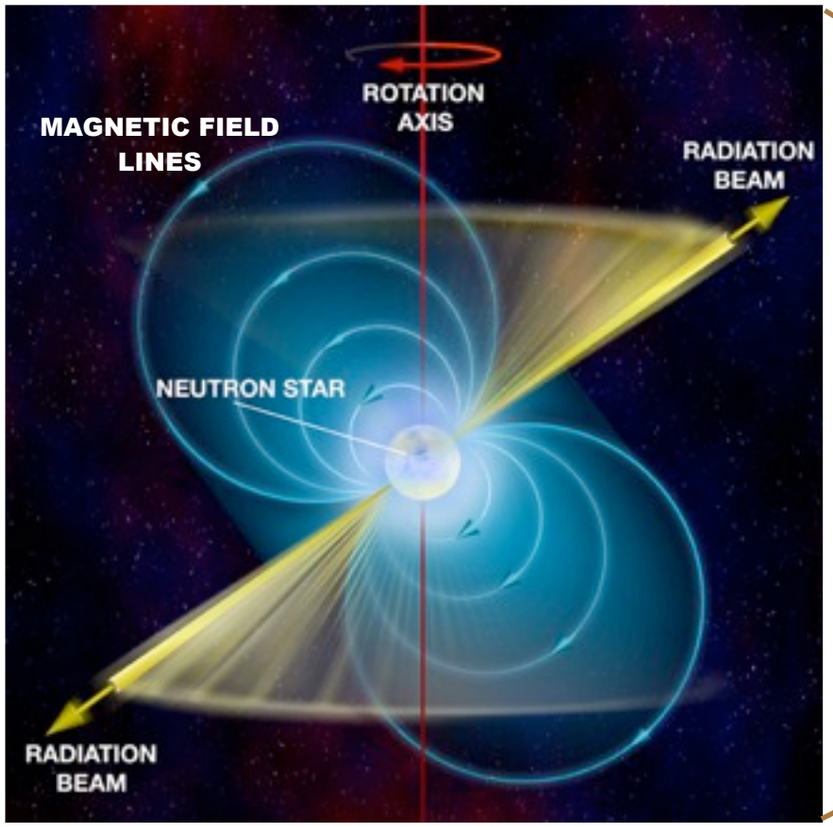
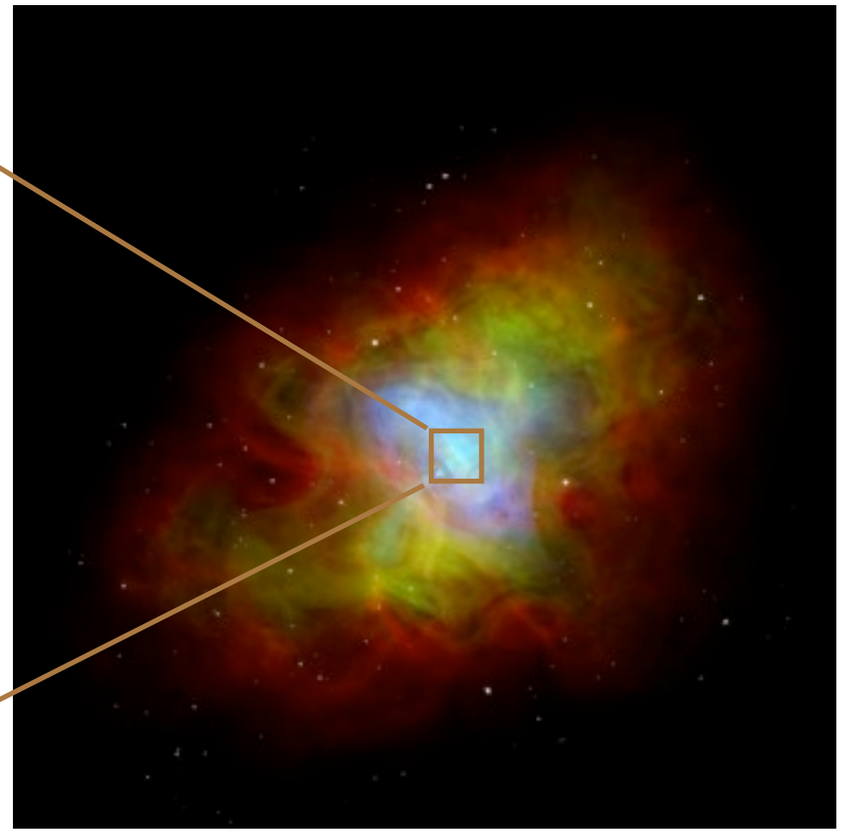
Studying the Morphology and Energy Spectra of Geminga and Boomerang at TeV Energies





http://apod.nasa.gov/apod/ap020920.html

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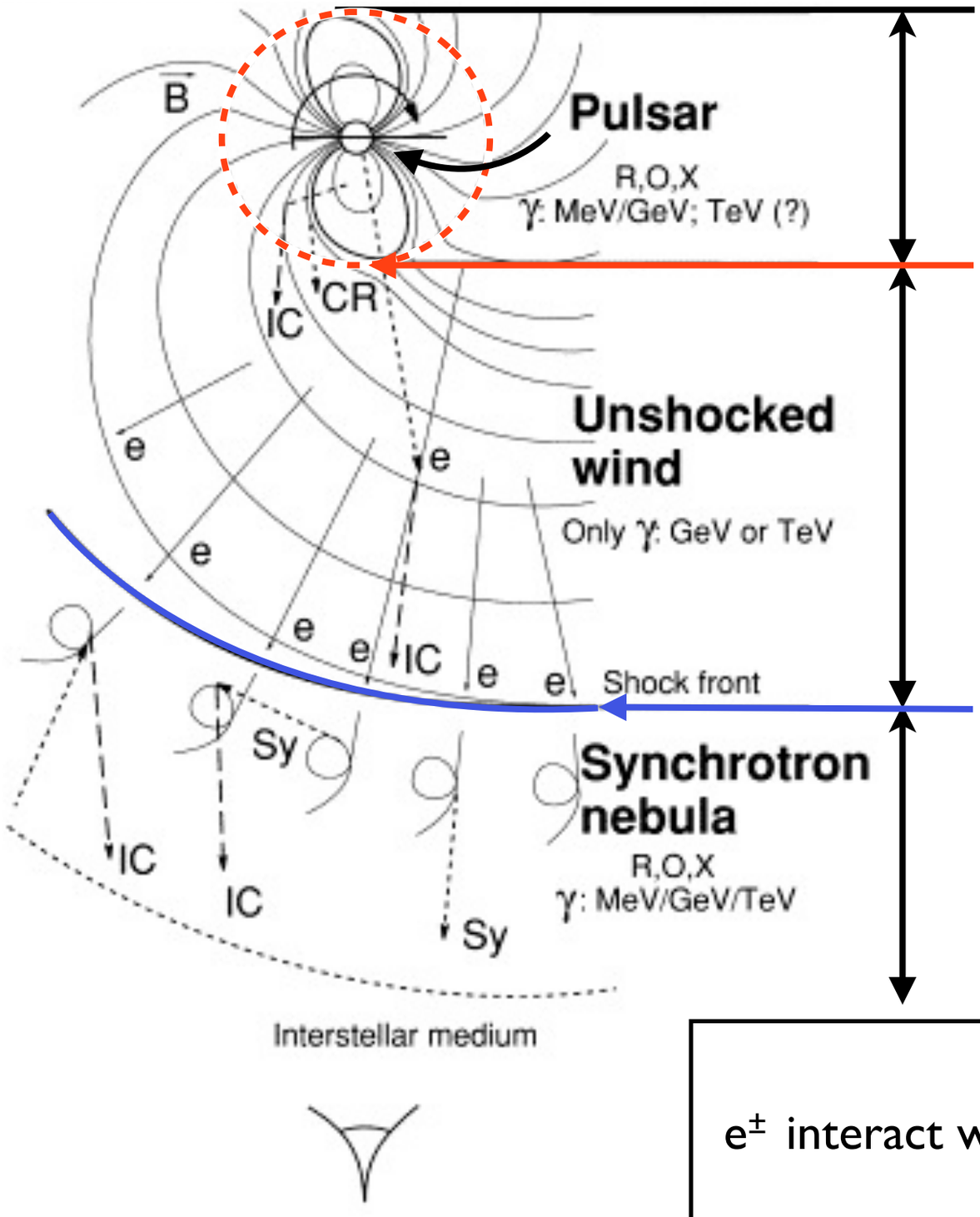
Pulsar and Pulsar Wind Nebula

