

Time-dependent Radiation

Transfer in the Internal Shock Model for Blazar Jets

Presented

By

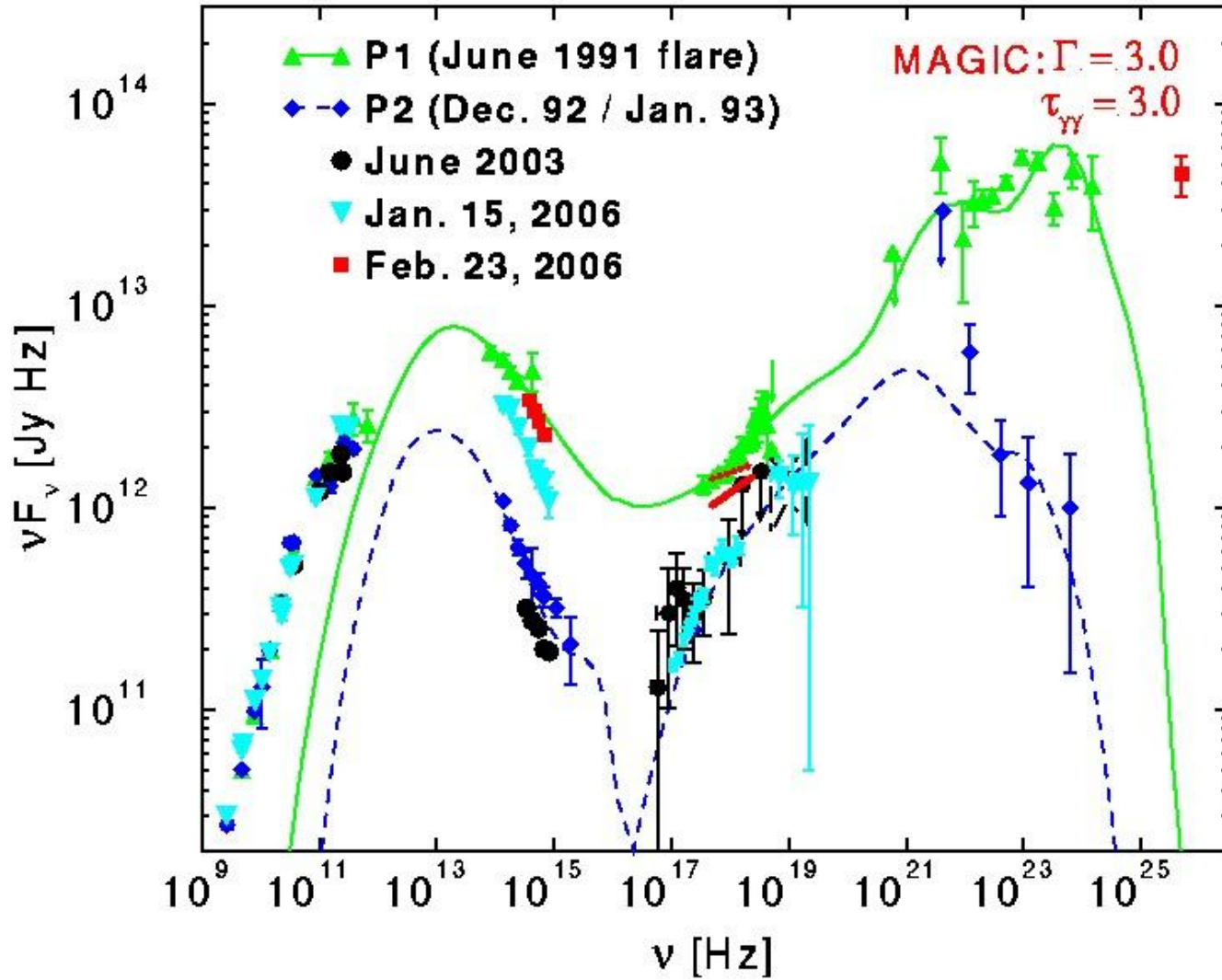
Manasvita Joshi

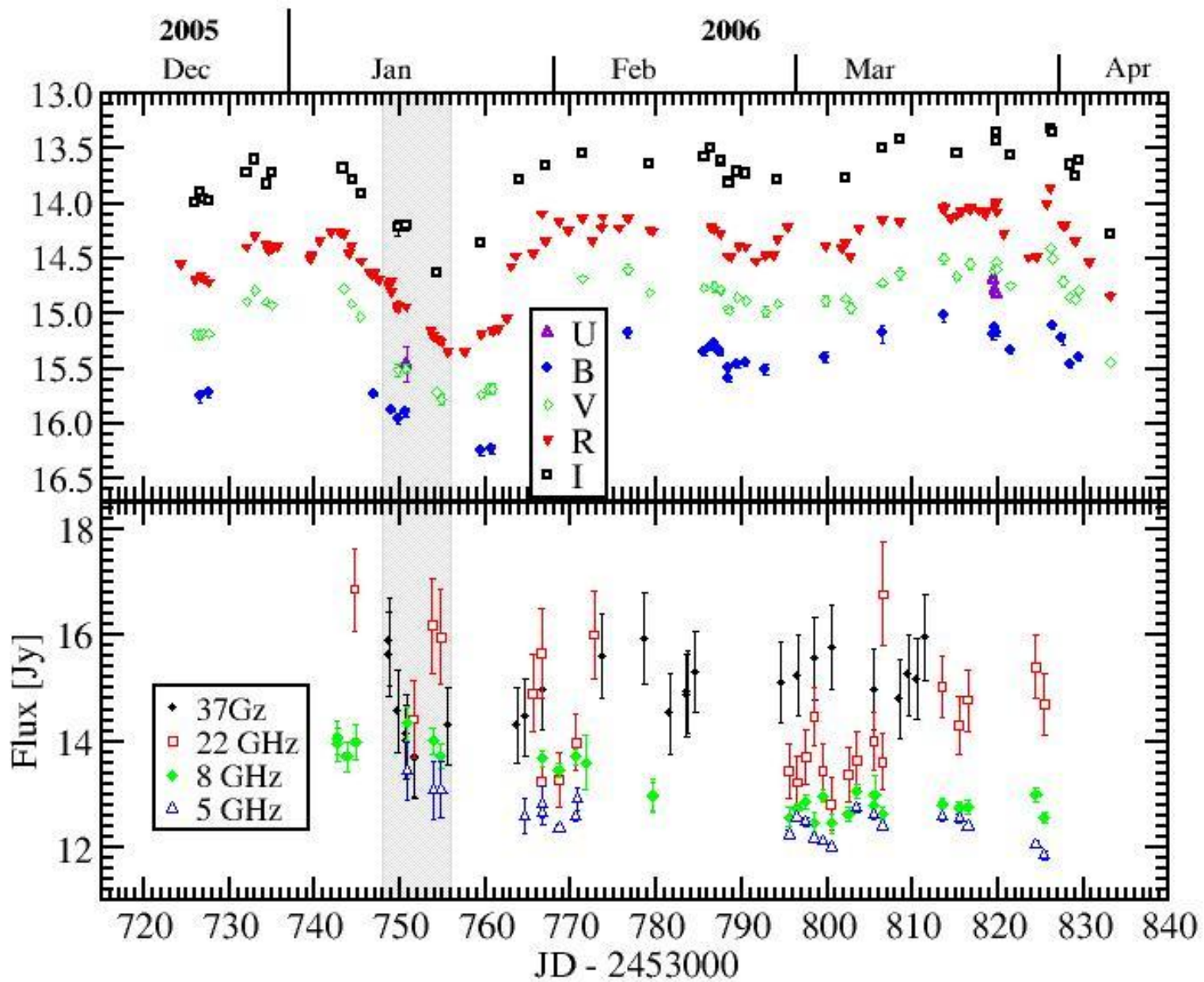
Ohio University, Athens, OH

Outline

- Internal shock model
 - Model sketch
 - First results
 - Work in progress
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3C279





