Photospheric emission from Stratified Jets

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Model for Emission Mechanism

Internal Shock Model

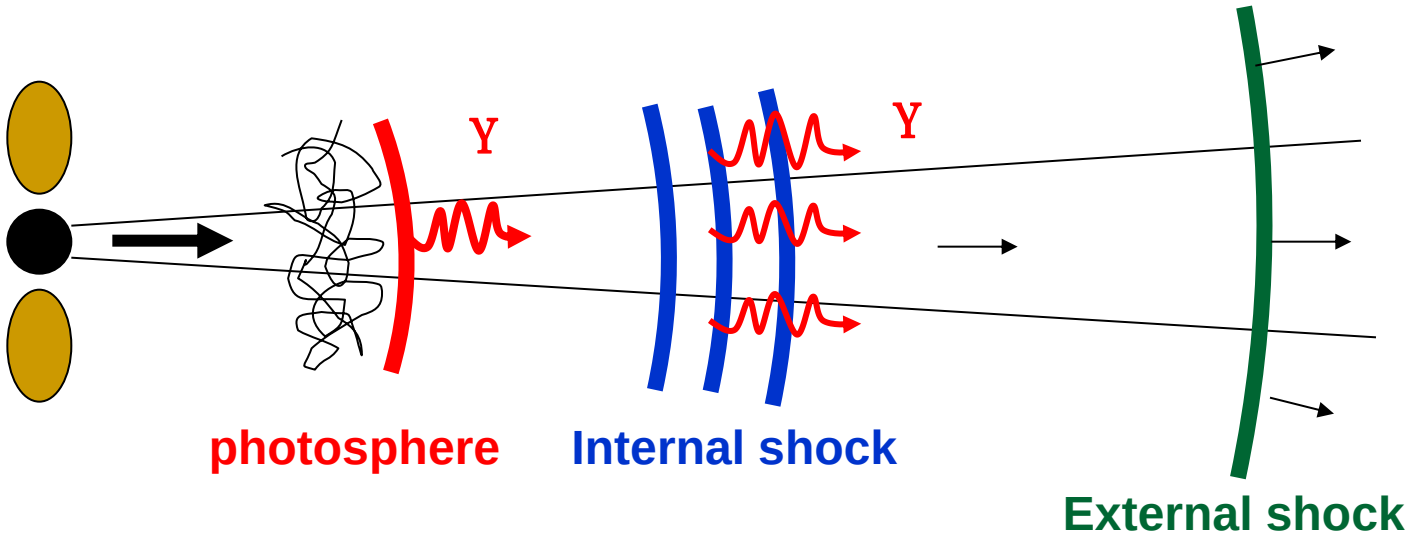
flaw

- Low efficiency for gamma-ray production
- too hard spectrum in low energy band (α)

Photospheric Emission Model

Natural consequence of fireball model

(e.g., Rees & Meszaros 2005, Pe'er et al.2005, Thompson 2007)



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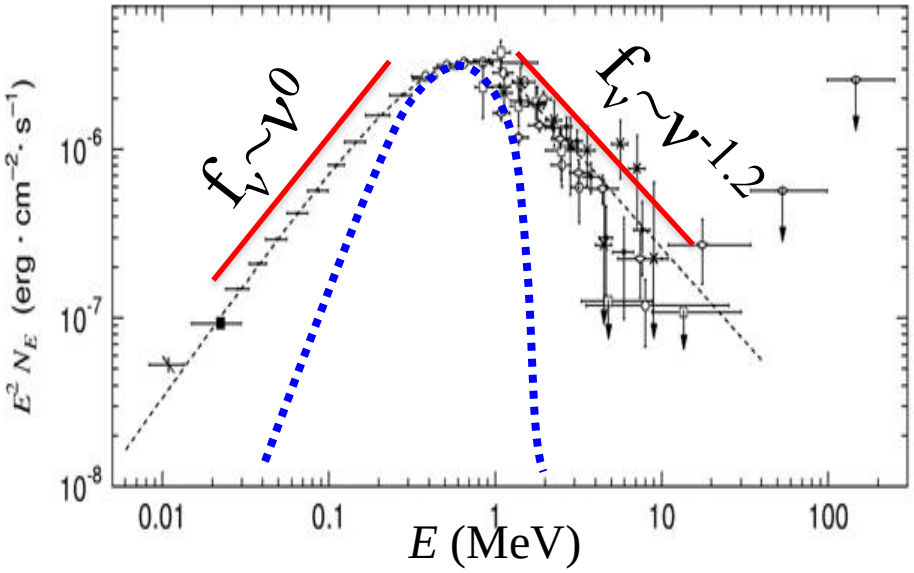


