Assessing the Impact of Hydrogen Absorption on the Characteristics of the Galactic Center Excess

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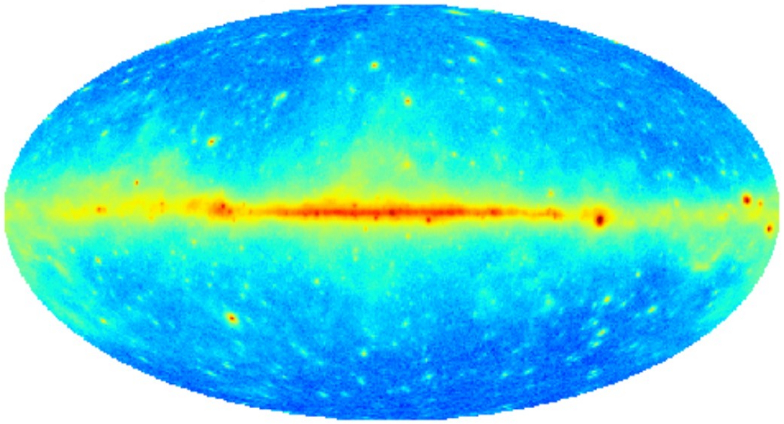
Article: Pohl, Macias, Coleman, Gordon, ApJ 2022, arxiv:2203.11626

Fermi-LAT Gamma-ray Sky



Data

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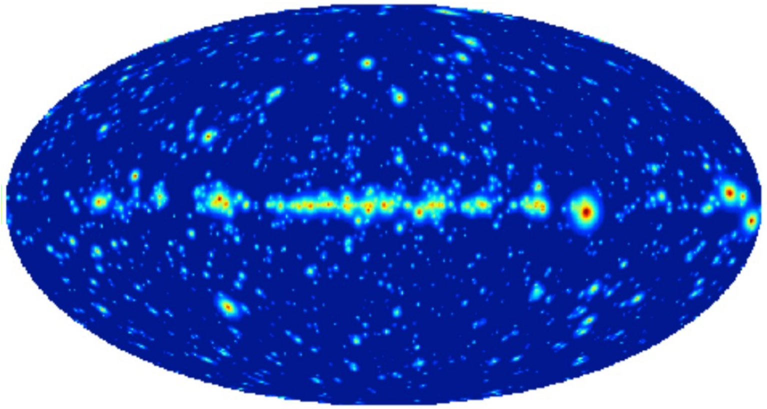

Point sources

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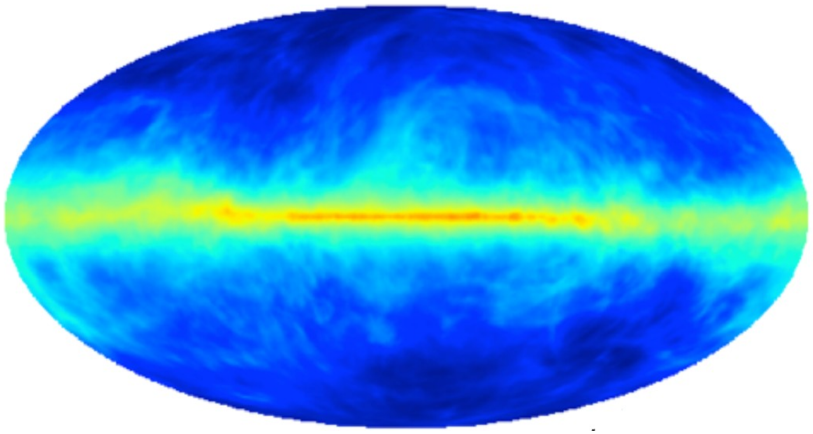

