Point Sources at the Galactic Center

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Identification of Dark Matter (IDM) '18
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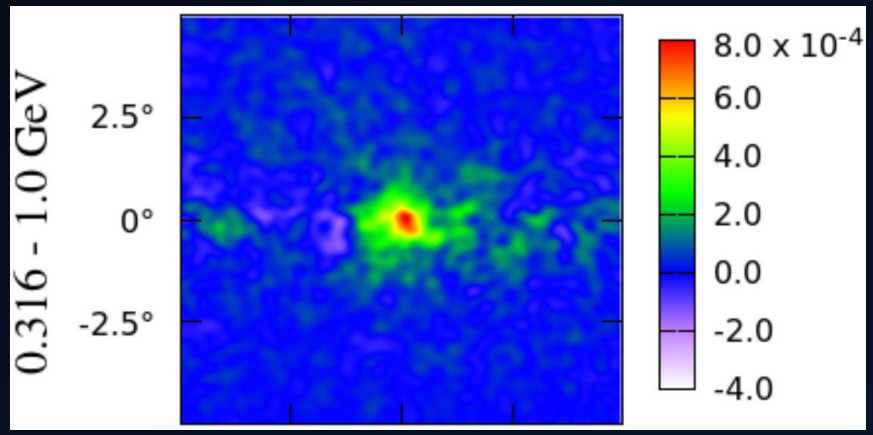
Work in progress with Tracy Slatyer

Massachusetts Institute of Technology

THE GEV GALACTIC CENTER EXCESS

- Excess peaked at 1-3 GeV, highly significant
- First discovered in 2009
  - Goodenough+Hooper 0910.2998
- Found to extend out to 10 degrees
  - Hooper+Slatyer 1302.6589
- By 2014, spatially consistent with DM
  - Daylan et al 1402.6703, Calore et al 1409.0042
- Small scale power found in inner Galaxy gamma rays
  - Bartels et al 1506.05104, Lee at al 1506.05124



Daylan et al (2014)

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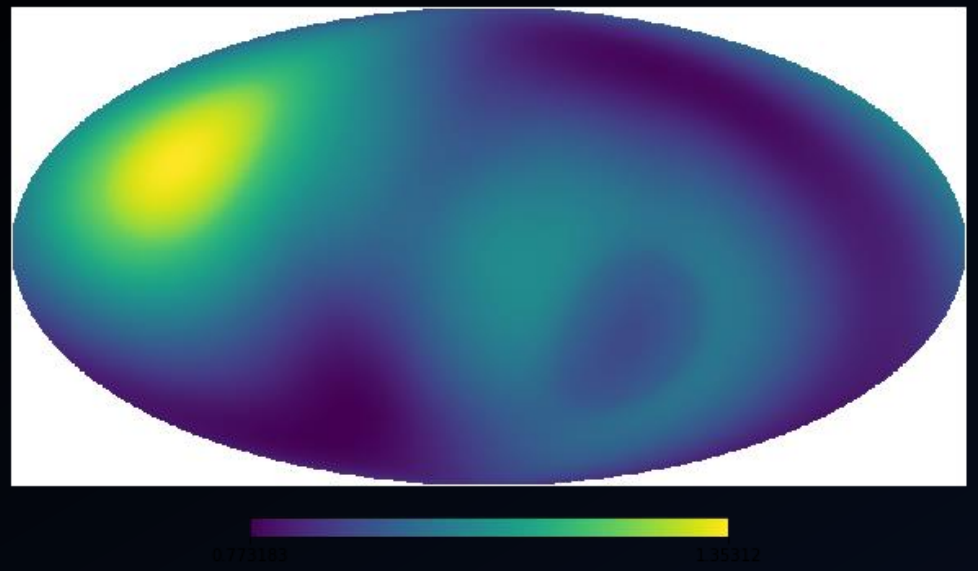
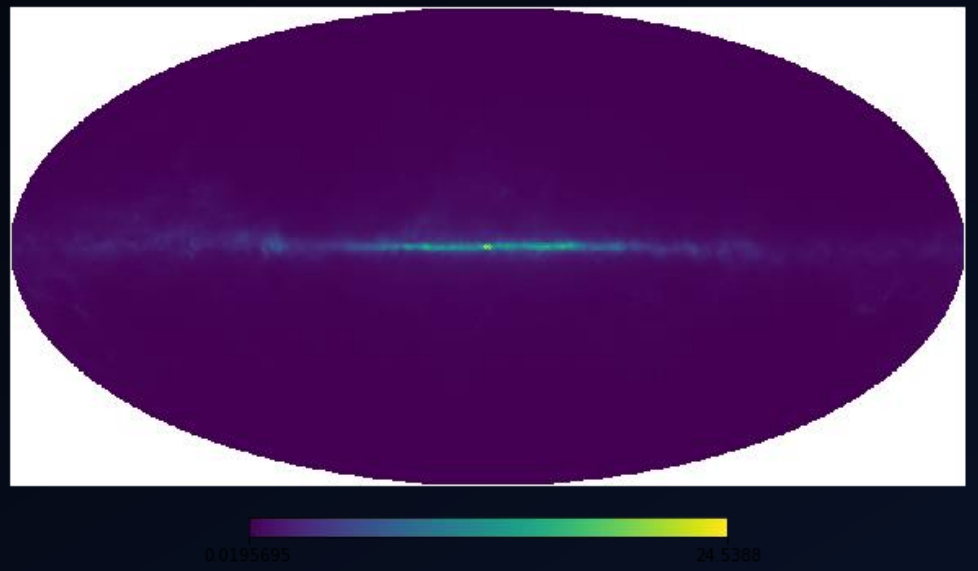
TEMPLATE FITTING METHOD

