HELLENIC REPUBLIC
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On the connection of radio and γ-ray emission of blazars

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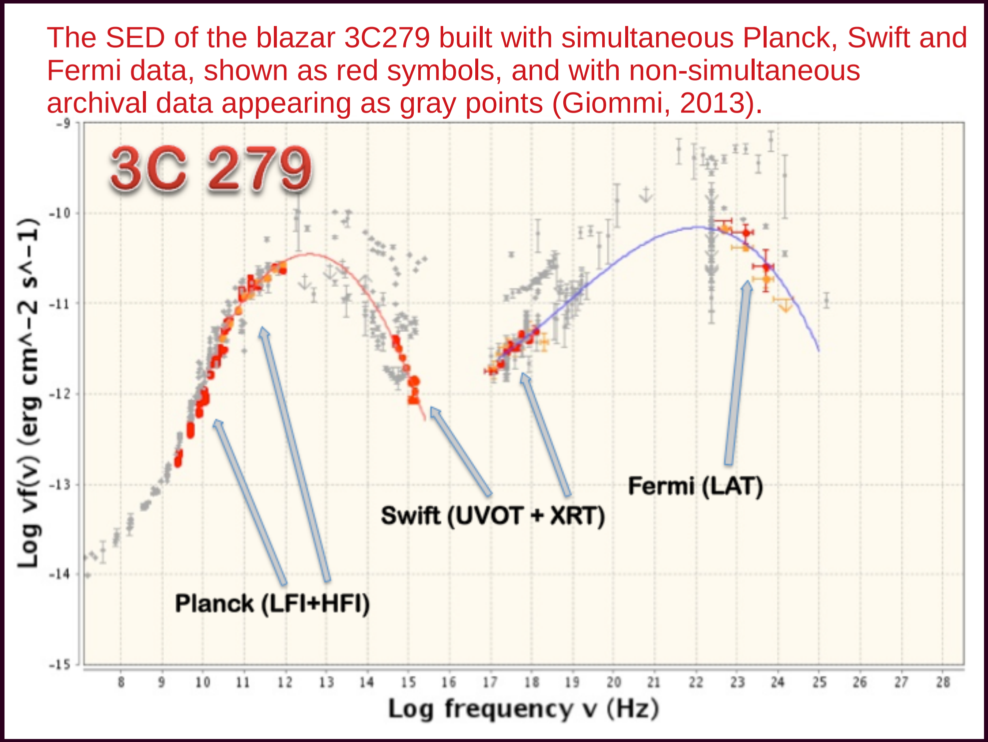
Collaborator: Maria Petropoulou

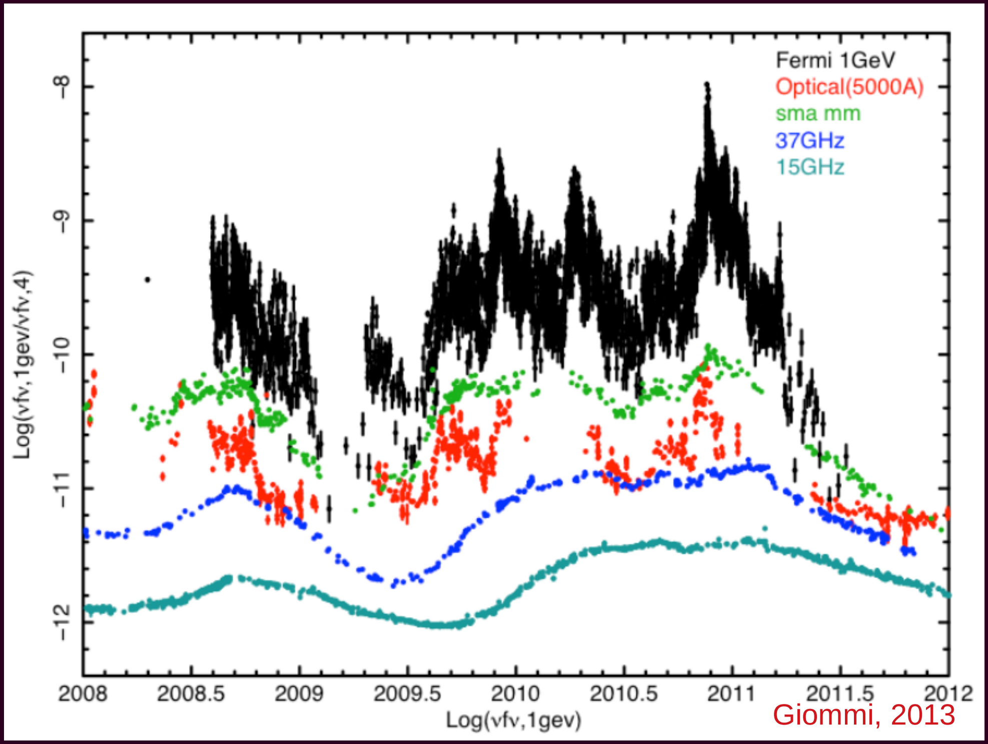
Monitoring the non-thermal universe, Cochem 2018