Radiation from a **Pulsar-wind-nebula** complex



~1000 km

Light Cylinder
where co-rotating speed = c

~0.1 pc

Shock front
where wind is terminated

>0.1 pc

$e^{\pm}$ accelerated

$e^{\pm}$ escape and blow outward

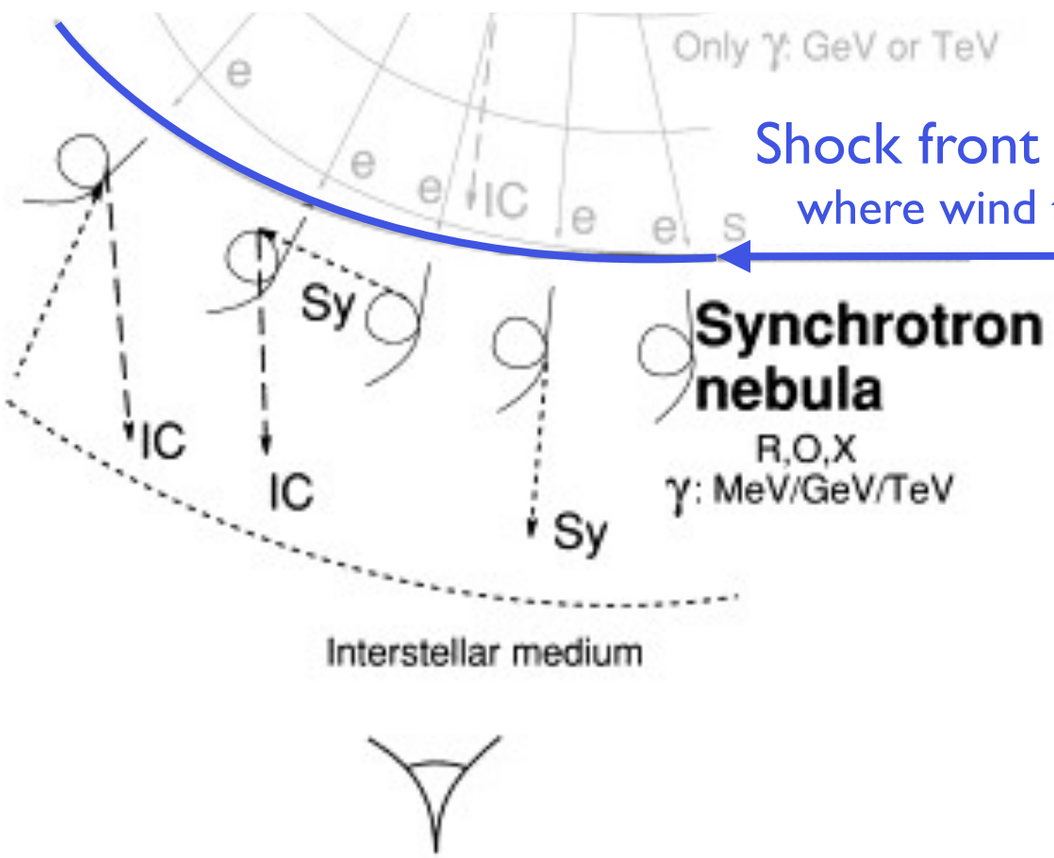
$e^{\pm}$ terminated by ambient medium

$e^{\pm}$ interact with magnetic field / photon field → γ

F. Aharonian, Very High Energy Cosmic Gamma Ray Emission, Fig. 1.8

Pulsar Wind Nebula

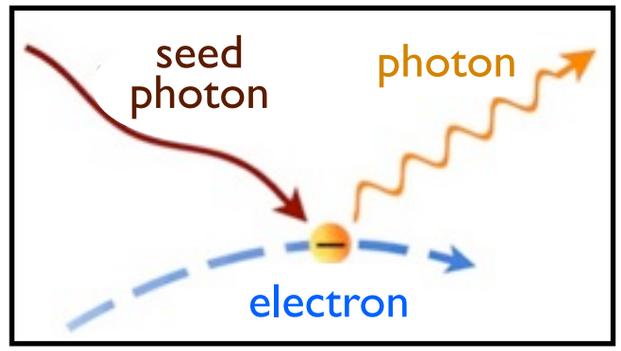
- $e^{\pm}$ accelerated to 10^{16} eV by the shock front (Fermi acceleration)
- Low magnetic field B ~ μG to mG
- Unpulsed emission



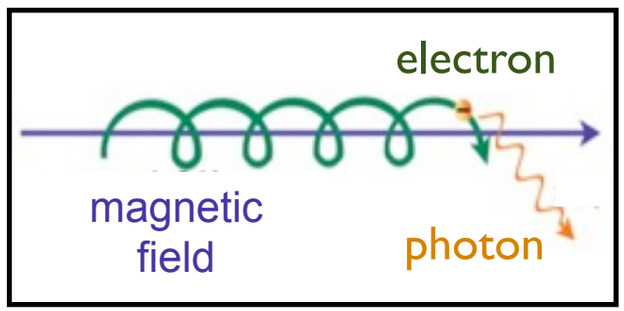
γ emission mechanisms:

TeV!

