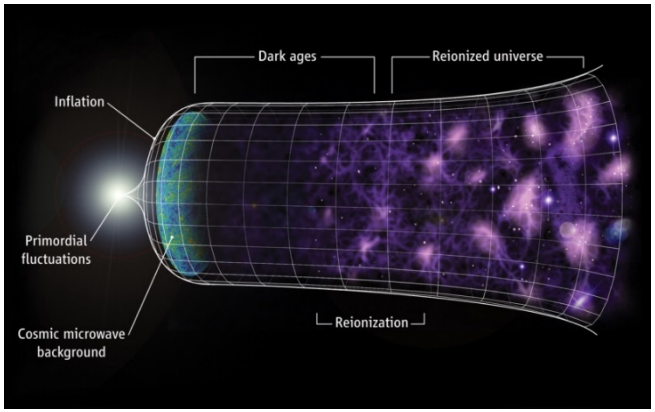
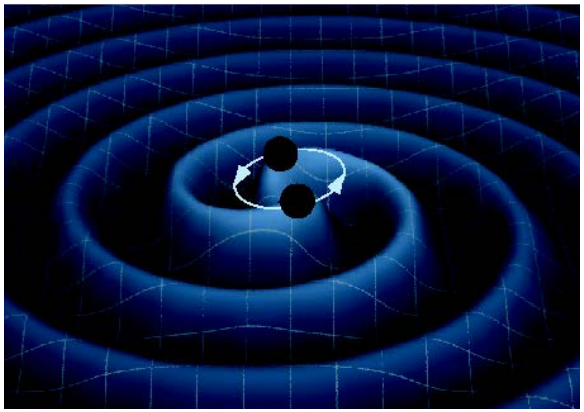
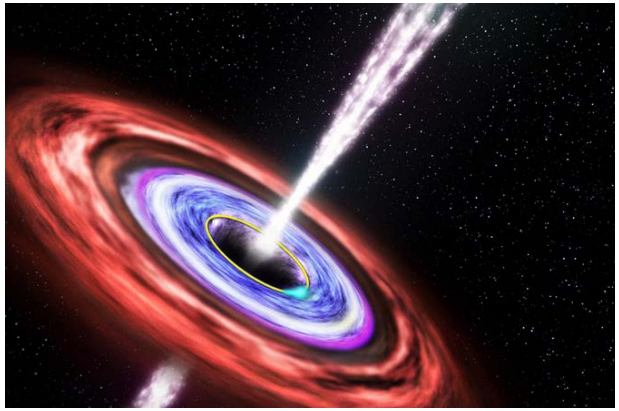
Physics of the Cosmos Program Analysis Group Report







Graça Rocha

Jet Propulsion Laboratory/Caltech
Chair, Physics of the Cosmos Program Analysis Group, PhysPAG
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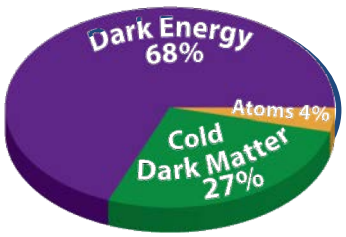
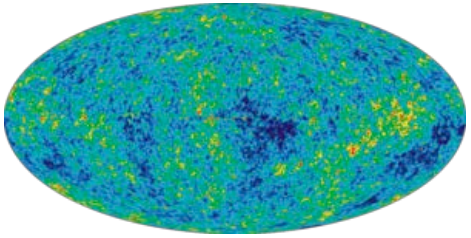
Advisory Committee, APAC, Meeting, 5 March 2020

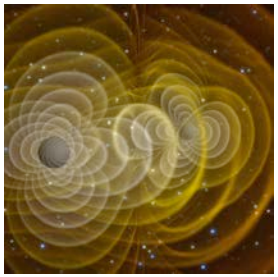
Outline

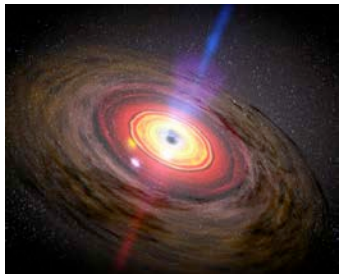
- **Introduction to PhysPAG (reminder)**
- **MultiMessenger Astrophysics SAG**
- **SIG Highlights, Activities and Goals**

