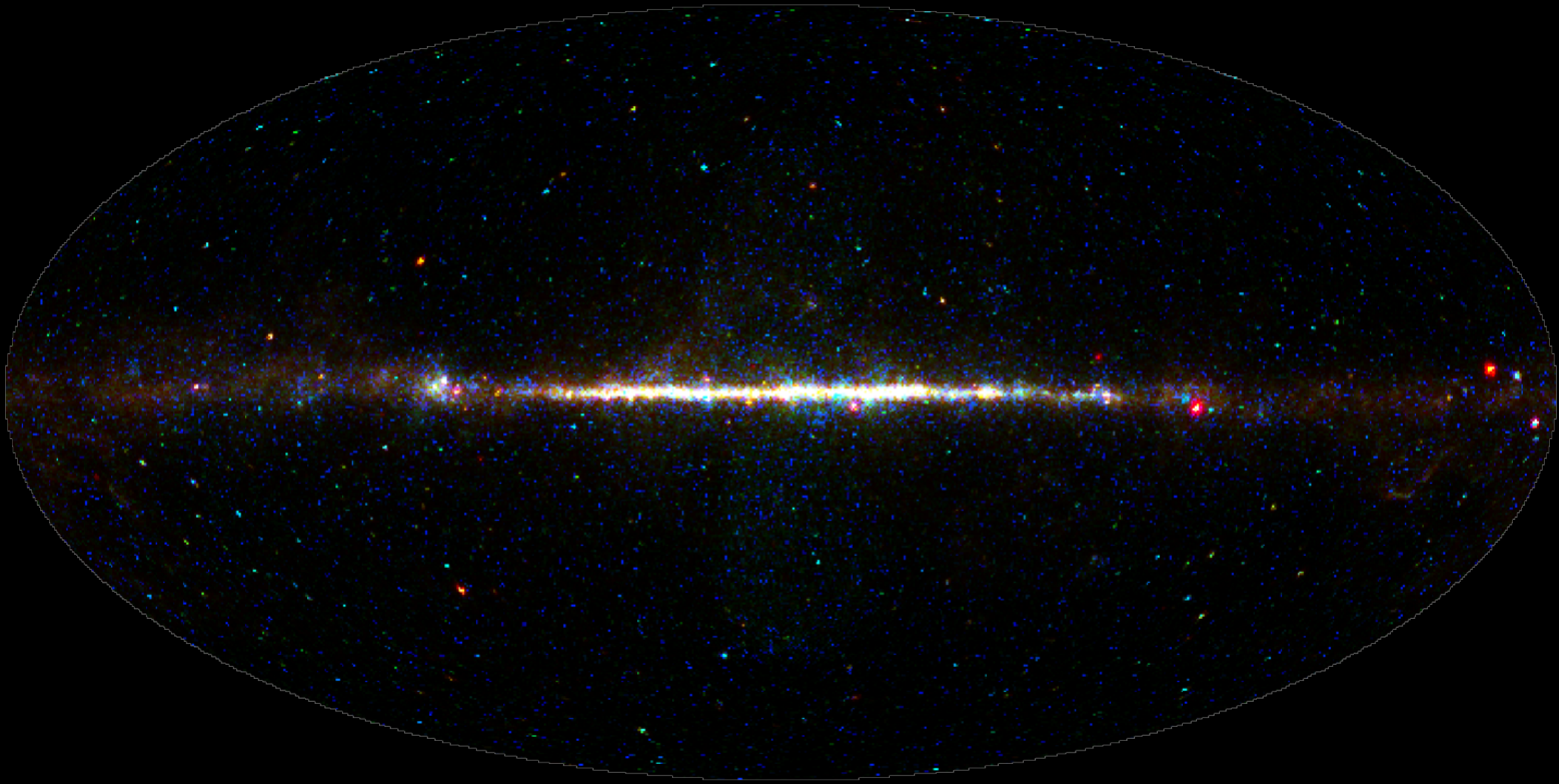
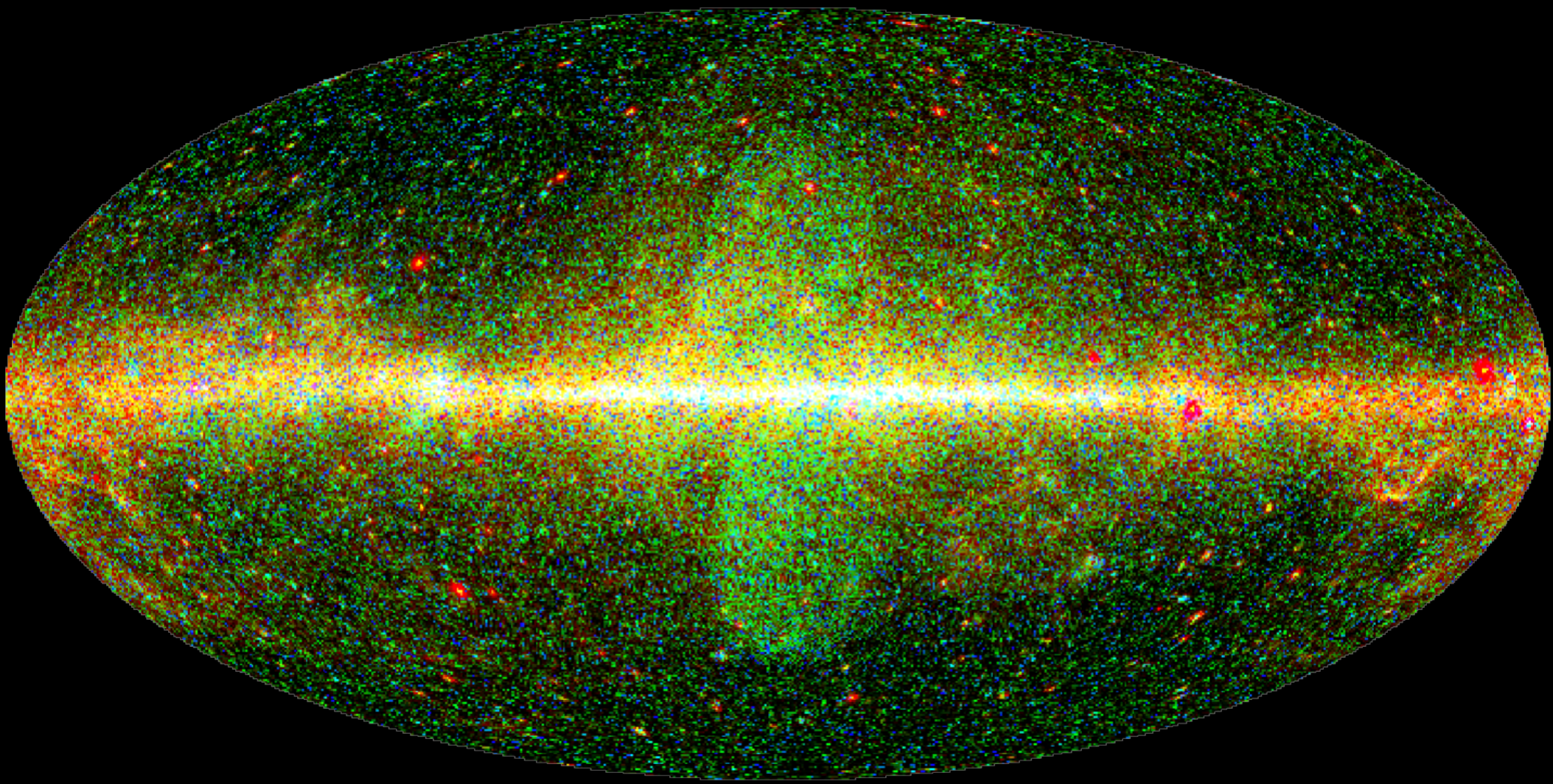
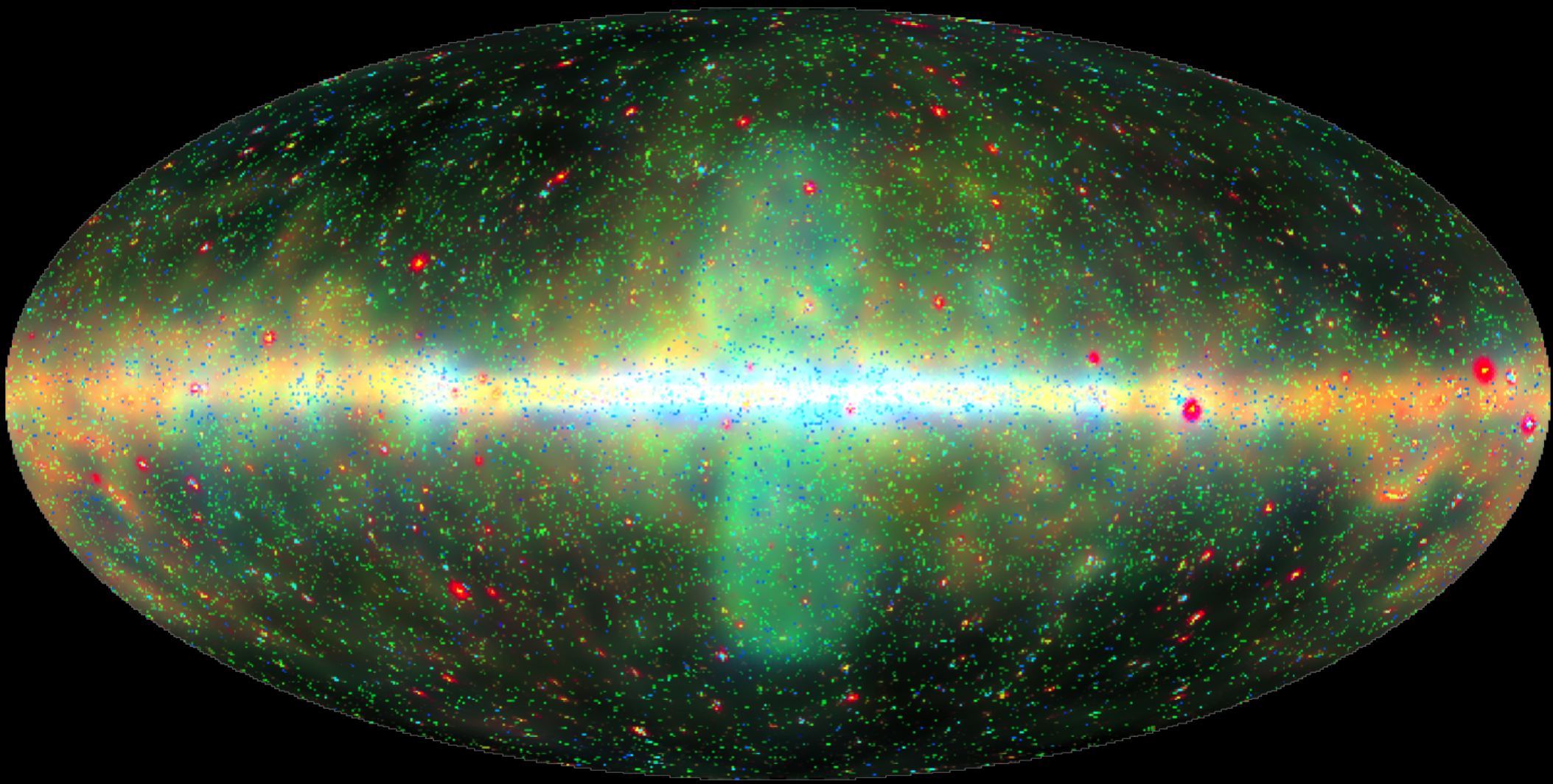
Dark matter search in the decomposed Fermi gamma-ray sky

Xiaoyuan Huang, Torsten A. Enßlin, Marco Selig
Excellencecluster Universe, TUM
Max Planck Institute for Astrophysics, LMU

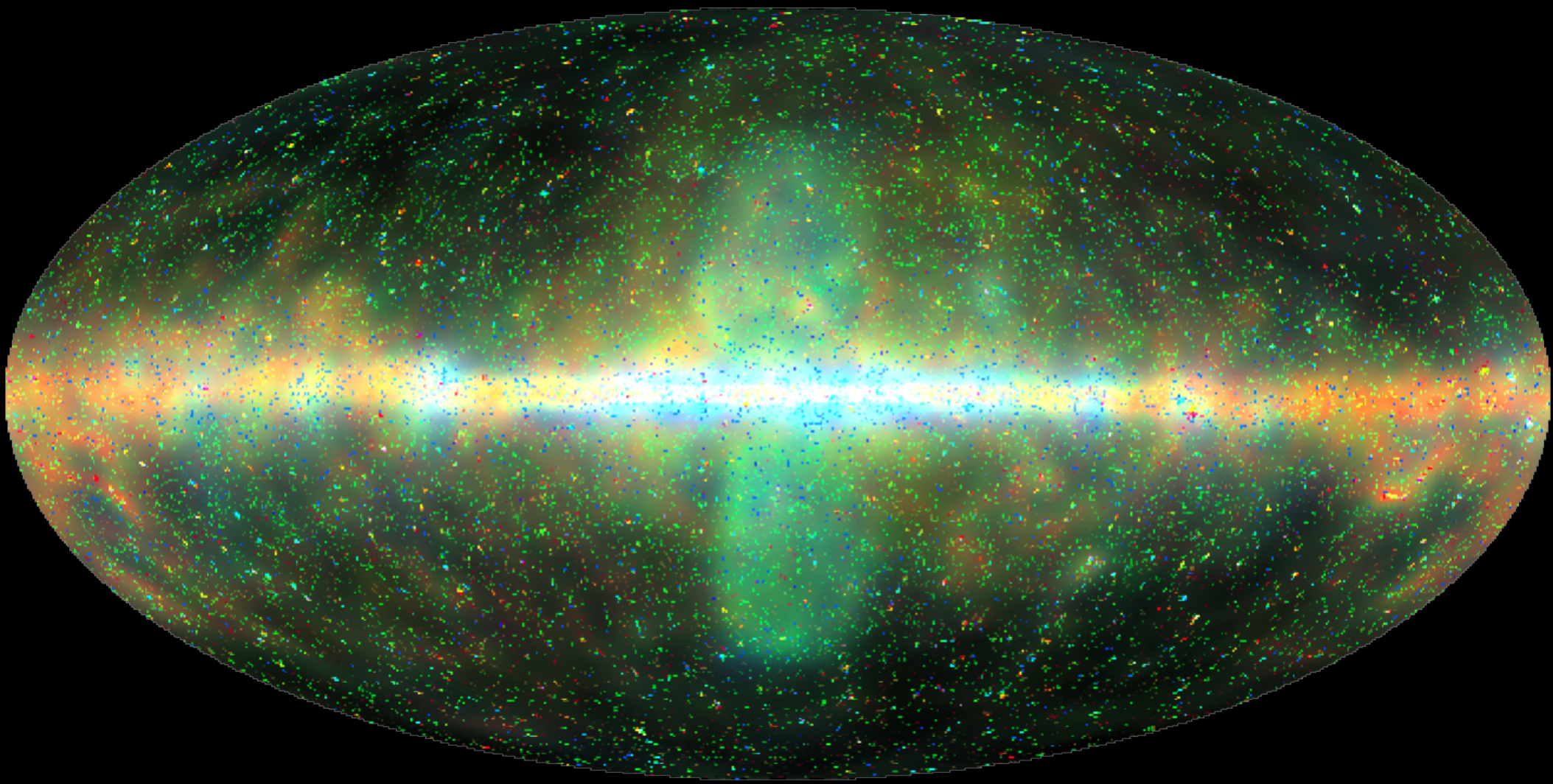




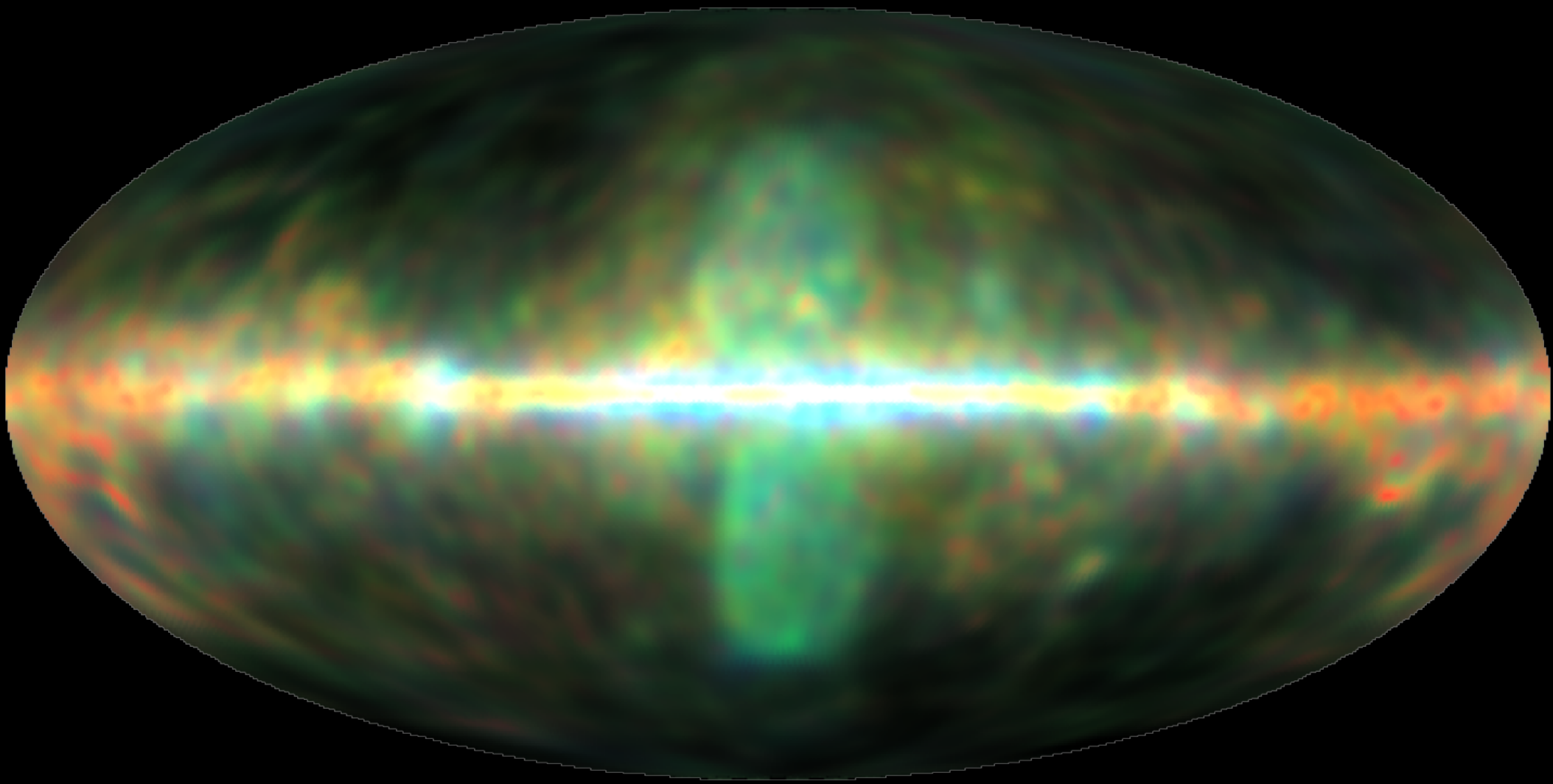
log-data



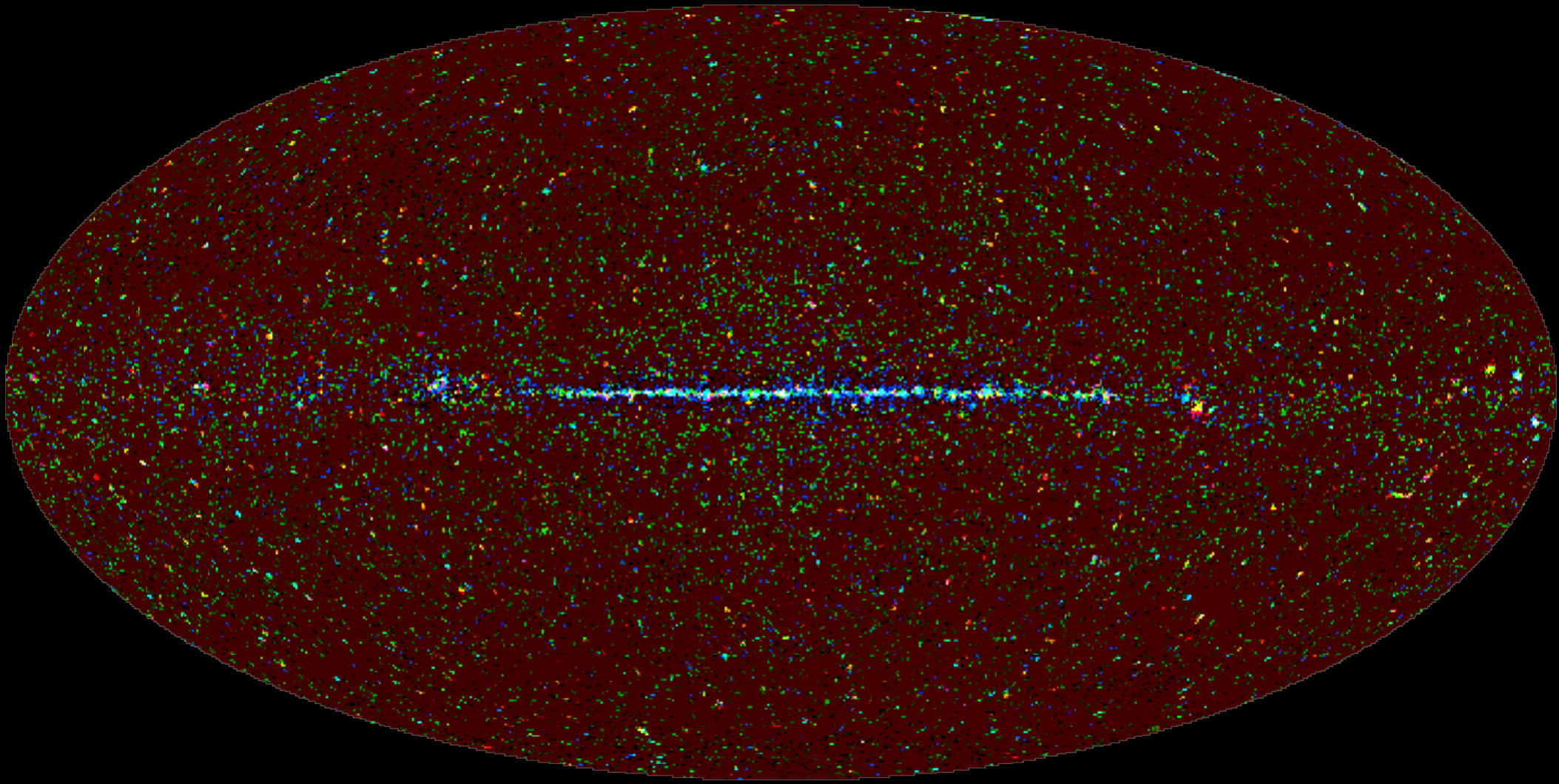
log-data . . . denoised



log-data . . . denoised . . . deconvolved



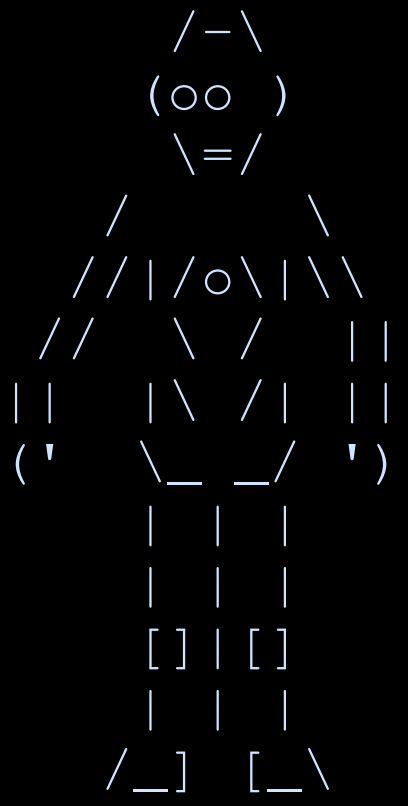
log-data … denoised … deconvolved … decomposed



