WMAP Excess Interpreted as WIMP Annihilation

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Outline

- WMAP ISM emission (expected)
- The Galactic synchrotron “Haze” (unexpected)
- WIMP annihilation (speculative)

"Standard Model"

"Standard Model" of Microwave Continuum Emission in the ISM

Synchrotron (relativistic electrons) $T \sim \nu^{-2.7}$ (-2.5? -3.0?)

Free -free (ionized H) $T \sim \nu^{-2.1}$

"Thermal" dust (vibrational) $T \sim \nu^{+2}$ (1.6? 2.2?)

(optically thin limit)

These are all well established.

(convention: $I \sim \nu^{\alpha}$, $T \sim \nu^{\beta}$)

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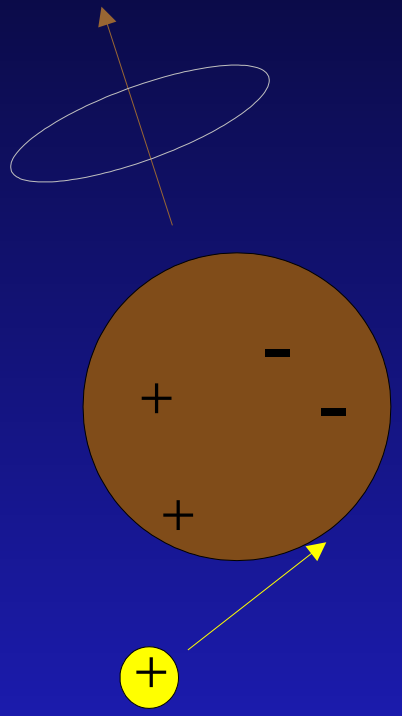
--> But cannot explain all observed ISM emission!

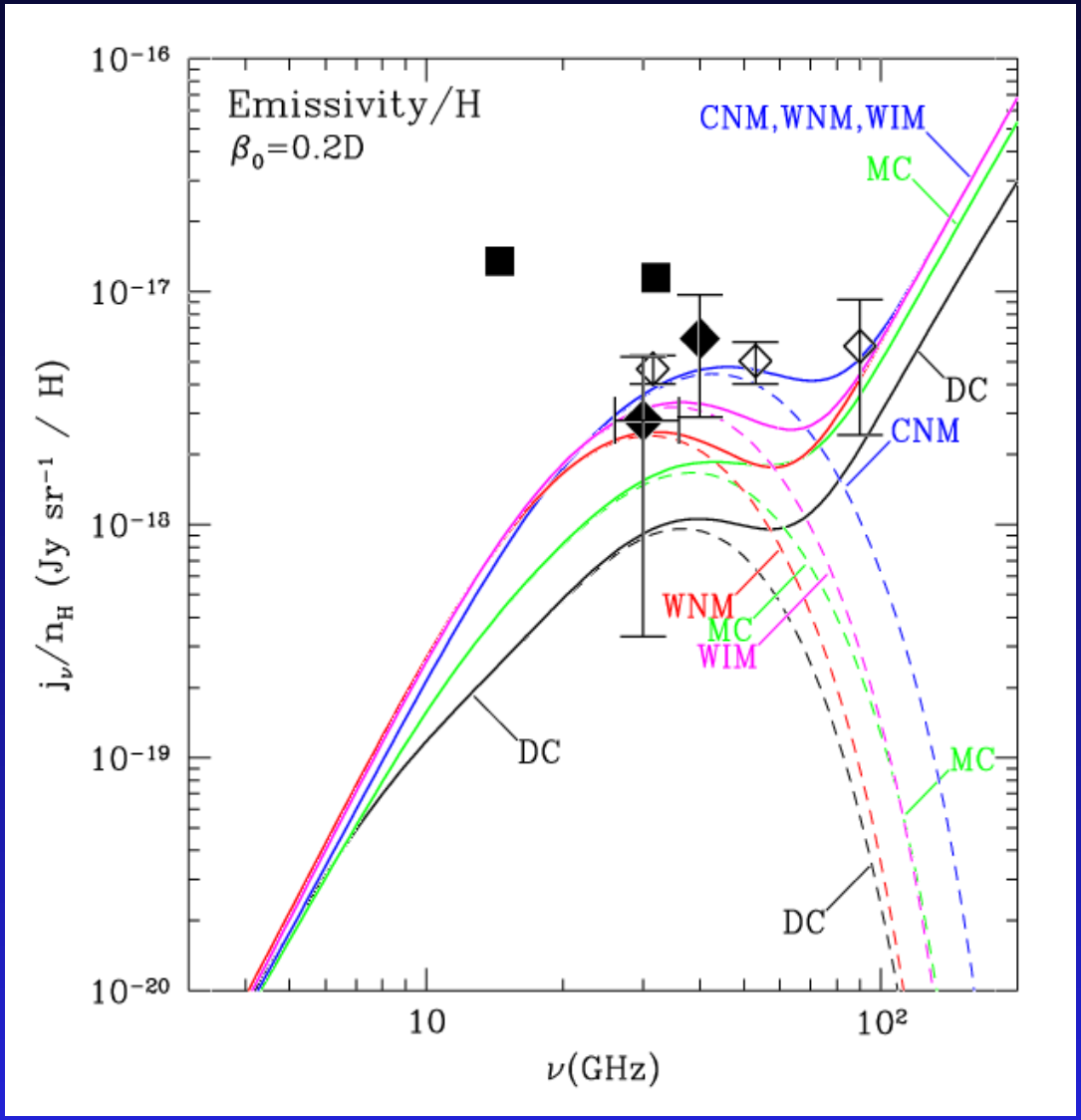
Spinning Dust Emission

Draine & Lazarian (1998)

- Small dust grains (1 nm, ~500 atoms)
- Not in T equillibrium with ISRF
- Have non -zero electric dipole
  (like most hydrocarbons)
- Fast ions spin them up to 10 -30 GHz
- Spin down by electric dipole emission



Microwave Emission per H atom



Draine & Lazarian 1998
with 5 dust models
and data from
- COBE
- Saskatoon
- OVRO

Note: OVRO too high

Dust -correlated Microwave emission: Selected Previous Work

Kogut et al. (1996)	COBE	31, 53 GHz
de Oliveira-Costa et al. (1997)	Saskatoon	30 GHz
Leitch et al. (1997)	OVRO	14 GHz
de Oliveira-Costa et al. (1998)	Cottingham/ Boughn	19 GHz
de Oliveira-Costa et al. (1999)	Tenerife	10, 15 GHz
Finkbeiner et al. (1999)	COBE	31, 53 GHz
Finkbeiner et al. (2002)	GB 140'	5, 8, 10 GHz
Banday et al. (2003)	COBE	19,31,53,90 GHz
Bennett et al. (2003)	WMAP	23 -94 GHz
Lagache (2003)	WMAP	23 -94 GHz
Finkbeiner (2004)	WMAP	23 -94 GHz
de Oliveira-Costa et al. (2003)	Tenerife/WMAP	10, 15 GHz
Finkbeiner et al. (2004)	GB GP survey	8, 14 GHz
Casassus et al. (2004)	CBI	26 -36 GHz

Interpretation of 20 -40 GHz Observations

The predicted spectrum from DL98 is ~flat

(in j_ν units)

Synchrotron ~ $\nu^{-0.7}$

Free -free ~ $\nu^{-0.15}$

How do we know it is not free -free?

The Smoking Gun

The spinning dust is expected to peak at ~15 GHz
(in temperature units)
and be dominated by free -free below 5 -10 GHz.

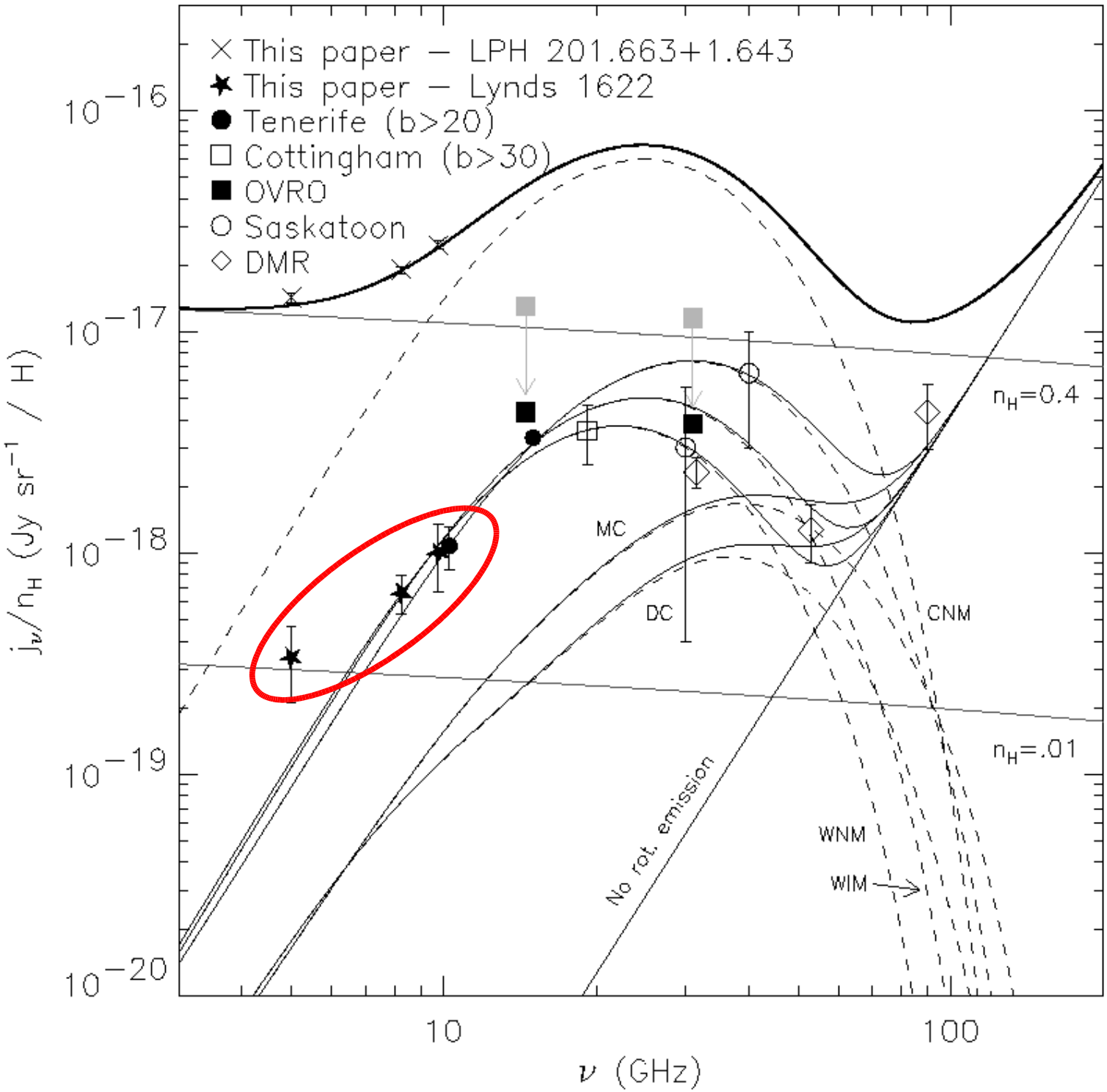
By observing at 5 -10 GHz one can hope to unambiguously detect spinning dust.

