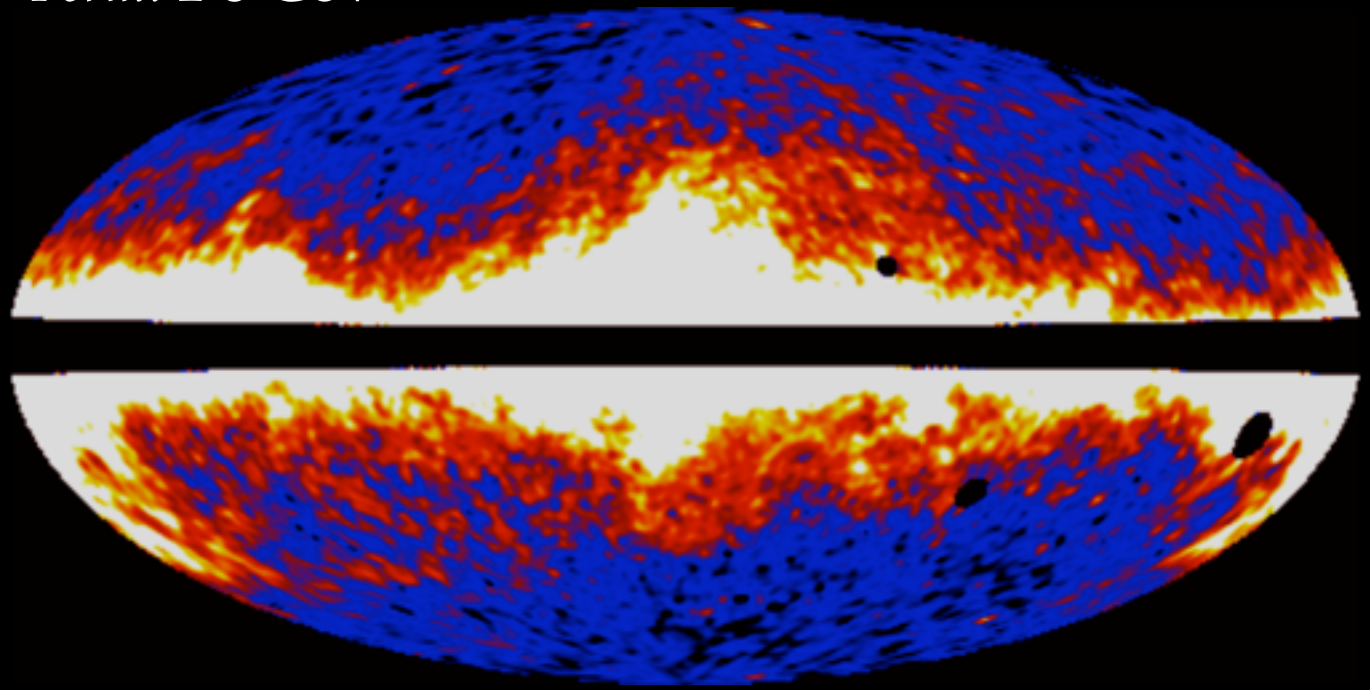
gamma-rays from the Galaxy

gamma-rays from the Galaxy: oof...

gamma-rays from the Galaxy: oof...

Fermi 2-5 GeV



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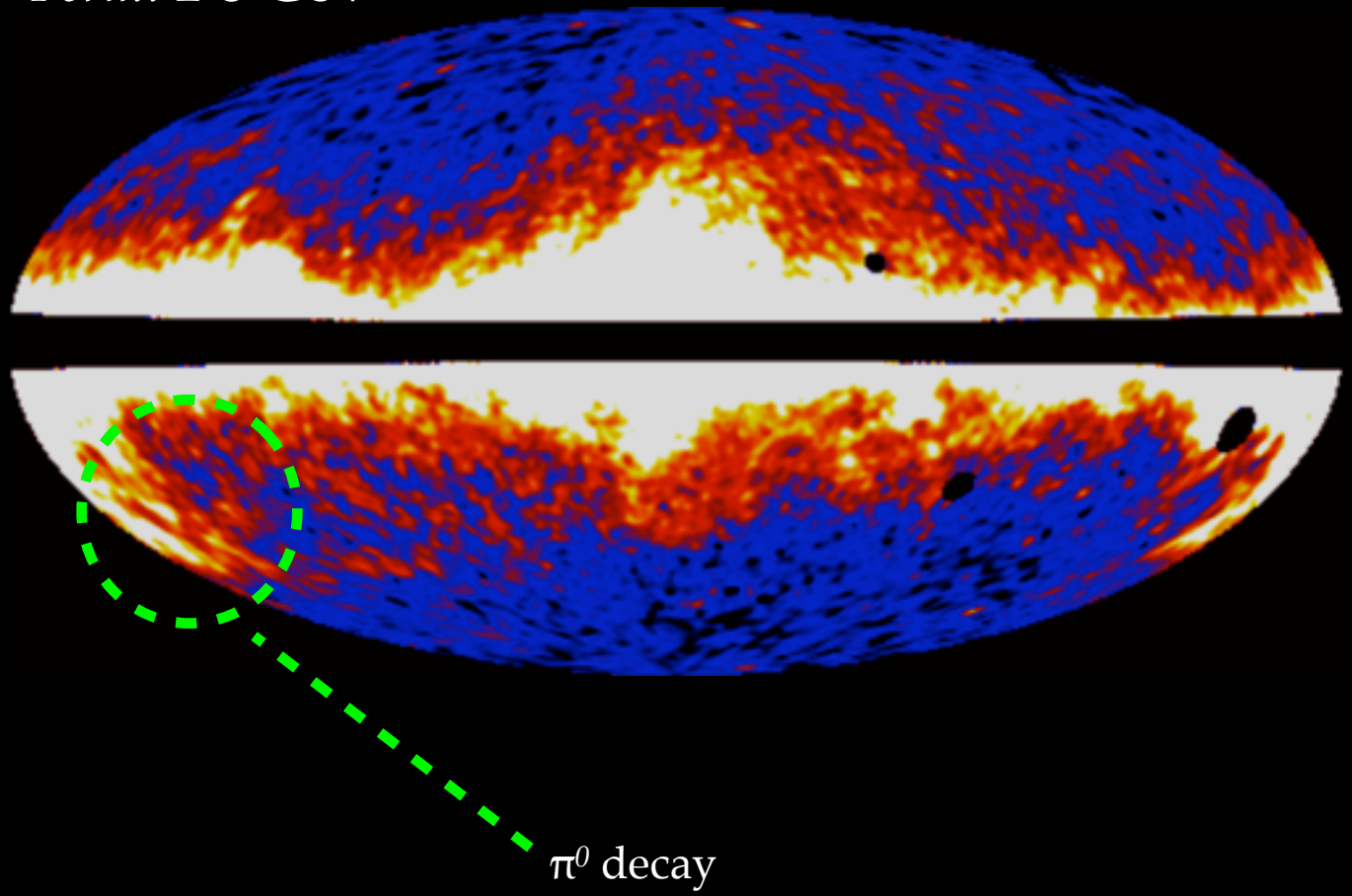
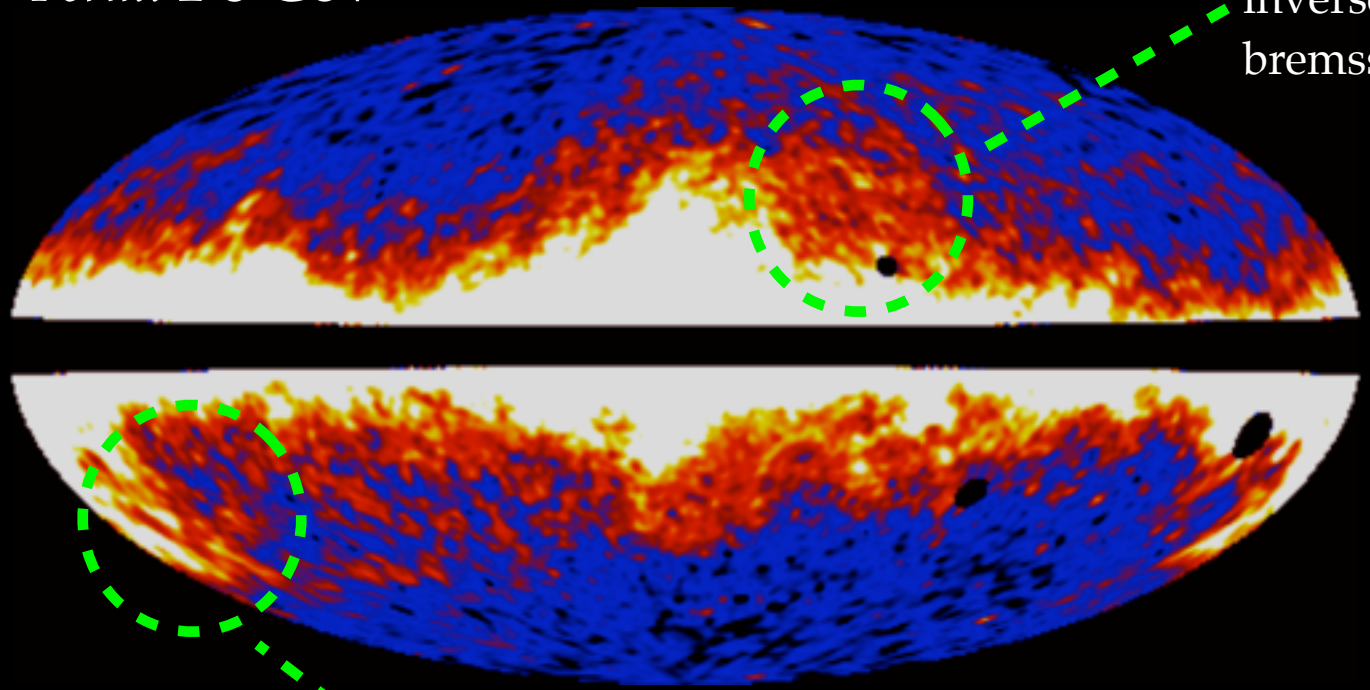


gamma-rays from the Galaxy: oof...

Fermi 2-5 GeV

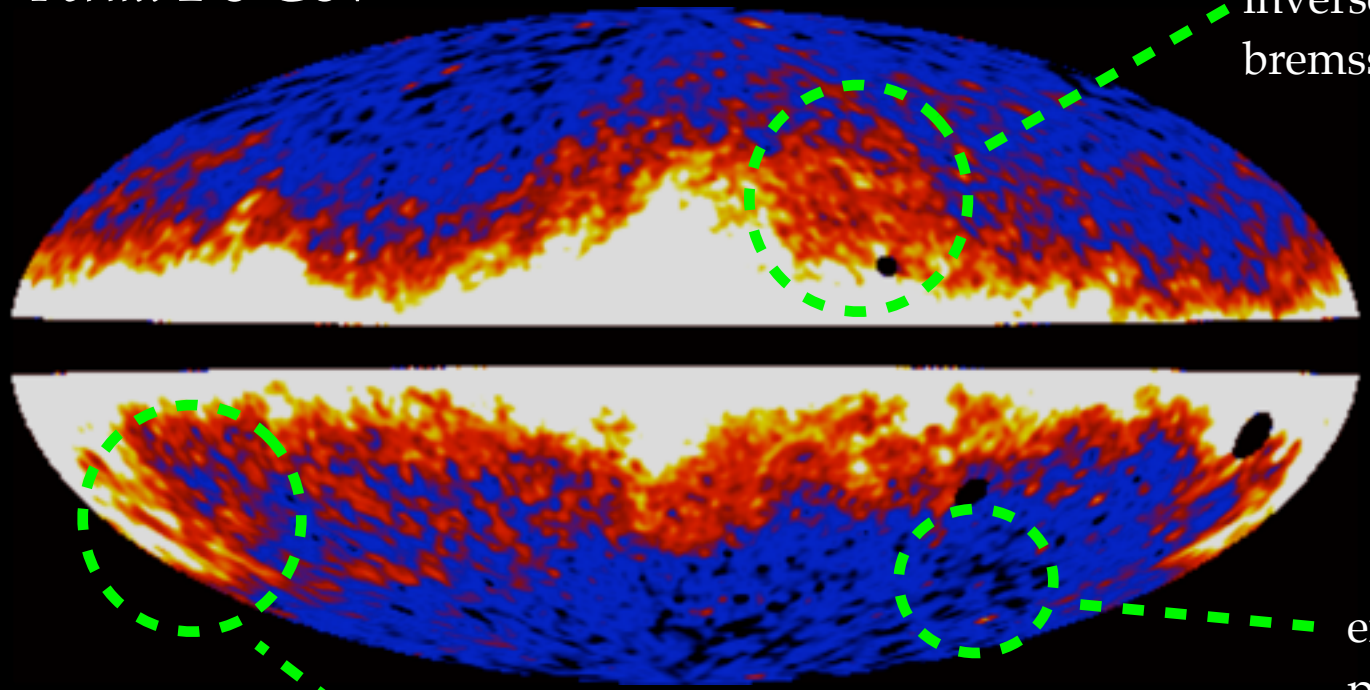


inverse Compton plus bremsstrahlung (subdominant)

π^0 decay

gamma-rays from the Galaxy: oof...

Fermi 2-5 GeV

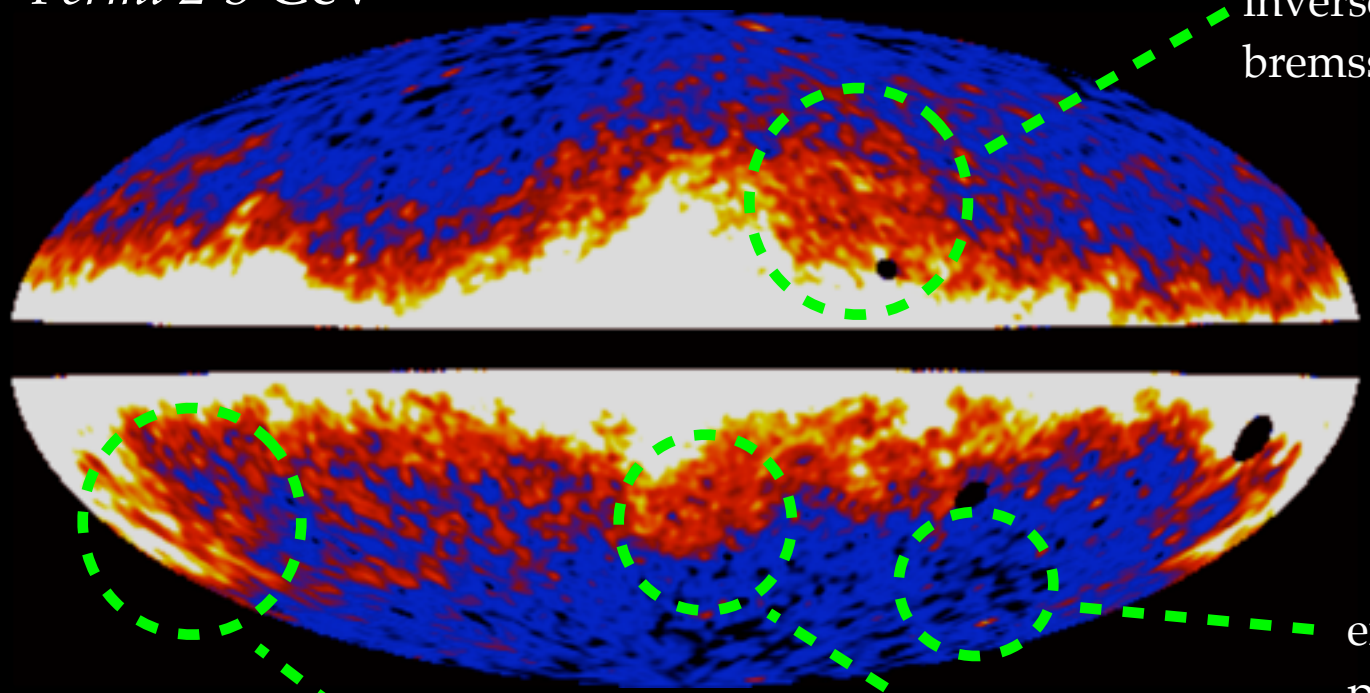


inverse Compton plus bremsstrahlung (subdominant)

extragalactic plus particle contamination

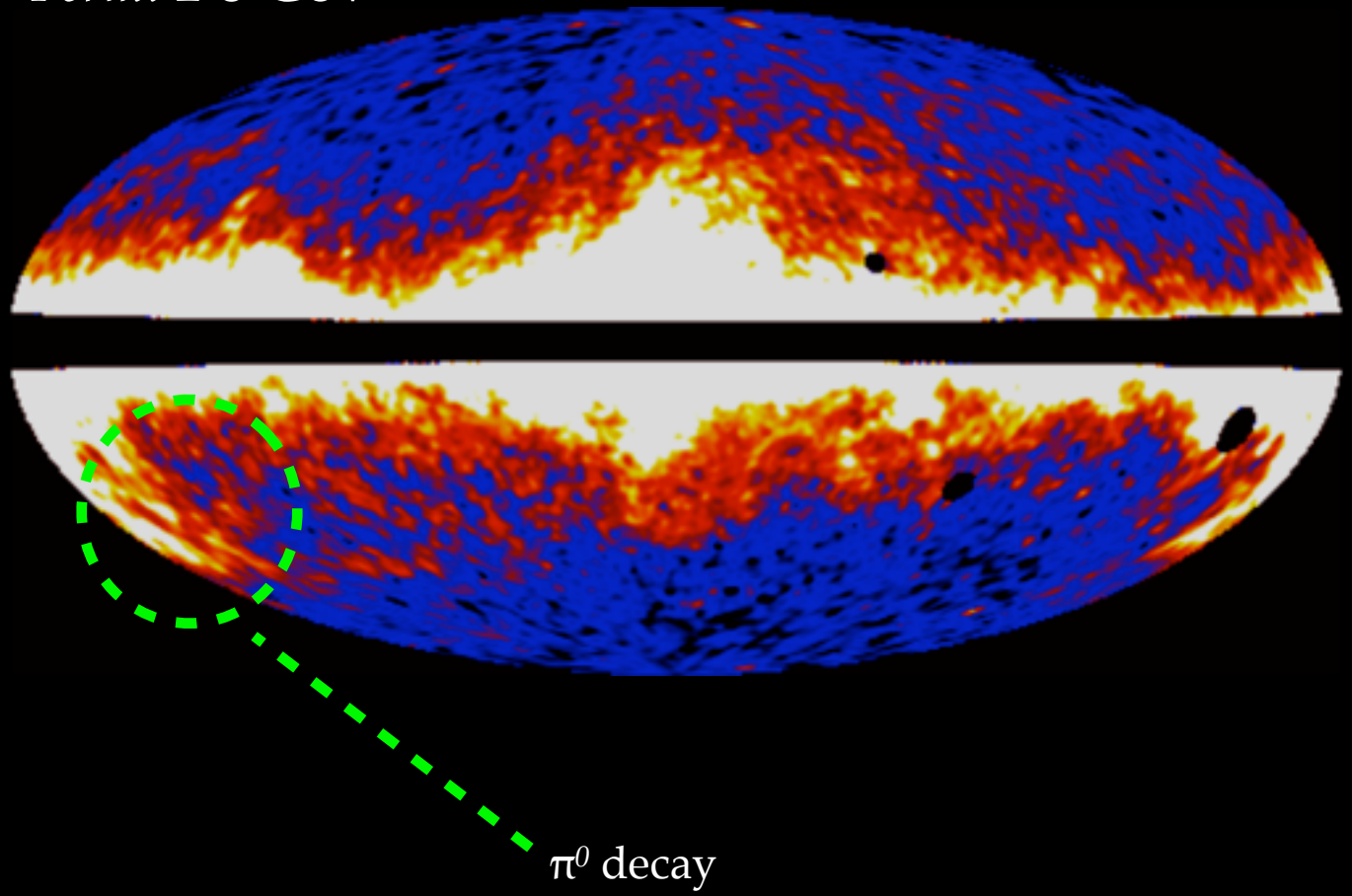
π^0 decay

gamma-rays from the Galaxy: oof...



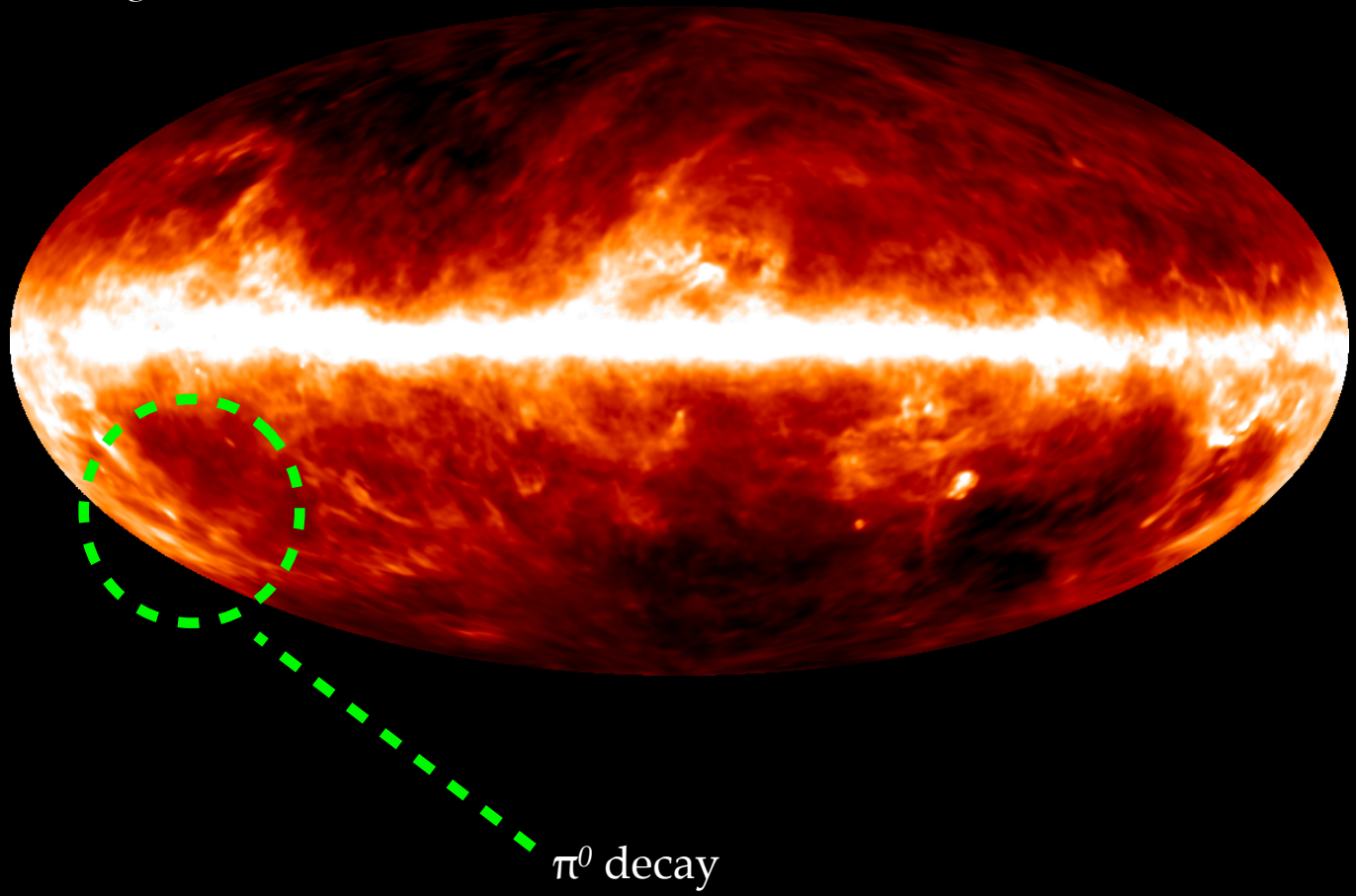
gamma-rays from the Galaxy: oof...

Fermi 2-5 GeV



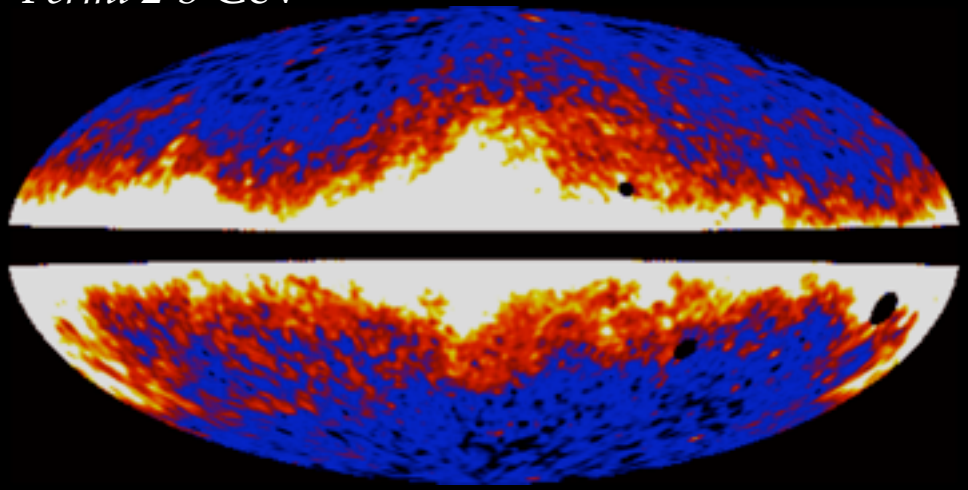
morphological tracers of emission

Schlegel, Finkbeiner, & Davis (1998)

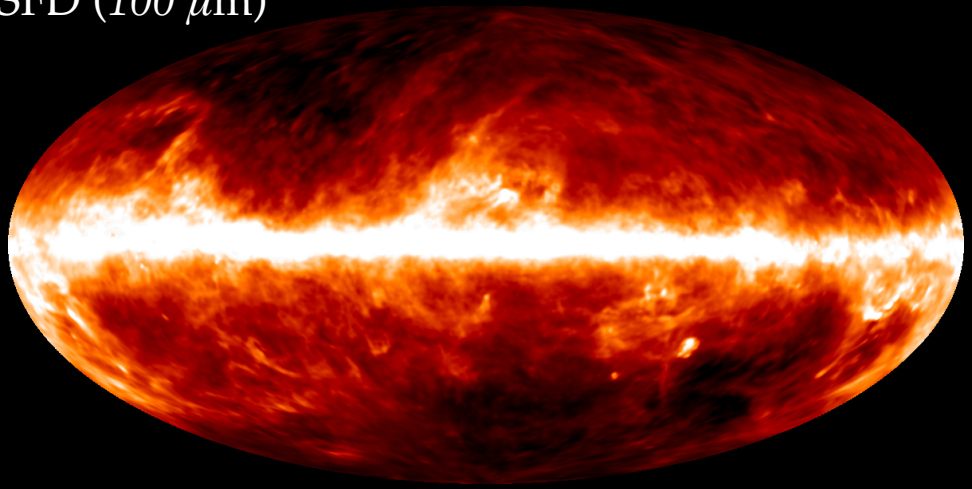


morphological tracers of emission

Fermi 2-5 GeV

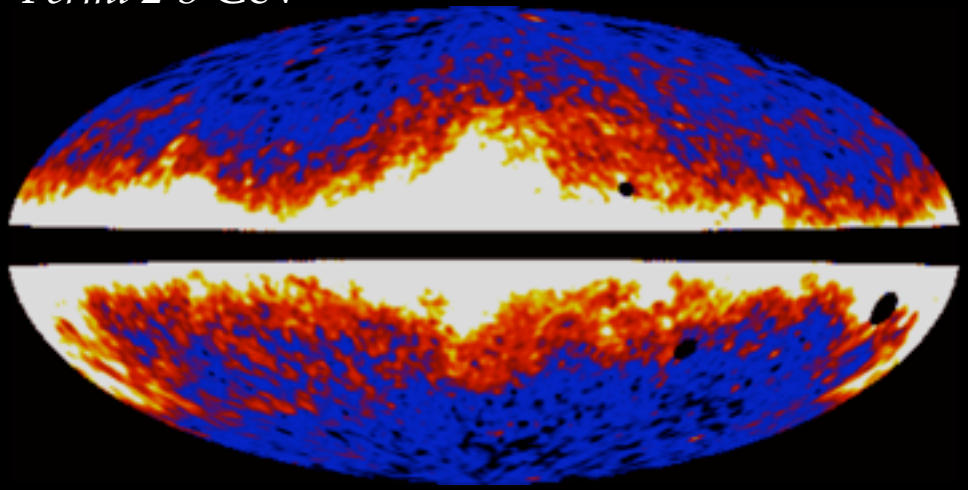


SFD (*100* μm)

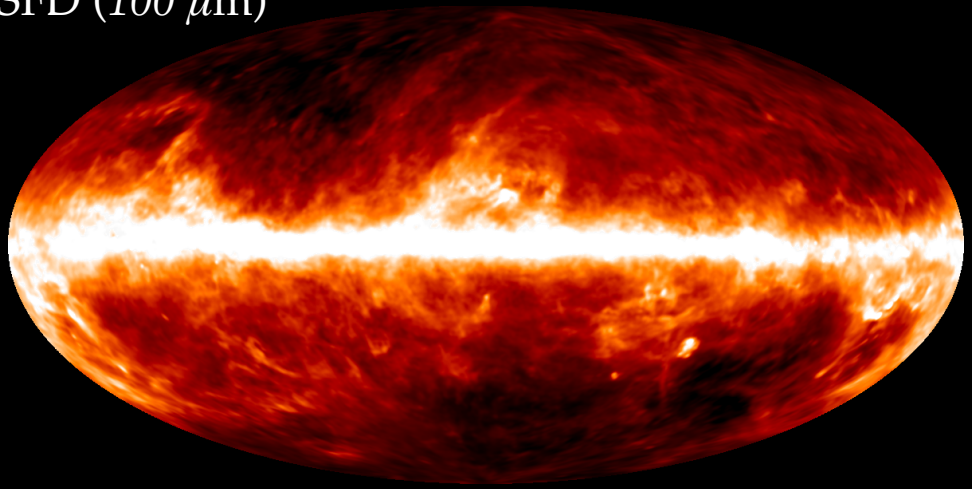


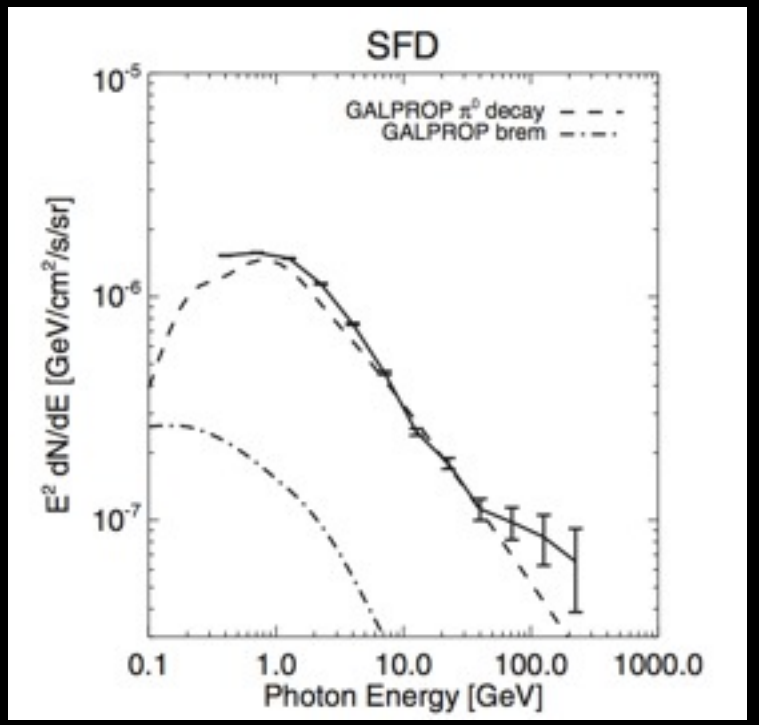
morphological tracers of emission

Fermi 2-5 GeV



SFD (*100* μm)

