NSF Physics Division Perspective

Jim Whitmore

AAAC Meeting

25 February 2019

Physics @ NSF

- Status of PA/THY/Grav/Plasma Programs
- CAREER awards
- NSF Funding Opportunities, FY 2019
  - MRI, MREFC, Midscale
- Research Infrastructure
- Program Highlights

Experimental Particle Astrophysics Programs

- Underground Physics (PA): This area supports university research that generally locates experiments in low background environments:
  - IceCube Science Program
  - Underground experiments, reactor neutrinos
  - Neutrino mass measurements
  - Searches for the direct detection of Dark Matter
- Cosmic Phenomena (PA): This area supports university research that uses astrophysical sources and particle physics techniques to study fundamental physics:
  - Astrophysical sources of cosmic rays, gamma rays, neutrinos

Particle Astrophysics	FY 2015	FY 2016	FY 2017	FY 2018
Funding (in $k)	$19,665	$18,253	$18,142	$18,717
Awards issued	26	16	17	25
CAREER awards	2	3	1	1

Program Directors: J. Cottam-Allen, J. Whitmore

Theory Program for Particle Physics

- Particle Theory is essential to the success of the entire Particle Physics mission. We support cutting-edge investigator-driven research in two programs:
  - Theoretical High-Energy Physics
  - Theoretical Particle Astrophysics and Cosmology
- Regular interactions with EPP, PA, Gravity Theory, Nuclear Theory, Astronomy, Materials Research, Mathematical Sciences, etc.
- Supporting individuals, RUI's, and special facilities or initiatives (Aspen Center for Physics, TASI summer school, LHC Theory Initiative, etc.)
- Trend: Dramatic increase in number of proposals—factor of two in last 5 years

Theory Programs	FY 2015	FY 2016	FY 2017	FY 2018
Funding (in $k)	$13,751	$13,232	$13,388	$13,427
Awards issued	28	30	26	32
CAREER awards	2	1	2	1

Program Director: K. Dienes

PHY Funding

(Dollars in Millions)

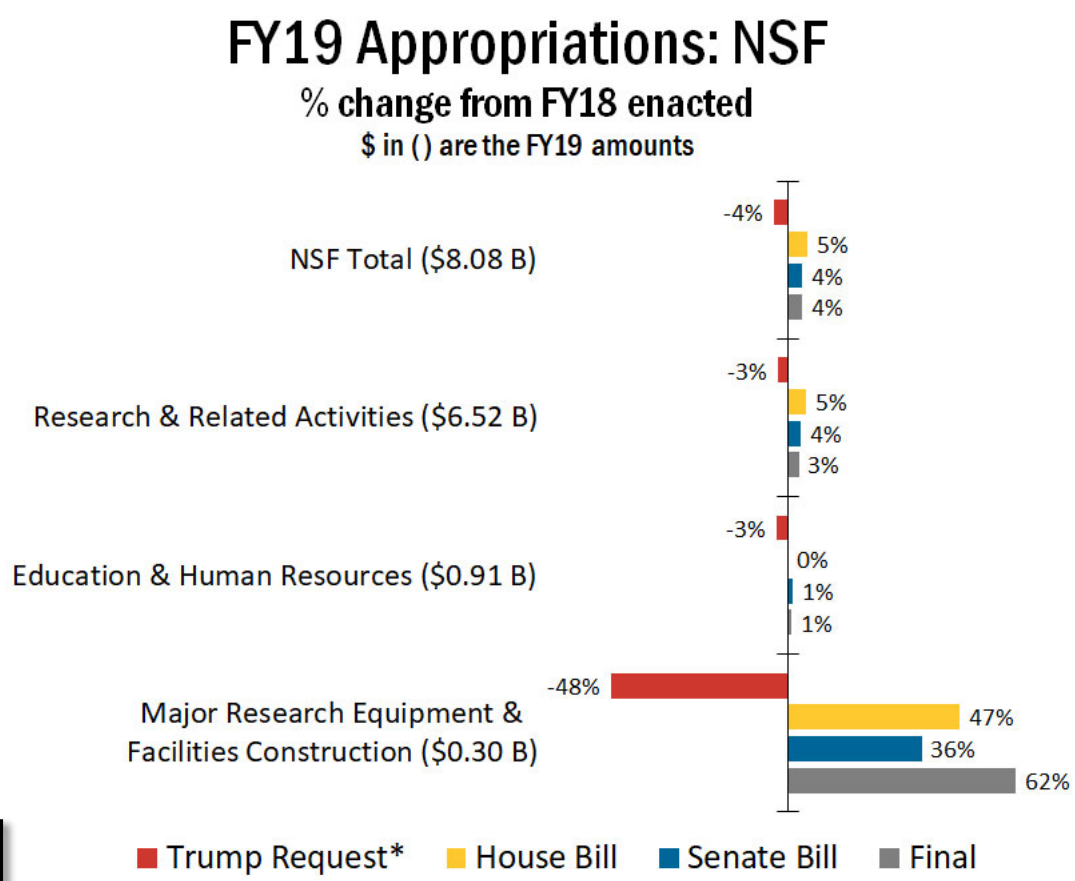
	FY 2017 Actual	FY 2018 (TBD)	FY 2019 Request	Change Over FY 2017 Actual Amount	Change Over FY 2017 Actual Percent
Total	**$281.43**	-	**$266.73**	**-$14.70**	**-5.2%**
Research	**178.57**	-	**159.01**	**-19.56**	**-11.0%**
CAREER	10.04	-	7.30	-2.74	-27.3%
Centers Funding (total)	4.60	-	5.00	0.40	8.7%
STC: Center for Bright Beams	4.60	-	5.00	0.40	8.7%
Education	**5.87**	-	**4.92**	**-0.95**	**-16.2%**
Infrastructure	**96.99**	-	**102.80**	**5.81**	**6.0%**
IceCube Neutrino Observatory (IceCube)	3.50	-	3.50	-	0.0%
Large Hadron Collider (LHC)	16.00	-	16.00	-	0.0%
Laser Interferometer Gravitational Wave Observatory (LIGO)[1]	41.93	-	45.00	3.07	7.3%
National Superconoducting Cyclotron Laboratory (NSCL)	24.00	-	24.00	-	0.0%
Midscale Research Infrastructure	5.85	-	8.00	2.15	36.8%
Pre-construction Planning:					
High-Luminosity LHC Upgrade Planning	5.71	-	6.30	0.59	10.3%

[1]FY 2017 includes one-time supplemental funding of $2.50 million for a critical vacuum repair.

(dollars in millions)

Account	FY 2018 Actual	FY 2019 Request	FY 2019 Enacted
Research and Related Activities	$ 6,380	$ 6,151	$ 6,520
Education and Human Resources	$ 904	$ 873	$ 910
Major Research Equipment & Facilities Construction	$ 186	$ 95	$ 296
Agency Operations & Award Management	$ 329	$ 334	$ 330
National Science Board	$ 4	$ 4	$ 4
Office of Inspector General	$ 15	$ 15	$ 15
Total, NSF	**$ 7,818**	**$ 7,472**	**$ 8,075**

Totals may not add due to rounding



The R&RA account, which funds six research directorates and the Office of Integrative Activities, will rise 3 percent to $6.52 billion.