So in 1999 we used ...

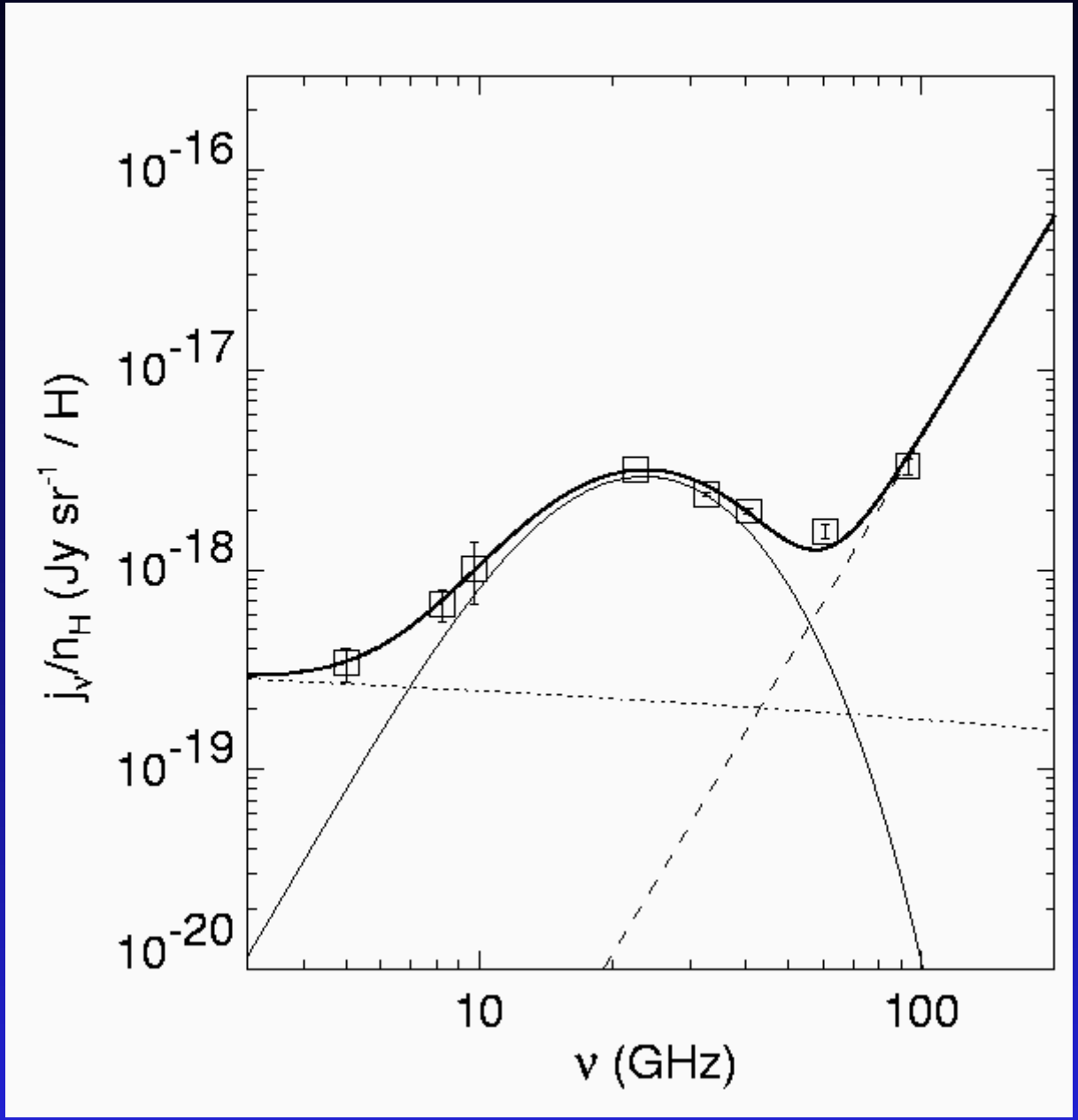
The 140 foot Telescope

R I P
(1964-1999)

Finkbeiner, et al. 2002



Lynds 1622 - Green Bank & WMAP



What about the diffuse ISM?

In order to measure this signal in the diffuse ISM, a high sensitivity, large scale survey is needed...

WMAP!

