Interstellar gas towards the VHE gamma-ray sources HESS J1640-465 and HESS J1641-463

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Introduction

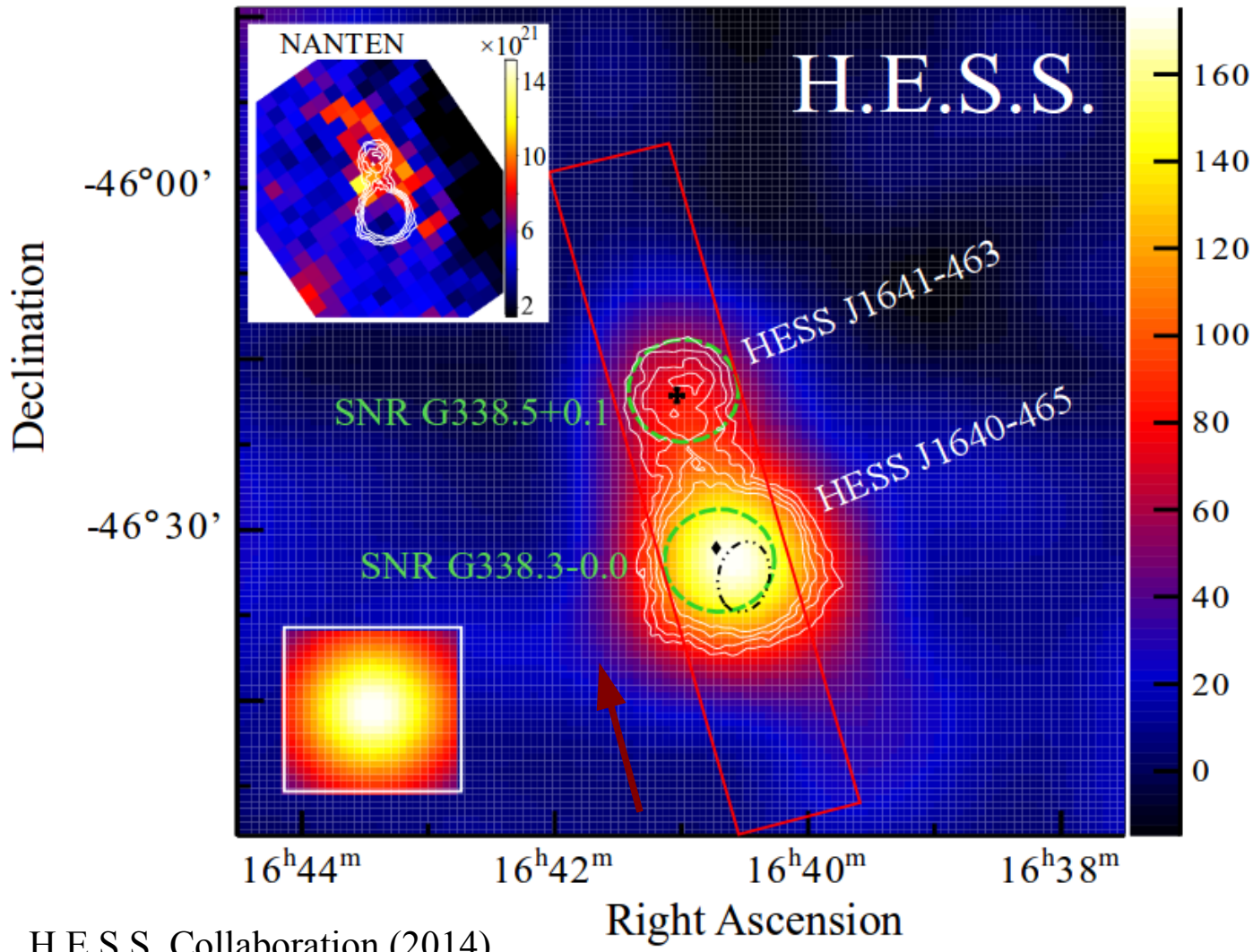
- **TeV gamma-ray sources in the galaxy**
  - Many sources have origins that are not yet fully understood yet
  - True nature of many sources are still being debated
    - Hadronic, leptonic or combination of both?

- **The interstellar medium and VHE astrophysics**
  - Use molecular lines to probe the interstellar medium towards VHE gamma-ray sources
  - What environment do theses sources exist in?
  - Morphological matches with TeV emission?
    - Hadronic interaction between cosmic-rays and ambient medium
      - pp interactions

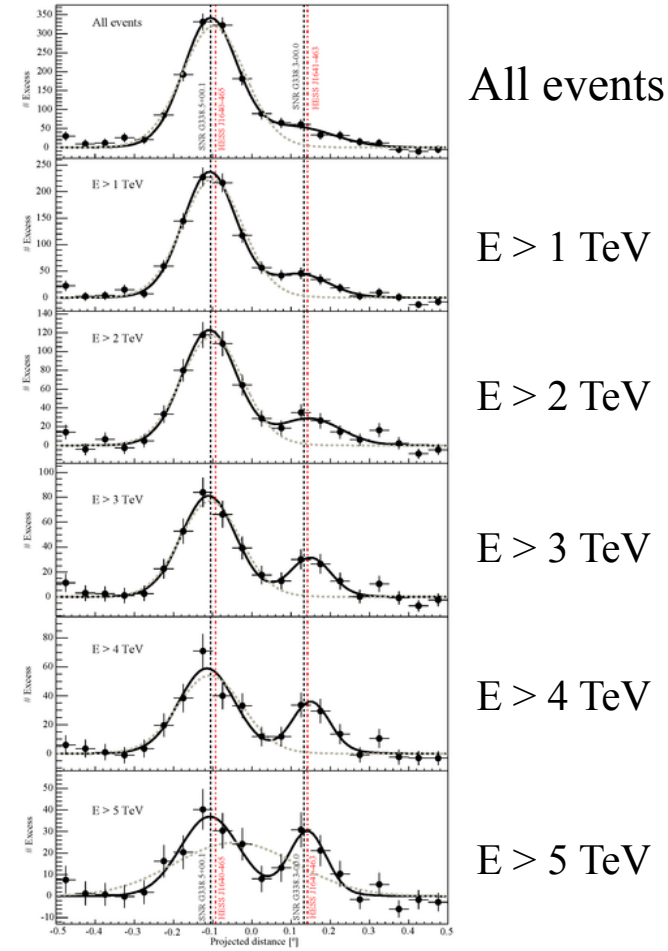
$$p + p \rightarrow \pi^{\pm,0} \qquad \pi^0 \rightarrow \gamma + \gamma$$

HESS J1640-465 & HESS J1641-463

- **HESS J1640-465:** Discovered as part of HESS survey of the galactic plane (2006)
- **HESS J1641-463:** Observations towards HESS J1640-465 during 2004-2011 revealed a new TEV source, HESS J1641-463



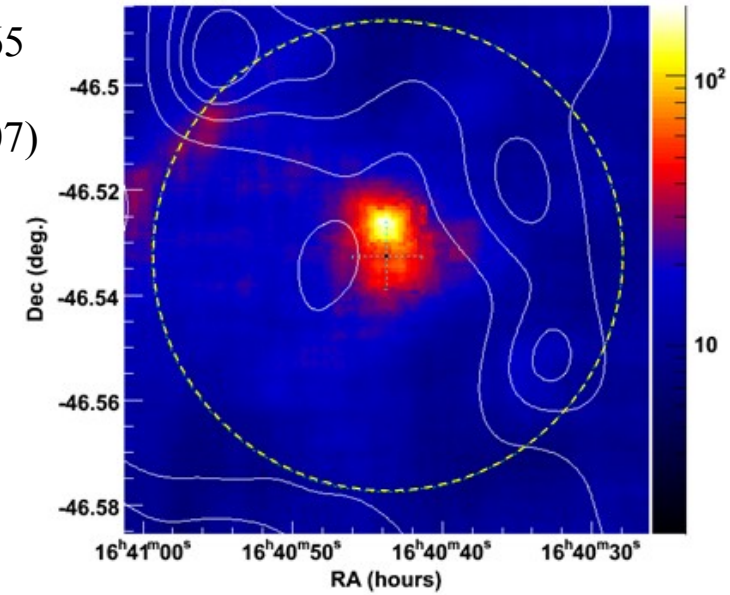
H.E.S.S. Collaboration (2014)

