The Search for Neutrino Point Sources

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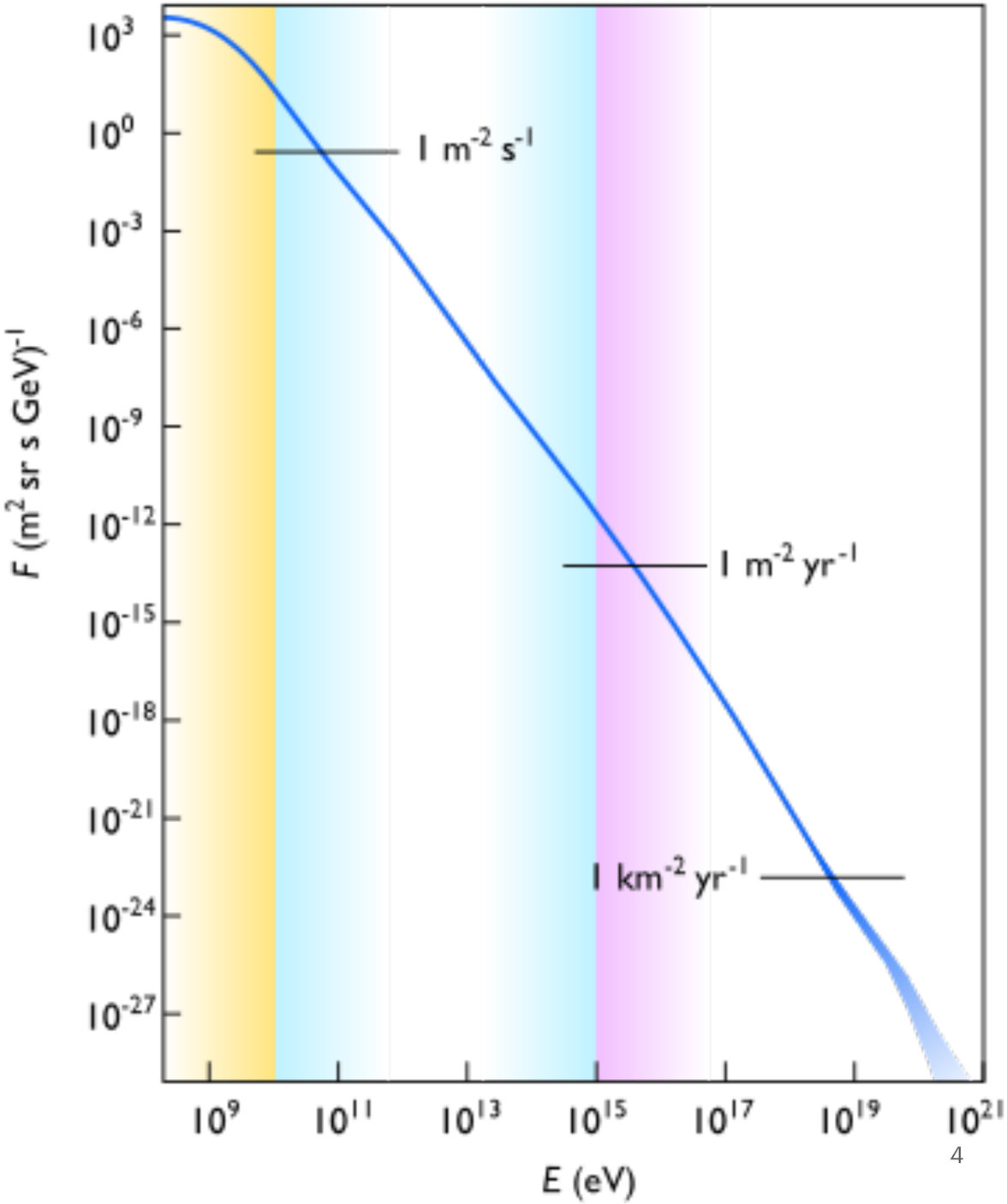
AERO
CLUB
WIEN

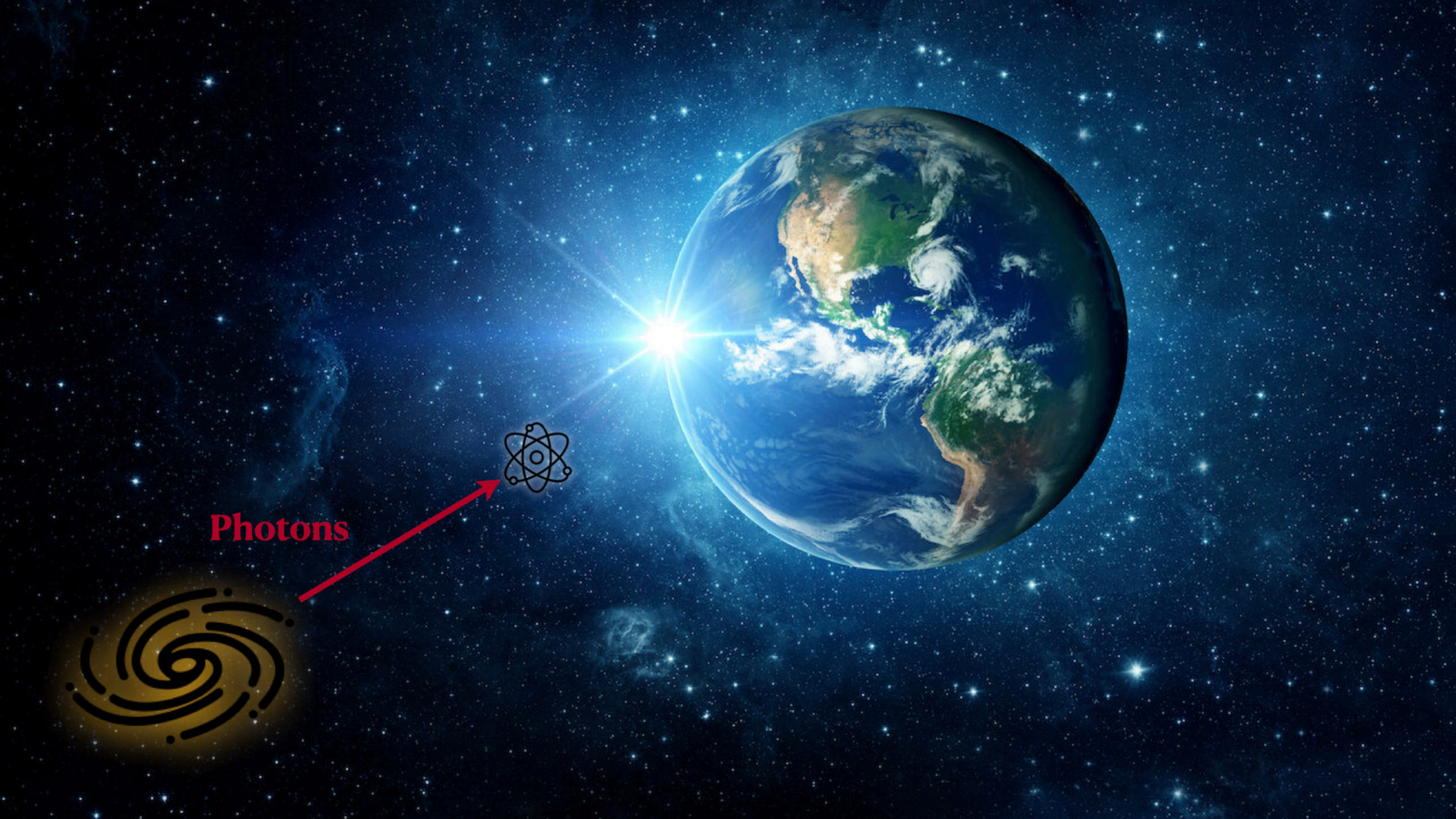
Cosmic rays

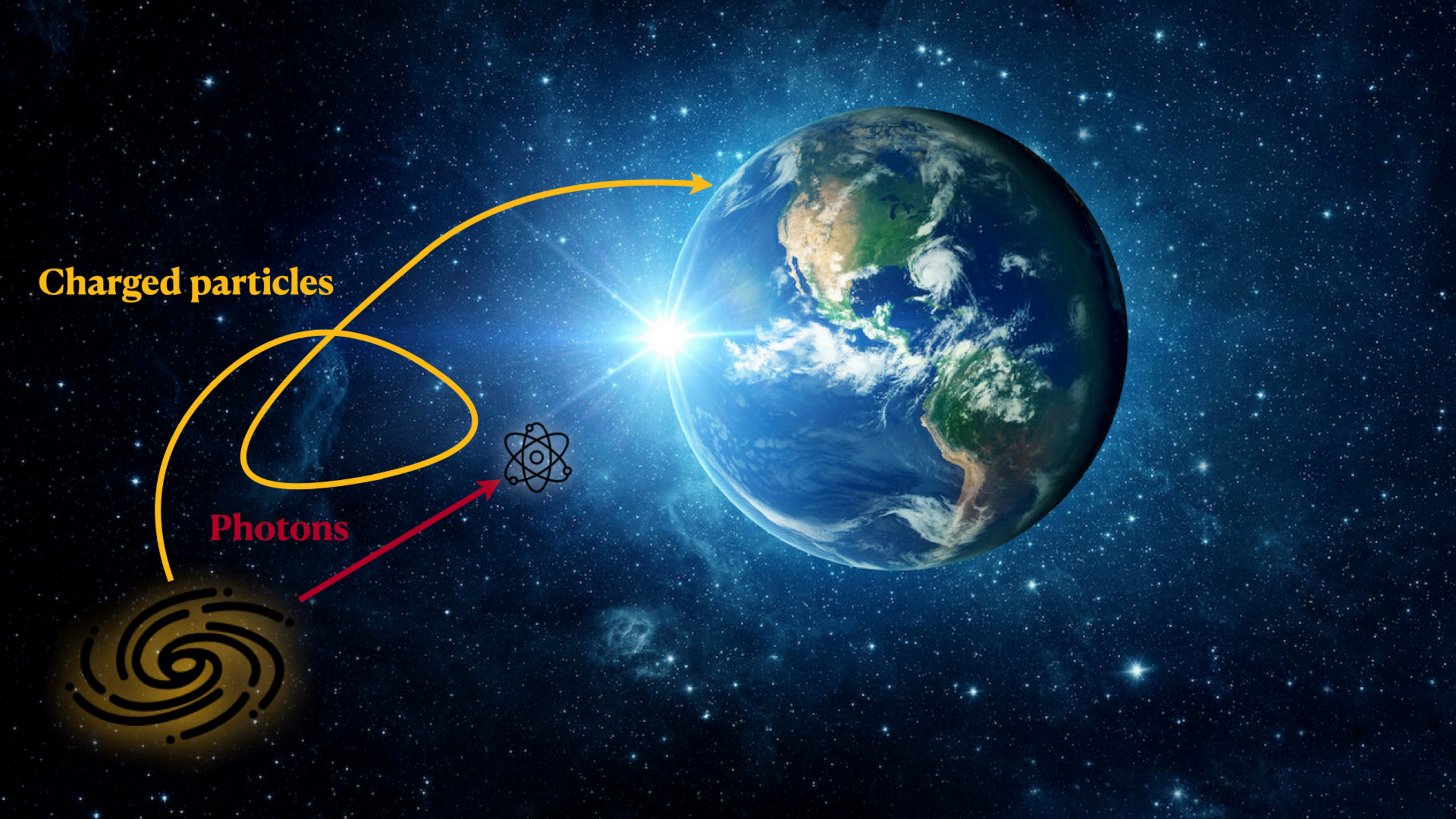
- Mainly protons, but also heavier nuclei
- Energies can exceed Large Hadron Collider (10^{13} eV) with a factor 10^6 or more

