Gamma ray emission from molecular clouds in association with close by supernova remnants

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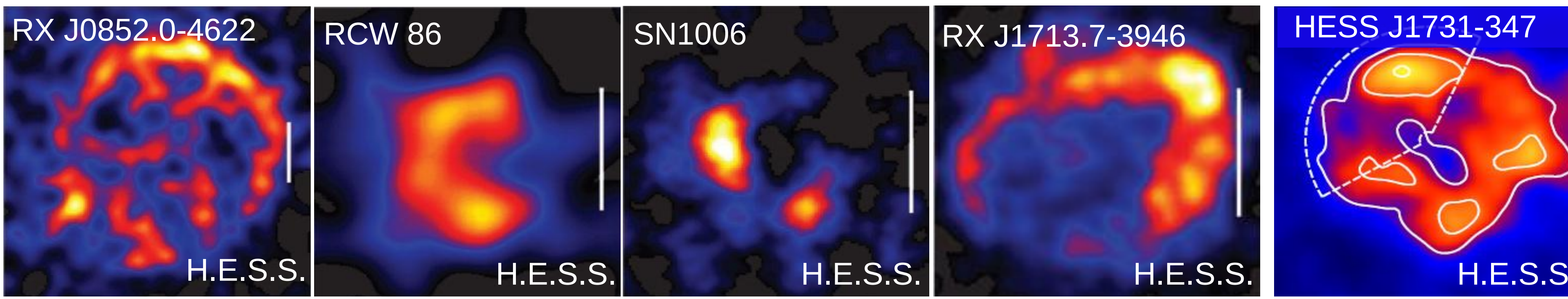
Erlangen Centre for Astroparticle Physics

Supernova Remnants – Sources of galactic cosmic rays?

SNR cosmic accelerators ?

- Gamma-ray emission expected



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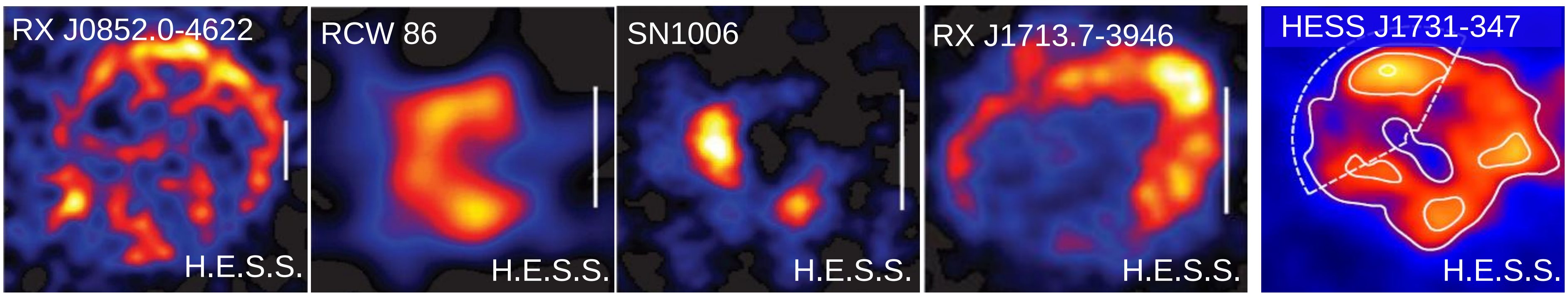


Open question (among others)

- What is the p/e ratio among accelerated particles?
- Where does acceleration cut off? Are they Pevatrons?

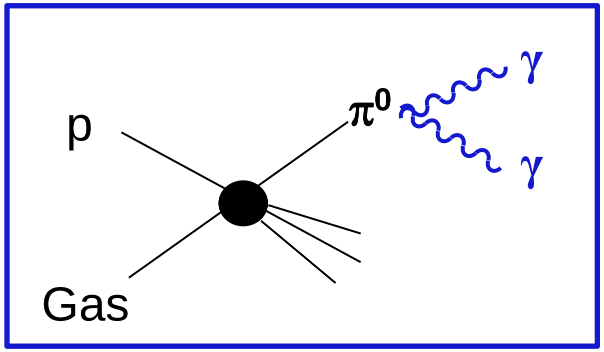
Emission Processes

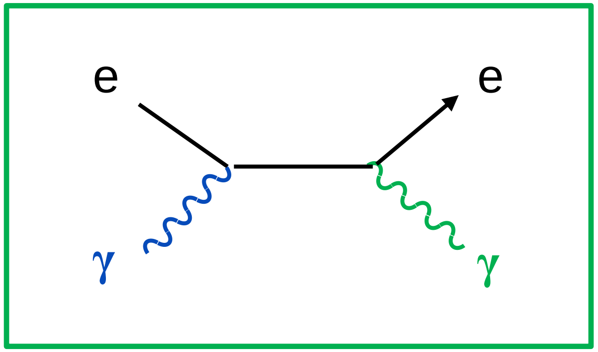
Hadronic

Pion decay: $\pi^o \longrightarrow \gamma\gamma$

Leptonic

Inverse Compton Effect





“Traditional” ansatz to disentangle the emission processes

- Multi-wavelength spectra
- Correlation studies

No conclusive answer

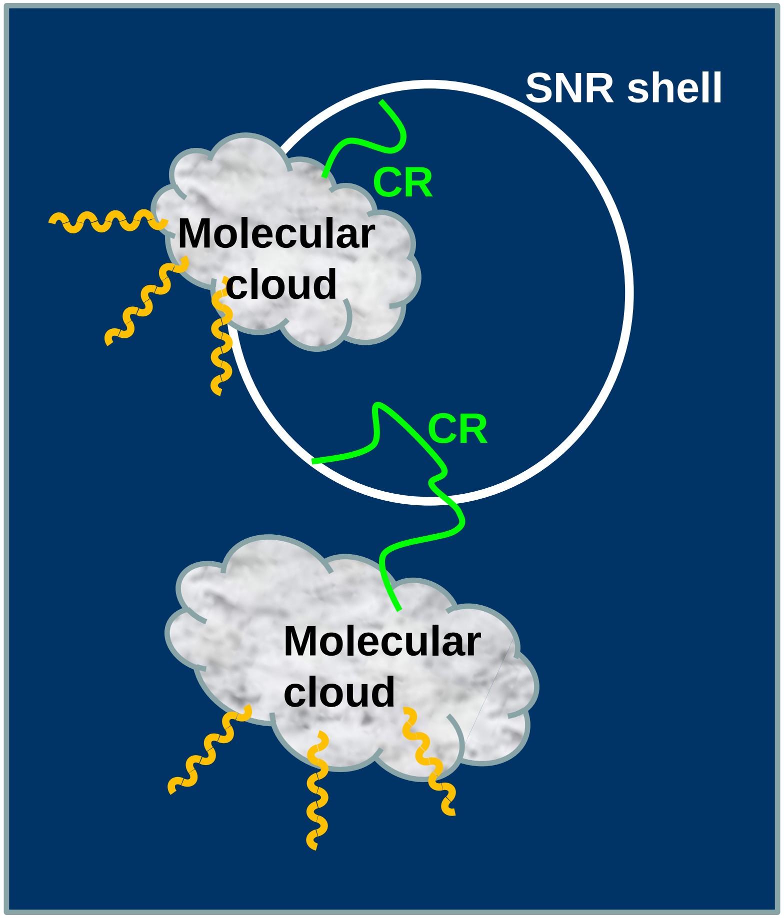
Molecular Clouds (MC)

