

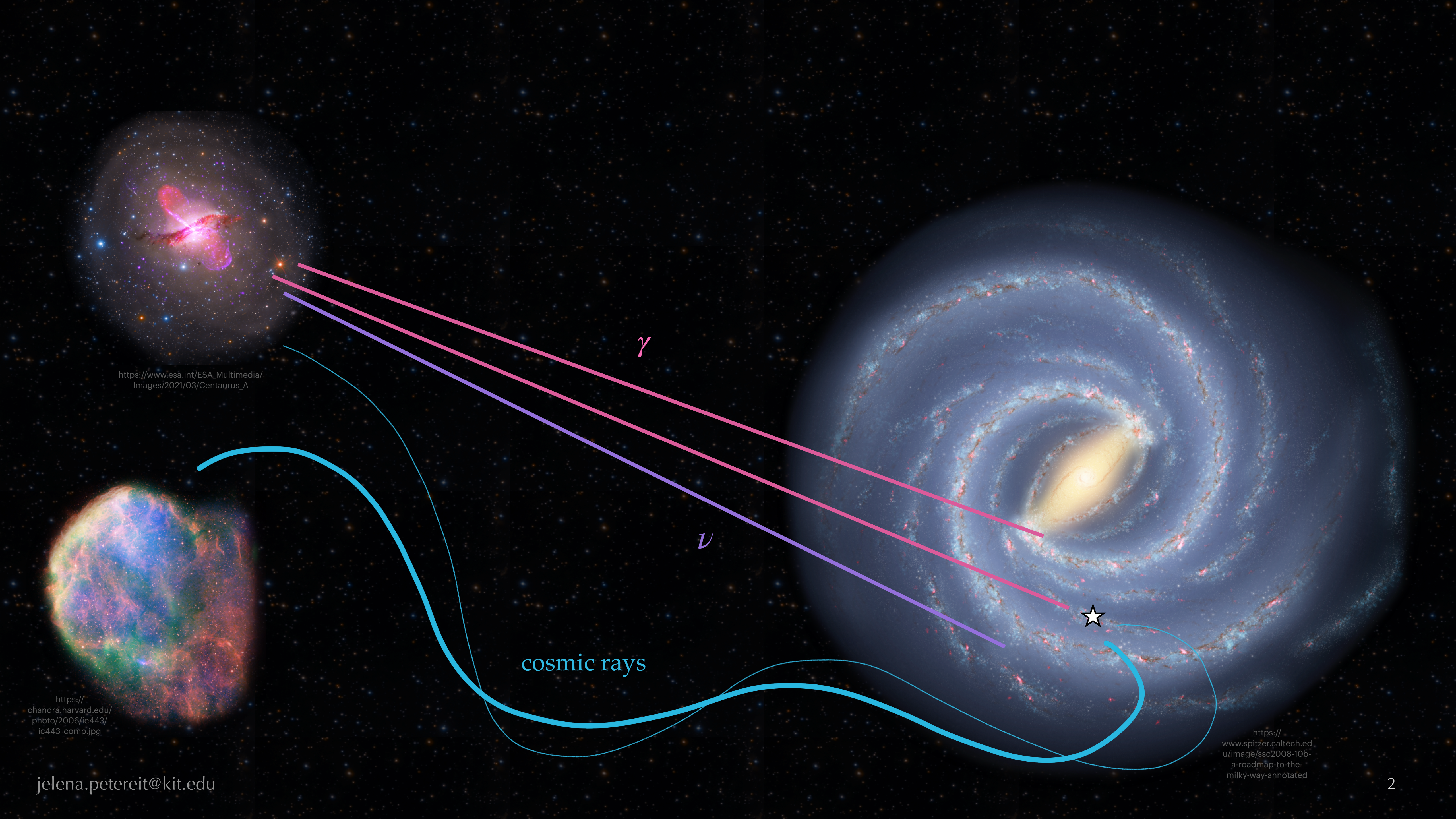
Development of a Second-Level Trigger for the Autonomous Detection of Air-Shower Radio Emission

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https://www.esa.int/ESA_Multimedia/Images/2021/03/Centaurus_A

https://chandra.harvard.edu/photo/2006/ic443/ic443_comp.jpg

<https://www.spitzer.caltech.edu/image/ssc2008-10b-a-roadmap-to-the-milky-way-annotated>

