

IPhT CEA-Saclay

Marco Taoso

**Towards an astrophysical
interpretation of the GC excess**

arXiv: 1507.06829

with D.Gaggero, P.Ullo, A.Urbano and M.Valli

TAUP 2015

Torino 7-11/09 2015



The Galactic Center GeV excess

There is convincing evidence that “standard” foreground models fail to explain the gamma-ray emission detected by Fermi-LAT from the Galactic center region.

Vitale and Morsell 0912.3828, Godenough, Hooper 0910.29998; Hooper, Linden 110.0006; Abazajian Kaplinghat 1010.2752; Hooper, Slatyer 1302.6589; Gordon, Macias 1306.5725; Huang,Urbano,Xue 1307.6862; Abazajian,Canac,Horiuchi,Kaplinghat 1402.4090; Daylan,Finkbeiner,Hooper,Linden,Portillo,Rodd,Slatyer 142.4090;Calore et al. 1409.0042; Calore,Cholis,Weniger 1409.0042; Fermi Collaboration: Fermi Symposium 2014, + ...

An excess is present with the following properties:

- Roughly spherically symmetric and centered at the GC.
- Extended at least up to 10 degrees.
- Spectrum peaks in the GeV range.

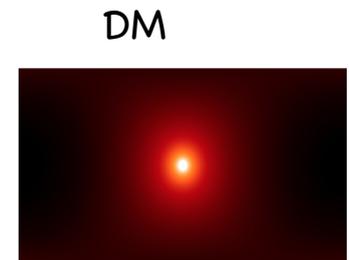
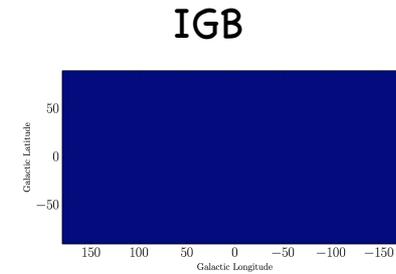
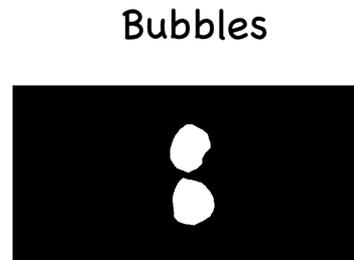
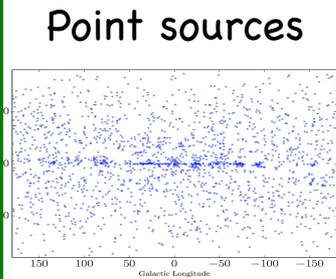
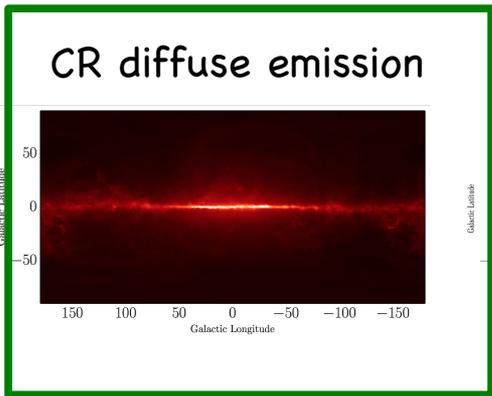
Strategy

We focus on a **ROI around GC** : $|b| < 20$ deg, $||l| < 20$ deg, $|b| > 2$ deg

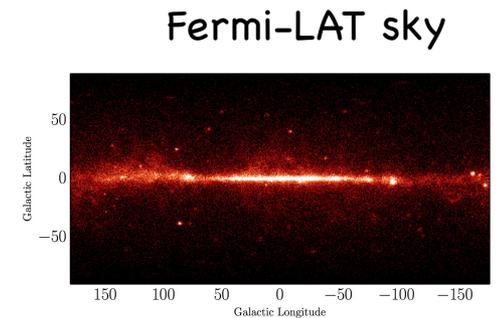
Perform template fitting analysis maximizing at each energy bin the following Poisson Likelihood:

$$-2 \ln(\mathcal{L}) = 2 \sum_i (e_i - o_i \ln(e_i)) + 2 \sum_i \ln(o_i!) + \chi_{\text{ext}}^2 :$$

Expected model counts Fermi-LAT counts

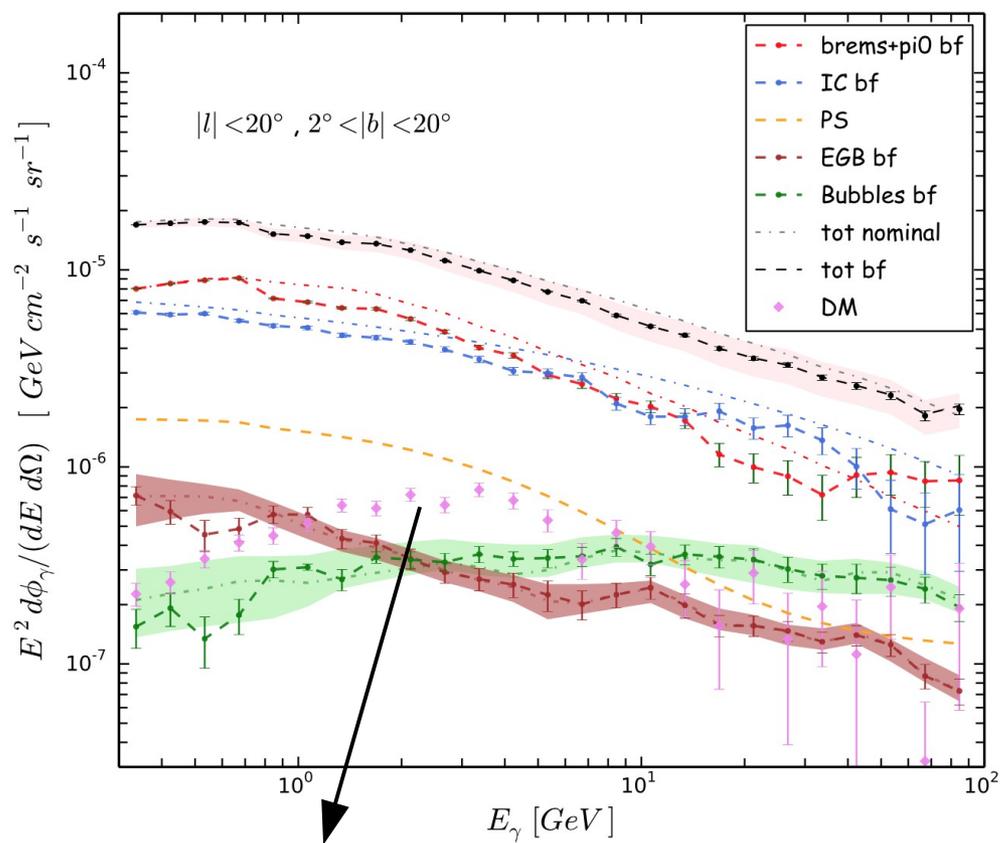


Models CR emissions: brem+pi0 from gas. IC from ISRF



"Standard diffuse" + DM

Adopting standard diffusion models, the presence of a DM template is favored by the fit by a large statistical significance.