- Dense n ~ 100 cm $^{-3}$
- Massive M_{CL} up to 10^6 $M_\otimes$

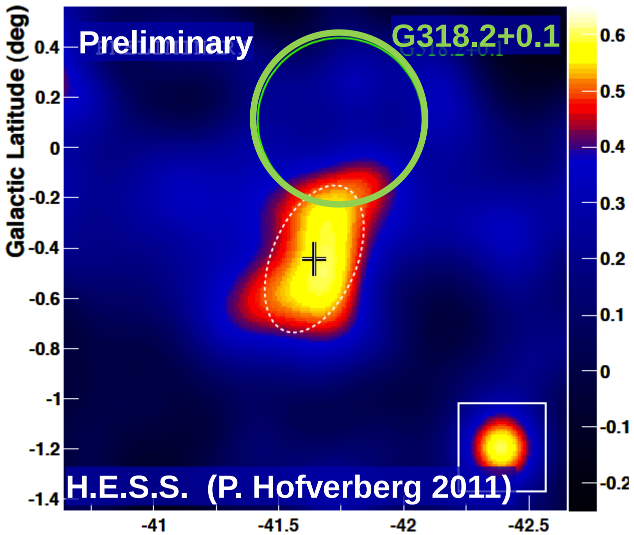
➡ Target material for accelerated p
  $\pi^o \rightarrow \gamma\gamma$
  enhanced gamma ray emission

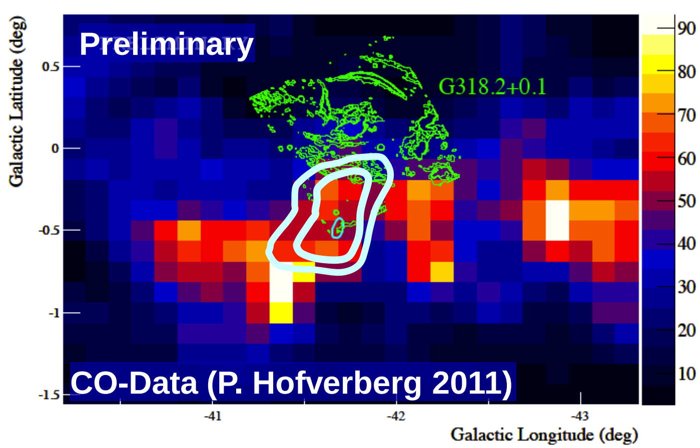
SNR / MC association

- Constrain SNR parameters
- Primary particle type
- Diffusion coefficient
- Maximum energy of accelerated particles



