High Energy Astrophysics and Cosmology from Space: NASA's Physics of the Cosmos Program

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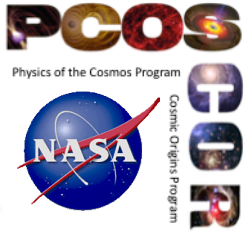
Where does Physics live at NASA?
Prioritization from Astro2010 Decadal Report



Astro2010 science themes map to the Astrophysics Division themes:

New Worlds	→	Exoplanet Exploration
Cosmic Dawn	→	Cosmic Origins
Physics of the Universe	→	Physics of the Cosmos

The highest priority science for Physics of the Universe are captured in the PCOS Science Objectives:

Dark Energy: Probe the nature of dark energy by studying the expansion rate of the universe and the growth of structure

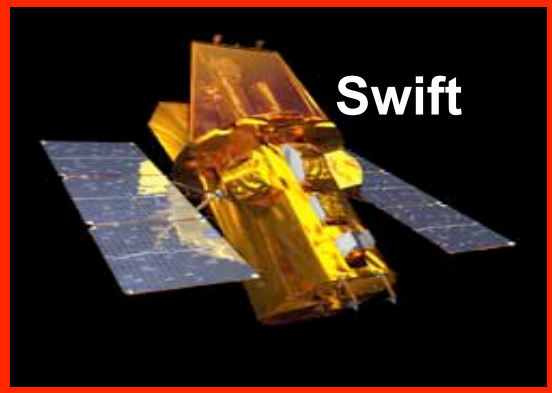
Theory of Inflation: Test the theory of inflation by measuring the polarization of the Cosmic Microwave Background.

Black Holes & General Relativity: Probe the properties of black holes and testing General Relativity using x-ray emission and gravitational waves.

PCOS MISSIONS

OPERATING

RELATED

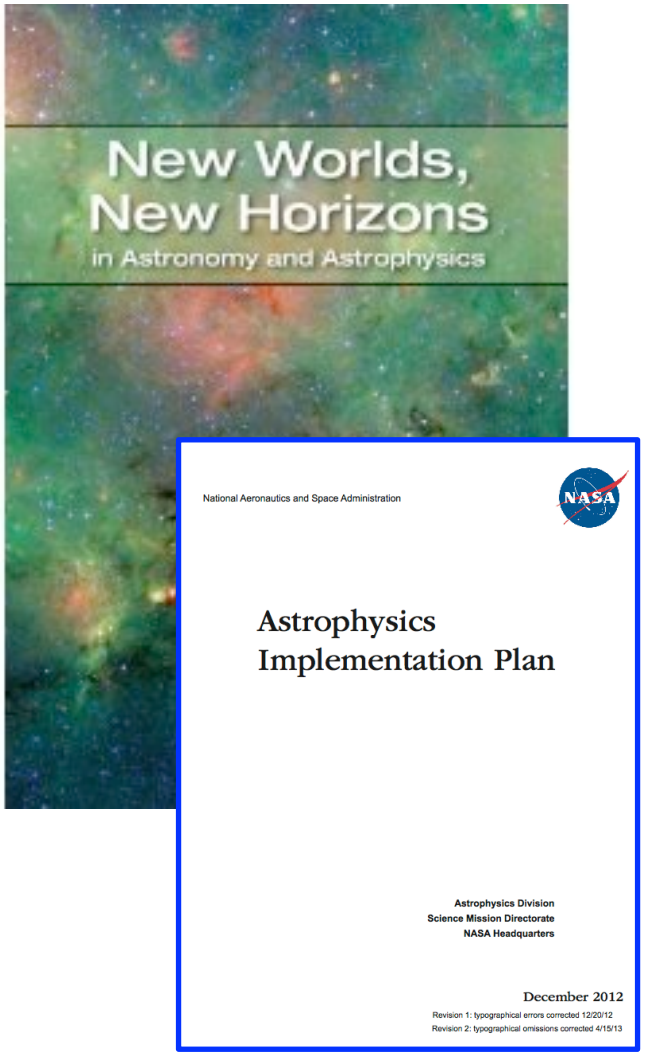


The near-future
PCOS Missions in Development

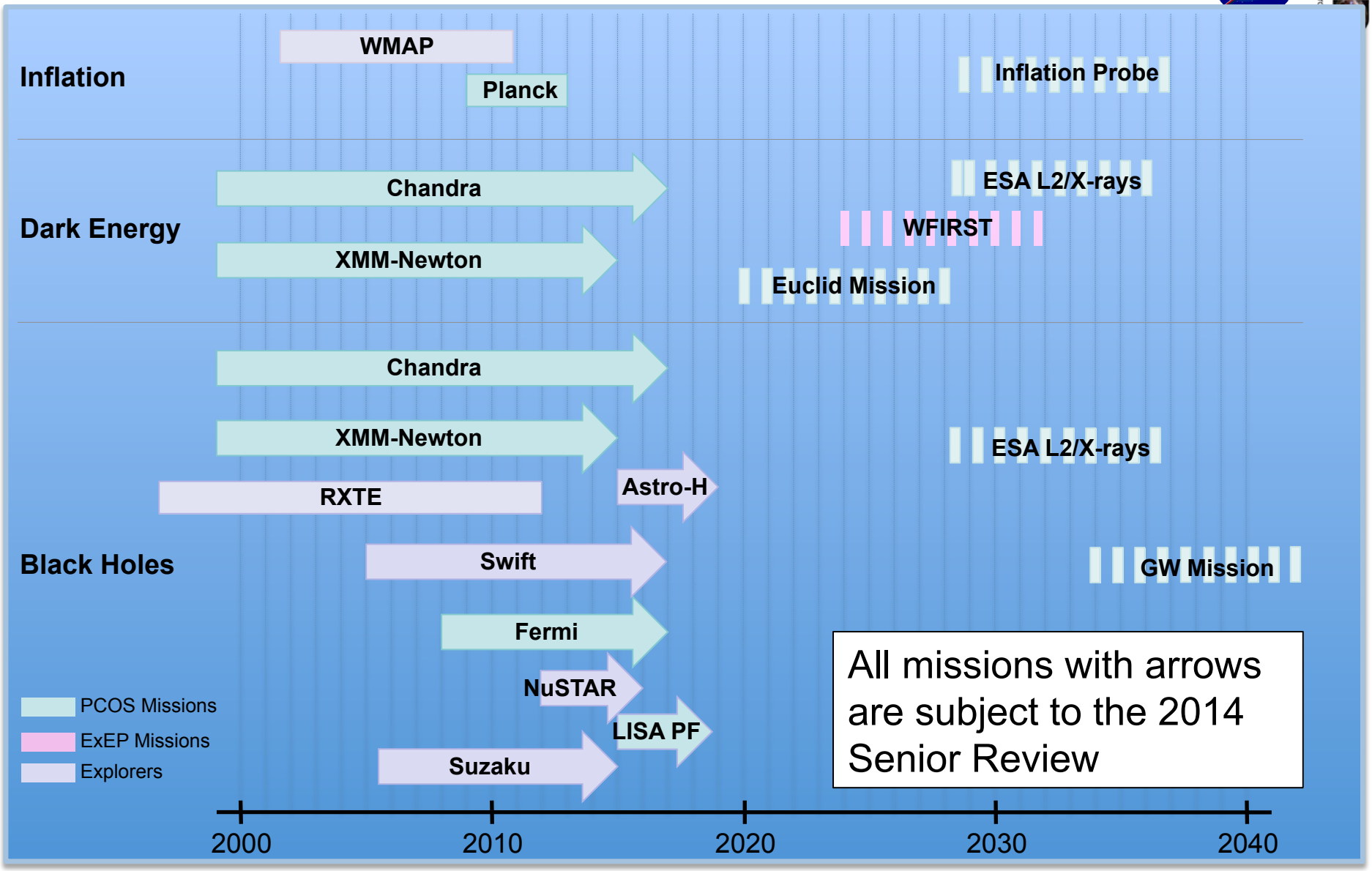
- Interestingly in the ENTIRE astrophysics division, there are five developmental projects being prepared for launch during FY14: Astro-H, NICER, TESS, Euclid, ISS-CREAM
- Note: FOUR of these five are either PCOS or PCOS-related projects!
- We also have a PCOS technology demonstration mission, LISA Pathfinder (launching 2015)

Physics of the Cosmos (PCOS): Scientific and Technical Stewardship for future missions

- **Provide scientific and technical stewardship for decadal-survey recommended missions:**
  - Of the six highly-ranked medium and large-scale space-based priorities in NWNH, three fall within the PCOS science program:
    - LISA (Gravitational Waves)
    - IXO (X-ray)
    - Inflation Probe (medium-scale)
  - NOTE: Although dark energy SCIENCE is within PCOS program, WFIRST is located within the Exoplanet Program



