CTA AUSTRALIA CONSORTIUM

Molecular gas studies towards PWNe

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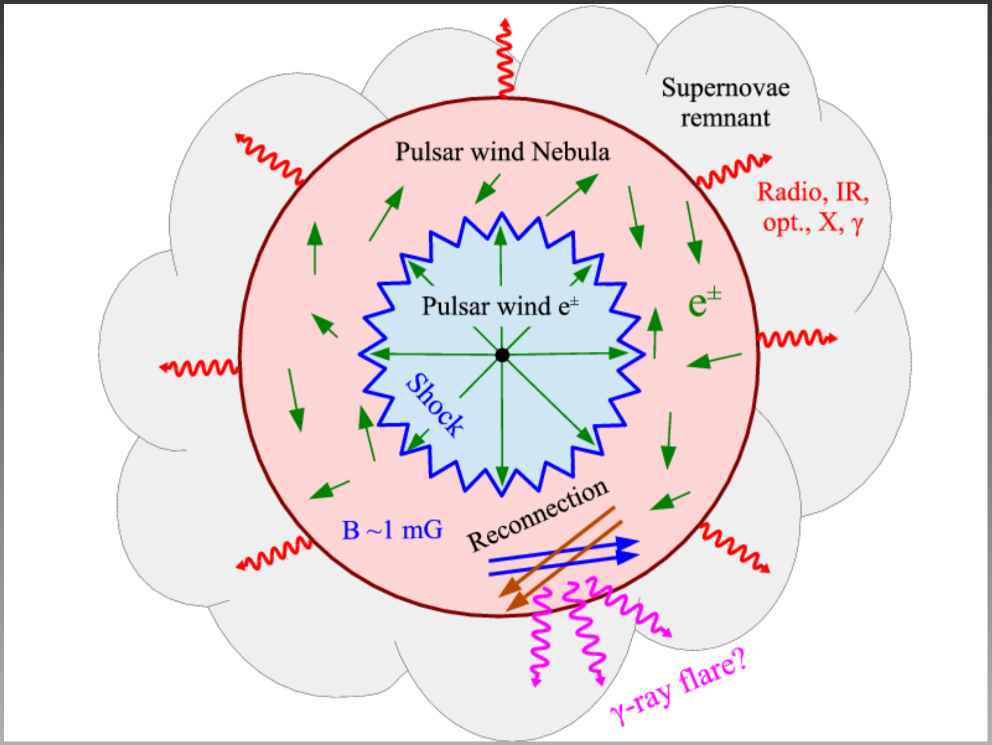
What are PWNe ?

- Pulsar wind escaping the pulsar magnetosphere

  → acceleration at the termination shock

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

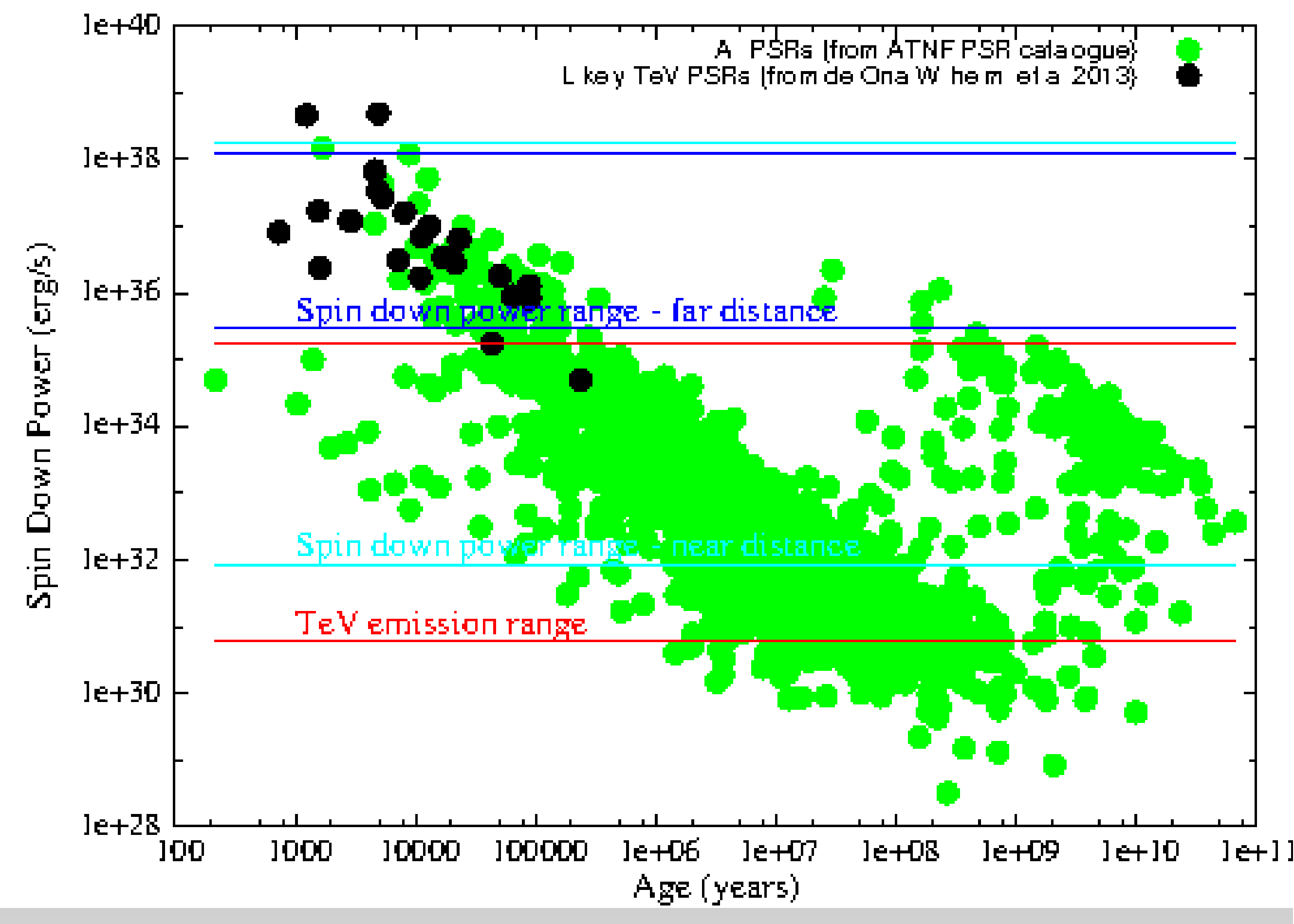
- Bubble expanding rapidly until crushed by its progenitor SNR reverse shock *(Blondin et al 2001)*.
- Possible bow shock morphology for PWNe escaping the SNR interior.



Sketch of the structure of the PWN

PWNe in TeV astronomy

- Most pulsar can energetically produce TeV emission
- PWNe are thus likely to remain the majority of the TeV source population in our Galaxy

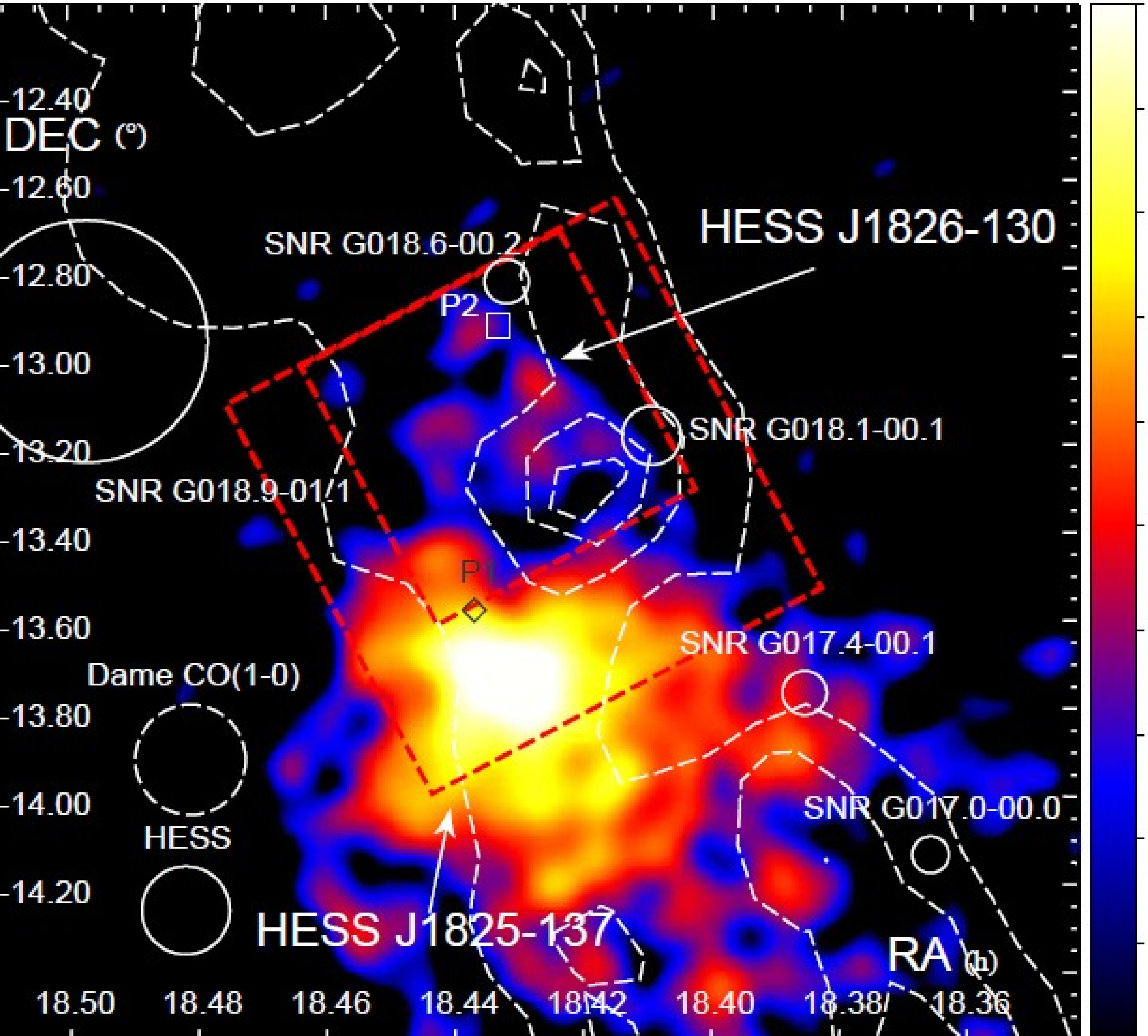


(Courtesy of P. de Wilt)

Motivation for gas studies

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

HESS J1825-137 and HESS J1826-130.



