The Gas Survey of HESS J1614-518 and HESS J1616-508 using the Mopra Telescope

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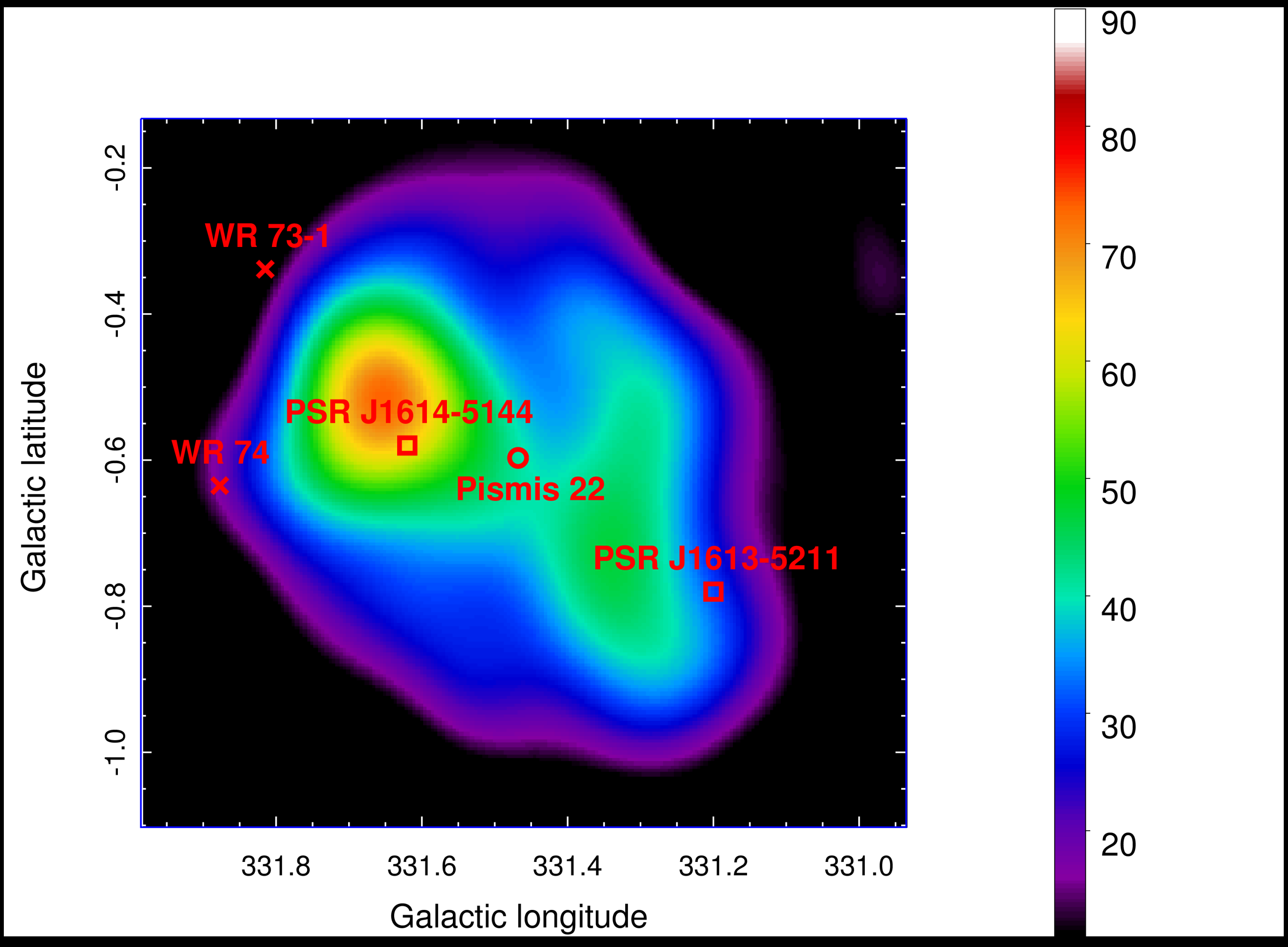
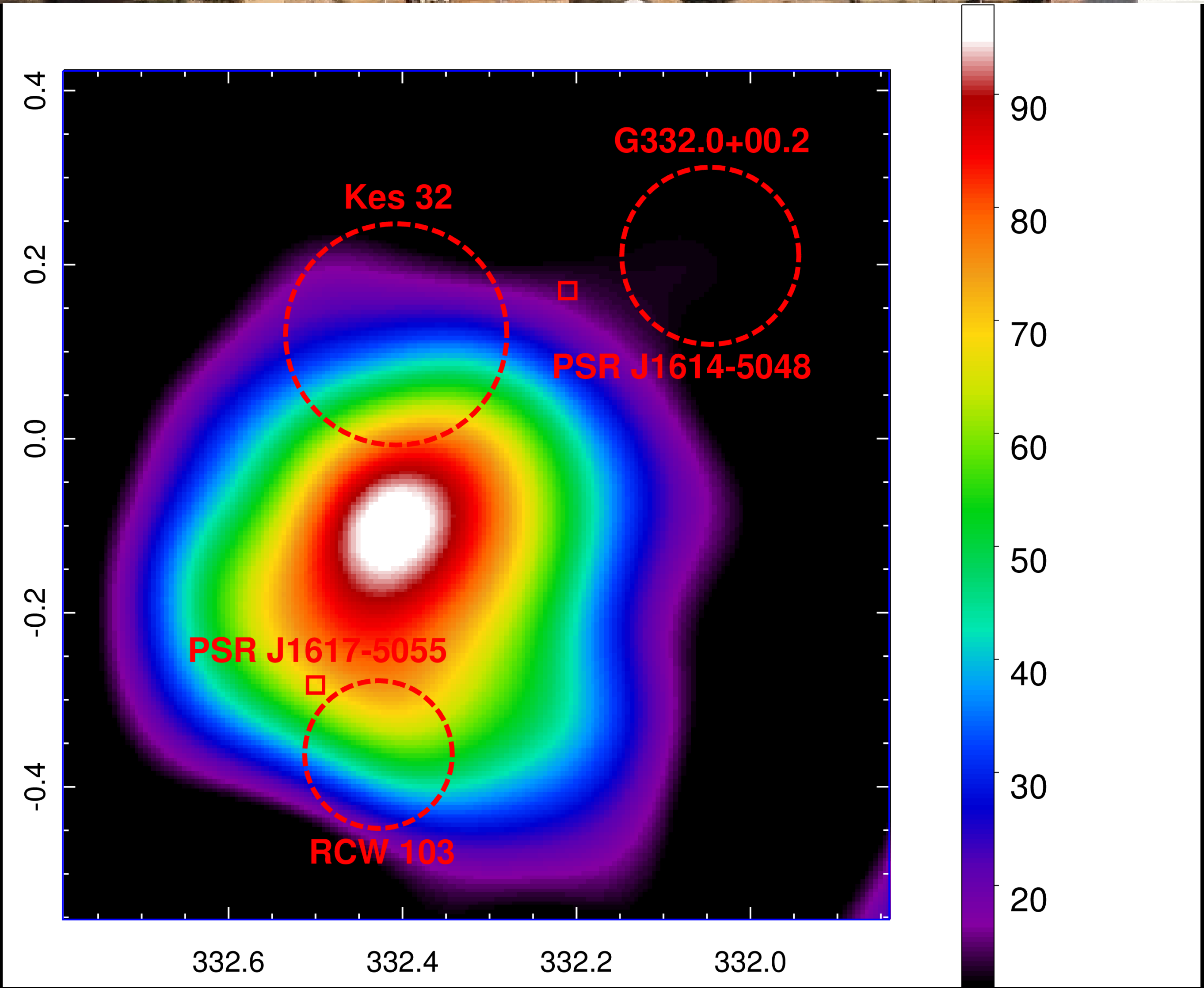
HESS J1614-518



