Molecular gas studies towards PWNe

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What are PWNe ?

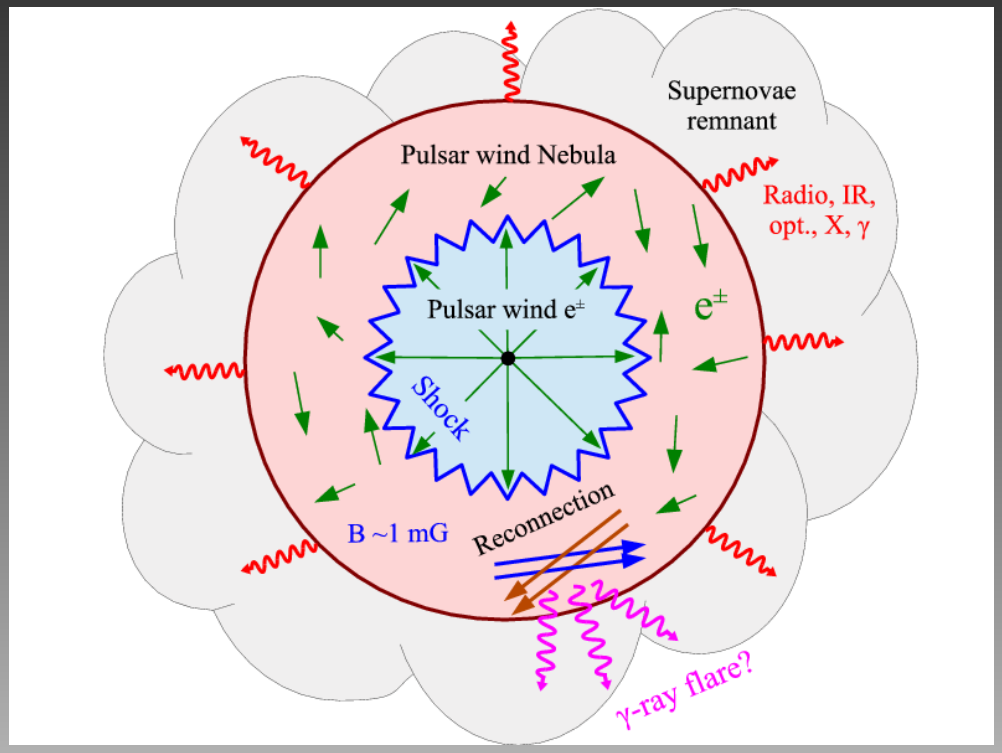
- Pulsar wind escaping the pulsar magnetosphere

  → acceleration at the termination shock

  → Broadband emission from Synchrotron (radio to x-rays)+IC emission.

- Bubble expanding rapidly until crushed by its progenitor SNR reverse shock *(Blondin et al 2001)*.

- Possible bow shock morphology for PWNe escaping the SNR interior.

