AAAC-Related Programs in the NSF/Physics Division

AAAC Meeting

November 17, 2014

Jean Cottam & Jim Whitmore

Program Directors for Particle Astrophysics

Marc Sher

Program Director for Particle Astrophysics and Cosmology Theory

Pedro Marronetti & Mark Coles

Program Directors for Gravitational Physics

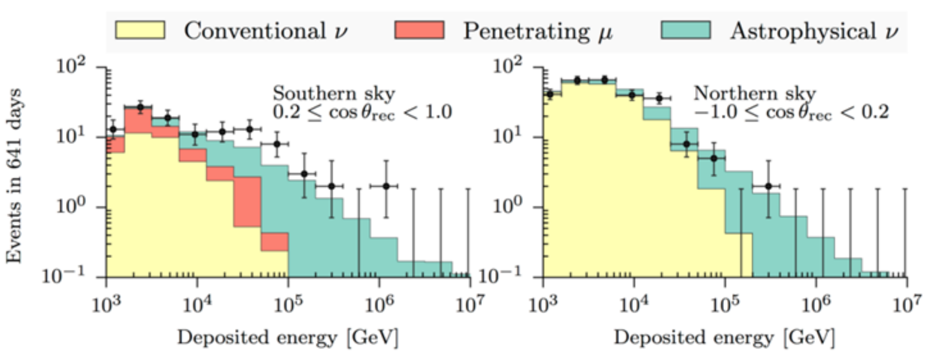
PA Highlights: HAWC

- The HAWC gamma ray observatory on the Sierra Negra volcano in Mexico is being built through joint funding of NSF, DOE and CONACyT in Mexico. HAWC is an Air Shower Detector with 250-300 Water Cherenkov Detector tanks covering 20,000 m^2 at 4100 m in Sierra Negra Volcano, Mexico. HAWC has been operational since August 2013 (as a 111-136 tank array) even as construction of the entire array continues. Tank construction is proceeding at approximately 3-4 tanks per week. HAWC electronics and software development continues on schedule. As of June 2014 they had 250 tanks constructed, 191 filled with water and 137 included in the data stream.

PA Highlights: IceCube

- *Deposited energy spectra from the Northern and Southern skies with the best-fit combination of atmospheric and astrophysical contributions. Below 3 TeV, the events observed from the Northern sky are adequately explained by atmospheric neutrinos. In the same energy range in the Southern sky, penetrating atmospheric muons account for the remaining events.*
- *Above 10 TeV, an extra component is required to account for the observed high-energy events, especially those in the southern sky. Since atmospheric neutrinos of any kind are often vetoed by accompanying muons, the excess is best explained by astrophysical neutrinos. Unlike atmospheric neutrinos, astrophysical neutrinos always arrive without accompanying muons.*
- *From these data, they derive the strongest upper limit yet on the flux of neutrinos from charmed-meson decay in the atmosphere: 1.52 times the benchmark theoretical prediction used in previous IceCube results at 90% confidence.*

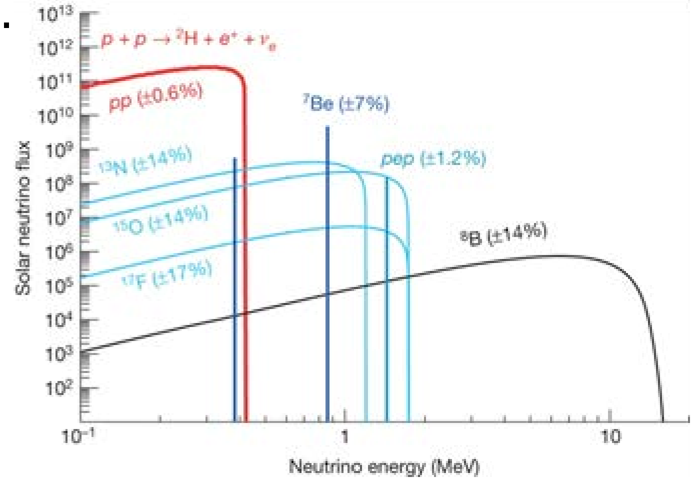
The “north" and “south" denote halves of the celestial sphere as observed from the Geographic South Pole rather than terrestrial hemispheres. The majority of atmospheric neutrinos observed from the northern sky are produced in air showers that reach ground level at points in the southern terrestrial hemisphere.



