Decomposing the diffuse soft X-ray background with eROSITA

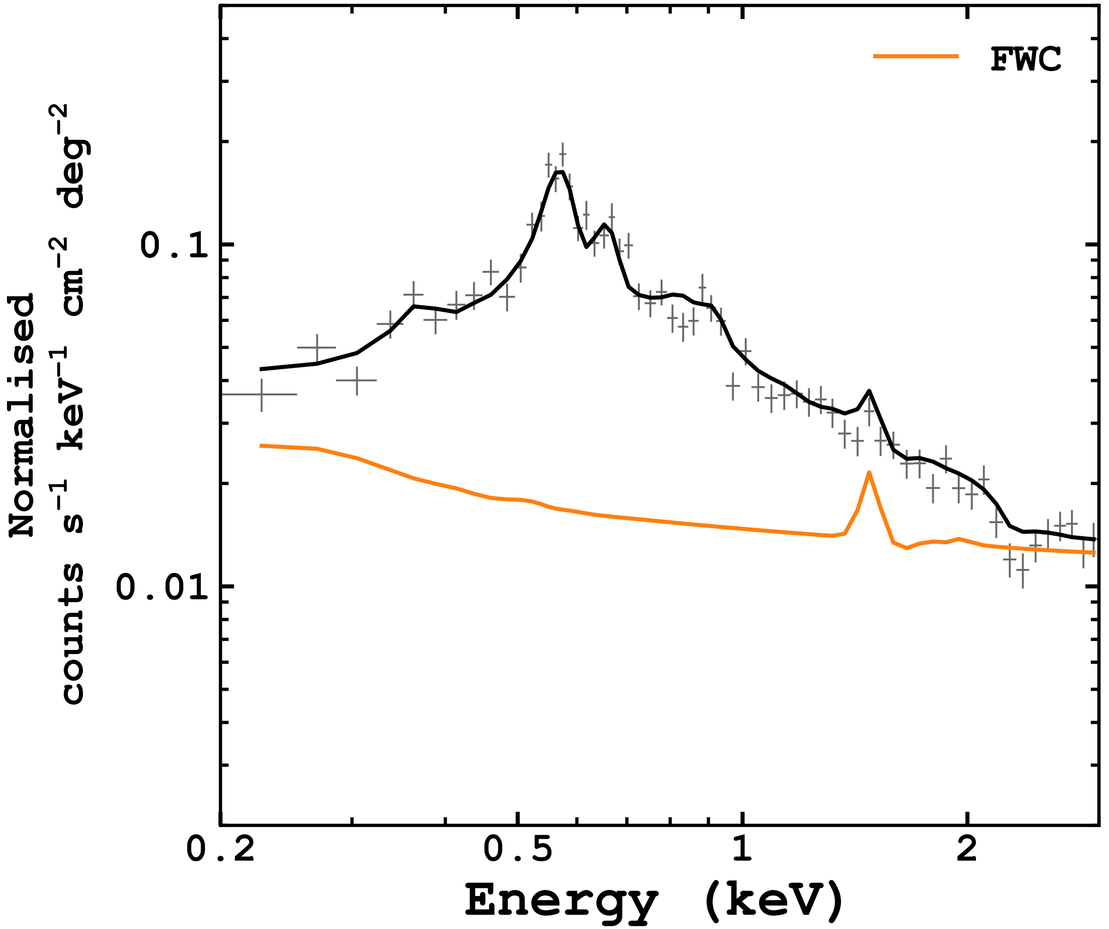
Michael Yeung

Michael Freyberg, Gabriele Ponti, Konrad Dennerl, Nicola Locatelli, Martin Mayer, Jeremy Sanders, Manami Sasaki, Andy Strong, Yi Zhang, Xueying Zheng, Teng Liu, Efrain Gatuzz

Charge exchange X-ray Universe 2024 Volos, Greece 20 June 2024

Diffuse Soft X-ray Background (SXRB)

*Absolutely not to scale



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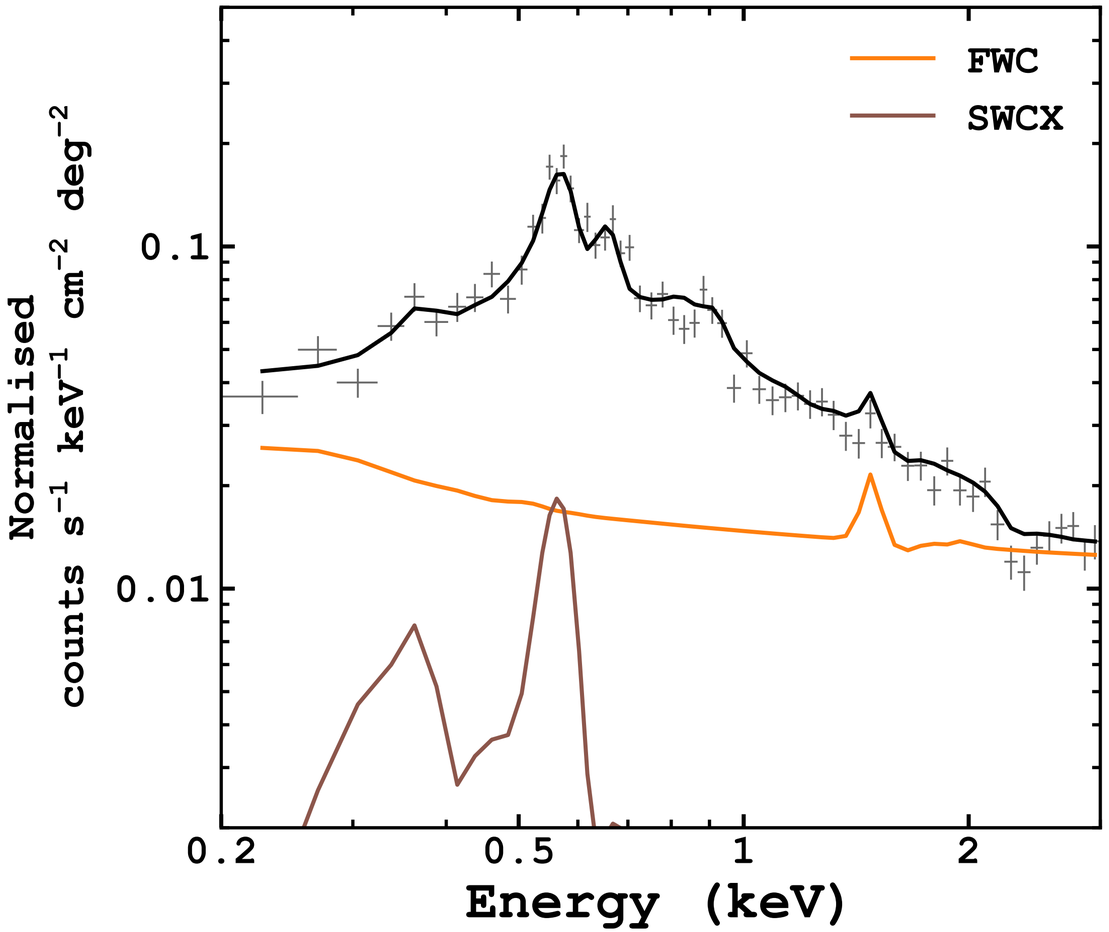

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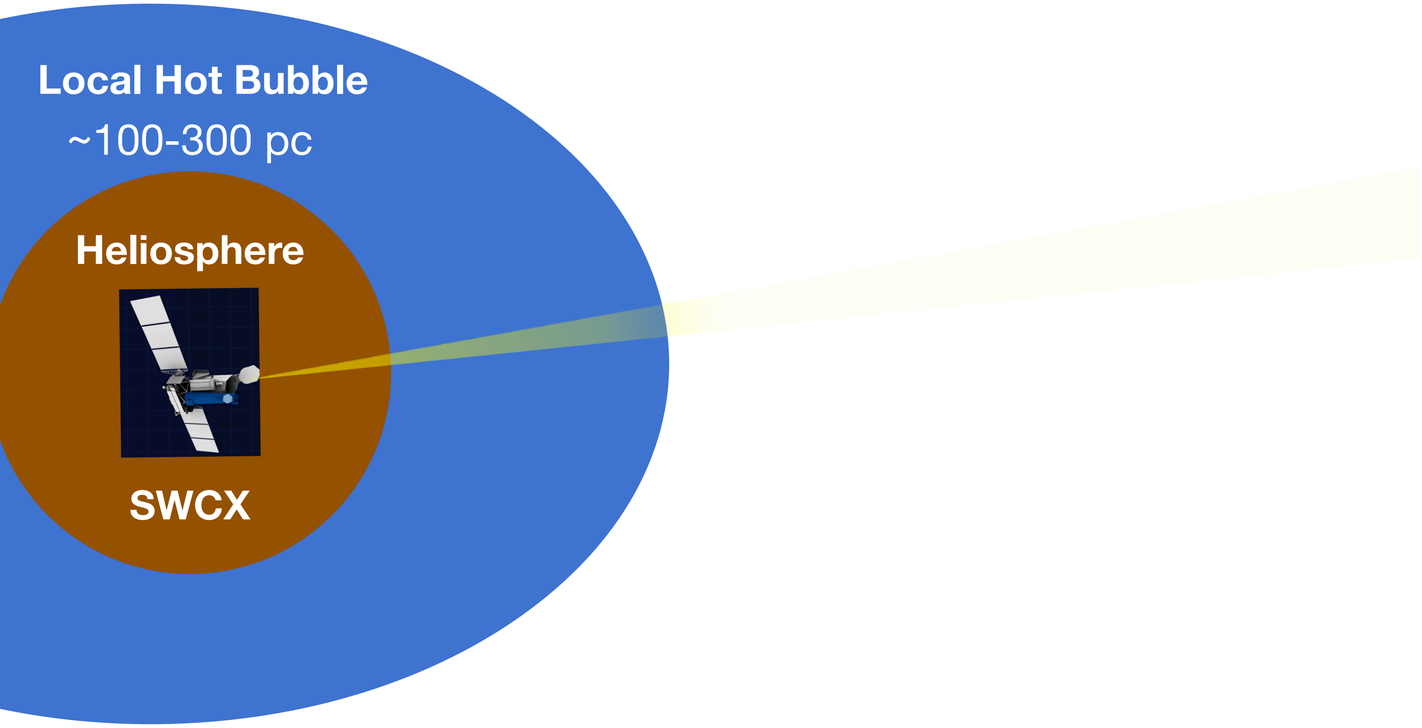

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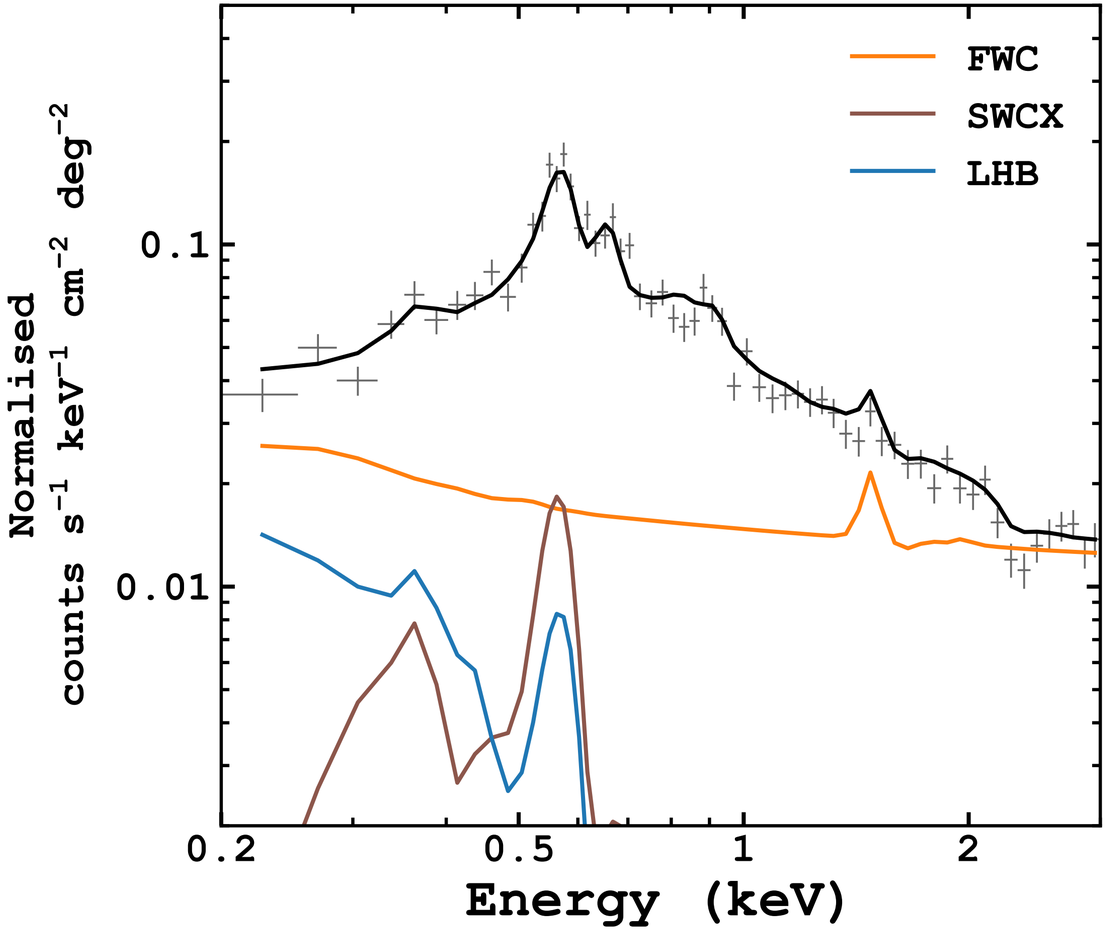

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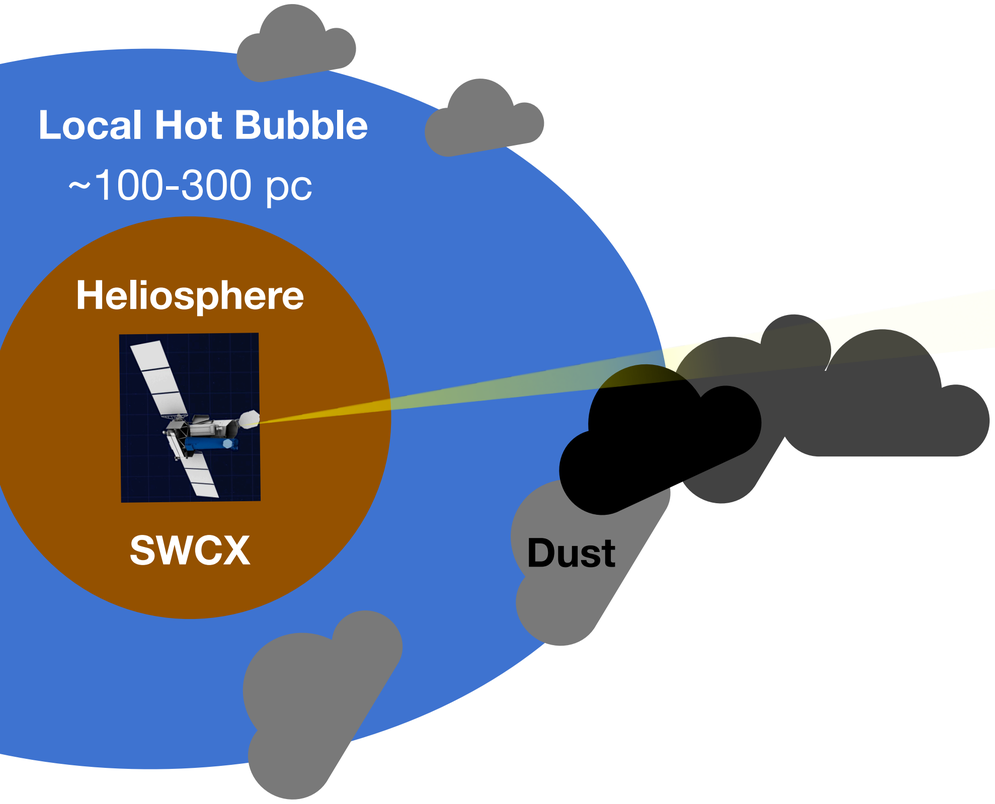

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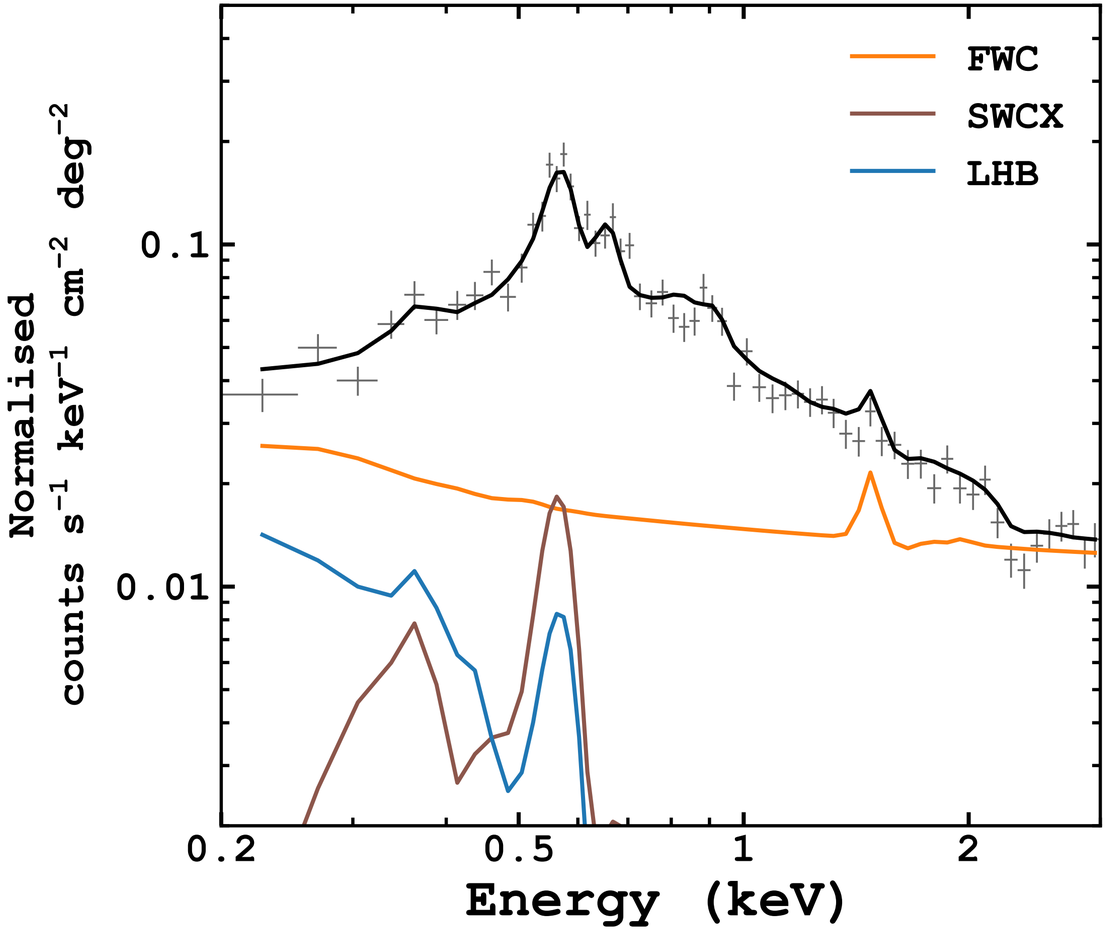

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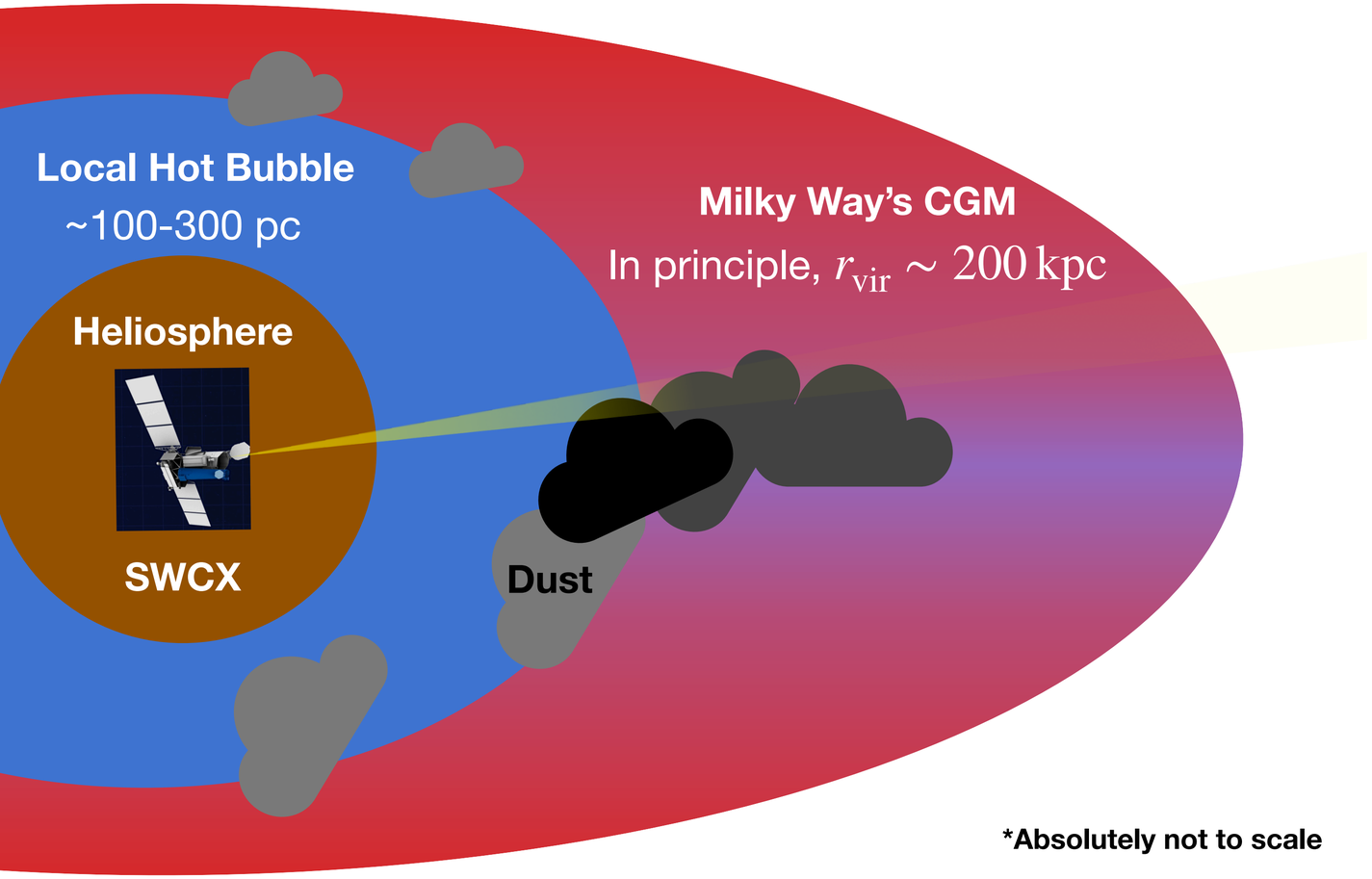

