

Fitting the spectral energy distributions of blazars with the JetSeT code



JetSeT

Jets SED modeler and fitting Tool

Andrea Tramacere

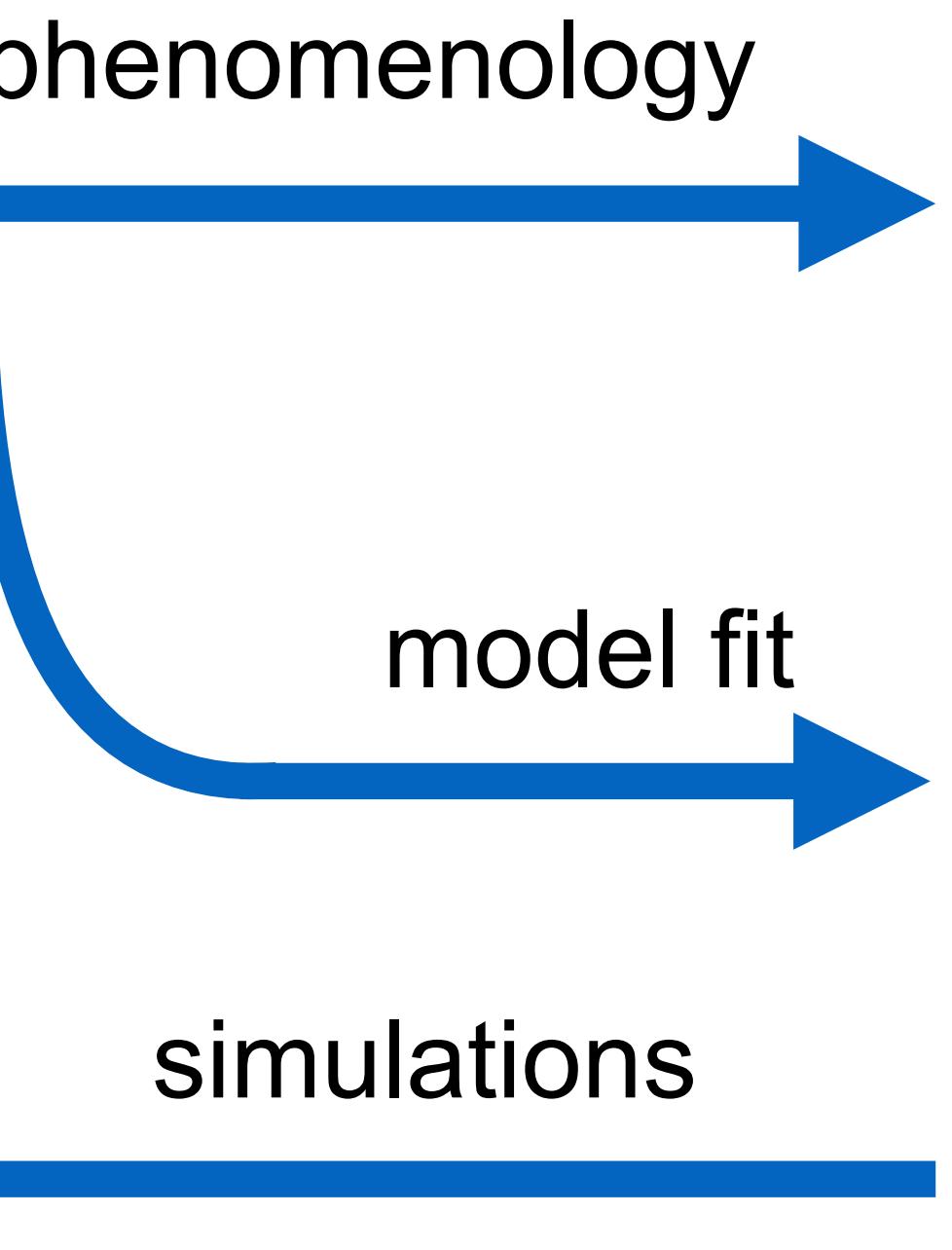
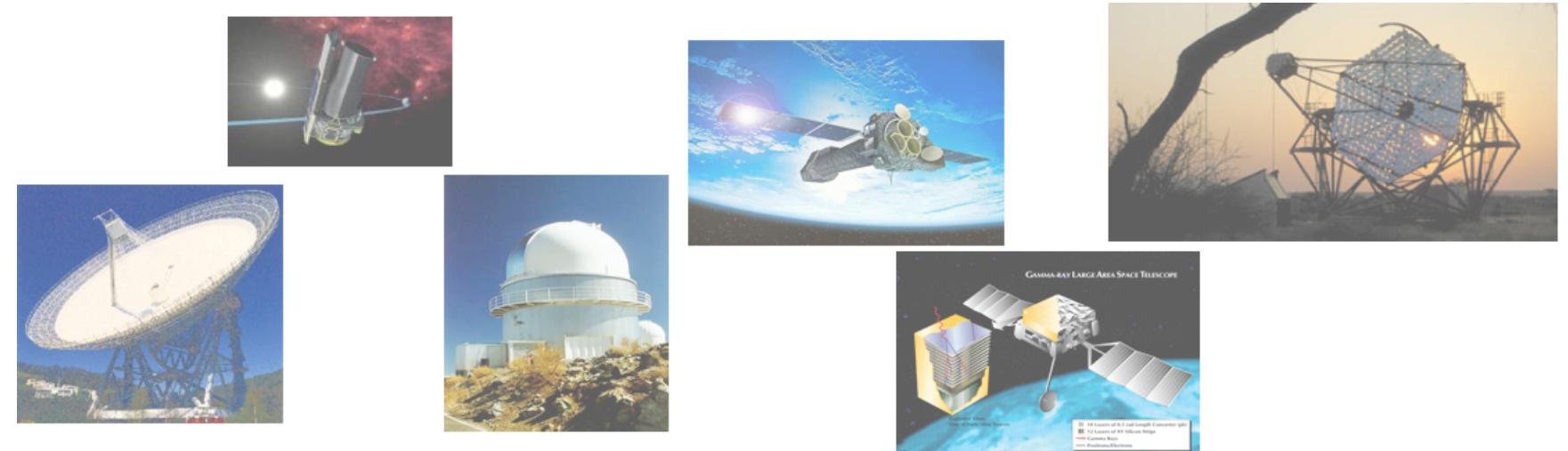
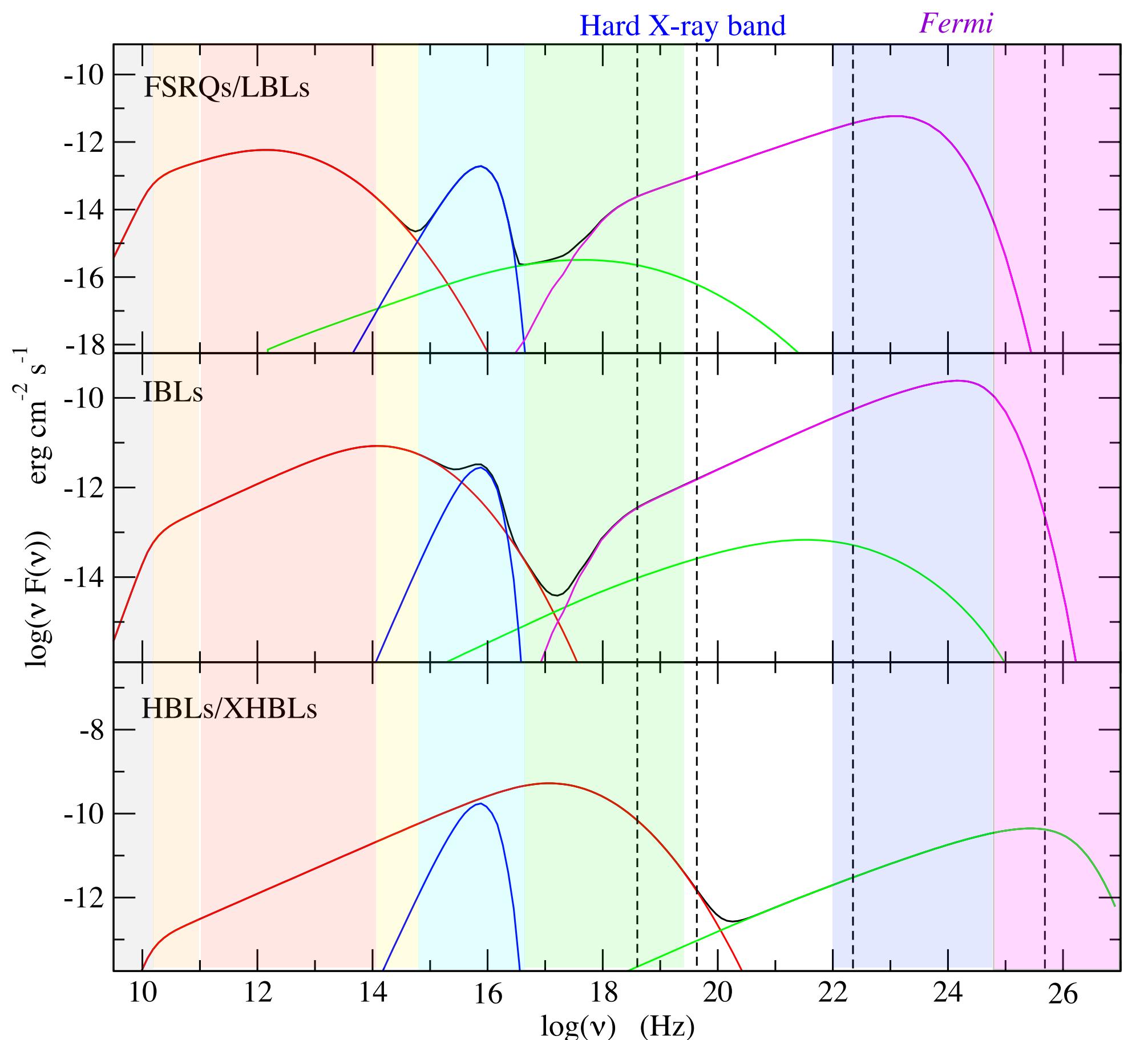
<https://jetset.readthedocs.io/en/latest/>

<https://github.com/andreatramacere/jetset>

<https://www.facebook.com/jetsetastro/>

JetSeT :Blazars in a nutshell

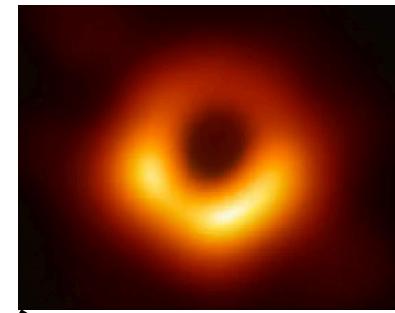
data



jet/disk

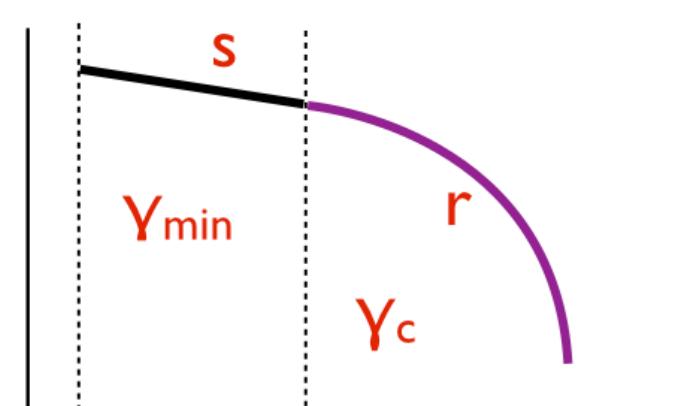
acc.

em.

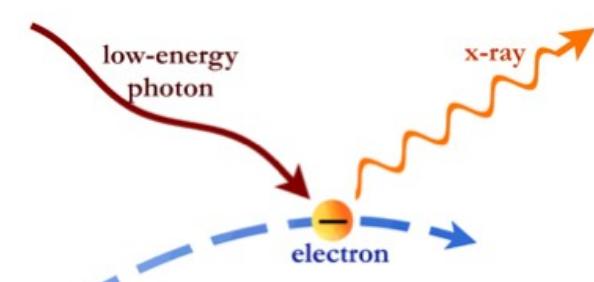
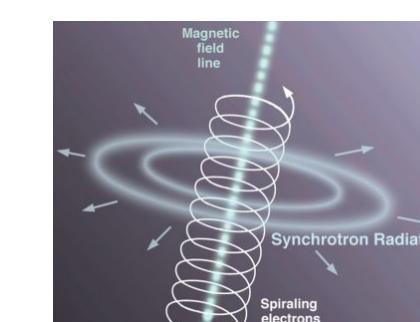