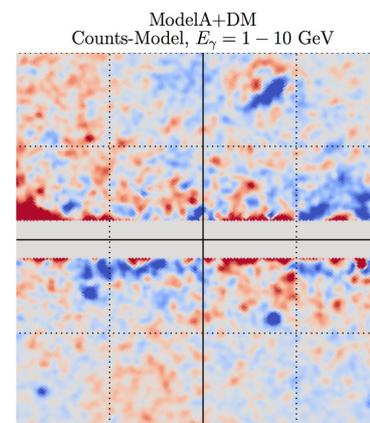
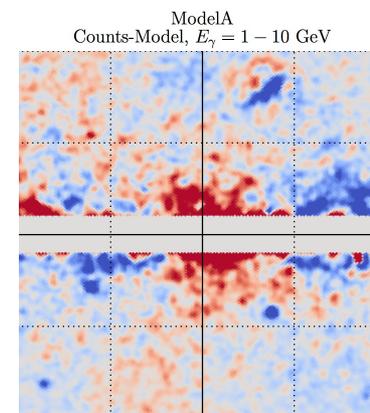


Bum-like DM energy spectrum

w/o DM

w/ DM

Data-Model

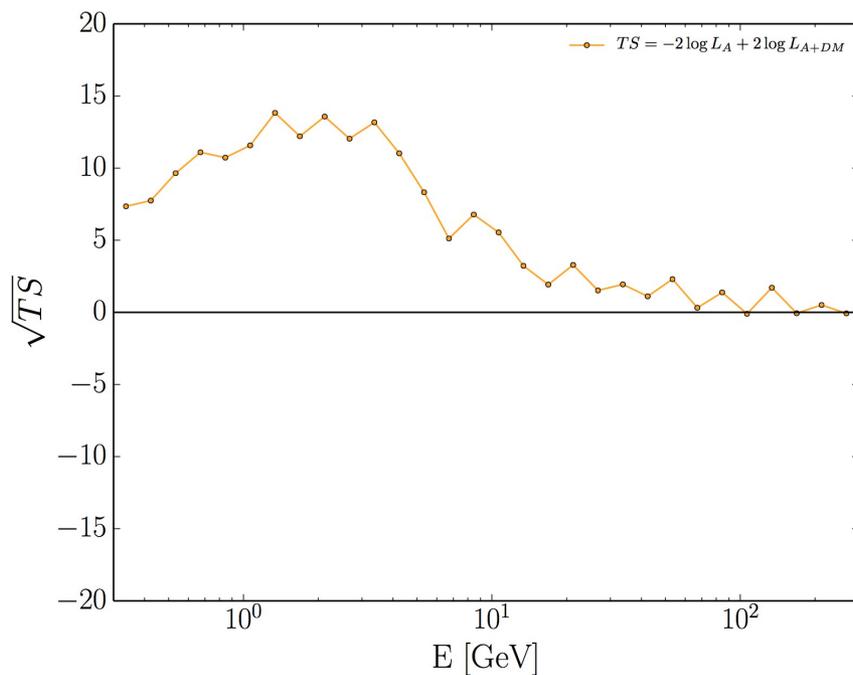


"Standard diffuse" + DM

Adopting standard diffusion models, the presence of a DM template is favored by the fit by a large statistical significance.

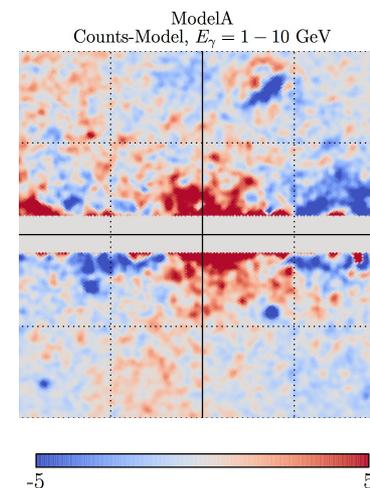
As statistical estimator we take the TS:

$$TS = -2 \log \frac{\mathcal{L}_{reference\ model}}{\mathcal{L}_{alternative\ model}}$$