$$p + p \rightarrow \pi + \dots$$

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$

$$\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$$

$$\pi^0 \rightarrow 2\gamma$$

γ

ν

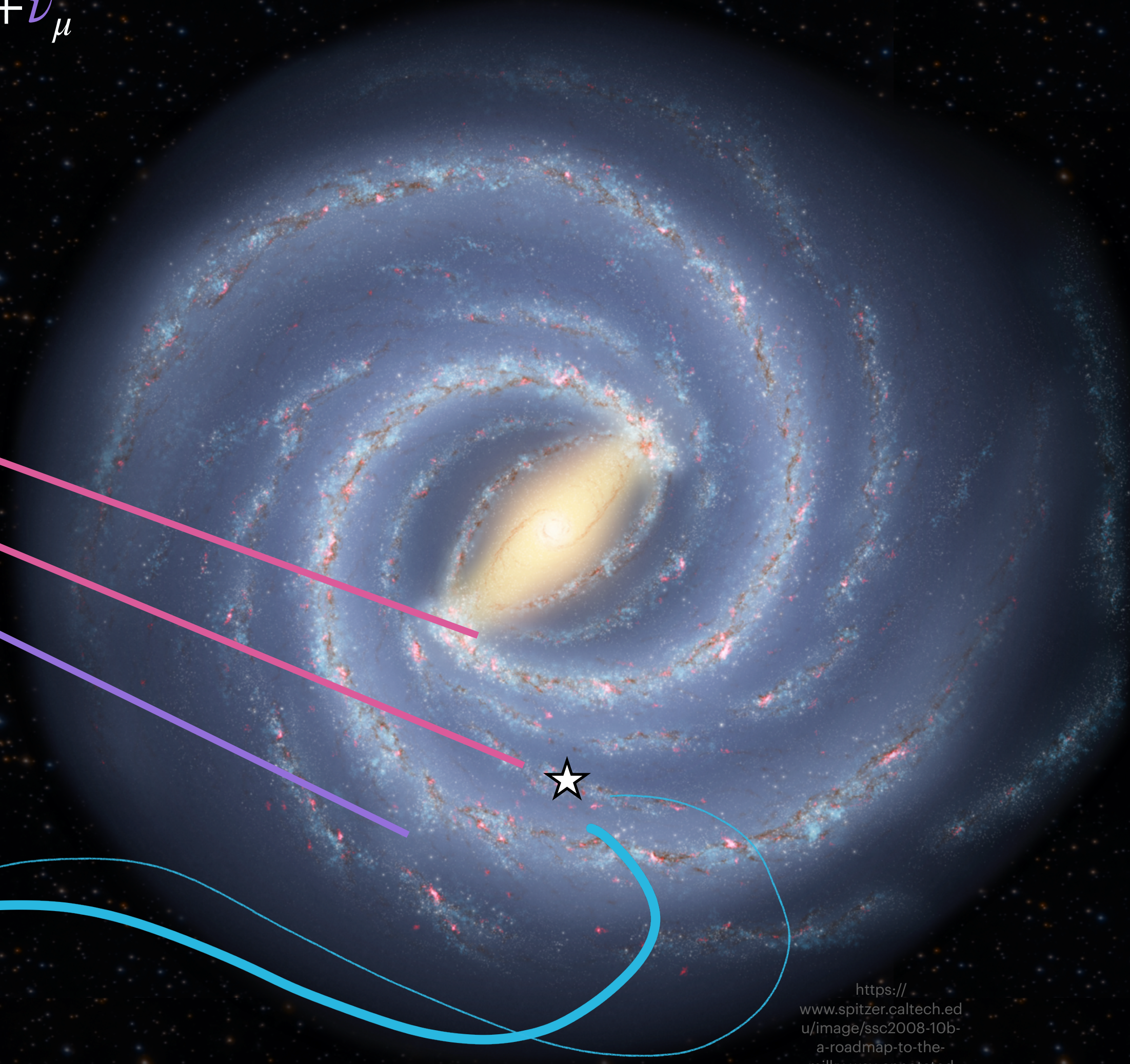
cosmic rays



https://www.esa.int/ESA_Multimedia/Images/2021/03/Centaurus_A



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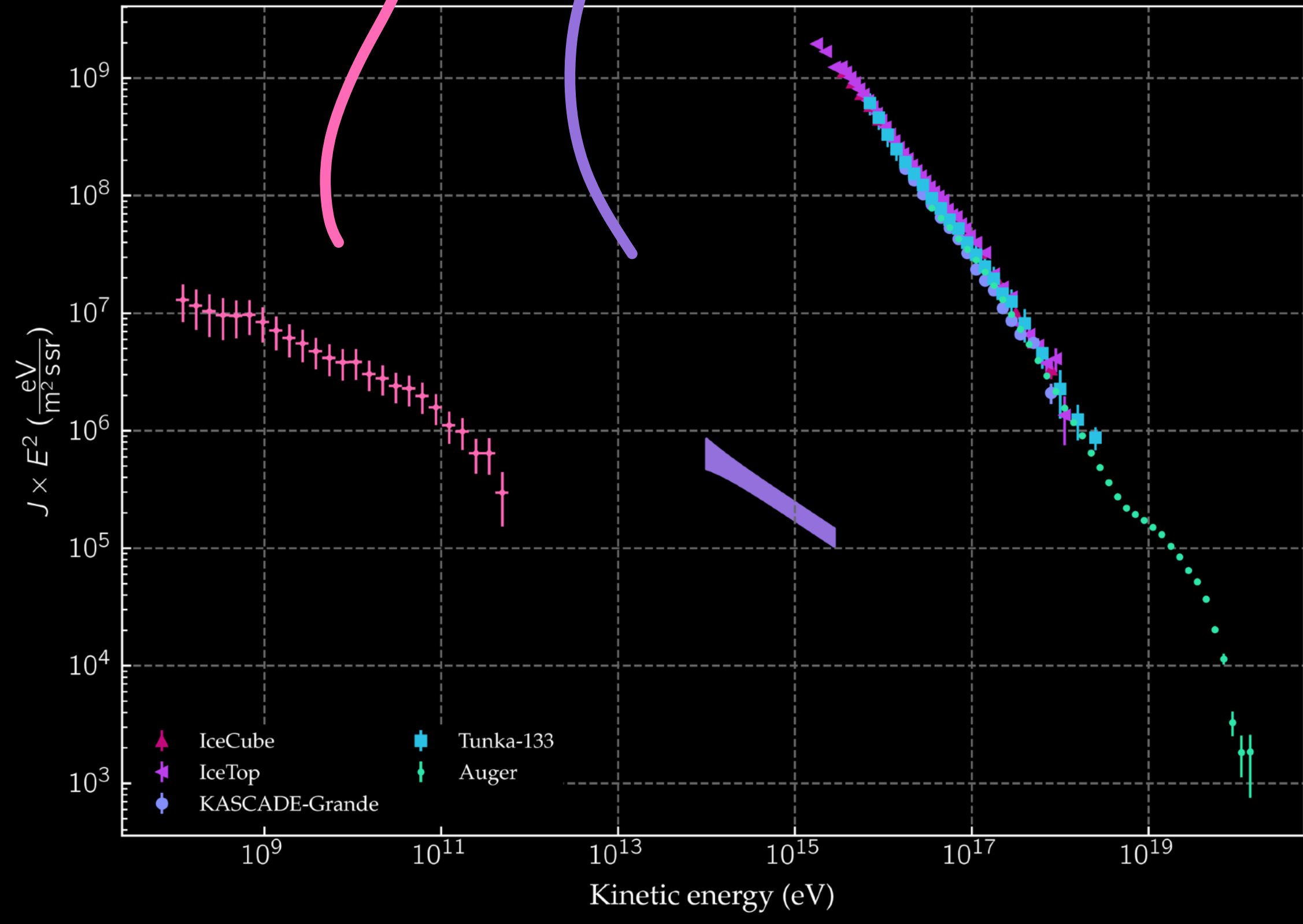
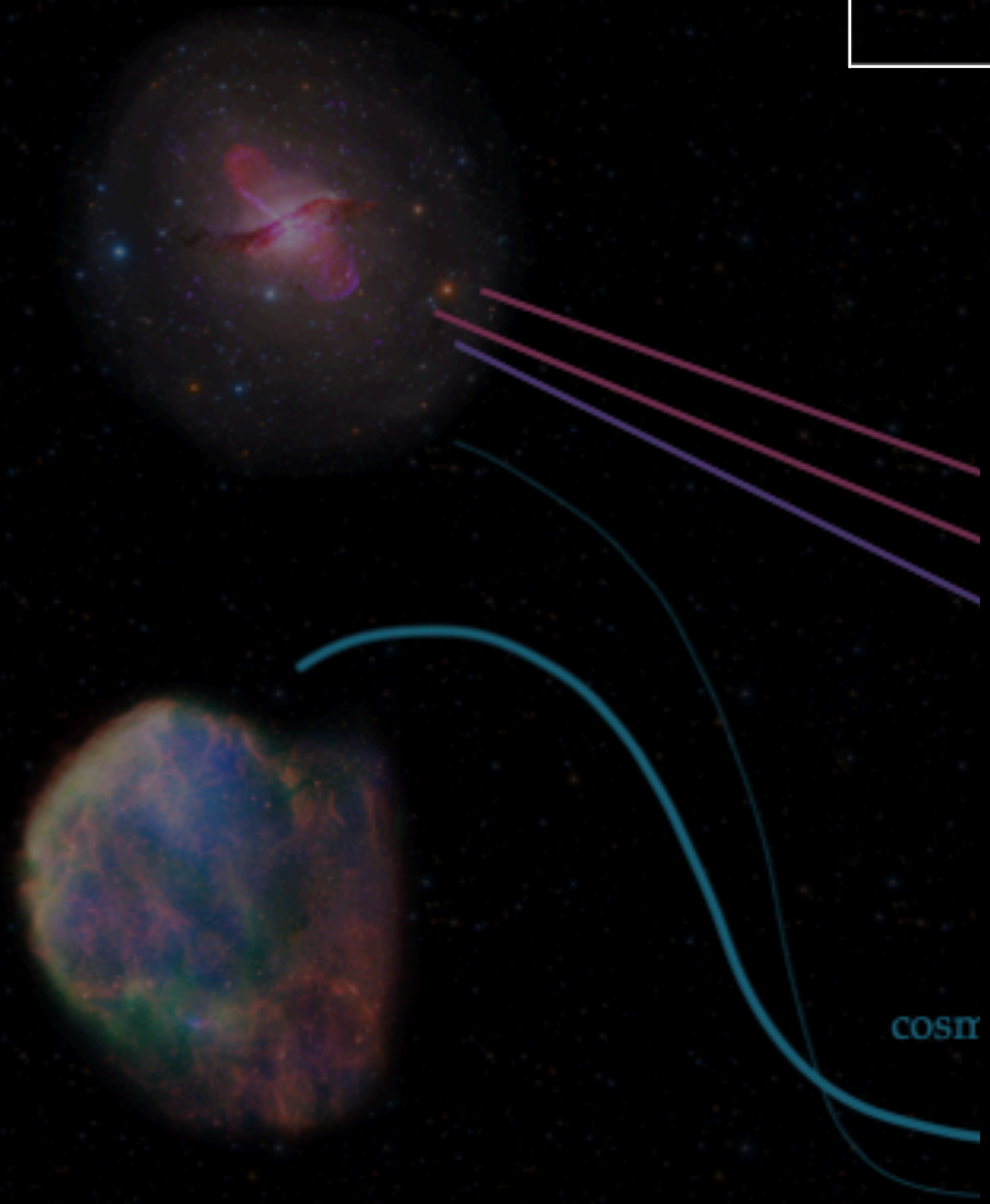
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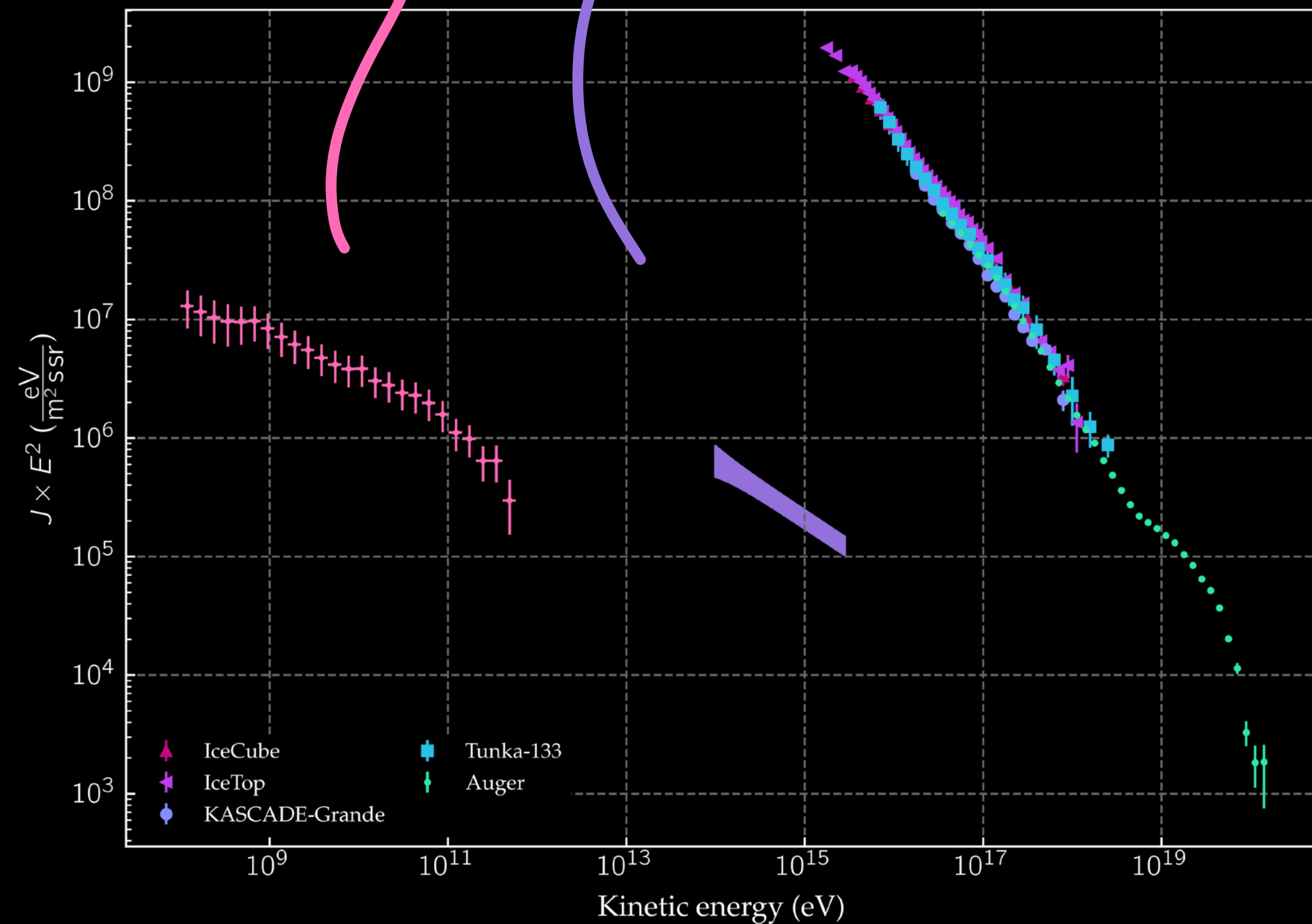
$$\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$$

