The Galactic Center Excess
&
511 keV Bulge Emission

Richard Bartels*
GRAPPA, University of Amsterdam
r.t.bartels@uva.nl

*in Collaboration with Francesca Calore, Emma Storm & Christoph Weniger

GRAPPA
GRavitation AstroParticle Physics Amsterdam

TeVPA, 7 August 2017
Columbus (OH), USA

UNIVERSITY OF AMSTERDAM

Part 1

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Part 1

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Part 2

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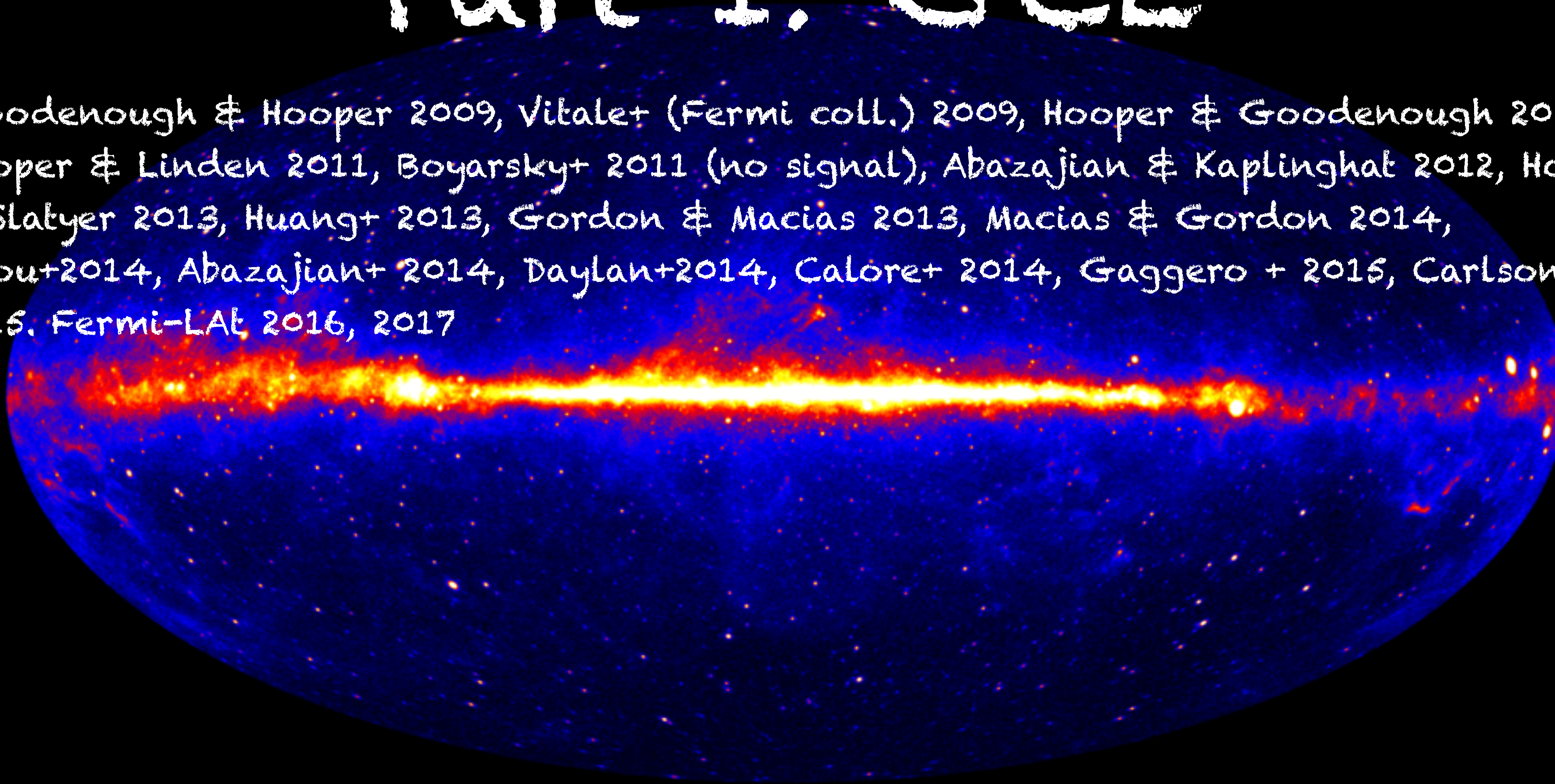
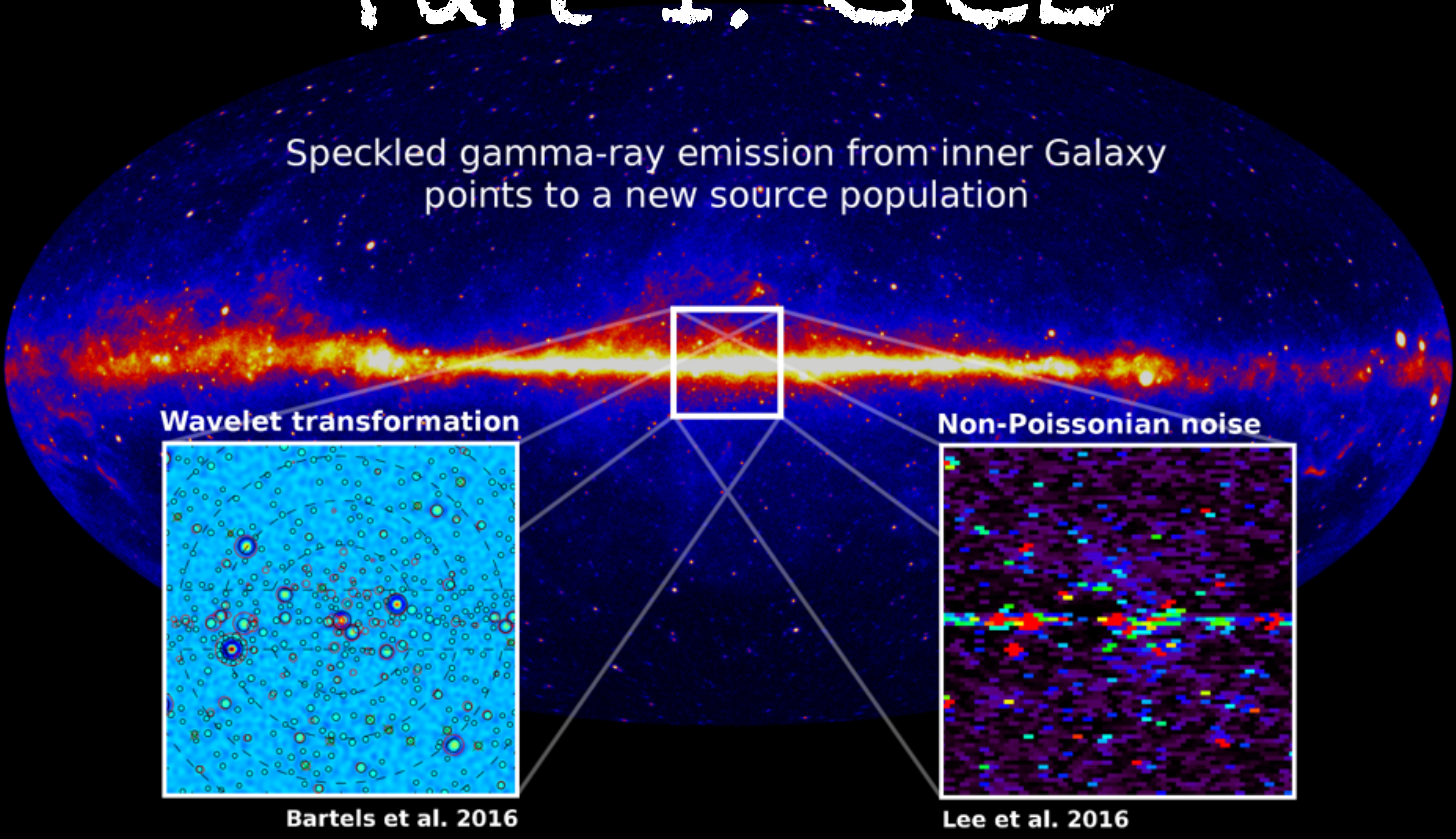
Part 1: GCE



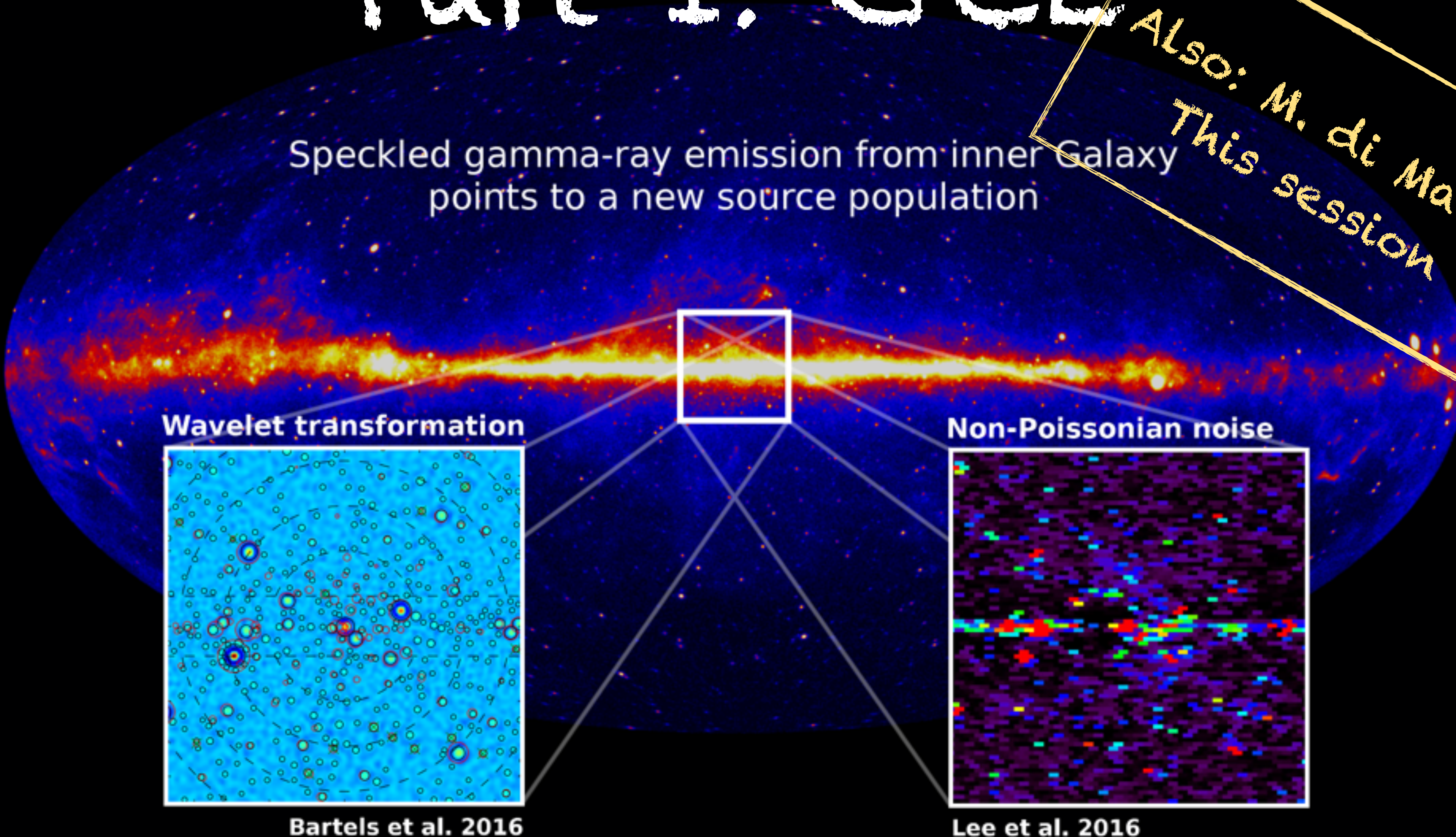
Goodenough & Hooper 2009, Vitale+ (Fermi coll.) 2009, Hooper & Goodenough 2011, Hooper & Linden 2011, Boyarsky+ 2011 (no signal), Abazajian & Kaplinghat 2012, Hooper & Slatyer 2013, Huang+ 2013, Gordon & Macias 2013, Macias & Gordon 2014, Zhou+2014, Abazajian+ 2014, Daylan+2014, Calore+ 2014, Gaggero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

Part 1: GCE



Speckled gamma-ray emission from inner Galaxy
points to a new source population
Wavelet transformation
Non-Poissonian noise
Bartels et al. 2016
Lee et al. 2016

