Balzan Fellowship for a Postdoctoral Researcher

Francis Halzen

2015 Balzan Prize for Astroparticle Physics Including Neutrino and Gamma-Ray Observation

Balzan GPC Advisers: Bengt Gustafsson, Luciano Maiani
Deputy Supervisor: Kael Hanson
Balzan Fellows: Daan Van Eijk and Marjon Moulai
Affiliated Institution: Wisconsin IceCube Particle Astrophysics Center (WIPAC) at the University of Wisconsin–Madison
Period: 2020-2023

Francis Halzen is the Vilas Research Professor and the Gregory Breit Distinguished Professor at the University of Wisconsin–Madison and Director of its Institute for Elementary Particle Physics.

The Wisconsin IceCube Particle Astrophysics Center (WIPAC) at the University of Wisconsin – Madison created the Balzan Fellowship for an outstanding postdoctoral candidate to work with the IceCube neutrino experiment, with special emphasis on future technologies and/or multiwavelength campaigns to advance the future of neutrino astronomy.

The IceCube Neutrino Observatory, the first detector of its kind, was designed to observe the cosmos from deep within the South Pole ice. It does so by recording the interactions of a nearly massless subatomic particle called the neutrino. IceCube is the world's largest particle detector, encompassing a cubic kilometer of ice. In 2013, IceCube discovered a flux of high-energy neutrinos reaching us from outside our own galaxy, with one recent event exceeding an energy of 10,000 TeV, one thousand times the energy of the protons accelerated in the Large Hadron Collider beams. In 2017, a multimessenger campaign involving telescopes looking across the electromagnetic spectrum pinpointed a rotating supermassive black hole as the source of a 290-TeV IceCube neutrino. Thus, the first source of the highest energy cosmic rays was identified—a century after their discovery.

More recently, aided by a decade of IceCube data and novel machine learning techniques, IceCube found evidence that cosmic neutrinos are produced in the close vicinity of supermassive black holes at the centers of Galactic nuclei, most prominently NGC 1068, NGC 4151, TXS 0506+056 (the same source we identified in the 2017 multimessenger campaign), PKS 1424+240, and Circinus. The team also mapped the Milky Way in neutrinos and found it to be a subdominant component of the neutrino sky – this is in contrast to light, where it is the most prominent feature of the sky at any wavelength. The beam of cosmic neutrinos additionally provides the opportunity to study neutrinos themselves, extending previous studies of atmospheric neutrinos to a new energy regime that far exceeds the reach of neutrinos produced by accelerator beams.

After an extensive international search, Daan Van Eijk was selected as the first Balzan fellow. Van Eijk was previously employed as a scientist at NIKHEF, Amsterdam, as coordinator of the integration of KM3NeT digital optical modules. KM3NeT is, like IceCube, a kilometer-scale neutrino detector, but to be deployed in the Mediterranean Sea and with a different design of its photosensors. The DOM, which is shorthand for digital optical module, is the basic detection element of the KM3NeT neutrino detector. Van Eijk's PhD research was performed at CERN, studying CP-violating decays using data from the LHC-B detector.

Van Eijk joined WIPAC in July 2017. Using his valuable expertise, Daan initiated a study of the KM3NeT DOM design for possible use as the detector element in a next- generation IceCube detector. Telescopes evolve. AMANDA, an experiment preceding IceCube, provided the proof of concept for a kilometer-scale detector by observing atmospheric neutrinos using natural ice as a particle detector. IceCube's discovery of a large flux of cosmic neutrinos has triggered the development of a next-generation instrument that will equip a volume of ice almost one order of magnitude larger. The experience gained with IceCube has augmented the capability to instrument a ten-times-larger volume of ice on a budget similar to the one for IceCube. Daan Van Eijk's stay at WIPAC coincided with the decision of the National Science Foundation to fund an upgrade of IceCube that will also be a pathfinder mission to build the next-generation telescope.

Daan not only participated in completing the design of the instrument but co-authored the white paper on the subject, "Neutrino astronomy with the next generation IceCube Neutrino Observatory." He completed an extensive study of novel photomultipliers that are considered for the next-generation detector, which is published in IOP's Journal of Instrumentation, JINST. In the same context, novel technologies that do not necessarily involve the IceCube technique will also be researched, such as radio detectors and horizontal cosmic ray air shower arrays. Upon completing two years as a Balzan fellow at the lead institution of the IceCube project, Daan returned to a permanent position at NIKHEF.

The second Balzan Fellowship was offered to Marjon Moulai. She received her PhD in 2021 from the Massachusetts Institute of Technology on a search for sterile neutrinos using the IceCube detector. Marjon is now working on IceCube science and is participating in the preparation of the Technical Design Report of the next-generation IceCube detector, which will be publicly released soon. A preliminary version of this document has been endorsed by the Decadal Survey on Astronomy and Astrophysics by the National Academy of Sciences.

With the expiration of the Balzan funds in 2023, WIPAC will provide funds to continue the Fellowship in the future.

Publications

Halzen, Francis, Daan Van Eijk and 400 other authors. “Neutrino astronomy with the next generation IceCube Neutrino Observatory.” (2019) arXiv:1911.02561 [astro-ph.HE].

Eijk, Daan van, J. Dorant, Christoph Wendt and Albrecht Karle. “Characterization of the HZC Photonics XP82B20D and XP1805D Photomultiplier Tubes for Low-Temperature Applications.” *JINST 14 P07009* (2019). arXiv:1904.11897 [physics.ins-det].

IceCube-Gen2 Technical Design Report, Parts I, II.