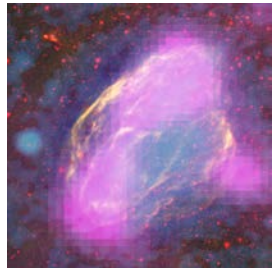
Physics of the Cosmos Science Objectives





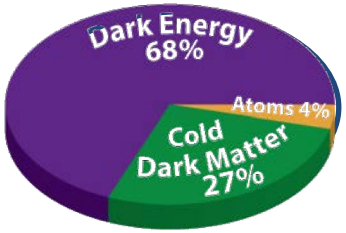


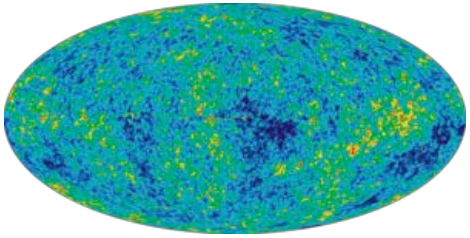


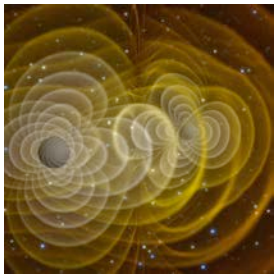


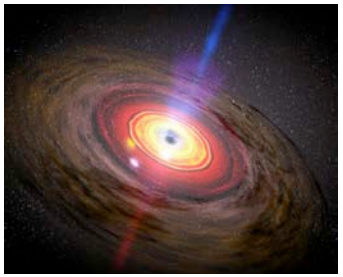
- **Increase our knowledge of dark energy**
- **Precisely measure cosmological parameters governing evolution of the universe and test inflation hypothesis of Big Bang**
- **Test validity of Einstein's General Theory of Relativity and investigate nature of spacetime**
- **Understand formation and growth of massive black holes and their role in evolution of galaxies**
- **Explore behavior of matter and energy in its most extreme environments**

Physics of the Cosmos Program Analysis Group









❑ Six Science Interest Groups (SIGs)

- Cosmic Rays (CR SIG)
- Cosmic Structure (COS SIG)
- Gamma-ray Astrophysics (GR SIG)
- Gravitational Waves (GW SIG)
- Inflation Probe (IP SIG)
- X-ray Astrophysics (XR SIG)

PhysPAG EC Membership

Name	Affiliation	Area of Expertise	Term Ends
John Conklin (Chair Emeritus)	Univ. of Florida	GW SIG	Dec 2020
Graça Rocha (Chair)	JPL/Caltech	IP SIG/CoS SIG	Dec 2020
Sylvain Guiriec	George Washington Univ.	GR SIG	Dec 2020
Kevin Huffenberger	Florida State Univ.	CoS SIG/IP SIG	Dec 2020
James Rhoads	GSFC	CoS SIG	Dec 2020
Abigail Vieregg	Univ. of Chicago	IP SIG / CR SIG	Dec 2020
Nicolas Yunes	Montana State Univ.	GW SIG	Dec 2020
Ryan Hickox (Vice Chair)	Dartmouth College	XR SIG	Dec 2021
Marcos Santander	Univ. of Alabama	CR SIG	Dec 2021
Jillian Bellovary	Queensborough Comm Coll.	GW SIG / XR SIG	Dec 2022
Sean McWilliams	WVU	GW SIG	Dec 2022
Bindu Rani	SURA, GSFC	GR SIG	Dec 2022
Grant Tremblay	SAO	XR SIG	Dec 2022

*New Roles

*New members as of January 2020

Goals of the MMA SAG

1. **Identify science goals that could be achieved by combining different astrophysical messengers measured by current and future ground- and space-based observatories**

2. **Identify 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, early 2030's**

3. **Determine how these enhanced or new science goals align with NASA Astrophysics Division's scientific priorities.**

4. **Identify the key qualitative technical drivers that are needed to achieve these science goals (e.g. wavelength, sensitivity, sky localization, latency, …)**
   - If feasible, determine desirable performance levels for each

