VHE Gamma-ray Pulsar Search with LHAASO

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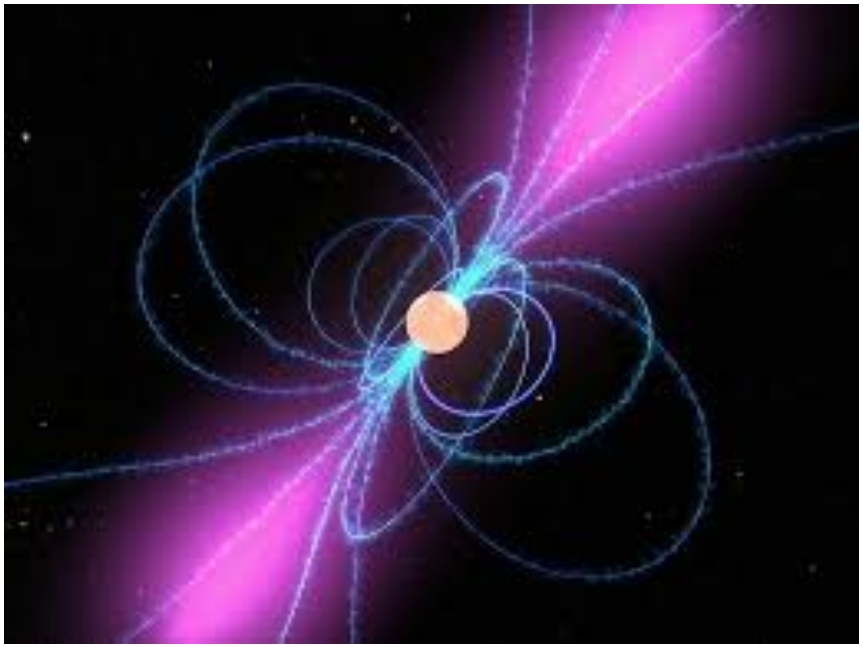
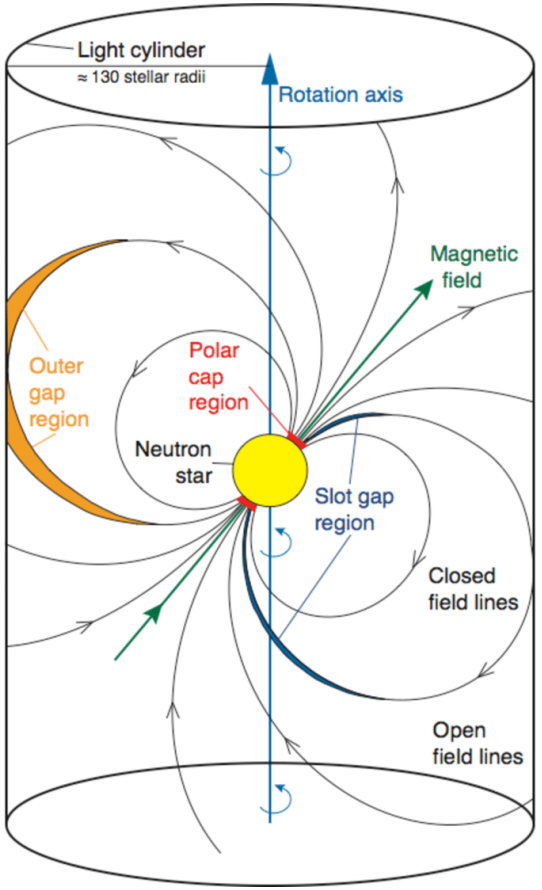
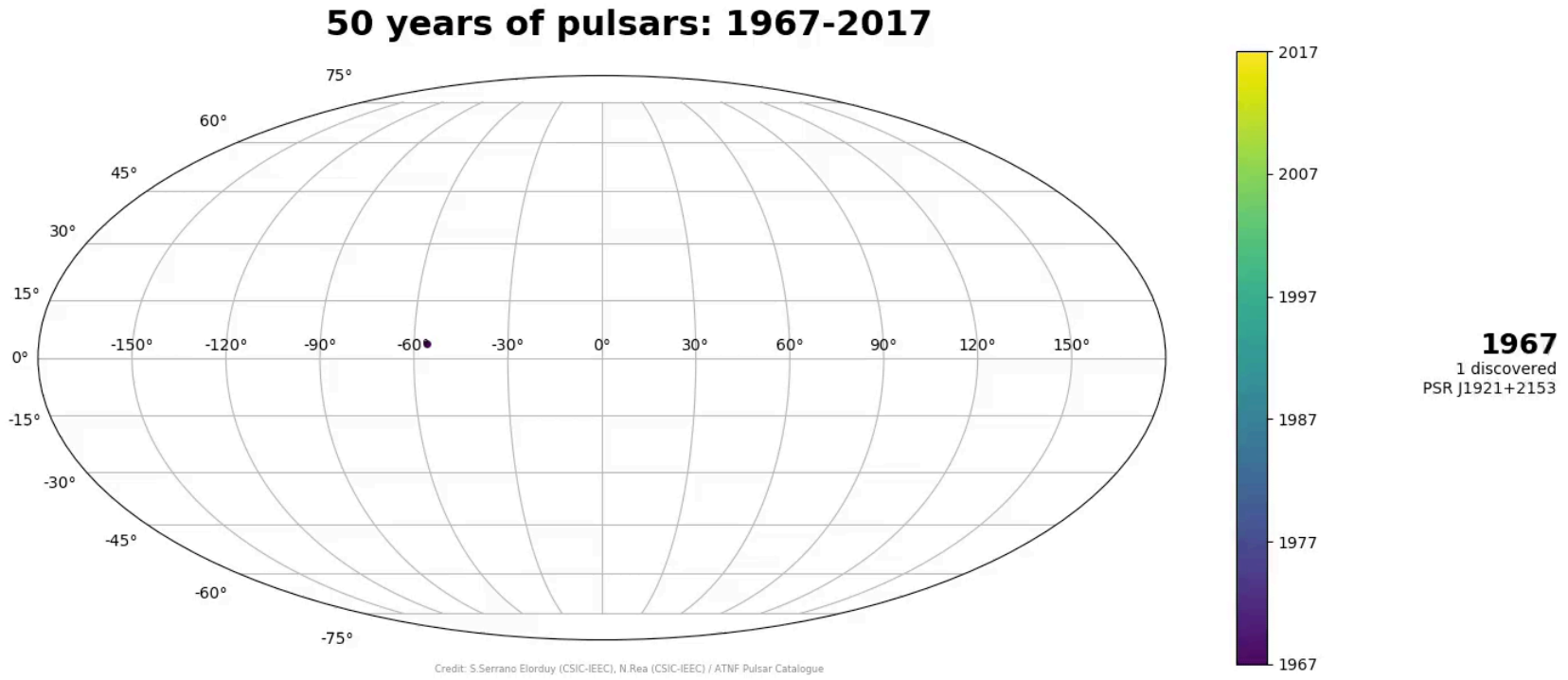
Pulsars

