The Galactic Center

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GRAPPA
GRavitation AstroParticle Physics Amsterdam

in the γ-sky
Oct. 23 2017, Garmisch

UNIVERSITY OF AMSTERDAM

Overview

1. GCE Analysis with SkyFACT

2. Standard template fitting <-> Skyfact

3. Can we see a GCE in the disk?

The Galactic Centre Excess

Goodenough & Hooper 2009, Vitale+ (Fermi coll.) 2009, Hooper & Goodenough 2011, Hooper & Linden 2011, Boyarsky+ 2011 (no signal), Abazajian & Kaplinghat 2012, Hooper & Slatyer 2013, Huang+ 2013, Gordon & Macias 2013, Macias & Gordon 2014, Zhou+2014, Abazajian+ 2014, Daylan+2014, Calore+ 2014, Gaggero + 2015, Carlson+ 2015. Fermi-LAt 2016, 2017

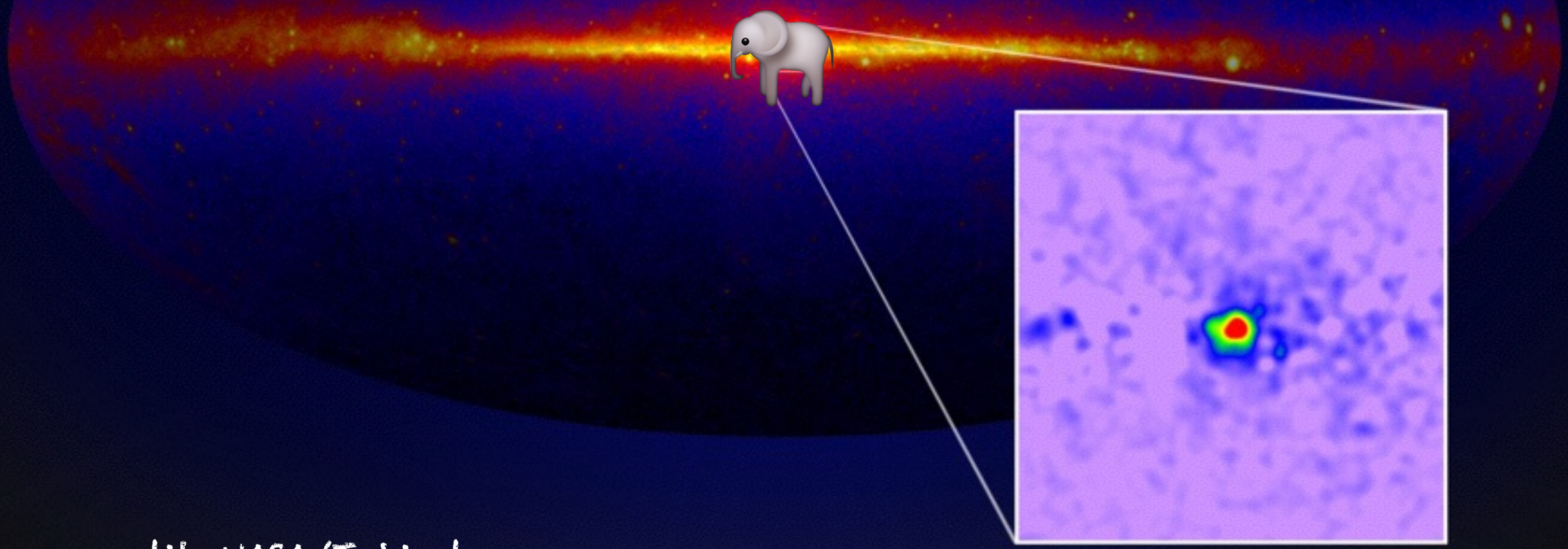
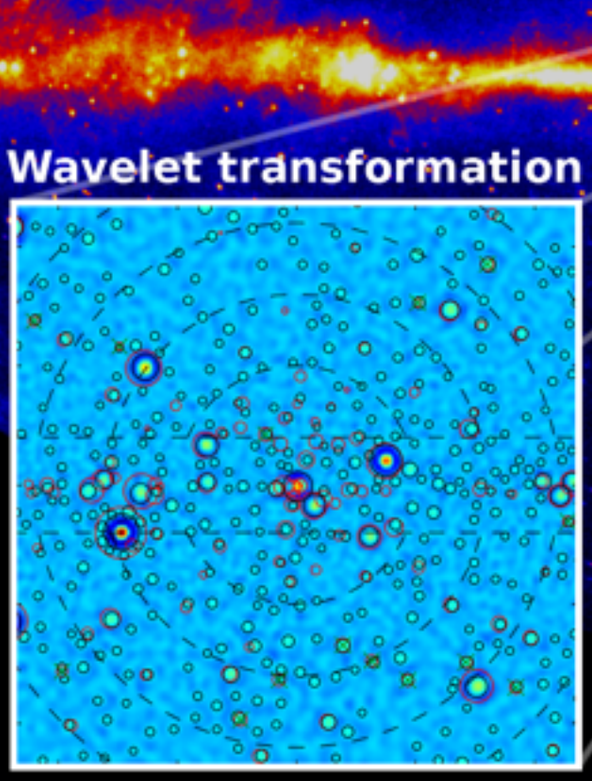


Image credit: NASA/T. Linden

The Galactic Centre Excess

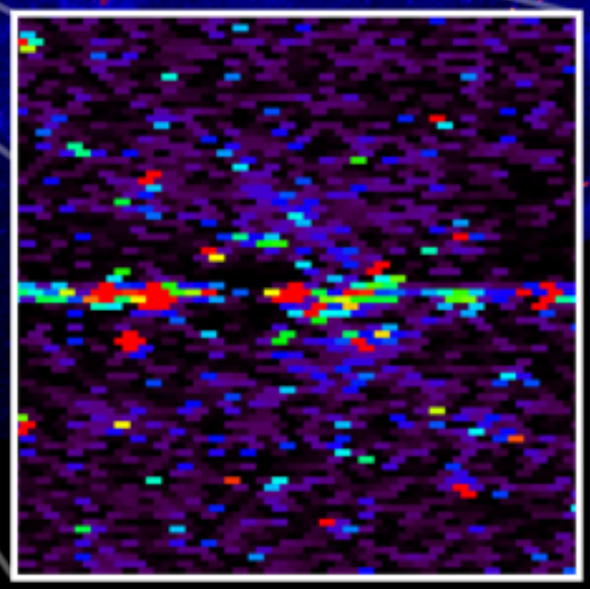
Speckled gamma-ray emission from inner Galaxy
points to a new source population