Questions

1. What is their origin?
2. How do they obtain these energies?




Photons


Charged particles
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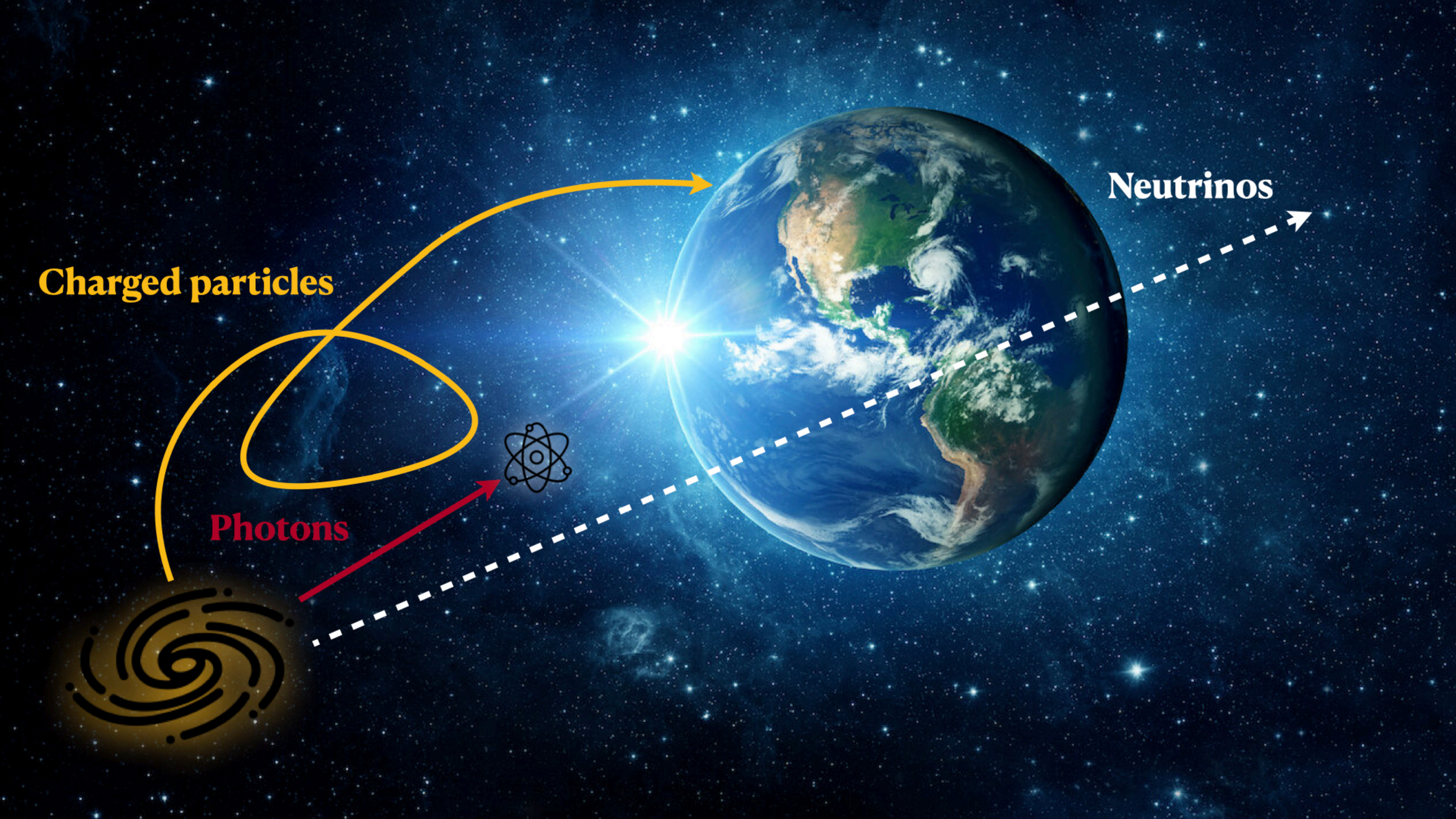
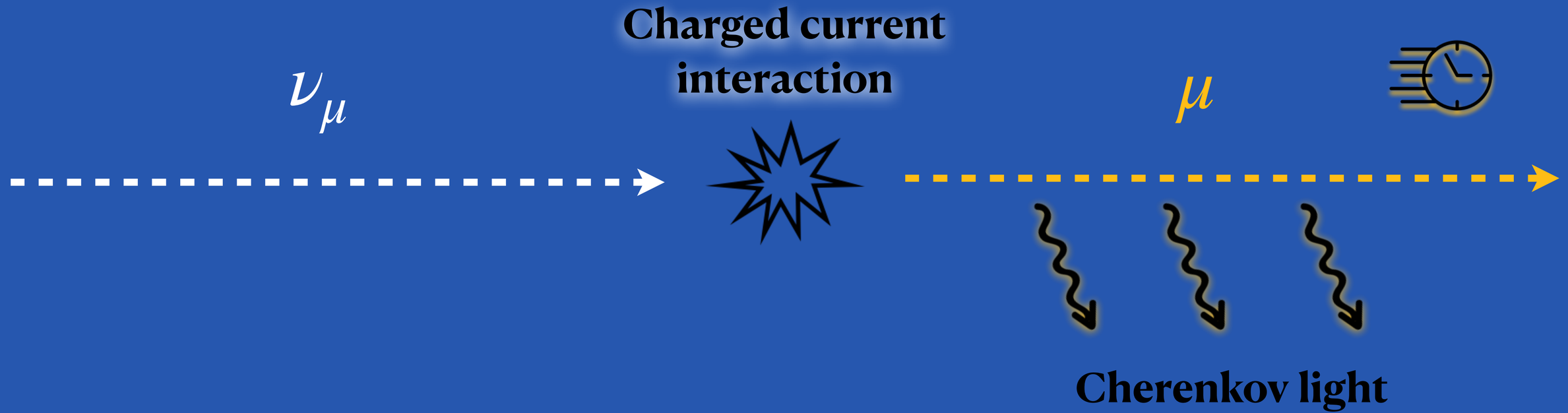
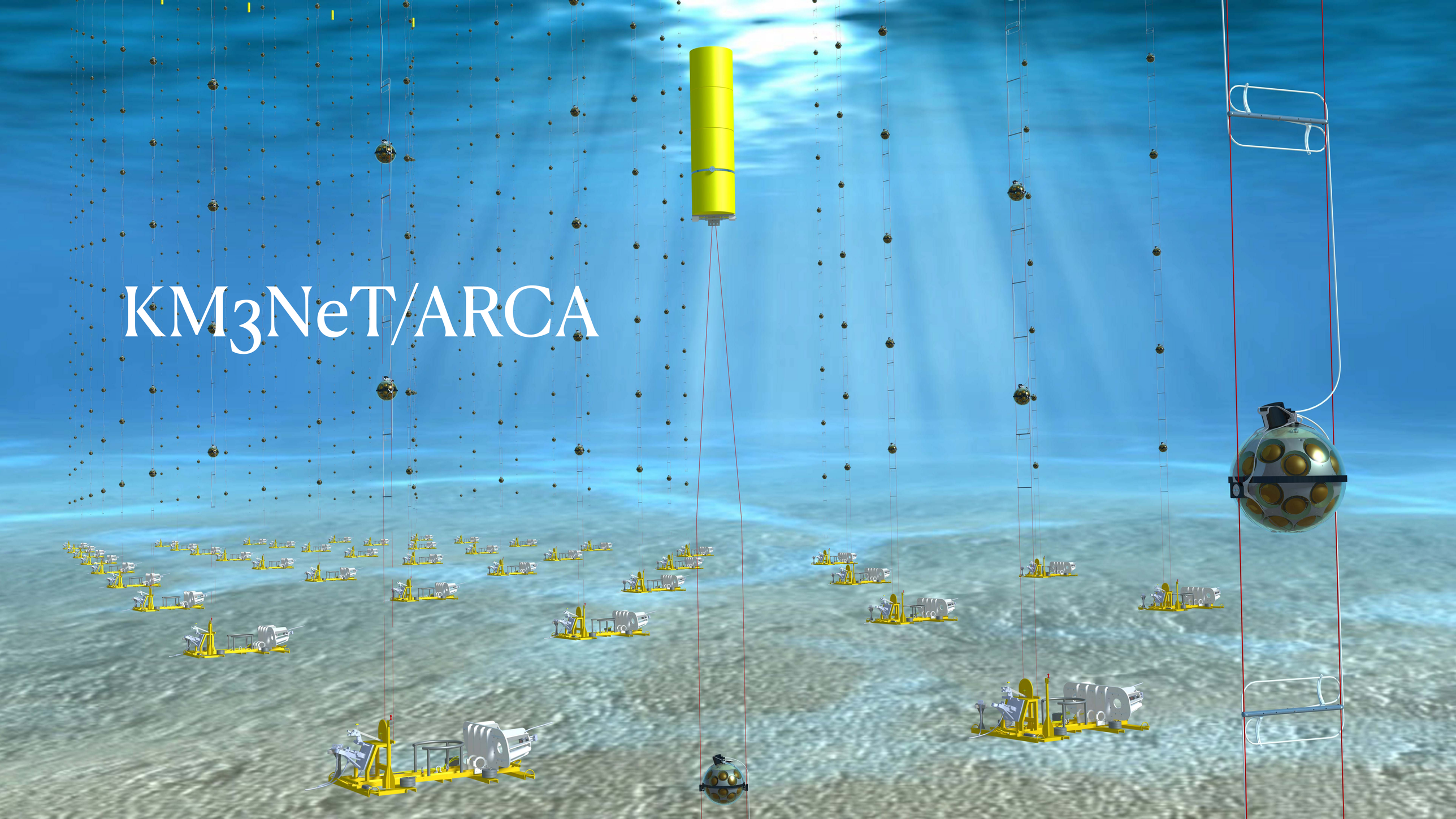
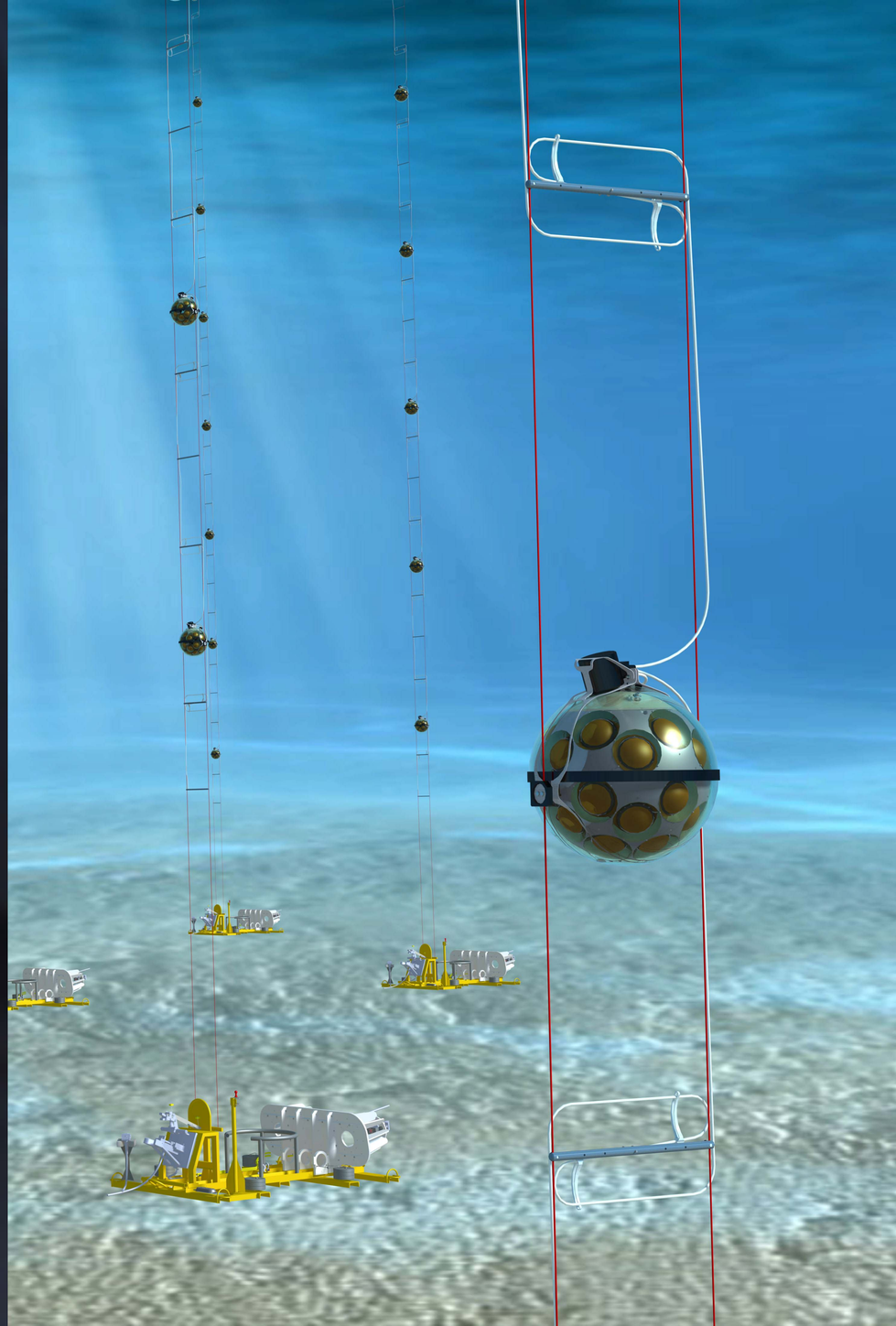

Neutrinos
Charged particles
Photons

Water



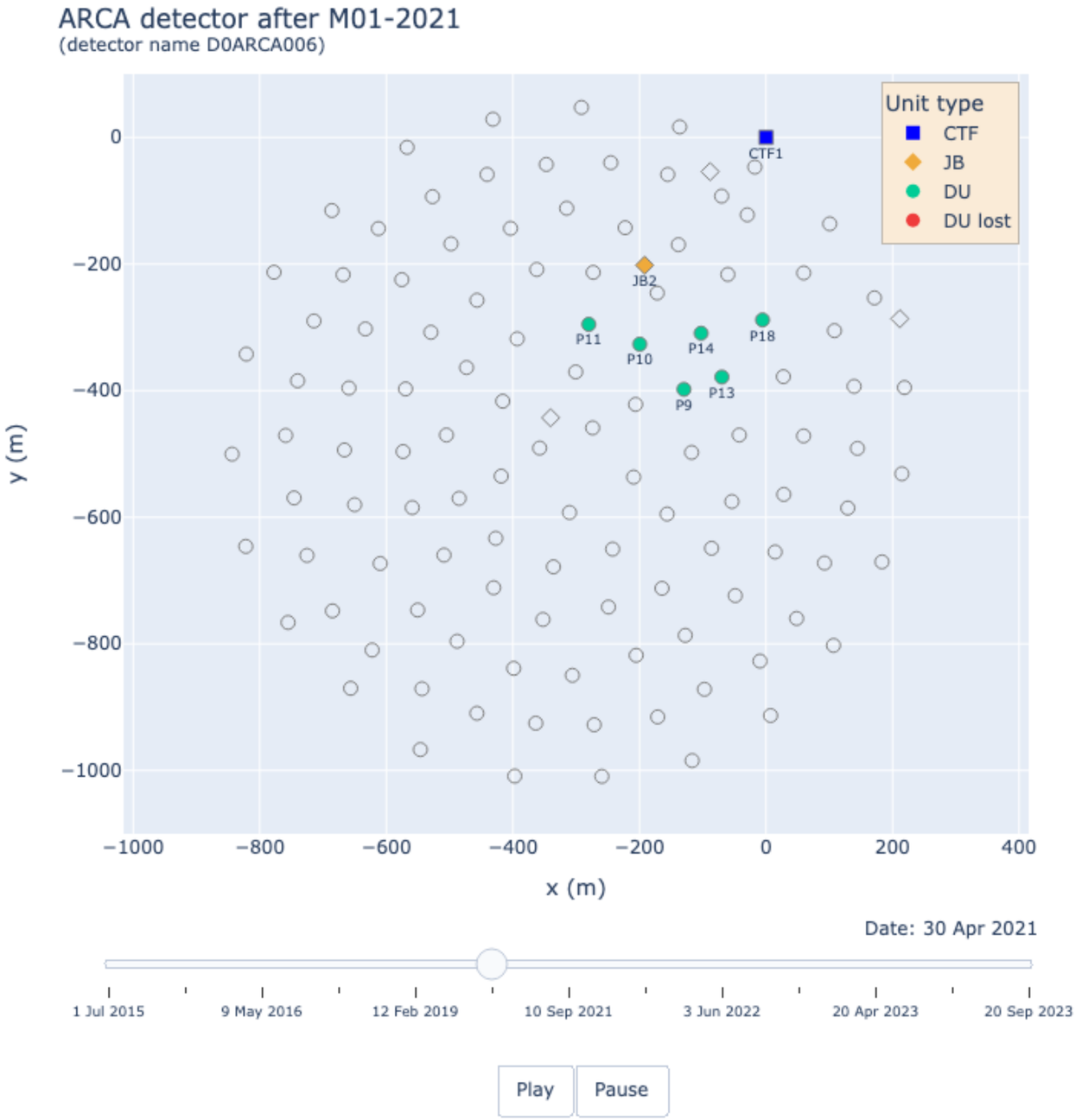

KM3NeT/ARCA



A growing detector

KM3NeT/ARCA

- Analysis includes data taken May 2021 - December 2022
- Detector configurations with 6-8-19-21 detection lines (DU)
- Currently operating 28 strings (of final 230)



