



National Aeronautics and Space Administration

PHYSICS OF THE COSMOS

Update from the ASTRA workshop and plan for delivery of ASTRA recommendations

PhysPAG Town Hall · September 28 2026





National Aeronautics and Space Administration

Questions? post them here:



PhysPAG Executive Committee



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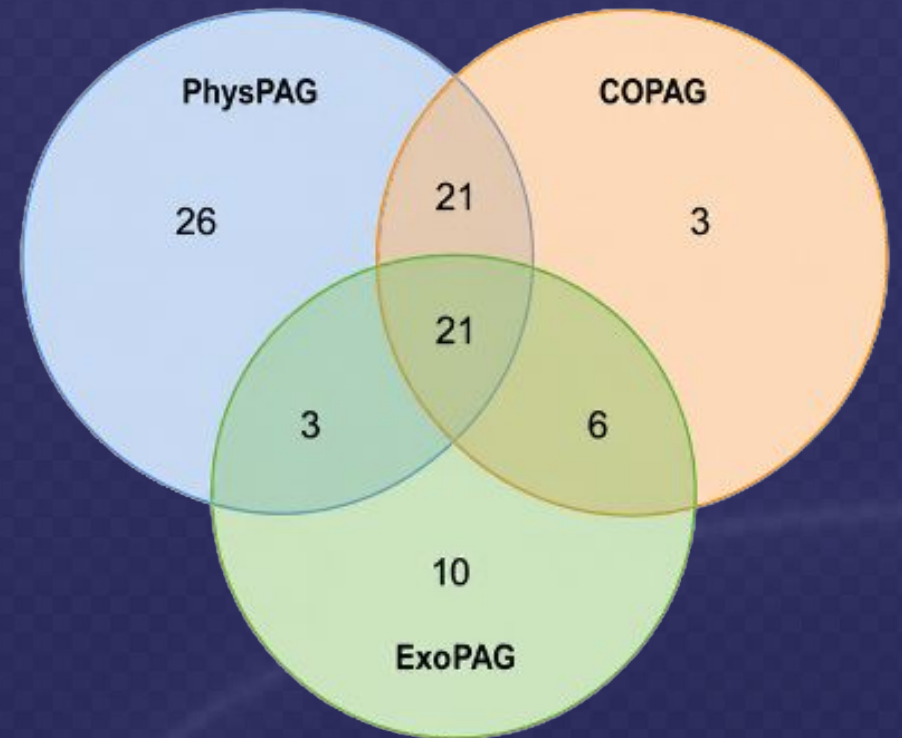


Igor Andreoni

University of North Carolina

Community response to the ASTRA call

- Working groups issued calls for input from the community and organized >40 meetings and seminars to coordinate the community response to the ASTRA call.
- Several working groups organized collaborative responses to the call for Mission Concept Descriptions due on July 1.
- Received a total of 91 mission concept descriptions, 74 of which had science goals aligned with PhysPAG (many mission concepts did align with more than one PAG).
- To organize further discussion, the PhysPAG Executive Committee read all mission concept descriptions and generated clusters of submissions that tackle a similar set of science questions and that could be studied under the same trade space umbrella within the ASTRA initiative.
- Mission clusters (or bins) were discussed and harmonized with COPAG and ExoPAG.



X-Ray Flagship Mission Study Update

- STDT Community Co-Chairs Selected
- Study Office key personnel have been confirmed from SAO, MSFC, and GSFC

Role	Individual
Study Manager	Steven Tompkins (GSFC)
Study Scientists	Grant Tremblay (SAO) Edmund Hodges-Kluck (GSFC) Phil Kaaret (MSFC)
Science Systems Lead	Paul Plucinsky (SAO)
Program Scientist	David Morris (HQ)
Program Executive	Julie Crooke (HQ)

**Expected Start: Early FY27 (post 10/2026)
PoP: ~4 years*



Megan Eckart
Director, Space
Science Institute, LLNL



Dave Pooley
Professor, Physics &
Astronomy, Trinity U.

- A call for nominations for the X-Ray STDT will be released soon
 - Will select ~10 individuals
 - Small honorarium
 - Travel
- Industry Call to support the study, optics dev, and manufacturing plan is being developed.
- International ex-officio members to be invited

Ad ASTRA Workshop

Over 130 talks and more than 50 poster presentations were given, with 320 attendees participating in person and an additional 248 participating online.

