Carbon Monoxide in Our Galaxy and Galactic Centre: Implications for Understanding Gamma-Ray Emission

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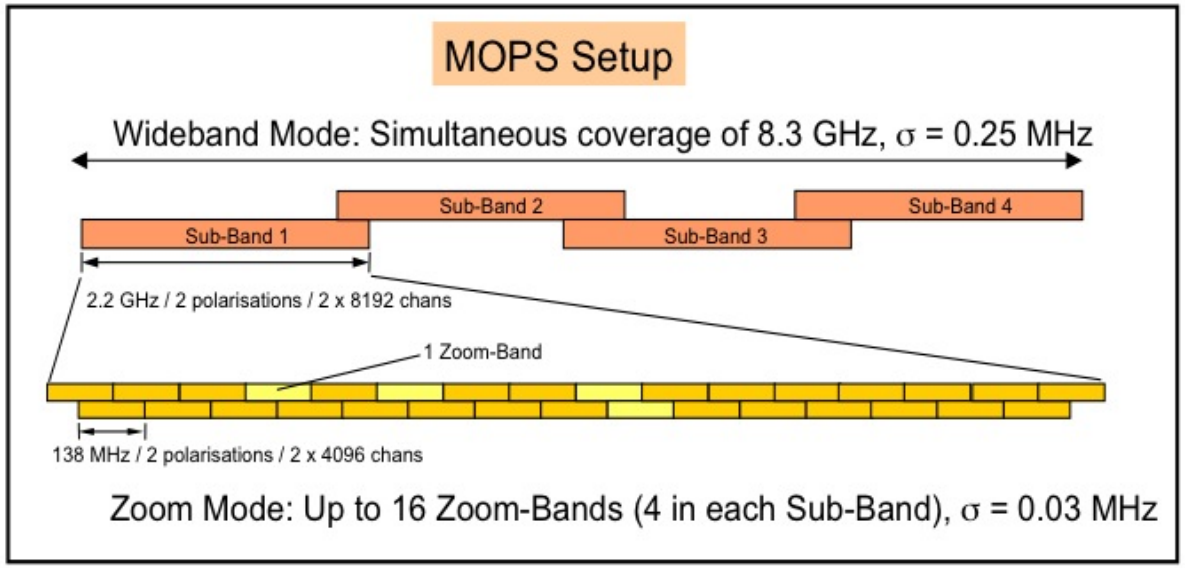
CTA Linkages in Australia: Friday 29$^{\mathrm{th}}$ November 2019

The Mopra Radio Telescope

The Mopra Radio Telescope is a 22m dish located outside of Coonabarabran. It's named for the rock!

It is used for long-wave mm astronomy and also for VLBI. Our group's interest is in molecular lines observable in the 3mm, 7mm, and 12mm bands.



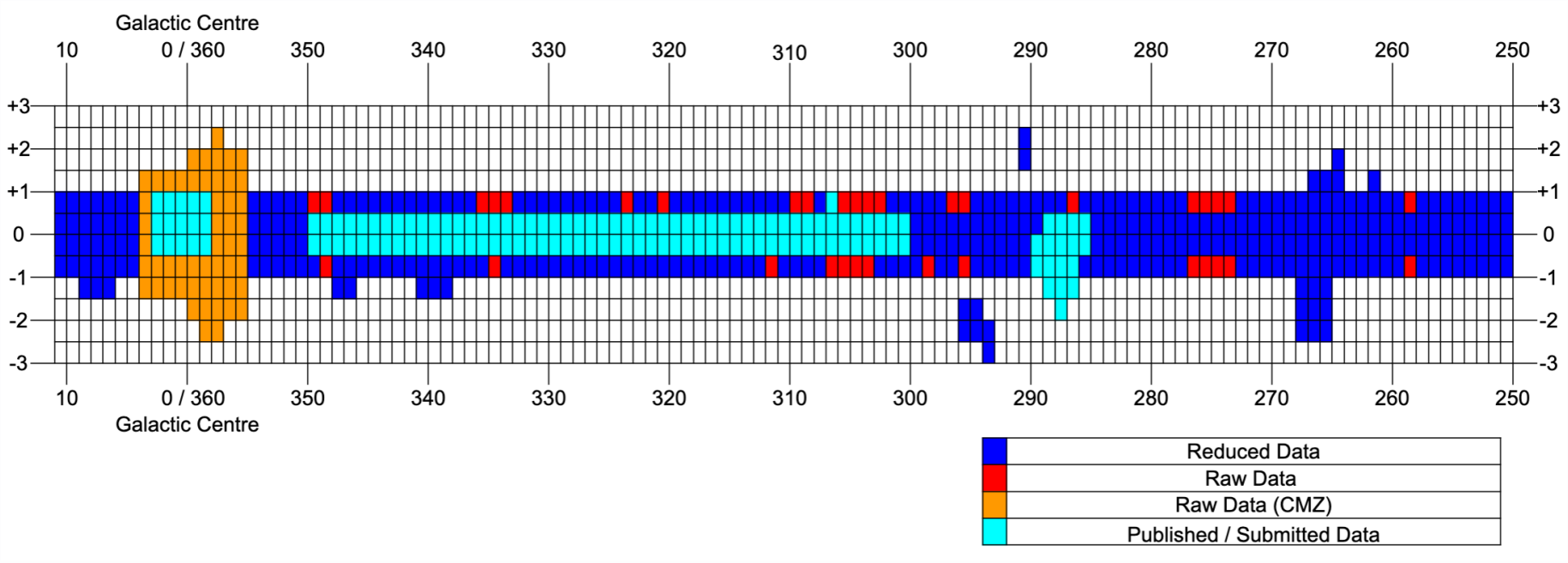
	Wideband Mode		Zoom Mode	
Receiver	Bandwidth	Resolution	Bandwidth	Resolution
12-mm (22GHz)	112 050 km/s	3.38 km/s	1 863 km/s	0.41 km/s
7-mm (44 GHz)	56 025 km/s	1.69 km/s	932 km/s	0.21 km/s
3-mm (90 GHz)	30 378 km/s	0.915 km/s	505 km/s	0.11 km/s

Mopra can observe four lines of CO simultaneously in zoom band mode:

^{12}CO, ^{13}CO, C^{18}O, C^{17}O.

These isotopologues are invaluable, because in many cases the ^{12}CO is optically thick.

Status of the Mopra SGP CO Survey



Publications:

- *The Mopra Southern Galactic Plane CO Survey*, Burton et al. (2013). Pilot region $l = 328^\circ - 329^\circ$

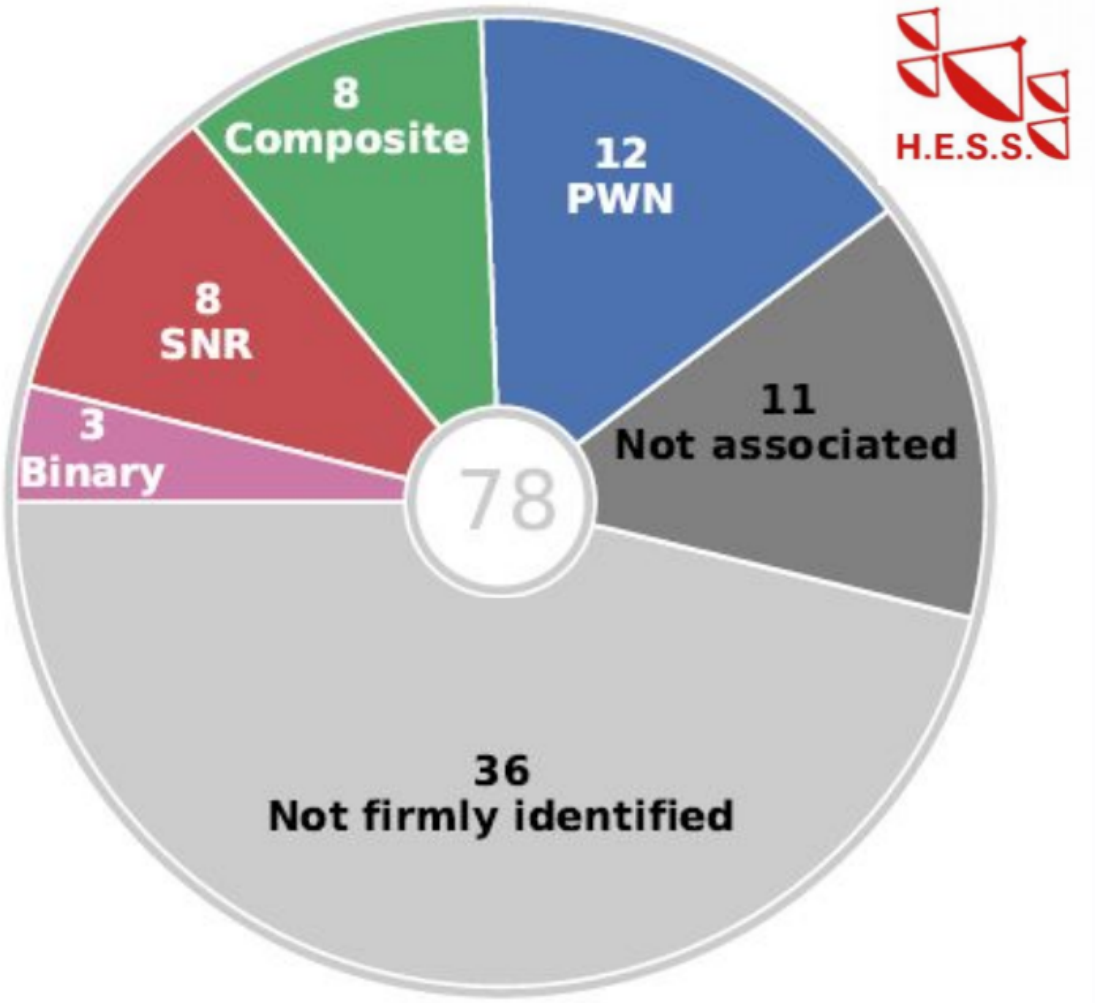
- *The Mopra Southern Galactic Plane CO Survey - Data Release 1*, Braiding et al. (2015). $l = 320^\circ - 330^\circ$