Inverse Compton Scattering



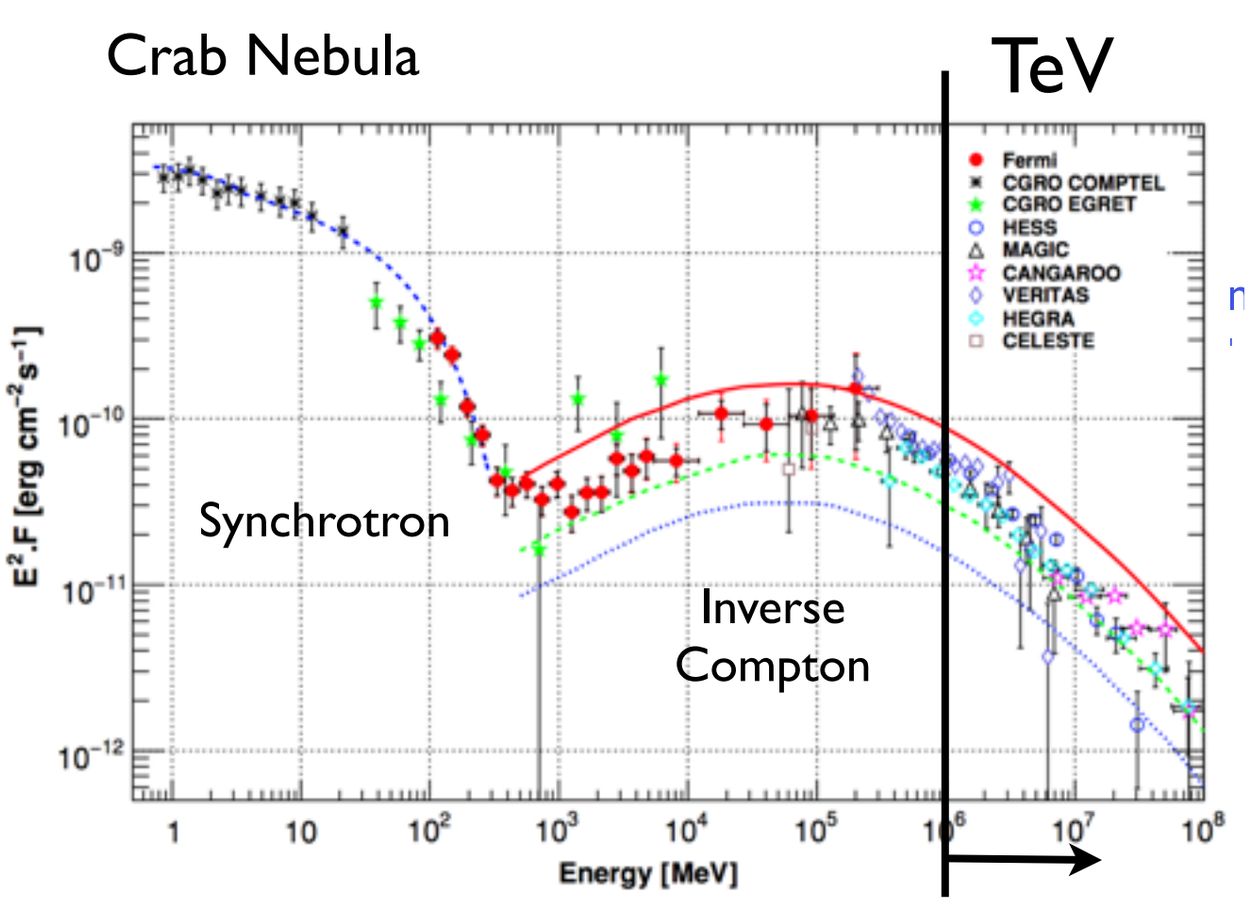
Synchrotron Radiation



F. Aharonian, Very High Energy Cosmic Gamma Ray Emission, Fig. 1.8

