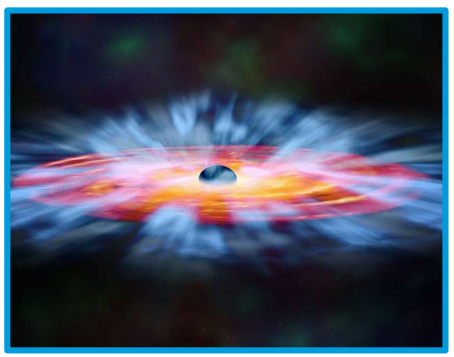
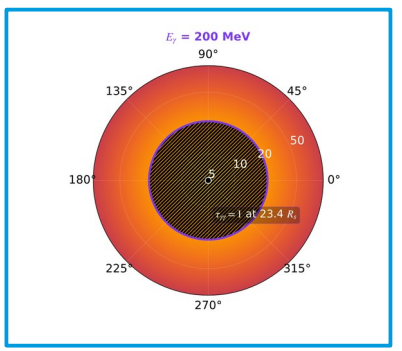
MULTI-ZONE AGN CORONAE AS THE SOURCE OF HIGH ENERGY NEUTRINOS AND GAMMA-RAYS



Presentation
by
Soumen Roy

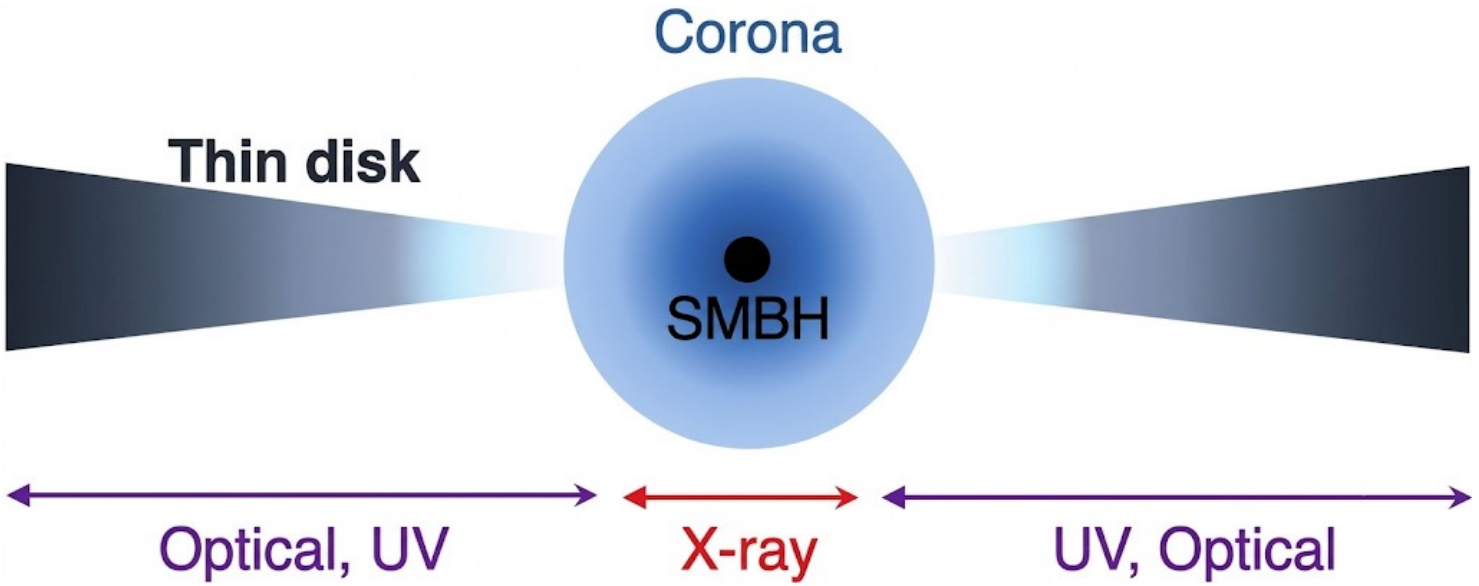


INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
GUWAHATI - 781039, ASSAM

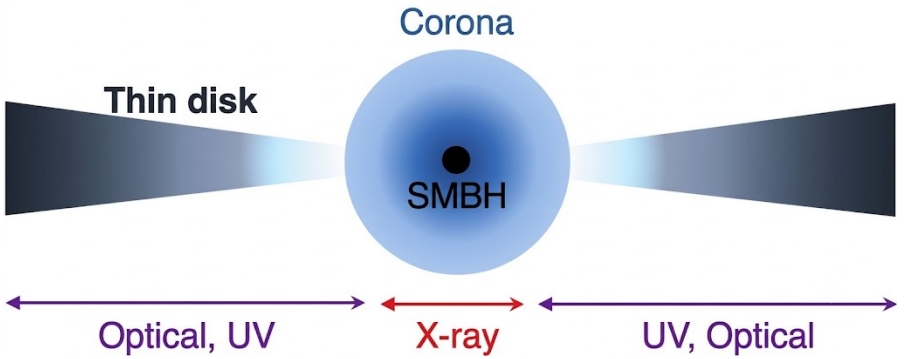
THE PHYSICS ACADEMY
OF THE NORTH EAST

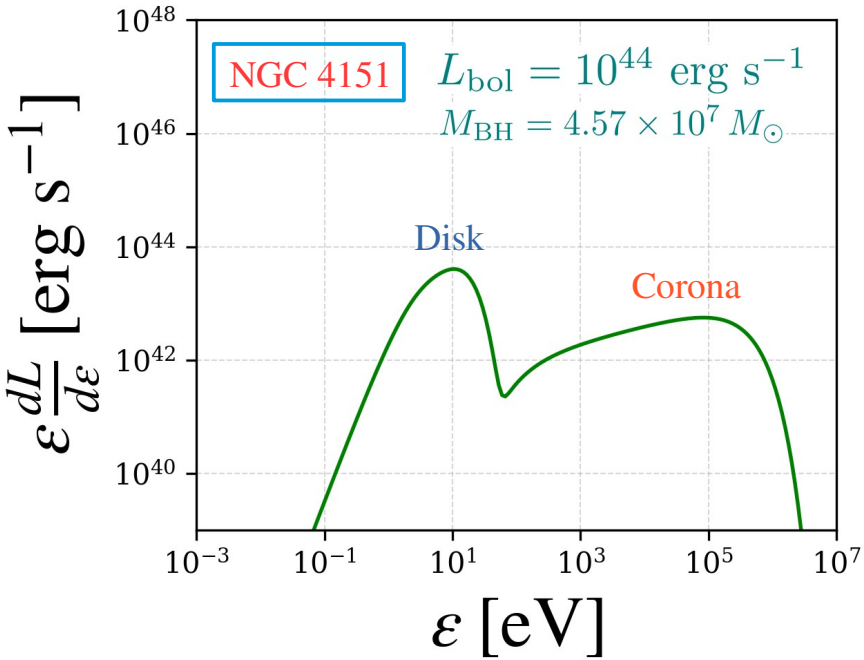
BODOLAND UNIVERSITY
KOKRAJHAR - 783370, ASSAM, INDIA

