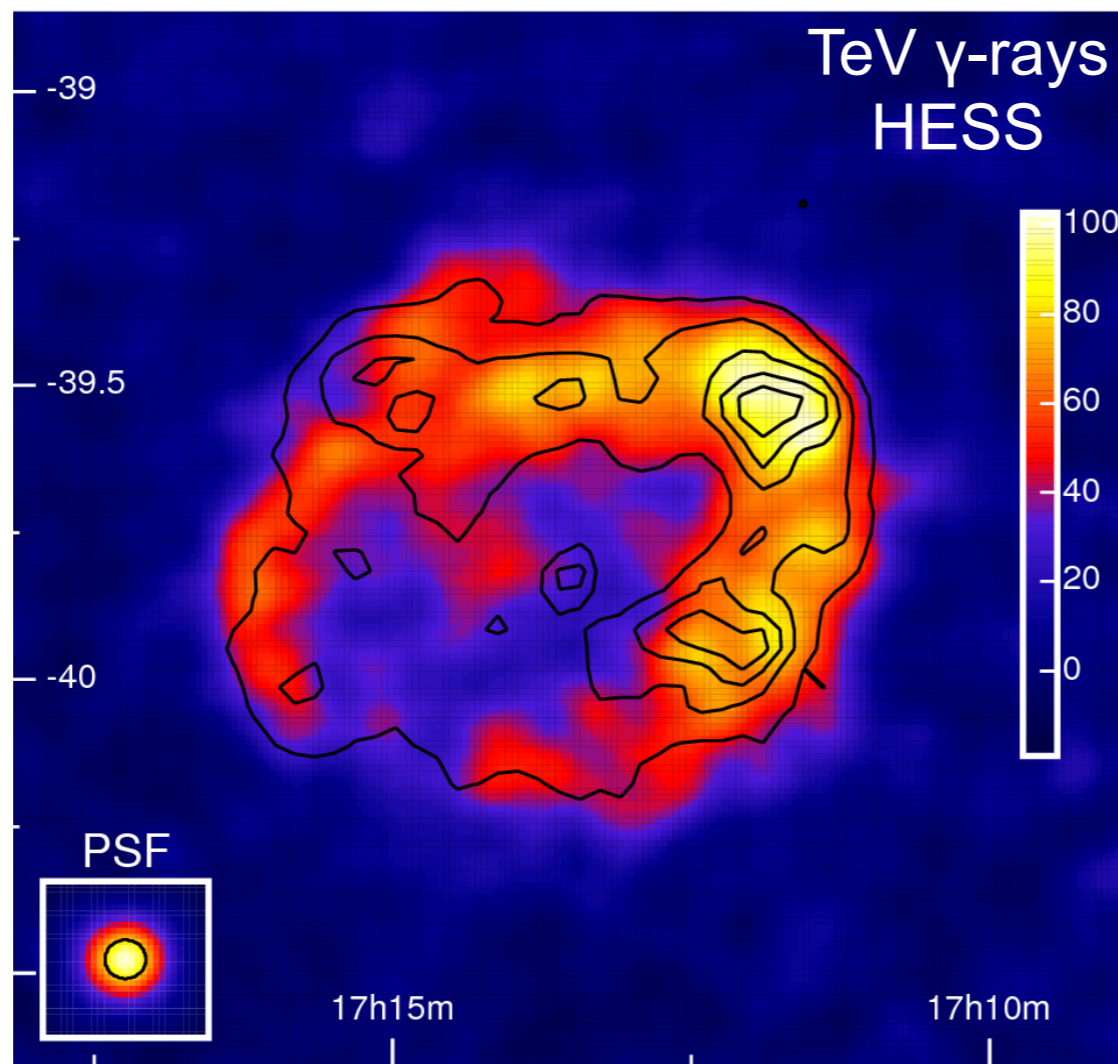


Extended Gamma-ray Sources

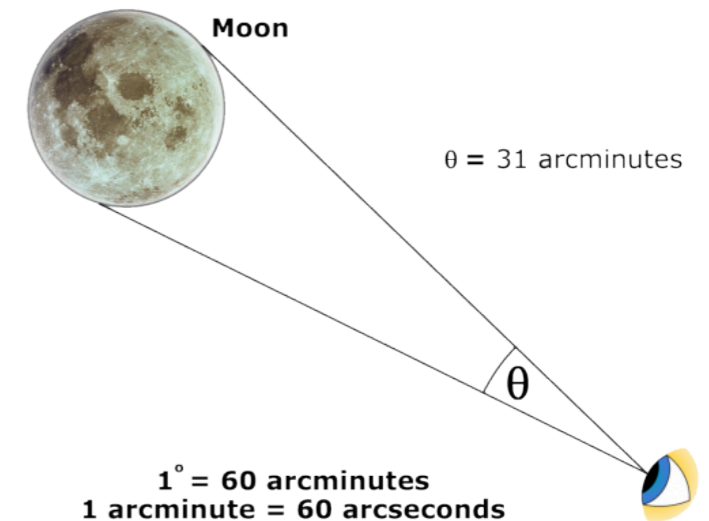
Another American story...

F_{ermi}H_AW_CV_{ERITAS}
Workshop 2014
College Park, MD Feb 11-12

Another American story...



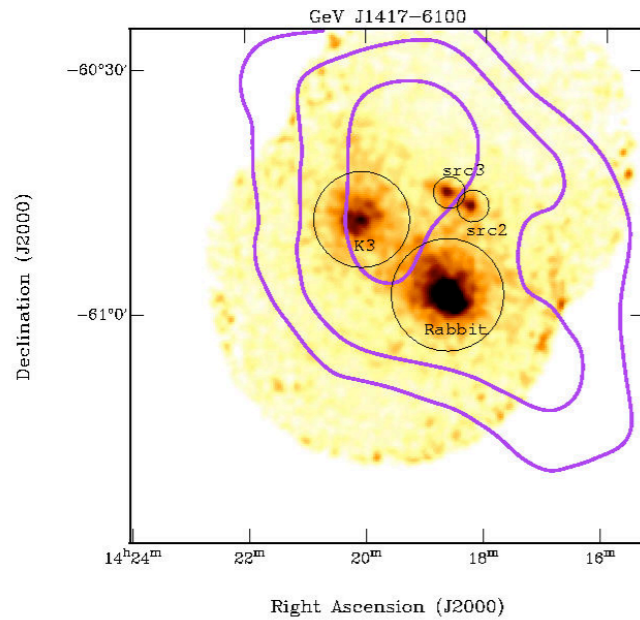
First image of a gamma-ray source



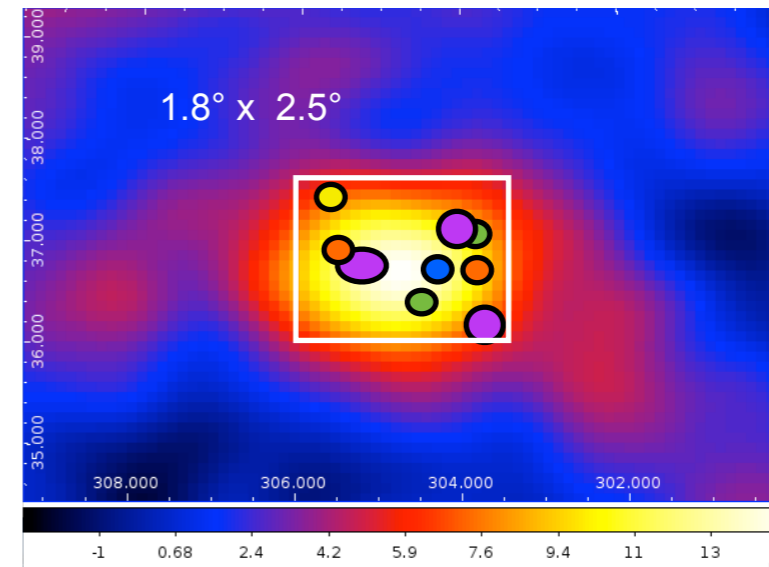
Spatial extension

Very important source property for correctly associating gamma-ray sources with their counterparts at smaller wavelengths

