Fermi Large Area Telescope observations of supernova remnants Kes 73 and Kes 79

Paul K. H. Yeung

Collaborators: Albert K. H. Kong, P. H. Thomas Tam, Yudong Cui, C. Y. Hui, Jumpei Takata, K. S. Cheng

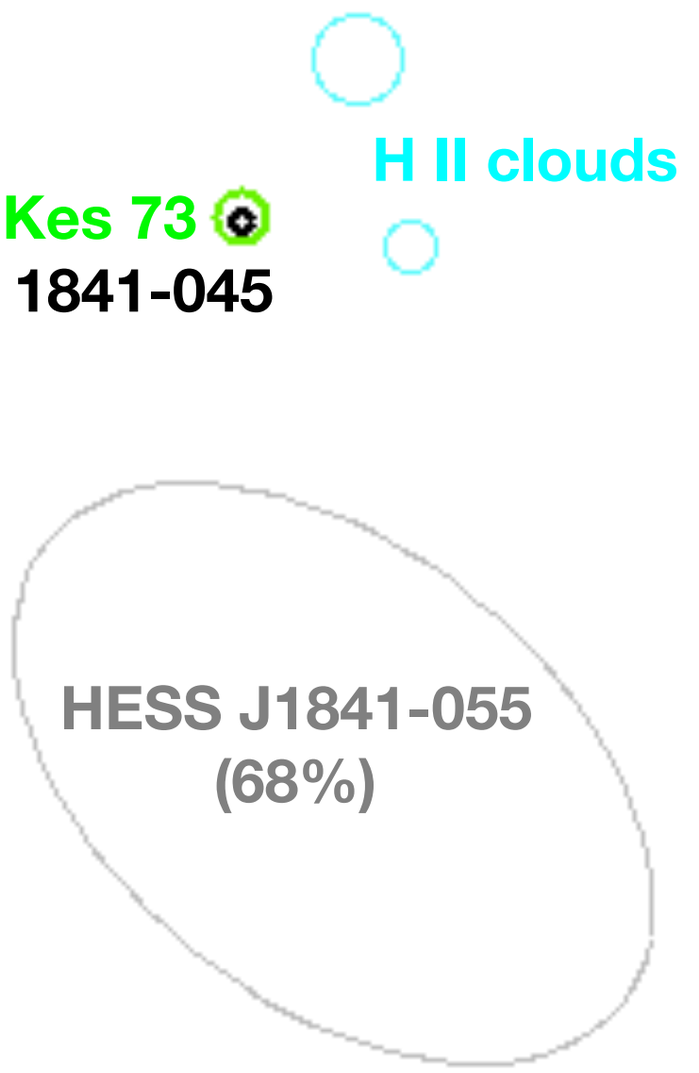
The contents of this presentation have been (or will be) published in journals:
Paul K. H. Yeung et al. 2017, ApJ, 837, 69 (for Kes 73)
Paul K. H. Yeung et al. 2017, MNRAS, submitted (for Kes 79)

