The Revolution Has Been Here a While Now: Where the Heck Have You Been?

Neal Weiner
Center for Cosmology and Particle Physics
NYU

Aspen Winter Conference 2010

There are anomalies and there are anomalies

- Standard Statement:
  - The SM Agrees With All Data Except Gravity
  - Really?

What physics beyond the standard model?

Theory driven

Hierarchy problem:

SUSY, technicolor, RS, ADD, little Higgs

=> scale driven

i.e., we know there's a weak scale

Anomaly driven

solar neutrino problem

atmospheric neutrino anomaly

Cosmic acceleration

Galactic rotation curves

17 keV neutrino

LSND

PVLAS

What physics beyond the standard model?

Theory driven
Hierarchy problem:
SUSY, technicolor, RS,
ADD, little Higgs

=> scale driven
i.e., we know there's a
weak scale

Anomaly driven
solar neutrino problem
atmospheric neutrino
anomaly
Cosmic acceleration
Galactic rotation curves
17 keV neutrino
LSND
PVLAS

standard model physics

How we discover physics beyond the standard

How we discover physics beyond the standard

- First you see a result and insist that the data and/or assumptions are completely unreliable and should be ignored

How we discover physics beyond the standard

- First you see a result and insist that the data and/or assumptions are completely unreliable and should be ignored
- When it all works out, you say, "Yes, yes, we've known about this for some time"

How we discover physics beyond the standard

- First you see a result and insist that the data and/or assumptions are completely unreliable and should be ignored
- When it all works out, you say, "Yes, yes, we've known about this for some time"
- Neutrino masses

How we discover physics beyond the standard

- First you see a result and insist that the data and/or assumptions are completely unreliable and should be ignored
- When it all works out, you say, "Yes, yes, we've known about this for some time"
  - Neutrino masses
    - "No, I meant something cool"

How we discover physics beyond the standard

- First you see a result and insist that the data and/or assumptions are completely unreliable and should be ignored
- When it all works out, you say, "Yes, yes, we've known about this for some time"
  - Neutrino masses
    - "No, I meant something cool"
  - Large mixing angles

How we discover physics beyond the standard

- First you see a result and insist that the data and/or assumptions are completely unreliable and should be ignored
- When it all works out, you say, "Yes, yes, we've known about this for some time"
  - Neutrino masses
    - "No, I meant something cool"
  - Large mixing angles
    - "Who knows anything about flavor?"

How we discover physics beyond the standard

- First you see a result and insist that the data and/or assumptions are completely unreliable and should be ignored
- When it all works out, you say, "Yes, yes, we've known about this for some time"

- Neutrino masses
  - "No, I meant something cool"
- Large mixing angles
  - "Who knows anything about flavor?"
- Cosmological constant

How we discover physics beyond the standard

- First you see a result and insist that the data and/or assumptions are completely unreliable and should be ignored
- When it all works out, you say, "Yes, yes, we've known about this for some time"

- Neutrino masses
  - "No, I meant something cool"
- Large mixing angles
  - "Who knows anything about flavor?"
- Cosmological constant
  - "Doesn't count - I meant something about new particles"

What we really want:
A Jobs Program

What we really want:
A Jobs Program

The Hierarchy problem and new dimensions at a millimeter.
Nima Arkani-Hamed, (SLAC) , Savas Dimopoulos, (Stanford U., Phys. Dept.) , G.R. Dvali, (ICTP, Trieste) .
SLAC-PUB-7769, SU-ITP-98-13, Mar 1998. 16pp.
Published in **Phys.Lett.B429:263-272,1998**.
e-Print: **hep-ph/9803315**

TOPCITE = 3000+
References | LaTeX(US) | LaTeX(EU) | Harvmac | BibTeX | Keywords | Cited 3908 times
Abstract and Postscript and PDF from arXiv.org (mirrors: au br cn de es fr il in it jp kr ru tw uk za aps lanl)
Journal Server [doi:10.1016/S0370-2693(98)00466-3]
ADS Abstract Service
CERN Library Record
SLAC Document Server
Bookmarkable link to this information

What we really want:
A Jobs Program

The Hierarchy problem and new dimensions at a millimeter.
Nima Arkani-Hamed, (SLAC) , Savas Dimopoulos, (Stanford U., Phys. Dept.) , G.R. Dvali, (ICTP, Trieste) .
SLAC-PUB-7769, SU-ITP-98-13, Mar 1998. 16pp.
Published in **Phys.Lett.B429:263-272,1998**.
e-Print: **hep-ph/9803315**

TOPCITE = 3000+
References | LaTeX(US) | LaTeX(EU) | Harvmac | BibTeX | Keywords | Cited 3908 times
Abstract and Postscript and
Journal Server [doi:10.1016
ADS Abstract Service
CERN Library Record
SLAC Document Server
Bookmarkable link to this in

A Large mass hierarchy from a small extra dimension.
Lisa Randall, (Princeton U. & MIT, LNS) , Raman Sundrum, (Boston U.) . MIT-CTP-2860, PUPT-1860, BUHEP-99-9, May 1999. 9pp.
Published in **Phys.Rev.Lett.83:3370-3373,1999**.
e-Print: **hep-ph/9905221**

TOPCITE = 3000+
References | LaTeX(US) | LaTeX(EU) | Harvmac | BibTeX | Keywords | Cited 4423 times
Abstract and Postscript and PDF from arXiv.org (mirrors: au br cn de es fr il in it jp kr ru tw uk za aps lanl)
Journal Server [doi:10.1103/PhysRevLett.83.3370]
ADS Abstract Service
CERN Library Record
Bookmarkable link to this information

What we really want:
A Jobs Program

The Hierarchy problem and new dimensions at a millimeter.
Nima Arkani-Hamed, (SLAC) , Savas Dimopoulos, (Stanford U., Phys. Dept.) , G.R. Dvali, (ICTP, Trieste) .
SLAC-PUB-7769, SU-ITP-98-13, Mar 1998. 16pp.
Published in **Phys.Lett.B429:263-272,1998**.
e-Print: **hep-ph/9803315**

TOPCITE = 3000+
References | LaTeX(US) | LaTeX(EU) | Harvmac | BibTeX | Keywords | Cited 3908 times
Abstract and Postscript and
Journal Server [doi:10.1016
ADS Abstract Service
CERN Library Record
SLAC Document Server
Bookmarkable link to this in

A Large mass hierarchy from a small extra dimension.
Lisa Randall, (Princeton U. & MIT, LNS) , Raman Sundrum, (Boston U.) . MIT-CTP-2860, PUPT-1860, BUHEP-99-9, May 1999. 9pp.
Published in **Phys.Rev.Lett.83:3370-3373,1999**.
e-Print: **hep-ph/9905221**

TOPCITE = 3000+
References | LaTeX(US) | LaTeX(EU) | Harvmac | BibTeX | Keywords | Cited 4423 times
in it jp kr ru tw uk za aps lanl)

Softly Broken Supersymmetry and SU(5).
Savas Dimopoulos, (Stanford U., ITP & Santa Barbara, KITP & Michigan U.) , Howard Georgi, (Harvard U.) .
HUTP-81/A022, May 1981. 25pp.
Published in **Nucl.Phys.B193:150,1981**.

TOPCITE = 1000+
References | LaTeX(US) | LaTeX(EU) | Harvmac | BibTeX | Keywords | Cited 1525 times
Journal Server [doi:10.1016/0550-3213(81)90522-8]
Scanned Version (KEK Library)
Bookmarkable link to this information

What we really want:
A Jobs Program

The Hierarchy problem and new dimensions at a millimeter.
Nima Arkani-Hamed, (SLAC) , Savas Dimopoulos, (Stanford U., Phys. Dept.) , G.R. Dvali, (ICTP, Trieste) .
SLAC-PUB-7769, SU-ITP-98-13, Mar 1998. 16pp.
Published in **Phys.Lett.B429:263-272,1998**.
e-Print: **hep-ph/9803315**

TOPCITE = 3000+
References | LaTeX(US) | LaTeX(EU) | Harvmac | BibTeX | Keywords | Cited 3908 times
Abstract and Postscript and
Journal Server [doi:10.1016
ADS Abstract Service
CERN Library Record
SLAC Document Server
Bookmarkable link to this in

A Large mass hierarchy from a small extra dimension.
Lisa Randall, (Princeton U. & MIT, LNS) , Raman Sundrum, (Boston U.) . MIT-CTP-2860, PUPT-1860, BUHEP-99-9, May 1999. 9pp.
Published in **Phys.Rev.Lett.83:3370-3373,1999**.
e-Print: **hep-ph/9905221**

TOPCITE = 3000+
References | LaTeX(US) | LaTeX(EU) | Harvmac | BibTeX | Keywords | Cited 4423 times
in it jp kr ru tw uk za aps lanl)

Softly Broken Supersymmetry and SU(5).
Savas Dimopoulos, (Stanford U., ITP & Santa Barbara, KITP & Michigan U.) , Howard Georgi, (Harvard U.) .
HUTP-81/A022, May 1981. 25pp.
Published in **Nucl.Phys.B193:150,1981**.

TOPCITE = 1000+
References | LaTeX(US) | LaTeX(EU) | Harvmac | BibTeX | Keywords | Cited 1525 times
Journal Server [doi:10.1016/0550-3213(81)90522-8]
Scanned Version (KEK Library)
Bookmarkable link to this information

If any one of these ideas is right, it could produce literally **hundreds** of citations

Nuclear Physics B347 (1990) 1–11
North-Holland

NEUTRINO MOMENTS, MASSES AND CUSTODIAL SU(2) SYMMETRY *

Howard GEORGI and Michael LUKE

Lyman Laboratory of Physics, Harvard University, Cambridge, MA 02138, USA

Received 17 April 1990

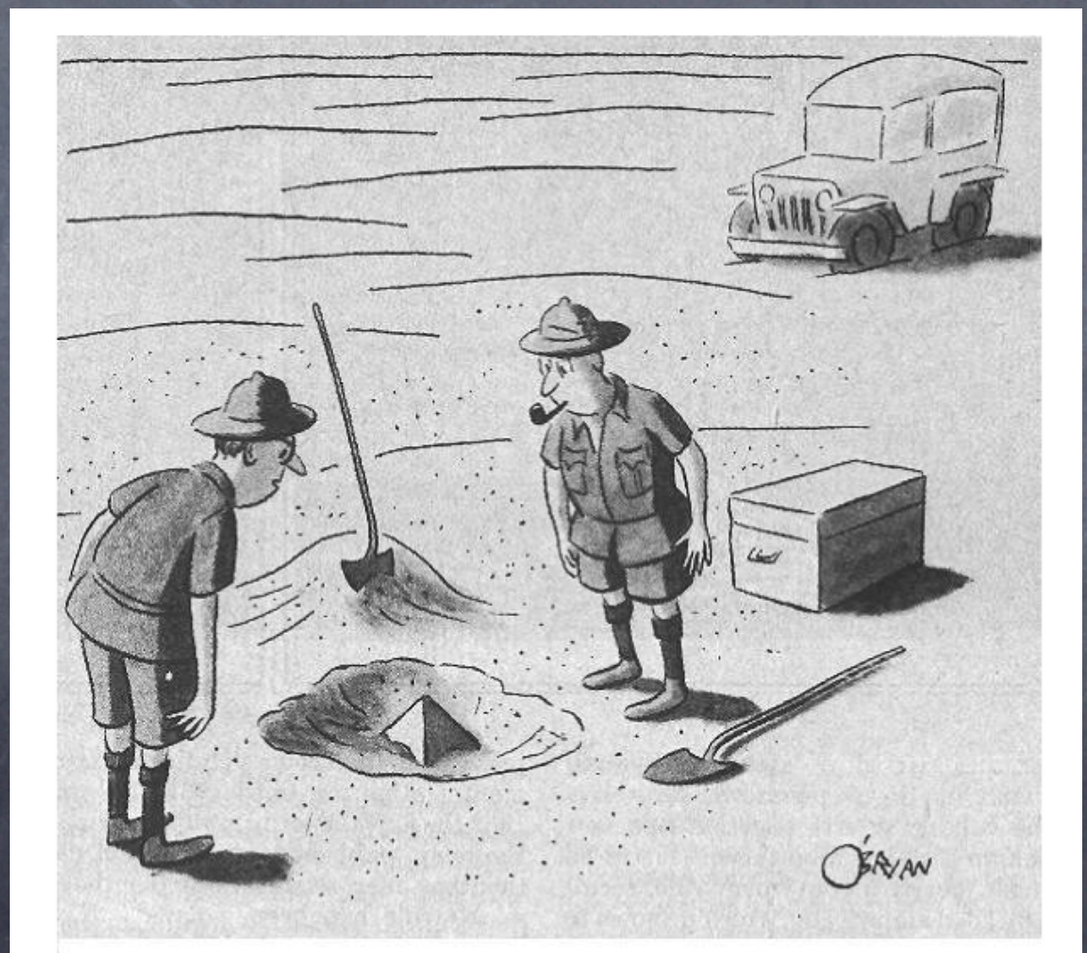
We identify and exemplify a new mechanism which leads to a nonzero magnetic moment for a neutrino, while suppressing the neutrino's mass. The mechanism requires that the contribution to the neutrino mass of the new particles that are responsible for its magnetic moment is approximately canceled by a contribution from neutral particles, related by a custodial SU(2) symmetry.

1. The problem

Most likely, the solar neutrino problem [1] has nothing whatever to do with particle physics. It is a great triumph that astrophysicists are able to predict the number of B^8 neutrinos coming from the sun as well as they do, to within a factor of 2 or 3 [2]. However, one aspect of the solar neutrino data, the apparent modulation of the flux of solar neutrinos with the sun-spot cycle, is certainly intriguing [3]. It is, of course, possible that this is an astrophysical problem rather than a particle physics problem. But that would require a synchronization of cycles of the interior of the sun with those of the convective layer, both in frequency and in *phase*. Thus it seems particularly interesting that there may be a particle physics explanation of this effect [4], involving a magnetic moment of the electron neutrino of the order of $10^{-11}\mu_B$.

Where to start: anomalies

- By and large, new signals start out sketchy and grow into something believable

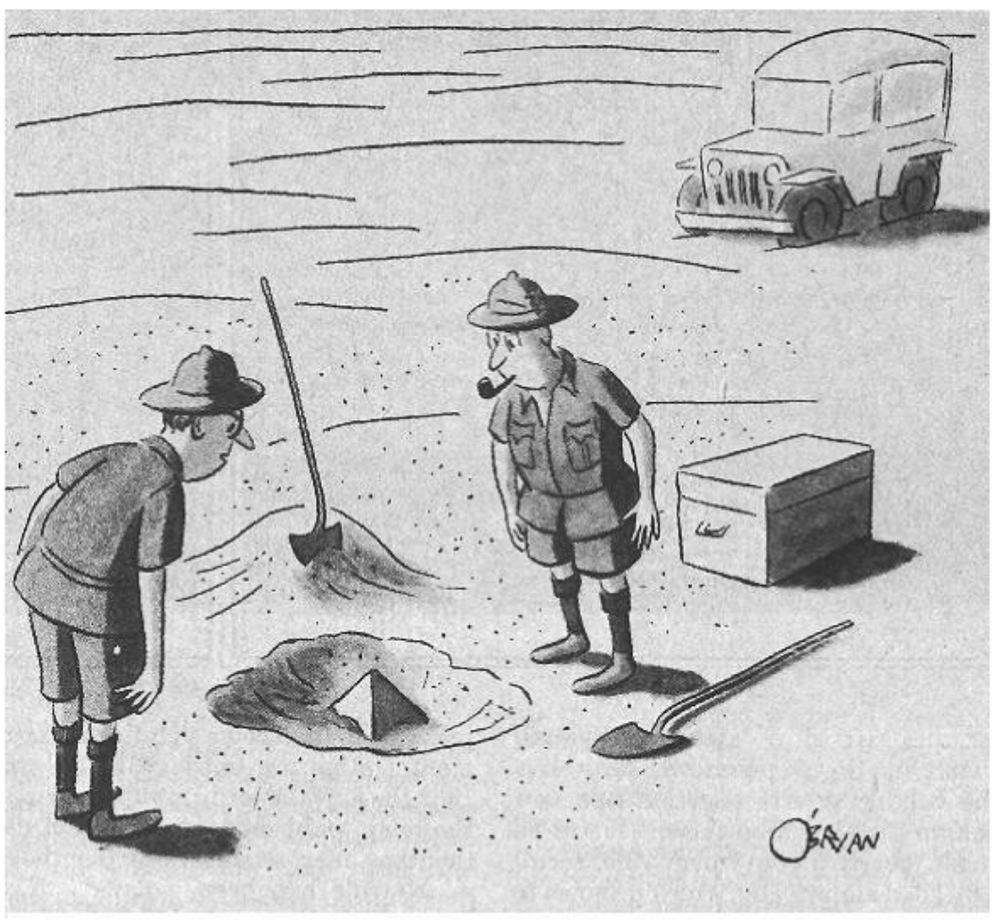


"This could be the discovery of the century. Depending, of course, on how far down it goes."

