A new Galactic Center extended source consistent with Inverse Compton emission from a population of high energy leptons

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http://www.physics.uci.edu/~kevork/ic_arxiv_v1.pdf

Anna Kwa, UC Irvine
Fermi Symposium, Nagoya 2014

With K. Abazajian[1], N. Canac[1], S. Horiuchi[2], & M. Kaplinghat[1]

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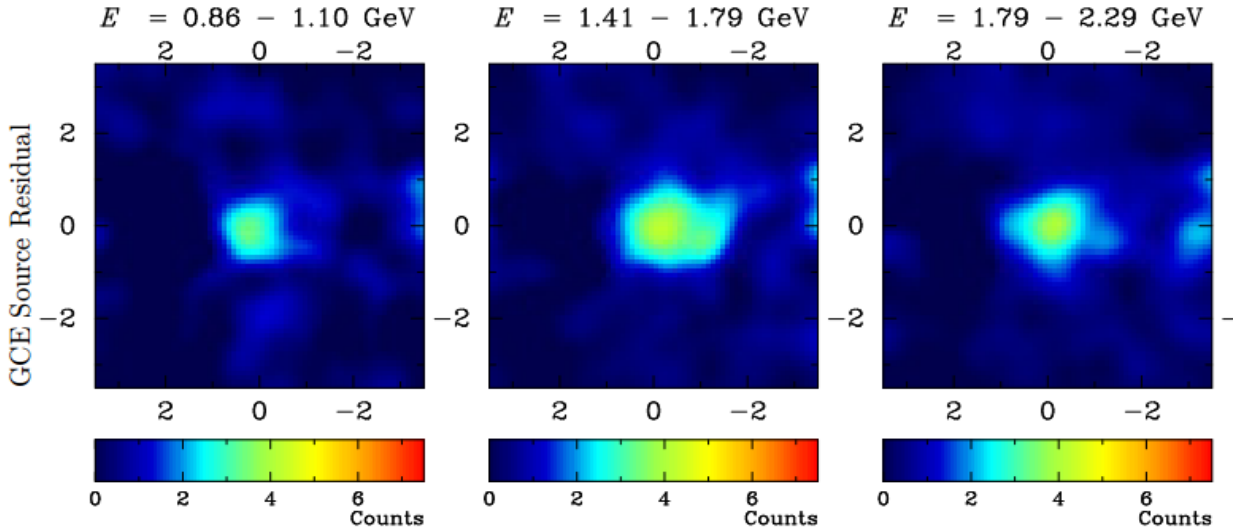
The galactic center excess (GCE): a well-studied feature †



Source associated residual-- Abazajian et al. (2014)

Possible interpretations of the excess emission:

- **Astrophysics: new astrophysical source(s)**
  e.g. CR injection, unresolved millisecond pulsars

- **Particle physics: WIMP dark matter annihilation**
  ~10 GeV WIMPs annihilating to τ leptons
  or
  ~35 GeV WIMPs matter annihilating to b quarks

† Vitale & Morselli (2009), Goodenough & Hooper (2009), Hooper & Linden (2011), Abazajian & Kaplinghat (2012), Macias & Gordon (2013), Cirelli et al. (2013), Abazajian et al. (2014), Daylan et al (2014), Calore et al. (2014) ...

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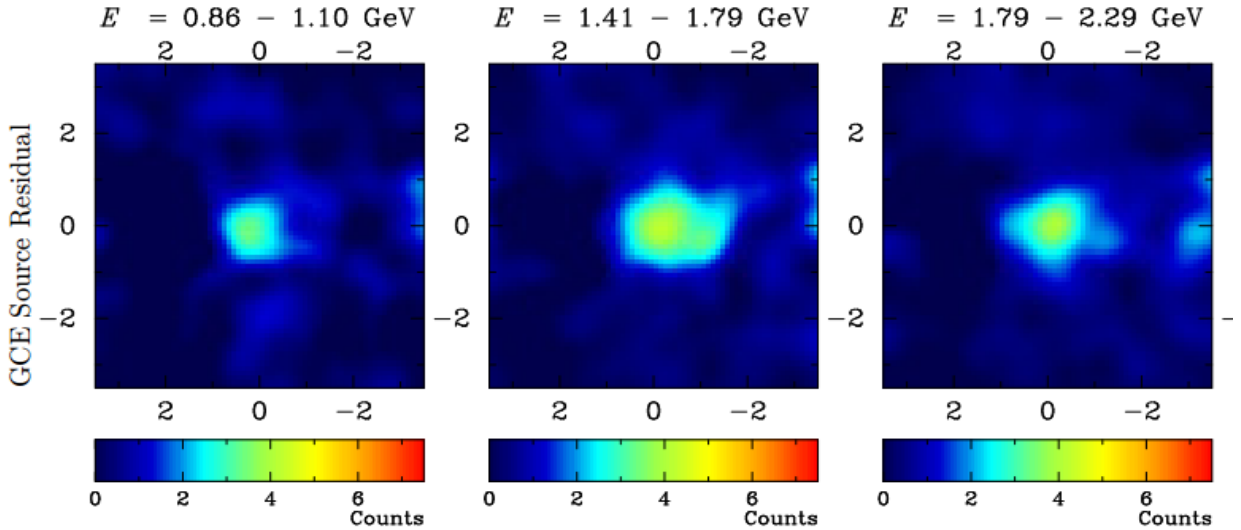

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leptonic sources

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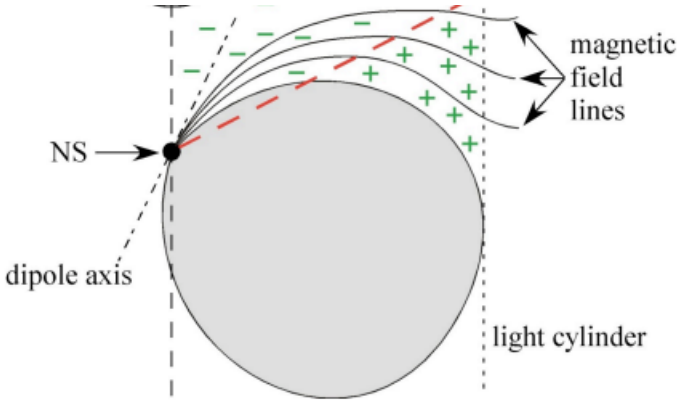
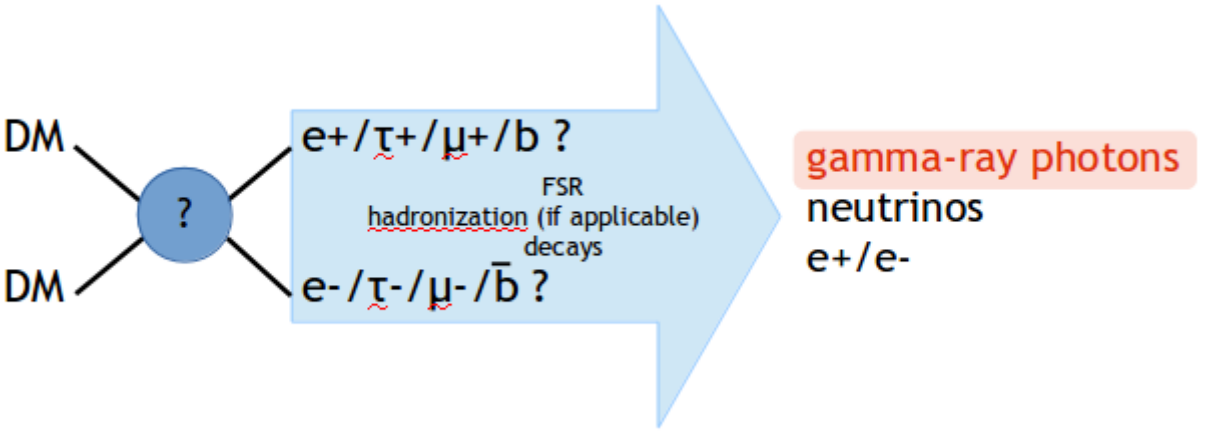
Observable signals from high energy astrophysical or DM sources:

1. 'Prompt' gamma-rays (seen as the GCE)
   - Produced at source-- directly trace the source's spatial distribution
   - Spherically symmetric about the galactic center





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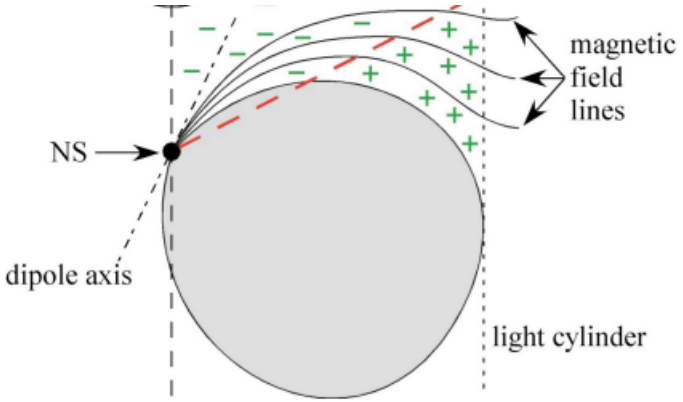
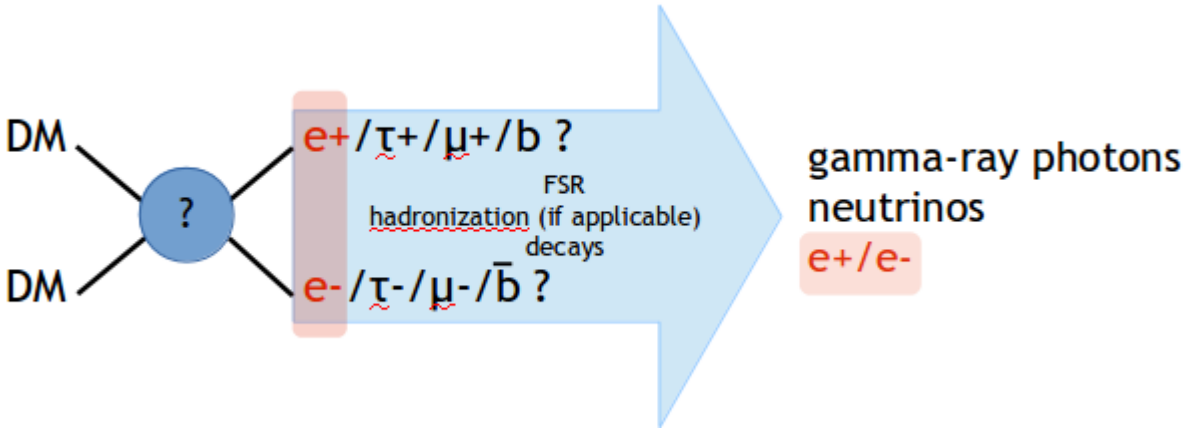


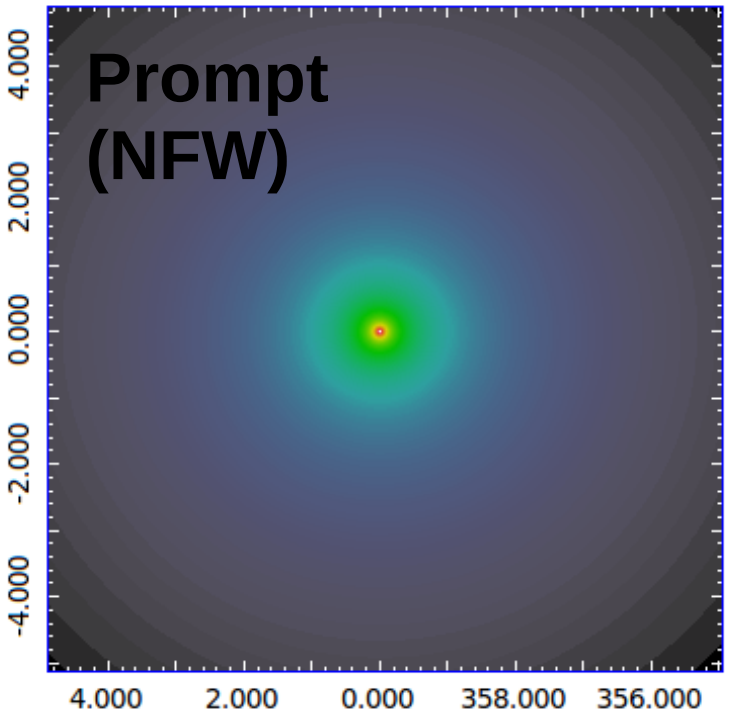


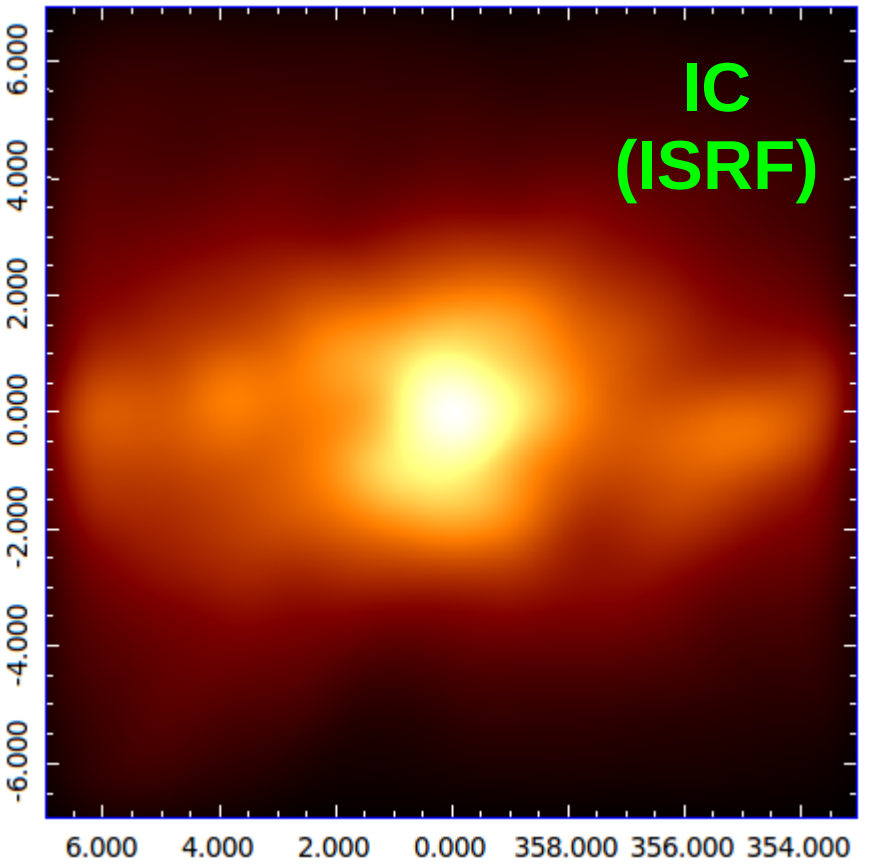
2. 'Secondary' gamma-rays from e+/e- interactions via
   - Bremsstrahlung: interactions with gas clouds
   - Inverse Compton: upscattering of background photons
   - ***IC and brems photons may not directly trace the source's spatial distribution***

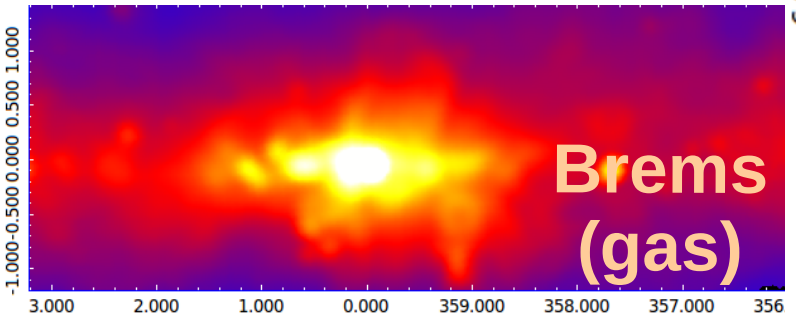
Most interpretations of the galactic center excess has focused on the prompt gamma-ray spectrum alone...

