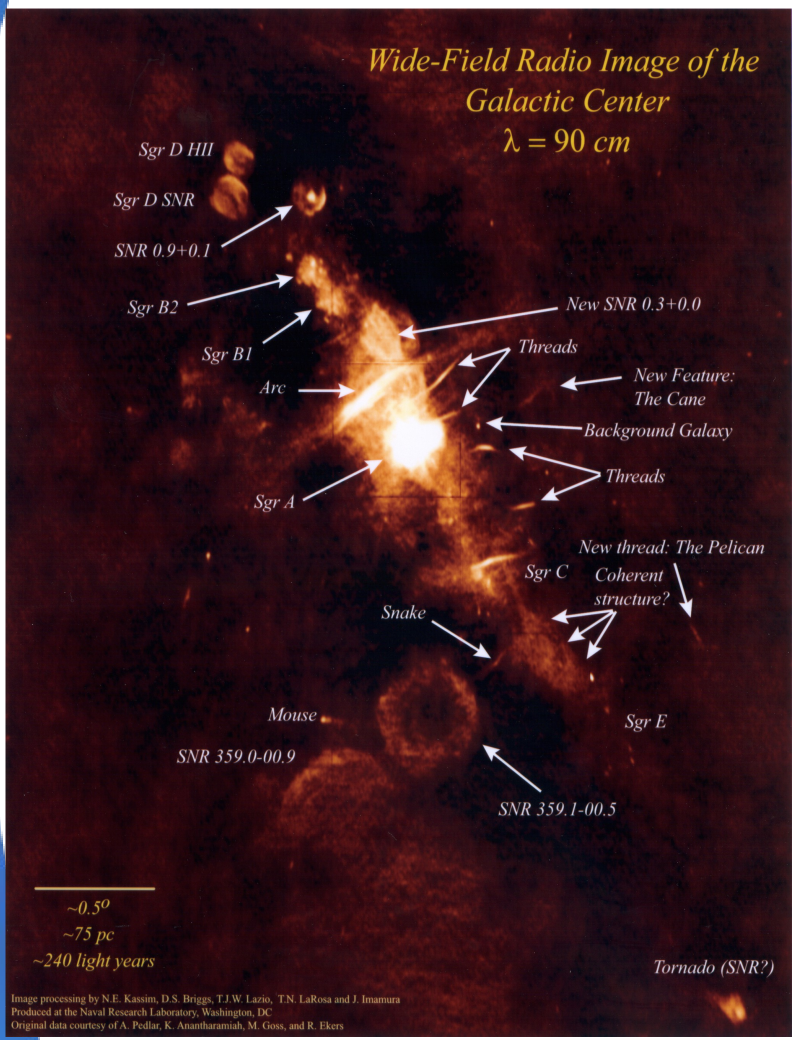
Origin of the high energy emission from the Galactic Center



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D.Malyshev (ISDC),
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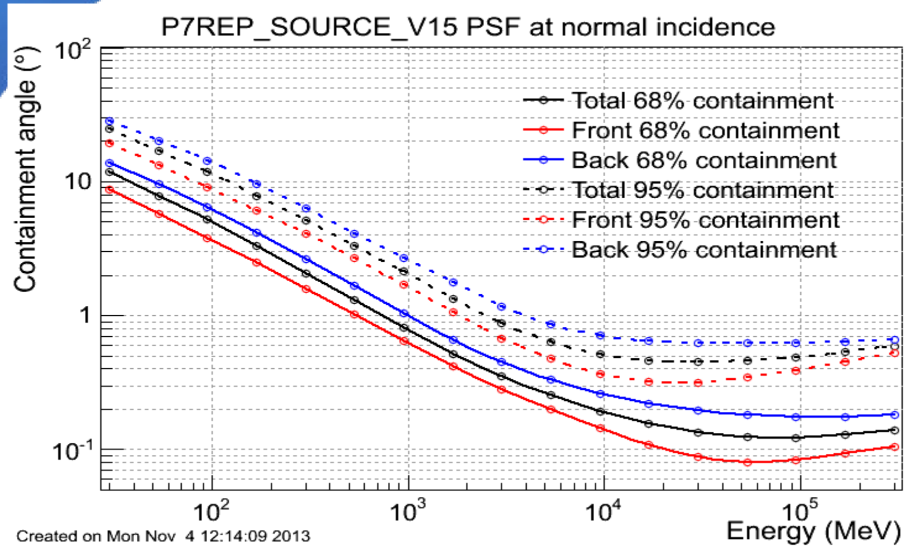
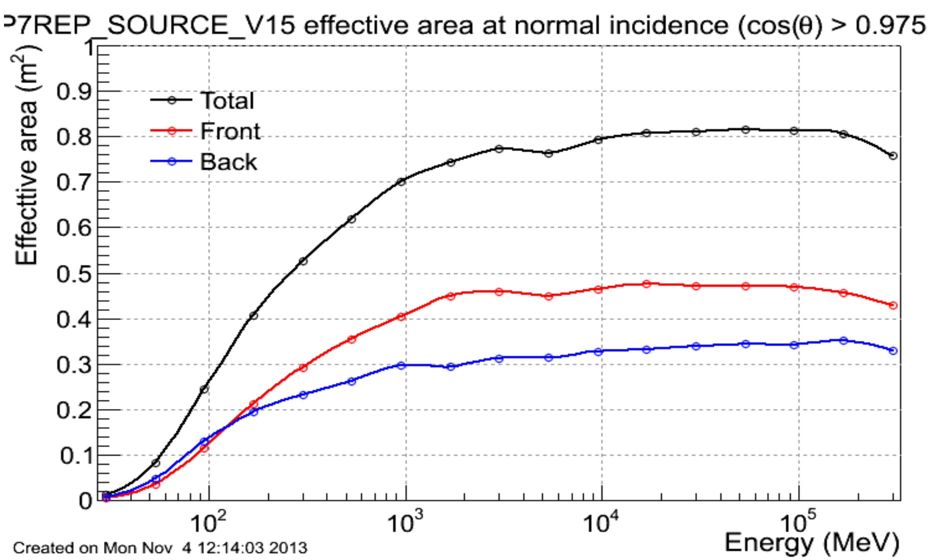
The X-ray Universe 2014, June 18, Dublin