*Not all anomalies included

Where to start: anomalies

- So let us consider the anomalies out there, and prepare ourselves for the revolution*

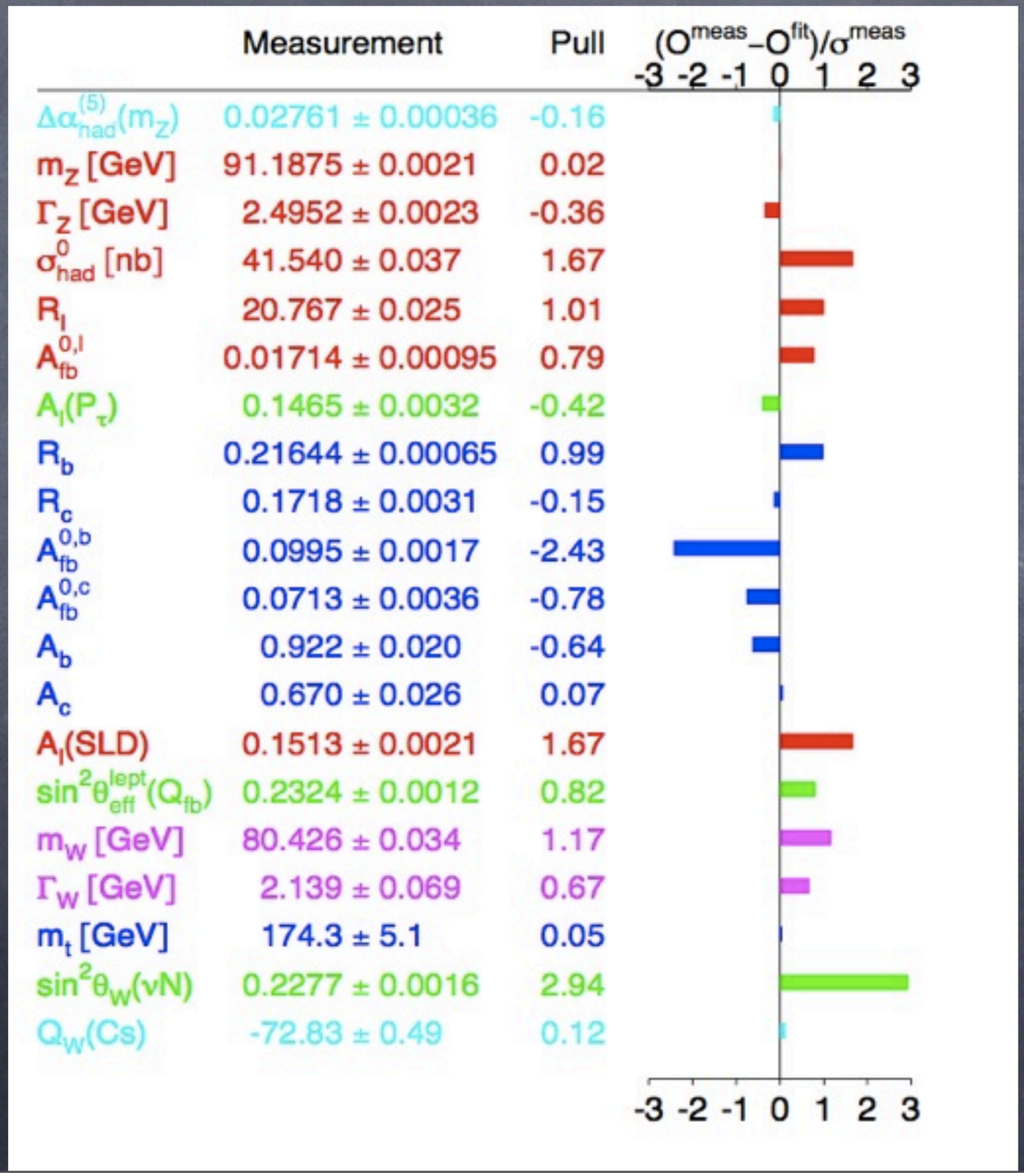


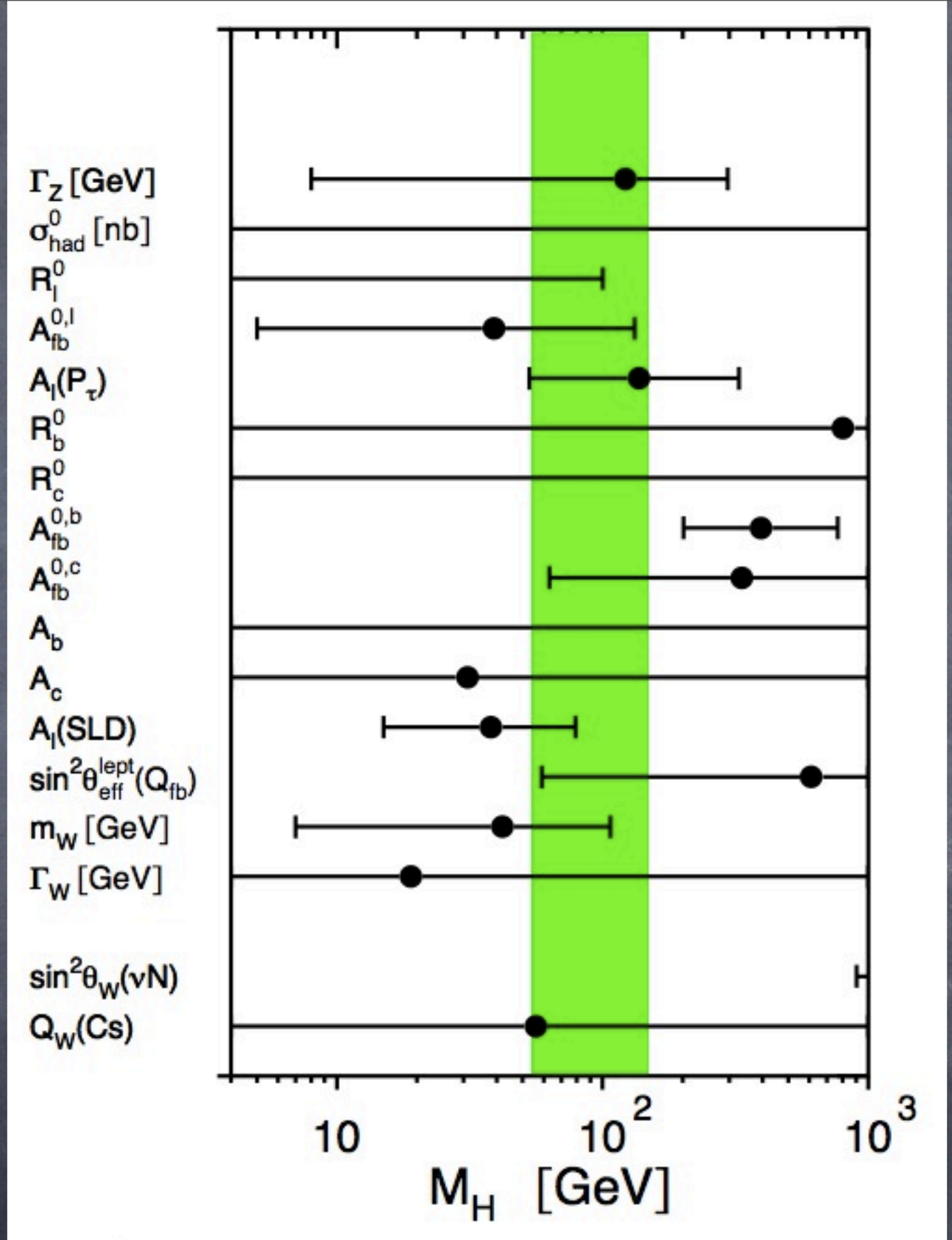
"This could be the discovery of the century. Depending, of course, on how far down it goes."

*Not all anomalies included

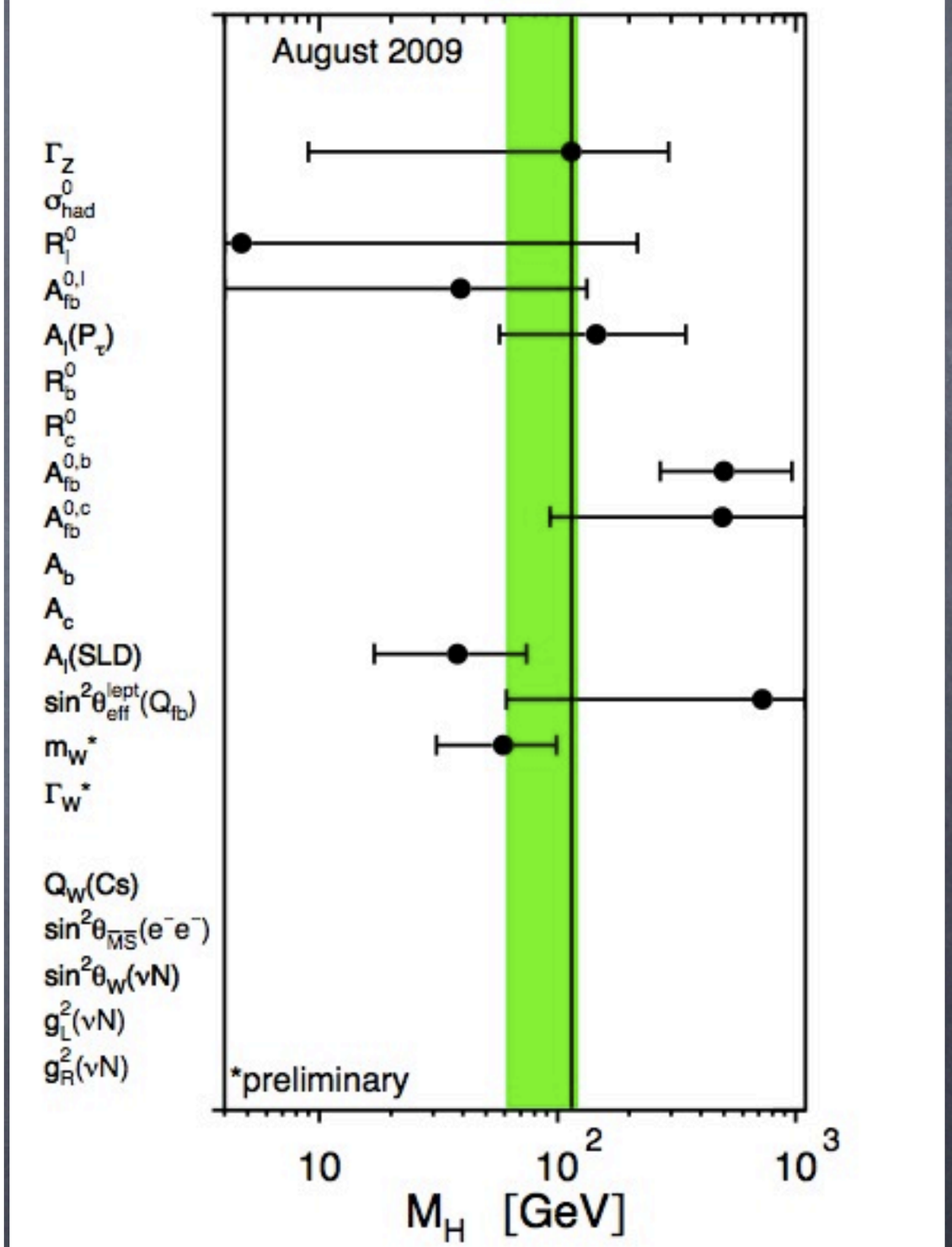
The Grandaddy of Precision Anomalies

props to Mike Chanowitz




Γ_Z [GeV]
σ^0_{had} [nb]
R^0_l
$A^{0,l}_{fb}$
$A_l(P_\tau)$
R^0_b
R^0_c
$A^{0,b}_{fb}$
$A^{0,c}_{fb}$
A_b
A_c
A_l(SLD)
$\sin^2\theta^{lept}_{eff}(Q_{fb})$
m_W [GeV]
Γ_W [GeV]
$\sin^2\theta_W(\nu N)$
Q_W(Cs)
10
10^2
10^3
M_H [GeV]