Part 1: GCE

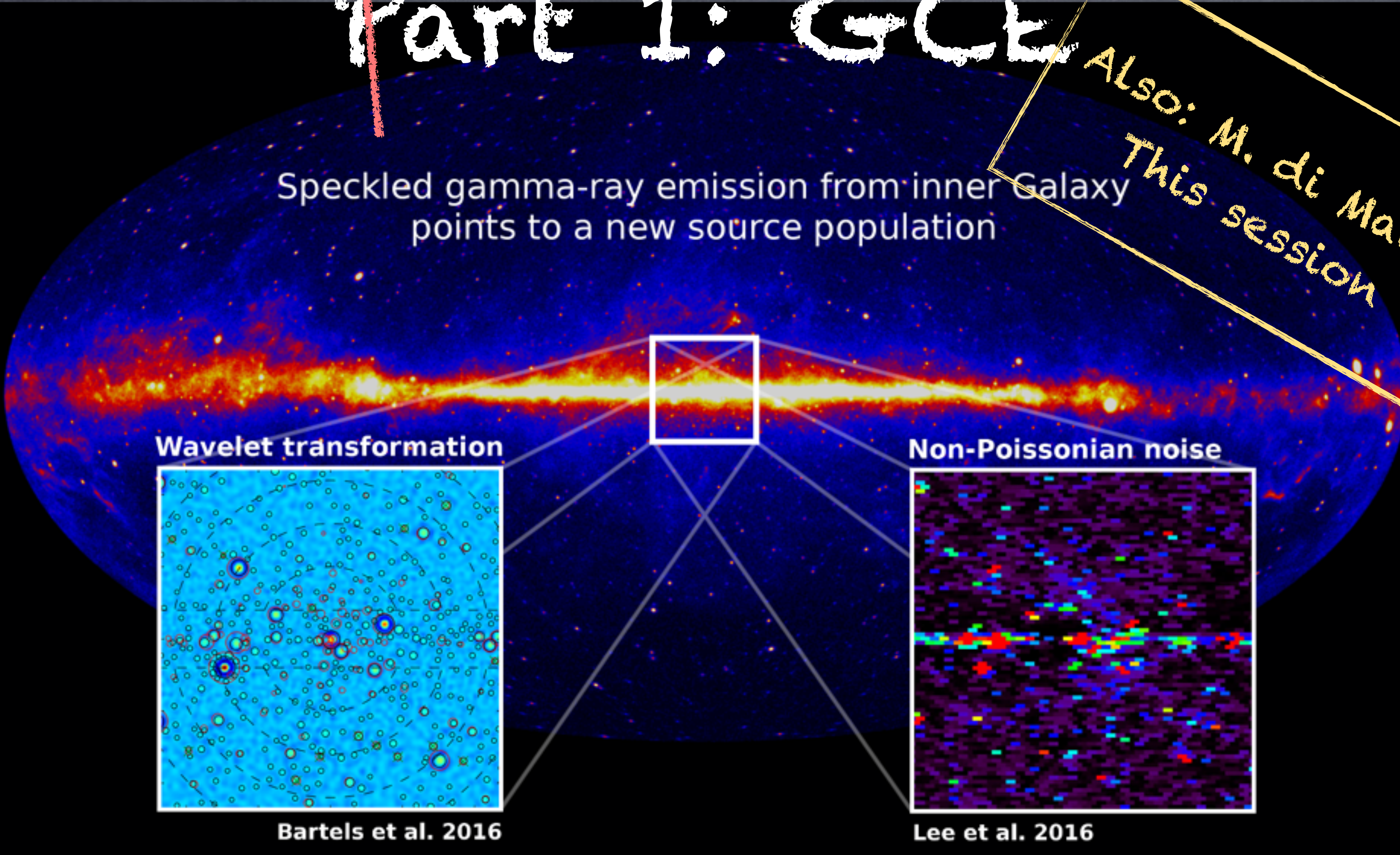


Also: M. di Mauro
This session

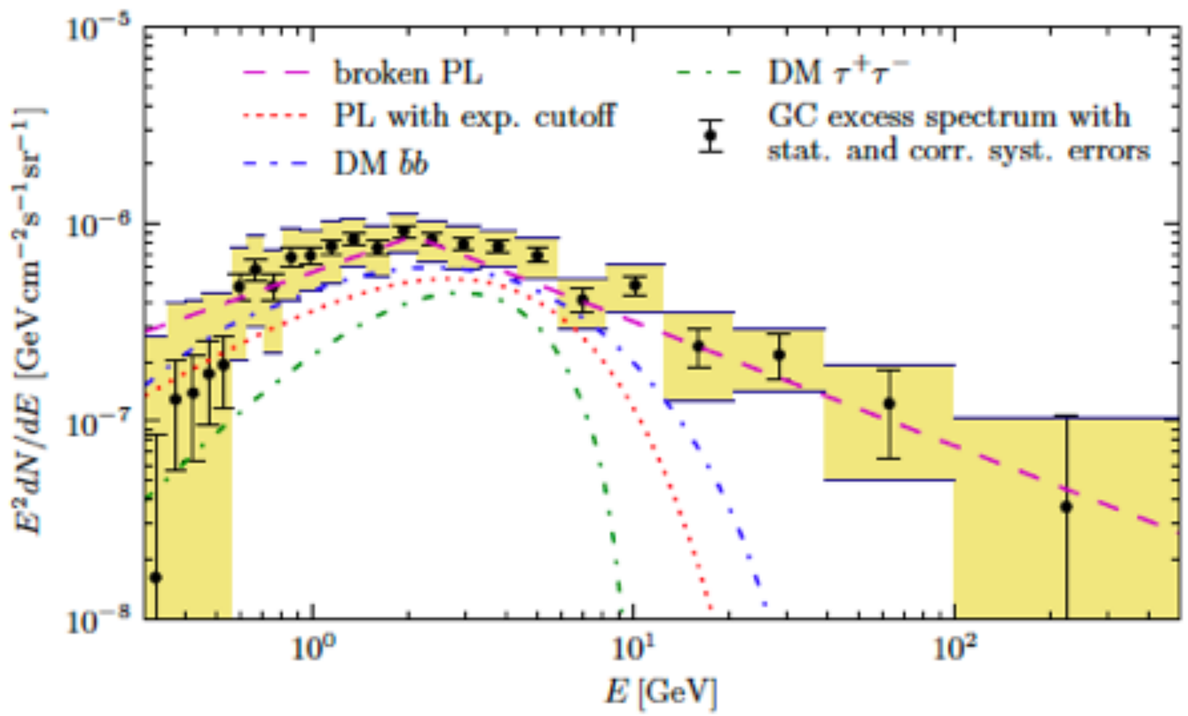
That's why I'm in this session =)

Part 1: GCE

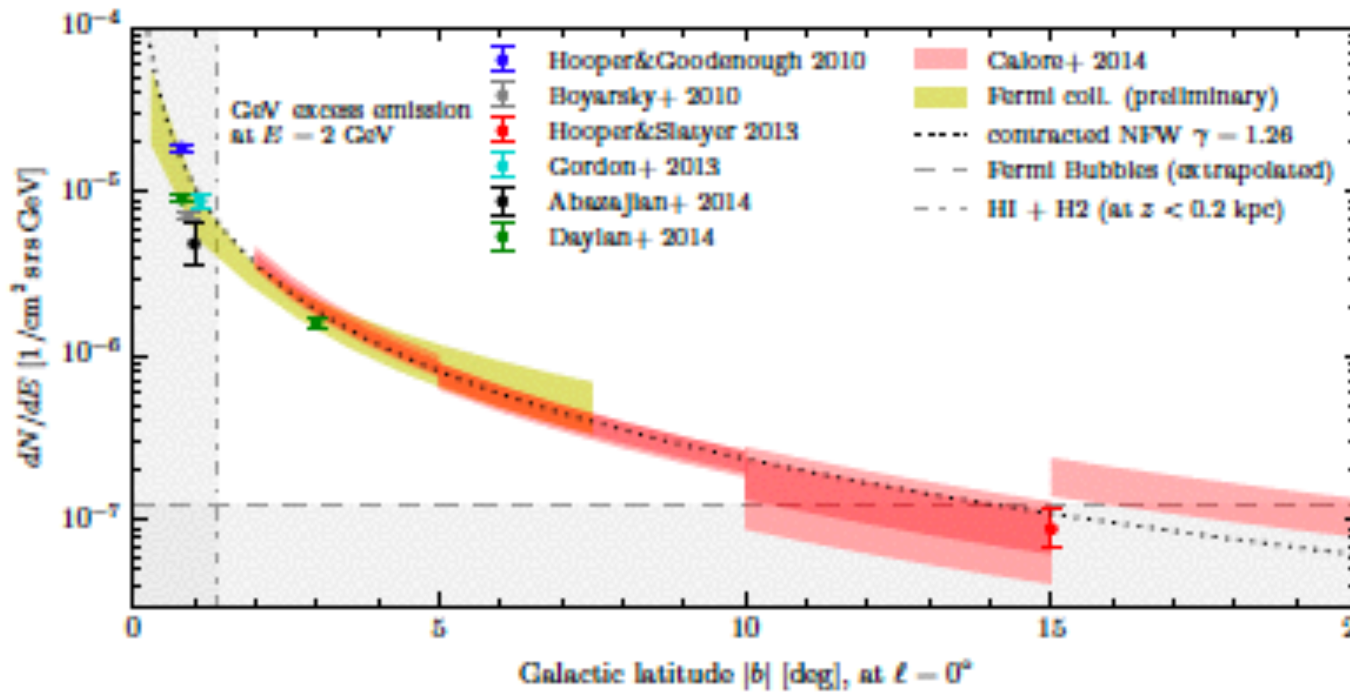
Also: M. di Mauro
This session



GCE features



Calore, Cholis & Weniger (2014)



Calore, Cholis, McCabe & Weniger (2015)

SkyFact

SkyFact

F. Calore
Wed. @16:00
arXiv:1705.04065

SkyFact

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Wed. @16:00
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Advantages

- Hybrid between image reconstruction & template fitting

Foreground/Background Templates

- Inverse-Compton
- Gas (pi0) emission
- IGRB
- 3FGL
- Fermi Bubbles

GCE Analysis

1) Fixed Templates

GCE Analysis

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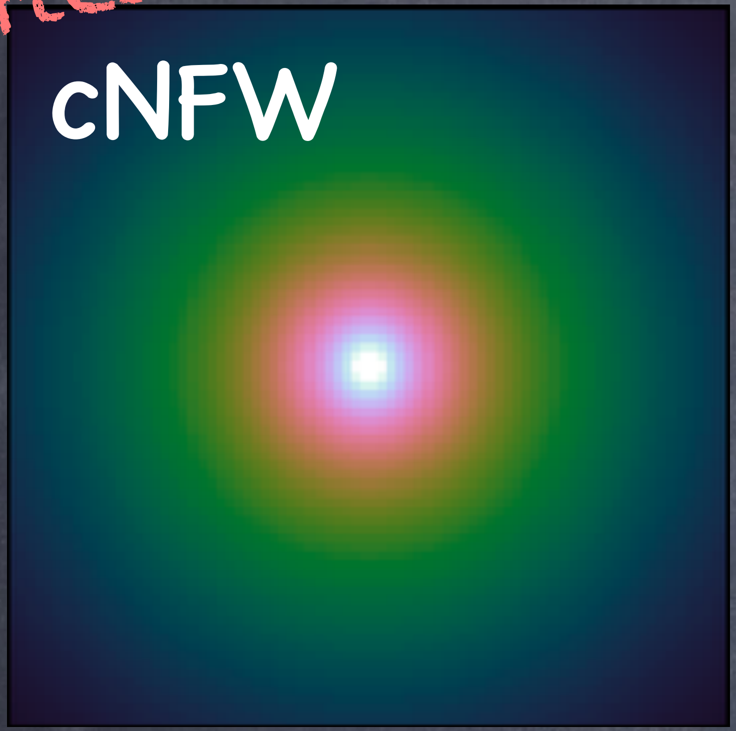
Bartels+ in prep.



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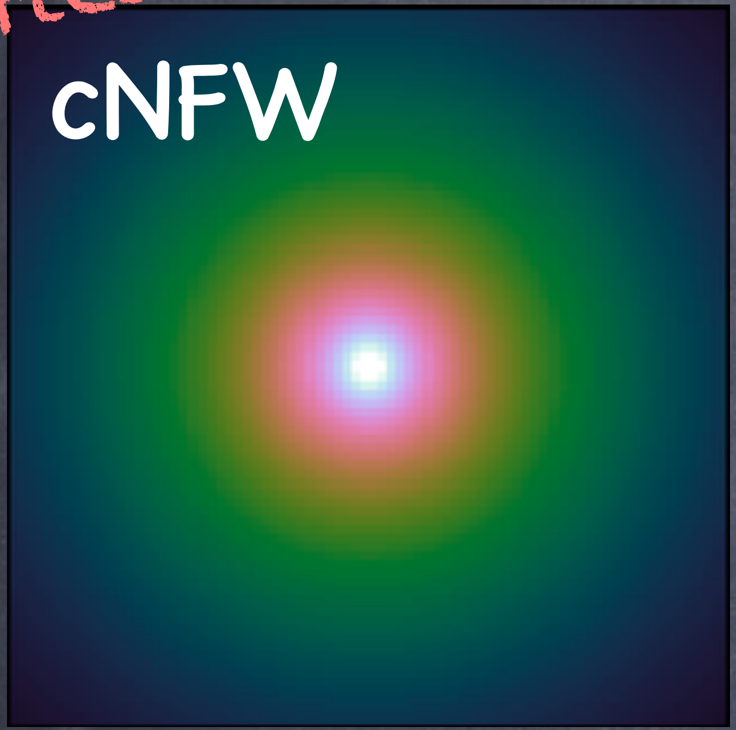

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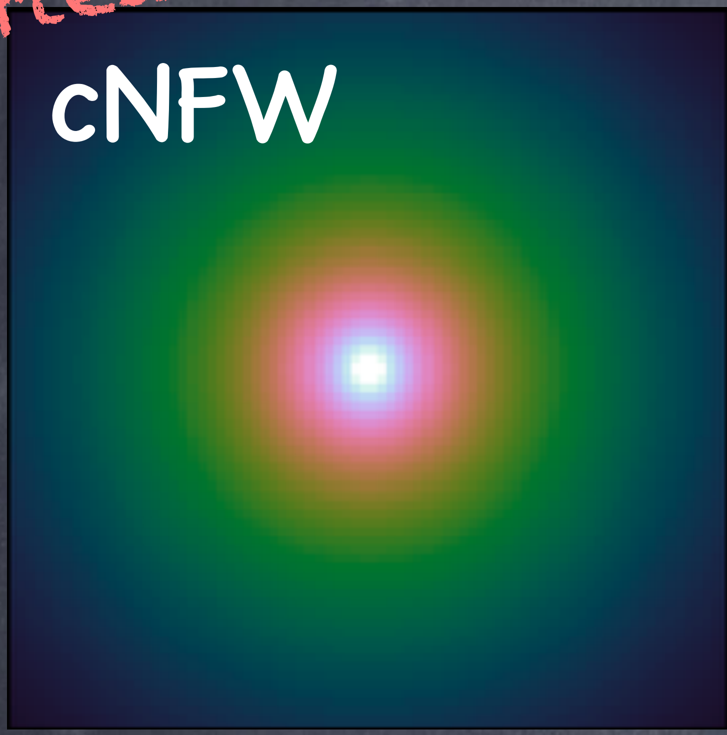

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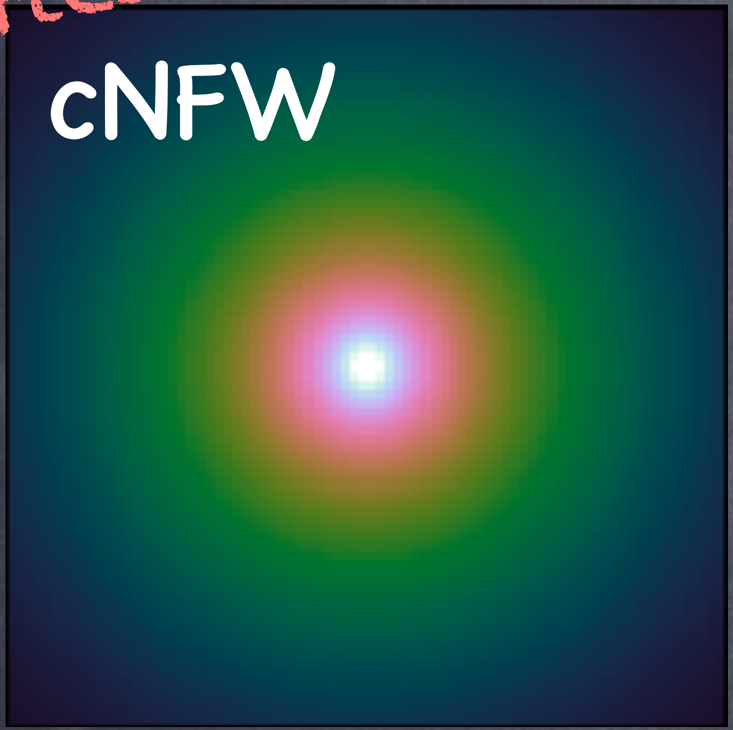

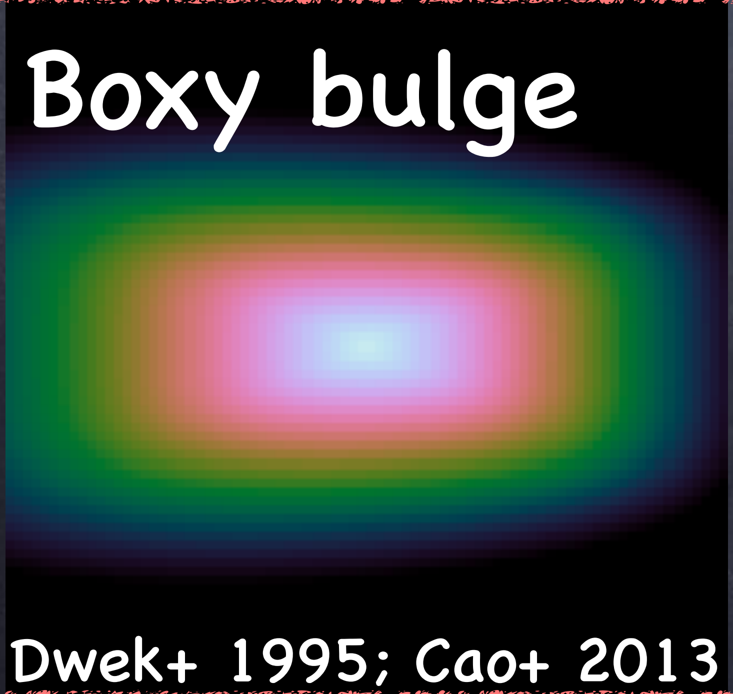

Superpositions of these

GCE Analysis

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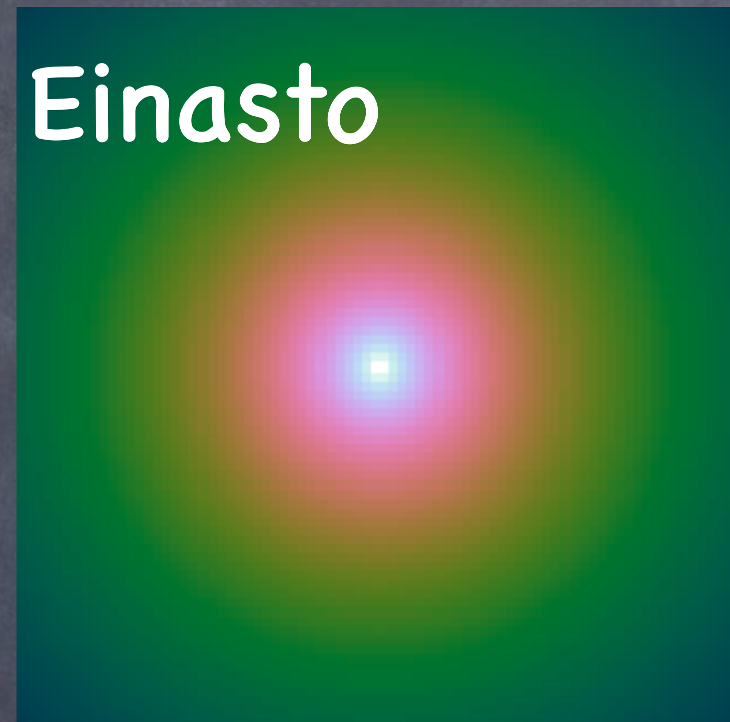
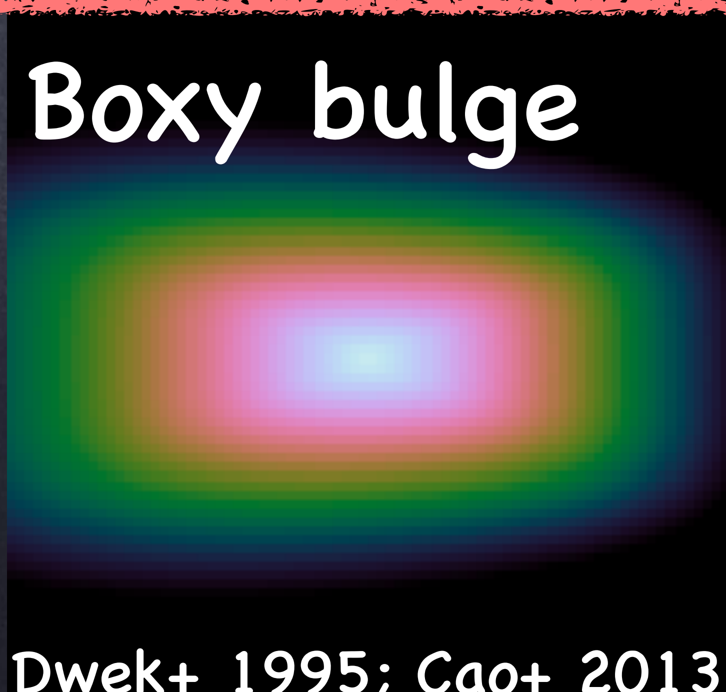
Bartels+ in prep.