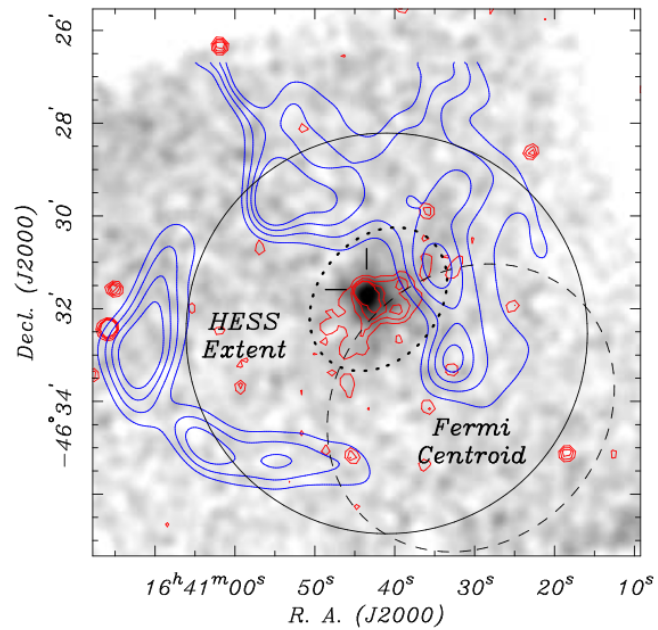


Projected gamma-ray flux

Observations in other high-energy wavelengths

HESS 1640-465
X-rays
Funk et al. (2007)



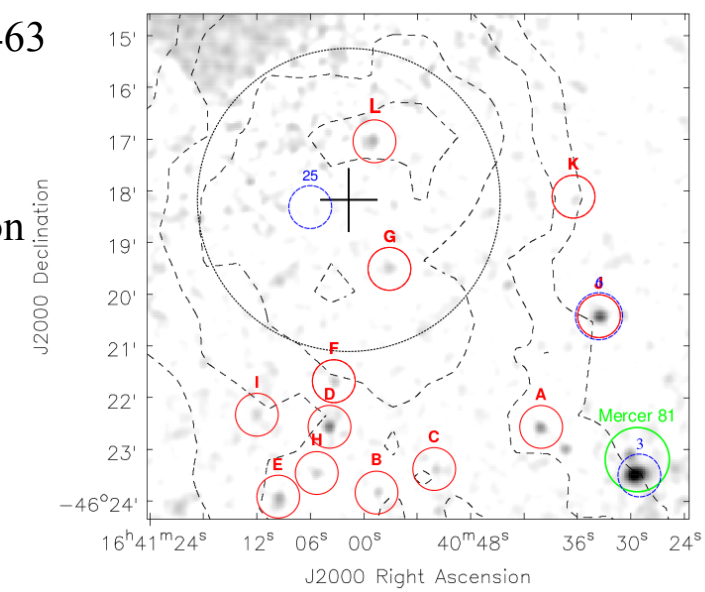


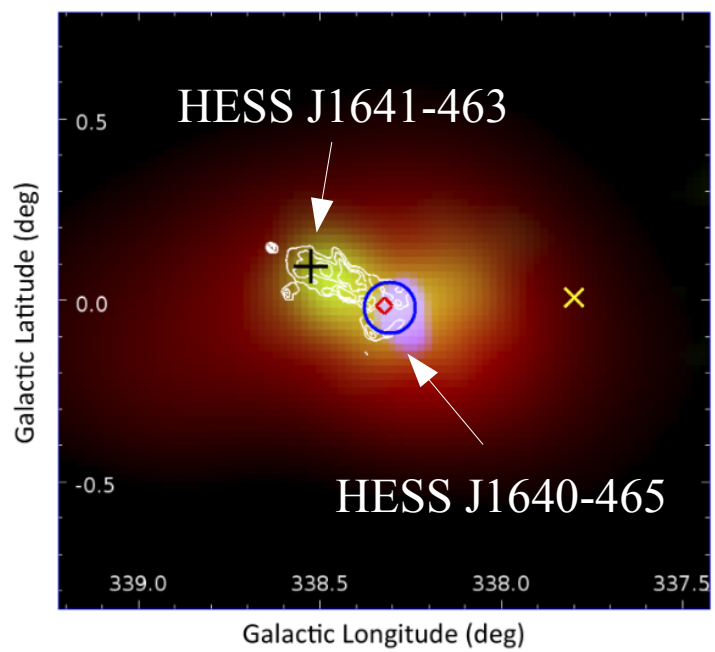
HESS 1640-465
Recent x-ray
pulsar detection

Gotthelf et al.
(2014)

HESS 1641-463
X-rays

H.E.S.S.
Collaboration
(2014)

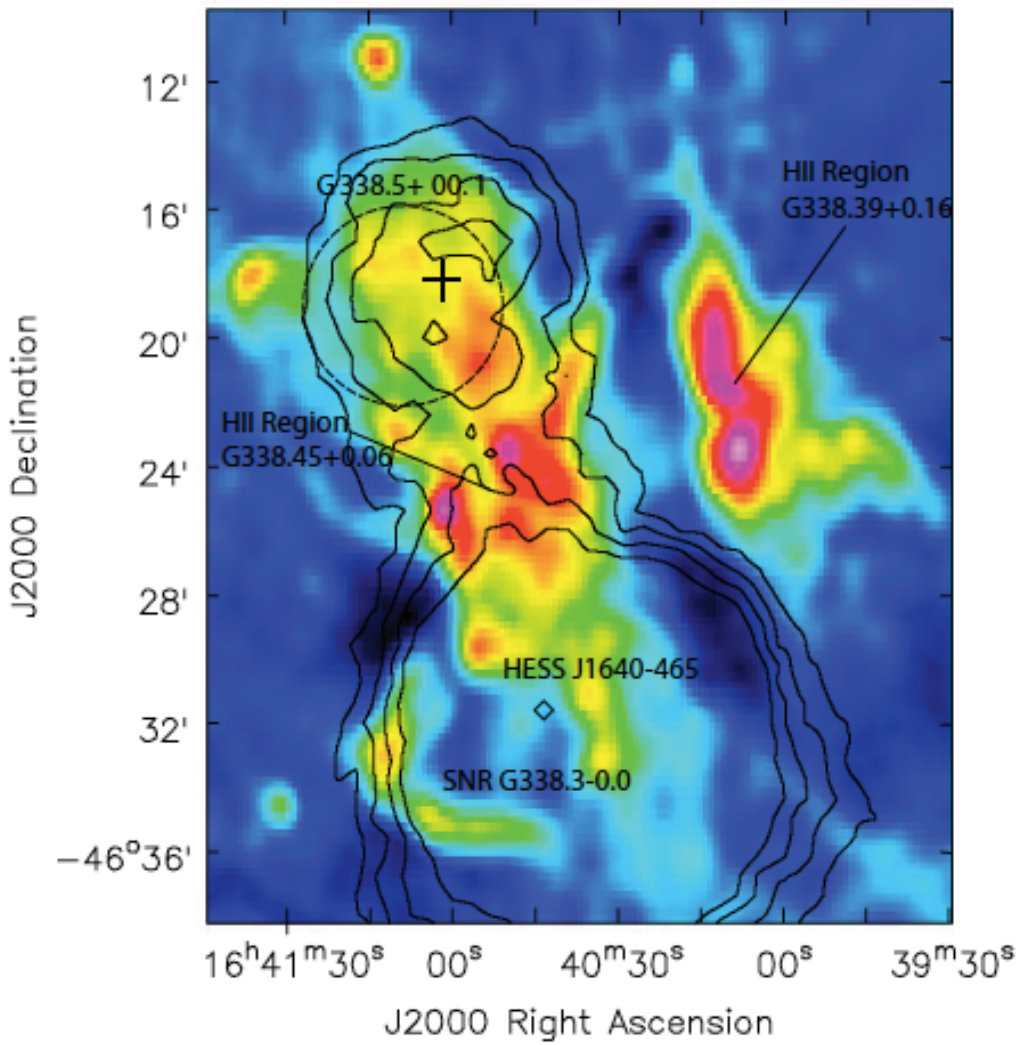




Fermi observations
2 distinct sources

Lemoine-Goumard
et al. (2014)