AGN Corona



Seed Photon Field





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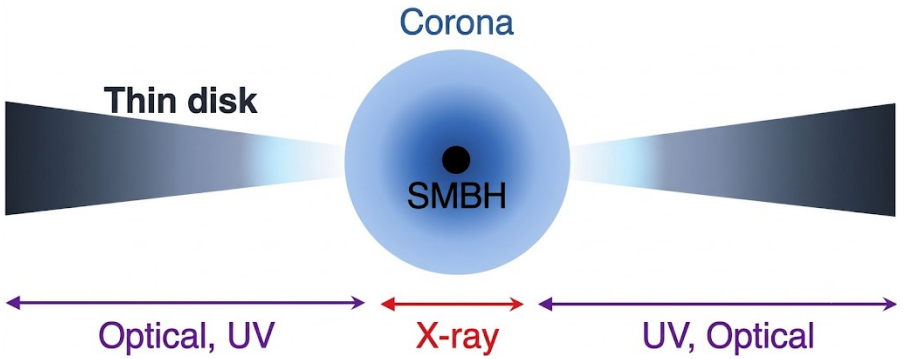
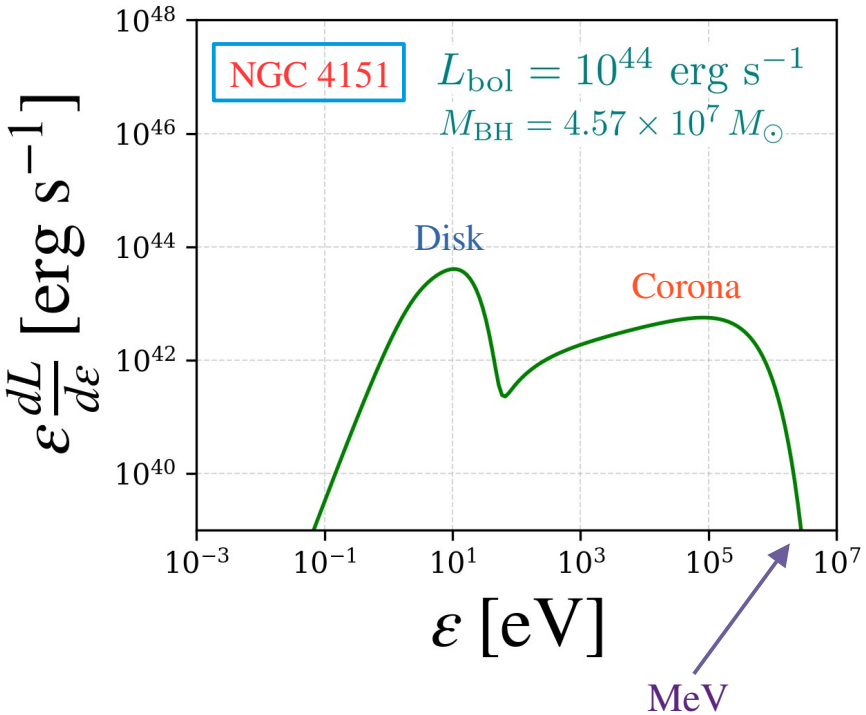
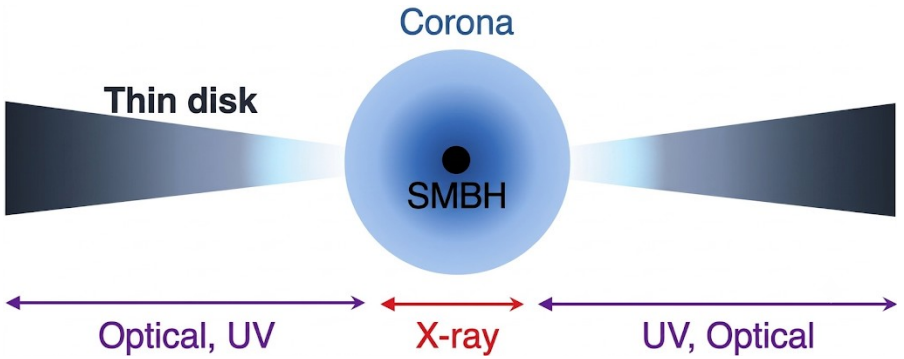