PA Highlights: Solar Neutrinos (Borexino)

- For the first time, a measurement of the solar power in the instant of its production has become possible. The results of this direct measurement by the Borexino collaboration were published recently in Nature.
- Until now, all solar energy measurements were based on light from the Sun's photosphere – the familiar sunlight which lights up our skies and warms the Earth. But the energy carried by this sunlight was produced in solar fusion reactions about 100,000 years ago – the average time for energy to percolate from the central regions of the Sun and reach its surface.
- Comparison between the Borexino measurement, performed in the INFN Gran Sasso underground laboratory, and those of the Sun's radiant energy reveals that the energy released today at the center of the Sun is exactly the same as that produced 100,000 years ago.

In the core of the Sun, energy is released through sequences of nuclear reactions that convert hydrogen into helium. The primary reaction is thought to be the fusion of two protons with the emission of a low-energy neutrino. These so-called ***pp* neutrinos** constitute nearly the entirety of the solar neutrino flux, vastly outnumbering those emitted in the reactions that follow.



PA Highlights: IceCube, LIGO and VIRGO

- “Multimessenger Search for Sources of Gravitational Waves and High-Energy Neutrinos: Results for Initial LIGO-Virgo and IceCube”: they report the results of a multimessenger search for coincident signals from the LIGO and Virgo gravitational-wave observatories and the partially completed IceCube high-energy neutrino detector, including periods of joint operation between 2007-2010. They find no significant coincident events, and use the search results to derive upper limits on the rate of joint sources for a range of source emission parameters.

Physics Division Allocation for FY 2014

- Approximately 2% for Operations - Panels, IPA Appointments, IPA Travel, M&S
- Approximately 30% for M&O for Facilities
  - ATLAS and CMS, IceCube, LIGO, NSCL
- Approximately 8% for Physics Frontiers Centers
  - Currently Ten
- Approximately 3% for Education and Broadening Participation
  - REU Sites, LIGO Education Center, QuarkNet
- Leaves 57% ($151.8 M) to Cover Six Major Areas of Physics
  - Experimental and Theoretical