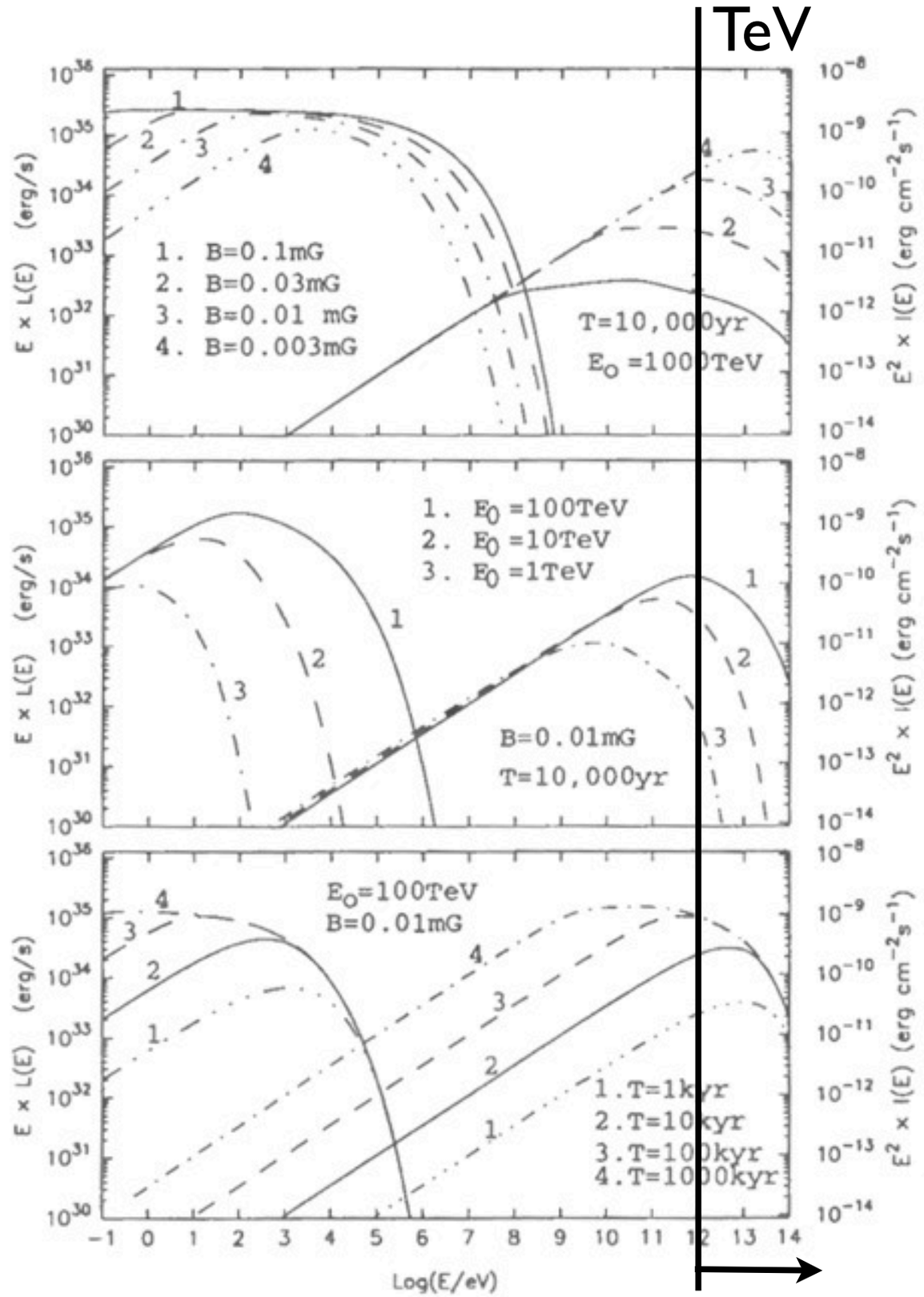
PWN Modeling

Crab Nebula



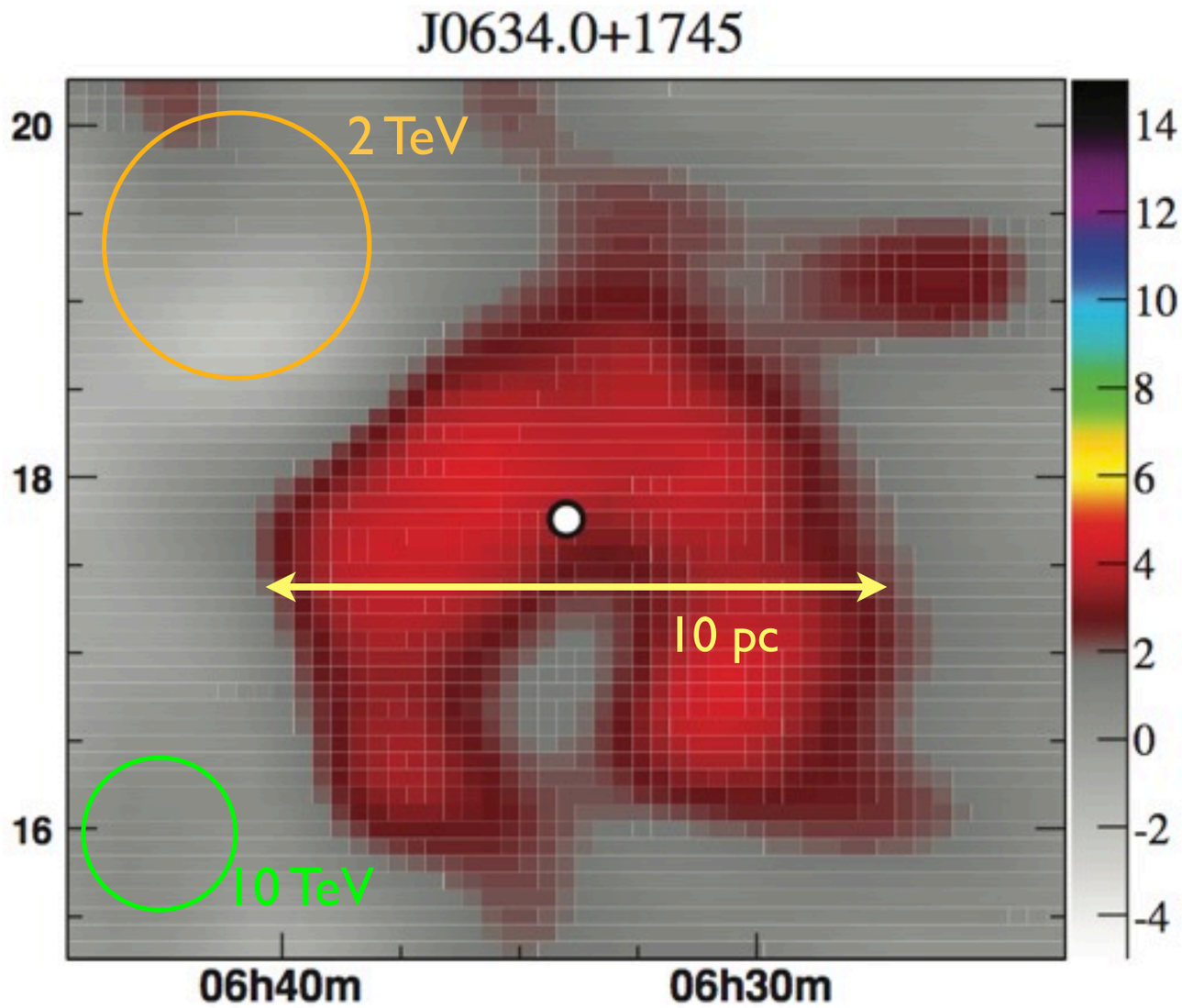
Different magnetic fields
100μG, 200μG, 300μG