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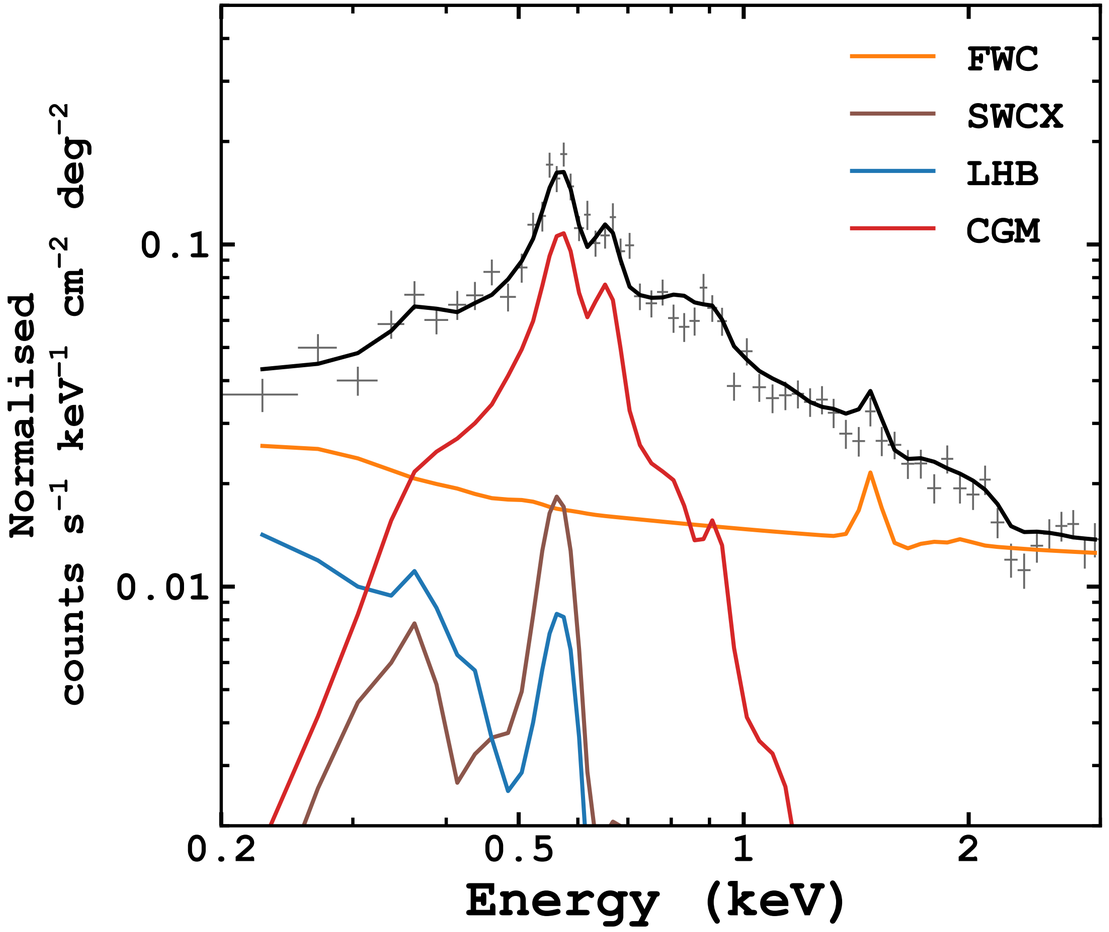

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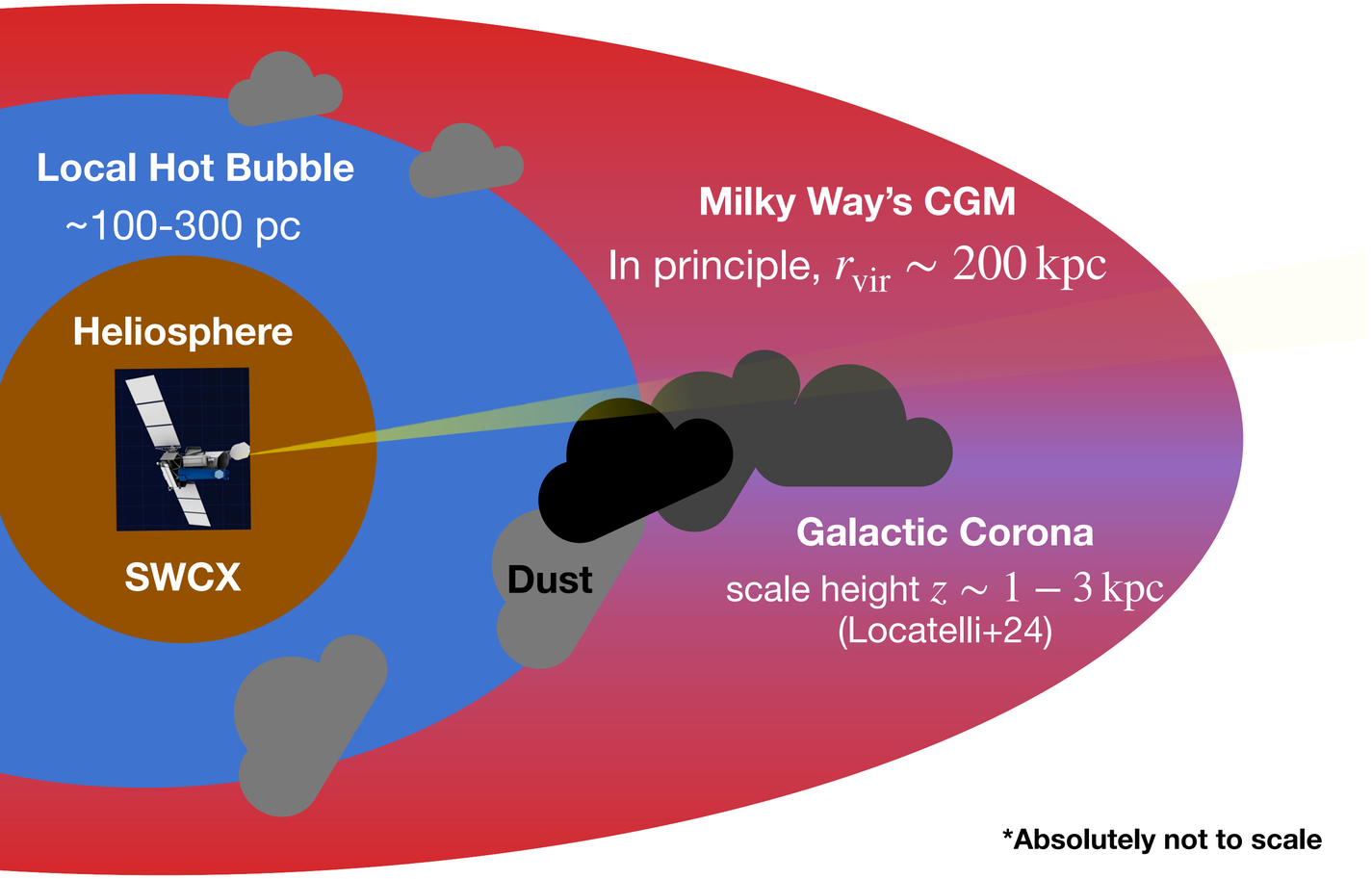

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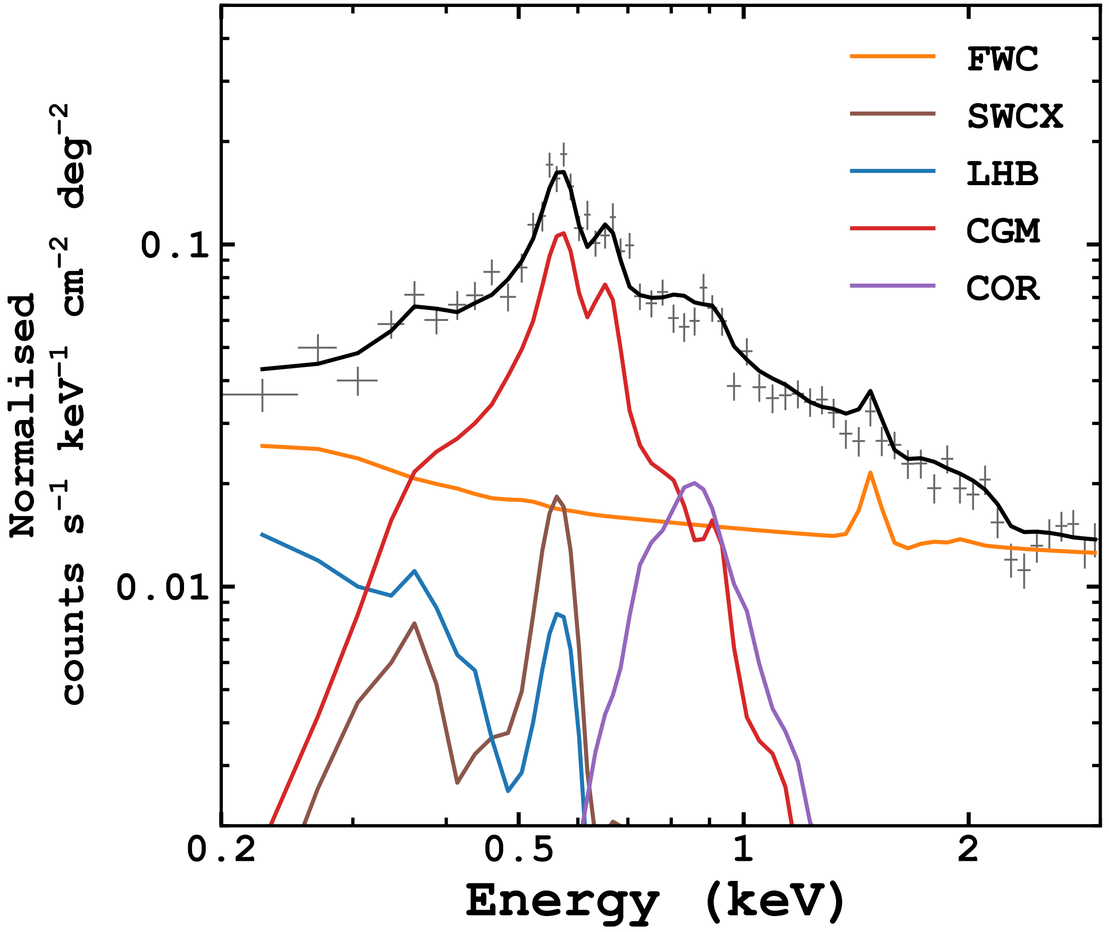

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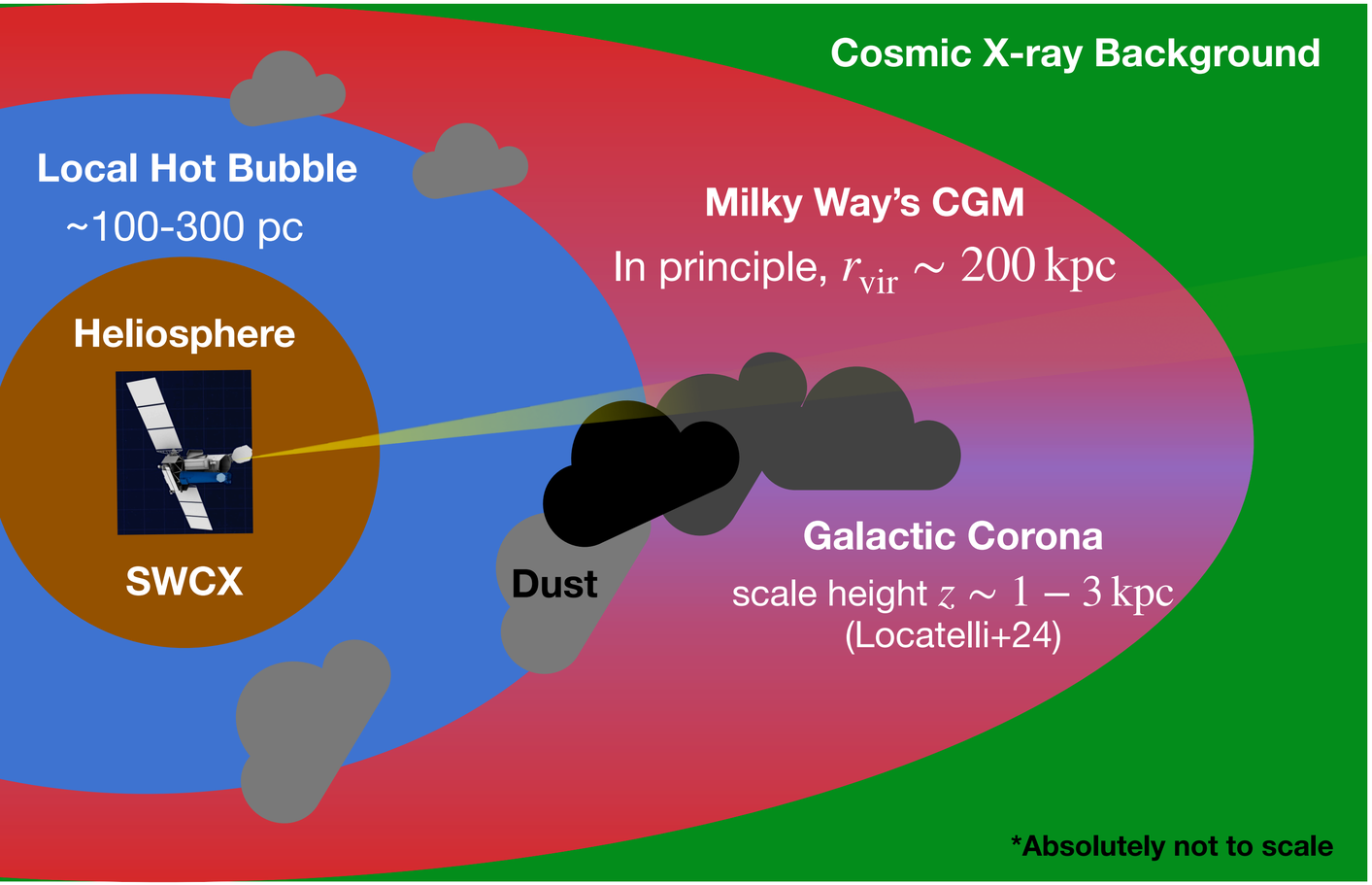

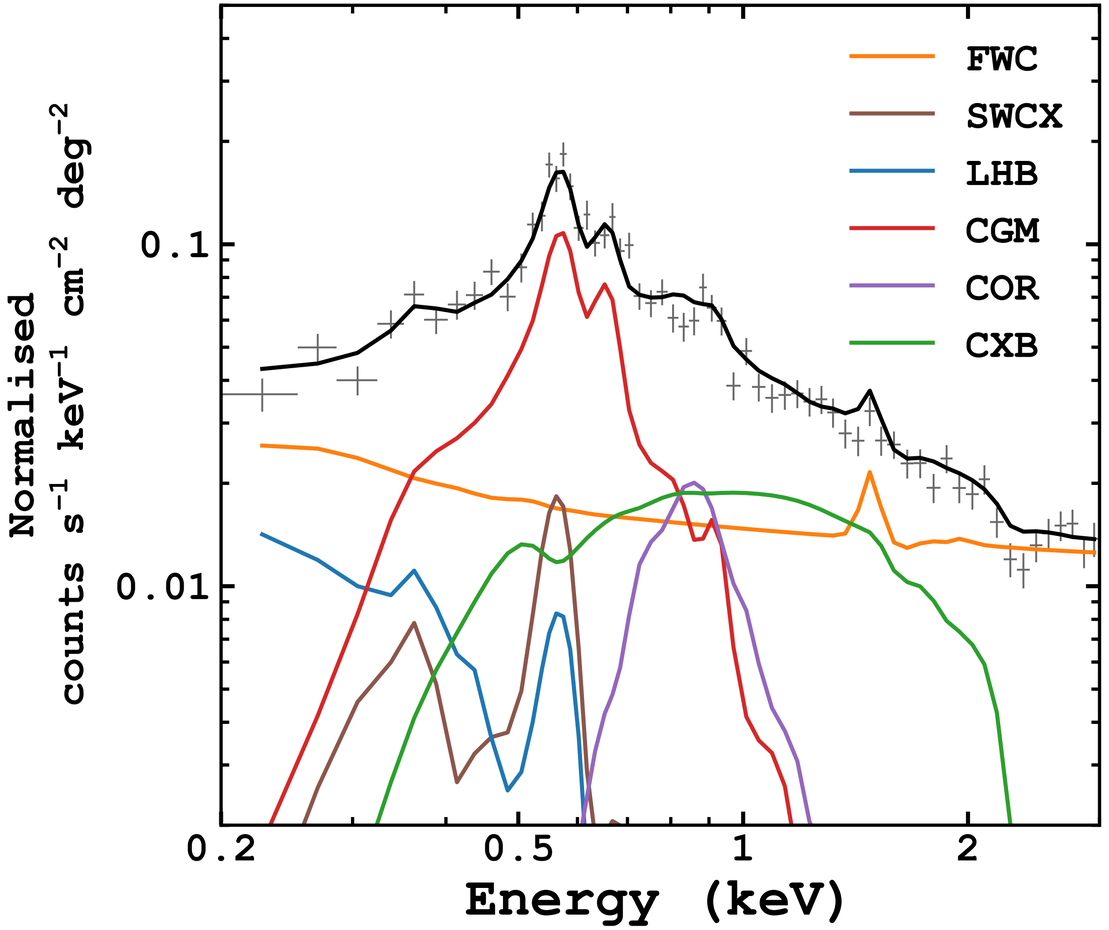

Scientific Questions

1. Local hot bubble (LHB) vs solar wind charge exchange (SWCX) fraction in foreground?

2. Physical Properties of LHB
   - kT
   - n_e
   - $P_{\text{themral}} = nkT$
   - 3D structure

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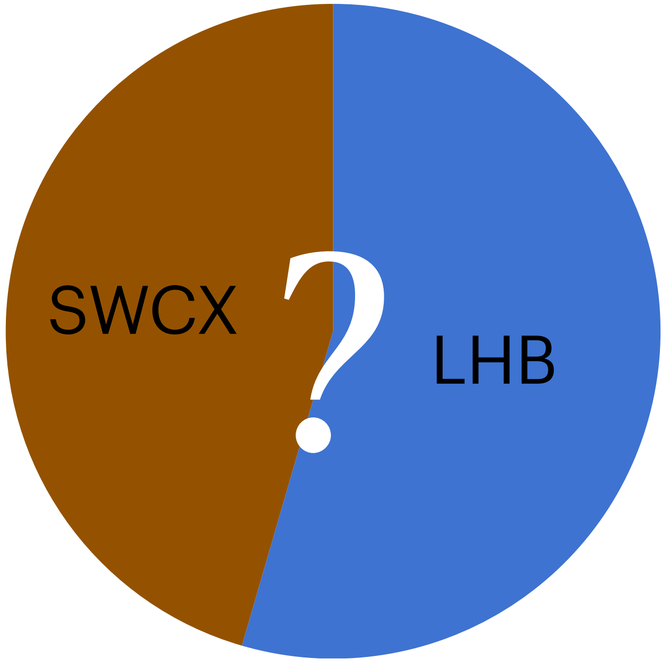
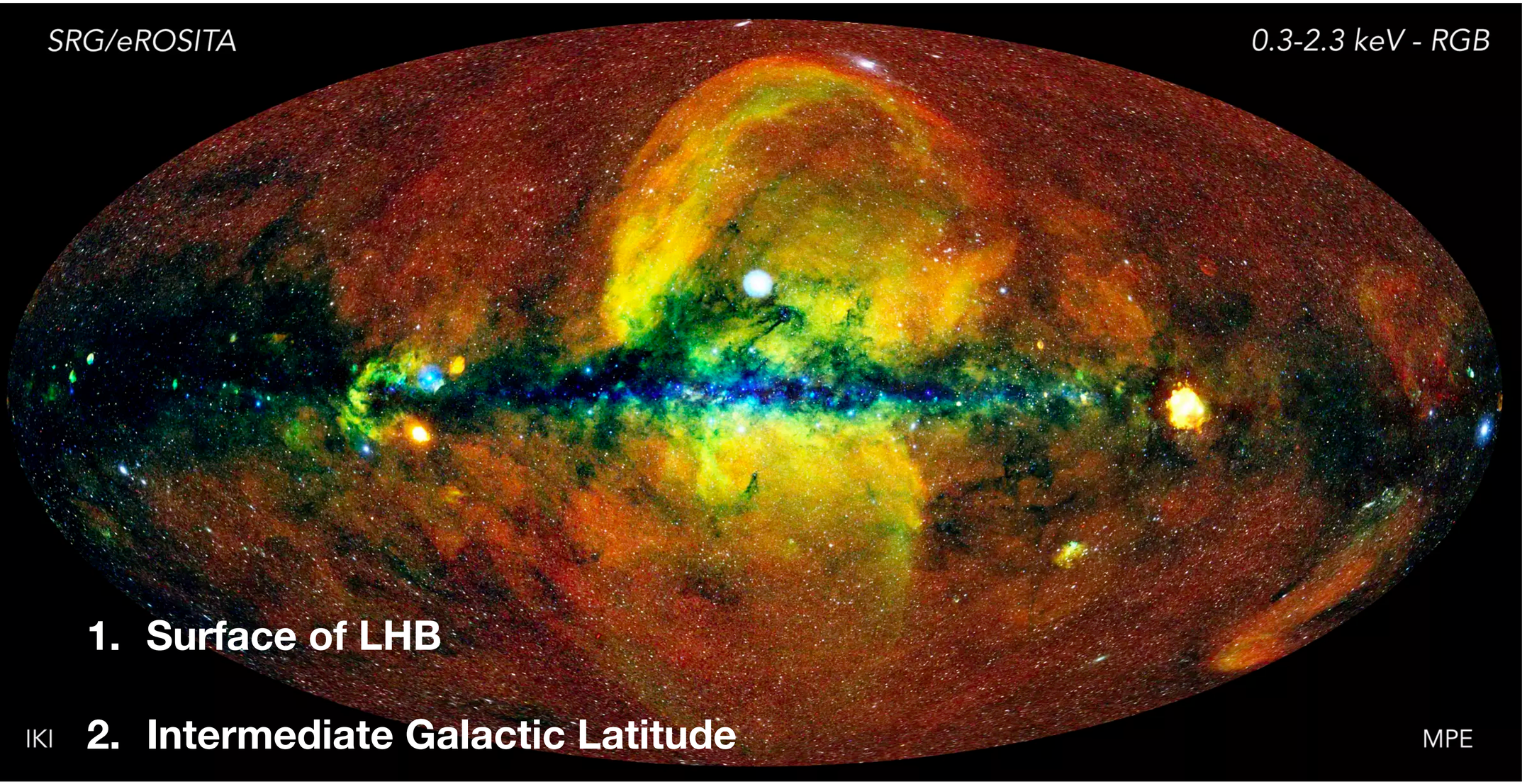
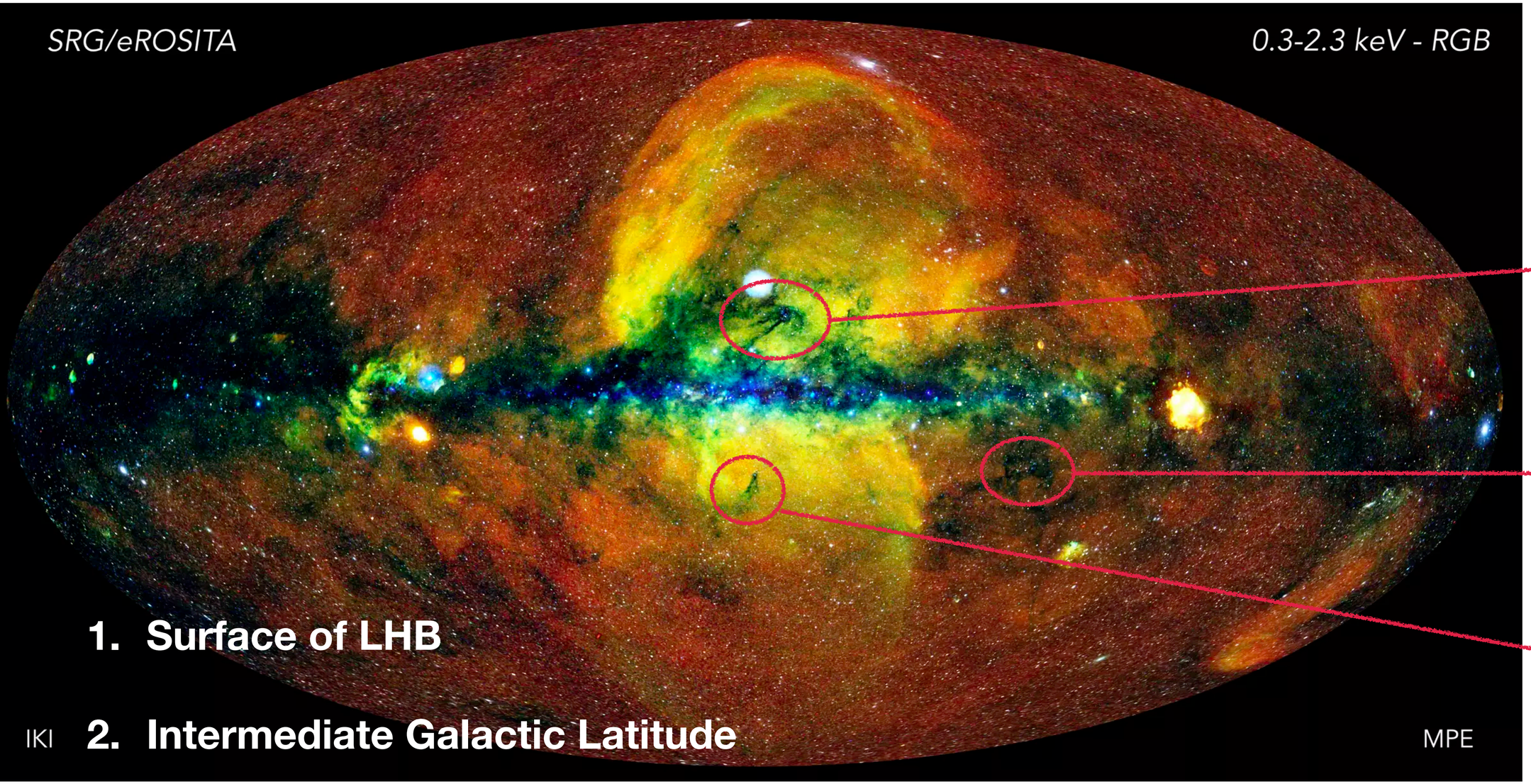