EGRET (PSF $\sim 1^\circ$ @ 1 GeV)
Kokaburra complex

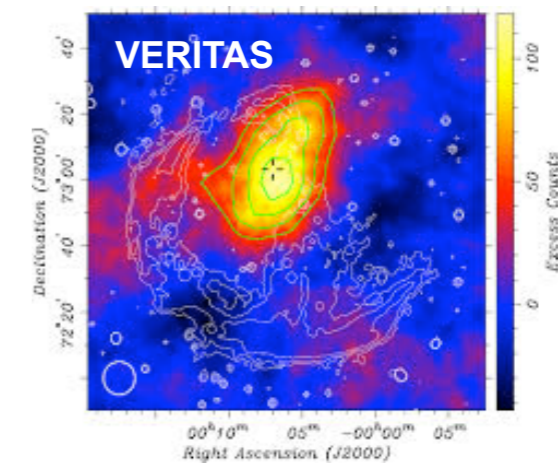
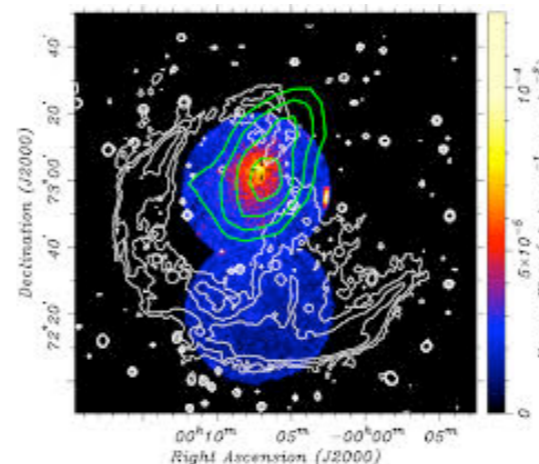
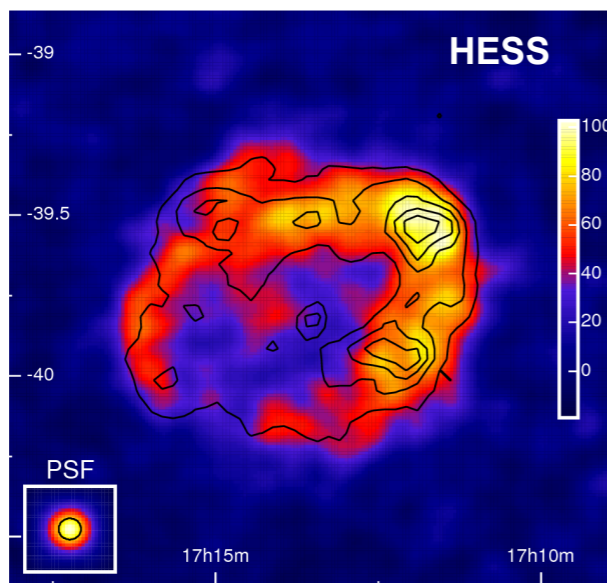


MILAGRO (PSF $\sim 0.5^\circ$ @ 20 TeV)
MGRO J2019+37



Finding a coherent source extension across different energy bands can help to associate a gamma-ray source to an otherwise confused counterpart

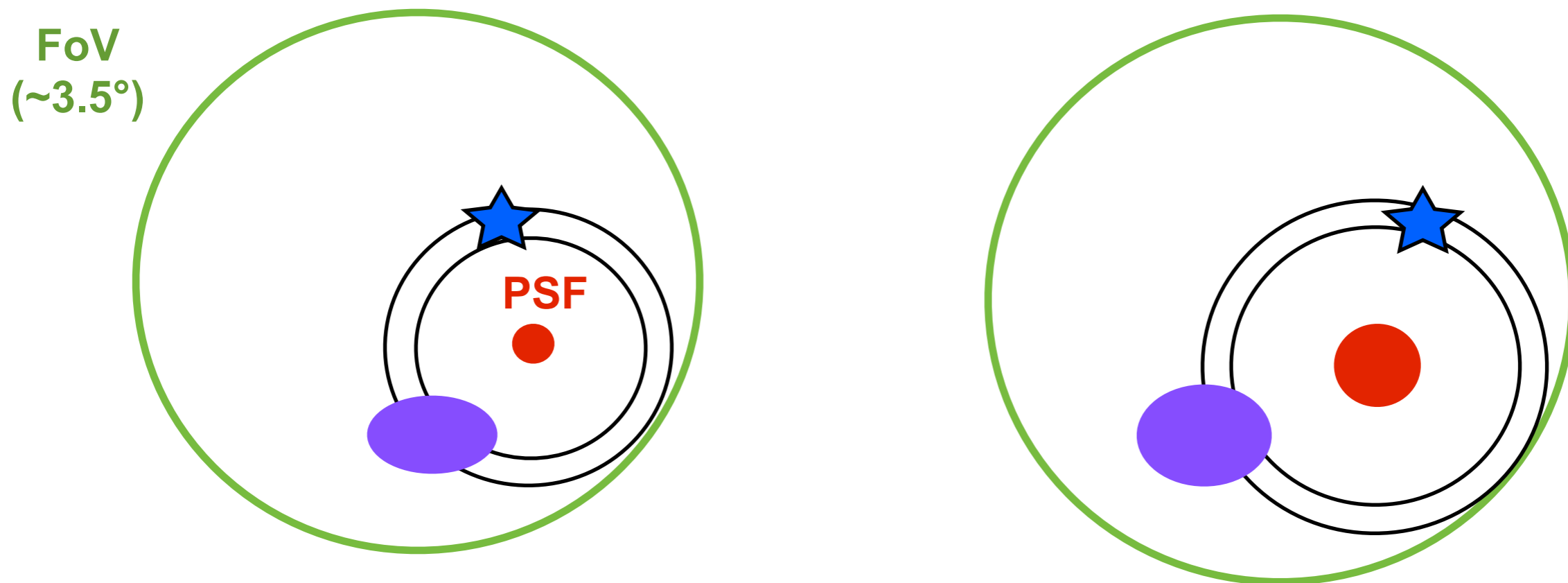
TeV/X-rays correlation



IACTs can do it !

GAMMA/HADRON separation removes 90% of the background events. The gamma-ray signal is found by estimating the background at each point of the sky and subtracting this (OFF map) to the events (ON map)

A) Ring Background Model (surveys, point source to moderate extension)



The background at ● is estimated using a ring of radius R around it.
A correction is applied that depends on the the area between the 'source' region and that of the 'background' region, and also the radial acceptance.

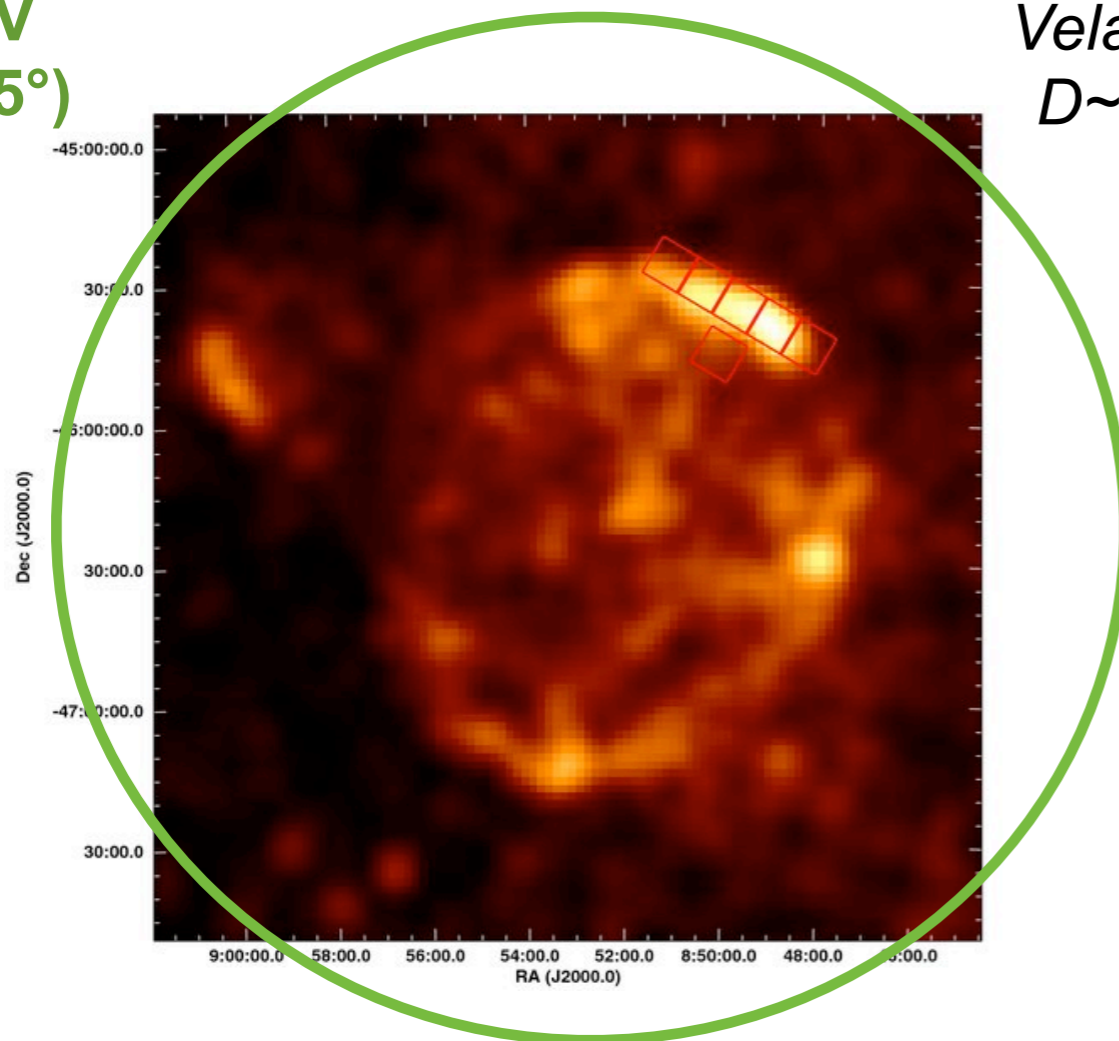
If a bright star or a known gamma-ray source falls into the radius, those region are excluded from the background estimation

IACTs can do it !