Galactic Diffuse

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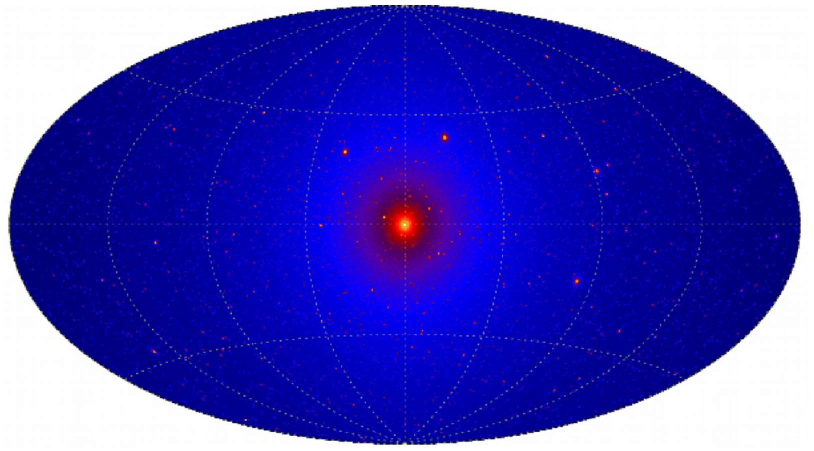
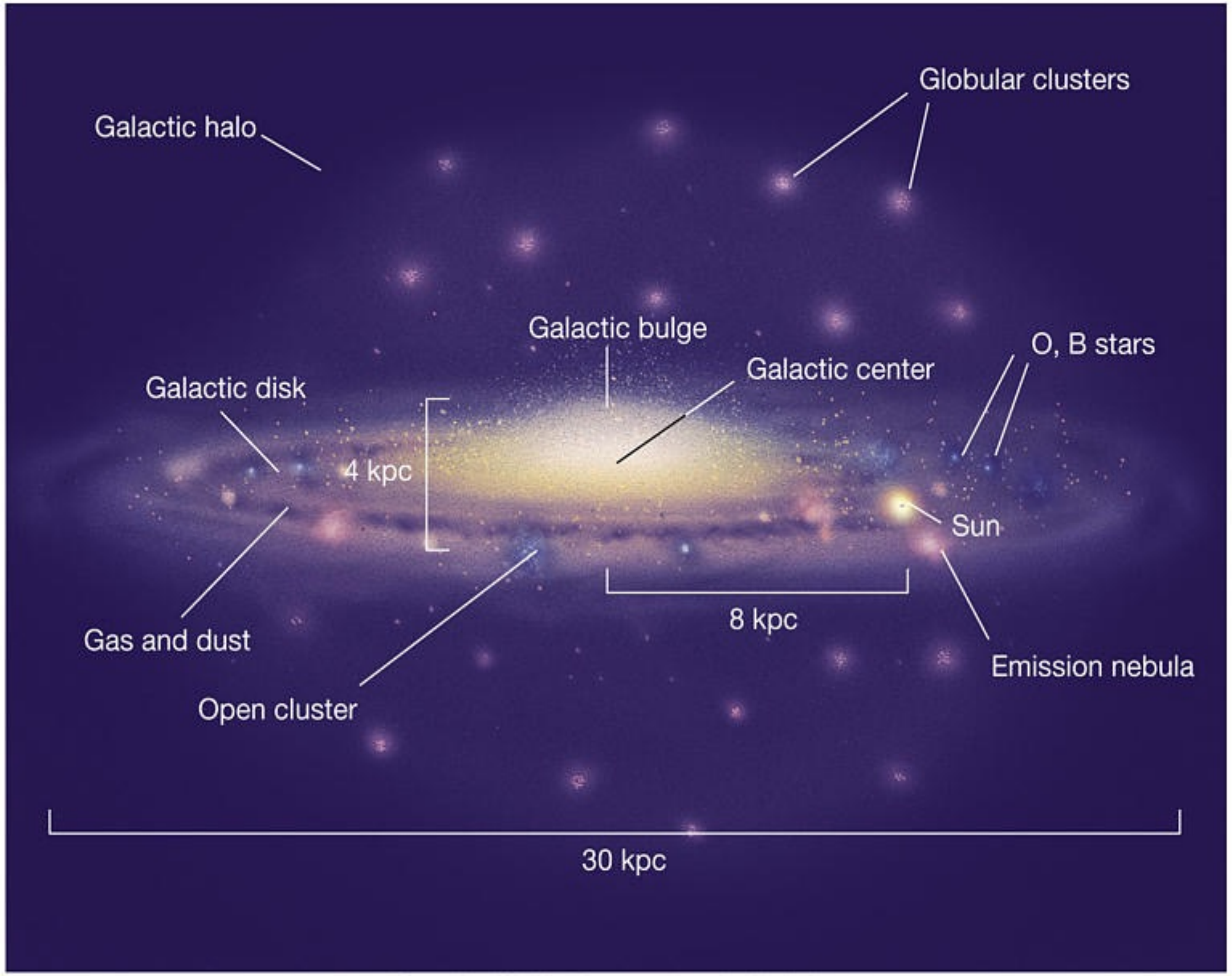
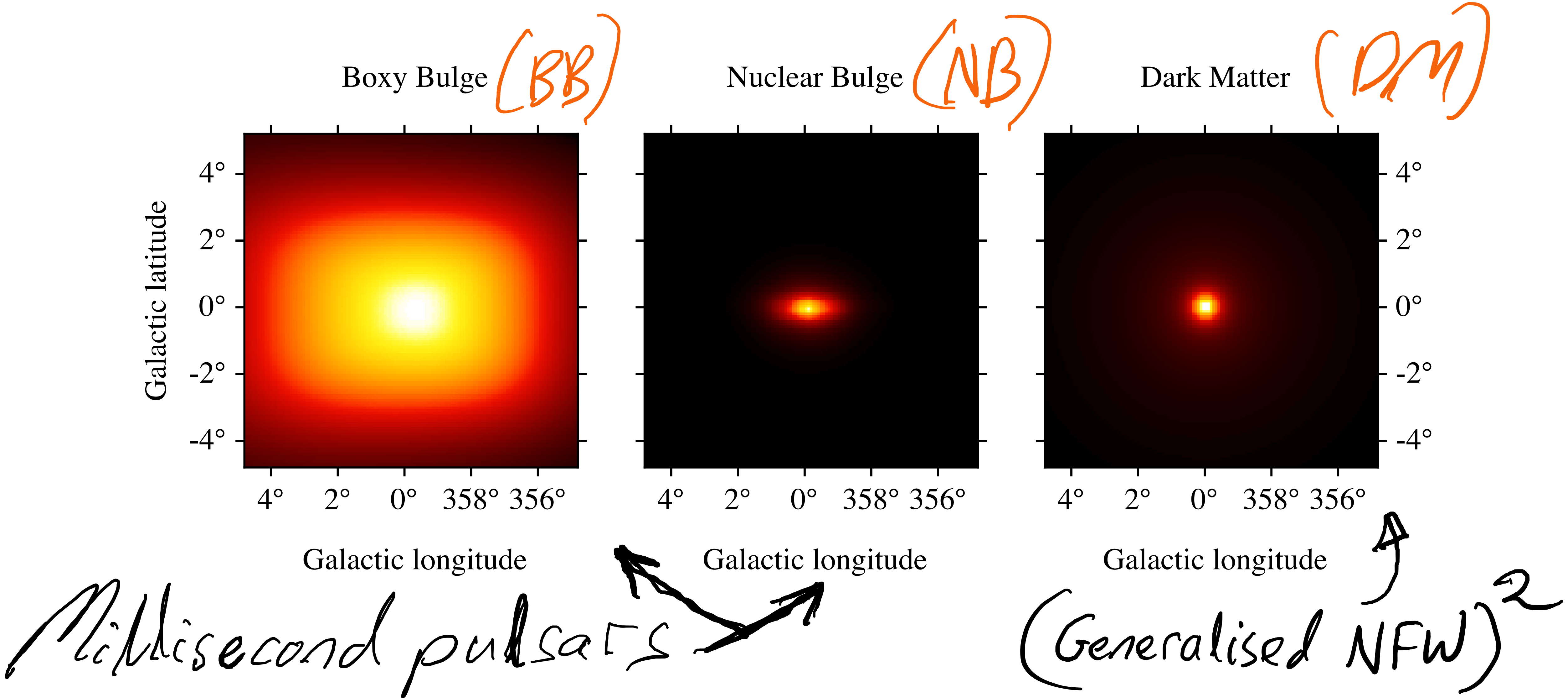


Dark Matter or Millisecond Pulsars?

Edge-on view of the Milky Way

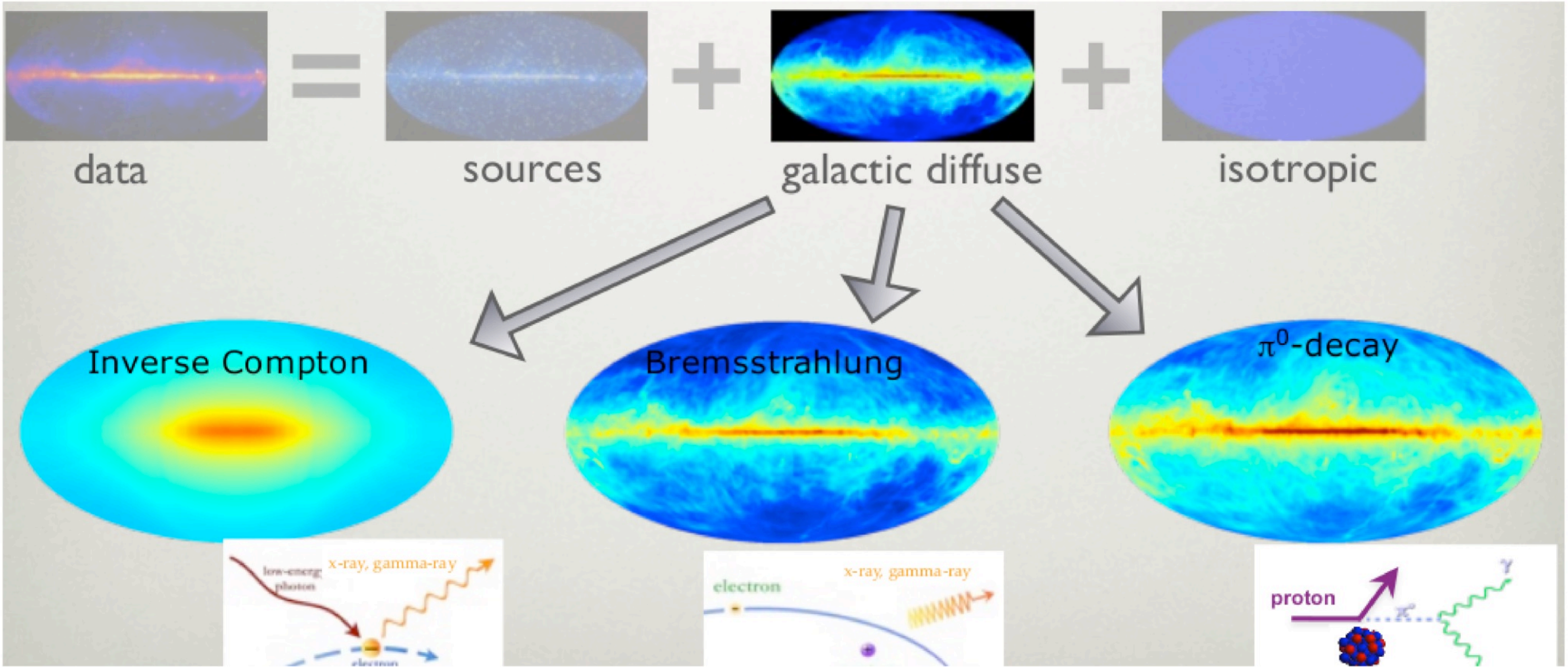




Boxy Bulge (BB)
Nuclear Bulge (NB)
Dark Matter (DM)
Galactic latitude
4°
2°
0°
-2°
-4°
4° 2° 0° 358° 356°
Galactic longitude
Millisecond pulsars
(Generalised NFW)^2