- Templates based on models / ansatzes / catalogs, include point spread function (PSF) smoothing and exposure for Fermi, provide expected counts/pixel
- Pixelize events, data is list counts/pixel, model data as a fixed combination of spatial templates
- Sum of templates = how many expected counts should be seen by Fermi in given pixel
- For given model, total likelihood is product of poisson likelihoods for each spatial pixel (smooth emission)

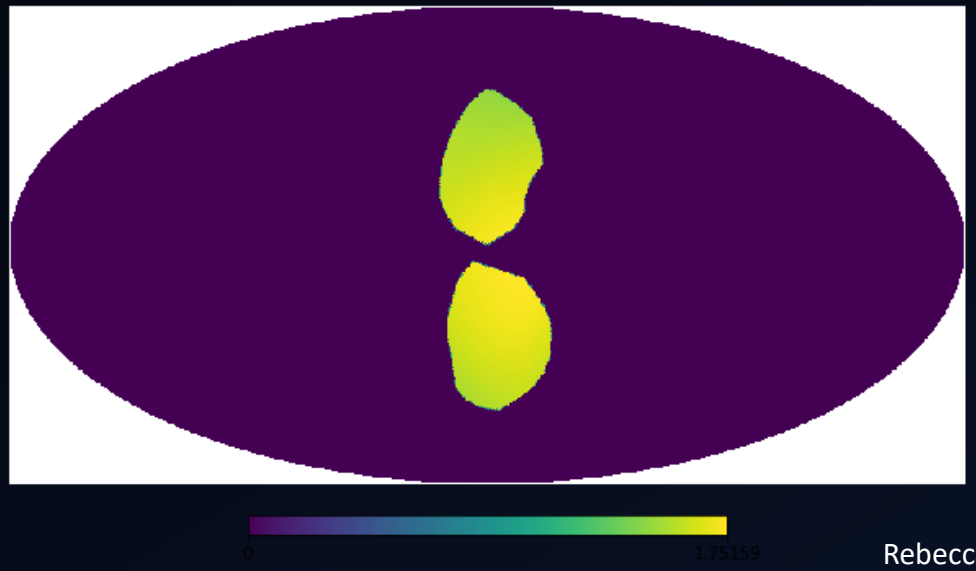
ISOTROPIC



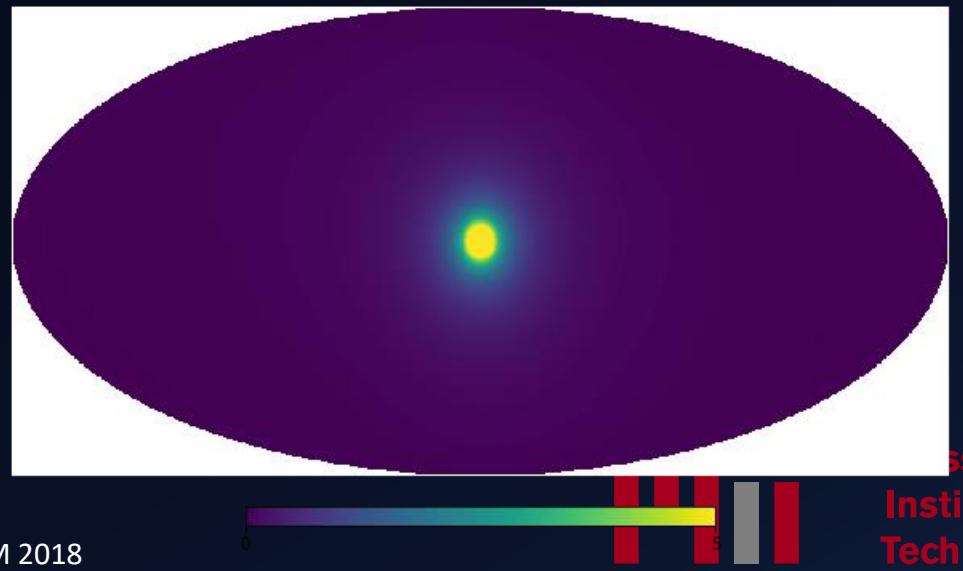
DIFFUSE



BUBBLES



NFW