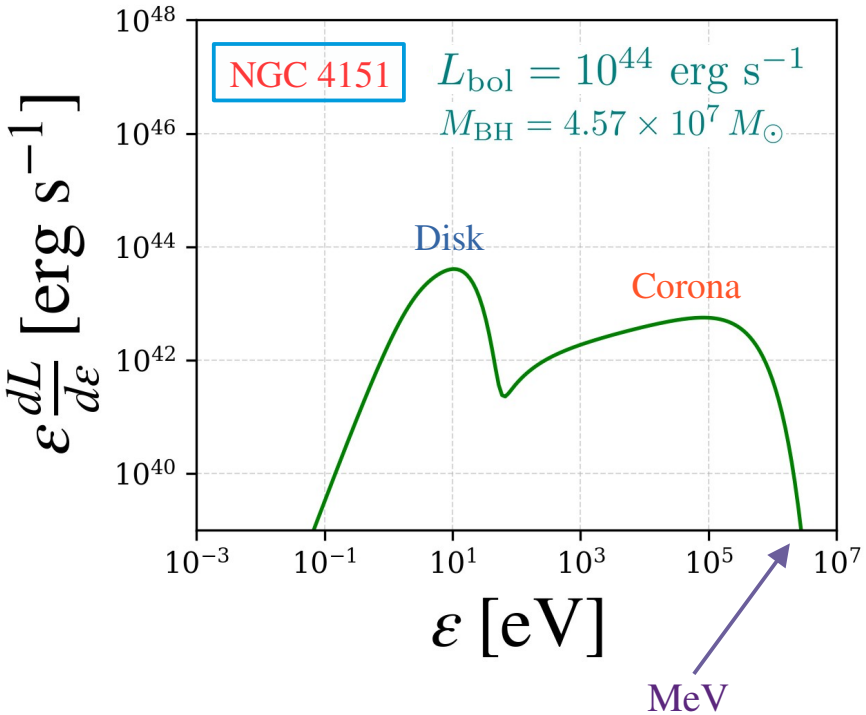


Fermi-LAT Report: GeV Energy Gamma-rays

IceCube Report: TeV Energy Neutrinos

Seed Photon Field

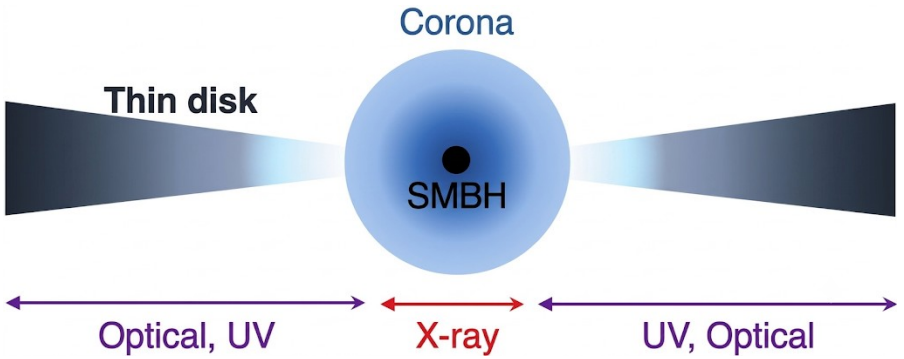


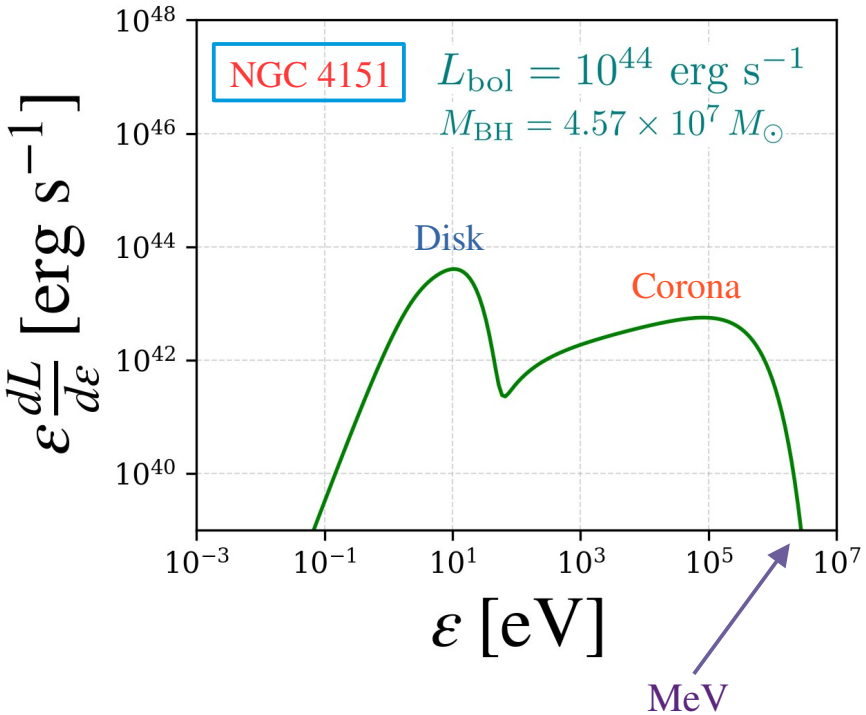


1. How this High Energy photon and neutrinos generated in AGN Corona?
2. Where they generated inside AGN Corona?
3. Are their actual production and escape region same?

K. Abe *et al.* [arXiv:2507.16527], IceCube Collaboration [arXiv:2510.13403]

Seed Photon Field





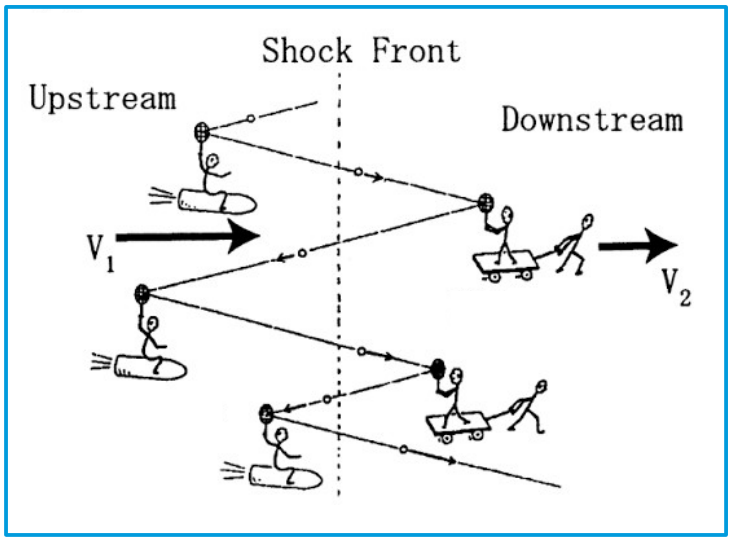
1. How this High Energy photon and neutrinos generated in AGN Corona?
2. Where they generated inside AGN Corona?
3. Are their actual production and escape region same? Not necessarily

K. Abe *et al.* [arXiv:2507.16527], IceCube Collaboration [arXiv:2510.13403]

Diffusive Shock Acceleration

- First order Fermi acceleration
- Charged particle gain high energies by repeatedly bouncing back and forth across an astrophysical shock wave.

$e \rightarrow$ High Energy γ (Inverse – Compton Emission)
$p \rightarrow$ High Energy ν (pp and pγ interaction)



