Tenth International Fermi Symposium

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Comparison of astrometric GeV and TeV observations

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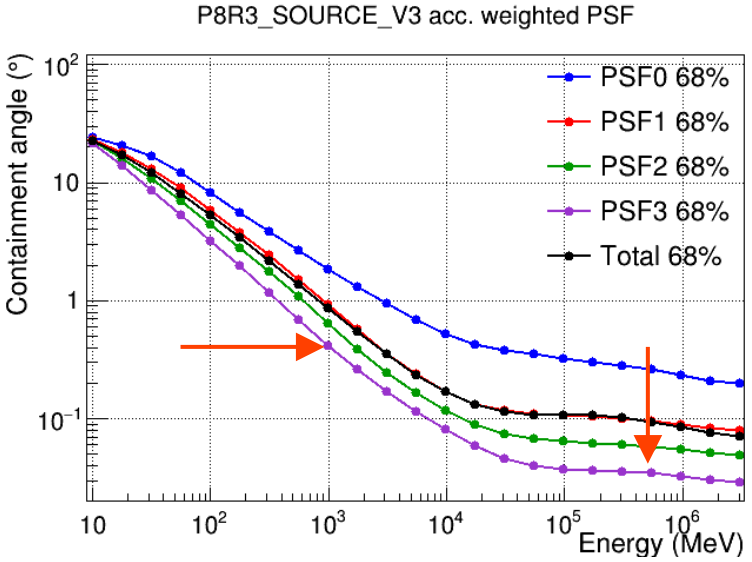
Gamma-ray astrometry

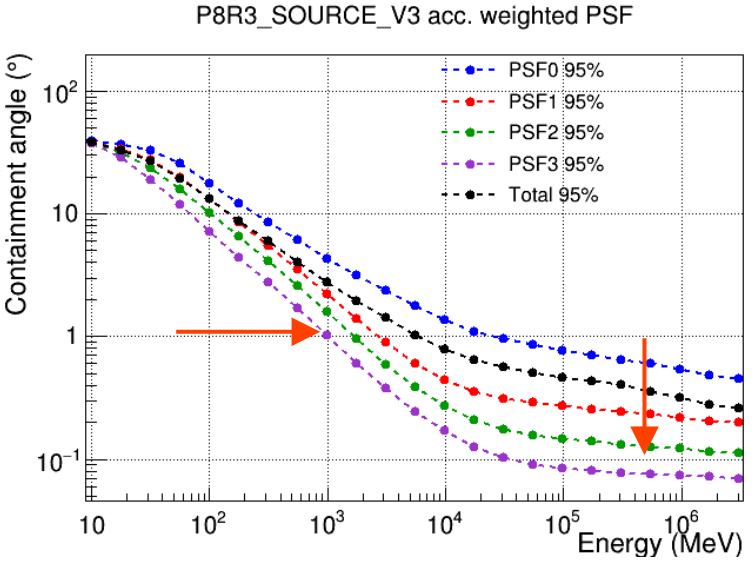
Gamma-ray astronomy (MeV-TeV) does not employ focusing optics.
Poor directional reconstruction of individual photons →
poor angular resolution → poor astrometry (VHE: systematics).
Variability → very high angular resolution (no astrometry)



LAT PSF

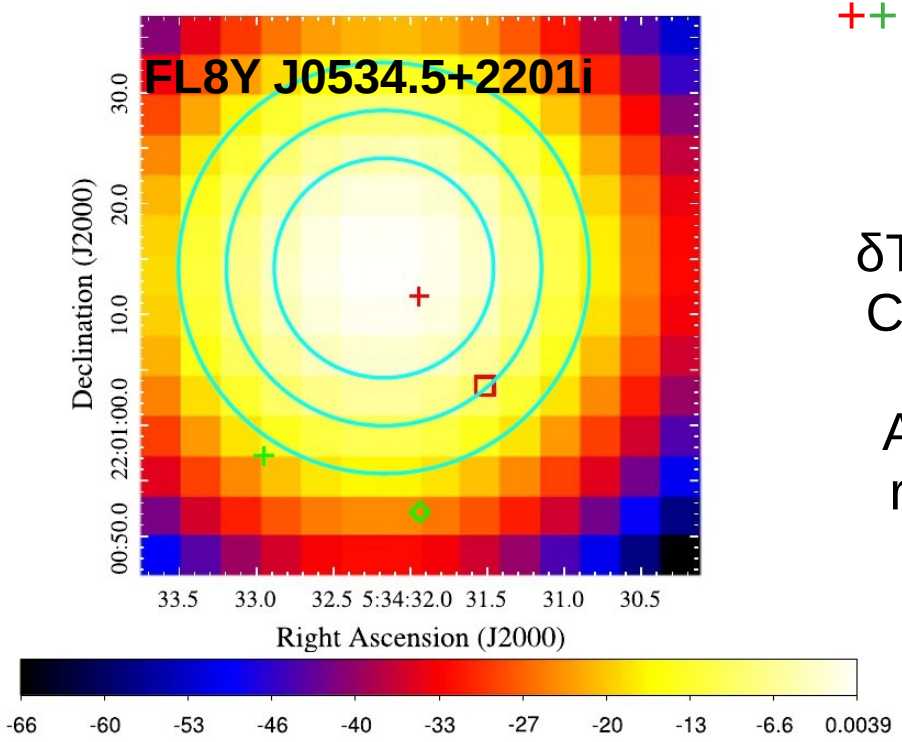
240” @ E>100GeV
For PSF3
(very few photons)

1/√N scaling



Astrometric studies of the Crab

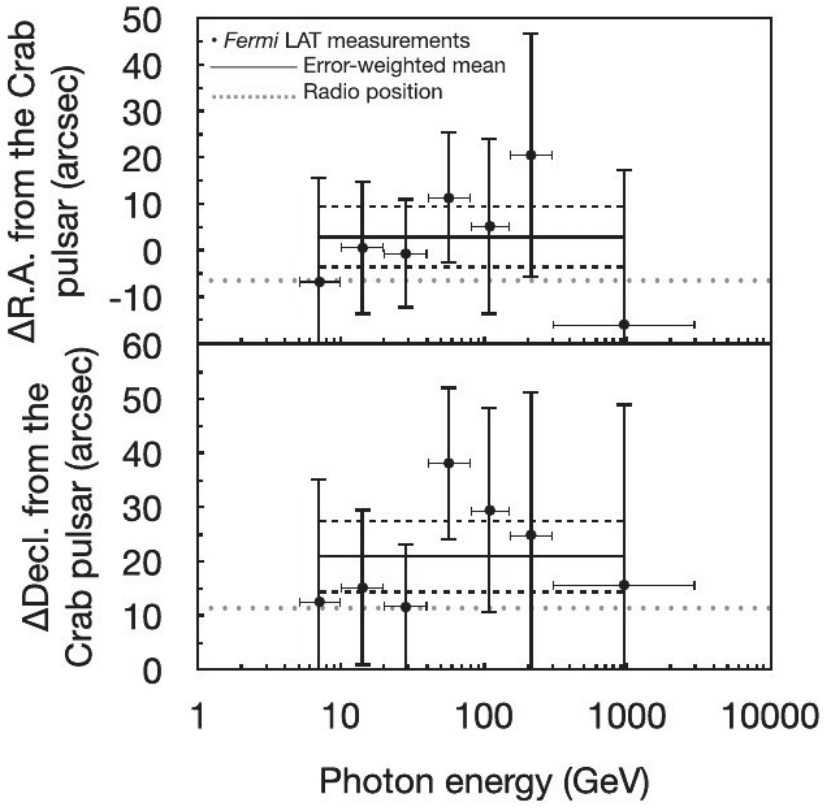
Yeung & Horns, ApJ 875, 123 (2019): 9 years of LAT data, E > 5 GeV
→ marginally significant offset?



