



# AstroParticle Physics at NSF

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# NSF Mission

The portfolio of awards made through the Physics Division has as primary goal “to promote the progress of science”, as expressed in the NSF act.

Awards in the portfolio support the research needed to address a scientific question that is at the frontier of knowledge as it is currently known, while at the same time extending and redefining that frontier. Inherent in the implementation of this portfolio, which includes significant support for students and junior scientists, is the preparation of the next generation of the advanced high tech workforce and the development of innovative new technologies that arise in the quest to answer some of the hardest questions that Nature can pose.



# CAVEAT!

- NSF Policy:
- We respond to proposals; however:
- We do not mention any proposal that is under review
- We do not mention any proposal that has been declined
- We only refer to awards that have been made



# Stardate 14 September 2015

The merger of two black holes and the birth of a new one.

## Event GW150914

Original black holes:

29 and 36 solar masses ( $M_{\odot}$ ).

Final black hole:

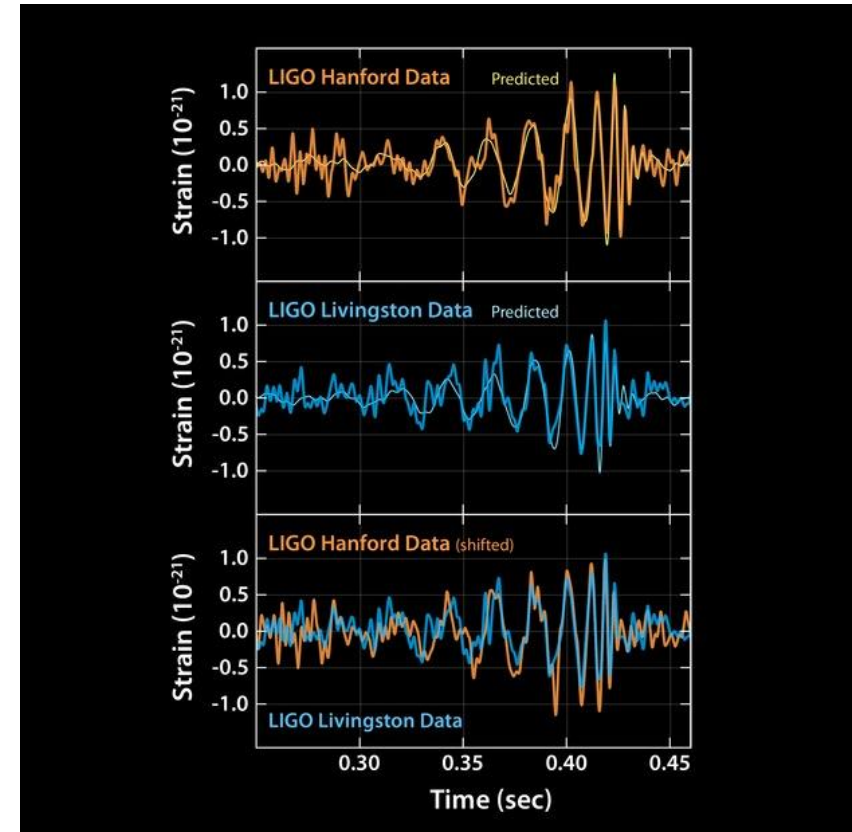
62  $M_{\odot}$  with dimensionless spin 0.67

Energy emitted: 3  $M_{\odot}$

Power emitted: 200  $M_{\odot}/s$

(140 billion trillion times that of the Sun)

