Diagnostic of the peak frequencies in the SEDs of Fermi Blazars

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on behalf of the Fermi-LAT collaboration

Outline

- Blazars SEDs: SSC and EC models (focus on leptonic one-zone homogeneous models)
- Phenomenological description of the peak frequencies
- Peak diagnostic in the γ_p^{IC} *vs* ν_p^S plane (numerical approach)
- Comparison with Fermi and quasi-simultaneous MW data

Active Galactic Nuclei zoology

~(1-5)% of galaxies have a bright core called AGN≈100-1000 galaxy luminosity

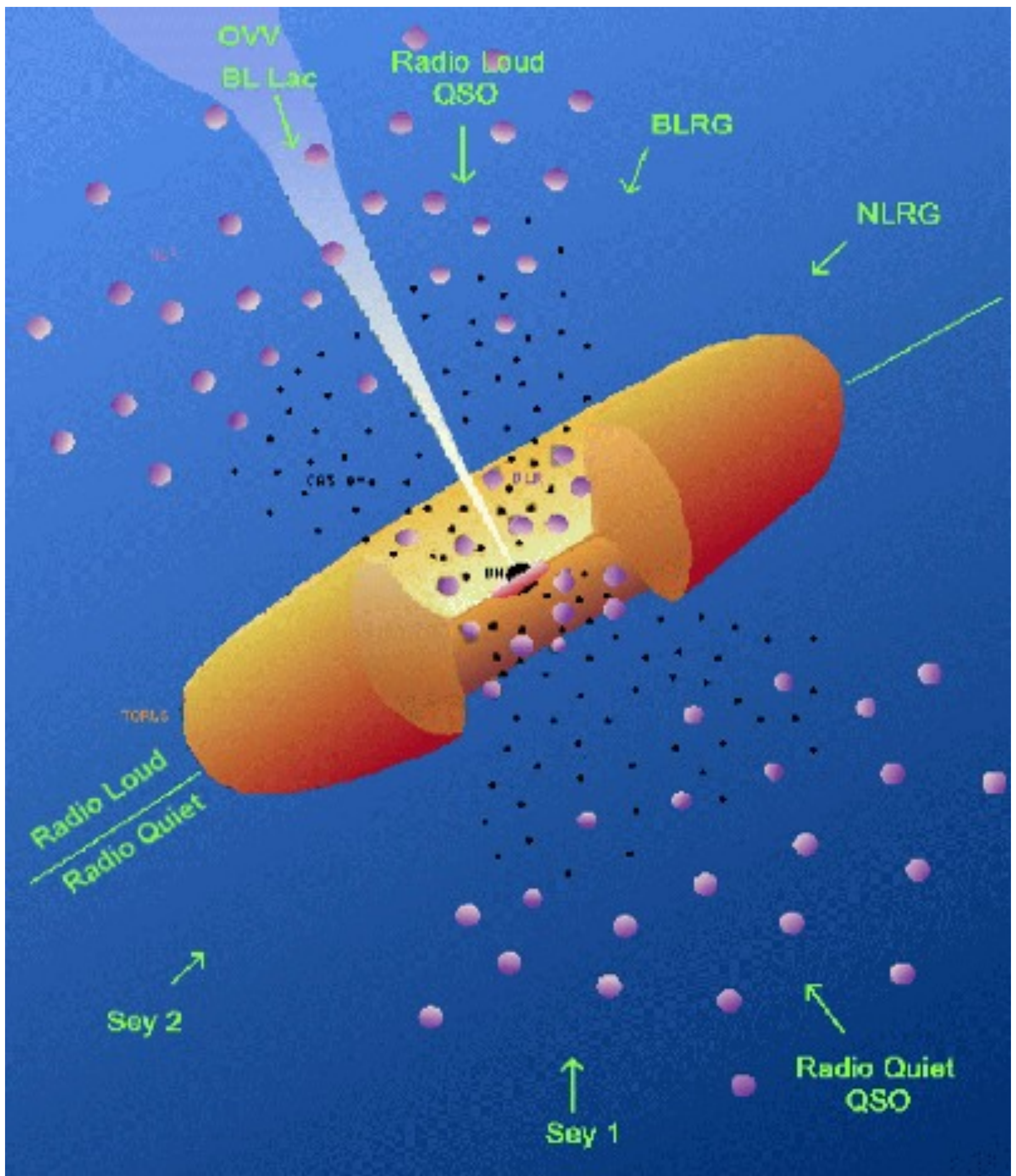
Radio quiet≈90%

Seyfert etc..

Radio loud≈10%

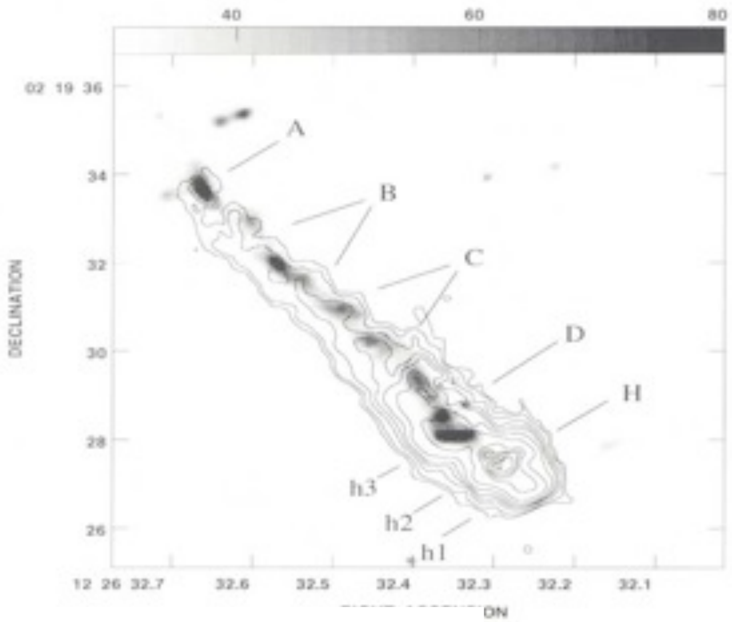
≈2000 Blazar

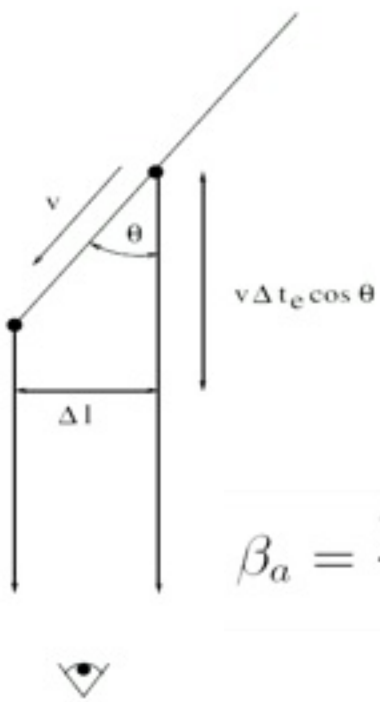
BL LAC + FSRQ



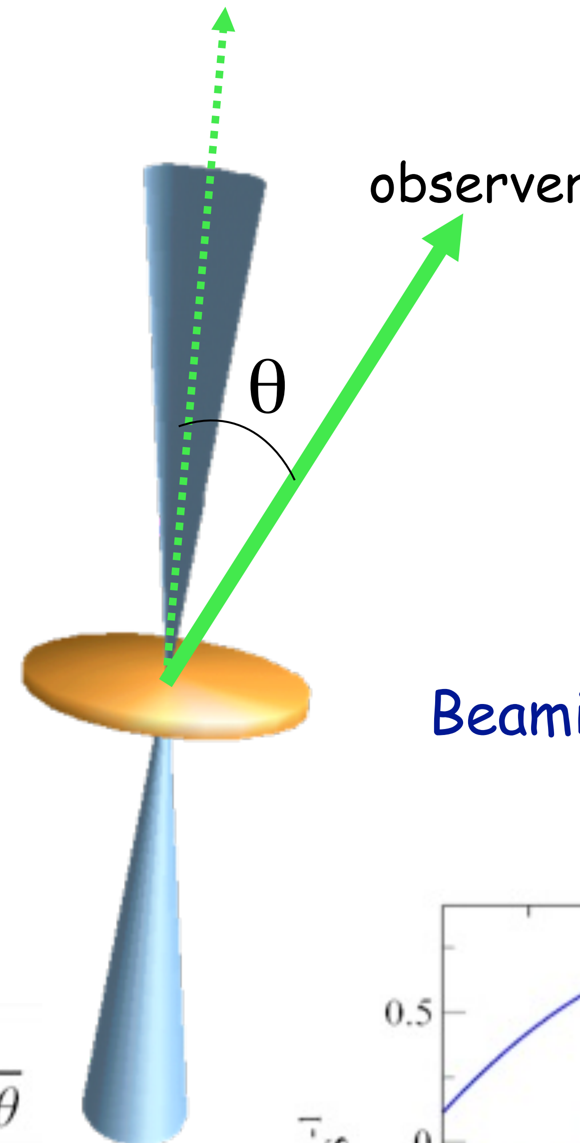
- Observed luminosities $10^{46\text{-}48}$erg/s
- Strong radio emission from compact cores
- High optical polarization
- Non thermal emission over the whole EM spectrum (radio to GeV/TeV)
- Rapid variability. (down to 10^2 s)
- Relativistic jets with Γ~5-20 @ small angles powered by accretion disk with S.M.B.H. ~ $10^{8\text{-}9}$ M sun

Beamed Emission



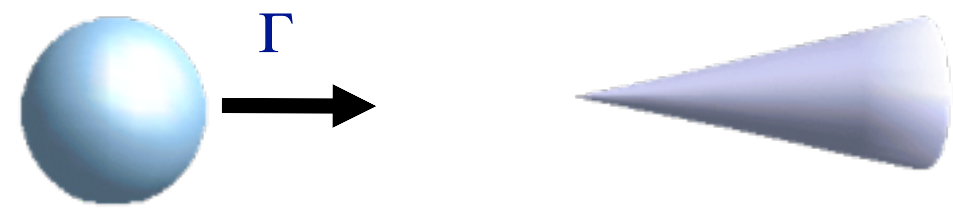


$$\beta_a = \frac{v_a}{c} = \frac{\beta \sin\theta}{1 - \beta\cos\theta}$$



rest frame : isotropic emission

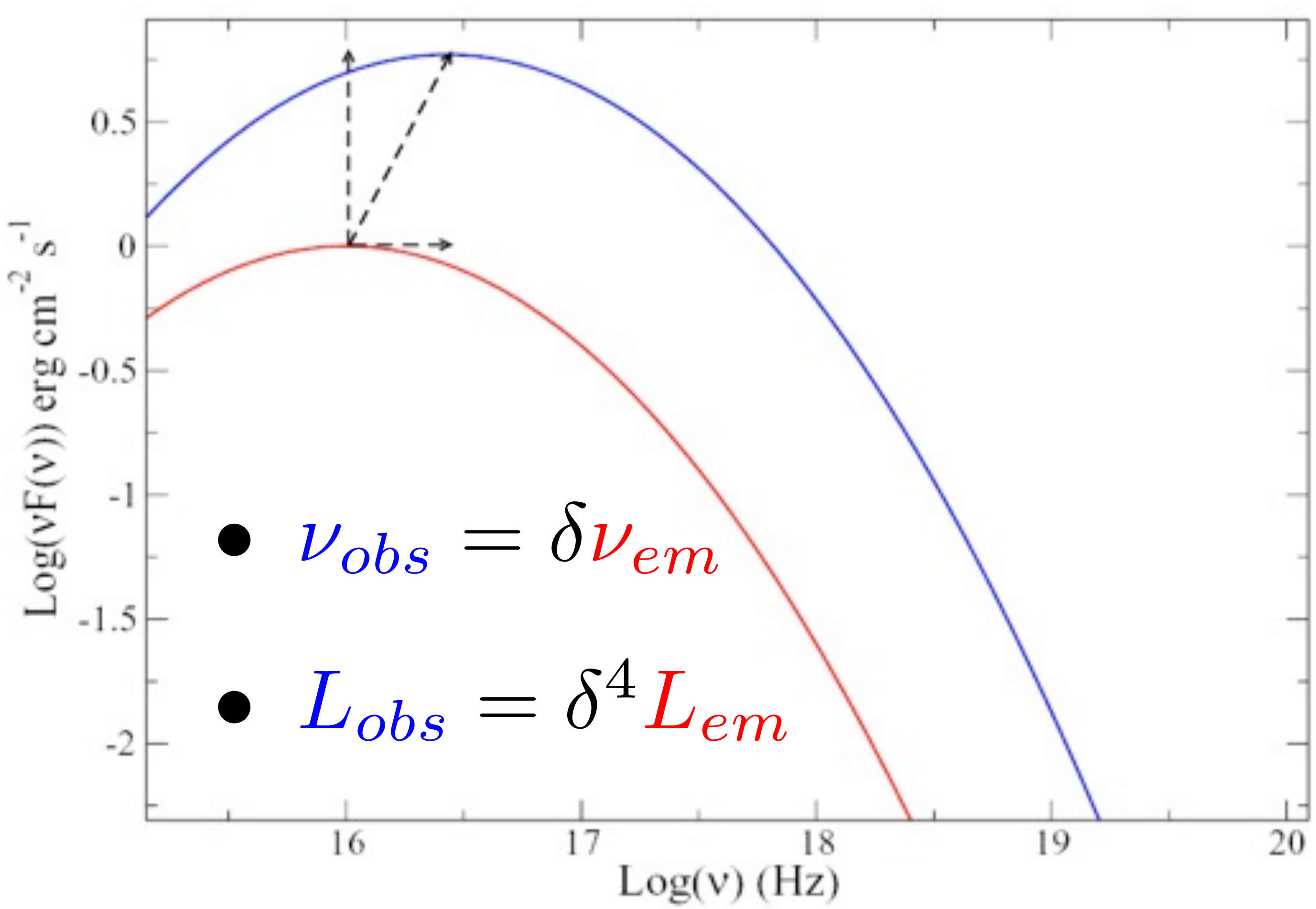
Observer frame: beamed



Beaming factor:

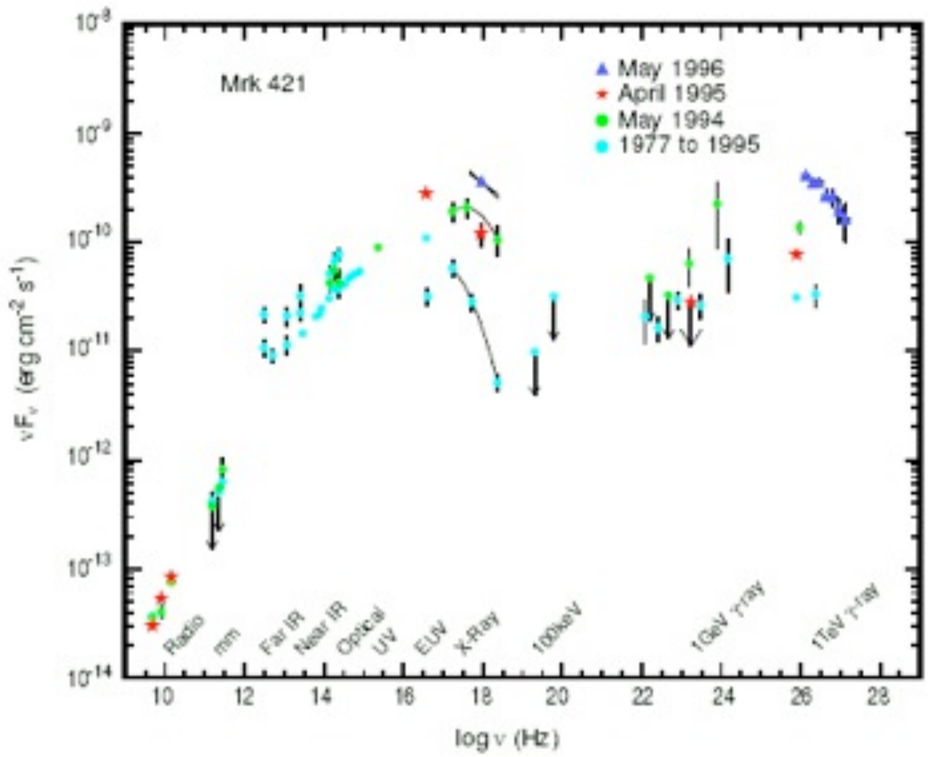
- $\delta = \frac{1}{\Gamma(1-\beta cos(\theta))}$
- $\theta = 1/\Gamma$