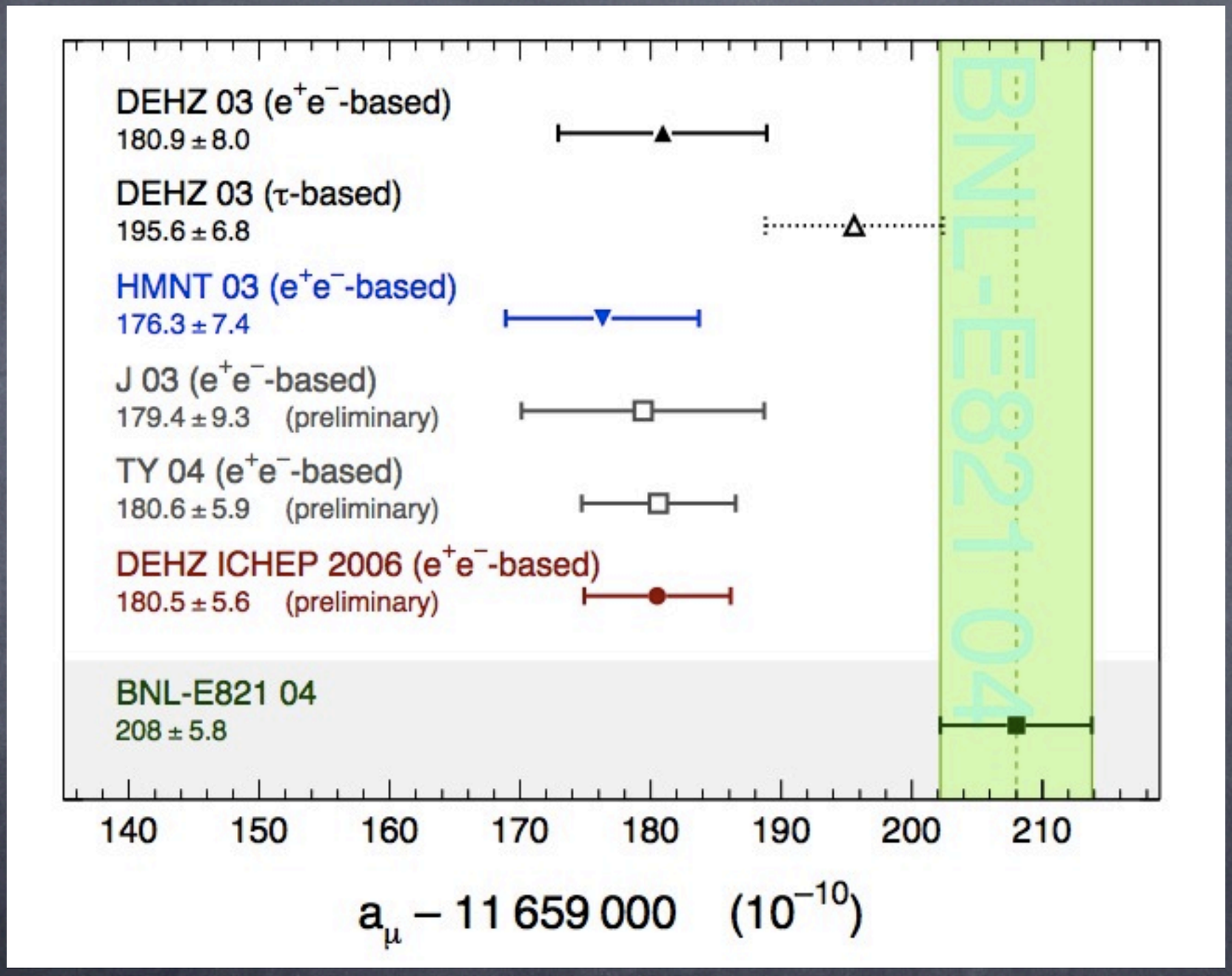
		Measurement with Total Error	Systematic Error	Standard Model fit	Pull
	$\Delta\alpha^{(5)}_{\rm had}(m^2_{\rm Z})$ [46]	0.02758 ± 0.00035	0.00034	0.02768	-0.3
a)	LEP-I line-shape and lepton asymmetries:				
	$m_{\rm Z}$ [GeV]	91.1875 ± 0.0021	[a] 0.0017	91.1874	0.0
	$\Gamma_{\rm Z}$ [GeV]	2.4952 ± 0.0023	[a] 0.0012	2.4959	-0.3
	$\sigma^0_{\rm had}$ [nb]	41.540 ± 0.037	[b] 0.028	41.478	1.7
	R^0_ℓ	20.767 ± 0.025	[b] 0.007	20.742	1.0
	$A^{0,\ell}_{\rm FB}$	0.0171 ± 0.0010	[b] 0.0003	0.0165	0.7
	+ correlation matrix [1]				
	τ polarisation:				
	$\mathcal{A}_\ell$ $(\mathcal{P}_\tau)$	0.1465 ± 0.0033	0.0016	0.1481	-0.5
	$q\bar{q}$ charge asymmetry:				
	$\sin^2\theta^{\rm lept}_{\rm eff}(Q^{\rm had}_{\rm FB})$	0.2324 ± 0.0012	0.0010	0.23138	0.8
b)	SLD				
	$\mathcal{A}_\ell$ (SLD)	0.1513 ± 0.0021	0.0010	0.1481	1.5
c)	LEP-I/SLD Heavy Flavour				
	$R^0_{\rm b}$	0.21629 ± 0.00066	0.00050	0.21579	0.8
	$R^0_{\rm c}$	0.1721 ± 0.0030	0.0019	0.1723	-0.1
	$A^{0,{\rm b}}_{\rm FB}$	0.0992 ± 0.0016	0.0007	0.1038	-2.9
	$A^{0,{\rm c}}_{\rm FB}$	0.0707 ± 0.0035	0.0017	0.0742	-1.0
	$\mathcal{A}_{\rm b}$	0.923 ± 0.020	0.013	0.935	-0.6
	$\mathcal{A}_{\rm c}$	0.670 ± 0.027	0.015	0.668	0.1
	+ correlation matrix [1]				
d)	LEP-II and Tevatron				
	$m_{\rm W}$ [GeV] (LEP-II, Tevatron)	80.399 ± 0.023		80.379	0.9
	$\Gamma_{\rm W}$ [GeV] (LEP-II, Tevatron)	2.098 ± 0.048		2.092	0.1
	$m_{\rm t}$ [GeV] (Tevatron [21])	173.1 ± 1.3	1.1	173.2	-0.1



Or maybe the Higgs really is light and decaying funnily?
(see talk by A. Haas)

- Proposals:
  - Light sparticles (esp sleptons/sneutrinos) (Altarelli et al)
  - New states mixing with bottom (Choudhury, Tait, Wagner)
  - Genuinely light Higgs decaying funnily (Dermisek+Gunion, Chang et al, Csaki et al...)

g-2



$$a_\mu^{SM} = a_\mu^{QED} + a_\mu^{EW} + a_\mu^{HLO} + a_\mu^{HHO}$$

Another tension?

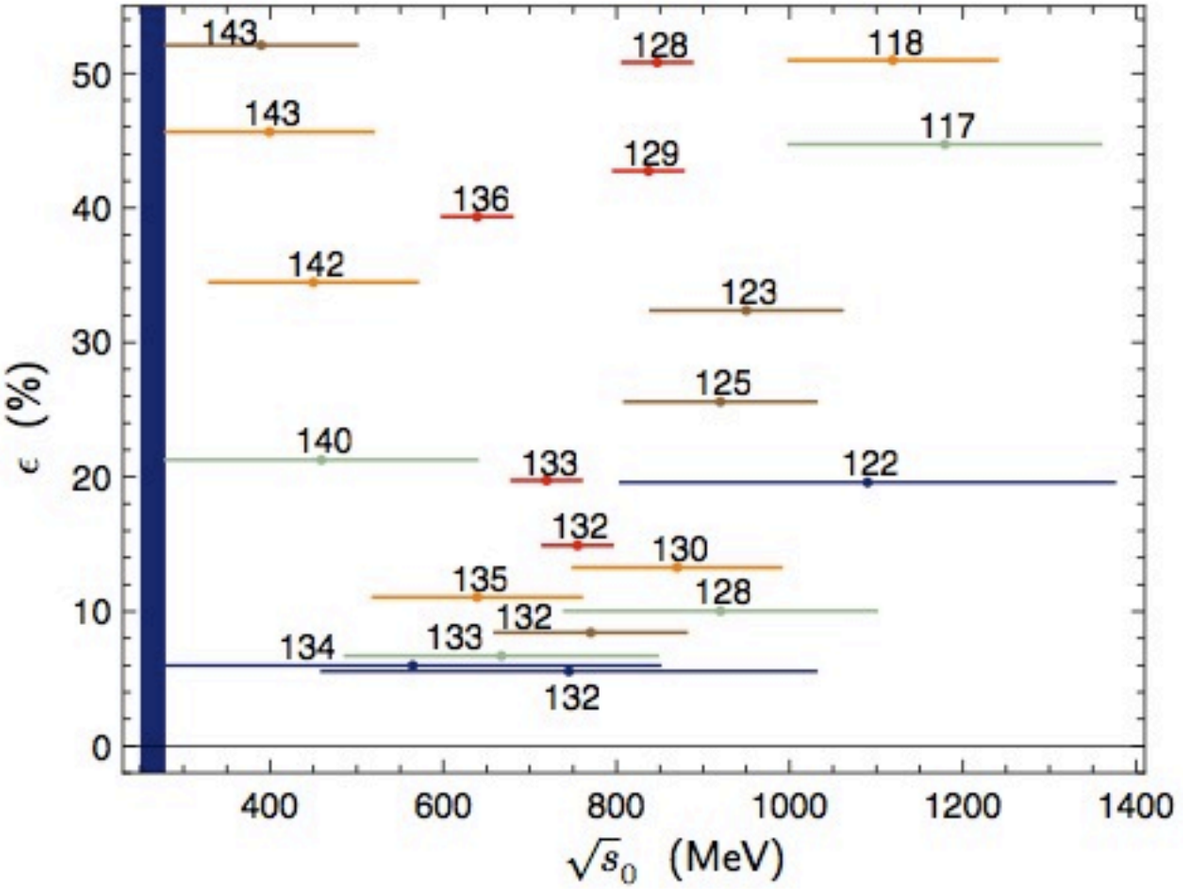


FIG. 3: Values of ϵ obtained increasing $\sigma(s)$ by $\epsilon\sigma(s)$, to bridge the Δa_μ discrepancy, in energy ranges $[\sqrt{s_0} - \delta/2, \sqrt{s_0} + \delta/2]$ for various values of $\sqrt{s_0}$ and δ. The number next to each segment indicates the M_H^{95} value (in GeV) induced by the $\epsilon\sigma(s)$ shift in that energy region. Same length segments are of the same color. The midpoint of each segment is displayed by a dot.

Passera, Marciano, Sirlin

Higgs
Mass

Need discrepancy
for SM consistency

AFB

Need discrepancy
for SM consistency

g-2

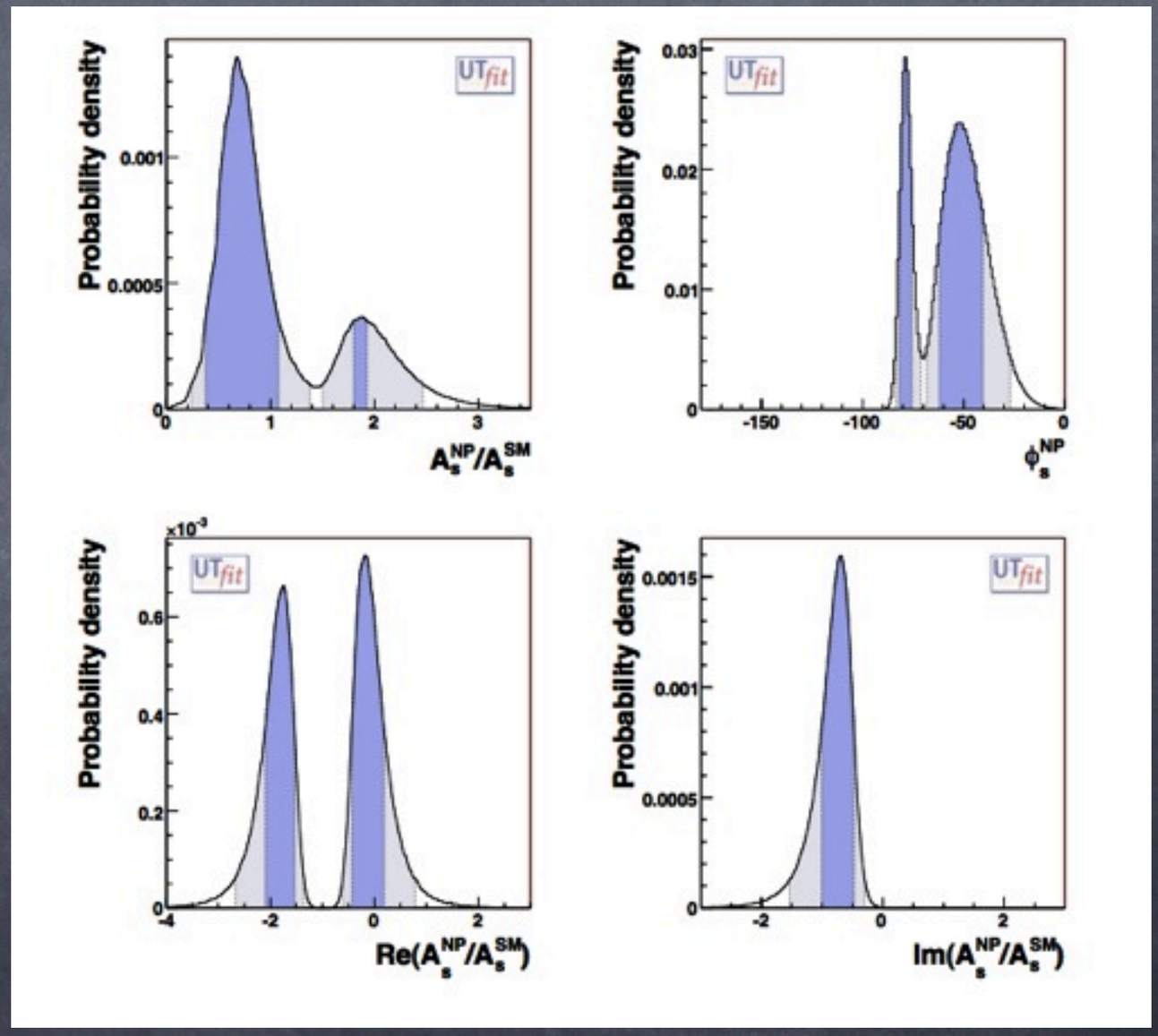
Heavy Flavor

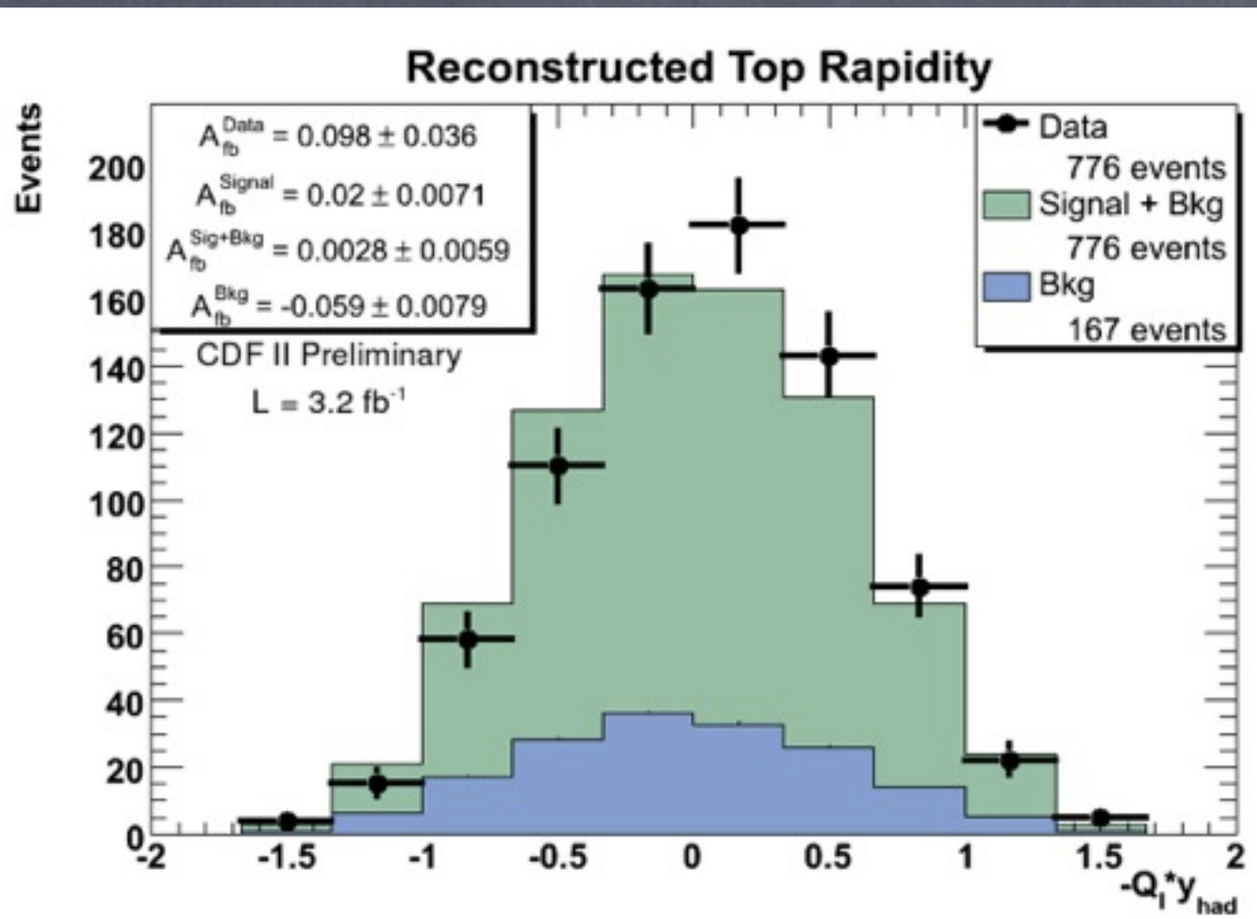
- Precision + a direct connection to the hierarachy problem