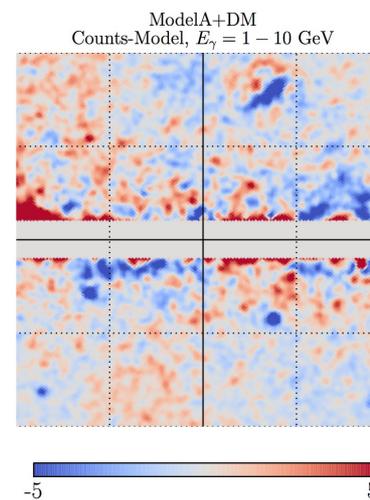


w/o DM

Data-Model

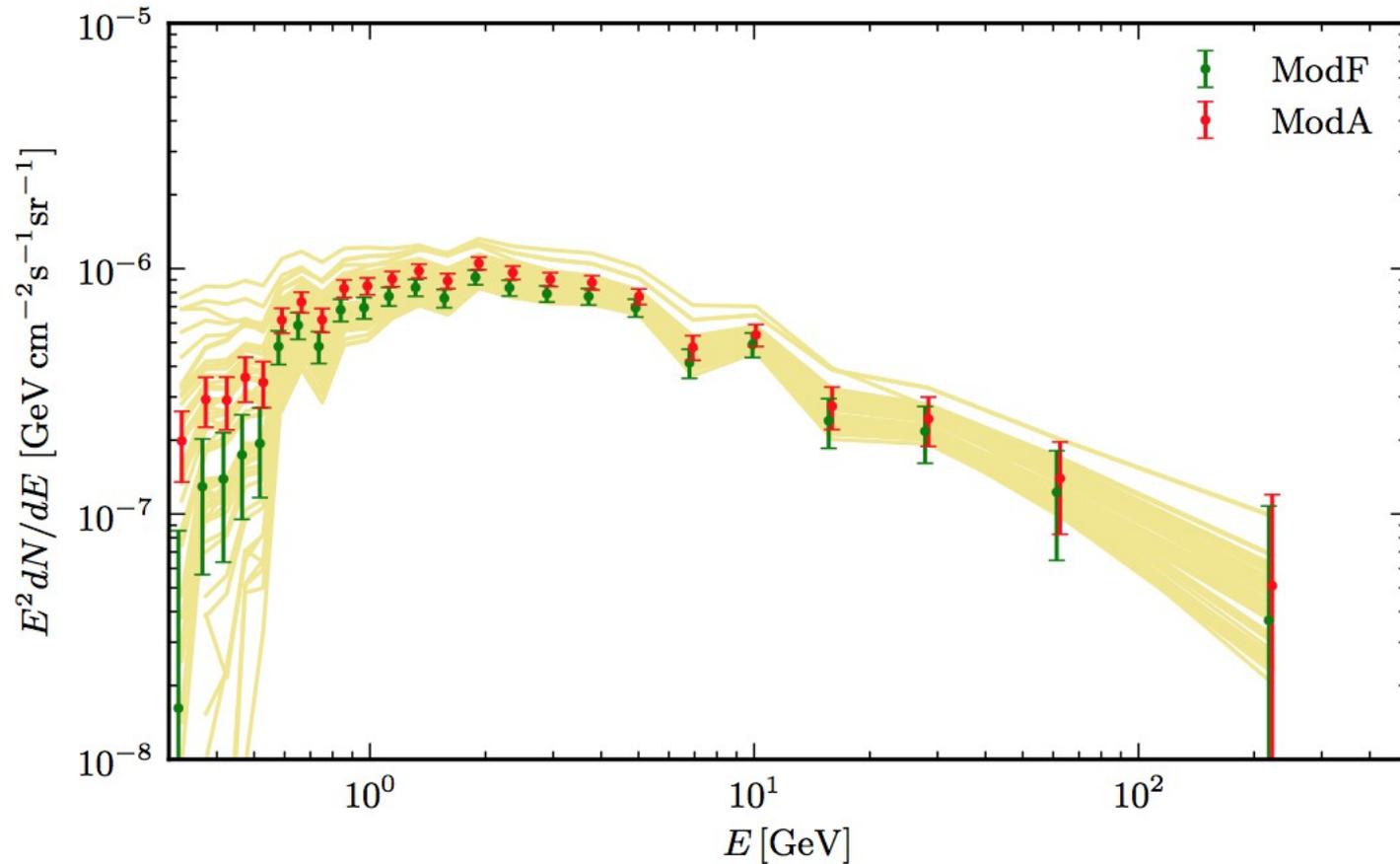


w/ DM



Systematics on diffuse emission

Systematics from modeling of diffuse emission + empirical systematics from data



Calore,Cholis,Weniger 1409.0042

See also Zhou, Liang, Huang, Li, Fan, Feng, Chang, 1406.6948

Aim of the work

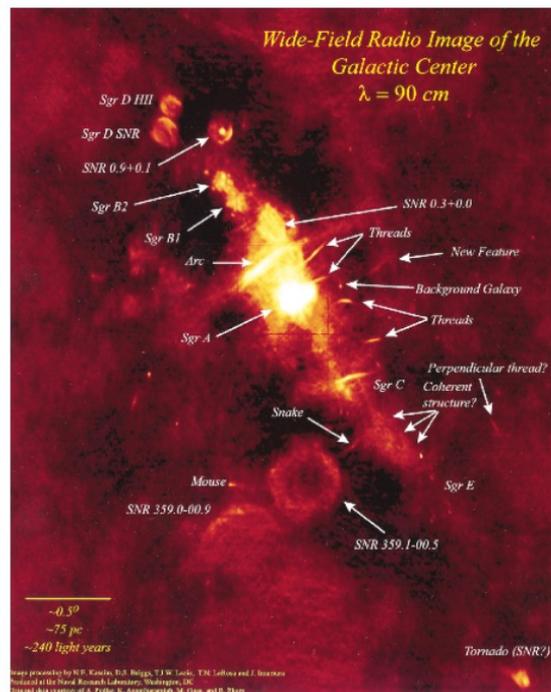
GC region very peculiar: large reservoir of gas in the 200–300 pc inner region, **large Star Formation Rate**, factor few hundreds larger than average galaxy rate (roughly few % of total SFR of the galaxy).

Standard diffuse gamma-ray templates are not optimized for the GC region and do not include those ingredients.

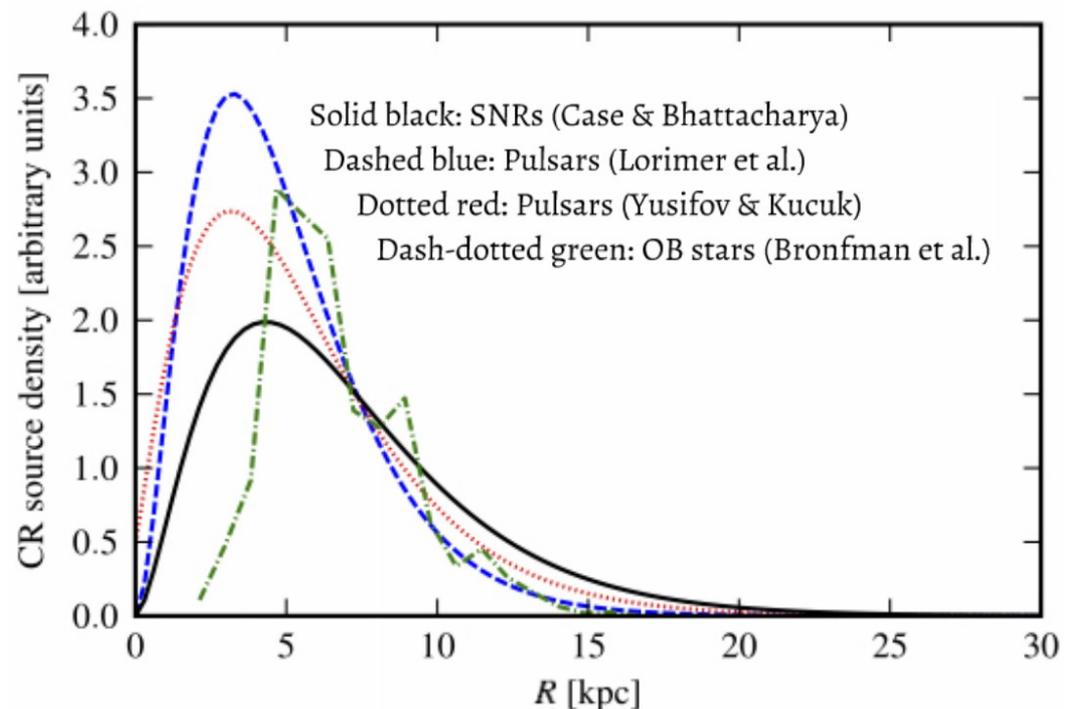
Ferriere et al. astro-ph/0702532, Figer et al. astro-ph/0208145, Longmore et al. 1208.4256