Nuclear bulge

Launhardt+ 2002

Superpositions of these

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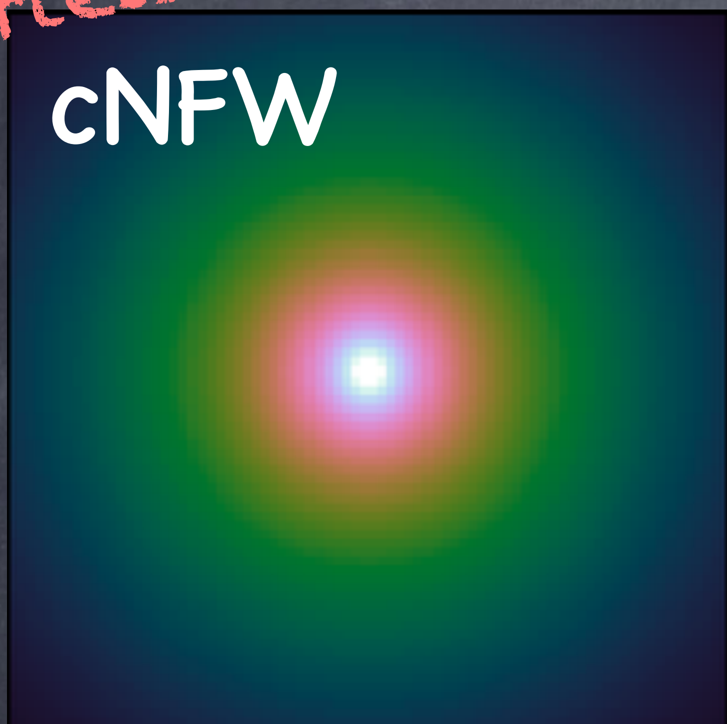

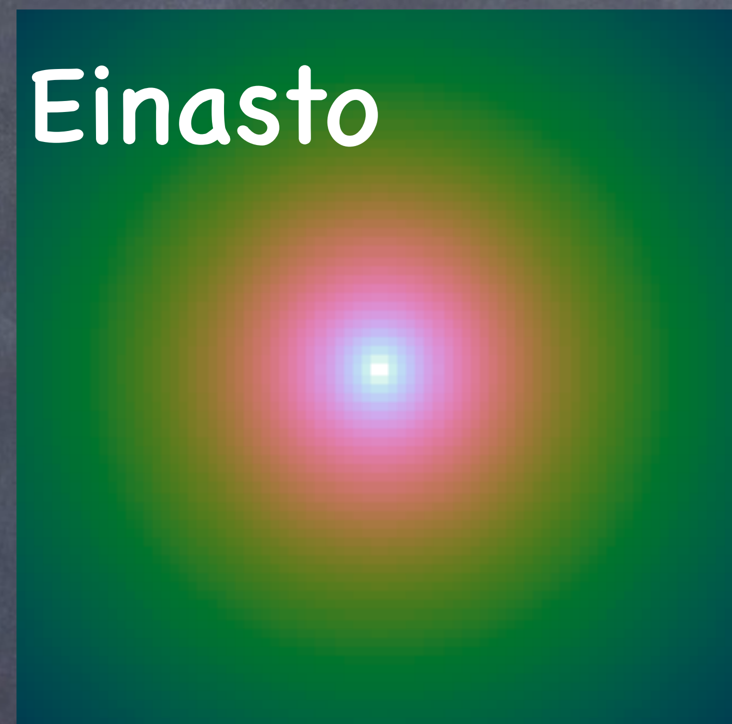

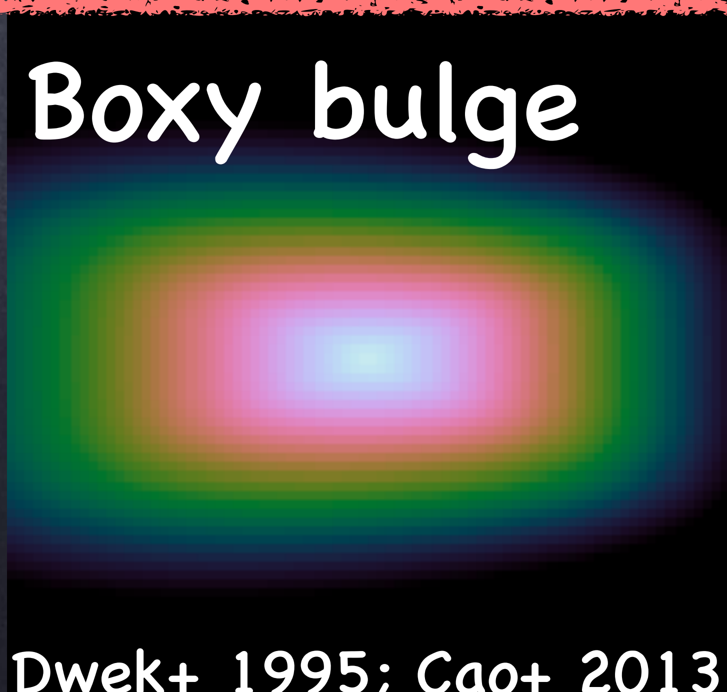

Nuclear bulge

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X-shape

Ness & Lang 2016

Superpositions of these

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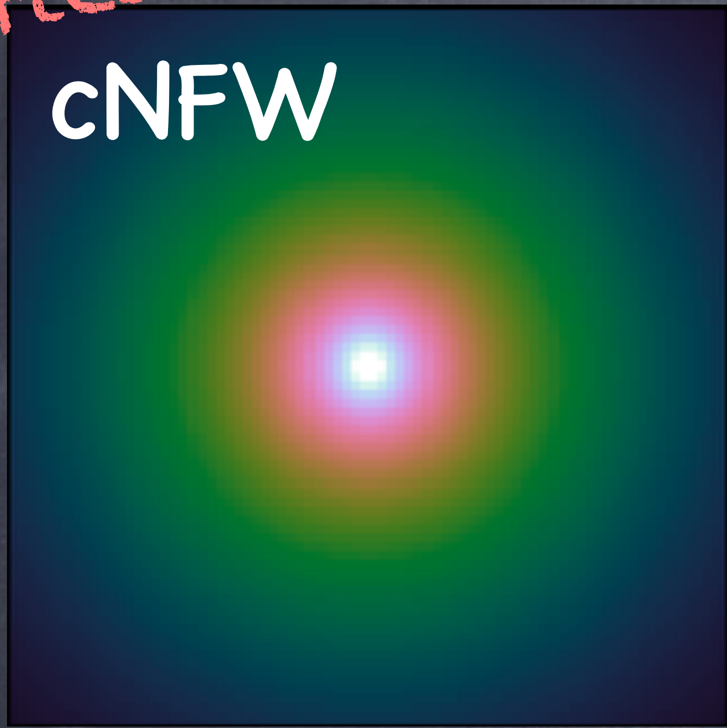
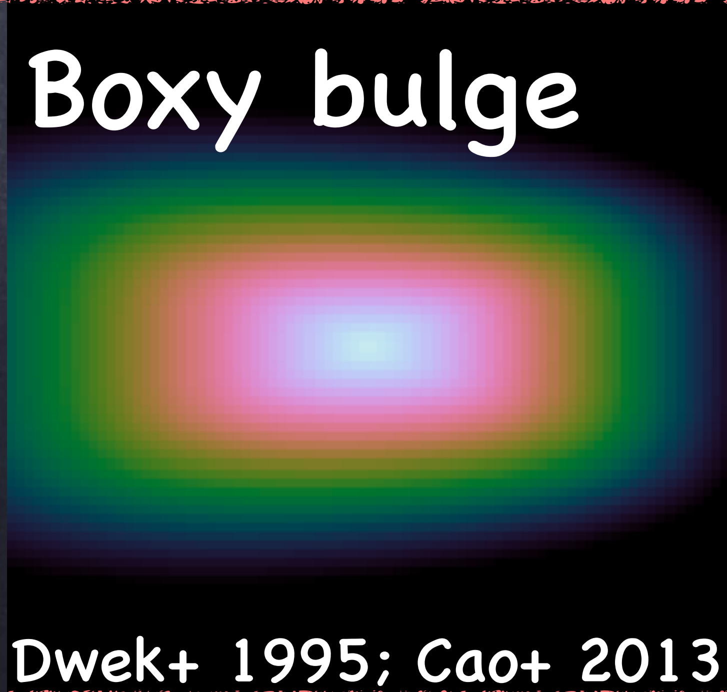


O. Macias, this session



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GCE Analysis

2) Fixed spectrum

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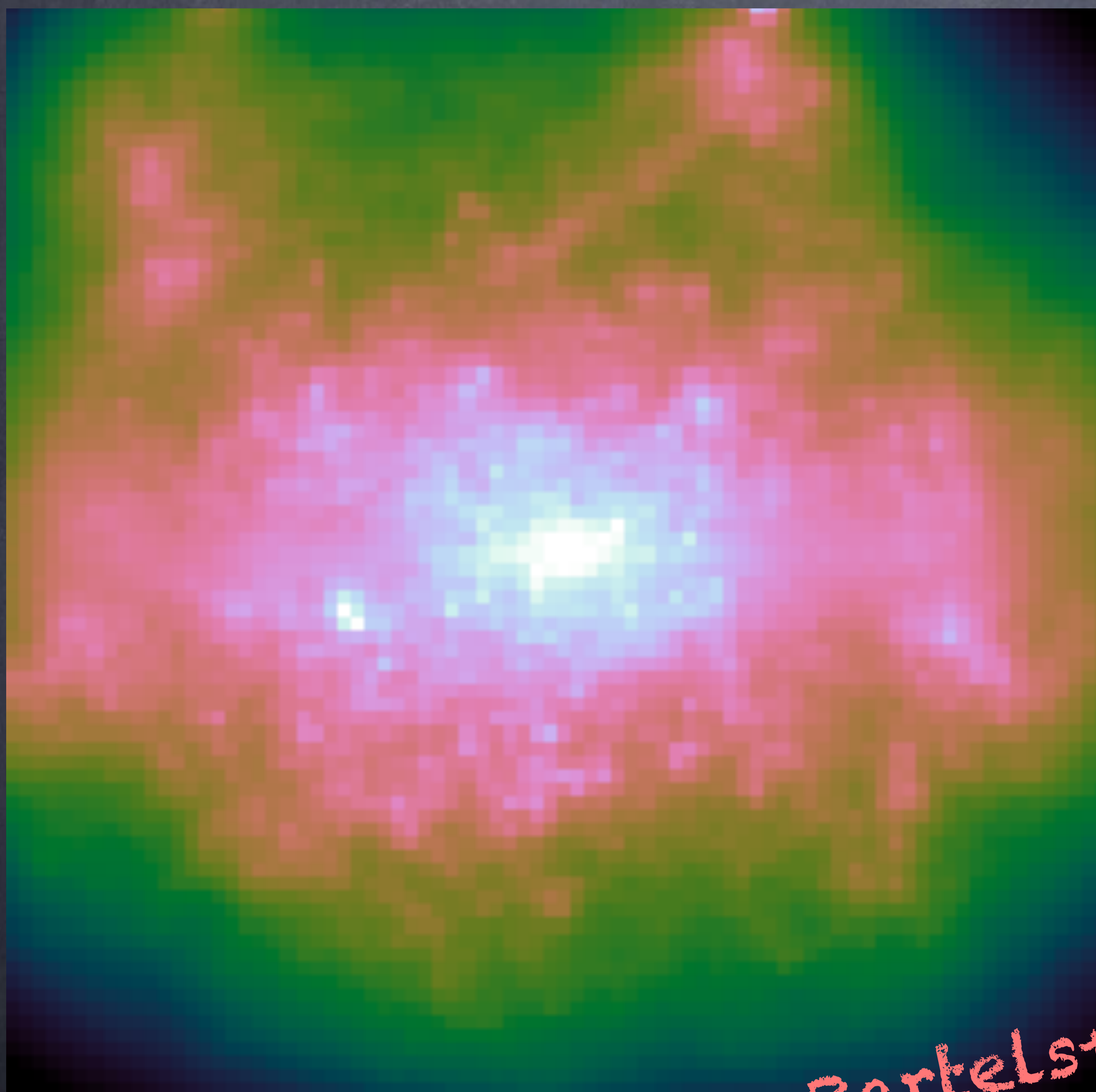