X-ray Shadowing with Molecular Clouds



Predehl+20

X-ray Shadowing with Molecular Clouds



Predehl+20

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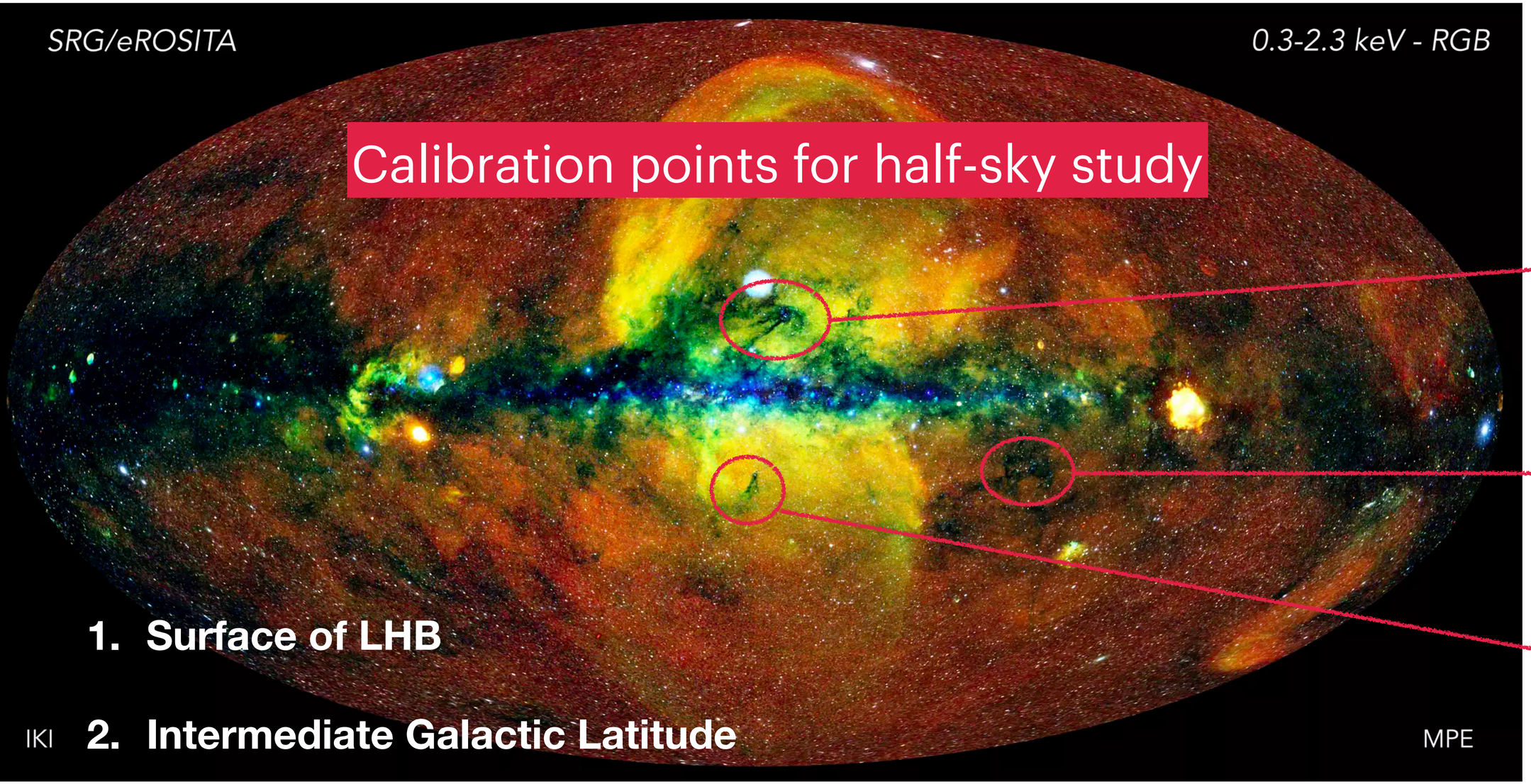