Notional Map of Astrophysics Missions to Top PCOS Science Objectives

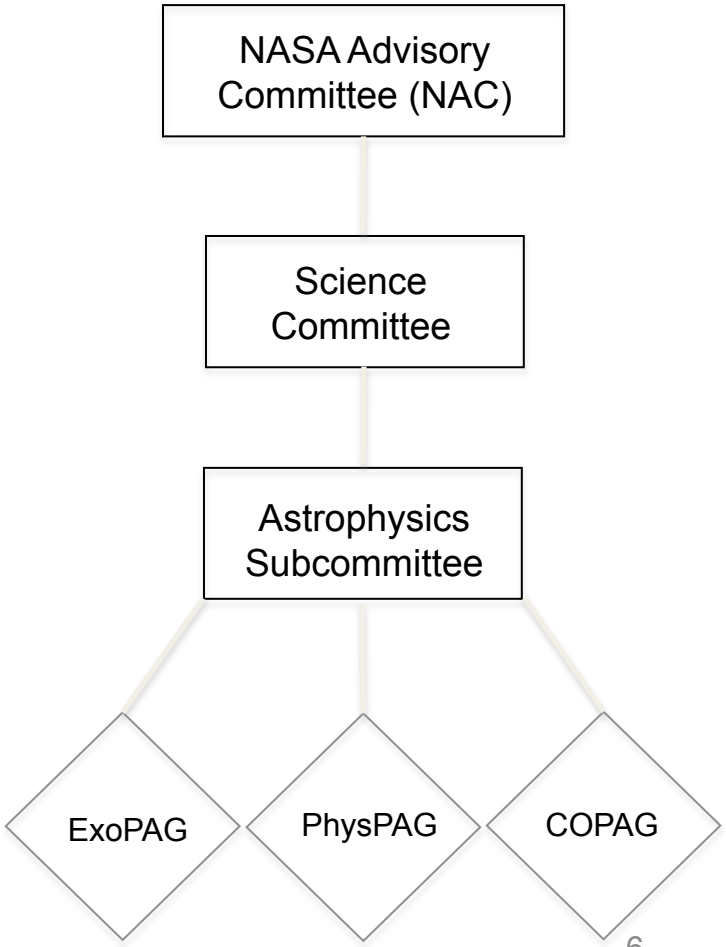


*Timelines for WFIRST, LISA, IXO, and Inflation Probe are for illustration purposes only

Communicating with NASA Astrophysics via the Program Analysis Groups (PAGs)

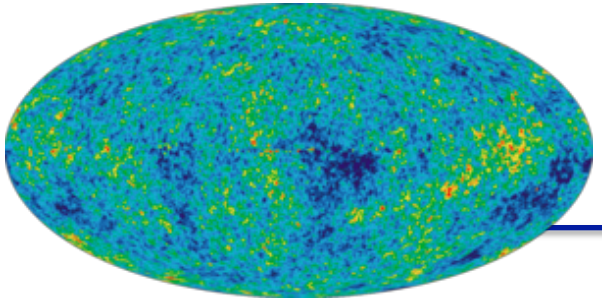
- The Physics of the Cosmos Program Analysis Group (PhysPAG) serves as a forum for soliciting and coordinating input and analysis from the scientific community in support of the PCOS program objectives.
- The Program Analysis Groups (PAGs) include all members of the community interested in providing input to NASA on issues of strategic importance via analysis studies
- PAGs hold regular public meetings.
- PAGs identify specific, well-defined topics for further detailed studies assigned to Study Analysis Groups (SAGs) as well as longer-standing, discipline-centered analysis groups – Science Interest Groups (SIGs). All are task forces of volunteers.

Advisory Committees

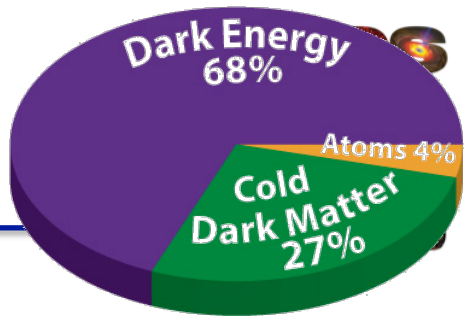


PhysPAG and SIGs

- **PhysPAG has five SIGs in operation for the Inflation Probe, Gamma Rays, Cosmic Rays, Gravitational Waves and X-rays.**
- **PhysPAG EC membership:**
  - J. Nousek, Chair, Penn State Univ., X-rays
  - J. Bookbinder, XRSIG chair, SAO, X-rays
  - M. Bautz, MIT, X-rays
  - **S. Hanany, IPSIG chair, Univ. of Minnesota, CMB**
  - J. Bock, Vice-chair, Caltech/JPL, CMB
  - **G. Mueller, GWSIG chair, Univ. of Florida, Gravitational Waves**
  - N. Cornish, Montana State Univ, Gravitational Waves
  - **J. Rhodes, JPL, Dark Energy**
  - R. Bean, Cornell, Dark Energy
  - A. Olinto, Univ. of Chicago, Astroparticles
  - Eun-Suk Seo, Univ. of Maryland, Astroparticles
  - **L. Hays, GSFC, GWSIG chair, Gamma rays**
  - M. McConnell, Univ. of New Hampshire, Gamma rays
- **Rotating off in Dec 2014, Call for applications in Fall 2014**



Physics of the Cosmos Science Objectives



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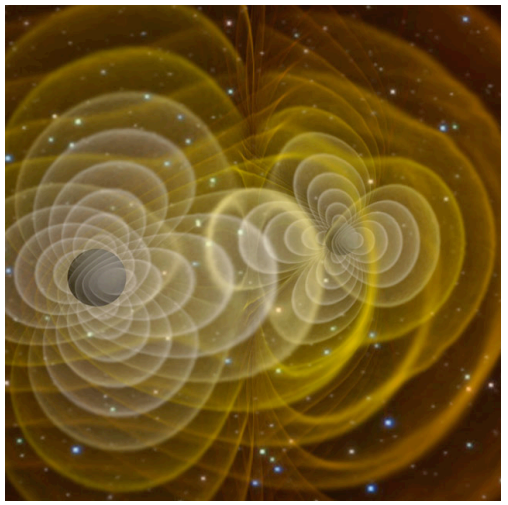
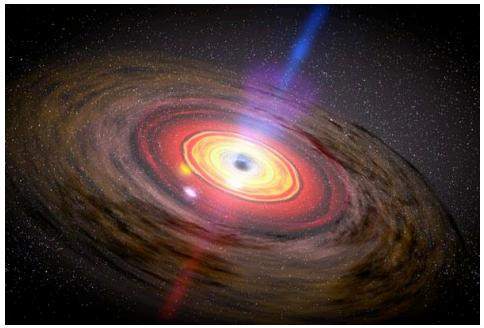
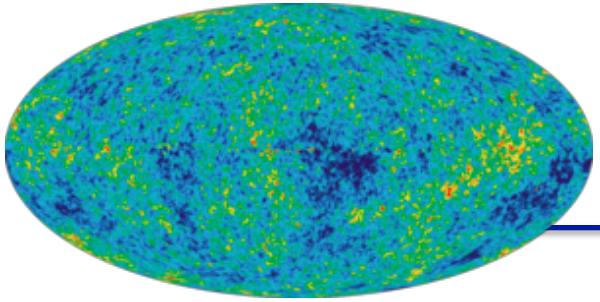




- Explore the behavior of matter and energy in its most extreme environments



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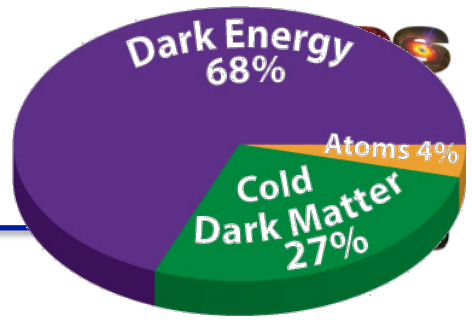

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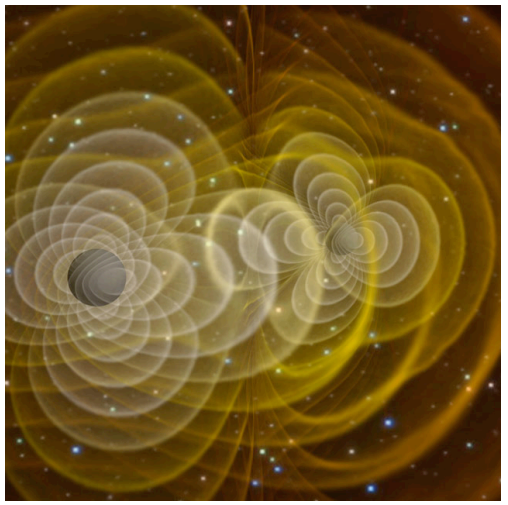