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

P1 : PSR J1826-1334

→ E_{SD} =2.8x10^{36} erg/s

→ d = 4 kpc

→ Powering PWN HESS J1825-137

P2 : PSR J1826-1256

→ E_{SD}=3.6x10^{36}erg/s

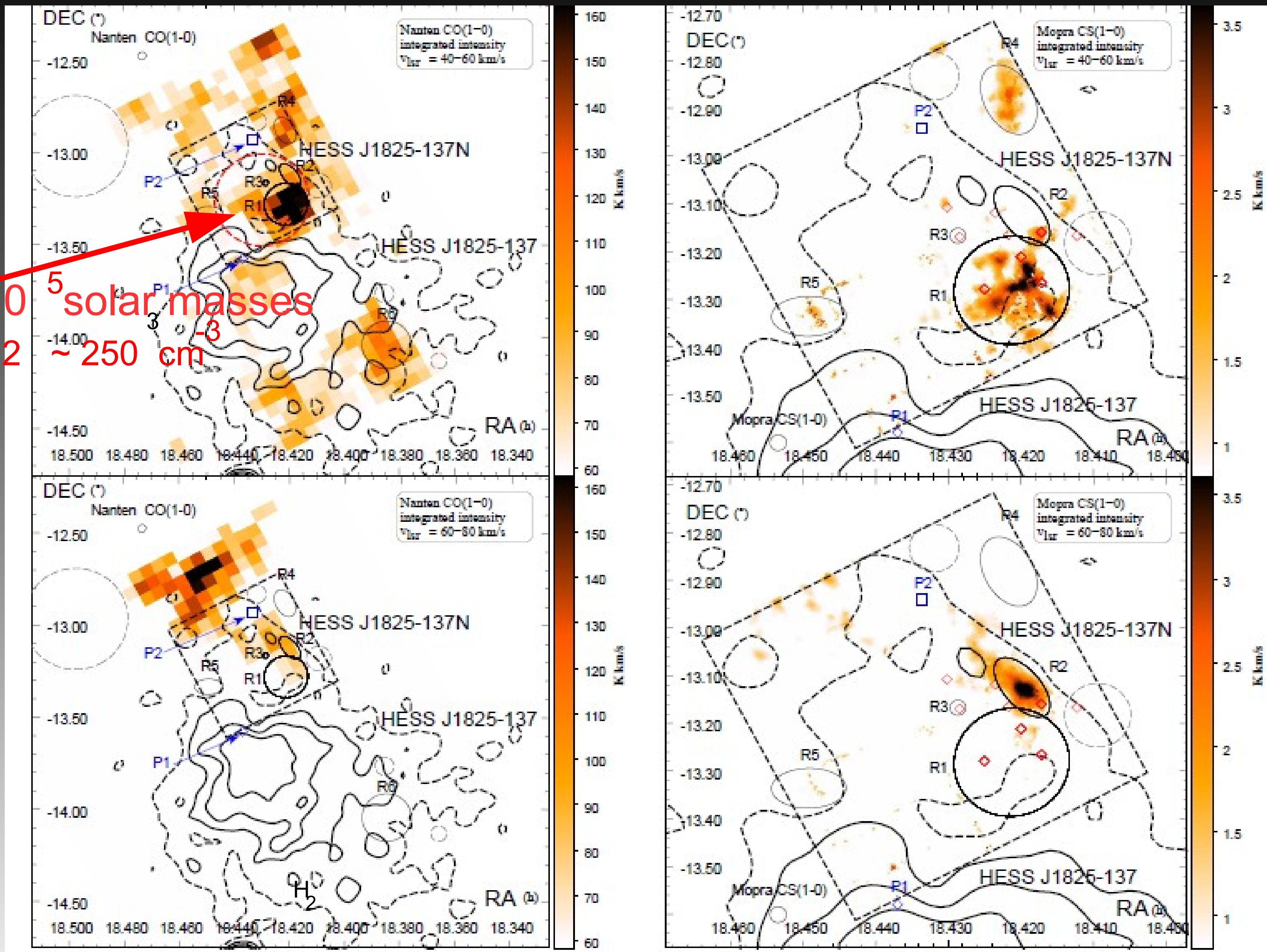
→ d =1.2-1.4 kpc (?)

(Wang 2011)

→ Powering PWN G018.5-0.4

(Roberts et al 2007)