Ophiuchus

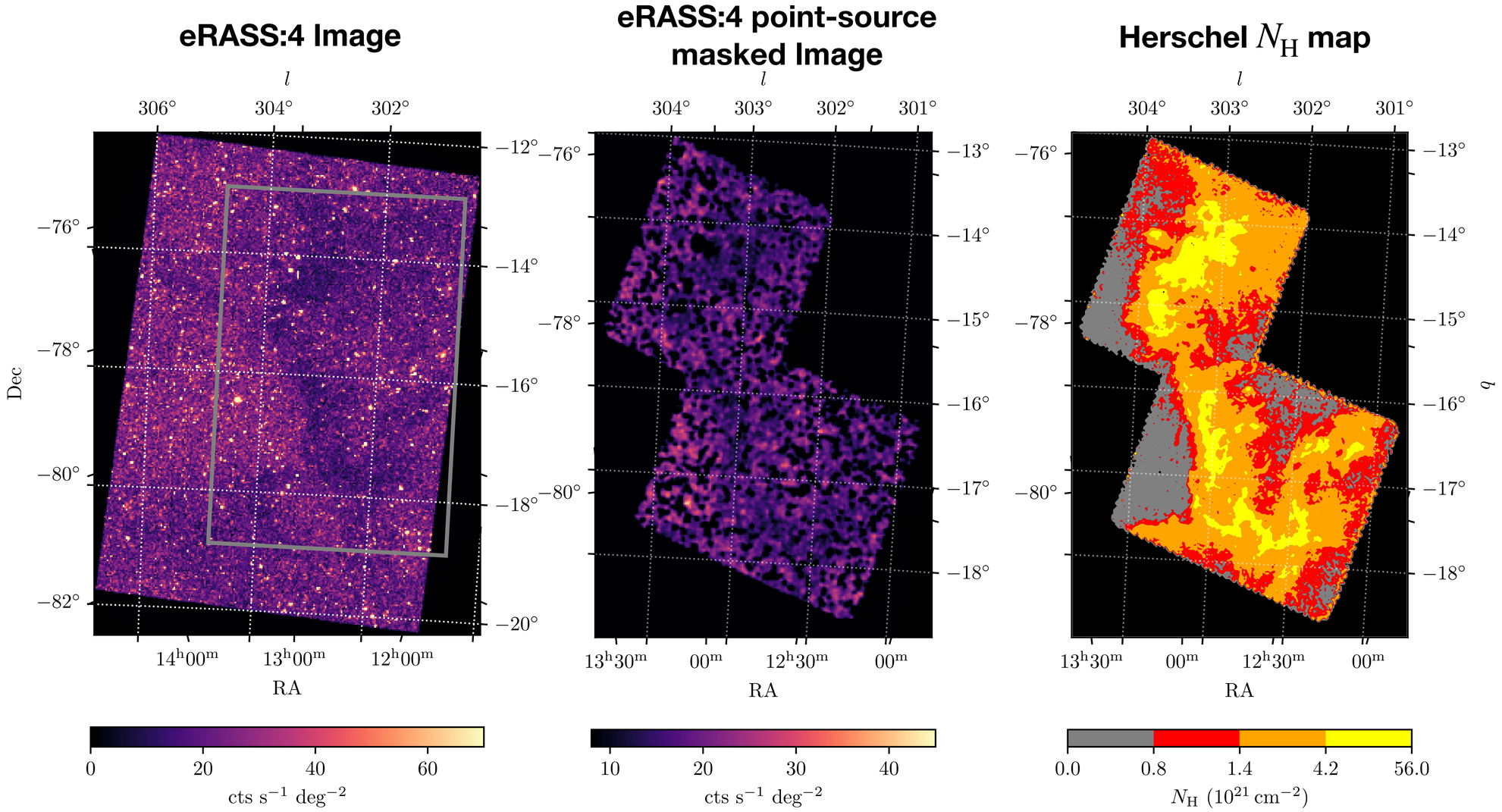
Chamaeleon

Corona Australis

Predehl+20

X-ray Shadowing

- Extract spectra from $N_{\rm H}$ contours and each eRASS

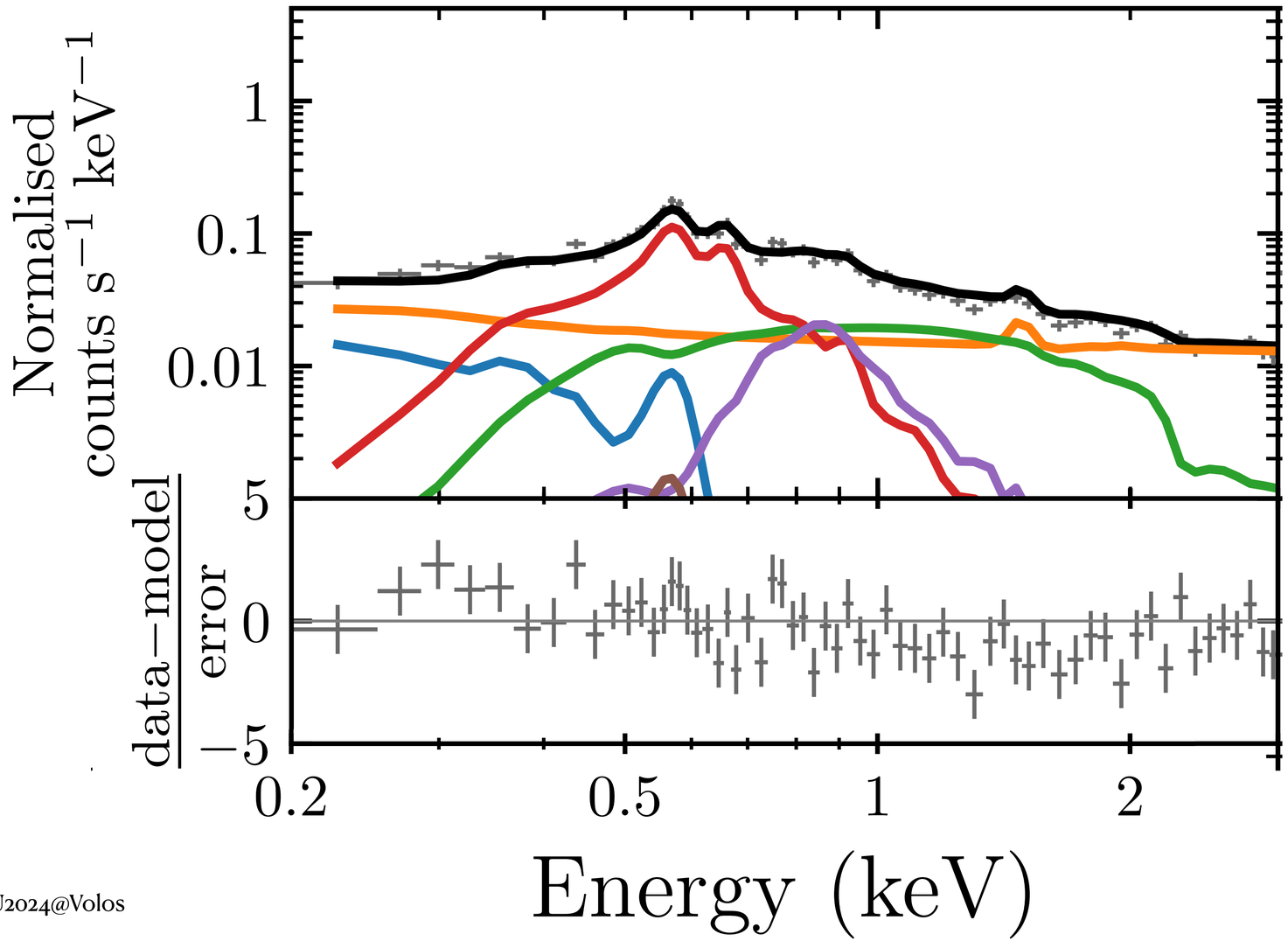


Cha II & III

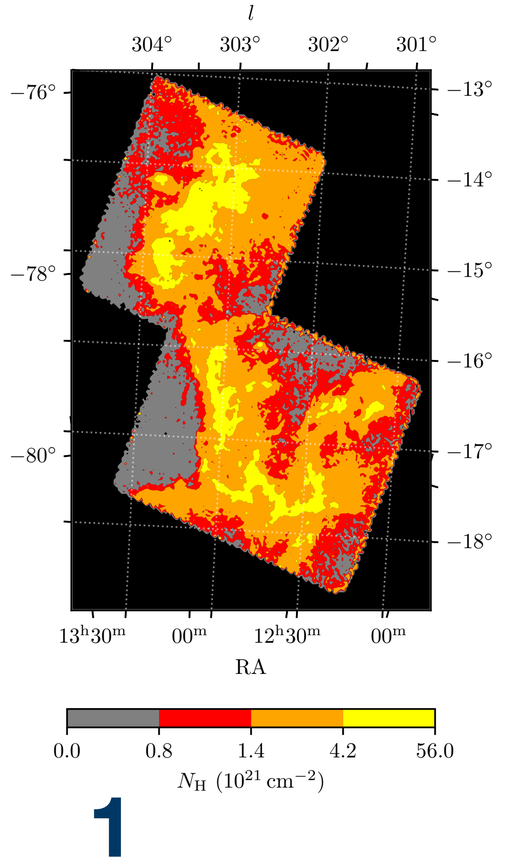
Yeung+23

Increasing $N_{\rm H}$

Aperture 1



eRASS1

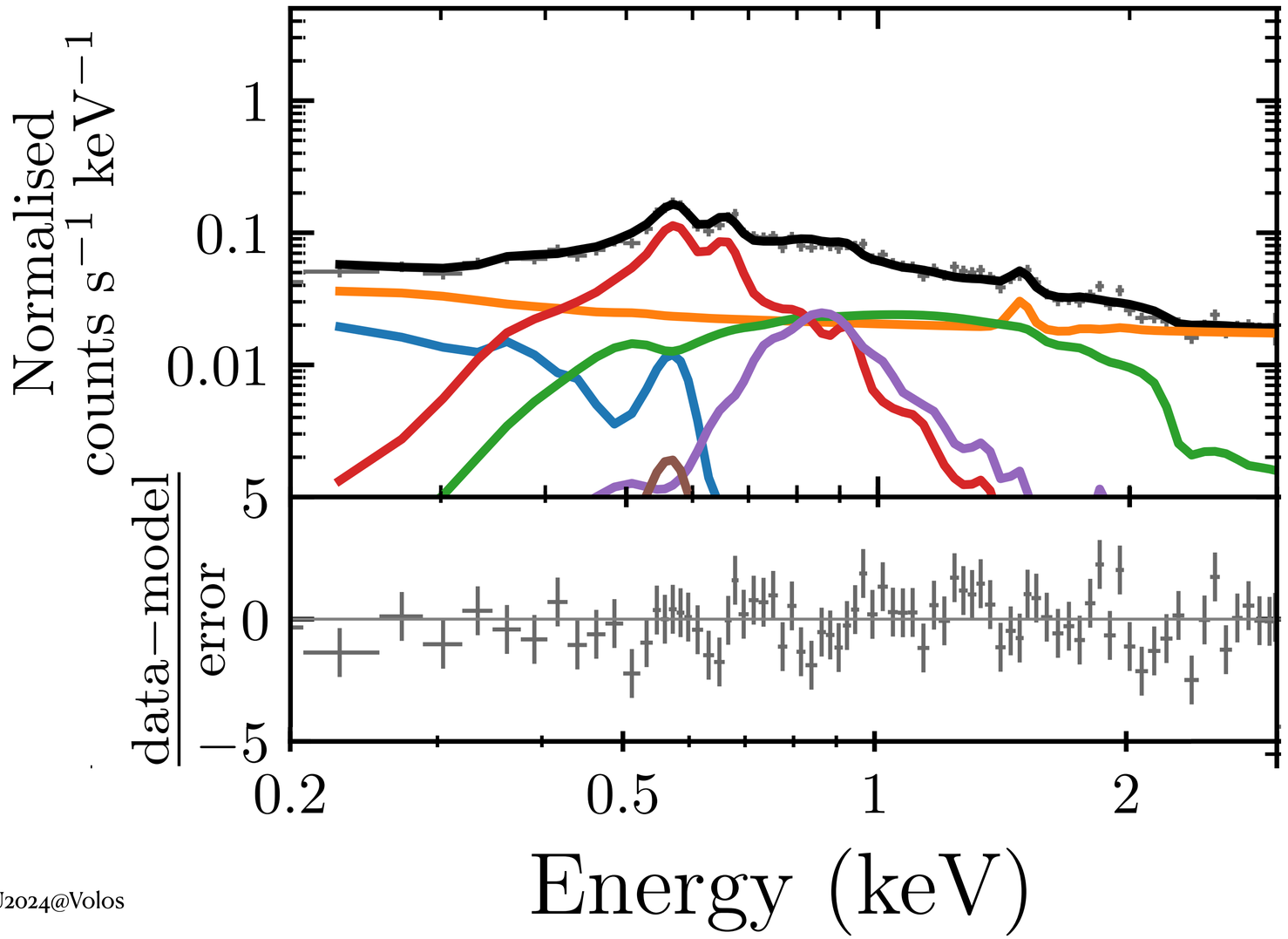


1

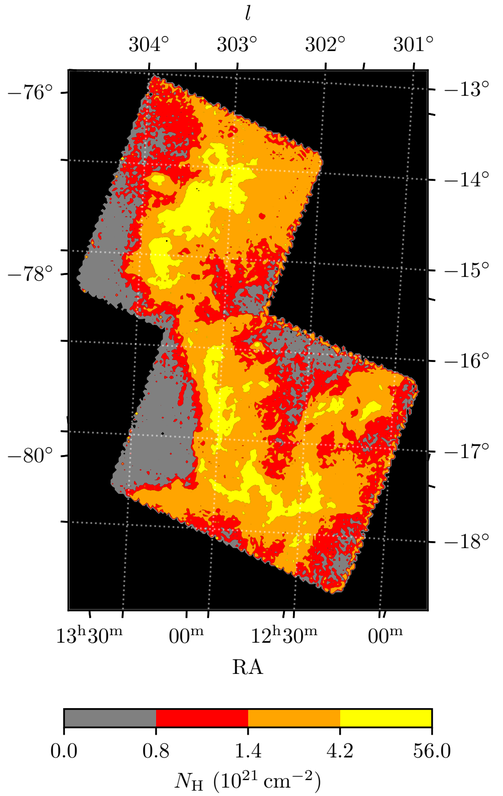
Yeung+23

Increasing $N_{\rm H}$

Aperture 2



eRASS1

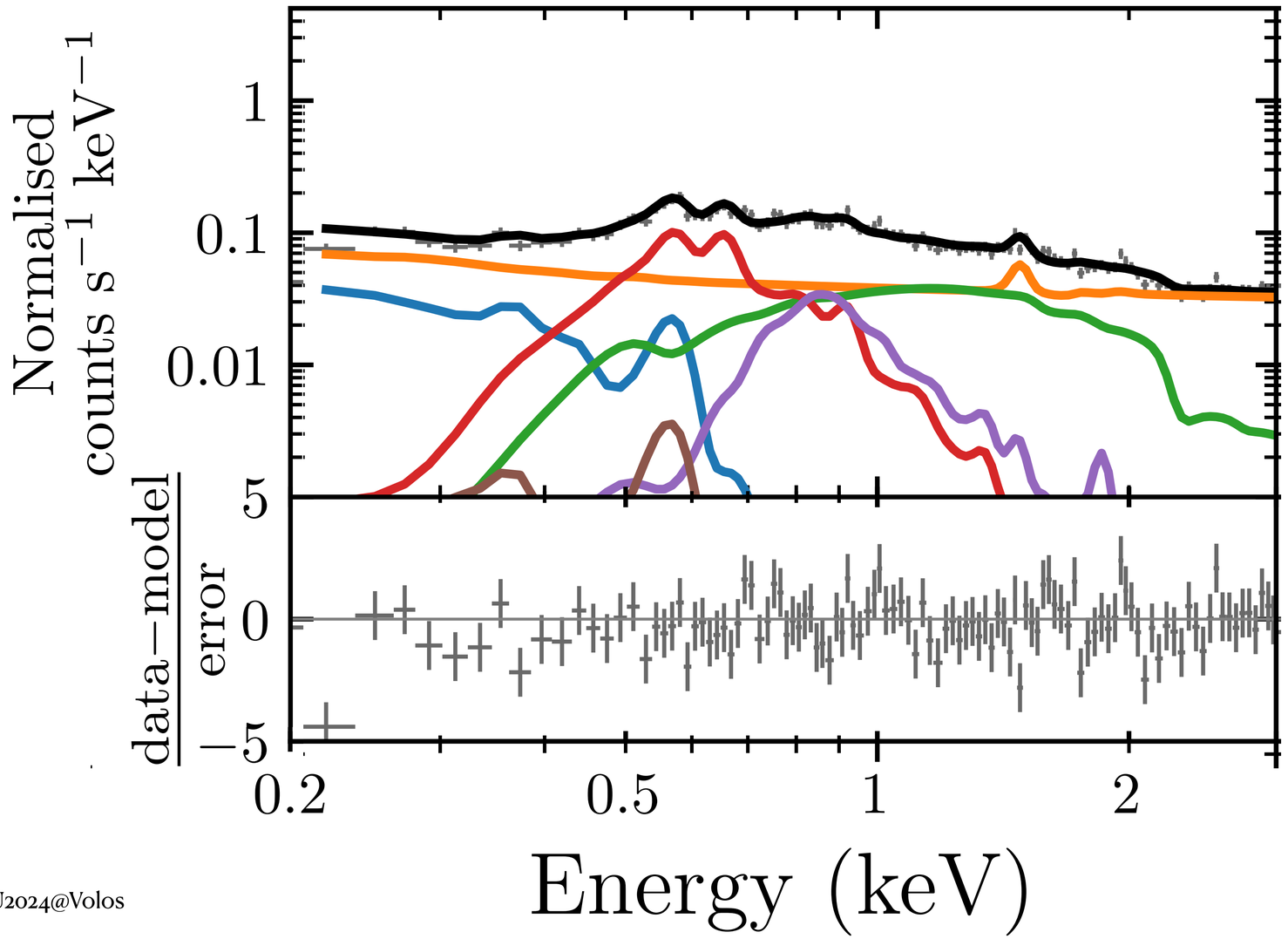


2

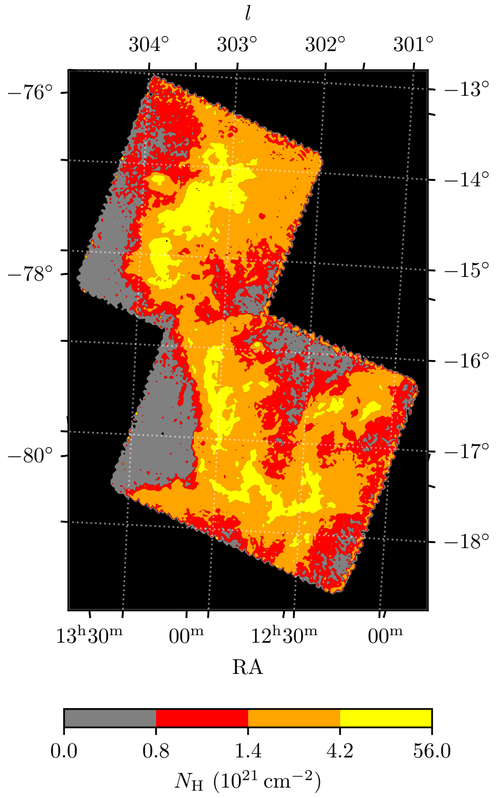
Yeung+23

Increasing $N_{\rm H}$

Aperture 3



eRASS1

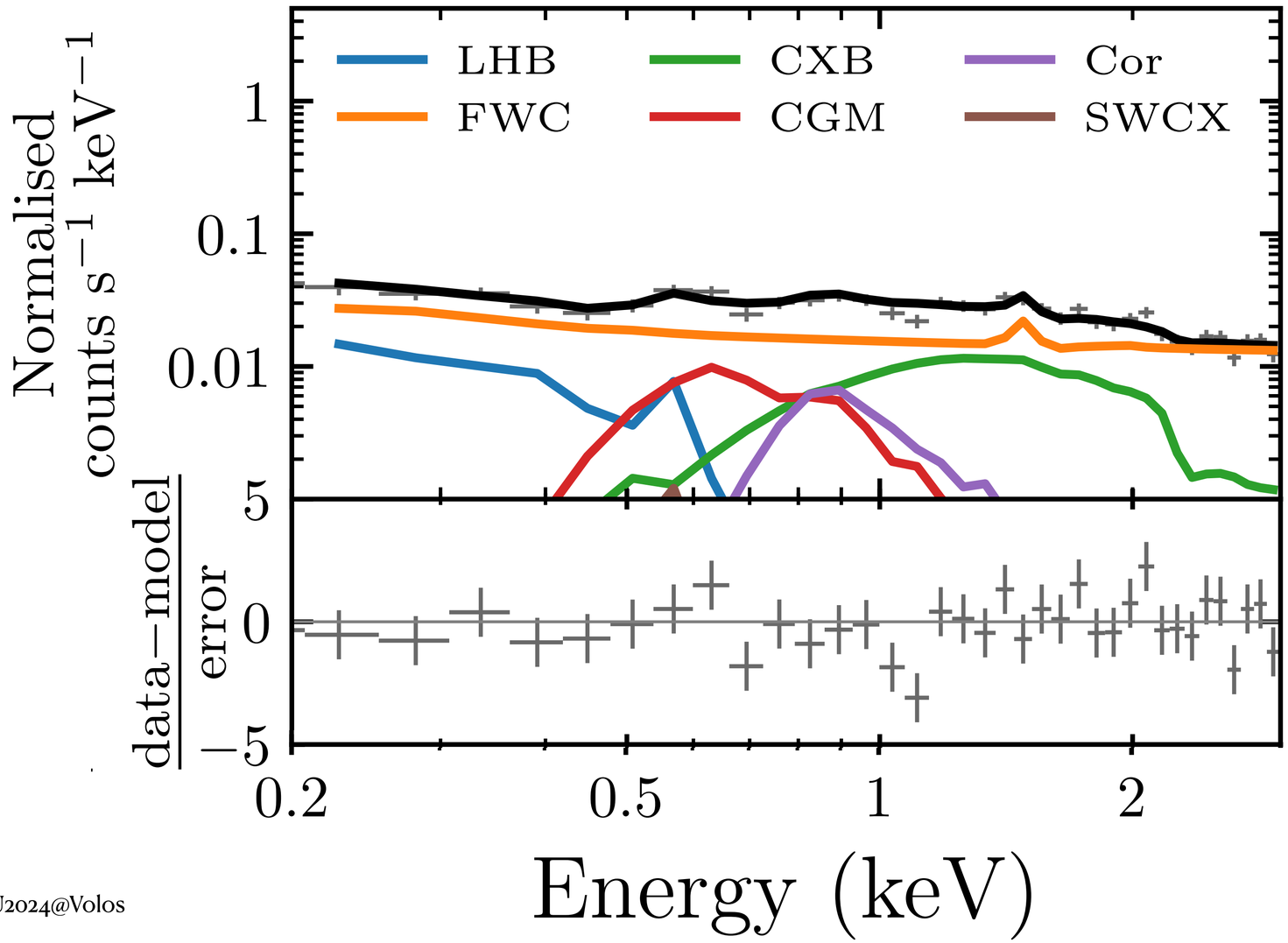


3

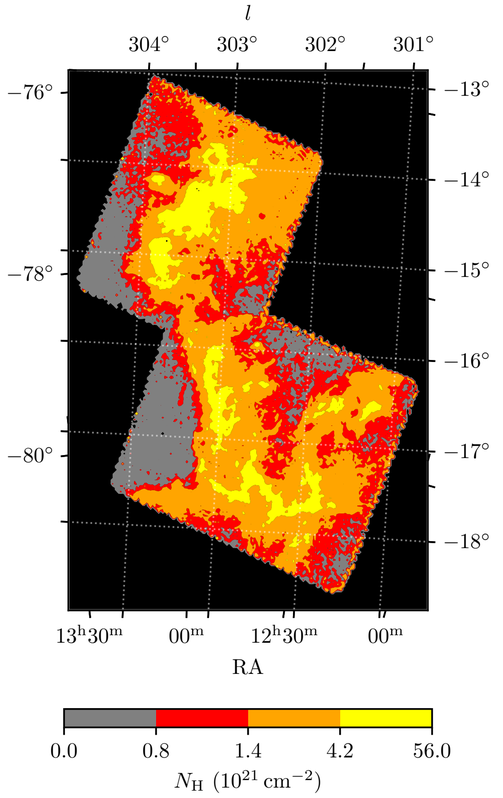
Yeung+23

Increasing $N_{\rm H}$

Aperture 4



eRASS1

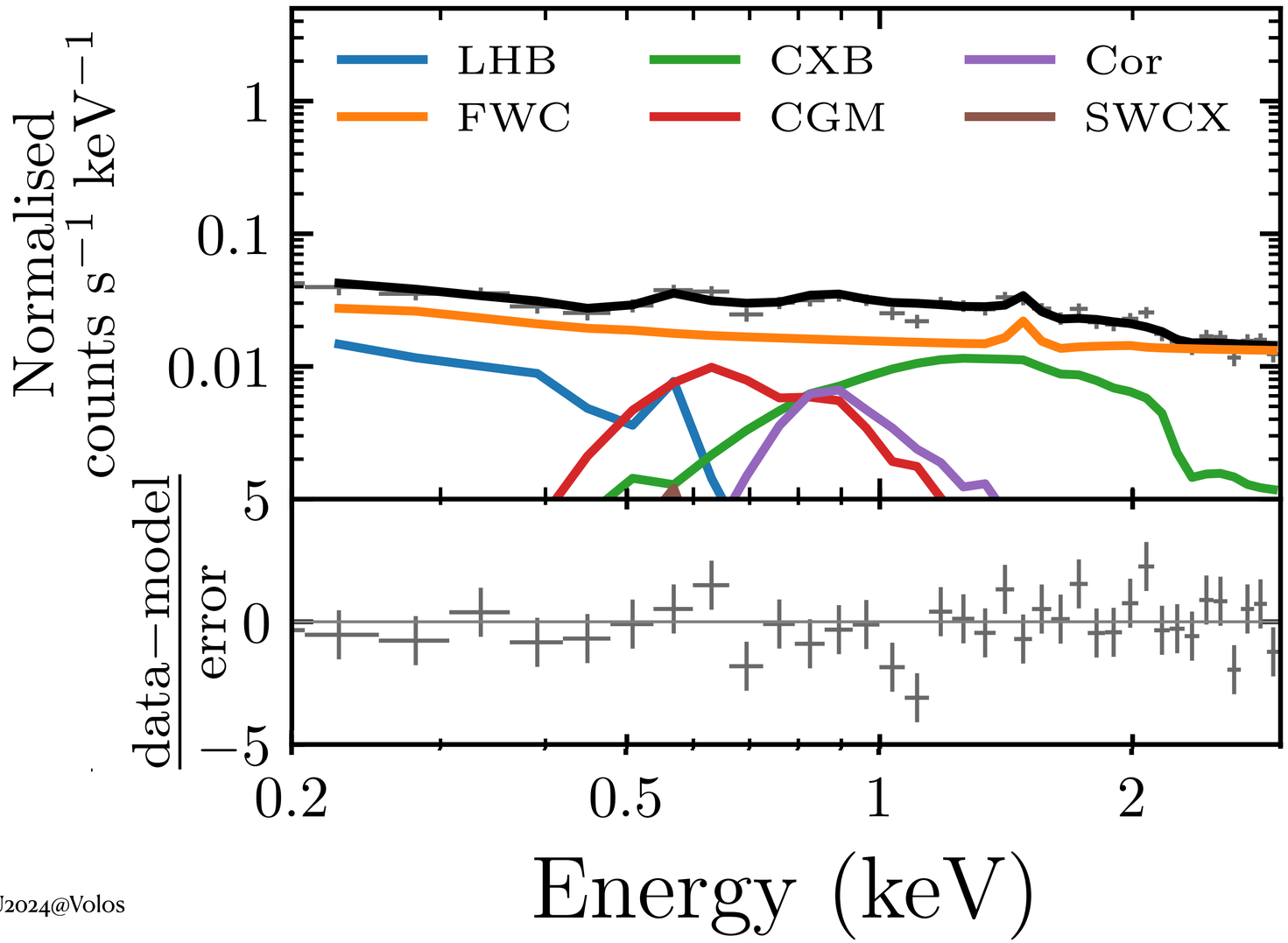


4

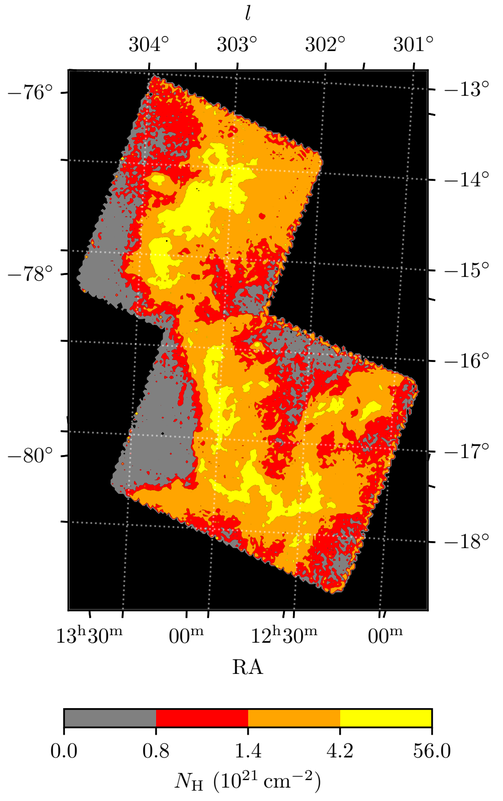
Yeung+23

Progressing Time (6 month step)

Aperture 4



eRASS1



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Yeung+23

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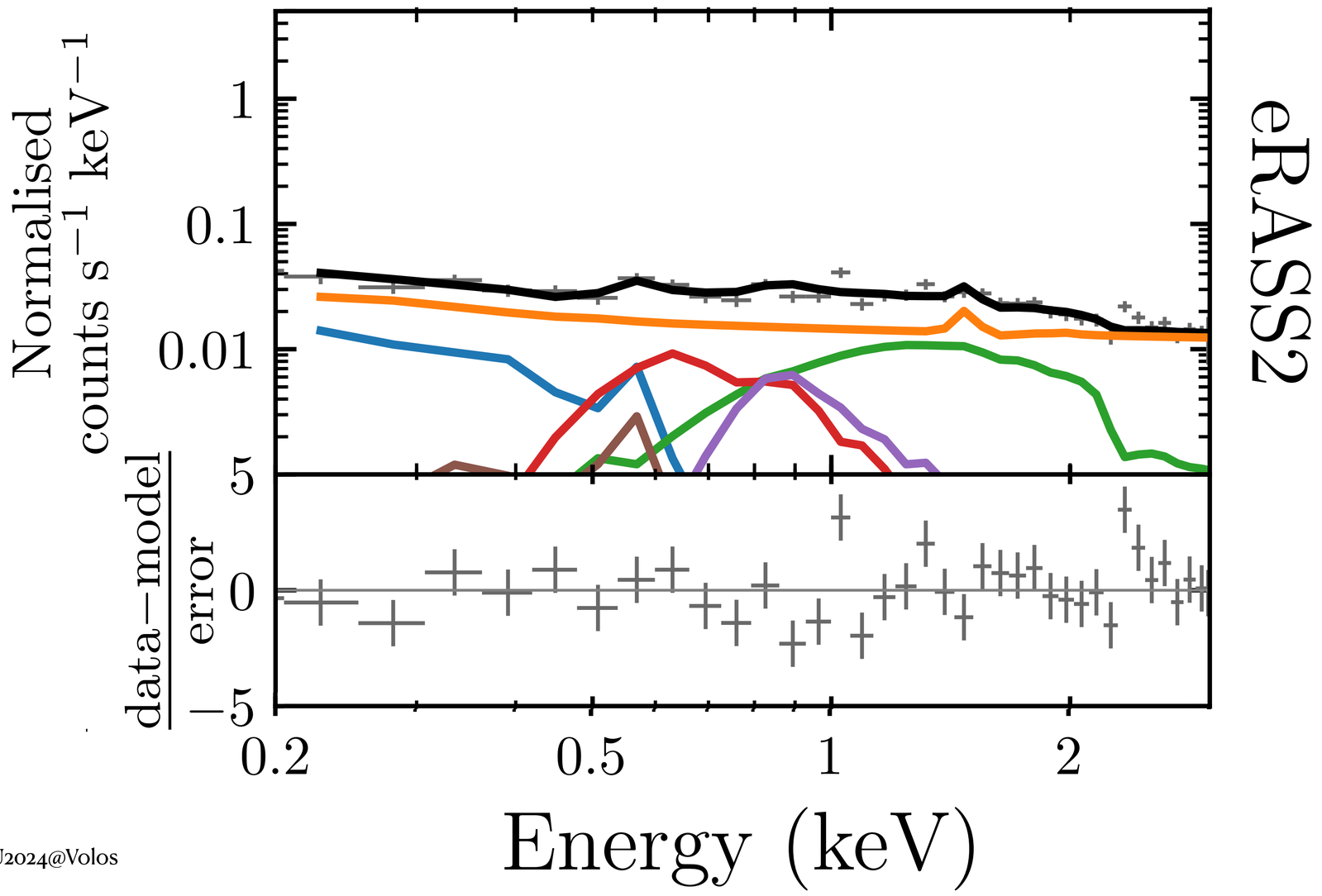
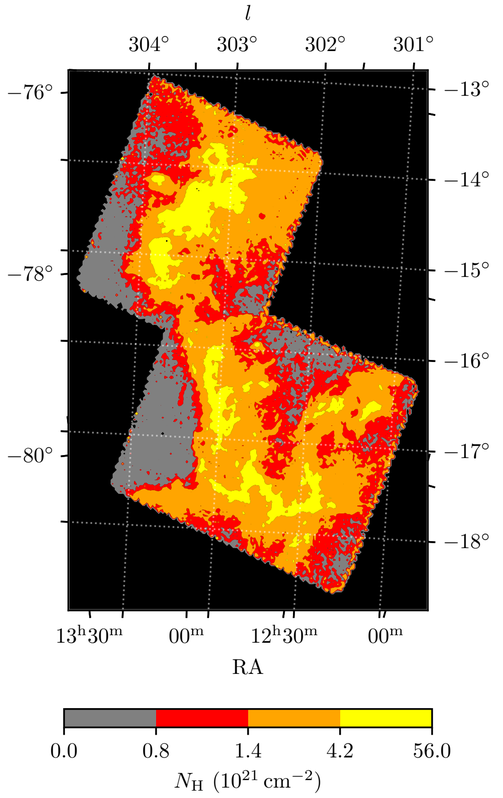


eRASS2



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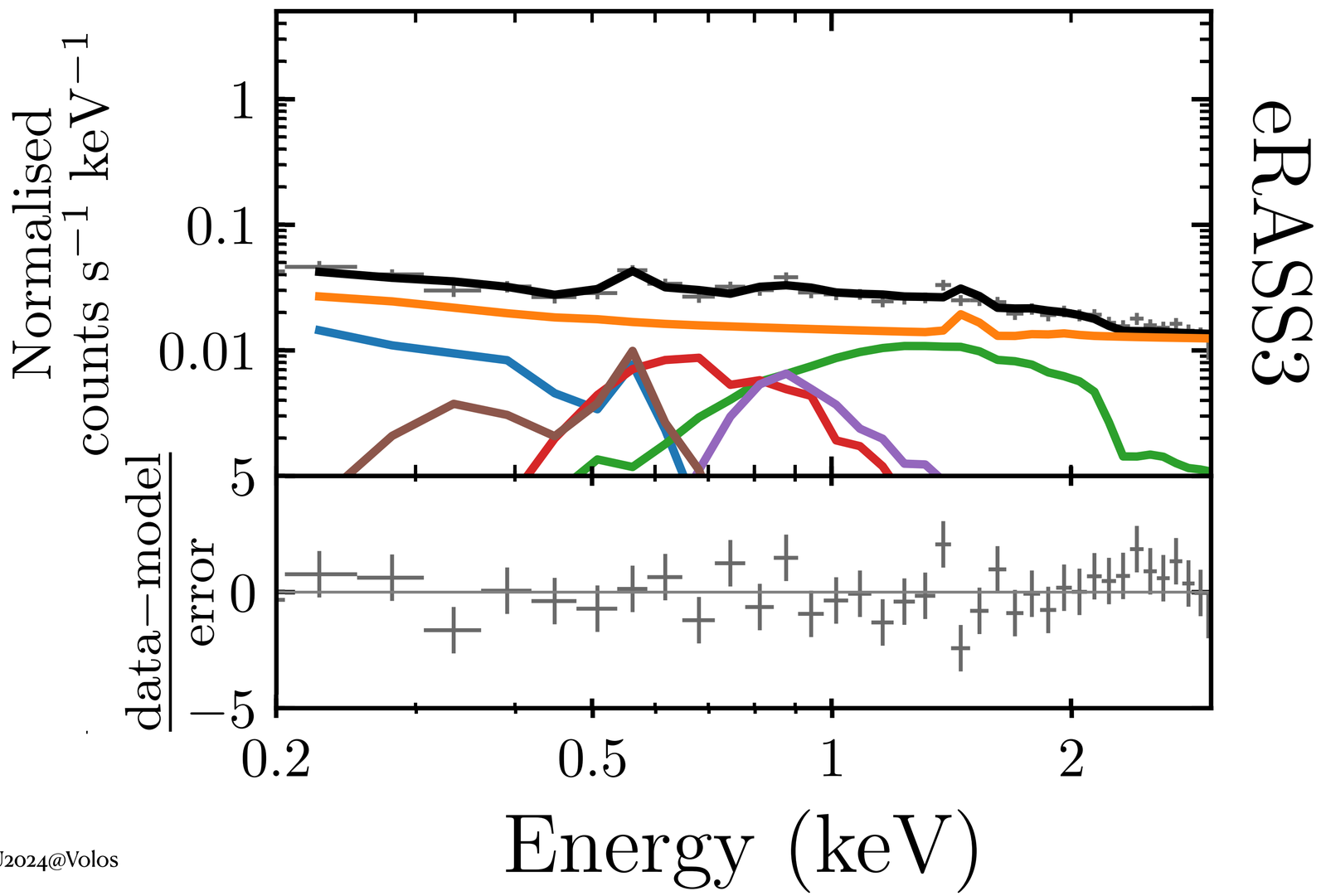
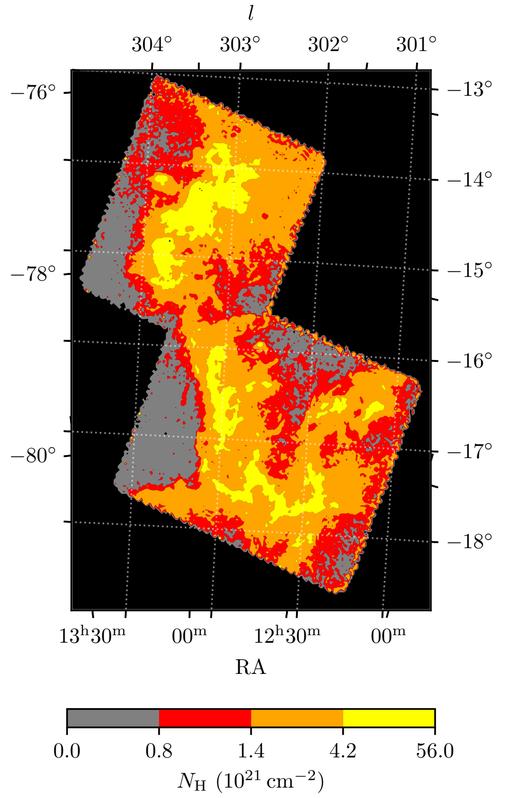