Boettcher et al., 2007, ApJ, 670, 968

Internal Shock Model

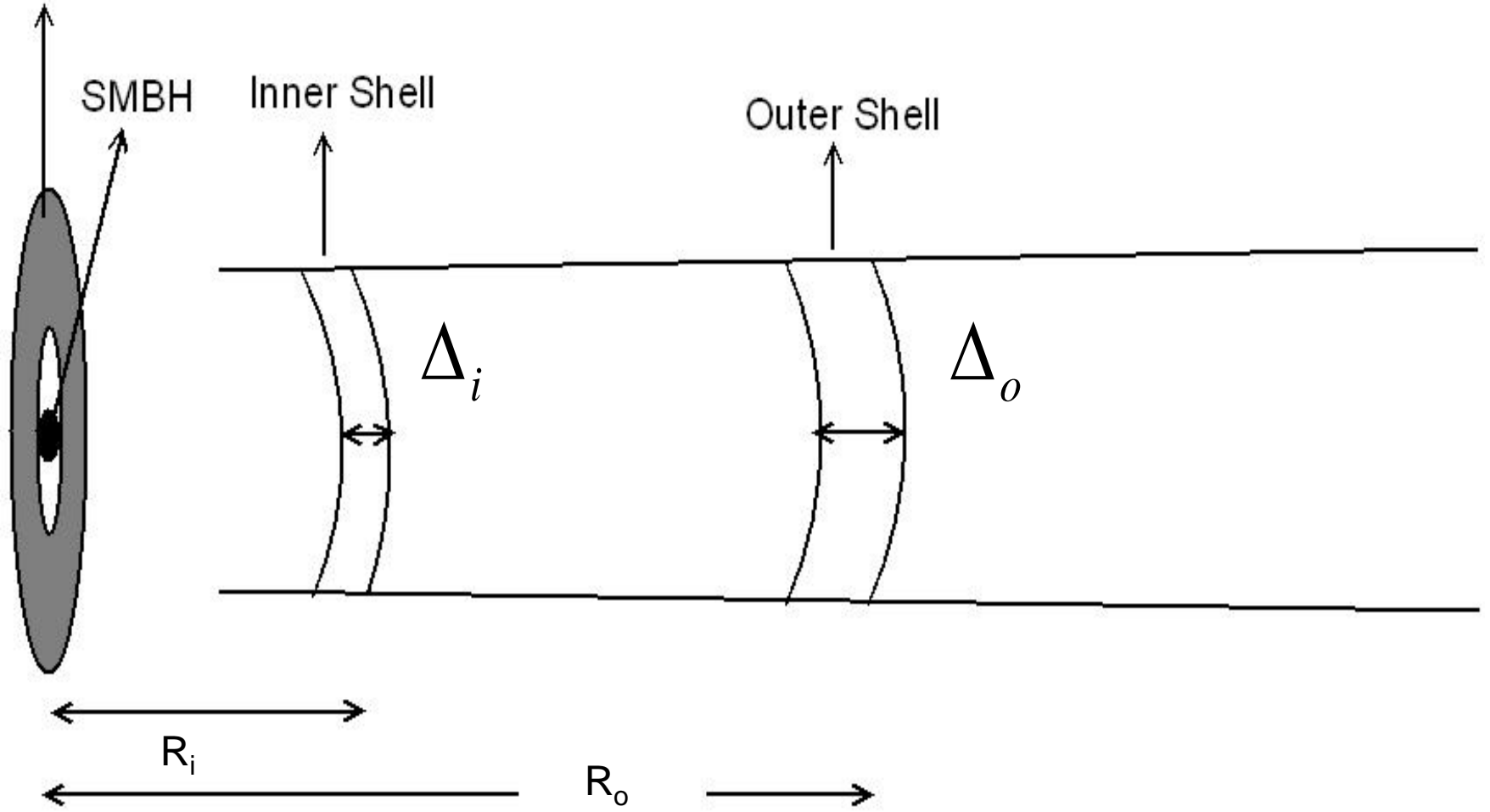
- Central engine (Black hole + accretion disk) ejects accelerating shells of plasma with different mass, energy, & velocity intermittently into the jet.
 - Faster inner shells, closer to central engine, catch up with slower outer shells.
 - Undergo inelastic collision to produce internal shocks.