What if we also consider the possible secondary emission?

Is there any gamma-ray emission associated with the expected spatial distributions of inverse Compton and bremsstrahlung processes?







Search procedure for secondary IC + bremsstrahlung emission

Innermost 7x7 degrees

Ultraclean photons

Standard maximum likelihood fit using the Fermi tools to obtain best-fit source spectra

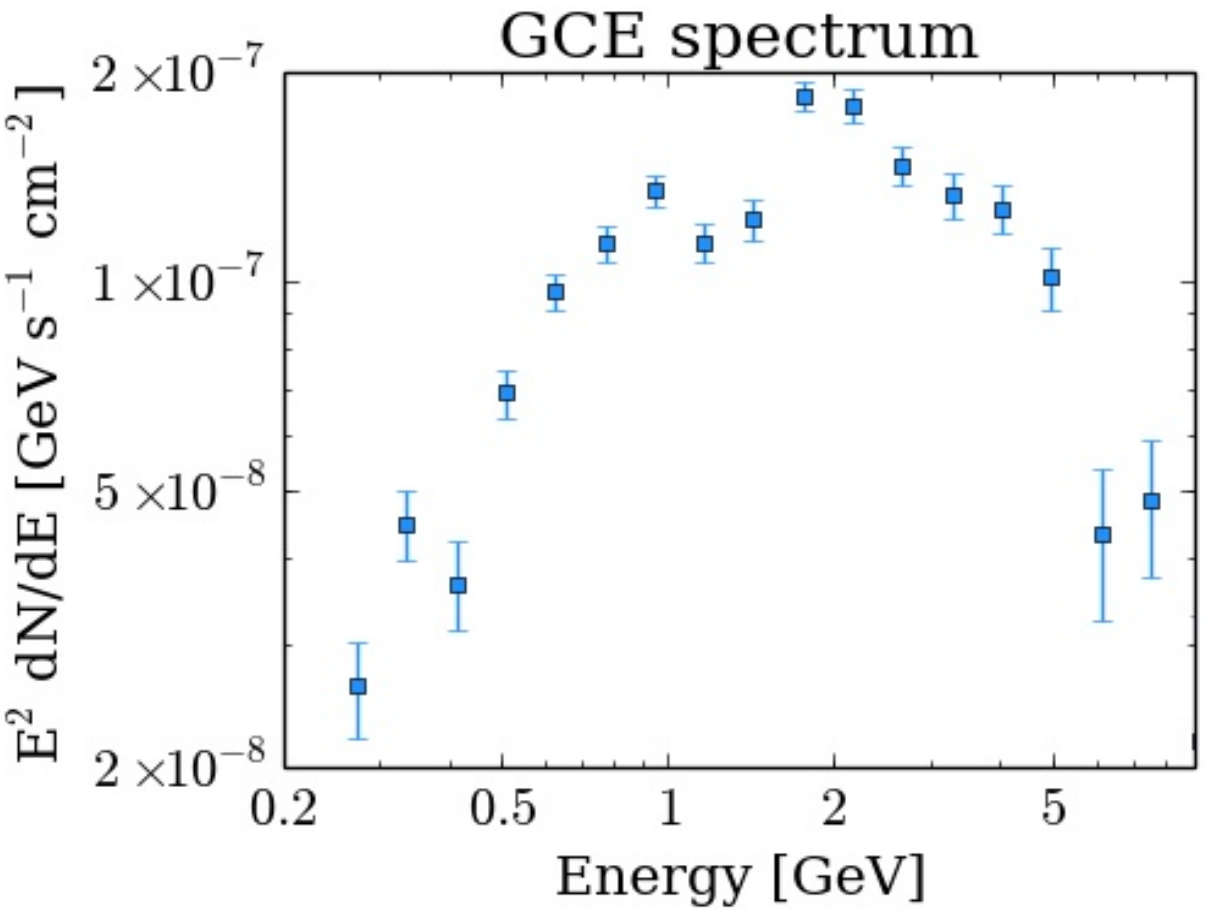
In addition to the standard Fermi templates, our model also includes

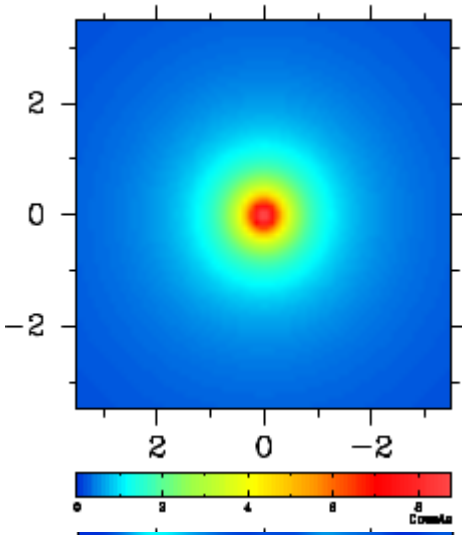
- 4 additional point sources: 'bkgd A', '1FGL J1744.0-2931c' + 2 new pt srcs found in residuals w/ high TS vals
- 'New diffuse' template (see Abazajian et al. 2014)

- Prompt emission template:
  Navarro Frenk White (NFW) template (γ =1.0)
- Inverse Compton (IC) template:
  WISE 3.4μm map-- traces infrared ISRF
- Bremsstrahlung (brems) template:
  Yusef-Zadeh 20 cm emission map-- traces gas distribution

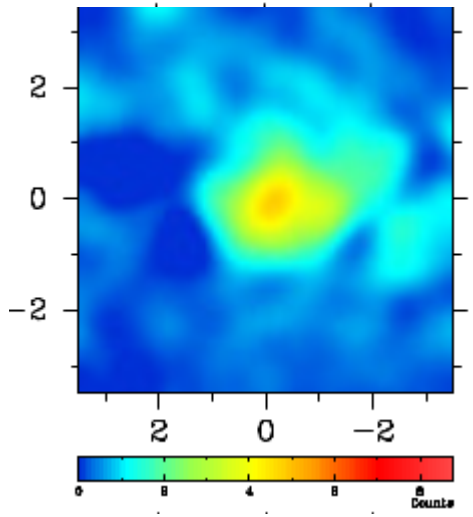
Results

(1) Spatial component corresponding to prompt emission/ NFW profile is detected at high significance (TS=208)