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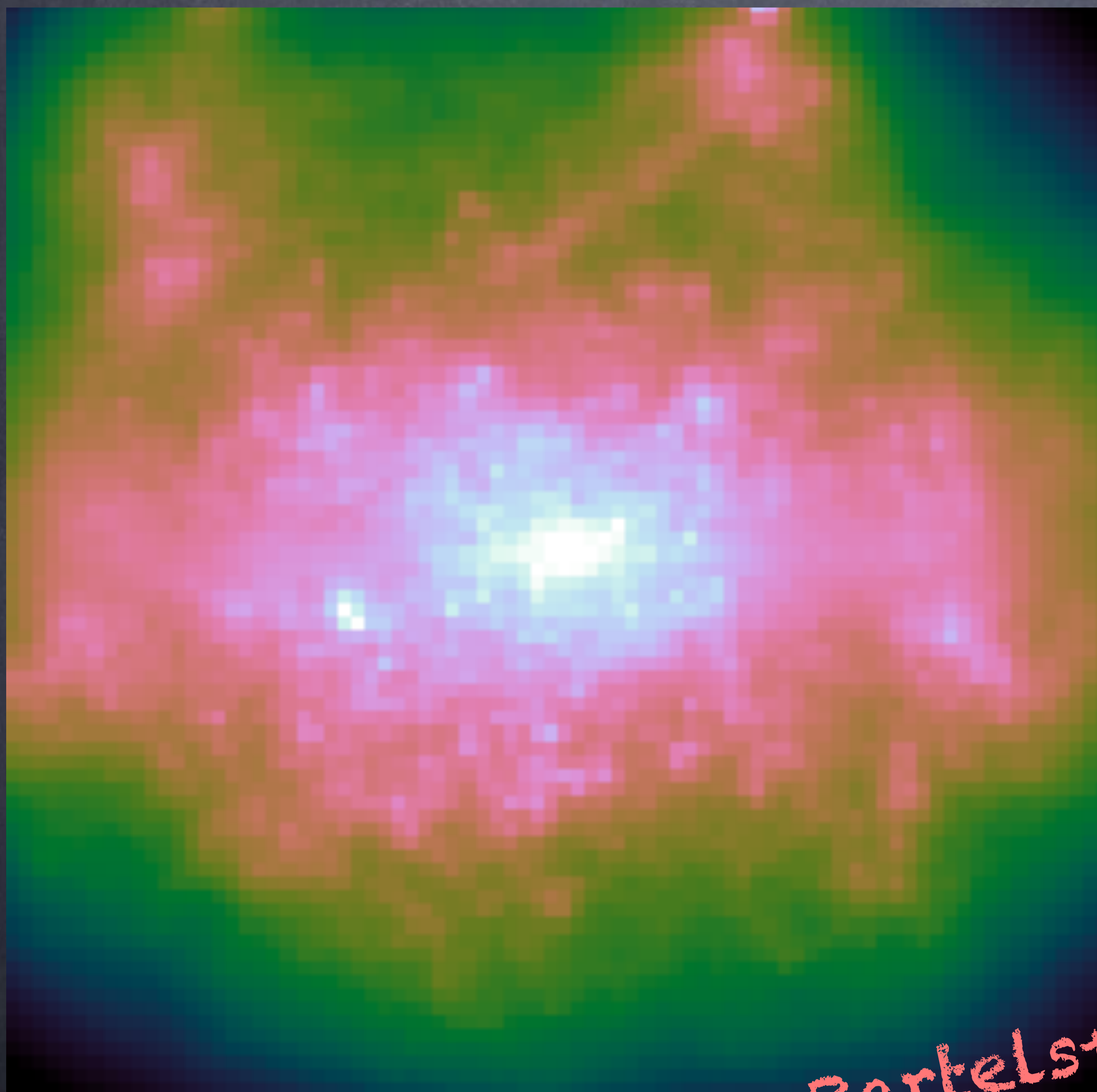

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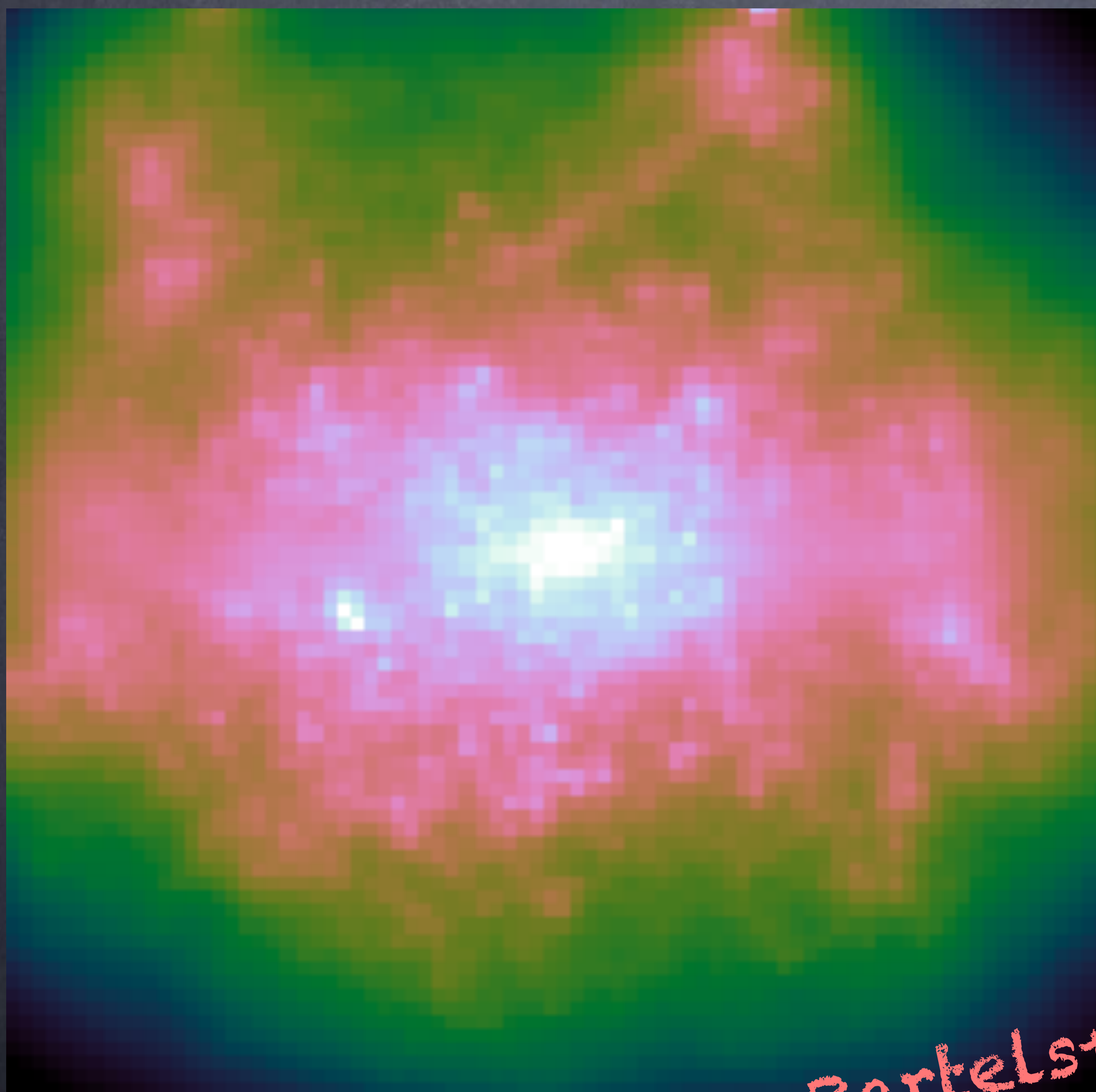

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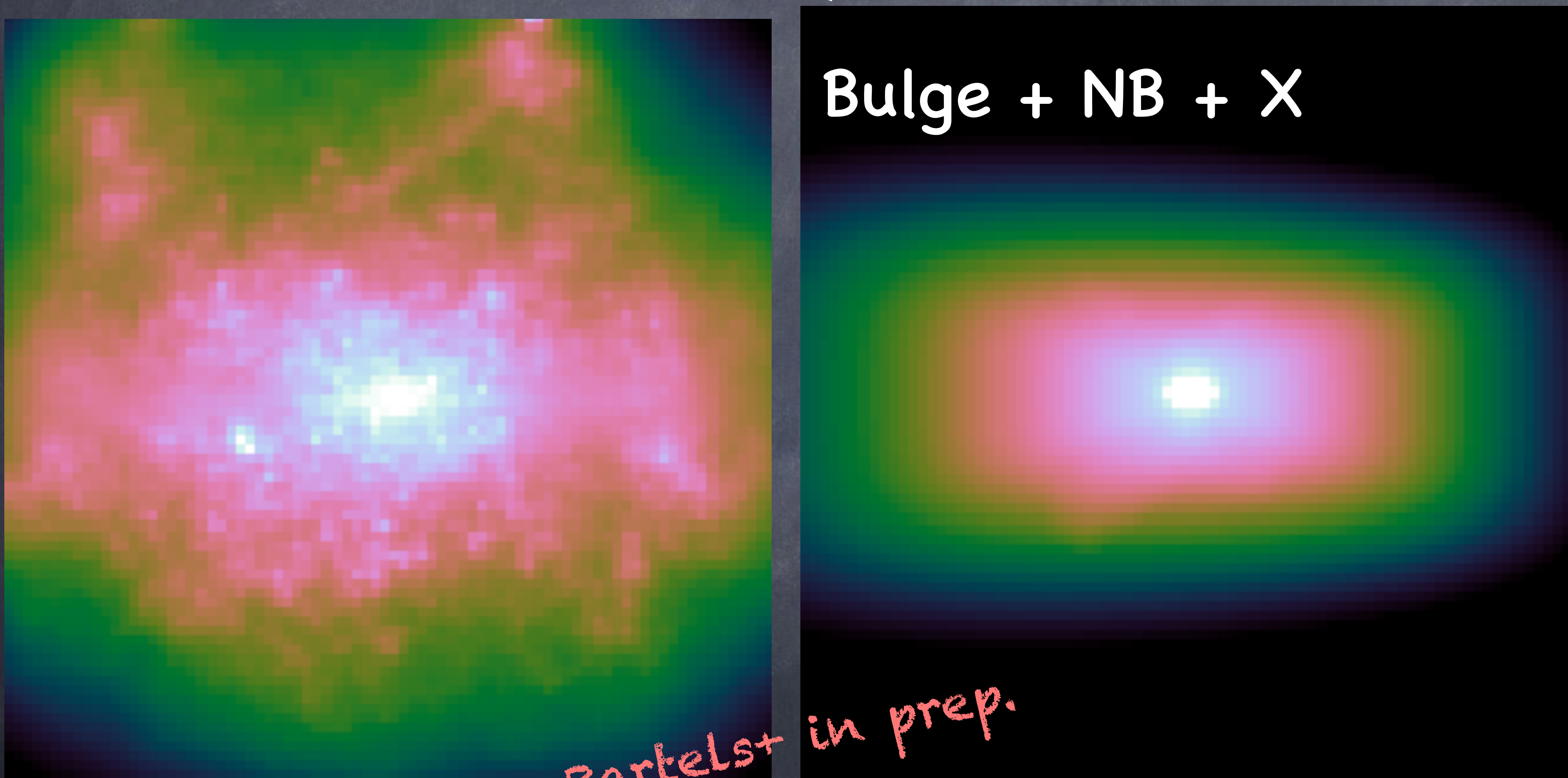
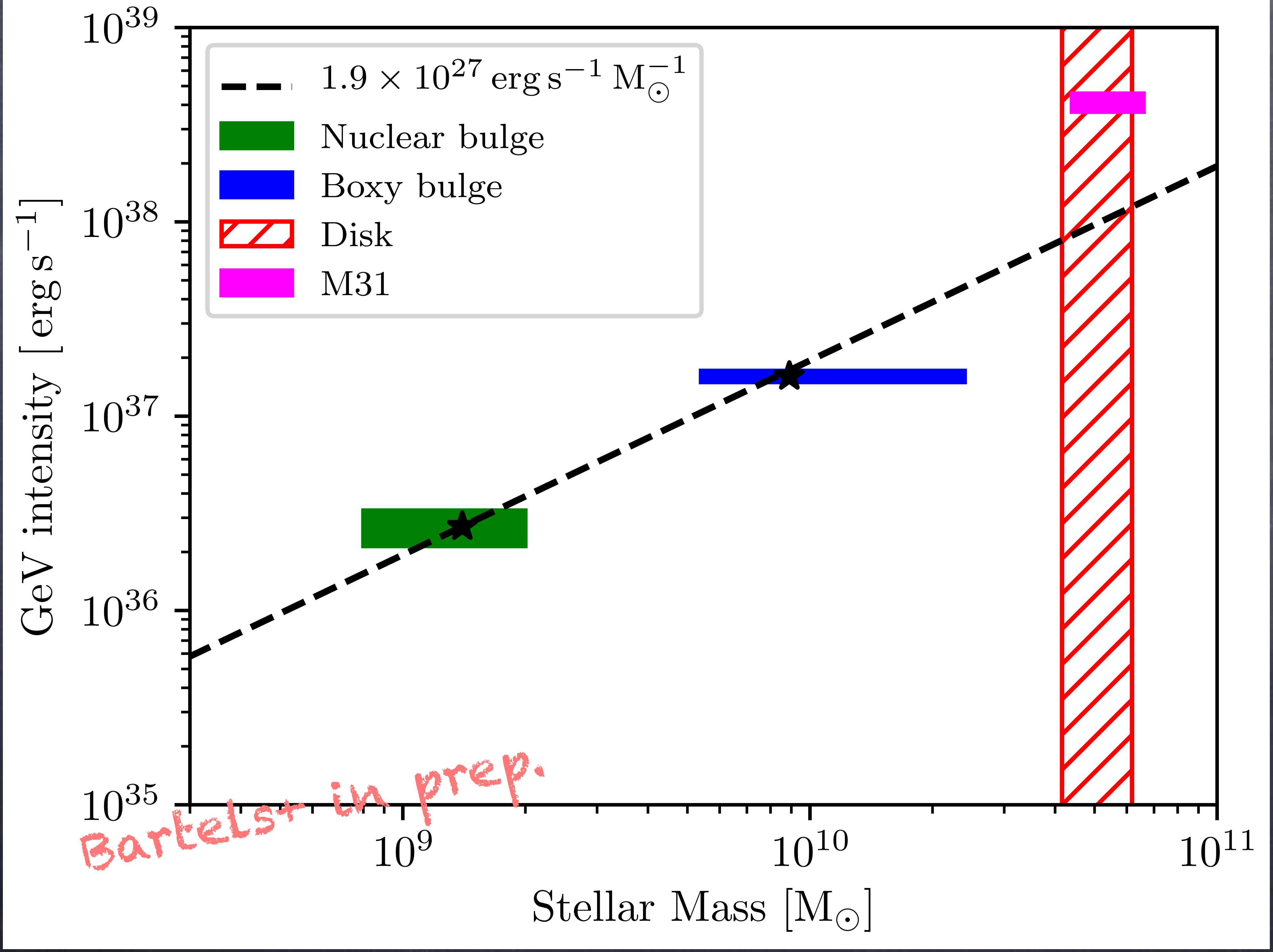
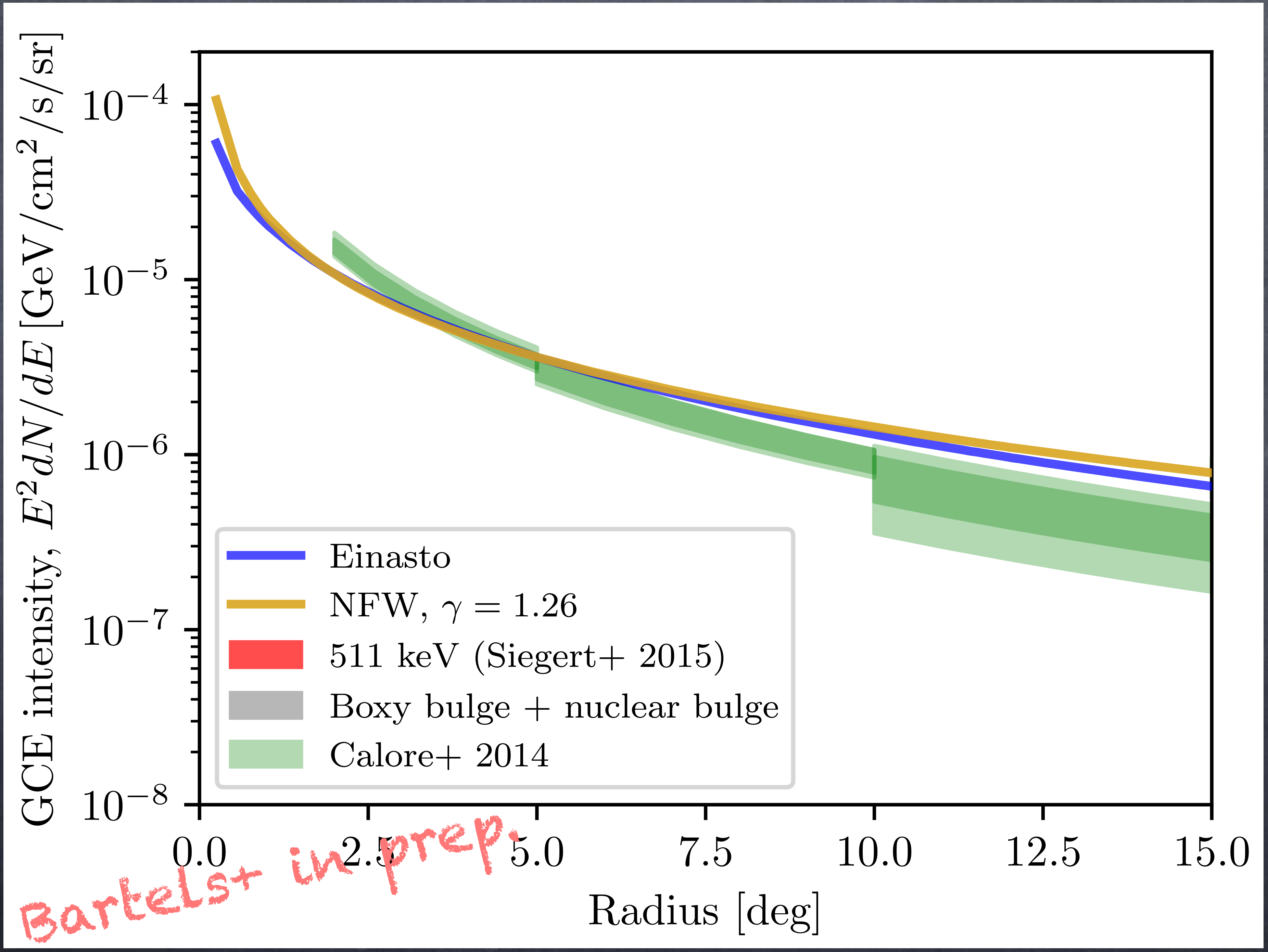


Bartels+ in prep.