- ⊙ High emission efficiency
- ⊙ Peak at ~1 MeV
- ✕ Non-thermal appearance

Dissipative process

Magnetic recconection

Giannios & Spruit 2007, Giannios 2008

Repeated Shock

Ioka + 2007, Lazzati & Begelman 2010

Proton-neutron collision

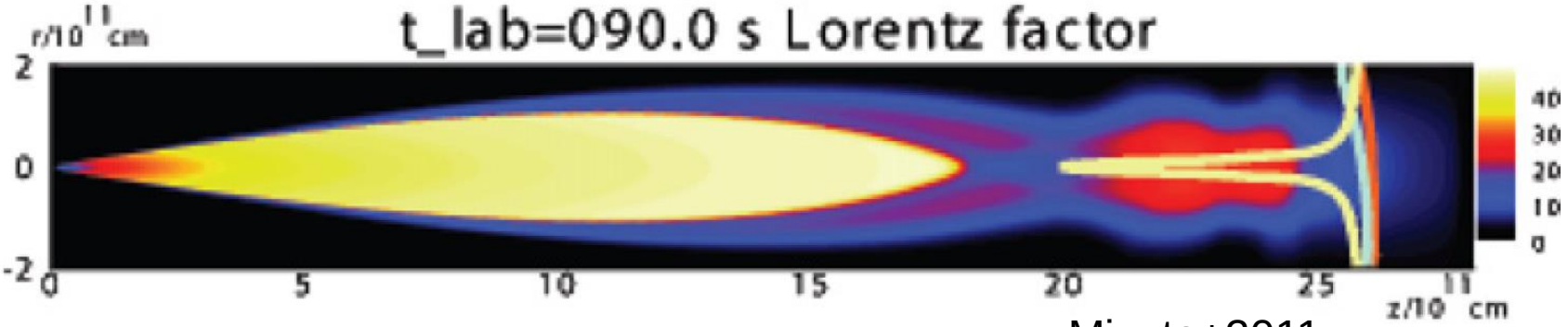
Derishev 1999, Beloborodov 2009, Vurm+2011

Physical broadening

relativistic pairs upscatter thermal photons

Geometrical broadening *A. Pe'er's talk: Lundman & Pe'er (2013)*

Structure of the jet can give rise to the non-thermal spectra



Mizuta+2011

Multi-dimensional structure of jet may be a key to resolve the difficulty

Our focus: Effect of the jet structure on the emission

Find the jet structure that can explain the observation

Stratified Jet structure

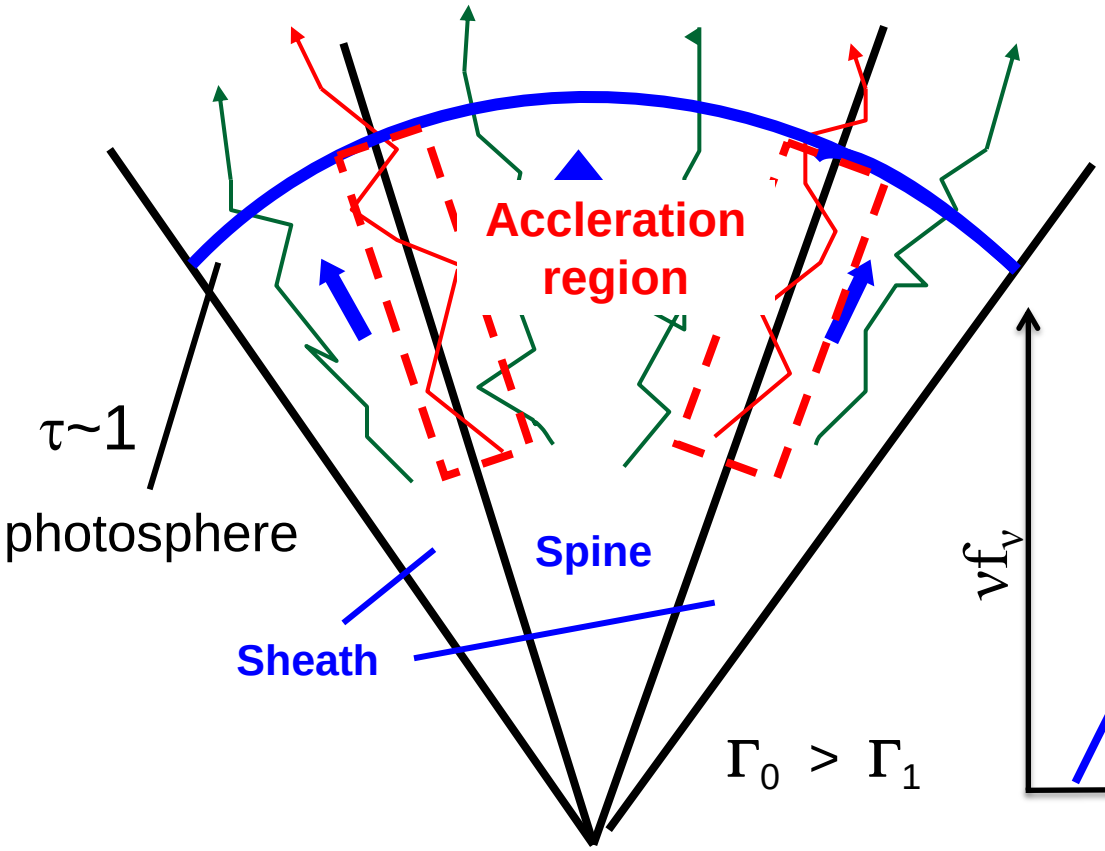
Pe'er's talk : Lundman & Pe'er (2013)