Wavelet transformation



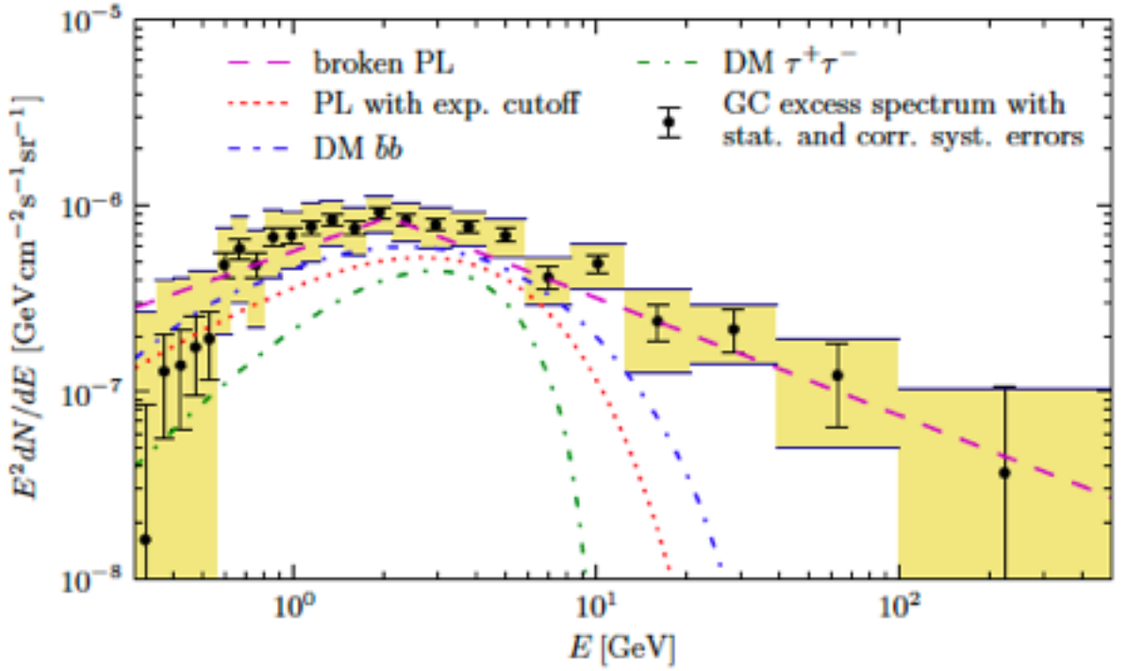
Bartels et al. 2016

Non-Poissonian noise

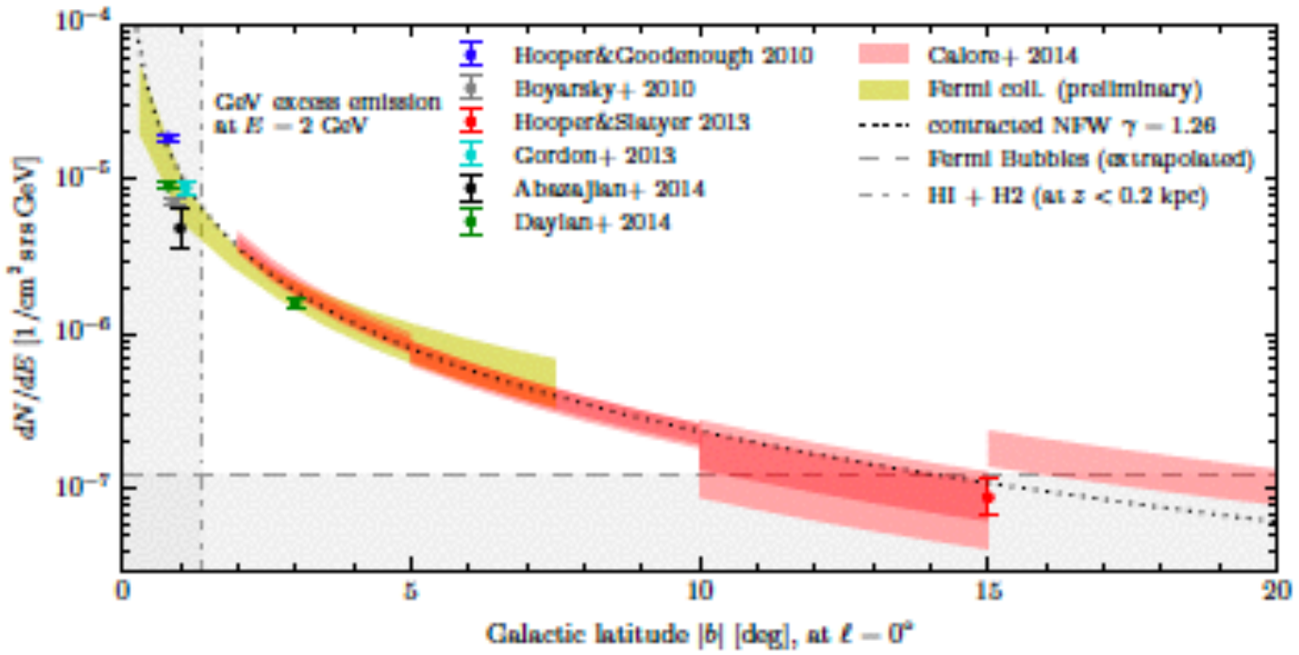


Lee et al. 2016

GCE features



Calore, Cholis & Weniger (2014)



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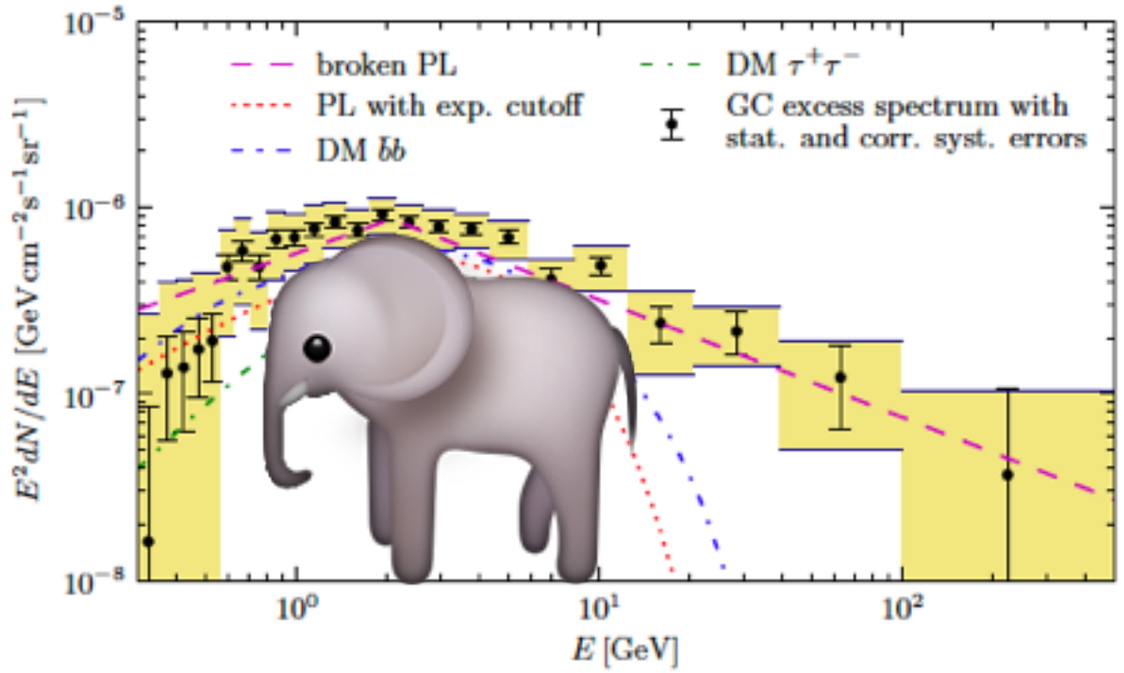

