Pulsations from the Vela Pulsar Down to 20 GeV with H.E.S.S. II

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Origin of the gamma-ray pulsed emission and its detections

Year 2015: >160 HE pulsars, 2 VHE pulsars

Detections by IACTs:
- Crab: 25 GeV – 1.5 TeV (MAGIC, VERITAS)
- Second VHE pulsar: Vela: 20 – 120 GeV (H.E.S.S. II)
Observations

- 24h high quality data collected in 2013 and 2014

- Zenith angle range [20° - 35°]
  - Mean 26°

- Disregarding information for CT 1-4

- Two glitches during observation period
  - MJD 55408
  - MJD 56555
Region of Interest

- 60 months of *Pass 8 Fermi*-LAT data were analysed

- Phase regions determined:

![Histogram showing regions P1, P2, P3, and background](image-url)

Fermi-LAT
> 10 GeV

Counts/bin

Phase
Reconstruction and Analysis

- Multivariate analysis using Hillas parameters and parameters from a 3D model of the air shower
  - Lemoine-Goumard, Degrange, and Tluczykont 2006
- Analysis cuts optimised for $\gamma$ ray events below 100 GeV to give the lowest energy threshold
- Effective area at 20 GeV and 20° zenith angle:
  \[ 1.9 \times 10^3 \text{ m}^2 \]
- Phasing of events done with an interface with the Tempo2 package
- Use the phase background region to determine excess in the P2 phase region

*Thanks* to Dr. Matthew Kerr of the Fermi-LAT collaboration for the pulsar timing solution
Phase Profile

- Pulse P2
- 9838 excess events
- H test significance
  14.6σ (pre-trials)
- Li-Ma significance
  12.8σ (pre-trials)
Stability with Time

- Li-Ma significance against size of the data set
- Expected square root dependence is observed
- Steady increase in significance throughout the data set
Stability in the Camera

- Look at events from the complete field of view
- Consider the number of pulsed excess counts as a function of the angular distance from the pulsar in the sky
- Distinct excess at the test position in the sky
Pulsed Li-Ma Significance Sky Map

- Compatible with a point source located at the position of the Vela pulsar from Radio observations
  - RA 08h 35m 21s
  - DEC -45° 10′ 35″
Pulsed Li-Ma Significance Distribution

- Consider the significance value over the entire sky map (previous slide)
- Excluding the gamma-ray source (outside the red line) gives good agreement with standard normal distribution

\[
\chi^2 / \text{ndf} = 170.9 / 105
\]

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>169.9 ± 2.4</td>
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<tr>
<td>Mean</td>
<td>0.1925 ± 0.0117</td>
</tr>
<tr>
<td>Sigma</td>
<td>0.9831 ± 0.0082</td>
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Energy Distribution

- Reconstructed energy distribution of pulsed excess events

- Expected distributions from Monte Carlo for a source with a power law spectrum with index -4.1

- Excellent data-Monte Carlo agreement

- The true energy (light violet) extends below 20 GeV
- H.E.S.S. I ULs and Fermi last energy bin UL constrain the power law obtained from Fermi Pass 8 and HESS II

- H.E.S.S. II energy range
  20 GeV – 120 GeV

- Systematics are under study

- H.E.S.S. II curved fit > 10 GeV is compatible with Fermi broadband fit and >10 GeV fit. But statistics above 10 GeV limit definite distinction between log parabola and power law
Conclusions

- High significance detection of the P2 pulse from the Vela pulsar with H.E.S.S. II
- CT5 able to operate down to 20 GeV using the phase to determine background rate
- Excellent agreement between H.E.S.S. II and Fermi-LAT
- Vela P2 peak spectrum measured up to 120 GeV
- These results will soon be submitted to a journal