FY 2019 Solicitation / Funding Opportunities

Physics Solicitation NSF 18-564

Division of Physics: Investigator-Initiated Research Projects (PHY)

PROGRAM SOLICITATION
NSF 18-564

REPLACES DOCUMENT(S):
NSF 17-561

National Science Foundation

Directorate for Mathematical & Physical Sciences
Division of Physics

Full Proposal Deadline(s) (due by 5 p.m. submitter's local time):

November 28, 2018

Fourth Wednesday in November, Annually Thereafter

AMO - Theory and Experiment; Gravitational Physics - Theory and Experiment; LIGO Research Support; Integrative Activities in Physics

December 04, 2018

First Tuesday in December, Annually Thereafter

Nuclear Physics - Theory and Experiment; Elementary Particle Physics - Experiment; Particle Astrophysics - Experiment [Computational Physics: starting December 2019]

December 11, 2018

Second Tuesday in December, Annually Thereafter

Elementary Particle Physics - Theory; Particle Astrophysics and Cosmology – Theory; Physics of Living Systems; Quantum Information Science

Deadlines

All past for FY2019

Current submissions must follow *Proposal & Award and Procedures Guide* (NSF 18-001)

NSF 18-564: Reviews of Long-Duration Activities

The Physics Division solicitation (NSF 18-564) states:

> *"NSF anticipates conducting comparative reviews of selected long-duration efforts on an as-needed basis. The intent of the review is primarily a strategic evaluation aimed at setting long-term scientific priorities… A long-duration effort review report will also provide context for reviews of future proposals from individuals and groups who wish to use associated instrumentation."*

This augments the existing NSF review process with reviews that are conducted on long-duration activities. They are intended to establish priorities for continued investments within the context of a individual program and taking into account the program's resource constraints. As a result of these reviews, NSF support for projects may be phased-out.

This was carried out for PA-CP Projects this year

Research Infrastructure

Mid-Scale Research Infrastructure

Mid-scale Research Infrastructure-1 (Mid-scale RI-1)

PROGRAM SOLICITATION
NSF 19-537

National Science Foundation

Preliminary Proposal Due Date(s) ***(required)*** (due by 5 p.m. submitter's local time):

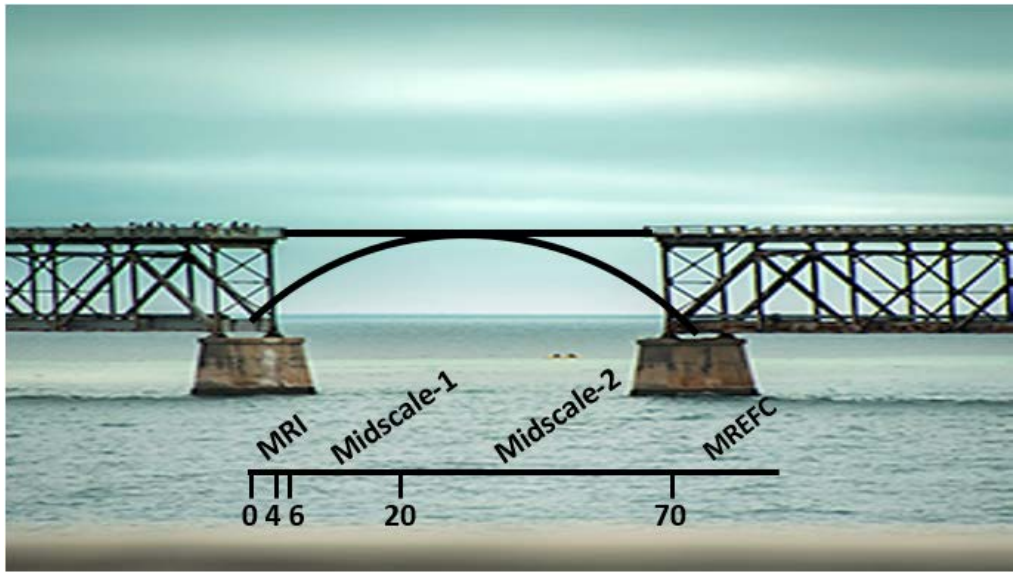
February 19, 2019

Full Proposal Deadline(s) (due by 5 p.m. submitter's local time):

May 20, 2019

By invitation only.

Two tracks:
(1) Design ($600k-$20M)
(2) Implementation ($6M-$20M)



Mid-Scale Research Infrastructure

Mid-scale Research Infrastructure-2 (Mid-scale RI-2)

PROGRAM SOLICITATION
NSF 19-542

National Science Foundation

Letter of Intent Due Date(s) ***(required)*** (due by 5 p.m. submitter's local time):

February 14, 2019

Preliminary Proposal Due Date(s) ***(required)*** (due by 5 p.m. submitter's local time):

March 11, 2019

Full Proposal Deadline(s) (due by 5 p.m. submitter's local time):

August 02, 2019

Submission by invitation only.

The NSF Mid-scale Research Infrastructure-2 Program (Mid-scale RI-2) supports implementation of projects that comprise any combination of equipment, instrumentation, computational hardware and software, and the necessary commissioning and human capital in support of implementation of the same.

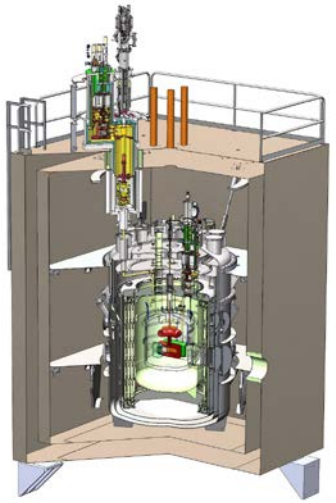
The total cost for Mid-scale RI-2 projects ranges from **$20 million to below** the minimum award funded by the Major Research Equipment and Facilities Construction (MREFC) Program, **currently $70 million.**

NSF 18-564: Physics Midscale

- It funds design and construction *or* acquisition of instrumentation
  - Competed within Physics
  - Pre-award R&D and post-award O&M costs must be covered by the originating program
- Midscale proposals come through the Division solicitation to individual programs and are competitively reviewed
  - Intellectual merit, broader impacts
  - Additional technical reviews for project feasibility, soundness, readiness
  - Availability of funding / opportunity costs to research program (including O&M impacts)

We currently have 8 Midscale projects in four programs (EPP, NP, Gravitational Physics, and PA)

Invested about $60M in the last 5 years



nEDM @ ORNL

LHCb@CERN Upstream Tracker upgrade (credit: CERN)