Wilkinson Microwave Anisotropy Probe

Full -sky data

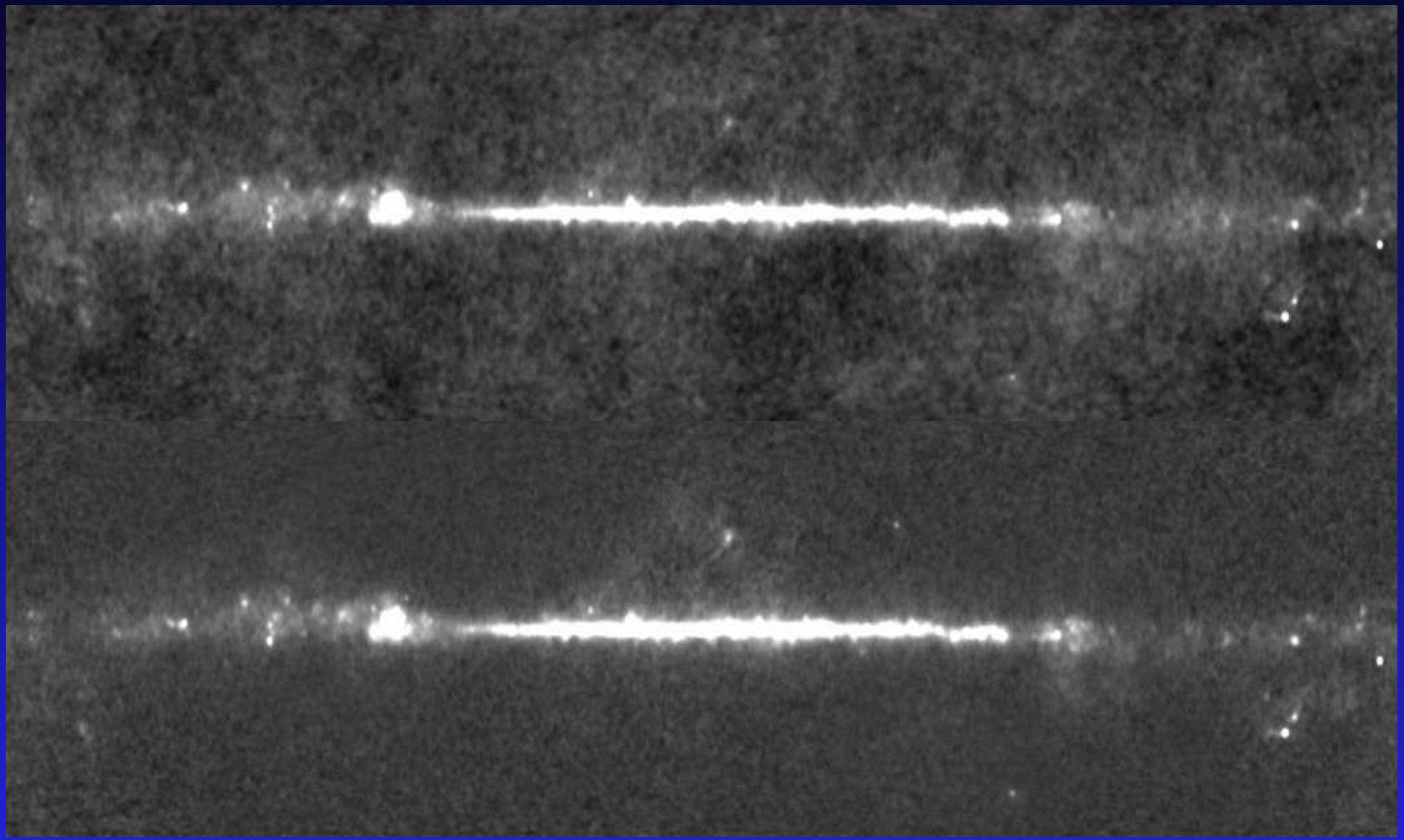
~ 0.2 mK in first year data

(23, 33, 41, 61, 94) GHz

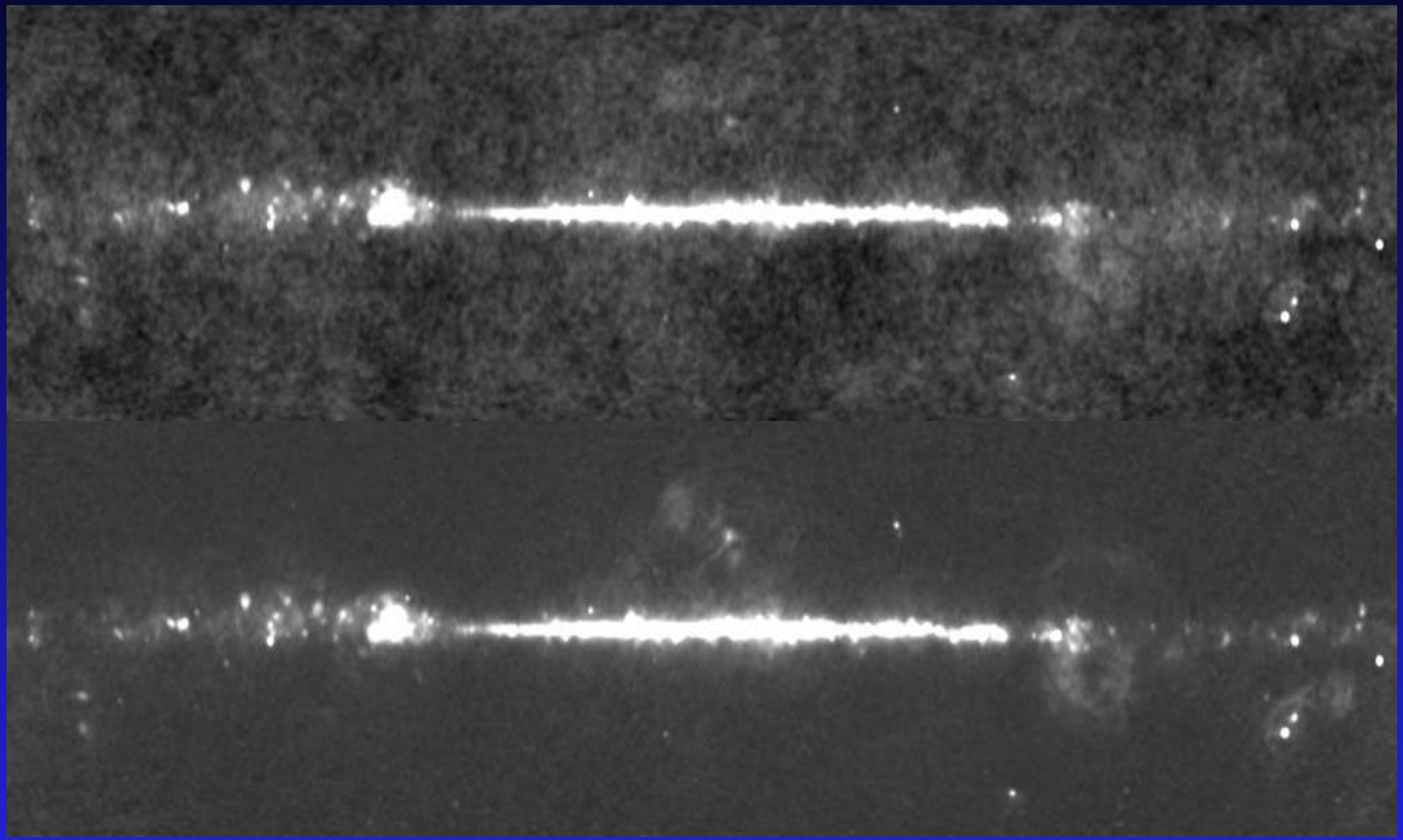
13' FWHM at 94 GHz

Data public as of Feb, 2003

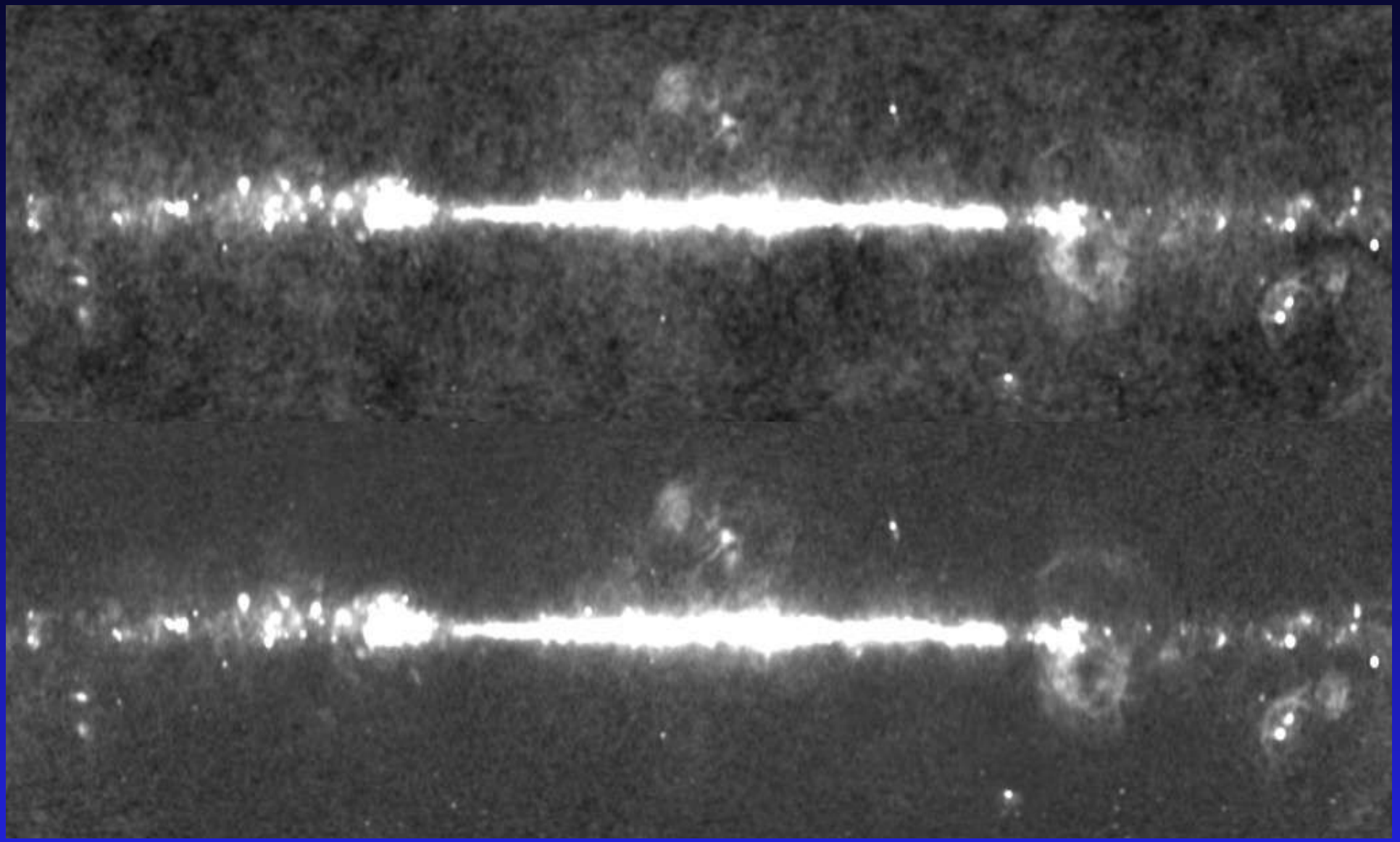
WMAP W-band (94 GHz)



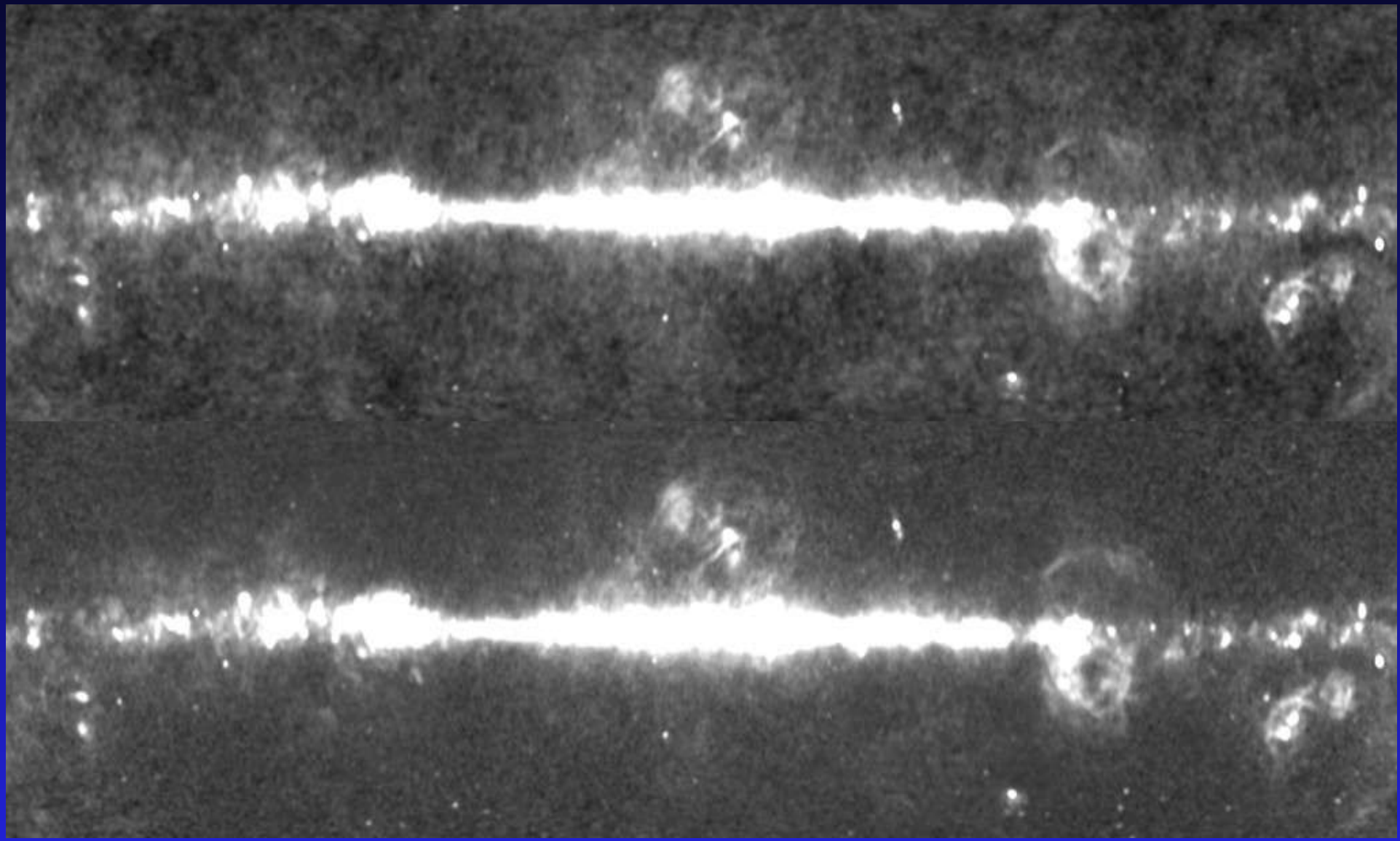
WMAP V-band (61 GHz)