HESS J1825-137 : MOPRA AND NANTEN

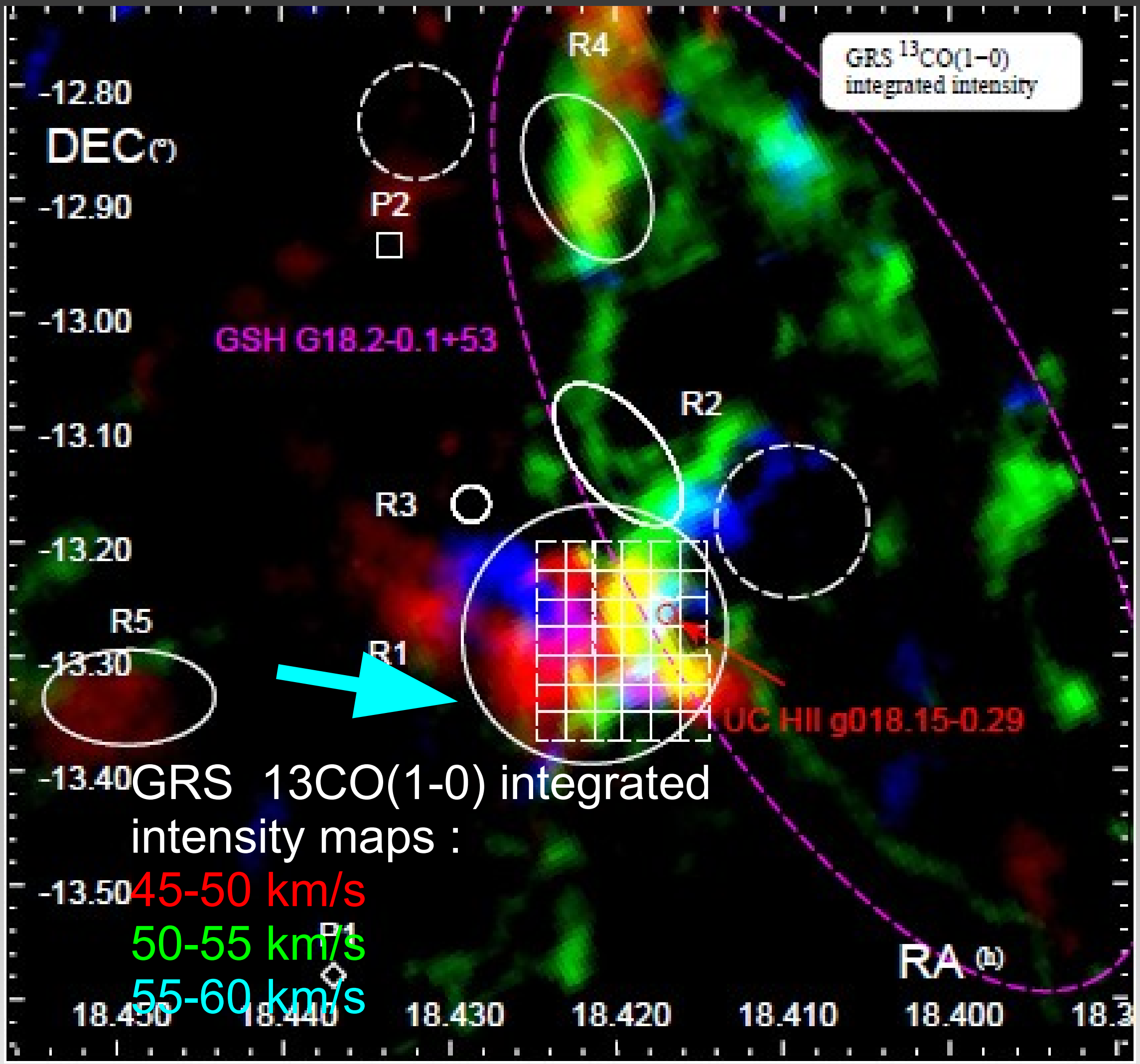


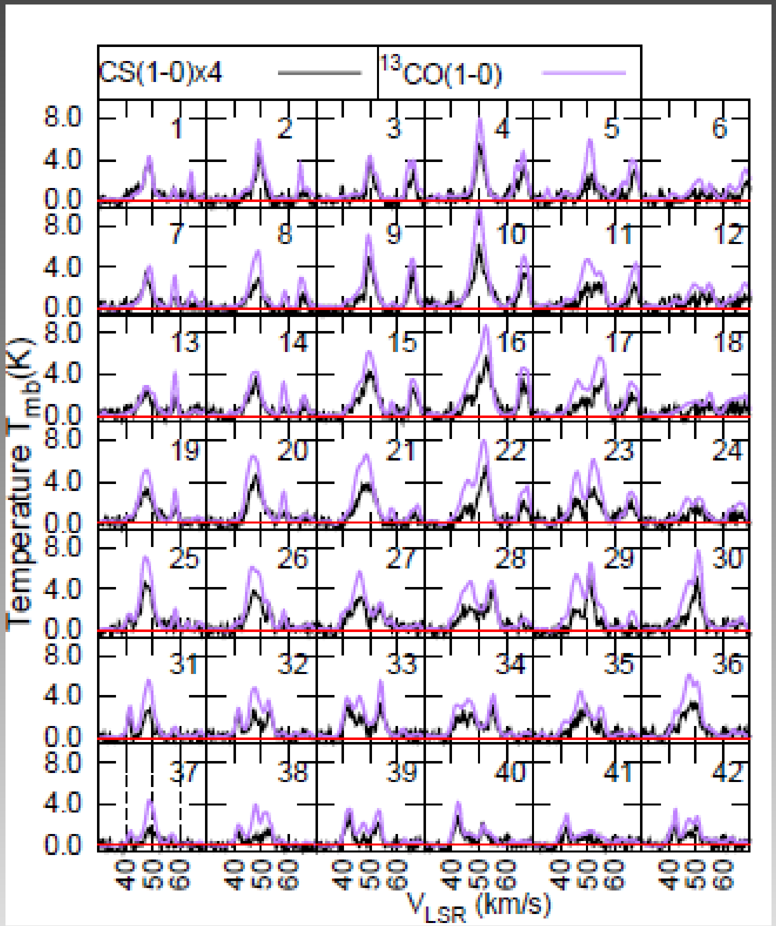
M=3x10^5 solar masses

nH2 ~ 250 cm^{-3}

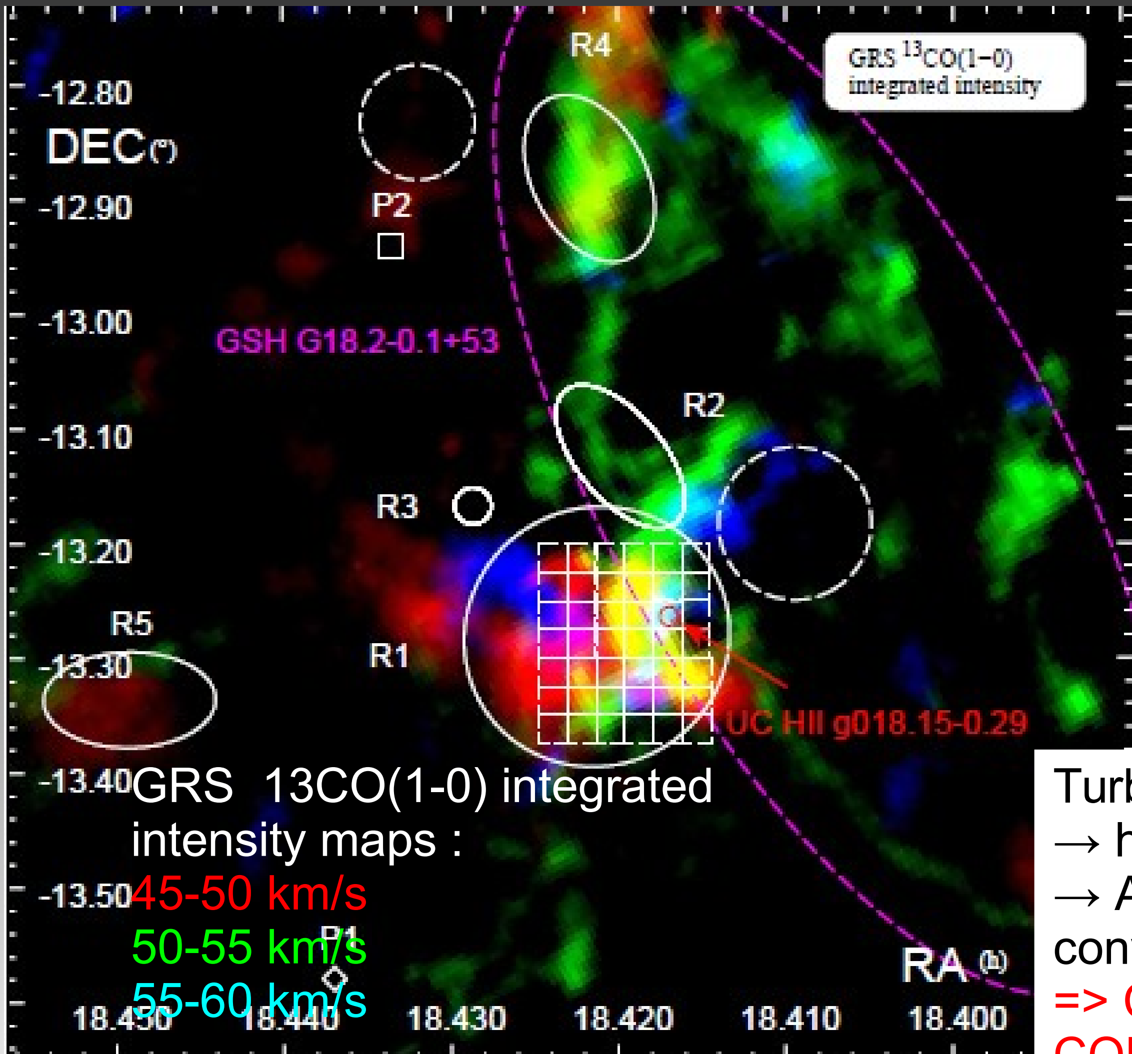
Voisin et al (2016)

HESS J1825-137
Cloud-Cloud collision (?)

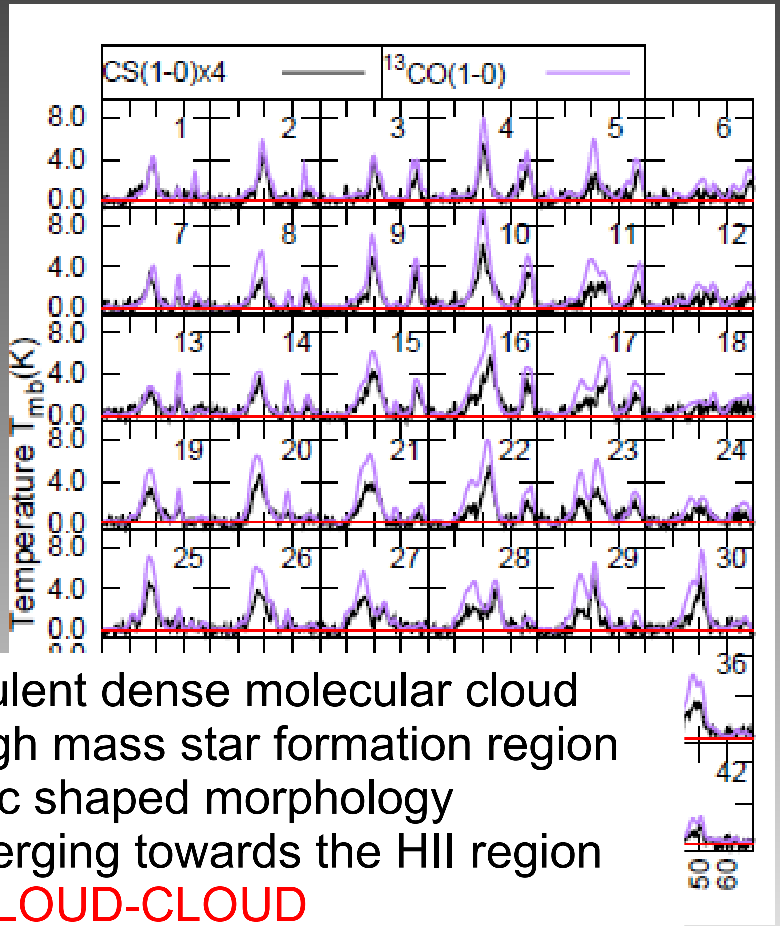




HESS J1825-137
Cloud-Cloud collision (?)