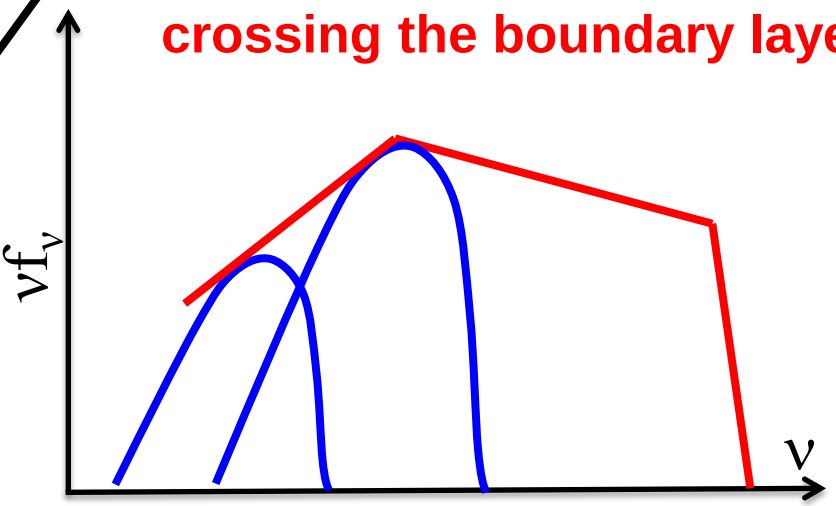
2 effects on the spectra

(I) multi-color effect

(II) Fermi acceleration of photons

Photons gain energy by crossing the boundary layer



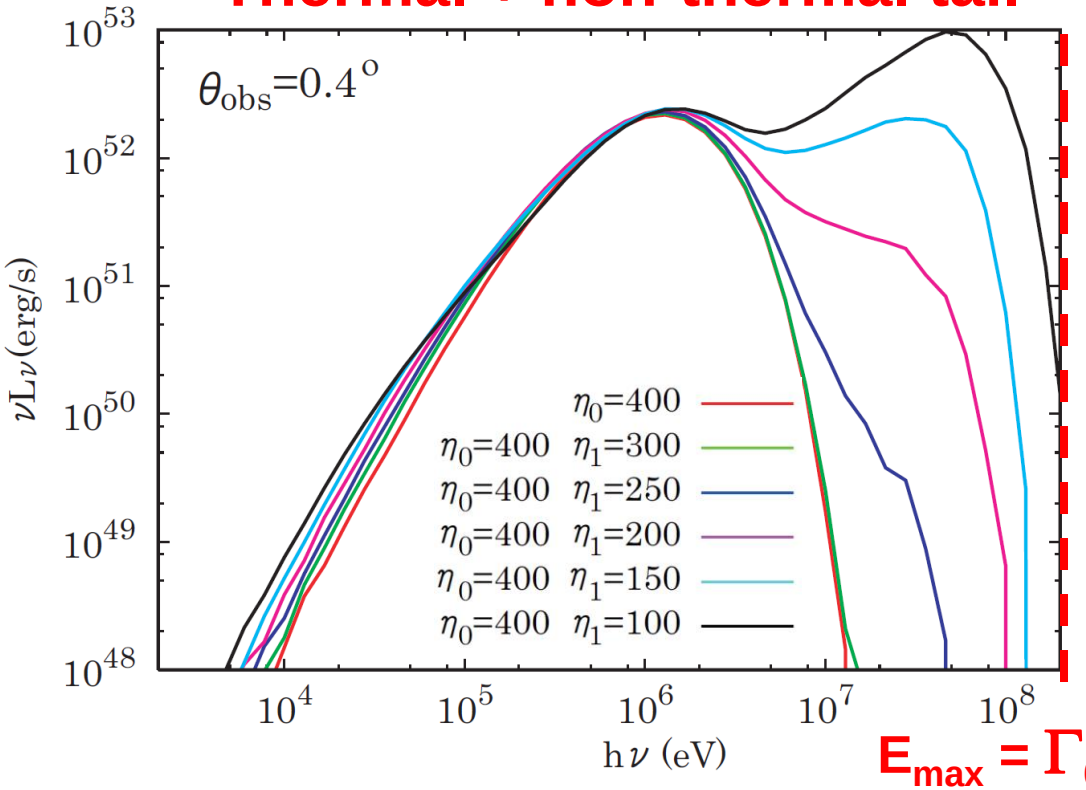


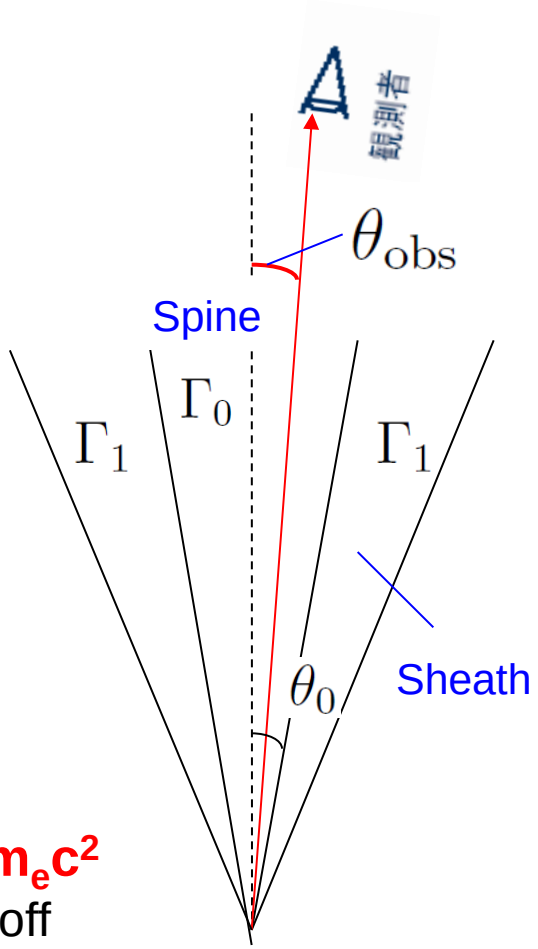
Propagation of photons are solved by Monte=Carlo method