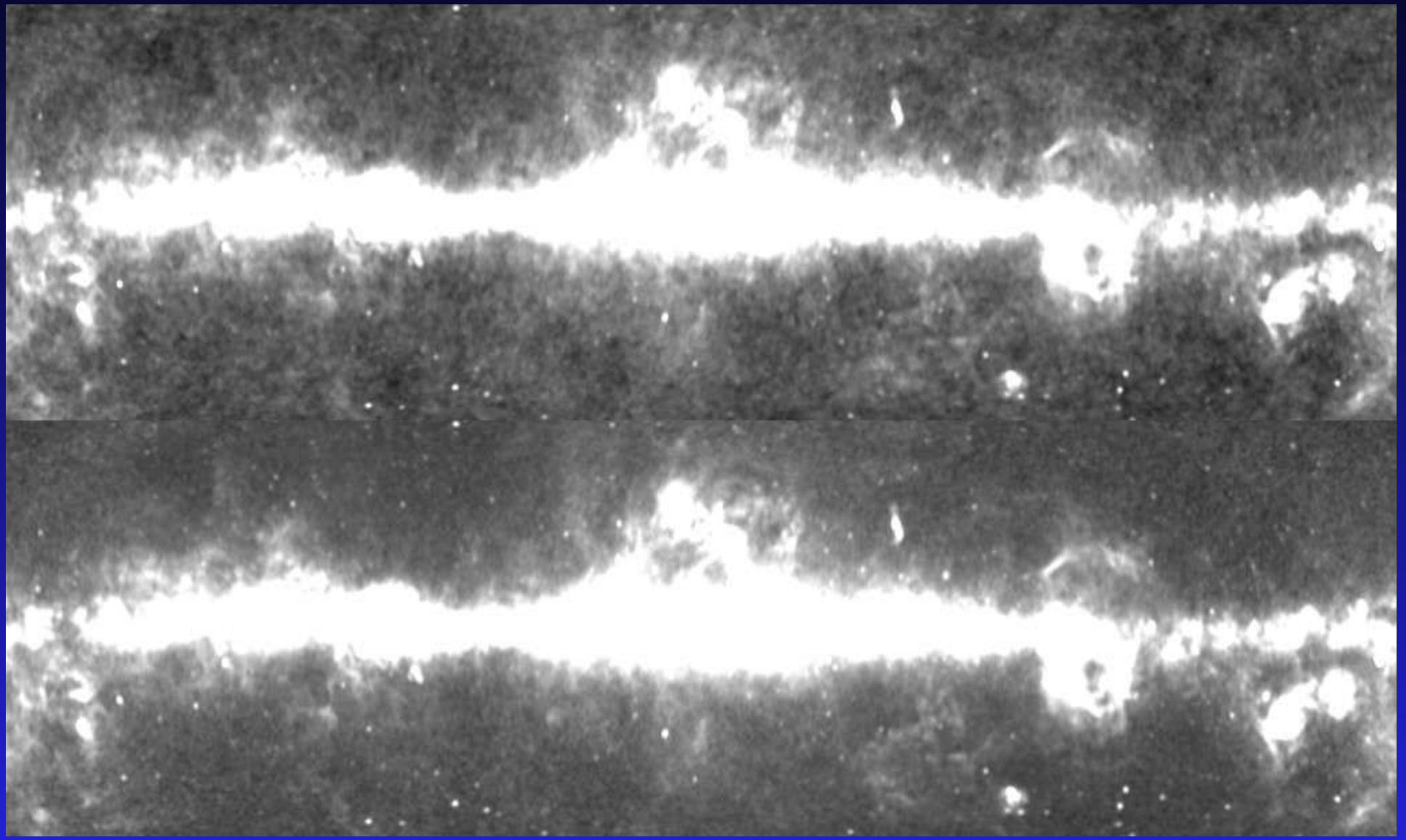
WMAP Q-band (41 GHz)



WMAP Ka-band (33 GHz)



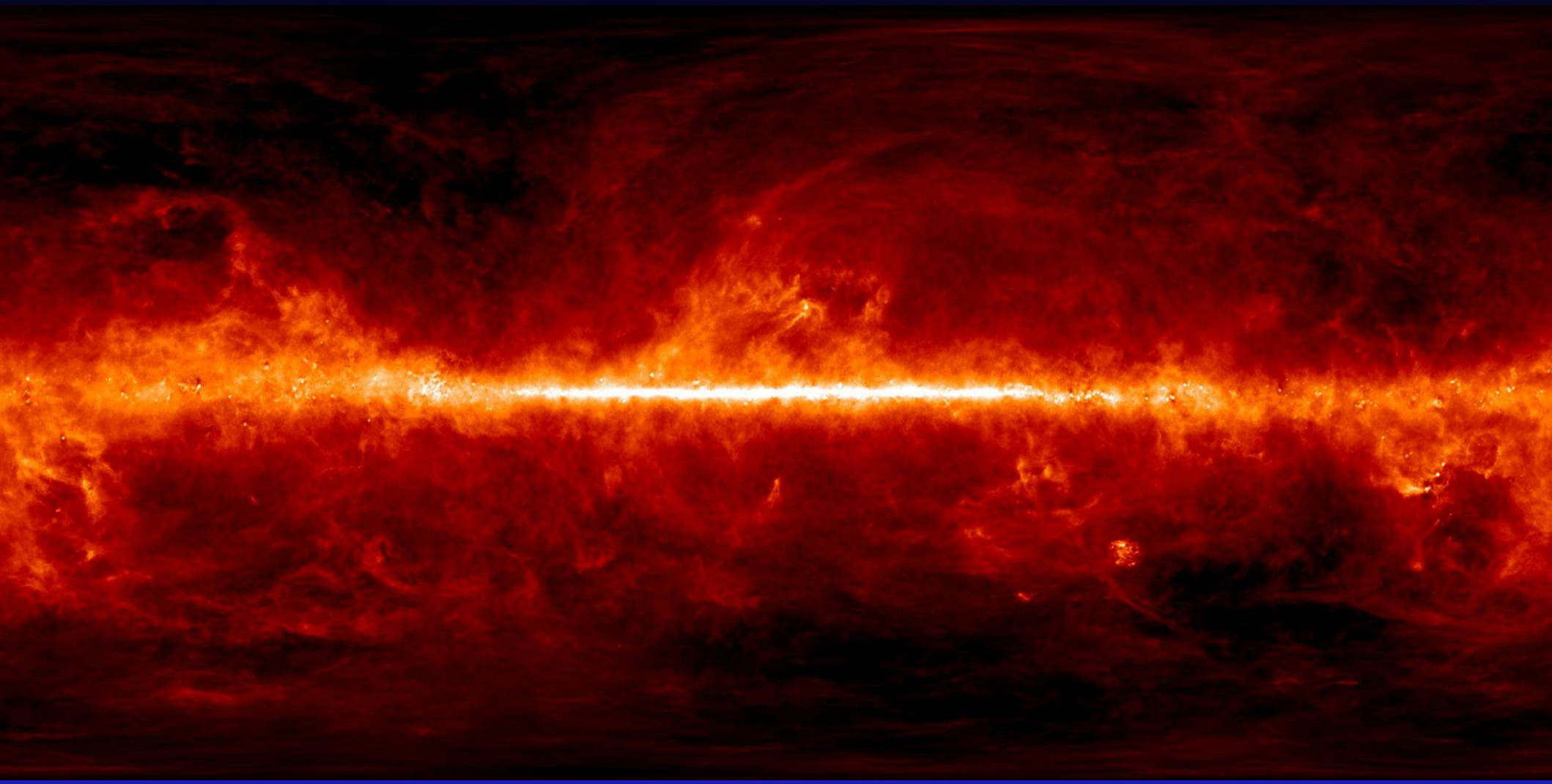
WMAP K-band (23 GHz)



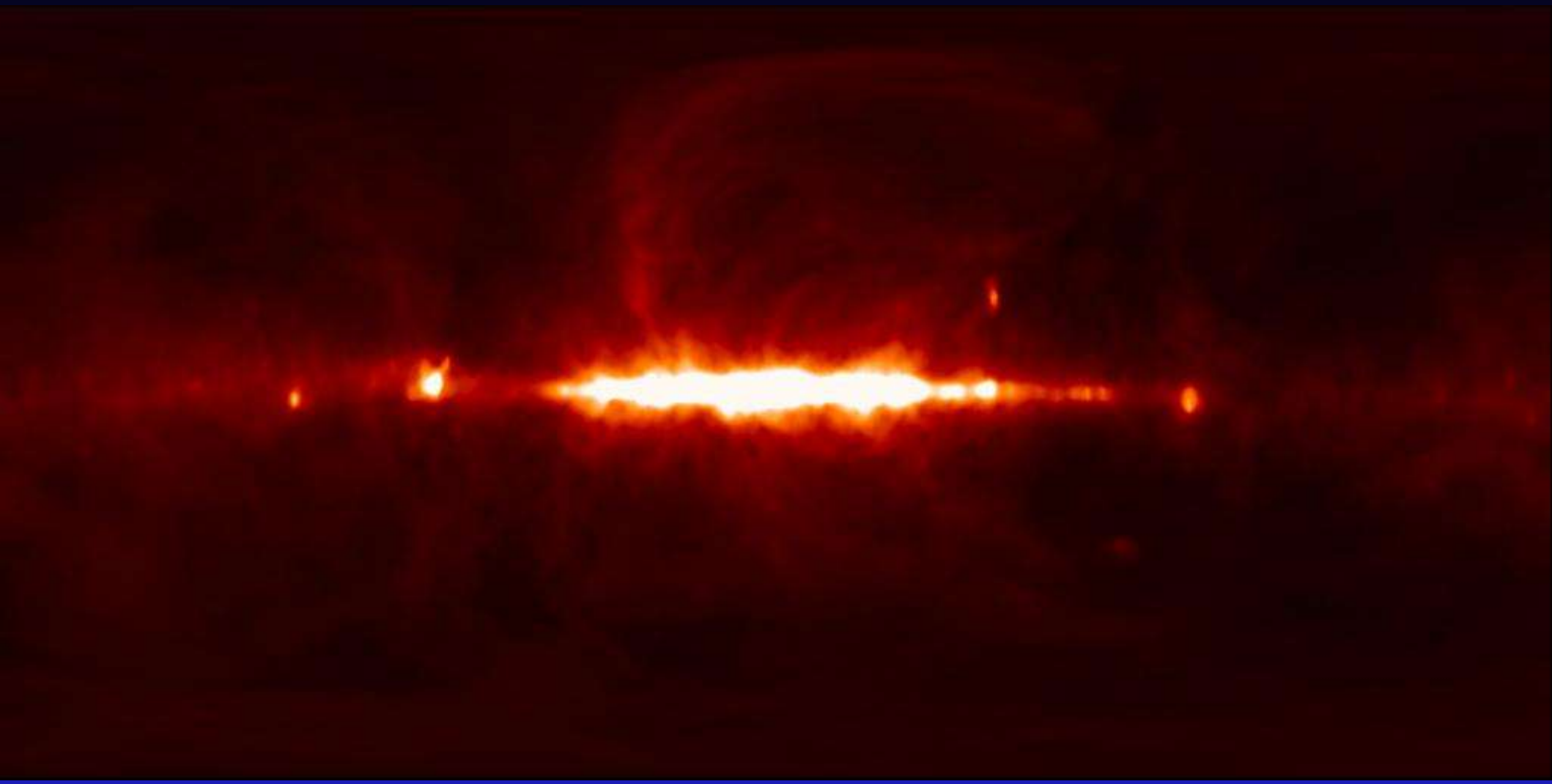
ISM Templates:

- Thermal dust - FIRAS,DIRBE
- "Soft" synchrotron - Haslam 408 MHz
- Free -free - Finkbeiner (2003)
- (from WHAM, SHASS, and VTSS)

