Time-dependent Radiation Transfer in the Internal Shock Model for Blazar Jets

Presented
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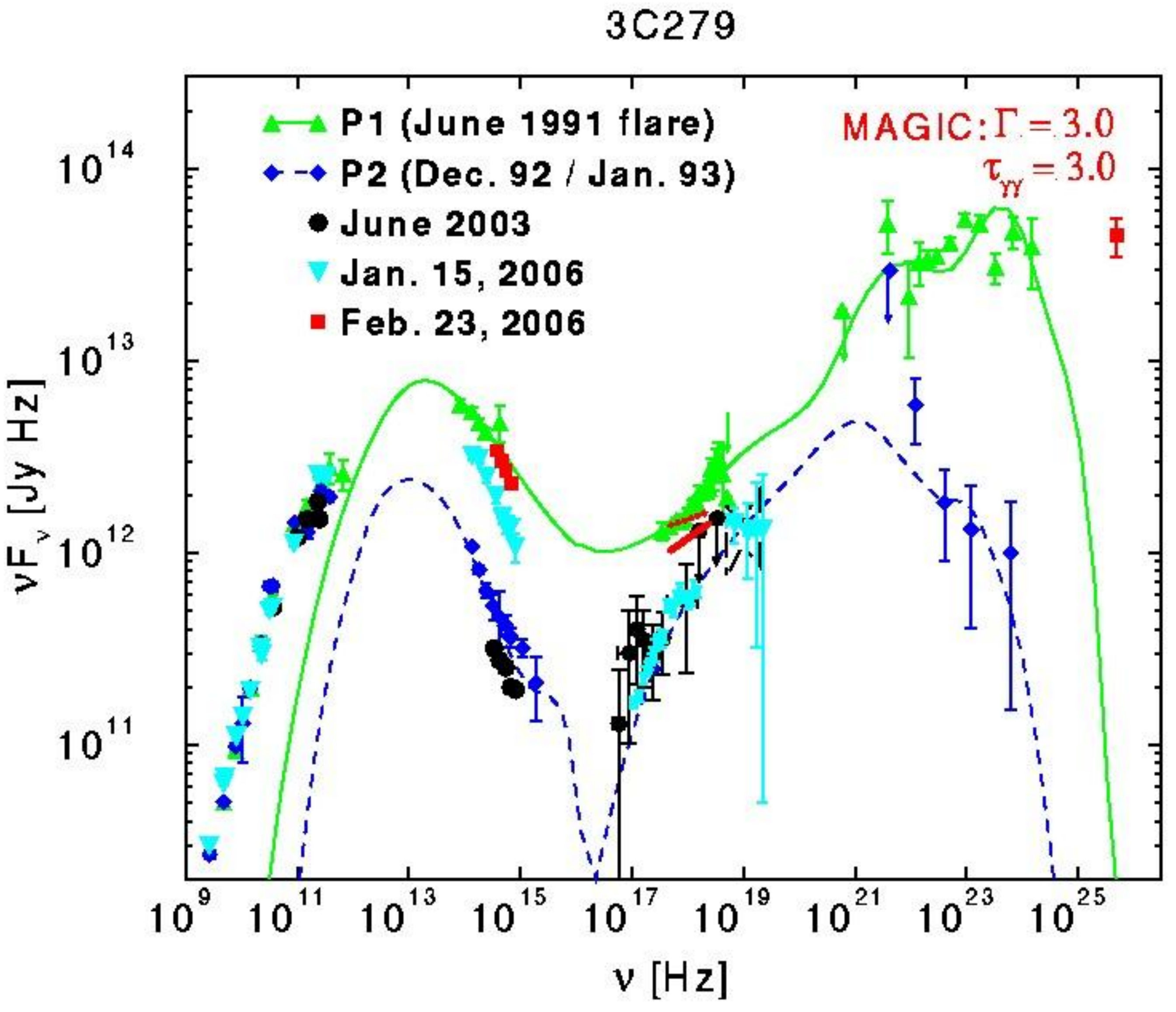
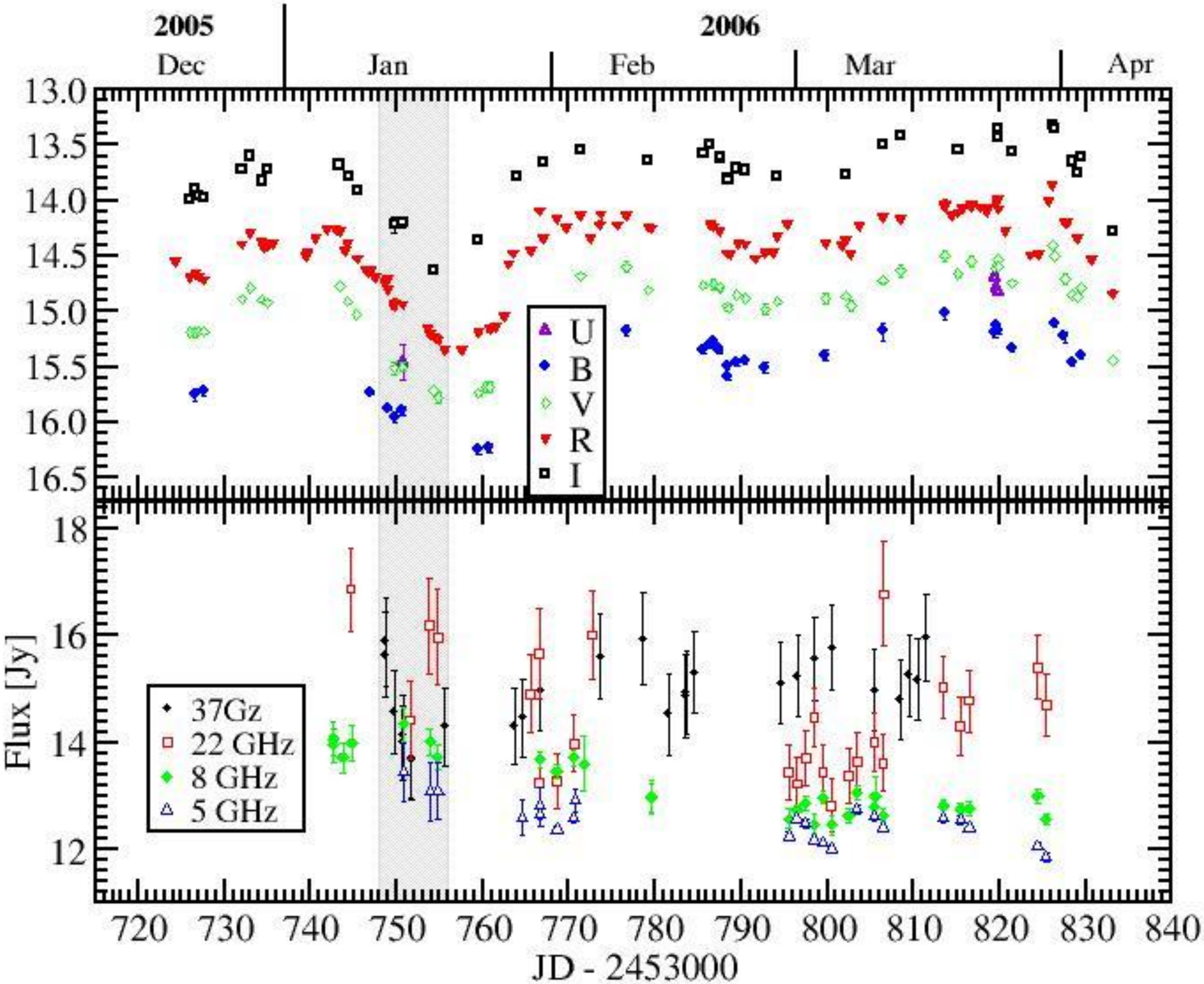
Outline