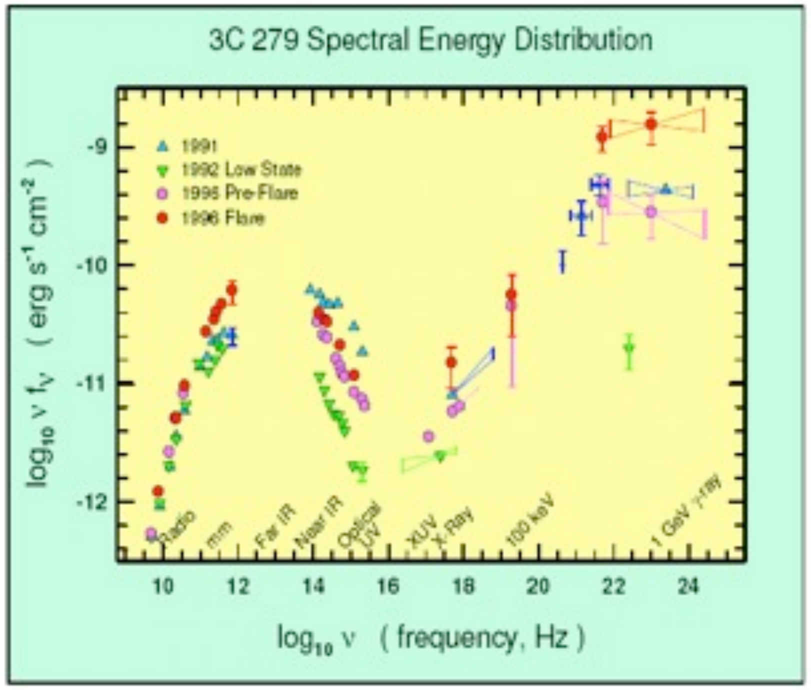
- $t_{obs} \sim t_{em}/\delta$
- $\nu_{obs} \sim \nu_{em}\delta$
- $\Omega_{obs} \sim \Omega_{em}/\delta^2$
- $L \sim \nu\Omega^{-1}t^{-1} \rightarrow L_{obs} \sim \delta^4 L_{em}$



- $\nu_{obs} = \delta\nu_{em}$
- $L_{obs} = \delta^4 L_{em}$

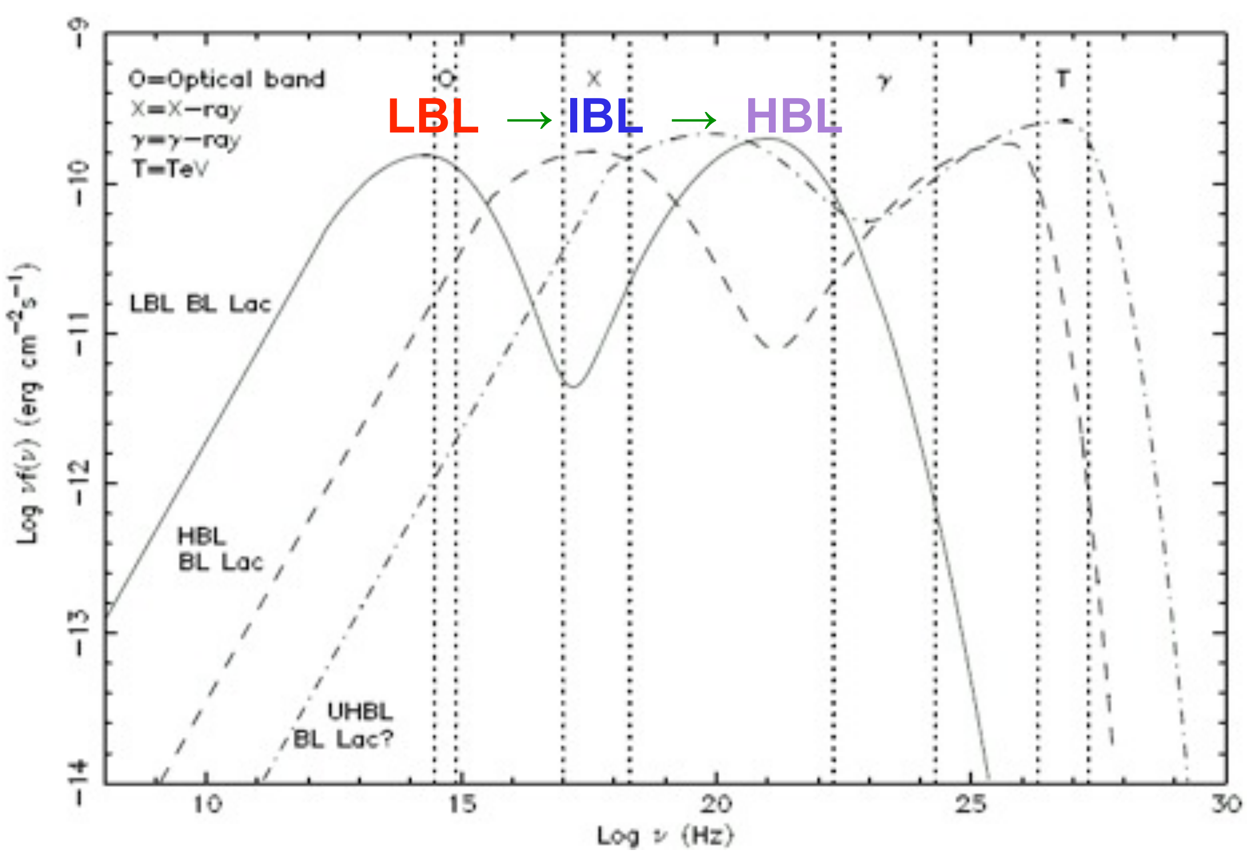
Spectral Energy Distributions SED





Two bumps SED:

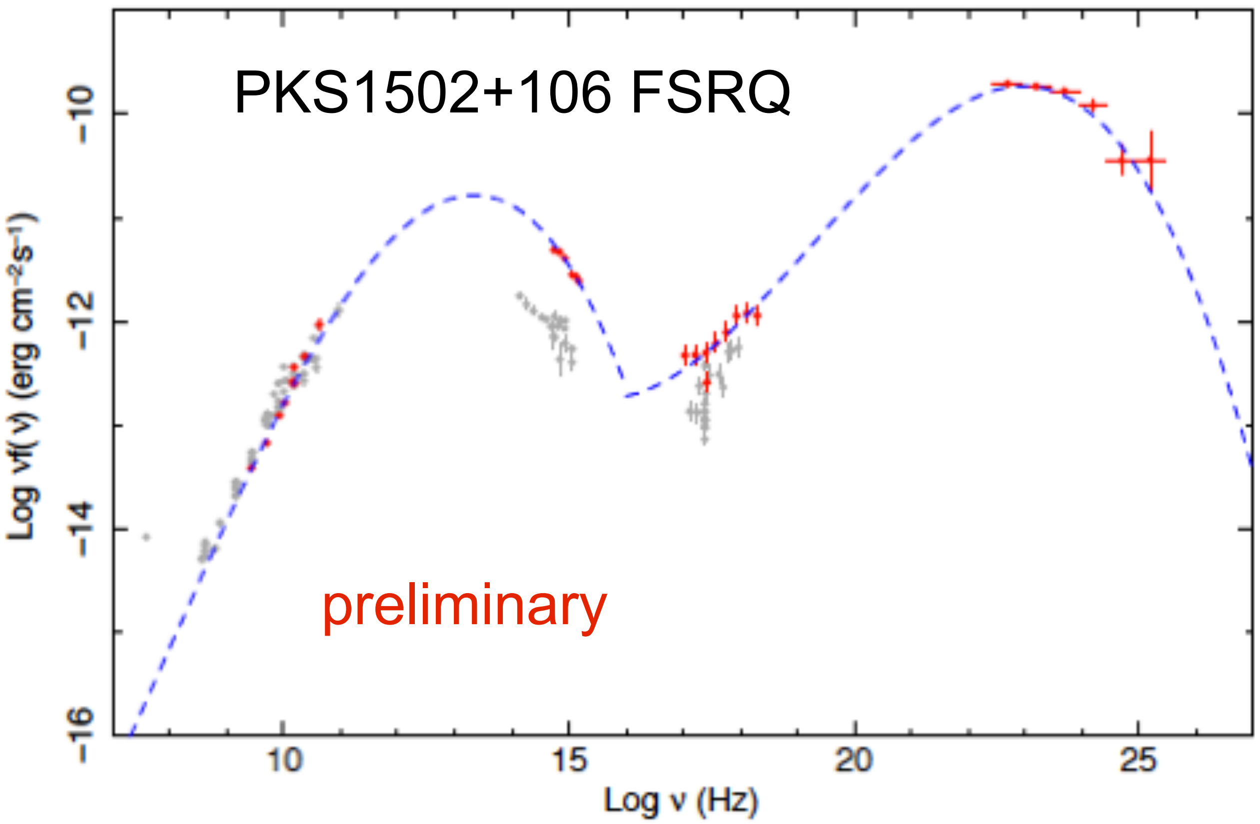
- Low Energy -> Synchrotron
- High Energy -> IC (SSC / EC)

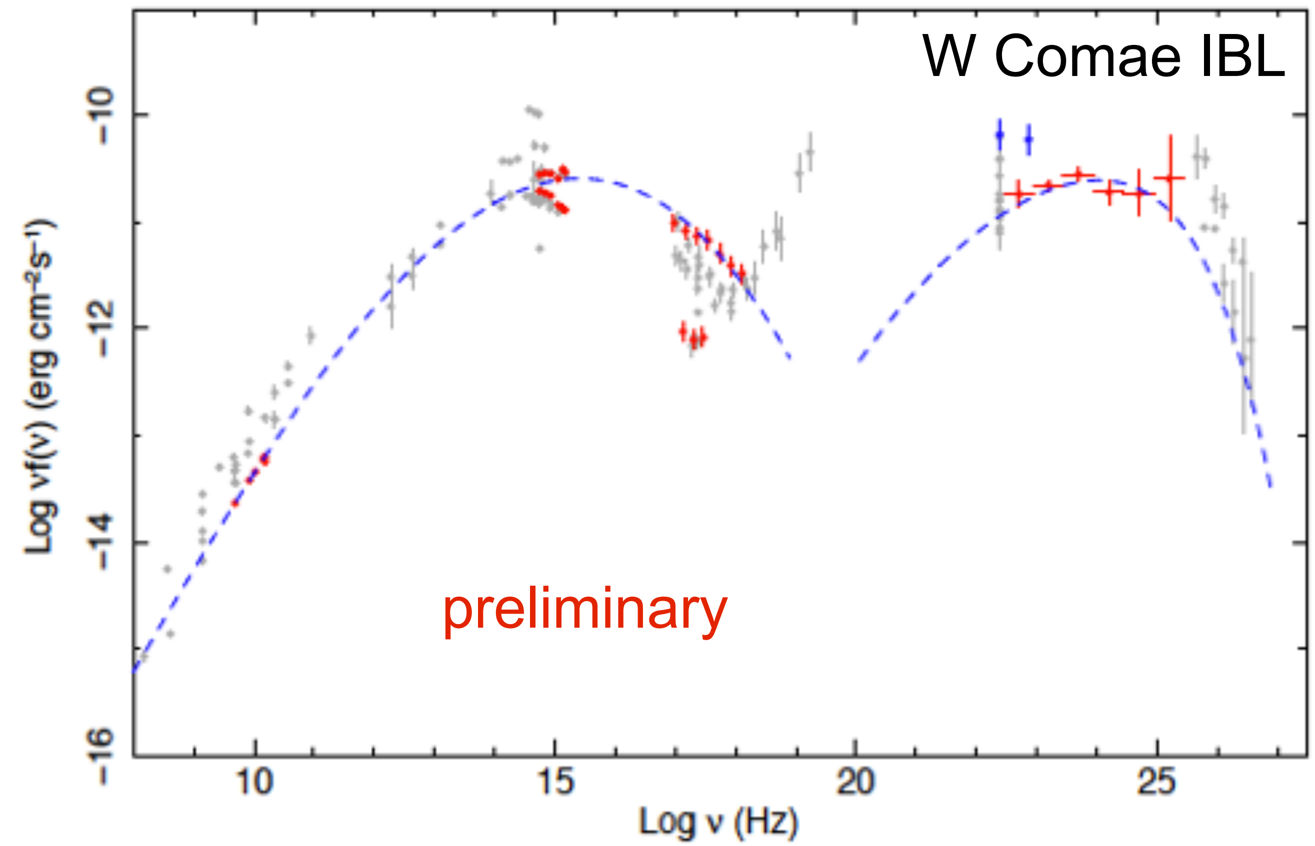


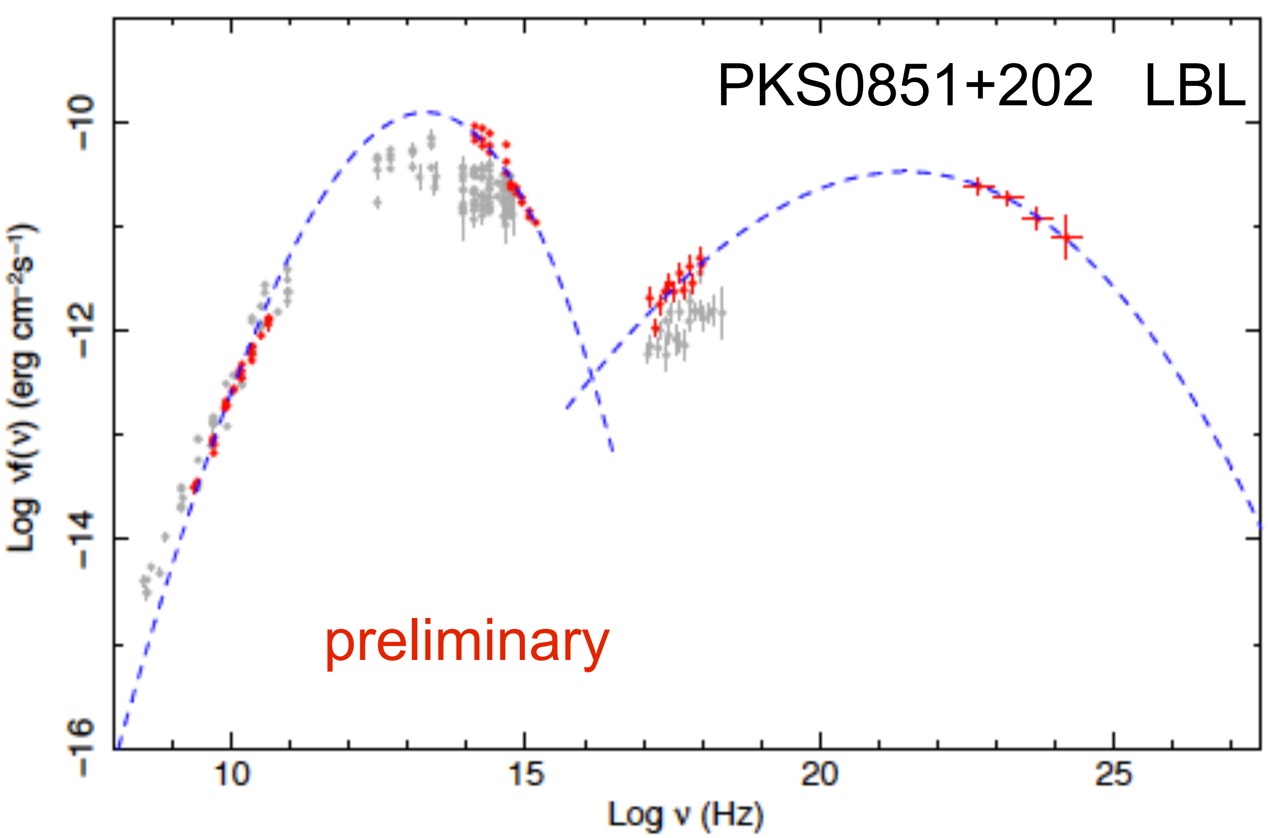
- FSRQ:
  - Synch peaks at lower energies (IR/Opt)
  - Emission Lines and blue-UV bumps (BBB) (Jets are not transparent)
  - L~10^{48} erg/s, higher z
  - IC dominance, IC>Sync