Local environment

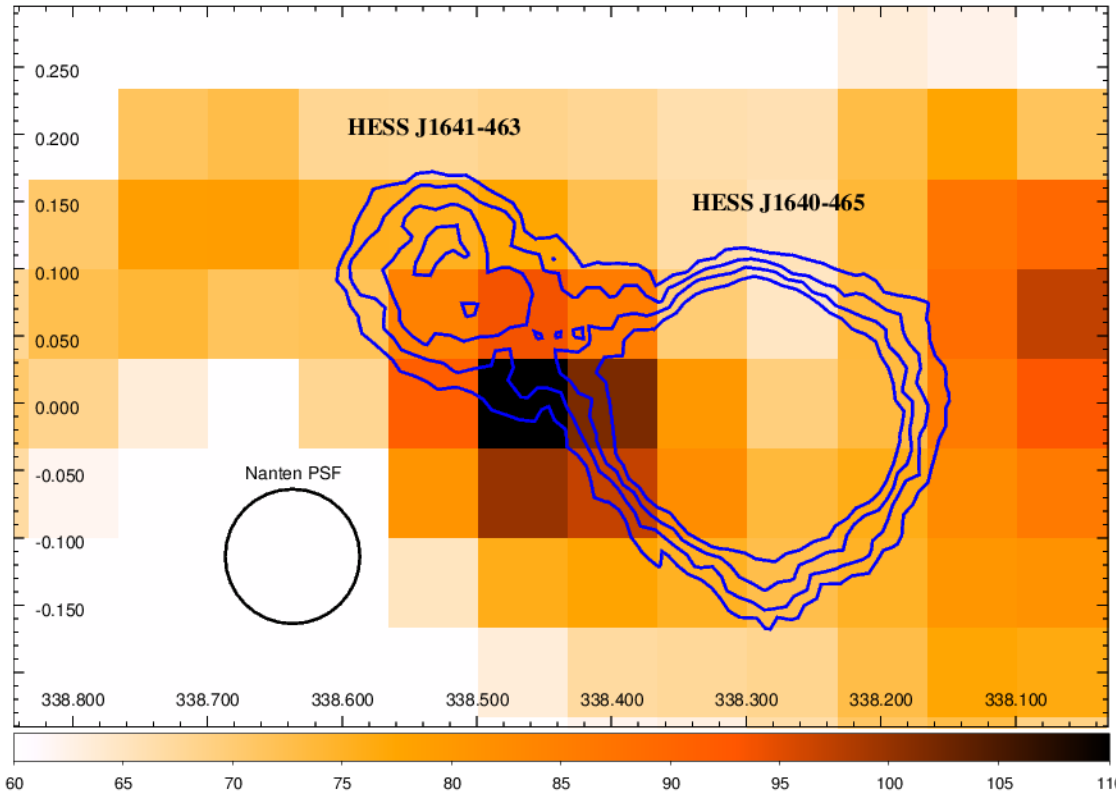


Colour: MOST 843 MHz

Oya et al. (2013)

- **HESS J1640-465 & HESS J1641-463 are seen towards supernova remnants**
  - SNR G338.3-0.0 and SNR G338.5+0.1 respectively
  - Distance to the SNRs is ~ 10-11 kpc (via HI absorption) in the Norma II spiral arm (Kothes & Dougherty 2007)
  - 11 kpc along this line of sight corresponds to a Vlsr of ~ -40 km/s
- **Both the SNRs and the HESS sources appear to be connected by the complex HII region G338.45+0.05**

Nanten observations

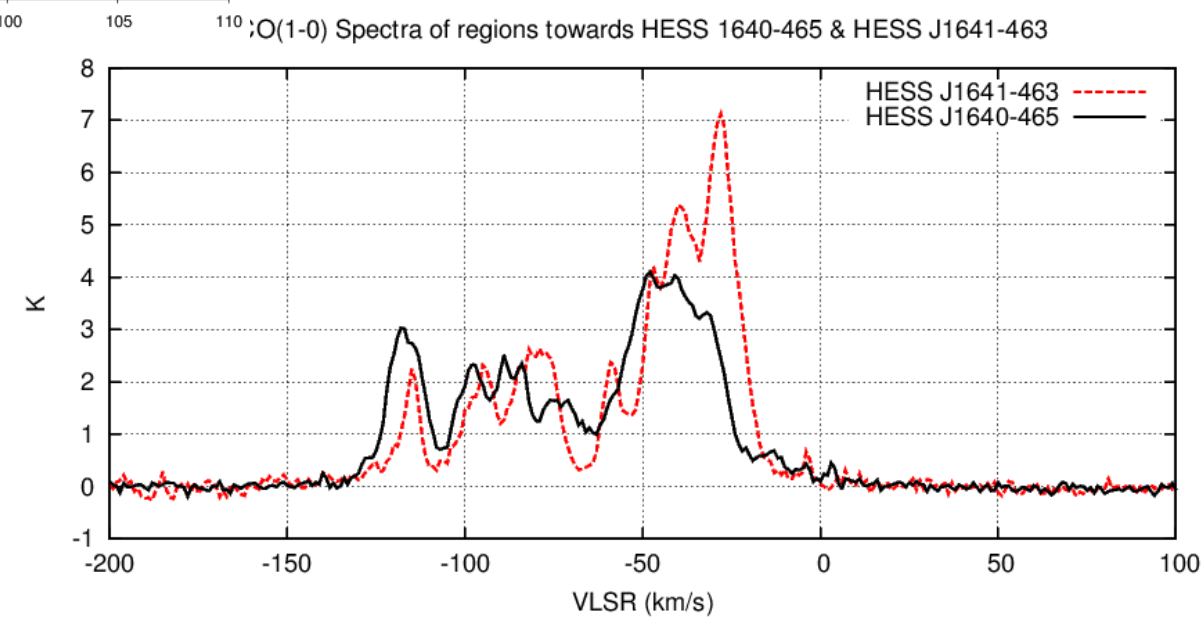


Nanten CO survey data

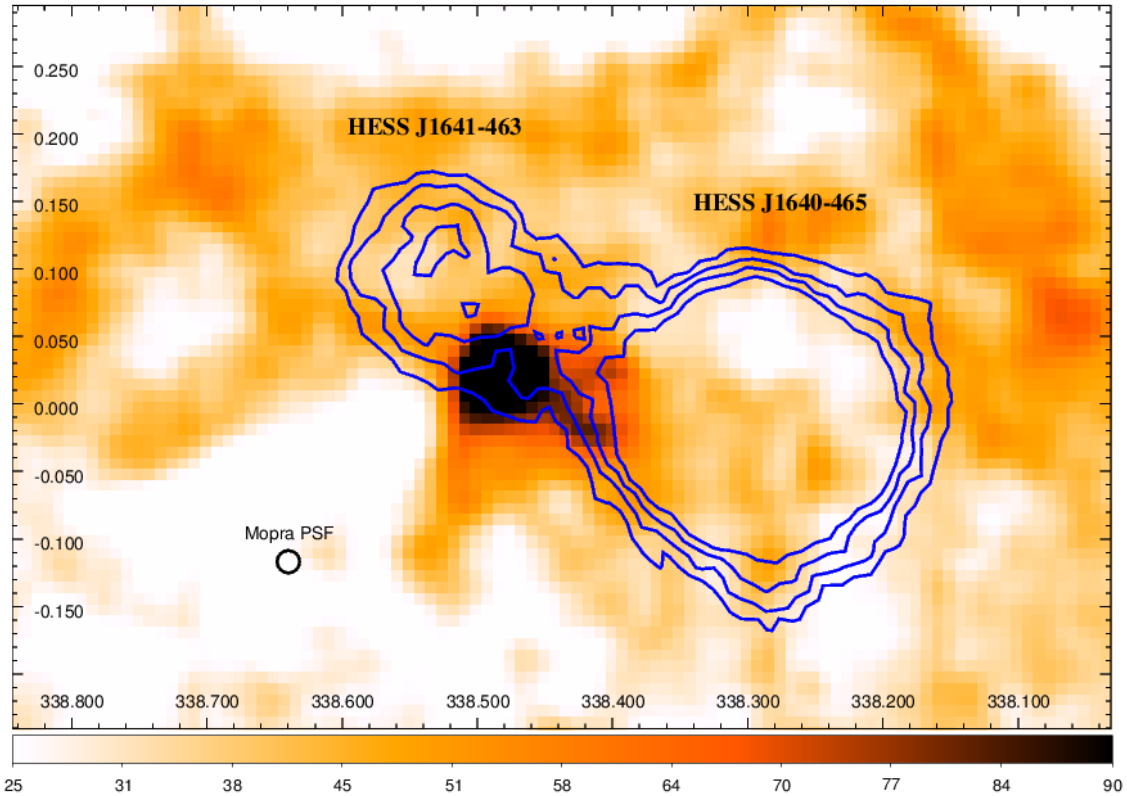
Left: Integrated 12CO(1-0) between -50 and -30 km/s