- Highly magnetized rotating neutron star
- Born in supernova explosion of massive stars (8-10 solar mass)
- Multiwavelength emission: radio, optical, X-ray, gamma rays





Pulsar Population



Rea 2017, Nature Astronomy, Vol. 1 p 829

- > 2900 in ATNF pulsar catalog
- > 250 Fermi-LAT γ-ray pulsars (Only **7** seen by EGRET in the 90's)

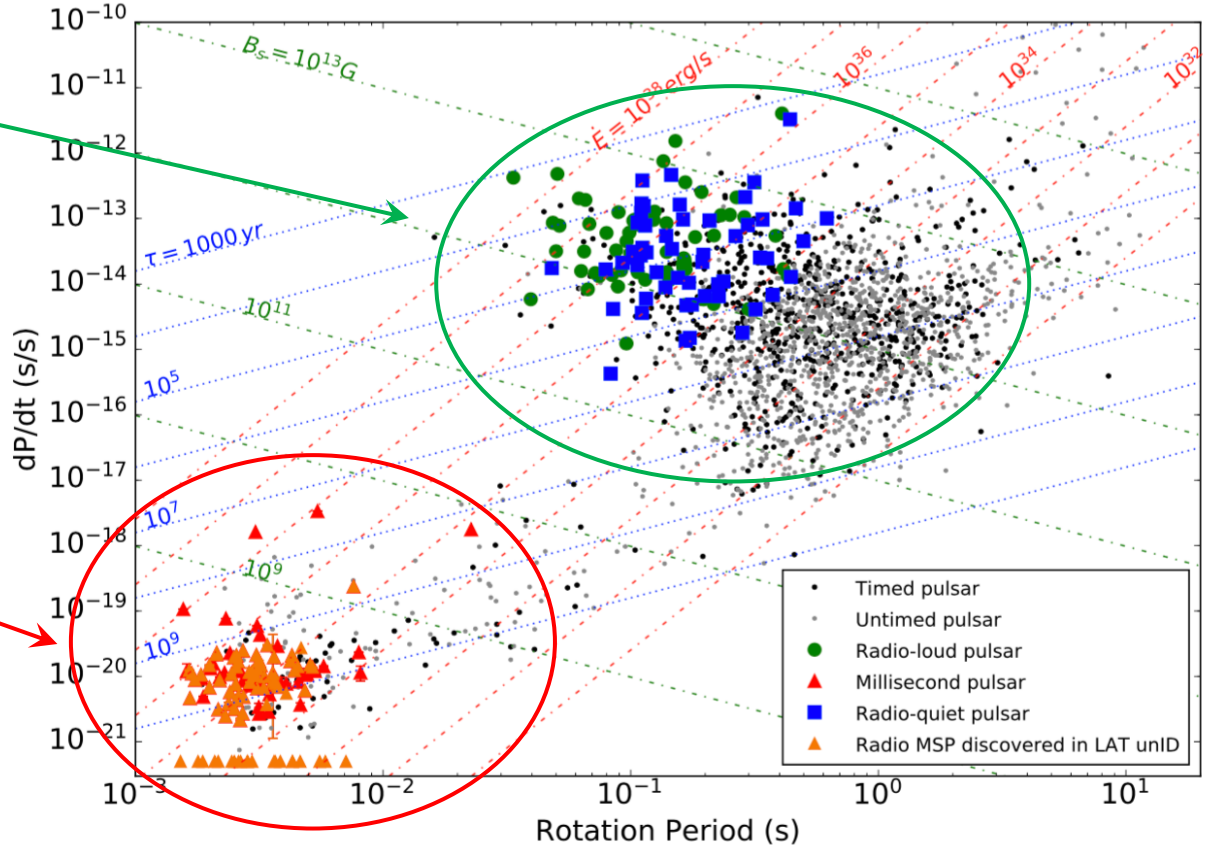
Public list: https://confluence.slac.stanford.edu/display/GLAMCOG/Public+List+of+LAT-Detected+Gamma-Ray+Pulsars

Pulsar Population

(Smith et al. 2017)

Young or middle aged: normal pulsars

Millisecond pulsars (MSP)



- MSPs are spun up or "recycled" through accretion from a binary companion star
- Colors: Fermi-LAT γ-ray pulsars

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Fermi-LAT Pulsar Search Techniques

1. Folding γ-ray photons using known pulsar ephemerides (timing model) from radio or X-rays (ex. 6 EGRET pulsars).

2. Blind searches for pulsations directly in the γ-ray data.
   - difficult

3. Multi-wavelength observations of LAT unidentified sources
   - Deep radio searches
   - Optical and/or X-ray counterpart identification