Outline

- Motivation
- Model
- Numerical Approach
- Results
- Summary

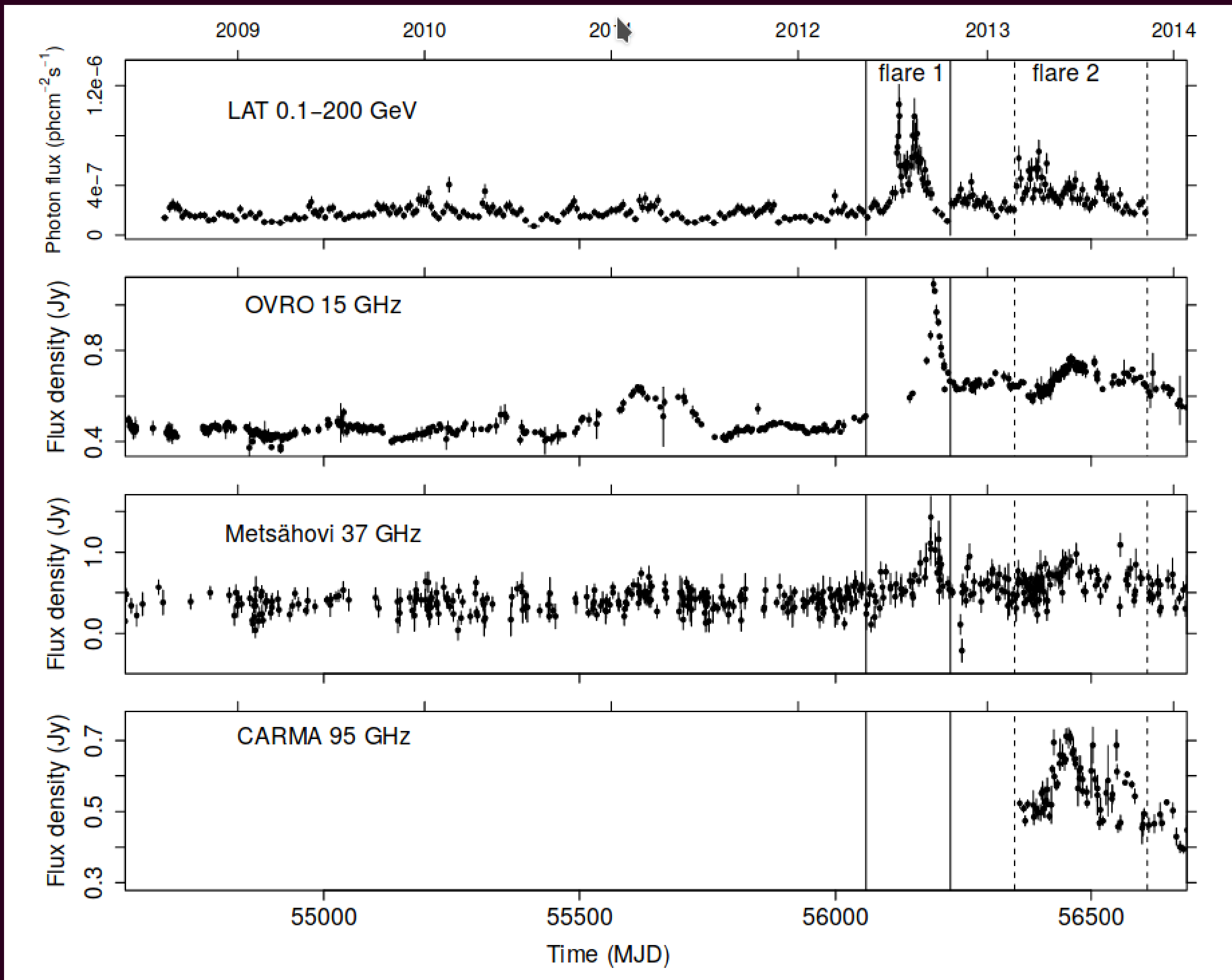
Motivation

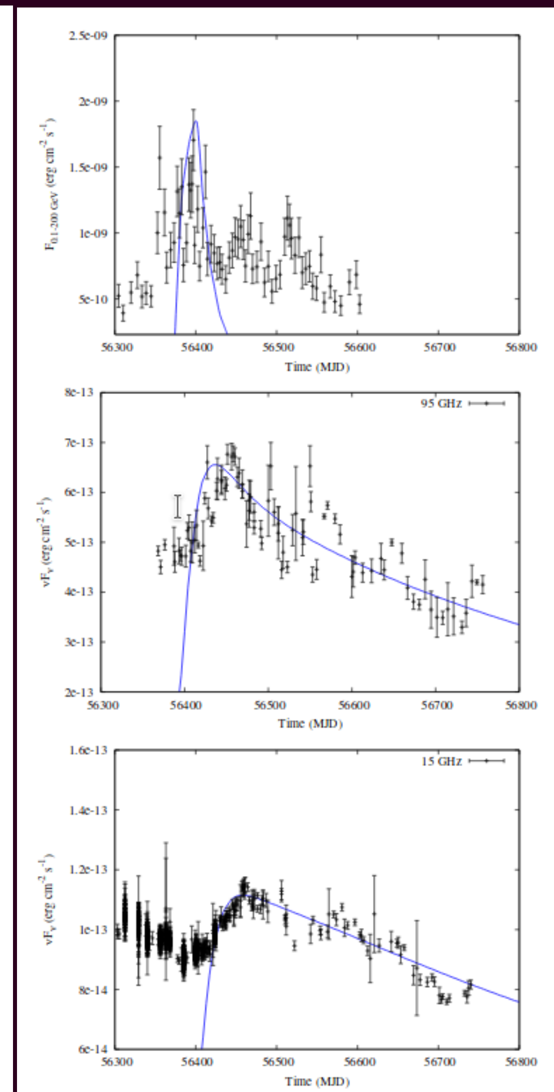




- Multi wavelength surveys
- Dedicated observations

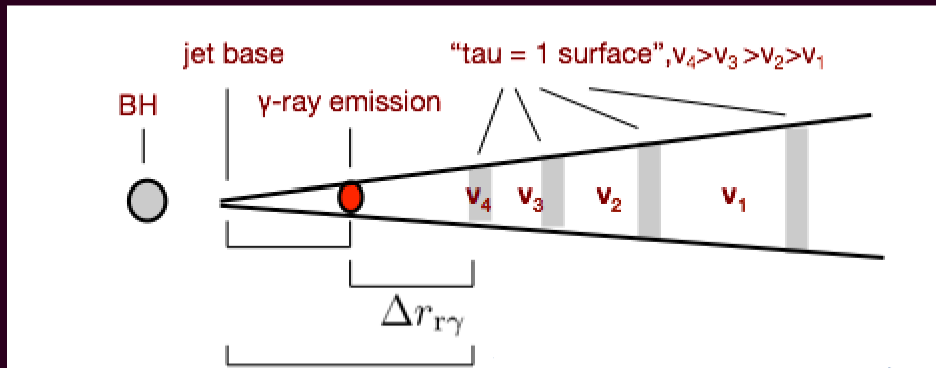
Challenges: The connection of γ-ray and radio emission

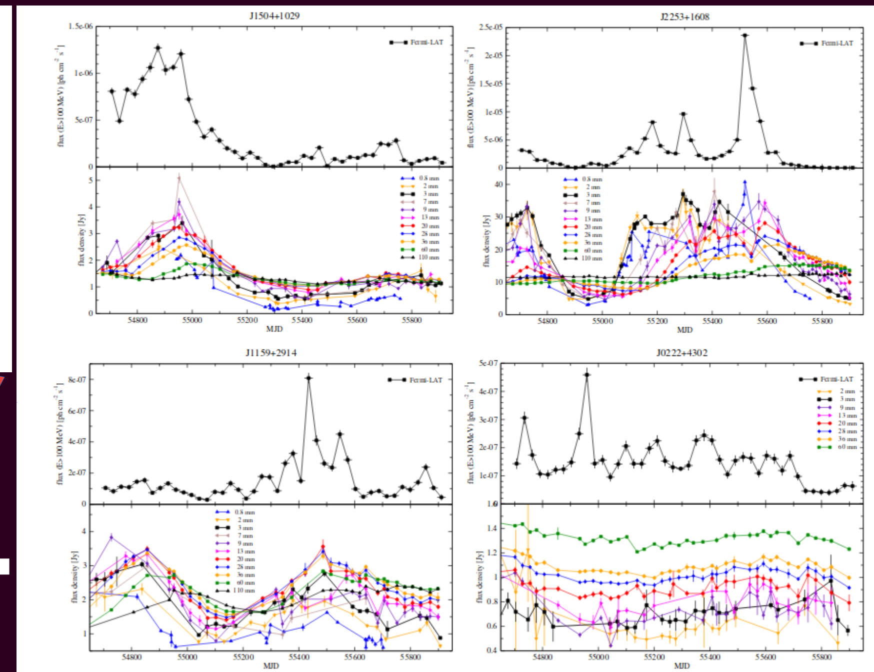




A combined radio and GeV gamma-ray view of the 2012 and 2013 flares of Mrk 421
(Hovatta et al., 2015)

