

## WINDOWS ON THE UNIVERSE (WOU)

WoU Funding (Dollars in Millions)			
	FY 2019 Actual	FY 2020 (TBD)	FY 2021 Request
<b>Stewardship Activities (MPS)</b>	<b>\$30.00</b>	-	<b>\$30.00</b>
<b>Foundational Activities</b>	<b>\$17.68</b>	-	<b>\$22.90</b>
MPS	17.68	-	21.00
OPP	-	-	1.90
<b>Total</b>	<b>\$47.68</b>	-	<b>\$52.90</b>

### Overview

For millennia, humankind has viewed the universe through the optical part of the electromagnetic spectrum to which human eyes are sensitive. Over the last half century, this range has been extended to observe electromagnetic radiation across the full spectrum from radio waves to X-rays and gamma rays. Observatories constructed and operated over the past two decades have extended this view to include high-energy particles such as neutrinos and cosmic rays. Most recently, with LIGO, NSF has established the ability to view the universe through gravitational waves. This ushers in the era of multi-messenger astrophysics. The three messengers—electromagnetic radiation, high-energy astrophysical particles, and gravitational waves—each provide unique information. Together, they provide a detailed picture of the Universe that allows scientists to study matter, energy, and the cosmos in fundamentally new ways—through several powerful and diverse “windows”. WoU builds these capabilities and accelerates the synergy and interoperability of the three messengers to realize integrated, multi-messenger astrophysical exploration of the Universe.

Prior investments have led to important recent discoveries that demonstrate the power of WoU. The coincident detection of gravitational waves and electromagnetic radiation identified a merging binary neutron star system, confirmed Einstein’s theory of General Relativity, and revealed critical information on the origin of heavy elements. Recent observations of high energy neutrino emission coincident with gamma-ray flares from the nucleus of an active galaxy have revealed for the first time an astrophysical source of high energy cosmic rays. These discoveries, along with others, have heralded the era of multi-messenger astrophysics.

WoU is anticipated to be a 10-year effort and builds upon decades of prior investments in individual and large-scale efforts. These include both presently operating observatories such as IceCube (for the detection of high-energy neutrinos) and LIGO (for the detection of gravitational waves) as well as development efforts for future experiments. In the FY 2019 Request, stewardship funding for WoU was first introduced and was complemented by the ongoing investments in foundational activities aimed at building capabilities for each of the three messengers. This funding strategy (stewardship funding supplemented with investments in foundational activities) will continue in FY 2021. These investments will also serve to grow the workforce not only for multi-messenger astrophysics but also for engineering, data science, and many other areas.

### Goals

1. *Enhancing and accelerating the theoretical, computational, and observational activities within the scientific community:* Support efforts within the scientific community to build the observational and analysis capabilities in each of the three window areas, integrate the different research communities to

develop full interoperability between the three windows, and develop a new workforce that is skilled in this new paradigm.

2. *Building dedicated instrumentation and capabilities*: Construct experiments and instrumentation or develop cyberinfrastructure that will make critical contributions to the multi-messenger research infrastructure by enabling new capabilities in energy range or sky coverage, improved sensitivity, or new experimental or computational capabilities. The Big Idea: Mid-scale Research Infrastructure program, described elsewhere in this chapter, is an essential part of realizing this goal.
3. *Exploiting current facilities and developing the next generation of observatories*: Enhance infrastructure and provide modest upgrades to enable full utilization of the current generation of multi-messenger facilities, and support planning and development for the next generation of observatories to accelerate progress to realize significantly greater capabilities and extend the scientific reach.

### **FY 2021 Investments**

WoU continues to be implemented through a dedicated program, “Windows on the Universe: The Era of Multi-Messenger Astrophysics (WoU-MMA).”<sup>1</sup> The WoU-MMA program includes the Division of Astronomical Sciences and the Division of Physics within MPS, and OPP within GEO. The WoU-MMA program will address all of the WoU goals. Stewardship funding (\$30.0 million) resides in the MPS Office of Multidisciplinary Activities but will be allocated to awards from all participating divisions and directorates on the basis of merit and portfolio balance. Participating divisions and offices may elect to supplement this allocation through foundational activities in core research programs in order to advance particularly compelling scientific opportunities related to WoU. For MPS this is expected to be primarily through research grants in astronomy, particle astrophysics, and gravitational physics. OPP will supplement the WoU allocation with grants from the Antarctic Astrophysics and Geospace Sciences program. Other NSF divisions may participate where activities originating in their divisions meet the WoU criteria.

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<sup>1</sup> PD 18-5115: [www.nsf.gov/funding/pgm\\_summ.jsp?pims\\_id=505593](http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505593)