“Physics of the Universe” Funding Details

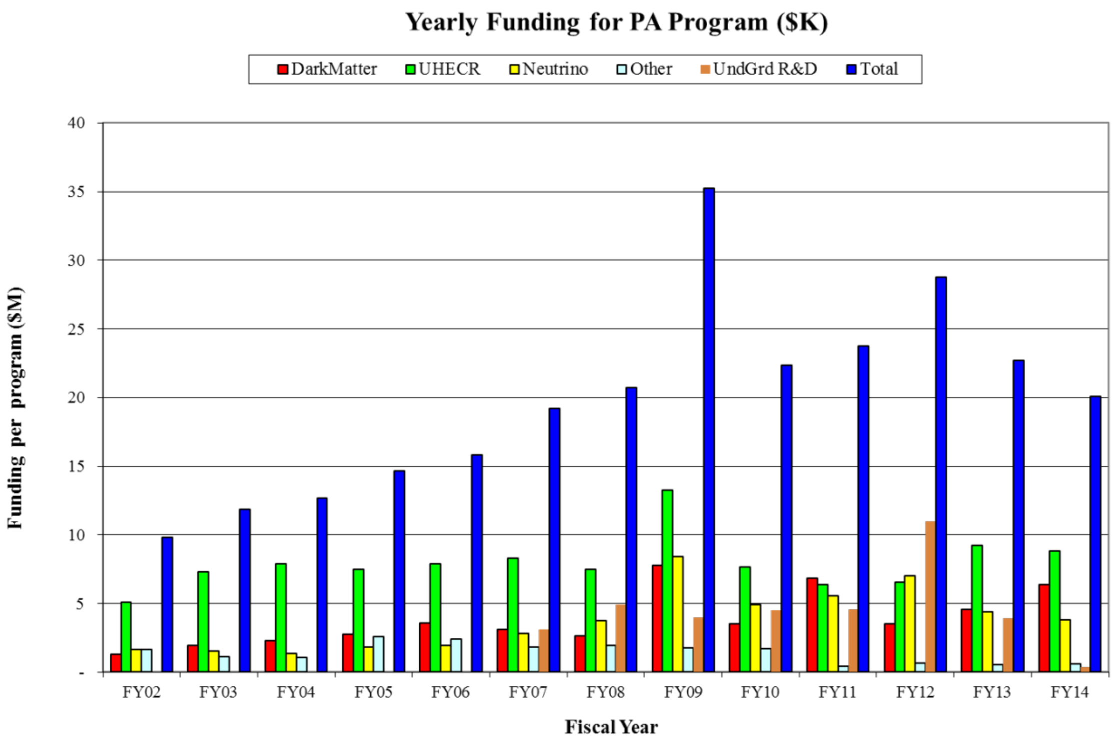
Experimental Particle Astro

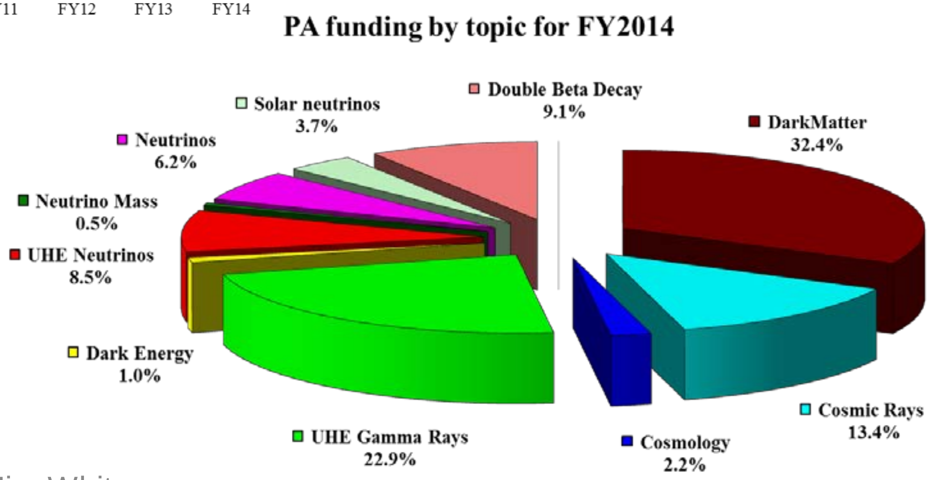
Experimental Gravitational Phys

(in M$)	FY 2008 Actuals	FY 2009 Actuals	FY 2010 Actuals	FY 2011 Actuals	FY 2012 Actuals	FY 2013 Actuals	FY 2014 Actuals
Particle Astrophysics	15.8	31.2	17.9	9.7	11.5	12.0	11.2
IceCube Ops	1.5	2.2	2.2	3.5	3.5	3.5	3.5
DUSEL Planning	2.0	22.0	28.9	10.2			
Underground R&D	5.0	9.6	4.6	6.0	11.0	3.9	0.4
Underground Physics				8.4	6.3	6.8	8.5
THY - Astro/Cosmo	~1.2	~1.9	~1.3	~1.4	1.1	0.9	1.5
THY - Gravitational Phys	3.8	6.9	4.7	3.9	4.0	4.1	5.2
Exp. Gravitational Phys	2.3	3.3	2.2	2.4	2.4	2.2	2.3
LIGO Research Support	7.4	12.7	8.4	8.7	8.6	7.5	6.8
LIGO M&O	29.5	30.3	28.5	30.3	30.4	30.5	36.4
Physics Frontier Centers	6.3	5.9	5.9	6.0	6.0	6.0	6.0
Total	73.8	126.0	104.6	90.5	84.8	77.4	81.8
Total Physics Division	285.0	377.6	307.8	280.3	277.4	247.4	261.6
% of Physics Division	25.9%	33.4%	34.0%	32.3%	30.6%	31.3%	31.3%
Adv LIGO MREFC	32.8	51.4	46.4	23.6	21.0	15.2	14.9

** FY2009 includes ARRA funding

Particle Astrophysics Program Funding





National Science Foundation Budget

National Science Foundation
Summary Tables
FY 2015 Request to Congress
(Dollars in Millions)

