

# Analysis Coordination and Publications

Naoko Kurahashi Neilson  
Analysis Coordinator

NSF Mid-Term Review  
29 April 2024



# Presenter Background

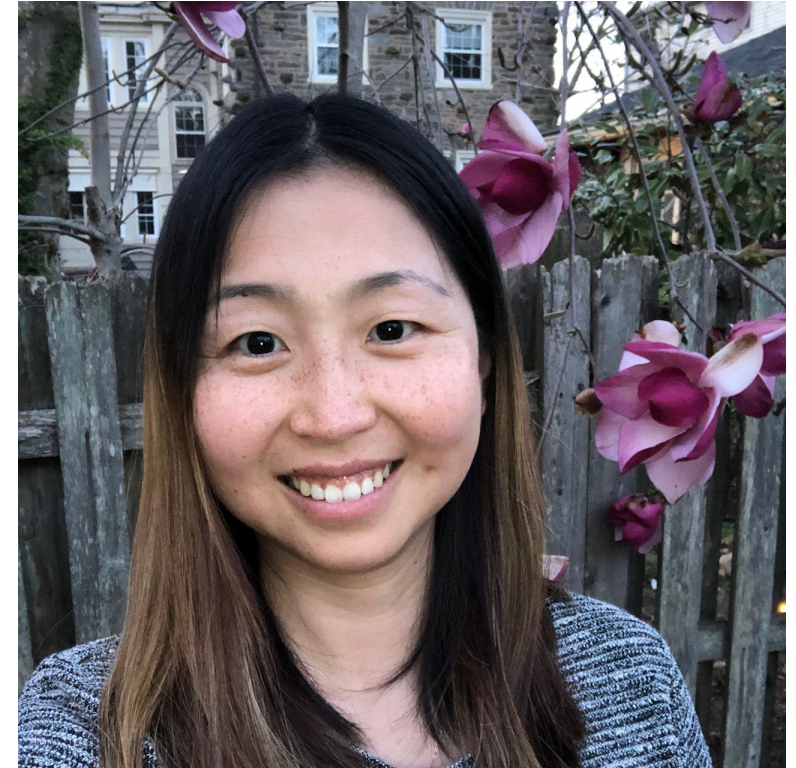
## Naoko Kurahashi Neilson, Analysis Coordinator (2024-)

### Previous Positions (IceCube)

- Deputy Analysis Coordinator (2022-2023)
- TFT Chair (2020-2022)
- Ombusperson (2019-2021)
- Point source/Neutrino sources Working Group Lead (2013-2019)
- Early Career Representative (2013)
- Offline L2 Processing Lead (2012)