++ FL8Y

δTS map of Crab PWN

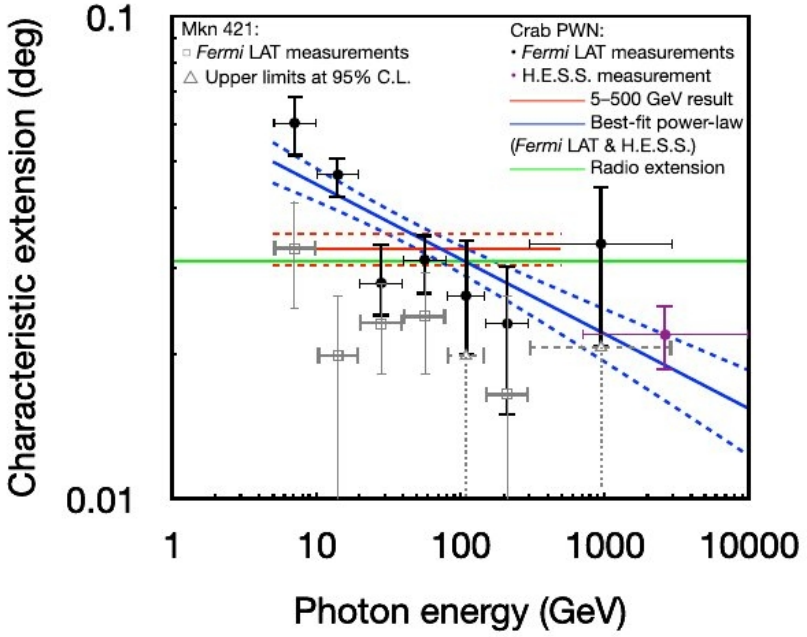
All others removed

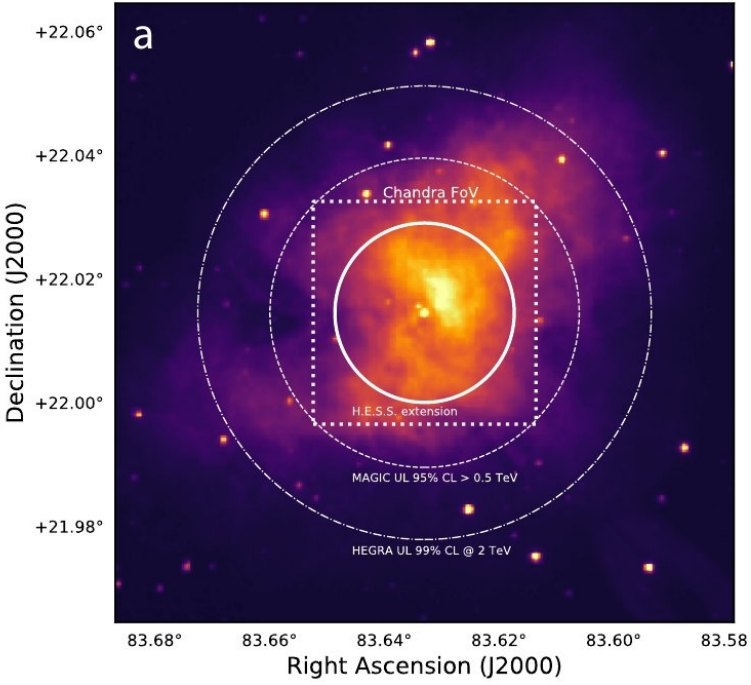


Crab: Extension

Yeung & Horns, ApJ 875, 123 (2019): 9 years of LAT data, E > 5 GeV
Energy dependent morphology (see H.E.S.S. collaboration, 2019, Nat. Ast. 476)

Caveats: single component (Mkn 421-like PSF)



