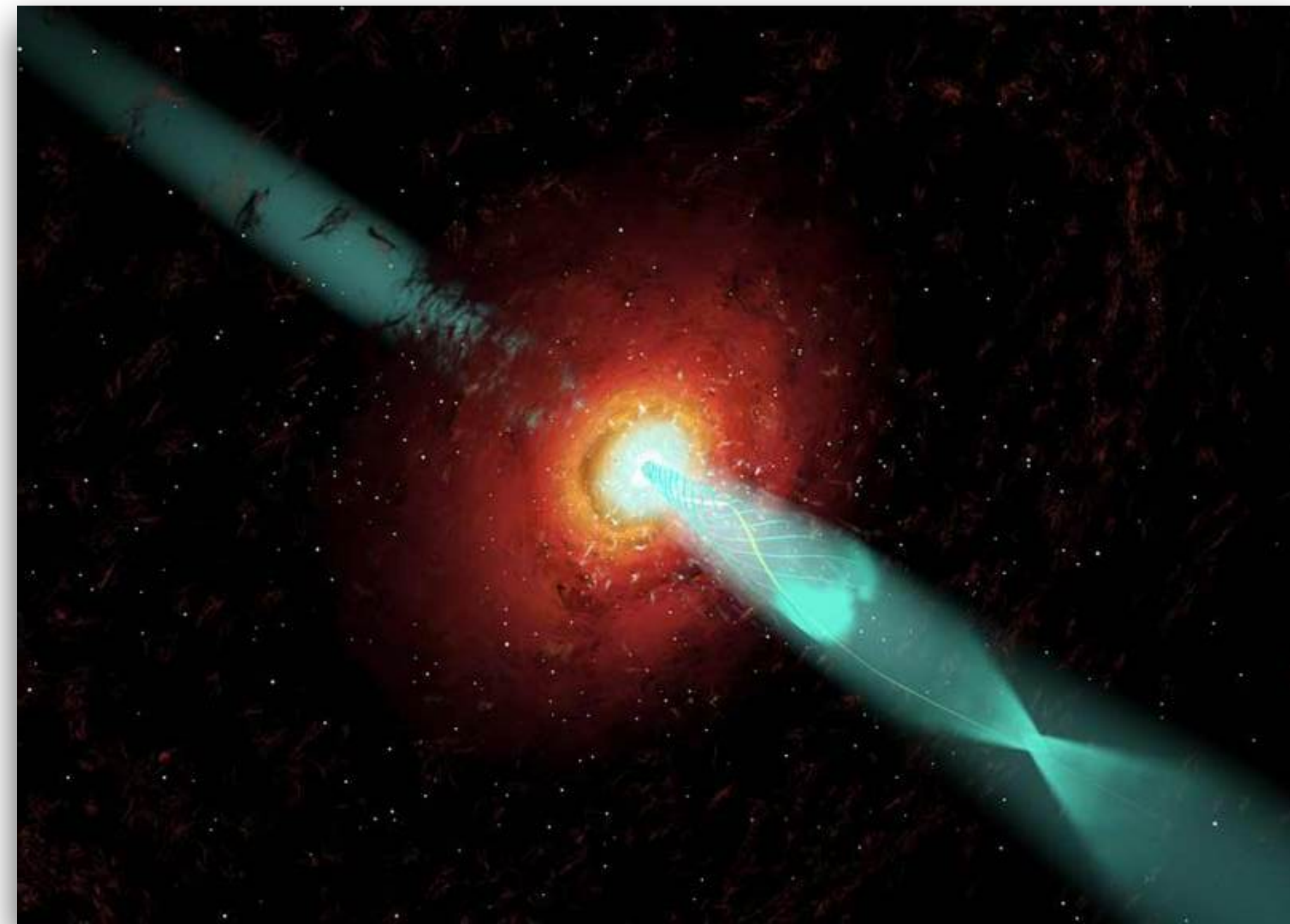


Mapping the Multimessenger Horizon for Cosmic Neutrino γ -ray Counterparts



Jose Carpio

Niels Bohr Institute

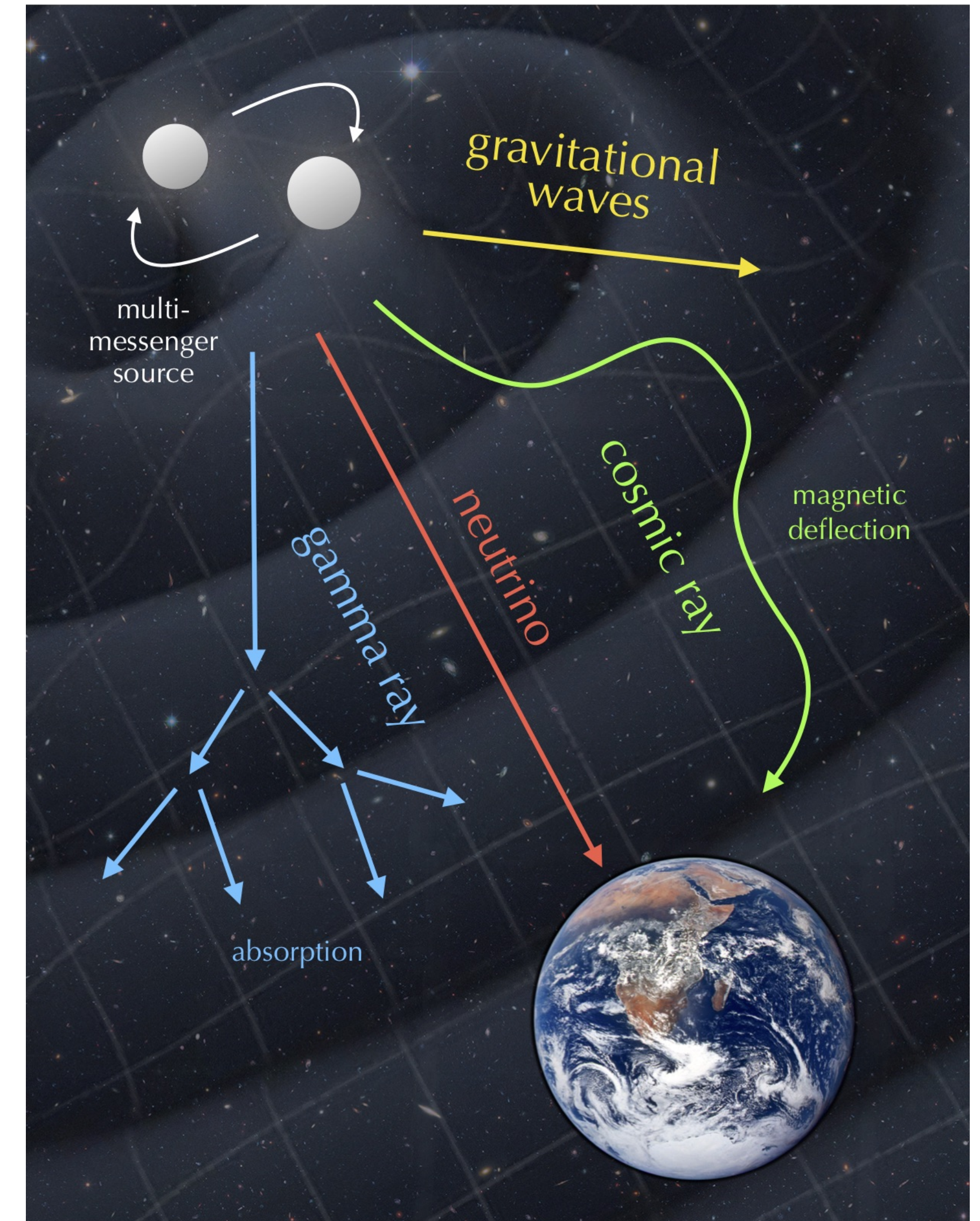
Collaborators: Tianyi Ding, Ali Kheirandish and Kohta Murase

Oct 15th, IPA 2026, Madison

ν s and γ -rays in multimessenger astronomy

Neutrinos:

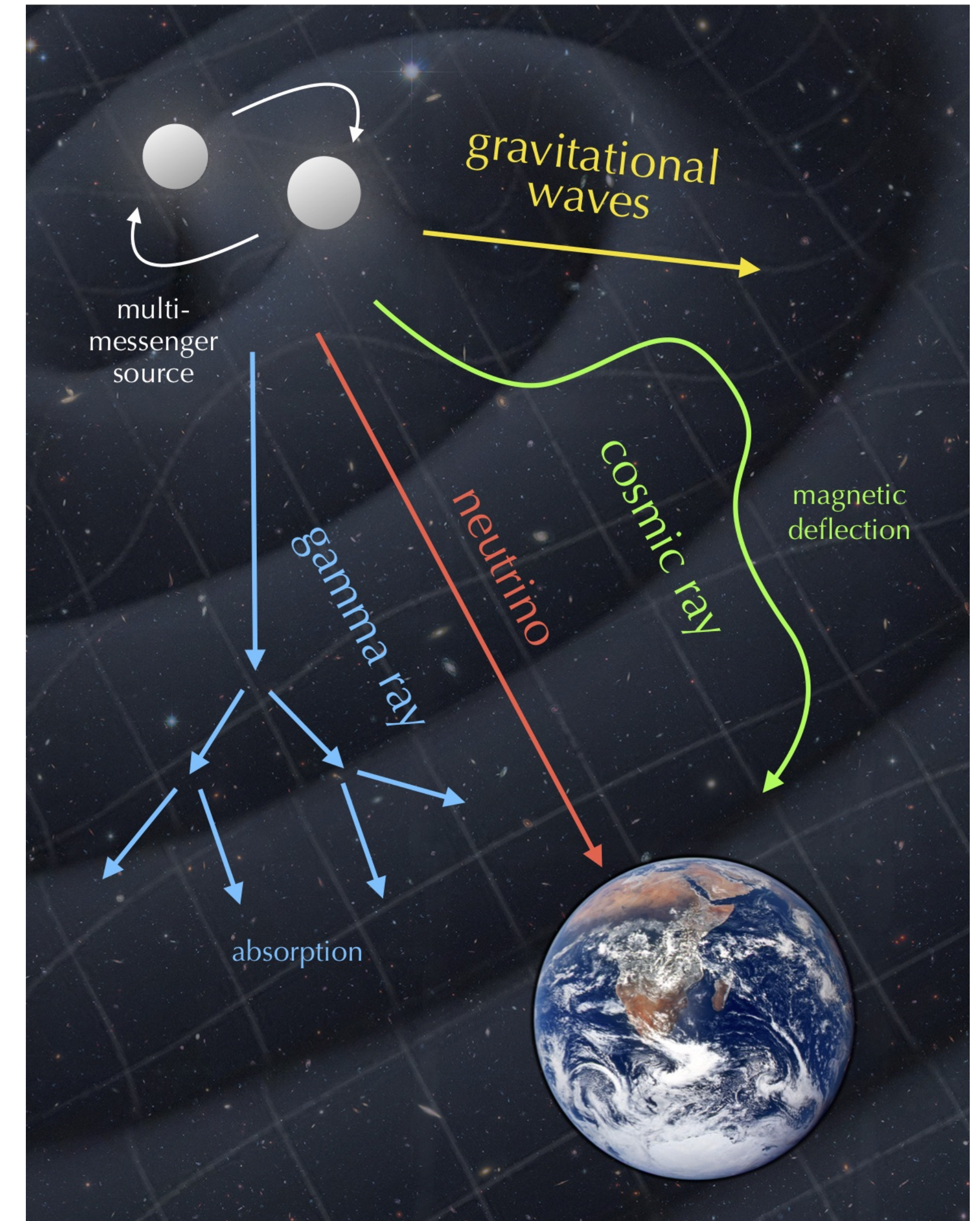
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- Point back to their sources
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ν s and γ -rays in multimessenger astronomy