- *The Carina Nebula and Gum 31 molecular complex: I. Molecular gas distribution, column densities and dust temperatures*, Rebolledo et al. (2016). Carina region

- *Mopra Southern Galactic Plane CO Survey - Data Release 3*, Braiding et al. (2018). $l = 300^\circ - 350^\circ$

- *The Mopra Central Molecular Zone Carbon Monoxide Isotopologue Survey. I: Techniques and First Results*, Blackwell et al. (*under revision*) = Galactic Centre region

HESS Sources: Leptonic or Hadronic?



Multiwavelength analysis can provide additional support for or limitations on different origin scenarios. Here we examine a few TeV gamma-ray sources together with Mopra CO data:

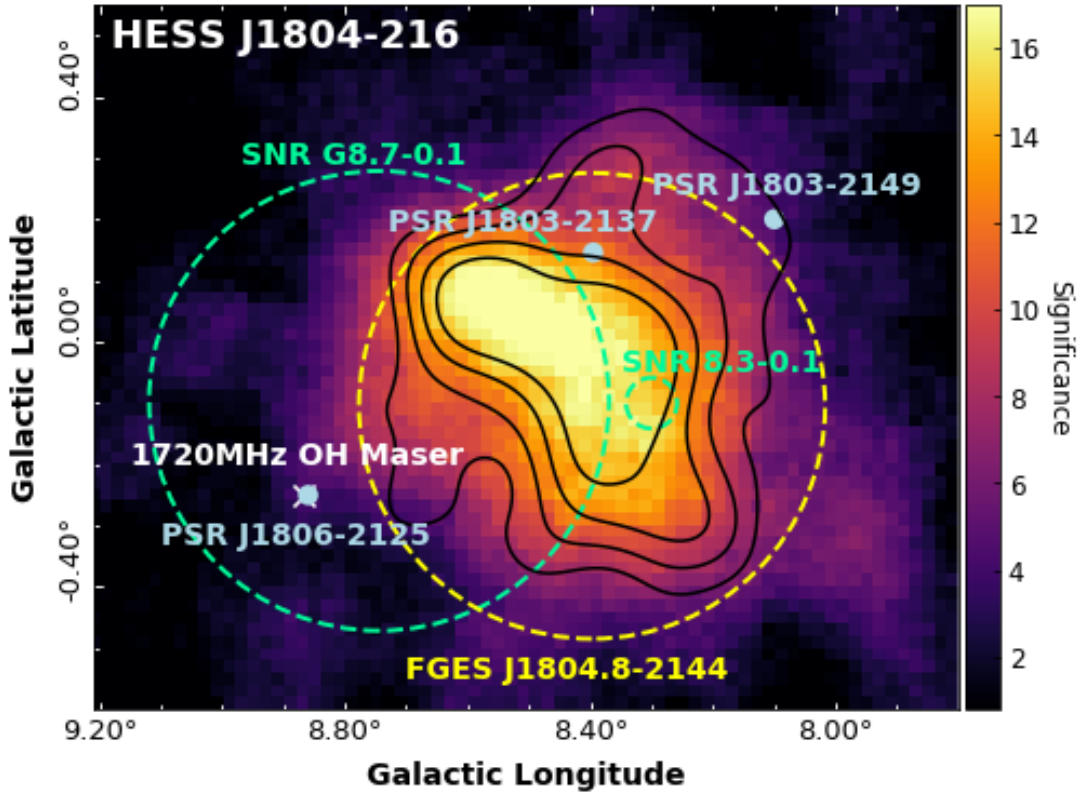
- HESS J1804–216
- RX J1713.7–3946
- SNR G1.9+0.3*
- HESS Diffuse Galactic Ridge
- HESS J1741–302

* No gamma-rays have been observed from this region yet, but it is the youngest SNR in the galaxy

HESS J1804-216

- HESS J1804-216 is one of the most mysterious and brightest TeV gamma-ray sources discovered
  - TeV gamma-ray luminosity of $L_\gamma = 5 \times 10^{33} (d/\mathrm{kpc})^2$ erg s^{-1}
- FGES J1804.8-2144 is the GeV Fermi counterpart to HESS J1804-216
- **SNR G8.7-0.1**
  - Age: 15 kyr
  - Distance: 4.5 kpc
- **1720MHZ OH Maser** confirms there is an SNR shock interacting with the gas
  - Distance: 4.6 kpc
- **SNR 8.3-0.1**
  - Distance: 16.3 kpc
- **PSR J1803-2137** is born outside SNR G8.7-0.1

  → No connection between the two



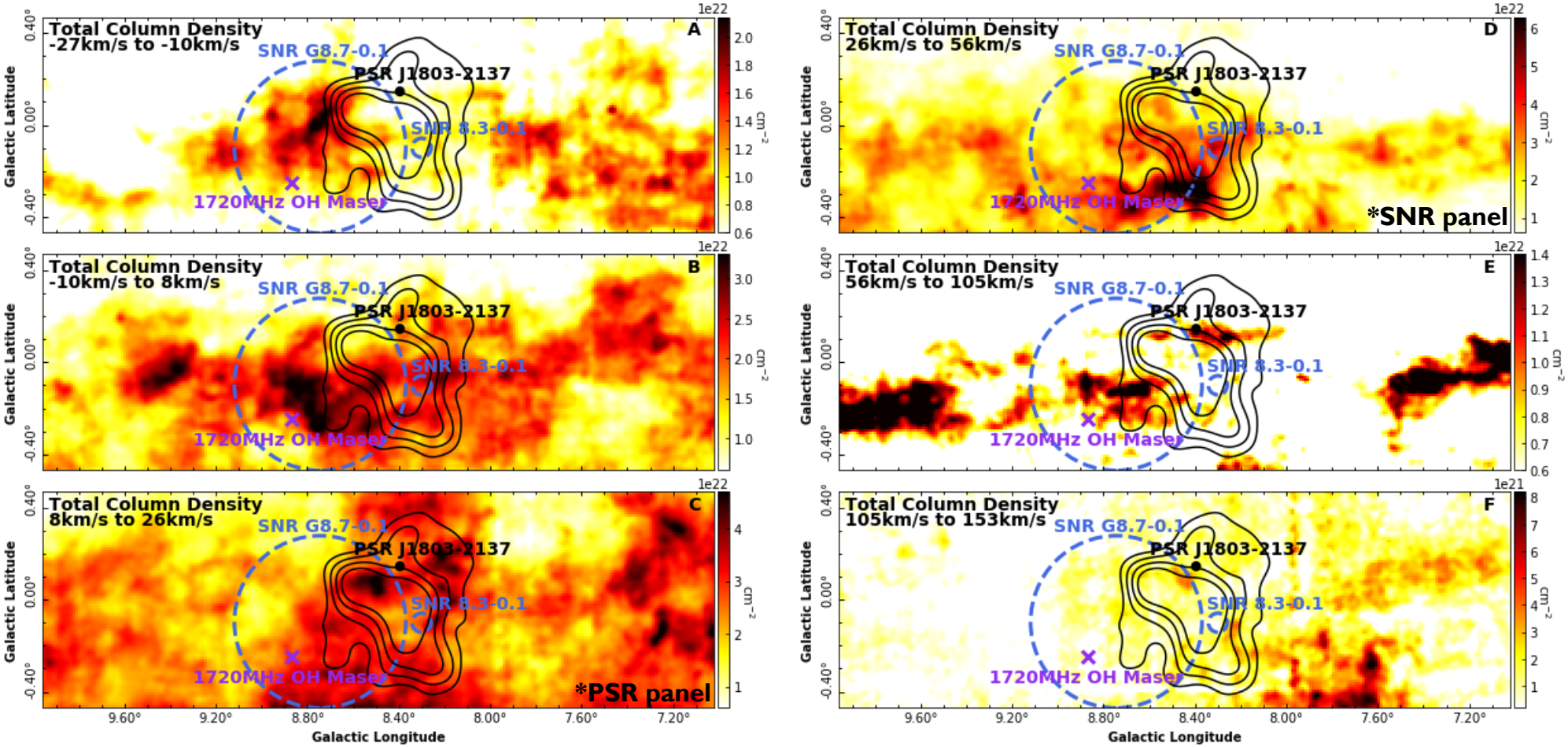
PSR	J1803-2137	J1803-2149	J1806-2125
Distance (kpc)	3.8	1.3	10
Age (kyr)	15.8	86.4	65
Spin down power, $\dot{E}$ (10^{35} erg s^{-1})	22.2	6.41	0.41
TeV gamma-ray efficiency ($L_\gamma/\dot{E}$)	3%	1%	120% (too high)