HESS J1616-508



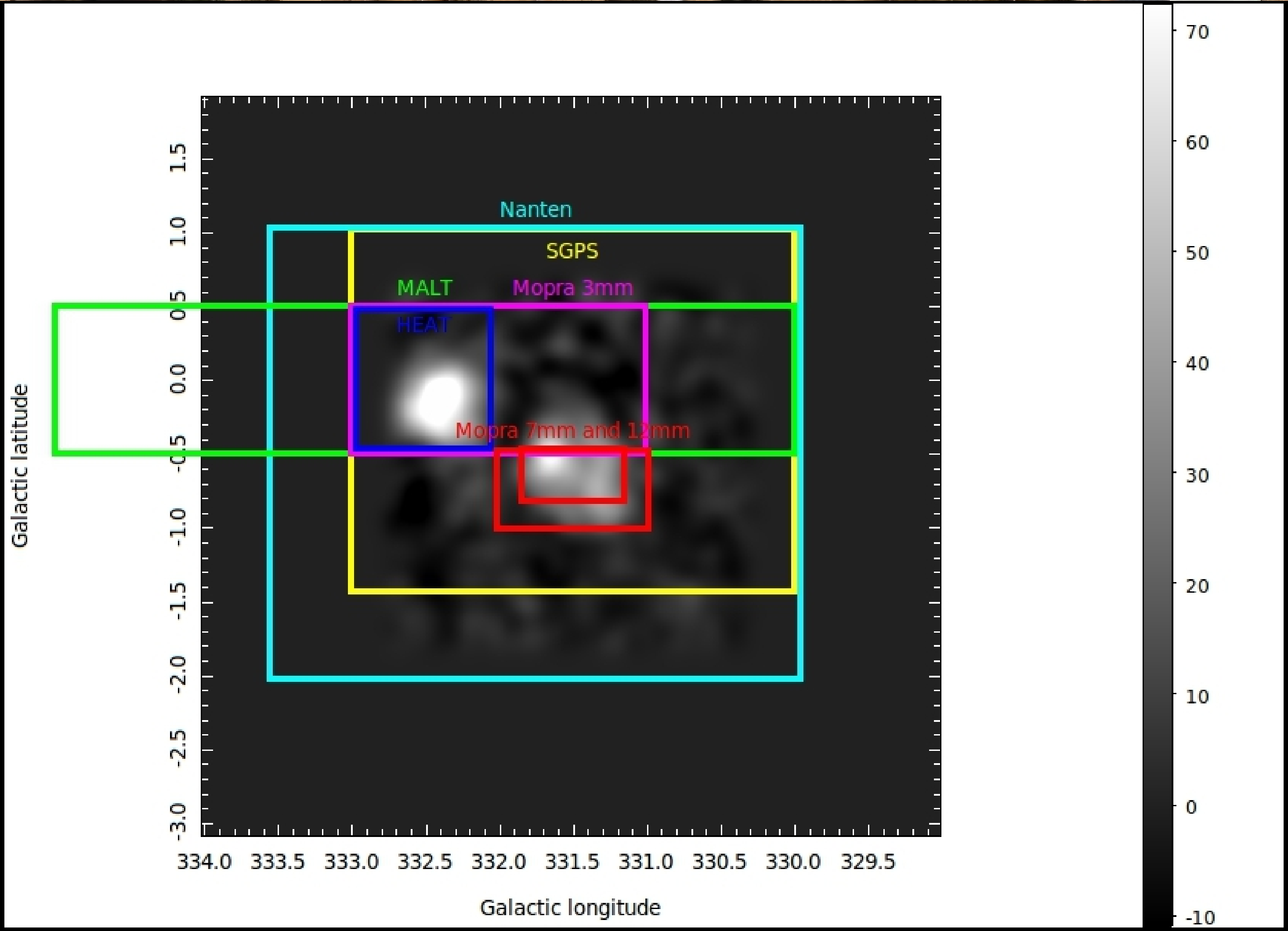
Gamma-rays and Molecular Gas

- Cosmic rays and electrons are accelerated at sites such as:
  - Supernova Remnants
  - Pulsar wind Nebulae
  - Wolf-Rayet Stars
  - Stellar Clusters

