Modelling the gamma-ray emission from regions adjacent to HESS J1825-137

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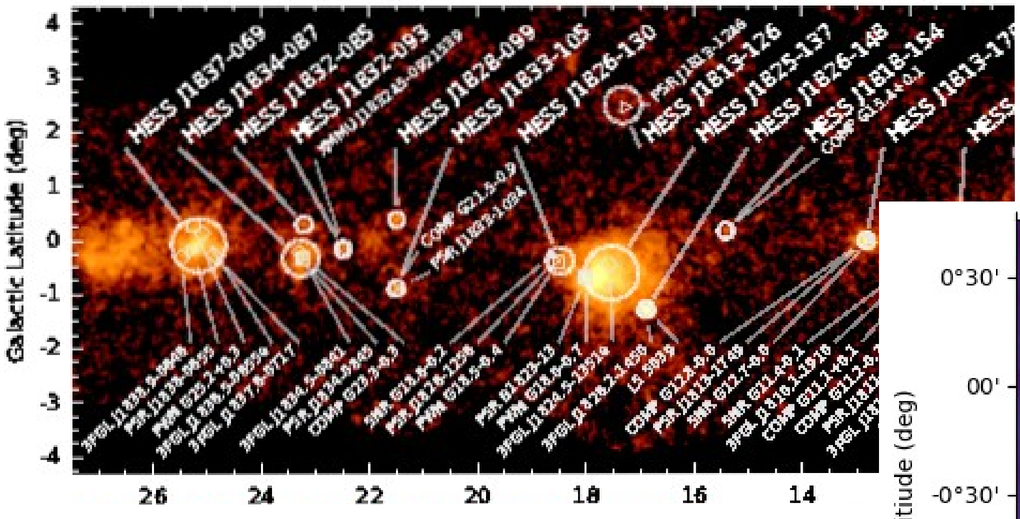
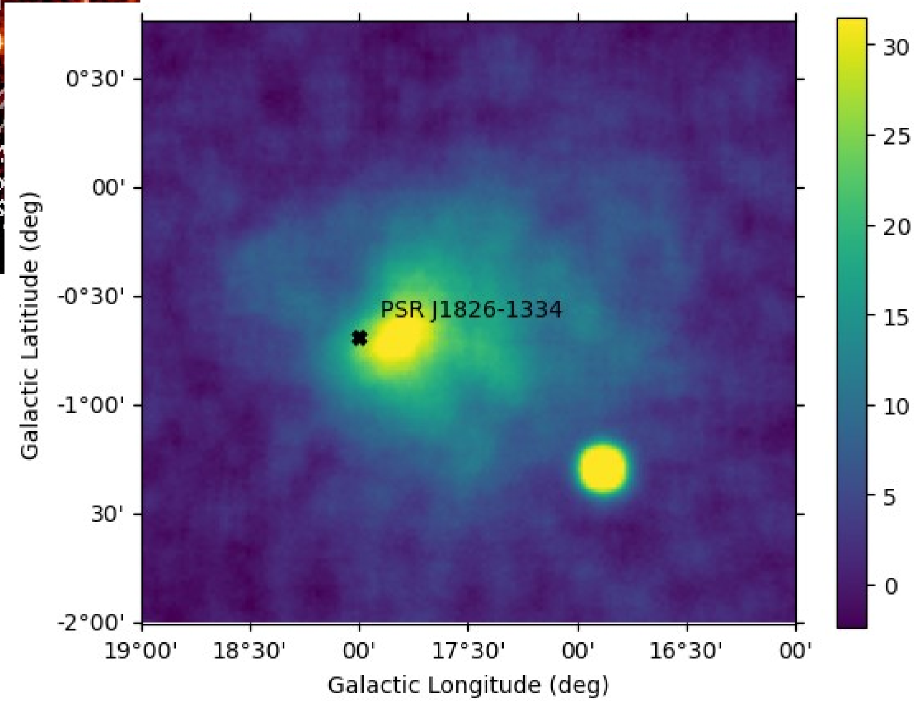
HESS J1825-137

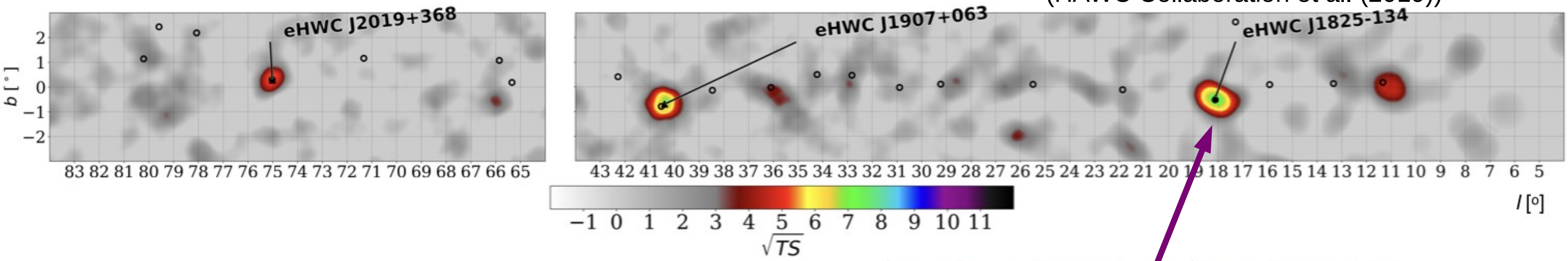


(H. E. S. S. Collaboration et al. 2018)