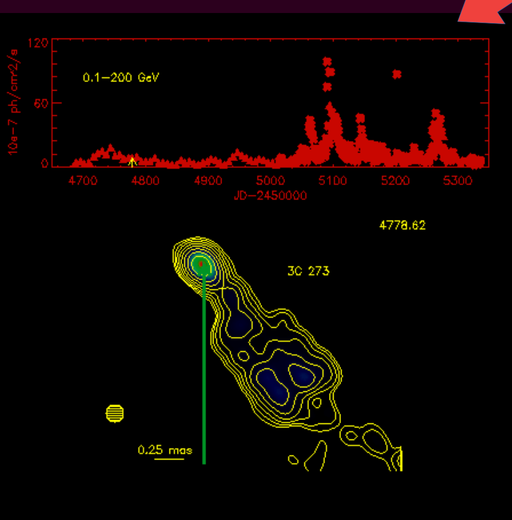
Radio monitoring

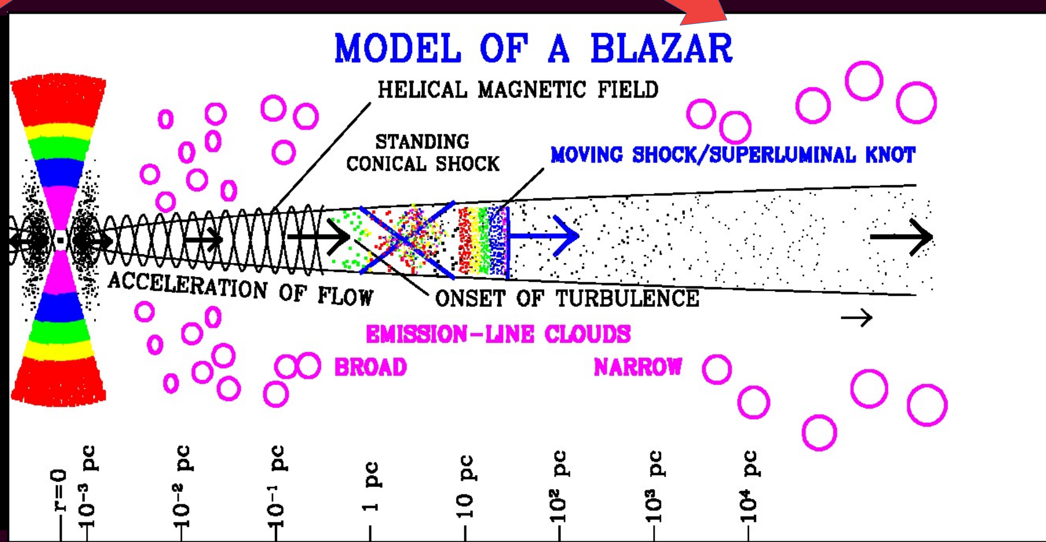


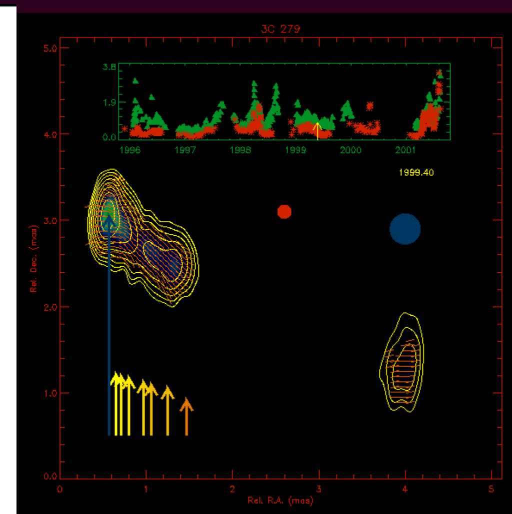


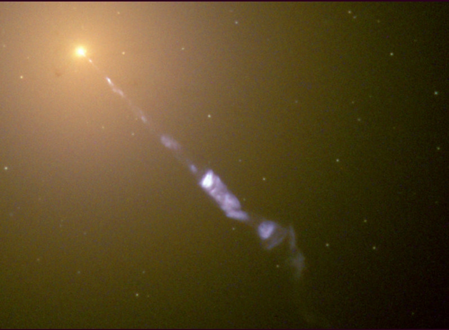
F-gamma project

Boston University Blazar Group



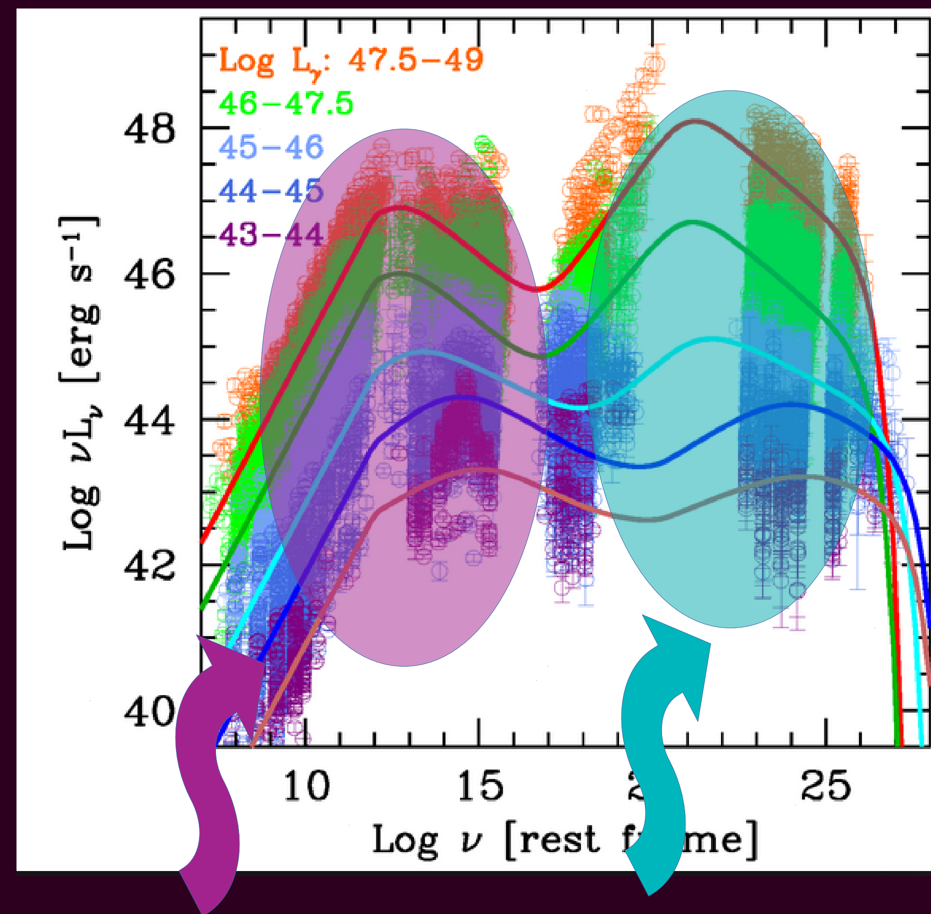






SED of Blazars

Ghisellini 2017



Parameters of the Leptonic Model :

- Radius of the source
- Magnetic Field Strength
- Characteristics of Electrons Energy Distribution
- Bulk Lorentz factor
- Doppler factor

Synchrotron

Inverse Compton Scattering

One-zone modeling

Kinetic equations of particles and photons

$$\frac{\partial n_i}{\partial t} + \frac{n_i}{t_{esc}} = L_i + Q_i$$

Numerical code:
Mastichiadis & Kirk, 1995, A&A

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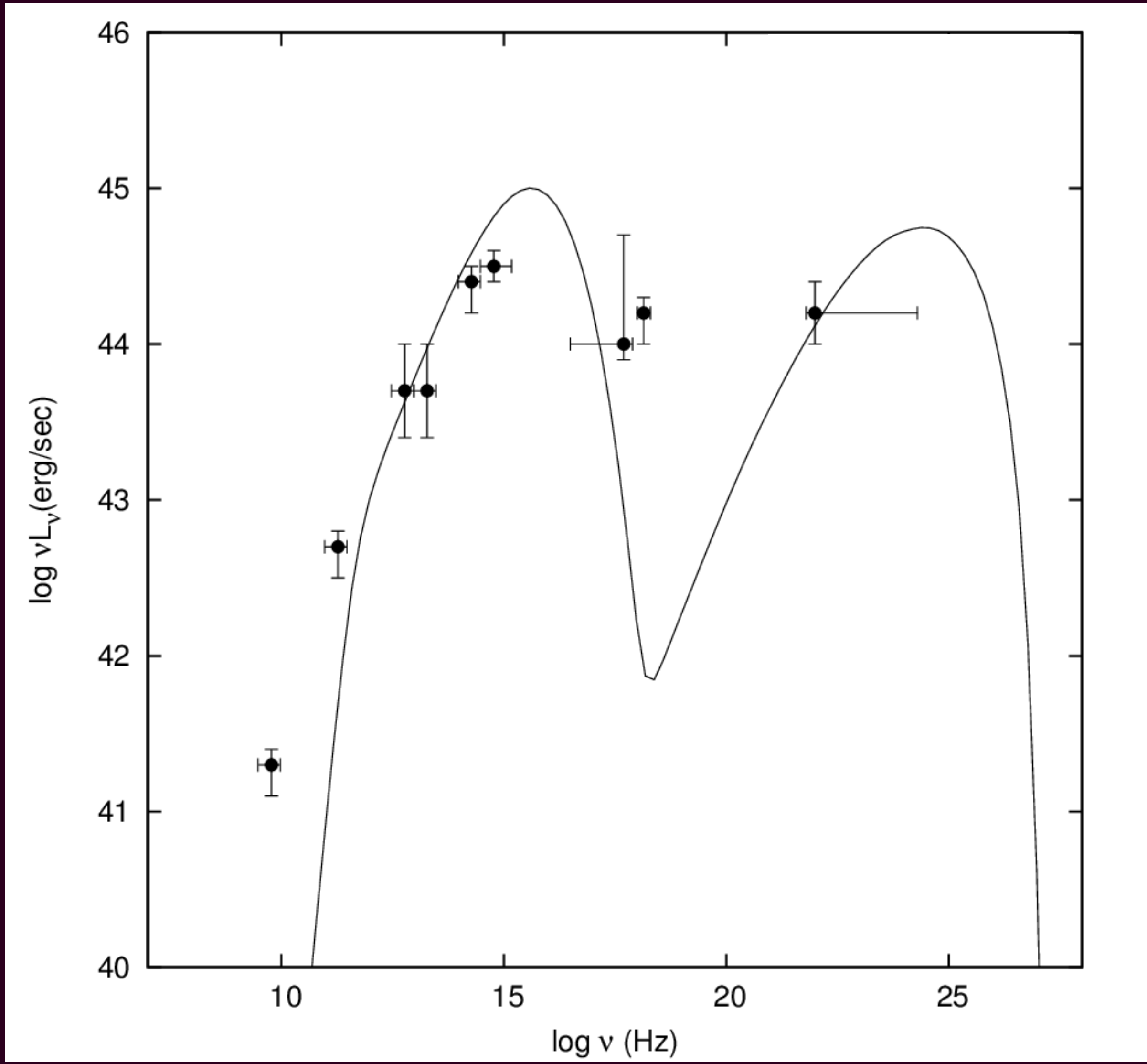