model

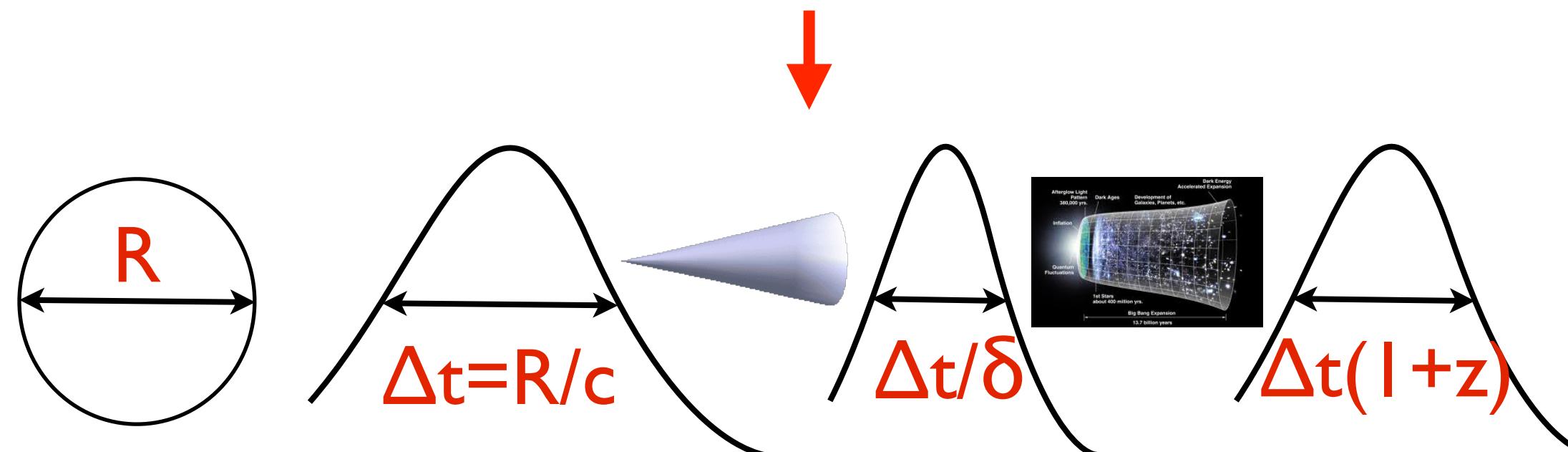
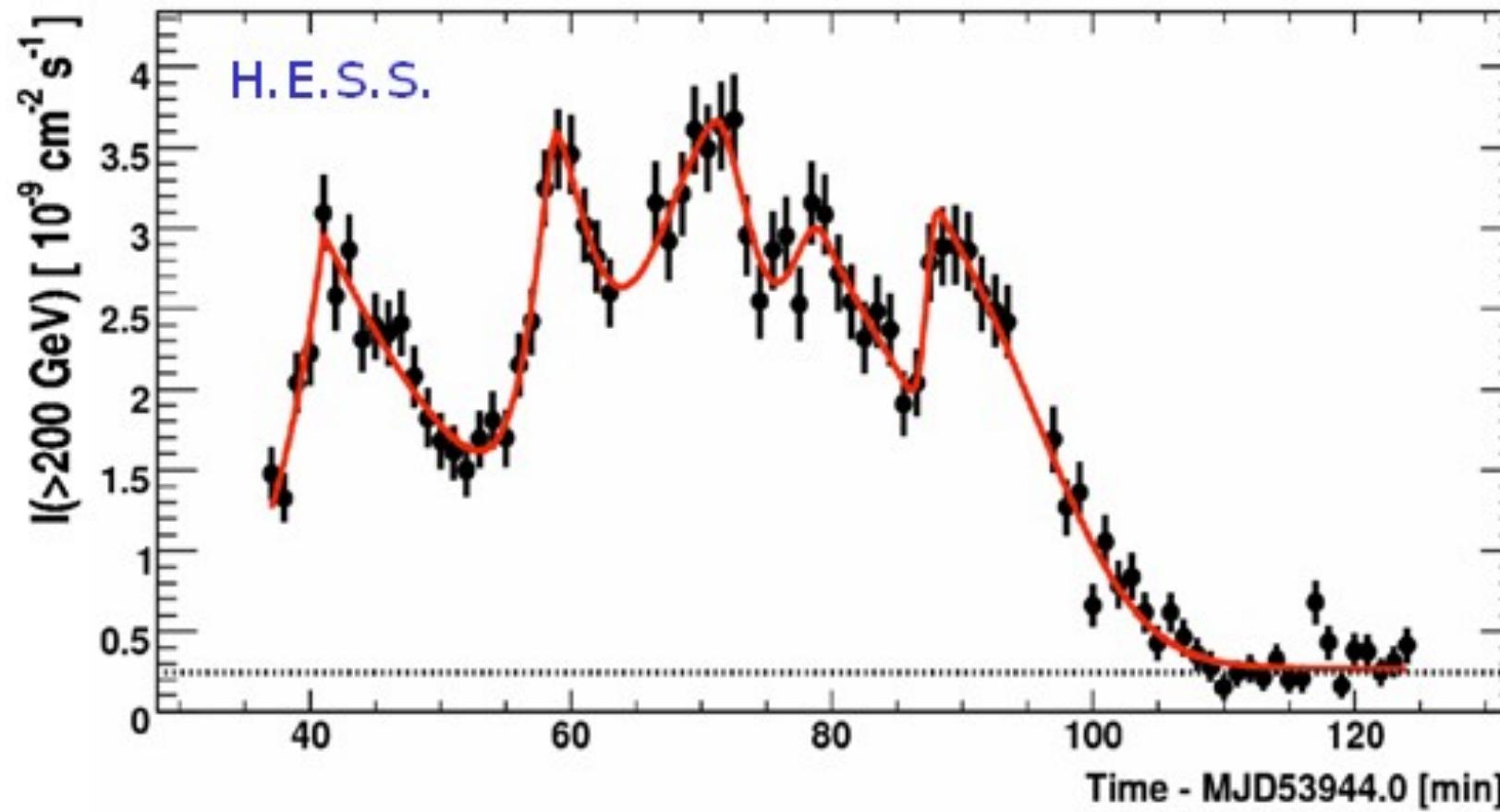
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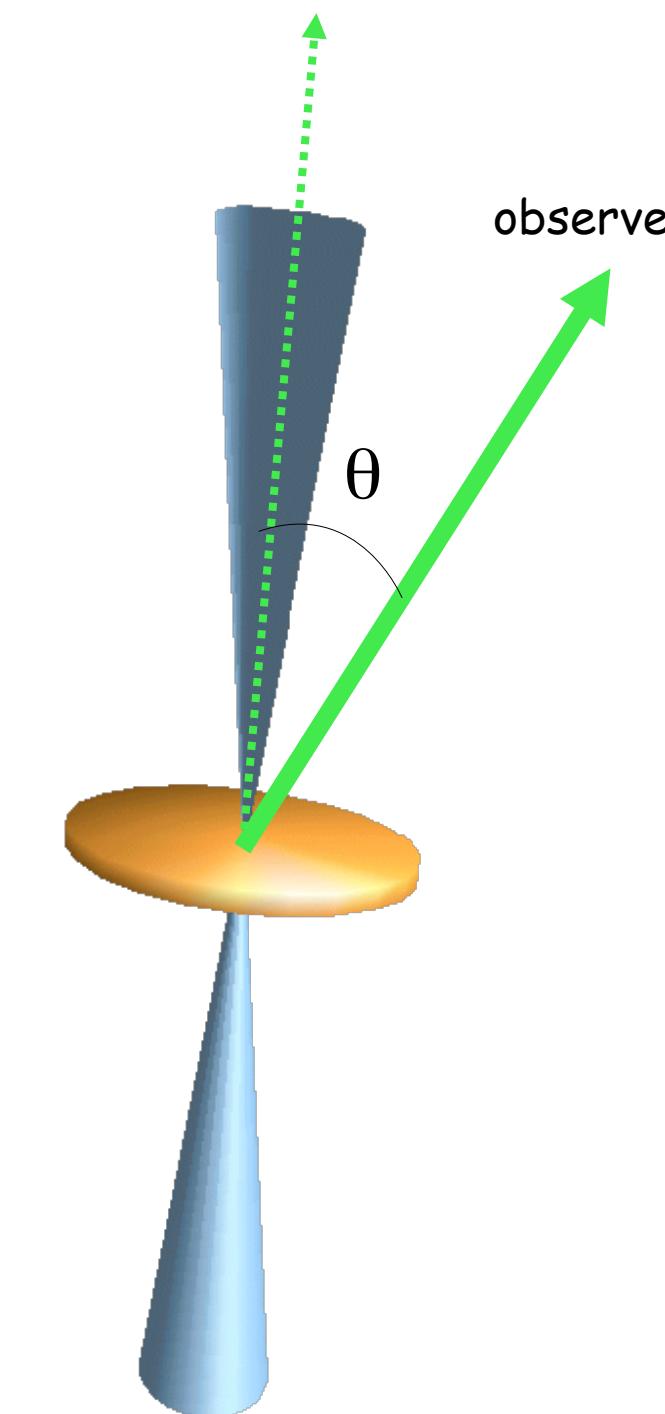
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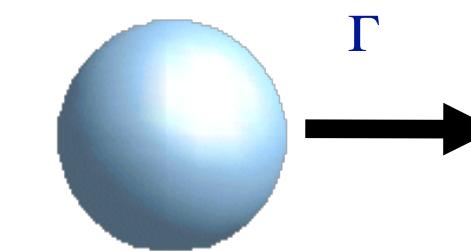
Beamed Emission



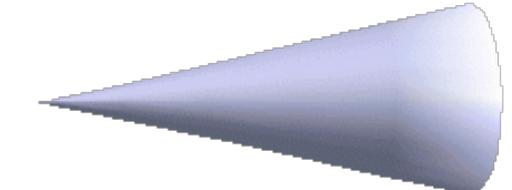
$$R \leq c \Delta t \delta / (1+z)$$



rest frame :
isotropic emission

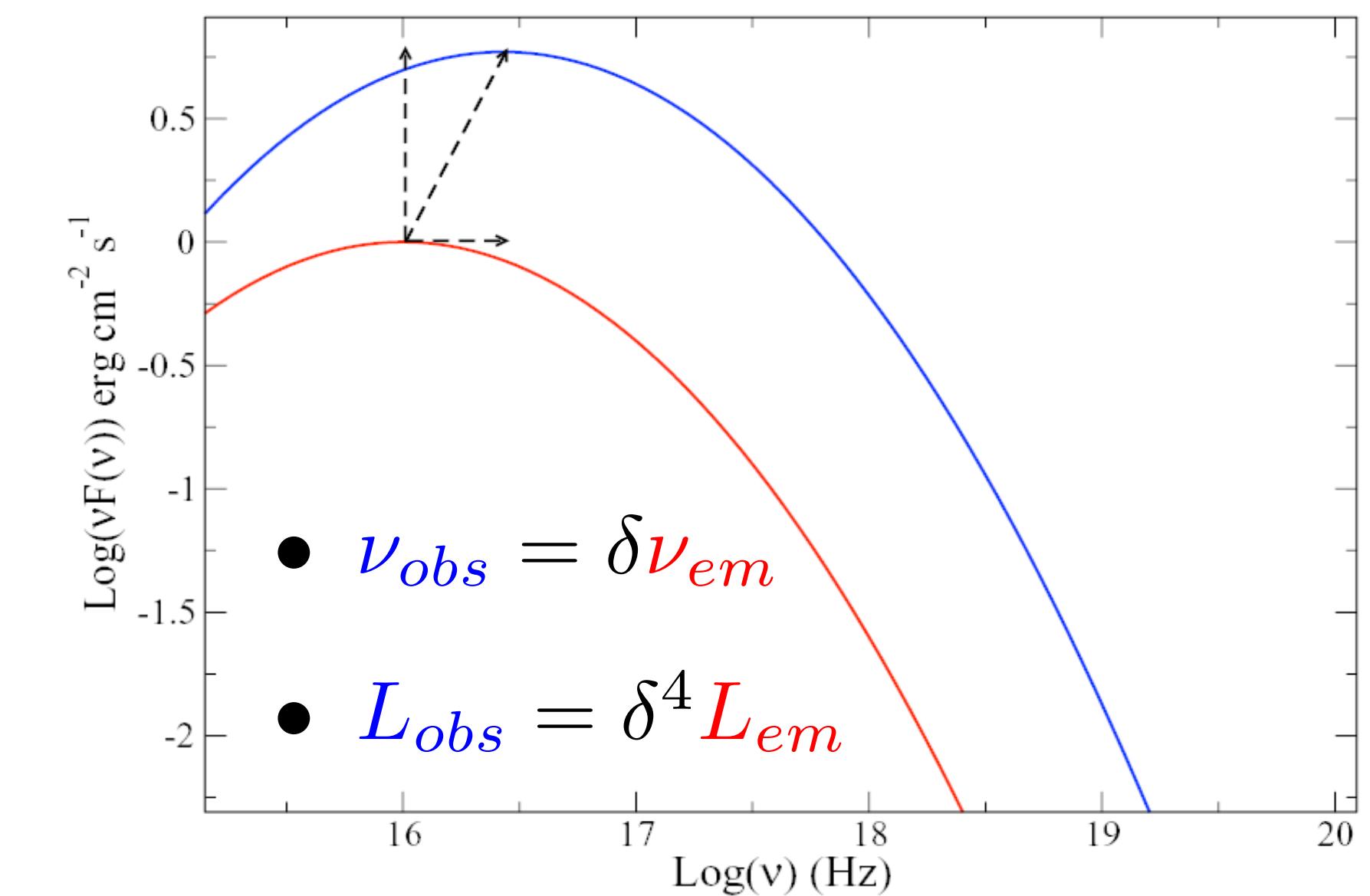


Observer frame: beamed

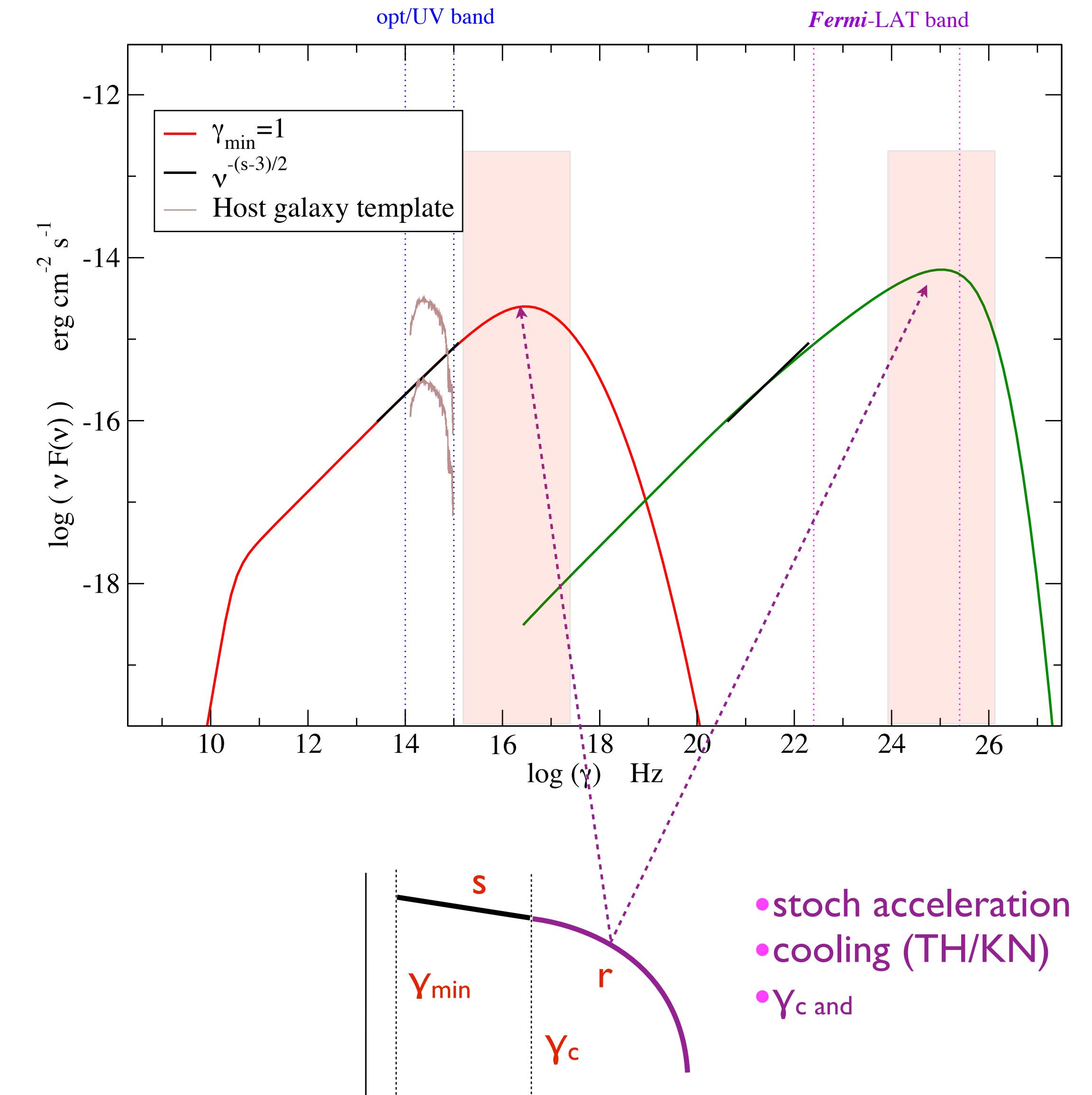
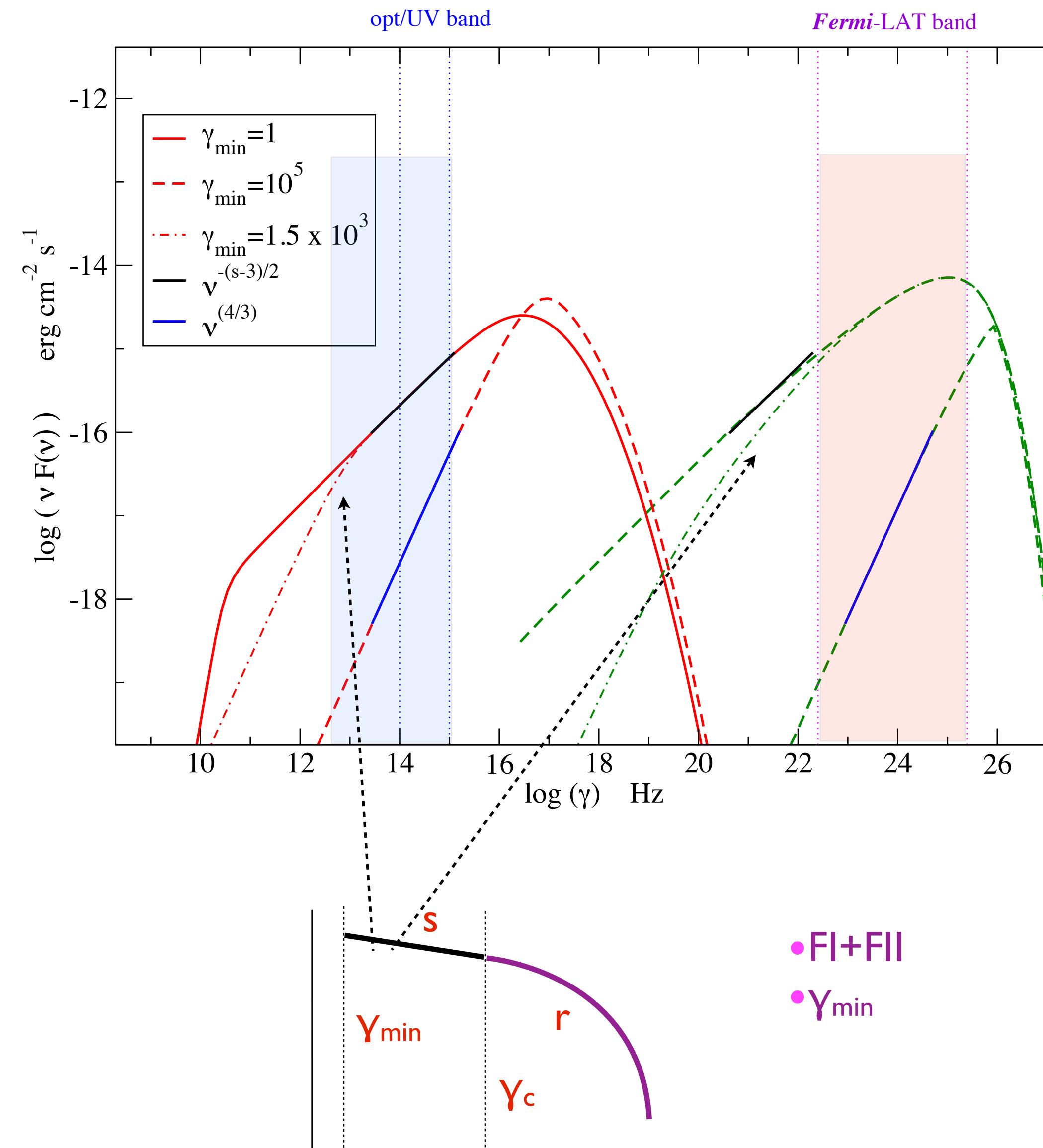