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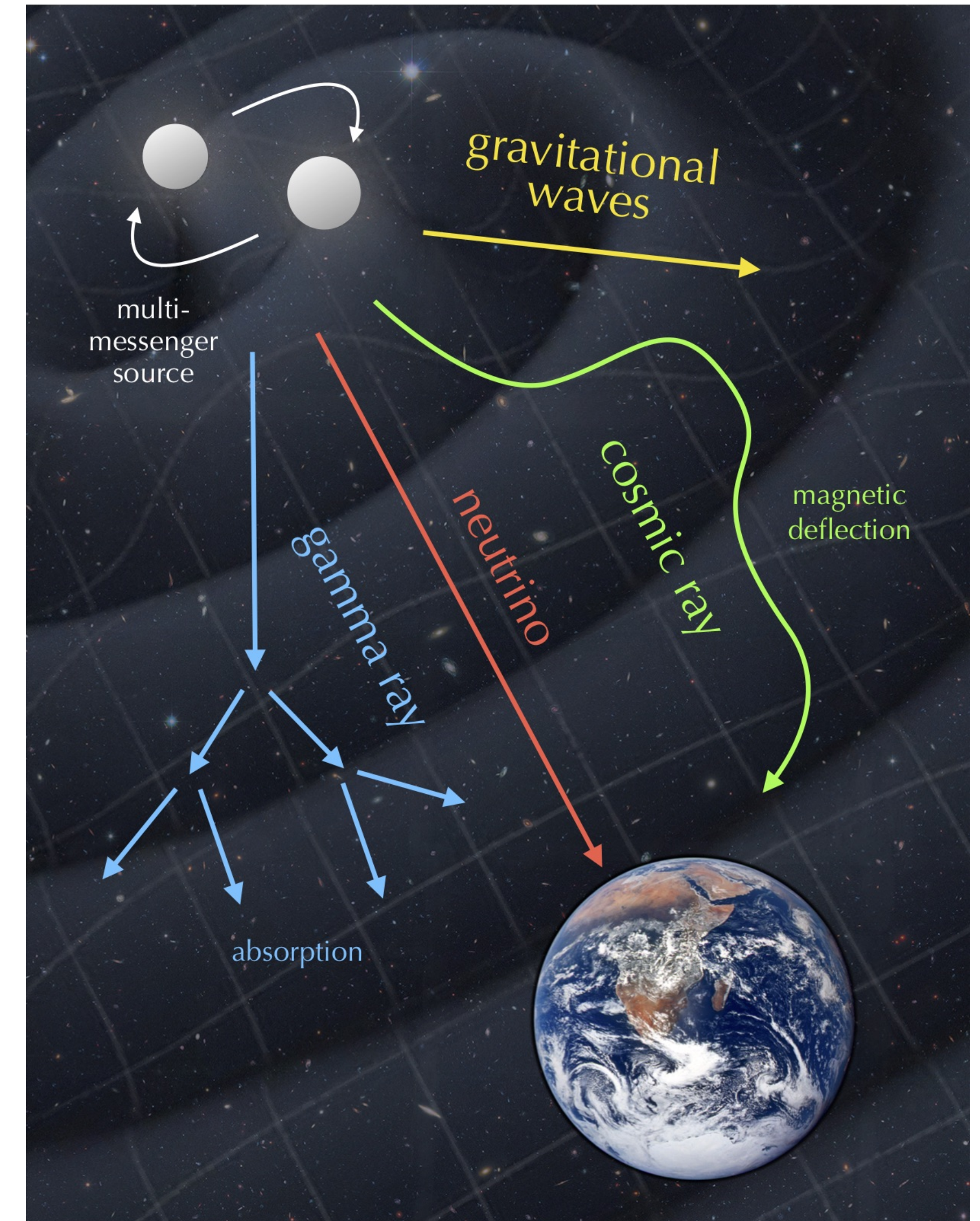
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- High energy γ -rays may be leptonic in nature, and does uniquely identify a source as a **hadronic** accelerator



ν s and γ -rays in multimessenger astronomy

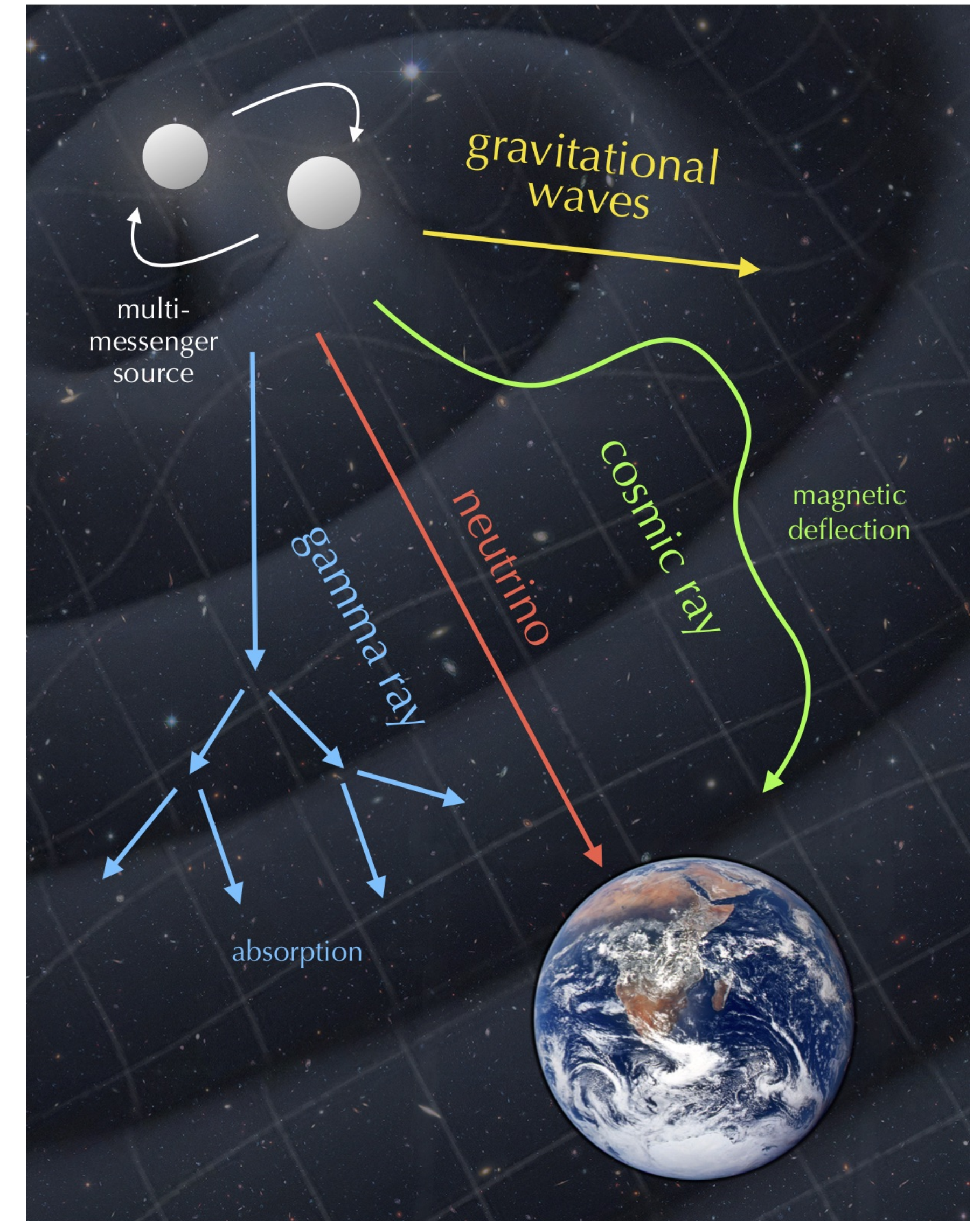
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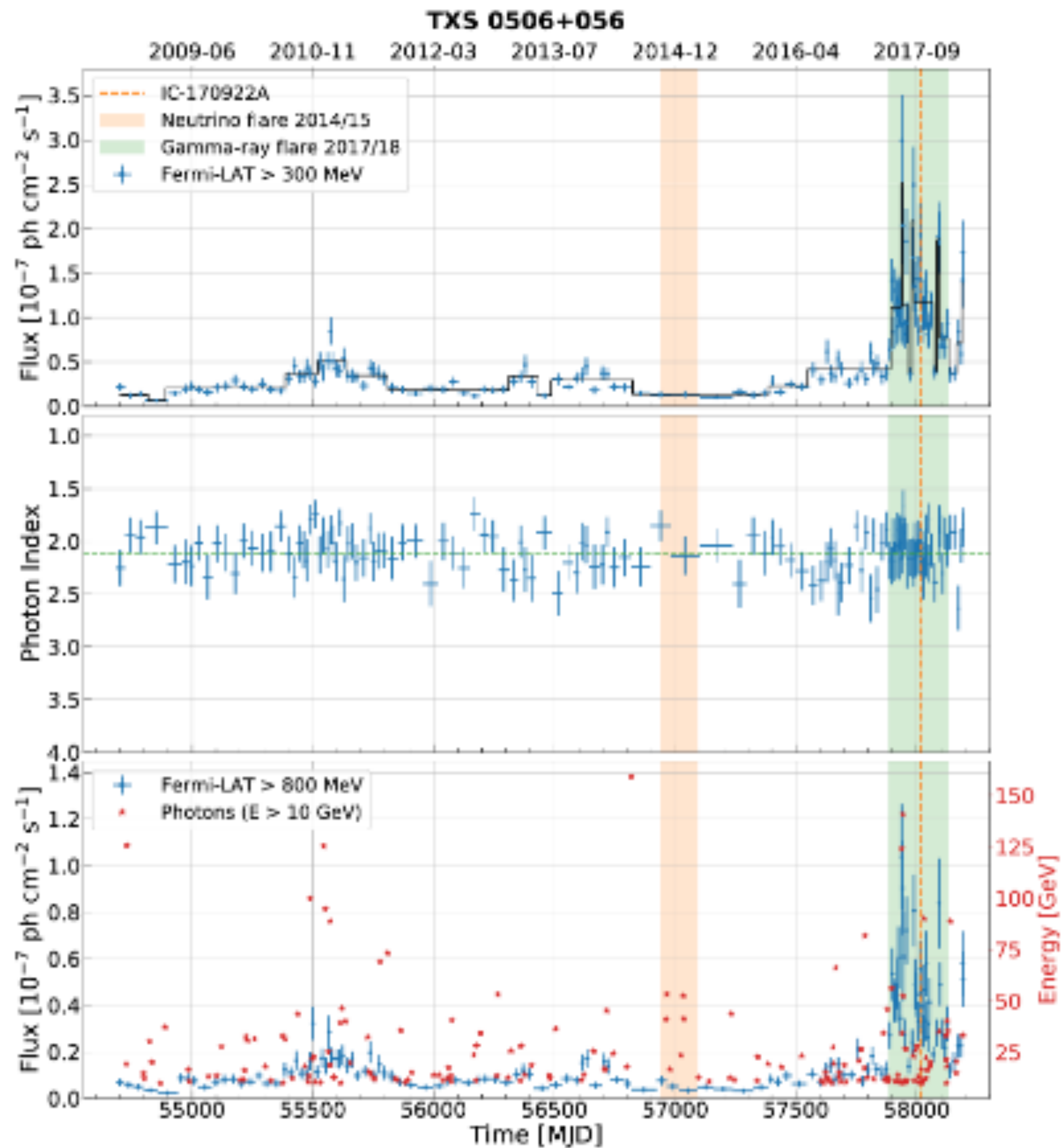
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The combination of γ -rays and neutrinos is important to understand the nature of cosmic accelerators