Denoising, Deconvolving, and Decomposing Photon Observations

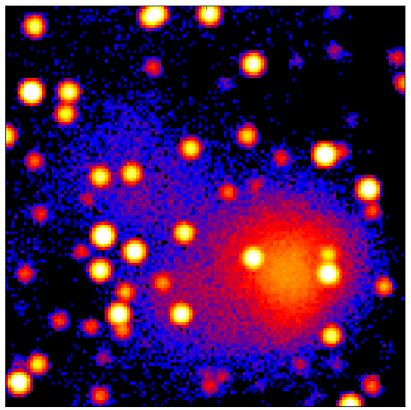
Selig et al. (2014)
www.mpa-garching.mpg.de/ift/d3po

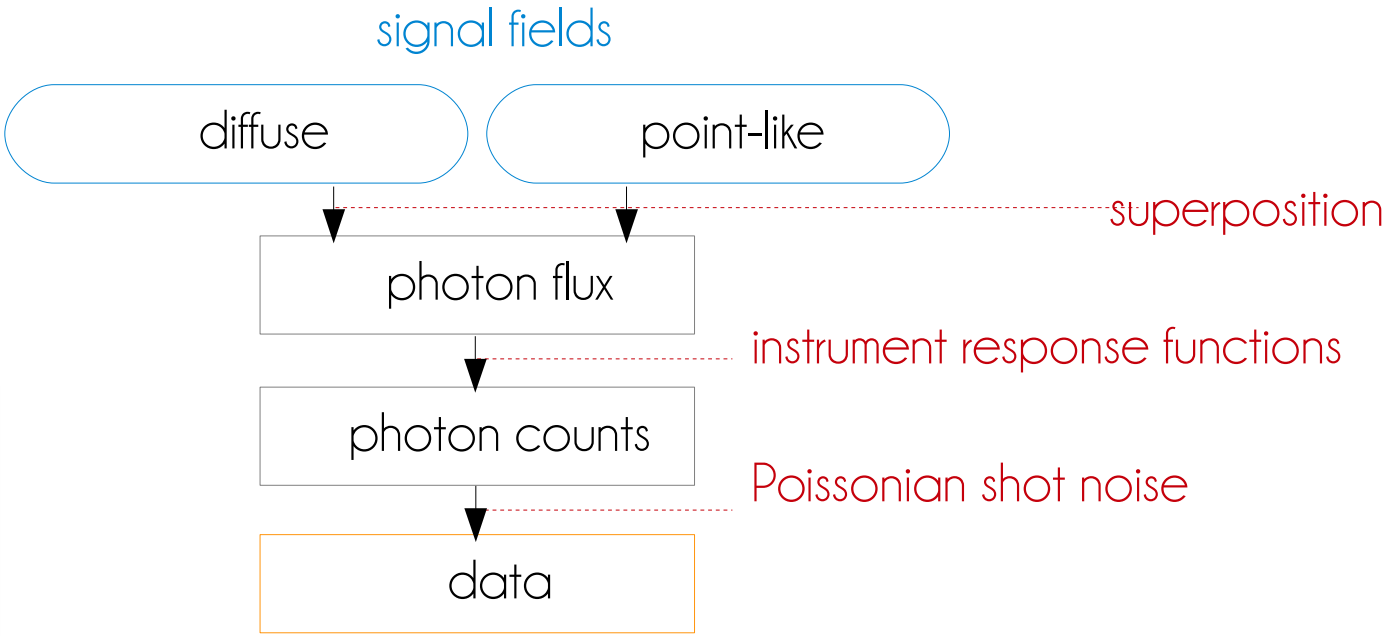
D^{3}PO



D^{3}PO – challenges

Selig & Enßlin (2014)
arXiv: 1311.1888

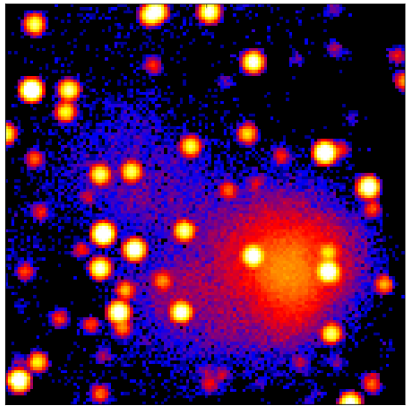


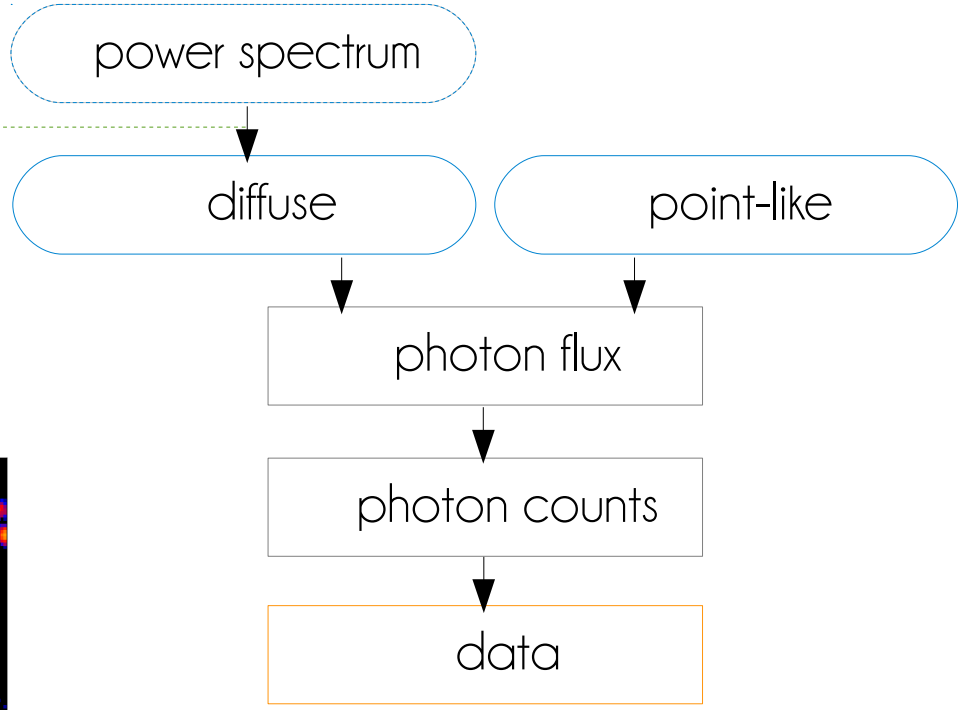


D^{3}PO – challenges & assumptions

Selig & Enßlin (2014)
arXiv: 1311.1888

log-normal

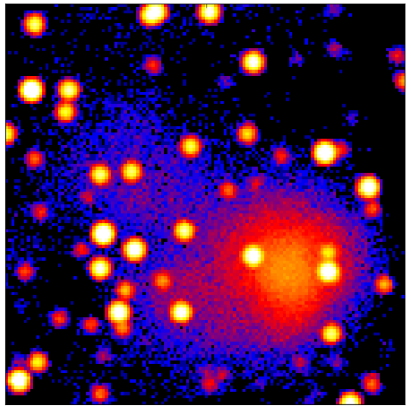


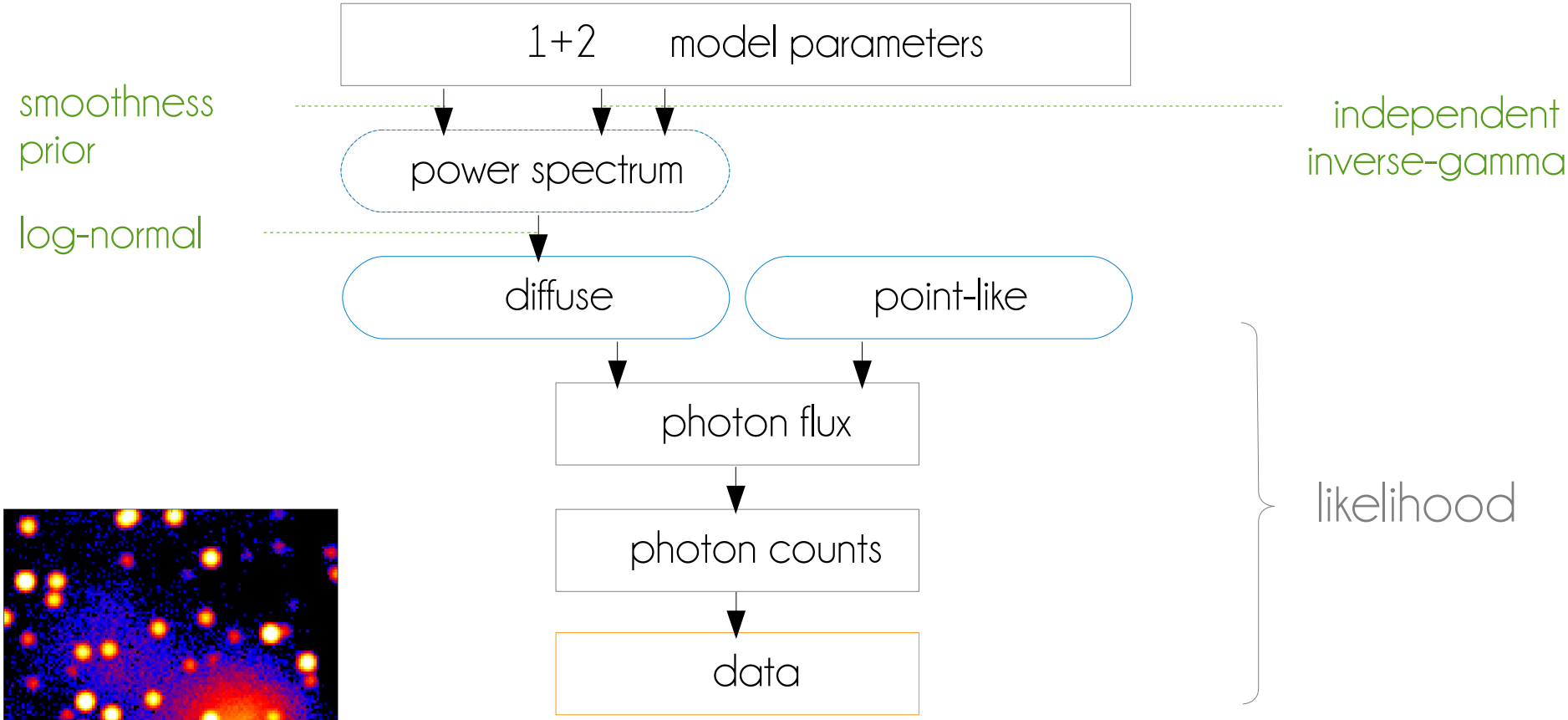


likelihood

D³PO – challenges & assumptions

Selig & Enßlin (2014)
arXiv: 1311.1888





D³PO – challenges & assumptions

Selig & Enßlin (2014)
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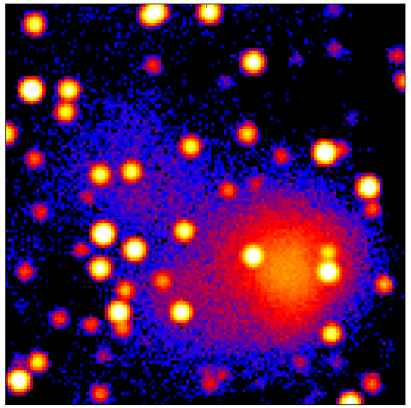
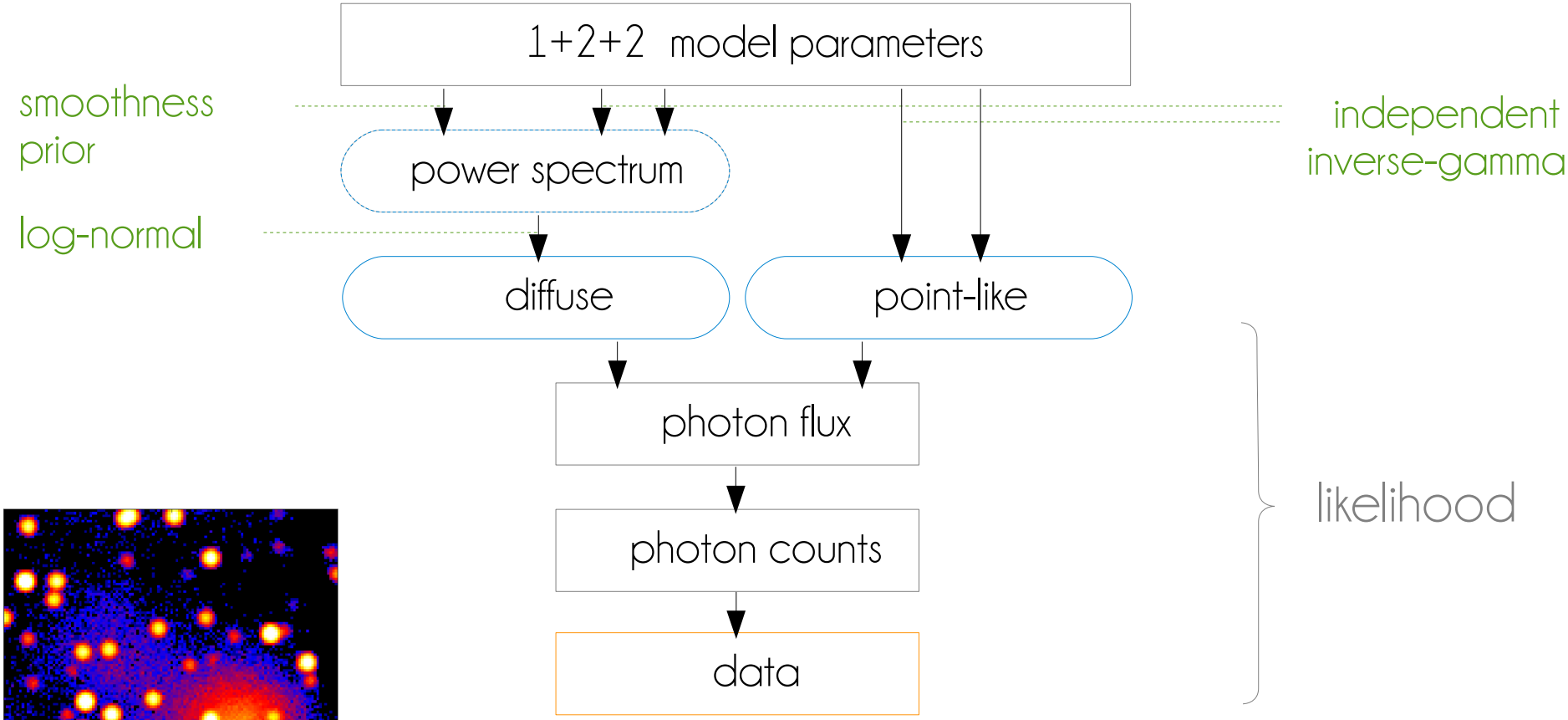
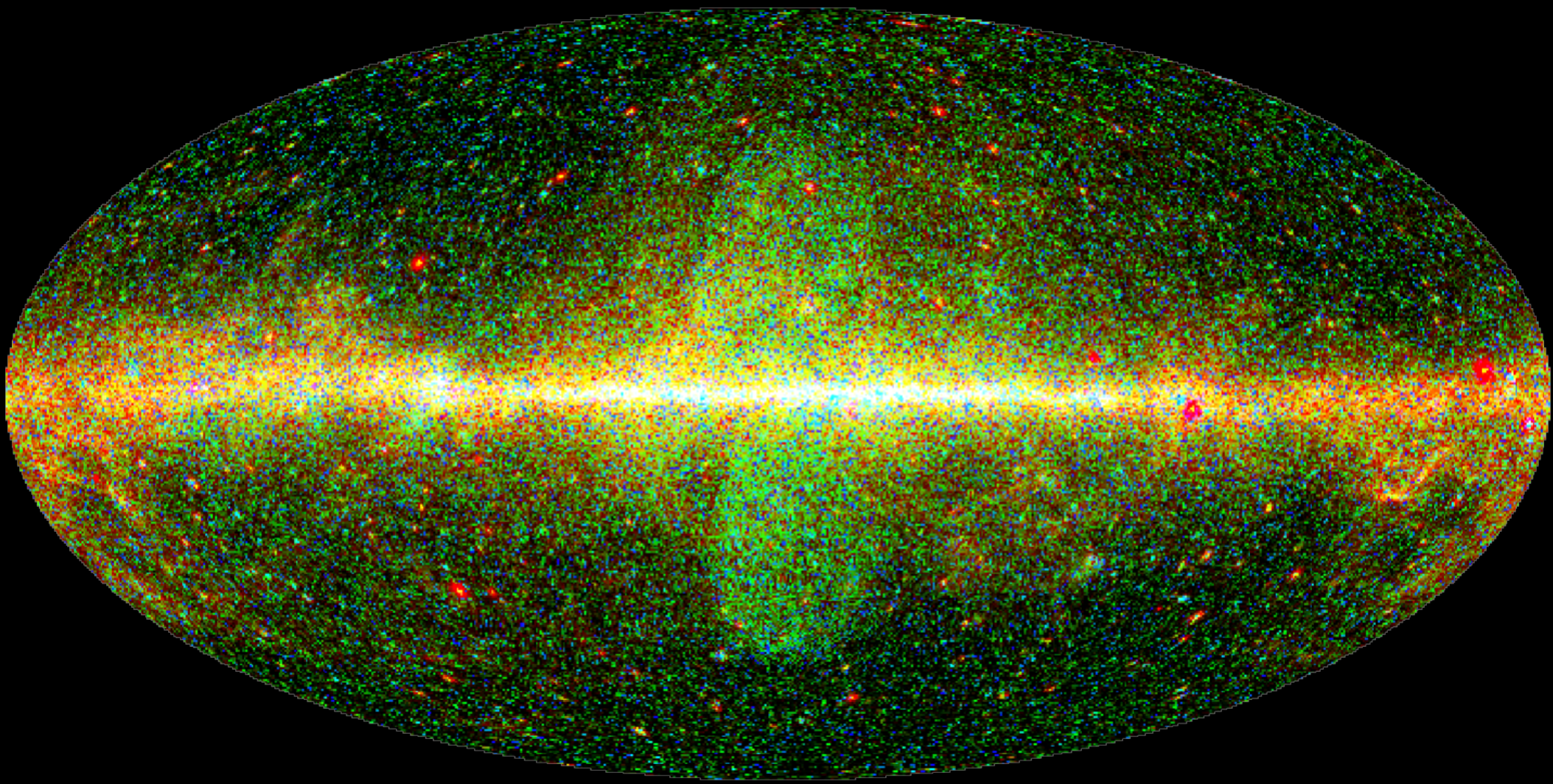
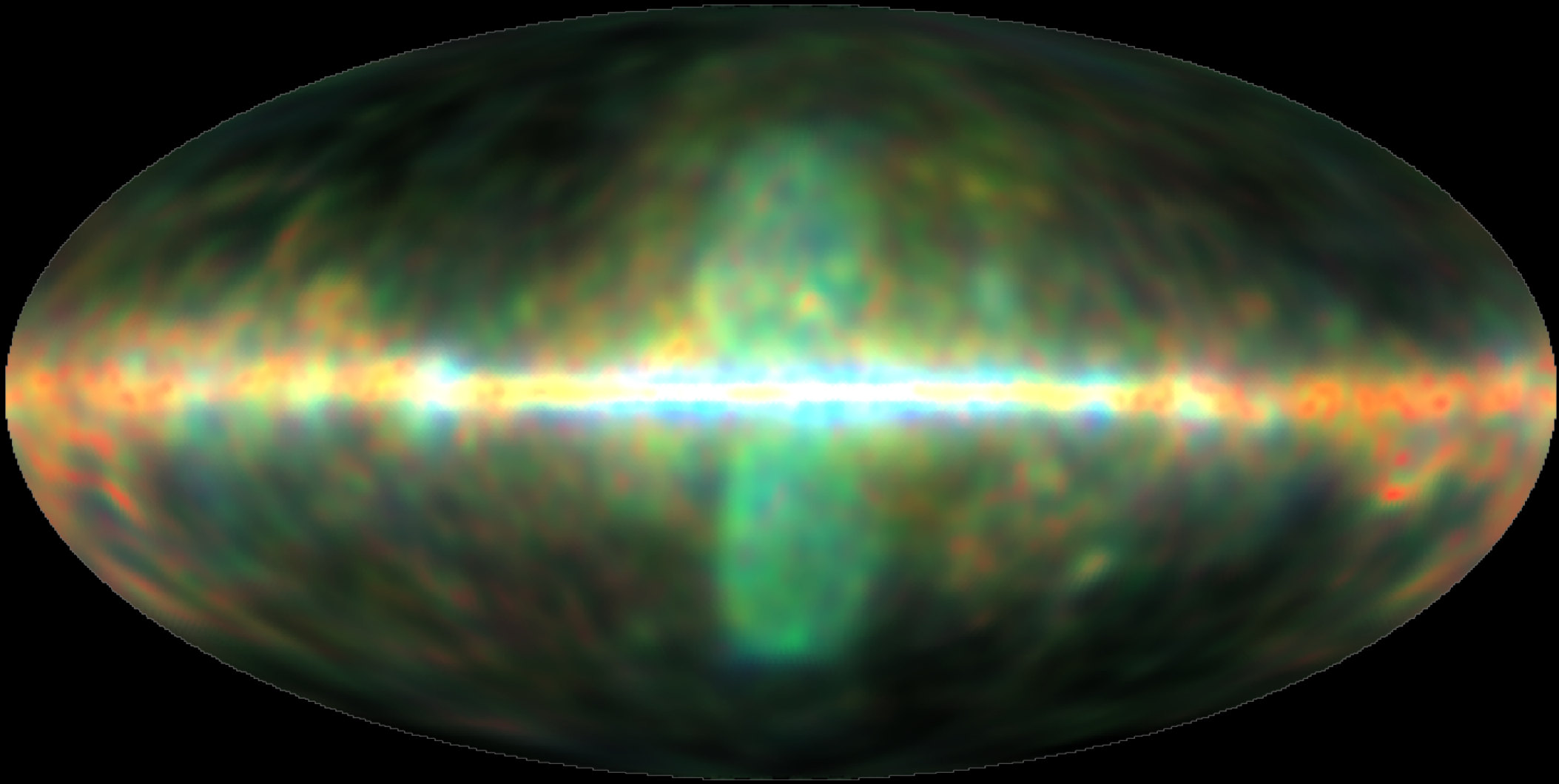