Beaming factor:

- $\delta = \frac{1}{\Gamma(1-\beta \cos(\theta))}$
- $\theta = 1/\Gamma$



SED shaping and constraining the electron distribution



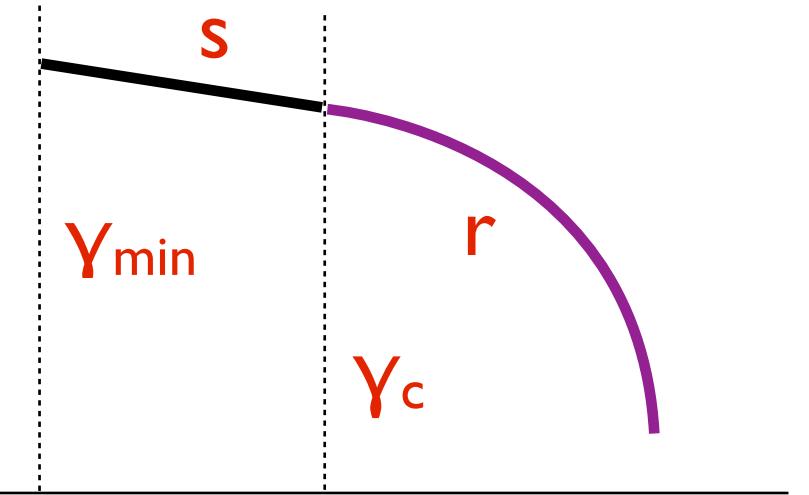
synchrotron basics

single particle

$$P_e(\nu, \gamma) = \frac{\sqrt{3}e^3 B \sin \alpha}{2m_e c^2} F(x)$$

$$\nu_c = \frac{3\gamma^2 q B \sin \alpha}{4\pi m_e c}$$

$$\nu_s \propto 10^6 B \gamma^2 \sin(\alpha)$$



particle distribution

$$N(\gamma) \propto \gamma^{-s}$$

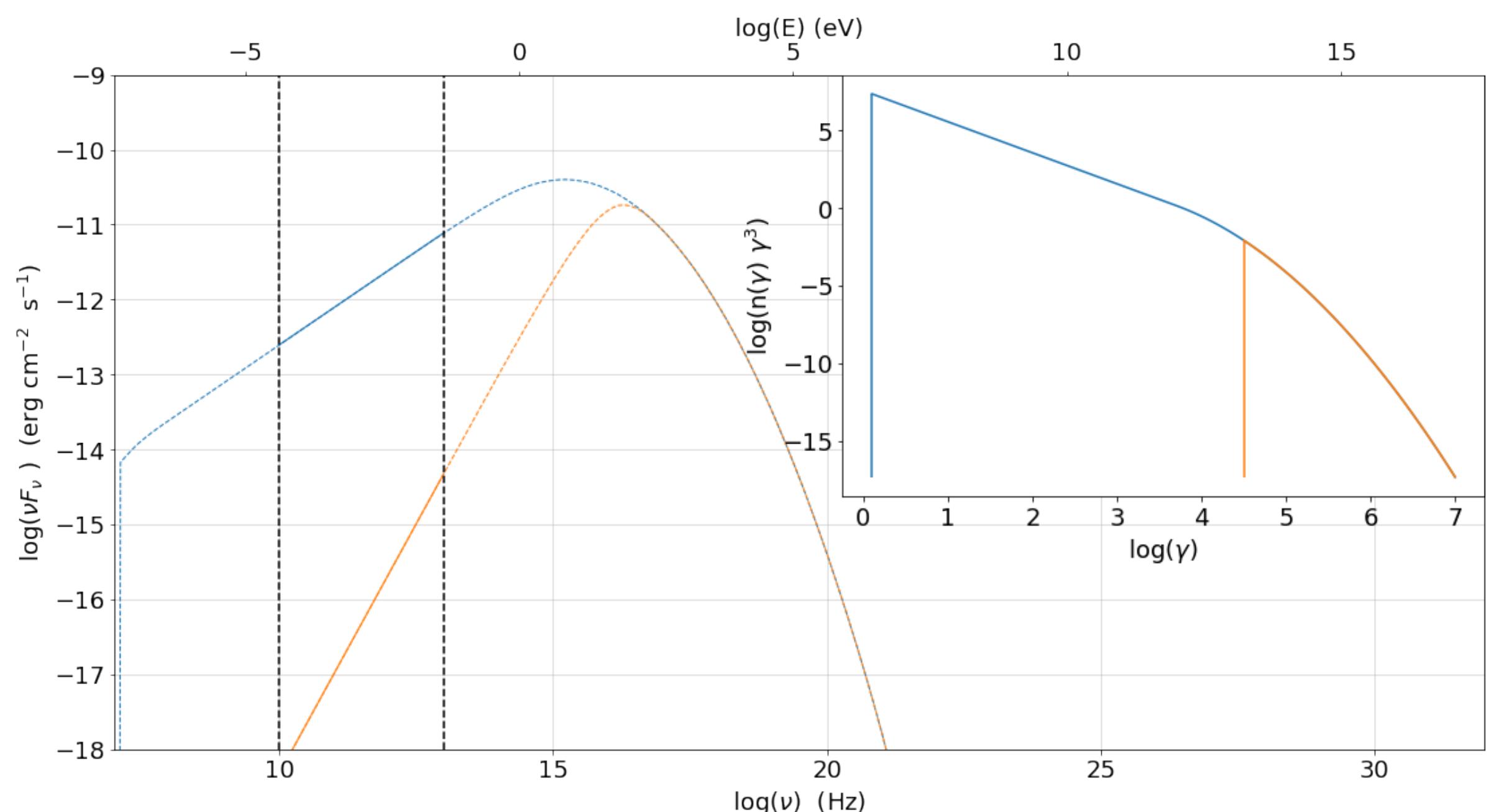
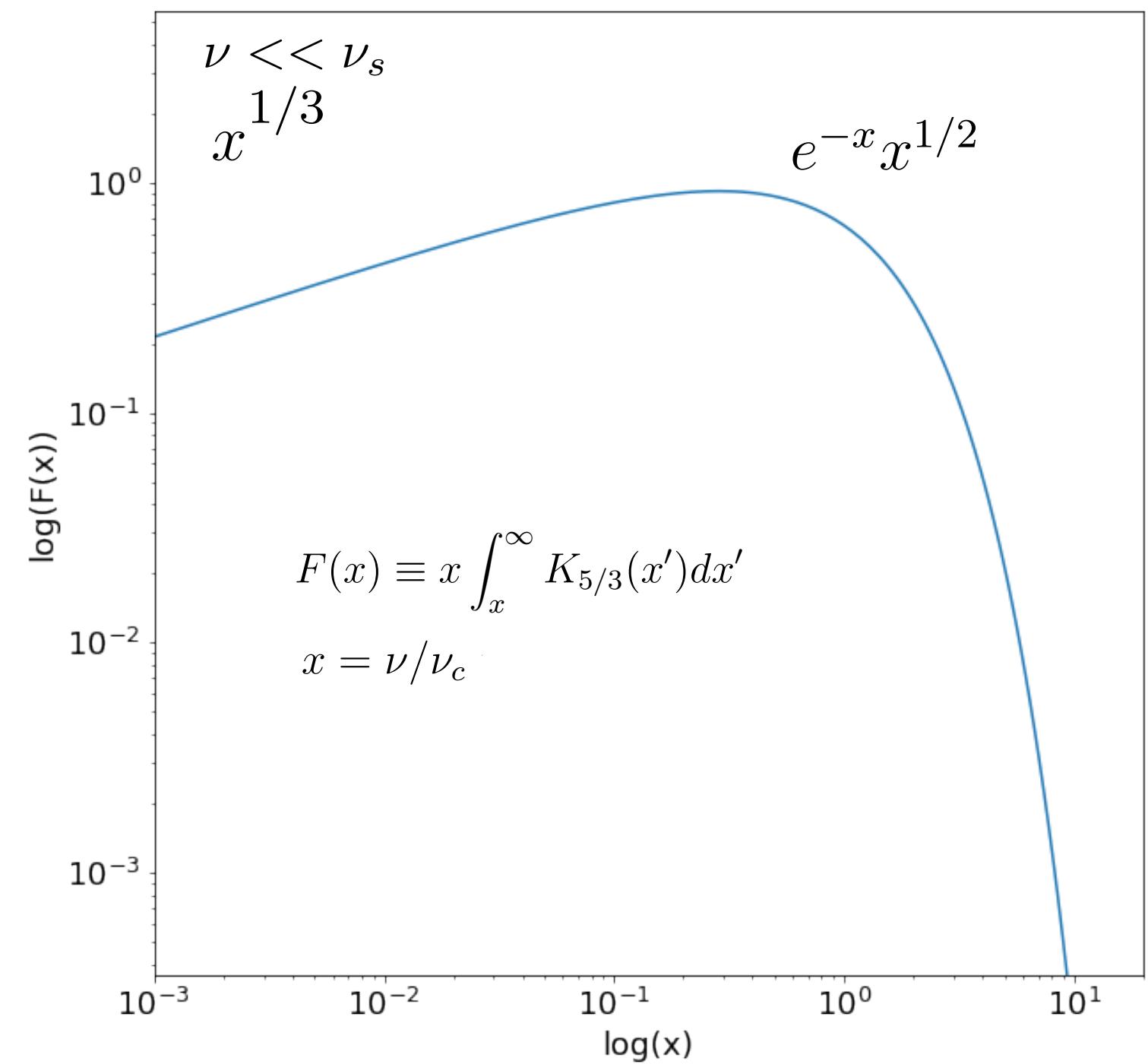
$$j_\nu^S(\nu) = \frac{1}{4\pi} \int_{\gamma_{min}}^{\gamma_{max}} P(\nu, \gamma) N(\gamma) d\gamma \propto \nu^{-\frac{s-1}{2}}$$

δ-approx relations

$$\text{SED} \propto N(\gamma) \gamma^3$$

$$S_p^{Sync} \sim \frac{dN(\gamma)}{d\gamma} \gamma_{3p}^3 B^2 \delta^4$$

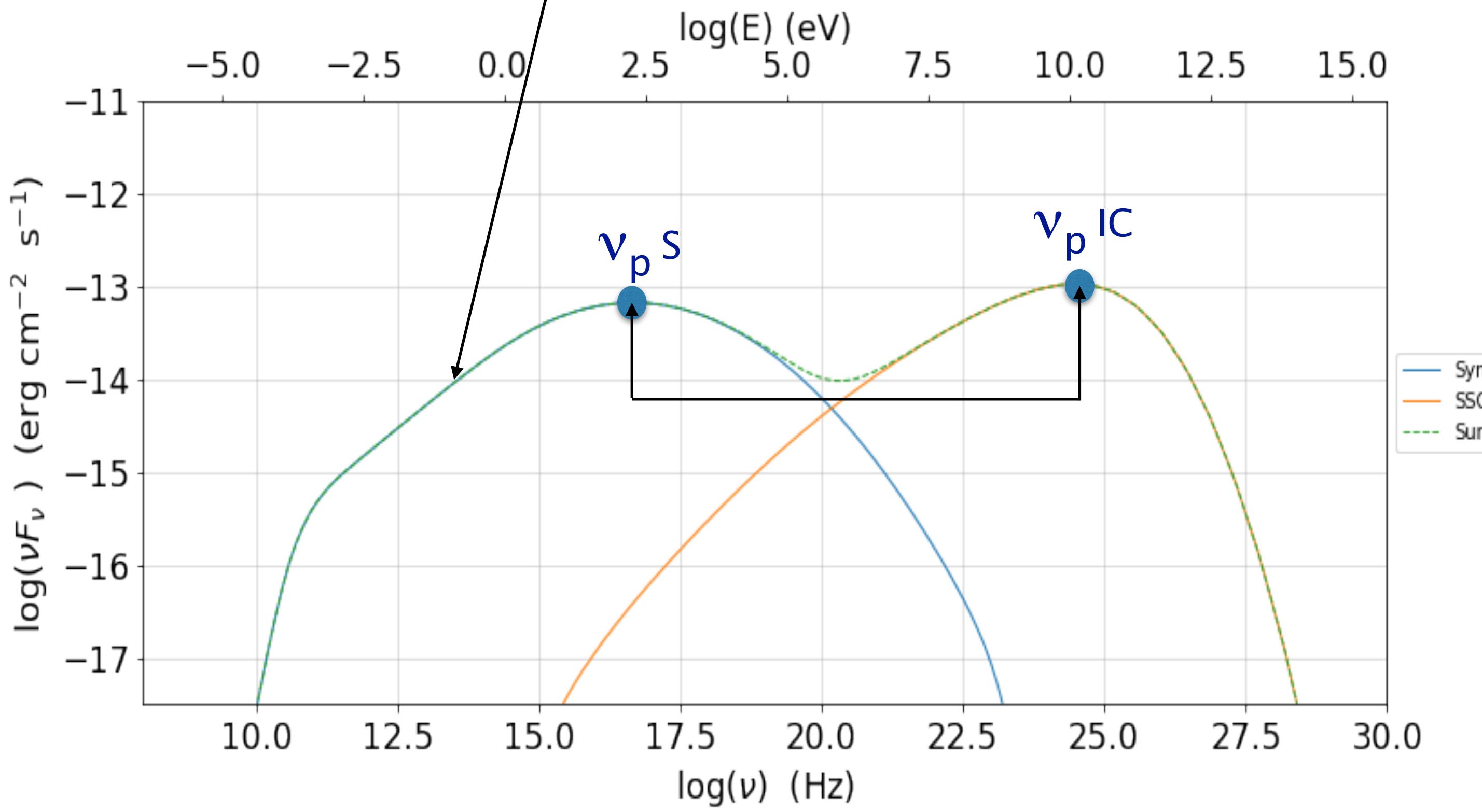
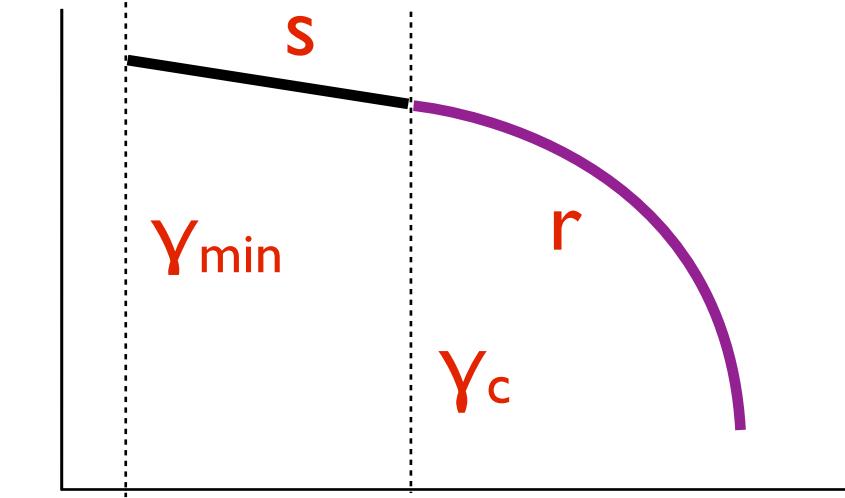
$$\nu_p^{Sync} \sim 3.2 \times 10^6 (\gamma_{3p})^2 B \delta$$