POISSON vs NON-POISSON TEMPLATE FITTING

- For smooth emission, likelihood is given by product of poisson likelihoods for each pixel
- Want to characterize smooth vs PS component
- For point sources, relationship between no. of photons observed and mean no. of photons is not poisson.
  - Probability of source(s) present in pixel
  - Probability source(s) producing certain no. of photons

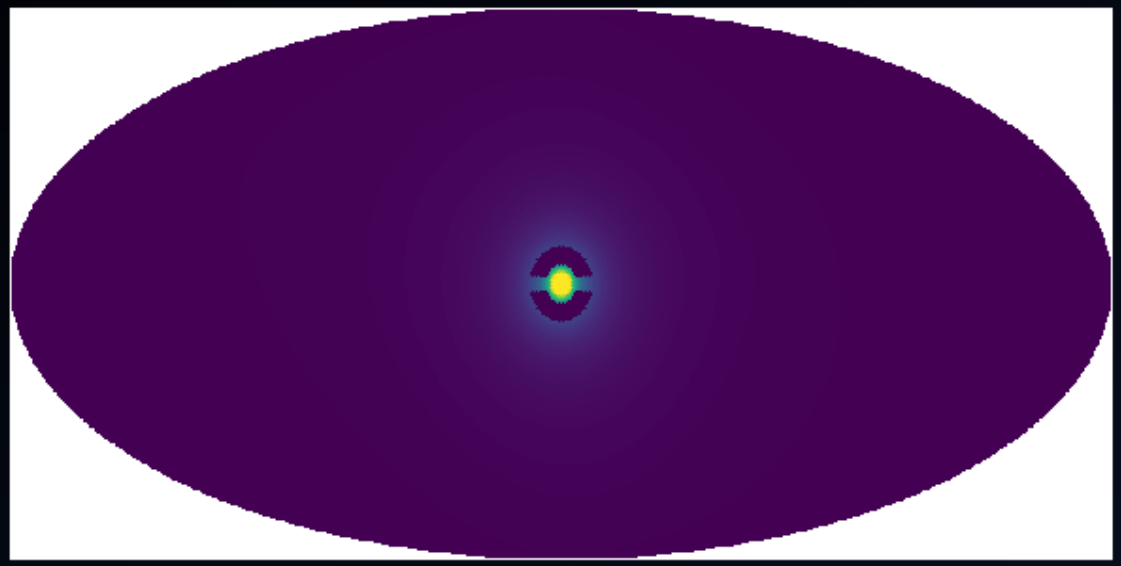
    (See Malyshev+Hogg (2011), Lee+Lisanti+Safdi (2015))
- Look for PS populations distributed along same templates (Lee at al (2015))