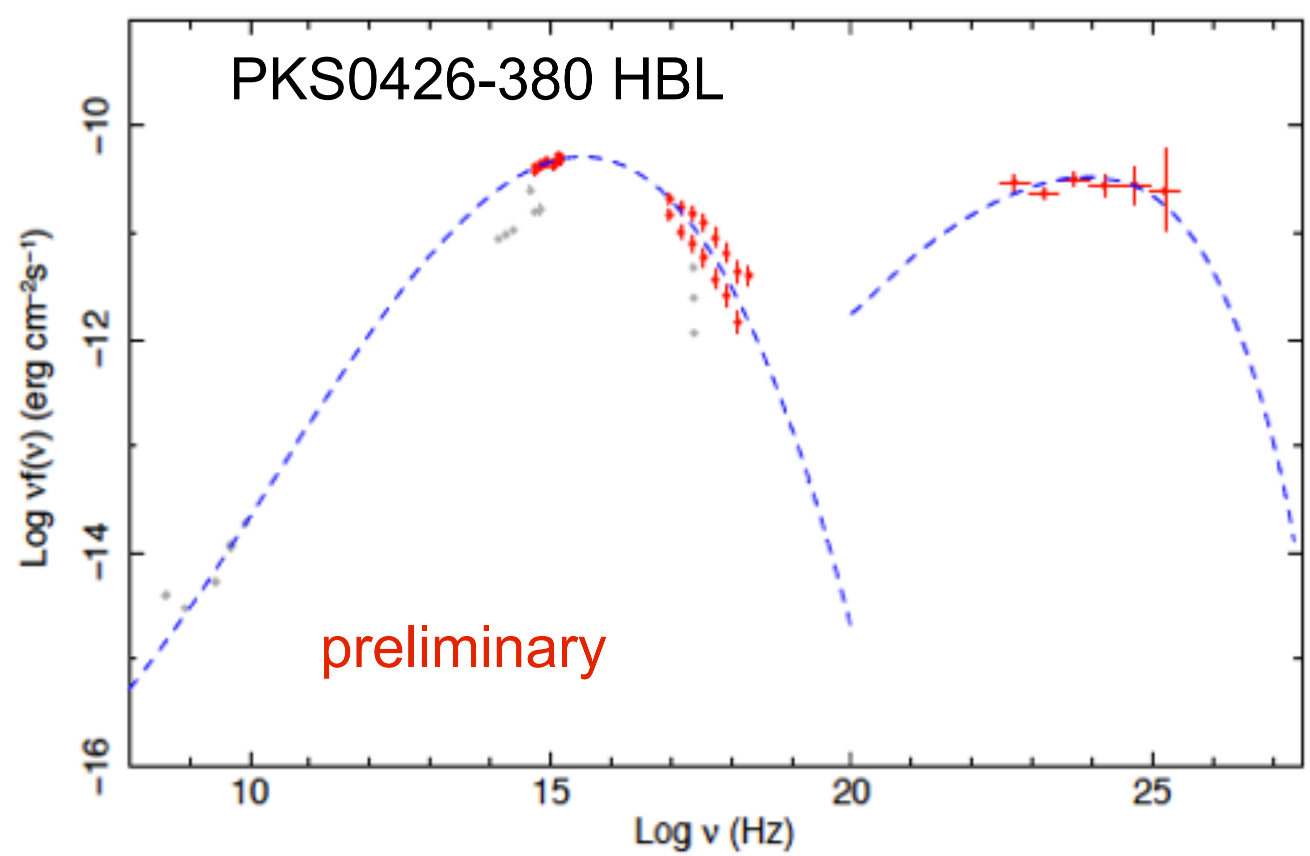
- BL LAC:
  - Synch peak at higher energies (**LBL → IBL → HBL**)
  - weak or absent lines (cleaned jets)
  - L~10^{46} erg/s, lower z
  - No Compton dominance IC ~ Sync

Typical Fermi and MW SEDs





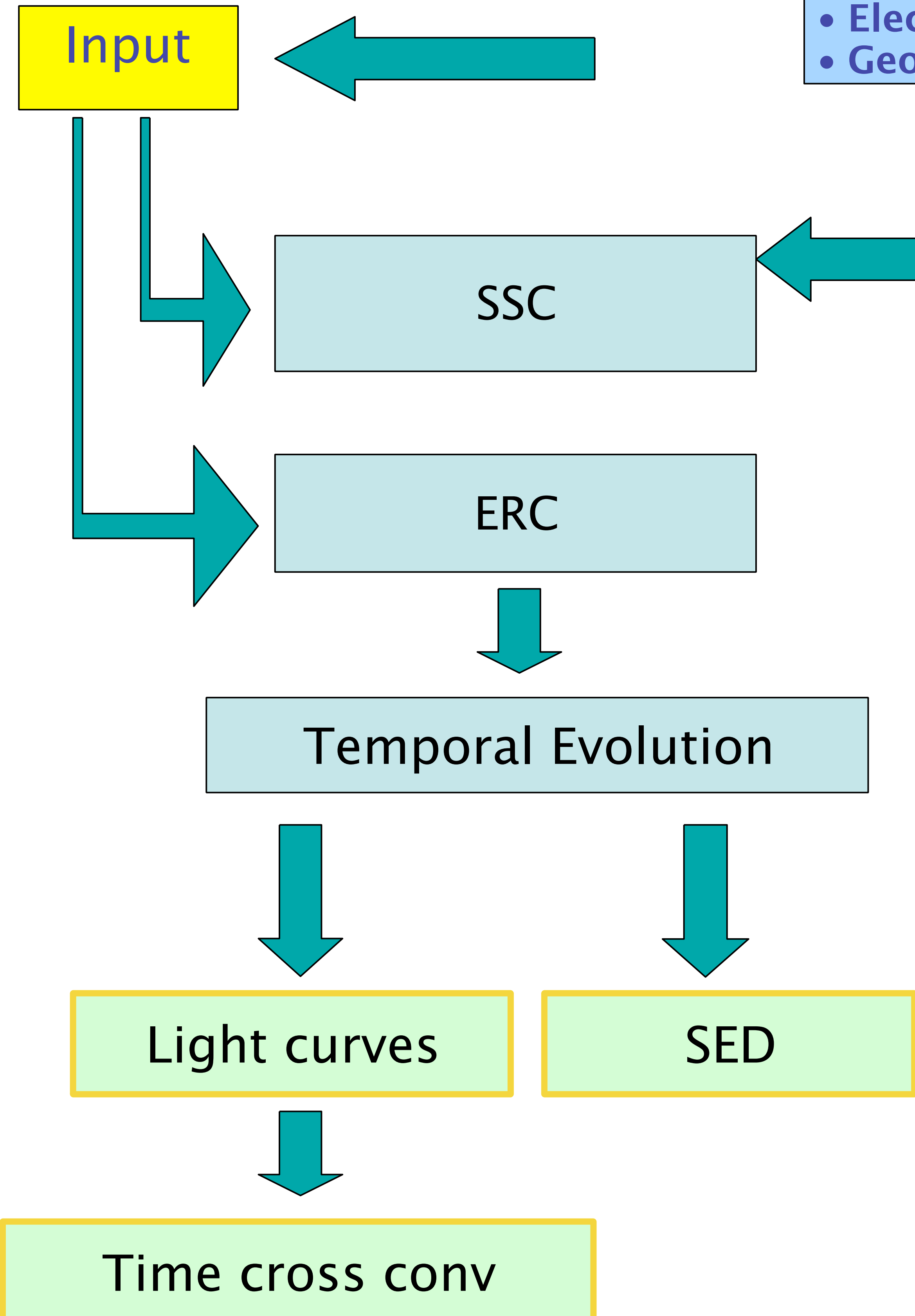


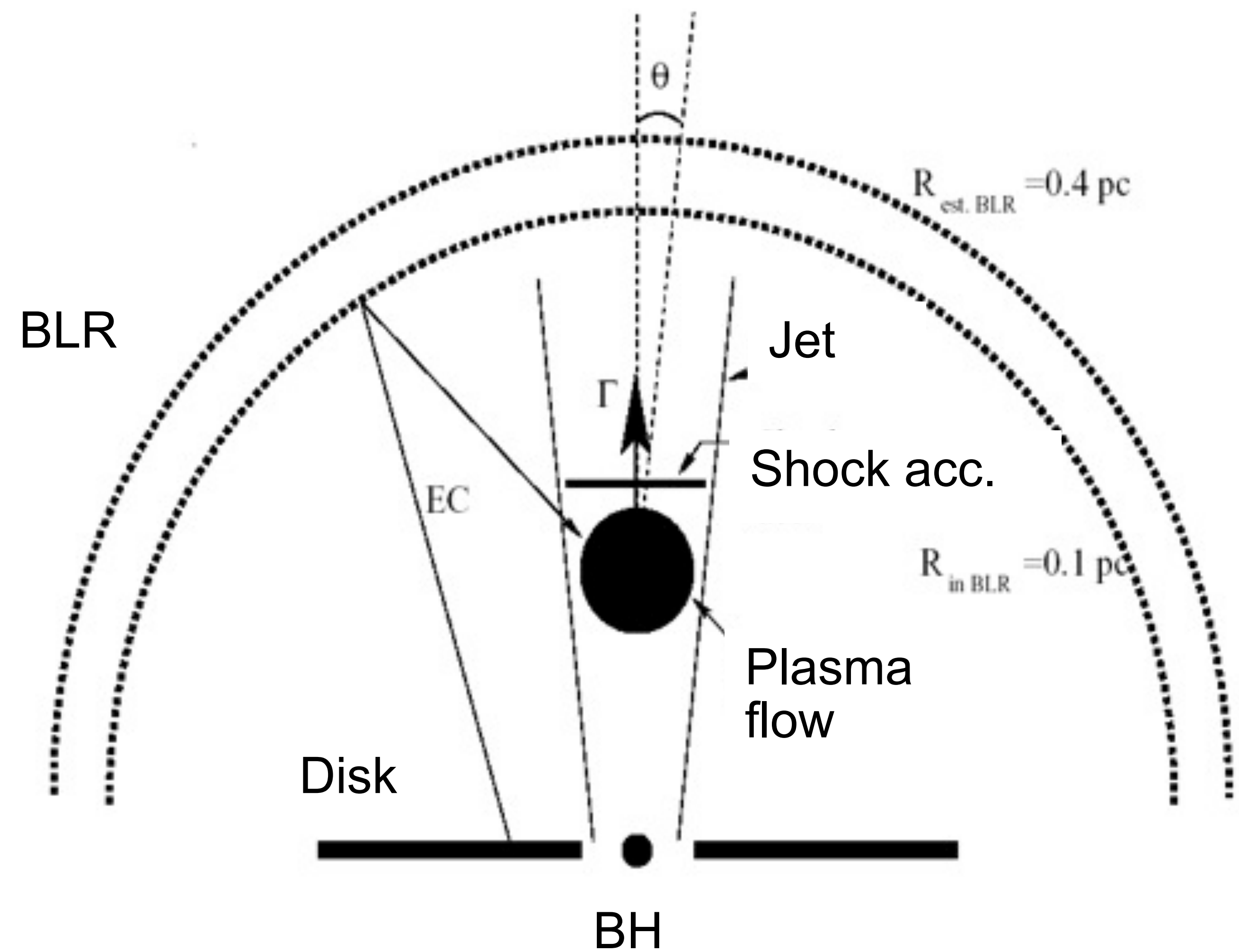


Paradigmatic Scenario :Operative Picture

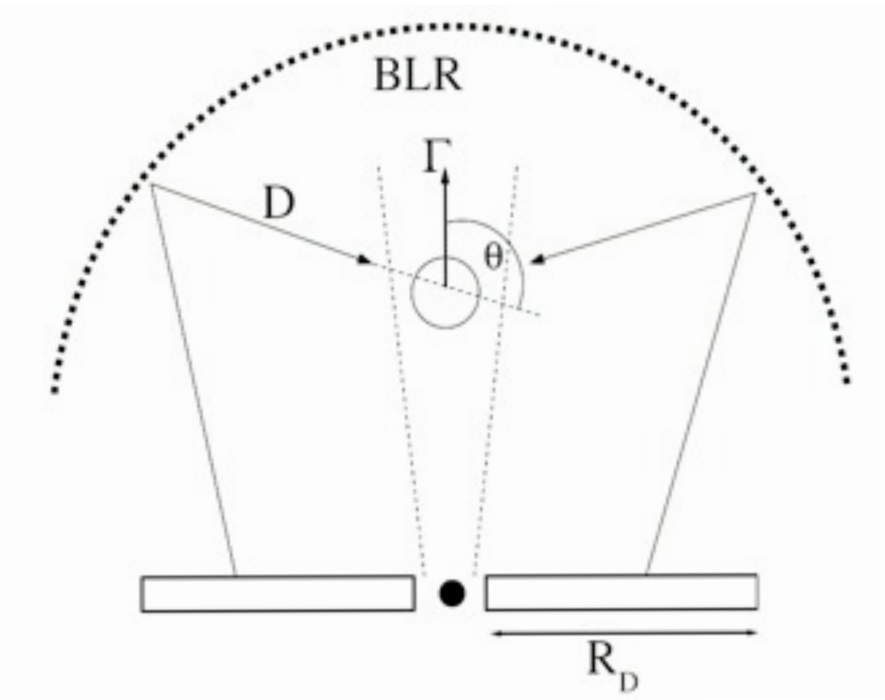
- **SSC/ERC model parameters**
- **Electron injection law**(power law, log-parabolic etc)
- **Geometric model** (homogeneous shell, planar shell)

- Accretion disk instabilities(CA):
- **shot shell for Internal shock**





External Compton scenario (FSRQ)



Sikora,Begelman, & Rees 1994

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

$$I_{\nu'} = \frac{1}{4\pi} \int d\Omega' \, \delta^3 I_{\nu=(\nu'/\Gamma)}$$

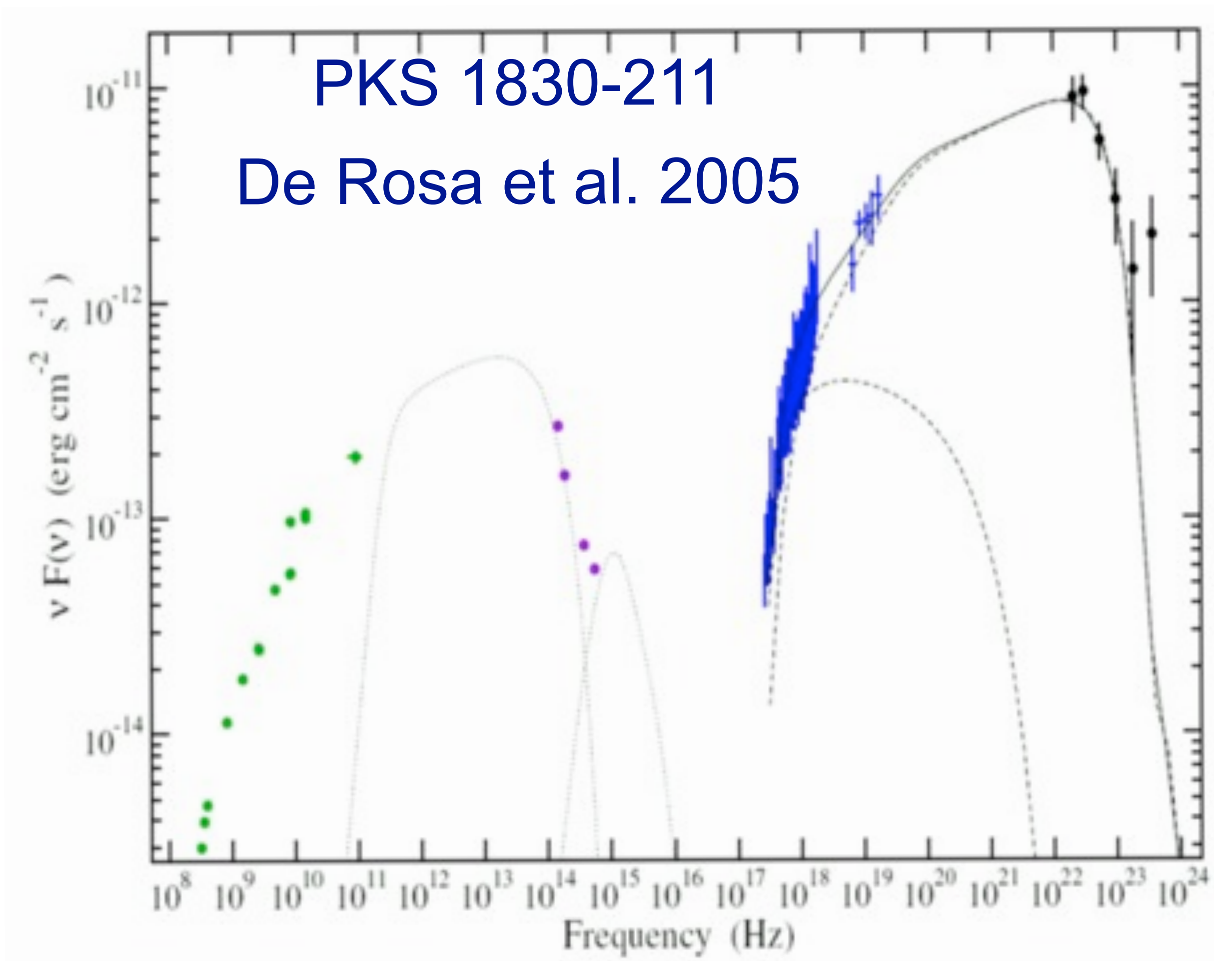
$$= \Gamma\tau \frac{L_{\rm nuc}}{4\pi R^2} f_{\nu=(\nu'/\Gamma)}(T_{\rm ext})$$