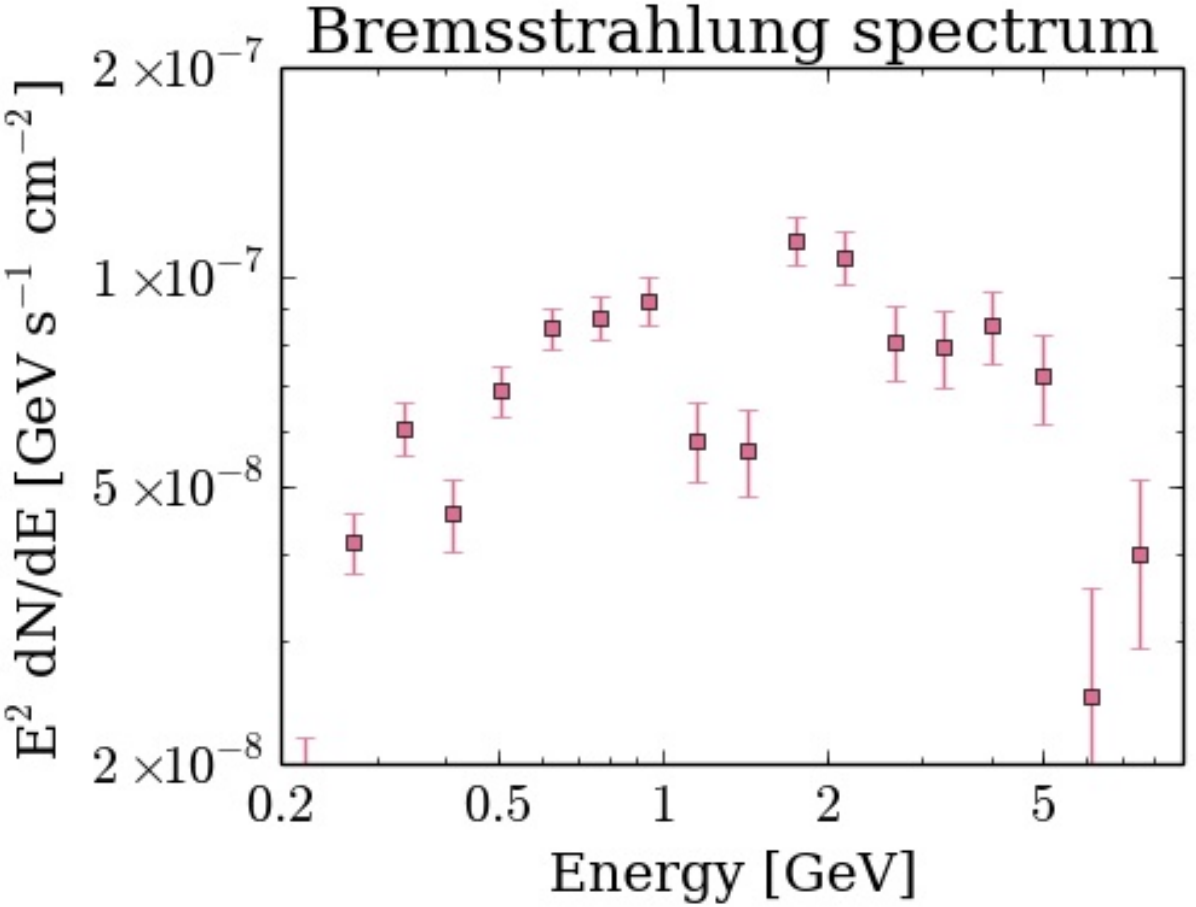
Model



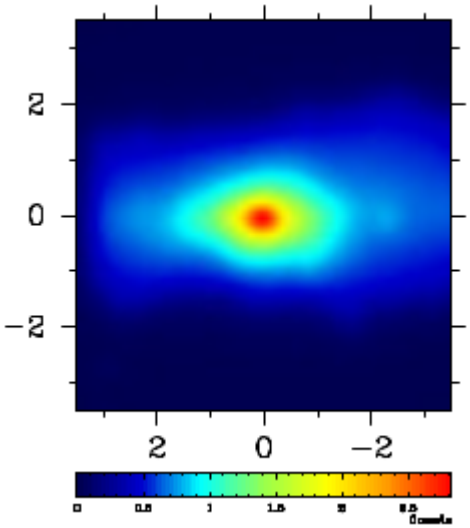
Source-associated residual

Results

(2) Spatial component corresponding to bremsstrahlung/ gas distribution is detected at high significance



(TS=97)



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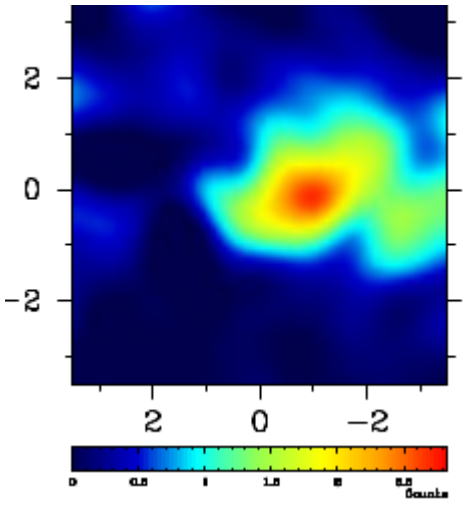
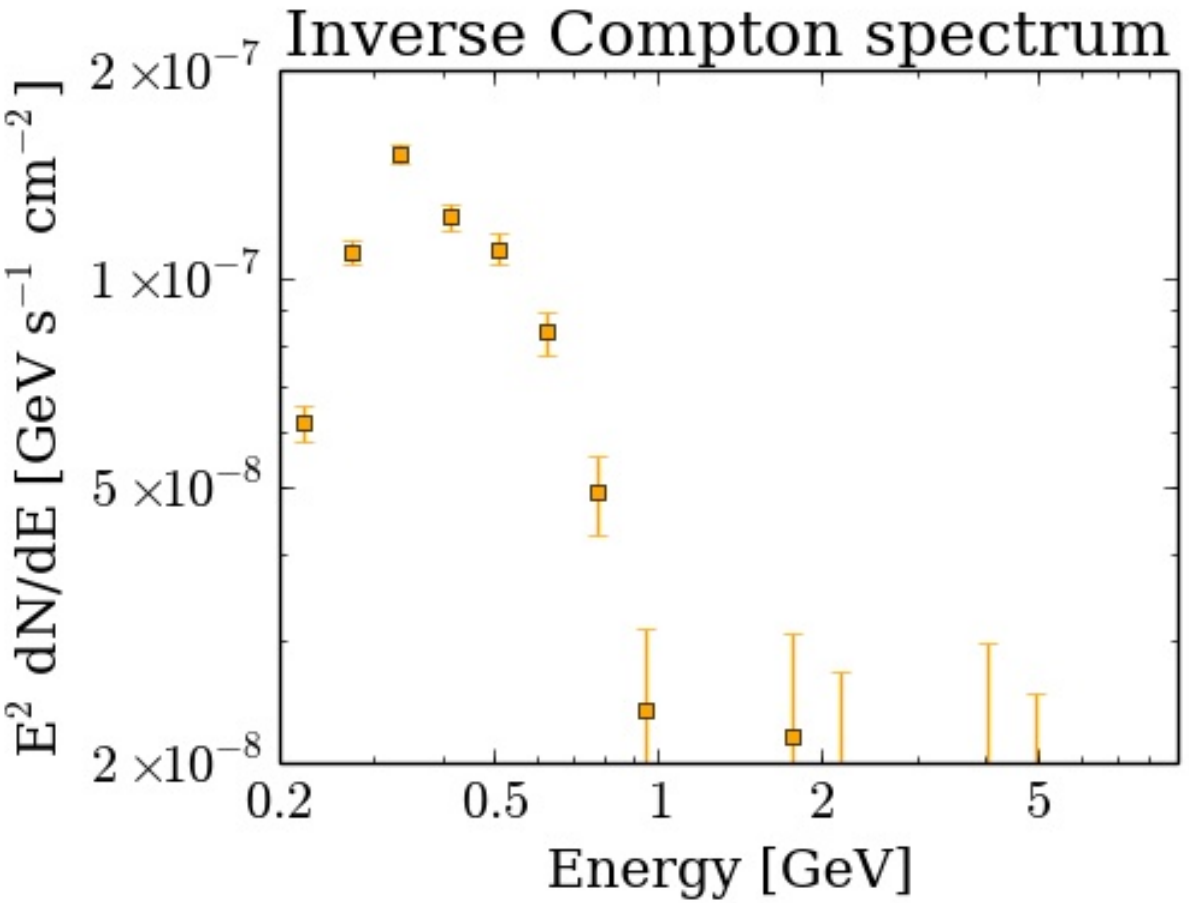


