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A Geometric Current Sheet Model for Dual-band Pulsar Light Curve Fitting

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1. Introduction

- The *Fermi* Large Area Telescope (LAT) Third Pulsar Catalog (3PC; Smith et al. 2023) contains light curves and spectra of nearly 300 pulsars, along with some interesting correlations between timing and spectral parameters, prompting further theoretical improvements.
- Traditional TPC / OG geometric models (Romani 1996; Dyks *et al.* 2003; Venter *et al.* 2009) locate emission regions inside the light cylinder.
- Global particle-in-cell (PIC) and magneto-hydrodynamic (MHD) models point to dominant dissipation in the current sheet regions beyond the light cylinder (Brambilla *et al.* 2015, 2018; Cerutti *et al.* 2016; Kalapotharakos *et al.* 2018; Philippov *et al.* 2015, 2018).
- We propose a geometric current sheet (CS) model as an interim measure.

Abstract

The launch of the *Fermi* Large Area Telescope (LAT) prompted renewed model development for high-energy pulsars. Such models typically focus on different physical regimes (e.g., global current flow, magnetic structure, pair creation microphysics, or emission and beaming). Magnetohydrodynamic (MHD) and particle-in-cell (PIC) models each have their respective strengths but are often computationally expensive to cover a suitably large parameter space. As a practical interim step, we are exploring a geometric current sheet model that focuses on the beaming geometry rather than pulsar energetics. This allows us to constrain the magnetospheric viewing geometry by fitting the dual-band light curves of several pulsars. We will present first results from this model compared to those of traditional models.

4. Discussion / Conclusions

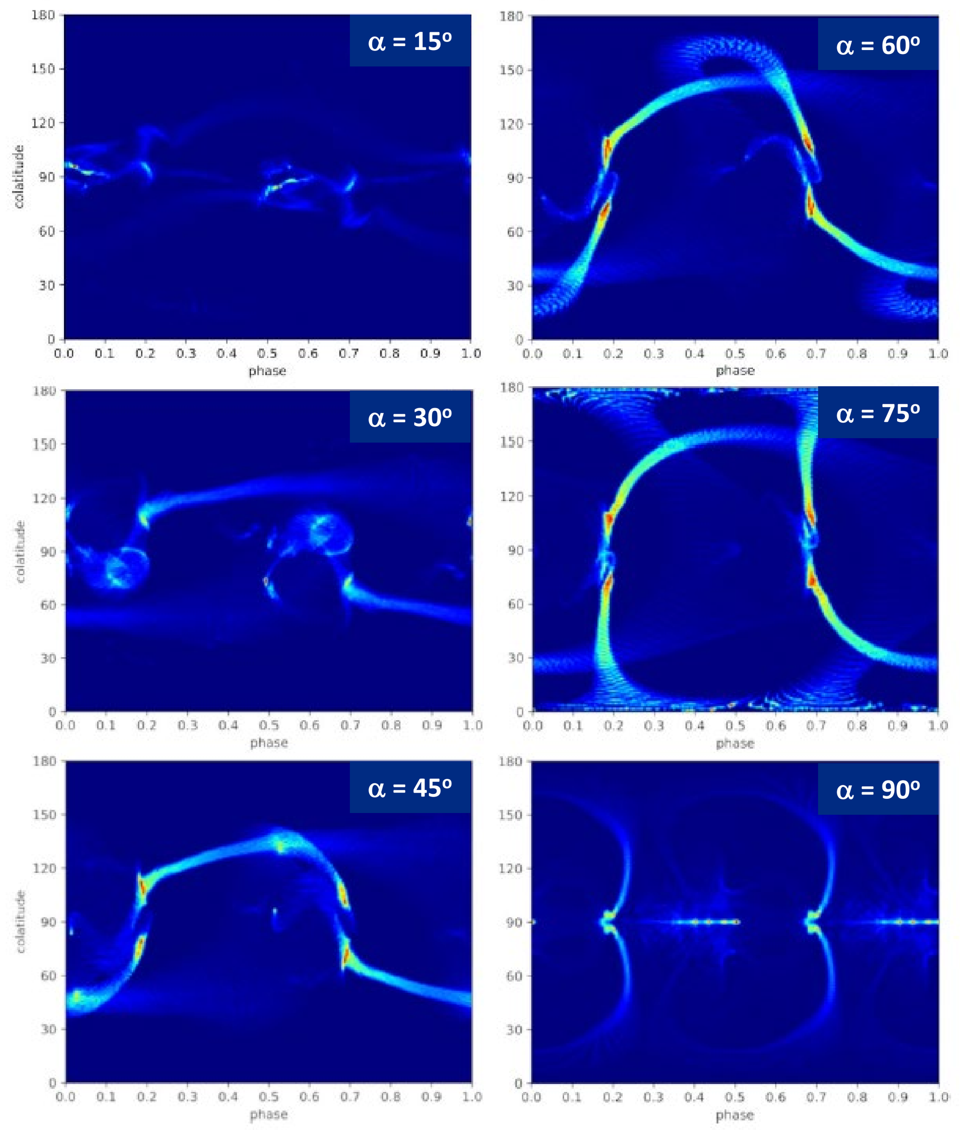
- The availability of high-quality data on a sizable high-energy pulsar population provides impetus for theorists to construct an overarching theoretical framework to explain the phenomenology.
- Our geometric CS model, combined with a low-altitude conal radio model, provides computationally-inexpensive light curve calculations that may facilitate a test of the generic emission geometry across the pulsar population.
- This implies the possibility of a comprehensive search of geometric parameter space in the interim period before machine learning techniques will yield surrogate models of computationally-expensive emission approaches.

