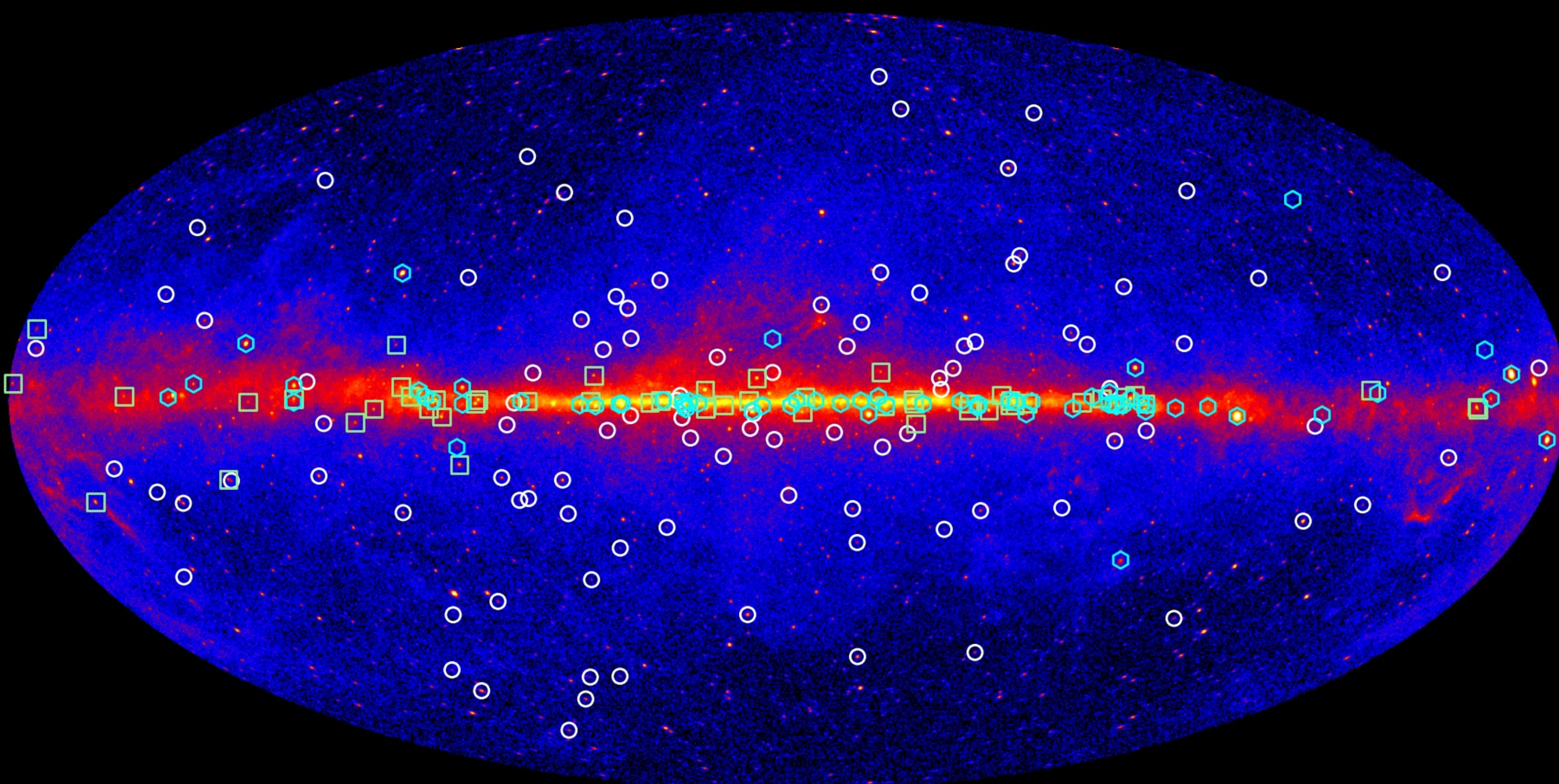
Pulsars



205 Gamma-ray Pulsars

Shown above are the gamma-ray pulsars detected with the LAT:

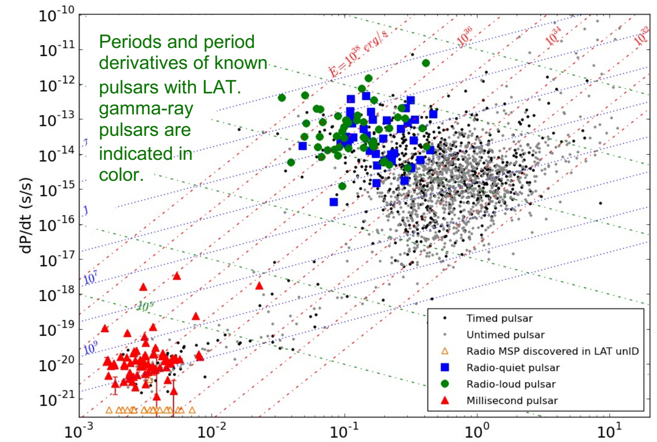
MSPs (○), young radio-selected (□), and young gamma-selected (○).