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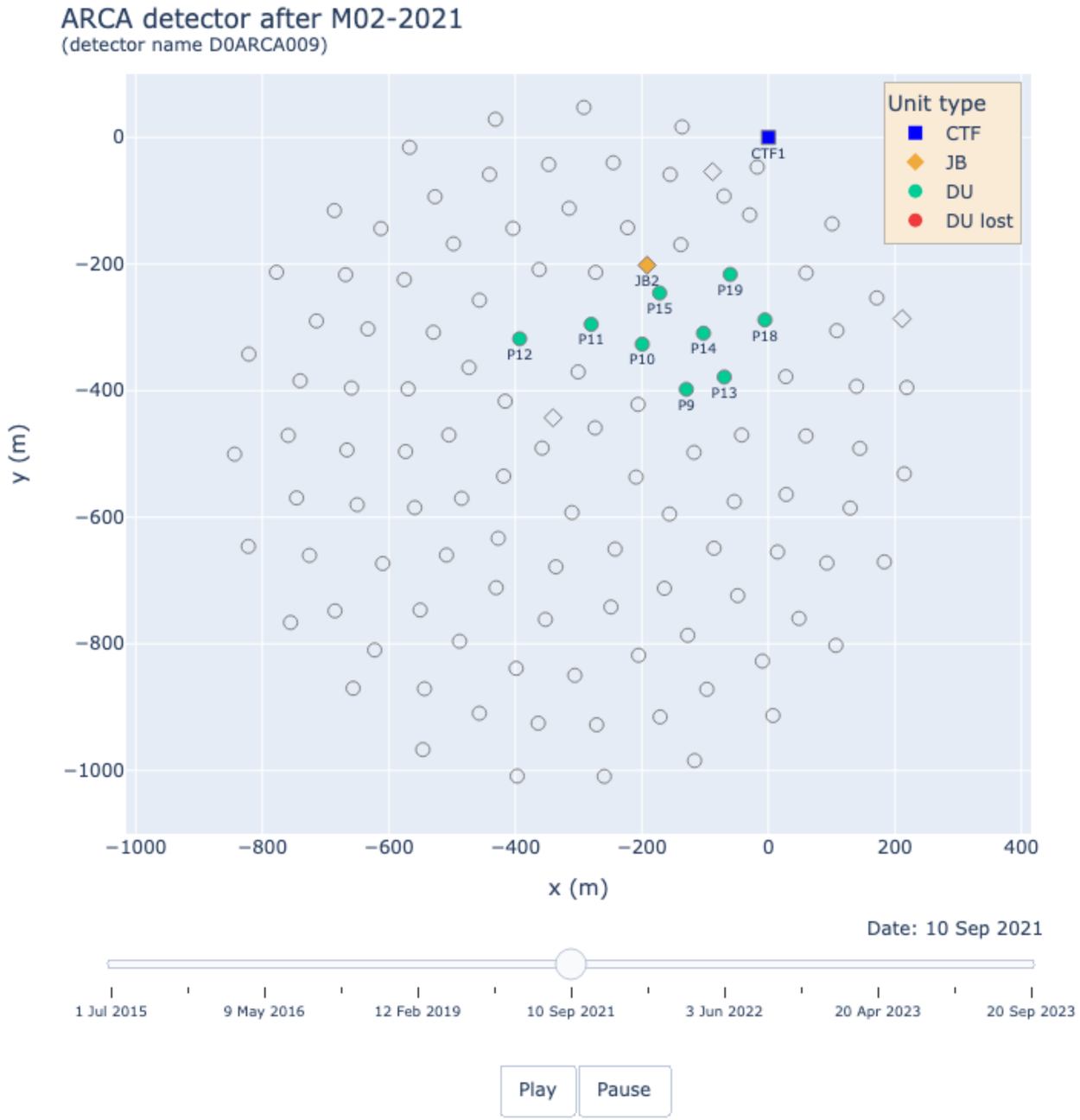

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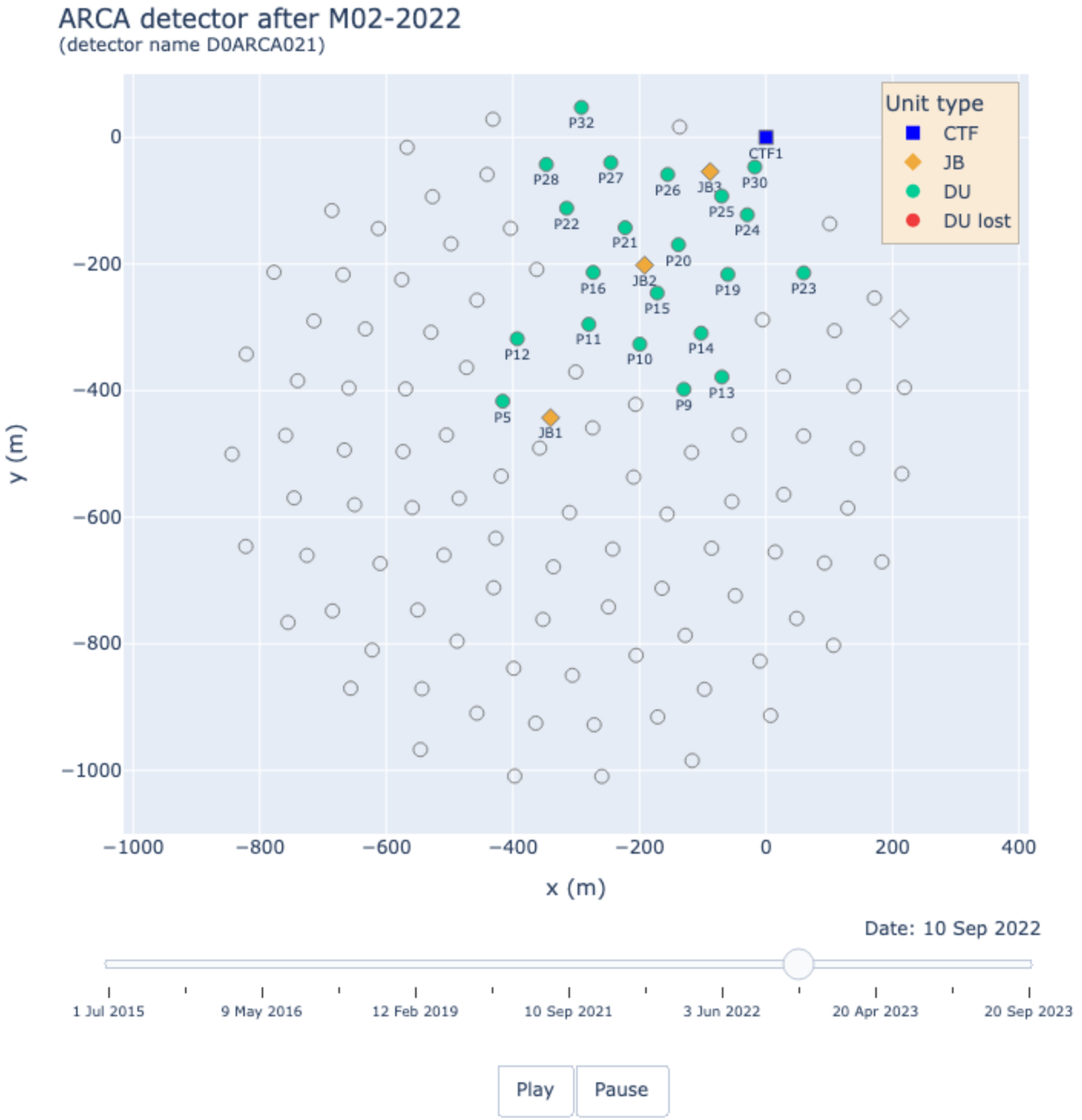

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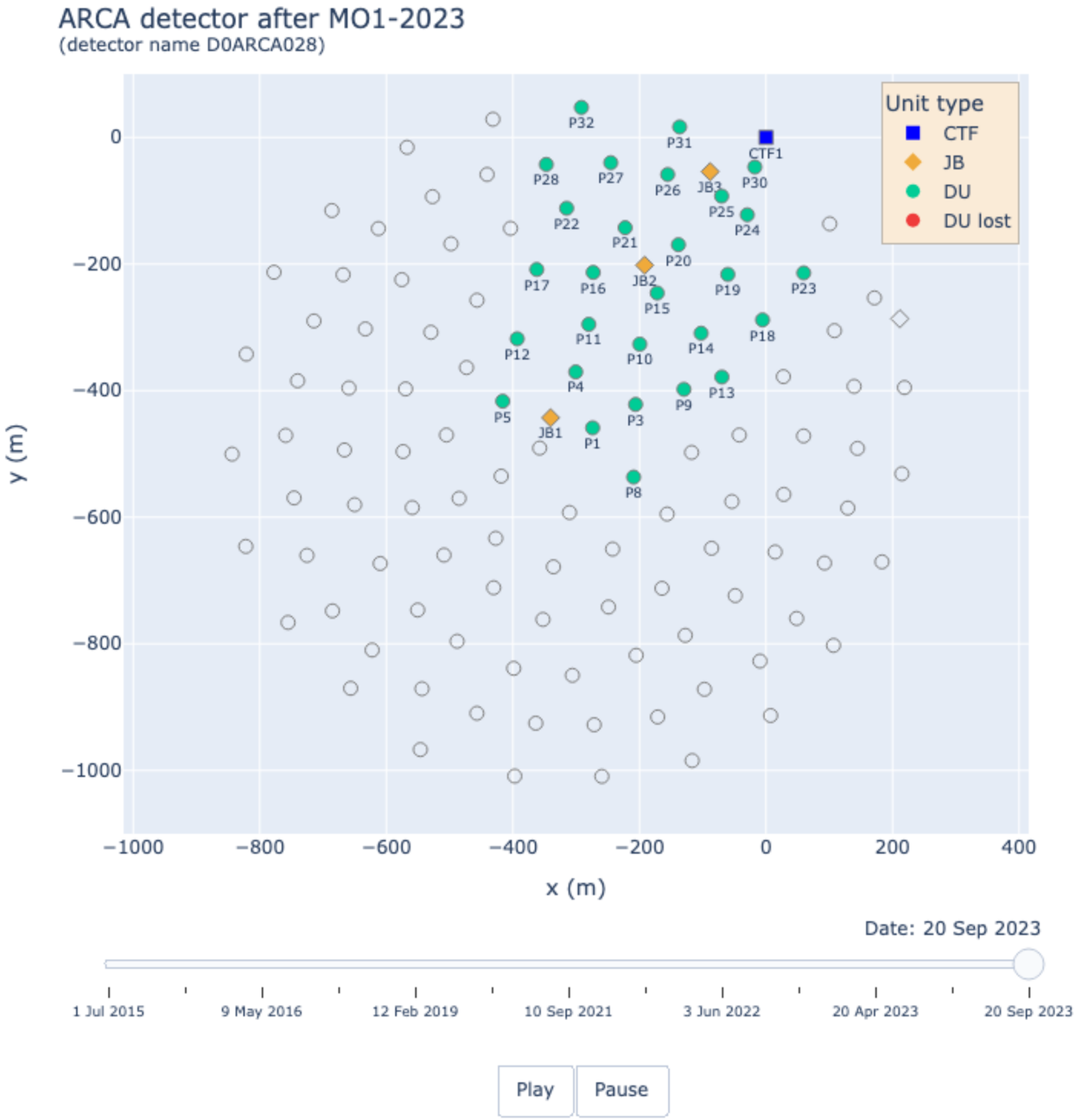
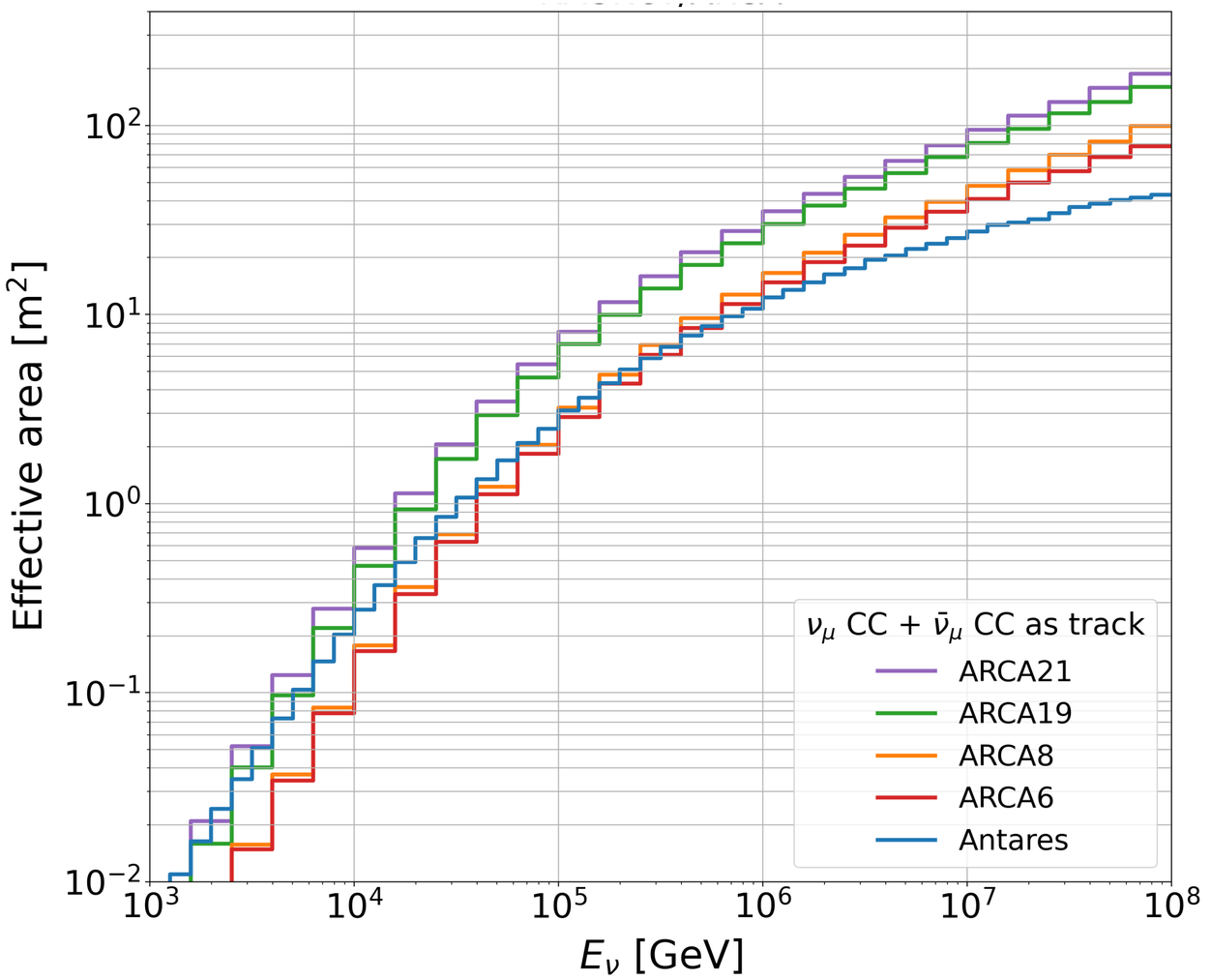