Two-component jet

Γ_0=400 θ_j=1° θ_0=0.5° θ_{obs}=0.4°

Thermal + non-thermal tail





$E_{max} = \Gamma_0 m_e c^2$

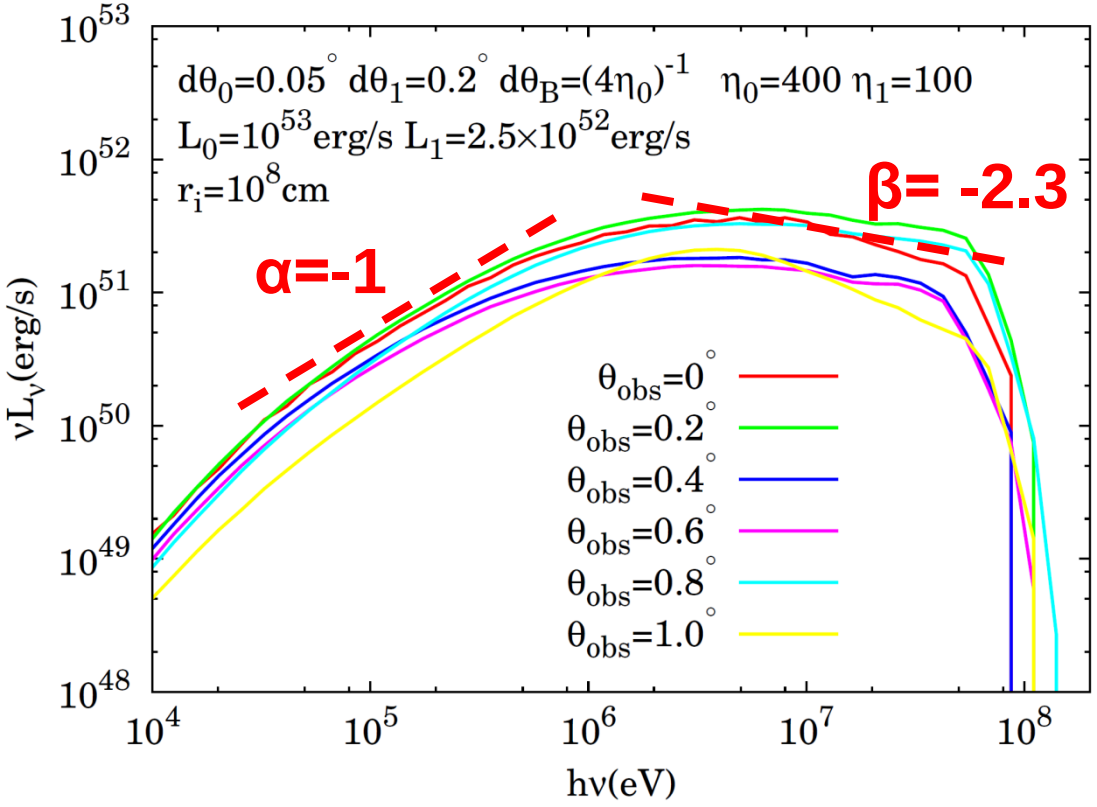
Klein-Nishina cut-off

Non-thermal tail becomes prominent as the relative velocity becomes larger

But limited only for small range of observer angle