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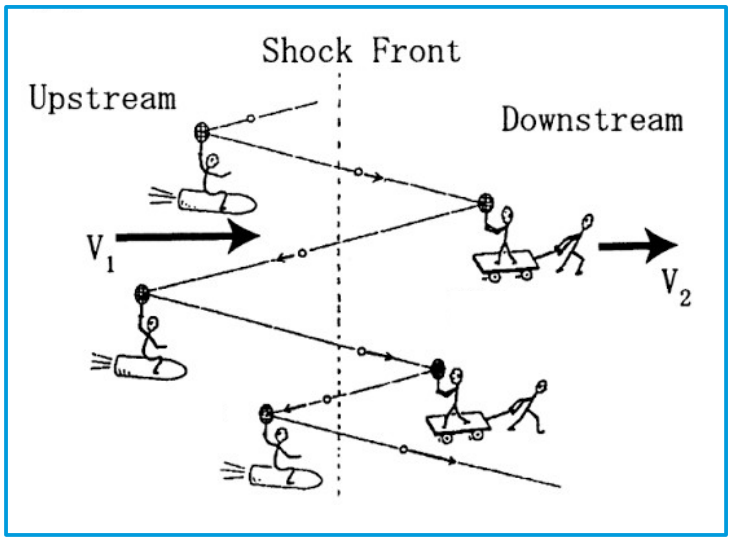
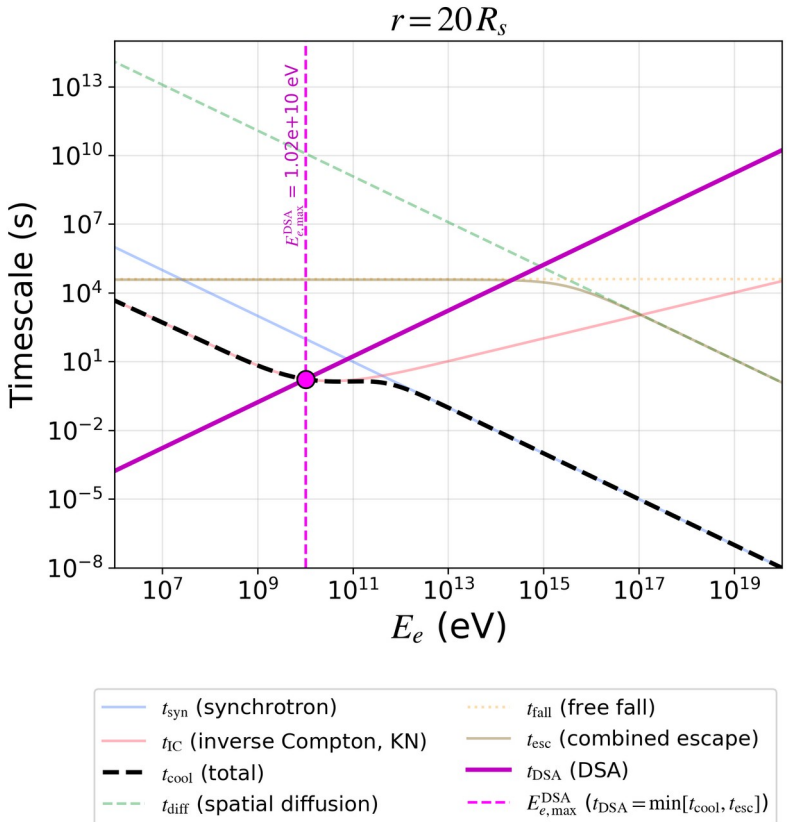
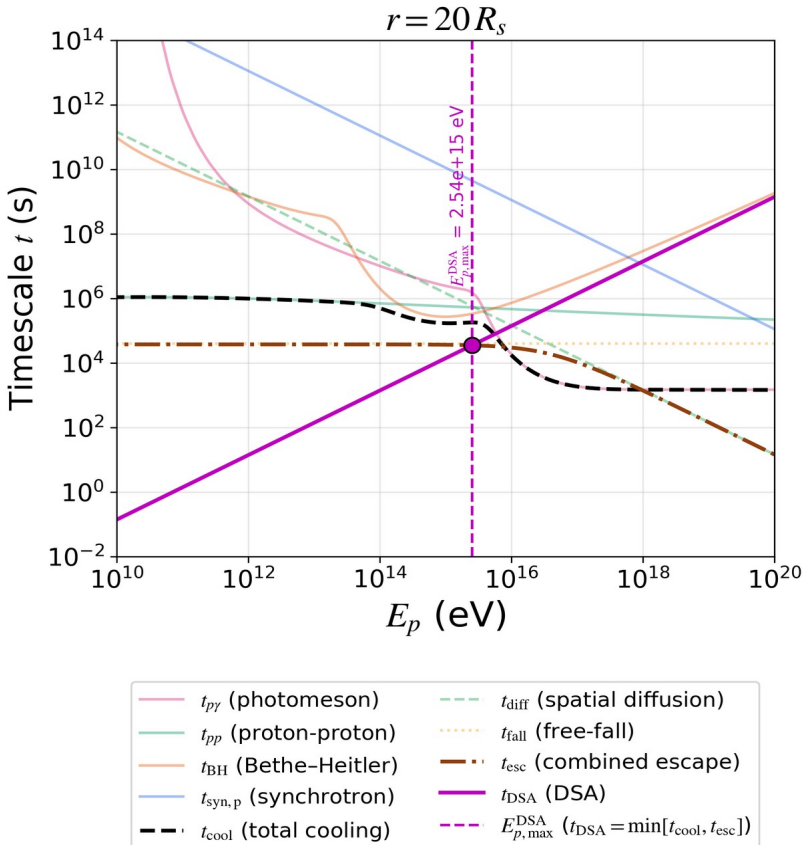


Diffusive Shock Acceleration

- Cooling Energy loss
- Particle Escape Rate

Maximum Energy



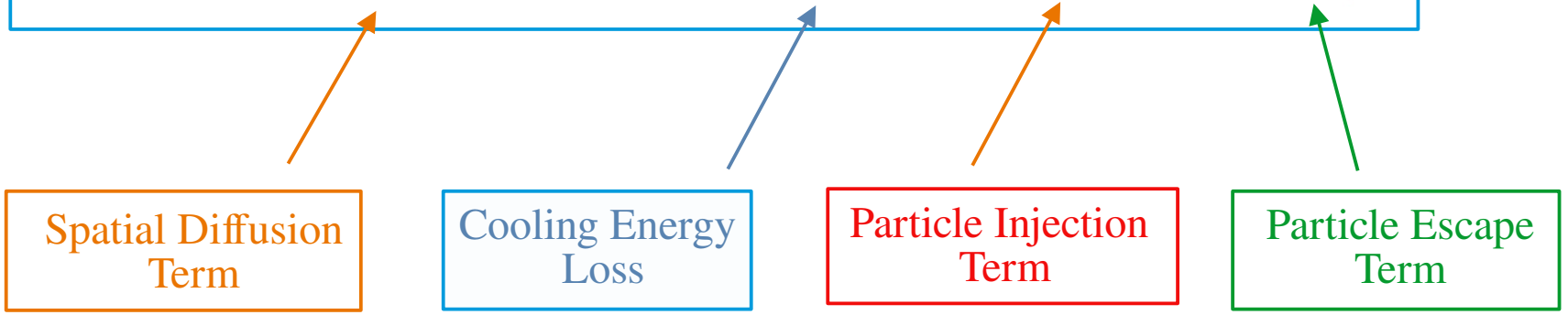


E_{max}

Non-Thermal Particle Transport

Particle Transport Equation Inside AGN Corona

$$\frac{\partial n_i}{\partial t} = \frac{1}{r^2}\frac{\partial}{\partial r}\left[r^2 D_i(E,r)\frac{\partial n_i}{\partial r}\right] - \frac{\partial}{\partial E}\left(\dot{E}_i n_i\right) + Q_i(E,r) - \frac{n_i}{t_{\mathrm{esc},i}}$$