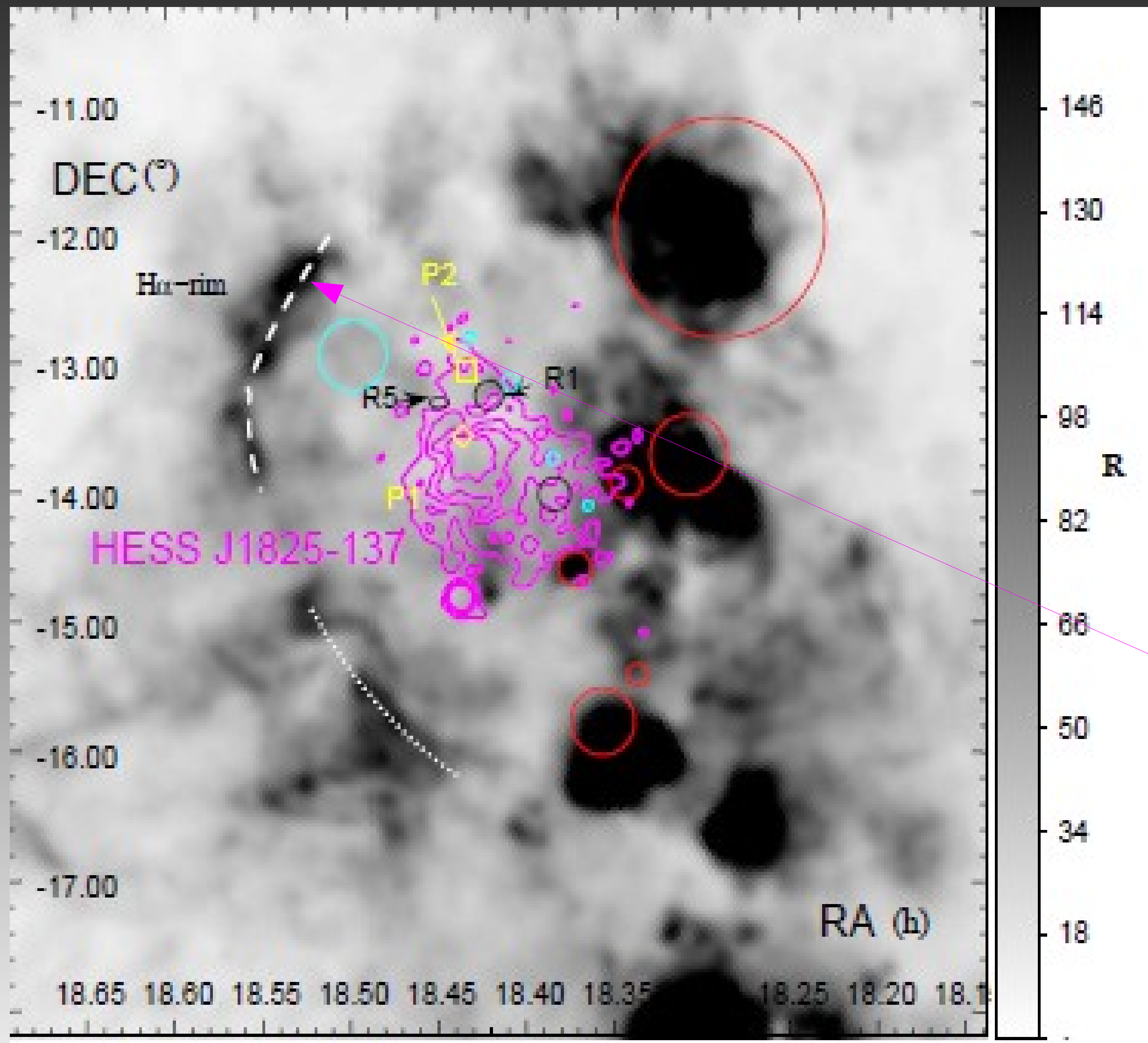


GRS 13CO(1-0) integrated intensity maps :
45-50 km/s
50-55 km/s
55-60 km/s



Turbulent dense molecular cloud
→ high mass star formation region
→ Arc shaped morphology converging towards the HII region
=> CLOUD-CLOUD COLLISION signatures
(e.g. Fukui et al 2014, Torii et al 2015)

HESS J1825-137 and the northern unidentified TeV source.



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

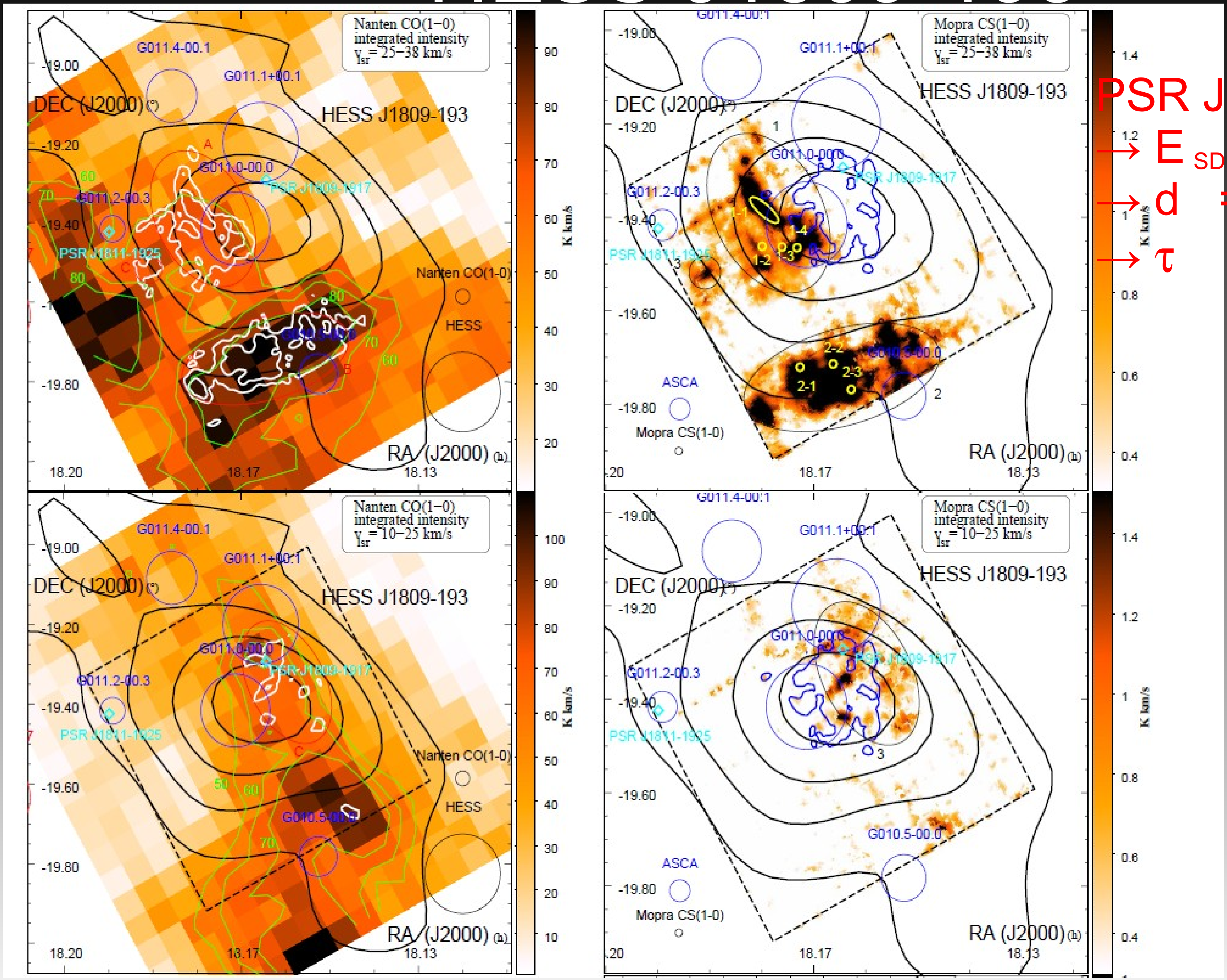
Rim discovered by Stupar et al (2008) location coincident with the P1's progenitor SNR predicted size R_{SNR} ~120 pc
(De Jager et Djannataï-Atai 2008)

HESS J1825-137 summary

- The turbulence found in region R1 appeared to be caused by Cloud-cloud collision.
  The progenitor SNR of HESS J1825-137 may not have reached the dense cloud.
- Hα SNR rim might be associated with the progenitor SNR

  → if so, major constraint regarding the ISM surrounding (very low gas density) and progenitor SNR age.
- CRs from the progenitor SNR of PSR J1826-1334 can contribute to the HESS J1826-130 TeV emission.