GOAL: study the impact of an enhanced SFR at the GC

90 cm observation of Central Molecular Zone



“Standard” CR sources distribution

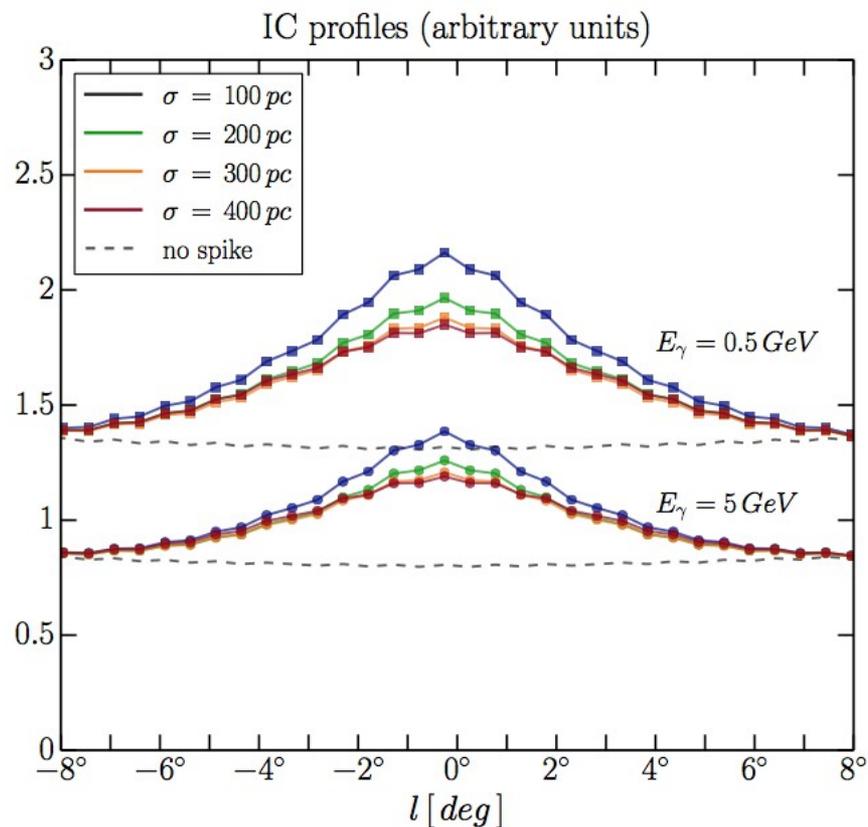
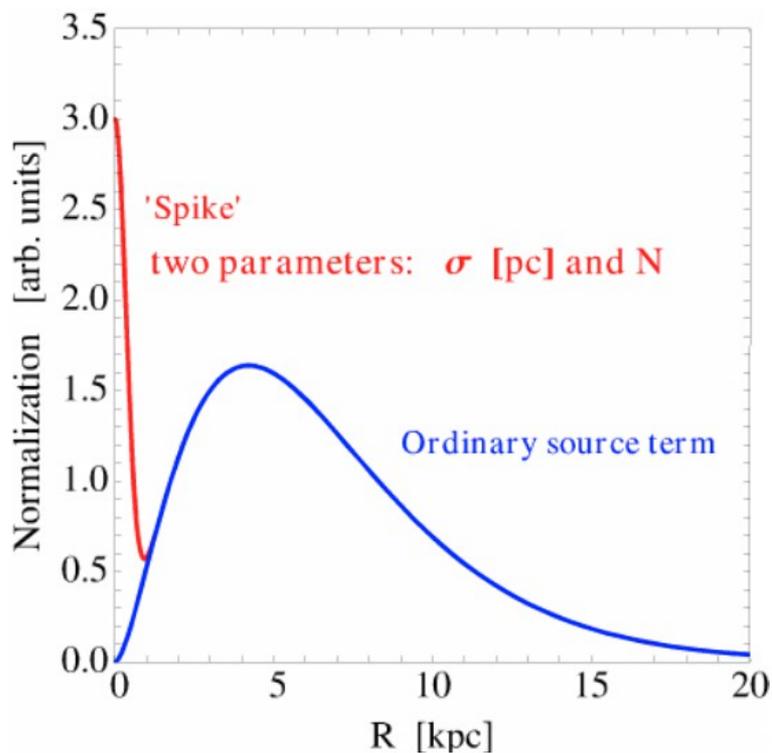


Increased CR source at the GC center

We add to the standard CR source distribution an extra term, modeled as a gaussian with a spatial extent around 100–400 pc.

Inverse Compton gives an extended gamma-ray emission (brem+pi0 more confined to the disk).

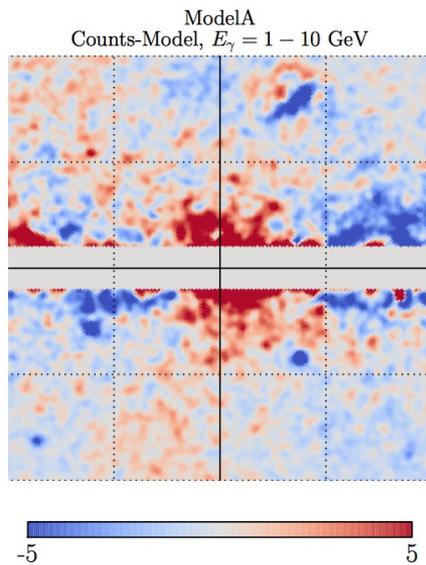
Important difference with DM: here the spectrum is that of overall IC emission while for DM is just an outcome of the fit.