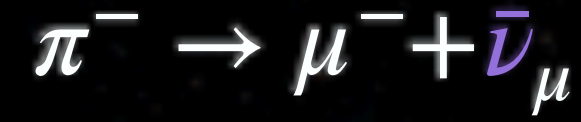
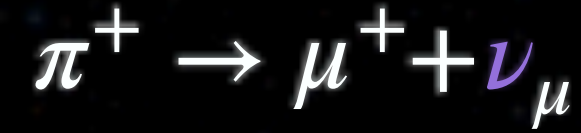
$$\pi^0 \rightarrow 2\gamma$$

open questions

- ★ UHECRs origin
- ★ UHECR suppression region
- ★ connection ν and CR

COSMOS





open questions

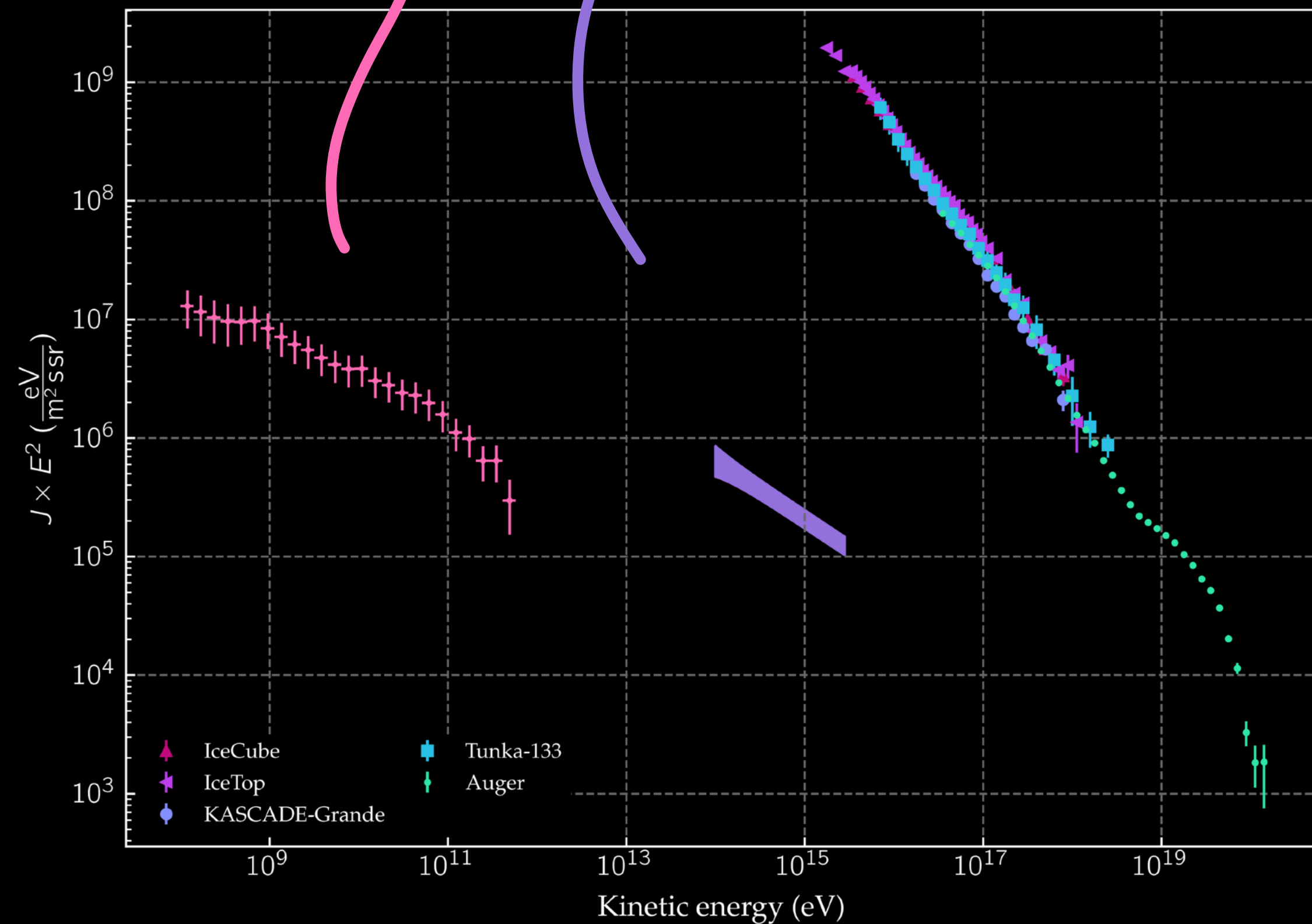
★ origins of UHECRs

low flux → large instrument

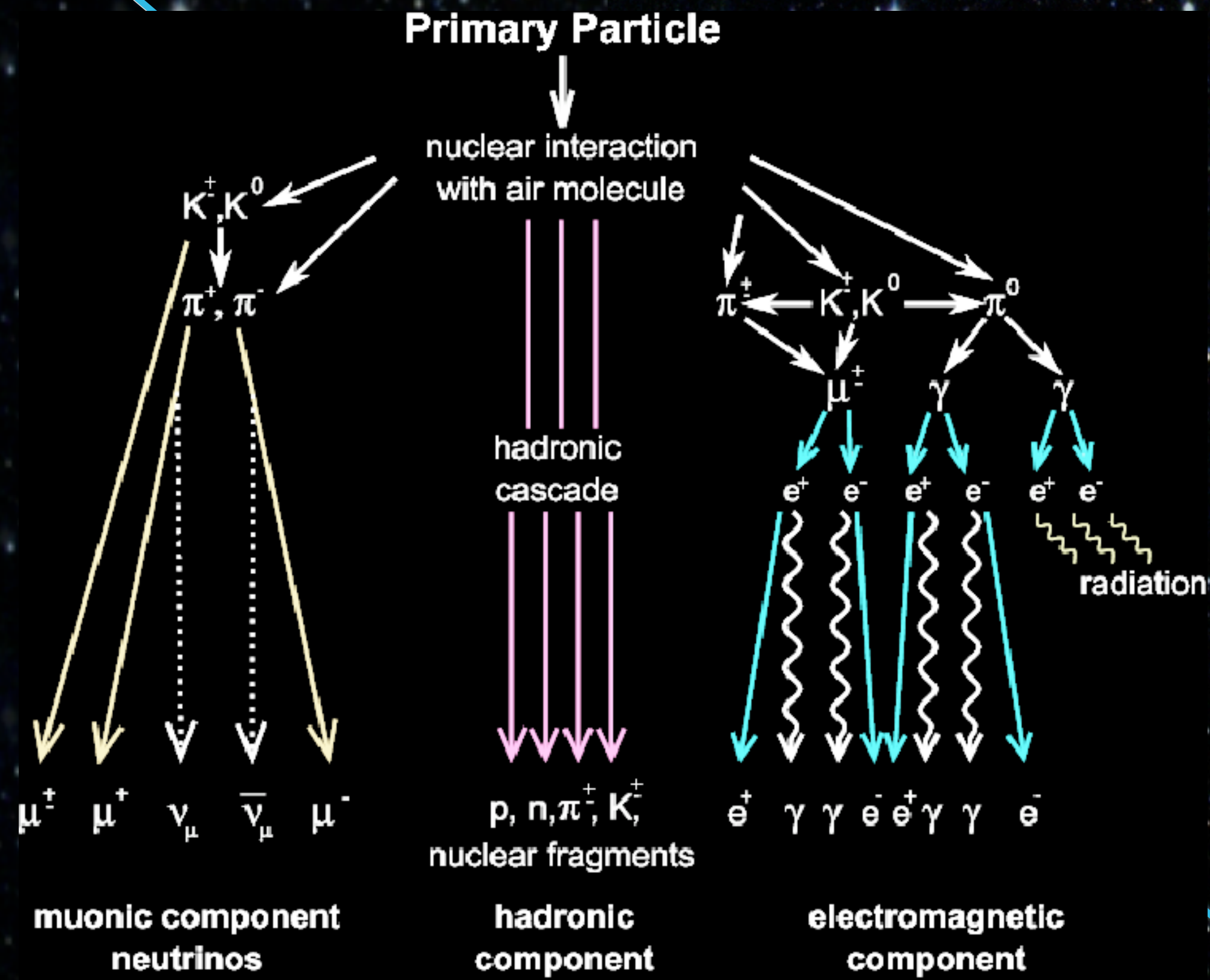
★ connection ν and CR