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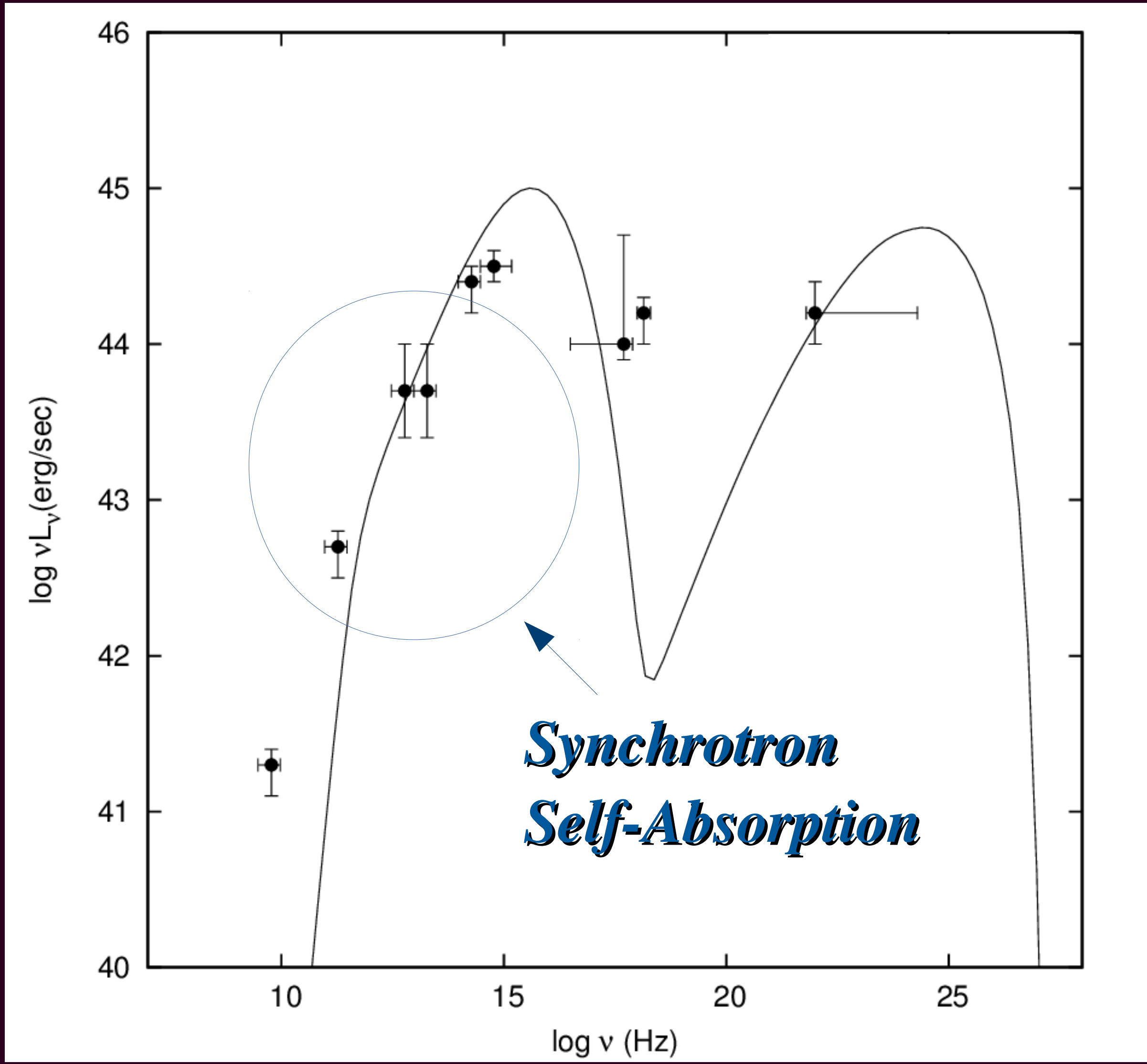

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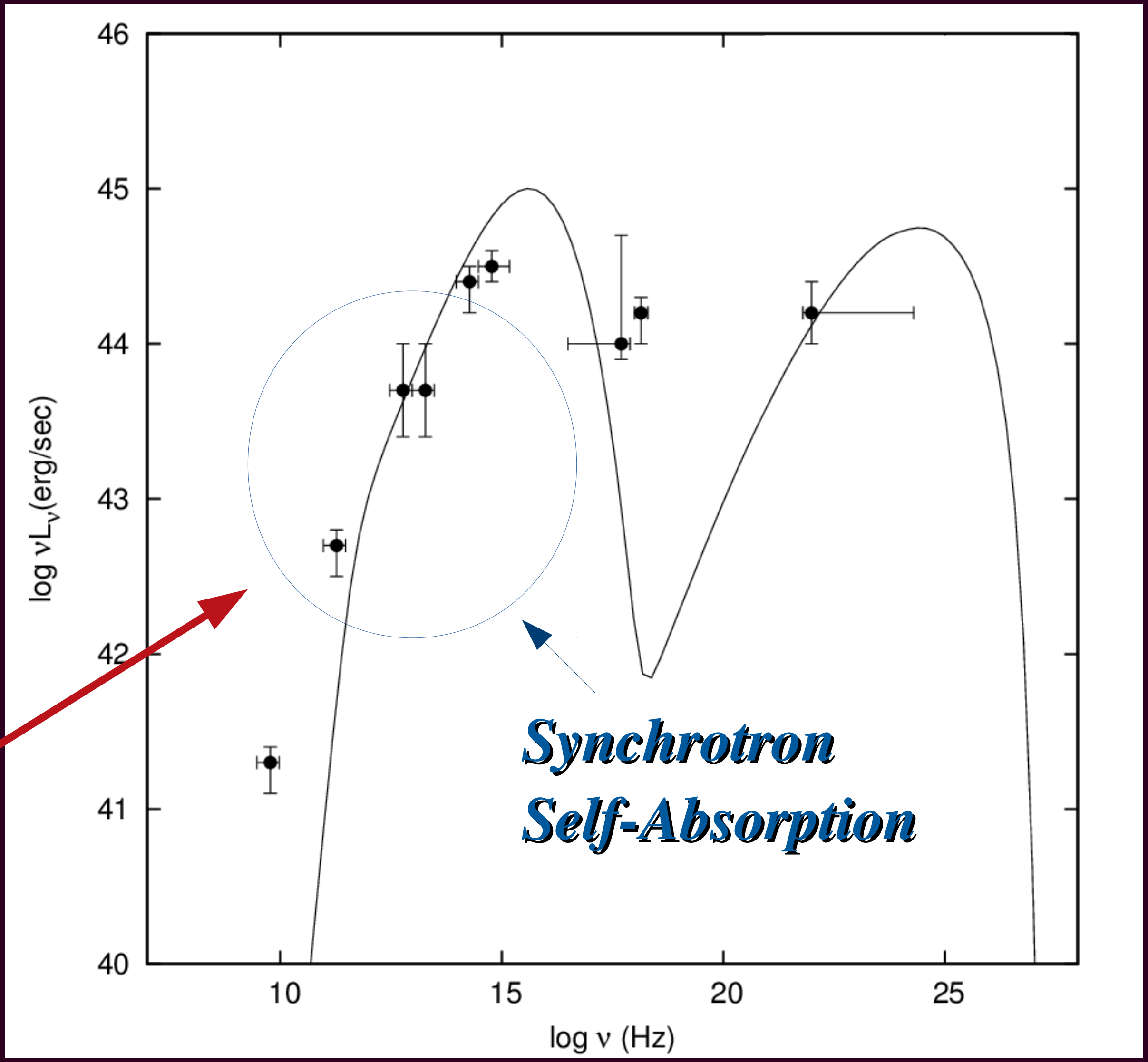
$$\tau_{ssa} = \alpha_{\nu_{ssa}} R$$