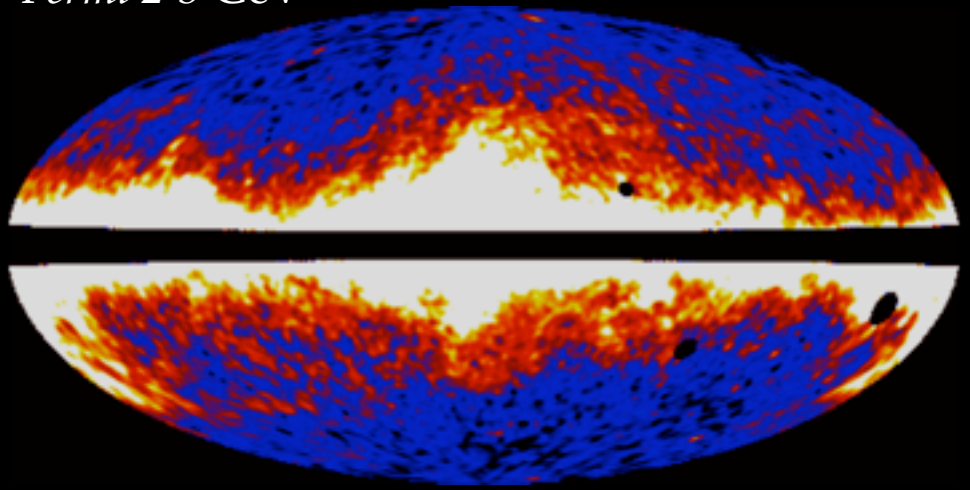




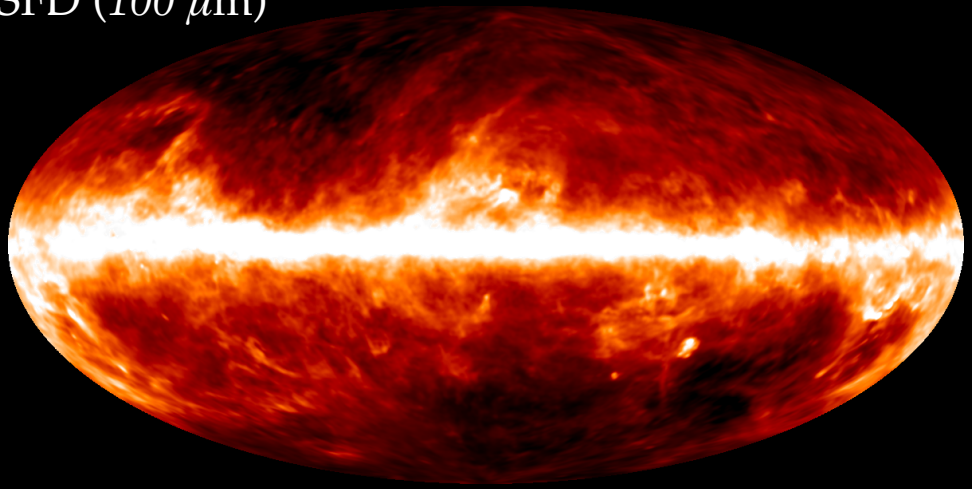
Dobler et al. (2010)

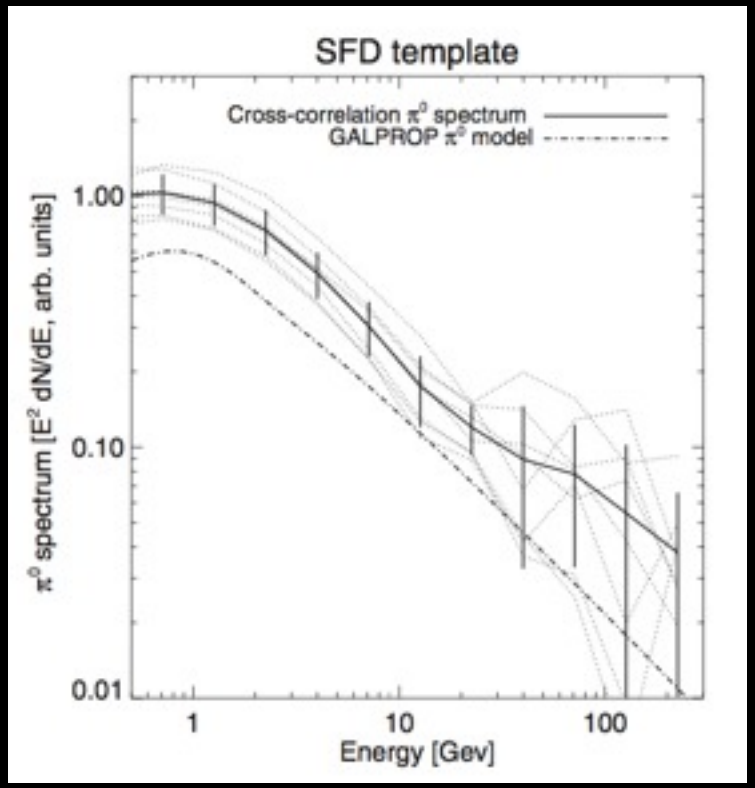
morphological tracers of emission

Fermi 2-5 GeV



SFD (*100* μm)

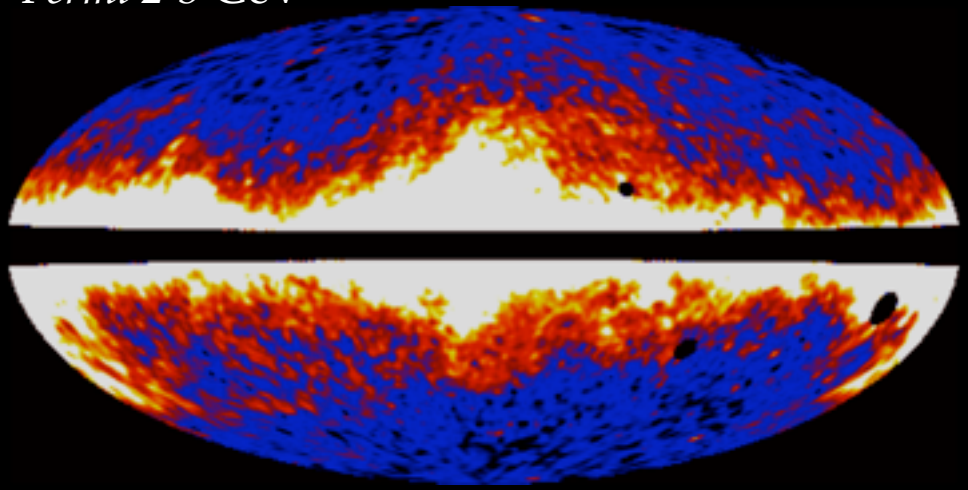




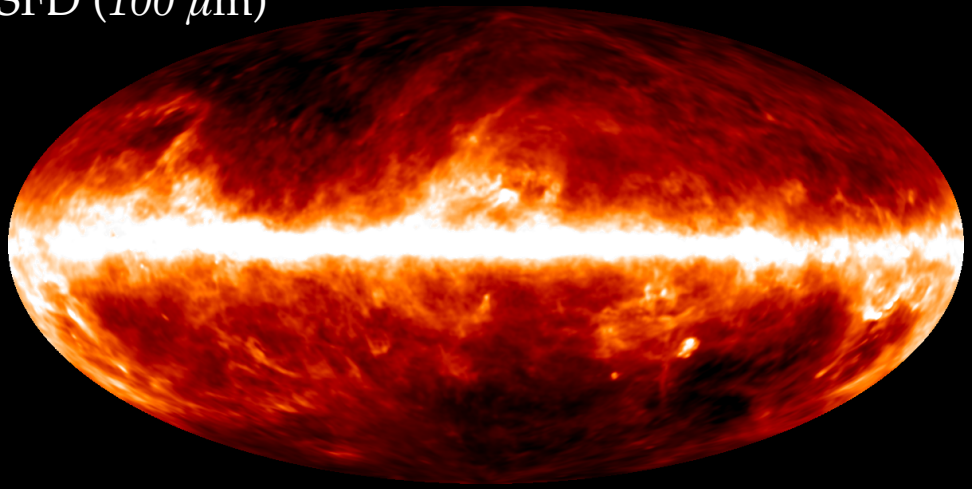
Dobler et al. (2010)

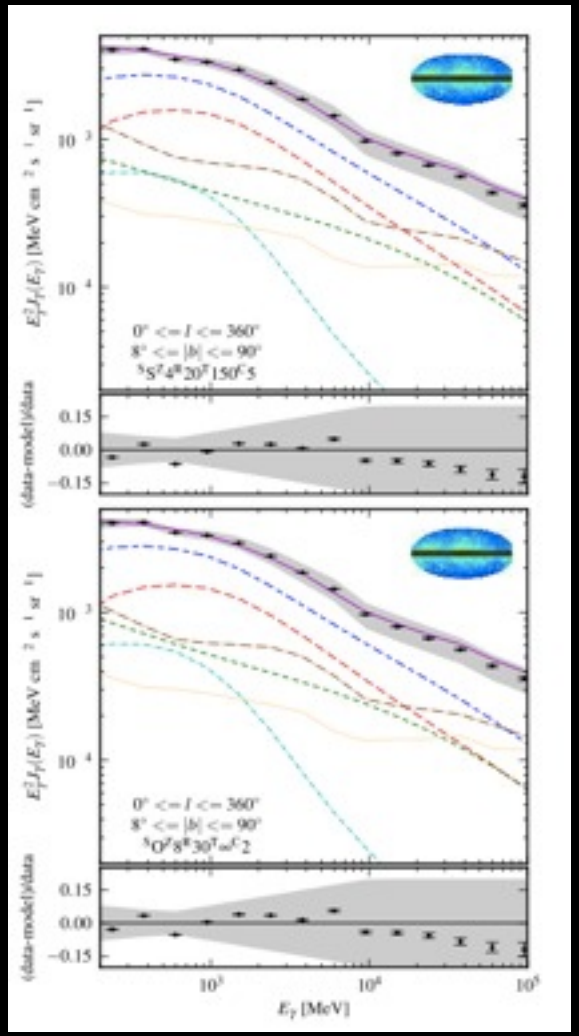
morphological tracers of emission

Fermi 2-5 GeV



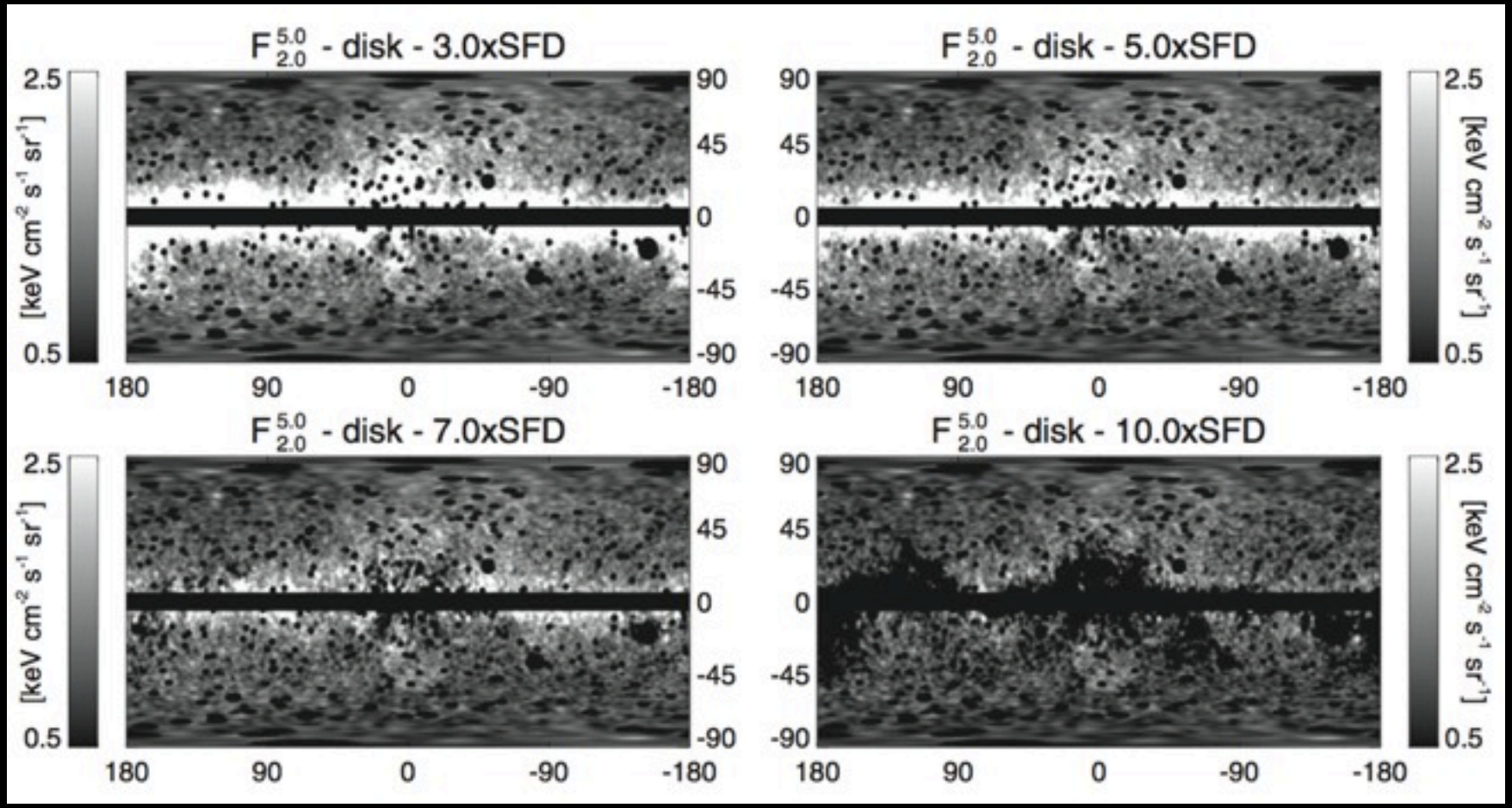
SFD (*100 μ*m)





Fermi collab. (2012)

morphological tracers of emission: CAUTION

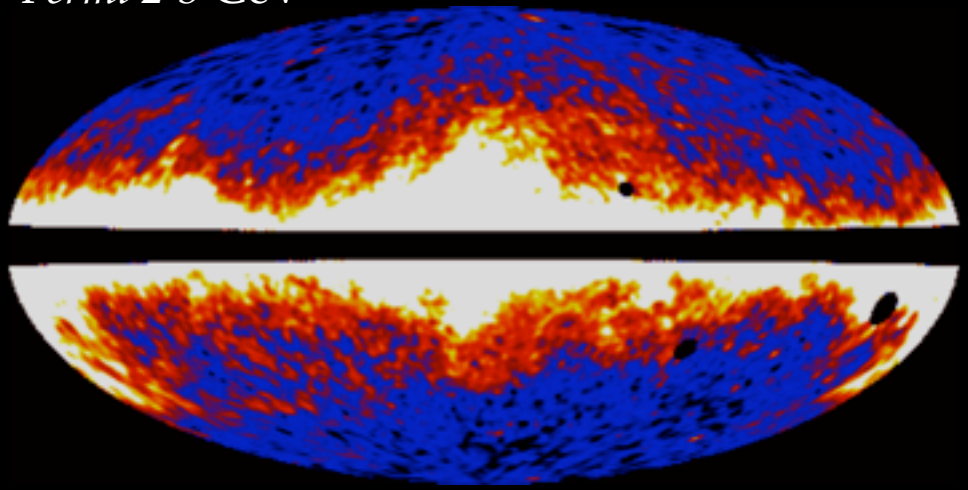


Dobler, Cholis, & Weiner (2011)

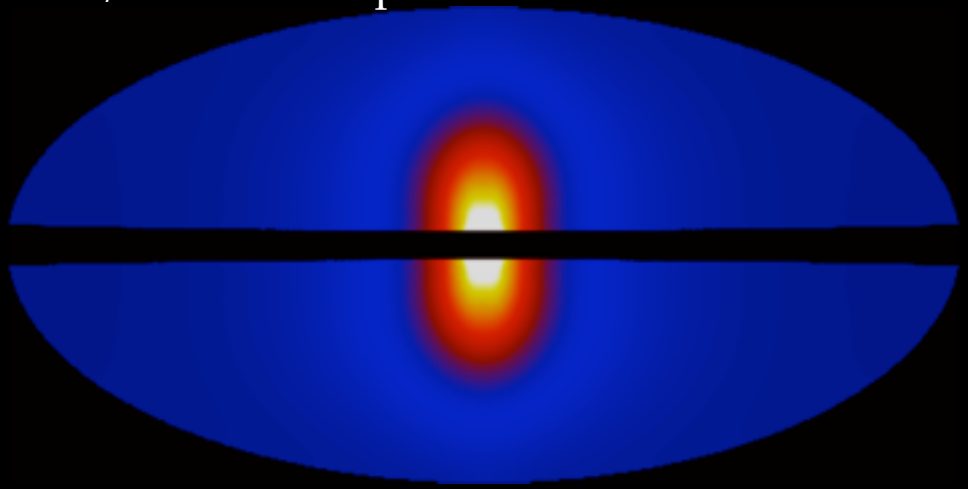
π^0-to-dust column ratio varies with position,
especially towards the center of the Milky Way

morphological tracers of emission

Fermi 2-5 GeV

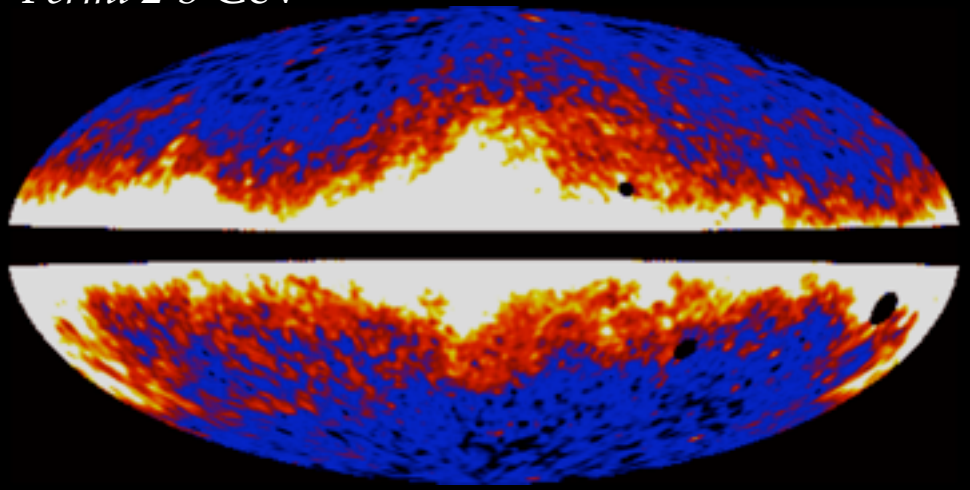


Haze/Bubbles template

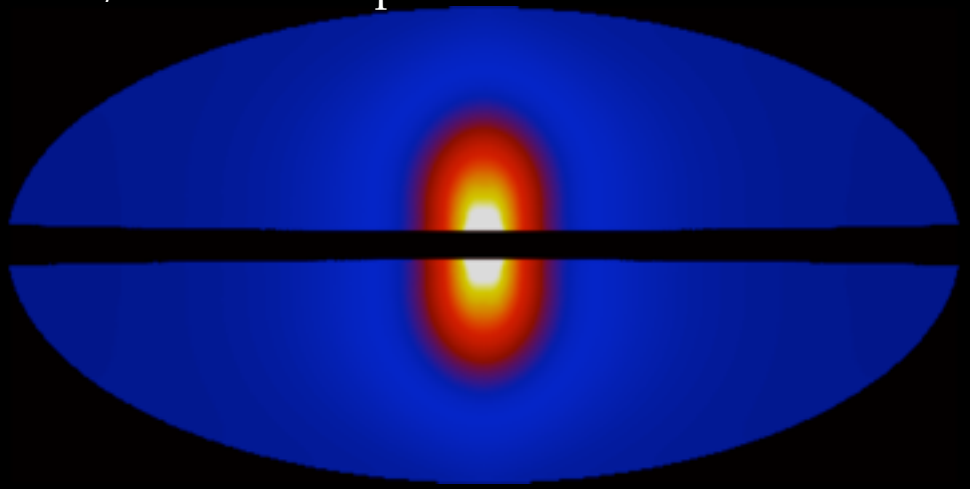


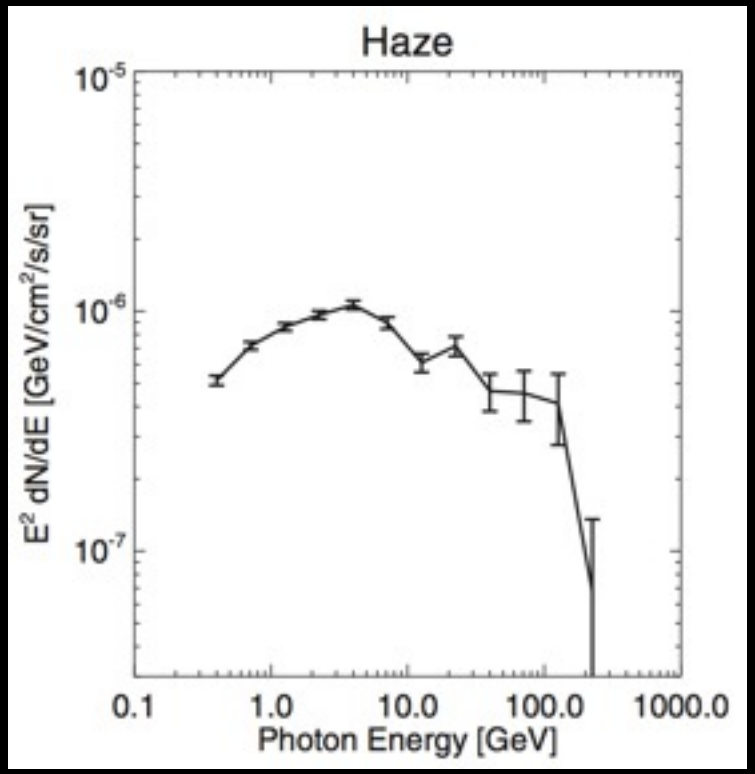
morphological tracers of emission

Fermi 2-5 GeV



Haze/Bubbles template

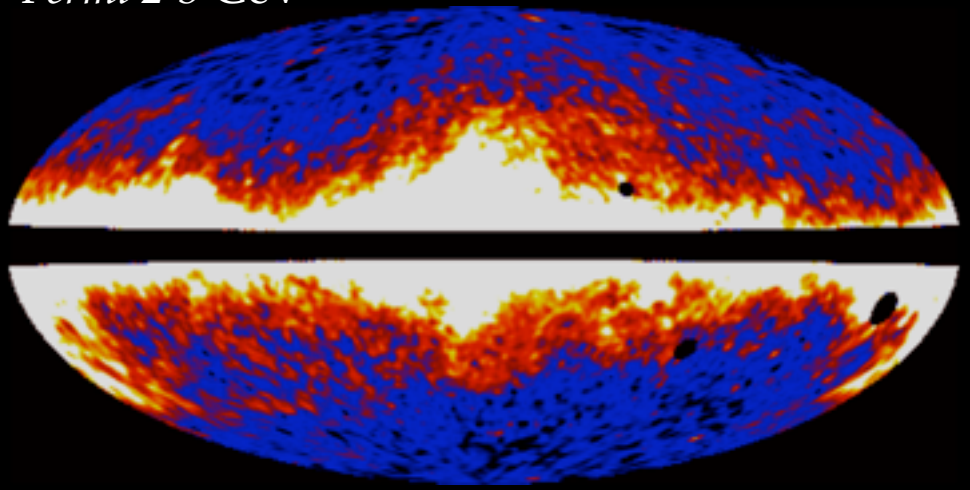




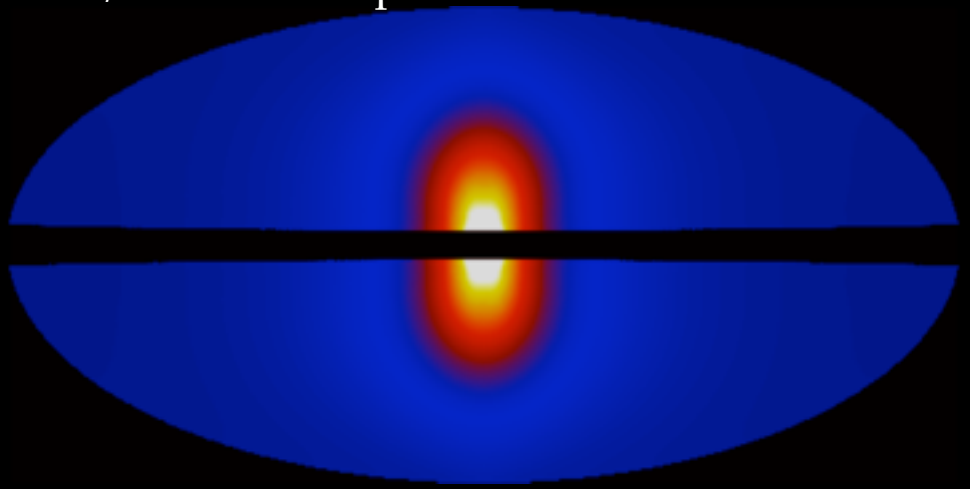
Dobler et al. (2010)

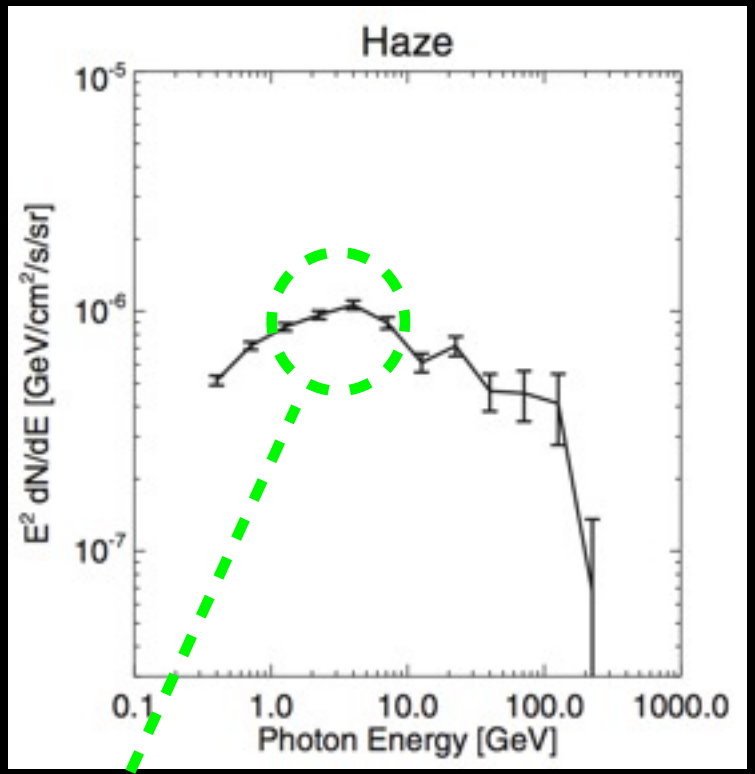
morphological tracers of emission

Fermi 2-5 GeV



Haze/Bubbles template



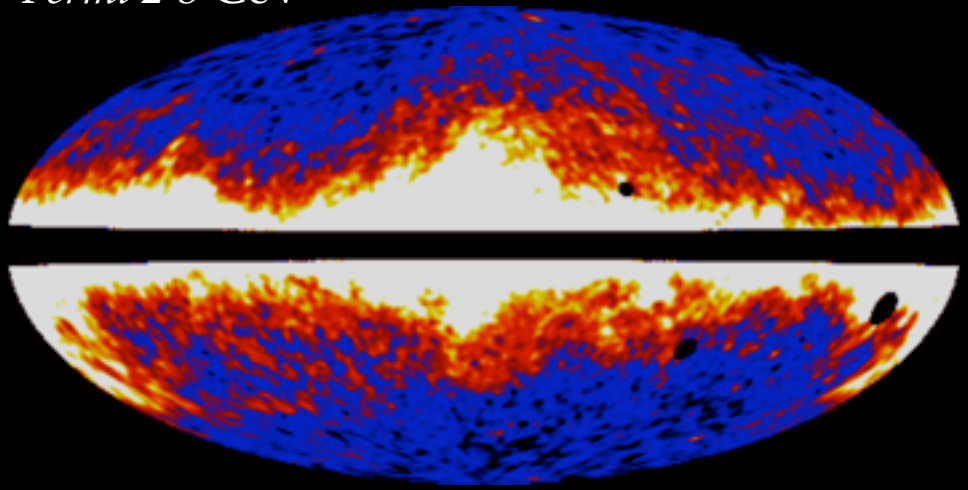


Dobler et al. (2010)

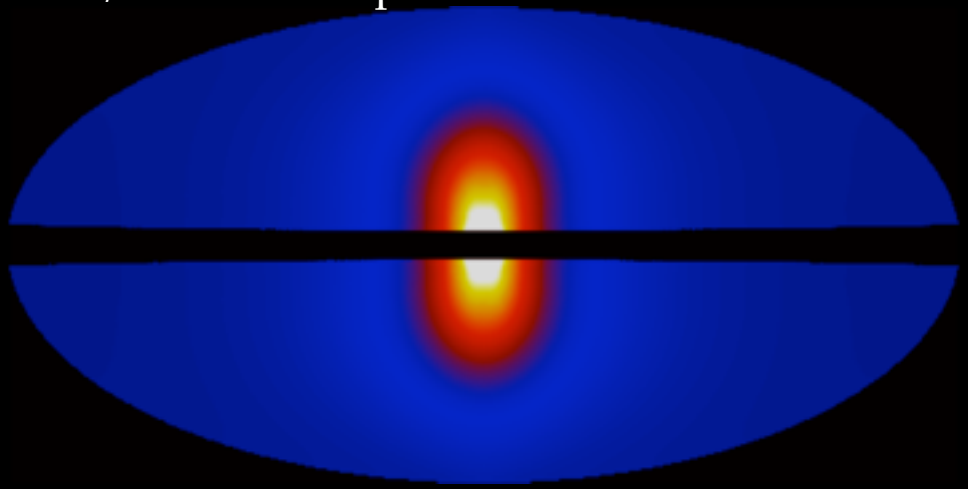
an ~5 GeV excess!!!