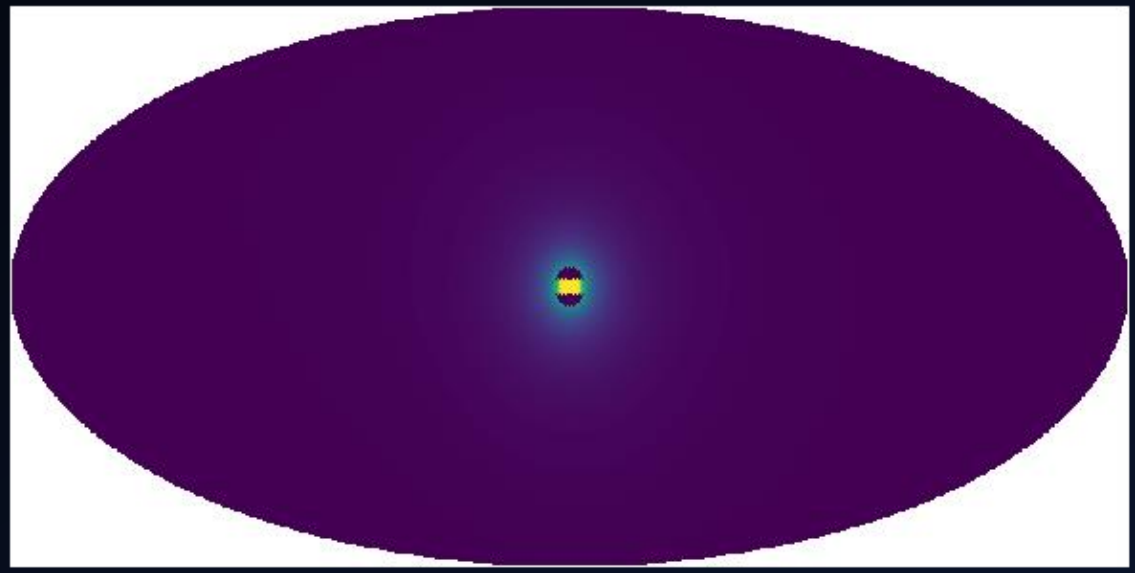
NPTF TOOLS

- Analyze data using NPTFit package (Mishra-Sharma, Rodd, Safdi 1612.03173)
  github.com/bsafdi/NPTFit

- Simulate NP data using NPTFit-Sim (Rodd+Toomey, in prog)

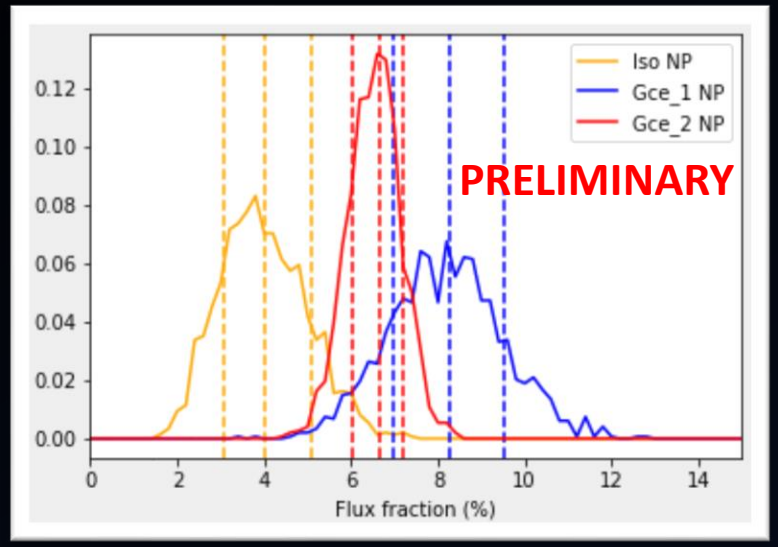
POINT SOURCES IN DIFFERENT REGIONS?