**Most powerful explosion recorded not including the Big Bang!**





# First Direct Detection of Gravitational Waves

## NSF's Laser Interferometer Gravitational Wave Observatory

Livingston, LA

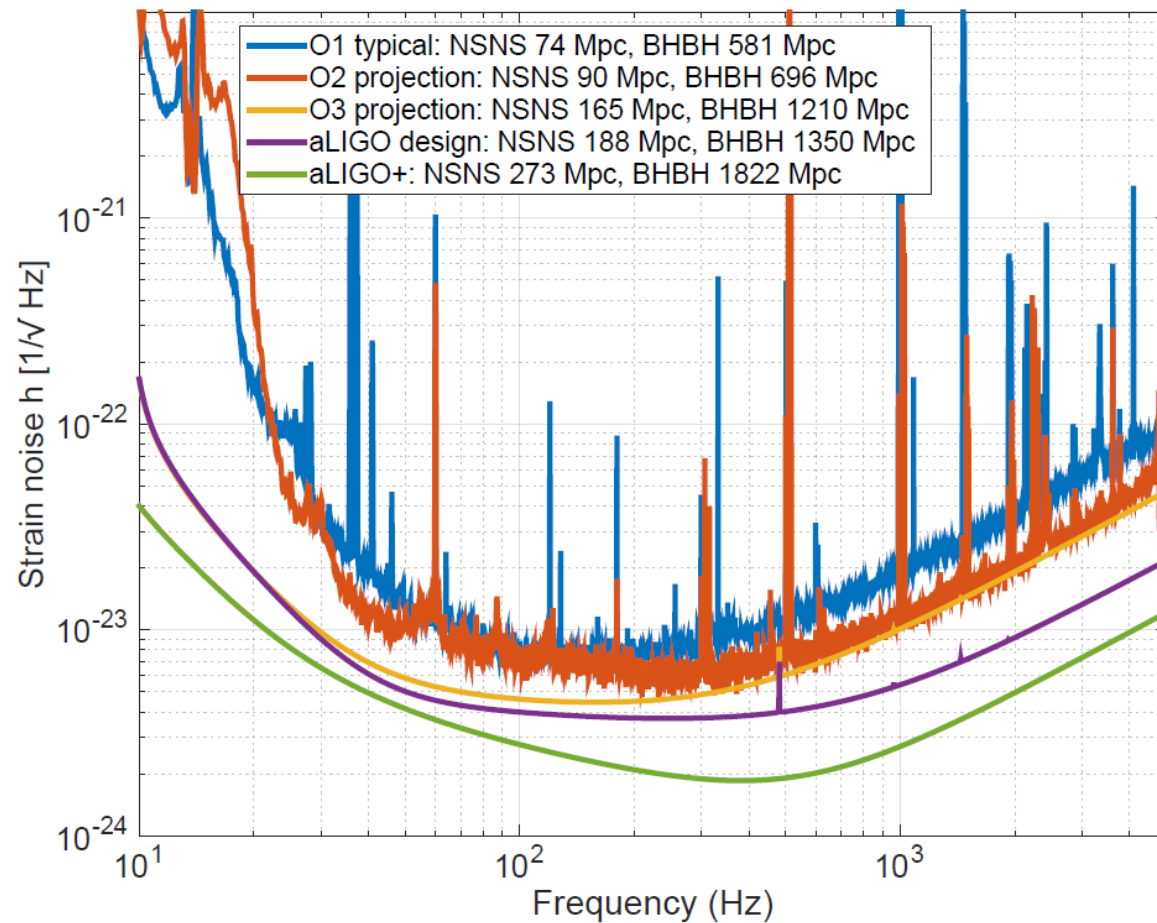


Hanford, WA

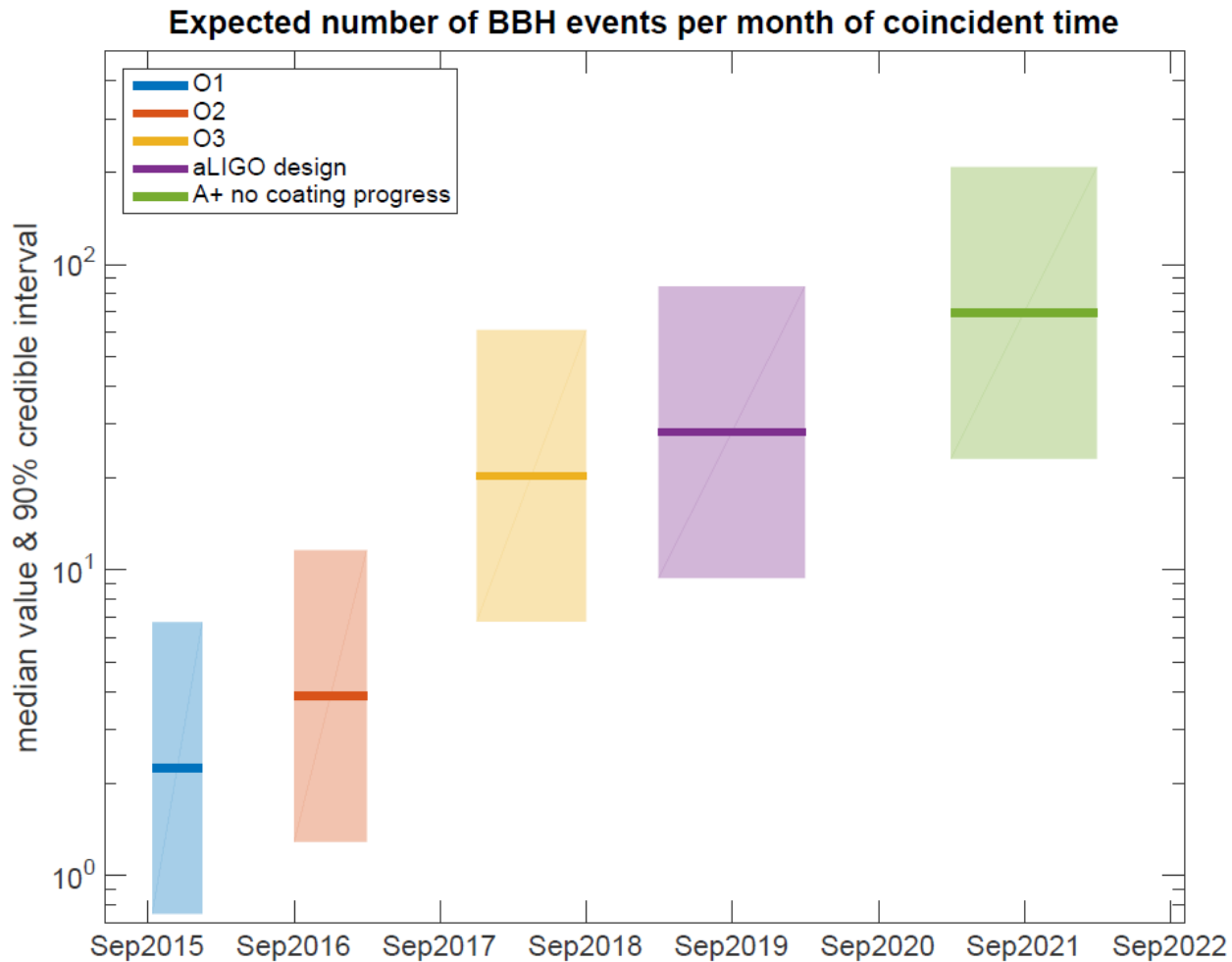


# LIGO future upgrades: Sensitivity

Projections toward aLIGO+ (Comoving Ranges: NSNS  $1.4/1.4 M_{\odot}$  and BHBH  $20/20 M_{\odot}$ )



# LIGO future upgrades: Detection rate





# Gravitational Waves at NSF

- **AdvLIGO (with VIRGO)** – strong collaboration
- **IndIGO (India)**: Prime Minister Narendra Modi met in Washington (March 31) with other senior scientists from the NSF to sign an agreement with the Indian Department of Atomic Energy and the Department of Science and Technology, to set up an observatory in India. This will be the third LIGO observatory, and the first one outside of U.S. India.
- **NANOGrav** (uses pulsar timing and studies a lower-frequency range than LIGO)





