TRICKING NON-POISSONIAN TEMPLATE FITTING:
Dark Matter Hiding At The Galactic Center?

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DESY Theory Workshop
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To appear, with Tracy Slatyer

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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
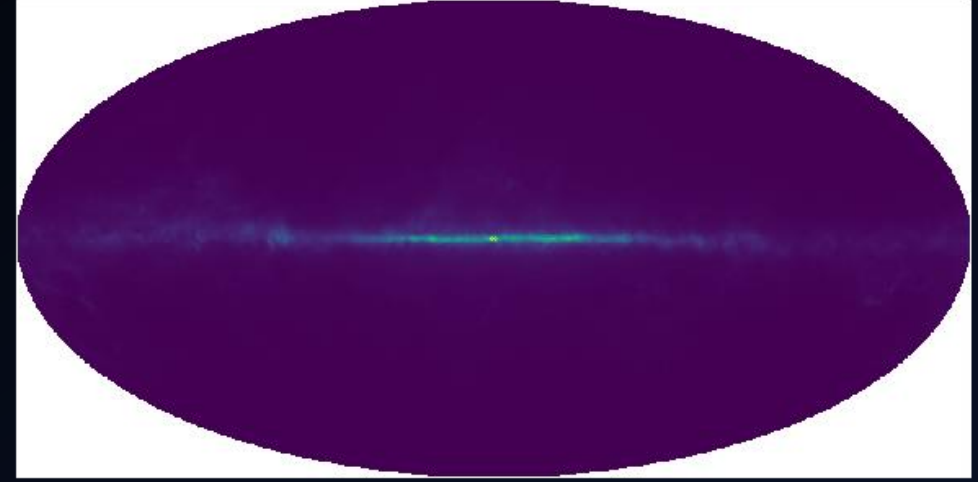 - Bartels et al 1506.05104, Lee at al 1506.05124

Daylan et al (2014)

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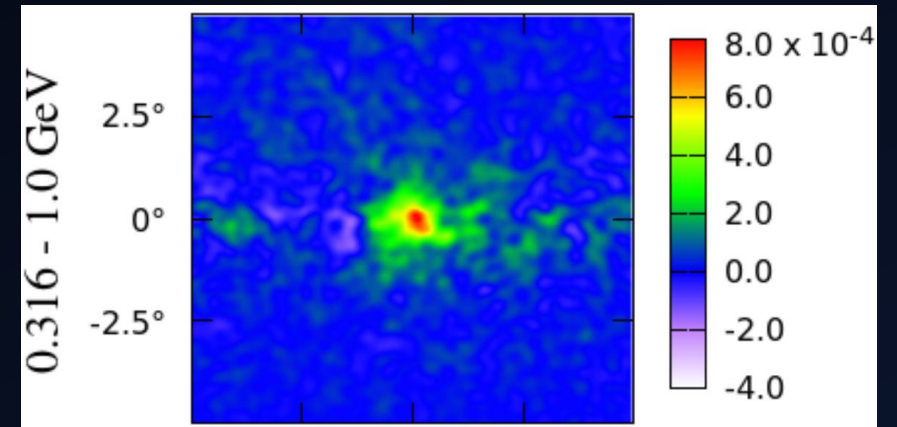
ISOTROPIC
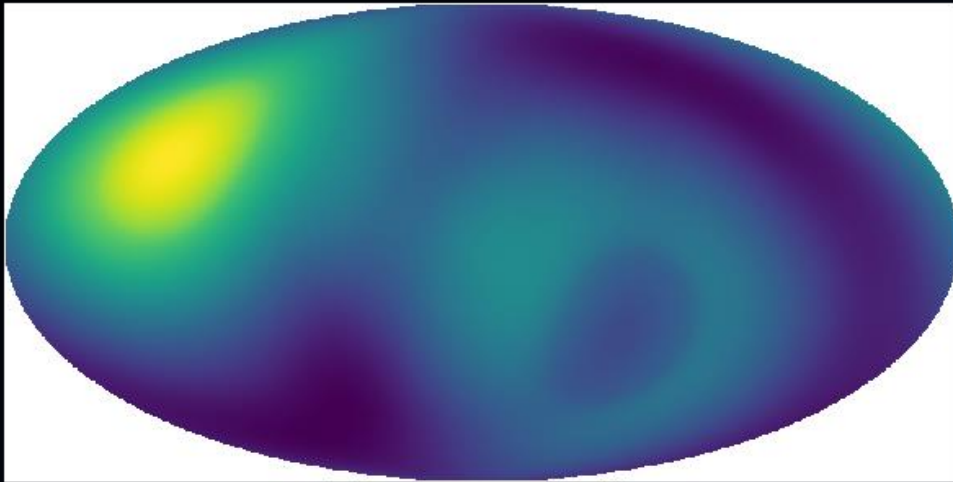
DIFFUSE

BUBBLES

NFW

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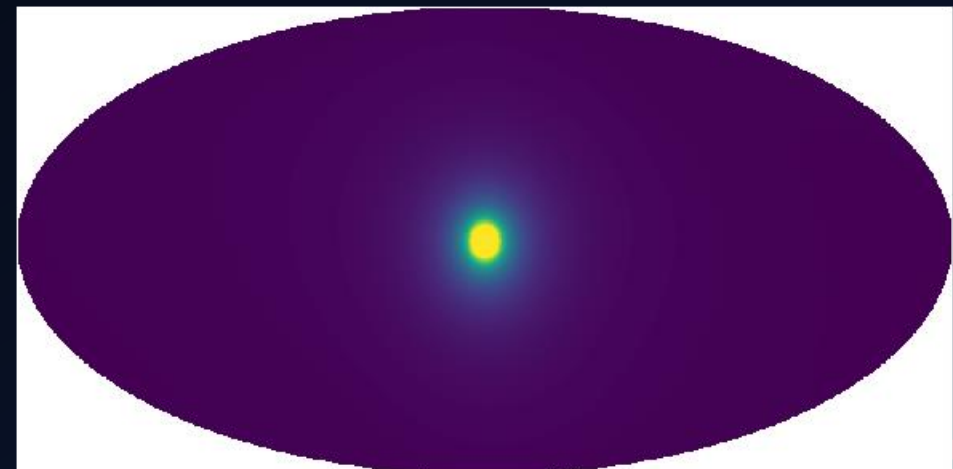
POISSON vs NON-POISSON TEMPLATE FITTING

- 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))

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PREFERENCE FOR POINT SOURCES AT THE GC
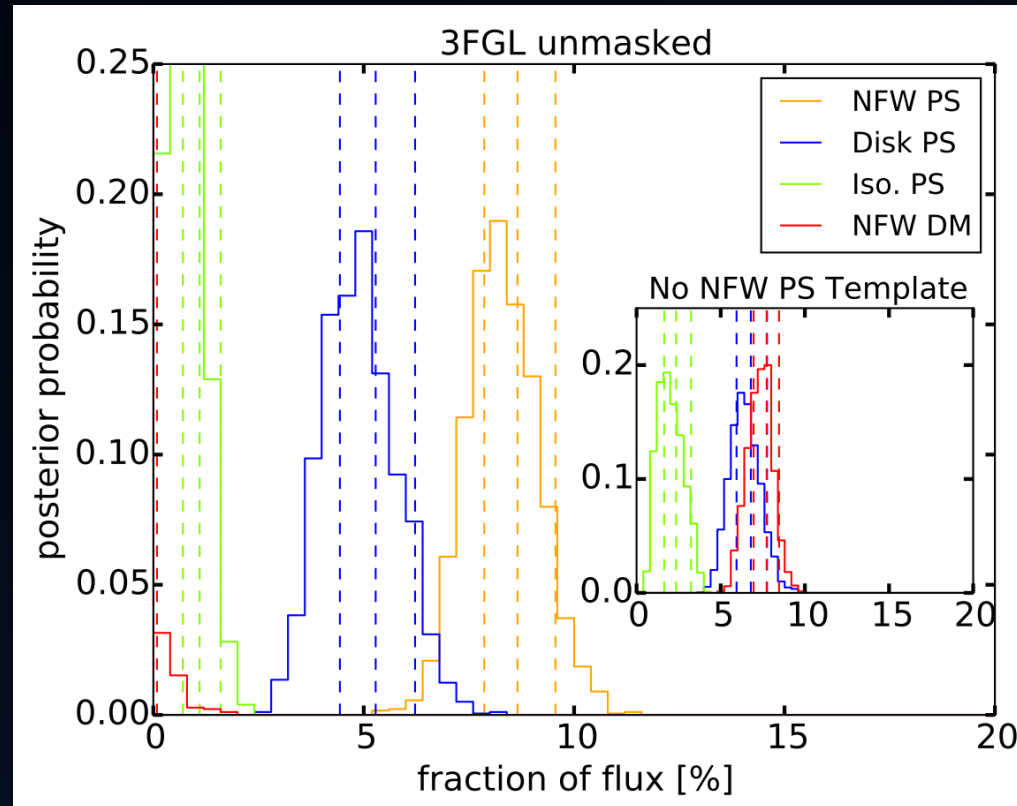
Lee, Lisanti, Safdi, Slatyer, Xue (PRL 2015)

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WHAT IS REALLY BEHIND THE PREFERENCE FOR PS?

Could the presence of unmodeled PS populations push up the NFW PS template, and push down the inferred dark matter signal?

