Multimessenger-Informed Characterization of High-Energy Neutrino Emission from Bright Seyfert Galaxies

TeVPA 2025

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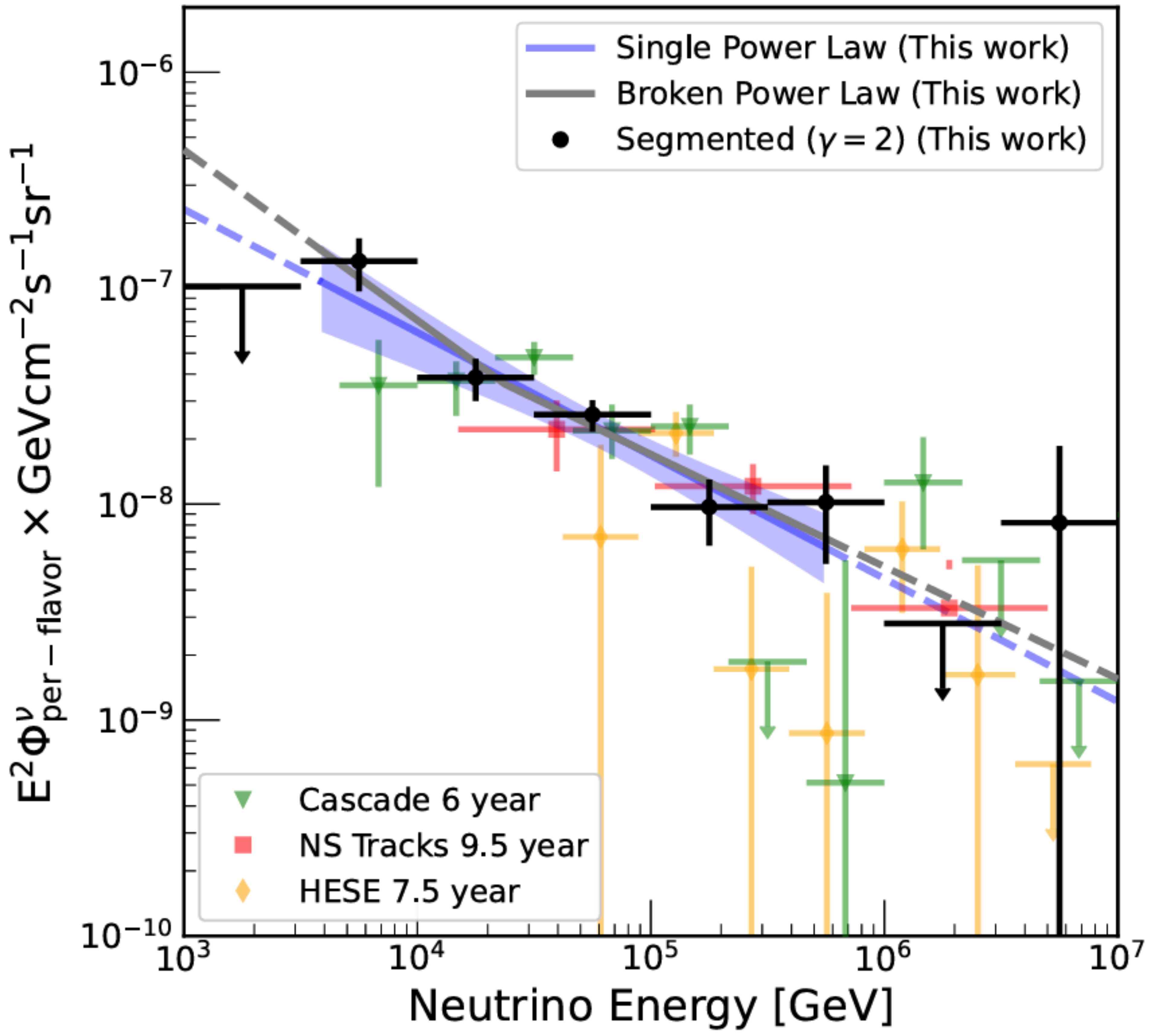
University of Nevada Las Vegas

Collaborators:
Ali Kheirandish (UNLV), Kohta Murase (Penn State)

The diffuse neutrino flux



IceCube 2024

- IceCube has seen a diffuse high-energy neutrino emission consistent with a power-law spectrum
- The nature of the sources (GRBs, blazars, TDEs, etc.) remains unknown

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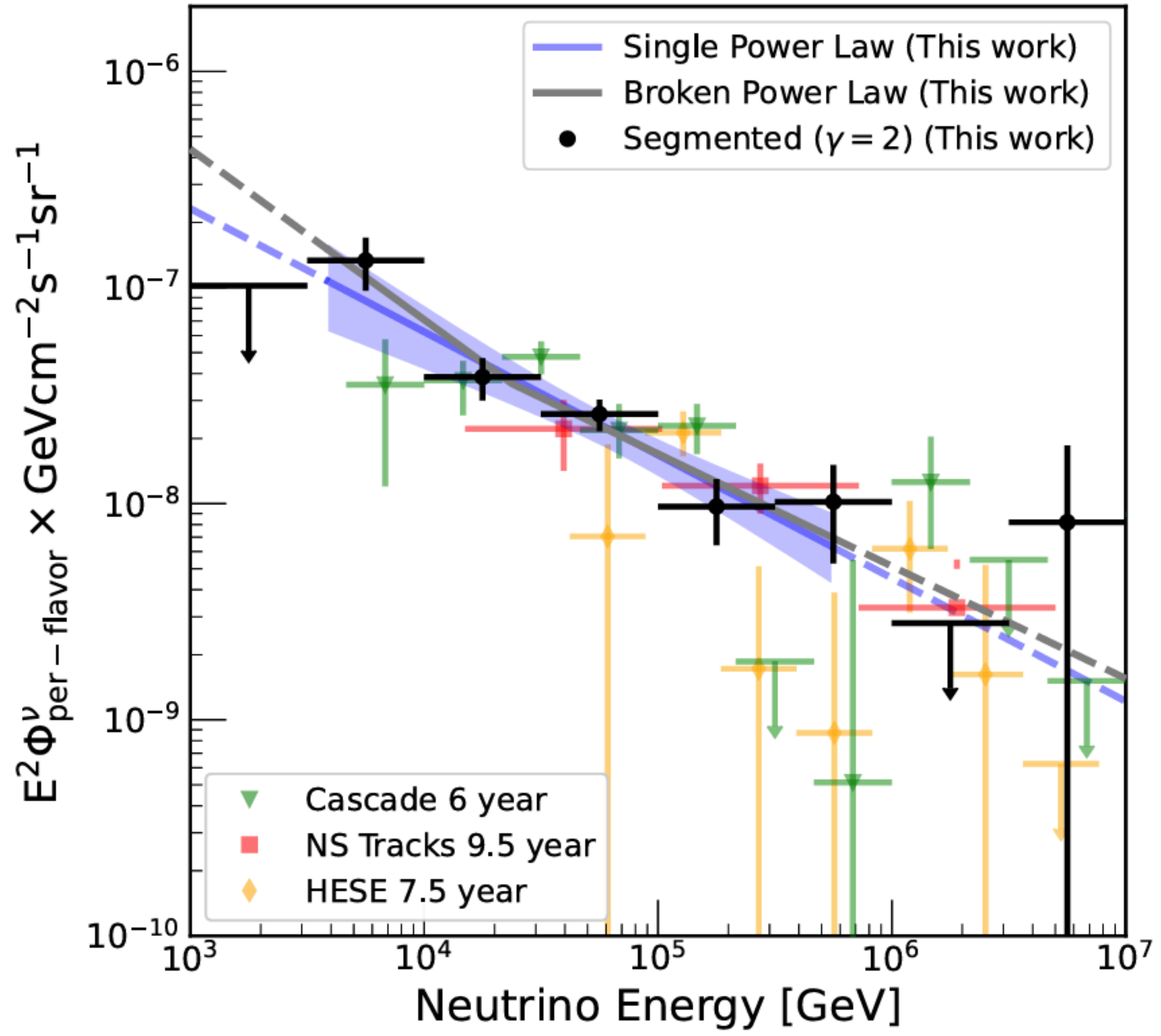

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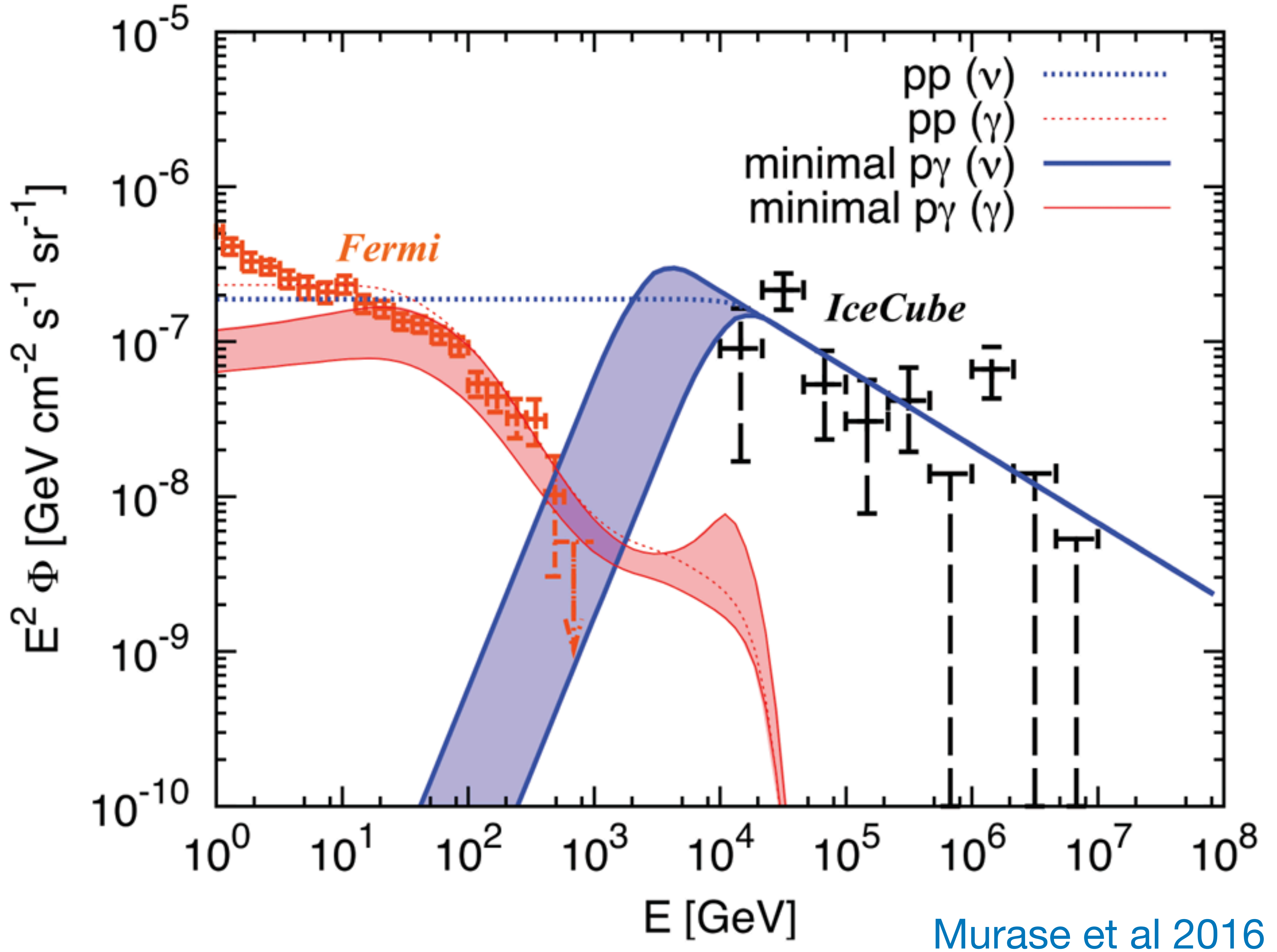
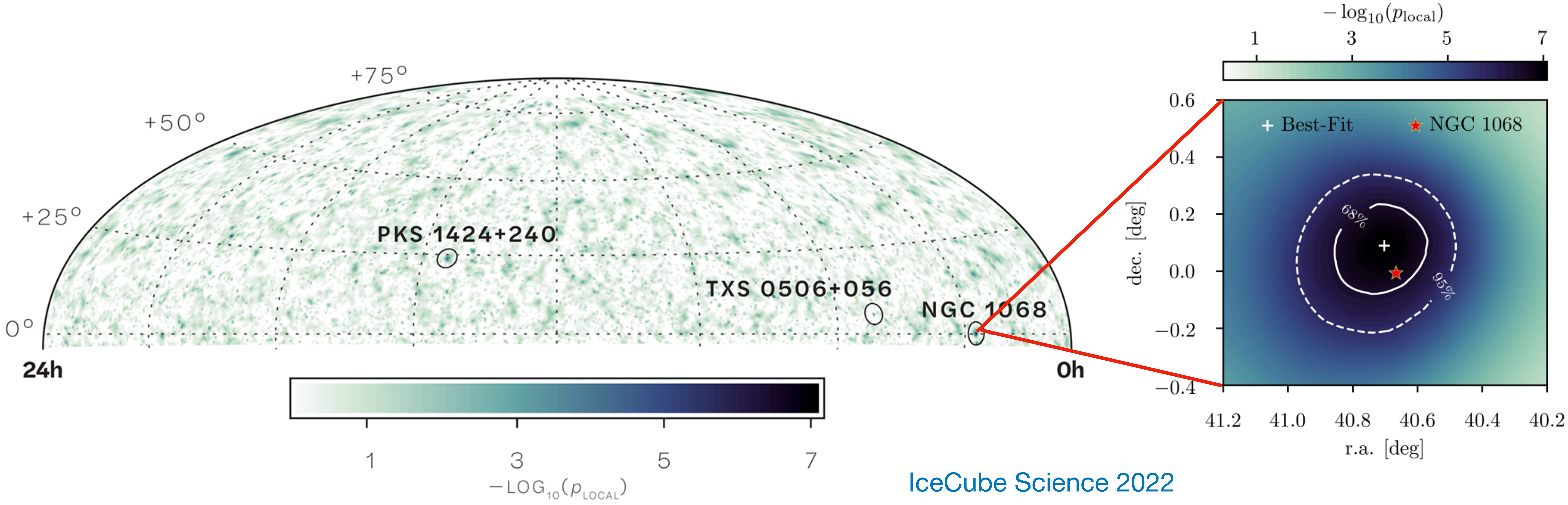


Murase et al 2016

- IceCube has seen a diffuse high-energy neutrino emission consistent with a power-law spectrum
- The nature of the sources (GRBs, blazars, TDEs, etc.) remains unknown
- γ-ray background points to γ-ray opaque sources as major contributors to the diffuse flux

NGC 1068



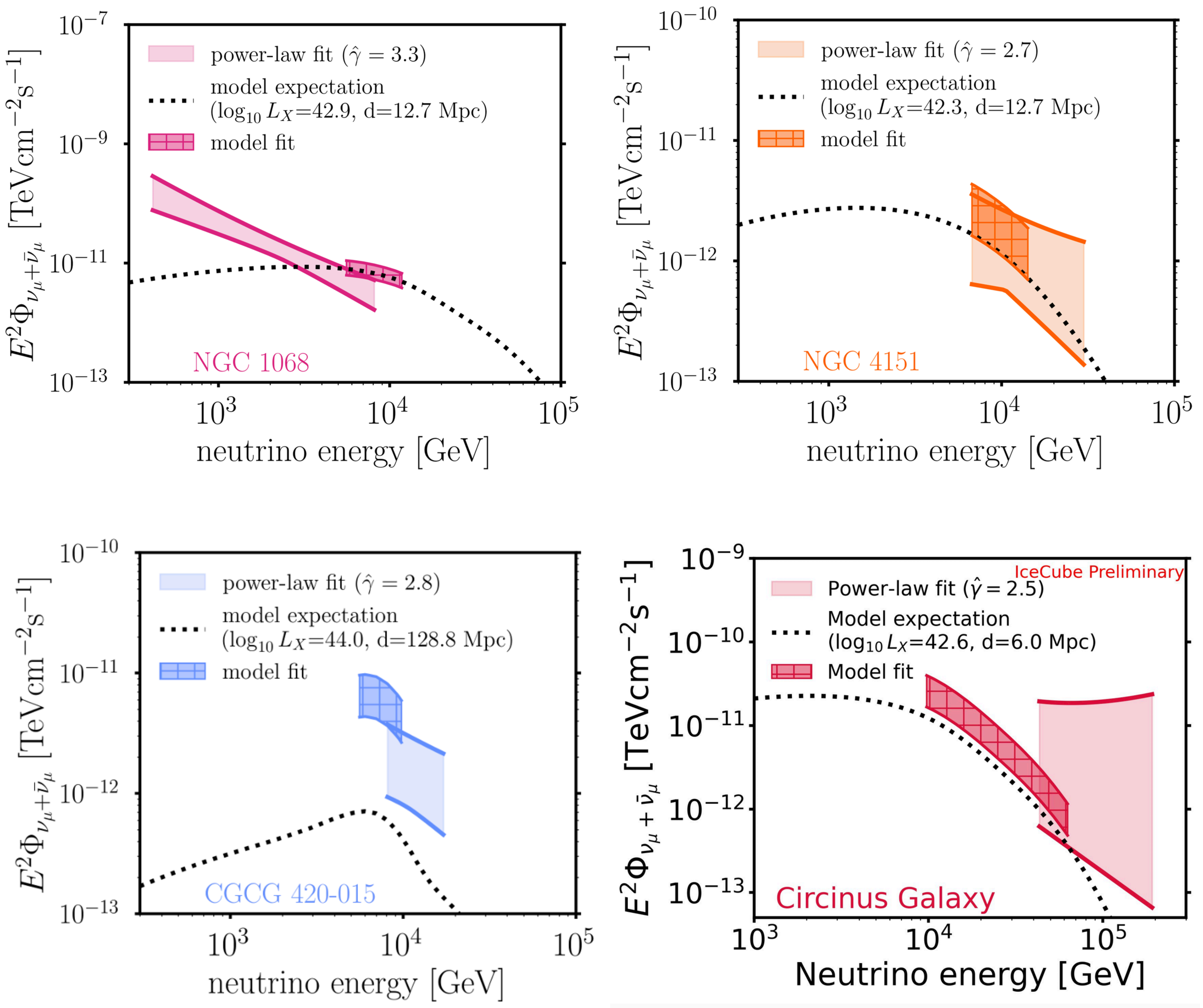
IceCube Science 2022

- NGC 1068 is the most significant source in the Northern Sky

- Example of a γ-ray obscured source

- Evidence of acceleration of cosmic rays

Neutrino emission from Seyfert galaxies



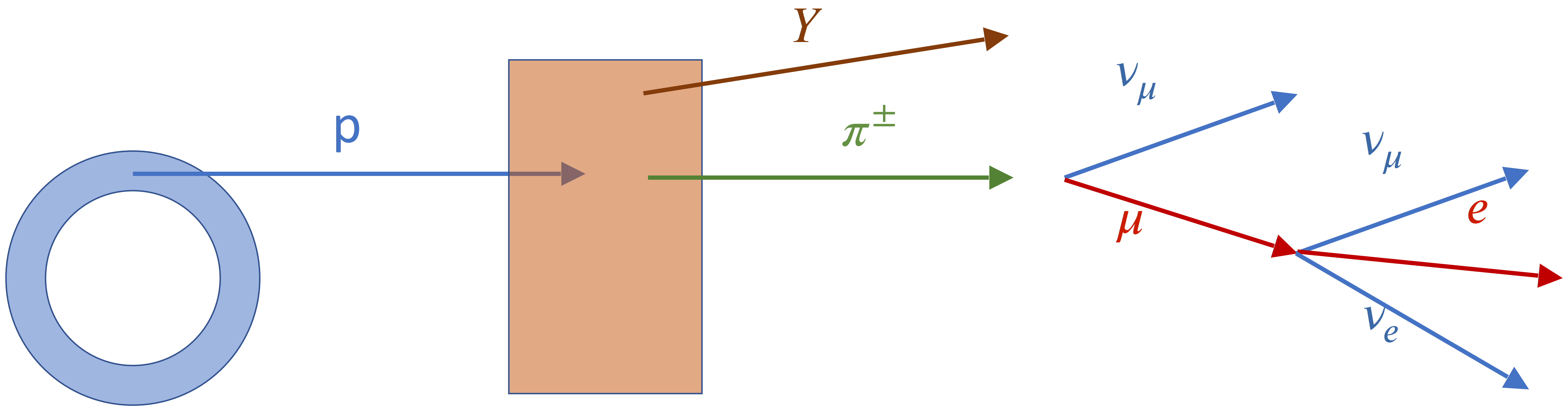
- Point source searches revealed additional Seyfert galaxies, all $\gamma-$ray opaque.
- CGCG 420+015 model expectation is below the fits
- Numerical simulations of strongly magnetized turbulence have trouble explaining the reported fluxes

IceCube 2024, IceCube 2025

Modeling neutrino emission in AGN cores

Neutrino emission is evidence

of **particle acceleration**



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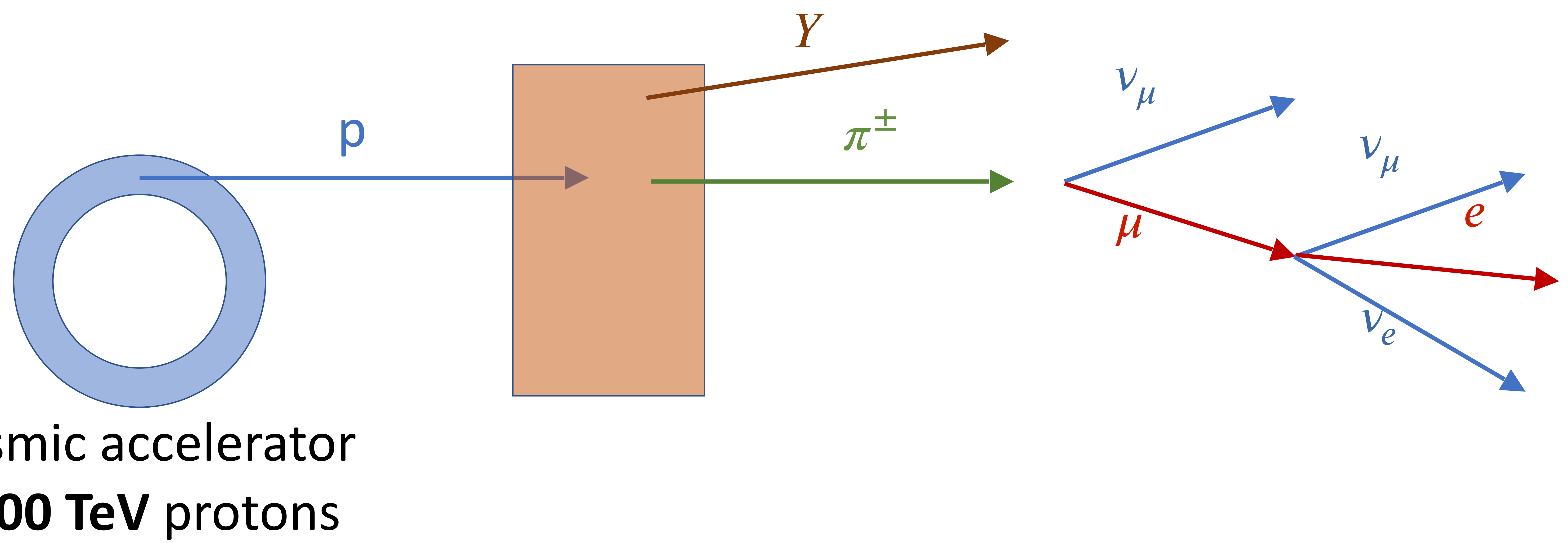

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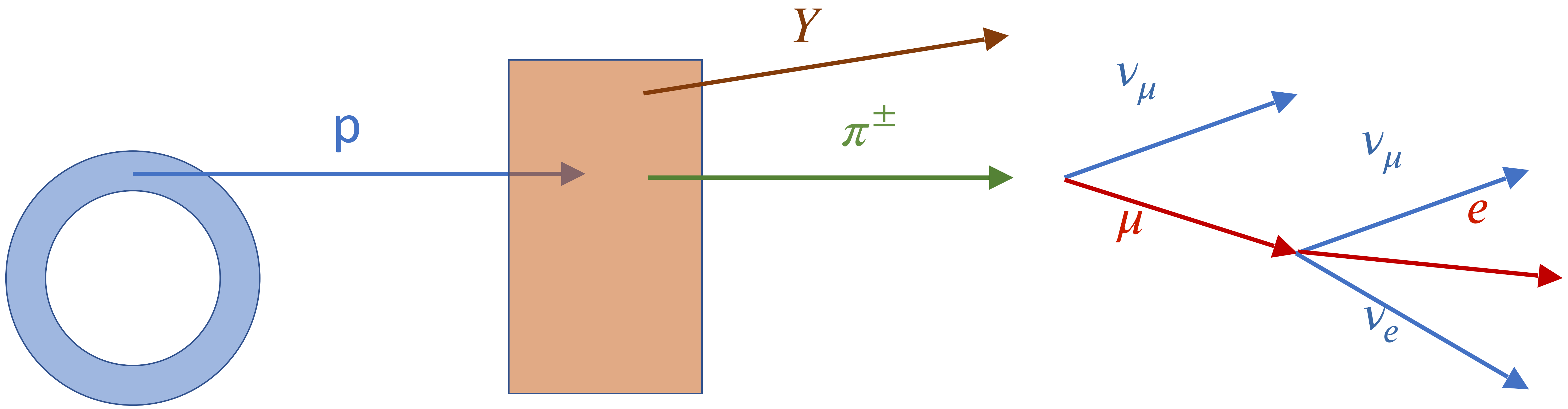