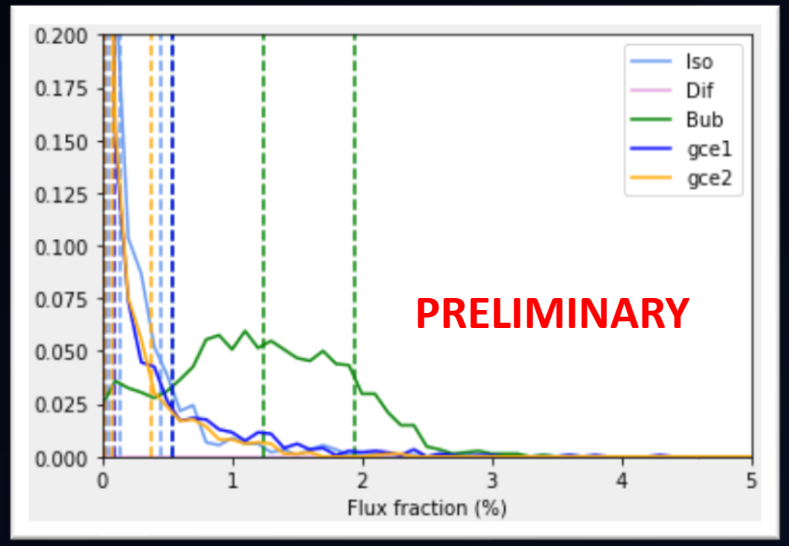


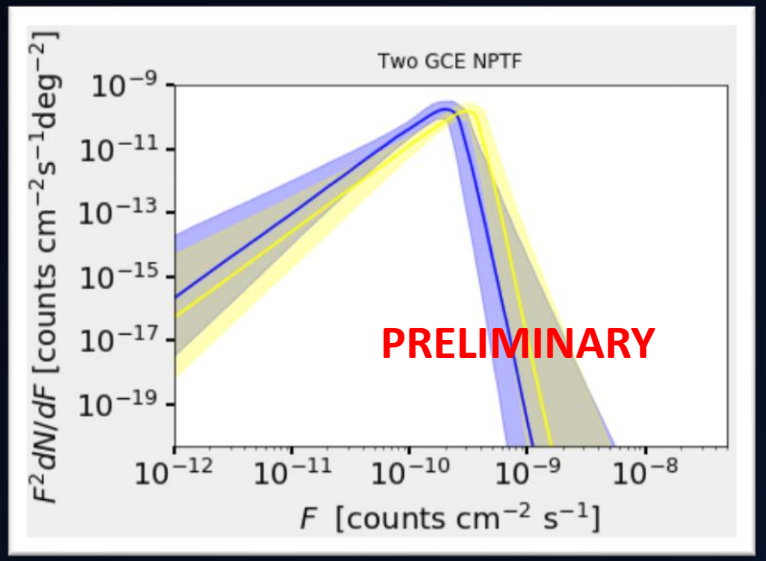


- Annulus study, regions: 2-3, 3-10, 2-5, 5-10, 2-8, 8-10 deg of GC

POINT SOURCES IN DIFFERENT REGIONS?







- Annulus study, region 1: 2-5 deg, region 2: 5-10 deg
  - Consistently see PS preference, contrary to Balaji et al 1803.01952
- Whatever drives PS interpretation extends outside 5 deg