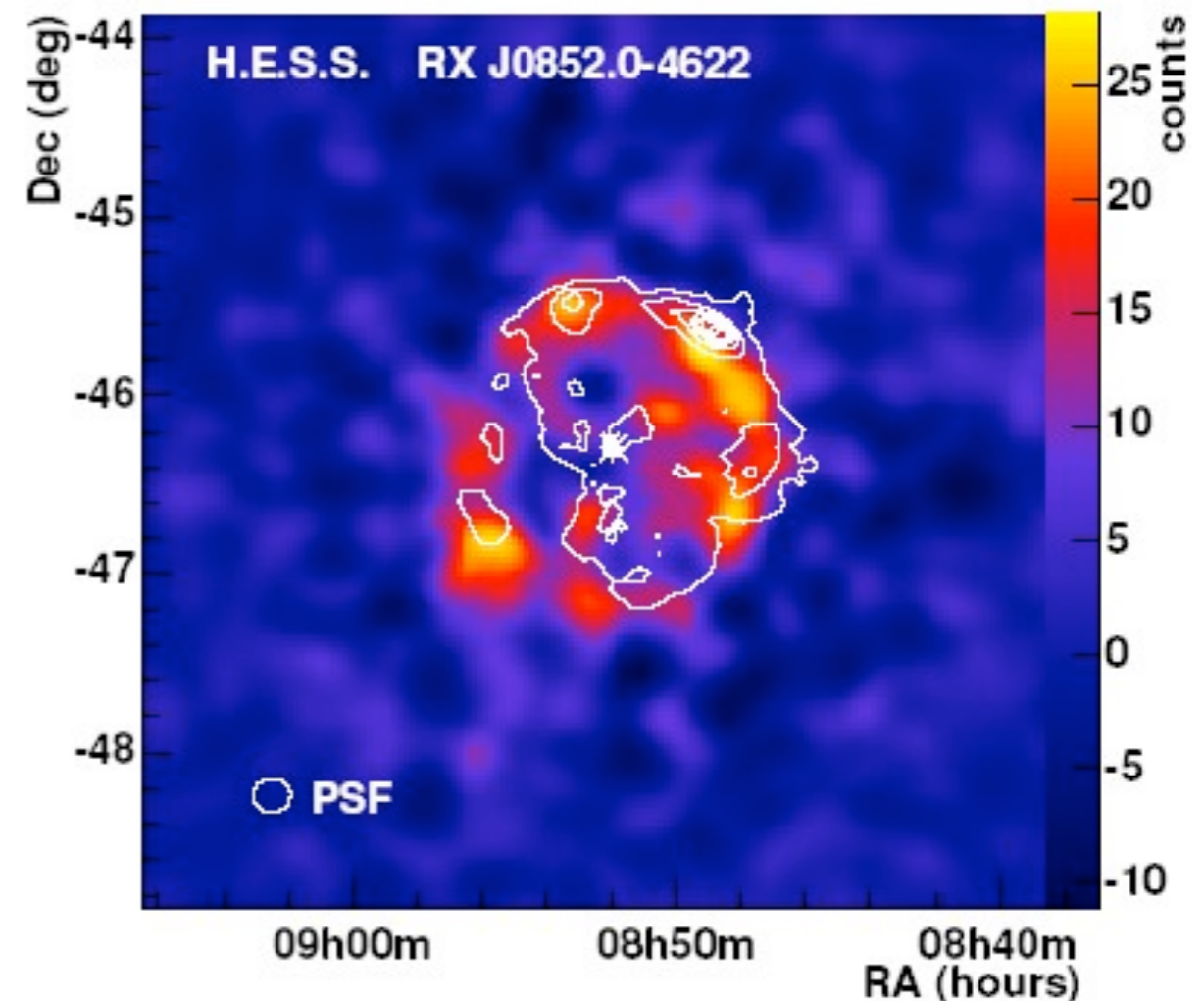
GAMMA/HADRON separation removes 90% of the background events. The gamma-ray signal is found by estimating the background at each point of the sky and subtracting this (OFF map) to the events (ON map)

B) ON/OFF
(very large extension)

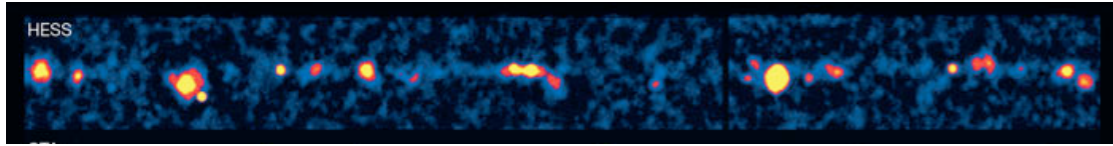
FoV
($\sim 3.5^\circ$)



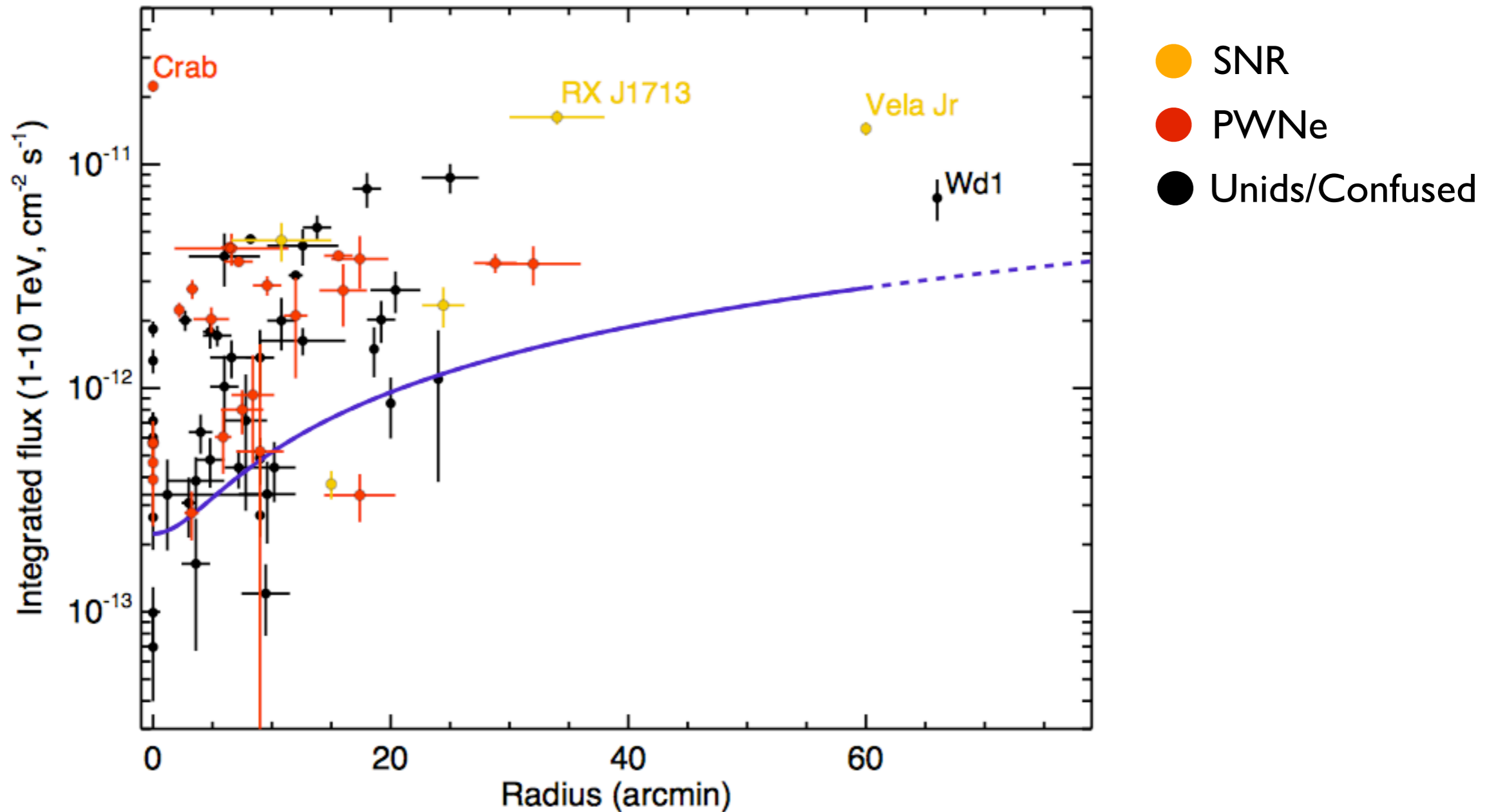
Vela Jr
 $D \sim 2^\circ$



What are IACTs seeing?