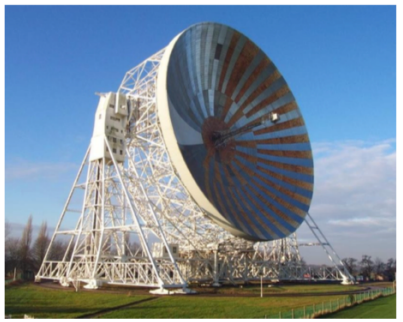
Folding with known ephemeris

==> over 50% of the current detection

Nanshan (China)

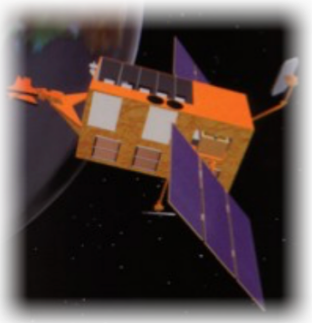
Nançay (France)

Parkes (Australia)

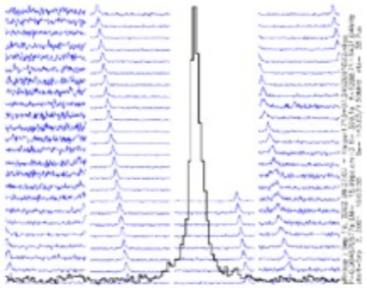


Jodrell Bank (UK)

Green Bank (US)



RXTE (X-rays)



+ other punctual contributions from Arecibo, Westerbork, etc.

Large pulsar timing campaign, allowing pulsation searches for >700 pulsars!

(Smith, Guillemot, Camilo et al., A&A 492, 923, 2008)

Thanks to all members of the Pulsar Timing Consortium!

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contributions
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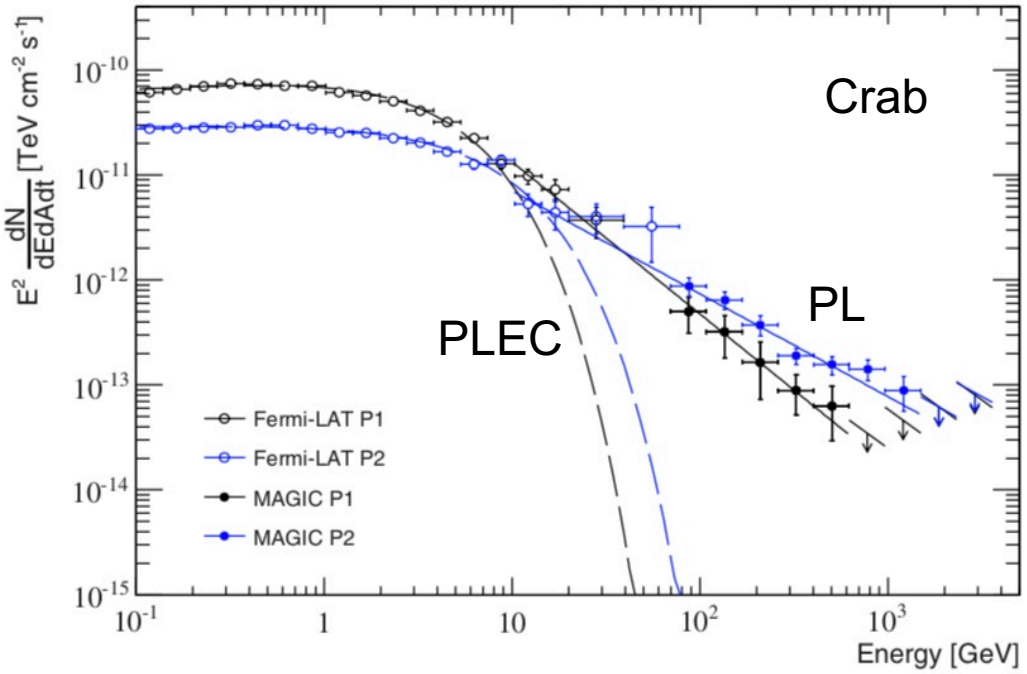
γ-ray Pulsar Spectrum