eRASS3



4

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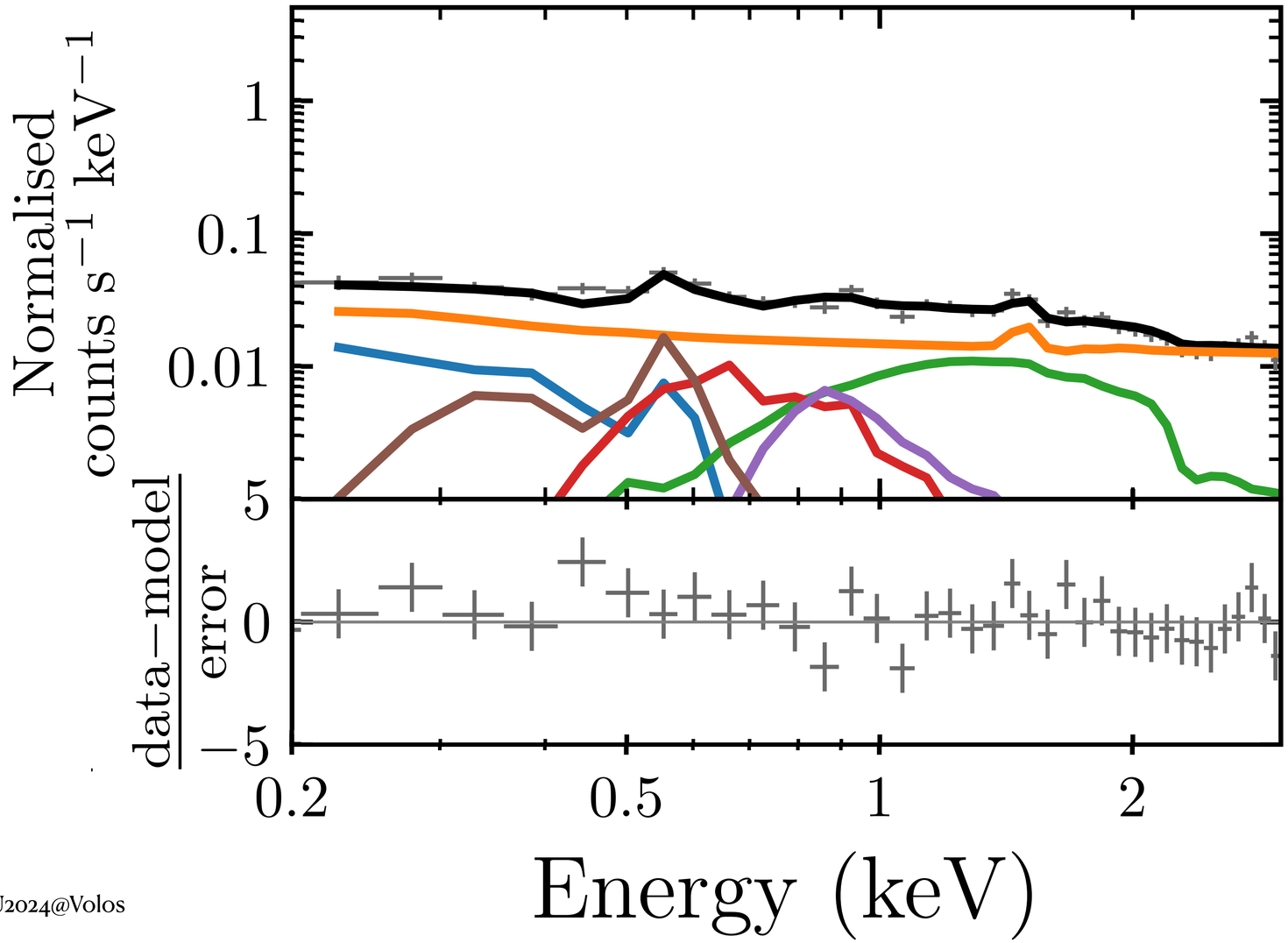
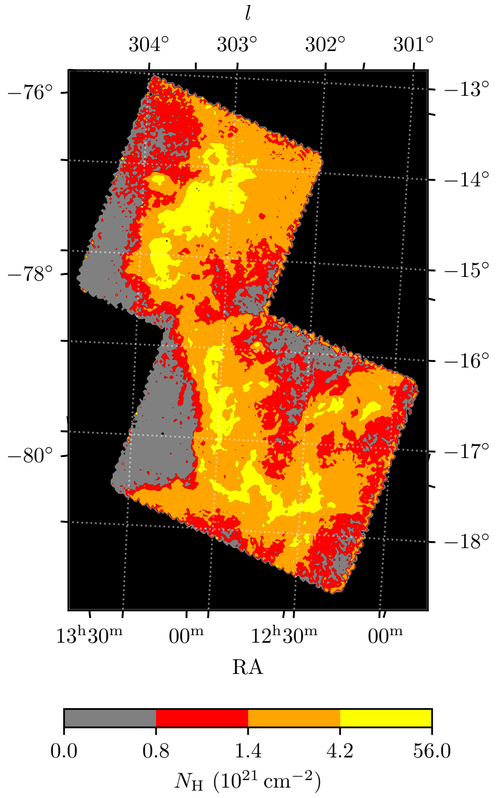


eRASS4

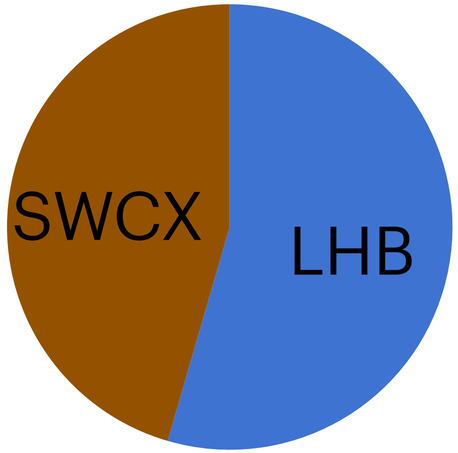


4

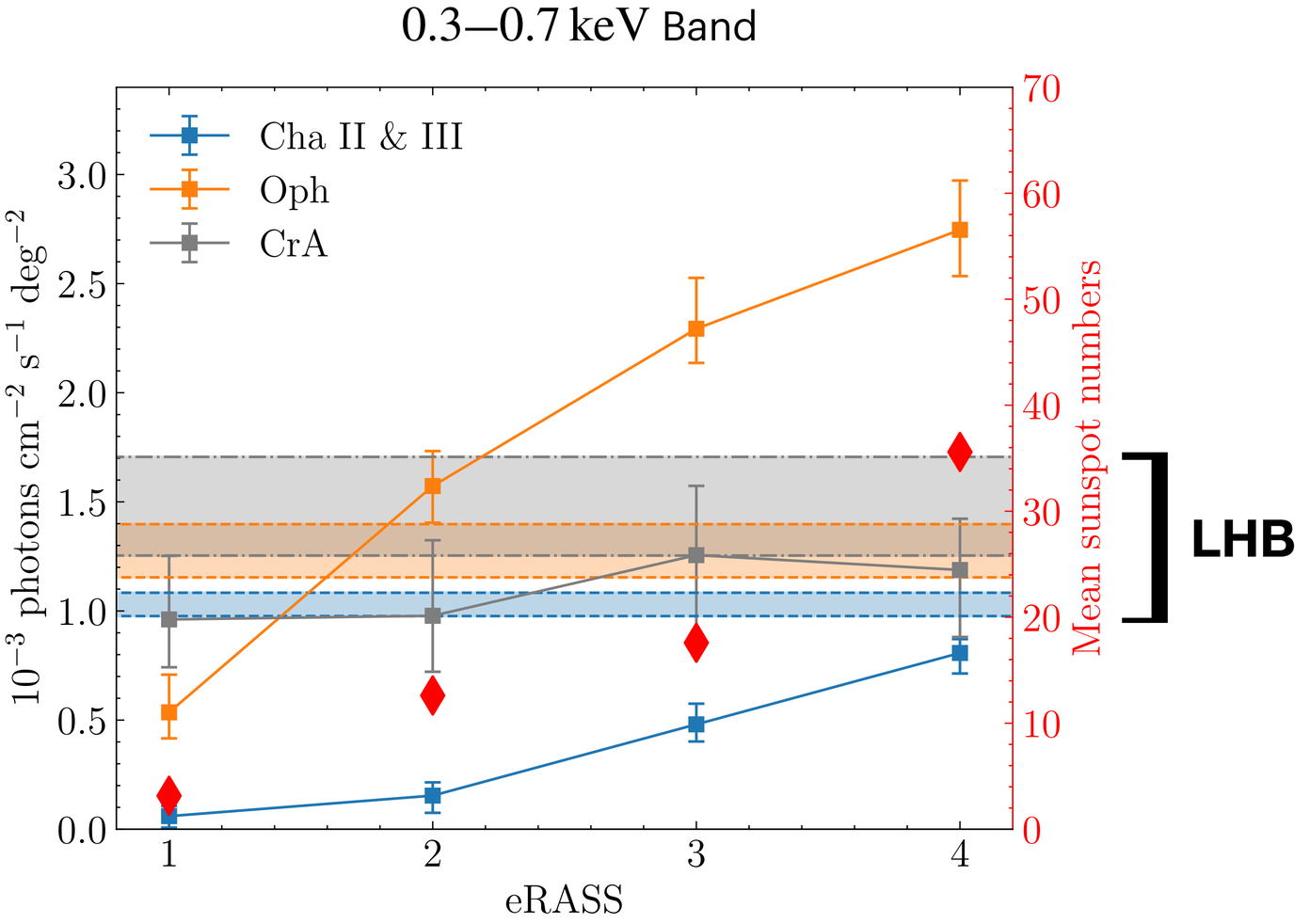
Yeung+23

SWCX Monotonically Increases with Solar Cycle

- Heliospheric SWCX correlates with solar cycle



- Dependence with ecliptic/ heliographic latitude



Yeung+23

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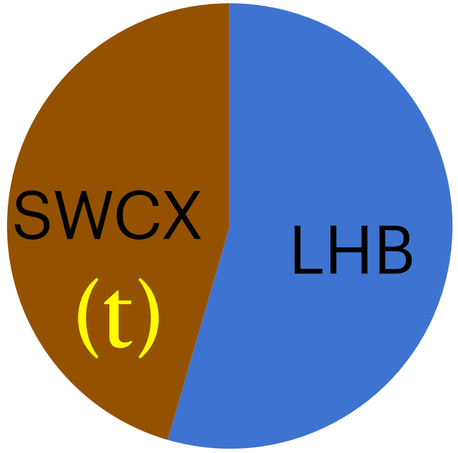

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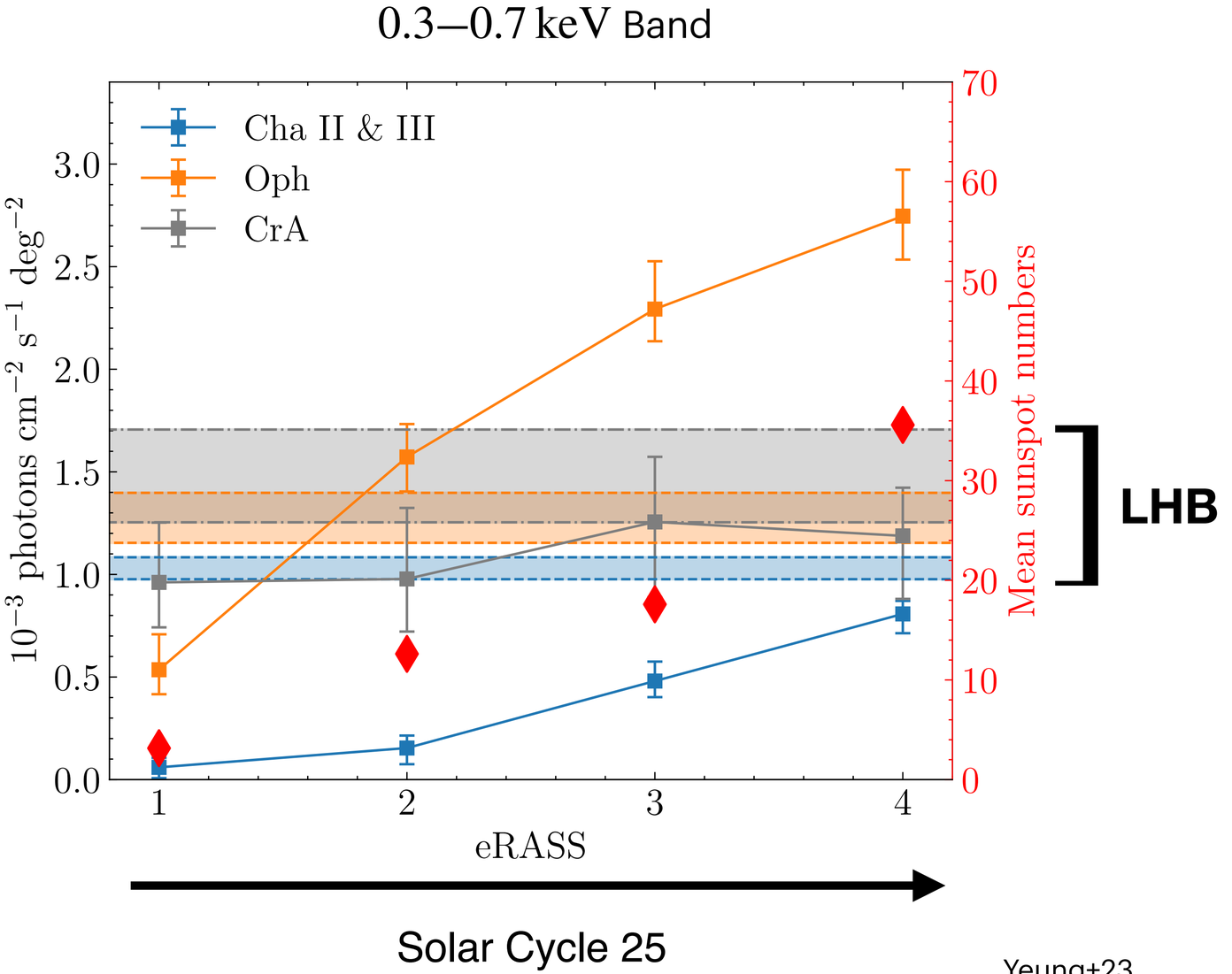

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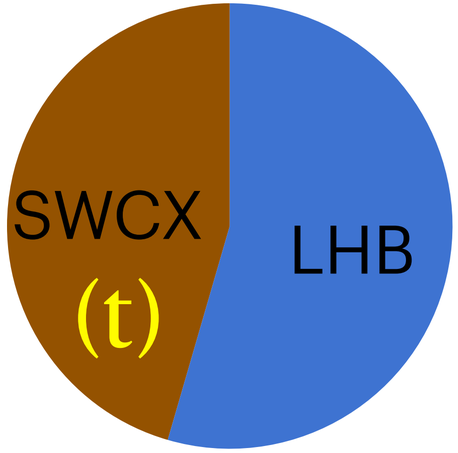

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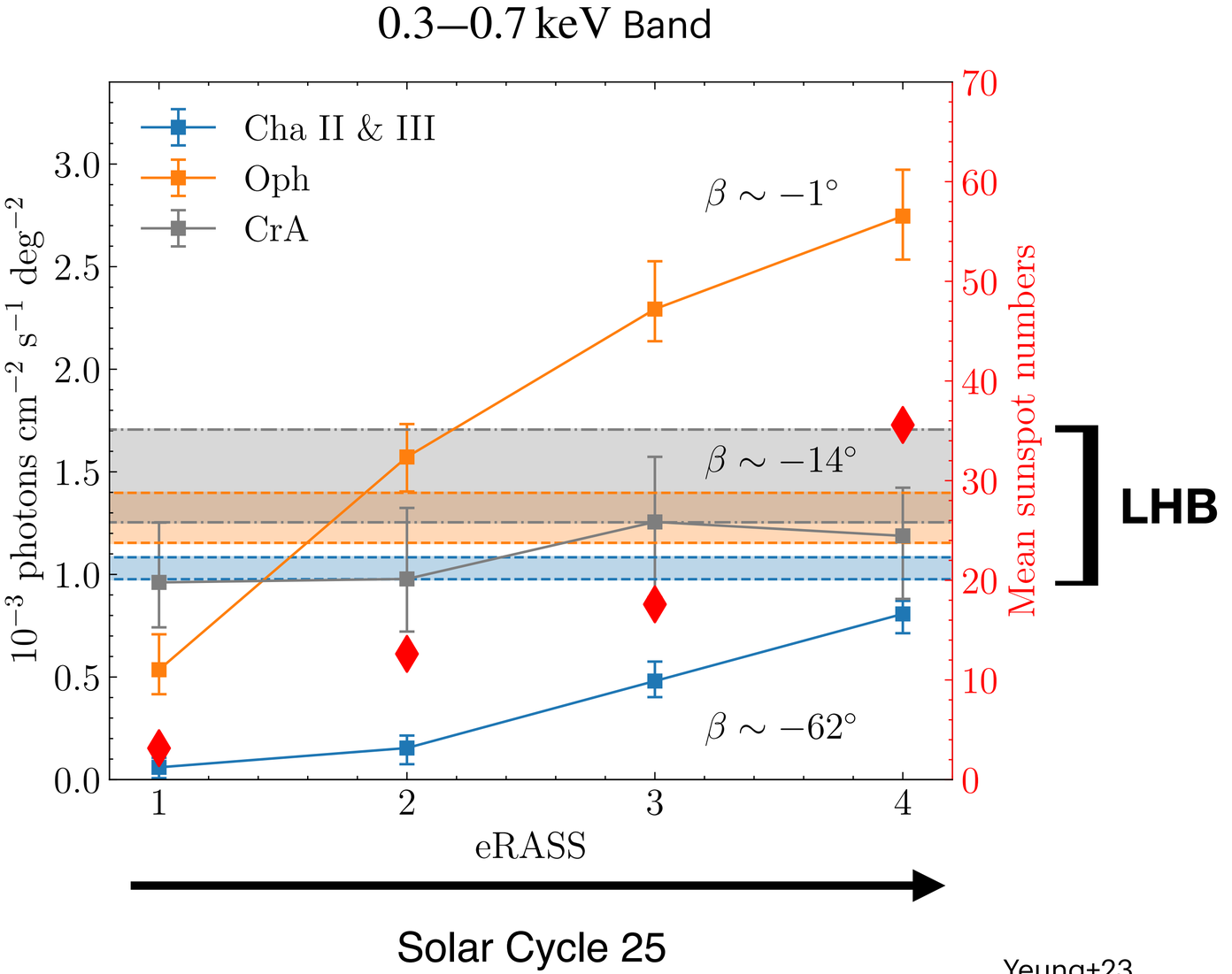
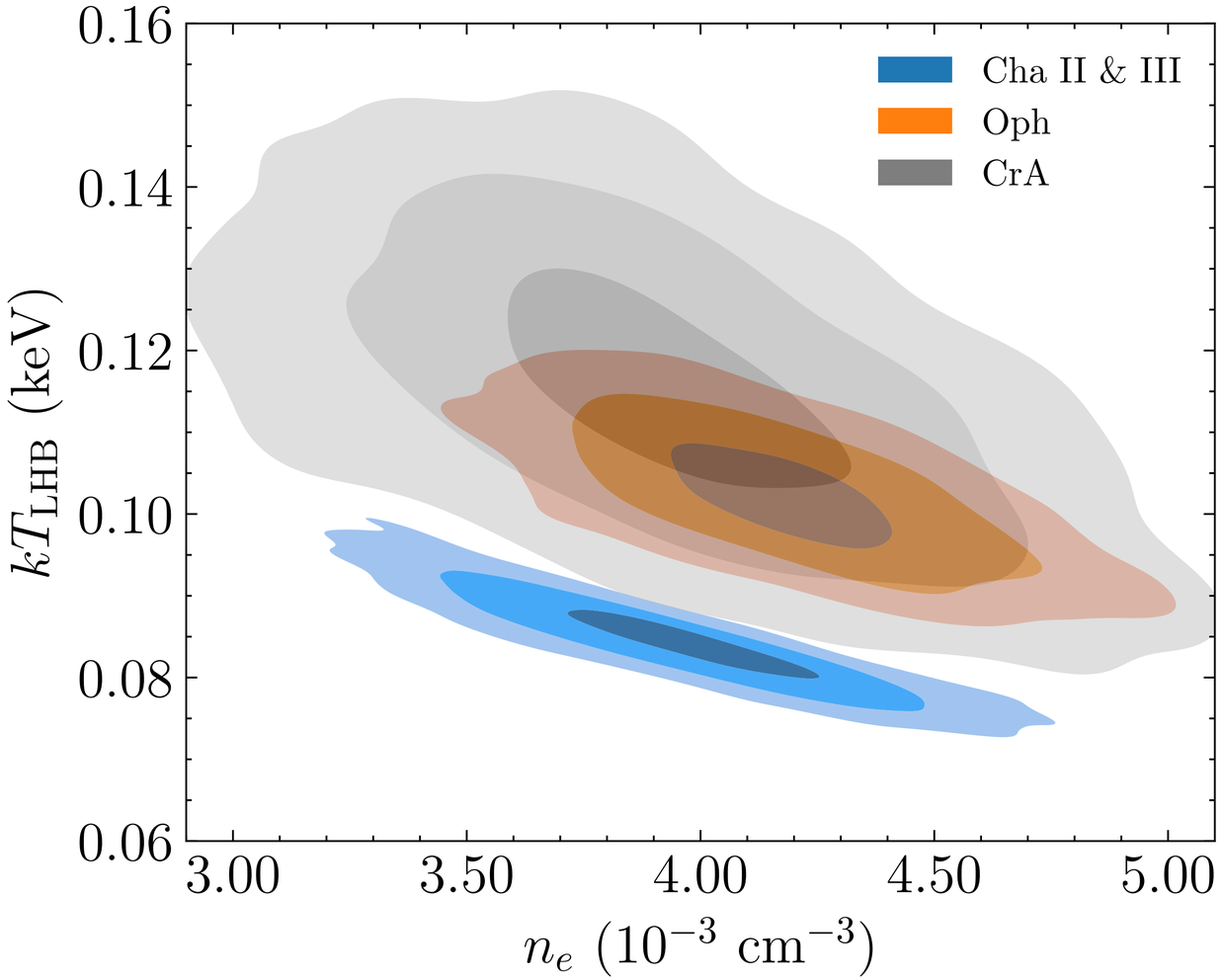


Yeung+23

LHB Properties from Shadowing

- Constant Density? ✓
- Constant temperature? ✗

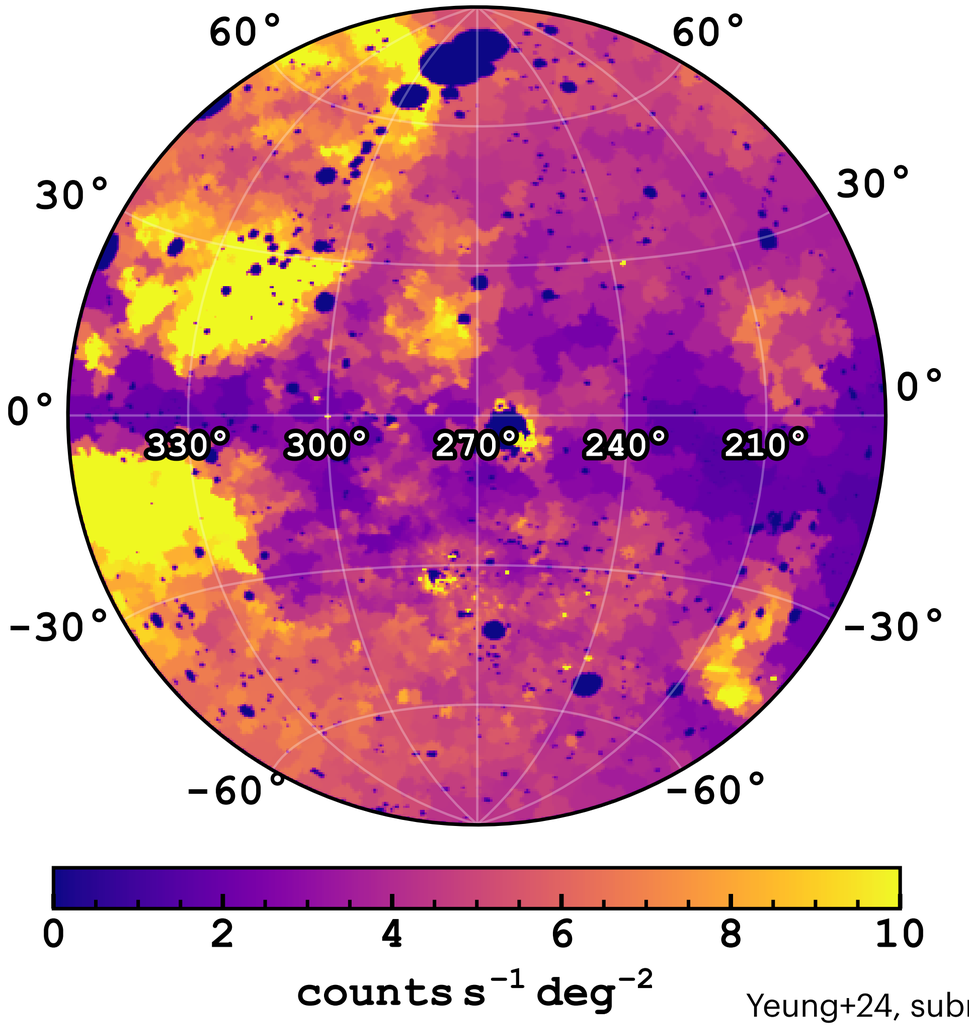


Yeung+23

Half-sky spectral analysis

- eRASS1 only (negligible SWCX)
- ~ 2000 equal S/N (=80) spectra
- Study spatial + spectral properties of background components

Binned $0.2 - 0.6\,\mathrm{keV}$ surface brightness



Yeung+24, subm.