IC emission basics

$$j_{\nu}^{SSC} = \frac{3}{4} \frac{h\nu\sigma_T c}{4\pi} \int_0^{\infty} n(\nu_0) d\nu_0 \int_{\gamma_{min}}^{\gamma_{max}} \frac{N(\gamma)}{\gamma^2} F_c(\gamma, \nu, \nu_0) d\gamma$$

↑
cross section



soft photon energy
in the e- rest frame

$$\epsilon' = \frac{h\nu'}{m_e c^2}$$

$$\epsilon' \ll m_e c^2$$

TH regime

$$\nu_p IC / \nu_p S \sim (4/3) \gamma_p^2$$

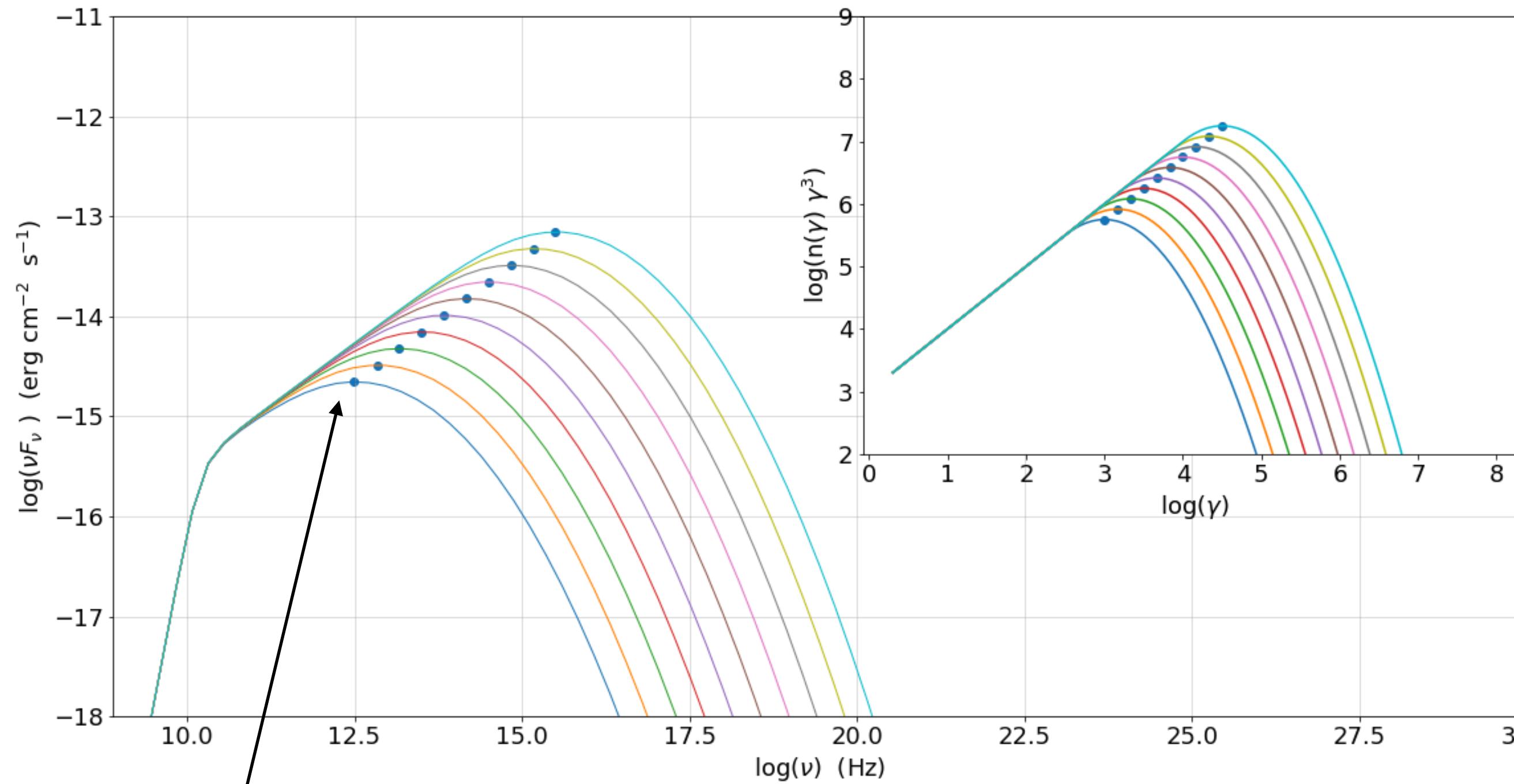
$$\epsilon' \geq m_e c^2$$

KN regime

$$\nu_p IC / \nu_p S \sim \gamma_p$$

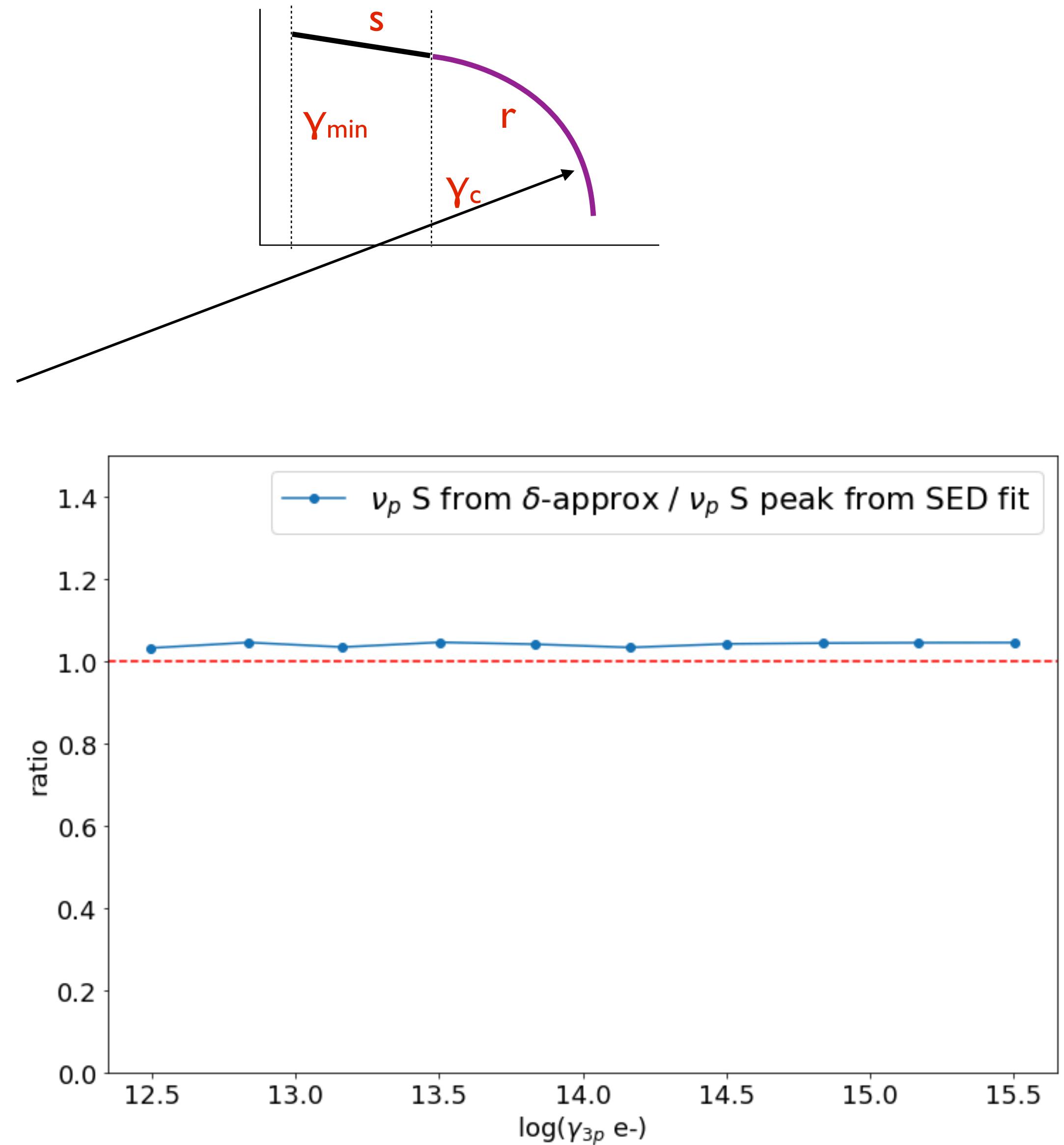
$$h\nu_p IC \sim m_e c^2 \gamma_p$$

Synchrotron emission Estimate of $\gamma_p s$ from $\nu_p s$

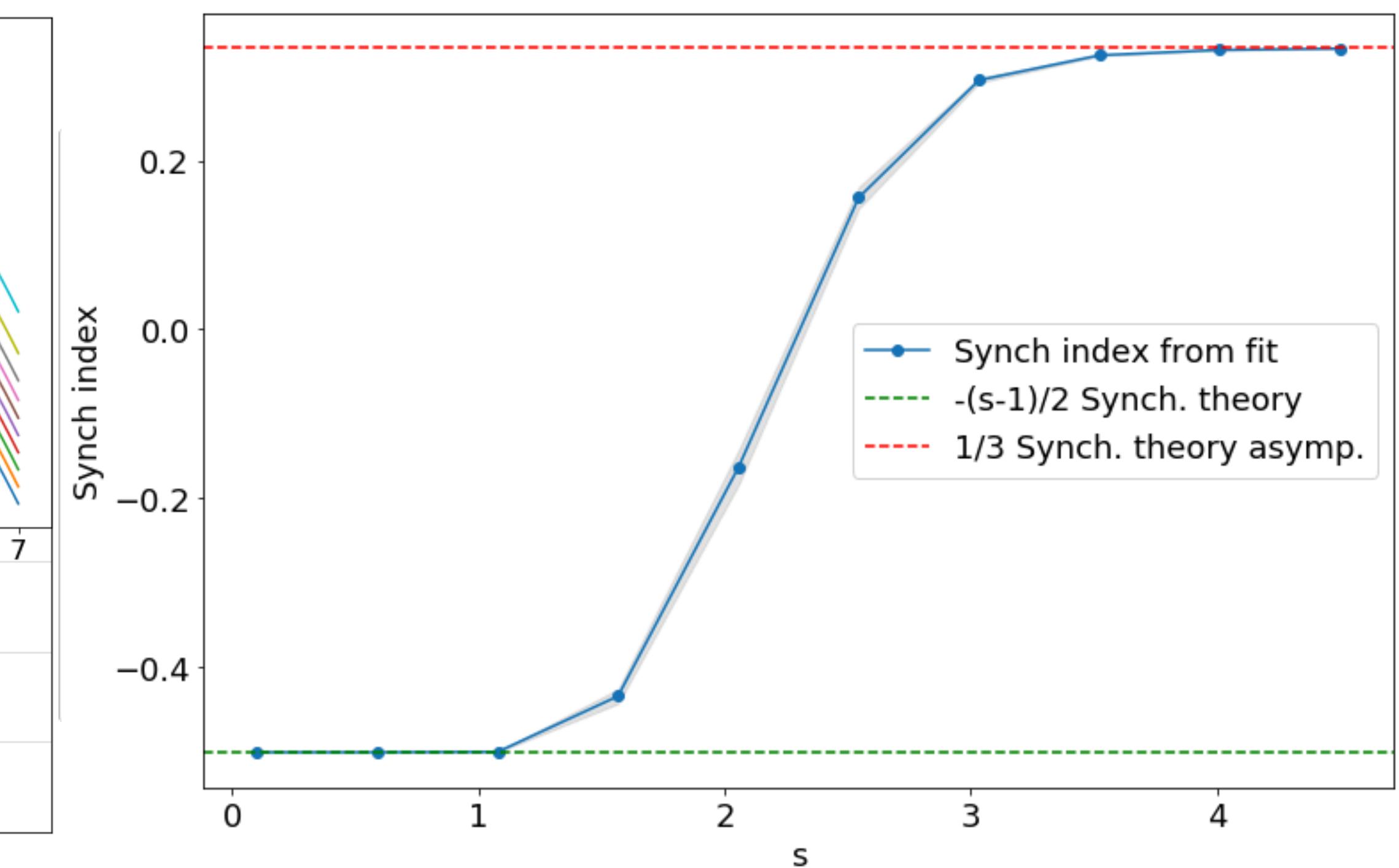
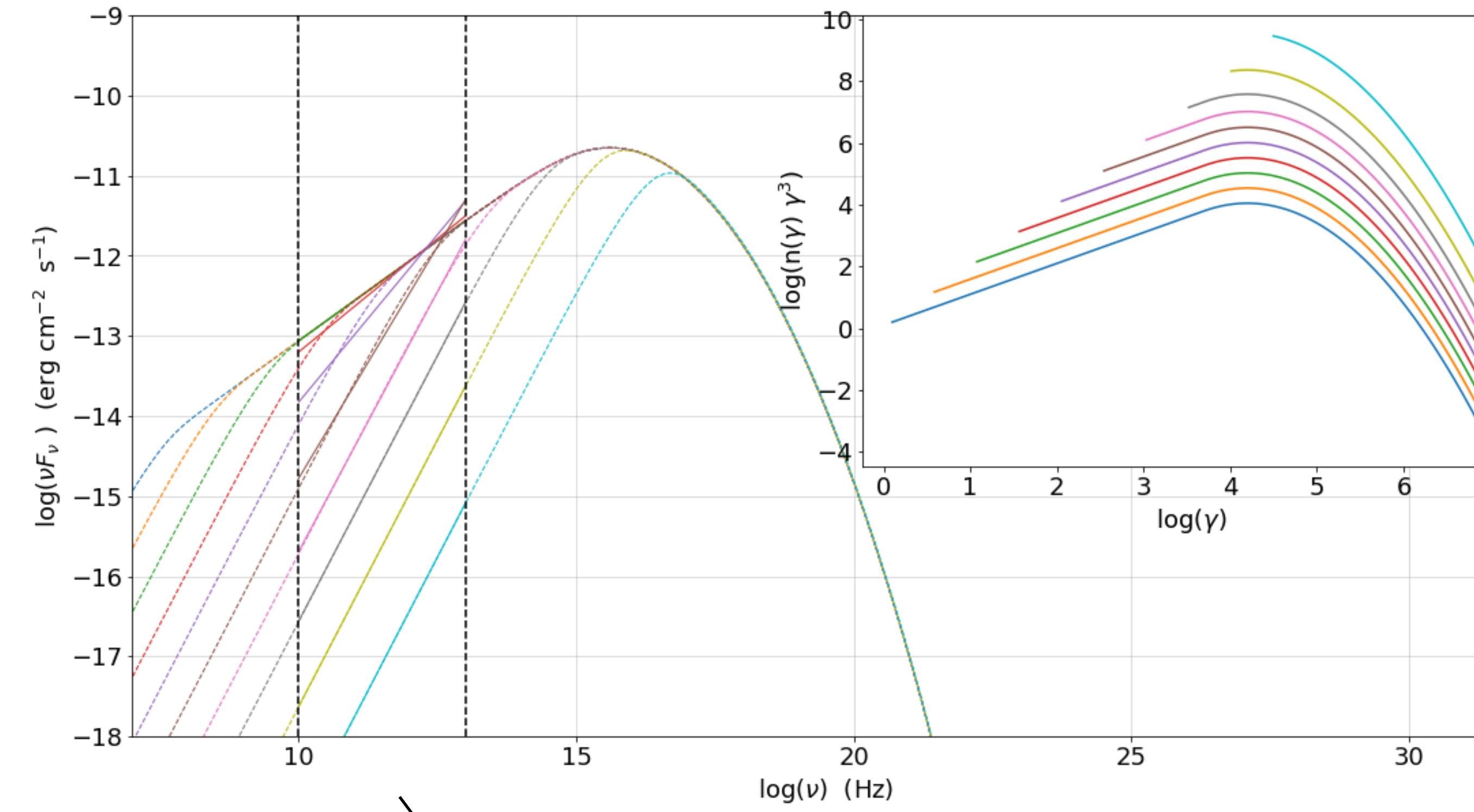