A global perspective

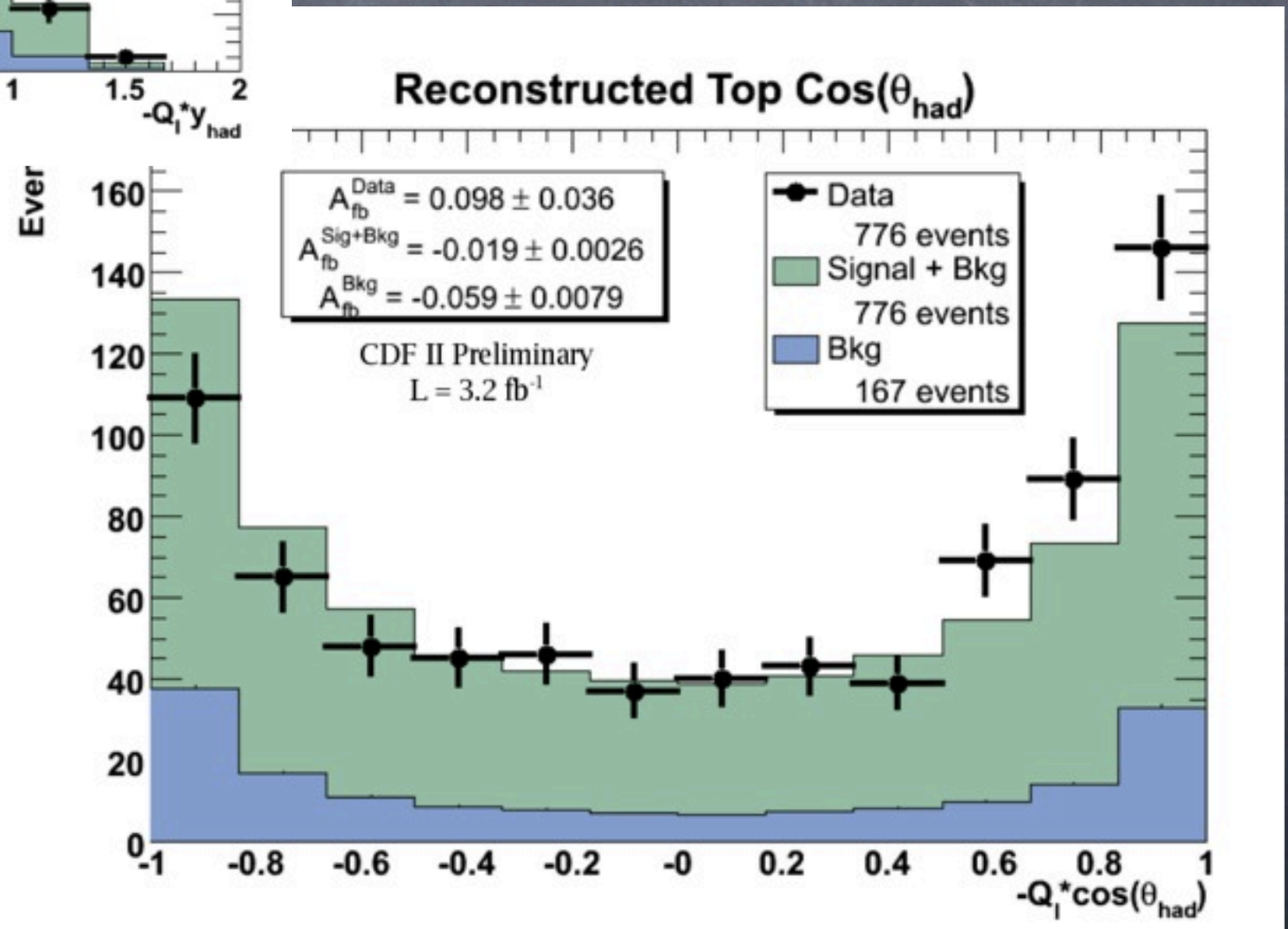
Observable	68% Prob.	95% Prob.
$\phi_{B_s}[^\circ]$	-19.9 ± 5.6	[-30.45,-9.29]
	-68.2 ± 4.9	[-78.45,-58.2]
C_{B_s}	1.07 ± 0.29	[0.62,1.93]
$\phi_s^{\rm NP}[^\circ]$	-51 ± 11	[-69,-27]
	-79 ± 3	[-84,-71]
$A_s^{\rm NP}/A_s^{\rm SM}$	0.73 ± 0.35	[0.24,1.38]
	1.87 ± 0.06	[1.50,2.47]
Im $A_s^{\rm NP}/A_s^{\rm SM}$	-0.74 ± 0.26	[-1.54,-0.30]
Re $A_s^{\rm NP}/A_s^{\rm SM}$	-0.13 ± 0.31	[-0.61,0.78]
	-1.82 ± 0.28	[-2.68,-1.36]
$A_{\rm SL}^s \times 10^2$	-0.34 ± 0.21	[-0.75,0.03]
$A_{\rm SL}^{\mu\mu} \times 10^3$	-2.1 ± 1.0	[-4.7,-0.3]
$\Delta\Gamma_s/\Gamma_s$	0.105 ± 0.049	[0.02,0.20]
	-0.098 ± 0.044	[-0.19,-0.02]

More than just MFV





Funny Tops



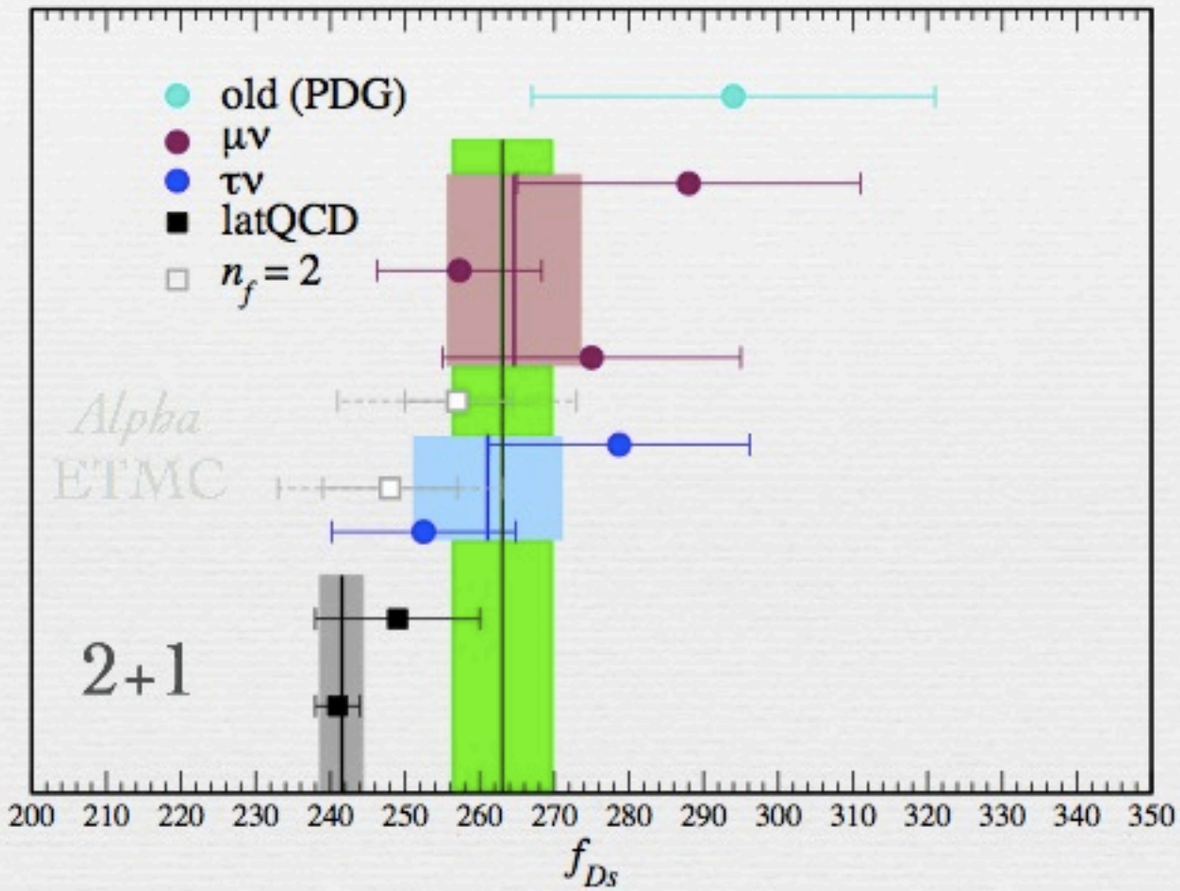
- Unfold method through p19:

$$A_{fb} = 19.3 \pm 6.5 \pm 2.4\%$$

- Flavor off diagonal 160 GeV Z'? (Jung, Murayama, Pierce, Wells)
- Color sextet or triplet (Shu, Tait, Wang)

Funny Charms?

With CLEO's papers of January 12, 2009



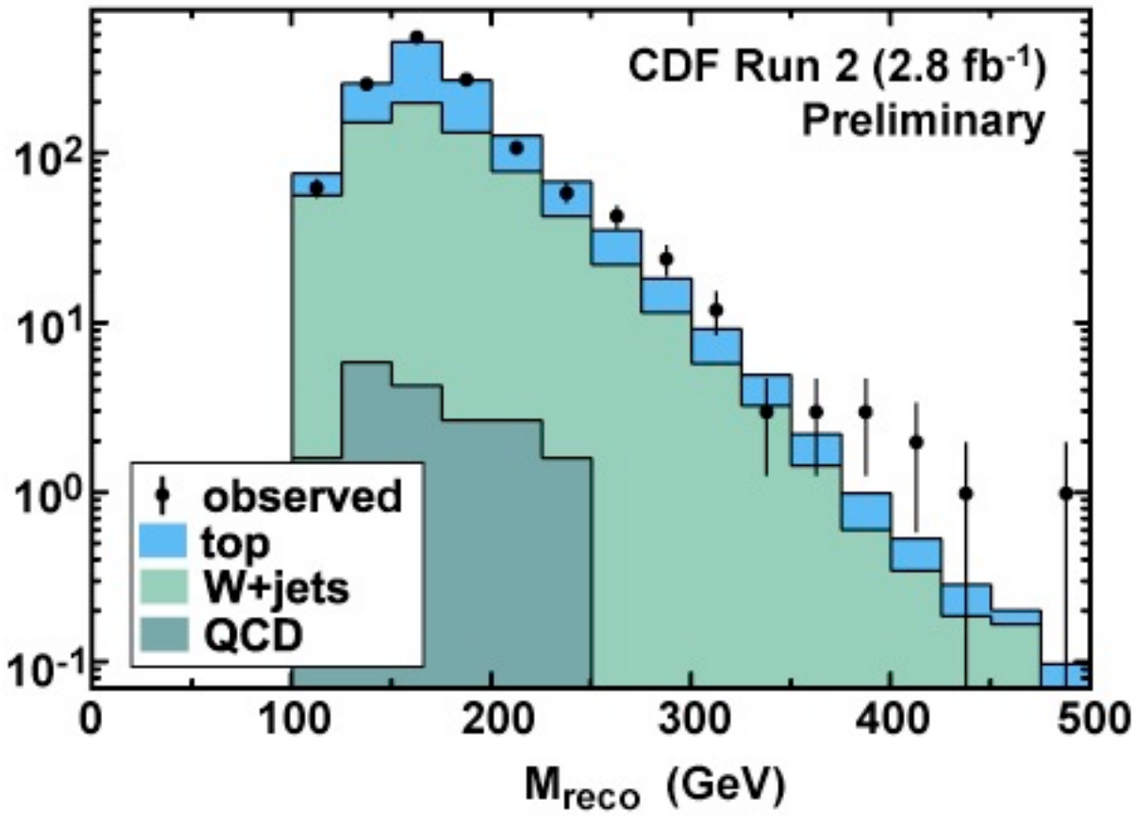
$\chi^2/\text{dof} = 0.73$

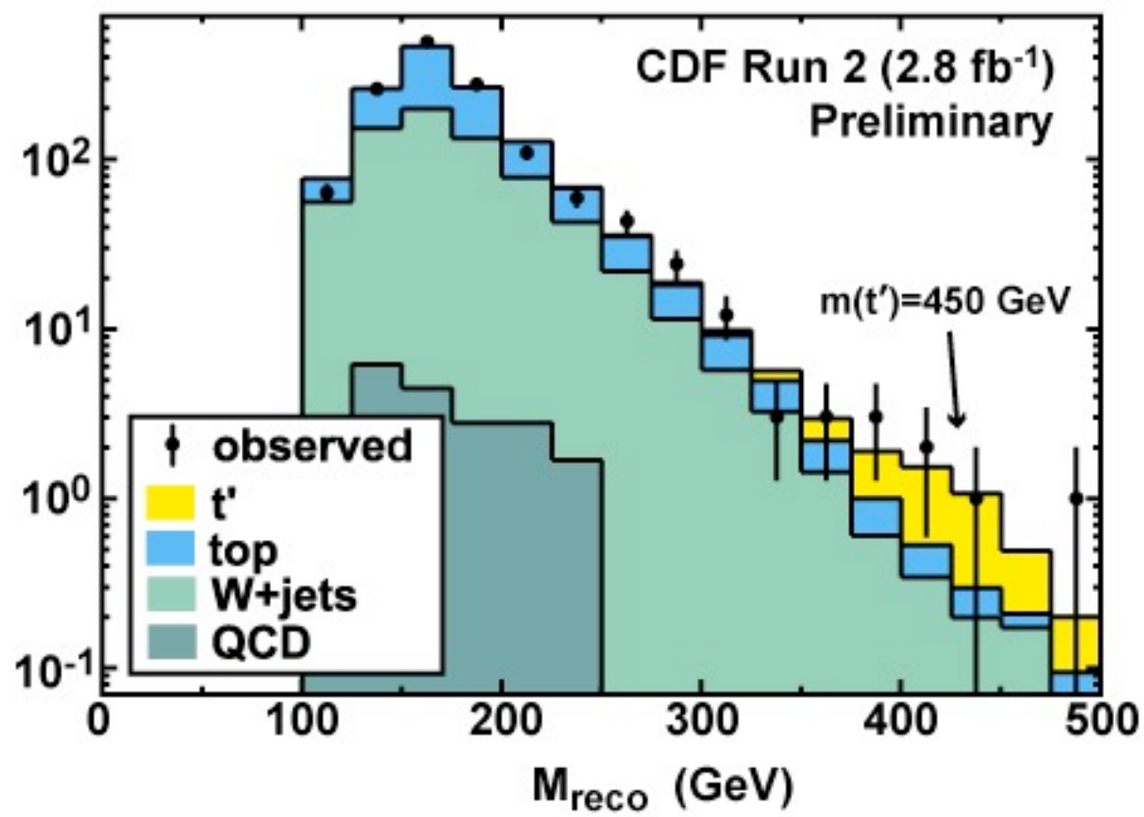
BaBar
CLEO
Belle
CLEO $\pi\nu$
CLEO $e\nu\nu$
Fermilab/MILC
HPQCD

a 3.0σ discrepancy, or $2.5\sigma \oplus 1.9\sigma$.

Leptoquarks? Higgs that couples to c,u, leptons?

New Tops?