G318.2+0.1 / HESS J1457-593





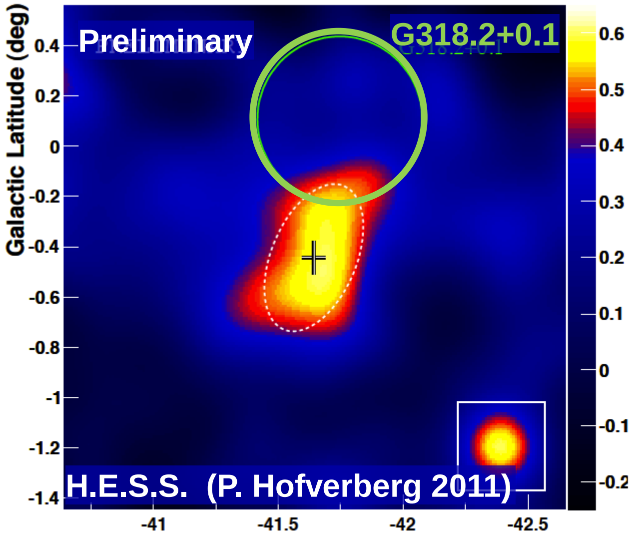
SNR – G318.2+0.1

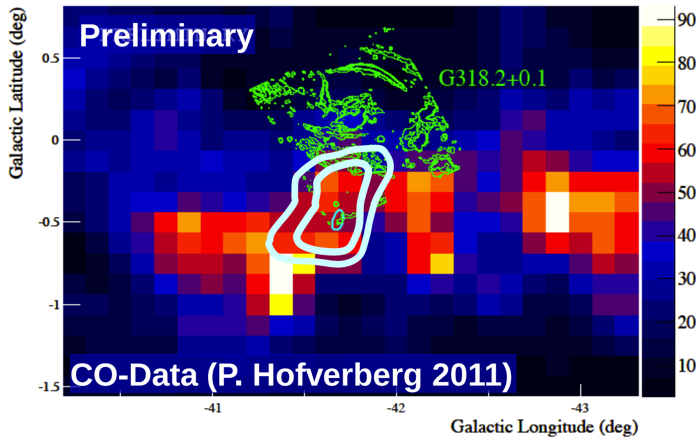
- age, distance unknown

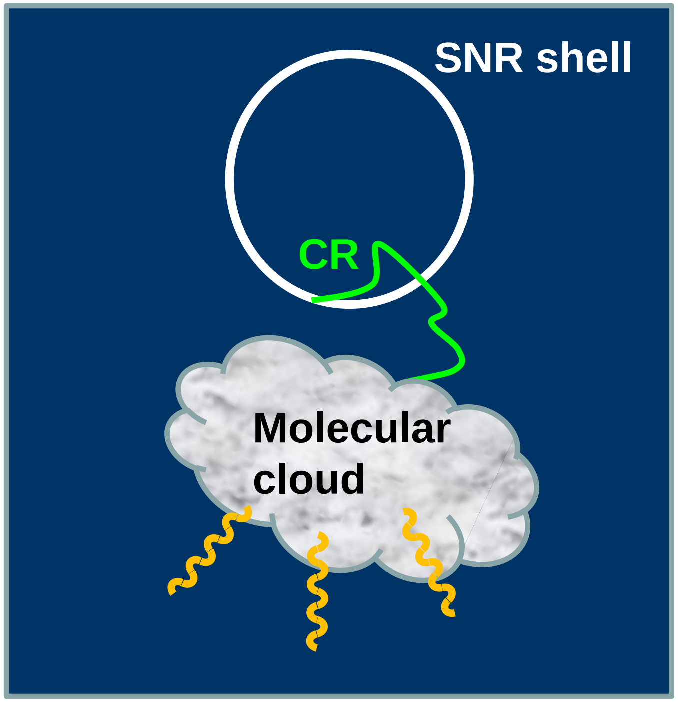
TeV gamma ray emission

- overlap with SNR rim
- positionally coincident with MC

G318.2+0.1 / HESS J1457-593

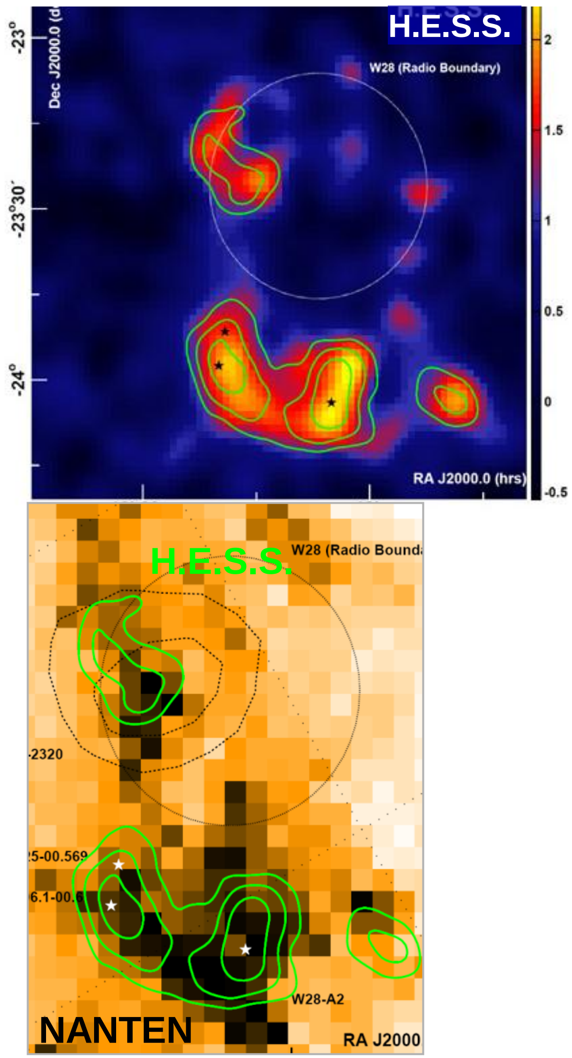






Assumption SNR – MC are associated
"fix" distance of G318.2+0.1 to 3.5 kpc
➡ age 8000 years

W 28



W 28

- Distance 2.5 kpc
- Age: $35{\cdot}10^3$ – $150{\cdot}10^3$ years

- energy content in CR ~ 10^{45} ergs
  (Gas density 10^4 cm^3)

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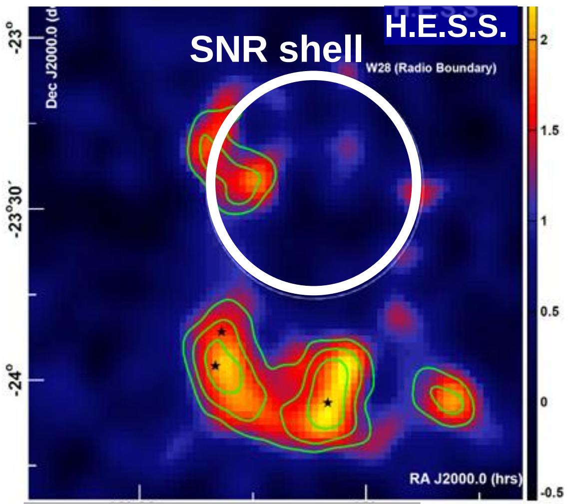

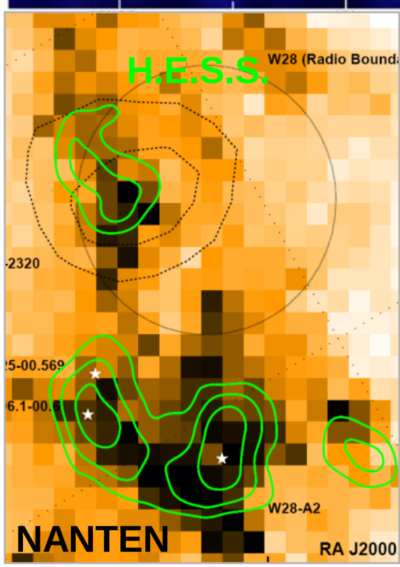

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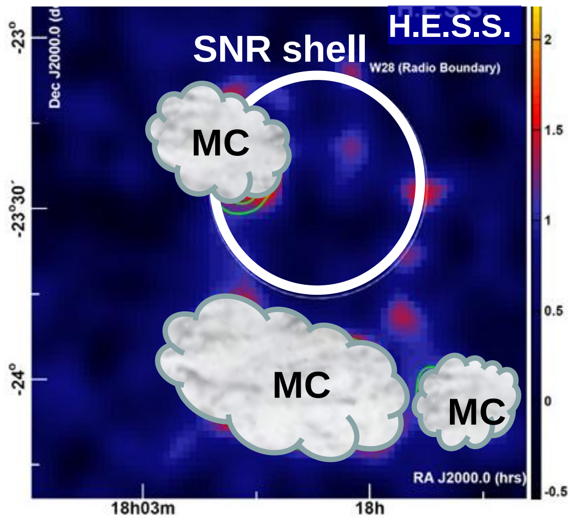