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



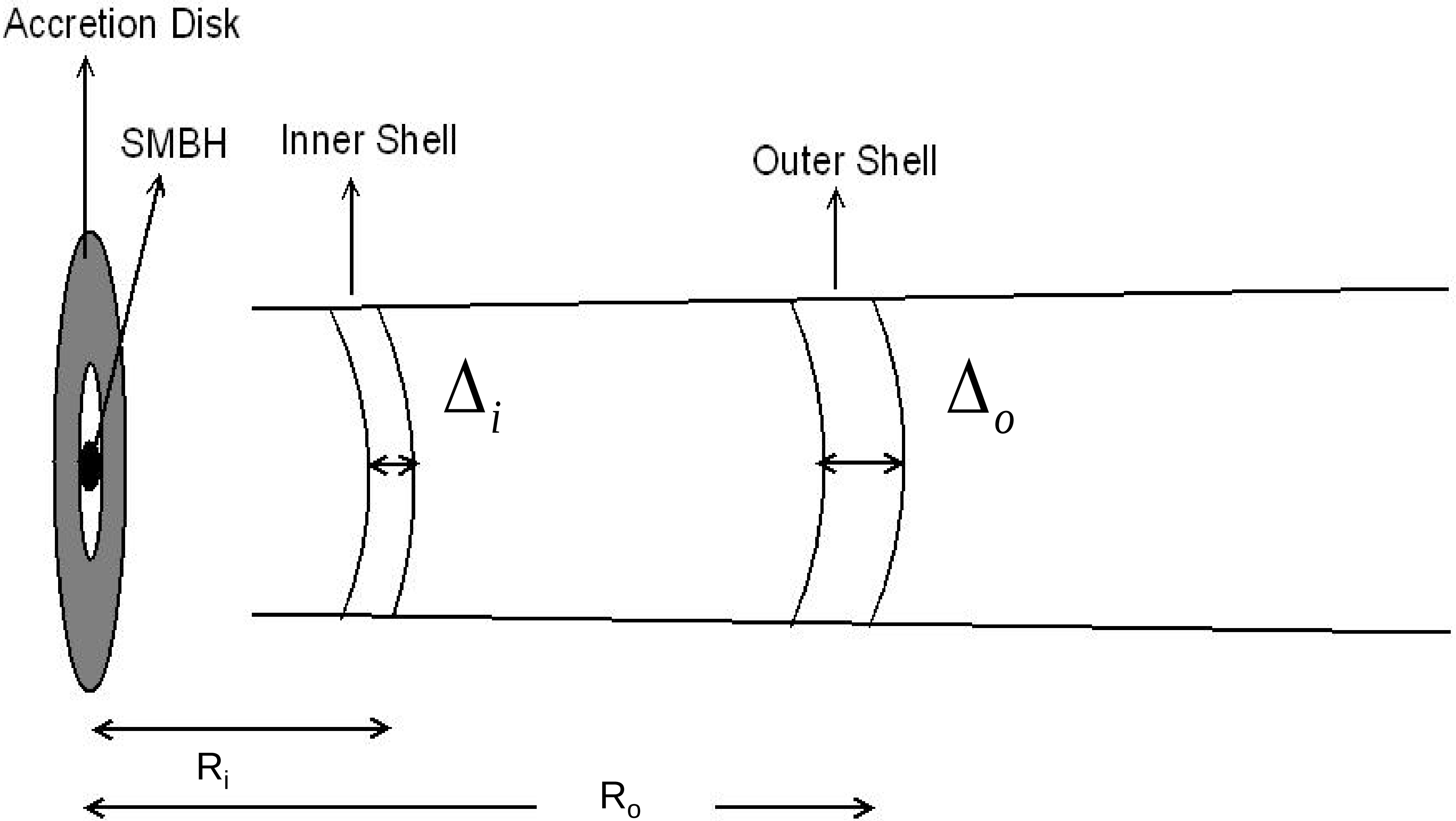
Boettcher et al., 2007, ApJ, 670, 968

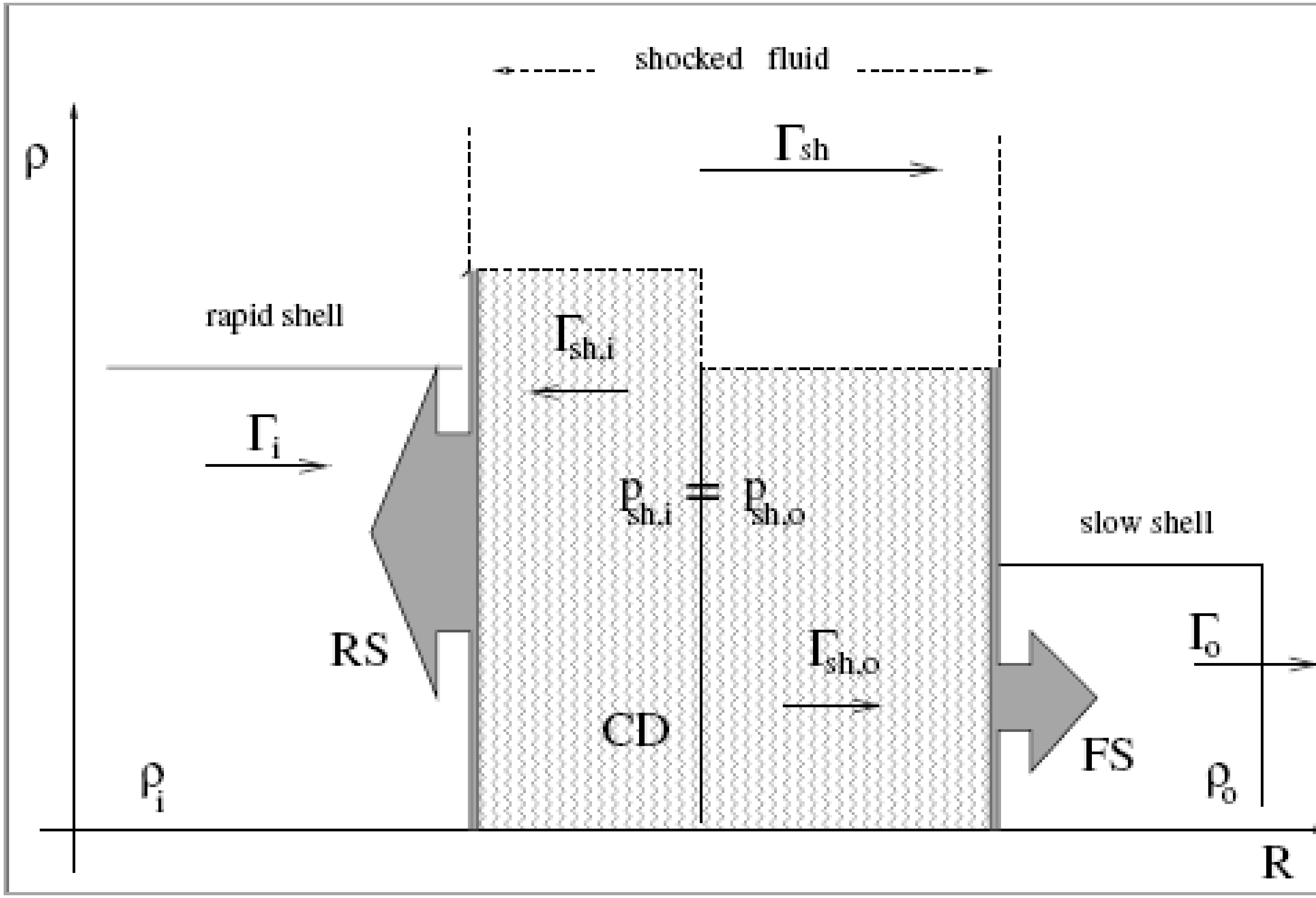


Boettcher et al., 2007, ApJ, 670, 968

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.


Accretion Disk