### Positions (Academic)

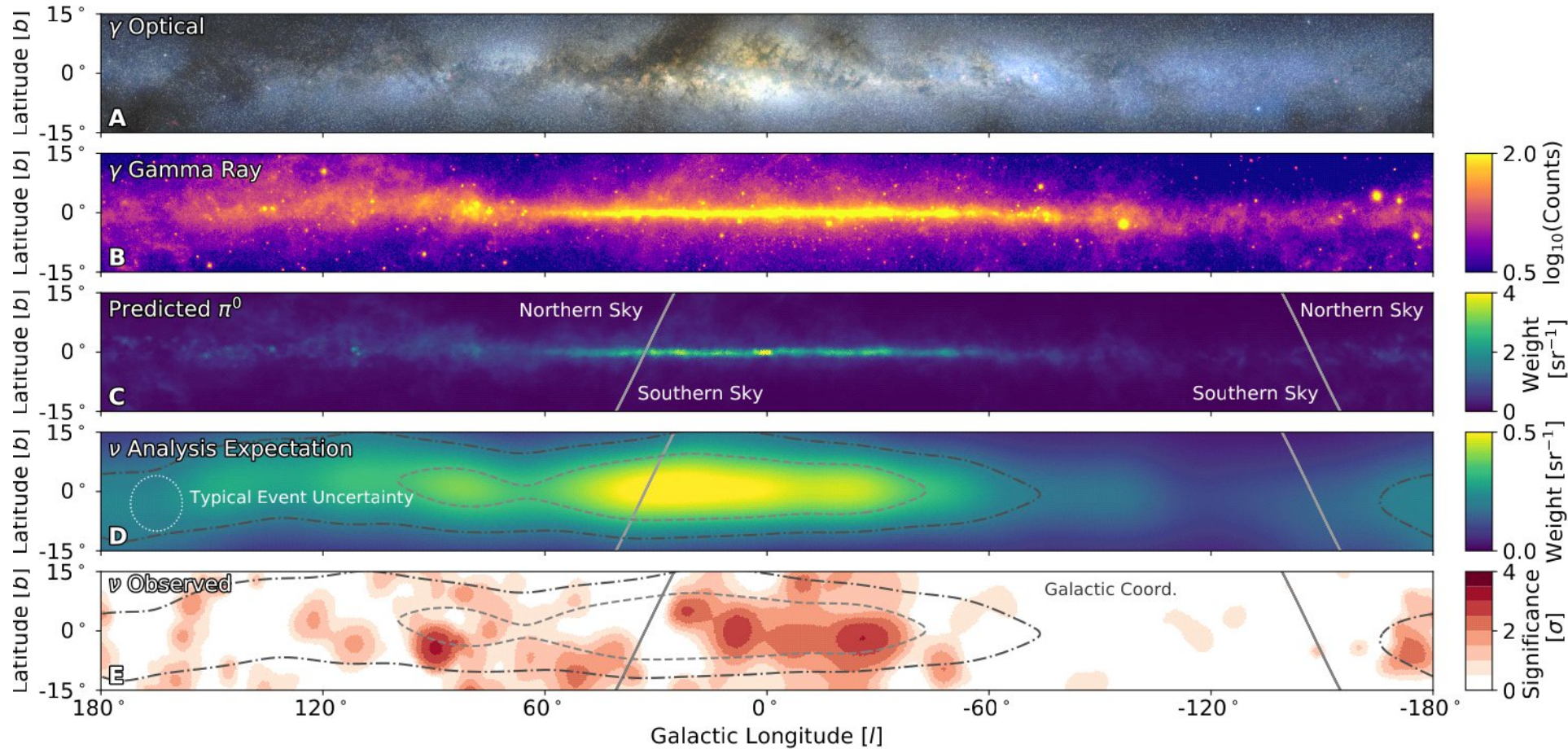
Associate Professor, Drexel University (2019-)  
Assistant Professor, Drexel University (2014-2019)  
Postdoc, University of Wisconsin (2010-2014)  
PhD Stanford University (2010)



# First Observation of the Milky Way in Neutrinos

Science 380 (2023) 1338

Announced June 2024



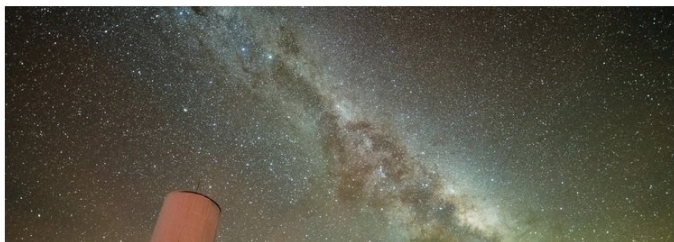


The New York Times

## Neutrinos Build a Ghostly Map of the Milky Way

Astronomers for the first time detected neutrinos that originated within our local galaxy using a new technique.

