of dark matter and dark energy. To enable current and future missions to address these questions, the PCOS Program Office (PO) engages with the community, executes the Strategic Astrophysics Technology (SAT) program, and facilitates formulation of new missions.

The PCOS Program Analysis Group (PhysPAG) includes everyone interested in the PCOS program via six Science Interest Groups (SIGs) and the Multimessenger Astrophysics (MMA) Science Analysis Group (SAG); this probably means you! Other articles in this newsletter give updates on the activities of our SIGs, including X-ray, Gamma-ray, Cosmic Ray, and Gravitational Wave SIGs, and the MMA SAG. The PhysPAG provides fora for the PCOS community to regularly engage with the PO. PhysPAG Executive Committee (EC) members organize meetings, collect and summarize community input, and report to the Astrophysics Advisory Committee (APAC) and the

The High Energy Astrophysics Division of the American Astronomical Soc
head.aas.org headsec@aas.org

HEAD Newsletter

- PCOS News article
- GW, CR, GR, X-ray SIG articles
- MMA SAG article

Physics of the Cosmos News

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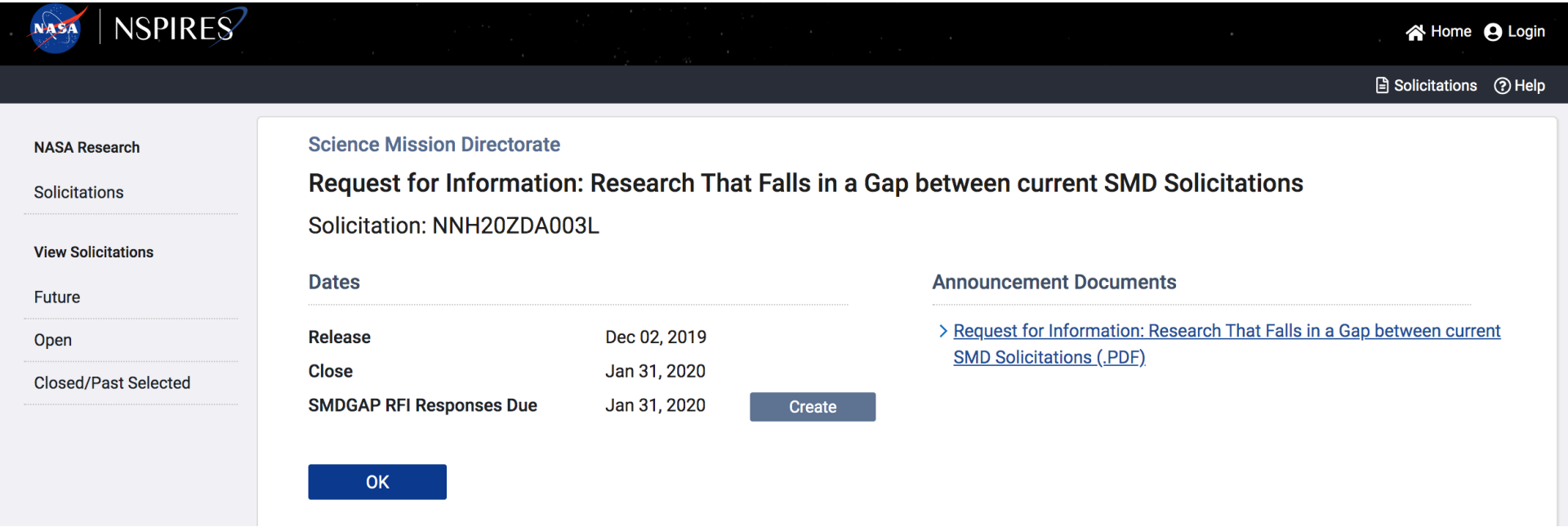
NASA Multimessenger Astrophysics Science Analysis Group

J. W. Conklin (Chair of the PhysPAG Executive Committee, U. Florida), John Tomsick (University of California Berkeley), Suvi Gezari (University of Maryland), T. J. Brandt (PCOS Chief Scientist, NASA/GSFC)

The NASA Multimessenger Astrophysics Science Analysis Group (MMA SAG) is analyzing potential scientific benefits of multimessenger observations made possible by NASA observatories in the 2020's and beyond, working in conjunction with each other or with other ground- and space-based instruments. This group is charged with (a) Identifying science goals that could be achieved by combining different astrophysical messengers measured by current and future ground- and space-based observatories, (b) identifying measurements that can be made by existing, currently approved, and future planned ground- and space-based observatories that could contribute to MMA in 2020's and early 2030's, (c) Determining how these enhanced or new science goals align with the NASA Astrophysics Division's scientific priorities, and (d) identifying key qualitative technical drivers that are needed to achieve these science goals. The MMA SAG is chaired

Science Mission Directorate is requesting information on Research that Falls in a Gap Between Current SMD Solicitations

