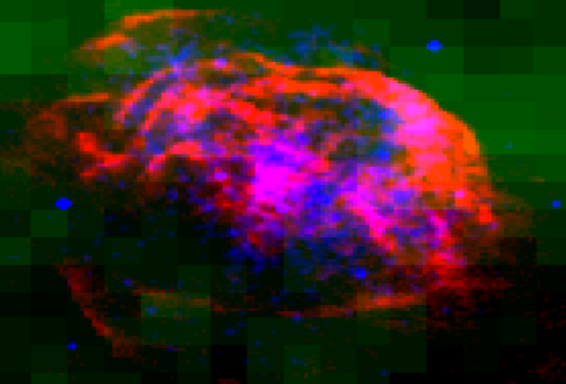
SNR G39.2-0.3: An hadronic cosmic ray accelerator



De Ona Wilhelmi et al. MNRAS, 497, 3581, 2020

Emma de Oña Wilhelmi[1], Iurii Sushch, Robert Brose, Enrique Mestre, Yang Su & Roberta Zanin

[1]DESY-Zeuthen

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

Unterstützt von / Supported by
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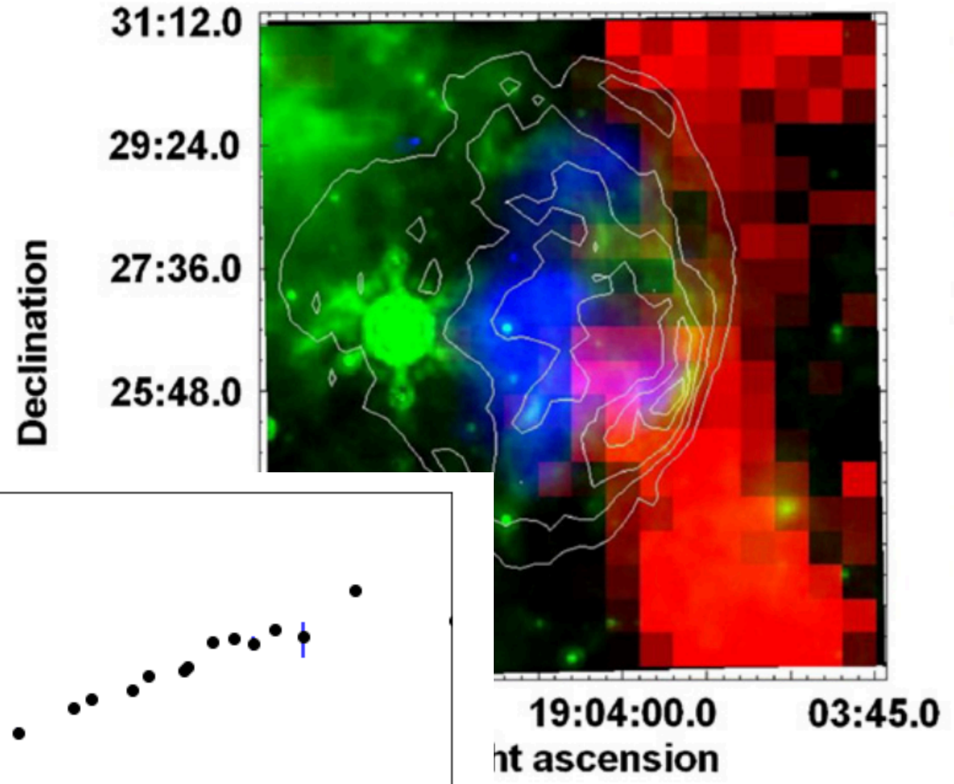
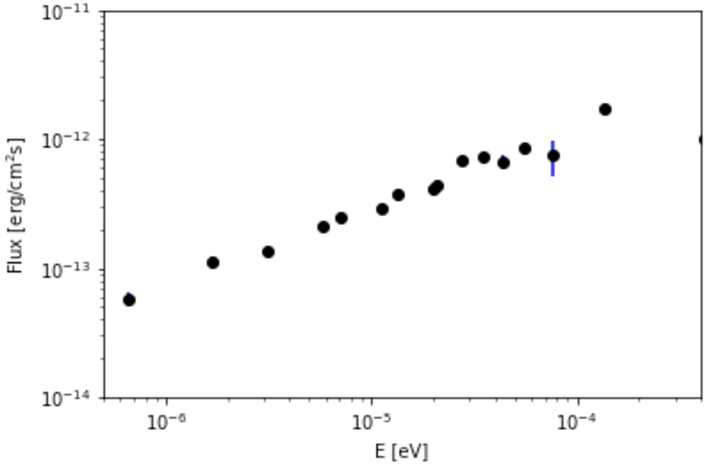
Core-collapse SNRs: SNR G39.2-0.3