Total column density maps

$$N(H) = N(HI) + 2N(H_2)$$

Column density of HI

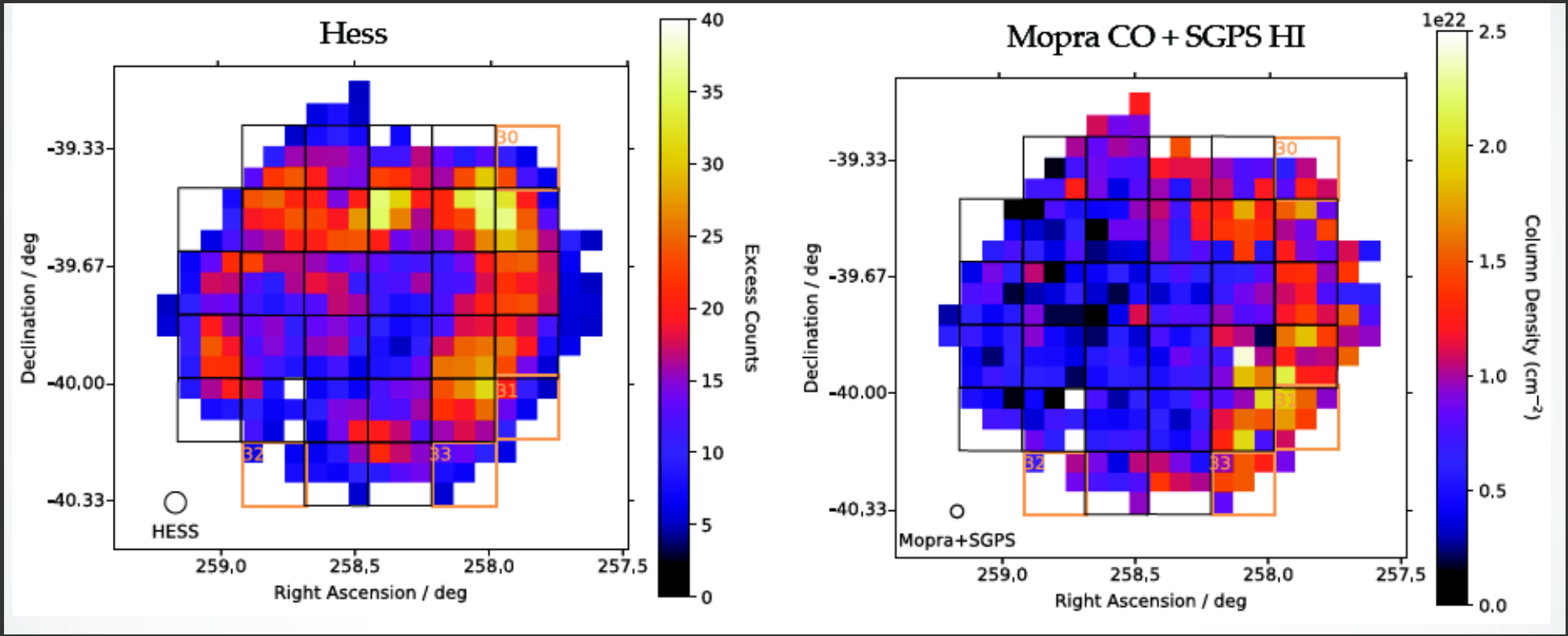
Column density of CO



** HI data from the Southern Galactic Plane Survey, CO data from the Mopra Survey

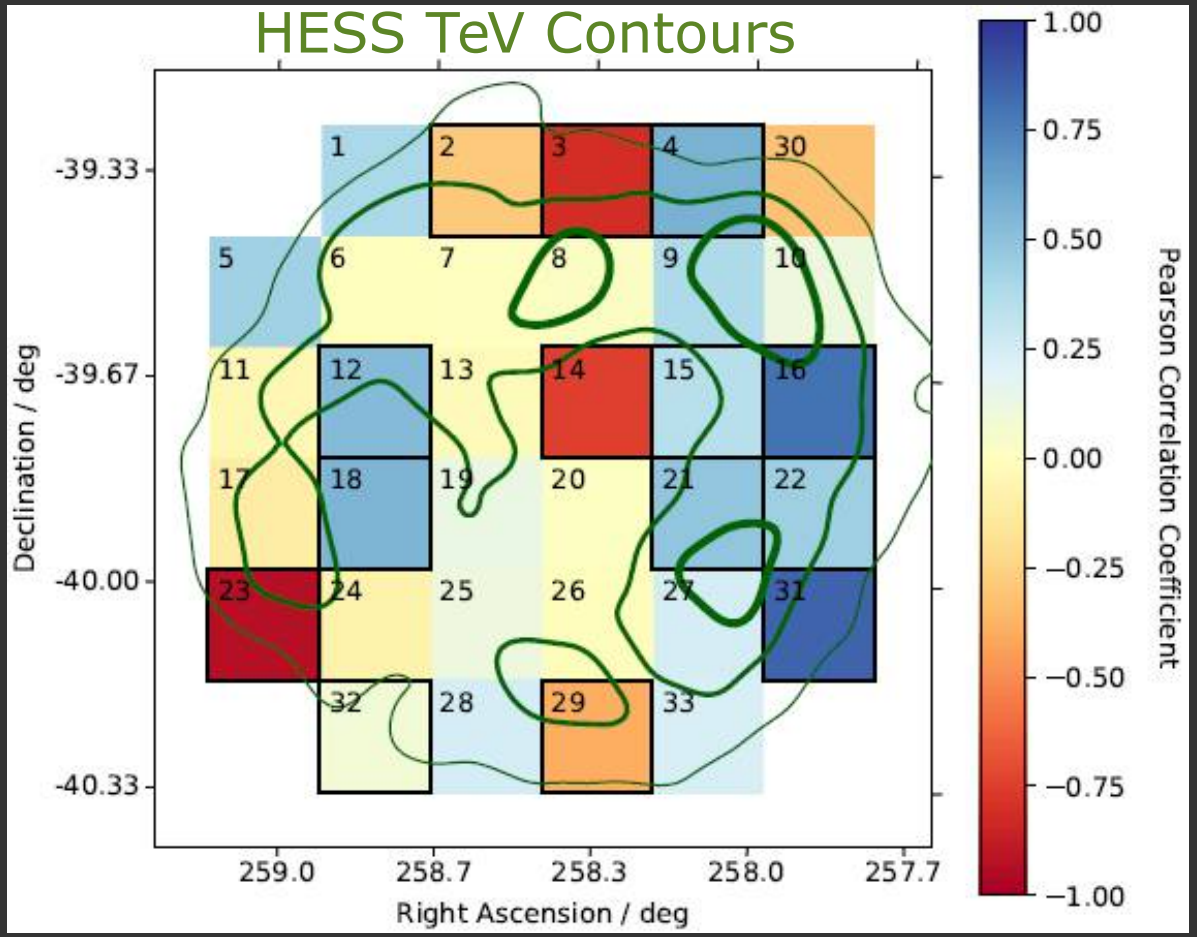
RXJ1713

Re-binning ISM Gas Data to HESS Resolution



- Each of the 29 regions from Tanaka et al. 2008
- (+ 4 more with sufficient pixels)
- Pixel size is 3.6’ by 3.6’
- Removed pixels with gamma excess counts < 5
- Each region has up to 9 pixels