Science Breakout Sessions

- Cosmology (13 talks)
- Compact Objects and Energetic Phenomena (21)
- Galaxies & Cosmic Rays (12)
- Exoplanets & Astrobiology (8)
- Stars & Stellar Populations (5)

Capabilities & Technology Breakout Sessions

- Sub-mm & FIR (11 talks)
- X-ray & UV (12)
- Radio (10)
- Multi-Mission Capabilities (6)
- Multiple Aperture Concepts (6)
- UV Optical IR (6)
- Gamma Rays (6)
- Gravitational Waves & Fundamental Physics (6)

Plus synthesis panel discussions, plenary sessions on new capabilities & emerging technologies, lessons learned from the Large Mission Studies and Astro2020 Decadal, and workshop summary talks on Key Science Questions and Key Capabilities for the 2030s and Beyond

Slides for all talks, recordings of plenary sessions, and poster pdfs available at the [Ad ASTRA workshop website](https://science.nasa.gov/ad-astro-workshop).





ASTRA Workshop: \$1B questions

- The first stars, galaxies, and black holes / reionization
- Growth of black holes through accretion and mergers / launching of jets
- Dark matter and dark energy
- The nature of gravity
- Cosmological tensions
- Nature and physics of dust
- Baryon cycle from CGM to stars
- Physics at the highest energies and densities
- Star and planet formation
- Origin of the elements
- The cosmic dark ages
- Feedback
- Planet statistics and architectures
- Habitability
- Origin of the highest-energy particles
- Physics of energetic explosions

(From Ryan Hickox's Workshop summary talk)



ASTRA Workshop: Multi-billion-dollar questions

- How did the Universe begin?
- What are dark matter and dark energy?
- How does physics work at the extremes of gravity, density, fields, and energy?
- How do stars and their planets form?
- How does feedback shape the growth of galaxies, black holes, and stars?
- How do black holes form and grow over cosmic time and how do they power energetic phenomena?
- How do we place habitable worlds in the population of stars and planets?

(From Ryan Hickox's Workshop summary talk)



The ASTRA process. Next steps.

Early Sep	ASTRA Workshop. PAGs finalize Mission Concept categories.
Late Sep	Each PAG discusses all concept categories, engage with the community, produce first prioritized list. • PhysPAG: Review panel style evaluations where the key science question and the trade space are identified for each concept bin. Strengths and weaknesses are discussed.
Early Oct	CrossPAG chairs meeting to merge 3 lists and identify consensus, points of disagreement. Produce first joint prioritized list.
Mid Oct	PAG ECs discuss the joint prioritized list, provide feedback.
Early Nov	CrossPAG chairs meeting to discuss and finalize recommendation to HQ.
Dec 11	Public talk. PAG chairs present recommendation to NASA HQ.
Jan 10-14 2027	Announcement of HQ selection of ASTRA concepts at AAS.
Feb 2027	Chairs of Study Teams selected.
Apr 2027	Study Team member selection finalized.



(Slide by Ian Crossfield)

19 cross-PAG mission concept bins

Concept bins harmonized with ExoPAG. Number of concepts in parentheses.

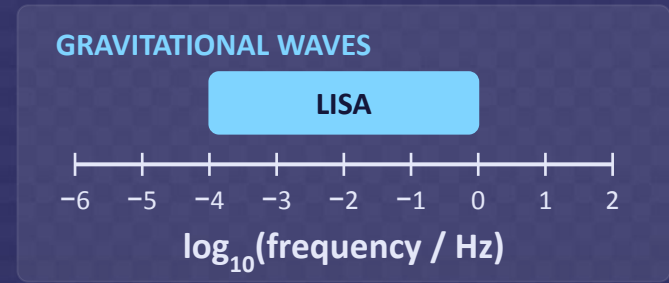
- Fundamental physics & cosmic geometry (3)
- UV/Optical spectroscopy (1)
- IR/mid-IR interferometry (4)
- Gamma-ray observatory (5)
- Gravitational waves (7)
- Space radio interferometry (3)
- Low frequency radio (2)
- Time-domain & distributed fleets/constellations (11)
- Direct imaging, high-contrast, planet surveys (8)
- Cosmic microwave background probe (2)
- Cosmic rays & particle astrophysics (8)
- Wide field X-ray survey (2)
- Far-IR interferometry (3)
- UV/Optical interferometry (3)
- Novel architectures (1)
- X-ray great observatory (4)
- X-ray interferometry (3)
- Wide-field IR survey (3)
- NIR/mid-IR/far-IR spectroscopy (9)

Grading rubric for ASTRA concept bins



Criteria	Rating weight
Science questions addressed (based on Astro2020, 2014 report, 2025 Astrophysics Technology Update, or additional evidence incl. science topics brought up in community workshops), and Science & investment scale are commensurate.	70%
Does the mission concept contribute to the scientific balance of the NASA fleet(*), and is it a good fit to the global astrophysics landscape?	20%
Does the mission concept appropriately consider newly available opportunities presented by recent advances by industry, private foundations, and international collaborations, as well as non-traditional mission architectures (proliferated apertures, radio from space, astrophysics from the Moon, etc.)	10%