$$\nu_p^{Sync} \sim 3.2 \times 10^6 (\gamma_{3p})^2 B \delta$$

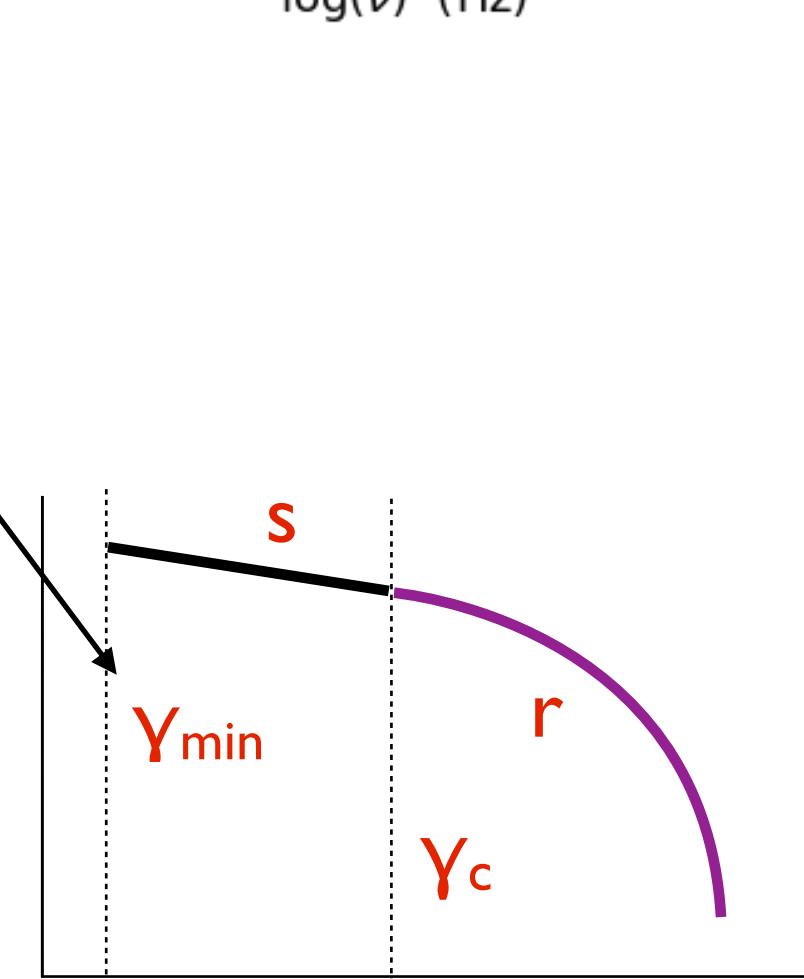
$$S_p^{Sync} \sim \frac{dN(\gamma)}{d\gamma} \gamma_{3p}^3 B^2 \delta^4$$



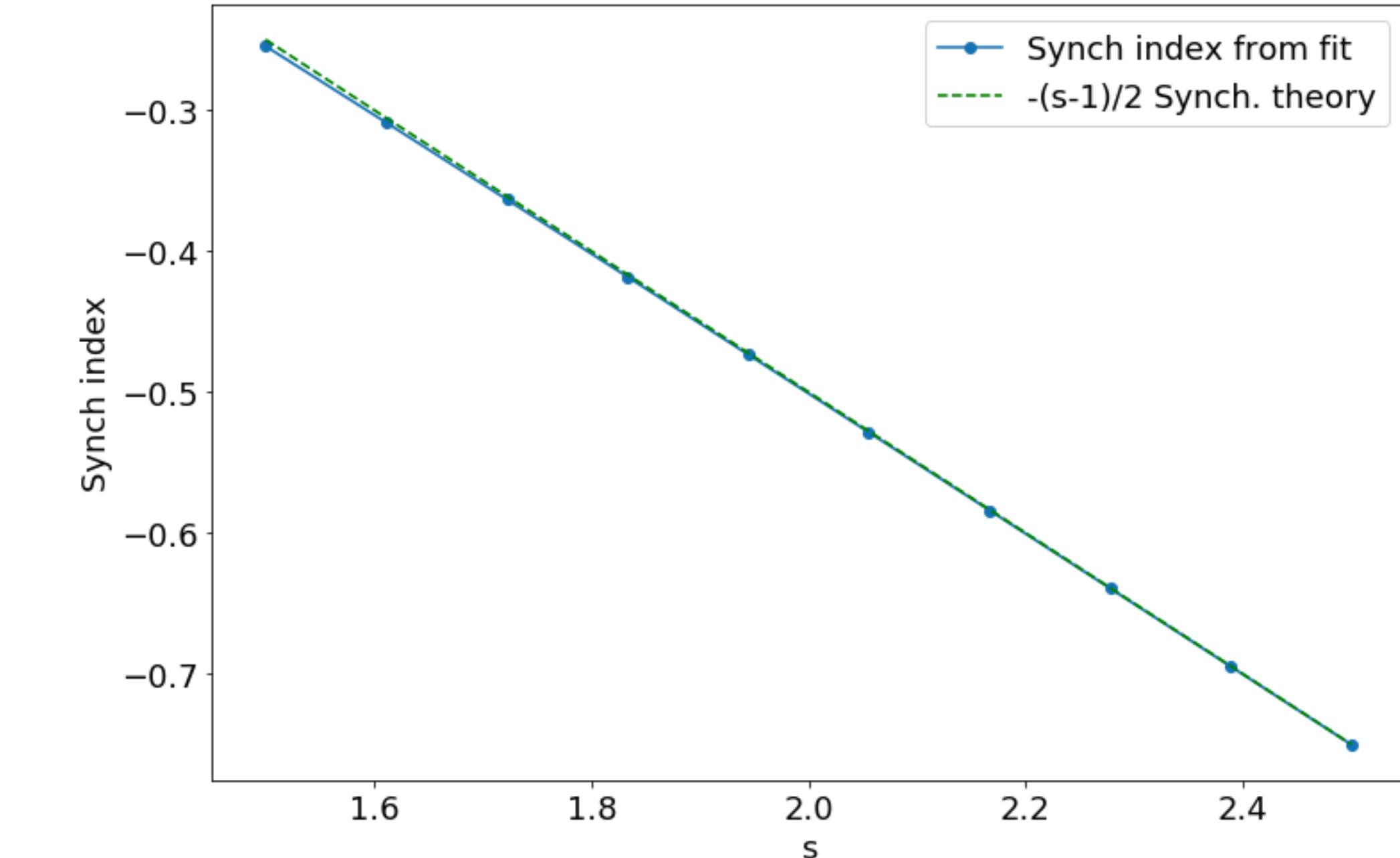
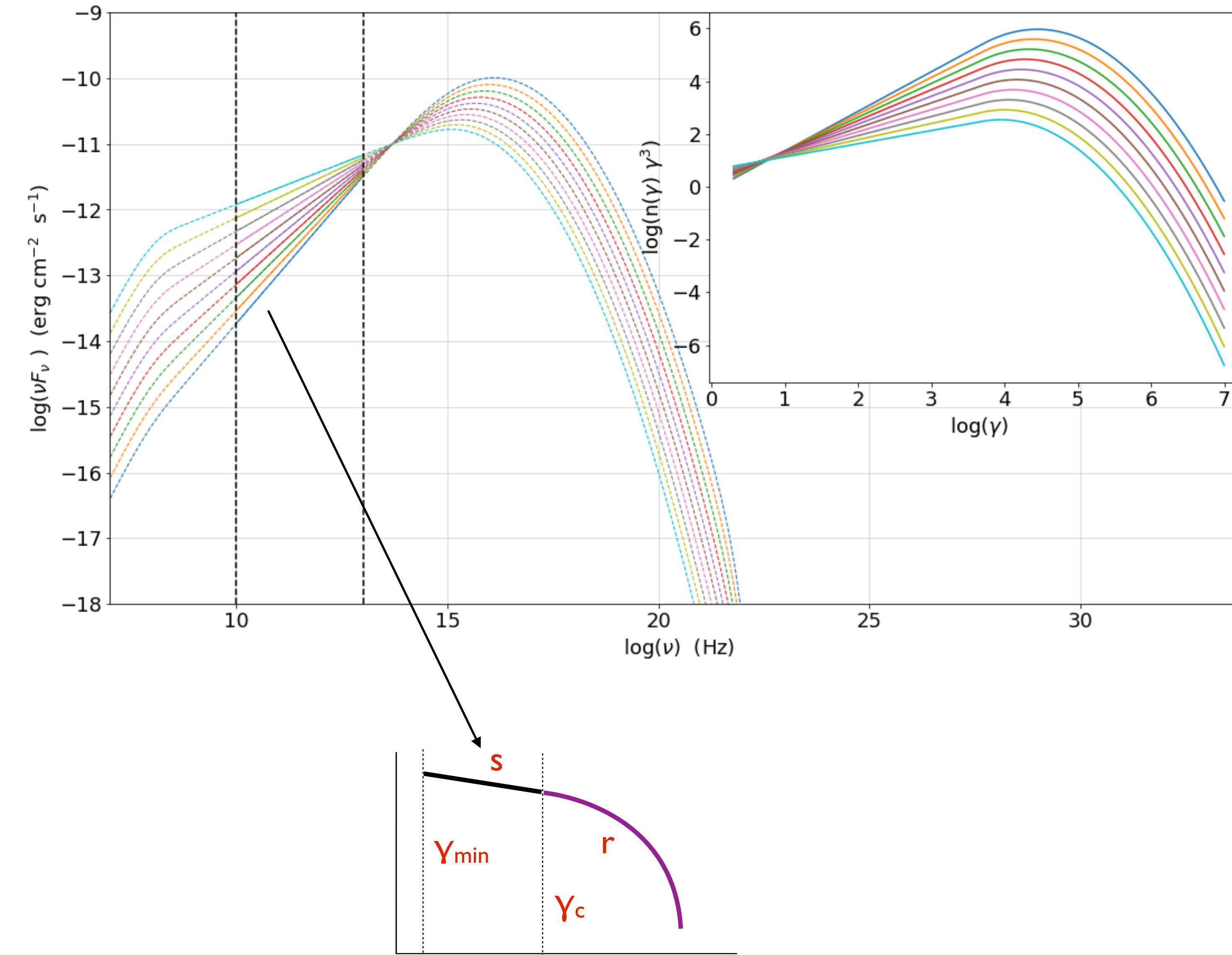
Synchrotron emission Estimate of γ_{min} from spectral index