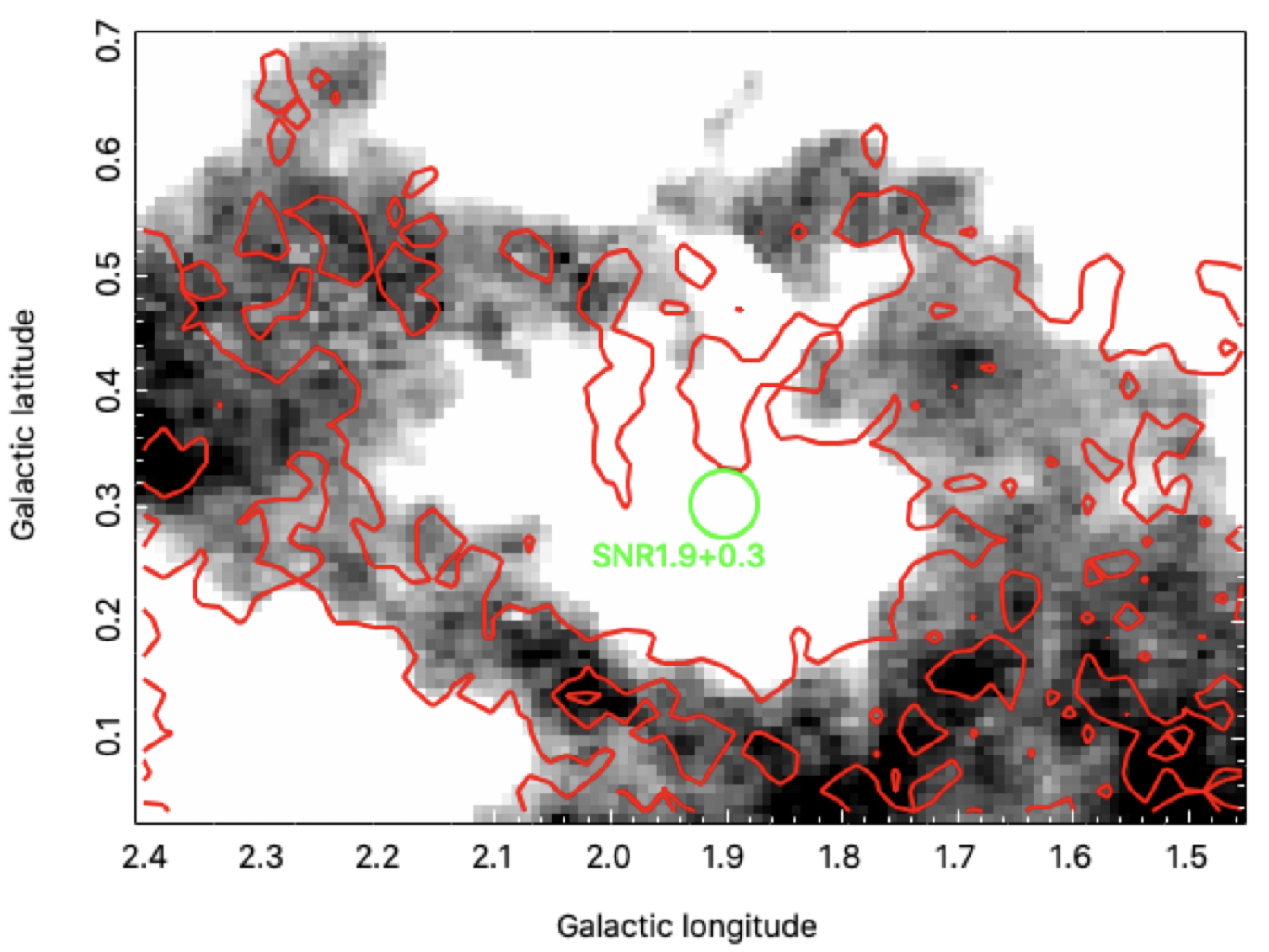
2D Map of Correlation Coe cients vs TeV



TeV/ISM

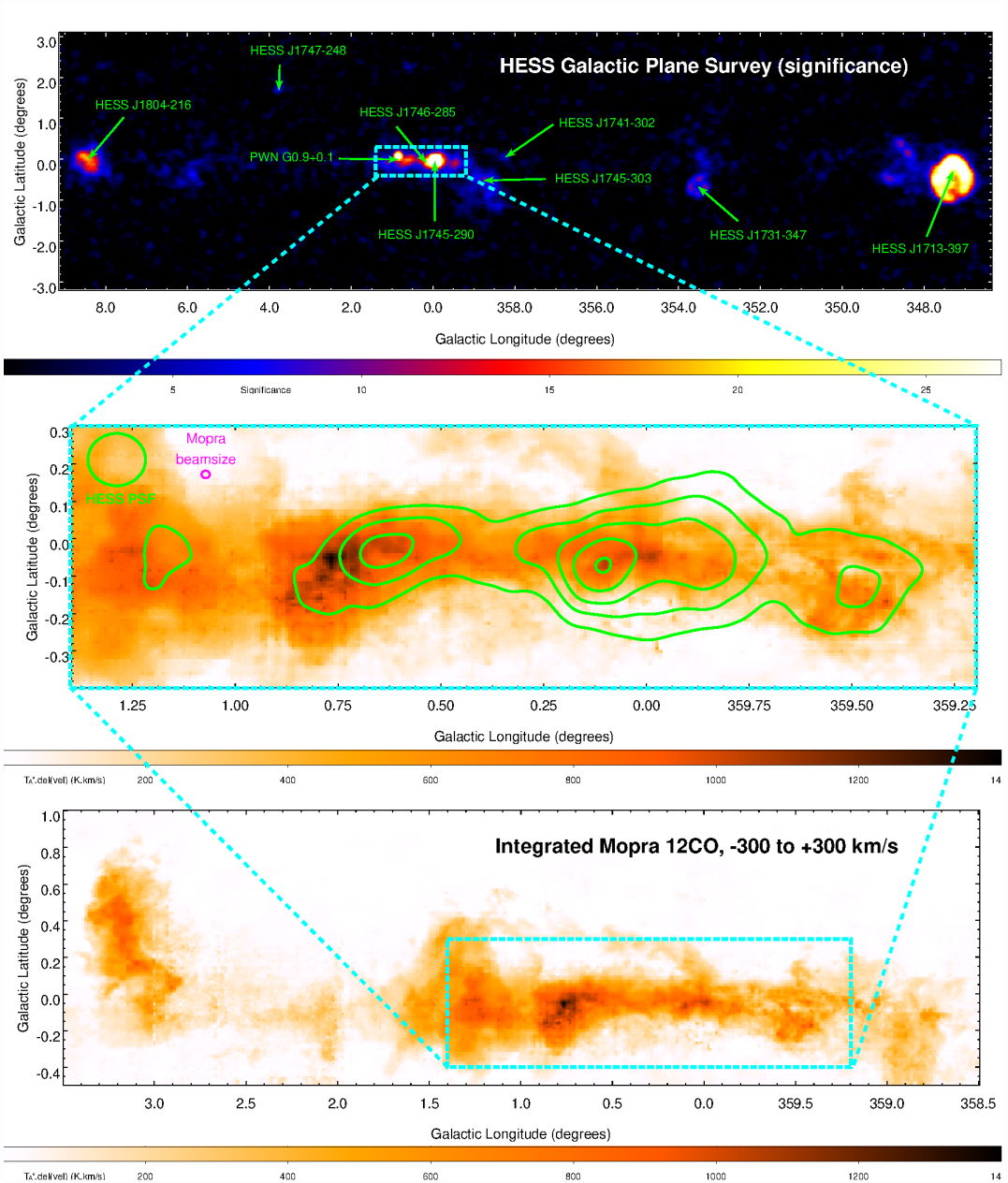
Anti-correlated Correlated

SNR G1.9+0.3



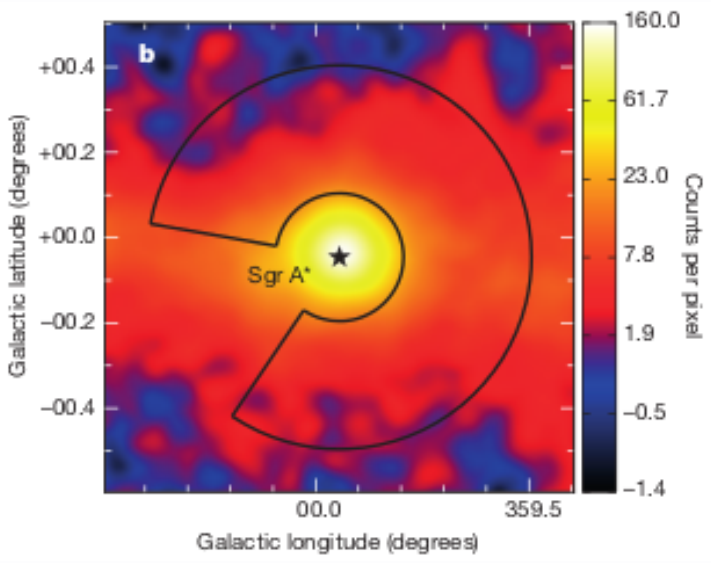
^{12}CO integrated between -55 km/s and -40 km/s, thresholded at 1.3σ to focus on the ring-like feature around the SNR. ^{13}CO contours for the same velocity range (thresholded at 0.9σ for the same reason) are overlaid in red. The green circle is the current diameter of the SNR.