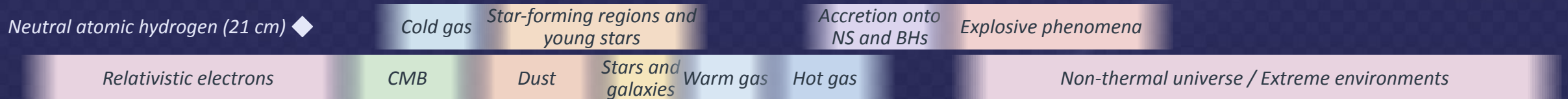
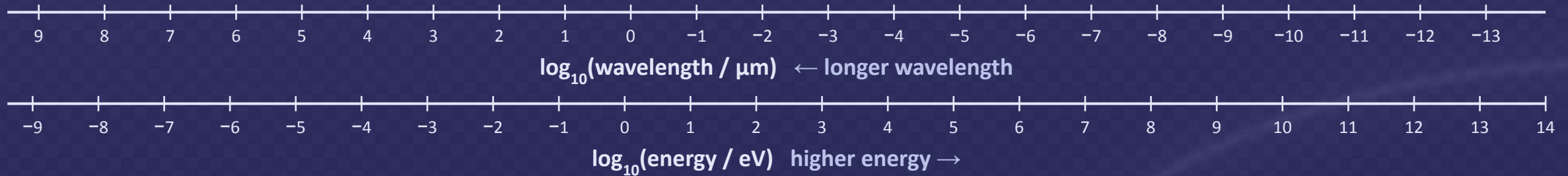
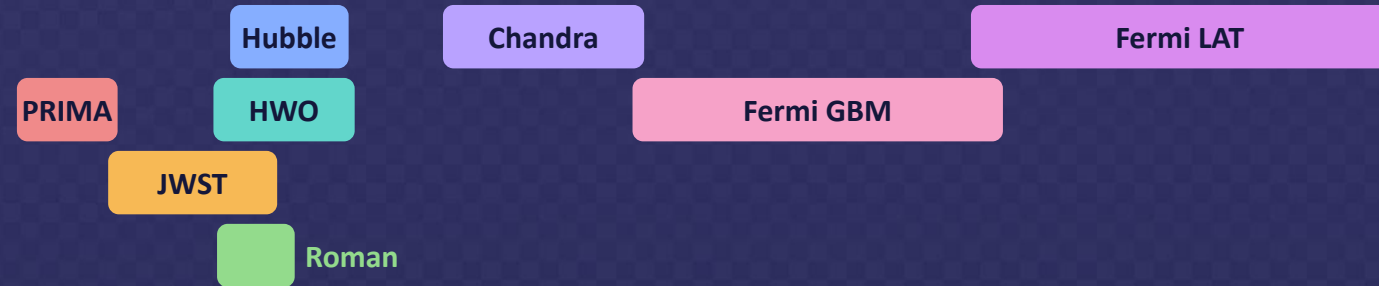
Fleet of NASA strategic missions



GREAT OBSERVATORIES



ACTIVE AND PLANNED MISSIONS





ASTRA Workshop: Multi-billion-dollar questions

- How did the Universe begin?
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- How do we place habitable worlds in the population of stars and planets?

(From Ryan Hickox's Workshop summary talk)

Final notes and questions

- The trade space for an X-ray probe has been studied in great depth and breadth by the community in the context of the probe competition. We do want to make sure that all this wealth of information feeds the decadal process (as well as what ASTRA studies).
- What other messages should the PhysPAG community send to HQ in addition to the ASTRA recommendations?
- Are there any science topics that did not come up in the Astro 2020 recommendations or the ASTRA Workshop summary science questions that we should be considering?
- In what other ways should the PhysPAG EC advocate for our community when we seek consensus with COPAG and ExoPAG and report our recommendations to HQ?

