Understanding pulsars and their environments at Very-High Energies

1st VHEGAM meeting: LST proposals by the Italian community

Giulia Brunelli (University of Bologna and INAF-OAS Bologna)

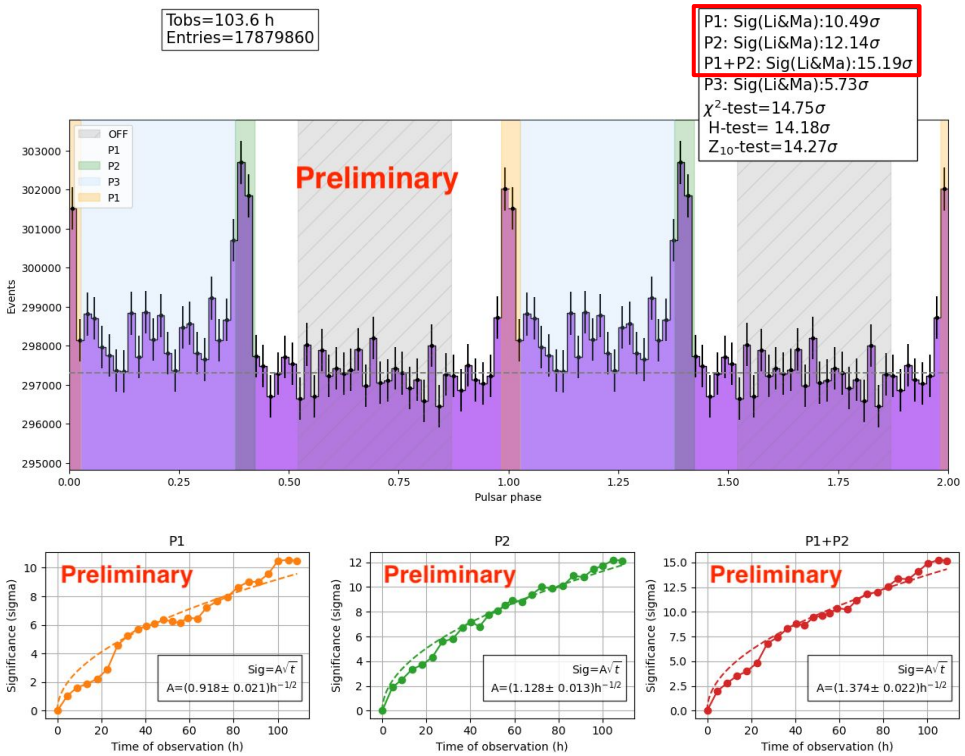
Supervisors:
Vito Sguera (INAF-OAS Bologna)
Roberta Zanin (CTAO)
Cristian Vignali (University of Bologna)

Pulsar studies with the LST-1

On behalf of the pulsar team: Giulia Brunelli, Álvaro Mas-Aguilar (GAE-UCM), Giovanni Ceribella (MPP), Rubén López-Coto (IAA) and Marcos López-Moya (GAE-UCM)