Cosmic accelerator
>100 TeV protons

Target: **X-ray** photons
have enough energy
for π production

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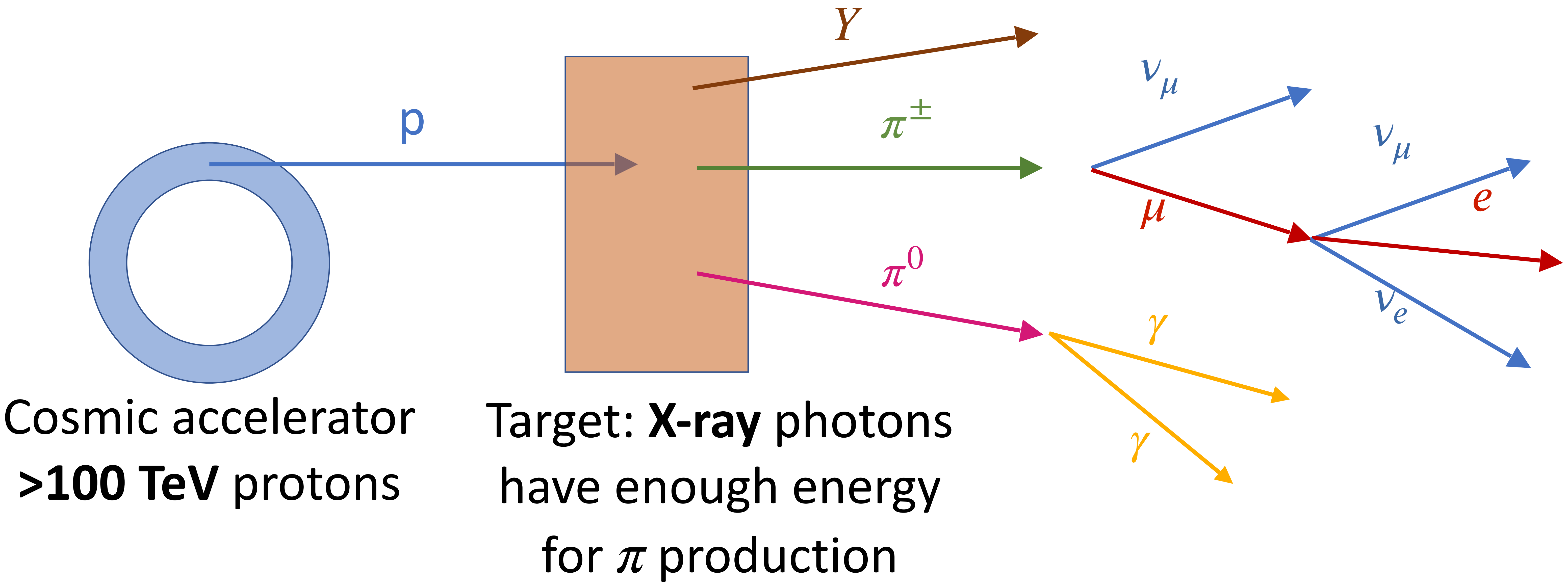
γ-rays are co-produced with neutrinos



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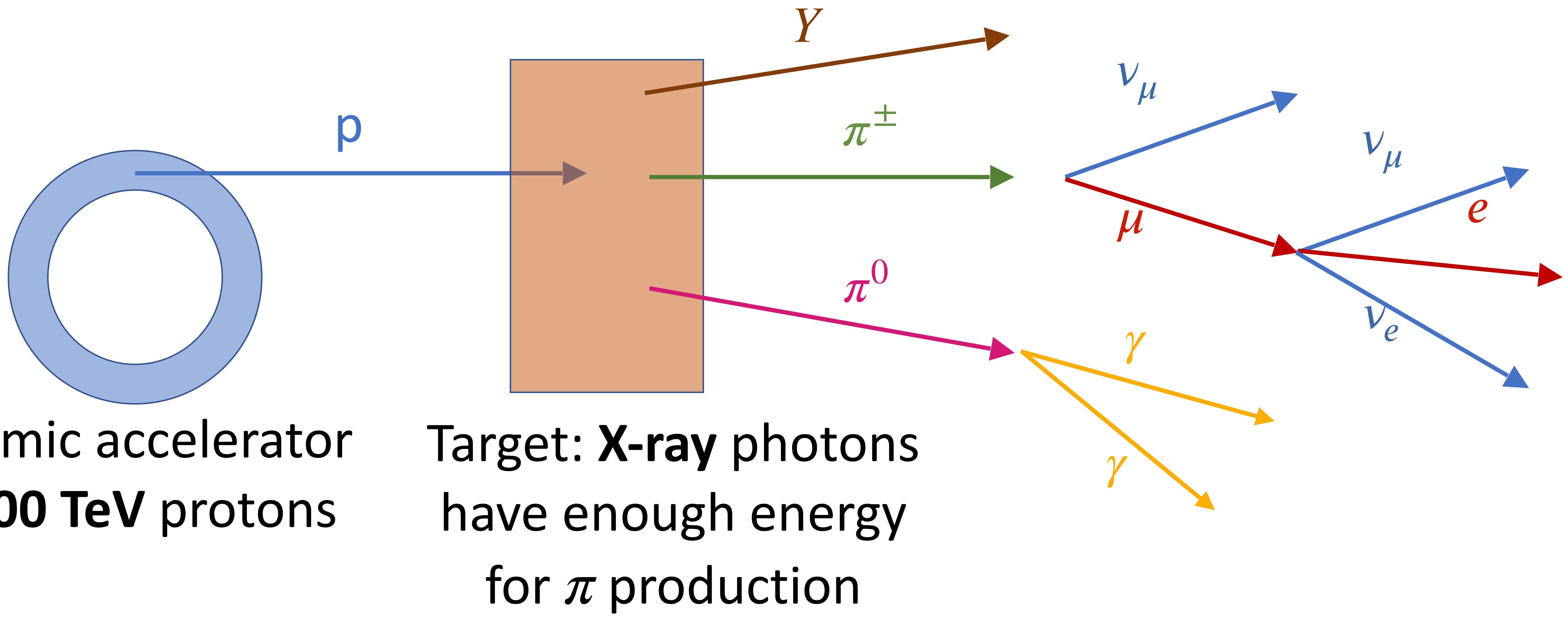

A γ-ray opaque source points to **dense** photon fields providing γ-ray **reprocessing**

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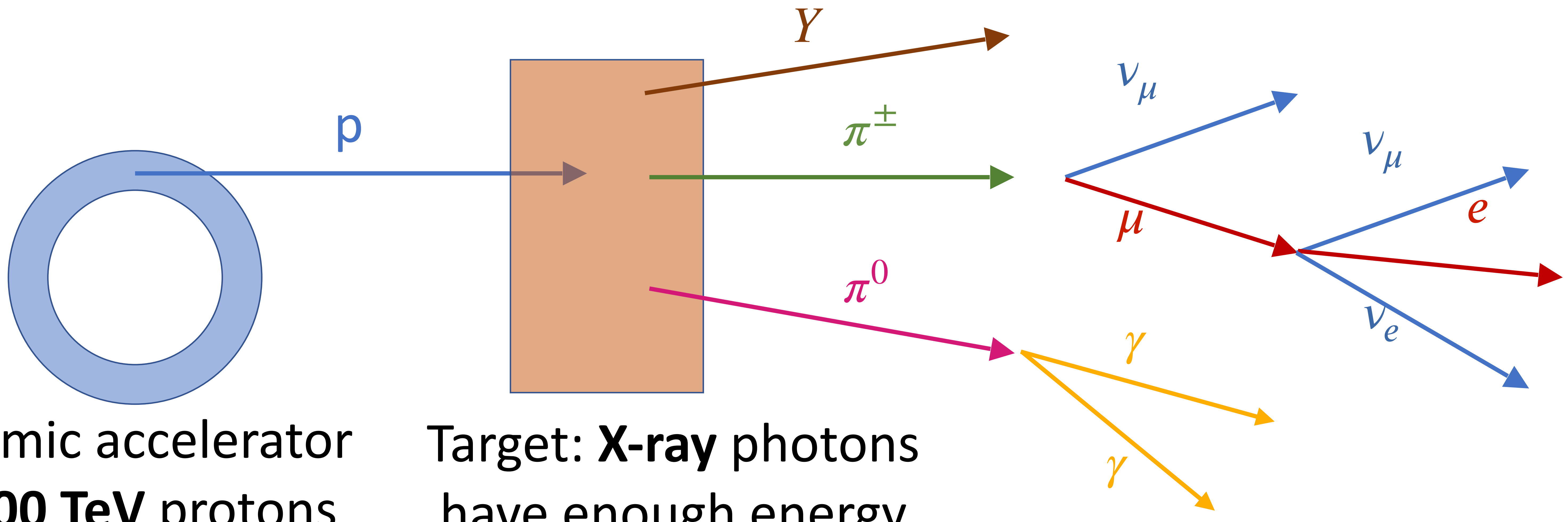

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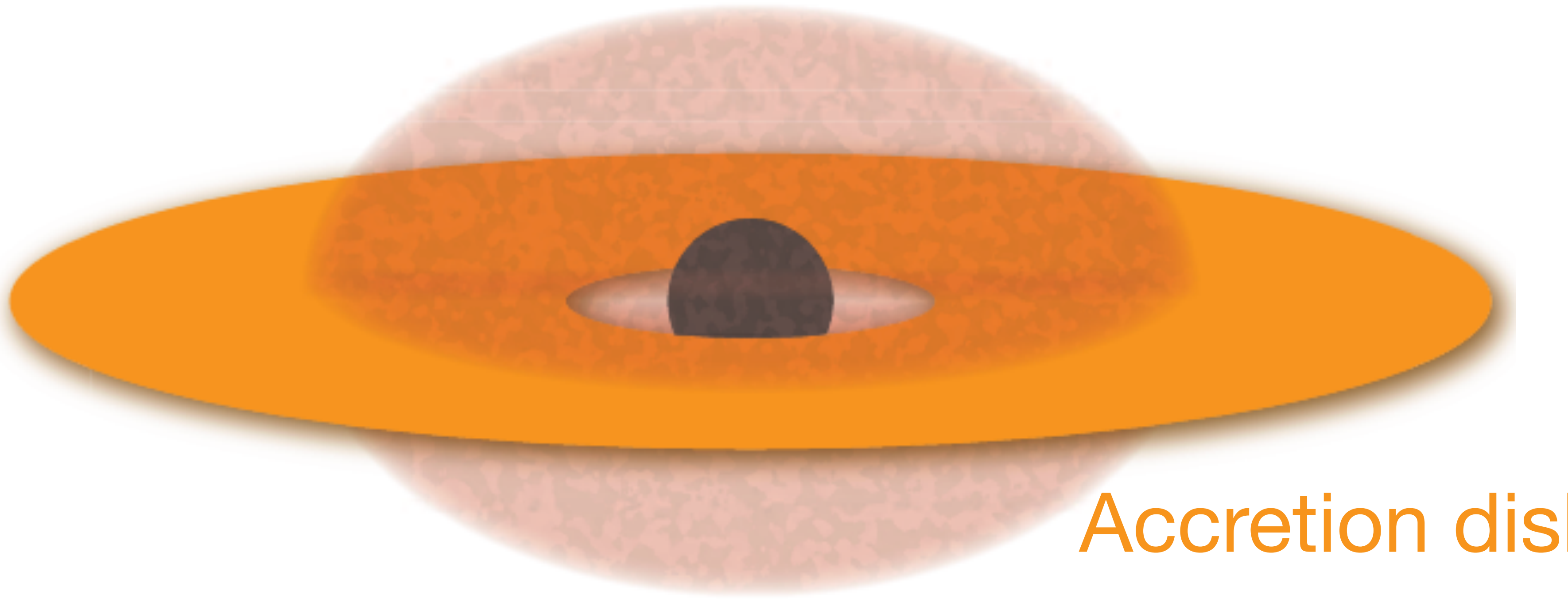
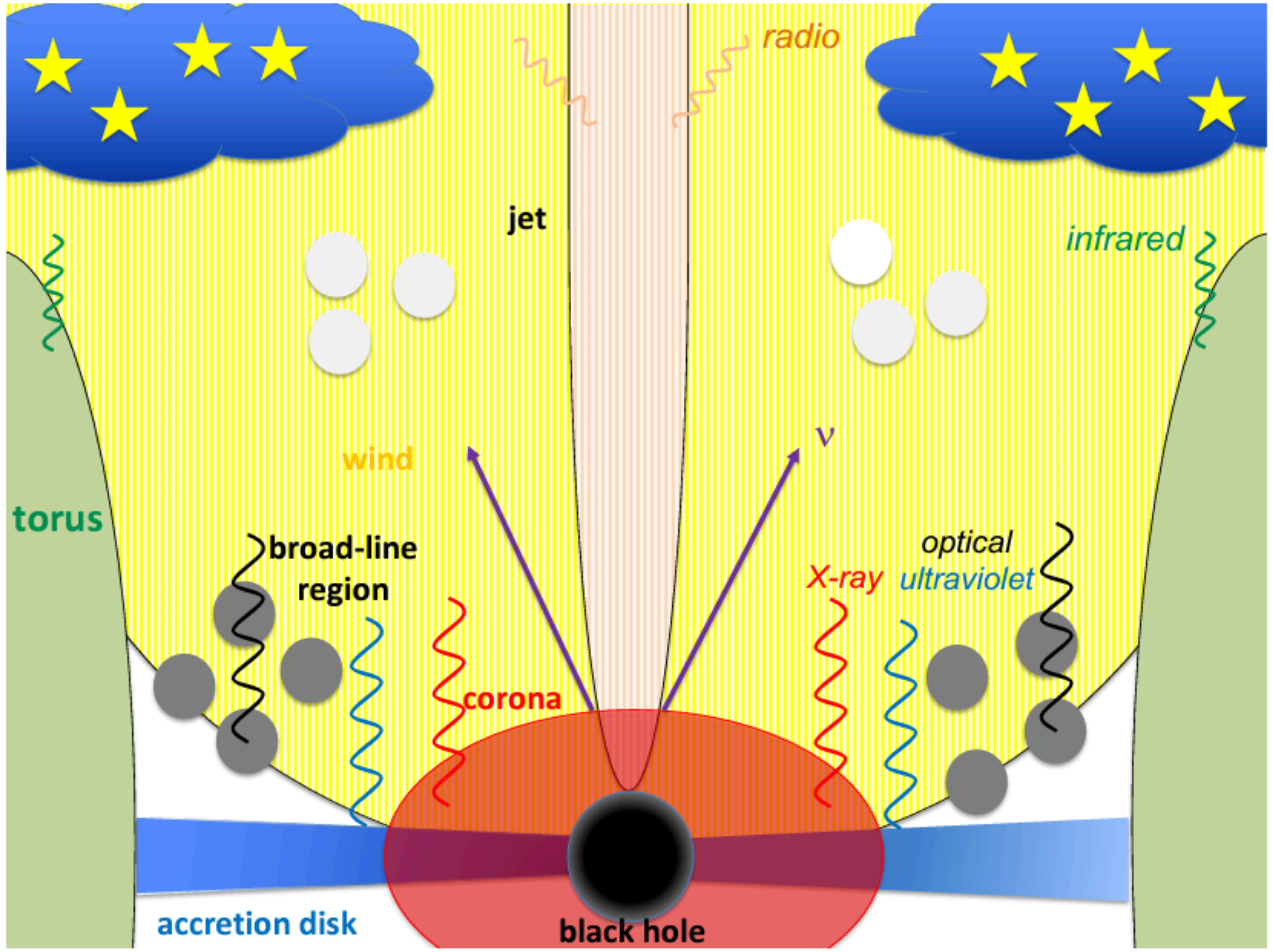
The disk-corona model may provide such an environment



Wilkins & Gallo 2015

AGNs - the multimessenger picture



Murase 2022

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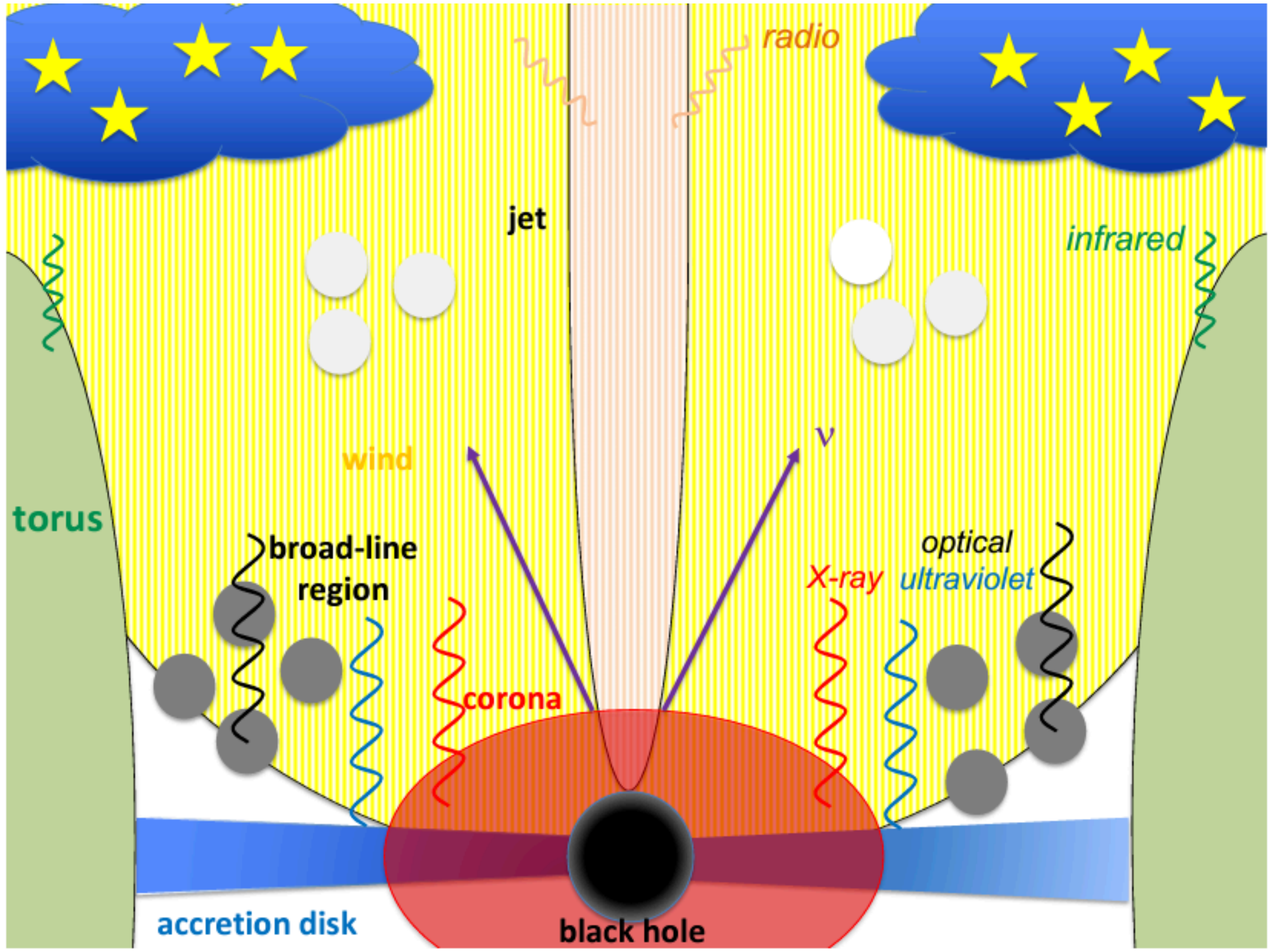

Murase 2022

Cosmic ray (CR) acceleration

- **Stochastic particle acceleration** in the corona
- CR energy cutoff at $\sim$ PeV energies

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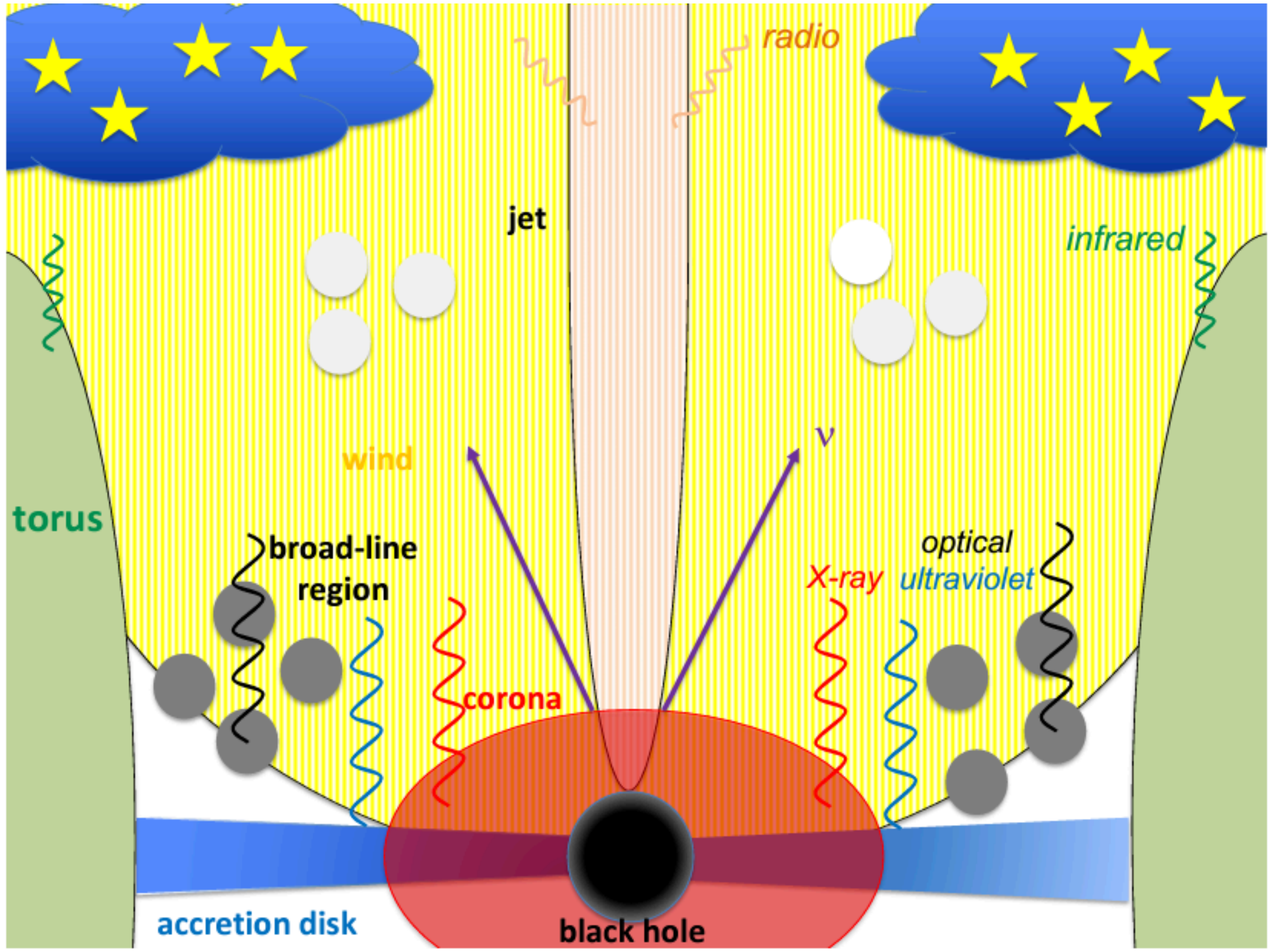

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Targets

Coronal X-rays and protons
(main targets for pp and $p\gamma$)