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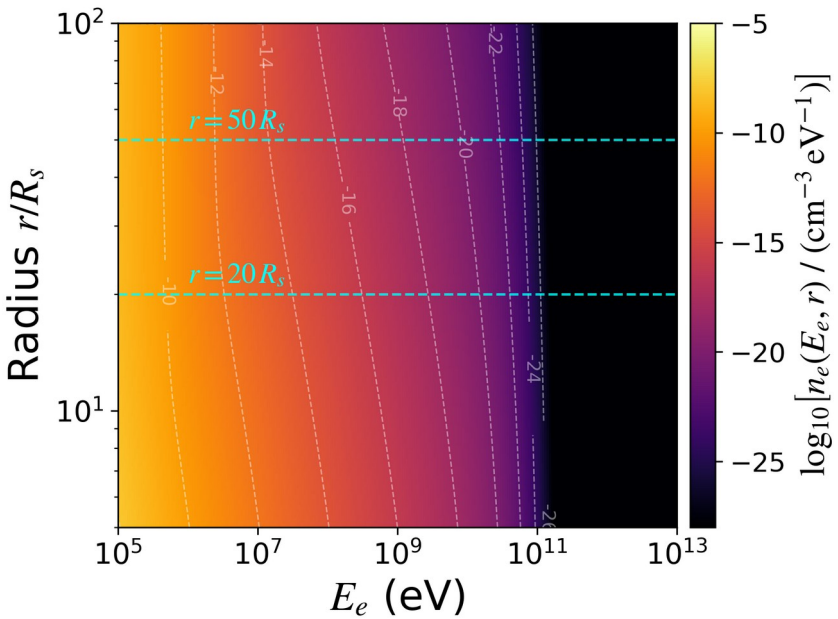
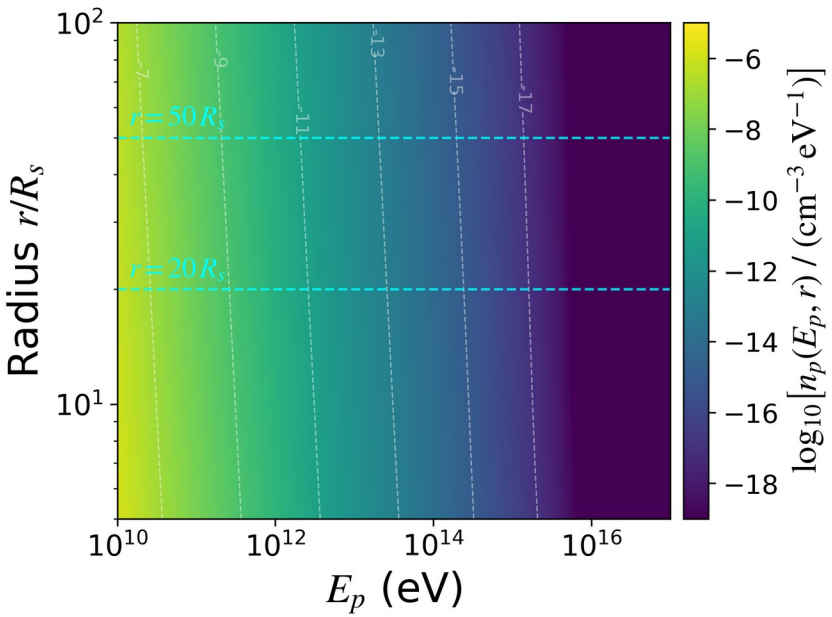
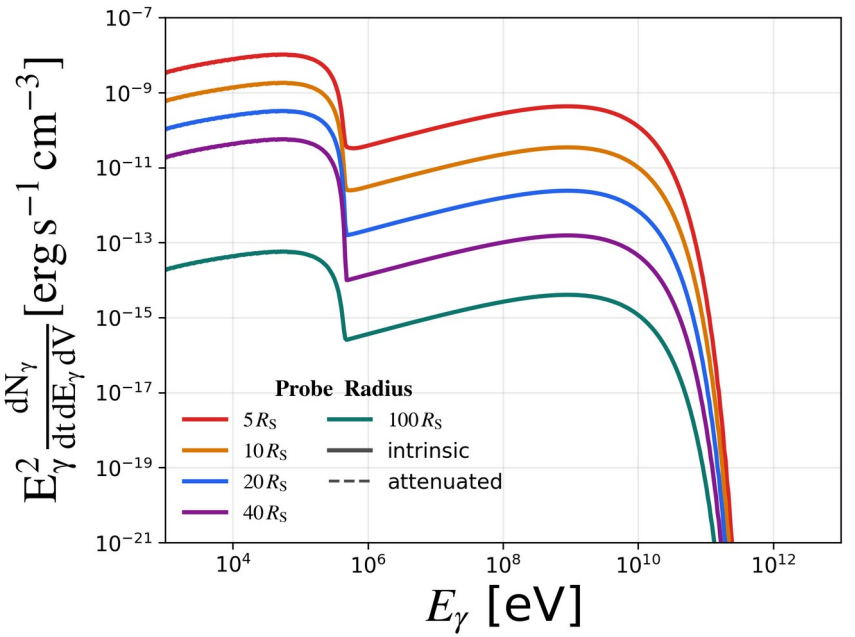




Inverse Compton Emission

$$j_{\mathrm{IC}}^{\mathrm{int}}(E_\gamma, r) = \int_{E_{e,\min}}^{E_{e,\max}} n_e(E_e, r) P_{\mathrm{IC}}(E_\gamma, E_e, r)\, dE_e$$

Intrinsic Emissivity



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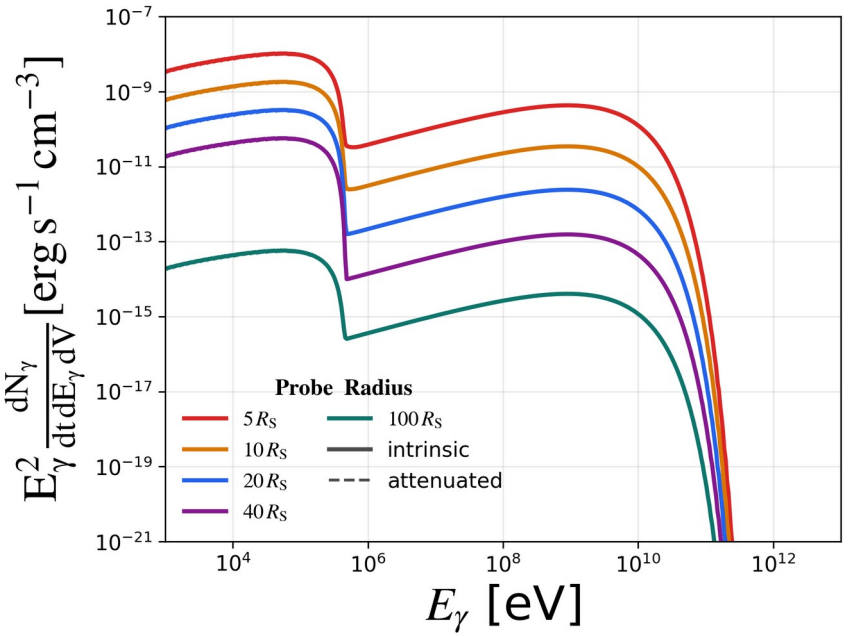
Intrinsic Emissivity

