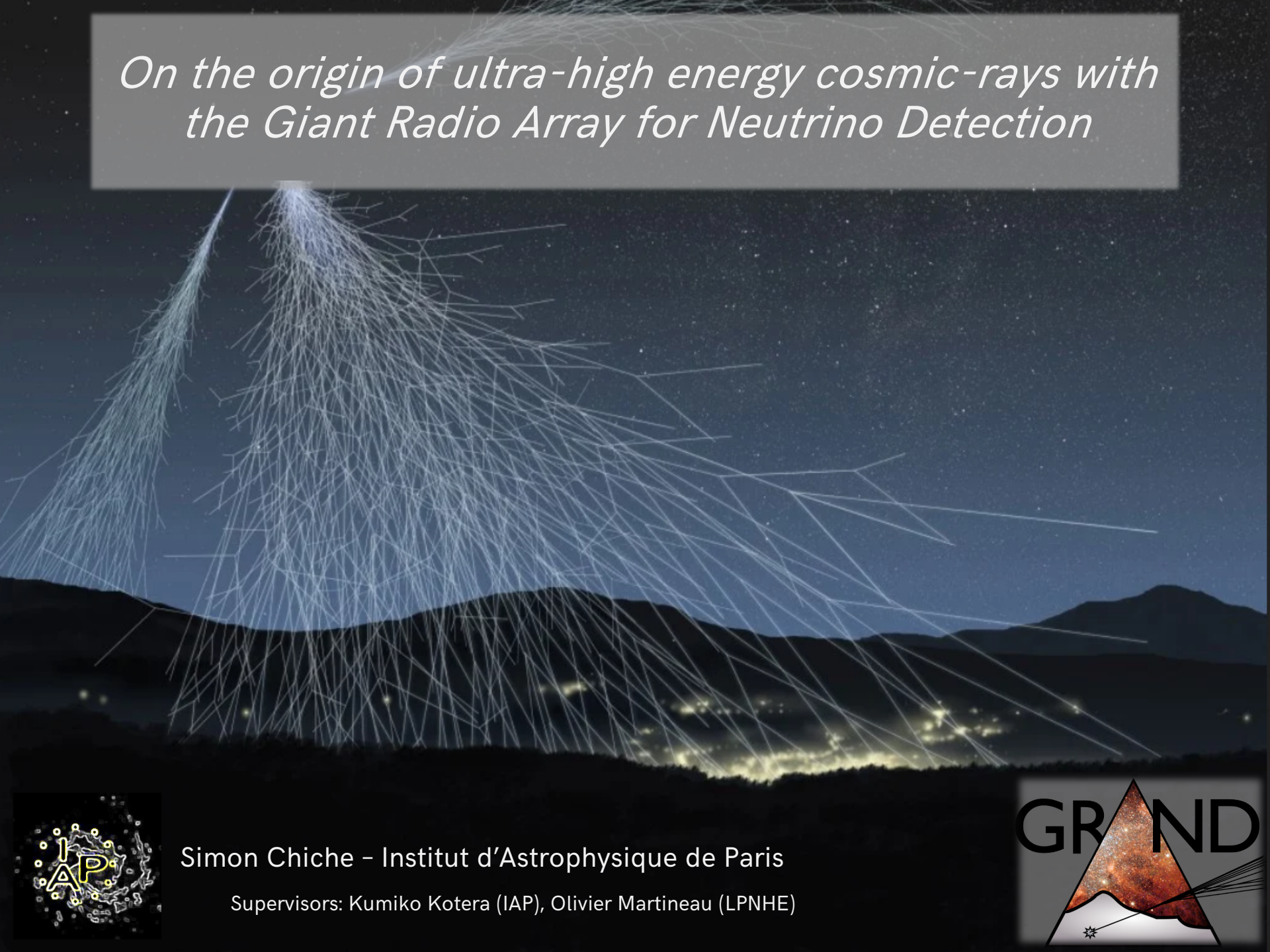
On the origin of ultra-high energy cosmic-rays with the Giant Radio Array for Neutrino Detection



