The Accelerating Electric Field in Gamma Ray Pulsar Magnetospheric Gaps

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Introduction: Model-dependent Calculation of $E_{||}$

- Gamma-ray emission from pulsars is thought to originate in magnetospheric gaps where particles are accelerated.
- Our goal: Calculate the magnitude of the accelerating parallel electric field
- We assume
  - Slot gap or outer gap model predicts the light curve shape; inherent assumptions of B field, emissivity
  - Pure curvature radiation above 100 MeV

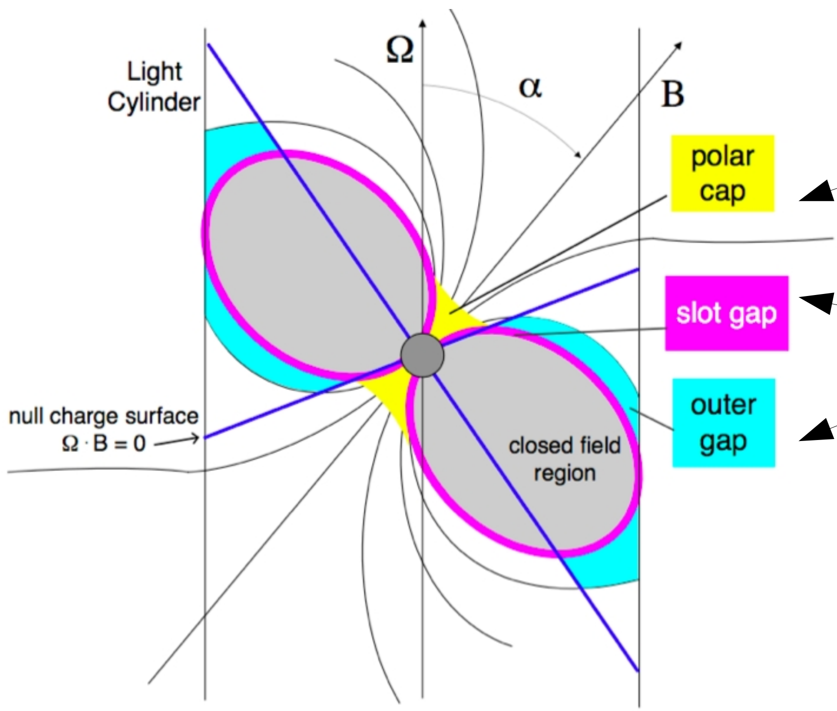
Obtaining $E_{||}$

- In curvature radiation (CR) reaction, accelerating E field related to cutoff energy and radius of curvature by

$$E_{\rm cut}^{\rm CR}/mc^2 = \frac{3}{2}\gamma_{\rm CR}^3 \frac{\lambda_{\rm C}}{\rho_{\rm c}} = 0.32\lambda_{\rm C}\left(\frac{E_{||}}{e}\right)^{3/4} \rho_{\rm c}^{1/2}$$

- So, we need E_c and ρ
  - E_c from phase resolved spectral analysis of gamma-ray pulsars
  - ρ from best fit model light curve

Pulsar Emission Models



Harding (2005)