FERMI/LAT Performance

Origin of the high energy emission from the Galactic Center

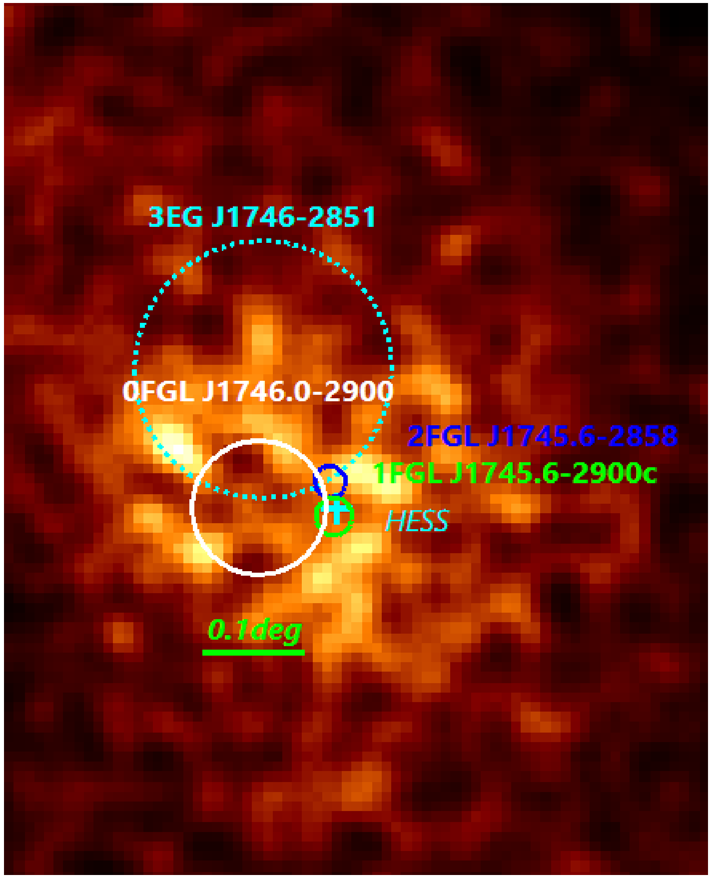




- Operates at 30MeV — 300GeV energies
- Field of view 2 sr
- Peak effective area ~8000cm^2 (4.5 times larger than EGRET)
- Energy resolution <10%
- Source localization <0.5' (1sigma radius for flux 10^{-7} cm^{-2}s^{-1} at high |b|)

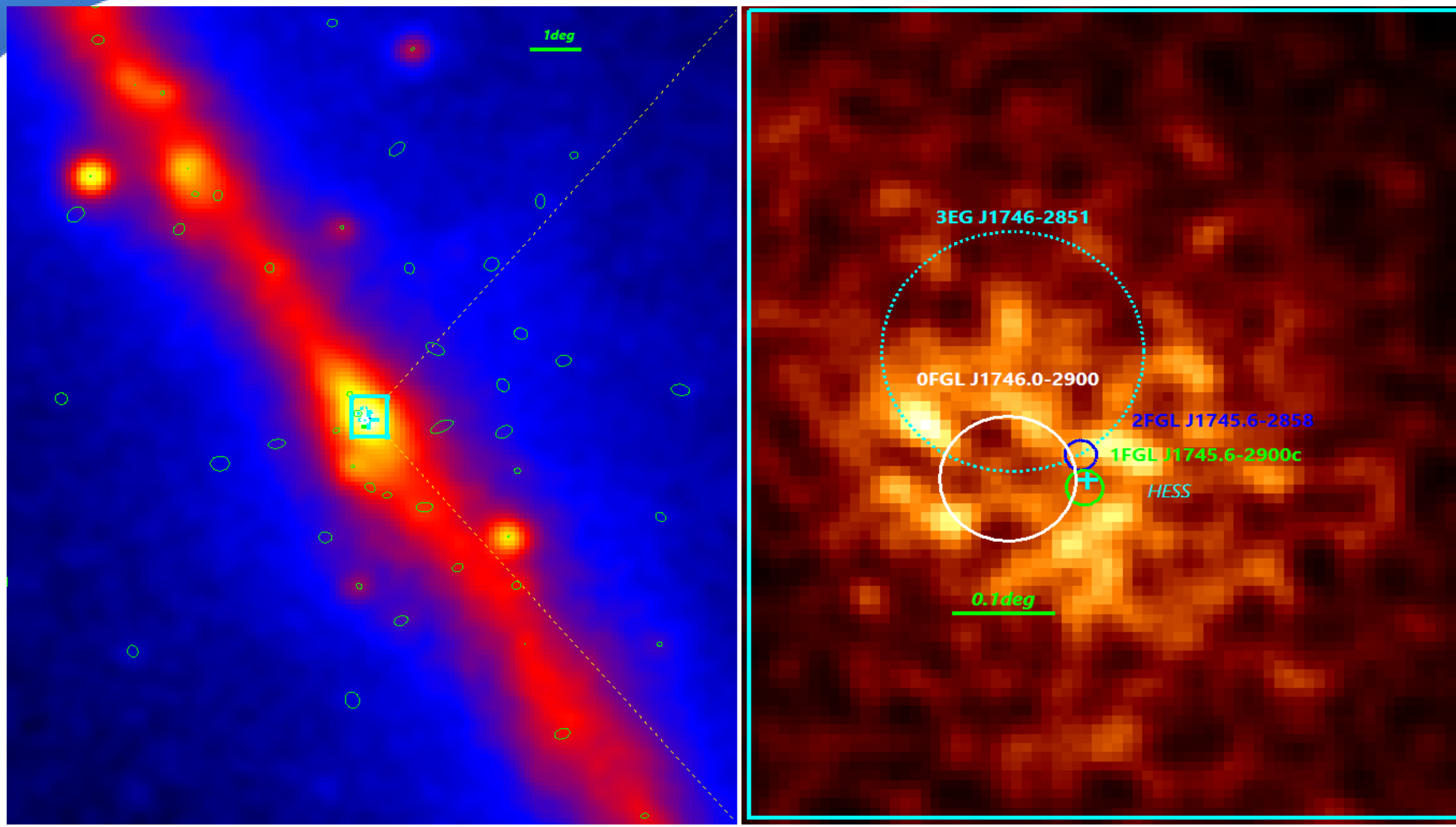
➔ Broad PSF (>5° at ~100MeV)