MMA SAG Organization

- **Chair, John W. Conklin, University of Florida**
  PhysPAG Co-chair, John Tomsick, UC Berkeley
  COPAG Co-chair, Suvi Gezari, University of Maryland
- **Organized around astrophysical sources (not λ or spectrum)**
  - Goal: form teams with people interested in the same sources but observing via different messengers

  1. **AGN, SMBH binaries, EMRIs**
     - Sarah Burke-Spolaor & Bindu Rani, co-leads
  2. **NS+NS, NS+BH, WD-WD binaries, GRBs**
     - Eric Burns, Colleen Wilson-Hodge, co-leads
  3. **Stellar mass BH-BH binaries**
     - Peter Shawhan, Saavik Ford, co-leads
  4. **FRBs, SNe Ia, SN remnants**
     - Geoff Clayton, lead

Summary of MMA SAG Activities

- **Solicited membership from broad astrophysics community**
  - SAG was open to all who wished to contribute
- **~Monthly telecons of full SAG, source teams met more frequently**
- **10 community science white papers organized by MMA SAG, including one overarching paper, submitted to Astro2020**
- **Organized sessions and gave presentations at conferences to facilitate community interaction, including:**
  - January 2018 AAS meeting, National Harbor – Formulate SAG charter
  - March 2019 AAS HEAD meeting, Monterey
  - April 2019 Astrophysics Landscape meeting, Potomac
  - January 2020 AAS meeting, Honolulu
    - Present SAG findings

MMA SAG Final Report

- **Final Report sent to the APAC one week ago:**
  - Summary of MMA SAG charter and goals
  - Summary of MMA possibilities
  - 12 sections summarizing specific opportunities
  - Discussion of communications across MMA observatories
  - Conclusions and summary of key findings
- **Summary of key findings provided in the next four charts**

- **<u>The PhysPAG EC requests acceptance of the MMA SAG Final Report and closeout of this SAG from the APAC</u>**

Summary of Key Findings of MMA SAG (1/4)

1. **Wide EM & GW wavelength coverage and neutrino detectors are needed; There are a few measurements in particular that are either currently lacking or exist now but will go offline in the near future**

   a. Observatories with fast response and focus on time-domain; Neil Gehrels Swift Observatory is good example, but it is old (2004), and a replacement would be needed to continue these type of observations

   b. Fermi provides vital MMA measurements, esp. GRB monitor; Launched in 2008, the end-of-life is is not too far on the horizon and thus a wide field GRB monitor replacement system should be considered in the near term

   c. X-Ray, UV and low-frequency gravitational waves can only be observed from space and should remain a priority of NASA's Astrophysics Division

Summary of Key Findings of MMA SAG (2/4)

2. **MMA requires NASA and NSF to collaborate, since both ground- and space-based measurements are needed; Proposing for time on both ground & space observatories can be a challenge**
   - Mismatching time frames of relevant NASA and NSF solicitations can be roadblock for simultaneous space and ground observations
   - More joint time proposal opportunities would be beneficial; Many proposals to one agency that includes observations from the other are considered 2nd or 3rd tier because they require multiple instruments
   - The separation of NSF and NASA solicitations for observing time can lead to a bifurcation of the astrophysics community, hindering interactions between certain sub-communities
   - It is important that disparate catalogs, database systems (e.g. GCN) can work together to facilitate analyses requiring multiple observations
   - Some MMA science can be performed using archived data; They do not require observing time, but personnel & computing time; More support for these resources without observing time are desirable

Summary of Key Findings of MMA SAG (3/4)

3. **Many MMA science cases in space require not only sufficient sensitivities in particular wavelengths, but also operational capabilities, e.g. rapid commanding to enable rapid re-pointing, and enhanced data taking modes**

   - Such capabilities require both communications and commanding infrastructure, as well as flexible scheduling of ground segments
   - Enhancements to autonomous and real-time capabilities of TDRSS is needed
   - Development of flexible and autonomous observation scheduling software for mission ground segments is important

Summary of Key Findings of MMA SAG (4/4)

4. **MMA now reaching fidelity where astrophysicists increasingly need to leverage progress in computer science and wide range of physics**

   - Capabilities needed include fluid dynamics and turbulence, plasma physics, atomic physics, numerical general relativity, nuclear and particle physics
   - To maximize the science learned from multi-messenger astronomy, it is important for these different disciplines to work together, sharing expertise

the Cosmic-Ray Science Interest Group highlights and updates (1/11)