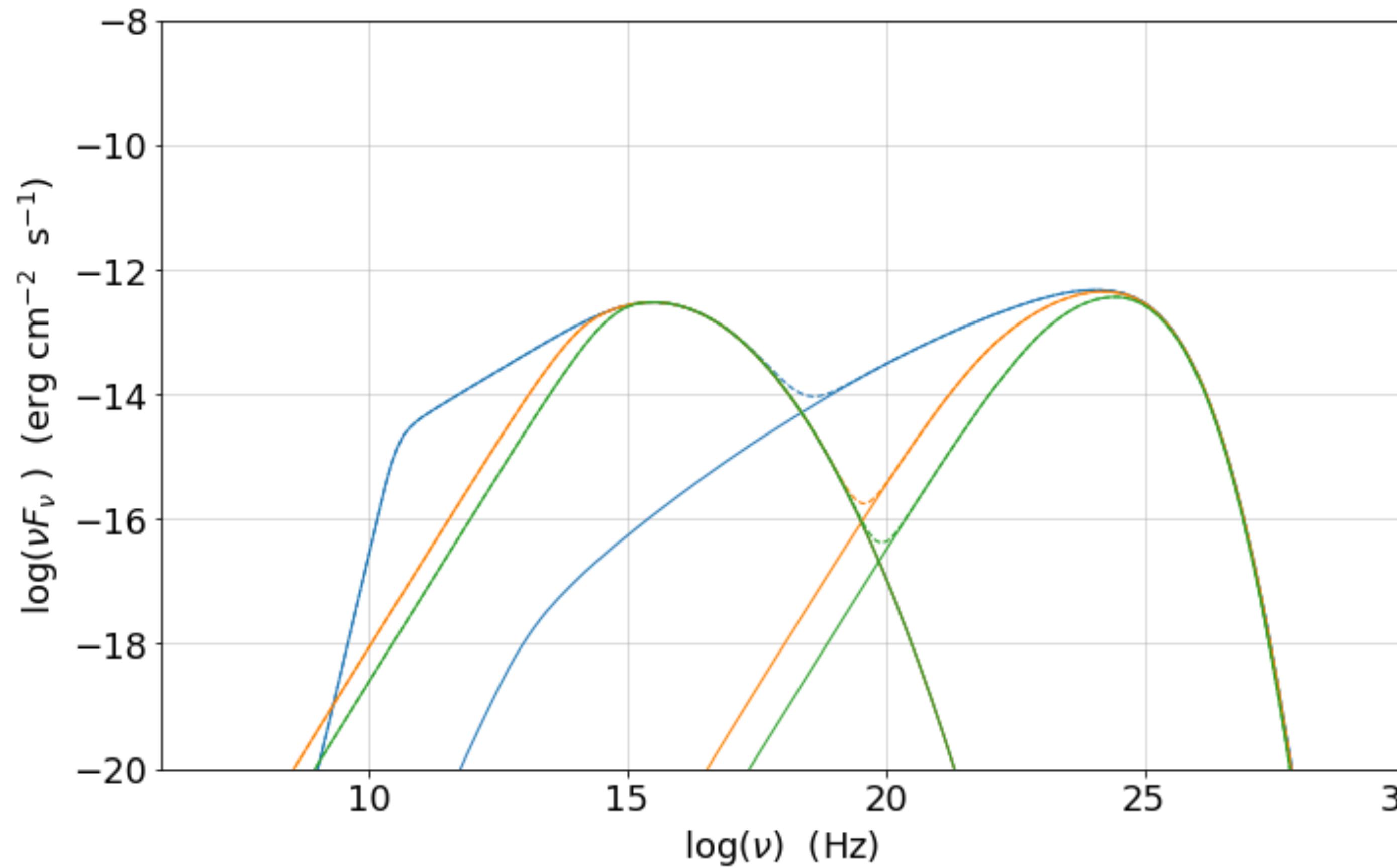
s is fixed



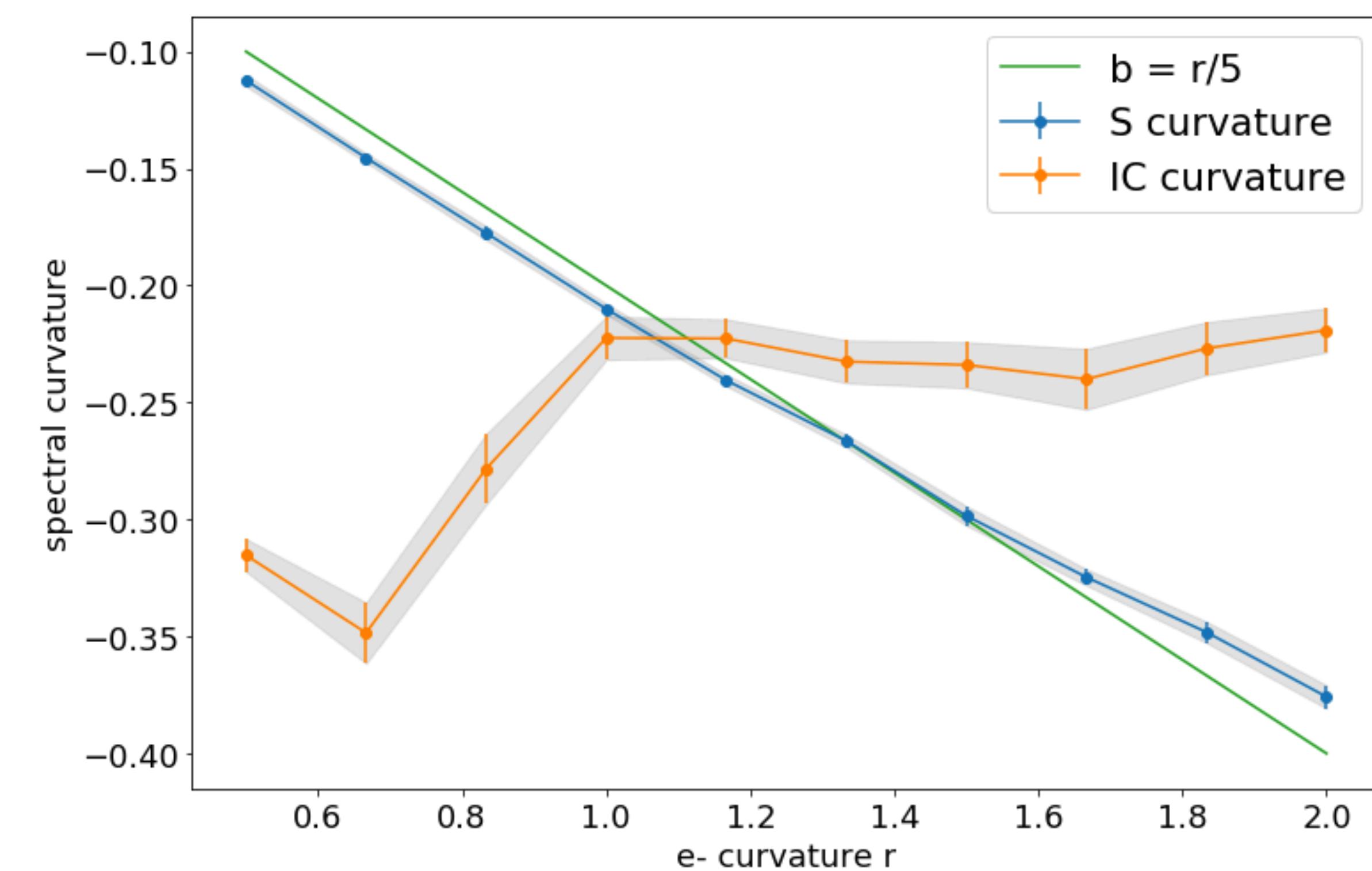
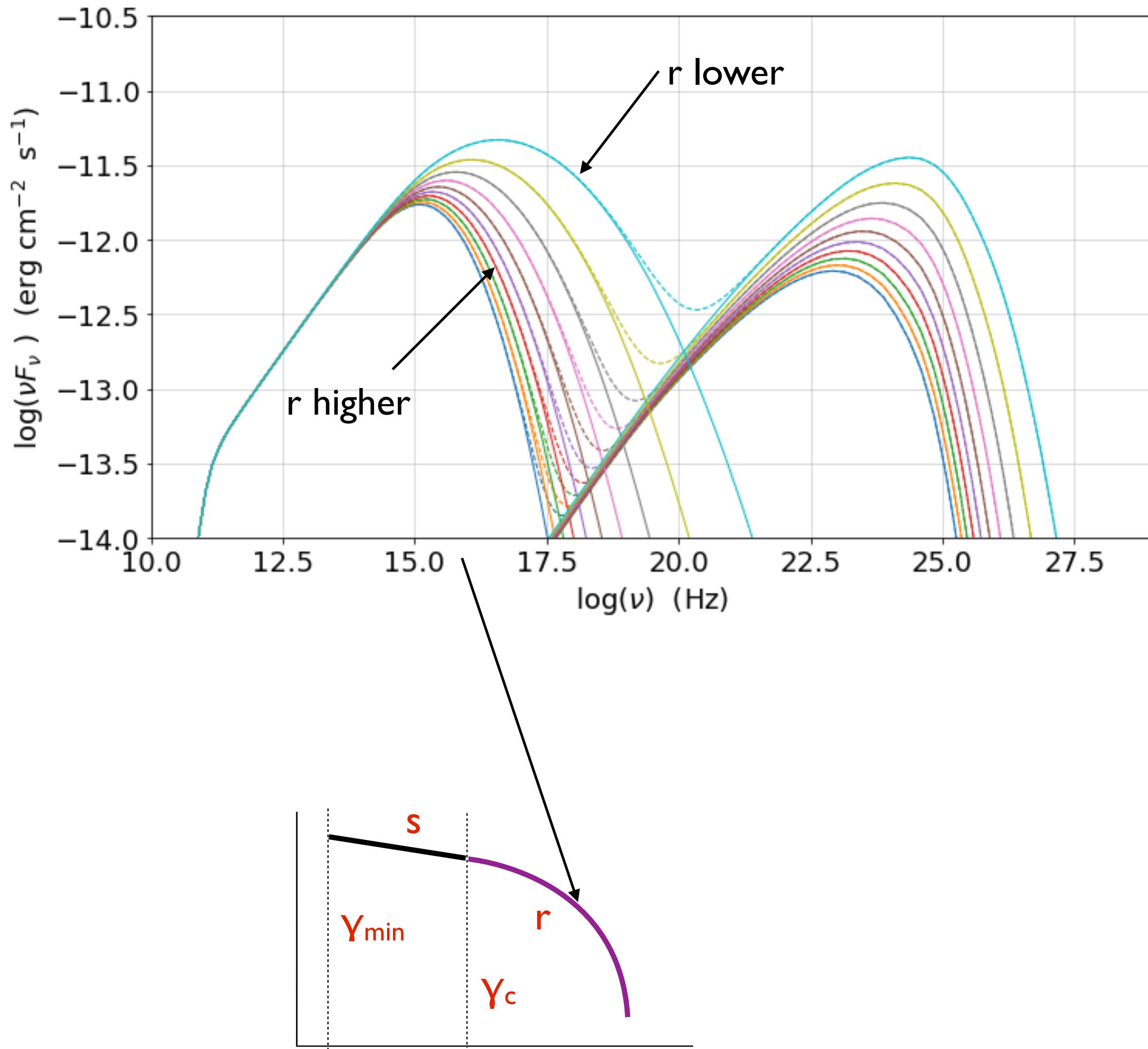
Synchrotron emission Estimate of s from spectral index



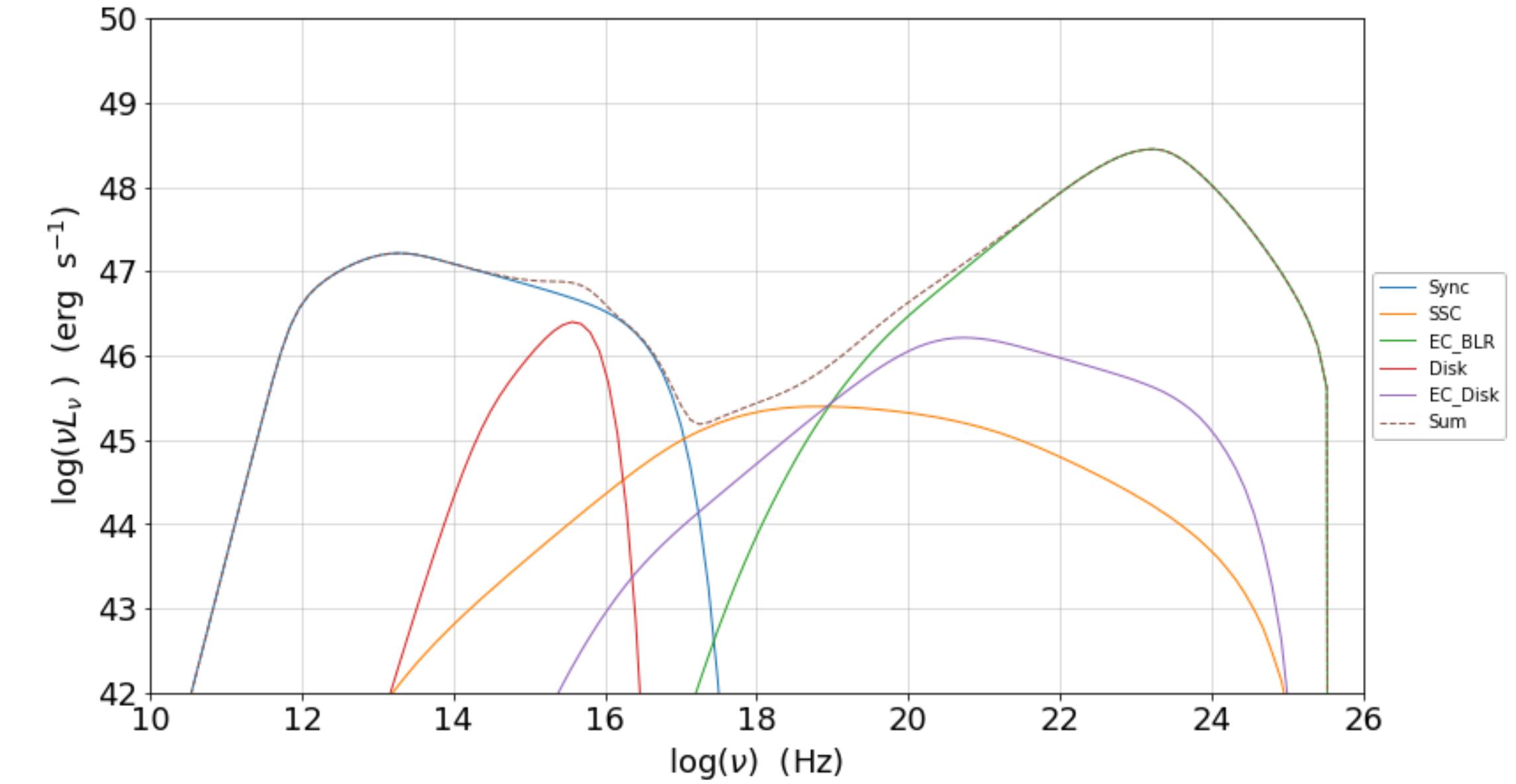
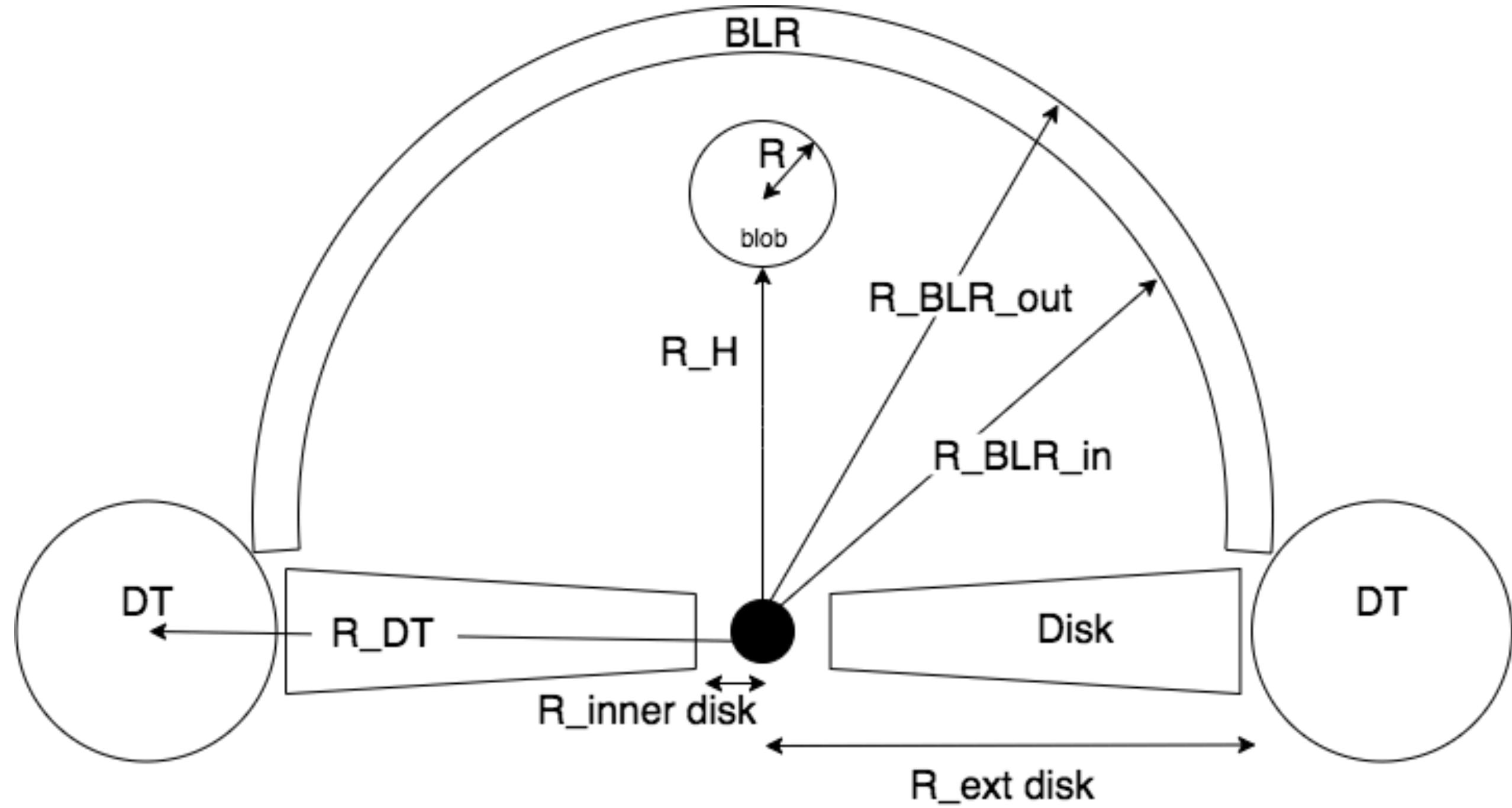
Adding the IC emission SSC case