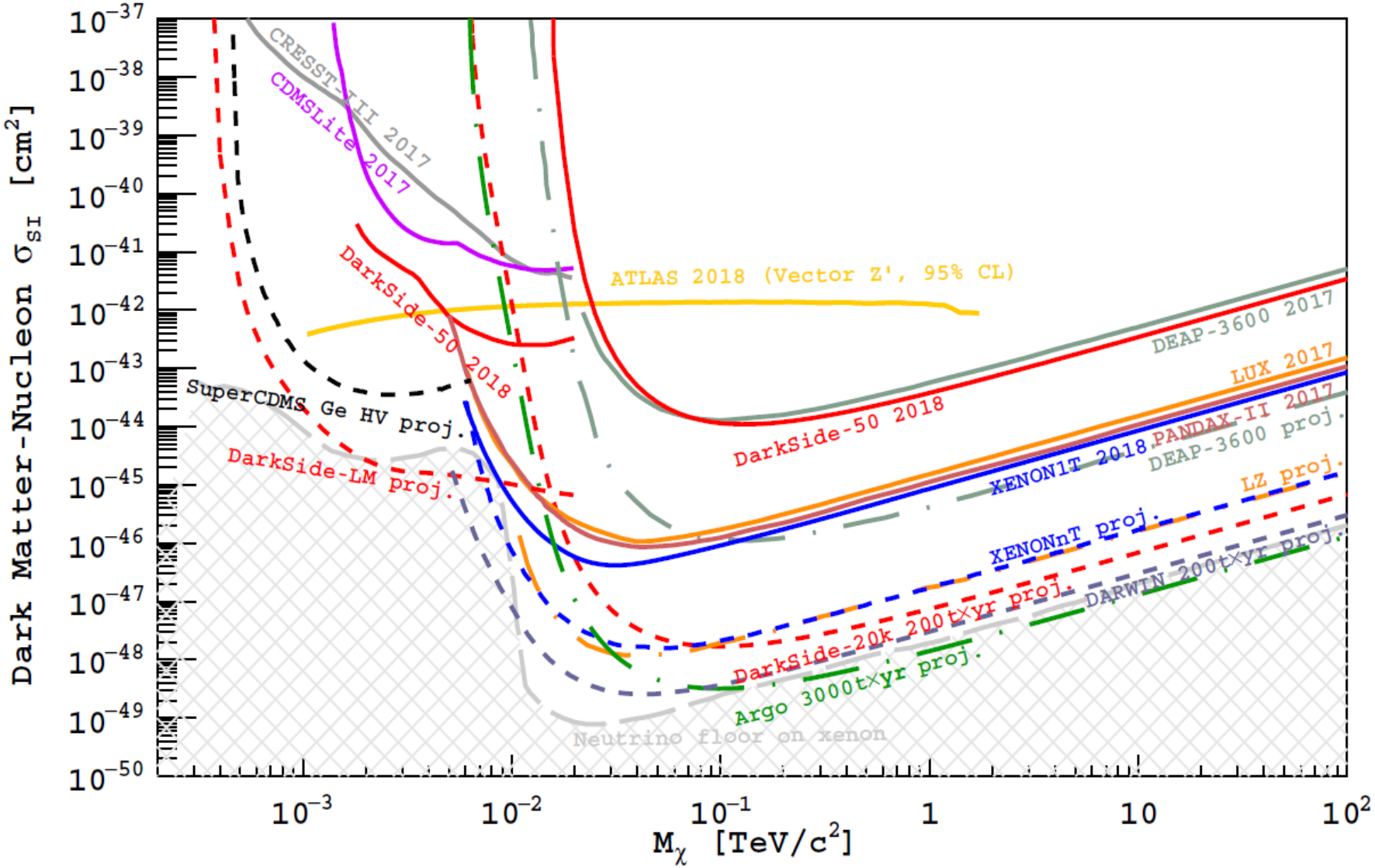
Research Infrastructure (summary)

Project Cost (~$million)		Funding Source				Funding Opportunity
From	To	R&D/Planning	Construction	Operations	Scope of Competition	
0	1.0	EPP or PA	EPP or PA	EPP or PA	EPP or PA	NSF 18-564
0.2	5.7	n/a	MRI (70%); University (30%)	n/a	PHY (<1.0) NSF (>1.0)	NSF 18-513
4.0	15	EPP or PA	PHY Midscale	EPP or PA	PHY	NSF 18-564
0.6-6.0	20	Midscale RI-1	Midscale RI-1	EPP or PA	NSF	NSF 19-537
20	70	Midscale RI-2	Midscale RI-2	EPP or PA	NSF	NSF 19-542
70	--	EPP or PA	MREFC	EPP or PA	NSF	N/A

New!