$$E' \sim \Gamma E_{\rm ext}$$

$$u'_{ext} \simeq \Gamma^2 u_{ext}$$

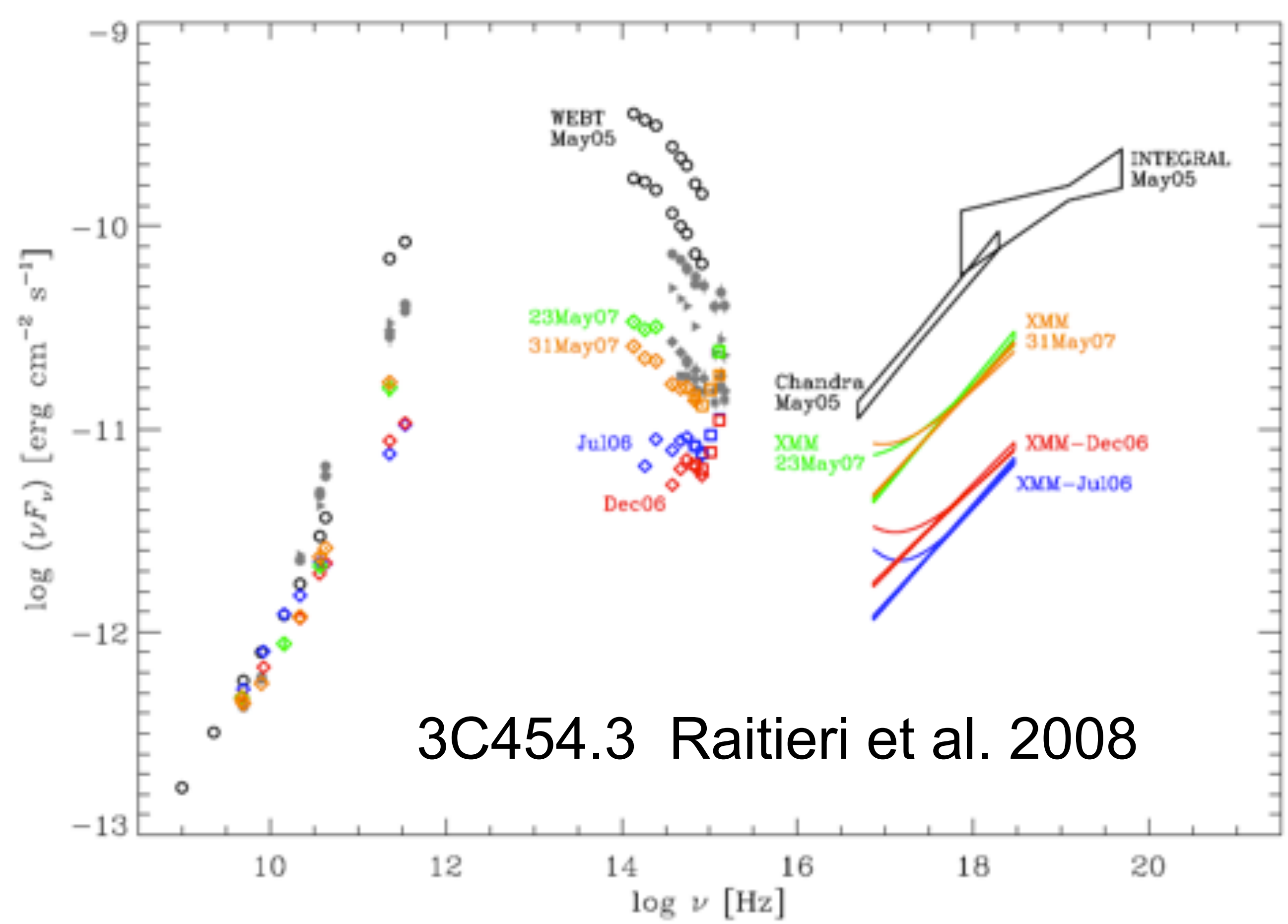
$$\nu_{ERC} \simeq \frac{4}{3}\gamma^2 \nu_{ext} \delta\Gamma$$

$$L_{ERC} \simeq \Gamma^6 U_{ext}$$



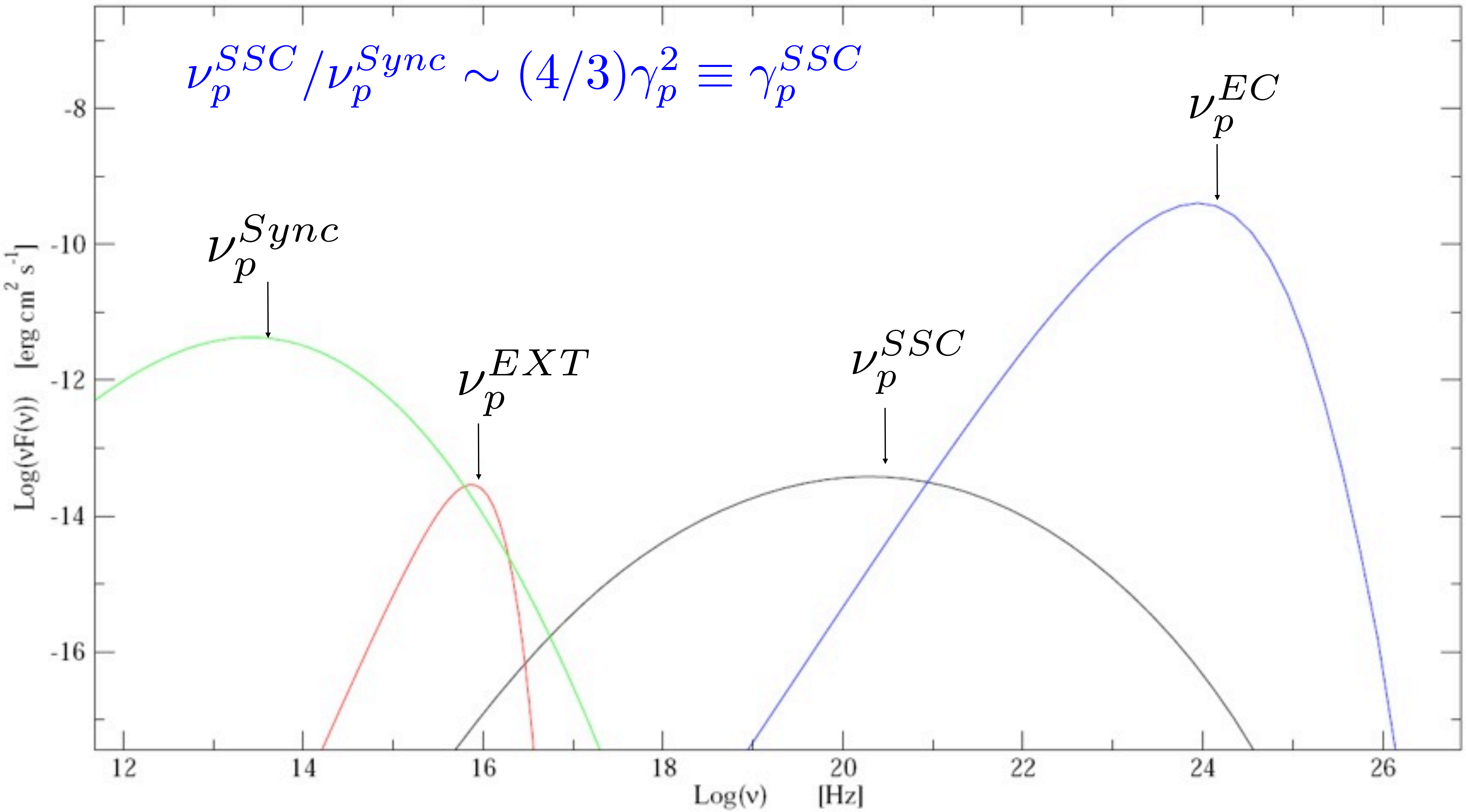
PKS 1830-211

De Rosa et al. 2005



3C454.3 Raitieri et al. 2008

Phenomenological approach to the peak frequency diagnostic



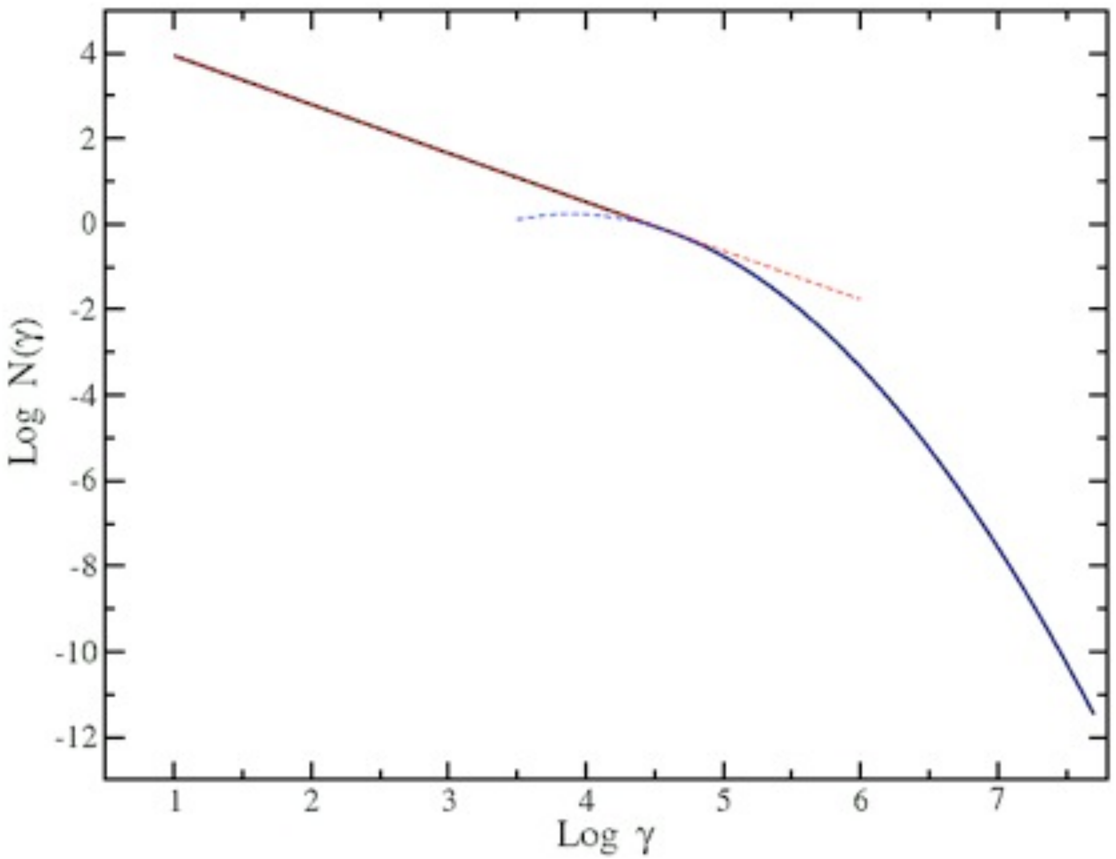
Two main biases:

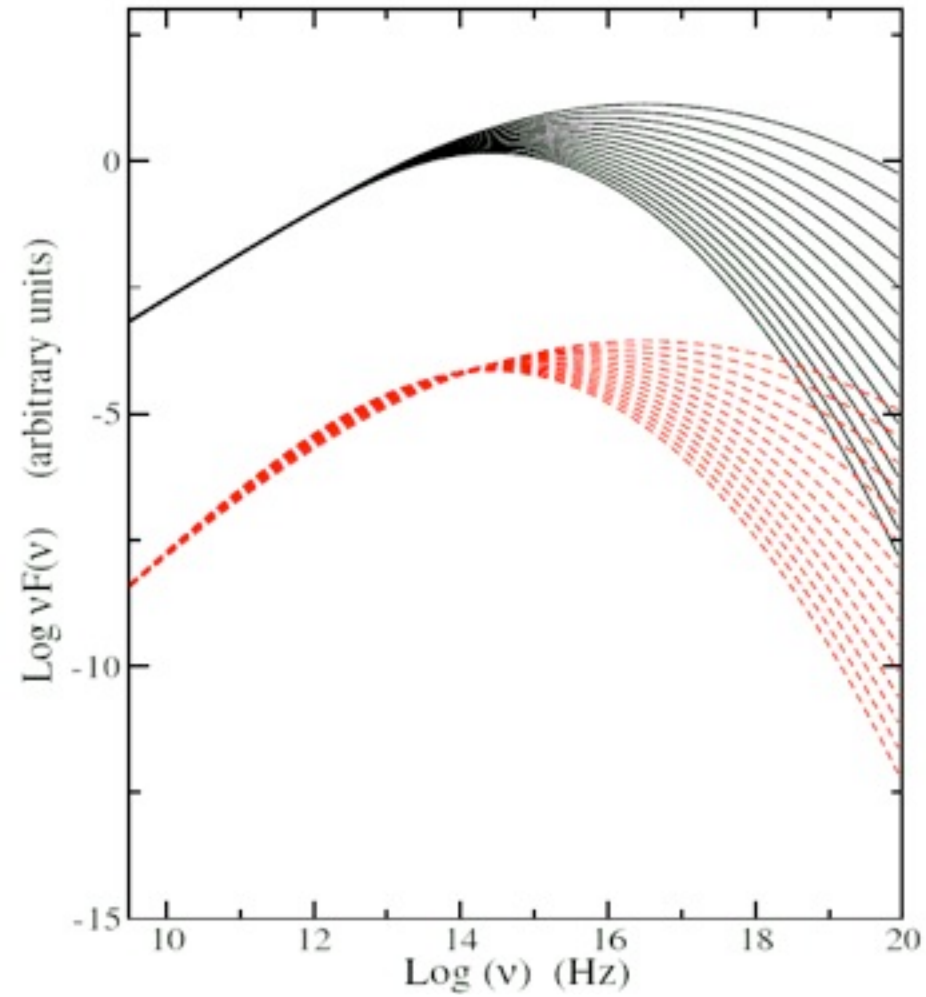
- KN effect, modulation on ν_p, γ_p is biased

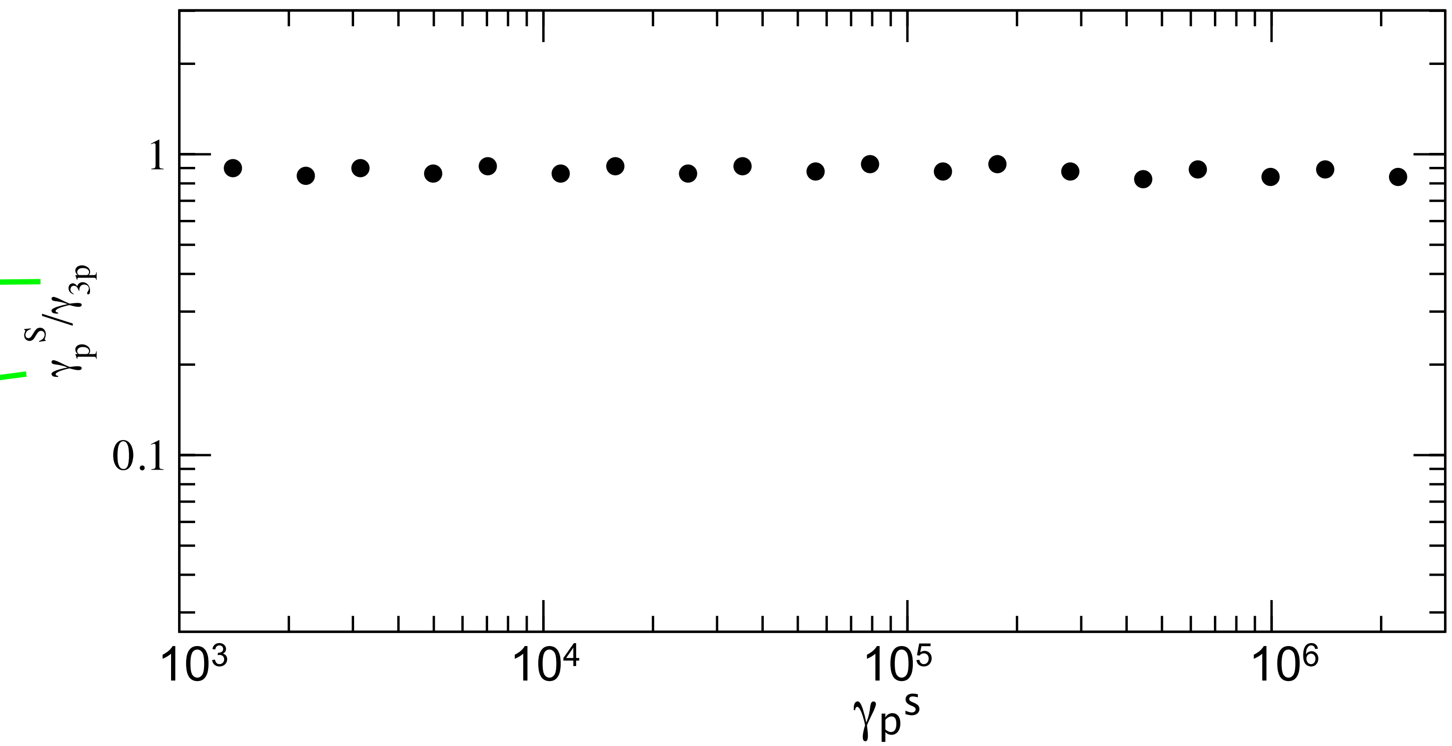
- In the case of EC (or second component) the synch peak frequency is not the peak frequency of the seed photons up-scattered, γ_p is biased

Peak frequency: Synchrotron emission

how to link the peak frequency of the synchrotron emission to the shape of the emitting electron energy distribution