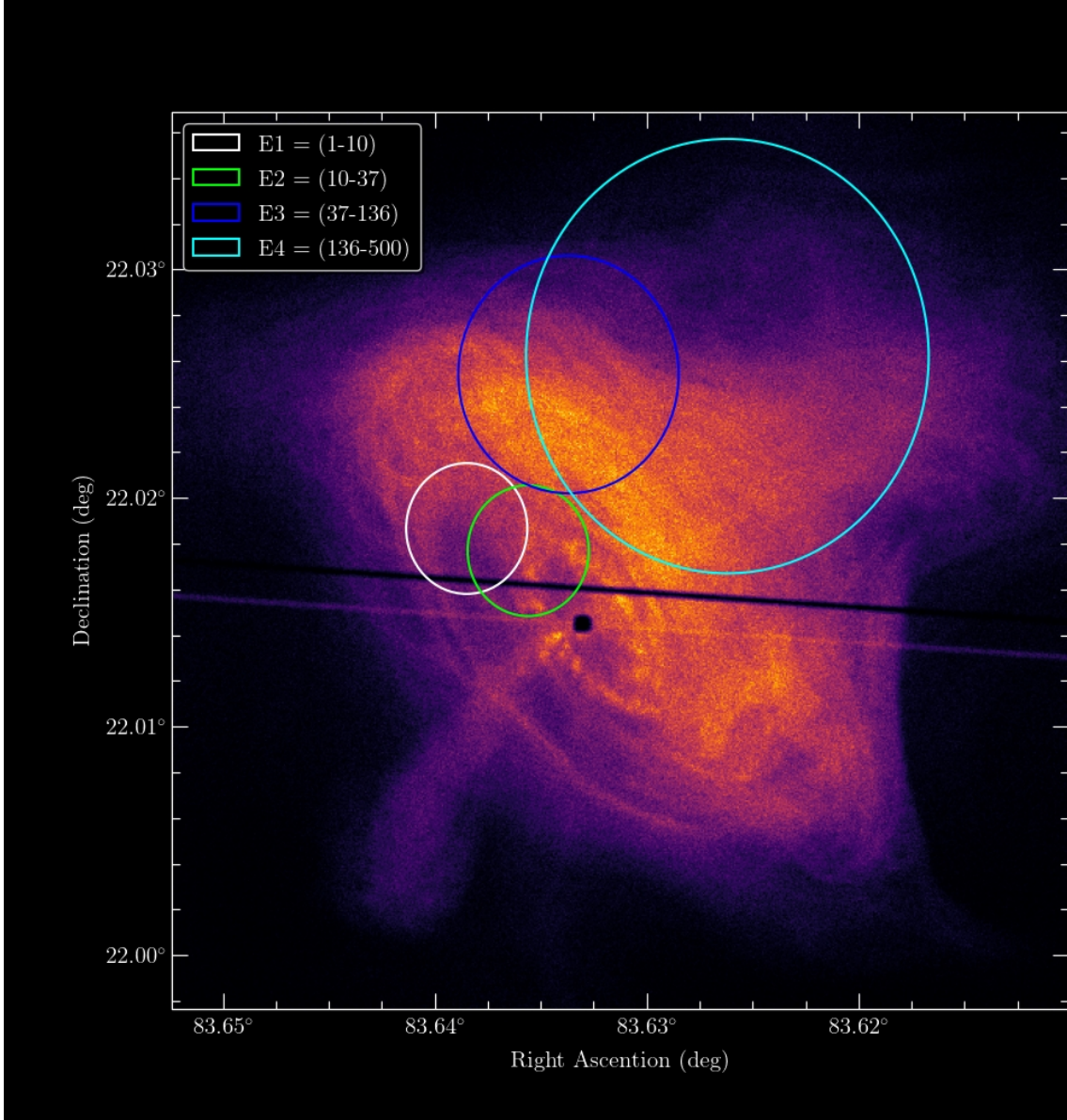


Crab center(s)

Extension of the Crab beyond PSF
→ astrometrometric comparisons
→ repeat Ackermann et al., 2013 (Fermi-LAT, arXiv: 1309.5416)

4 energy bins above 1 GeV, all times
Here: PSF3 SOURCE

All centroids offet from Crab pulsar
Non-monotonous shift with energy.
Uncertainty driven by N_{photon}.



Cross-check astrometry

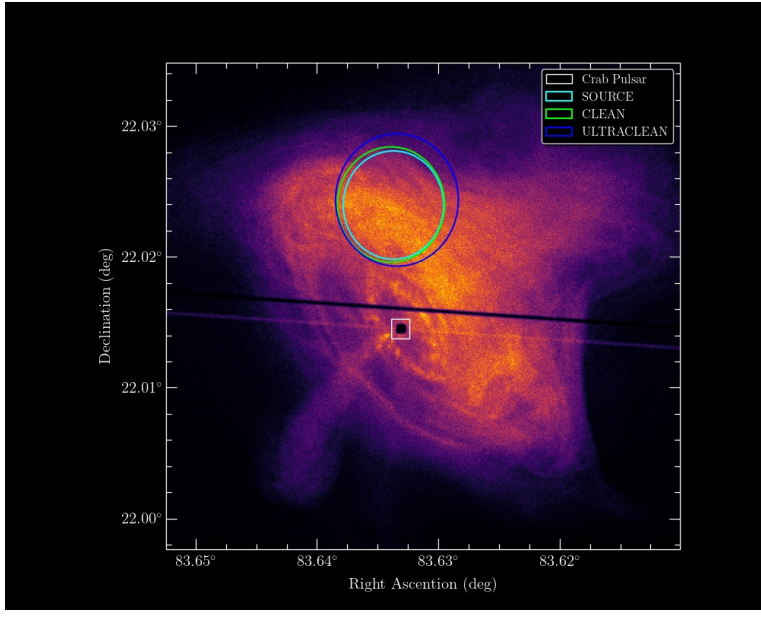
Results have been cross-checked in several ways:

Splitting the whole data set in 2 by time
(2008-2015, 2015-2022);

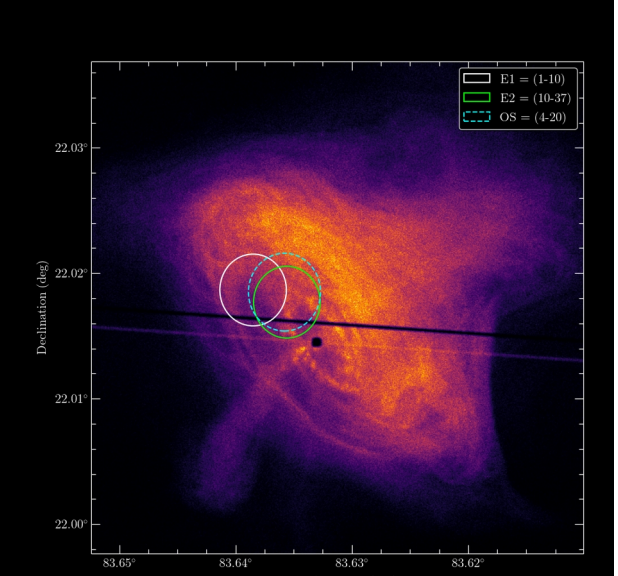
Gaussian/disk convolutions with PSF;

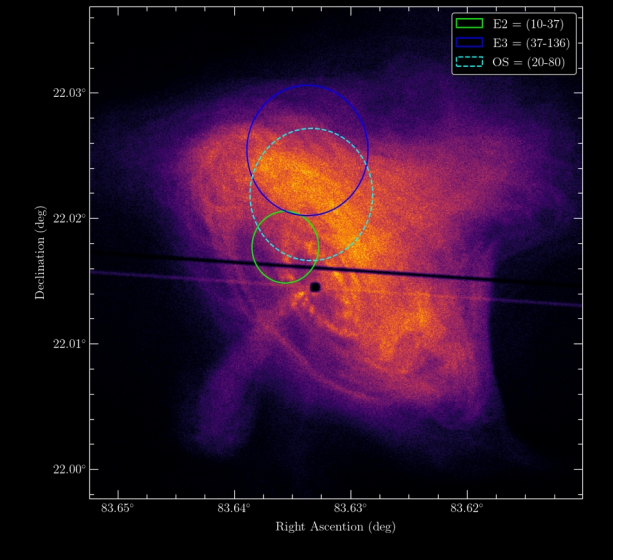
Different photon quality
Quality vs. photon statistics → astrometry;

Comparisons to AGN
(as has been done by most astrometry/PSF studies).



Photon classes 37-136 GeV





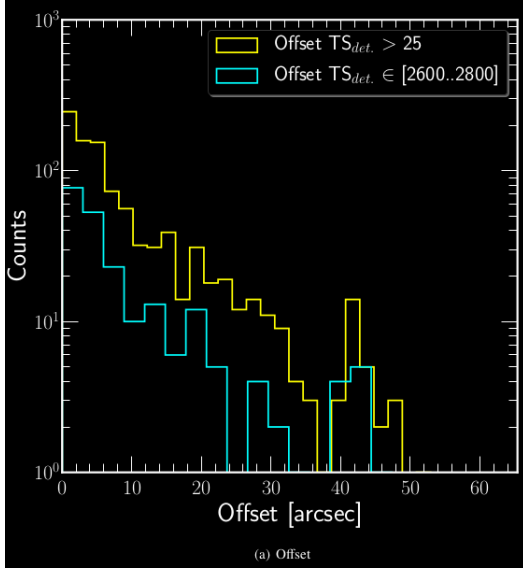
Crab center(s)

Further Tests:

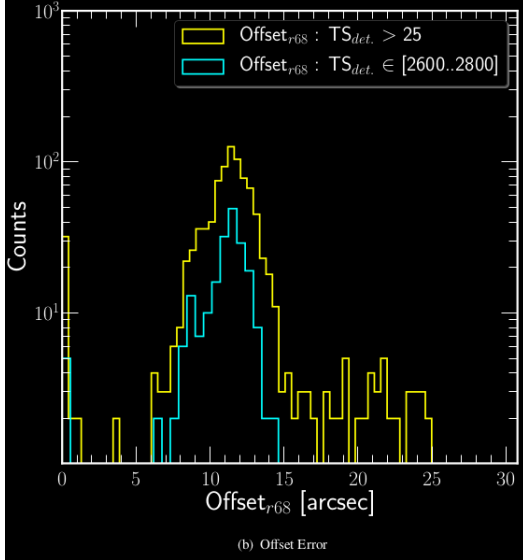
Neighboring sources (e.g. Geminga)
No significant shifts of centroids with E.