Credit: The Fermi-LAT Collaboration

New Insights into Pulsar Physics from *Fermi*

Pulsars are **rotating neutron stars** created when massive stars explode as supernovae. They are continually spinning down due to electromagnetic dipole torques, losing most of their energy to magnetized particle winds. A smaller part of their energy loss appears as radiation across the electromagnetic spectrum, with **most of the power concentrated in the gamma-ray band.**

There are presently ~2400 pulsars known with the vast majority seen only in radio, but the numbers detected at optical, X-ray and gamma-ray wavelengths are increasing. The pulsar population divides into two categories: young pulsars, with rotation periods of ~0.01-1 seconds and surface magnetic fields around 10^{12} G, and those with millisecond periods that have much lower surface fields. The millisecond pulsars (MSPs) are thought to be recycled from the canonical pulsar population through spin-up by accretion from a binary companion.



With the help of radio and X-ray pulsar astronomers who provide timing solutions, LAT scientists are digging down into the less energetic population. However, some notable, highly-energetic pulsars remain undetected in gamma rays.

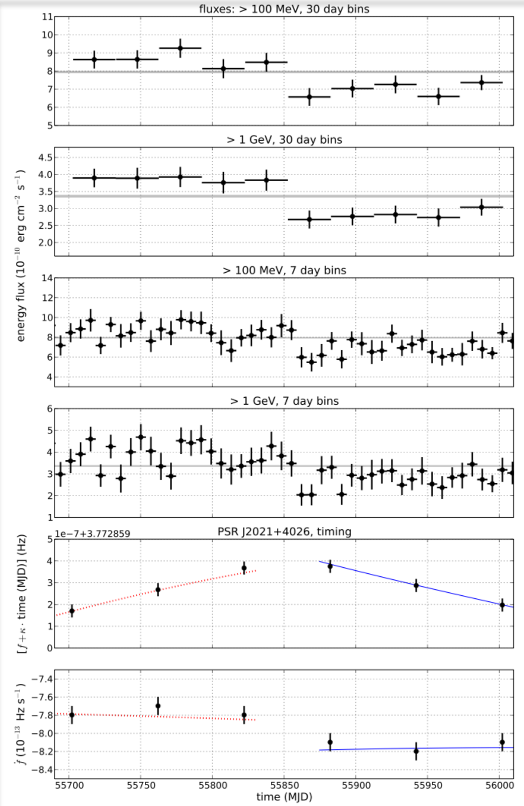
Pulsar Science with the LAT

The *Fermi* Large Area Telescope (LAT) has revolutionized pulsar science by detecting and studying the gamma-ray properties of 205, including young (both radio-loud and radio-quiet) and recycled pulsars (both in the Galactic field and globular clusters).

Emission above 100 MeV implies that electrons are accelerated to **energies of at least 10 TeV.** LAT observations have established that the acceleration and gamma-ray emission take place far above the neutron star surface.

The LAT is the first instrument to discover pulsars through their gamma-ray pulsations alone. Because many of these pulsars are radio-quiet, the LAT is uncovering a previously hidden population, providing a more unbiased survey of core-collapse supernovae in our Galaxy.

For an up-to-date list of *Fermi*-LAT detected pulsars, see: http://tinyurl.com/fermipulsars



The *Fermi* LAT light curve (top 4 panels) of PSR J2021+4026 centered on its drop in flux and change in period and spin-down rate (bottom 2 panels)

Advances in Pulsar Physics

Prior to the launch of *Fermi*, the >100 MeV flux from pulsars was thought to be non-variable. This criterion, combined with a curved spectral shape, has been successfully used to target unassociated LAT sources for blind gamma-ray and radio pulsar searches (resulting in multiple radio and gamma-ray discoveries). However, the *Fermi* LAT detection of **a significant drop in flux, accompanied by an increase in slowdown rate,** of PSR J2021+4026 (see left figure) shows that the axiom of pulsar high-energy stability is not true. This variability is thought to be evidence for **global changes in the pulsar magnetosphere.** Additionally, several MSPs have recently been observed to transition between rotation-powered pulsars and low-mass X-ray binaries, and in two cases the transitions were accompanied by significant changes in the observed gamma-ray flux.

Curvature radiation from particles accelerated along magnetic field lines is thought to be the primary mechanism for pulsar emission above 100 MeV, but this should exhibit a cutoff near a few GeV and cannot produce emission above a few tens of GeV. The recent detections by TeV telescopes of pulsed emission from the Crab and Vela pulsars above 100 GeV suggests that either an extra component becomes dominant at these energies or a new mechanism is needed all together. The *Fermi* LAT catalog of sources above 10 GeV includes **significant pulsed detections** of 20 (12) pulsars above 10 (25) GeV. As LAT continues to collect data, the >10 GeV statistics will improve making it possible to better characterize this emission and constrain or rule out models.

Fermi Gamma-ray Space Telescope

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

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.