➔ Strong astrophysical diffuse background at low |b|...



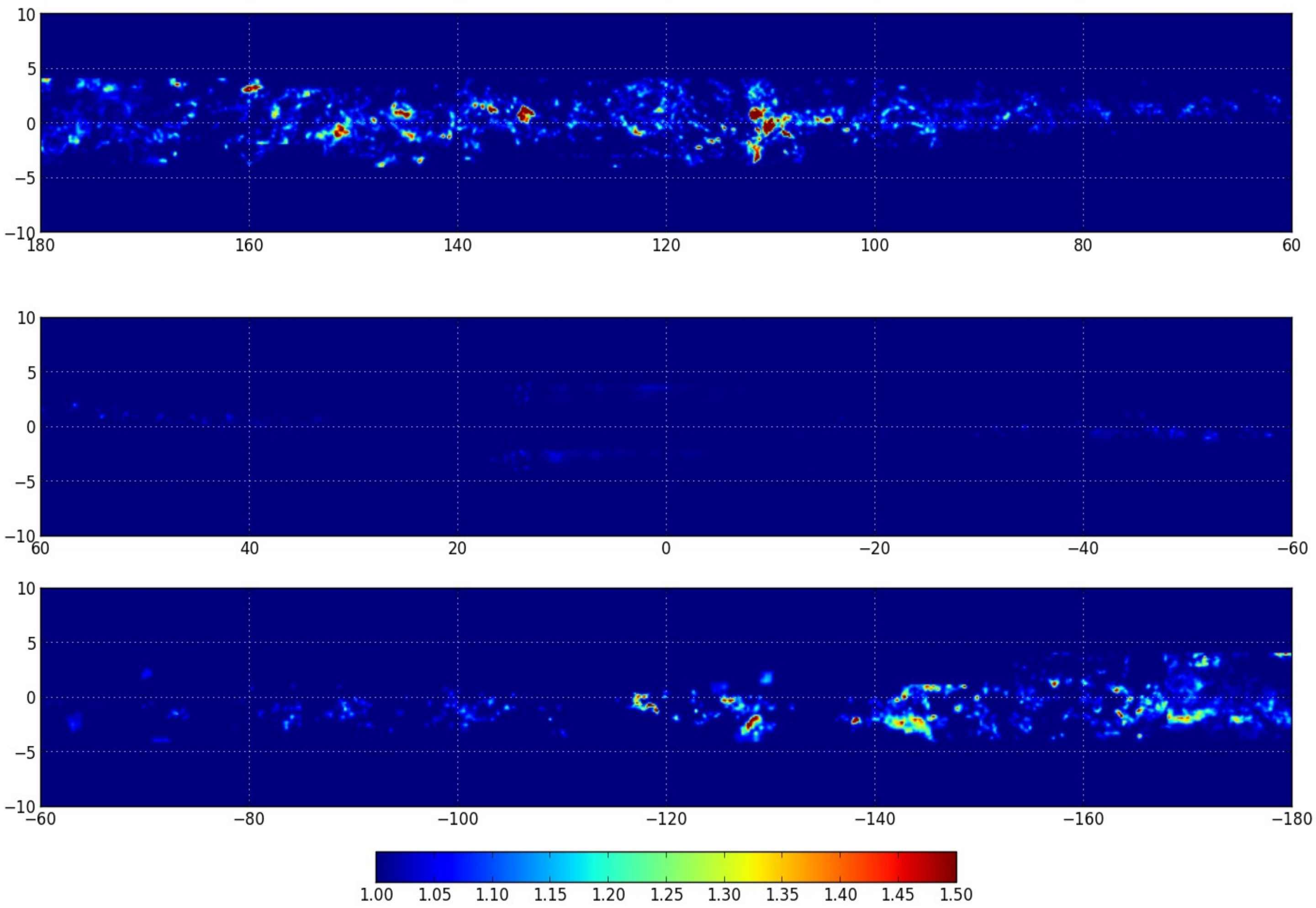
Complicate data analysis:

- Point source characteristics depend on the diffuse model used in their extraction.
- Some diffuse regions (like gas clouds regions) can be confused with point sources.
- Concetration of sources in the galactic central region creates confusion. It is difficult to distinguish between point sources and diffuse emission.
- The determination of flux/spectrum of the source is accomplished with a fitting procedure – maximum likelihood optimization technique.