Kes 73

Kes 73

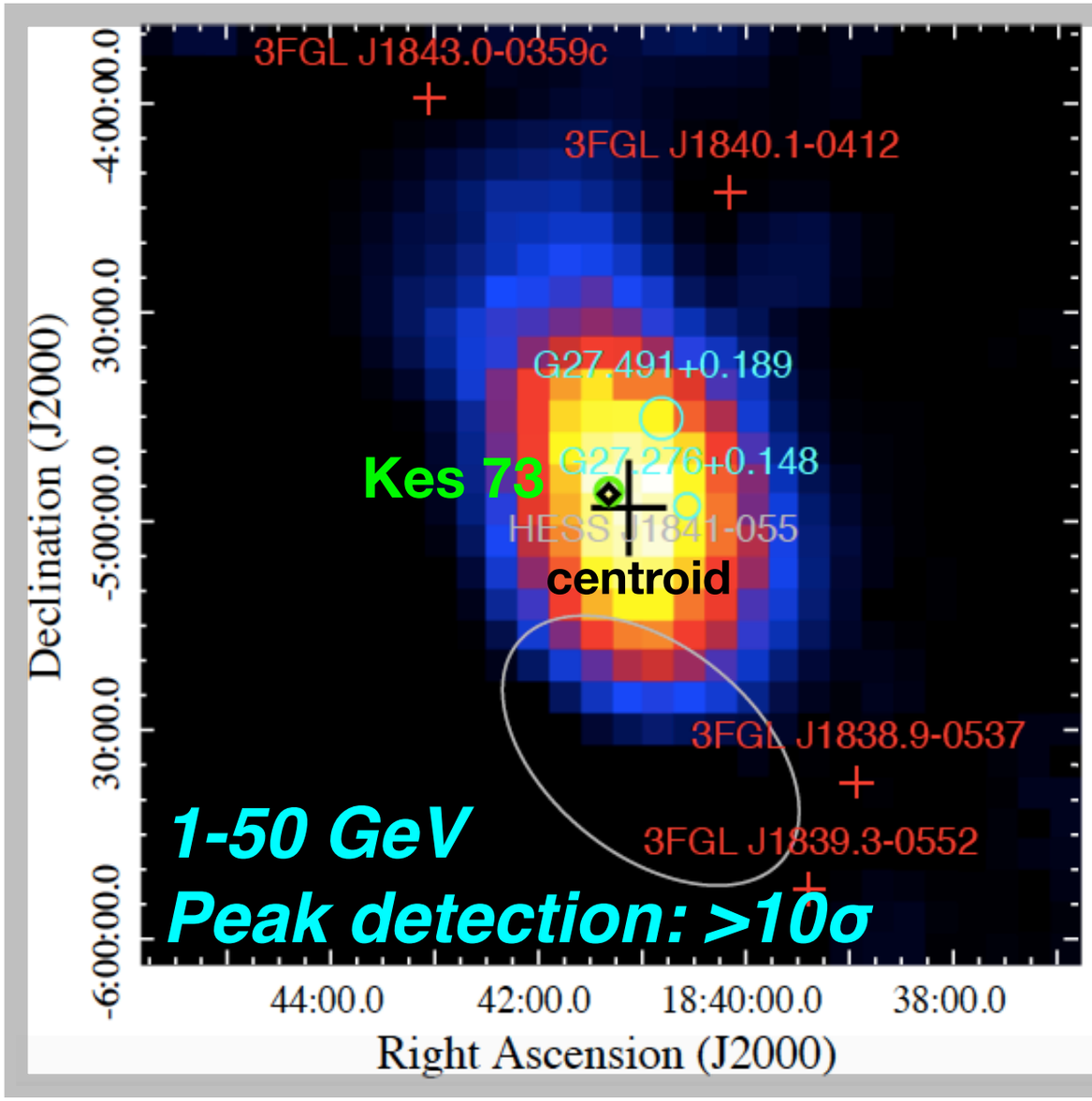
Environment

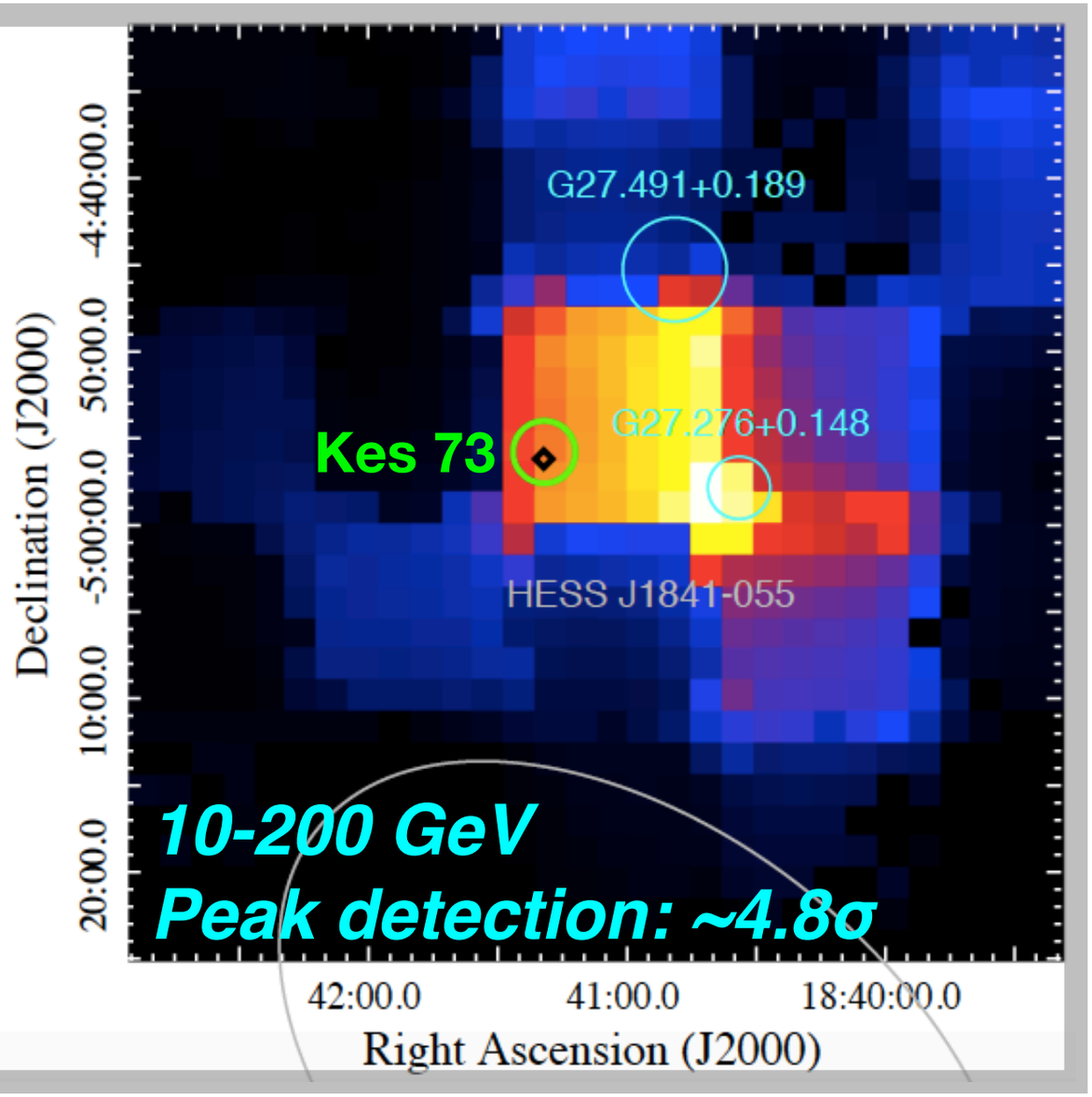
- SNR Kes 73 contains a central magnetar (1E 1841-045)
- The entire system has a young age of 750-2100 yr
- Its region shows intense TeV emission at the northern edge of the extended source HESS J1841-055 ***(The origin of our motivation)***
- Kes 73 is tightly interacting with molecular clouds (MCs)