Blazar: TXS 0506

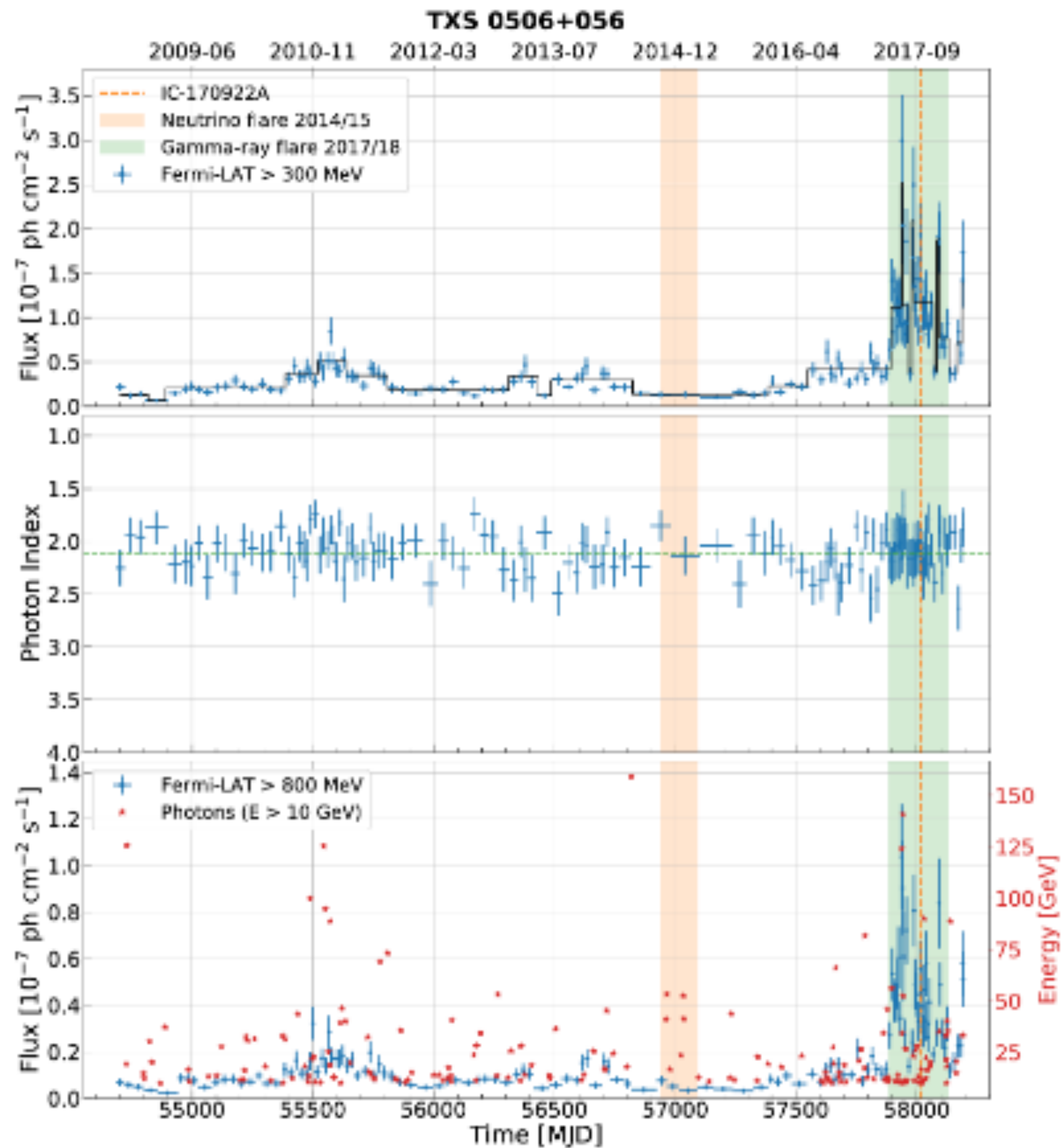


Example of multimessenger astronomy with neutrinos

2017 Flare

- IceCube: One **~290 TeV** event;
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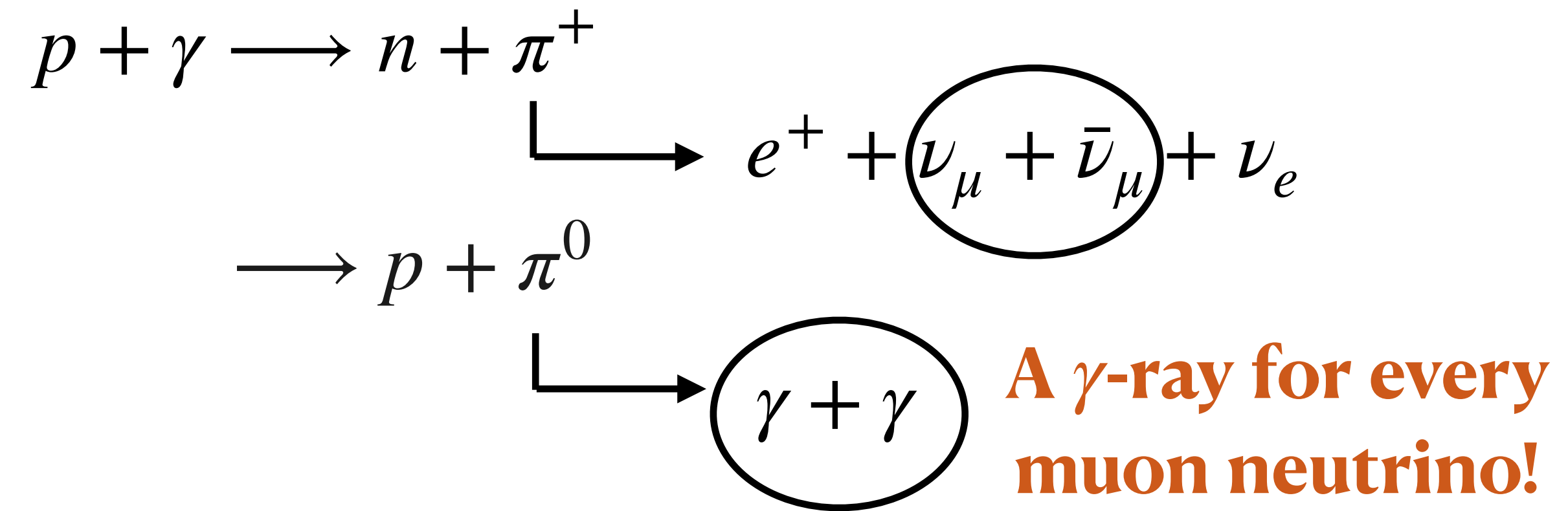
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Archival search

- 2014/2015 neutrino flare $\rightarrow$ 110 day flare with ≈ 13 events
- No clear γ -ray flare counterpart in Fermi data

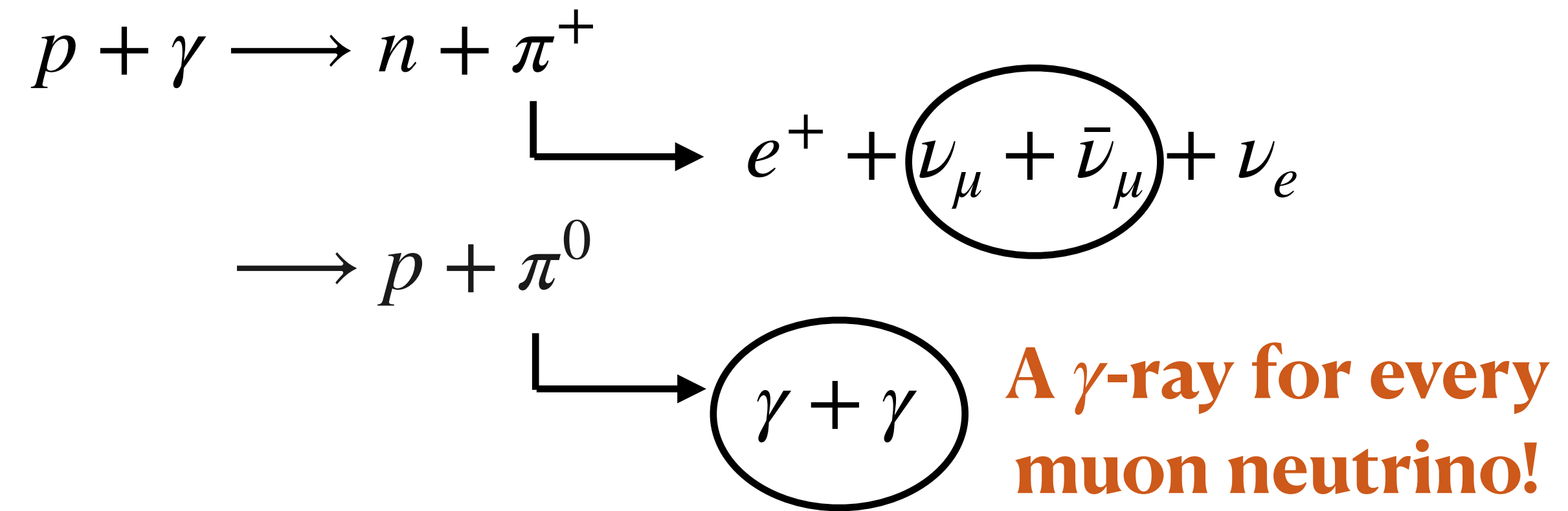
Importance of γ -rays in neutrino astronomy

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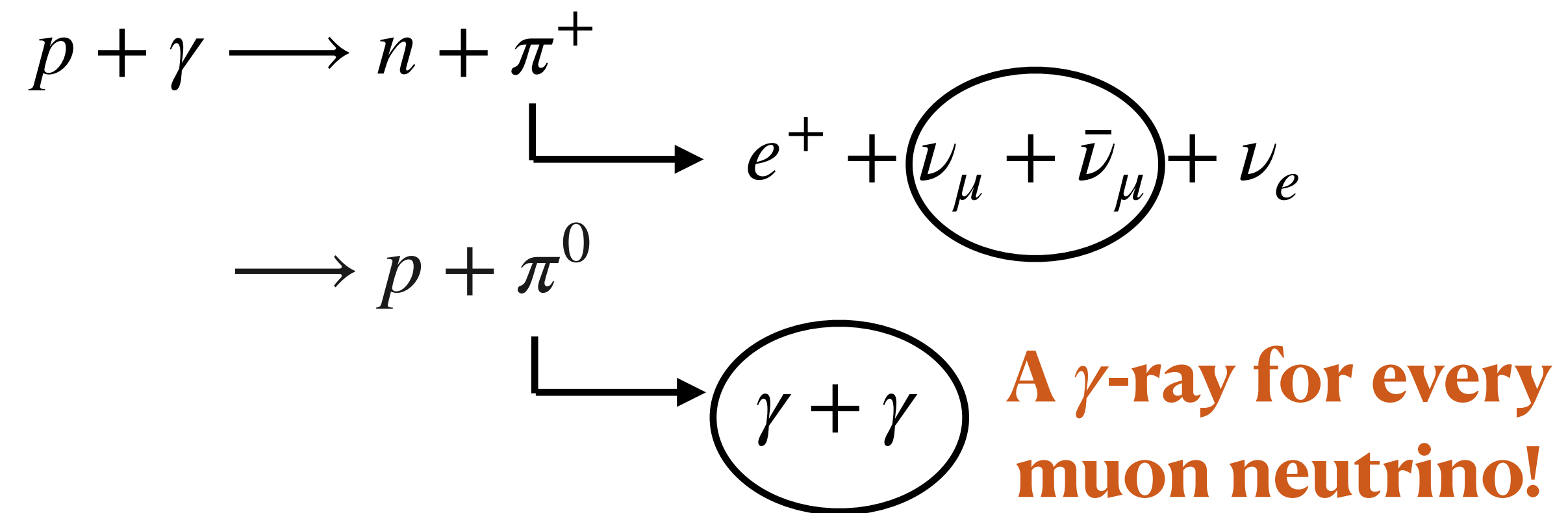


$$E_\nu \approx \frac{1}{4}E_{\pi^+} \qquad E_\gamma \approx \frac{1}{2}E_{\pi^0}$$

Comparable neutrino and photon energies

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Comparable neutrino and photon energies

$$\frac{1}{3} \sum_{\alpha} E_{\nu}^2 \frac{dN_{\nu}}{dE_{\nu} dt} \approx \frac{1}{4} E_{\gamma}^2 \frac{dN_{\gamma}}{dE_{\gamma} dt}$$