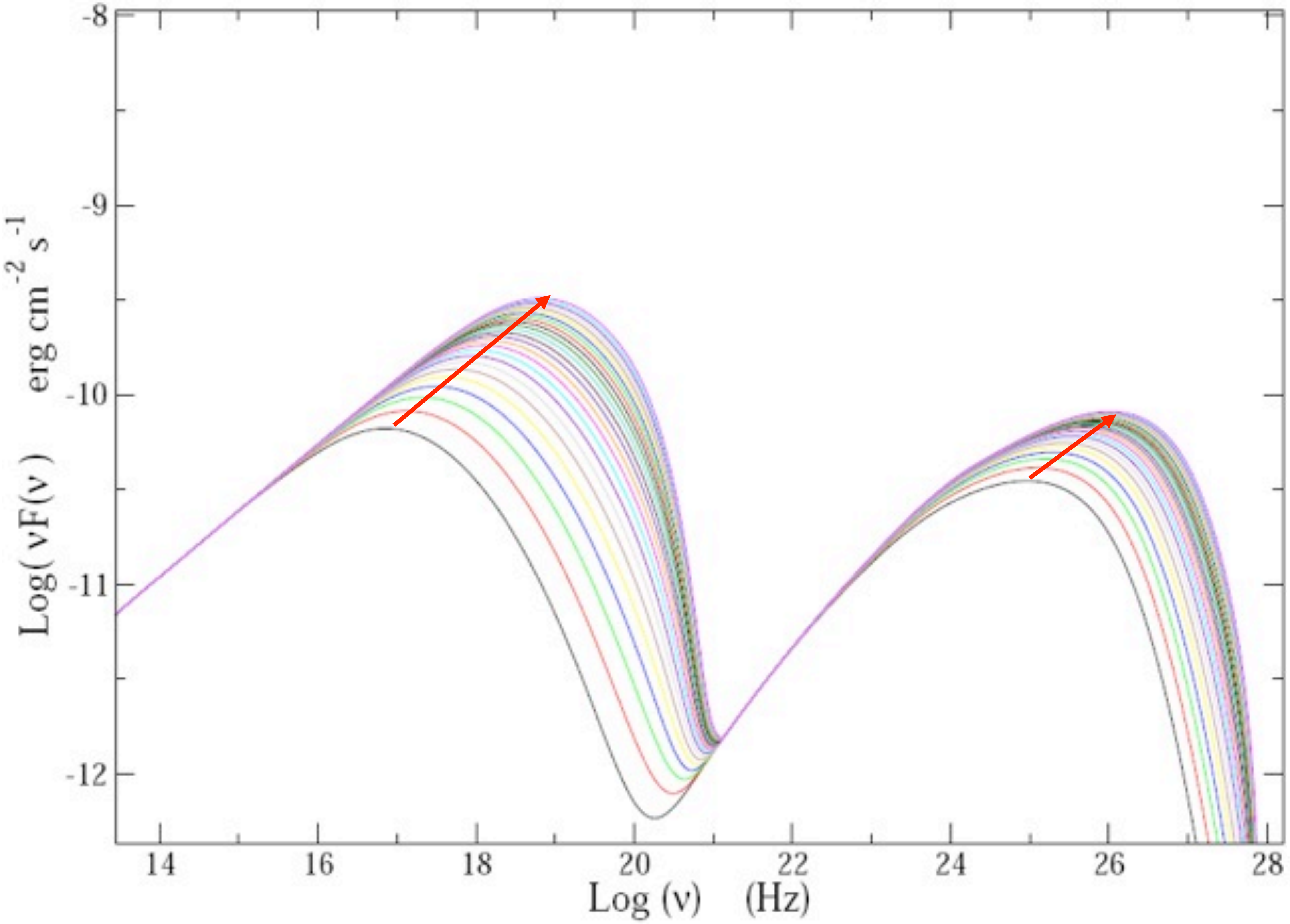


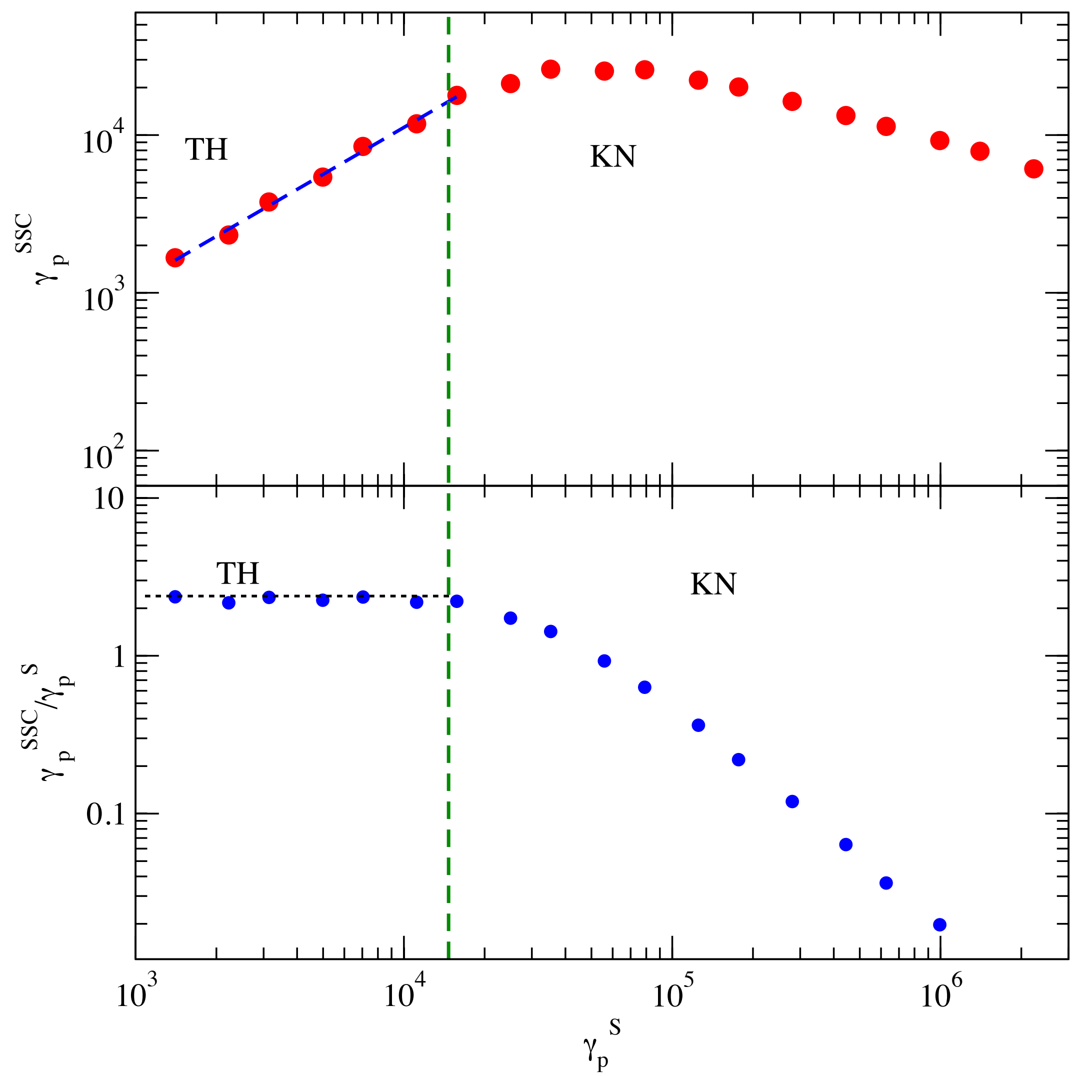
$$S_p^{Sync} \sim \frac{dN(\gamma)}{d\gamma}\gamma_{3p}^3\ B^2\ \delta^4$$

$$\nu_p^{Sync} \sim 3.2 \times 10^6\ (\gamma_p^S)^2\ B\ \delta$$

γ_{3p} is the peak of $dN(\gamma)/d\gamma\ \gamma^3$

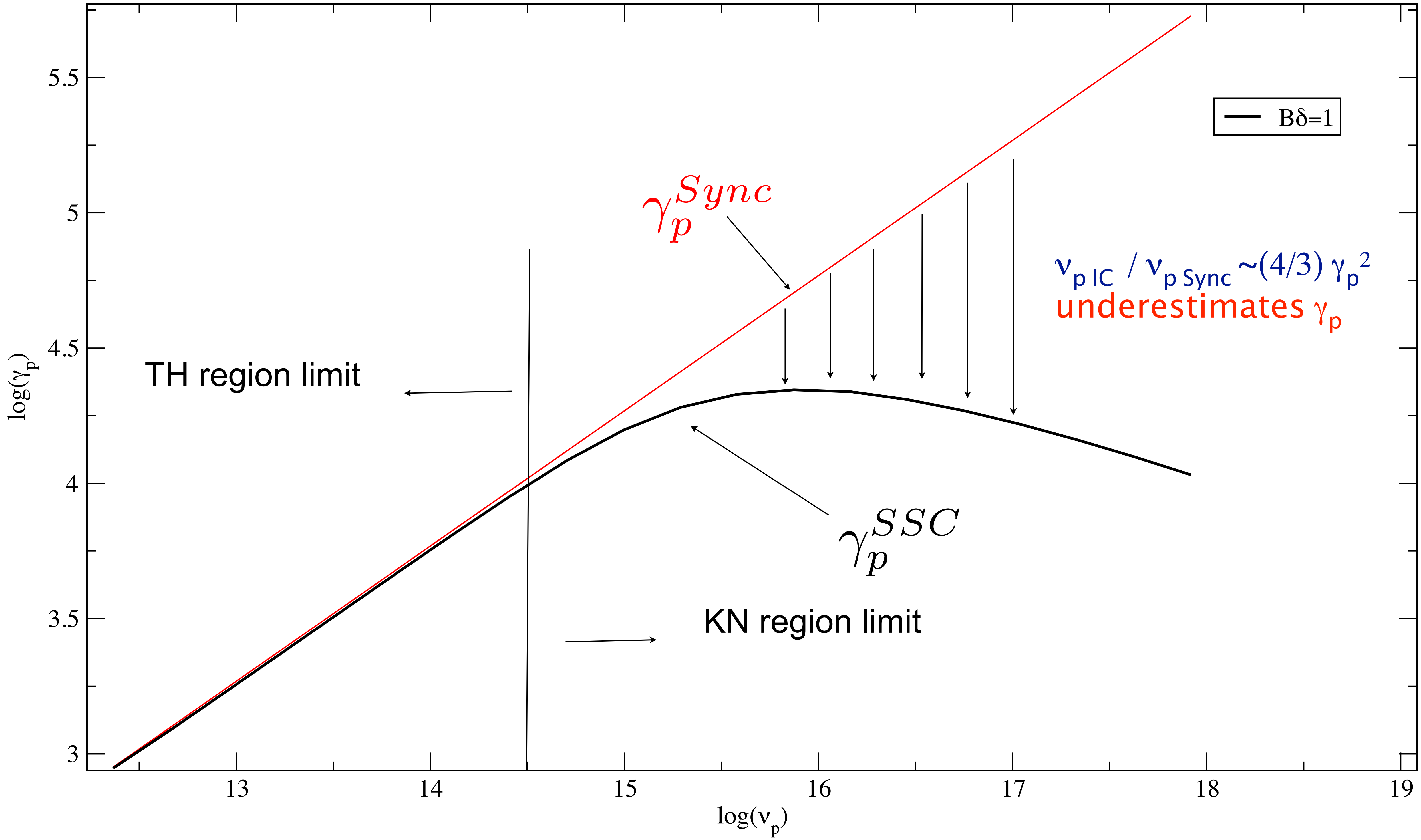
SSC/EC: KN effect bias





- $\nu_{p\ IC} / \nu_{p\ Sync} \sim (4/3)\ \gamma_p^2 \equiv \gamma_p^{SSC}$ is true only in TH regime
- Δ Ep Synch ~ 2 decades
- Δ Ep SSC ~ 1 decade (KN) suppression

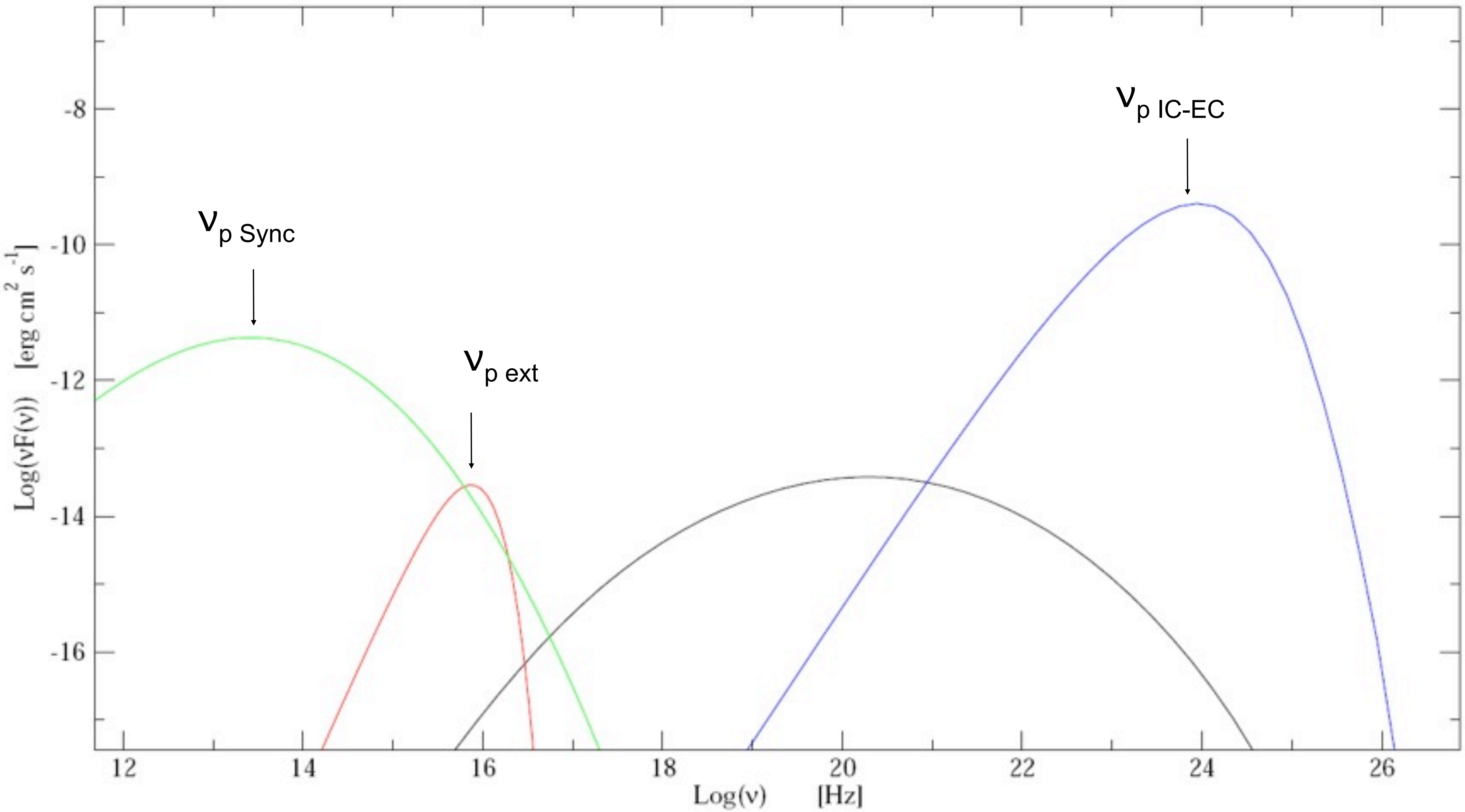
SSC KN bias in the γ_p^{IC} *vs* ν_p^S plane



$$B = 0.1,\ \delta = 10,\ n(\gamma) = K \times 10^{-r\ \log_{10}(\gamma/\gamma_p)^2},\ r = 0.4,\ \gamma_p = [10^2 - 10^5]$$

$$N = \int n(\gamma) d\gamma = 1,\ R = 10^{15} cm,\ \tau_{BLR} = 0.1,\ T_{disk} = 10^5 K$$