Kes 73

LAT Morphology

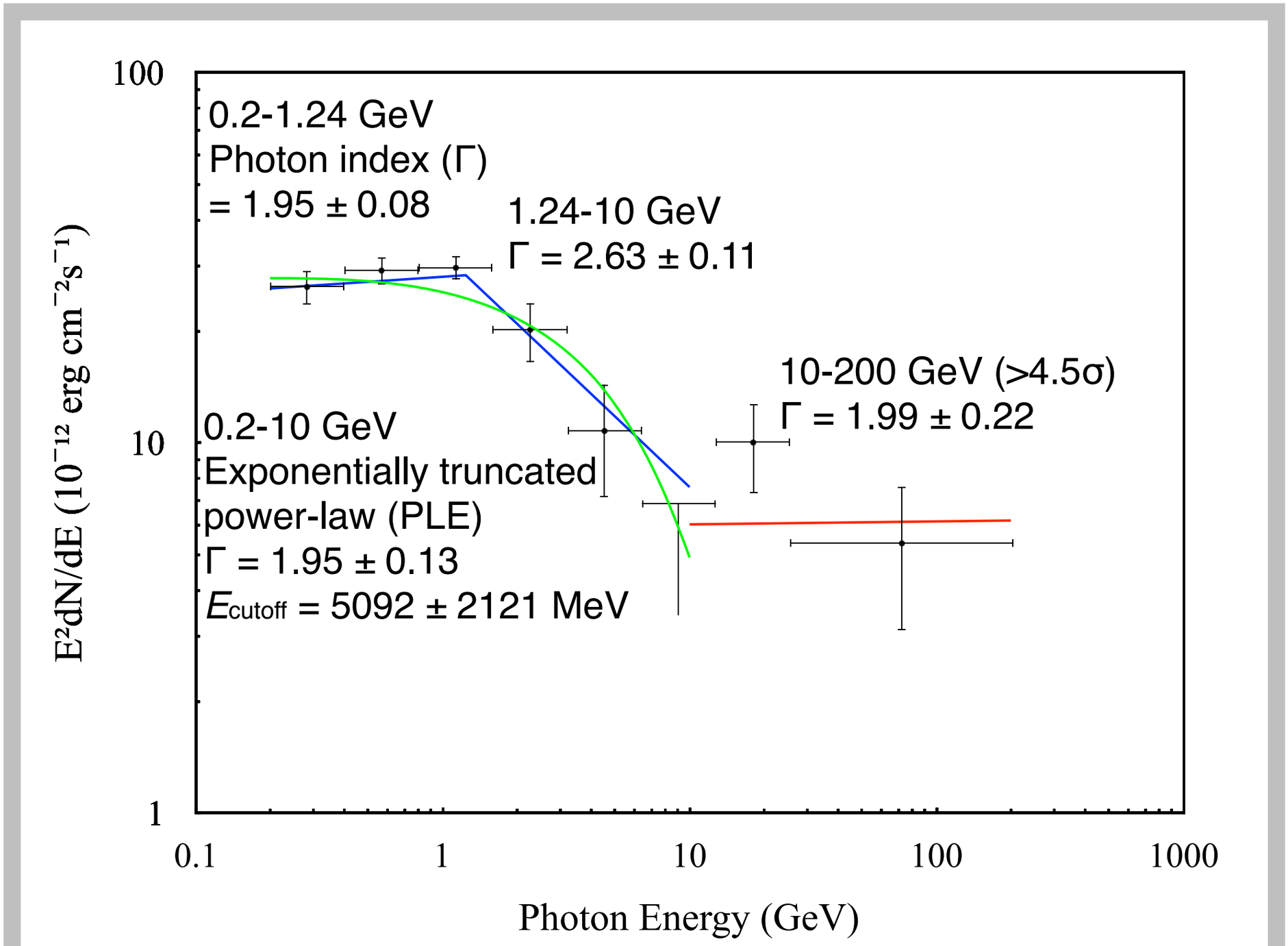




Radius of extension: ~0.32°

Kes 73

LAT Spectrum



Kes 73

Relations with SNR

Mechanism 1: Hadronic proton-proton interaction with MCs *(unlikely to dominate)*

- In this scenario, the actual γ-ray source should be the proton collision sites (MCs) rather than the proton acceleration sites (SNR shocks), contradicting the morphology observed by LAT.