SMBH
Inner Shell
Outer Shell
Δ_i
Δ_o
R_i
R_o



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.

Spada et al., 2001, MNRAS, 325, 1559

- 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

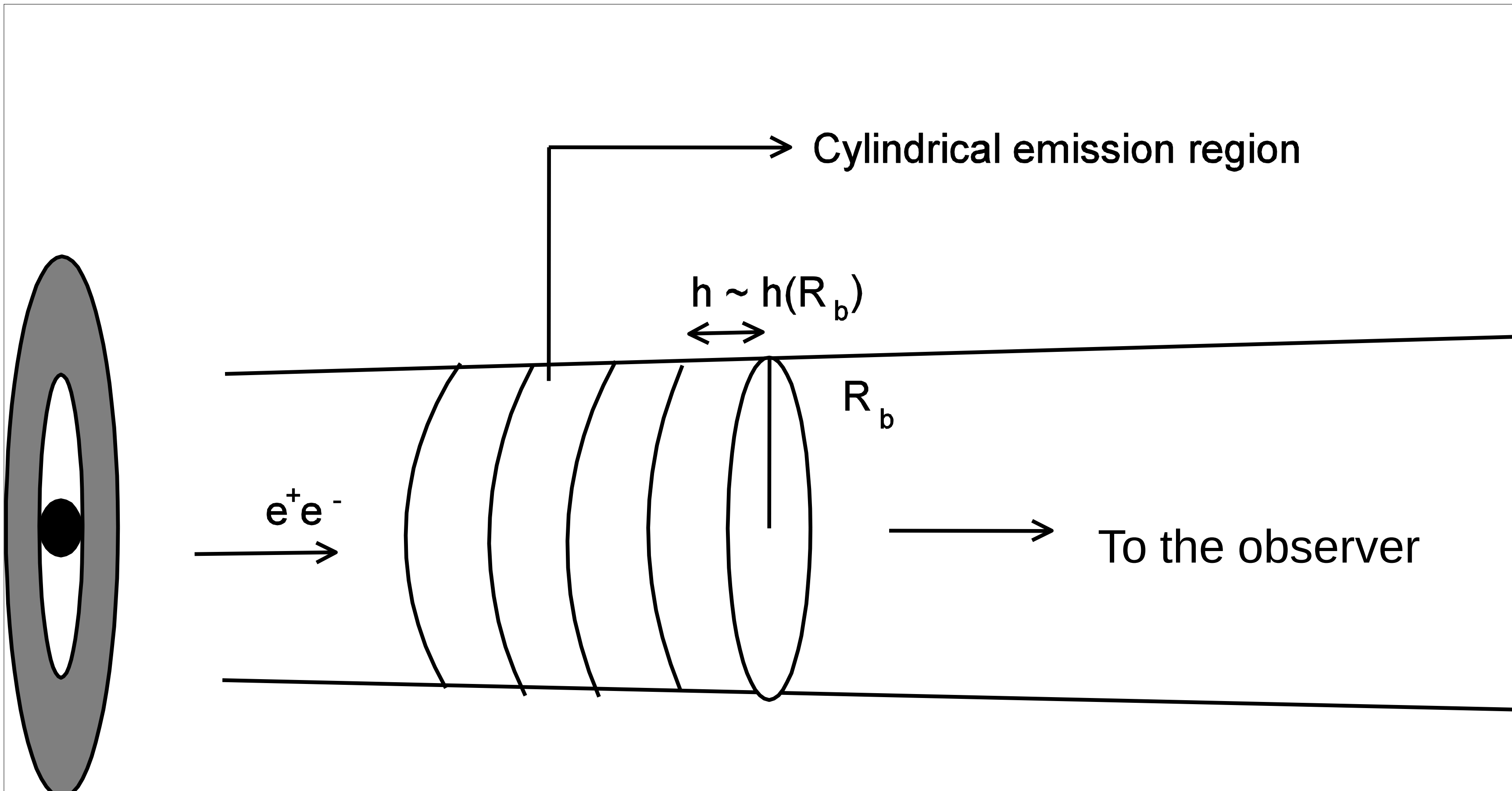
- Minimum random Lorentz factor (RLF) of electrons.