→ origin of CR through neutrinos

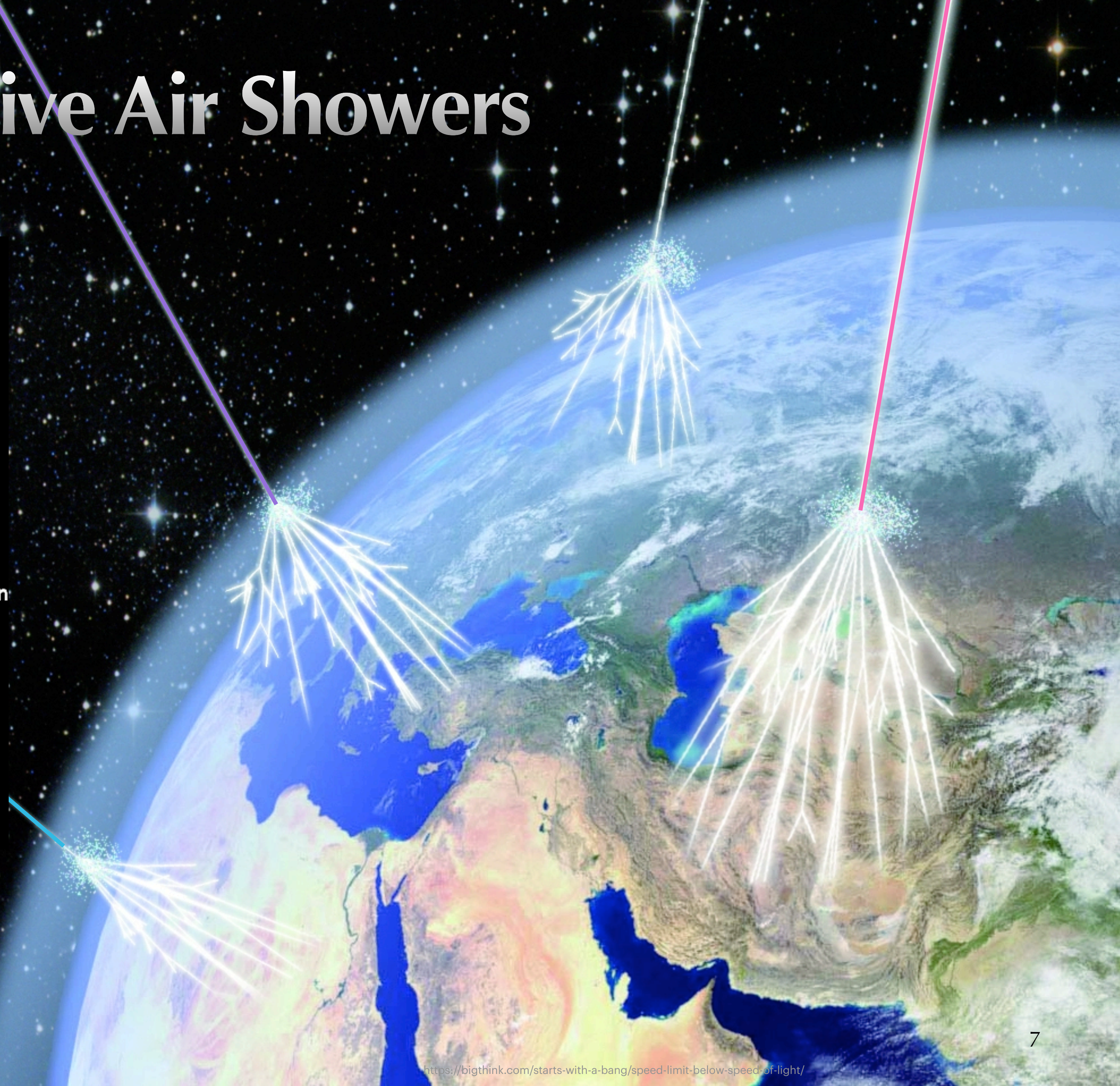
COSMOS



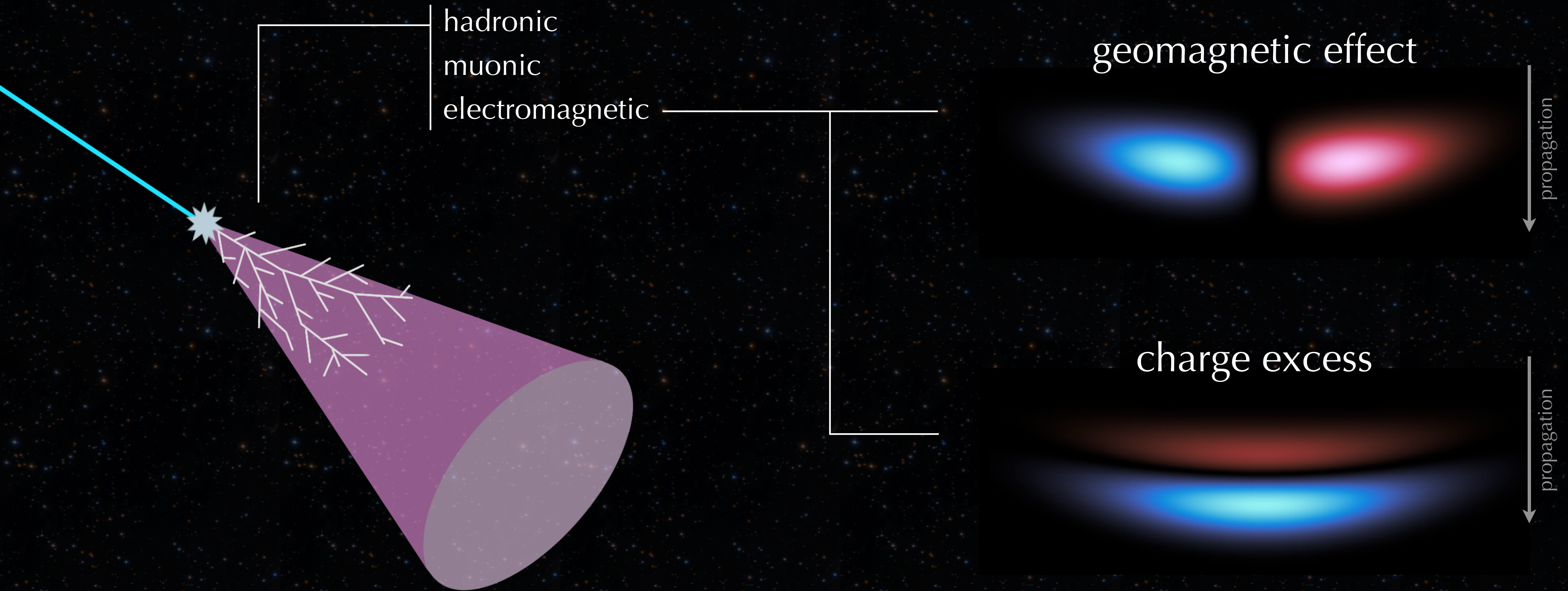
Extensive Air Showers



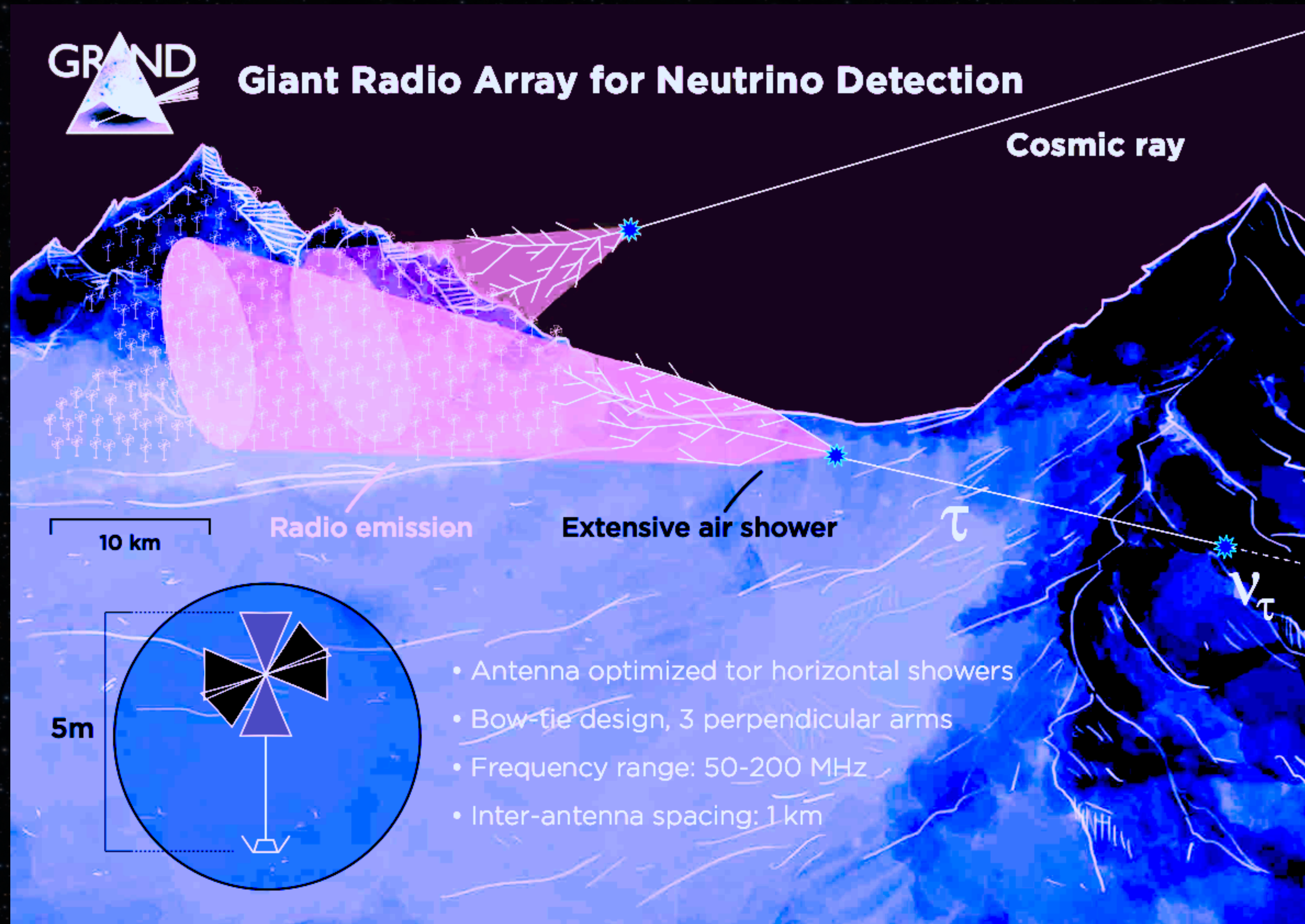
<https://hdl.handle.net/11124/72515>



Radio Emission of Air Showers



Giant Radio Array for Neutrino Detection



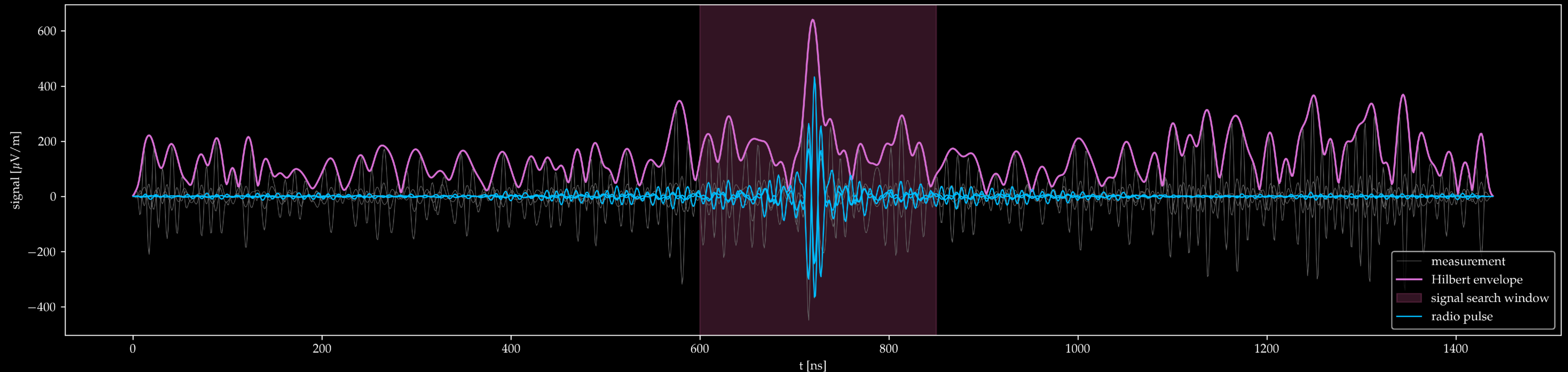
detection area