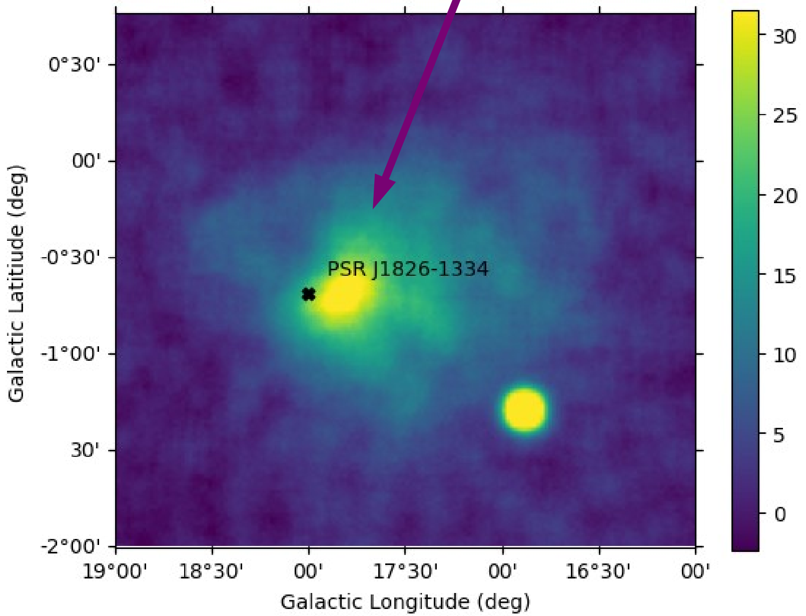


HESS J1825-137

(HAWC Collaboration et al. (2019))



- HAWC observatory observes γ-rays > 100 TeV from this source.
- A TeV halo can be seen around HESS J1825-137.



(H. E. S. S. Collaboration et al. 2018)

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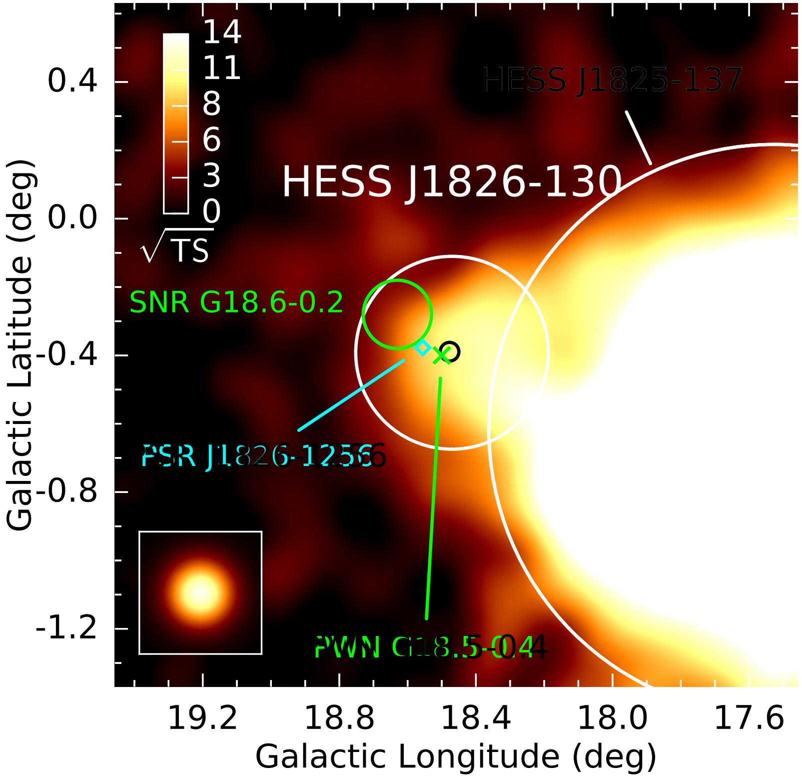
HESS J1826-130

(H. E. S. S. Collaboration et al. 2018)

- Possible PeVatron candidate.
- Originally considered an extension of HESS J1825-137.

Come back to this later...



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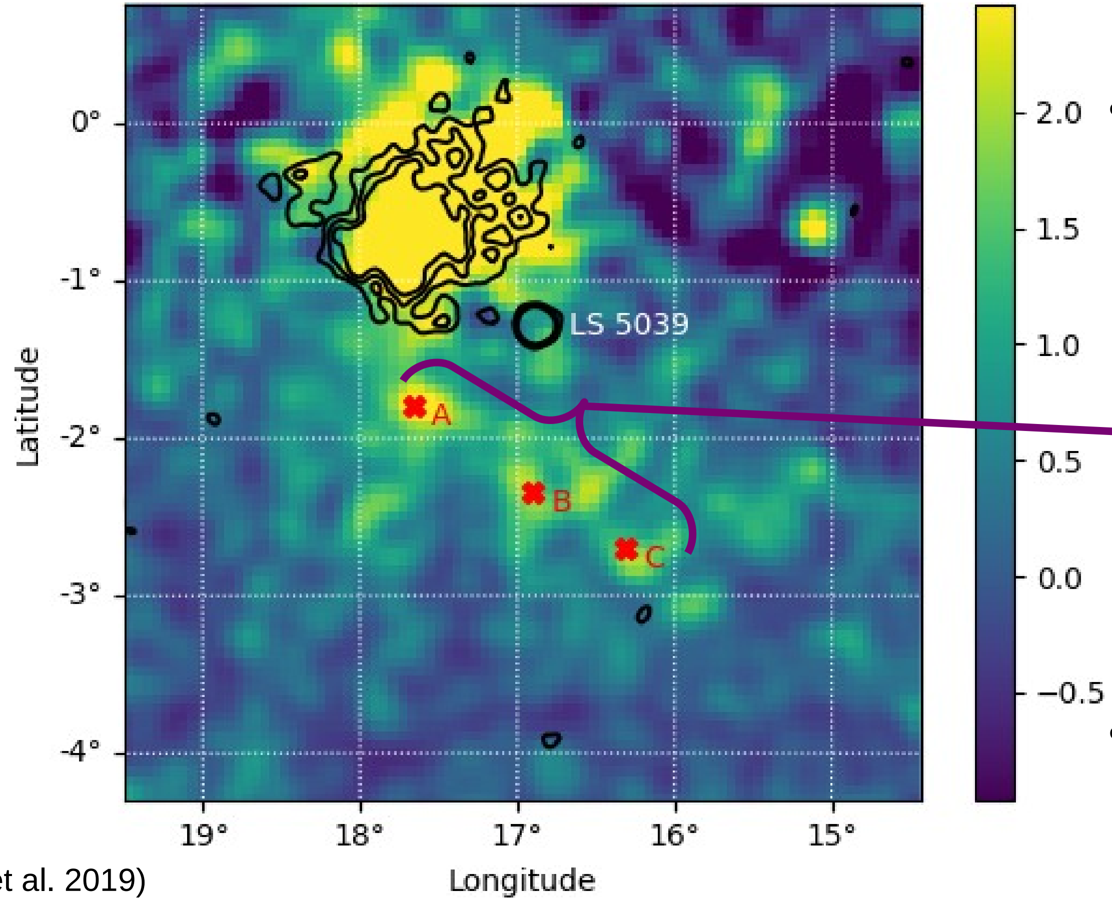
Yama