IC emission TH/KN regime and peak curvature



External Compton Scenario



Transformation of the radiative fields

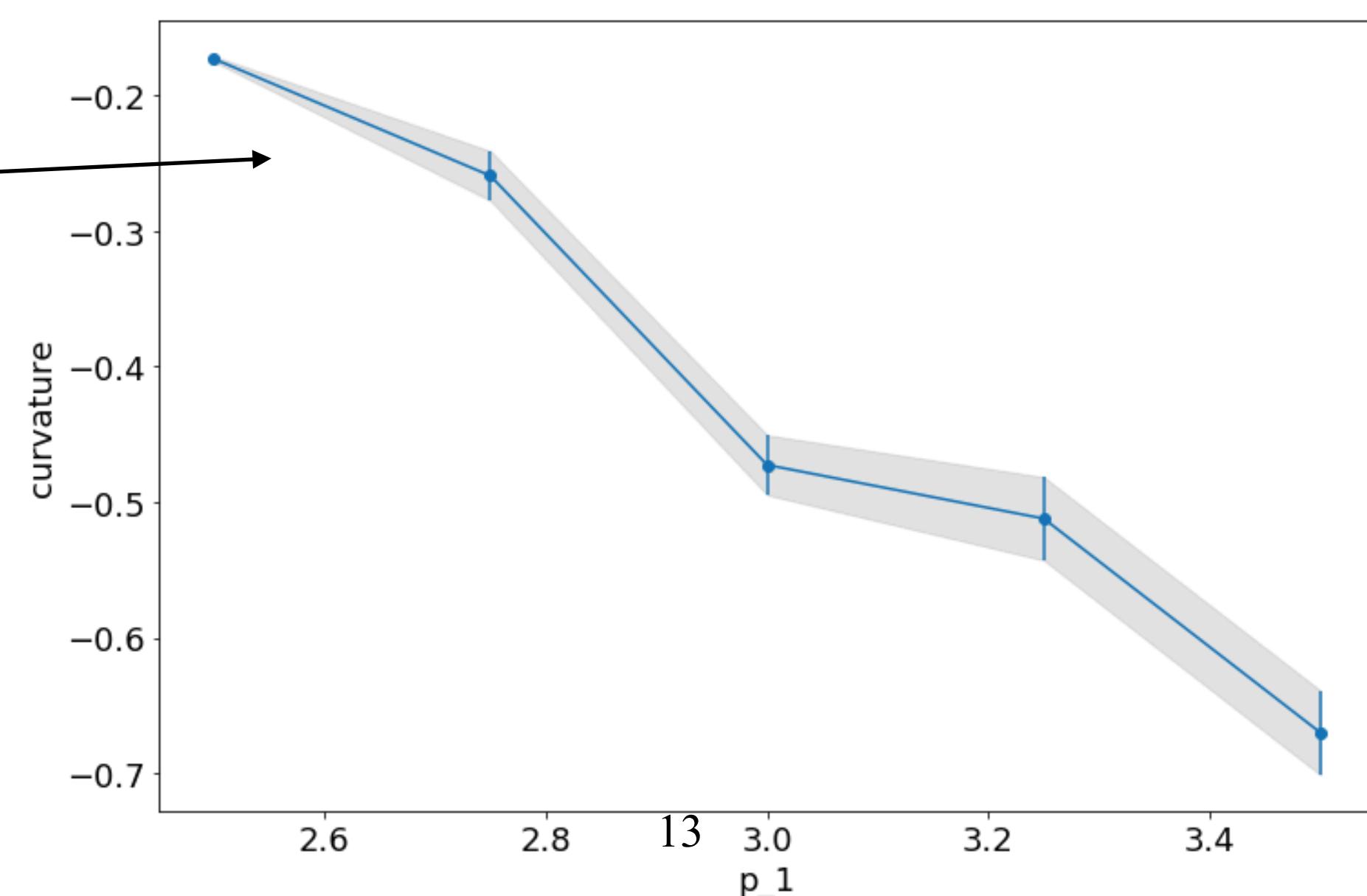
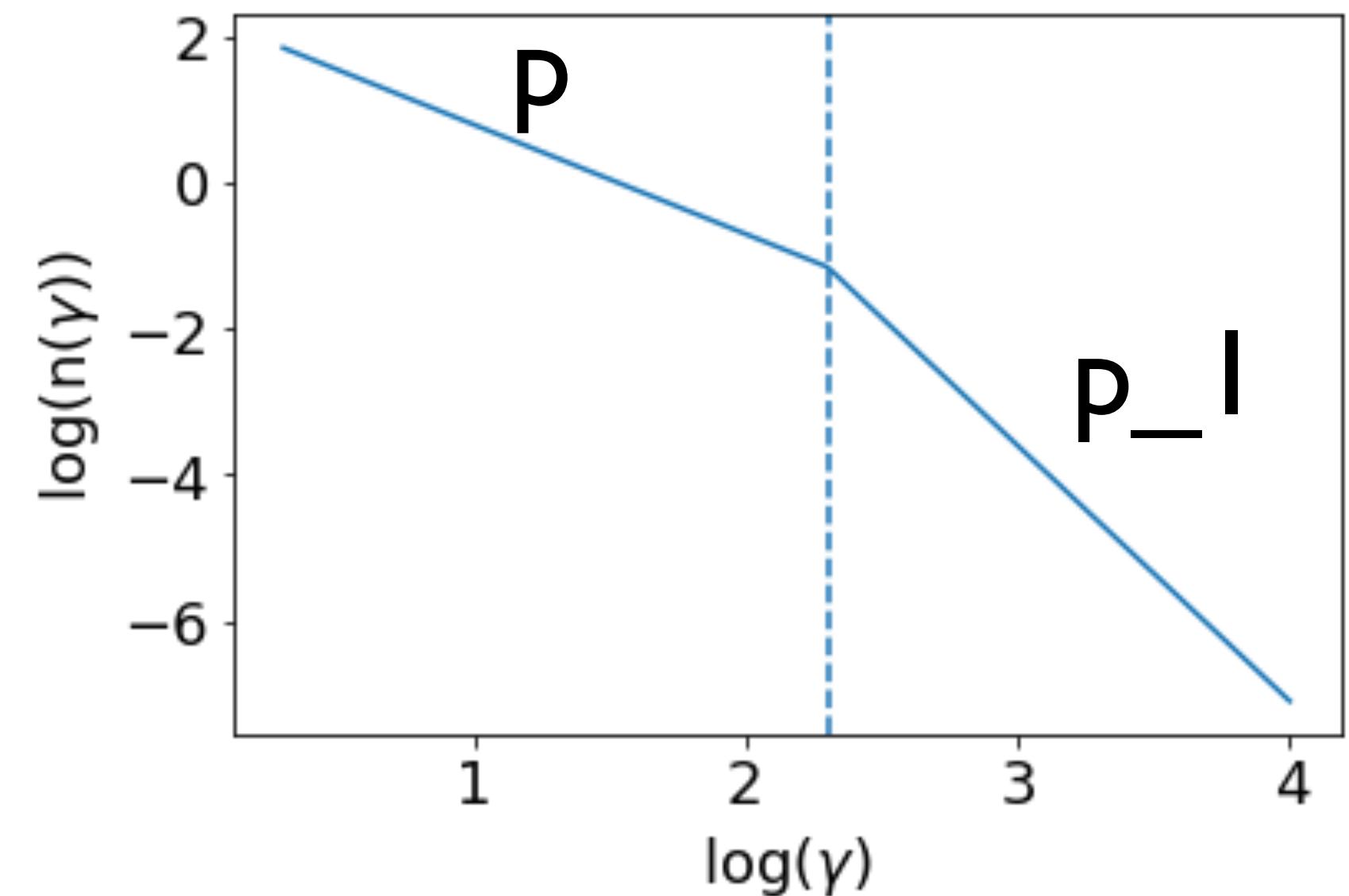
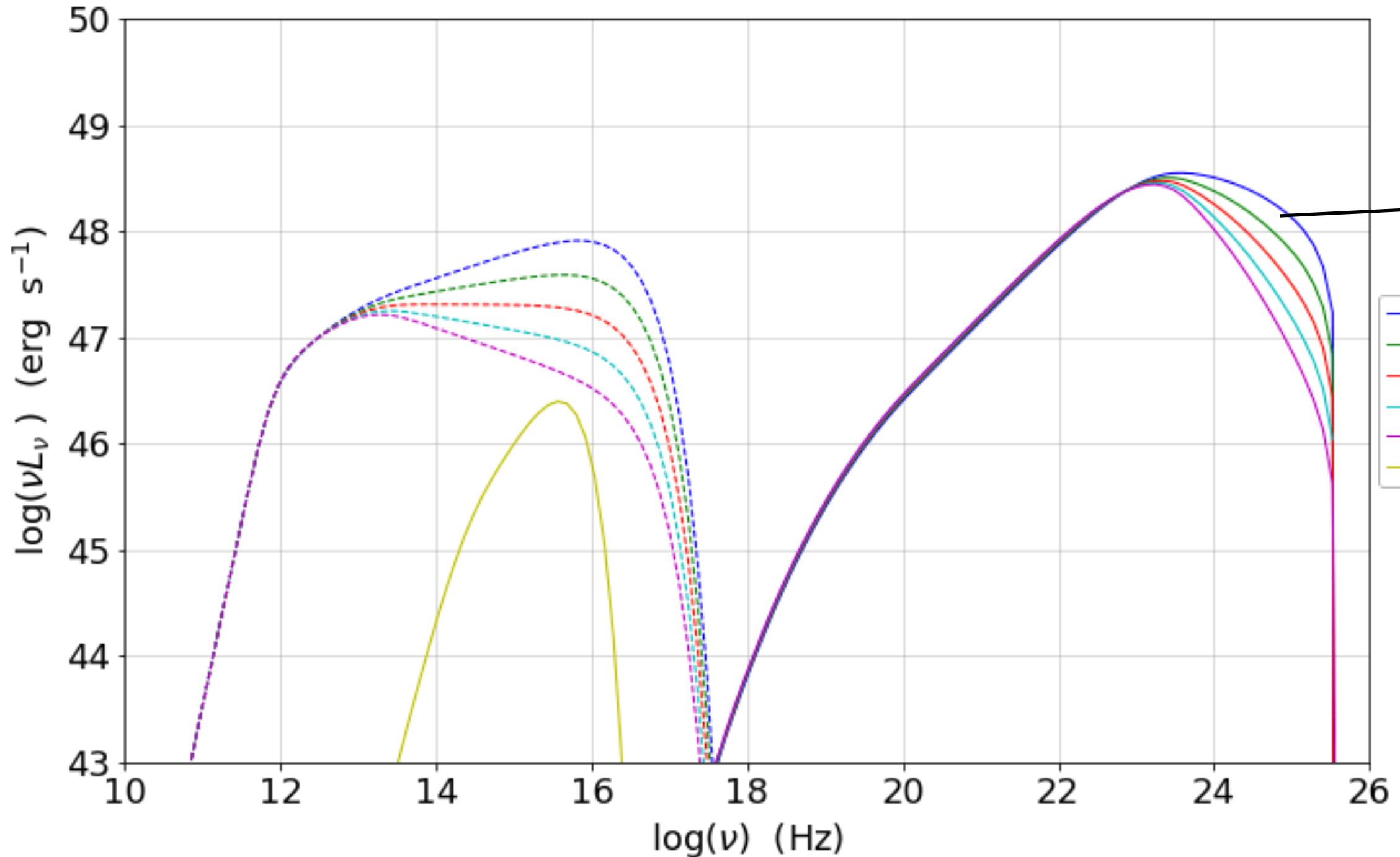
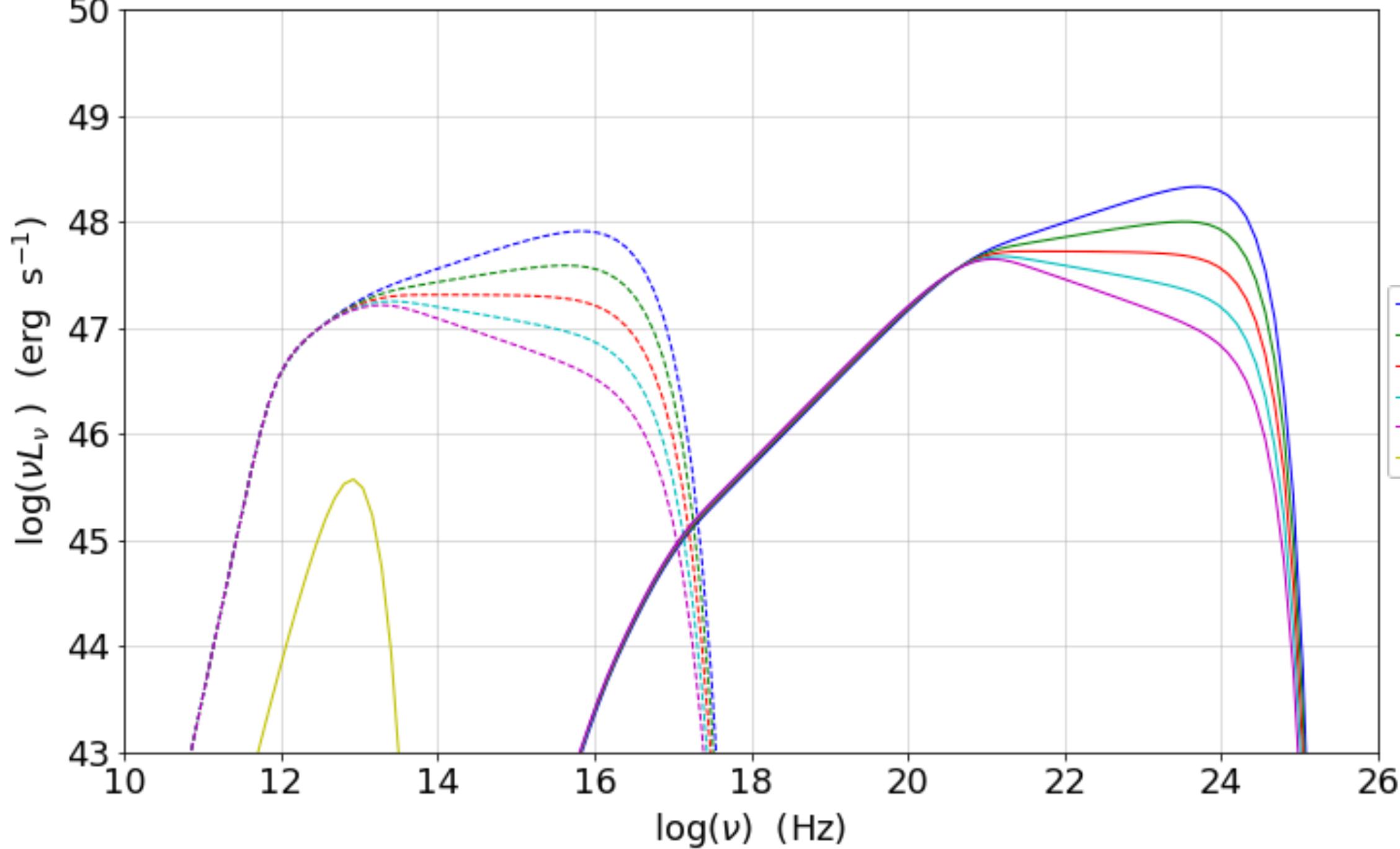
$$I_{v'} = \frac{1}{4\pi} \int d\Omega' \delta^3 I_{v=(v'/\Gamma)} \\ = \Gamma \tau \frac{L_{\text{nuc}}}{4\pi R^2} f_{v=(v'/\Gamma)}(T_{\text{ext}})$$

$$u'_{ext} \simeq \Gamma^2 u_{ext} \\ L_{ERC} \simeq \Gamma^6 U_{ext}$$

$$\eta = \frac{\dot{\gamma}_{IC}}{\dot{\gamma}_{sync}} = \frac{U_{ph}}{U_B}$$

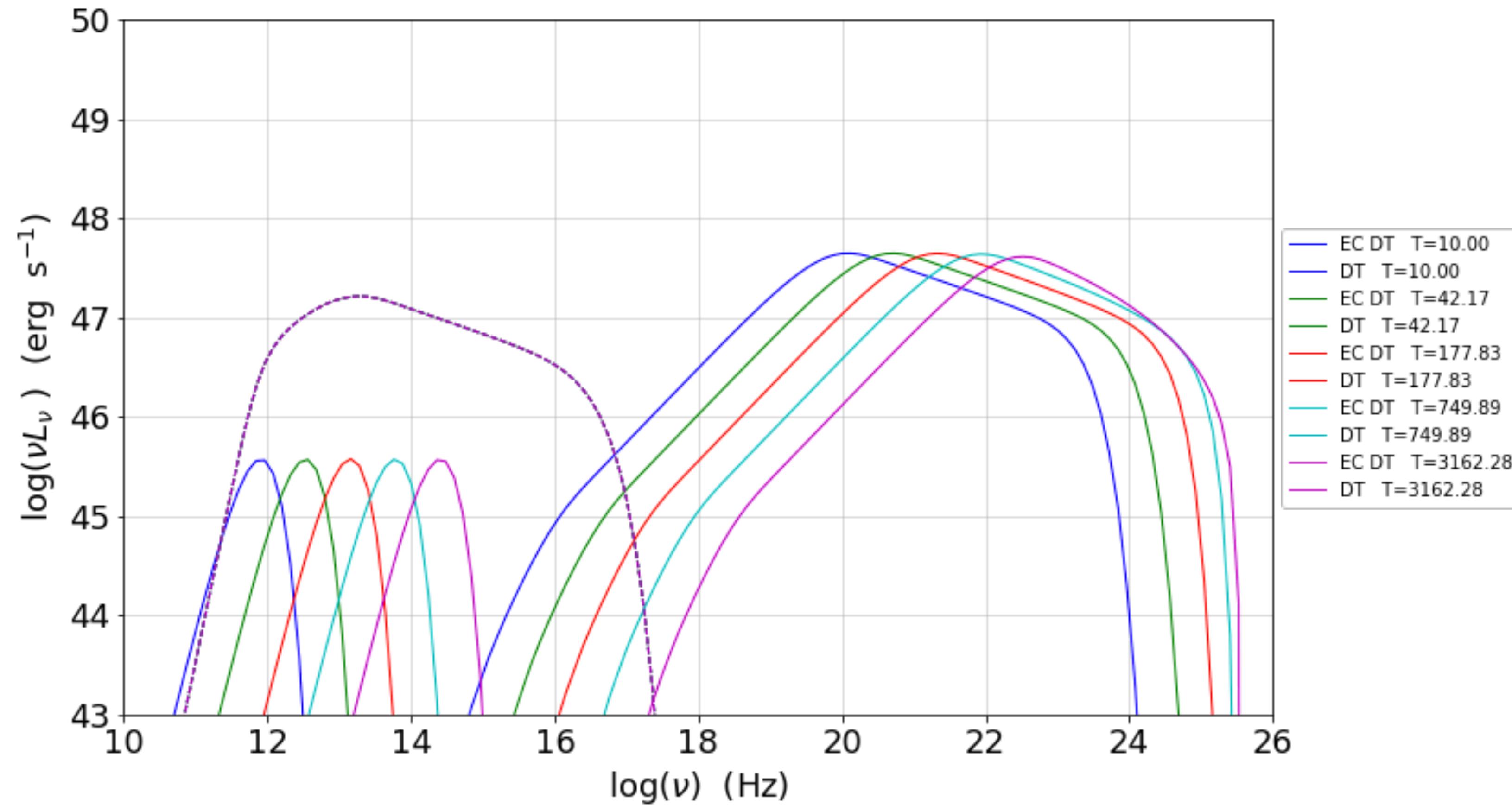
$$\epsilon^{-3} I_\epsilon \text{ and } \epsilon^{-2} j(\epsilon, \Omega) \\ \frac{u(\epsilon, \Omega)}{\epsilon^3} = \frac{u'(\epsilon', \Omega')}{\epsilon'^3} = i n v.$$