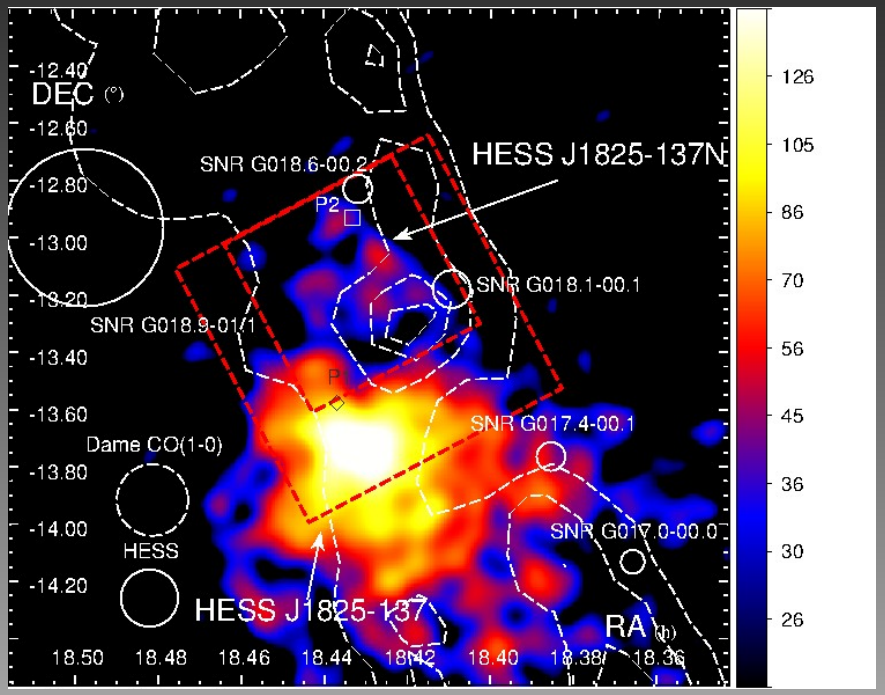


Sketch of the structure of the PWN

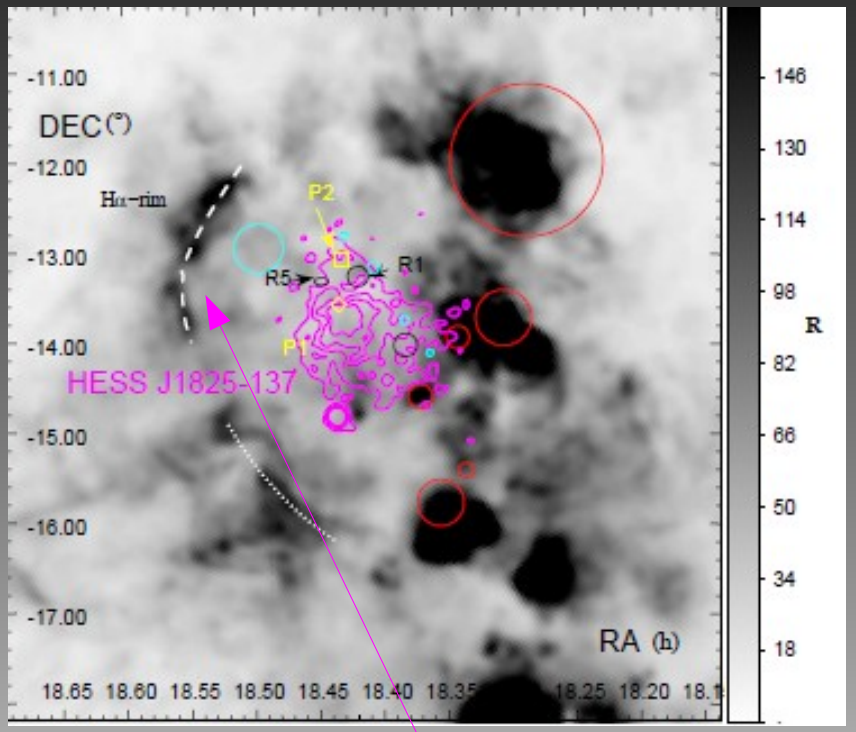
Motivation for gas studies

- Help explain the PWNe TeV morphology
- Provide additional constraints regarding the PWNe distance.
- Provide direct evidence of hadronic components in the PWN via the gamma-rays from p-p interaction.

HESS J1825-137 and the northern unidentified TeV source.