A. Abdo, et al., ApJ, 708, 1254



F. Aharonian, Very High Energy Cosmic Gamma Ray Emission, Fig. 6.21

Geminga

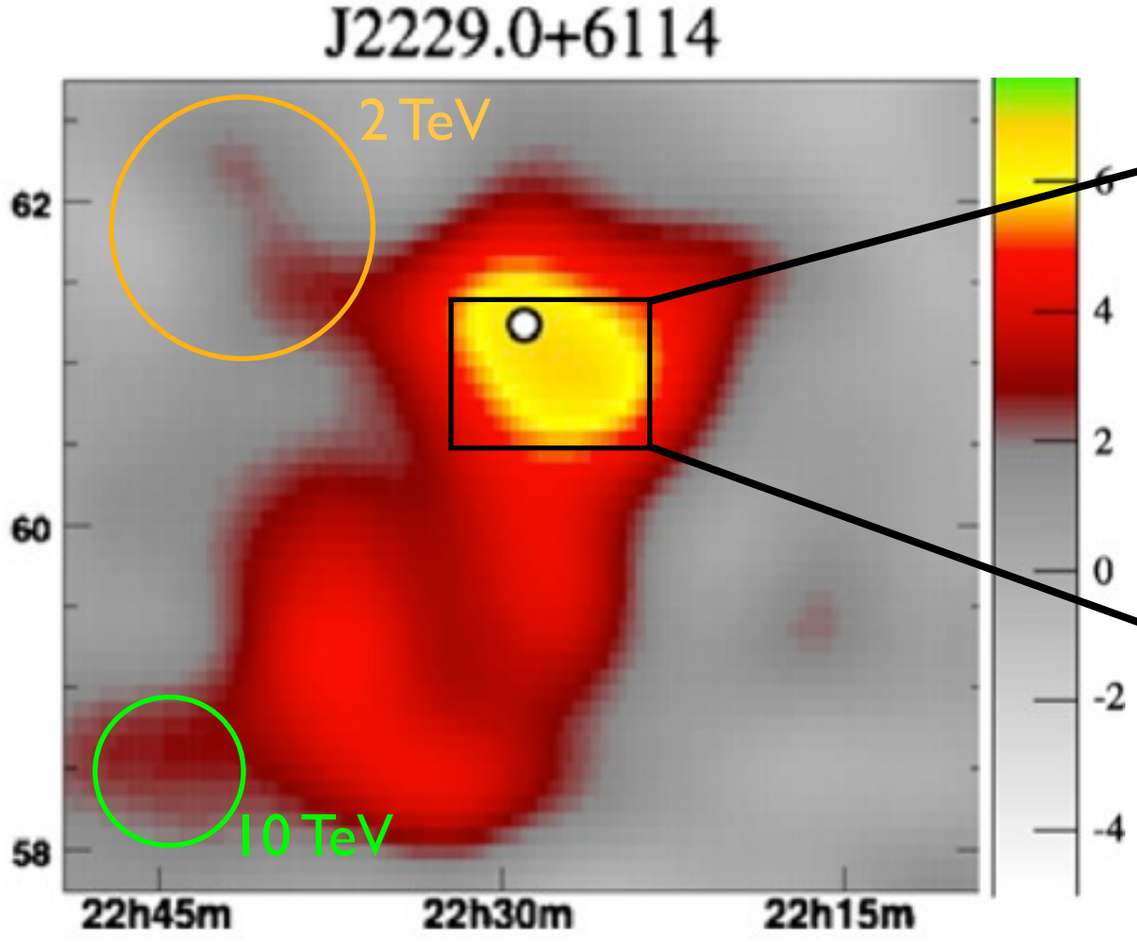


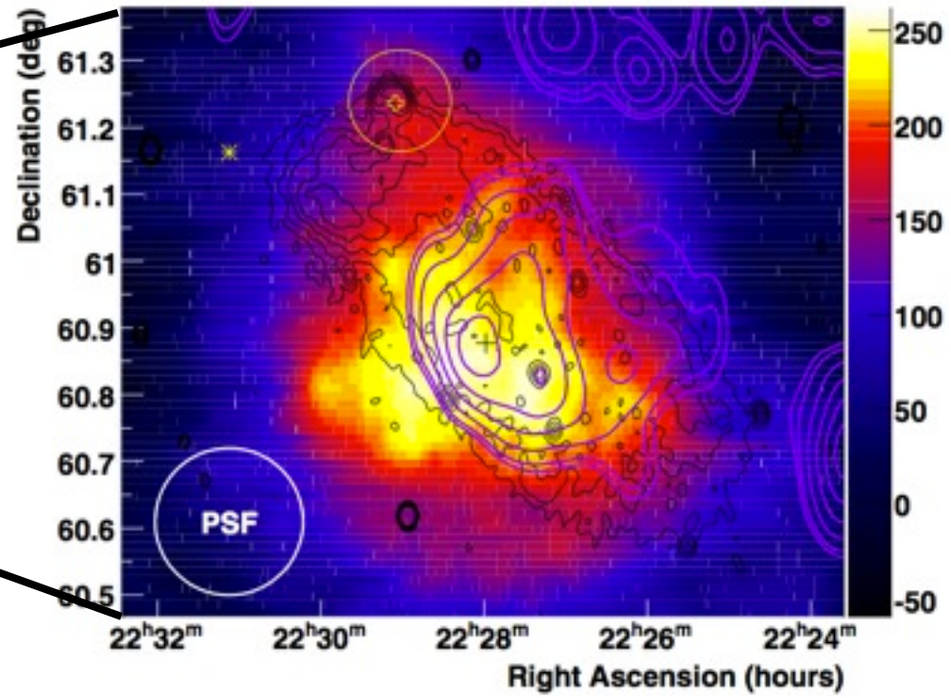
A.Abdo, et al., ApJ, 700, 127

Milagro PSF-smoothed map
Bin size: 0.1 deg

- Associated with PSR J0634.0+1745
- Age ~ 370 k year
- Spin-down energy ~ 3.26 * 10^{34} erg/s
- Period 0.237s
- Distance ~ 250 parsec
- 2.6 degree extent seen by Milagro

Boomerang



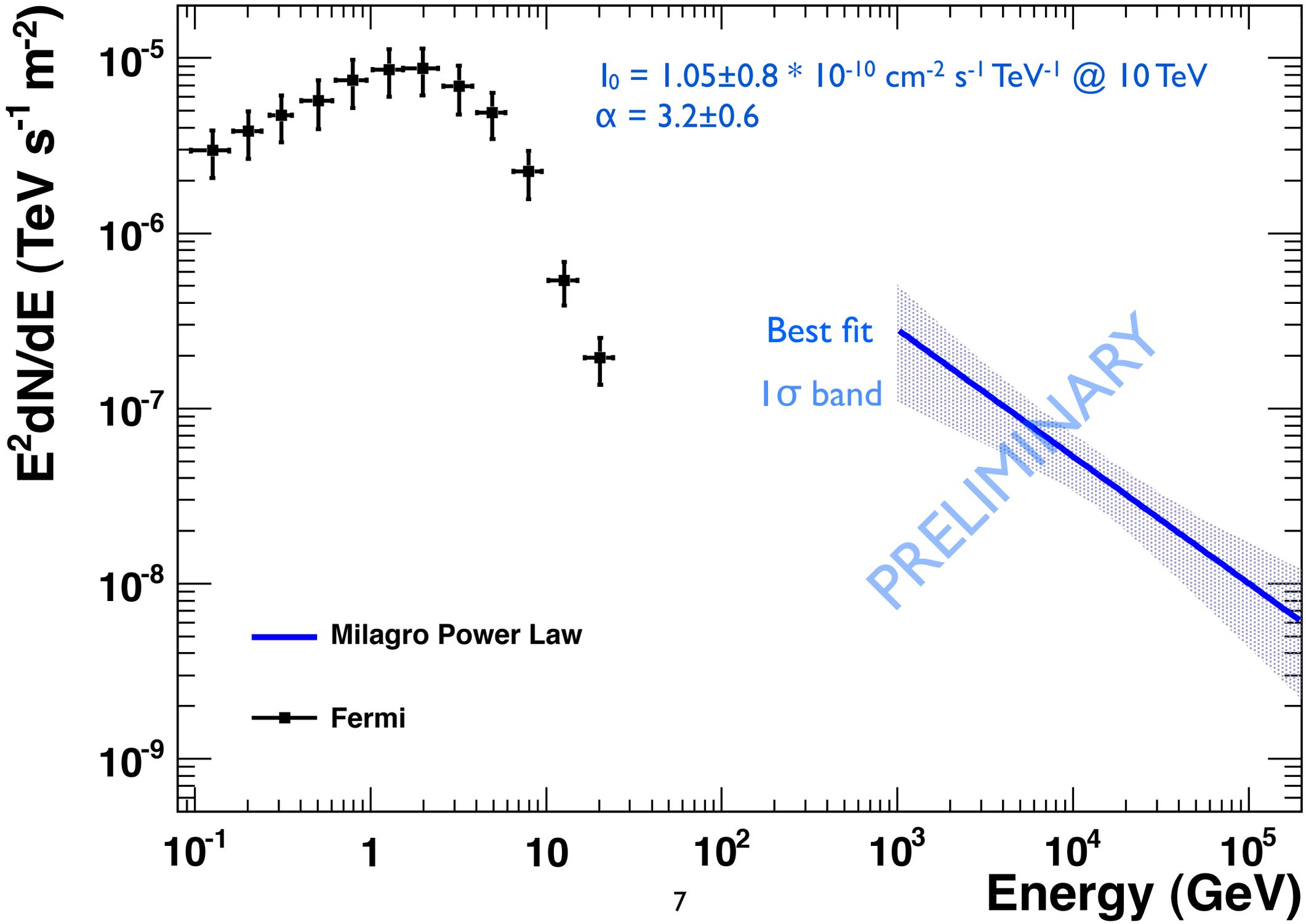


- Associated with PSR J2229+6114 and SNR G106.3+2.7
- Age ~ 10 k year
- Spin-down energy ~ 2.2 * 10^{37} erg/s
- P = 51.6ms
- Distance ~ 800 parsec