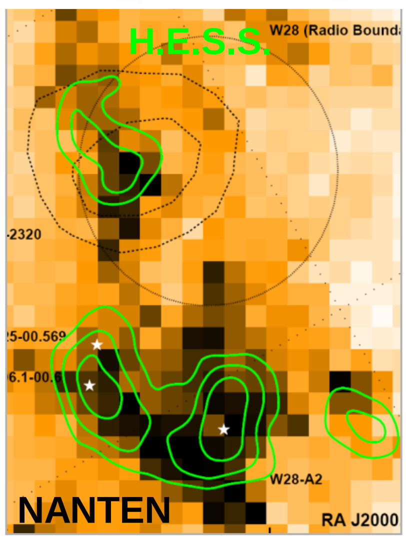

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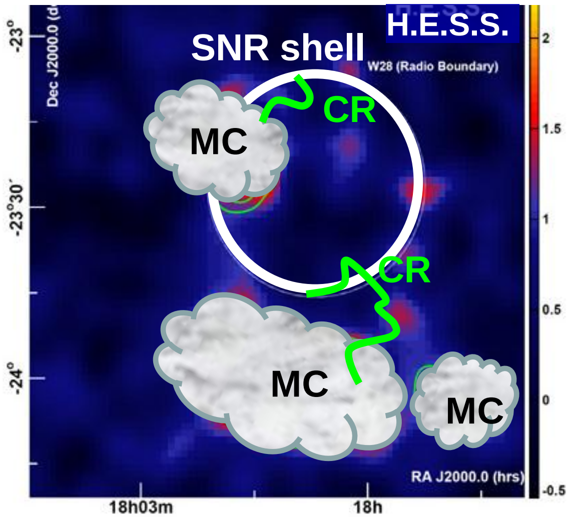

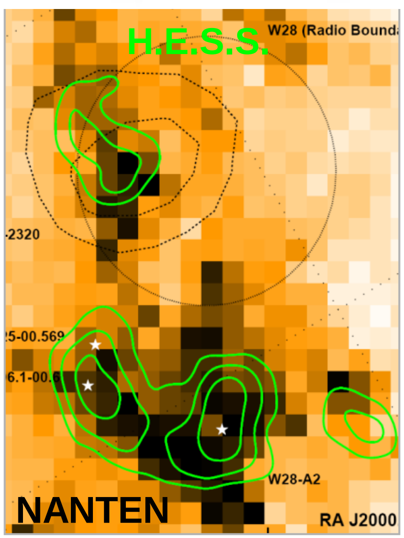

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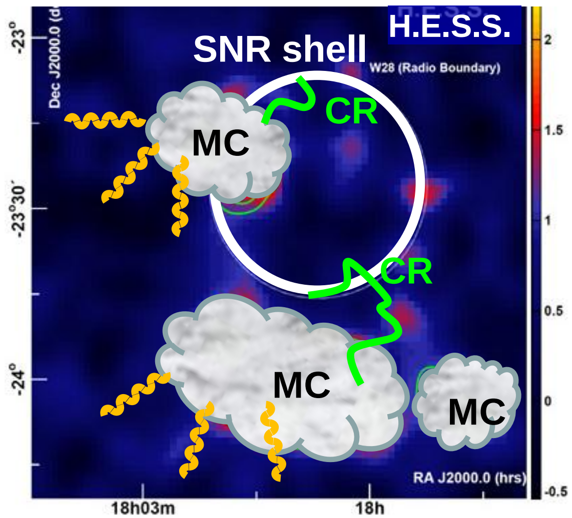

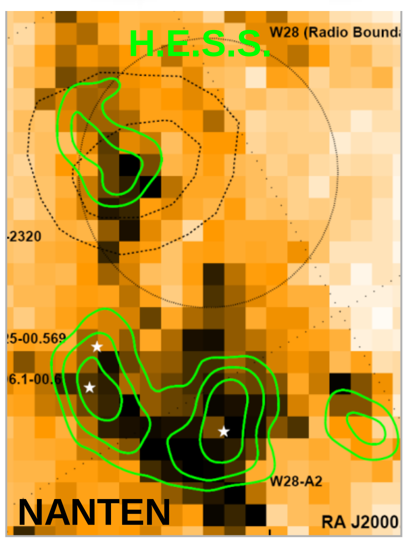

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Diffusion coefficient

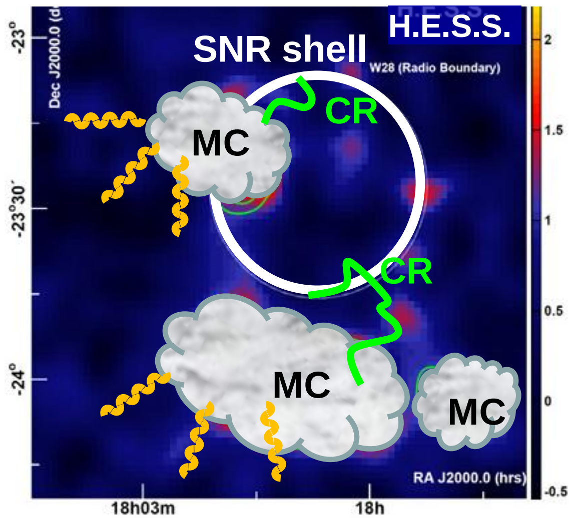
High energy particles escape first $t_{esc} \approx t_{age}$