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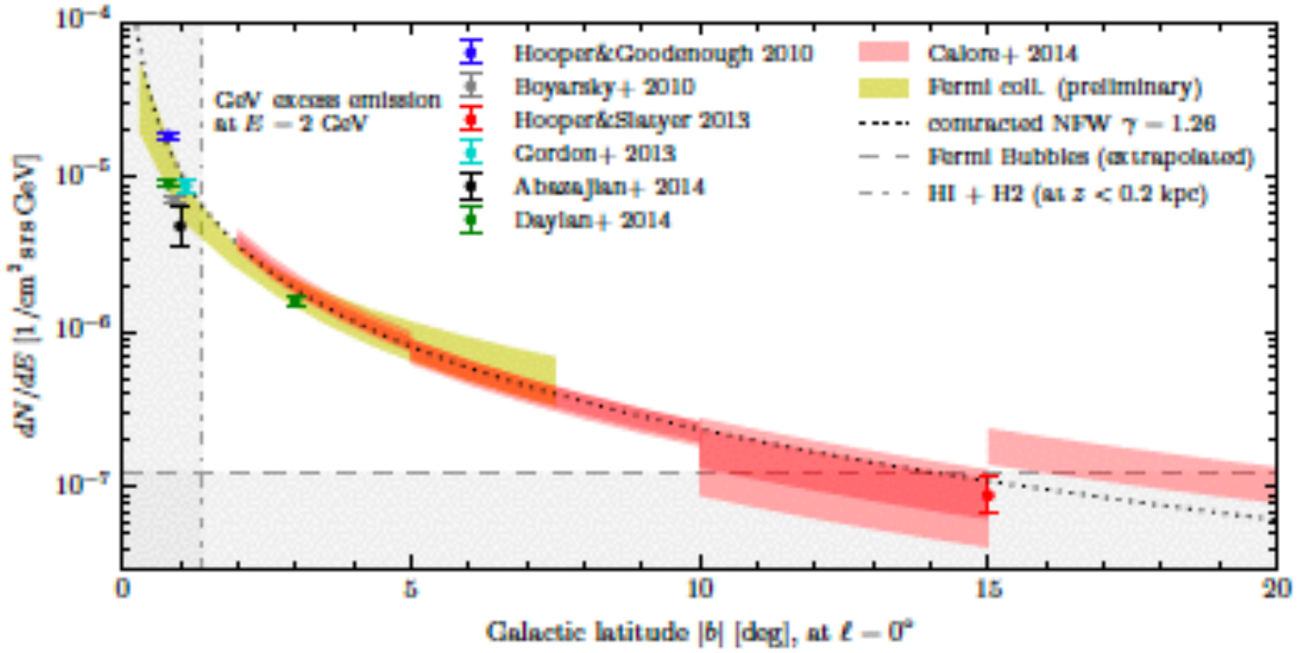

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Emma Storm
Sun 12:00
arXiv:1705.04065

Summary:

- Hybrid between image reconstruction & template fitting

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- Hybrid between image reconstruction & template fitting

This means:
freedom in spectral and spatial templates to adapt to errors/incompleteness!

e.g. "dark gas"

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Emma Storm
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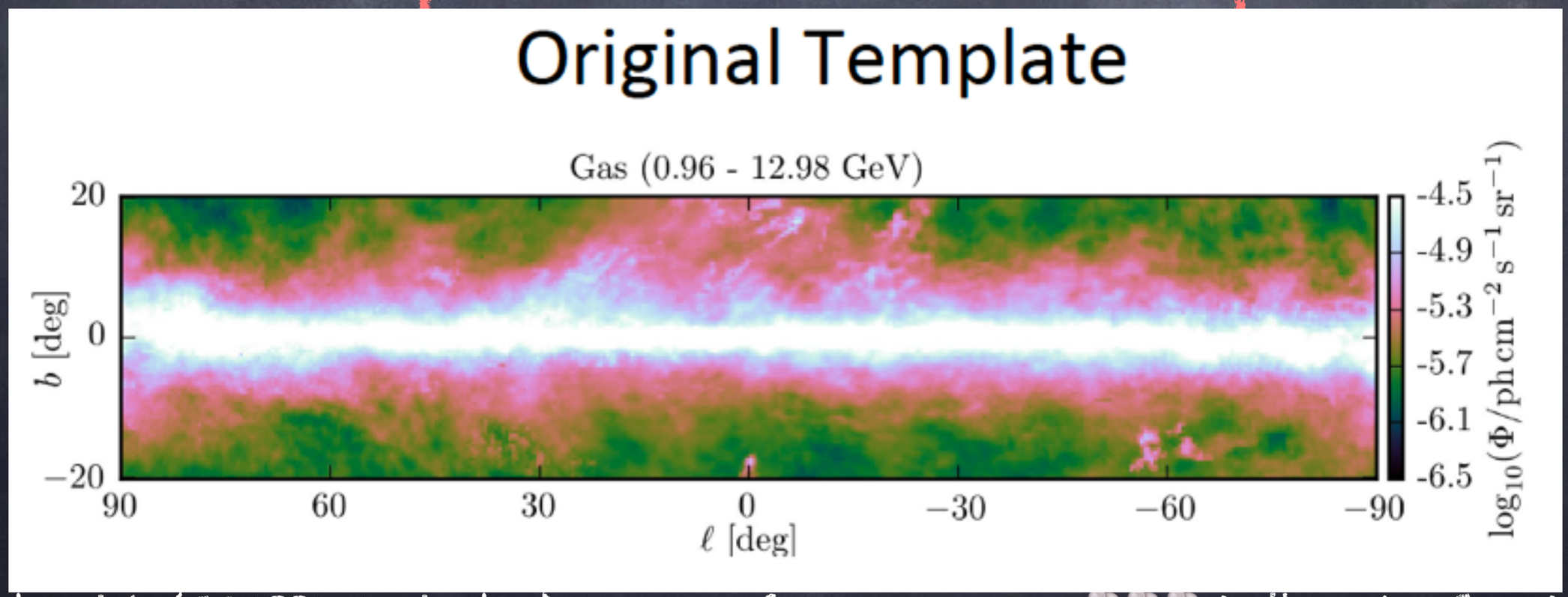
Summary:

- Hybrid between image reconstruction & template fitting



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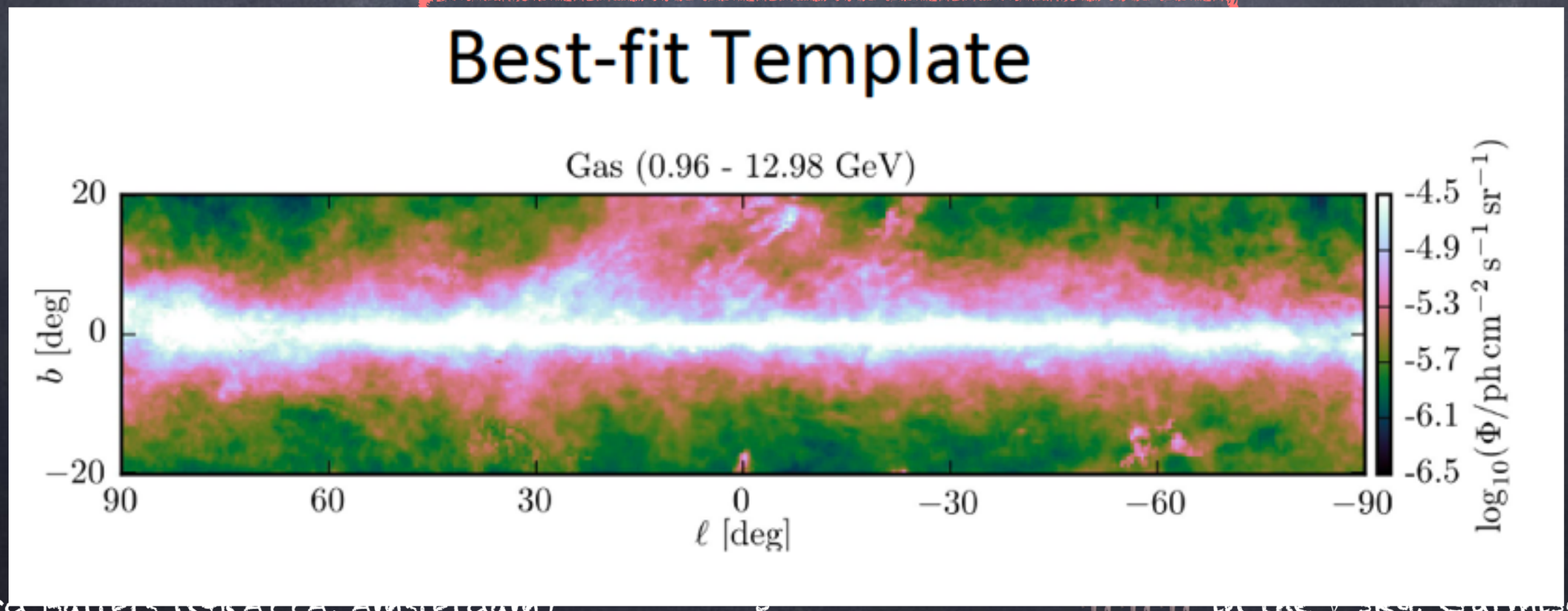
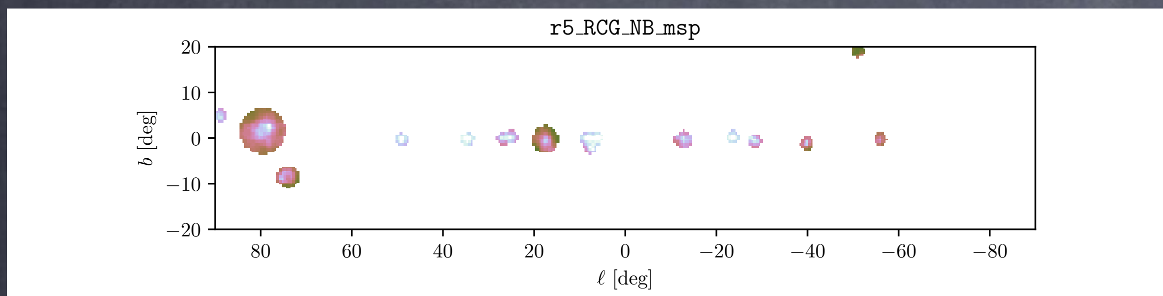
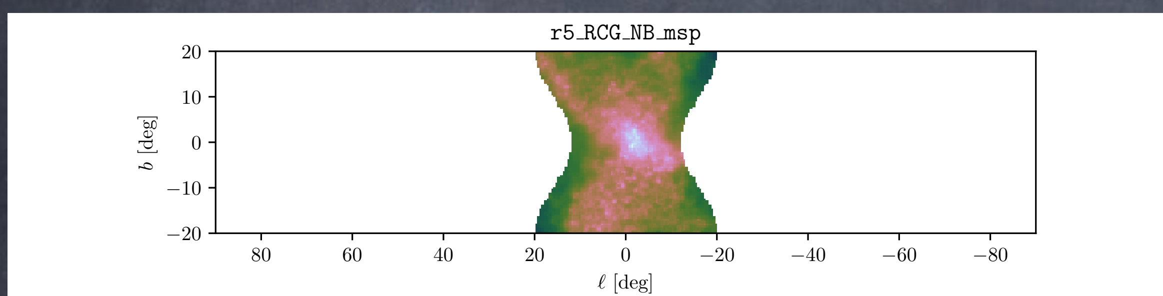
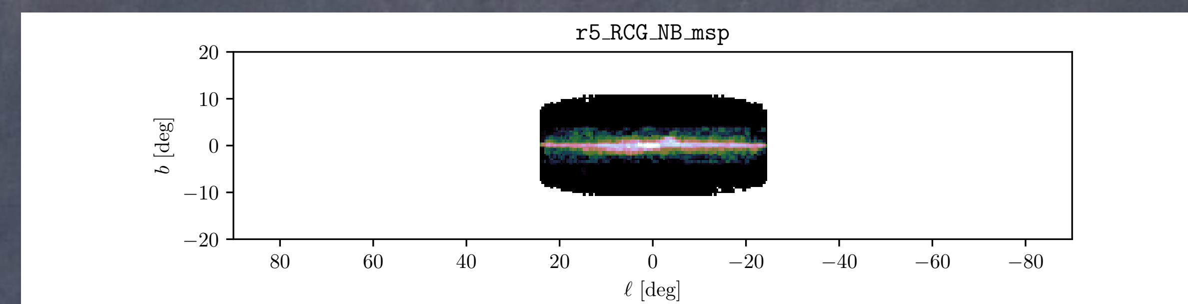
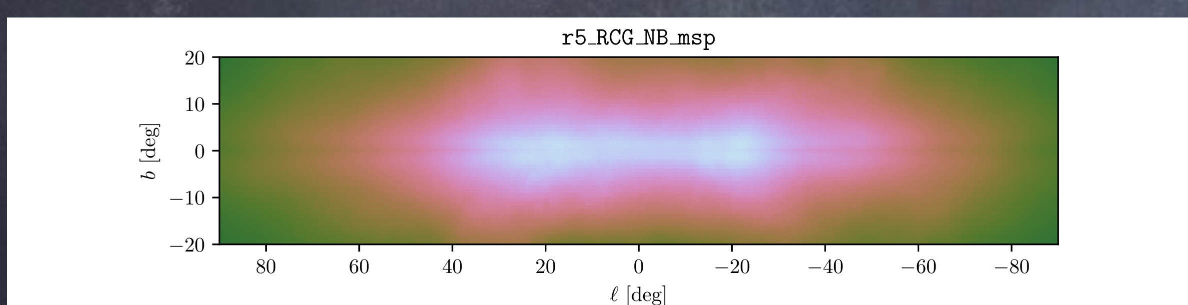