Nanten2

Right: 12CO (1-0) spectra in regions towards HESS J1640-465 and HESS J1641-463



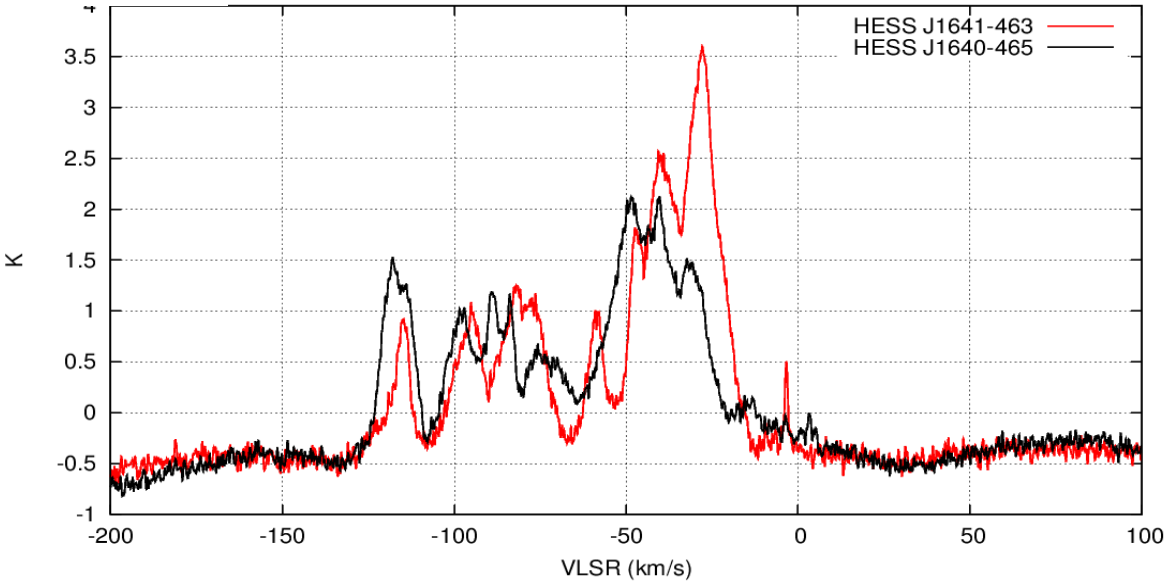
MopraCO survey data



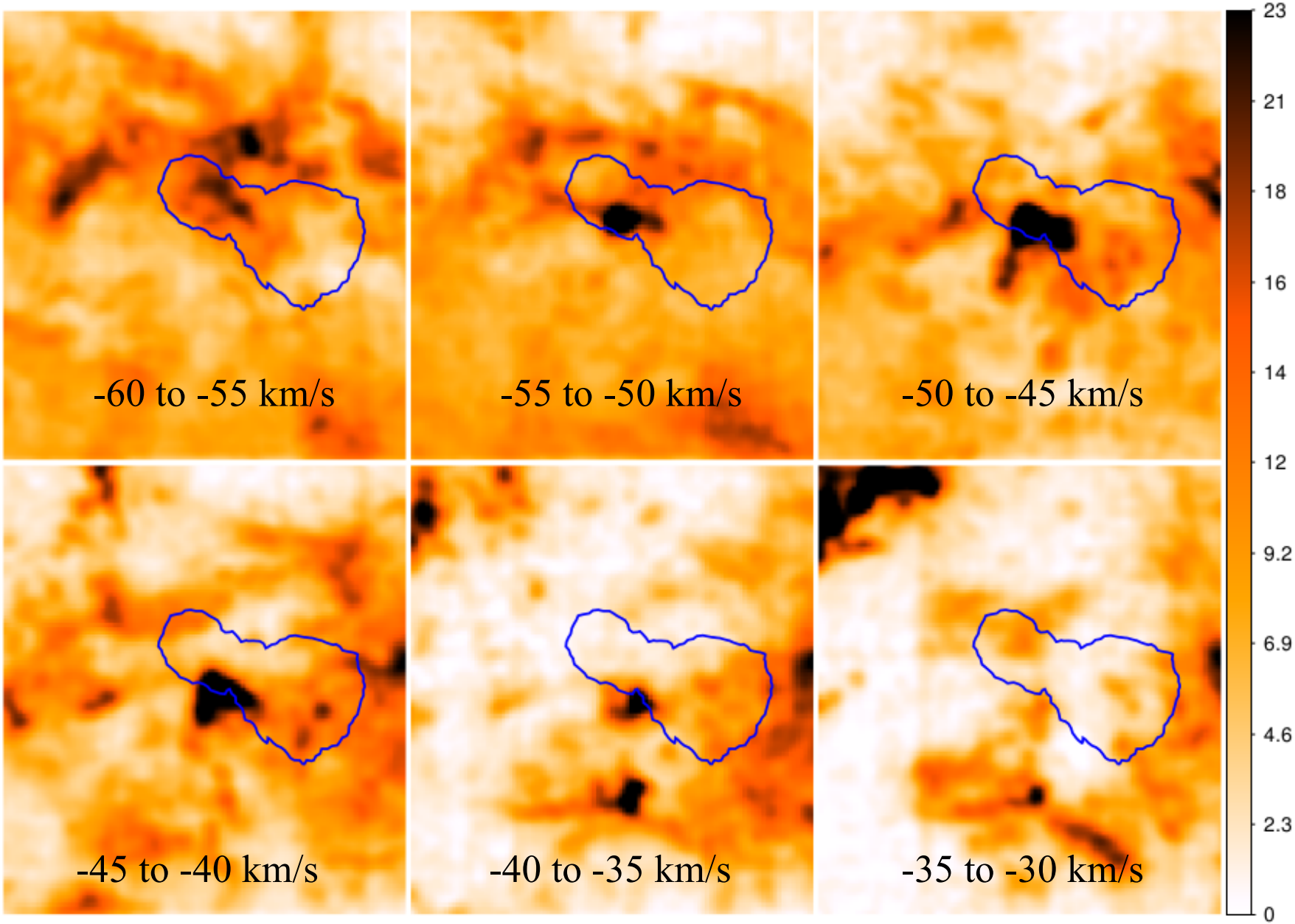
Mopra Galactic Plane CO survey data

Left: Integrated 12CO(1-0) between -50 and -30 km/s