Share full article



### RESEARCH

#### RESEARCH ARTICLES

##### NEUTRINO ASTROPHYSICS

## Observation of high-energy neutrinos from the Galactic plane

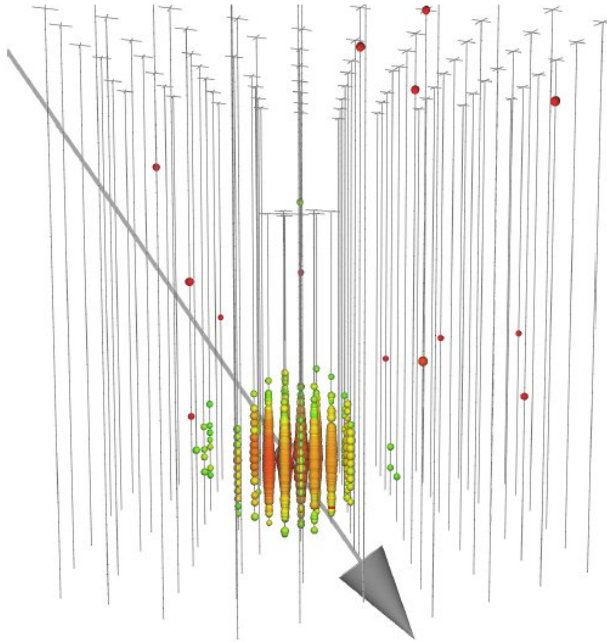
IceCube Collaboration\*†

The origin of high-energy cosmic rays, atomic nuclei that continuously impact Earth's atmosphere, is unknown. Because of deflection by interstellar magnetic fields, cosmic rays produced within the Milky Way arrive at Earth from random directions. However, cosmic rays interact with matter near their sources and during propagation, which produces high-energy neutrinos. We searched for neutrino emission using machine learning techniques applied to 10 years of data from the IceCube Neutrino Observatory. By comparing diffuse emission models to a background-only hypothesis, we identified neutrino emission from the Galactic plane at the  $4.5\sigma$  level of significance. The signal is consistent with diffuse emission of neutrinos from the Milky Way but could also arise from a population of unresolved point sources.

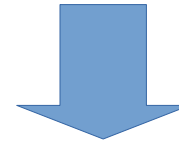
neutrino ( $\nu_e$ ) with nuclei, as well as scattering interactions of all three neutrino flavors [ $\nu_e$ , muon neutrino ( $\nu_\mu$ ), and  $\nu_\tau$ ] on nuclei. Because the charged particles in cascade events travel only a few meters, these energy depositions appear almost point-like to IceCube's 125-m (horizontal) and 7- to 17-m (vertical) instrument spacing. This results in larger directional uncertainties than tracks. Tracks are elongated energy depositions (often several kilometers long), which arise predominantly from muons generated in cosmic-ray particle interactions in the atmosphere or muons produced by interactions of  $\nu_\mu$  with nuclei. The energy deposited by cascades is often contained within the instrumented volume (unlike tracks), which provides a more complete measure of the neutrino energy (19).

Searches for astrophysical neutrino sources are affected by an overwhelming background of muons and neutrinos produced by cosmic-

## Cascade Event



Uses event stream previously unutilized for astronomy



Key enablers (in both data selection and reconstruction) is Deep Learning!

Use existing data in clever ways with enabling technologies = more discovery!

# In fact, discovery rate is accelerating...



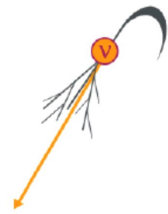
1988

Telescope in the Ice Envisioned



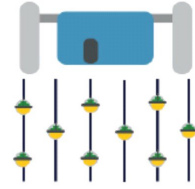
2000

AMANDA Completed



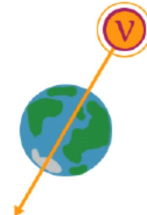
2001

Atmospheric Neutrinos Detected



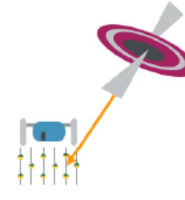
2011

IceCube Completed



2013

Astrophysical Neutrinos Discovered



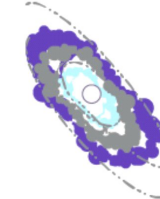
2018

First Source TXS 0506+056 Identified



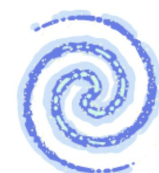
2021

Glashow Resonance Neutrino Identified



2022

Second Source NGC 1068 Identified



2023

Third Source Milky Way Identified

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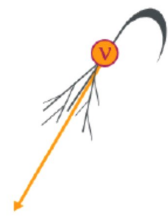
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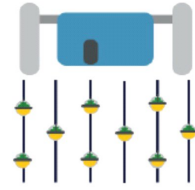
2000

AMANDA Completed



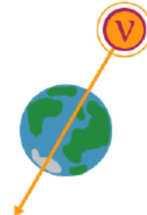
2001

Atmospheric Neutrinos Detected



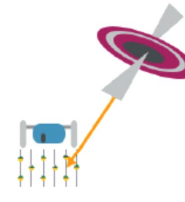
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IceCube Completed



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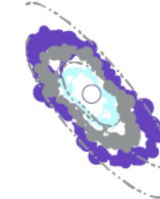
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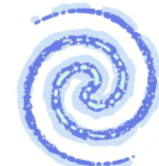
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Glashow Resonance Neutrino Identified