Oversampling energy bins
← (non-monotoneous shift).

Model of Gaussian components,
Convolution, background, sampling
and reconstruction or results.
→ consistency



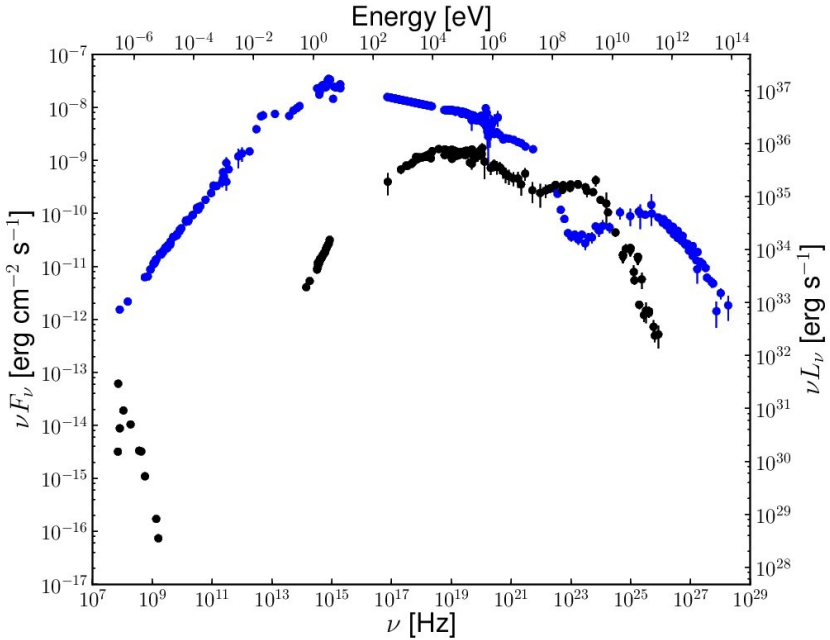
(a) Offset

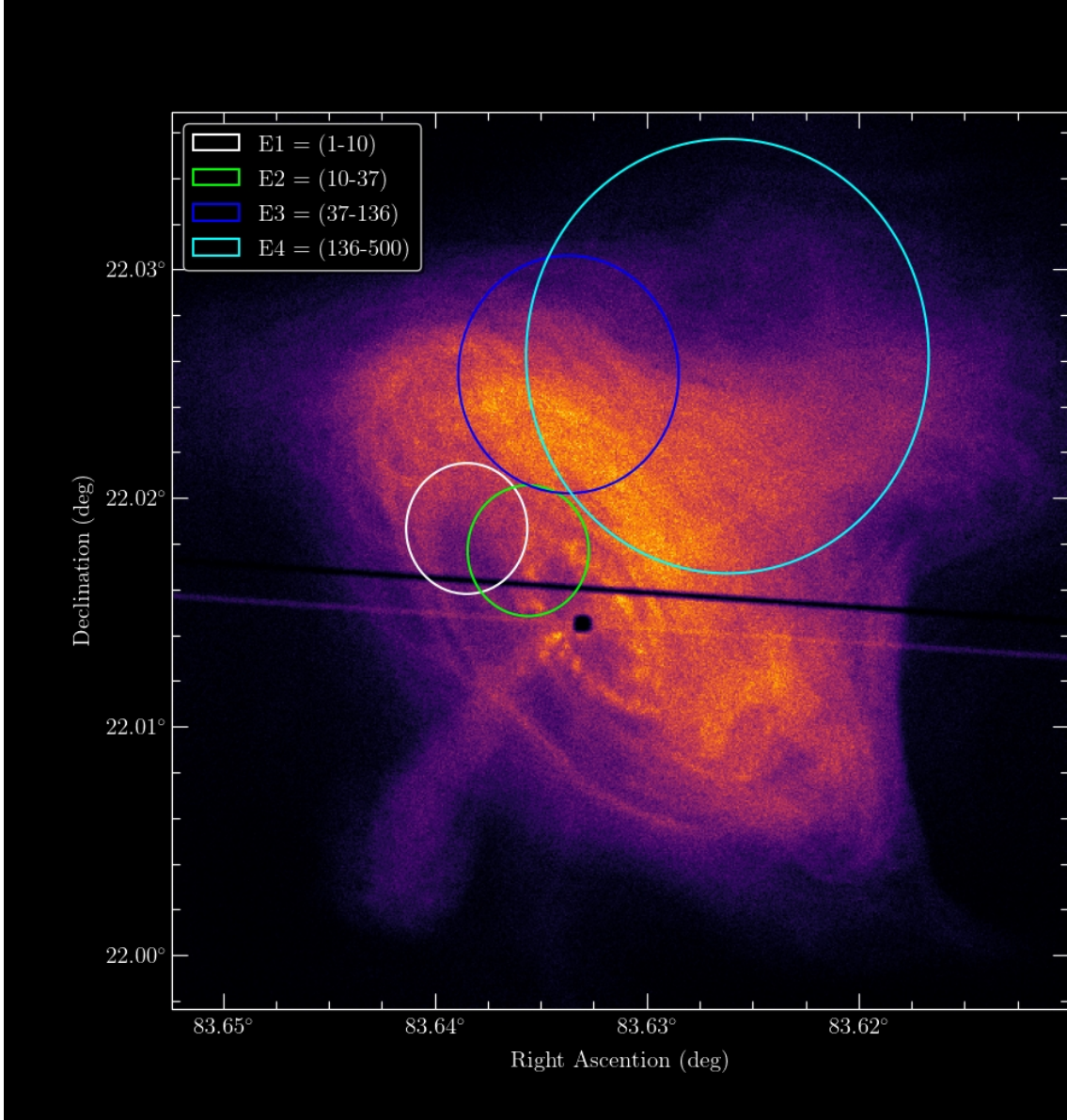


(b) Offset Error

2 components

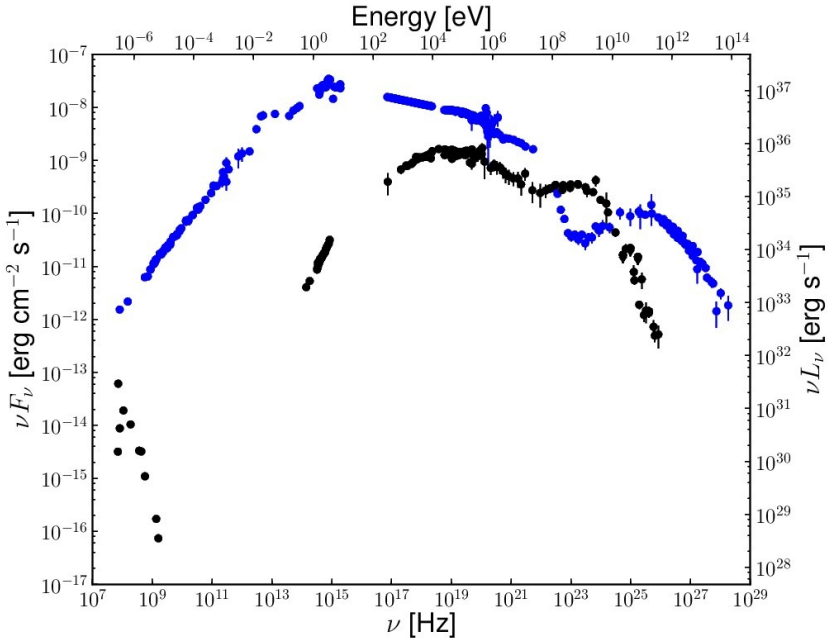