				FY 2015 Request over:			
				FY 2013 Actual		FY 2014 Estimate	
NSF by Account	FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	Amount	Percent	Amount	Percent
BIO	$679.21	$721.27	$708.52	$29.31	4.3%	-$12.75	-1.8%
CISE	858.13	894.00	893.35	35.22	4.1%	-0.65	-0.1%
ENG	820.18	851.07	858.17	37.99	4.6%	7.10	0.8%
Eng Programs	*658.84*	*691.68*	*693.18*	*34.34*	*5.2%*	*1.50*	*0.2%*
SBIR/STTR	*161.34*	*159.39*	*164.99*	*3.65*	*2.3%*	*5.60*	*3.5%*
GEO	1,273.77	1,303.03	1,304.39	30.62	2.4%	1.36	0.1%
MPS	1,249.34	1,299.80	1,295.56	46.22	3.7%	-4.24	-0.3%
SBE	242.62	256.85	272.20	29.58	12.2%	15.35	6.0%
IIA	434.28	481.59	473.86	39.58	9.1%	-7.73	-1.6%
U.S. Arctic Research Commission	1.39	1.30	1.41	0.02	1.4%	0.11	8.1%
Research & Related Activities	**$5,558.88**	**$5,808.92**	**$5,807.46**	**$248.58**	**4.5%**	**-$1.46**	**0.0%**
Education & Human Resources	**$834.62**	**$846.50**	**$889.75**	**$55.13**	**6.6%**	**$43.25**	**5.1%**
Major Research Equipment & Facilities Construction	**$196.49**	**$200.00**	**$200.76**	**$4.27**	**2.2%**	**$0.76**	**0.4%**
Agency Operations & Award Management	**$293.50**	**$298.00**	**$338.23**	**$44.73**	**15.2%**	**$40.23**	**13.5%**
National Science Board	**$4.10**	**$4.30**	**$4.37**	**$0.27**	**6.7%**	**$0.07**	**1.6%**
Office of Inspector General	**$13.17**	**$14.20**	**$14.43**	**$1.26**	**9.5%**	**$0.23**	**1.6%**
OIG FY 2013 ARRA Actual Obligation	$1.16						
Total, NSF	**$6,901.91**	**$7,171.92**	**$7,255.00**	**$353.09**	**5.1%**	**$83.08**	**1.2%**

Totals may not add due to rounding.

MPS/PHY Budget

MPS Funding
(Dollars in Millions)

	FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	Change Over FY 2014 Estimate Amount	Percent
Astronomical Sciences (AST)	$232.17	$239.06	$236.24	-$2.82	-1.2%
Chemistry (CHE)	229.39	235.79	237.23	1.44	0.6%
Materials Research (DMR)	291.09	298.01	298.99	0.98	0.3%
Mathematical Sciences (DMS)	219.02	225.64	224.40	-1.24	-0.5%
Physics (PHY)	250.45	266.30	263.70	-2.60	-1.0%
Office of Multidisciplinary Activities (OMA)	27.22	35.00	35.00	-	-
Total, MPS	**$1,249.34**	**$1,299.80**	**$1,295.56**	**-$4.24**	**-0.3%**

Totals may not add due to rounding.

PHY Funding
(Dollars in Millions)

	FY 2013 Actual	FY 2014 Estimate	FY 2015 Request	Change Over FY 2014 Estimate Amount	Percent
Total, PHY	**$250.45**	**$266.30**	**$263.70**	**-$2.60**	**-1.0%**
Research	**164.72**	**165.99**	**159.35**	**-6.64**	**-4.0%**
CAREER	7.68	7.34	7.34	-	-
Centers Funding (total)	1.16	0.02	0.02	-	-
Nanoscale Science & Engineering	1.16	0.02	0.02	-	-
Education	**5.31**	**6.98**	**5.97**	**-1.01**	**-14.5%**
Infrastructure	**80.42**	**93.33**	**98.38**	**5.05**	5.4%
IceCube	3.45	3.45	3.45	-	-
Large Hadron Collider (LHC)	18.00	17.37	18.00	0.63	3.6%
Laser Interferometer Grav. Wave Obs.	30.50	36.43	39.43	3.00	8.2%
Nat'l Superconducting Cyclotron Lab.	21.50	22.50	22.50	-	-
Research Resources	6.97	13.58	15.00	1.42	10.5%

Totals may not add due to rounding.