- Defines the energy distribution of particles with which they are injected by the shock into the region – describes the acceleration.

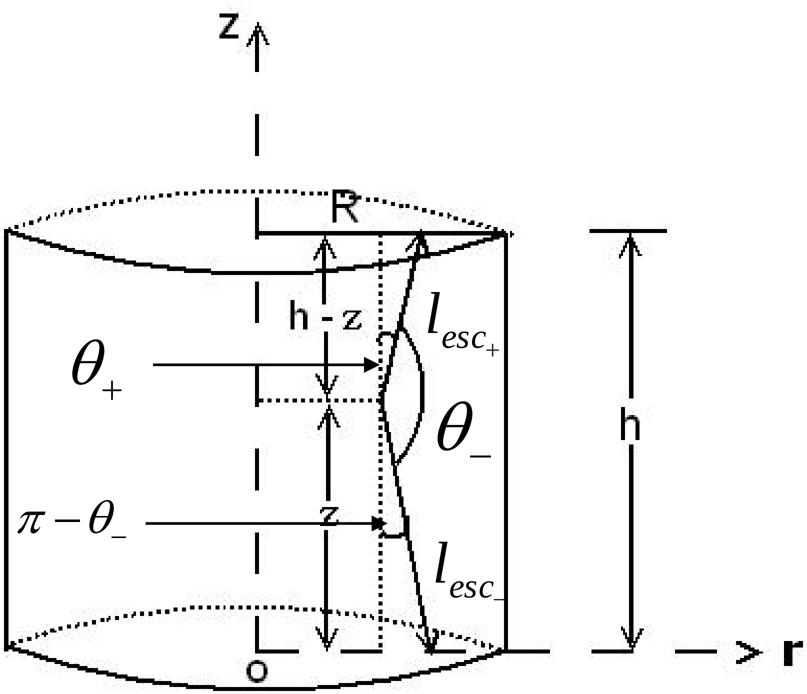
- B´ & RLF used to calculate the synchrotron and SSC spectrum.

Model Sketch

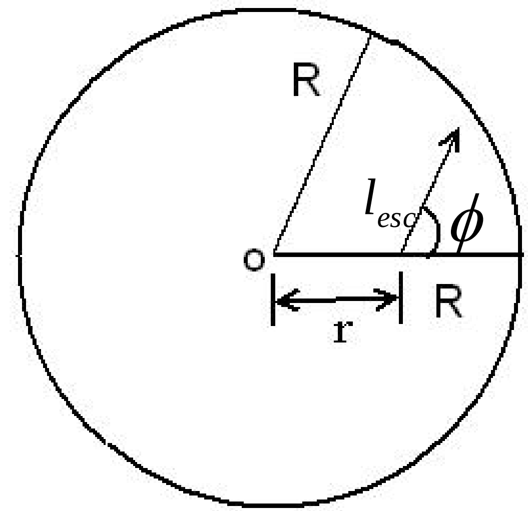
- Inhomogeneous cylindrical region with multiple zones.