- The ~1-10 GeV spectrum of the Kes 73 region is significantly steeper than those of all other young SNR-MC sources.

Kes 73

Relations with SNR

Spectral comparison among ***young-SNR associated sources*** detected by Fermi LAT

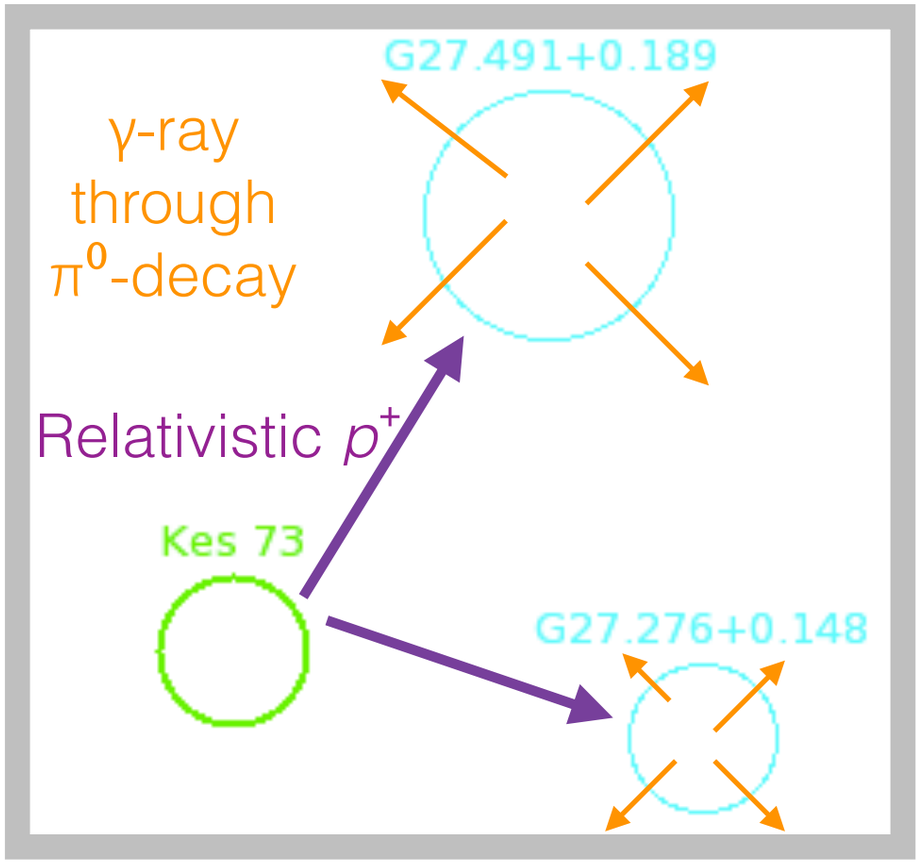
Source/Region	SNR age (kyr)	Energy band (GeV)	Photon index
The Kes 73/1E 1841-045 region	**0.75-2.1**	**0.2-1.24**	**1.95 ± 0.08**
		1.24-10	**2.63 ± 0.11**
		10-200	**1.99 ± 0.22**
Cas A	~0.34	0.5-50	2.0 ± 0.1
RX J0852.0-4622	2.4-5.1	1-300	1.85 ± 0.06
RX J1713.7-3946	~1.6	0.5-300	1.53 ± 0.07
Crab Nebula	~1.0	0.1-~1	3.59 ± 0.07
		~1-13.9	1.48 ± 0.07
		13.9-300	2.19 ± 0.17
RCW 103	~2.0	1-300	2.0 ± 0.1
Tycho	~0.44	0.3-~500	2.14 ± 0.09

Kes 73

Relations with SNR

Mechanism 1: Hadronic proton-proton interaction with MCs *(unlikely to dominate)*

- Only ~5% of cosmic rays accelerated in Kes 73 can reach the H II clouds.
  Kes 73 shows *no* signs of being thermal composite.
  —> The shocked interstellar medium interacting with Kes 73 is *not* that abundant.