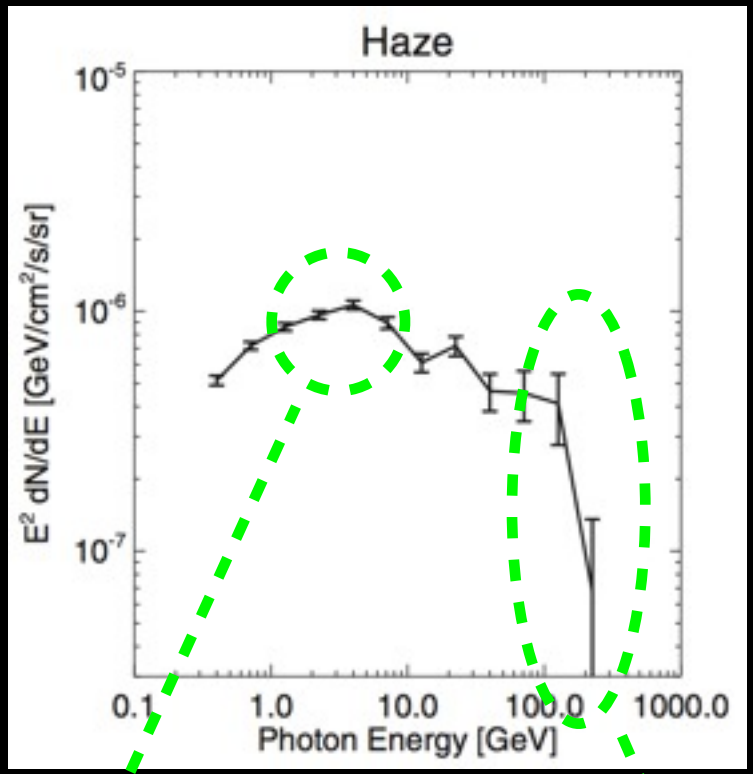
morphological tracers of emission

Fermi 2-5 GeV



Haze/Bubbles template





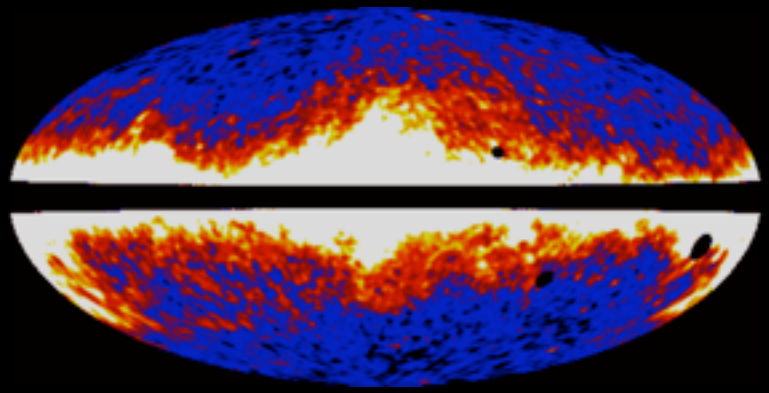
Dobler et al. (2010)

an ~5 GeV excess!!!

...and a LINE!!!

Greg Dobler (KITP/UCSB)

the Fermi *Haze a.k.a.* Fermi *Bubbles*



Fermi data 2-5 GeV

Greg Dobler (KITP/UCSB)

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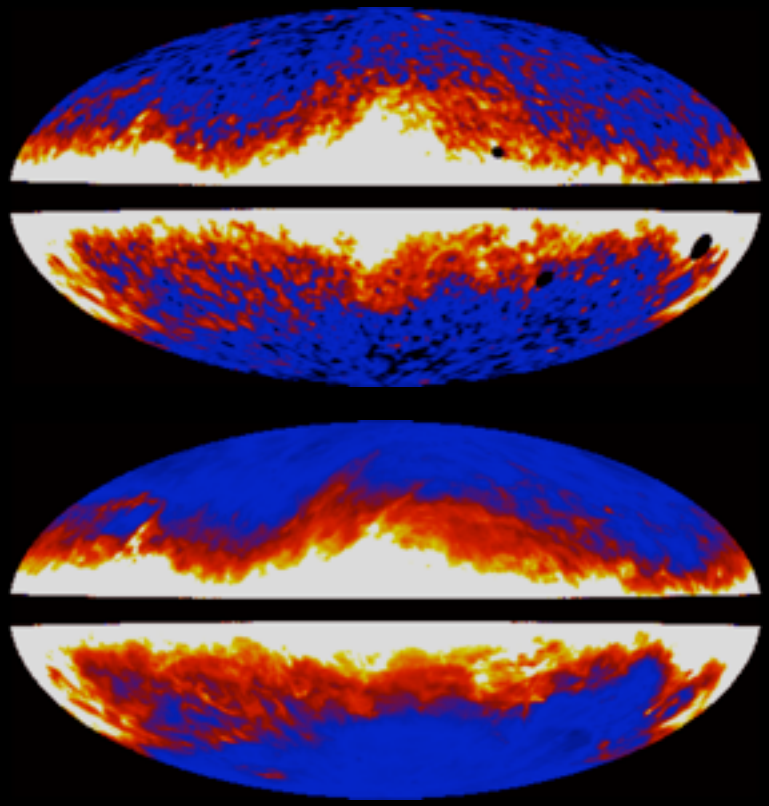

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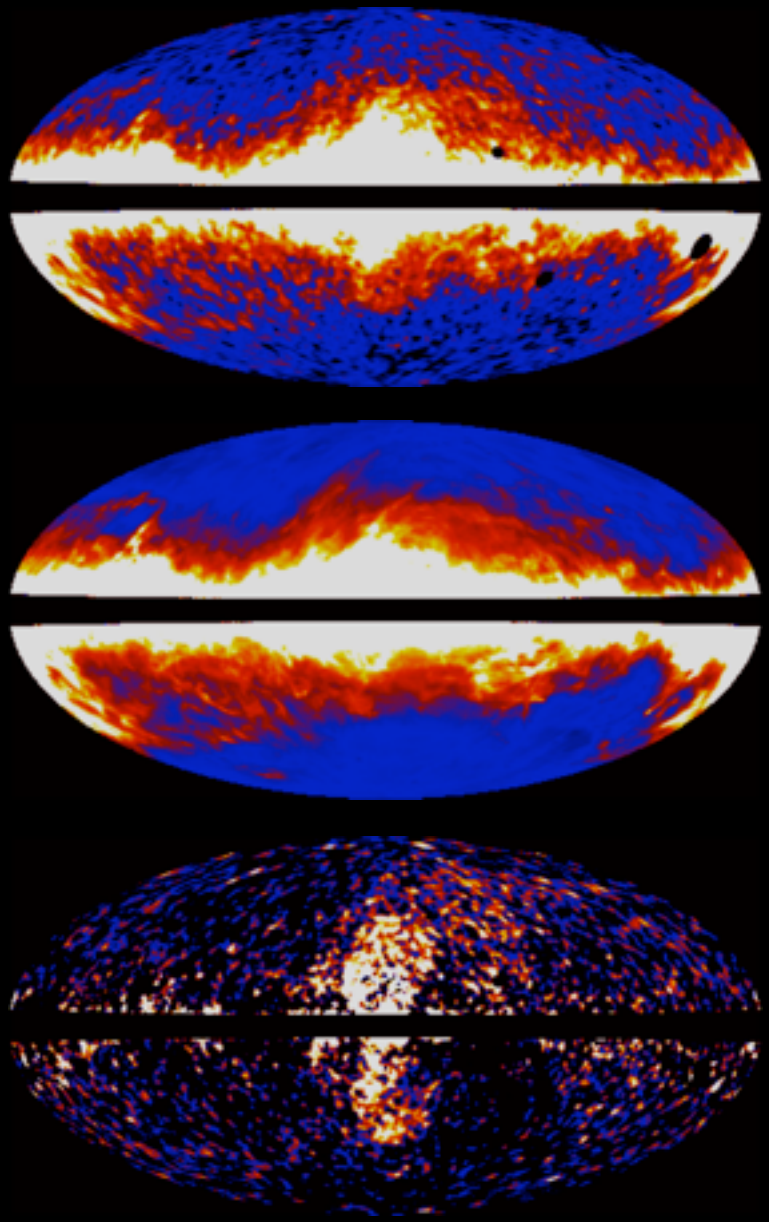

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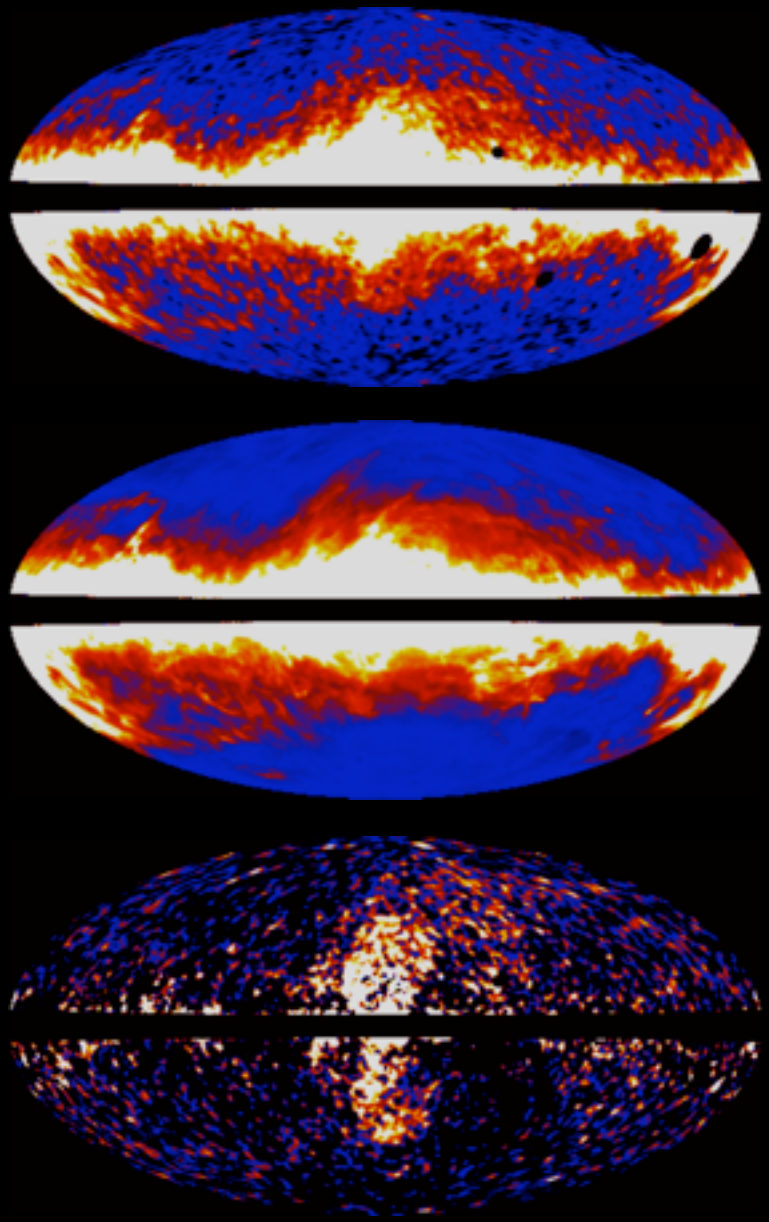
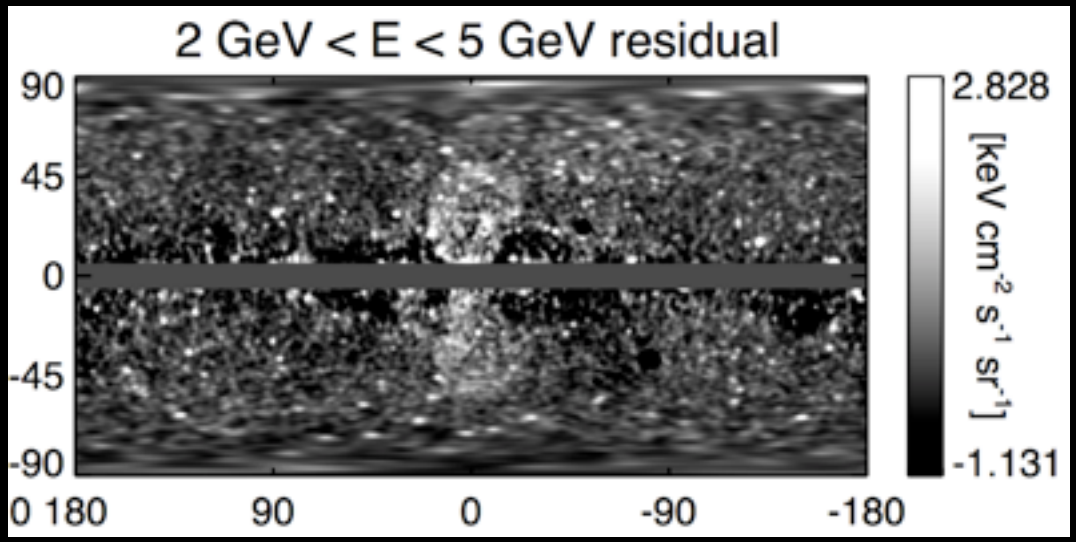
the Fermi *Haze a.k.a.* Fermi *Bubbles*



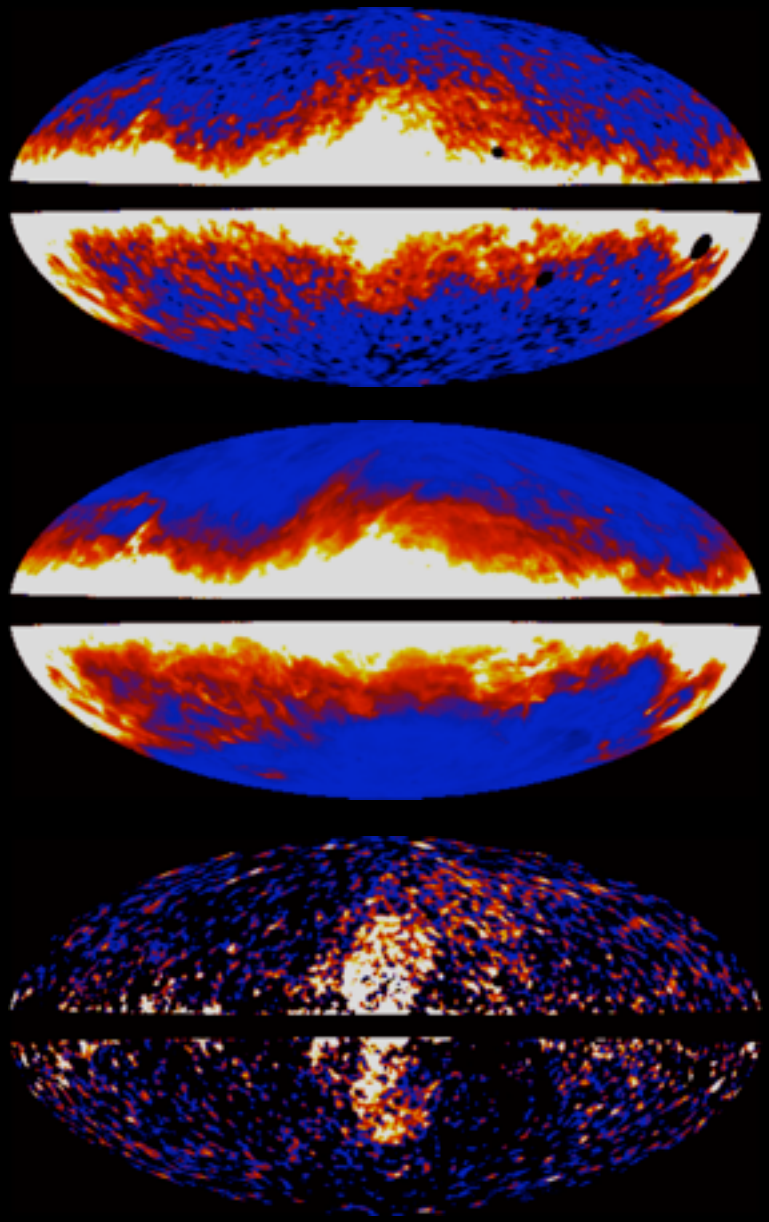
Dobler et al. (2010)



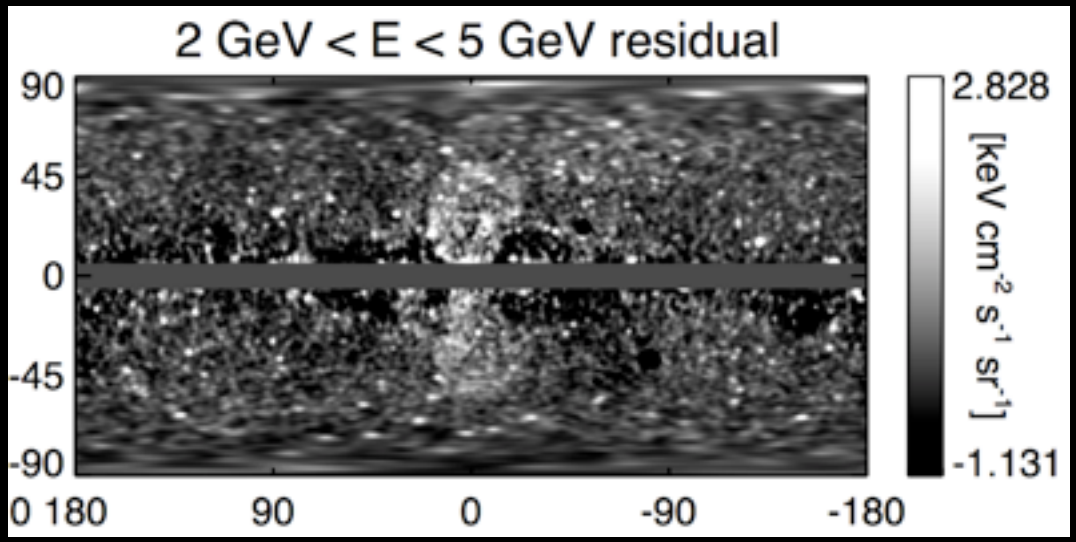
Fermi "haze"

Greg Dobler (KITP/UCSB)

the Fermi *Haze a.k.a.* Fermi *Bubbles*



Dobler et al. (2010)

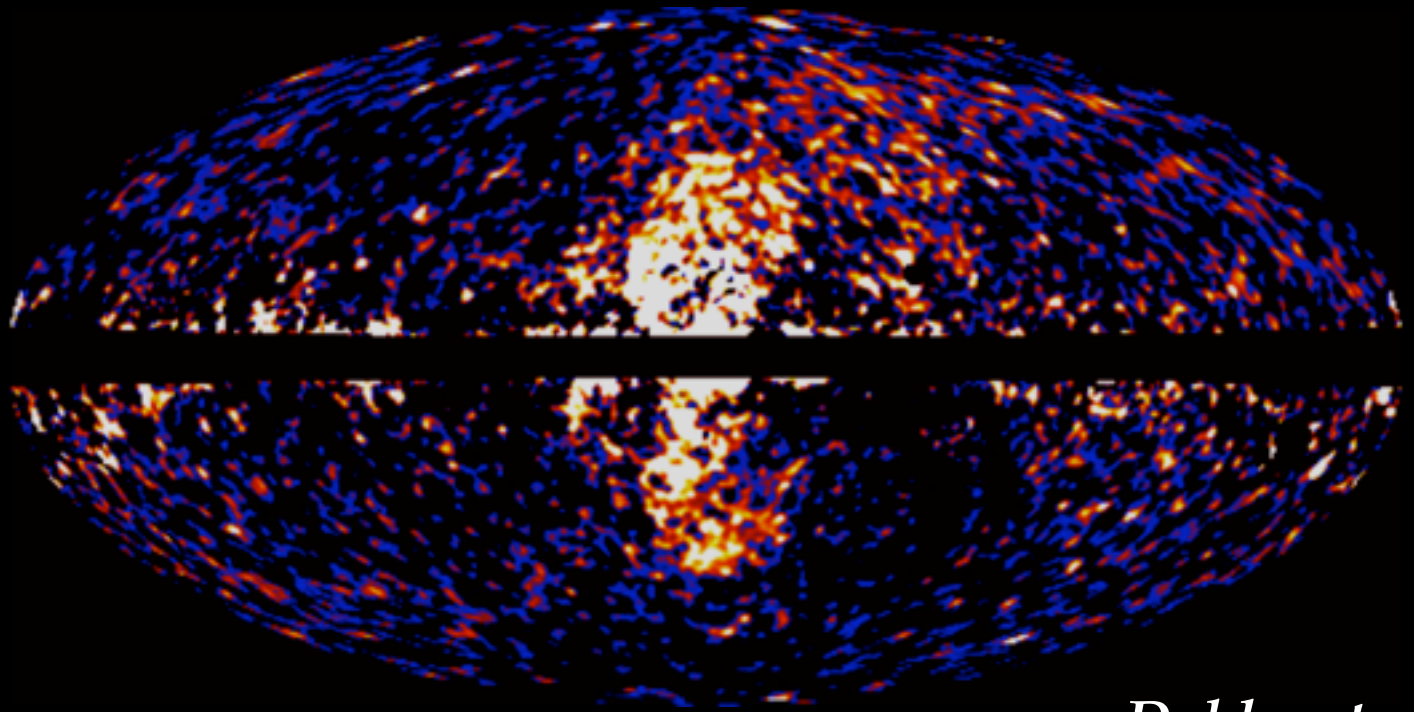


Fermi "haze"

...and later the "*Fermi* bubbles"

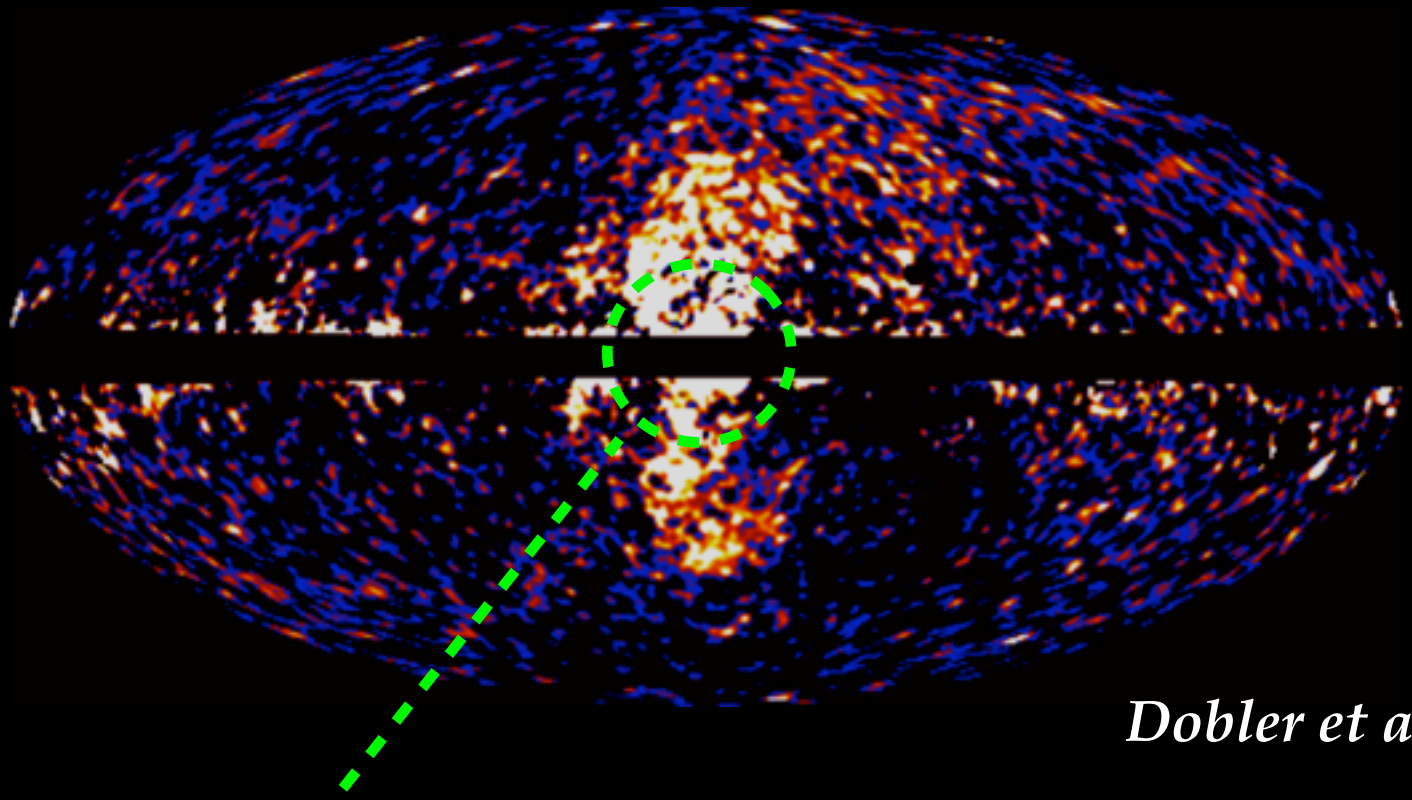
(Su et al., 2010)

the Fermi *Haze a.k.a.* Fermi *Bubbles*



Dobler et al. (2010)

the Fermi *Haze a.k.a.* Fermi *Bubbles*

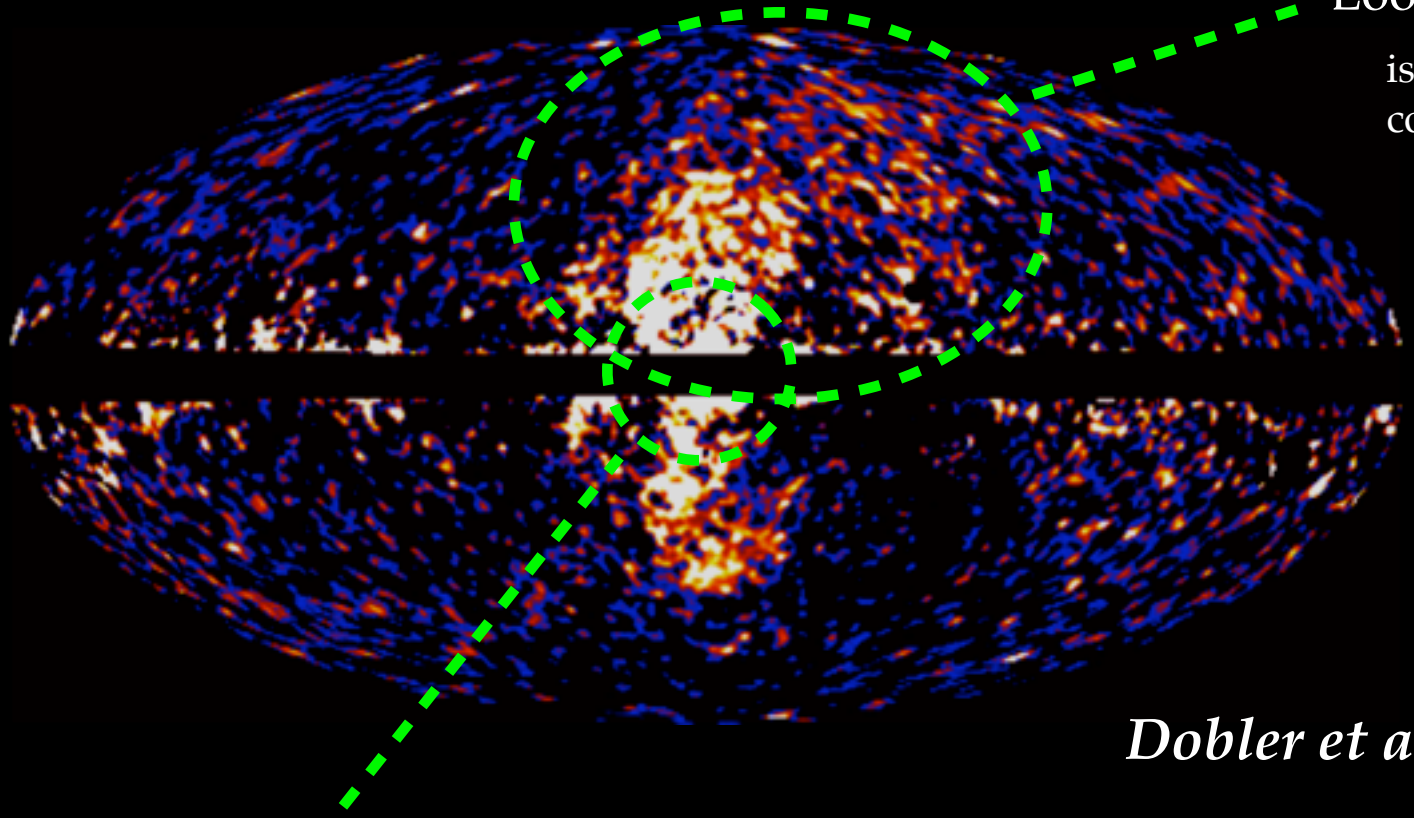


Dobler et al. (2010)

does it extend to the center?