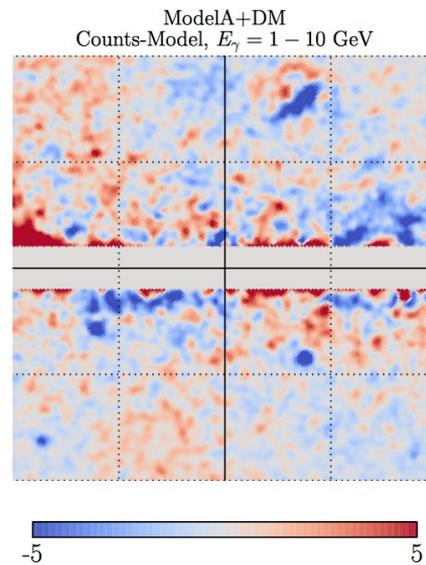
Residual counts

Most of the excess absorbed by the modified IC templates

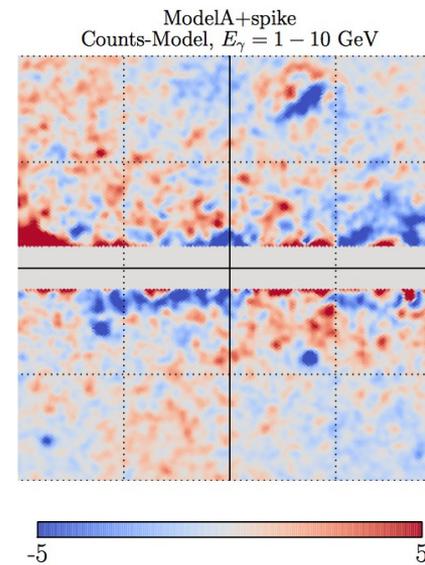
Standard diffuse



Standard diffuse+DM

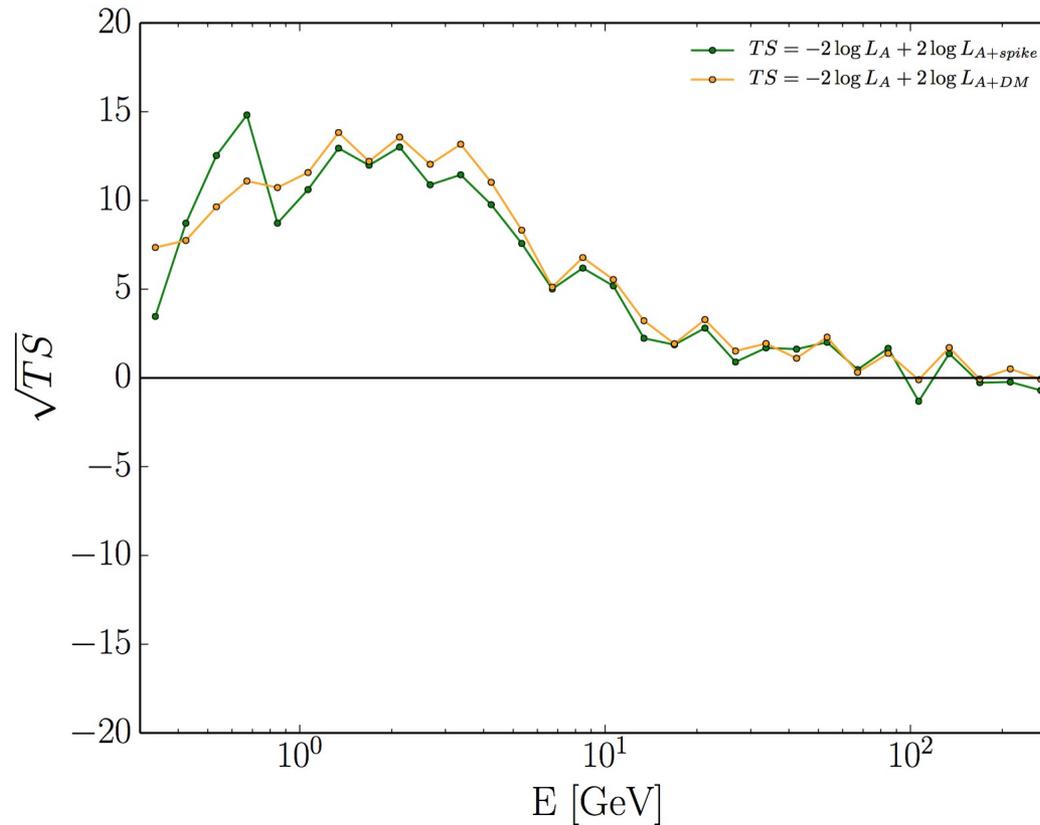


Model with modified source term



Improvement of the fit

$\sigma = 300 \text{ pc}$, $N = 2.2\%$

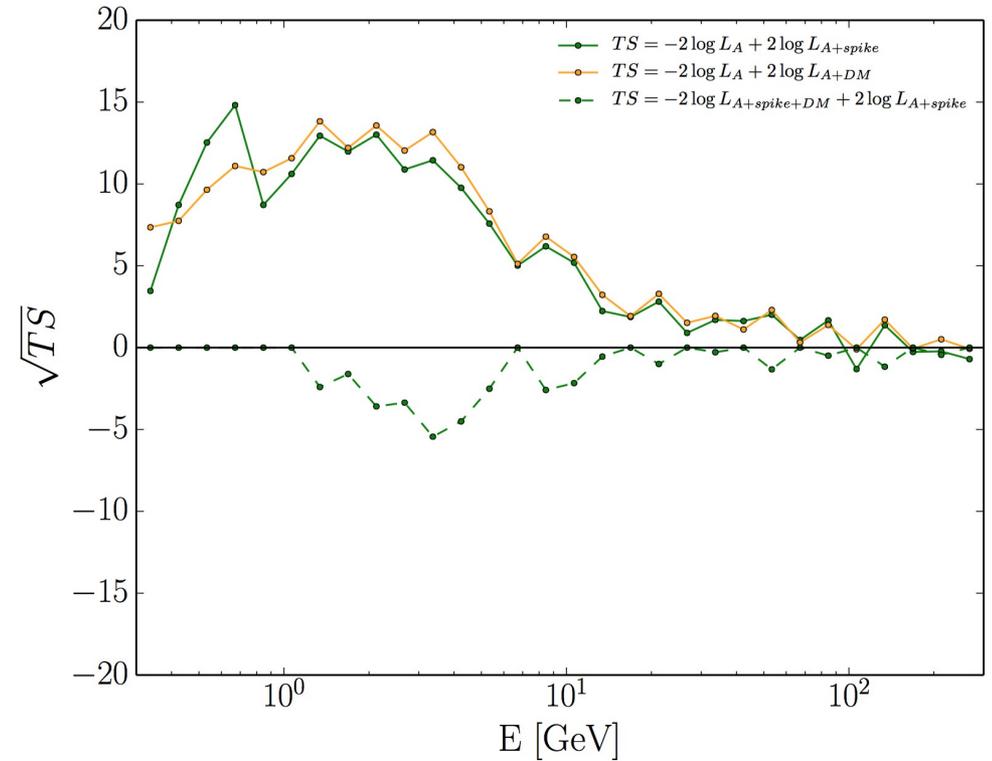
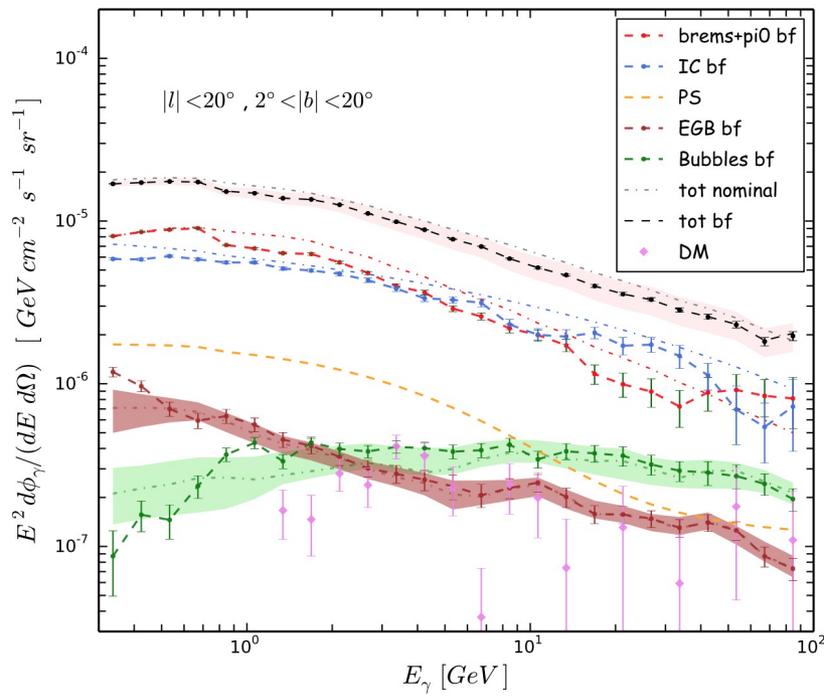


DM template and new CR model gives similar improvement.

Need source term at the center giving 2% of the total CR injection in the galaxy:
reasonable value according to current literature.

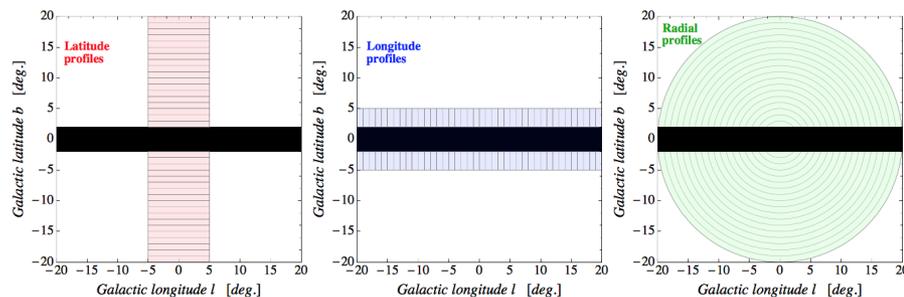
Add also DM template

Adding the DM template to the new diffuse emission model gives a moderate improvement of the fit in few energy bins.