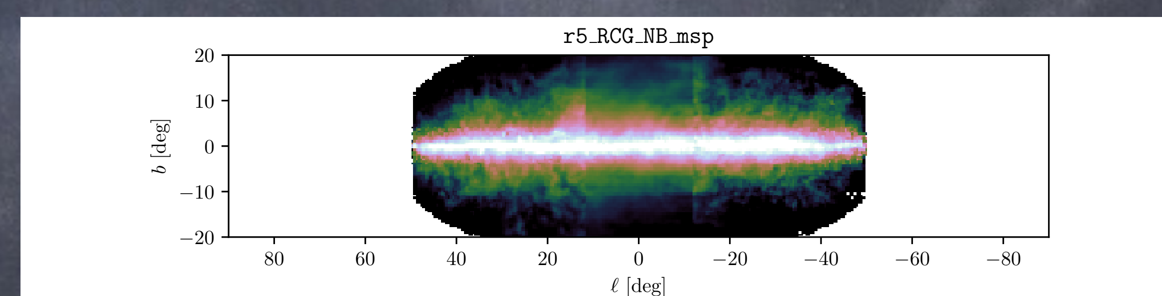
Fore- Background

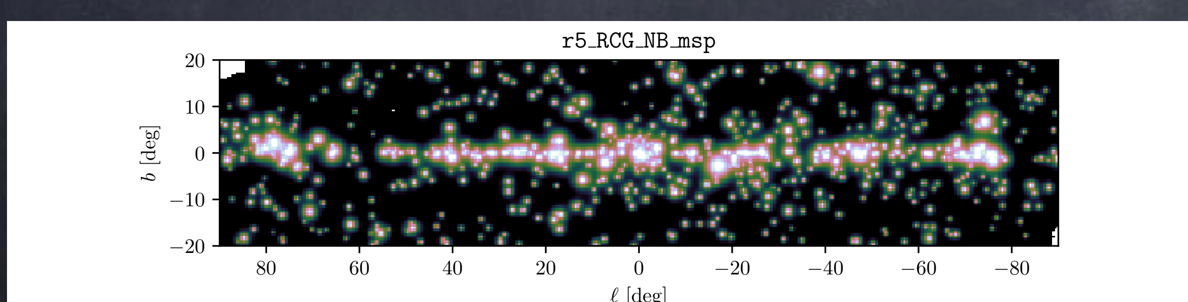


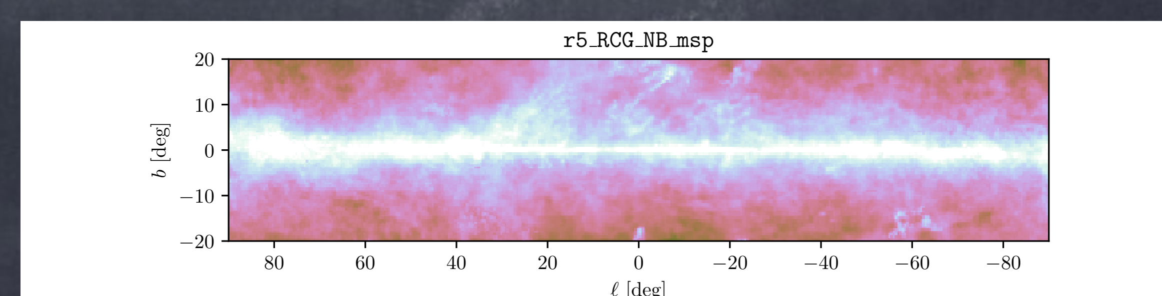












GCE Morphology

- Reanalysis using SkyFACT

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DM

Bartels+ in prep.

GCE Morphology

- Reanalysis using SkyFACT

DM

Stellar Mass distribution

Nuclear bulge

Launhardt+ 2002

Bartels+ in prep.

Results

Run	$-2\ln\mathcal{L}$	
	free spectrum	MSP spectrum
r5_RCG_NB_X	647808.1	648020.2
r5_RCG_NB	647831.2	648027.5
r5_RCG	647884.7	648061.7
r5_BulgeGC	647916.5	648140.3
r5_Einasto	647961.4	648188.6
r5_NFW126	648021.8	648242.4
r5_NFW100	648049.8	648278.6

Results

TS ~ 150 difference between bulge and DM template

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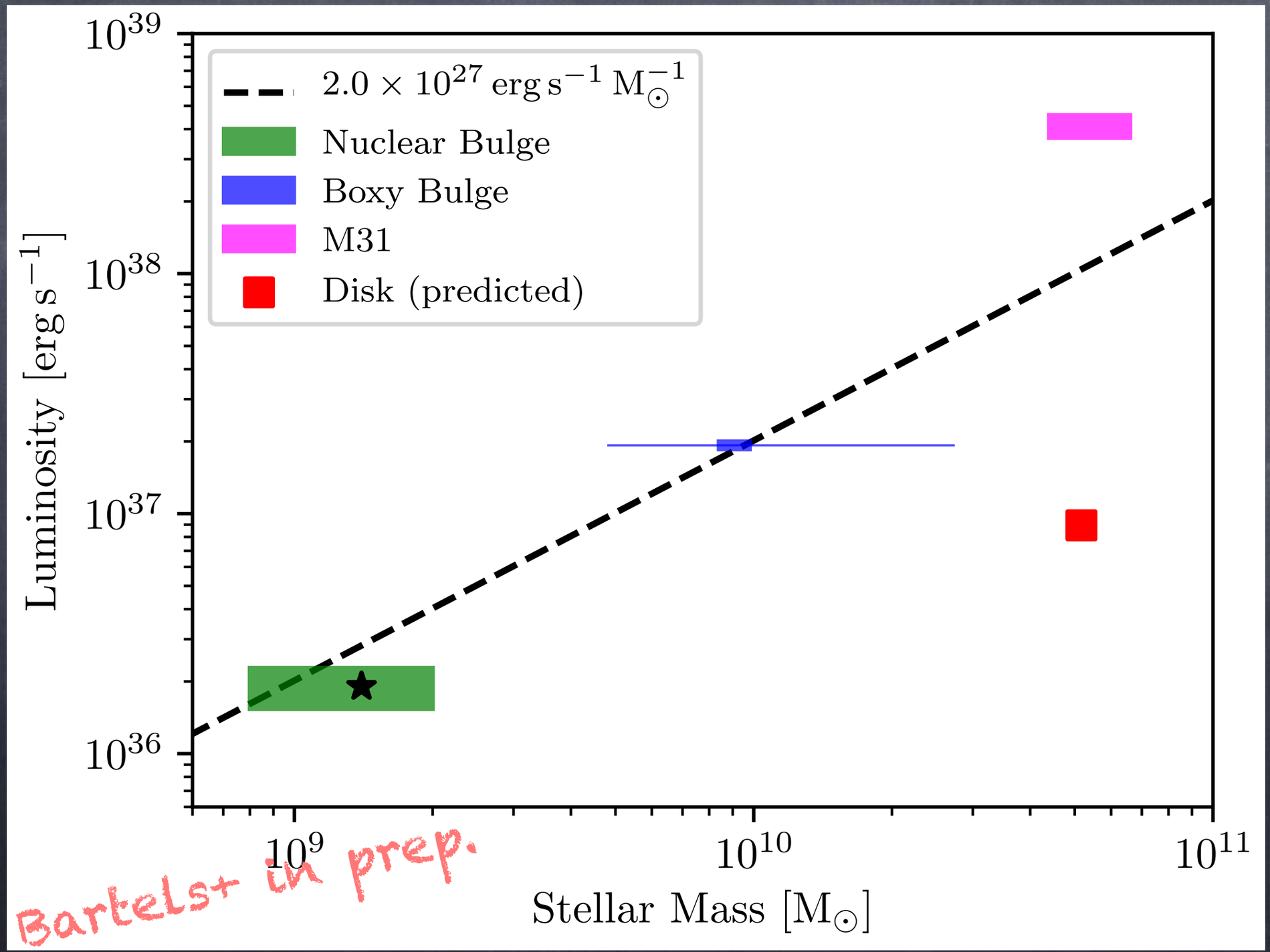
GCE vs. Stellar Mass