- At low (~100MeV) energies the region in which the fitting should be performed should exceed ~10deg radius. The number of free parameters for the fit can reach few hundreds – extensive use of computer time. The time for fit convergence – few weeks.

FERMI/LAT overview



- Note, that the diffuse background model can be changed significantly with the new software release and may affect the result.

Fermi/LAT observations of GC

The first results of *Fermi* observations of the GC were presented by J.Cohen-Tanugi on behalf of *Fermi* -LAT collaboration during the 2009 *Fermi* Symposium (11 month).

In 2010 Chernyakova et al. analyzed 25 months of the data. On the base of 1FGL catalog they presented the updated GC spectrum and propose a model of diffusion of CRs in GC ambient medium which allowed to explain the observed spectrum.

Leptonic (e.g. Hinton & Aharonian 2007, Kusunose 2012) and hybrid (Guo 2013) models were also recently proposed in order to explain the observed GC spectrum.

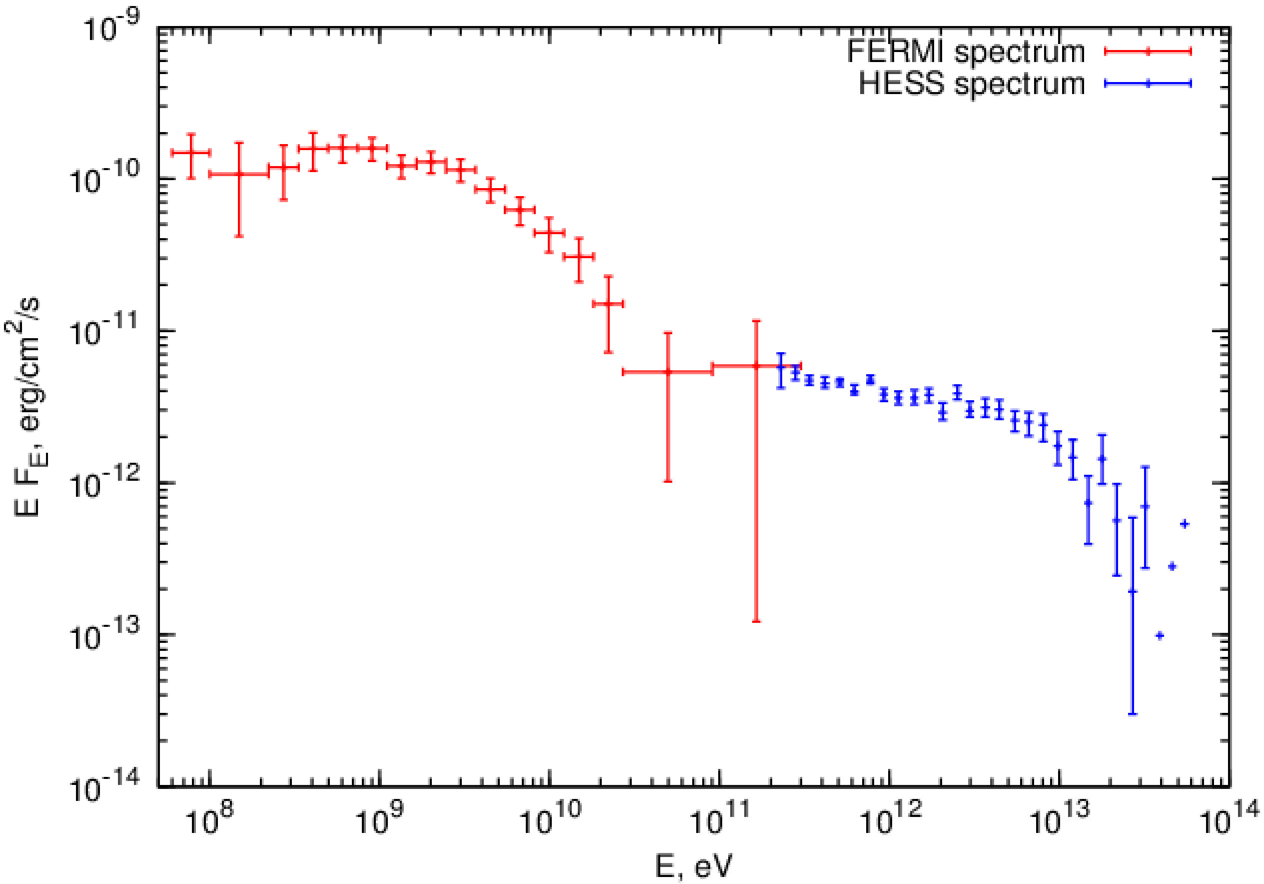
In recent works of Yusef-Zadeh (2013), Abazajan (2014), authors used 2FGL catalog sources to obtain the GC spectrum. In the last paper authors argue on diffuse nature of GC FERMI/LAT source, that can be a signature of DM decay.