HESS excess count map overlaid by the Dame CO(1-0) contours

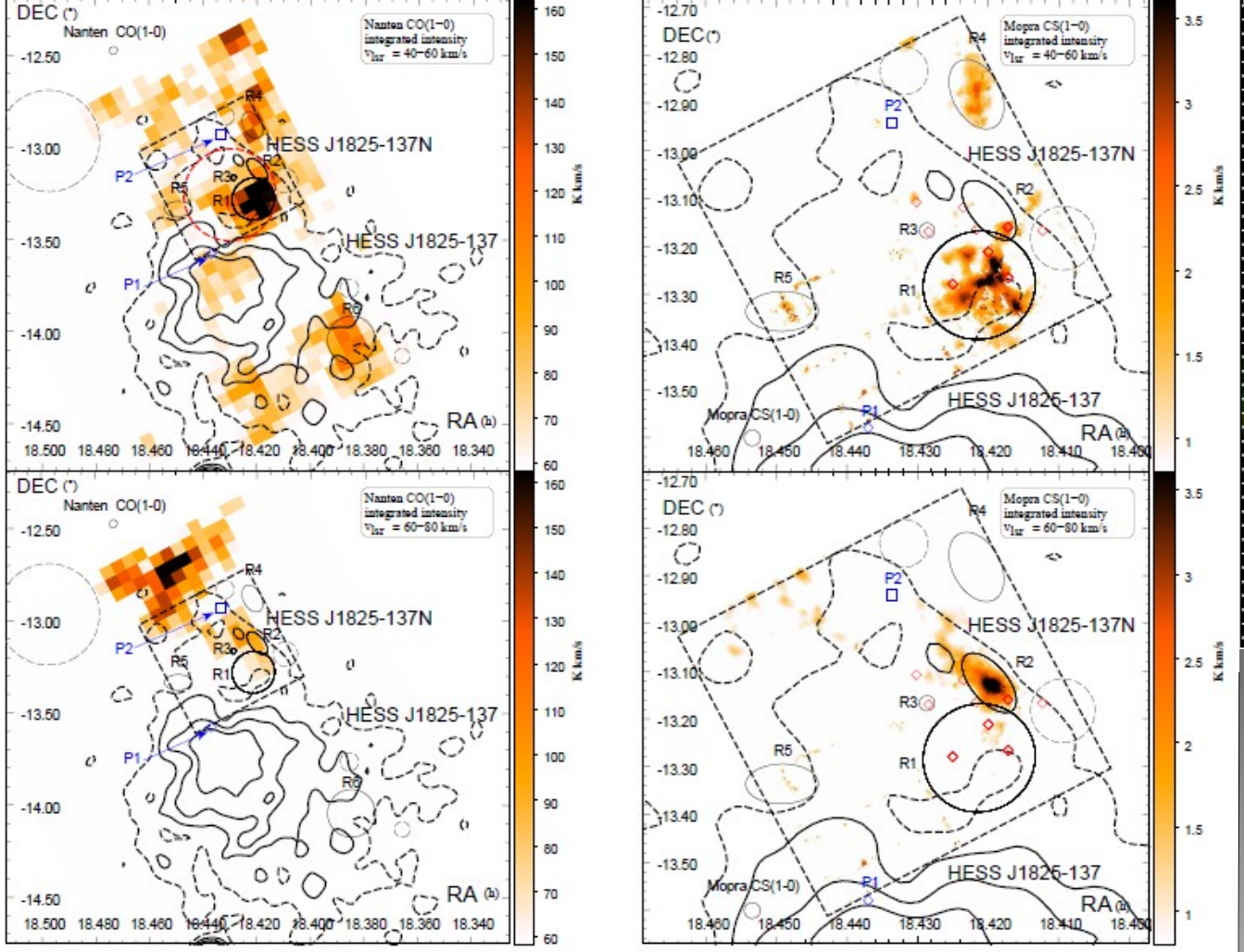


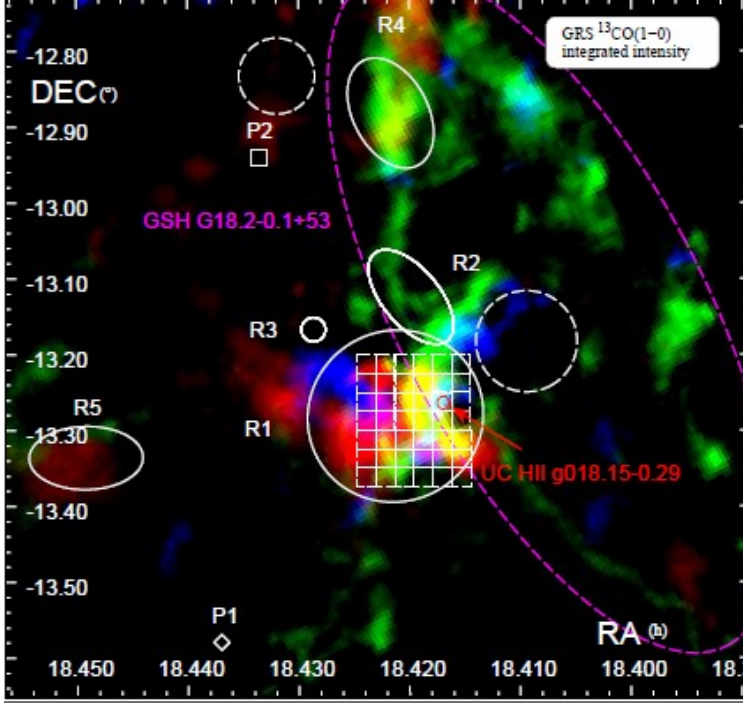
Hα image towards HESS J1825-137
Red circles: HII regions *(Anderson et al 2014)*

Rim location coincident with the P1's progenitor SNR predicted size R_{SNR}~120 pc *(De Jager et Djannataï-Atai 2008)*

P1 : PSR J1826-1334
→ E_{SD}=2.8x10^{36}erg s^{-1}
→ d = 4 kpc
→ Powering PWN HESS J1825-137

P2 : PSR J1826-1256
→ E_{SD}=4.9x10^{36}erg s^{-1}
→ Predicted d = 1.2-1.4 kpc *(Wang 2011)*
→ Powering PWN G018.5-0.4 *(Roberts et al 2007)*





CO(1-0) and CS(1-0) integrated intensity between 40-60 km/s (top) and between 60-80 km/s (bottom)

Cloud in the red circle : M=5x10 ^{5} solar masses

$n_{H_2} \sim 250\ cm^{-3}$

GRS 13CO(1-0) integrated intensity maps :

45-50 km/s

50-55 km/s

55-60 km/s

Turbulent dense molecular cloud → high mass star formation region

→ Arc shaped morphology converging towards the HII region

=> CLOUD-CLOUD COLLISION signatures

(e.g Torii et al 2015, Fukui et al 2014)

HESS J1825-137N : Associated with HESS J1825-137 progenitor SNR ?

- Using the derived density + Eq. 3 from Aharonian et al (1994)

  → $F(>270\ \mathrm{GeV}) = 1.2\times10^{-10}\left(E_{\mathrm{SN}}/3\times10^{51}\ \mathrm{ergs}\right)\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$

  → greater than the observed photon flux (rough estimation) :

  $F_{\mathrm{obs}}(>270\ \mathrm{GeV}) \approx 5.5\times10^{-12}\ \mathrm{ph\ cm}^{-2}$

  By a factor of ~20 !!!!!!!!!!!!

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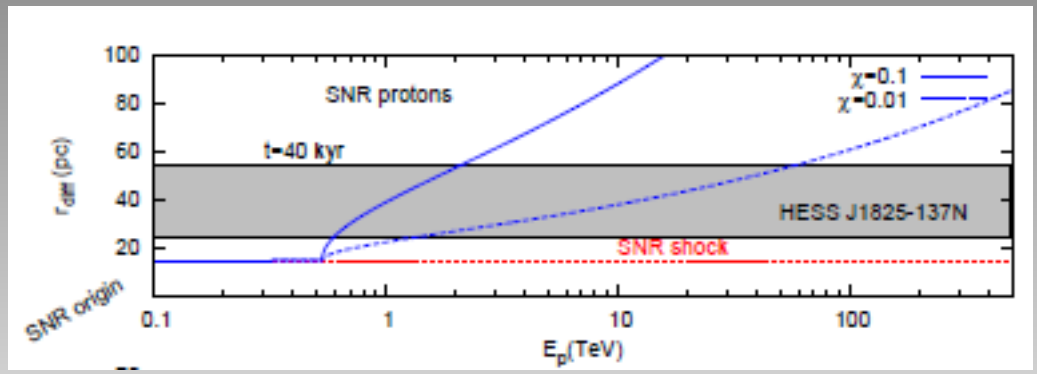
Effect of cooling losses after t=40 kyr → only reduce the flux by a factor of ~2

Effect of escaping particles ?
→ depend on the diffusion coefficient suppression factor χ.
→ χ will affect the observed the TeV morphological and spectral properties of the TeV emission towards HESS J1825-137N



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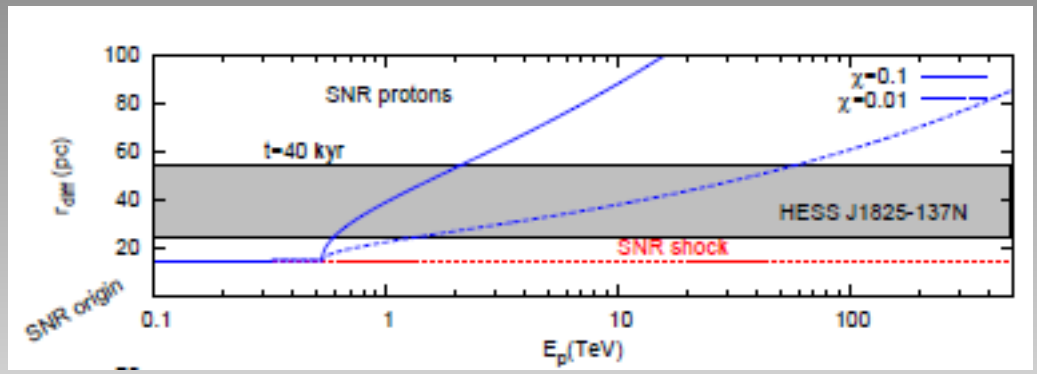


CR particles may also not have interacted with all the gas there .