In the 1-10 GeV and 10-37 GeV bands the Crab pulsar dominates the total flux → and the centroids. Gamma-PWN dominates >100 GeV.

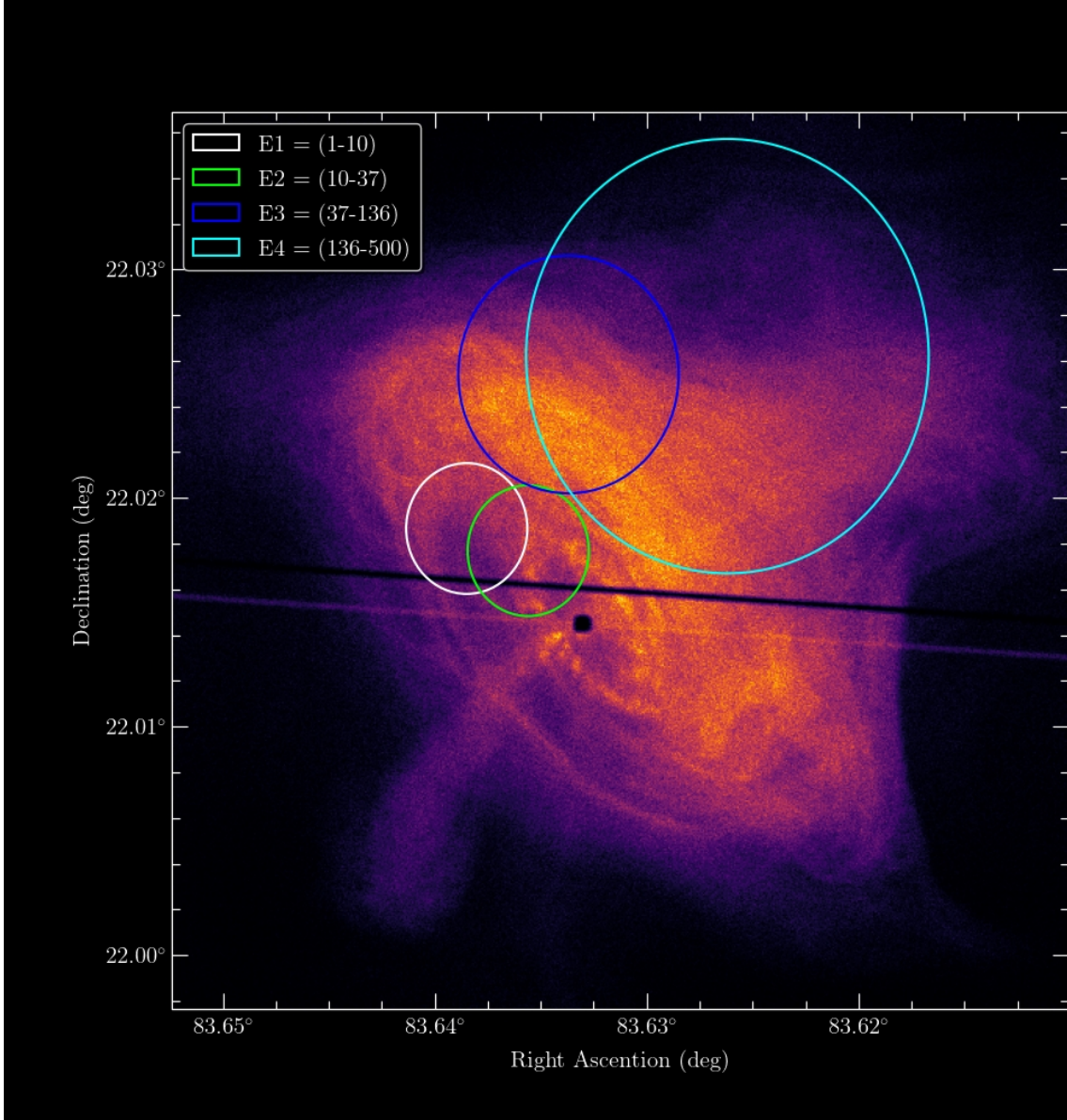




Decomposition

Astrometric decomposition possible.
Two-component-fit required.
Pulsar position/PSF constraints.





VHE Extension

Highest energy bands contain little contamination from pulsar.