pair production $(\gamma\gamma \rightarrow e^+e^-)$



Inverse Compton Emission

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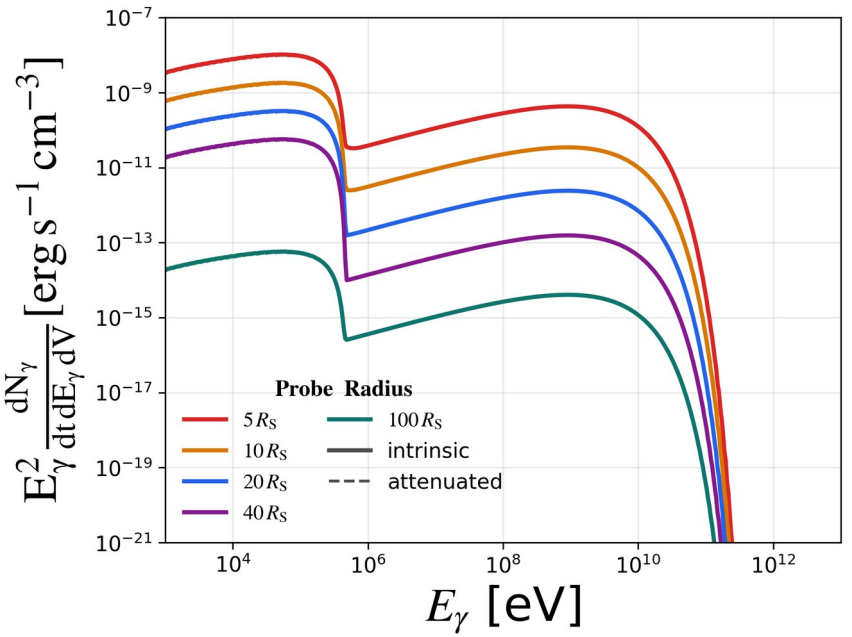
Intrinsic Emissivity

pair production $(\gamma\gamma \rightarrow e^+e^-)$

$$\tau_{\gamma\gamma}(E_\gamma, r) = \int_r^\infty dr' \int_{-1}^{1} d\mu \, \frac{1-\mu}{2} \times \int_{\varepsilon_{\rm th}}^{\infty} d\varepsilon \, n_{\rm ph}(\varepsilon, r') \, \sigma_{\gamma\gamma}(E_\gamma, \varepsilon, \mu)$$

Optical Depth



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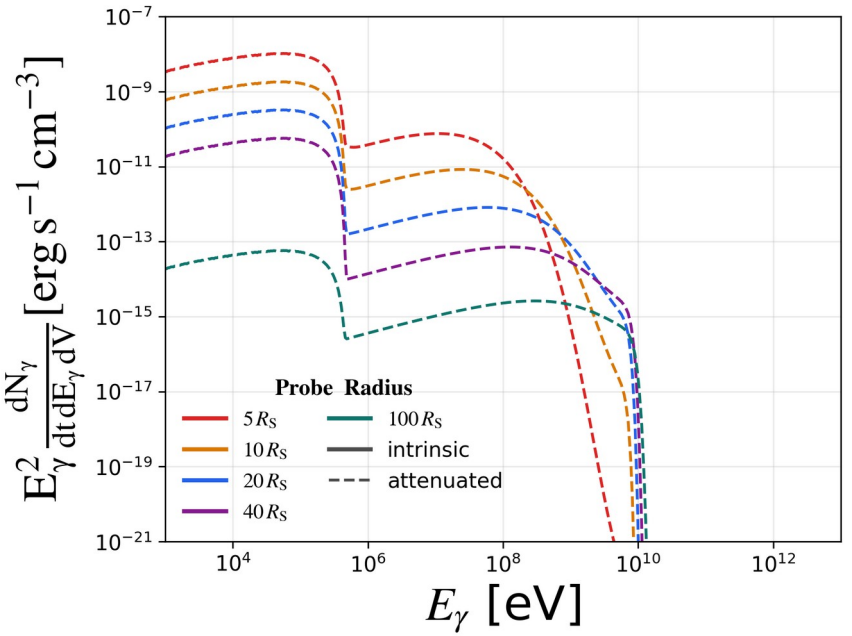
Optical Depth



$$j_{\rm IC}^{\rm esc}(E_\gamma, r) = j_{\rm IC}^{\rm int}(E_\gamma, r)\, \exp[-\tau_{\gamma\gamma}(E_\gamma, r)]$$

Photon Sphere

$$j_{\rm IC}^{\rm esc}(E_\gamma, r) = j_{\rm IC}^{\rm int}(E_\gamma, r)\ \exp[-\tau_{\gamma\gamma}(E_\gamma, r)]$$

$$\tau_{\gamma\gamma}(E_\gamma,\, r_\gamma) = 1$$

Photon Sphere

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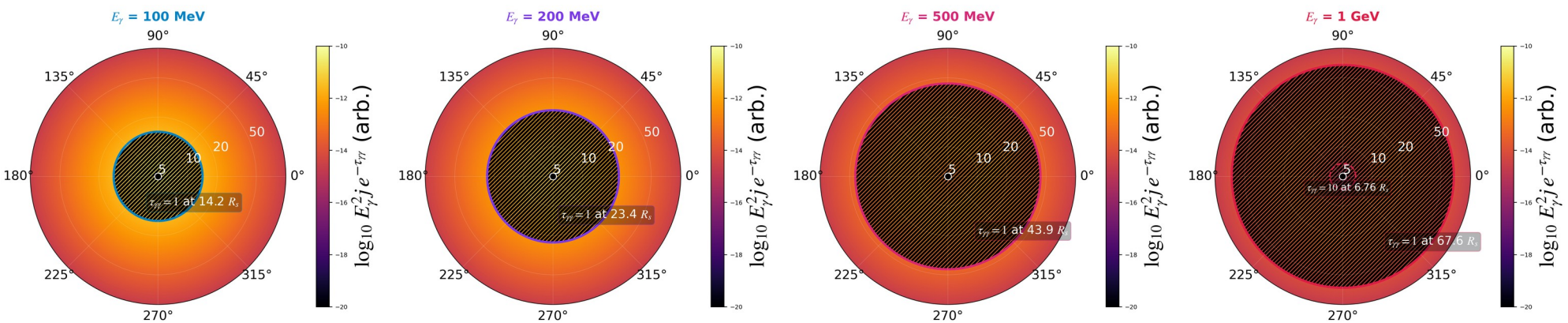
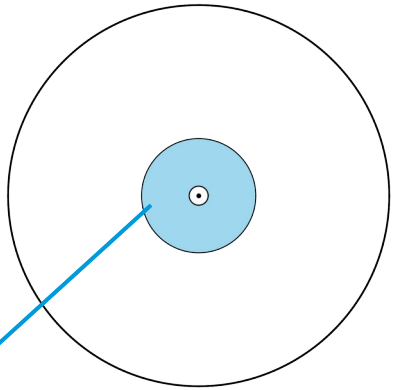
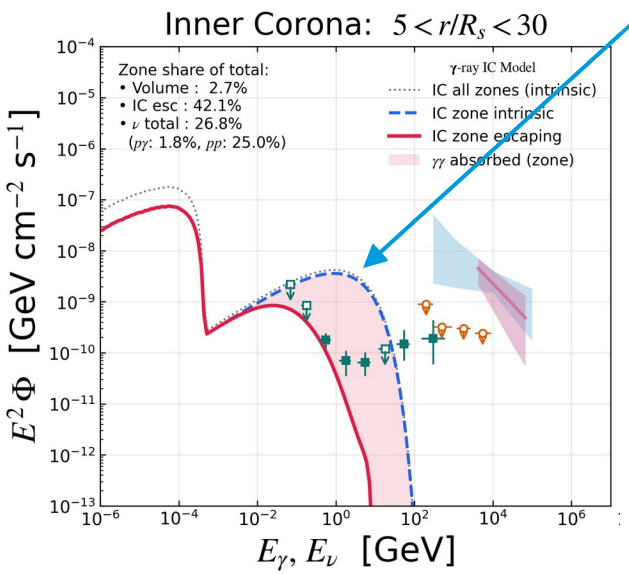