External Compton Scenario and TH/KN

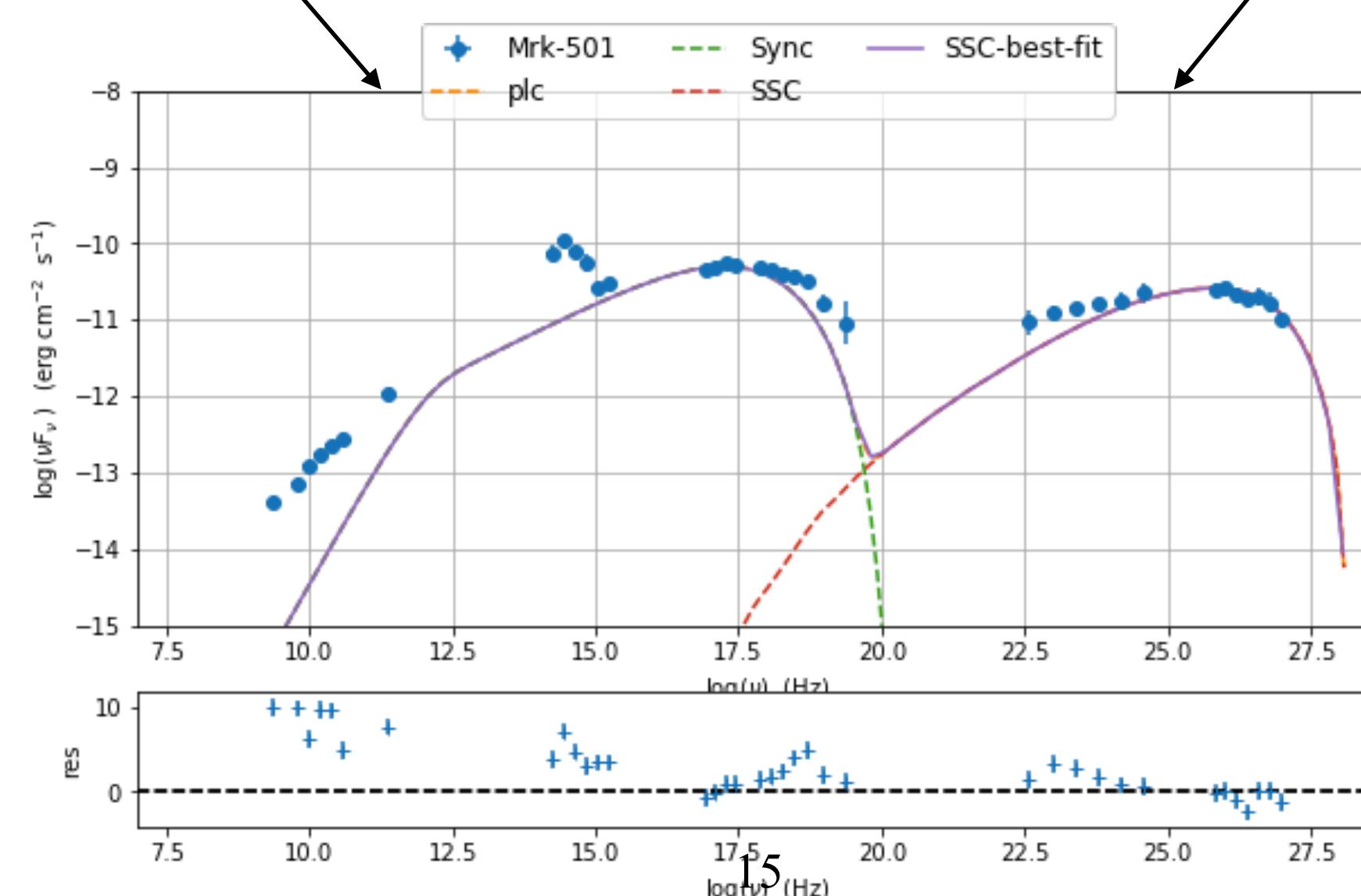
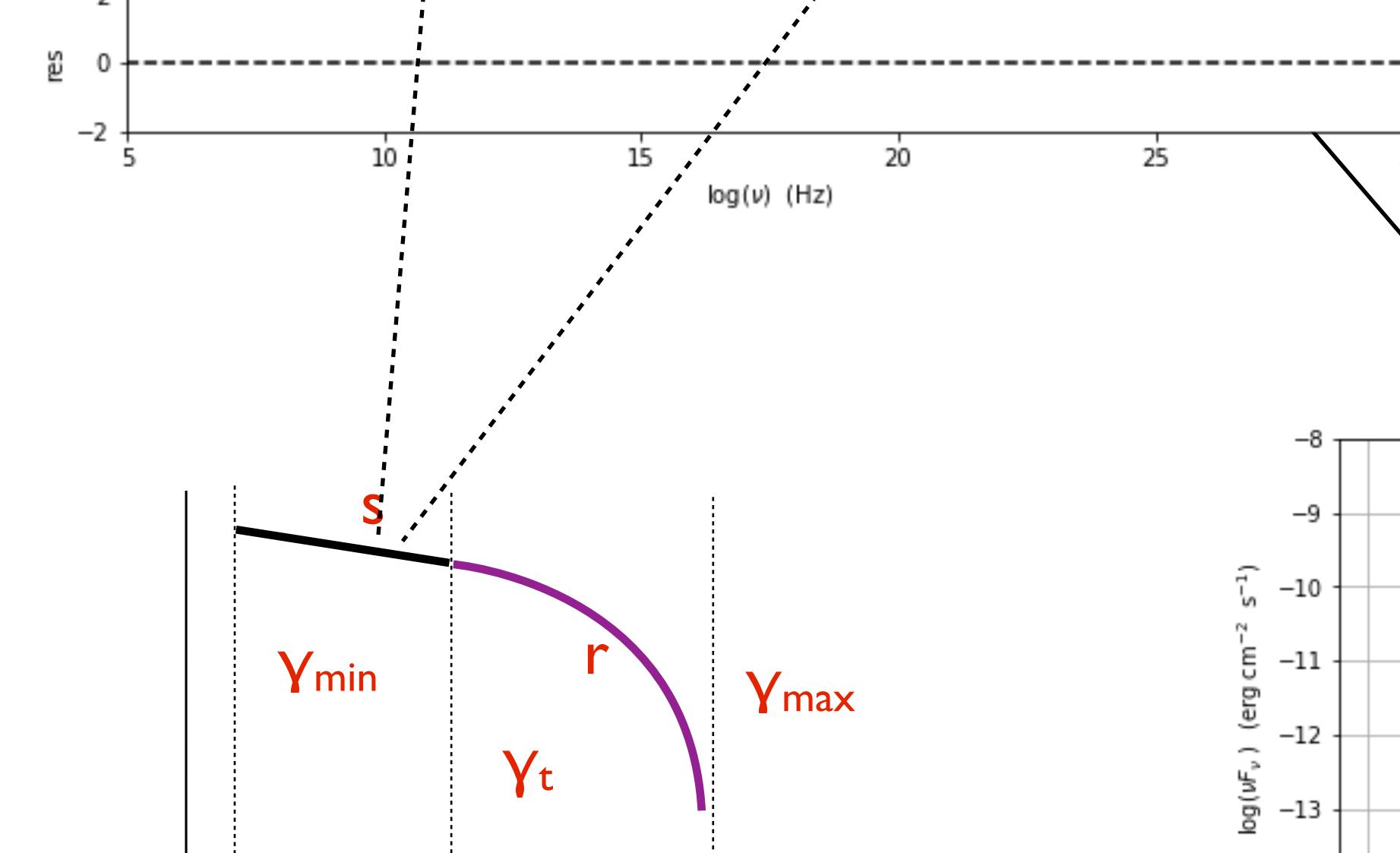
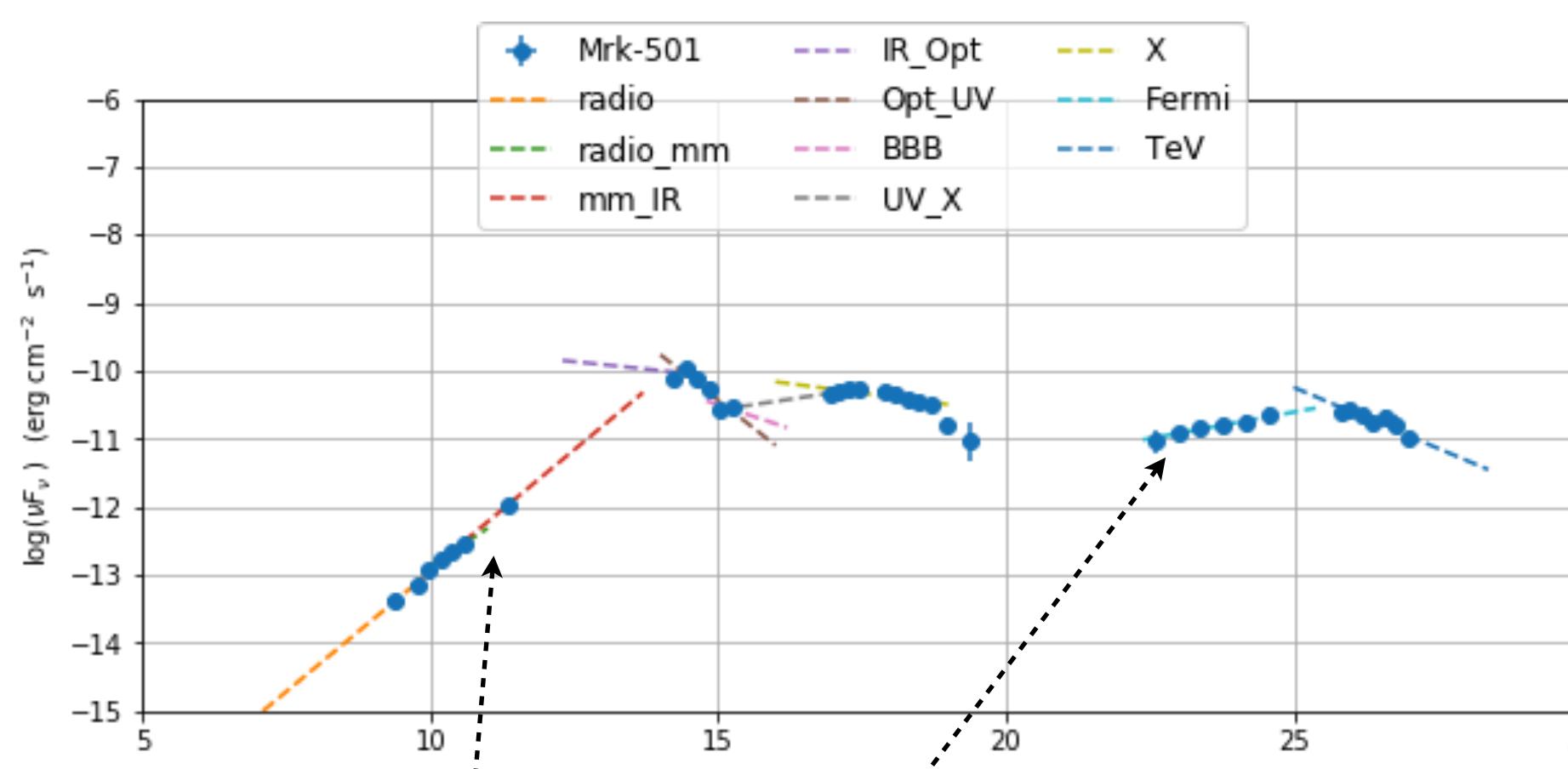


External Compton Scenario and external seed photons energy

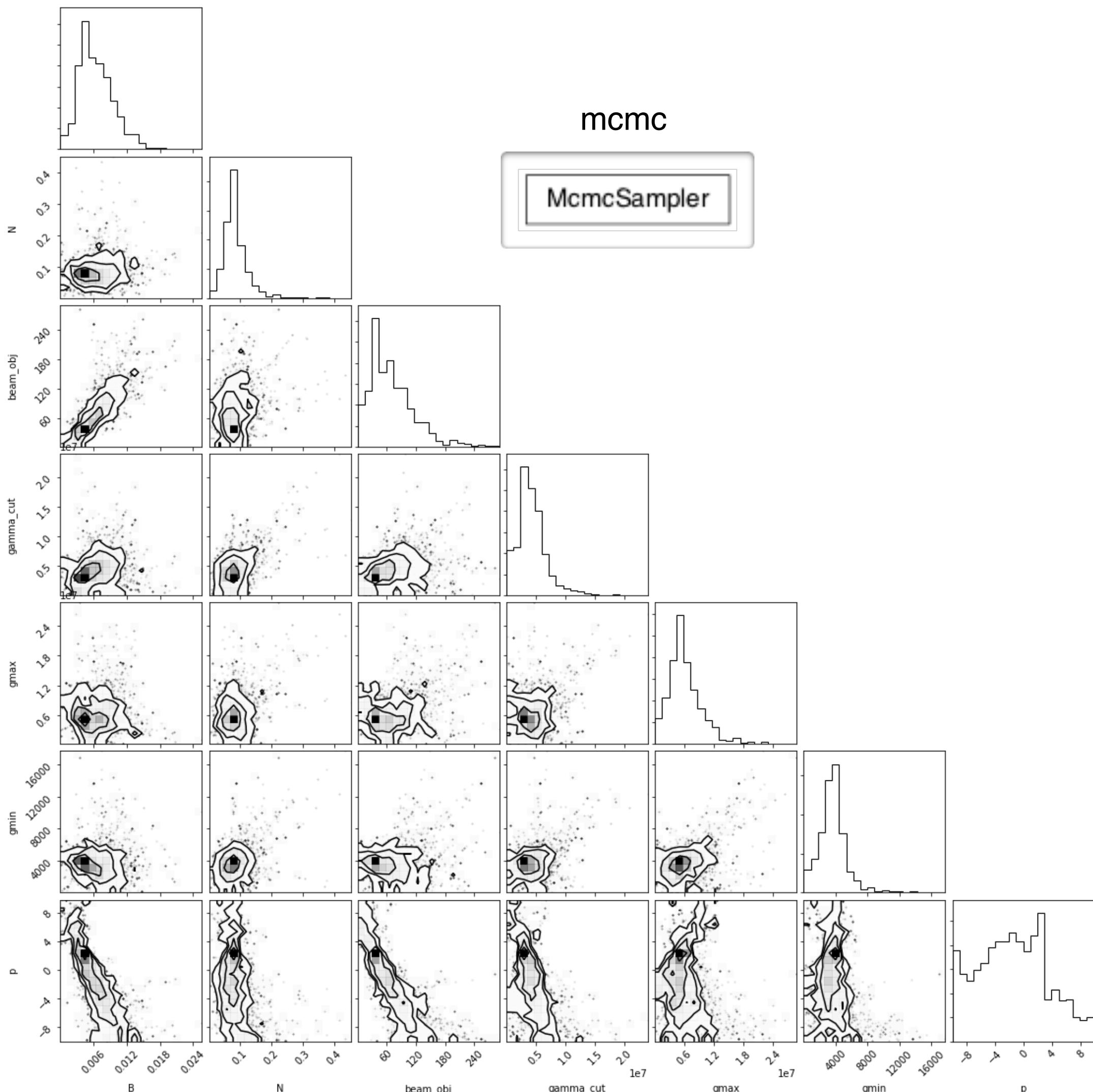
$$v_{p\ EC} \sim (4/3) \gamma^2 v''_{p\ ext} \delta \Gamma / (1+z) \quad v'_{seed-IC} = v''_{p\ ext} \Gamma$$



JetSeT SED shaping and model constraining (Mrk 501)



JetSeT model fitting MCMC



model_manager

minimizer