Low-altitude acceleration and emission

High-altitude, outer magnetospheric acceleration and emission

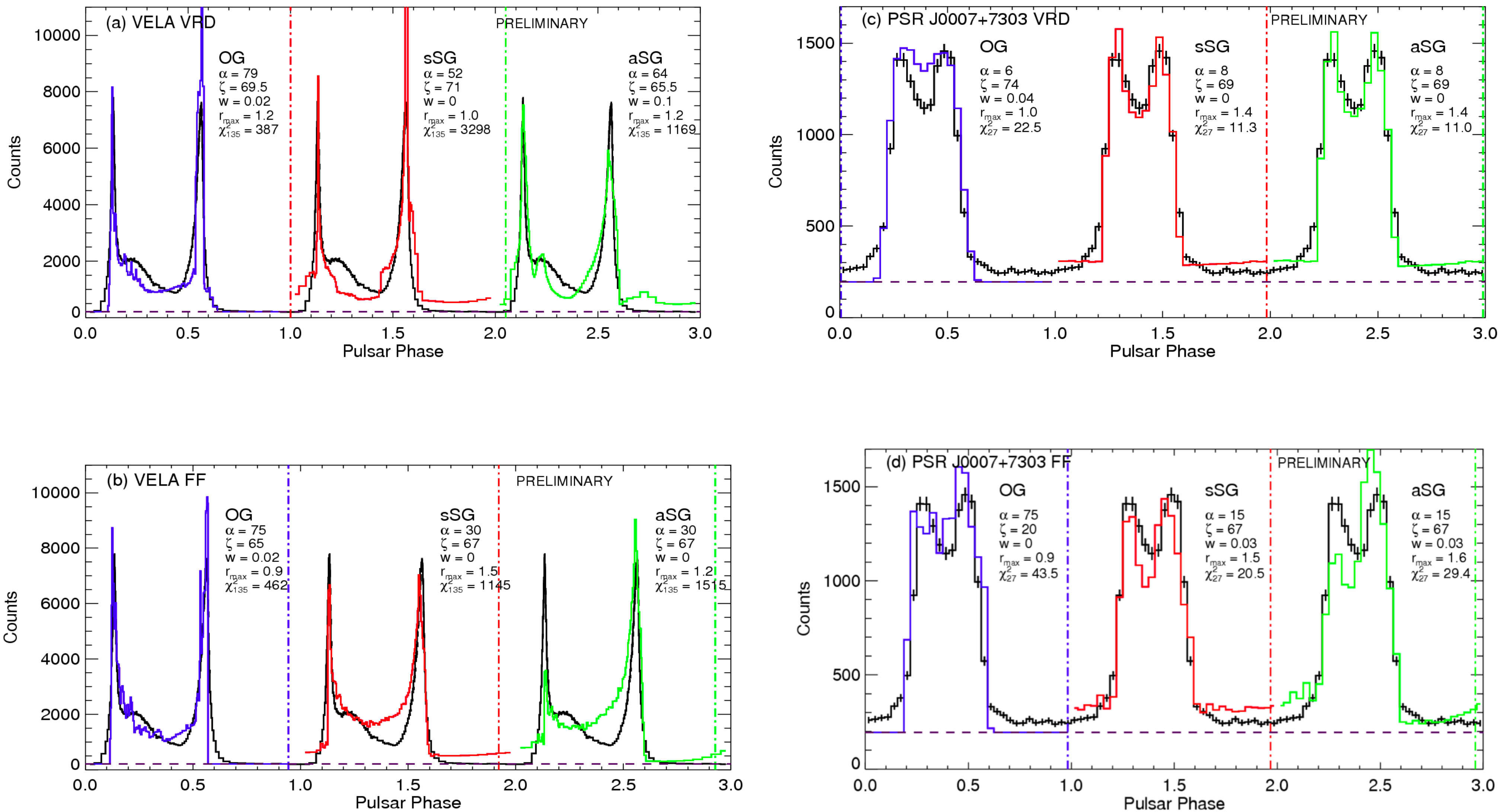
Slot Gap (Muslimov & Harding 2004)

- Symmetric, asymmetric cases (Harding & Muslimov 2011)

Outer Gap (Romani & Yadigaroglu 2005)

- Simulate light curves with above emission models, in vacuum and force-free B fields
- Use Markov chain Monte Carlo maximum likelihood method to find best fit light curve parameters.
- Parameters: $\alpha, \zeta, w, r_{max}, s$
- Output: Light curve, emission radii, radii of curvature, |B| in each phase bin