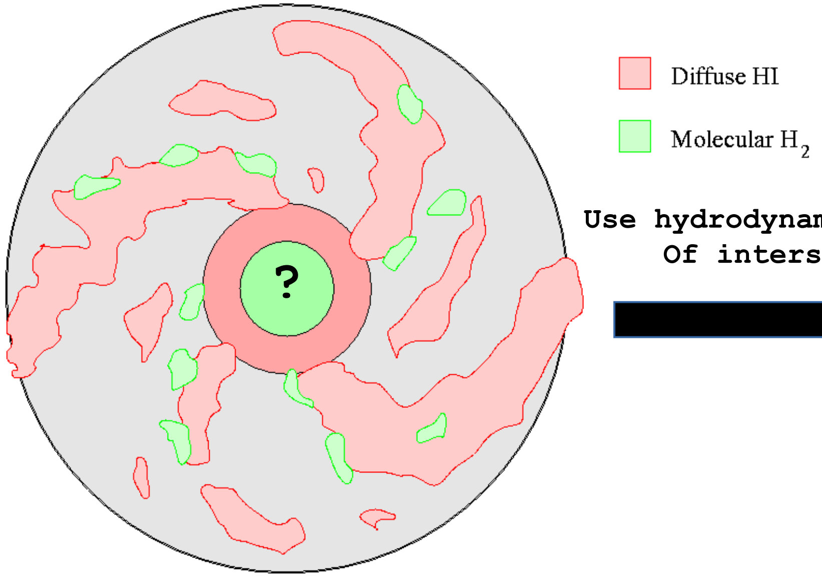
Galactic Diffuse Emission

- Generated using gas column densities, and a GALPROP (Strong+2007) generated Inverse Compton (IC) intensity map.



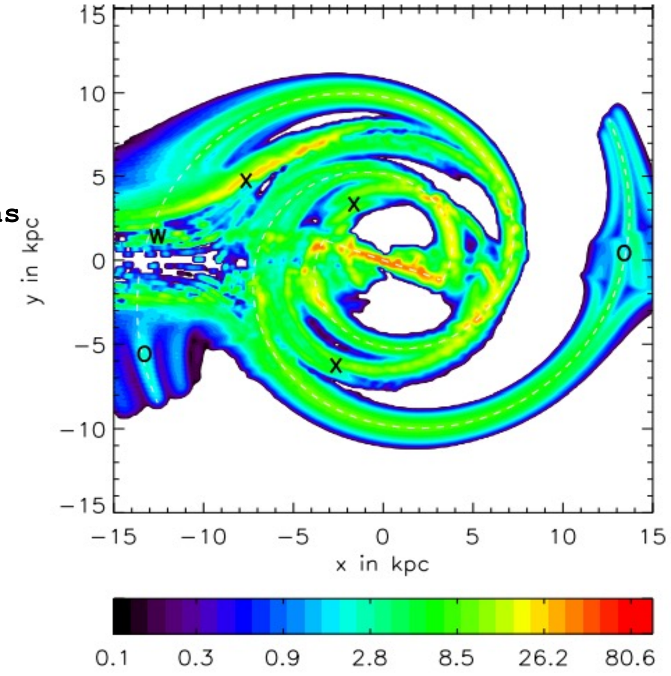
Gas column densities computed with the help of Hydrodynamical simulations

Image Credit:http://spiff.rit.edu/classes/phys230/lectures/ism_gas/ism_gas.html



Use hydrodynamical simulations
Of interstellar gas

Pohl et al. (2008)

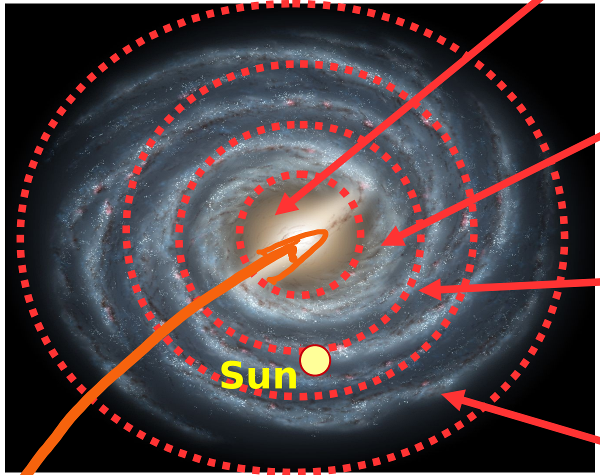


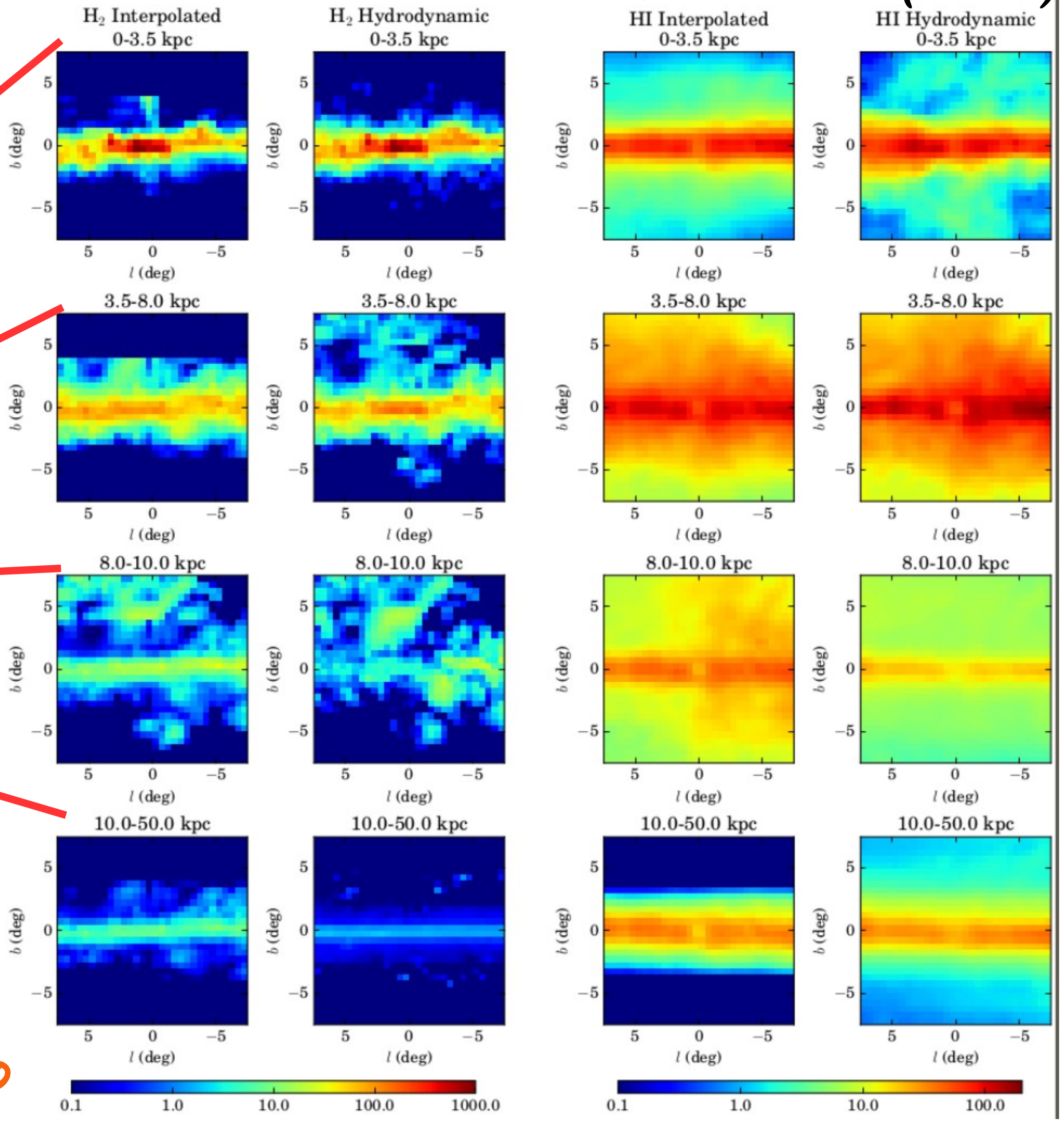
- Hydrodynamical simulations take into account the gravitational potential of the Galactic bar.
- Allows kinematic resolution at the Galactic center.
- HI is derived from 21cm LAB survey or more recently the HI4PI survey.
- H2 is traced by 2.6mm CO emission from Center for Astrophysics survey