HESS observations of GC

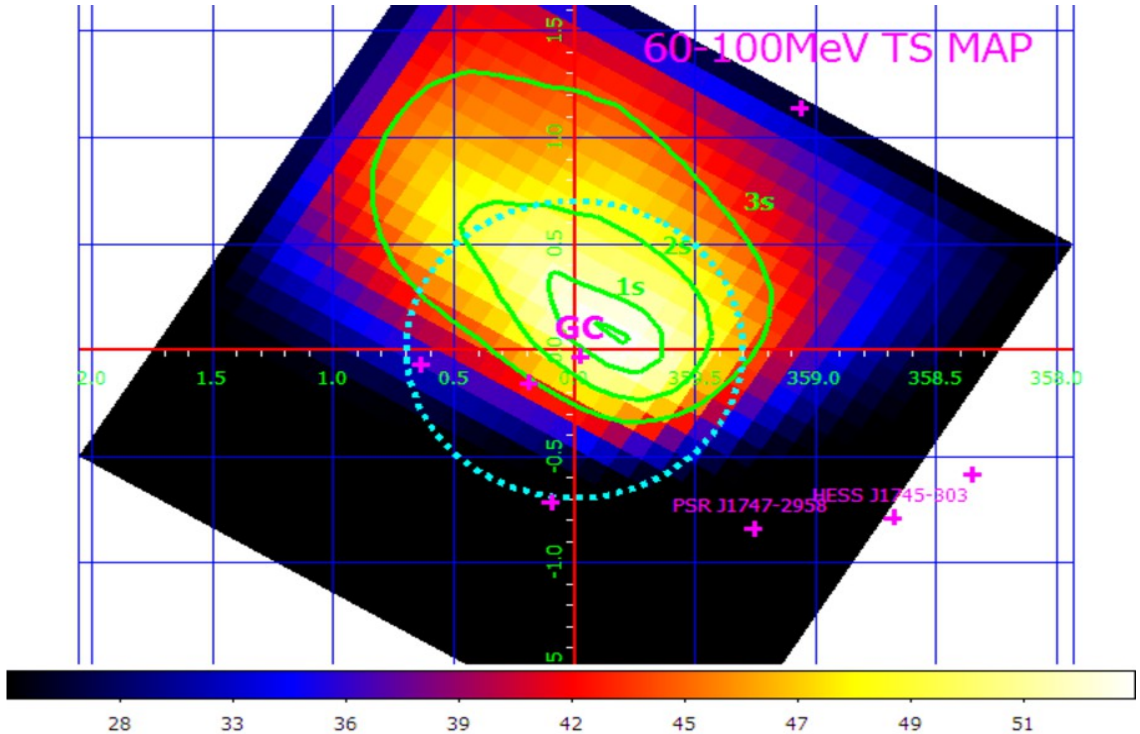
Despite the fact that the GC TeV gamma-ray source is a point-like object for the HESS (Aharonian et al., 2004), the 0.07° PSF of the instrument and the extremely crowded and complex nature of the region does not allow the unambiguous identification of the source(s) of gamma-ray emission.

With the latest data, however, it is possible to place the center-of-gravity of the TeV point source within the central 6" of the Galaxy(Acero et al. 2010), leaving only a handful of possible sources:

- the central black hole itself, Sgr A* (Aharonian & Neronov 2005),
- a plerion discovered within the central few arcseconds (Hinton & Aharonian 2007)
- a putative “black hole plerion” produced by the wind from Sgr A* (Atoyan & Dermer 2004),
- the diffuse10 pc region surrounding Sgr A* (Aharonian & Neronov 2005; Ballantyne et al. 2007, 2010).

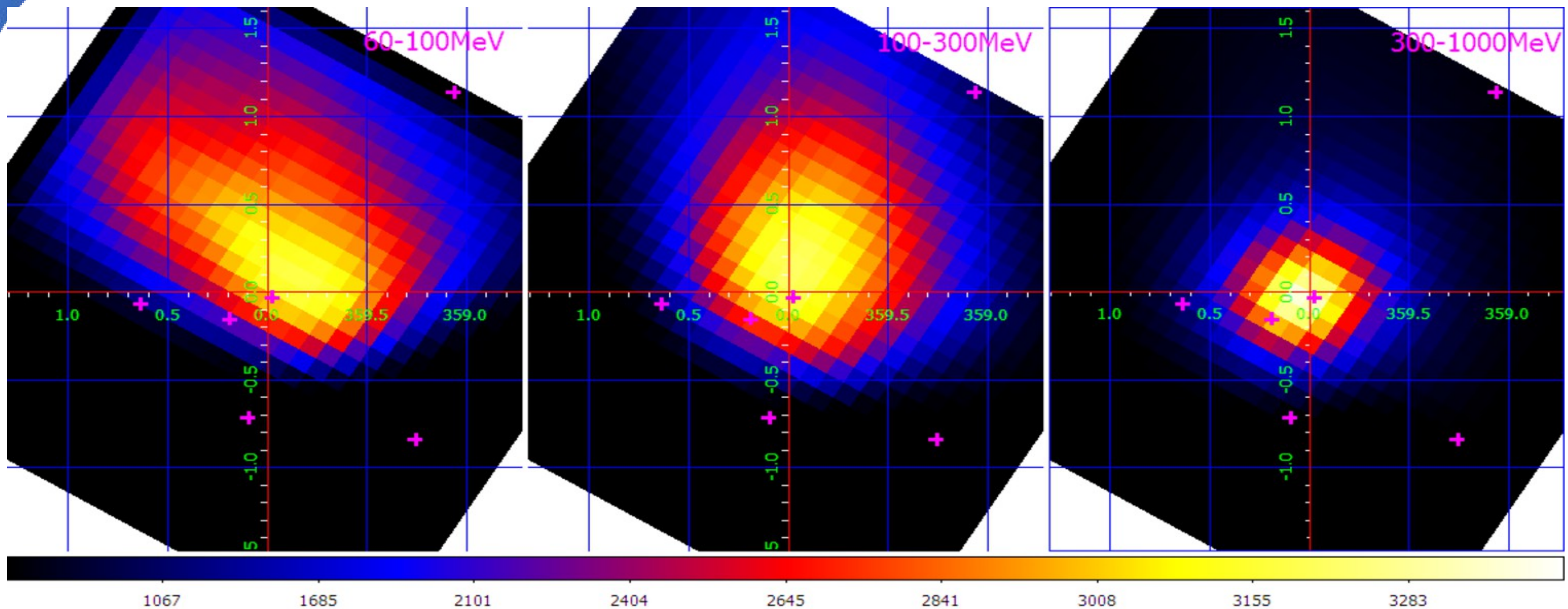


In our work we analyze 66 months of FERMI/LAT data, include into analysis all 2FGL sources and consider low-energy (60-100MeV) data. 10% systematic errors were added. We do not observe clear low-energy cutoff.