A growing detector

KM3NeT/ARCA

Growing detector leads to

- Higher acceptance
  —> More neutrinos / day

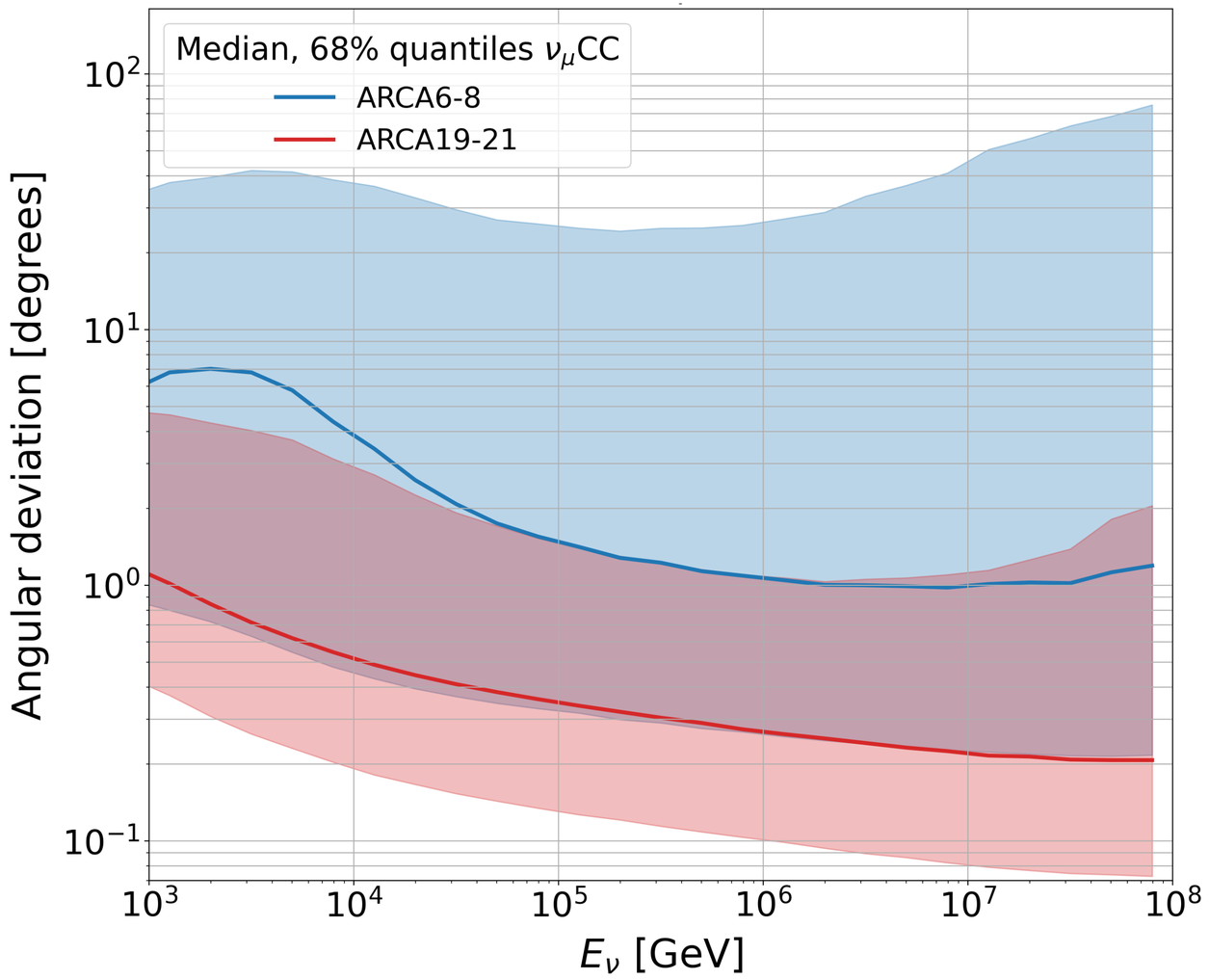


A growing detector

KM3NeT/ARCA

Growing detector leads to

- Higher acceptance
- Better detector resolution



A growing detector

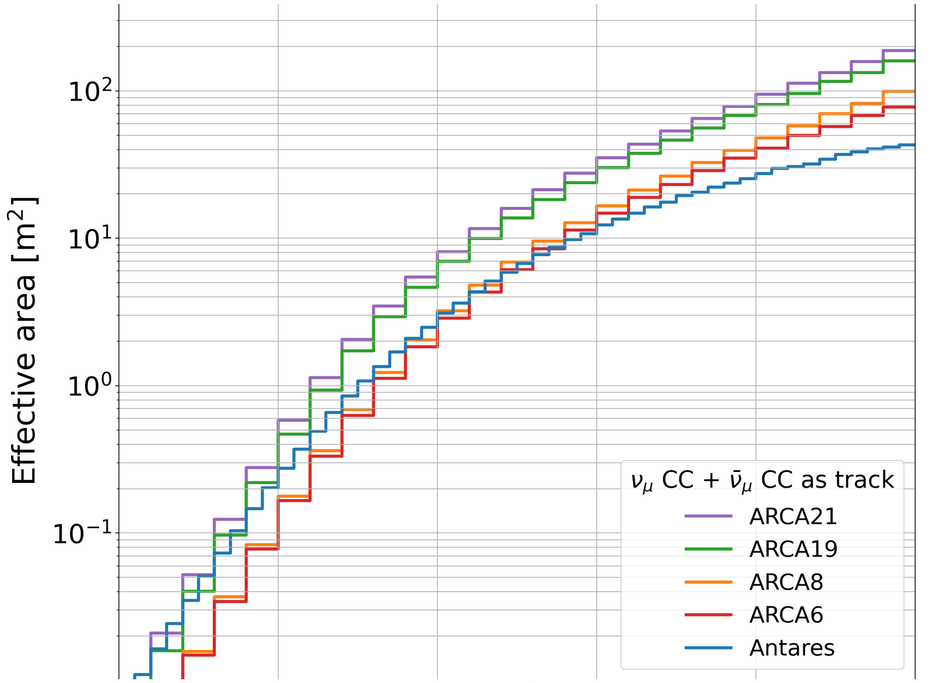
KM3NeT/ARCA

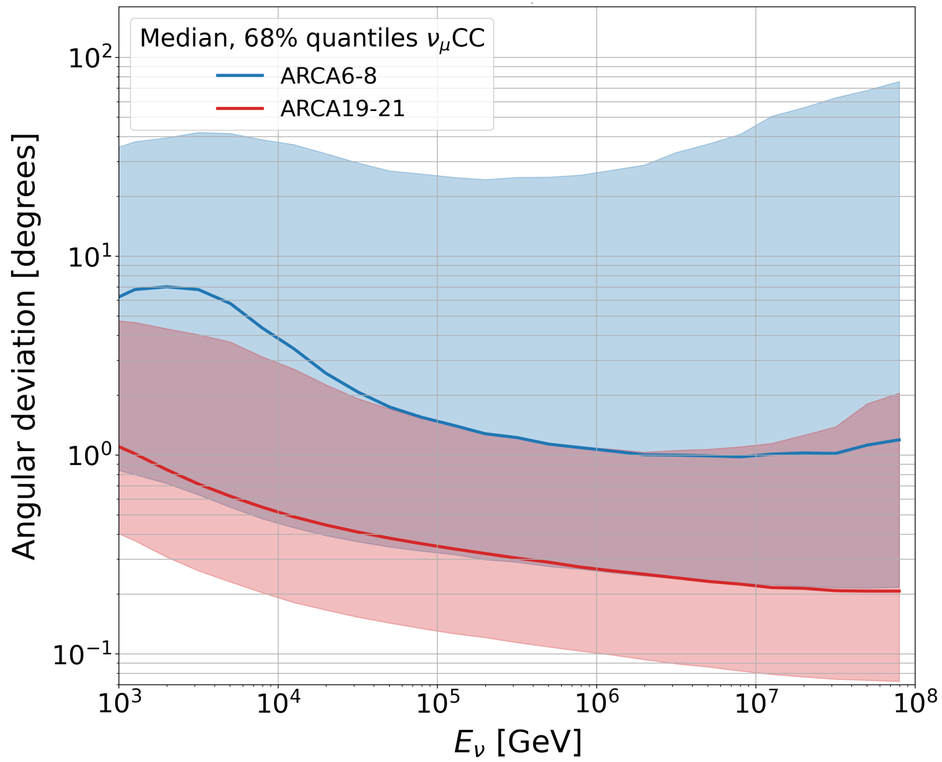
Growing detector leads to

- Higher acceptance
- Better detector resolution

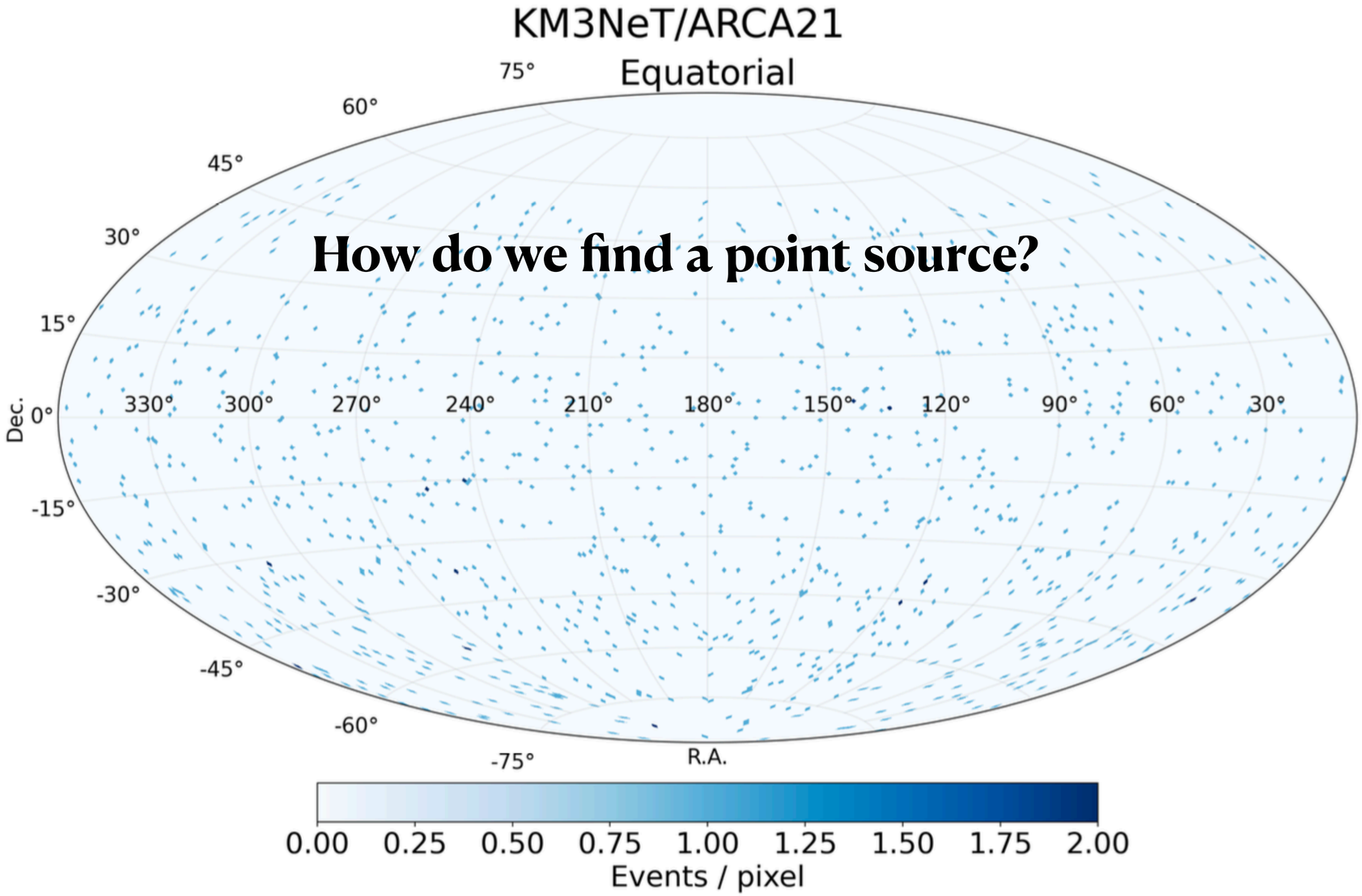
Easier to discriminate signal from background

Period	Atmospheric muons	Atmospheric neutrinos	Cosmic neutrinos
ARCA6-8	13278	746	9.4
ARCA19-21	545	804	7.0





Neutrino Point Sources

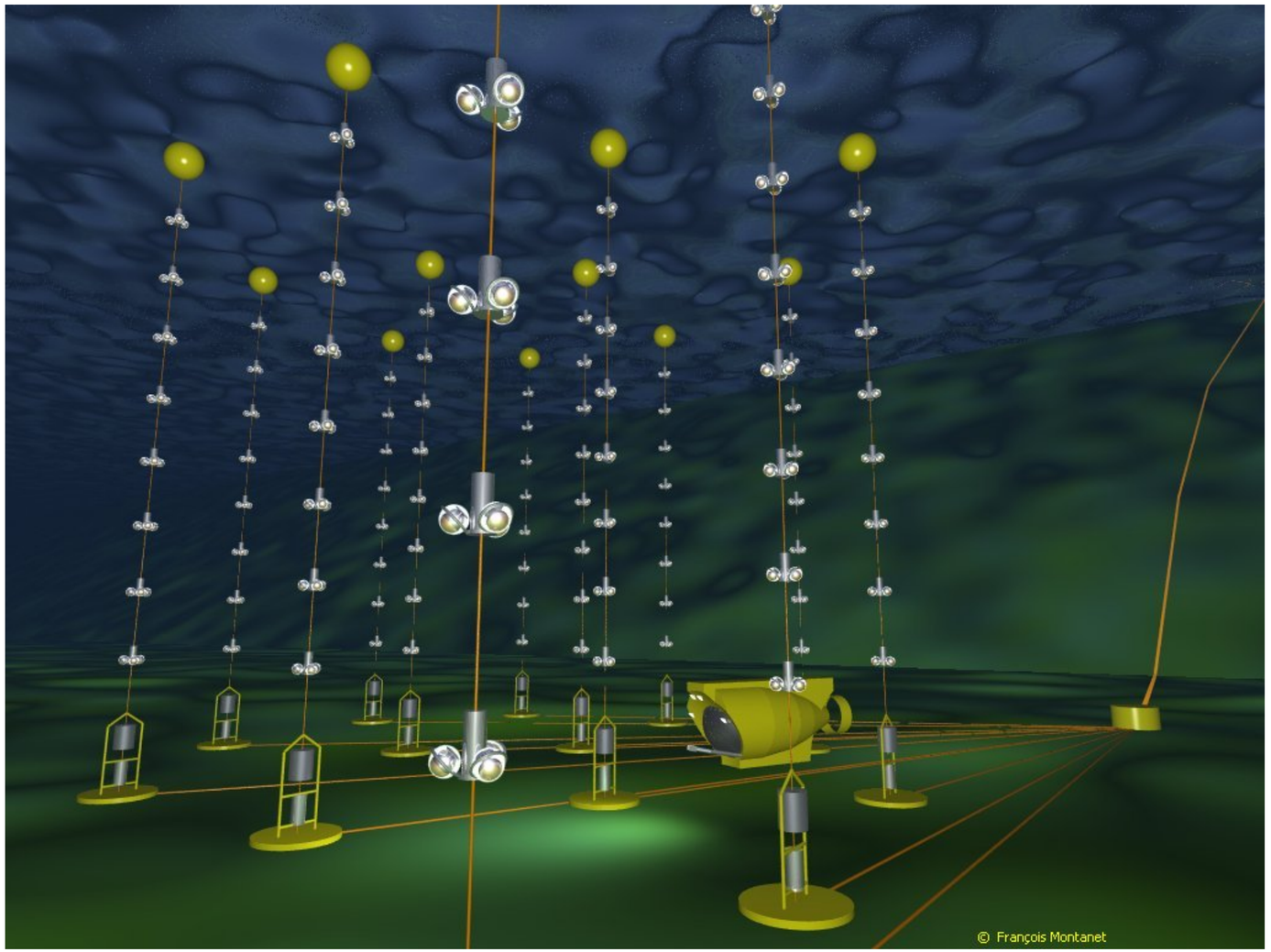


How do we find a point source?