- ★ 200 000 km² (by the 2030s)
- ★ 1 antenna / km²

inclined air showers CR and ν



Radio Trigger



typical trigger methods

- ★ envelope of traces
- ★ shape of signal (width, amplitude, ...)

most detectors

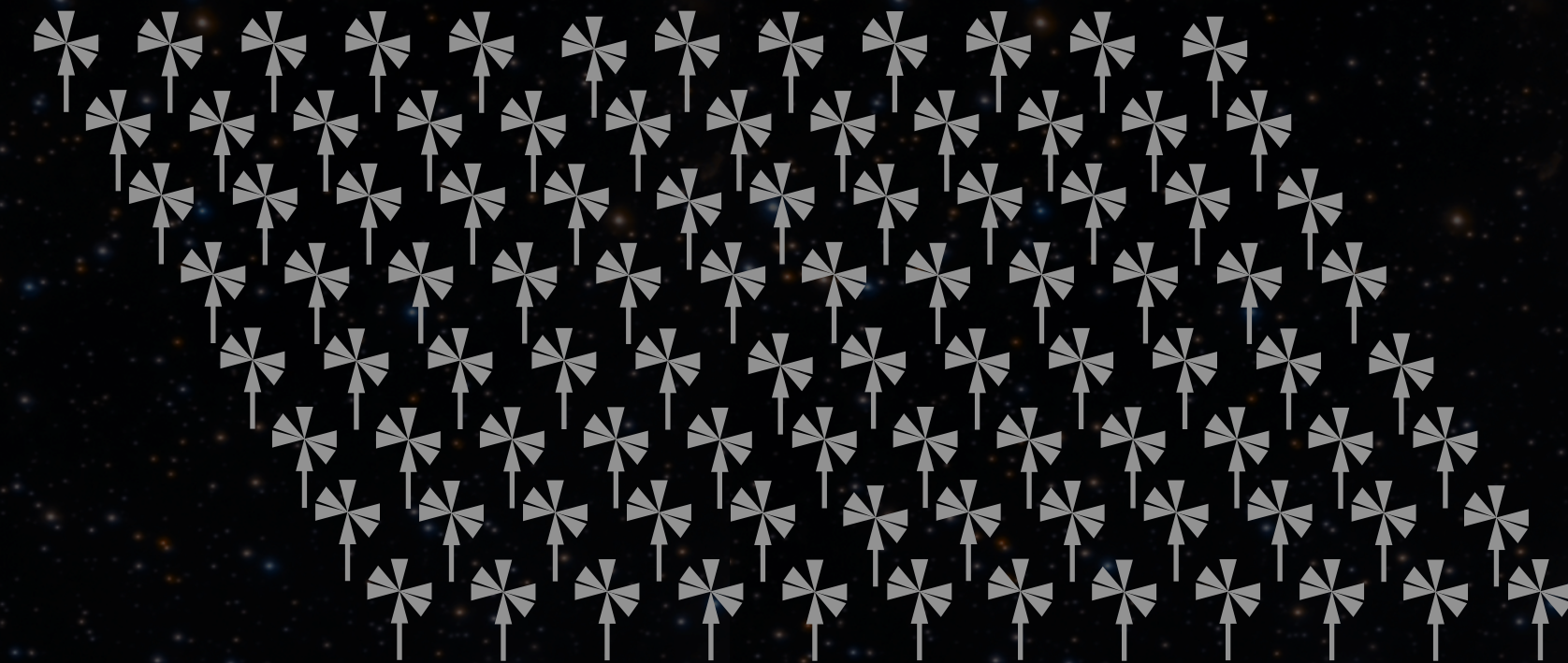
trigger radio with info from other detection methods
→ possible because of hybrid detection and small scale of radio