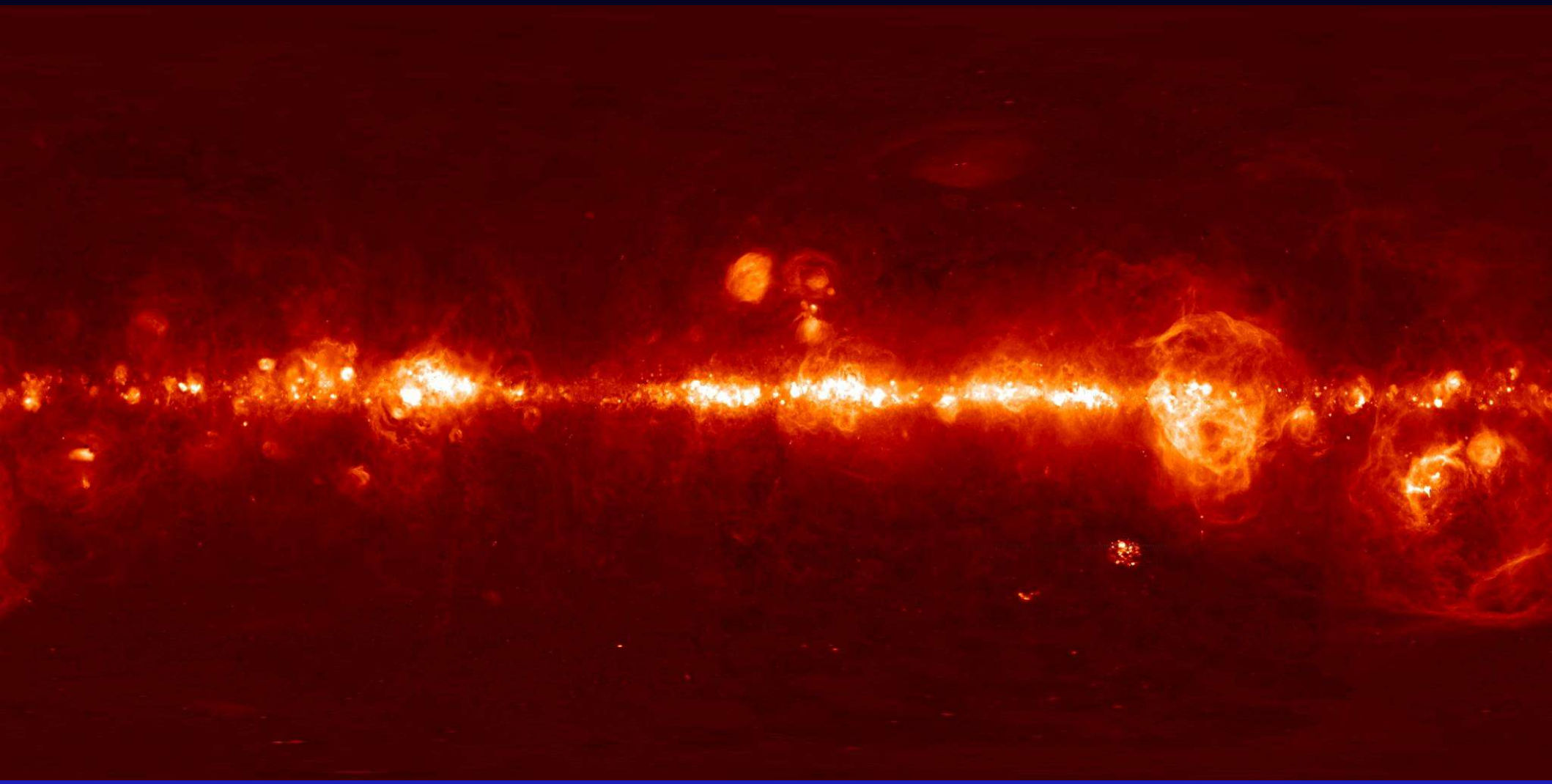
Dust emission (Schlegel et al. 1998)

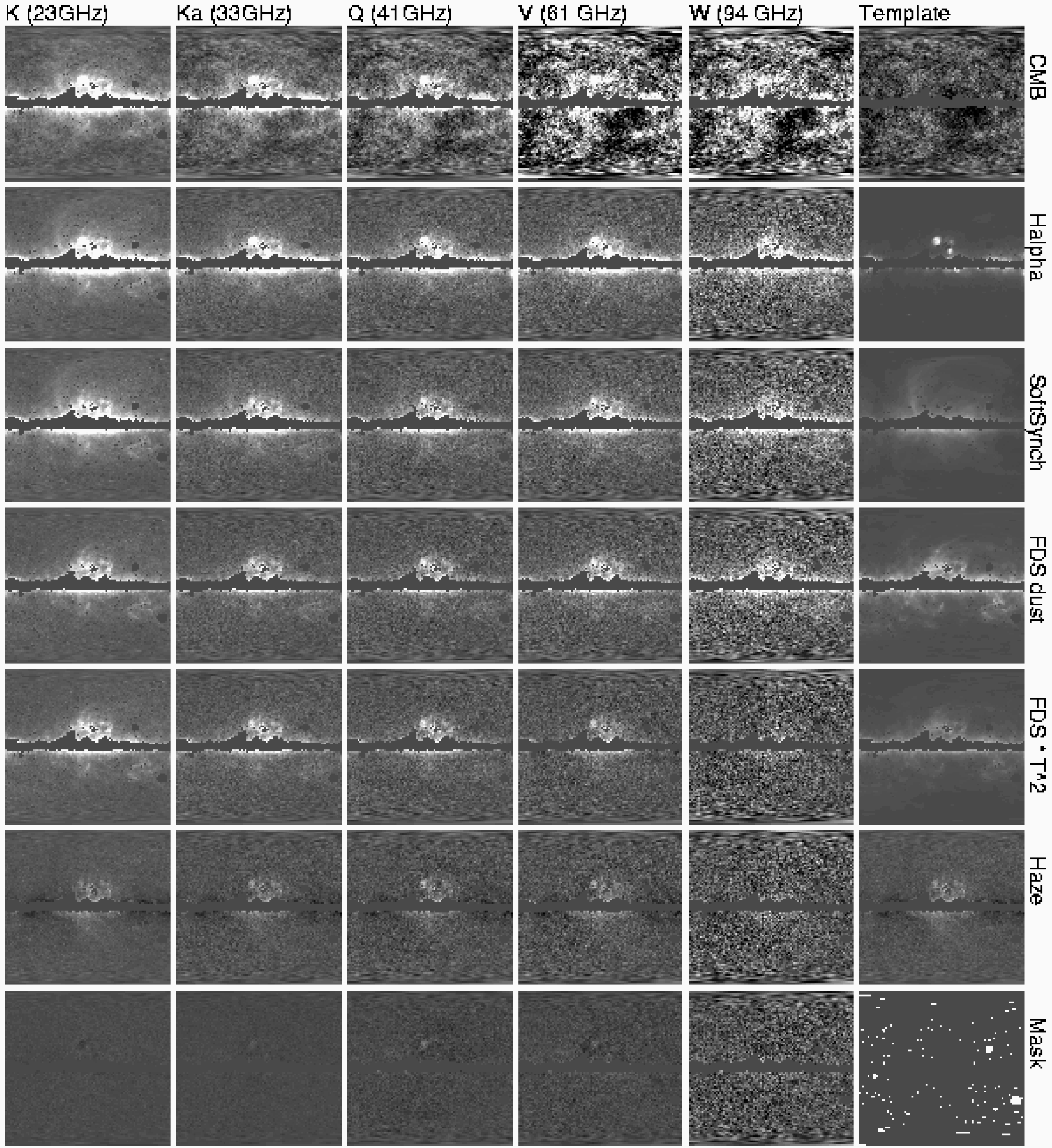


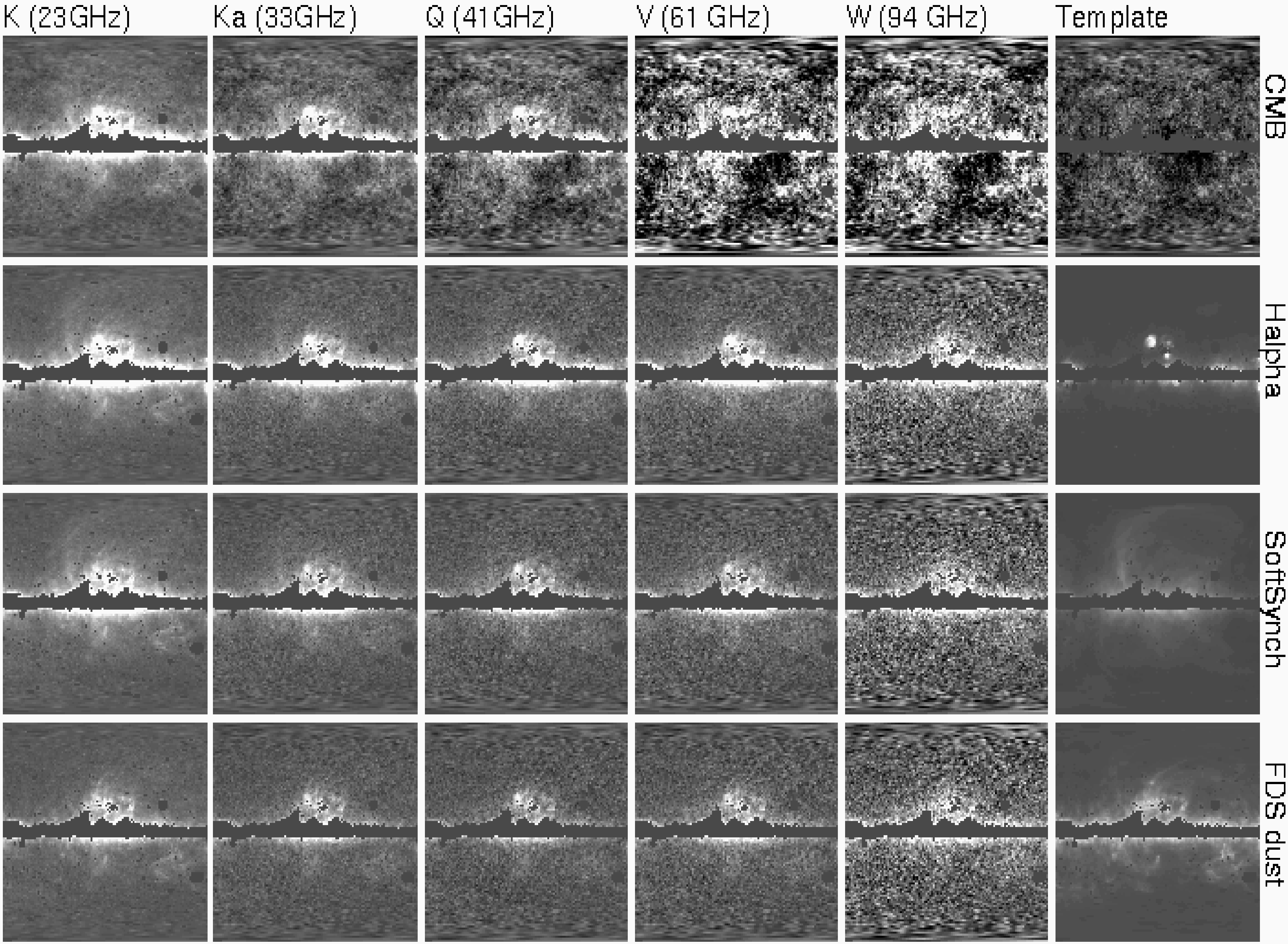
Synchrotron emission (Haslam 1982)



H emission (Finkbeiner 2003)




K (23GHz)
Ka (33GHz)
Q (41GHz)
V (61 GHz)
W (94 GHz)
Template
CMB
Halpha
SoftSynch
FDS dust
FDS * T^2
Haze
Mask