Right: 12CO (1-0) spectra in regions towards HESS J1640-465 and HESS J1641-463

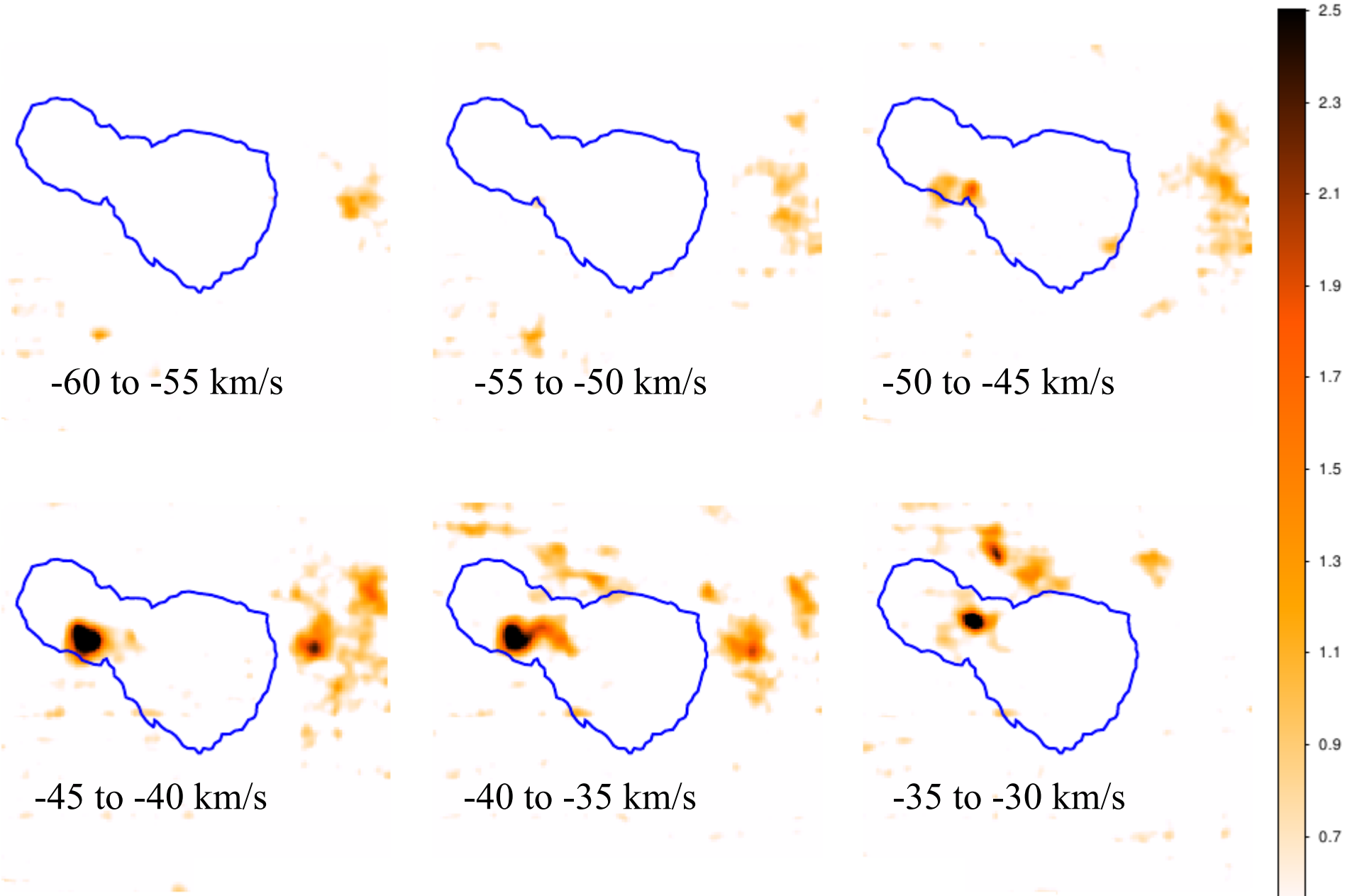


MopraCO survey data



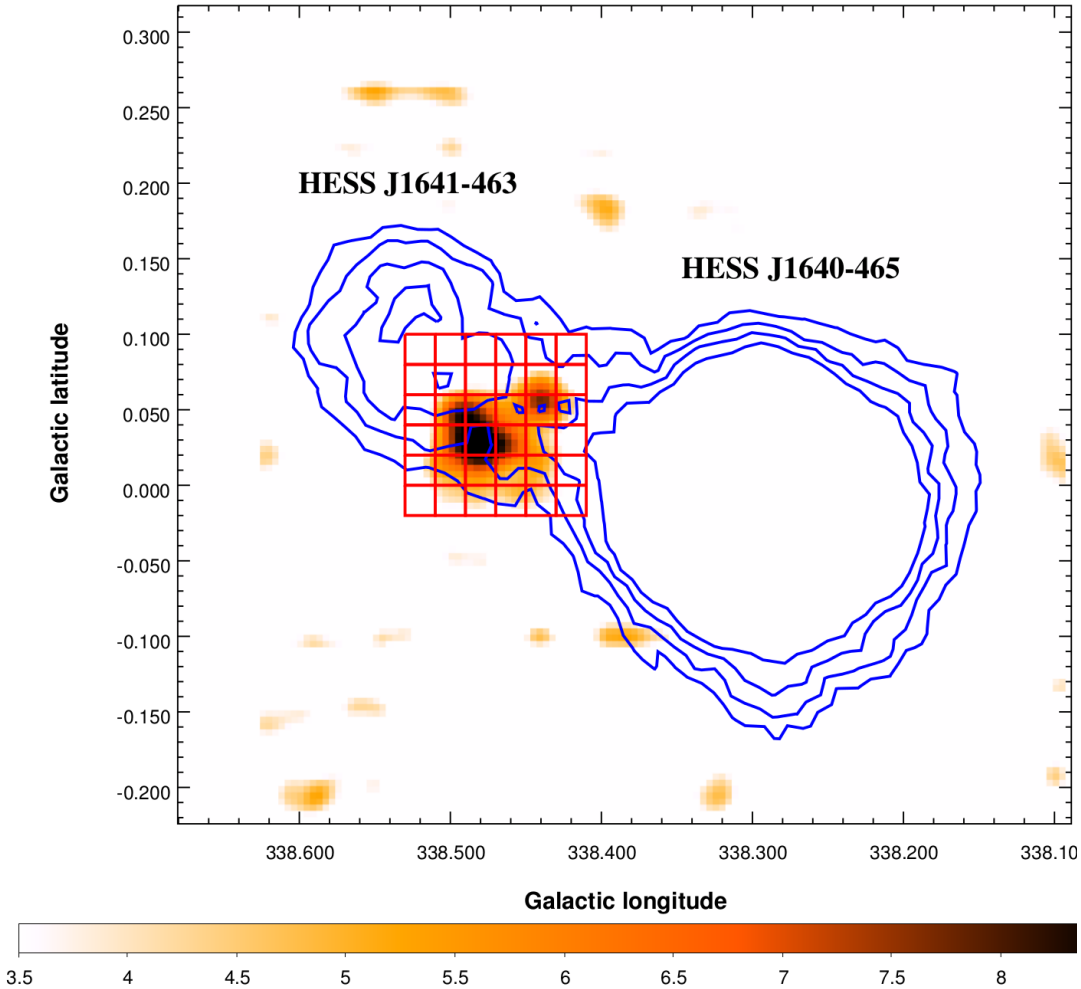
Integrated 12CO(1-0) slices

Mopra 7mm data: CS(1-0)

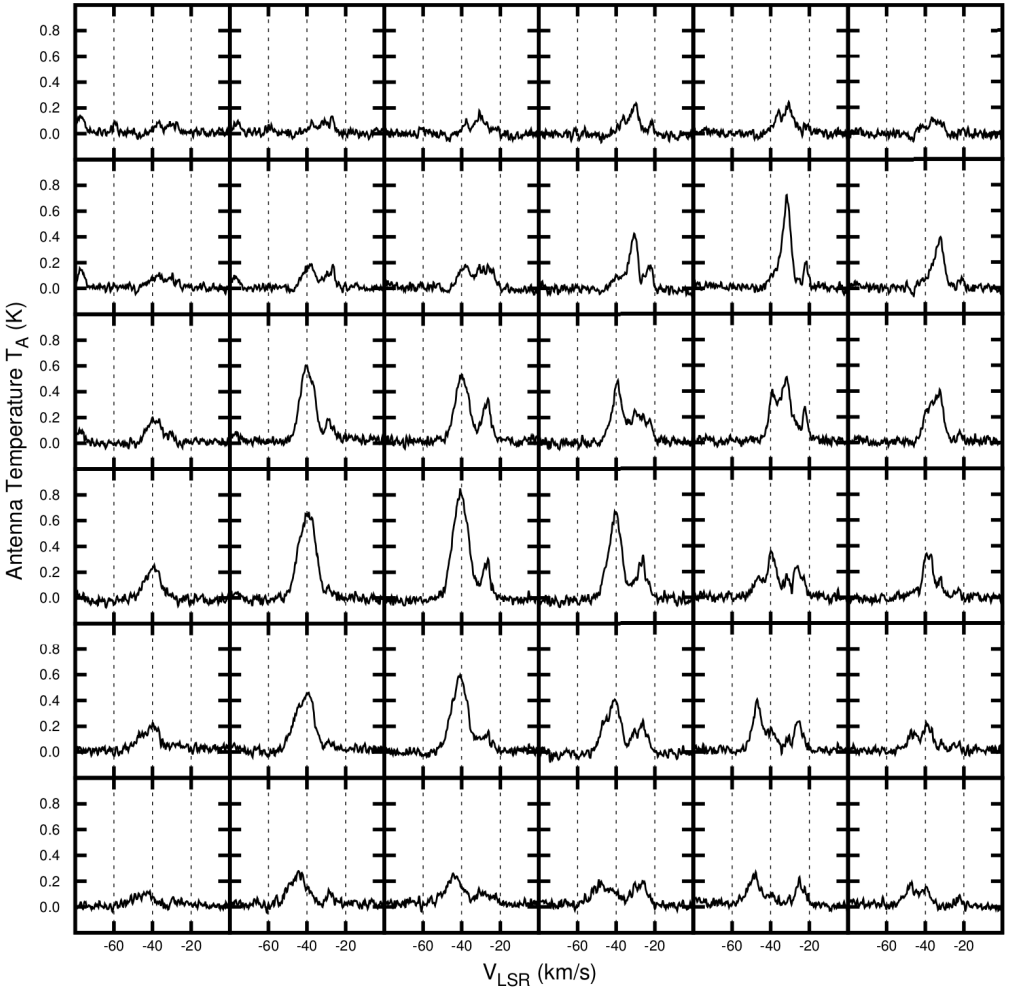


Integrated CS(1-0) slices

Mopra 7mm data: CS(1-0)