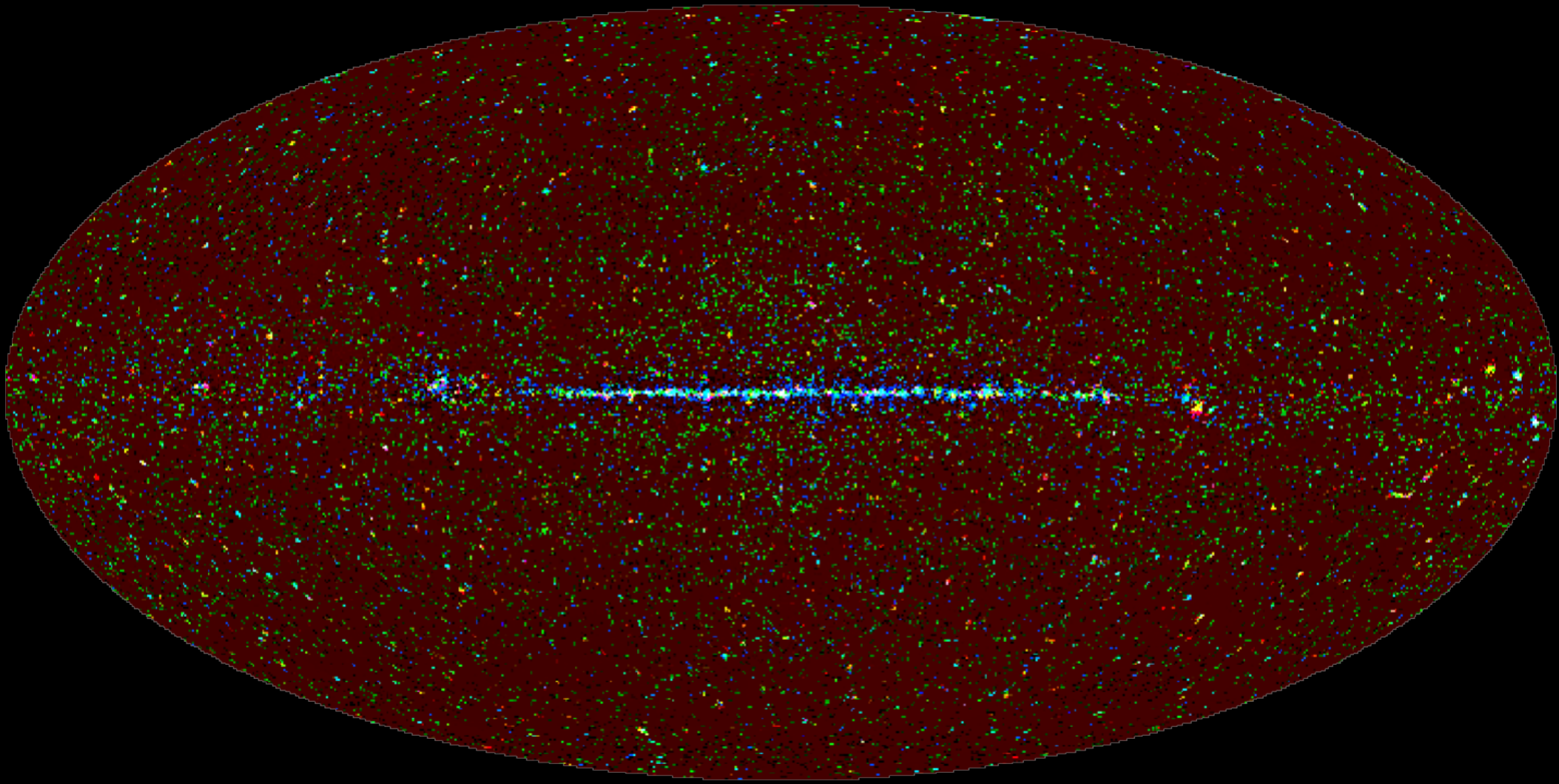
log-data

Selig, Vacca, Oppermann, Enßlin (2015)

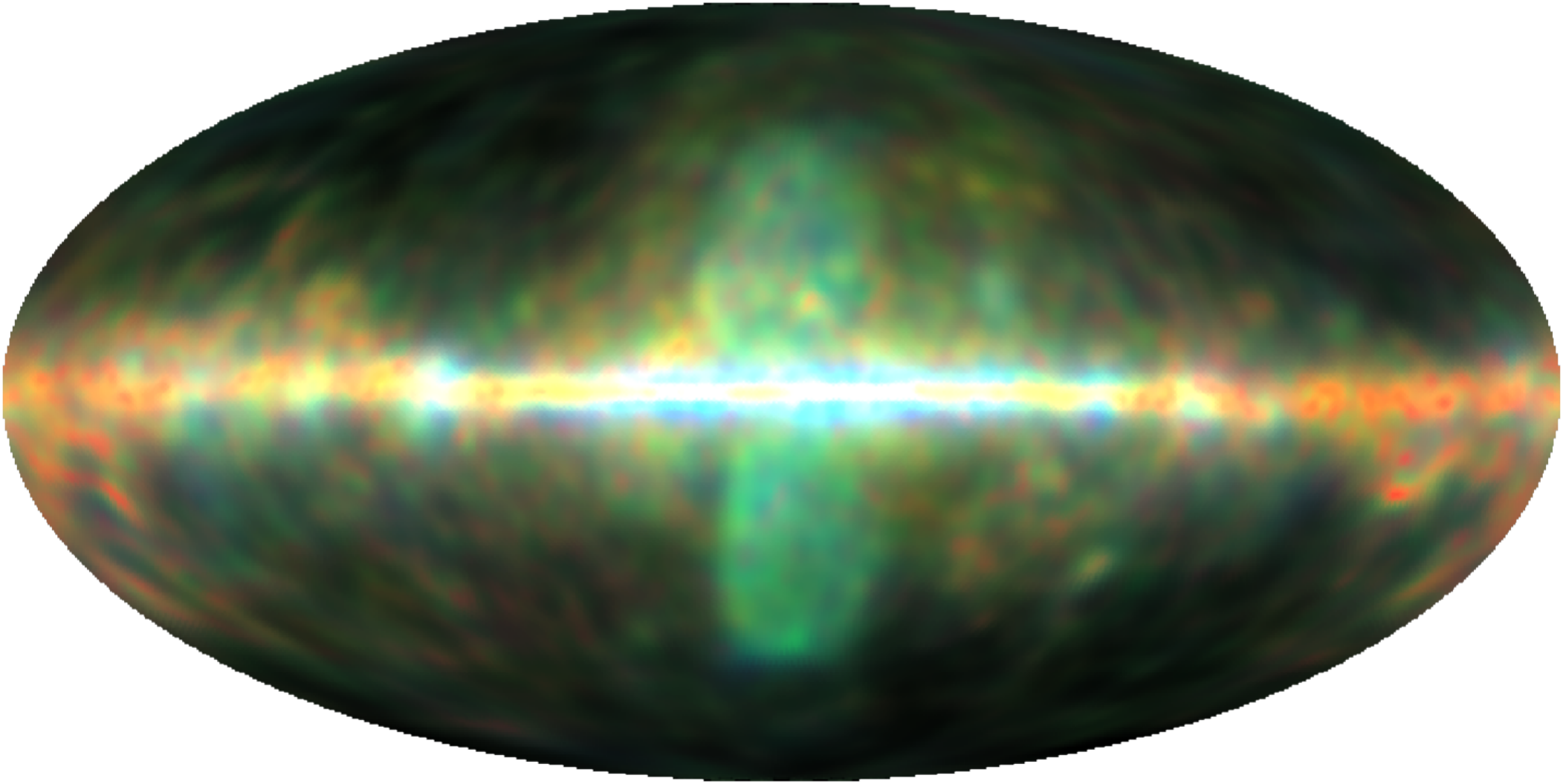


log-data … denoised … deconvolved … decomposed

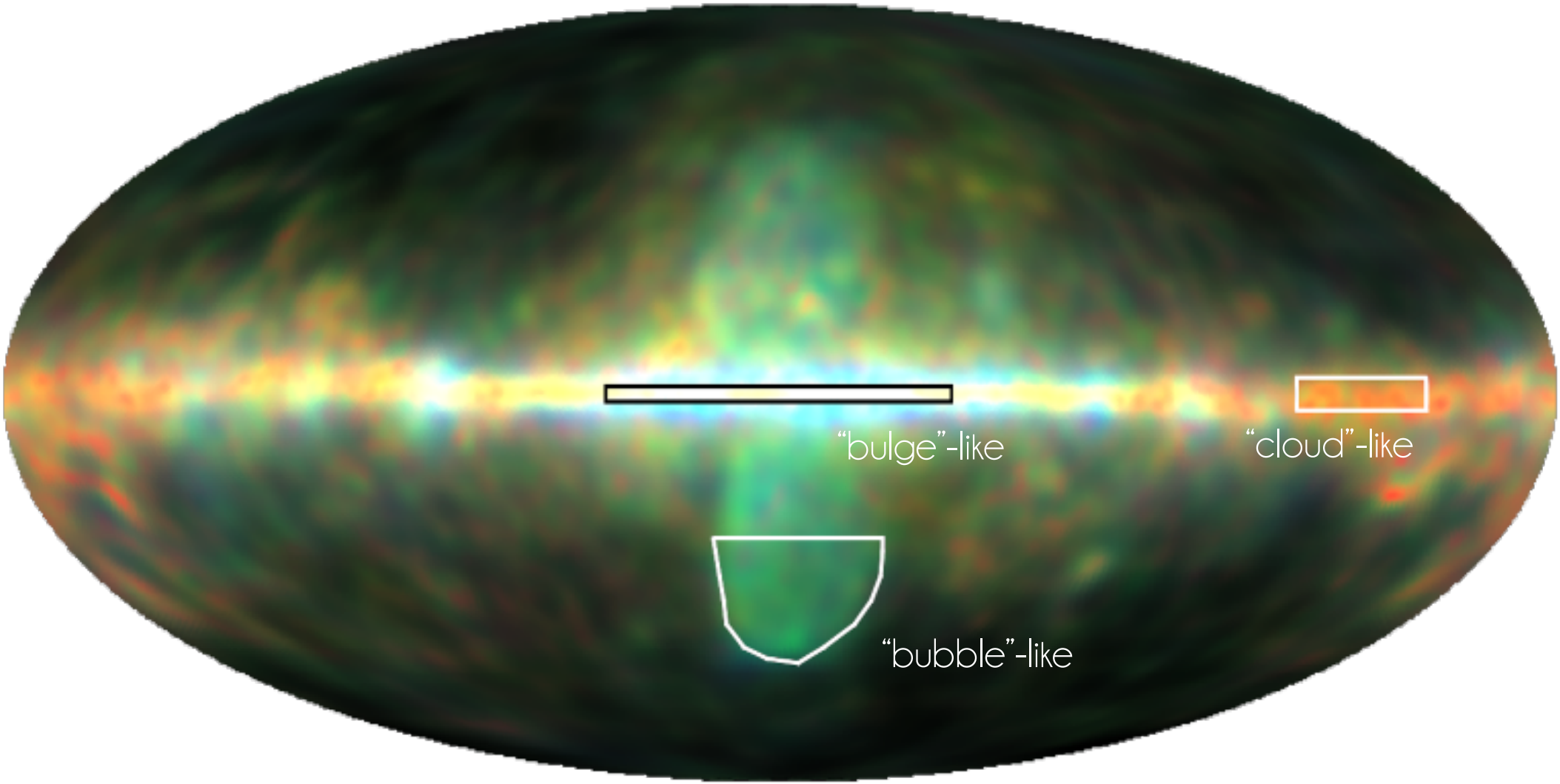
Selig, Vacca, Oppermann, Enßlin (2015)