Interpolated vs Hydrodynamical method

Used Pohl et al. (2008) 3D hydrodynamic model.

Macias et al. (2016)





Hess Ridge not included as its morphology is very similar to the NB.

There are noticeable morphological differences between the two methods.

Radiation transport

$$\frac{dI}{ds} = j_c + j_l - \alpha_l I$$

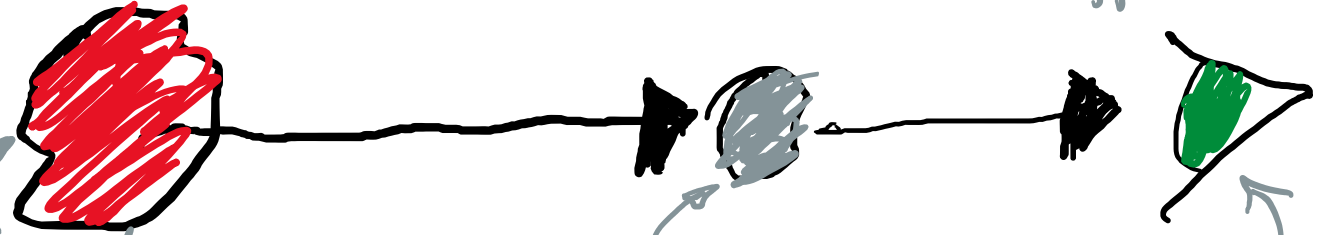
intensity

continuum emission coefficient

line emission coefficient

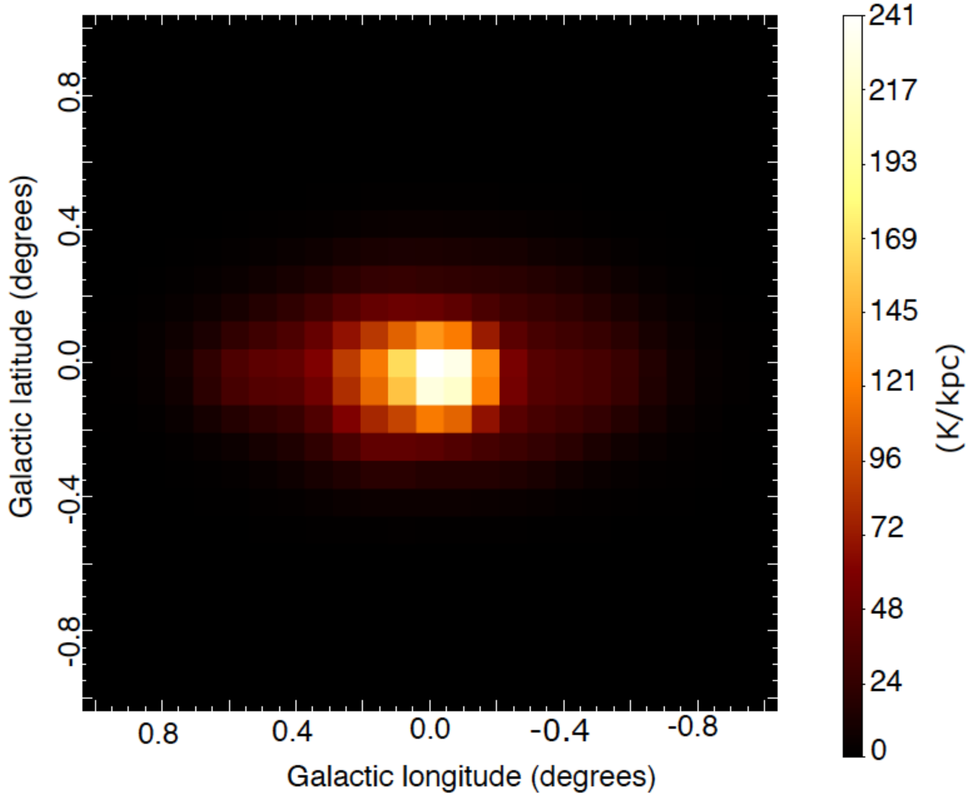
line emission absorption coefficient

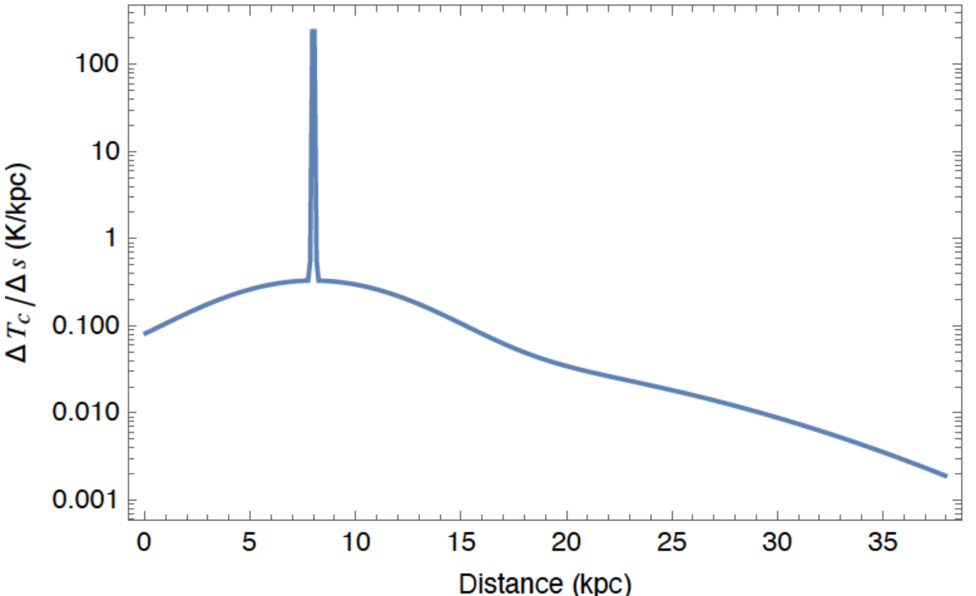
line of sight distance



Continuum emission model based on CHIPASS and Stockert data sets

- Continuum data fitted with an axisymmetric model.
- Top: Cross section at a distance of 8 kpc from the solar system.
- Bottom: Profile for *(l,b)=(0º, 0º)*.