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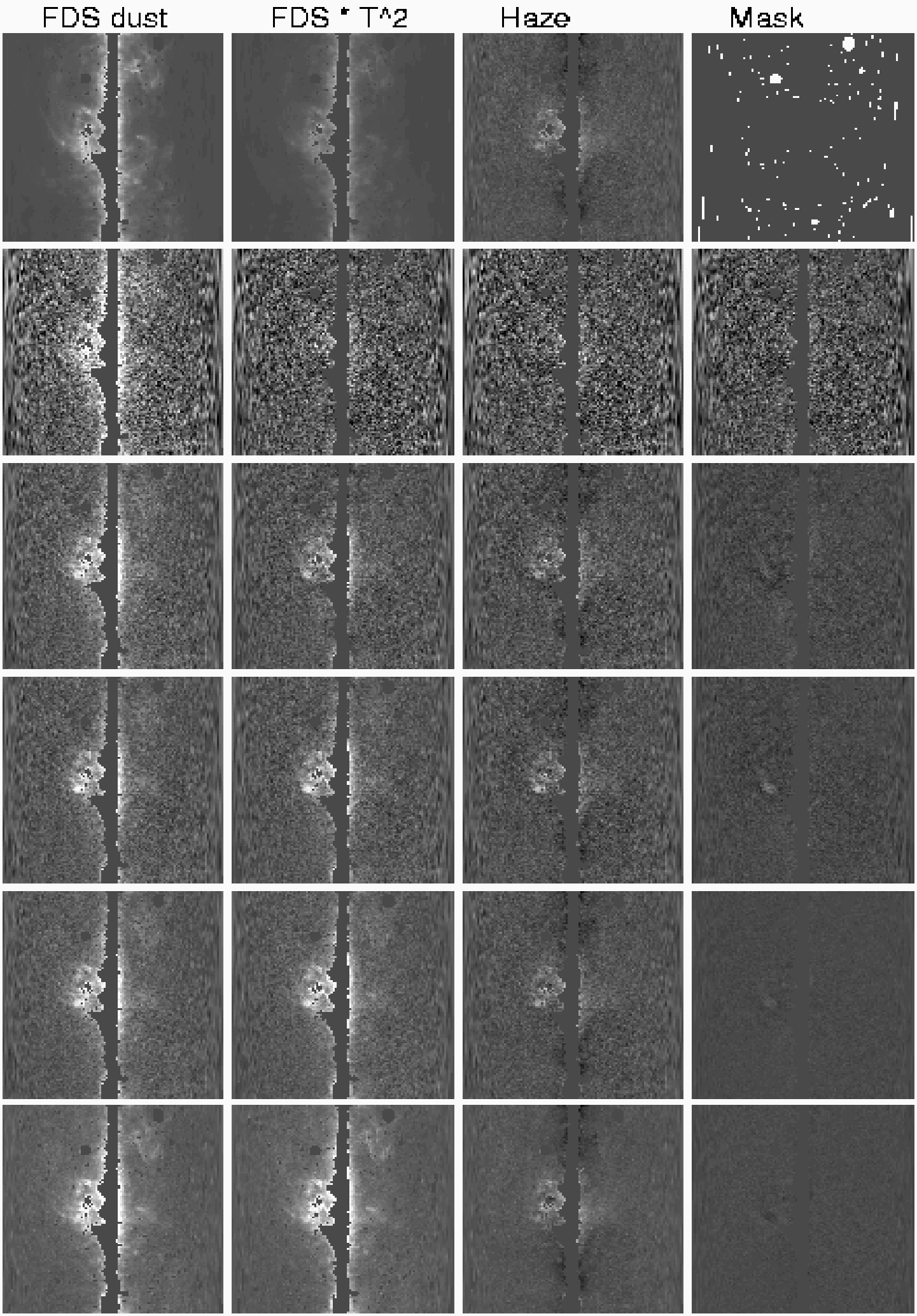
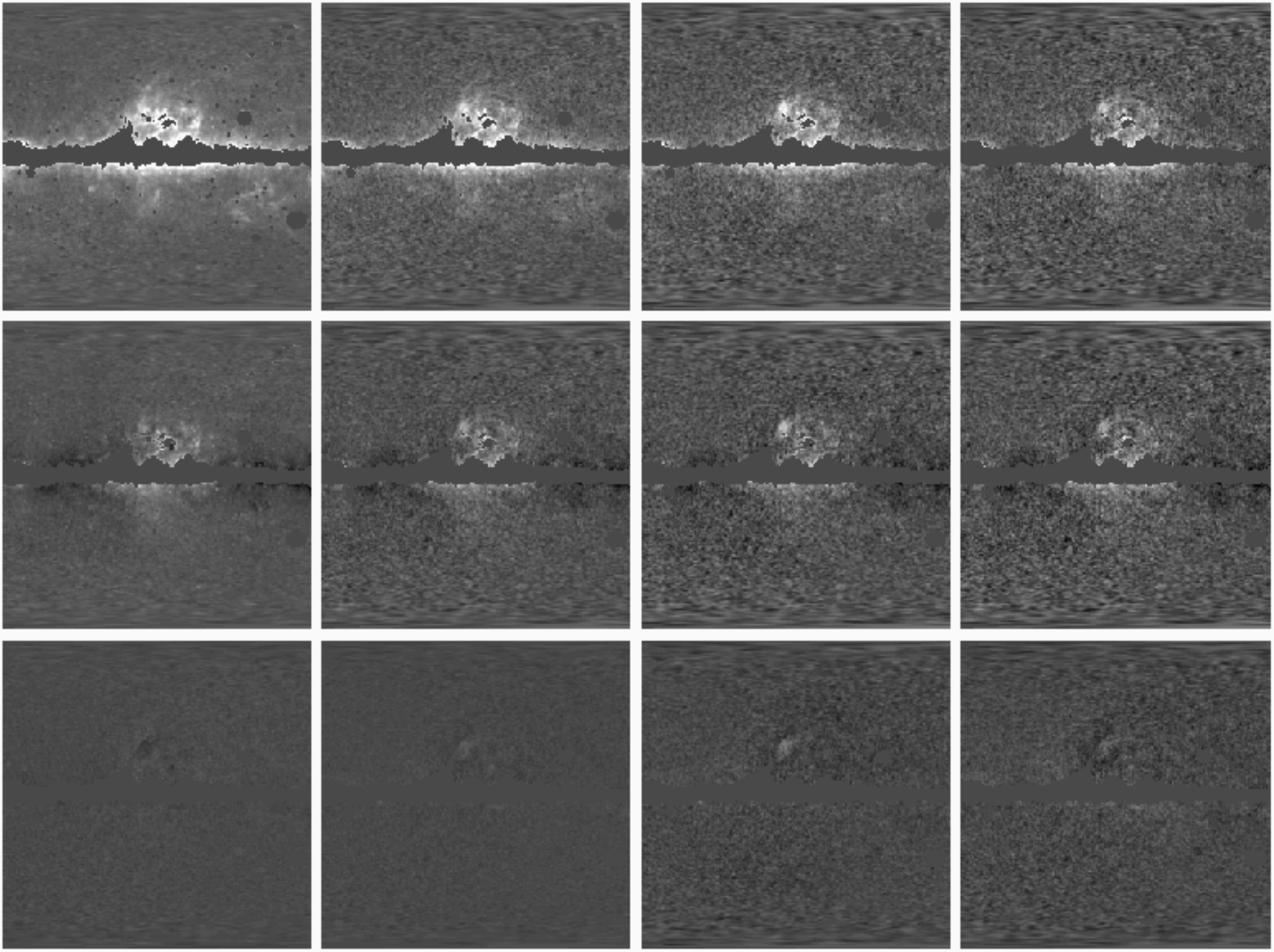

FDS dust
FDS * T^2
Haze
Mask



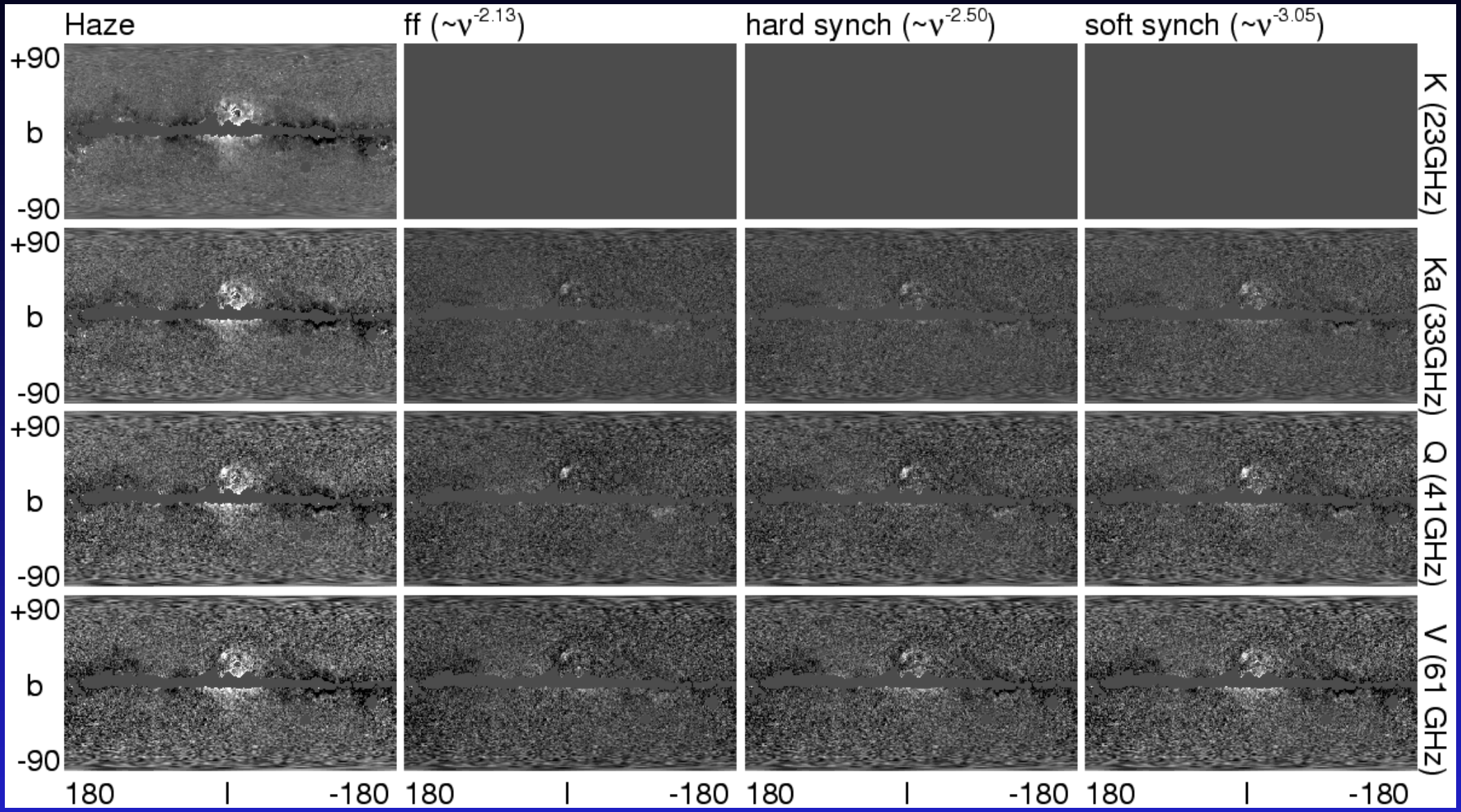
The Haze

Appears south of Galactic center (within 20-30 deg)
Not much emission in other templates
Has a free -free spectrum

The Gas must be hot (~ 100,000 K)
Chi^2 near unity for most bands

In general this four component template fit, including "spinning dust," fits well.