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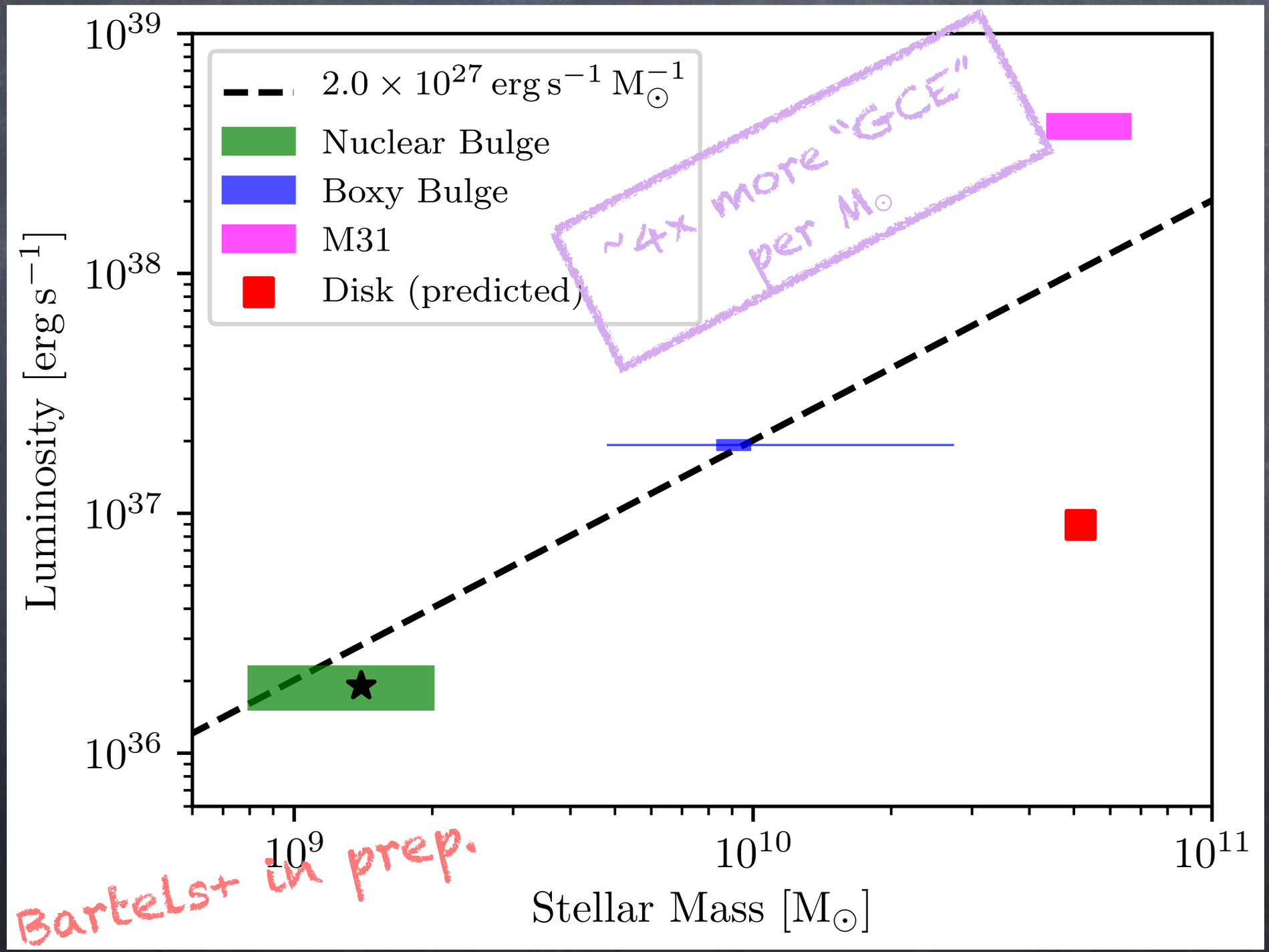

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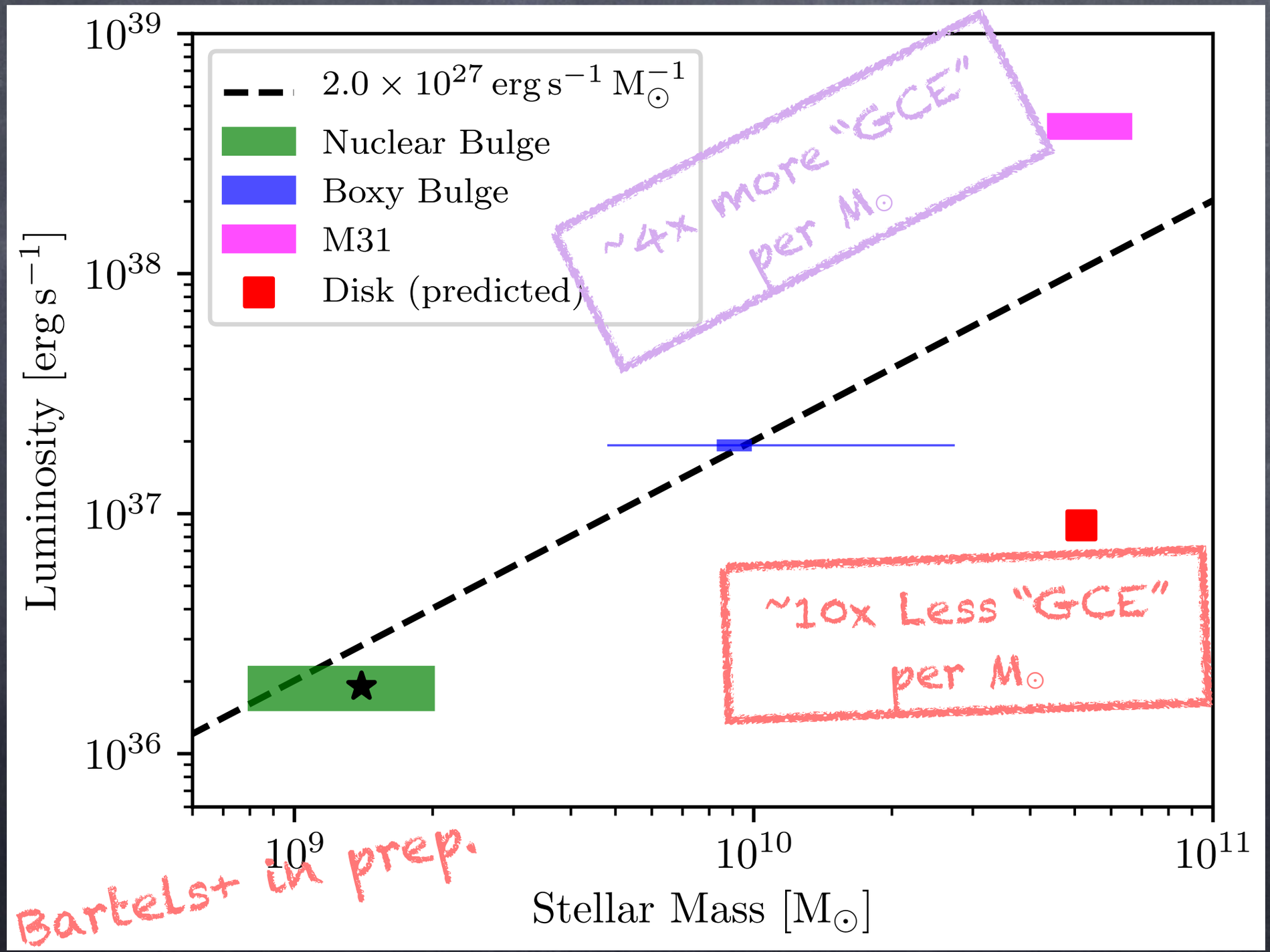
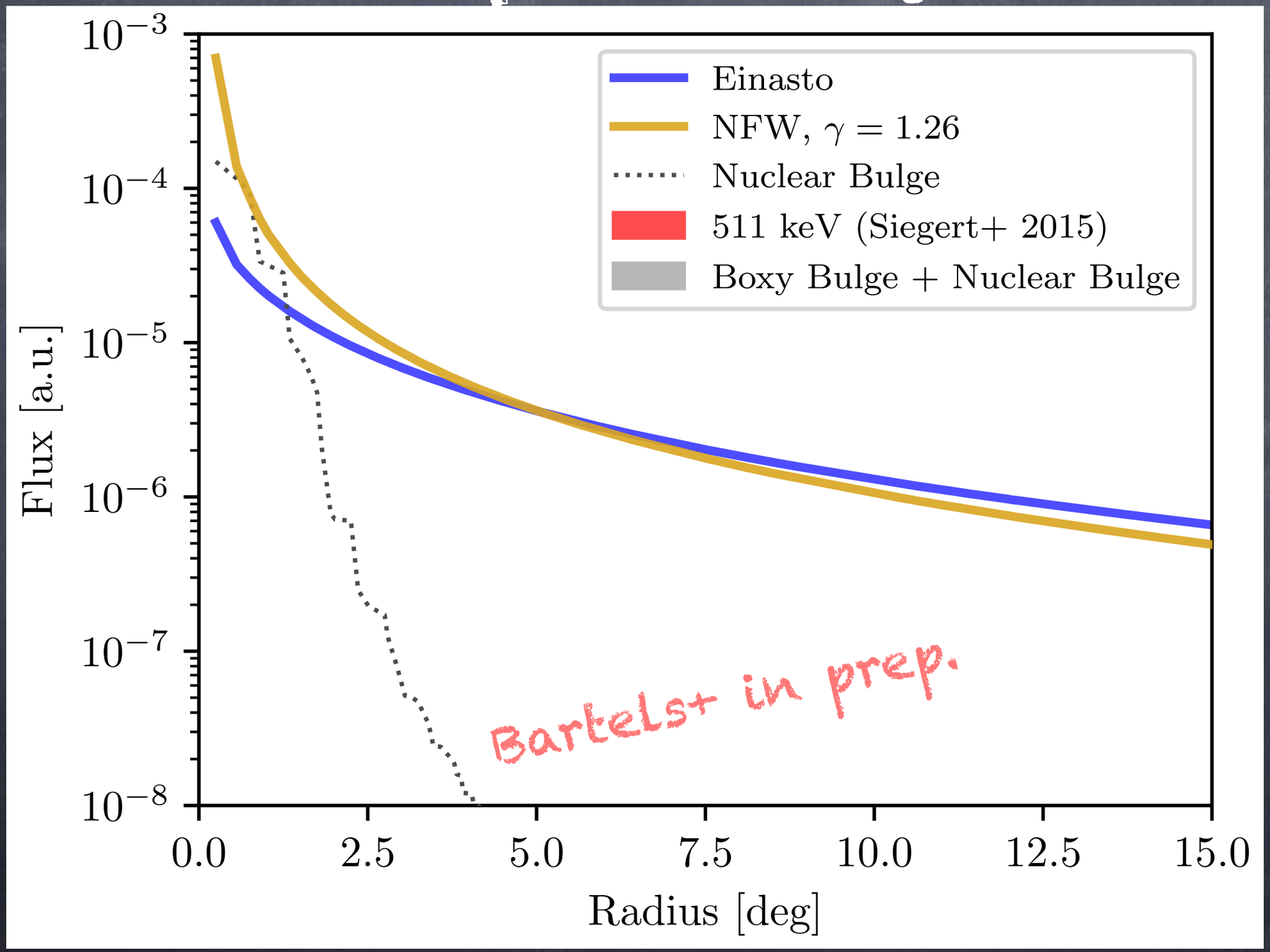