Questions? scan here:



Please send any feedback to your favorite PhysPAG EC member

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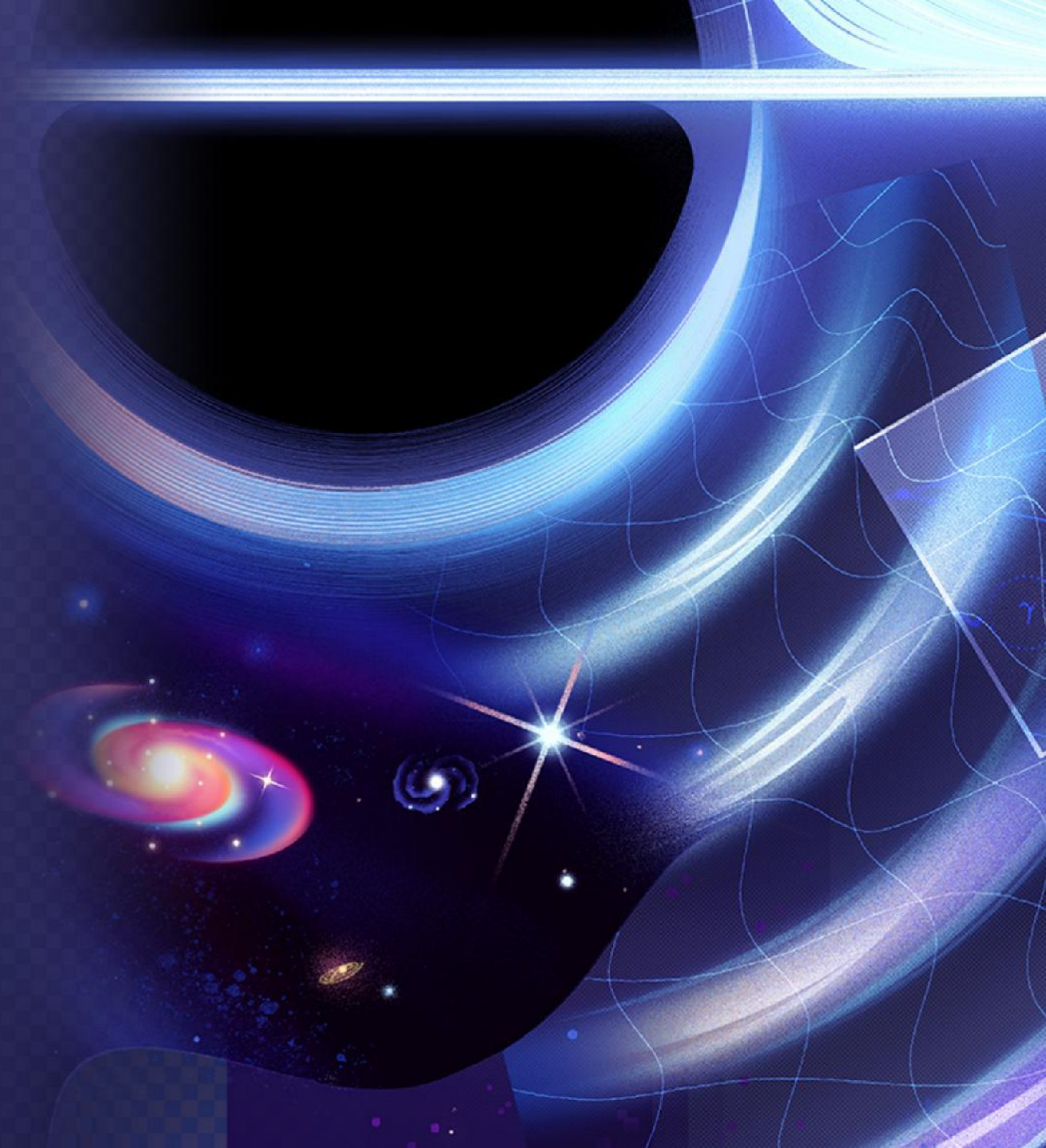
University of North Carolina



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Thank you!