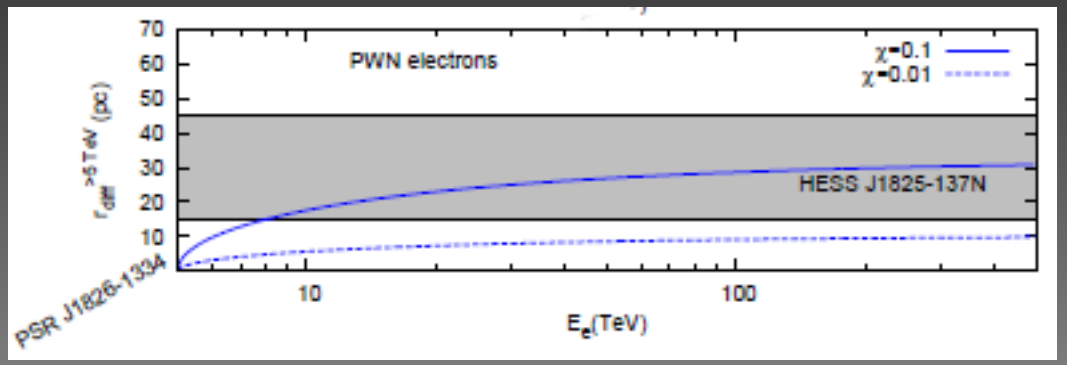
NONETHELESS, ITS CONTRIBUTION IS LIKELY TO BE SIGNIFICANT !!!!!!

HESS J1825-137N :Other contribution ?

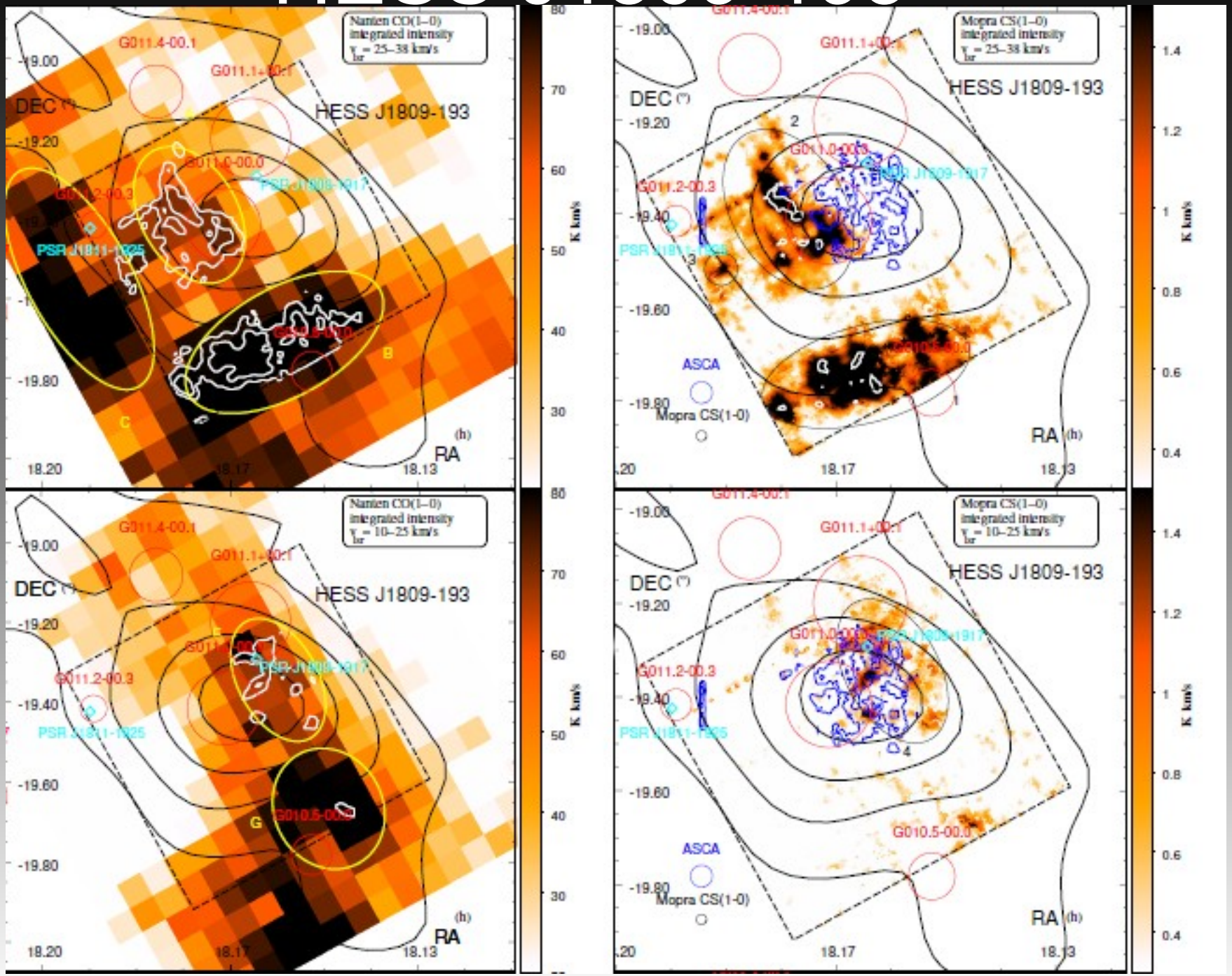
PWN HESS J1825-137 ?
→ electrons ? Possibly, electrons can reach HESS J1825-137N if χ>=0.1
→ protons ? Plausible, require only ~3% of the total PWN energy budget transfered to electrons. (Conditions apply !)