EC bias



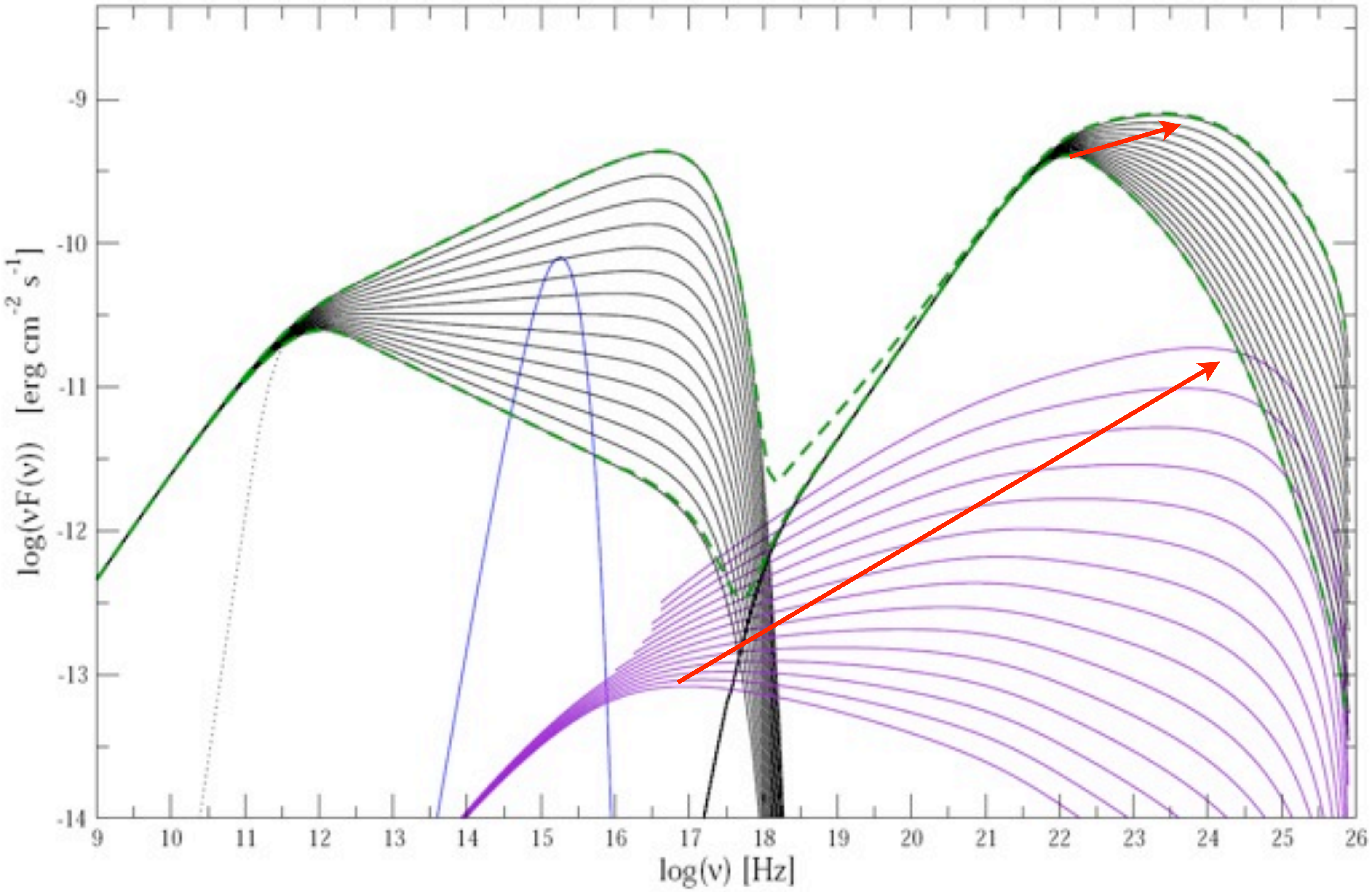
$\nu_{p\ EC} \sim (4/3)\,\gamma^2\,\nu''_{p\ ext}\,\delta\Gamma\,/(1+z)$

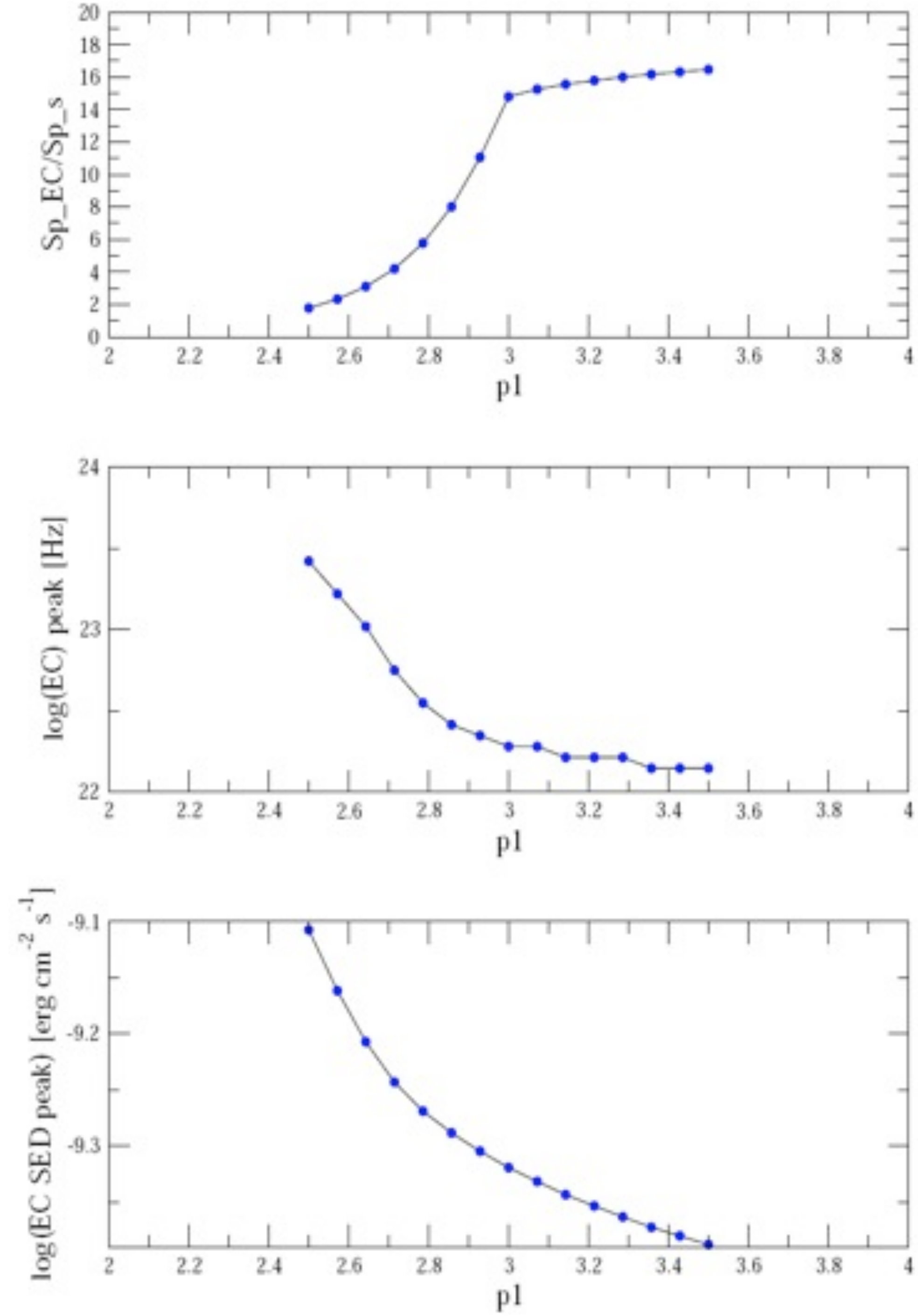
$\nu_{p\ IC}\,/\,\nu_{p\ Sync} \sim (4/3)\,\gamma_p^{\ 2}$ ⟶ overestimates γ_p

$\nu'_{seed\text{-}IC} = \nu''_{p\ ext}\Gamma \quad >> \quad \nu'_{p\ Sync}$ ← emitting region rest frame

$\sim 10^{16}$ Hz $\qquad \sim 10^{13}/\delta$ Hz

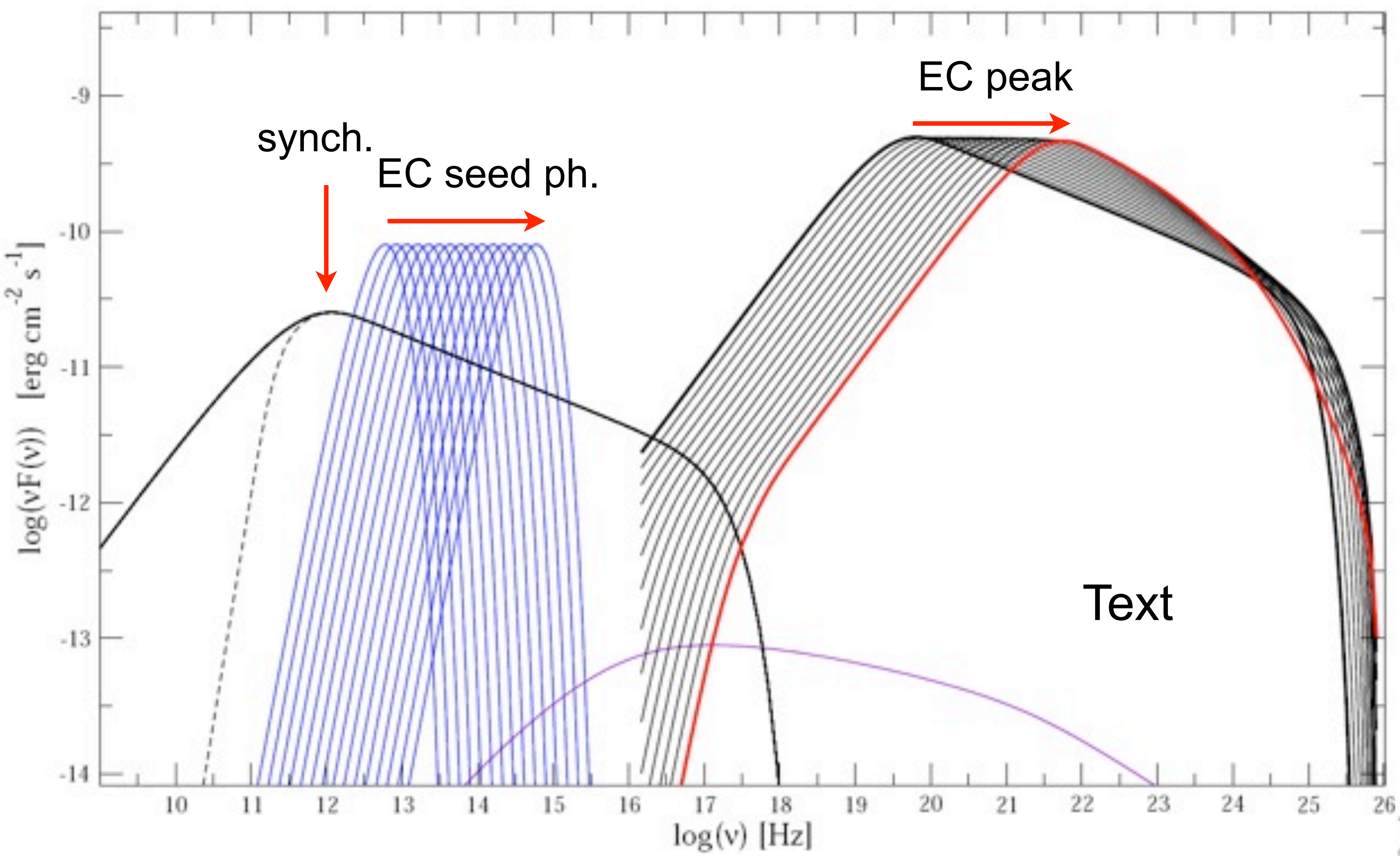
EC bias: change in the shape of the electron energy distribution

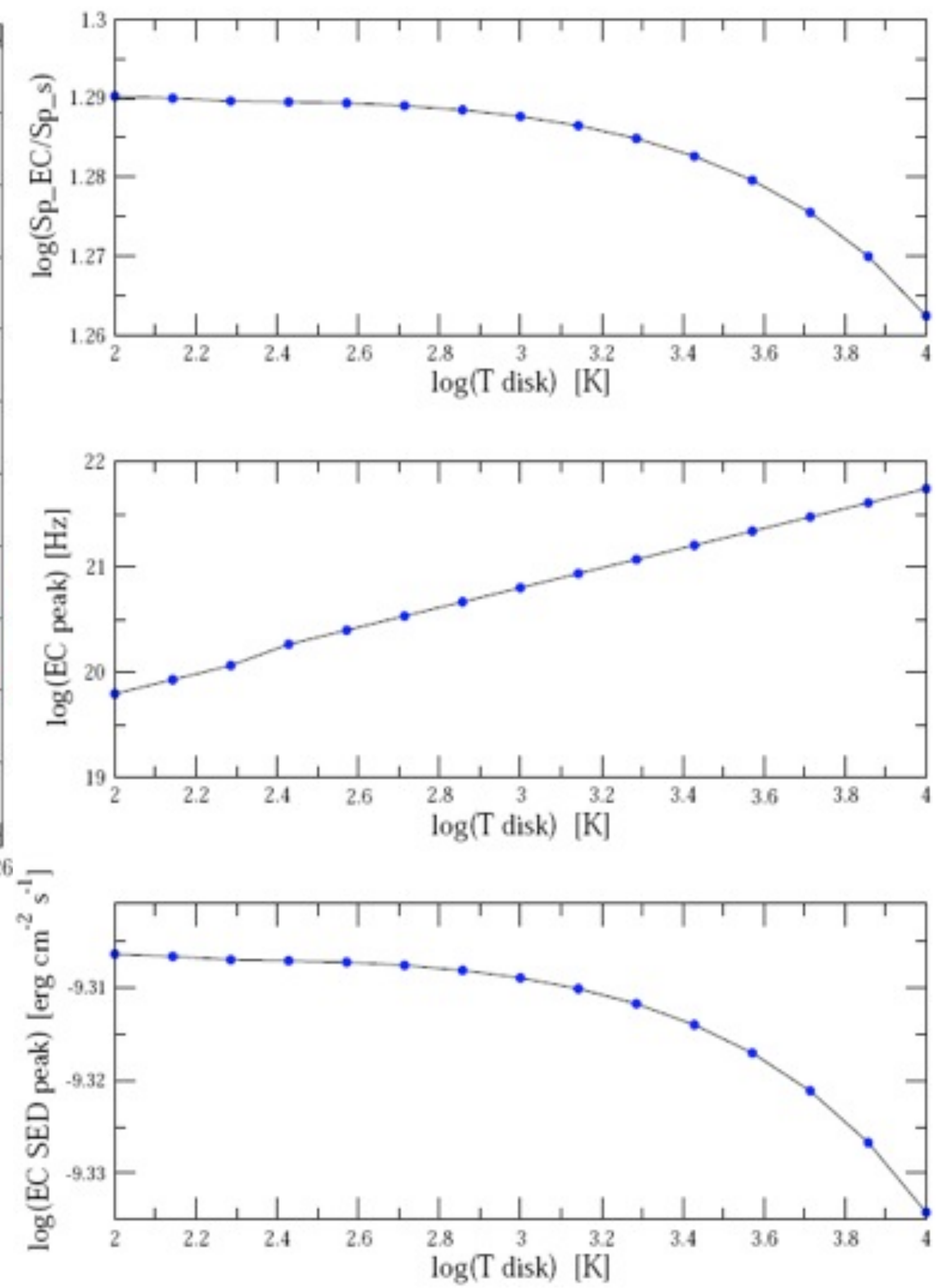




- No or weak hard X-ray spectral evolution, soft X-ray depends strongly on g max
- KN mimics curvature and/or absorption
- Comp dominance change mainly due to S, EC power ~ steady
- SSC not relevant in the gamma, may show a soft X-ray softening

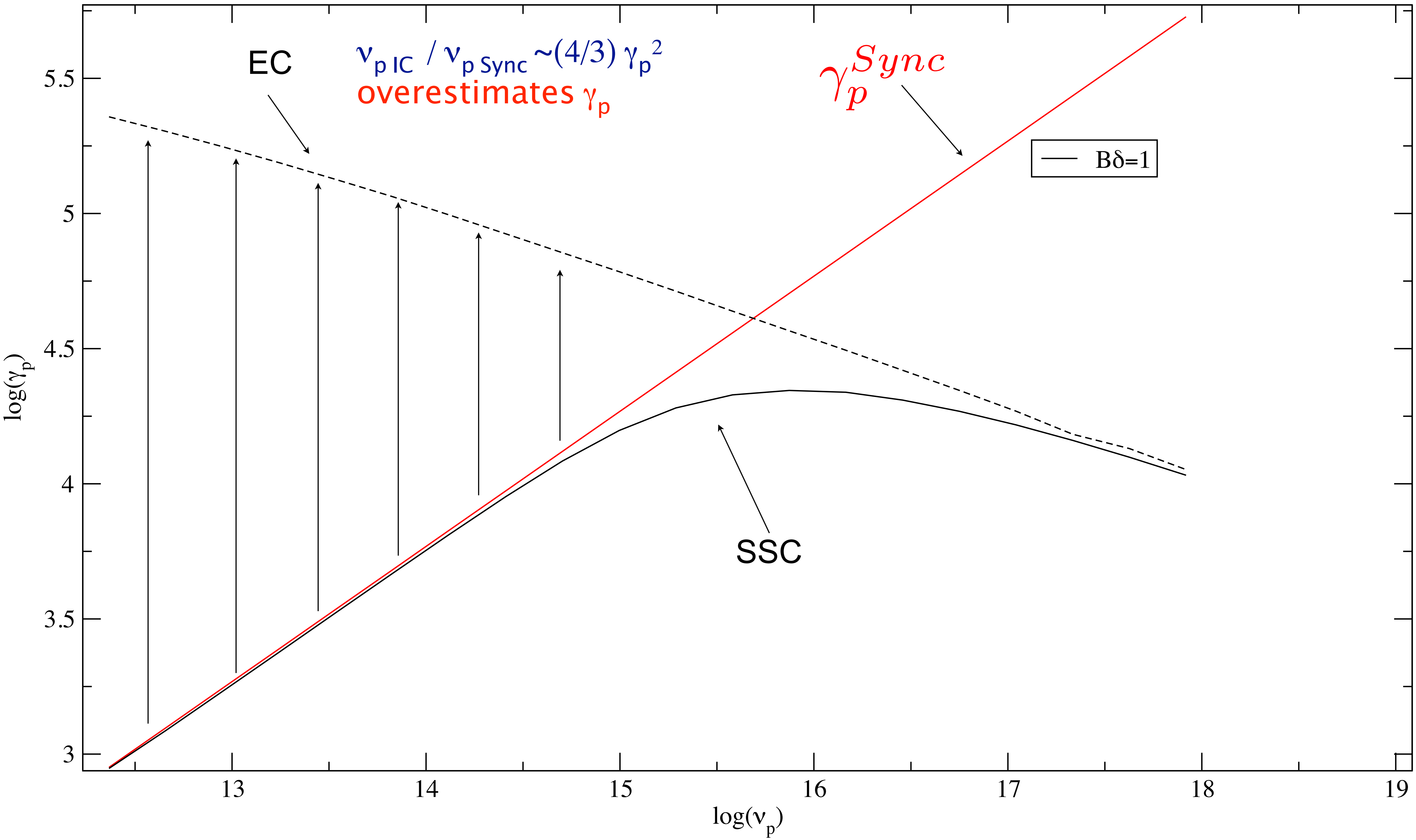
EC bias: change the Energy of the seed photons