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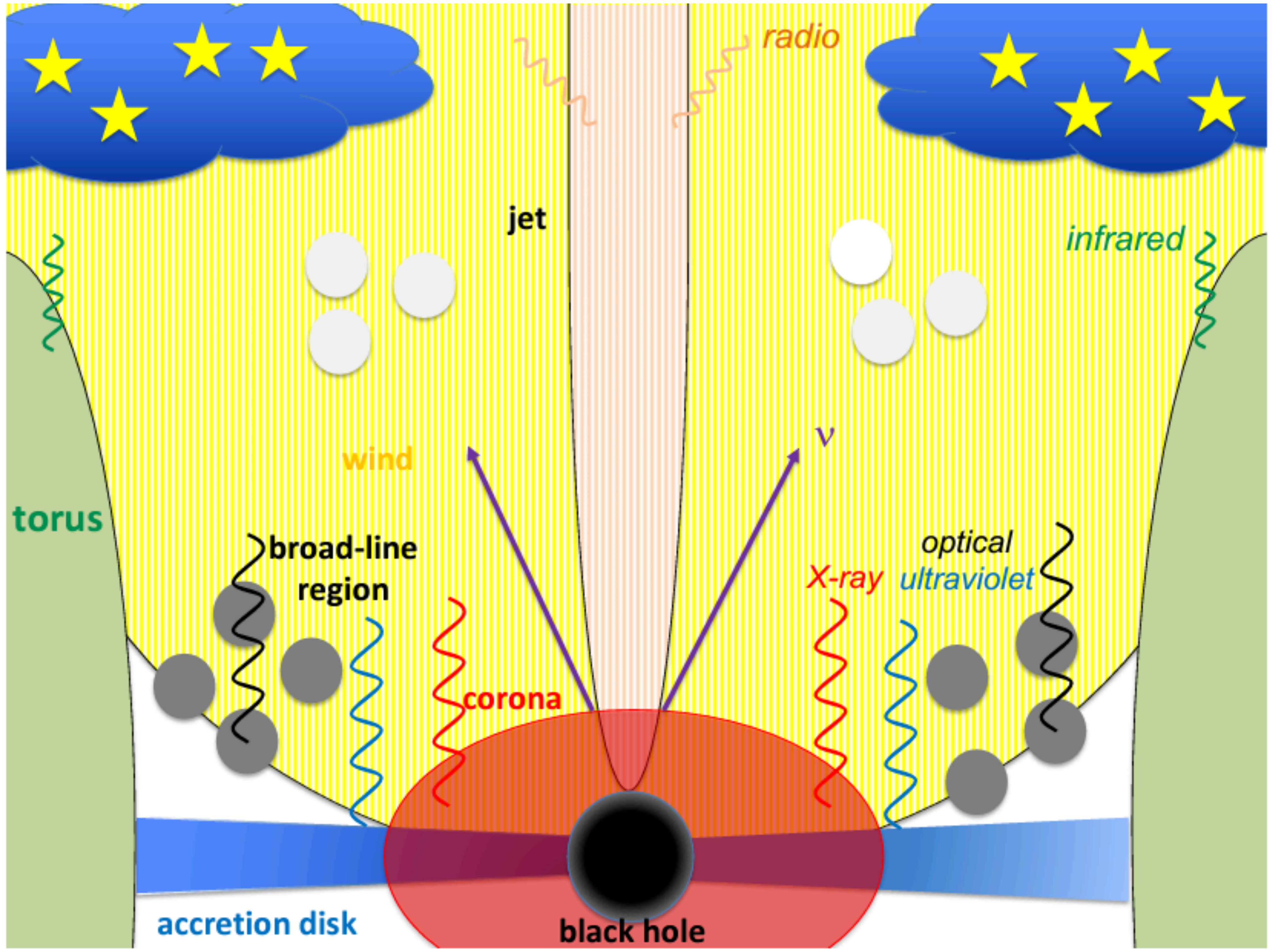

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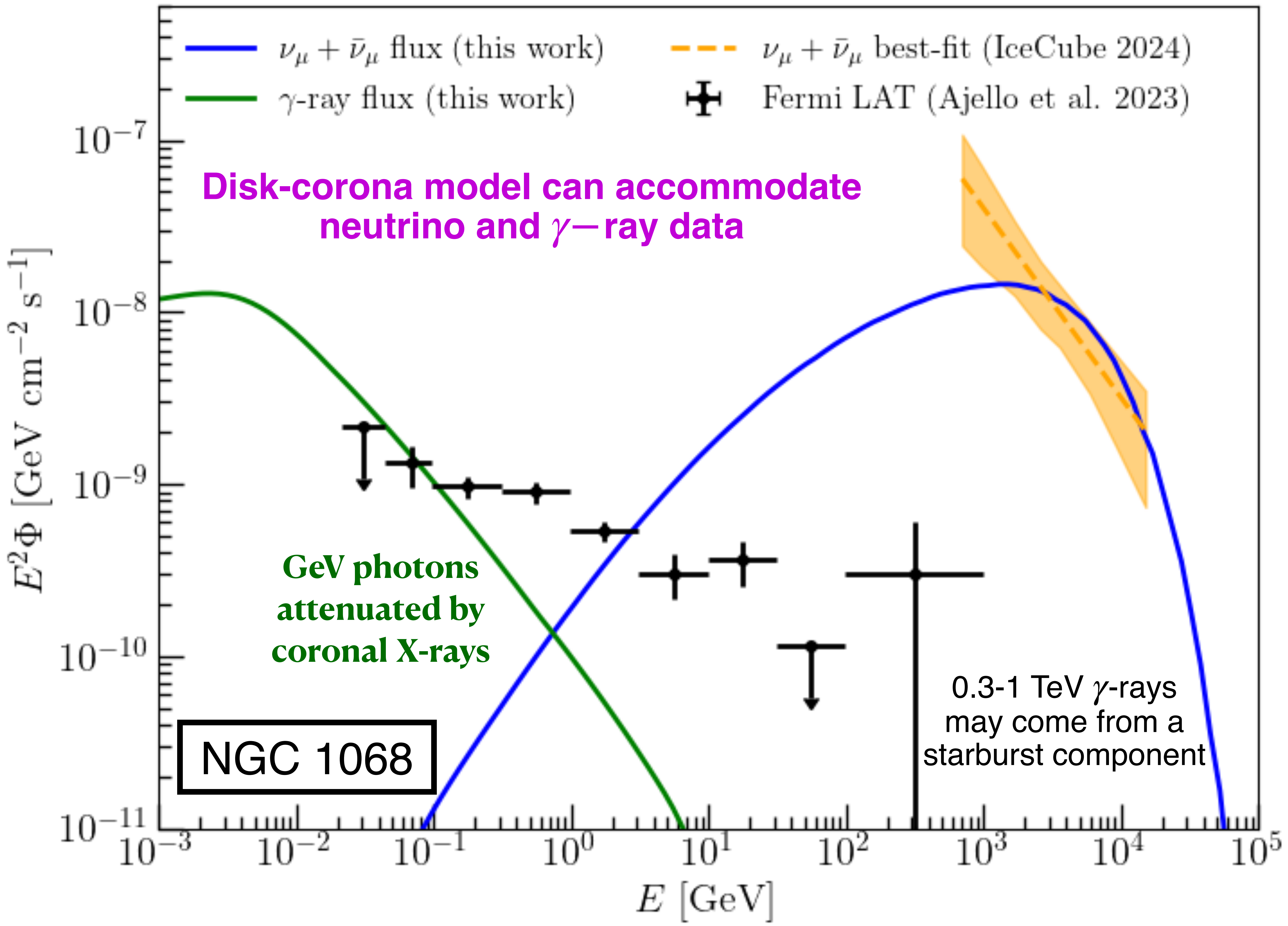

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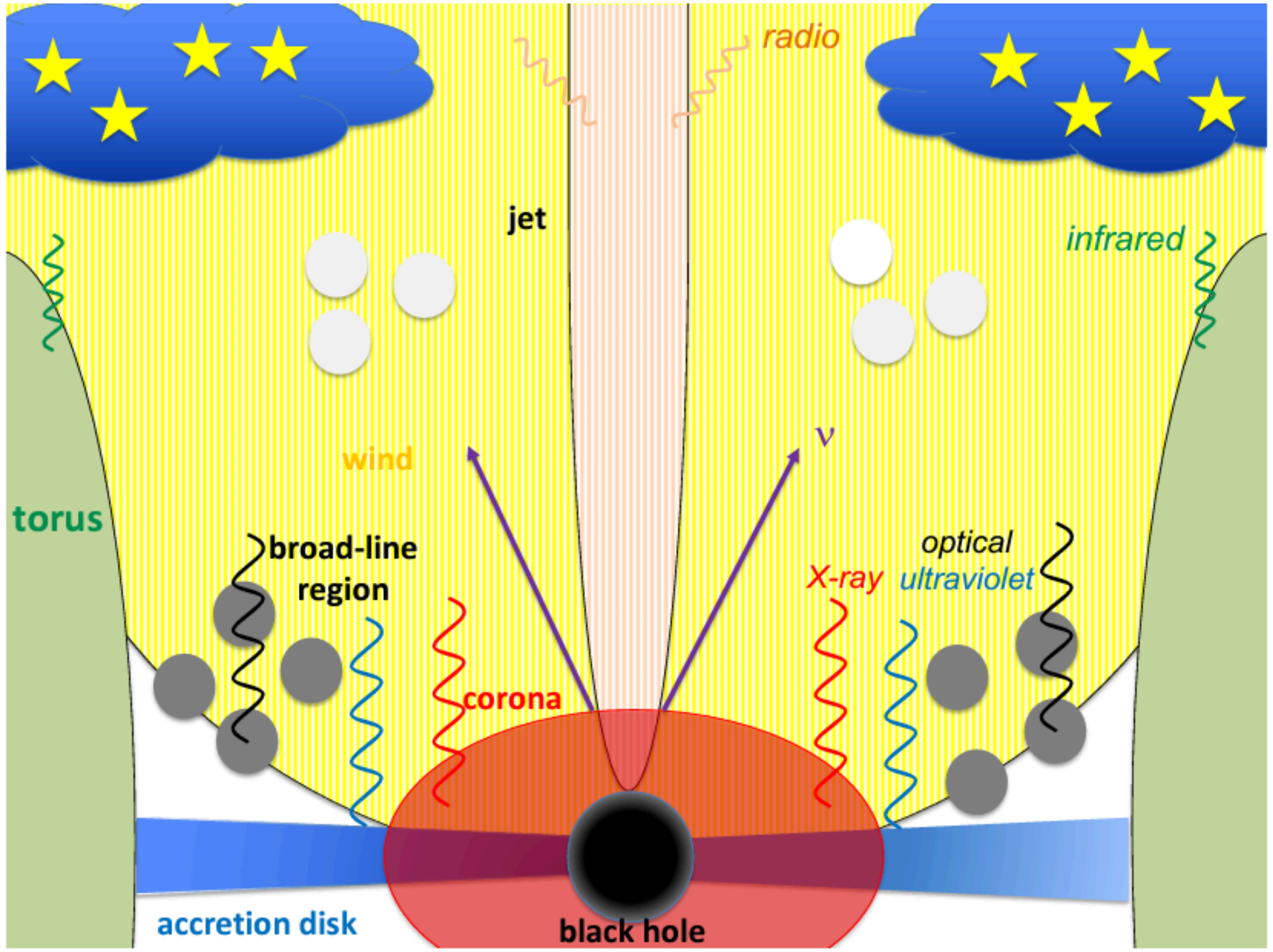

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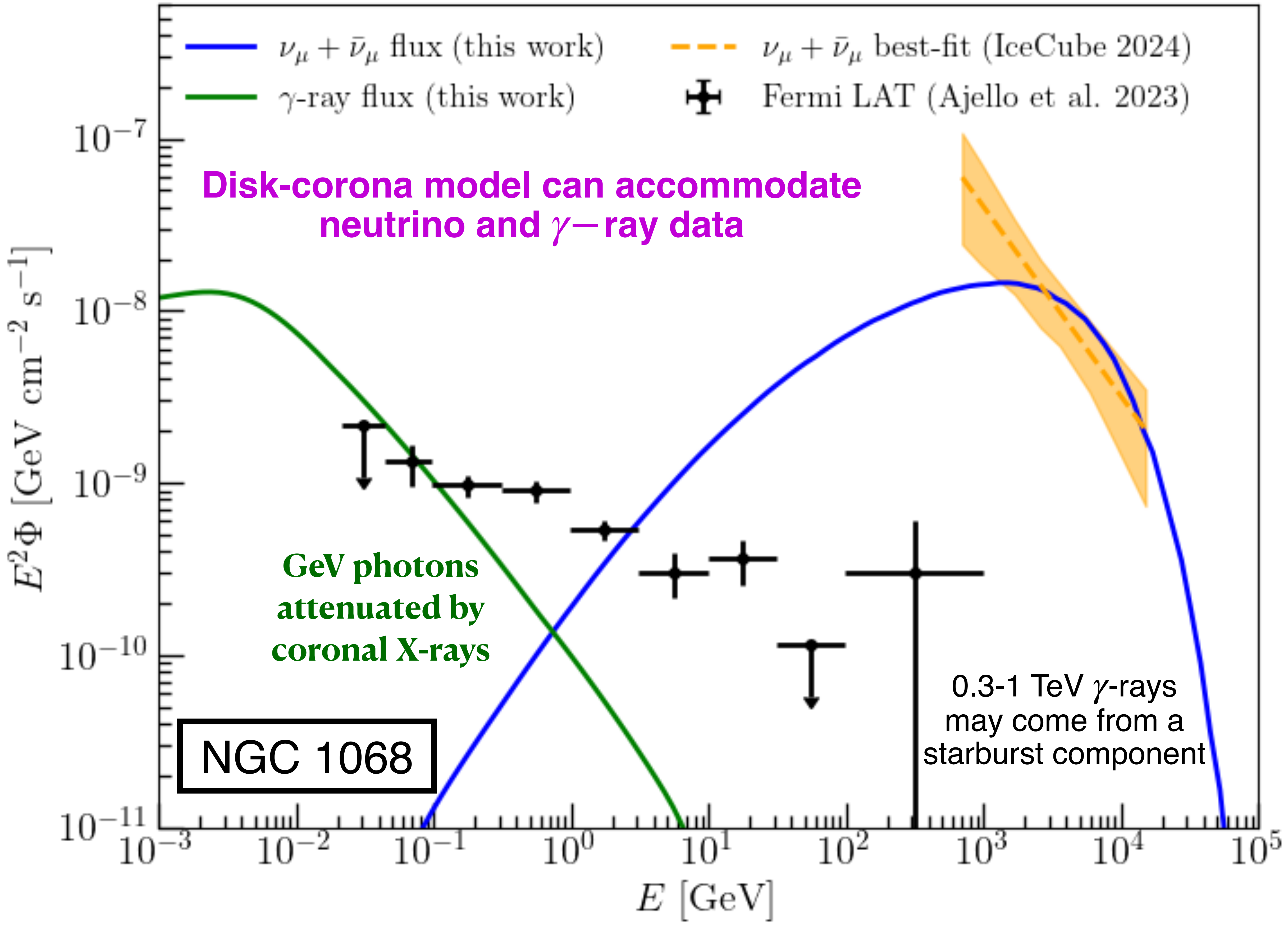

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Features

Non-power law neutrino spectra

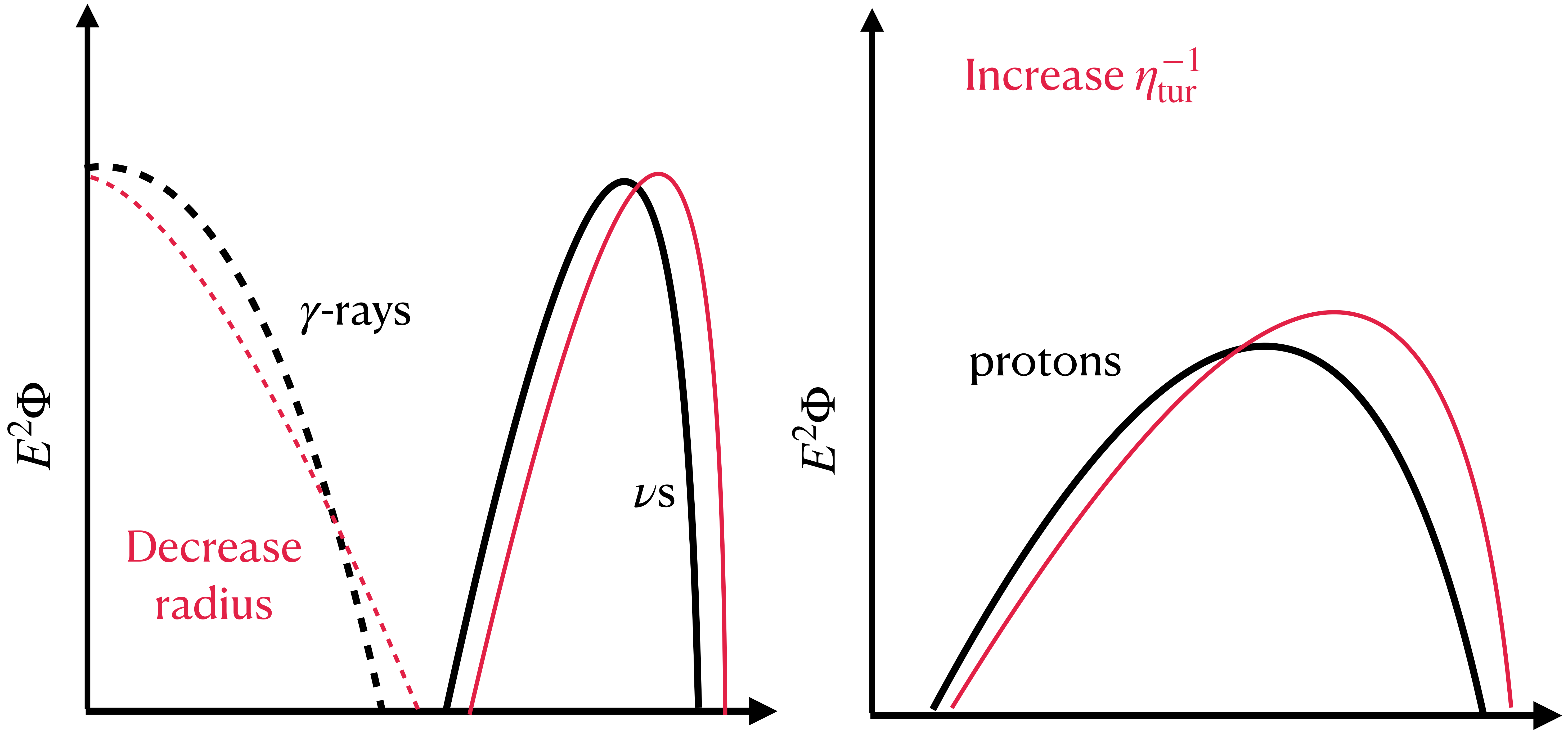
Hadronic explanation for high-energy γ-rays

Testing the disk-corona model

Parameters

Intrinsic X-ray luminosity L_X
CR to thermal pressure ratio
Emission radius
Turbulence strength $\eta_{\rm tur}$

Choose model parameters



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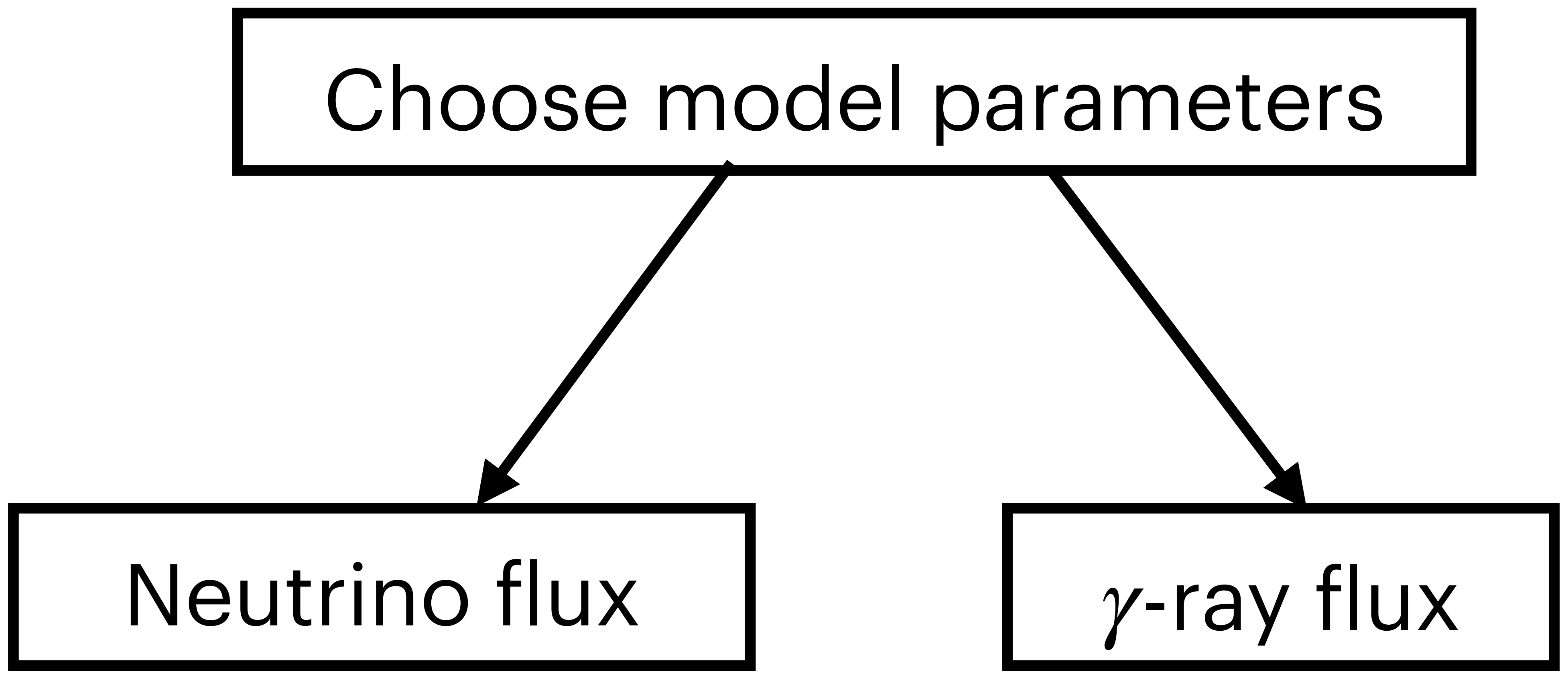