- **CC Type IIL/b** SNRs expands in a very dense medium, after undergo a RSG phase
- Bright NIR H_2 emission
- 3-7 kyrs, at ~6 kpc
- V_{LST} ~ 69 or 88 km/s
- E ~3.5 x 10^{50} erg (7x10^{50}erg) for filling factor ff=1 (0.25)
- B ~ 100uG (~140uG) for ff=1 (0.25)

Harrus & Slane 1999

X-ray
mid-IR
^{12}CO (85-88 km/s)





Synchrotron spectrum

Su et al 2011

SNR G39.2-0.3: Multi-wavelength

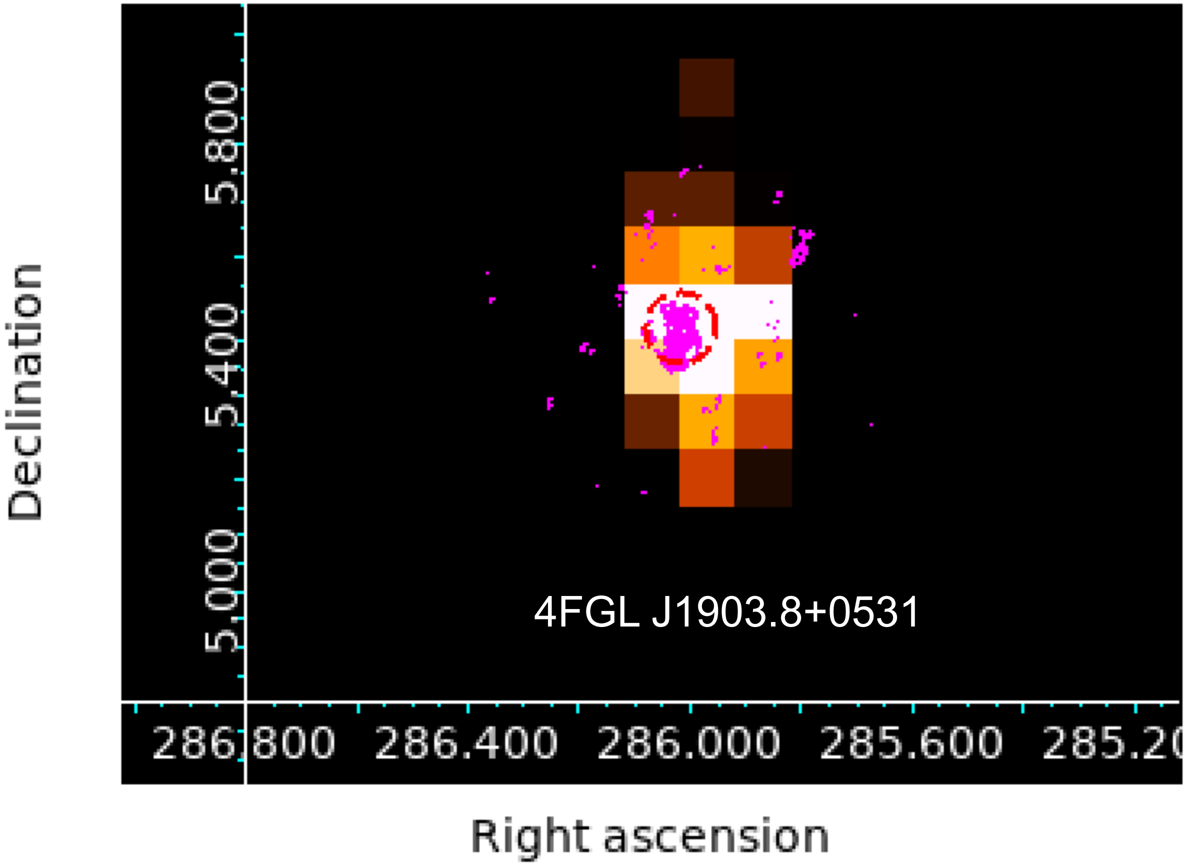