Carrigan et al.
ICRC 2013



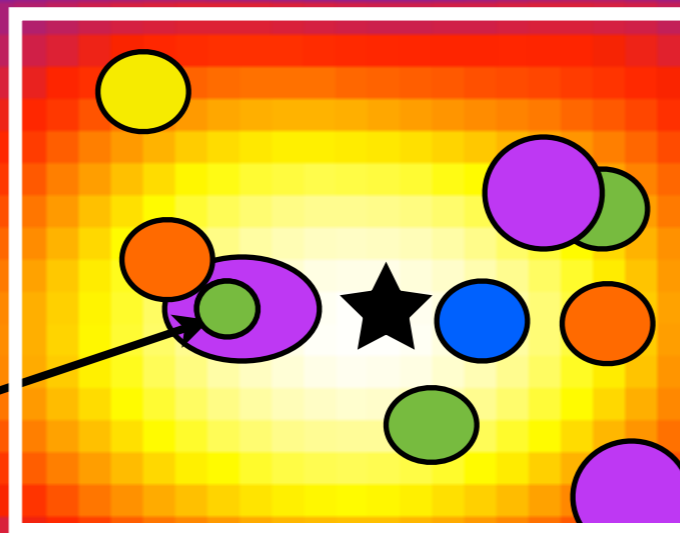
HESS Galactic Survey sources (~ 70) (unbiased selection) reveals the sample is likely incomplete, with reduced sensitivity to large and faint sources

Milagro

E ~ 20 TeV

Brightest reported TeV diffuse source in the Galaxy, 80% C.U.
Located towards Cyg OB1

1.8° x 2.5°



PSR J2021+3651

$\dot{E} = 2.1 \times 10^{36}$ erg/s

Milagro Coll. ApJ 91L:664 (2007)
- association with pulsar

Paredes et al. A&A 507:241 (2009)
Zabalza & Paredes AICP (2010)
- association with HII region

Bednarek, MNRAS 382:367 (2007)
- association with Ber87,
young cluster in Cyg OB1

308.000

306.000

304.000

302.000

-1

0.68

2.4

4.2

5.9

7.6

9.4

11

13

MGRO J2019+37

Known SNR, PWNe

2FGL sources

HII regions

Hard X-ray transient

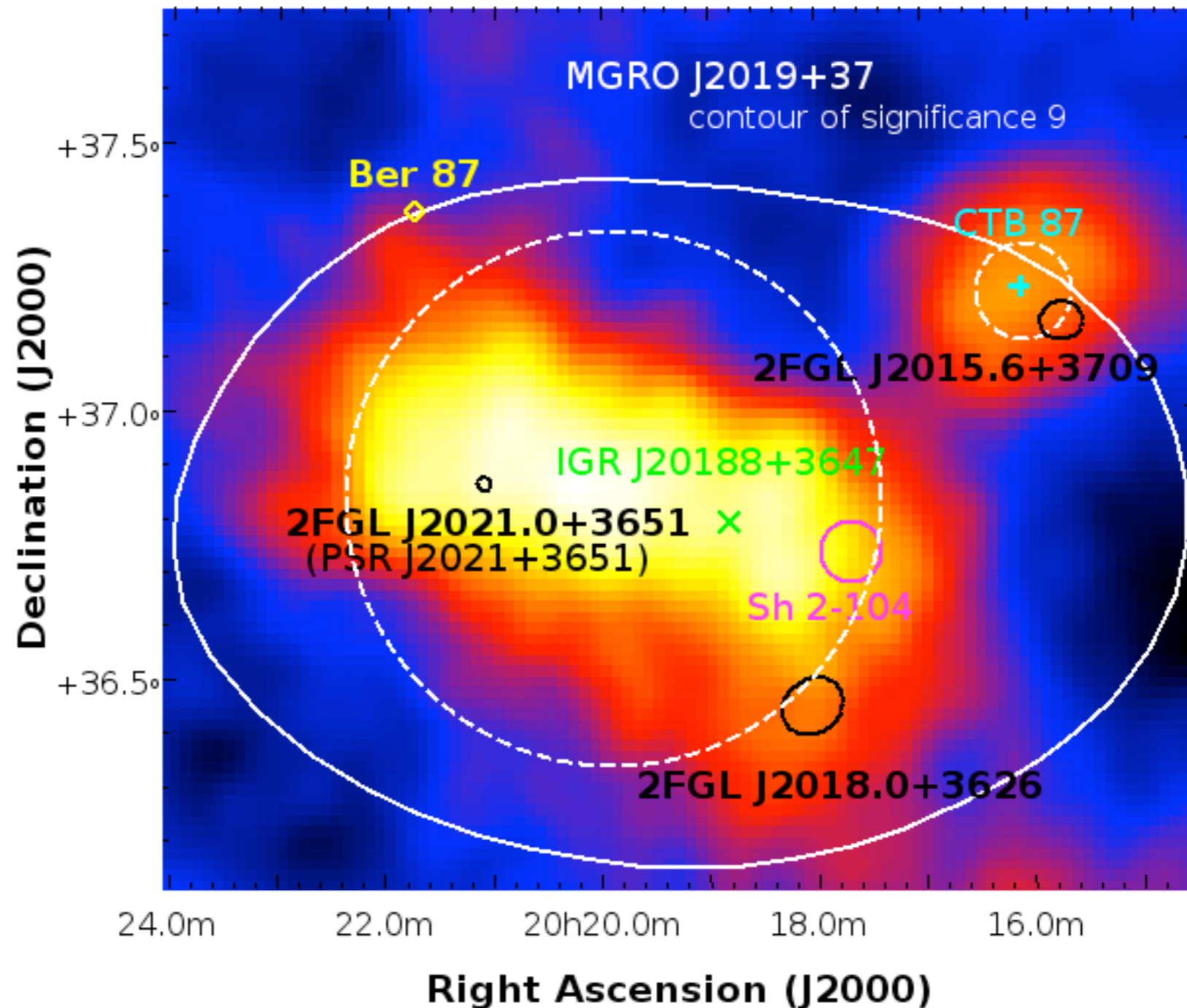
Young clusters
Cyg OB1

WR binaries

VERITAS observations

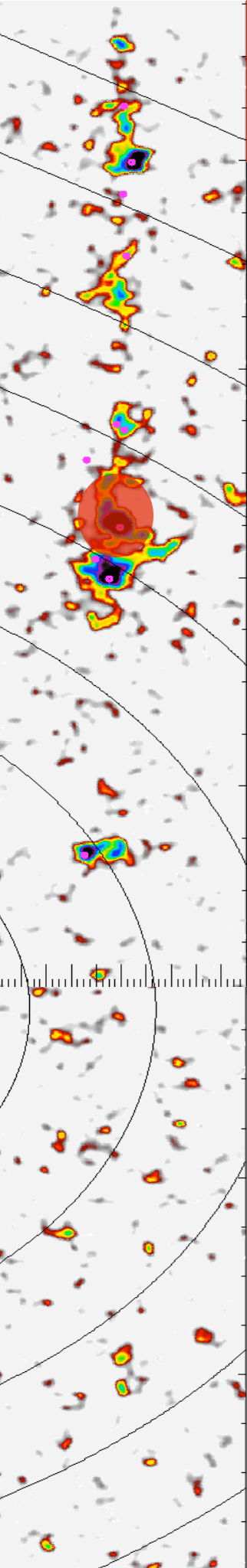
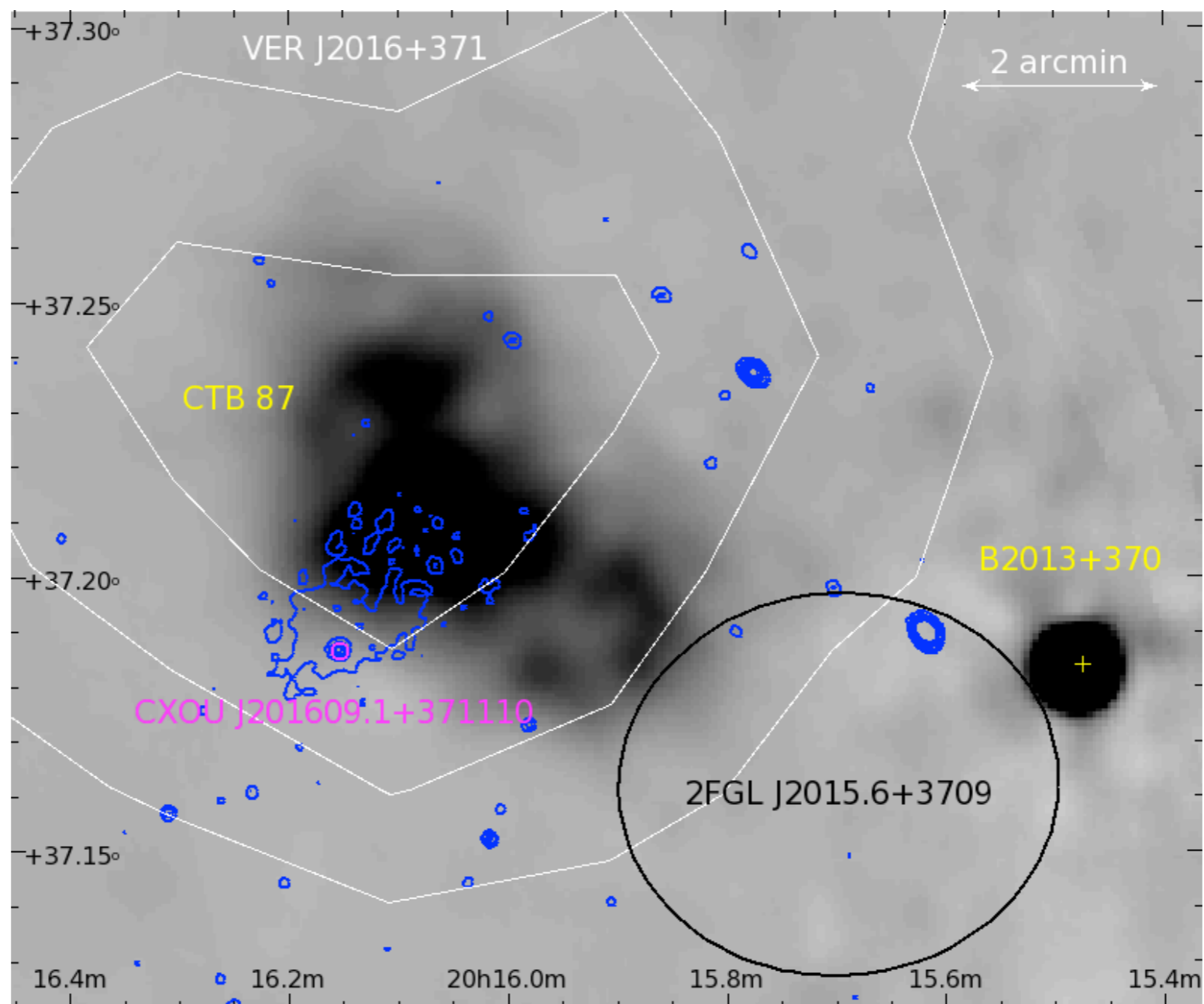
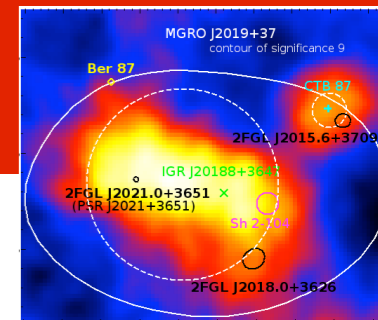
Aliu et al. 2014, accepted ApJ