Candidate Sources

101 candidate sources

- Interesting objects from other ν telescopes



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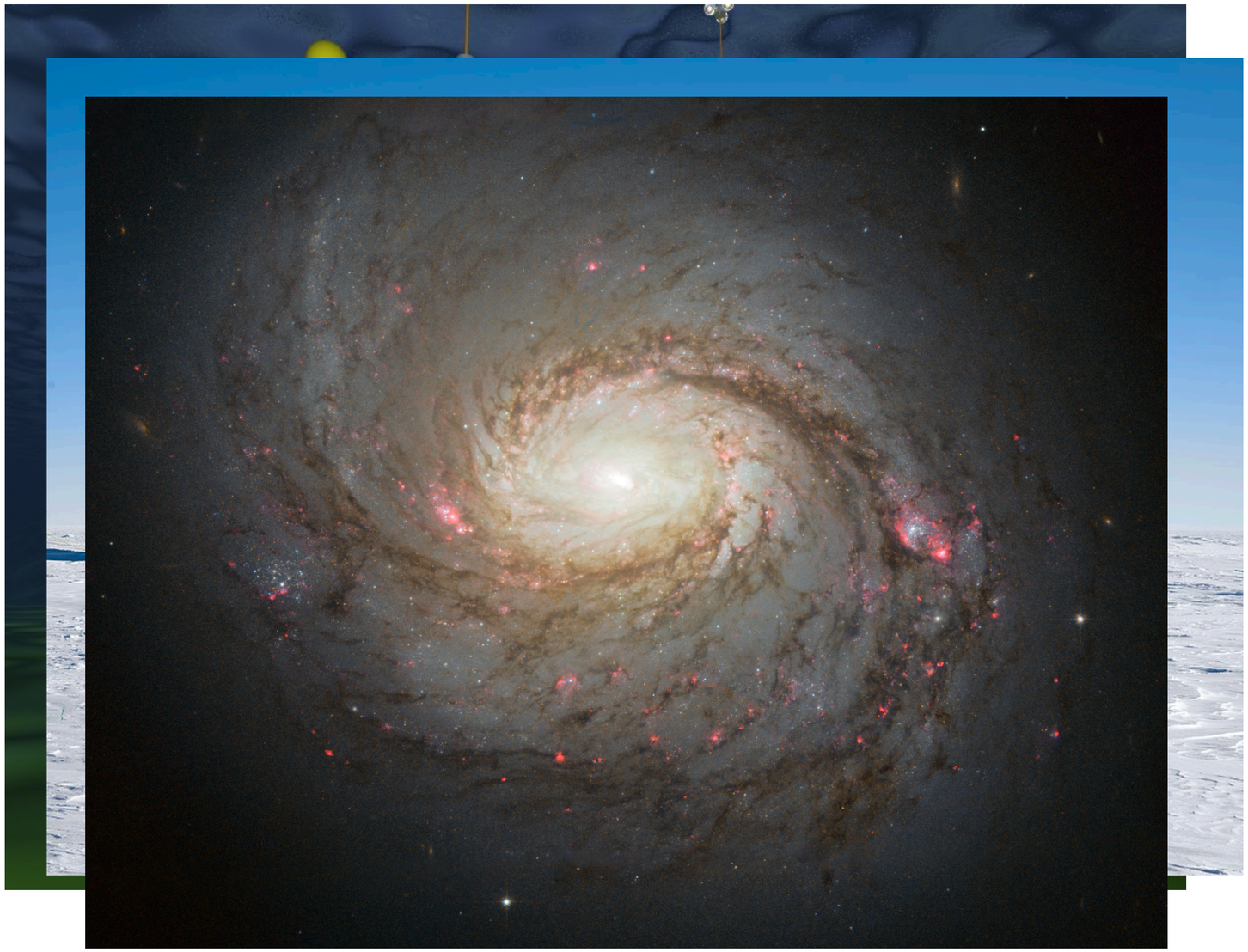
Examples: NGC 1068



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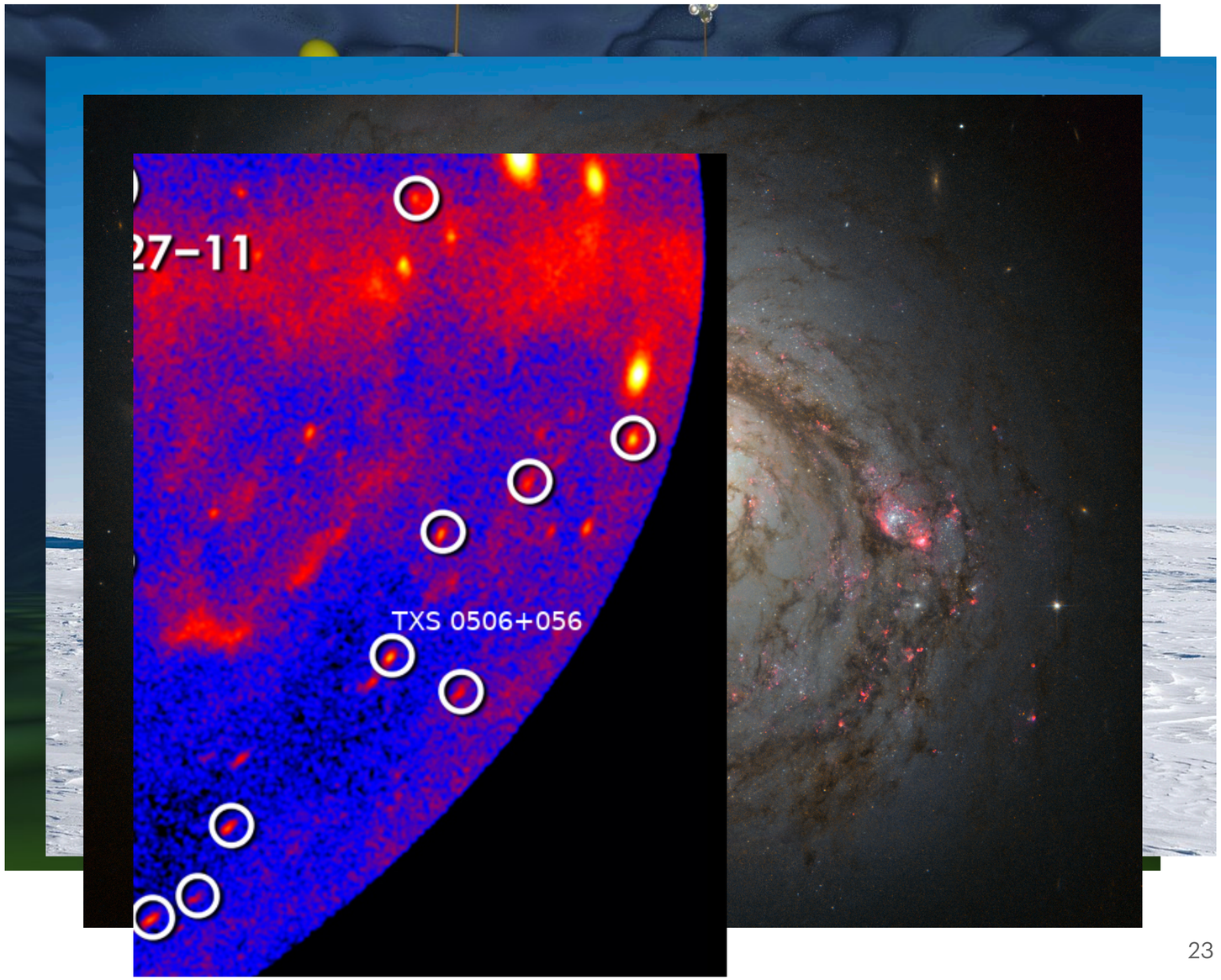
Examples: NGC 1068, TXS 056+056



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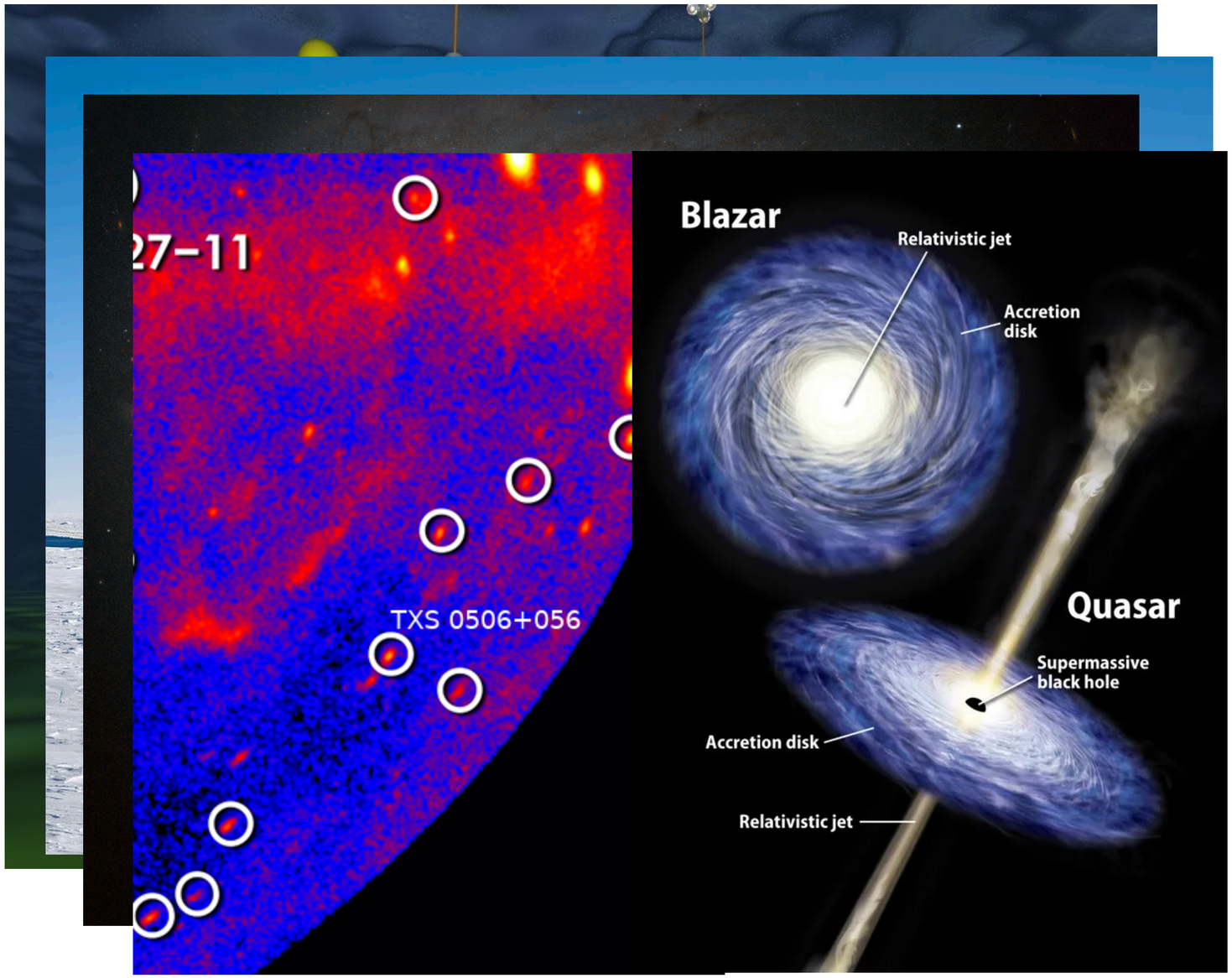

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Examples: NGC 1068,
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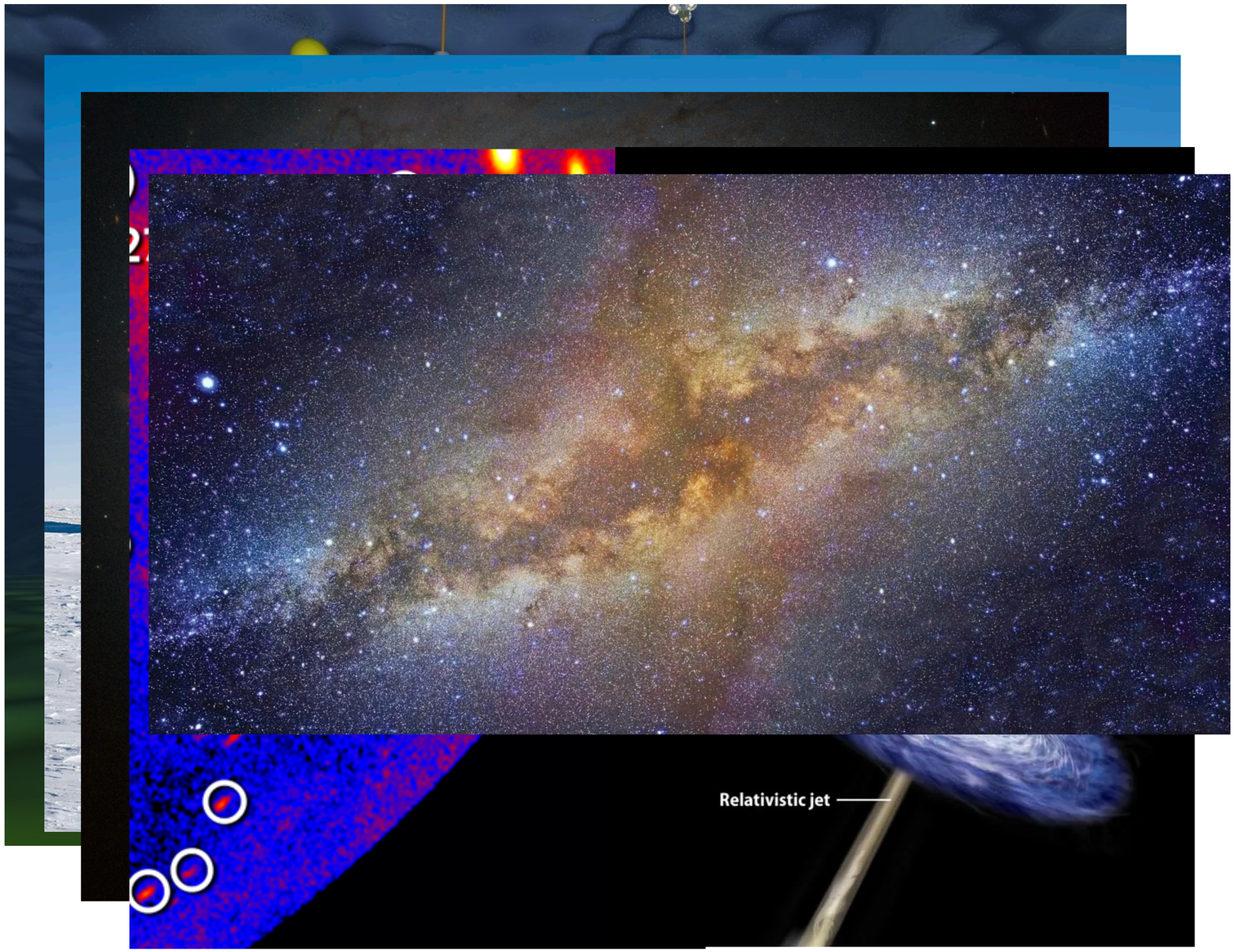