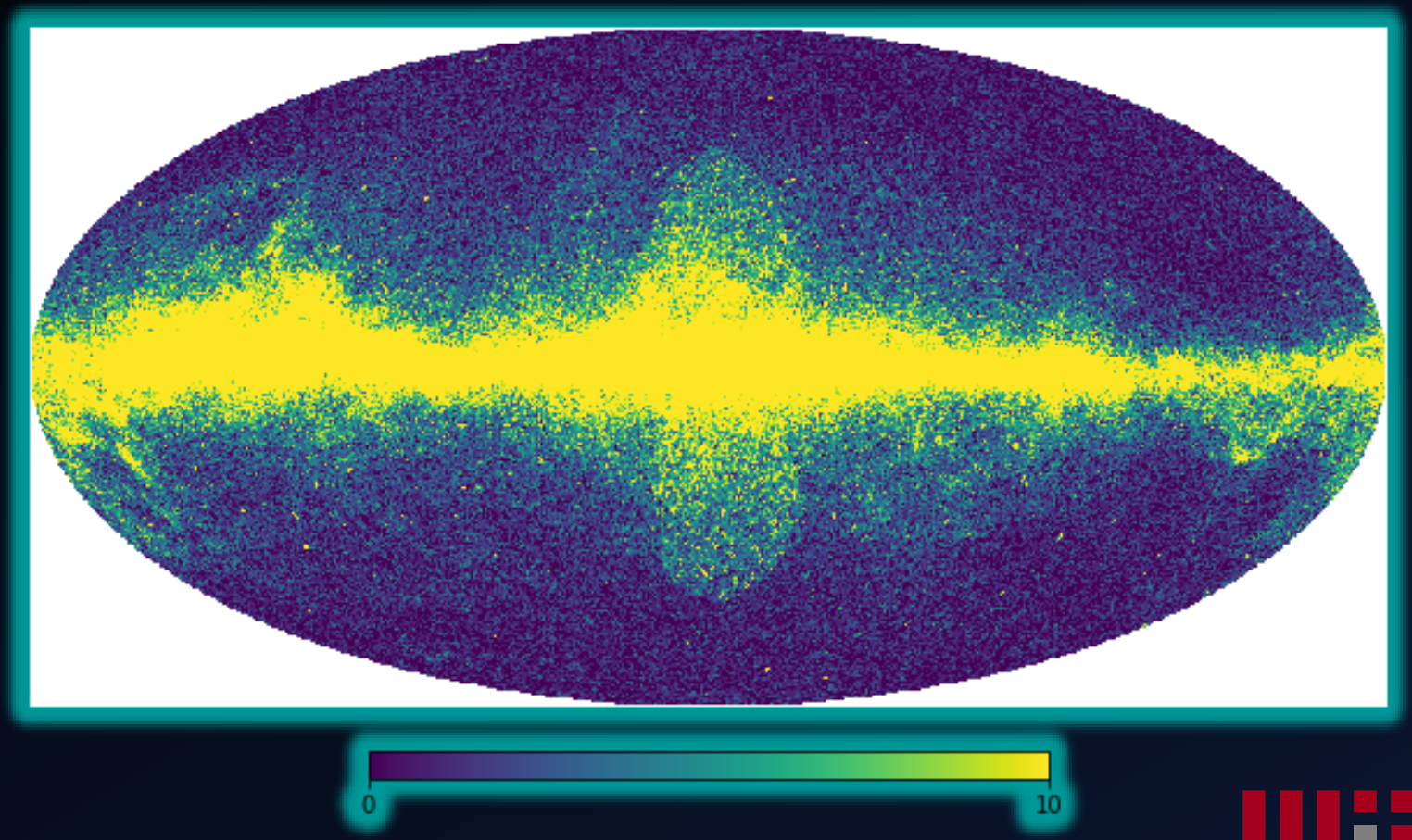
1802.02152

WHAT IS REALLY BEHIND THE PREFERENCE FOR PS?

- Standard analysis uses disk, NFW, isotropic PS templates
- Could the presence of unmodeled PS populations push up the GCE PS template, and push down the inferred dark matter signal?