HESS J1809-193



PSR J1809-1917

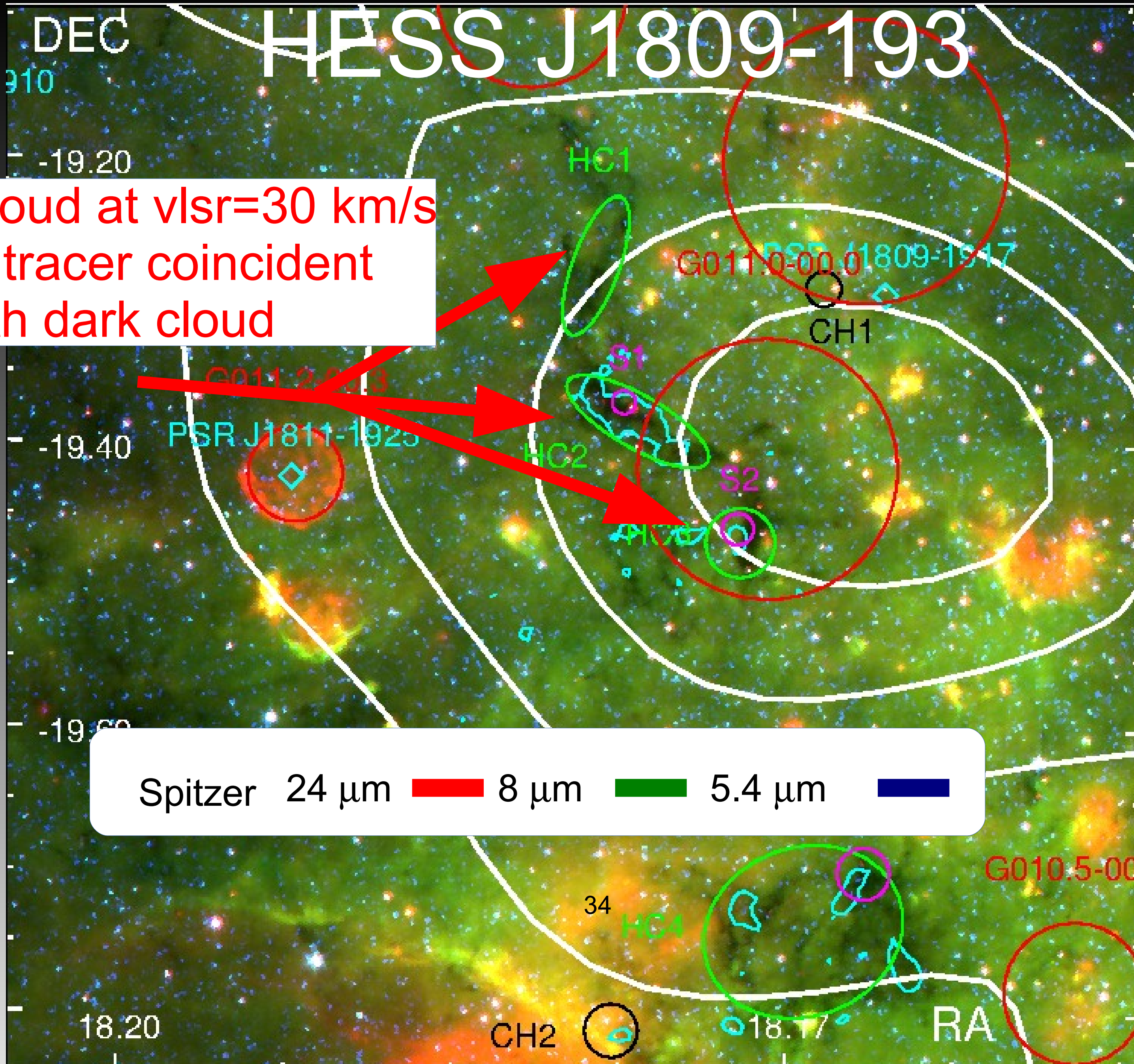
→ E_{SD} = 1.1x10^{37}erg/

→ d = 3.7 kpc

→ τ = 51 kyr

HESS J1809-193

IR Dark cloud at vlsr=30 km/s
+shock tracer coincident
with dark cloud



Mopra $C^{34}S(1-0)$

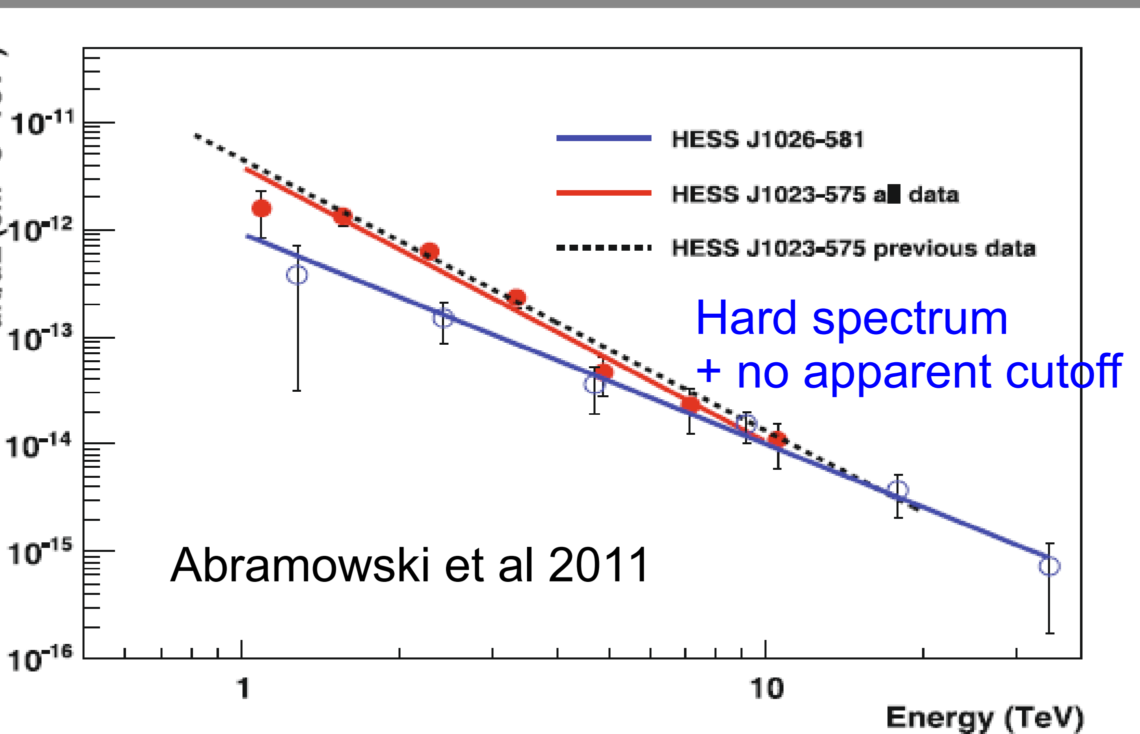
SiO (1-0,v=0)

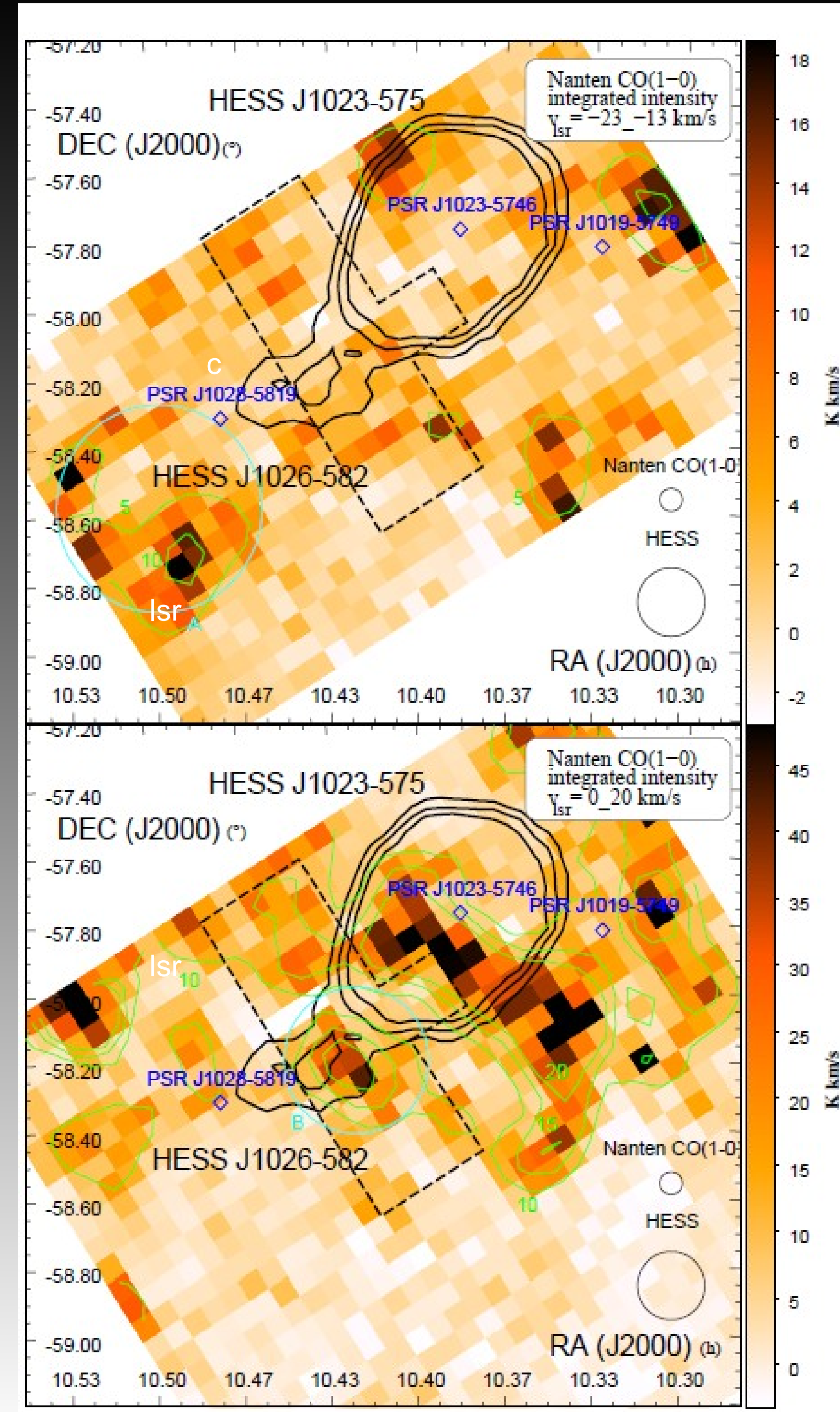
$HC_3N(5-4)$

=> SNR G011.0-0.0 at d=3.6 kpc (?), progenitor SNR of PSR J1809-1917 ?