GCE vs. Stellar Mass



Surprising?



GCE intensity, $E^2 dN/dE$ [GeV/cm^2/s/sr]
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
0.0
2.5
5.0
7.5
10.0
12.5
15.0
Radius [deg]
Einasto
NFW, $\gamma = 1.26$
511 keV (Siegert+ 2015)
Boxy bulge + nuclear bulge
Calore+ 2014
Bartels+ in prep.

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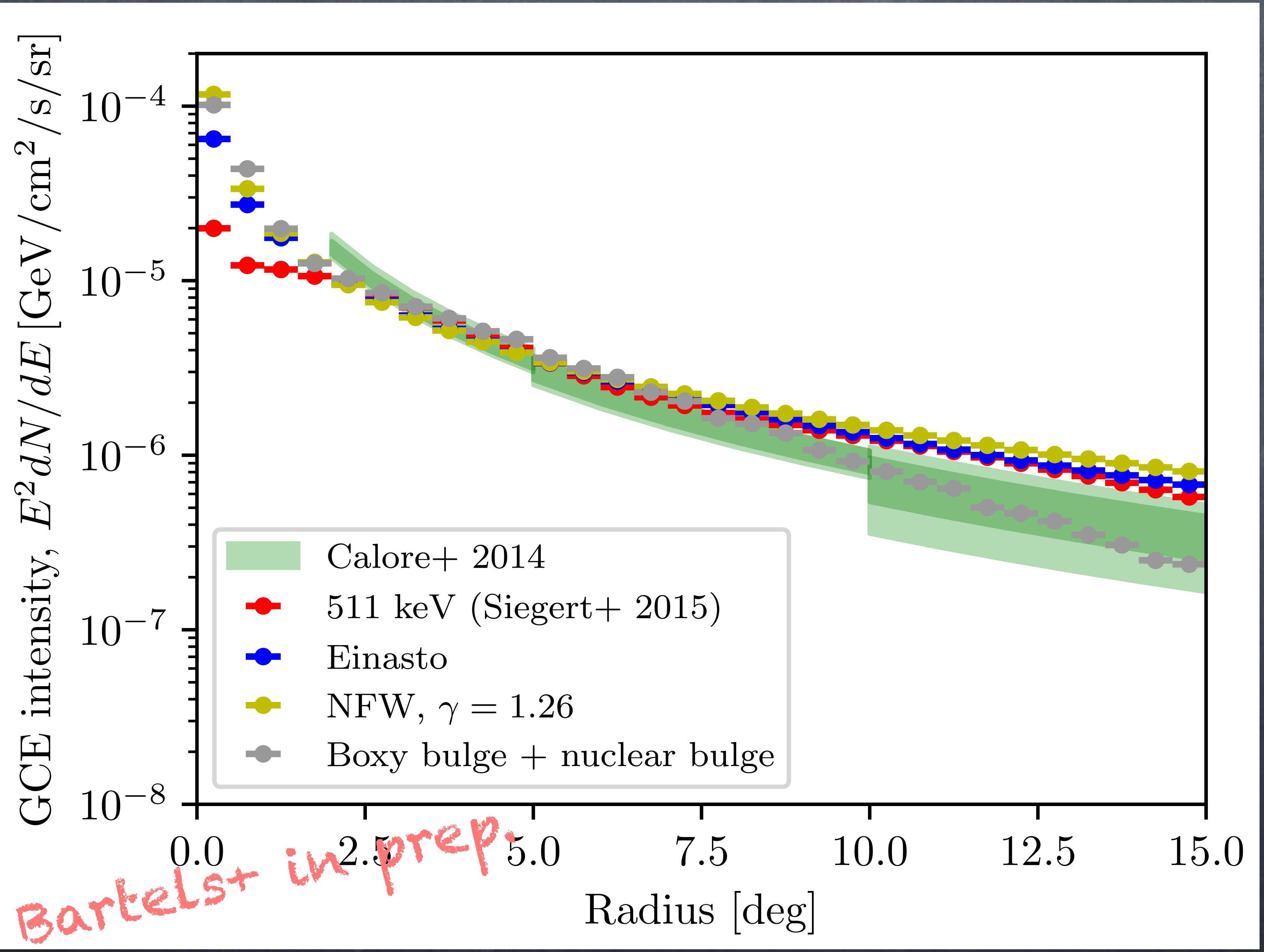
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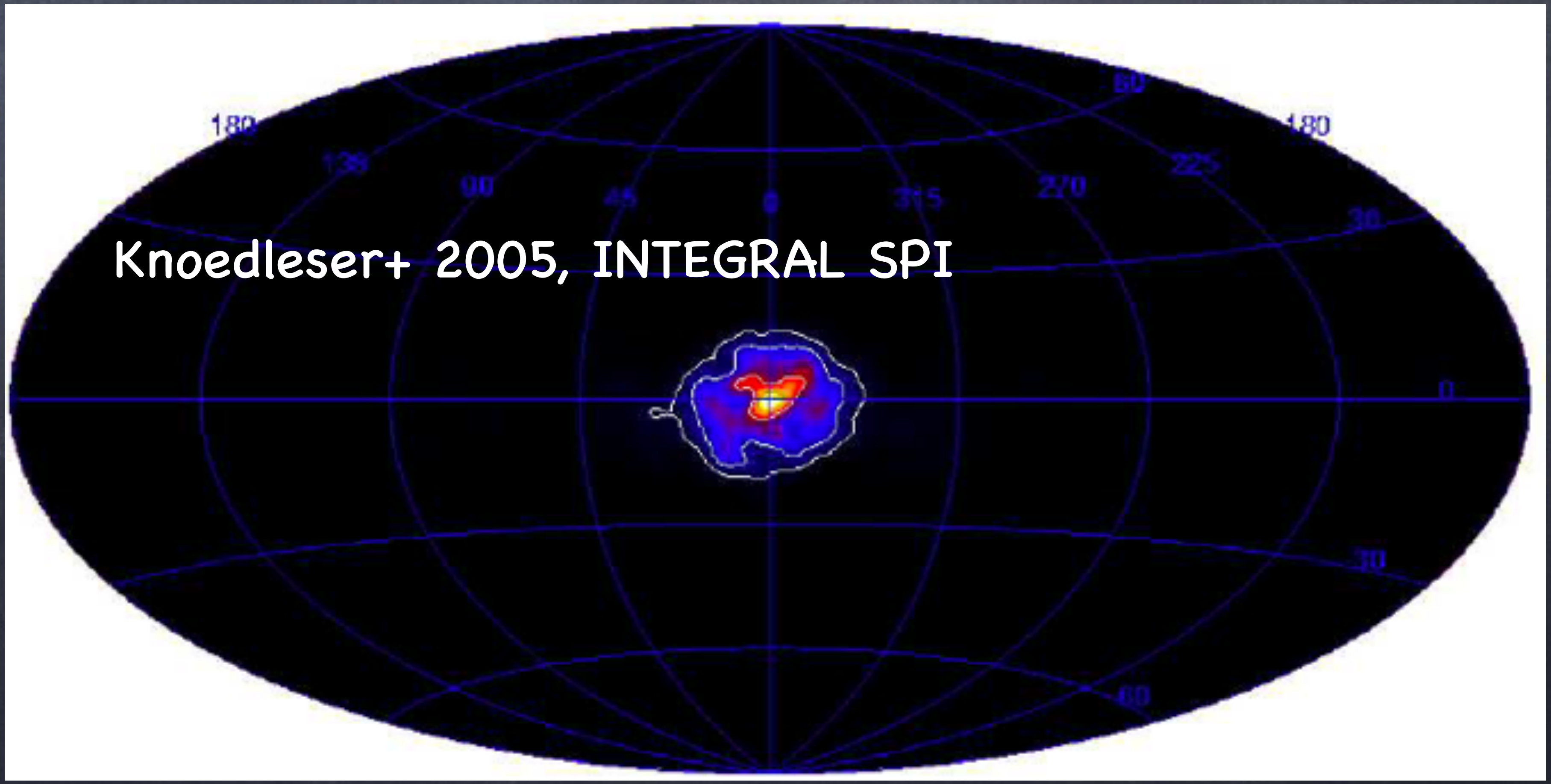
Conclusions part 1

1. The GCE from skyfact is more oblate wrt previous analyses
2. It traces stellar mass in the inner galaxy! MSPs?

Part 2: GCE & 511 keV

- 511 keV: positron annihilation
- Morphology appears similar to that of the GCE



Population synthesis

1. Thermonuclear SNe (Crocker+ 2016)

2. Low Mass X-ray binaries (LMXBs)

- MSP progenitors

- Positrons from jets of accreting BHs
  (Guessoum+ 2005; Bandyopadhyay+ 2008)
- 511 keV observed in microquasar jet!
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ultracompact X-ray binaries in the Bulge

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$\dot{M}$

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  - Calculate Power in BH jets (NSs have too weak jets!!)

Takeaway recipe

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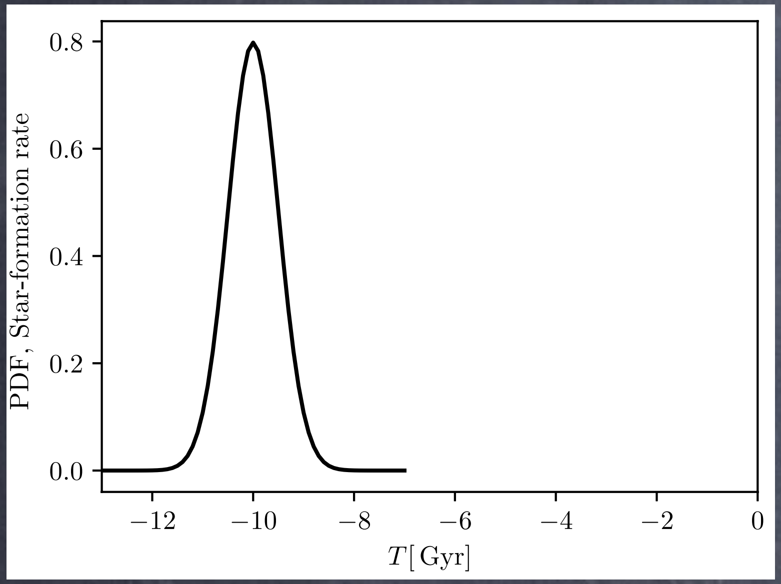
star-formation rate



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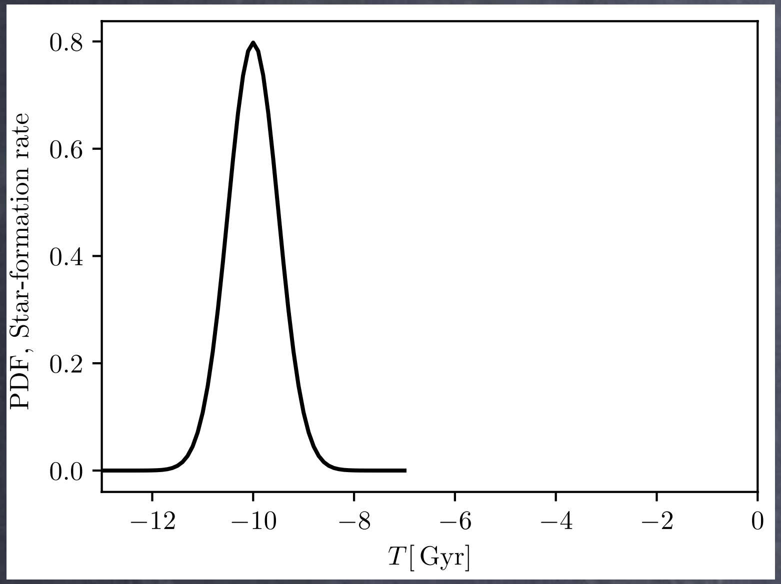
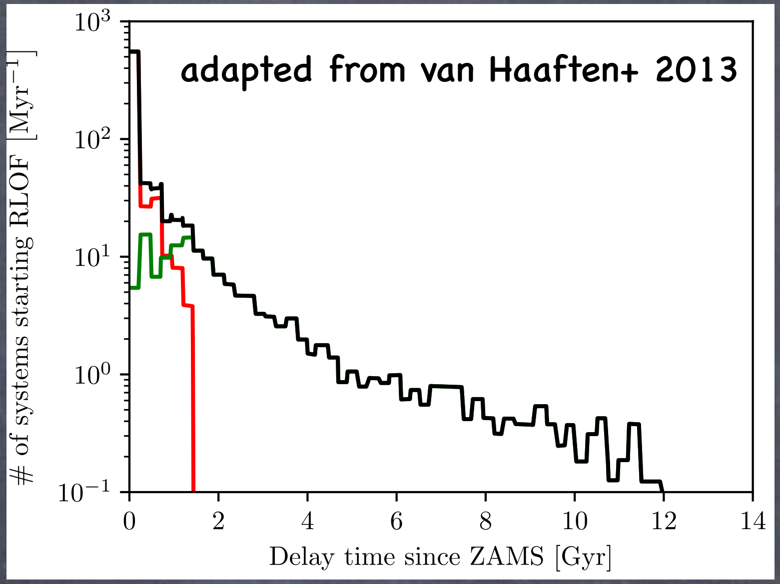


+

Delay Time



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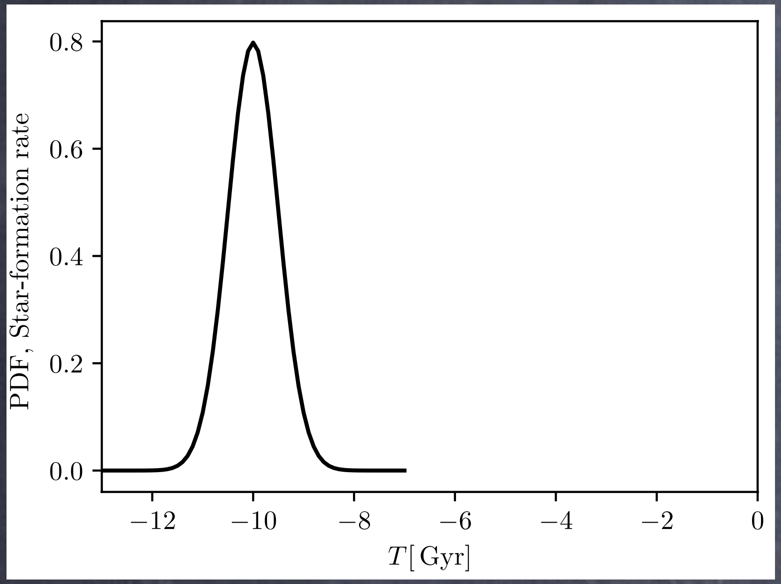