PWN G018.5-0.4 ? Yes !
Spatially close to the TeV source
Constraint on distance is however required.

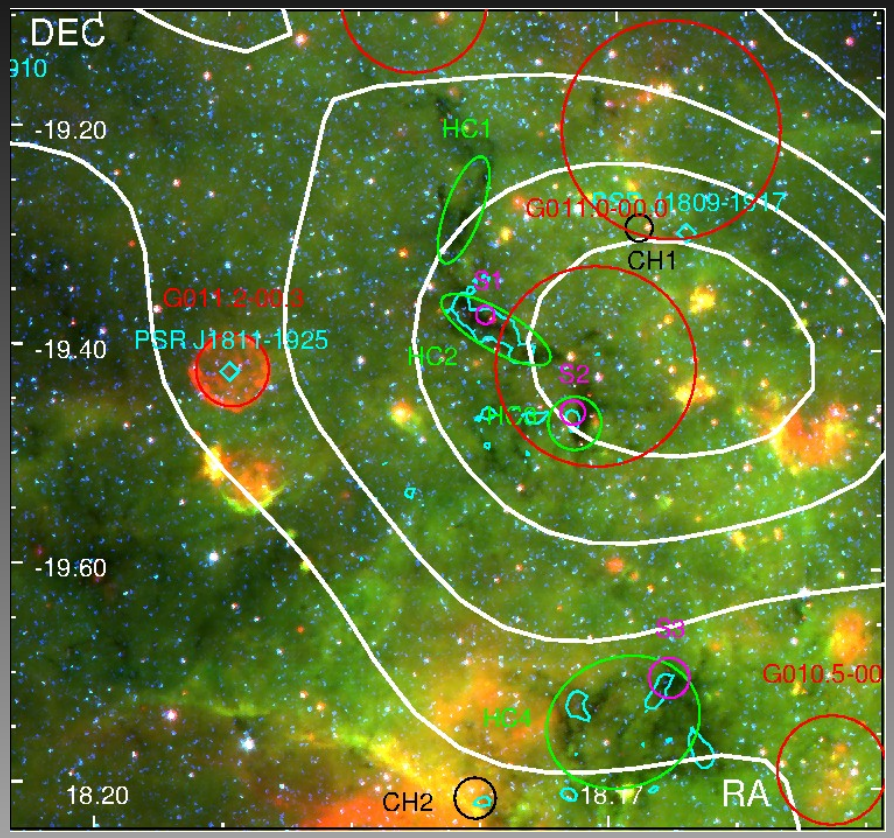
SNR G018.6-0.2 and SNR G018.2-0.1 ?
Unlikely !
→ SNRs angular size too small : located in the background