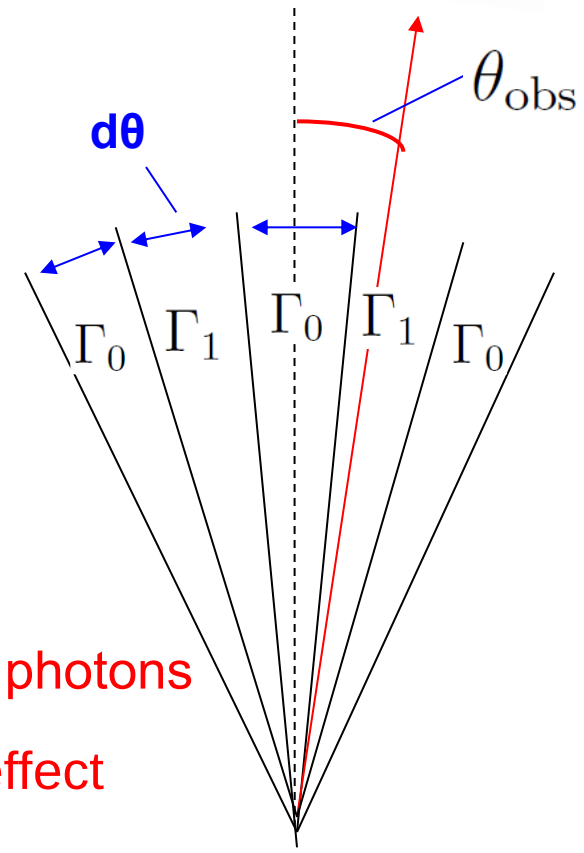
$|\theta_{obs} - \theta_0| < \Gamma^{-1} \sim 0.14° \ \Gamma_{400}^{-1}$

Multi-component jet



Γ_0=400 Γ_1=100

$d\theta_0=0.05^\circ$ $d\theta_1=0.2^\circ$



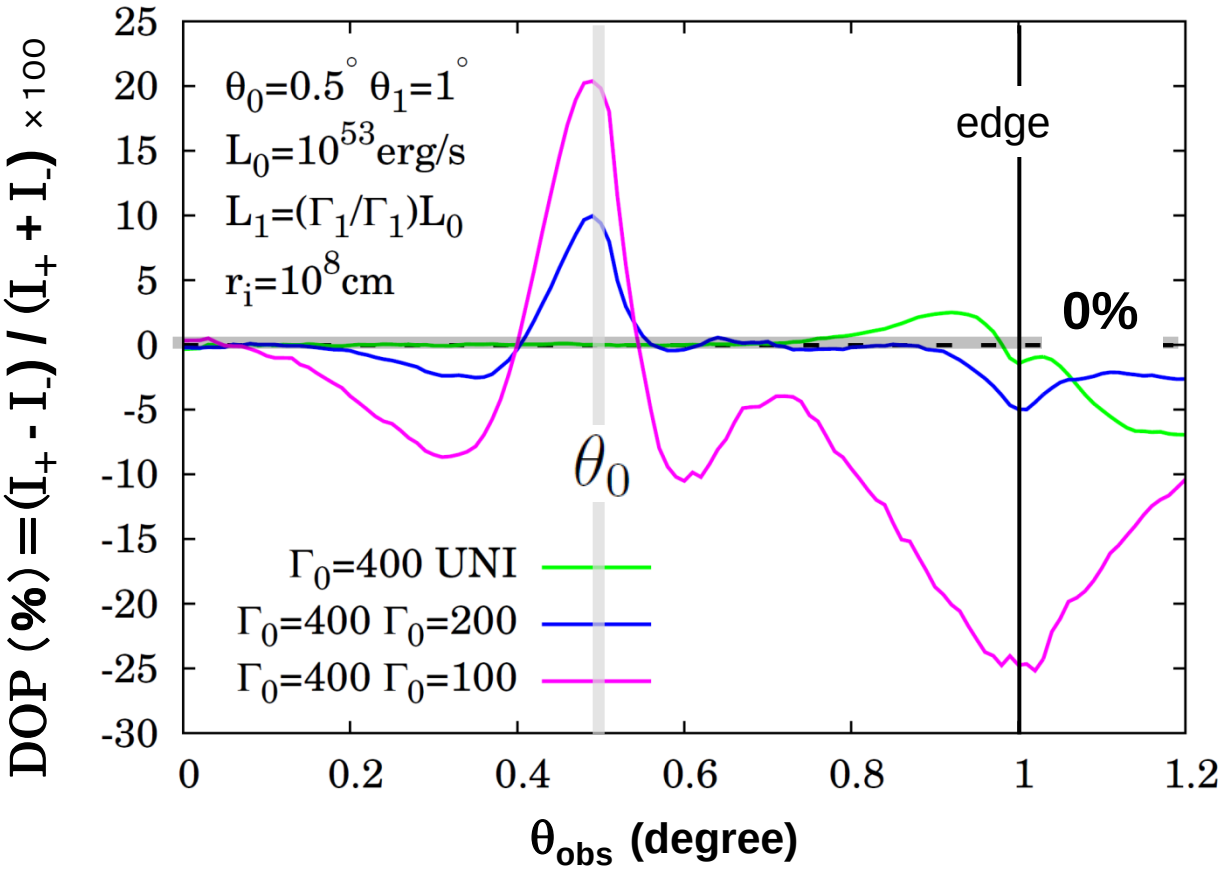
Interval of velocity shear $d\theta < 2\Gamma^{-1}$

