Discovery of VHE Emission Near PSR J1831-0952 with HESS: A new gamma-ray Discovered Pulsar Wind Nebula?

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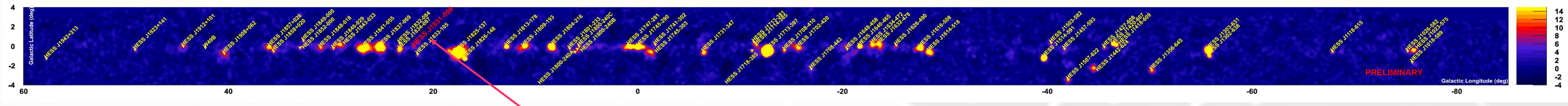
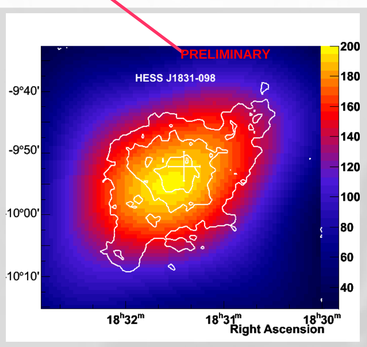
Abstract: The HESS galactic plane survey, undertaken since 2004, has revealed more than 50 Very High Energy (VHE) gamma-ray sources. We report here on the latest discovery of an extended source near the 67 ms pulsar PSR J1831-0952. Adopting the DM distance of the pulsar (4.3 kpc), less than 1% of its spin-down energy would be required to provide the observed luminosity of the VHE source. Multi-wavelength searches have not revealed any other plausible counterpart yet. If the VHE emission originates within a wind nebula around PSR J1831-0952 this would constitute another case of a gamma-ray discovered pulsar wind nebula. The morphology and spectrum of the extended emission, assumed as a single source are presented and its nature is discussed.



Discovery of HESS J1831-098

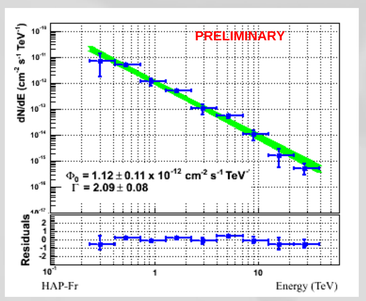
Live Time=40.4 hrs (33.8 hrs corrected)
Significance= 8.4σ with Multi-Variate Analysis [1]
NON = 3168, NOff = 15262, Excess = 484 evts
Position: 277.86°, -9.86°
→ 18h31m26s - 09d 51m 36s
Extended source σ = 0.15° ± 0.03°
(assuming a symmetrical gaussian shape)



Excess with significance contours @ 5,6,7 σ

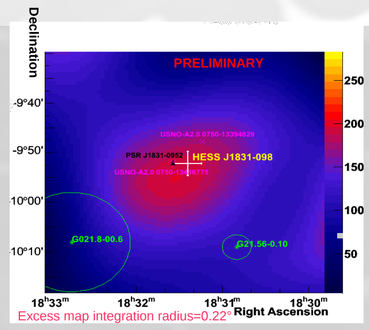
Spectrum

The TeV spectrum with integration radius of 0.3º
power-law fitting result
$\varphi_0(E=1TeV) = 9.5 \pm 1.3 \times 10^{-13}$ cm^{-2} s^{-1} TeV^{-1}
Γ=2.1 ± 0.1 → hard spectrum
Flux (E>1 TeV) = 1.0 x 10^{-13} cm^{-2} s^{-1} (~4% Crab)



Multi-wavelength

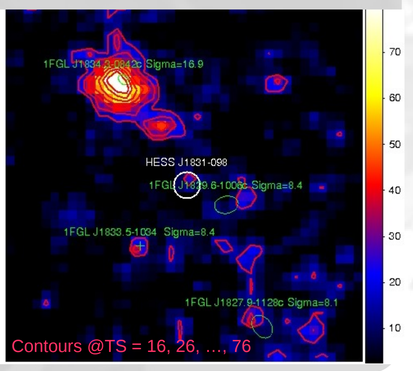
PSR J1831-0952 discovered by Parkes in 2006 [3]
Distance 4.32 kpc, Edot=1.1 x10^{36} ergs/s
P=67.2ms, characteristic age=128 kyrs
Given HESS L_γ(1-20TeV) =1.05x10^{34} ergs/s:
→ needed efficiency of ε = L_γ/Edot ~ 1%
→ size ~ 20 (d/4.32kc) pc
PSR distance to HESS centroid= 0.05° → ~7.4 pc
→ Comparable to other asymmetrical VHE PWNe
→ Would imply PSR transverse velocity ~60 km s^{-1} or a blown wind nebula scenario



Excess map integration radius=0.22°

X-rays
No plausible counterpart (XMM, Chandra, ROSAT)

First Fermi Catalog
No obvious counterpart
Nearby confused source 1829.6-1006c
See detailed 10-100 GeV analysis below



Contours @TS = 16, 26, …, 76

Fermi analysis [10-100] GeV near *l* = 22°

Data set: MJD 54682 → 55661=979 days
8 sources/hotspots (TS > 25) are found above 10 GeV
1FGL J1834.3-0842c, J1829.6-1006c & J1827.9-1128c confused sources split