2. Model: Building a Bridge

Older Geometric Models	Geometric CS Model	Emission Models
• Analytic retarded-vacuum-dipole (RVD) B-field (Deutsch 1955).	• Numerical force-free (FF) B-field	• Numerical FF B-field
• Calculations in co-rotating frame	• Calculations in lab frame	• Calculations in lab frame
• Up to 1 R_{LC}	• Beyond 1 R_{LC}	• Beyond 1 R_{LC}
• No emission physics	• No emission physics	• Emission physics (spectra) Beaming effects
• Lorentz transformation to lab frame	• Beaming effects	

3. Results

Figure 1: Phaseplots from the geometric CS model, with α indicated in the top right corner.



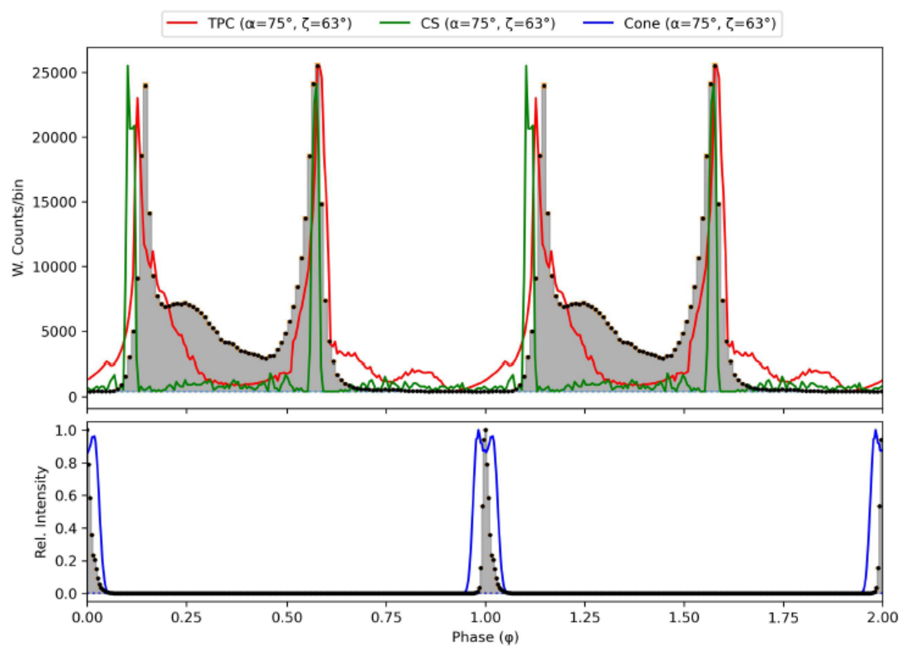


Figure 2: Example by-eye fits of radio and gamma-ray light curves for the Vela pulsar.

References

Brambilla, G., Kalapotharakos, C., Harding, A.K., & Kazanas, D. 2015, Testing Dissipative Magnetosphere Model Light Curves and Spectra with *Fermi* Pulsars, ApJ, 804, 84.
Brambilla, G., Kalapotharakos, C., Timokhin, A.N., Harding, A.K., & Kazanas, D. 2018, Electron-Positron Pair Flow and Current Composition in the Pulsar Magnetosphere, ApJ, 858, 81.
Cerutti, B., Philippov, A.A., & Spitkovsky, A. 2016, Modelling High-energy Pulsar Light Curves from First Principles, MNRAS, 457, 2401.
Cerutti, B., Philippov, A.A., & Dubus, G. 2020, Dissipation of the Striped Pulsar Wind and Non-thermal Particle Acceleration: 3D PIC Simulations, A&A, 642, A204.
Deutsch, A.J. 1955, The Electromagnetic Field of an Idealized Star in Rigid Rotation in Vacuo, Annales d'Astrophysique 18 (1955) 1.
Dyks, J. & Rudak, B. 2003, Two-Pole Caustic Model for High-Energy Light Curves of Pulsars, ApJ, 598, 1201.
Kalapotharakos, C., Brambilla, G., Timokhin, A.N., Harding, A.K., & Kazanas, D. 2018, Three-dimensional Kinetic Pulsar Magnetosphere Models: Connecting to Gamma-Ray Observations, ApJ, 857, 44.
Philippov, A.A., Spitkovsky, A., & Cerutti, B. 2015, Ab Initio Pulsar Magnetosphere: Three-dimensional Particle-in-cell Simulations of Oblique Pulsars, ApJL, 801, L19.
Philippov, A.A., & Spitkovsky, A. 2018, *Ab initio* Pulsar Magnetosphere: Particle Acceleration in Oblique Rotators and High-energy Emission Modeling, ApJ, 855, 94.
Romani, R.W. 1996, Gamma-ray Pulsars: Radiation Processes in the Outer Magnetosphere, ApJ, 470, 469.
Smith, D.A., Abdollahi, S., Ajello, M. *et al.*, 2023, The Third *Fermi* Large Area Telescope Catalog of Gamma-Ray Pulsars, ApJ, 958, 191.
Venter, C., Harding, A.K., & Guillemot, L., 2009, Probing Millisecond Pulsar Emission Geometry Using Light Curves from the *Fermi*/Large Area Telescope, ApJ, 707, 800.