# CMB at NSF

- CMB-S3 currently ramping up to 10k detectors ( $\sim 10^{-3} \mu\text{K}$ ) by 2020
- Current best limit on tensor-to-scalar ratio:  $r < 0.09$  (95% C.L.) from (BICEP2/Keck w/Planck)
- CMB-S4 planning for  $\sim 500\text{k}$  detectors ( $\sim 2 \times 10^{-4} \mu\text{K}$ ) by  $\sim 2024$ ;
  - Community Planning Efforts underway
  - Expected performance:
    - spanning 30-300 GHz and  $\geq 70\%$  of the sky;
    - $r \leq 0.001$
    - $\sigma(\Sigma m_\nu) = 16 \text{ meV}$  and  $\sigma(N_{\text{eff}}) = 0.020$
- Atacama: ACT, Polarbear/Simons, CLASS
- South Pole: SPT, BICEP2/KECK Array, BICEP3



# Dark Energy at NSF

## *Future*

- **LSST – Large Synoptic Survey Telescope – 20 months (third FY) into a 98-month NSF MREFC construction project, with DOE camera; survey start on track for October 2022; dark energy (Stage IV) one of 4 primary goals**
- **DESI – Dark Energy Spectroscopic Instrument – DOE-supported spectrograph on NSF’s Mayall telescope in Arizona; Stage IV experiment under construction; survey start in FY 2020; only limited NSF role**

## *Current*

- **DES – Dark Energy Survey – Stage III experiment; 3<sup>rd</sup> season of 5 now completed; DOE-supplied camera on NSF’s Blanco telescope in Chile; NSF supports data management system and telescope operations**
- **HETDEX, SDSS/BOSS; theory support**



# Dark Matter at NSF

- LUX (for 300-day run): expect to end in May 2016
- SuperCDMS at SNOlab – passed CD-1
- XENON1T – commissioning; data taking by summer 2016
- DArkSide-50 – currently running through May 2017 with UAr
- DRIFT-II d – support operations for 500-day run through August 2018
- Axions: ADMX-HF (Yale U.), ALPS-II (DESY)
- Other efforts: DAMIC; GPS, NaI R&D
- DarkLight (Phase-I) at JLAB



# Neutrino Properties at NSF -1

- LBNF-DUNE – No direct support at this time
- NOvA, MINOS
- SBL projects – R&D on Liquid Argon
  - LArIAT, MicroBooNE, SBND (formerly LAr1ND), MINERvA
- Hyper-K – Nothing yet
  
- Sterile neutrinos – IsoDAR:  $^8\text{Li}$  decay source designed to search for sterile  $\nu$ ; current R&D to develop high intensity  $\text{H}^{2+}$  ion source



## Neutrino Properties at NSF - 2

- $0\nu\beta\beta$ :
- CUORE, MJD, EXO-200, SNO+, Super-NEMO: currently funding operations and limited R&D on “demonstrators”
- NSAC 2015 Long Range Plan (Oct 2015): Recommendation 2 of 4 – *“We recommend the timely development and deployment of a U.S.-led ton-scale neutrinoless double beta decay experiment.”*
- NSAC NLDBD Report (Nov 2015): “the subcommittee strongly recommends that R&D efforts aimed at solving specific technical issues relevant to the downselect decision be supported.”
- NSF/DOE a coordinated and unified approach to address R&D needs (July 2015) – Joint Review Solicitation soon.
- Neutrino Mass: Project-8 – supported for R&D (tritium beta decay spectrum)



# HE Universe at NSF - 1

- Gamma Rays:
- VERITAS – NSF-supported operations
- HAWC – NSF-supported operations
- CTA – R&D for prototype SCT at Whipple
- Cosmic Rays:
- Pierre Auger: NSF plans to support Common Fund as long as its scientists are funded by NSF
- TA – NSF-supported operations



# HE Universe at NSF - 2

- High Energy Neutrinos:
- IceCube Neutrino Observatory at South Pole:
  - Established the world's best limit on a flux of cosmogenic neutrinos discovering tens of neutrino events with energies at/above 100 TeV, and three neutrino events at the PeV level - the highest energy neutrinos ever detected
  - ICNO operations will continue for a new 5-year run (through March 2021)
- ARA – funded for 5 stations at South Pole and operations through December 2018
- ARIANNA – funded for 7 stations (near McMurdo at Ross Ice Shelf) and operations through December 2017