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

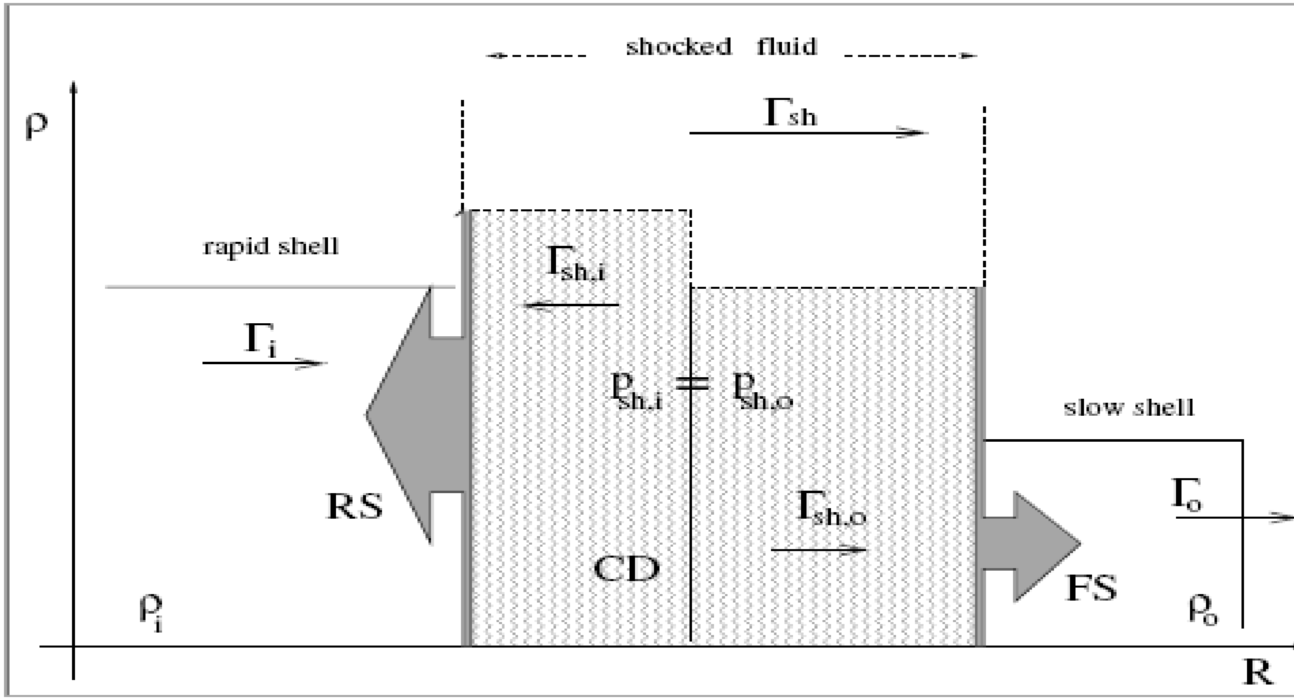


View from the top

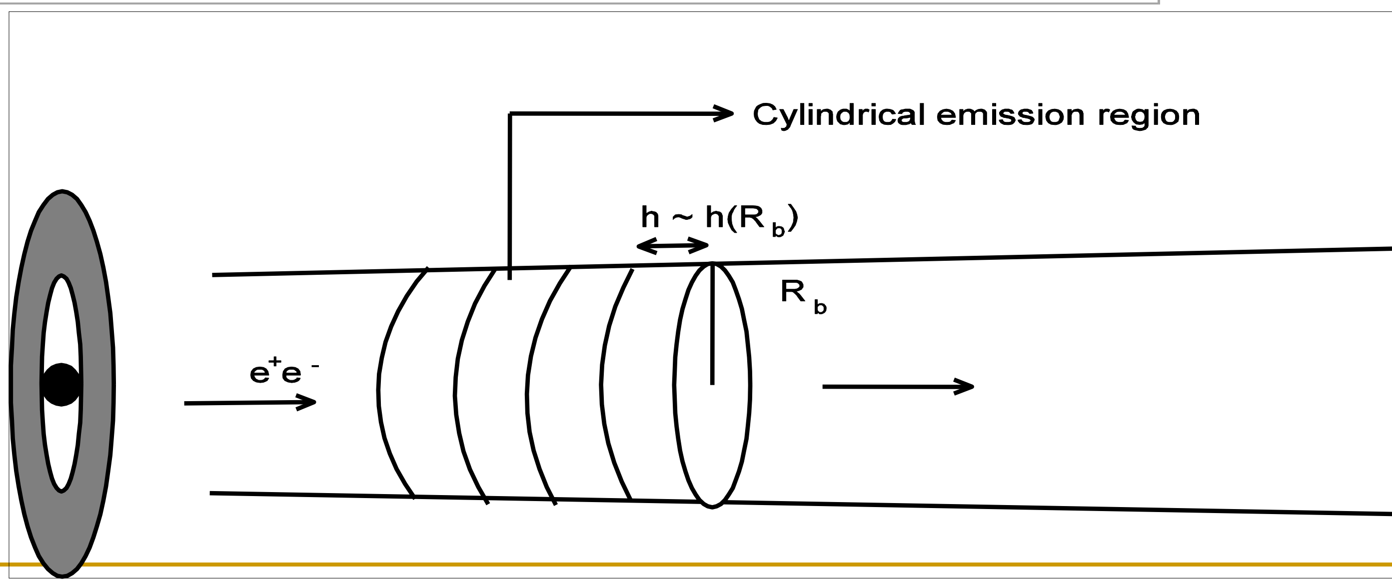


$$Put\ \cos\theta = \mu$$