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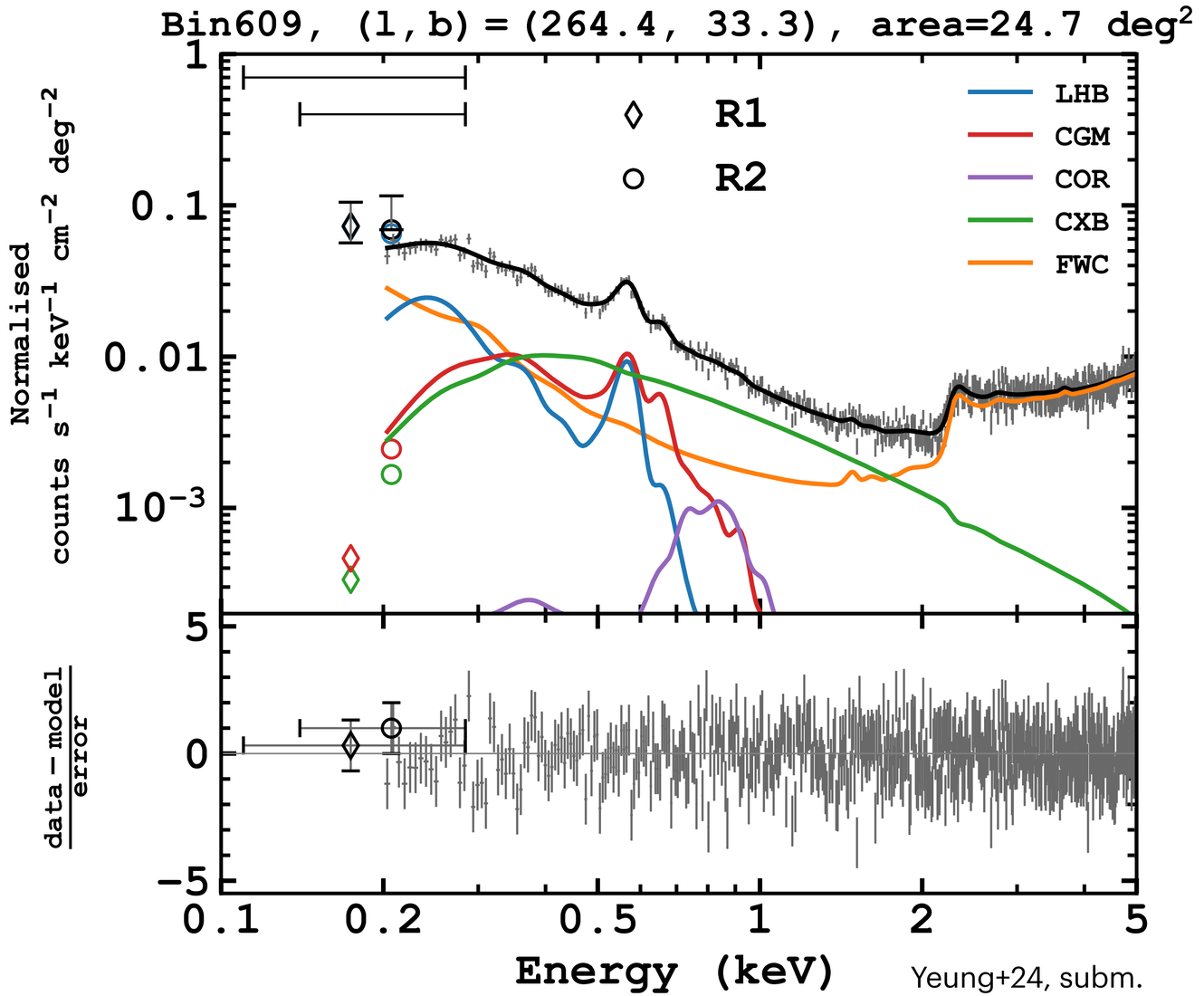
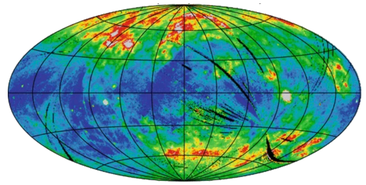


Yeung+24, subm.

Half-sky spectral analysis



Snowden+97

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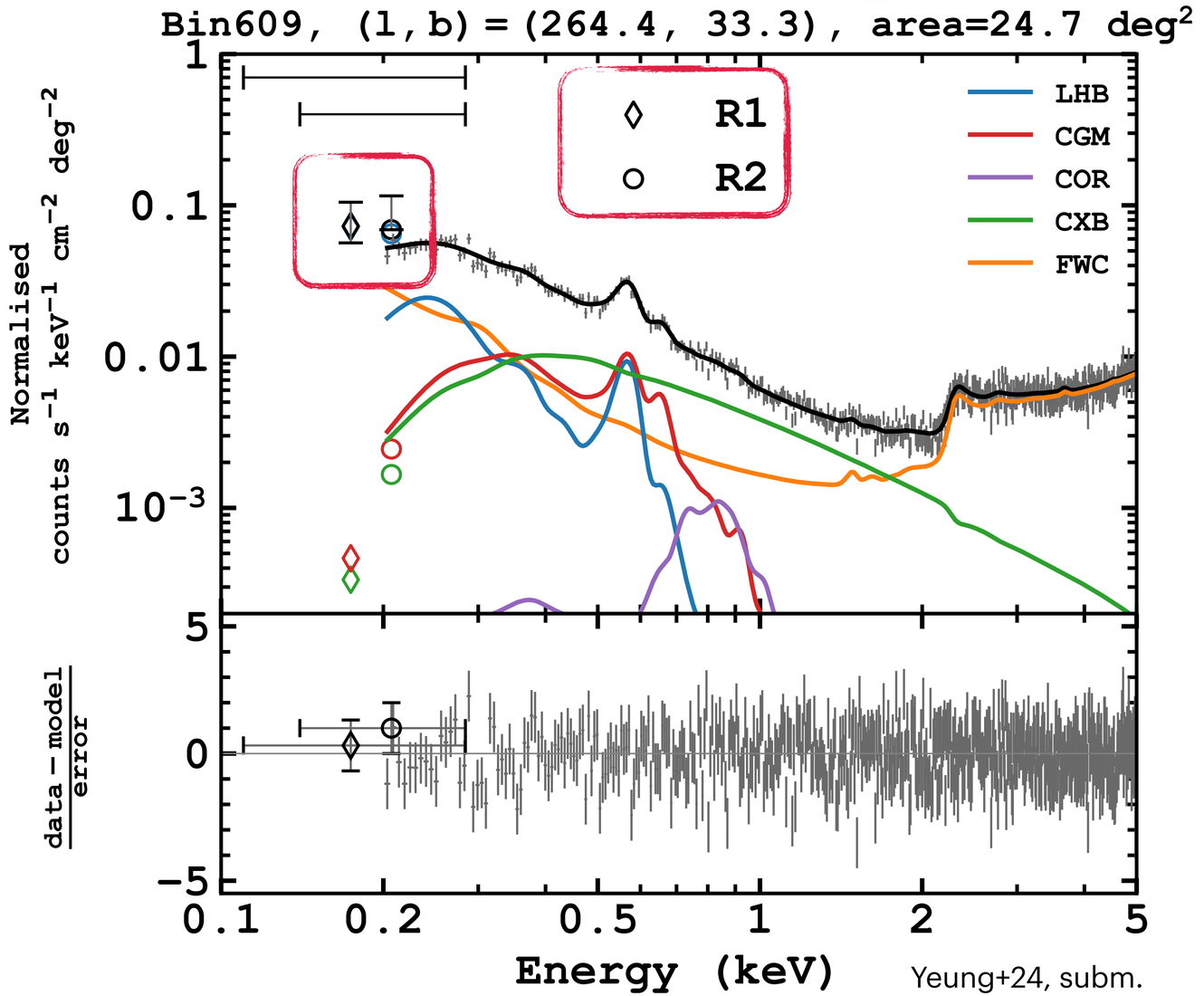
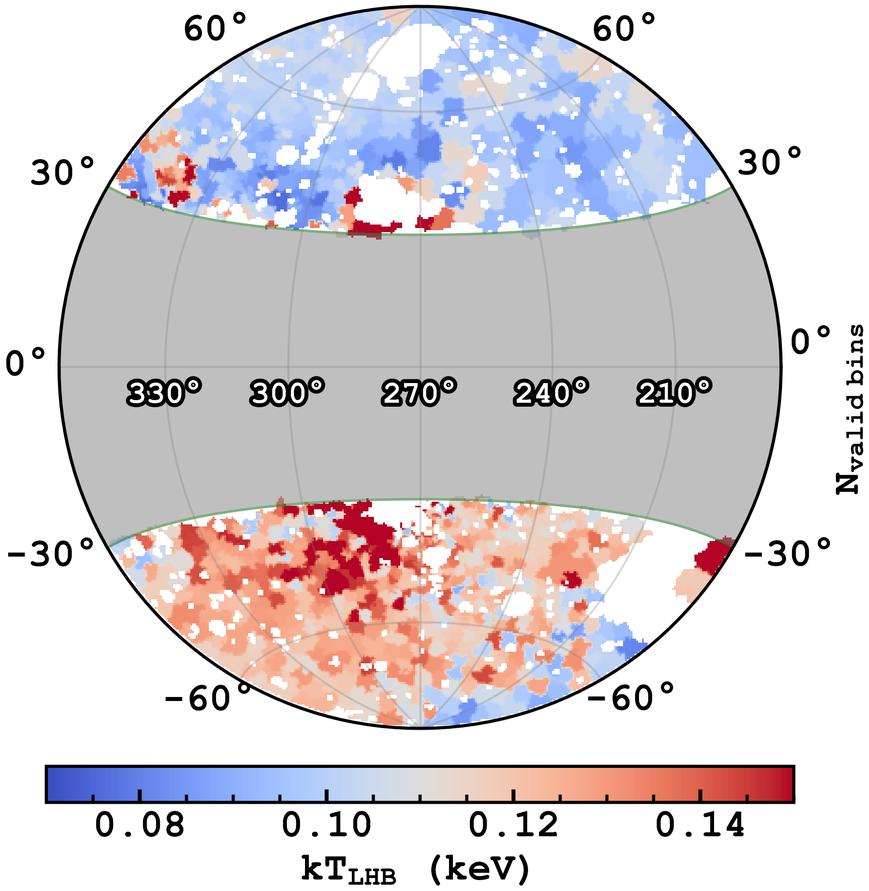
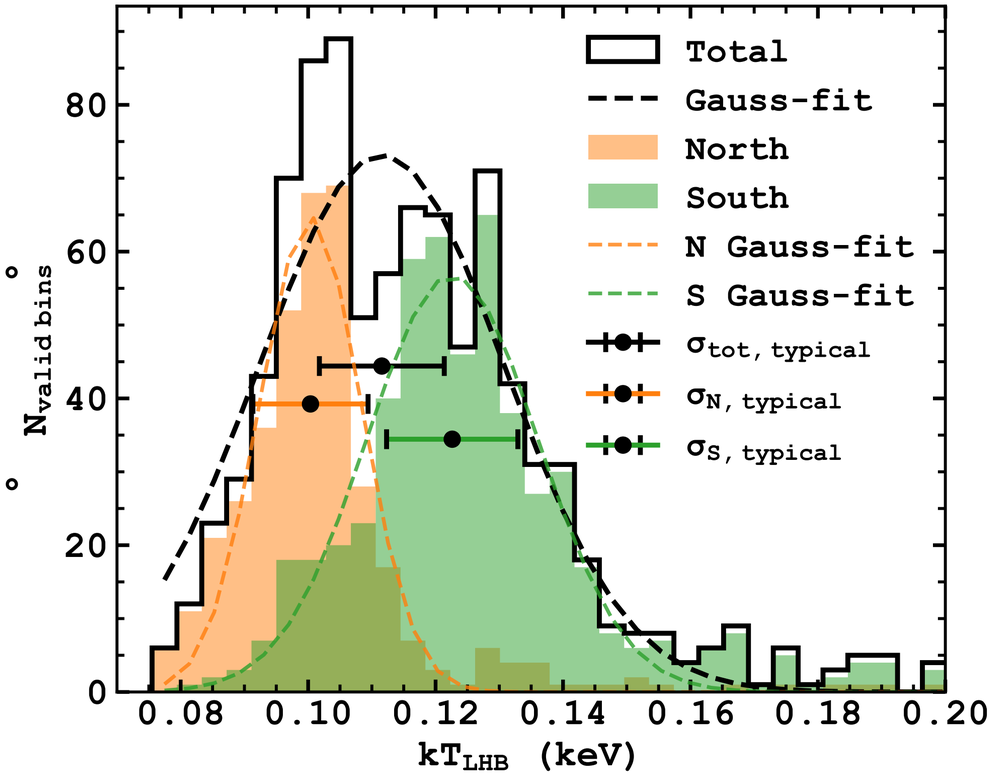


Yeung+24, subm.

Large-scale LHB Temperature Gradient

- North-South temperature dichotomy
  - N: 0.10 ± 0.01 keV
  - S: 0.12 ± 0.01 keV
- Relic of most recent SN explosion?

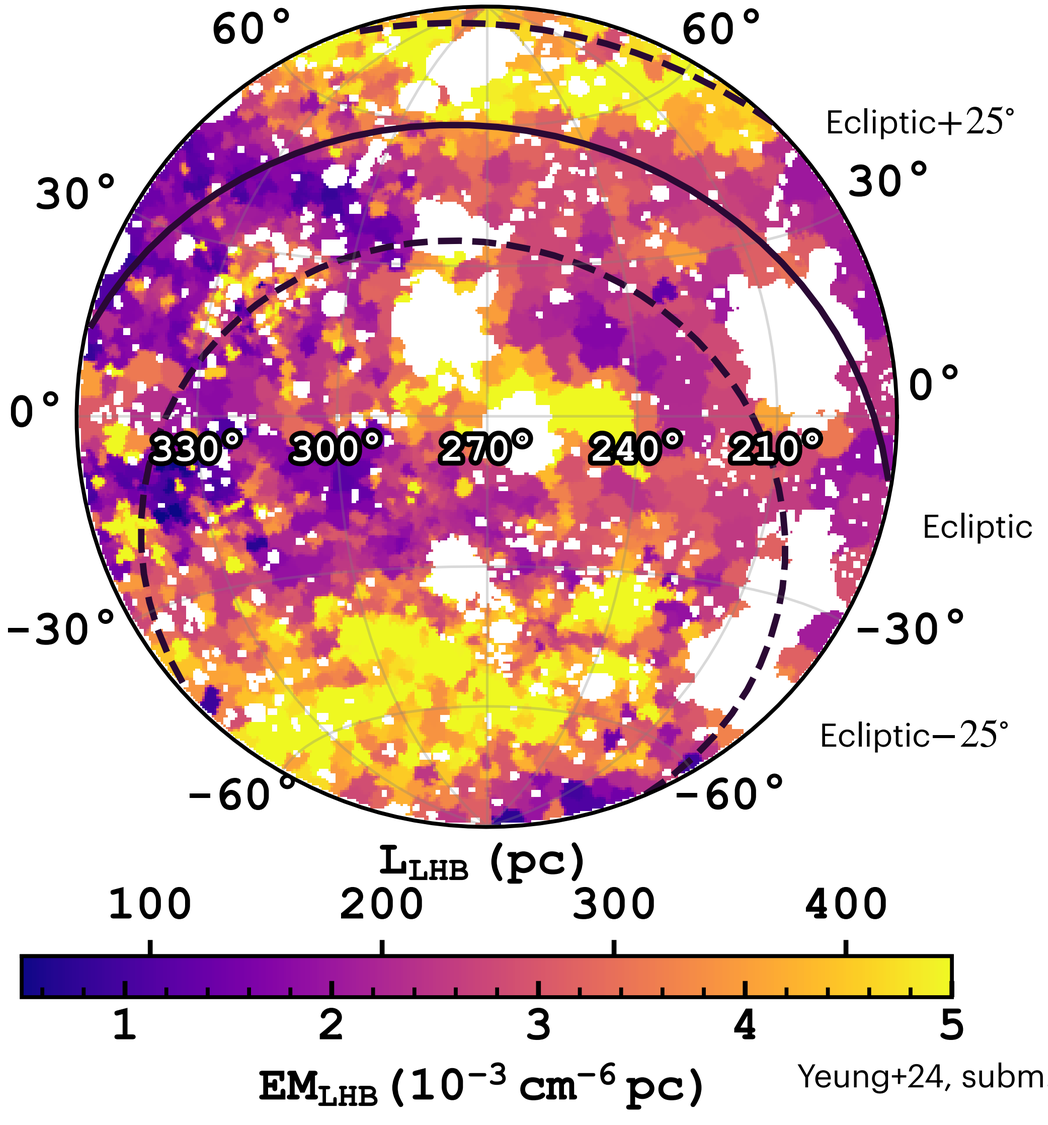




Yeung+24, subm.

LHB Emissions Measure

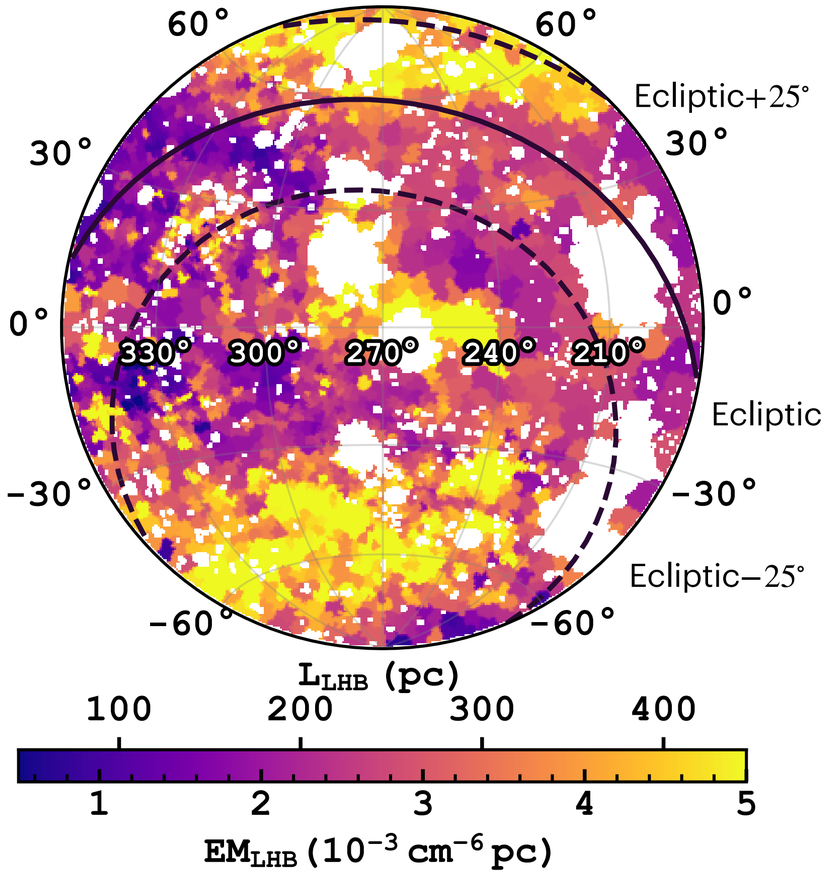
- EM does not correlate with the ecliptic
  - minimal SWCX in eRASS1



Yeung+24, subm.

LHB Structure

- Using $n_e = 4 \times 10^{-3}\,\mathrm{cm}^{-3}$ from shadowing



$$L = \frac{\mathrm{EM_{LHB}}}{1.2 n_e^2}$$

Yeung+24, subm.

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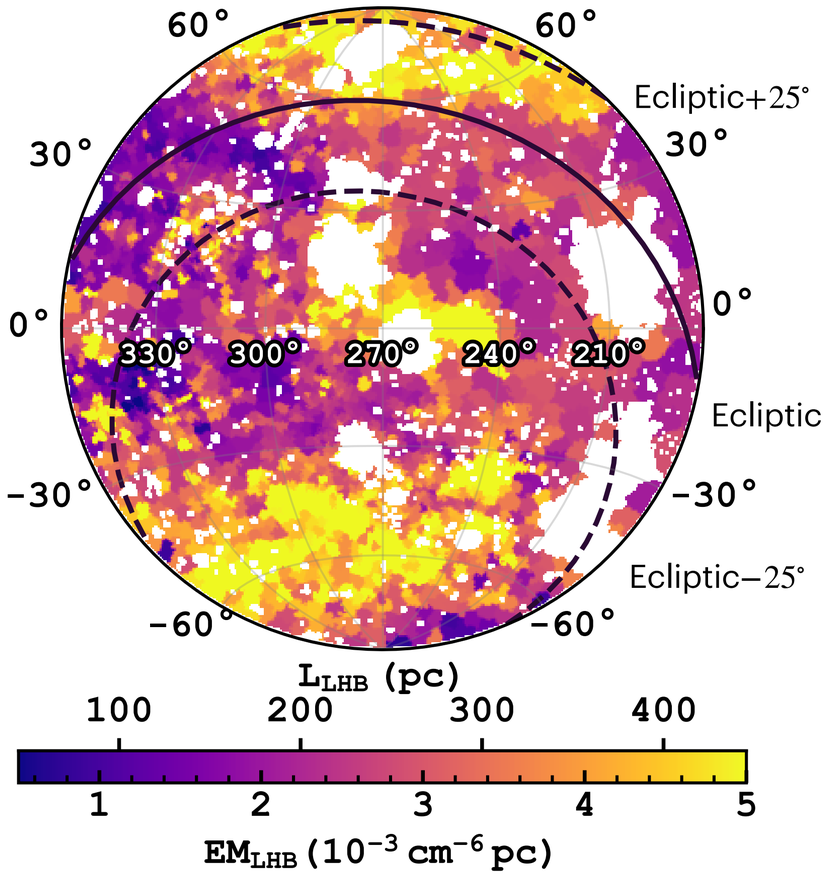

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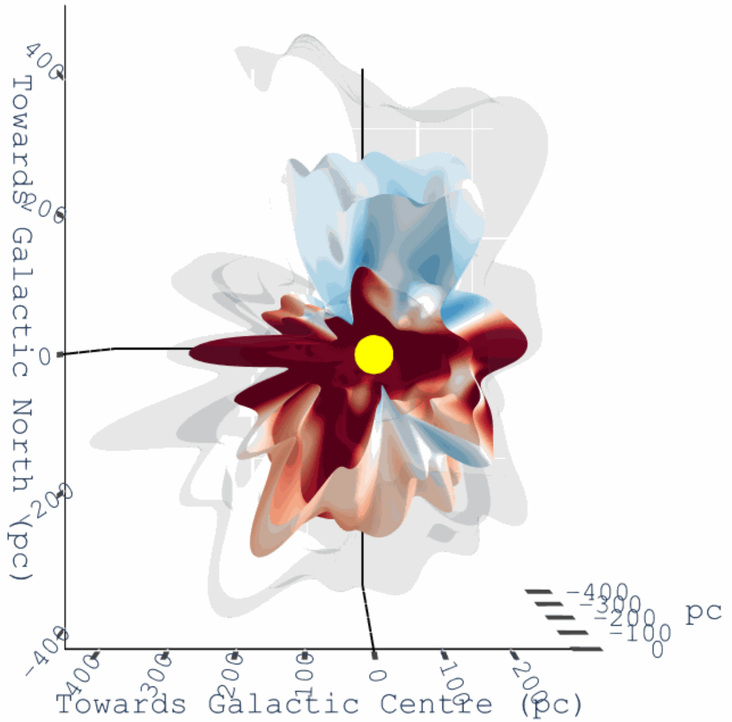
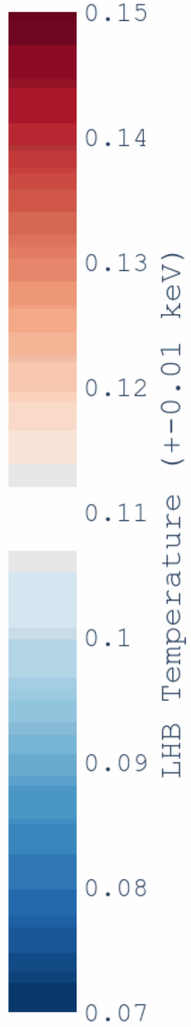


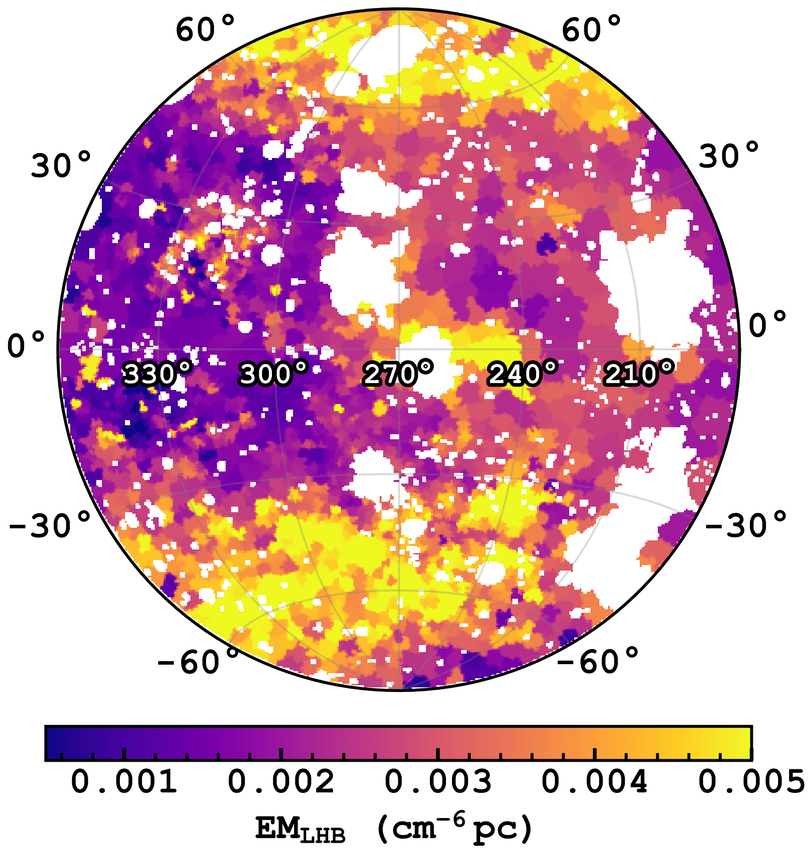


Yeung+24, subm.