A Few Highlights

Direct Dark Matter Searches

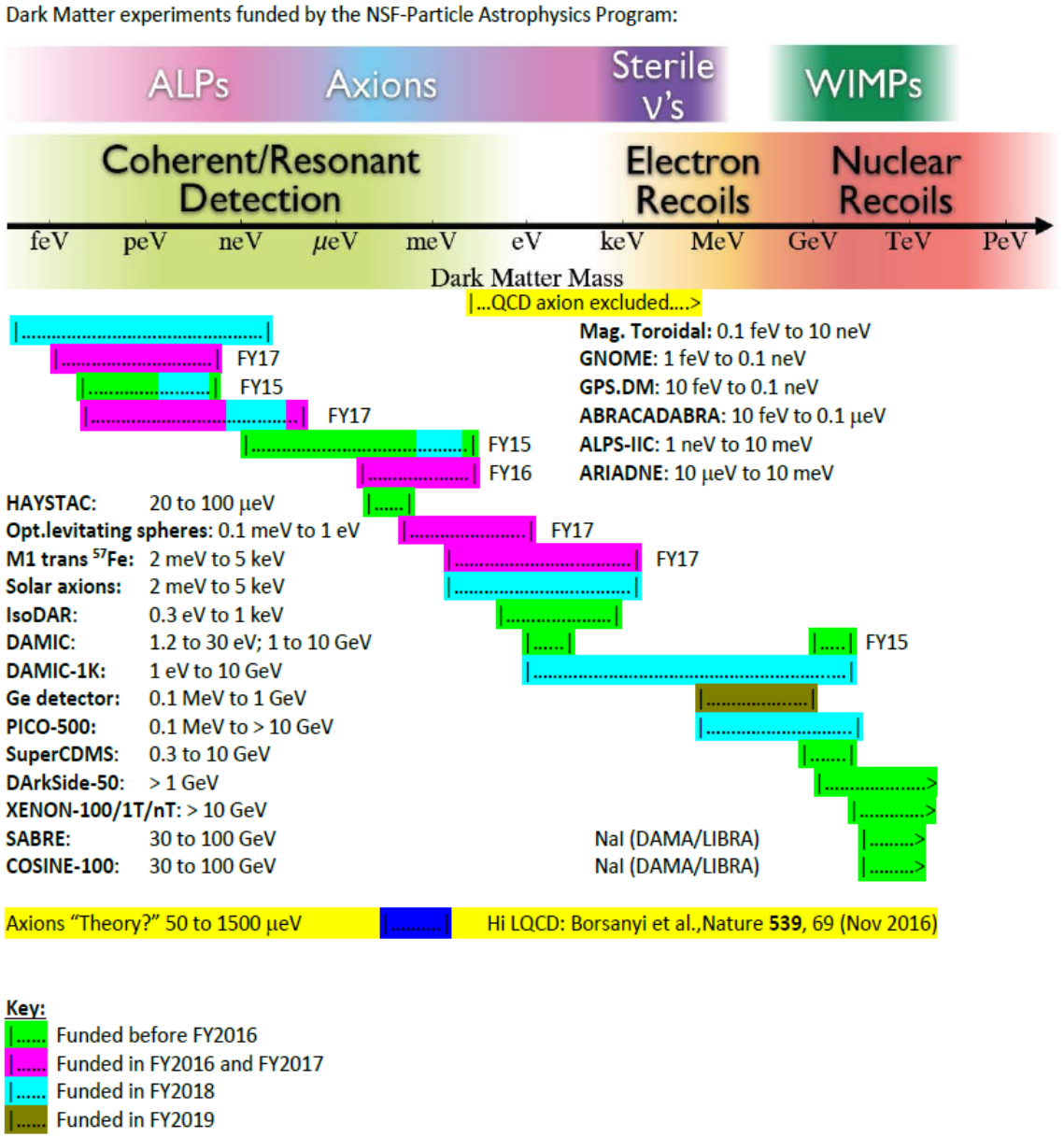


Solid curves = published
Dashed curves = projected

From DArkSide
(February 2019)

Dark Matter

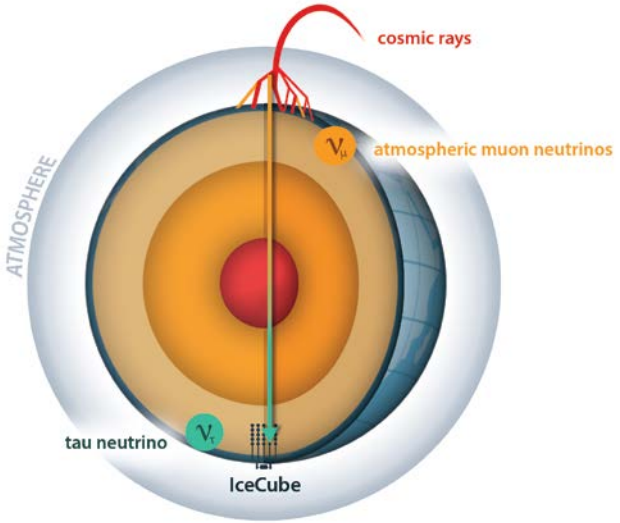
- We need to search for low-mass Dark Matter;
- In PA, we are funding the following projects searching for DM in the region for masses < 1 MeV

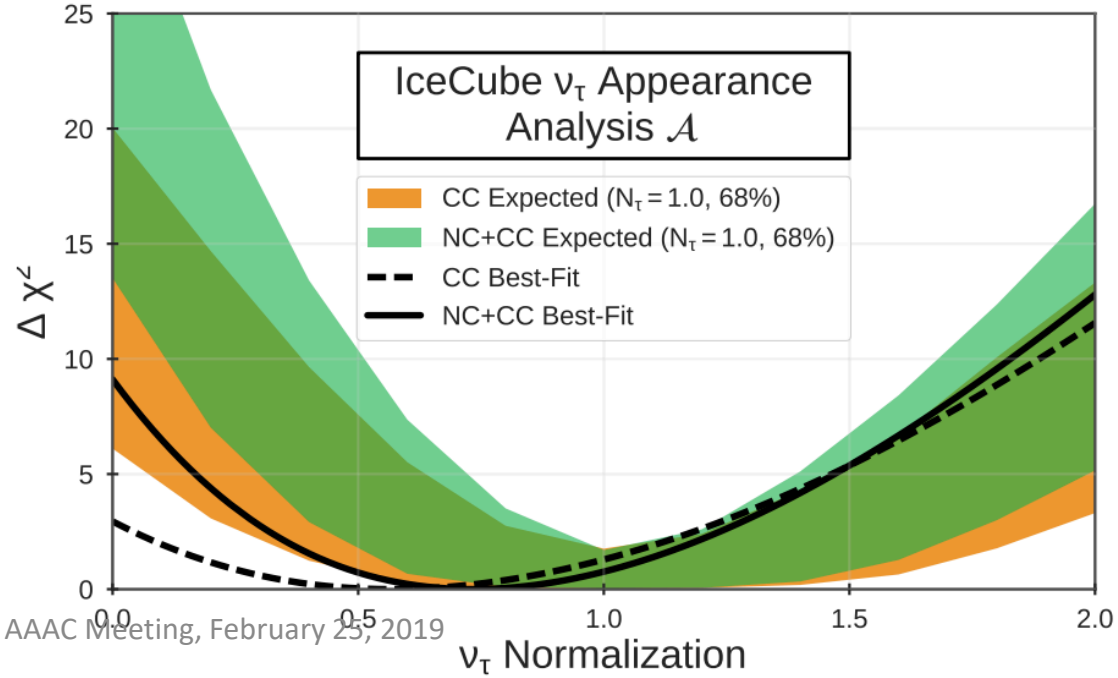


Measurement of Atmospheric Tau Neutrino Appearance with IceCube

The IceCube Collaboration has just performed its first measurement of tau neutrino appearance in oscillations of atmospheric muon neutrinos, which **excluded the absence of tau neutrino oscillations at a significance of 3.2σ,** confirming previous observations by OPERA and Super-Kamiokande.

More importantly, this result is also the leading measurement of the tau neutrino "normalization," the ratio of the detected number of tau neutrinos arising from oscillations to the predicted number from the standard neutrino oscillation picture. **The measured tau "normalization" is consistent with the standard picture but suggests that future IceCube measurements of this quantity could reveal new physics.** These results have just been submitted to the journal *Physical Review D*.

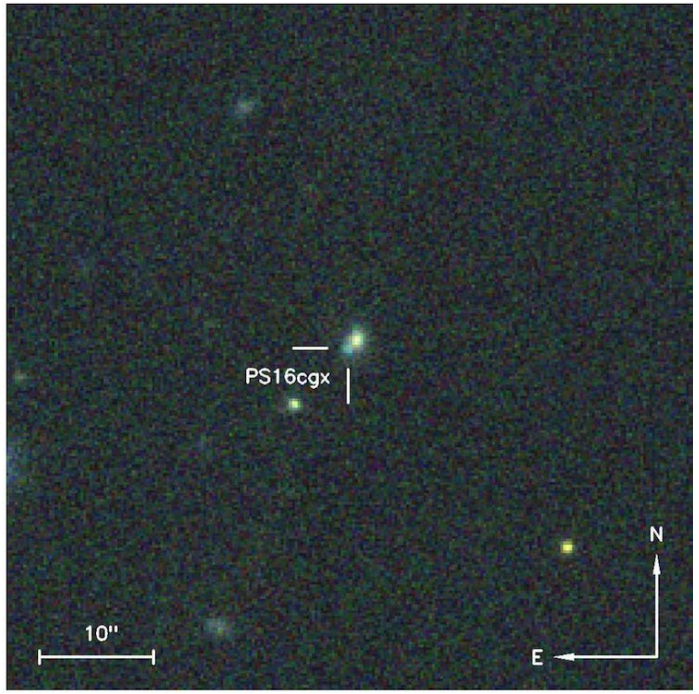




Search for transient optical counterparts with IceCube and Pan-STARRS1

In a recent publication submitted to Astronomy and Astrophysics, the IceCube Collaboration and Pan-STARRS1 scientists have searched for counterpart transient optical emission associated with IceCube high-energy neutrino alerts.