- * Deep exposure: 75 hrs
- * Two sources within the 9σ significance contours of Milagro



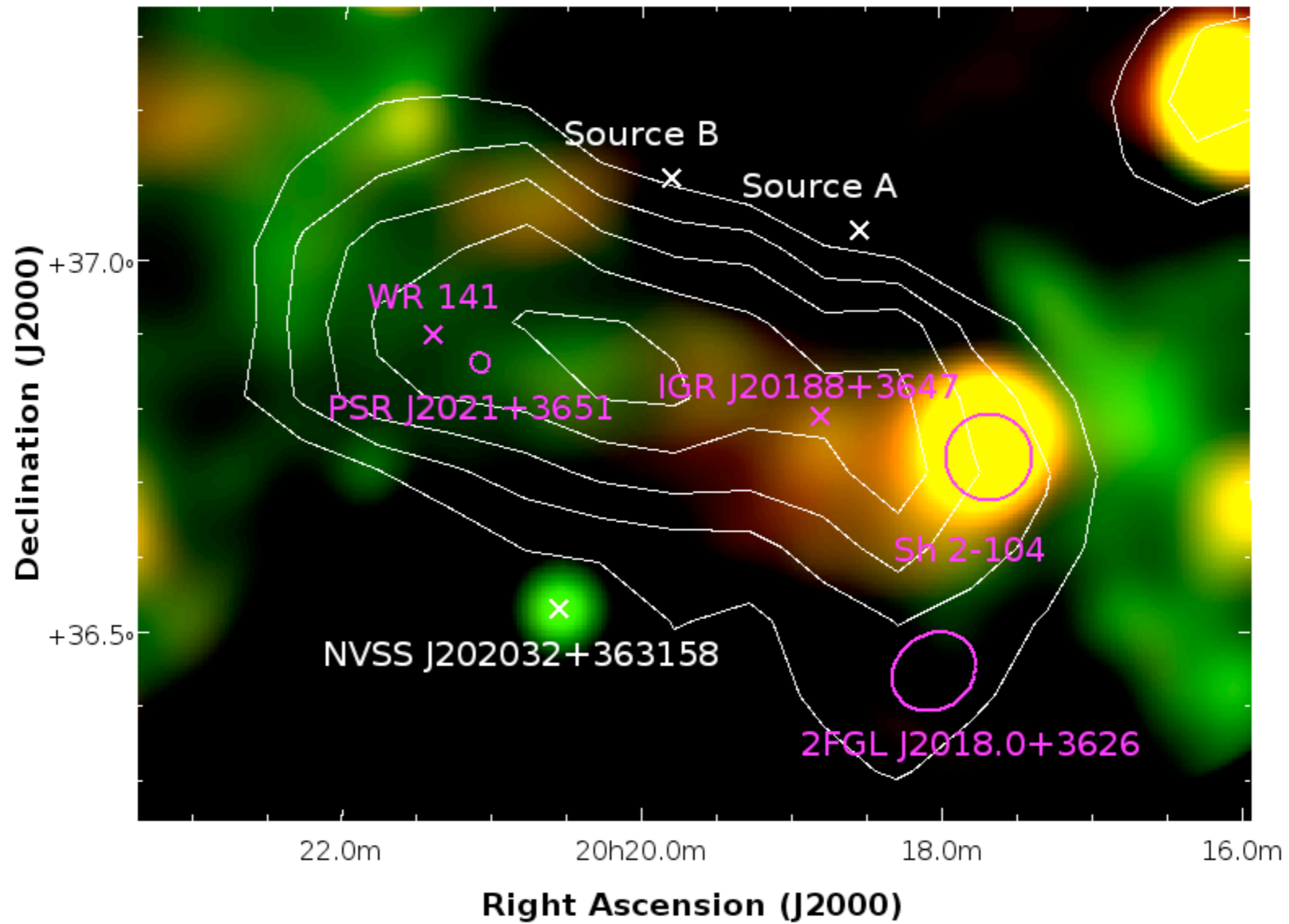
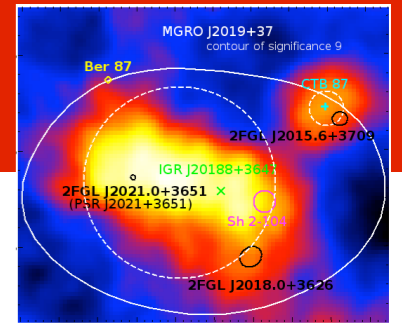
MW picture

VER J2016+371



MW picture

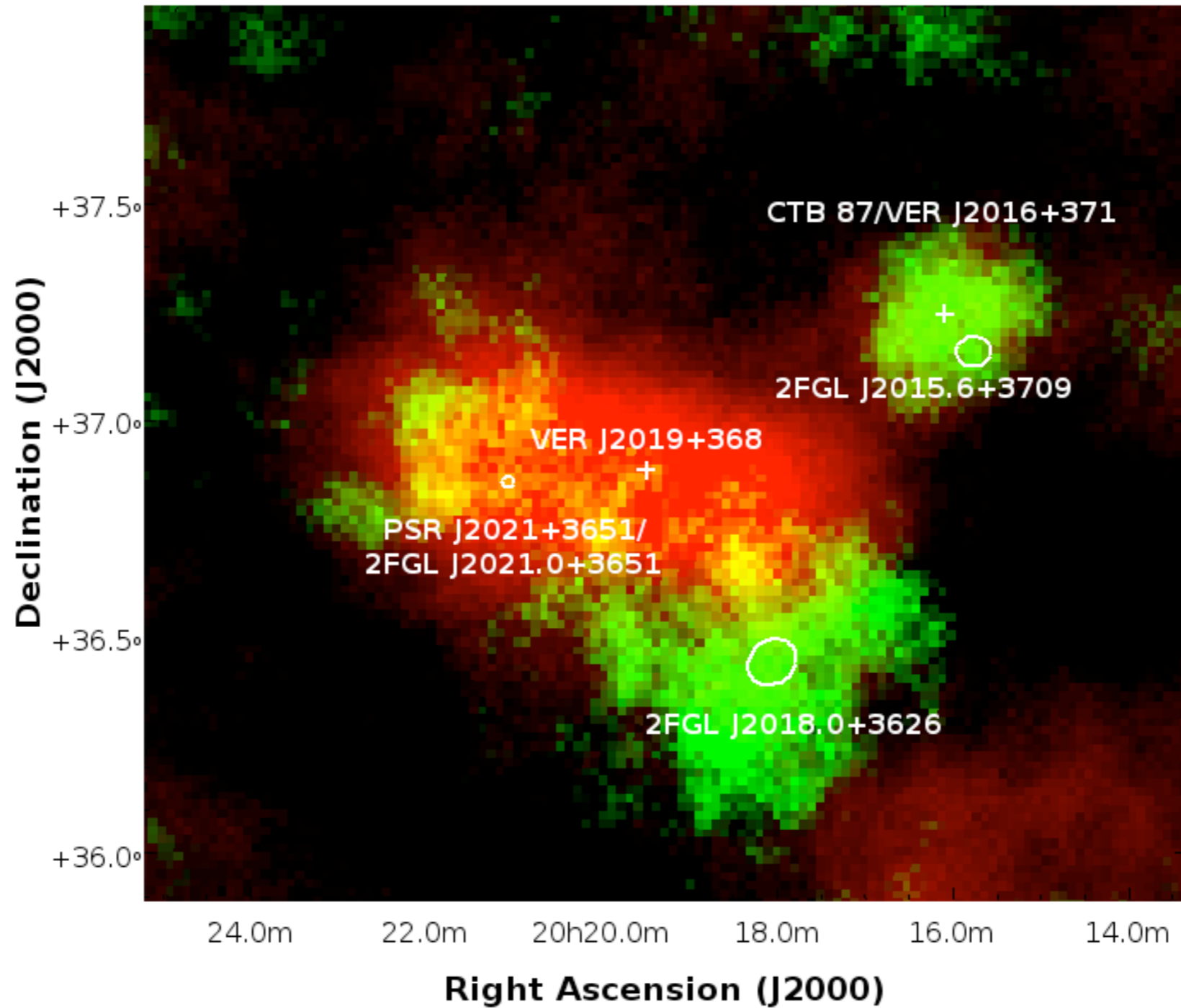
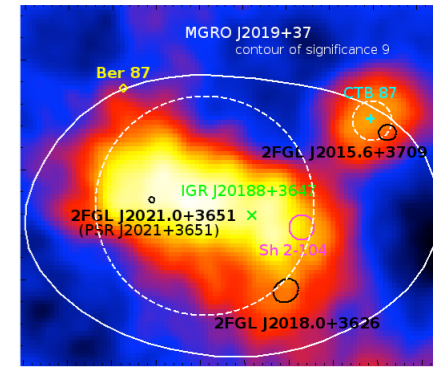
VER J2019+368