High Energy Observations: Fermi LAT

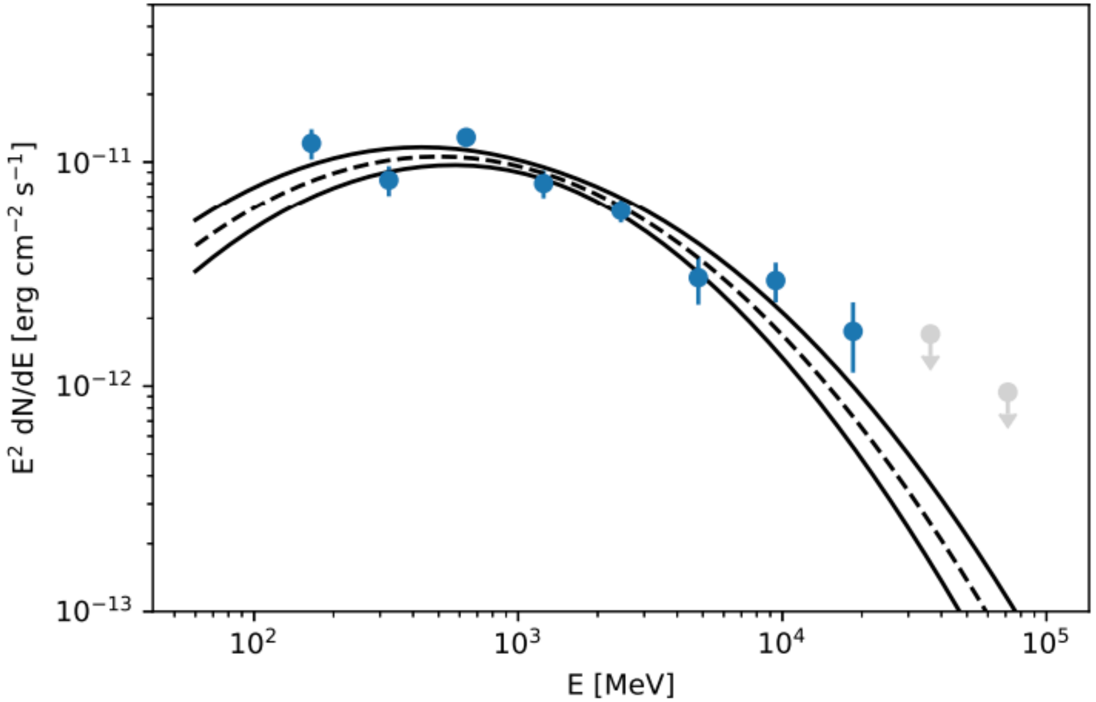
$$\frac{dN}{dE} = N_o \left(\frac{E}{E_{break}}\right)^{(-\alpha+\beta\log(E/E_{break}))}$$

$$N_o = (8.7 \pm 0.7)10^{-13}\ MeV^{-1}/cm^2\ s$$

$$\alpha = 2.6 \pm 0.1, \beta = 0.20 \pm 0.03, E_{break} = 2.3\ GeV$$

LAT E>3 GeV





dOW et al. 2020

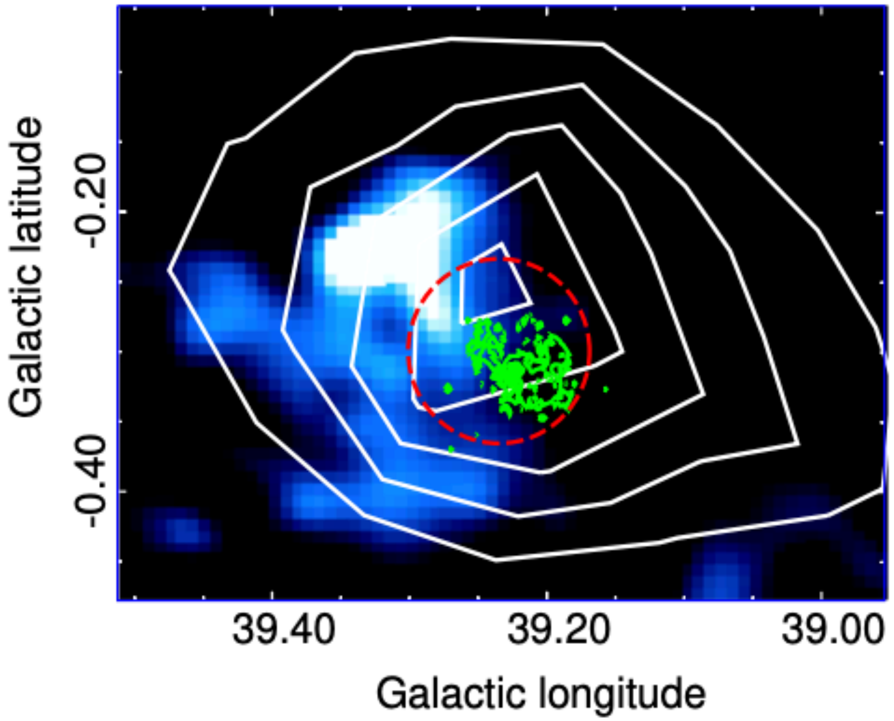
SNR G39.2-0.3: Multi-wavelength spectrum