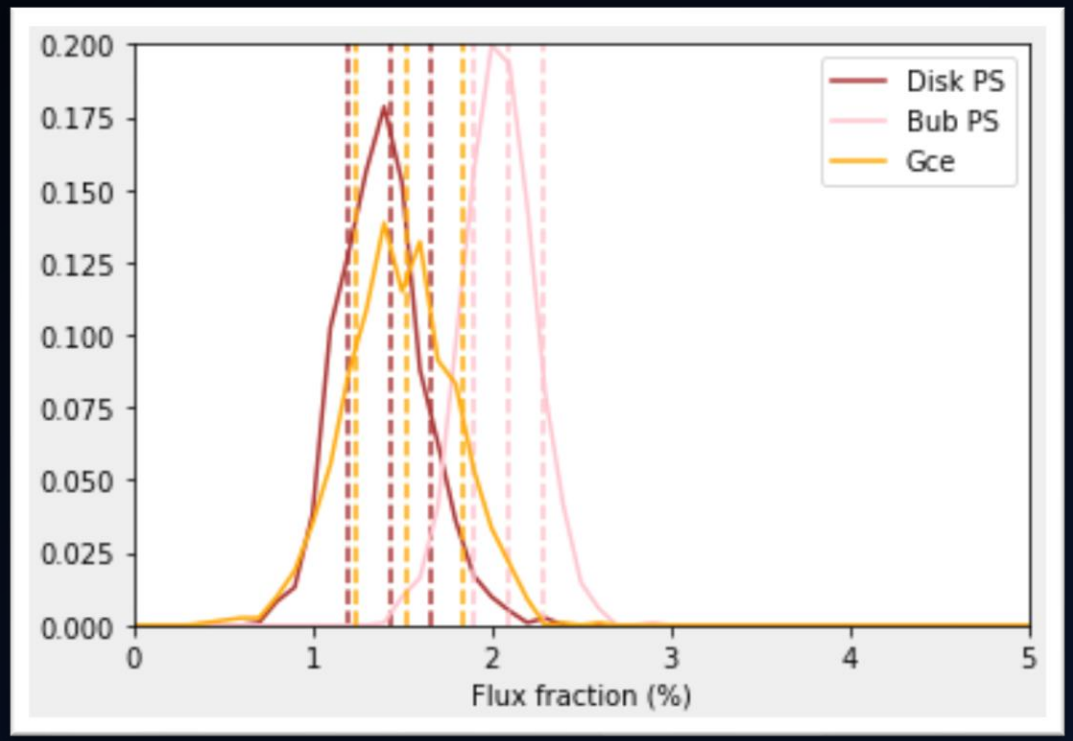
Simulate PS along the disk and bubbles, and poissonian isotropic, bubbles, and diffuse components, and dark matter.

PS Bubbles are the new ingredient, which we simulate as a possible source of bias (potential gas clumps, 1802.02152)



Analyze this data, with exactly the same templates.

Return same normalizations.



What if we simulate the PS bubbles and the DM, but analyze the data with GCE distributed PS instead of the PS bubbles?

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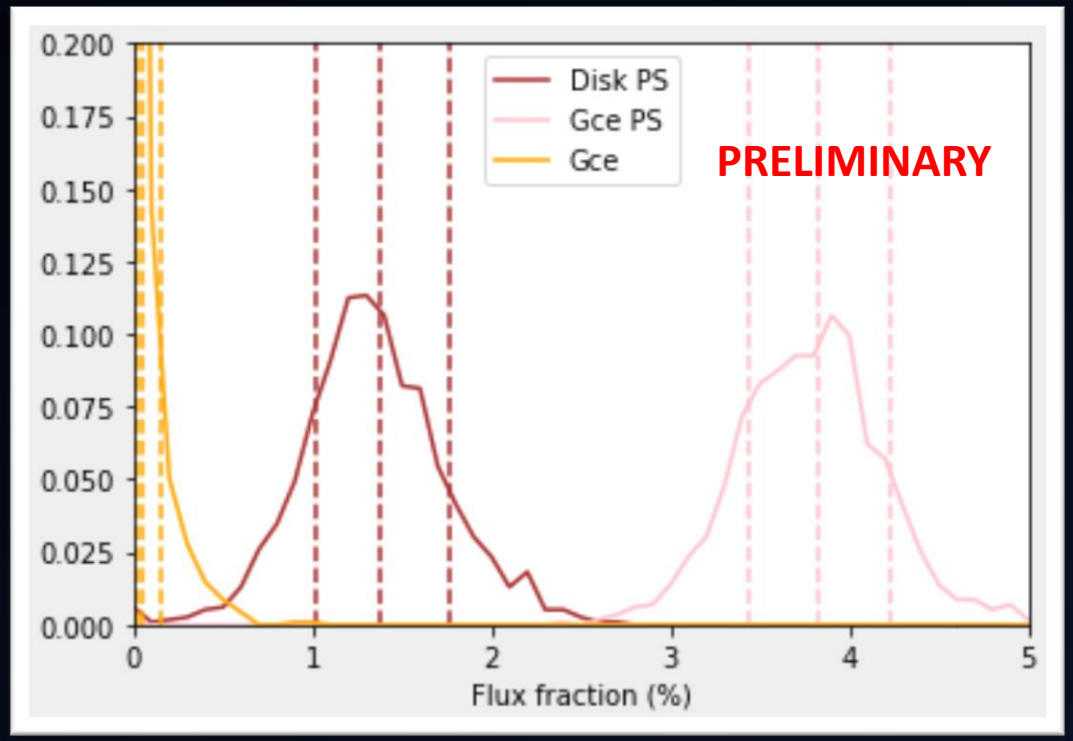

The NPTF attributes the dark matter signal to point sources.