- source of ~few GeV excess directly?
- injection of hard spectrum cosmic-rays?

the Fermi *Haze a.k.a.* Fermi *Bubbles*



Loop I "excess"

issue for cluster constraints?

Dobler et al. (2010)

does it extend to the center?

source of ~few GeV excess directly?

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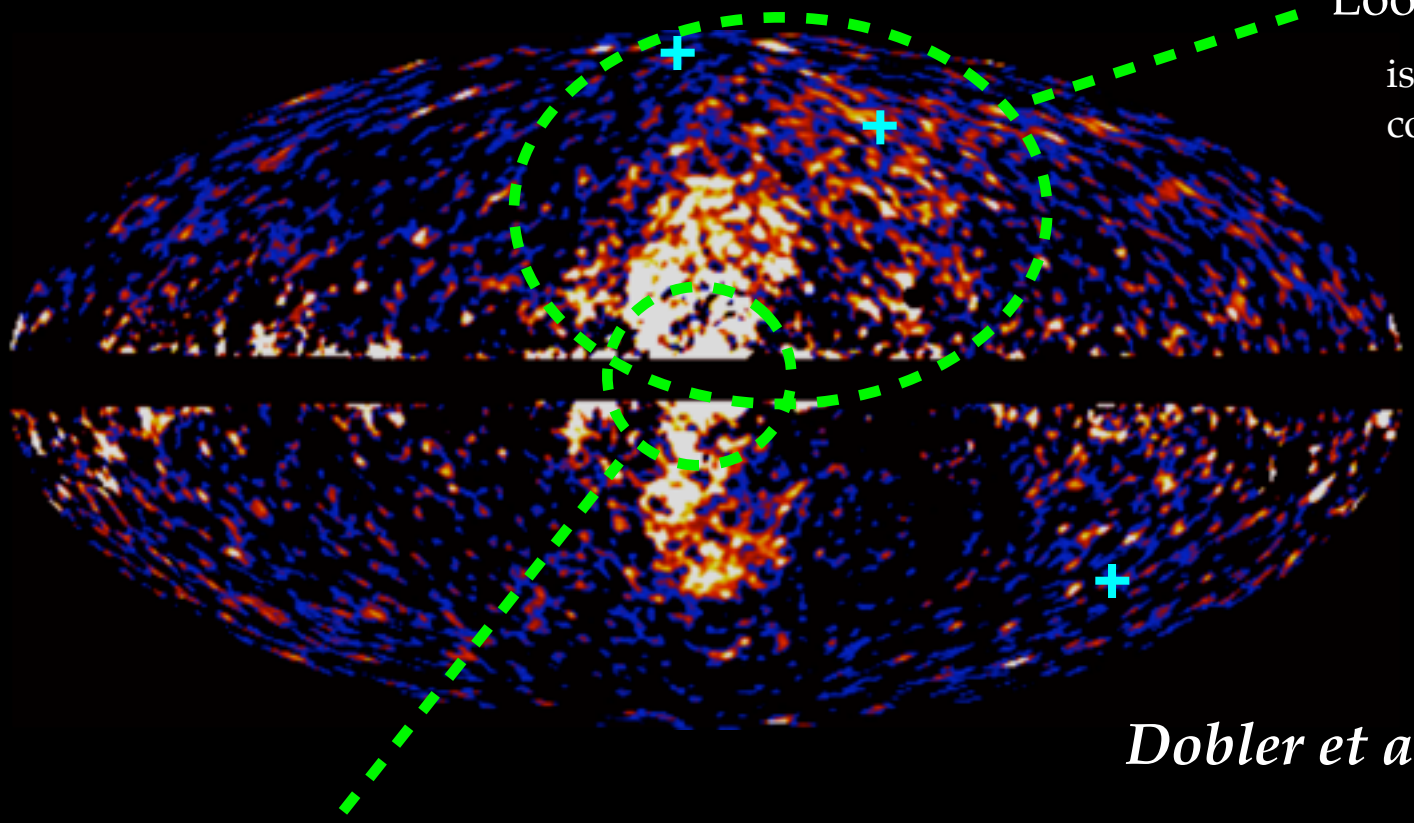
Greg Dobler (KITP/UCSB)

the Fermi *Haze a.k.a.* Fermi *Bubbles*



Loop I "excess"

issue for cluster constraints?

Dobler et al. (2010)

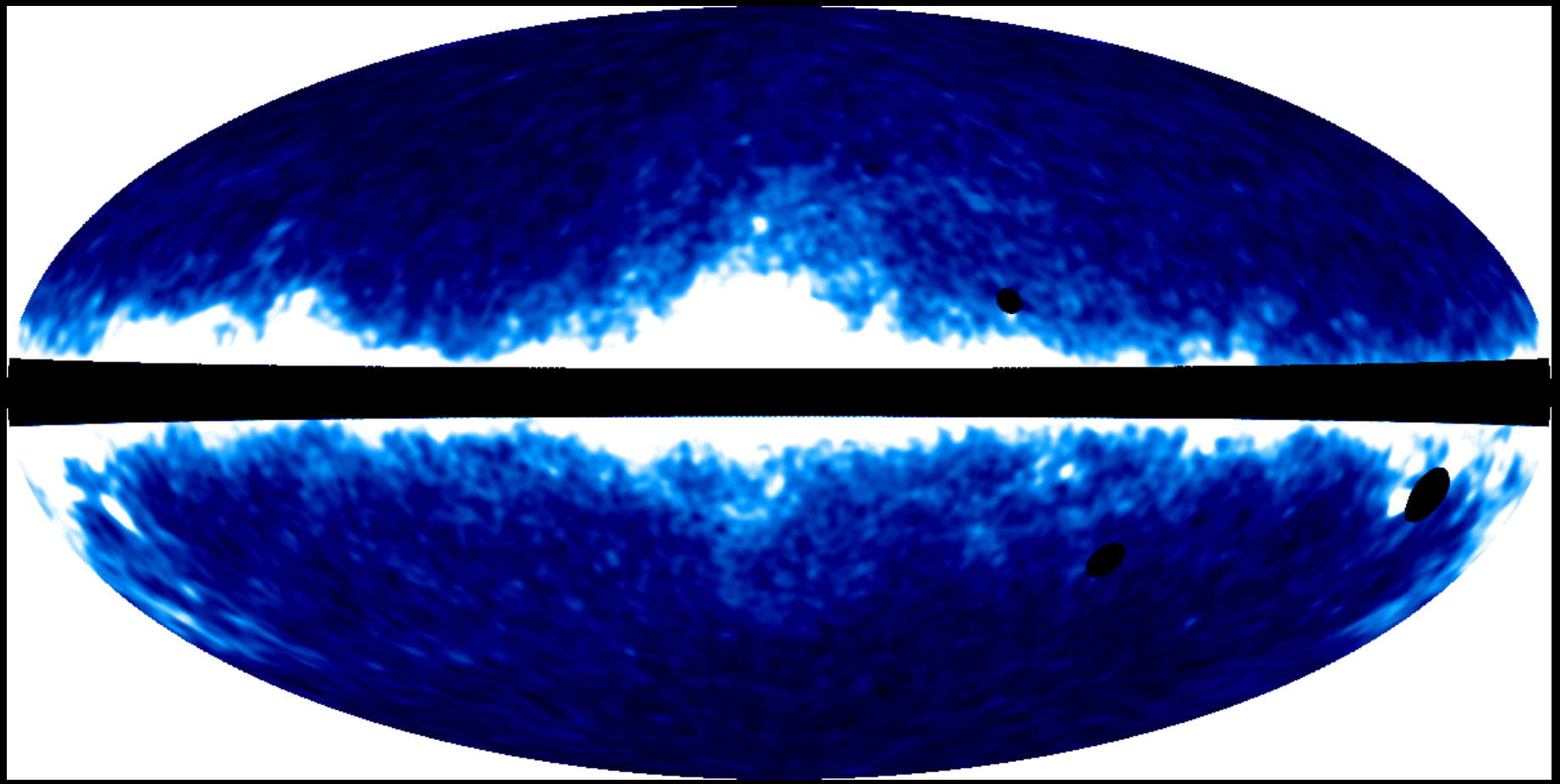
does it extend to the center?

source of ~few GeV excess directly?

injection of hard spectrum cosmic-rays?

no templates required...

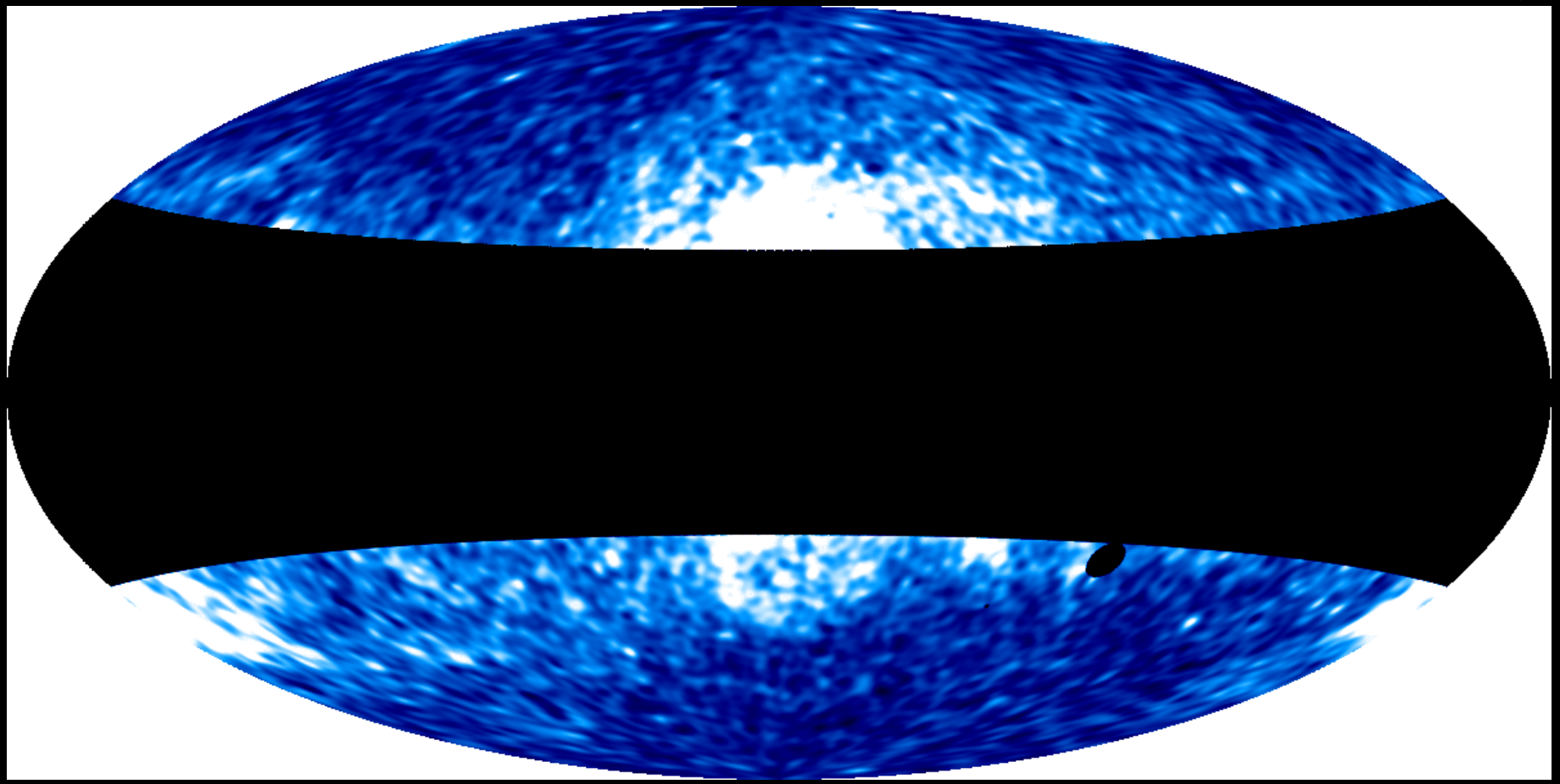
Dobler et al. (2010)



Fermi 2-5 GeV

no templates required...

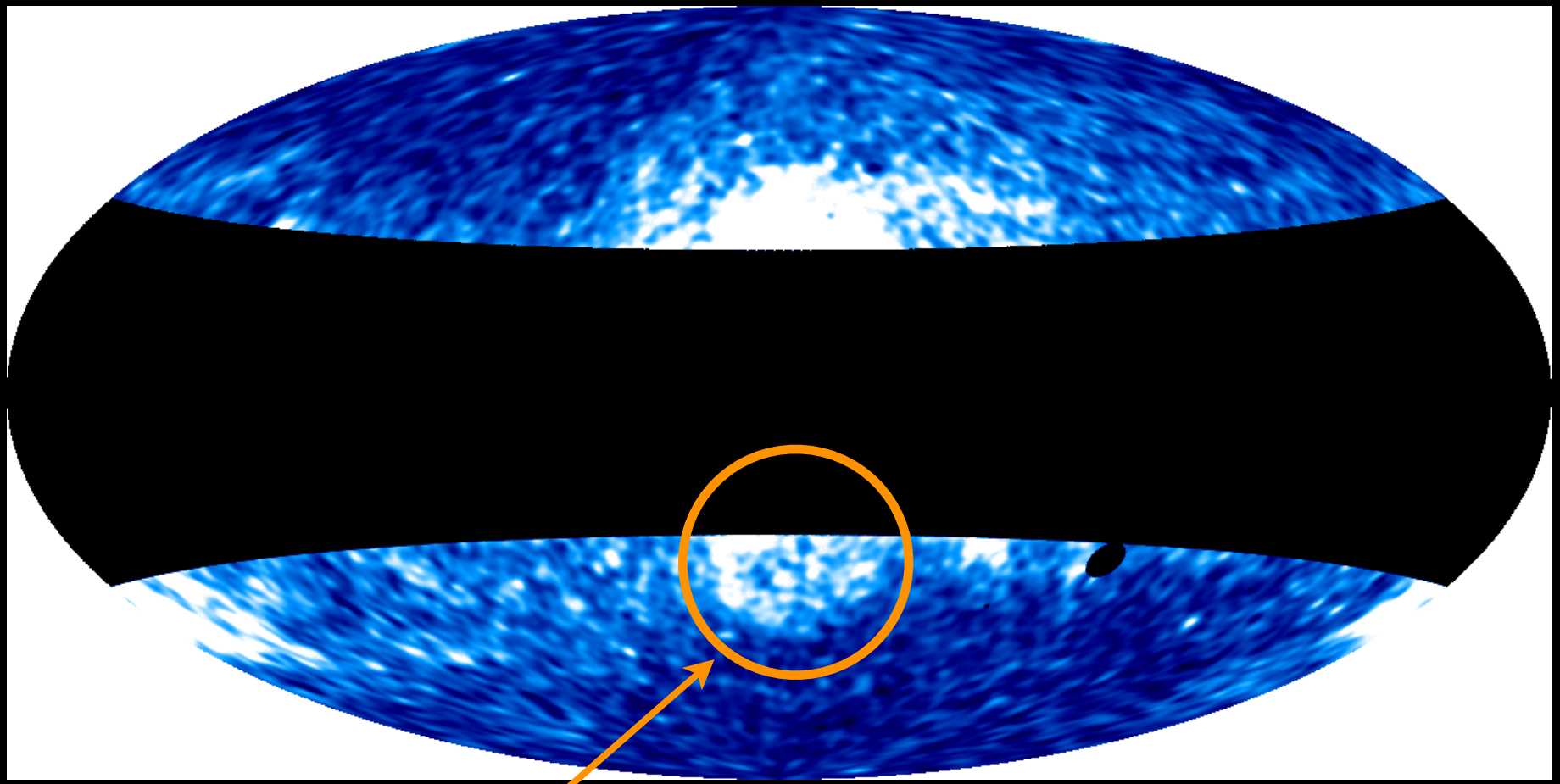
Dobler et al. (2010)



Fermi 2-5 GeV

no templates required...

Dobler et al. (2010)



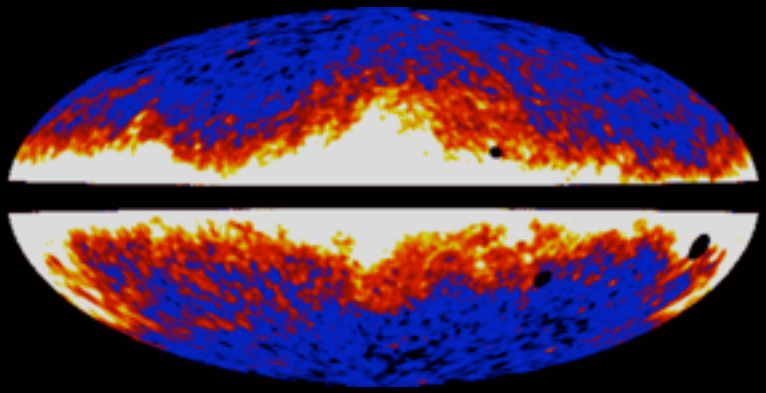
Fermi 2-5 GeV

visible ***even*** with ***no*** templates, ***no*** fitting, ***no*** subtraction, etc...

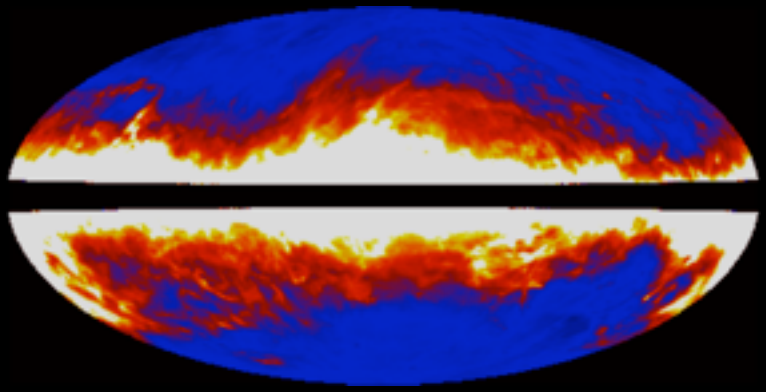
Greg Dobler (KITP/UCSB)

the Fermi haze/bubbles

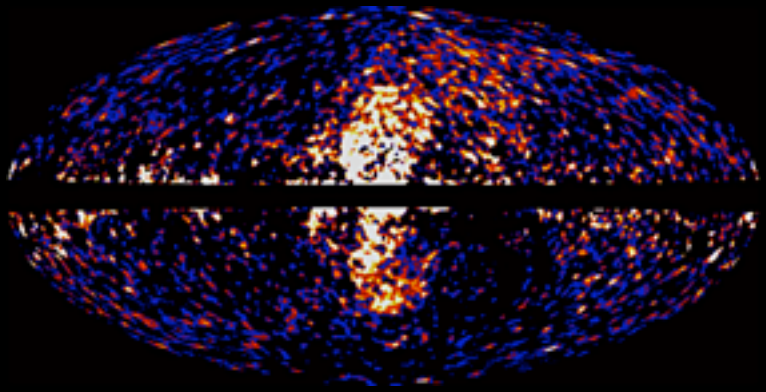
Fermi data 2-5 GeV

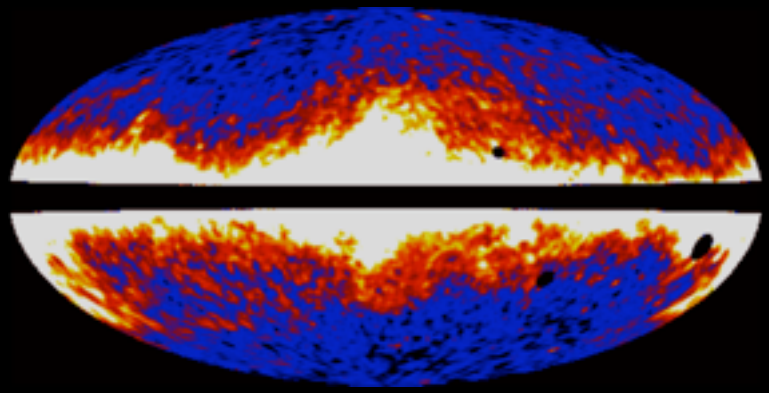


diffuse model 2-5 GeV



Fermi "haze/bubbles"

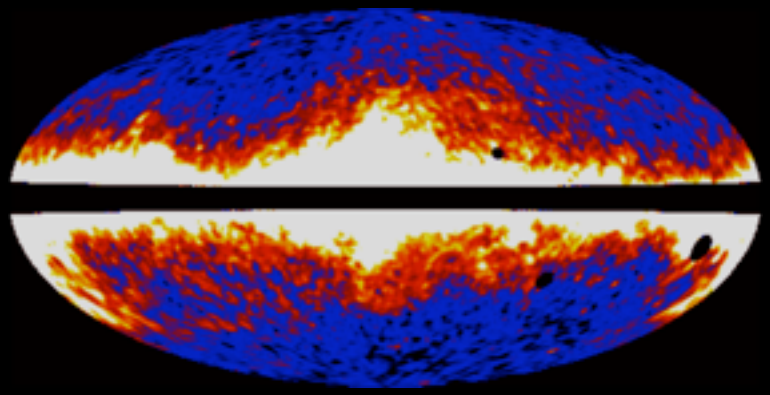




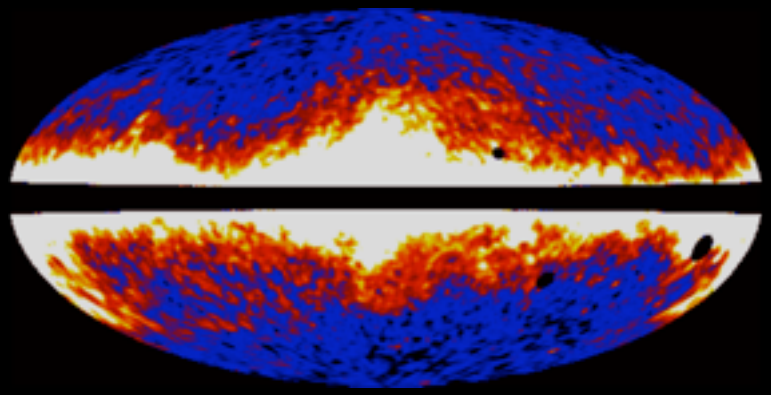
Fermi data 2-5 GeV

Greg Dobler (KITP/UCSB)

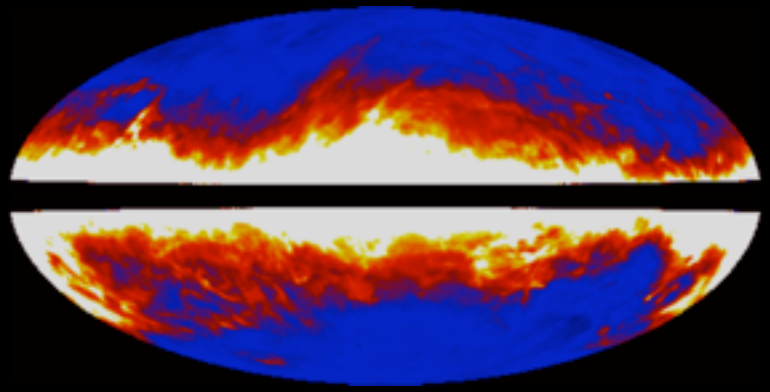
the Fermi haze/bubbles



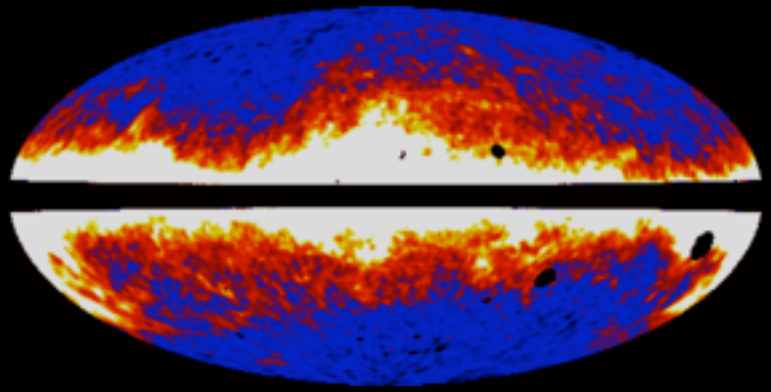
Fermi data 2-5 GeV



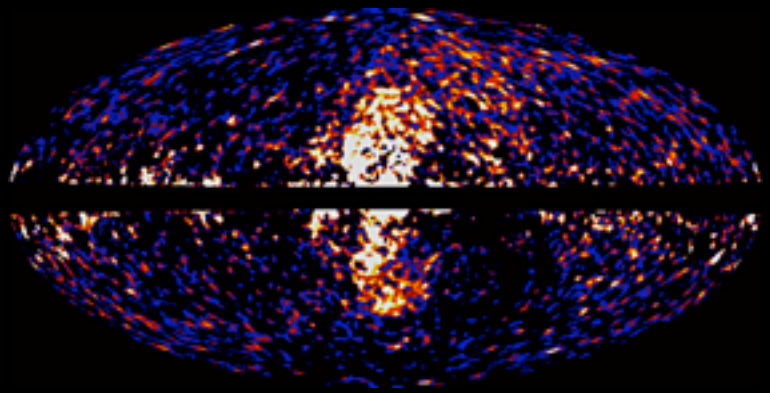
Fermi data 2-5 GeV



diffuse model 2-5 GeV



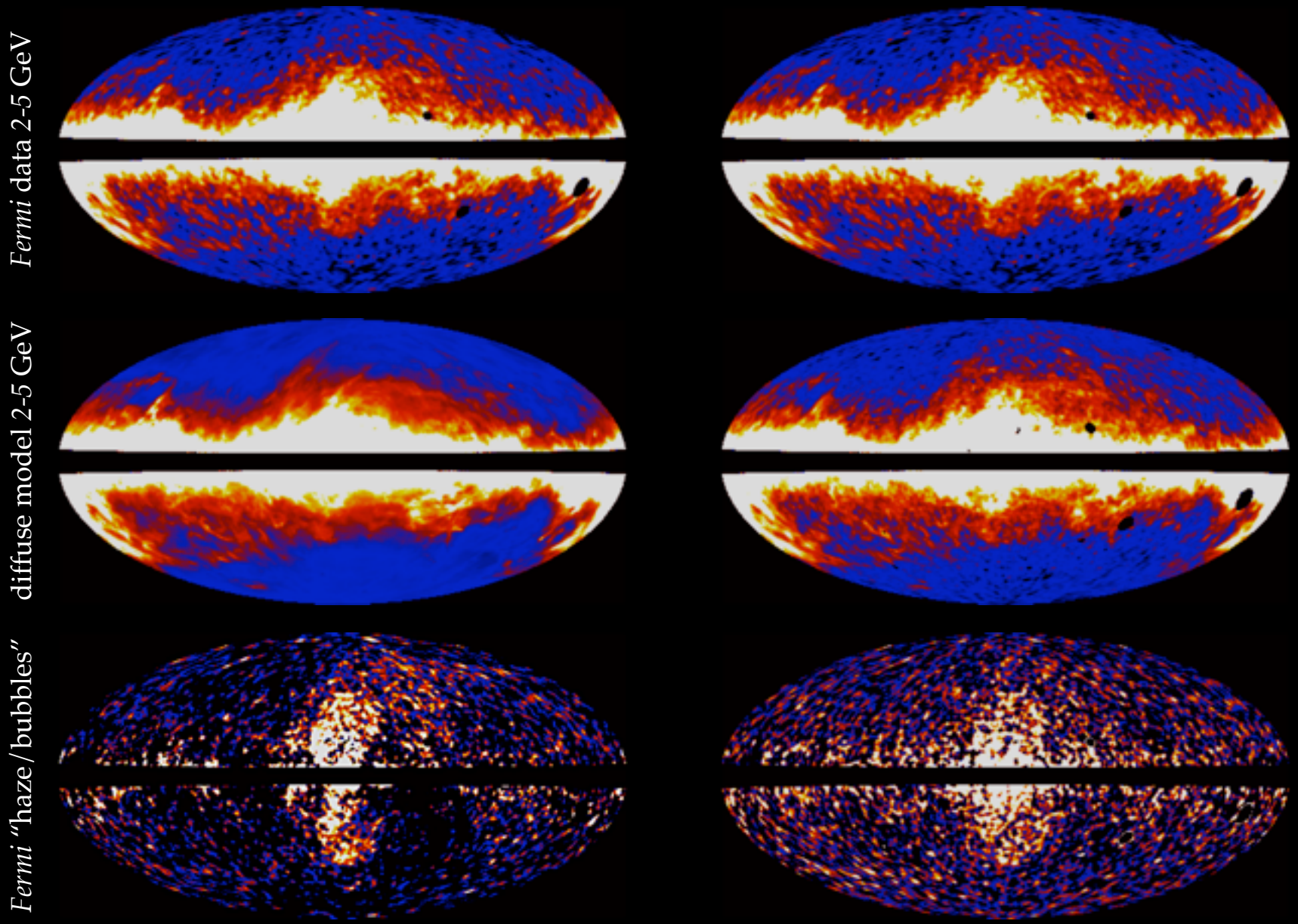
Fermi data 0.5-1 GeV



Fermi "haze/bubbles"

Greg Dobler (KITP/UCSB)

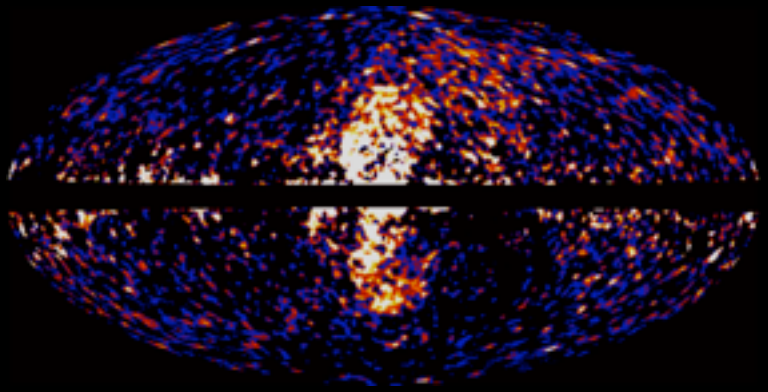
the Fermi haze/bubbles

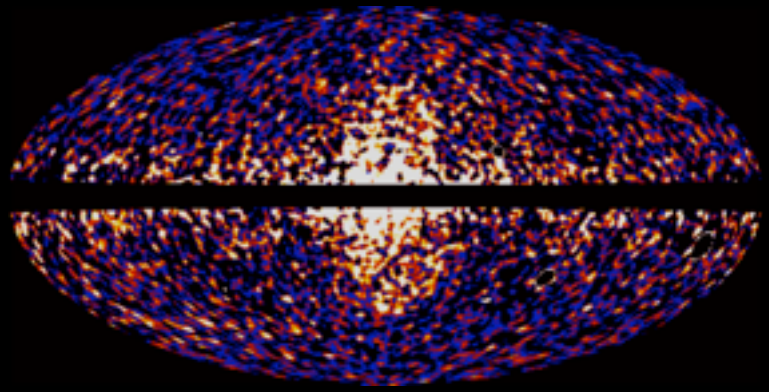


AGN jet-blown bubble

DM annihilation

Fermi "haze/bubbles"