Radio Observations: MWISP

Su et al 2011

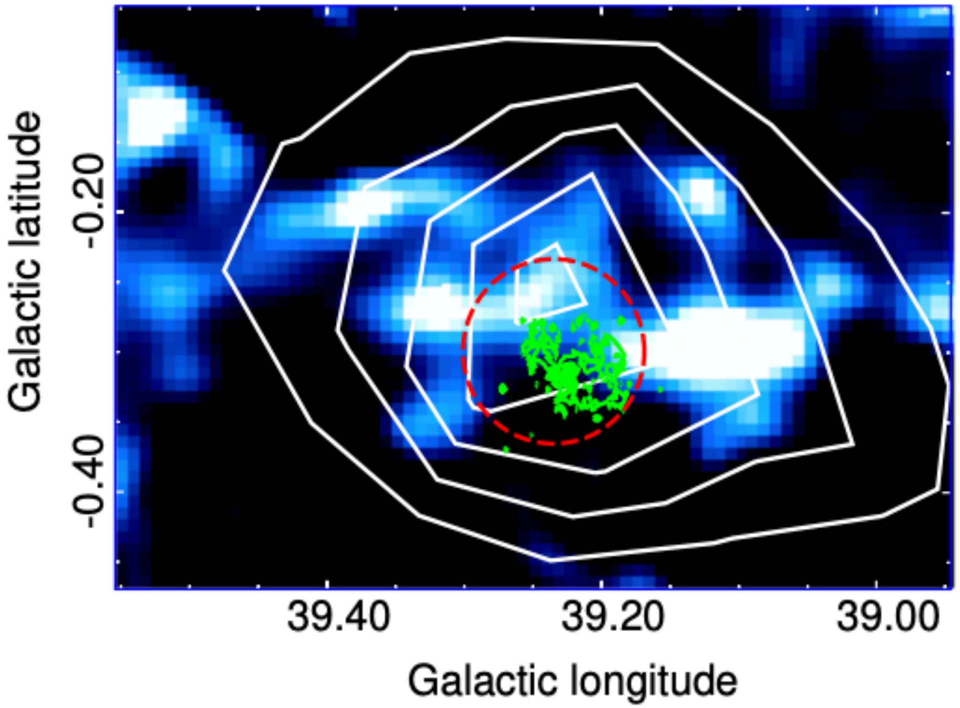
- We analyzed ^{12}CO and ^{13}CO from MWISP Survey
- The ~80 km/s seems to be favored, based on the gas/gamma-ray distribution.

67 – 74 km/s (440 cm^{-3})