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

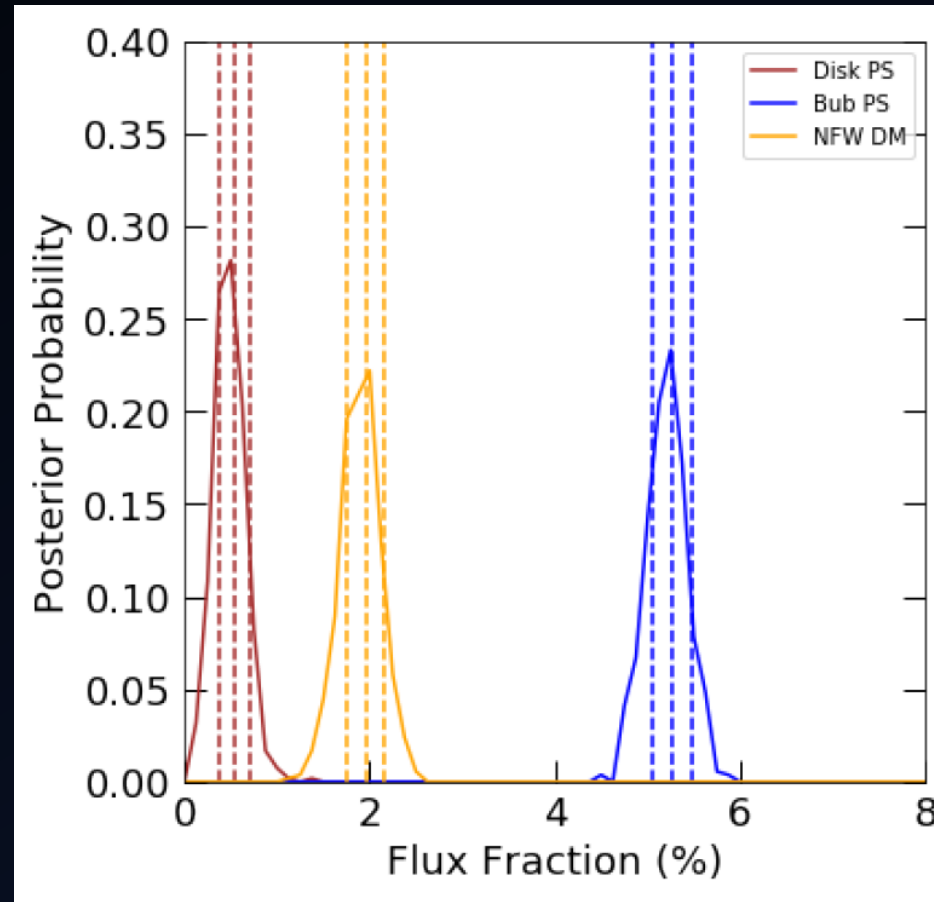PS Bubbles are the new ingredient, which we simulate as a possible source of bias (potential gas clumps, 1802.02152)
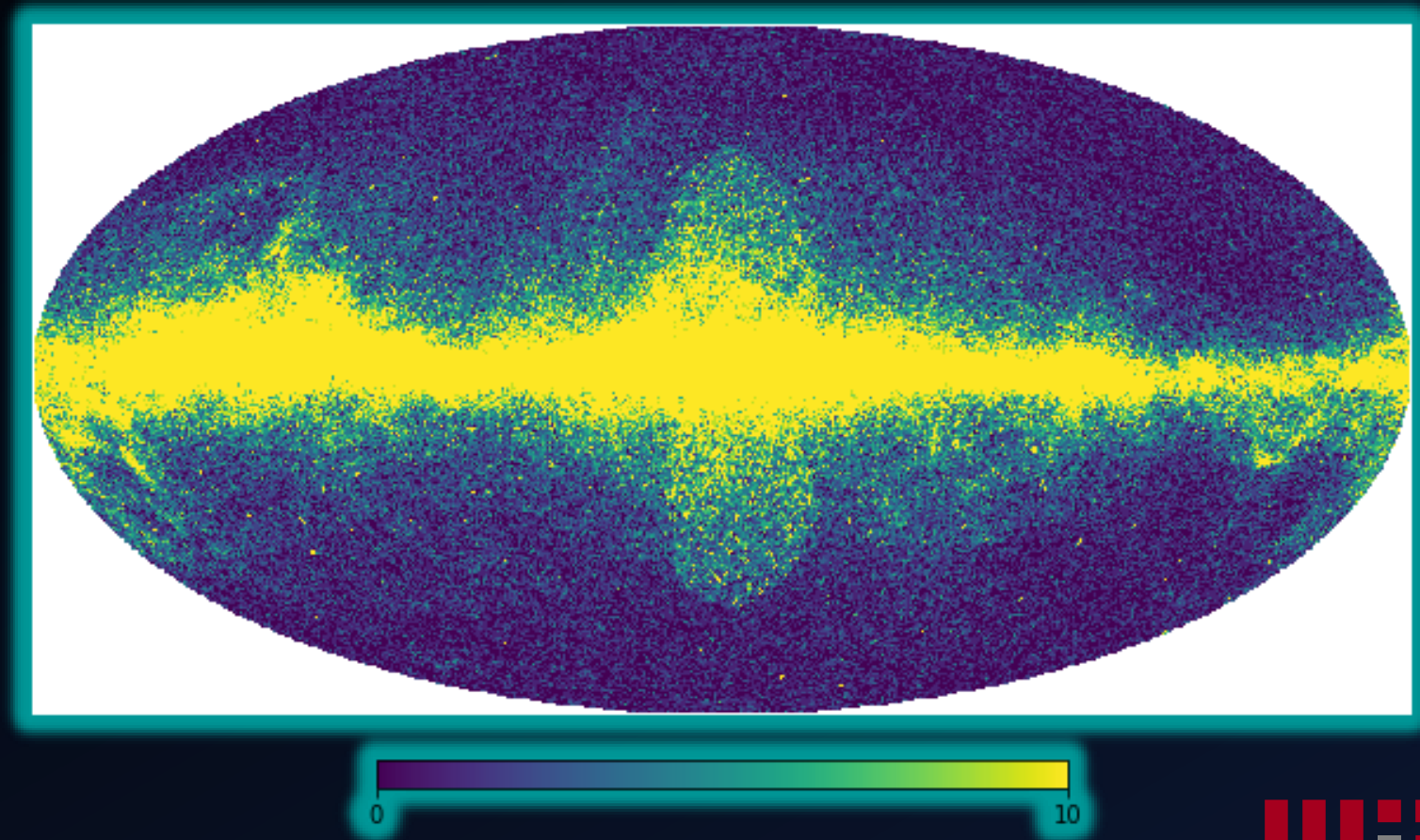

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Analyze this data, with exactly the same templates.

Return same normalizations.

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

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What if we simulate the PS bubbles and the DM, but analyze the data with NFW distributed PS instead of the PS bubbles?
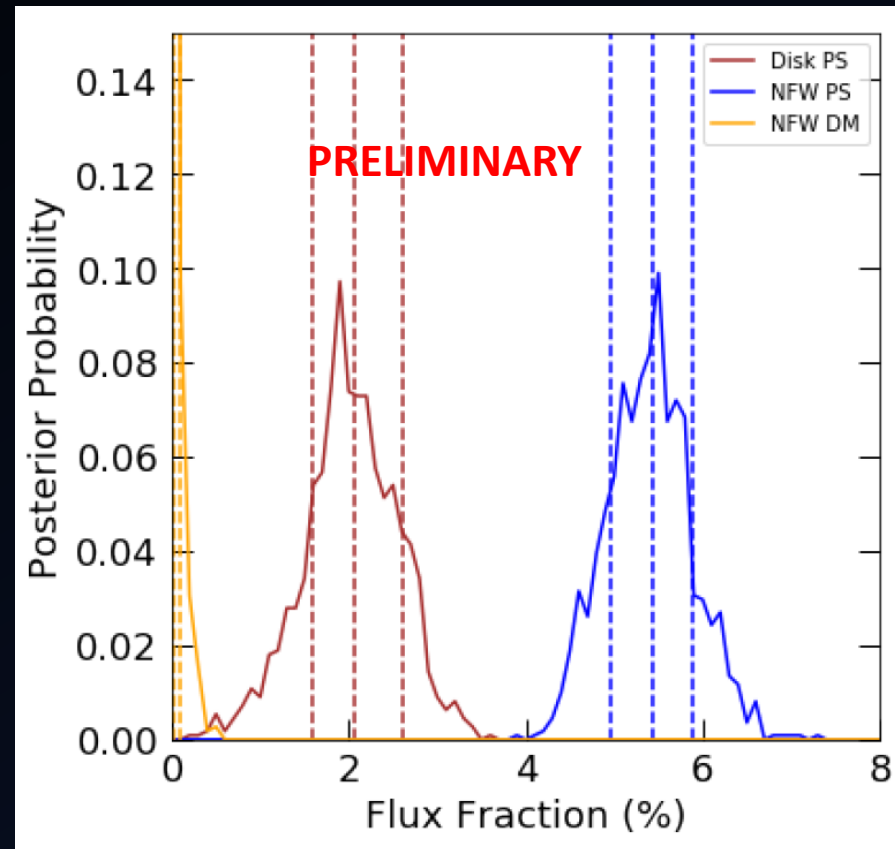
The NPTF attributes the dark matter signal to point sources.

