Time-dependent modeling of blazar polarization

Xuhui Chen

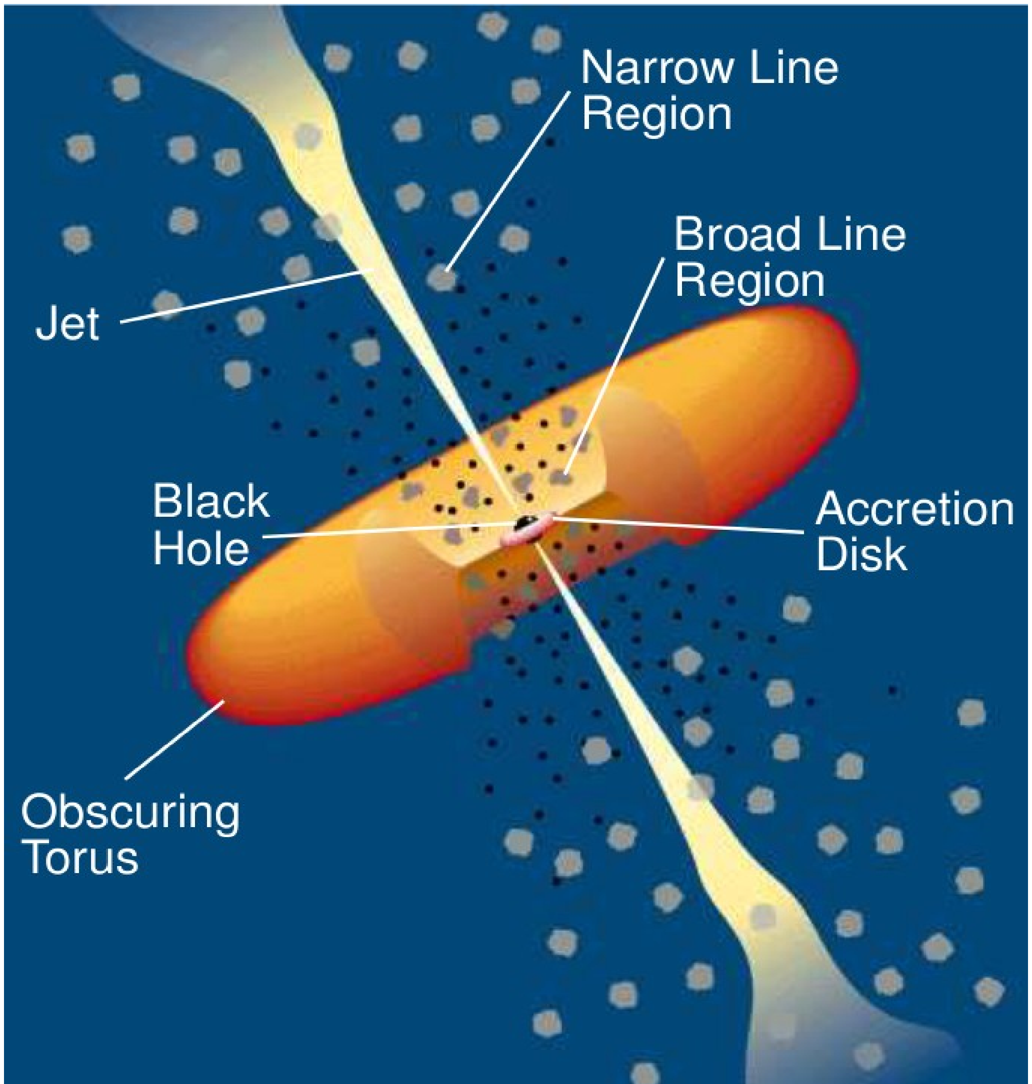
Collaborators:
Haocheng Zhang (Ohio U, USA),
Markus Böttcher (North-West U, South Africa)

Recent Results in Astrophysics
14.01.2014, DESY, Zeuthen

Outline

- Introduction
- Model setup with helical B
- Modeling results with polarization
- Discussion

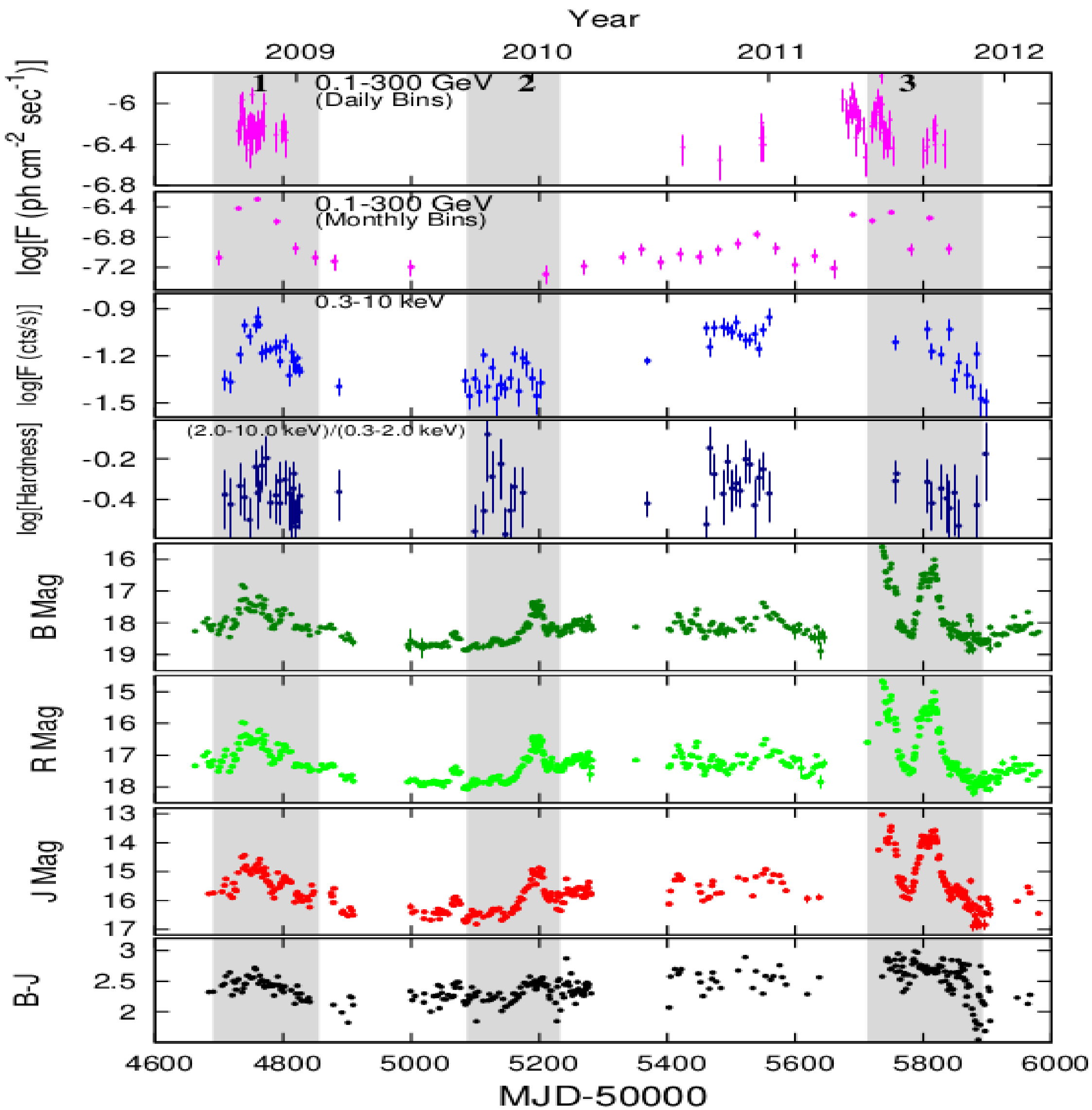
Active Galactic Nucleus (AGN)