- Accelerated particles can encounter magnetic fields, photons or matter

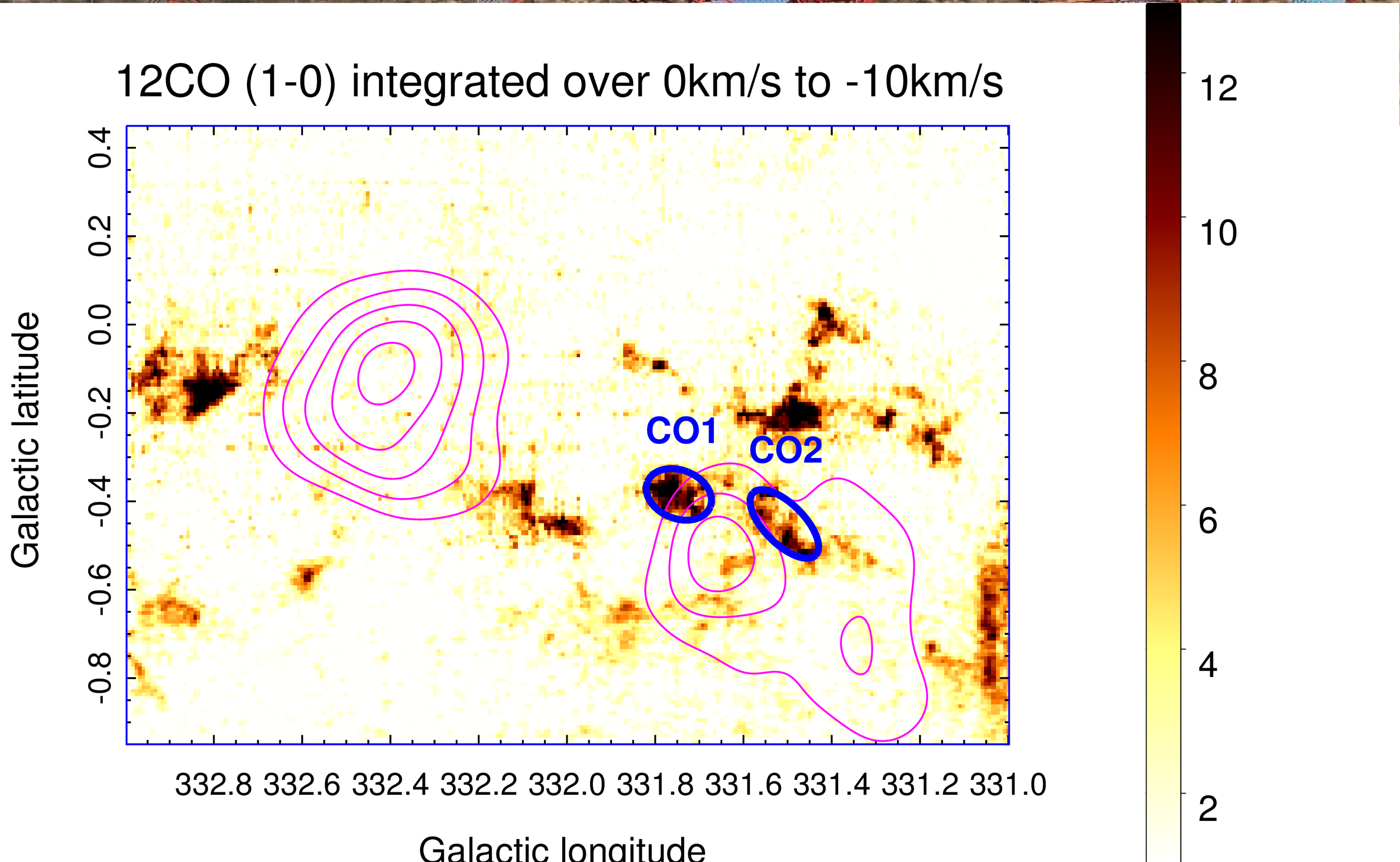
- Cosmic-ray interactions with ISM can lead to bight gamma-ray emission with a steep spectrum