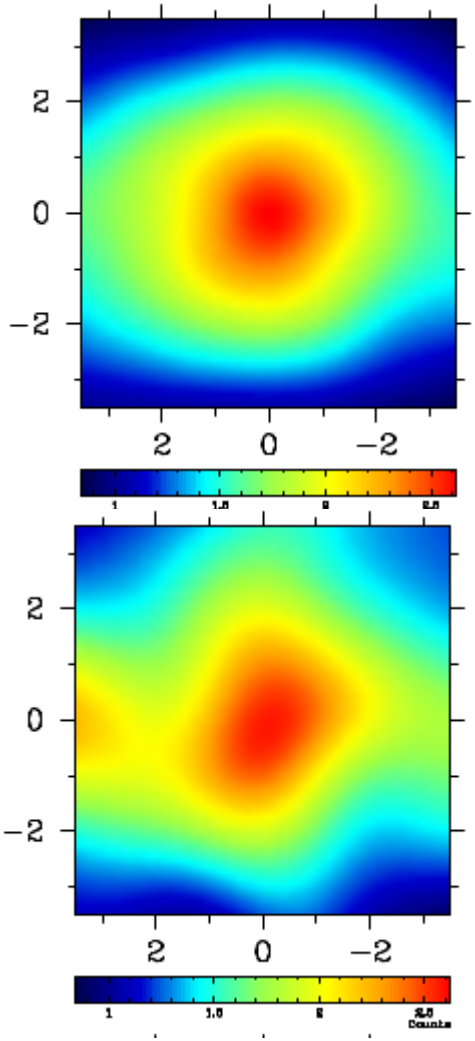
Source-associated residual

Results

(3) *For the first time, a spatial component corresponding to Inverse Compton/ ISRF is detected at high significance*

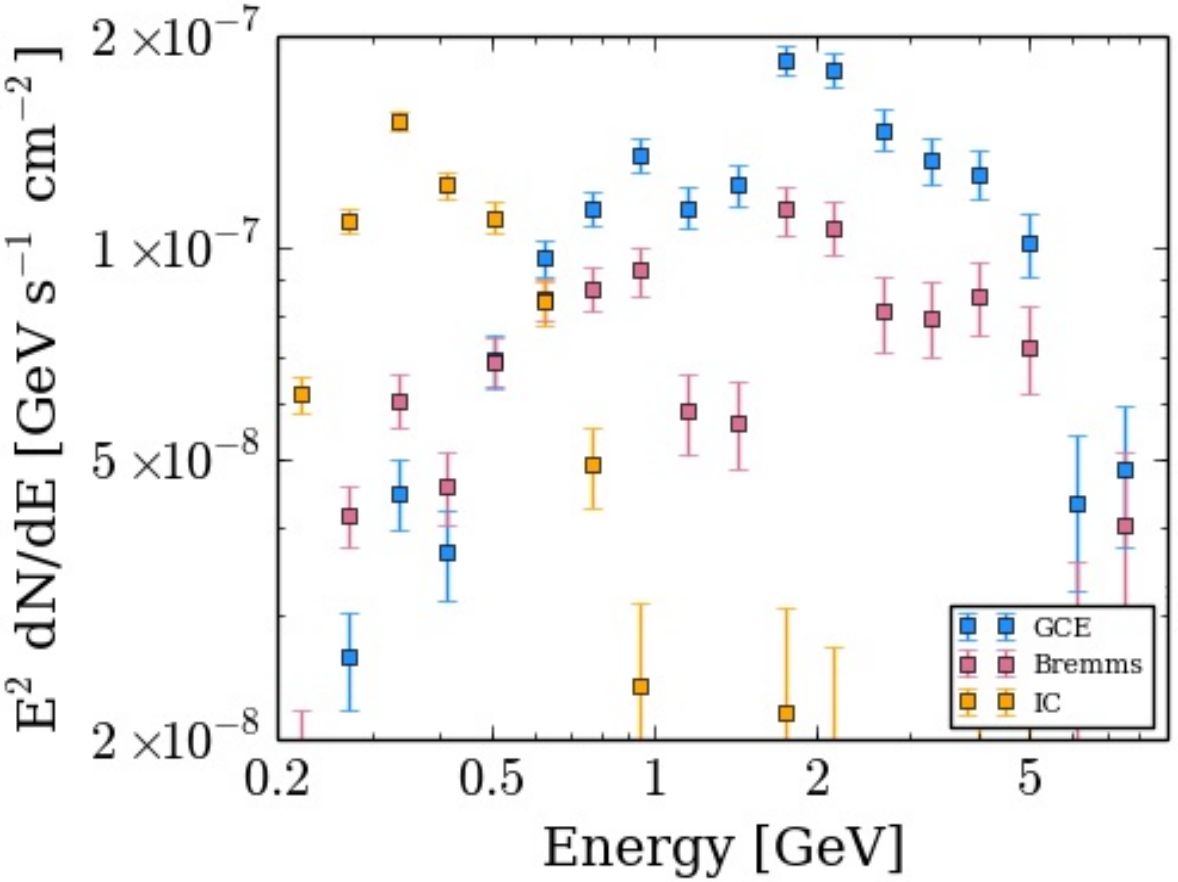
(TS=197)