Jet moving relativistically

Blazars: Along the Jet

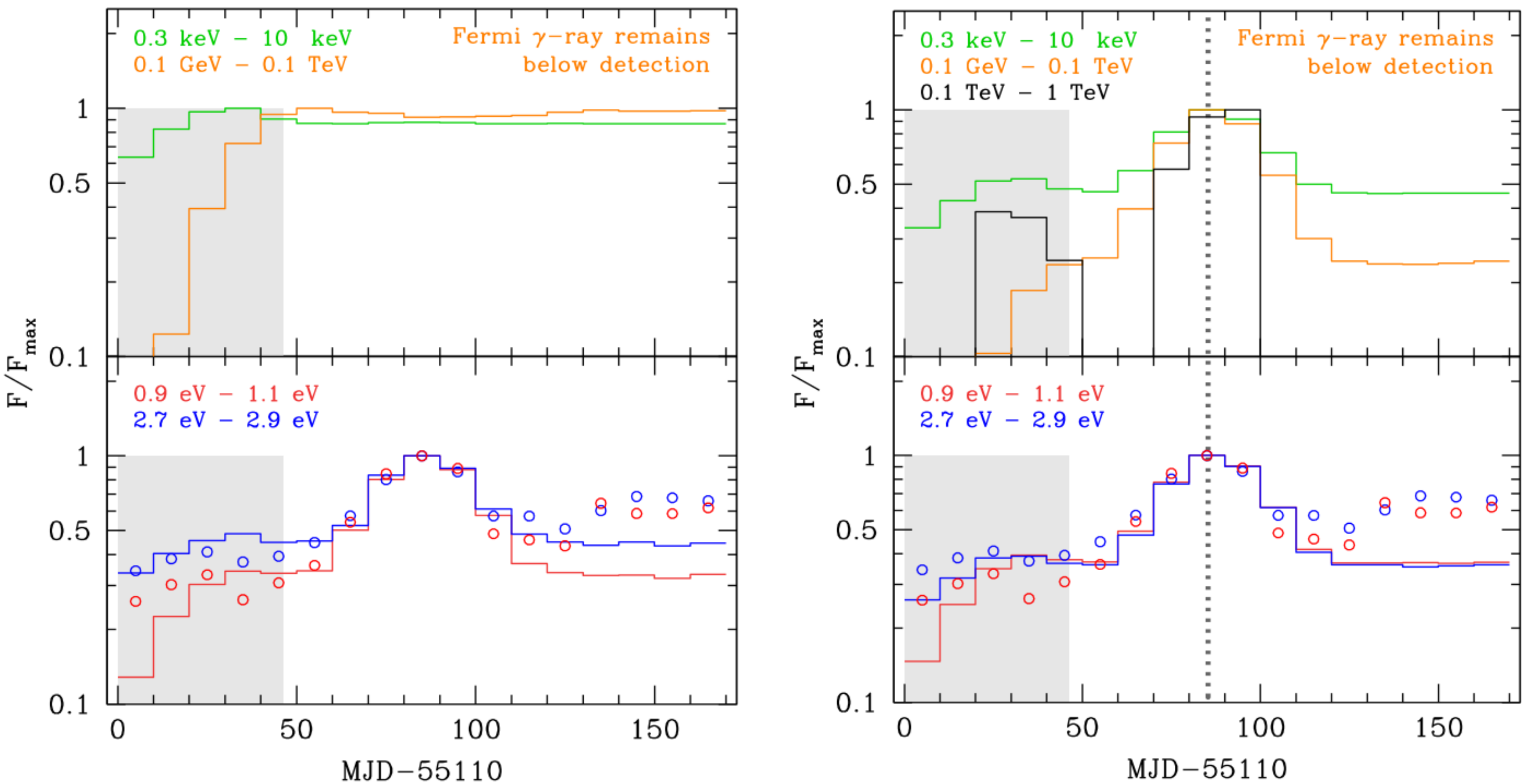
PKS 0208-512



Linear optical polarization of 11.53% measured in 1985
(Impey & Tapia 1988)

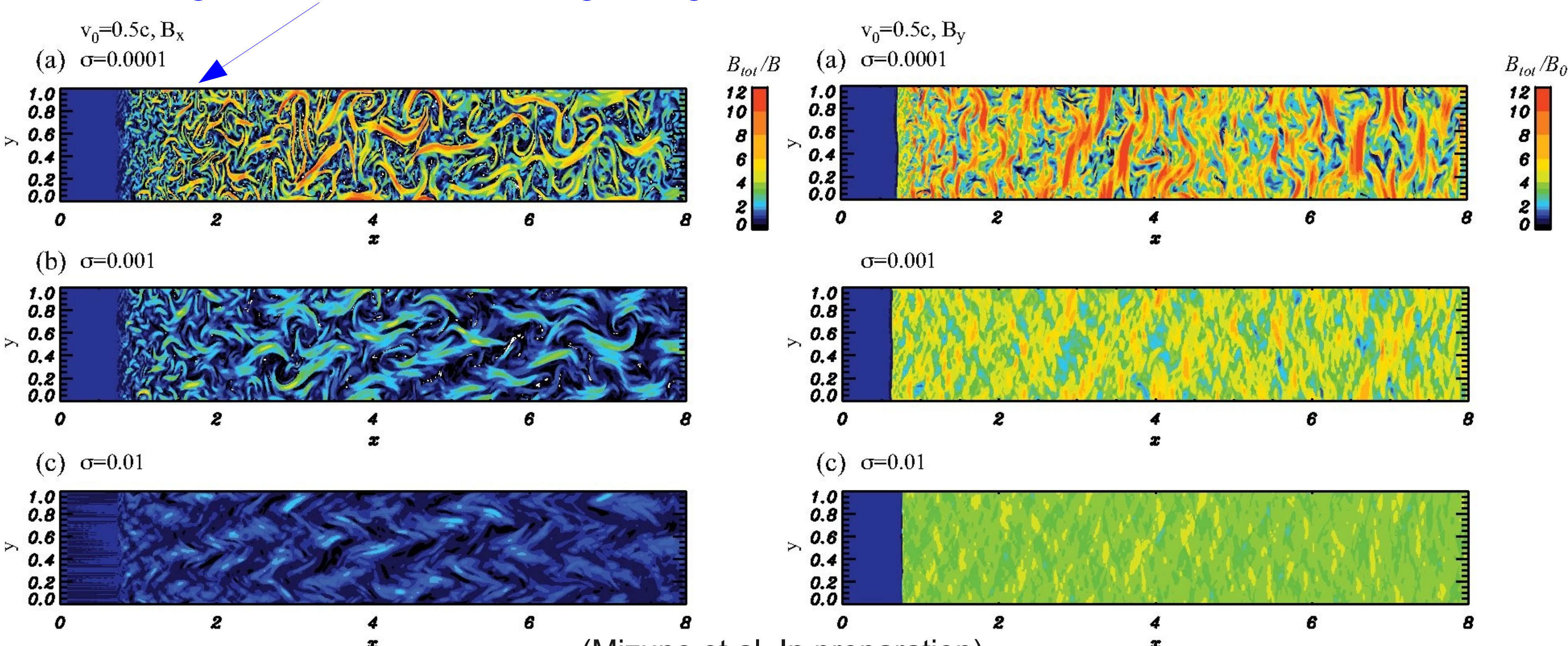
External Compton Model -- Light Curves

B change | Acceleration change



MHD simulation of magnetic field amplification

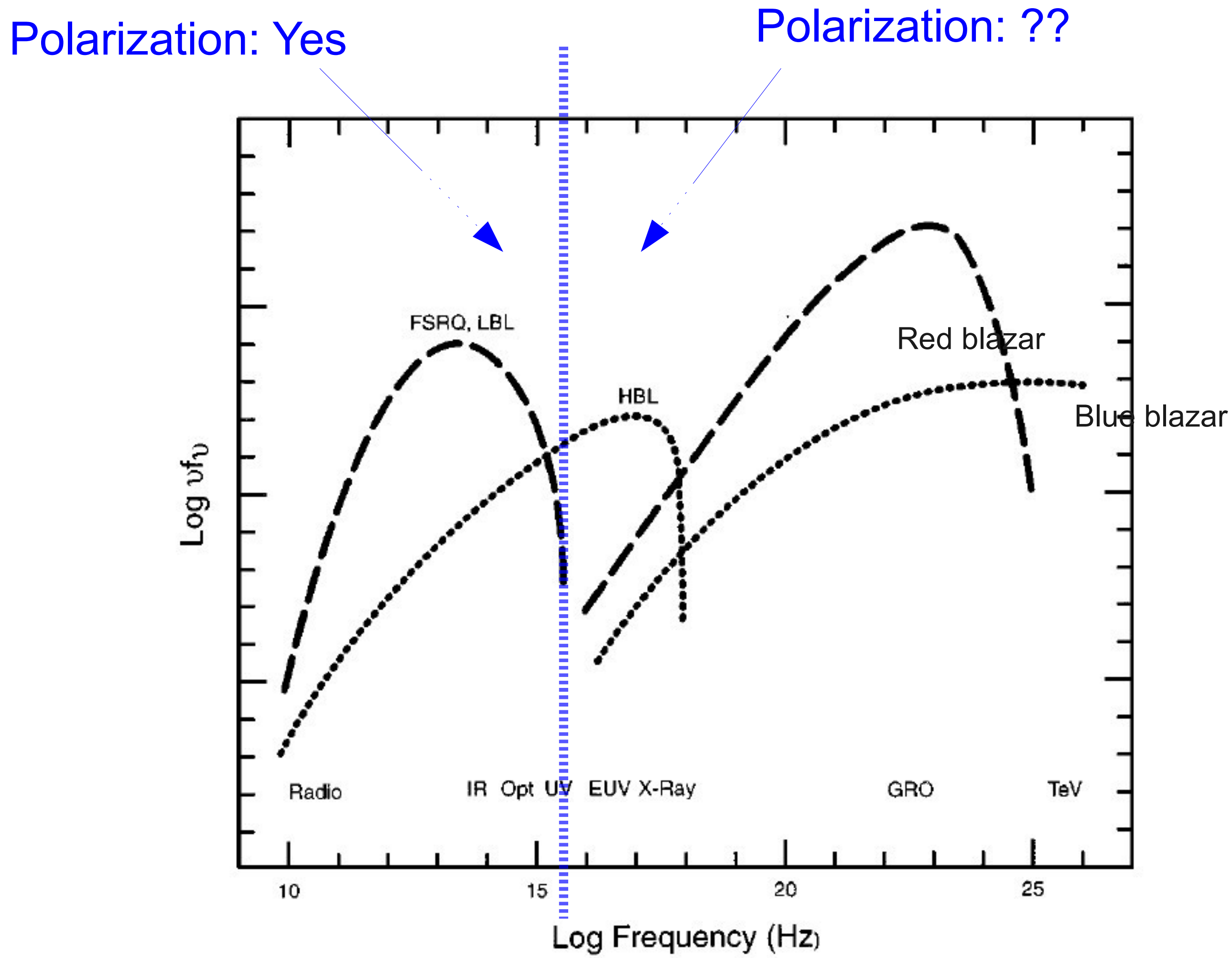
Strong turbulence at the beginning



(Mizuno et al. In preparation)

The postshock magnetic field is more ordered with perpendicular magnetic field (right).