When **following five alerts sent during 2016-17, researchers found one supernova worth studying, SN PS16cgx**.



Transient PS16cgx showed a rising light curve over two days, which is a typical signature of a young supernova, possibly undergoing a potential explosion epoch where very high energy neutrinos could be produced.

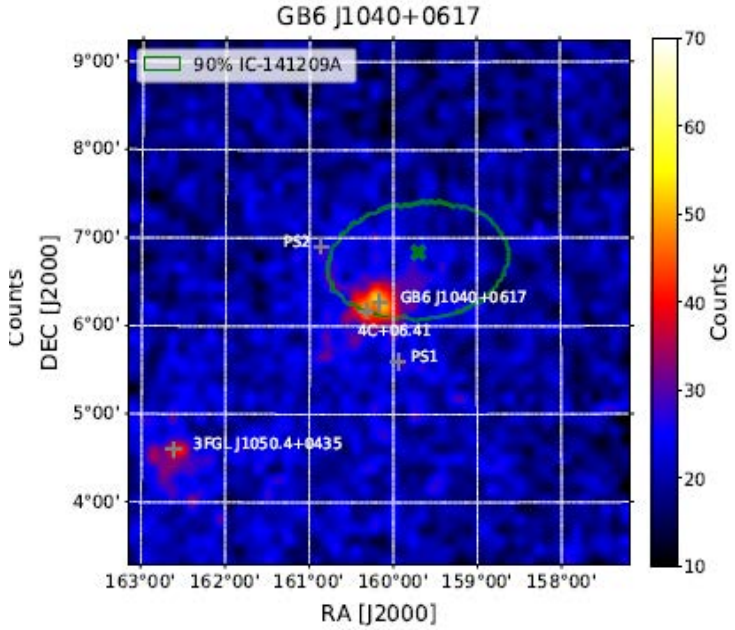
However, a more detailed analysis showed **that it is most likely a Type Ia supernova, i.e., the result of a white dwarf explosion, which is not expected to produce neutrinos.**

Their findings show that spectroscopic follow-up and multicolor photometric coverage of the light curves of candidate sources are crucial.

Investigation of two *Fermi*-LAT gamma-ray blazars coincident with high-energy neutrinos detected by IceCube

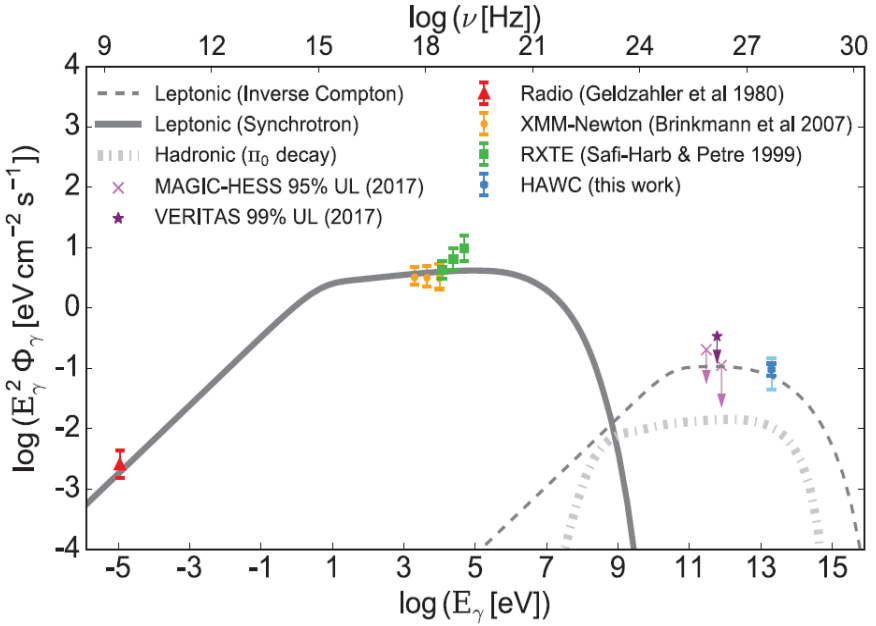
In a new paper by the IceCube Collaboration with the Fermi-LAT collaboration and the ASAS-SN telescopes, researchers went back to eight years of archived IceCube data searching for high-energy neutrino events that could have triggered an alert such as IC-170922A, which culminated with the identification of TXS as its source.

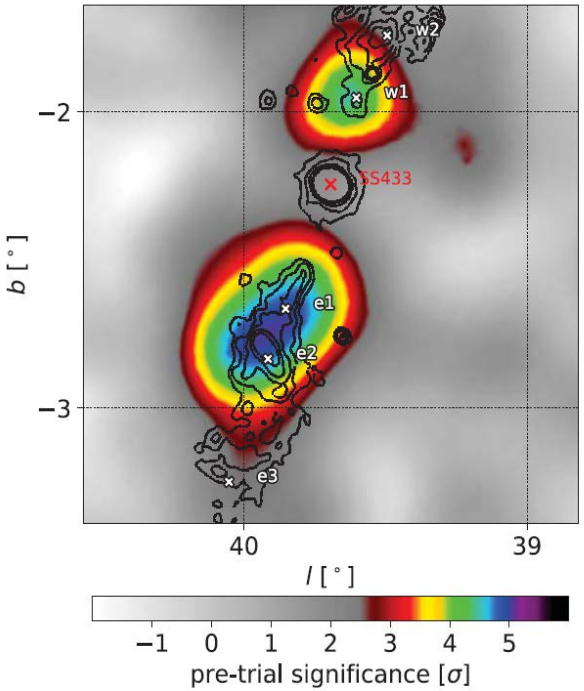
A second neutrino, dubbed IC-141209A, was found in spatial coincidence with blazar GB6 J1040+0617, a plausible but unconfirmed source of this neutrino that will be further investigated for flares of lower energy neutrinos.
The results of this long-term search of high-energy neutrino emission from blazars also confirm that this type of active galaxy cannot account for the majority of the diffuse neutrino flux seen by IceCube and that the source of most of the high-energy neutrinos is still unknown. These results have recently been submitted to *Astronomy and Astrophysics*.



HAWC: Very high energy particle acceleration powered by the jets of the microquasar SS 433

SS 433 is a binary system containing a supergiant star that is overflowing its Roche lobe with matter accreting onto a compact object (either a BH or NS). Two jets of ionized matter with a bulk velocity of $\sim \mathbf{0.26}\boldsymbol{c}$ extend from the binary, perpendicular to the line of sight, and terminate inside W50, a supernova remnant that is being distorted by the jets.