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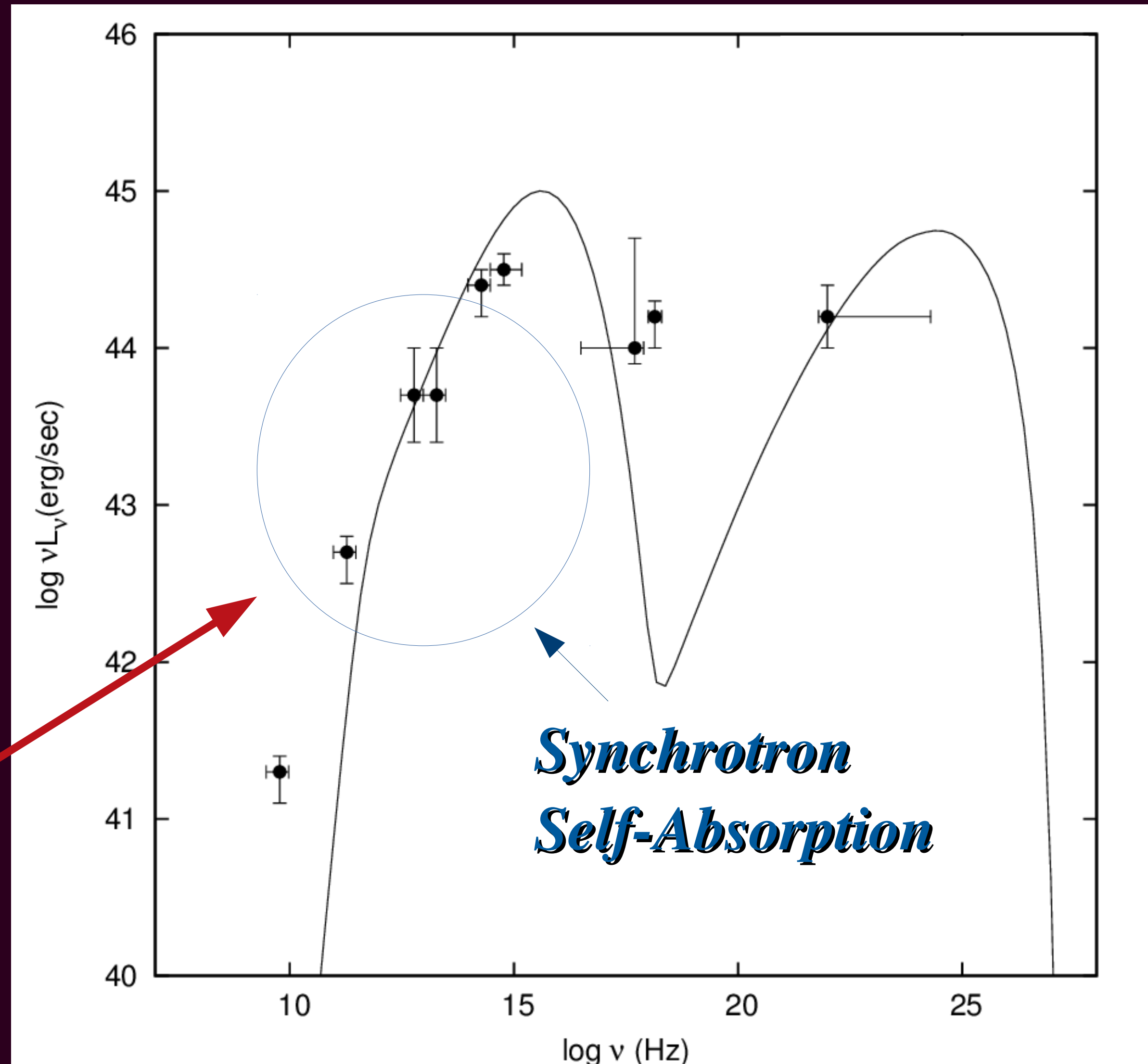

$$\tau_{ssa} = \alpha_{\nu_{ssa}} R$$

$$\alpha_{\nu_{ssa}} = \frac{\sqrt{3}e^3}{8\pi m}\left(\frac{3e}{2\pi m^3 c^5}\right)^{p/2} C(B\sin\alpha)^{p+2}\Gamma\left(\frac{3p+2}{12}\right)\Gamma\left(\frac{3p+22}{12}\right)\nu^{-\frac{p+4}{2}}$$

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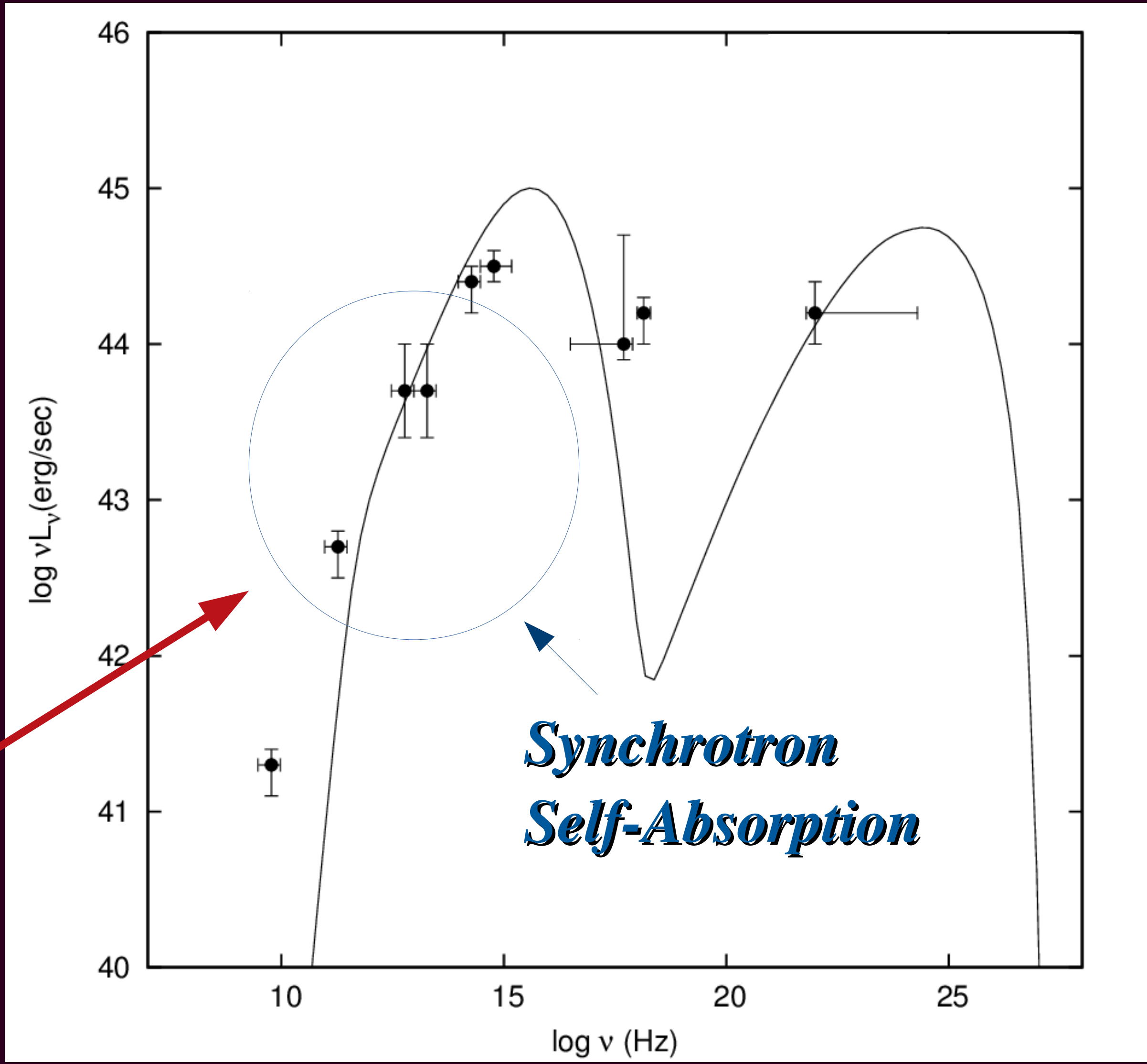