The Haze



Is it free -free or synchrotron?

What is the “haze”

Best current guess:
synchrotron emission from a “hard” cosmic ray electron spectrum (harder than $dN/dE \sim E^{-2}$)

Tests:
*cosmic ray ICS scattering observed by EGRET
*microwave polarization (coming soon!)

What is the “haze”

What is the source of the electrons?

The “standard” supersymmetric dark matter candidate particle, the neutralino self-annihilates; produces high energy (10s – 100ish) GeV particles.

We know the cross section and approximate mass.
We know the MW dark matter halo (roughly)
-> Can model electron creation, propagation, and energy loss, and predict synchrotron...

Assumptions:

$< v> = 2\ 10^{-26}$ cm^3/s

mass = 100 GeV

spherical symmetry (only care about center)

diffusion is isotropic

$K(E) \sim (3 + (E/1\text{GeV})) 3\ 10^{-27}$ cm^2/s; =0.6

(Webber et al.)

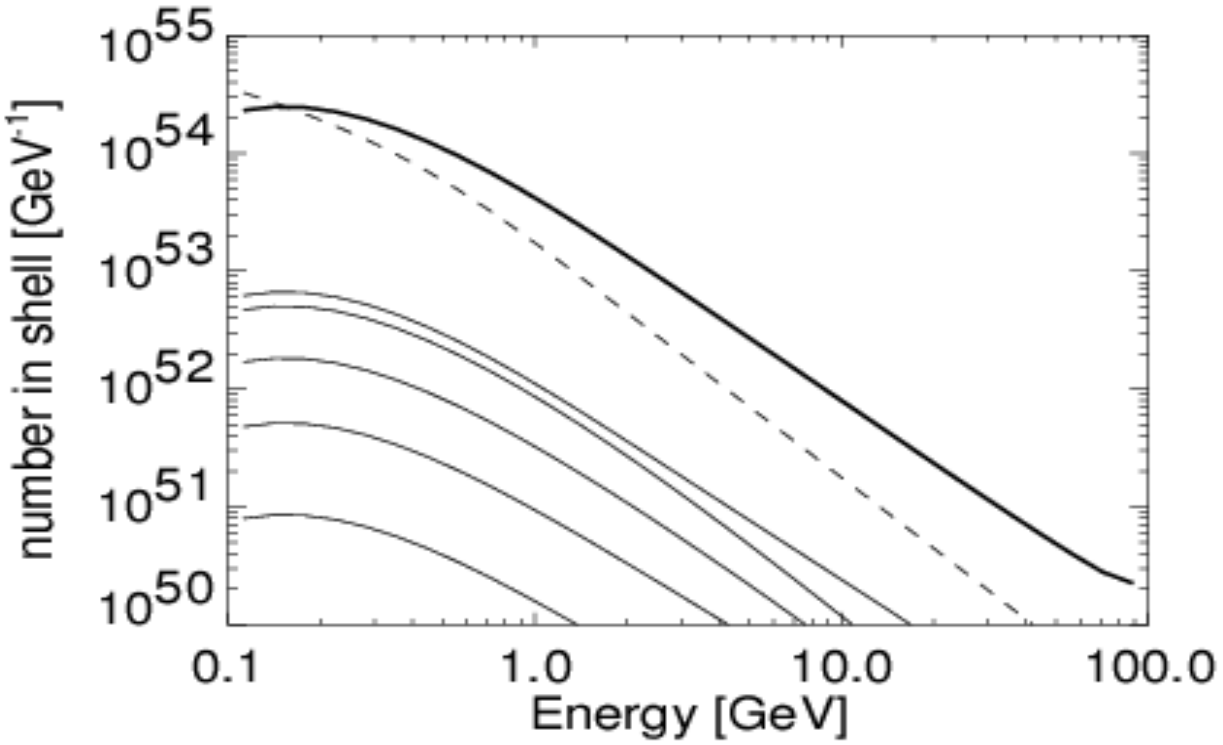
injection spectrum is hard

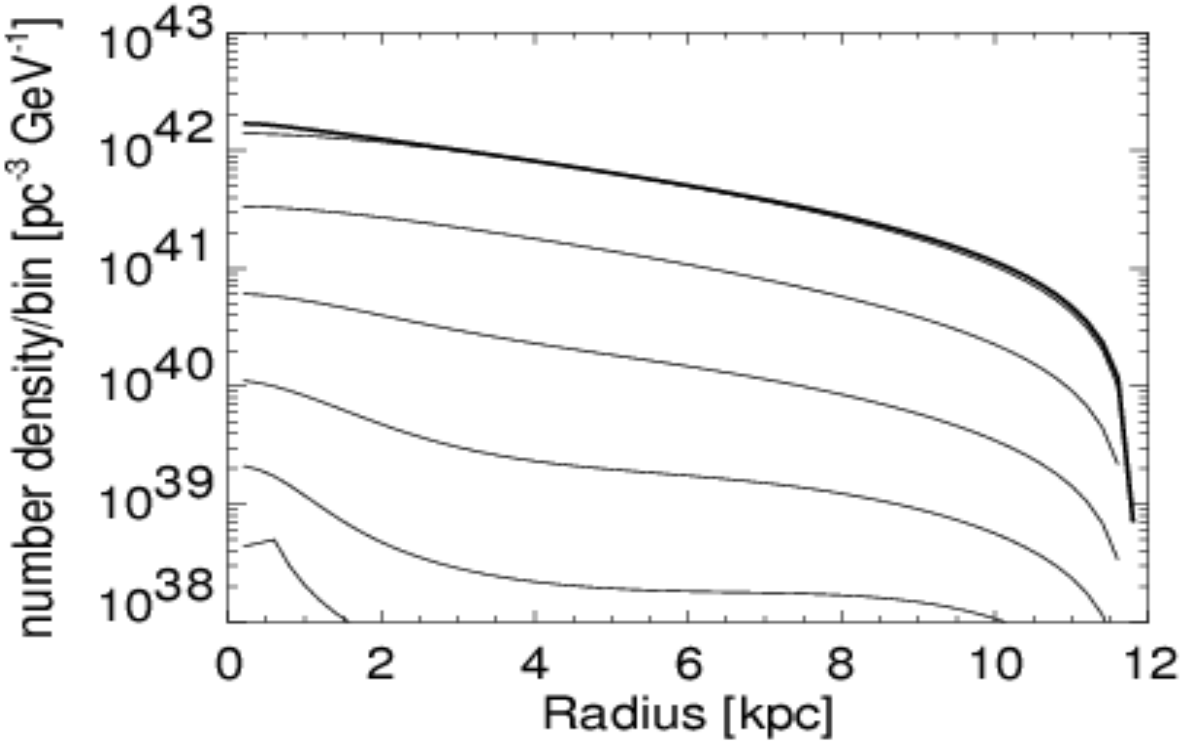
starlight from Strong, Moskalenko & Reimer (2000)

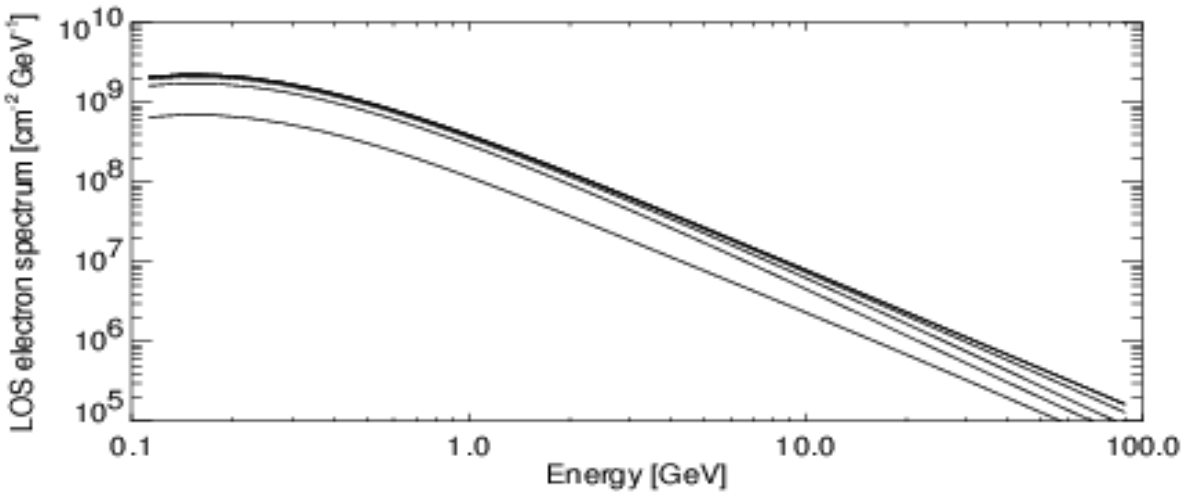
B-field from Han (2004)

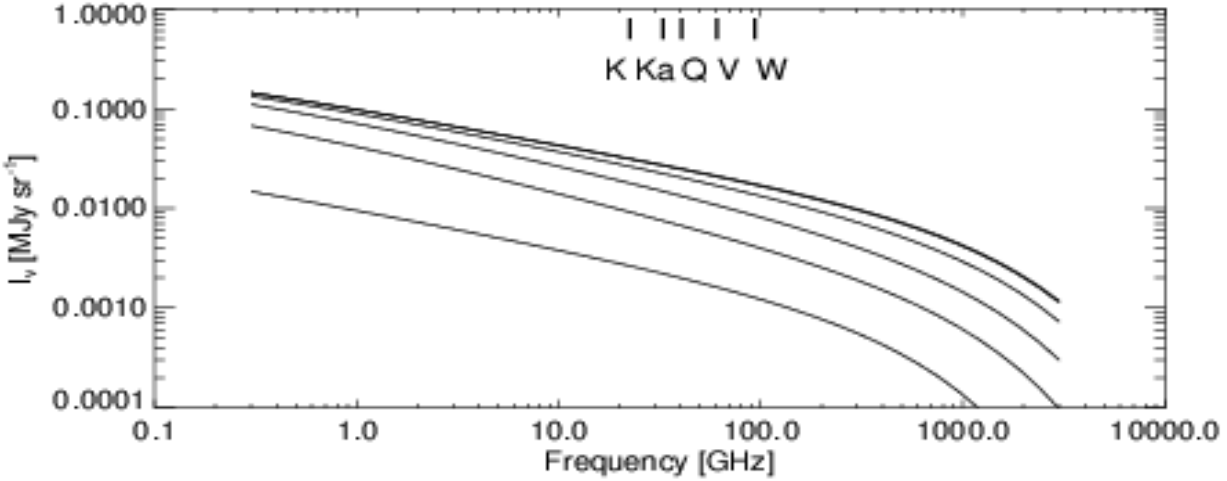
all reasonable assumptions; all could be better...