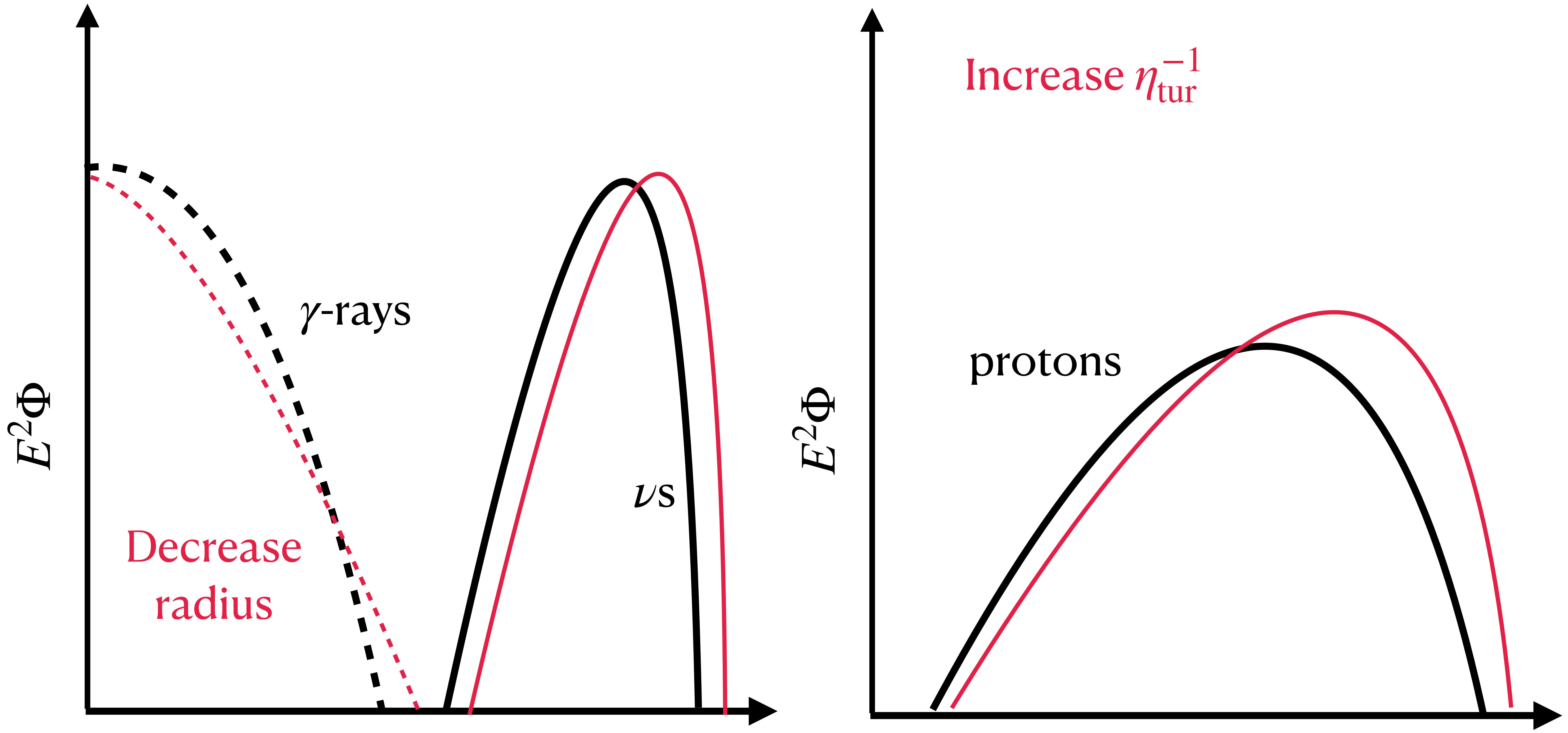

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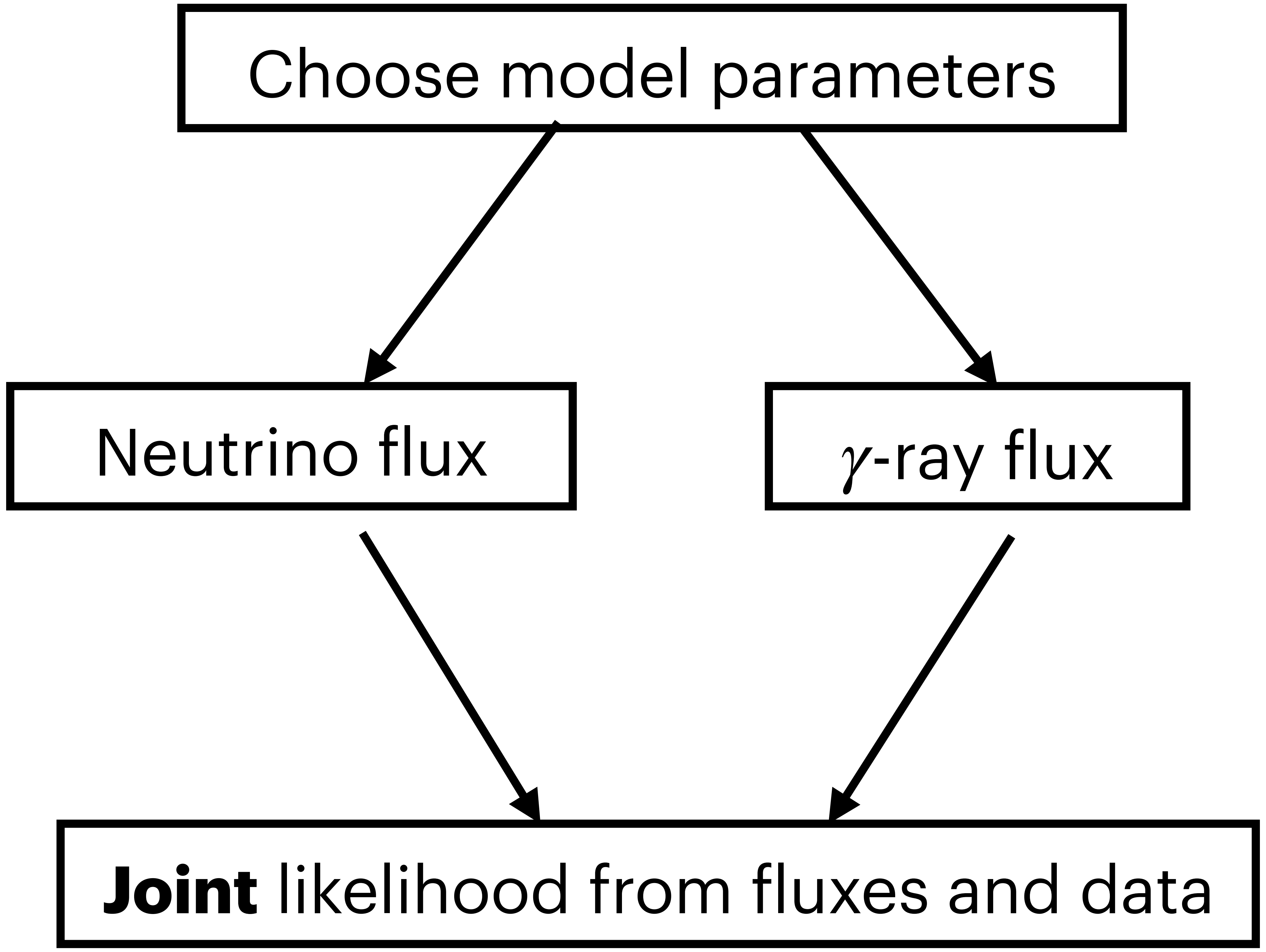
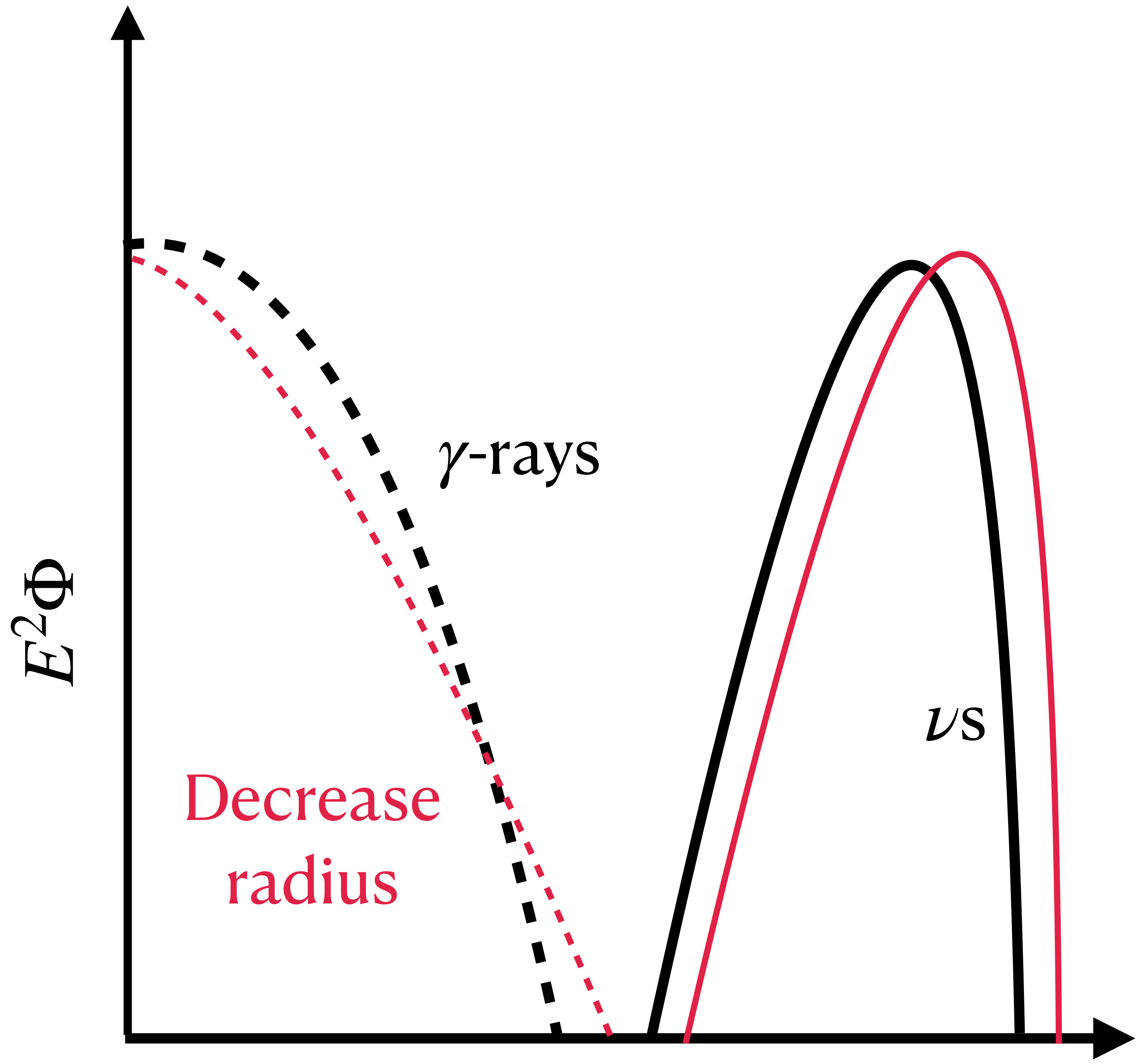
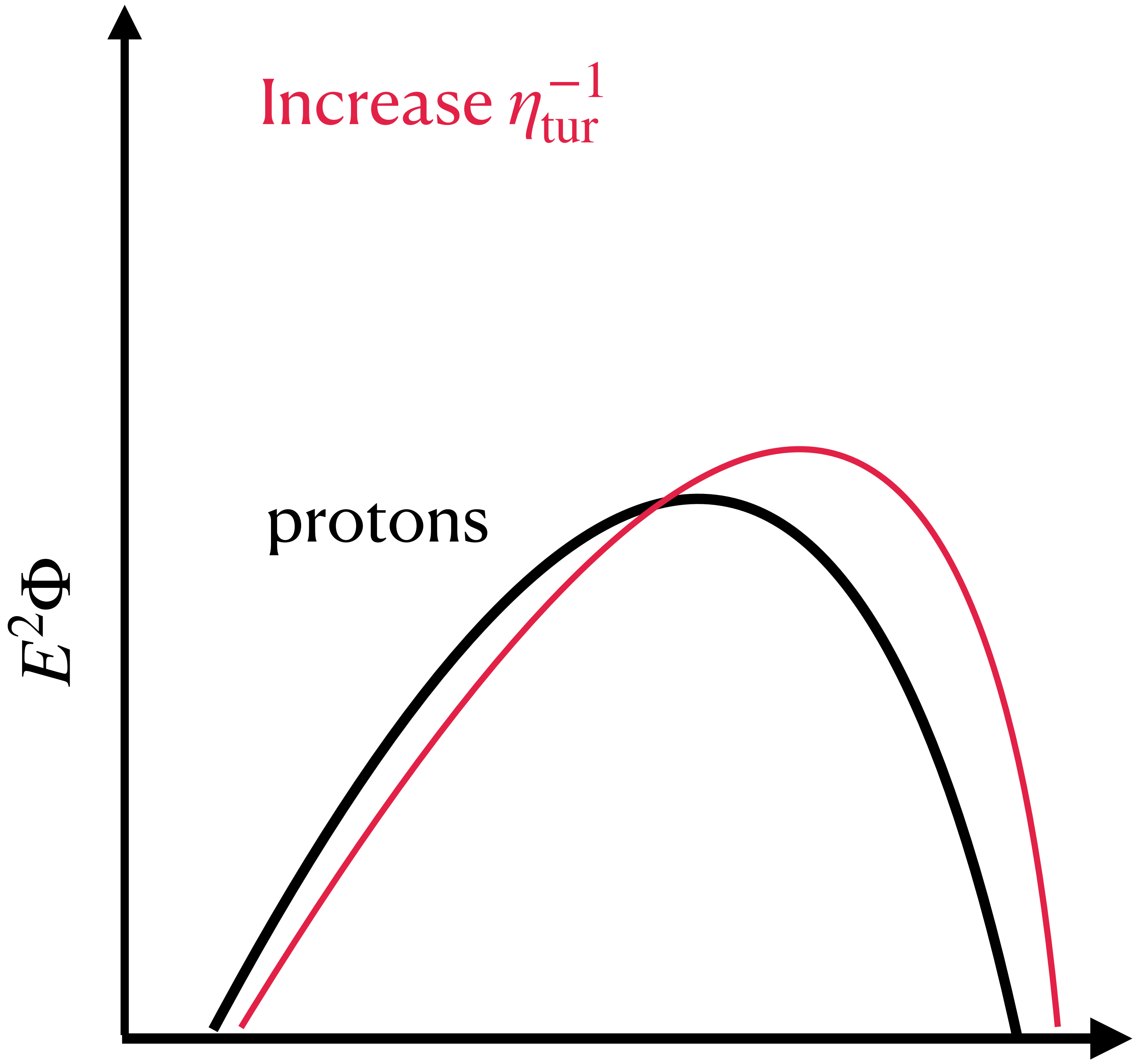
IceCube neutrino data

Fermi-LAT γ-ray data







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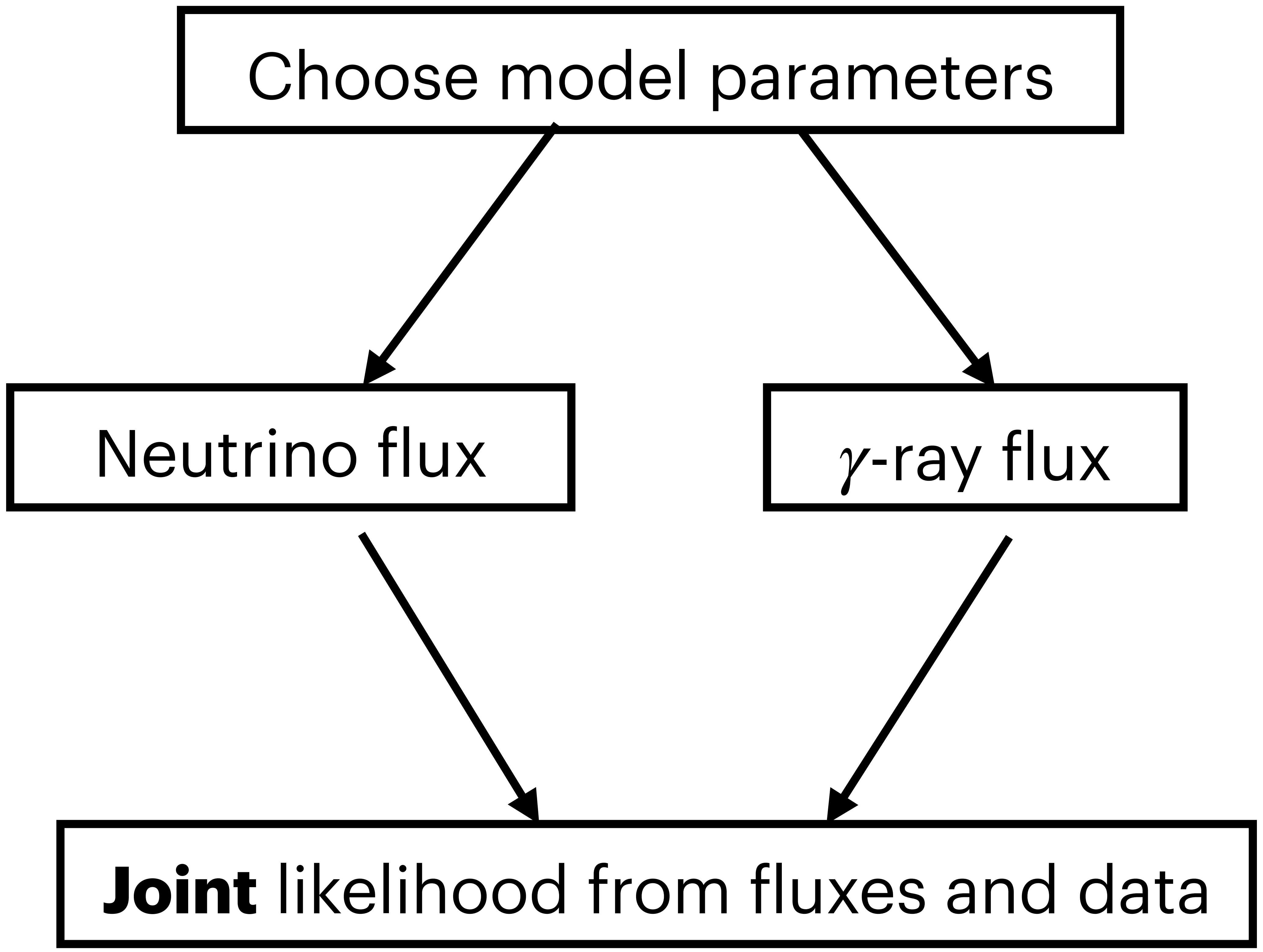