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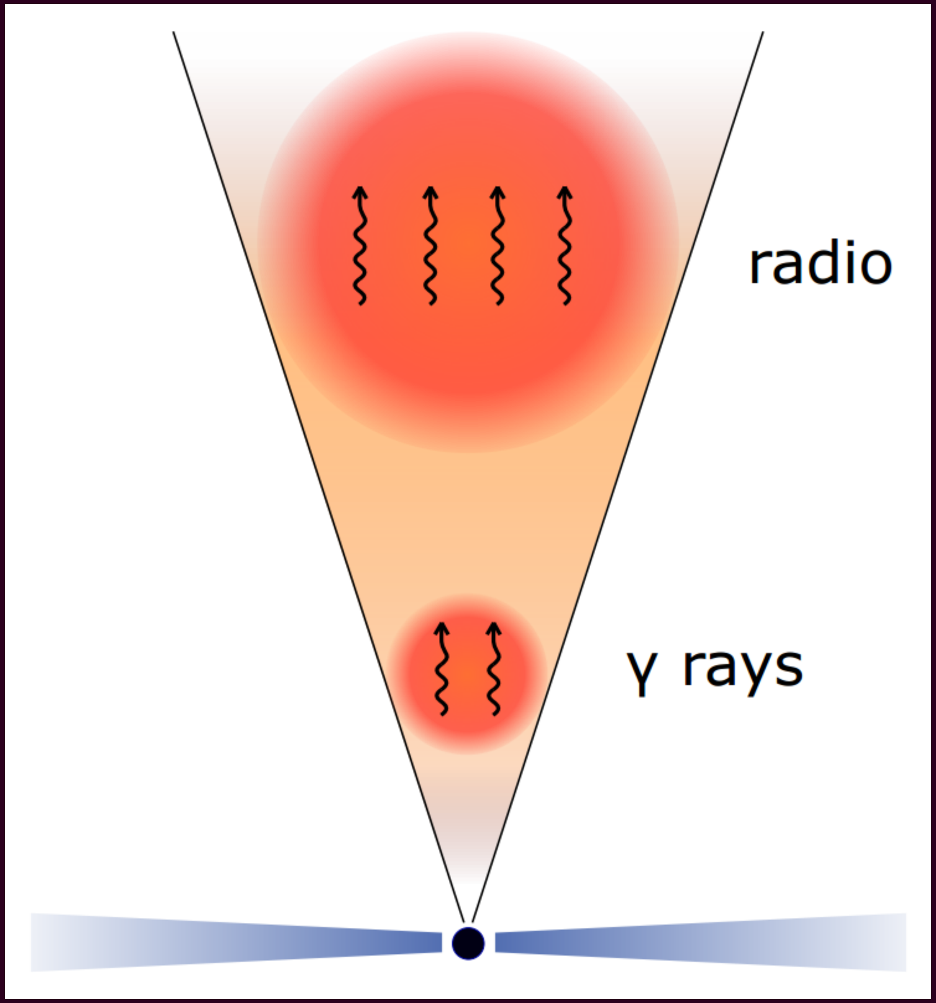
Model: A uniform Jet



- Localization of γ-ray and radio emission
- Spherical regions of accelerated particles move toward the jet and at the same time are expanding.

A proposed model for a uniform conical jet can be found at Potter & Cotter series of papers.

Numerical Approach: Source's Expansion

- Physical Processes for a Leptonic Model
  - ✓ Synchrotron Radiation
  - ✓ Inverse Copton Scattering
  - ✓ Synchrotron Self Absorption
  - ✓ Photon-Photon Absorption
  - ✓ **Adiabatic Losses**

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    - ✓ **Adiabatic Losses**

A new numerical code based on Mastichiadis & Kirk, 1995, 1997

An example: Synchrotron and Adiabatic Losses

$$\frac{\partial N(\gamma,t)}{\partial t} - \frac{\partial}{\partial \gamma}\left[(A_{syn}(R)\gamma^2 + A_{exp}(R)\gamma)N(\gamma,t)\right] = \tilde{Q}(\gamma,t)$$

Adiabatic losses:

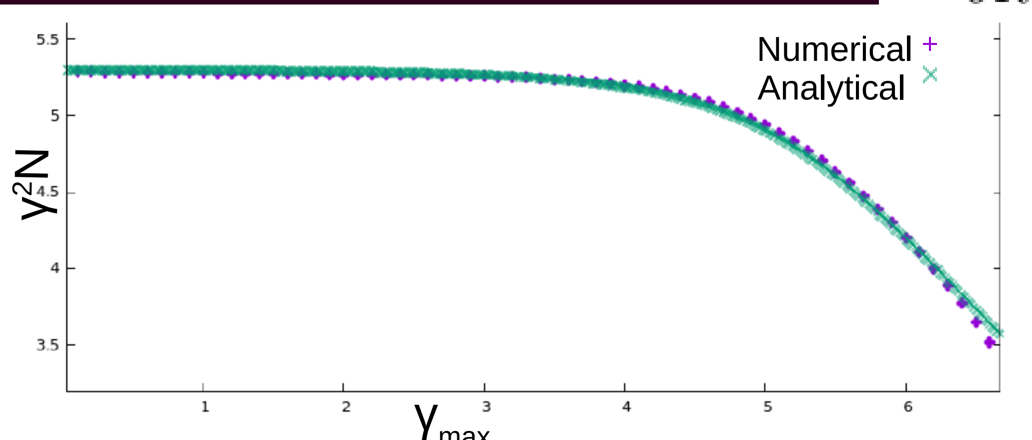
$$\left(-\frac{dE}{dt}\right)_{ad} = \frac{1}{R}\frac{dR}{dt}E, \;\; \frac{dR}{dt} = u$$

$$-\left(\frac{dE}{dt}\right)_{ad} = \frac{u}{R}E \Rightarrow -\left(\frac{d\gamma}{dE}\right)_{ad} = \frac{u}{R}\gamma$$

Synchrotron losses:

$$\left(-\frac{d\gamma}{dt}\right)_{syn} = \alpha B^2\gamma^2 \text{ with } \alpha = \frac{\sigma_\tau c}{6\pi m_e c^2}$$

$$\frac{\partial N(\gamma,R)}{\partial R} - \frac{\partial}{\partial \gamma}\left[\left(\frac{\beta}{uR^x}\gamma^2 + \frac{1}{R}\gamma\right)N(\gamma,R)\right] = Q(\gamma,R)$$



A comparison of the analytical and numerical solution

Preliminary Results

Adiabatic Expansion

$$R = R_0 + u_{exp} t$$

Magnetic Field Strength

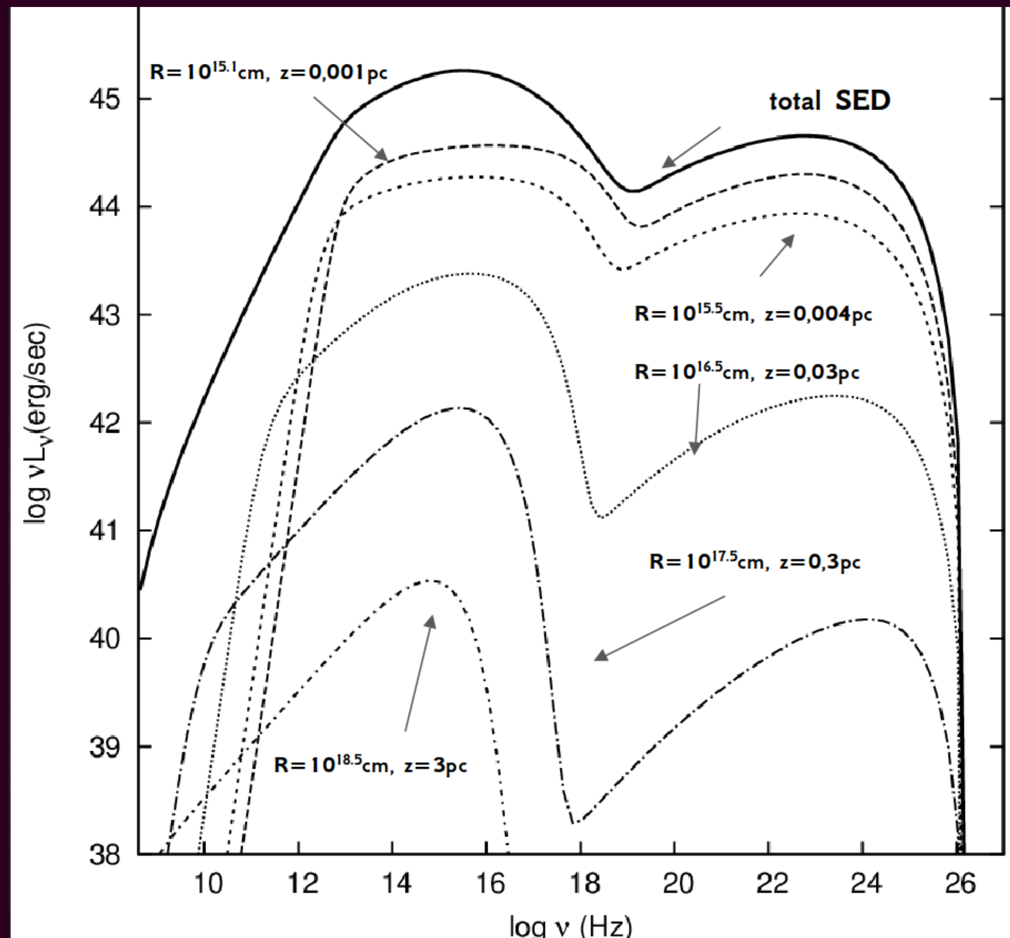
$$B = B_0 \left(\frac{R_0}{R} \right)^x$$