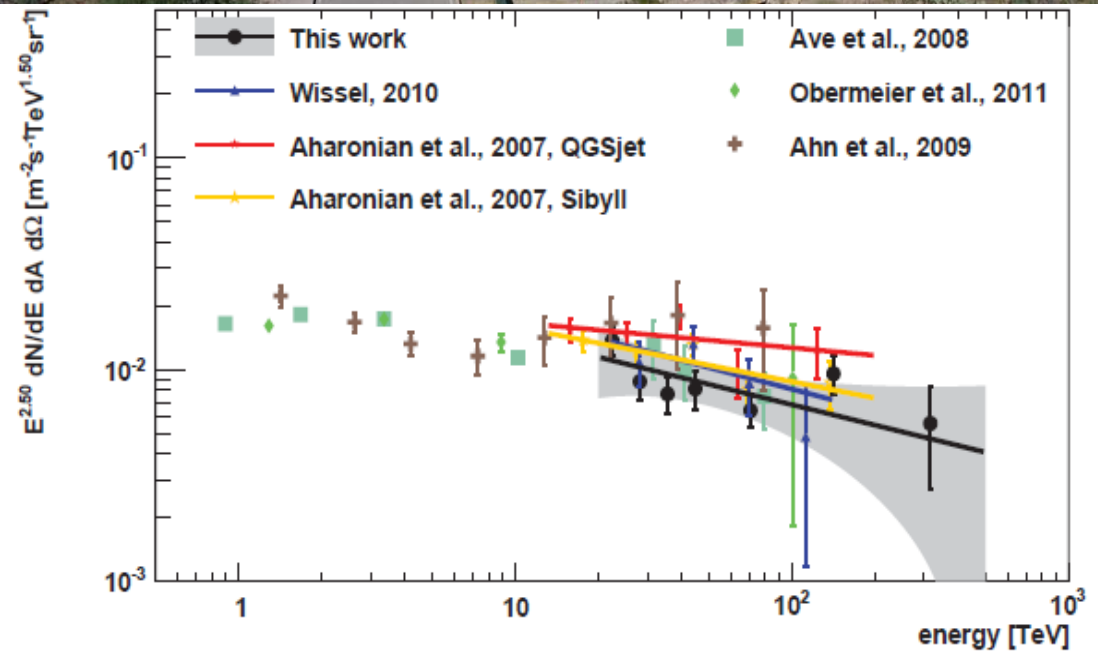




At energies > 100 GeV), the particle fluxes of γ rays from X-ray hotspots around SS 433 have been reported as flux upper limits. In this energy regime, it has been unclear whether the emission is dominated by electrons that are interacting with photons from the CMB through inverse-Compton scattering or by protons interacting with the ambient gas.

We have measured photon energies of at least 25 TeV, and these are certainly not Doppler boosted, because of the viewing geometry. We conclude that the emission from radio to TeV energies is consistent with a single population of electrons with energies extending to at least hundreds of TeV in a magnetic field of $\sim$ 16 micro-Gauss.

Measurement of the Iron Spectrum in Cosmic Rays by VERITAS



(b) Differential flux multiplied by $E^{2.5}$ to improve the visual clarity.

We present a new measurement of the energy spectrum of iron nuclei in cosmic rays from 20 TeV to 500 TeV. The measurement makes use of a template-based analysis method, which, for the first time, is applied to the energy reconstruction of iron-induced air showers recorded by the VERITAS array of imaging atmospheric Cherenkov telescopes.

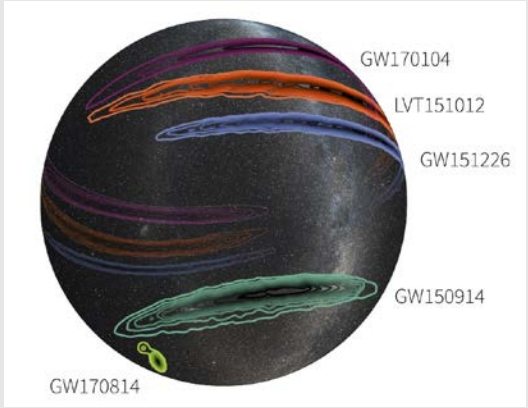
The measured energy spectrum is compatible with a power-law shape, agreeing well with previous measurements in this energy range with improved statistical uncertainty at the highest energies.

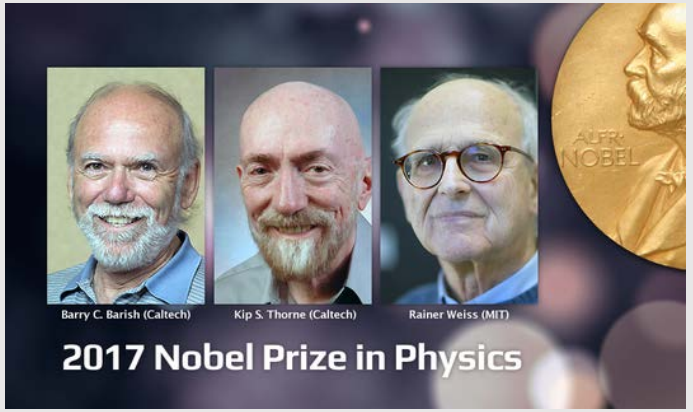
While there is no indication for a cutoff or spectral break in the spectrum given the present data, this analysis is not sensitive to a potential cutoff or softening in the iron spectrum above hundreds of TeV.