In order to verify our low-energy analysis we built 60-100 MeV test-statistic map of GC region. All diffuse and point-like source beyond 0.7° circle (dashed cyan line circle) are subtracted.

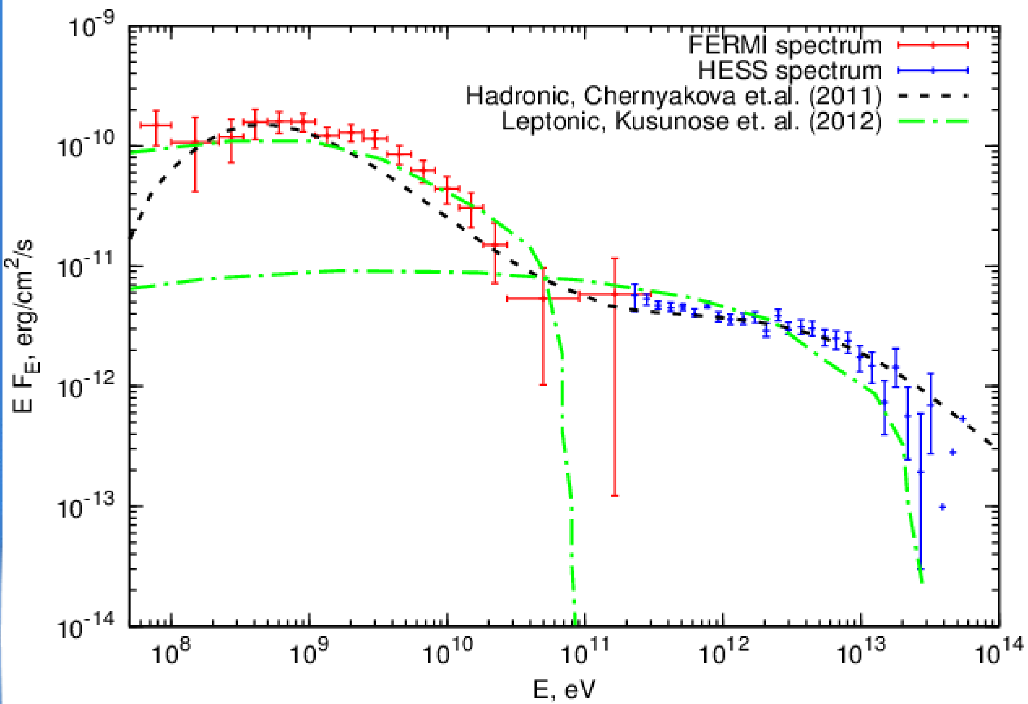
The contours for the localization significance are shown with solid green lines and correspond to significances of 1, 2 and 3 sigma. Note, that catalog coordinates of GC deviate from maximum TS position only at 1sigma level.

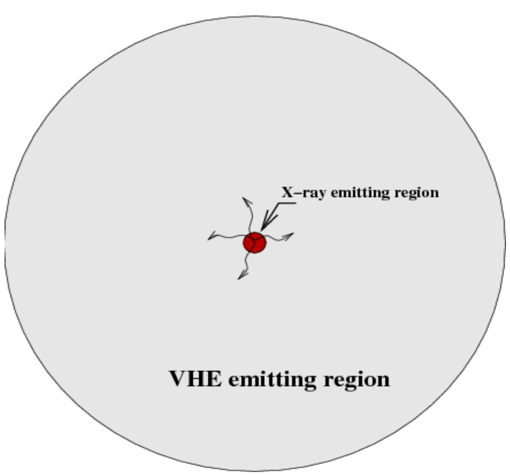


The maximum of TS corresponds to the most probable position of GC.

At higher (100-300MeV and 300-1000MeV) energies the position of brightest pixel at TS map shifts to the catalog GC position.

Hadronic model, Chernyakova et. al. 2011





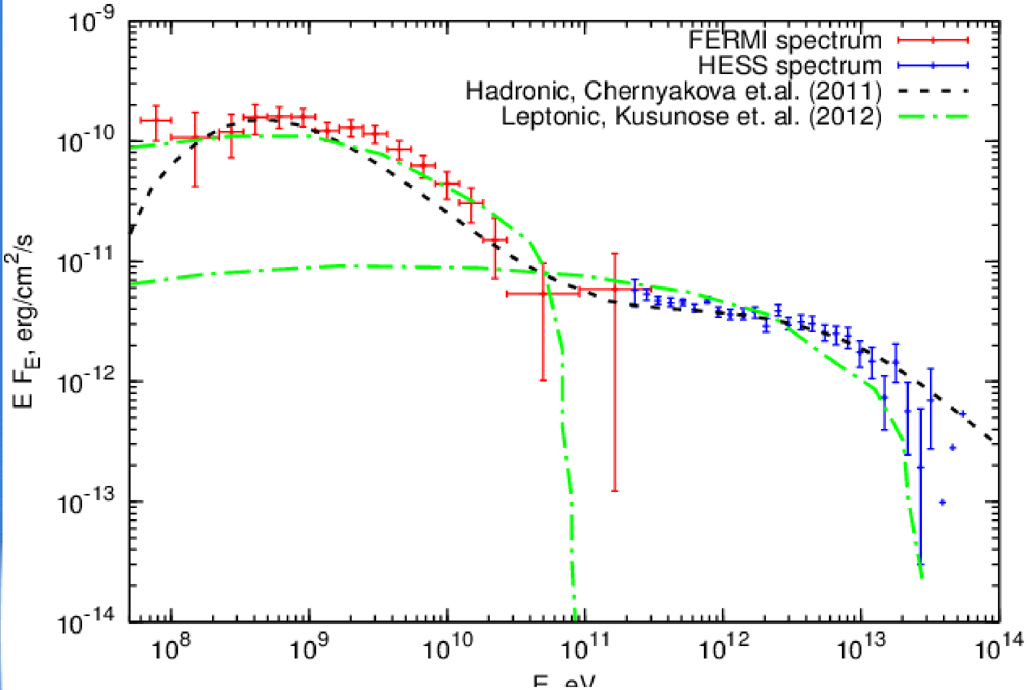
X-ray and low-energy emission come from the central object.