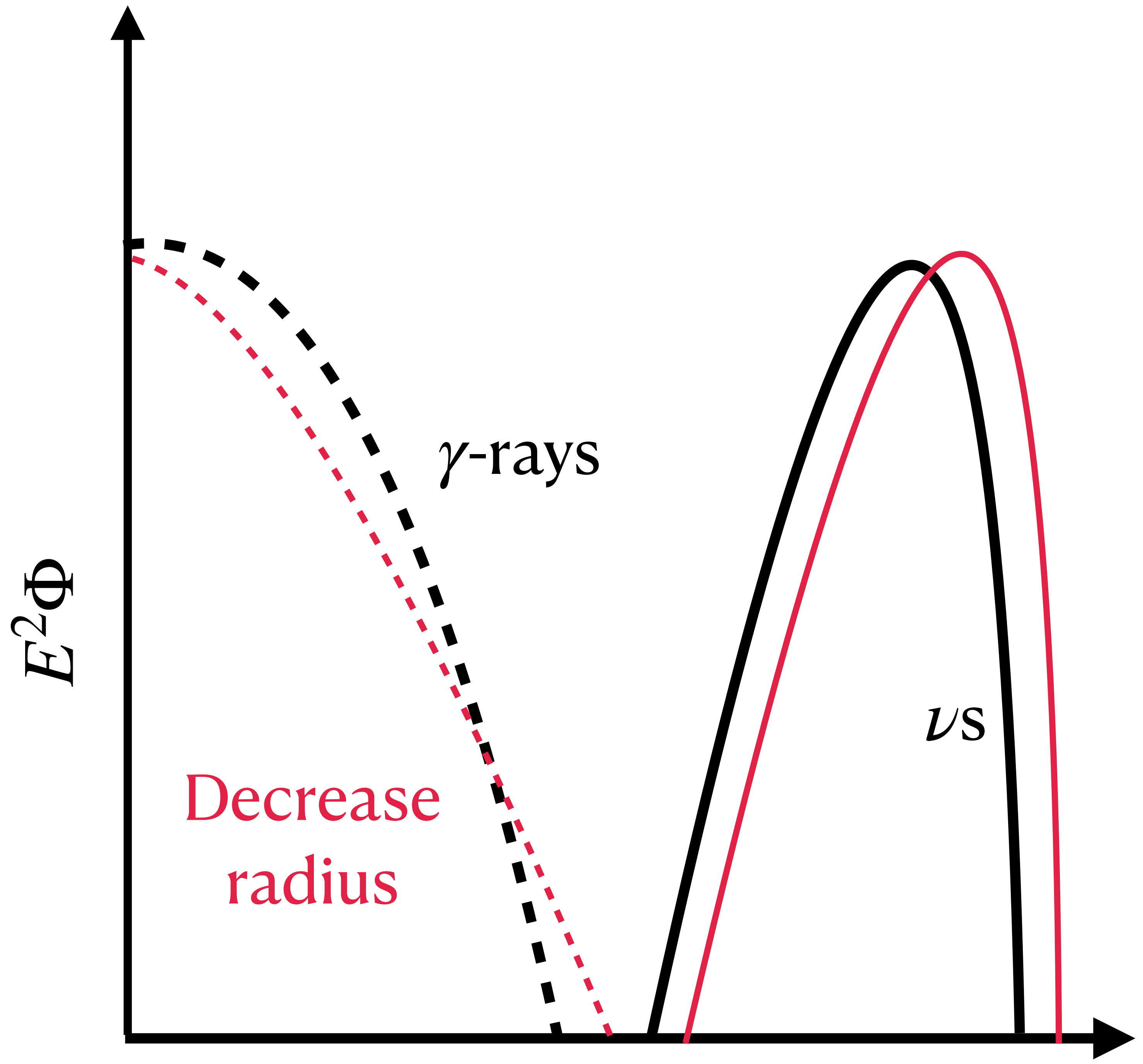

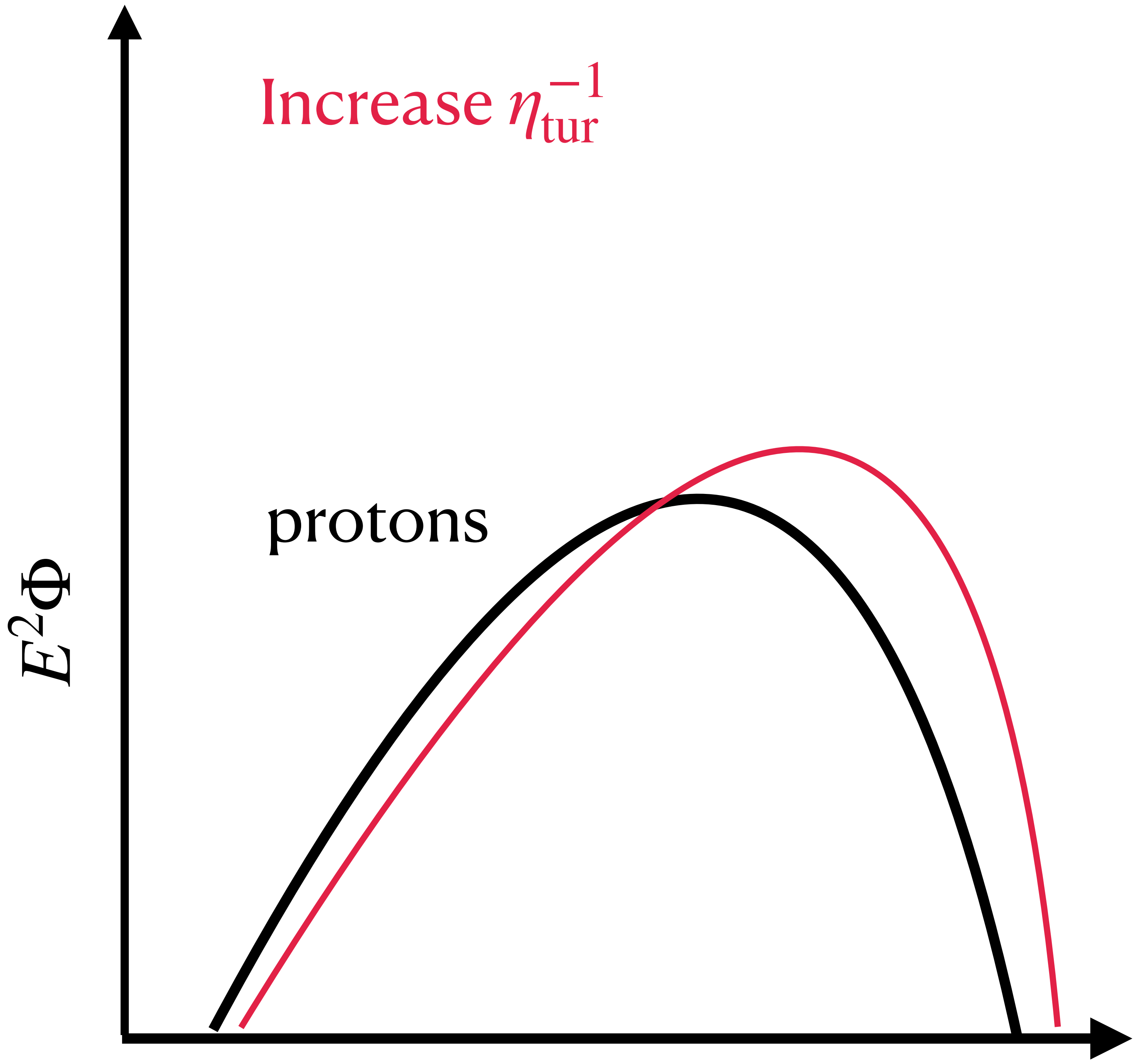

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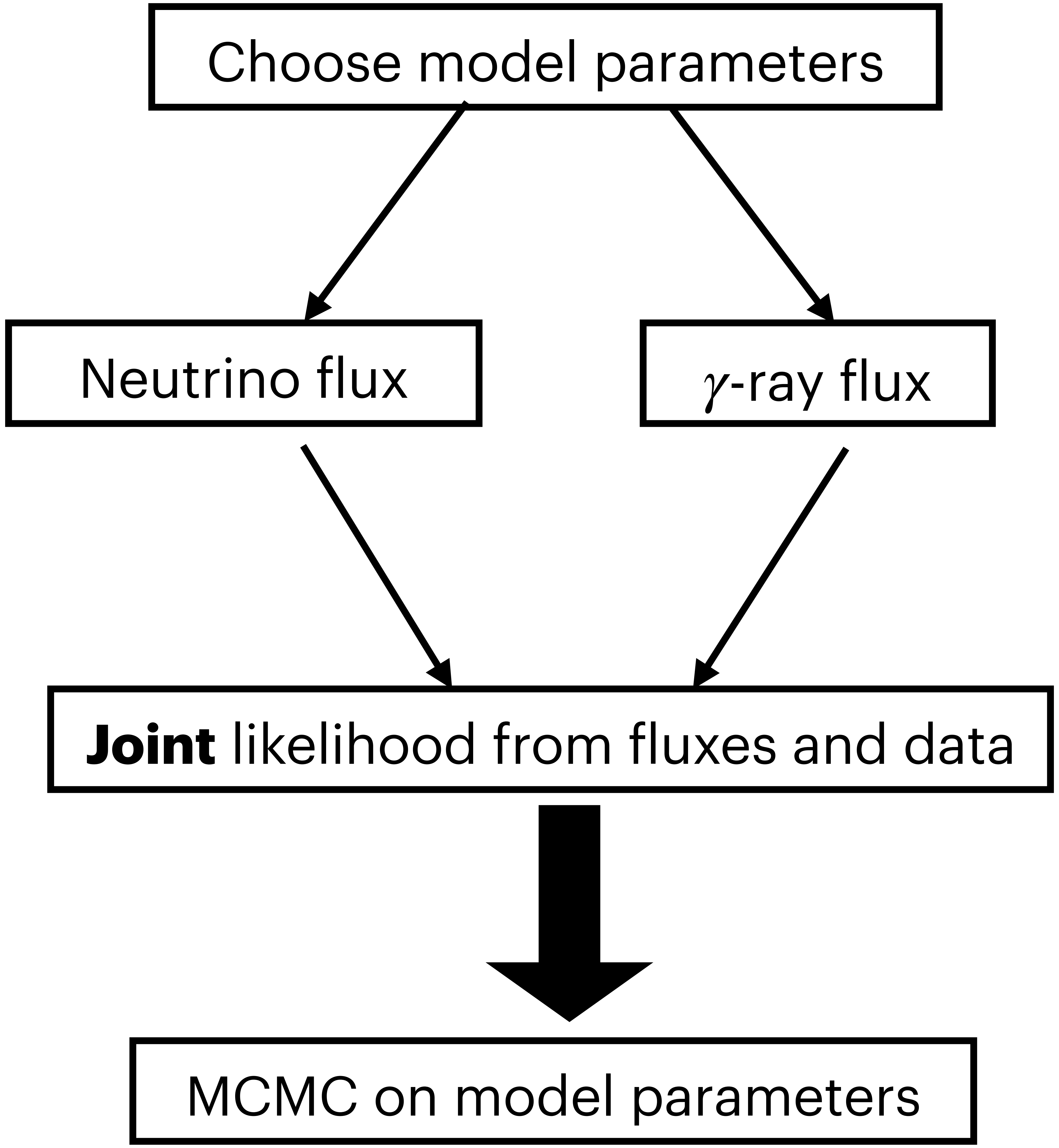
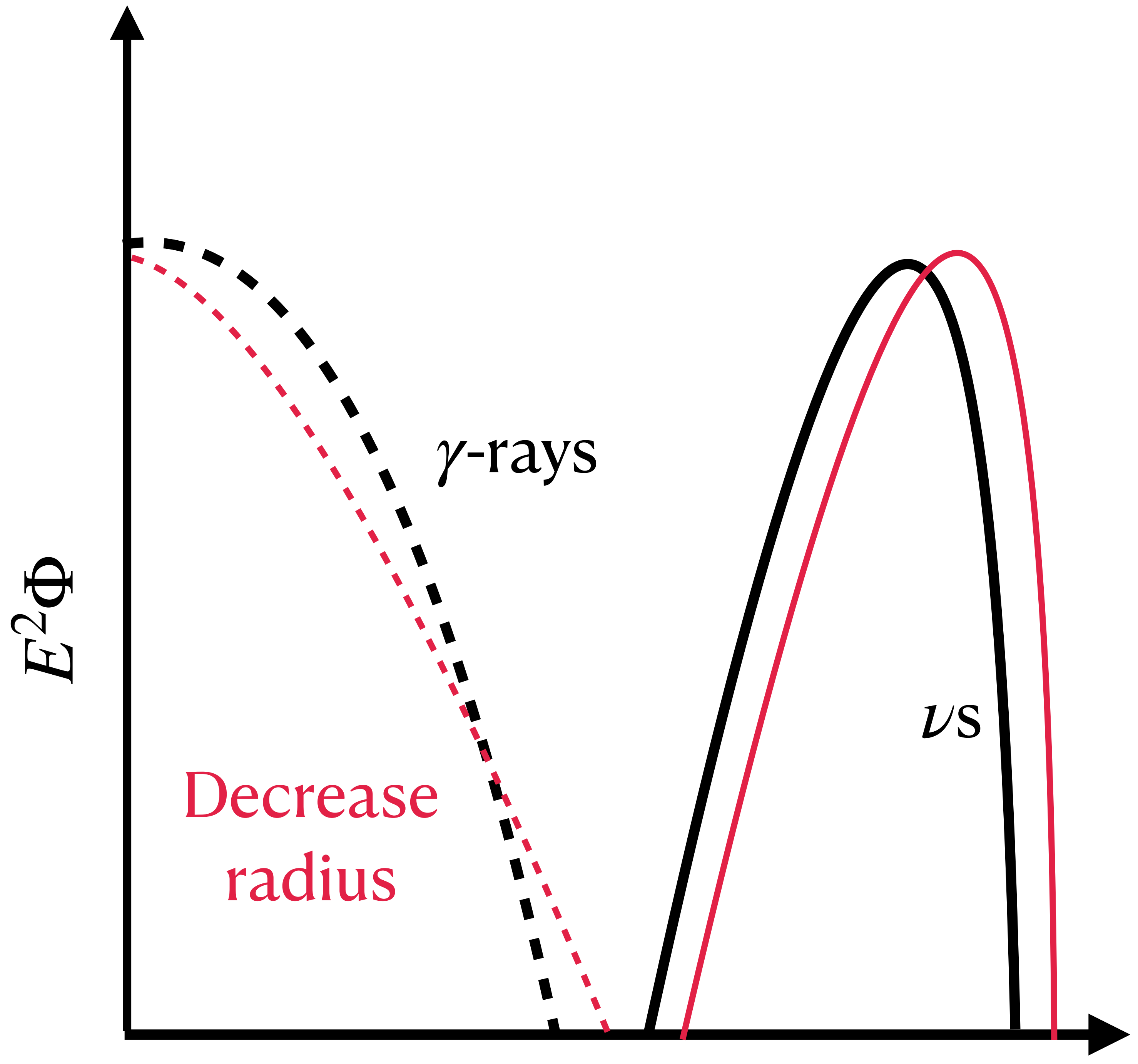
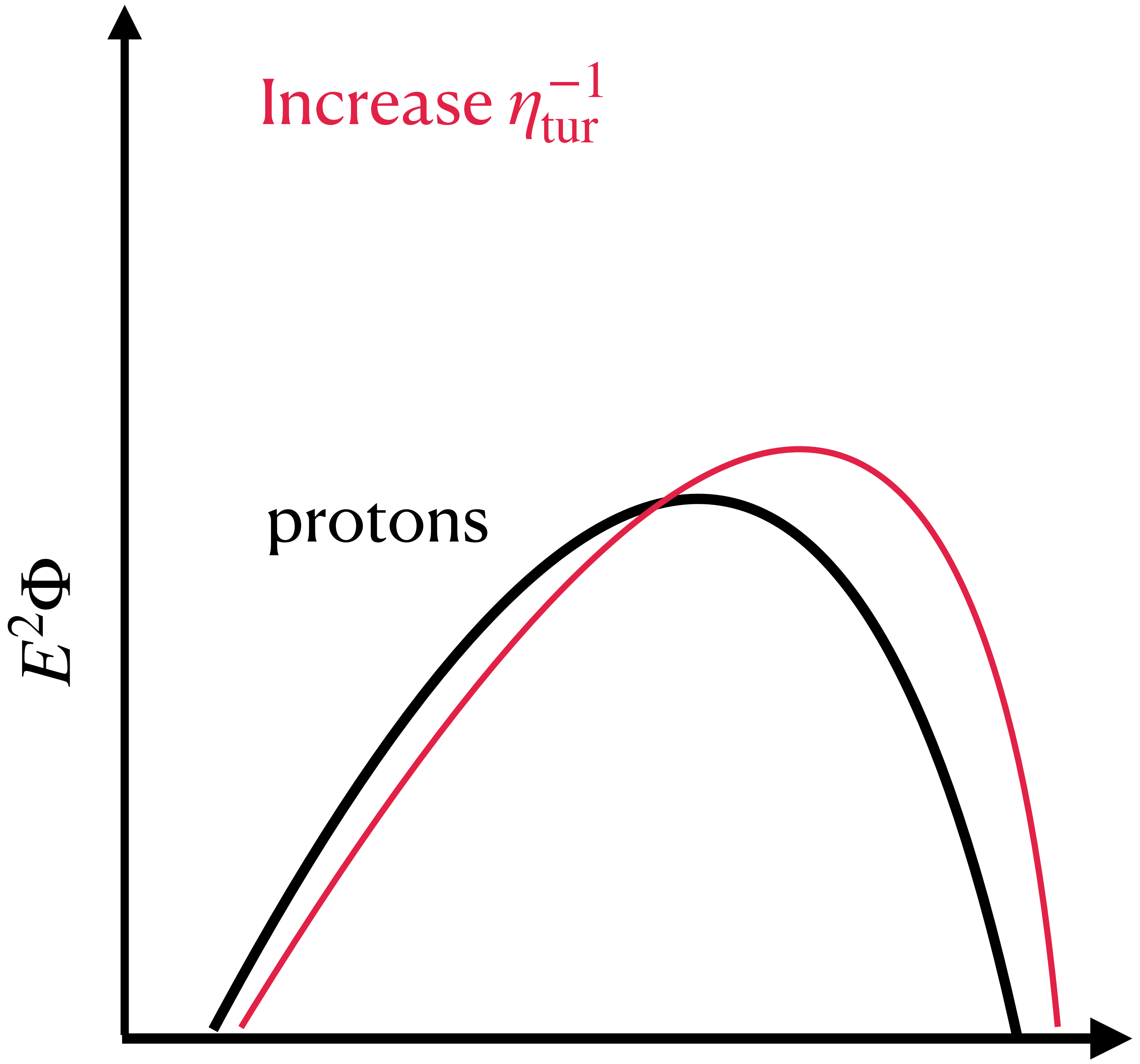


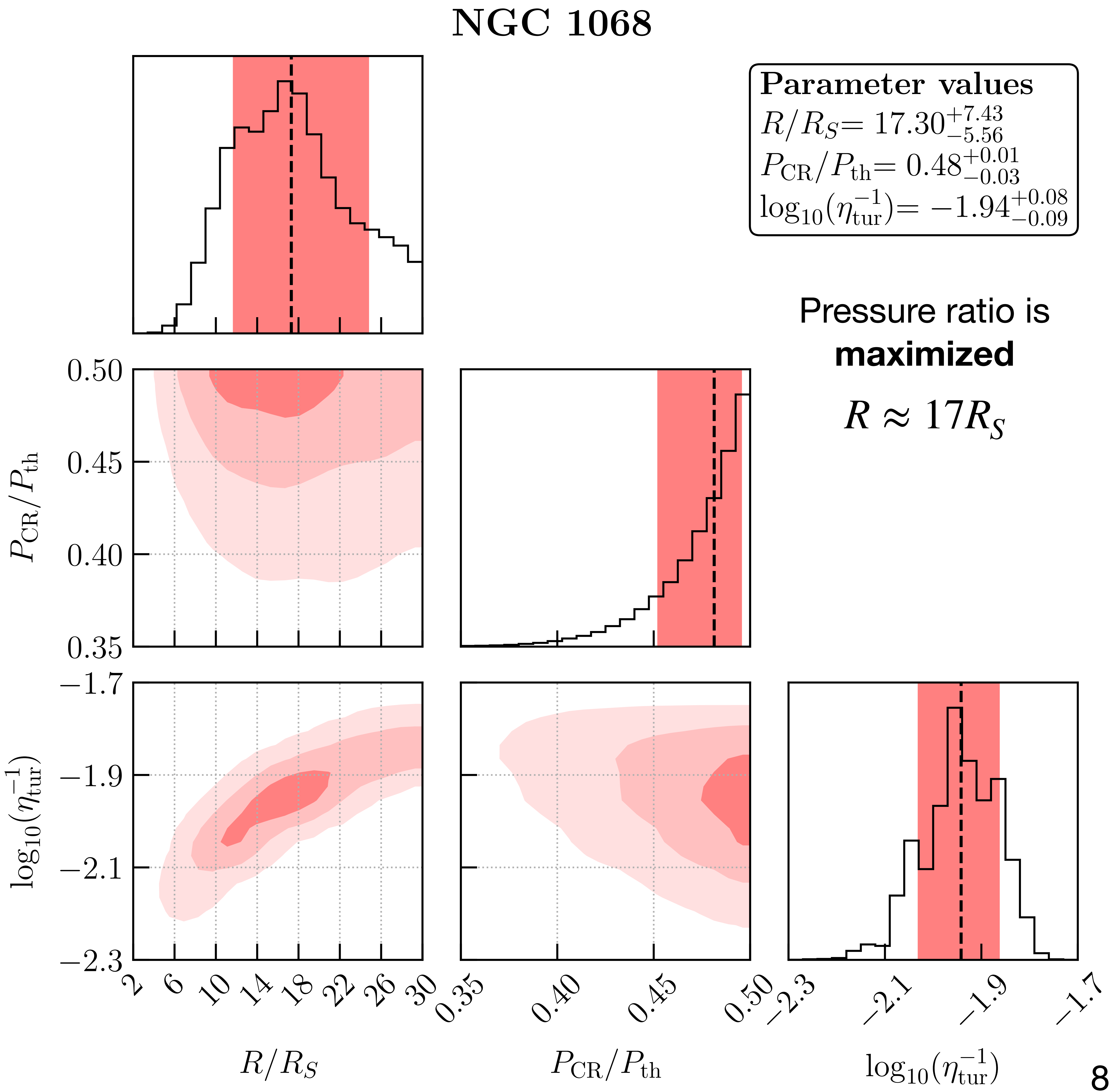




Parameter scan - NGC 1068

Intrinsic X-ray luminosity: 3×10^{43} erg s^{-1}

$M_{\mathrm{BH}} = 1.8 \times 10^{7}\ M_{\odot}$



Pressure ratio is **maximized**

$R \approx 17 R_S$

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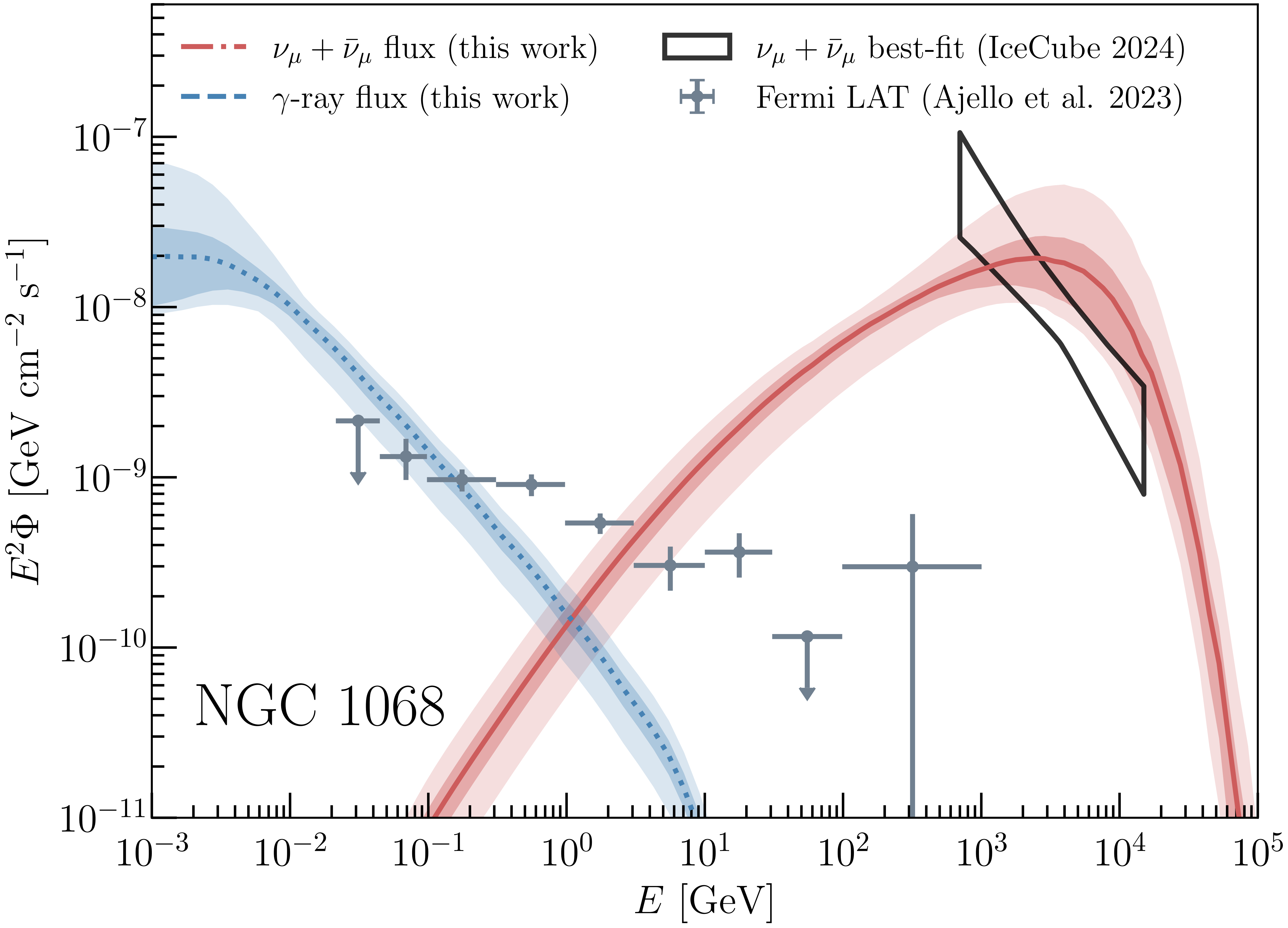

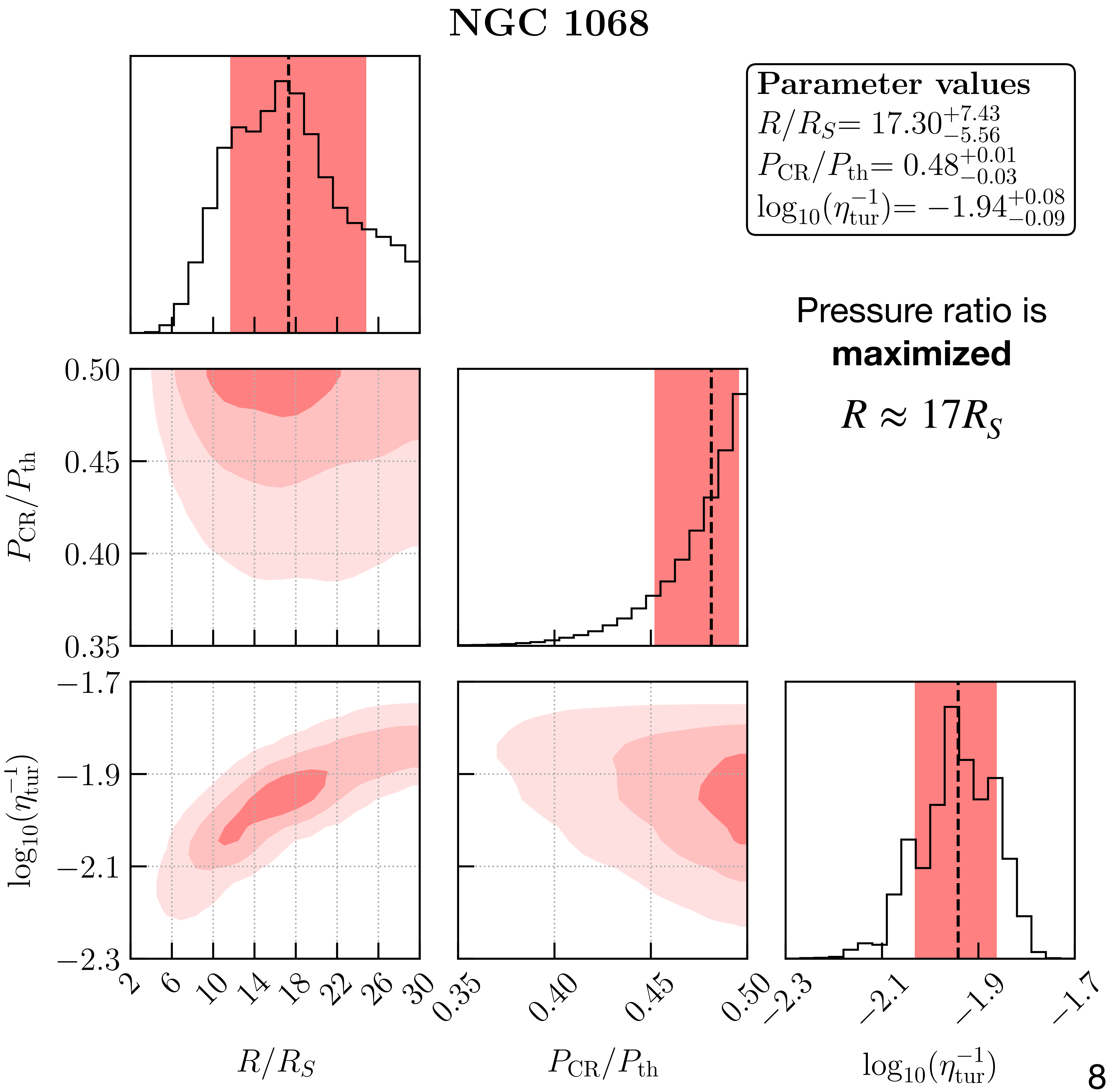

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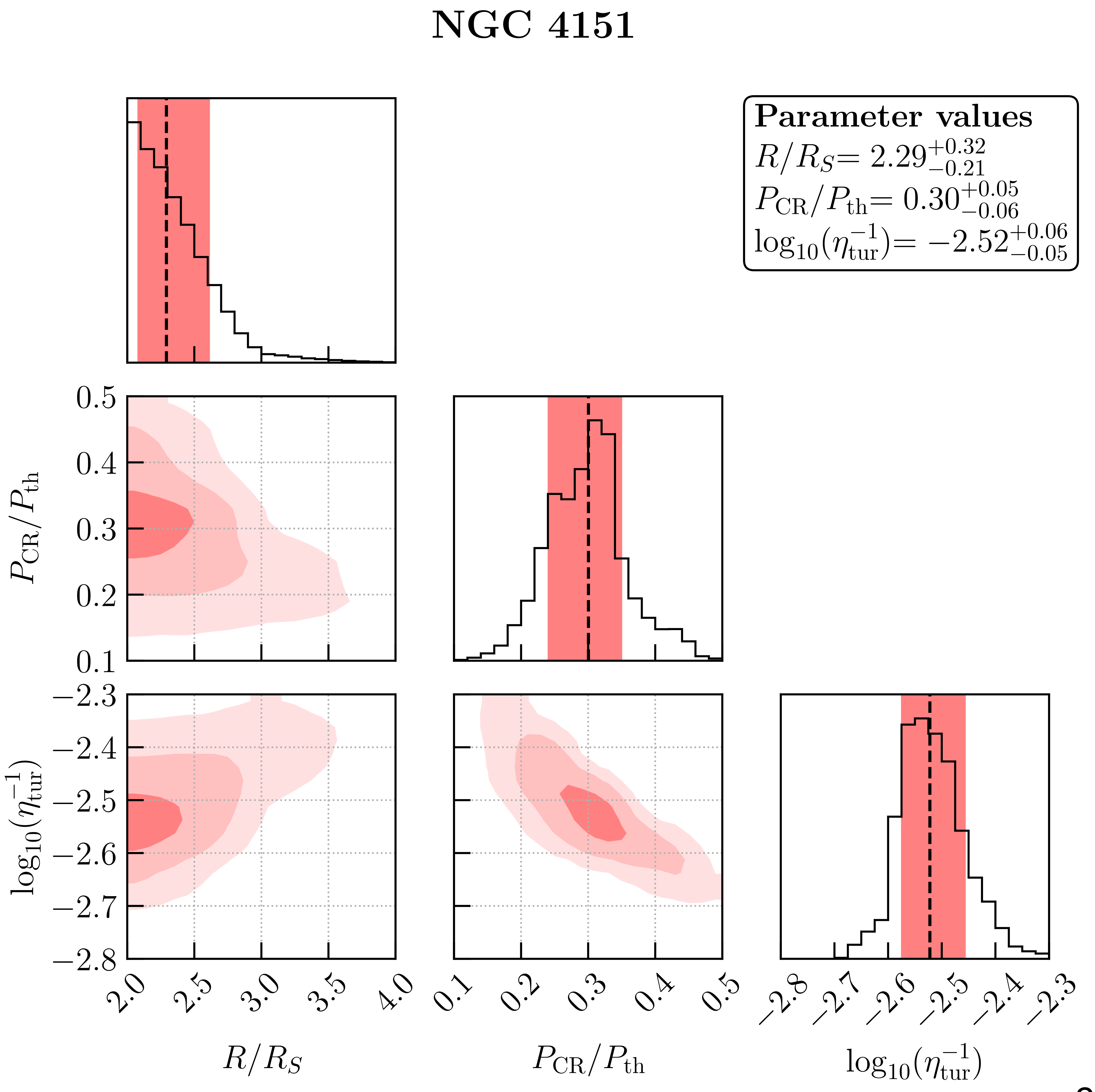