Fermi "haze/bubbles"

Guo, Matthews, Dobler, & Oh (2011)

$$\frac{d\rho}{dt} + \rho\nabla\cdot\mathbf{v} = 0,$$

$$\rho\frac{d\mathbf{v}}{dt} = -\nabla(P + P_{\rm c}) - \rho\nabla\Phi + \nabla\cdot\mathbf{\Pi},$$

$$\frac{\partial e}{\partial t} + \nabla\cdot(e\mathbf{v}) = -P\nabla\cdot\mathbf{v} + \mathbf{\Pi}:\nabla\mathbf{v},$$

$$\frac{\partial e_{\rm c}}{\partial t} + \nabla\cdot(e_{\rm c}\mathbf{v}) = -P_{\rm c}\nabla\cdot\mathbf{v} + \nabla\cdot(\kappa\nabla e_{\rm c}),$$

Dobler, Cholis, & Weiner (2011)

$$\frac{\partial\psi}{\partial t} = \frac{\partial(b\psi)}{\partial E} + \vec{\nabla}(D\vec{\nabla}\psi) + Q,$$

$$\vec{\nabla}(D\vec{\nabla}\psi) = \frac{1}{r}\frac{\partial}{\partial r}(rD_{rr}\frac{\partial\psi}{\partial r} + rD_{rz}\frac{\partial\psi}{\partial z}) + \frac{\partial}{\partial z}(D_{zz}\frac{\partial\psi}{\partial z} + D_{zr}\frac{\partial\psi}{\partial r}),$$

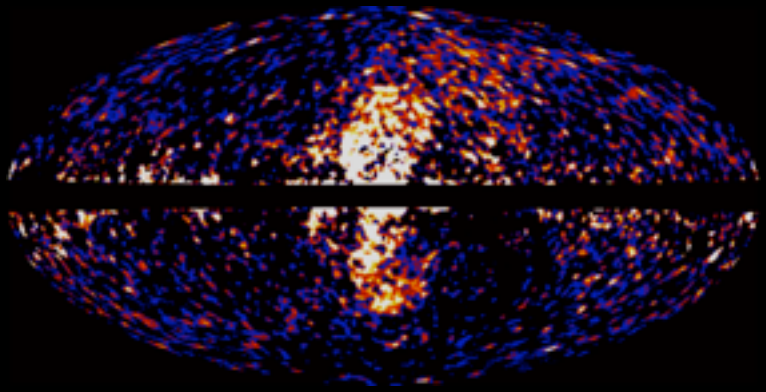
$$D_{ij} = D_0\left(\frac{\nu^2\delta_{ij} + \Omega_i\Omega_j}{\nu^2 + \Omega^2}\right),$$

$$Q(r,z) = \frac{1}{2}\langle\sigma v\rangle\frac{dN}{dE}\left(\frac{\rho(r,z)}{M_\chi}\right)^2,$$

Greg Dobler (KITP/UCSB)

AGN jet-blown bubble

DM annihilation



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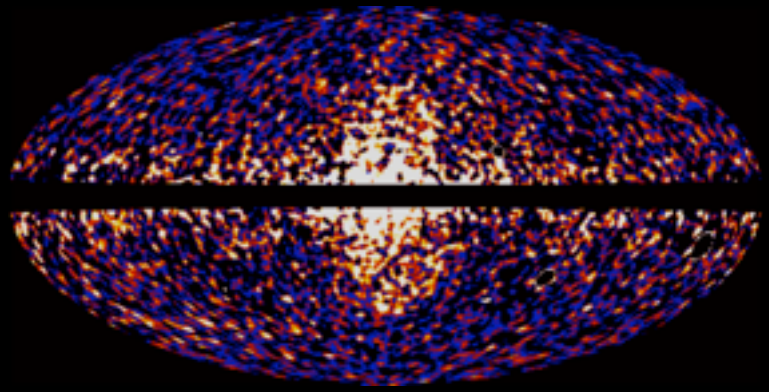

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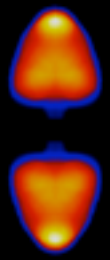
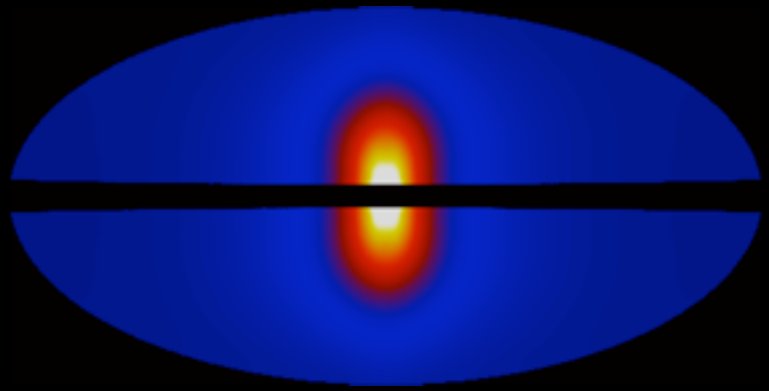


Guo, Matthews, Dobler, & Oh (2011)



Dobler, Cholis, & Weiner (2011)

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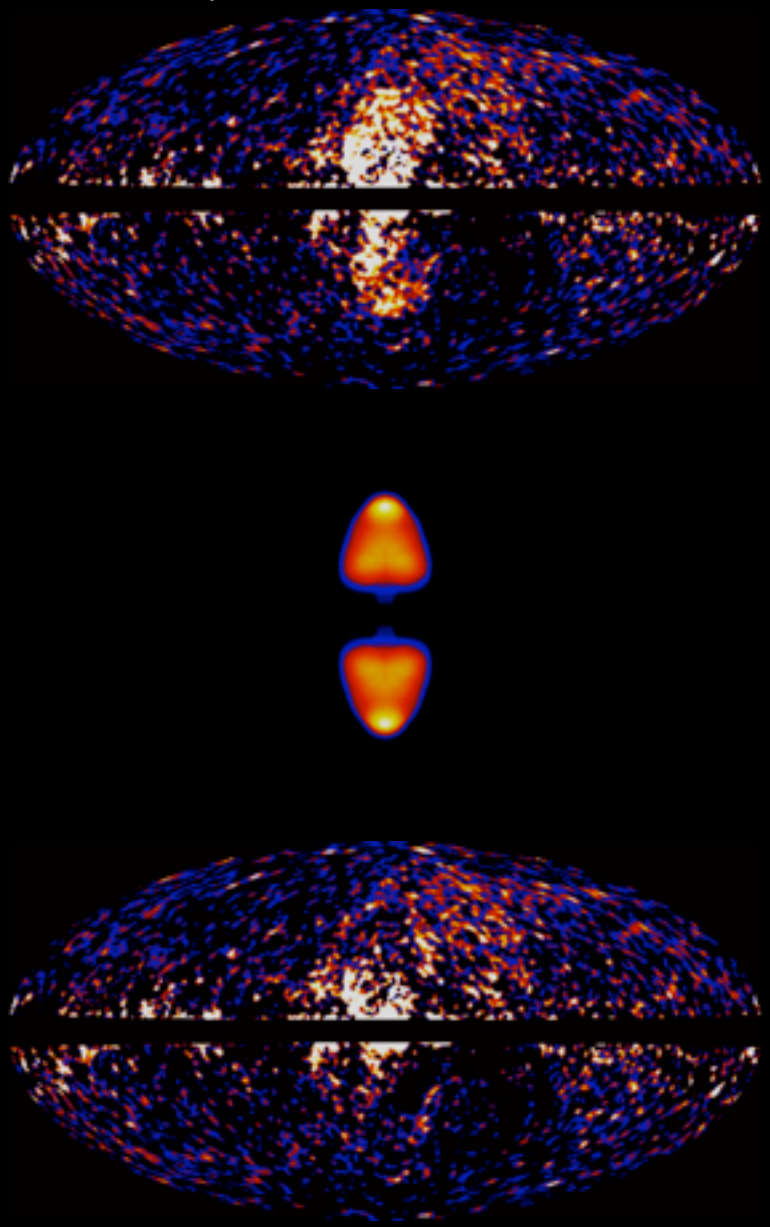

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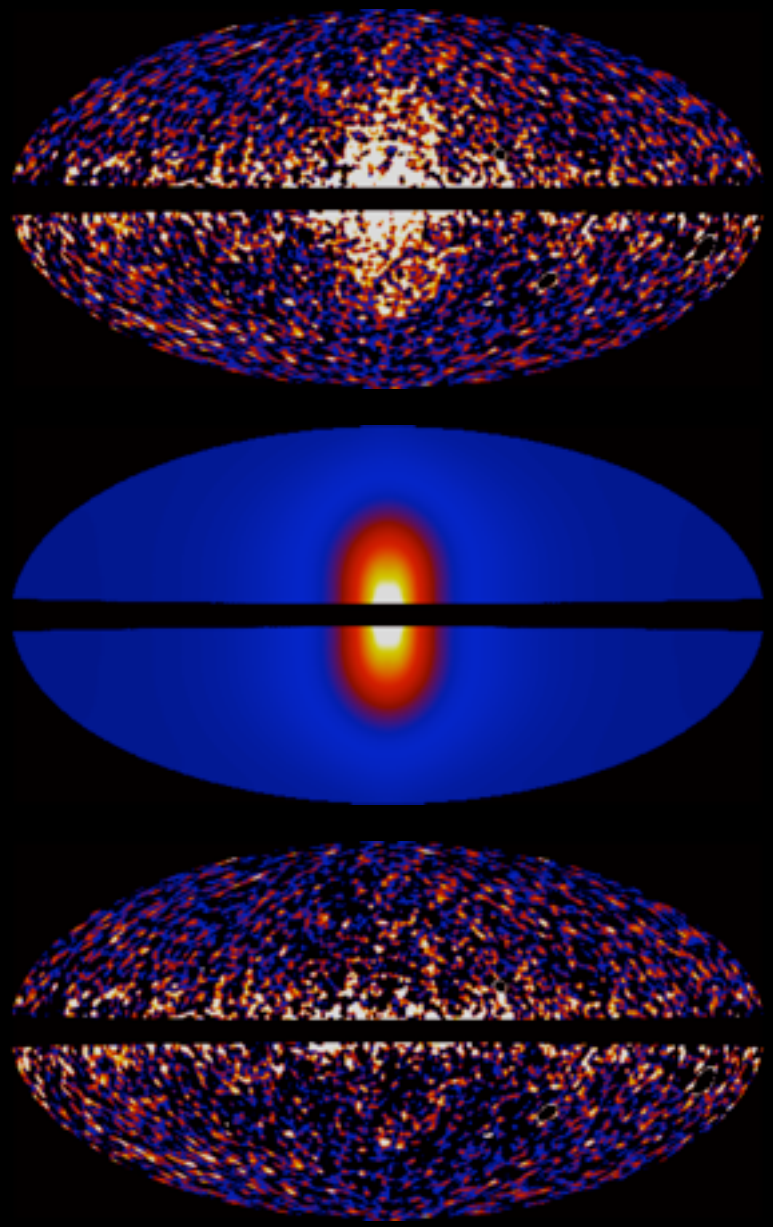

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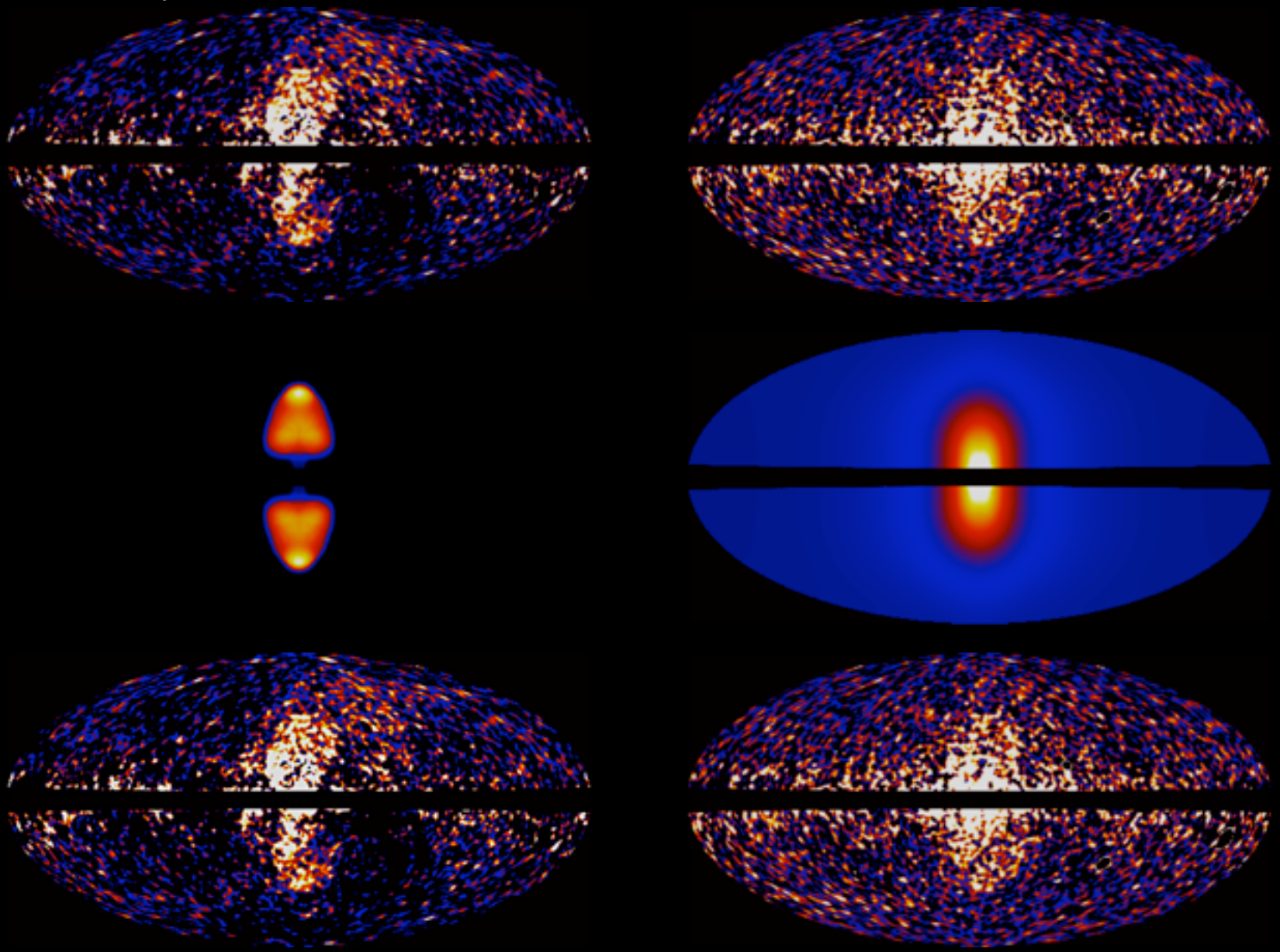

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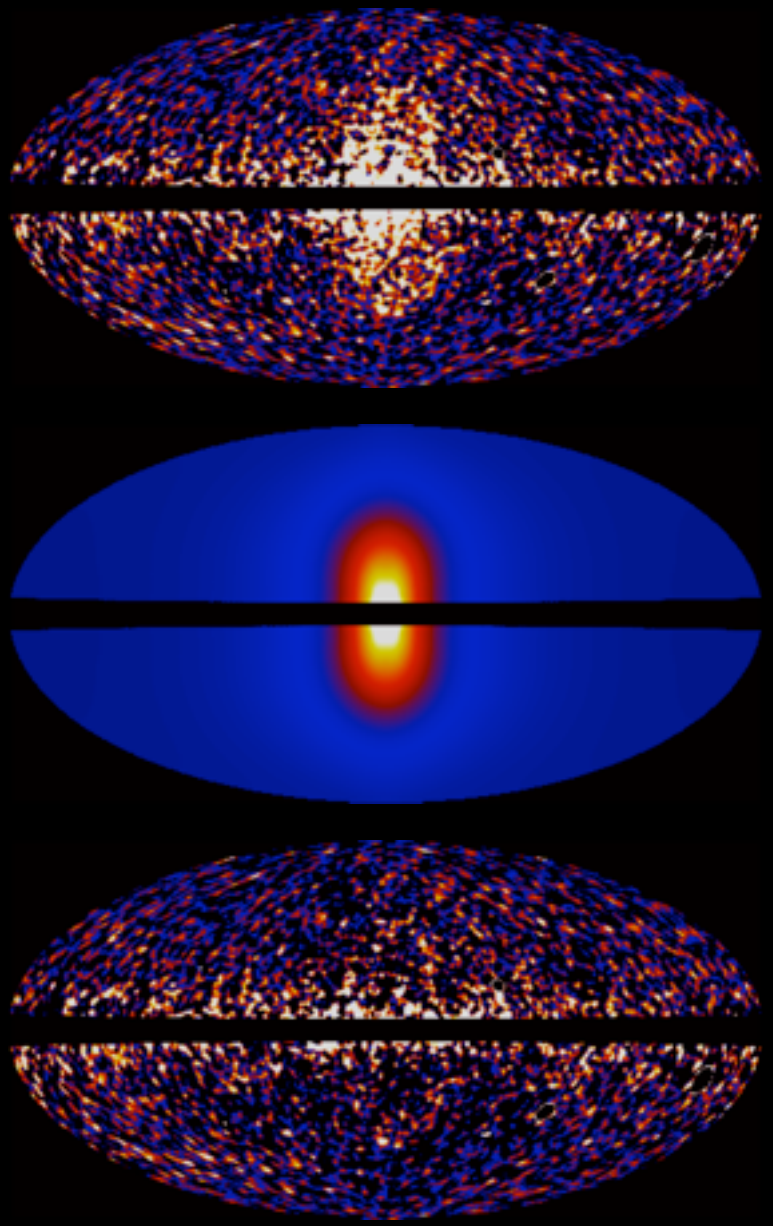

Fermi "haze/bubbles"

Dobler, Cholis, & Weiner (2011)

DM annihilation

THE *FERMI* GAMMA-RAY HAZE FROM DARK MATTER ANNIHILATIONS AND ANISOTROPIC DIFFUSION

GREGORY DOBLER[1], ILIAS CHOLIS[2,3], AND NEAL WEINER[3,4]
[1] Kavli Institute for Theoretical Physics, University of California, Santa Barbara Kohn Hall, Santa Barbara, CA 93106, USA; dobler@kitp.ucsb.edu
[2] Astrophysics Sector, La Scuola Internazionale Superiore di Studi Avanzati and Istituto Nazionale di Fisica Nucleare, Sezione di Trieste, via Bonomea 265, 34136 Trieste, Italy; ilias.cholis@sissa.it
[3] Center for Cosmology and Particle Physics, Department of Physics, New York University, New York, NY 10003, USA; neal.weiner@nyu.edu
[4] School of Natural Sciences, Institute for Advanced Study, Princeton, NJ 08540, USA
Received 2011 February 26; accepted 2011 July 26; published 2011 October 12

The most significant outstanding issues are the sharp "edges" of the haze at high latitudes and also the morphology of the haze at low latitudes. Sharp edges are not particularly expected with either a DM annihilation or an astrophysical (such as winds or

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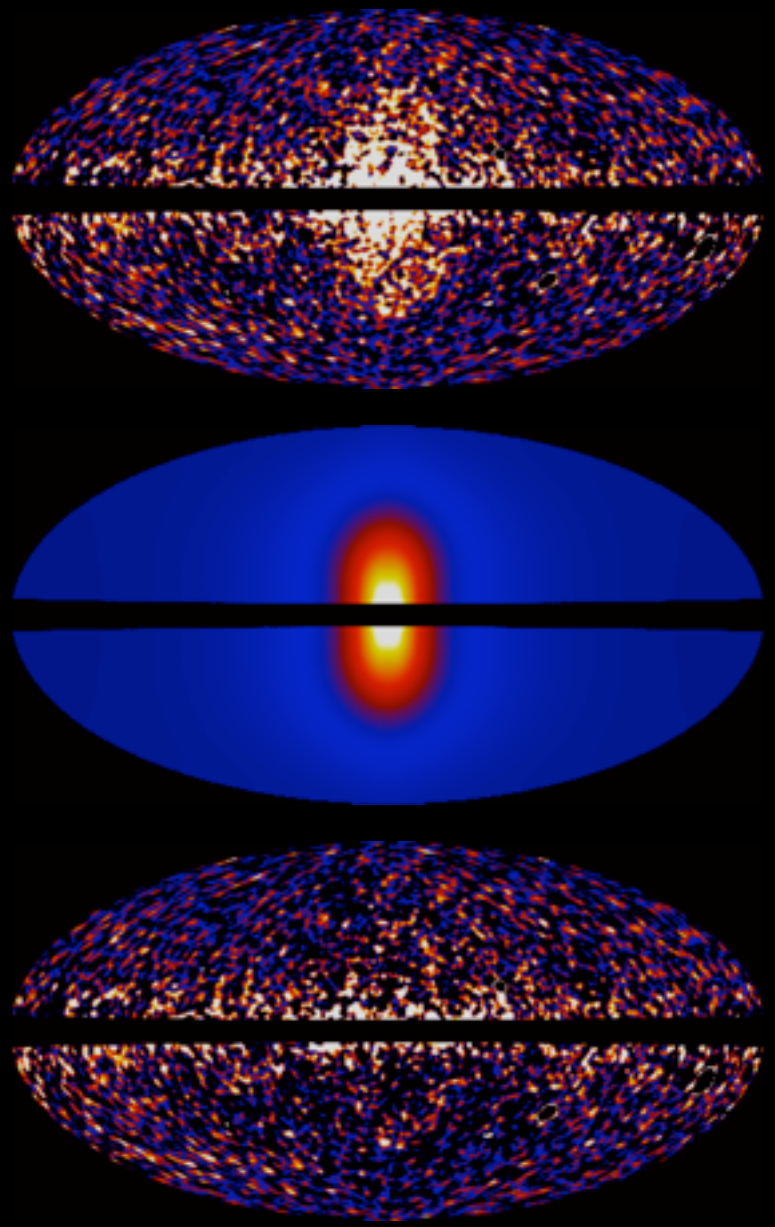
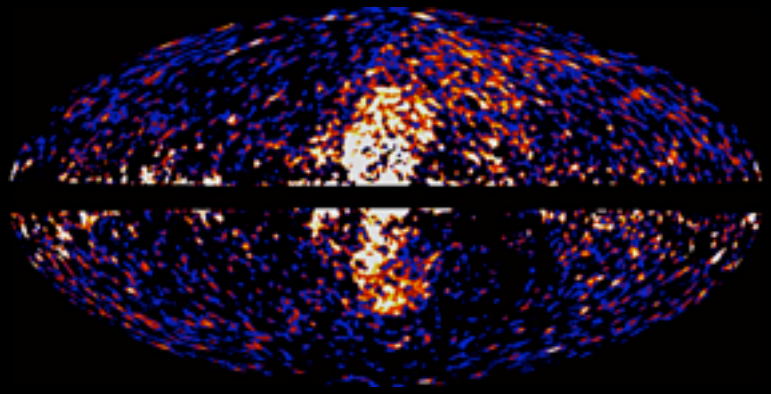
If these features persist in future data, such hybrid scenarios are inevitable.



Fermi "haze/bubbles"

Dobler, Cholis, & Weiner (2011)

are the edges "real"?



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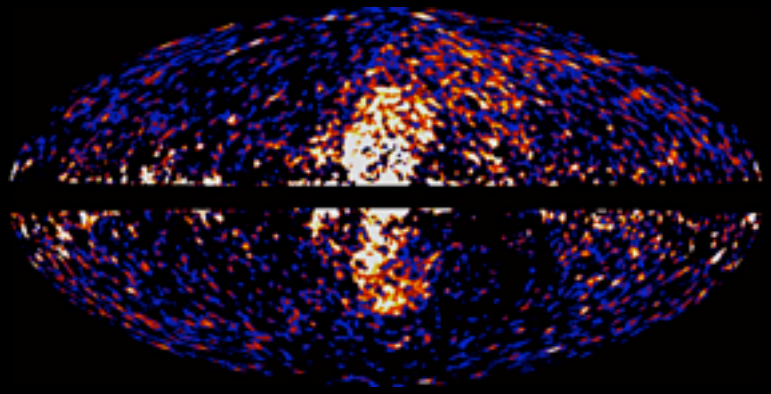

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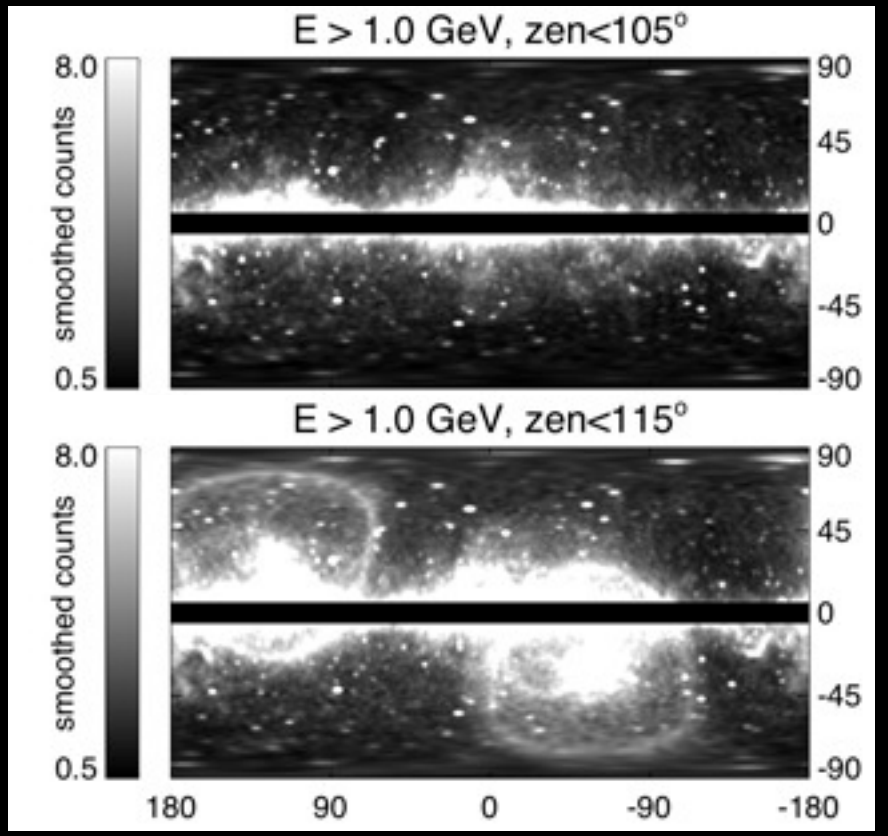
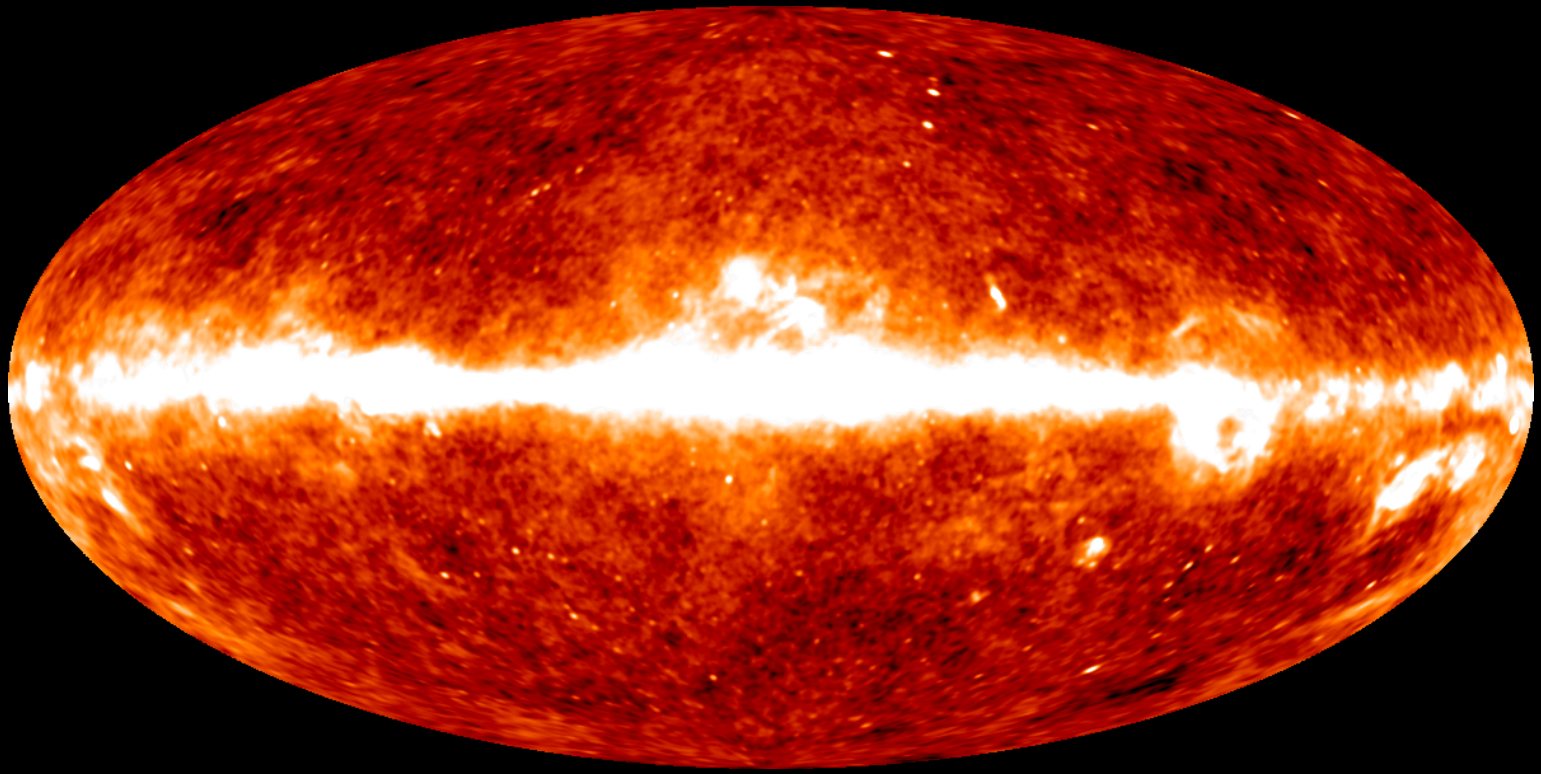


to the microwaves...