Electrons Luminosity

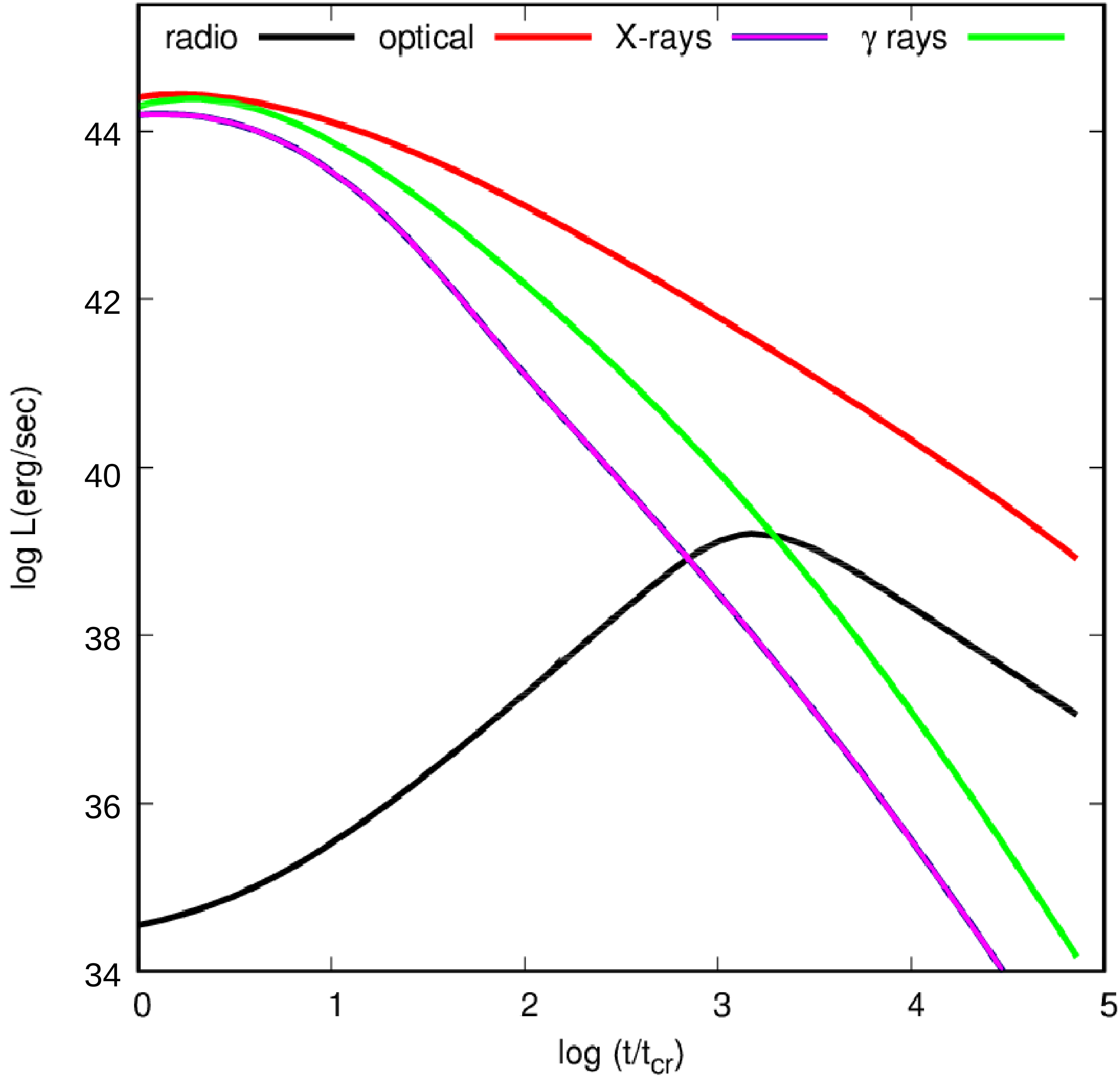
$$L_e^{inj} = L_{e0}^{inj} \left(\frac{R_0}{R} \right)^x$$

Electrons Energy Distribution

$$Q_e(\gamma) = k_e \gamma^{-p} \quad \gamma_{min} \le \gamma \le \gamma_{max}$$

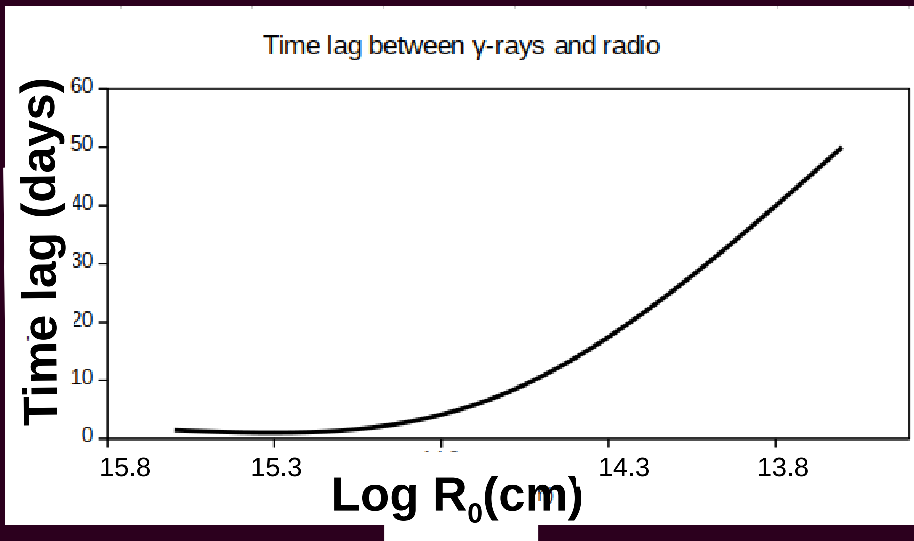


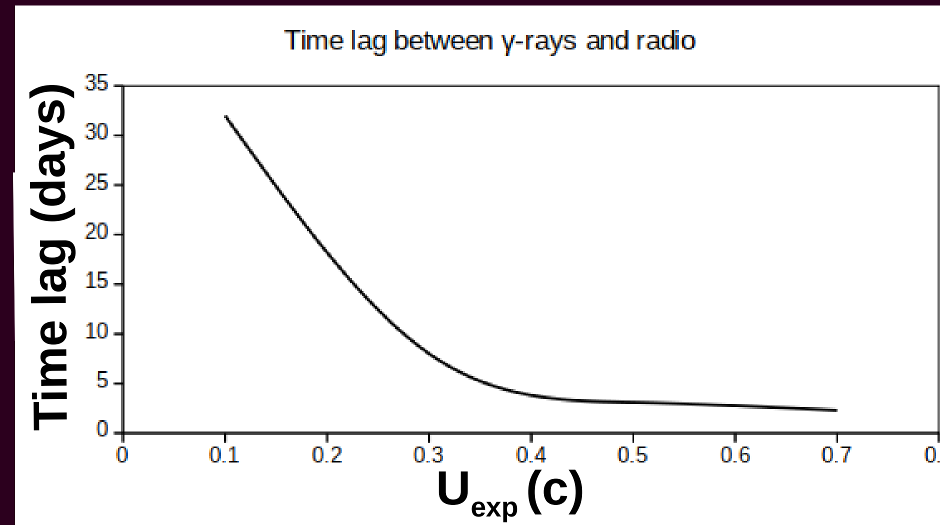
B_0=10G ,
$R_0=10^{15}$cm
$L_e=10^{42}$erg/sec
u_{exp}=0.3c
z_0=0.001pc
$\gamma_{min}=10^0$, $\gamma_{max}=10^5$
p=2
δ=10



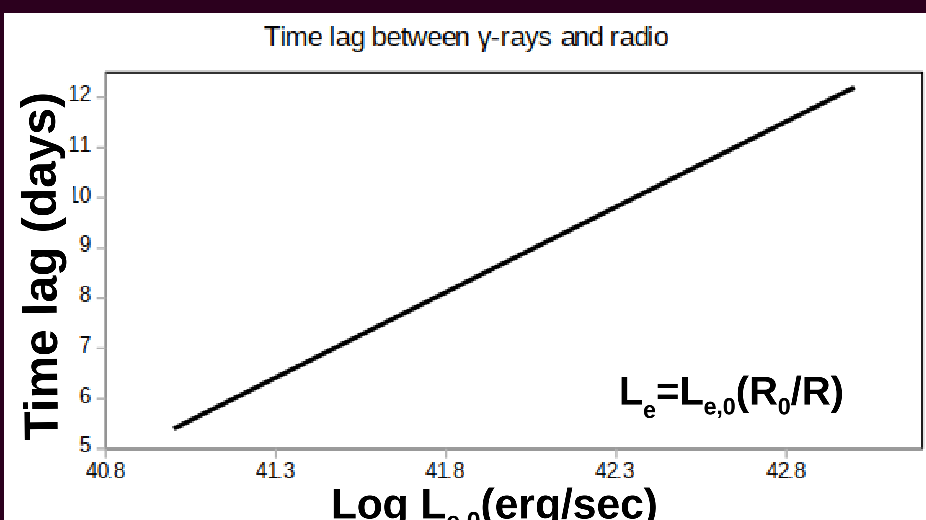
radio
optical
X-rays
γ rays
log L(erg/sec)
log (t/t_cr)
44
42
40
38
36
34
0
1
2
3
4
5