A.Abdo, et al.,ApJ, 700, 127

V.Acciari, et al.,ApJ, 703, 6

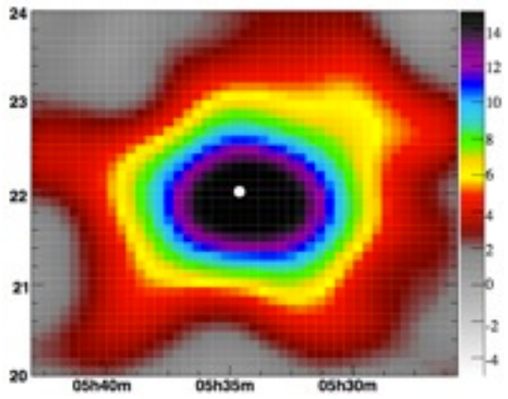
Spectral Analysis on Geminga



Optimizing the Method on Extended Sources

Point source analysis:

Crab

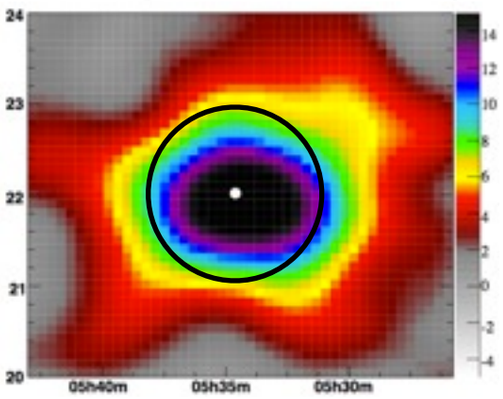


← excess in one 0.1 by 0.1 degree bin on PSF-smoothed map may underestimate the flux for extended sources

A.Abdo, et al., ApJ, 750, 63

Extended source analysis (preliminary):

Integrate over (source radius + 1.58 PSF)



← Integrate over (0 deg + 1.58 PSF)

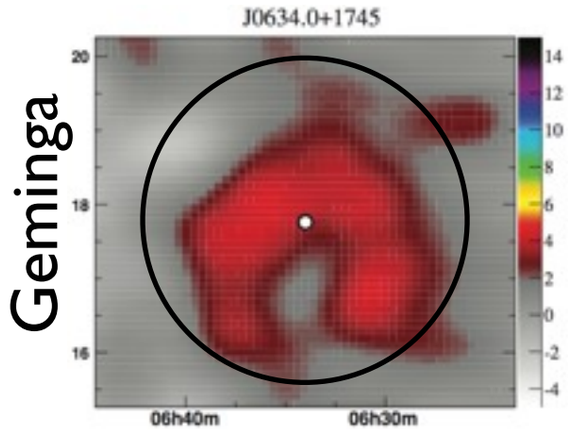
Testing on Crab nebula

	Crab (point) Power law	Crab (extended) Power law
flux norm [10^{-14} cm^{-2} s^{-1} TeV^{-1}]	6.5 6.1-6.9	7.88 7.13-8.65
energy norm [TeV]	10	10
index	3.1 3.0-3.2	2.975 2.9-3.05
Integral flux 1-100 TeV [10^{-10} cm^{-2}s^{-1}]	39.0	37.7

PRELIMINARY

Optimizing the Method on Extended Sources

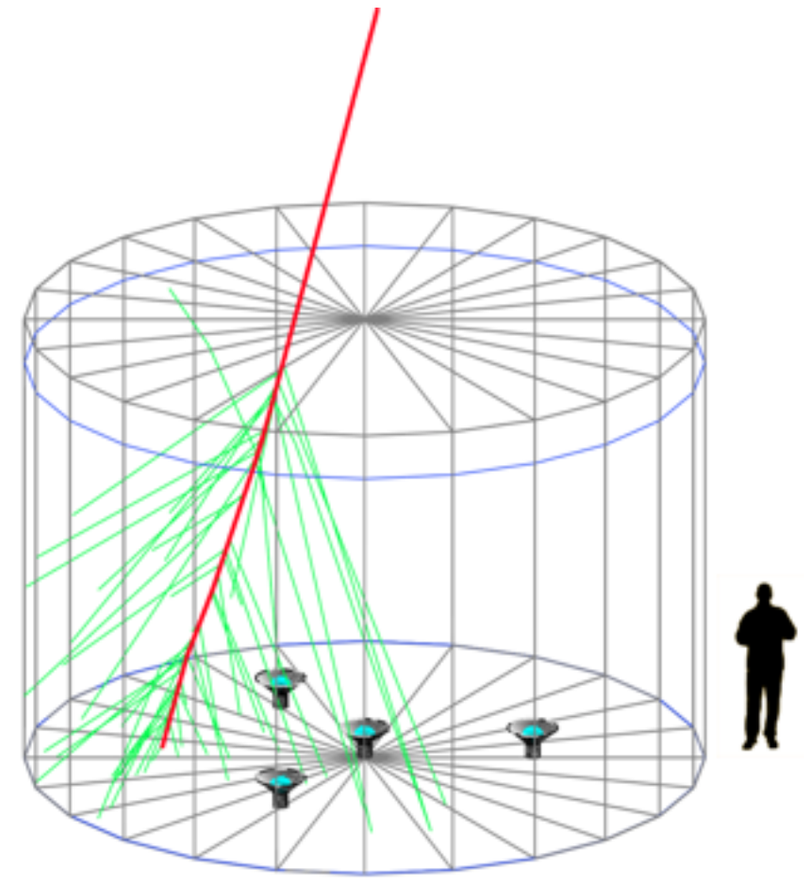
Extended source analysis (preliminary):



← Integrate over (1.3 deg + 1.58 PSF)

	Geminga (point) Power law	**Geminga (extended) Power law**
flux norm [10^{-14} cm^{-2} s^{-1} TeV^{-1}]	1.05 0.27-1.80	5.32 3.38-7.17
energy norm [TeV]	10	10
index	3.2 2.6-3.5	2.725 2.475-3.0
Integral flux 1-100 TeV [10^{-10} $cm^{-2}s^{-1}$]	7.6	16.3