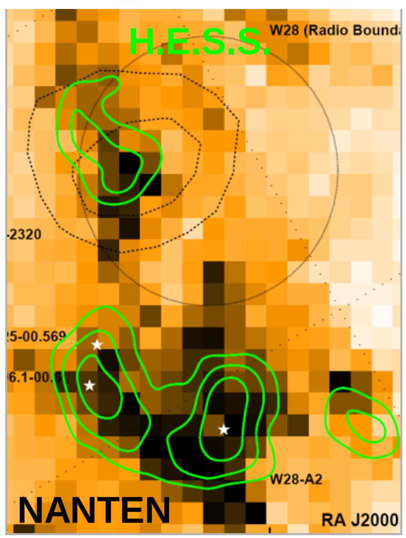
$$l_d \approx \sqrt{D \cdot t_{age}}$$

$$F_\gamma \propto f_{CR} \frac{M_{MC}}{d^2}$$

Gabici et al. 2010

W 28





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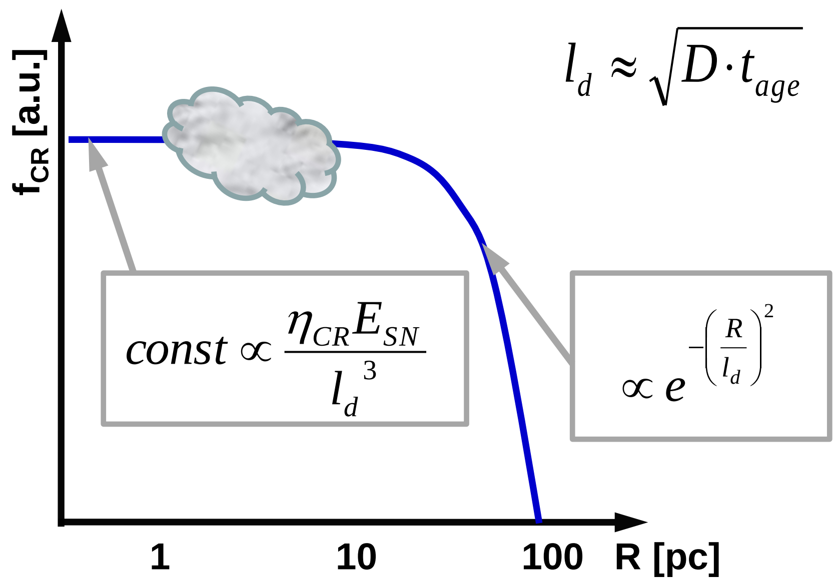

Gabici et al. 2010

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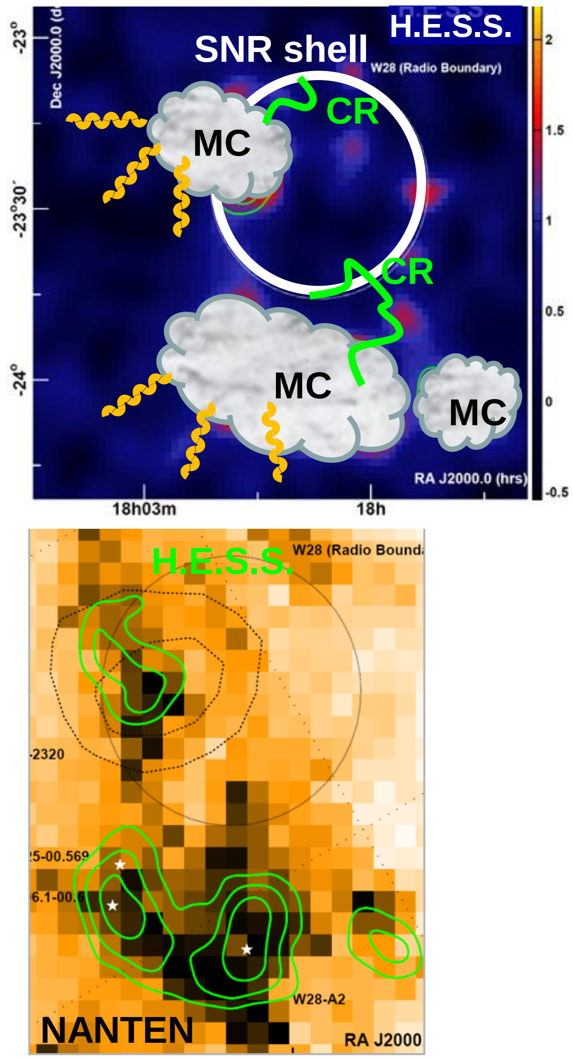

$$F_\gamma \propto \frac{\eta_{CR} \cdot E_{SN}}{\left(\chi \cdot D_{gal} \cdot t_{age}\right)^{3/2}} \left(\frac{M_{MC}}{d^2}\right)$$

$$D_{gal} \approx 10^{28} \left(\frac{E}{10\,\mathrm{GeV}}\right)^{\delta} \frac{\mathrm{cm}^2}{\mathrm{s}}$$

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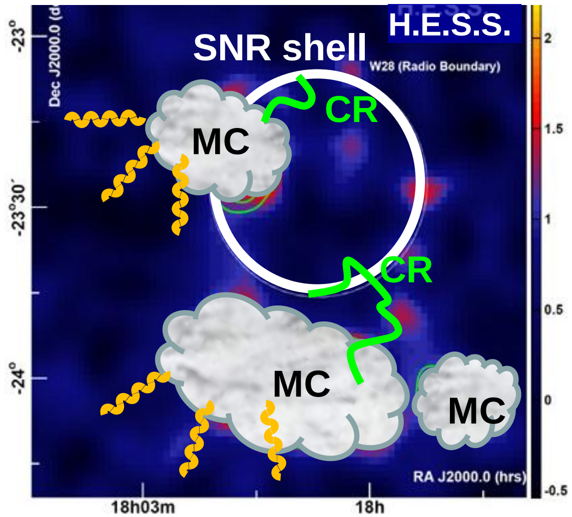

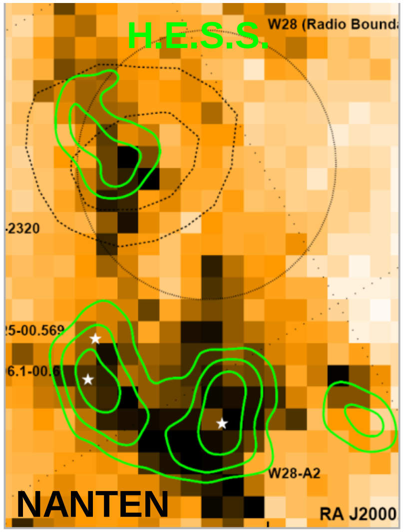

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Fit to data, free parameter $\frac{\eta_{CR}}{\chi^{3/2}}$

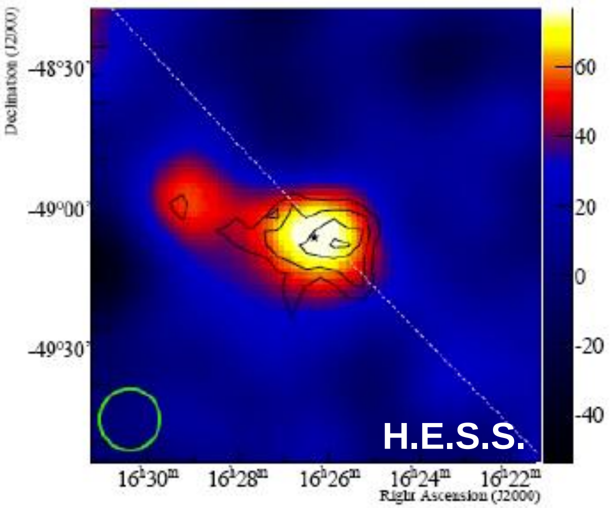
Virtually the same results for

$$\begin{aligned}(\eta, \chi) &= (10\%, 0.028) \Rightarrow l_d \approx 70\,\mathrm{pc}\\ &= (30\%, 0.06) \Rightarrow l_d \approx 95\,\mathrm{pc}\\ &= (50\%, 0.085) \Rightarrow l_d \approx 115\,\mathrm{pc}\end{aligned}$$