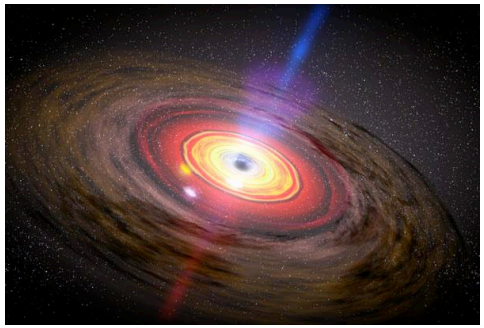

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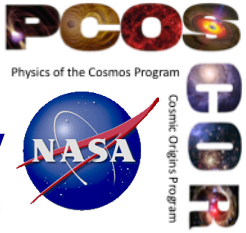
Expand our knowledge of dark energy



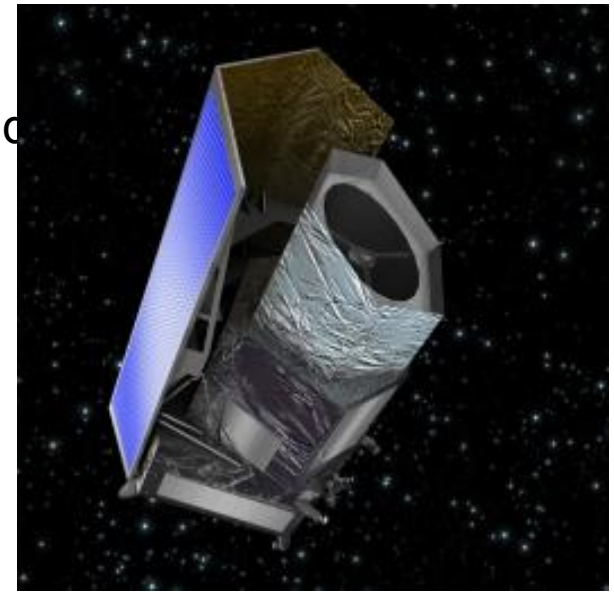
- **Key NASA activities in this area:**
  - Euclid (ESA Mission, launching 2020, NASA contributing hardware ++)
  - WFIRST/AFTA (launch ~2024, NASA-led)
  - Note: Jason Rhodes up next!

Euclid Science Objectives

Two primary Euclid surveys:

- a weak lensing survey
- galaxy redshift survey (Baryon Acoustic Oscillations / Redshift Space Distortions)

- 15,000 square degree survey, with near-IR imaging and spectroscopy
- NIR focal plane needed for redshifts for millions of galaxies



1. *Dark Energy Properties*. Measure the Dark Energy equation of state parameters, w_p and w_a to 0.7% and 3.5% precision, respectively (when combined with Planck)

2. *Beyond Einstein's Gravity.* (measure galaxy clustering growth factor exponent, γ to precision ~ 2%.)

3. *The nature of dark matter*. (measure sum of neutrino masses**).**

4. *The seeds of cosmic structure*. (measure initial condition parameters)

Euclid

A visible and near-infrared telescope to explore cosmic evolution

euclid

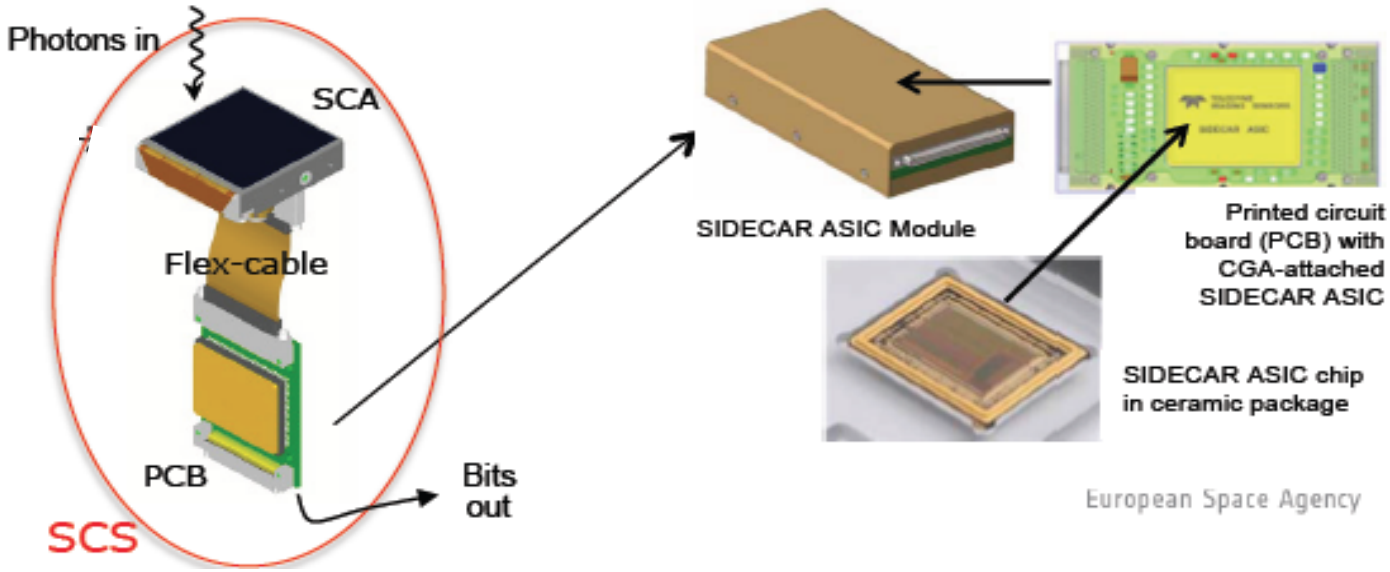
- **ESA Cosmic Vision 2015-2025 Mission**, M-Class with NASA participation.
- 1.2-m mirror, visible & near-IR images, spectra
- **Launch Date**: Mar 2020

CURRENT STATUS:

- **~50 U.S. scientists are members of the Euclid Consortium that will analyze the data, and make maps of the sky.**
- **First experimental manufacturing run for the Euclid near-infrared detectors to in process (ESA).**
- **NASA will buy, test and characterize the flight infrared detectors starting in ~ 2015, depending out experimental manufacturing run.**
- **NASA developing ground system node and U.S. science center.**

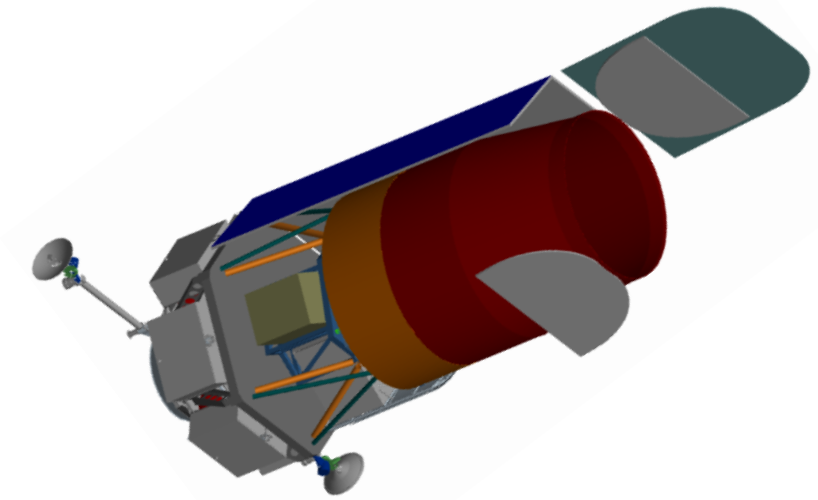
NASA hardware contribution to ESA's Euclid mission

- **NASA's contribution to the Euclid mission will be the Near Infrared Spectrograph and Photometer (NISP) flight focal plane subassemblies that meet ESA's requirements for testing characterization:**
  - **16 flight (plus 4 flight spares) "triplet" Sensor Chip Systems (SCS)**
    - **2Kx2K HgCdTe array (H2RGs) + flex cable + SIDECAR ASIC control electronics**
  - **First flight SCS delivery to ESA planned in ~2015 (under evaluation)**



WFIRST / AFTA Widefield Infrared Survey Telescope with Astrophysics Focused Telescope Assets (EXOPLANET MISSION)

- **Top priority in 2010 Decadal Survey**
  - #1 Large Priority: Widefield IR survey telescope
  - #1 Medium Priority: Technology for direct imaging and characterization of exoplanets
- **Study Baseline Payload:**
  - 2.4m existing telescope assets
  - Widefield imager
  - Coronagraph



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 2016. If start in 2017, launch by ~2024
- **Currently in pre-formulation**
- **Maturing key technologies to TRL 5 by FY17 and TRL 6 by FY19**