HESS J1026-582

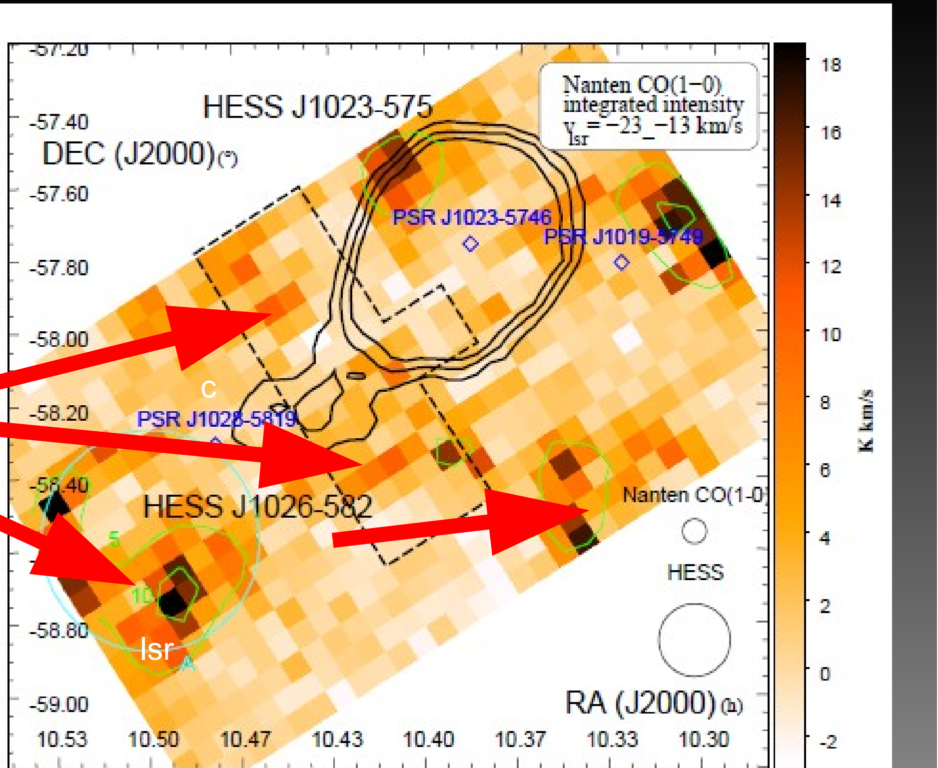
PSR J1028-5819
→ E_{SD} = 8.43x10^{35} erg/s
→ d = 2.3 kpc
→ τ = 89 kyr
Pulsed emission detected by FERMI-LAT but not coincident with TeV emission (Acero et al 2013).

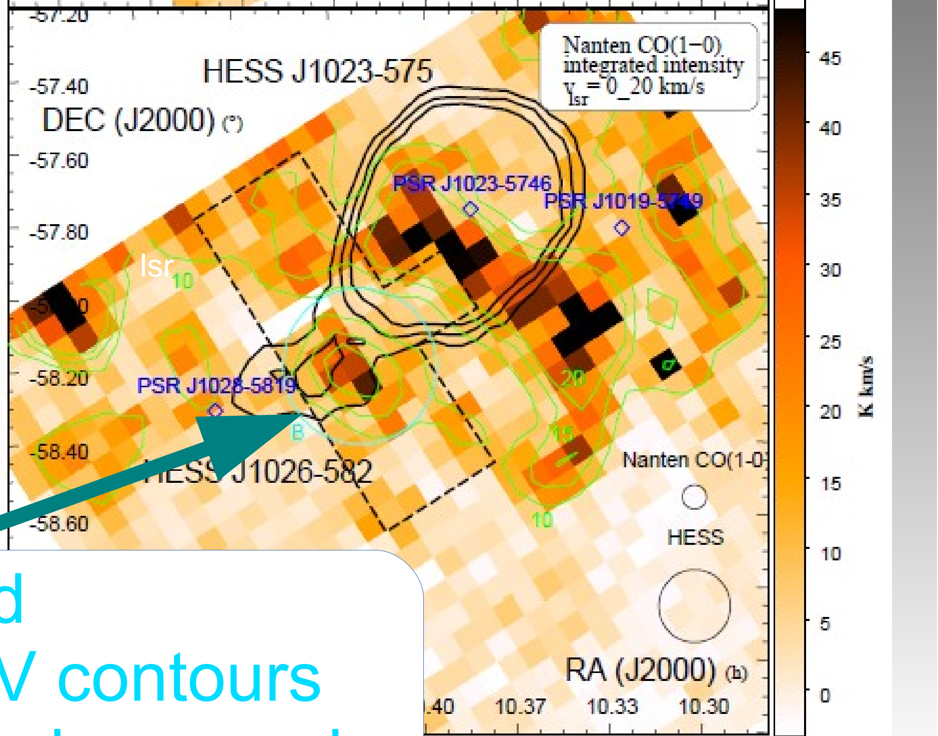


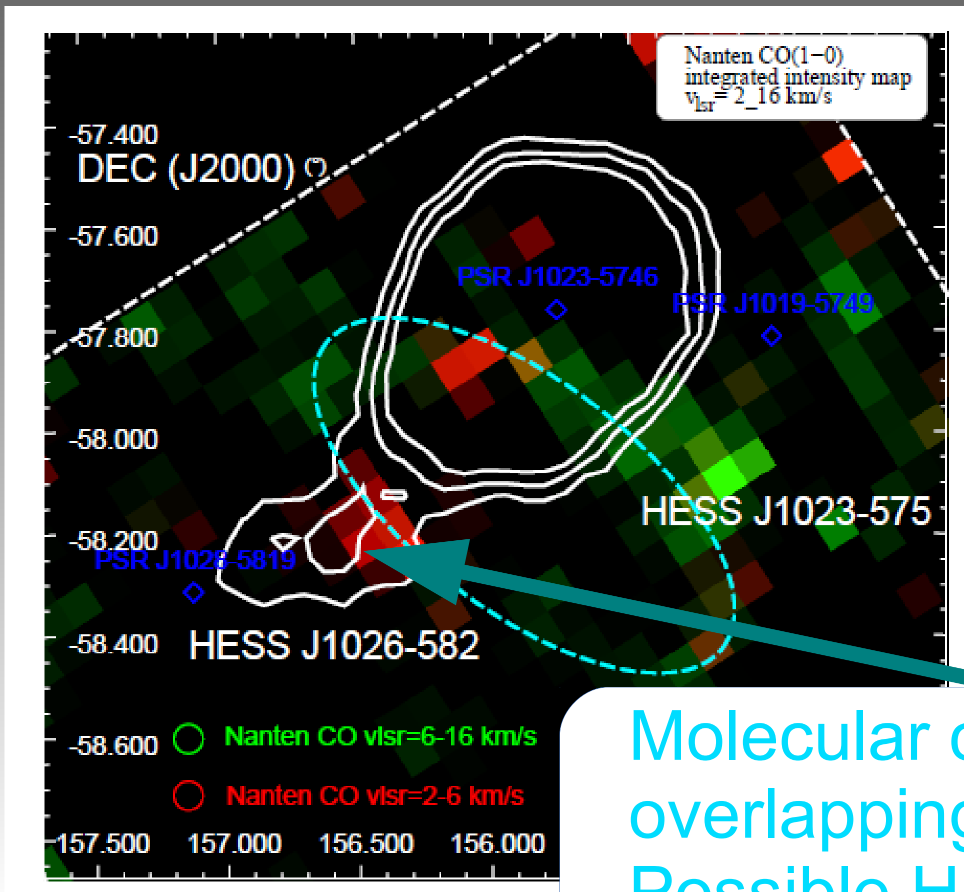


HESS J1026-582

Anticorrelation with TeV contours
at Vlsr=-23_-13 km/s.
→ Support PWN scenario at d=2.3 kpc