➡ Diffusion coefficient is suppressed

Gabici et al. 2010

HESS J1626-490

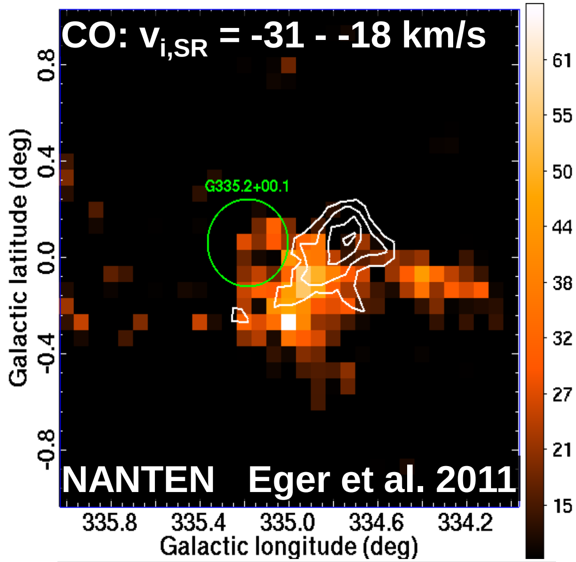


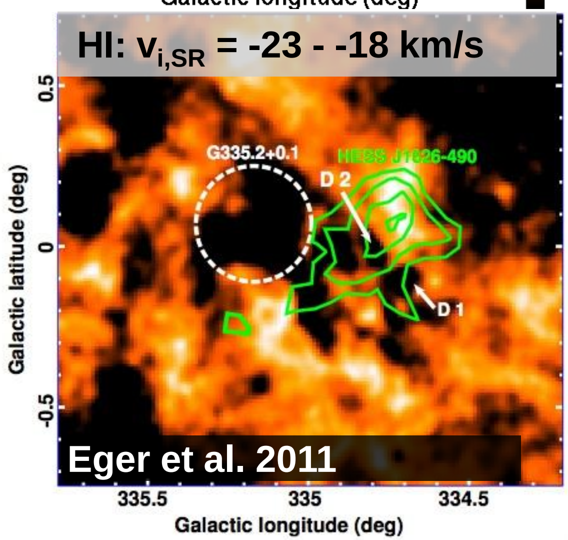
2008

Not unambiguously identified with any source seen at lower energies

- SNR close by; no enhanced target material
- Possible X-ray counterpart

HESS J1626-490





Molecular cloud

- $1.8 \cdot 10^4$ $M_{\otimes}$, distance 1.8 kpc
- overlap with gamma ray emission

HI – Data

- density depression spatially consistent with SNR
 expanding shock front or stellar wind that has blown out the neutral gas
- similar distance as MC

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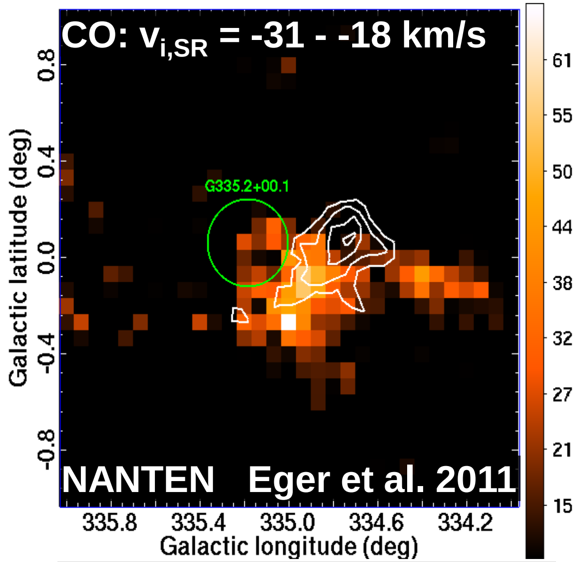

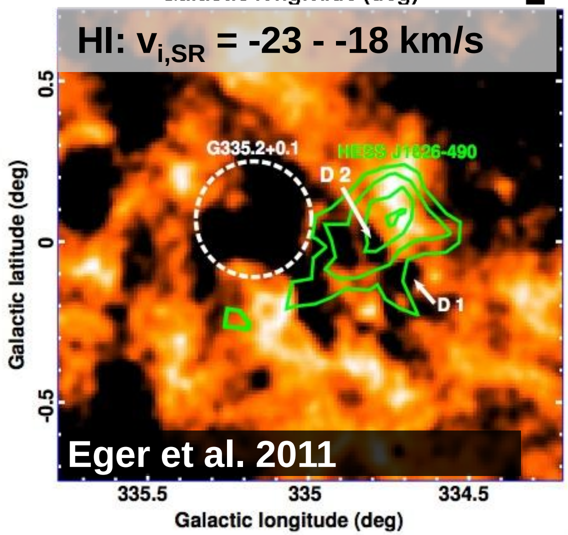

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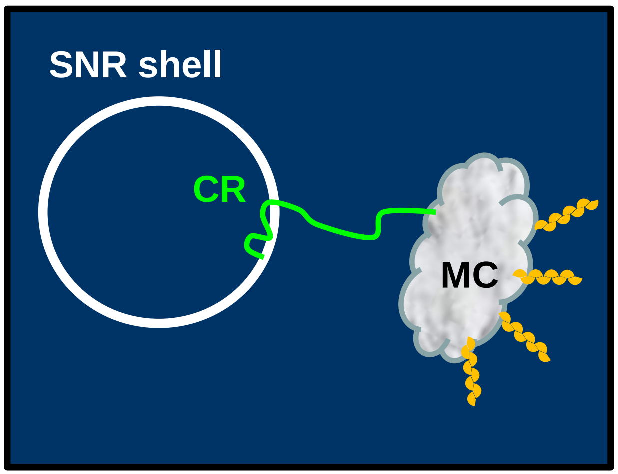