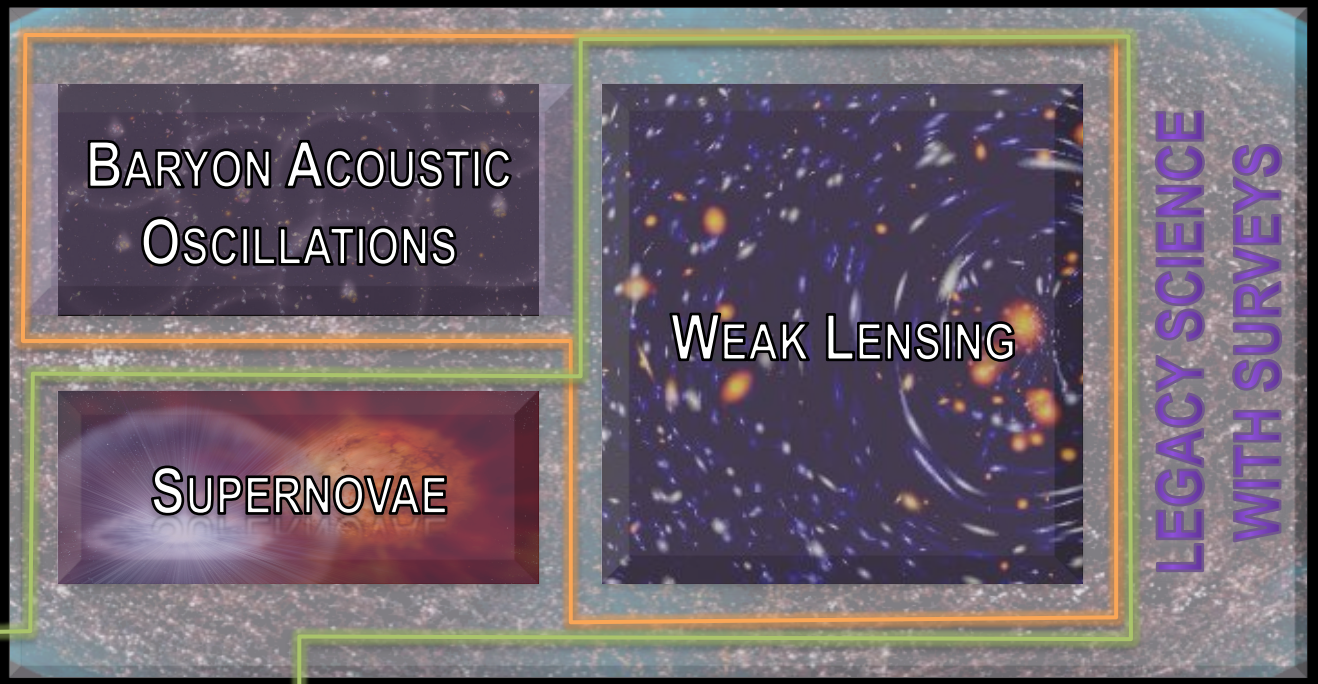
DIFFERENCES WITH EUCLID FOR DARK ENERGY:

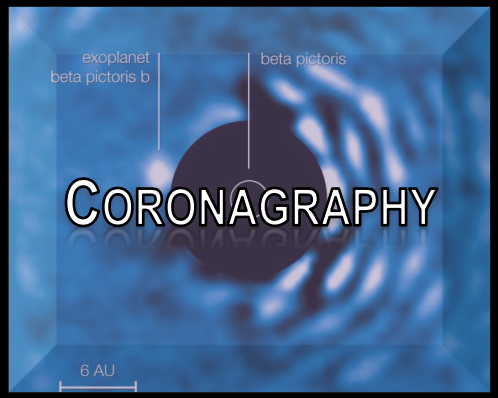
- Includes SN 1a survey (2700 SN from z=0-1.7)
- Deeper surveys over smaller area

WFIRST Science (from N. Gehrels)

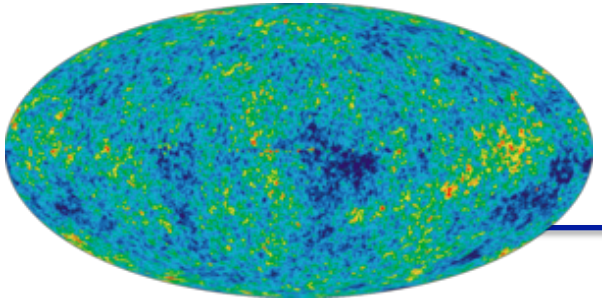
complements Euclid

complements LSST

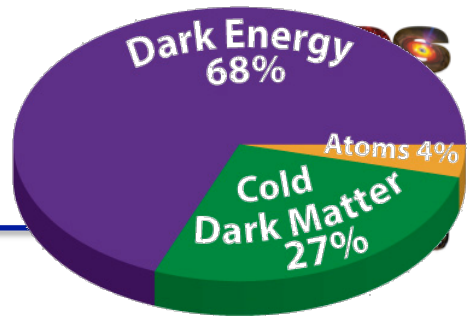




continues Great Observatory legacy



Physics of the Cosmos Science Objectives



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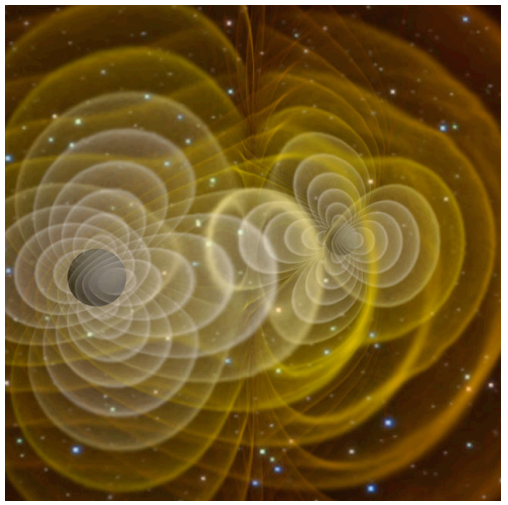
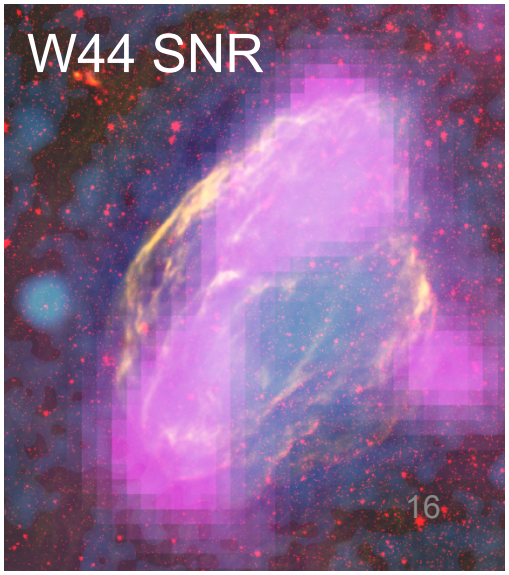
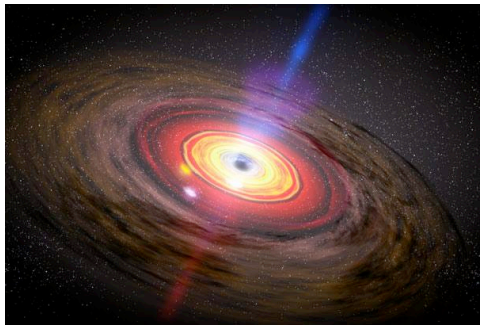