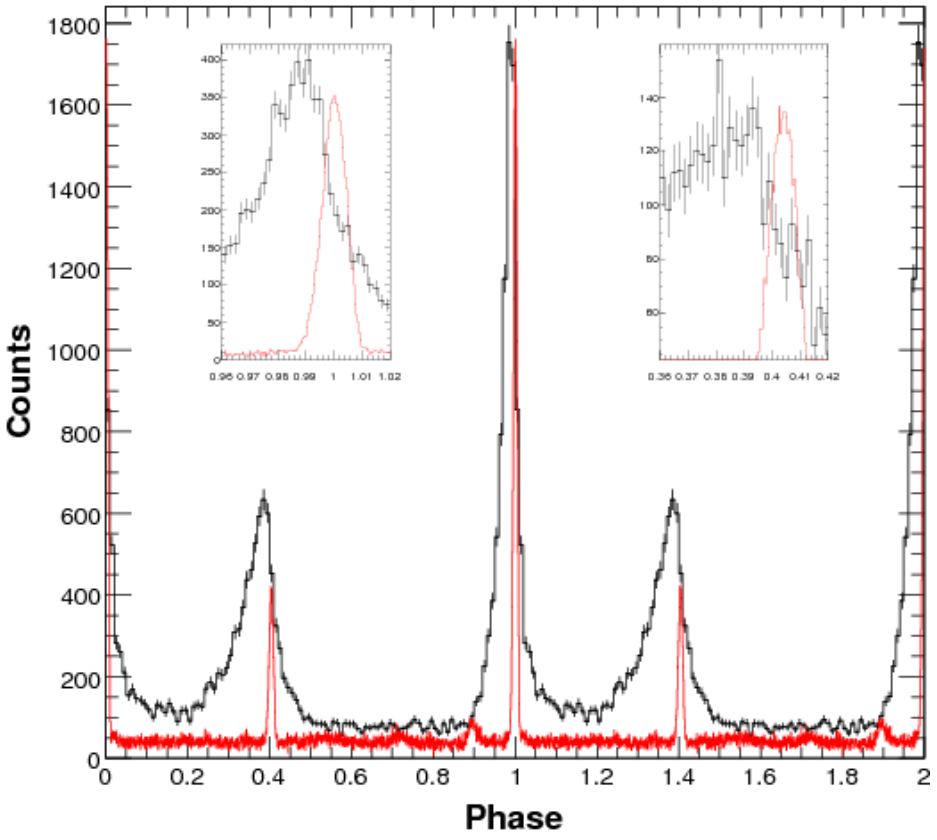
(MAGIC collaboration 2016)