Co-production of ν and γ is *inevitable*

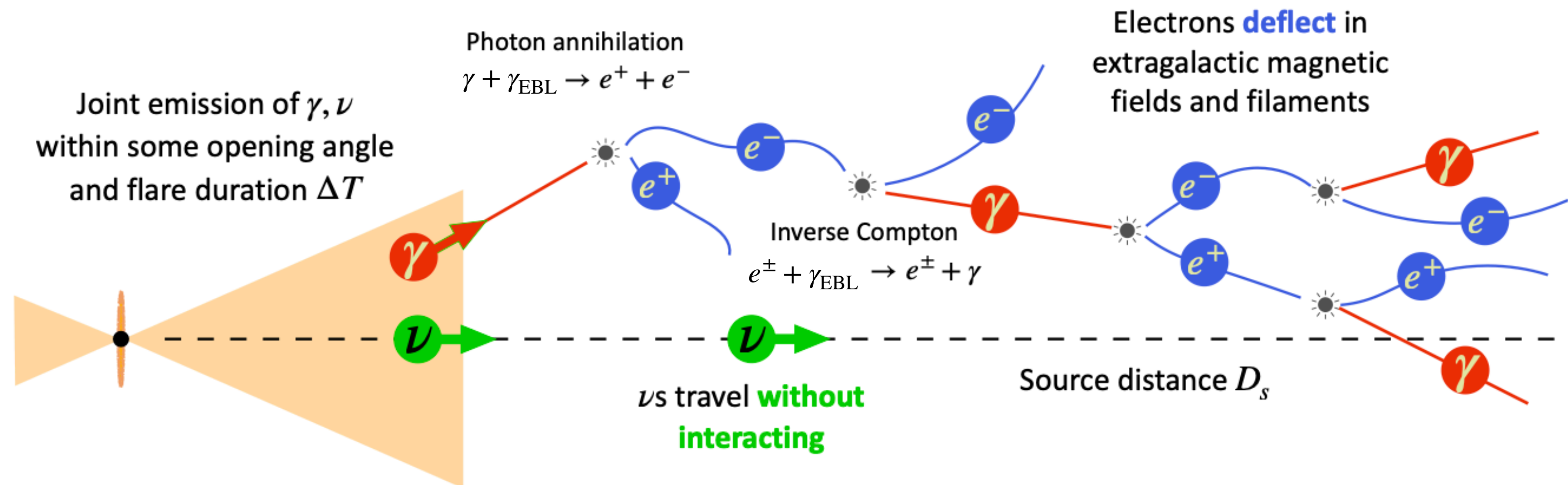
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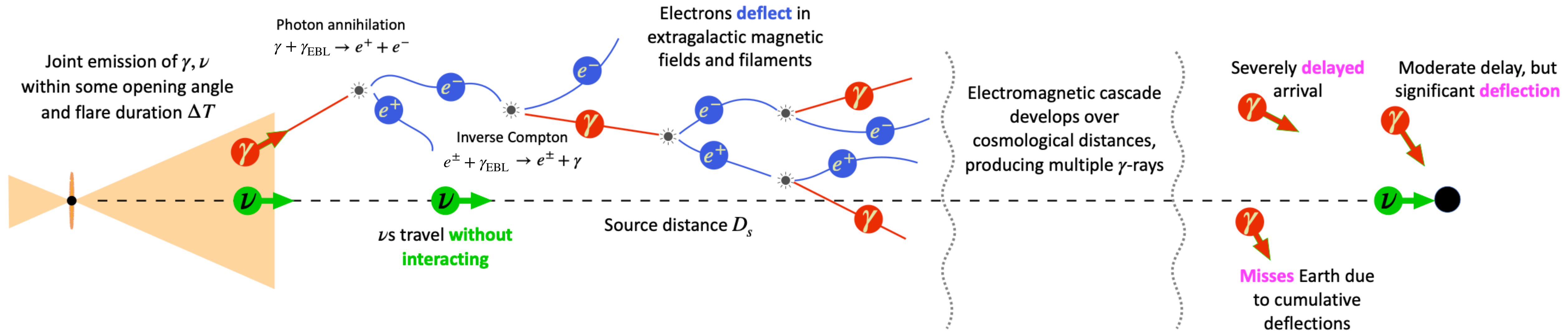
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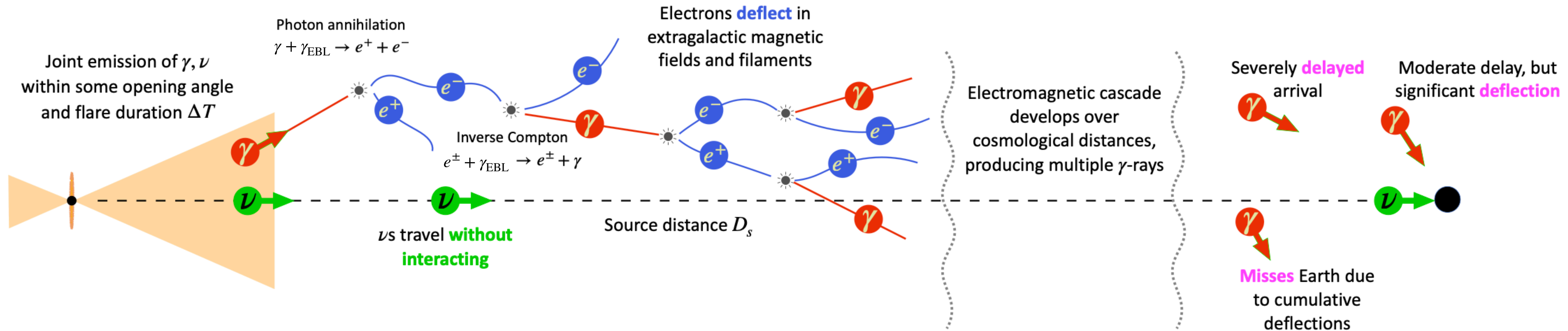
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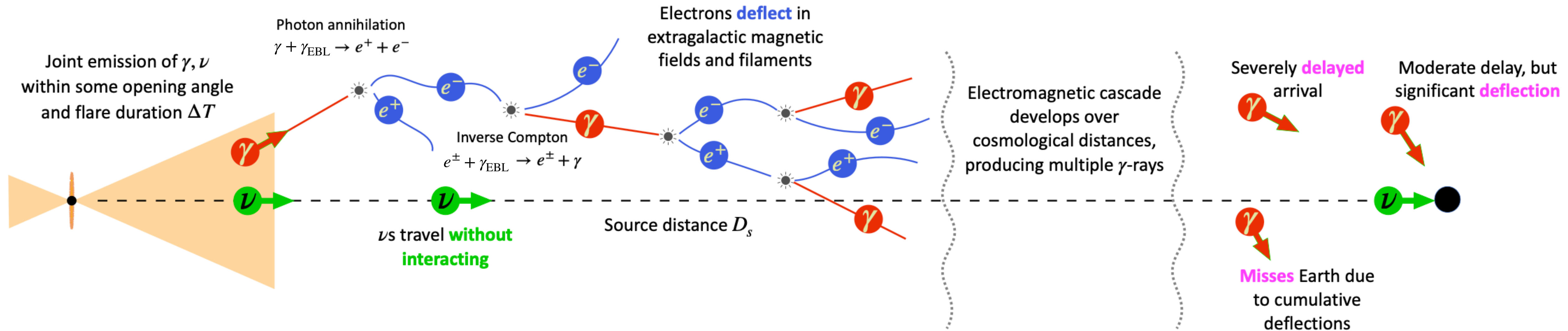


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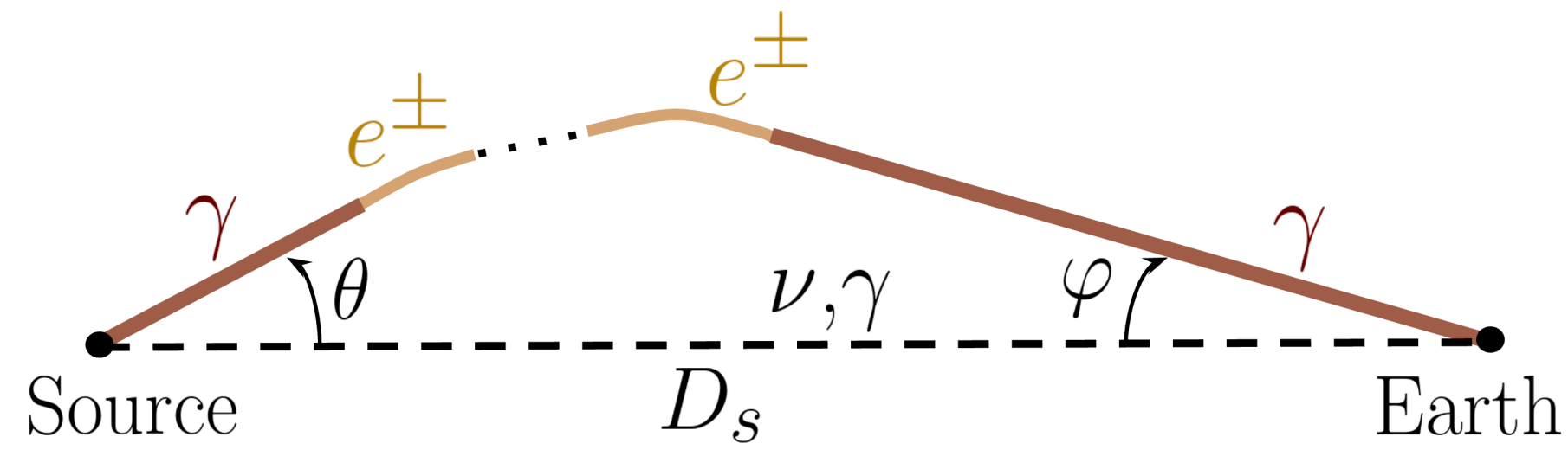
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Given a source, can we observe **joint neutrino- γ -ray observations?**