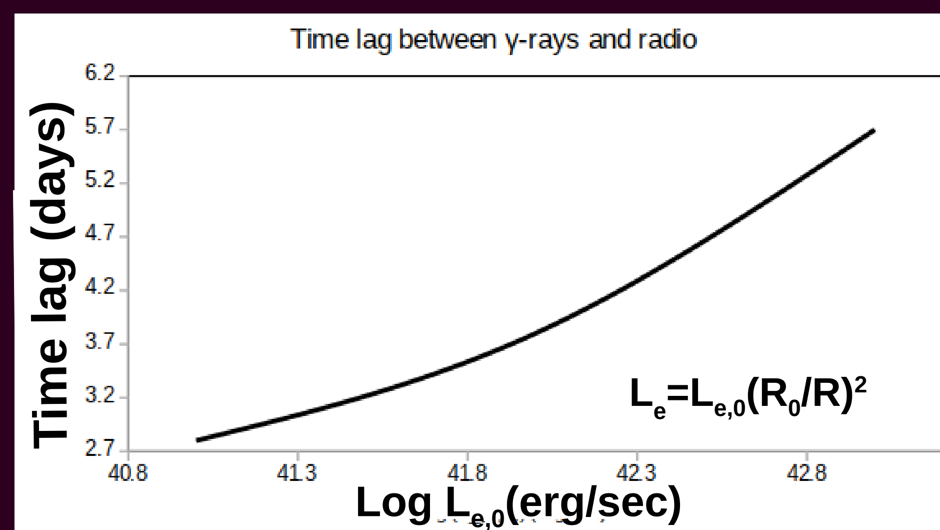
Preliminary Results





$B=B_0(R_0/R)^2$, B_0=10G , $R_0=10^{15}$cm, $L_e=L_{e,0}(R_0/R)$, $L_{e,0}=10^{42}$erg/sec,
u_{exp}=0.3c, z_0=0.001pc, $\gamma_{min}=10^0$, $\gamma_{max}=10^5$,p=2, δ=10





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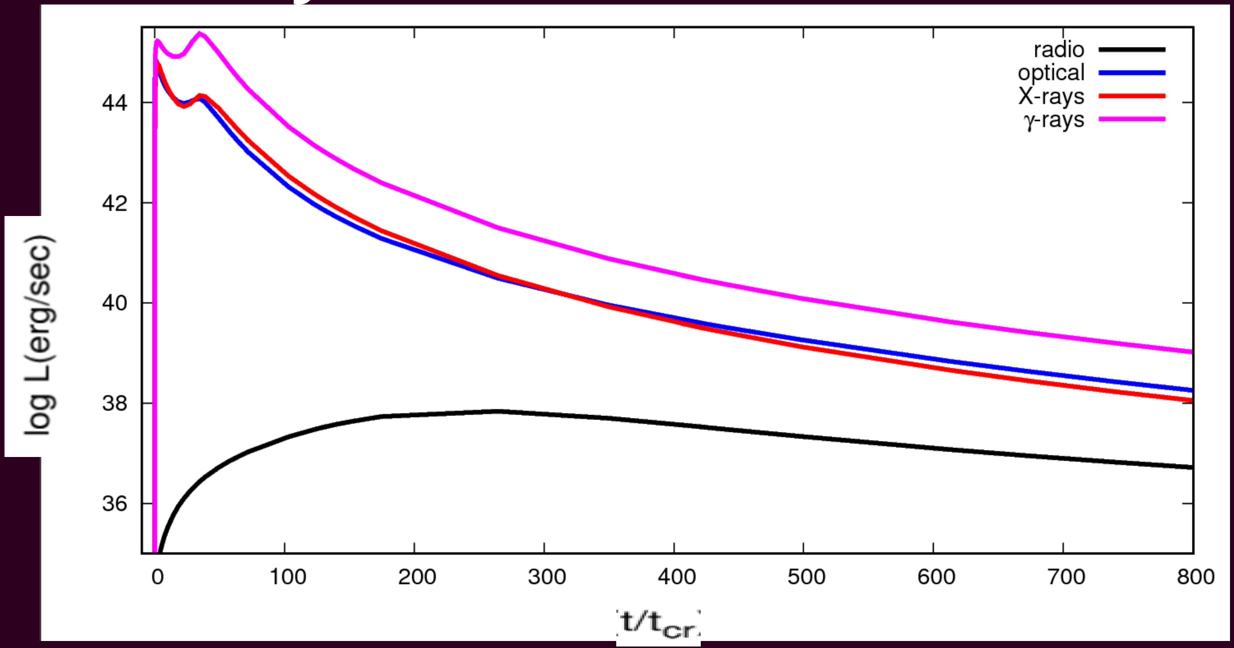
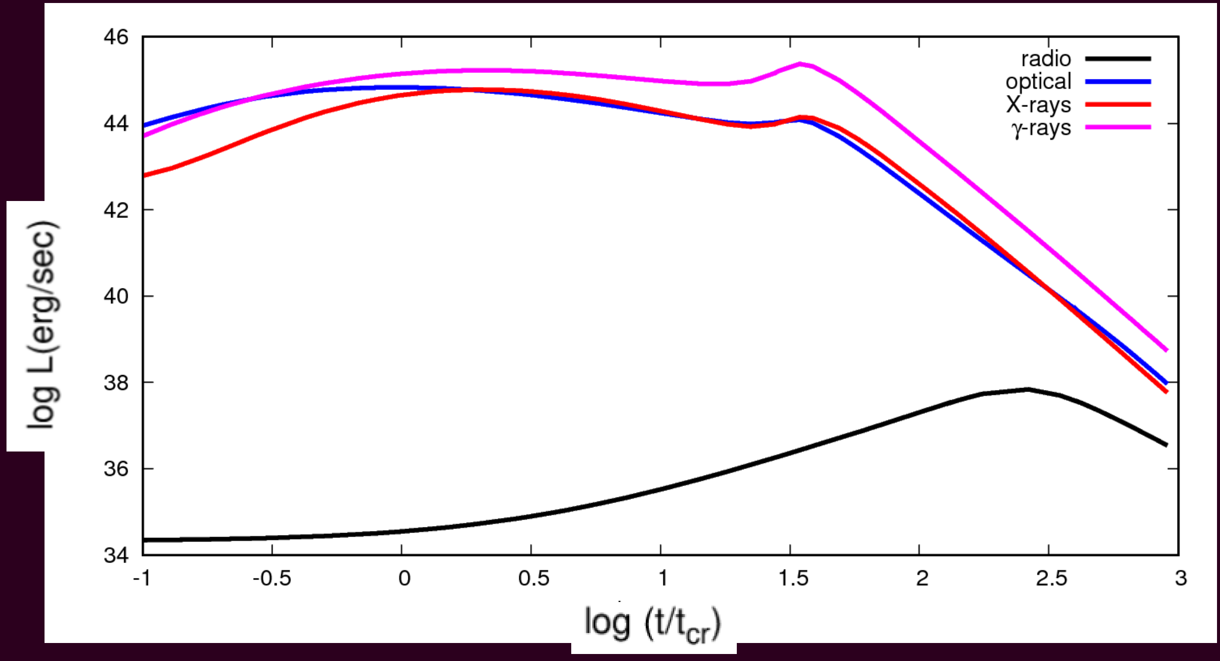
Lorentzian Electron Energy Distribution

$$Q_e(\gamma, t) = k_e \gamma^{-p} \left(1 + \frac{(\alpha - 1) w^2}{4(t - t_o)^2 + w^2} \right)$$





Take-home message:

In order to explain the connection between γ-ray and radio emission:

- We have created a new expanding numerical code
- We propose a model of a uniform jet

Work in progress:

- Searching the parameter phase space
- Self-consistent particle acceleration

Thank you!