Kes 73

Relations with SNR

Mechanism 2: Leptonic inverse-Compton (IC) scattering of soft photons

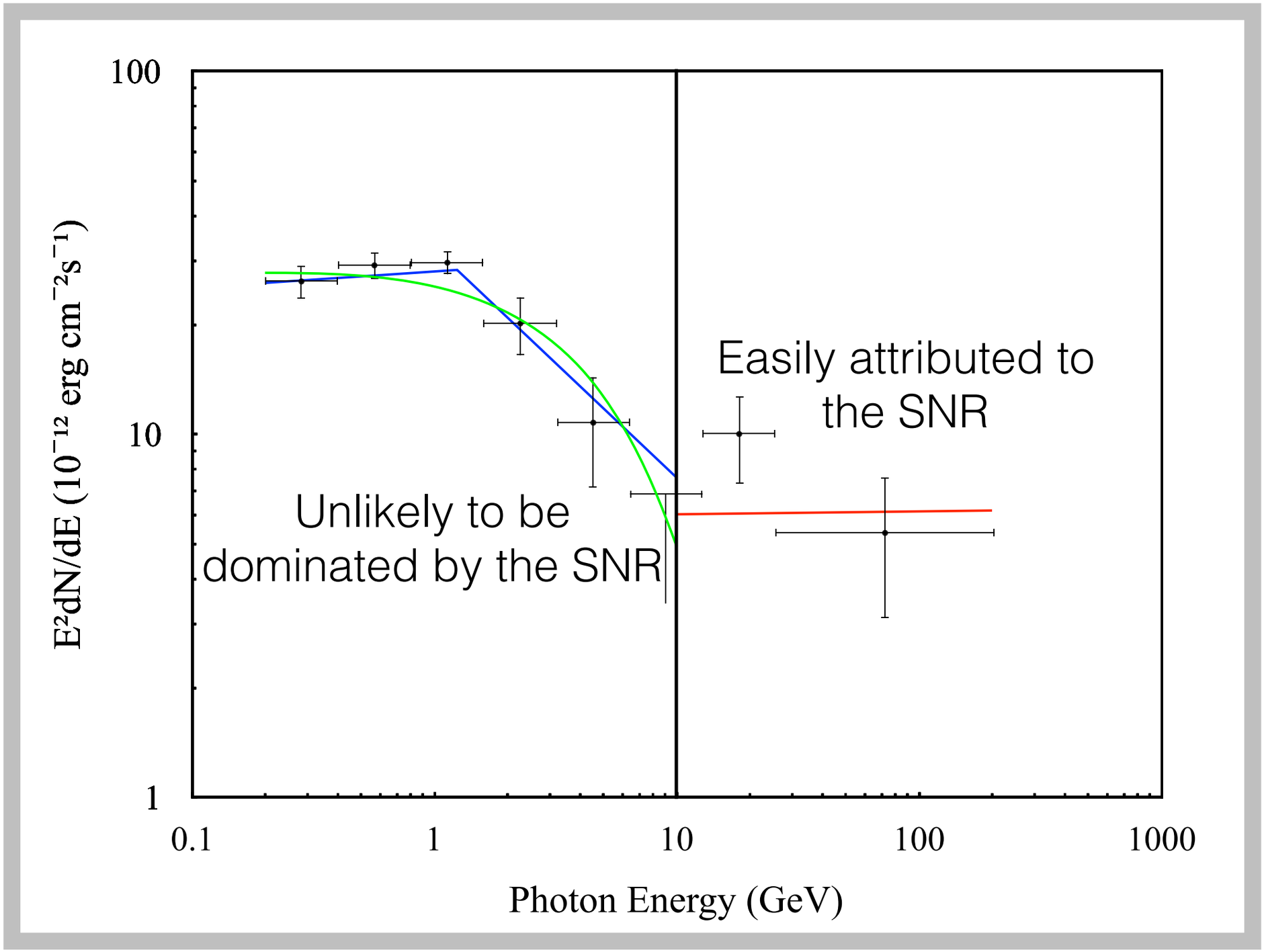
Mechanism 3: Complicated hadronic emission beyond one-zone models

- Both are possibly dominating the 10-200 GeV emission

- These scenarios had been proposed for 2.4-5.1 kyr old SNR RX J0852.0-4622 and ~1.6 kyr old SNR RX J1713.7-3946.

Kes 73

Summary



Kes 73

Future Work

Recommended follow-up tasks:

- To model the Kes 73/1E 1841-045 system as a single source independent from HESS J1841-055 in the TeV regime.

Anticipated scientific outcomes:

- Physically meaningful comparisons between GeV and TeV spectra can be performed.

- We can compare the GeV-TeV spectrum of the Kes 73/1E 1841-045 region to those of RX J0852.0-4622, RX J1713.7-3946 and Crab Nebula.