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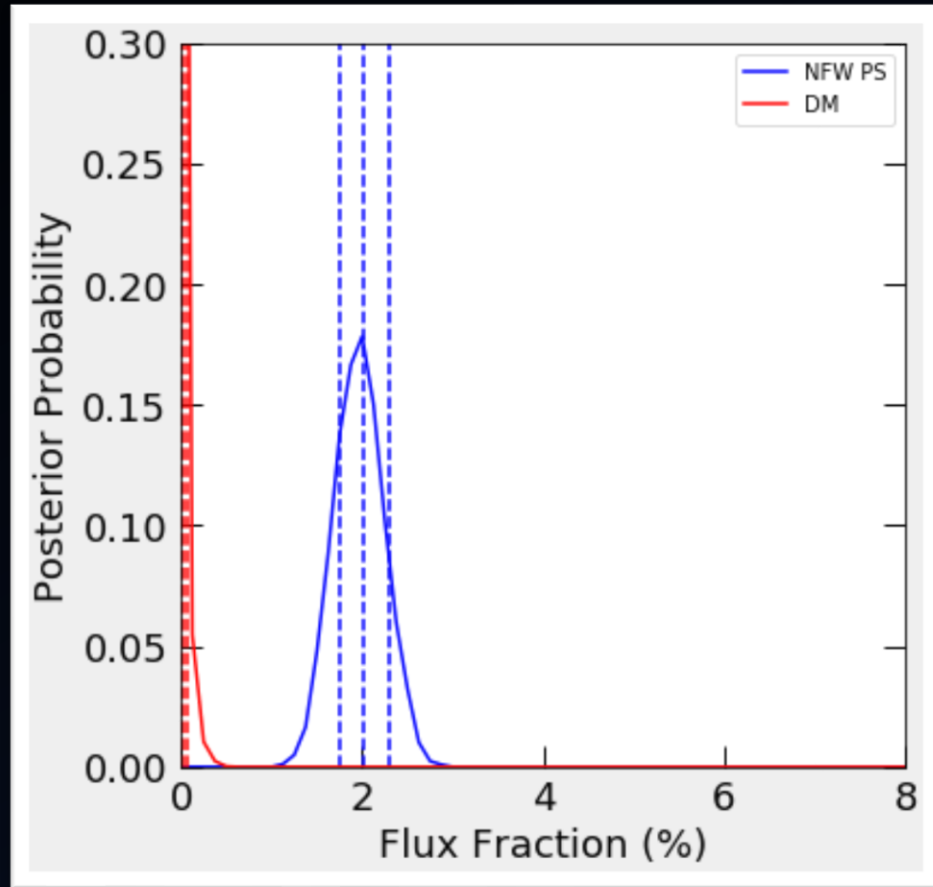
ARE THERE PS ASSOCIATED WITH THE BUBBLES?

- 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

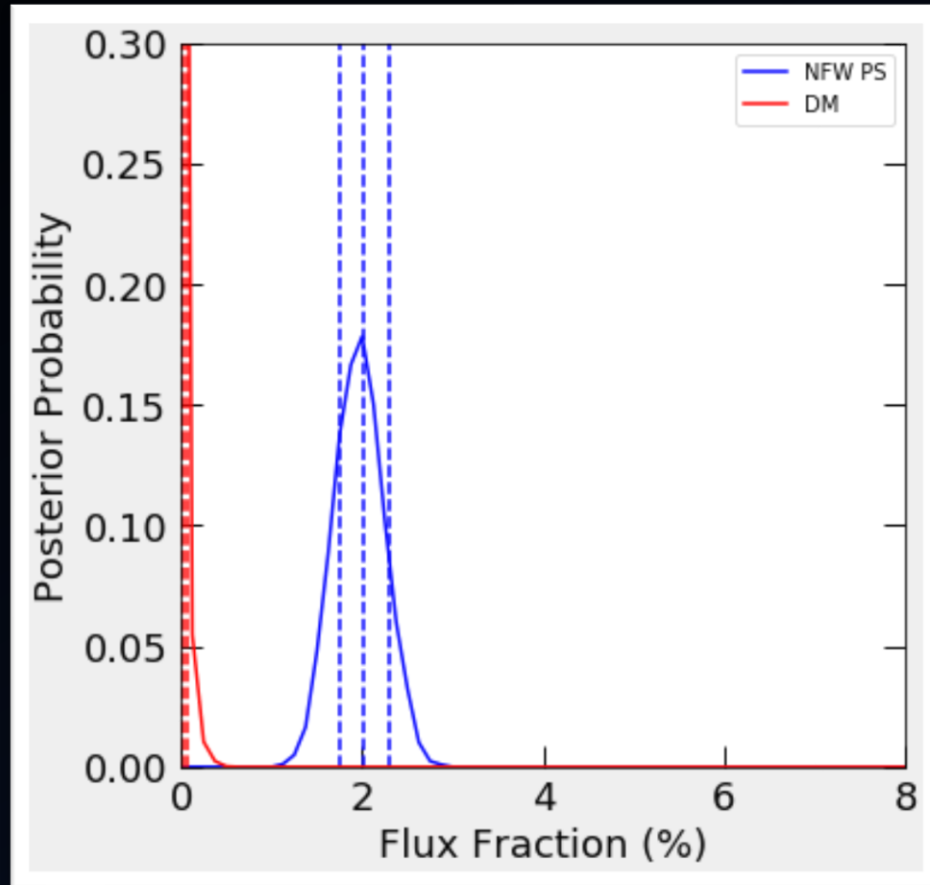Point sources do not appear to be present in the Fermi Bubbles.

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TESTING WITH THE REAL FERMI DATA