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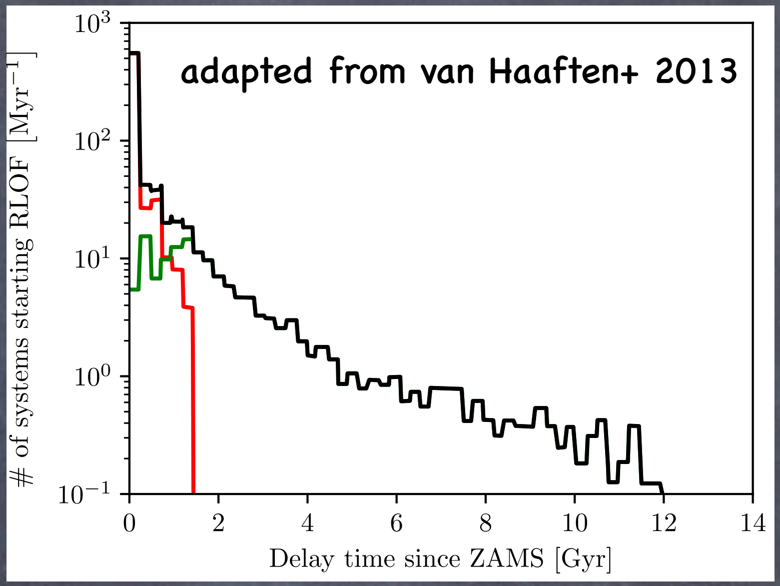


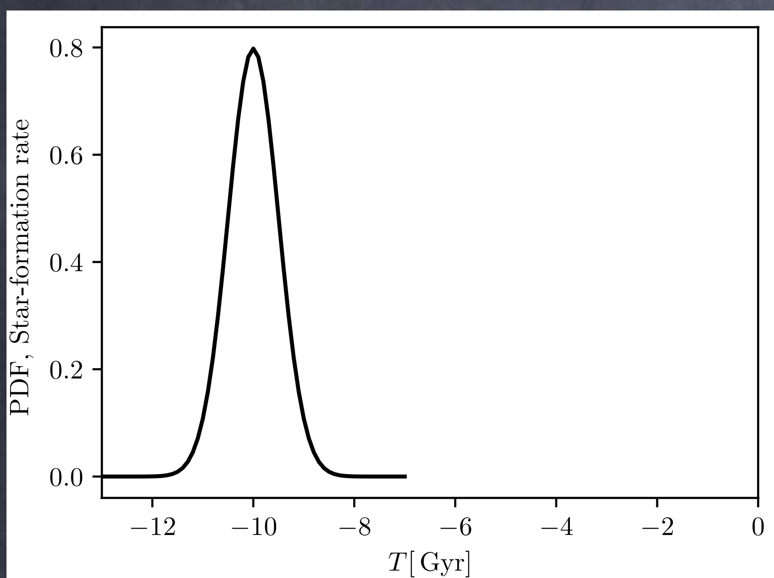
+

UCXB Evolution

$$\dot{M} \propto \left(\frac{T_{\rm age}}{1\,{\rm yr}}\right)^{-\frac{14}{11}}$$

Takeaway recipe

star-formation rate



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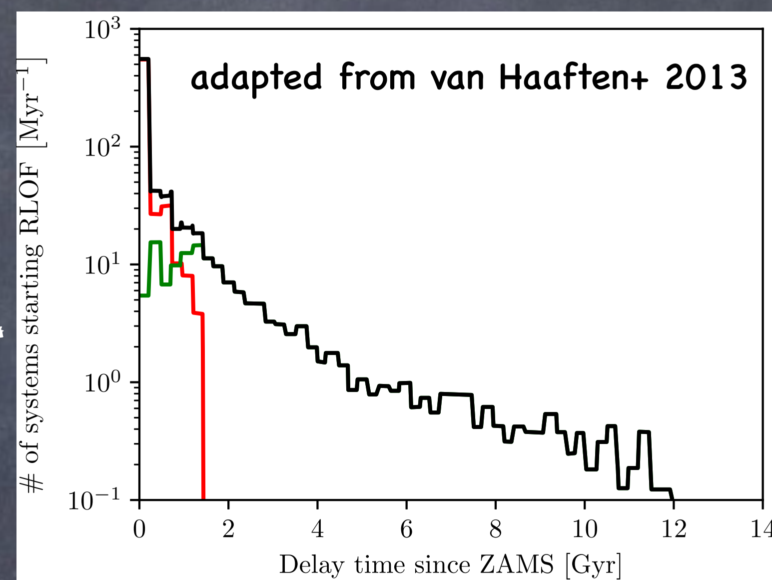

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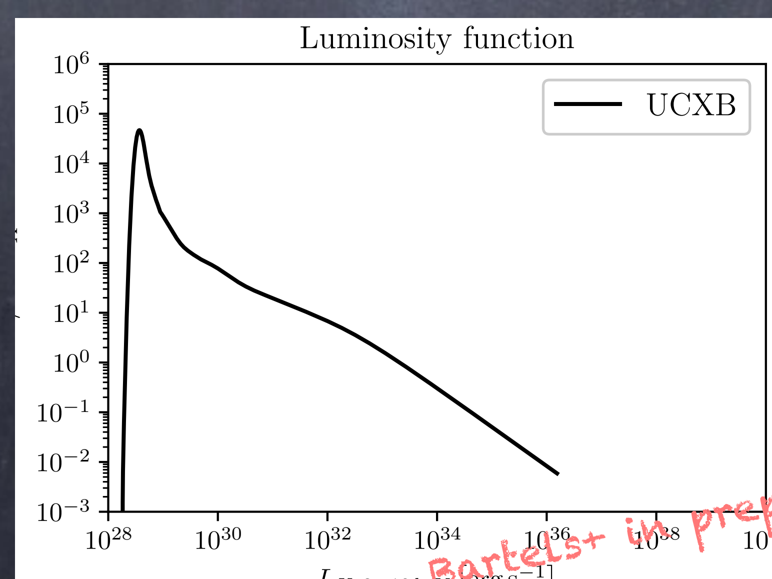

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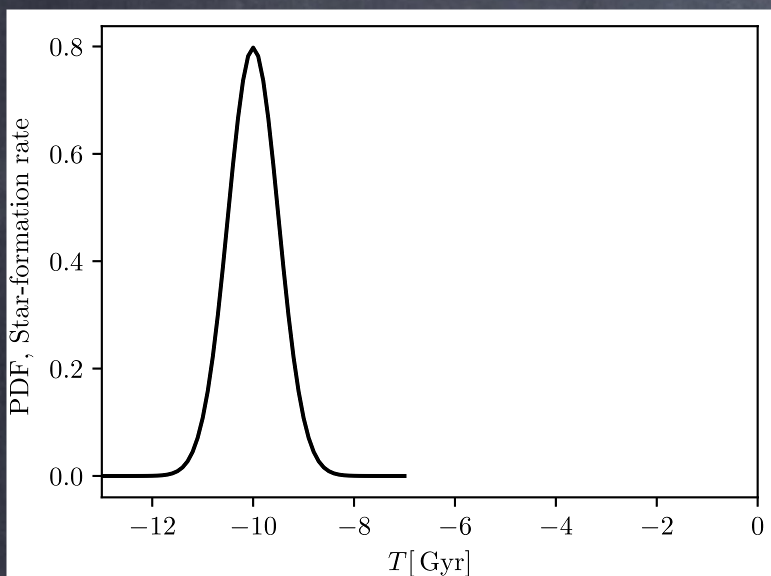

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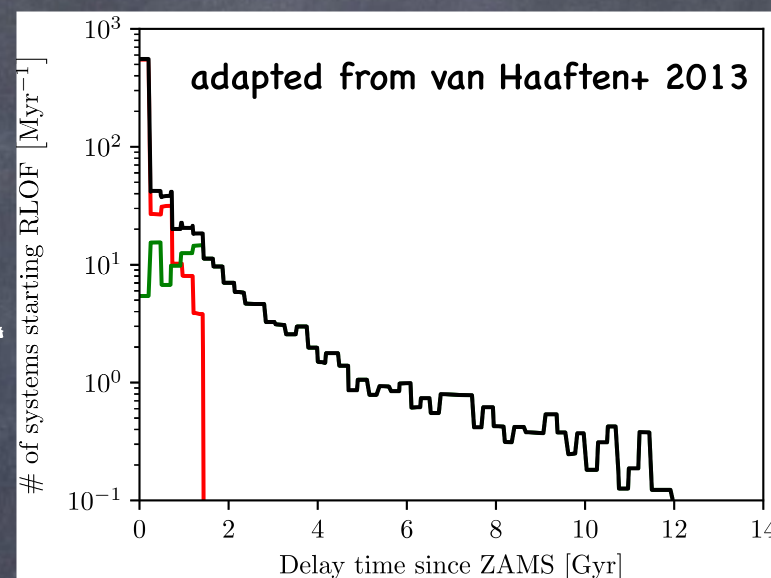

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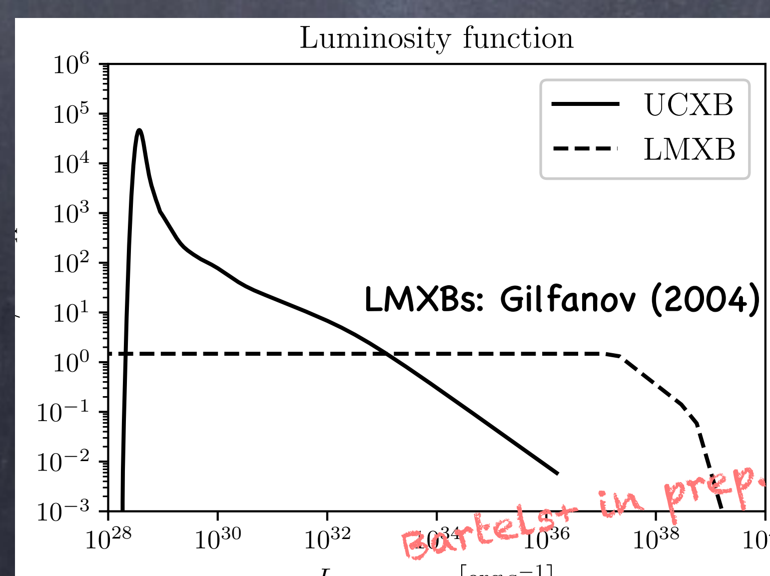

Jet kinetic power & positrons

$$L_J \propto \dot{M} \propto \begin{cases} L_X^{0.5}\,(\mathrm{BH}) \\ L_X\,(\mathrm{NS}) \end{cases}$$

Fender+ (2003)

$$\dot{N}_{e^+} = \frac{L_J}{2\Gamma\,\langle\gamma\rangle\,m_e c^2}$$

Heinz & Sunyaev (2002)

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Heinz & Sunyaev (2002)

We assume a cold, pair dominated jet

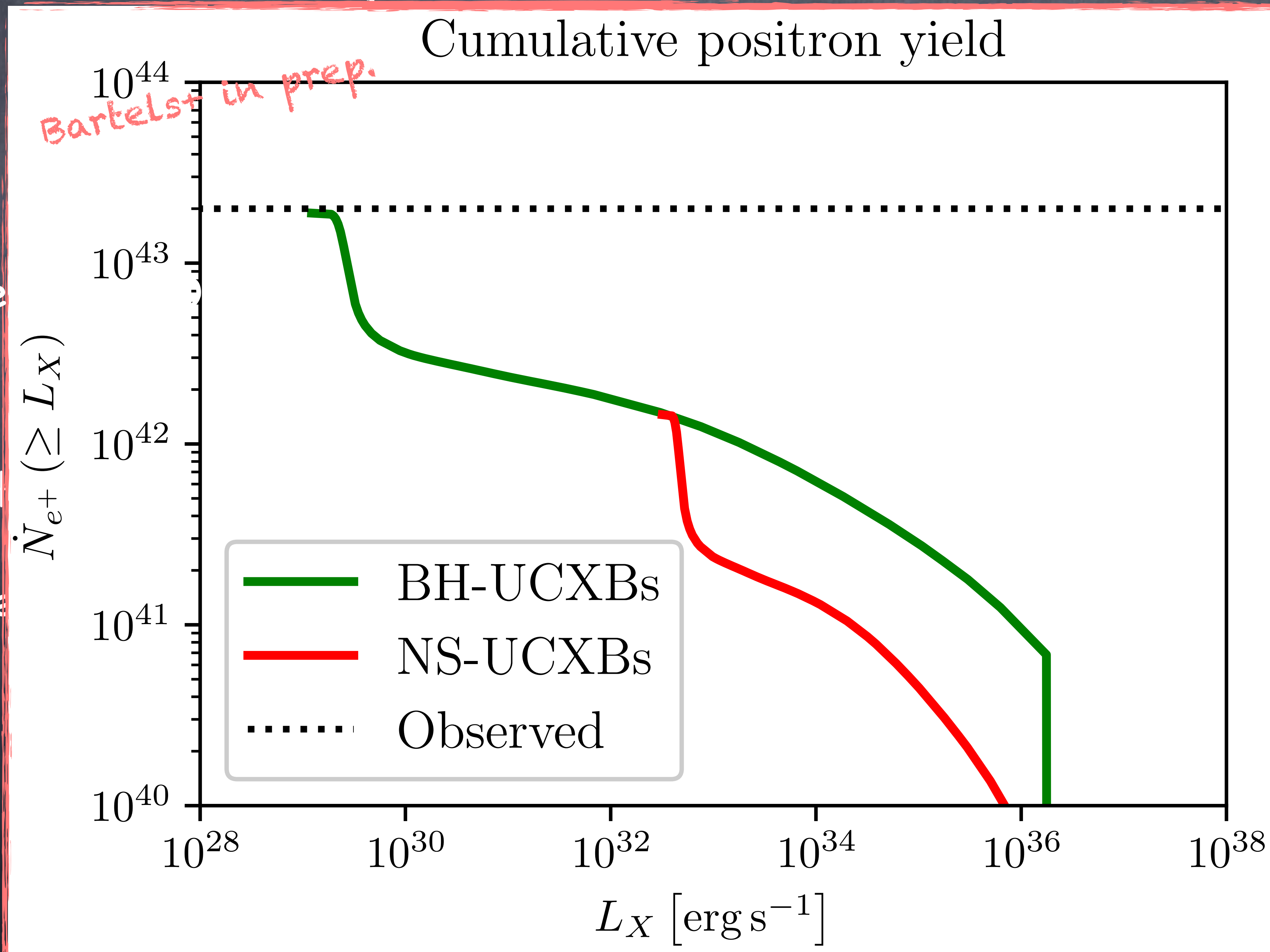
Jet kinetic power & positrons

L_J ... cold, ...ed jet

Fe...

$\dot{N}_{e^+}$

He...



Conclusions part 2

- Evolutionary channel of Millisecond pulsars through LMXBs can explain both the 511 keV and GCE signals from the Bulge!