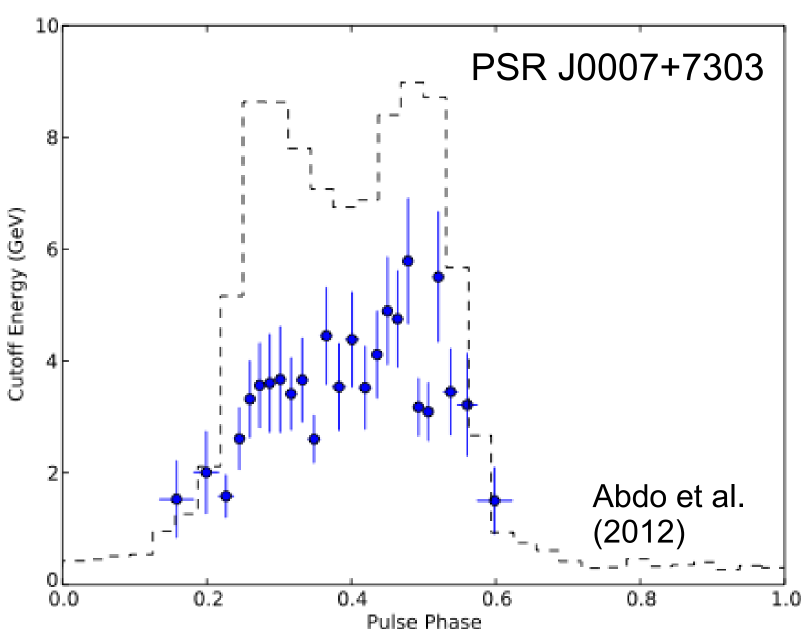
Light Curve Fits

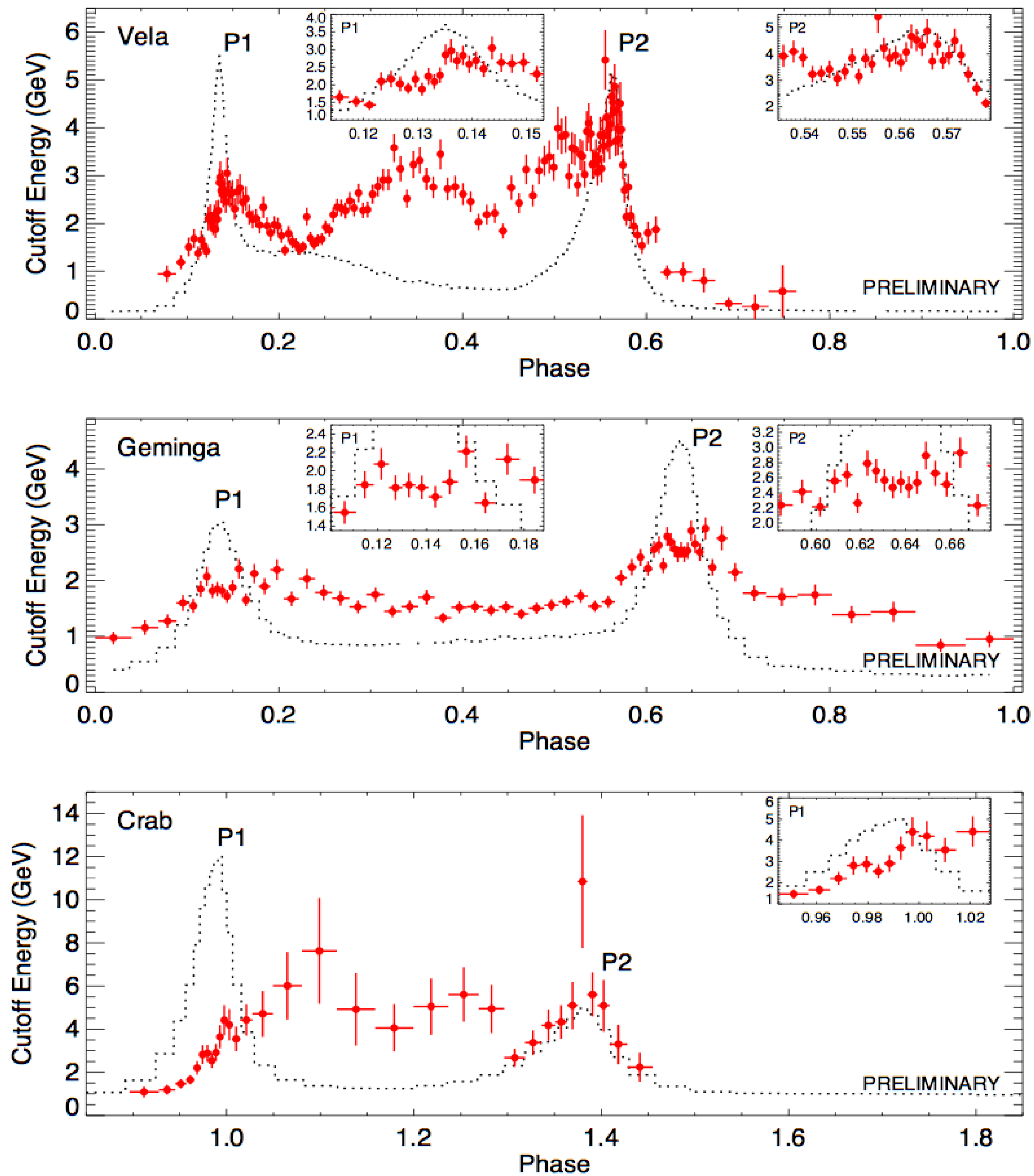


Cutoff Energies

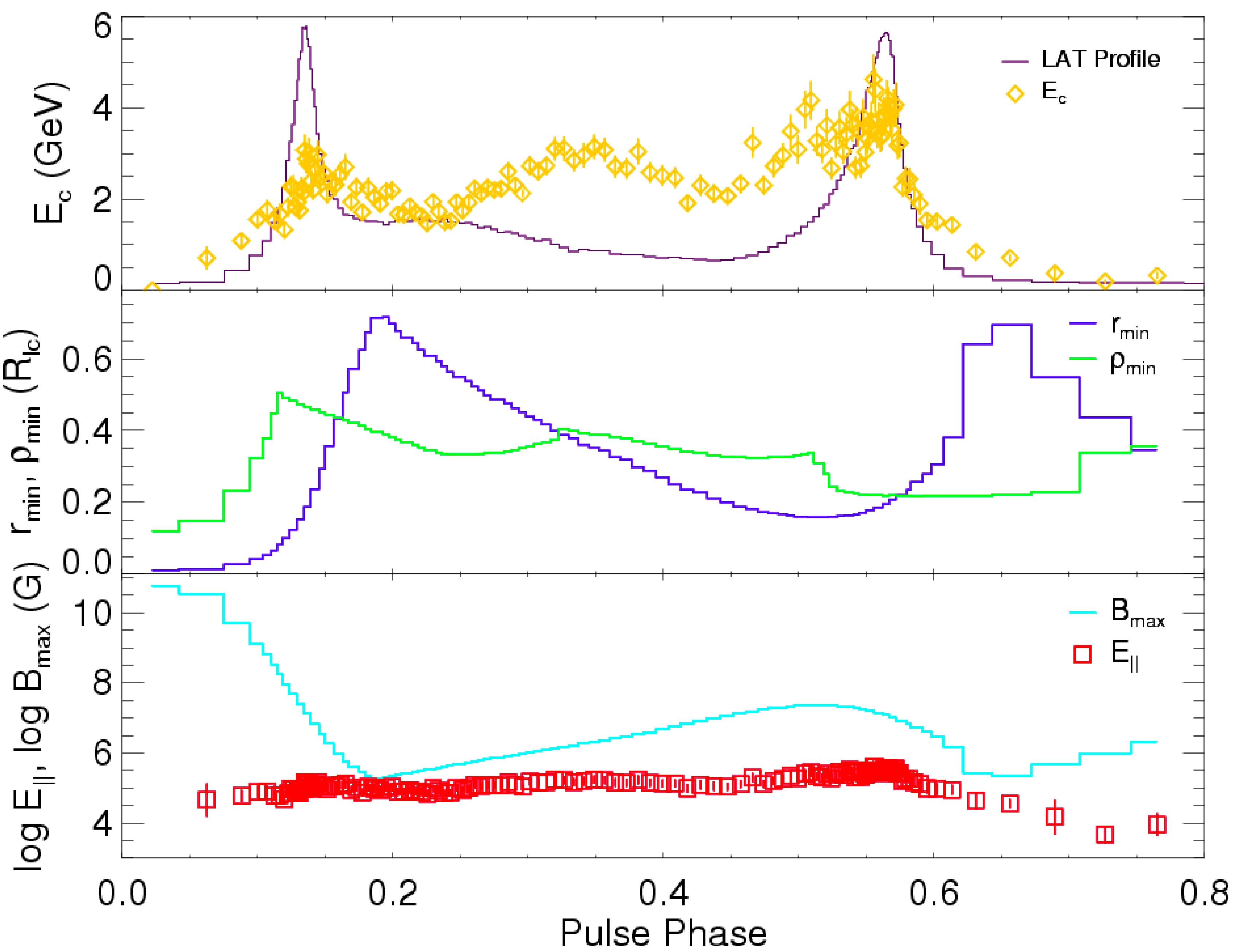
- Divide light curve into fixed count phase bins of 3000 counts/bin
- Fit exponentially cut-off power law in each phase bin

$$\frac{dN}{dE} = N_0 \left(\frac{E}{E_0}\right)^{-a} \exp\left[-\left(\frac{E}{E_c}\right)^{b}\right]$$