 - These shocks accelerate particles, which then radiate.
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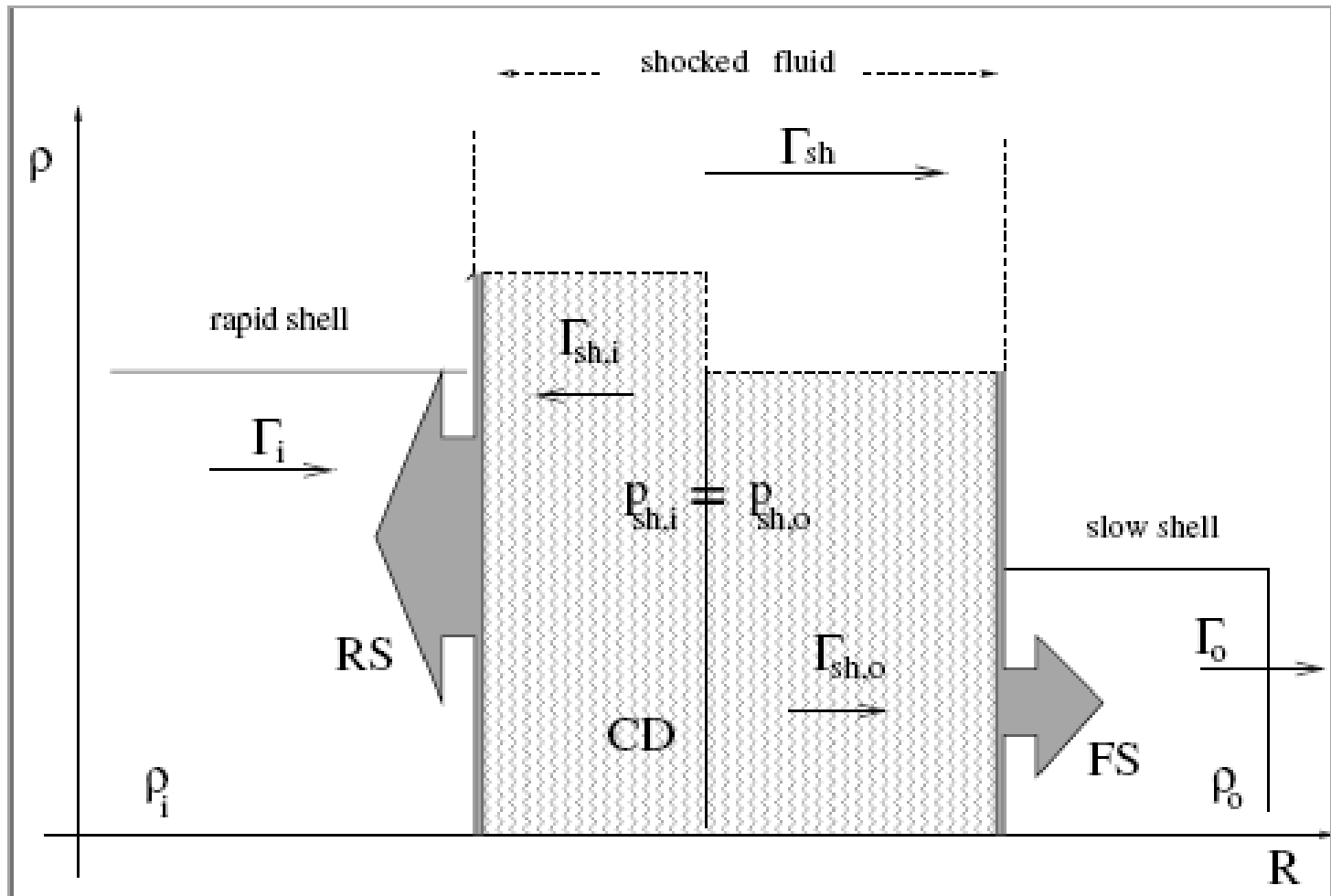
Accretion Disk

SMBH

Inner Shell

Outer Shell





Collision results in formation of 2 shocks: Forward shock (FS) & Reverse shock (RS) separated by a CD.

FS propagates in the outer shell & RS propagates backward in the inner shell.