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REGULAR DATA

INJECTED DM SIGNAL + DATA
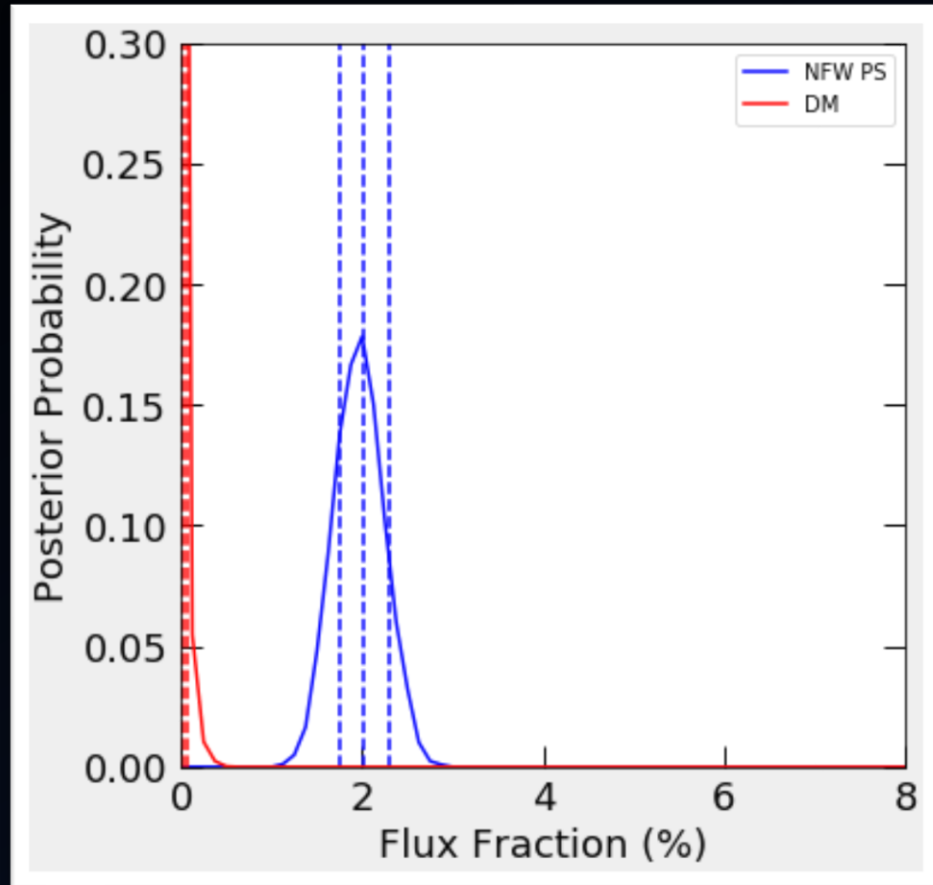

Zero DM!
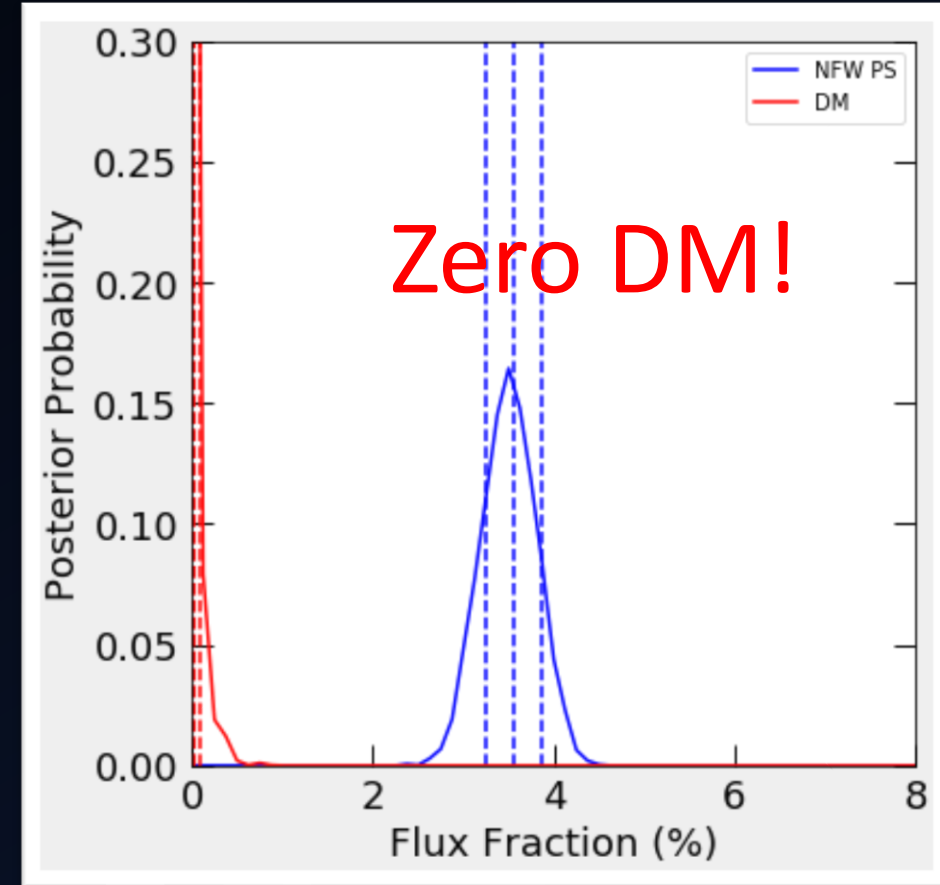
PRELIMINARY

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REGULAR DATA

LARGER INJECTED DM SIGNAL + DATA

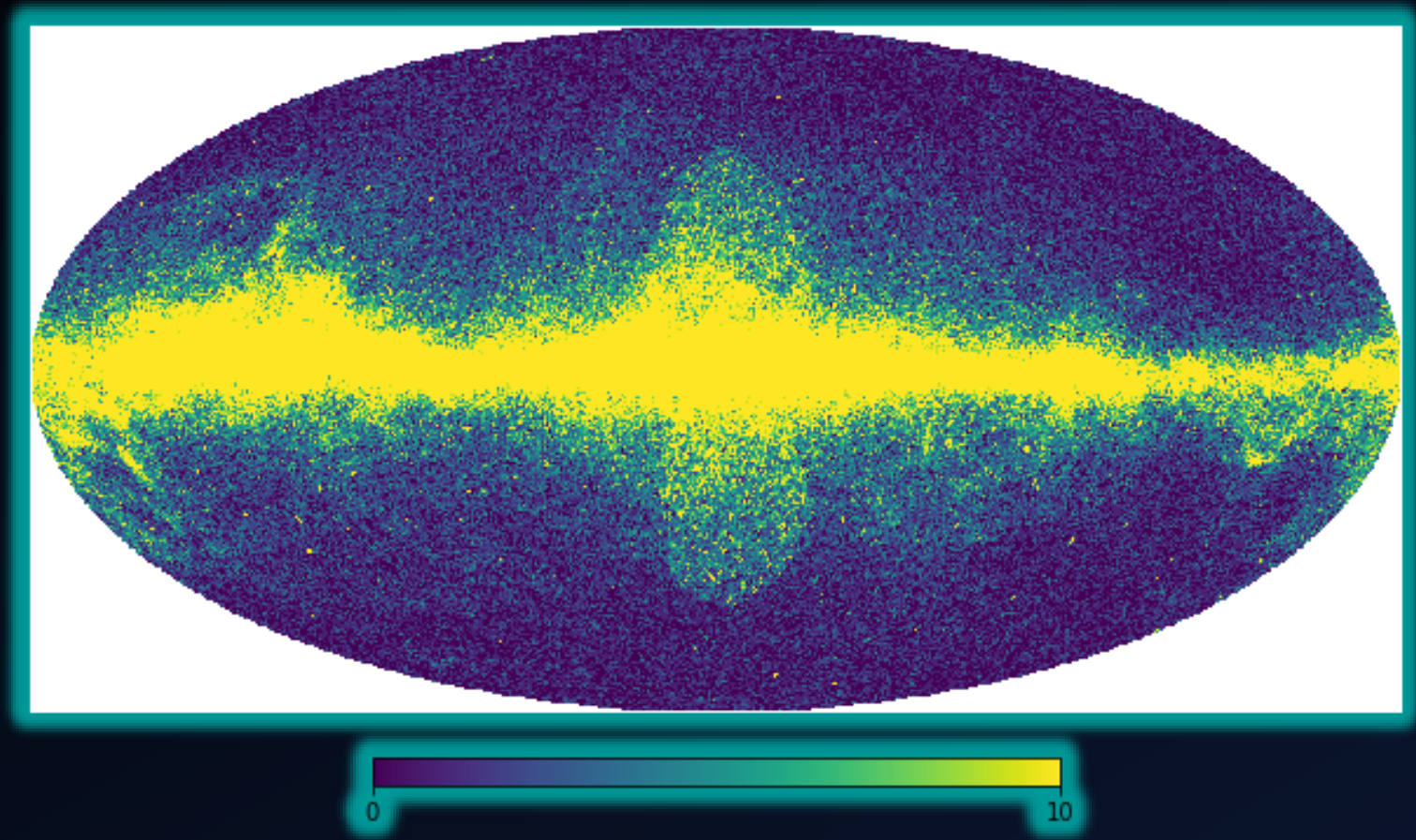Rebecca Leane

REGULAR DATA

LARGER INJECTED DM SIGNAL + DATA

Zero DM!
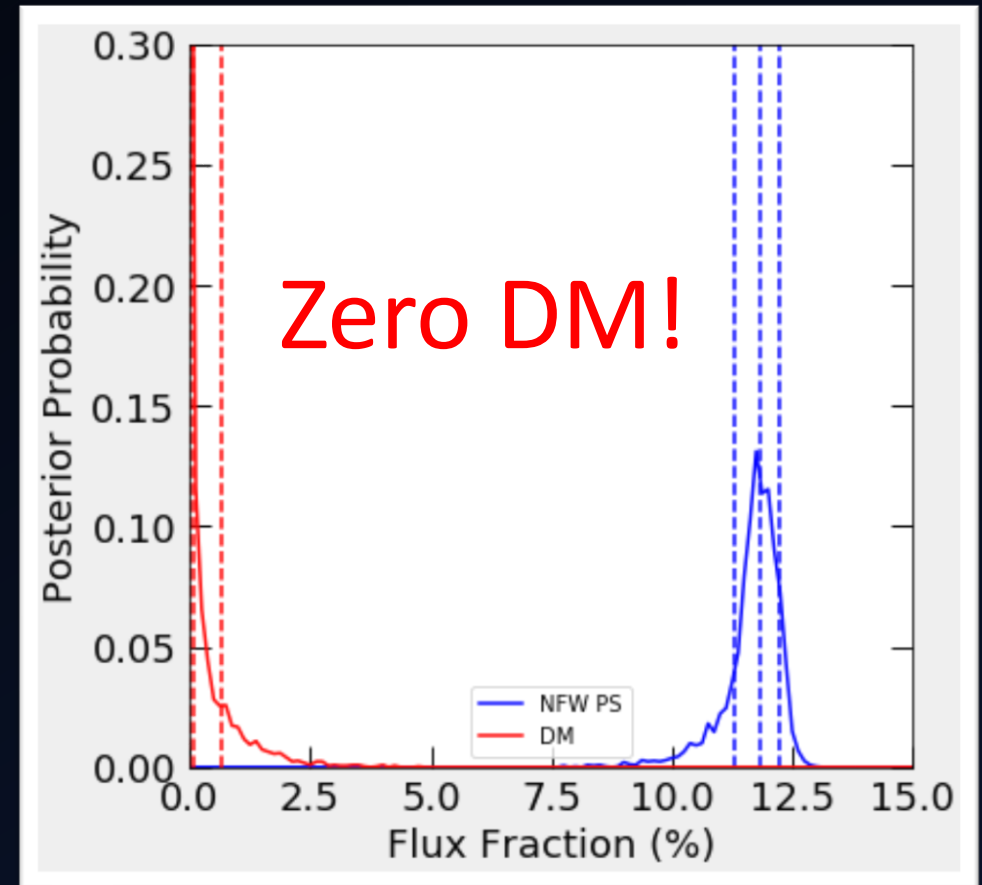
PRELIMINARY

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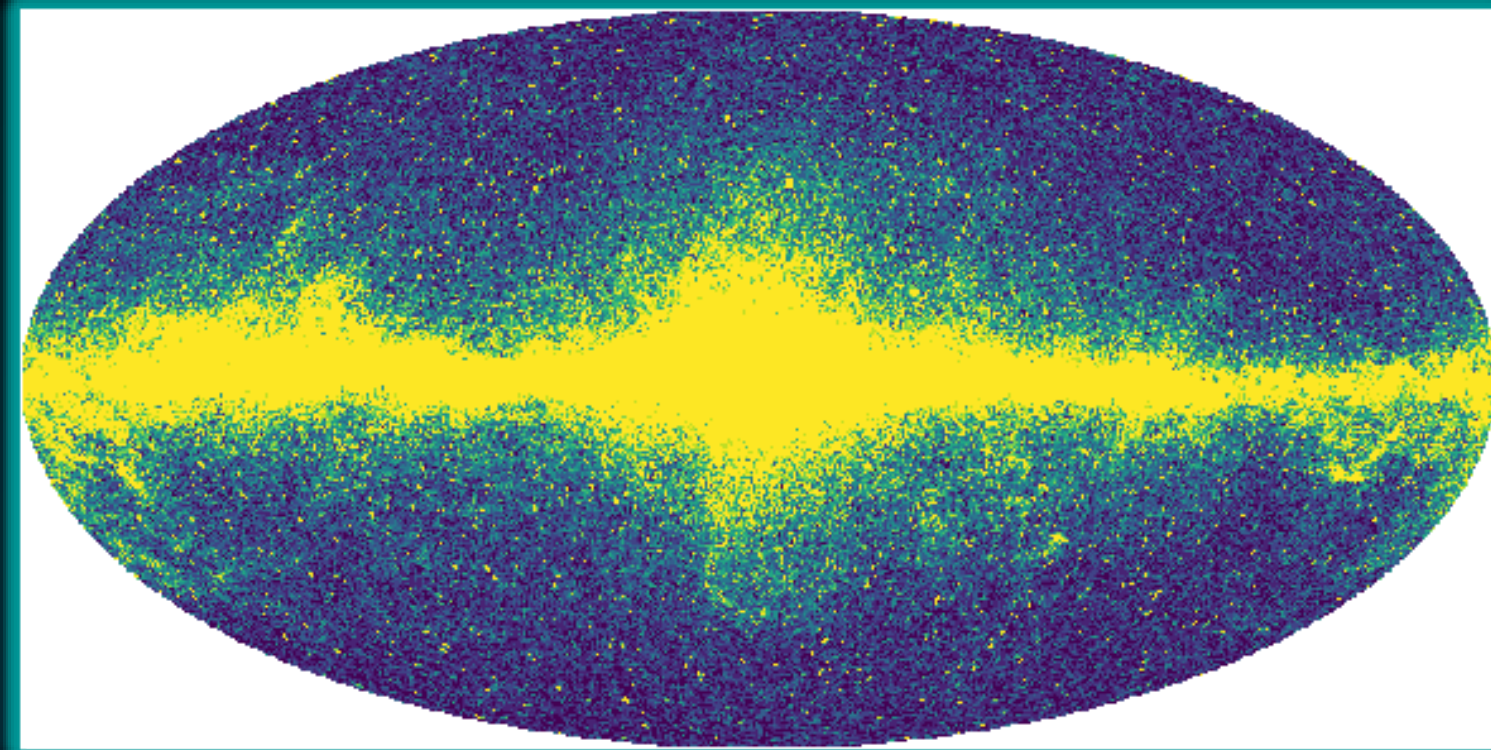Massachusetts Institute of Technology