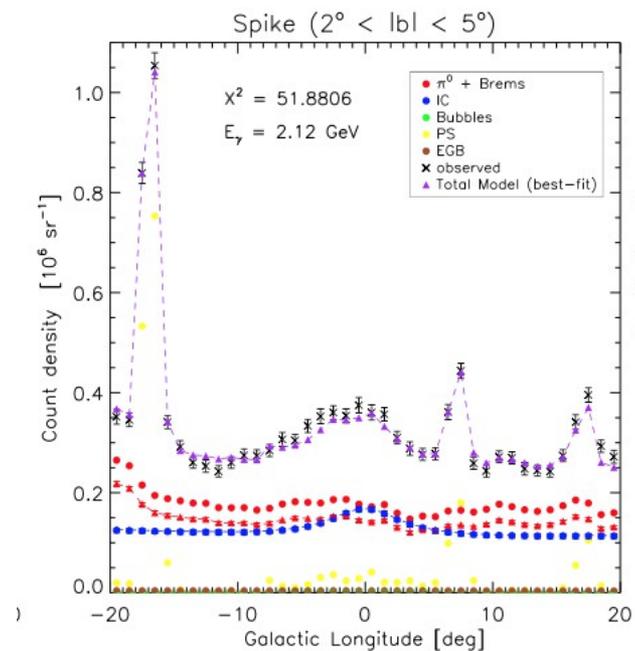
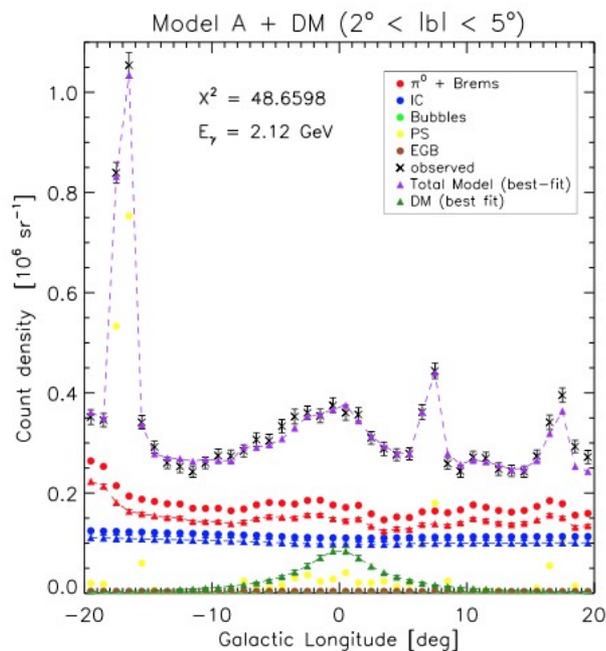


Analysis of gamma-ray profiles

Inside the ROI compute the counts profiles in radial-longitudinal-latitude directions and compare with the outcome of the fit performed in the entire ROI.



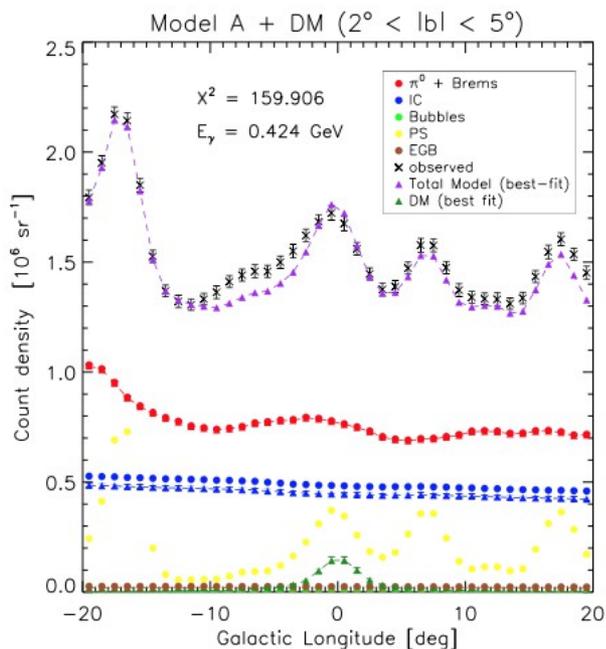
Longitude profile. Energy bin centered at 2 GeV



Analysis of gamma-ray profiles

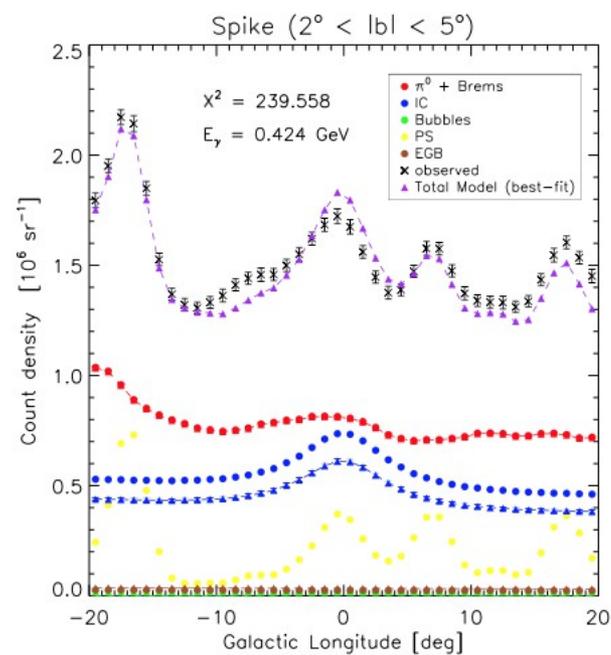
In the first energy bins the model with the extra source slightly overshoots the data at low latitudes.

Standard diffuse +DM



0.4 GeV

Modified diffuse model



Analysis of gamma-ray profiles

Overall good fits of the gamma-ray profiles inside our ROI for mid-large energies.

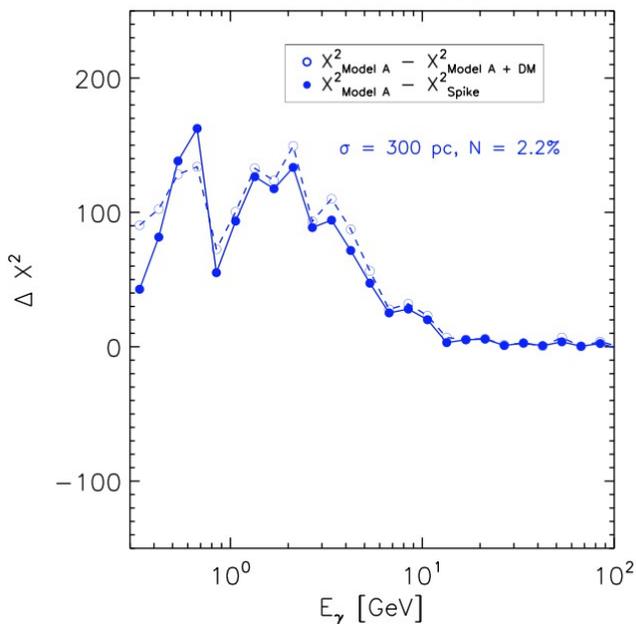
Agreement not optimal in the lowest energy bins.

Remind: the spectrum is correlated with the overall IC! For DM is just data-driven.