- Following the approach of Spada et al., 2001, MNRAS, 325, 1559

Γ_{sh} = bulk Lorentz factor (BLF) of the shocked fluids in AGN (lab) frame

- From Γ_{sh} , evaluate shell widths after the shocks, internal energies of E_{RS} & E_{FS} for the RS & FS resp. & the shell crossing time of the shocks – in lab frame.
- Use these parameters to calculate comoving magnetic field B' (in the frame of the shocked fluid)

$$B' = \frac{1}{\Gamma_{sh}} \sqrt{\frac{2\varepsilon_B E_{sh}}{R_c^2 \Delta_{sh}}}$$

$$\varepsilon_B = U_B' / U_{sh}'$$

U_B' = comoving magnetic field energy density

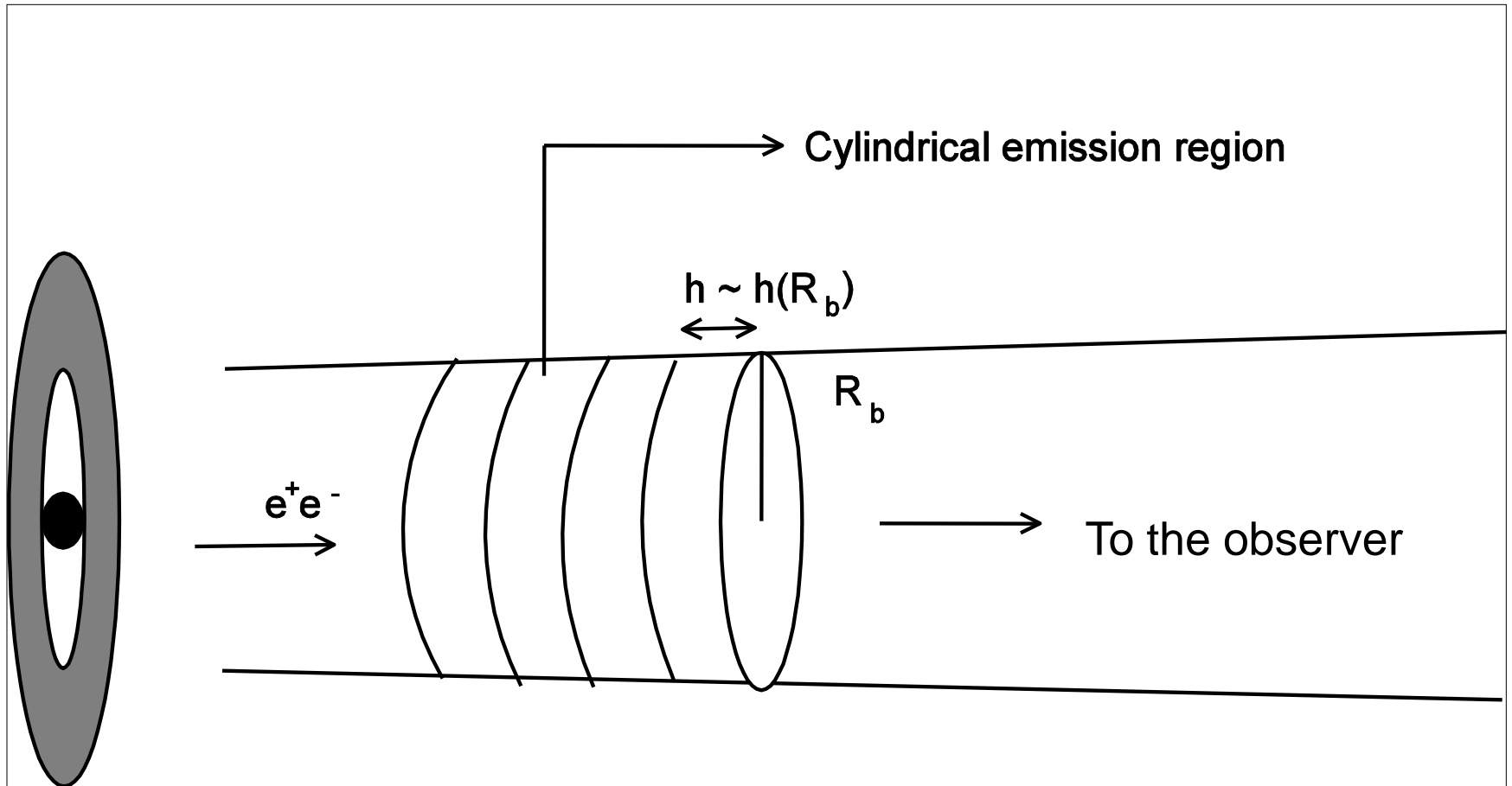
U_{sh}' = comoving internal energy density of shock