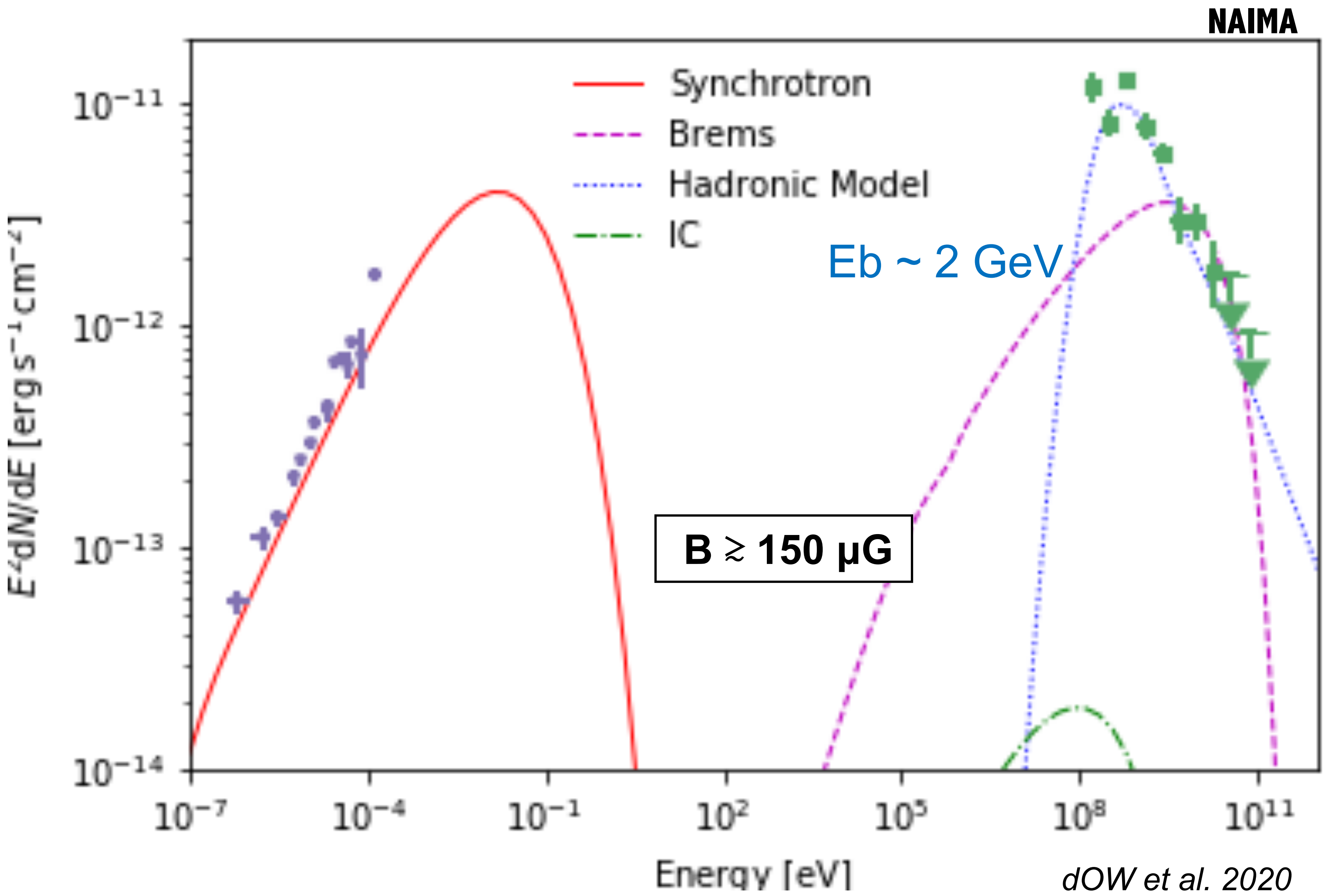


80– 88km/s (326 cm^{-3})

dOW et al. 2020



SNR G39.2-0.3: Spectral Modeling



dOW et al. 2020

$W_p = 3.2^{+1.1}_{-0.8} 10^{49}$ erg

Broken power-law function:

$E_b = 220 \pm 70\,\mathrm{MeV}$

$s_1 = 2.0 \pm 1.5$ and $s_2 = 2.78 \pm 0.06$

Power-law function:

$s = 2.75^{+0.04}_{-0.06}$

SNR G39.2-0.3: Spectral Modeling

Hadronic constraints

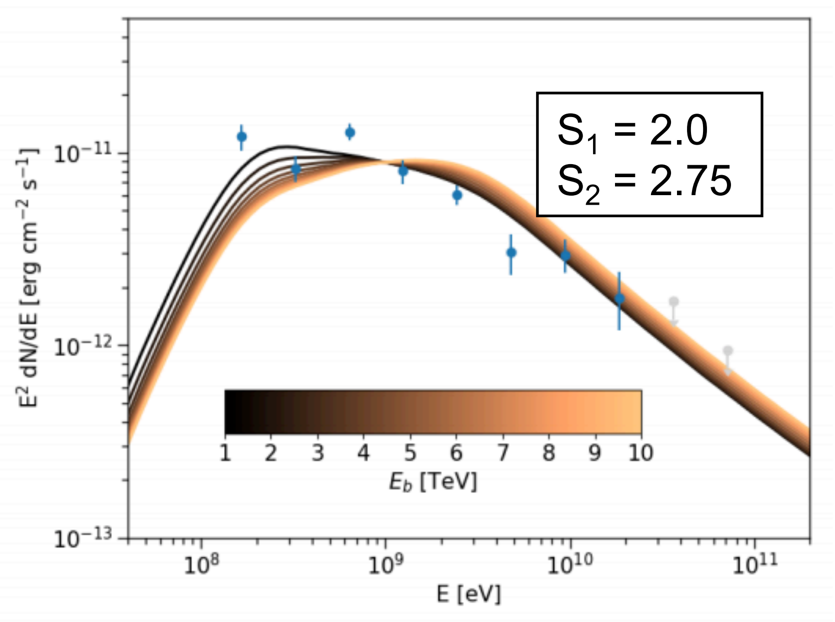
- The large magnetic field should boost the acceleration of particles into high energies, but a break in protons at ~220 MeV is observed **=> Slow shock, effective particles escape, heavy composition?**

➢ Old dynamical age scenario

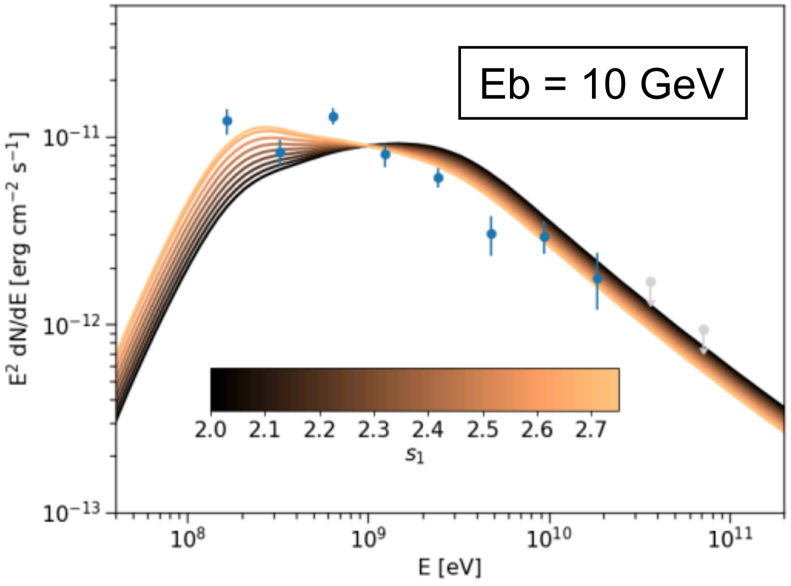
slow shock and effective escape of high energy particles