Energy Dependence Morphology

● > 1 TeV

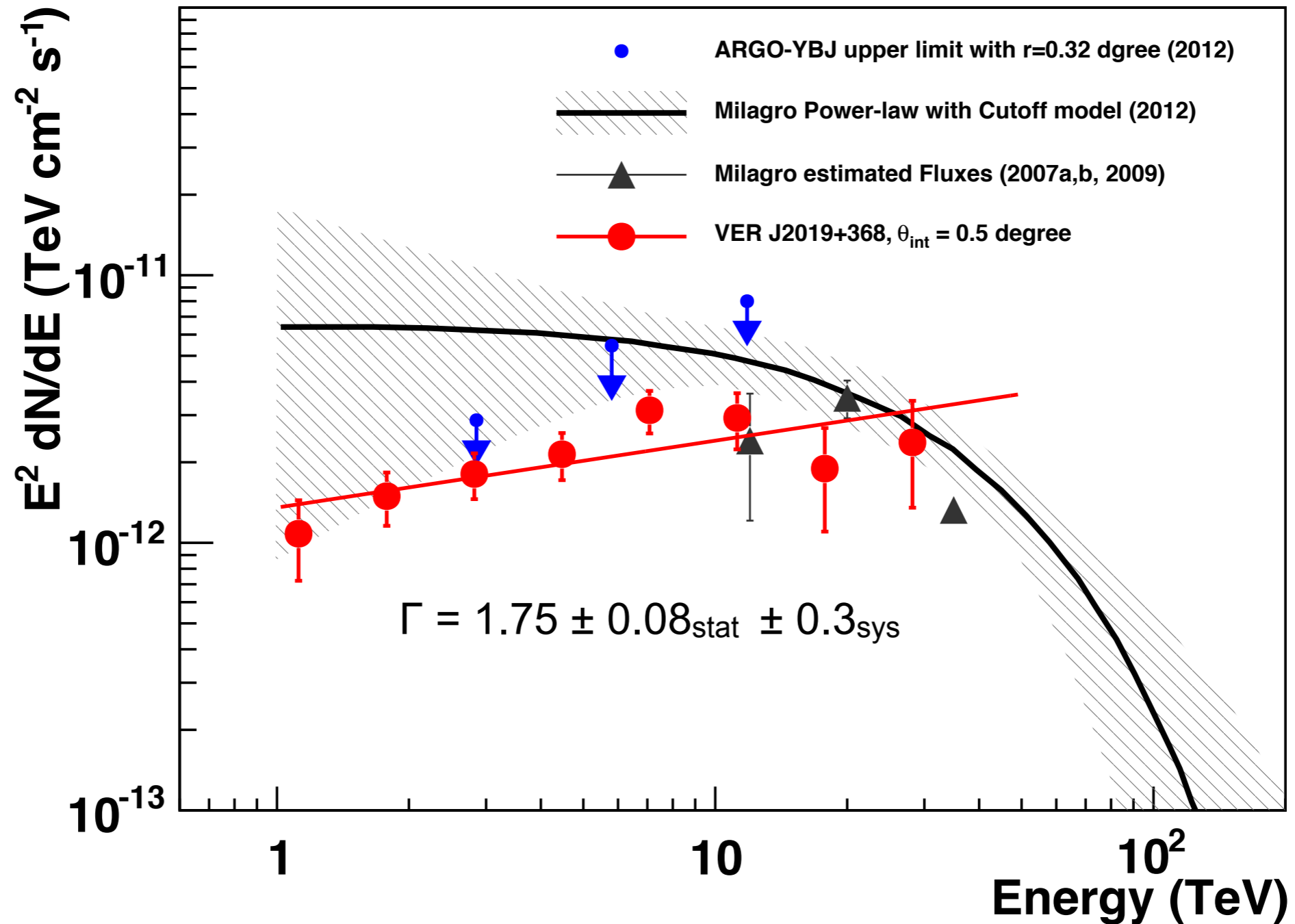
● < 1 TeV



Comparing TeV points

Aliu et al. 2014, accepted ApJ

The spectrum VER J2019+368 is compatible with the Milagro flux points at 12, 20 and 35 TeV and the ARGO upper limit flux