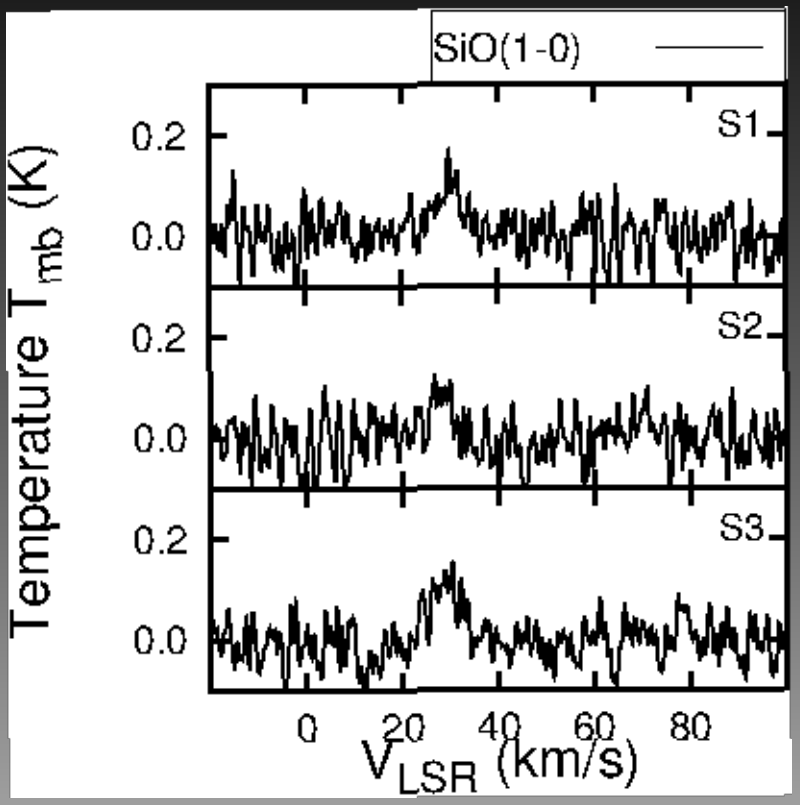


HESS J1809-193



HESS J1809-193



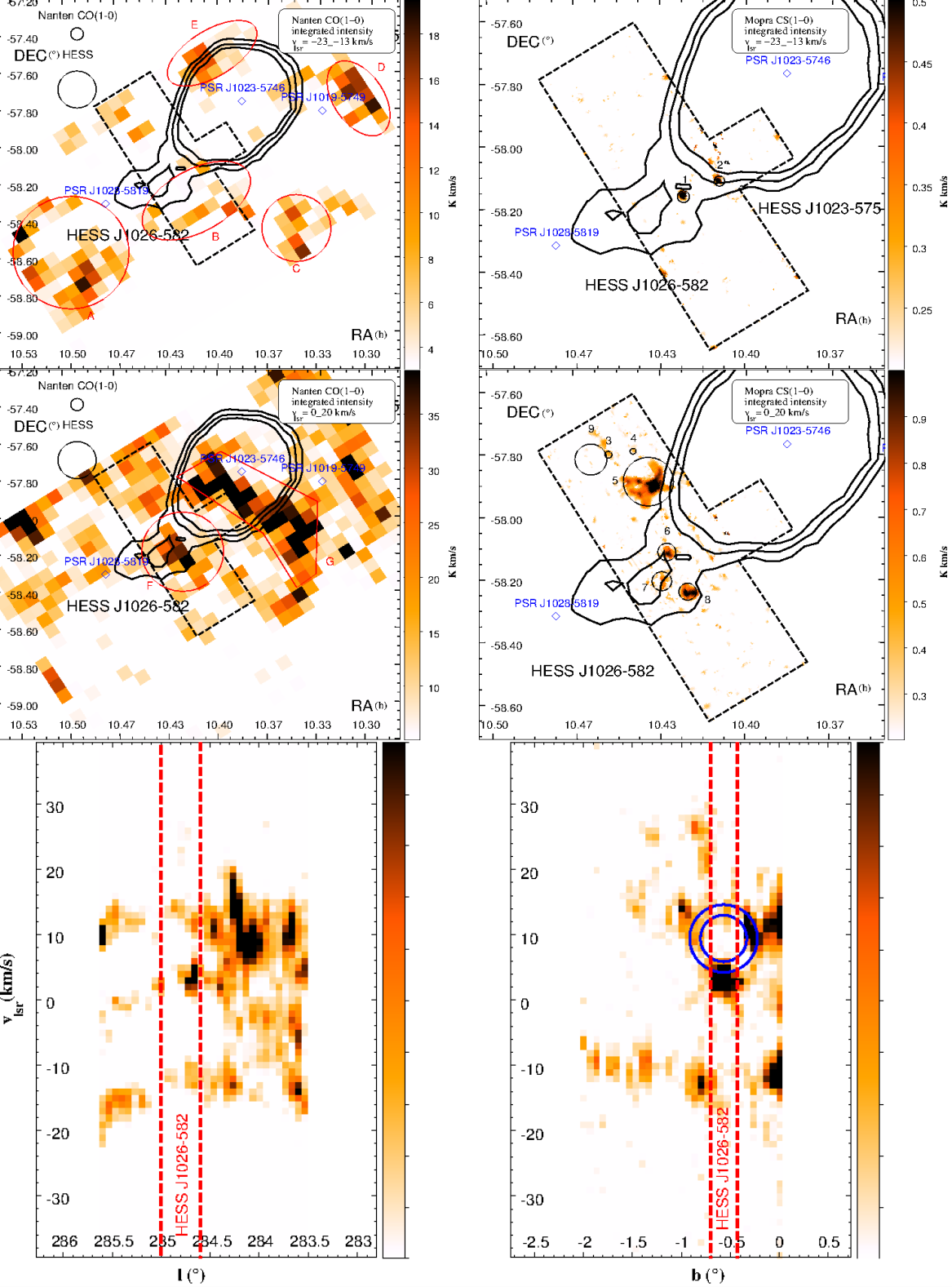


24 μm 8 μm 5.4 μm Spitzer

$C^{34}S$(1-0) in cyan contours

- IR Dark cloud spatially coincident with $C^{34}S$(1-0) and HCCCN(5-4,F=4-3).
- SiO(1-0) detection coincident with IR dark cloud and next to SNR

=> SNR at d=3.6 kpc ? Possible Hard X-ray enhancement adjacent to the molecular cloud (?).



HESS J1026-582

The PeVatron

PSR J1028-5819

→ E_{SD} = 8.43x10 erg s

→ d = 2.3 kpc

→ τ_c = 89 kyr

Pulsed emission detected by FERMI-LAT but not coincident with TeV emission.

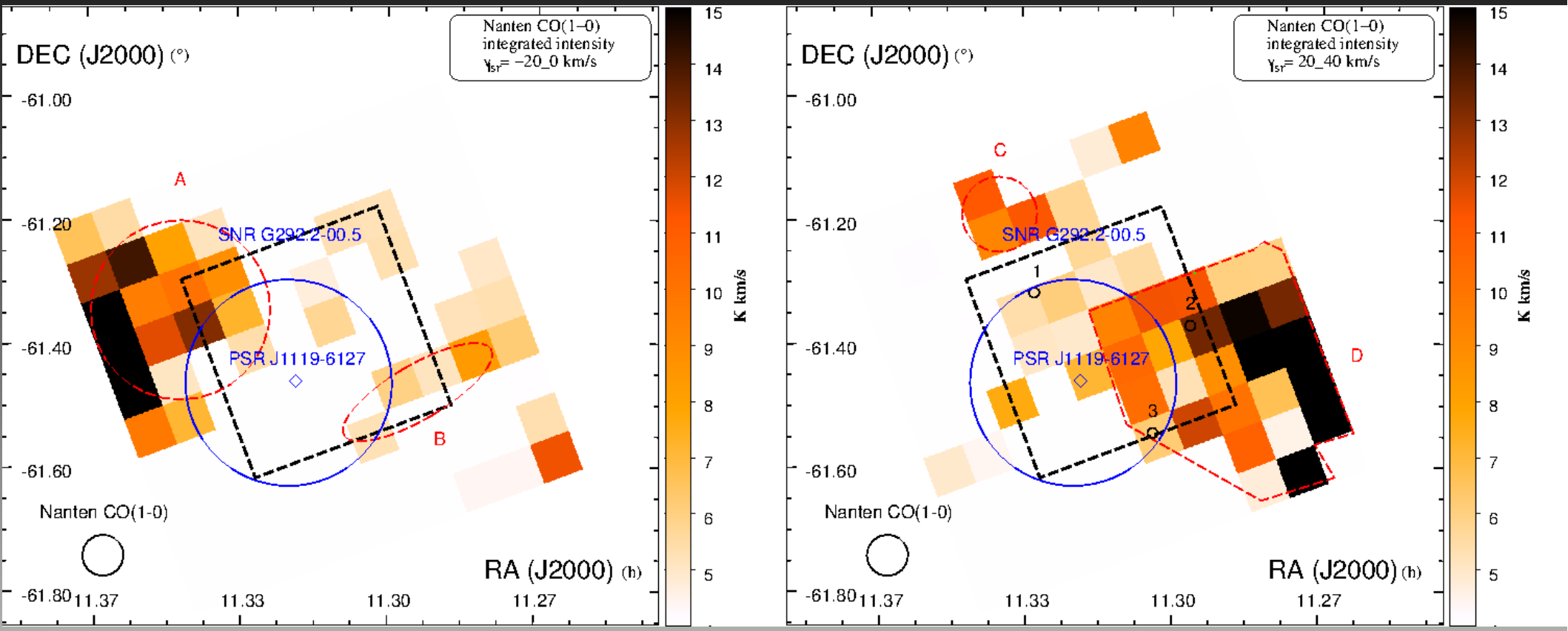
V_{lsr} =-23 to -13 km/s, molecular cloud adjacent to pulsar and TeV source → Support PWN scenario.