CDF Run 2 (2.8 fb-1)
Preliminary
observed
top
W+jets
QCD
Mreco (GeV)

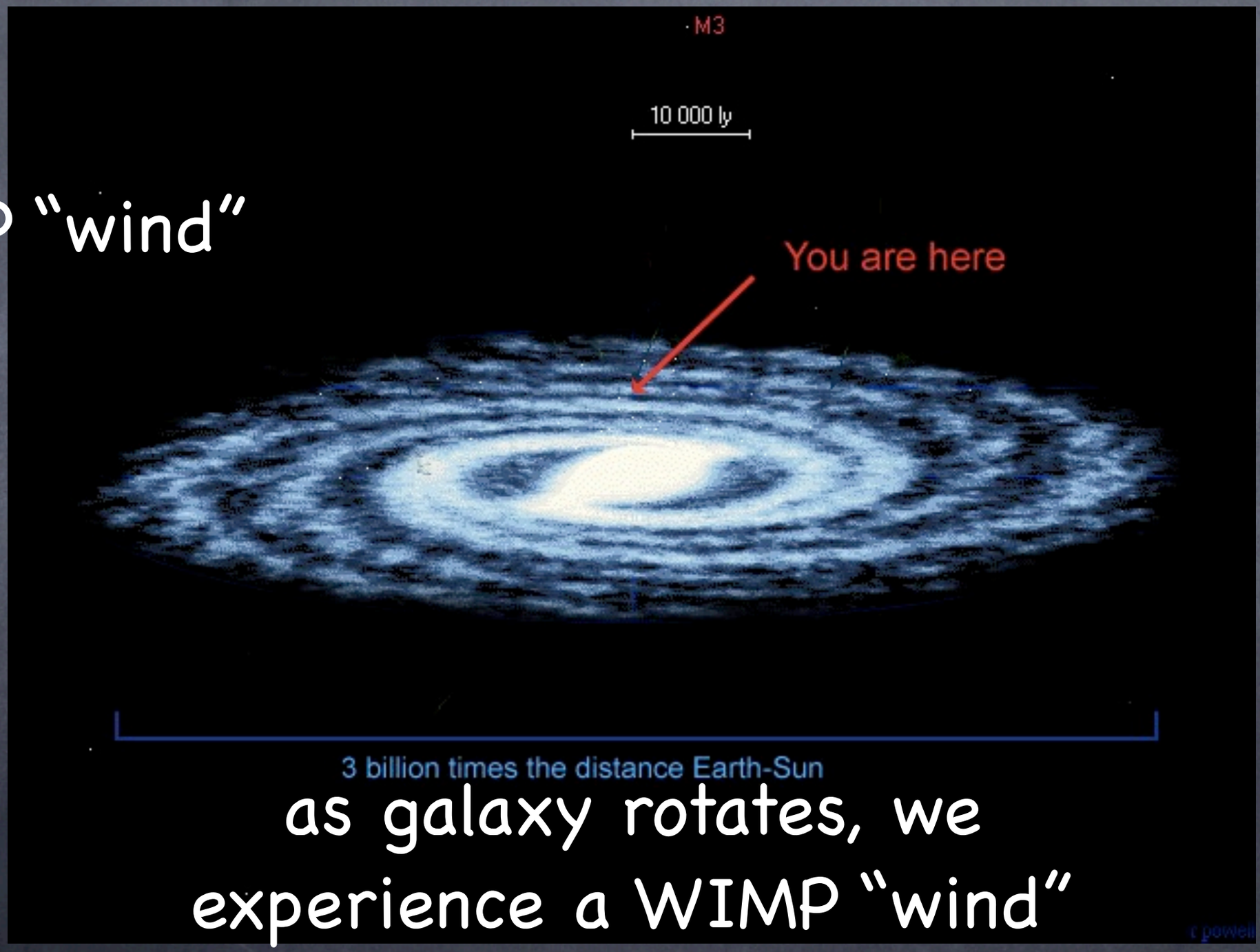

CDF Run 2 (2.8 fb-1)
Preliminary
m(t')=450 GeV
observed
t'
top
W+jets
QCD
Mreco (GeV)

Maybe Particle Physics is too Messy

- Need a clean, controlled environment to see anomalies

seasonal variation

WIMP "wind"



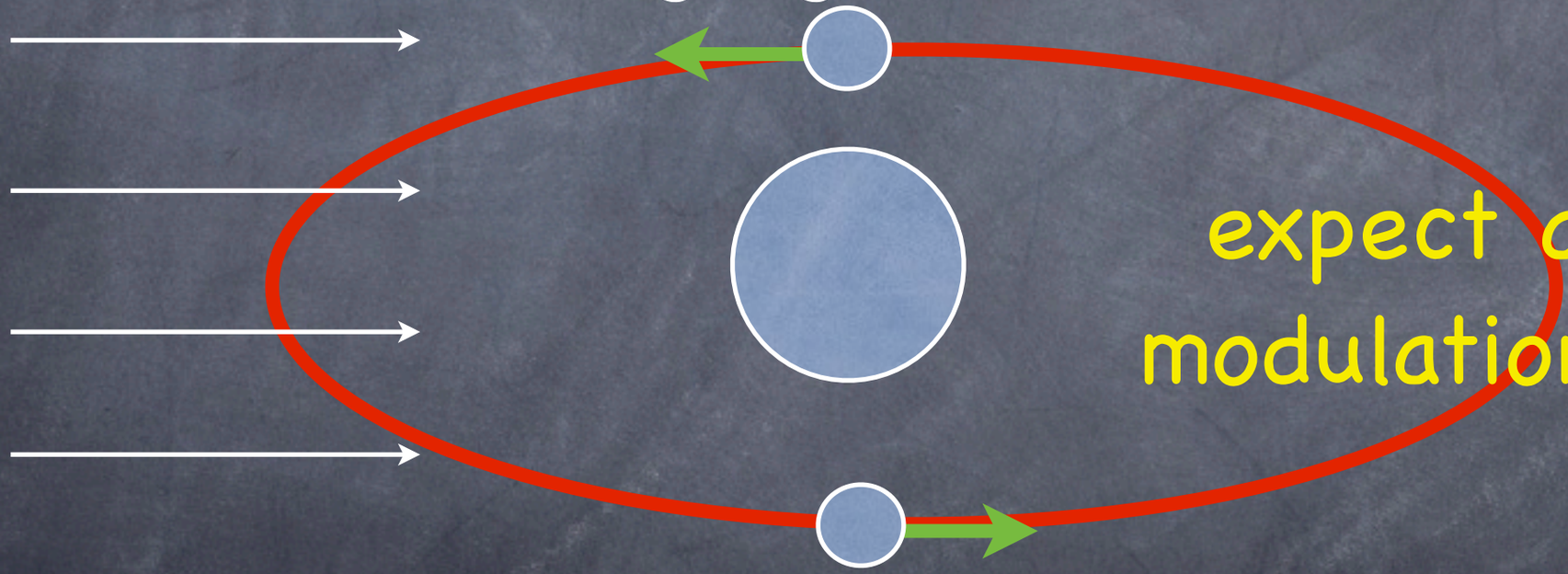
as galaxy rotates, we experience a WIMP "wind"

Drukier, Freese, Spergel Phys.Rev.D33:3495-3508,1986

seasonal variation

in the summer,
moving against wind

WIMP "wind"

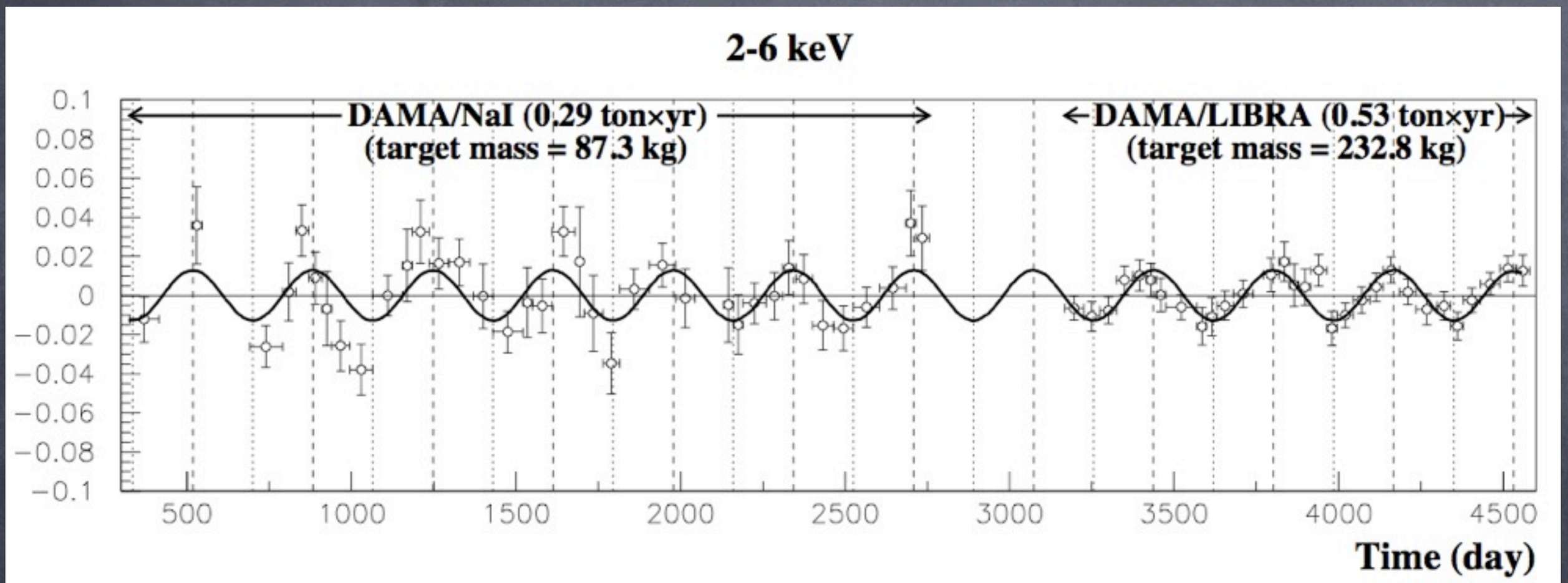


expect an annual modulation in signal!

in the winter,
moving against wind

Drukier, Freese, Spergel Phys.Rev.D33:3495-3508,1986

DAMA experiment

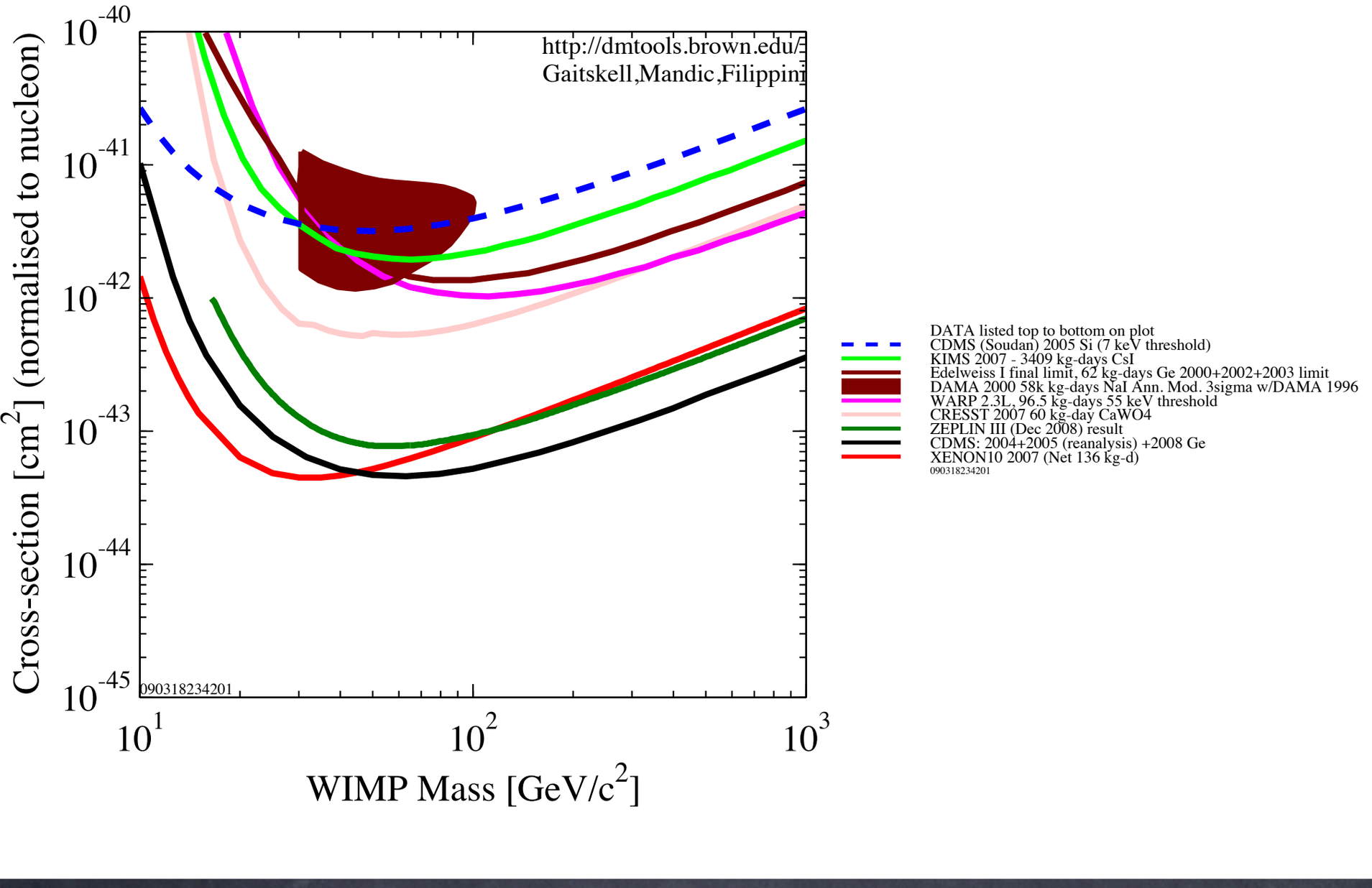


Bernabei et al., Eur.Phys.J.C56:333-355,2008

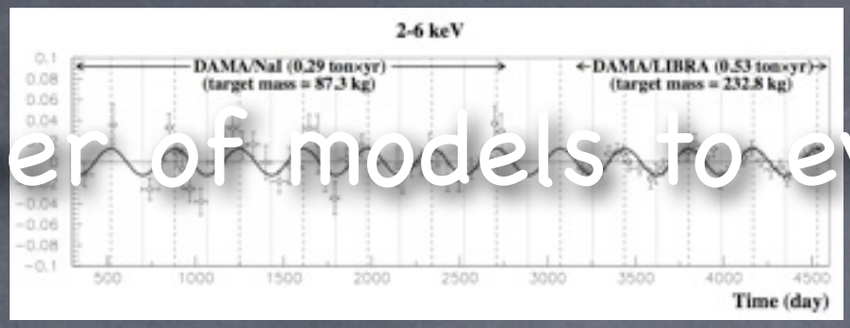
- 8.3 sigma signal for modulation
- only in "single hit" events
- proper phase
- only in low energy bins