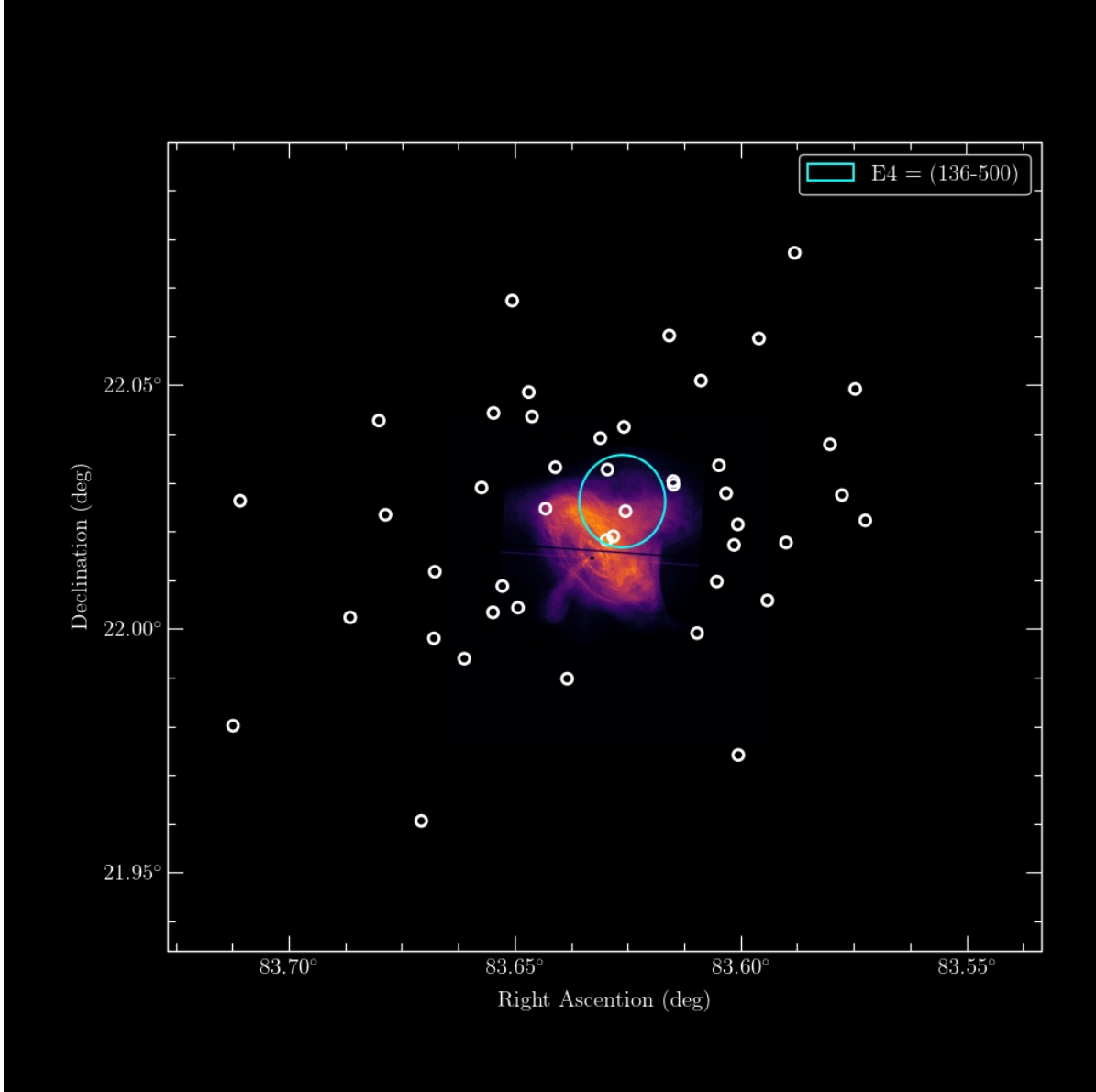
→ 2-component fit not preferred.

Offset from pulsar least significant

Extension highly significant.

Elongation marginally significant.

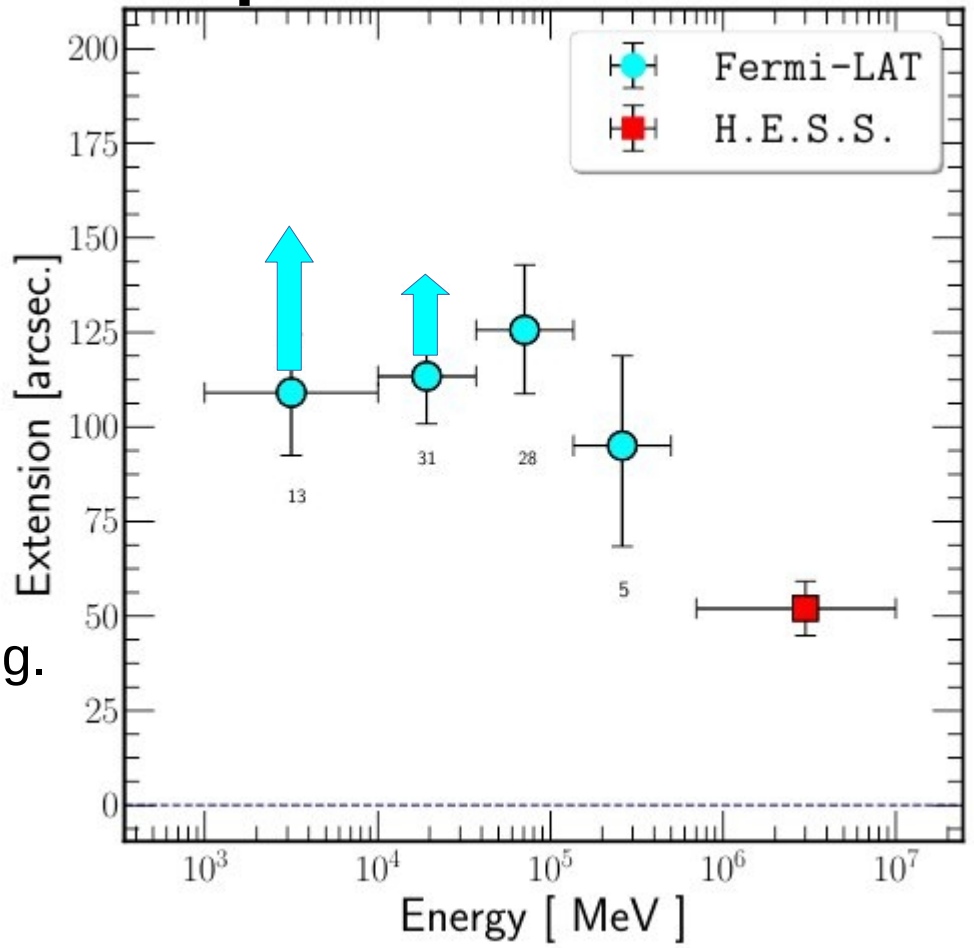
Elongation not along the torus.

