

Angle-dependent Synchrotron and SSC Polarization from Ordered Magnetic Fields in Blazar Jets

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Why polarization?

- The geometry of the B-field governs the acceleration and radiation of the particles.
- SEDs alone cannot uniquely determine B-field orientation.
- Polarization provides an additional observable to probe the B-field geometry inside relativistic jets.
- Goal: Explore the effects of B-field orientations on synchrotron and SSC polarization.

One-zone Leptonic Model

- Power-law electrons

$$n_e(\gamma) = n_0 \gamma^{-P}, (\gamma_1 \leq \gamma \leq \gamma_2) \quad (1)$$

- Synchrotron emission (Rybicki & Lightman, 1979):

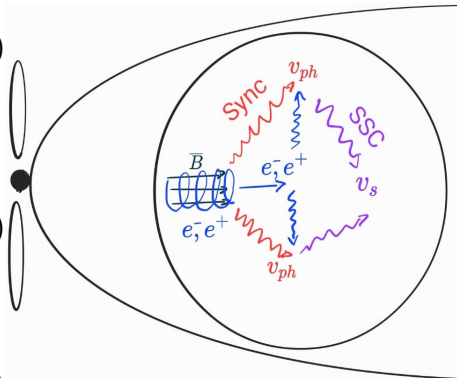
$$j_\nu^{\text{syn}} \propto B \sin \varphi \int n_e(\gamma) F(x) d\gamma \quad (2)$$

- Synchrotron photons:

$$n_{\text{ph}} \propto \frac{j_\nu^{\text{syn}}}{h\nu} \quad (3)$$

- SSC emission (Böttcher et al., 2012):

$$j_\nu^{\text{SSC}} \propto \int_1^\infty n_e(\gamma) d\gamma \int_{-1}^1 d\eta_{\text{ph}} \int_0^{2\pi} d\phi_{\text{ph}} \int_0^\infty n_{\text{ph}}(\nu) (1 - \beta\mu) \frac{d\sigma_C}{d\epsilon_s} d\nu. \quad (4)$$

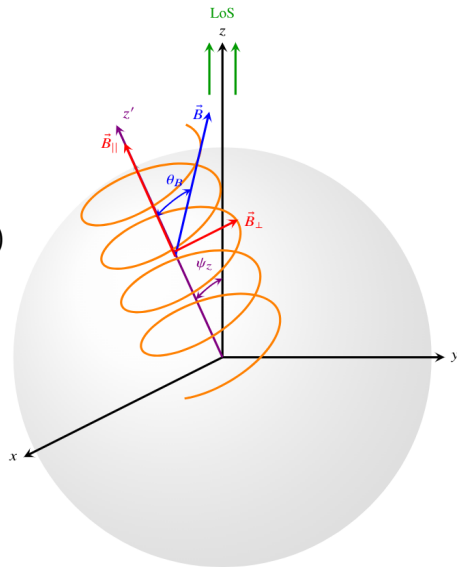


Helical Magnetic-Field Geometry

$$\hat{\mathbf{B}}_{\text{hel}} = \sin \theta_B \frac{\hat{\mathbf{z}}' \times \hat{\mathbf{r}}_{\text{syn}}}{|\hat{\mathbf{z}}' \times \hat{\mathbf{r}}_{\text{syn}}|} + \cos \theta_B \hat{\mathbf{z}}', \quad (5)$$

where, $\tan \theta_B = B_{\text{tor}}/B_{\text{pol}}$.

- $\theta_B = 0^\circ$: purely poloidal.
- $\theta_B = 45^\circ$: equal poloidal and toroidal components.
- $\theta_B = 90^\circ$: purely toroidal.