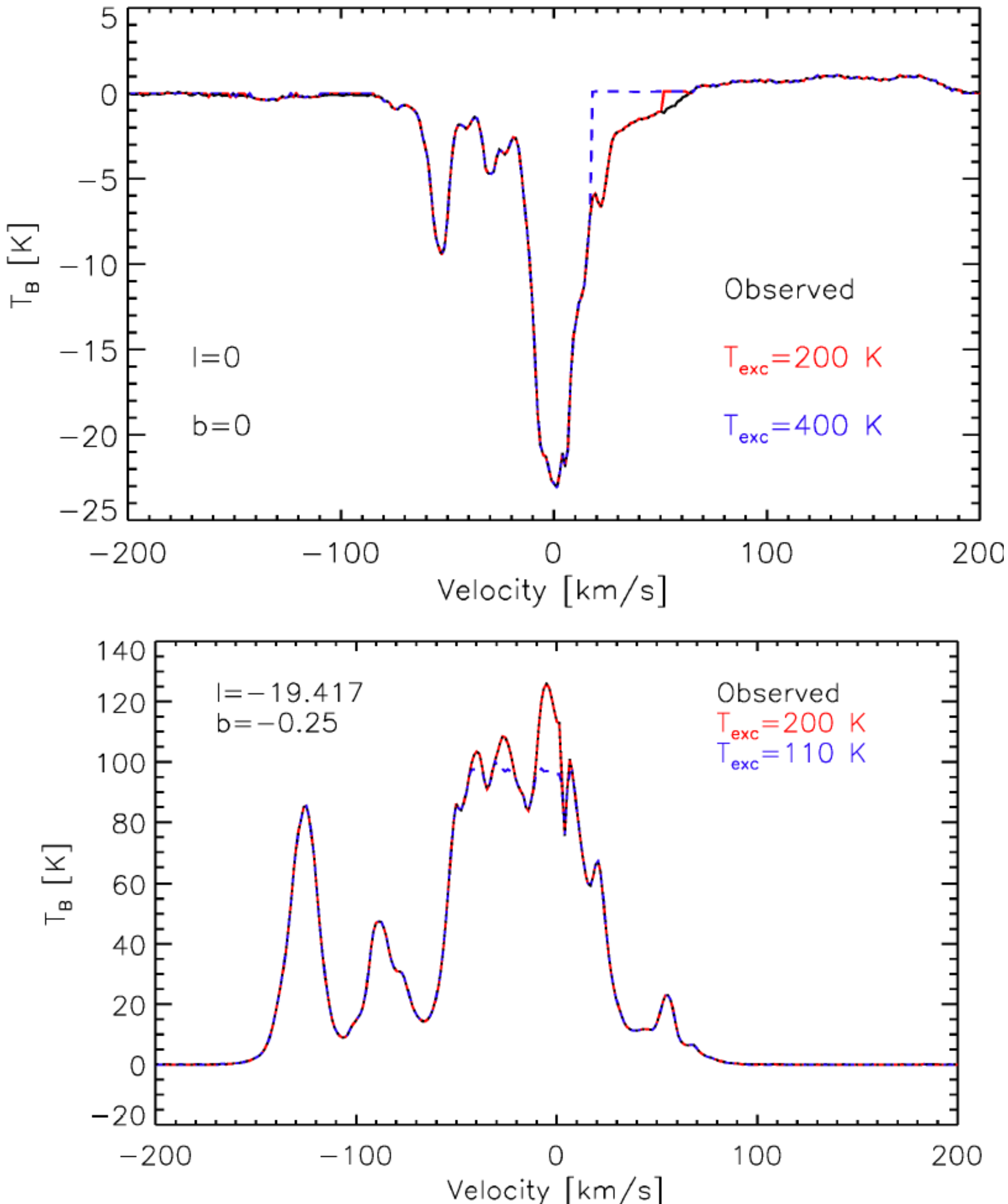




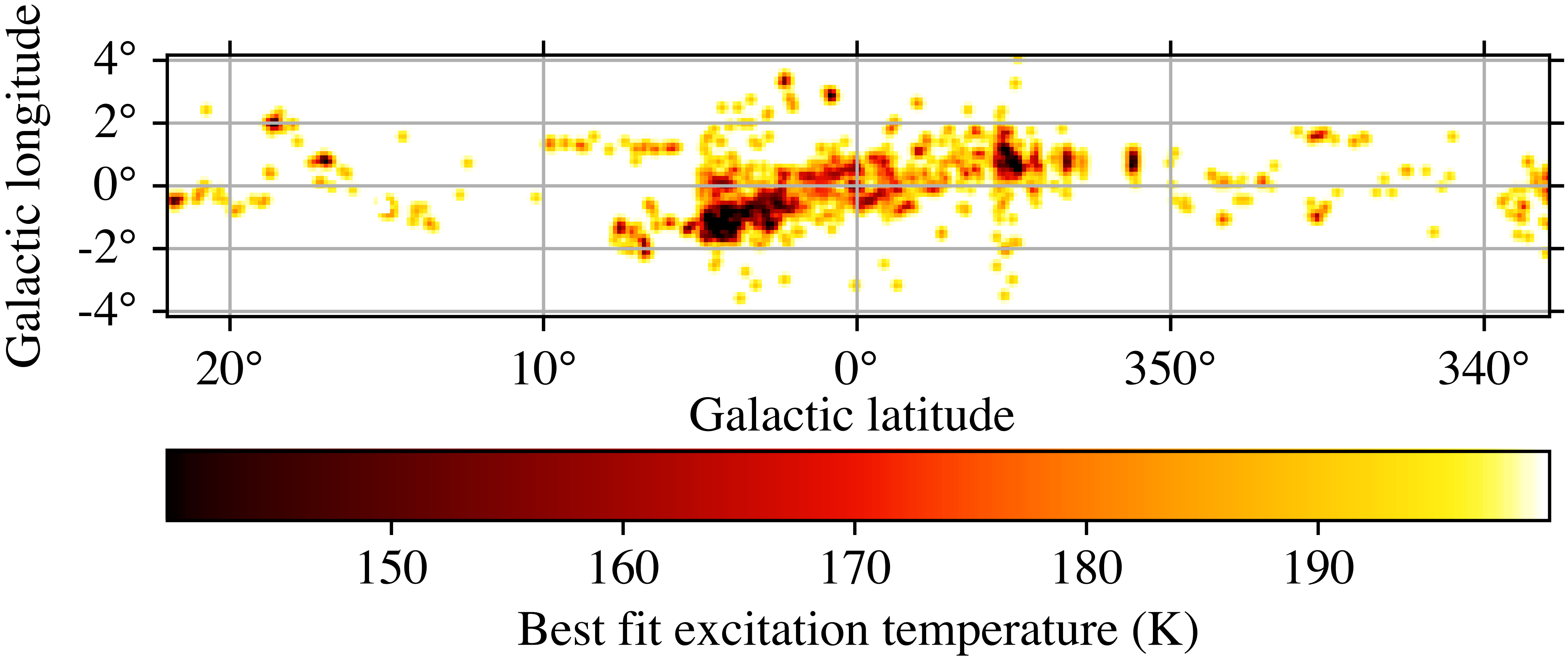
HI spectrum

- Comparison of the HI spectrum observed toward the Galactic Center (top panel).
- The absorption feature could be caused by cold gas immediately in front of the Galactic Center, whereas most of the gas clouds have temperatures of a few hundred Kelvin.