❑ CR SIG

- Hosted a mini-symposium at 2019 April APS meeting in Denver on direct and indirect cosmic-ray measurements and ultra-high-energy neutrinos
- ~**16** Science White Papers submitted to Astro2020 on cosmic rays, either addressing questions of origin, composition, spectrum, or their multi-messenger connections
- SIG chairs encouraged the community to contact them with questions and suggestions on activities or topics they would like to see the group address

the Gamma-Ray Science Interest Group highlights and updates (2/11)

❑ GR SIG

- Coordinated sessions at AAS in Seattle, HEAD meeting in Monterey, and 2020 AAS in Honolulu

- Produced webpage to coordinate relevant Science White Papers for Astro2020. Held workshops and telecons to organize community in writing of white papers.
  - **74** Science White Papers mentioned gamma-rays in the title or abstract.

- Contributed a paragraph to the May 2019 HEAD newsletter on the status of Gamma-ray missions (Transient Astrophysics Observatory (ISS-TAO), Compton Spectrometer and Imager (COSI-X), Glowbug, BurstCube)

the Gamma-Ray Science Interest Group highlights and updates (3/11)

Gamma-Ray SIG Session

Wednesday, 8 January 2020
1:15 P.M.–2:45 P.M., Room: : 303A

GRSIG session at AAS meeting

Agenda

	Welcome	Sylvain Guiriec
1:15–1:25 P.M.	**Fermi Result Highlights**	Liz Hays
1:25–1:35 P.M.	**COSI Result Highlights**	Carolyn Kierans
1:35–1:45 P.M.	**Status of Glowbug**	Eric Grove
1:45–1:55 P.M.	**AMEGO**	Julie McEnery
1:55–2:05 P.M.	**GRAMS**	Tsuguo Aramaki
2:05–2:15 P.M.	**ETCC/SMILE**	Toru Tanimori
2:15–2:25 P.M.	**MoonBEAM**	Michelle Hui
2:25–2:35 P.M.	**TAP**	Judy Racusin
2:35–2:45 P.M.	**Gamow**	Nick White
	Open Discussion if time permits	

WebEx

Gamma-Ray SIG Session
Wednesday, 8 January 2020
1:00 P.M. | Hawaii Time (Honolulu, GMT-10:00) | 2 hrs
Meeting number (access code): 905 835 799
Meeting password: Aas2020!
When it's time, join the meeting.

the Gravitational Waves Science Interest Group highlights and updates (4/11)

❑ GW SIG

- Helped organize the community regarding **3** APC white papers for Astro2020:
  - LISA mission APC, building the WG field, GW Astronomy Beyond LISA

- Helped organize the community regarding **4** Voyage2050 white papers
  - Improved sensitivity in LISA band, Low frequencies, Mid-band frequencies,
    Improved sky localization

- Continued interactions with the LISA Consortium regarding development of LISA

the Gravitational Waves Science Interest Group highlights and updates (5/11)

GW SIG

- Organized session at January 2020 AAS, Honolulu
  - GWSIG Overview
  - LISA mission update
  - Intro talks by new SIG Co-chairs,
    - Jillian Bellovary, Sean McWilliams
  - NASA LISA Study Team update
- Organized session at April APS 2020, Washington, DC
  - GWSIG and PCOS overview
  - LISA mission update
  - NANOGrav update
- Discussing ways to incorporate more activities outside of LISA
  - LIGO/Virgo and associated EM follow-ups
  - Pulsar timing arrays
  - Future space GW missions beyond LISA

the Inflation-Probe Science Interest Group highlights and updates (6/11)

IP SIG

- Main activity of community was production of ~ **20** Science whitepapers and **8** APC whitepapers for Astro2020 decadal.