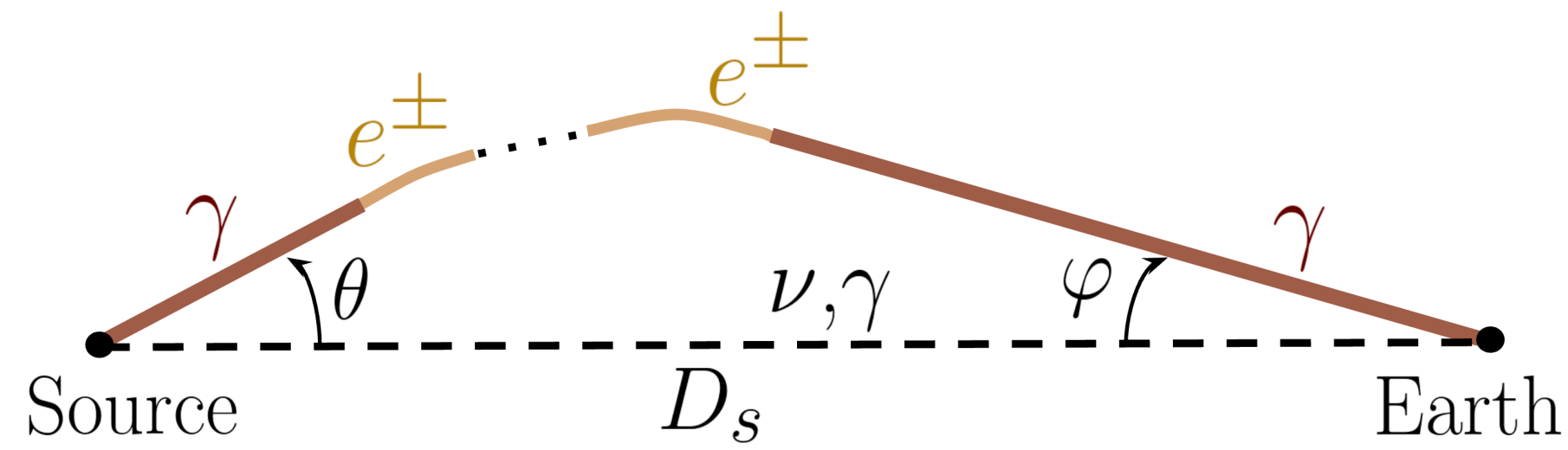
Computing the γ -ray cascade



Propagation handled with **modified CRPropa3**

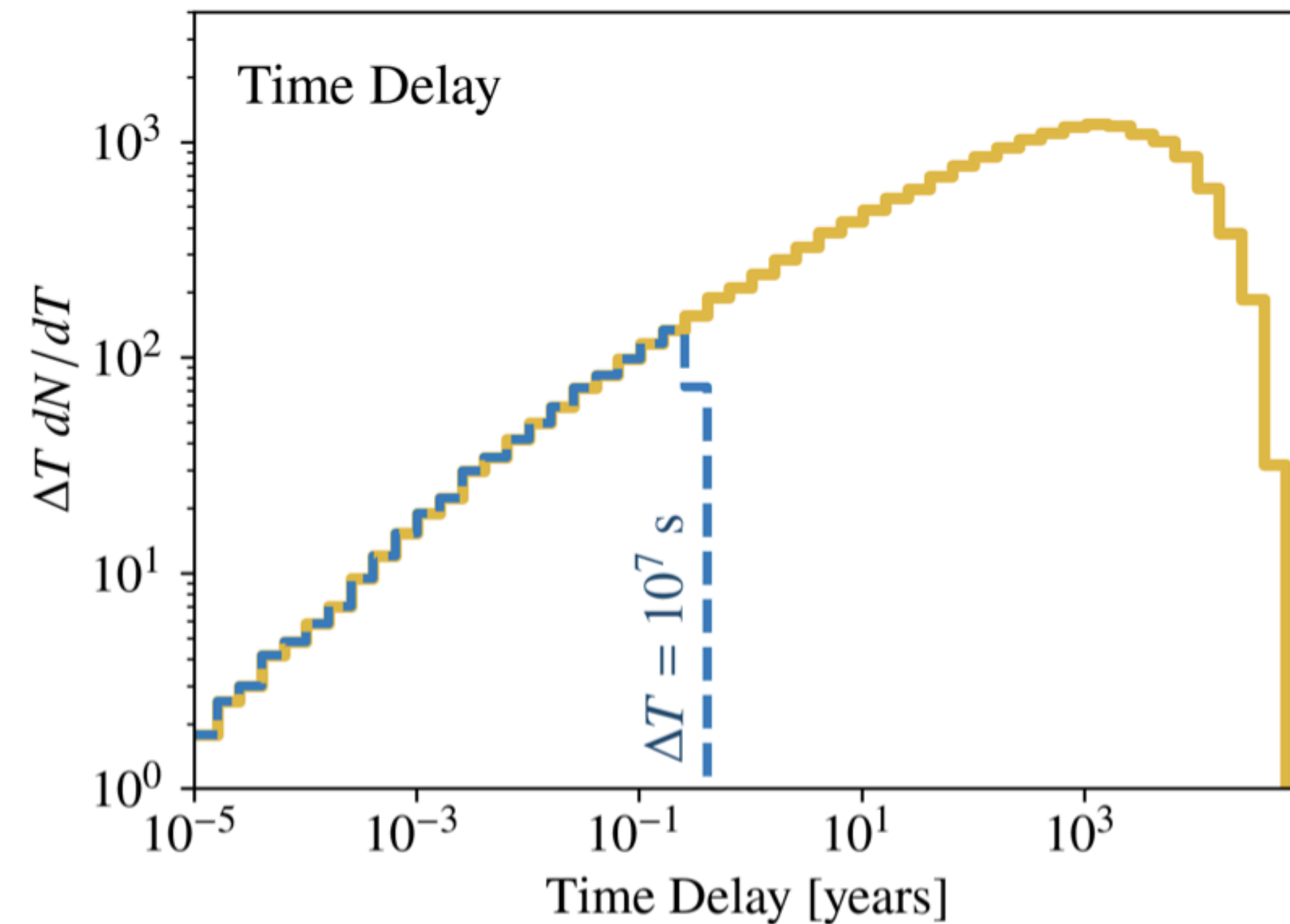
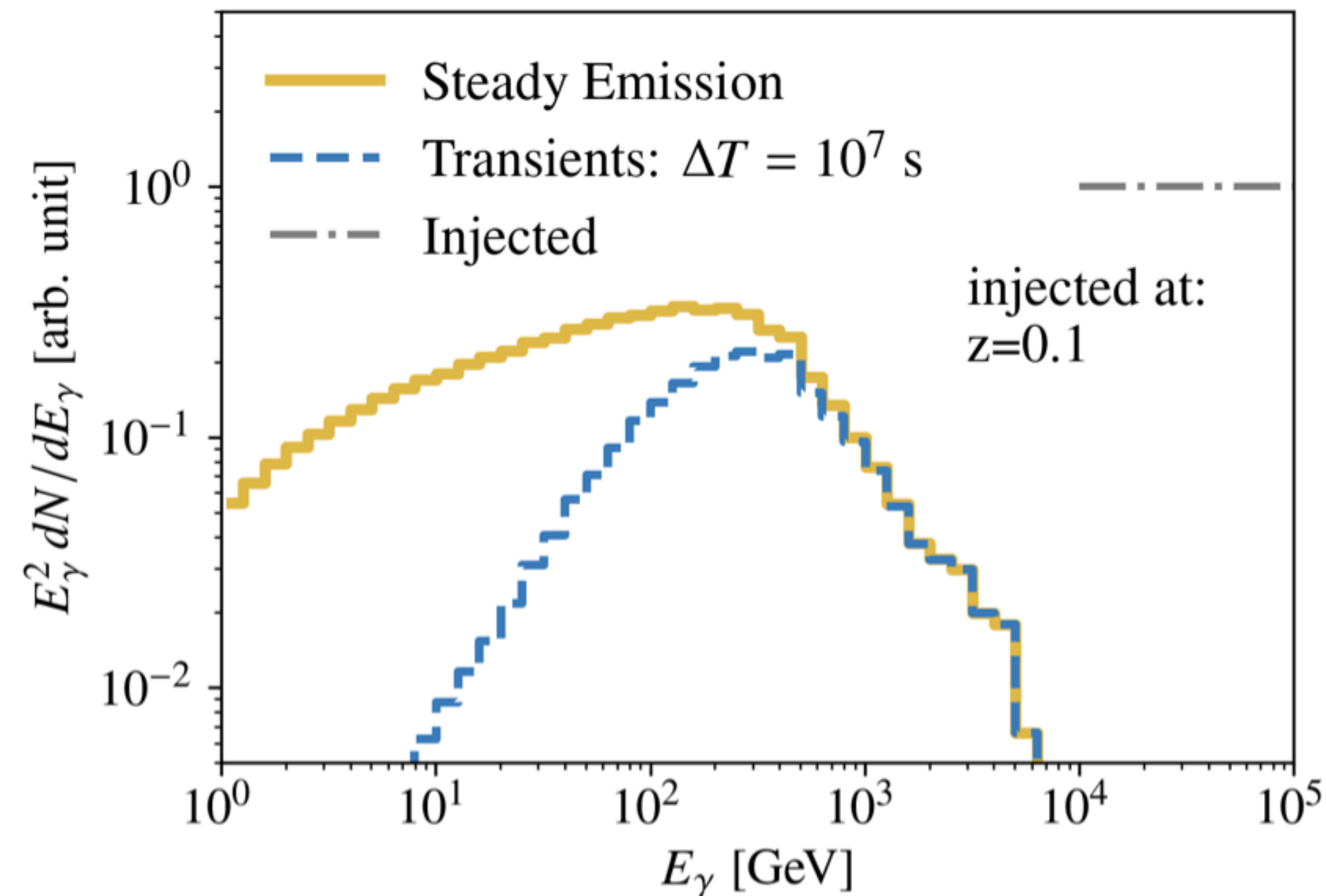
1. Emission within angle θ
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Computing the γ -ray cascade

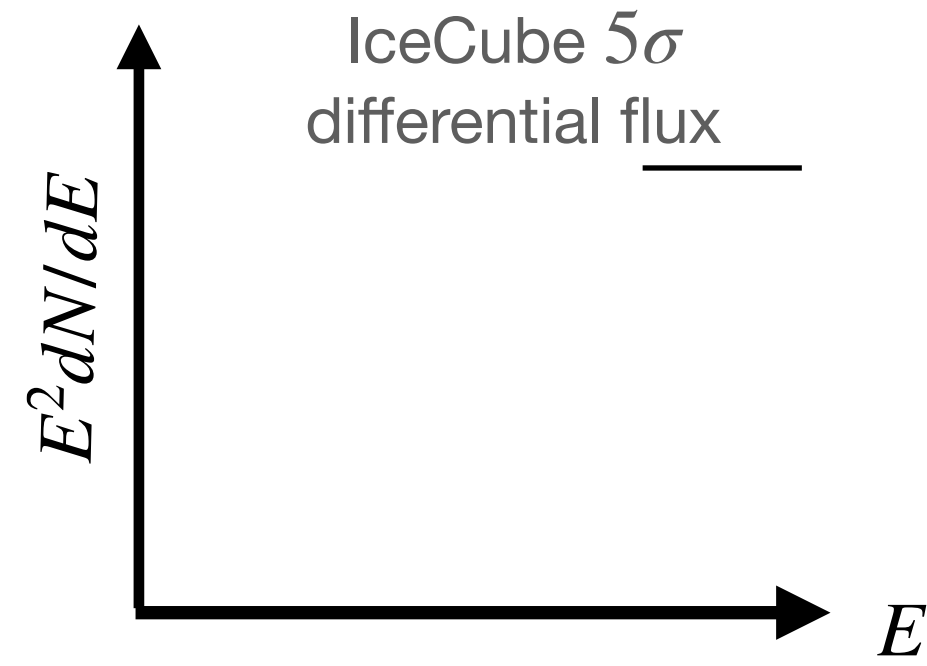


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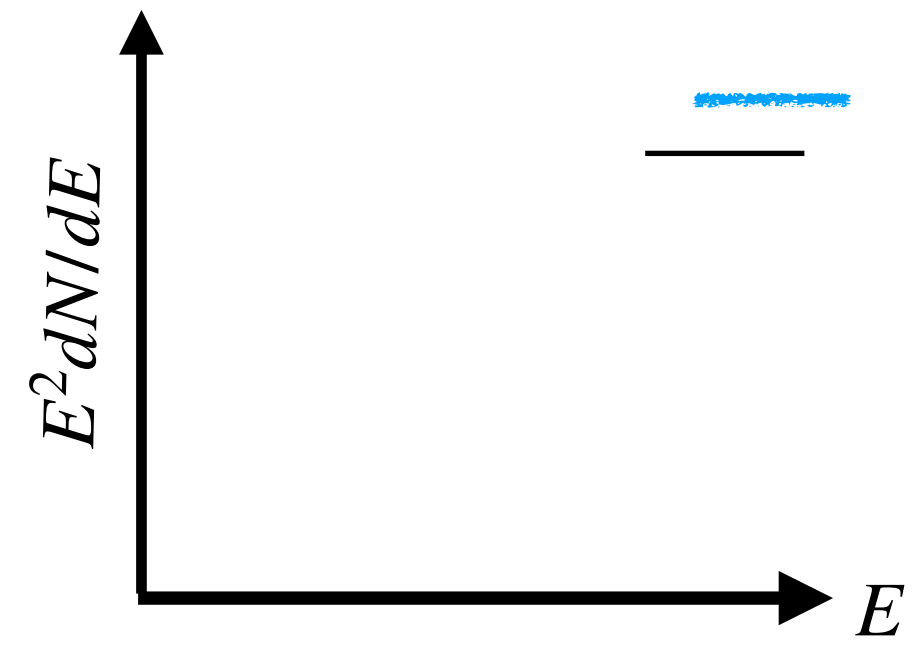
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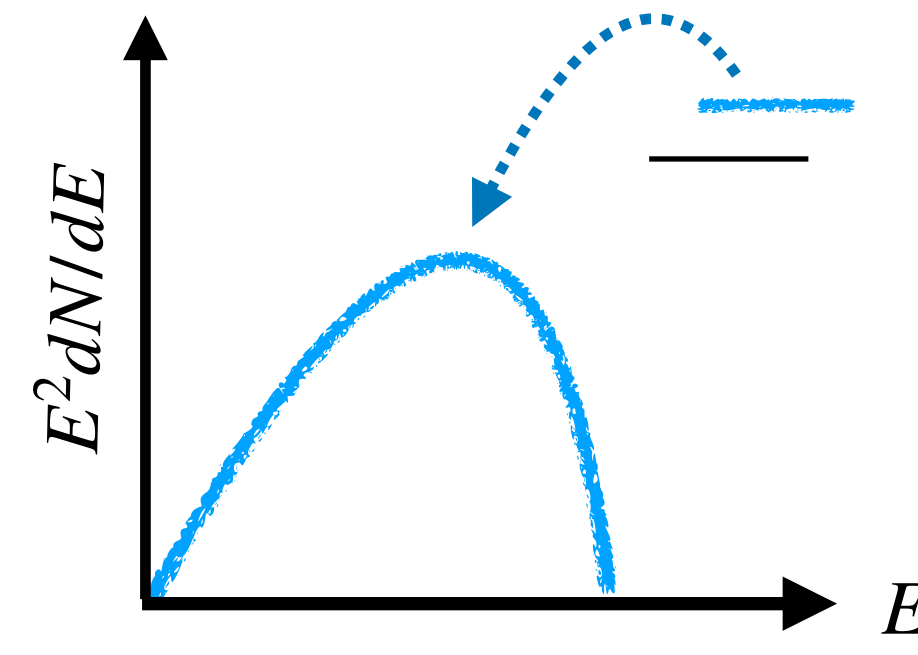
Can we observe the GeV counterpart?



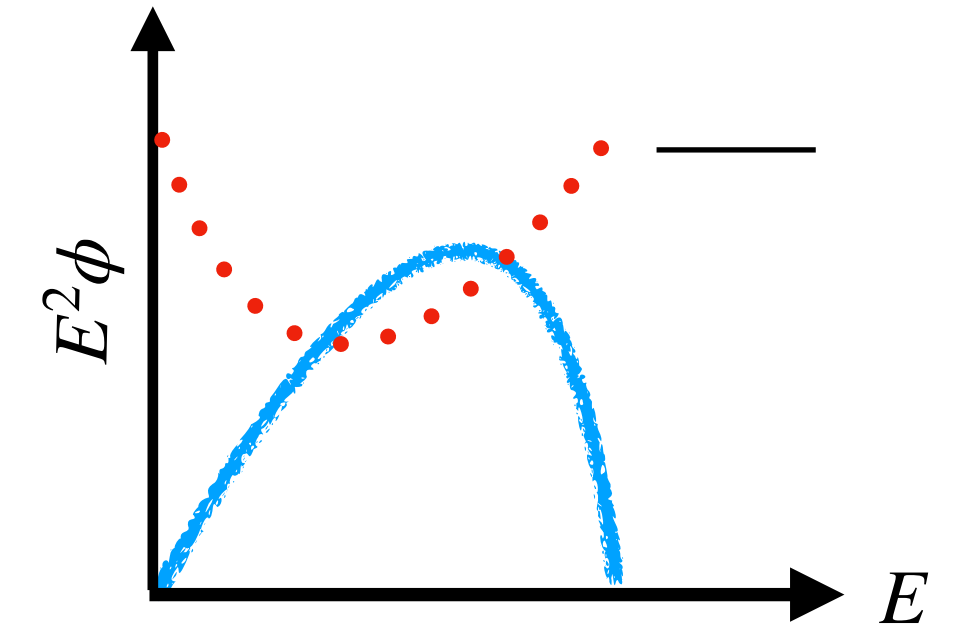
1. Assume a ν spectrum at the **production** site