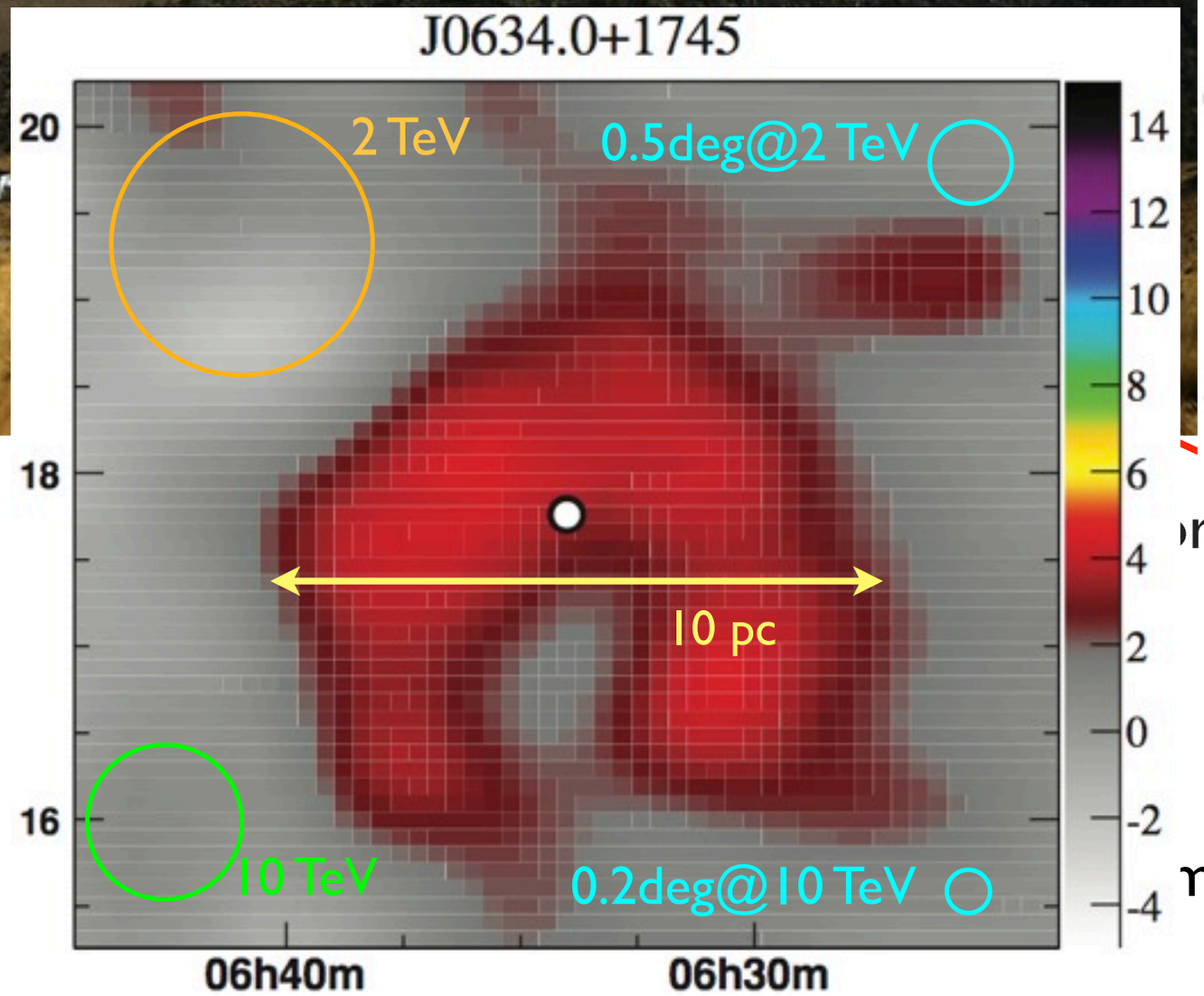
HAWC

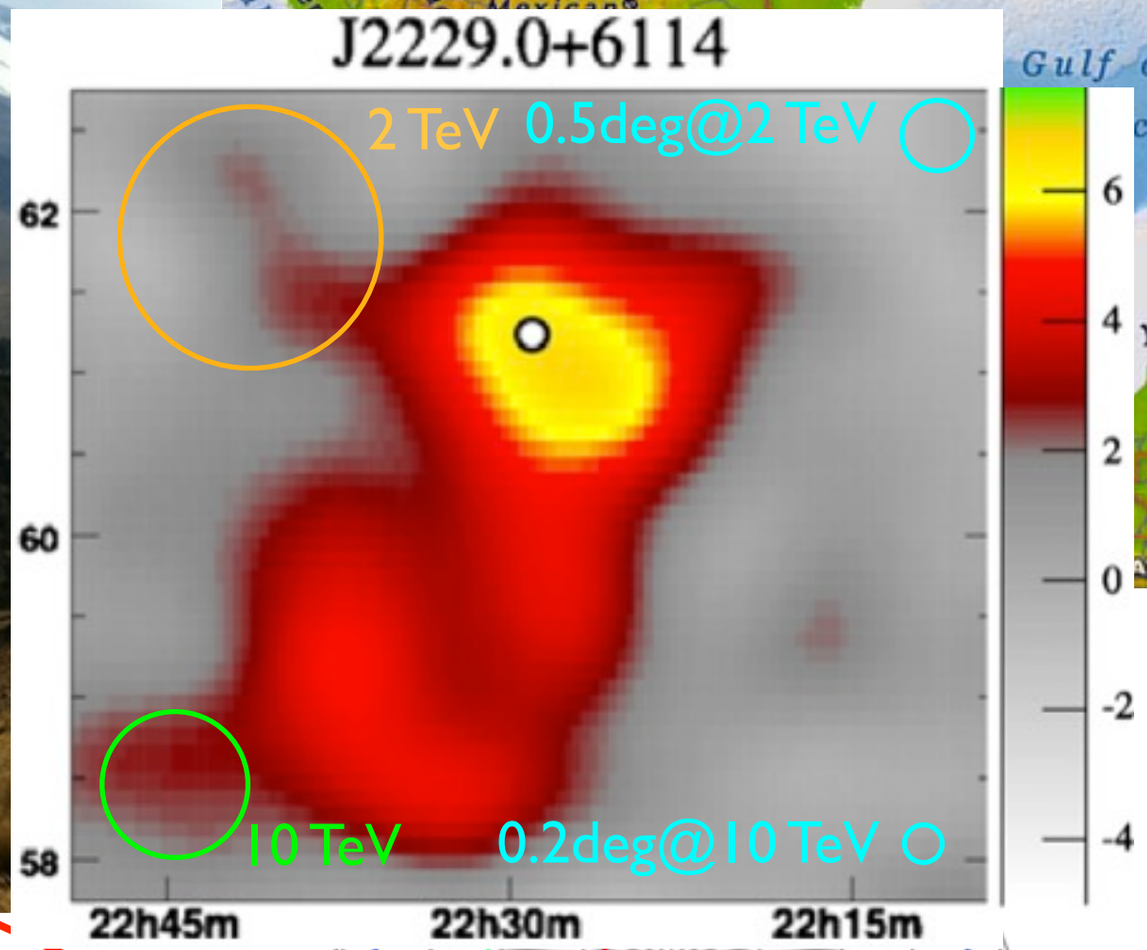


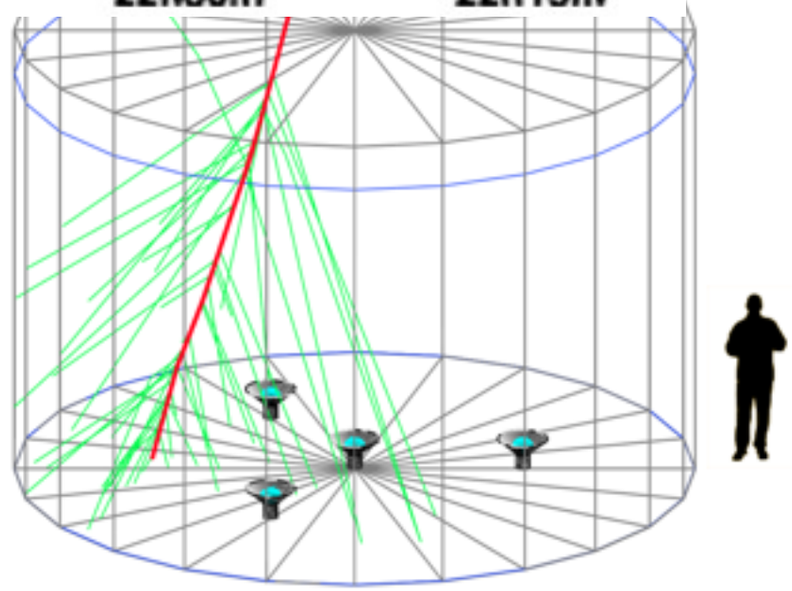
- High Altitude Water Cherenkov
- Altitude: 4100 meters
- 0.1 TeV~100 TeV, FoV ~2 sr, >90% duty cycle
- 300 water Cherenkov detectors
- 10% of the array is operational from last fall
- 30% of the array will be deployed this summer
- 100% in summer 2014

HAWC

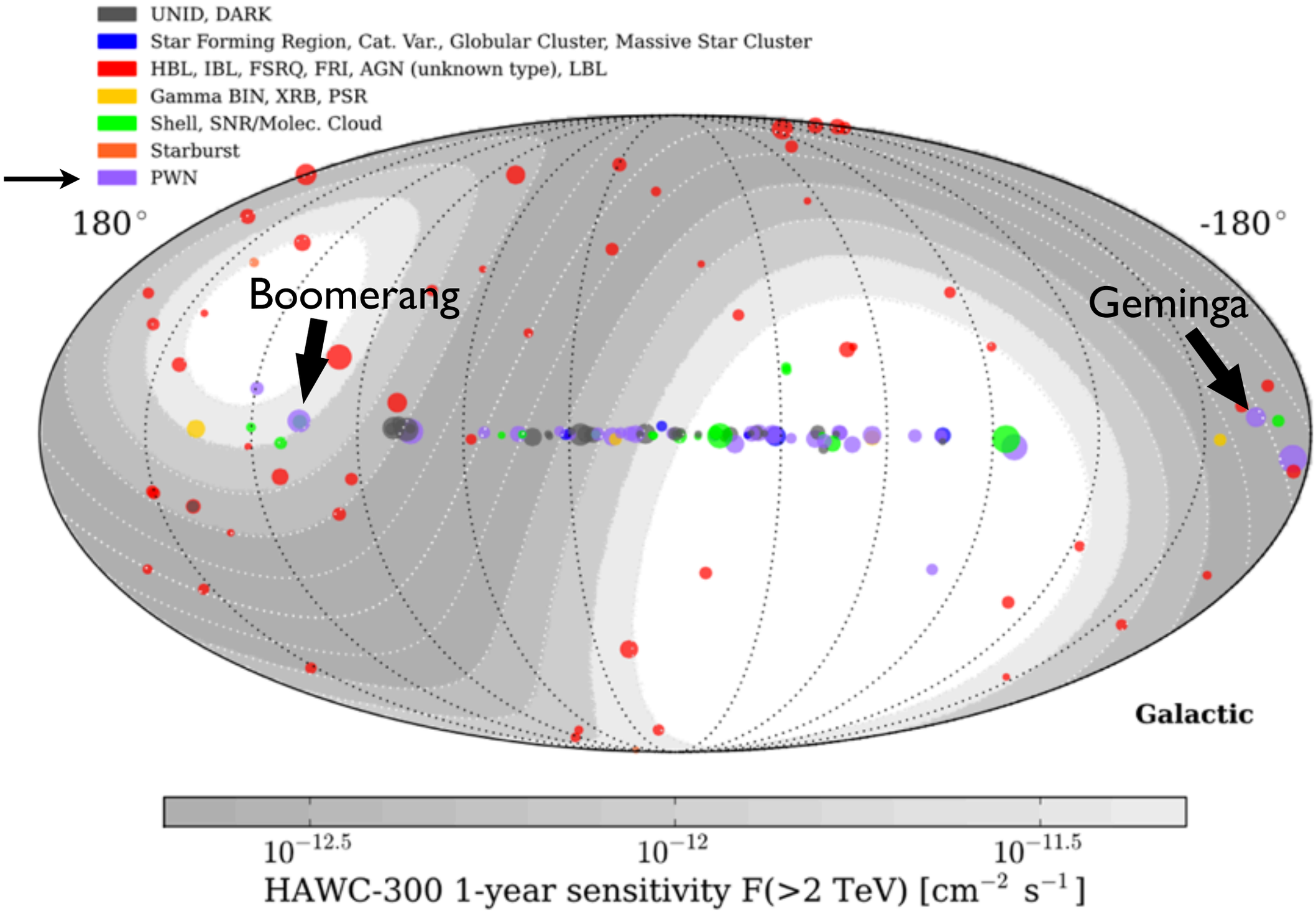
Improvement on angular resolution!







HAWC Sensitivity



HAWC Sensitivity to PWNe

A.Abdo, et al.,ApJ, 700, 127

Milagro dec = +35
HAWC dec = +19

source	declination	sigma in 8 year Milagro	sigma in 1 year HAWC
Crab	+22.05	17.2	169.0
Geminga	+17.76	3.5	41.8
Boomerang	+61.24	6.6	10.5
MGRO J1908+06	+6.03	7.4	58.0
MGRO J2019+37	+36.83	12.4	51.2
MGRO J2031+41	+41.19	7.6	64.3
0FGL J0631.8+1034	+10.57	3.7	24.5

Improvement on sensitivity!

Outlook

- Majority of galactic TeV sources are PWNe.
- Spectral analysis on extended sources needs to be optimized.
- Multi-wavelength study and model development on PWNe are important to understand the spectra and features.
- HAWC is a ground-based gamma ray detector that will detect the PWNe with the highest sensitivity at the highest energy range.

HAWC construction
Jan 2012 - Feb 2013

Thank you!