Balzar Polarization



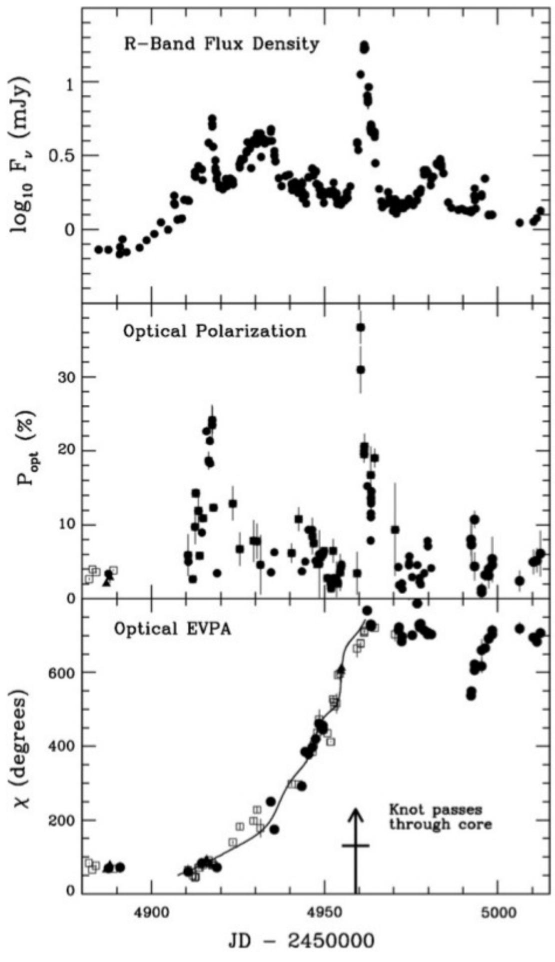
(Sambruna et al.,1996)

General optical polarization

- A large portion of FSRQs and almost all BL Lacs are highly polarized (Impey & Tapia 1990)
- Blazar optical flux and polarization degree:
    - 10/33 show correlation
    - 4/33 show anti-correlation
- No significant correlation between optical spectral color and polarization degree (Ikejiri et al. 2011)
- Optical and radio polarization correlation is not clear (not correlated, Impey & Tapia 1990; correlated with no time delays, D'arcangelo et al. 2009)

Polarization change during blazar flares

PKS 1510-089

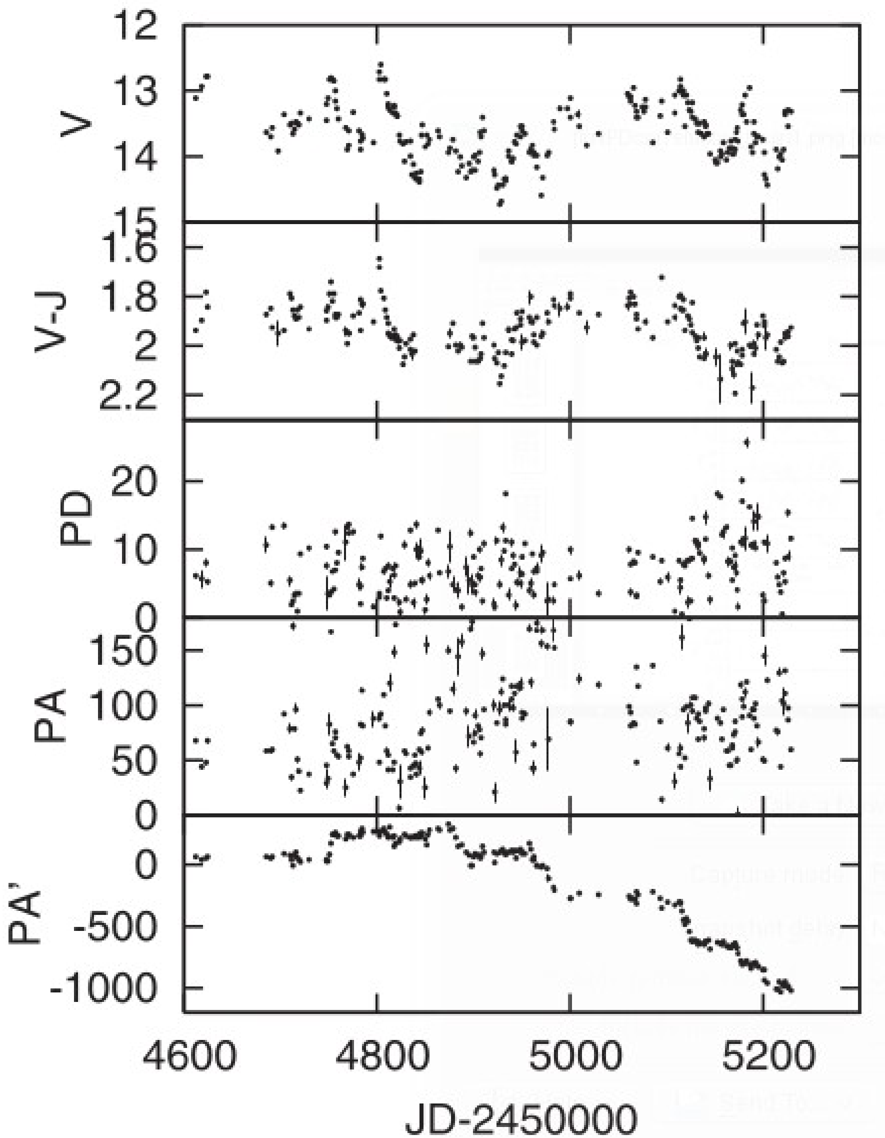


(Marscher et al. 2010)

Polarization degree varies between 2% and 35%, and correlates with flux

Rotation of polarization angle by 720°

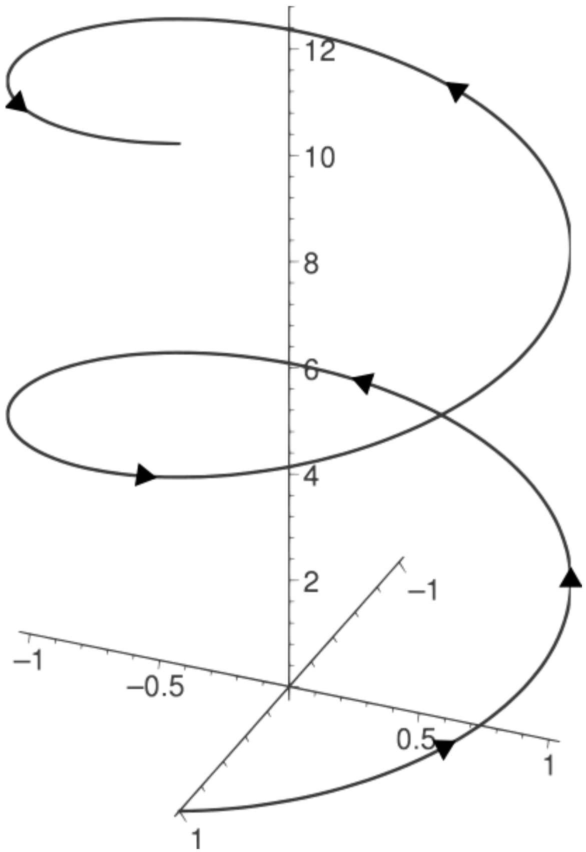
S5 0716+714

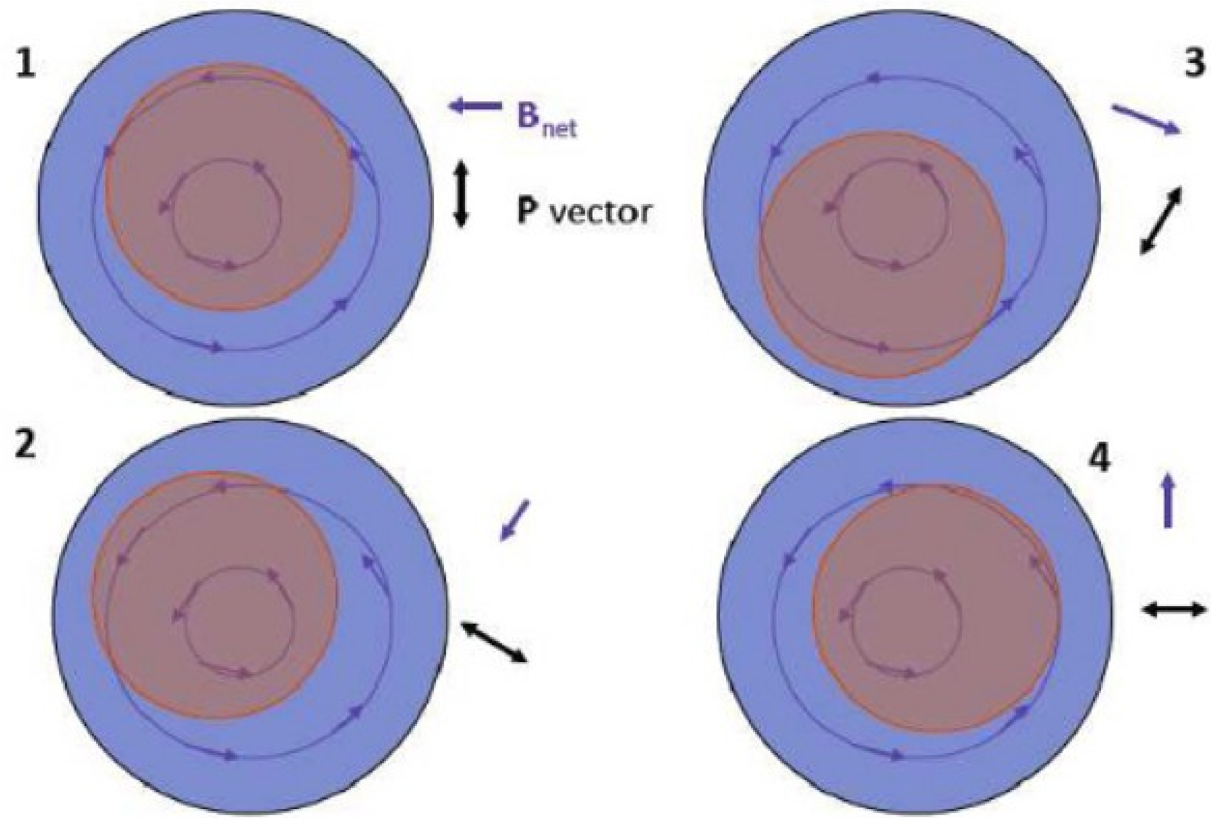


polarization angle shows step-like rotation

(Ikejiri et al. 2011)