Towards the Galactic Centre

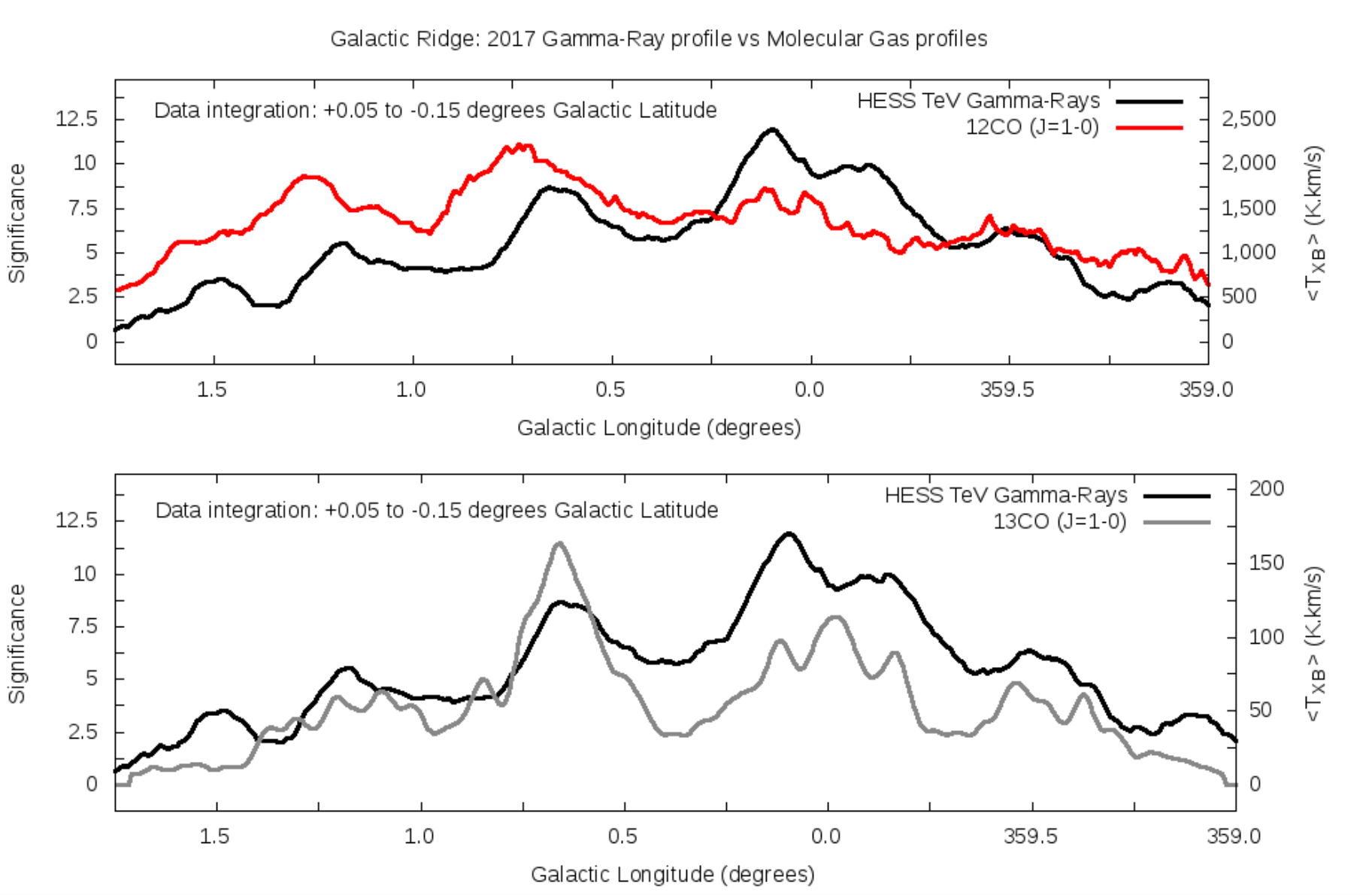


Galactic Centre TeV Sources:

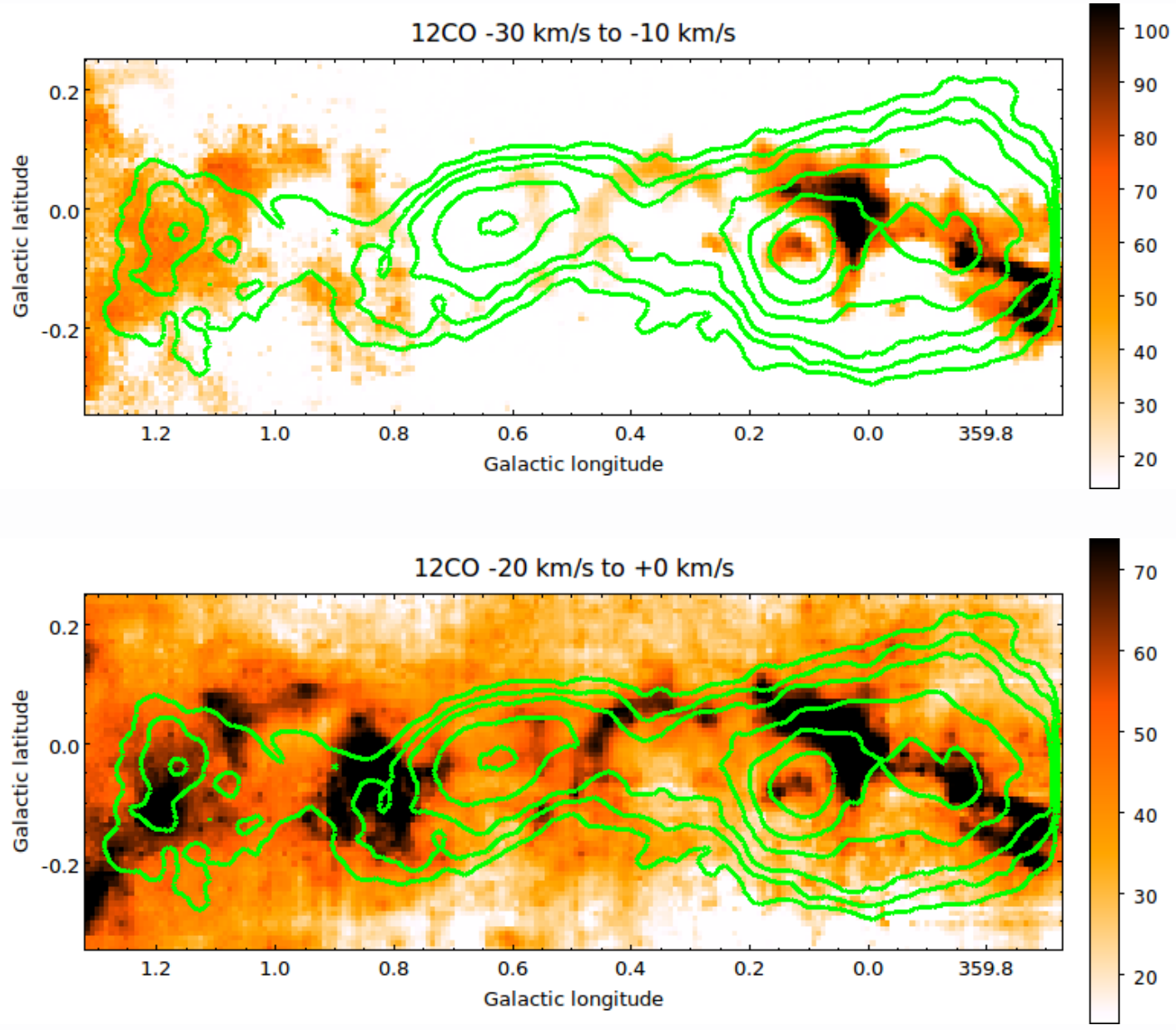
- HESS J1745–290
  Sgr A* or SNR Sgr A East?
- PWN G0.9+0.1
- HESS J1745–285
  The "Arc Source"
- HESS Diffuse Galactic Ridge
- HESS J1741–302
- The HESS GC PeVatron