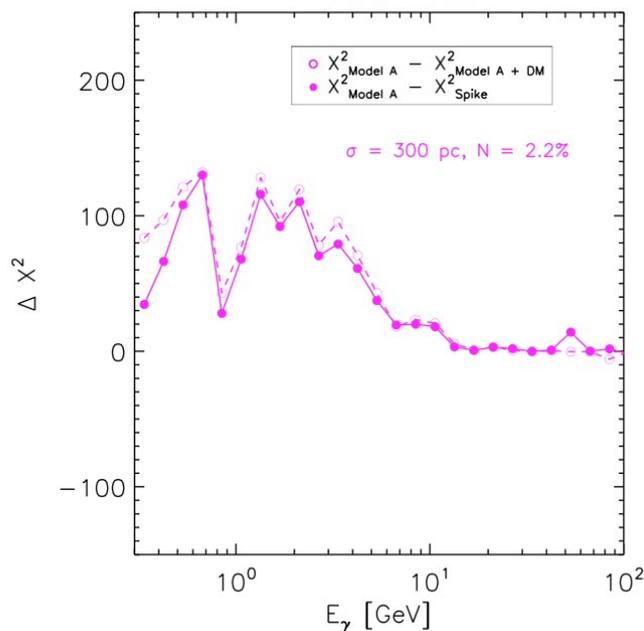
Caveats:

- systematic uncertainties in LAT data are particularly relevant at those energies.
- propagation of CR at those low energies in the GC is not under control.

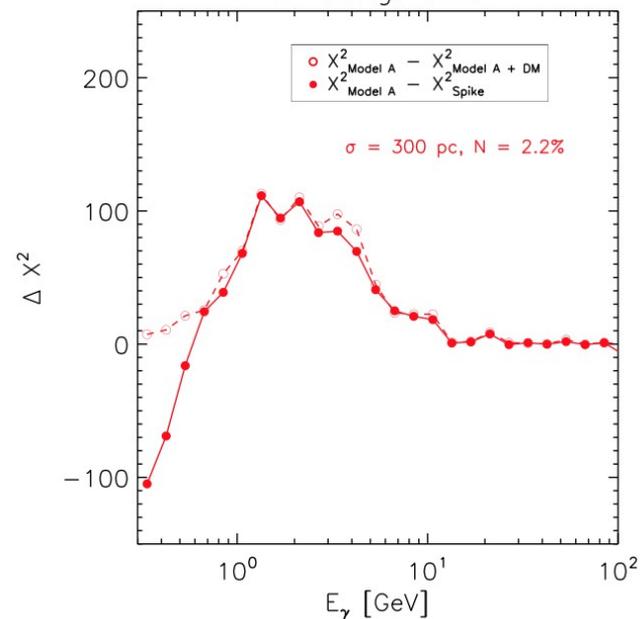
χ^2 Radial Test



χ^2 Lat. Test



χ^2 Long. Test



Conclusions

- We have considered an enhanced CR source distribution at the GC, motivated by observations.

For realistic values of the parameters, the IC emission associated with this ingredient has morphological and spectral features very similar to that of the GC excess.

Most of/all the excess can be explained.

- Some features of the excess are not well described in this scenario, at least with the same level of precision as in the case of the DM interpretation, see the low energy spectrum.

Systematic uncertainties can partially explain this. Likely, this model is an oversimplified picture of the emission from the few-hundreds pc of the galaxy.

TAKE HOME MESSAGE: the emission from the inner galaxy is far to be well understood and it can affect at large extent the analysis of the diffuse emission, thus the searches for DM signals.

We need to obtain a more realistic description of the inner galaxy.

THANKS

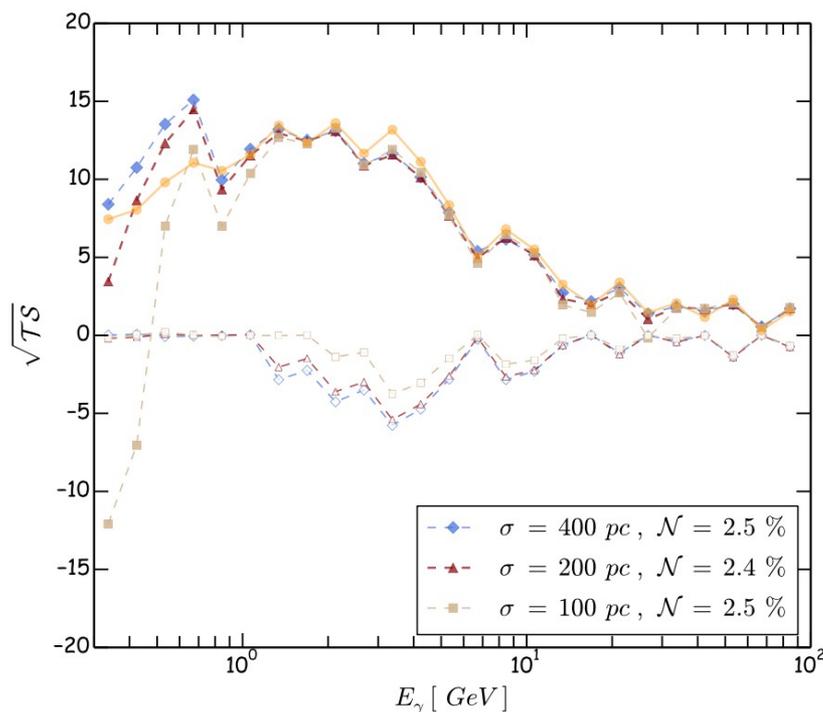
Spatial extension of CR source at the center

We test different sizes of the source term at the center of the galaxy.

Results: for enhancements inside 200–400 pc and with a CR injection around 2% of the total, we obtain similar results than before.

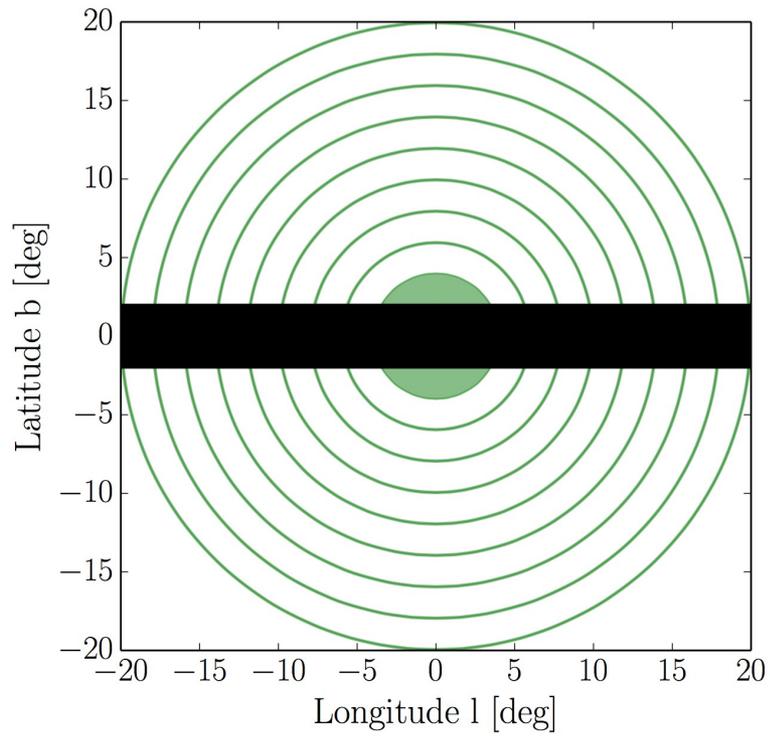
The new ingredient produces a large improvement of the fit and reabsorbs (at least partially) the GC excess.

For smaller spatial extents the IC template is too narrow.