Source	R.A.	Dec	TS	Comment
J1834.5-0841	18 34 35.9	-08 41 31.3	96	Extended : Part of 1FGL J1834.3-0842c
J1832.7-0914	18 32 43.3	-09 14 15.8	45	Part of 1FGL J1834.3-0842c
J1833.6-1035	18 33 39.8	-10 35 17.5	32	High energy tail of PSR J1833-105 pulsed emission
J1827.3-0844	18 27 22.8	-08 44 55.9	29	Not in 1FGL
J1828.6-1001	18 28 41.1	-10 01 48.2	26	Part of 1FGL J1829.6-1006c
J1828.5-1123	18 28 35.5	-11 23 43.7	26	1FGL J1827.9-1128c
J1825.5-1131	18 25 34.7	-11 31 30.3	26	West of 1FGL J1827.9-1128c
J1831.3-0949	18 31 21.7	-09 49 10.2	25	Accordance with HESS source:

No significant emission is detected : a hot-spot with TS=25 (per-trials) is seen @ R.A. =18:31:21.7, Dec = -09:49:10.2 (near HESS source centroid)
TS rises to 36 in [10-300] GeV (an additional photon of 160 GeV)
TS drops to 12 in [30-100] GeV

U.L. Flux (E 30-100 GeV) ~ 5x10^{-11} ph cm^{-2} s^{-1}

Expected HESS source Flux in the Fermi range :
Extrapolating the HESS integral flux to the 30-100 GeV range (assuming a power-law) **:**
Flux (E [30-100] GeV) ~ 3.5 x10^{-11} ph cm^{-2} s^{-1}
→ Close but lower than the flux U.L. Obtained through Fermi data

Discussion

Origin of The VHE Emission

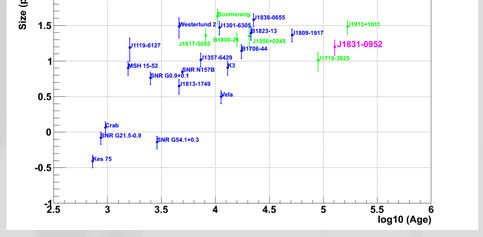
Is HESS J1831-098 the **Wind Nebula** of PSR J1831-0952?

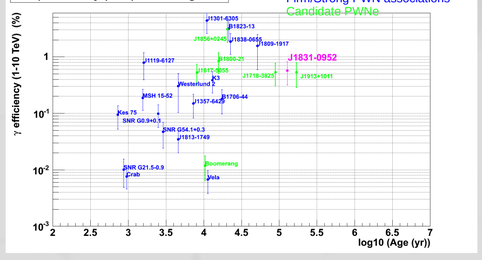
Pros
✓ Energetic pulsar in the vicinity with offset in the range of other asym PWNe
✓ Efficiency (1%) → In the range of other VHE PWN systems
✓ Extended source (20 (d/4.32kc) pc) → In the range of other PWNe

Cons
✗ Age
- 128 kyr and assuming spectrum without cutoff → the maximum measured energy of 30 TeV implies a very low magnetic field of ~1μG (assuming IC scattering of 2.7K CMBR).
- Assuming a magnetic field in the reasonable range of 3 to 5 μG would result in a PWN age of 5 -10 kyr.

However large overestimates may occur as the pulsar characteristic age is estimated assuming that the initial spin period is negligible (i.e. for high spin-down energy loss rate of pulsar); e.g. case of PSR J1400-6326 where true age is 1-2 kyr as compared to characteristic age of 12.7 kyr.

Size and efficiency vs Age





Summary

•A new extended source, HESS J1831-098, has been detected above 230 GeV at a significance level of 8.4 sigma in 33.8 hrs. The source's spectrum is hard with a photon index of 2.1±0.1and with a flux of ~4% of the Crab nebula. It has a large angular size of σ = 0.15˚ and the centroid distance of 0.05˚ from PSR J1831-0952.
•The spatial coincidence with the energetic PSR J1831-0952 favours a wind nebula-type emission, although no PWN at other wavebands has been detected so far.
•If the VHE emission originates within a wind nebula around PSR J1831-0952, this would constitute a gamma-ray discovered pulsar wind nebula; however other scenarios, such as SNR shell emission can not be excluded.
•If the true age is close to the characteristic age, HESS J1831-098 would be among the oldest TeV PWNe.
•The analysis of Fermi data in the [10-100] GeV range shows 8 sources/hotspots in the vicinity of the HESS source. No significant emission is seen above 10 GeV in coincidence with HESS J1831-098. However a flux UL ~ 5x10^{-11} ph cm^{-2} s^{-1} from a TS=25 (pretrials) hot-spot within the boundaries of the HESS source is derived which is higher than its extrapolated flux (E [30-100] GeV) ~ 3.5 x10^{-11} ph cm^{-2} s^{-1}.
•Multi-wavelength (including X-ray) observations of the HESS source are needed for further investigation on its nature.

References

1. Bechereni, Y., et al., to appear in Astroparticle Physics, Volume 34, Issue 12, July 2011, Pages 858-870.
2. De Jager, O.C., and Djannati-Ataï, A., Neutron Stars and Pulsars, Springer ASSL, 357,2009,XV,eds. W. Becker, 451-479.
3. Manchester, R. N., Hobbs, G. B., Teoh, A. & Hobbs, M., AJ, 129, 1993-2006 (2005).