

---

## Very High Energy Observations Of PSR B1823-13

---

T.A. Hall,<sup>1,2</sup> I.H. Bond, P.J. Boyle, S.M. Bradbury, J.H. Buckley, D. Carter-Lewis, O. Celik, W. Cui, M. Daniel, M. D’Vali, I.de la Calle Perez, C. Duke, A. Falcone, D.J. Fegan, S.J. Fegan, J.P. Finley, L.F. Fortson, J. Gaidos, S. Gammell, K. Gibbs, G.H. Gillanders, J. Grube, J. Hall, D. Hanna, A.M. Hillas, J. Holder, D. Horan, A. Jarvis, M. Jordan, G.E. Kenny, M. Kertzman, D. Kieda, J. Kildea, J. Knapp, K. Kosack, H. Krawczynski, F. Krennrich, M.J. Lang, S. LeBohec, E. Linton, J. Lloyd-Evans, A. Milovanovic, P. Moriarty, D. Muller, T. Nagai, S. Nolan, R.A. Ong, R. Pallassini, D. Petry, B. Power-Mooney, J. Quinn, M. Quinn, K. Ragan, P. Rebillot, P.T. Reynolds, H.J. Rose, M. Schroedter, G. Sembroski, S.P. Swordy, A. Syson, V.V. Vassiliev, S.P. Wakely, G. Walker, T.C. Weekes, J. Zweerink

(1) *University of Arkansas at Little Rock, Dept. of Physics and Astronomy, Little Rock, AR 72204, USA* (2) *The VERITAS Collaboration—see S.P. Wakely’s paper “The VERITAS Prototype” from these proceedings for affiliations*

---

### Abstract

To date three plerionic systems have been detected as emitters of very energetic photons. As part of an ongoing study of pulsar systems at the Whipple observatory, observations of the plerion PSR B1823-13 are being conducted. Observations were made with the Whipple 10 m gamma-ray telescope utilizing the high resolution, 490 pixel camera.

### 1. Introduction

Four sources of detected very high energy (VHE) gamma radiation are associated with systems containing pulsars. Three of these sources (Crab Nebula [11], Vela pulsar [12], and PSR B1706-44 [6]) represent a class of objects known as plerions. A plerion is a compact nebula resulting from a relativistic particle wind emanating from a pulsar interacting with the pulsar’s environment.

PSR B1823-13 is a young, spin-powered pulsar with characteristics similar to both Vela and PSR B1706-44. Observations in the X-ray band [3] have revealed that PSR B1823-13 is powering a compact synchrotron nebula (plerion) with a physical size similar to that seen in the other plerionic sources (Crab, Vela, and PSR B1706-44). PSR B1823-13 is 7th in a rank ordered list of  $E/d^2$ .

In addition to the X-ray detection of this young isolated neutron star, the position of PSR B1823-13 is near the EGRET unidentified source, 3EG 1823-

1314 [5]. This EGRET source is also one of the stronger detections in the Lamb 1 GeV catalog [7]. The above factors make PSR B1823-13 a prime candidate for observations in the VHE band.

## 2. Observations and Analysis

The observations of PSR B1823-13 presented here were made with the Whipple 10 m gamma-ray telescope located on Mt. Hopkins in southern Arizona [2]. These data were collected during the spring of 2000. During this time, the telescope utilized a high resolution camera consisting of an array of 490 photomultiplier tubes mounted at the focal plane of the reflector. A detailed description of the telescope and its characteristics can be found in [2, 4].

Images of extensive air showers initiated by high-energy photons and cosmic rays are made by recording the Čerenkov radiation emitted as the shower propagates through the atmosphere. By making use of distinctive differences in the angular distribution of light and the orientation of the shower images, it is possible to differentiate a gamma ray initiated event from a very large hadronic background.

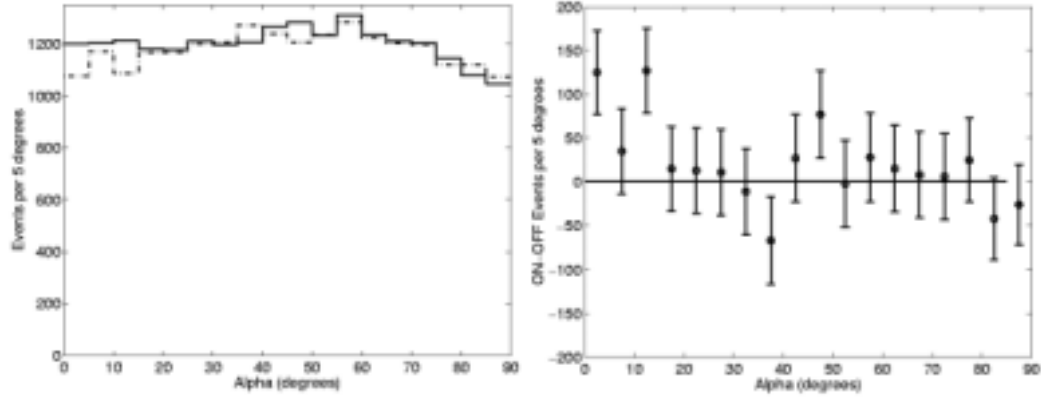
### 2.1. Unpulsed Analysis

The observations reported here were collected in the ON/OFF observation mode. In ON/OFF mode, the candidate source position is observed for 28 minutes (ON run) followed by a 28 minute reference observation (OFF run) taken at the same azimuth and elevation as the ON run. The OFF region is used to estimate the background counts in the ON region.