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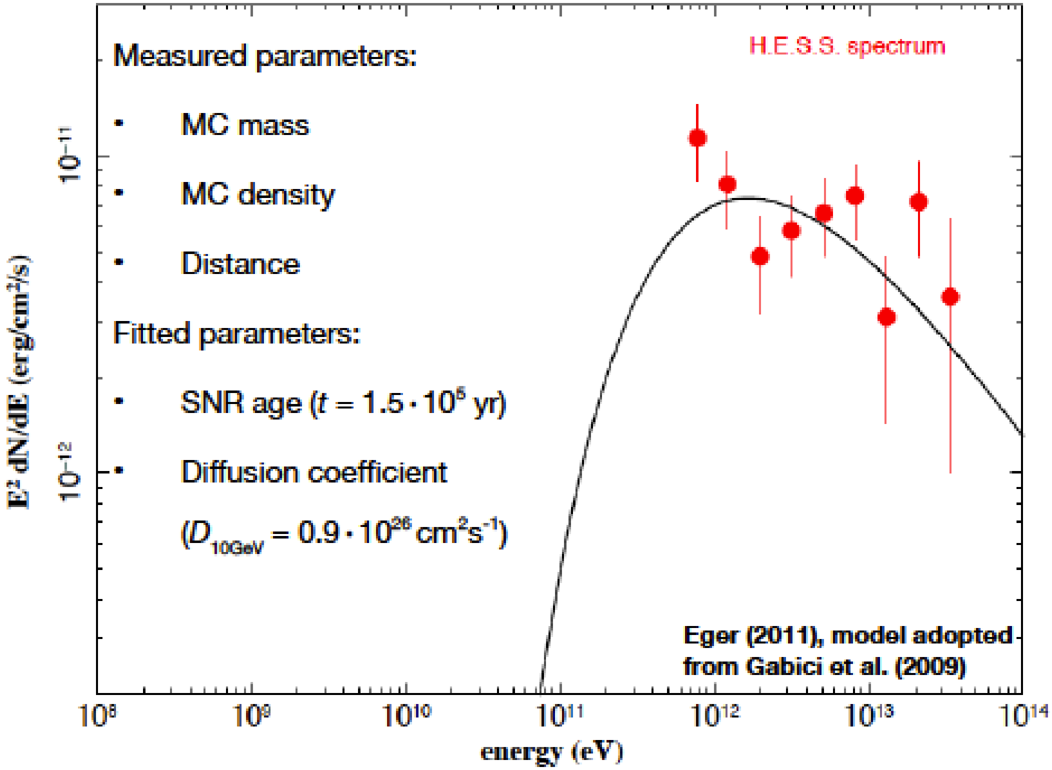
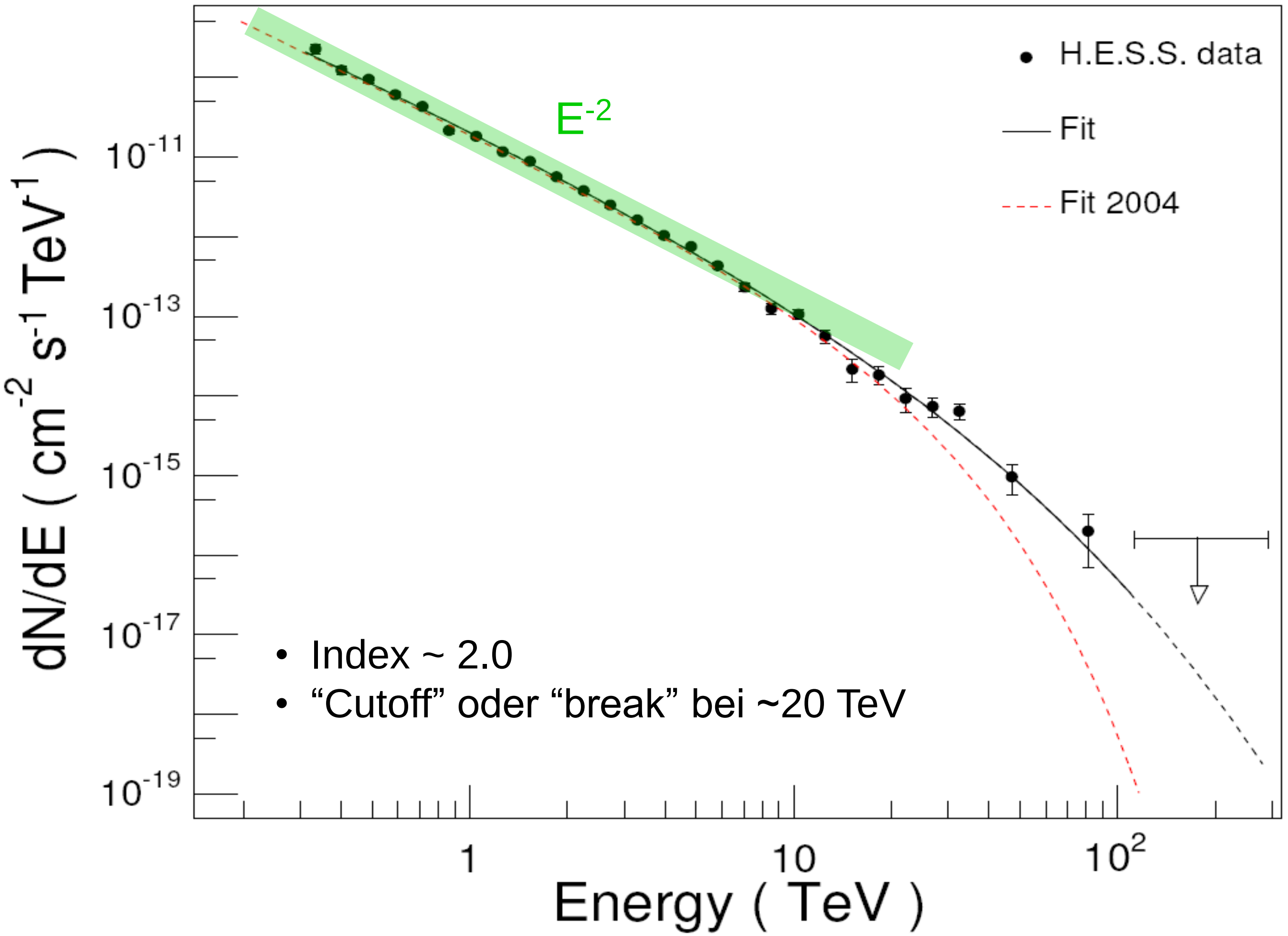
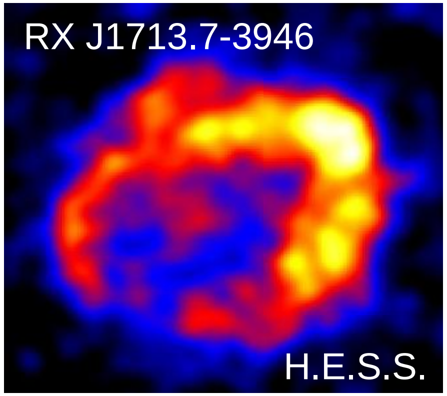


SNR / MC Association – What can we learn ?
Are SNRs CR Pevatrons ?