Stokes Formalism

- Polarized synchrotron radiation field (e.g., [Rybicki & Lightman, 1979](#)):

$$\mathbf{j}_\nu^{\text{syn}} = \begin{pmatrix} j_I^{\text{syn}}(\nu, \varphi) \\ j_Q^{\text{syn}}(\nu, \varphi) \\ j_U^{\text{syn}}(\nu, \varphi) \end{pmatrix} \propto B \sin \varphi \begin{pmatrix} \langle F(x) \rangle \\ \langle G(x) \rangle \cos 2\chi \\ \langle G(x) \rangle \sin 2\chi \end{pmatrix} \quad (6)$$

- Polarized SSC radiation field (e.g., [Nagirner & Poutanen, 1993](#)):

$$\mathbf{j}_\nu^{\text{SSC}} \propto \int n_e(\gamma) d\gamma \int d\nu (1 - \beta\mu) \frac{d\sigma_c}{d\epsilon_s} [\bar{\mathbf{R}}(-\theta_2) \cdot \bar{\mathbf{M}}(\mu') \cdot \bar{\mathbf{R}}(\theta_1) \cdot \mathbf{n}_{\text{ph}}] \quad (7)$$

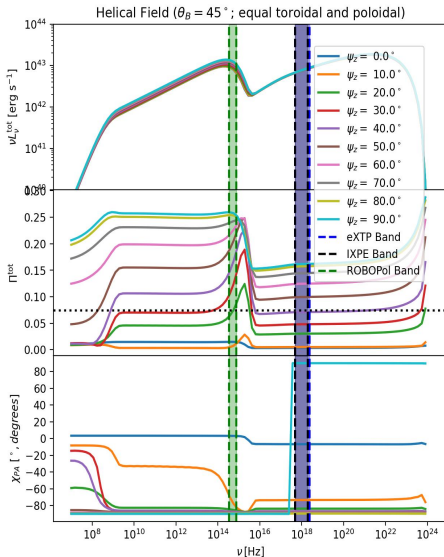
- Stokes Luminosities: $\mathbf{L}_\nu = \int \mathbf{j}_\nu dV$ (8)

- Linear polarization degree and angle:

$$\Pi_\nu = \frac{\sqrt{(L_Q^{\text{tot}})^2 + (L_U^{\text{tot}})^2}}{L_I^{\text{tot}}}, \quad \chi_{\text{PA}} = \frac{1}{2} \text{atan2}(L_U^{\text{tot}}, L_Q^{\text{tot}}) \quad (9)$$

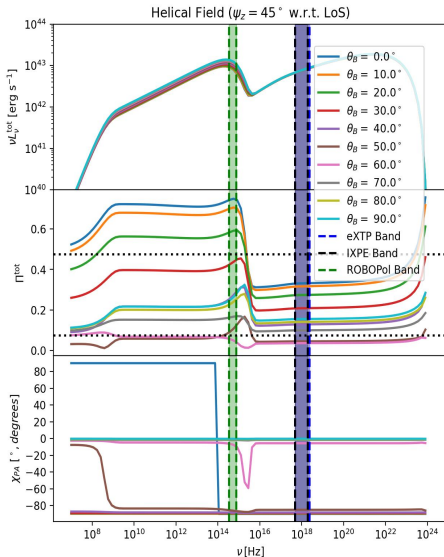
Fixed $\theta_B = 45^\circ$: vary the viewing angle

- Fixed: $\theta_B = 45^\circ$
- Vary: $\psi_z \in \{0^\circ, 10^\circ, \dots, 90^\circ\}$
- The spectrum is relatively the same.
- PD is strongly viewing-angle dependent.
- EVPA also carries geometric information.



Fixed $\psi_z = 45^\circ$: vary the field pitch angle

- Fixed: $\psi_z = 45^\circ$.
- Vary: $\theta_B \in \{0^\circ, 10^\circ, \dots, 90^\circ\}$
- Very similar SEDs.
- Dramatically different PD.
- Polarization breaks spectral degeneracy.



Summary and Outlook

- Developed an angle- and polarization-dependent leptonic blazar model.
- Similar SEDs can produce very different polarization signatures.
- Polarization signatures constrain both magnetic field and viewing geometry.
- Next stage:
 - Synchrotron Self-Absorption
 - $\gamma\gamma$ absorption
 - Comparison with polarimetric observations