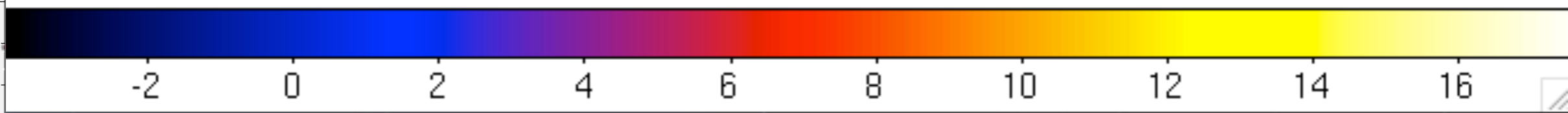


Milagro

E ~ 20 TeV

TeV J2032+41

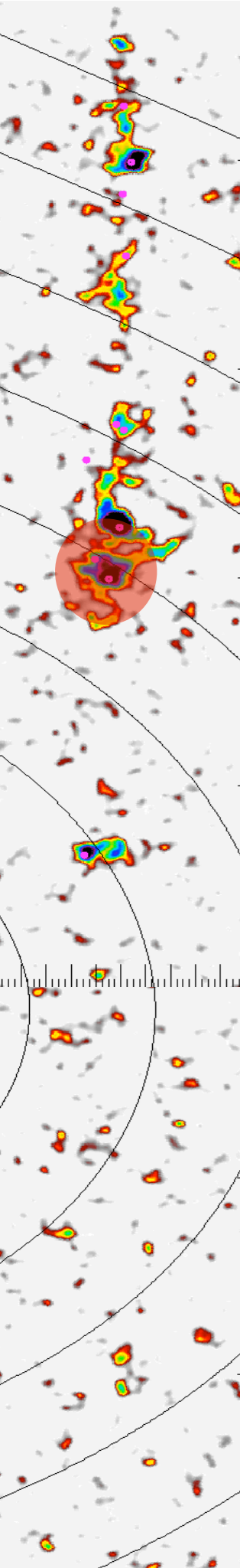
VER J2019+407



MGRO J2031+41

● VERITAS survey sources

● LAT sources



Milagro

E ~ 20 TeV

TeV J2032+41

PSR

VER J2019+407

Binary

PSR

PSR/SNR

EG

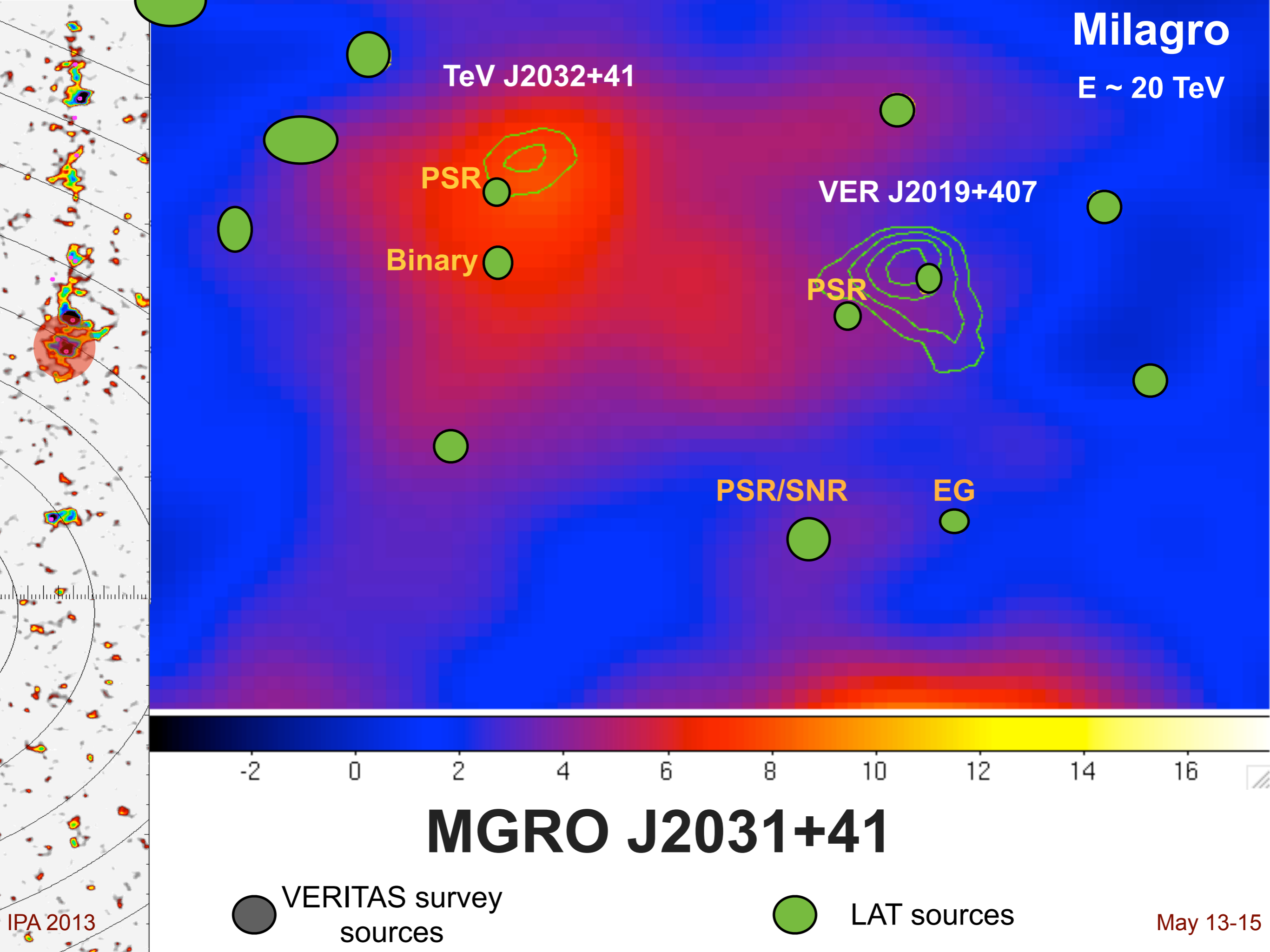
MGRO J2031+41

● VERITAS survey sources

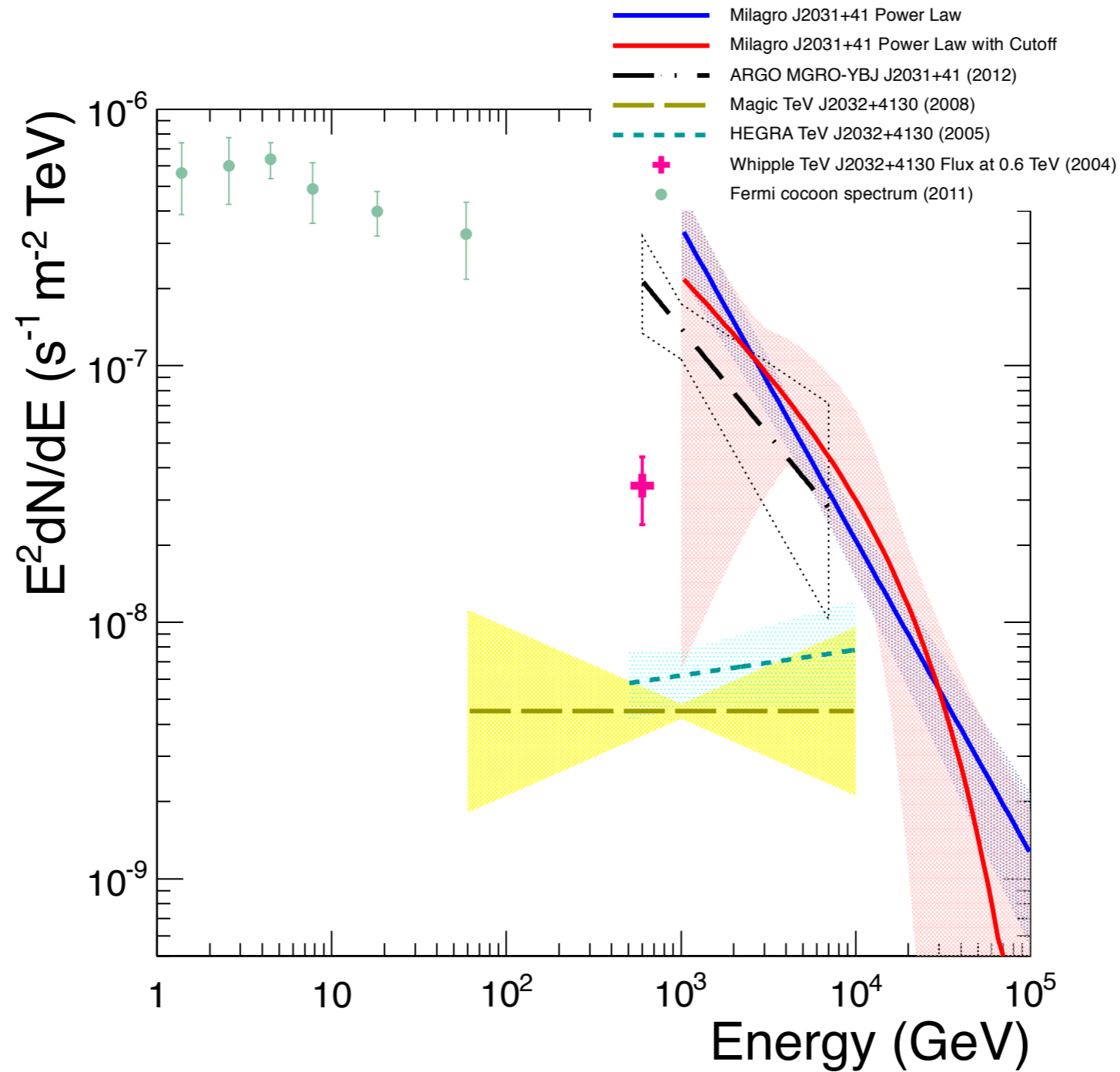
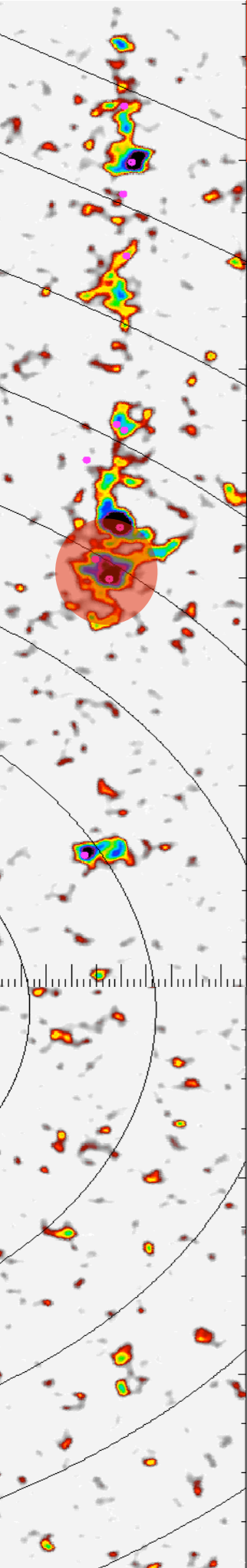
● LAT sources