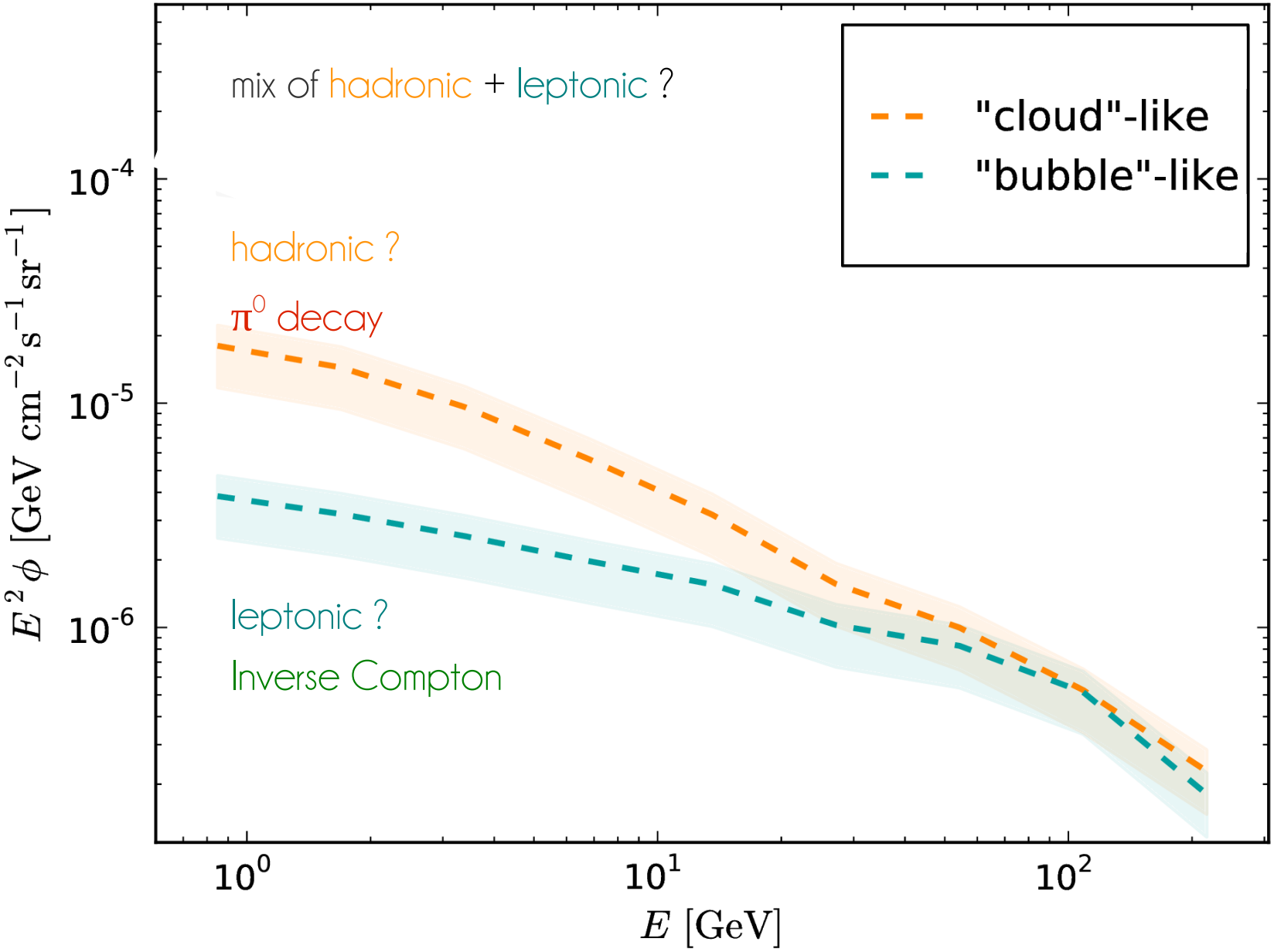
Diffuse gamma-ray sky



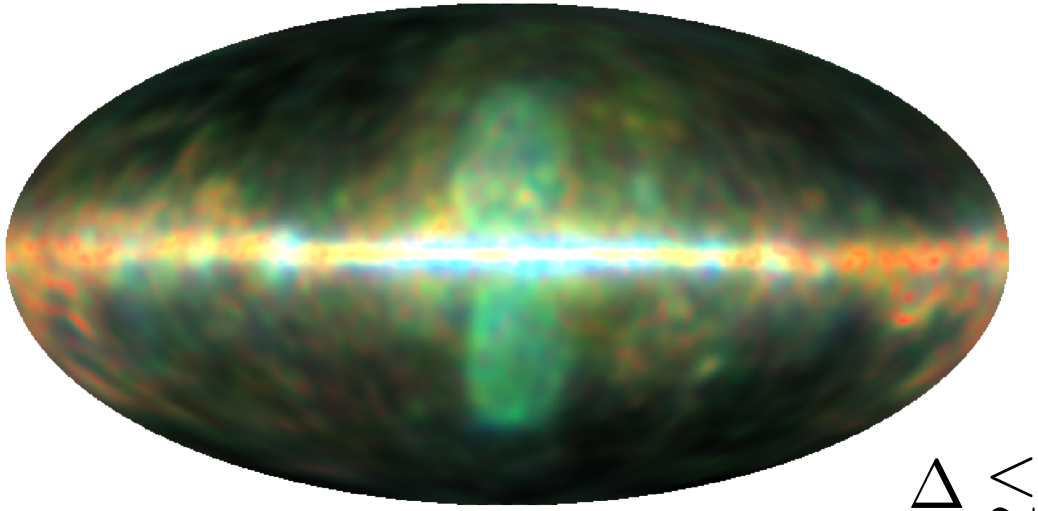
Diffuse gamma-ray sky



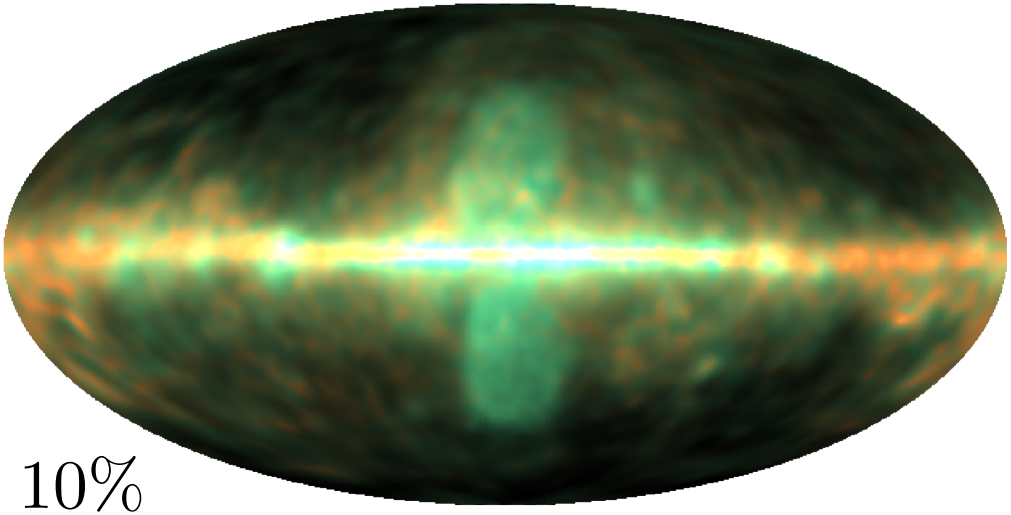
Spectra of diffuse components



diffuse flux

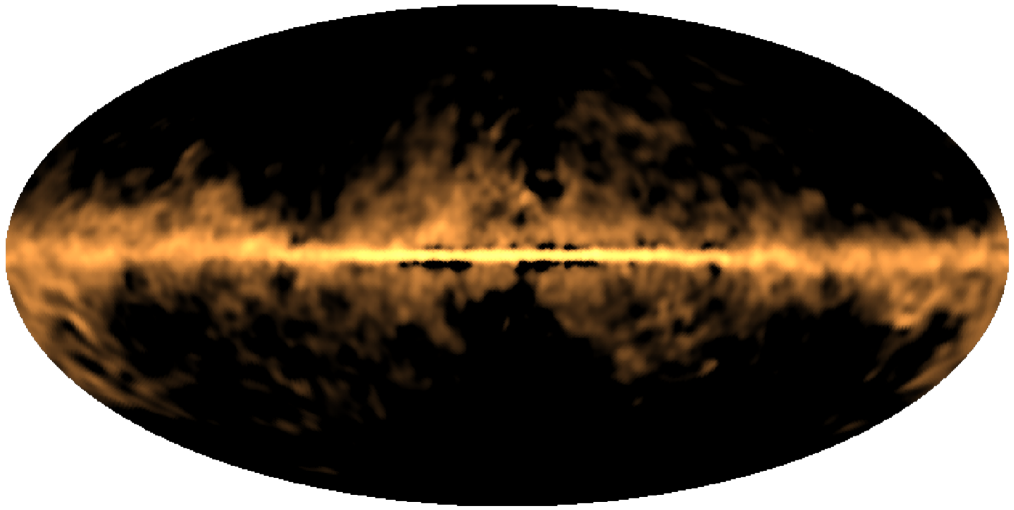


superposition

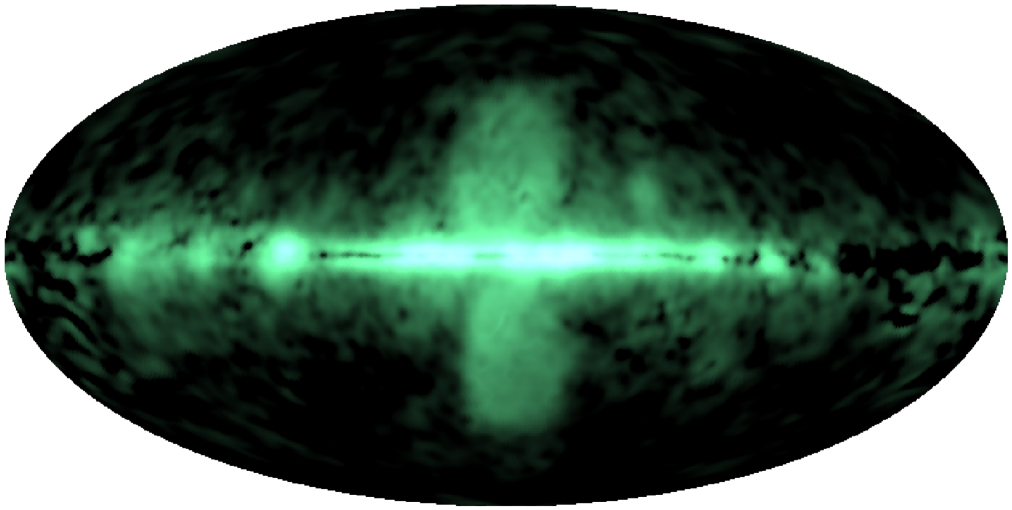


$\Delta \lesssim 10\%$

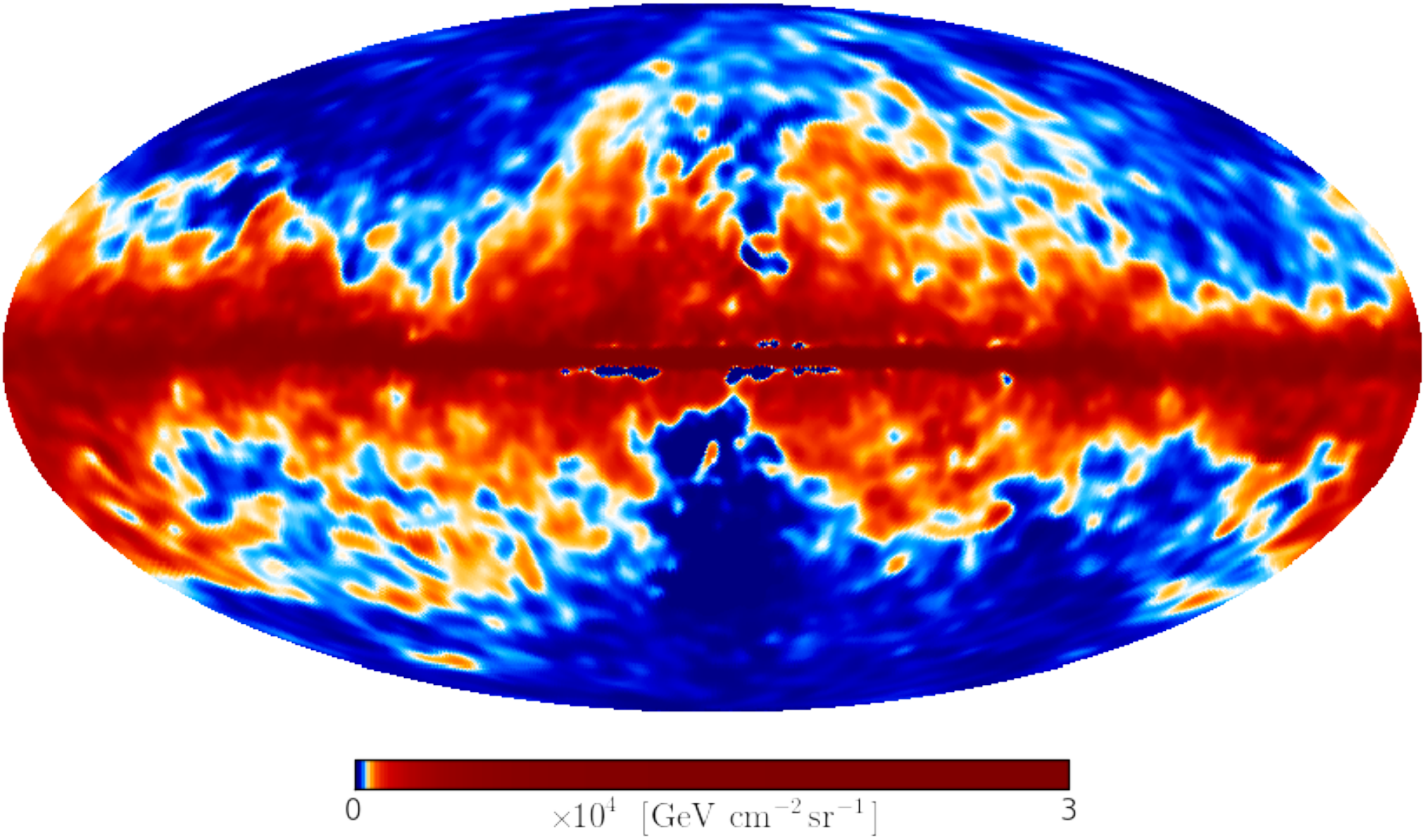
“cloud”-like



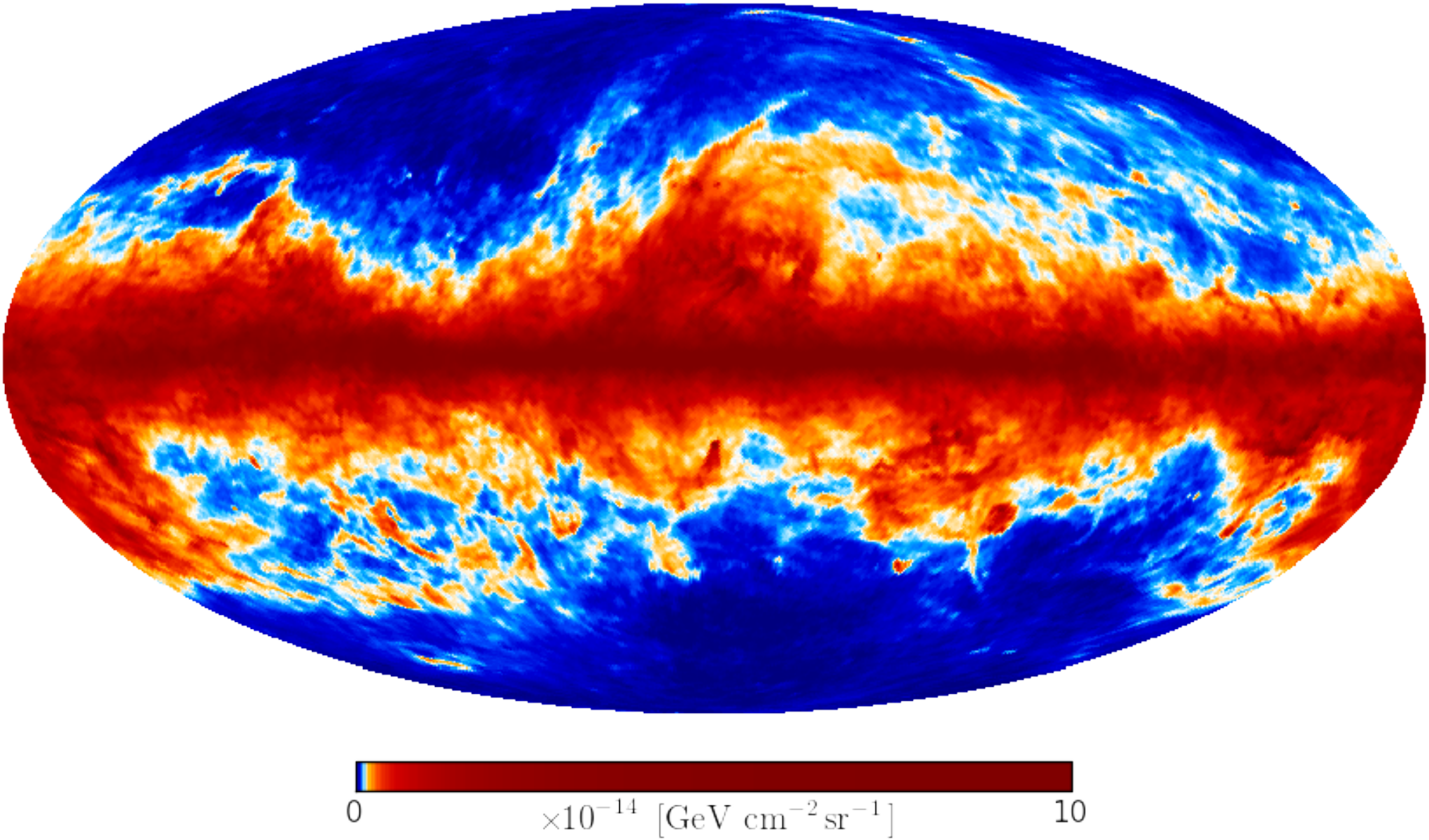
“bubble”-like

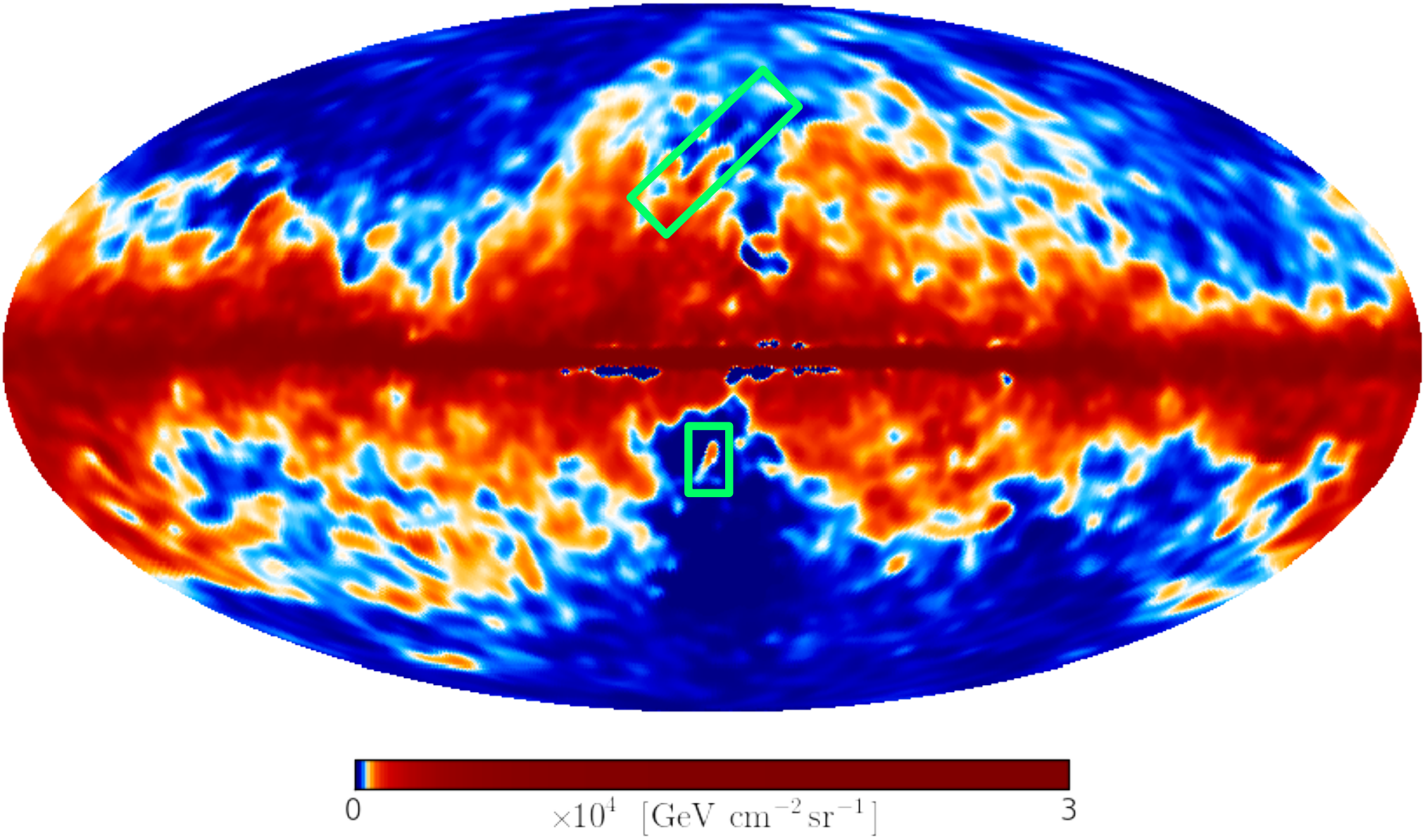


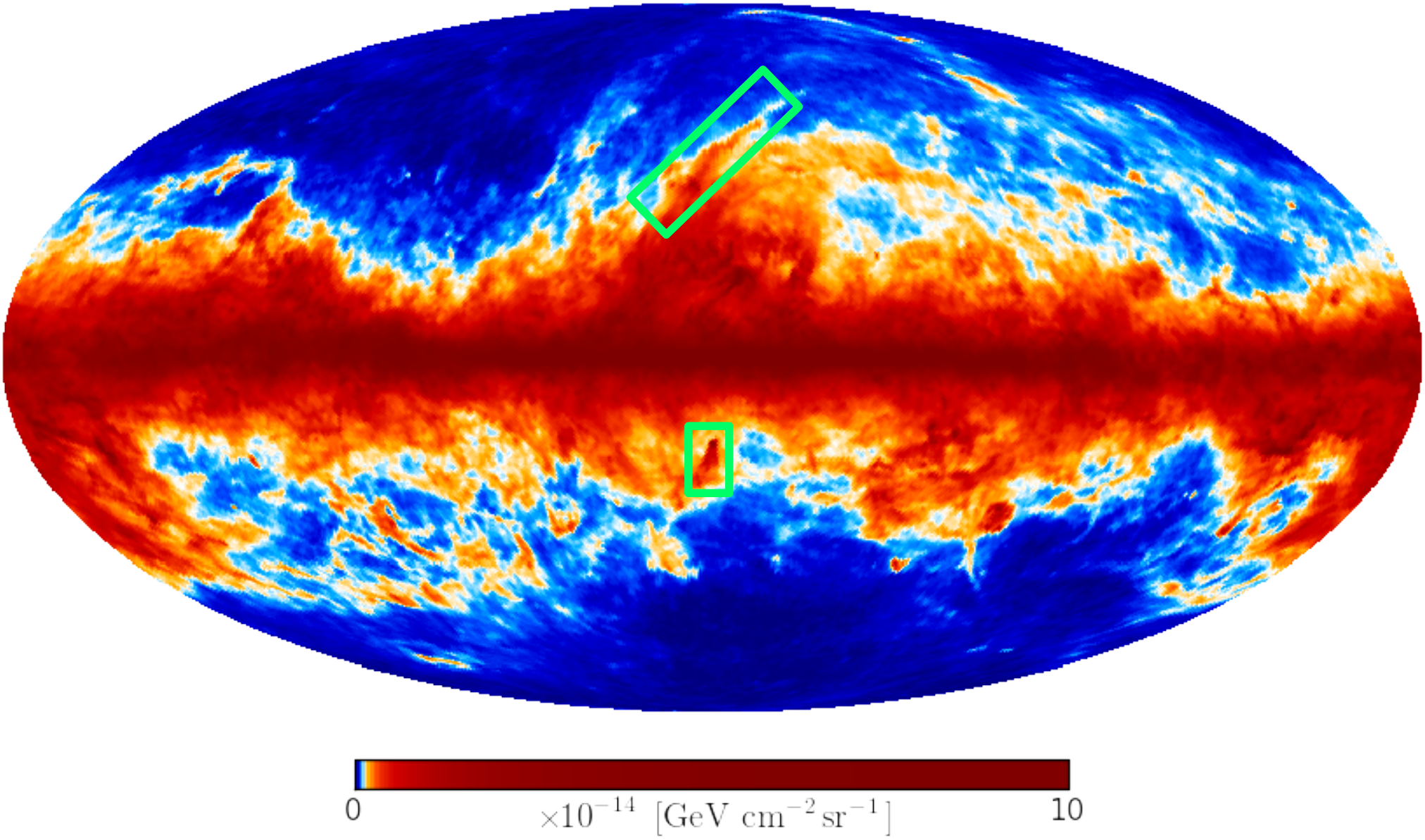
"cloud"-like



Planck dust map




0
3
$\times 10^4$ [GeV cm^{-2} sr^{-1}]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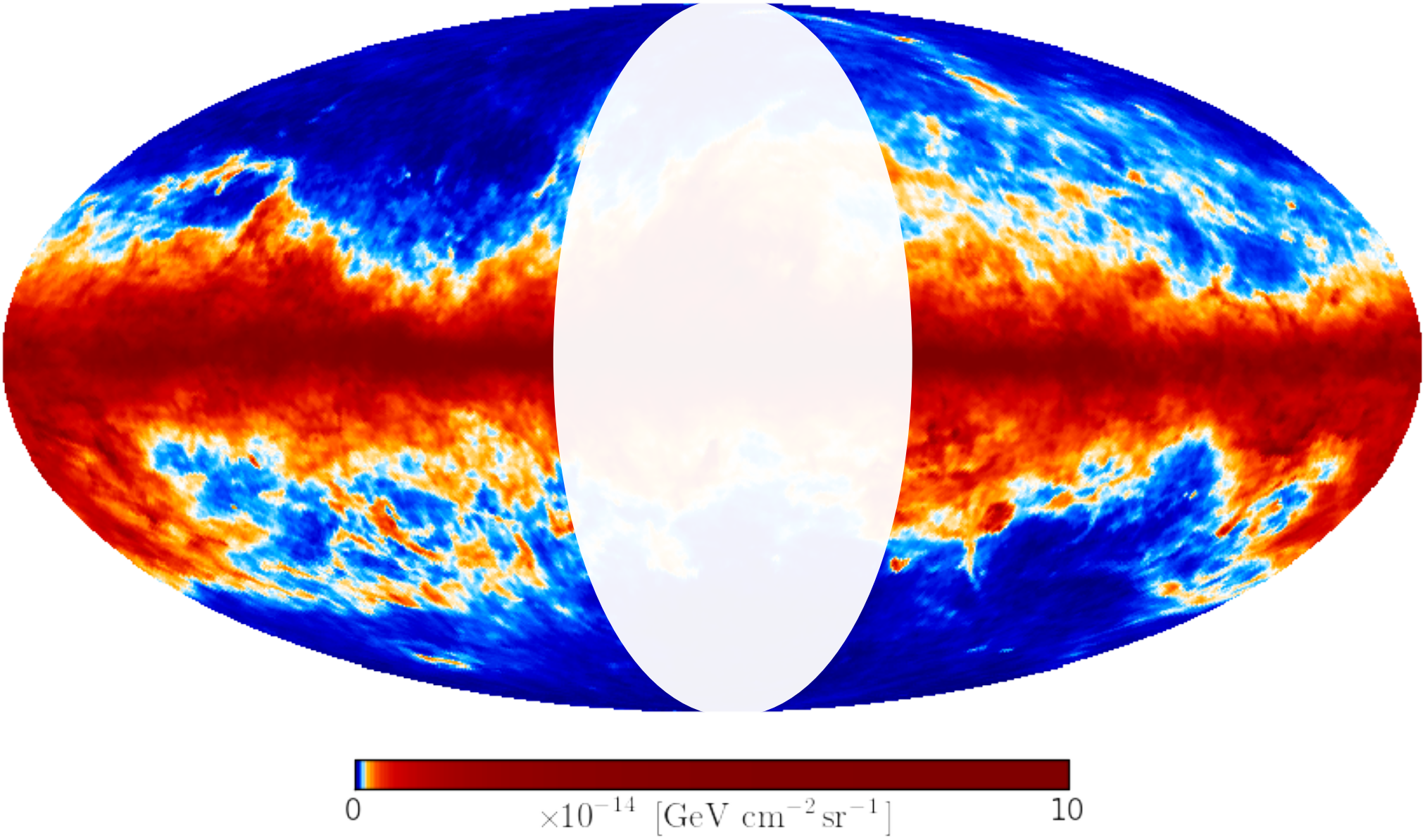
10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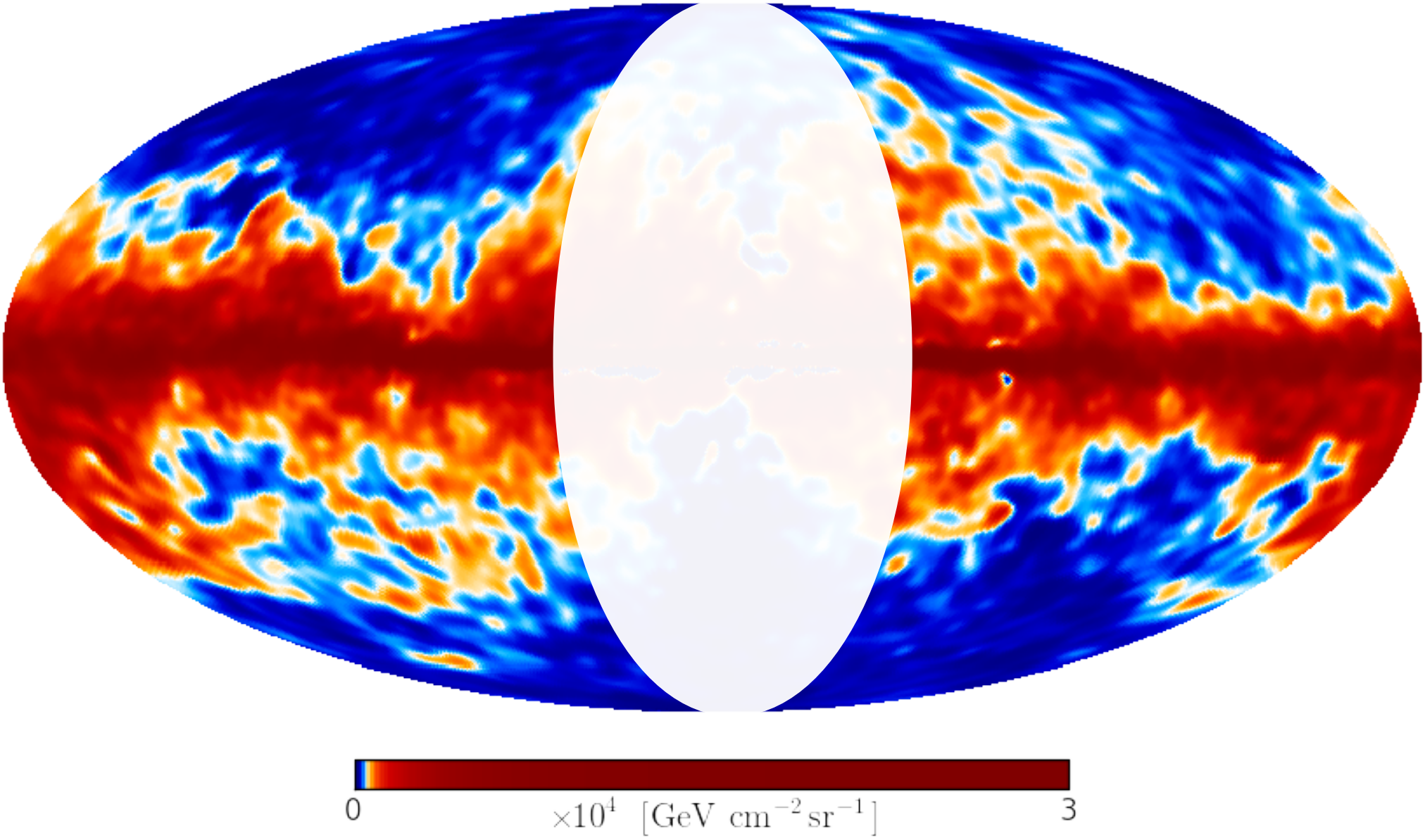
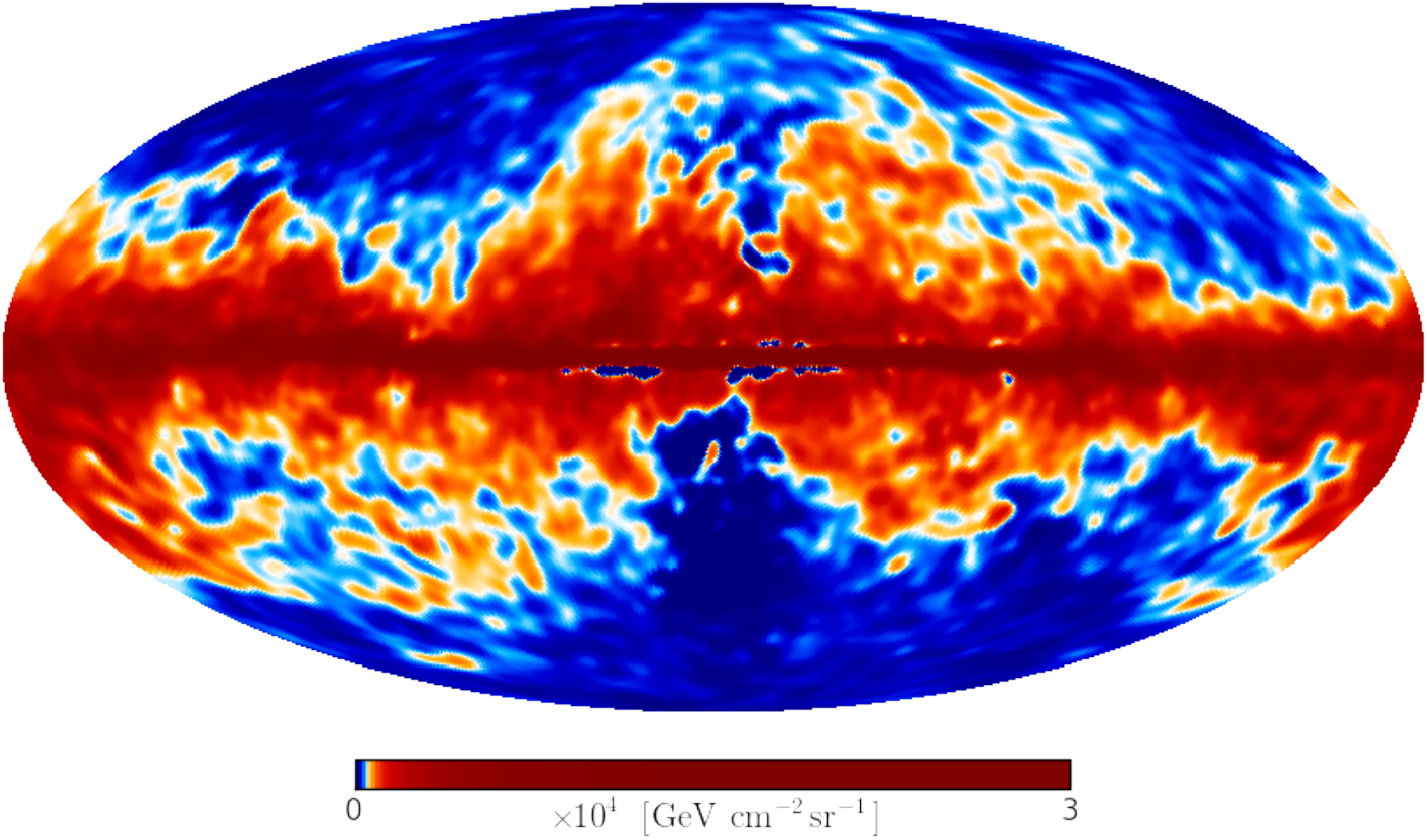
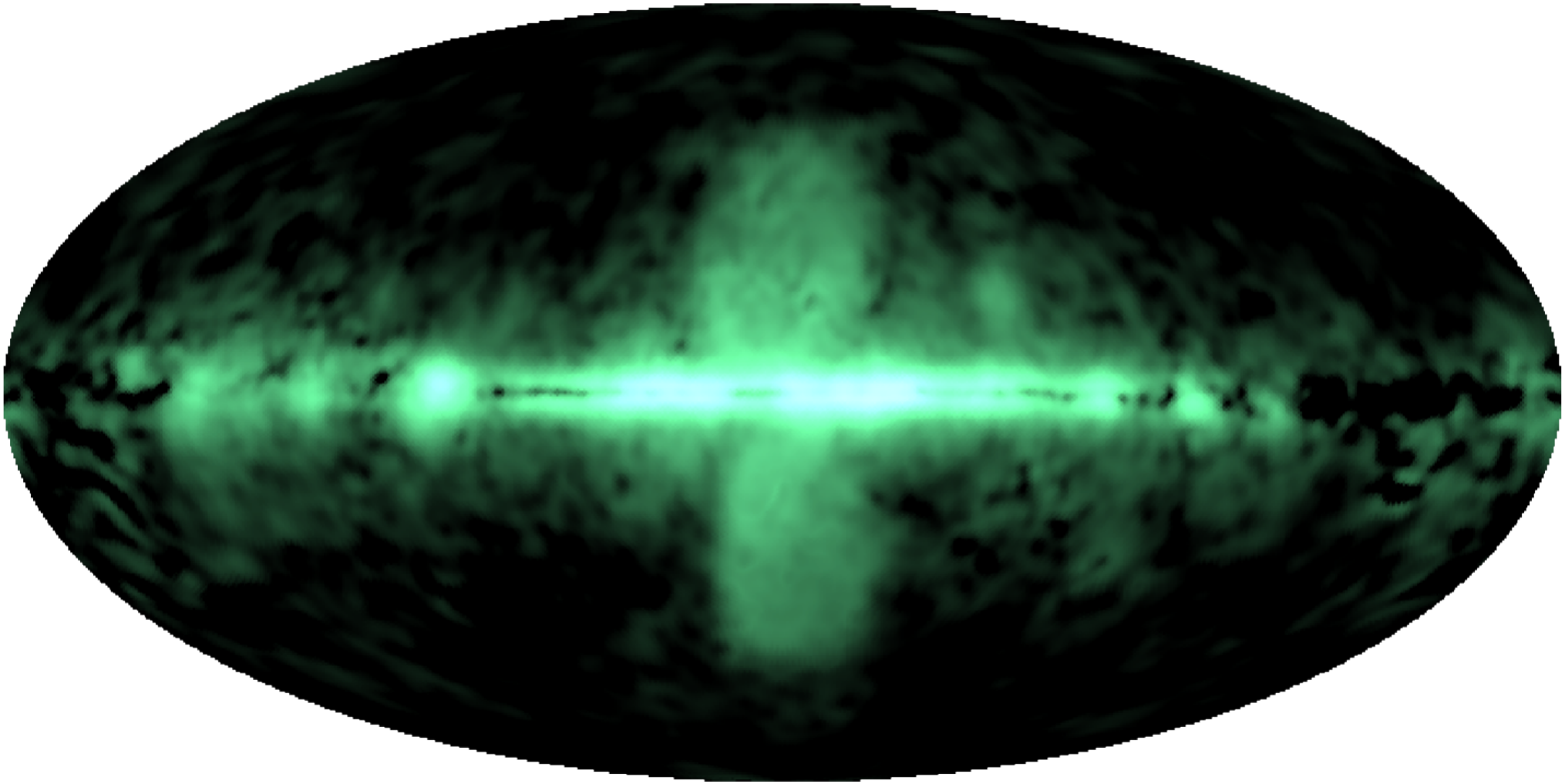
10