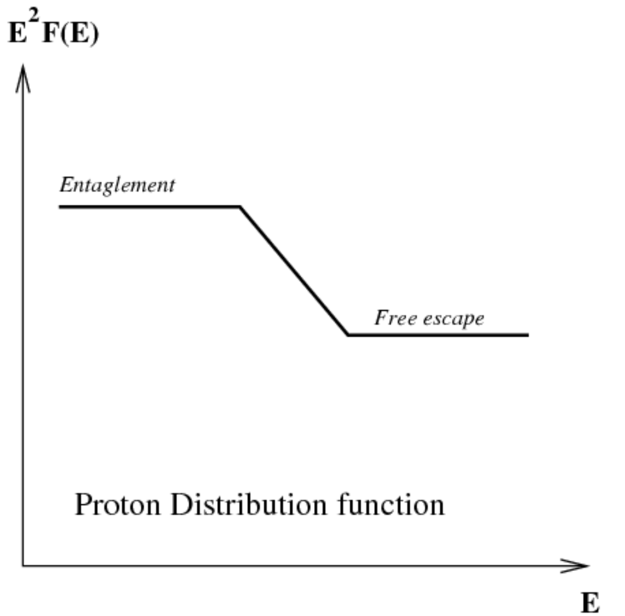
The same central object is a source of high energy protons and electrons.

As proposed in Aharonian & Neronov (2005), a significant fraction of the protons accelerated near the black hole may enter the surrounding gaseous environment and initiate VHE gamma-ray emission through neutral pion production and subsequent decay.

The diffusion of protons is described by relativistic (Jutner) analog of transport equation → no super-luminal particles.

Hadronic model, Chernyakova et. al. 2011





Diffusion coefficient is the (power law) function of energy → diffusion times are different at low and high energies.

At high (TeV) energies protons move almost with the speed of light and thus their number in the cloud remain constant.

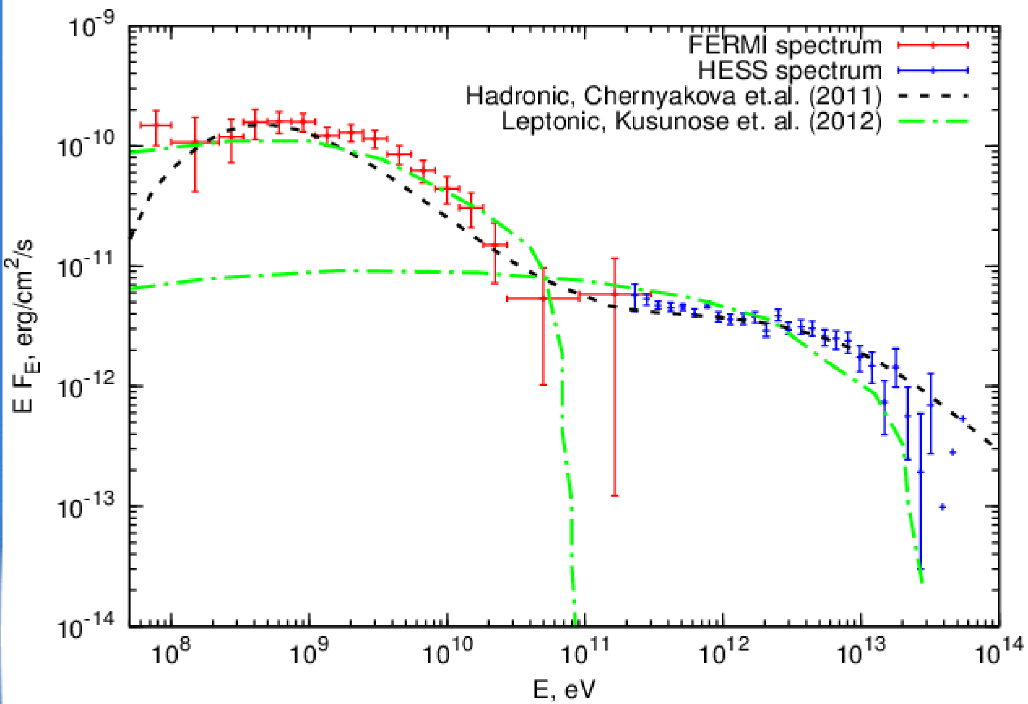
At low (GeV) energies due to diffusion protons are entangled and their number in the cloud grows with time.

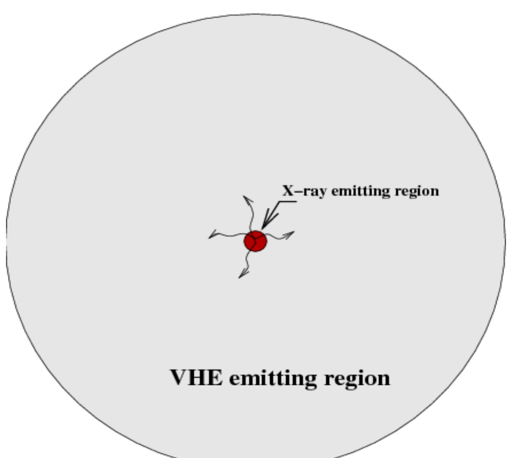
The shape of the spectrum is the same at low and high energies and similar to injected from central source (~E^{-2}).