Gas Surveys

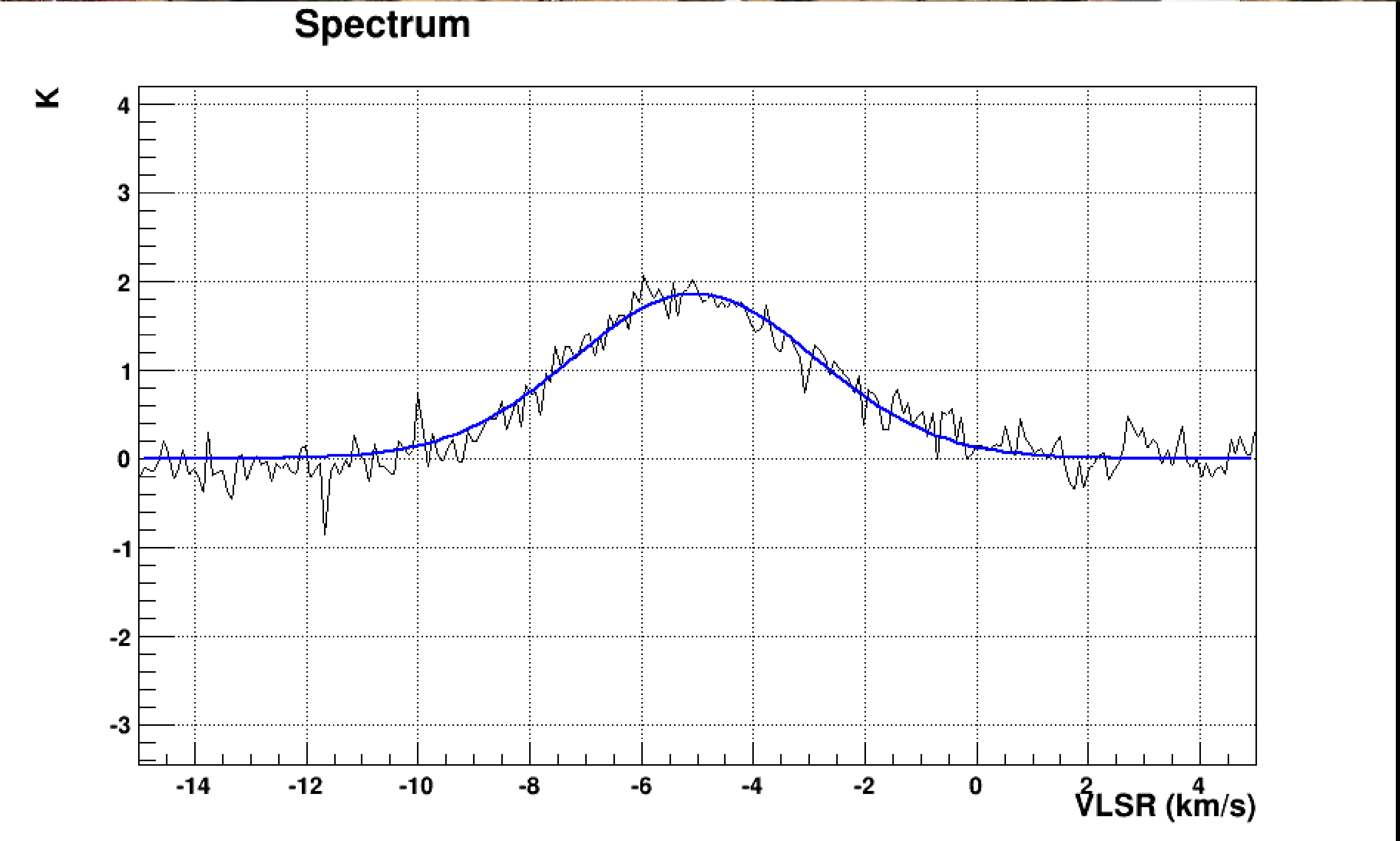


Nanten
SGPS
MALT
Mopra 3mm
HEAT
Mopra 7mm and 12mm
Galactic latitude
Galactic longitude
334.0 333.5 333.0 332.5 332.0 331.5 331.0 330.5 330.0 329.5
1.5 1.0 0.5 0.0 -0.5 -1.0 -1.5 -2.0 -2.5 -3.0
70 60 50 40 30 20 10 0 -10