Self-Trigger

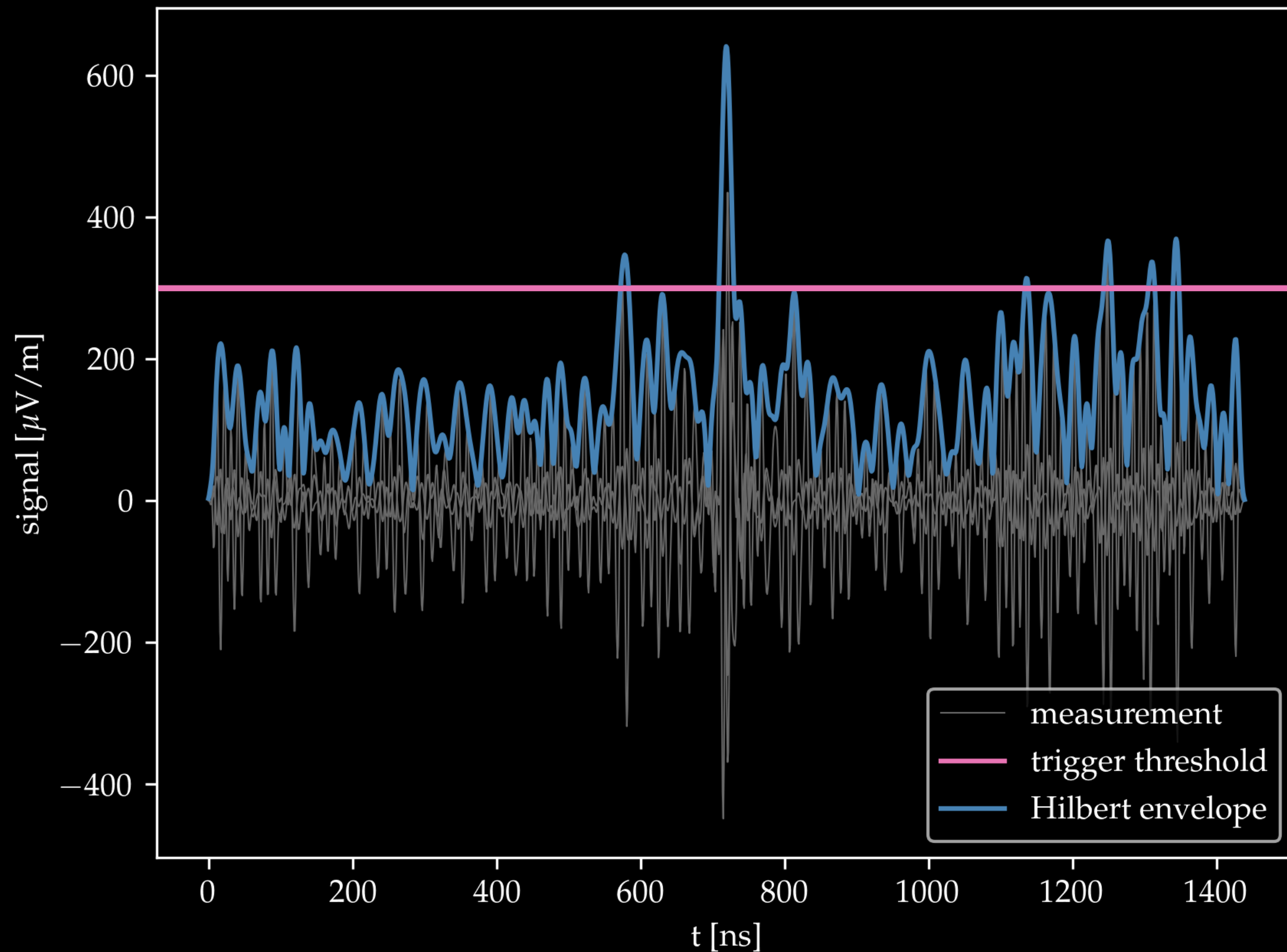
- ★ **GRAND**: self-trigger mandatory on such large scale
- ★ **NUTRIG project**: development of multilevel self-trigger for radio



GRAND
200 000 km²

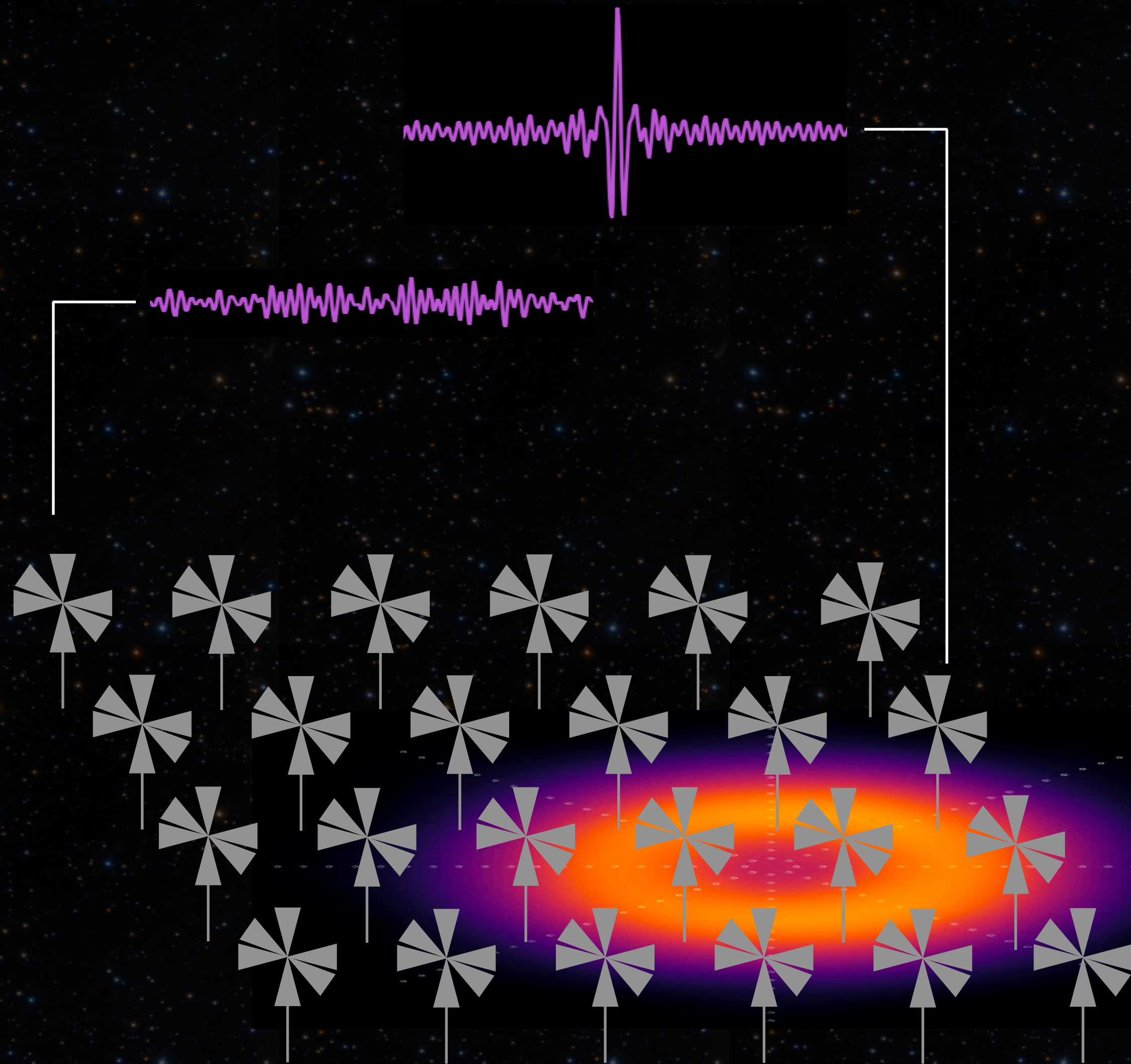


Trigger — level one



- ★ **preliminary statistical trigger**
- ★ induced by **transient wide-band pulses** with amplitudes significantly above stationary noise level

Trigger — level two



first ideas for the second-level trigger

- ★ for triggered antennas, consider
 - ★ signal strength
 - footprint characteristics
 - ★ spatial clusters
 - ★ lonely stations
- ★ find expected patterns for
 - ★ pulse shape
 - ★ arrival times
 - ★ polarizations