The photon spectrum from pp collisions looks similar to proton spectrum.

~100MeV cutoff in photon spectrum is un-avoidable due to cutoff in p-p crossection.

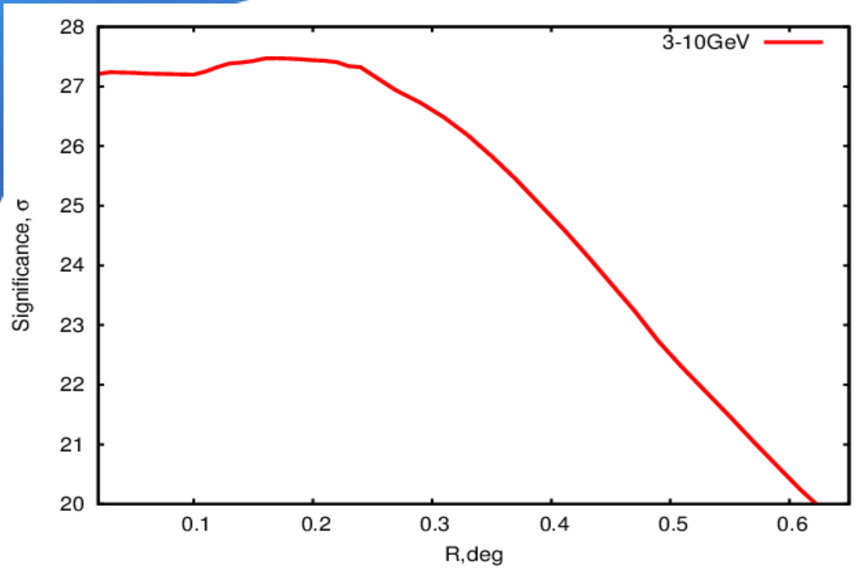
Leptonic model, Kusunose et. al. 2012

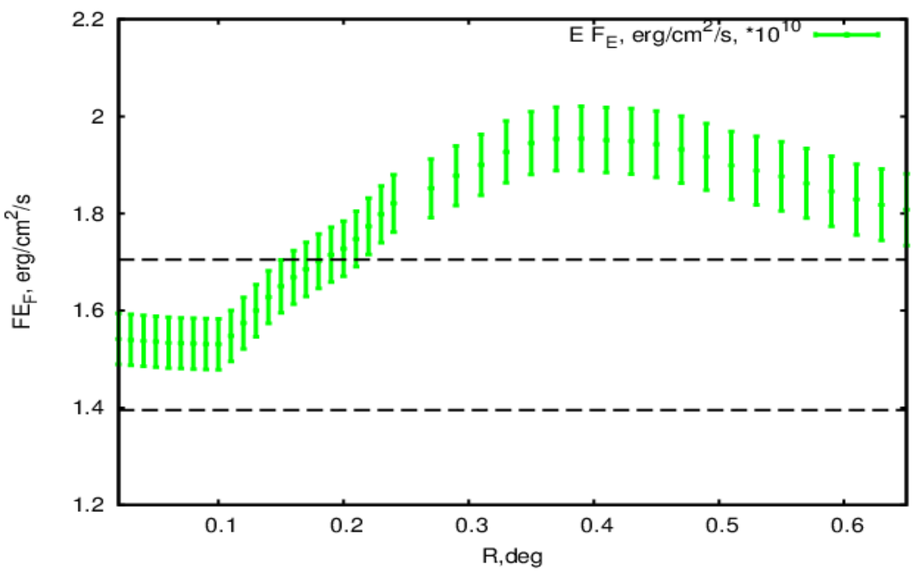




- Non-thermal electrons are supplied by NIR/X-ray flares of Sgr A*
- The spectrum of electrons is described with broken powerlaw:
  i~1.3 below ~250MeV
  i~2.6 at 250MeV – 50GeV
- Escaped electrons are accumulated in ~10^{18}cm region with magnetic field ~10^{-4}G
- FERMI/LAT GeV spectrum is due to inverse Compton scattering of the electrons on soft photons emitted by stars and dust around the central black hole.
- HESS TeV spectrum originates from different source(s), e.g. pulsar wind nebulae.

Morphology of the Galactic Center





- To discriminate between point- and diffuse- morphologies proposed in the literature we model GC as a disk of certain radius and investigate the dependance of the detection significance on the disk size.
- We perform simulations in 1-3GeV and 3-10GeV energy bands with the similar results.
- The signicance slightly increases (by 0.3sigma) at R = 0.2° and rapidly decreases at R ~0.3°
- For the radii R<0.25° the flux attributed to GC changes within 10% systematic error.

Conclusions

- We present the spectrum of the Galactic Center from the analysis of 66 months of FERMI/LAT data, taking into account all 2FGL sources. Low-energy (60-100MeV) results are also presented.

- Both, hadronic (Chernyakova et. al. 2010) and leptonic (Kusunose et. al. 2012) models describe the data reasonably well.
  Low (60 MeV) energy detection of the GC can indicate the presense of low-energy leptonic component in hadronic model or give a preference to pure leptonic model.

- We do not confirm the diffuse morphology of the Galactic Center. Assuming GC to be a disk of radius R, our analysis statistically can not exclude any radii $R<0.3^{\circ}$.
  The attributed to GC flux is consistent with one for point-source within 10% systematic errors.

Thank you for attention!

Go raibh maith agat as aire!