Existing explanation for polarization angle swing



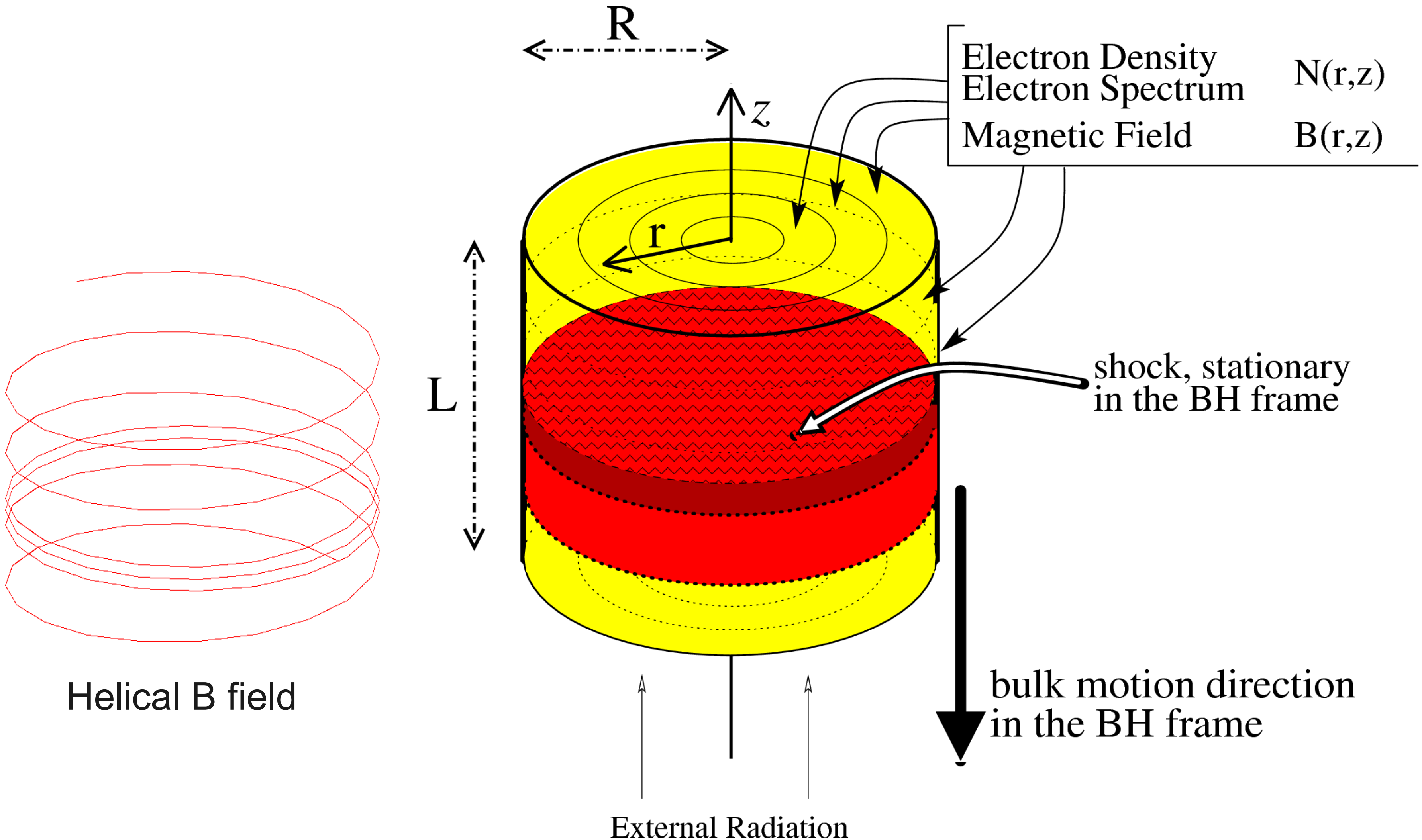


(Marscher 2013)

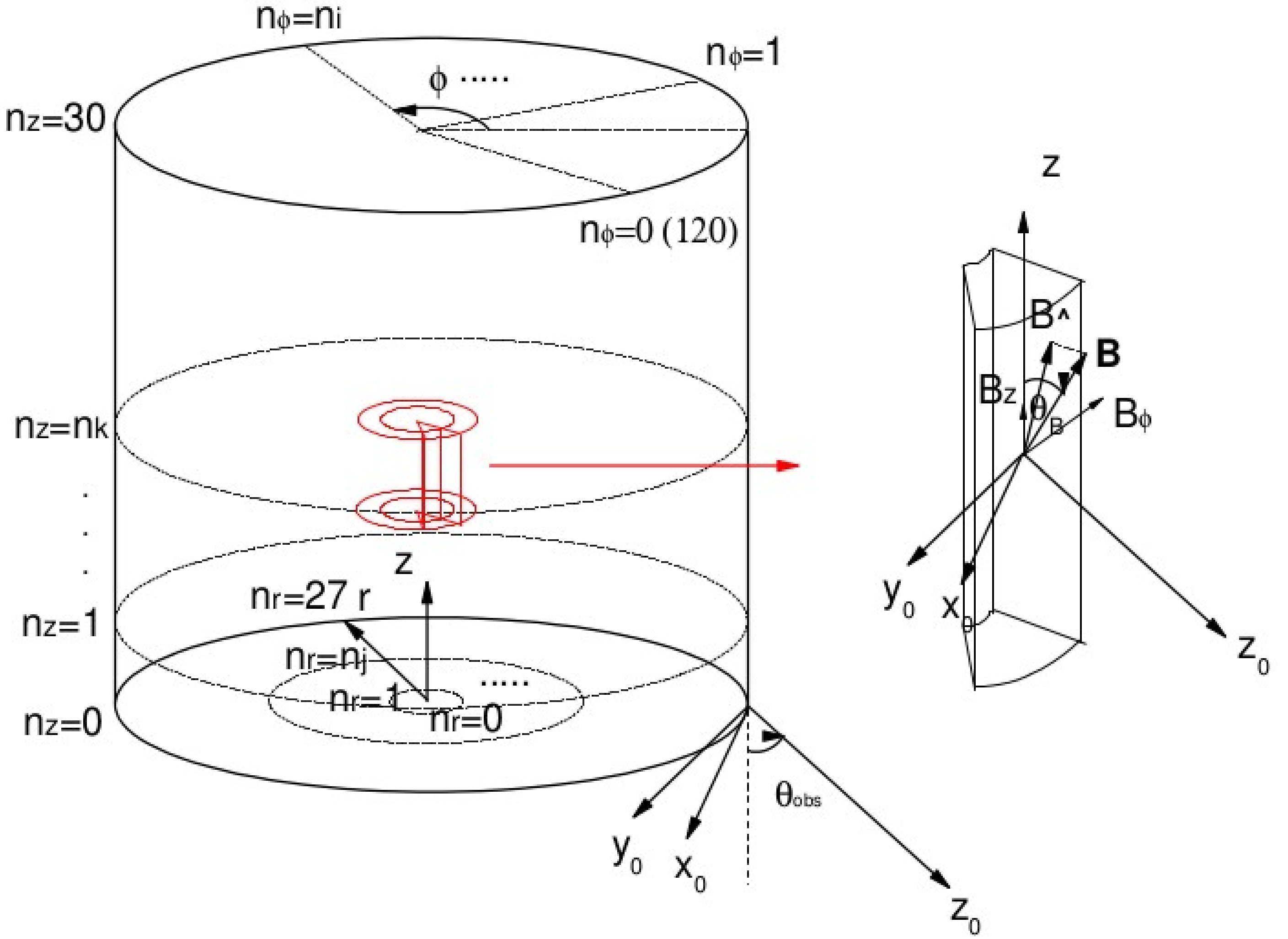
Outline

- Introduction
- Model setup with helical B
- Modeling results with polarization
- Discussion