(Araya et al. 2019)

- A 2019 paper by Araya et al described new GeV emission observed by Fermi-LAT to the south of HESS J1825-137.

What particle accelerator accelerates particles to necessary energetics?

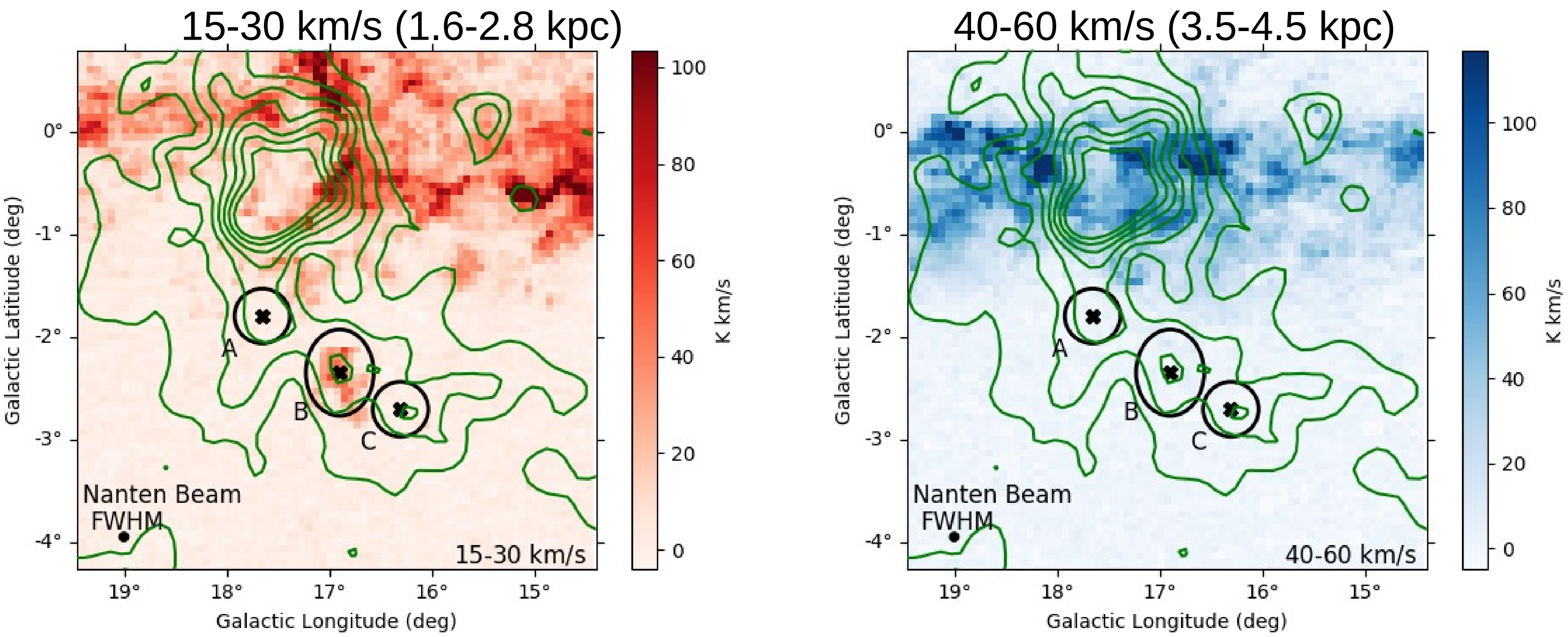
- Related to HESS J1825-137 or LS 5039?

Possible Accelerators of High Energy Particles

- HESS J1825-137
  - Impulsive (progenitor SNR)
    - Hadronic
    - Leptonic
  - Continuous (PWN)
    - Hadronic
    - Leptonic
- LS 5039
  - Impulsive (progenitor SNR)
    - Hadronic
    - Leptonic
  - Continuous (radio jet)
    - Hadronic
    - Leptonic

PWN : Pulsar Wind Nebula
SNR: Supernova Remnant

NANTEN 12CO(1-0) data



Gamma-ray flux due to proton-proton and bremsstrahlung interactions is proportional to the density of gas