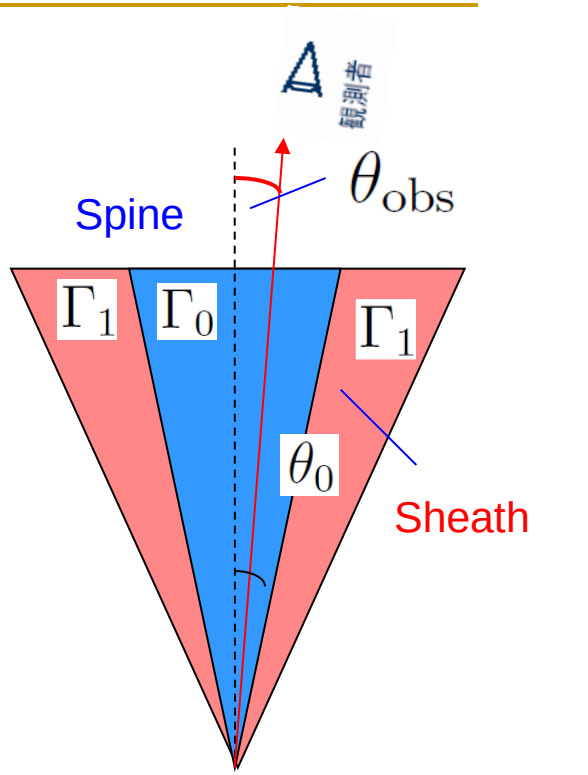
high energy spectra (β) is reproduced by accelerated photons

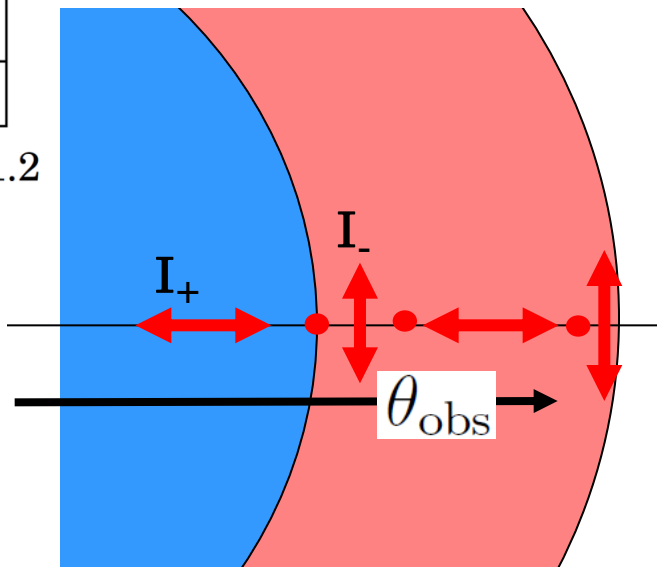
Low energy spectra (α) is reproduced by multi-color effect
(Lundman & Pe'er 2013)