Surprising?


Einasto
NFW, $\gamma = 1.26$
Nuclear Bulge
511 keV (Siegert+ 2015)
Boxy Bulge + Nuclear Bulge
Bartels+ in prep.
Flux [a.u.]
Radius [deg]
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
0.0
2.5
5.0
7.5
10.0
12.5
15.0

2. From Traditional Template Fitting to SkyFACT

Why was this not found in the past??

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- Past studies checked for non-sphericity: negative results.
  (Daylan+ 2014, Calore+ 2014, but also see Linden+ 2016 & Fermi-LAT Collaboration 2017)

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- We connected SkyFACT analysis to Calore+ 2014 analysis (implementing differences one by one)

Template Fitting ↔ Skyfact

old

A1	Reproduction of Calore et al. (2015b), with spatial DM template.
A2	Reproduction of Calore et al. (2015b), with spatial stellar mass template.
B1	A1 gas/ICS templates changed to Run5 templates (1 gas template).
B2	A2 gas/ICS templates changed to Run5 templates (1 gas template).
C1	B1 with longitude extended to $\|l\| \leq 90°$.
C2	B2 with longitude extended to $\|l\| \leq 90°$.
D1	C1 with modulation as in Run5.
D2	C2 with modulation as in Run5.
E1	D1 with disk unmasked
E2	D2 with disk unmasked
F1	E1 with two gas rings used.
F2	E2 with two gas rings used.
G1	F1 with extended sources added in.
G2	F2 with extended sources added in.
H1	G1 with spectral bubble template.
H2	G2 with spectral bubble template.

New

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New

DM preferred

Bulge preferred

Template Fitting ↔ Skyfact

old

Template	χ^2 (1) NFW $\gamma = 1.26$	χ^2 (2) RCG_NB	$\Delta\chi^2$
A	147174.1	147486.0	-311.9
B	165359.2	167419.6	-2060.4
C	718013.4	721344.0	-3330.6
D	562568.4	562995.2	-426.8
E	655669.2	654782.6	886.6
F	655113.2	654947.4	165.8
G	651279.8	651022.9	256.9
H	648635.9	648484.5	151.4

G2	F2 with extended sources added in.
H1	G1 with spectral bubble template.
H2	G2 with spectral bubble template.

New

Template Fitting ↔ Skyfact

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New

Difference arises when:
- Modulation is turned ond
- Unmasking the disk

3, "Disk-GCE"

Estimate of GCE in the disk

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   assuming some luminosity function.

4. Get total disk flux & luminosity!

Results

Bulge

- **Flux**

$1.8 \times 10^{-09}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$

- **Lum. vs. Mass**

$2 \times 10^{27}\,\mathrm{erg\,s^{-1}\,M_\odot}$

Disk

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$3 \times 10^{-09}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$

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Results

B/D ~ 0.8
(but the bulge is twice as luminous)