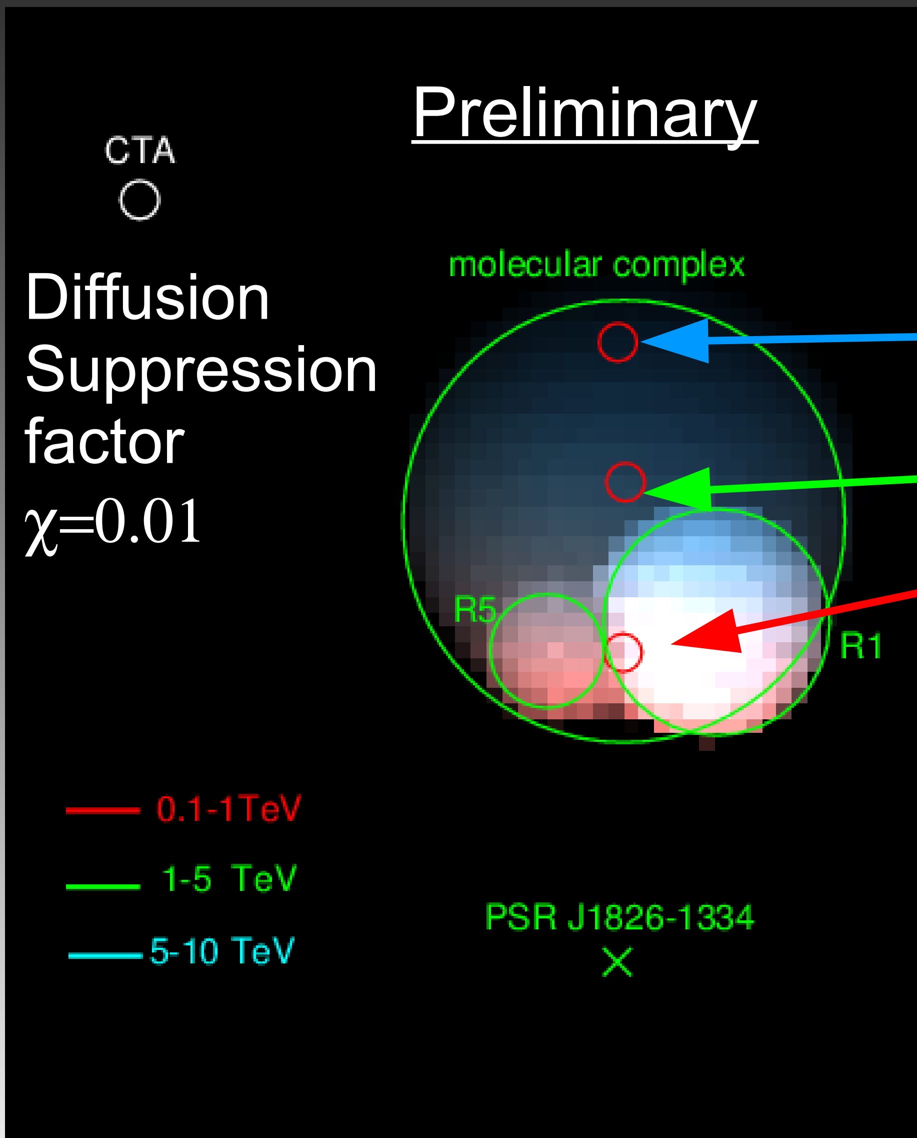


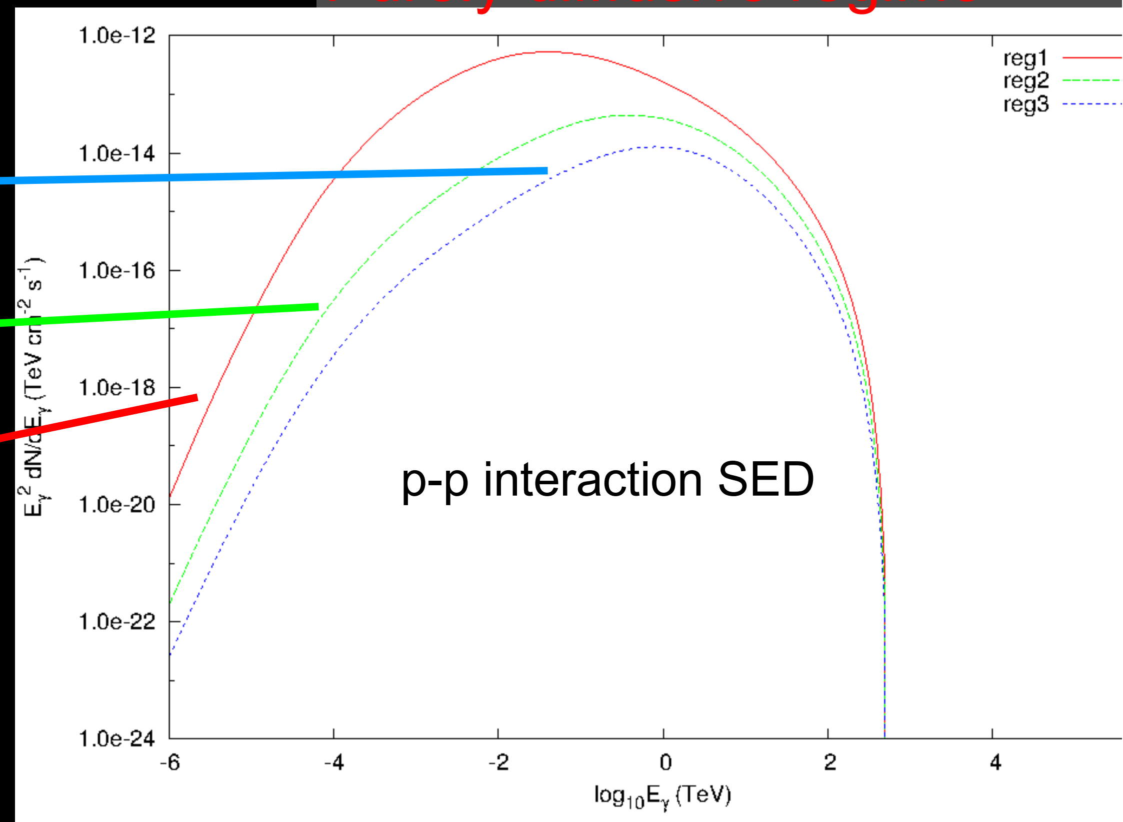


Molecular cloud overlapping TeV contours
Possible Hadronic scenario

CTA :Linking gas study to TeV morphological study

Assumption : Isotropic
Energy dependent diffusion
+ radiative losses.
Purely diiffusive regime

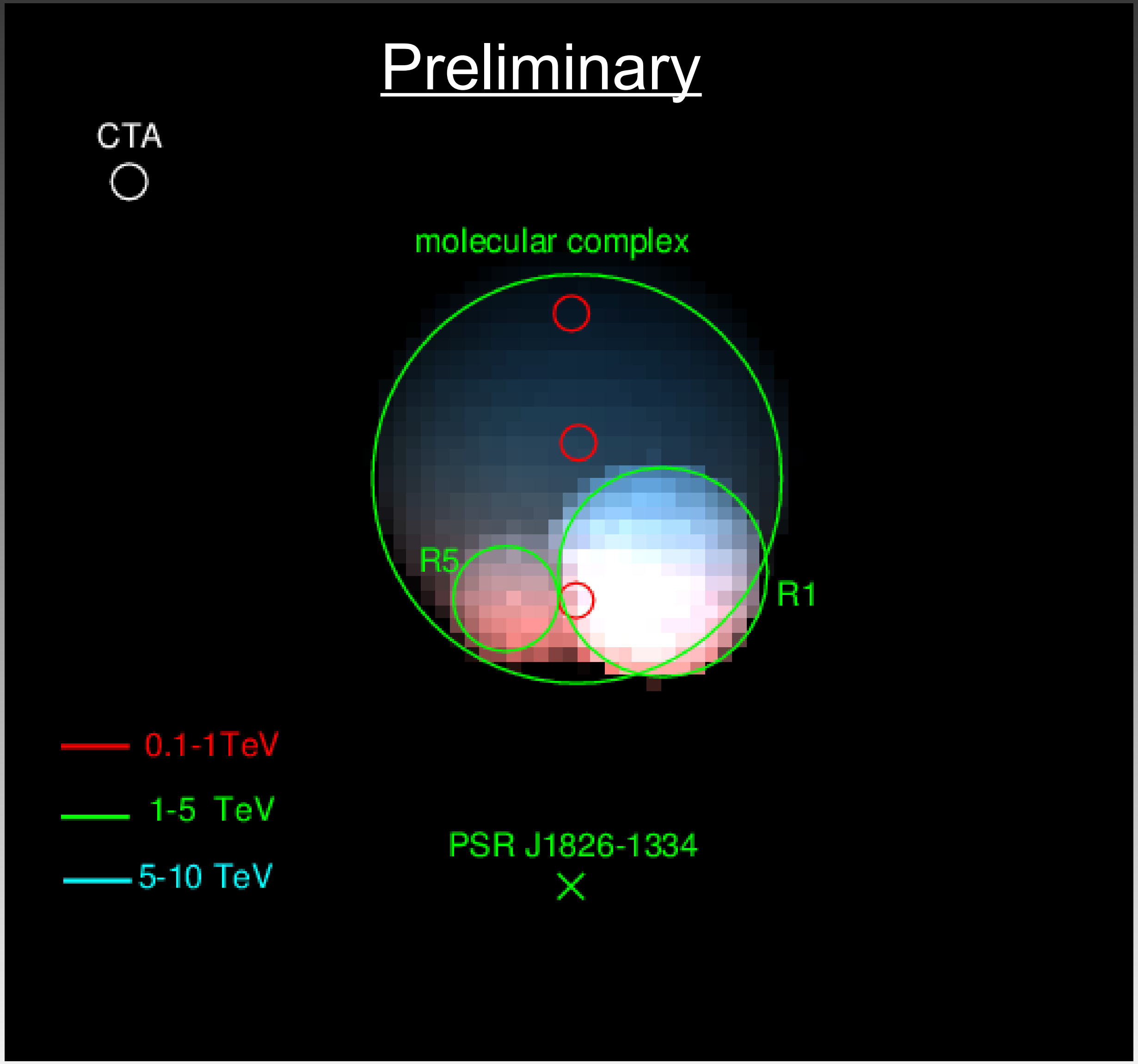




A morphological TeV analysis co
Help constraint origin of some
unidentified TeV sources