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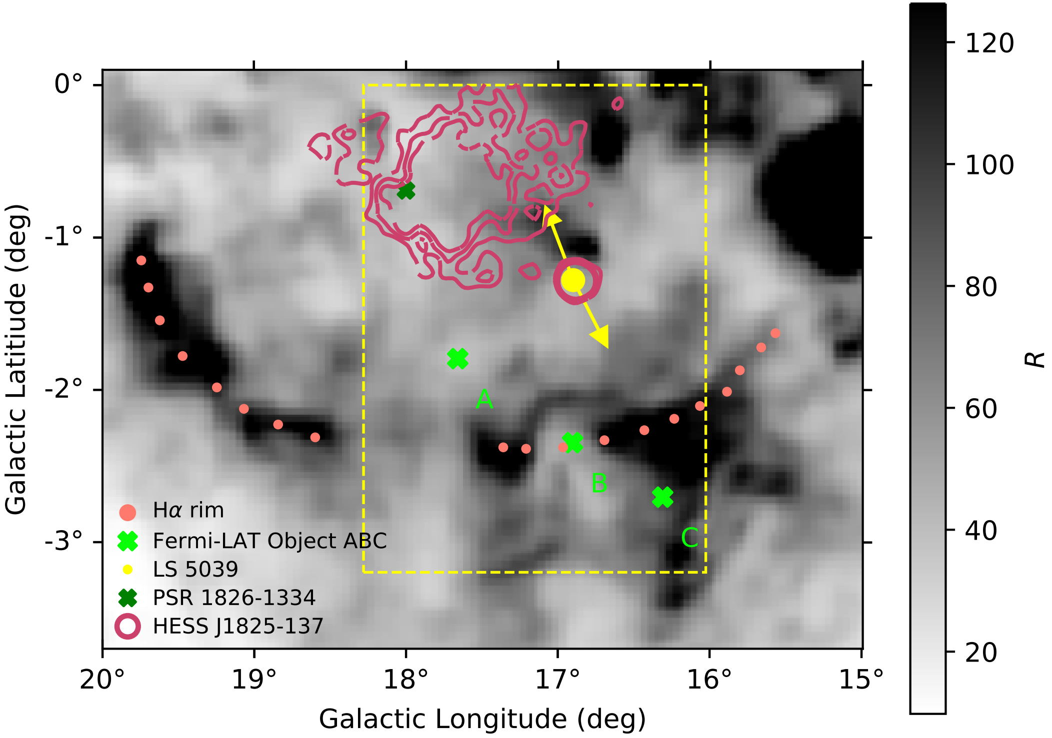
Hα data



(Finkbeiner 2003)

- Possible SNR rim for HESS J1825-137 seems to intersect Yama-B
- Hα “hole” towards object B which the CO cloud seen in the 15-30 km/s range seems to fit into.
- Radio jets from LS 5039 seem to point in the general direction of Yama.

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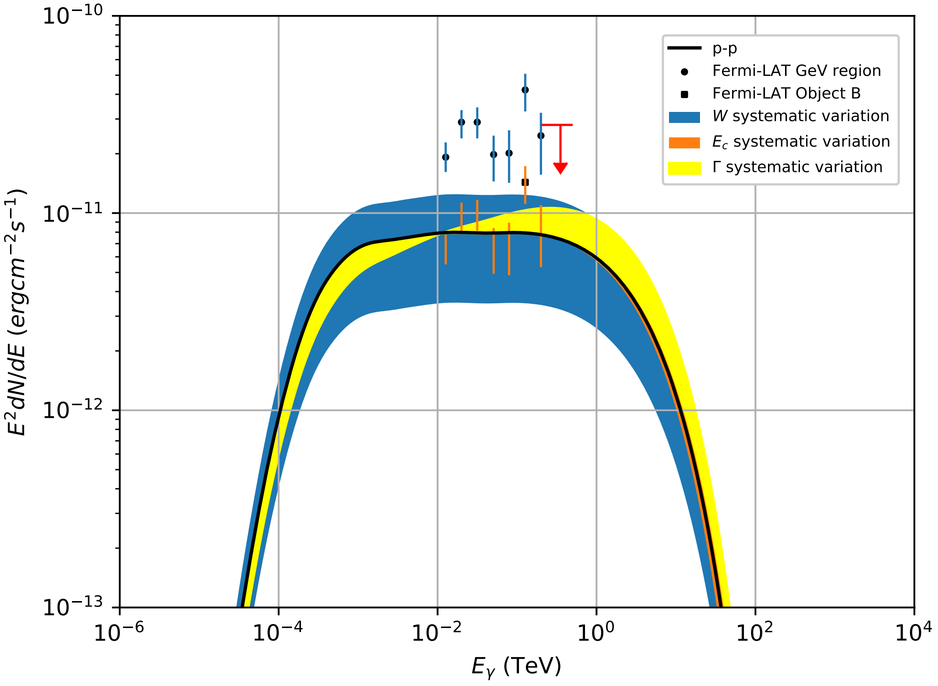
Progenitor SNR for HESS J1825-137 as the accelerator?



Successful models:

- Hadronic – Impulsive – Yama-B – 21 & 40 kyrs
- Assuming constant energy density, the SNR contains 5x10^{50} ergs of energy.
- BUT the model has to explain Yama-A and Yama-C simultaneously
- Yama-A & C requires > 10^{51} ergs within SNR.

Note: During modelling, only consider the object's (eg Yama-B) contribution to the total SED.

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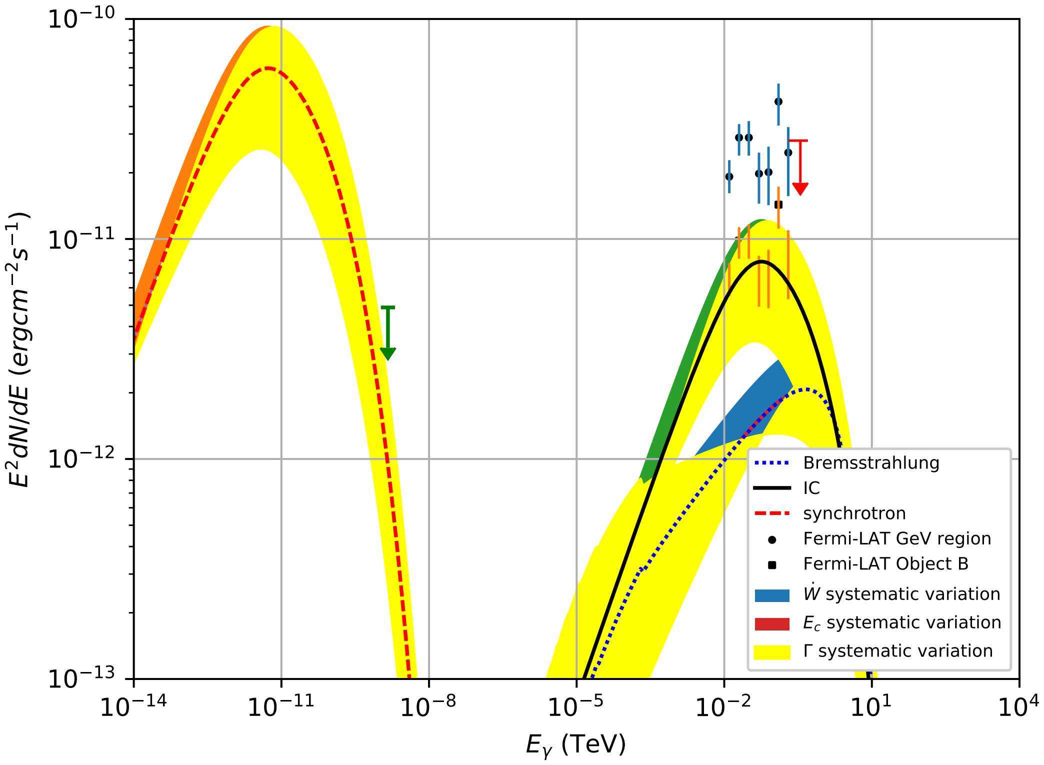
PWN for HESS J1825-137 as the accelerator?