BUT....

V_{lsr} =0 to 20 km/s, molecular cloud coincident with TeV emission+ Cavity coincident with HESS J1026-582

→ Hadronic component ?

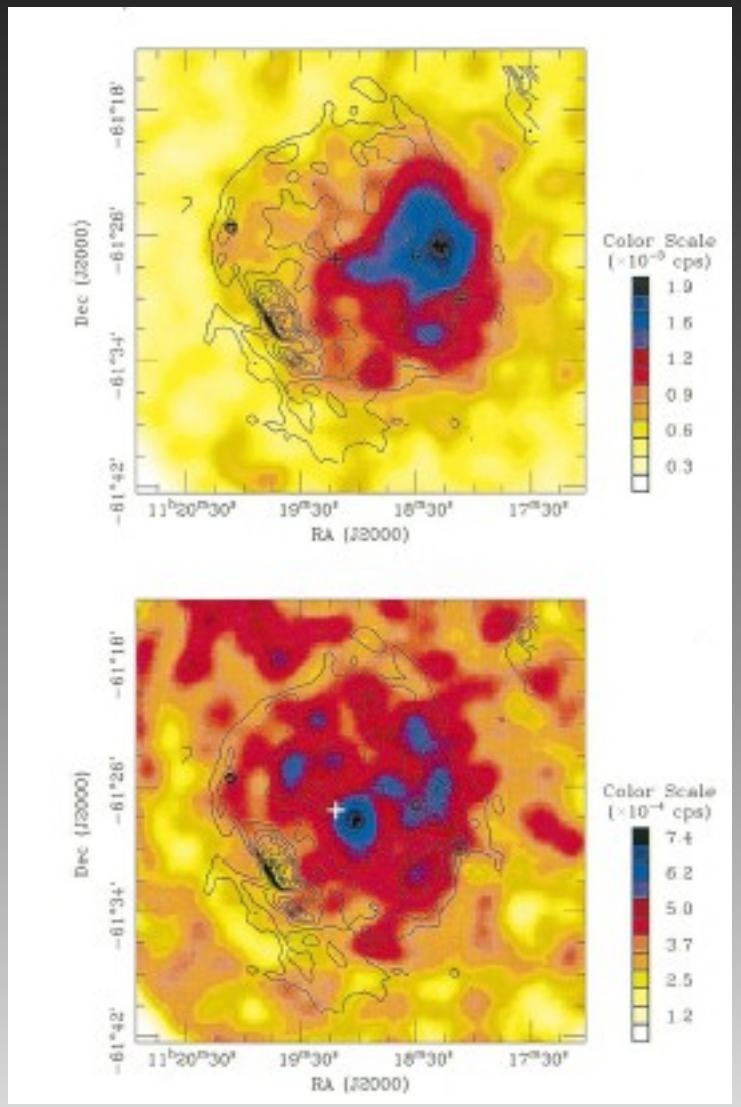
SNR G292.2-0.5



Young SNR t~1900 yr associated with PSR J1119-6127.
Distance : d=3.6-6.3 kpc from X-ray absorption column density *(Safi-Harb et al 2005)*
d=8.4 kpc from HI absorption analysis + location in Carina arm *(Caswell et al 2004)*

V_{lsr} = -20 to 0 km/s (near/far d~2/5 kpc) → molecular cloud adjacent to SNR.
V_{lsr} = 20 to 40 km/s (d~9.5 kpc) → partial overlap between the molecular cloud and SNR.
→Hard X-ray enhancement ?