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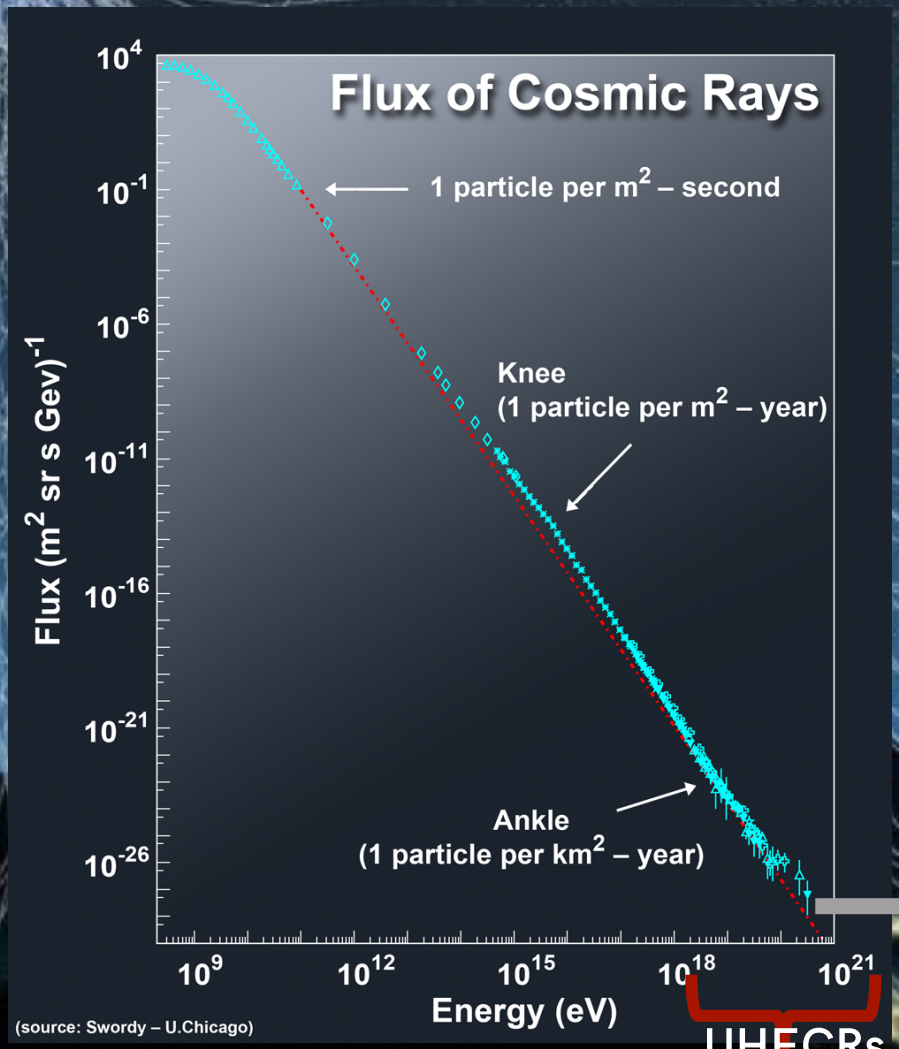
The mystery of ultra-high energy cosmic rays (UHECRs)

- Cosmic rays: high energy atomic nuclei (protons, iron nuclei, etc)
- Most energetic particles in the universe (ultra-high energy cosmic rays: $E > 10^{18} eV$)
- **Where do they come from?**



- At the lowest energy: Solar origin
- Intermediate energy: SNR (galactic origin)
- Ultra-high energy: ?