2022

Second Source NGC 1068 Identified



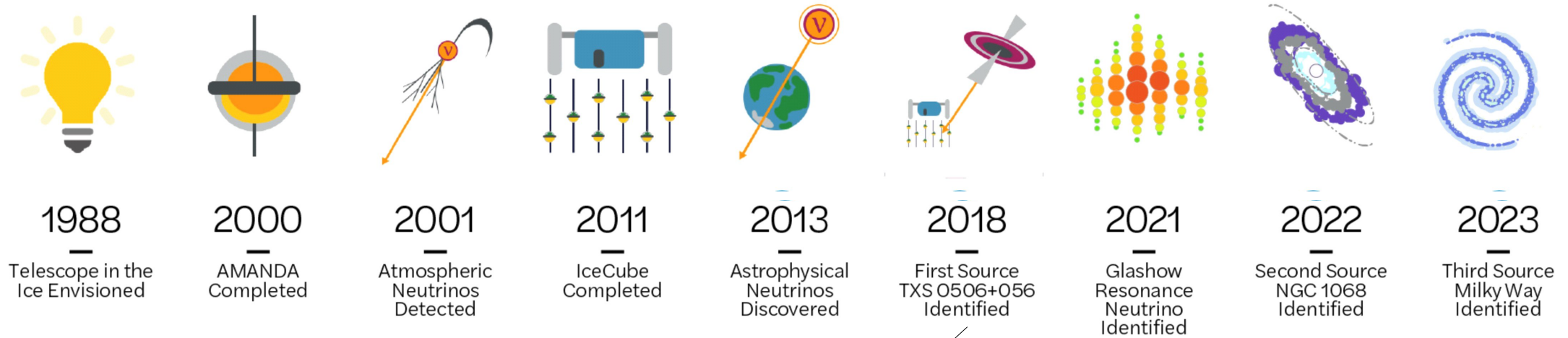
2023

Third Source Milky Way Identified



New Simulation Technique (MuonGun)

# In fact, discovery rate is accelerating...

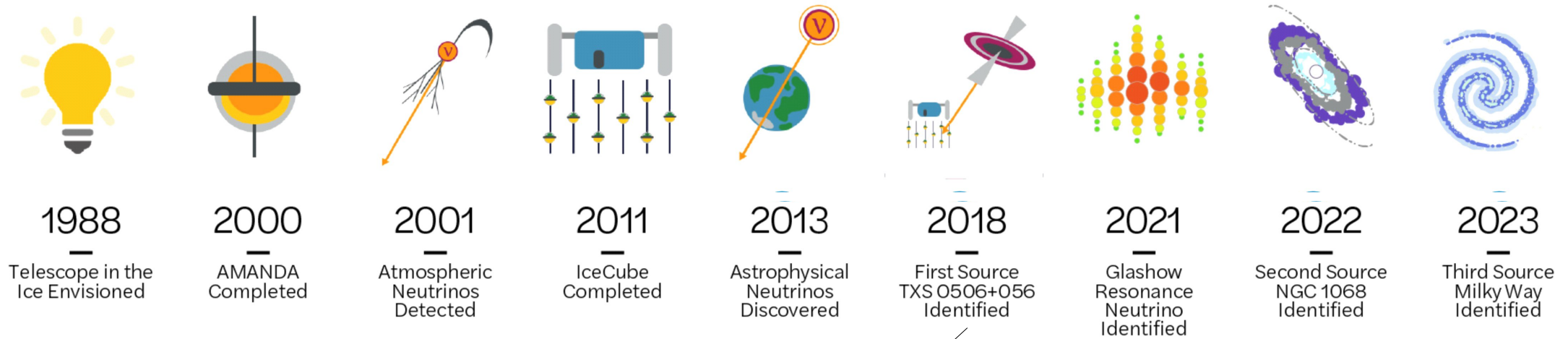


New Simulation Technique (MuonGun)

