EXPLORING THE EXTREME UNIVERSE
Multimessenger Studies with the Pierre Auger Observatory

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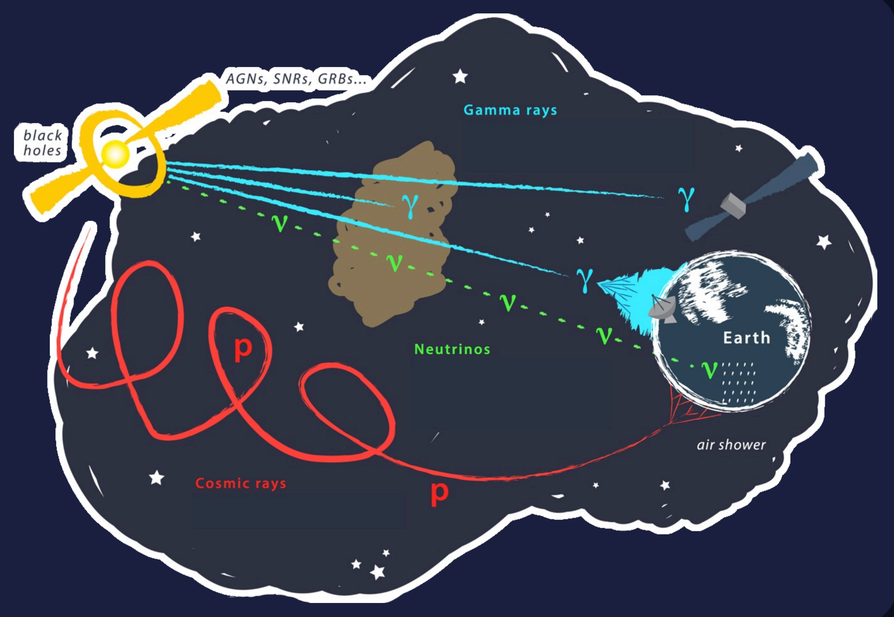
WHY DO WE CARE?

UHECRs → at the edge of revealing **origin and acceleration mechanisms**

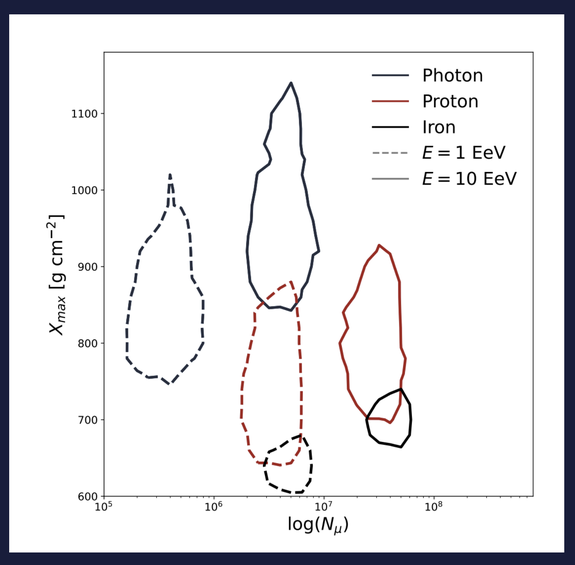
UHE photons and neutrinos:

- **Multimessenger observations:** unique probes to provide **direct information on** their **sources**
- Smoking guns for fundamental physics, and our understanding of the extreme Universe

The **Pierre Auger Observatory** offers **unprecedented exposure** to them



PHOTONS



UHE-photons → highly relevant for:

- Probing the **mass composition** of UHECRs
- unveiling the **local universe sources**
- Searching for **SHDM annihilation** signatures in the Galactic centre
- Source-targeted search → using astrophysical catalogues

Photons are identified using **Xmax** and the **number of muons**

Models on **photon fluxes** are affected by **small uncertainties**

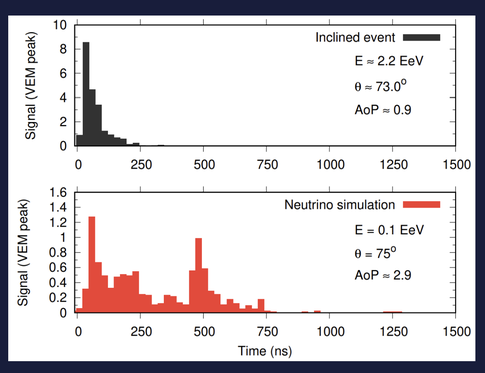
NEUTRINOS

UHE-neutrinos → window into the **deep universe** that is opaque to photons

Neutrinos are sought through **highly inclined showers** initiated **deep in the atmosphere**