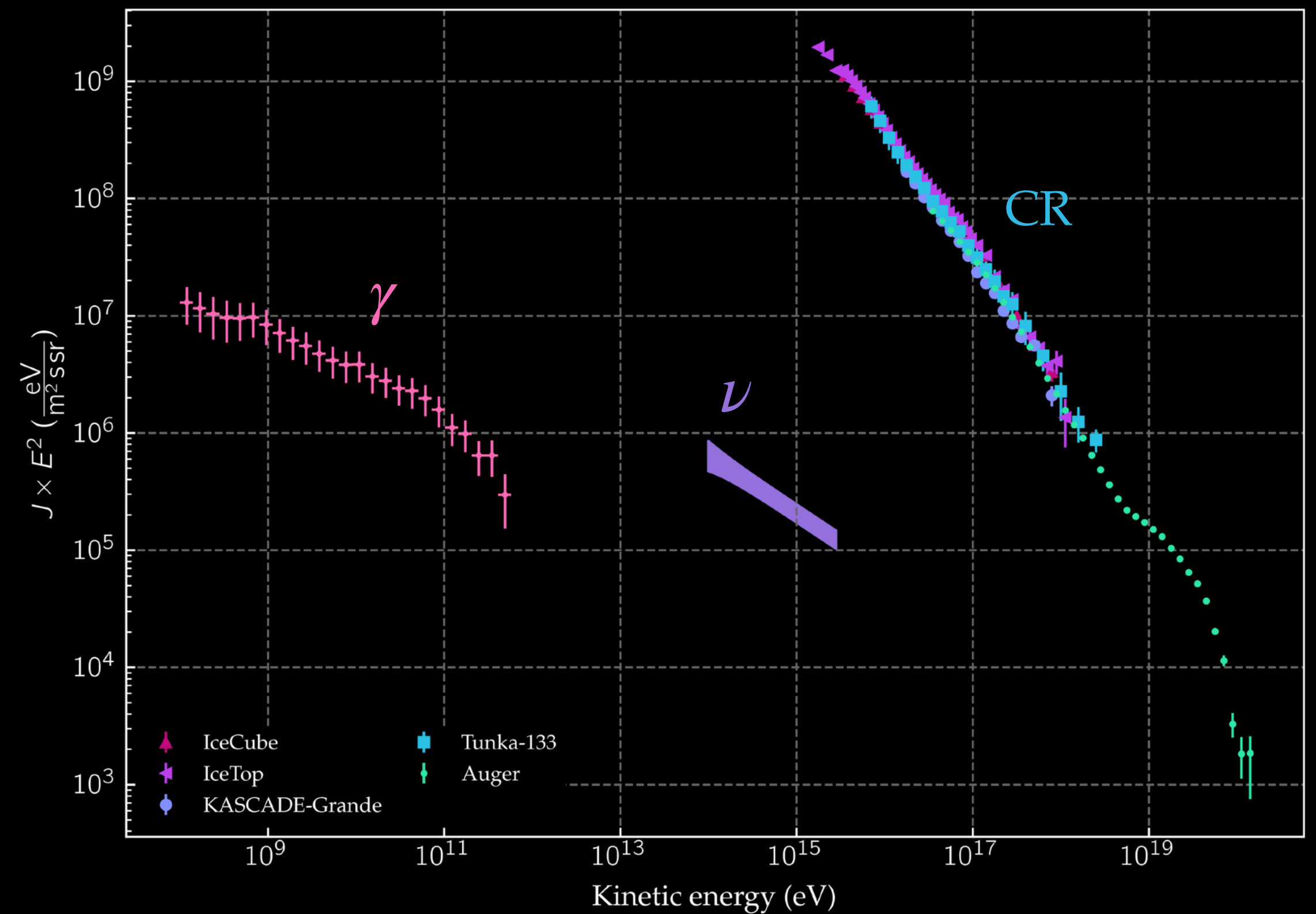
Outlook

motivation

- ★ origin of CR through neutrinos
- ★ low flux → **large instrument**

next steps

- ★ deployment of GRAND antennas
- ★ develop self-trigger on first and second level

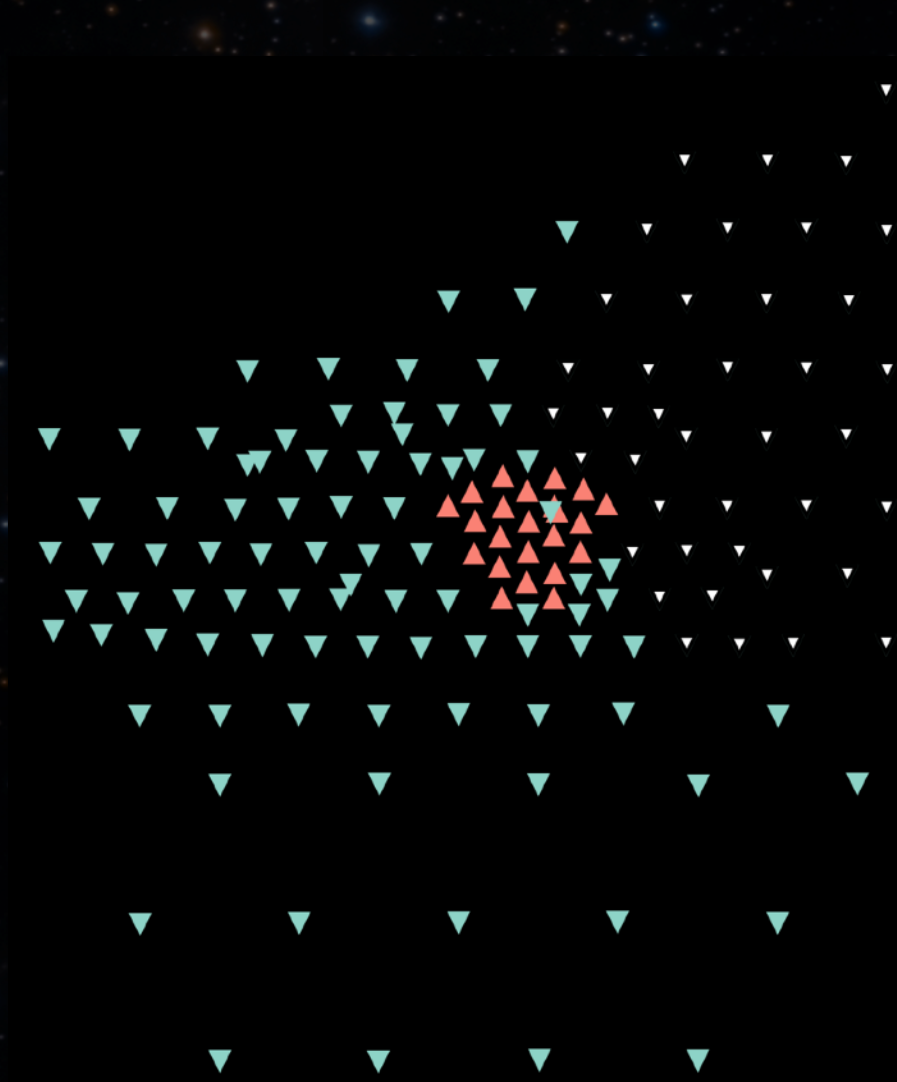




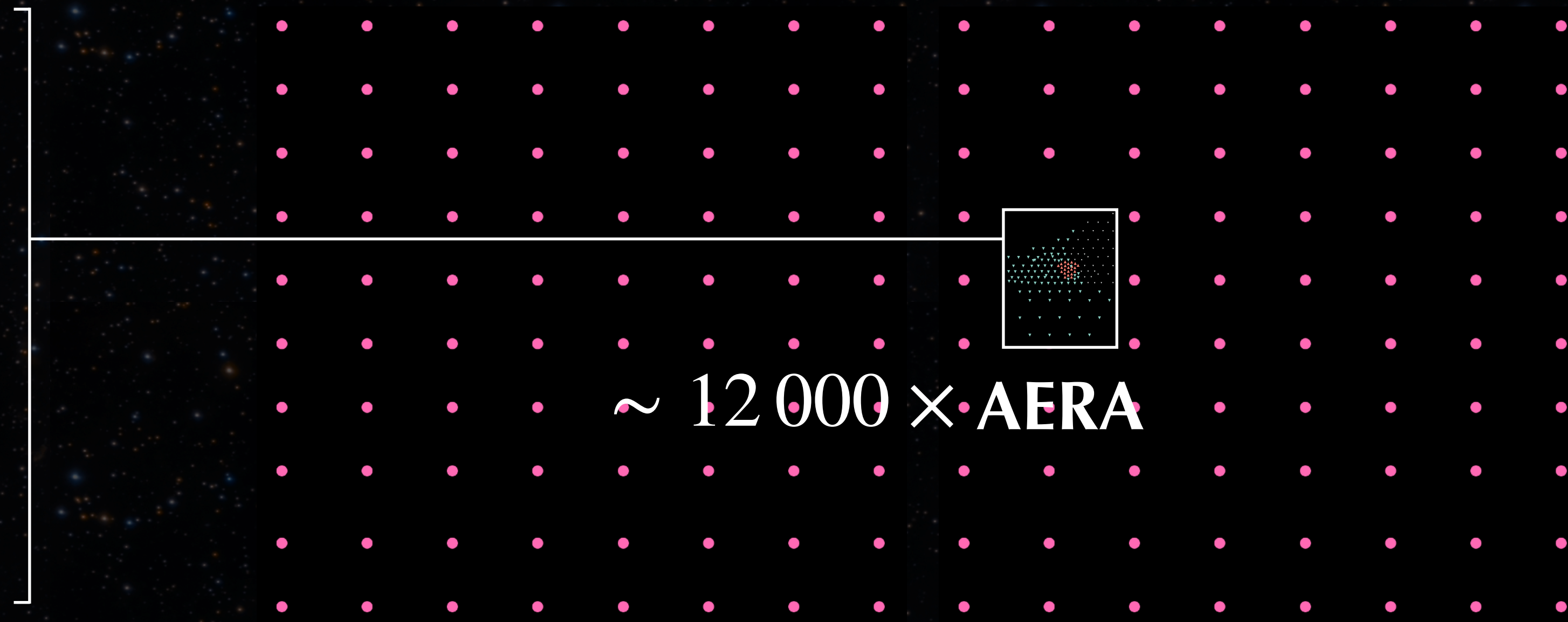
Backup

Self-Trigger

- ★ **GRAND**: self-trigger mandatory on such large scale
- ★ **NUTRIG project**: development of multilevel self-trigger for radio