We don't know the exact nature of these particles

We don't know the sources

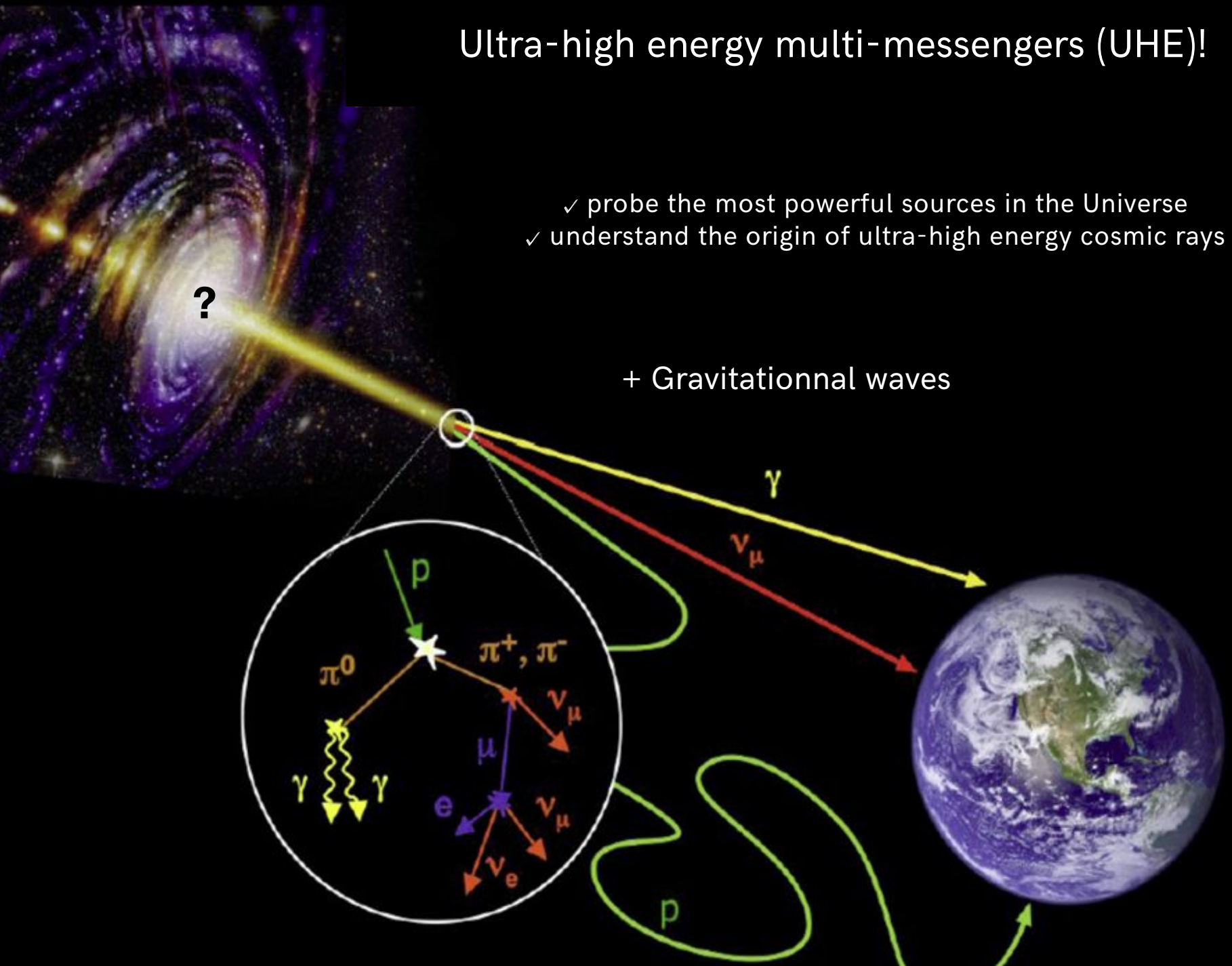
We don't know the acceleration mechanisms

Very low flux:
$1. km^{-2}. century^{-1}$

Ultra-high energy multi-messengers (UHE)!