0
3
$\times 10^4$ [GeV cm^{-2} sr^{-1}]

“cloud”-like = cold/dense ISM

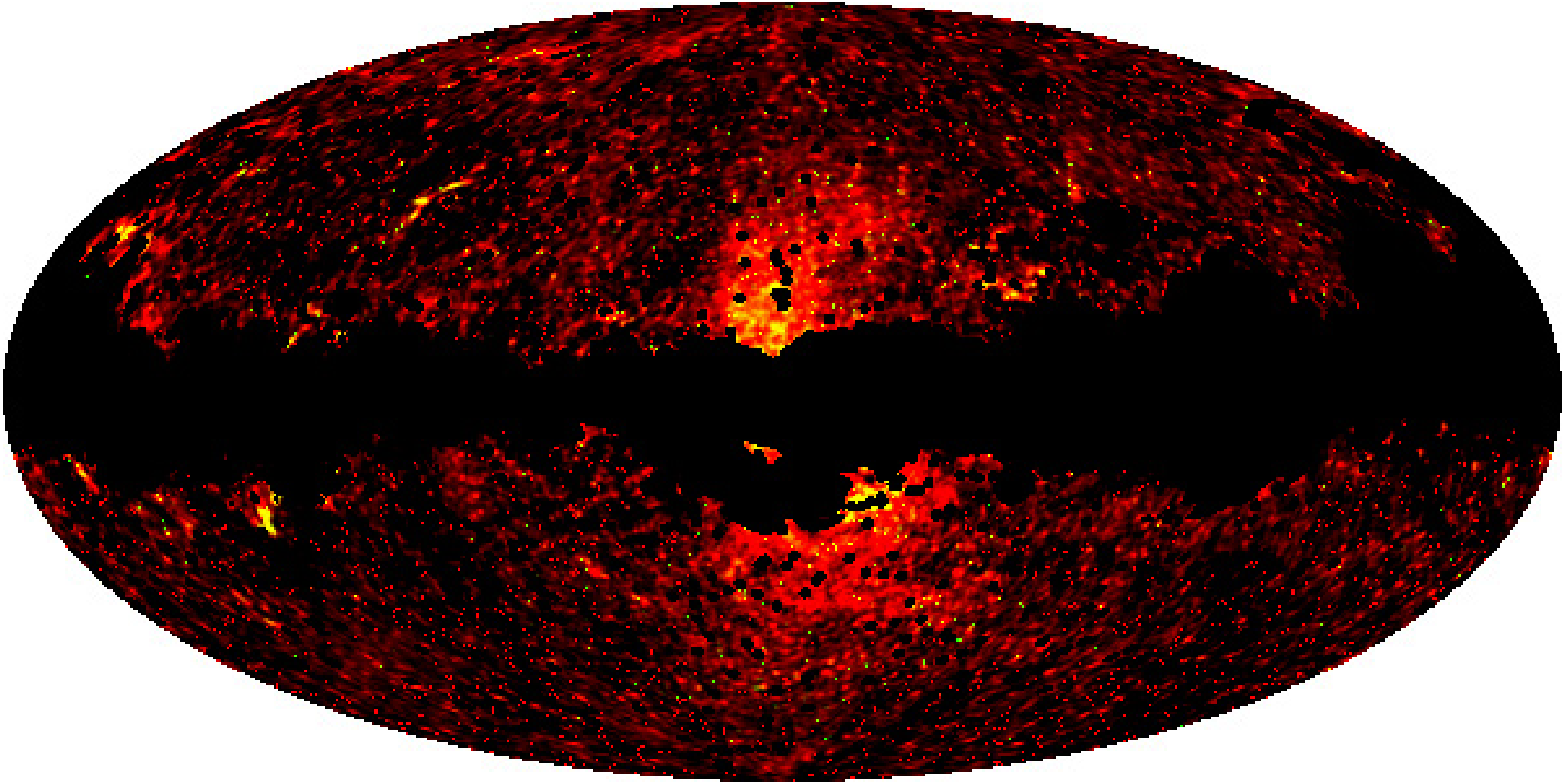


bubble-like



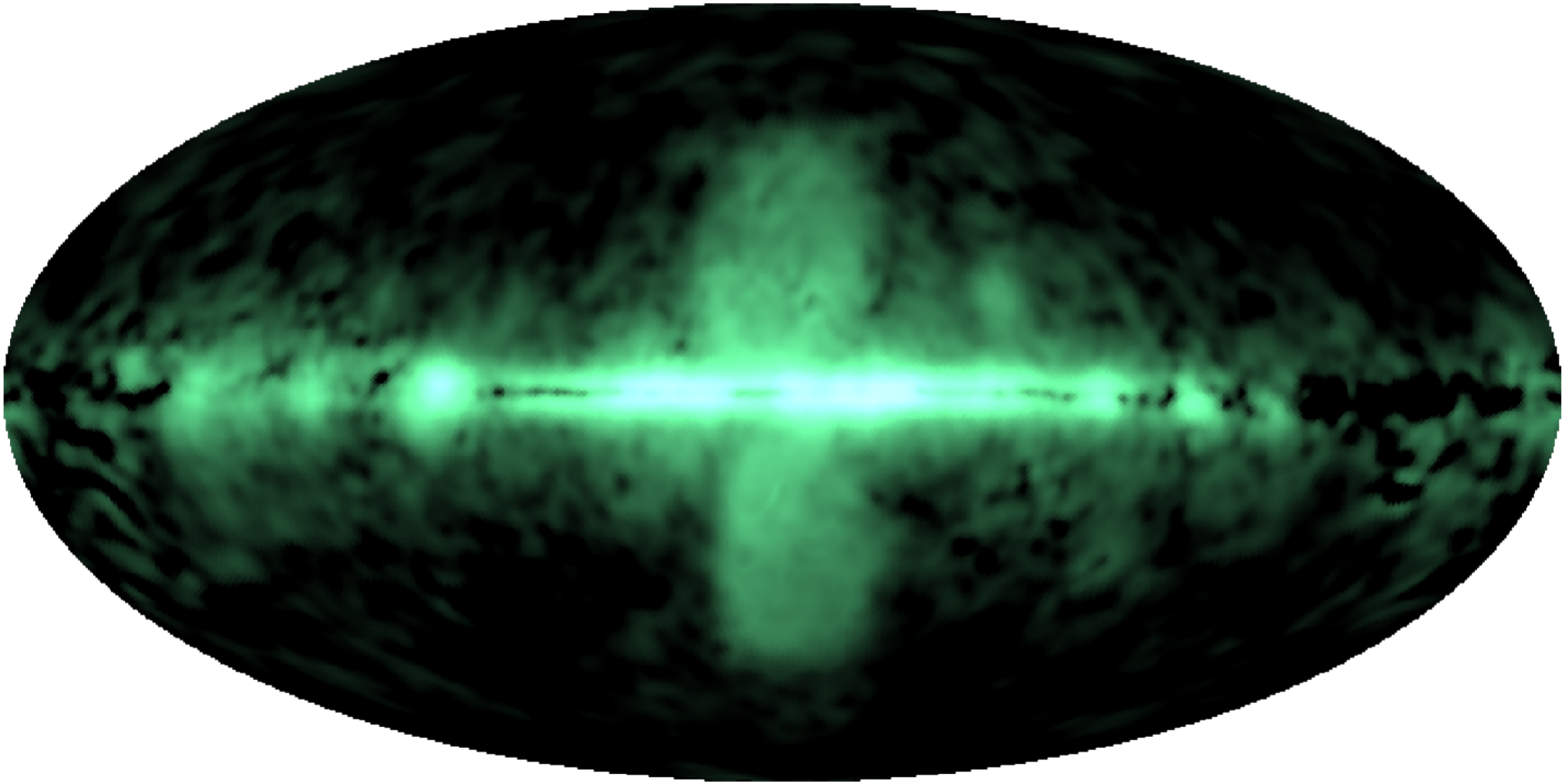
Photon spectral index: **2.4** – Inverse Compton?

Panck-haze @ 30GHz (Planck 2013)

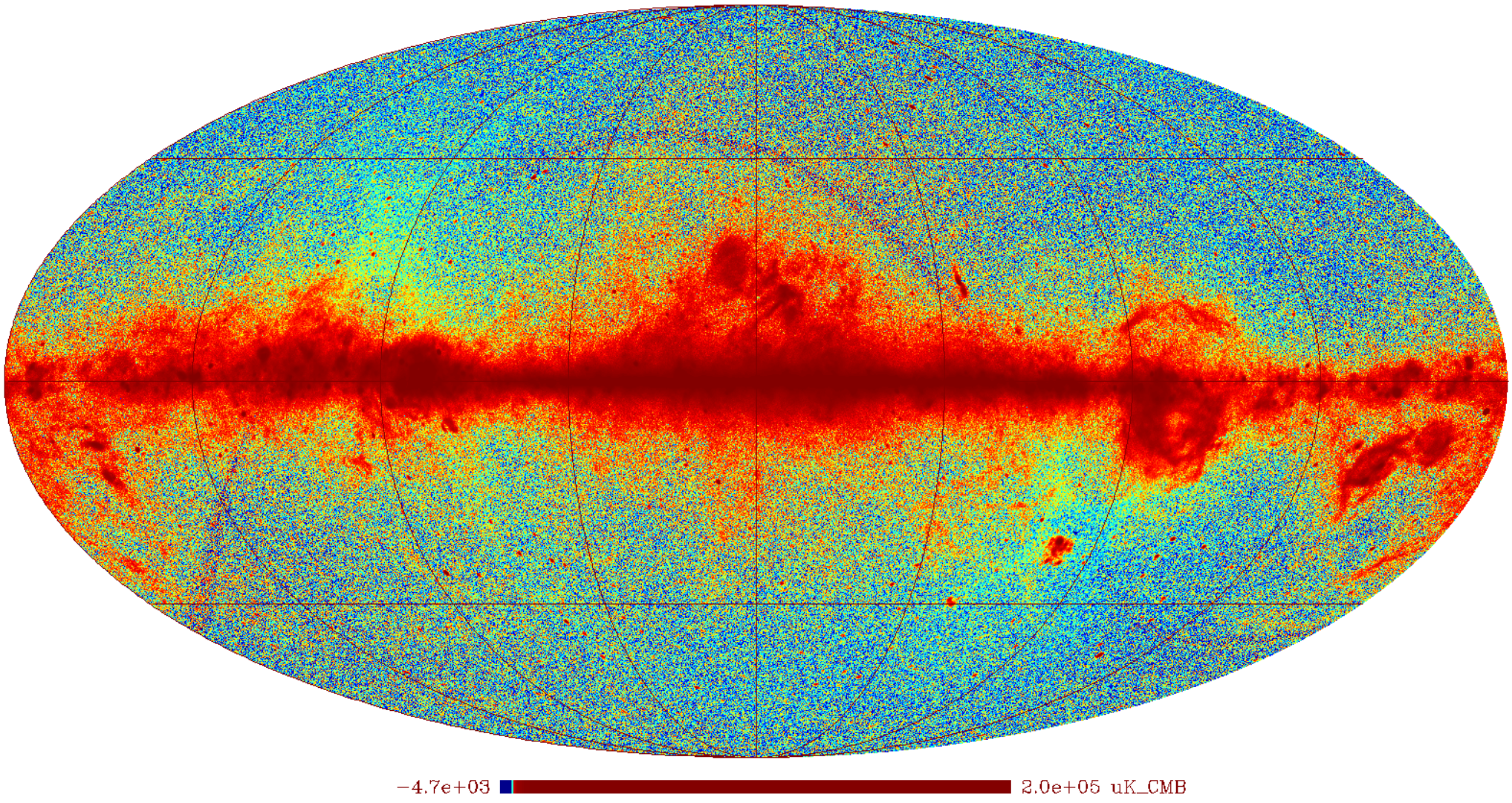


Photon spectral index: **2.56** – Synchrotron?