polarization

two-component jet



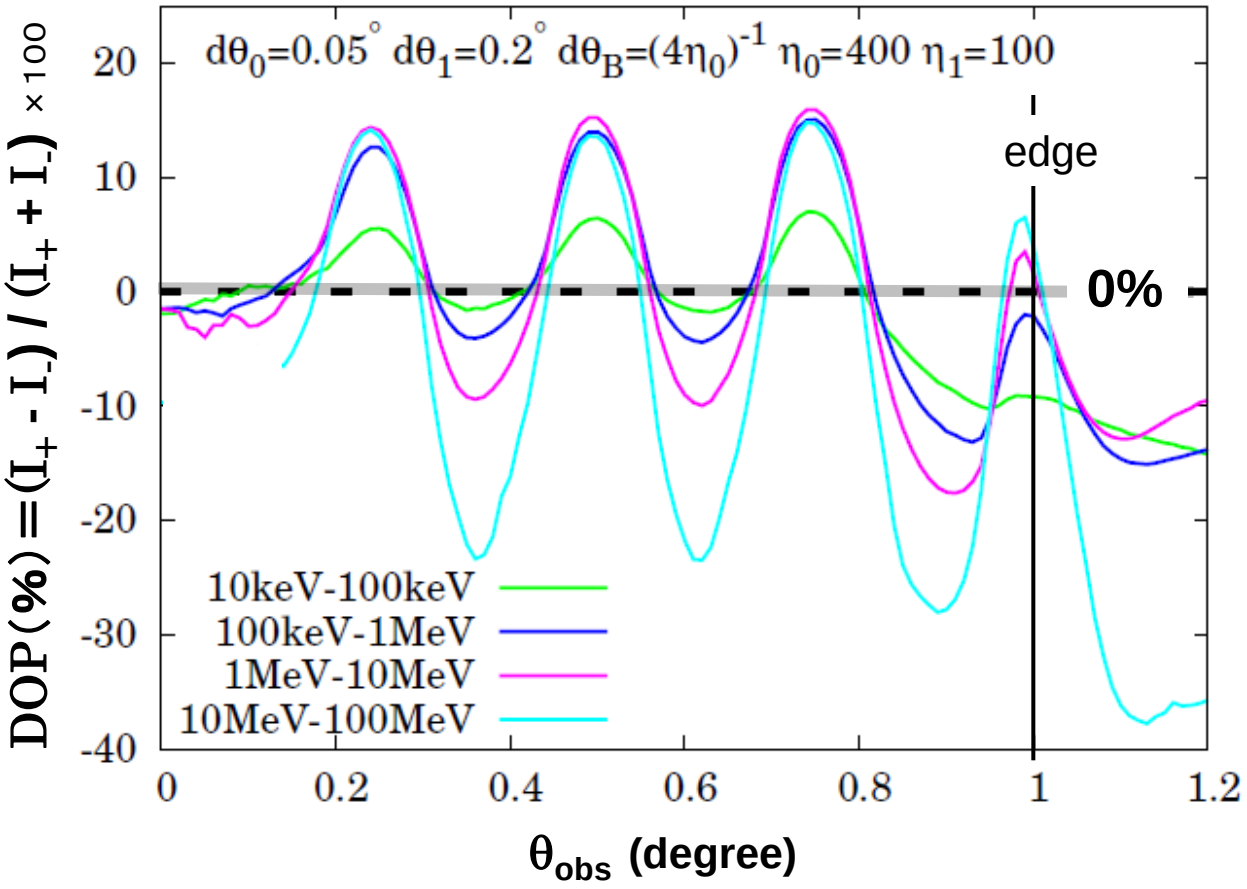




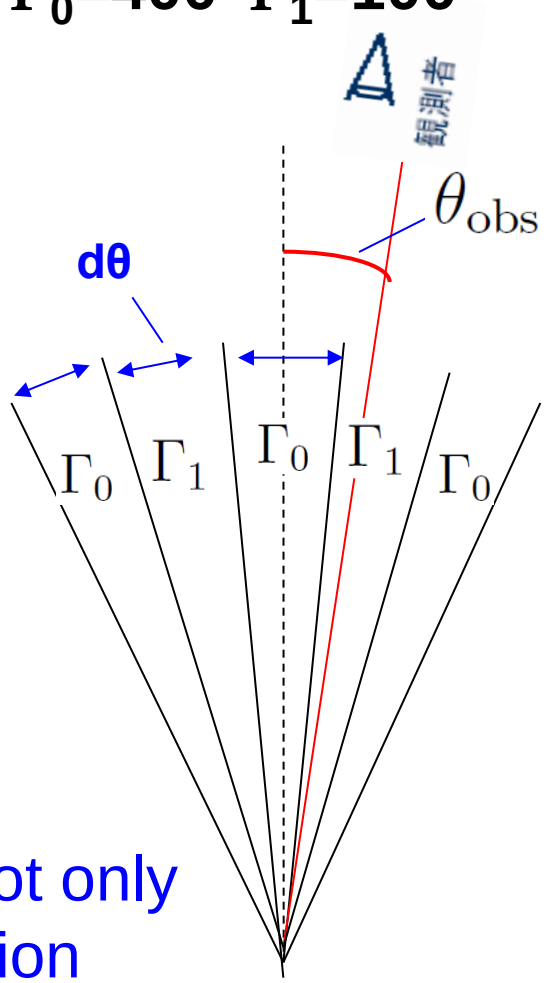
Degree of polarization (DOP) becomes larger as the relative velocity becomes large

