Artifact Sources Near Bright EGRET Pulsars

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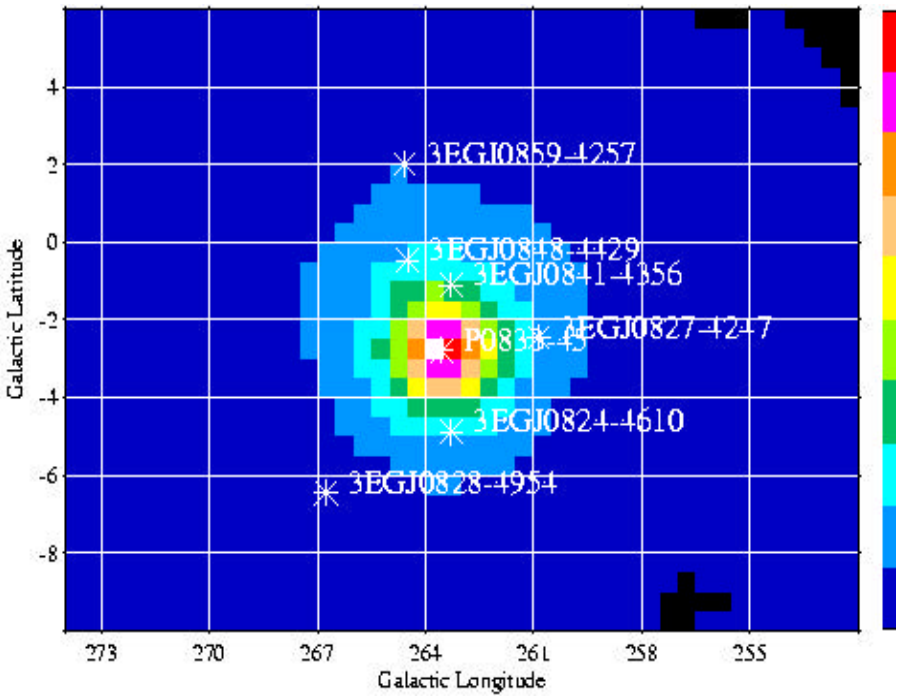
ABSTRACT

As noted in the Third EGRET Catalog, six sources near the bright Vela pulsar are thought to be artifacts: 3EG J0824-4610, 3EG J0827-4247, 3EG J0828-4954, 3EG J0841-4356, 3EG J0848-4429, and 3EG J0859-4257. This conclusion is based on analysis of phase-resolved maps of the pulsar region. The artifact sources are statistically significant only in the on-pulse maps where Vela itself is bright. Details of this analysis show that there is at most one source in addition to Vela in this region. Additional analysis using the same phase-resolved-map technique suggests that one of the four sources near the Crab pulsar, 3EG J0521+2147, is also likely to be an artifact. Both of the sources closest to Geminga are detected at comparable levels in both on-pulse and off-pulse maps, supporting their validity. These results illustrate the difficulty of detecting weak sources near bright ones, even using modeling techniques such as maximum likelihood.

Description of the Problem



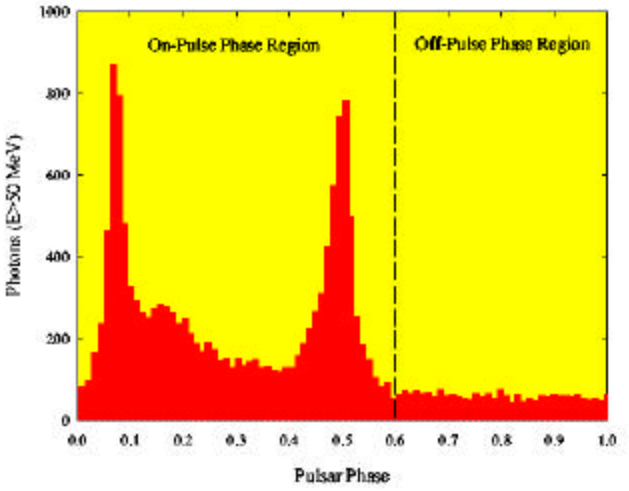
Map of gamma-ray intensity (E>100MeV) in the Vela region for CGRO cycles 1-4. Positions and names of EGRET sources are taken from the third EGRET catalog (Hartman et al. 1999).