Kes 79

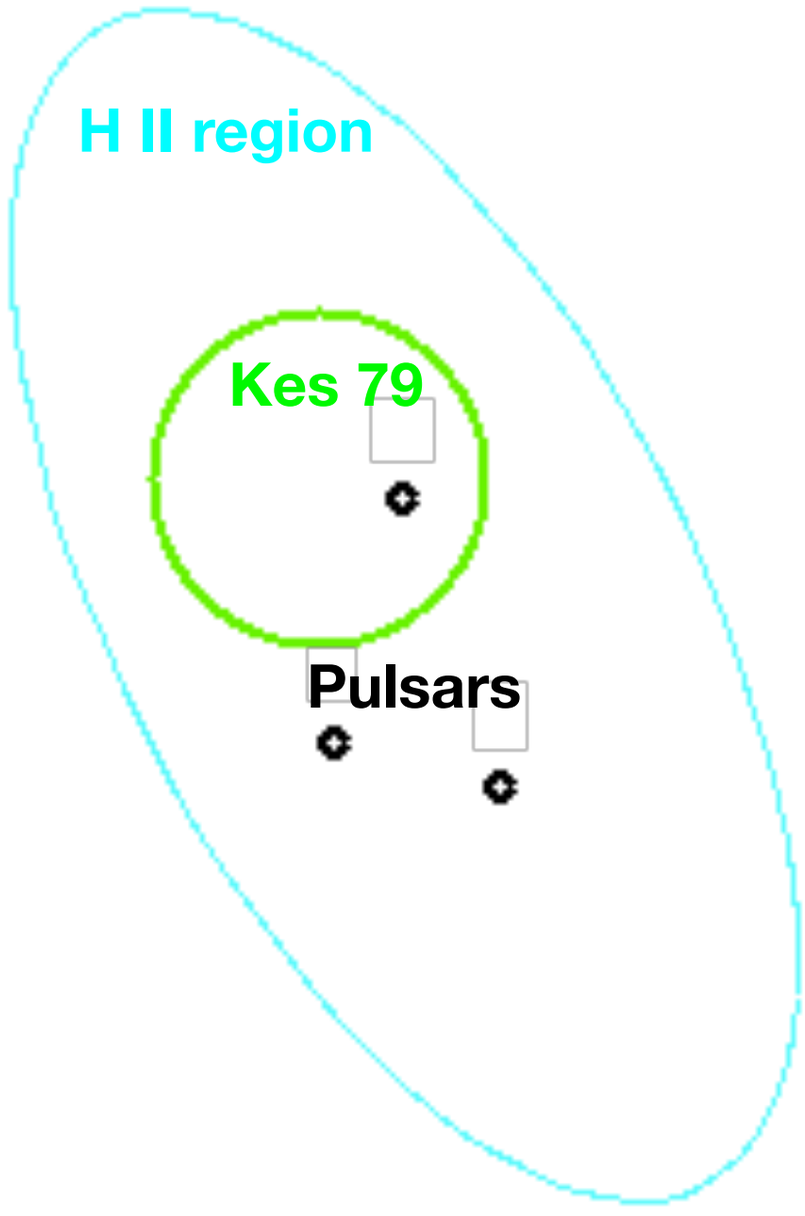
Kes 79

Environment

- SNR Kes 79 contains a pulsar at its center, and is adjacent to two other pulsars

