

# Geometric modelling of radio and $\gamma$ -ray light curves of 6 *Fermi* LAT pulsars

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## Abstract

The launch of the Large Area Telescope (LAT), on board the *Fermi* spacecraft, has led to an astounding increase in the number of known  $\gamma$ -ray pulsars. This wealth of new data has generated renewed interest in the field of pulsar astrophysics, with many of the established geometric models for  $\gamma$ -ray emission coming under fresh scrutiny. In this work the outer gap (OG) and two-pole caustic (TPC) geometric  $\gamma$ -ray models are employed alongside a simple empirical radio model to obtain best-fit light curves by eye for six single-peak *Fermi* LAT pulsars first reported by Weltevrede et al. (2010). These best-fit solutions aim to reproduce both the shapes of the radio and  $\gamma$ -ray light curves, and the radio-to- $\gamma$  phase lag. A parameter study of the geometric models is also conducted, and the increased qualitative understanding of these models thus gained is then employed to obtain the best fits possible. The combination of radio and  $\gamma$ -ray models is found to be remarkably powerful in constraining the values of the geometric parameters of the individual pulsars: the inclination and observer angles. Generally the constraints implied by the radio model act perpendicularly to those implied by the  $\gamma$ -ray models, thus yielding smaller solution contours. The constraints on the geometric parameters obtained for the six *Fermi* LAT pulsars in question agree quite well with those obtained by Weltevrede et al. (2010). This agreement is remarkable considering that the approach employed in this study is independent from the one employed by Weltevrede et al. (2010). The errors obtained in this study on the values of the inclination angle for each pulsar are generally smaller than those obtained by Weltevrede et al. (2010). As a secondary result, the value of the flux correction factor, which is a measure of how well the observed  $\gamma$ -ray energy flux of the pulsar correlates with the overall  $\gamma$ -ray energy flux, is constrained for each pulsar.

*Key words:* *Fermi* LAT, pulsars: geometric light curve modelling,  $\gamma$ -rays, individual pulsars: PSR J0631+1036, PSR J0659+1414, PSR J0742–2822, PSR J1420–6048, PSR J1509–5850, PSR J1718–3825.



## Opsomming

Die lansering van die Large Area Telescope (LAT), gehuisves aanboord die *Fermi* ruimtetuig, het gelei tot 'n verstommende toename in die aantal bekende  $\gamma$ -straalpulsare. Hierdie rykdom van nuwe data het gelei tot hernieude belangstelling in pulsarastrofisika, met baie van die gevestigde geometriese  $\gamma$ -straalmodelle wat opnuut bestudeer word. In hierdie studie word die “outer gap” (OG) en “two-pole caustic” (TPC) geometriese modelle sowel as 'n eenvoudige empiriese radiomodel gebruik om beste-passing ligkrommes met die oog vir ses enkel-piek *Fermi* LAT pulsare, oorspronklik deur Weltevrede et al. (2010) aangemeld, te verkry. In hierdie studie word vereis dat 'n beste-passing oplossing beide die vorm van die radio- en  $\gamma$ -straalligkrommes, sowel as die relatiewe faseverskil tussen hierdie twee profiele, reproduseer. 'n Parameterstudie in die konteks van die geometriese modelle word ook uitgevoer, en die verworwe kwalitatiewe insig word dan ingespan om die bes moontlike passings te verkry. Die kombinasie van radio- en  $\gamma$ -straalmodelle blyk merkwaardig beperkend te wees ten opsigte van die geometriese parameters: die kantel- en waarnemershoek. Oor die algemeen werk die radiomodel-beperkings loodreg in op die data ten opsigte van die rigting waarin die  $\gamma$ -straalmodel-beperkings daarop inwerk, wat beteken dat die finale oplossingskontoere kleiner is. Die beperkings op die geometriese parameters verkry vir elk van die ses pulsare stem baie goed ooreen met dié verkry deur Weltevrede et al. (2010). Hierdie ooreenstemming is merkwaardig wanneer in ag geneem word dat die benaderings wat ingespan is in die twee studies onafhanklik van mekaar is. Die foutgrense op die waardes verkry in hierdie studie vir die kantelhoek van die onderskeie pulsare is oor die algemeen kleiner as die foutgrense verkry deur Weltevrede et al. (2010). As 'n sekondêre resultaat word die waarde van die vloed-korreksiefaktor, wat 'n maatstaf is van hoe verteenwoordigend die waargenome  $\gamma$ -straalenergievloed is van die algehele  $\gamma$ -straalenergievloedverspreiding, beperk vir elk van die pulsare.

*Sleutelwoorde:* *Fermi* LAT, pulsare: geometriese ligkrommemodellering,  $\gamma$ -strale, individuele pulsare: PSR J0631+1036, PSR J0659+1414, PSR J0742–2822, PSR J1420–6048, PSR J1509–5850, PSR J1718–3825.



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Dedicated to my mother and my sister.



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# Nomenclature

|     |                       |
|-----|-----------------------|
| CR  | Curvature Radiation   |
| LAT | Large Area Telescope  |
| LC  | Light Curve           |
| MSP | Millisecond Pulsar    |
| NS  | Neutron Star          |
| OG  | Outer Gap             |
| PC  | Polar Cap             |
| PFF | Pair Formation Front  |
| RVM | Rotating Vector Model |
| SG  | Slot Gap              |
| SR  | Synchrotron Radiation |
| TPC | Two-pole Caustic      |