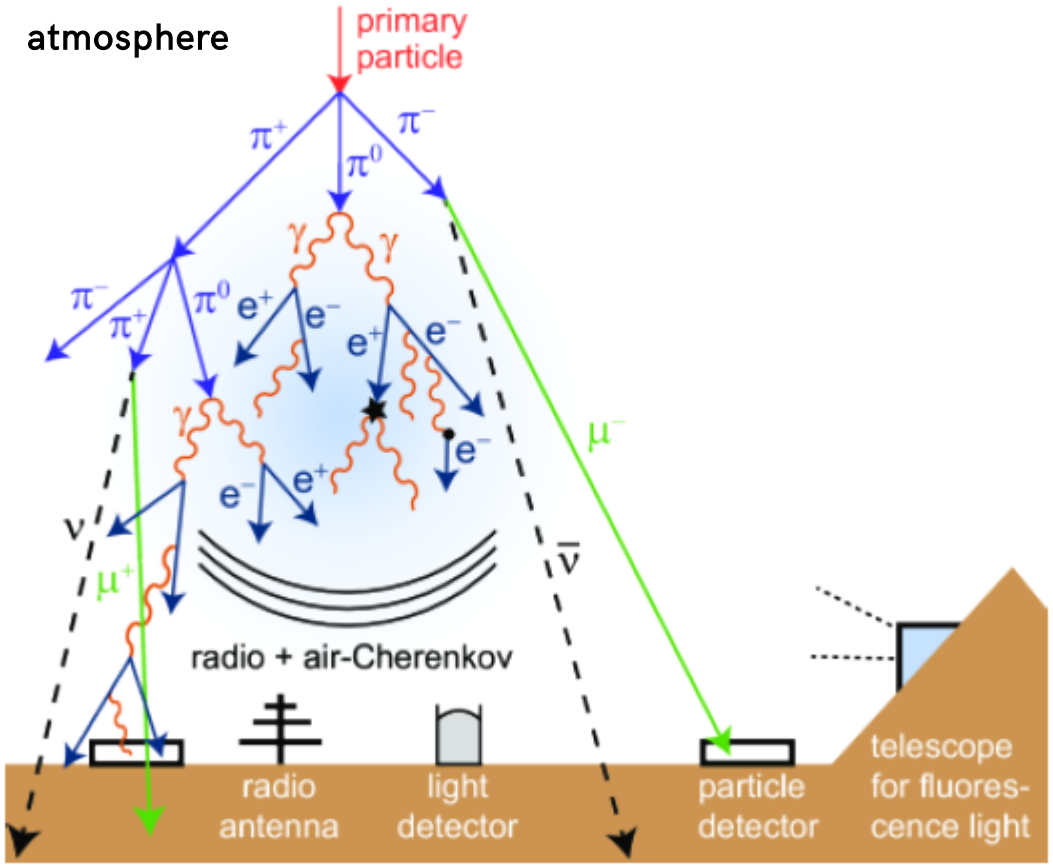
✓ probe the most powerful sources in the Universe
✓ understand the origin of ultra-high energy cosmic rays

+ Gravitationnal waves



Extensive air showers (EAS)

Interaction of high energy astroparticles with the atmosphere: shower/cascade of secondary particles!



Schröder (2019)

- Hadronic component: mainly π decaying into μ and ν
- Electromagnetic part: e^+, e^-, γ

Main emissions:

- Cherenkov light
- Fluorescence light
- Radio emission

We can detect the signal originating from the electromagnetic part with radio antennas!