bubble-like

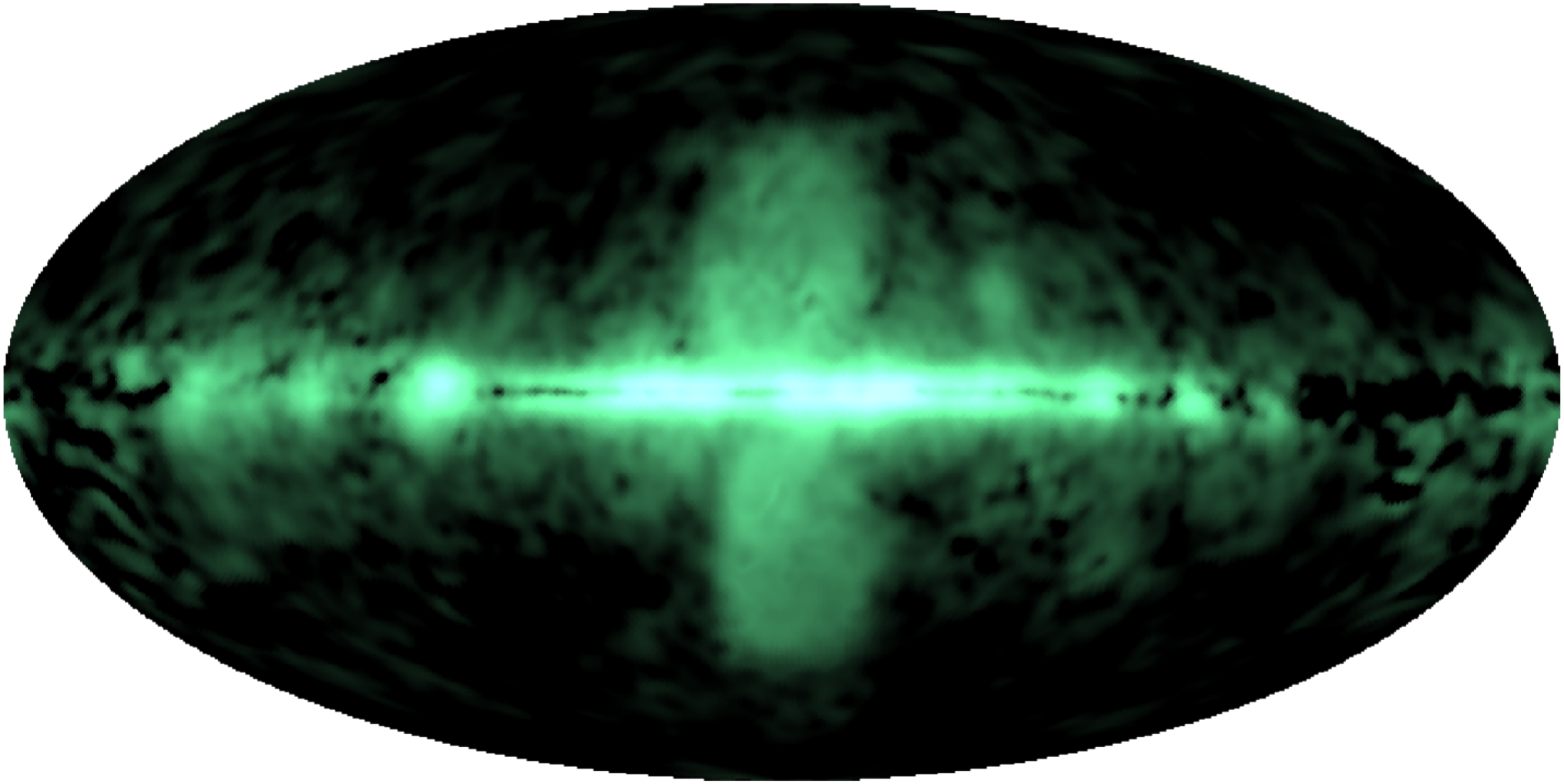


Planck 2013 low frequency component

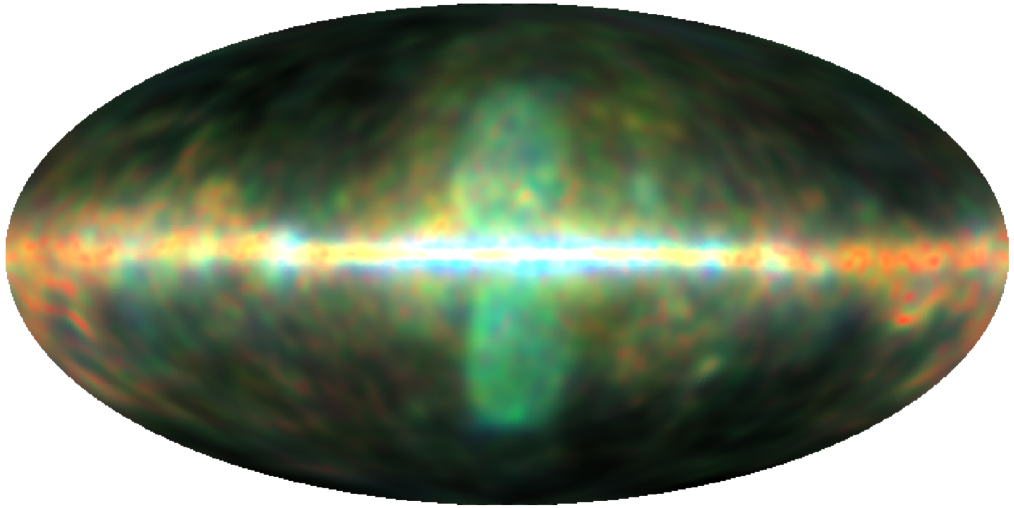


Free-free and synchrotron emission tracing hot ISM

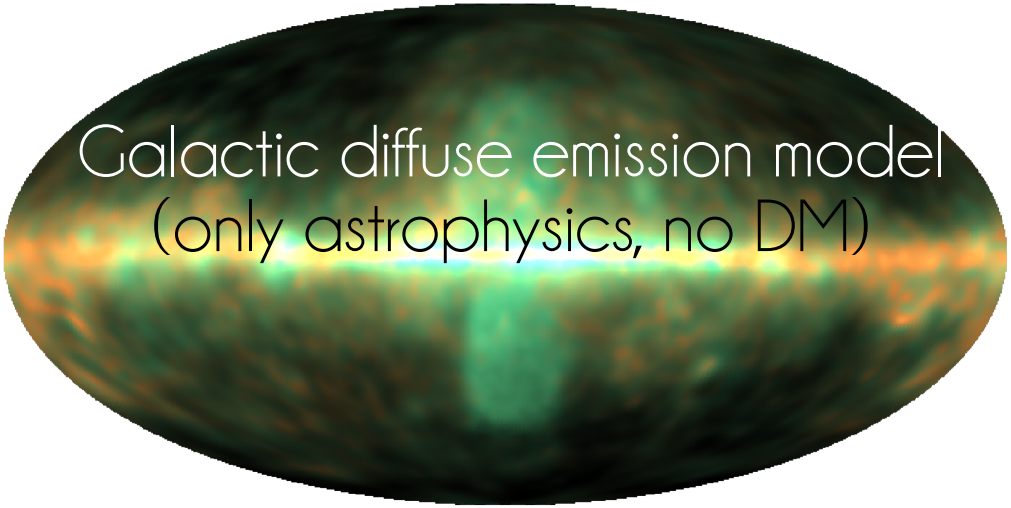
“buble”-like = hot/dilute ISM



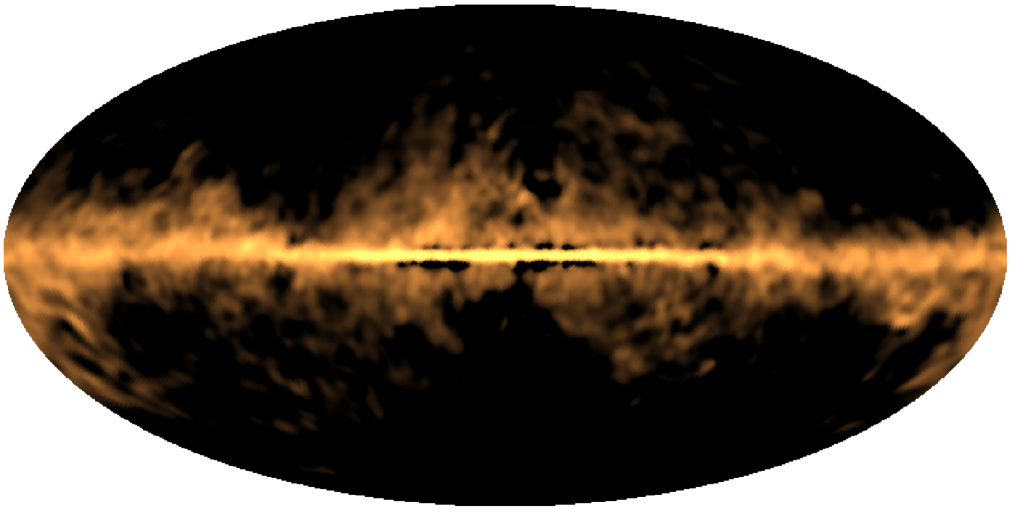
diffuse flux



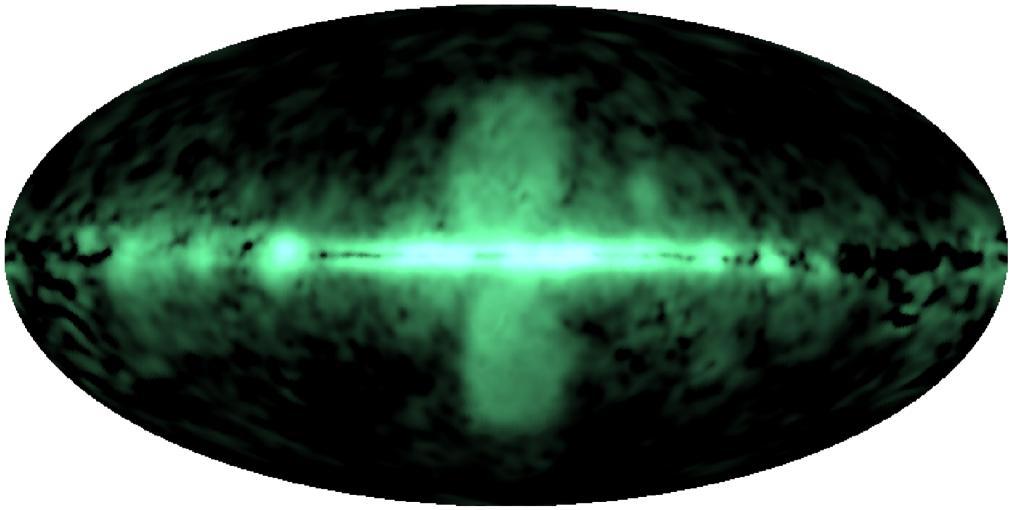
superposition



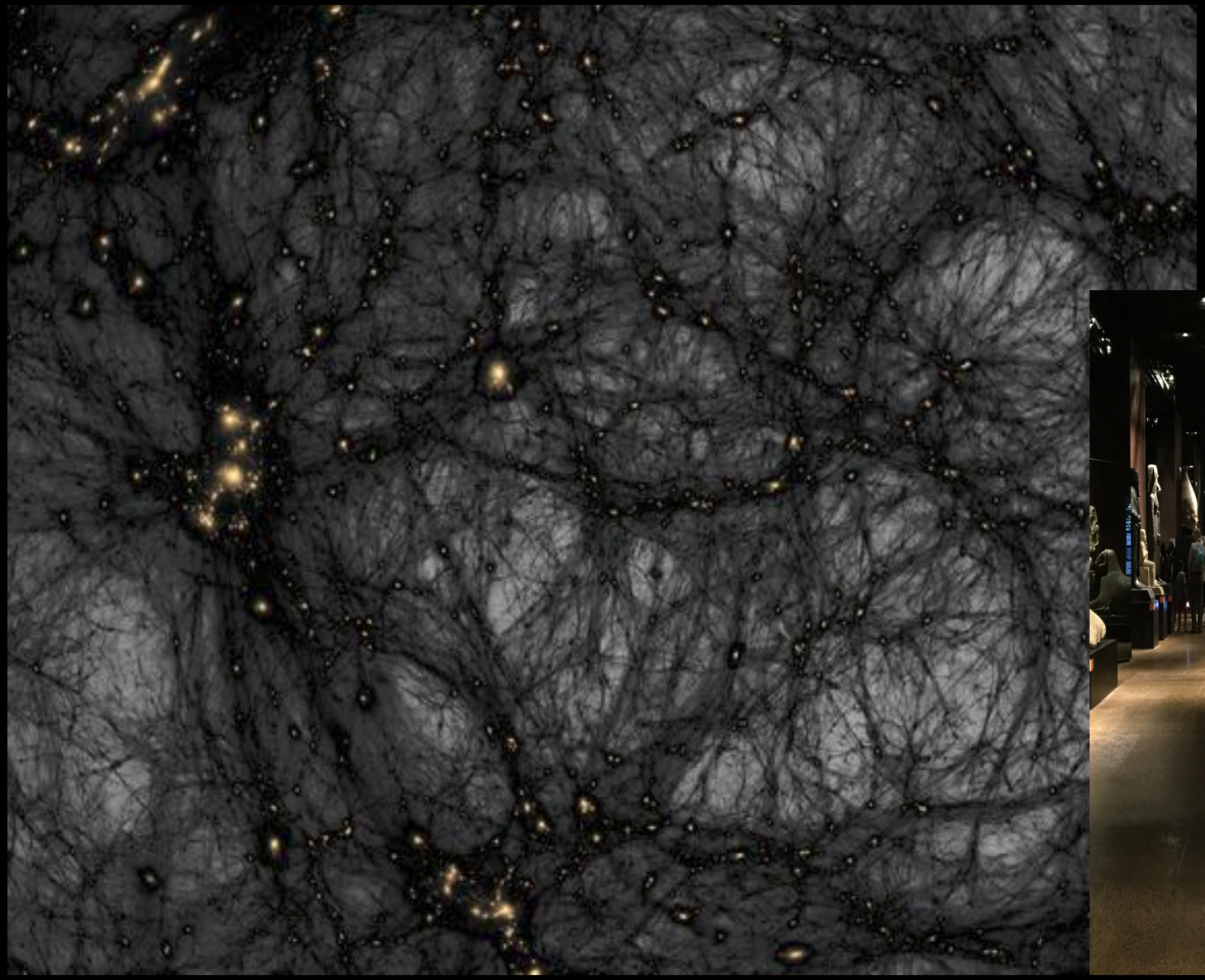
“cloud”-like = cold ISM



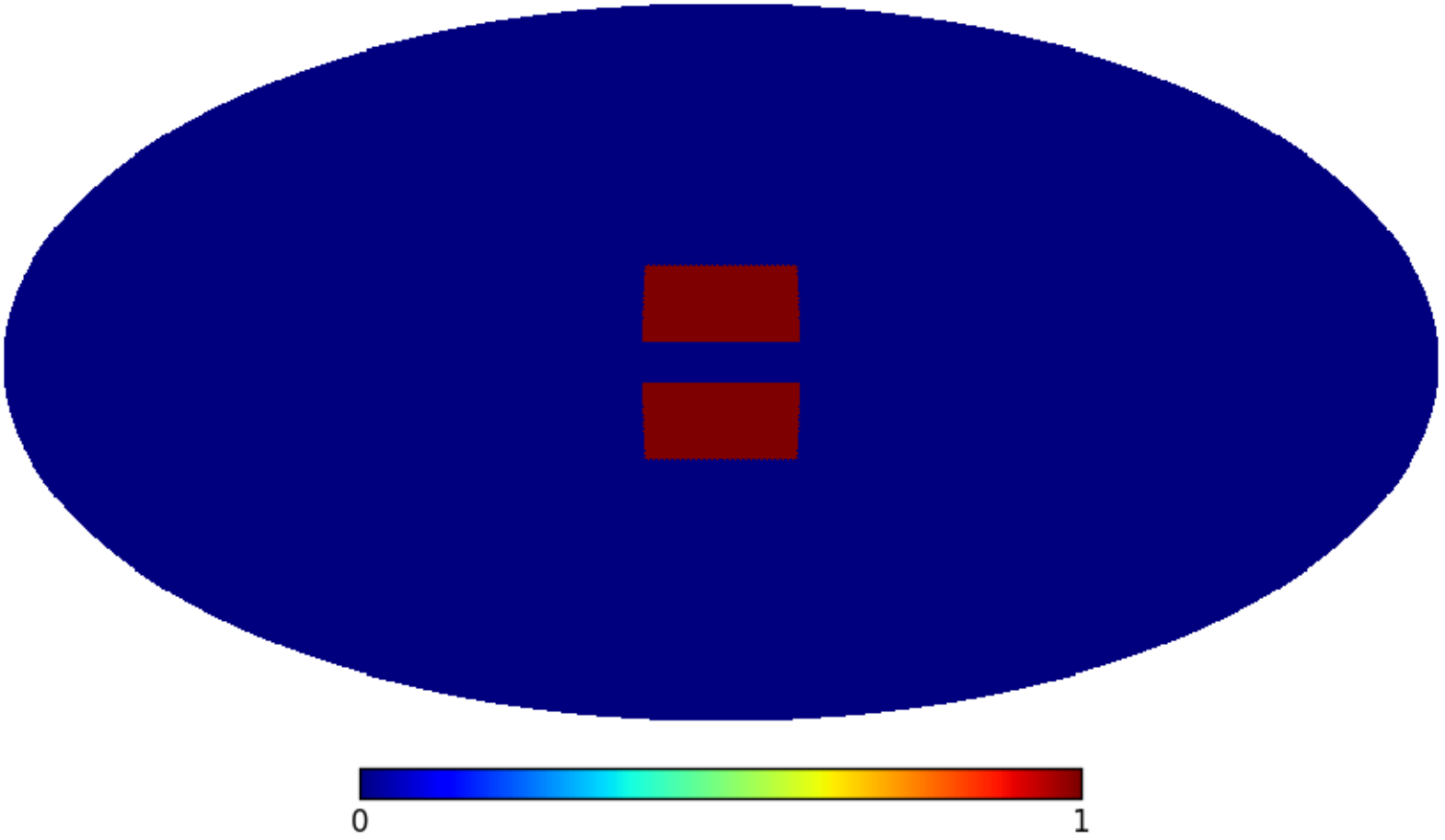
“bubble”-like = hot ISM



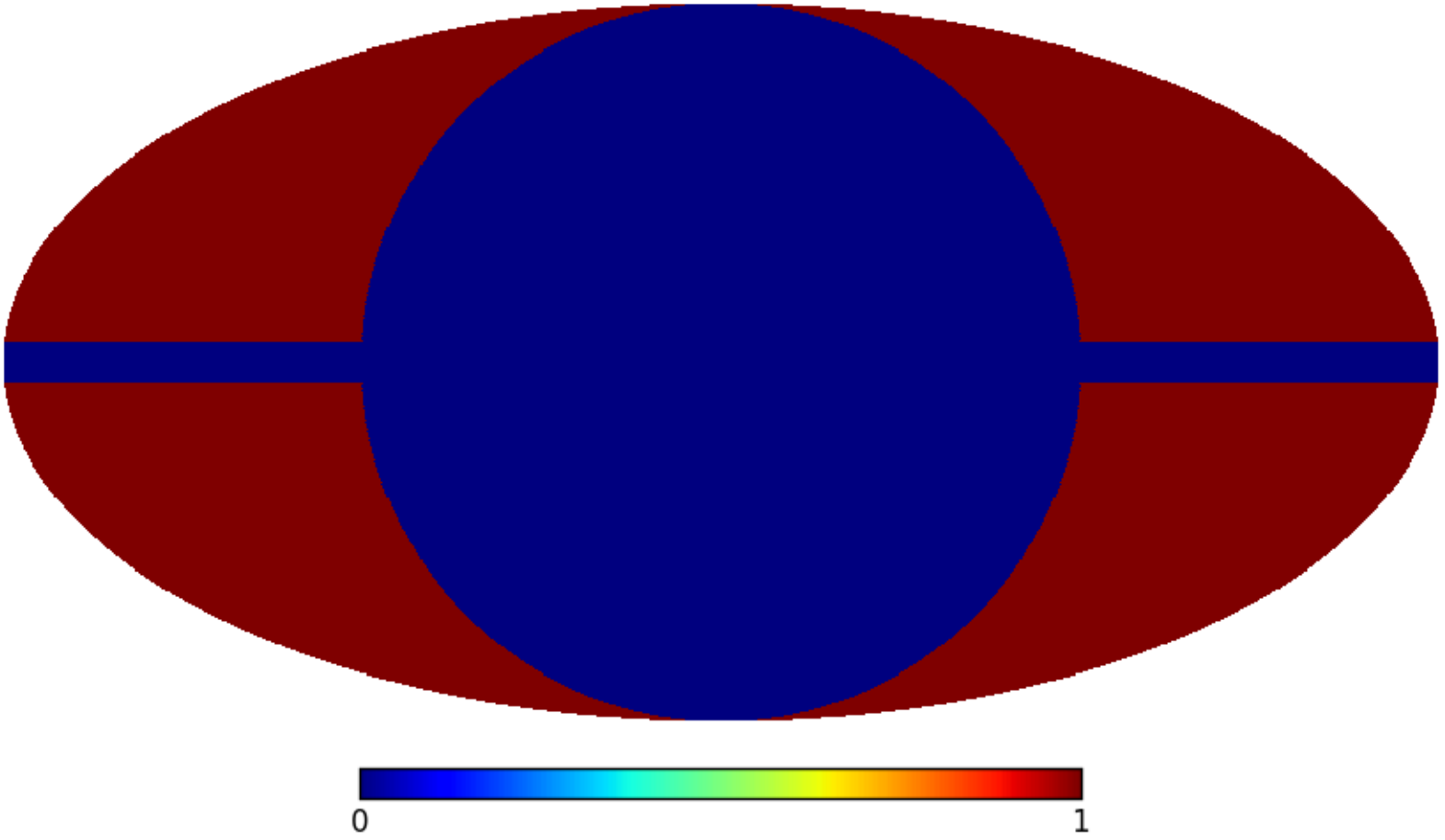
Let's hunt dark matter



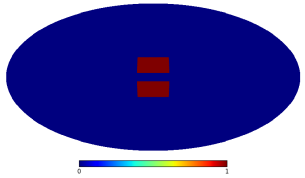
Primary region of interest

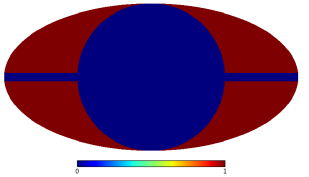


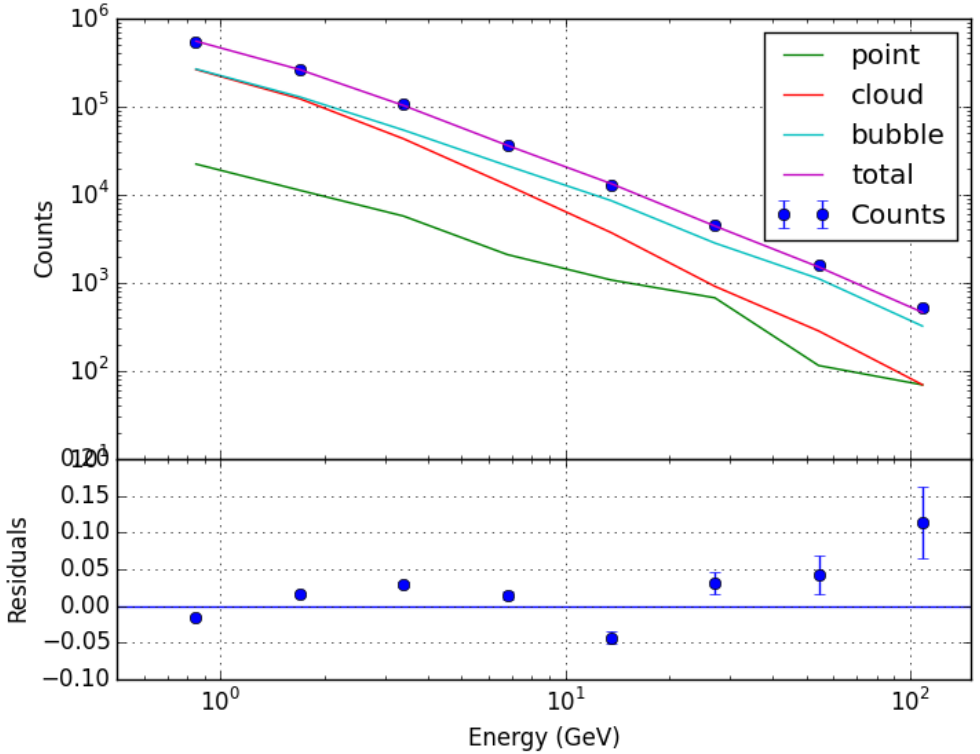
Test region of interest

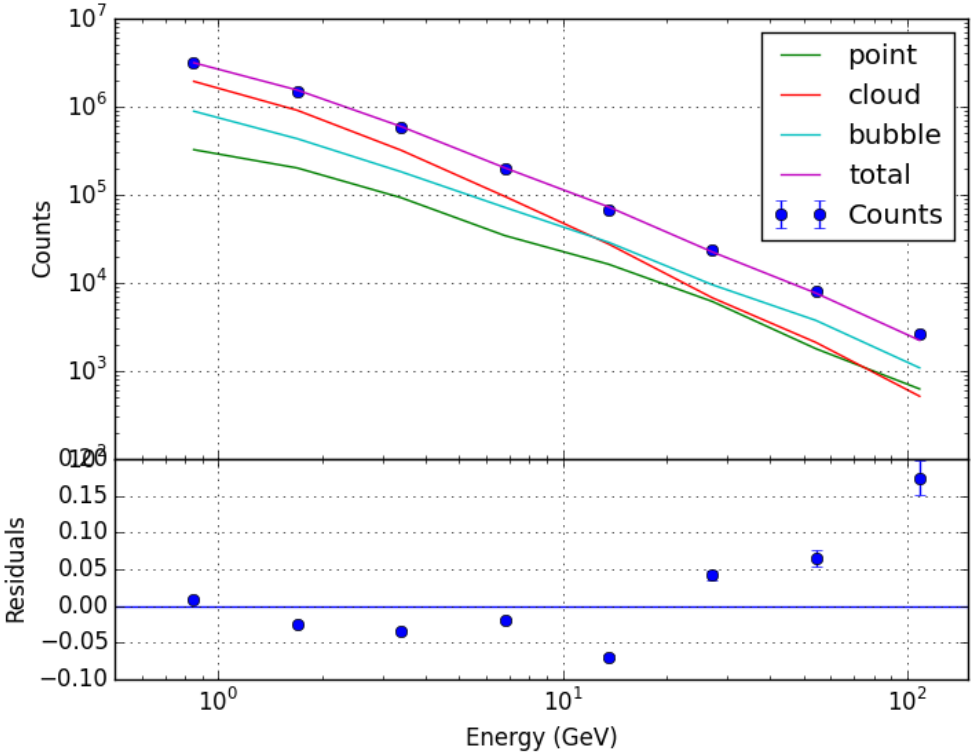


Photon counts









DM annihilation likelihood

$$\chi^2(p) \equiv -2\sum_i \ln L_i\left(d_i|p\right)$$

Pixel
Energy bin
Detector (front/back)

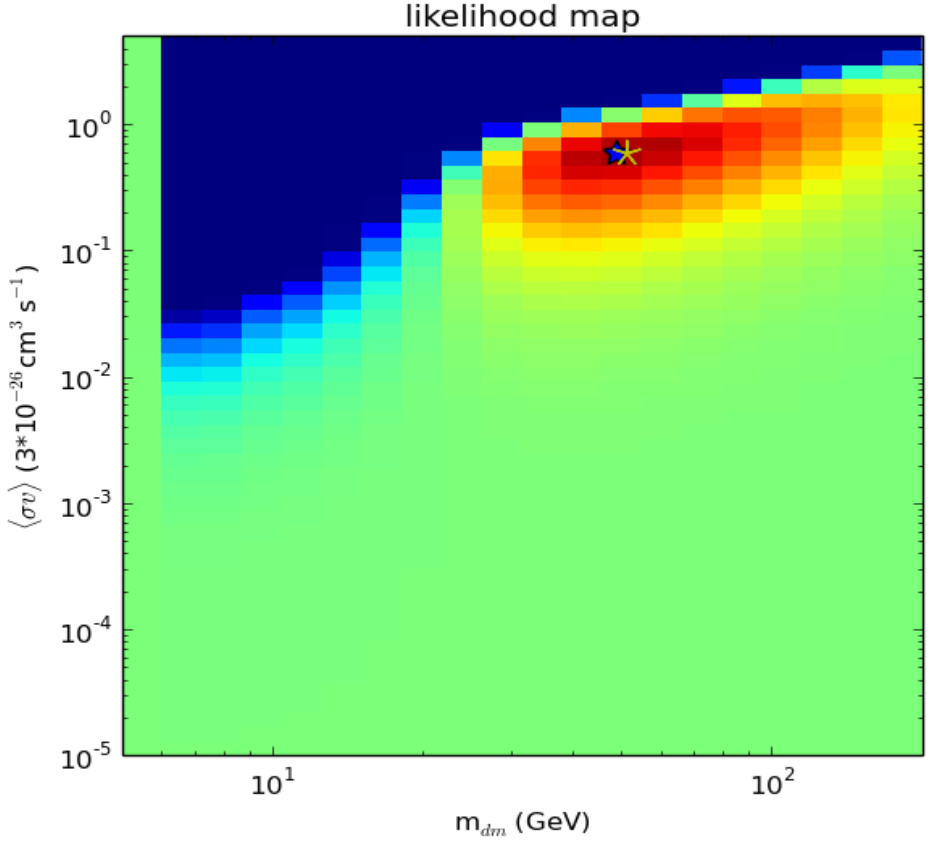
$$\ln L_i\left(d_i|p\right) = \sum_{jk}\left[n_{\rm obs}^{ijk}\ln\lambda^{ijk} - \lambda^{ijk} + \ln\left(n_{\rm obs}^{ijk}!\right)\right]$$

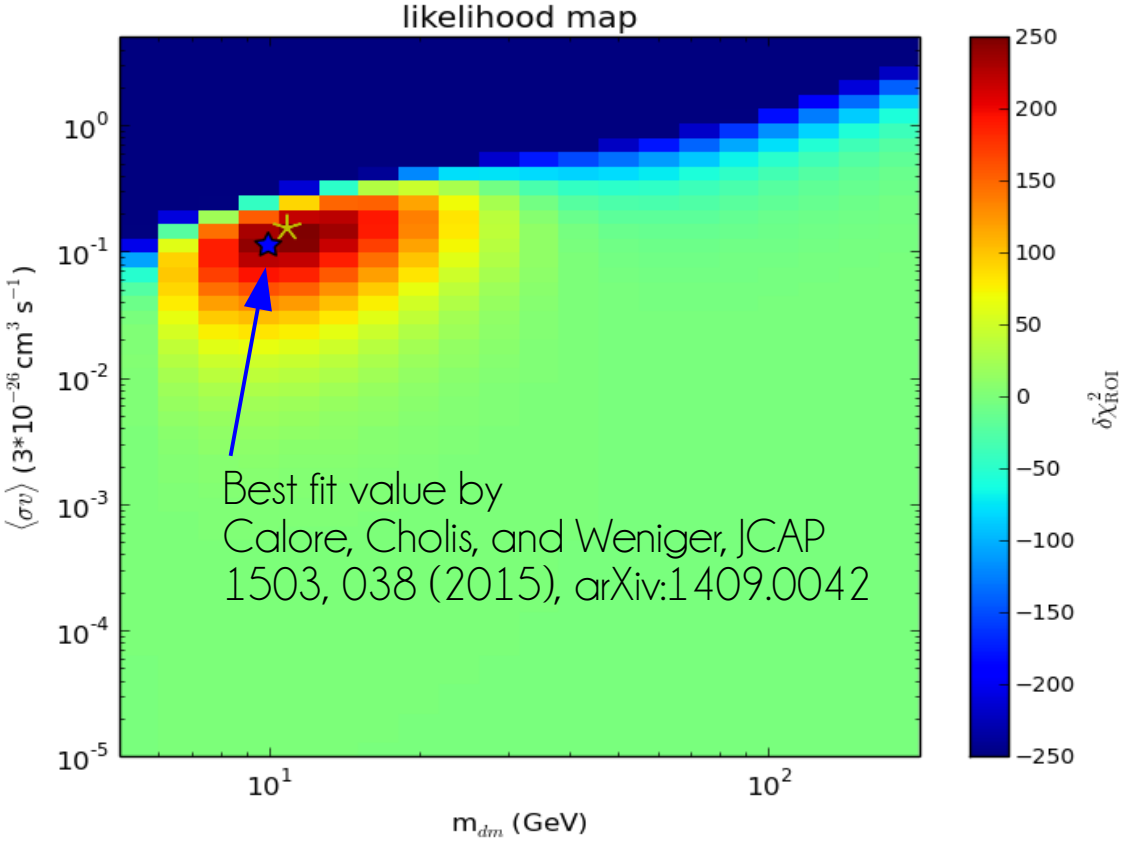
$$\lambda^{ijk} = n_{dm}^{ijk} + \alpha_i n_c^{ijk} + \beta_i n_b^{ijk} + n_{point}^{ijk}$$