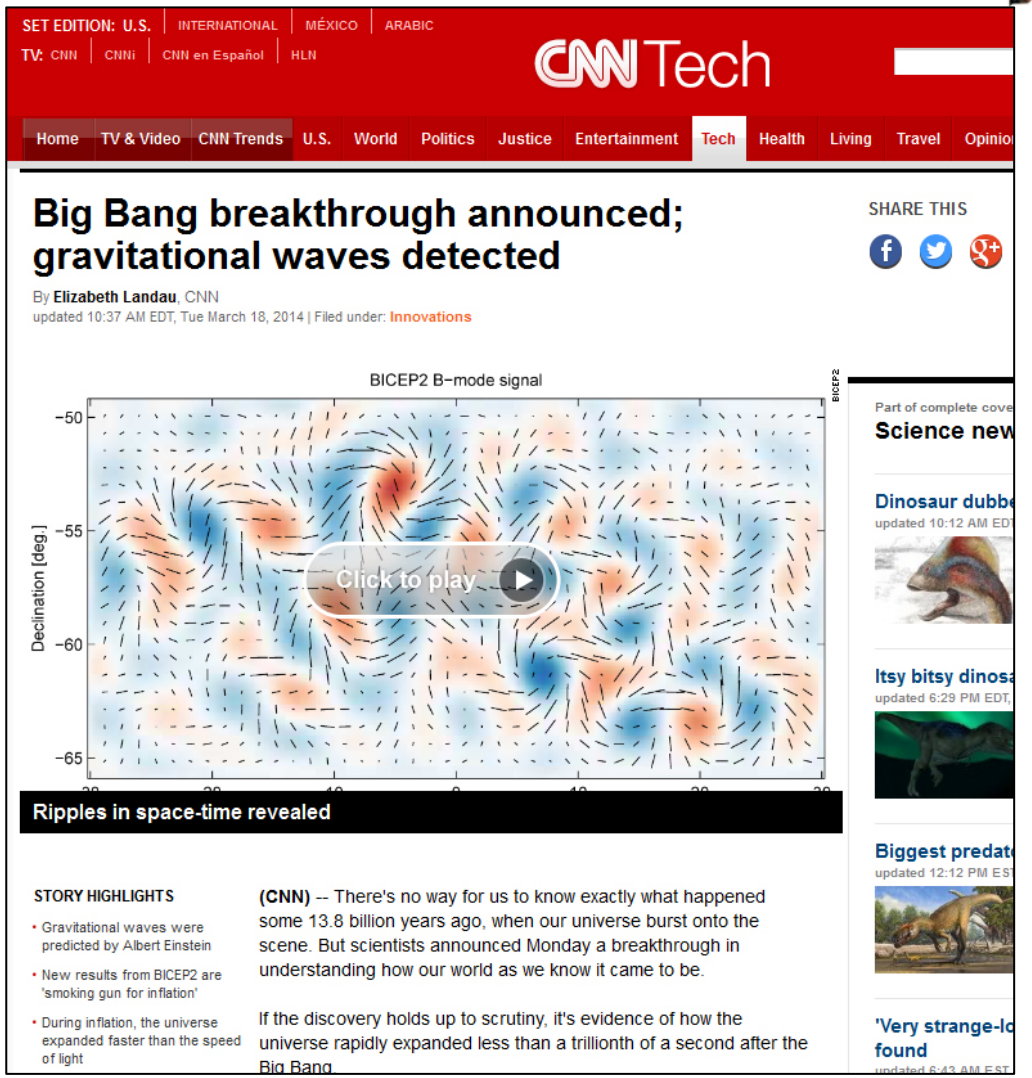
- Explore the behavior of matter and energy in its most extreme environments

Cosmological parameters and testing inflation hypothesis of the Big Bang

- **Prime measurement: B-mode polarization of the Cosmic Microwave Background arising from primordial gravitational waves**
- **There are significant data analysis activities ongoing for PCOS mission Planck (which ceased operations in 2013)**
- **Outside the PCOS program, there has been much progress from the ground and with balloon experiments**
- **Shaul Hanany speaks after this.**

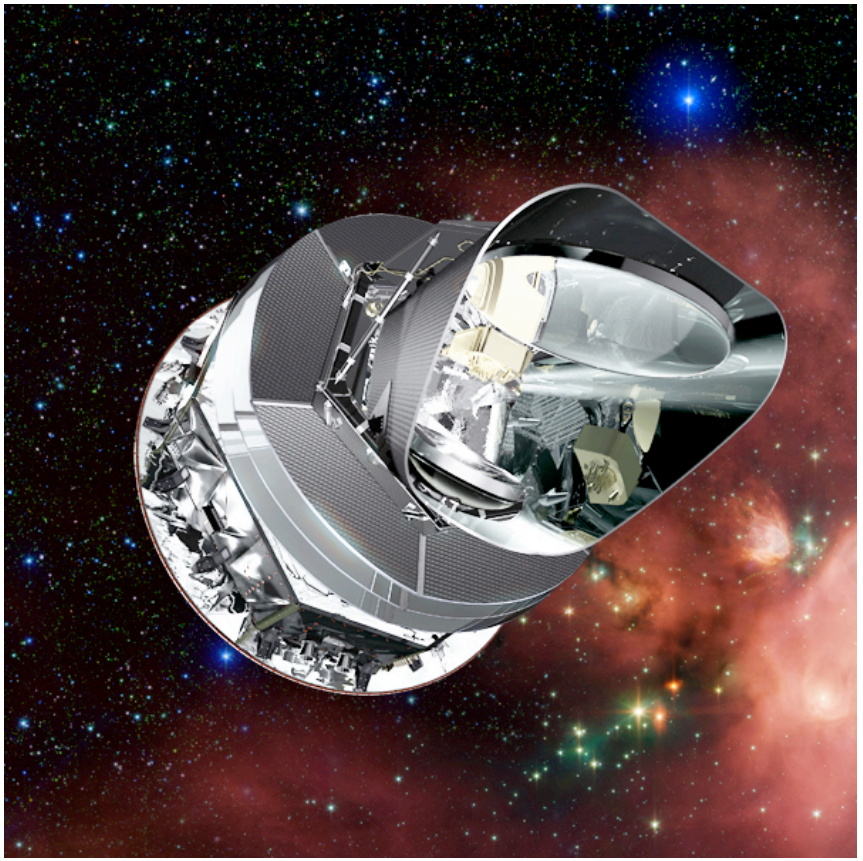
CMB 2014: Two confirmations of B-mode polarization

- **Gravitational lensing of primordial E-modes** (SPT collaboration: Hanson et al. 2013, arXiv:1307.5830; POLARBEAR collaboration: Ade et. al. 2014, arXiv: 1403.2369)
- **Cosmological signal from primordial grav. waves** (BICEP2 collab: Ade et al. 2014, arXiv:1403.3985)
- **Stick around after this!** Session J4: Invited Session: Probing Inflation with the CMB" Speaker: Jamie Bock Room: *Chatham Ballroom C*



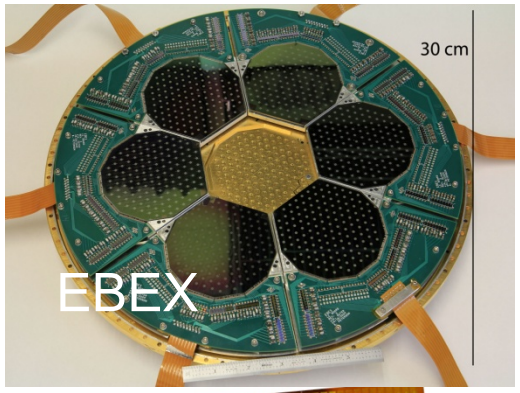
CMB Polarization from space: Planck

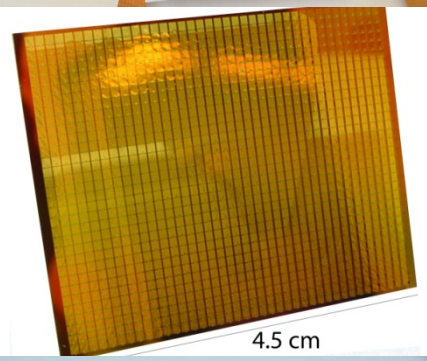
- CMB polarization results from Planck to be released by October 2014 and expected to be sensitive enough to test BICEP2 results.
- There exists some tension between Planck results on the scalar-to-tensor ratio, r, and that from BICEP2.

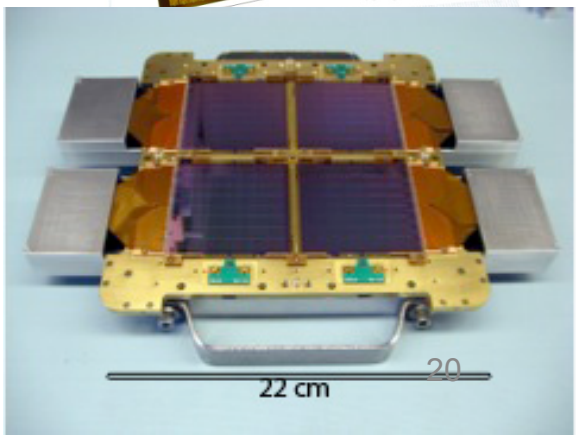


CMB Polarization from Space, Balloons

- **Note: APRA balloon experiments are "outside PCOS" programmatically.**
- **Currently NASA supports three balloon-borne experiments that probe the polarization properties of the CMB covering 90-600 GHz with Transition-Edge (TES) bolometers with different polarimetric approaches :**
  - 2012: E and B experiment (EBEX; P.I. Hanany)
  - 2014 TBD: Suborbital Polarimeter for Inflation Dust and the Epoch of Reionization (SPIDER; P.I. Bill Jones)
  - 2015:Primordial Inflation Polarization Explorer (PIPER; P.I. Al Kogut)