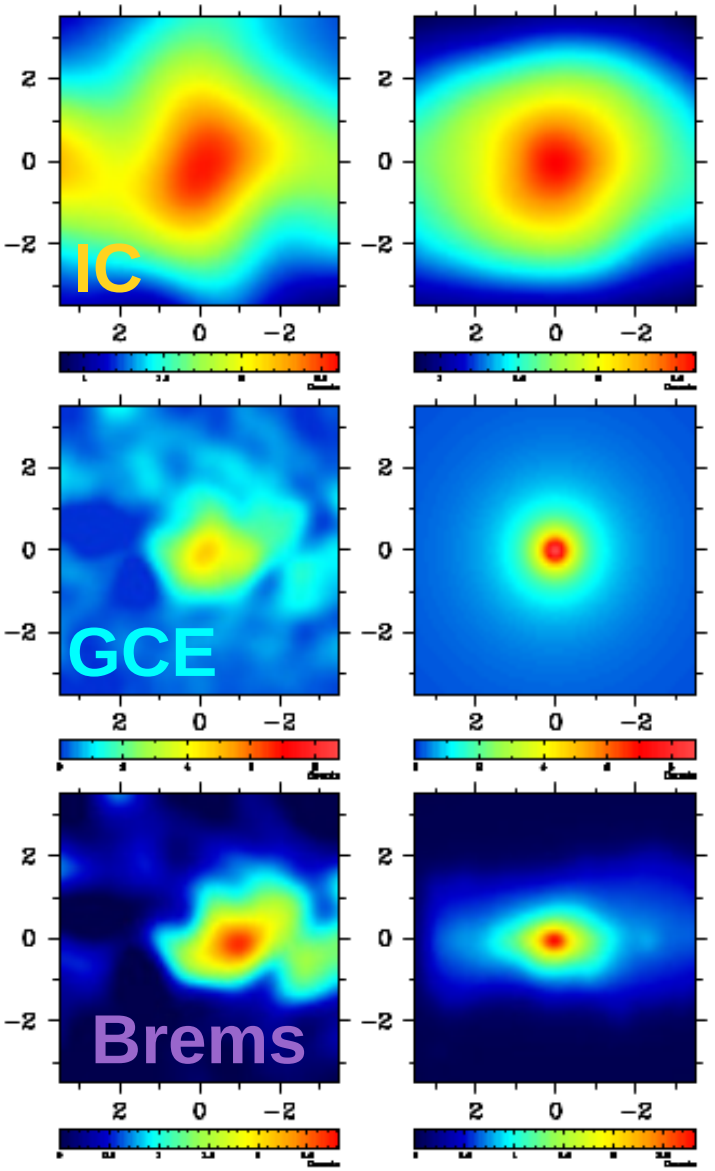




Results

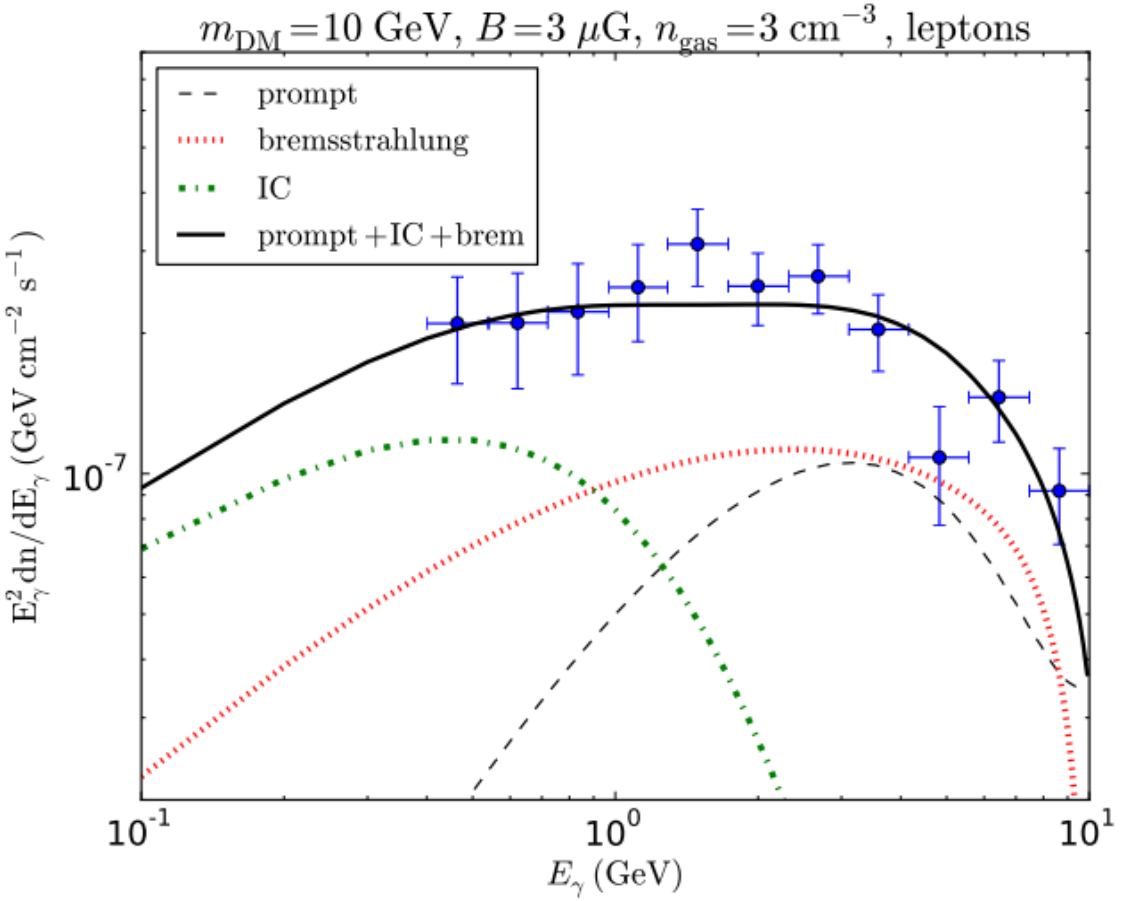
Multiple sources of extended emission with distinct spectra can be observed in the galactic center





Might the signals share a common origin?

For dark matter interpretations invoking XX → leptons, we can calculate the spectra of prompt, IC, and bremsstrahlung emission and compare to observed spectra.



Example calculation from Lacroix et al. 2014

(1) Find best-fit leptonic DM model to the GCE spectrum

(2) Calculate the electron injection spectrum from DM annihilation (PPPC4DMID, Cirelli+13)

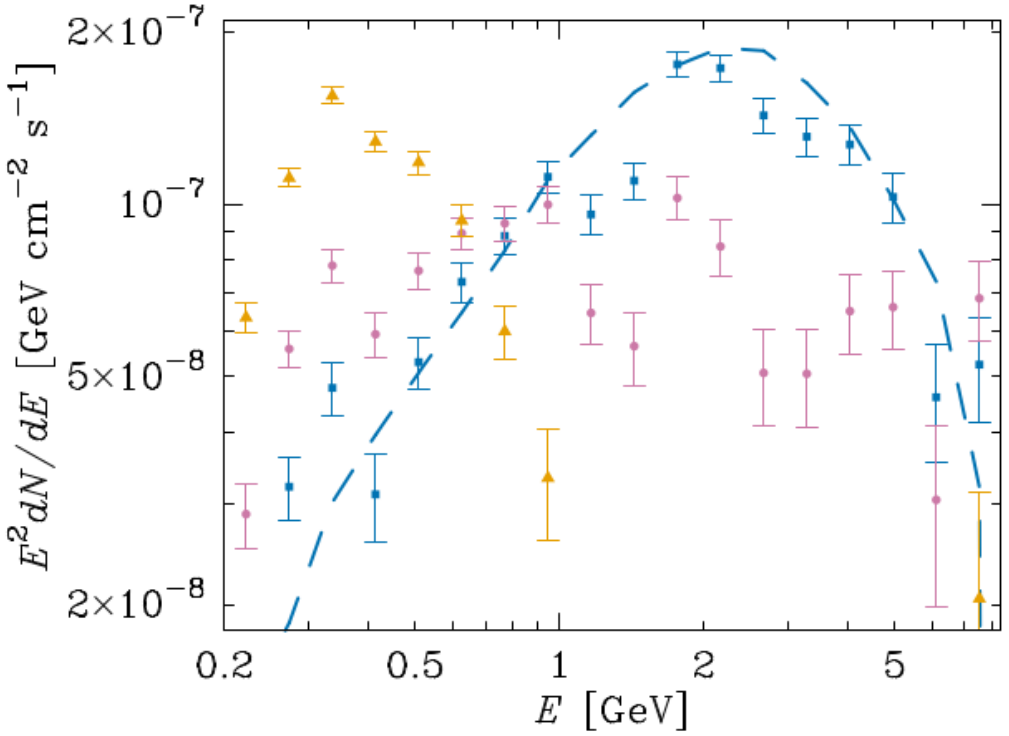
(3) Calculate diffusion and IC + brems energy losses (Lacroix+14)

Interpretation #1: dark matter

Best-fit DM mass and cross section, assuming direct annihilation into 1/3 each μ/e/τ *

m_{DM} ~ 8 GeV

$\langle\sigma v\rangle = 3.6 \times 10^{-26}$ cm^3/s



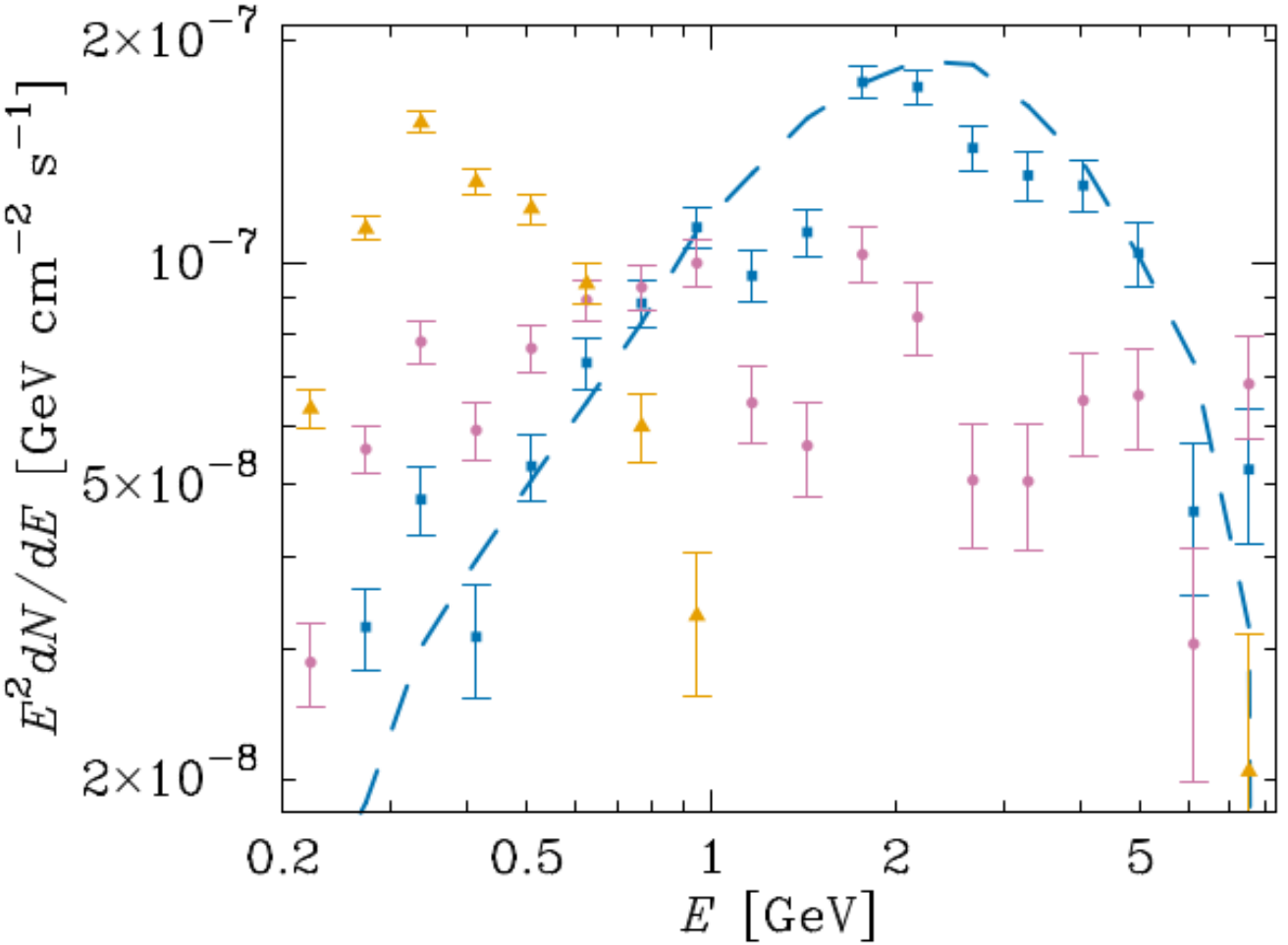
* In tension with AMS-02 constraints on leptonic annihilation channels!
(Bringmann+14, Bergström+13)