- APC whitepapers:
  - 3 related explicitly to space-based projects: PICO, LiteBIRD, and description of a program for CMB spectral distortions
  - Others related to technological development or ground-based projects (Ground-based efforts highly complementary to space based efforts)
  - 1 paper, “The need of better tools to design future CMB experiments”, has a sub-section dedicated to space vs ground complementarity

- For information on the SWP please take a look at the IP SIG webpage

the Inflation-Probe Science Interest Group highlights and updates (7/11)

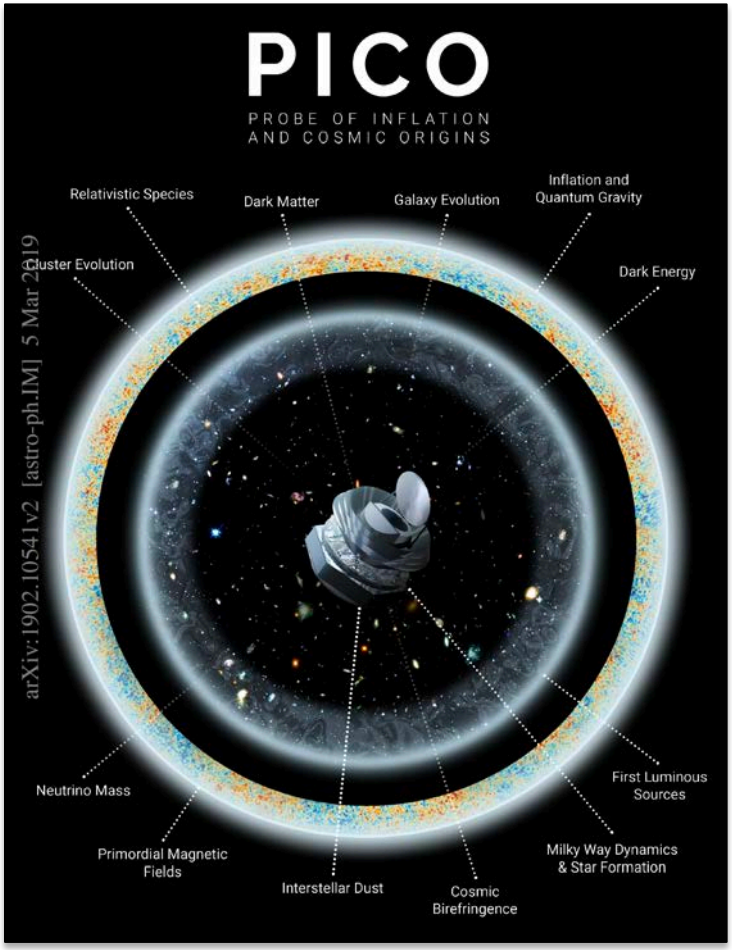
IP SIG

- Organized session at April APS 2020, Washington, DC
  - IPSIG Update
  - PICO (Probe of Inflation and Cosmic Origins) update
    - *'Building upon a legacy of successful measurements, the next decade holds tremendous potential for new, exciting CMB discoveries…..'*
  - Complementarity of Space and Ground-Based CMB Experiments
  - Interplay of Foregrounds and Systematics: The Case for Low-Frequency Observations
  - Connecting the CMB Foregrounds, Galactic ISM, and Magnetic Field Modeling with IMAGINE
  - Data Analysis - Do We Have All The Necessary Tools?
- Continue organizing sessions an engage the community

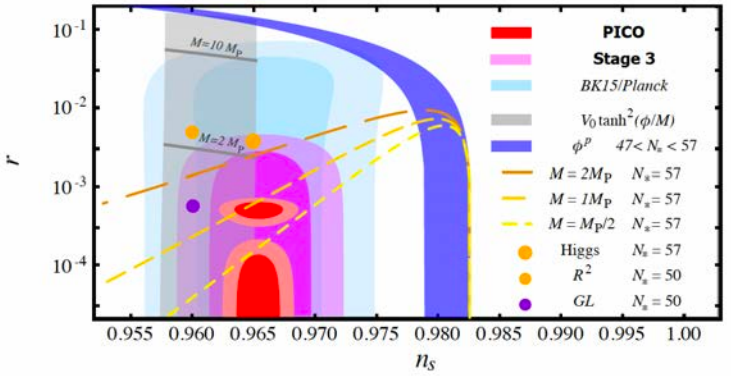
the Inflation-Probe Science Interest Group highlights and updates (8/11)