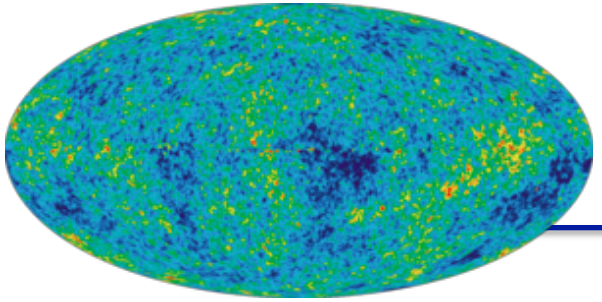




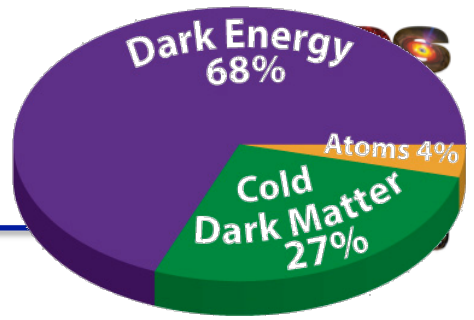


CMB Polarization, The Inflation Probe

- **2nd ranked medium-scale mission in decadal survey**
- **Please see the 2013 Astrophysics Implementation Plan which states mission studies for an Inflation Probe will start no earlier than 2015**
- **Community activities:**
  - An Inflation Probe Science Interest Group (IPSIG) telecon is planned for April 10
  - A CMB planning workshop is planned, that will include IPSIG discussions, for September in Minnesota (Point of Contact: Shaul Hanany, U. of Minnesota)



Physics of the Cosmos Science Objectives



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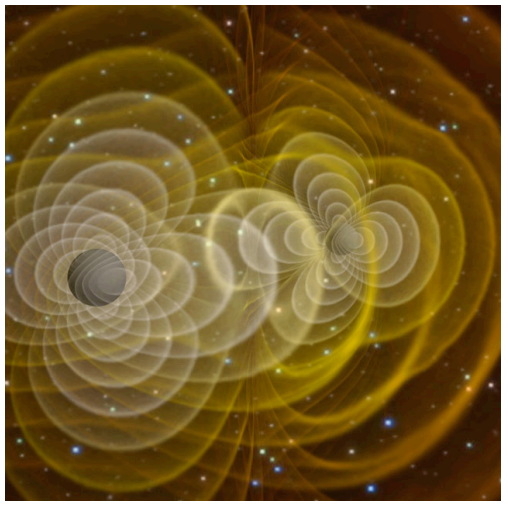

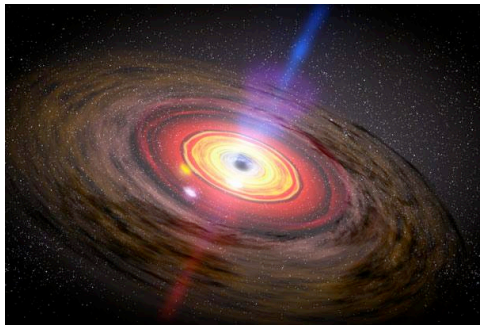

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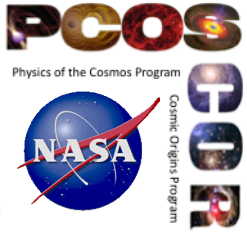
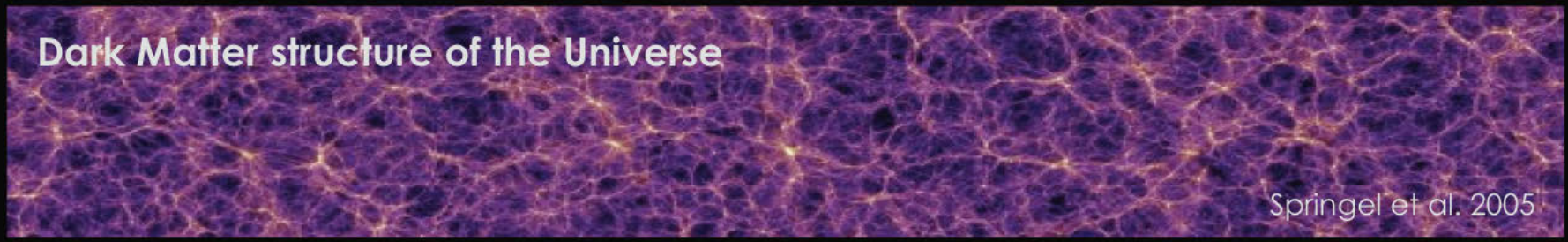
General Relativity and Evolution of Black Holes



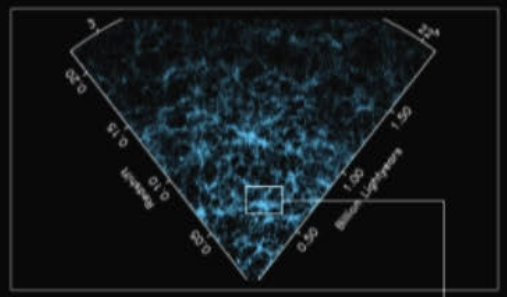
- **Two major decadal survey priorities fit under these science themes: LISA and IXO**
- **Recent decisions by ESA:**
  - L2 (launch 2028) will be an X-ray mission following the Hot and Energetic Universe theme
  - L3 (launch 2034) will be a gravitational wave observatory following the Gravitational Universe theme.
- **Also have operating missions and upcoming launches:**
  - PCOS: Chandra, XMM-Newton, related: NuSTAR, Swift
  - Related: Astro-H (2015, JAXA) and NICER (2016, ISS)
- **NEAR-TERM LAUNCH: LISA Pathfinder in 2015**
- **Gravitational waves likely detected by LIGO ~2016-2018**
- After this: Neil Cornish & Jay Bookbinder

ATHENA+

Why does the observable universe look the way it does?



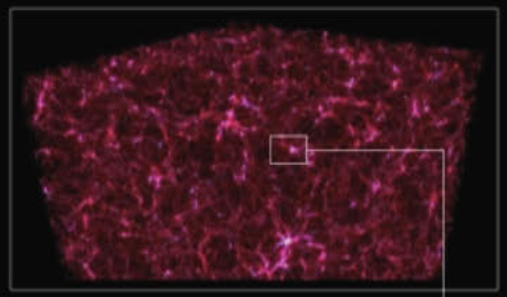
THE COLD UNIVERSE



LARGE SCALE GALAXY DISTRIBUTION

STARS AND GALAXIES

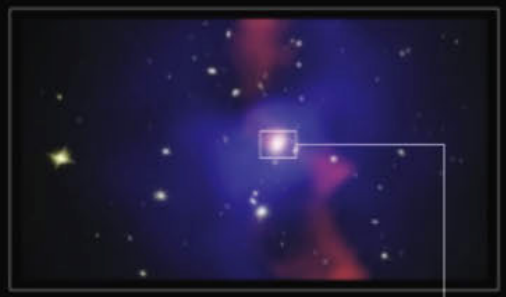
THE HOT UNIVERSE



INTERGALACTIC MEDIUM

GALAXY CLUSTERS & GROUPS

THE ENERGETIC UNIVERSE



COSMIC FEEDBACK

BLACK HOLES

ESA's L2 Advanced X-ray Observatory (launch ~2028)

- **NASA and ESA are discussing a potential NASA contribution.**
  - NASA is interested in contributing to this mission because it is responsive to the U.S. Decadal Survey. The U.S. Decadal Survey recommended an international partnership for an advanced X-ray observatory.
- **NASA's FY15 budget request supports a potential L2 partnership**
  - US scientists are participating in proposal(s) in response to the ESA mission concept call for proposals; proposals due April 15, 2014
  - ESA will select US members to participate on the L2 Science Study
  - NASA will continue investing in technologies likely to be appropriate for an L2 contribution; investments include both directed and competed SAT investigations
  - NASA is budgeting for
    - development of contributed flight hardware
    - US participation in the L2 science team
    - US contribution to the science ground system

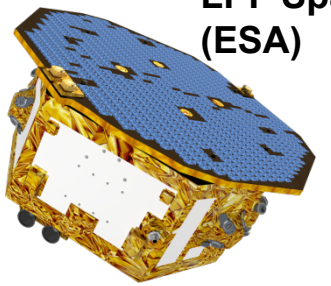
Future Gravitational Wave Observatory (Launch 2030's)

- **A space-based gravitational wave observatory was recommended by Astro2010 as the third priority under large space missions**
- **NASA and ESA are discussing a potential NASA contribution to ESA L3**
  - ESA L3 planned for 2034 launch
  - NASA is interested in contributing to this mission because it is responsive to the U.S. Decadal Survey. The U.S. Decadal Survey recommended an international partnership for a gravitational wave observatory.
- **Discussions between ESA and NASA are ongoing; the partnership likely will be subject to Astro2020 decadal approval**
- **NASA (PCOS) looks forward to community input via the GWSIG and PhysPAG regarding the future**

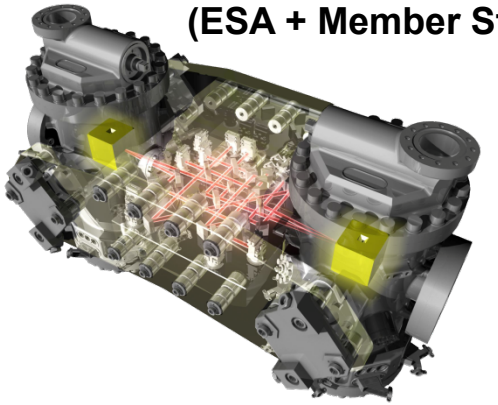
LISA Pathfinder Background (Launching in 2015!)