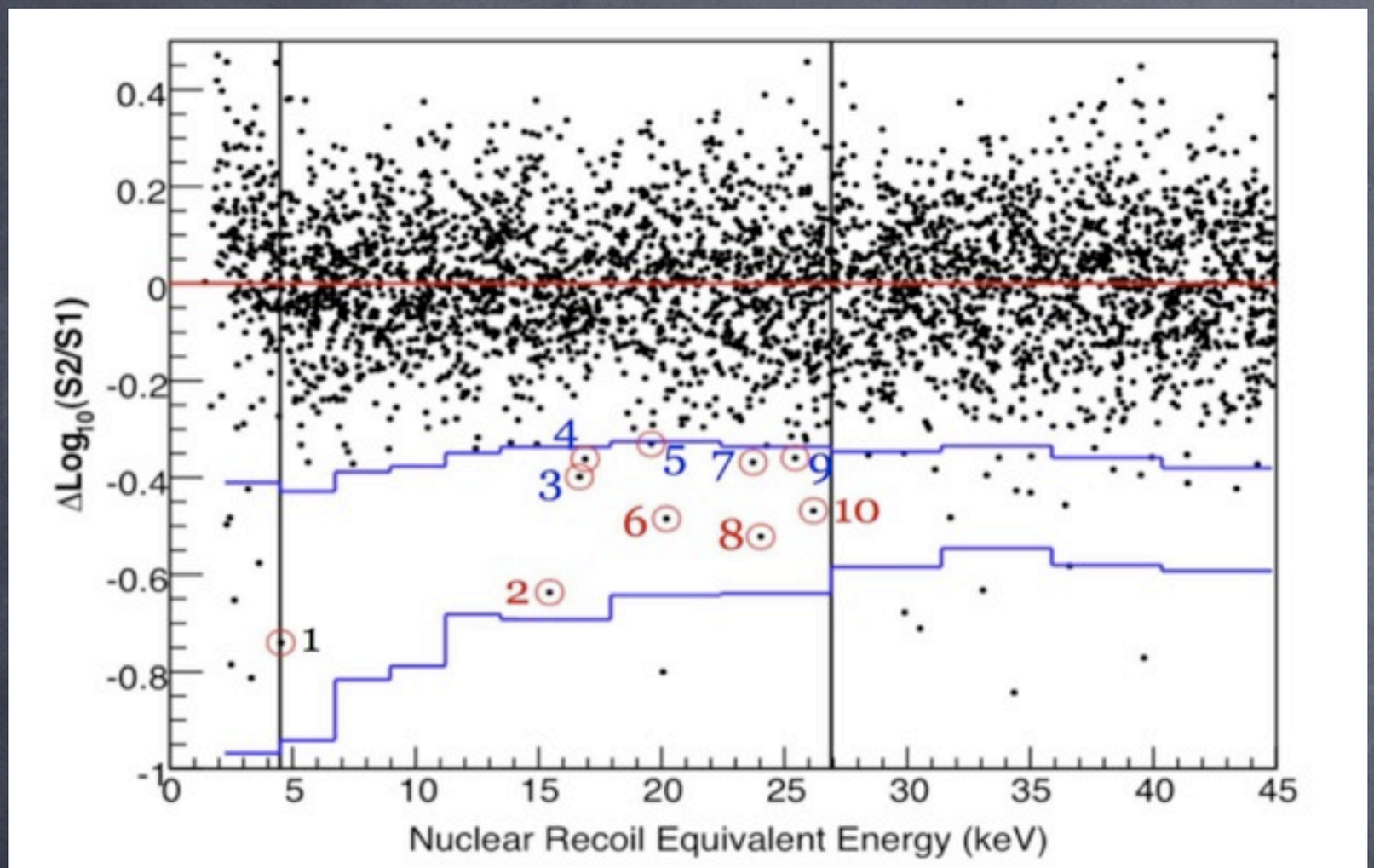
Dark matter?

Small problem...

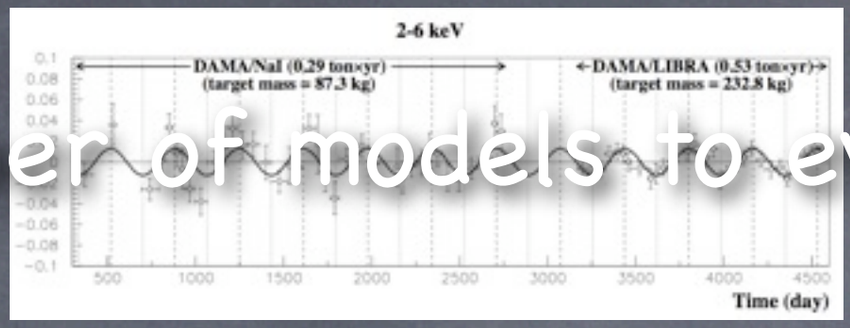


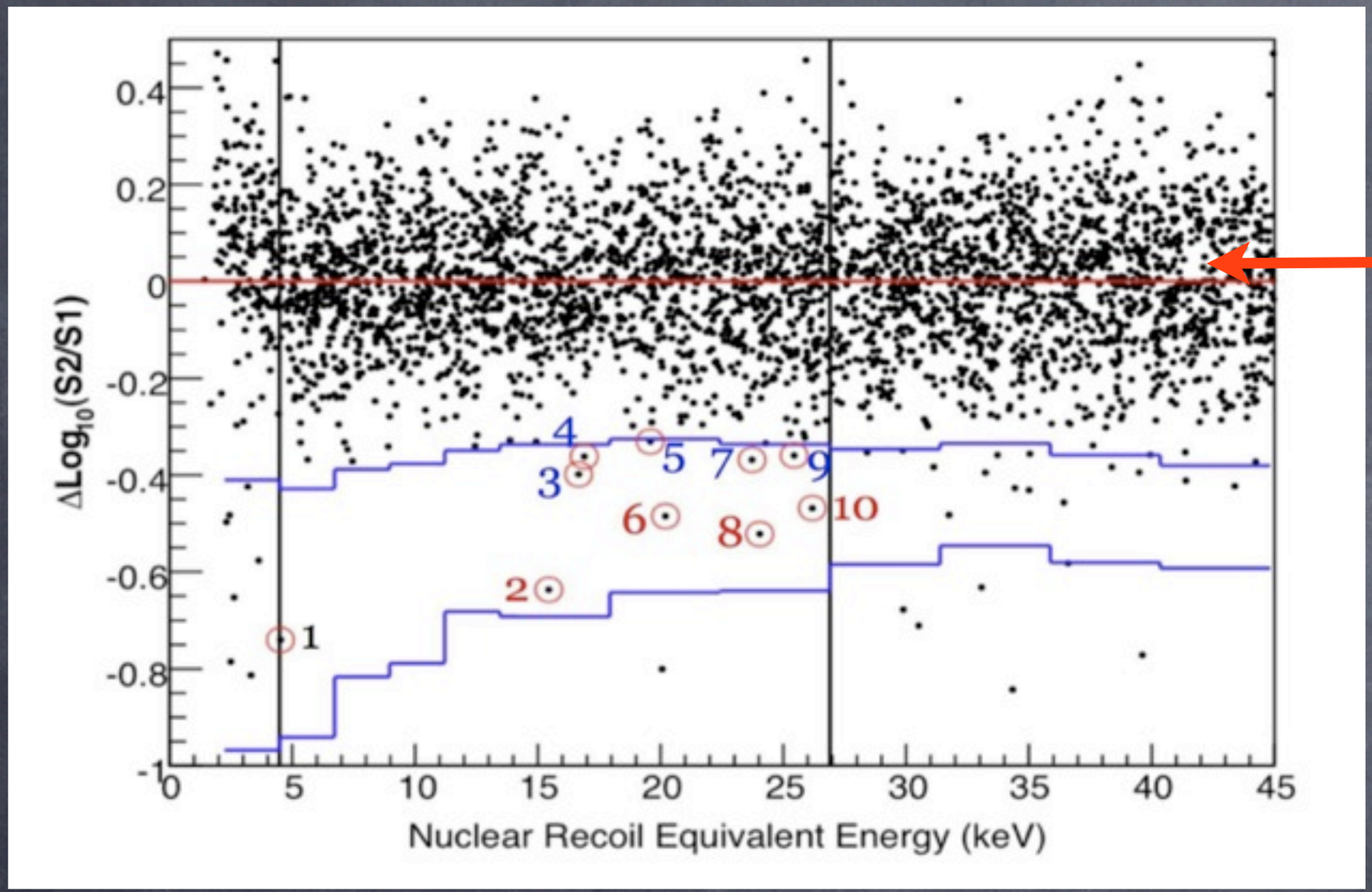
Increasing number of models to evade other limits





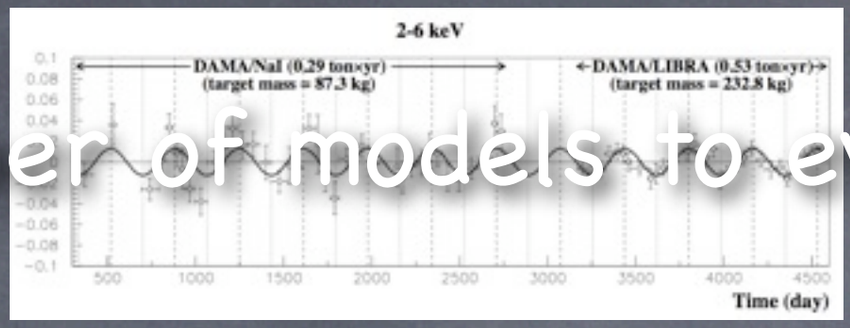
Increasing number of models to evade other limits

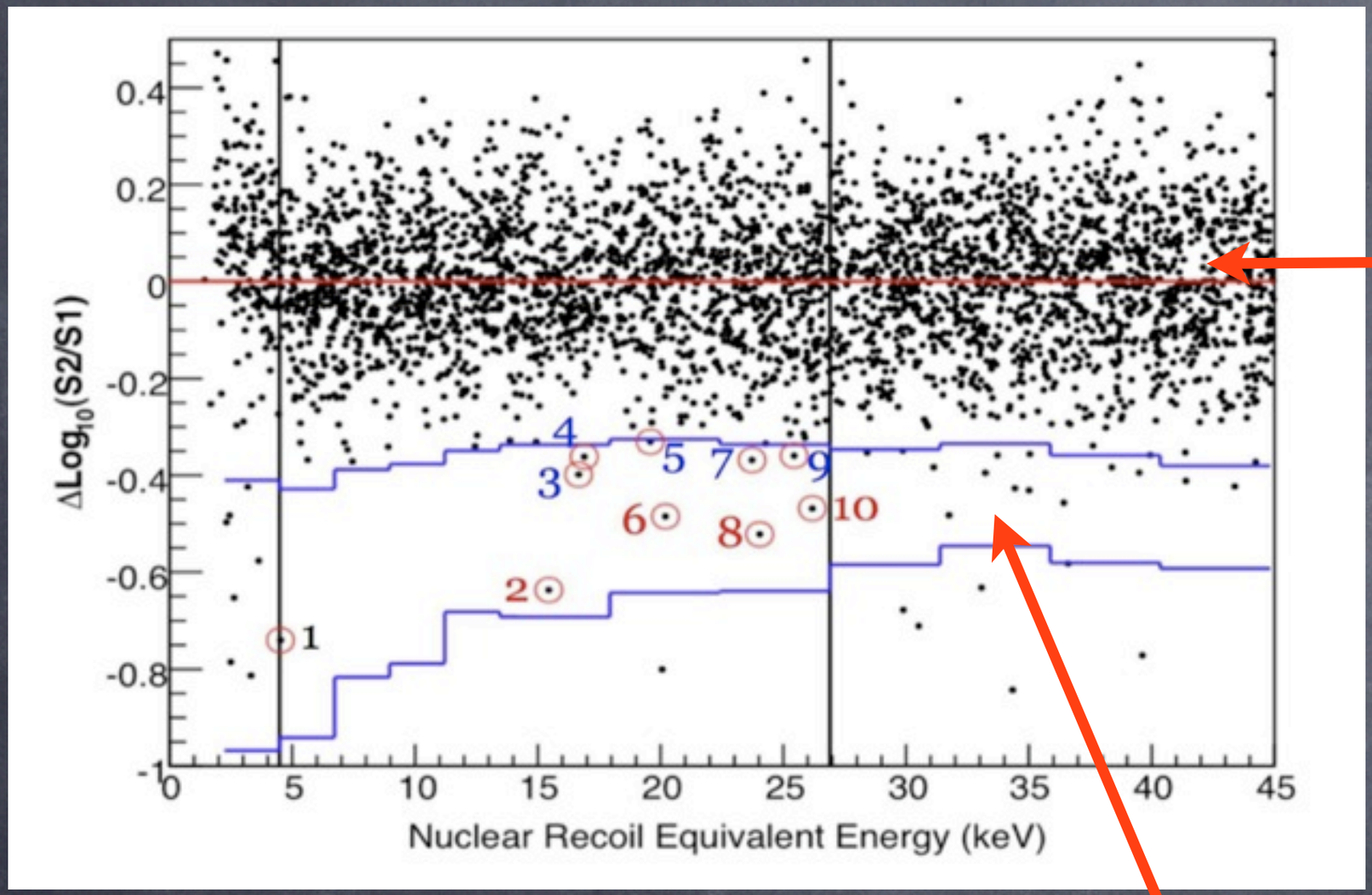




move your signal here (electron scattering DM)

Increasing number of models to evade other limits

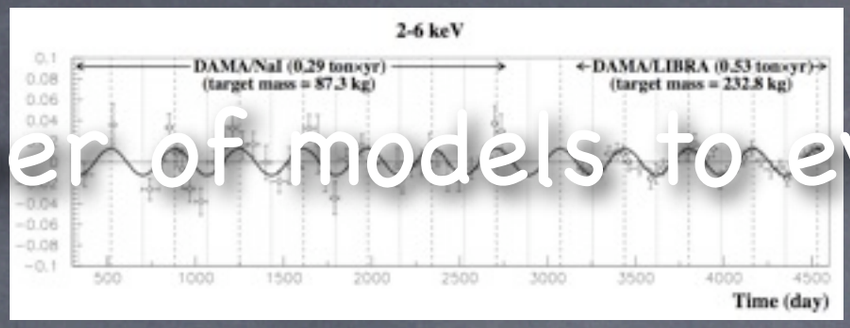


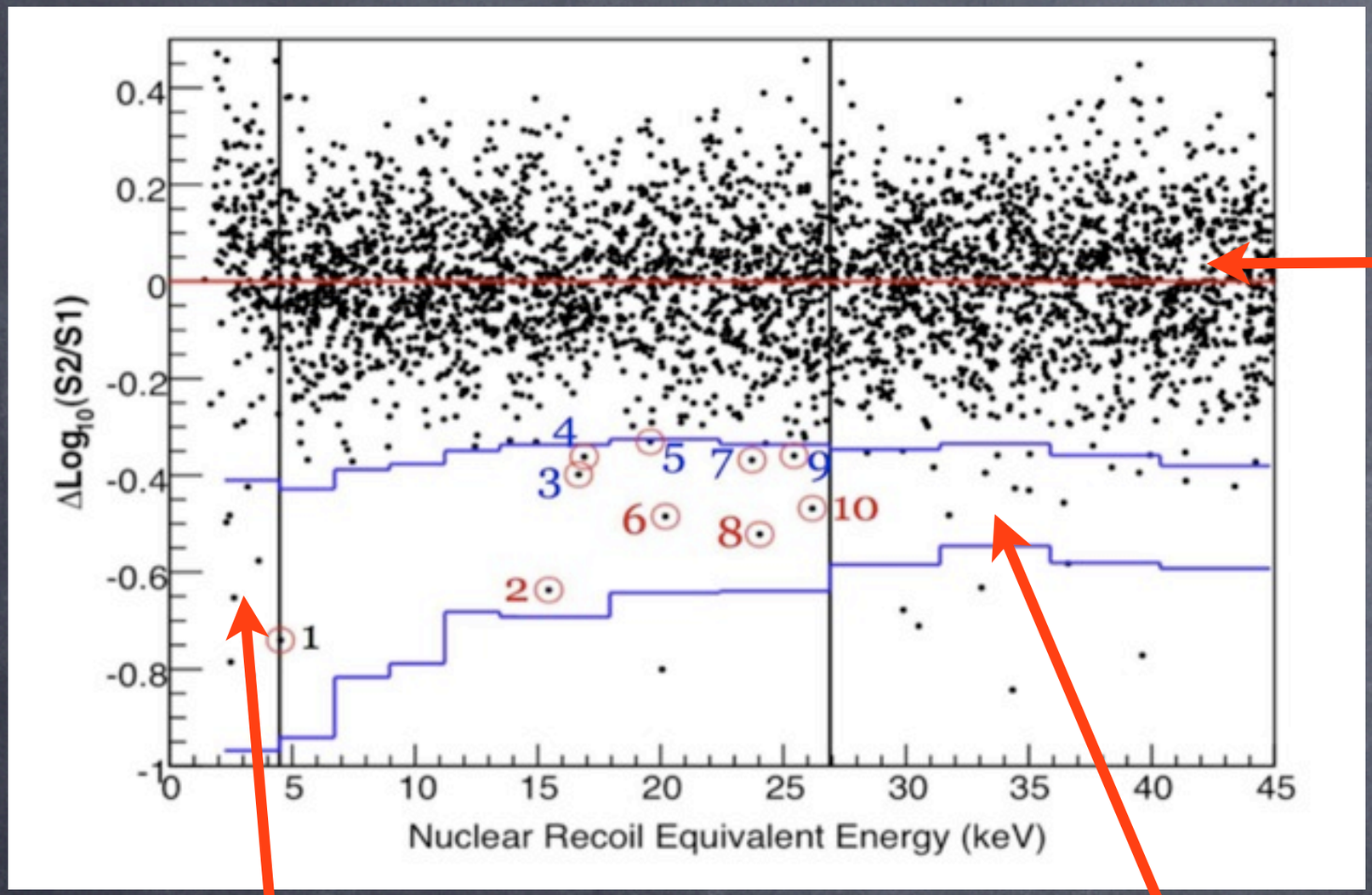


move your signal here (electron scattering DM)

move your signal here (inelastic DM, q^2 dependent scatterings)