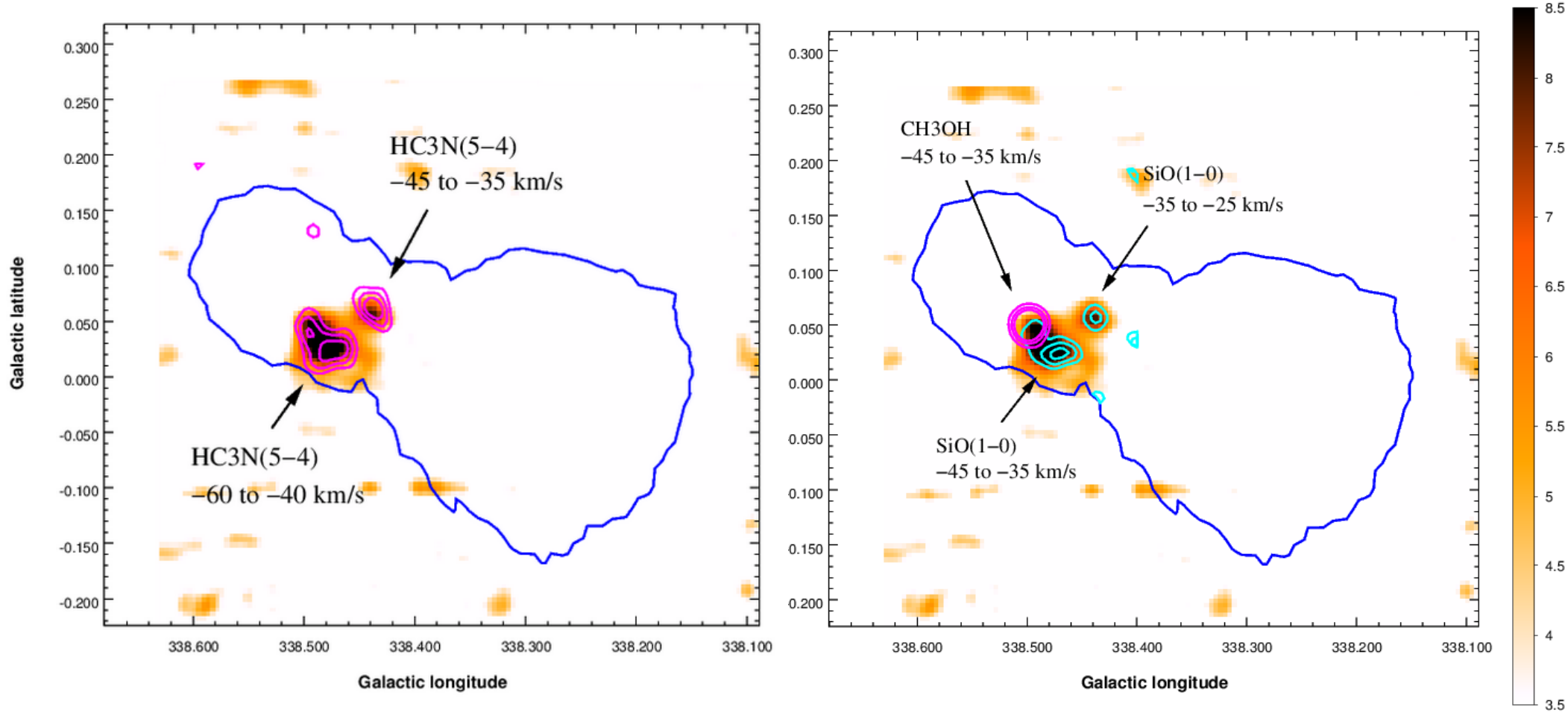
Integrated image of CS(1-0) emission between -56 and -16 km/s



CS(1-0) spectra of the grided regions indicated in red in the image opposite.

Mopra 7mm data

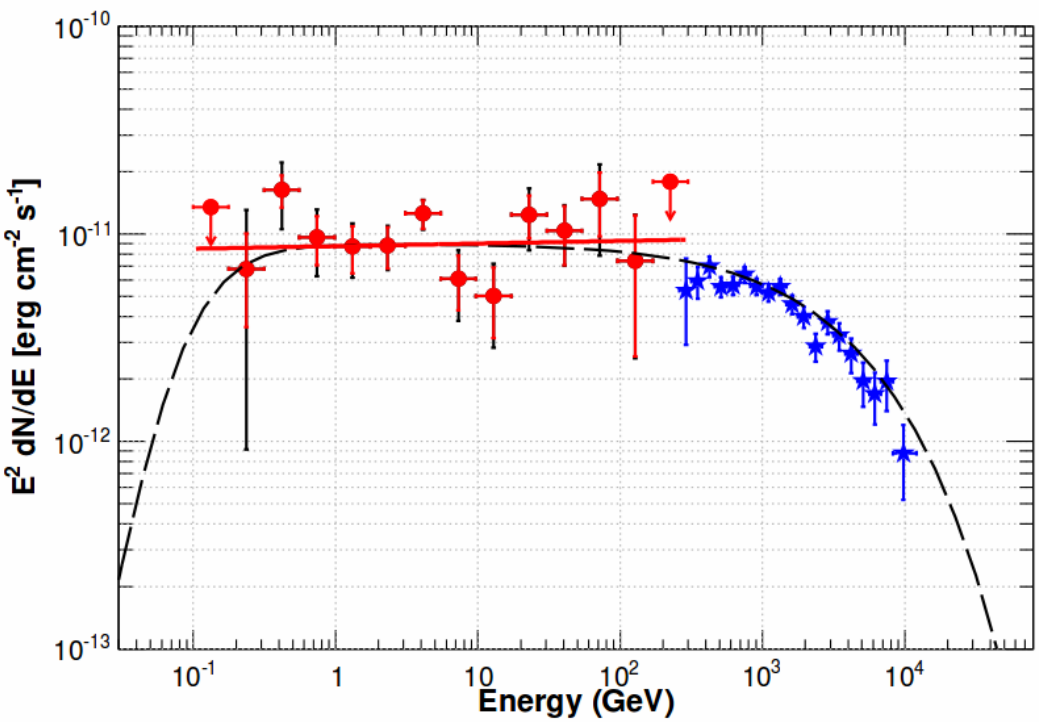
Detections in HC3N(5-4), CH3OH and SiO(1-0)



Background: Integrated CS(1-0) emission
between -56 and -16 km/s

Origin of HESS J1640-465

- Hadronic
  - Significant overlap between TeV emission and north-western part of SNR G338.3-0.0
  - Spectral shape similar to other VHE gamma-rays sources identified as SNRs interacting with molecular clouds
  - Hadronic production model assuming gas density of 150 cm-3 (Lemoine-Goumard et al. 2014)
- Leptonic
  - Newly discovered pulsar suggests that PWN could be in part powering the TeV source.
  - (Accelerated electrons producing TeV gamma-rays via inverse-Compton scattering)



HESS J1640-465

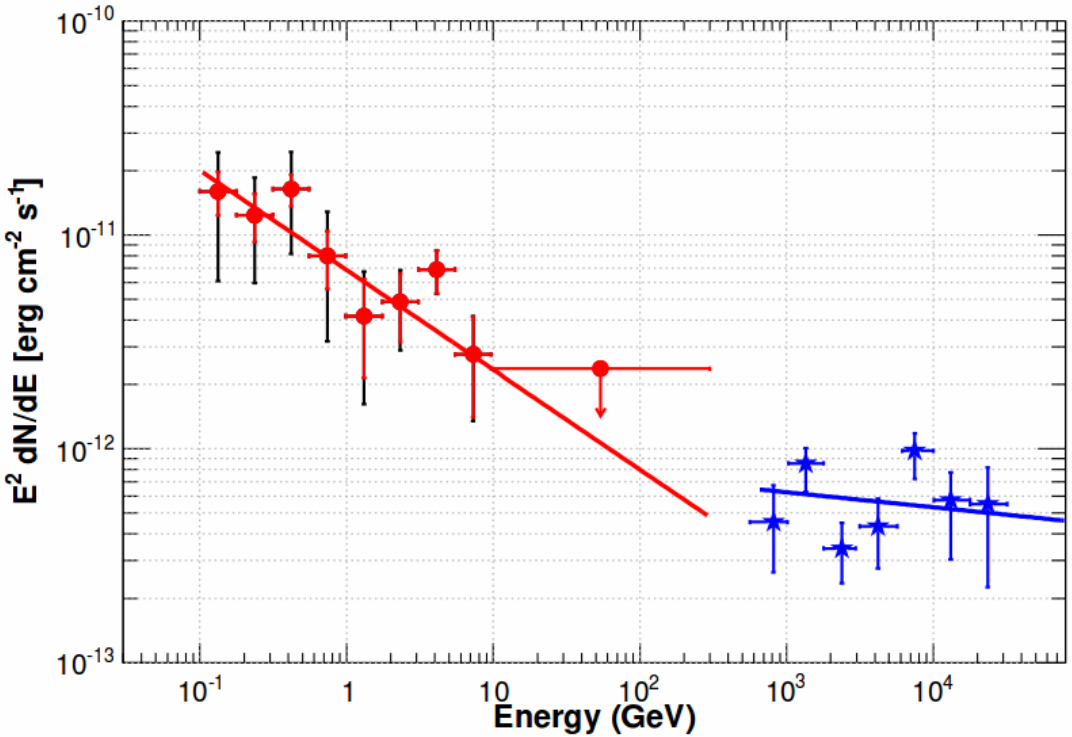
Red – Fermi data points
Blue – HESS data points
Dashed line - Hadronic production model