- Leptonic – Continuous – 21 & 40 kyrs
- Required injection luminosity of electrons ~ 10^{37} ergs/s
- Spin down power of pulsar ~ 10^{36} ergs/s
- May represent an earlier epoch in the PWN history where spin down ~ 10^{38} ergs/s (braking index n=3)
- Why would the entirety of the spin down power from pulsar be channelled into Yama?

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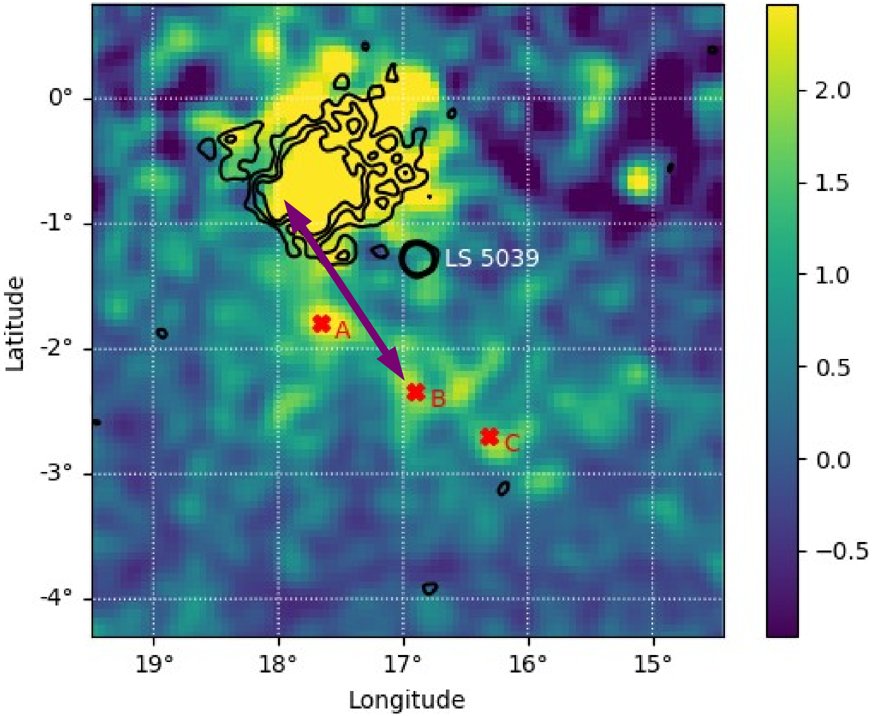
HESS J1825-137 particle transport



(Araya et al. 2019)

- Model electron diffusion vs cooling time between PWN and Yama-B
- Assuming basic diffusion

$$R(E,t)=\sqrt{2D(E,t)B}$$

$$D(E,t)=\chi D_0\sqrt{\frac{E/TeV}{B/3\mu G}}$$

- Requires fast diffusion (χ>0.1) for electrons to reach Yama in the age of HESS J1825-137
- OR requires a more powerful pulsar

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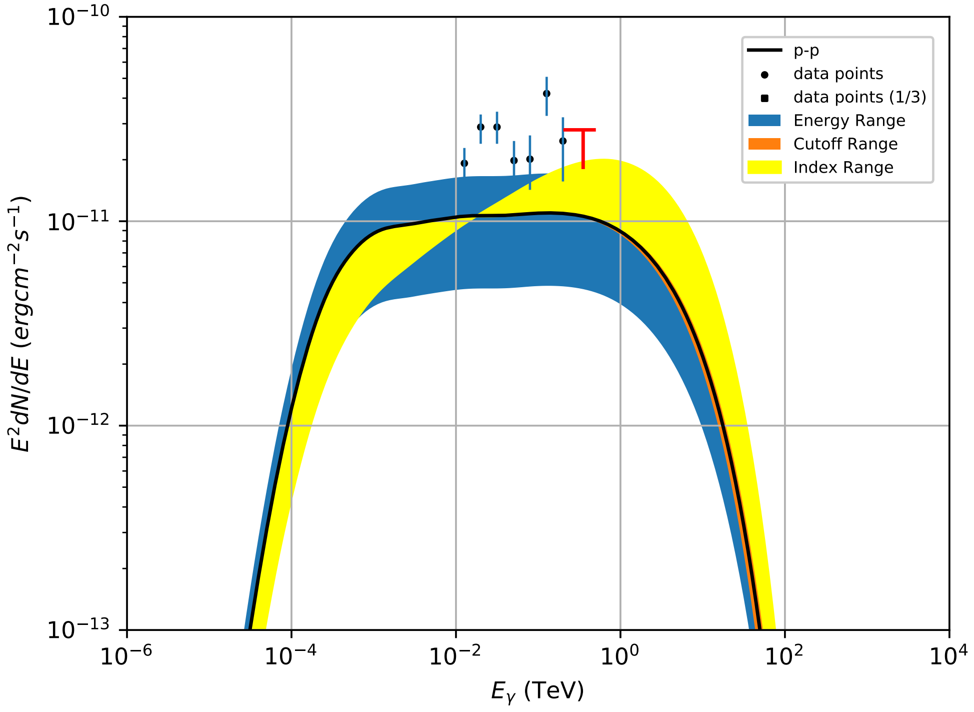
Progenitor SNR for LS 5039



- Using ages between $10^3 – 10^6$ yr.
- No impulsive model meets necessary conditions to be successful (energetics ~ 10^{51-52} ergs)
- The SNR associated with the compact object within LS 5039 would be fading or already apart of the ISM.