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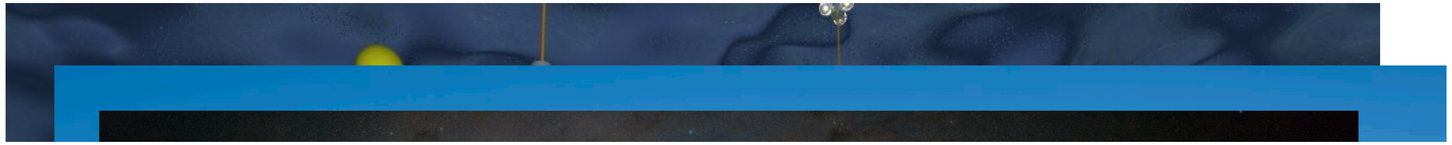

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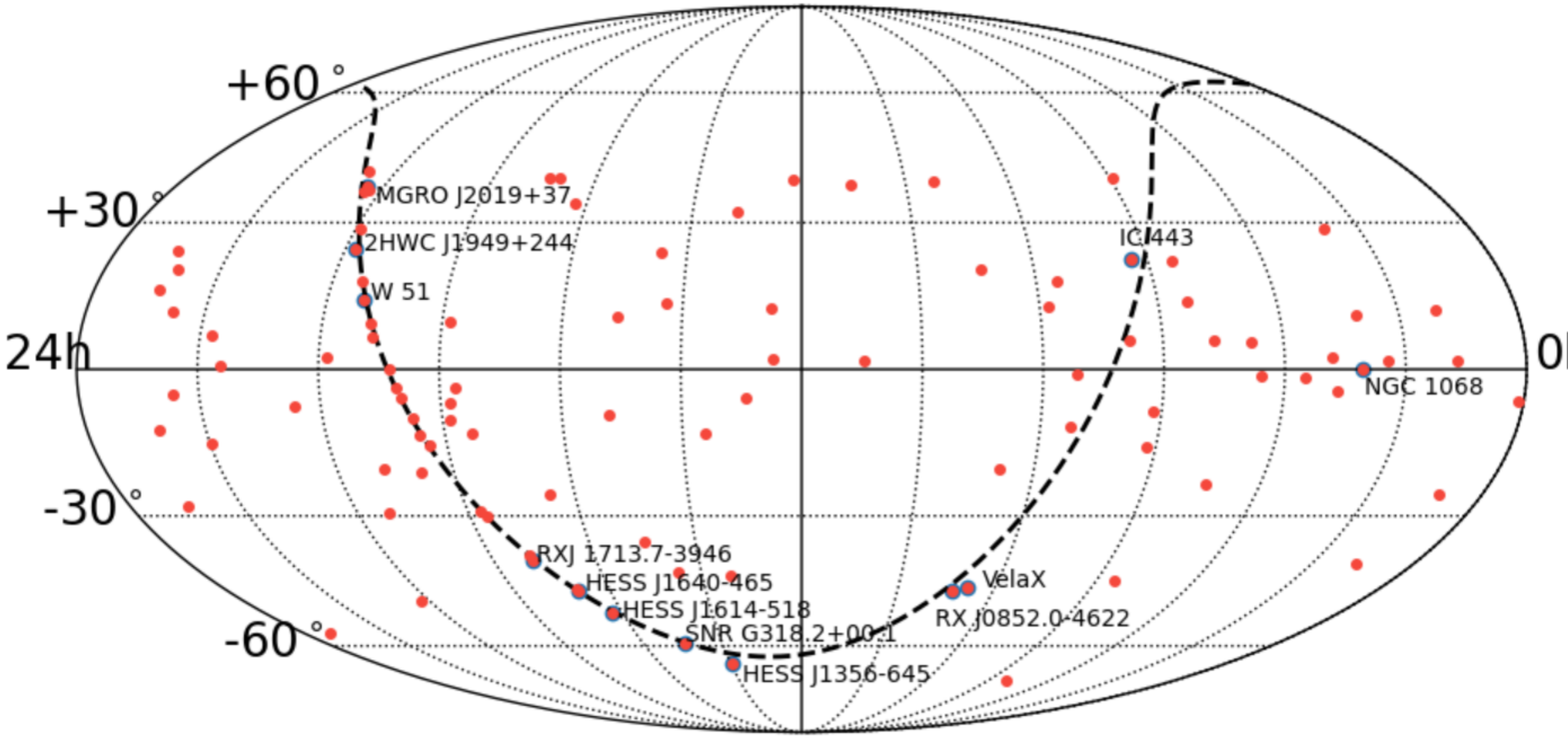
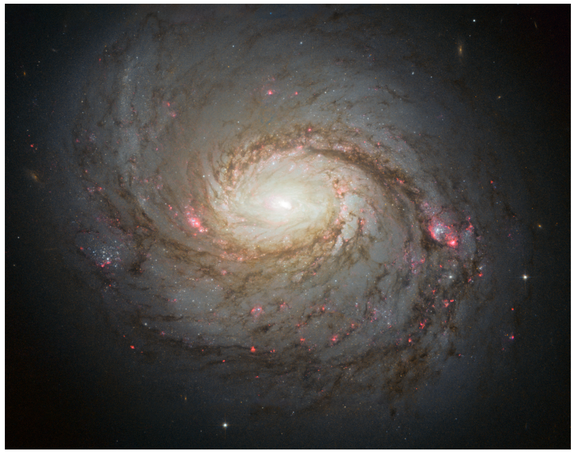


Method

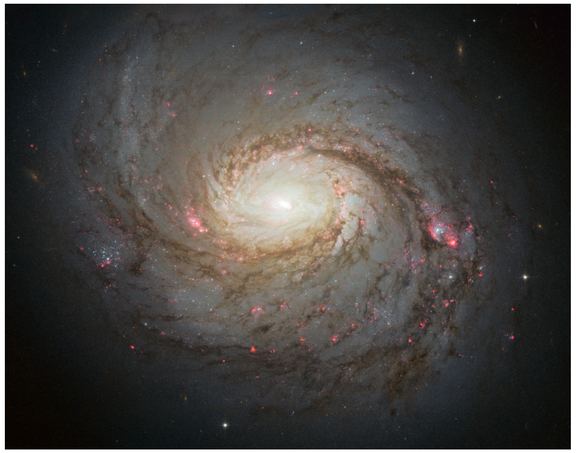


Source flux model

$$\phi_\nu = \phi_0 \times E^{-\gamma}$$

$$\gamma = 2.0, 2.5, 3.2$$

Method



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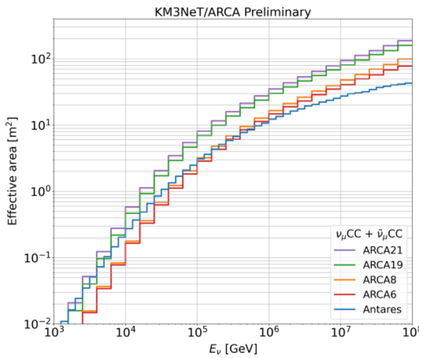

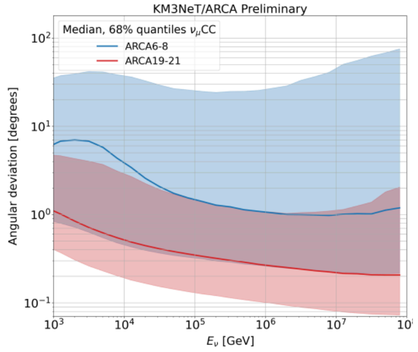

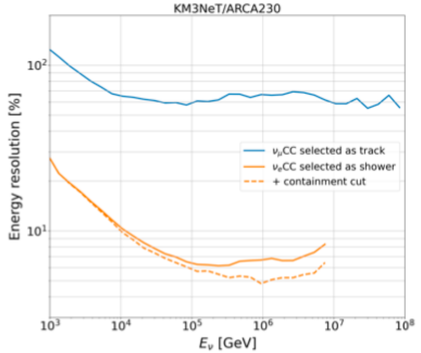

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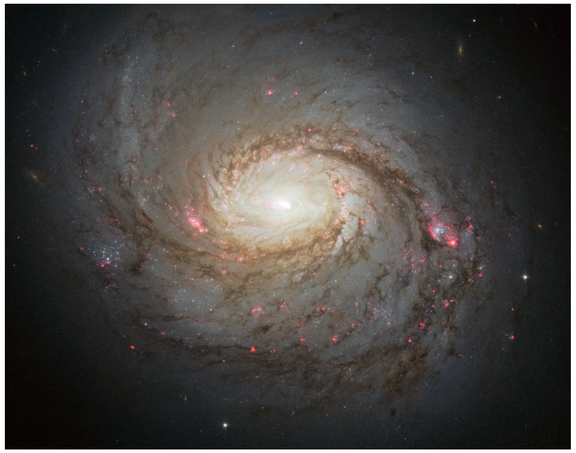

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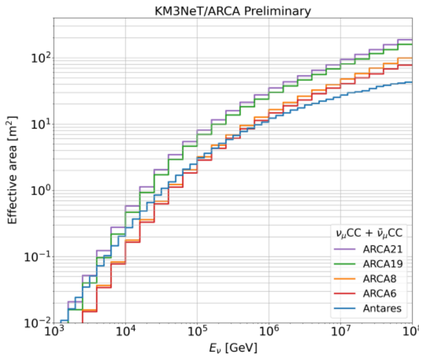
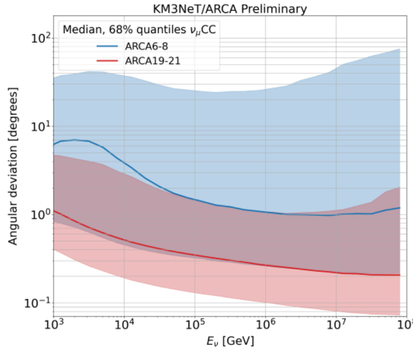
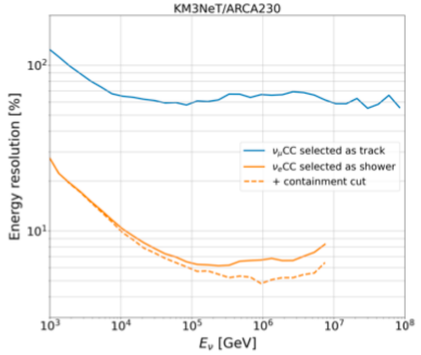
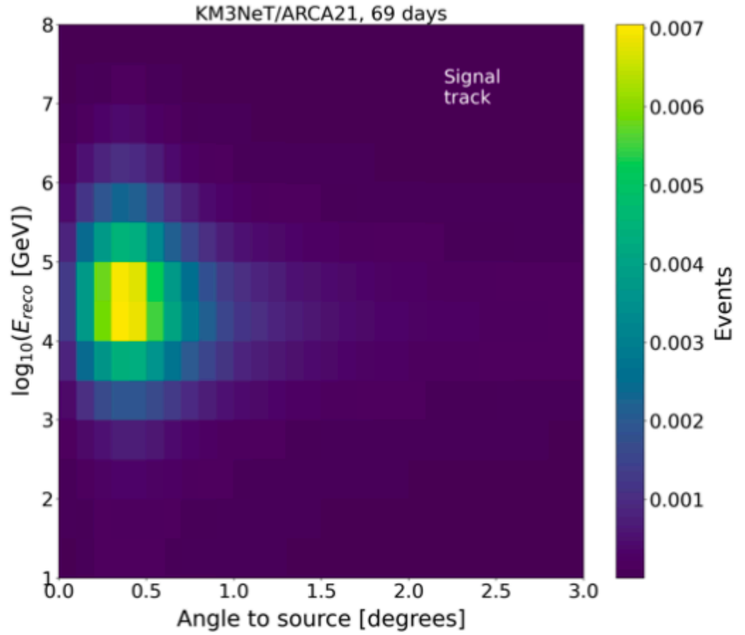
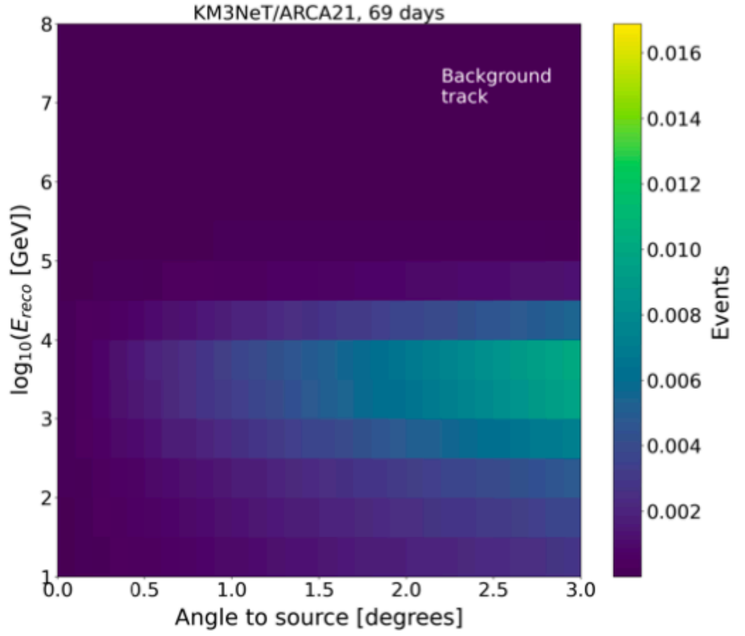






Expected signal & background





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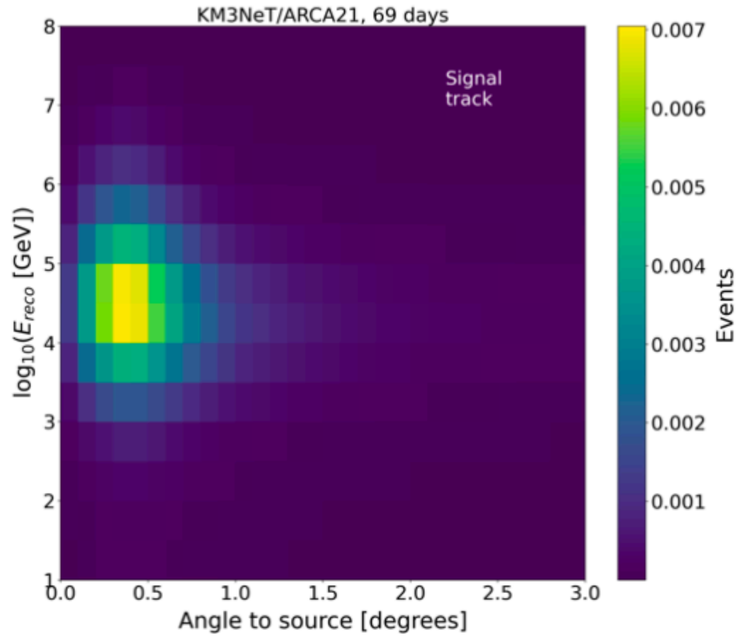