SNR G292.2-0.5 ASCA

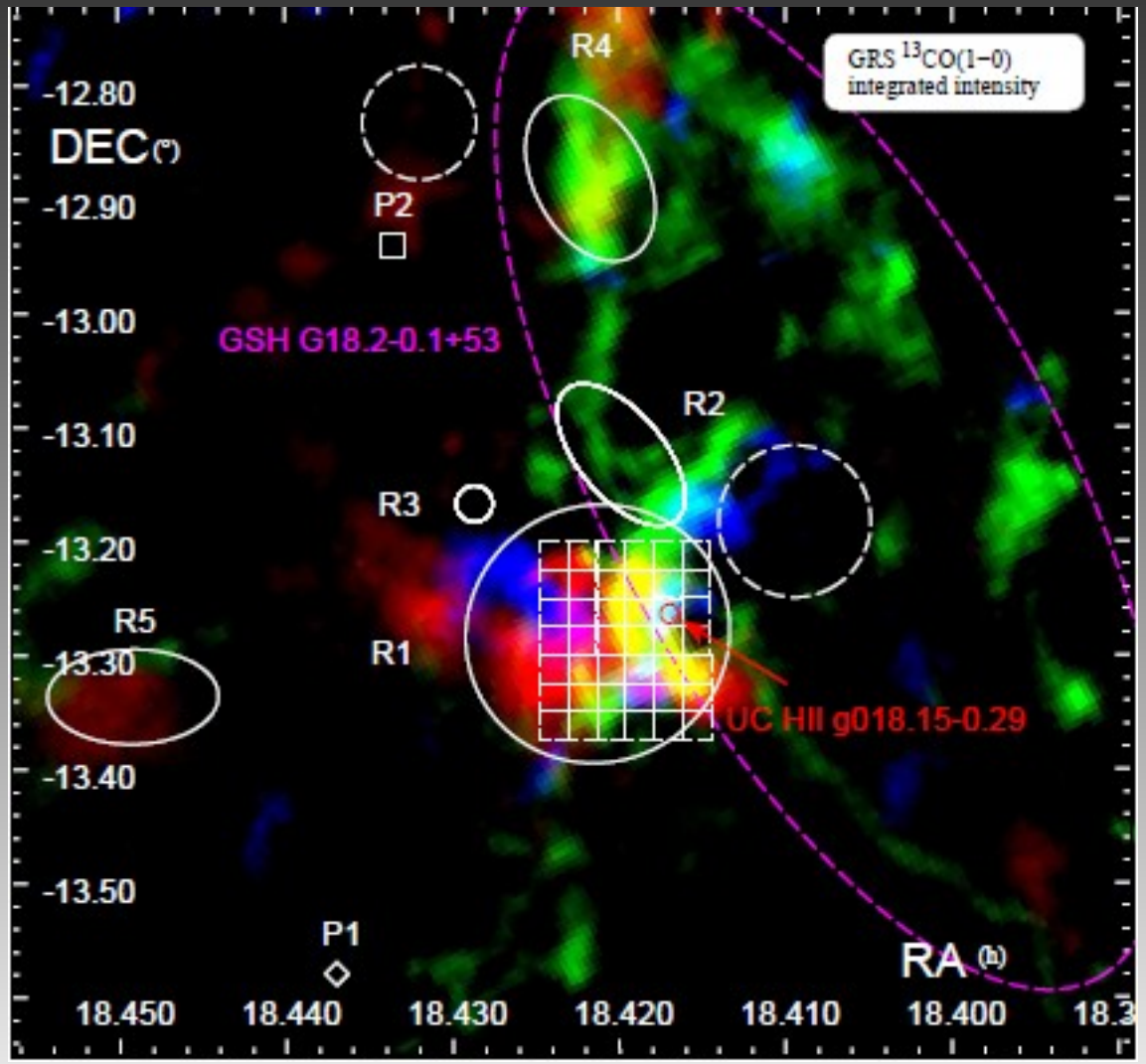


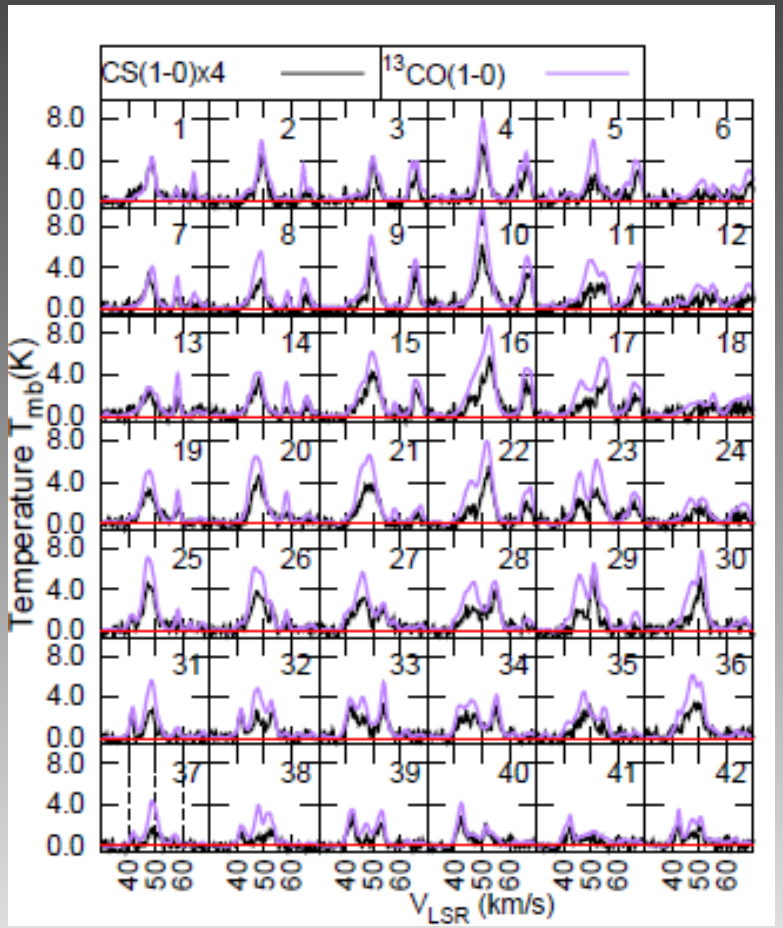
ASCA X-ray image towards SNR G292.2-0.5 in the soft band (0.8-3.0 keV, top) and in the hard band (3.0-10 keV, bottom) *(Pivovaroff et al 2001).*

- Hard X-ray towards the pulsar, correlation with the CO(1-0) at v_{lsr} =20-40 km/s +strong soft X-ray absorption towards the NE

- X-ray enhancement towards the West of the pulsar coincident with the molecular cloud at v_{lsr} =20-40 km/s.
  → The ISM analysis seems to agree with the distance d~9.5 kpc (based on galactic rotation model)

ADDITIONAL SLIDE I : Cloud-Cloud collision





CONCLUSION

- Mopra and Nanten is an important tool to understand morphological and spectral properties of TeV emission and provide additional contraints on the PWNe candidates.

- Mopra rocks so it must live on !