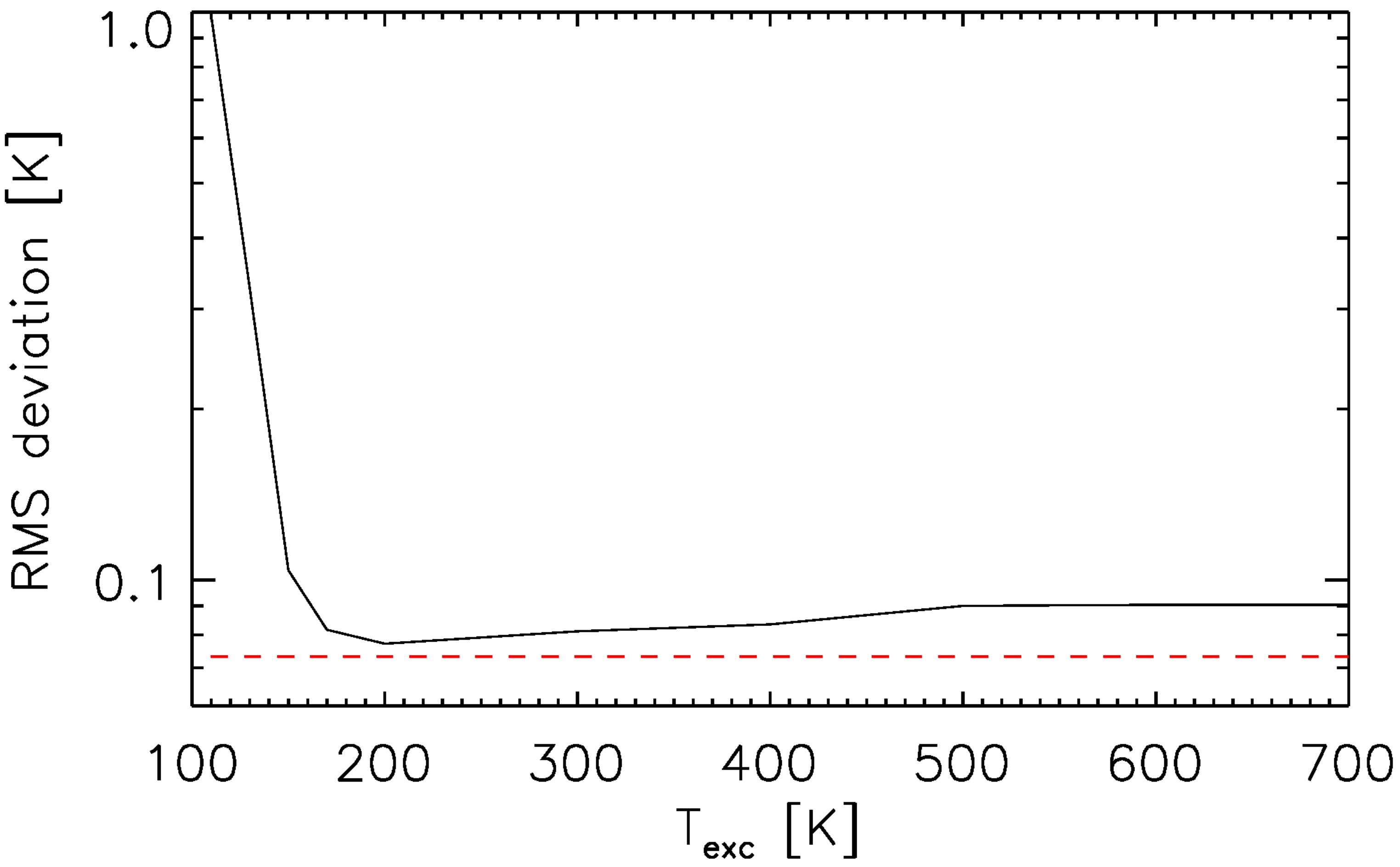
- A line of sight with a high intensity peak (bottom panel) needs larger T_{exc}.



Best-fit excitation temperature for each line of sight.