May 13-15

IPA 2013



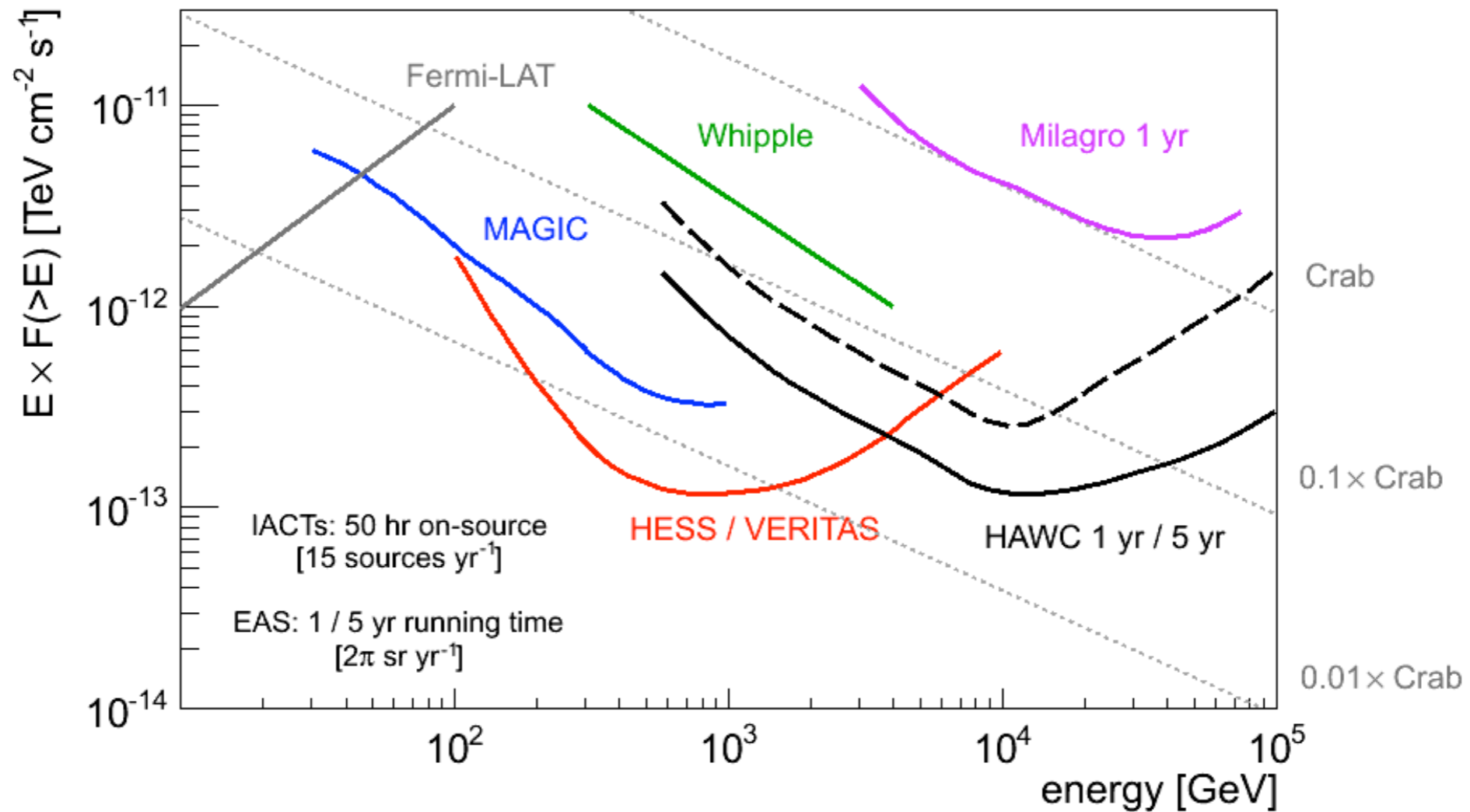
Spectrum, no agreement!



MILAGRO Coll., 2012
<http://arxiv.org/abs/1202.0846>

IACTS spectrum do not match Milagro. Milagro matches the Fermi 'Cocoon'. What's going on? HAWC ?

Angular Resolution

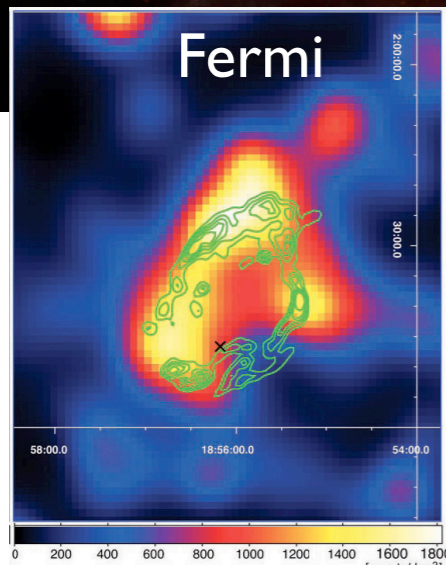
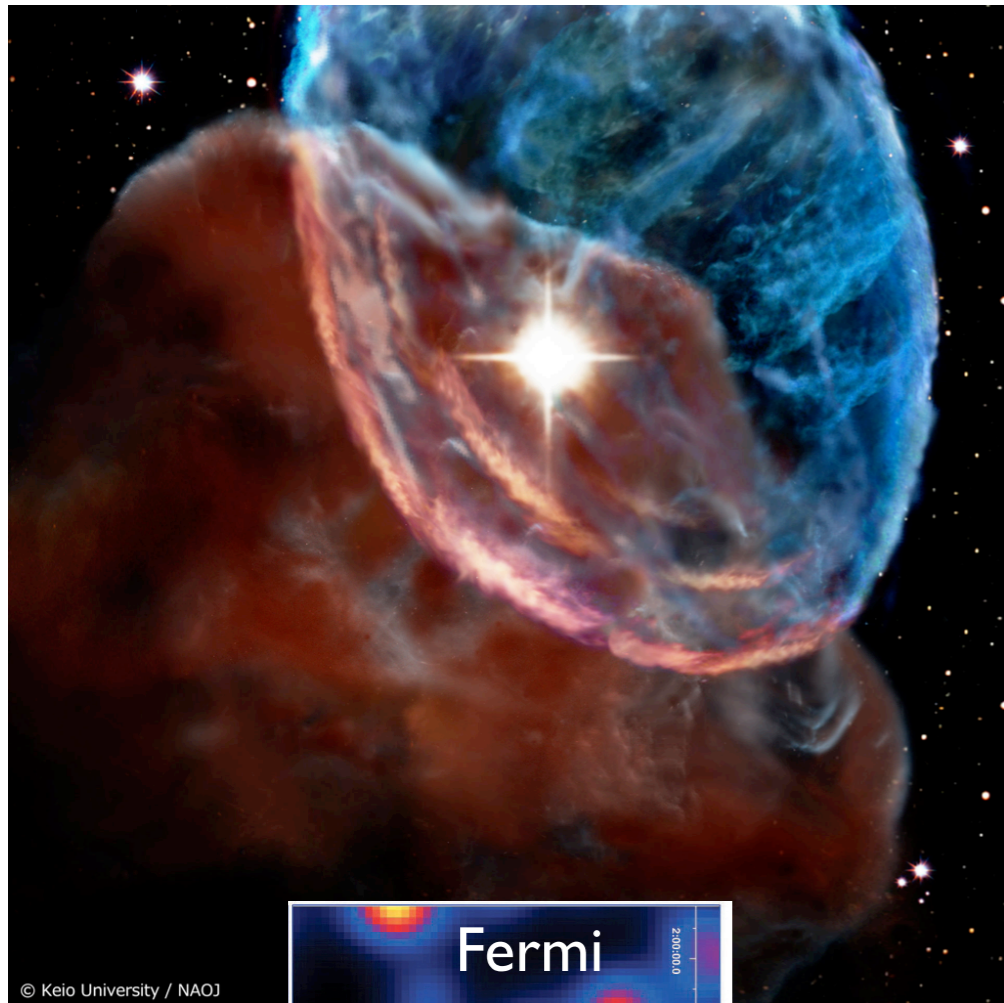


$\sim 0.5^\circ$ at 1 GeV to $< 0.1^\circ$ (> 10 GeV)	$\sim 0.15^\circ$ at 150 GeV $< 0.1^\circ$ (> 1 TeV)	$\sim 0.5^\circ$ at 1 TeV $< 0.2^\circ$ (> 10 TeV)
Fermi	VERITAS	HAWC

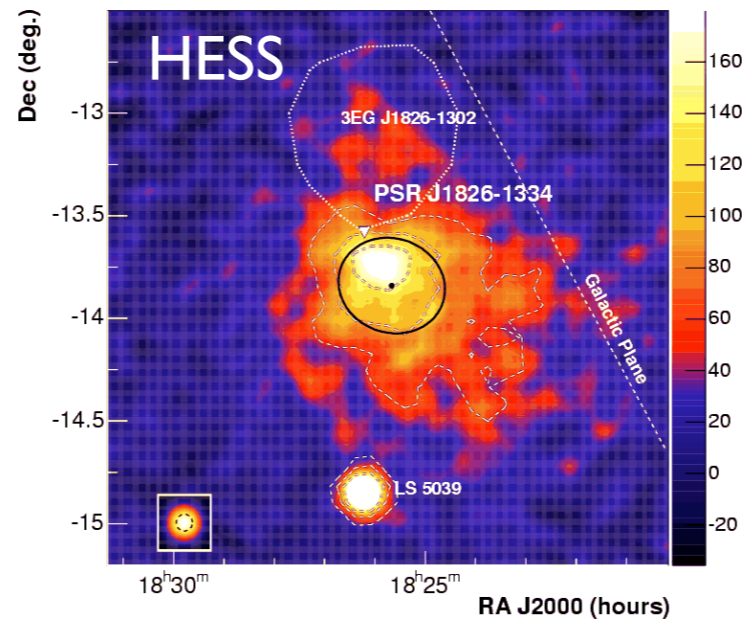
Angular resolution is gonna be more consistent than ever before in the a large part of the gamma-ray energy band.

Type of Astrophysical Sources

SNRs & MC



PWNe



Nearby Galaxies



Radio Galaxies