Components: dark matter, cloud-like, bubble-like, point sources

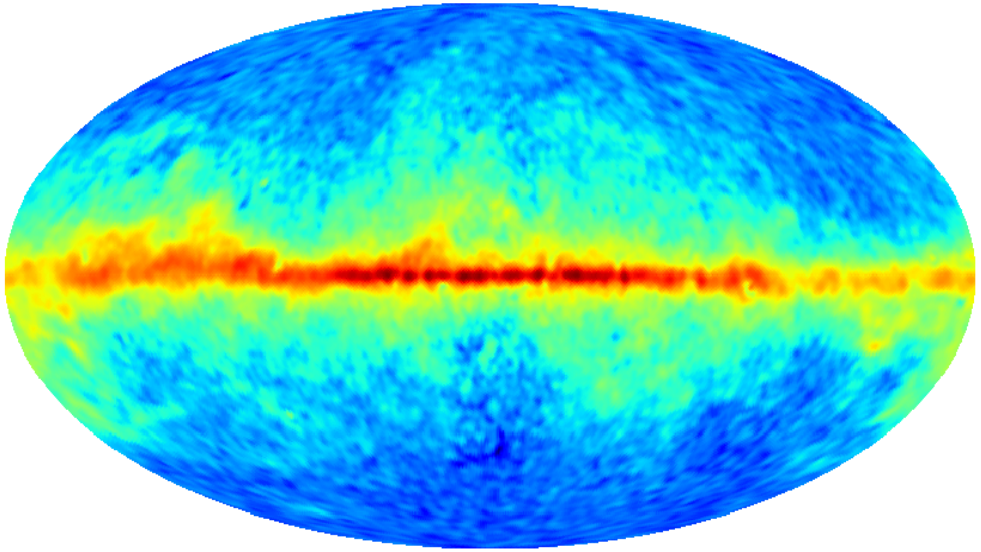
DM annihilation likelihood

$b\bar{b}$ $\tau^-\tau^+$

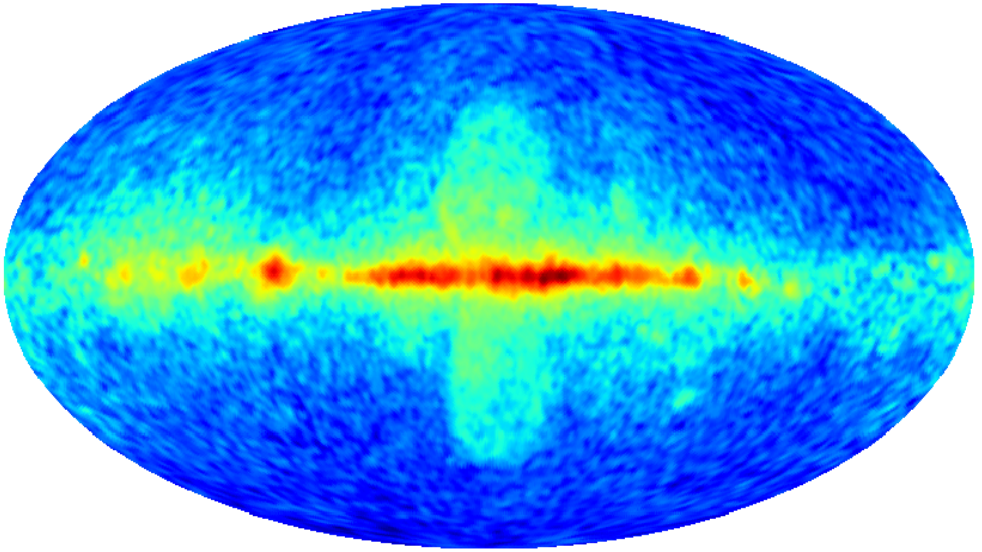




Modified astrophysics maps



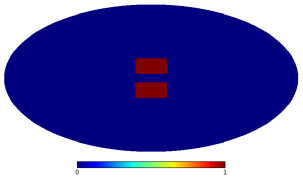
Cloud-like (cold ISM)



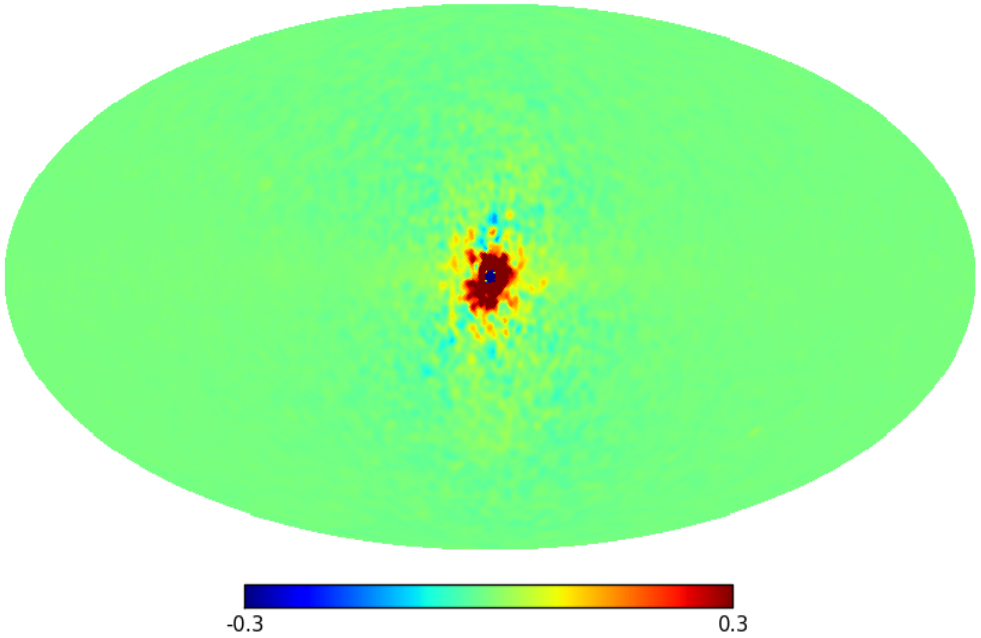
Bubble-like (hot ISM)

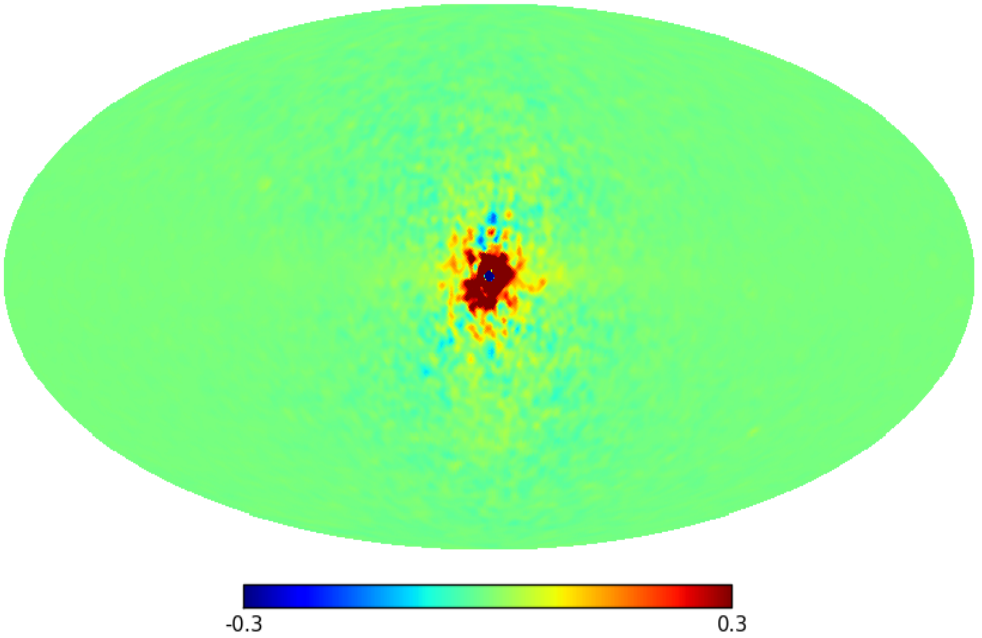
DM annihilation likelihood

$b\bar{b}$



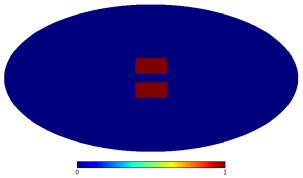
$\tau^{-}\tau^{+}$



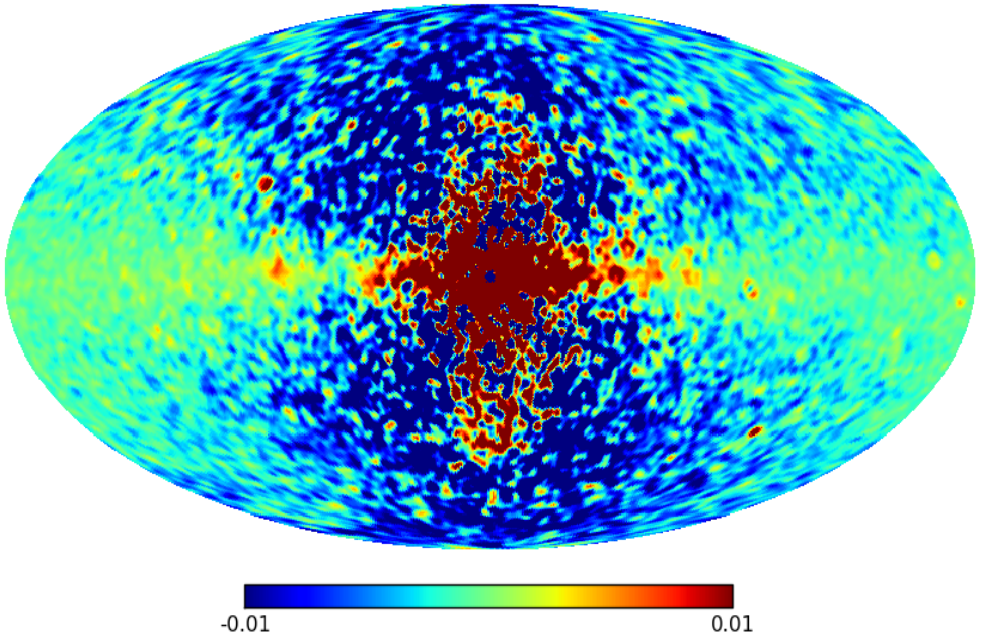


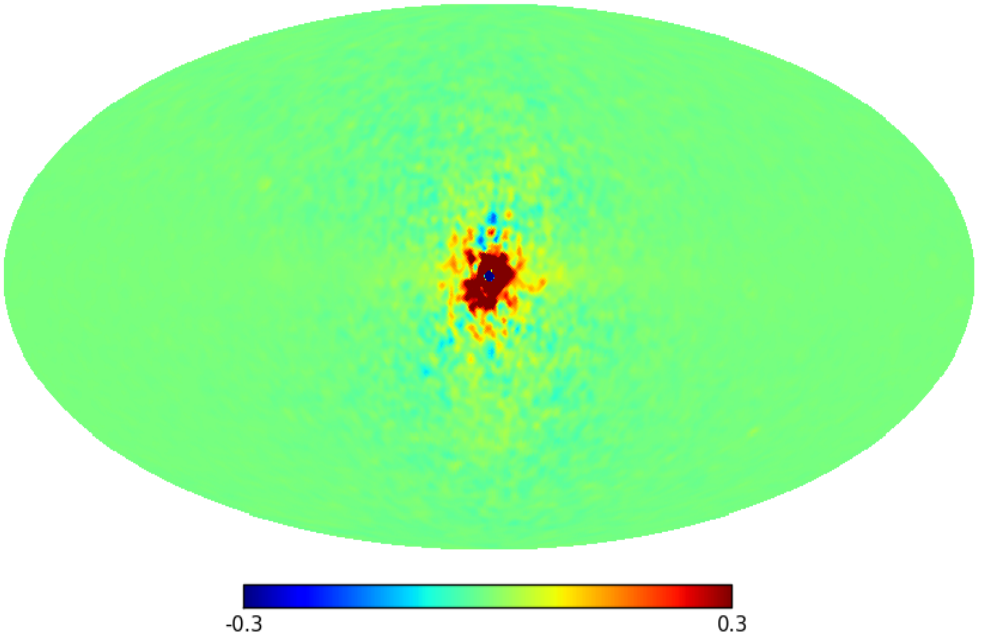
DM annihilation likelihood

$b\bar{b}$

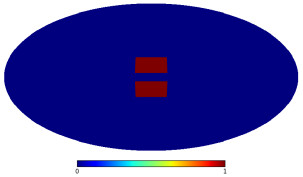


$\tau^- \tau^+$

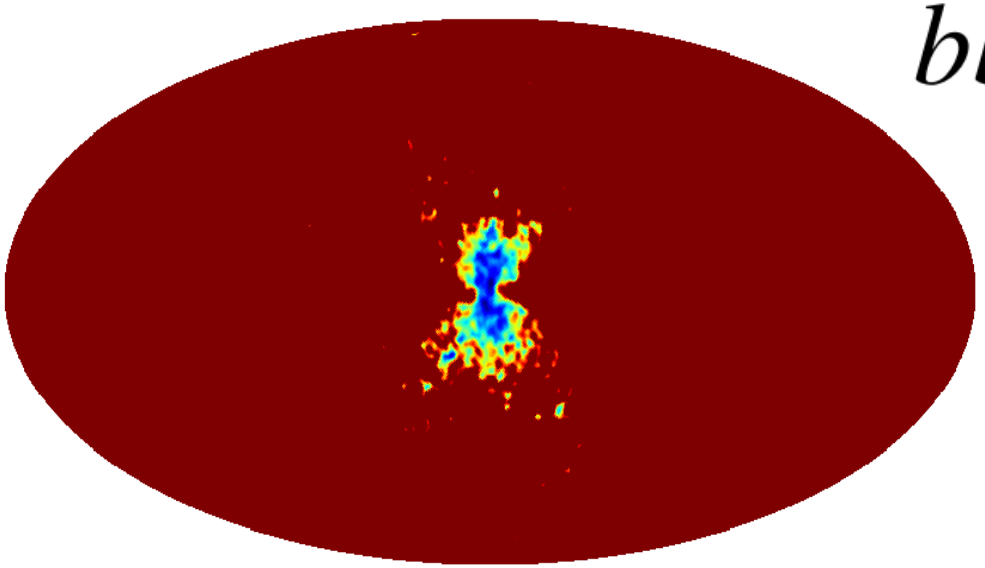




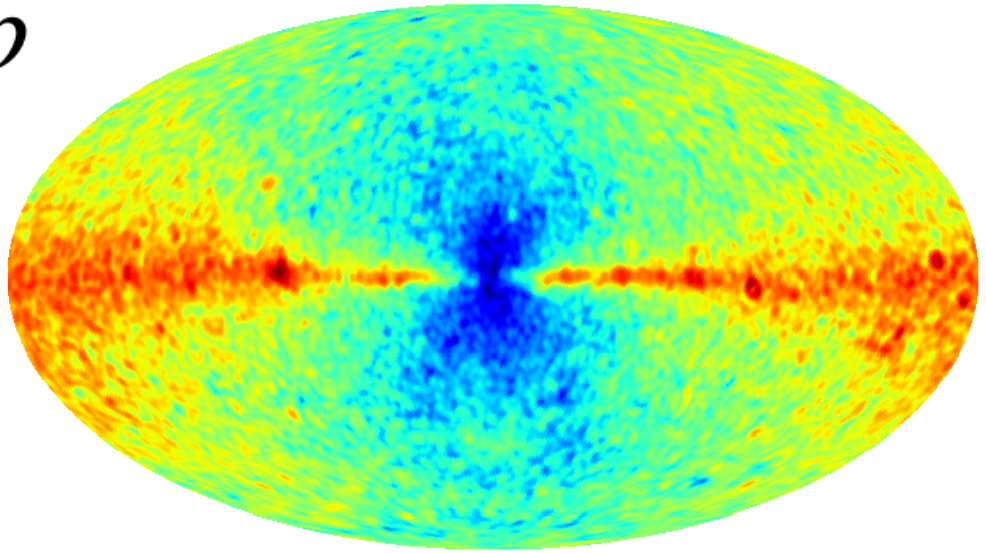
DM template modification as wanted by the data



$b\bar{b}$



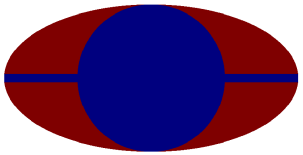
linear



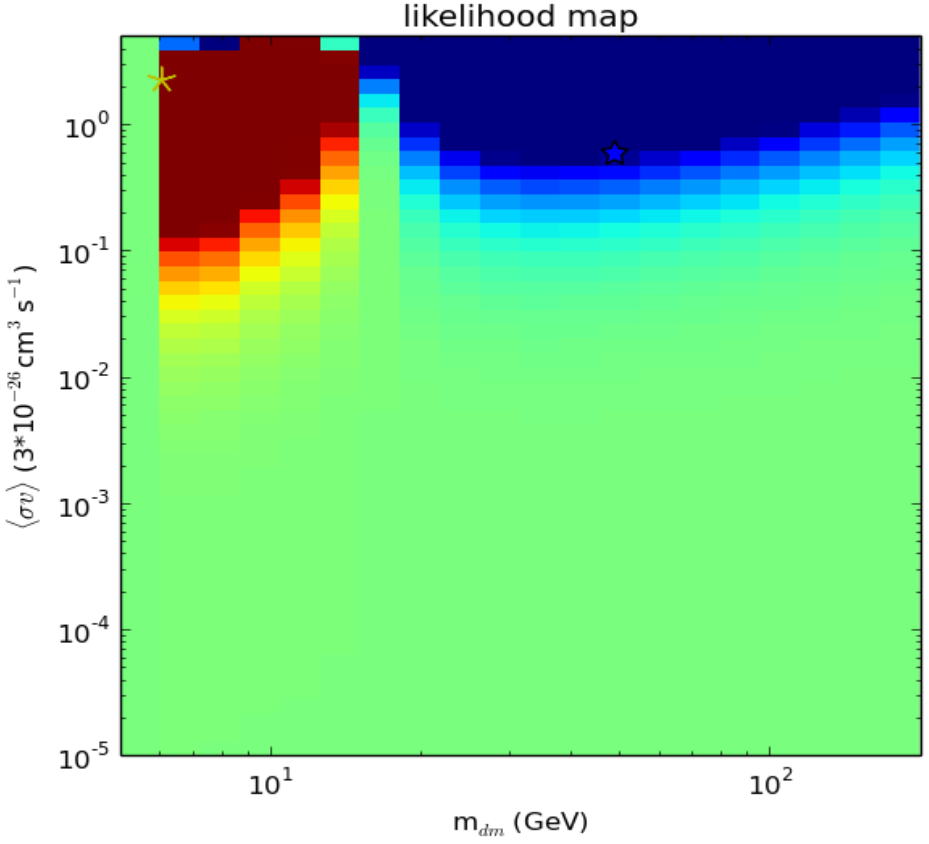
Log-10

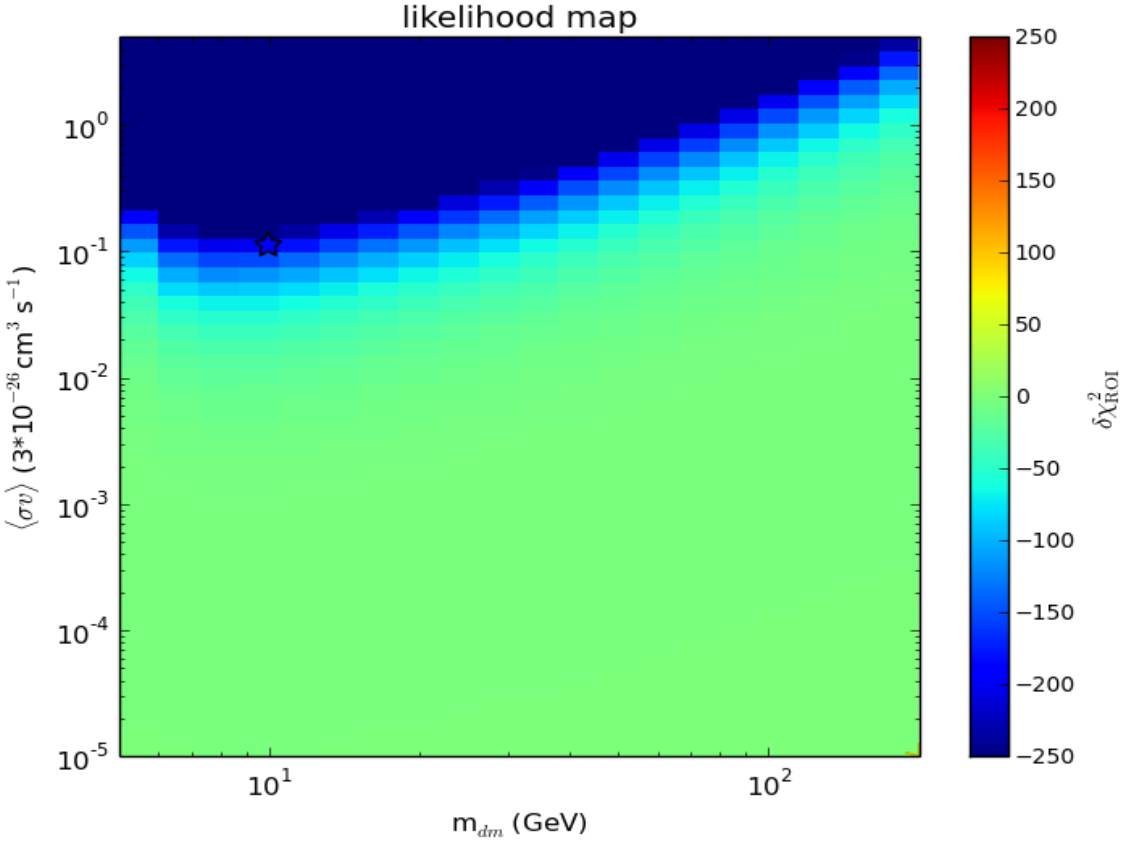
DM annihilation likelihood

$b\bar{b}$



$\tau^- \tau^+$





Conclusions

D³PO decomposed Fermi data (Selig et al. 2014, 2015) shows
- cold ISM gamma component (hadronic emssion)
- hot ISM gamma component (IC emission)
- point sources

Assuming this to be the non-DM Galactic model we
- confirm presence of DM-like central Galactic gamma excess
- find also preference of data for such DM-like component in astrophysical emission regions

→ additional astrophysical component mimicking DM annihilation is a plausible scenario

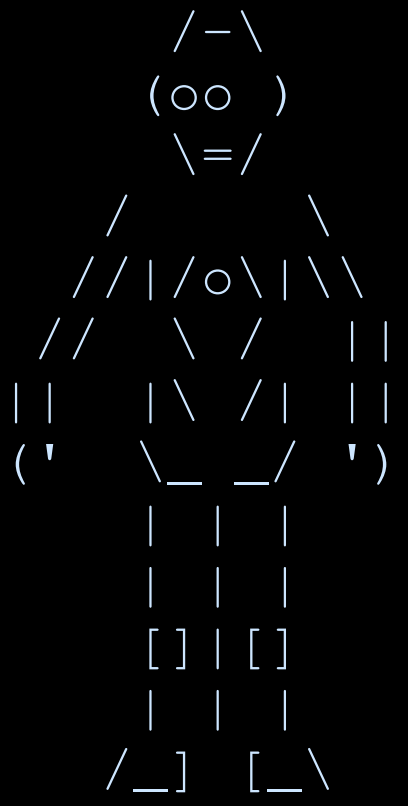
Morphological information matters !

Thank
you!