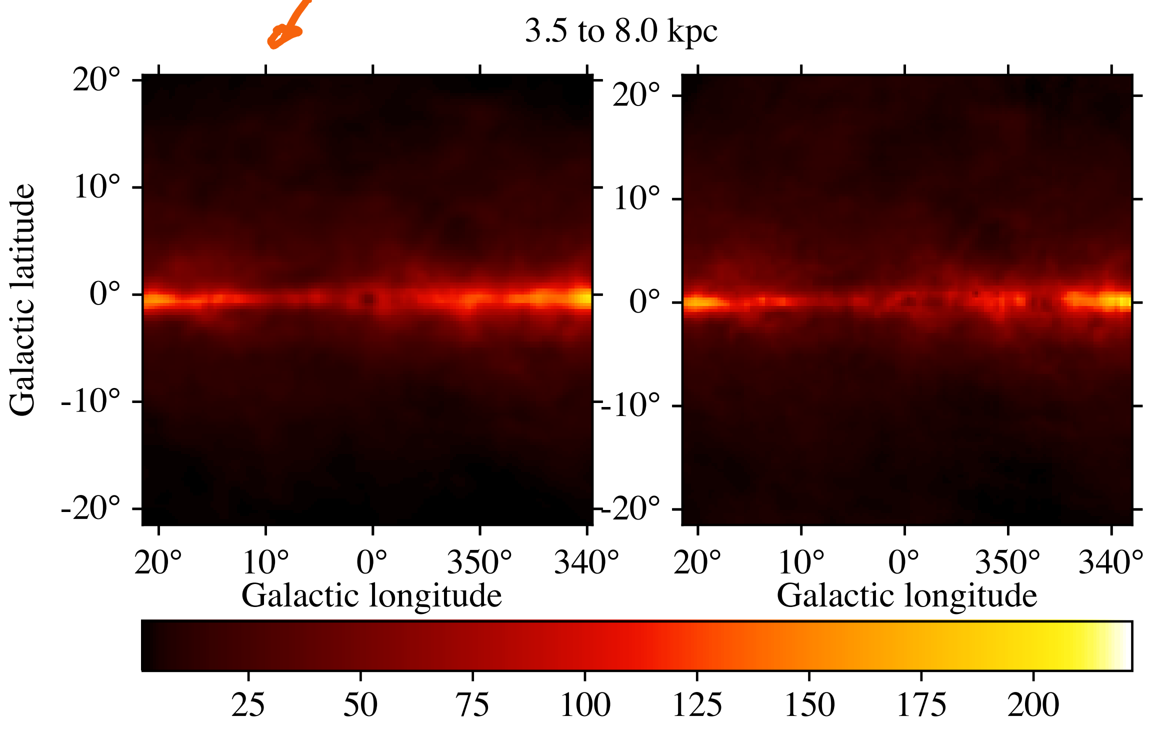


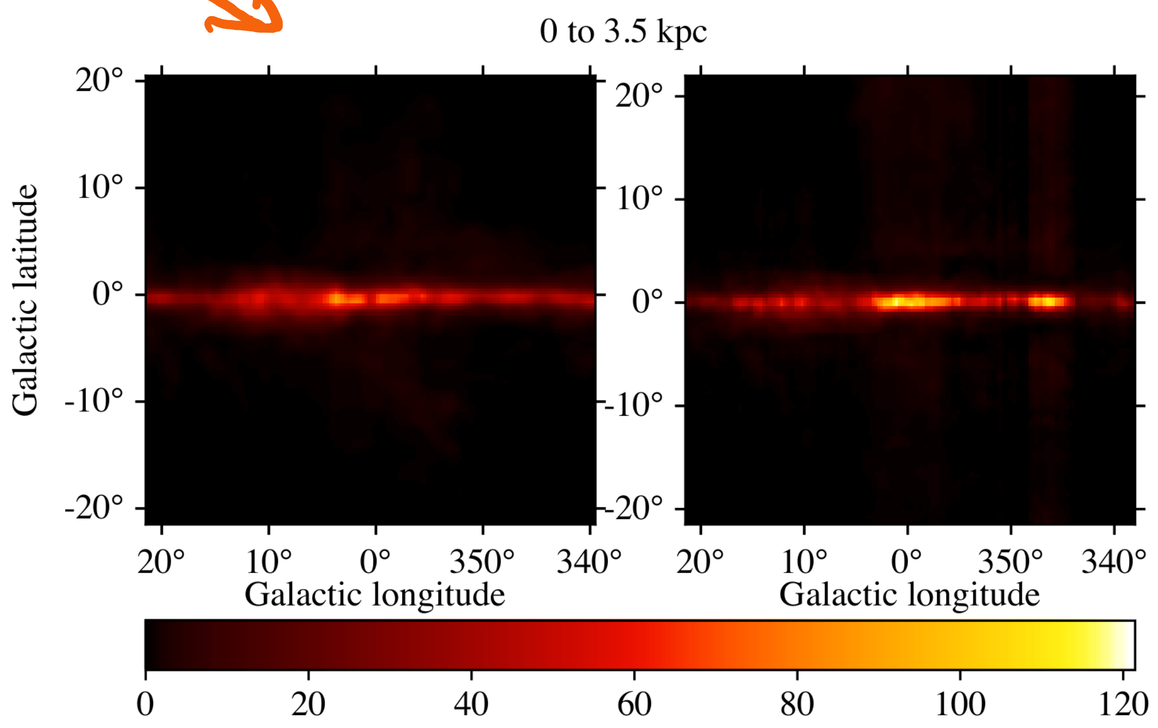
Averaged difference between the model spectra and the observed spectra