2. Calculate the **associated** γ -ray spectrum at production

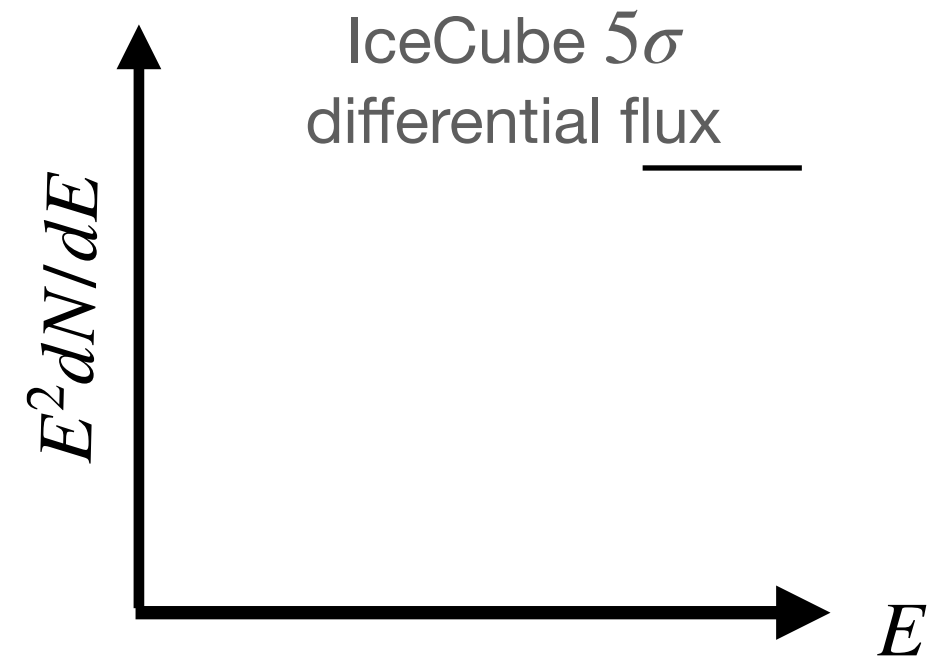


3. Calculate the **propagated** γ -ray spectrum (**transparent source**)

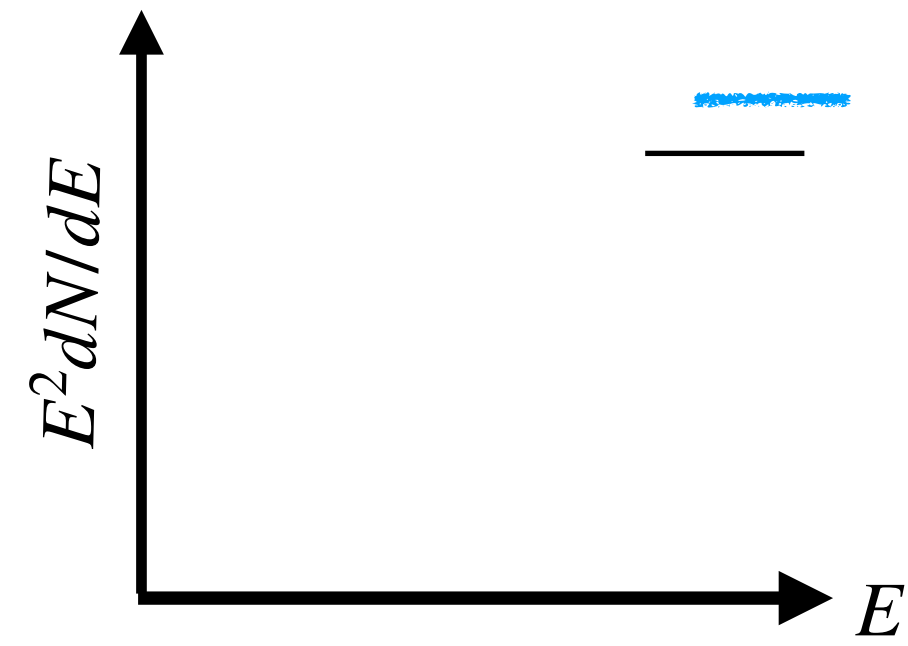


4. Convert ν and γ -ray spectra to fluxes. Compare against γ -ray detector sensitivities

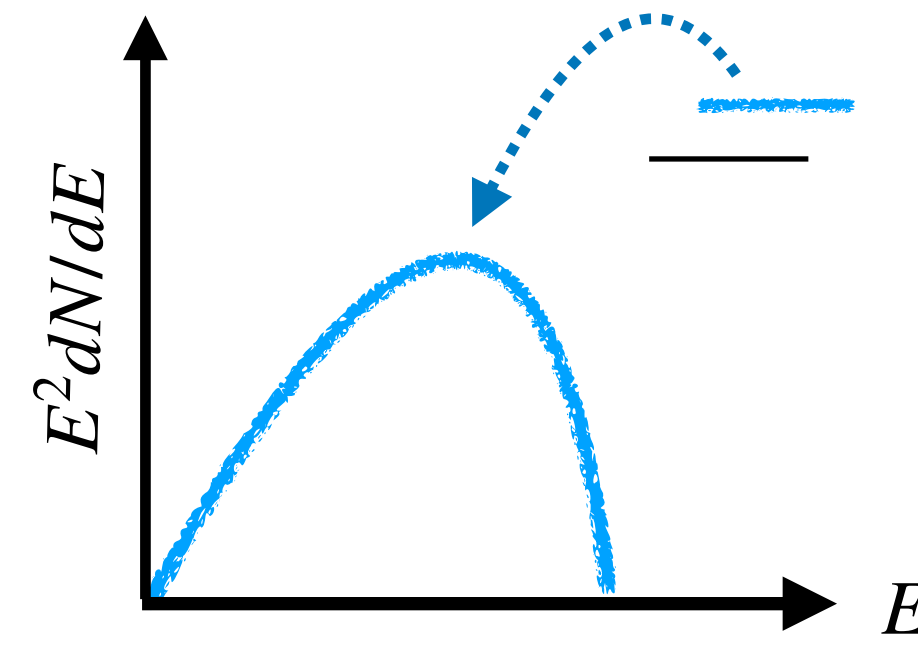
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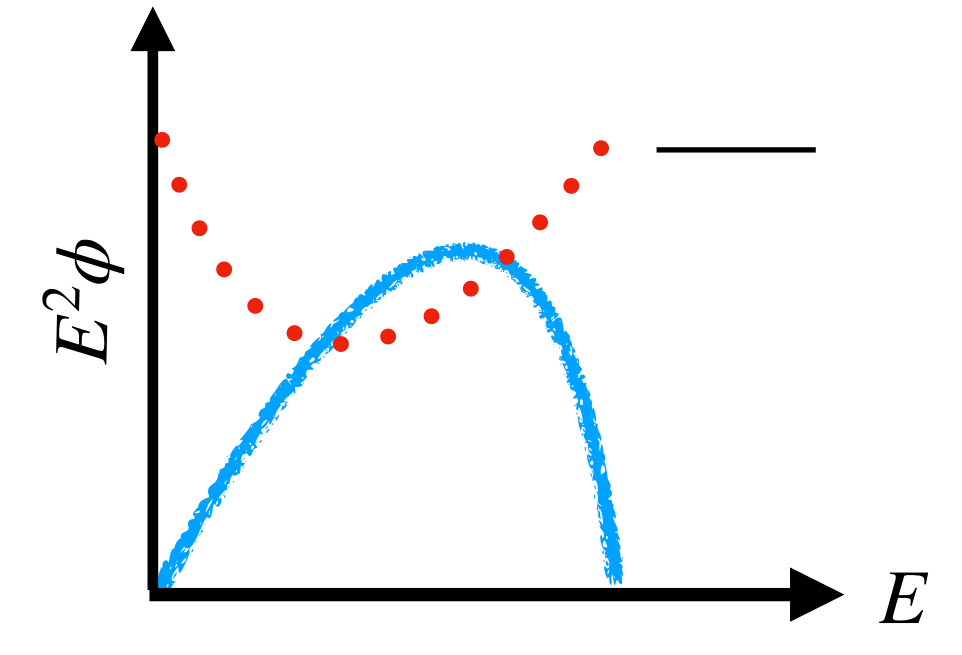
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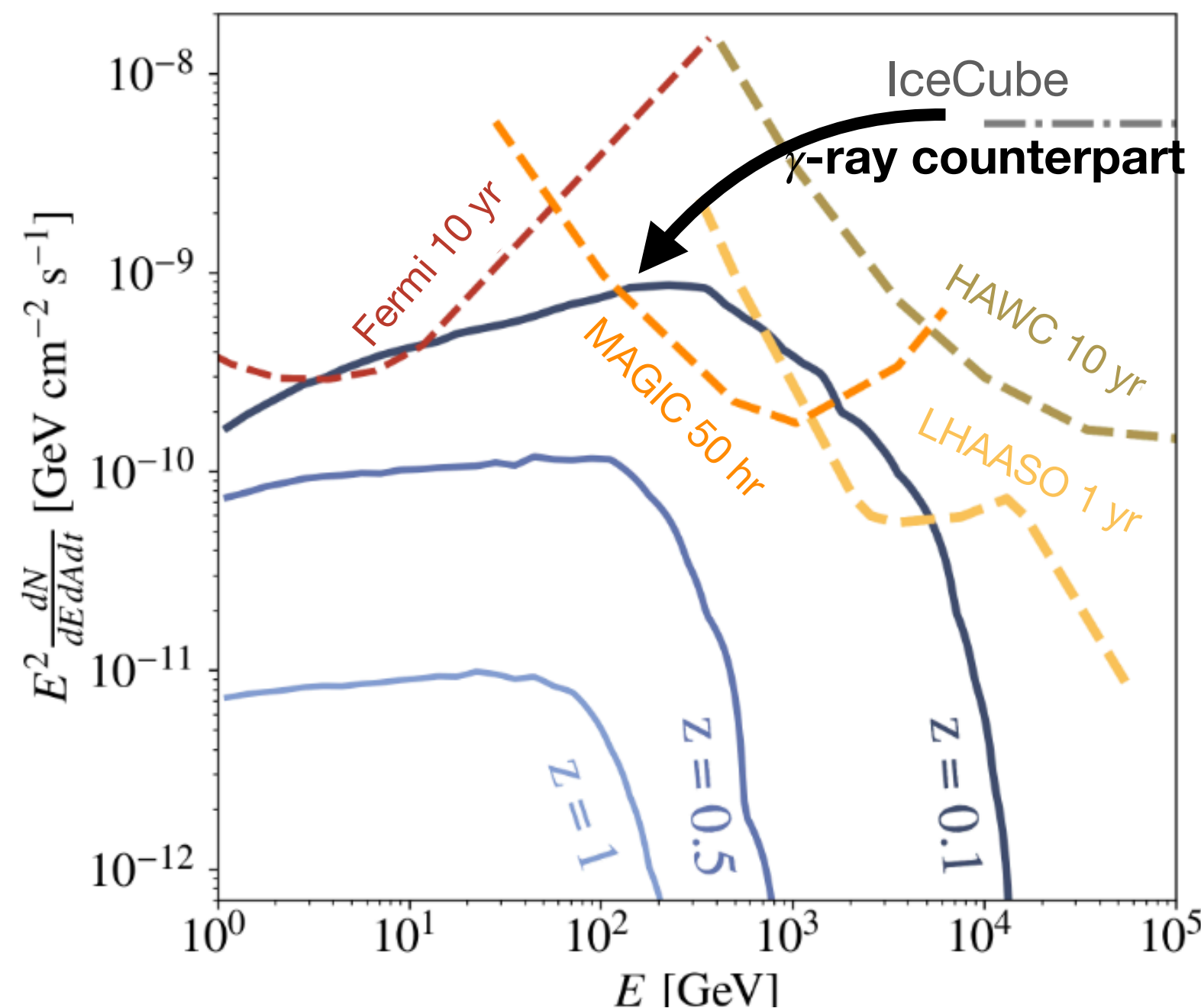
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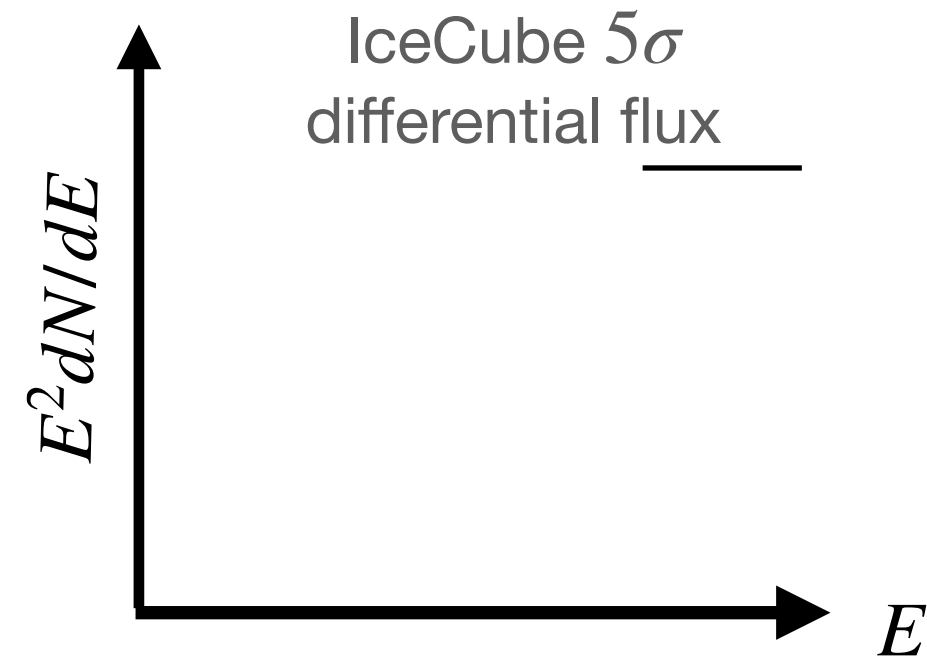
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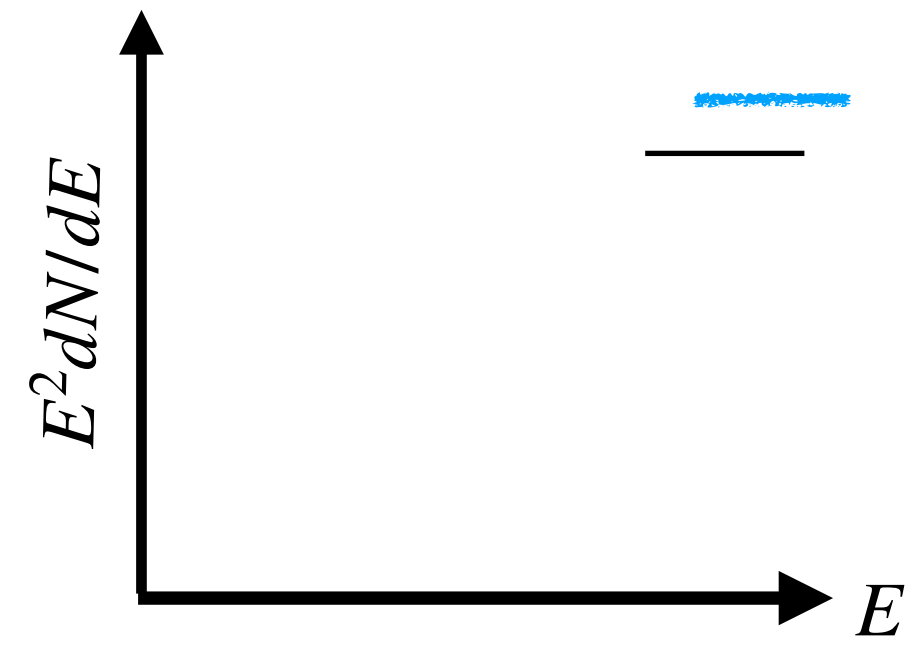
When calculating the counterpart, we account for