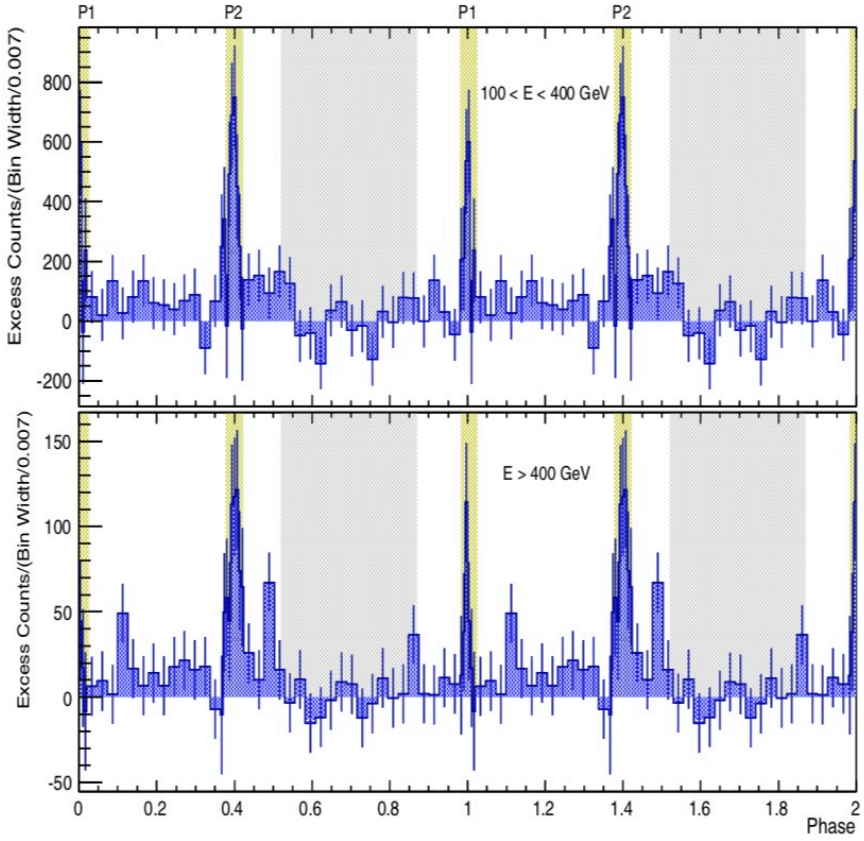
- LAT: PowerLaw + Exponential cutoff (PLEC)
- Cutoff at a few GeV: synchro-curvature inside the light cylinder
- BUT: Vela, Crab, Geminga and B1706-44 detected at >100 GeV by IACTs (HESS, MAGIC, VERITAS…)
- Theories: synchro-curvature or ICS (in the magnetosphere or in the pulsar wind)

γ-ray Pulse Profile

typically 2 peaks

VHE synchonized with HE: same emission region (ICS)





(Fermi-LAT collaboration 2010)

Black: LAT; Red: radio

Crab

(MAGIC collaboration 2016)

Search Pulsar with LHAASO

Folding LHAASO photons using ephemerides from Fermi-LAT

Motivation:

Prob particle acceleration at VHE in small scale

Advantages of LHAASO:

1. Survey mode: large sky coverage, good for systematic searches of TeV pulsars
2. Large photon collection: good for pulsation search
3. Continuous survey: good for accumulating the pulsation significance

1. 大视场巡天，覆盖脉冲星数量多，可以对脉冲星进行系统性搜索
2. 收集光子数多，有利于脉冲搜索
3. 不间断巡天，有利于提高脉冲的显著性

Search Pulsar with LHAASO

Folding LHAASO photons using ephemerides from Fermi-LAT

Feasibility:

1. Lower energy band of LHAASO at hundreds of GeV, comparable sensitivity to HESS, MAGIC, etc.
2. Known LAT pulsar positions, no need for high angular resolution of LHAASO
3. Lower background subtraction requirement of pulsation search than source detection, only need a good timing model
4. We have good experience in pulsar searching
5. Fermi-LAT could provide updated and continuous timing models as well as technical supports

Search Pulsar with LHAASO

Folding LHAASO photons using ephemerides from Fermi-LAT

General plan:

1. Select good candidates of >100 GeV/TeV pulsars from LAT pulsars
2. Update LAT pulsar timing models each half or one year: follow the similar strategy of searching LAT pulsars using radio timing models
3. Fold LHAASO photons using updated timing models

Pulsations might be detected (> 5σ) by LHAASO earlier than the pulsar source detecion, due to different test methods in timing and source deteciton, as well as possoible sharp pulsation peaks (happend with Fermi-LAT)

Technical requirements:

1. Develope tempo2 plugin for LHAASO as is done for Fermi-LAT
2. Develope pulsar search pipeline

Summary

- Pulsar search is a good science for LHAASO
- We have advantages and experience/resources to carry out the project

Thanks!