Tension may be loosened by:

- uncertainties large, up to factor of 10 if taking adiabatic contraction into account
- annihilation through vector mediator

Interpretation #1: dark matter

Predictions of prompt and secondary emission from an 8 GeV WIMP with democratic lepton annihilation:



Prompt emission (blue)

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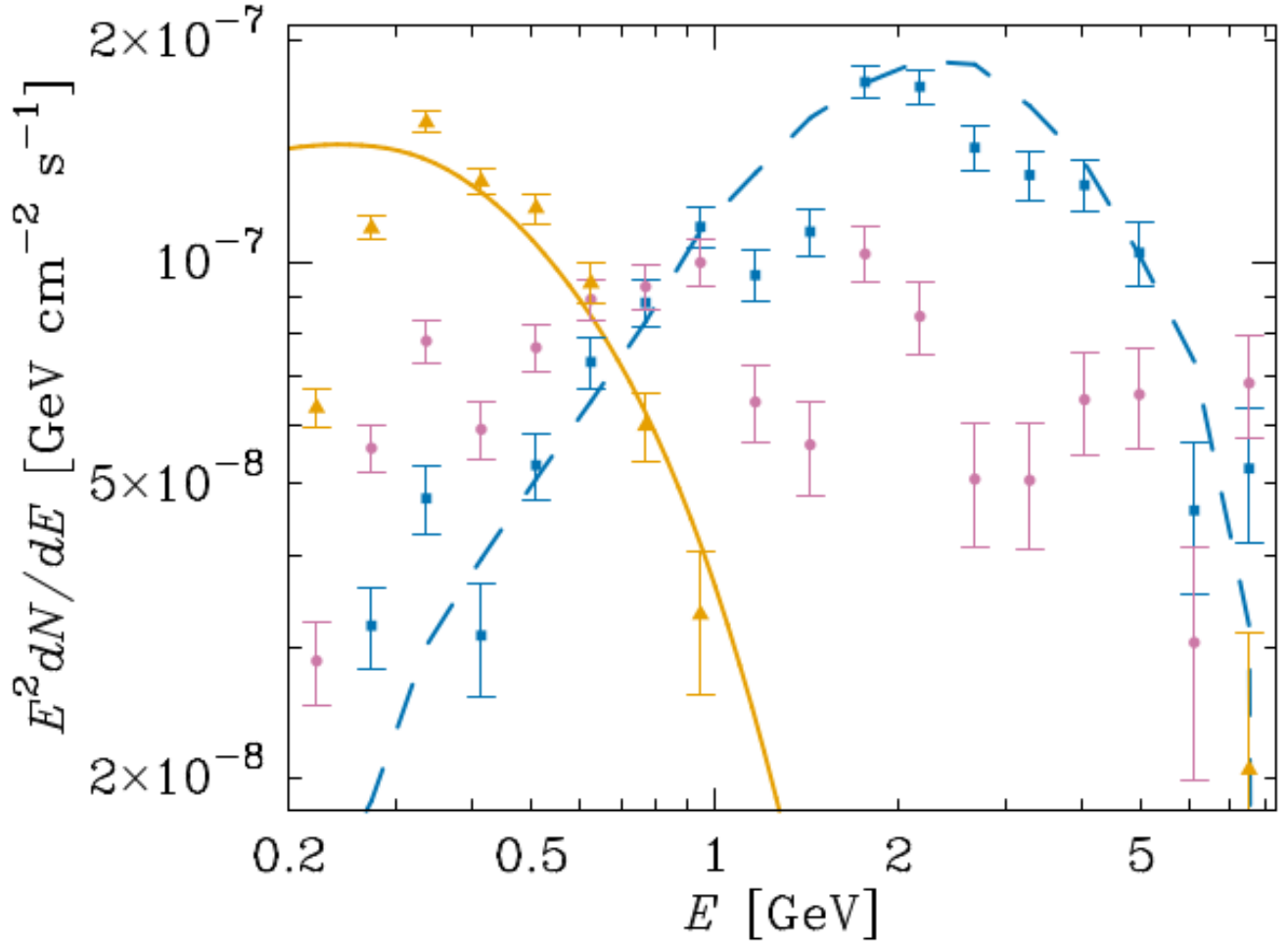

Prompt emission (blue) + IC emission (orange)