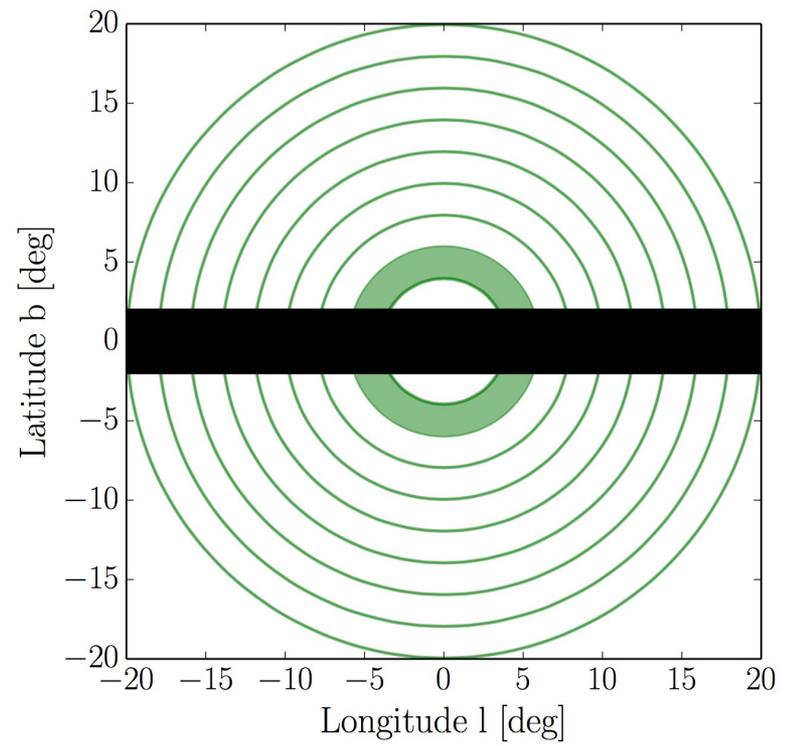


Subregions

2-4 deg



4-6 deg



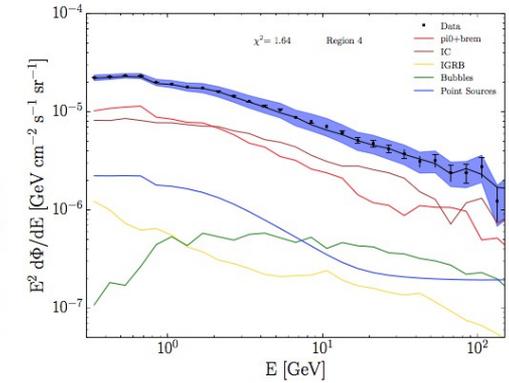
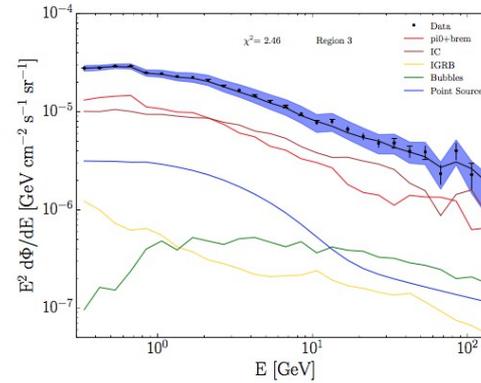
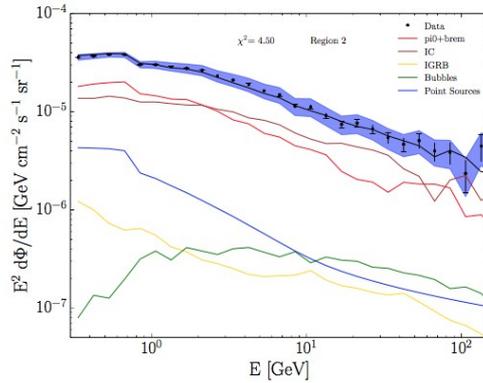
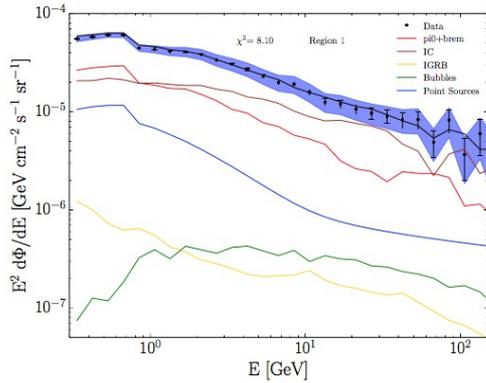
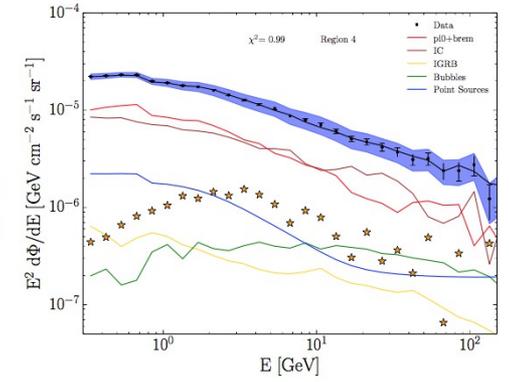
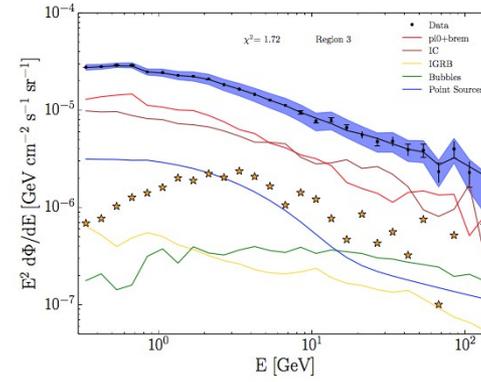
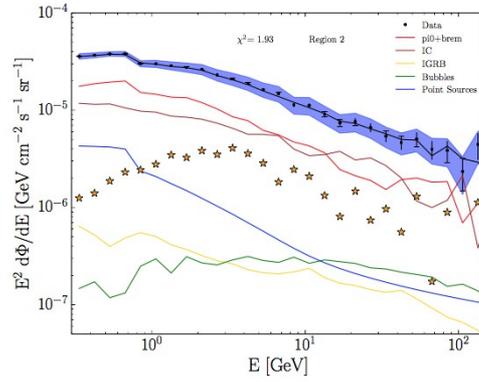
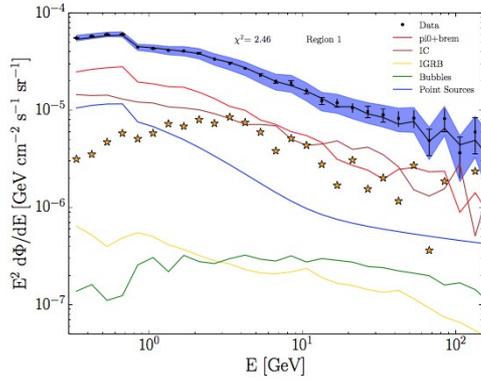
Subregions

2-4 deg

4-6 deg

6-8 deg

8-10 deg



First row: "Standard" diffuse + DM

Second row: diffuse with modified CR term