Geometry of our cylindrical jet model



Geometry for the polarization calculation

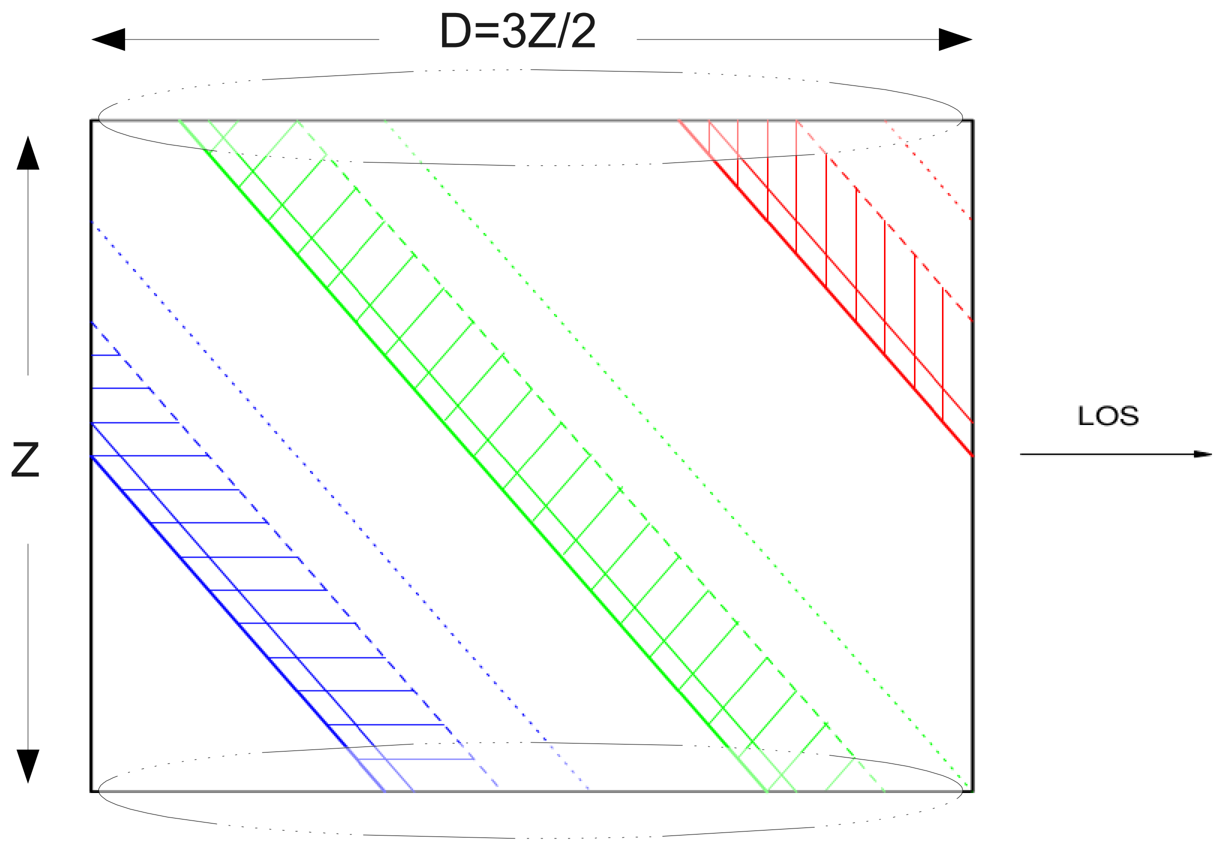


Stokes Parameters

Stokes parameter		Photon observation		Particle observation
I		Intensity		Intensity
P_1	+1, −1	Plane polarization	+1, −1	Spin in z direction
P_2	+1, −1	Plane polarization at an angle of $\pi/4$ to the right	−1, +1	Spin in x direction
P_3	+1	Left circular polarization	−1 +1	Spin in y direction
	−1	Right circular polarization		

(McMaster 1961)

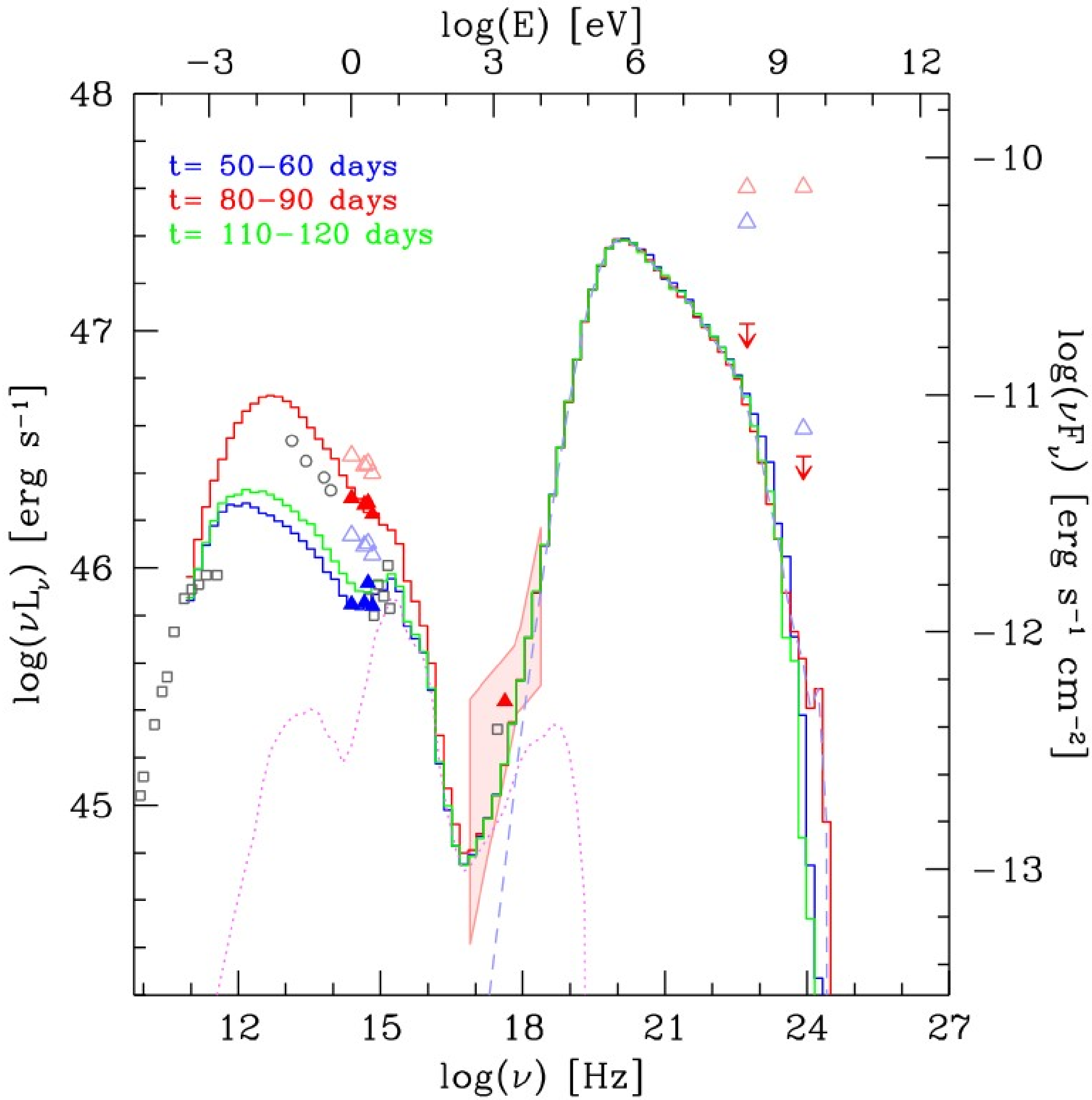
Shock excited regions, deformed by light travel time effect



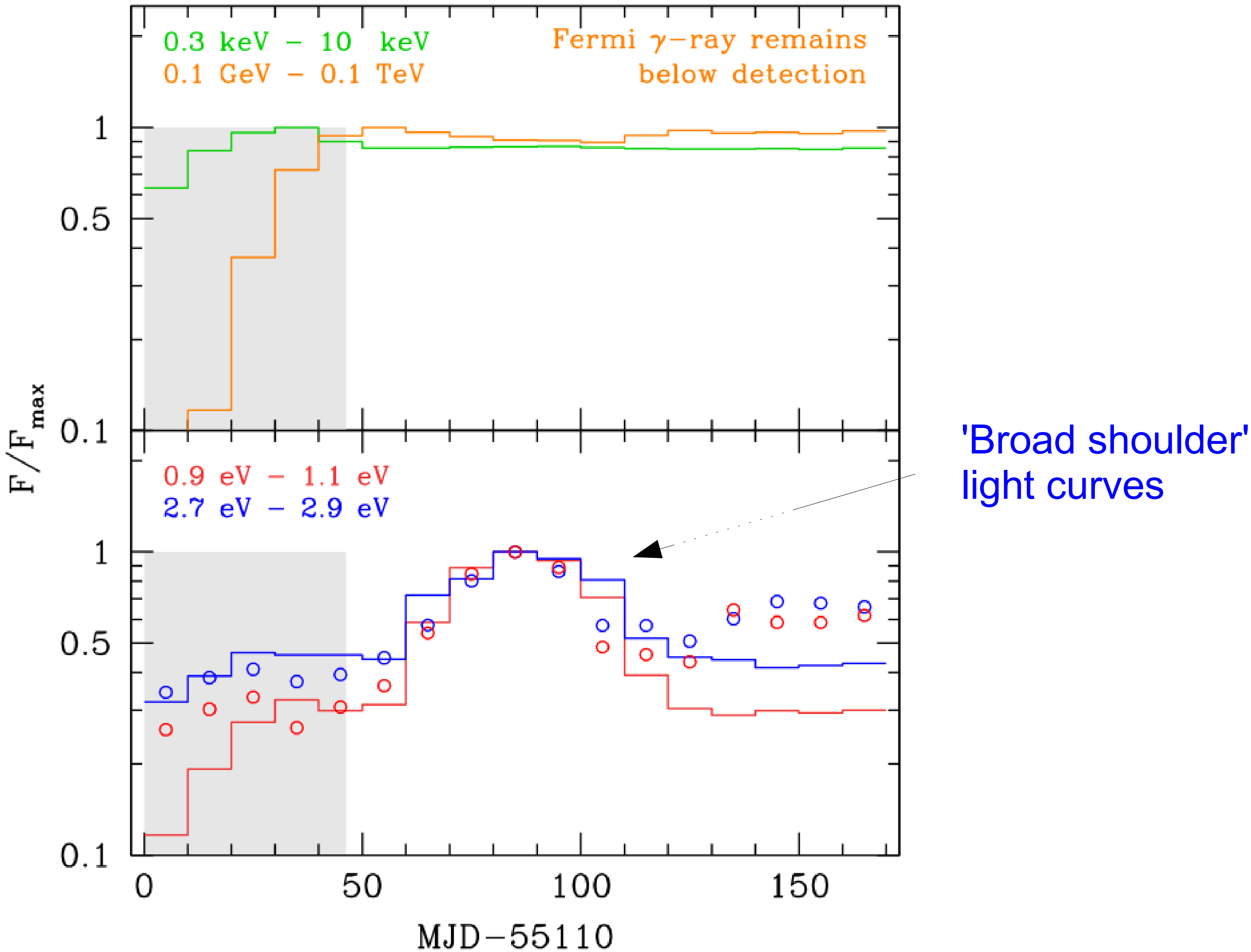
Outline

- Introduction
- Model setup with helical B
- Modeling results with polarization
- Discussion

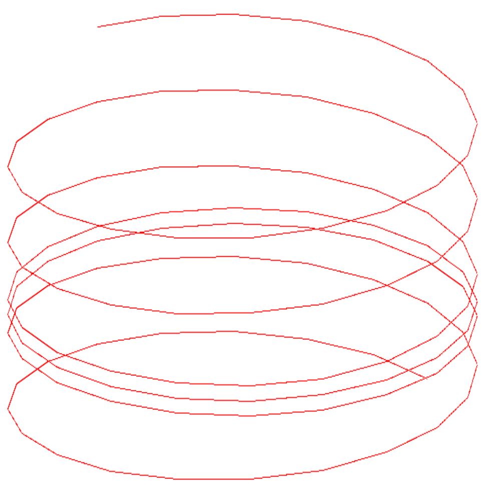
Spectral Energy Distributions (SED)