The Giant Radio Array for Neutrino Detection (GRAND)

GRAND : Giant radio array of 200 000 radio antennas over 200 000 km^2

Detection of air showers induced by ultra-high energy astroparticles

Inclined showers with mountains as targets

cr, γ

few kms

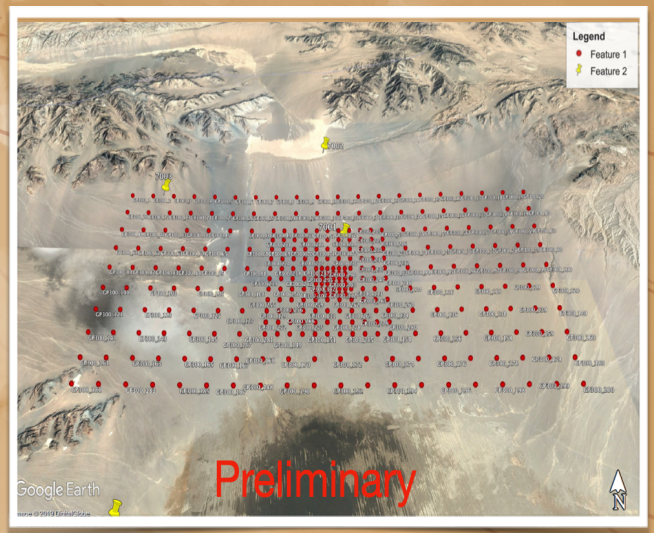
Geomagnetic effect:
Radio signal:
quelques 100 MHz

>30 km

ν_τ

τ

GRANDProto300 first prototype in 2021!



Prototype of 300 antennas, 200km^2

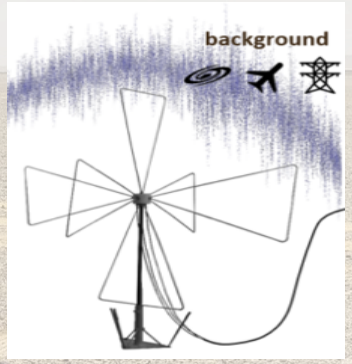
Detection of astroparticles with E_{range} = $10^{16.5}$-10^{18} eV

GRANDProto300: Challenges of radiodetection

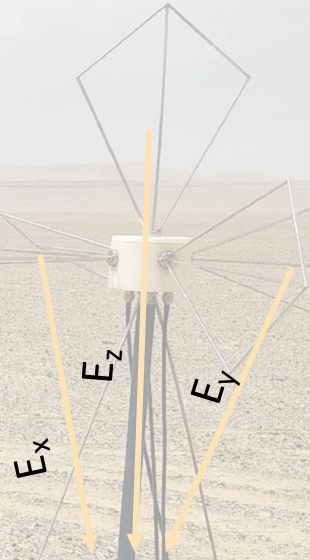
- Autonomous detection of astroparticles → Grail of radiodetection!

Current experiments: radio antennas associated with particles detectors

For large scale experiments as GRAND we can not go for such methods



Overwhelming noise from human emissions



We have to identify the radio signal among the noise!

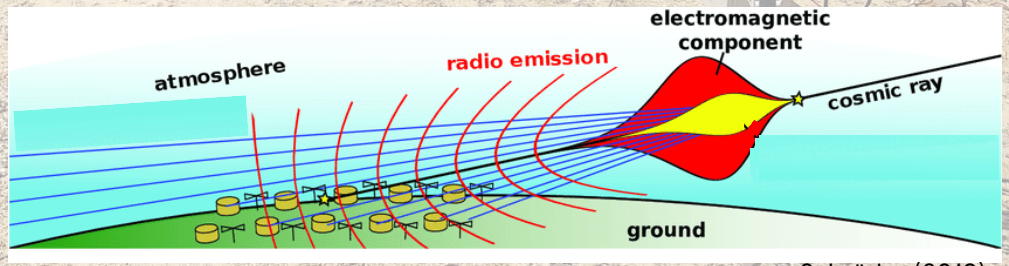
Polarisation : Promising method to tackle those challenges!