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

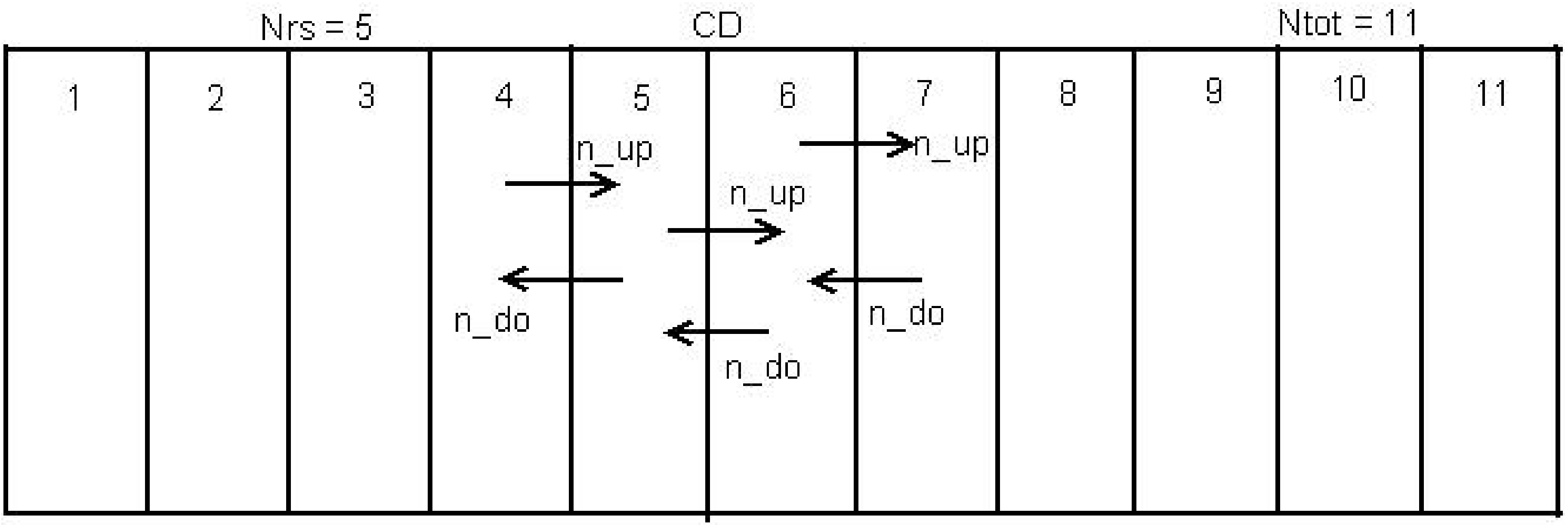


shocked fluid
ρ
Γ_{sh}
rapid shell
$\Gamma_{sh,i}$
Γ_i
$p_{sh,i} = p_{sh,o}$
slow shell
RS
Γ_o
$\Gamma_{sh,o}$
CD
FS
ρ_i
ρ_o
R