Increasing number of models to evade other limits



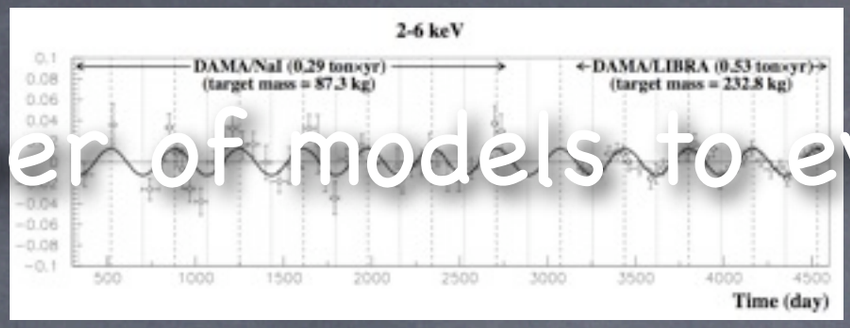


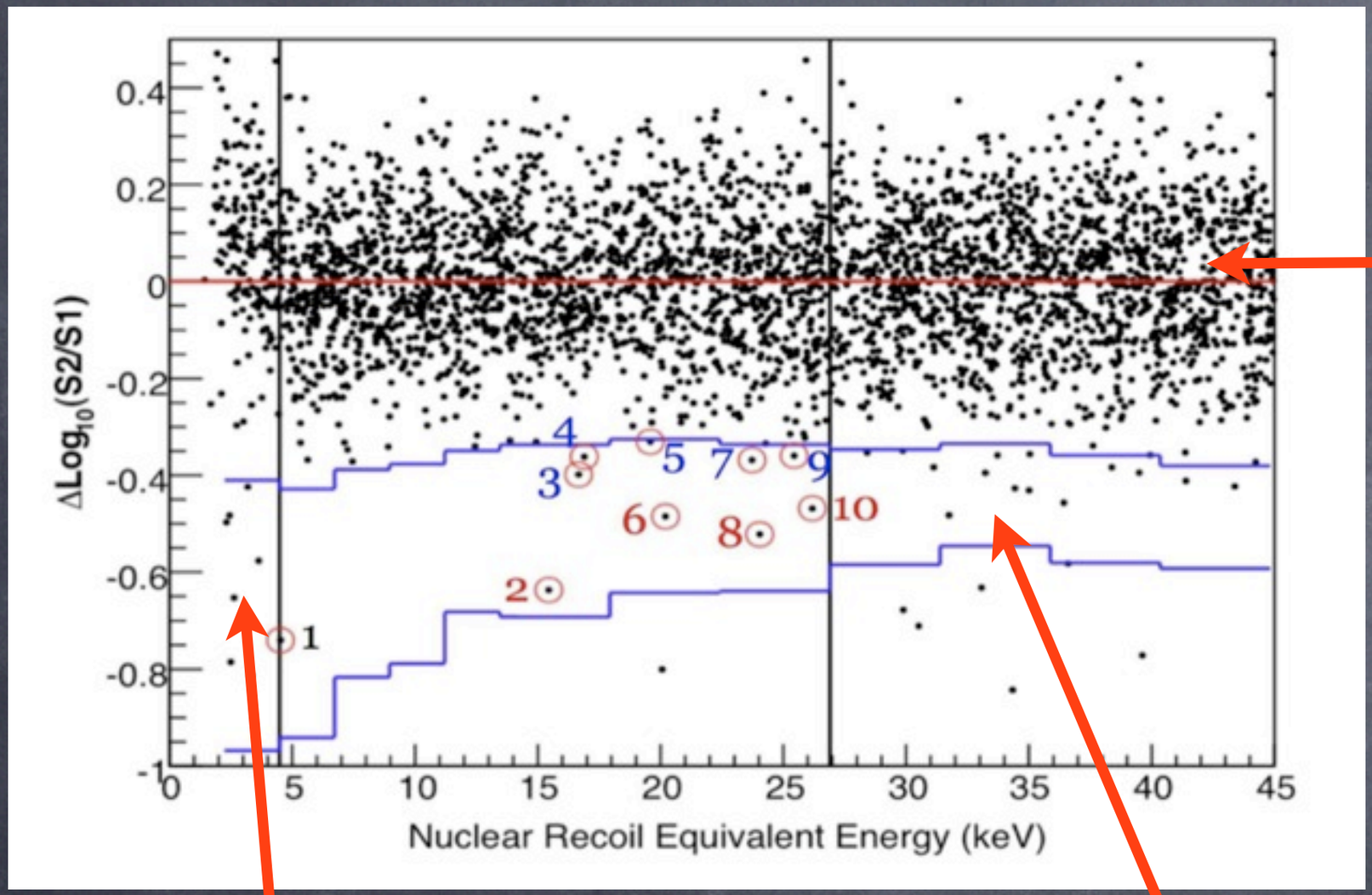
move your signal here (electron scattering DM)

move your signal here (light DM)

move your signal here (inelastic DM, q^2 dependent scatterings)

Increasing number of models to evade other limits





move your signal here (electron scattering DM)

move your signal here (light DM)

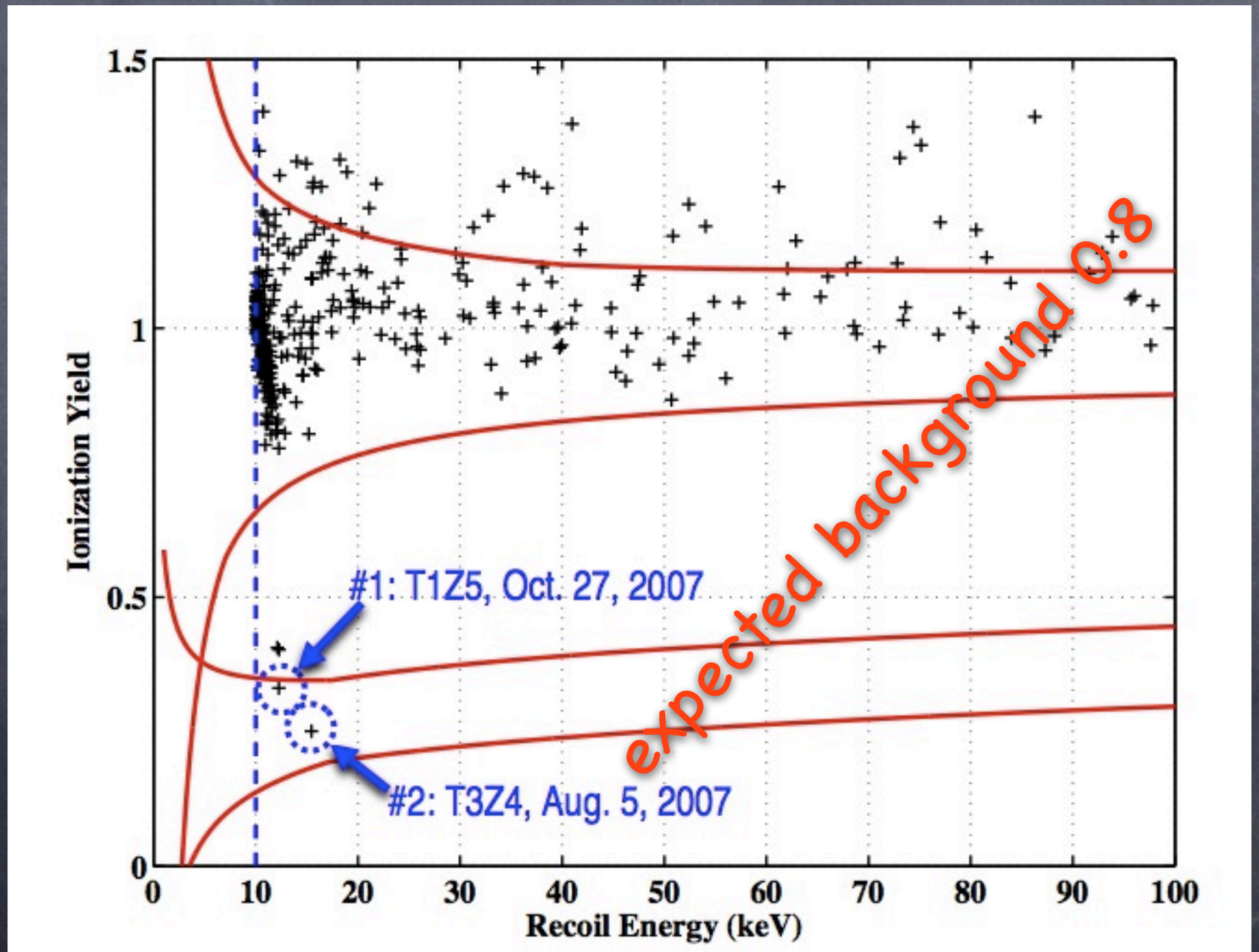
move your signal here (inelastic DM, q^2 dependent scatterings)

move your signal off this plot (resonant scattering)

CDMS

Results from the Final Exposure of the CDMS II Experiment

Z. Ahmed,[19] D.S. Akerib,[2] S. Arrenberg,[18] C.N. Bailey,[2] D. Balakishiyeva,[16] L. Baudis,[18] D.A. Bauer,[3] P.L. Brink,[10] T. Bruch,[18] R. Bunker,[14] B. Cabrera,[10] D.O. Caldwell,[14] J. Cooley,[9] P. Cushman,[17] M. Daal,[13] F. DeJongh,[3] M.R. Dragowsky,[2] L. Duong,[17] S. Fallows,[17] E. Figueroa-Feliciano,[5] J. Filippini,[19] M. Fritts,[17] S.R. Golwala,[19] D.R. Grant,[2] J. Hall,[3] R. Hennings-Yeomans,[2] S.A. Hertel,[5] D. Holmgren,[3] L. Hsu,[3] M.E. Huber,[15] O. Kamaev,[17] M. Kiveni,[11] M. Kos,[11] S.W. Leman,[5] R. Mahapatra,[12] V. Mandic,[17] K.A. McCarthy,[5] N. Mirabolfathi,[13] D. Moore,[19] H. Nelson,[14] R.W. Ogburn,[10] A. Phipps,[13] M. Pyle,[10] X. Qiu,[17] E. Ramberg,[3] W. Rau,[6] A. Reisetter,[17,7] T. Saab,[16] B. Sadoulet,[4,13] J. Sander,[14] R.W. Schnee,[11] D.N. Seitz,[13] B. Serfass,[13] K.M. Sundqvist,[13] M. Tarka,[18] P. Wikus,[5] S. Yellin,[10,14] J. Yoo,[3] B.A. Young,[8] and J. Zhang[17]
(CDMS Collaboration)



Still... a lot of interest

SPIRES

HEP :: HEPNAMES :: INSTITUTIONS :: CONFERENCES :: EXPERIMENTS :: JOBS :: VIDEOS

FIND C ARXIV:0912.3592

Paper **1** to **26** of **26**

Browse Author | Format: Standard (incl. cites) | Sort: No Sort (fastest)

Display again

• • •

9) **CDMS II Inspired Neutralino Dark Matter in Flipped SU(5).**
Ilia Gogoladze, Rizwan Khalid, Shabbar Raza, Qaisar Shafi, . Dec 2009. Temporary entry
e-Print: **arXiv:0912.5411** [hep-ph]

References | LaTeX(US) | LaTeX(EU) | Harvmac | BibTeX | Keywords | Cited 1 time
Abstract and Postscript and PDF from arXiv.org (mirrors: au br cn de es fr il in it jp kr ru tw uk za aps lanl)
Bookmarkable link to this information

10) **The Simplest Dark-Matter Model, CDMS II Results, and Higgs Detection at LHC.**
Xiao-Gang He, Tong Li, Xue-Qian Li, Jusak Tandean, Ho-Chin Tsai, . Dec 2009. 9pp. Temporary entry
e-Print: **arXiv:0912.4722** [hep-ph]

References | LaTeX(US) | LaTeX(EU) | Harvmac | BibTeX | Keywords | Cited 3 times
Abstract and Postscript and PDF from arXiv.org (mirrors: au br cn de es fr il in it jp kr ru tw uk za aps lanl)
Bookmarkable link to this information

11) **Implications of CDMS II result on Higgs sector in the MSSM.**
Junji Hisano, Kazunori Nakayama, Masato Yamanaka, . Dec 2009. 5pp. Temporary entry
e-Print: **arXiv:0912.4701** [hep-ph]