- Reconstruction of shower parameters

Current experiments: vertical showers ($\theta < 70°$)

GRAND detection of inclined showers ($\theta > 70°$)

Asymmetries, ground reflections effects



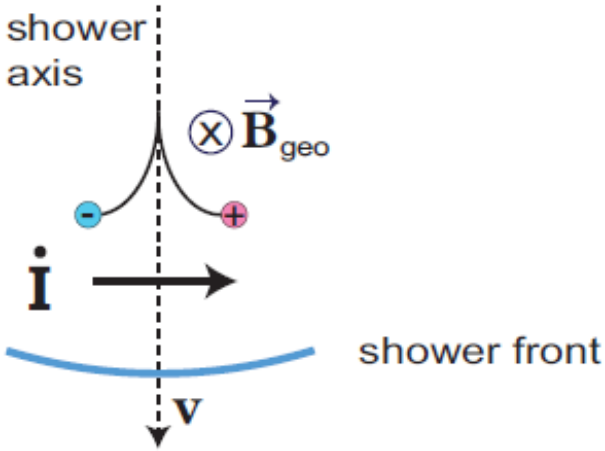
Schröder (2019)

Towards an autonomous detection of cosmic-rays

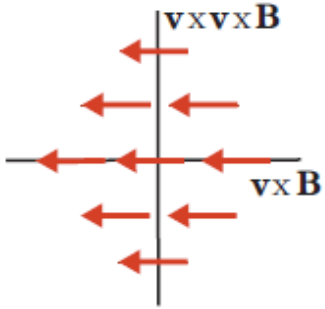
(Chiche, Kotera, Martineau, Tueros, D. de Vries, in prep.)

Polarisation: Electric field direction

Induced dipole due to B_{geo}



Polarisation orthogonal to B_{geo}



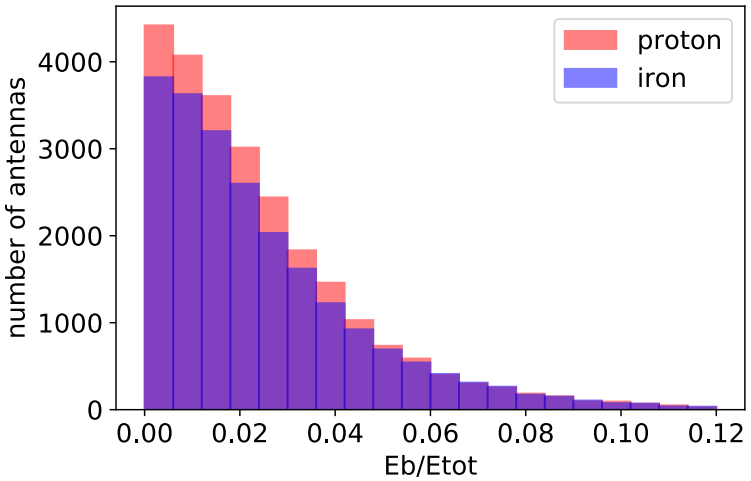
polarization in shower plane at detector

Geomagnetic emission

$\vec{E} \cdot \overrightarrow{u_b}/|\vec{E}| << 1$

criterion for air-shower identification

Test on numerical cosmic-ray simulations

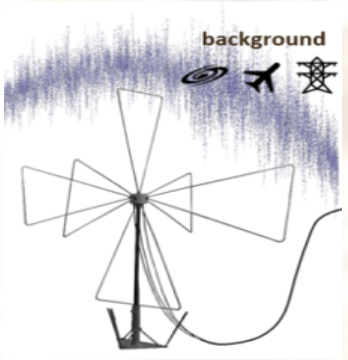


Cut at 7%: rejection of 99.9% of noise induced events and trigger for 95% of antennas

Conclusion

GRANDProto300

A pathfinder for the GRAND experiment



- 300 antennas to be deployed in 2021
- Promising method for cosmic-ray air shower identification!

GRAND 200k

A Giant radio array with unprecedented sensitivity to UHE neutrinos

- Multi-messenger approach to tackle UHECRs sources
- Open the path towards UHE neutrino and gamma ray astronomy

Exciting times are coming!