Multi-Zone Emission



3D Volume Fraction = 2.7%



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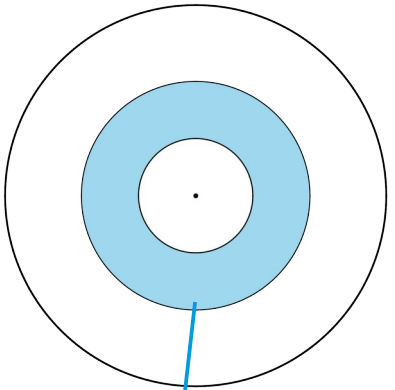
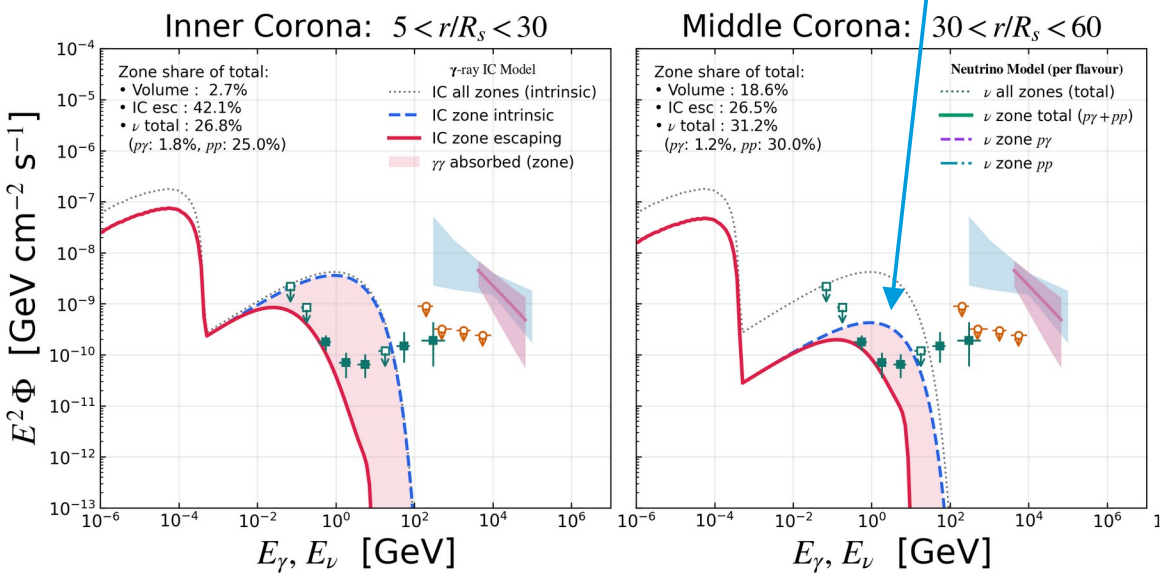
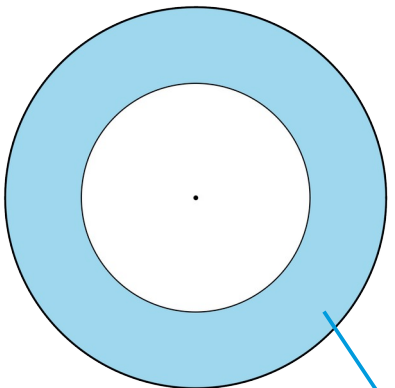


