PROCEEDINGS OF SCIENCE

TeV Gamma-Ray Emission Observed from Geminga with HAWC

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Geminga is a radio-quiet pulsar 250 parsecs from Earth that was first discovered as a GeV gamma-ray source and then identified as a pulsar. Milagro observed an extended TeV source spatially consistent with Geminga. HAWC observes a similarly extended source. Observations of Geminga's flux and extension will be presented.

PoS(ICRC2015)719

The 34th International Cosmic Ray Conference,
30 July- 6 August, 2015
The Hague, The Netherlands

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1. Introduction

Geminga is an important high energy source. It is one of the closest known middle aged pulsars [1] at approximately 250 pc [2]. It was discovered in γ-rays with the SAS-2 experiment [3] before being observed in other wavelengths. Pulsations were first observed in X-rays [4] with ROSAT and later EGRET [5] but have not been observed in the TeV range [6, 7, 8]. X-ray Multimirror Mission-Newton observations show a pulsar wind around Geminga with an extent of a few arc minutes [9]. Observations of TeV emission associated with Geminga would bolster the interpretation that Geminga is a nearby cosmic-ray accelerator [10, 11, 12] which could possibly explain the observed positron excess [13, 14, 15].

Milagro reported Geminga as a possible TeV source in 2007 [16] with a significance of 5.1σ before trials but below discovery threshold after trials. In 2009 Milagro made a "definitive detection" of a region of extended $(2.6^{+0.7}_{-0.9})^{\circ}$ emission spatially consistent with Geminga [17] with a significance of 6.3σ. This would imply a region of emission approximately 6 to 12 pc in extent. The Tibet Air shower array reported an excess of 2.2σ at the location of the pulsar but did not report extended emission [18].

Imaging Atmospheric Cherenkov Telescopes (IACTs) have observed Geminga without significant detection [6, 19, 7] for over two decades. An extended, hard TeV source is extremely difficult to observe with the IACT technique. Milagro's observation implies an extended, hard spectrum source.

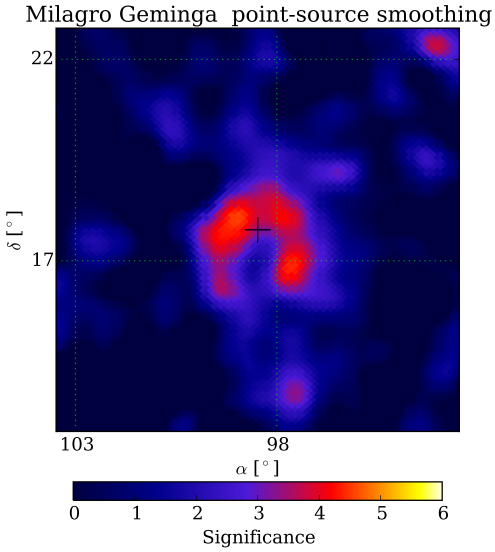
HAWC was inaugurated on March 20th, 2015 with over 250 Water Cherenkov Detectors (WCDs) and a predicted point source sensitivity of 10 times that of its predecessor Milagro. The water Cherenkov technique allows HAWC to have a nearly 100% duty cycle and large field of view, making the HAWC observatory an ideal instrument for the study of transient phenomena and able to see large scale diffuse features in the TeV sky. In this proceeding we describe the analysis of gamma rays TeV from the Geminga remnant using the 250-tank configuration of the HAWC array, hereafter referred to as HAWC-250.

2. Results

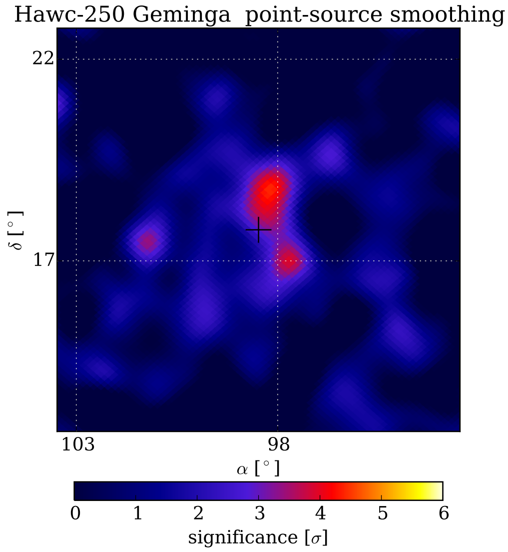
In this paper we present HAWC's preliminary results showing an extended region of emission consistent with that observed with Milagro. HAWC-250, where the number of operating water Cherenkov detectors ranged from 247 to 293, data were used for this analysis. Data taken from November 26th 2014 to May 6th 2015 totaling to a live-time of 149 days[1]. These data result in a $\sim 38\sigma$ detection of the Crab [20]. Milagro, for comparison, reported $\sim 17\sigma$ on the Crab in the same data set used for their Geminga analysis [17].