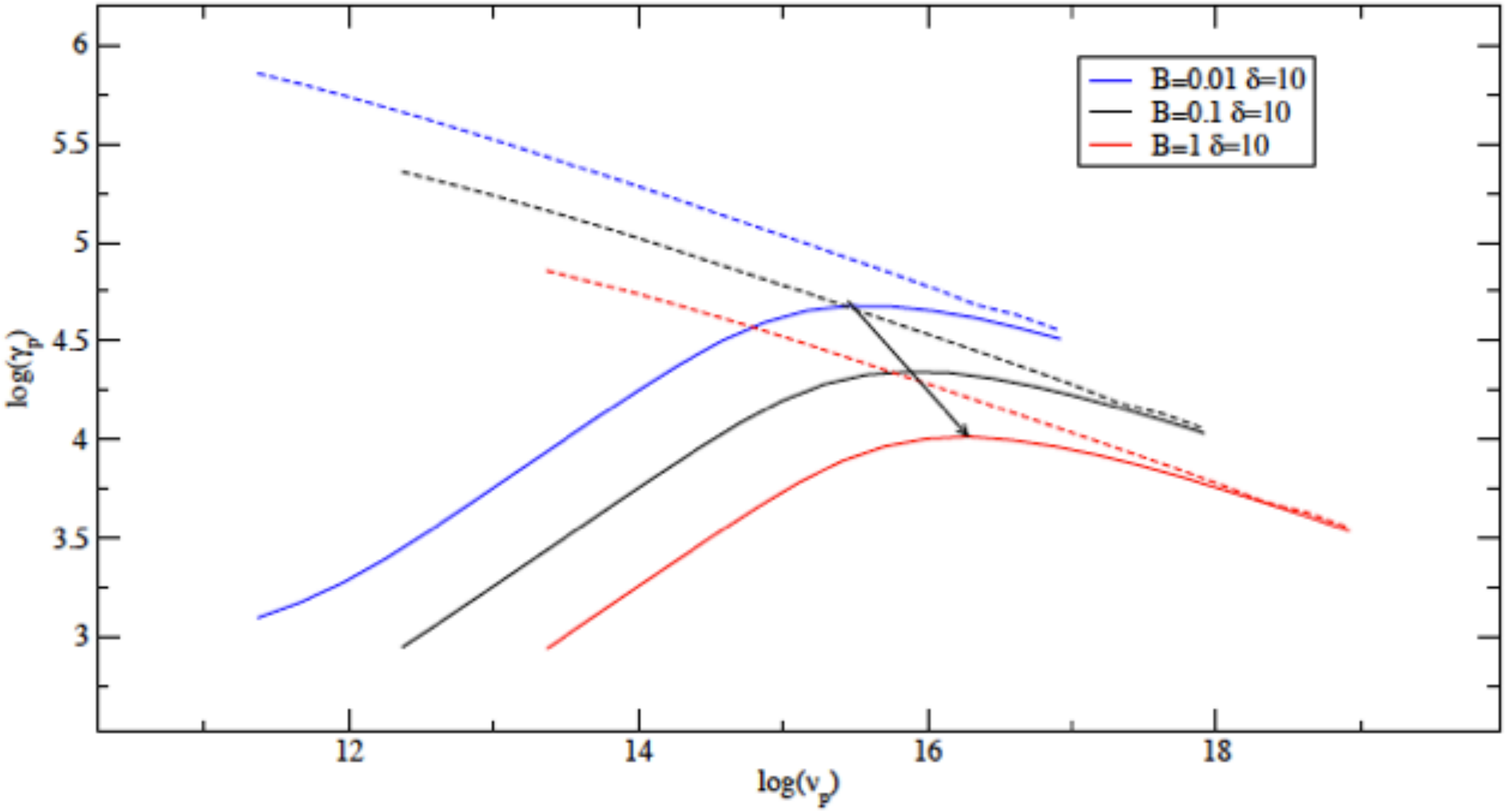


- Change in the energy external photons
- Transition from TH to KN
- In TH regime we can see PL shape (if e- have PL shape), this means that external seed photons are IR
- The KN regime turns the spectrum to curved even of the e- shape is PL

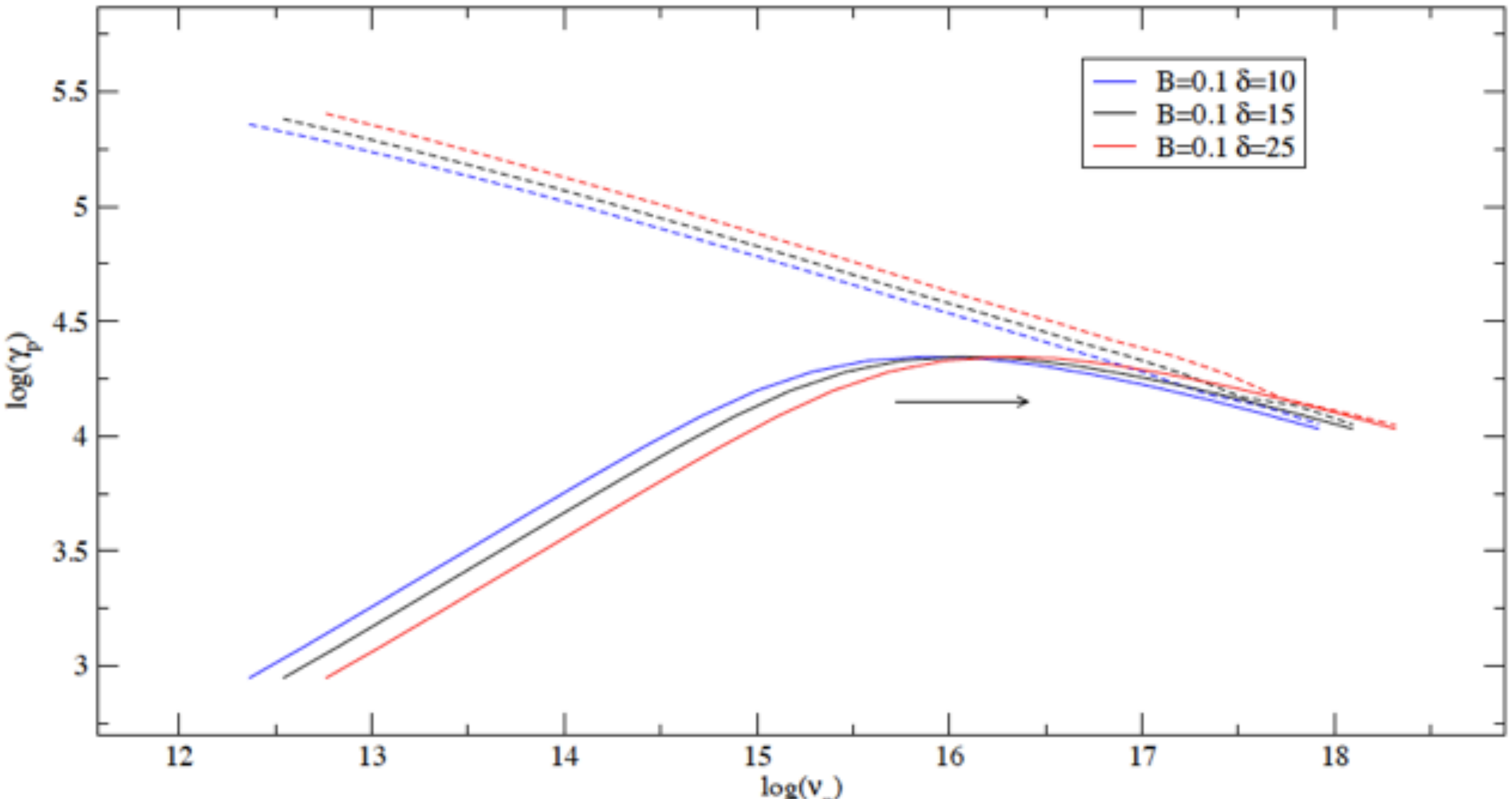
EC bias in the γ_p^{IC} *vs* ν_p^{S} plane



Effects from B and δ



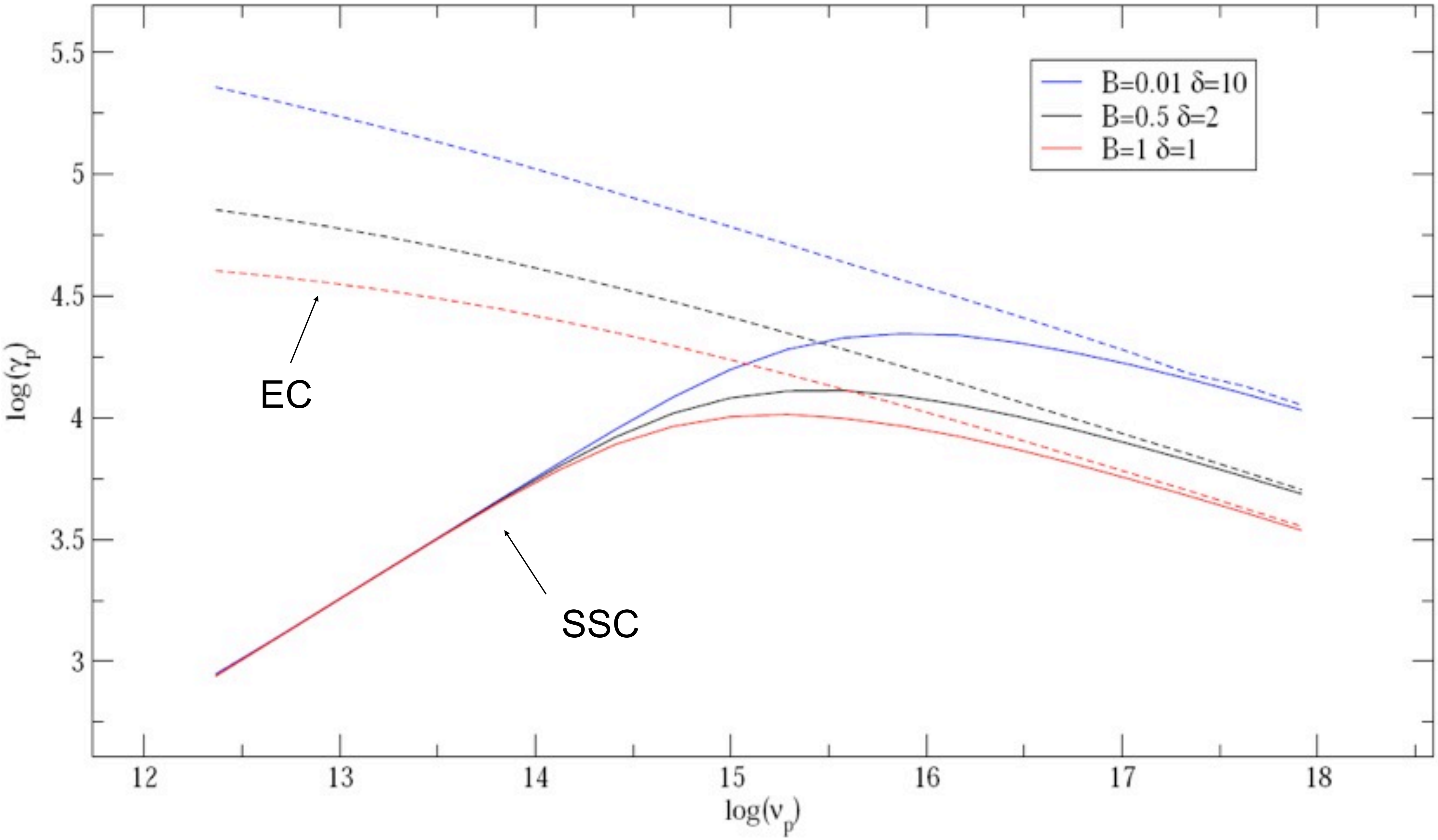
- KN is "delayed"
- γ_p decreases because $\nu_{p\ Sync}$ is higher with the same of value of γ_p
- $\nu_{p\ Sync} \sim 3.2\ 10^6\ (\gamma^S{}_p)^2\ B\ \delta\ /\ (1+z)$



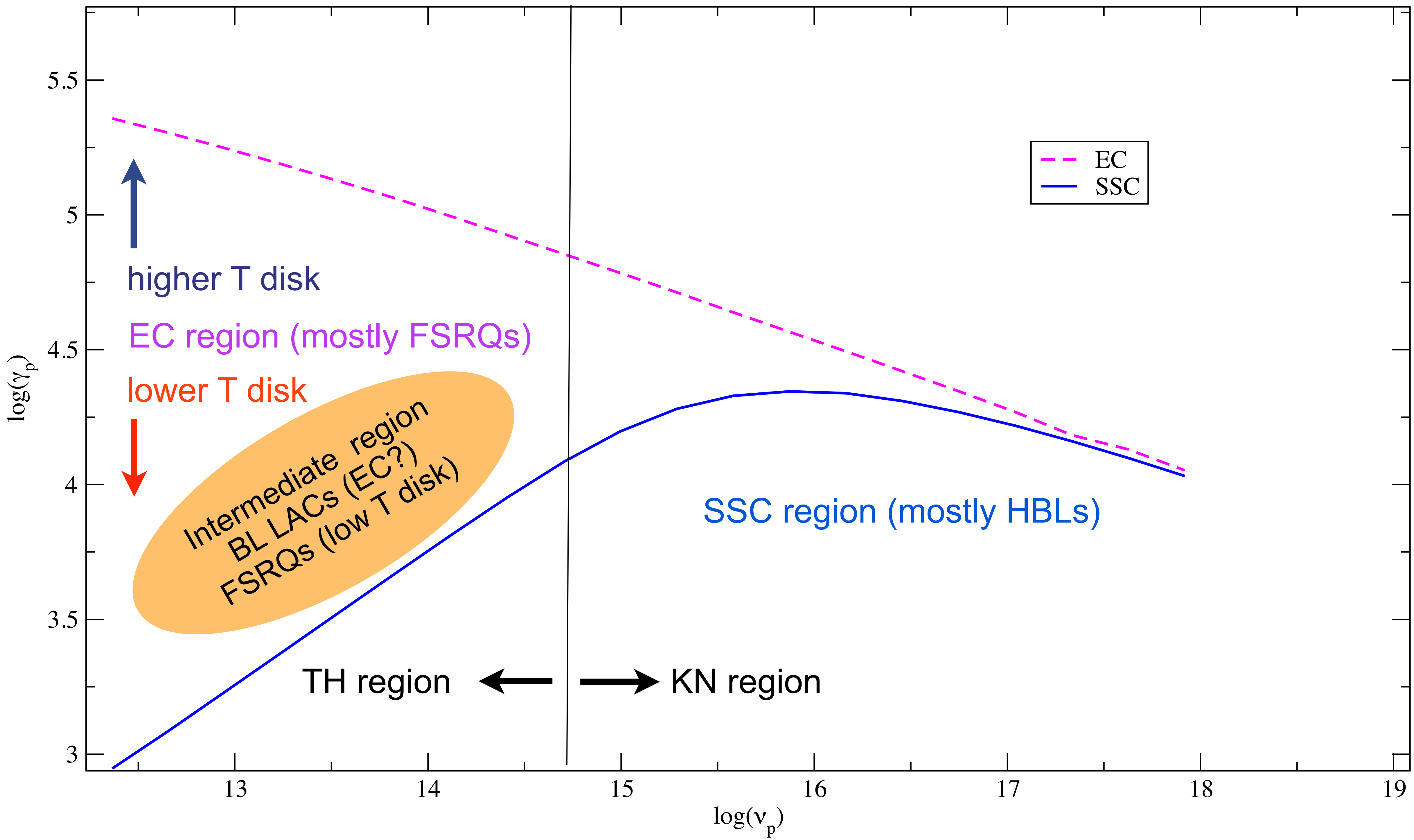
- Only KN is "delayed", no effect on γ_p