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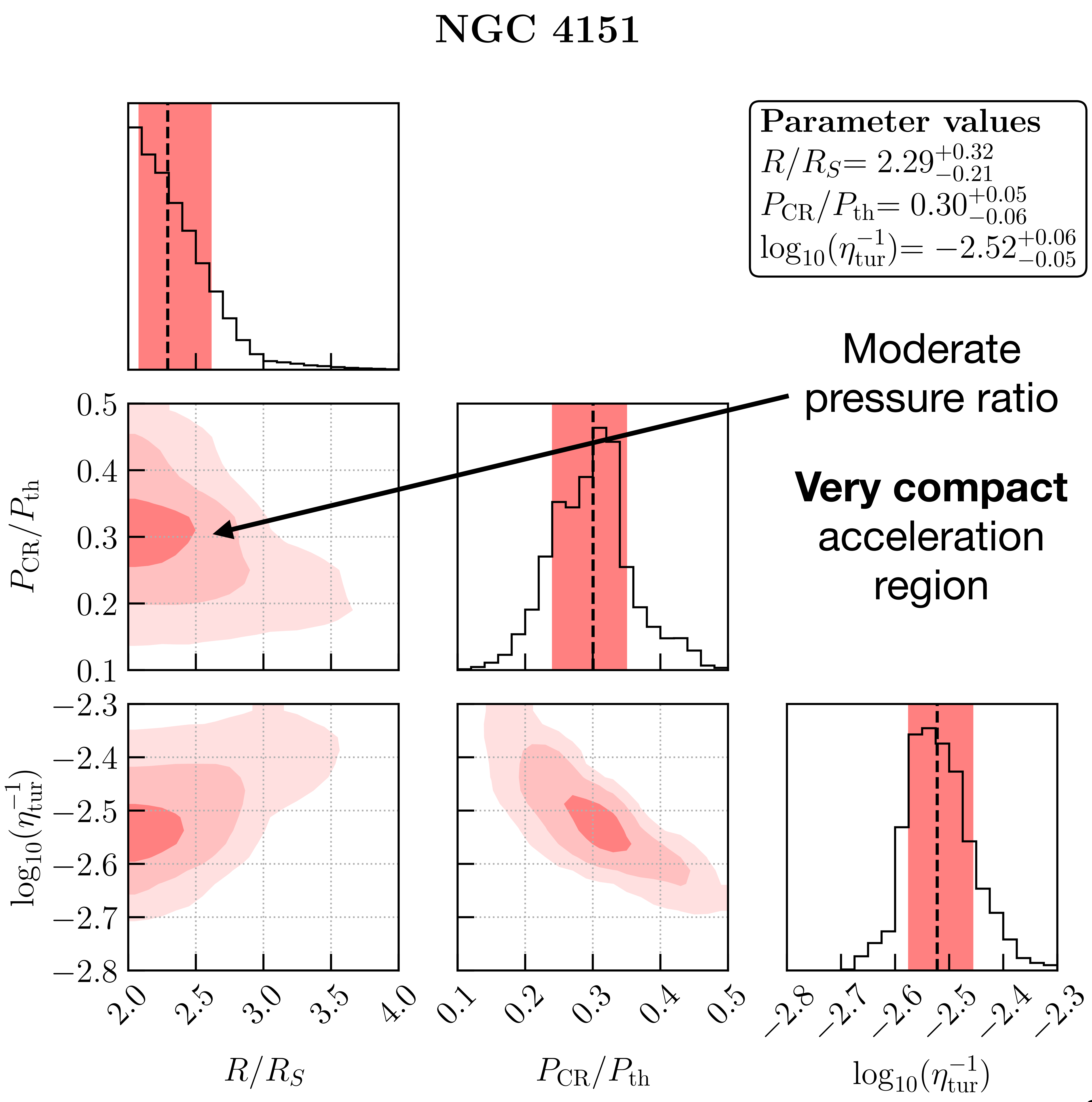

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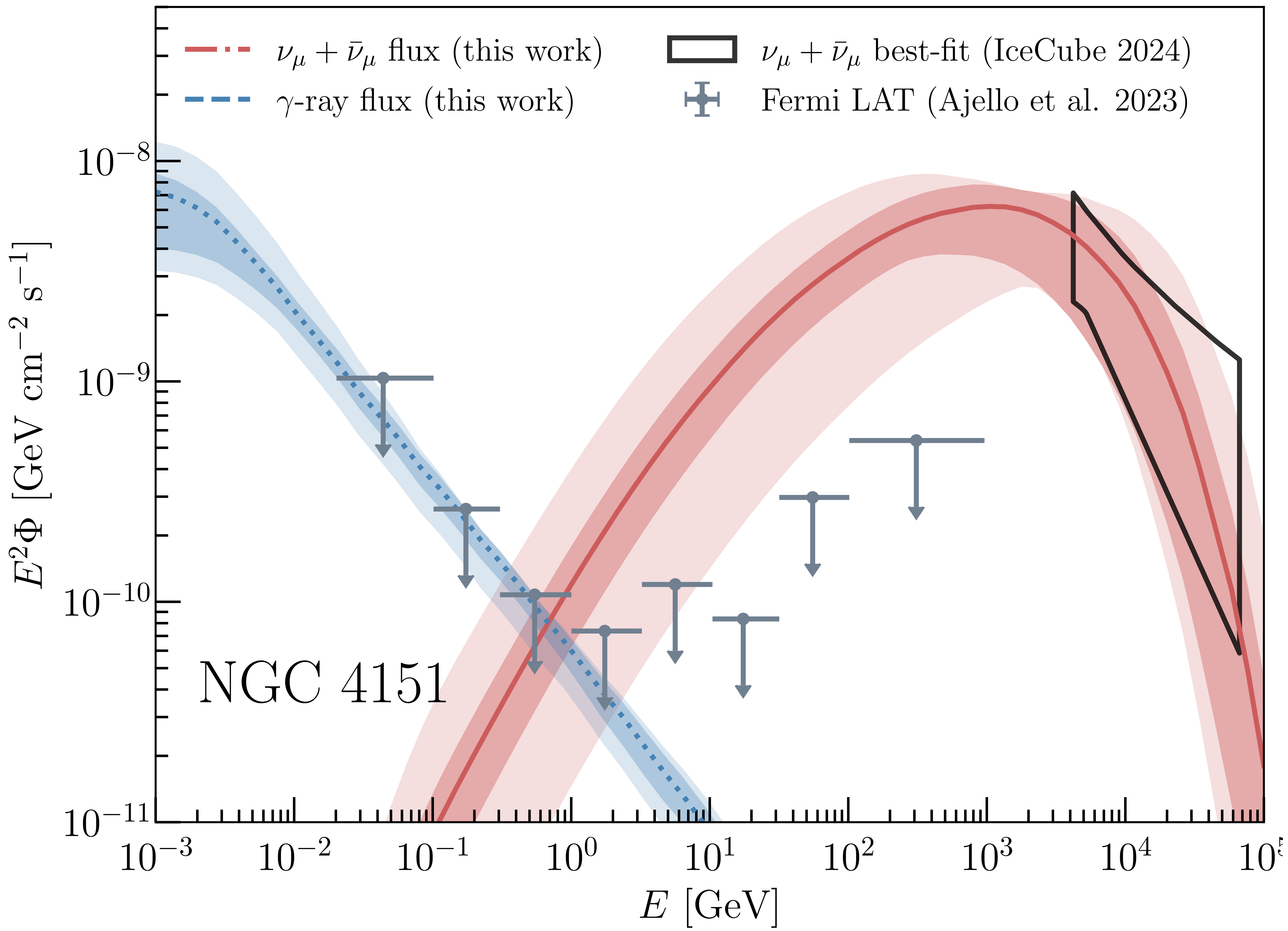

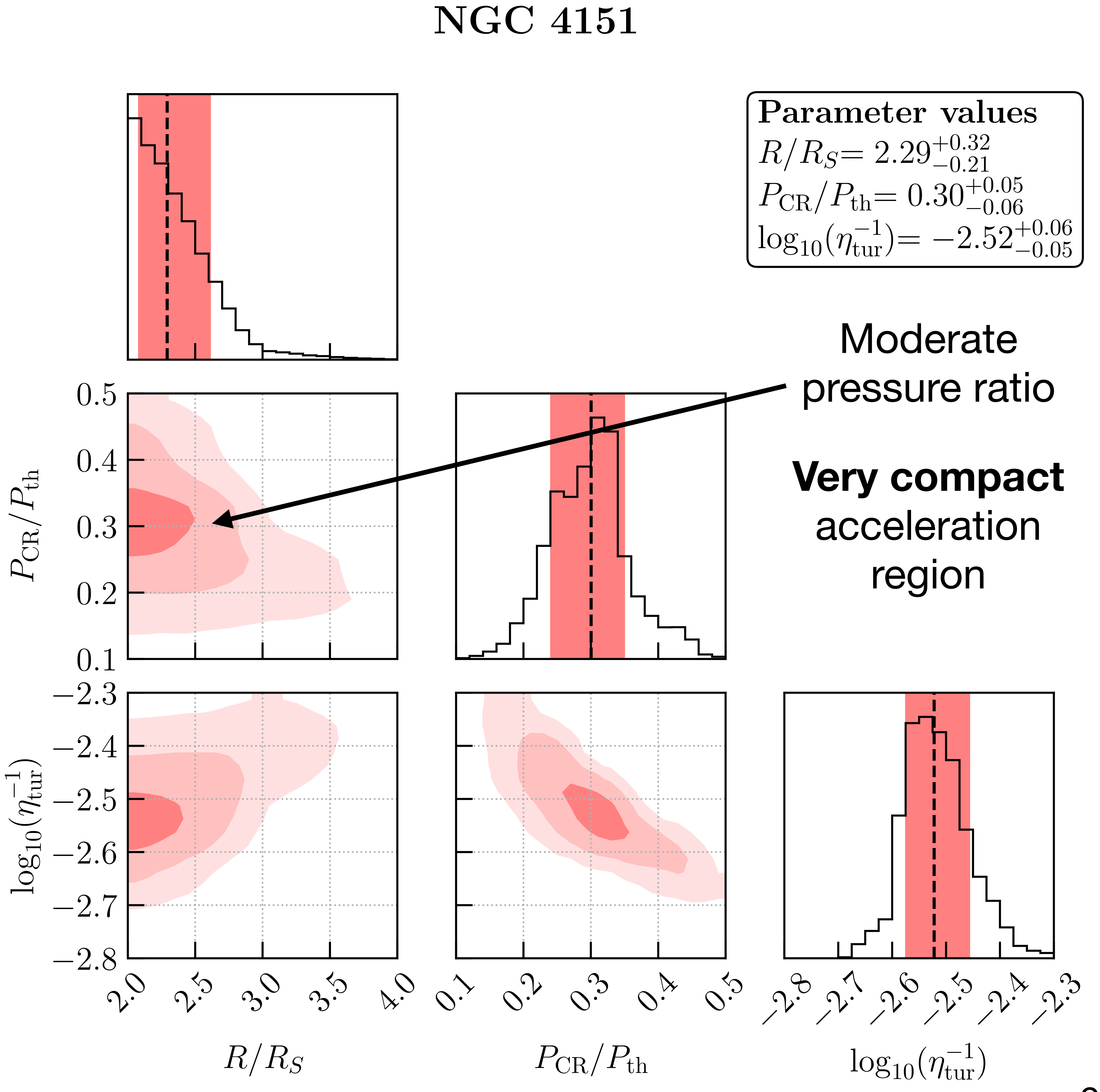

Moderate pressure ratio

Very compact acceleration region

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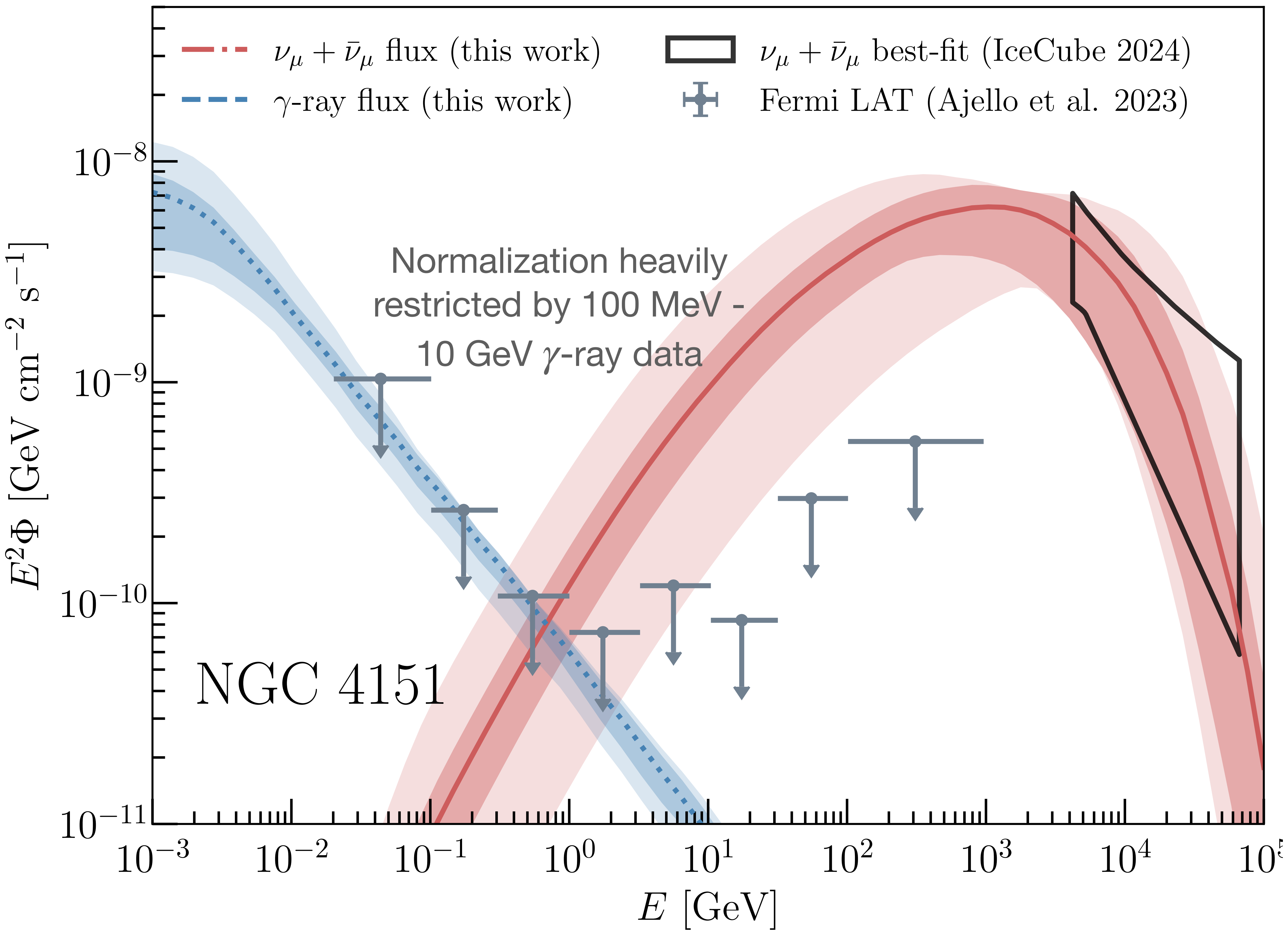

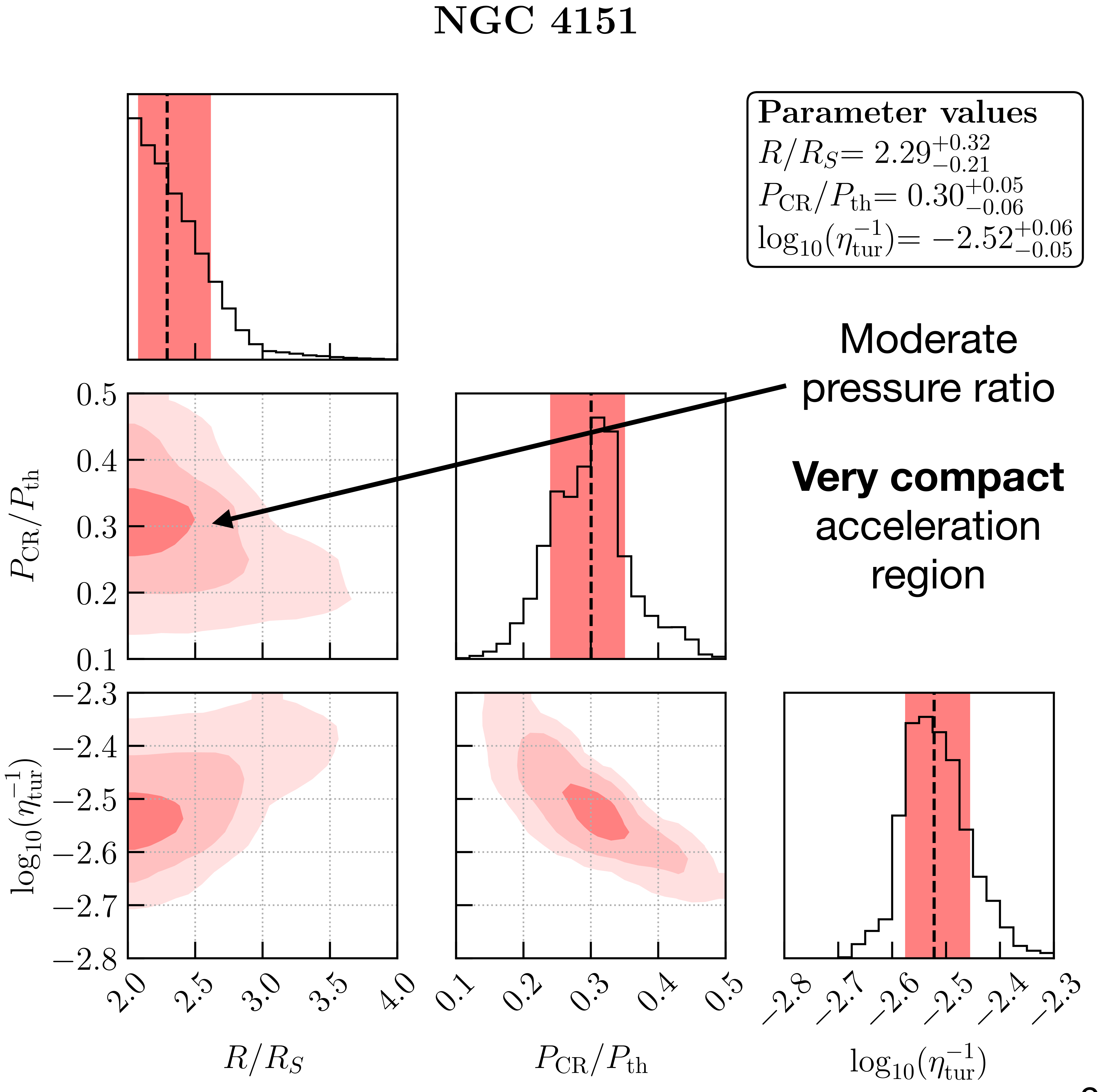

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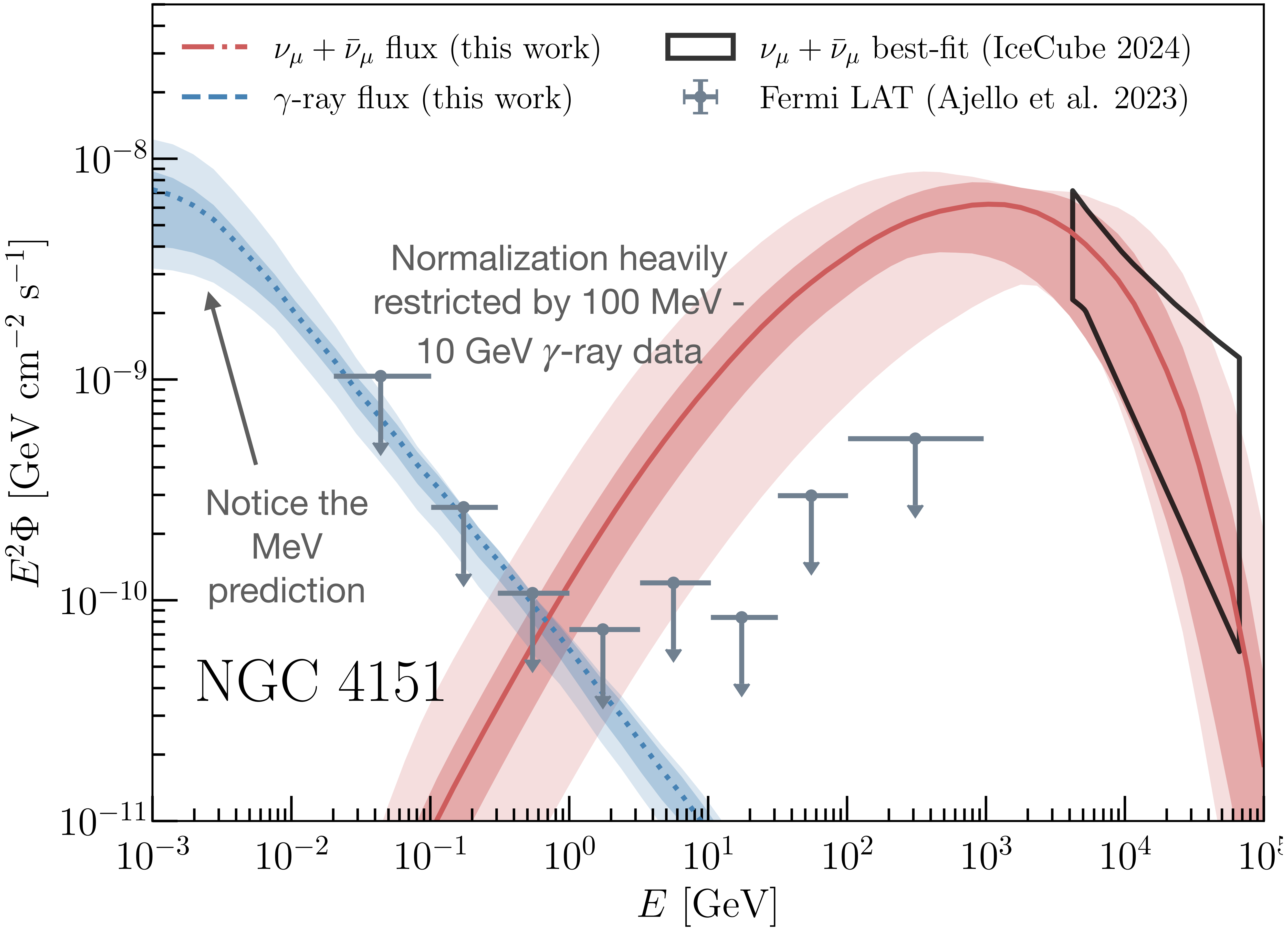

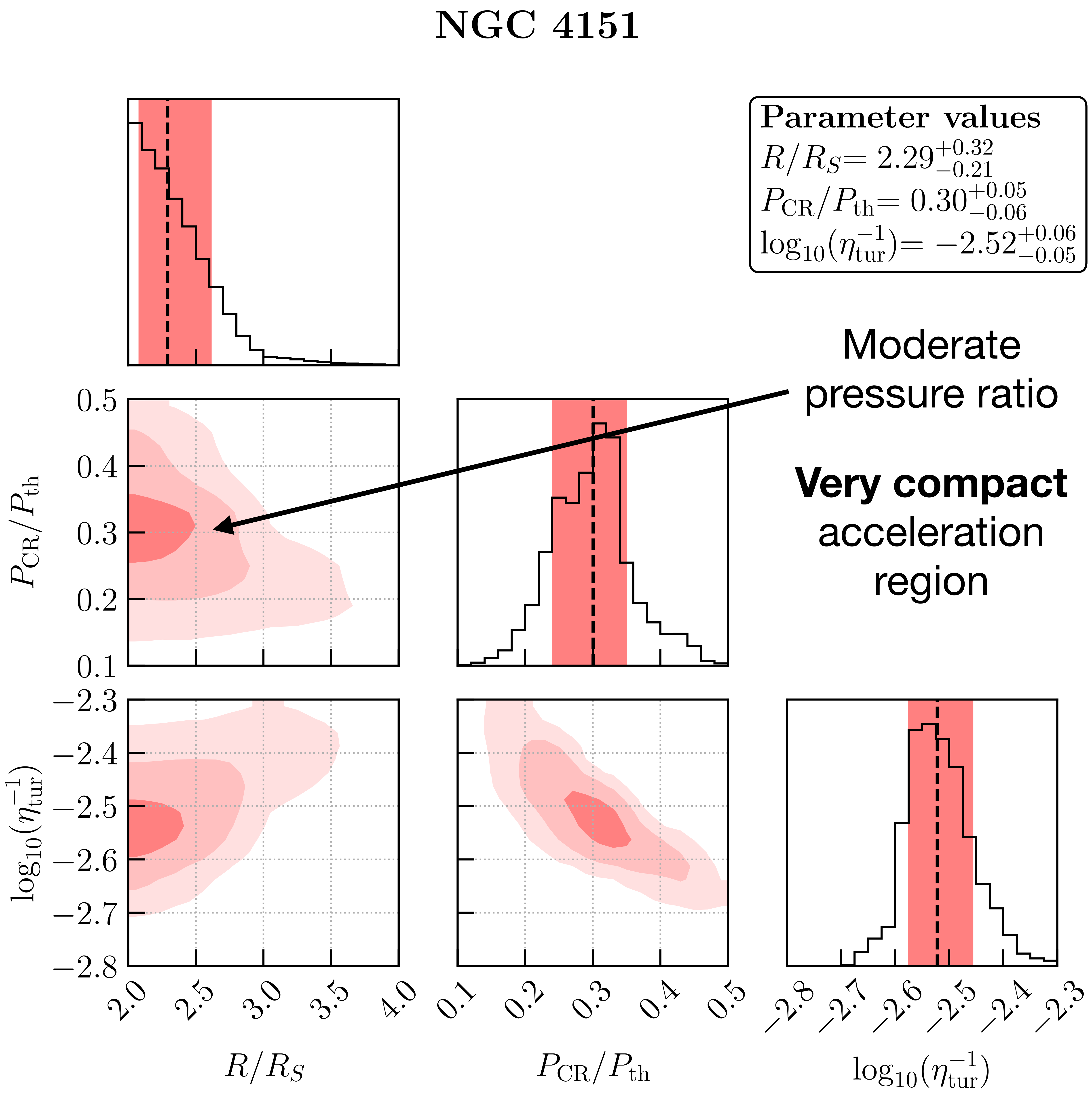

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Can neutrinos provide some insight?