BOMBARD THE GALAXY!

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BOMBARD THE GALAXY!

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REGULAR DATA

PRELIMINARY

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REGULAR DATA

BOMBARDED DM SIGNAL + DATA

Hardly...

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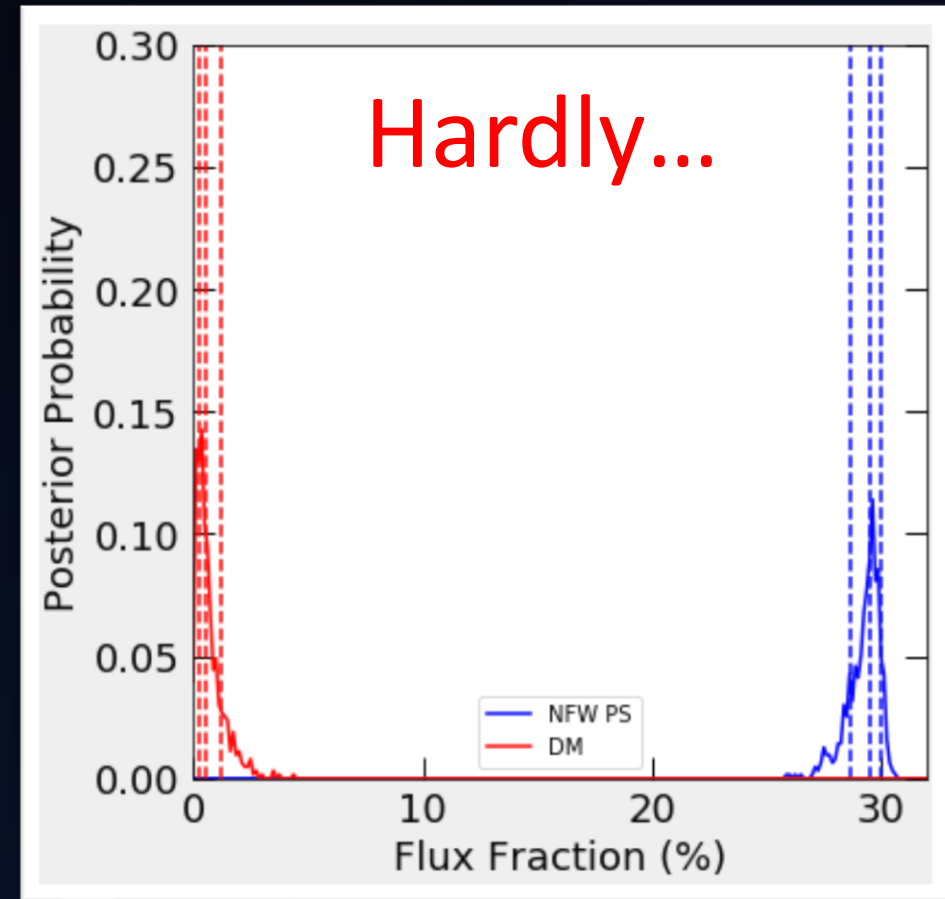
PRELIMINARY

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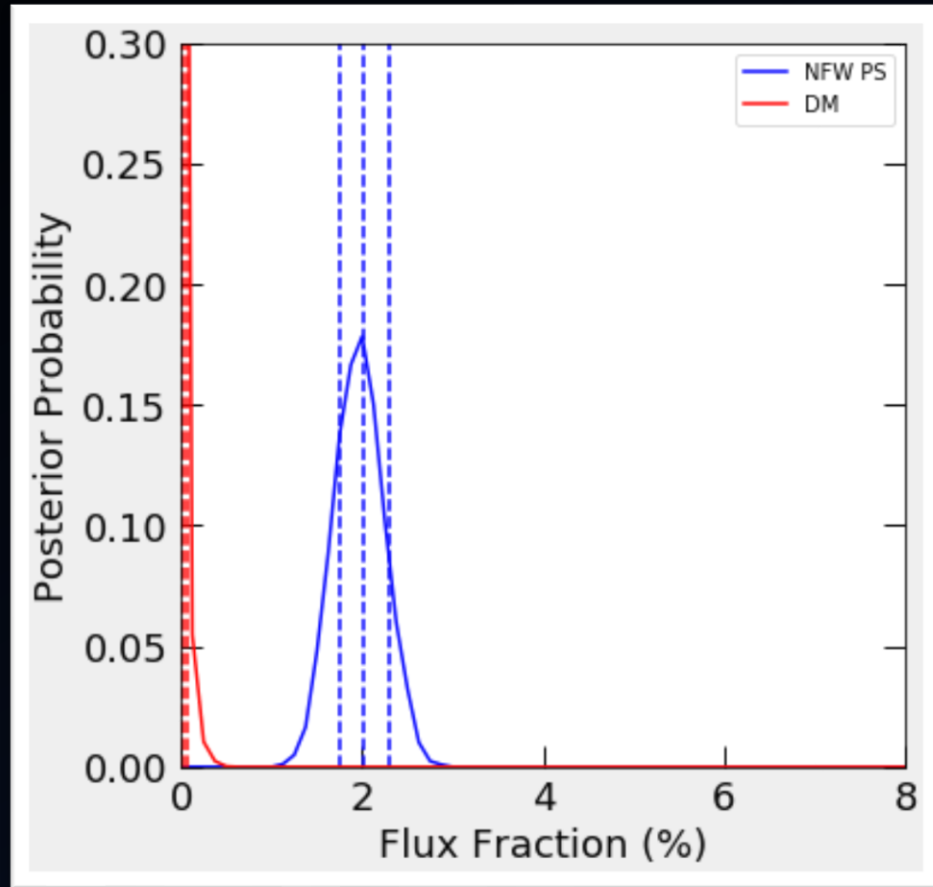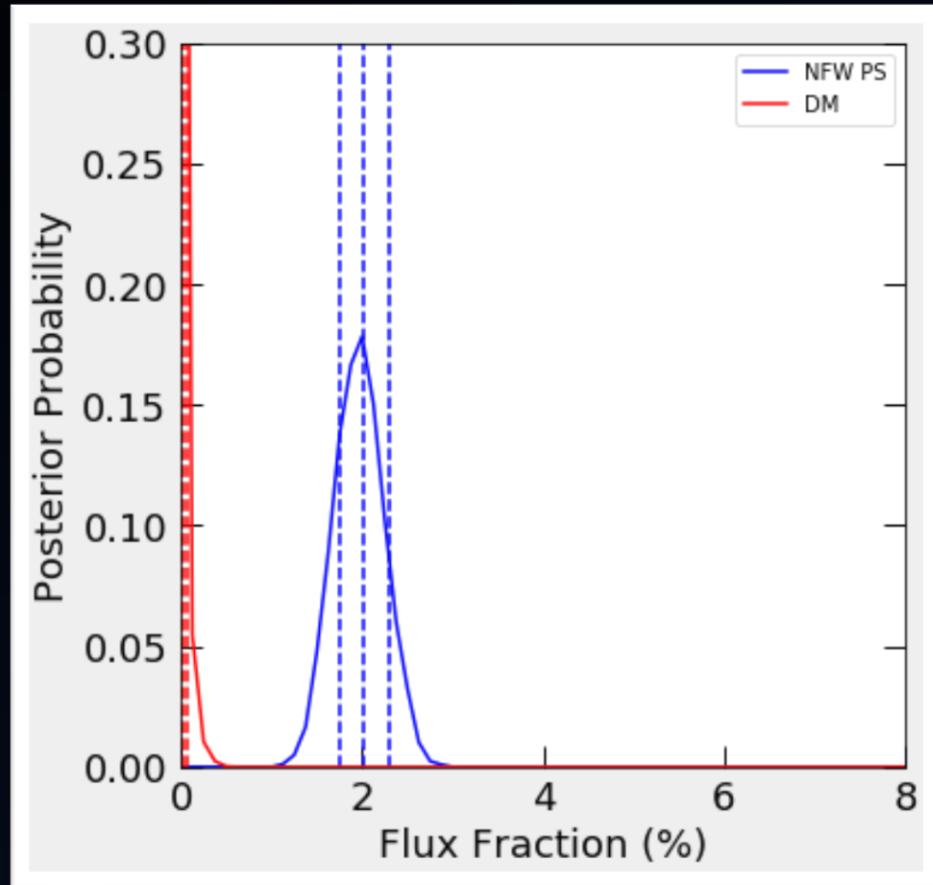
REGULAR DATA