WMAP 23 GHz

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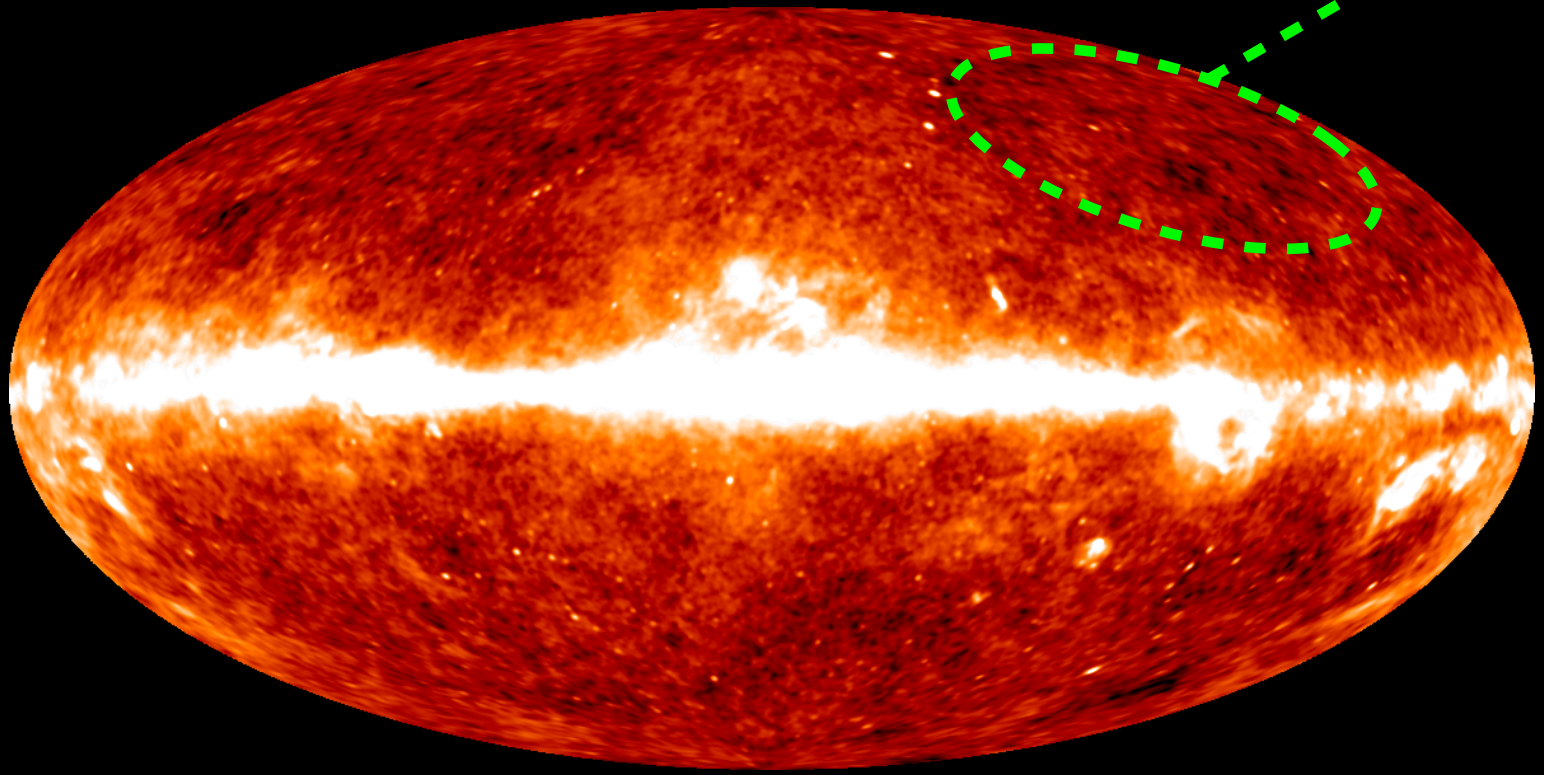

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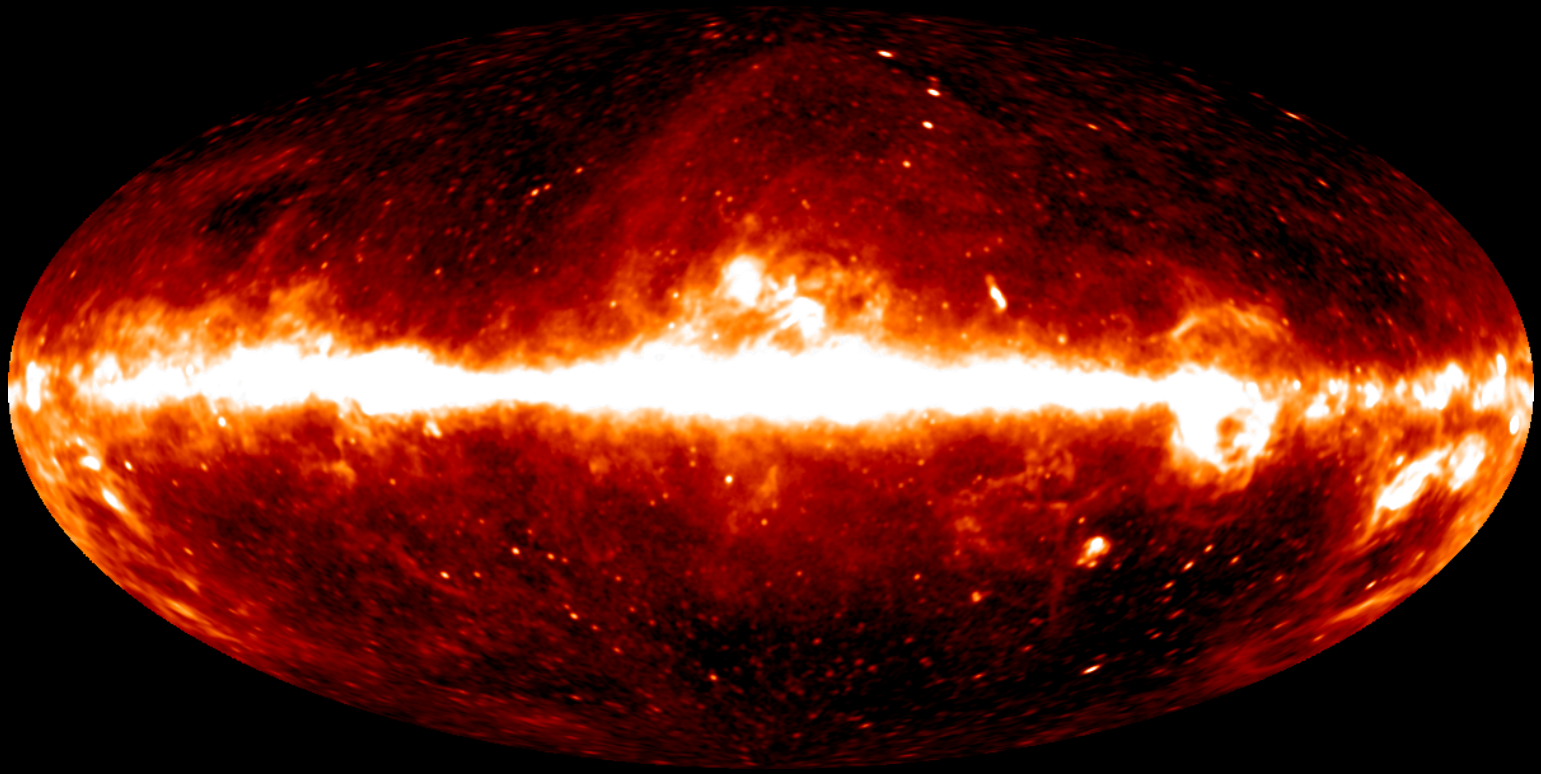
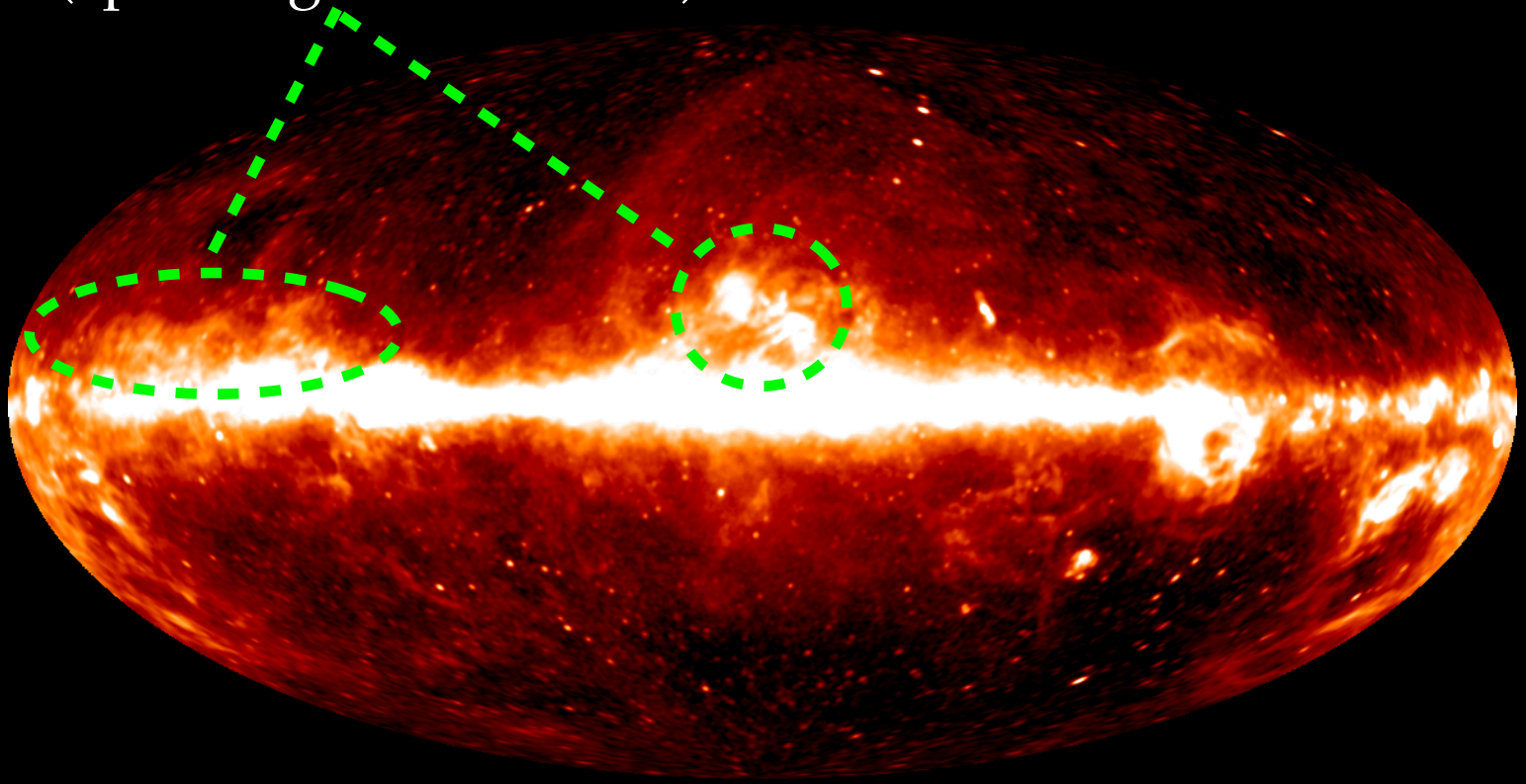


WMAP 23 GHz

to the microwaves...

dust (spinning and thermal)



WMAP 23 GHz

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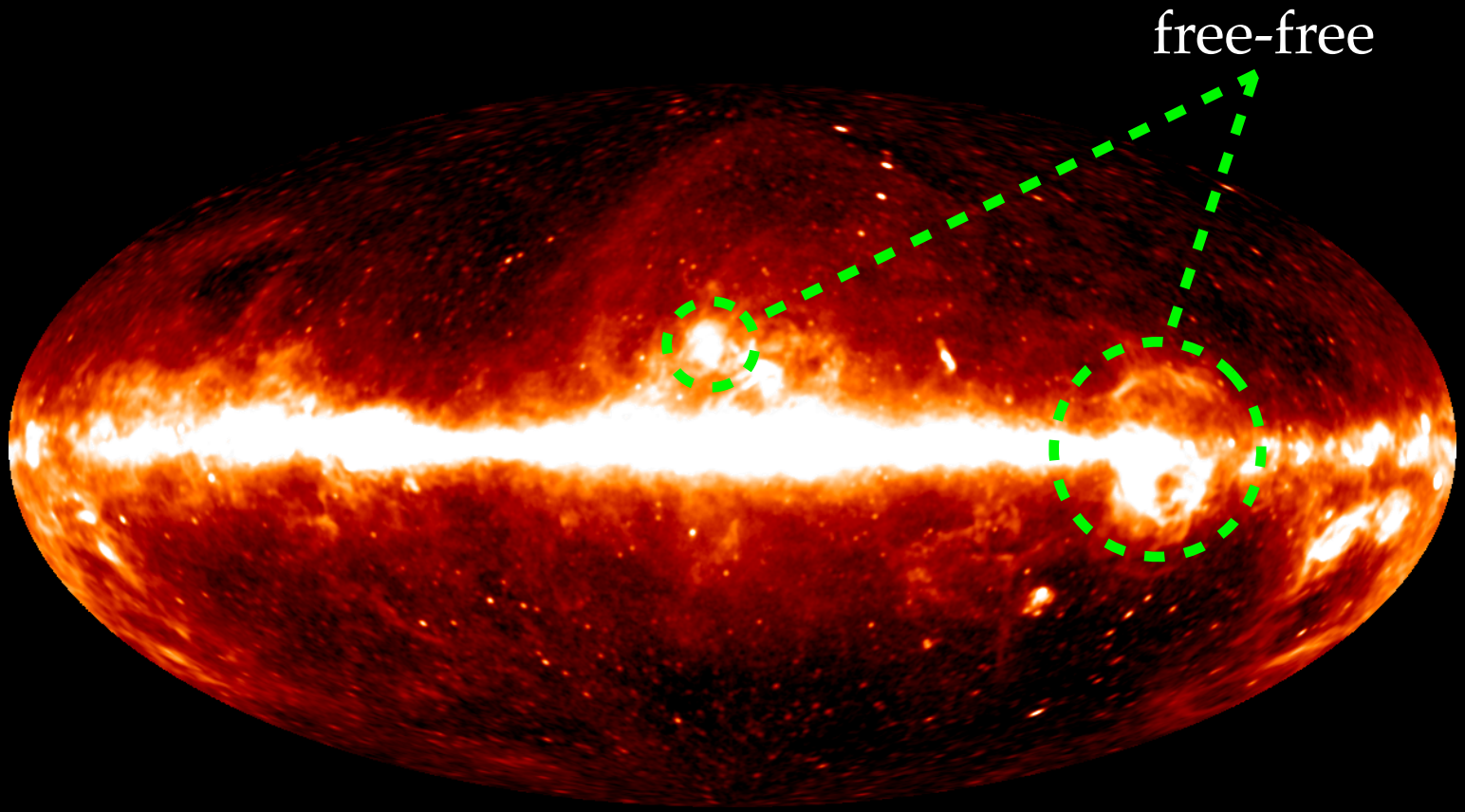

WMAP 23 GHz

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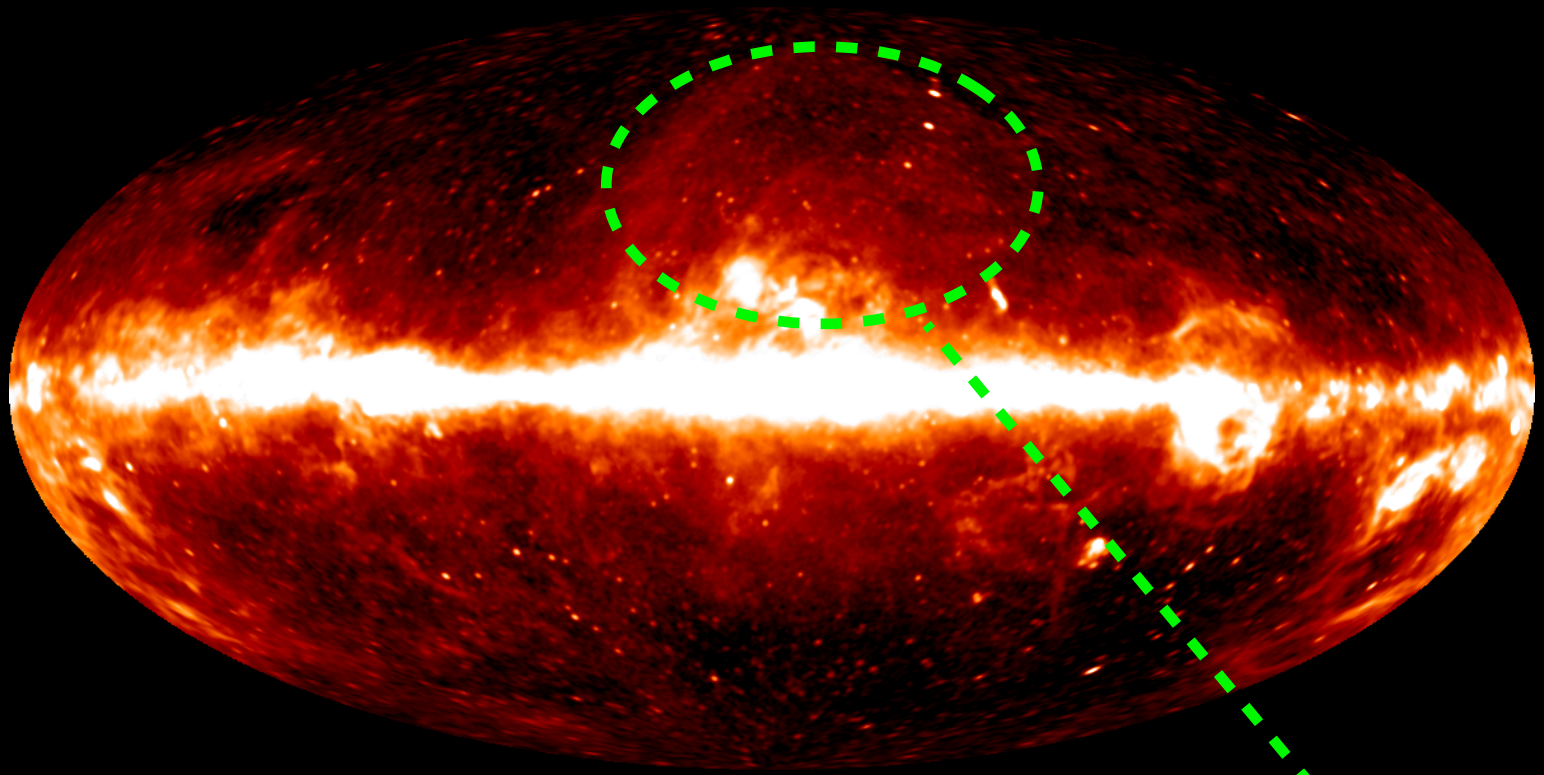
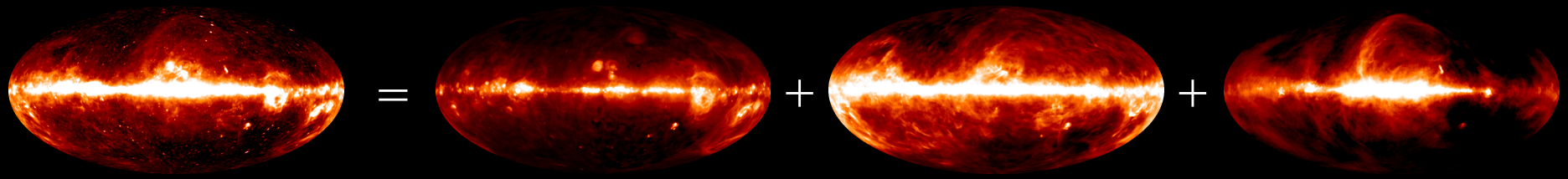


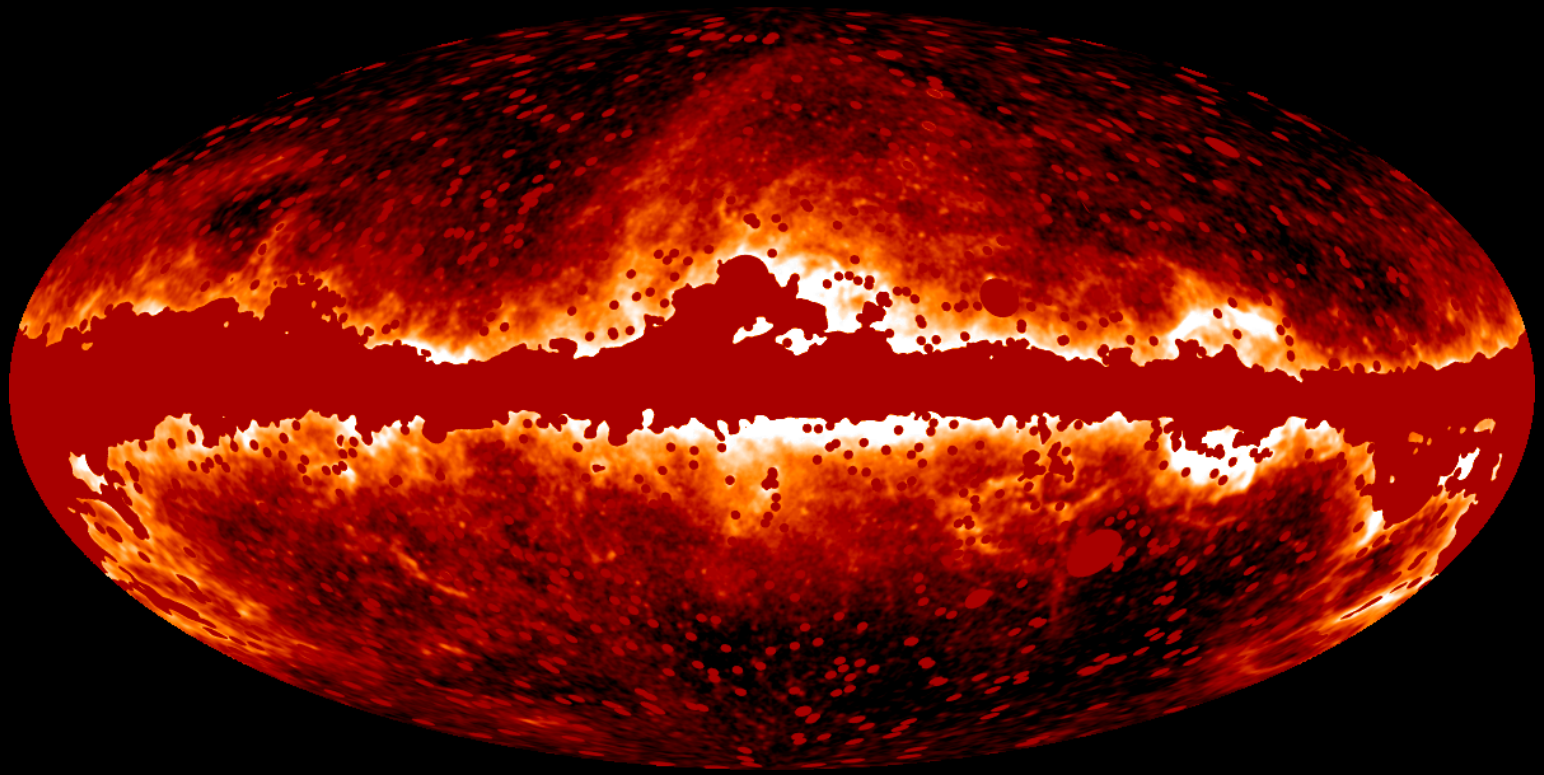
WMAP 23 GHz

synchrotron

Greg Dobler (KITP/UCSB)

$$a_\nu = (\mathbf{P}^T \mathbf{n}_\nu^{-1} \mathbf{P})^{-1} (\mathbf{P}^T \mathbf{n}_\nu^{-1} \mathbf{d}_\nu)$$





WMAP 23 GHz

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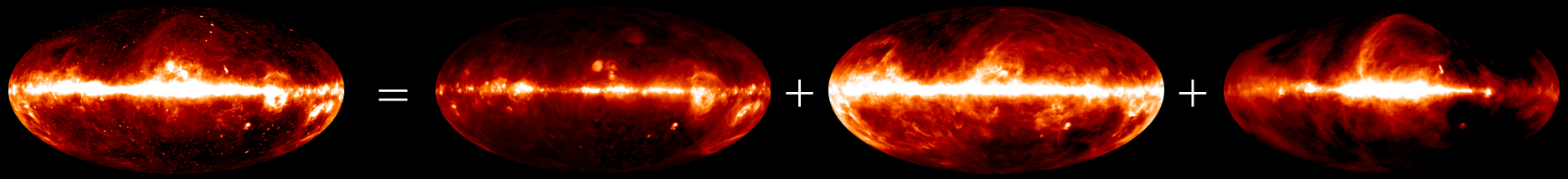
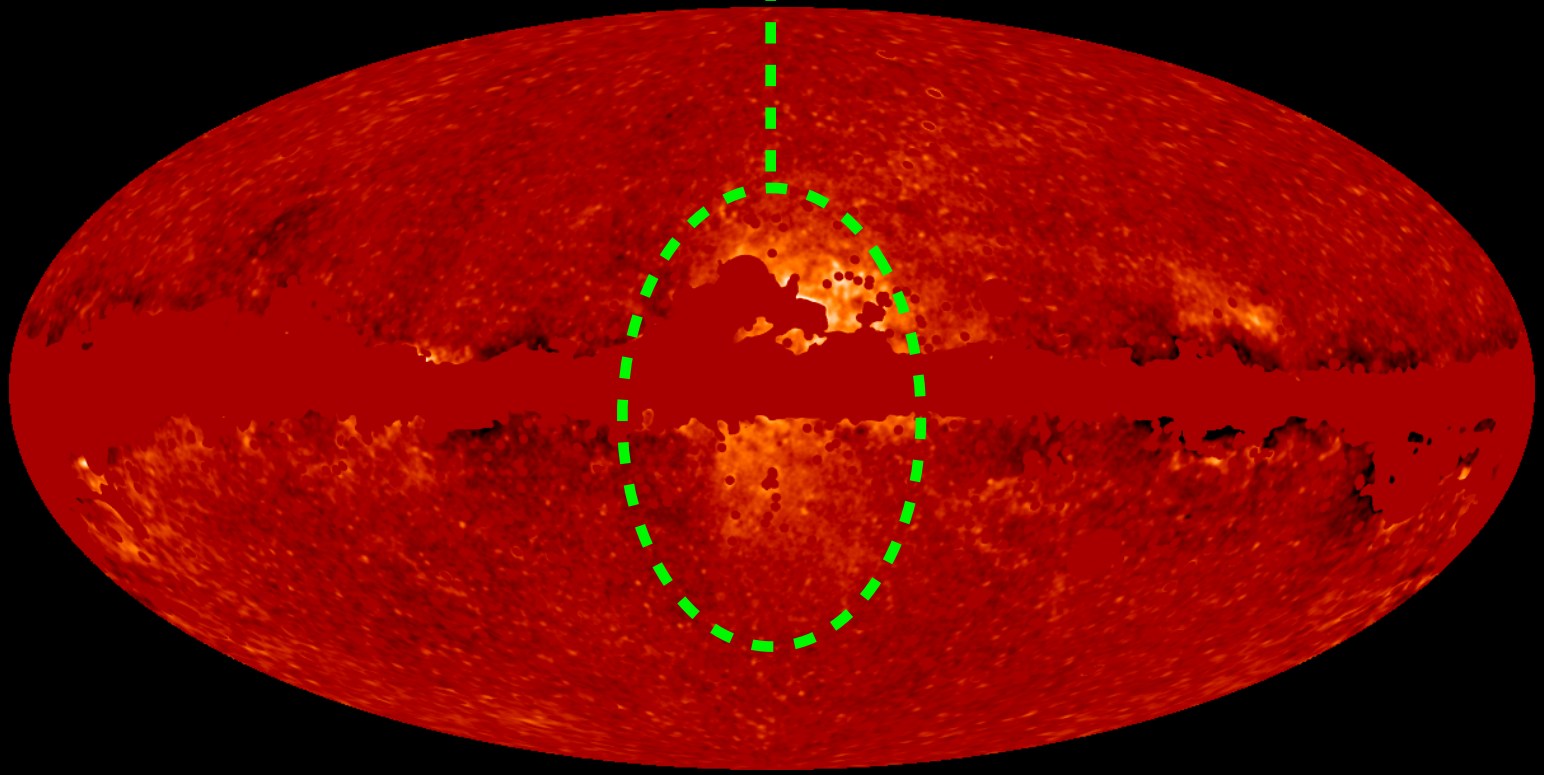


microwave “haze”



WMAP 23 GHz

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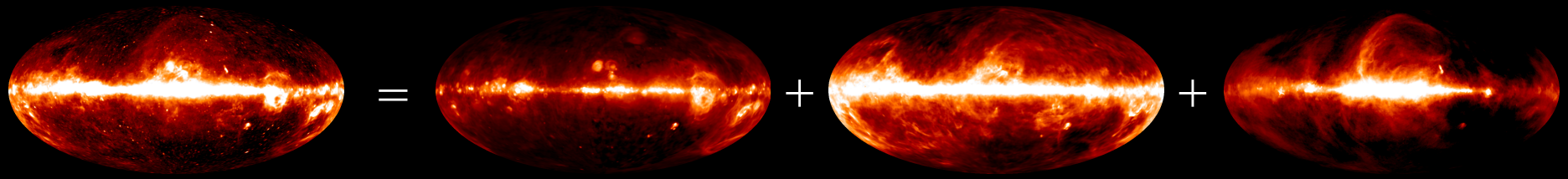