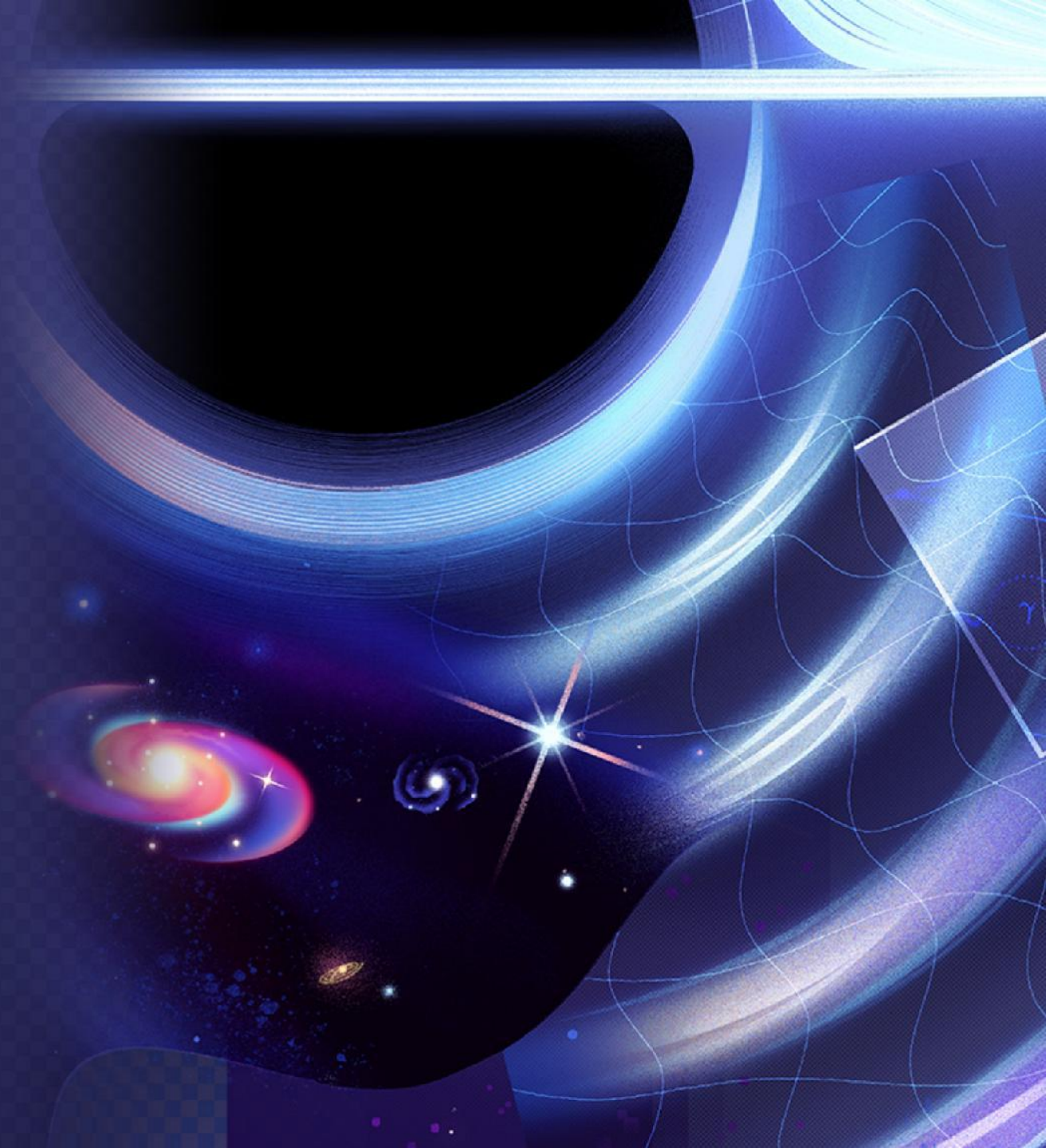
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Backup slides



Nine active, standing Science Interest Groups



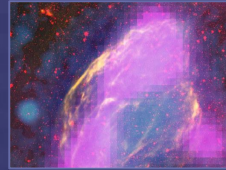
Science Interest Groups (SIGs & STIGs) keep engagement with the communities that PhysCOS represents.



Astrophysics from the Moon, Mars, and Beyond

AMMB STIG

Nivedita Mahesh · Marin Anderson



Cosmic Ray and Neutrino

CRN SIG

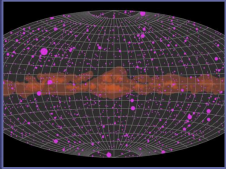
Tsuguo Aramaki · Stephanie Wissel · Priyarshini Ghosh · Keith McBride · Philip von Doetinchem



Cosmic Structure

CoS SIG

Johannes U. Lange · Dida Markovic · Pam Marcum



Gamma Ray

GR SIG

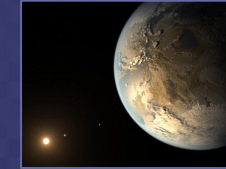
Manel Errando · Jeremy Perkins · Cori Fletcher · Sylvain Guiriec · Tiffany Lewis



Gravitational Wave

GW SIG

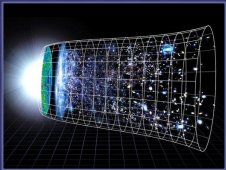
Tingting Liu · Simon Barke · Michael Katz



Habitable Worlds Observatory

HWO SIG

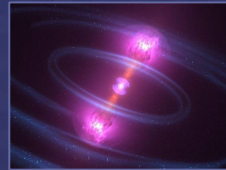
Jessie Christiansen · Laura Mayorga · Joe Burchett · Vivian U · Richard Massey · Fabio Pacucci



Inflation Probe

IP SIG

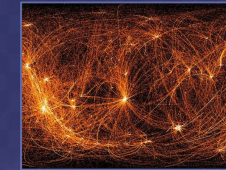
Abigail T. Crites · Tom Essinger-Hileman



Time Domain Multi-Messenger Astrophysics

TDAMM SIG

Rebekah Hounsell · Brad Cenko · Christos Panagiotou · Igor Andreoni · Lauren Alderoty



X-Ray

XR SIG

David Pooley · Chien-Ting Chen · Breanna Binder · Steven Ehlert · Scott Randall · Fabio Pacucci

Multiple short-term Analysis Groups

Science Analysis Groups (SAGs) are chartered to answer a specific question, then deliver a report and stand down.