Bδ degeneracy: expectation for Bδ =1

$$\nu_p^{Sync} \sim 3.2 \times 10^6 \; (\gamma_p^S)^2 \; B \; \delta/(1+z)$$



analysis of observed data in the γ_p^{IC} *vs* ν_p^S plane



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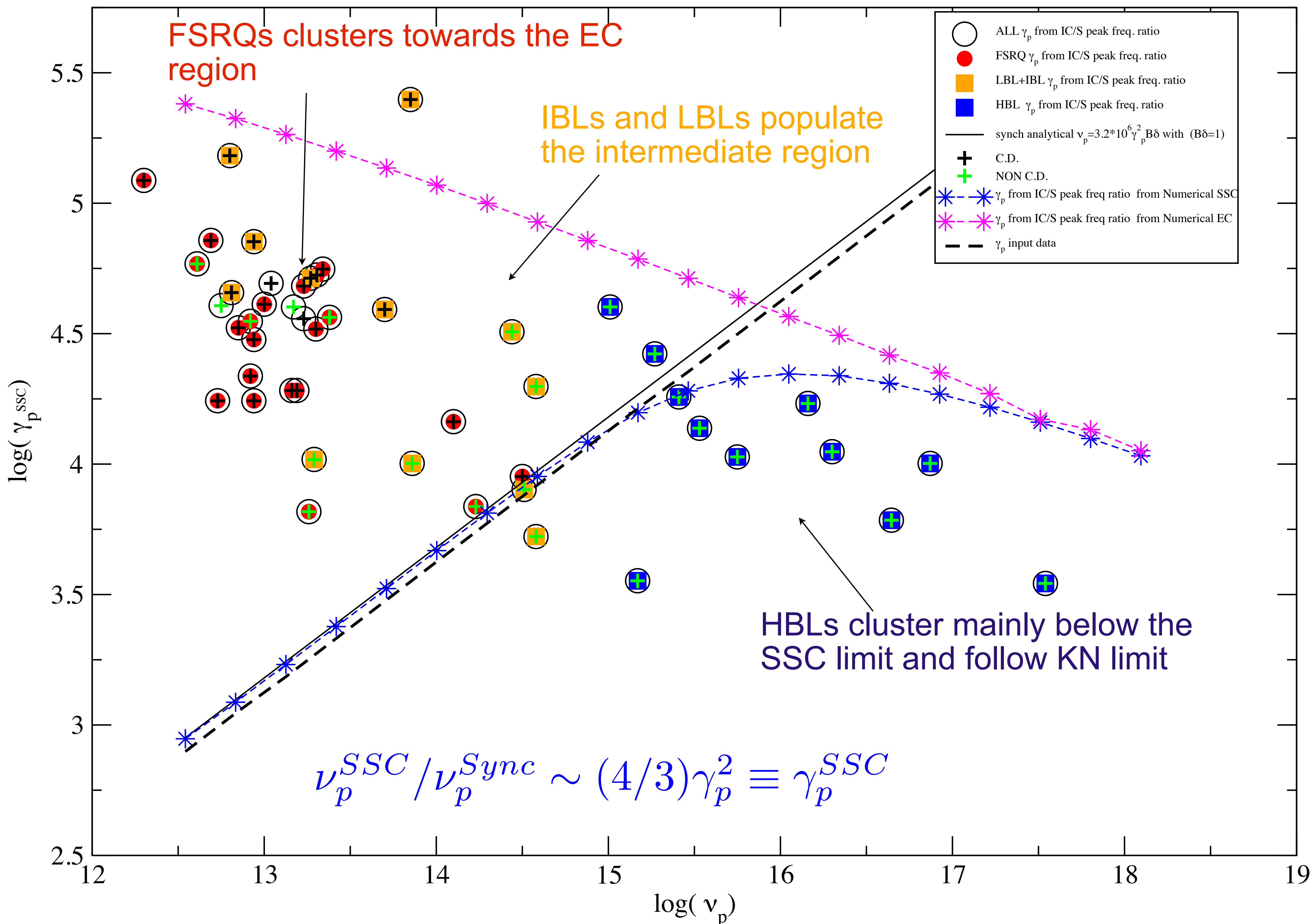
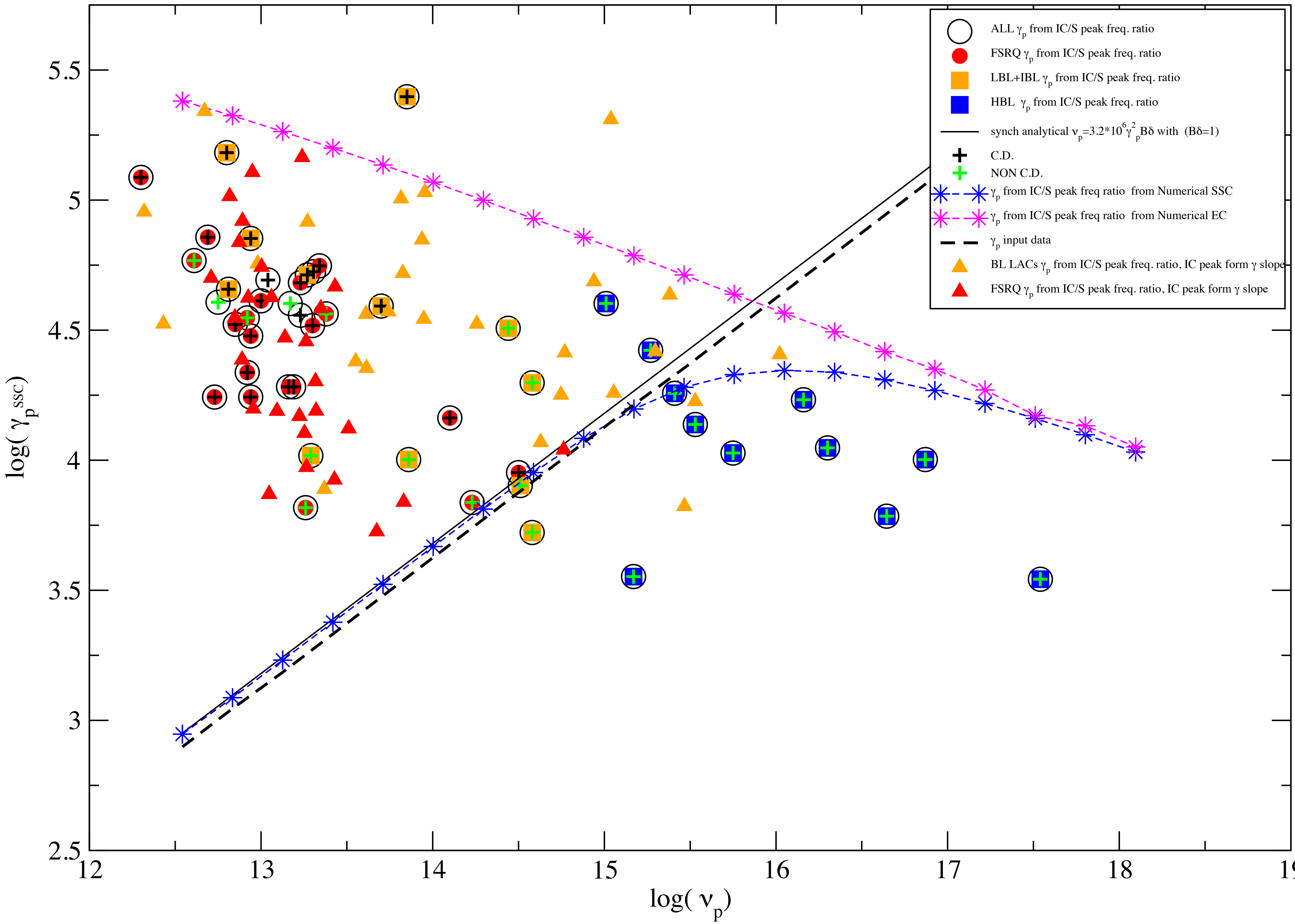


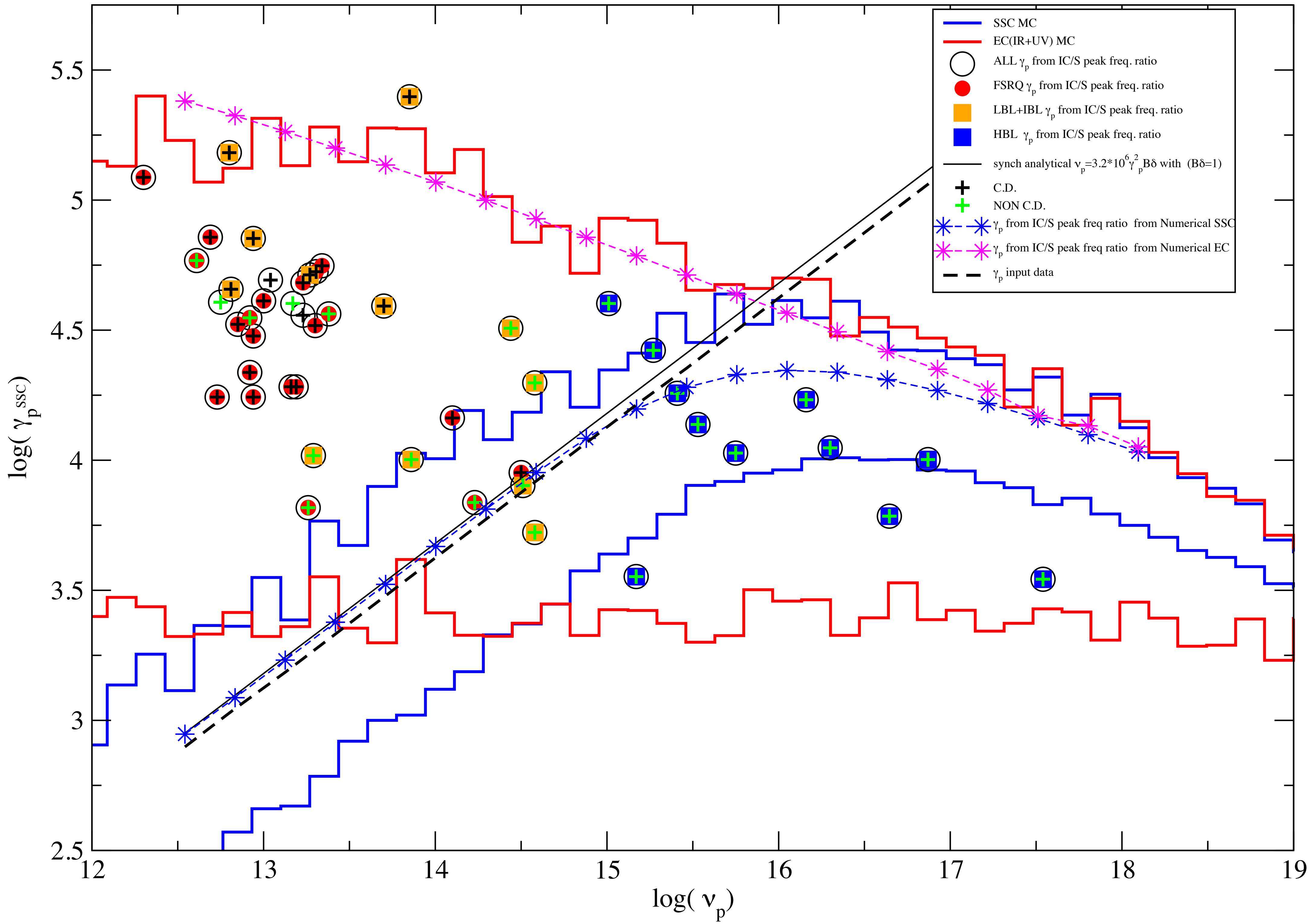
48 sources with SEDs peak constrained by polynomial fit (cubic)
23 FSRQ, 11 HBL, 12 IBL+LBL (23 BL LACs) + 2 BZU
24 C.D., 24 Non C.D.

C.D. objects cluster in the EC region, non C.D. follow mainly the SSC trend

analysis of observed data in the γ_p^{IC} *vs* ν_p^S plane

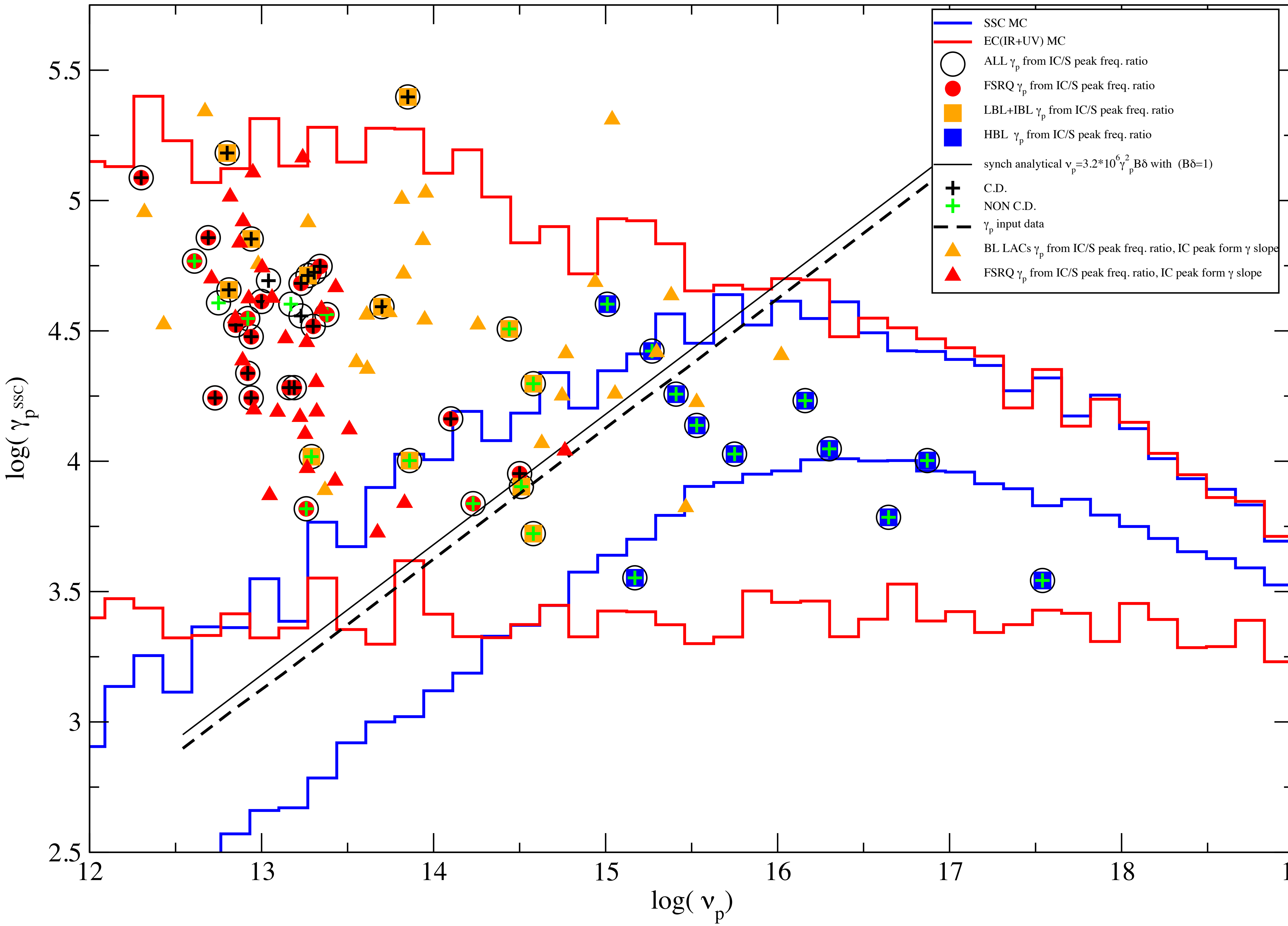


analysis of observed data in the γ_p^{IC} *vs* ν_p^S plane



To take into account the $B\delta$ degeneracy and the effect of T_{disk} we use 1000 MC realizations, with δ ranging in the interval [10-15], B in the interval [0.01-1] G and T in the interval $[10 - 10^{4.5}]$ K

analysis of observed data in the γ_p^{IC} *vs* ν_p^S plane



Conclusions

- For the first time high quality quasi simultaneous MW SED are investigated to look for signature of SSC and EC models
- We use these data to perform a peak analysis in the γ_p-vs-ν_p plane
- HBLs follow mainly the SSC(TH/KN) trend
- IBLs-LBLs populate the SSC(TH) region up to the EC region
- FSRQs populate mainly the EC region
- C.D. object are contained between the EC region and the SSC(TH)
- HBLs are always non C.D.
- We need to increase the statistics, to understand better how are populated the different regions
- We need to investigate better the variability and its connection with the C.D. and/or the peak position (BBB, etc...), and how objects migrate across paths in the parameter space
- EC vs multi-component models