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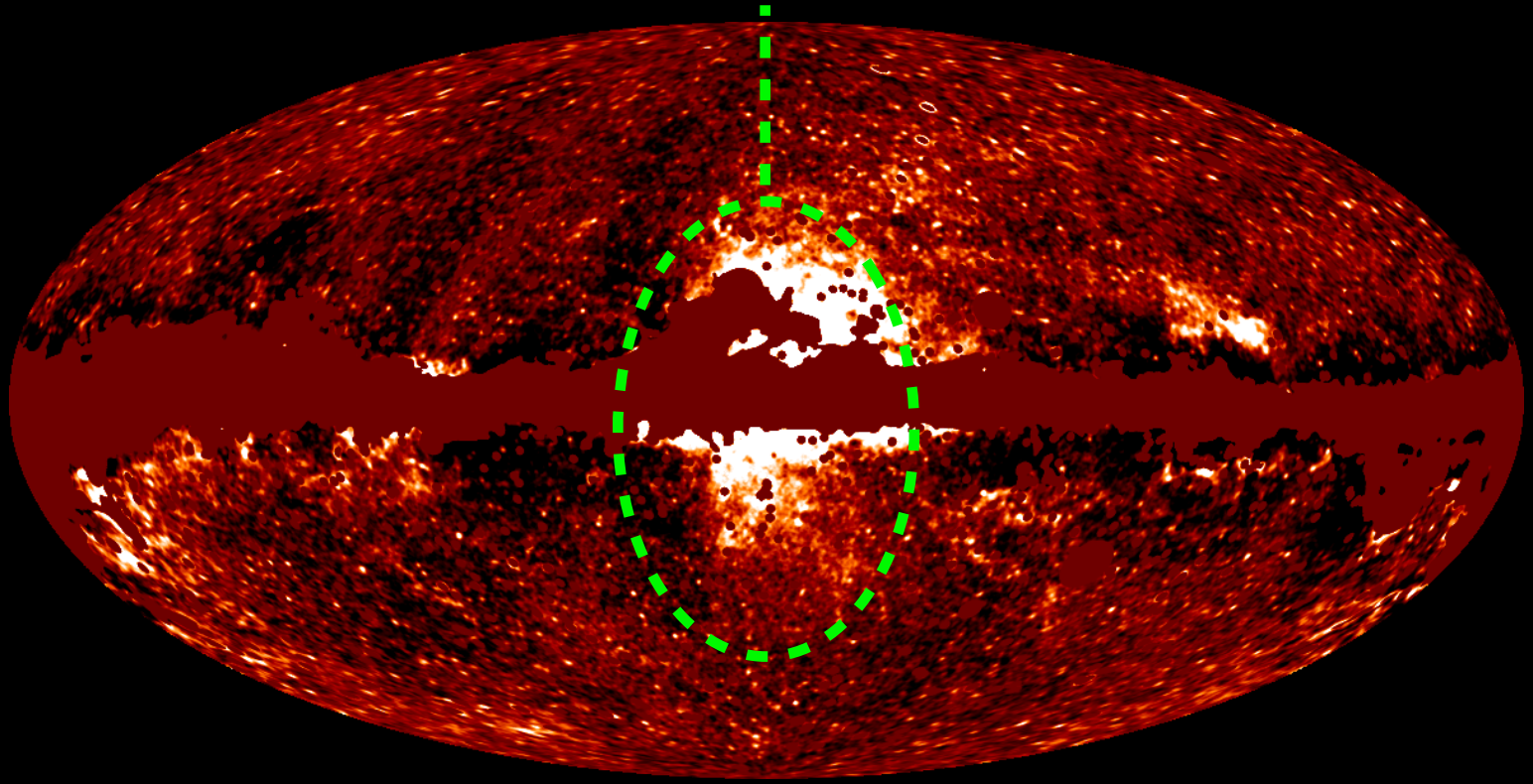

WMAP 23 GHz

"full sky fit"

Greg Dobler (KITP/UCSB)

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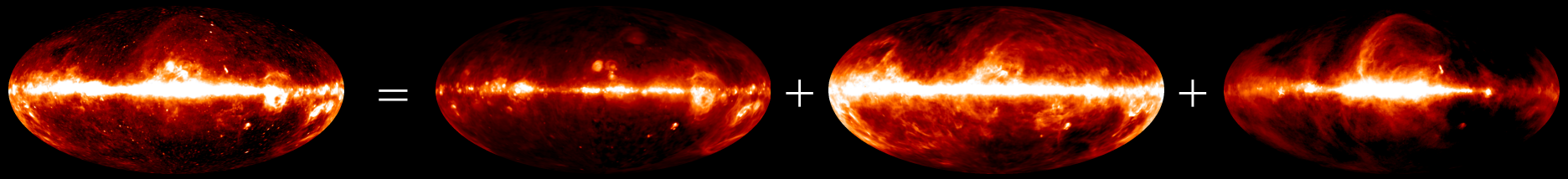

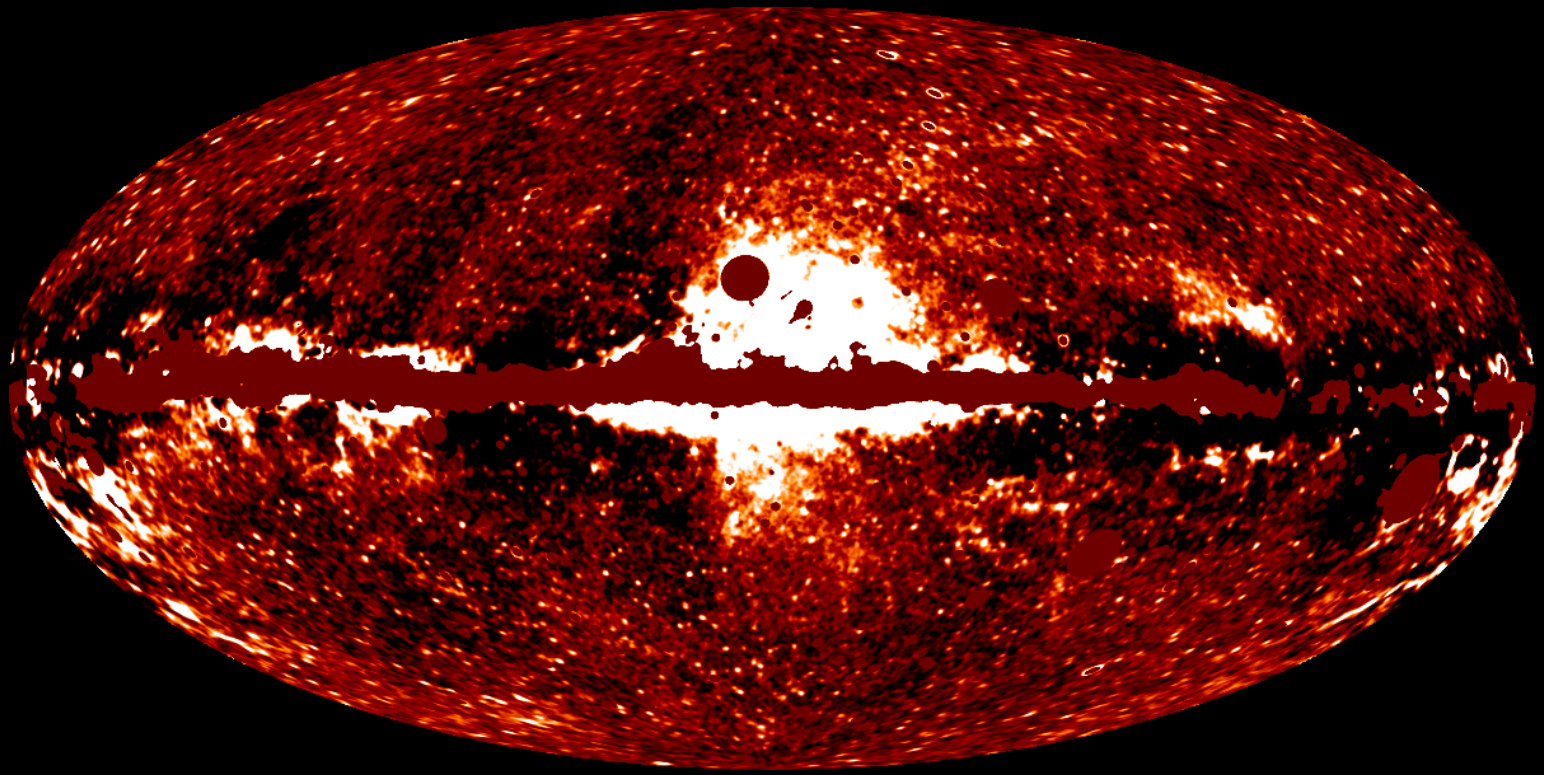

WMAP 23 GHz

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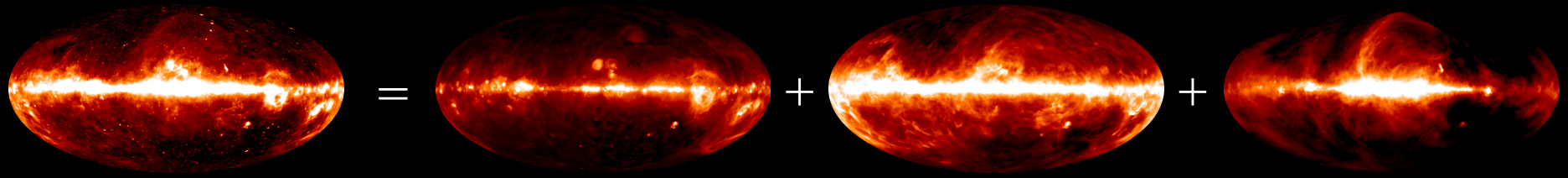
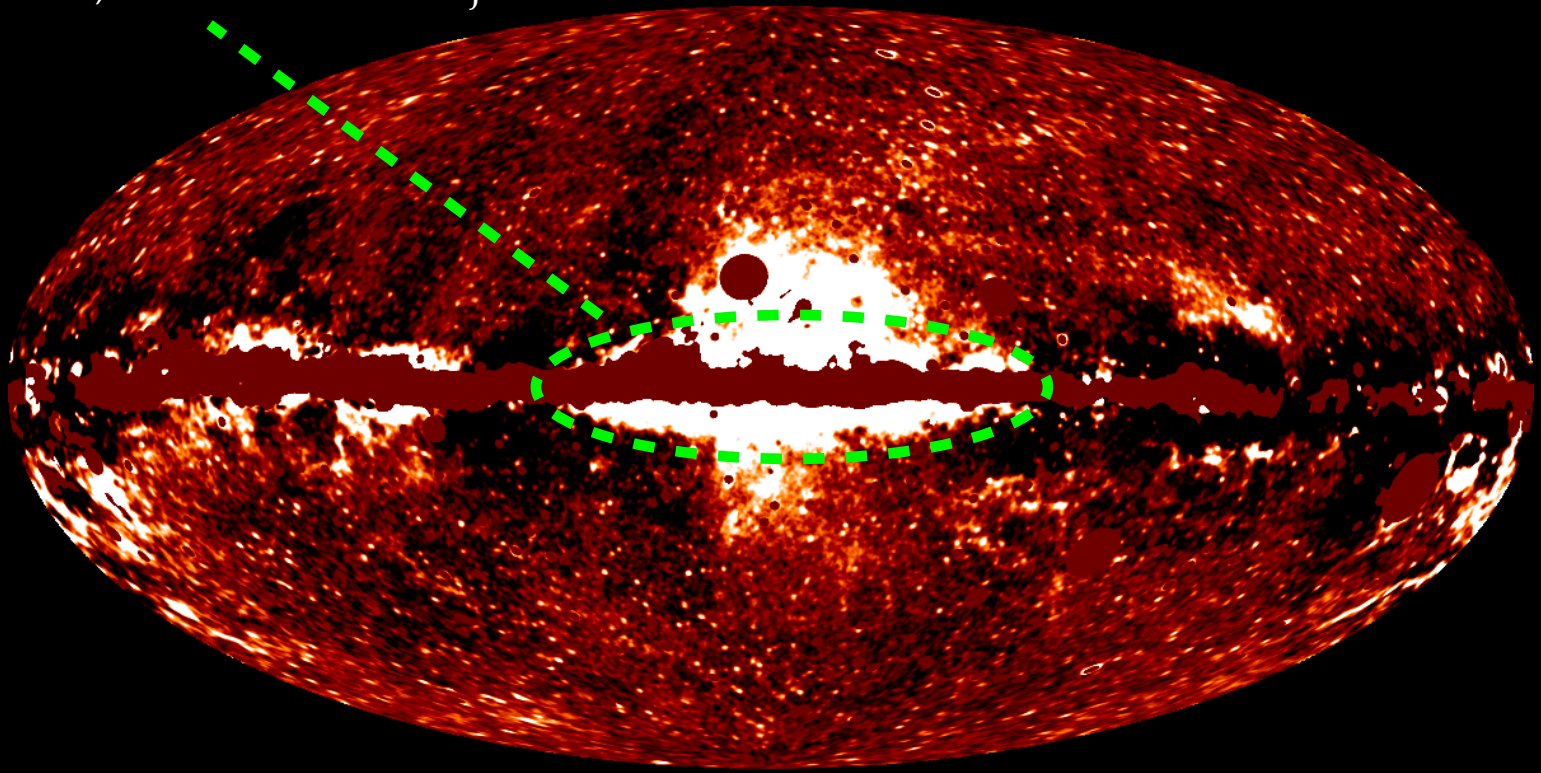


energy dependent diffusion lengths? (e.g., *Mertsch & Sarkar 2010*),
pulsars?, modified source injection?



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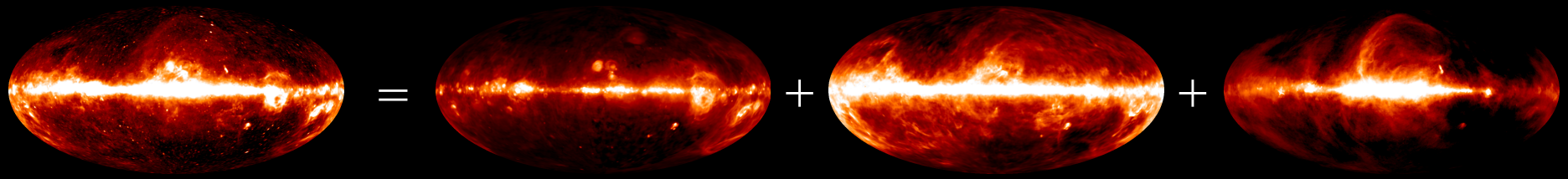
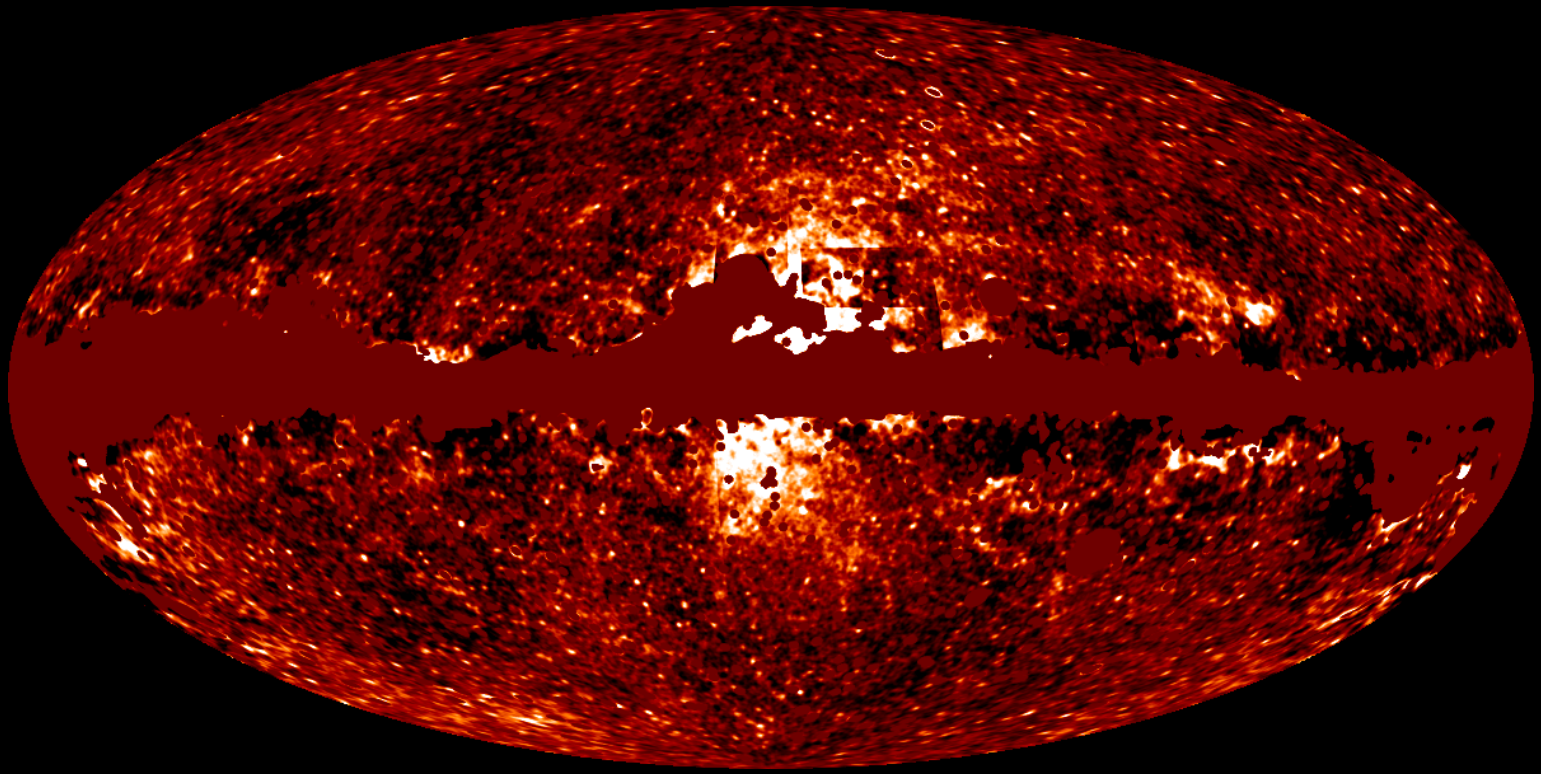


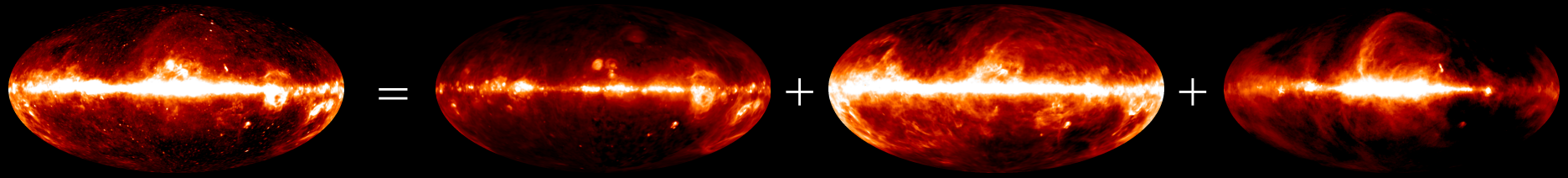
microwave haze



WMAP 23 GHz

"regional fit"

$$a_\nu = (\mathbf{P}^T \mathbf{n}_\nu^{-1} \mathbf{P})^{-1} (\mathbf{P}^T \mathbf{n}_\nu^{-1} \mathbf{d}_\nu)$$



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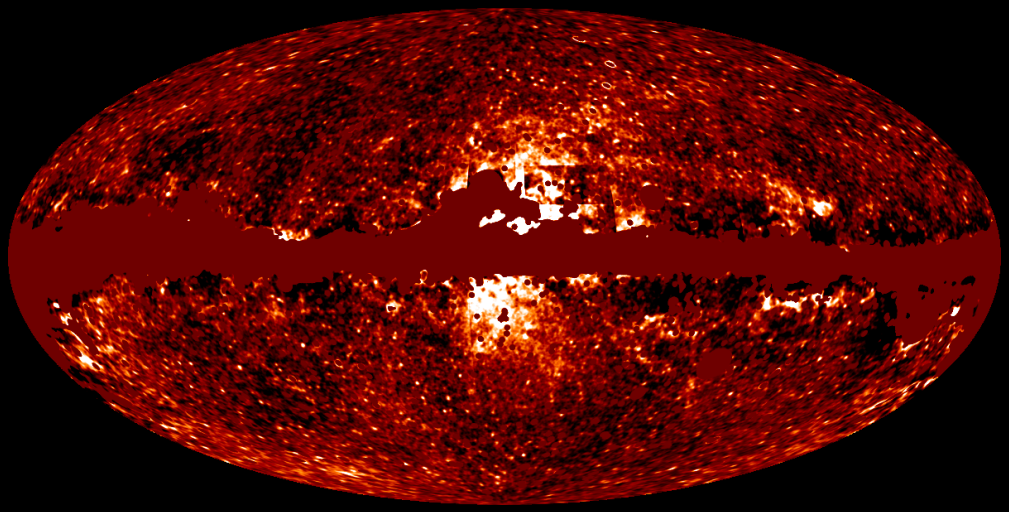

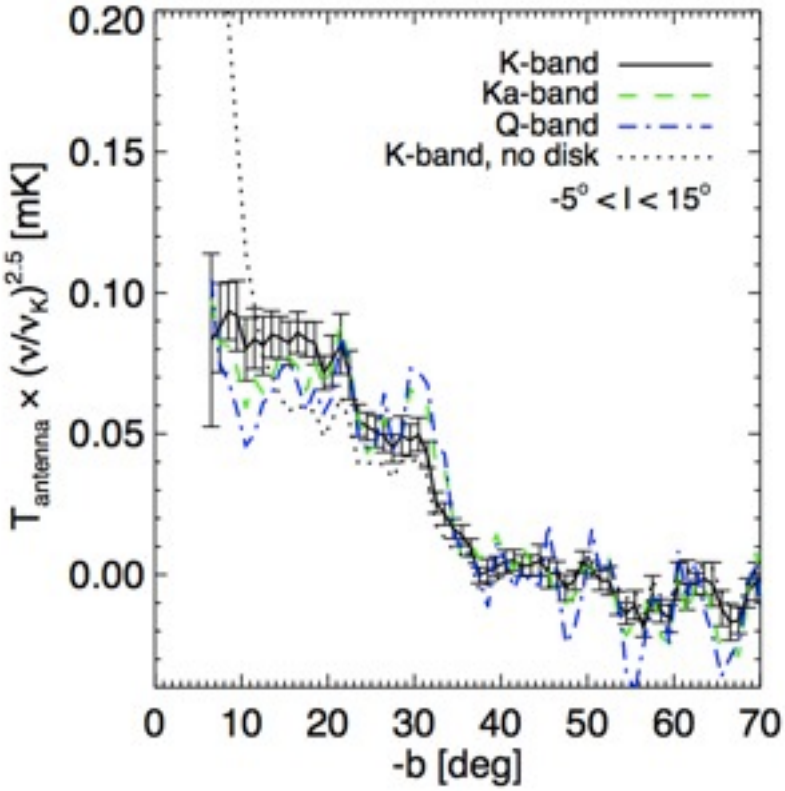

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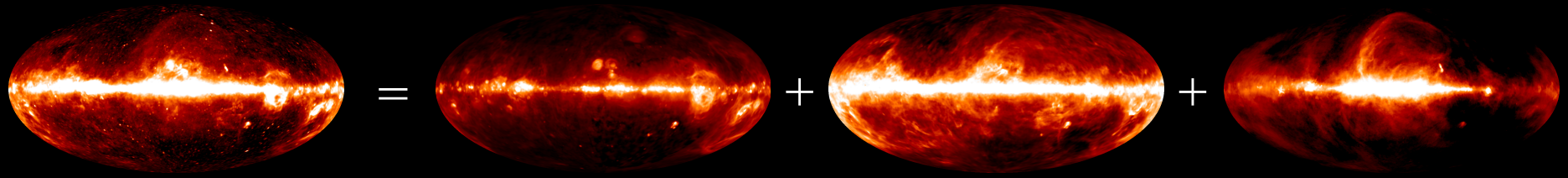

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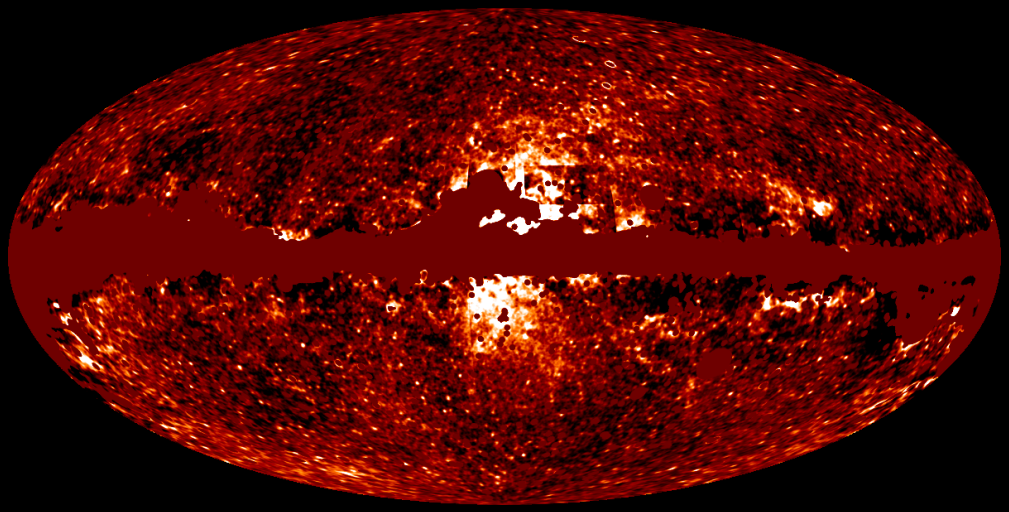

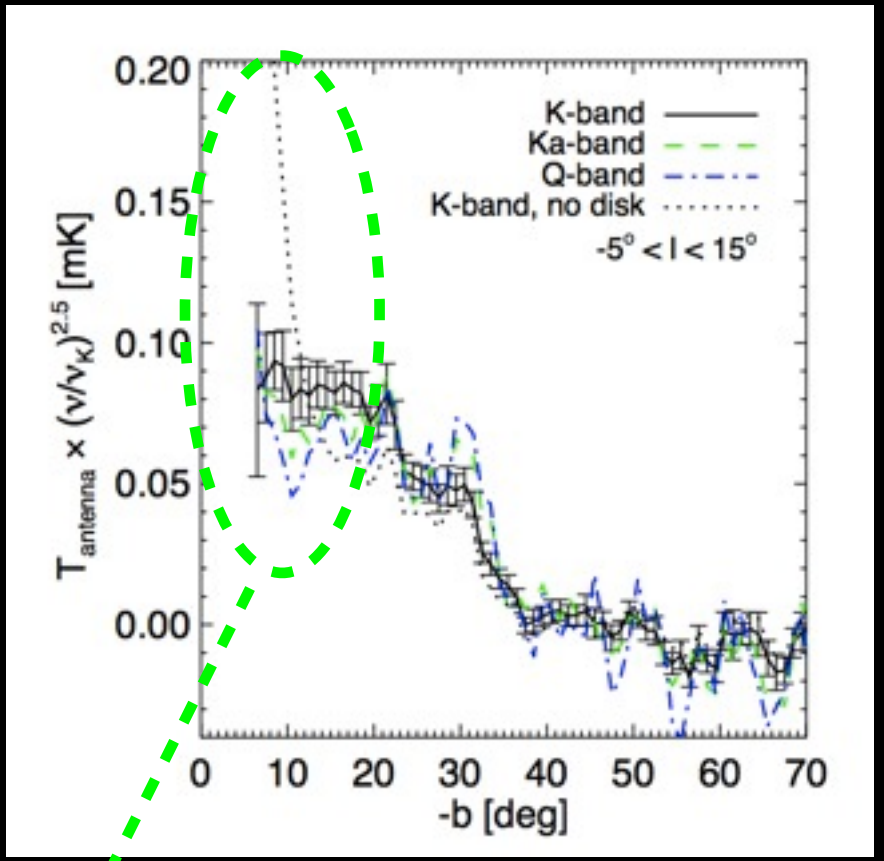

significant "tension" with DM models

Dobler (2012)

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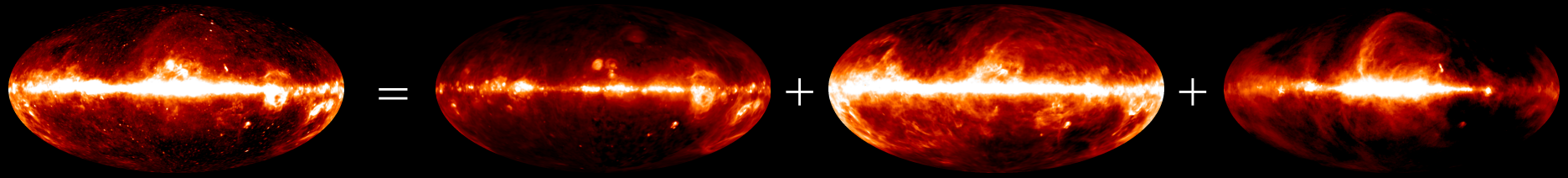

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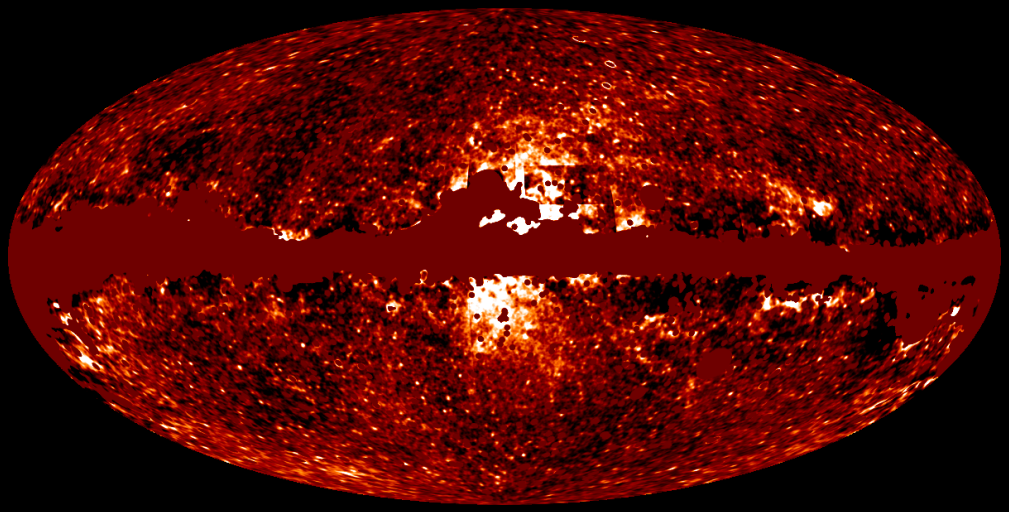