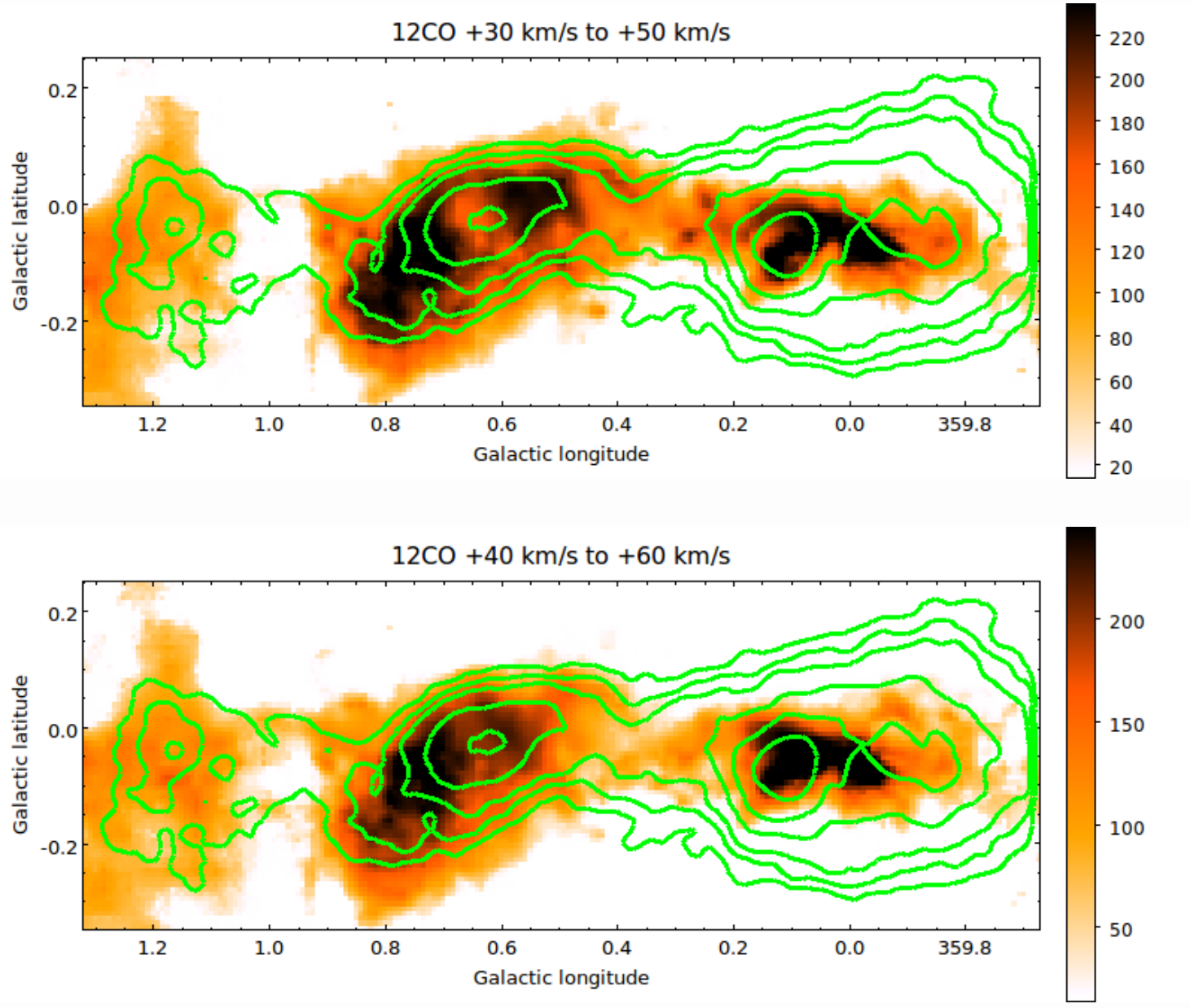
The HESS Diffuse Galactic Ridge



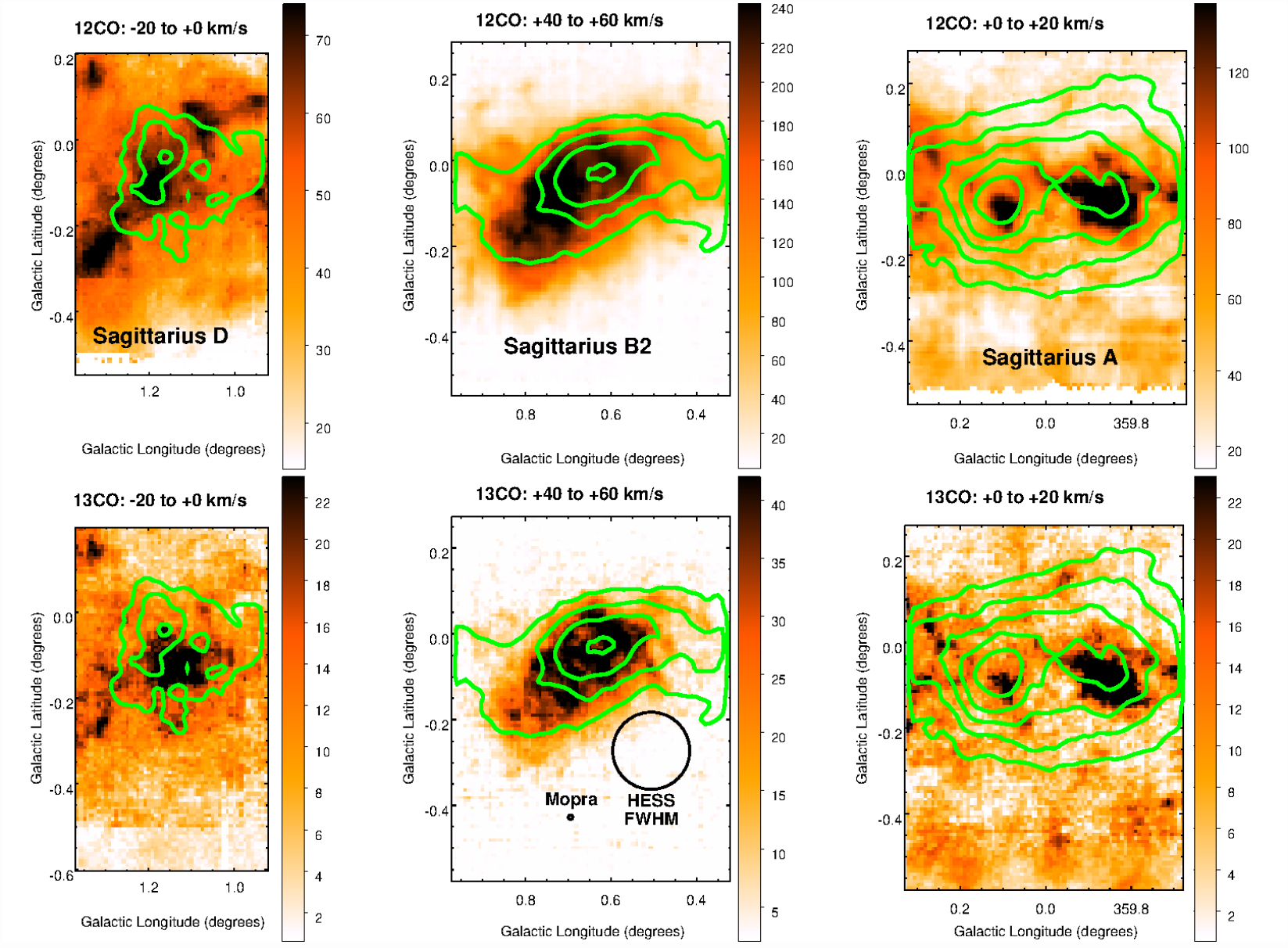
The HESS Diffuse Galactic Ridge



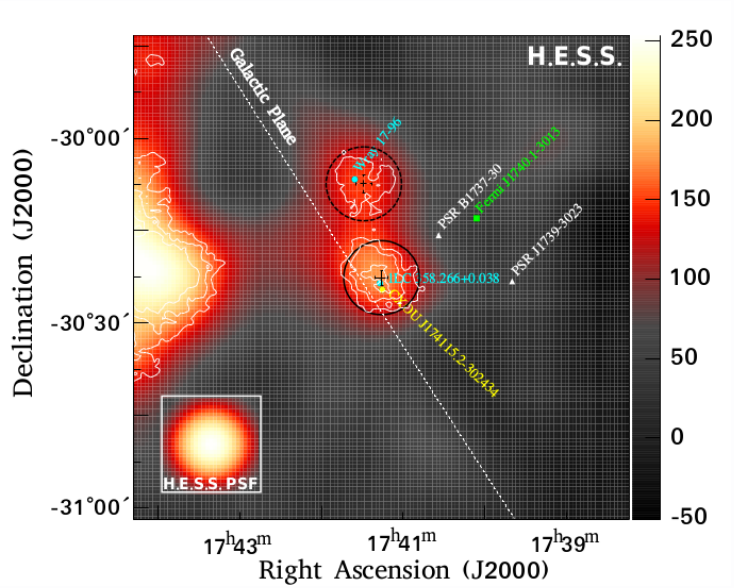
The HESS Diffuse Galactic Ridge

