A Search for Pulsations from Geminga Above 100 GeV with VERITAS

Last Updated Monday, 19 October 2015 07:43

Located at the nearby distance of ~200 pc, the Geminga pulsar is the second brightest GeV source in the gamma-ray sky and the prototypical "radio-quiet" pulsar. It has a period of 237 ms, a spin-down age of $3 \times 10^5$ years and a spin-down luminosity of $3.2 \times 10^{34}$ erg s$^{-1}$. The phasogram of the Geminga pulsar is dominated by two emission peaks separated by a "bridge" of enhanced emission. The spectrum of the Geminga pulsar is well described by a power law with an index of $1.3 \pm 0.01$ at low energies, followed by a spectral break at ~2.5 GeV. Above the break energy, a sub-exponential cut-off in the spectrum is favored over a pure exponential or super-exponential and Lyutikov (2012) argues that above the spectral break, the spectrum can be described by a power law, a behavior similar to what has been
measured by VERITAS and MAGIC in the Crab pulsar above the spectral break.

Following a 70 hr observation, the VERITAS array has placed limits on emission from the P1 and P2 phase above 135 GeV at the level of ~0.25% Crab Nebula level. These limits represent the most constraining limits set to date on the gamma-ray emission from the pulsar in this energy regime, surpassing previous limits by over an order of magnitude. From a 5.2 year analysis of Fermi data we find that above 10 GeV, pure power laws with indices between 5.1 and 5.5 are compatible with the spectral points and predict a level of emission below the VERITAS limits. This indicates that Geminga is still a viable candidate for inverse-Compton emission and such emission could be detected above 100 GeV by the forthcoming Cherenkov Telescope Array within ~100 hrs of observation.

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Figure 1: The phase-folded light curve of the Geminga pulsar as measured by the Fermi-LAT. The Fermi light curve contains all events that fell within a 2° radius centered on the position
of the Geminga pulsar. The energy-dependent evolution of the light curve is in clear agreement with the light curves presented in Saz Parkinson et al. (2012) and Ackermann et al. (2013). The P1 and P2 emission peaks were fitted with asymmetric Gaussian functions above 5 GeV and 10 GeV, respectively. These fits, which are plotted as smooth black curves in panel (b), were used to define the signal regions for the P1 and P2 spectral analyses. These phase regions, [0.072 - 0.125] for P1 and [0.575 - 0.617] for P2, are indicated as vertical dashed lines. The background-event sample for the VERITAS analysis was selected from the phase range [0.7 - 1.0]. There is no evidence of pulsed emission above 100 GeV at any phase in the VERITAS data plotted in panel (c).

Figure 2: Measured SEDs and flux upper limits for the Geminga pulsar. Measurements of the Crab Nebula and pulsar are plotted for comparison. The Geminga limits and fluxes shown for PACT, Crimea, HEGRA, Whipple and Ootacamund were derived from the integral values reported by those experiments, assuming a power law with index 2.5 in each case.