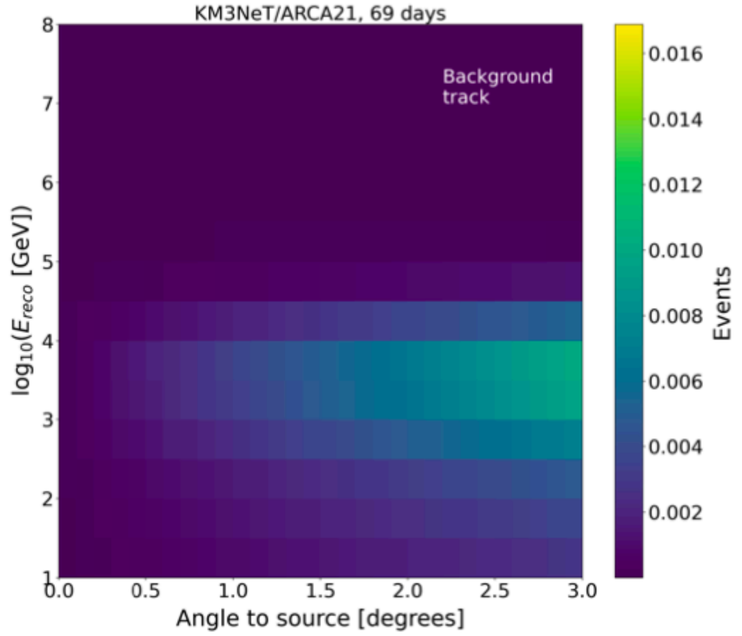

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Pseudo experiments with varying ϕ_0

$$\phi_\nu = \phi_0 \times E^{-\gamma}$$

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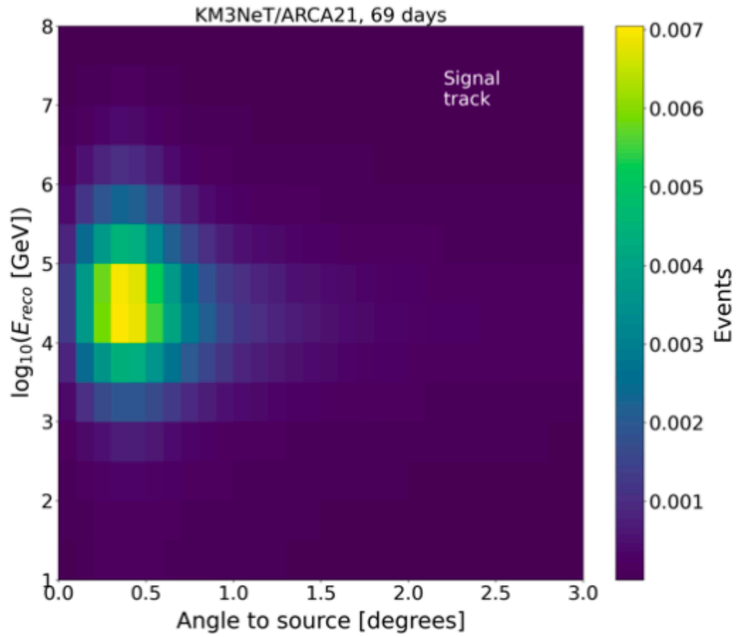

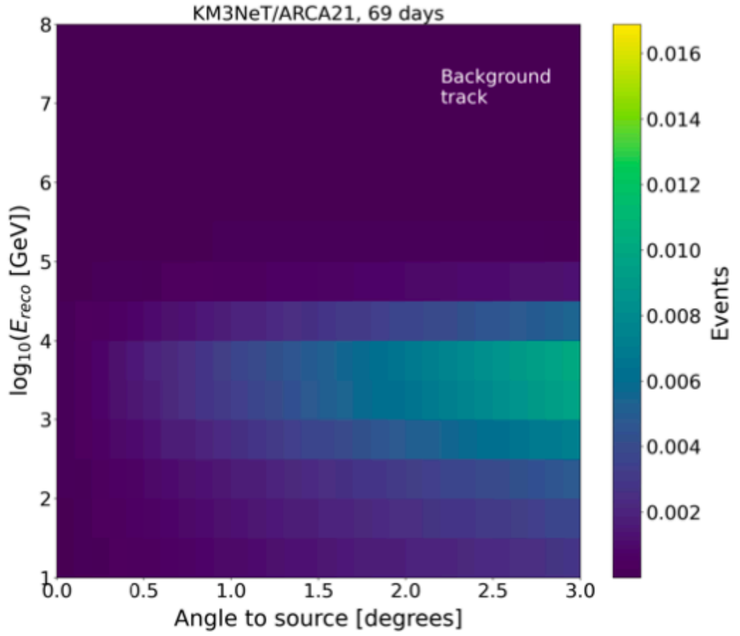

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Test statistic

Log likelihood ratio with

$$\log \mathscr{L} = \sum_{i \in bins} = N_i \log(B_i + S_i) - B_i - S_i$$

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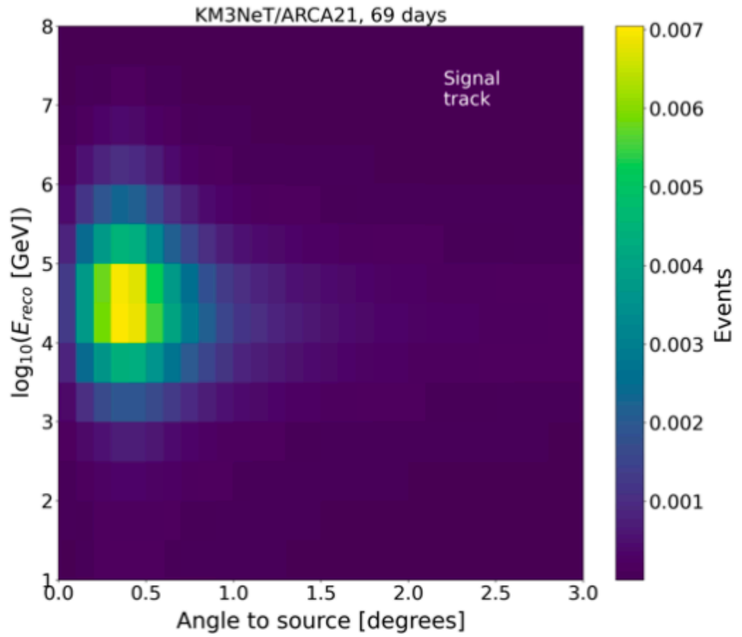

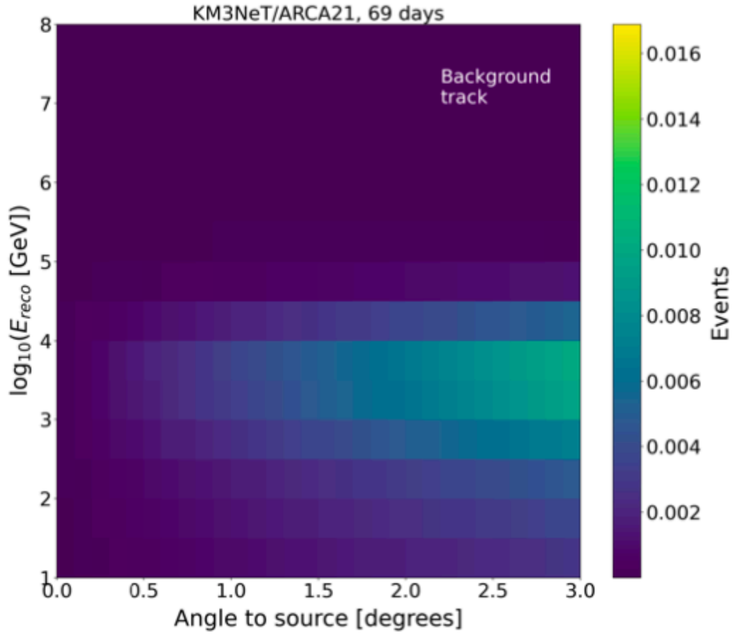

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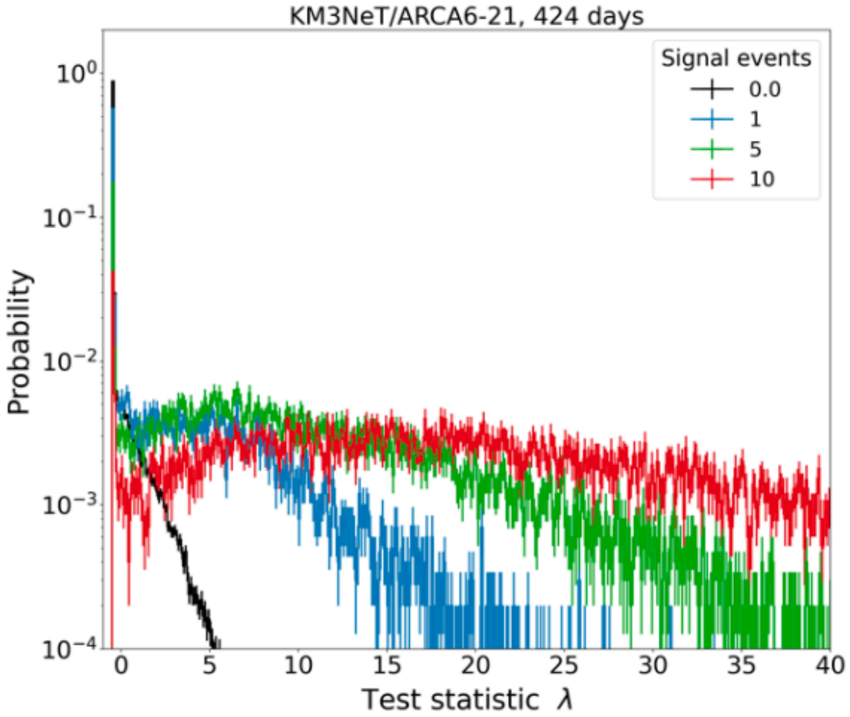

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Results...

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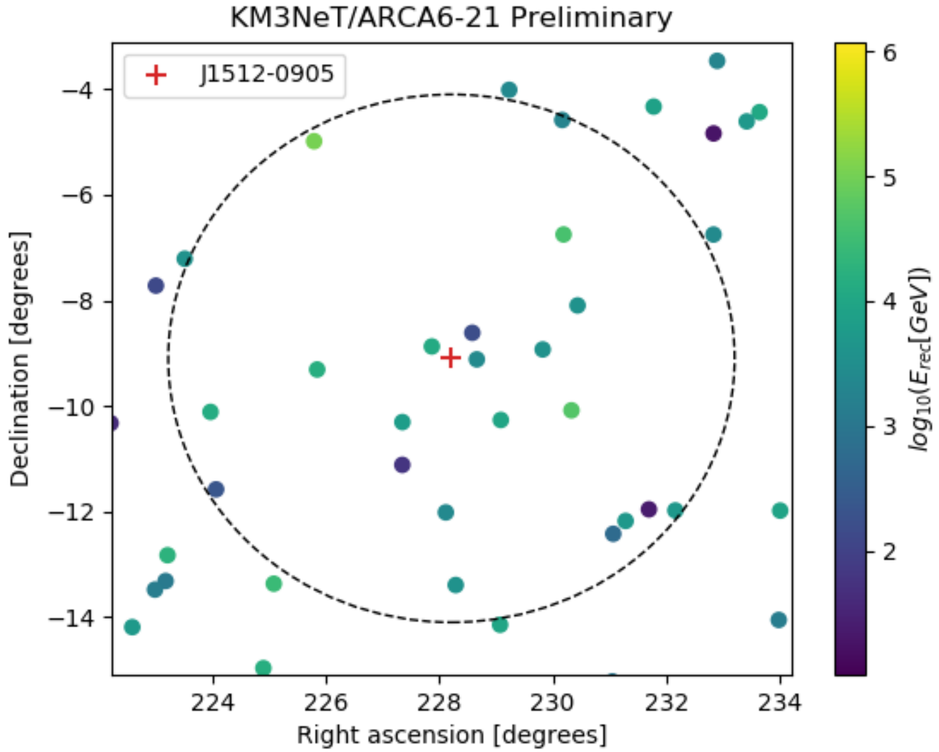
None of the 101 candidate sources is significantly detected...

Results

The most signal-like sources are:

$\gamma = 2$: Active galactic nucleus J1512-0905

- Pre-trial p-value = 0.011
- Post-trial p-value = 0.66



Note: dataset is dominated by atmospheric muons from ARCA6-8 period

Results

The most signal-like sources are:

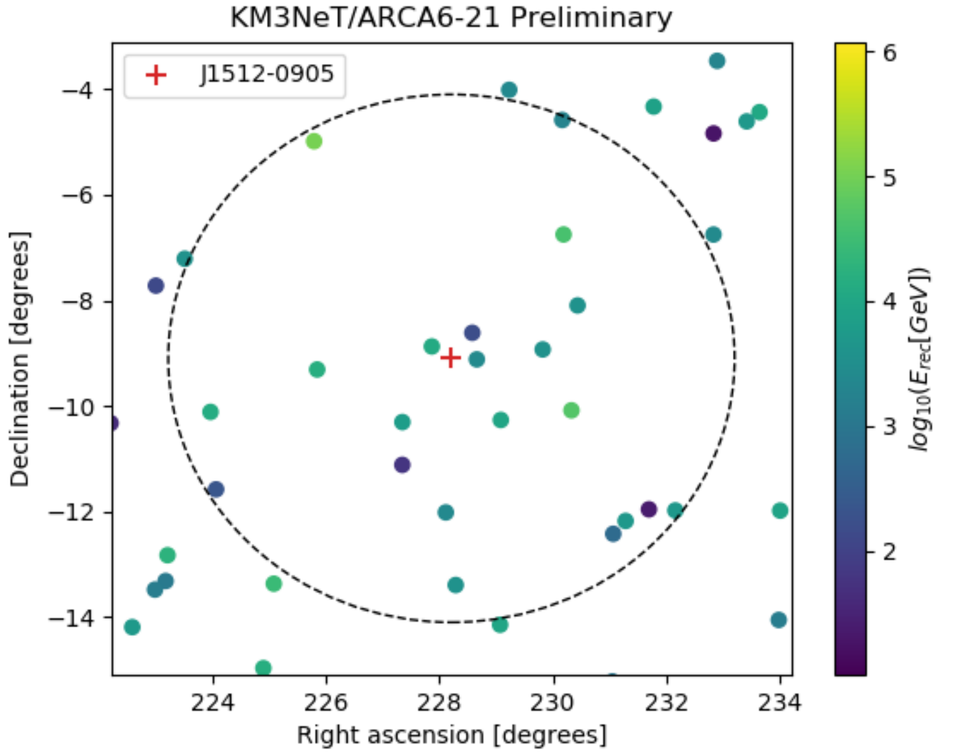
$\gamma = 2$: Active galactic nucleus J1512-0905