3 clouds with distinct densities

Linking gas study to TeV Hadronic source HESS J1825 prog. SNR

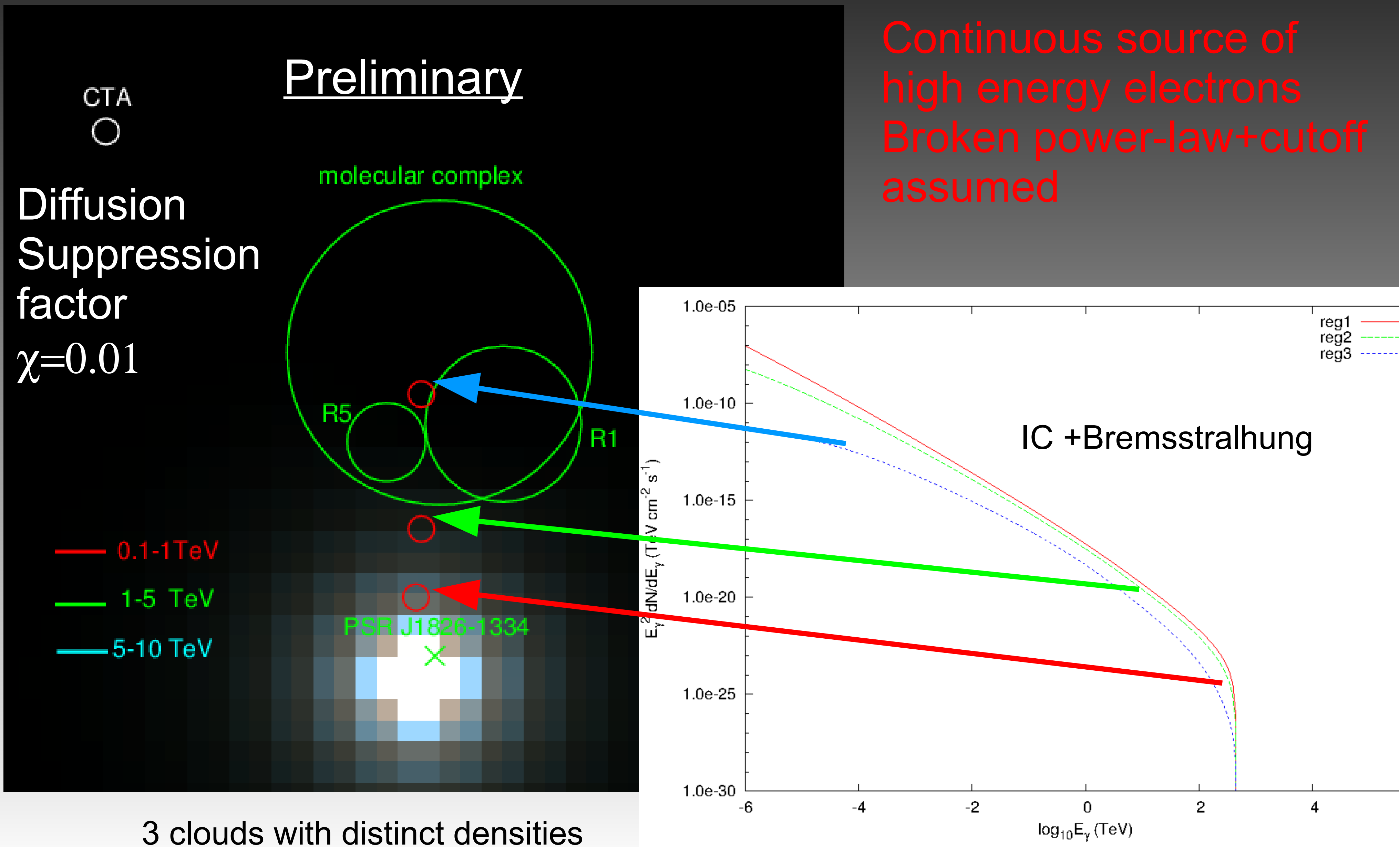


More uniform TeV morphology at Higher energies overlapping the ISM gas in slow diffusion scenario

MUCH SOFTER spectra expected in a fast diffusion scenario (see Aharonian et al 1996)

CTA :Linking gas study to TeV leptonic source

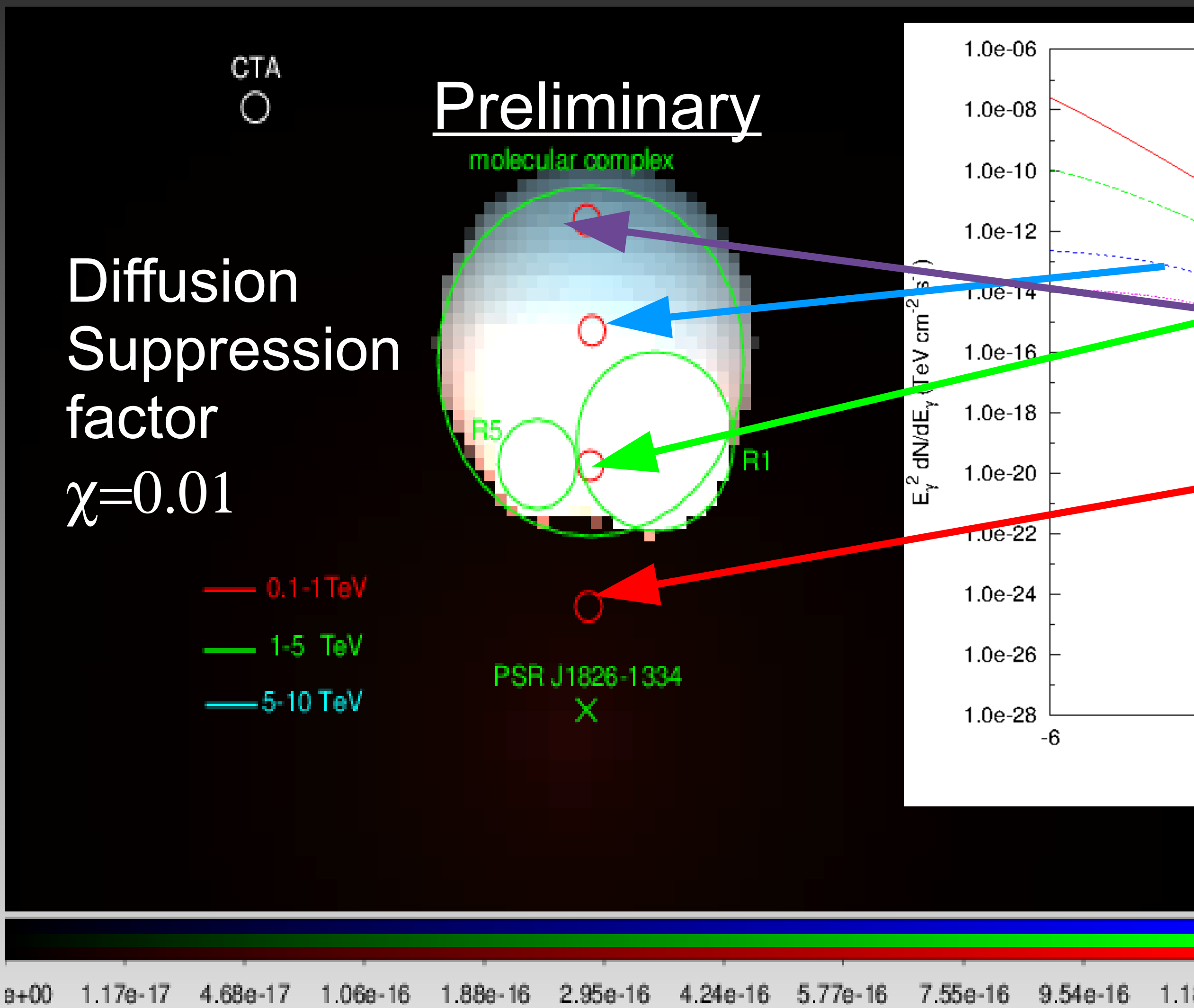
Continuous source of high energy electrons
Broken power-law+cutoff assumed

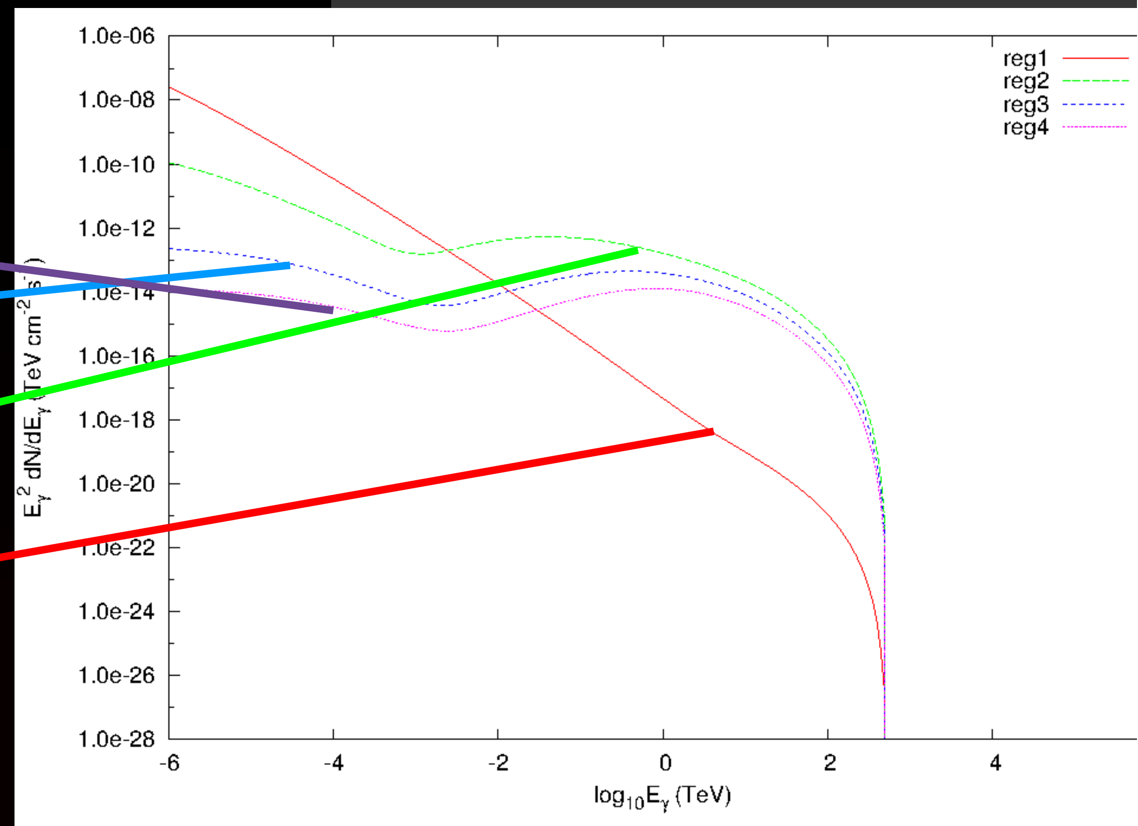


3 clouds with distinct densities

Hadrons+leptons ALTOGETHER !

Diffusion Suppression factor
χ=0.01





3 clouds with distinct densities

I STILL NEED TO CALIBRATE THE INPUT PARAMETERS PROPERLY

POINTS TO REMEMBER

- Understanding the gas distribution (molecular +atomic) is important to understand the morphology of PWNe morphology at TeV energies, their composition (electrons/hadrons), their distance.
- Using the data from all wavelength studies (radio, optical, X-ray, gamma-ray) is clearly vital to grasp the dynamics/interaction between PWNe(+progenitor SNR) and the surrounding ISM

FUTURE WORK

- Finishing my PhD+2nd paper
- Optimise the diffusion model and look for key features (e.g. spectral index) at all wavelengths which could further constraint the nature of some TeV sources.
- Implement non isotropic diffusion models (see Nava and Gabici 2010)
- Study of the LMC