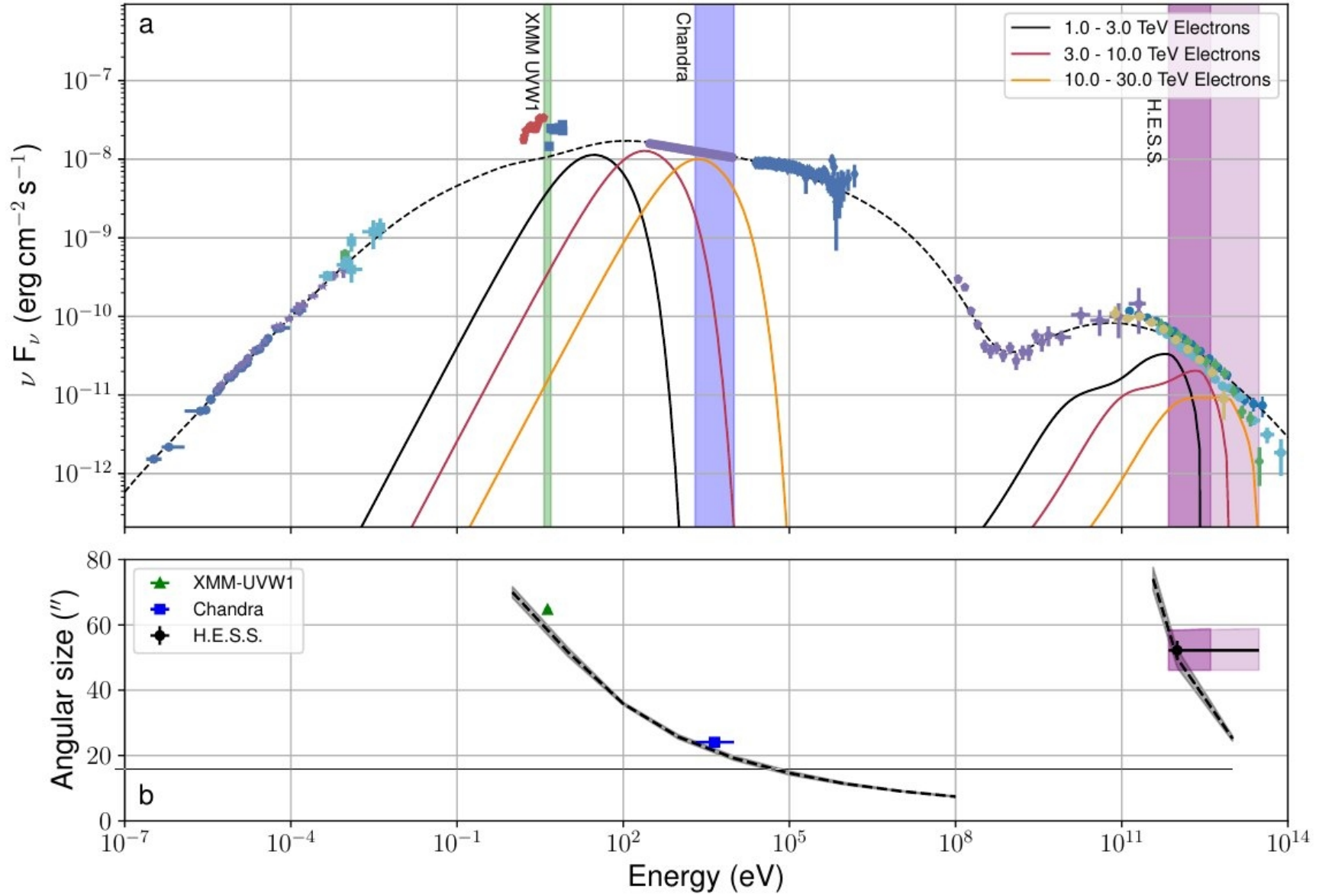


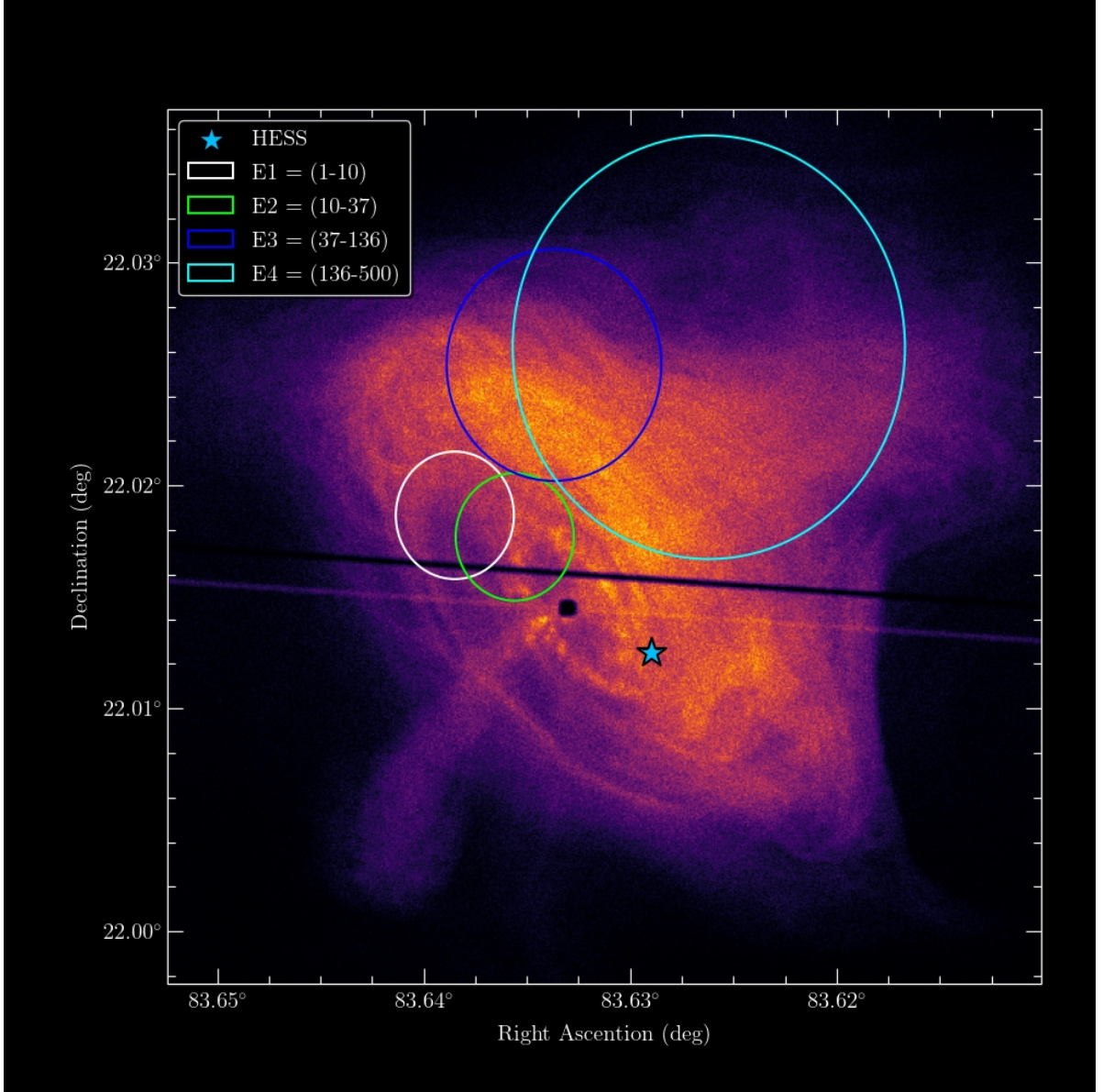
Extension of two-component model

Extension in single component fit
is affected by the spatial offset
from the pulsar. - *increasing?*

Nonetheless, two component fits in
energy bands < 40 GeV yield a *larger*
extension of the Crab nebula
resulting in an energy dependent size,
matching expectations on electron aging.



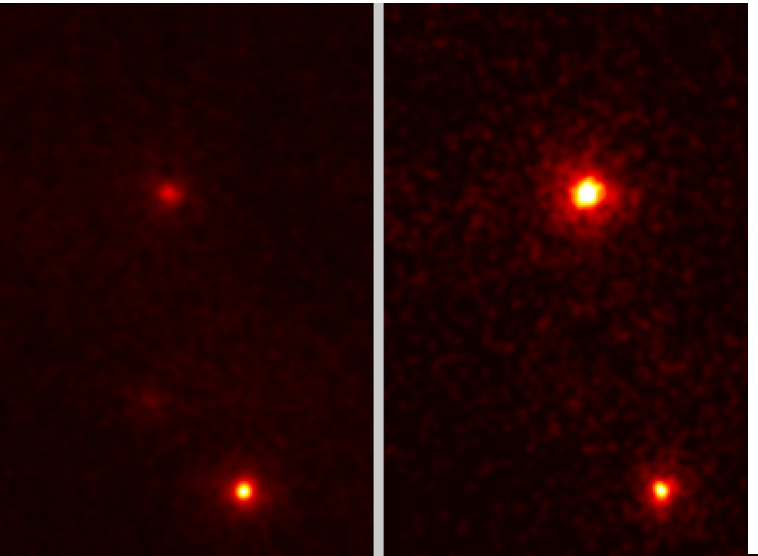

a
XMM UVW1
Chandra
H.E.S.S.
1.0 - 3.0 TeV Electrons
3.0 - 10.0 TeV Electrons
10.0 - 30.0 TeV Electrons
ν F$_\nu$ (erg cm^{-2} s^{-1})
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
b
XMM-UVW1
Chandra
H.E.S.S.
Angular size (″)
80
60
40
20
0
10^{-7}
10^{-4}
10^{-1}
10^{2}
10^{5}
10^{8}
10^{11}
10^{14}
Energy (eV)