LHB Structure and Tunnels

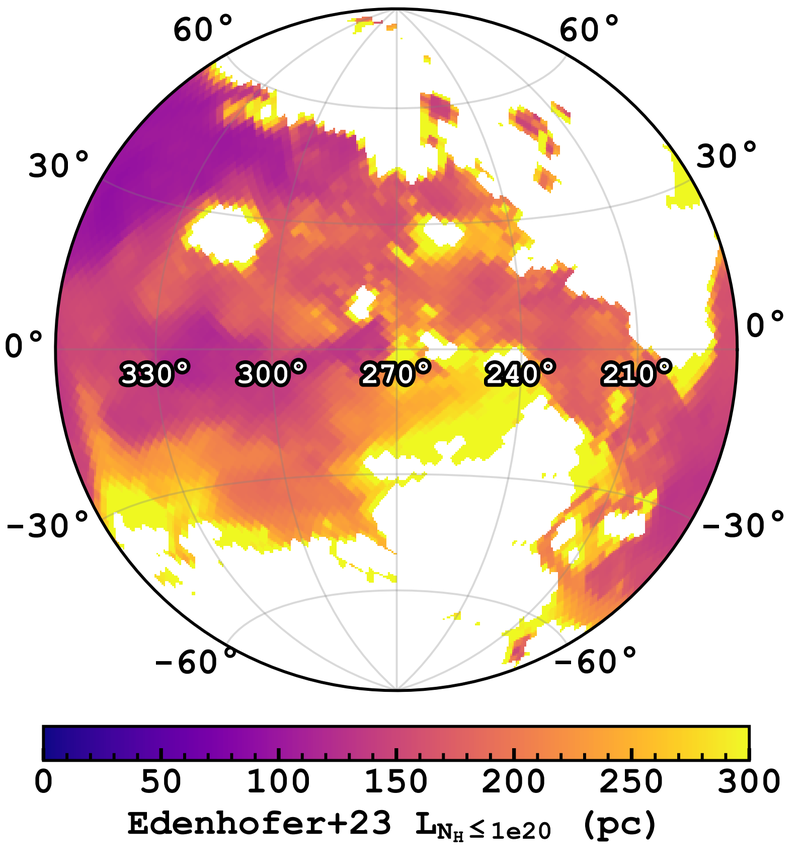
- Anti-correlate with dust

LHB Emission Measure



Yeung+24, subm.

Dust (inferred from Gaia)

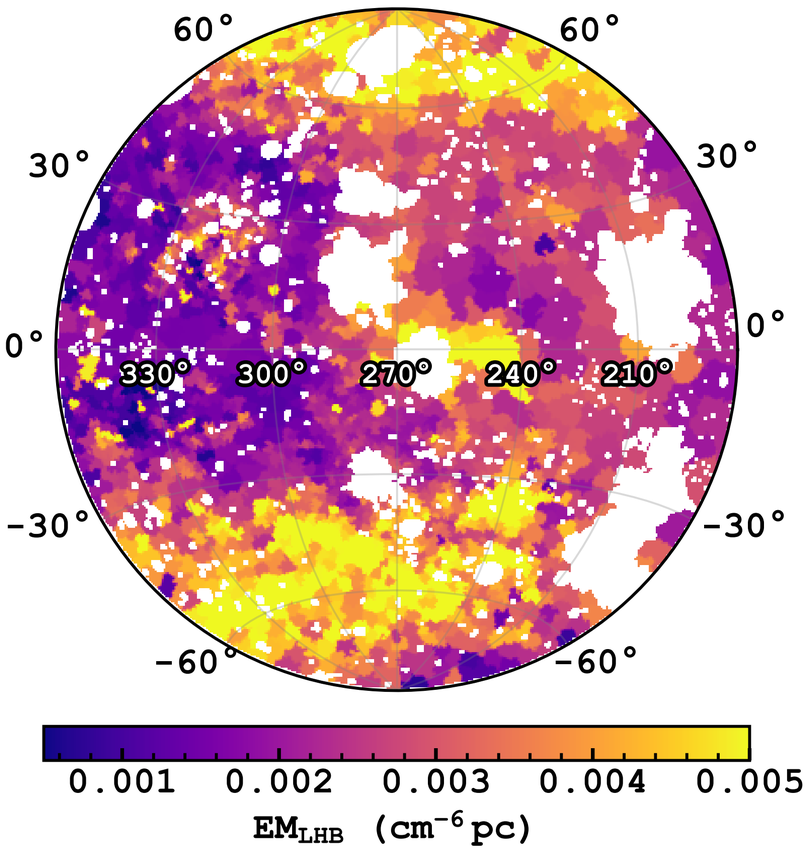


Edenhofer+23

LHB Structure and Tunnels

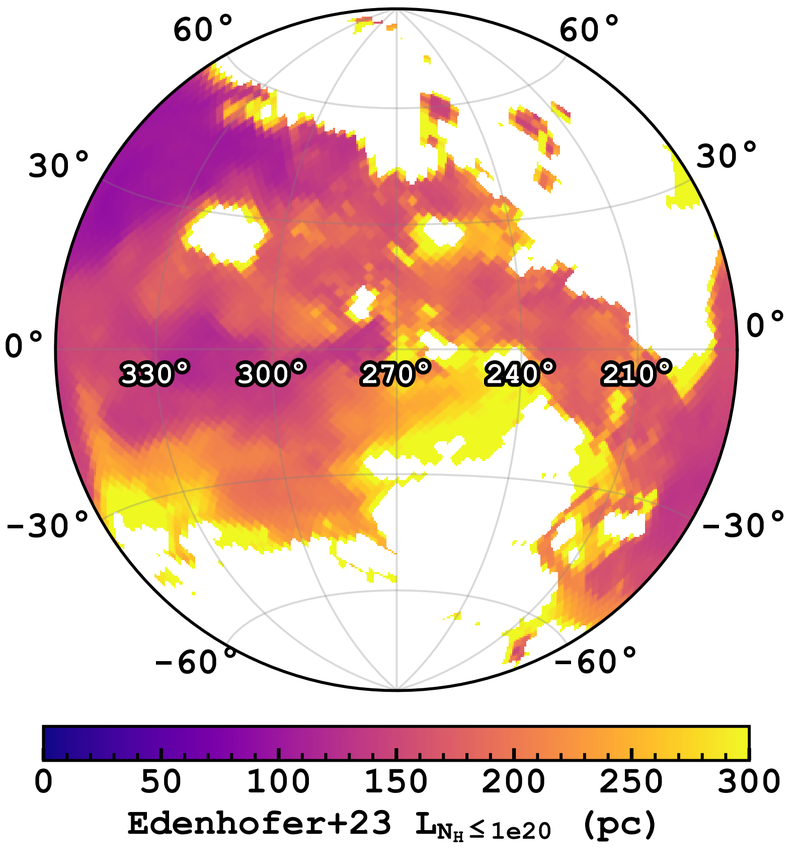
- Anti-correlate with dust
- Appearance of tunnels to nearby superbubbles

LHB Emission Measure



Yeung+24, subm.

Dust (inferred from Gaia)

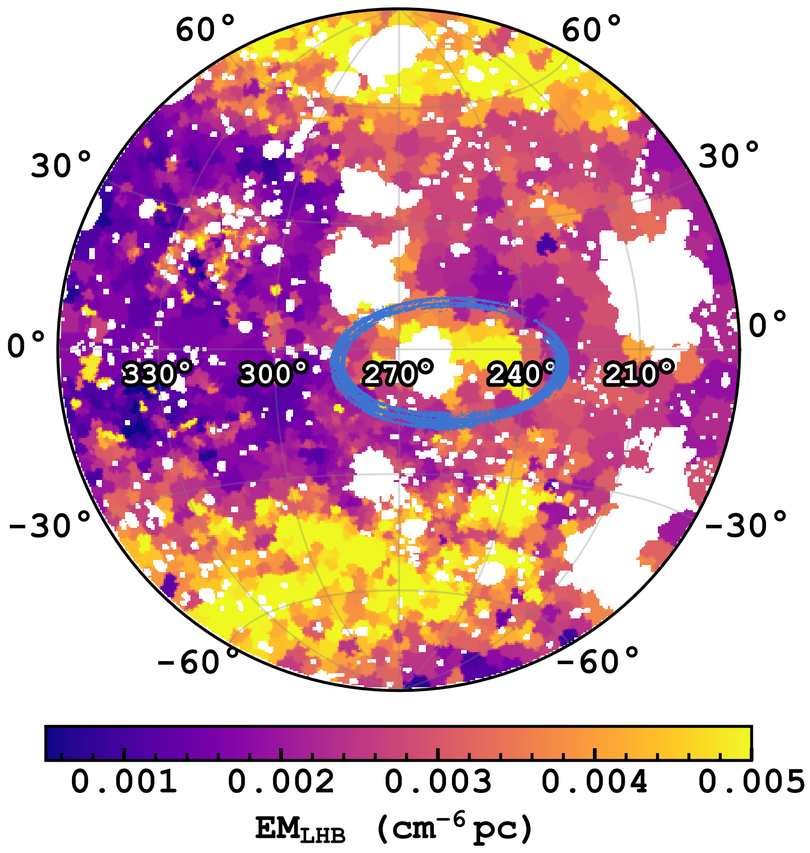


Edenhofer+23

LHB Structure and Tunnels

- Anti-correlate with dust
- Appearance of tunnels to nearby superbubbles
  - β CMa tunnel (since Gry+85)

LHB Emission Measure



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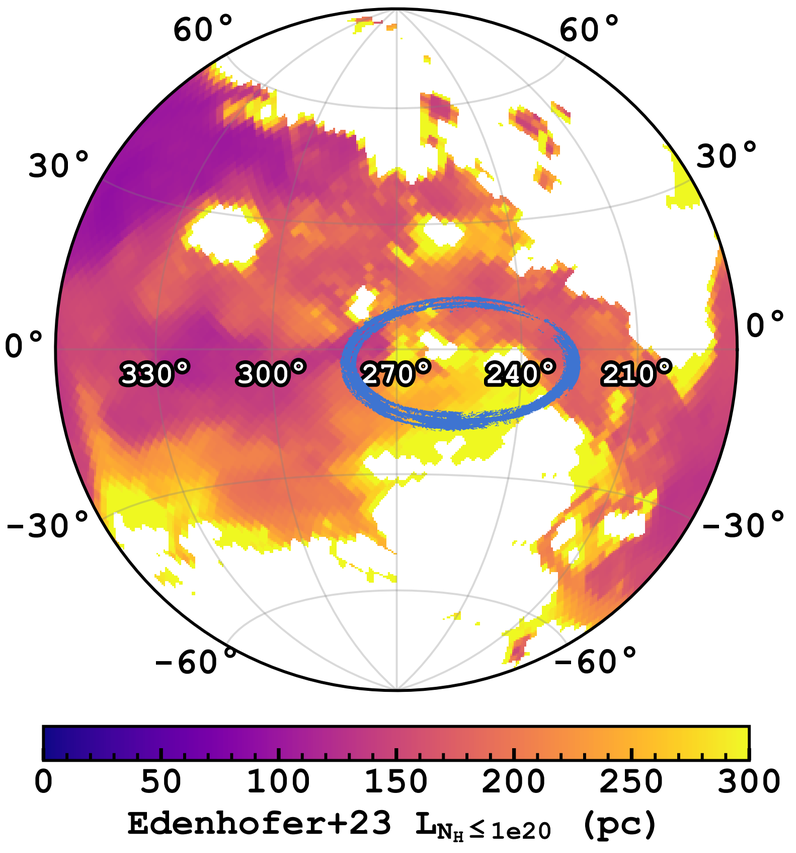

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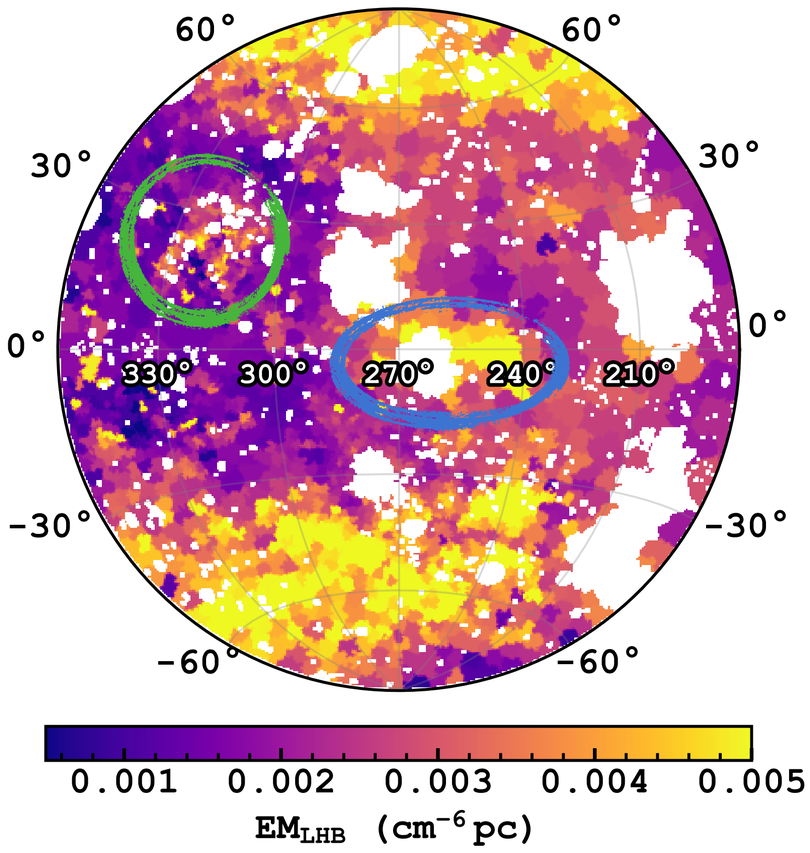

Yeung+24, subm.

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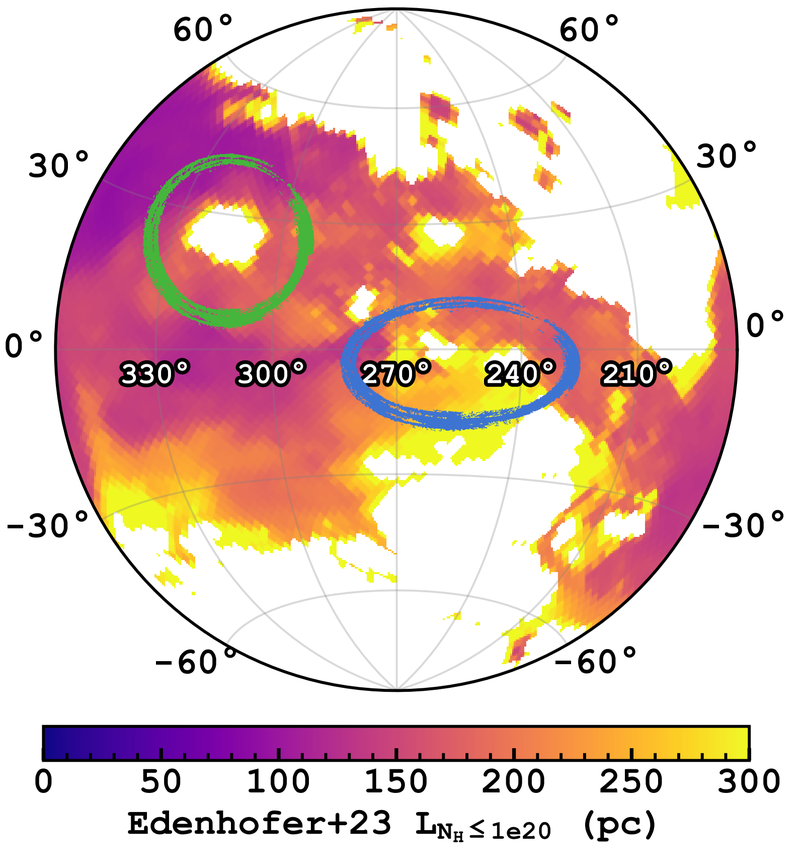
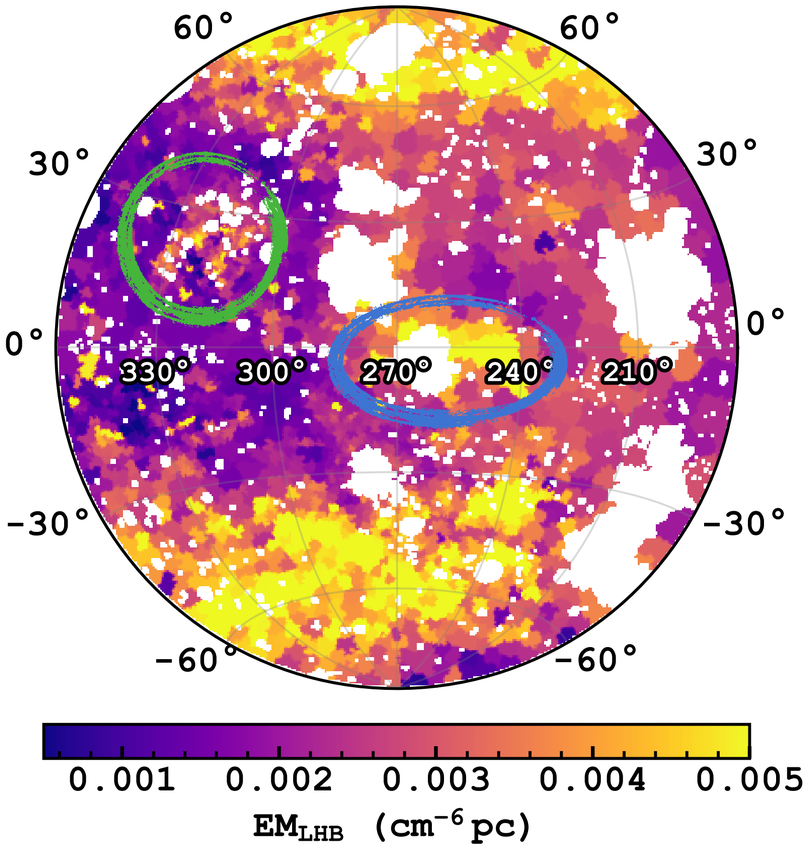


Edenhofer+23

LHB Structure and Tunnels

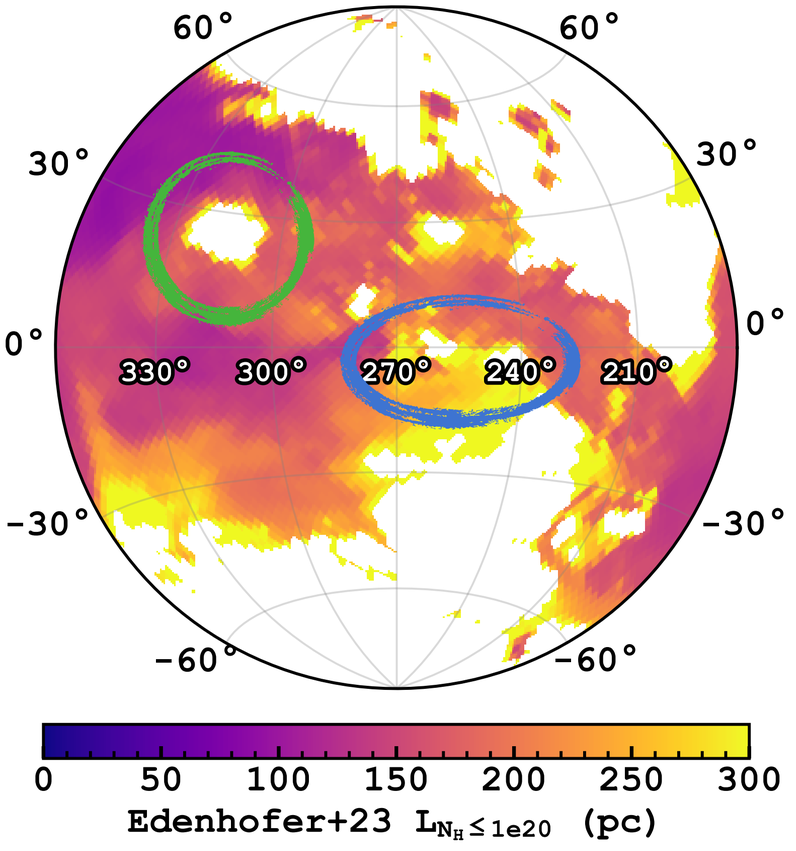
- Anti-correlate with dust
- Appearance of tunnels to nearby superbubbles
  - β CMa tunnel (since Gry+85)
  - Centaurus tunnel
- SN sustain widespread hot ISM (Cox & Smith 1974)

LHB Emission Measure



Yeung+24, subm.