The figure above shows a gamma-ray intensity map of the Vela region (E>100 MeV). The region is strongly dominated by one bright source - the Vela pulsar. Nevertheless, maximum likelihood analysis of the EGRET maps suggests that there are six additional sources in the vicinity of Vela, shown with their names and locations from the third EGRET catalog (Hartman et al. 1999). None of these is obvious in the map.

Because Vela is pulsed, we can greatly reduce its influence on the analysis by constructing phase-resolved maps, separating the data into on-pulse and off-pulse components. If these additional sources are real, they should appear consistently in both maps; if they are artifacts resulting from fluctuations in the distribution of photons from Vela, then they would be seen mostly in the on-pulse map where Vela is bright.

Similar analysis can be done for the other bright pulsars Crab and Geminga.

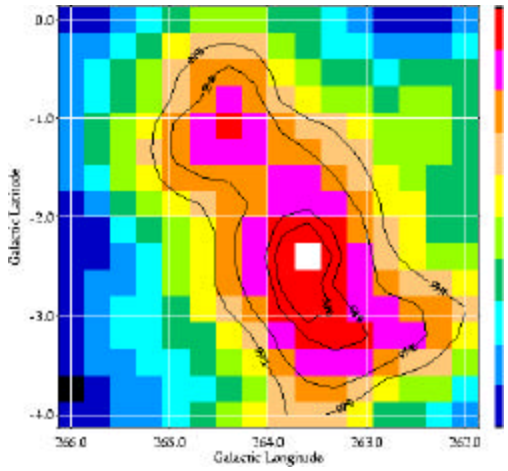
Vela Pulsar



The light curve of the Vela gamma-ray pulsar shows two distinct regions: phase 0 - 0.6 (on-pulse) includes the vast majority of the photons, while phase 0.6 - 1.0 (off-pulse) is much weaker. In the off-pulse region, Vela itself is just a 5σ detection (Fierro et al 1998).

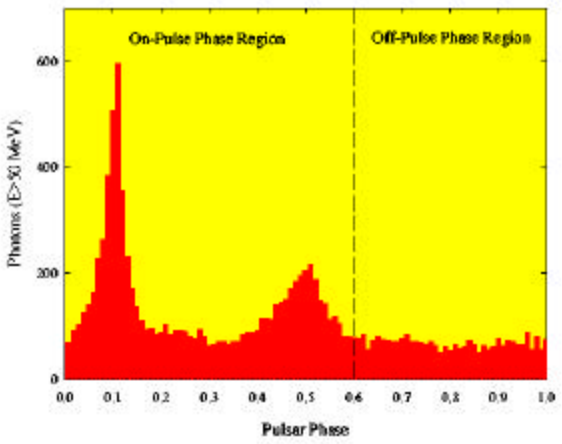
Maximum likelihood analysis was carried out for cataloged sources in the Vela region, using the E>100 MeV on-pulse and off-pulse maps. Because the on-pulse region occupies 60% of the phase, the "expected" counts in the unpulsed region should be 2/3 of those seen in the on-pulse map. As seen in the table below, in all cases the off-pulse counts were well below the expected count rates. With the possible exception of 3EG J0848-4429 (which is about 2σ below the expected value), all these sources appear to be artifacts.

Source	Off-pulse s	Off-pulse counts	Catalog s	Expected counts
3EG J0824-4610	1.7	48 ± 30	9.3	235 ± 54
3EG J0827-4247	1.2	42 ± 36	6.1	205 ± 50
3EG J0828-4954	2.8	72 ± 28	5.9	153 ± 31
3EG J0841-4356	0.0	< 72	5.3	386 ± 67
3EG J0848-4429	3.8	147 ± 41	5.7	230 ± 56
3EG J0859-4257	1.6	51 ± 34	5.1	138 ± 36



This likelihood map of the off-pulse map of the Vela region shows that the most significant source is Vela itself, at l = 263°.55, b = -2°.79. A possible second source near l = 264°.5, b = -1°.2 is consistent in position with 3EG J0848-4429; however, when both sources are modeled, the second source falls below the EGRET acceptance threshold.