Active

Future Large Gamma-Ray Mission Concepts

Elizabeth Hays · Henric Krawczynski

Cosmic Microwave Background Probe

Shaul Hanany · Brendan Crill · Tom Essinger-Hileman

Future Innovations in Gamma Rays

Christopher Fryer · C. Michelle Hui · Paolo Coppi · Milena Crnogorcevic · Tiffany Lewis · Marcos Santander · Zorawar Wadiasingh

Broad-Band X-ray Observatory

Chien-Ting Chen · Kristin Madsen · Daniel Stern

High Angular Resolution X-ray Imager

Kimberly Weaver · Herman Marshall · Mark Schattensburg · Breanna Binder

Lynx 2030

Steven Ehlert · Fabio Pacucci

X-ray timing

Tom Maccarone · Krista Lynne Smith · Zaven Arzoumanian · Riccardo Arcodia

Nuclear Cross Sections

Priya Ghosh · Philip von Doetinchem

New Great Observatories (cross-PAG)

Grant Tremblay · Meredith MacGregor · John O'Meara · Jessie Christiansen · Amanda Hendrix

Origin of the Isotopes

Eric Burns · Carolyn Kierans · Chris Fryer

Seven analysis groups have been launched by PhysPAG since Summer 2025 in preparation for the Astro 2030 decadal and in response to the ASTRA initiative.

PhysPAG bridges NASA and the community



Time-domain & Distributed Fleets/Constellations

Science Questions:

- What engines power gamma-ray bursts, tidal disruption events, and other transients?
- What are the EM counterparts of gravitational-wave and neutrino events?
- How are the heaviest elements forged?
- What is the equation of state of ultra-dense matter?
- How do black holes accrete and grow, and how many are obscured?

Trade space to be studied:

- Single-spacecraft mission vs. constellation.
- Coded-mask vs. focusing; LEO, L2 or lunar site.
- How does the choice of instrument or instrument suite map to science return?

Submitter	Mission concept name/summary
McCully	Constellation of SmallSats
Kocevski	The Hydra Constellation
Stern	HERMEX: High-Energy Rapid-response Mission
Quintana	Proliferated Astronomical Observatory (PAO)
DerKacy	Multimessenger Transient Response Constellation
Singer	MITHRA: TDAMM Observatory at the Lunar South Pole
Ray	STROBE-X
Gorjian	PanChromia: The EM Machine for TDAMM Science
Arzoumanian	DEUS-X: The Dynamic Extreme Universe in X-rays
Boyajian	LUSTER-net: Lunar Time-domain Survey Network

Gravitational Waves



Science Questions:

- How did massive black hole seeds form and grow?
- Did inflation, phase transitions or cosmic strings leave a primordial GW background?
- What are the properties of dense matter and the population of compact objects?
- Does gravity deviate from general relativity in the strong-field regime?

Trade space to be studied:

- Band: μHz , mHz or deci-Hz.
- Interferometry, optical clocks, or cold atoms.
- Lunar-based instrument vs spacecrafts.

Submitter	Mission concept name/summary	Subcluster
Leibrandt	Asteroids μHz Gravitational Wave detection	μHz
Buonanno	Multiband GW Observatory	
Ganapathy	GW with space optical clocks	dHz
Gaaloul	AEDGE atom interferometer	
Slutsky	Decihertz Interferometer Space Mission	
Jani	Laser Interferometer Lunar Antena	

Cosmic Rays & Particle Astrophysics

Science Questions:

- What are the particle properties of dark matter?
- What are the sources of and particle acceleration mechanisms of galactic cosmic rays?
- Are cosmic rays connected to gamma-rays, neutrinos, gravitational waves, and do originate from the same source classes?
- Where do ultra-high energy cosmic rays originate?
- Where did the heavy elements form and what are the r-process vs s-process contributions?