R_c = collision radius

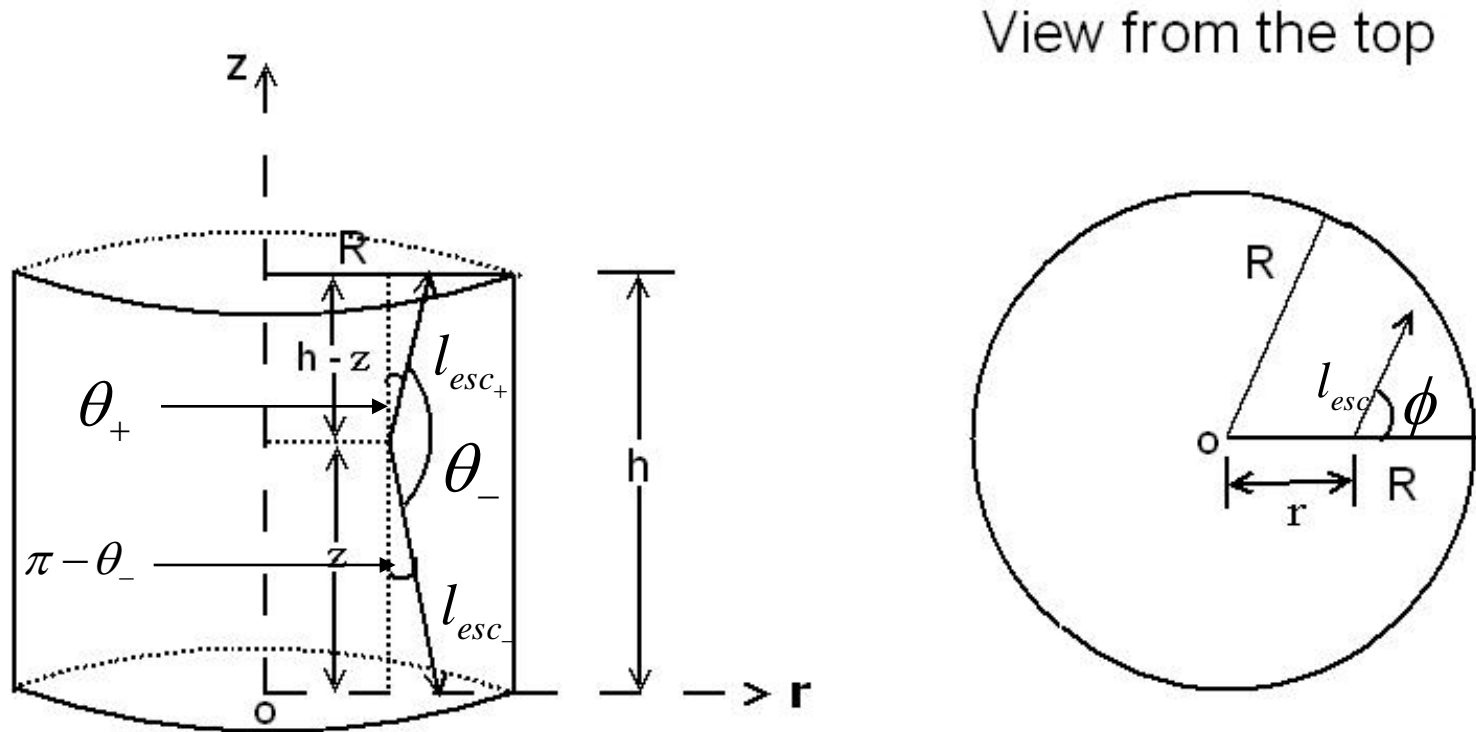
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- Minimum random Lorentz factor (RLF) of electrons.
 - Defines the energy distribution of particles with which they are injected by the shock into the region – describes the acceleration.
 - B' & RLF used to calculate the synchrotron and SSC spectrum.
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Model Sketch

- Inhomogeneous cylindrical region with multiple zones.