Lemoine-Goumard et al. (2014)

Origin of HESS J1641-463

- Connection between VHE gamma-ray spectra & HE gamma-ray spectrum is unclear
  - 2 mechanisms/sources producing photons in each energy band?

- VHE hadronic origin – Galactic PeVatron?
  - If SNR G338.5+0.1 were young (~1000 years old), it could accelerate particles to required energies. Would require a very hard proton energy spectrum.
  - CRs from SNR G338.3-0.0 could have diffusively reached the gas towards 1641.
    - Higher energy CRs would reach the gas earlier thus hardening the proton/gamma spectrum



HESS J1641-463

Red – Fermi data points
Blue – HESS data points
Solid lines - best spectral fits

Lemoine-Goumard et al. (2014)

Summary

- Interstellar medium towards HESS J1640-465 and HESS J1641-463
  - Primarily using molecular line data from Nanten and Mopra
- Investigation of galactic TeV sources
  - Analysis of the gas in the region and its properties essential in investigating the origins of VHE sources
- Linkages with other ISM projects:
  - MopraCO, MopraGam, SPLASH, HEAT, HOPS, Nanten, MALT45 etc.



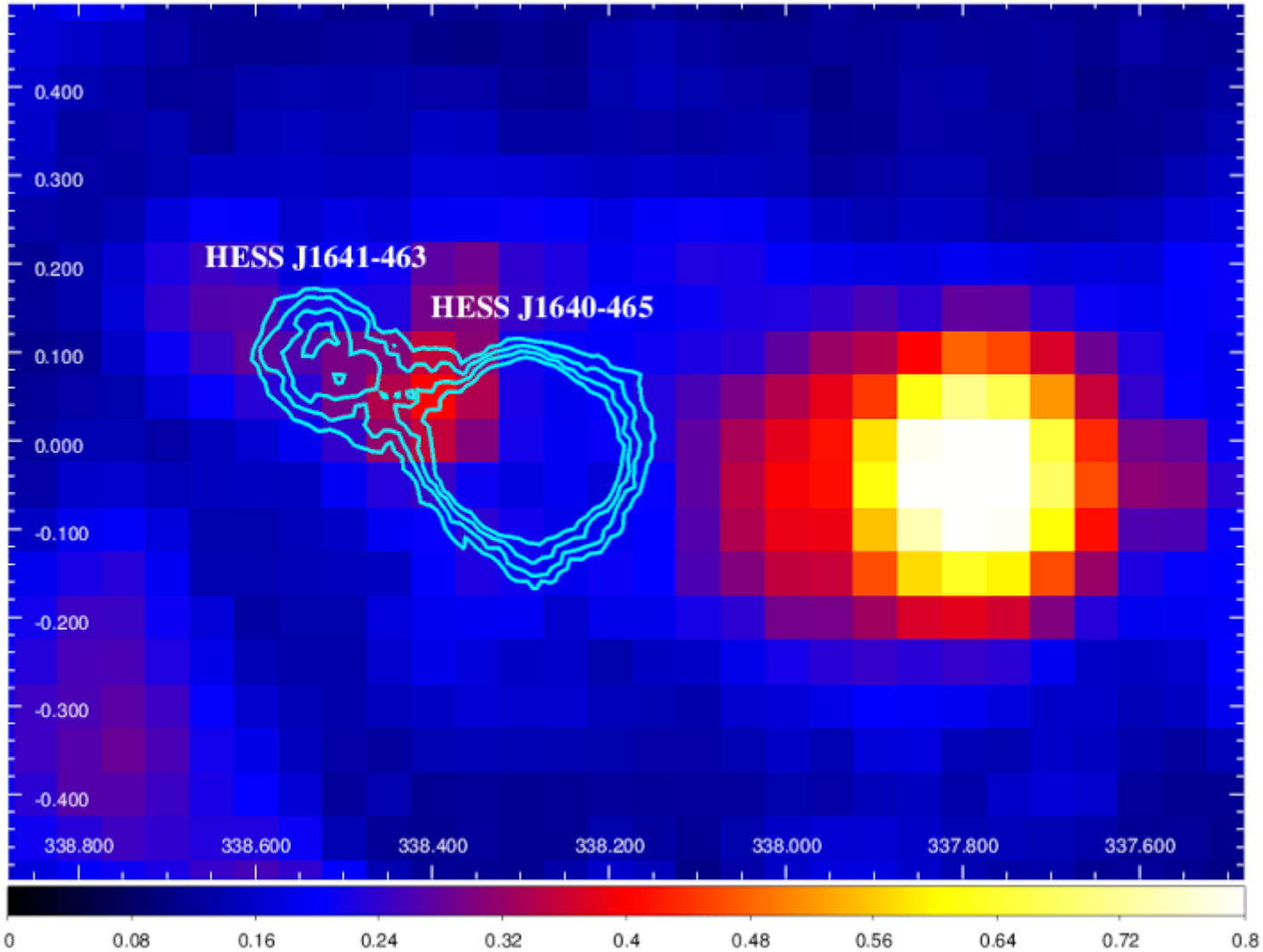

- High resolution molecular line studies will be excellent counterparts to next generation ground-based gamma-ray observatories

cta
cherenkov telescope array

Thanks for your attention

SPLASH

- **Southern Parkes Large Area Survey in Hydroxl**

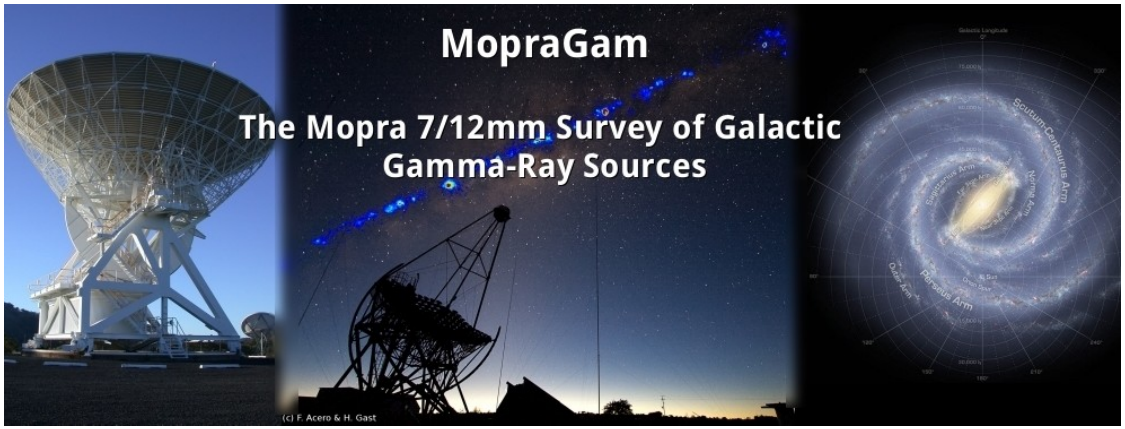


Peak pixel image of 1720 MHz OH emission from SPLASH data

Summary and future work

- Interstellar medium towards HESS J1640-465 and HESS J1641-463
  - Analysis of the gas in the region and its properties
  - Using survey data from Nanten as well as 3mm, 7mm and 12mm Mopra observations
  - Other molecular line surveys important to build up complete picture
    - E.g. SPLASH (Southern Parkes Large Area Survey in Hydroxl)