Implementation of Streamlined Realtime Alerts



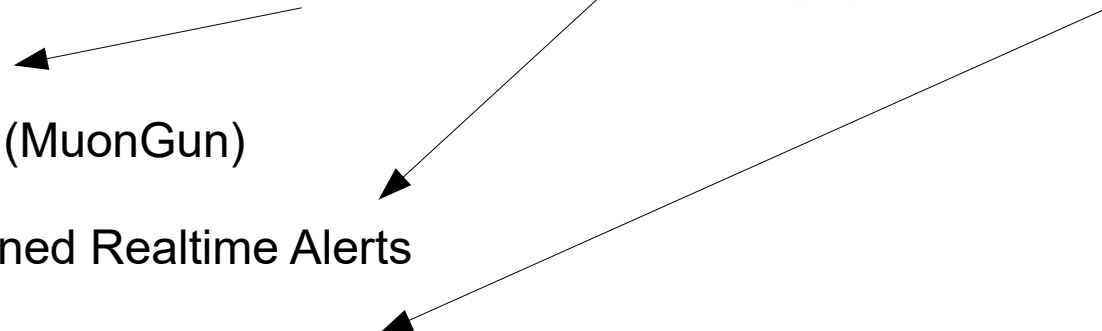
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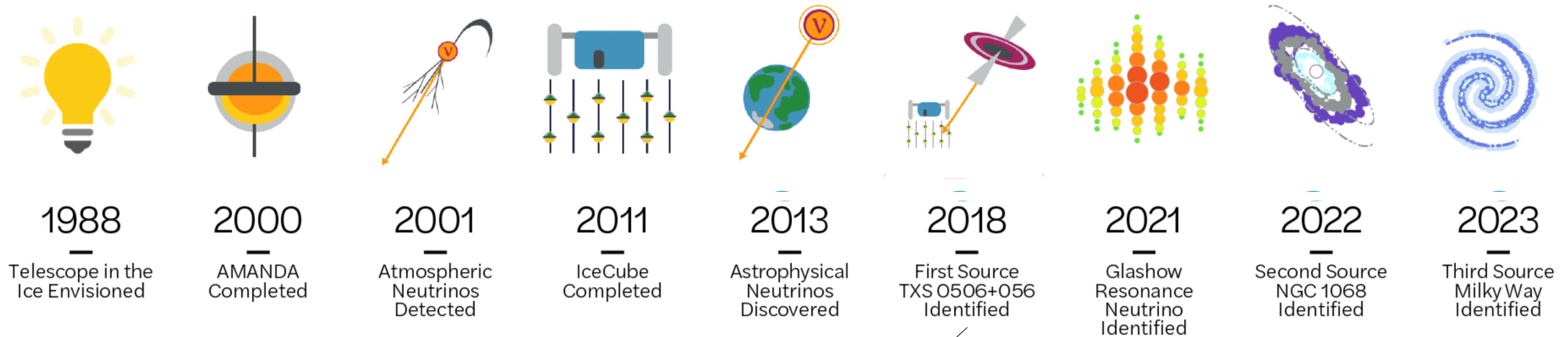
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Implementation of Streamlined Realtime Alerts

Pass 2 Reprocessing



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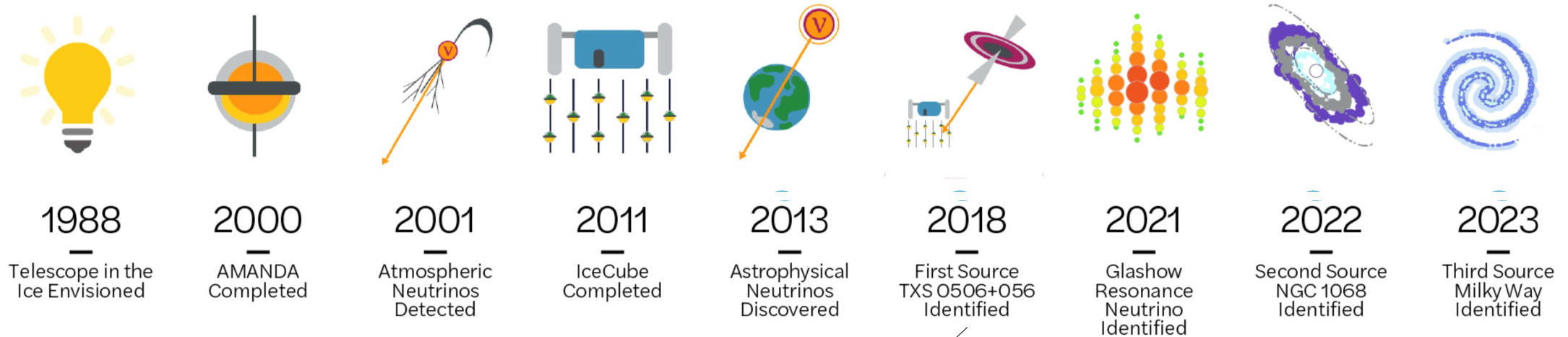
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Deep Learning/Machine Learning