Dust (inferred from Gaia)

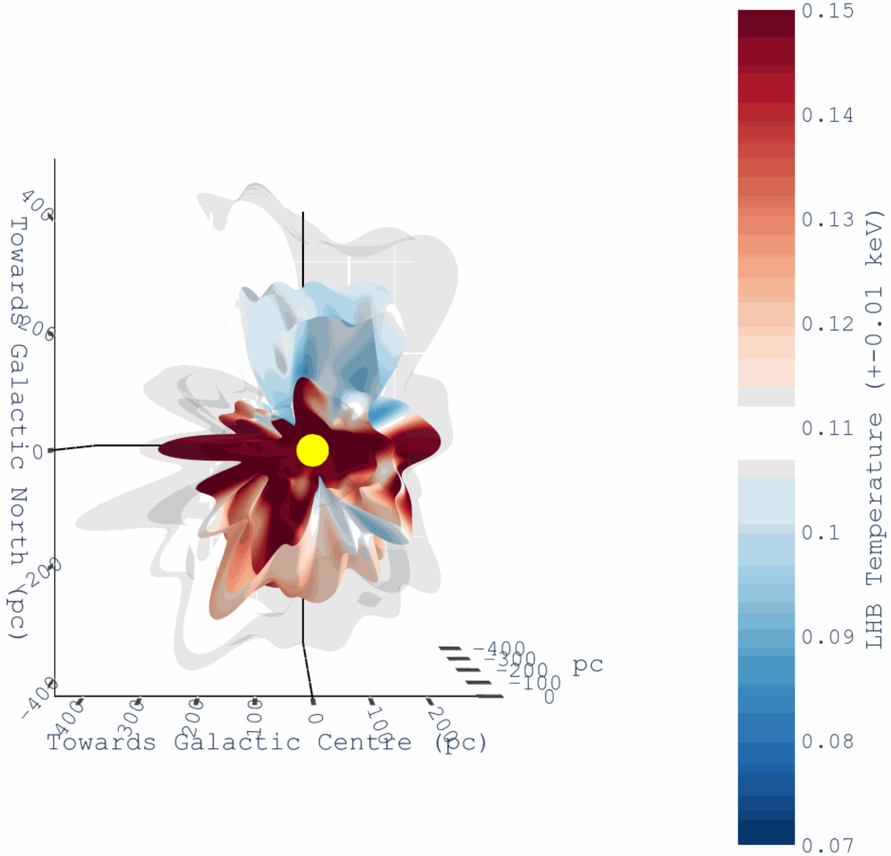


Edenhofer+23

Summary

- Shadowing of giant molecular clouds (Yeung+23)
  - monotonic increase of heliospheric SWCX with solar cycle
  - ecliptic latitudinal dependence of SWCX intensity (solar wind density)
  - LHB density approximately constant

- Half-sky spectral analysis at solar minimum (Yeung+24, subm.)
  - North-South LHB temperature dichotomy
  - LHB more extended at high latitudes
  - Presence of interstellar tunnels



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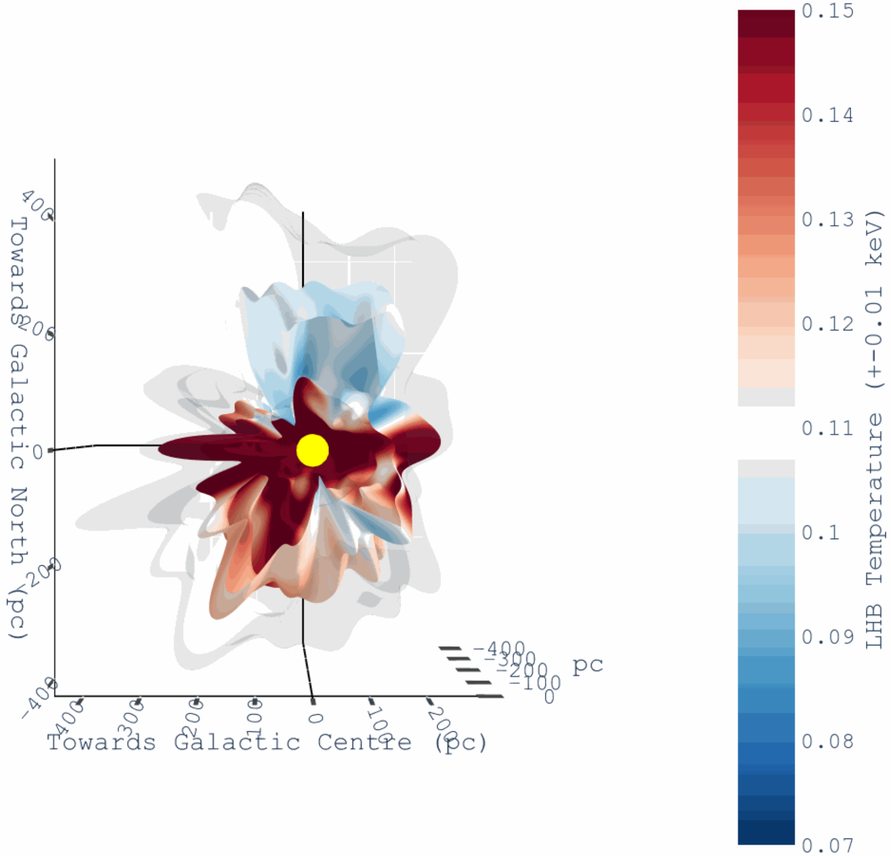
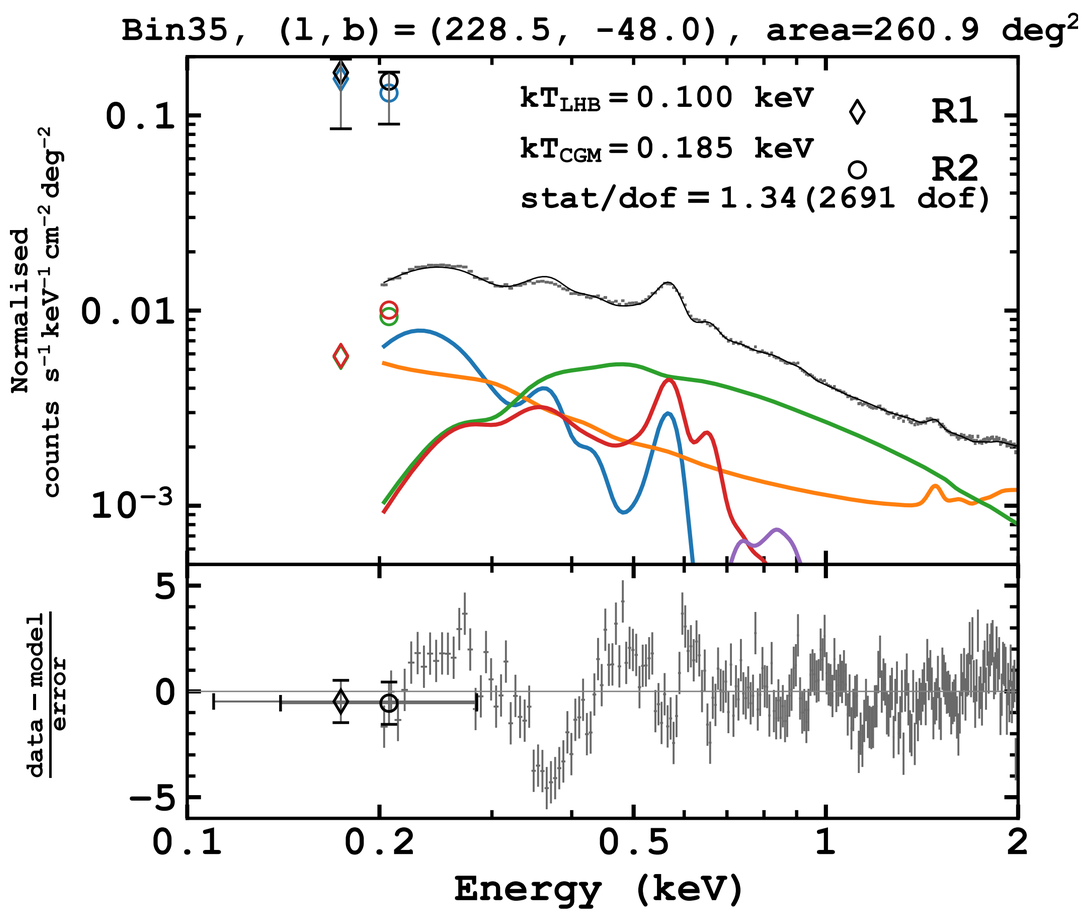
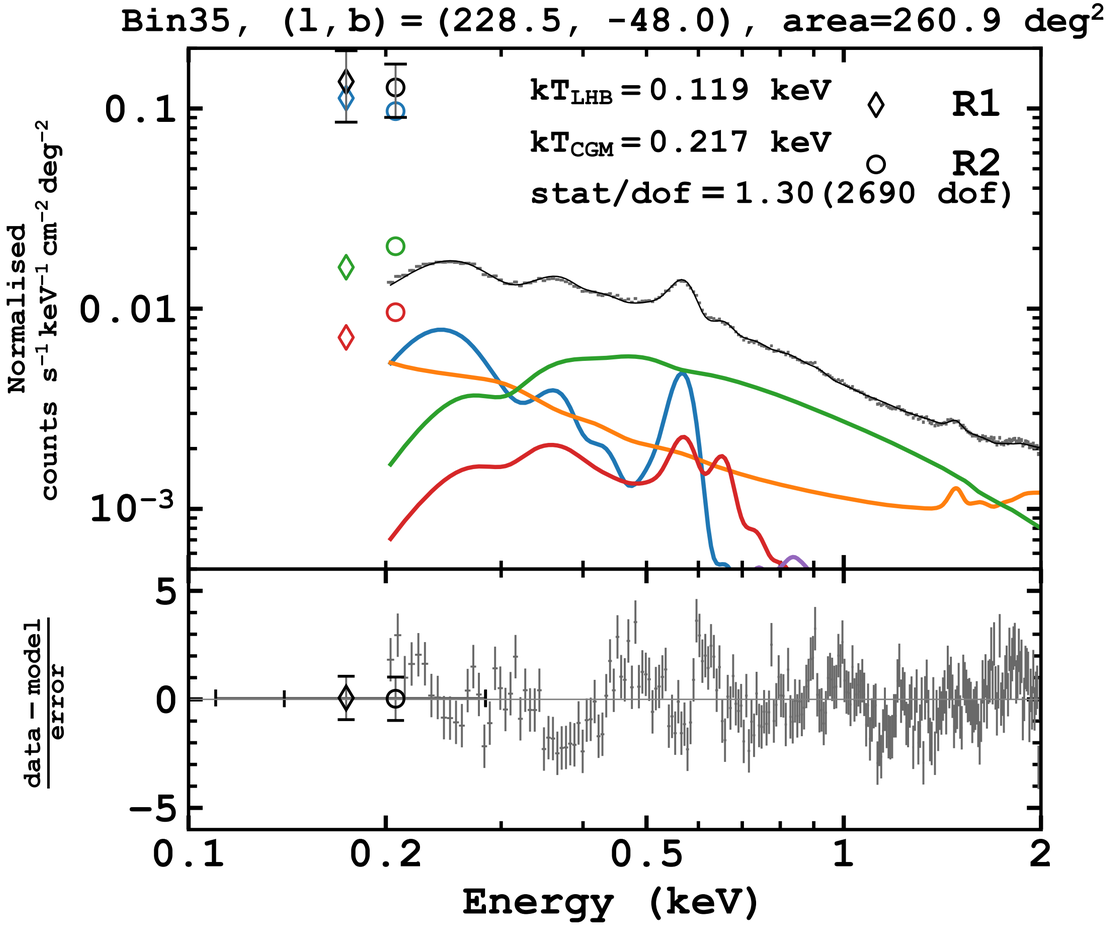


Spectral evidence of temperature difference

Applying fit in North to South

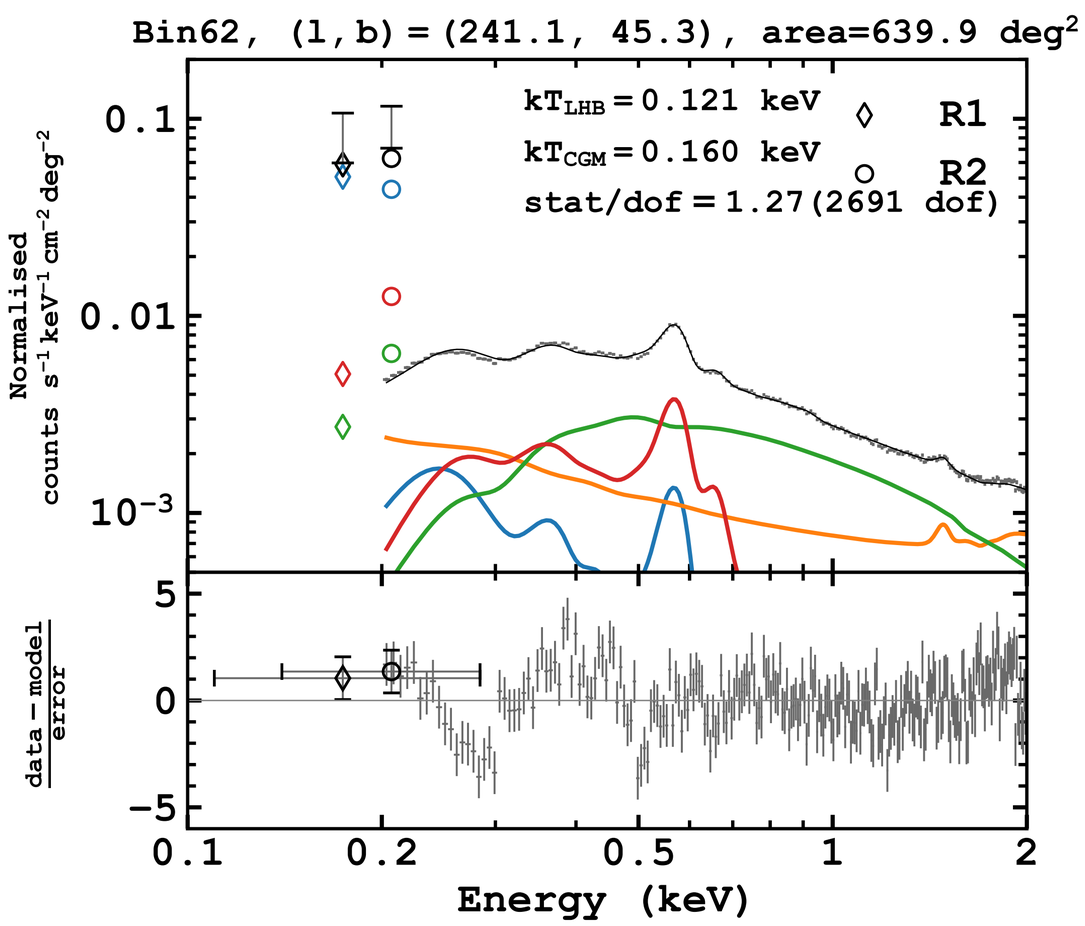


Best-fit

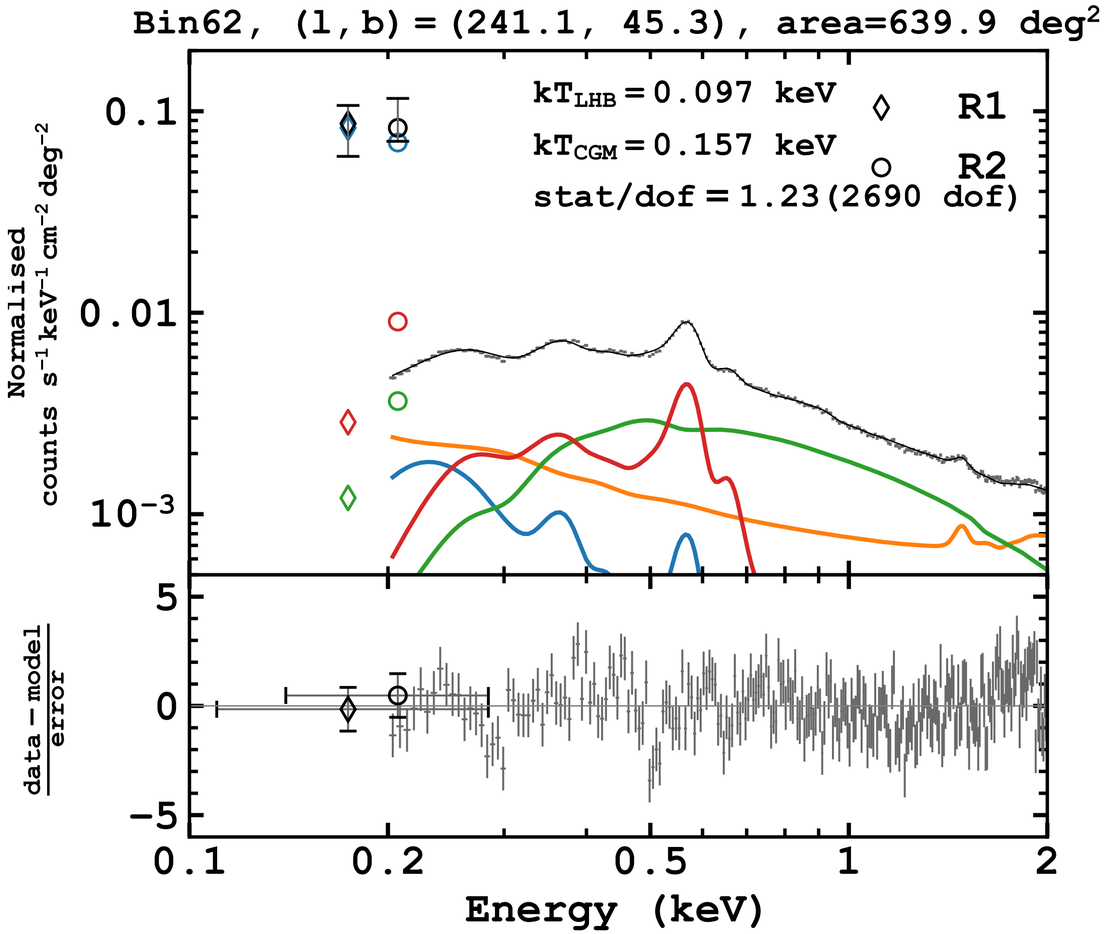


Spectral evidence of temperature difference

Applying fit in South to North

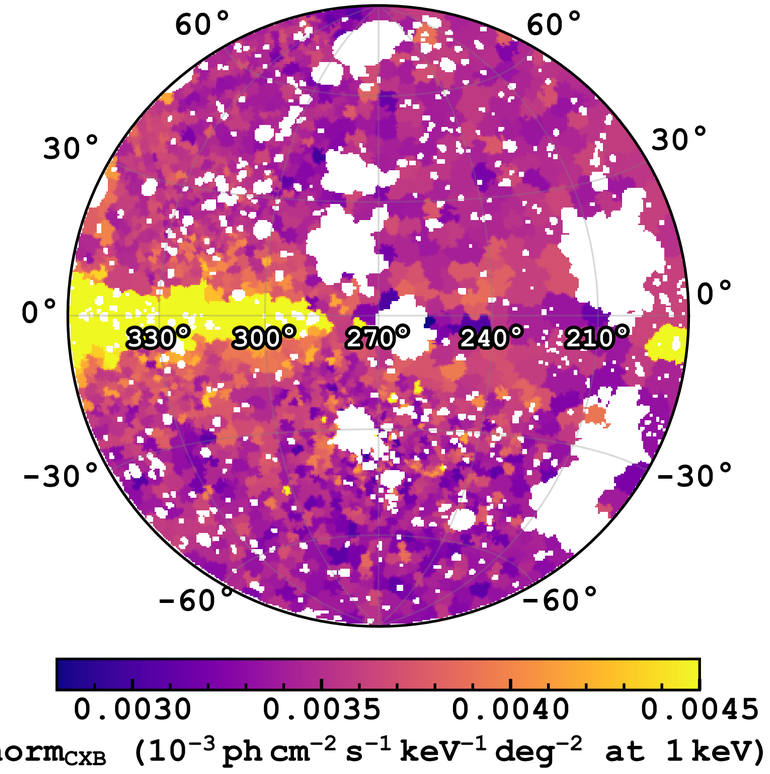


Best-fit

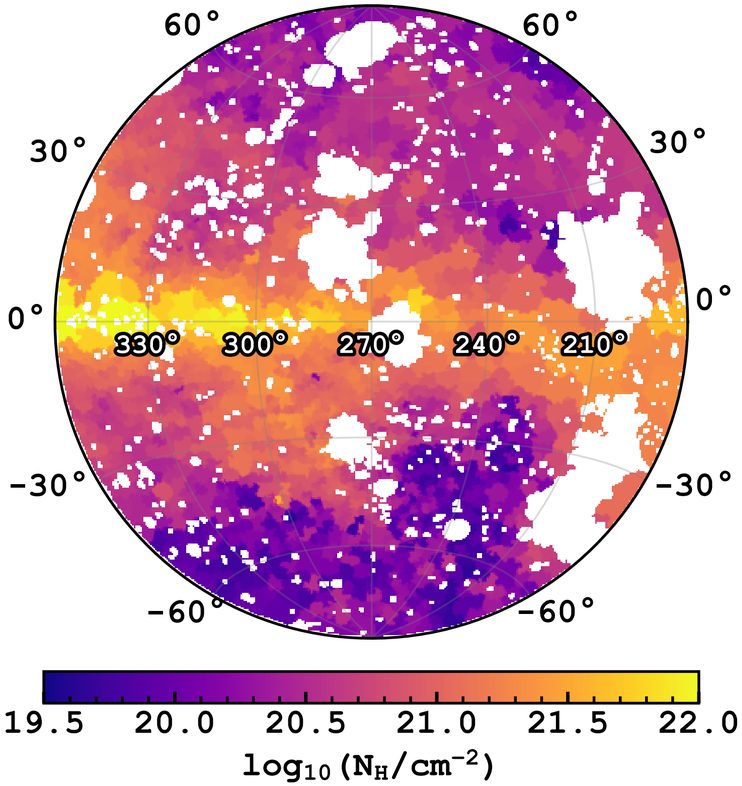


Cosmic X-ray Background & $N_{\rm H}$

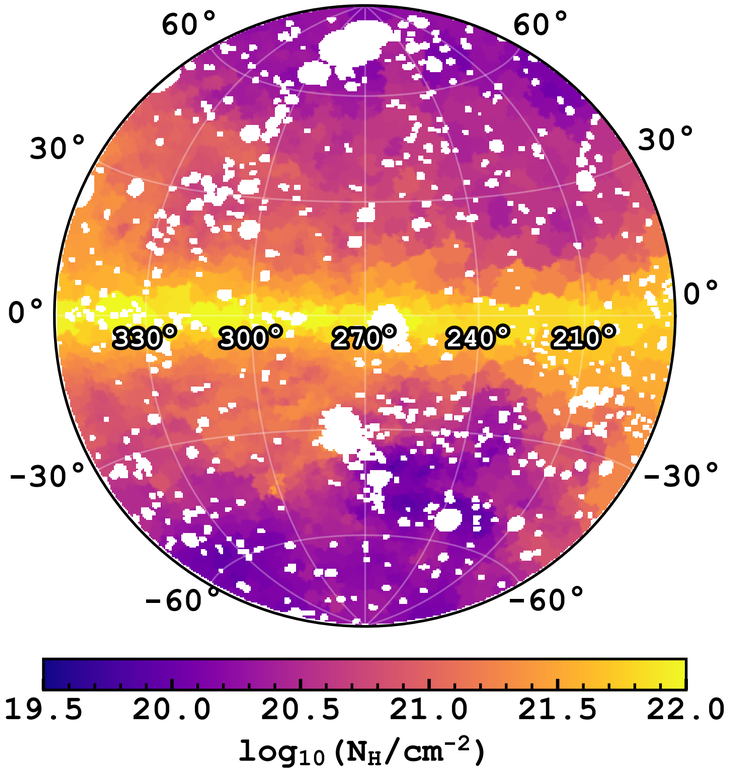
- Uniform CXB normalisation (within 10% above the plane)
- X-ray fitted $N_{\rm H}$ closely relating to total $N_{\rm H}$ traced by HI4PI and Planck



Fitted



HI4PI and Planck



Robustness of Spectral Fits