ARE THERE PS ASSOCIATED WITH THE BUBBLES?

- Check several regions of sky: within latitudes of 20, 40, 60 deg, 2 or higher degrees masked through plane
- Analyze with and without PS in Fermi bubbles.
  - Include isotropic PS, disk PS at lower latitudes, plus poisson templates
- See no meaningful change in Bayes factor

Point sources do not appear to be present in the Fermi Bubbles.

SUMMARY

- GCE firmly detected, generation unknown
- Point sources appear to be preferred in several sky regions, including at b>5 degrees
- Simulated data was used to examine if unaccounted for PS populations can bias NPTF methods
- PRELIMINARY: we have found a proof-of-principle example where a simulated dark matter signal can instead be attributed to PSs by the NPTF, in a simulation including unmodeled sources in the Fermi Bubbles
- In Fermi data, find no evidence for PS correlated with the Fermi Bubbles

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EXTRA SLIDES

DIFFUSE TEMPLATE

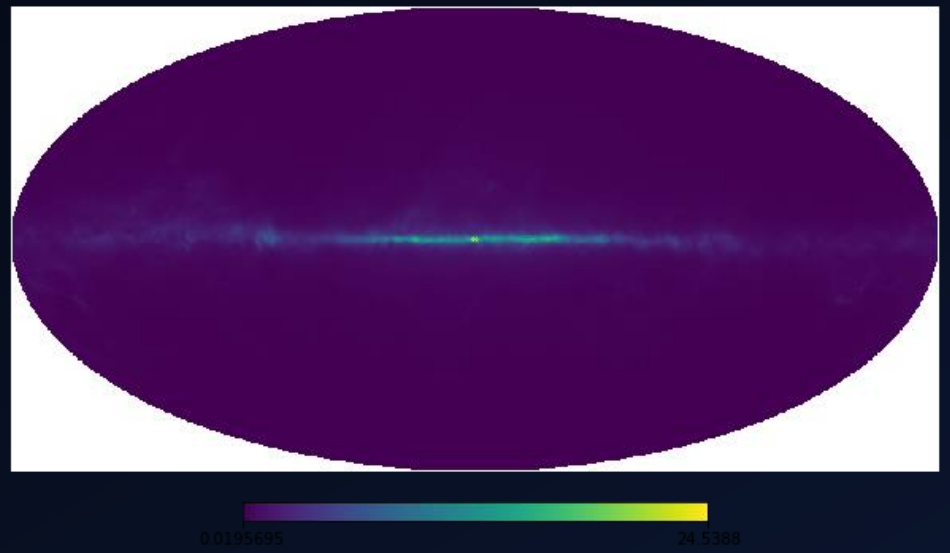
Diffuse gamma-ray emission in Milky Way

= Gas density x CR proton density

+ gas density x CR electron density

+ photon density x CR electron density

Use Fermi diffuse model, p6v11



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EXCESS CANDIDATES

- Pulsars
  - Matching gamma-ray spectrum
  - Small scale power in inner Galaxy gamma-ray emission
  - BUT why don't we see the low-mass X-ray binaries in the Inner Galaxy?
  - AND luminosity function of pulsars doesn't match Lee at al (2015)
    - Population of MSPs would have to be different to those in disk of the Milky Way or globular clusters
- Cosmic Outbursts
- Annihilating DM?

GCE MORPHOLOGY

- Spherically symmetric around GC (axis ratios within 20% of unity)
- Scales $r^{-2.4}$ extending out to around 10°
- DM annihilation interpretation implies $r^{-2.4}$ out to at least about 1.5 kpc