Pulsar Wind Nebulae

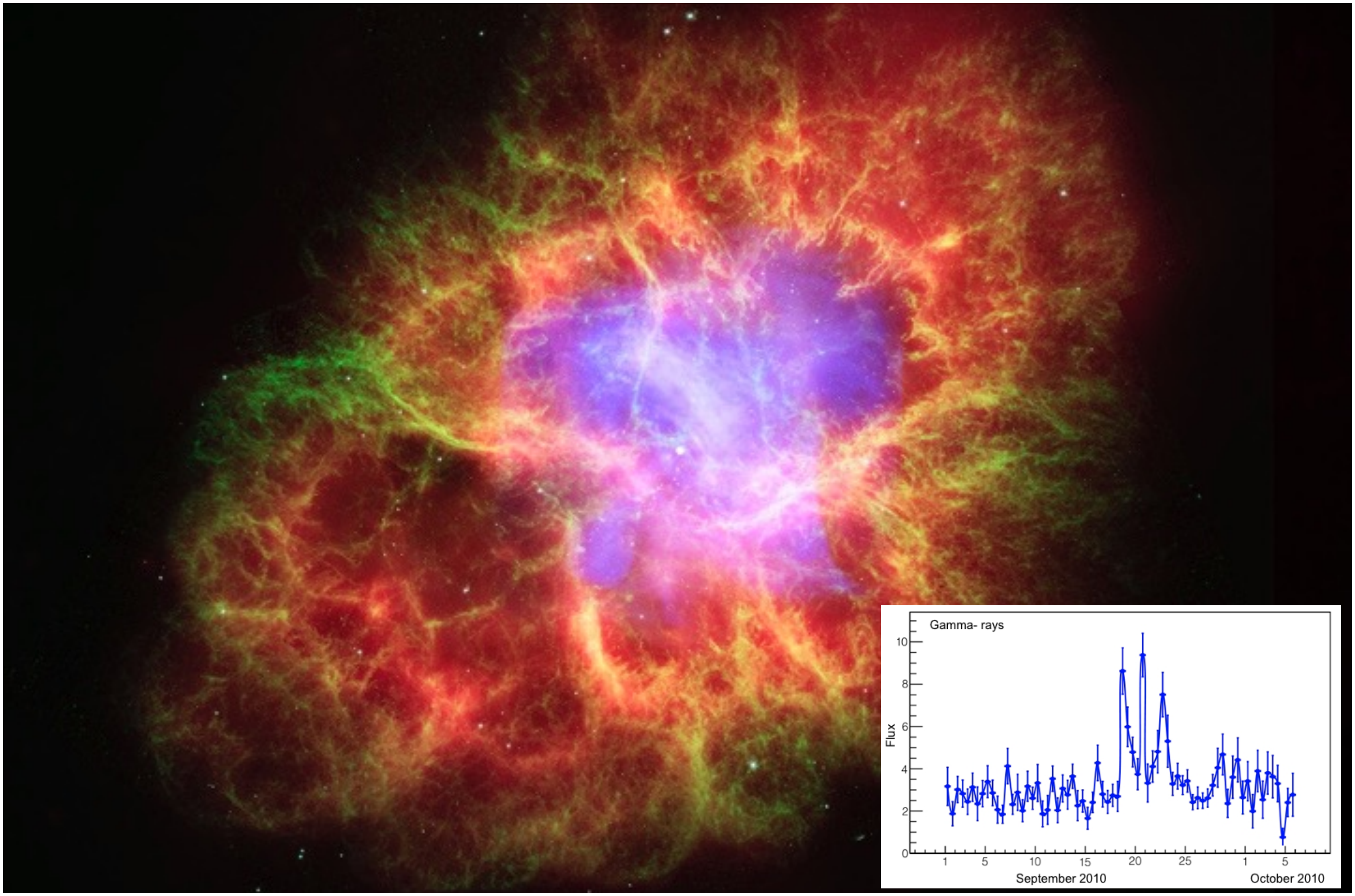


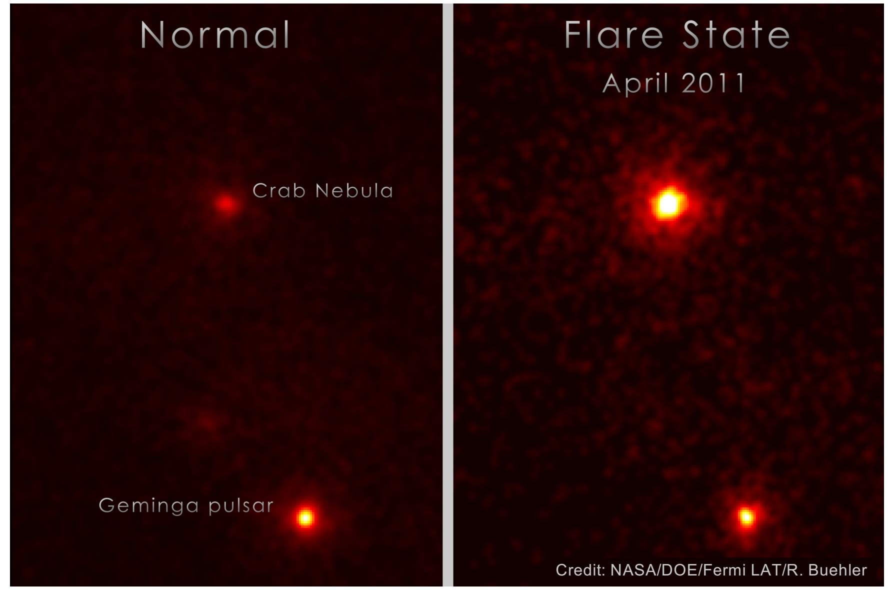
Image: NASA, ESA, CXC, JPL-Caltech, J. Hester and A. Loll (Arizona State Univ.), R. Gehrz (Univ. Minn.), and STScI; plot: The Fermi-LAT Collaboration