Laser Interferometric Gravitational-Wave Observatory

The 3rd Observational Run (O3) will start in April 2019

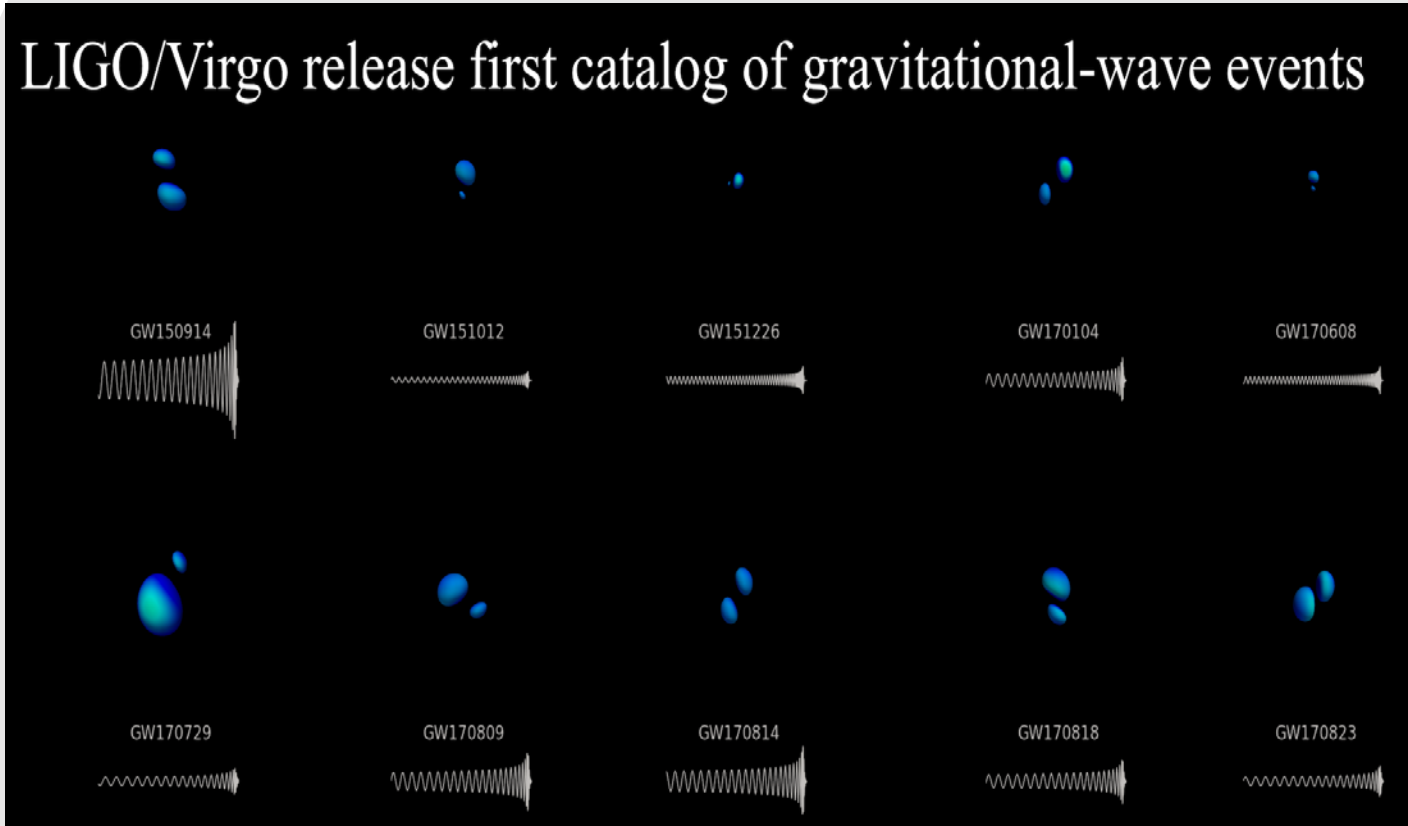
In the meantime, commissioning of the instruments have increased the LIGO reach by 20-30%. This would increase the detection rate by a factor of 2.





LIGO
Four new binary black holes!

On December 1, 2018, the LIGO Scientific Collaboration and the Virgo Collaboration announced the full results of their searches for gravitational-waves from stellar-mass coalescing compact binaries with an advanced detector network. **In addition to the six previously announced binary black hole and single binary neutron star detections, this includes four new binary black hole mergers**: GW170729, GW170809, GW170818, and GW170823



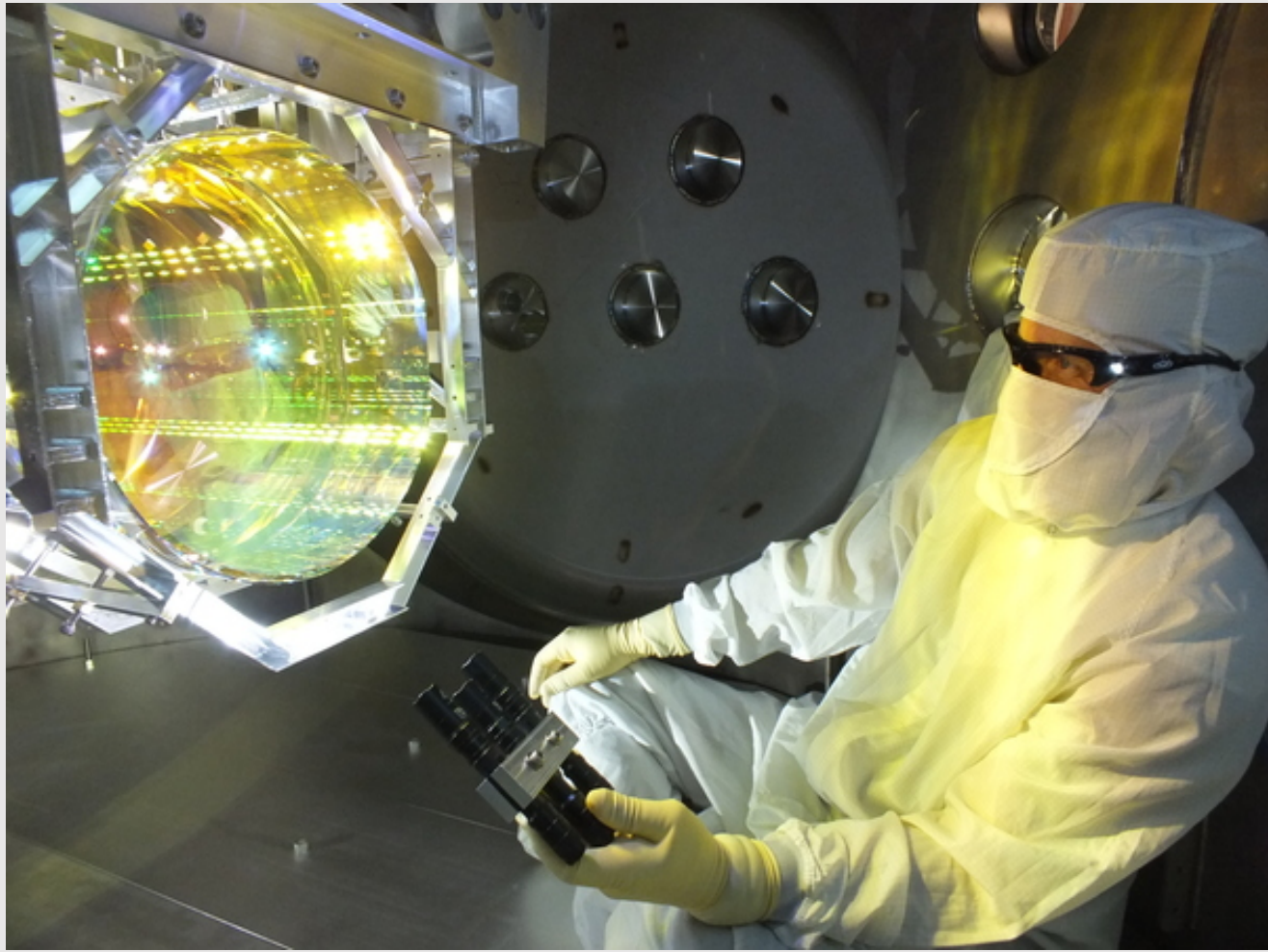
LIGO
A+ Upgrade

NSF, UKRI (United Kingdom) and ARC (Australia) have awarded approximately $35M for the LIGO upgrade known as A+.