CO Region Selection



CO Line Fitting



Gas Parameters

RoI	$\bar{T}_A^*$	err $\bar{T}_A^*$	N_{H_2}	err N_{H_2}	M	err M	ρ	err ρ
CO1	19.3	3.7	2.9×10^{21}	5.5×10^{20}	23.4	0.4	7258.0	138.8
CO2	18.0	2.4	2.7×10^{21}	3.6×10^{20}	43.3	0.6	6051.5	81.5
CO3	4.3	3.7	6.5×10^{20}	5.6×10^{20}	253.0	21.8	214.6	18.5
CO4	34.0	3.2	5.1×10^{21}	4.9×10^{20}	690.9	6.6	3690.1	35.1
CO5	52.0	11.7	7.8×10^{21}	1.7×10^{21}	62868.5	141.1	550.4	1.2
CO6	36.3	7.8	5.4×10^{21}	1.2×10^{21}	54752.7	118.1	424.5	0.9
CO7	52.2	11.0	7.8×10^{21}	1.7×10^{21}	46359.4	97.9	758.9	1.6
CO8	12.8	3.6	1.9×10^{21}	5.5×10^{20}	5381.4	153.2	393.8	11.2
CO9	92.4	7.7	1.4×10^{22}	1.1×10^{21}	20420.6	16.9	2673.4	2.2
CO10	16.2	3.1	2.4×10^{21}	4.6×10^{20}	10263.5	195.1	270.0	5.1
CO11	124.3	5.0	1.9×10^{22}	7.4×10^{20}	73711.5	294.6	3014.9	12.0
CO12	91.0	11.1	1.4×10^{22}	1.7×10^{21}	27814.0	34.0	2180.9	2.7
CO13	52.6	13.5	7.9×10^{21}	2.0×10^{21}	8891.1	22.9	1845.5	4.8
CO14	27.1	6.5	4.1×10^{21}	9.8×10^{20}	2946.4	70.9	1216.5	29.3
CO15	39.8	9.1	6.0×10^{21}	1.4×10^{21}	6428.6	14.7	1403.8	3.2
CO16	7.1	4.1	1.1×10^{21}	6.1×10^{20}	24498.3	1413.9	55.3	3.2
CO17	90.0	13.9	1.4×10^{22}	2.1×10^{21}	17757.6	27.4	3183.8	4.9
CO18	22.8	8.2	3.4×10^{21}	1.2×10^{21}	16341.5	58.9	300.1	1.1
CO19	41.0	9.2	6.1×10^{21}	1.4×10^{21}	37677.5	84.9	592.5	1.3

Table 4.7: The gas parameters calculated for RoI CO1 to CO19. The average telescope beam temperature, $\bar{T}_A^*$, in Kelvin, the column density N_{H_2}, in cm^{-2}, the mass, M, in solar masses and the density, ρ, in H_2 per cm^{-3} are presented with their statistical errors.

Modelling the Gamma-ray flux

- We need to relate the ISM and cosmic rays in order to suggest that the gamma-rays are produced from hardonic origin
- Cosmic rays can produce pions in collisions with the ISM
- Neutral pions decay into two gamma-rays
- Using knowledge of the amount of gas in the regions, we can estimate the cosmic-ray flux required to produce the gamma-ray flux