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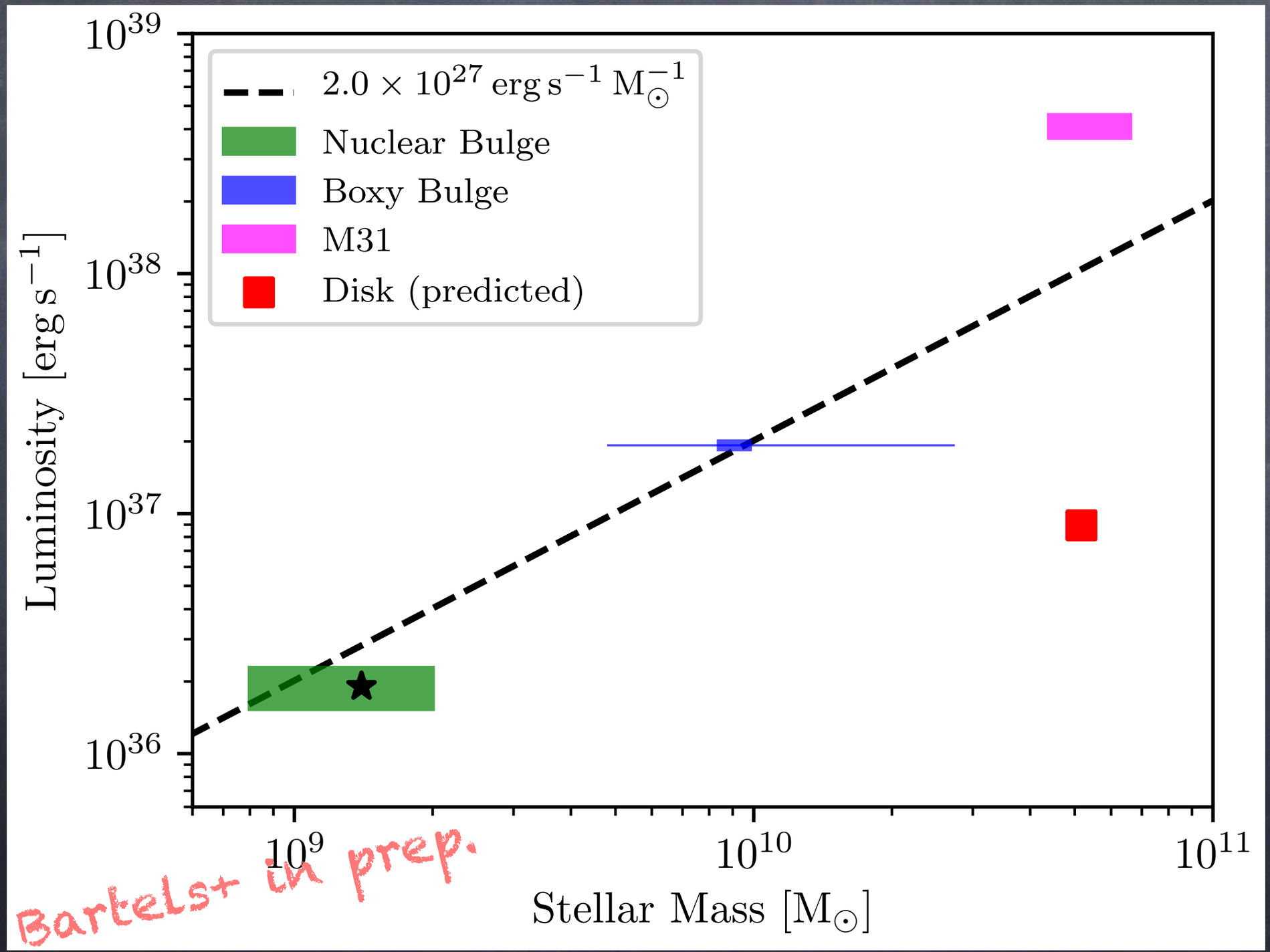
~10x more MSPs per $M_\odot$

GCE vs. Stellar Mass



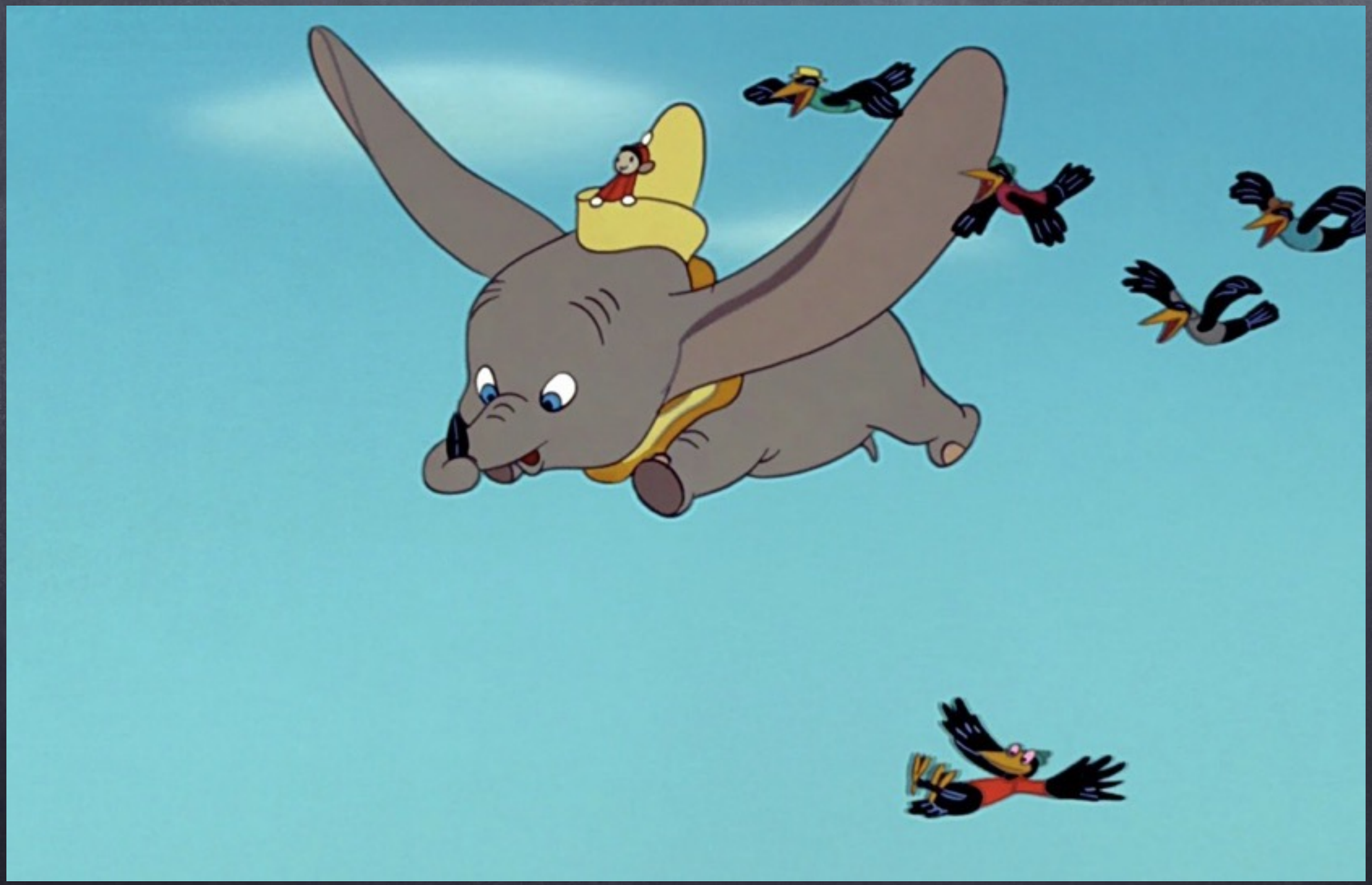
Can we detect it?

- 8% of ICS in our ROI (180° x 41°)
- 2% of π^0
- This will be hard ...

Conclusion

- Reanalysed the GCE with SkyFACT
- We find a correspondence with the Bulge + nuclear bulge
- GCE appears to trace stellar mass

THANK YOU :)



Backup: spectra