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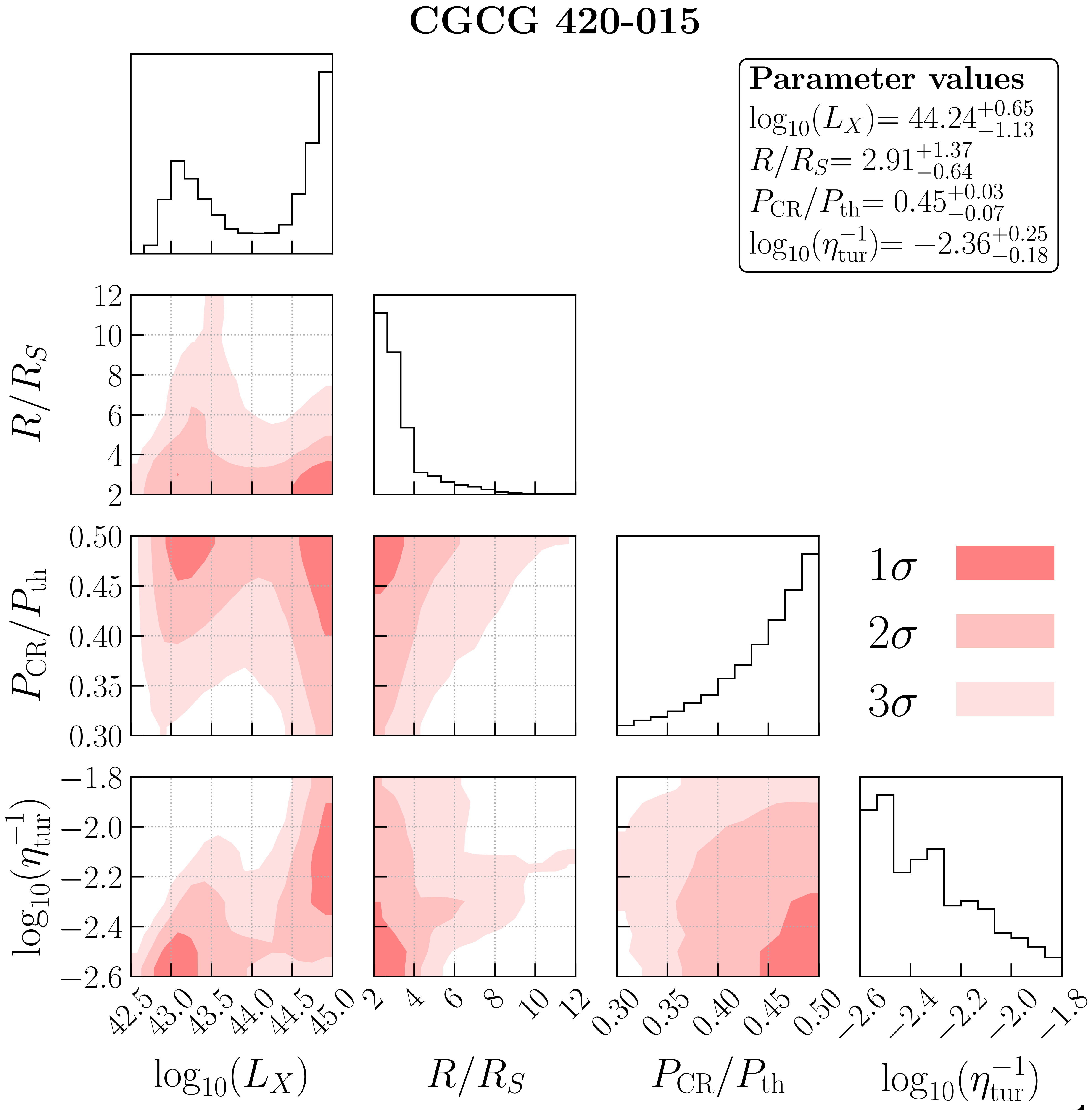

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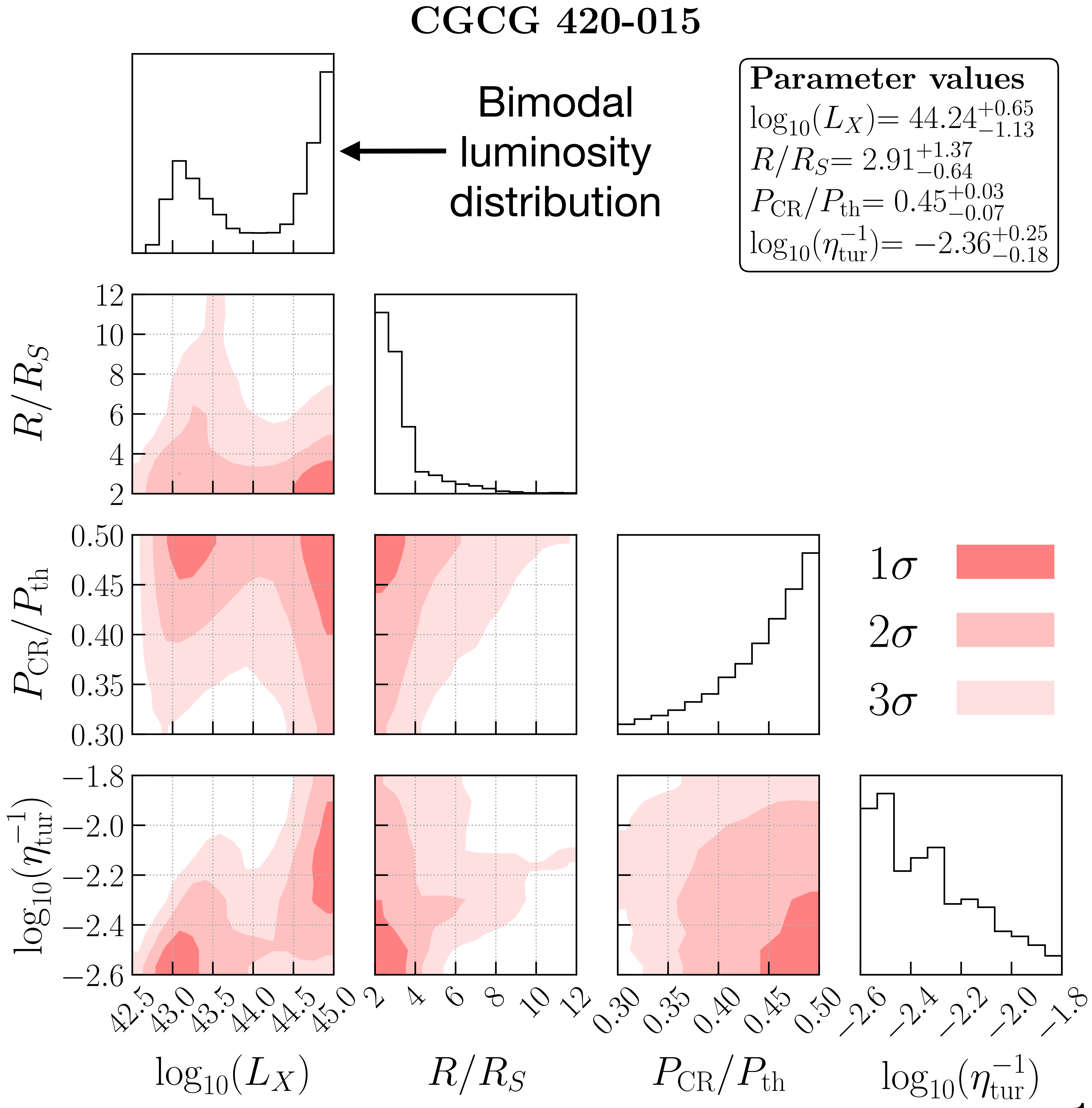

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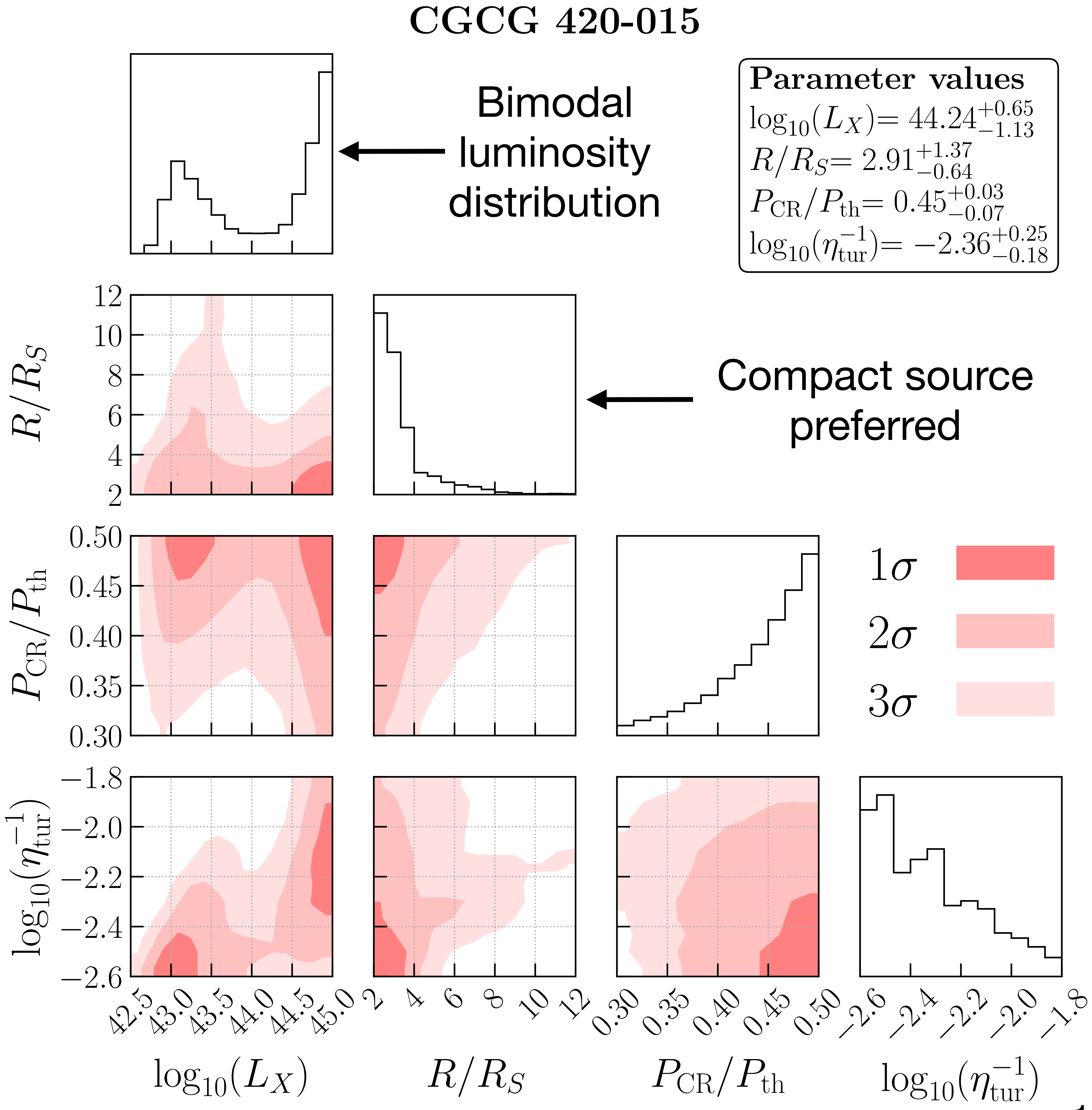

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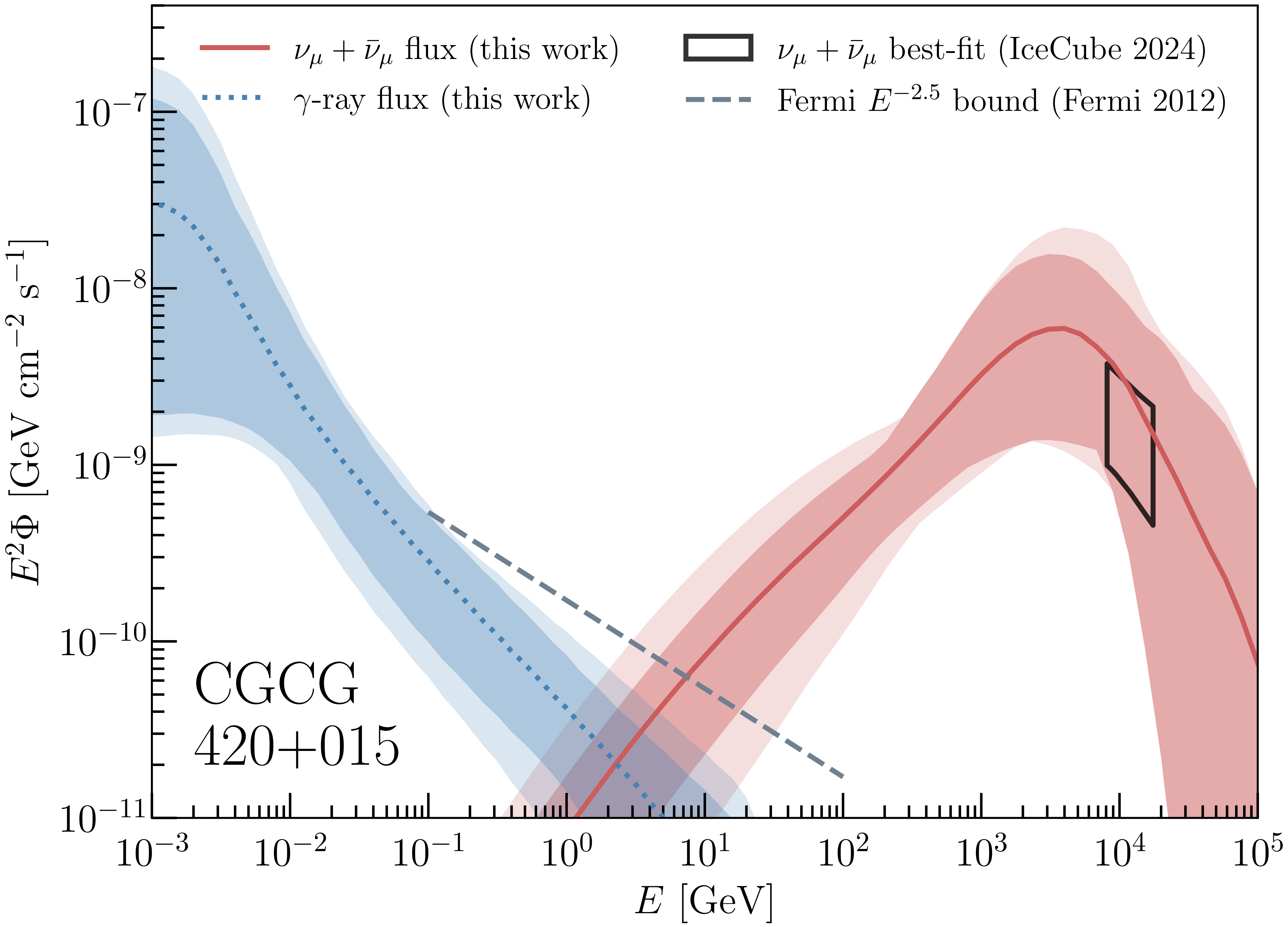

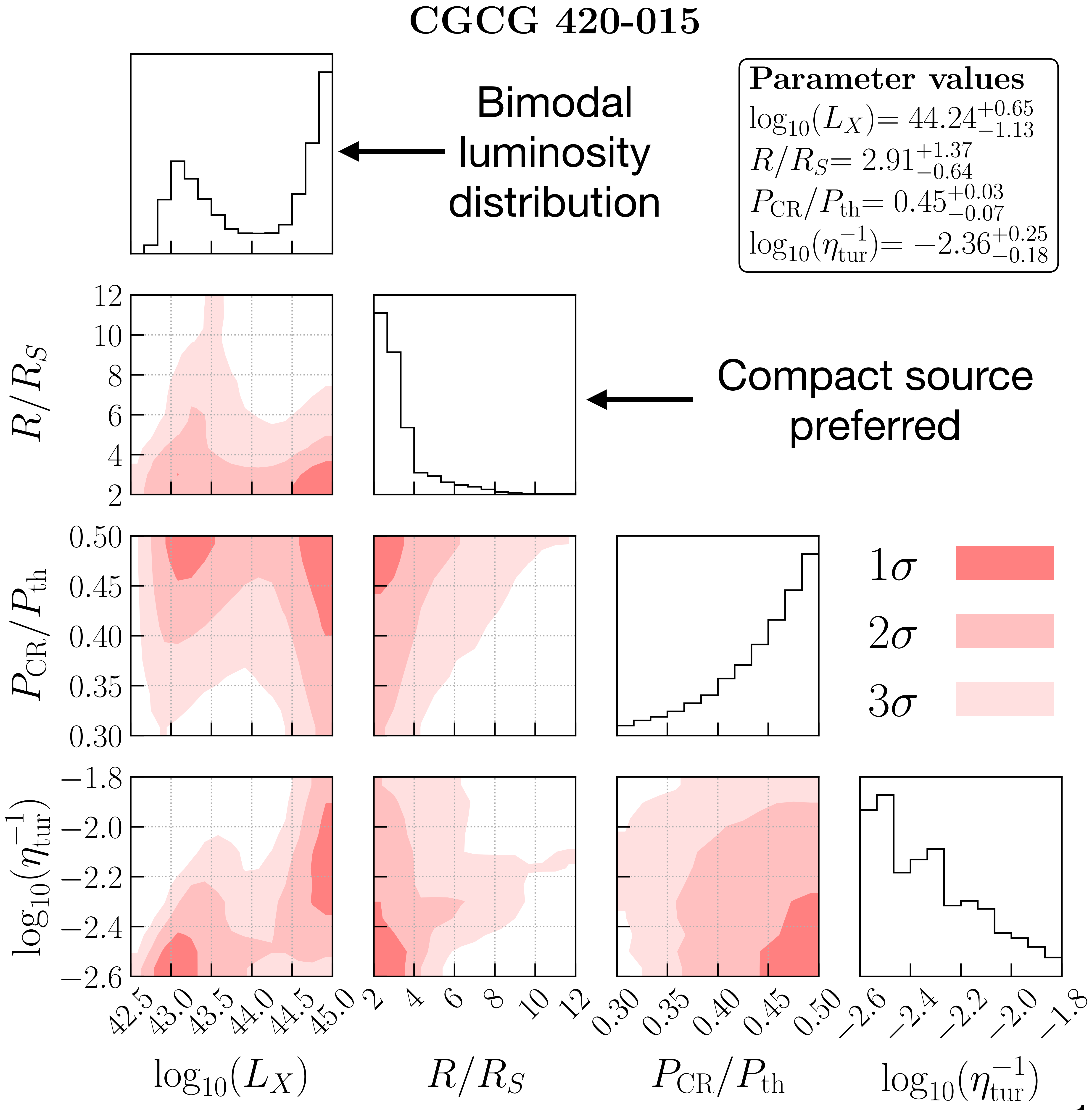

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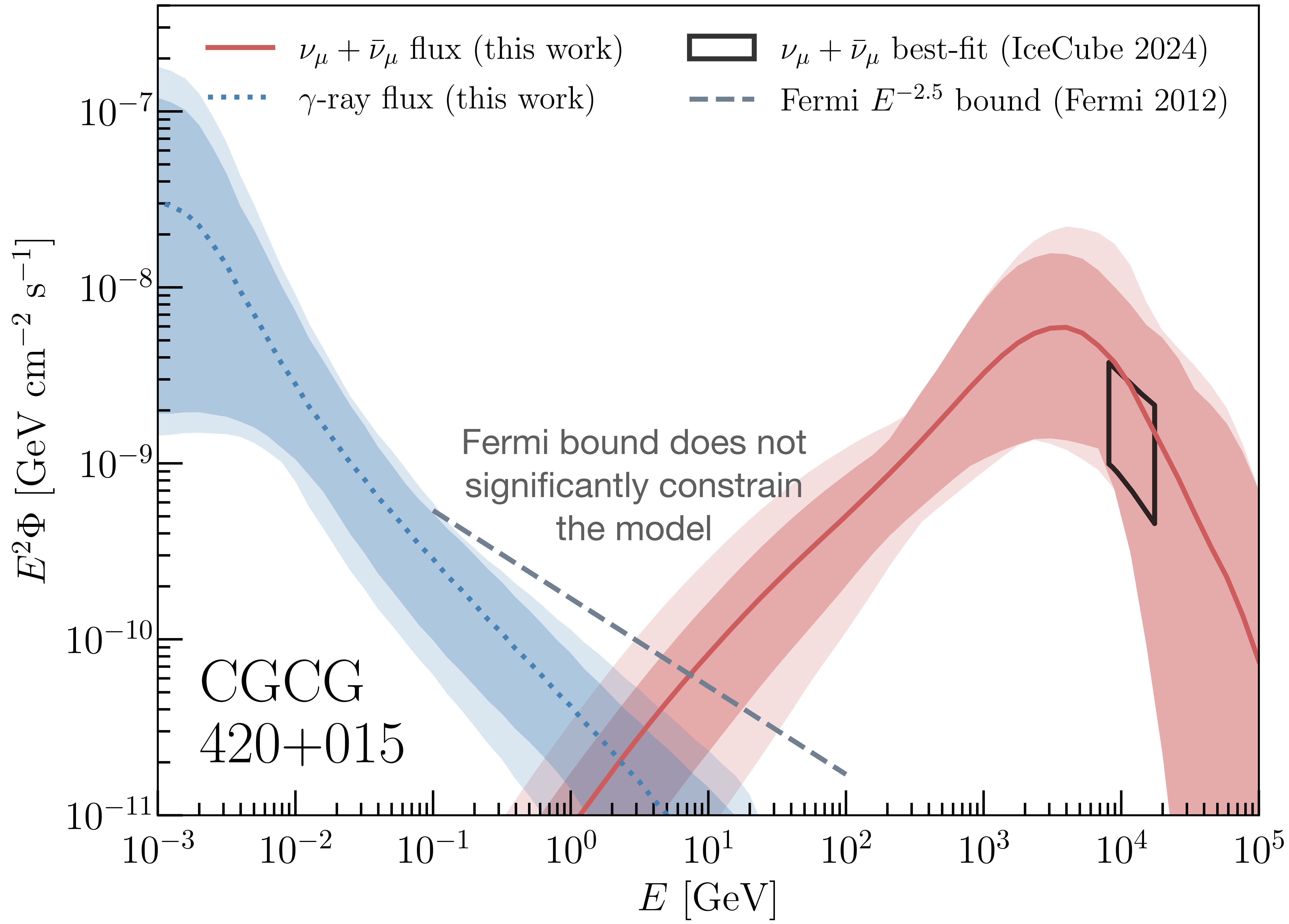