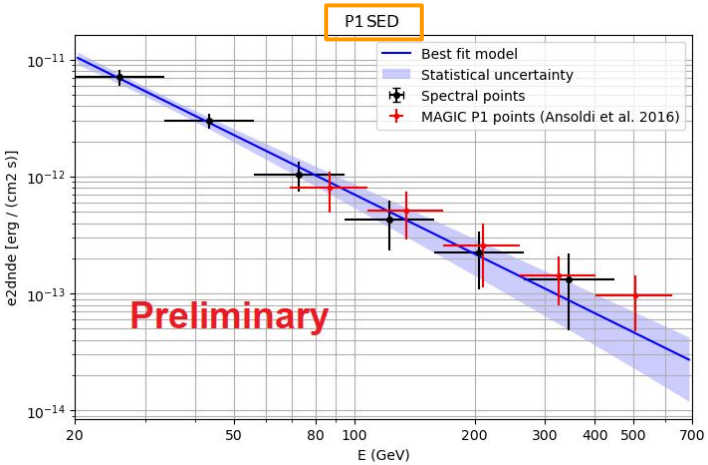
Results on the Crab pulsar: phaseogram

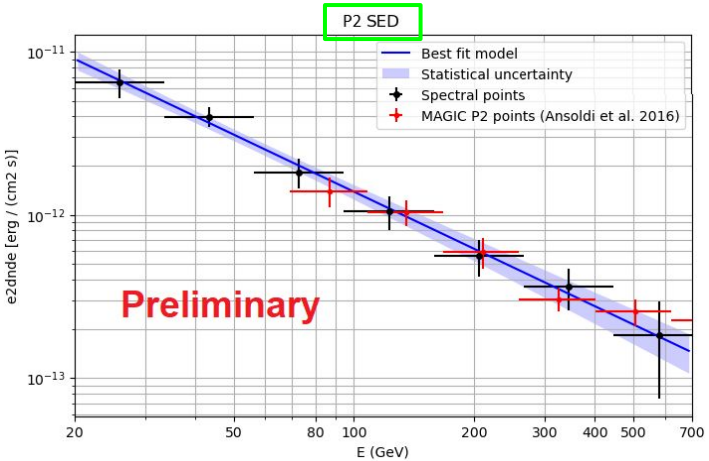
- First pulsar detected by the LST-1 in 2019, regularly observed during the commissioning phase[1]
- 103 hours of good quality data with zenith angle zd<50°
- Both peaks detected above 10σ, bridge emission at ~6σ



Results on the Crab pulsar: SED

- P1 steeper than P2:
  - **P1 SED**: PL with $\Gamma = -3.69 \pm 0.19$ up to 450 GeV
  - **P2 SED**: PL with $\Gamma = -3.16 \pm 0.10$ up to 700 GeV
  - Compatible with previous MAGIC results[2]

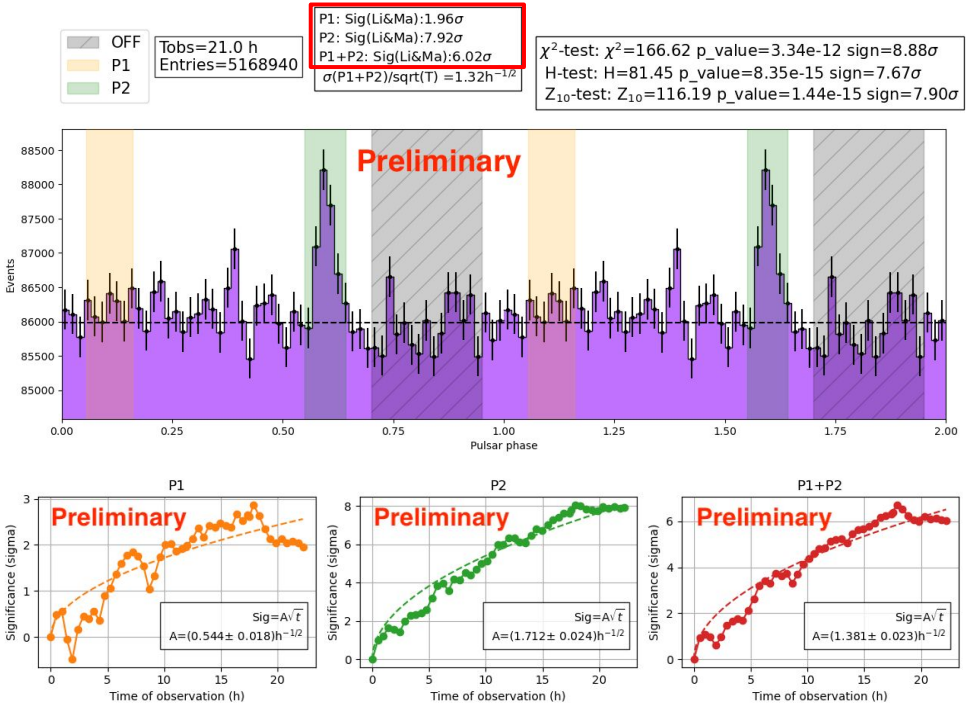




- Joint fit with *Fermi*-LAT confirms a PL extension at VHEs

Results on the Geminga pulsar

- Detected for the first time by MAGIC in 2020[3]; second pulsar detected by the LST-1 in 2022
- 21 hours of good quality data with zenith angle zd<25°
- P2 detected at ~8σ
- P1 not detected for now