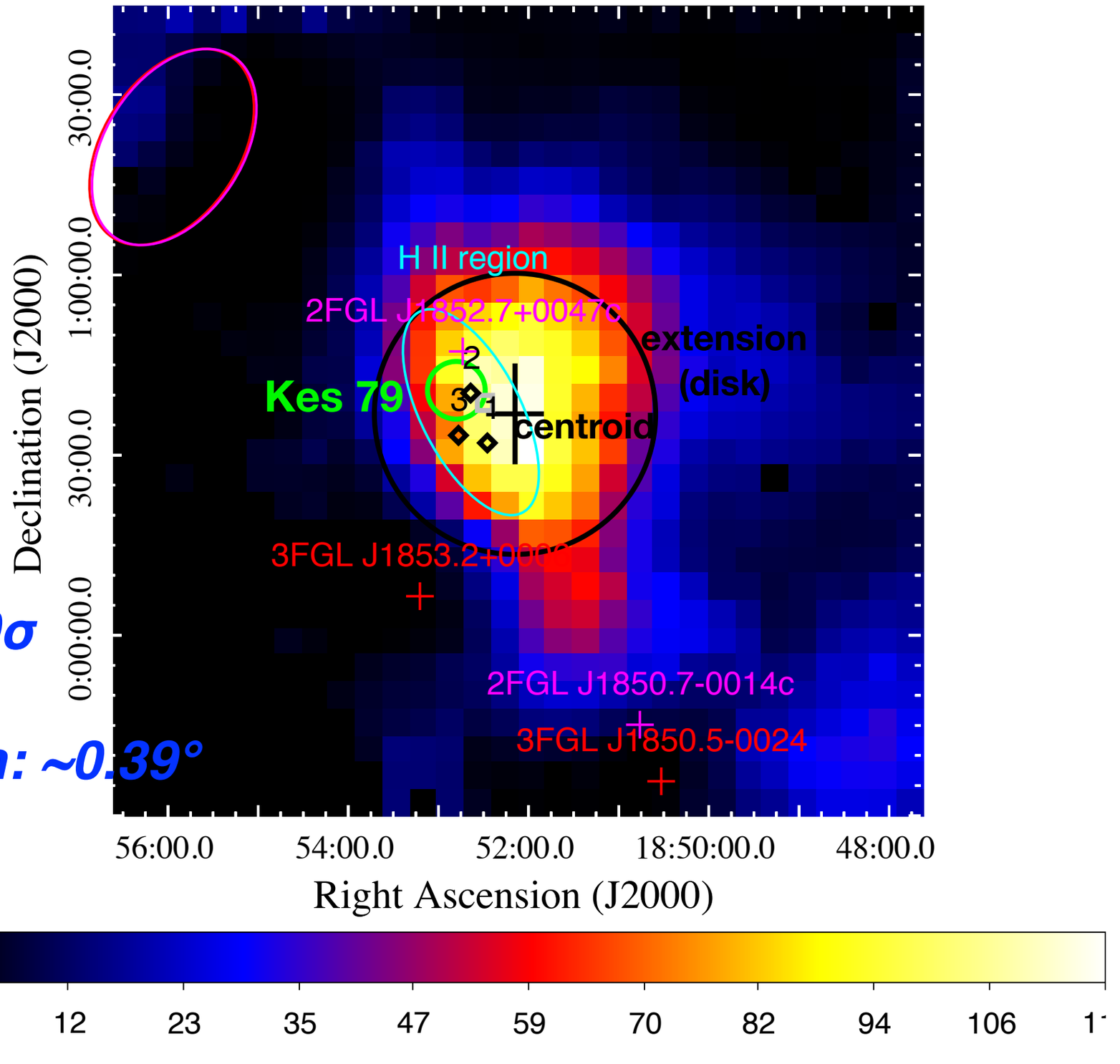
- The SNR age is 4.4-6.7 kyr

- Kes 79 is interacting with surrounding H II clouds



Kes 79

LAT Morphology



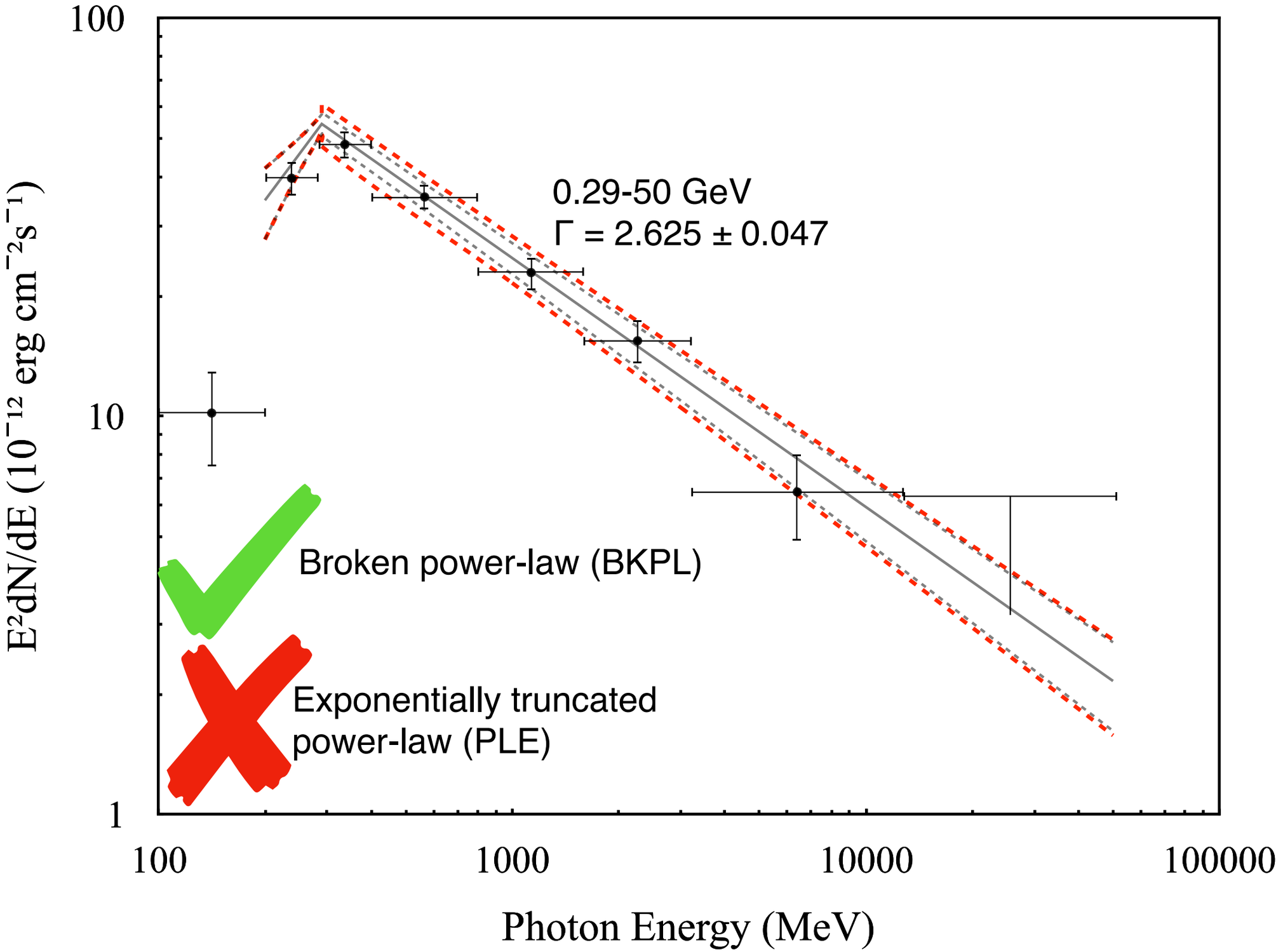
1-50 GeV

Peak detection: >10σ

Radius of extension: ~0.39°

Kes 79

LAT Spectrum



Kes 79

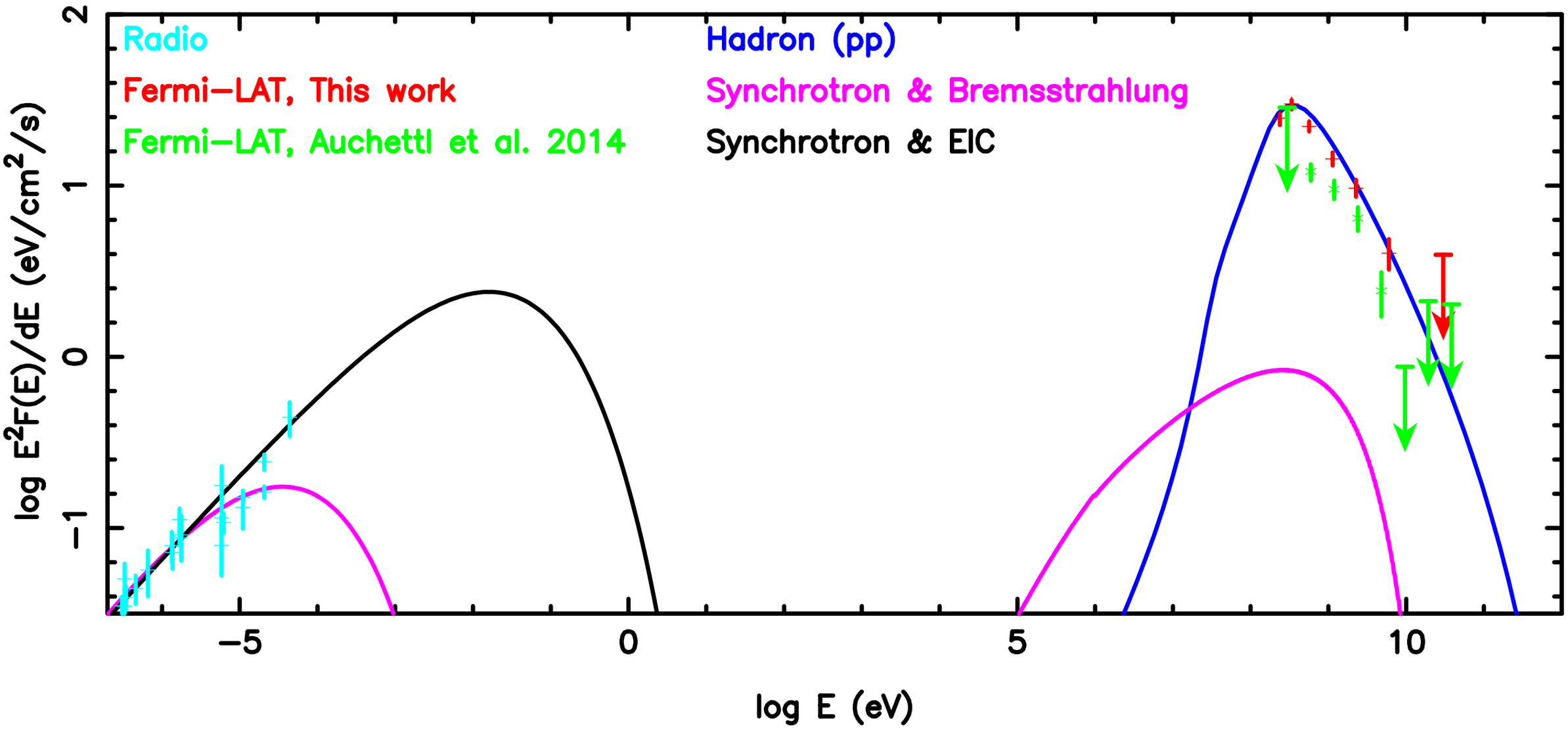
Relations with SNR

- Targeted particles for CR interaction
  - **Giant MCs** (for hadronic collision & bremsstrahlung): 70 H cm^{-3}
  - **Galactic soft-photon background** (for EIC): 1 eV cm^{-3}, 40 K
  - **CMB** (for EIC): 0.25 eV cm^{-3}, 2.73 K

Kes 79

Relations with SNR

Hadron & Lepton models **(fit independently)**



Kes 79

Relations with SNR

General CR properties				
Total energy	10^50 erg			
e^-/p^+ energy ratio	0.01			
Various physical models				
	CR spectral parameters			
	Index	Minimum cutoff energy (GeV)	Exponential cutoff energy (GeV)	Magnetic field (μG)
pp	**2.9**	**1**	**1000**	**–**
Syn & EIC **(max)**	2.0	0.001	60	100
Syn & Brems **(max)**	1.8	0.001	3 too low	60

<0.1% GeV flux

<2% GeV flux

Kes 79

Summary

- GeV flux is dominated by SNR
- Hadronic model is most plausible
- Pulsars' combined contribution (rotational + magnetic): <1/3 GeV flux

Kes 79

Future Work

Recommended follow-up tasks:

- Investigate SNR evolution history, acceleration process & diffusion environment of CRs, and MC structures
- Study it in TeV (previous HESS detection: ~2.7σ)

Anticipated scientific outcomes:

- Further testify the hadronic (pp) scenario

Supplementary Notes for Kes 73

Kes 73

Morphological Studies in Different Bands of Fermi

Energy Band	Radius of Extension	Error	2ln(Lext/Lpt)	
(GeV)	(deg)			
0.3-1	**0.167**	**0.091**	**1.30**	**point-like**
1-3	0.369	0.040	37.13	
3-200	0.383	0.046	21.89	

The centroid doesn't shift at all.

To be published in the proceeding of the 7th Fermi Symposium 2017

Keep calm

and

analyze Fermi data