polarization

multi-component jet that reproduces Band spectra



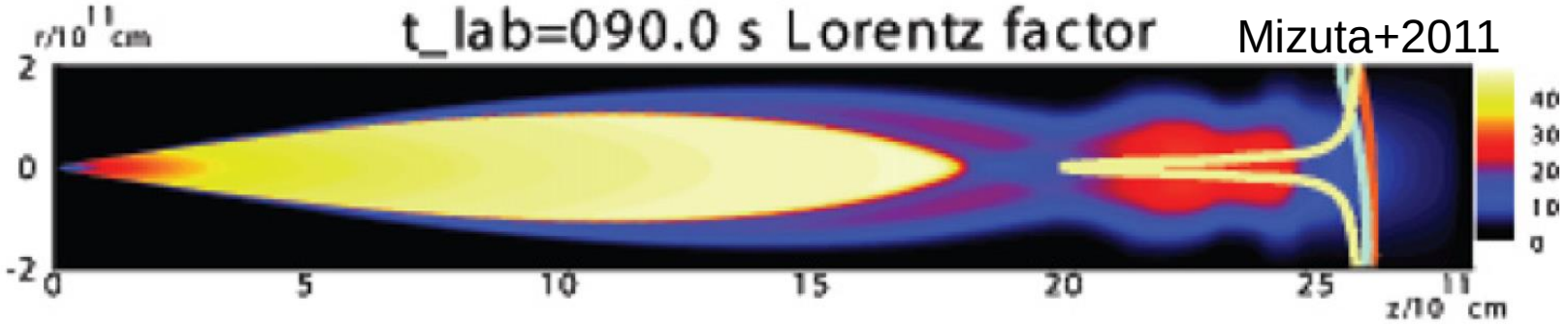
Γ_0=400 Γ_1=100

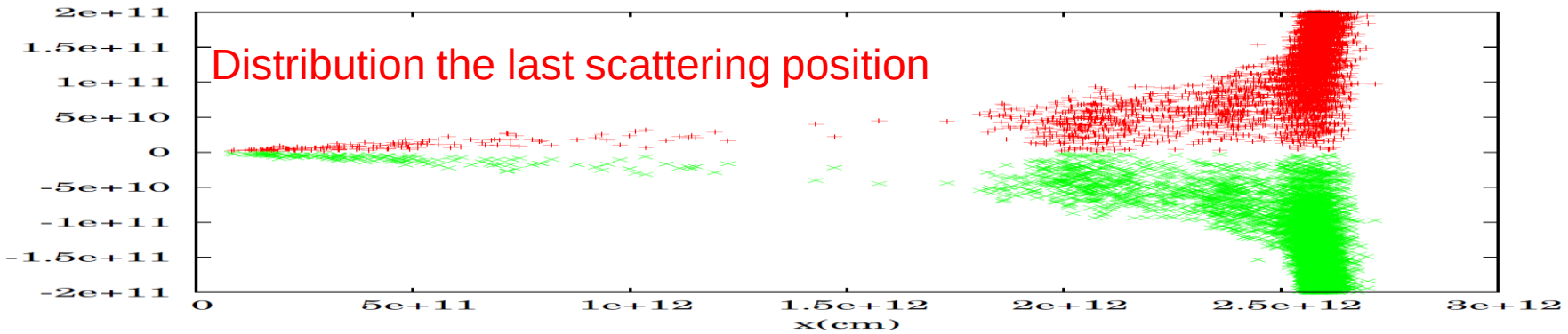


High polarization degree (>10%) is predicted not only in the off-axis region but also in the on-axis region

On-going project

2D Hydrodymical simulation of relativistic jet as a background fluid





Detail of spectra, polarization and lightcurves for more realistic case can be obtained

3D Hydrodymical simulation of relativistic jet as a background fluid

simulation by J. Matsumoto

Summary

- Stratified jet can produce a power-law non-thermal tail above the peak energy

  non-thermal particle is not required

- Multi-component jet can reproduce Band function irrespective to the observer angle

  β is reproduced by the accelerated photons

  α is reproduced by the multi-color effect

- Degree of polarization tends to increase as the relative velocity increases

  High DOP (>10%) is predicted for the jet structure that reproduces Band function

Futrure works

- Photon accelerations in various structures

  shocks, turbulence

- Hydrodymical simulation of relativistic jet as a background fluid