- **LISA Pathfinder (LPF) is an ESA-led dedicated technology demonstrator mission for LISA-like space-based gravitational-wave observatories.**
  - Key goal: demonstrate drag-free test masses as an inertial reference for future gravitational wave missions.
  - Validates disturbance error budget for LISA-like missions
- **LPF components**
  - Spacecraft: Provided by ESA, includes cold-gas microthrusters and drag-free control software
  - LISA Technology Package (LTP): A European payload composed of a full drag-free system
  - ST7 Disturbance Reduction System (ST7-DRS): A NASA payload (JPL)

LPF Spacecraft (ESA)



LTP (ESA + Member States)

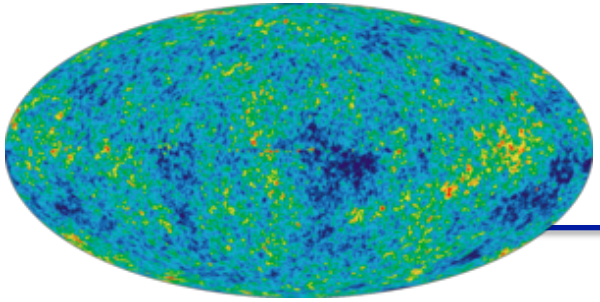


ST7-DRS (JPL)

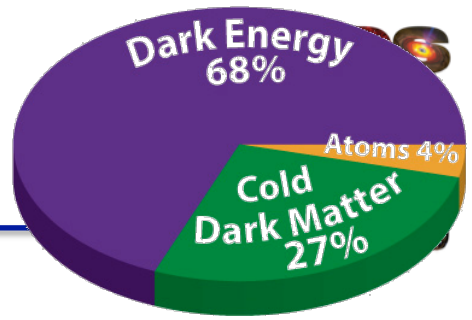
LISA Pathfinder Status

- **LPF Current Status: Late stages of integration with *launch expected in July 2015*.**
  - Preparations for mission and science operations underway with numerous exercises/ test campaigns planned for the coming year

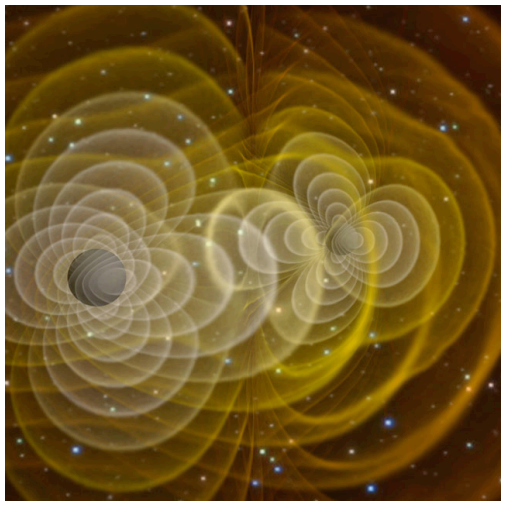
Transfer Orbit Thermal Test

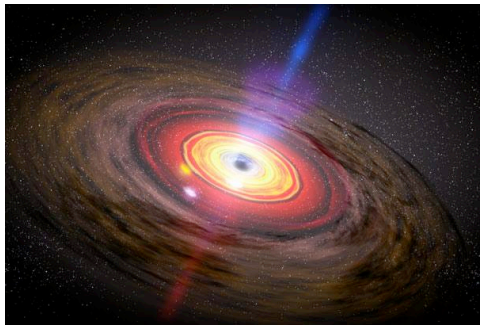


Physics of the Cosmos Science Objectives



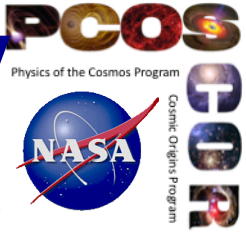
- Expand our knowledge of dark energy
- Precisely measure the cosmological parameters governing the evolution of the universe and test the inflation hypothesis of the Big Bang
- Test the validity of Einstein's General Theory of Relativity and investigate the nature of spacetime
- Understand the formation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





- **Explore the behavior of matter and energy in its most extreme environments**

Explore the behavior of matter and energy in its most extreme environments



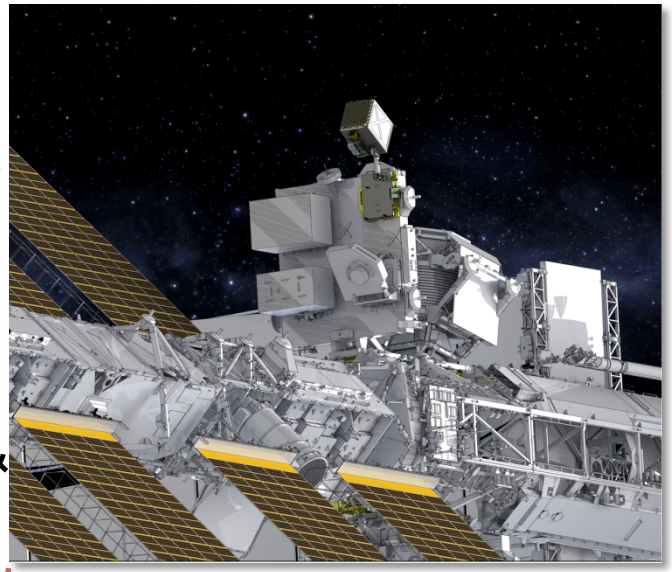
- **The only formal activity within the PCOS portfolio in this area is the operating mission, Fermi**
- **Related missions in development (under the PCOS science theme):**
  - NICER
  - ISS-CREAM
- **IMMEDIATELY after this: Angela Olinto and Liz Hays**

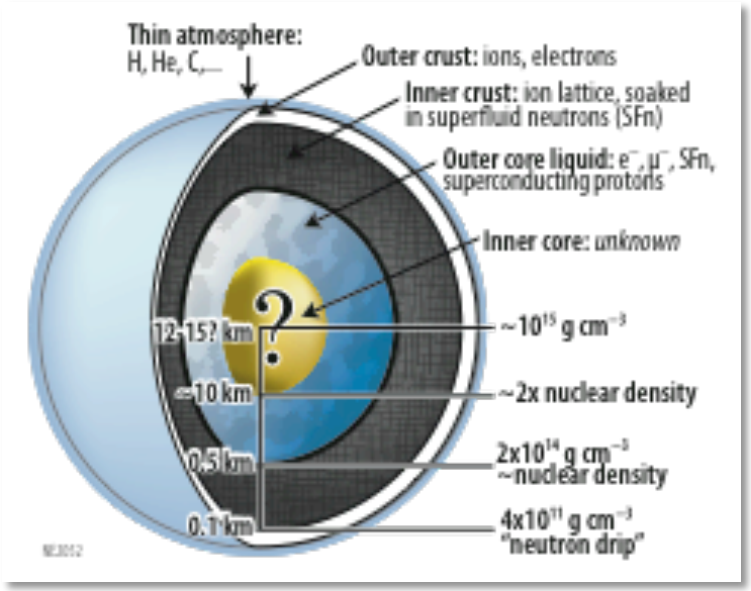
GeV results continue to pour in

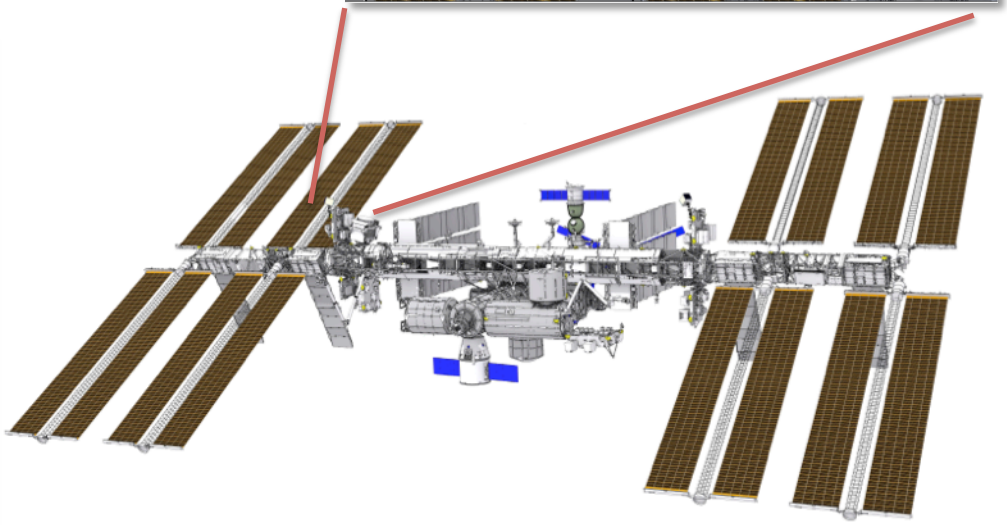
- **Note: GeV results have swept the last four AAS Rossi prizes and won the 2012 APS Panofsky prize (Bill Atwood)**
- **Recent discovery of record-setting (brightest) gamma ray burst by Fermi April 27, 2013**