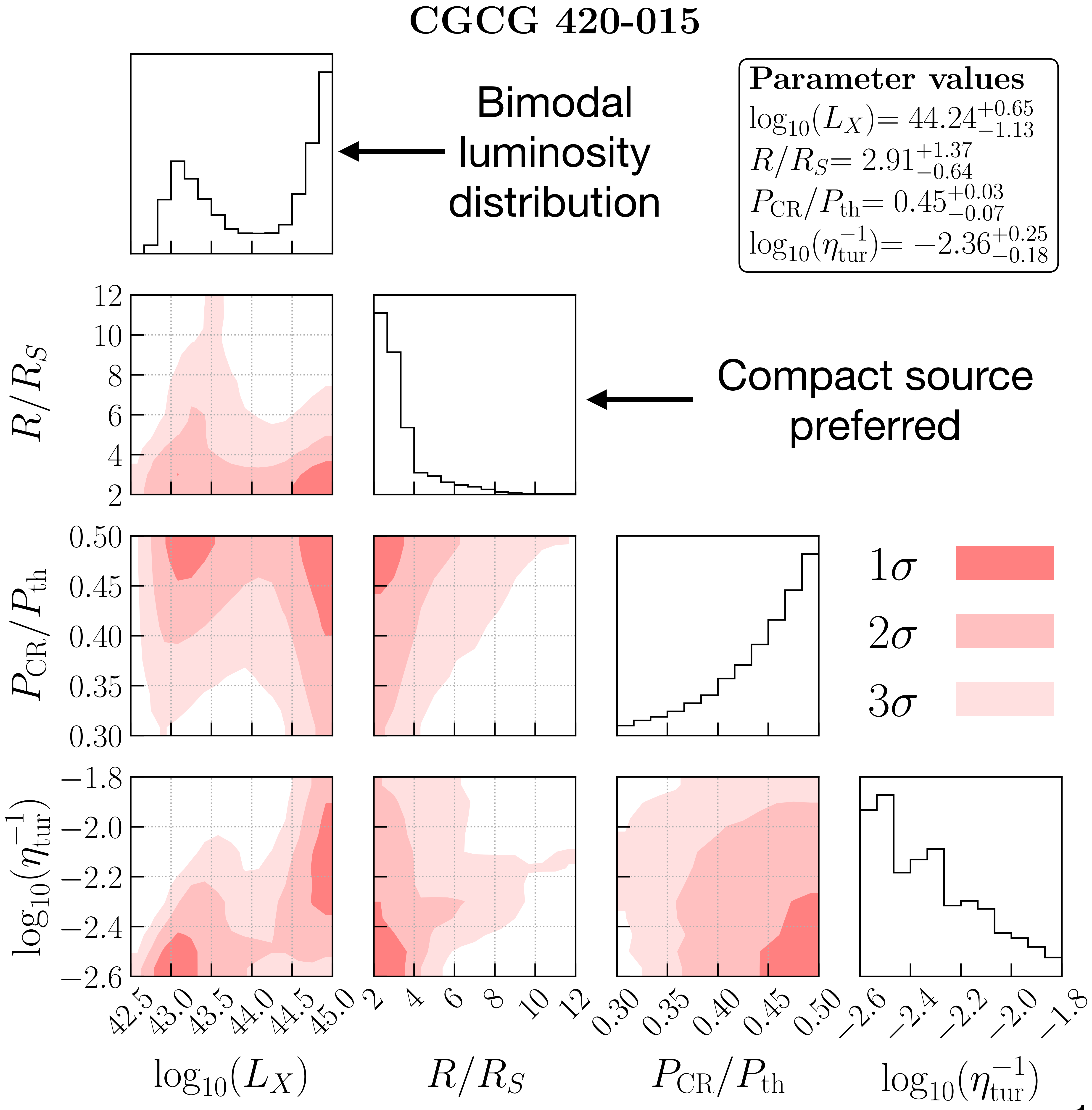

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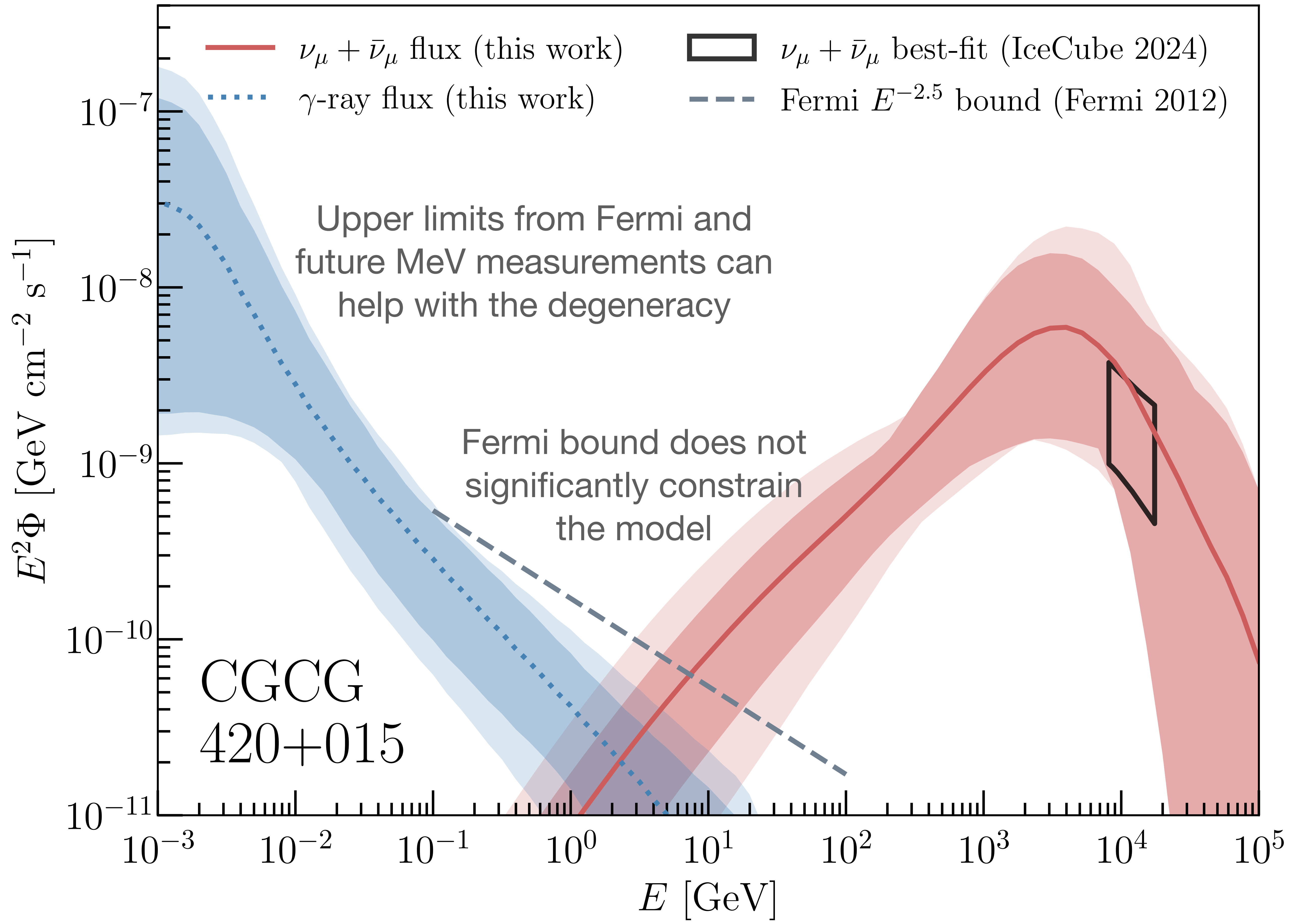

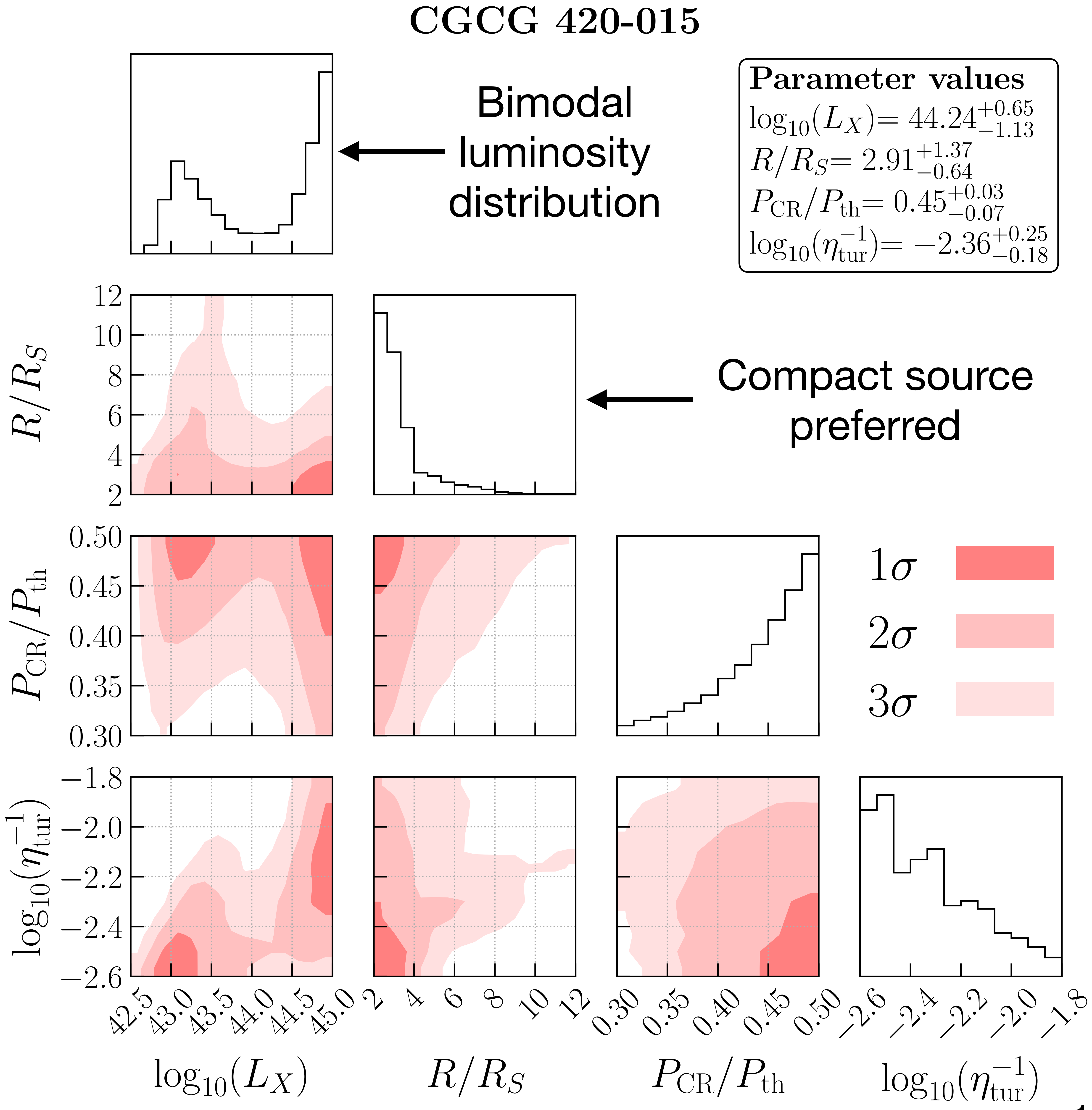

AGN contributions to the diffuse neutrino flux

Compare two models:

RS17: $R = 17.3R_S,\ \ P_{\rm CR}/P_{\rm th} = 0.48,\ \ \eta_{\rm tur} = 87$

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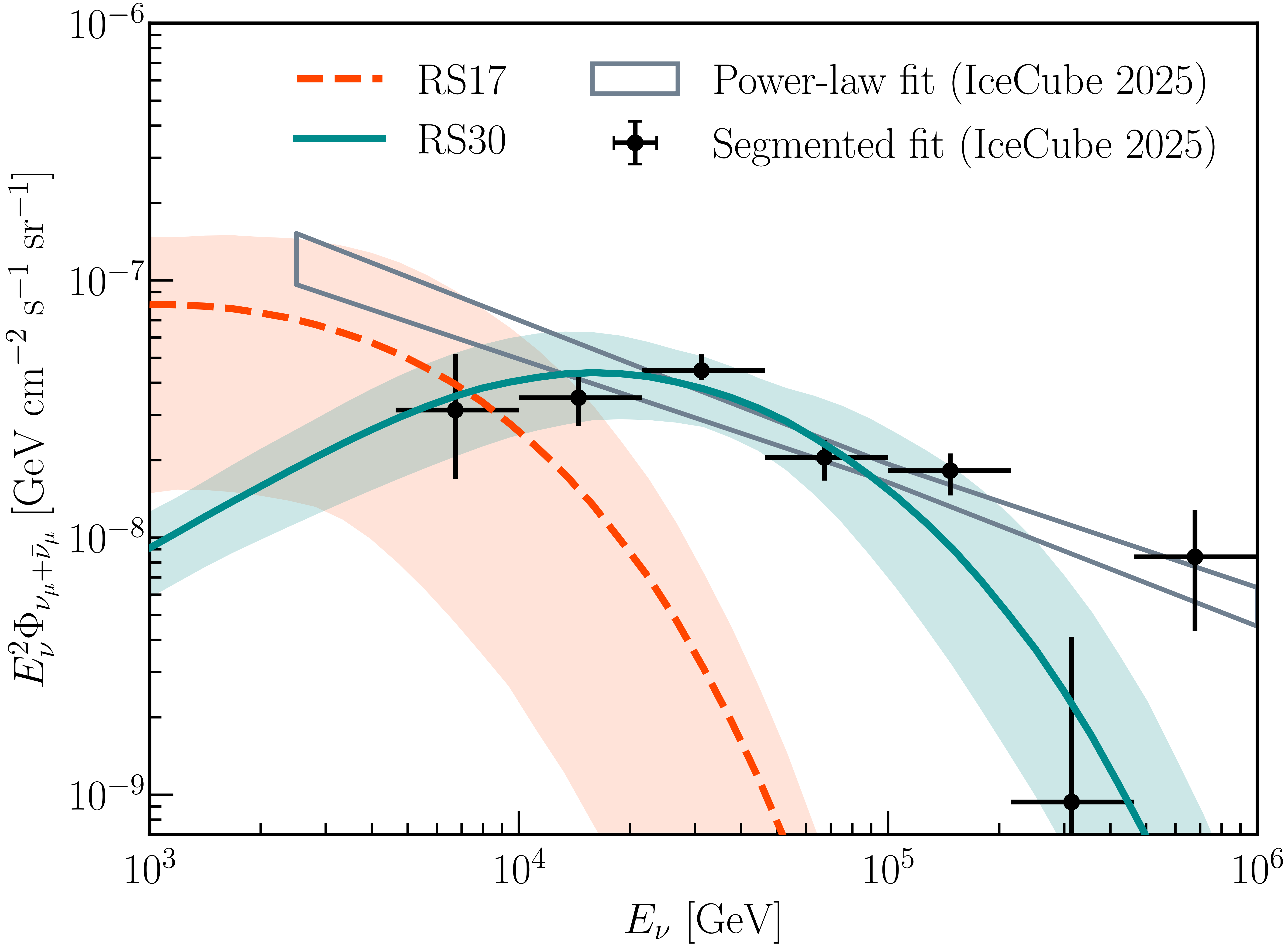

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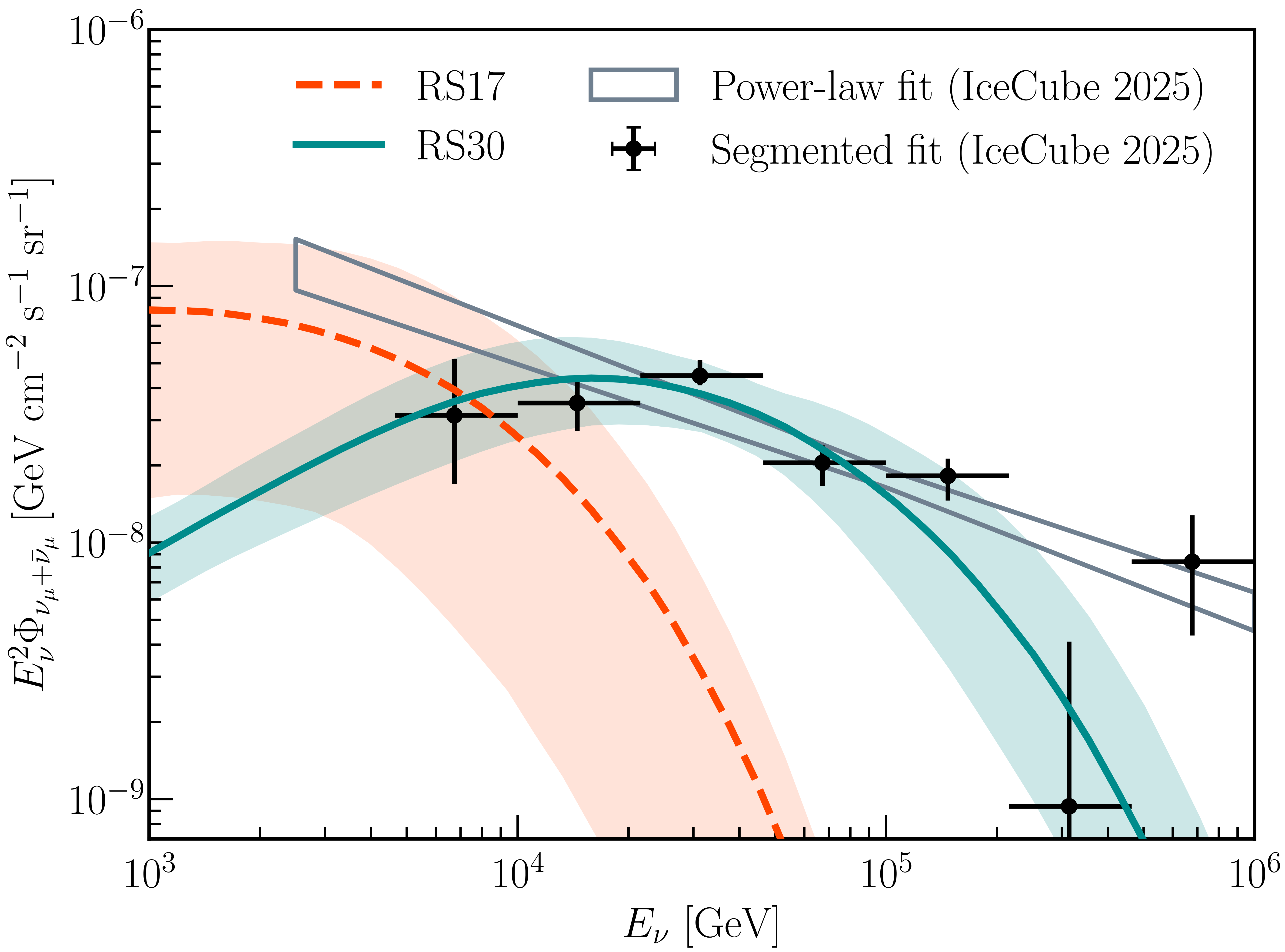
- Low L_X sources provide most of the diffuse flux
- Sources in $z \approx 0.5 - 1.5$ contribute significantly to the diffuse flux



AGN contributions to the diffuse neutrino flux

Compare two models:

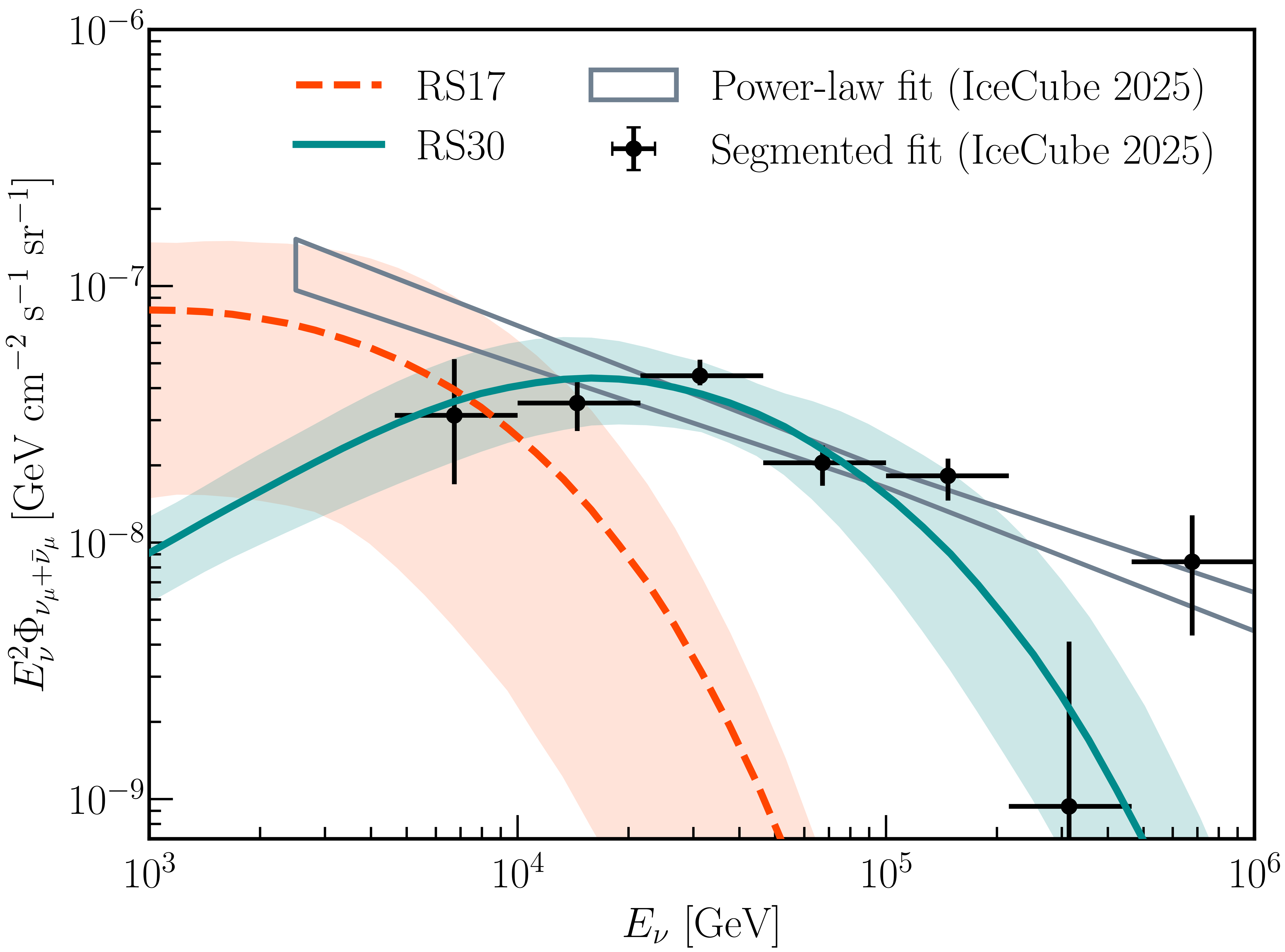
RS17: $R = 17.3R_S, \ P_{\rm CR}/P_{\rm th} = 0.48, \ \eta_{\rm tur} = 87$

RS30: $R = 30R_S, \ P_{\rm CR}/P_{\rm th} = 0.01, \ \eta_{\rm tur} = 10$

We use the Ueda et al. 2014 formalism for the source distribution function and fit for parameters

- Low L_X sources provide most of the diffuse flux
- Sources in $z \approx 0.5 - 1.5$ contribute significantly to the diffuse flux

- RS17 contributes to 10-20 TeV neutrinos
- RS30 adjusts well to the 1 TeV - 100 TeV data



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Going forward

- Increased neutrino statistics can give further insight on proton maximum energies
- MeV observations are crucial to constrain the γ-ray cascades
- Diffuse neutrino flux measurements need additional input from AGN point sources to improve local distribution function fits