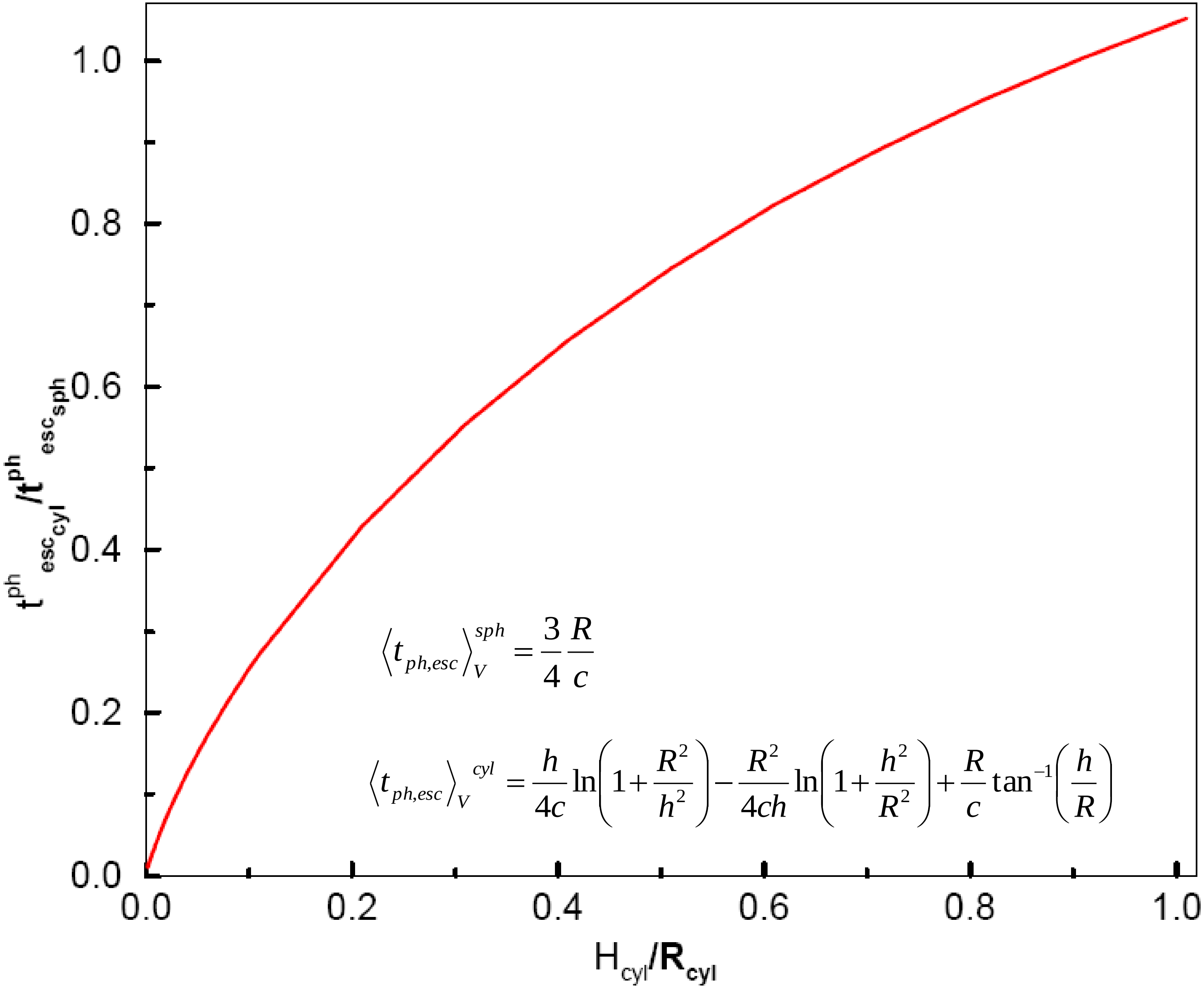


Cylindrical emission region
h ~ h(R b)
R b
e+e -

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

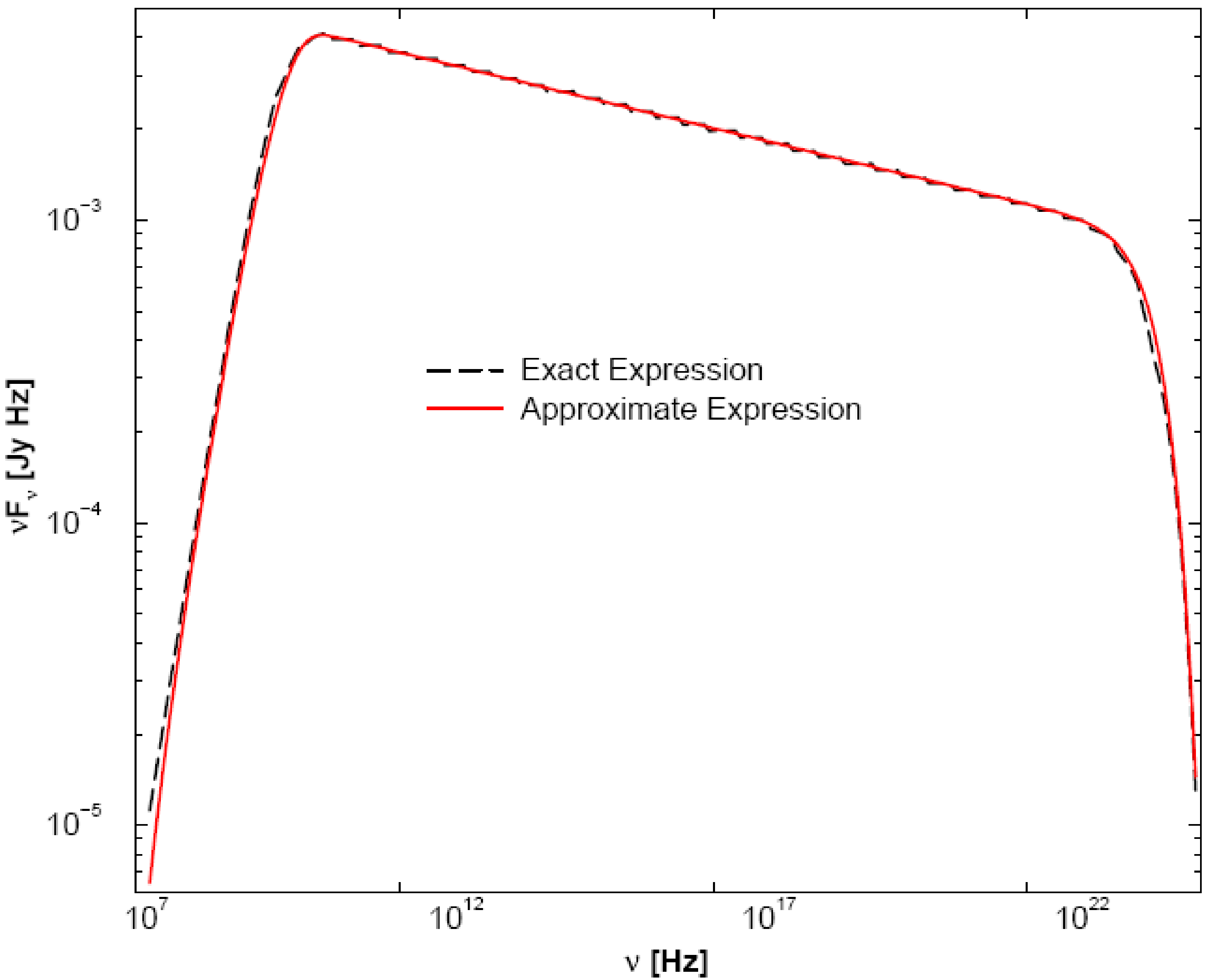
and $$x = \frac{4\pi m_e c}{3e} \frac{\nu}{B\gamma^2}$$

- Approximate expression for R(x) being used

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

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

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 accleration mechanism in that object.

First Results

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

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

$$Put \cos\theta = \mu$$

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

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

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

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