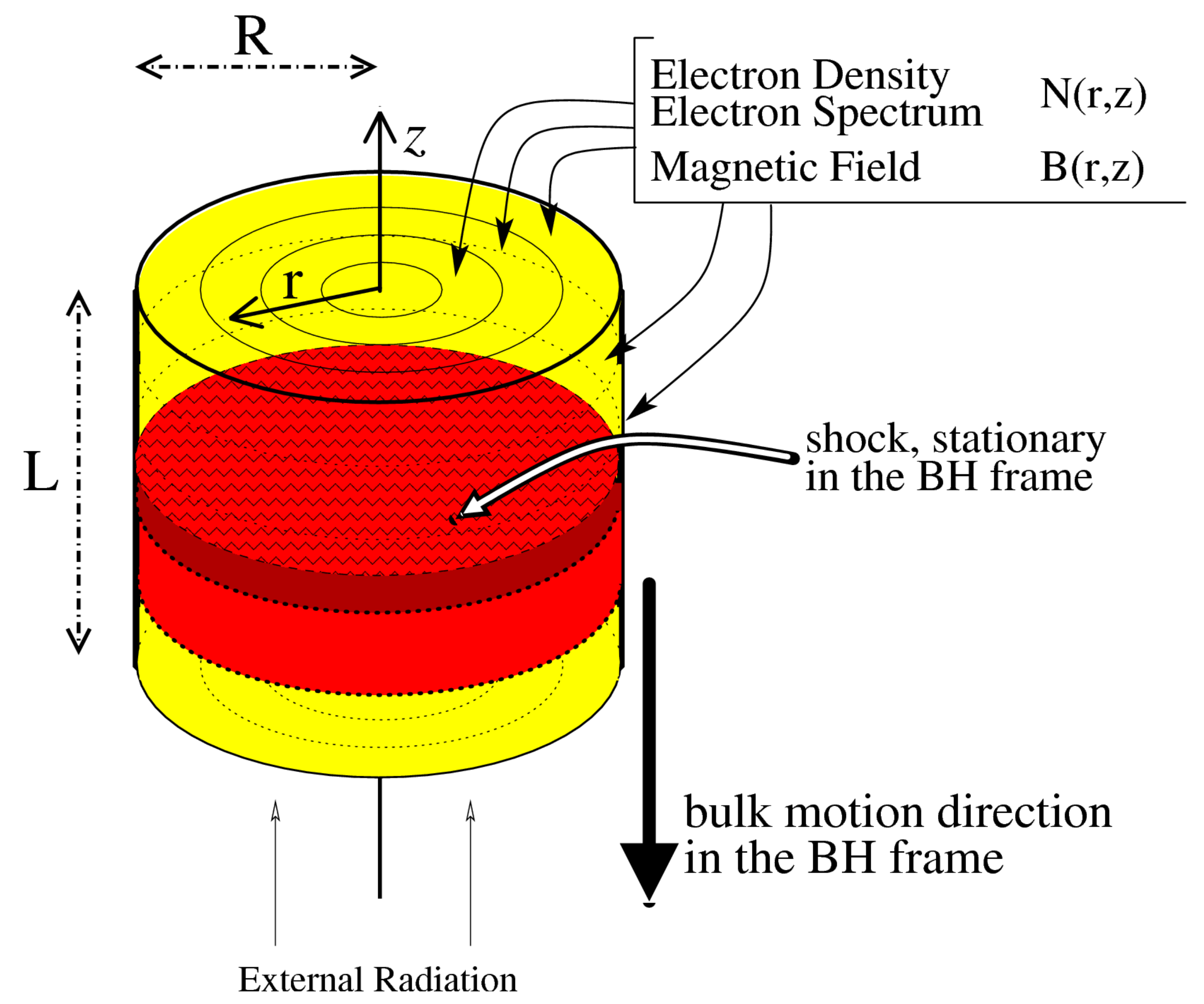


Light curves

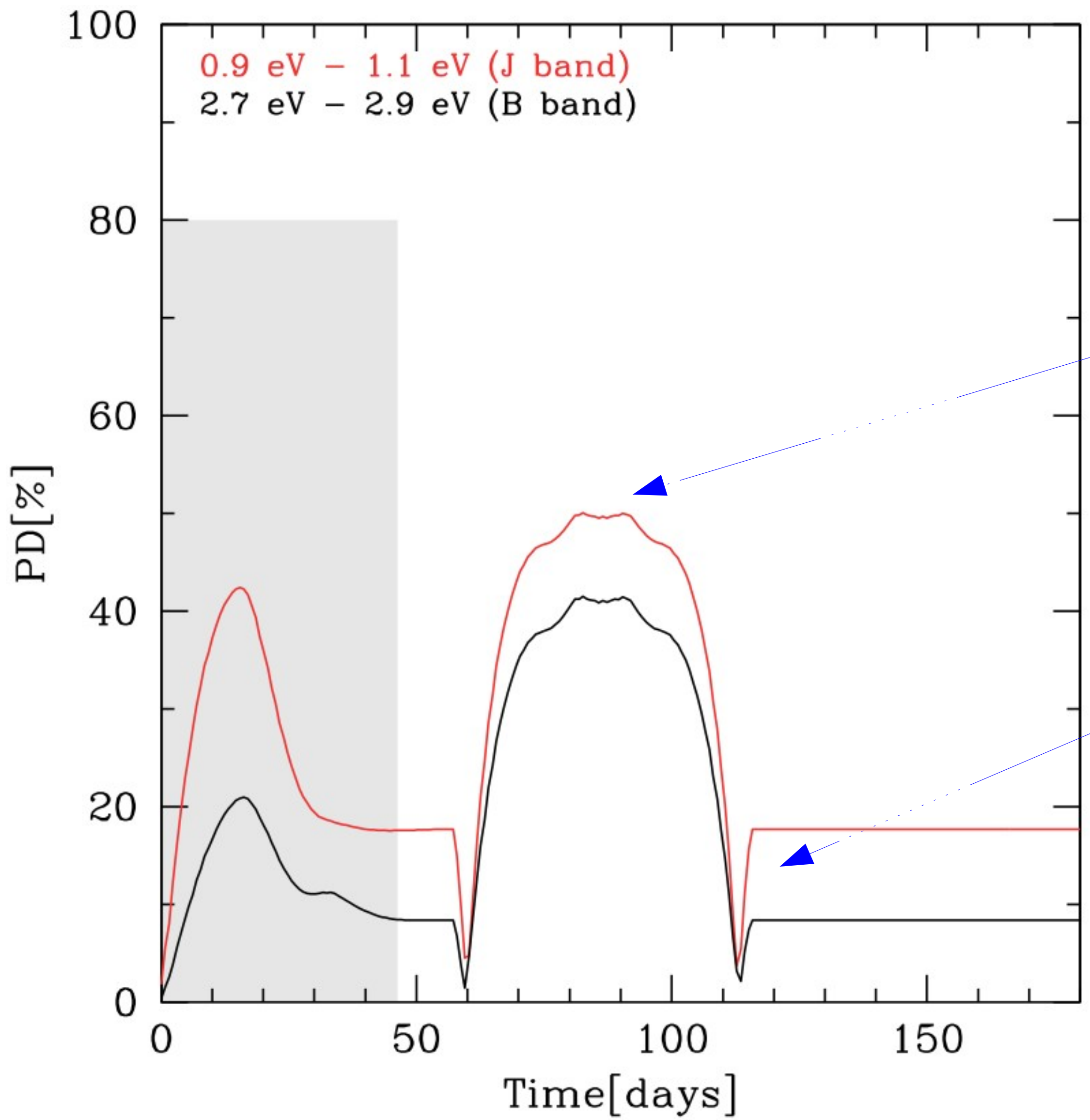


Geometry of our cylindrical jet model





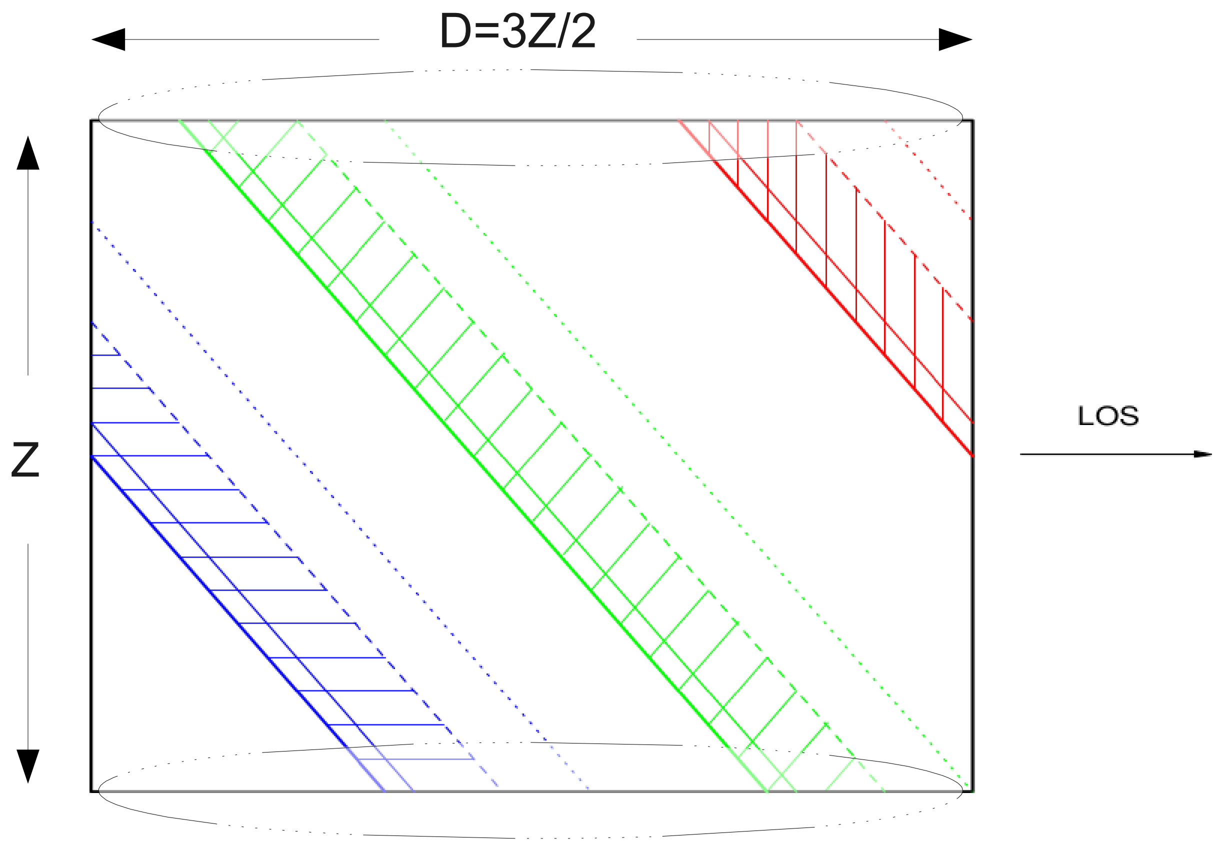
Polarization Degree Change



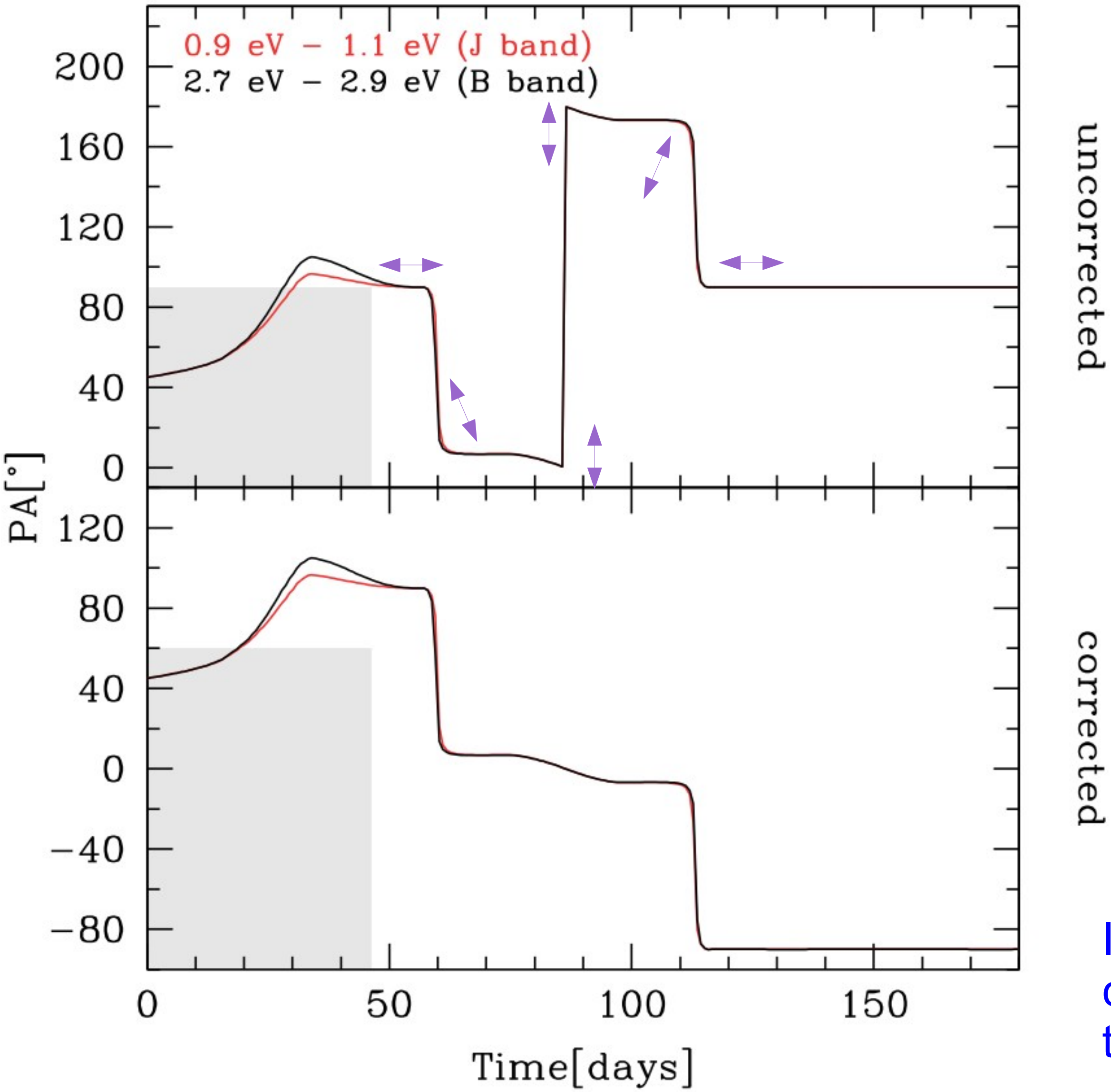
Small dip during the peak of flare

Polarization decrease, anti-correlates with flux increase

Shock excited regions, deformed by light travel time effect



Polarization Position Angle (PA) Swing