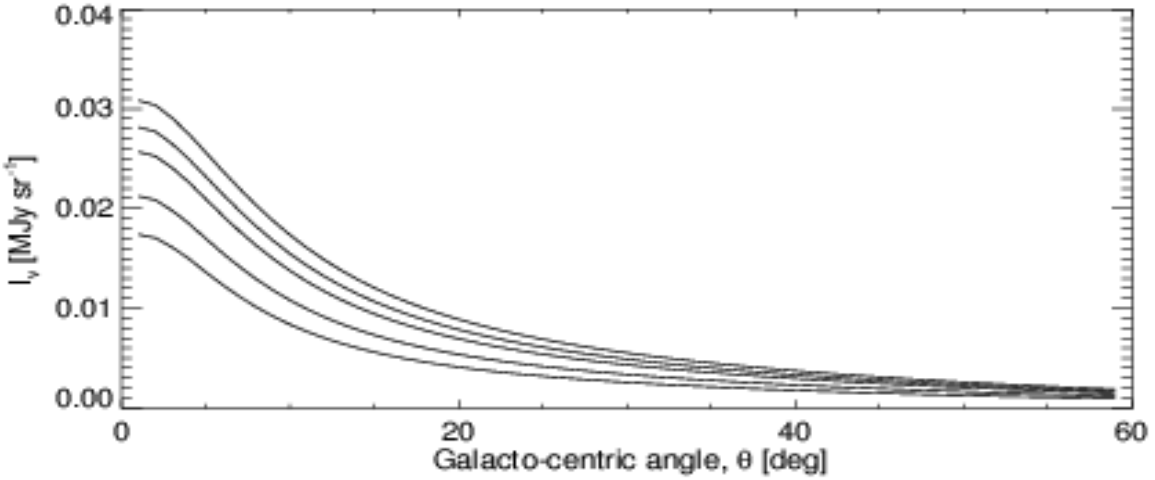
$$\frac{d}{dt}n(E,\mathbf{x}) = \nabla \cdot (K(E,\mathbf{x})\nabla n) + \frac{\partial}{\partial E}\left[b(E,\mathbf{x})n\right] + Q(E,\mathbf{x})$$

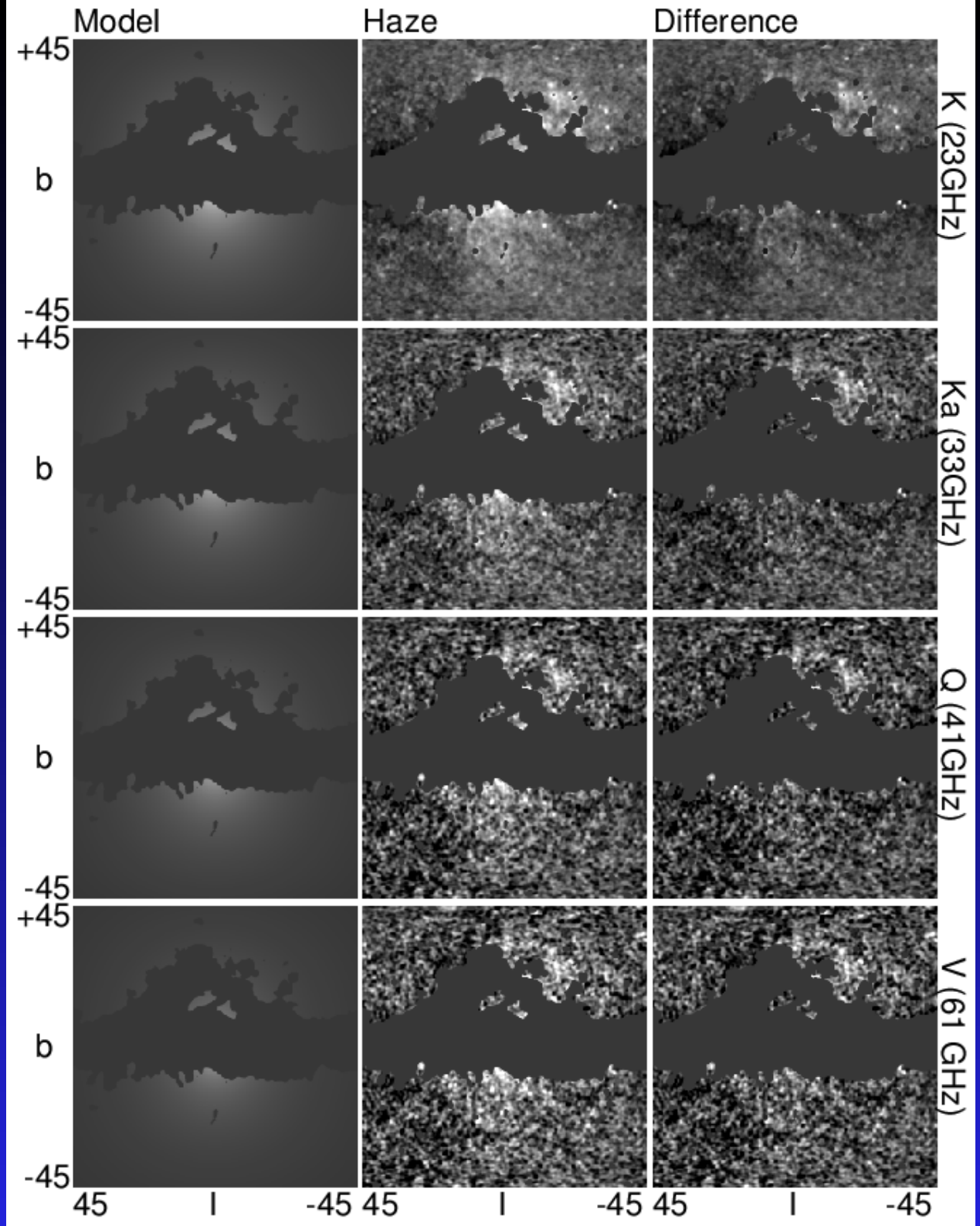

number in shell [GeV^{-1}]
10^{55}
10^{54}
10^{53}
10^{52}
10^{51}
10^{50}
0.1
1.0
10.0
100.0
Energy [GeV]


number density/bin [pc^{-3} GeV^{-1}]
10^{43}
10^{42}
10^{41}
10^{40}
10^{39}
10^{38}
0
2
4
6
8
10
12
Radius [kpc]


LOS electron spectrum [cm^{-2} GeV^{-1}]
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
0.1
1.0
10.0
100.0
Energy [GeV]


K Ka Q V W
1.0000
0.1000
0.0100
0.0010
0.0001
I_ν [MJy sr^{-1}]
0.1
1.0
10.0
100.0
1000.0
10000.0
Frequency [GHz]


0.04
0.03
0.02
0.01
0.00
I_ν [MJy sr^{-1}]
0
20
40
60
Galacto-centric angle, θ [deg]


Model
Haze
Difference
+45
b
-45
K (23GHz)
Ka (33GHz)
Q (41GHz)
V (61 GHz)
45
l
-45

What is the “haze”

*The cross section and density are fixed
(in the simplest case).
*mass is free parameter, but constrained.

*A dark matter model using very simple assumptions and one free parameter fits the data.

*This could have been off by many orders of magnitude, and wasn't.

Tooth Fairy count

A new idea must explain at least one interesting problem per “tooth fairy”

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A self-annihilating WIMP exists (e.g. ,)

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It IS the dark matter

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A self-annihilating WIMP exists (e.g. ,),

It IS the dark matter,

Its annihilation products go to e^+e^- with a hard spectrum, up to high (10s GeV) energy.

Tooth Fairy count

High TFC, but:

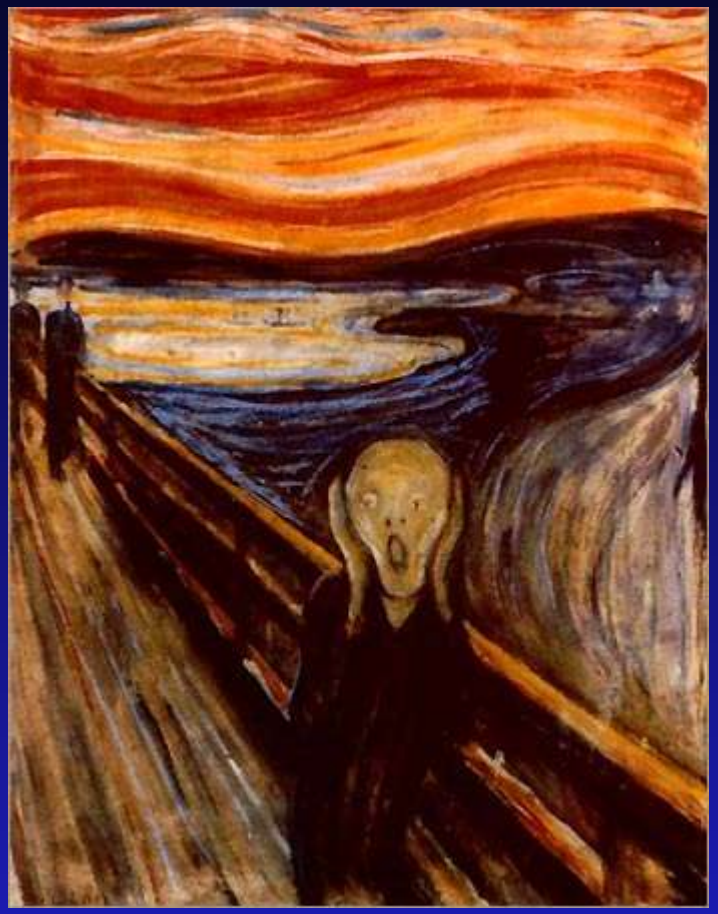
SUSY (for example) would solve
fundamental problems in particle physics.
Explain dark matter
Explain excess gamma-ray and microwave emission

Nightmare Scenario

The LHC/LC, etc. find nothing.

SUSY wrong.

We have no idea what is going on.



The Scream – Edvard Munch
Munch Museum, Oslo (now in private hands)

Future work

Model propagation/diffusion better
- more realistic boundary conditions
- better magnetic field estimate
- photon field, with directional information

Model expected ICS better

Obtain better gamma-ray measurements
(GLAST, VERITAS, INTEGRAL, etc.)

Improve WMAP foreground analysis
-> determine required injection spectrum
--> constrain models!