Major Undertakings in FY 2014 in PHY

- Launch of New Academic-Based Program in Accelerator Science
- Initiation of Formal Midscale Funding Program
- Initiation of Funding for Upgrades on LHC Detectors ATLAS, CMS, and LHCb
- Selection of Dark Matter G2 Experiments in Coordination with DoE
- First Steps in NSF Response to P5 Report

Accelerator Science Program

FY2014 Portfolio:

- 60 proposals, 52 projects (some proposals were collaborative)
- Request total $70M
- 12 awards $9M

	Amount ($)	No. awards
Beam Dynamics	520,397	2
Plasma	1,469,900	3
Sources	1,006,910	2
SRF	4,522,786	2
Education	700,000	1
Other	720,000	2
Total	8,939,993	

New in FY 2014: Mid-Scale Instrumentation

One of the most critical needs of research projects funded through the Physics Division is that of having cutting-edge instrumentation that enables investigators to remain competitive in a rapidly-changing scientific environment.

- The Physics Division has established a Mid-Scale Instrumentation Fund.
  - Dear Colleague Letter *NSF 13-118*: "Announcement of Instrumentation Fund to Provide Mid-Scale Instrumentation for FY2014 Awards in Physics Division"
- This is not a separate program to which investigators can apply directly. PIs should request funding for specialized equipment as part of a regular proposal to a disciplinary program in the Division. The Program Officer can then request funds be provided through the Mid-Scale Instrumentation Fund.

Mid-Scale Instrumentation

- Resources from the Mid-Scale Instrumentation Fund can be used for off-the-shelf purchases or for construction of specialized equipment.
- Mid-Scale Instrumentation Fund resources are intended to be one-time investments in the research project and require that the project have a well-defined beginning and end.
- Merit reviews proceed through the base programs or special reviews.
- Funding Levels begin at TPC of ~$4.0M and can go up to TPC of ~$20.0M.
  - Prior year examples: formerly called the APPI Program
  - Has provided significant instrumentation and development for PA experiments: $27.5M over the period FY08 – FY14.
  - Examples HAWC, XENON1T, Double Chooz, SPT, DA-50, MJD, SCDMS…

Mid-Scale awards for FY14: Phase-I Upgrades for ATLAS and CMS and the LHCb Upgrade:

- $28.9M over the period FY14 – FY18.

P5 Recommendations: Direct Dark Matter

"The experimental challenge of discovery and characterization of dark matter interactions with ordinary matter requires a multi-generational suite of progressively more sensitive and ambitious direct detection experiments. This is a highly competitive, rapidly evolving field with excellent potential for discovery. The second-generation direct detection experiments are ready to be designed and built, and should include the search for axions, and the search for low-mass (<10 GeV) and high-mass WIMPs. Several experiments are needed using multiple target materials to search the available spin-independent and spin-dependent parameter space. This suite of experiments should have substantial cross-section reach, as well as the ability to confirm or refute current anomalous results. Investment at a level substantially larger than that called for in the 2012 joint agency announcement of opportunity will be required for a program of this breadth."

Recommendation 19: Proceed immediately with a broad second-generation (G2) dark matter direct detection program with capabilities described in the text. Invest in this program at a level significantly above that called for in the 2012 joint agency announcement of opportunity.

U.S. Portfolio of G2 Dark Matter Investments

The U.S. portfolio of G2 dark matter investments will include the following:

- **LUX-Zeplin (LZ)** and **Super CDMS – SNOLAB** for their collective sensitivity to both low and high-mass WIMPS
- **ADMX-Gen2** to search for Axions
- Coordinated efforts in **R&D** to test and develop a broad range of technologies for future experiments

Budgets and project timelines are still being determined and will depend on the final budget allocations. The agencies are working with the project leadership to implement the projects expeditiously. Funding for ADMX-Gen2 began in FY2014. Funding for LZ and SuperCDMS-SNOLAB is expected to begin in FY2015.

No dedicated solicitations for R&D proposals are planned. Proposals should be submitted under the general program solicitations. R&D funding will be coordinated between the two agencies.