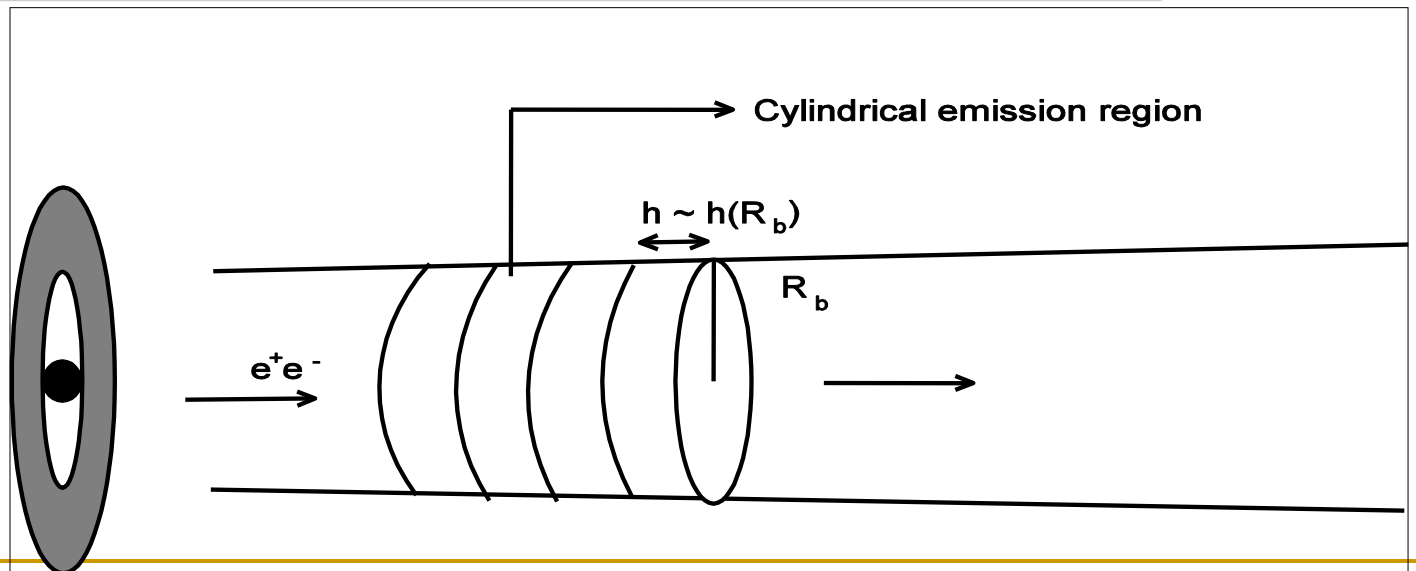
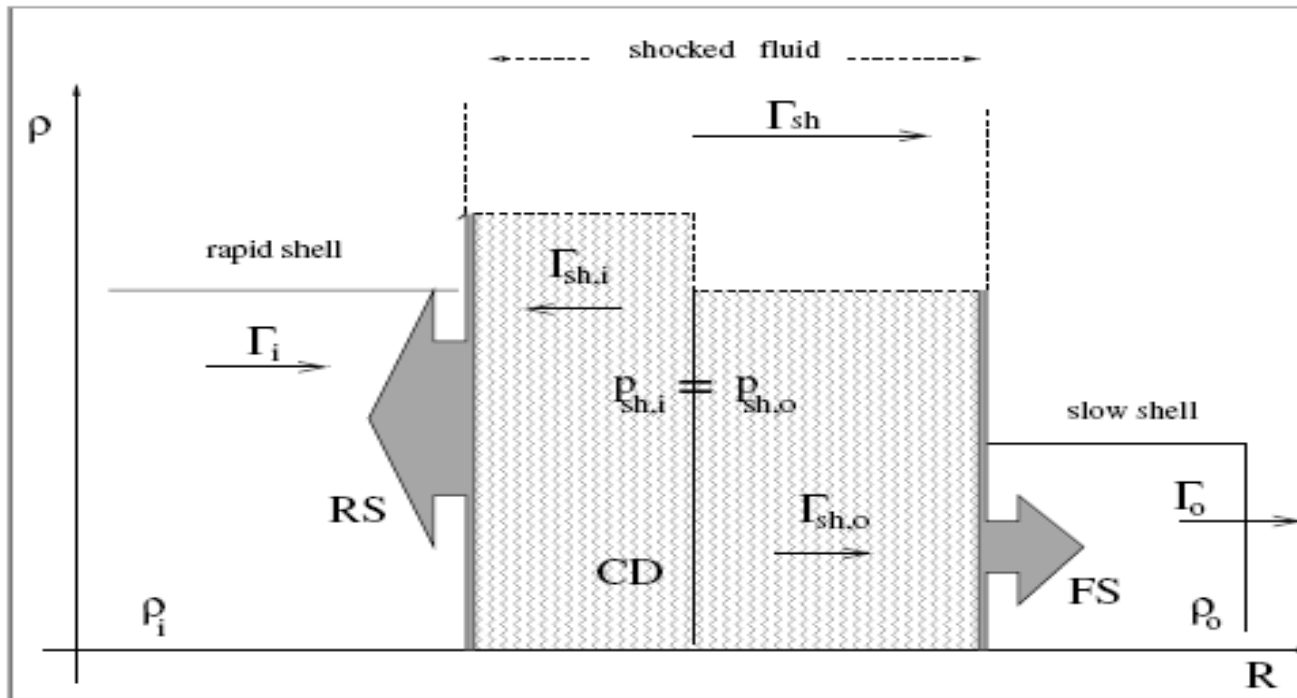


Appropriate photon escape probability functions of each zones need to be considered.