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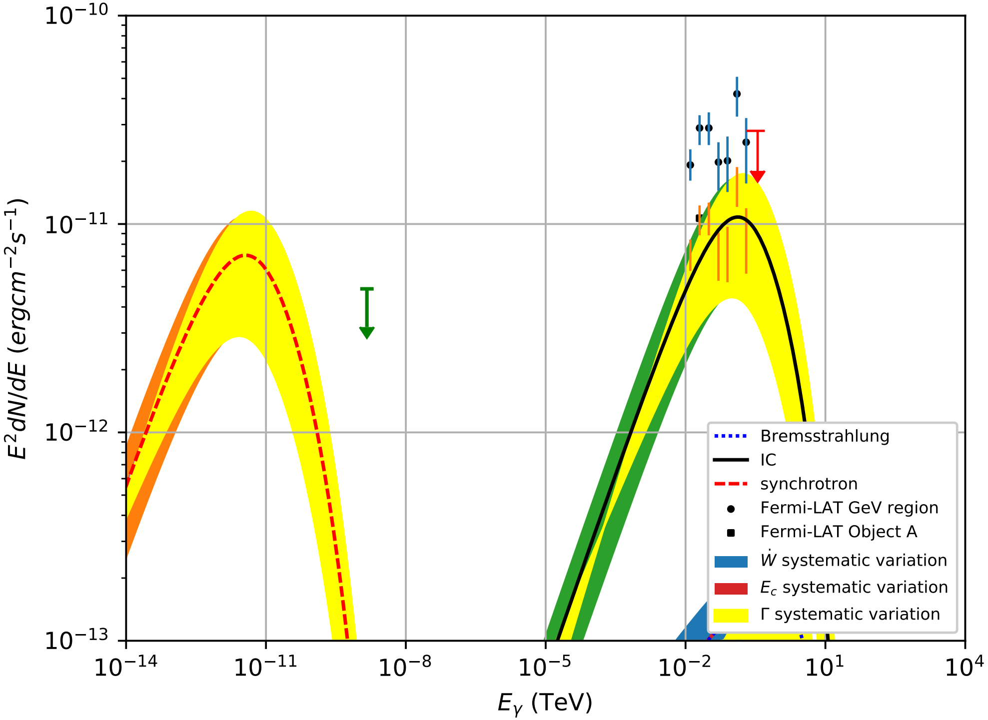
Continuous injection of particles from LS 5039 via accretion



- Leptonic – Continuous – 1x10^6 yrs
- Accretion power of matter onto compact object from companion star = 8 x 10^{35} ergs/s (Casares et al. 2005)
- Requires injection luminosity ~ 10^{36} ergs
- Possible within systematic variation.
- LS 5039 ~ 0.1 million years old (Moldón et al. 2012)

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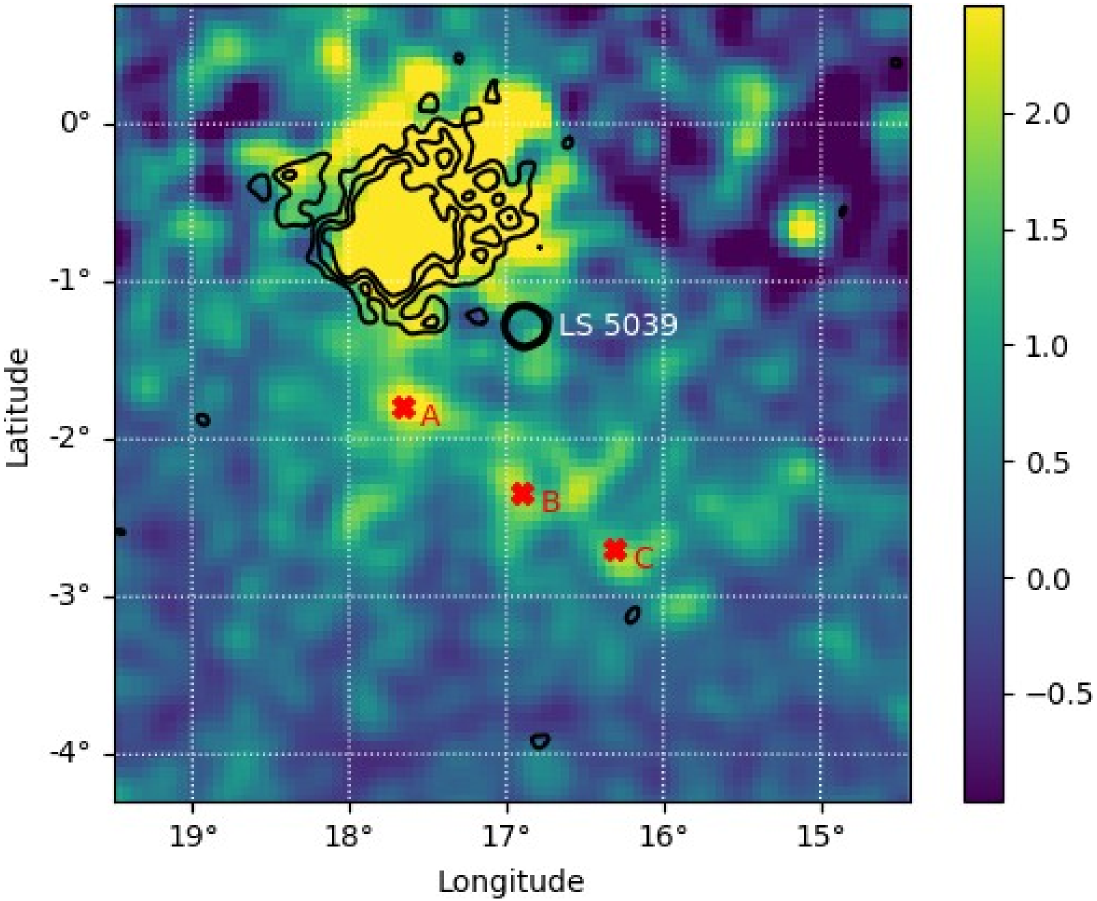
HESS J1825-137 & LS 5039 combination