PHY comments on CTA & CMB

CTA:

- NSF/PHY informed them that it could only be funded via PHY Mid-Scale Funding and noted that at the requested level it would not fit with the anticipated PHY budget

CMB:

- NSF/PHY and NSF/PLR attended the DOE-HEP review on SPT-3G at ANL; PHY is funding part of SPT operations and some parts of SPT-3G (with PLR and AST)
- Planning further coordination activities among offices that fund CMB experiments

NSF Response to Recommendations of P5

- MPSAC Subcommittee on NSF Response to Strategic Plan for Particle Physics Outlined in the May 2014 Particle Physics Project Prioritization Panel Report
  - Full Text of Charge can be Found at: http://www.nsf.gov/mps/advisory.jsp
- The committee is **not** expected to revisit the P5 charge, priorities, or conclusions. Rather, the committee is expected to focus on the balance of NSF investments [in particle physics] in light of the P5 report.

- Based on the science drivers identified in the P5 report, how should the NSF target its investments in such a way that they maximize the NSF impact and visibility?
- Should the Physics Division target specific areas or should it invest broadly?
- What criteria should the Physics Division use to balance support between small-scale, mid-scale and large projects?
- How should the Division of Physics define a unique role in areas of common interest with DOE?

NSF Response to Recommendations of P5

In response to P5, the Division of Physics is considering the following scenario for major investments in the next 10 years:

- An investment in LHC Phase 2 Upgrades, which could range from the midscale to the MREFC level, and Midscale investments in other scientific priority areas identified by P5.
- In the context of P5 and NSF priorities as elaborated in its Strategic Plan*, this subcommittee is asked to assess this scenario and how it contributes to and impacts the Physics Division mission.
- This analysis should be undertaken assuming both a budget that is flat at the FY 2014 level and a budget at constant FY2014 dollars for particle physics funding over the 10-year period of FY 2015 through FY 2024.

*http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf14043

Timeline:

- Charge Delivered to Panel: August, 2014
- Interim Report Given to MPSAC: November 2014 MPSAC Meeting
- Final Report Due to MPSAC: January 2015 MPSAC Meeting

Subcommittee Chair: Young-Kee Kim, University of Chicago

Backup Slides

Division of Physics

Denise Caldwell
Director

Brad Keister
Deputy Director

Facilities

- Large Hadron Collider — *Saul Gonzalez*
- IceCube — *Jim Whitmore*
- LIGO — *Mark Coles*
- NSCL — *Gail Dodge*

Experiment

- Atomic, Molecular, Optical, and Plasma — *John Gillaspy, Steve Gitomer*
- Elementary Particle Physics — *Saul Gonzalez, Randy Ruchti, Jim Shank*
- Particle Astrophysics — *Jean Cottam-Allen, Jim Whitmore*
- Gravitational Physics — *Mark Coles, Pedro Marronetti*
- Nuclear Physics — *Gail Dodge*
- Physics of Living Systems — *Krastan Blagoev*
- Accelerator Science — *Saul Gonzalez*

Theory

- Atomic, Molecular, and Optical — *Ann Orel*
- Elementary Particle Physics, Astrophysics, and Cosmology — *Marc Sher*
- Mathematical Physics — *Earle Lomon*
- Gravitational Physics — *Pedro Marronetti*
- Nuclear Physics and Nuclear Astrophysics — *Bogdan Mihalia*
- Physics of Living Systems — *Krastan Blagoev*
- Accelerator Science — *Saul Gonzalez*

Cross-cutting

- Physics Frontier Centers — *Jean Cottam-Allen*
- Education and Interdisciplinary Research — *Kathy McCloud*
- Physics at the Information Frontier — *Bogdan Mihalia, Ann Orel, Jim Shank*
- Physics Instrumentation

PA Program Scope & Currently Supported Projects

- Direct Dark Matter Detection – WIMP and non-WIMP experiments

  SuperCDMS, XENON, LUX, DArkSide, COUPP, PICASSO, DRIFT, ADMX-HF, DM-Ice

- Indirect Dark Matter Detection

  VERITAS, HAWC, IceCube

- Cosmic Ray, Gamma Ray, and UHE Neutrino Observatories

  IceCube, VERITAS, HAWC, Auger, Telescope Array, ARA, ARIANNA

- Dark Energy

  LSST

- Cosmic Microwave Background

  SPT, ACT-Pol (w/ Gravity)