Crab Pulsar

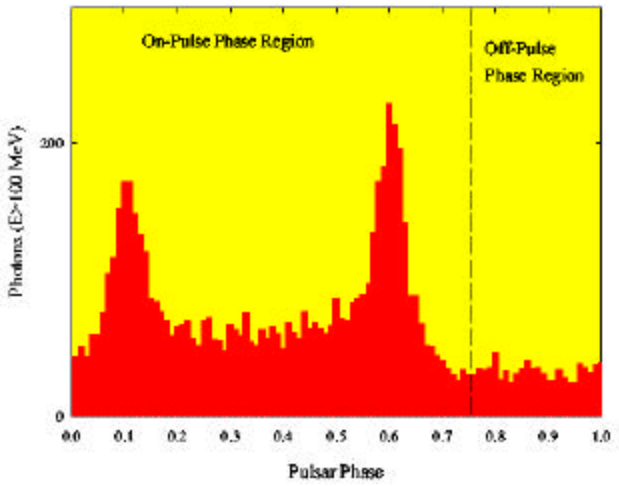


The light curve of the Crab gamma-ray pulsar shows two distinct regions: phase 0 - 0.6 (on-pulse) includes the majority of the photons, while phase 0.6 - 1.0 (off-pulse) is weaker. Unpulsed emission from the Crab, seen in the off-pulse phase region, is thought to originate from the nebula (DeJager et al. 1996)

Maximum likelihood analysis was carried out for cataloged sources in the Crab region, using the E>100 MeV on-pulse and off-pulse maps. Because the on-pulse region occupies 60% of the phase, the "expected" counts in the unpulsed region should be 2/3 of those seen in the on-pulse map, or 40% of those in the combined map. As seen in the table below, in most cases the off-pulse counts were consistent with the expected count rates. The exception is 3EG J0521+2147, which is about 3.6σ below the expected value. This source appears to be an artifact, while the rest are validated by the off-pulse analysis.

Source	Off-pulse σ	Off-pulse counts	Catalog σ	Expected counts
3EG J0520+2556	**4.4**	**138 ± 35**	**6.2**	**142 ± 24**
3EG J0521+2147	**2.3**	**71 ± 33**	**7.2**	**190 ± 28**
3EG J0530+1323	**22.0**	**869 ± 51**	**33.2**	**834 ± 80**
3EG J0542+2610	**2.2**	**85 ± 40**	**4.9**	**131 ± 29**
3EG J0546+3948	**4.0**	**93 ± 26**	**5.9**	**94 ± 18**

Geminga Pulsar



The light curve of the Geminga gamma-ray pulsar shows two distinct regions: phase 0 - 0.75 (on-pulse) includes the majority of the photons, while phase 0.75 - 1.0 (off-pulse) is weaker. Unlike the Vela pulsar, Geminga itself shows strong emission at all phases (Fierro et al. 1998); unlike the Crab, Geminga has no prominent supernova remnant surrounding it.

Maximum likelihood analysis was carried out for cataloged sources in the Geminga region, using the E>100 MeV on-pulse and off-pulse maps. Because the on-pulse region occupies 75% of the phase, the "expected" counts in the unpulsed region should be 1/3 of those seen in the on-pulse map, or 25% of those in the combined map. As seen in the table below, in both cases the off-pulse counts were consistent with the expected count rates. The 3EG J0617+2238 result is about 2.3σ below the expected value but remains a strong detection.

Source	Off-pulse σ	Off-pulse counts	Catalog σ	Expected counts
3EG J0617+2238	**6.8**	**192 ± 33**	**17.4**	**269 ± 18**
3EG J0628+1847	**4.2**	**123 ± 32**	**6.3**	**118 ± 20**

Conclusions

- Using phase-resolved maps in regions around bright pulsars provides an additional dimension to the study of nearby sources. Choosing off-pulse phases reduces the impact of the pulsars.
- Techniques such as maximum likelihood, although powerful, are limited by the quality of the modeled point spread function and fluctuations in the data. For EGRET, the long observations over its nine year life meant that the bright pulsar statistics were actually greater than the statistics used for calibrating the point spread function.
- At least six, and probably seven, of the sources in the third EGRET catalog are likely artifacts caused by the presence of bright sources nearby: one near the Crab, and five or six near Vela. Neither of the sources closest to Geminga appears to be in question.
- In regions around bright sources, there is no substitute for intrinsic angular resolution. The GLAST Large Area Telescope, with its combination of improved spatial resolution and much better sensitivity at the higher energies where the point spread function is much narrower, will improve greatly on the ability to resolve weak sources near bright ones.

Selected references

De Jager, O.C., Harding, A.K., Michelson, P.F., Nel, H.I., Nolan, P.L., Sreekumar, P., and Thompson, D.J., 1996 ApJ, 457,253

Fierro, J.M. et al. 1998 ApJ, 494, 734

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