Search for VHE Emission from the MSP PSR J0218+4232

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Introduction

PSR J0218+4232 is one of the most energetic millisecond pulsars (MSPs) known and has been considered one of the best candidates for Very High Energy (VHE) gamma-ray emission (E>100 GeV). We analyze 11.5 years of Fermi-LAT data (100 MeV-870 GeV) + ~90 hours of MAGIC data (20 GeV - 20 TeV). We find evidence for pulsed emission above 25 GeV based on Fermi-LAT data, but no evidence of VHE emission with MAGIC. We give an overview of the theoretical models that can interpret the lack of VHE emission.

Overview of PSR J0218+4232

- 2.32 ms pulsar (VLBI parallax)
- MSP + white Hb dwarf (~ 0.2M_
- 2 day orbital period
- Distance d ~ 3kpc
- Bright in Radio, X-rays, hard X-rays (non-thermal emission) [1]

Fermi-LAT Analysis

- 1st detection of GeV γ-ray pulsations by Fermi-LAT [2]
- Hints of pulsed emission >10 GeV in 1PFL catalogue [3]
- Hints of pulsed emission >25 GeV [4]

We give an overview of the theoretical models that can interpret the lack of VHE emission.

Motive for VHE Observation:

- 1st detection of GeV γ-ray pulsations by Fermi-LAT [2]
- Hints of pulsed emission >10 GeV in 1PFL catalogue [3]
- Hints of pulsed emission >25 GeV [4]

Overview of Fermi-LAT Analysis

- 11.5 years of data (August 2008 - February 2020).
- Energy range: 100 MeV - 870 GeV
- Region of Interest (RoI): 15° x 15°

Search for Pulsed emission > 1 GeV:

- PDF Test Statistic (TS)
- Null Hypothesis: NO pulsation (in HE range)
- Likelihood Ratio test: determine if HE events have ~ distribution
- Probability Density Function (PDF)

Fermi-LAT Phasogram

- Regions of Interest (RoI): 15° x 15°
- Energy range: 100 MeV - 870 GeV
- Low-energy template

LAT Spectrum

- Falls steeply (Γ=4.5) at E>10 GeV
- Extracted from the whole phase range.
- E>20 GeV: Upper limits only

Power Law with Exponential Cutoff

\[ \frac{dN}{dE} = \frac{N_0}{(E/E_0)^\Gamma - 1} \exp(-E/E_0) \]

E > 10 GeV

\[ N_0 = 0.03 \times 10^{11} \text{cm}^{-2} \text{s}^{-1}\text{MeV}^{-1} \]

MAGIC Analysis

- 87 hours of data (Nov. 2018- Nov. 2019).
- Stereoscopic mode with Sum-Trigger-II system [5]
- Zenith range = 13°-30°
- Atmospheric Transmission > 0.85

Implements the MAGIC Data in the sub-100 GeV range.

MAGIC Spectrum

- Energy range > 20 - 200 GeV
- NO evidence of Pulsation
- Background estimation: 3 source-free reflected regions
- NO detection of PSR J0218 at VHE
- Theoretical Models:
  - SC model
  - No detection of PSR J0218 at VHE
  - No Pulsed/Unpulsed Emission in MAGIC data (E>100 GeV)

Lack of VHE emission (MAGIC)

- Consistent with theoretical models:
  - Models do not predict VHE emission.

We are searching for a second component of charged and accelerated particles able to emit VHE emission.

Theoretical Modelling

- Force-free magnetosphere Model [6]
  - Trajectories of particles injected at neutron star surface
    - From UV to VHE γ-ray
    - 2 populations of particles
      - Primary e^+/e^-: accelerated by E_0
      - Secondary e^+/e^-: from polar cap pair cascade
  - Emission: Synchro-Curvature and Inverse Compton
  - Although the model can account for the detected X-ray emission, it fails to predict the correct level (and spectral shape) of the LAT-detected GeV emission, suggesting that further refinements are required.

Lack of VHE emission (MAGIC)

- Consistent with theoretical models:
  - Models do predict VHE emission.

We are searching for a second component of charged and accelerated particles able to emit VHE emission.

References


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