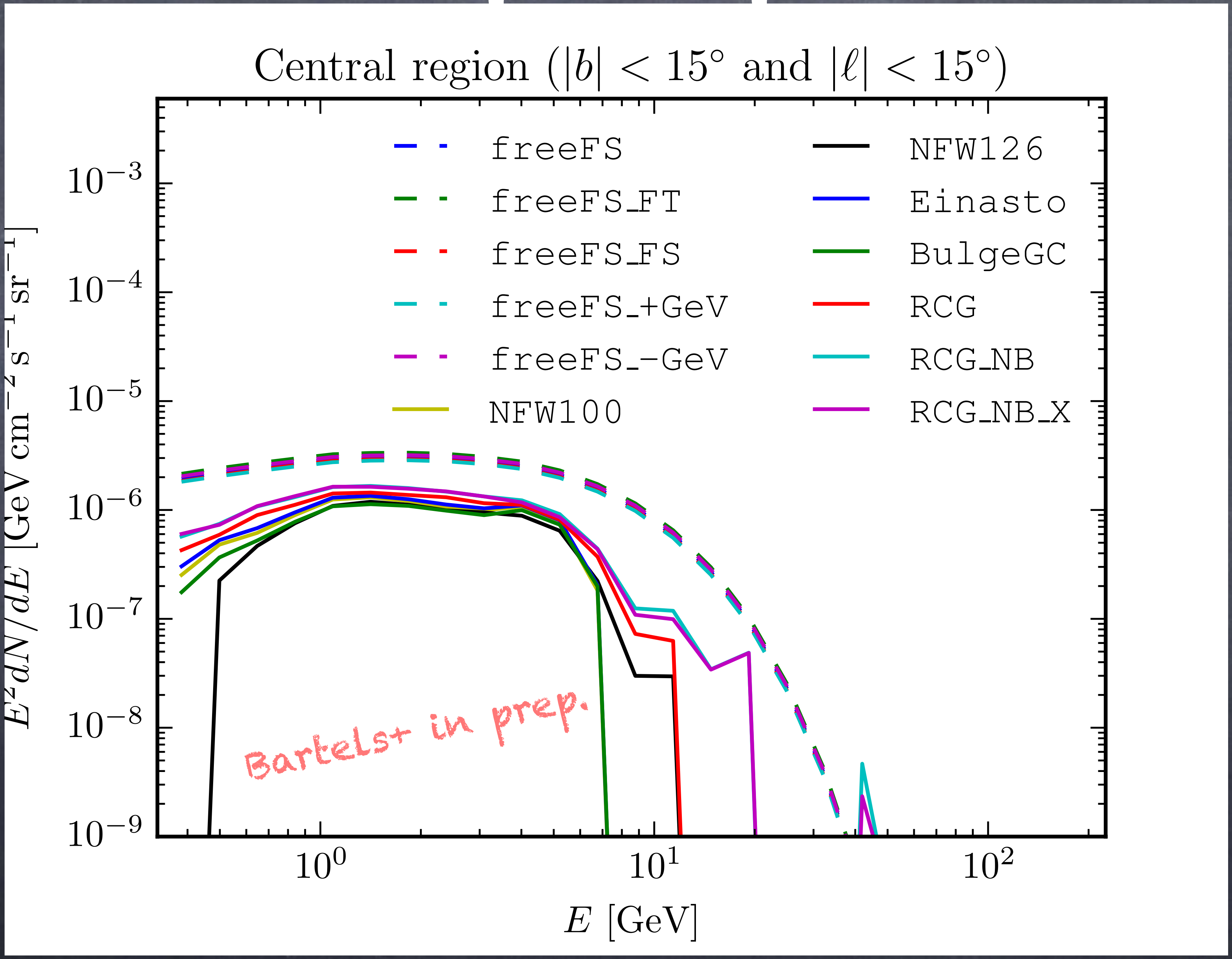
Conclusion

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

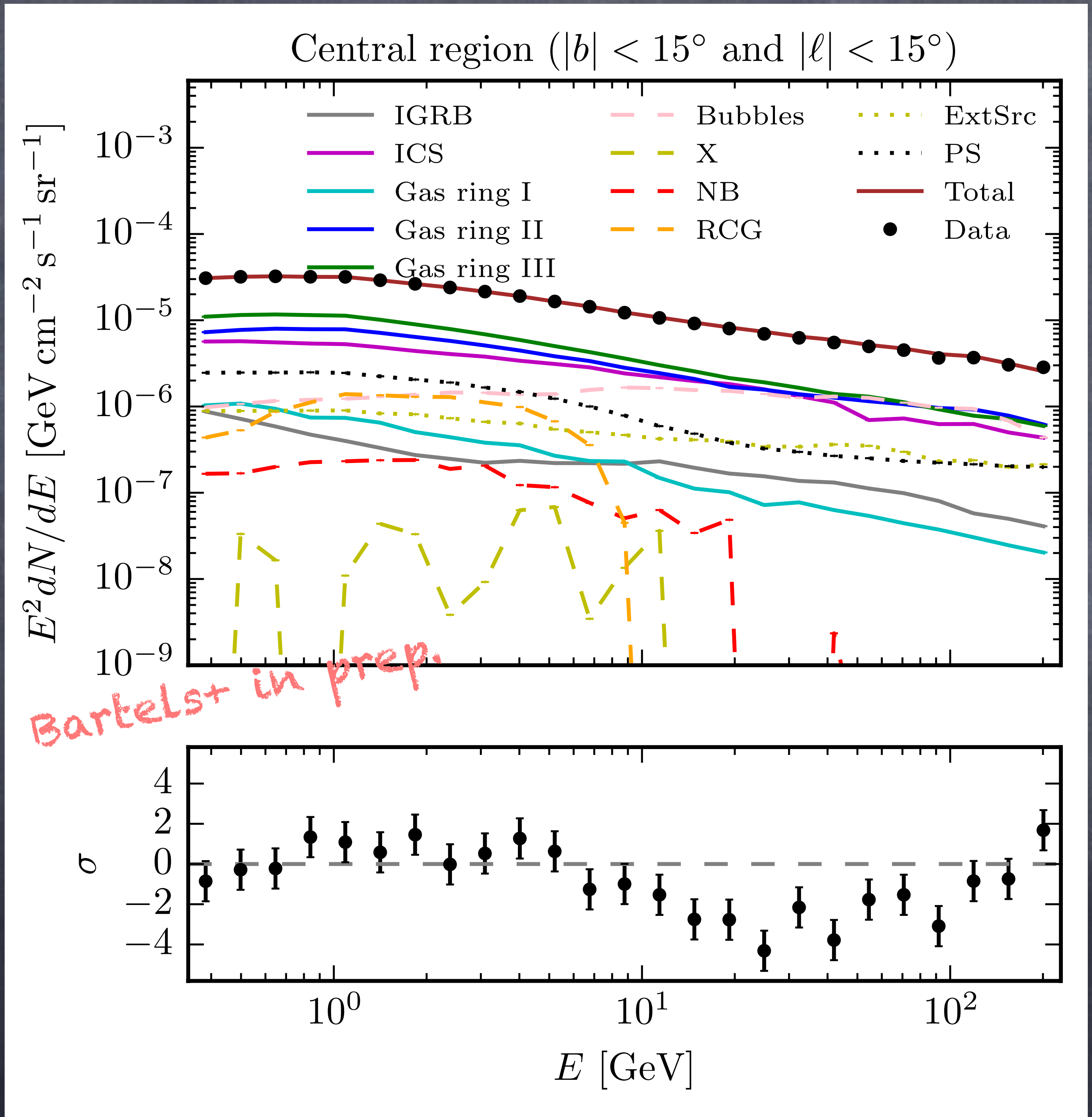
- 511 keV and GCE could be related through population synthesis

THANK YOU :)

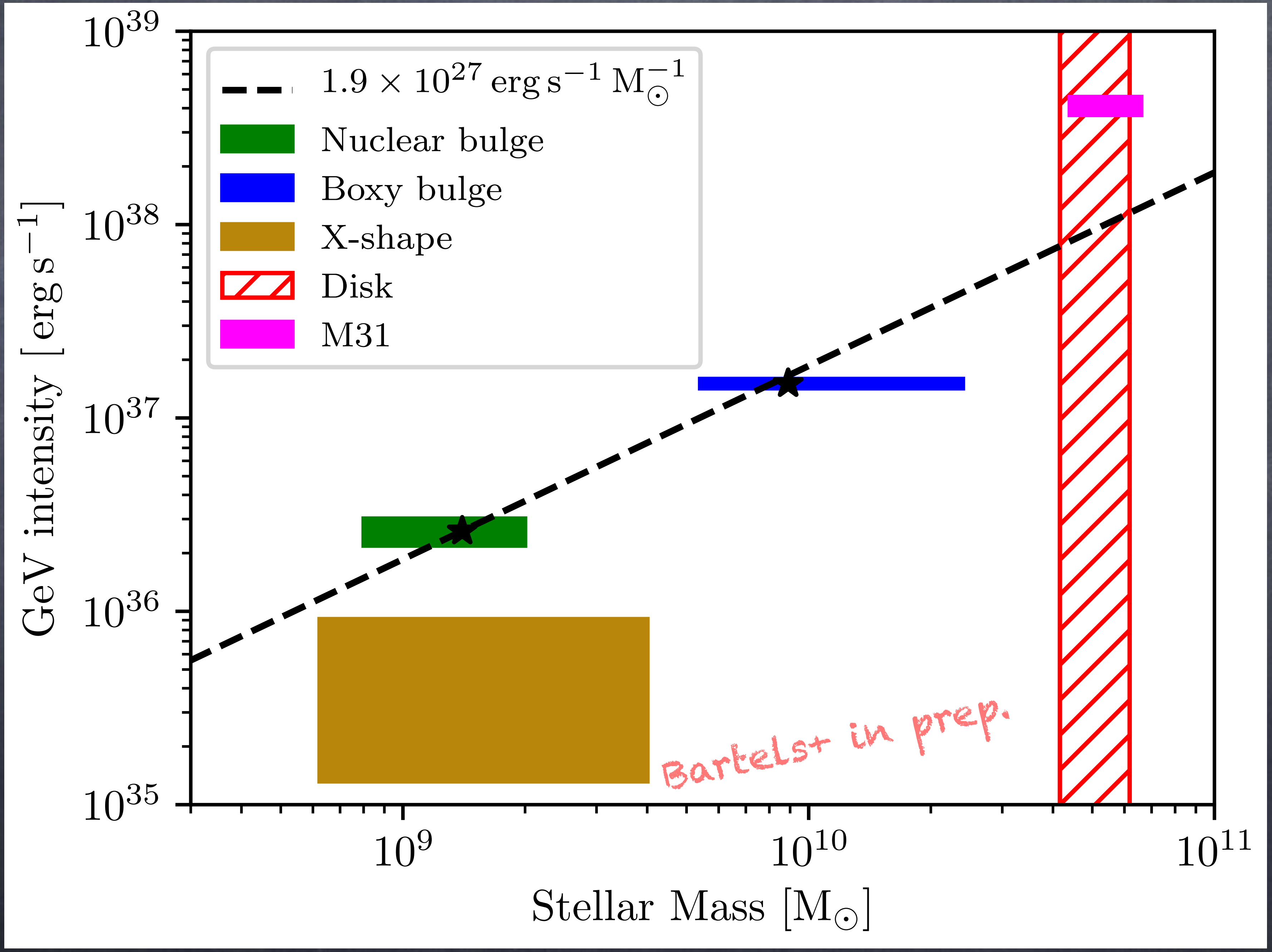
Backup: Spectra



Backup: spectra 2

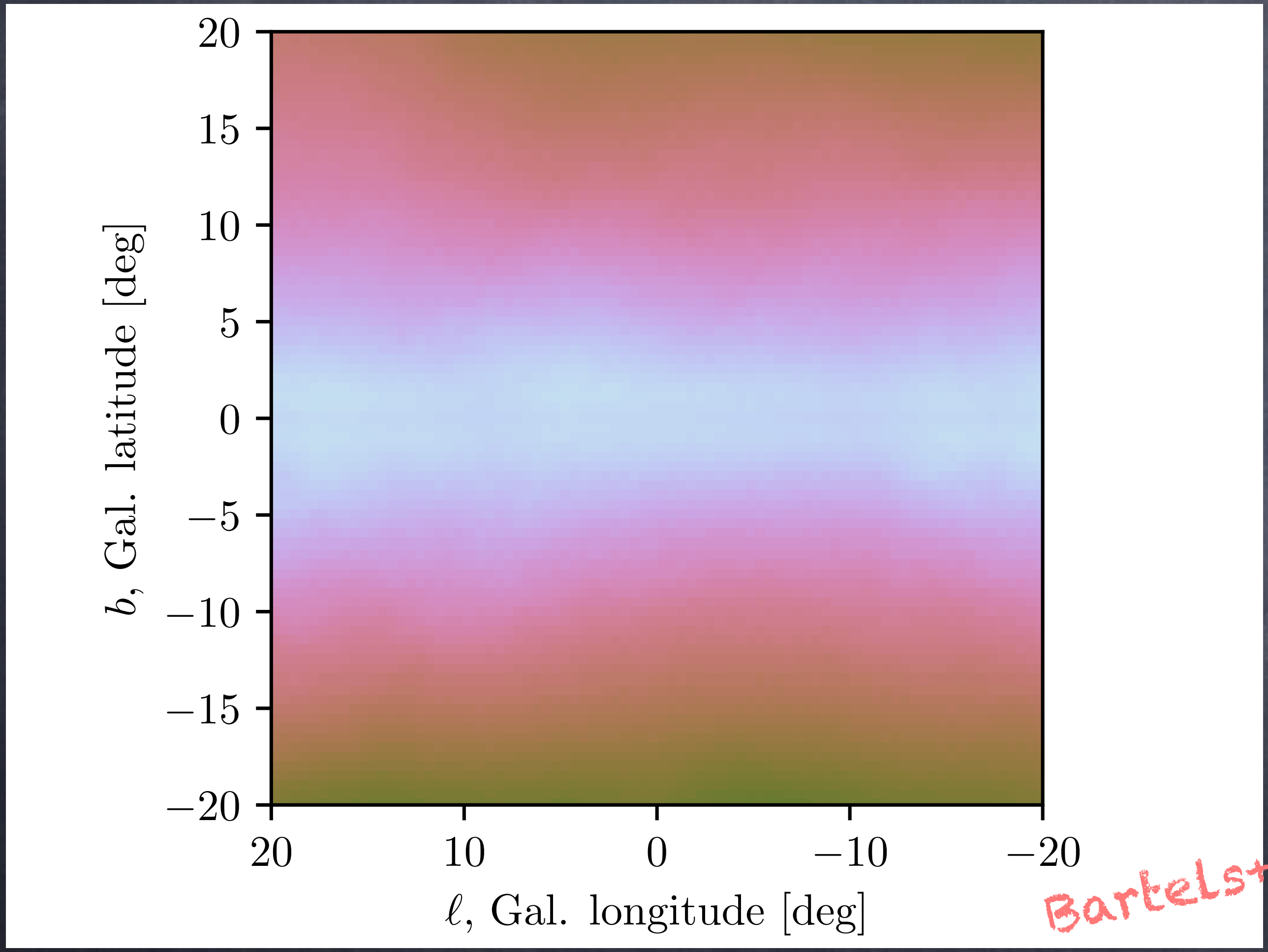


Backup: X-shape

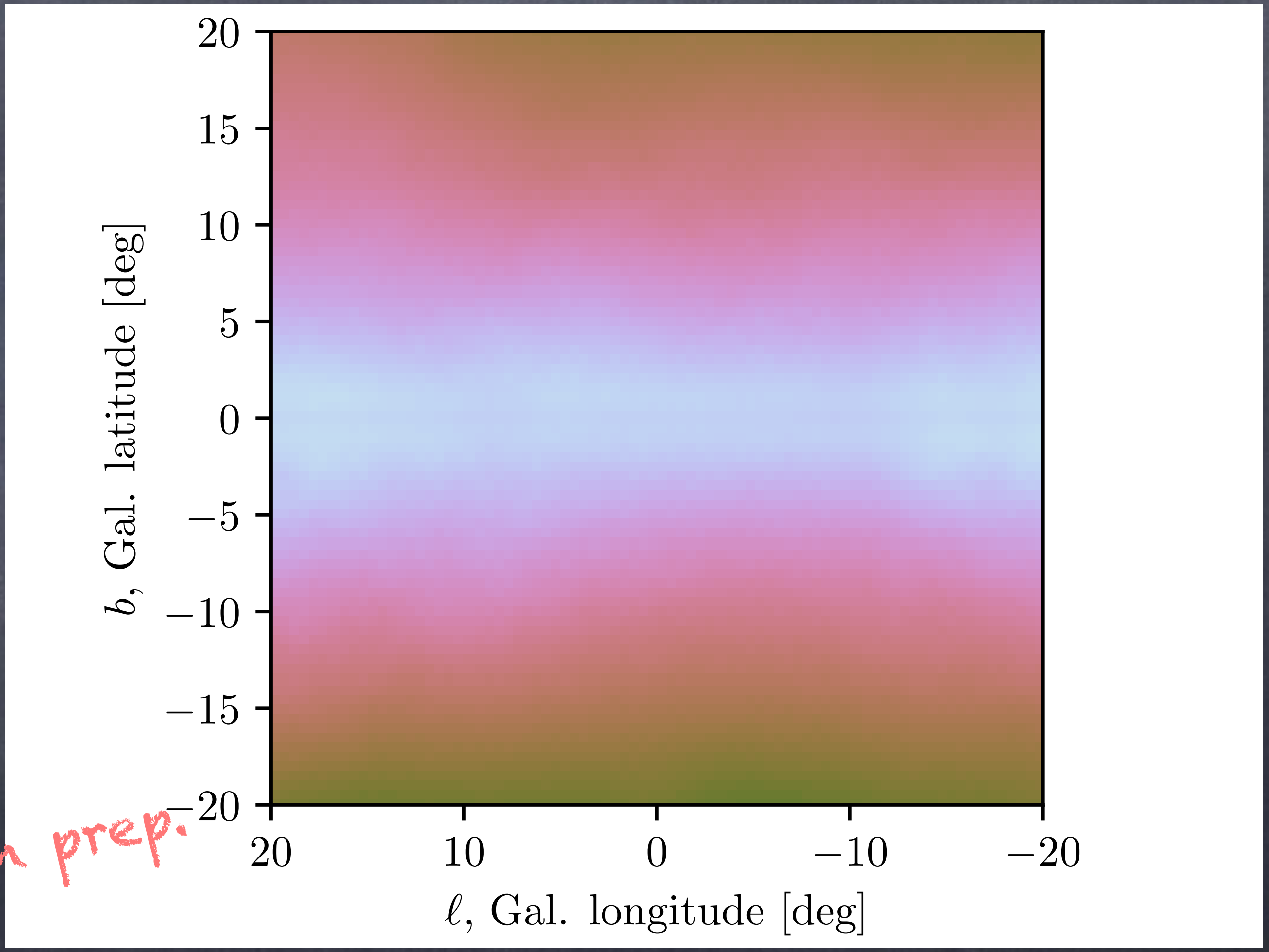


OTHER COMPONENTS

NFW



BULGE



Bartels+ in prep.