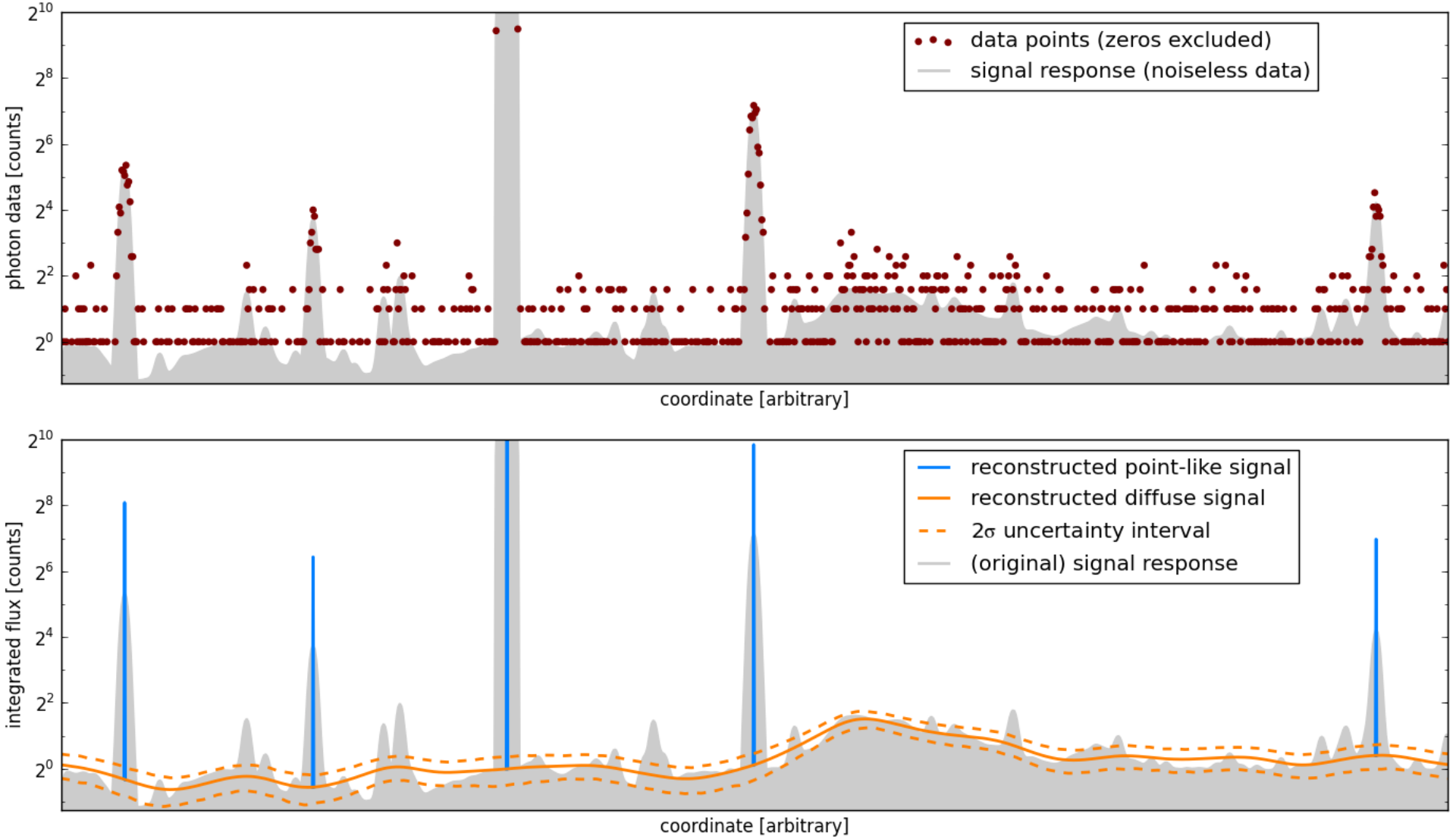
Denoising, Deconvolving, and Decomposing Photon Observations

www.mpa-garching.mpg.de/ift/d3po

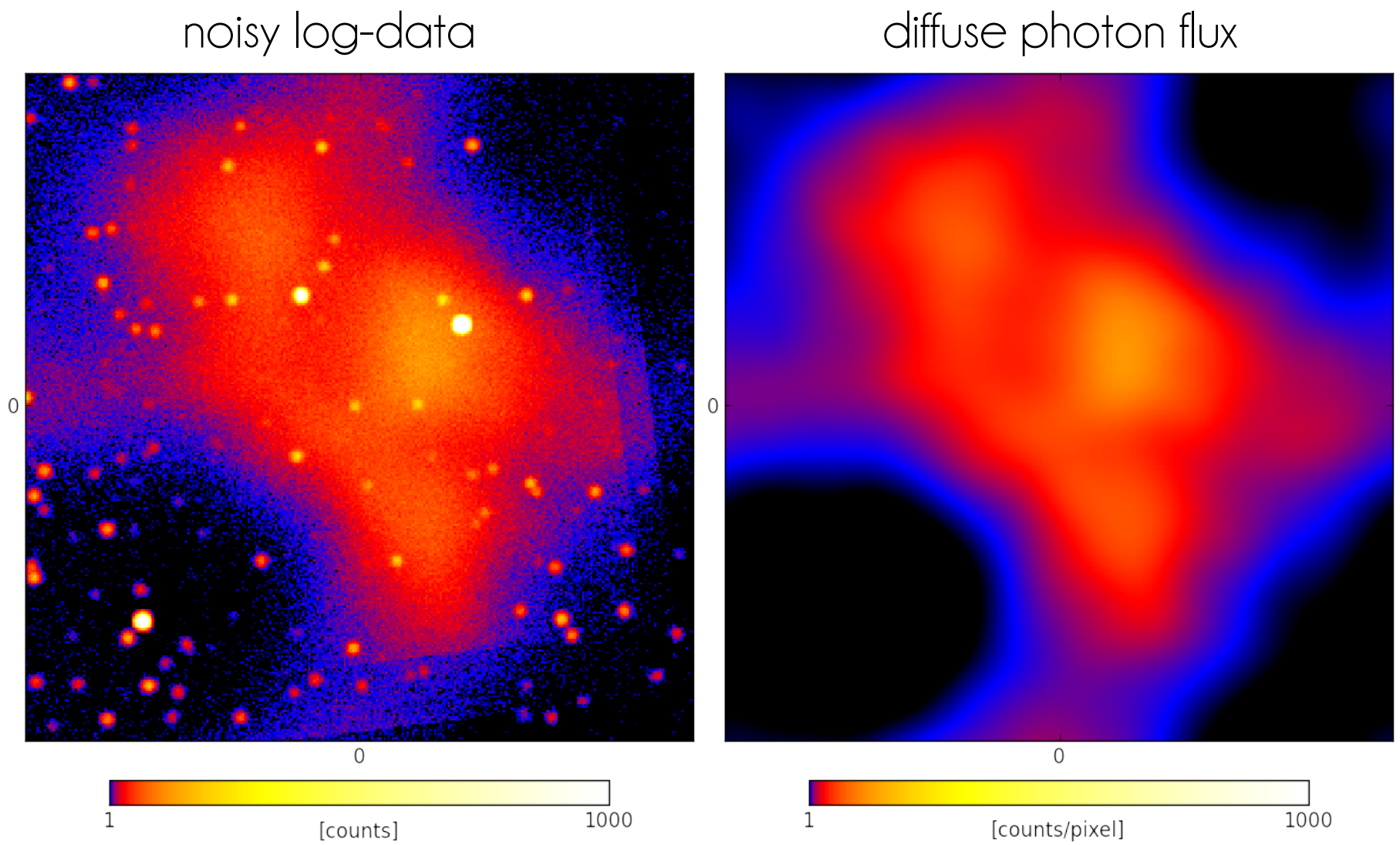
D³PO



D^{3}PO – 1D scenario

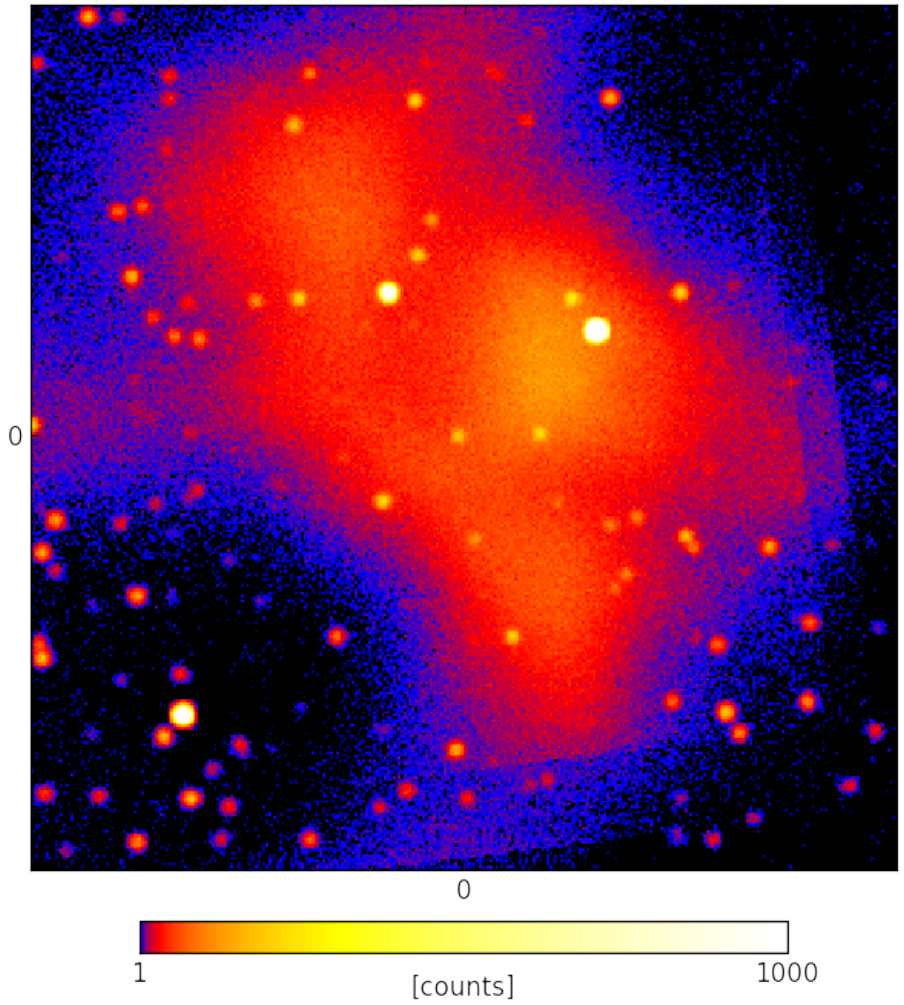


D^{3}PO – 2D scenario

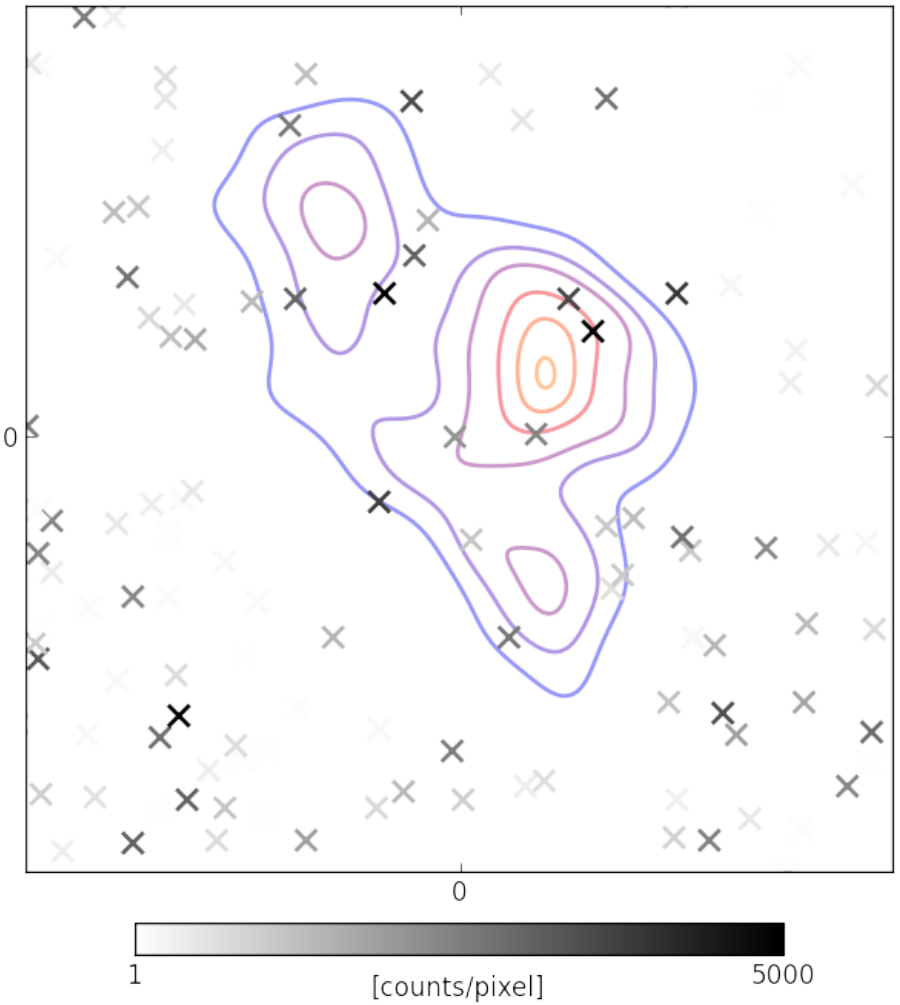


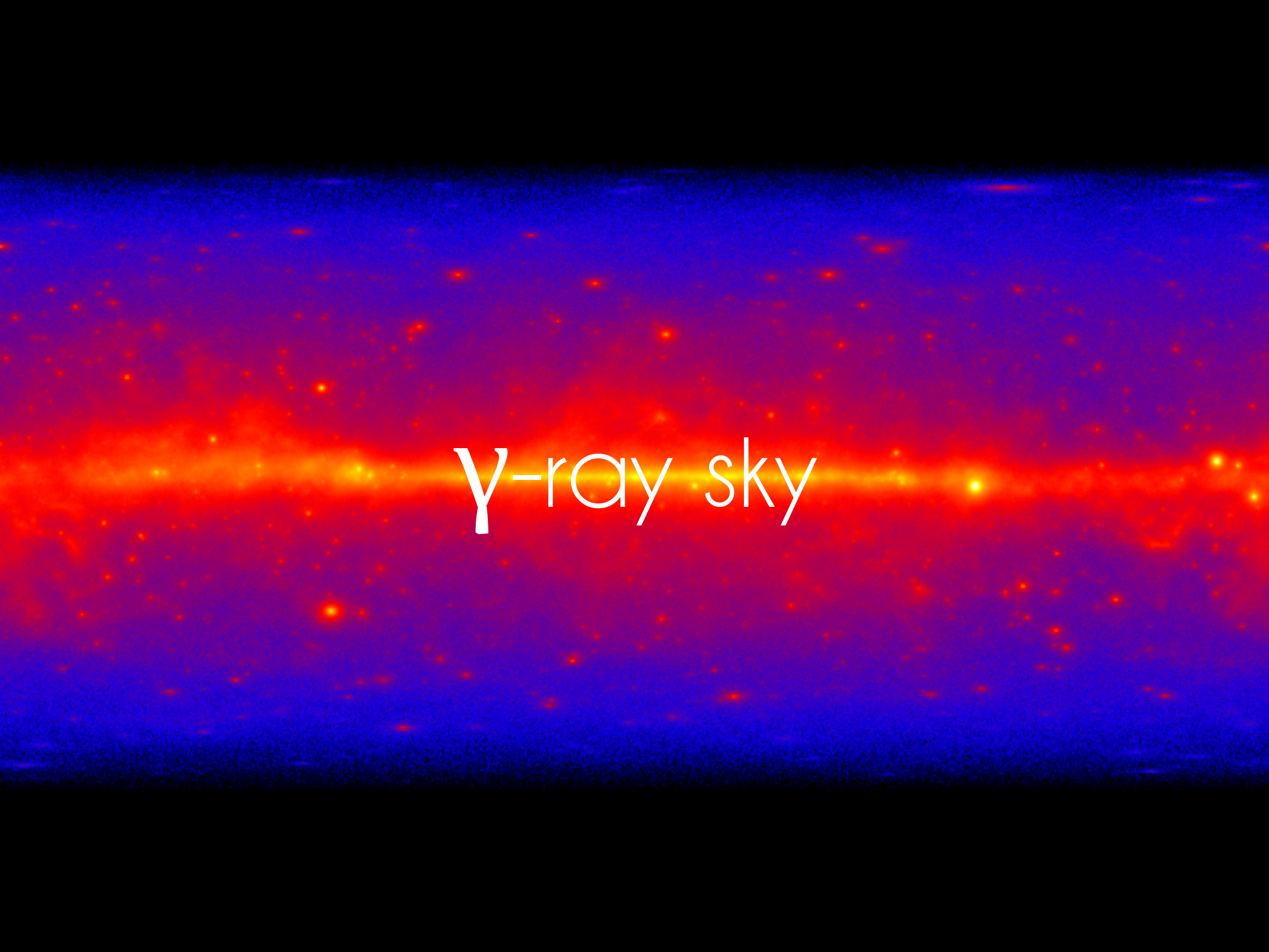
D³PO – 2D scenario

noisy log-data

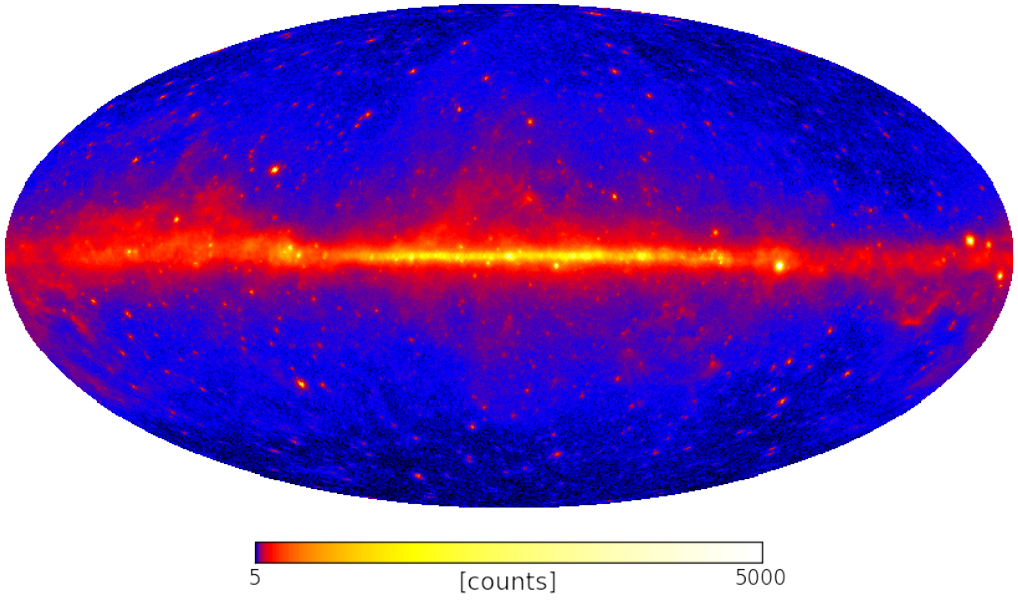


point-like photon flux

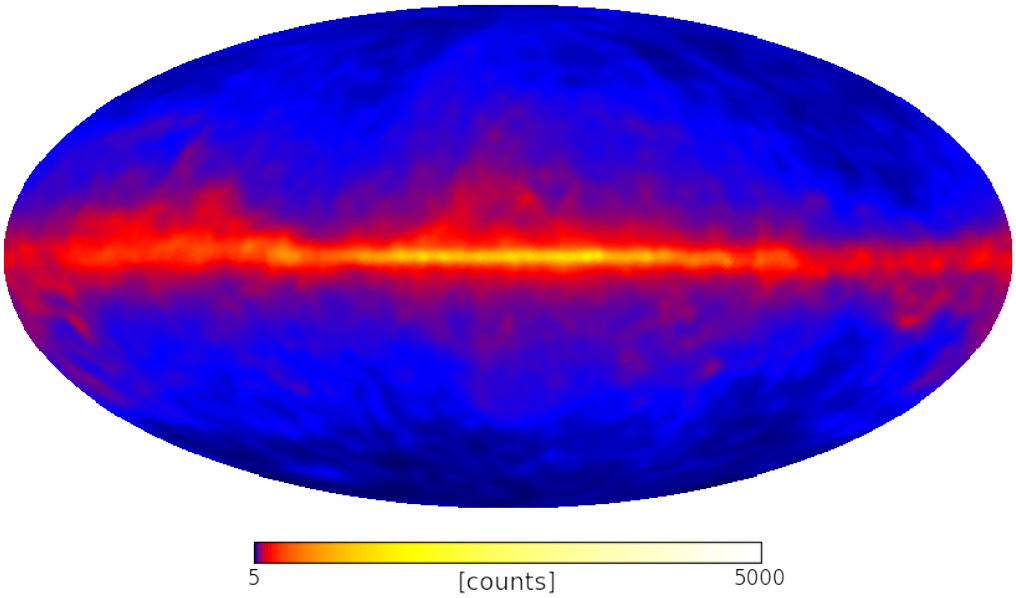



γ-ray sky

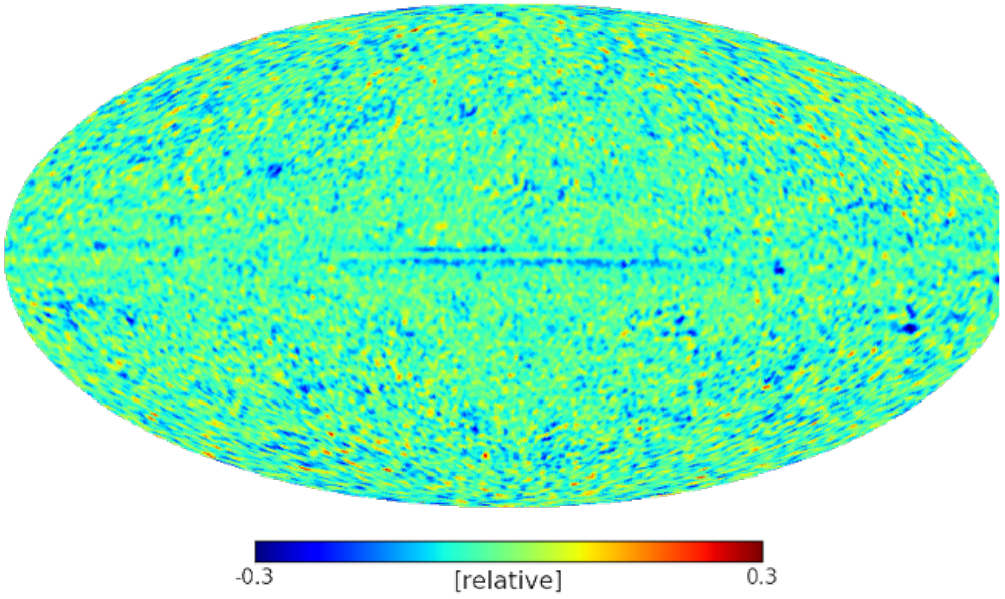
photon data



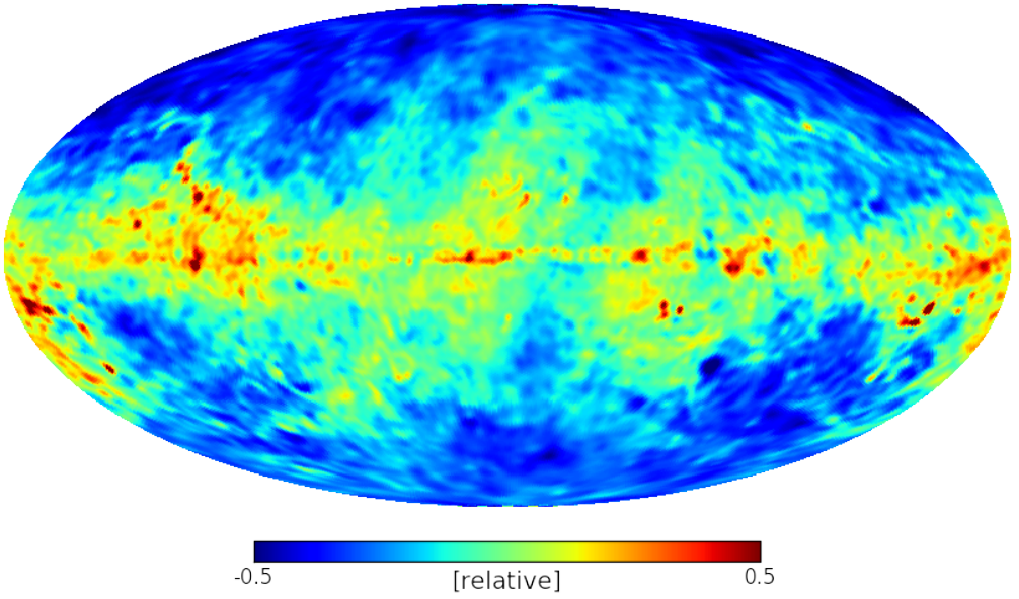
diffuse flux



relative residuals



relative difference to Fermi map



Online resources

Online material (info/codes/docu/data/maps):

IFT: www.mpa-garching.mpg.de/ift

NIFTy: www.mpa-garching.mpg.de/ift/nifty

D³PO: www.mpa-garching.mpg.de/ift/d3po

Data: www.mpa-garching.mpg.de/ift/fermi