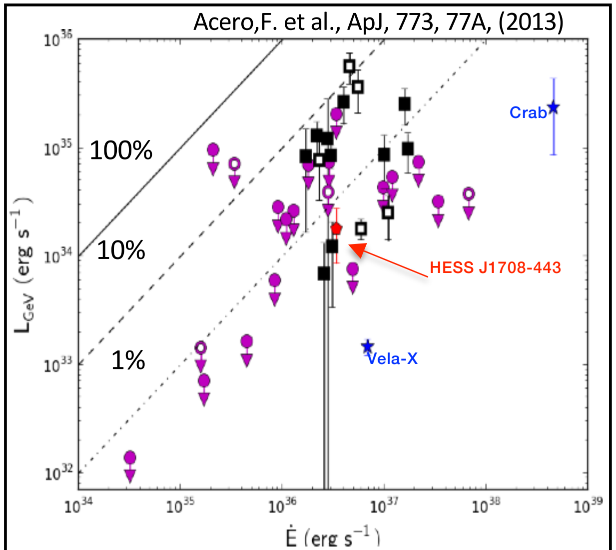
Pulsar Wind Nebulae and Fermi

Most of the spin-down luminosity of energetic, young pulsars is carried away in a **magnetized particle wind.** This wind expands into the surrounding medium, decelerating as it sweeps up ejecta from the supernova and forming a termination shock. These pulsar wind nebulae (PWNe) contain both the relic accelerated particles from the pulsar and particles accelerated within the termination shock.

While PWNe are the dominant Galactic source class at TeV energies, to date few have been detected at GeV energies. In association with multi-frequency studies, Fermi provides **new constraints on the emission models and physical properties** of the nebula (magnetic field, injection spectrum, pulsar efficiency).

The Crab nebula is a uniquely active PWN. Fermi detects emission from both the young pulsar and the surrounding nebula (in the off-pulse phase). Long held to be the standard candle of high-energy astrophysics, the Crab exhibited **strong gamma-ray flares** on time-scales as short as half a day, far smaller than the dynamical timescales in the nebula. The suspected radiation mechanism is synchrotron emission, which at 1 GeV requires $\gamma \sim 3\text{-}10 \times 10^9$, making the Crab an active “PeVatron”.



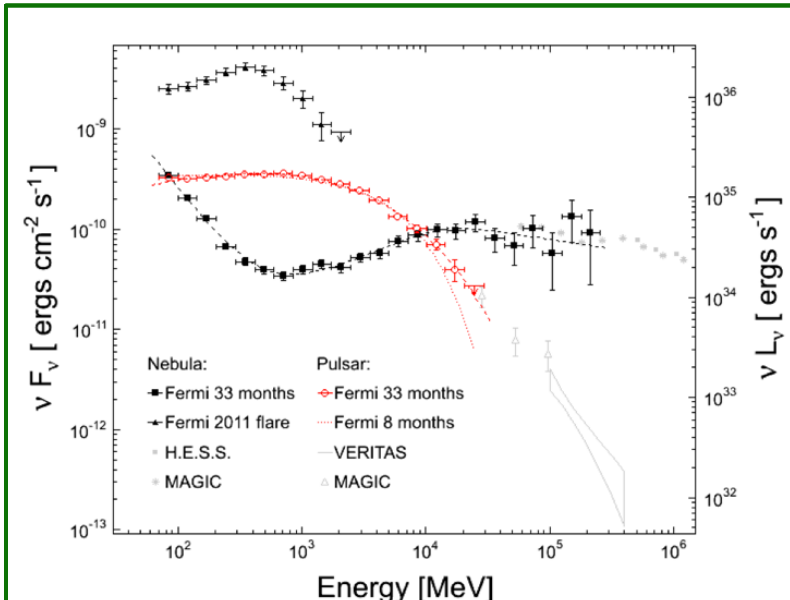


Dependence of PWN luminosity on pulsar spin down power for LAT-detected pulsars. Fermi identified PWN are marked as solid boxes. Pulsars with significant off-pulse emission of unknown origin are marked as blue squares. Upper limits are also shown as magenta circles. Diagonal lines represent gamma-ray efficiency.

PWNe Science with the LAT

Fermi probes a key window into the nature (leptonic/hadronic) of non-thermal radiation. LAT detections of PWNe trace the particle population (via Inverse Compton emission peaking in the TeV). Many PWNe show an energy-dependent morphology indicative of cooling mechanisms.

11 PWNe have been associated in the third Fermi-LAT source catalog. A larger number could not be identified since often there are strong GeV backgrounds emitted by the pulsar and/or the supernova remnant . The Fermi Science Tools allow selection of off-pulse phases to exclude the pulsar emission.



Spectral energy distributions of the Crab pulsar (red) and PWN (black) as seen by the LAT and other gamma-ray telescopes. The red curve shows the spectral fit of the pulsar using LAT data. The nebula spectrum during the brightest flare in April 2011 (MJD 55666.997-55667.366) is also shown.

For more information, visit http://fermi.gsfc.nasa.gov/

Fermi Gamma-ray Space Telescope

NASA's Fermi mission is an astrophysics and particle physics partnership managed by NASA's Goddard Space Flight Center in Greenbelt, Md., and developed in collaboration with the U.S. Department of Energy, with important contributions from academic institutions and partners in France, Germany, Italy, Japan, Sweden and the United States.