- Neutrino Properties

  Double Chooz, Daya Bay, CUORE, MJD, SuperNEMO, EXO, Project 8

- Solar Neutrinos

  Borexino, HALO, SNEWS

Polar Programs

AST

Theory Program Scope & Currently Supported Projects

- Dark Matter - direct detection
  - Limits of direct detection experiments due to neutrino backgrounds
  - Flavor symmetry effects on signatures
  - Studies of DM interactions with various nuclei
  - Computational resources for dark matter density simulations
- Dark Matter - indirect detection (decay or annihilation of DM)
  - Studies of photons and positrons from dwarf galaxies (such as LMC,SMC)
  - Cosmic ray flux predictions as backgrounds for indirect DM signals.
  - Effects of cosmic variance on astrophysical indirect DM signals
  - Effects of resonant DM annihilation and effects from various DM candidates
- Dark Matter - galactic structure
  - Simulations of various DM candidates
  - Search for microstructures due to DM
- Inflation
  - Non-Gaussian perturbations in inflation and effects on CMB and Large Scale Structure
  - Alternative models to inflation
- Cosmic Strings
  - Effects on CMB and Large Scale Structure
  - Observational signatures
  - Theoretical evolution of string networks.

Gravitational Physics Programs

The Gravitational Physics program supports research at the frontiers of science aimed towards answering questions about the nature of space and time, the gravitational attraction at atomically small and cosmological large distances and the use of gravitational waves to explore the universe.

- The **Experimental Gravitational Physics** program supports research that includes tests on the inverse distance square law of gravitational attraction, Lorentz invariance and Equivalence Principle as well as the direct detection of gravitational waves. This program oversees the management of the construction, commissioning, and operation of the Laser Interferometer Gravity Wave Observatory (LIGO), and provides support for LIGO users and other experimental investigations in gravitational physics and related areas. This includes tasks that range from instrument science, data analysis and detector characterization to source population calculations and the connection between the gravitational waves and the electromagnetic and neutrino signatures of astrophysical events.

- The **Theoretical Gravitational Physics** program supports research on classical and quantum gravity theory, including gravitational wave source simulations and other phenomena associated with strong field gravity and the interface between gravitation and quantum mechanics. This includes formulating new approaches for theoretical, computational, and experimental research that explore the fundamental laws of physics and the behavior of physical systems and, in some cases, interpreting the results of experiments. The effort also includes a considerable number of interdisciplinary grants.

Gravitational Physics Scope & Currently Supported Projects

Theory

- Structure of General Relativity (GR)

  Mathematical GR, Classical Field Theory, Properties of horizons and singularities, Stability of Einstein Field Equations (EFE) solutions

- Alternative Theories of Gravity

  Extensions of GR, Scalar-Tensor Theories, Testing of Alternative Theories using current and future Gravitational Wave (GW) detectors

- Unified Theories

  Unification of Quantum Mechanics and Gravity: Loop Quantum Gravity (not String Theory), Approximations to Unified Theories, Semi-classical field theories

- Astrophysics

  Numerical Relativity (NR) as a tool to find solutions of the EFE with astrophysical relevance. Modeling of black holes, neutrons stars, quark stars (in binaries or in isolation). Generation of GW signals for LIGO searches

Experiments

- Short Range Experiments

  Deviations from Inverse Square Law, Weak Equivalence Principle tests, Search for Lorentz Symmetry violations

- Long Range Experiments

  Lunar Laser Ranging, Detection of relic GWs in the Cosmic Microwave Background (Atacama Cosmology Telescope)

- LIGO
  - Instrument Science: Mirror Coatings, Laser Interferometry, Squeezed Light, Noise Isolation
  - Data Analysis: Sky Localization, Connection with EM and Particle observations (Multi-messenger Astronomy), Search Algorithm Development, GW Template Construction. GW Sources Synthesis
  - Outreach: LIGO Science Education Center (Livingston, LA)

New in FY 2014: Dark Matter Solicitation

The current generation of direct dark matter experiments should all achieve their projected sensitivities and complete operations within the next few years. The more sensitive, "second generation" direct detection experiments, will then be required to either search with increased sensitivity or to measure in detail the detected dark matter.

- These next generation experiments will be selected through a solicitation with funding beginning in FY 2014.
  - Solicitation *NSF 13-597: “Support for Construction of Direct Detection Dark Matter Experiments in Particle Astrophysics”*
- NSF and DOE are closely coordinating the review, selection and funding of the awards and subsequent support for the experiments. The resulting program will be joint NSF/DOE portfolio of investments in the next generation of Dark Matter experiments.
- We expect to announce selections shortly.