PA between 0°-180°

Consecutive PA change <90°

In a single flare, the corrected PA appears to rotate by 180°

Outline

- Introduction
- Model setup with helical B
- Modeling results with polarization
- Discussion

Summary

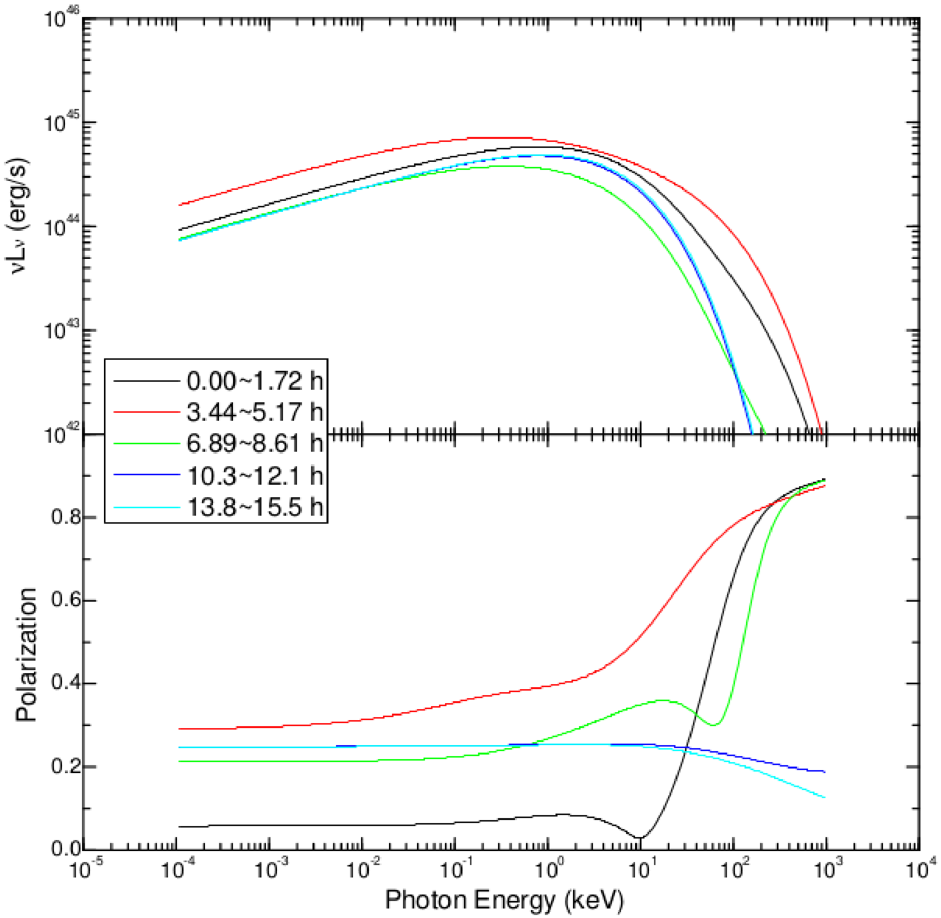
- Polarization correlates with flux in a complicated way.
- Helical magnetic field combined with light travel time effects can explain the apparent rotation of polarization angles.