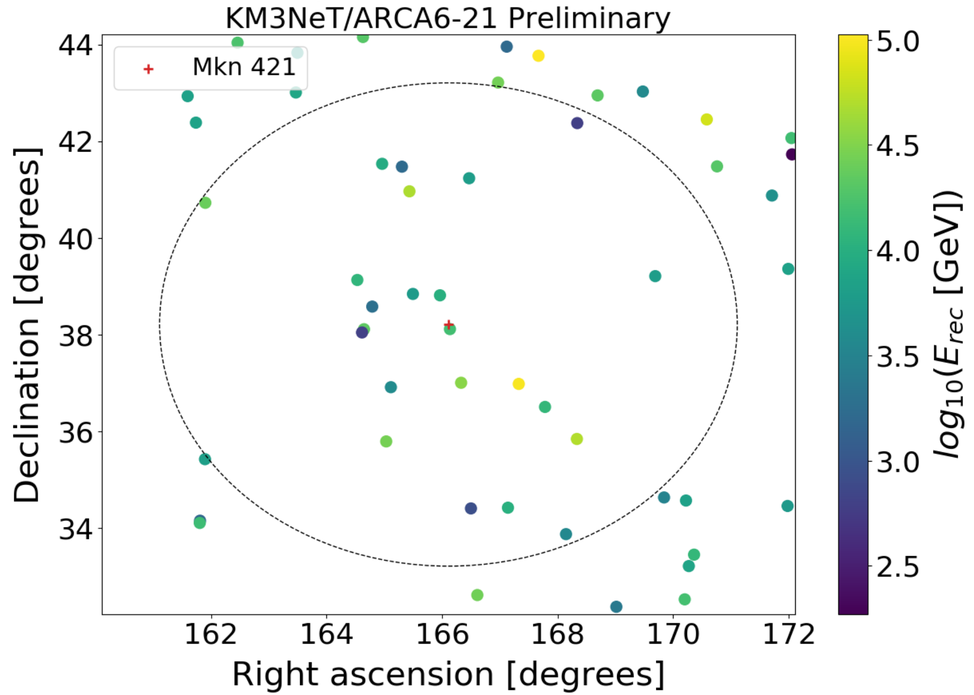
- Pre-trial p-value = 0.011
- Post-trial p-value = 0.66

$\gamma = 2.5$: Bright blazar Mkn 421

- Pre-trial p-value = 0.020
- Post-trial p-value = 0.56

Note: dataset is dominated by atmospheric muons from ARCA6-8 period



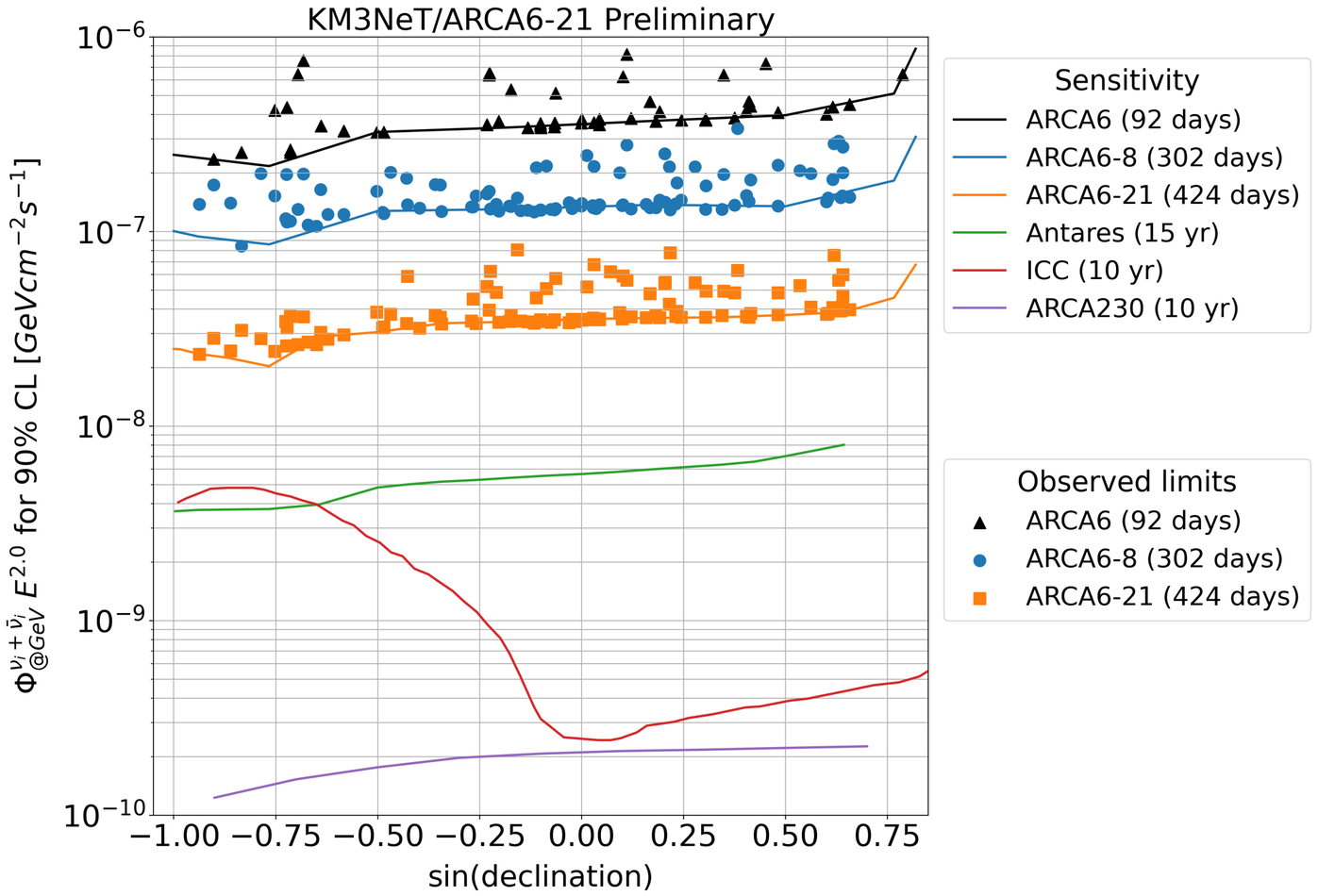


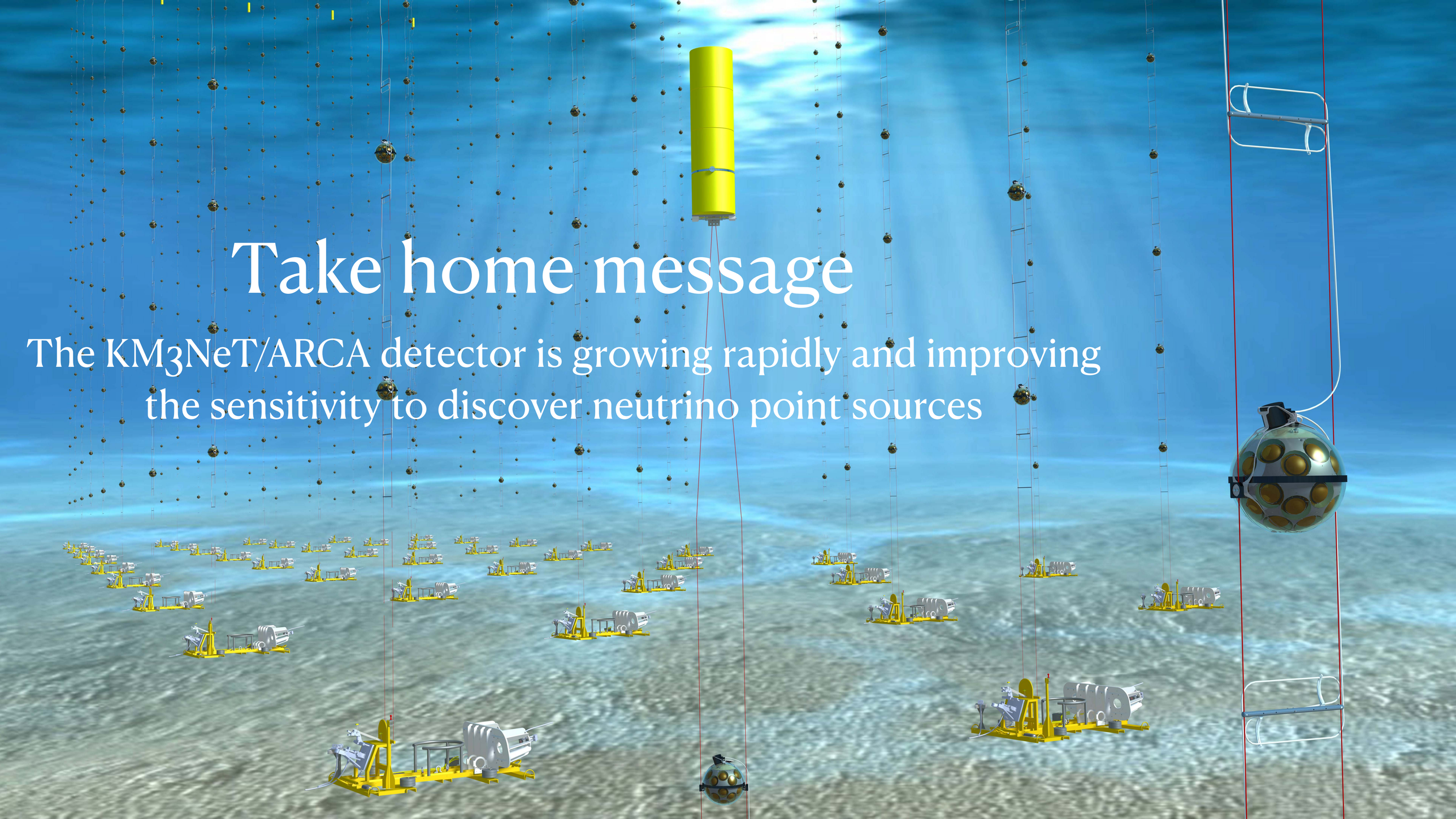
Observed limits

- No significant detection made
  —> Set limits on ϕ_ν

- ϕ_ν that would give higher test statistic than observed in 90% of the cases

- Growing detector and dataset
  —> Sensitivity becomes competitive





Take home message

The KM3NeT/ARCA detector is growing rapidly and improving the sensitivity to discover neutrino point sources

Backup

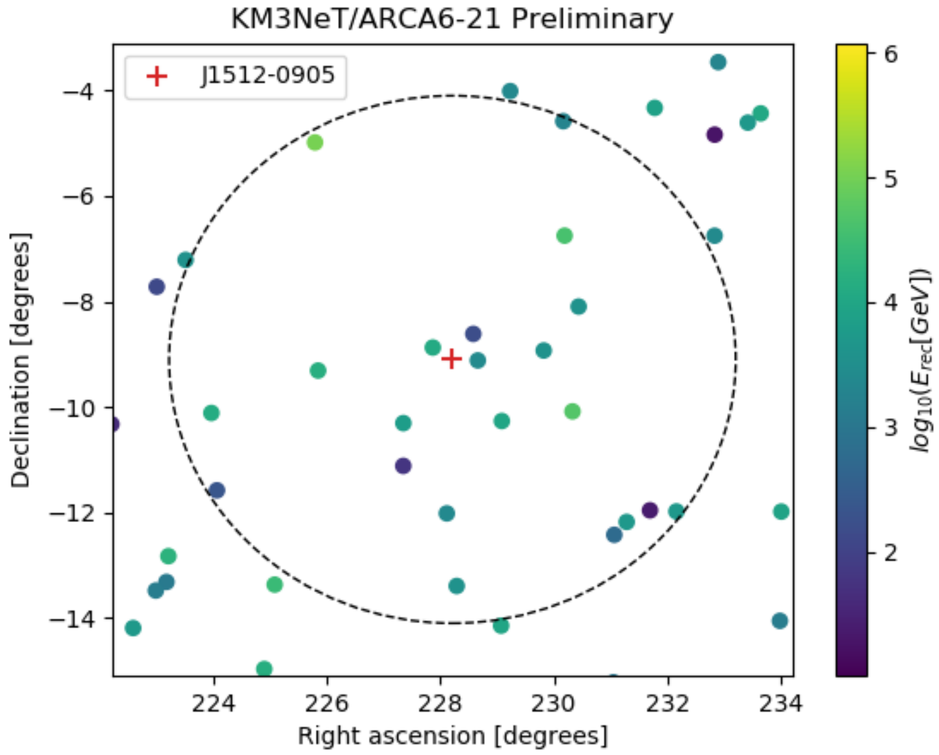
Most signal like sources: J1512-0905

$\gamma = 2$: Active galactic nucleus J1512-0905

- Pre-trial p-value = 0.011
- Post-trial p-value = 0.66

New theories suggest regions where neutrinos are produced are opaque to γ-rays

—> So we also search for blazars with very bright radio component

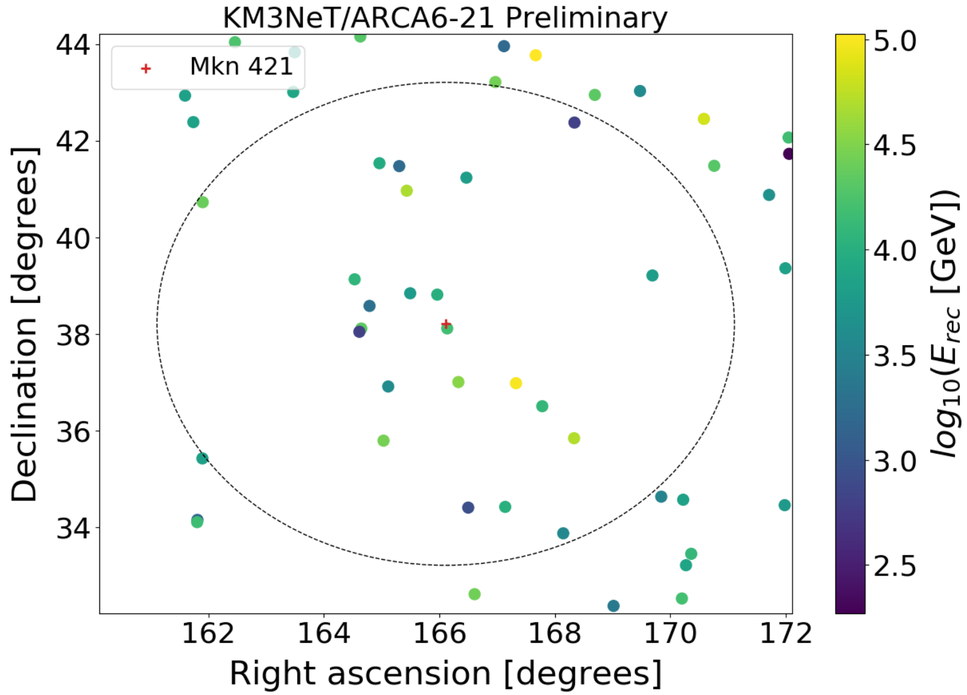


Backup

Most signal like sources: Mkn 421

$\gamma = 2.5$: Bright blazar Mkn 421

- Pre-trial p-value = 0.020
- Post-trial p-value = 0.56

Variable and intense γ ray emission

Suspected to be a supermassive black hole