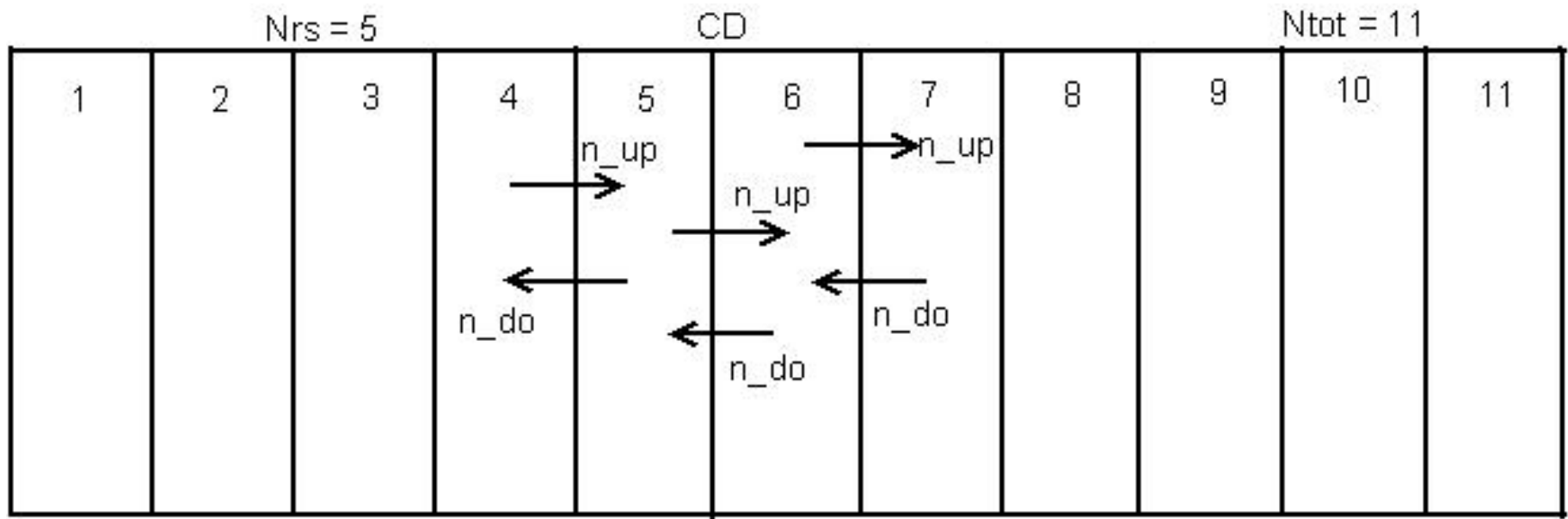


Put $\cos \theta = \mu$

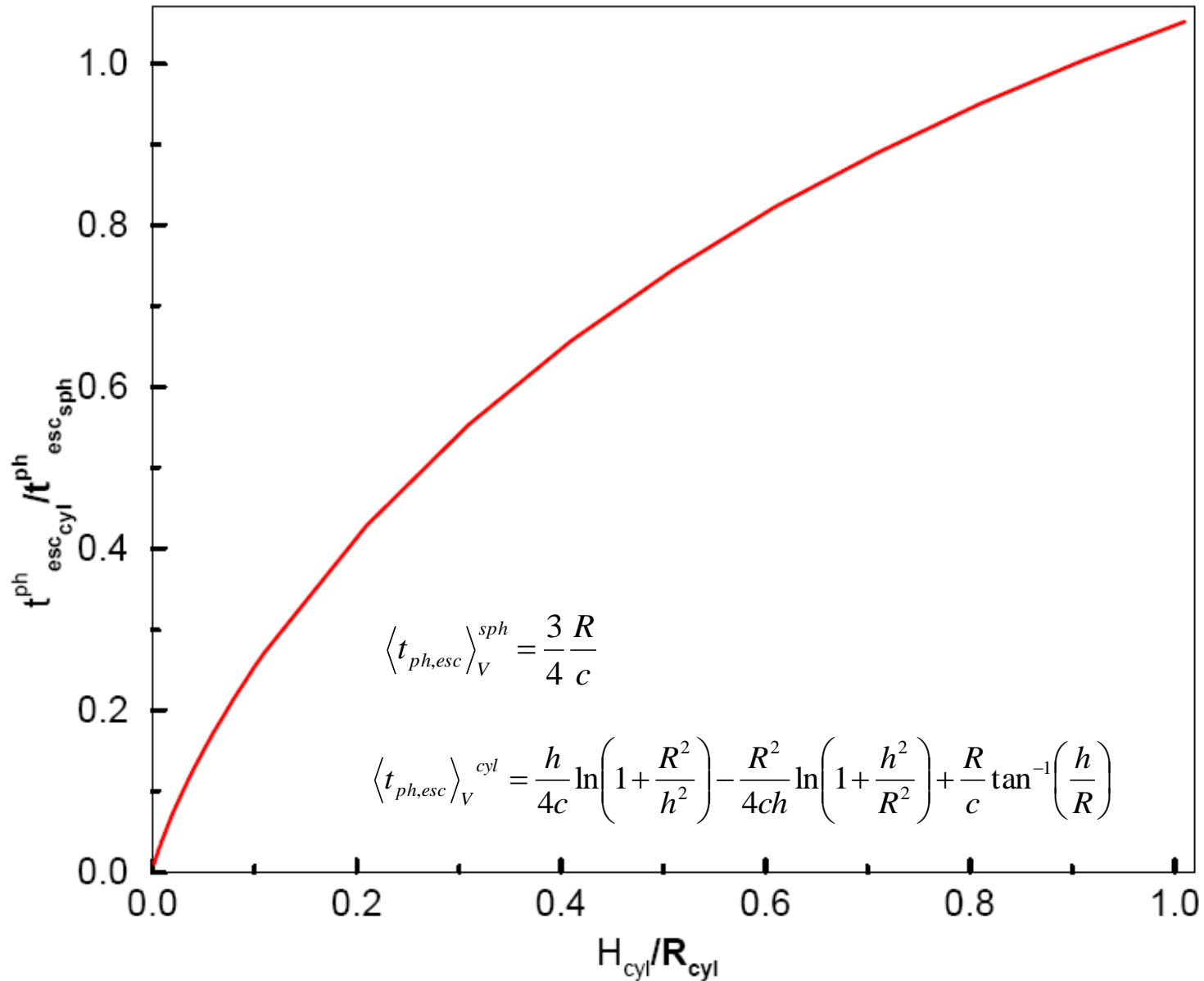
$$\langle t_{ph,esc} \rangle = \frac{1}{4\pi c} \int_0^{2\pi} d\phi \left[\int_{-1}^{\mu_{crit-}} l_{esc-}(\theta, \phi; r, z) d\mu + \int_{\mu_{crit-}}^{\mu_{crit+}} l_{esc} d\mu + \int_{\mu_{crit+}}^{+1} l_{esc+} d\mu \right]$$



Time-dependent radiation transfer considered within each zone & in between each zone.