NICER
(Neutron star Interior Composition ExploreR)

- *PI: Keith Gendreau, NASA GSFC*
- ***Science:*** Understanding ultra-dense matter through observations of neutron stars in the soft X-ray band
- ***Launch:*** August 2016, SpaceX-12 resupply
- ***Instrument:*** X-ray (0.2–12 keV) "concentrator" optics and silicon-drift detectors. GPS position & absolute time reference



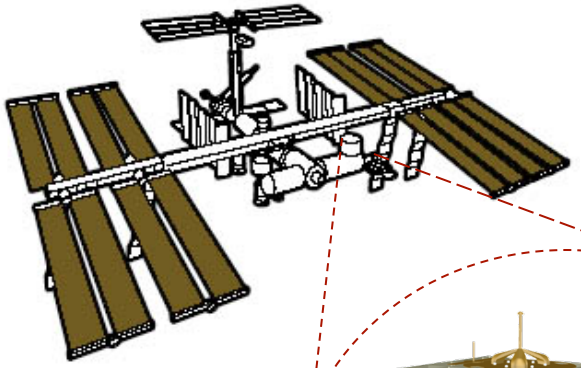


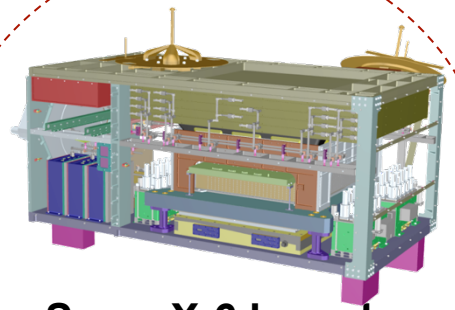


ISS-CREAM (CREAM for the ISS)

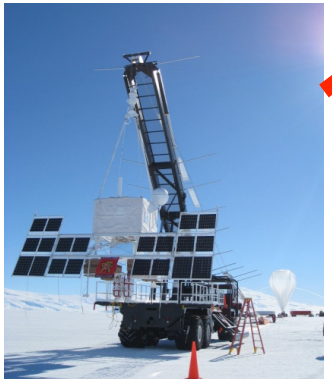
Cosmic Ray Energetics And Mass (CREAM)

- P.I.: Eun-suk Seo, Univ. of Maryland
- CREAM measures the energy spectra from 10^{12} to $>10^{15}$ eV over the elemental range from protons to iron.
- Building on the success of the balloon flights, the payload is being transformed for accommodation on the ISS (based on an APRA proposal).
- It extends the energy reach of direct measurements of cosmic rays to the highest energy possible to probe their origin, acceleration and propagation.





SpaceX-6 launch December 2014



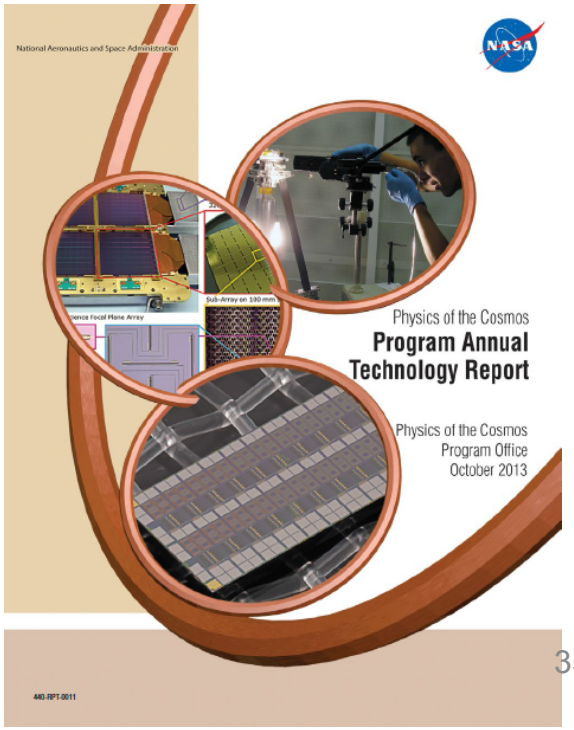
Increase the exposure by an order of magnitude

How can you interact with NASA's Physics of the Cosmos program?

PCOS community activities

- Encourage your finishing students and early-career postdocs to apply for the Einstein fellows' program
  - Einstein Fellows hold their appointments at a Host Institution in the U.S. for research that is broadly related to the science goals of the NASA Physics of the Cosmos program.
- The PhysPAG provides input on technology needs to the PCOS program office that are fed into the PCOS Annual Technology Report (PATR) each year.

Laura Blecha, 2012 Fellow



Keeping up with PCOS

- **Sign up for email announcements, or for a Science Interest Group**

National Aeronautics and Space Administration

Physics of the Cosmos Newsletter

February 2014 Vol. 4 No. 1

Welcome to 2014 from the PCOS Program Office

Mansoor Ahmed, *PCOS Program Manager*
Ann Hornschemeier, *PCOS Chief Scientist*

Welcome to the first 2014 Physics of the Cosmos program newsletter. You will find, as compared to the last edition in August 2013, that this is a shorter read! The theme for the last newsletter was "PCOS science and technology that is not in the PCOS program" and included updates on suborbital and Explorer activities. If you have suggested areas of focus for a future PCOS newsletter, please contact us (Ann Hornschemeier, *PCOS Chief Scientist* and Mansoor Ahmed, *PCOS Program Manager*) with your suggested themes/ideas.

Contents

The highlights of this newsletter include the European Space Agency's selections of themes for their next large space missions, the L2 and L3 launch opportunities. Please see the article by Paul Hertz on this topic as well as related articles on

NASA Sees 'Watershed' Cosmic Blast in Unique Detail

On April 27, 2013 a blast of light from a dying star in a distant galaxy became the focus of astronomers around the world. The explosion, known as a gamma-ray burst and designated GRB 130427A, tops the charts as one of the brightest ever seen.

A trio of NASA satellites, working in concert with ground-based robotic telescopes, captured never-before-seen details that challenge current theoretical understandings of how gamma-ray bursts work.

Gamma-ray bursts are the most luminous explosions in the cosmos, thought to be triggered when the core of a massive star runs out of nuclear fuel, collapses under its own weight, and forms a black hole. The black hole then drives jets of particles that drill all the way through the collapsing star and erupt into space at nearly the speed of light. The most energetic emission, with billion-electron-volt (GeV) gamma rays, is thought to arise when the jet slams into its surroundings, forming an external shock wave.

The Gamma-ray Burst Monitor (GBM) aboard NASA's Fermi Gamma-ray Space Telescope captured the initial wave of gamma rays from GRB 130427A. In its first three seconds alone, the "monster burst" proved brighter than almost any burst previously observed.

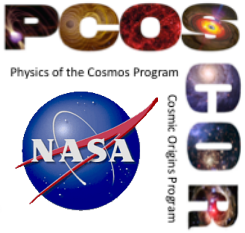
"The spectacular results from Fermi GBM show that our widely accepted picture of MeV gamma rays from internal shock waves is woefully inadequate," said Rob Preece, a Fermi team member at the University of Alabama in Huntsville who led the GBM study.

Read the full article at http://www.nasa.gov/content/goddard/nasa-sees-watershed-cosmic-blast-in-unique-detail/#.Us9IBfZQ38Q

This incredible discovery made the cover of Science magazine, accessible at this link: http://www.sciencemag.org/content/343/6166.cover-expansion

As shown on the cover of the January 3, 2014 issue of Science magazine, this image represents an artist's conception of gamma-ray burst (GRB) 130427A, one of the brightest and longest-lived GRBs observed to date. GRBs such as this one occur when the core of a massive star runs out of nuclear fuel, collapses, and forms a black hole that drives a powerful jet of plasma traveling close to the speed of light. Image credit: NASA/Fermi and Sonoma State University/Aurore Simonnet

Upcoming PCOS/PhysPAG Community Interaction Opportunities



- **Full list of upcoming SIG meetings on website.**
- **August 2014, HEAD meeting in Chicago**
  - PhysPAG/PCOS Town Hall
- **January 2015 Seattle AAS**
  - Half-day PhysPAG meeting
  - XRSIG, CosmicSIG, GammaSIG meetings
  - Reports from NASA's Program Analysis Groups
  - PCOS Table in NASA HQ SMD area
- **April 2015, APS (DAP) meeting in Baltimore, MD**
  - CosmicSIG meeting
  - Other activities, TBD
- **MORE INFO: pcos.gsfc.nasa.gov/physpag**

THANK YOU

Ann.Hornschemeier@nasa.gov

pcos.gsfc.nasa.gov

(Sign up for email list at "PCOS News and Announcements tab)