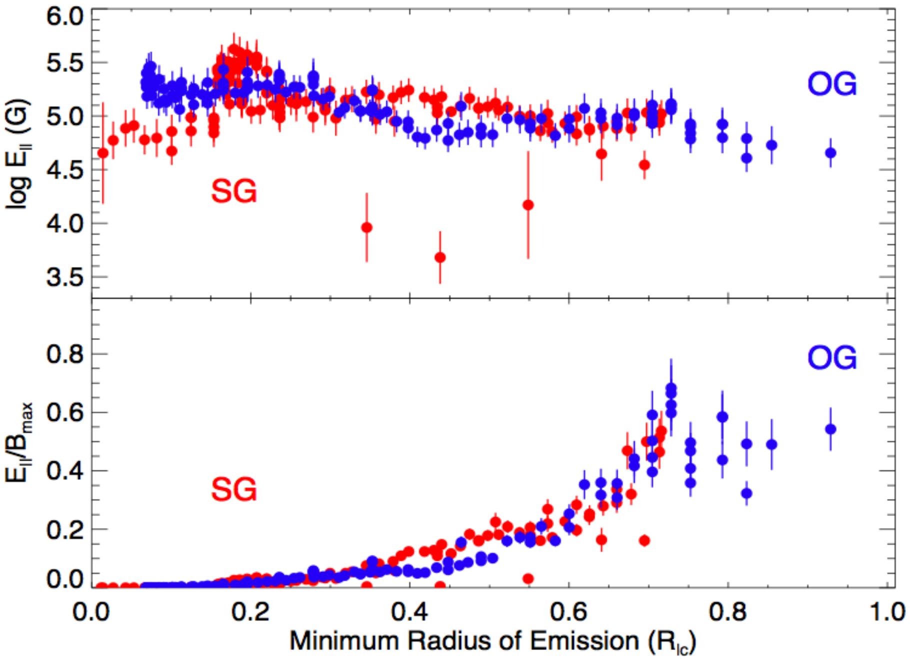




Vela Phase Resolved Results

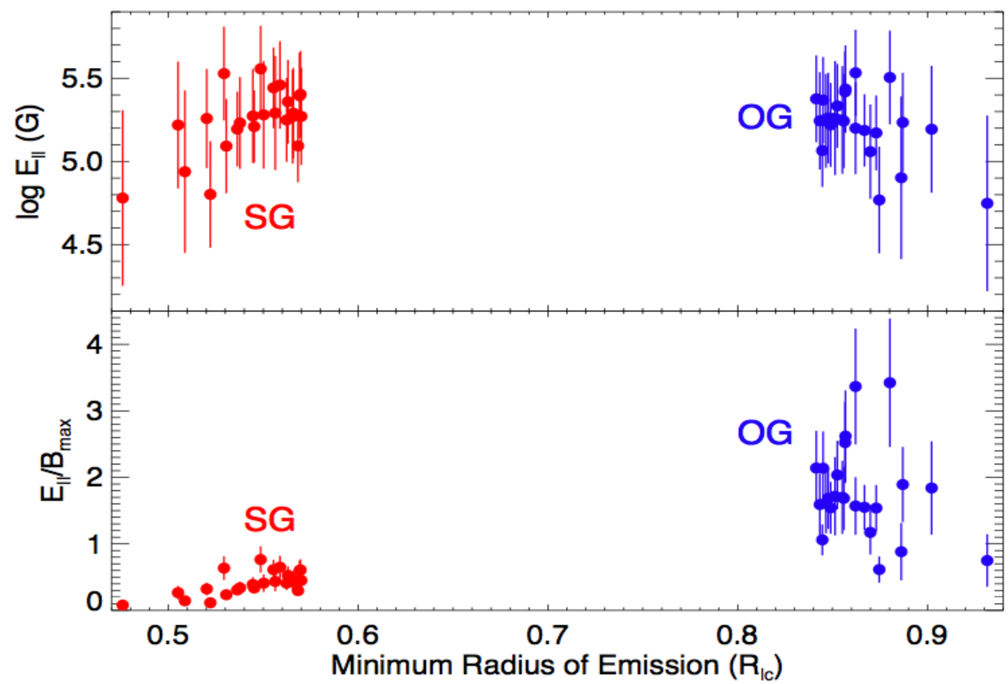


Results: $E_{||}$ with Emission Radius



Vela, vacuum case

PSR J0007+7303, vacuum case



Conclusions

- The FF model has too large of a lag between radio and γ-ray peaks, so the vacuum retarded dipole is favored thus far.
- At this time, we cannot conclusively rule out OG or SG from light curve fits.
- Asymmetry in $E_{||}$ reduces off-peak emission, improving SG fits.
- $E_{||}$ is calculated from E_c and simulated ρ_c, and may be an additional way to compare models.
- $E_{||}$~constant with emission radius
- In some cases, $E_{||} > B_{max}$. This may be a way to additionally constrain/compare/rule out emission models.

Backup Slides

Conclusions

- Outer gap better fits off-peak emission
- Slot gap better reproduces wings of profiles
- Slot gap consistently has too high off-peak emission
- Slot gap peak/off-peak emission increases with larger r_{max} – important to go to very high altitudes to better reproduce light curves
- Force-free B produces too great a lag between radio and γ-ray peaks – vacuum field fits light curves better

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- $E_{\parallel}$ is calculated from E_c and simulated ρ_c, and may be an additional way to compare models.