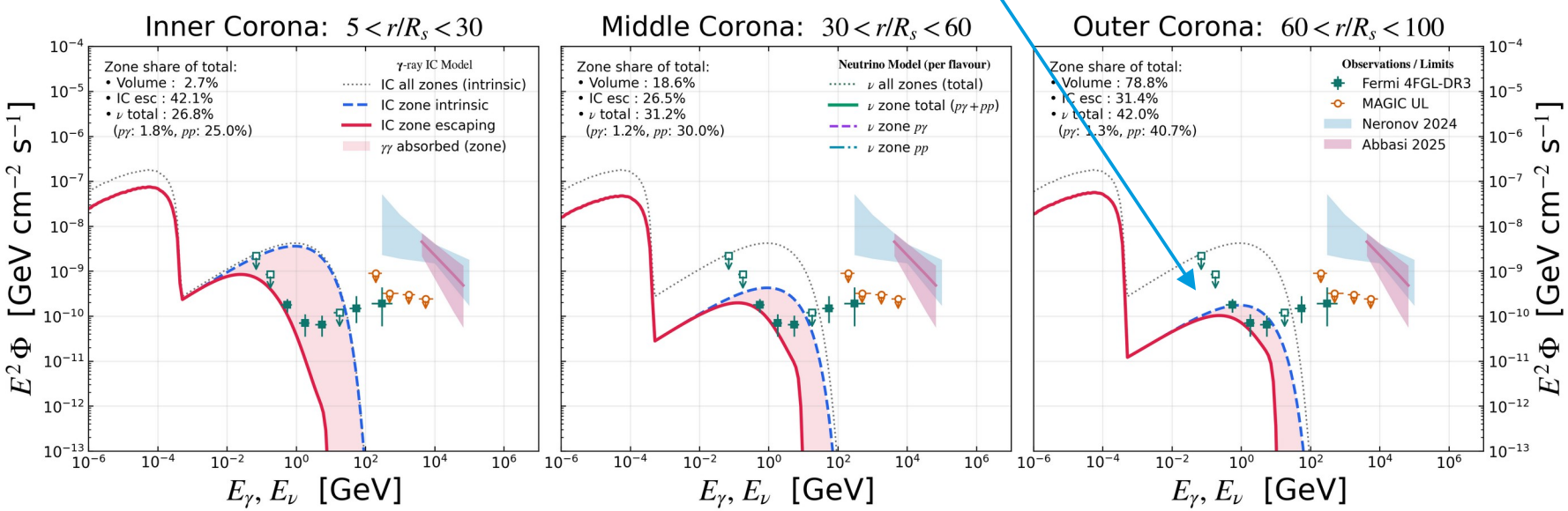
3D Volume Fraction = 26.5%



Multi-Zone Emission

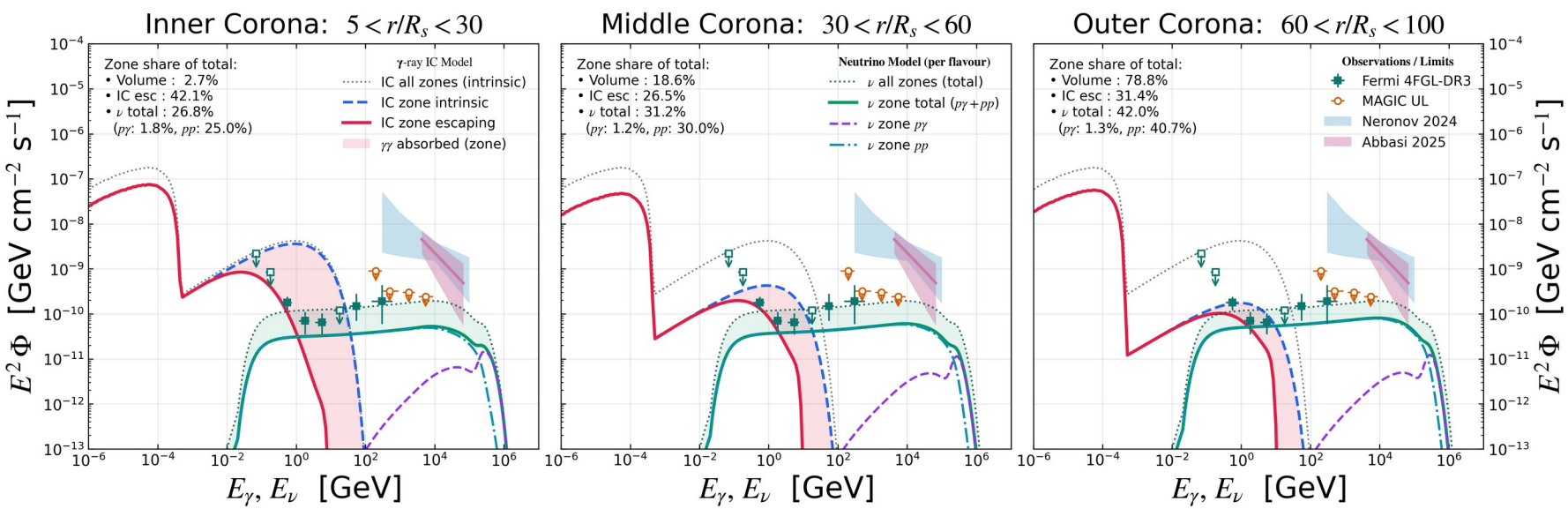


3D Volume Fraction = 78.8%



Multi-Zone Emission

$$pp \to \pi^{\pm} \to \nu_\mu\,(\bar{\nu}_\mu)$$
$$\to \pi^0 \to \gamma\gamma$$



Thank You!

Characteristic Timescale

$$t_{\mathrm{cool},e}^{-1} = t_{\mathrm{syn},e}^{-1} + t_{\mathrm{IC},e}^{-1}$$

Electron Cooling

$$t_{\mathrm{cool},p}^{-1} = t_{\mathrm{syn},p}^{-1} + t_{pp}^{-1} + t_{p\gamma}^{-1} + t_{\mathrm{BH}}^{-1}$$

Proton Cooling

Particle Escape

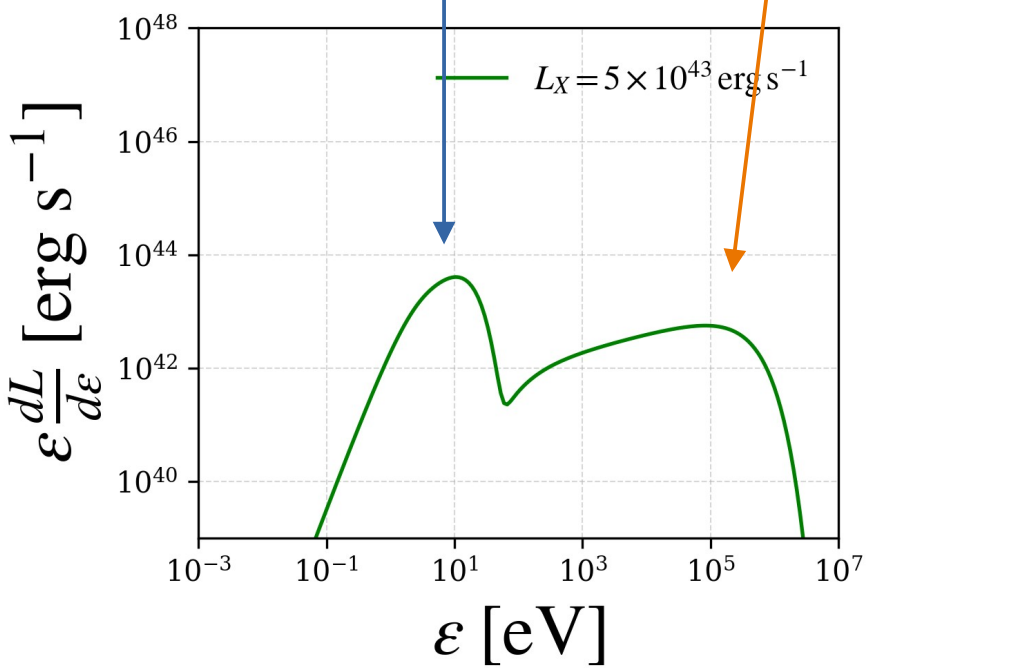
$$t_{\mathrm{esc},i}^{-1} = t_{\mathrm{diff},i}^{-1} + t_{\mathrm{fall}}^{-1}$$

Target Photon Field

$$\varepsilon^2 n_{\rm ph}(\varepsilon, r) \simeq \frac{1}{4\pi r^2 c}\left[\varepsilon\frac{dL_{\rm disk}}{d\varepsilon} + (1+\tau_{\rm T})\,\varepsilon\frac{dL_X}{d\varepsilon}\right]$$

big blue bump

coronal X-ray



Optical Depth and Photospheric Radius