- Currently using gas data to model and constrain TeV gamma-ray origin scenarios
  - More information on similar projects on the MopraGam website: http://www.physics.adelaide.edu.au/astrophysics/MopraGam/



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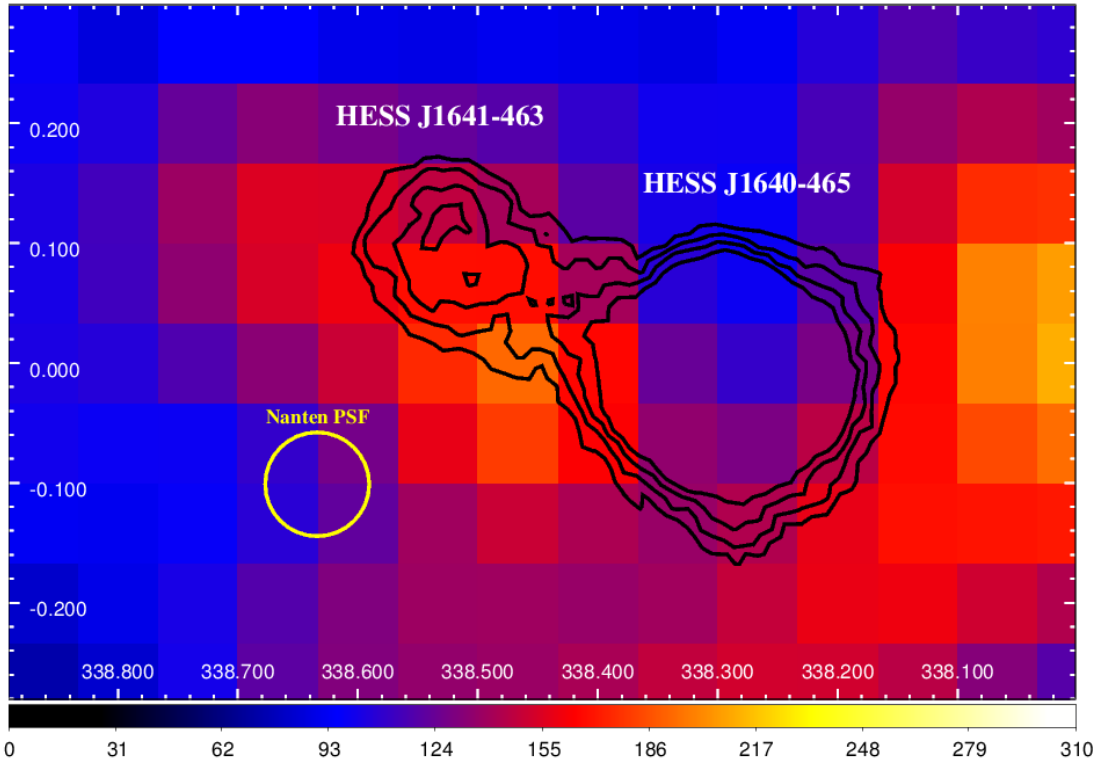
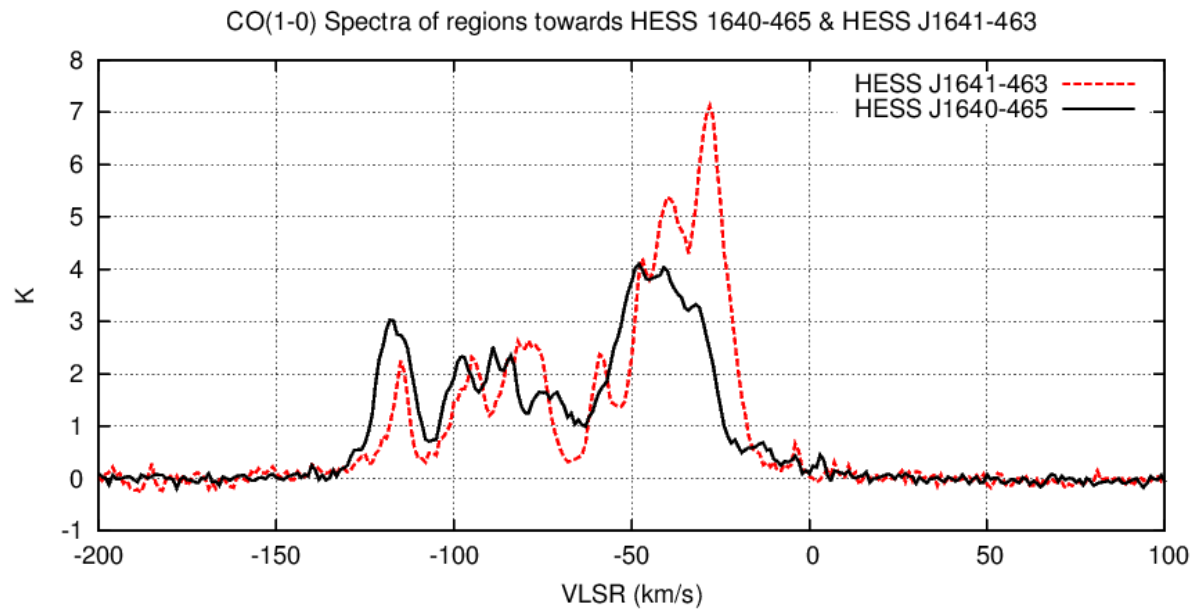


Nanten CO survey data

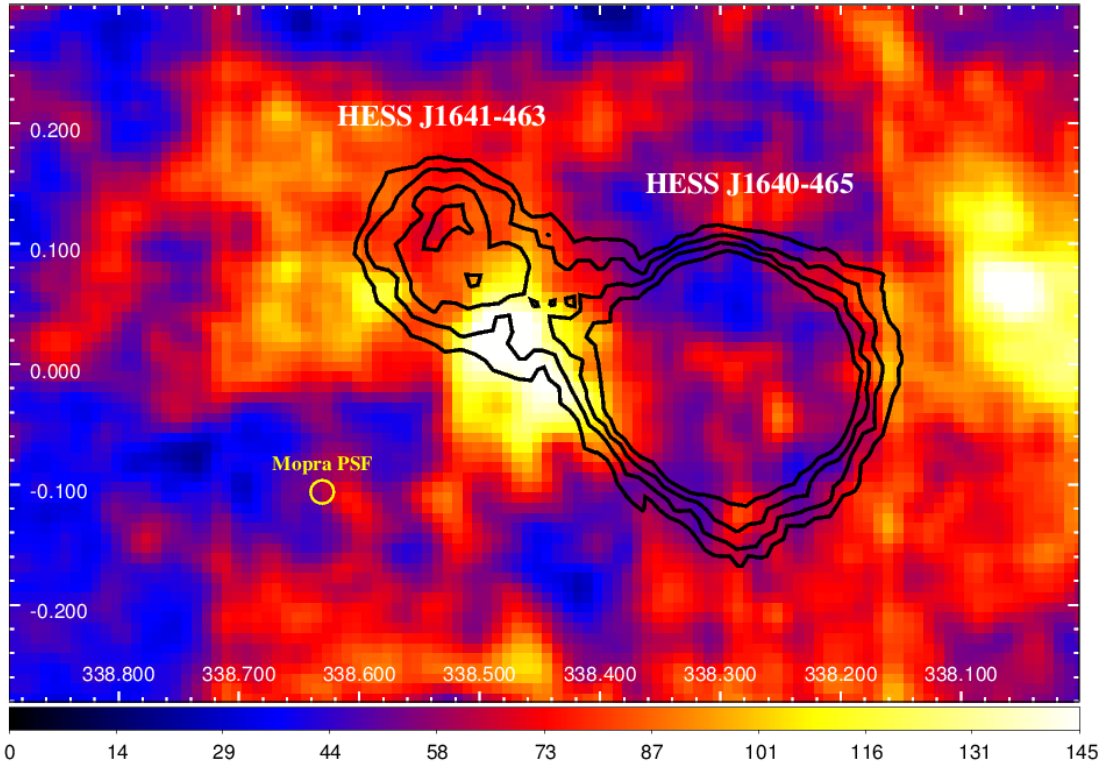
Left: Integrated 12CO(1-0) between -68 and -12 km/s

Nanten2

Right: 12CO (1-0) spectra in regions towards HESS J1640-465 and HESS J1641-463



MopraCO survey data



Mopra Galactic Plane CO survey data

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