Neutral hydrogen templates

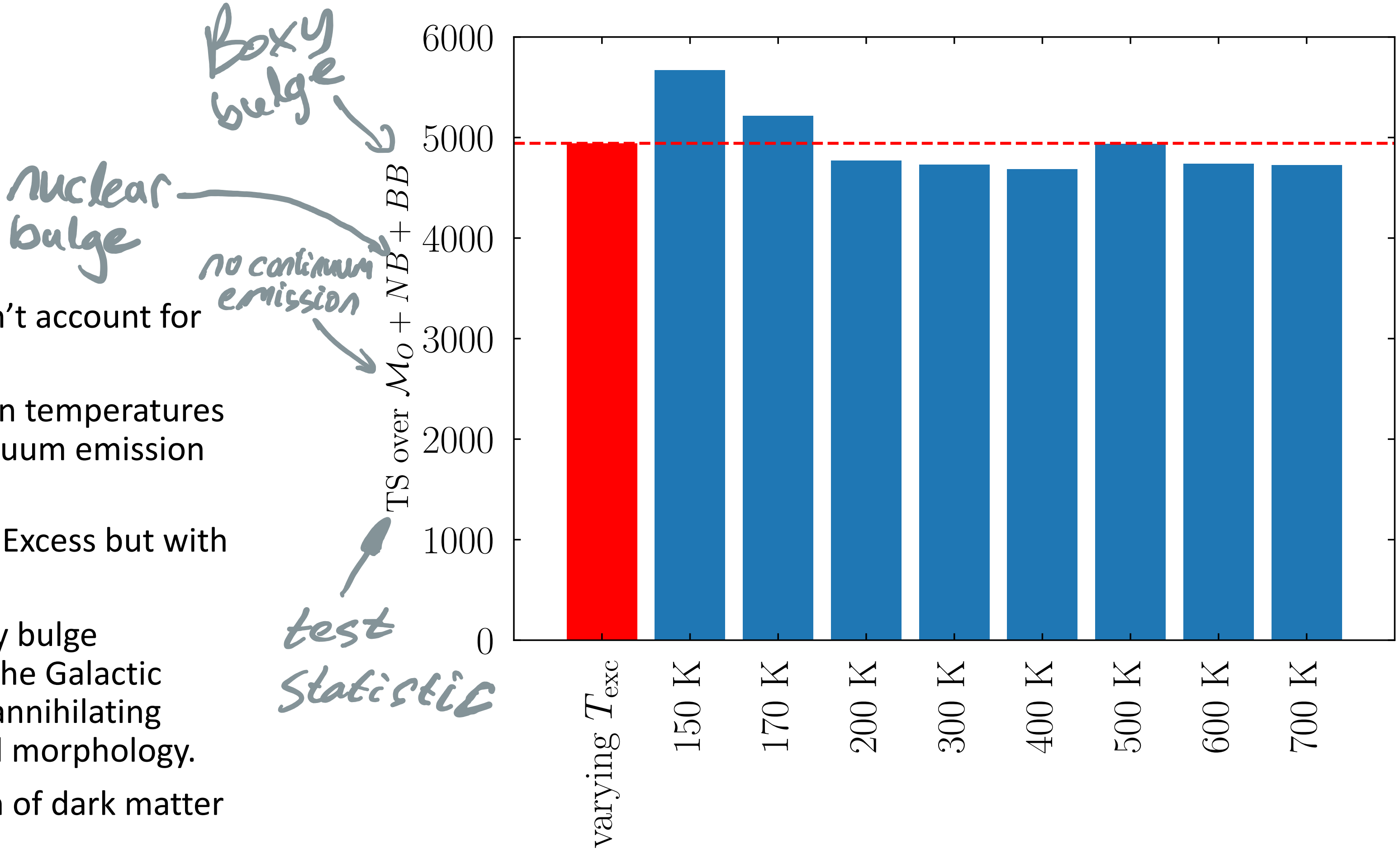
Continuum emission not included





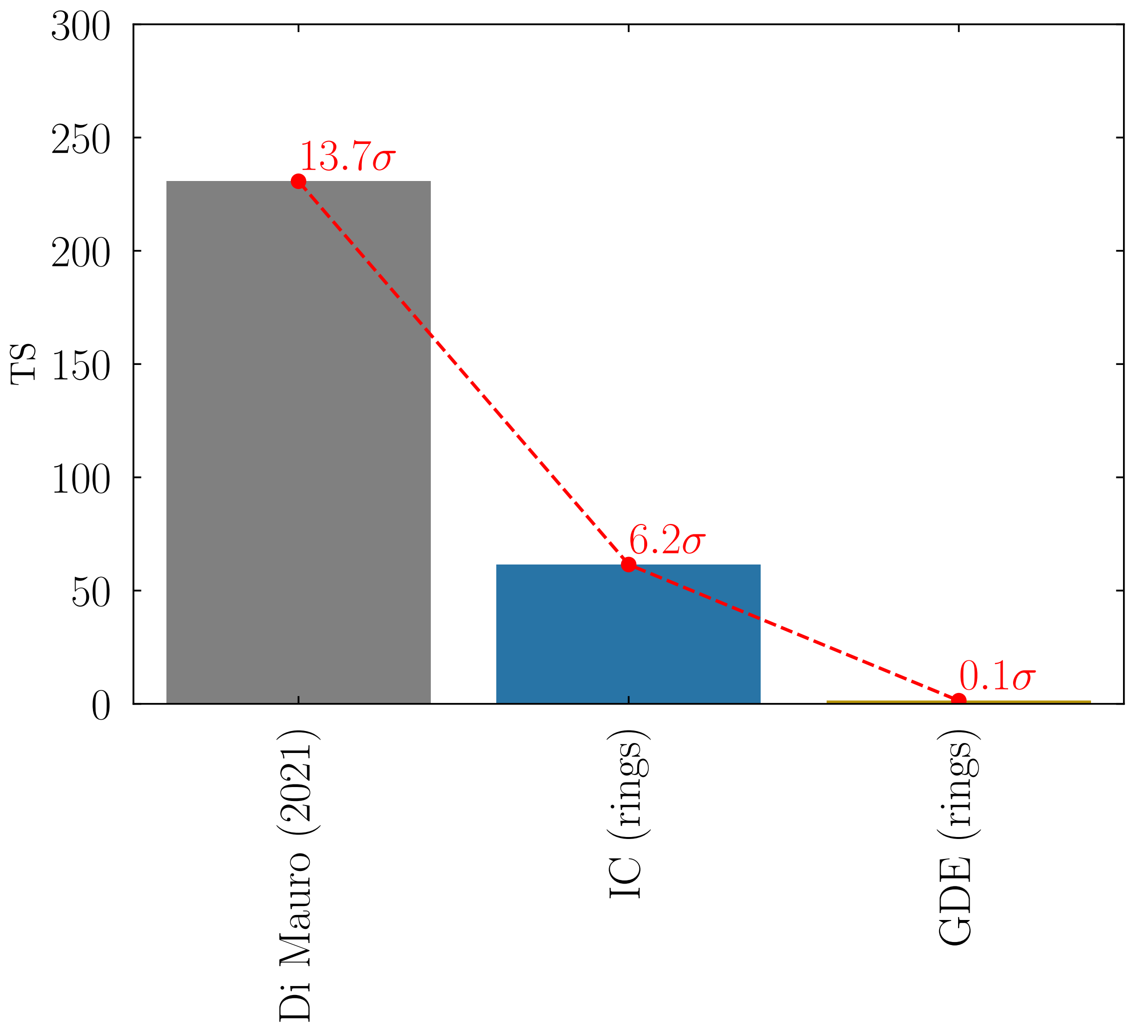
Fermi-LAT Likelihood

- Dashed line is for old method which didn't account for continuum emission.
- As can be seen, a wide range of excitation temperatures fit the Fermi-LAT data better once continuum emission is accounted for.
- We still find a significant Galactic Center Excess but with a slightly reduced significance.
- The unresolved MSP model with its boxy bulge morphology still provides a better fit to the Galactic Center Excess in comparison to the self-annihilating dark matter model with its NFW squared morphology.
- Once the MSPs are included the addition of dark matter only has a 0.1 σ sigma significance.



Di Mauro (2021) results

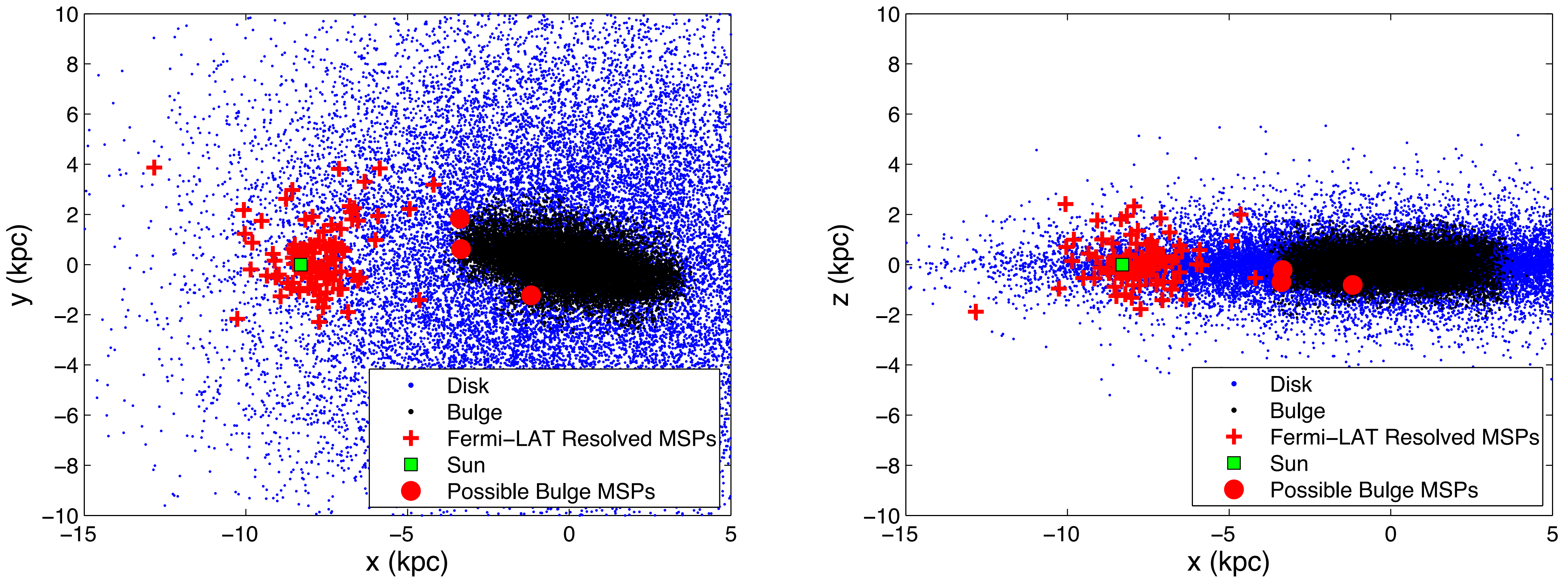
- The figure shows the significance of the dark matter model once the millisecond pulsar model has been included.
- The millisecond pulsar explanation only rules out the dark matter explanation once the intensity of the Inverse Compton (IC) and the rest of the Galactic Diffuse Emission (GDE) is allowed to vary non-parametrically.
- We are currently working on a project where we find that McDermott et al. (2022) have a similar problem in that they did not let the components of the GDE vary non-parametrically.



Conclusions

- Accounting for the continuum emission improves the gamma-ray Galactic Diffuse Emission modelling.
- We still find that the boxy bulge + nuclear bulge morphology of the millisecond pulsar model is preferred over the generalised NFW squared morphology of the dark matter self-annihilation model.
- Recent work by Di Mauro (2021) and McDermott et al. (2022) have different conclusions, mainly due to inflexible Galactic Diffuse emission and Inverse Compton models.

Distribution of Disk and Bulge Millisecond Pulsars (MSPs)



- See *Ploeg, Gordon, Crocker, and Macias, "Comparing the Galactic Bulge and Galactic Disk Millisecond Pulsars", JCAP12(2020)035* for more details.