HAWC gains much of its sensitivity improvement over Milagro from its improved point spread function [20]. Extended objects do not benefit as much from this improvement as their flux is spread over a larger solid angle. HAWC's low energy sensitivity is also greatly improved. At high energies, HAWC and Milagro have similar effective areas. Thus, hard spectrum, extended sources do not benefit from the improved low energy sensitivity of HAWC.

[1] See [20] for more details on this data set.

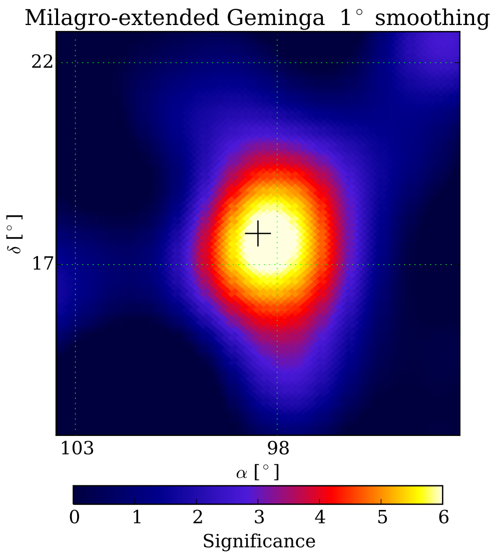


(a) Milagro

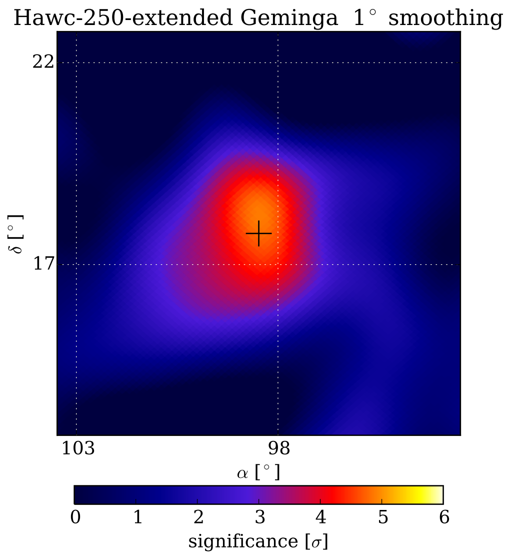


(b) HAWC

Figure 1: The significance for a 10°x10° region around Fermi source J0634.0+1745, the Geminga pulsar. HAWC's energy threshold is significantly lower than that of Milagro's for these data.



(a) Milagro



(b) HAWC

Figure 2: The significance after smoothed by an additional 1° Gaussian of a 10°x10° region around Fermi source J0634.0+1745, the Geminga pulsar. HAWC's energy threshold is significantly lower than that of Milagro's for these data.

The region around Geminga can be seen for both HAWC and Milagro optimized for point source detections[2] in Fig. 1, while Fig. 2 shows the same data with an additional 1° smearing to highlight extended sources.

HAWC has exceeded the integrated point-source sensitivity of its predecessor, Milagro, by over a factor of two in just 149 days of live-time and confirms Milagro's observation of an extended TeV source spatially coincident with the Geminga pulsar. It will continue to update the community on this extremely interesting source over its lifetime.

Acknowledgments

We acknowledge the support from: the US National Science Foundation (NSF); the US Department of Energy Office of High-Energy Physics; the Laboratory Directed Research and Development (LDRD) program of Los Alamos National Laboratory; Consejo Nacional de Ciencia y Tecnología (CONACyT), Mexico (grants 260378, 55155, 105666, 122331, 132197, 167281, 167733); Red de Física de Altas Energías, Mexico; DGAPA-UNAM (grants IG100414-3, IN108713, IN121309, IN115409, IN111315); VIEP-BUAP (grant 161-EXC-2011); the University of Wisconsin Alumni Research Foundation; the Institute of Geophysics, Planetary Physics, and Signatures at Los Alamos National Laboratory; the Luc Binette Foundation UNAM Postdoctoral Fellowship program.

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