SUBTRACTED DM SIGNAL + DATA

Zero DM.
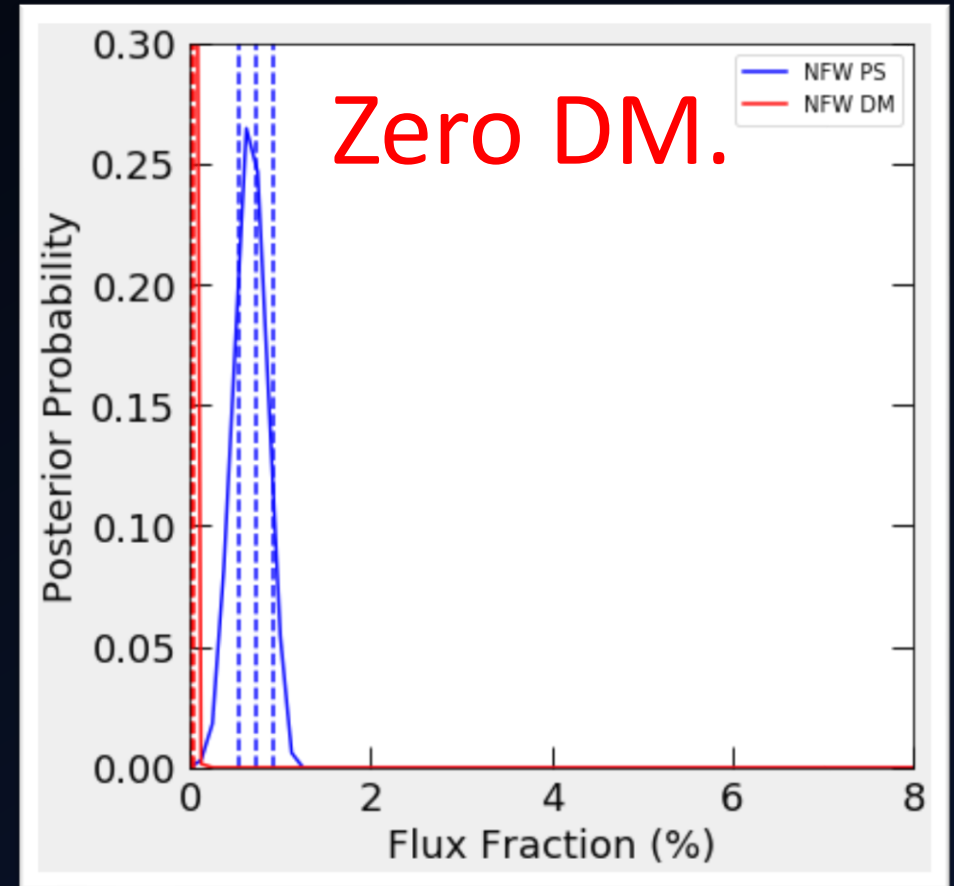
PRELIMINARY

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SUMMARY

- GCE firmly detected, generation unknown

- Simulated data was used to examine if unaccounted for PS populations can bias NPTF methods

- Simulated DM signal is misattributed to PSs by the NPTF, in a sim including unmodeled sources in the Fermi Bubbles

- Find no evidence for PS correlated with the Fermi Bubbles

- Injecting DM signal into real Fermi data: confirms possible effect!

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EXTRA SLIDES

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DIAGNOSING THIS IN THE DATA

- Injecting and subtracting DM signal into real Fermi data: confirms possible

- When wrong template is identified, Bayes factor tends to get worse

- Still successfully compares combinations of templates

- Detection of currently unresolved MSP by radio telescopes possible within next few years

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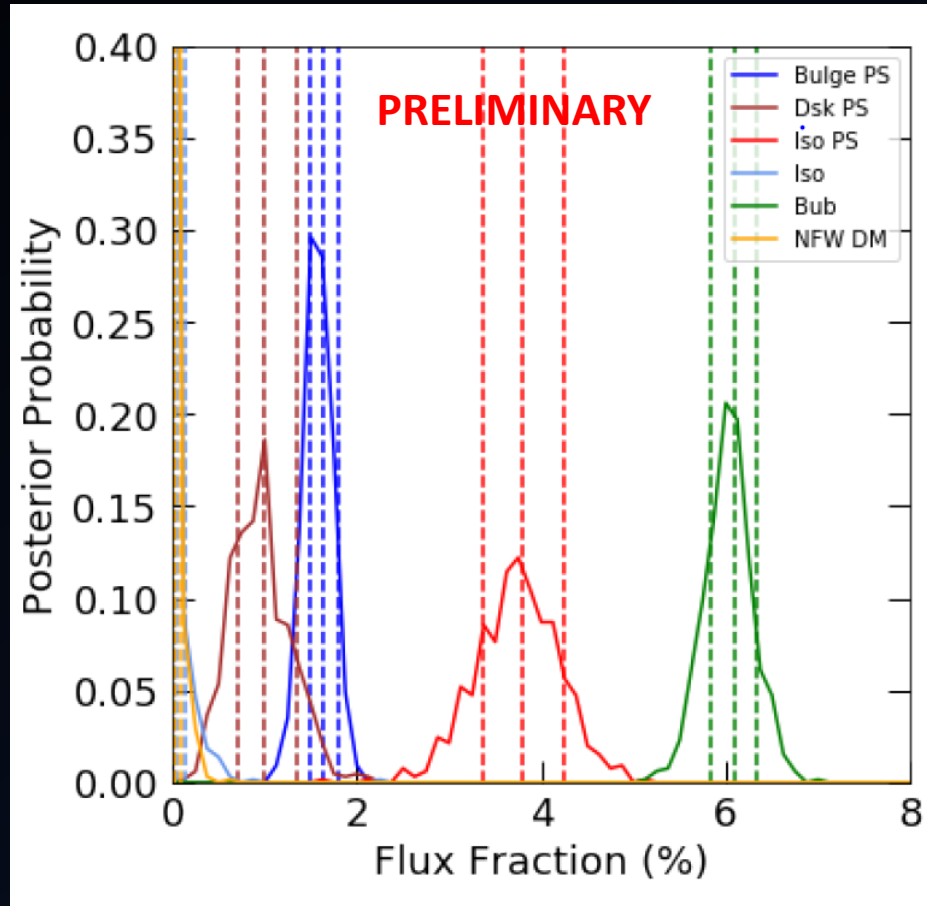
WHAT ABOUT THE BOXY BULGE?
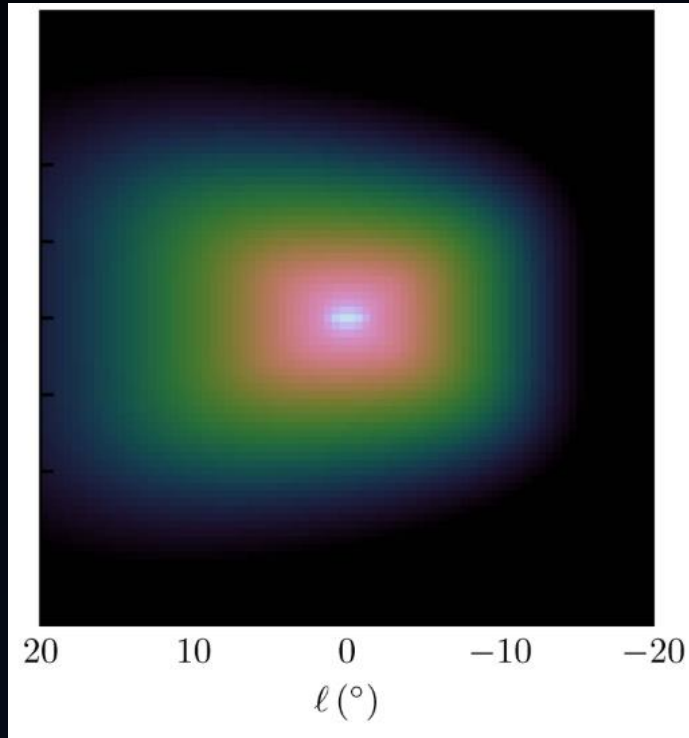
- Population of stars at the GC