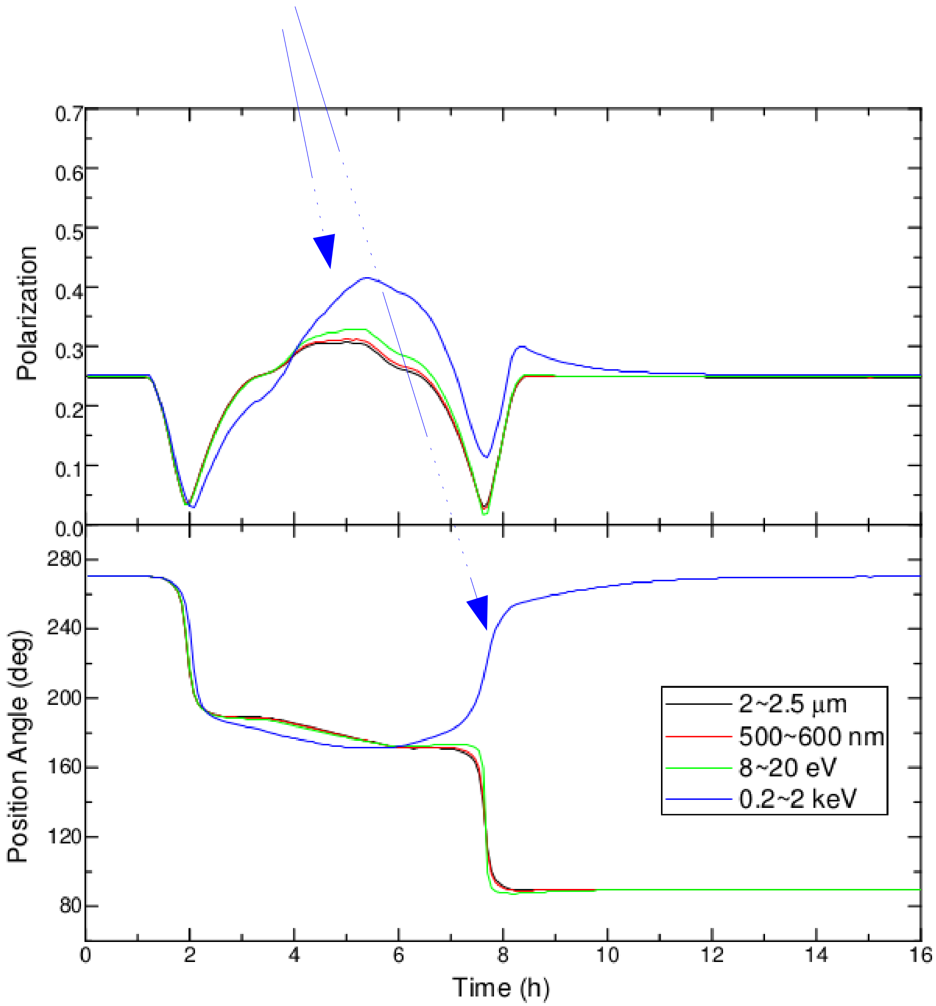
Future work

- Couple the radiation modeling with MHD simulation
- Calculate time dependent inverse Compton polarization
- Compare the particle acceleration from PIC simulation and FP equation
- Study the effect of conical shock geometry

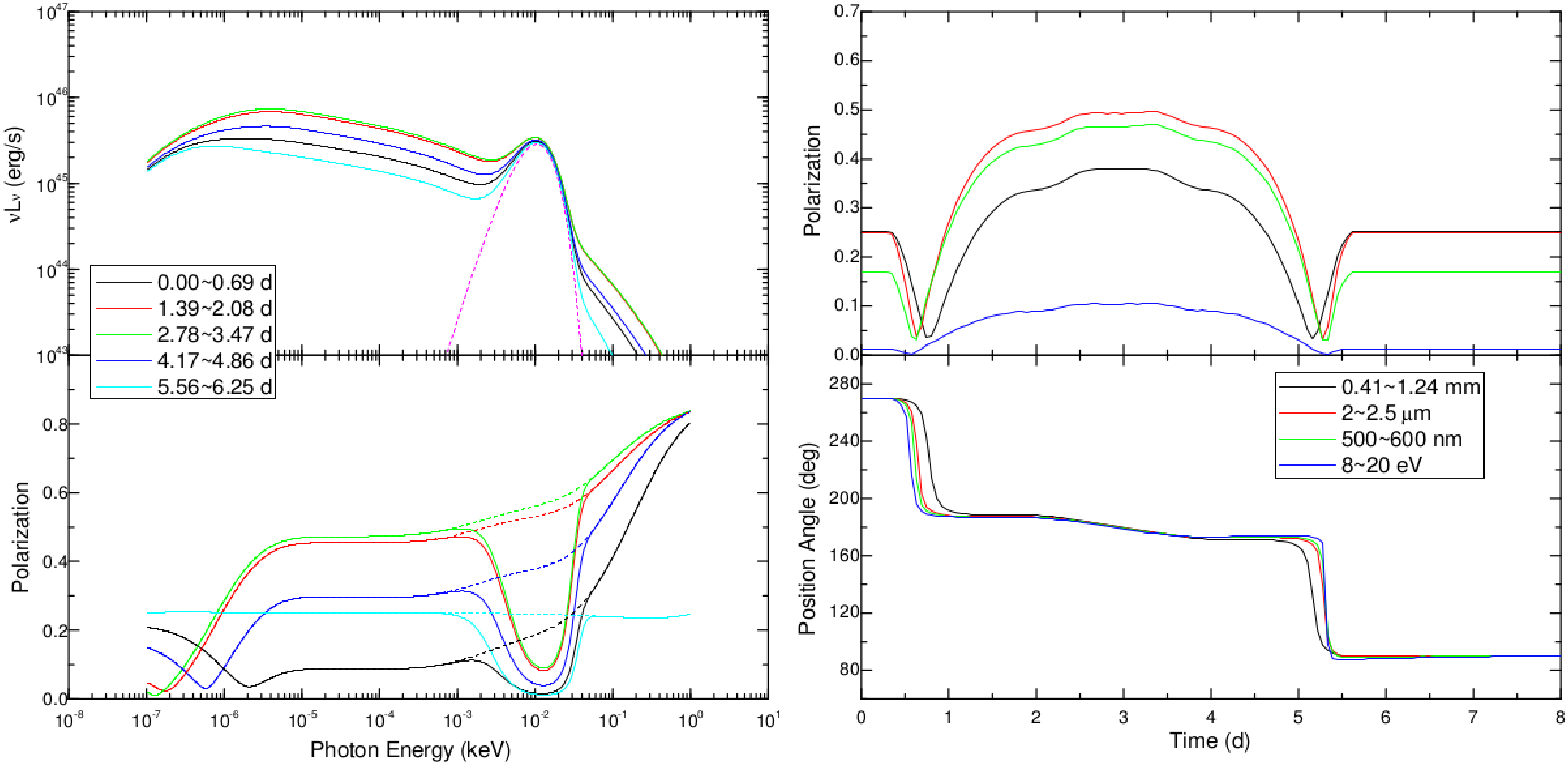
Mrk 421 Polarization (Synchrotron Self-Compton)

Different behavior of the X-ray polarization

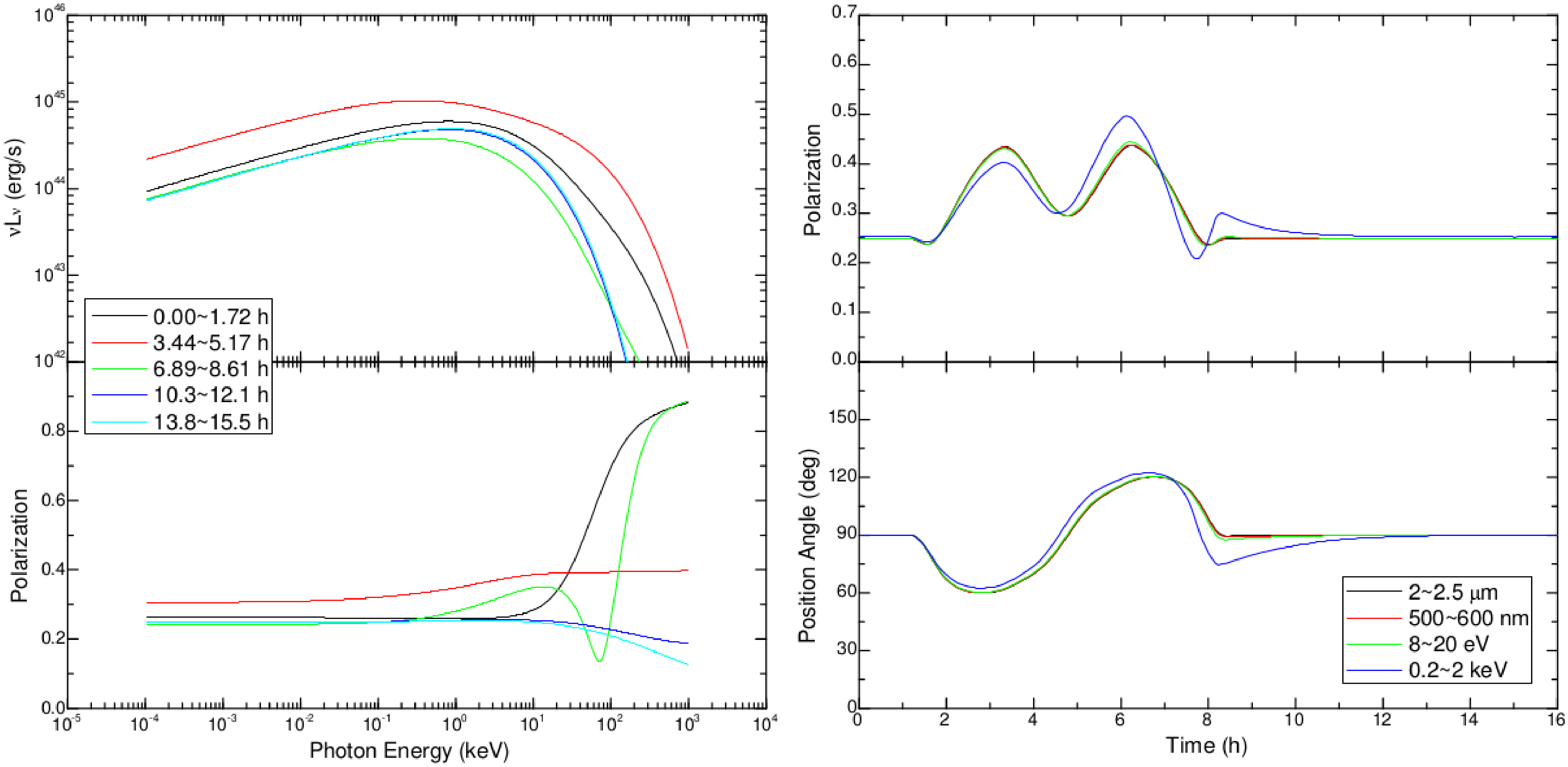




PKS 1510-089 Polarization (External Compton)



Mrk 421 Polarization, change B strength only



PKS 1510-089 Polarization, change B strength only