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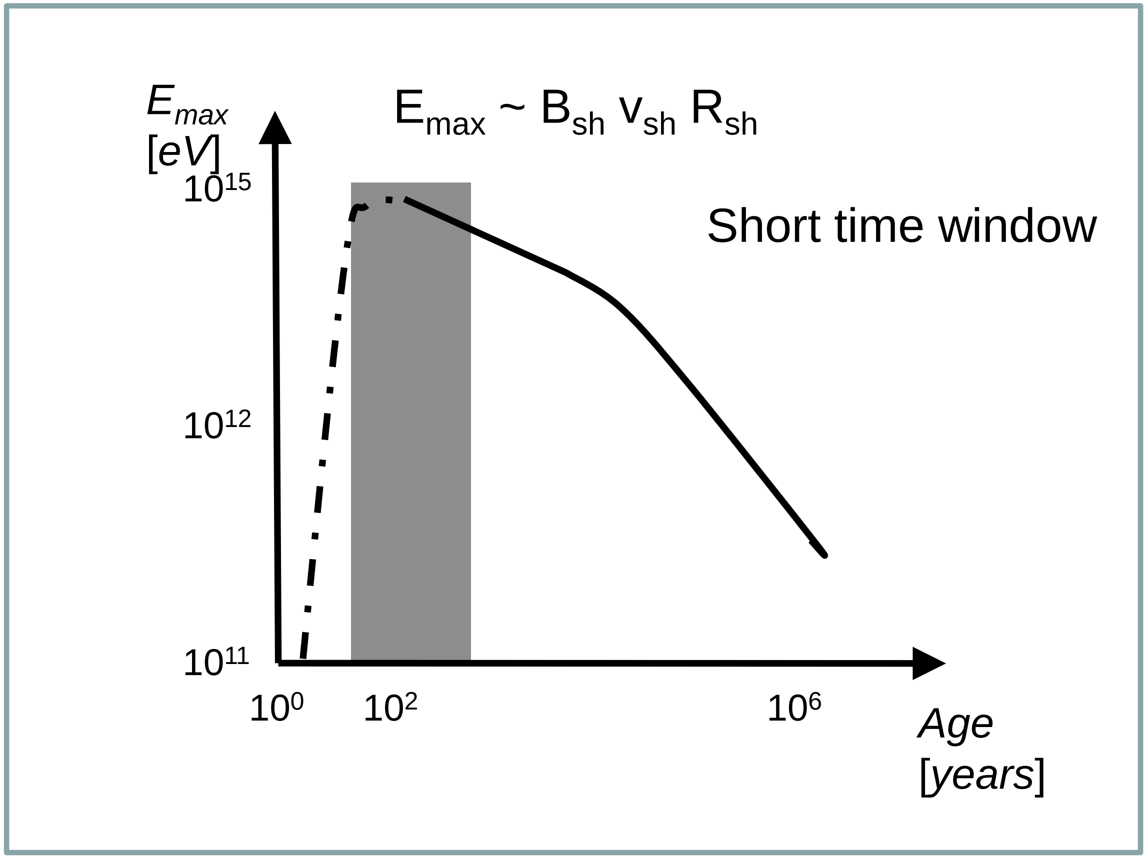

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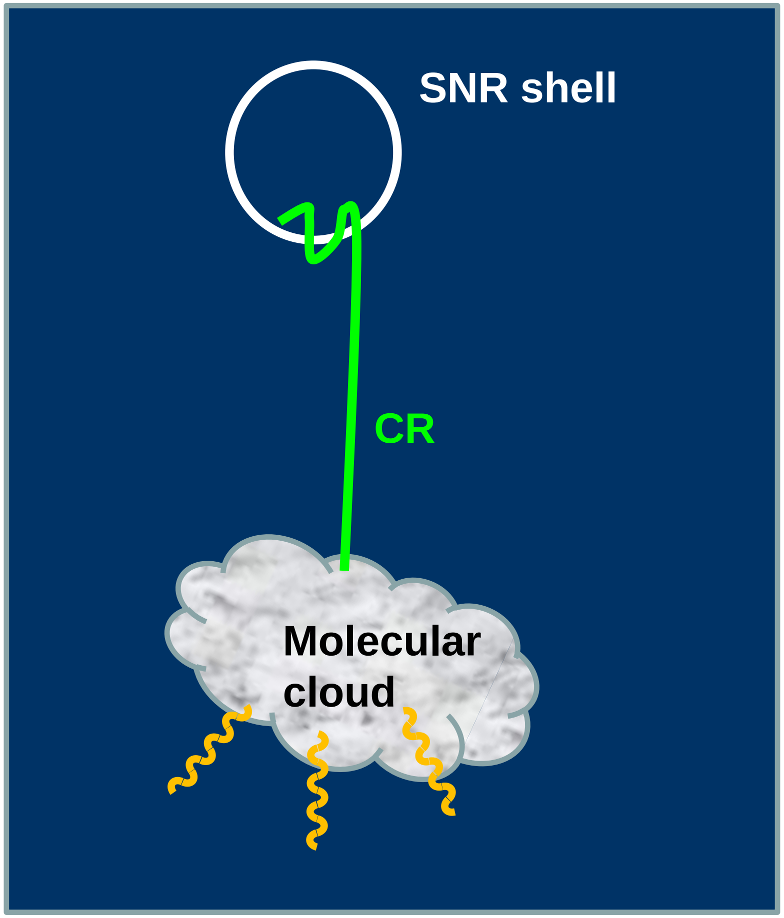

detect the “stages” of SNRs twice

➡ prolong observation window

up to now no Pevatrons found

Gabici et al. 2007

Summary

Supernova remnant / MC association

- Disentangling leptonic / hadronic scenarios
- Constrain SNR parameters
- Diffusion coefficients
- Search for Pevatrons

➡ Still more statistic needed

Thanks you for your attention !