- Unmodeled candidate could impact interpretation of the data

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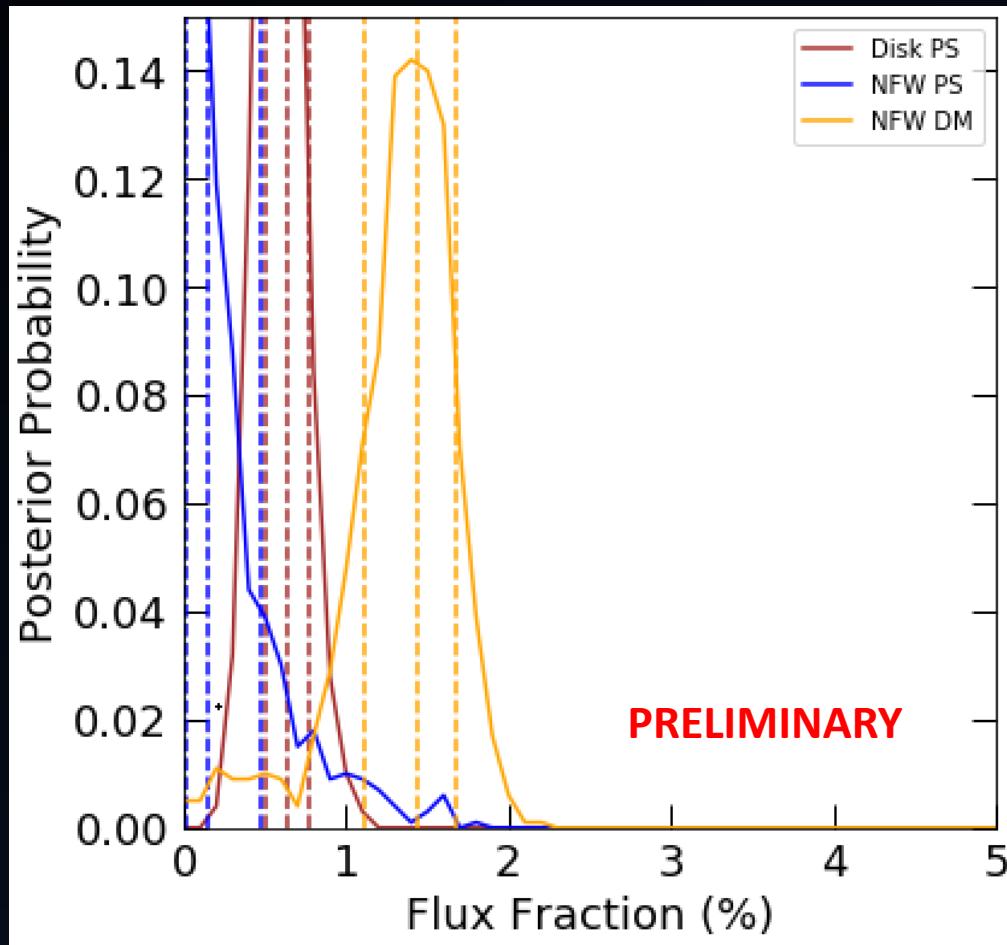# BOXY BULGE CAN EXPLAIN GCE

- Find evidence for PS associated with the Boxy Bulge!

- Can do just as well as NFW PS. Beats in some cases.

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...BUT CAN'T TRICK THE NPTF

In simulated data, successfully recover the DM component when Bulge emission is simulated, and is analysed with NFW PS.

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POINT SOURCES

- Small scale power can be attributed to astrophysical point sources (PSs)

- Resolved PS: can be easily detected individually

- Unresolved PS: not sufficiently individually bright, with angular extent below the resolution of the detector

- Collectively many sub-detection threshold PSs can make a substantial contribution in gamma rays and explain the GCE

- Key candidate are millisecond pulsars

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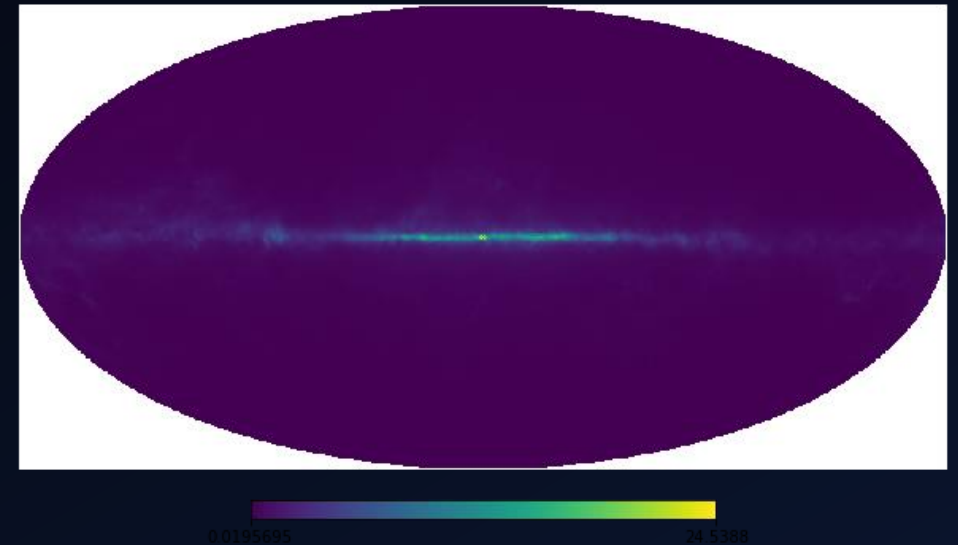
DIFFUSE TEMPLATE

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?

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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

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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)
  github.com/nrodd/NPTFit-Sim