- Due by Jan 31



https://nspires.nasaprs.com/external/viewrepositorydocument?cmdocumentid=720357&solicitationId={D82B2B9A-5F6D-B0C6-741A-6950D1D6F0E1}&viewSolicitationDocument=1

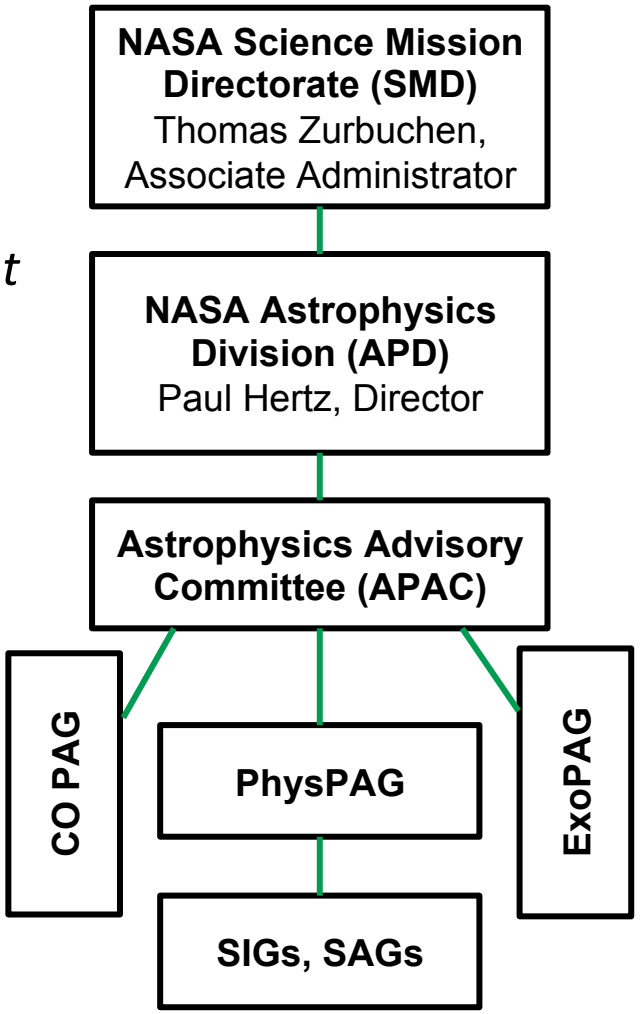
PhysPAG

Physics of the Cosmos Program Analysis Group

- **Purpose:**
  - provide input to NASA relevant to PCOS
  - help NASA inform interested parties about PCOS doings
- **Membership:** ***You!***

  Anyone interested in providing input to NASA relevant to its Physics of the Cosmos Program
- **Leadership:**
  - **Executive Committee** (EC):
    - Chair Emeritus: John Conklin
    - Chair: Graça Rocha
    - Vice Chair: Ryan Hickox
  - 13 EC members chair 6 Science Interest Groups (**SIGs**): longer-standing discipline-specific fora
  - support formation of Science Analysis Groups (**SAGs**): group created to analyze a specific science question
  - facilitate **info flow** between NASA and community

Communication Network:



For more info: https://pcos.gsfc.nasa.gov/physpag/physpag-ec.php

PhysPAG Science Interest Groups

- PhysPAG Executive Committee members chair 6 Science Interest Groups
  - **X-ray SIG** (XR SIG)
  - **Gamma-ray SIG** (GR SIG)
  - **Cosmic Ray SIG** (CR SIG)
  - **Gravitational Wave SIG** (GW SIG)
  - **Cosmic Structure SIG** (CoS SIG)
  - **Inflation Probe SIG** (IP SIG)
- SIGs serve as **forums for soliciting, discussing, and coordinating community input**.
- Come talk w us **here** & at **APS April, HEAD, ...**

For more info: https://pcos.gsfc.nasa.gov/physpag/physpag-sigs.php

Let's Chat!

Sparks

- What have you found useful?
  - SIGs? SAG?
  - professional exchange of ideas?
  - white paper preparations?
  - Strategic Astrophysics Technology (SAT) program?
  - ?
- What would you like to see more of ? or less of ?
  - more community leadership?
  - ?
- What do you need from NASA?
- What are you concerned about?

Conclusions

Come talk with us!

AAS Sessions:

- Joint PAG & Sun 5 Jan 9.30a, room 323A: **COR Great Observatories SAG**
- Tues 7 Jan 9.45a, room 303A: **Gravitational Wave SIG**
- Tues 7 Jan 1.15p, room 303A: **Multimessenger Astrophysics SAG**
- Wed 8 Jan 9.15a, room 303A: **X-ray SIG**
- Wed 8 Jan 1.15p, room 303A: **Gamma-ray SIG**

+ **PCOS table** at the NASA booth (exhibit hall)
+ chat during coffee, etc!

At APS, HEAD, …

Have an idea where we could collaborate to enable better science? Let me know! (t.j.brandt@nasa.gov)

Sign up for our mailing list!

https://pcos.gsfc.nasa.gov/pcosnews-mailing-list.php