Summary and future prospects

- Excellent performance of the LST-1 and low energy threshold
- More studies are needed to shed light on the emission mechanisms
- Current status:
  - The analysis of the Crab is being completed
  - The new cycle of observations of Geminga has started
- A new candidate for the the LST-1 is the **Dragonfly pulsar** (PSR J2021+3650):
  - Young (τ_c ~ 17 kyr) radio pulsar with a period of P ~ 104 ms
  - Detected in the γ-rays for the first time in 2008[4] and in 2009 by *Fermi*-LAT[5]: the light curve exhibits two narrow peaks
  - LST-1 is a good candidate for the observation of Dragonfly: visible at low zenith (zd<25°), most of the emission concentrated in the GeV band, summer source

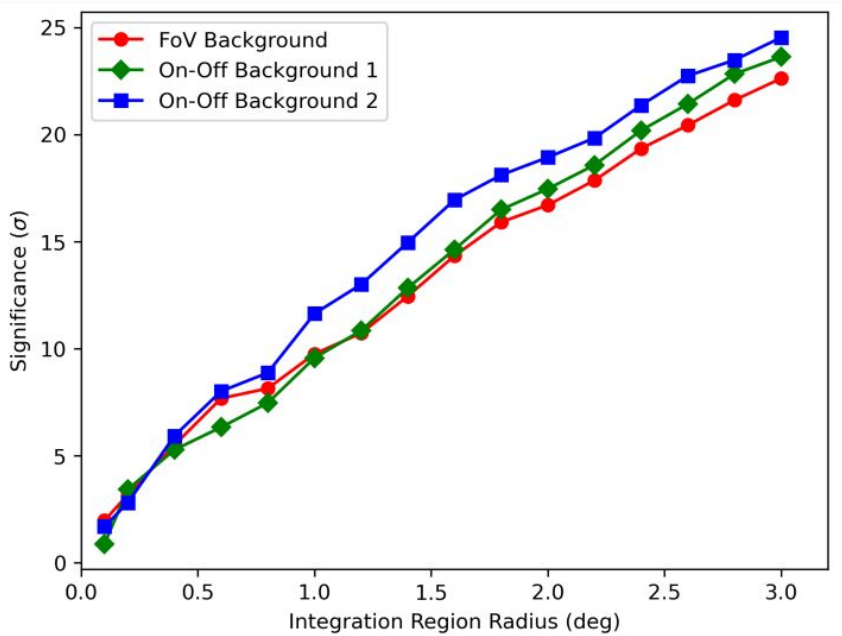
Pulsar TeV haloes

TeV haloes

- Degree-wide TeV emission thought to be generated via Inverse Compton scattering of the ambient photon fields
- Commonly found around middle-aged pulsars (τ_c > 10s kyr)
- Still not well known, but relevant also for cosmic ray transport
- Mainly observed with particle detectors → challenging for IACTs due to their small FoV and the large source extension

H.E.S.S. Collaboration results on the Geminga halo

- First detection of a TeV halo with an IACT
- Wobble observations with a 1.6° offset and different background estimation techniques
- The source is larger than 3° → the true extent within the H.E.S.S. energy range is ~50 pc
- Low magnetic field to match the X-ray observations



References

[1] *Observations of the Crab Nebula and Pulsar with the Large-sized Telescope Prototype of the Cherenkov Telescope Array* (LST Collaboration, 2023)

[2] *Teraelectronvolt pulsed emission from the Crab Pulsar detected by MAGIC* (Ansoldi et al, 2016)

[3] *Detection of the Geminga pulsar with MAGIC hints at a power-law tail emission beyond 15 GeV* (MAGIC Collaboration, 2020)

[4] *Discovery of High-Energy Gamma-Ray Pulsations from PSR J2021+3651 with AGILE* (Halpern et al, 2008)

[5] *Pulsed gamma-rays from PSR J2021+3651 with the Fermi Large Area Telescope* (Abdo et al, 2009)

First results of pulsar observations with the LST-1 (Mas-Aguilar et al, 2023)

Detection of extended γ-ray emission around the Geminga pulsar with H.E.S.S. (H.E.S.S. Collaboration, 2023)