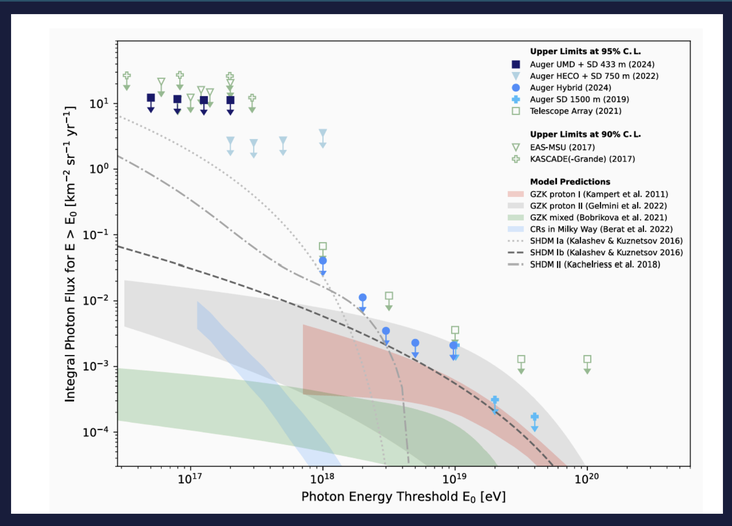
They are showers marked by a **significant electromagnetic component**

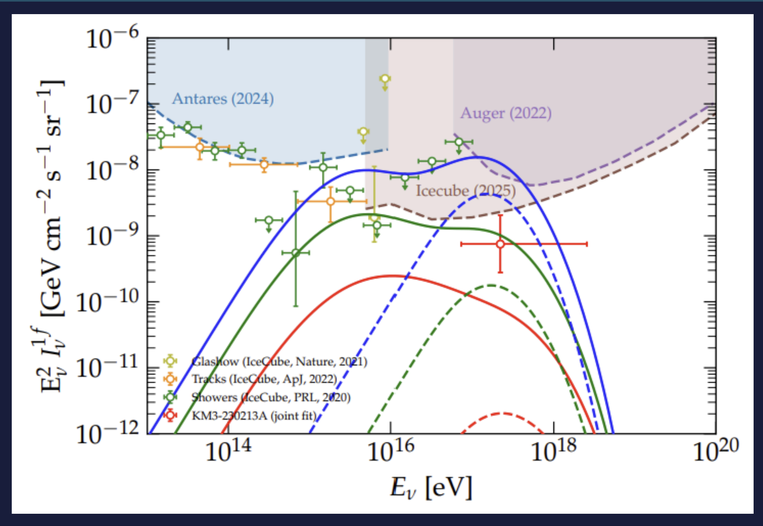
To identify them → observables containing information on the temporal spread at the SD stations



THE MOST STRINGENT UPPER LIMITS

The Pierre Auger Observatory has already set the most **stringent upper limits** at very high energies and could be the first observatory to detect them!





Scan to explore Auger science!

References:
[1] A. Aab et al. (Pierre Auger Collaboration), "Probing the origin of ultra-high-energy cosmic rays with neutrinos in the EeV energy range using the Pierre Auger Observatory", JCAP 10 (2019) 022 arXiv:2104.00109 (2019)
[2] A. Abdul Halim et al. (Pierre Auger Collaboration), "Search for photons above 10^{18} eV by simultaneously measuring the atmospheric depth and the muon content of air showers at the Pierre Auger Observatory", Phys. Rev. D 110, 062005 (2024) DOI: https://doi.org/10.1103/PhysRevD.110.062005
[3] A. Cermenati et al. "Scrutinizing the cosmogenic origin of the KM3-230213A event: A Multimessenger Perspective", arXiv:2507.11993