AERA
17 km²

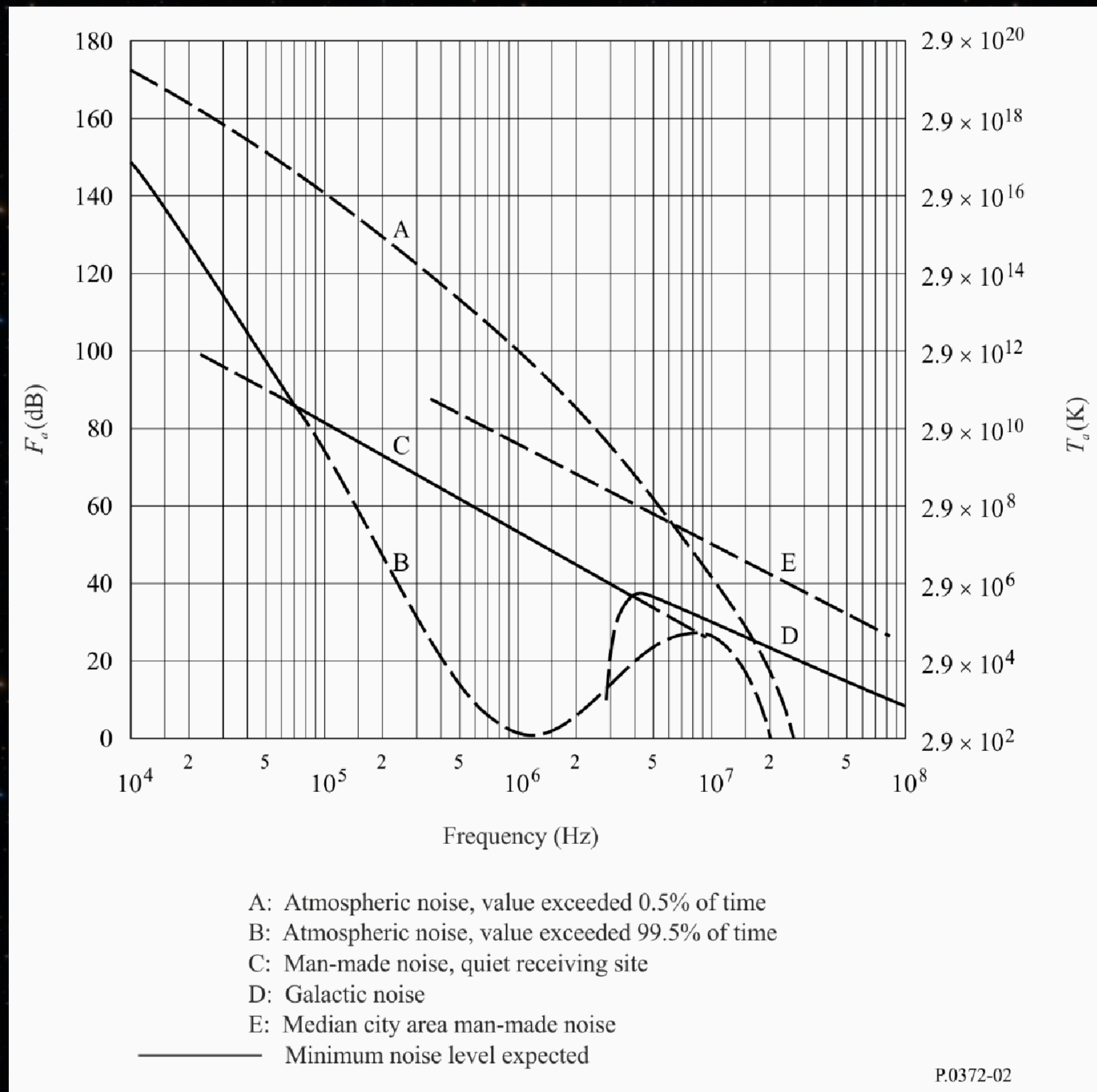


~ 12 000 × AERA

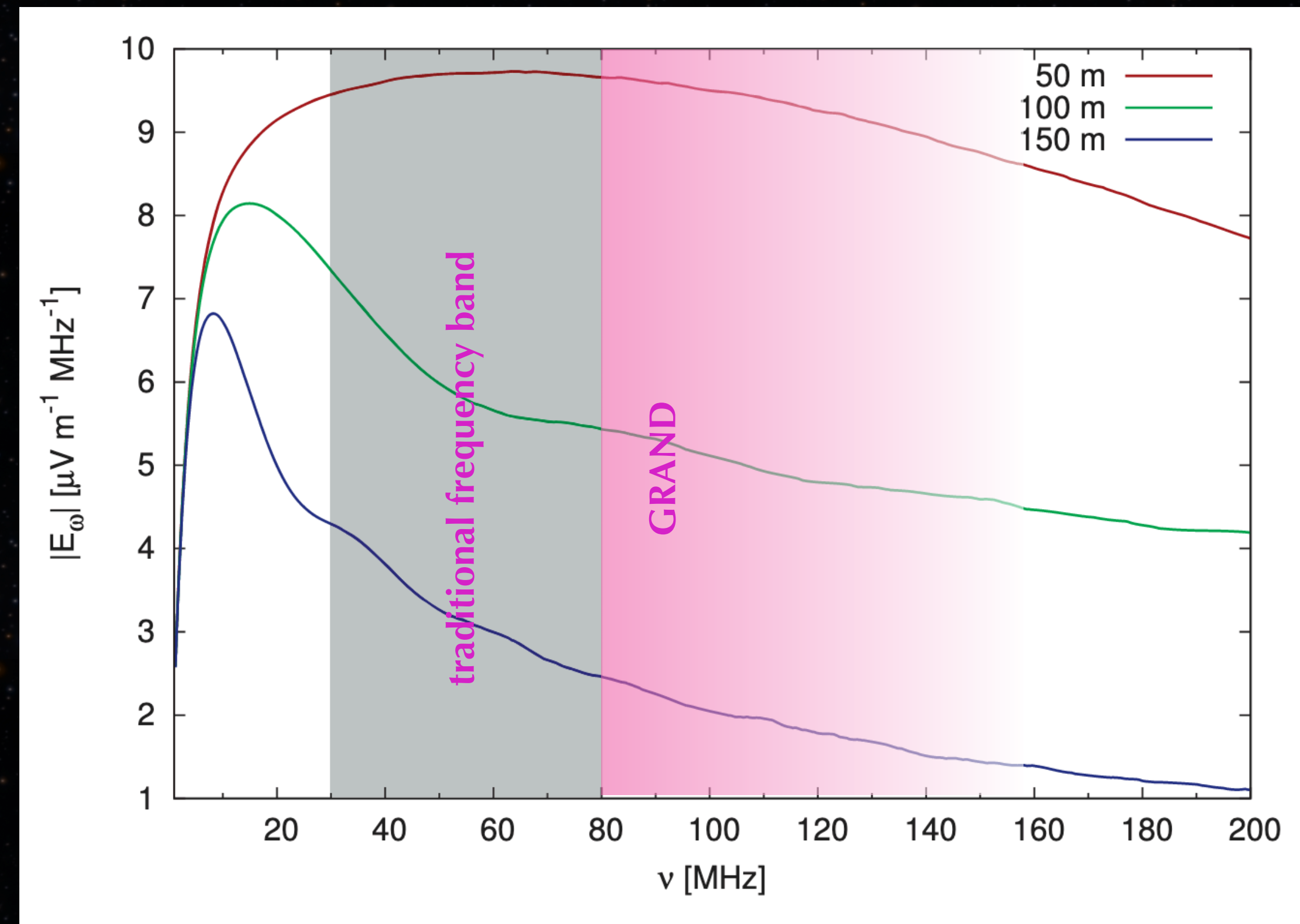
GRAND
200 000 km²

Frequency Domain

frequency range for various categories of noise



spectra of radio signals for different observers



Spectra of radio signals for different observers:
50 m, 100 m and 150 m from the shower axis.

https://www.iap.kit.edu/tunka-rex/downloads/Kostunin_Thesis_KIT_TunkaRex.pdf

https://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.372-16-202208-!!!PDF-E.pdf