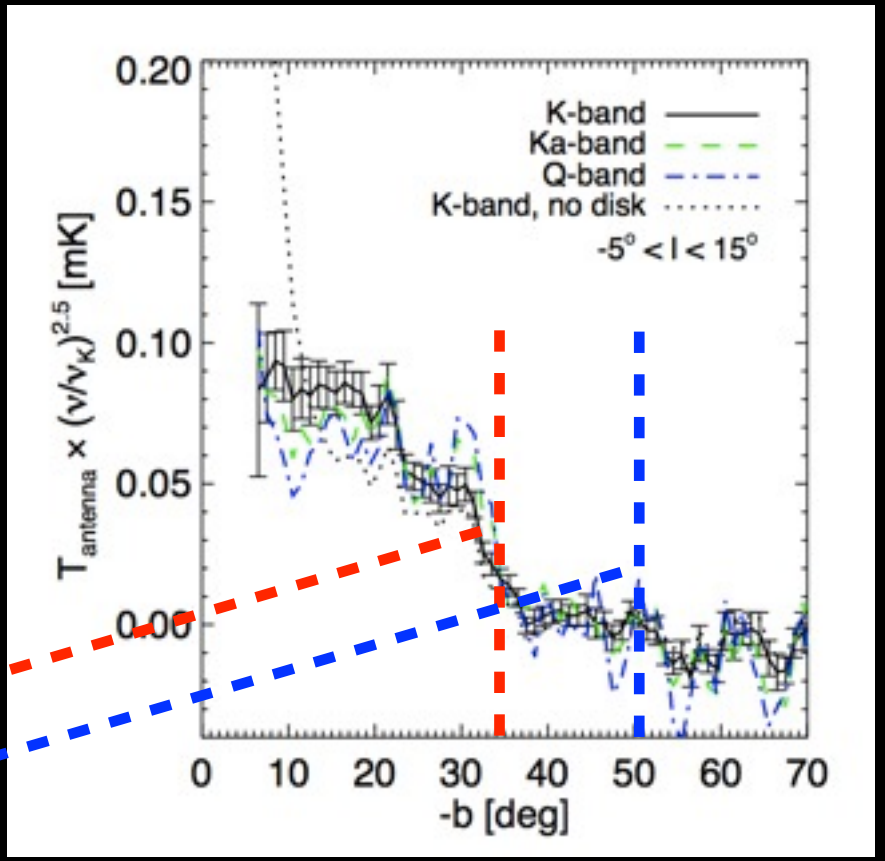

WMAP "drops" here (b~-35°)

Fermi "cuts off" here (b~-50°)

Dobler (2012)

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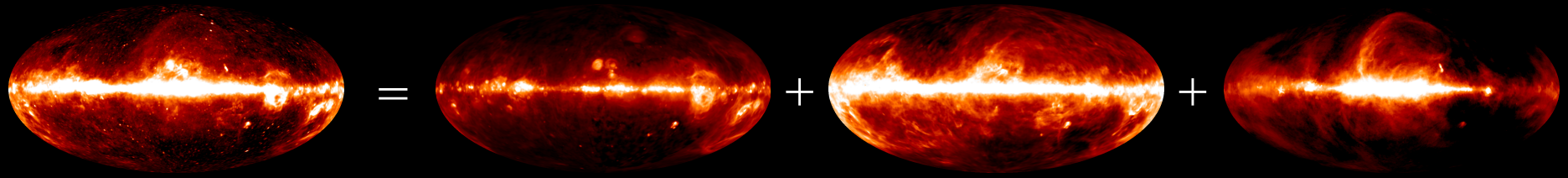

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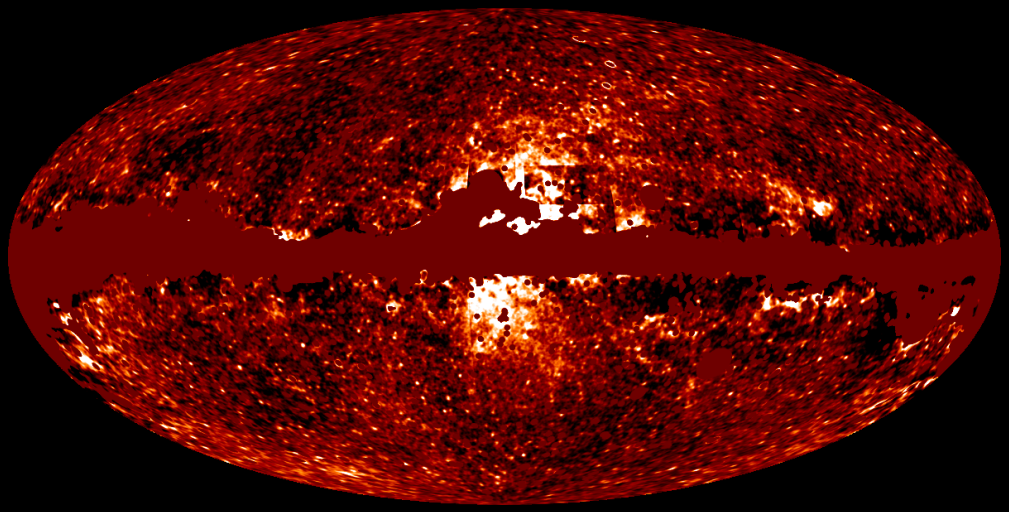
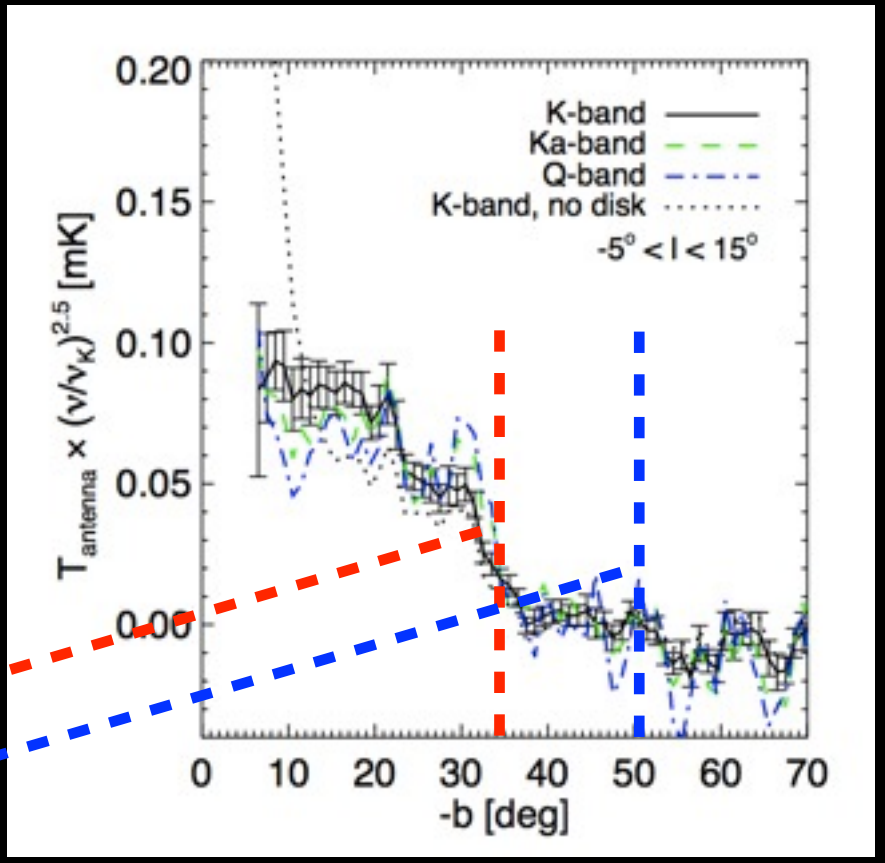


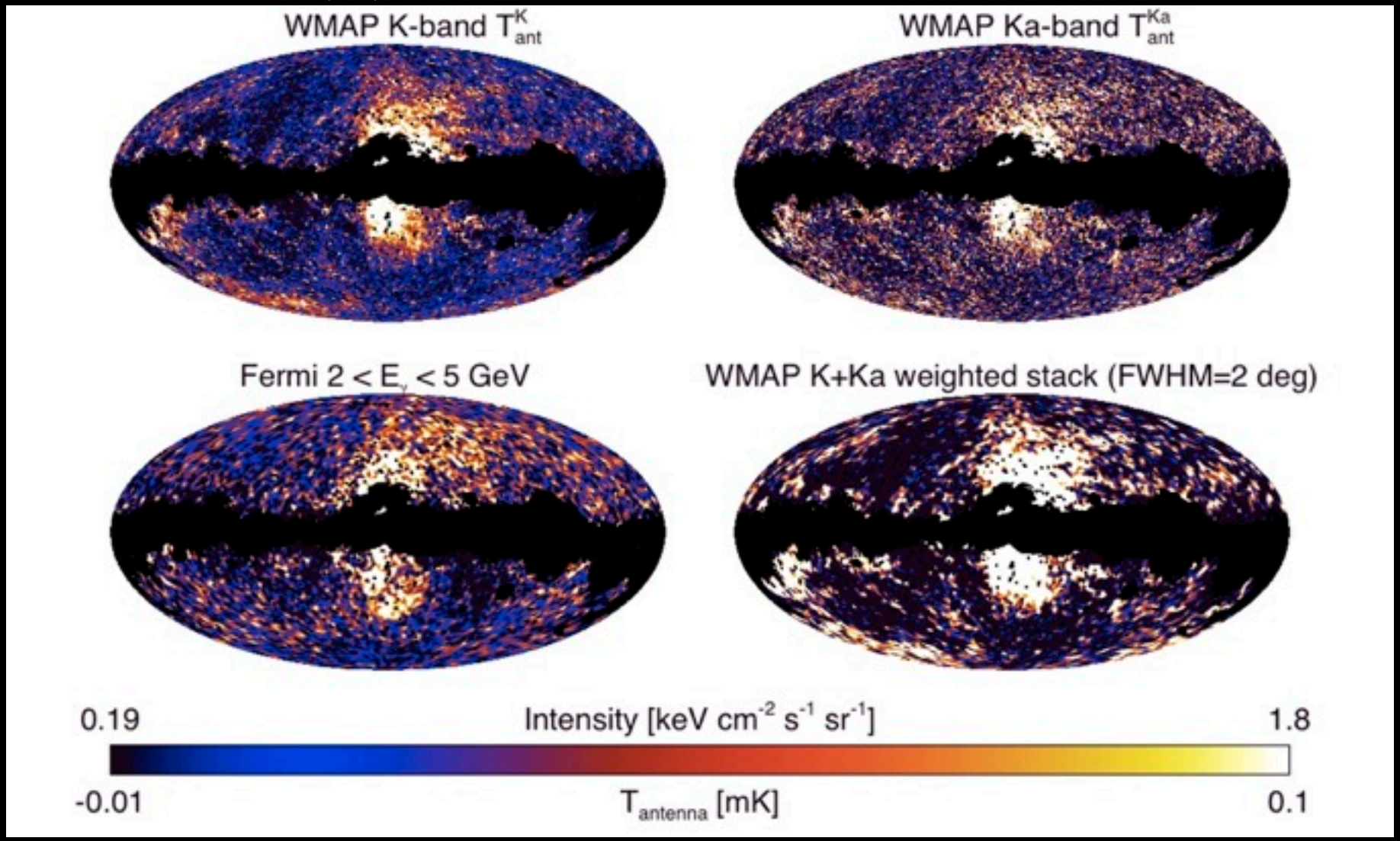


WMAP "drops" here (b~-35°)

Fermi "cuts off" here (b~-50°)

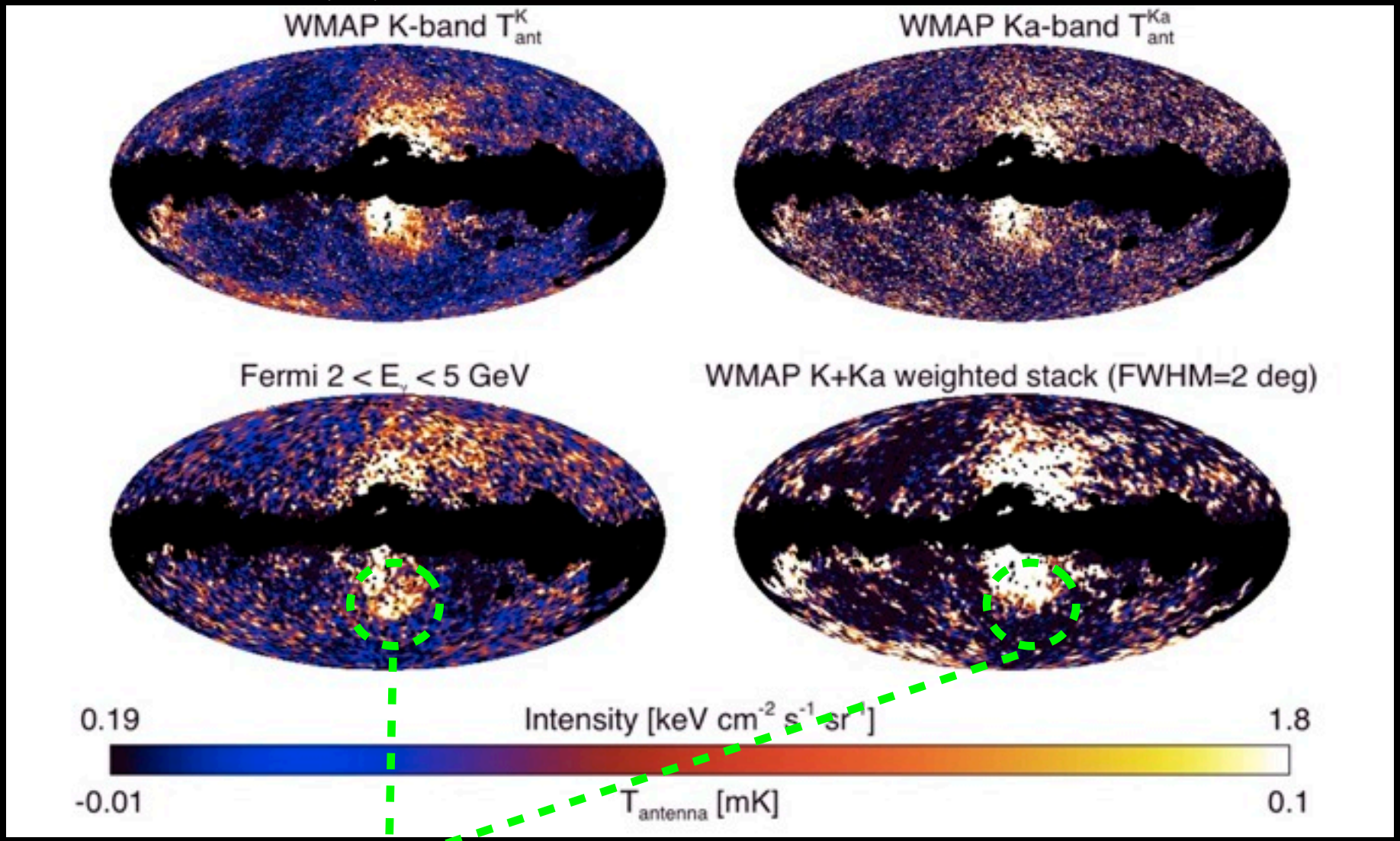
are they the same structure? are the *Fermi* edges "real"? *Dobler (2012)*

Dobler (2012b, in prep)



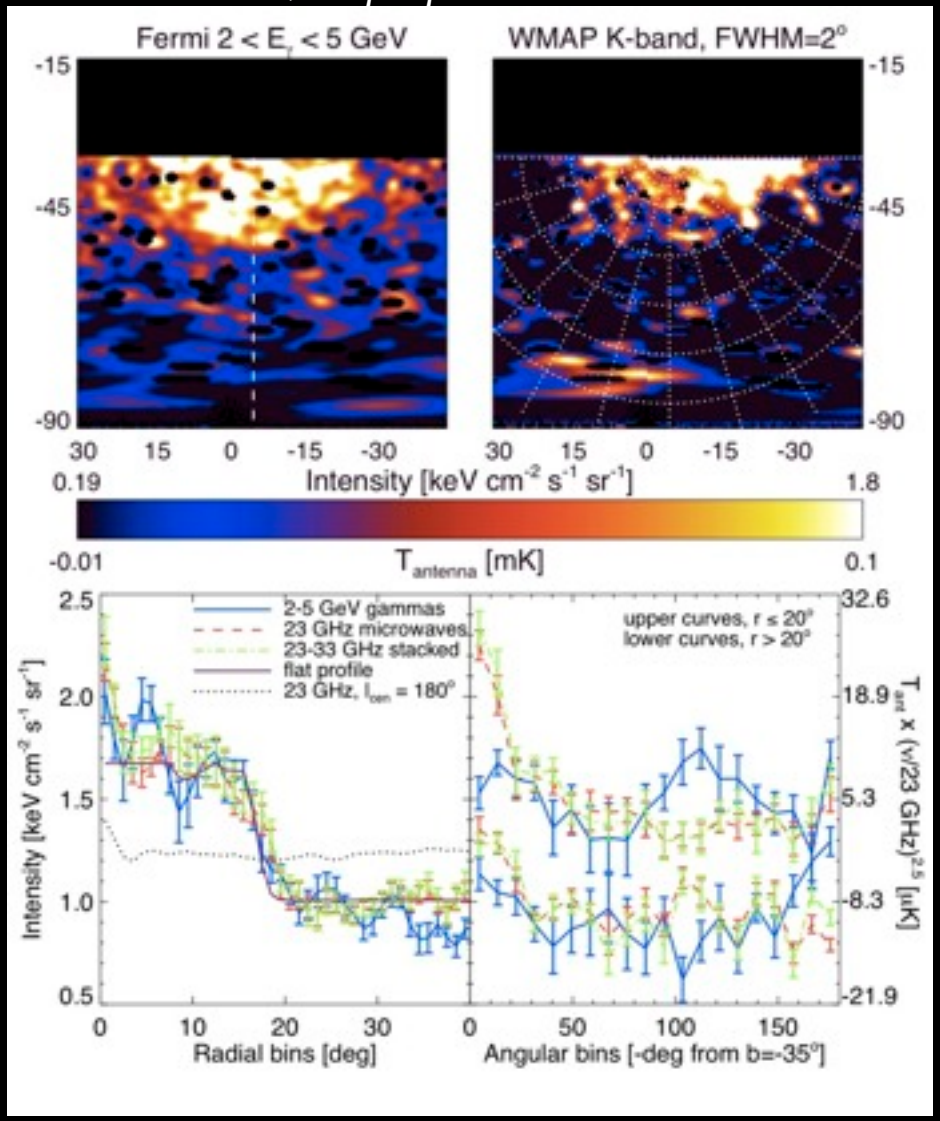
are they the same structure? are the *Fermi* edges "real"?

Dobler (2012b, in prep)



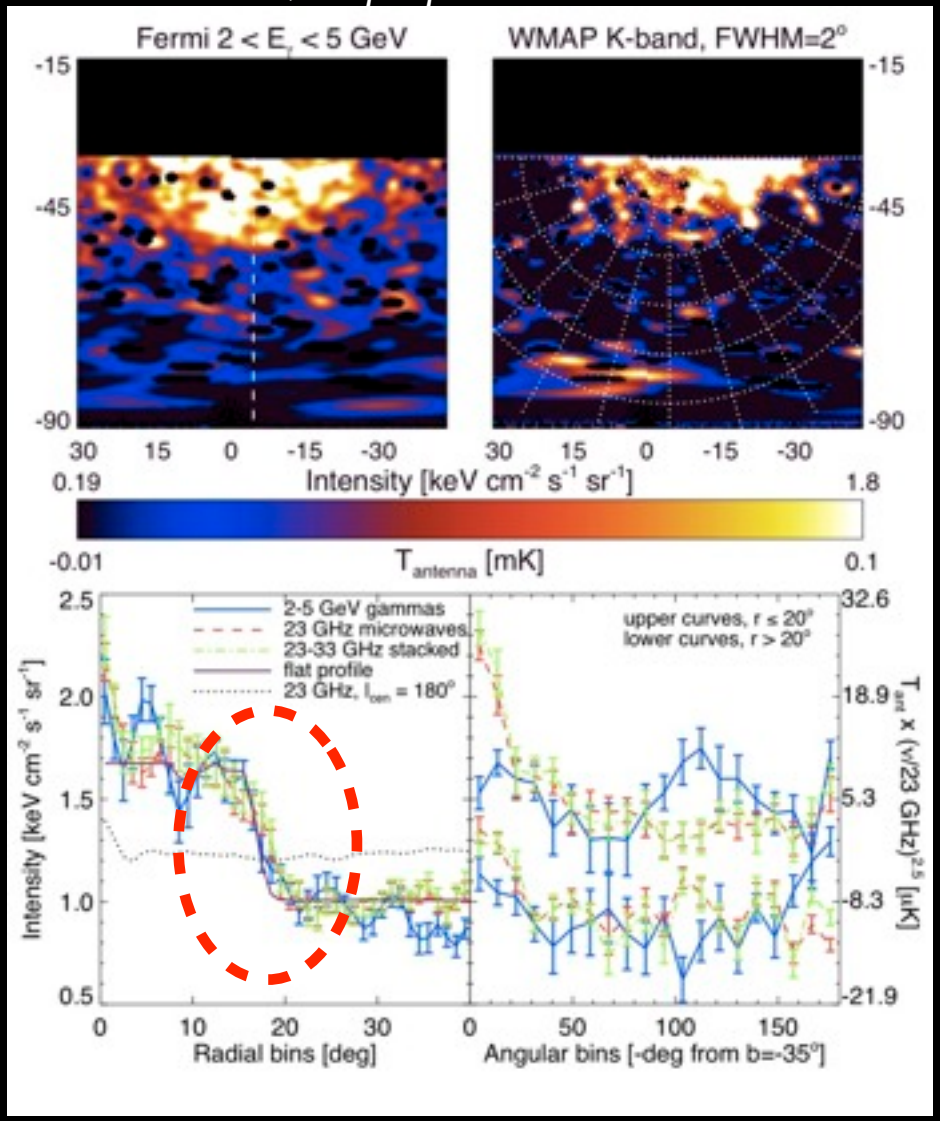
coincident "edge"?

Dobler (2012b, in prep)



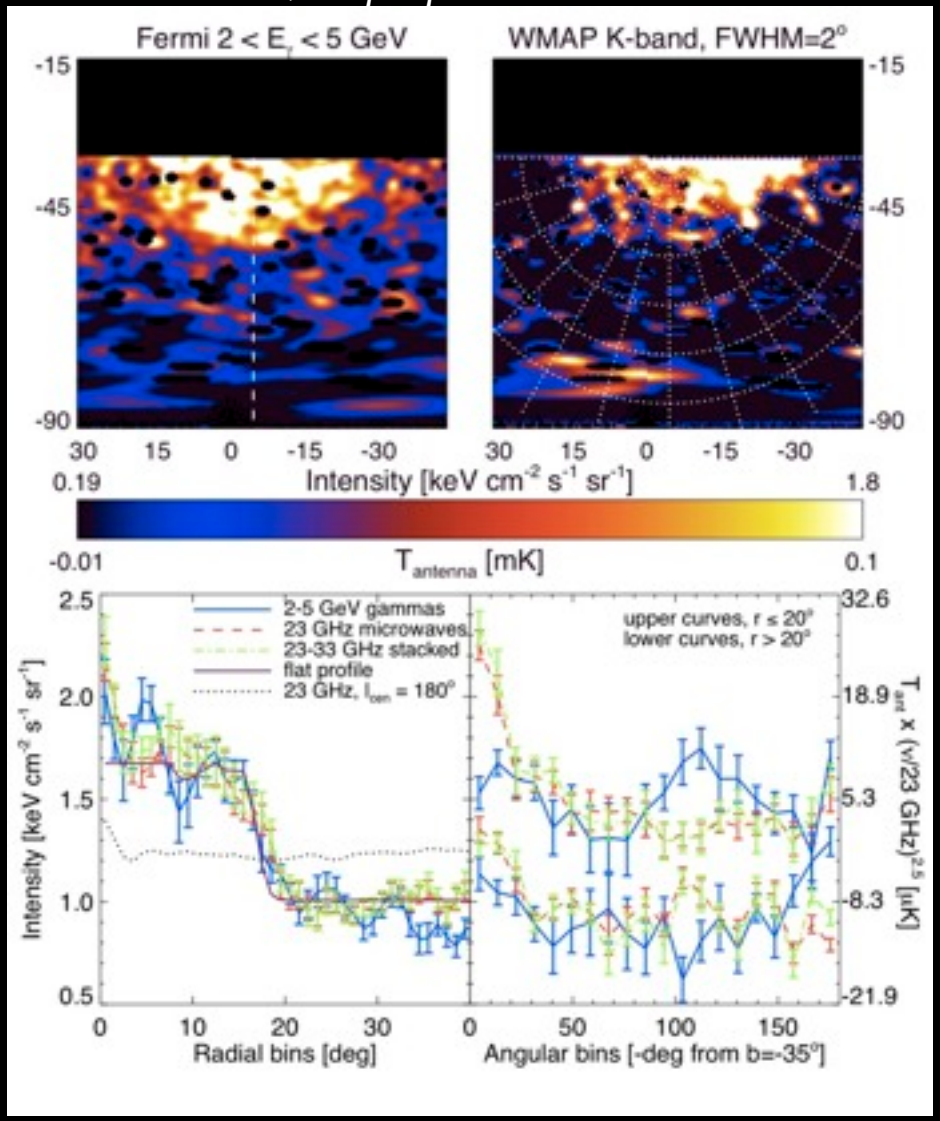
coincident “edge”? *YES!*

Dobler (2012b, in prep)



coincident "edge"? *YES!*

Dobler (2012b, in prep)



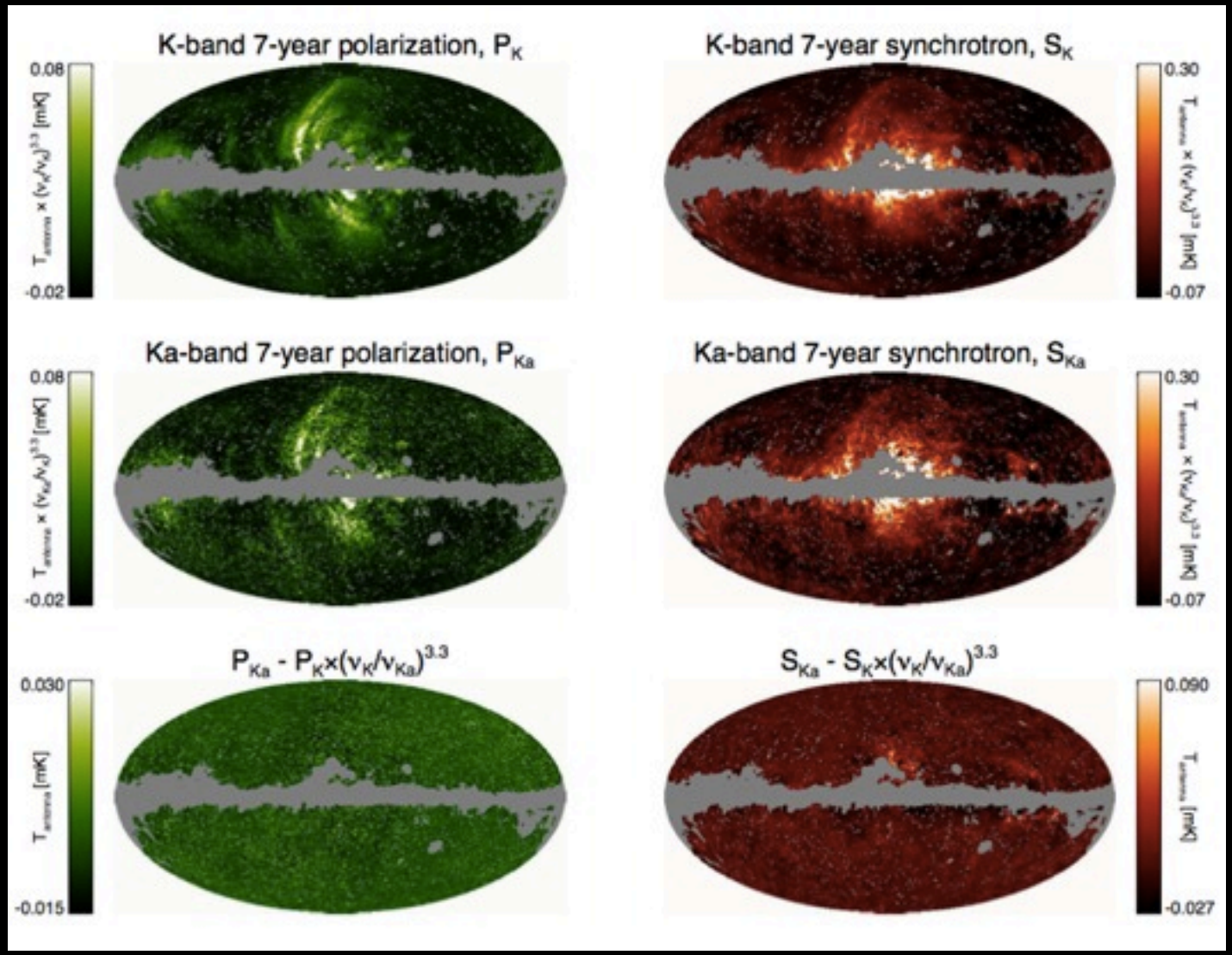
independent confirmation that the *Fermi* Haze/Bubbles edges are ***real***

demonstrates conclusively that the microwave and gamma-ray haze/bubbles are the ***same structure*** observed at multiple wavelengths

strongly suggests an inverse Compton origin for the gamma-ray emission

coincident "edge"? *YES!*

polarization



Dobler (2012)