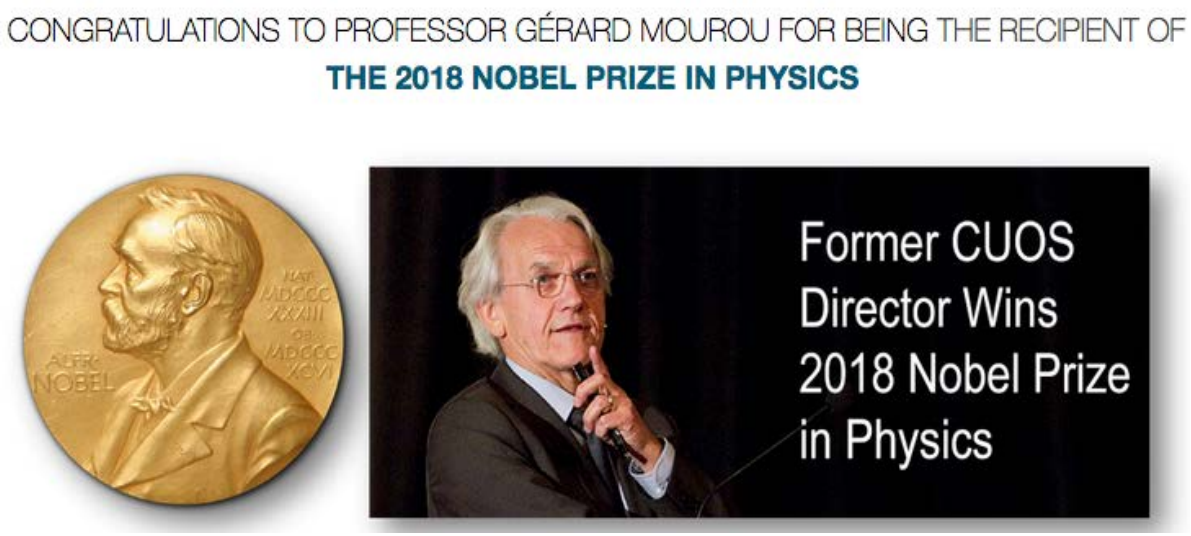
The upgrade consists on replacing the mirror coatings with new low-absorption materials, and incorporating frequency dependent squeeze light.

The upgrade would increase LIGO's sensitivity by 70% of the Advanced LIGO design (a factor of 3 of O2's) and its **detection rate to about one black hole merger per day**.

A+ would start construction after O3 (2020) and be operational in 2024.



2018 Nobel Prize in Physics



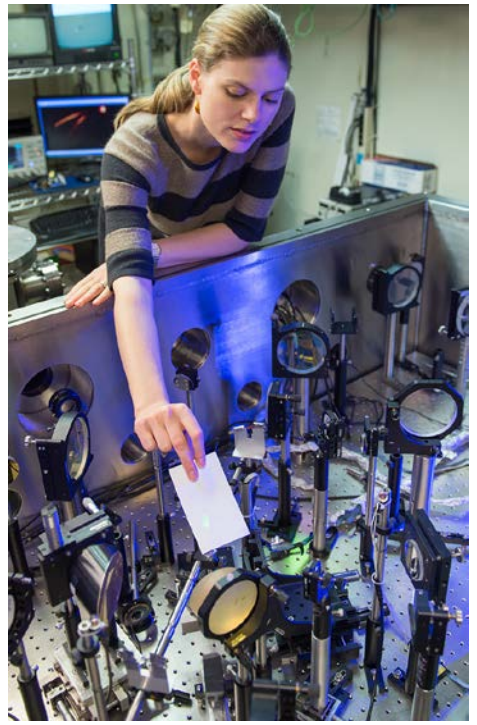
See: https://cuos.engin.umich.edu/

- Prof. Gerard Mourou was the founding Director of the Center for Ultrafast Optical Science (CUOS) – NSF Science and Technology Center at U. Michigan (1990 – 2001), where the original CPA idea was further developed and matured.

- Better understanding of astrophysical systems and phenomena, from planetary interiors to magnetic dynamo to cosmic rays is being enabled by modern high intensity and high energy lasers.

- Such laboratory astrophysics studies have been made possible by the invention of Chirped Pulse Amplification (CPA) by Strickland and Mourou in 1985.

One of the more recent CUOS members, Prof. Louise Willingale is the recipient of the 2018 NSF CAREER award "Relativistic Electron Driven Magnetic Reconnection" to conduct high-energy-density laboratory experiments at the U. Michigan T-cubed laser facility.



A WoU-MMA workshop:
Plasma Physics of Neutron Star Mergers

- The workshop was held at the Flatiron Institute in NYC in October, 2018 co-sponsored by NSF and Simons Foundation

Flatiron Institute Hosts National Science Foundation Workshop on the Plasma Physics of Neutron Star Mergers

Thomas Sumner
October 10, 2018

On August 17, 2017, scientists witnessed one of the most dramatic collisions in the universe. Two dense neutron stars had combined in a galaxy 130 million light-years away, generating ripples through space-time and emitting bursts of light. The observations of the event sparked scientific breakthroughs across many areas of cosmology, but many questions linger.

From October 1-3, 2018, experts gathered at the Flatiron Institute to discuss the biggest outstanding questions and the most promising research opportunities surrounding the physics of neutron star mergers. The gathering, hosted by the Flatiron Institute's Center for Computational Astrophysics (CCA) and supported by the National Science Foundation, focused on the plasma physics and magnetic processes associated with neutron star mergers.

Astrophysicists Yuri Levin and Eliot Quataert lead a discussion during a meeting on the plasma physics of neutron star mergers.

- Lead organizers:
  - Ellen Zweibel, U. Wisconsin
  - Eliot Quataert, UC Berkeley
  - Yuri Levin, Columbia U.

NASEM Plasma 2020 Decadal Survey is now underway

- Co-sponsored by NSF (MPS, GEO, ENG), DOE (SC, NNSA, ARPA-E), and DOD (AFOSR, ONR); co-chaired by Prof. Gary Zank (U. Alabama-Hunstville) and Prof. Mark Kushner (U. Michigan)
- There is topical scope overlap between Plasma 2020, Astro 2020, and the mid-decadal for Solar and Space Physics in the areas of plasma astrophysics and space plasma physics
- Currently, there is no mechanism for active coordination among NSF, NASA, and DOE in the area of plasma astrophysics, which is undergoing significant expansion with new faculty hires, rapidly advancing numerical modeling capability, as well as better observational and laboratory experimental capabilities.

Additional Program Highlights

PA: **IceCube Phase 1 Upgrade awarded. Midscale Award under Windows on the Universe. Multi-Messenger Astrophysics.**

Astro2020 Decadal underway

THY: **TASI Summer School (now exclusively supported by NSF) renewed for next 5 years**

APS J. J. Sakurai Prize for 2019 – awarded to Profs. Lisa Randall (Harvard) and Raman Sundrum (Maryland).

ALL: **Committee of Visitors! This had to be postponed and has been rearranged for June 20-21, 2019**