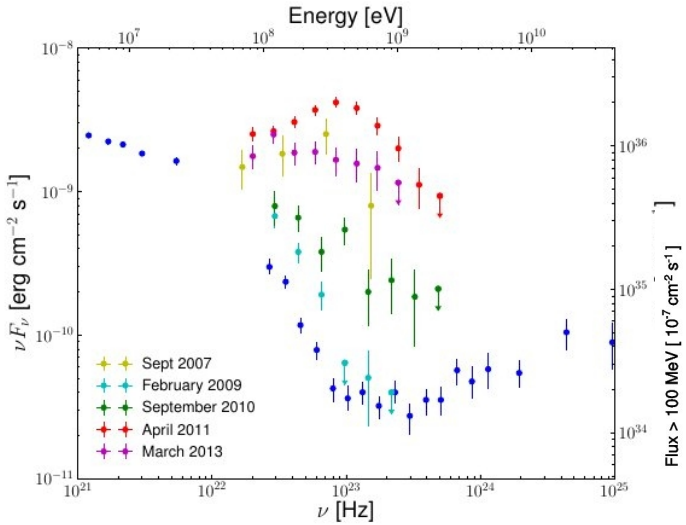

HESS
E1 = (1-10)
E2 = (10-37)
E3 = (37-136)
E4 = (136-500)
22.03°
22.02°
22.01°
22.00°
Declination (deg)
83.65°
83.64°
83.63°
83.62°
Right Ascention (deg)

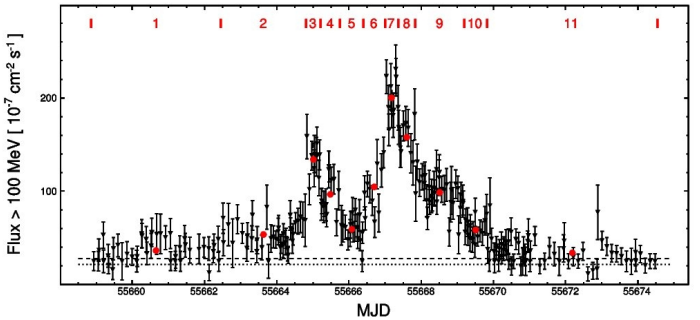
Crab Flares

Over short periods of time (~days), the 100 MeV – 10 GeV flux increases by up to a factor of 10. The origin of flares is unclear. Astrometric localisation?
→ no shift found in combined data-set from 8 flares.

→ Simulation (PSF at pulsar location, X-ray maximum) does not lead to significant astrometric differences. → Fermi go on!

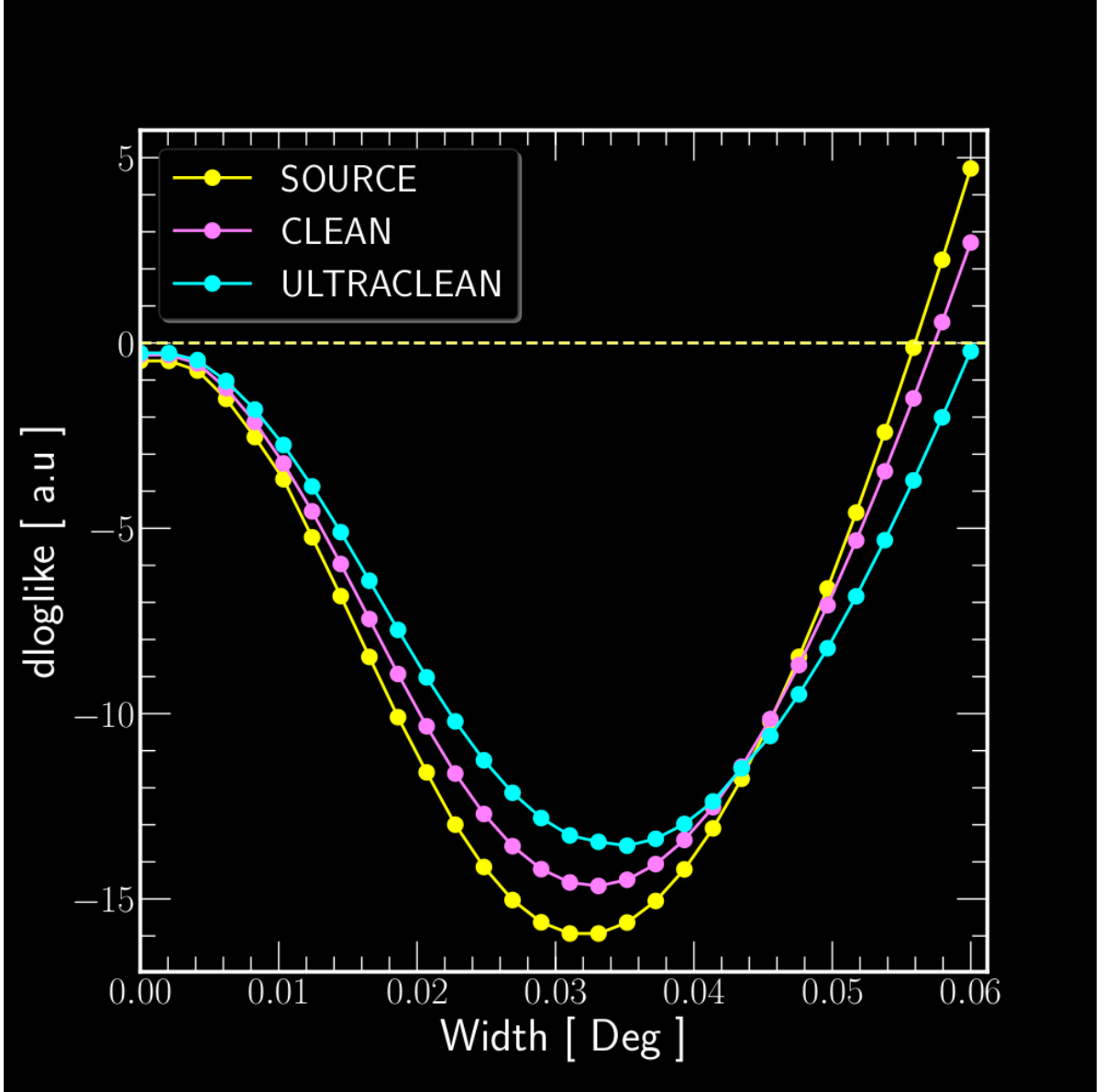






backup

diagrams


SOURCE
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