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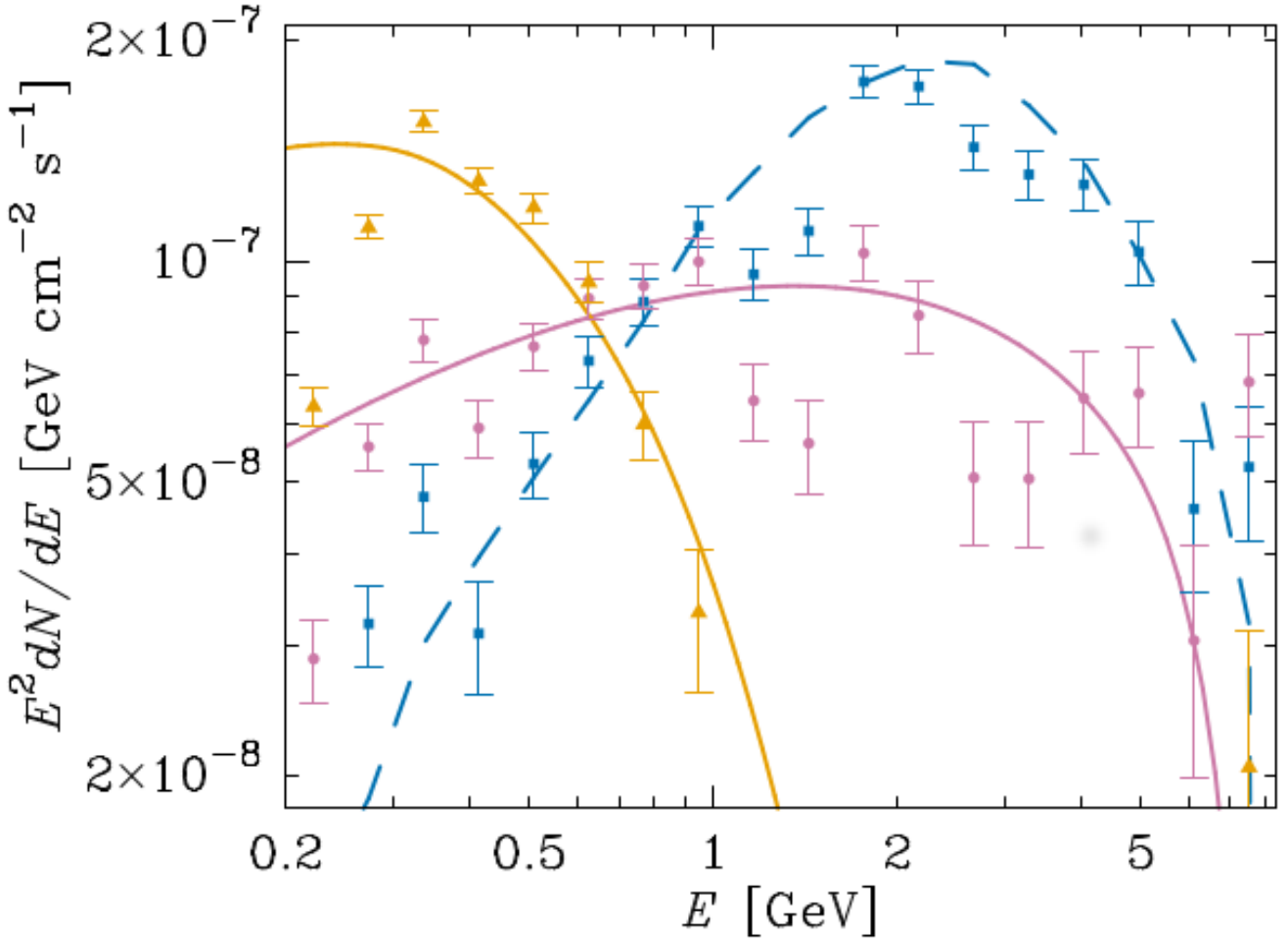
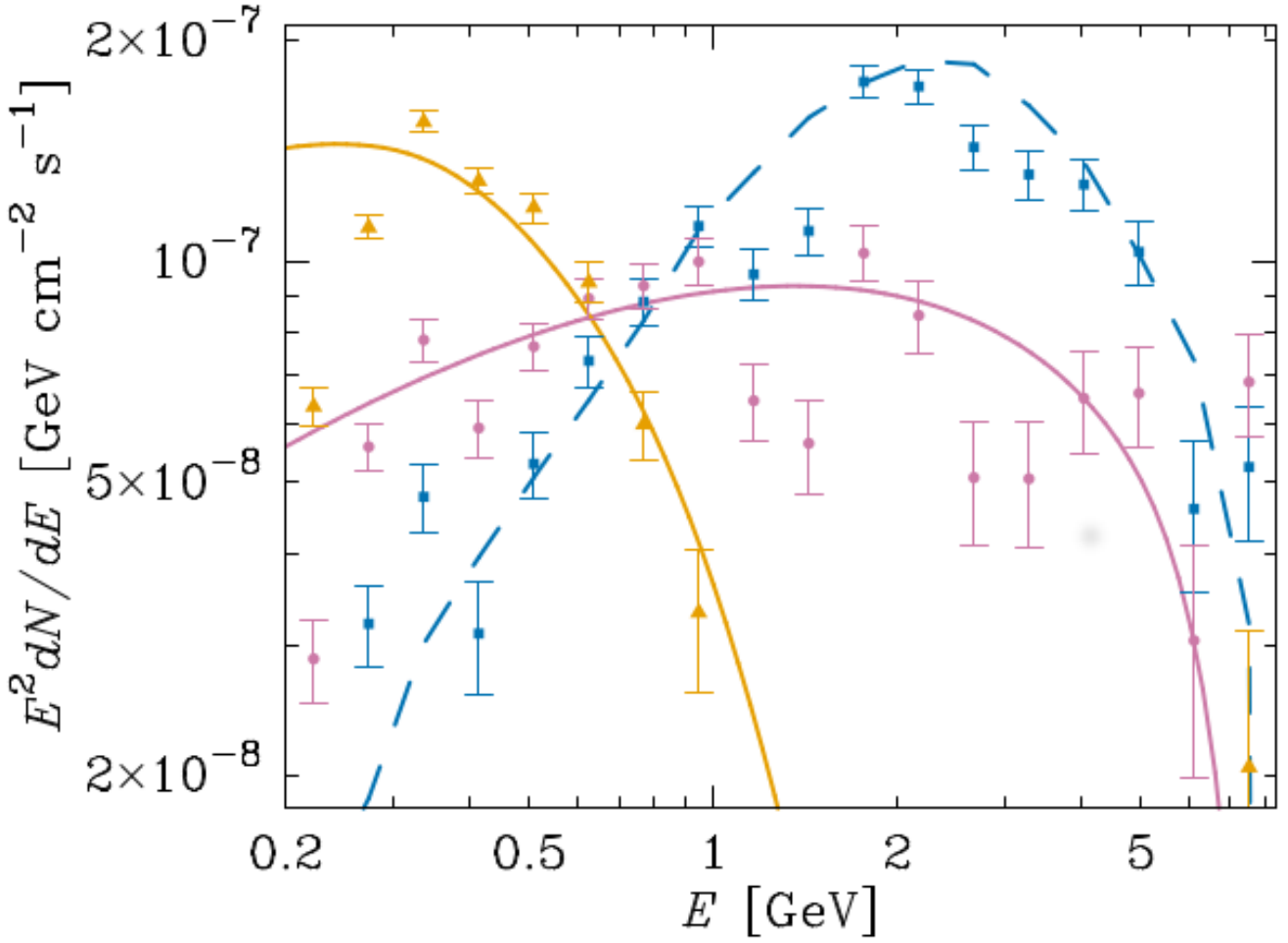


Prompt emission (blue) + IC emission (orange) + bremsstrahlung (pink)

Interpretation #1: dark matter

Spectra associated with the extended templates are consistent with predictions for prompt, IC, & brems emission from a single high-energy lepton population resulting from WIMP annihilations



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Interpretation #2: astrophysics

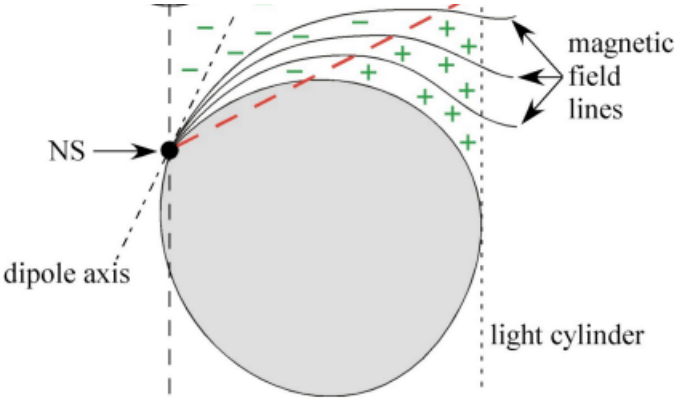
Cosmic ray injection from the galactic center

- GCE component is produced by injection burst(s) of higher energy leptonic CRs that undergo IC scattering (Petrović et al. 2014)
- IC and brems components produced by quasistatic injection of lower energy leptonic CRs

Millisecond pulsars: well-know e+/e- sources

- GCE component emitted from e+/e- in pulsar magnetosphere
- IC and brems components produced when e+/e- escape and interact with ISRF or gas
- Could provide a single origin for both prompt and secondary emissions

  → Would imply a break in the escaped e+/e- spectrum around 8 GeV



In conclusion,

- In addition to the previously studied GCE and bremsstrahlung emission, *we detect a new gamma-ray extended source at the galactic center that is consistent with IC emission from a population of high-energy electrons*

- Both IC and bremsstrahlung components are consistent with being produced by the same population of electrons

- Viable single-source origins for all three extended emission components include 1) MSPs and 2) dark matter annihilation via leptonic channels

- *If the three components share a common origin, the IC and bremsstrahlung signals will be extremely important in further understanding the galactic center excess!*