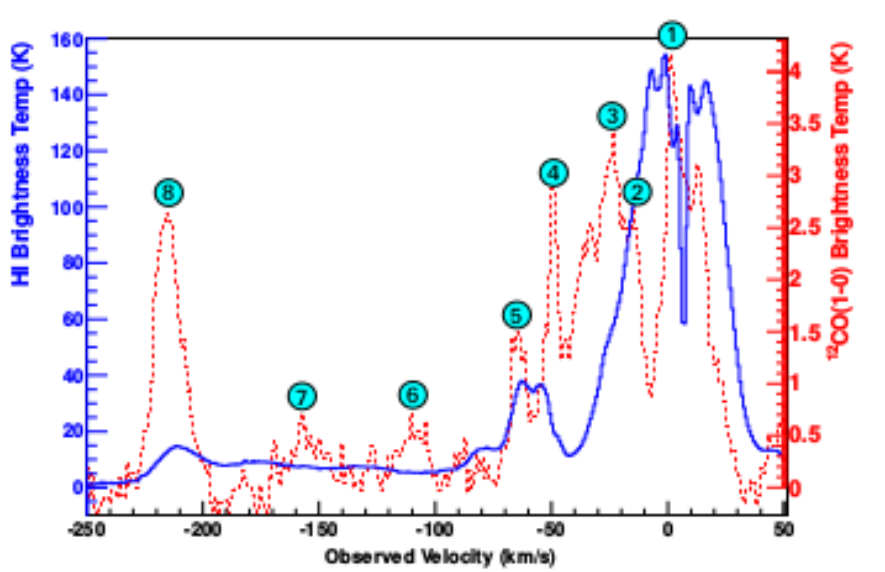


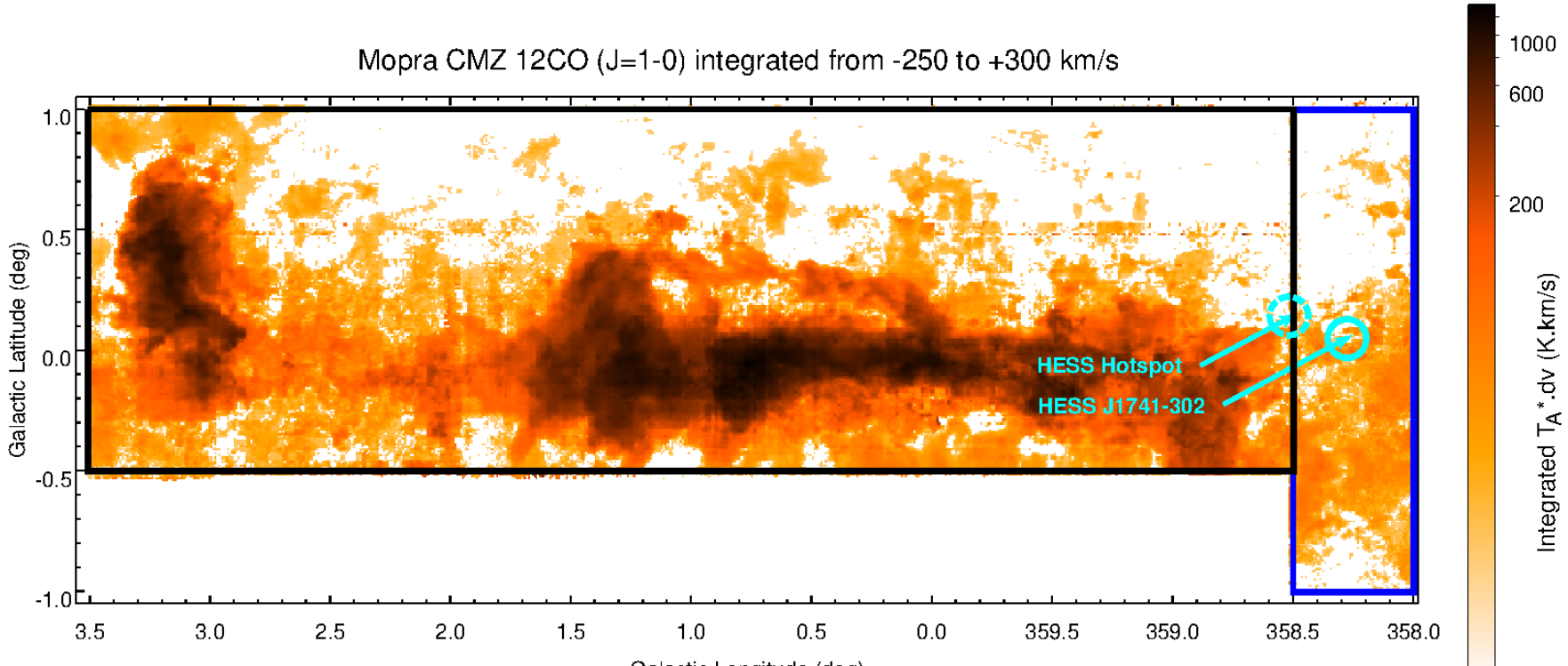
The HESS Diffuse Galactic Ridge



HESS J1741–302







HESS J1741–302

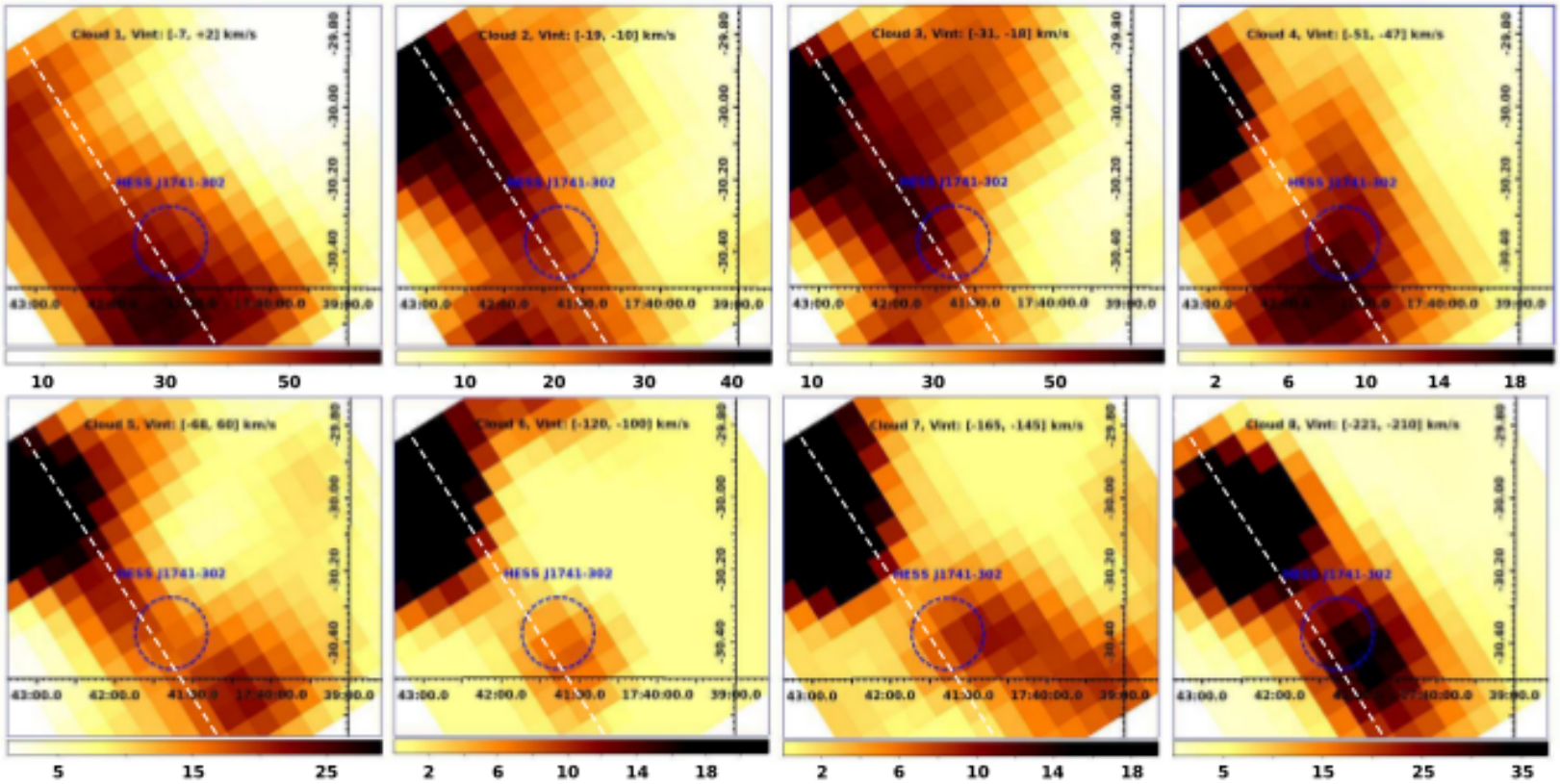
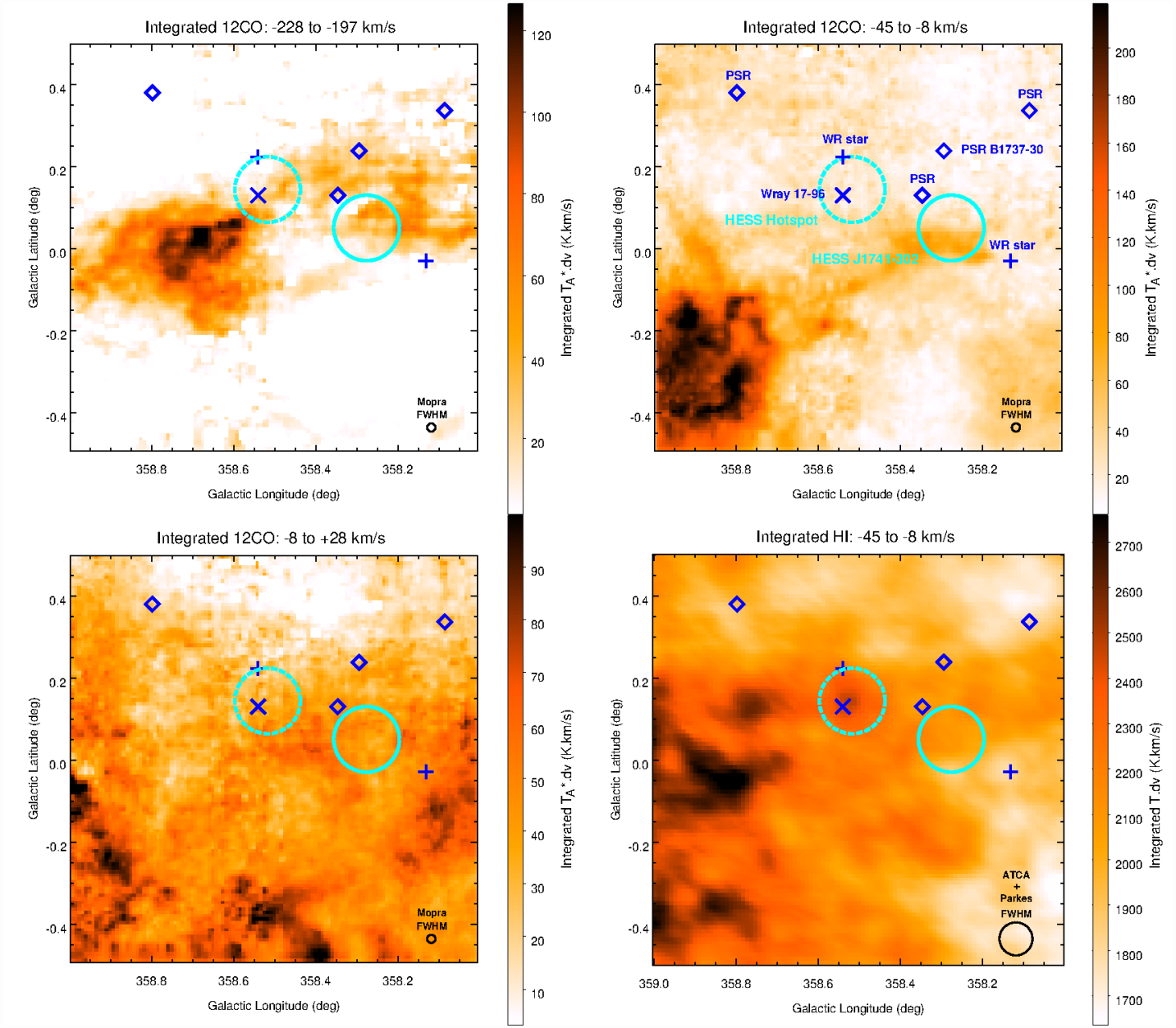