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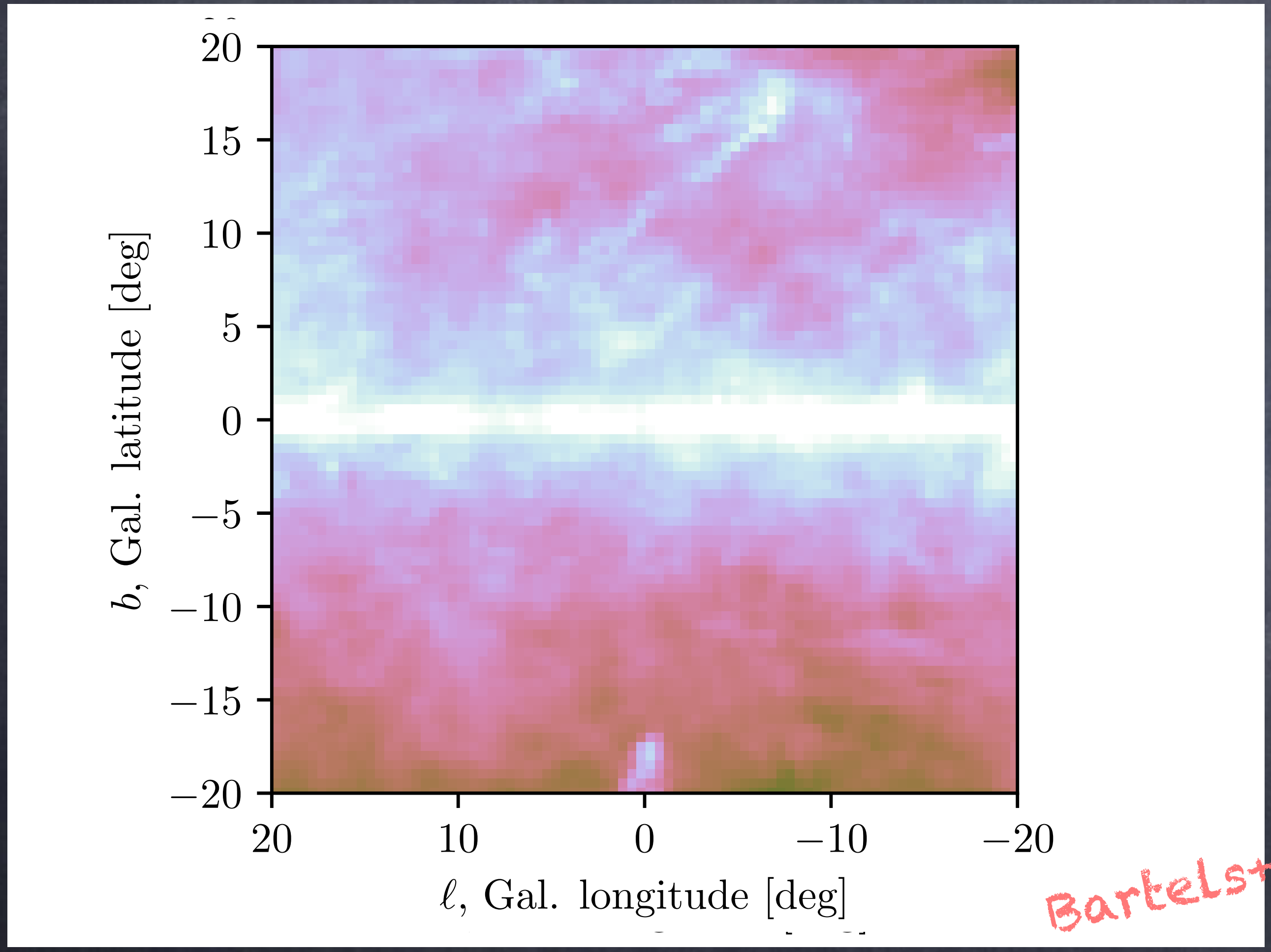

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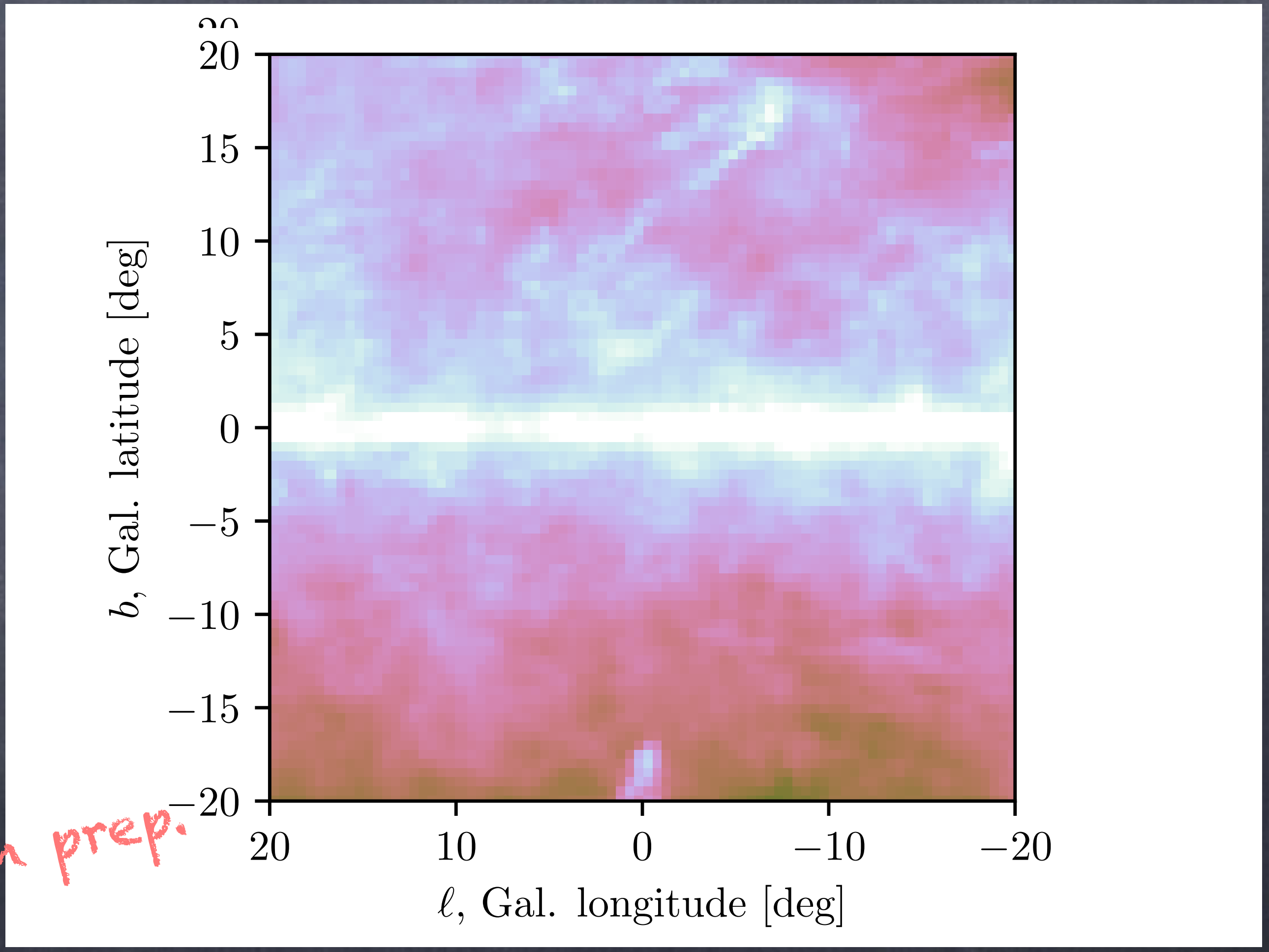

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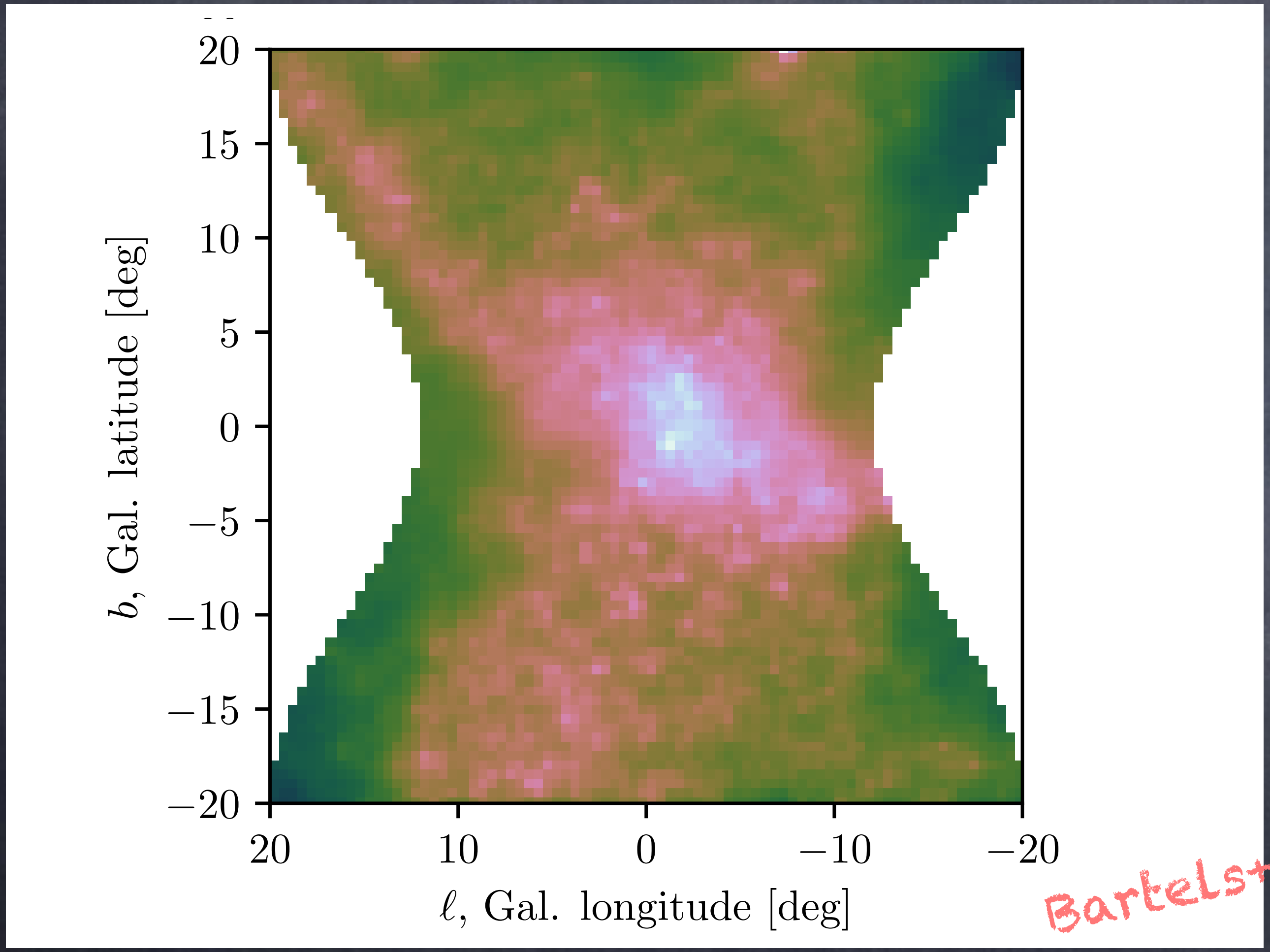

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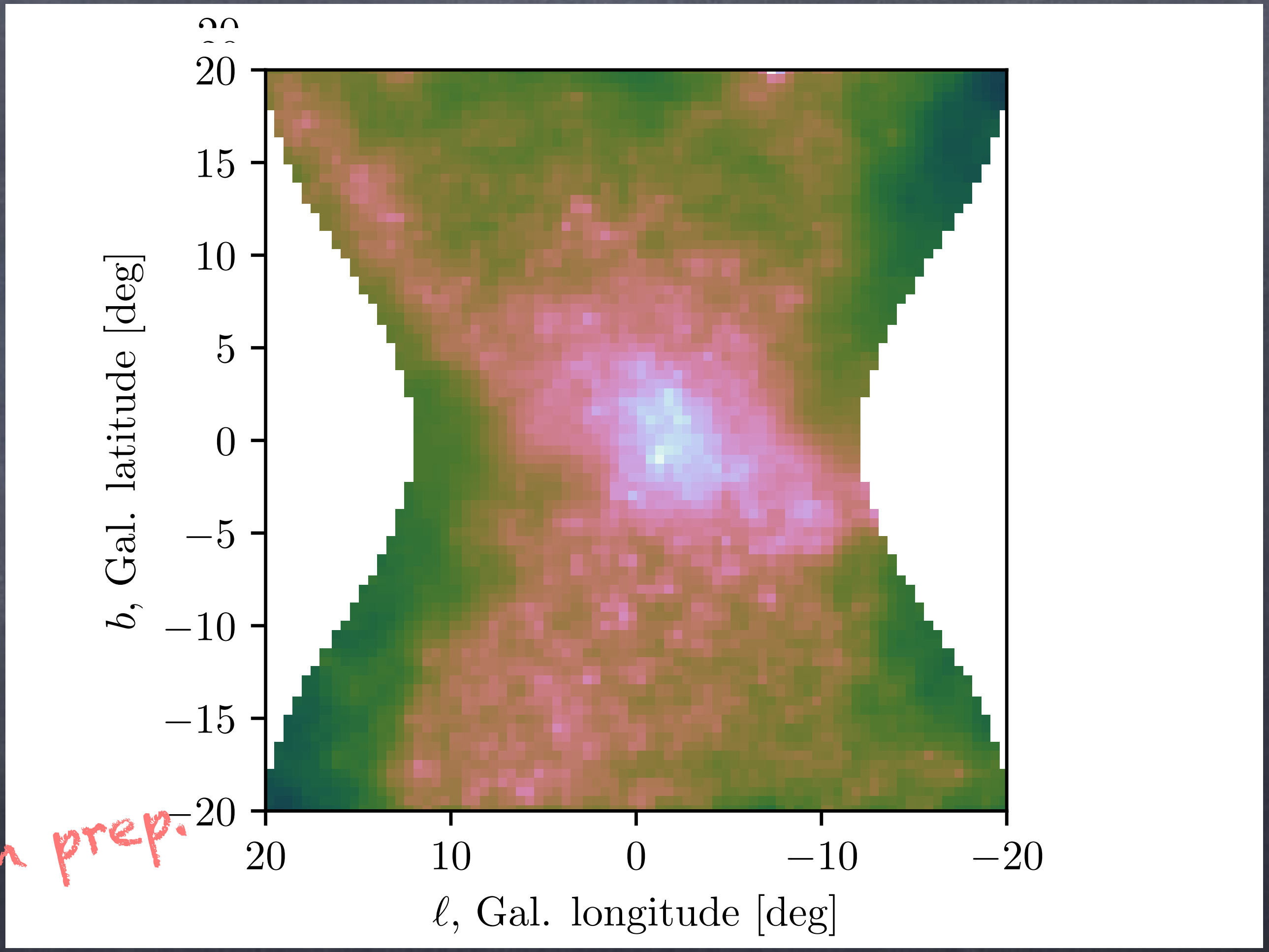

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