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POINT SOURCES IN DIFFERENT REGIONS?
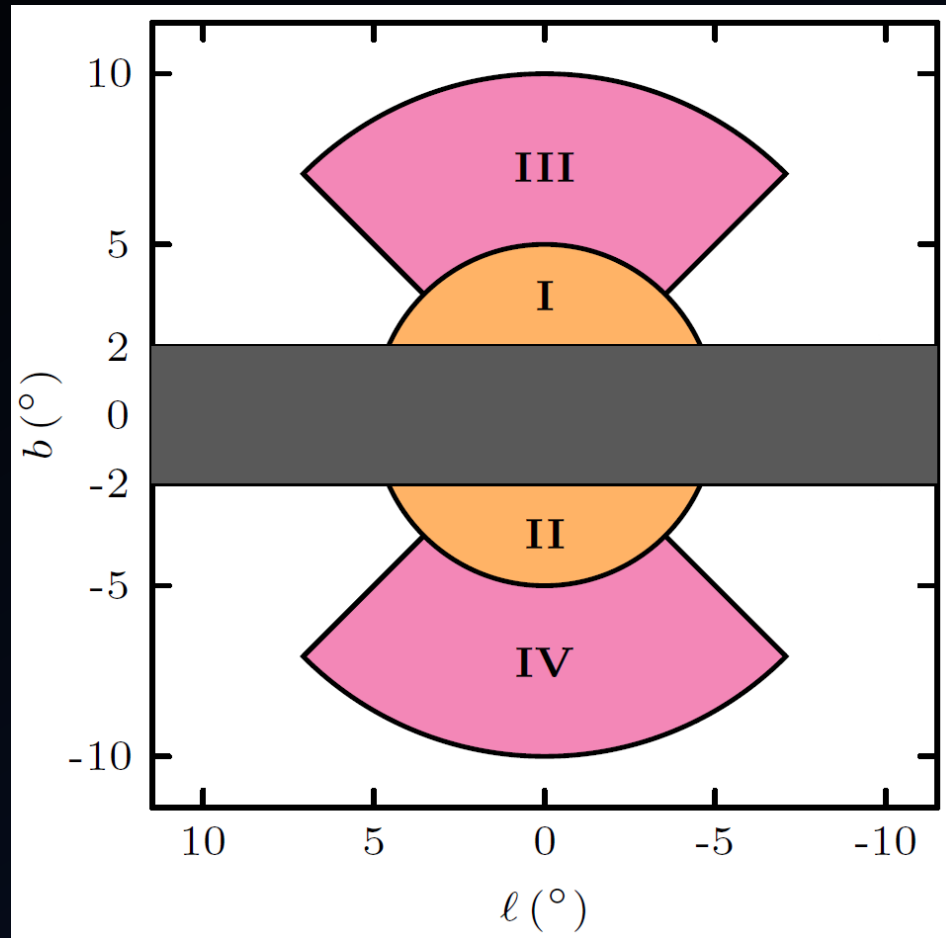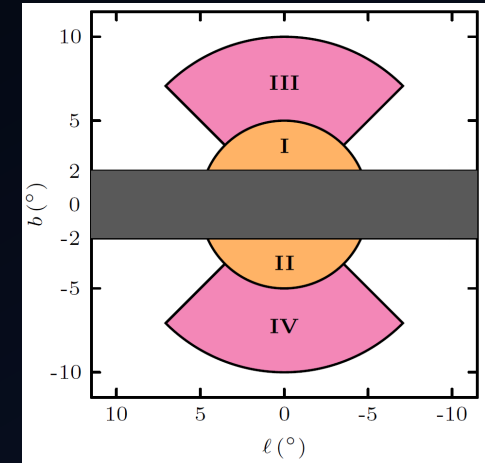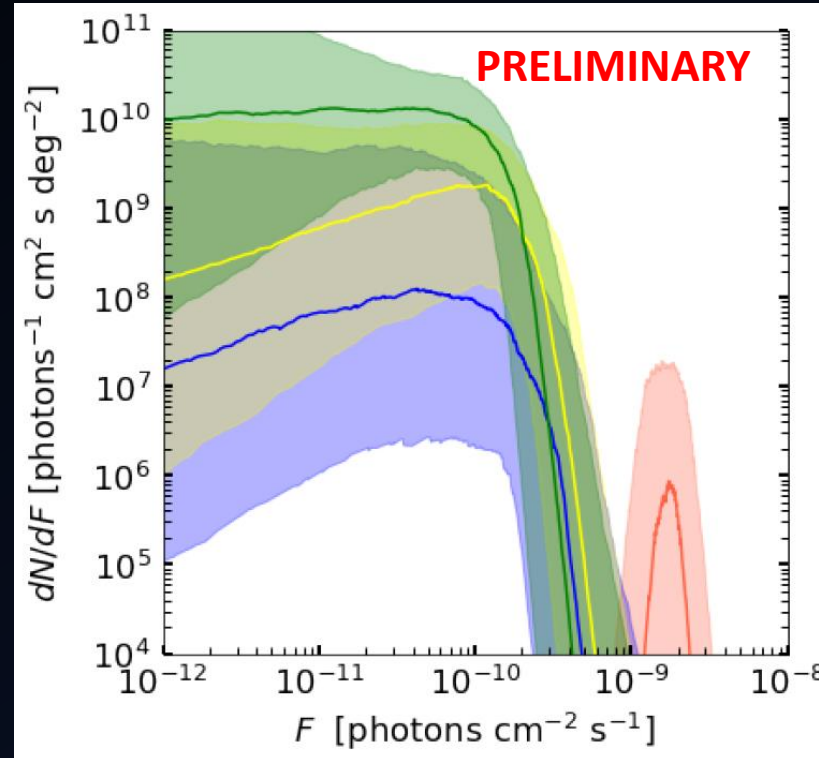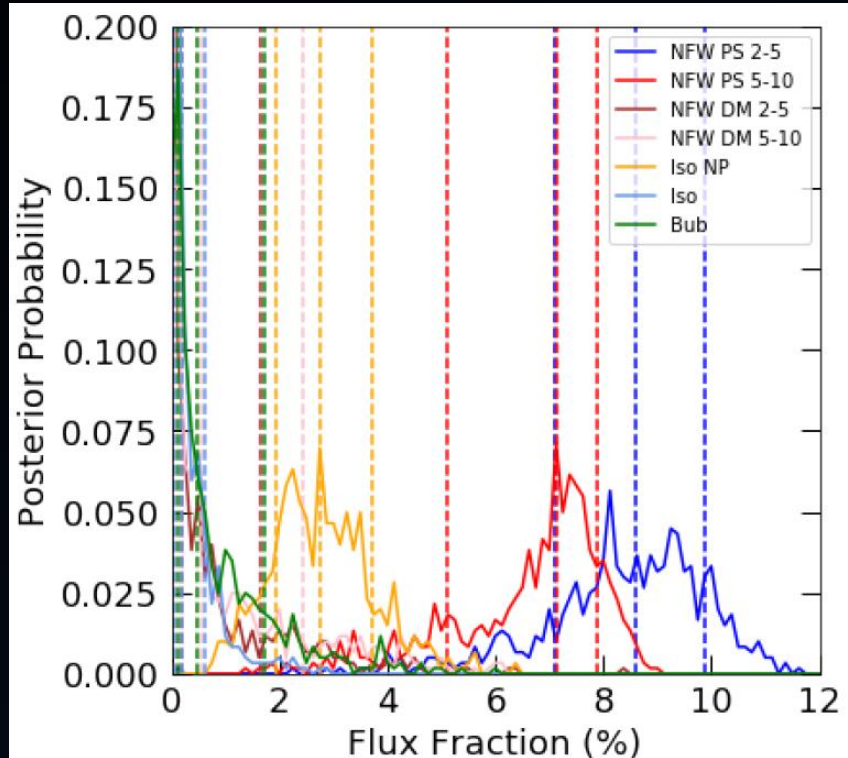

- Annulus study, regions: 2-5, 5-10 deg of GC

- Recently found smooth emission preference for b>5deg
  Balaji et al 1803.01952

- Also consistent with regions from earlier studies
  Calore et al 1409.0042
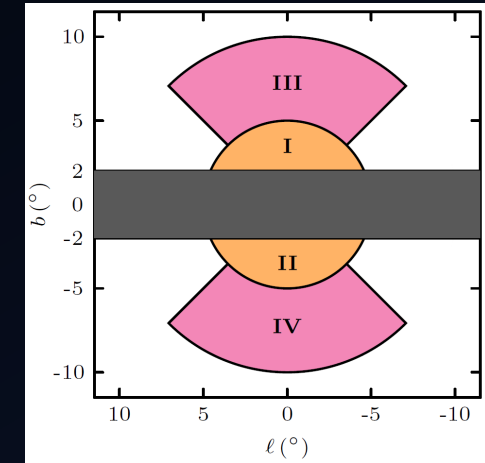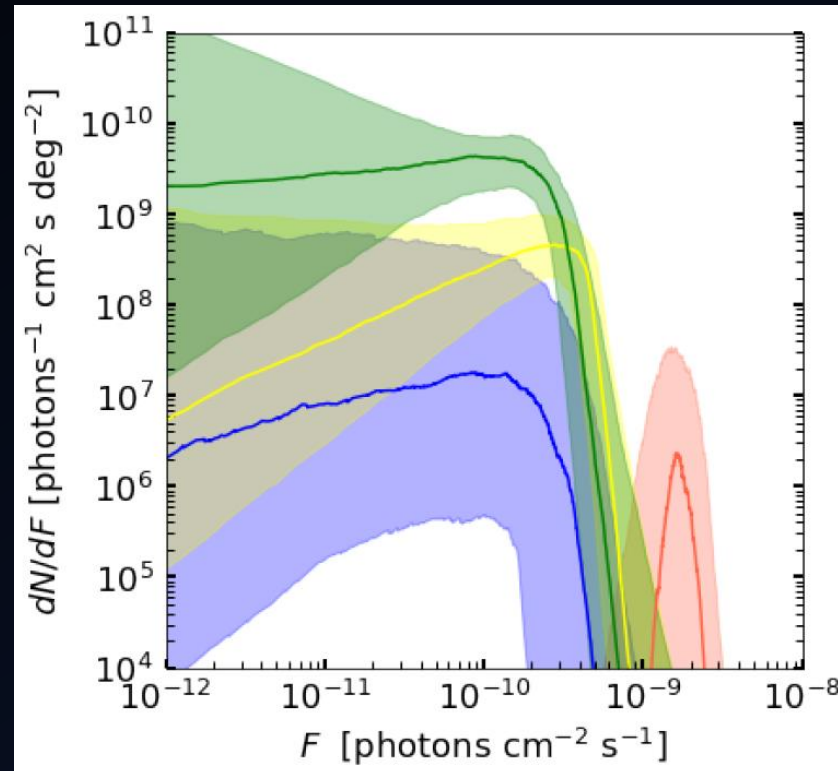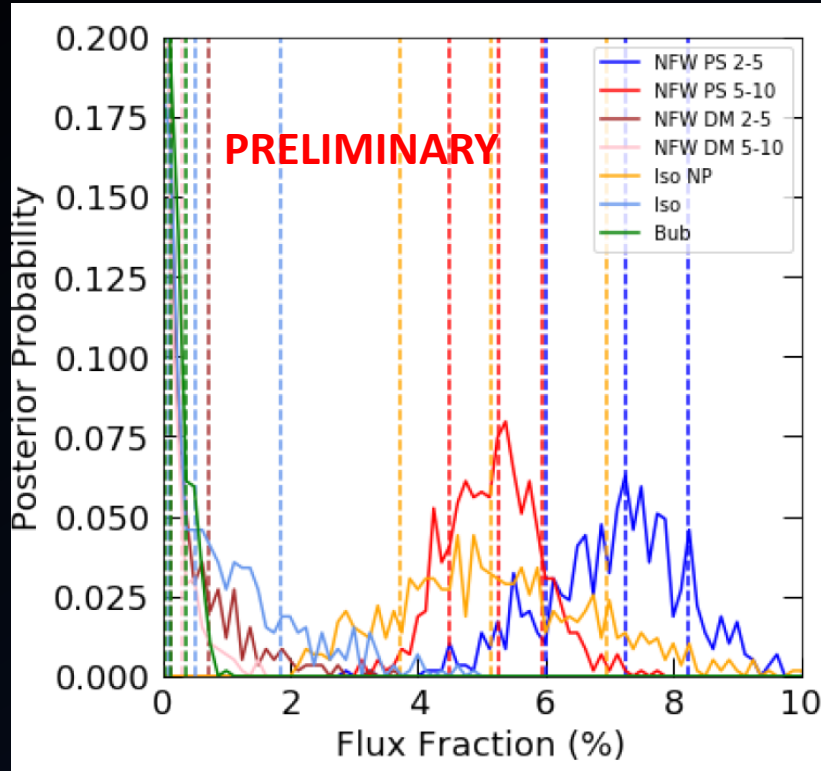
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SOUTHERN HEMISPHERE

PRELIMINARY

- Consistently see PS preference, contrary to Balaji et al 1803.01952
- Whatever drives PS interpretation extends outside 5 deg

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NORTHERN HEMISPHERE

- Consistently see PS preference, contrary to Balaji et al 1803.01952

- Whatever drives PS interpretation extends outside 5 deg

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