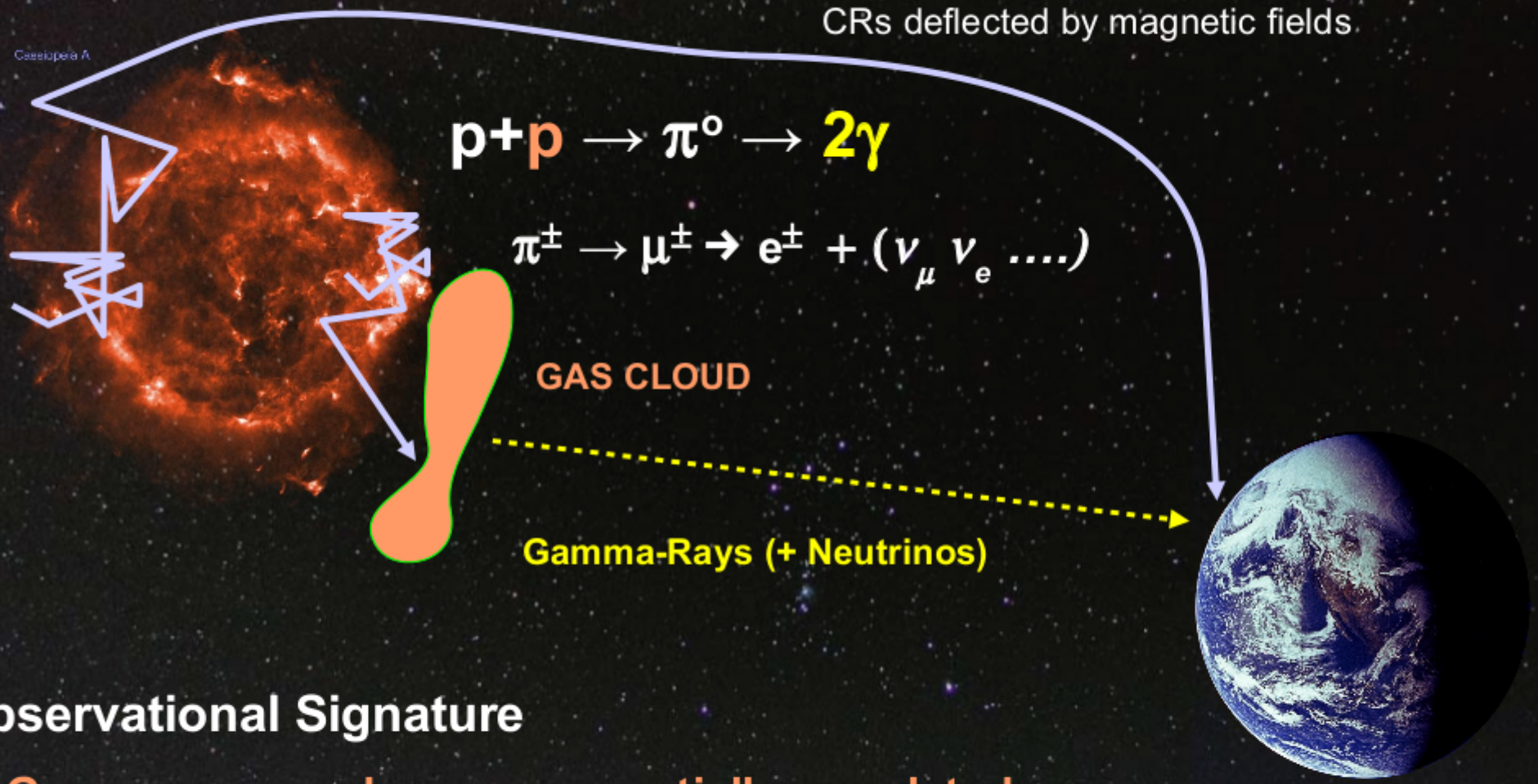
Fig. 4. Integrated ^{12}CO column density maps of the region around HESS J1741−302 for each cloud as labelled in Fig. 3. Velocity integration intervals used for producing the corresponding column density map is given for each cloud. The dashed blue circles show the HESS J1741−302 region which is marked with a dashed black circle in Fig. 1 while the white dashed line indicates the orientation of the Galactic plane. The color scale is in the units of 10^{20} cm^{-2}.

HESS J1741–302




Thank you...
http://www.physics.adelaide.edu.au/astrophysics/MopraGam/
(c) F. Acero & H. Gast

Gamma Rays from multi-TeV Cosmic-Rays (p, He ...etc)



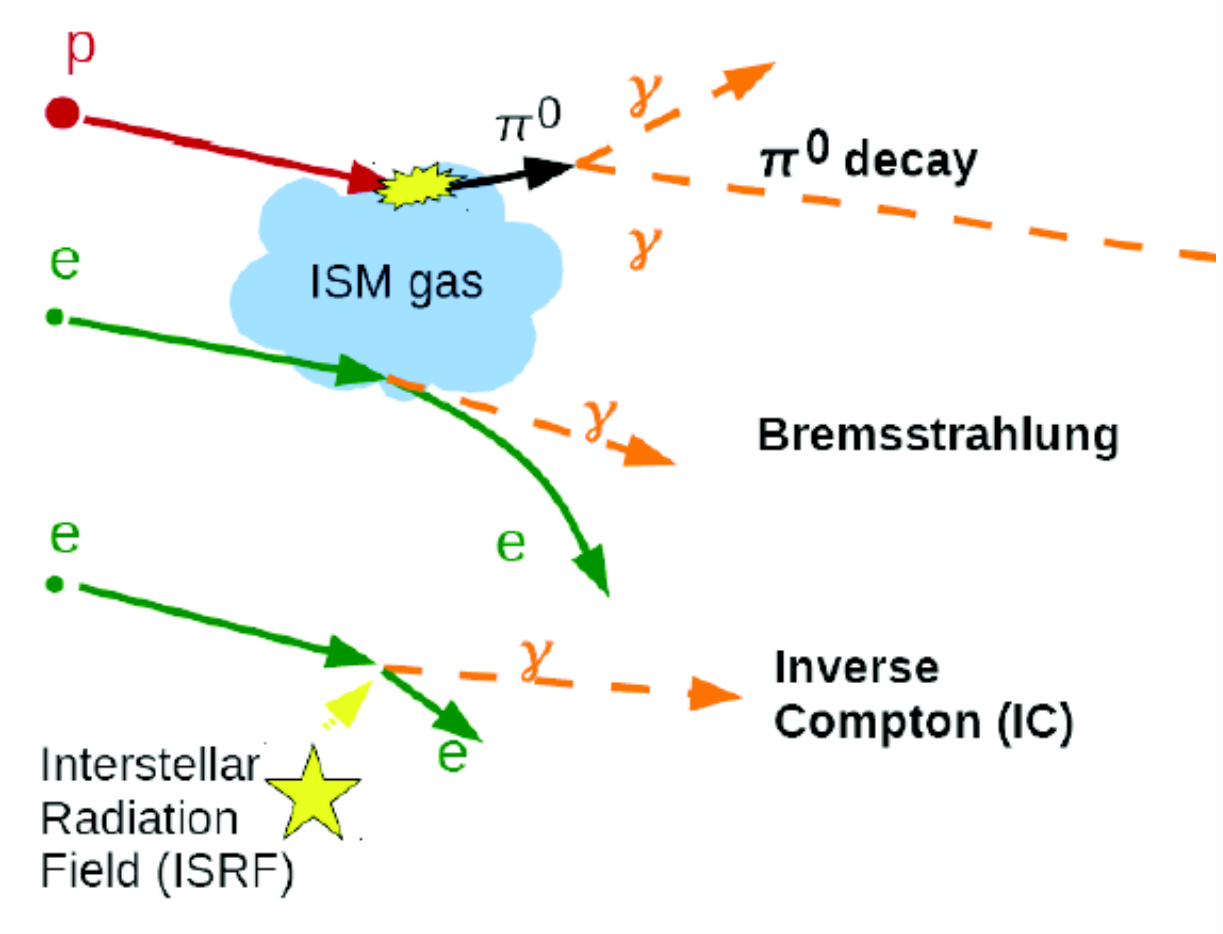
Observational Signature

→ Gamma-rays and gas are ~ spatially correlated
(need to measure gas in all chemical states)

→ Intimate connection with mm-radio astronomy (tracing gas)

→ Expected gamma-ray flux F_γ ~ (cosmic-ray density) x (gas mass) / (distance)^2

The Origin of H.E.S.S. Sources



Hadronic

Leptonic

Leptonic