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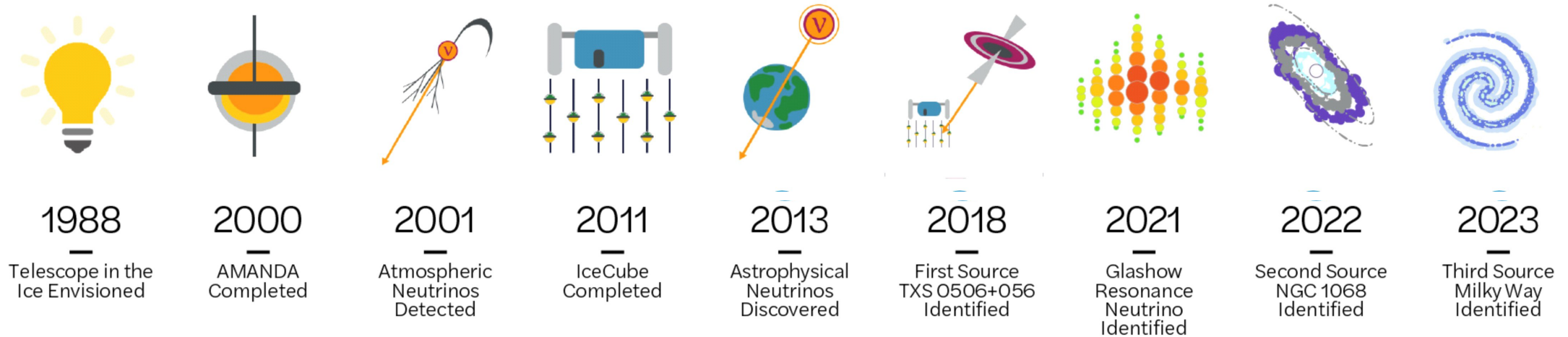
Pass 2 Reprocessing

Deep Learning/Machine Learning

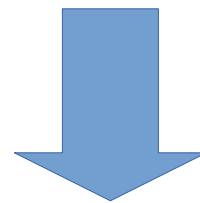


Every discovery is connected to a new area of M&O

# In fact, discovery rate is accelerating...



Every discovery is connected to a new area of M&O



New discoveries and expansion in to previously unpredicted science subfields linked to new M&O area

# Publications by Numbers

51 Papers Published Since April 2021

## By Journals

*Science* 2

*Physical Review Letters* 4

*Astrophysical Journal Letters* 6

*Nature Physics* 2

*The Astrophysical Journal* 16

*Physical Review D* 9

*Journal of Cosmology and Astroparticle Physics* 2

*European Physical Journal C* 3

*Journal of Instrumentation* 5

*The Cryosphere* 1

*Computer Physics Communications* 1

## By Working Groups

Neutrino Sources 26

Realtime 1

Beyond Standard Model 9

Diffuse 7

Supernova 3

Cosmic Ray 2

Calibrations 1

“Technical” 6 (this includes hardware, new reconstruction techniques, simulation, etc)

# Working group breakdown hides the diversity of topics

Examples:

Diffuse Working Group include...

- Flux spectral measurement
- Flavor Ratio
- Tau Appearance

Supernova Working Group include...

- Any low energy ( $\leq 10\text{GeV}$ ) Source

**Diversification of Science Topics!**

**Even after 13 years, IceCube finds new areas to explore!**

# What does this mean for M&O?

- Closer coordination between M&O and Analysis sides
  - Ex: Simulation Needs
    - Review of simulation needs done in 2023
    - Realignment on M&O side to better support simulation needs
- M&O evolves as discoveries continue

## M&O SimProd — Actions

- Hardware
  - New filesystem, additional 3 PB storage (~5 years)
  - Migration of old simulation almost complete
- Communication
  - P. Desiati as “simulation liaison” with WG Technical Leads
  - plans to improve technical calls w/r/t simulation
- Technical support
  - [Simulation Production workshop](#) at this meeting (today!)
  - another virtual workshop planned for this summer
  - Investigating simulation issue tracking system



Screenshot from the Spring 2024 Collaboration Meeting

Me (Analysis) and John Kelley (M&O) giving a joint talk to present findings and adjustments going forward on simulation

M&O support directly affects science (and vice versa!), both in new discoveries and new areas for IceCube to make an impact!