First Results



- Acc. to Crusius & Schlickeiser, 1986, A&A, 164, L16

$$P_r(\nu) = c_2 B \int_0^{\infty} dE N(E) R(x)$$

where,

$$c_2 = \frac{3^{1/2} e^3}{4\pi m_e c^2}$$

and

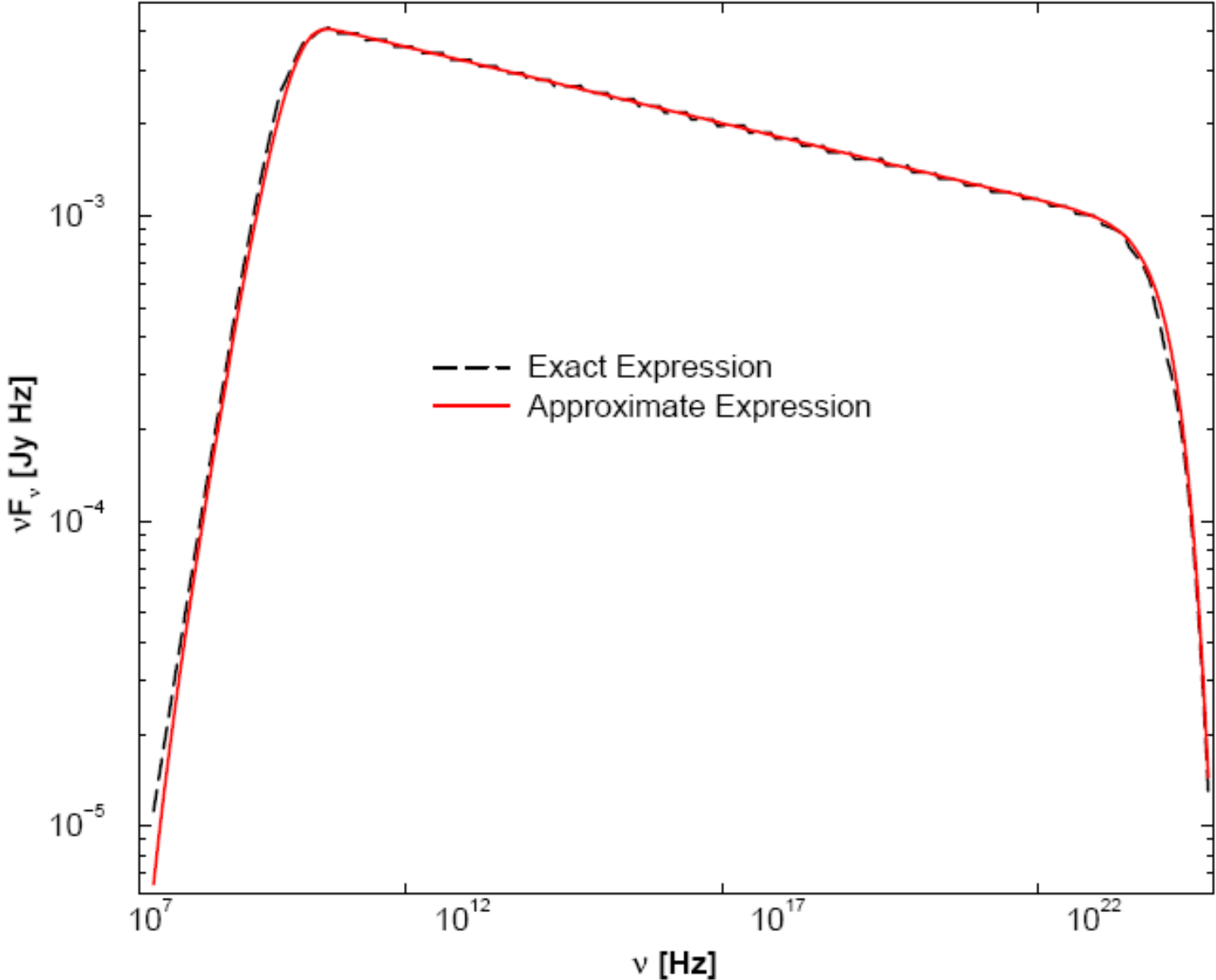
$$x = \frac{4\pi m_e c}{3e} \frac{\nu}{B\gamma^2}$$

- Approximate expression for $R(x)$ being used

$$R(x) = a_1 x^{0.20949} e^{-x} - a_2 x^{-0.79051}$$

$$a_1 = 1.08895, \text{ and } a_2 = 2.35861 \times 10^{-3}$$

Synchrotron Spectrum



Work in progress

- Synchrotron and SSC spectrum.
 - EC component needs to be incorporated.
 - Code testing – reproduction of SED and theoretical interpretation of multiwavelength data of 3C 279.
 - Prediction of dominant acceleration mechanism in that object.
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First Results

$$\langle t_{ph,esc} \rangle_V = \frac{1}{V} \int \langle t_{ph,esc} \rangle dVol$$

$$\langle t_{ph,esc} \rangle = \frac{1}{4\pi c} \int_0^{2\pi} \int_0^{\pi} l_{esc}(\theta, \phi; r, z) \sin \theta d\theta d\phi$$

Put $\cos \theta = \mu$

$$\langle t_{ph,esc} \rangle = \frac{1}{4\pi c} \int_0^{2\pi} d\phi \left[\int_{-1}^{\mu_{crit-}} l_{esc-}(\theta, \phi; r, z) d\mu + \int_{\mu_{crit-}}^{\mu_{crit+}} l_{esc} d\mu + \int_{\mu_{crit+}}^{+1} l_{esc+} d\mu \right]$$

$$\langle t_{ph,esc} \rangle_V = \frac{h}{4c} \ln \left(1 + \frac{R^2}{h^2} \right) - \frac{R^2}{4ch} \ln \left(1 + \frac{h^2}{R^2} \right) + \frac{R}{c} \tan^{-1} \left(\frac{h}{R} \right)$$

$$\langle t_{ph,esc,up} \rangle_V = \frac{\langle t_{ph,esc} \rangle_V}{\langle \Omega_+ \rangle} = \frac{2\pi(R^2 + Rz)}{2\pi Rz} \langle t_{ph,esc} \rangle_V = \langle t_{ph,esc,down} \rangle_V$$

$$\langle t_{ph,esc,side} \rangle_V = \frac{\langle t_{ph,esc} \rangle_V}{\langle \Omega_{side} \rangle} = \frac{2\pi(R^2 + Rz)}{2\pi Rz} \langle t_{ph,esc} \rangle_V$$