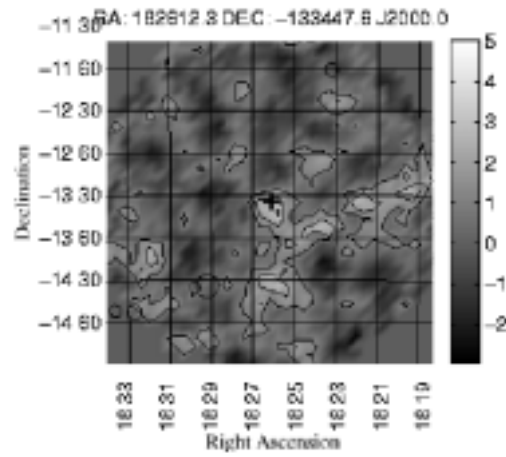
During the 2000 observing season, 430 minutes of ON source data (16 on/off pairs) were acquired. A moment analysis routine [9] utilizing the parameter cuts was applied to the data yielding a  $3.4 \sigma$  excess (0.7 g/min) in an ALPHA analysis. Figure 1 displays the ALPHA distribution and the ON minus OFF counts as a function of ALPHA angle. A flux upper limit of  $2.6 \times 10^{-11} \text{cm}^{-2} \text{s}^{-1}$  at a peak energy of 1 TeV was derived at a confidence level of 99.9%. A 2-Dimensional analysis [8] was also applied to the data yielding a 3.1 sigma excess near the position of PSR B1823-13 as seen in Figure 2.

### 2.2. Periodic Analysis

The arrival times of Čerenkov events were recorded by a GPS clock and a 10 MHz oscillator calibrated by a GPS second mark to achieve an absolute time resolution of  $0.1 \mu\text{s}$ . All arrival times were then transformed to the solar system barycenter using the JPL DE200 planetary ephemerides [10]. The phase of each event passing the parameter cuts was calculated using the appropriate ephemeris for the epoch of the data. To test for the presence of a periodic signal,  $\chi^2$  and



**Fig. 1.** Results of the ALPHA analysis of PSR B1823-13. Plots show the ALPHA distribution and the ON minus OFF counts in  $5^\circ$  bins.



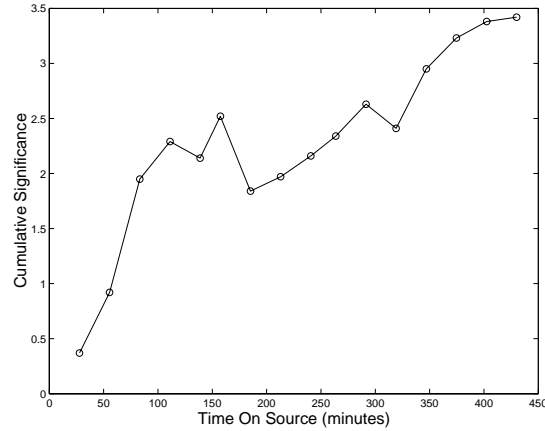
**Fig. 2.** 2D analysis of PSR B1823-13. Curves represent  $1\sigma$  contours. The position of PSR B1823-13 is indicated with a cross.

$Z_m^2$  tests were performed. The analysis of event arrival times showed no evidence of modulation at the pulsar period.

In order to calculate an upper limit for pulsed emission, a method utilizing the  $Z_2^2$  statistic, which assumes a sinusoidal pulse profile, was used. The pulsed fraction at a peak energy of 1 TeV is found to be less than 6% of the background at a confidence level of 99.9%.

### 3. Discussion

Results from the observations of PSR B1823-13 show an excess in the ALPHA distribution consistent with a weak source. Figure 3 shows the cumulative



**Fig. 3.** Cumulative significance of the observations of PSR B1823-13.

significance obtained from the analysis. The gradual increase in significance may be due to a weak, persistent gamma-ray source. Further observations are currently being conducted. The results of these new observations will be presented at the conference.

#### 4. Acknowledgments

We acknowledge the technical assistance of E. Roache and J. Melnick. We would also like to thank A. Lyne and Z. Arzoumanian for providing radio ephemerides for this report. This research is supported by grants from the U. S. Department of Energy, by Enterprise Ireland, and by PPARC in the UK.

#### 5. References

1. Catanese M. et al. 1998, ApJ 501, 616
2. Cawley M.F., Fegan D.J., Harris K., Kwok P.W., Hillas A.M. 1990, Experimental Astronomy 1, 173
3. Finley J.P., Srinivasan R., Park S. 1996, ApJ 466, 938
4. Finley J.P. et al. 2001, in Proc. 27th ICRC (Hamburg, Germany), OG 2.5
5. Hartman R.C., et al. 1999, ApJS 123, 79
6. Kifune T. et al. 1995, ApJ 438, L91
7. Lamb R.C., Macomb D.J. 1997, ApJ 488, 872
8. Lessard R.W., Buckley J.H., Connaughton V., Le Bohec, S. 2001, APh 15, 1
9. Reynolds P.T. et al. 1993, ApJ 404, 206
10. Standish E.M. Jr. 1982, AAP, 114, 297
11. Weekes T.C. et al. 1989, ApJ 342, 379
12. Yoshikoshi T. et al. 1997, ApJ 487, L65