It's a exciting time for Inflation-probe science

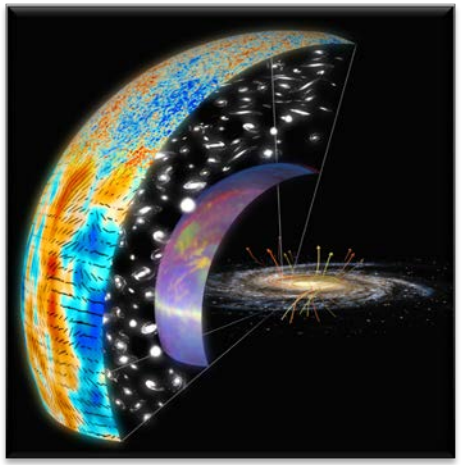
Final report delivered to NASA and Astro2020



PICO APC paper



KISS study: Designing future CMB experiments

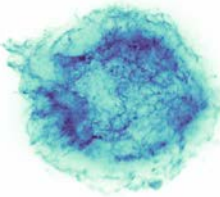


Several
APC papers

the X-ray Science Interest Group highlights and updates (9/11)

❑ XR SIG

- Coordinated sessions at AAS in Seattle, HEAD meeting in Monterey, and the 2020 AAS meeting in Honolulu
- Produced webpage coordinating community Astro2020 Science White Papers
  - **> 50** Science White Papers relevant to X-ray astronomy, covering very wide range of science, (including supermassive black holes and AGN, galaxies, groups, clusters, and the circumgalactic medium, star formation, the interstellar medium, exoplanets, supernovae and supernova remnants, stellar-mass black holes, and neutron stars)
  - XRSIG highlighted science in these White Papers at AAS and HEAD sessions.
- Provided a similar overview of Astro2020 APC papers for the 2020 AAS meeting in Honolulu
- Provided updates to the community on US involvement in Athena, and the progress of the NASA concept study for the Lynx Observatory.
- Major recent milestones in X-ray astronomy:
  - Successful launch in July of Spectrum X-Gamma S/C with eROSITA & ART-XC telescopes. Update on mission was given in the X-Ray SIG session at the AAS meeting in Honolulu



It's an exciting time for X-ray Astrophysics

eROSITA

The first data are exquisite

Not an optical image!

ATHENA

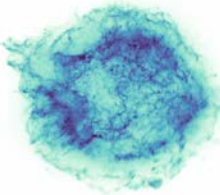
Recently passed Mission Formulation Review

Transition to ESA Phase B1

X-RAY OBSERVATORY LYNX

Final Report delivered to Astro2020

A new epoch of discovery



The XRSIG Splinter at AAS 235 - *(Standing room only!)*

- Summary and analysis on APC White Papers to Astro2020 relevant to X-ray astronomy
- Update from recently launched SRG/eROSITA with a first look at some of the data
- Update on opportunities with XRISM X-Ray Imaging and Spectroscopy Mission
- Overview of potential for a diffraction-limited X-ray mission

Organizing an excellent splinter for APS in April

XRSIG Goals for the coming year

It is the start of a new era for X-ray astronomy.

- As we await the results of Astro2020, the XRSIG will hold multiple events specifically designed to make X-ray astronomy more accessible to an even broader community.
- X-ray astrophysics is not niche science. It is a window into how our Universe really works.

PhysPAG EC current goals (under discussion)

- Improve access for (researchers at) under-resourced institutions
  - Discussing the 'How' – how to ascertain the needs of under-resourced institutions and how to proceed to improve access

- Preparation for Decadal outcomes:
  - Look into and analyze complementarities of flagships - with other flagships, and/or other potential future missions
  - Look at what other agencies are doing
  - Look into gaps in submitted science in APC white papers
  - Answer the question: *'Where do you think your community is least well prepared for an outcome of the Decadal?'*

PhysPAG/SIG Meetings and Activities

- **Winter AAS meeting, January 2020, Honolulu**

- **April APS, April 2020, Washington, DC**
  - We will have a PCOS/PhysPAG session, and
  - several SIG sessions: GR SIG, GW SIG, IP SIG, and XR SIG

  https://pcos.gsfc.nasa.gov/physpag/meetings/APS_2020/APS2020-agenda.php

- **AAS HEAD, September 2020**
  - Planning has begun and we will have PCOS sessions likely including X-Ray and Gamma-Ray SIG