RATPAC[1] code to model the radiation

E_b > 3 GeV => Turnover shift to high energies



Soft spectrum works
but then should be different from radio electrons



[1]Sushch et al. 2018, Brose 2020

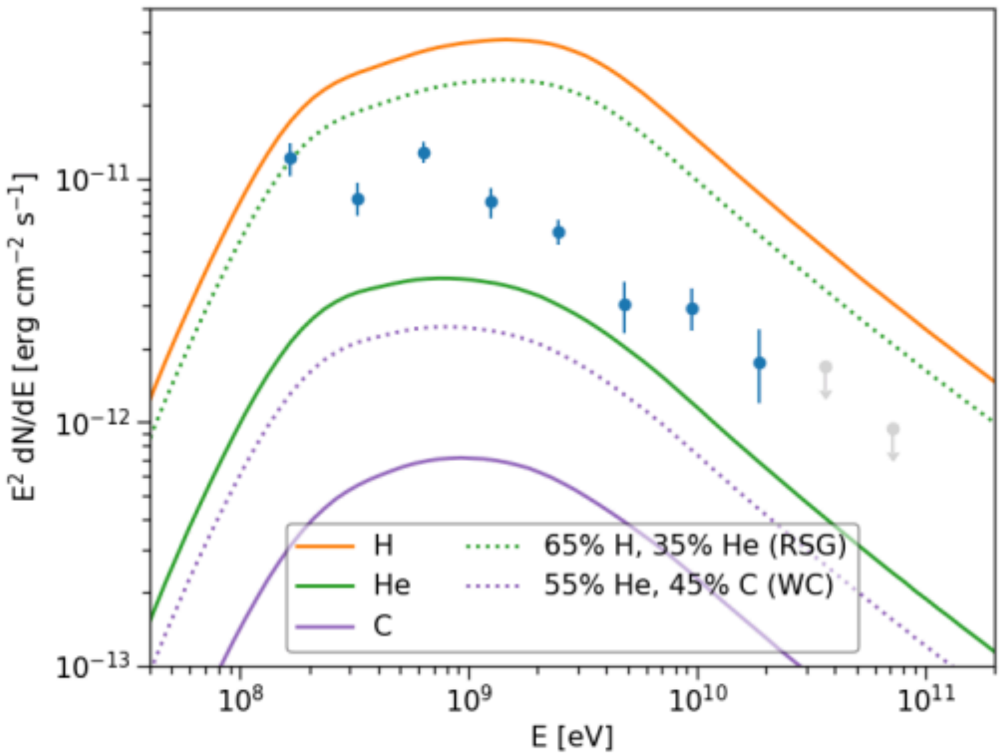
SNR G39.2-0.3: Spectral Modeling

Hadronic constraints

- The large magnetic field should boost the acceleration of particles into high energies, but a break at ~220 MeV is observed **=> Slow shock? Or effective particles escape?**

➢ Heavy Composition

A Wolf-Rayet Wind (WC) shifts the peak to ~0.8 GeV



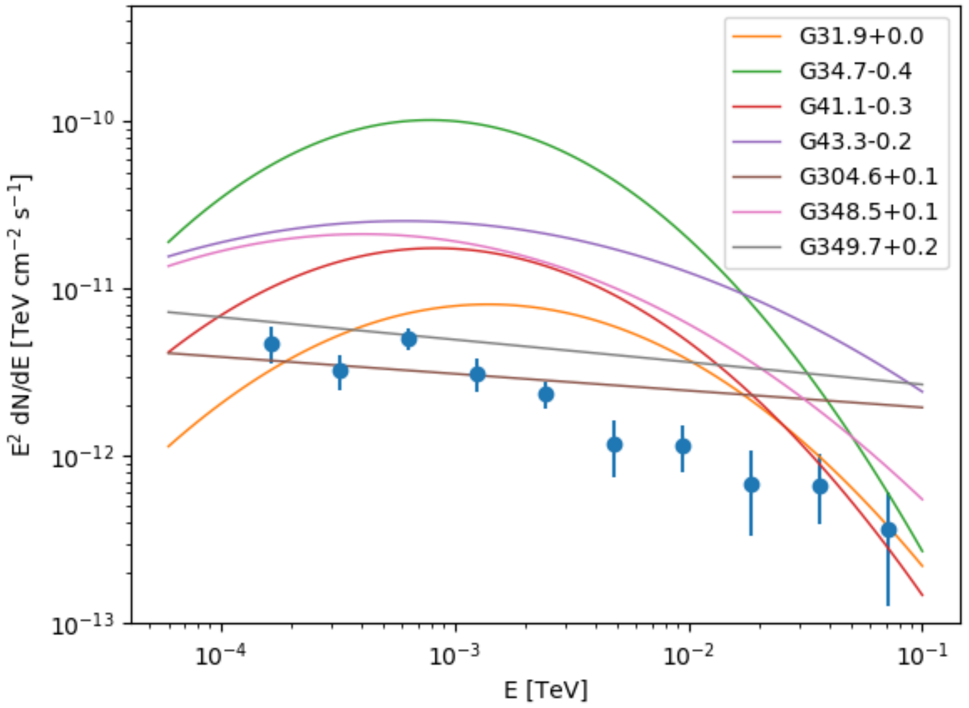
$$\frac{dN_i}{dp} = \begin{cases} N_{0,i} p^{-s_1}, & \text{if } p < Zp_b \\ N_{0,i} (Zp_b)^{-s_1+s_2} p^{-s_2}, & \text{otherwise.} \end{cases}$$

*different acceleration process of electrons and protons?