(Araya et al. 2019)

A combination of processes from LS 5039 & HESS J1825-137 is still possible

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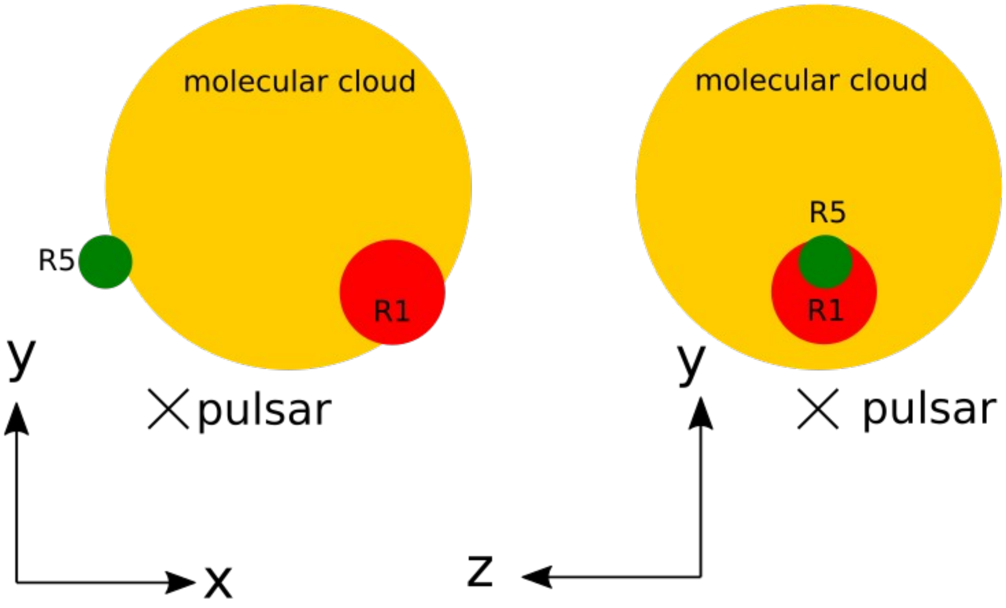
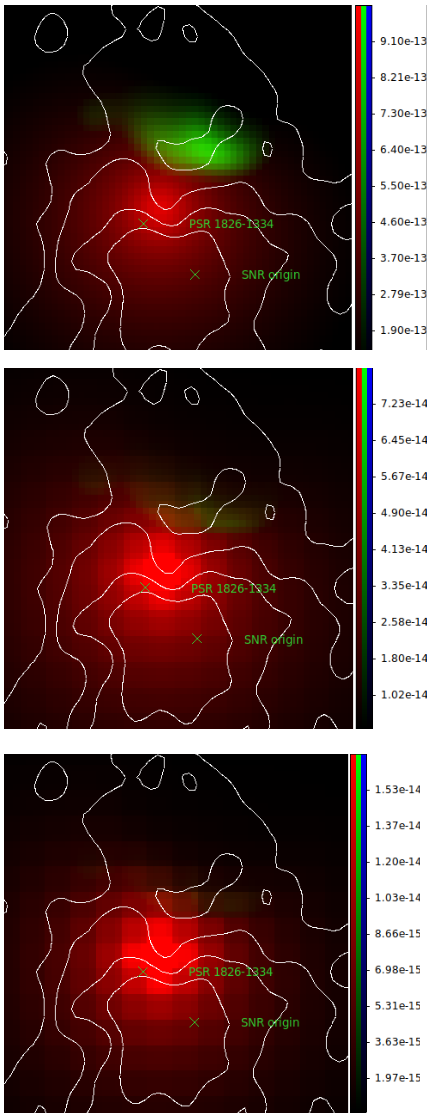
What's next?

MULTIZONE MODELLING!





0.1-1 TeV

1-5 TeV

5-10 TeV

- Multizone Modelling involves solving the particle transport equation over a 3D grid of varying ISM density and B-field.