Trade space to be studied:

- Particle detection techniques
- Mission architectures (Lagrange point observatory, lunar surface detectors)

Submitter	Mission concept name/summary	Subcluster
Krizmanic / Venters	Space-based ultrahigh energy particles	Ultra high energy cosmic rays and neutrinos
Marrochesi	Lunar Cosmic Ray Observatory	Galactic high energy cosmic rays
Ghosh	Iron-to-actinides Isotopes	
von Doetinchem	Low-energy antinuclei	Anti-nuclei and dark matter searches/cosmic rays
von Doetinchem	AMS-100 Magnetic Spectrometer	
Wakely	Next Generation Magnetic Spectrometer	
Aramaki	GRAMS	
Von Doetinchem	GAPS	

Cosmic Microwave Background probe

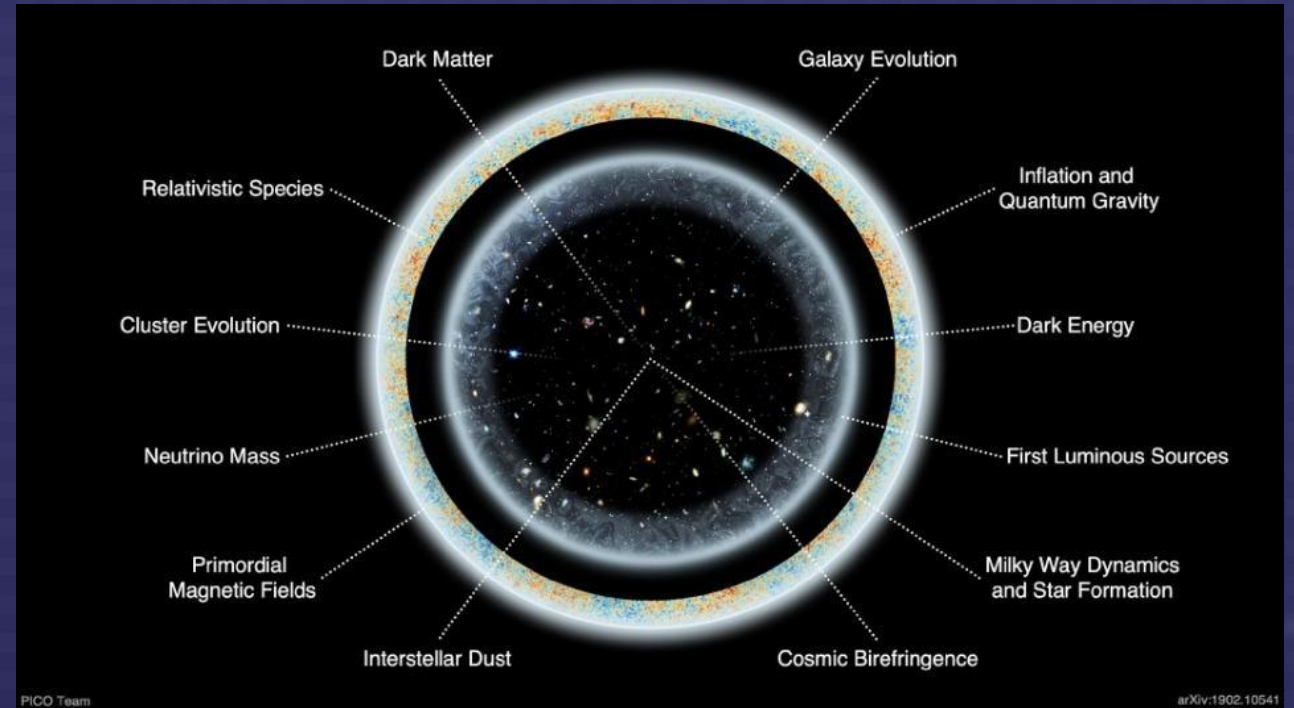


Science goals:

- Probe the physics of the Big Bang by constraining the energy scale at which inflation occurs.
- Determine the sum of neutrino masses and test Beyond the Standard Model physics.
- Probe the formation of the earliest luminous structures and determine the history of cosmic star formation.
- Reveal the variable and transient mm/sub-mm sky.

Trade space to be studied:

- Optimize frequency coverage, aperture and temperature.
- Detector technologies: TES, MKID, TKID, Coherent/Paramo, or combinations.



Submitter	Mission concept name/summary
Crill	CMB Probe +
Pradhan	CMB polarization probe

Gamma-Ray Observatory



Science Questions:

- How are heavy elements made and distributed?
- How do supermassive black holes form and grow?
- What are relativistic jets made of, and how do they accelerate particles?
- How does light behave in magnetar fields, and what is dark matter?