Conclusions

And future applications

- SNR G39.2-0.3 is an hadronic accelerator with a high magnetic field => Why is then so inefficient in accelerating protons to high energies (E_b = 2.3 GeV)
  - Dynamical old SNR? Eb ~ 10-100 GeV and radio emission suggests a high-energy break*
  - Heavy composition? The spectrum might be a hint of heavier composition



18 SNRs detected in the GLIMPSE Legacy science program on Spitzer (Reach et al. 2006)

BACKUP SLIDES

Contact Emma de Ona Wilhelmi

DESY. Deutsches
Elektronen-Synchrotron

www.desy.de

SNR G39.2-0.3: Spectral Modeling

Leptonic constraints

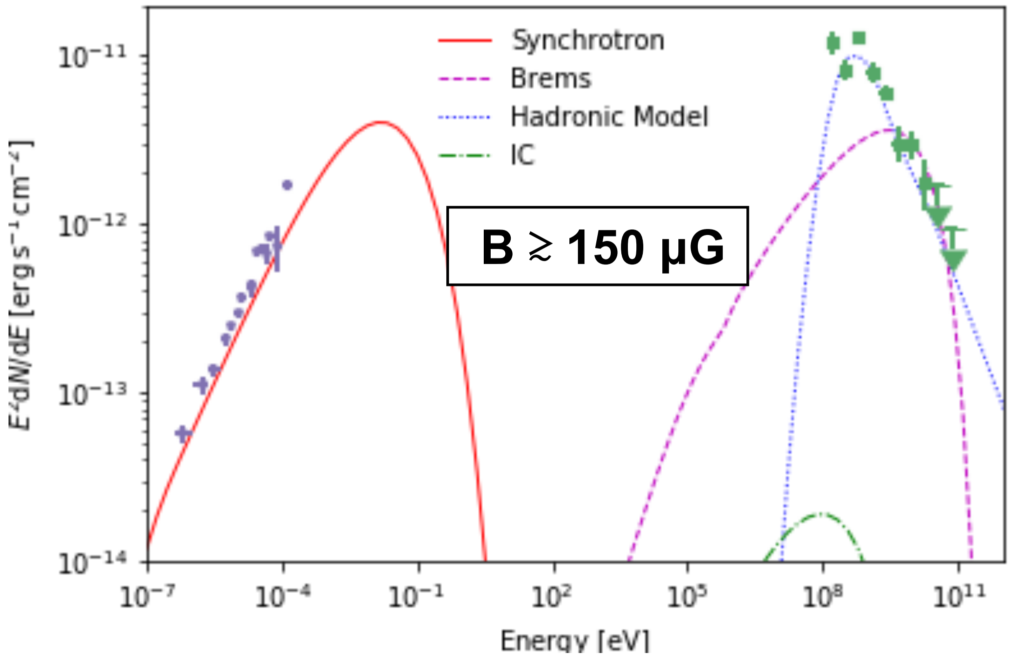
- Spectral Index constrained by radio => 1.8 vs Bremms: No < $3x10^{34}$ eV^{-1} (for n ~400 cm^{-3})
- Amplified magnetic field, that can be due to:

❖ Compression (B_o ~10 μG, ξ ~ 15)

$$B_d = B_0\sqrt{\frac{2\xi^2+1}{3}}$$

❖ Turbulent field due to MHD instabilities (v_{sh} ~150 km/s, σ=5%, ξ ~ a few)

$$B_d \approx \sqrt{\frac{4\pi n m_p \sigma}{\xi}} v_{\rm shock}$$



SNR G39.2-0.3: Spectral Modeling

Hadronic constraints

- Compression of Galactic CRs?

$$n_{\rm comp}(p) = \xi^{2/3} n_{\rm GCR}(\xi^{-1/3} p)$$

$$\xi \equiv n_{\rm shell}/(r n_0)$$

Compression radius

Shell density

Cloud density

$$\xi \simeq 94 \left[\frac{n_0}{1\,{\rm cm}^{-3}}\right]^{1/2} \left[\frac{B_0}{1\,\mu{\rm G}}\right]^{-1} \left[\frac{v_{\rm sh}}{10^7\,{\rm cm/s}}\right]$$

For ξ=10, f=0.18 =>M ~ $4\times10^4 M_o$

2 times the total cloud mass that can be accumulated in the SNR (Vsnr n_o η_H = 2×10^4 Mo)