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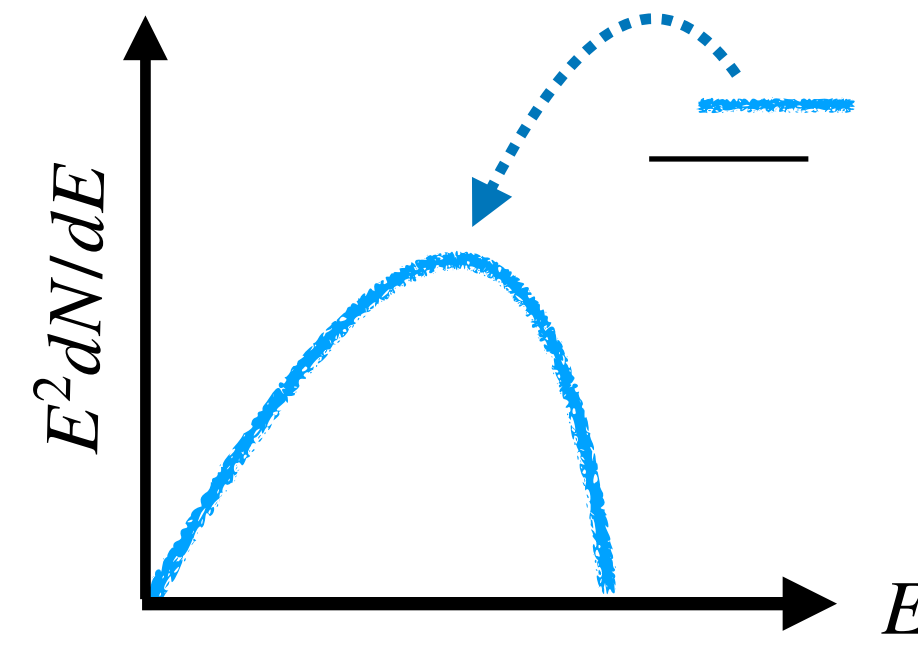
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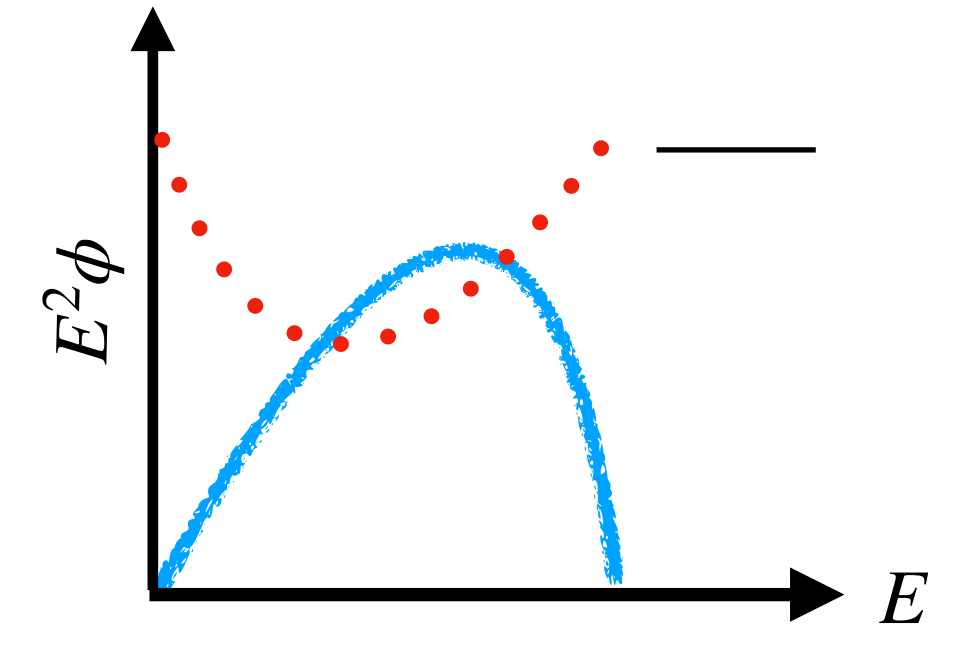
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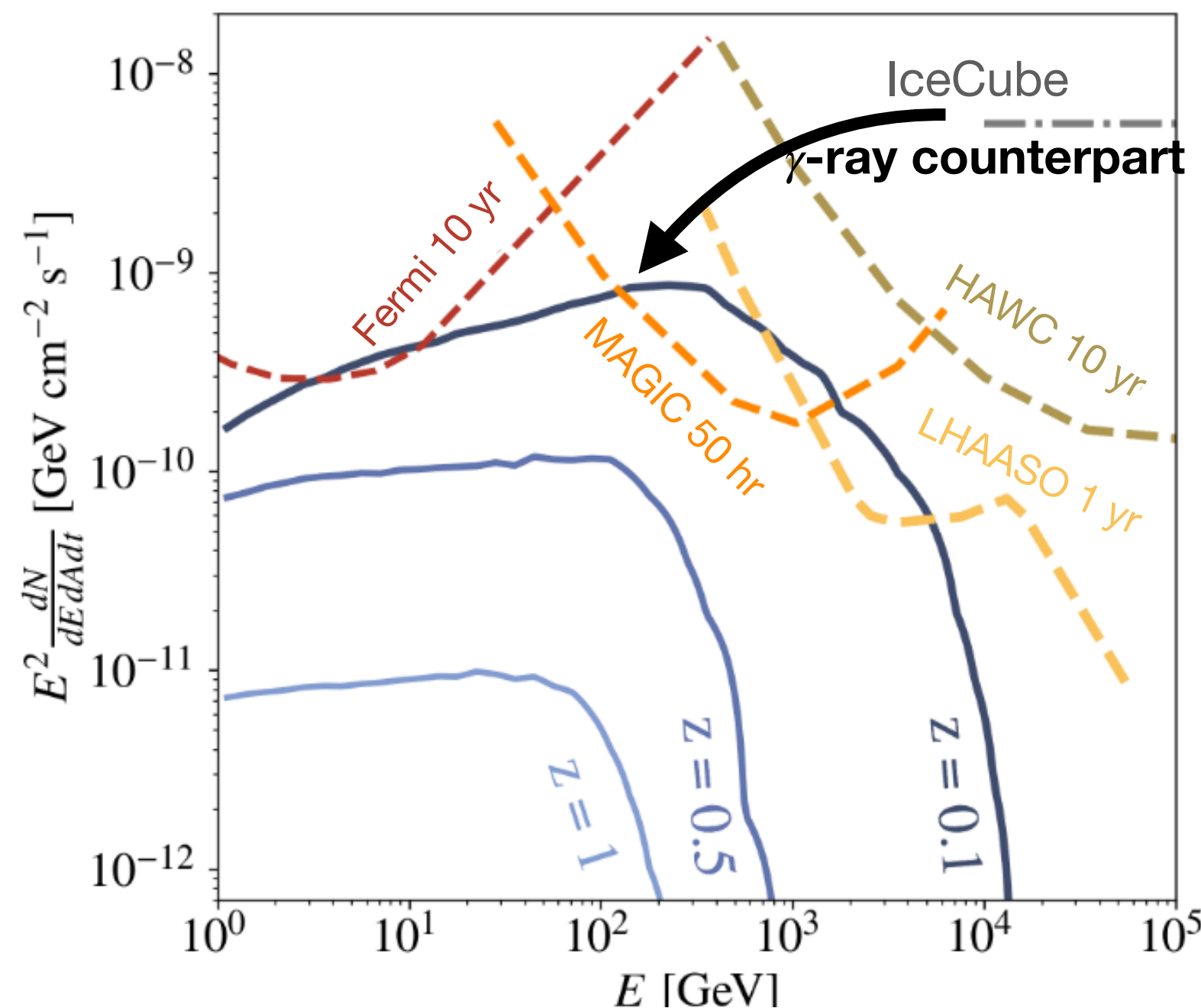
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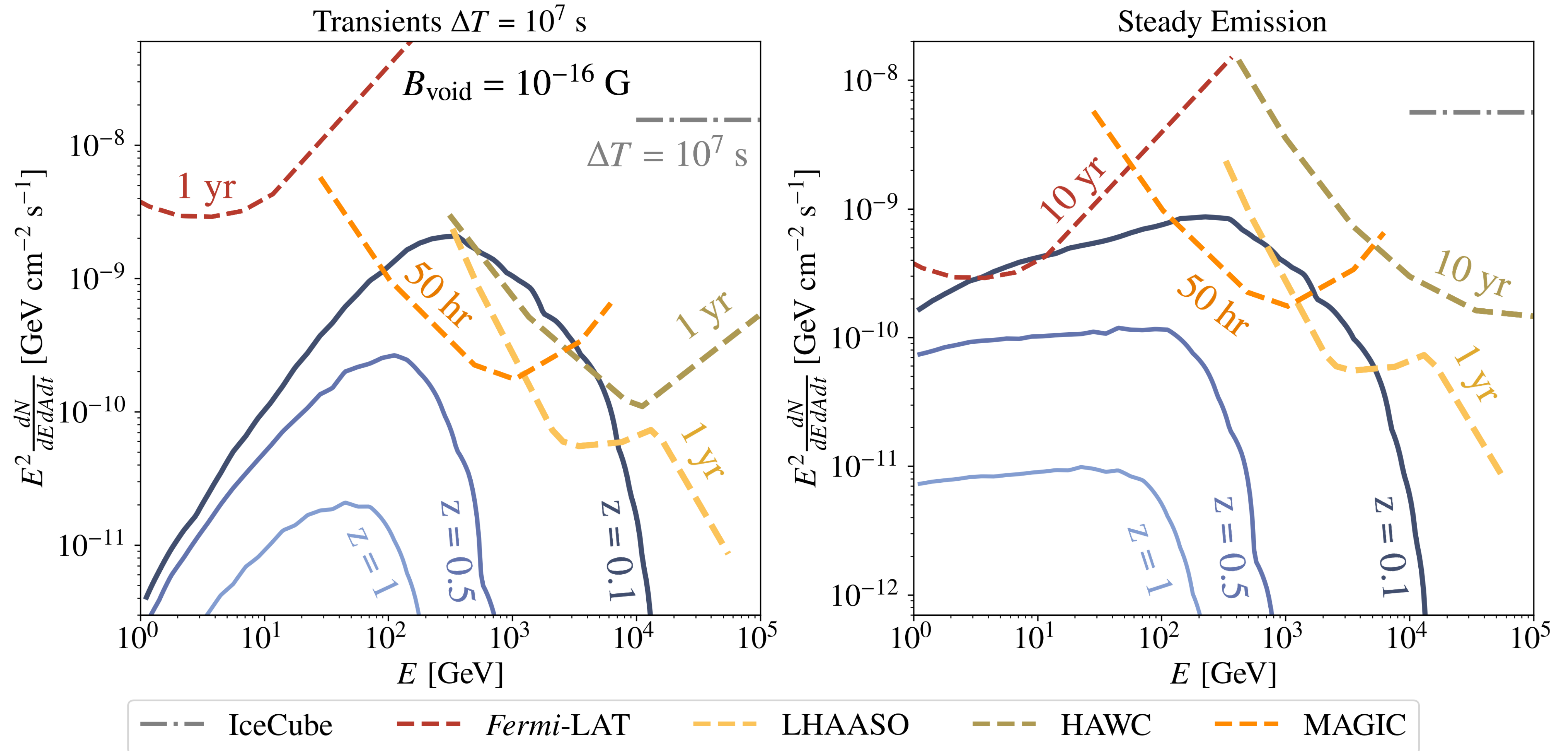
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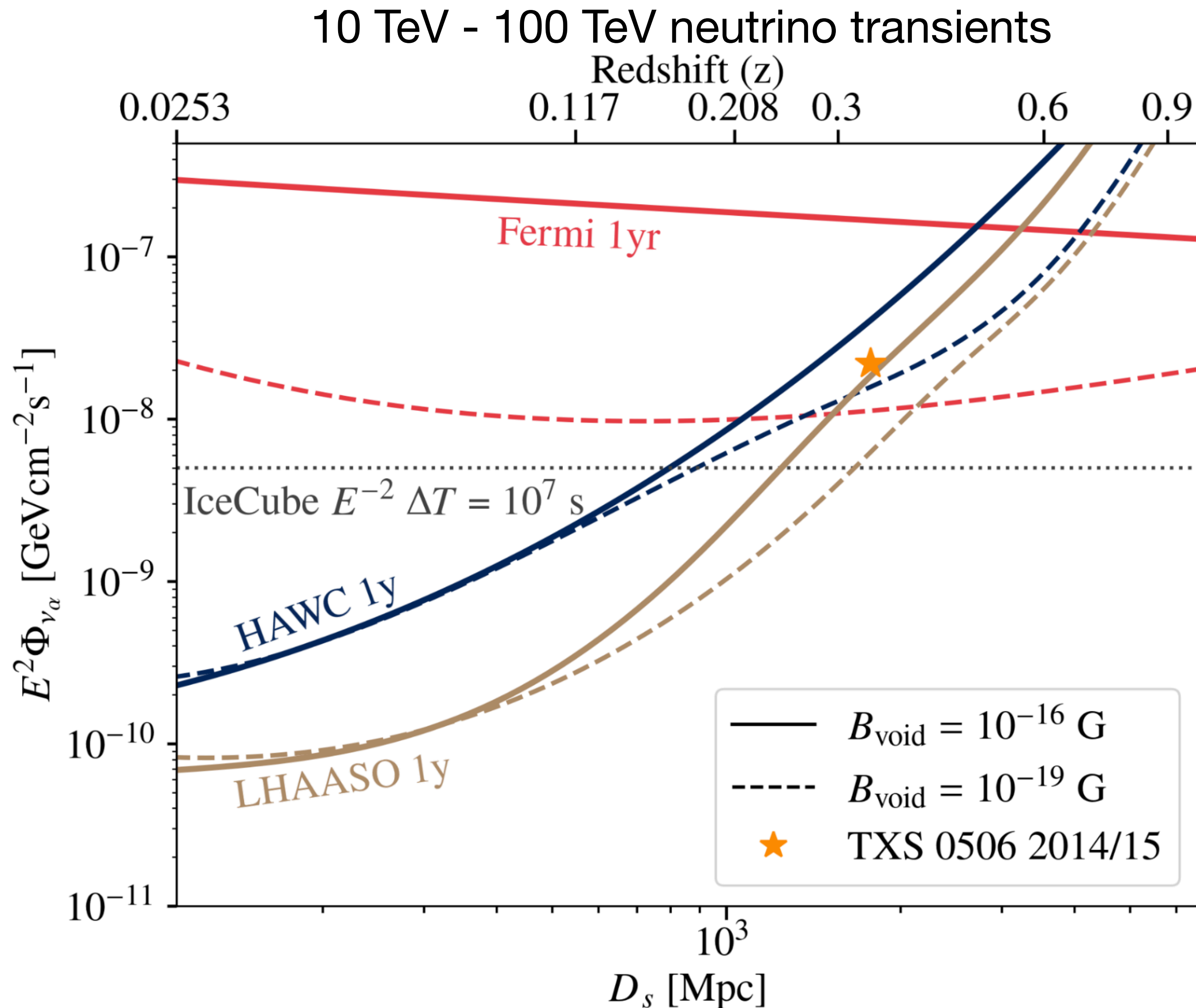
Depending on the source distance, we may not be sensitive to the γ -ray signal, marking a **multimessenger horizon**.