Trade space to be studied:

- Detector technology (silicon, scintillation, liquid argon)
- Science tradeoffs with emphasis on the Compton regime (MeV) or pair regime (GeV)

Submitter	Mission concept name/summary
Perkins	A Gamma-Ray observatory
Bhaumik	AEGIS-MeV all-sky observatory
Zoglauer	ARCTIS Compton/Pair tracker
Aramaki	GRAMS
Miller	TANGO nuclear gamma-ray observatory

Low frequency radio



Science Questions:

- What happened during the cosmic Dark Ages, and does the 21-cm signal obey Λ CDM?
- Can Dark Ages 21-cm probe dark matter microphysics and inflation beyond the CMB?
- Do rocky exoplanets sustain magnetic fields, and does that make them habitable?
- How do stellar coronal mass ejections, winds and energetic particles erode exoplanet atmospheres?

Trade space to be studied:

- Lunar farside array vs. free-flying smallsats.
- Array scale, frequency range, lunar-night power.

Submitter	Mission concept name/summary
Lazio	MegaWave Radio Surveyor
Anderson	Ultra-Long Wavelength Observatory from the Lunar Farside

Space radio interferometry



Science Questions:

- Do black hole spacetimes obey general relativity, and what are their masses and spins?
- How do supermassive black holes grow, and are sub-parsec binaries the nHz GW source?
- How are relativistic jets launched — by black hole spin, disk winds, or both?
- How do relativistic transients evolve at microarcsecond scales?

Trade space to be studied:

- Cis-lunar free-flyers, LEO swarm, or lunar site.
- 3–10 m apertures; 86–690 GHz; onboard correlation.

Submitter	Mission concept name/summary
Johnson	Space-VLBI Frontier Observatory
Vallejos	L-RAIL
Bari	Time-Resolving Explorer

X-ray great observatory



Science Questions:

- How did the first supermassive black holes form, from heavy or light seeds?
- How do AGN and stellar feedback heat and enrich hot gas in galaxies and clusters?
- Where are the missing baryons, and how do hot halos and the CGM evolve?
- What powers X-ray transients, and how do compact-object populations differ?
- How does stellar high-energy activity erode exoplanet atmospheres?

Trade space to be studied:

- Angular resolution vs. effective area and FOV and bandpass.
- X-ray optics: silicon, silicon pore, or slumped glass.

Submitter	Mission concept name/summary
Reynolds	A Chandra Successor in the 2030s
Pacucci	An Iteration on Lynx for the Science of the 2030s
Günther	X-ray grating spectroscopy as a mission enhancement
Madsen	The Broad-Band X-ray Observatory (BBXO)

Wide field X-ray survey



Science Questions:

- Where is the universe's missing hot gas, and how does it trace the cosmic web?
- How do exploding stars and growing black holes heat and enrich that gas?
- How do black holes grow, and how much of that growth is hidden behind dust and gas?
- What high-energy radiation do planet-hosting stars pour onto their planets?

Trade space to be studied:

- Grazing-array grasp vs. one large telescope.
- Transition-edge sensor calorimeters, or superconducting tunnel junction and distributed read-out imaging detectors.

Submitter	Mission concept name/summary
Vargas	Ardua: The Baryon Cycle from Stars to the Cosmic Web
Maksym	XESS: X-ray Extremely Wide-field Spectroscopic Surveyor

X-ray interferometry



Science Questions:

- Can we image the corona, disk and jet-launching region of accreting black holes?
- How common are binary SMBHs, and can we resolve the AGN pairs that precede LISA?
- How do stellar flares, coronae and winds erode exoplanet atmospheres?
- Where are cosmic rays accelerated, and how do AGN jets feed back on clusters?
- Are there intermediate-mass black holes in globular clusters?

Trade space to be studied:

- L2 formation flying vs. a lunar-pole array.
- Wolter delay lines vs. Michelson beam splitters.

Submitter	Mission concept name/summary
Marshall	A Diffraction-Limited Milli-arcsecond X-ray Imager
Weaver	Accretion Explorer Interferometer
Weaver	Lunar X-ray Interferometer (LUX-I)

Fundamental physics & Cosmic Geometry

Fundamental physics & cosmic geometry

- Is the Hubble tension new physics? Measure H_0 without the distance ladder.
- Is dark energy evolving? Constrain w_0 and w_a with geometric distances.
- Do the field equations of gravity hold in the local vacuum?

Trade space: 4–20 nodes, km to tens-of-AU arms; laser/radio links, clocks, inertial sensing.

Submitter	Mission concept name/summary
Dominguez	GPC-SWARM / The COSMOSCOPE
McQuinn	Cosmic Positioning System
Turyshev	TETRA: Heliocentric Field-Equations Observatory

A coordinated fleet of Flaglet-scale missions

- Can four \$1–2B missions cover 80% of Astro2020 priority science?
- What are relativistic jets made of, from gamma-ray through radio?
- How do supermassive black holes grow, including obscured populations?

Submitter	Mission concept name/summary
Caputo	A Coordinated Fleet of Flaglet-Scale Missions