The Kelner Model

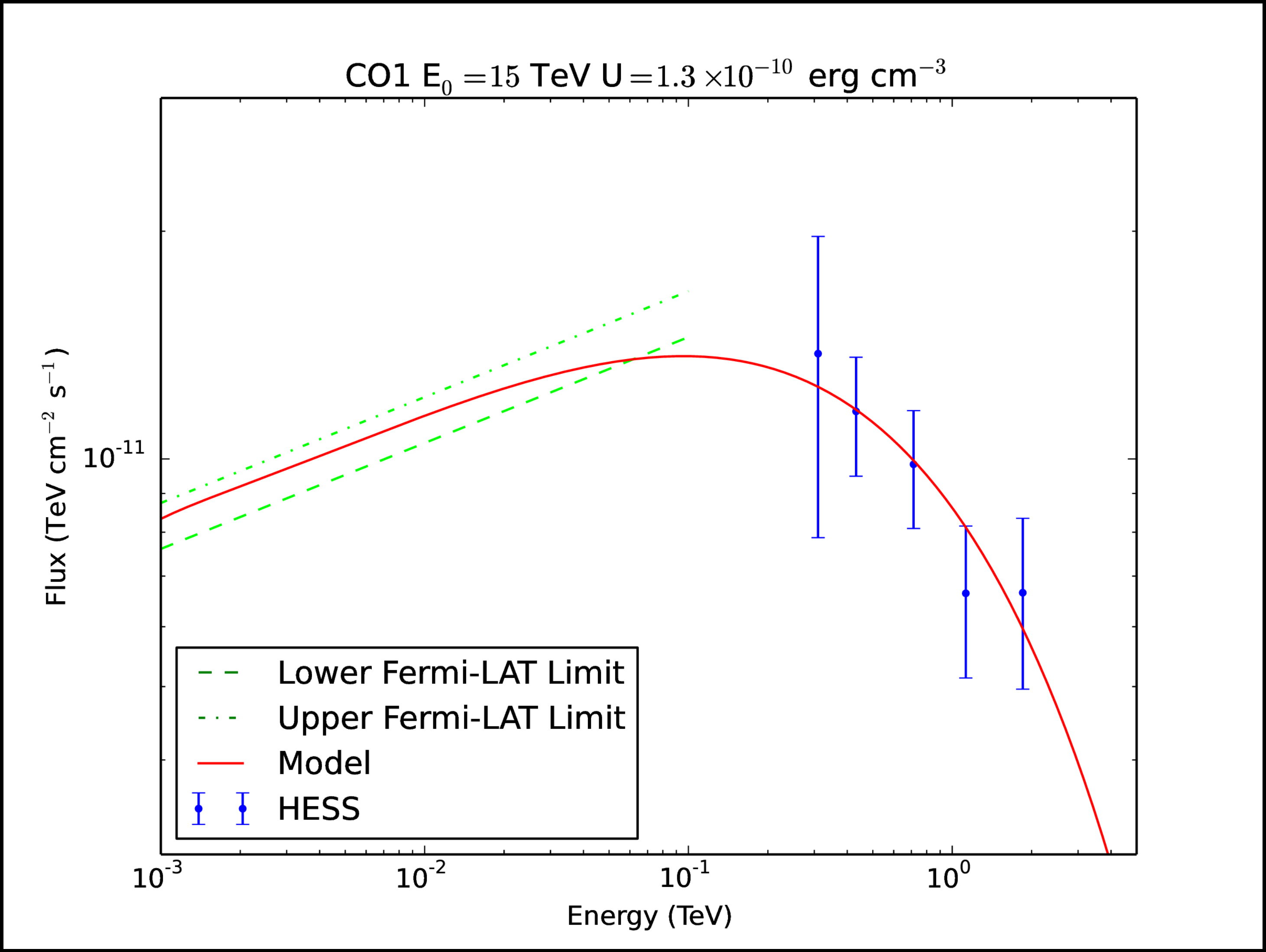
- CR spectrum parameterisation

$$J_P(E_P) = A E_p^{-\alpha} \exp\left[-\left(\frac{E_p}{E_{max}}\right)^{\beta}\right]$$

- Set constant A using the following normalisation

$$\int_{1\mathrm{TeV}}^{\infty} E_p J_p(E_p)\, dE_p = U \ \mathrm{erg\ cm^{-3}}$$

Fitting the CO regions



Diffusion of CRs

- The distance that particles can diffuse over a certain time period is:

$$d = \sqrt{6Dt}$$

- Where the diffusion coefficient given by

$$D(E_P, B) = \chi D_0 \left(\frac{E_{max}/GeV}{B/3\mu G} \right)^{0.5} \ \mathrm{cm}^2\ \mathrm{s}^{-1}$$

- Thus, we can calculate the upper limit on the CR diffusion distance from each potential accelerator. Clouds within that distance can then have their required CR flux compared to the fractional flux available assuming a typical SNR energy budget.

Conclusions and Future Work

- Only ROI CO1, CO2 and CO25 had a reasonable required CR energy budget and were within the maximum diffusion radius form a potential accelerator.
- CO1 and CO2 were within the velocity range of Pismis 22
- CO25 was within the velocity range of WR 74
- All HESS J1616-508 potential accelerators were excluded from generating gamma-rays from a hadronic origin
- Future work:
  - Improve the modelling of gamma-ray production and diffusion
  - Focus on the production of gamma-rays from leptonic interactions
  - Spectroscopy of Pismis 22 to determine spectral types of individual stars