Can we observe the GeV counterpart?

Assuming a γ -ray transparent neutrino source



Multimessenger horizon



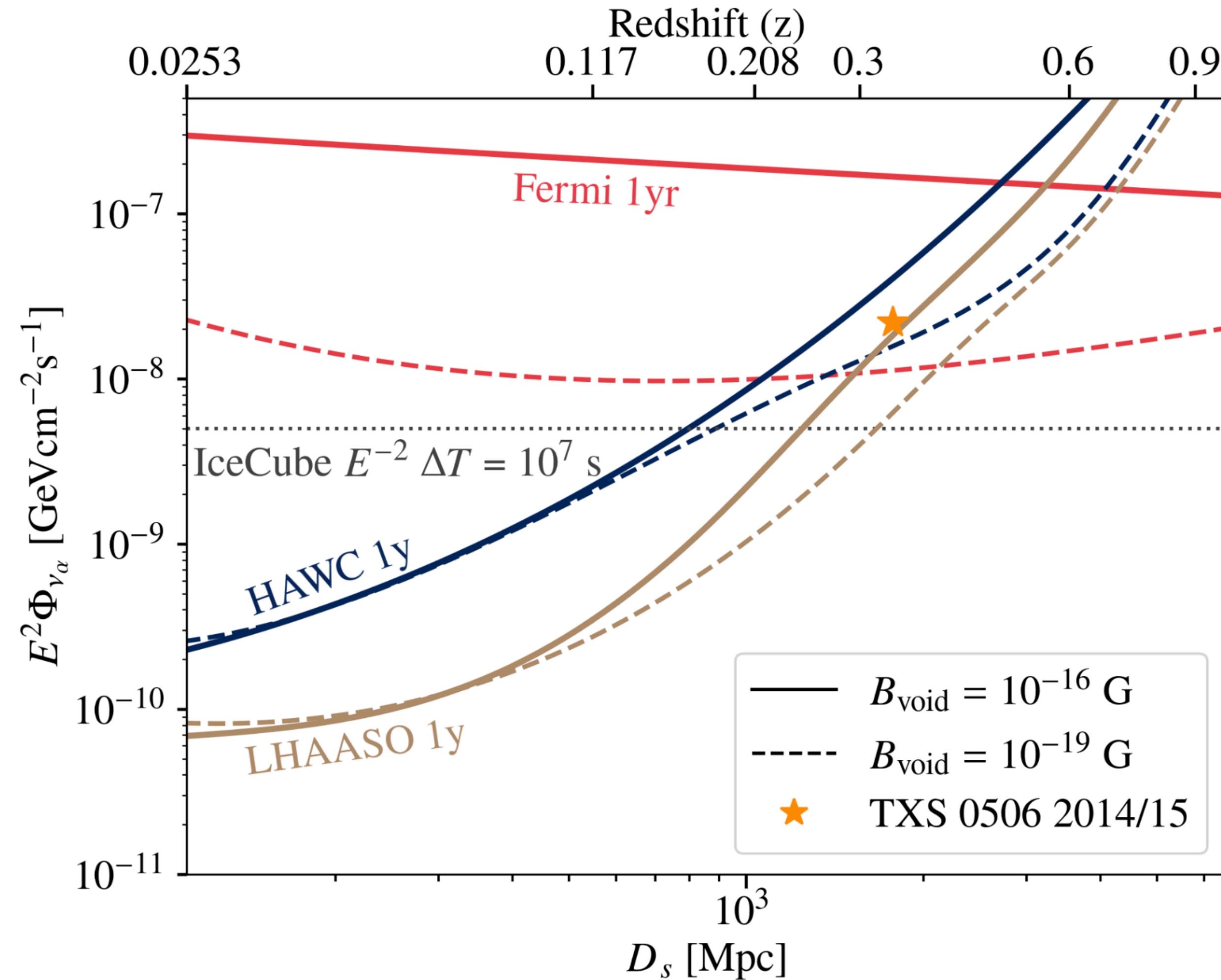
Two different $B_{\text{void}} \rightarrow$ different cascade development

HAWC quickly loses sensitivity

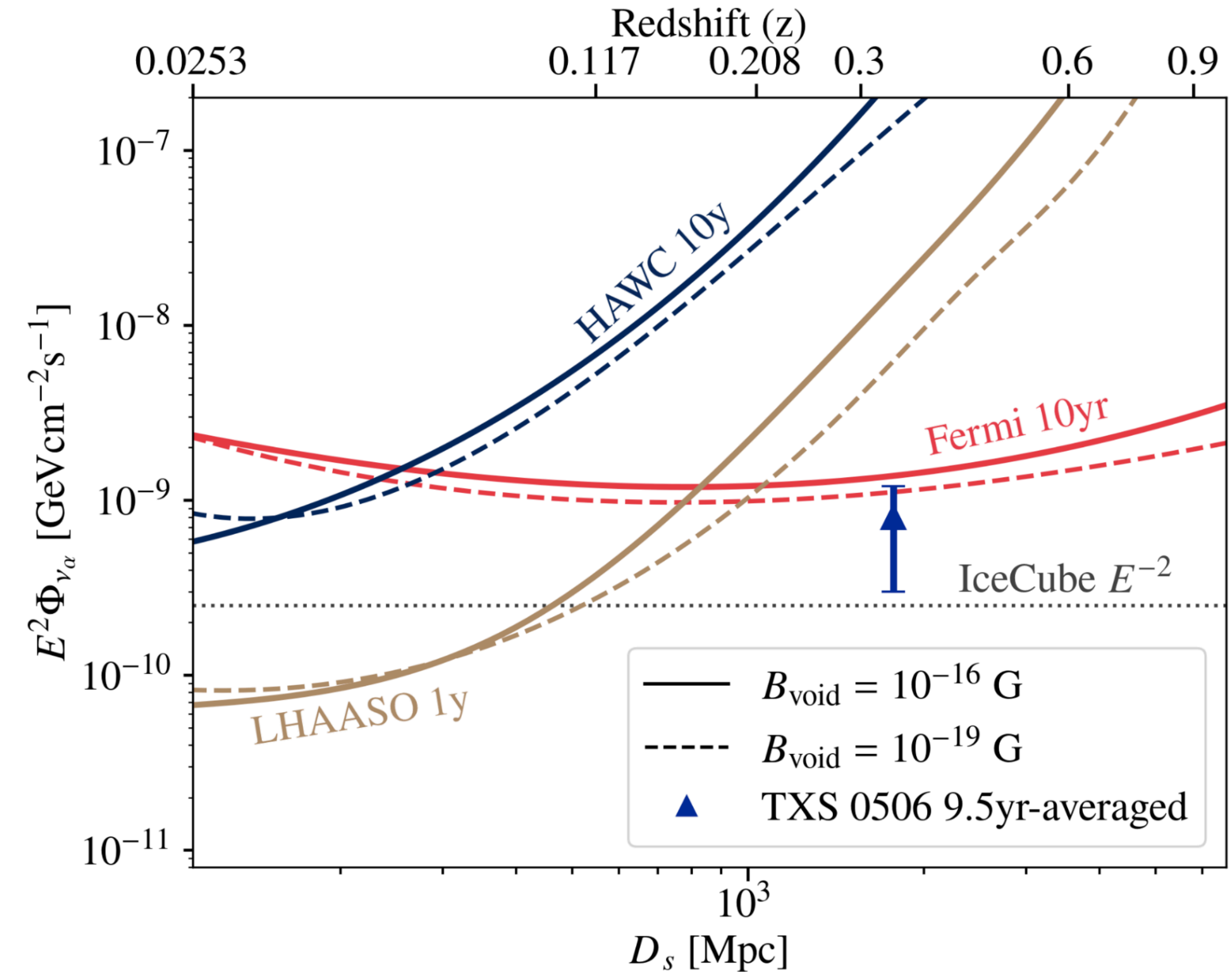
Transient have to be very neutrino-bright to enable multimessenger observations with Fermi

Multimessenger horizon

10 TeV - 100 TeV neutrino transients



10 TeV - 100 TeV steady neutrino sources



Summary and Outlook

- Developed a framework to quantify the neutrino flux required for joint neutrino-gamma-ray measurements.
- Calculated multimessenger horizons for both steady and transient sources
- Understanding the electromagnetic cascade gives insight on the neutrino production mechanism and source opaqueness.
- The method provides a baseline to interpret current and future multimessenger detections.