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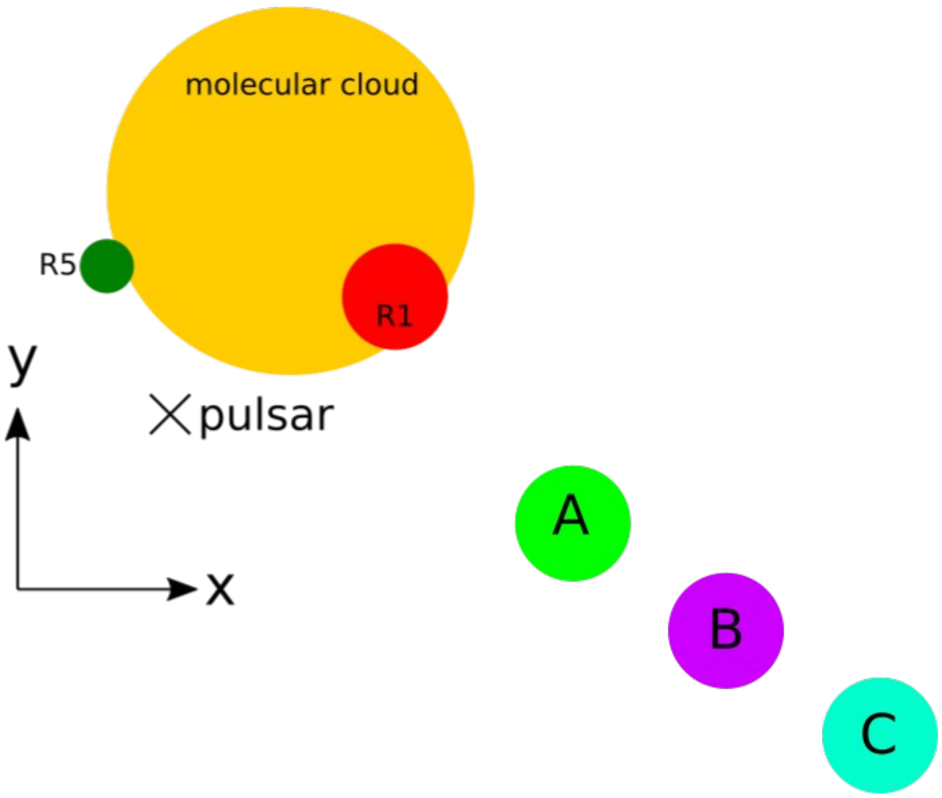
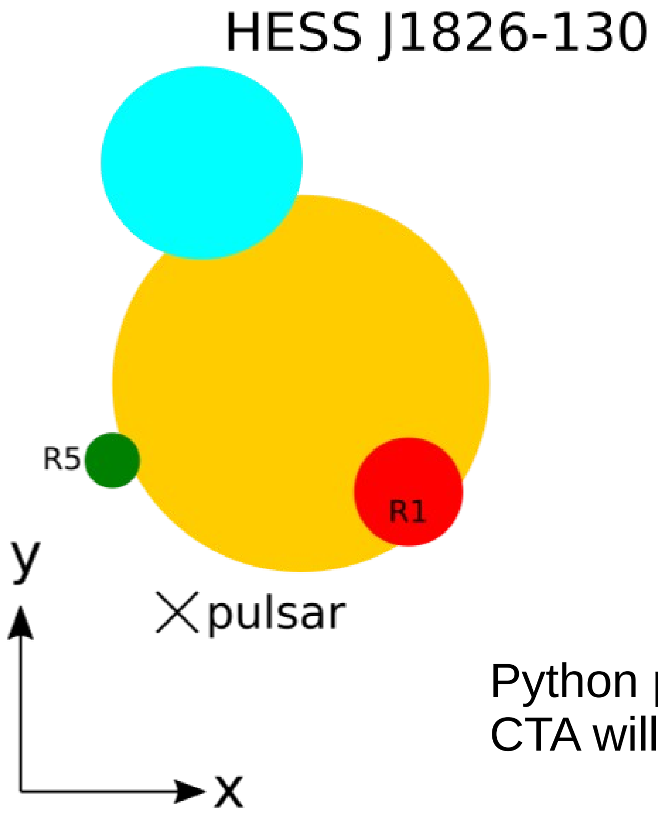
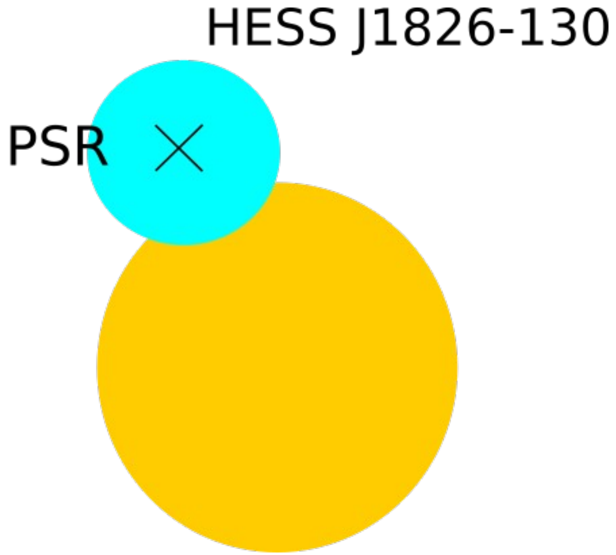
Yama



HESS J1826-130



OR



Python package *gamma-py* can predict what CTA will see.

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Outline

- Attempted to model the GeV Fermi-LAT emission towards the south of HESS J1825-137.
- The source of acceleration of high energy particles resulting in this emission was assumed to be either an accelerator linked to HESS J1825-137 or LS 5309.
- Neither model alone could explain the GeV gamma-rays. A combination of the two sources may still be possible.
- The next step is Multizone Modelling towards the Fermi-LAT emission.
- Multizone Modelling towards HESS J182-130 will attempt to predict CTA observations.

References for single and multizone modelling:

- Sano, H., Yamane, Y., Voisin, F., et al. 2017a, ApJ, 843, 61
- Voisin, Fabien. "Environment Studies of Pulsar Wind Nebulae and Their Interactions with the Interstellar Medium." 2017.

Backup – Equations governing SED

Hadronic (proton-proton):

$$p+p \rightarrow \pi^0 + \pi^+ + \pi^-$$
$$\pi^0 \rightarrow \gamma + \gamma$$

$$\frac{dN}{dE_\gamma} = \int_{E_p=E_\gamma}^{\infty} A_{max}(T_p) F(E_\gamma, T_p) dE_p$$

Multiplicity of neutral pions — Parameterisation Function

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Backup – Equations governing SED

Leptonic (Inverse Compton):

$$e^{-*} + \gamma^{*} \rightarrow e^{-} + \gamma$$

$$\frac{dN}{dE_\gamma} = \frac{3}{4} \sigma_T c \int \frac{n(\epsilon) d\epsilon}{\epsilon} F_{KN}(E_e, E_\gamma, \epsilon)$$

(Bremsstrahlung):

$$e^{-*} + Z \rightarrow e^{-} + Z + \gamma$$

$$\frac{dN}{dE_\gamma} = nc \int d\sigma(E_e, E_\gamma, Z) dE_e$$

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Backup – Equations governing SED

(Synchrotron):

$e^{-*} + B \rightarrow e^{-}$

$$P(\nu) = \frac{\sqrt{3}\, e^3 B}{mc^2} \frac{\nu}{\nu_c} \int_{\frac{\nu}{\nu_c}}^{\infty} K_{\frac{5}{3}}(x)\, dx$$

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SUB CRUCE LUMEN