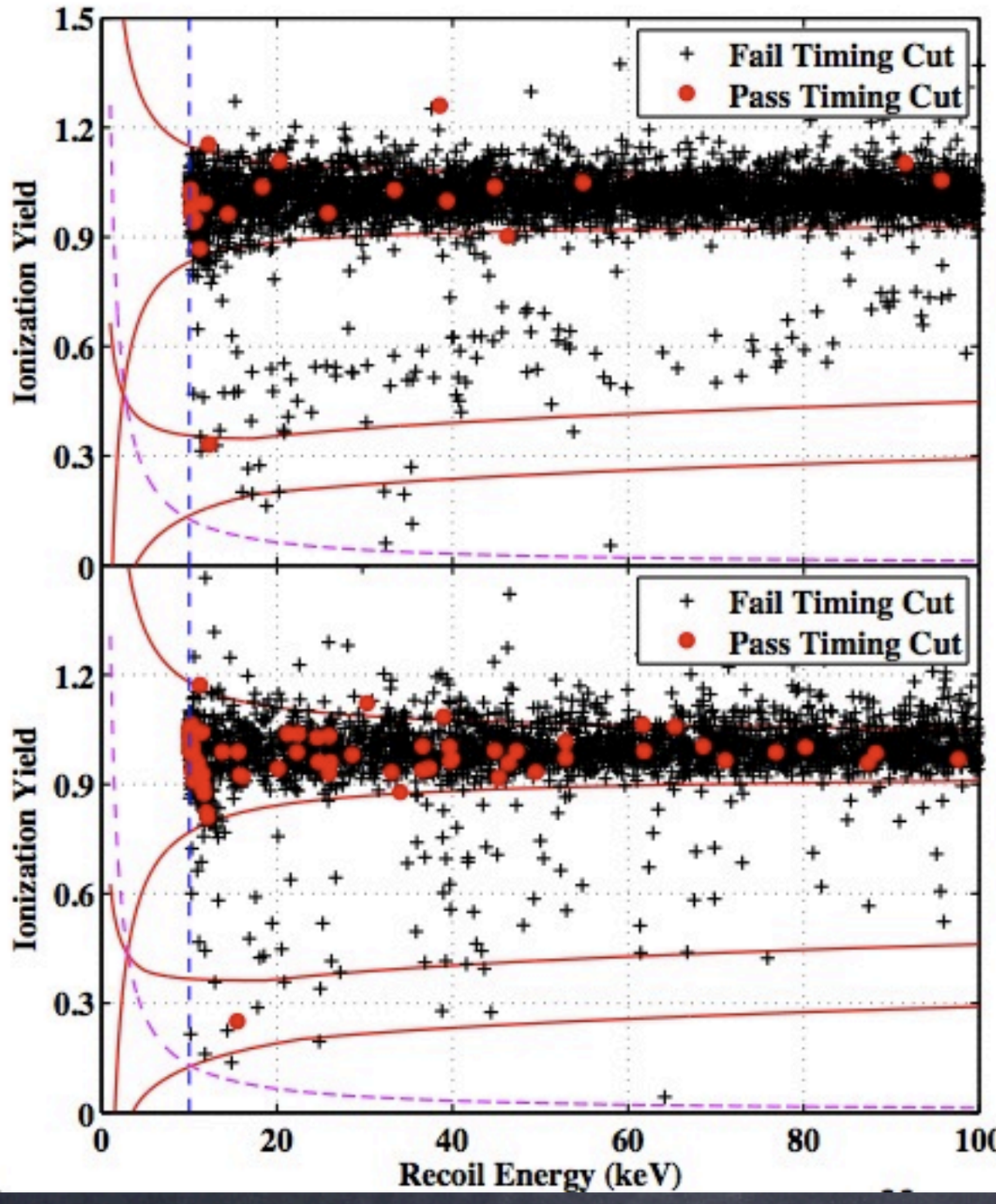
References | LaTeX(US) | LaTeX(EU) | Harvmac | BibTeX | Keywords | Cited 2 times
Abstract and Postscript and PDF from arXiv.org (mirrors: au br cn de es fr il in it jp kr ru tw uk za aps lanl)
Bookmarkable link to this information

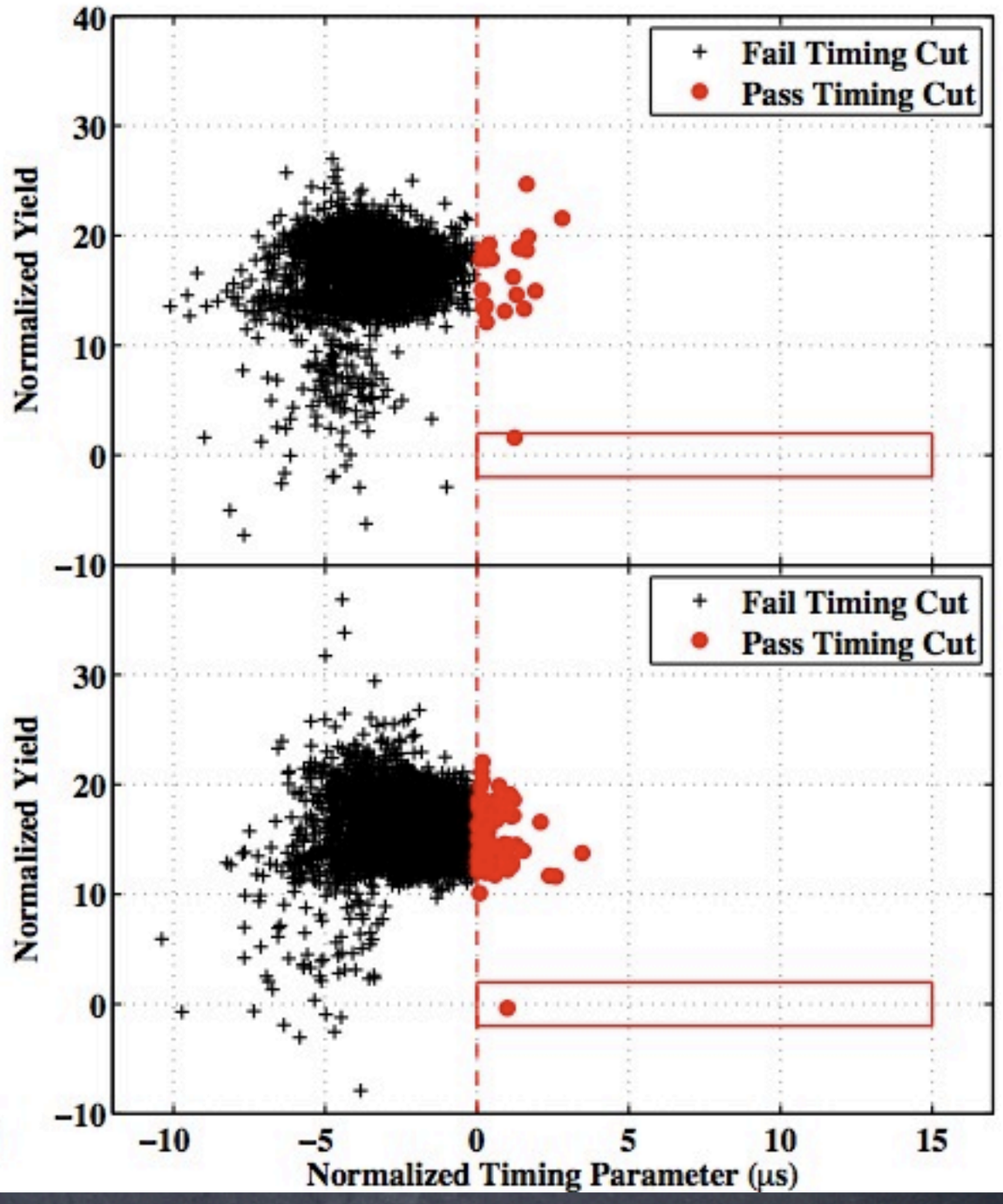
12) **Implication on Higgs invisible width in light of the new CDMS result.**
Kingman Cheung, Tzu-Chiang Yuan, . Dec 2009. 6pp. Temporary entry
e-Print: **arXiv:0912.4599** [hep-ph]

References | LaTeX(US) | LaTeX(EU) | Harvmac | BibTeX | Keywords | Cited 1 time
Abstract and Postscript and PDF from arXiv.org (mirrors: au br cn de es fr il in it jp kr ru tw uk za aps lanl)
Bookmarkable link to this information

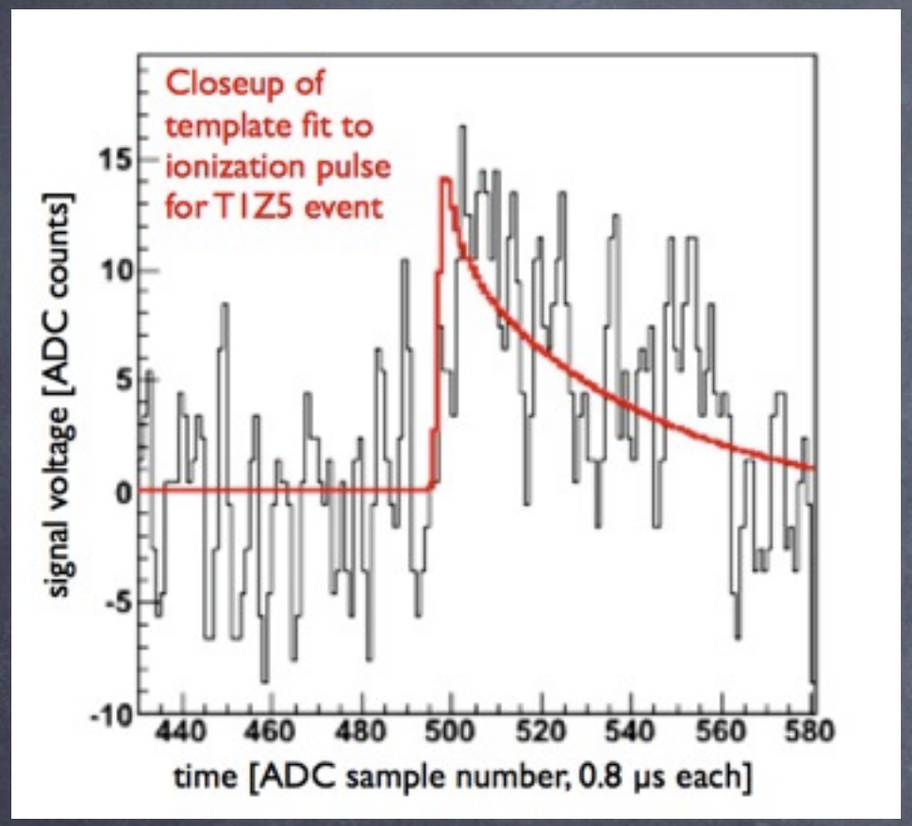
#1: T1Z5

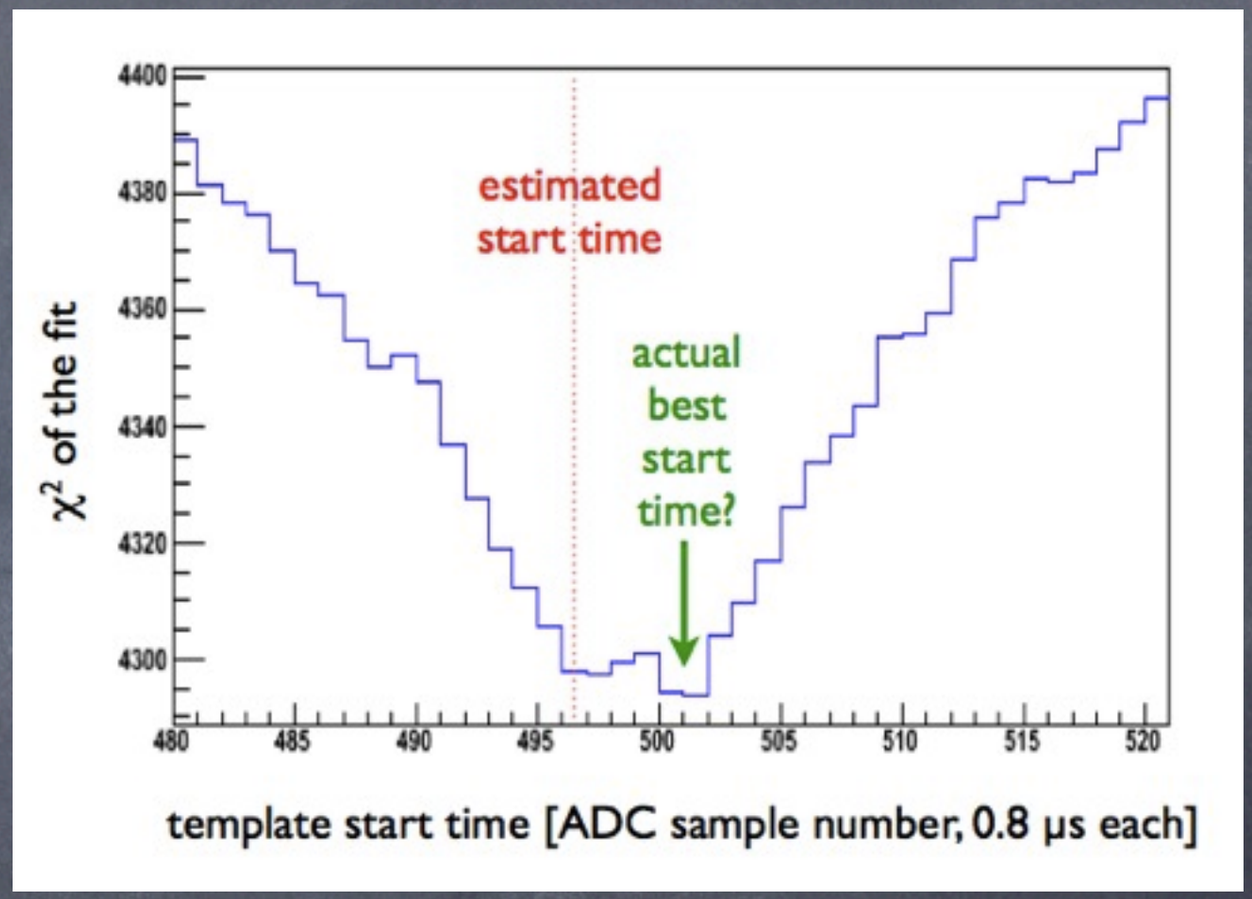
#2: T3Z4


Fail Timing Cut
Pass Timing Cut
Ionization Yield
Recoil Energy (keV)
0
20
40
60
80
100
0.3
0.6
0.9
1.2
1.5

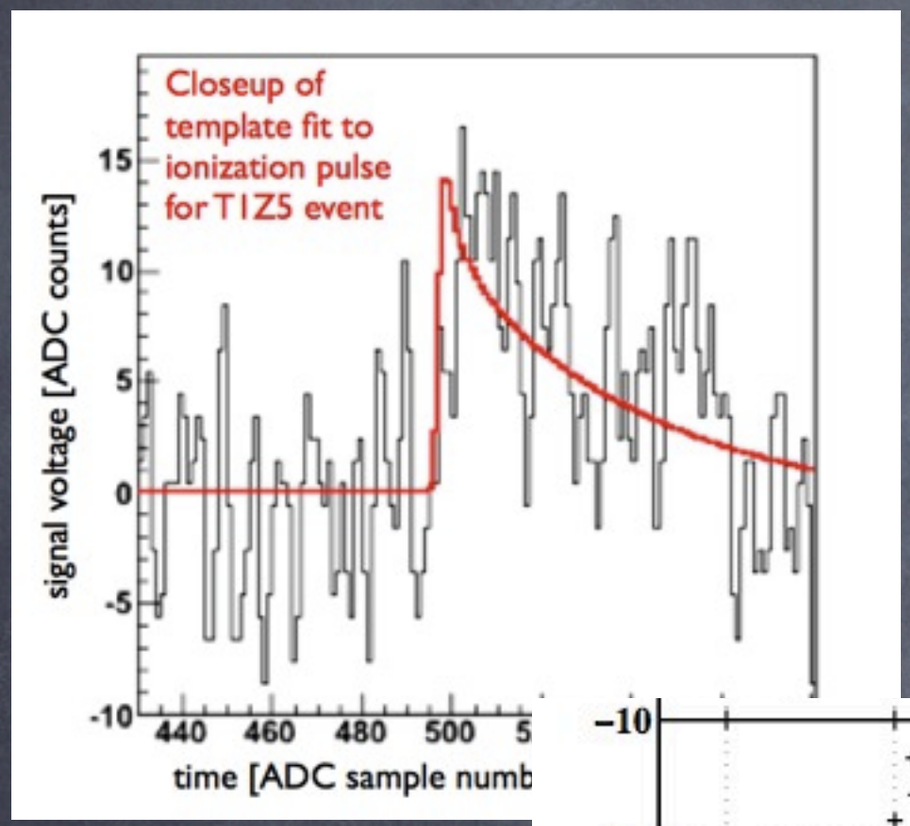

Fail Timing Cut
Pass Timing Cut
Normalized Yield
Normalized Timing Parameter (μs)
−10
−5
0
5
10
15
20
30
40

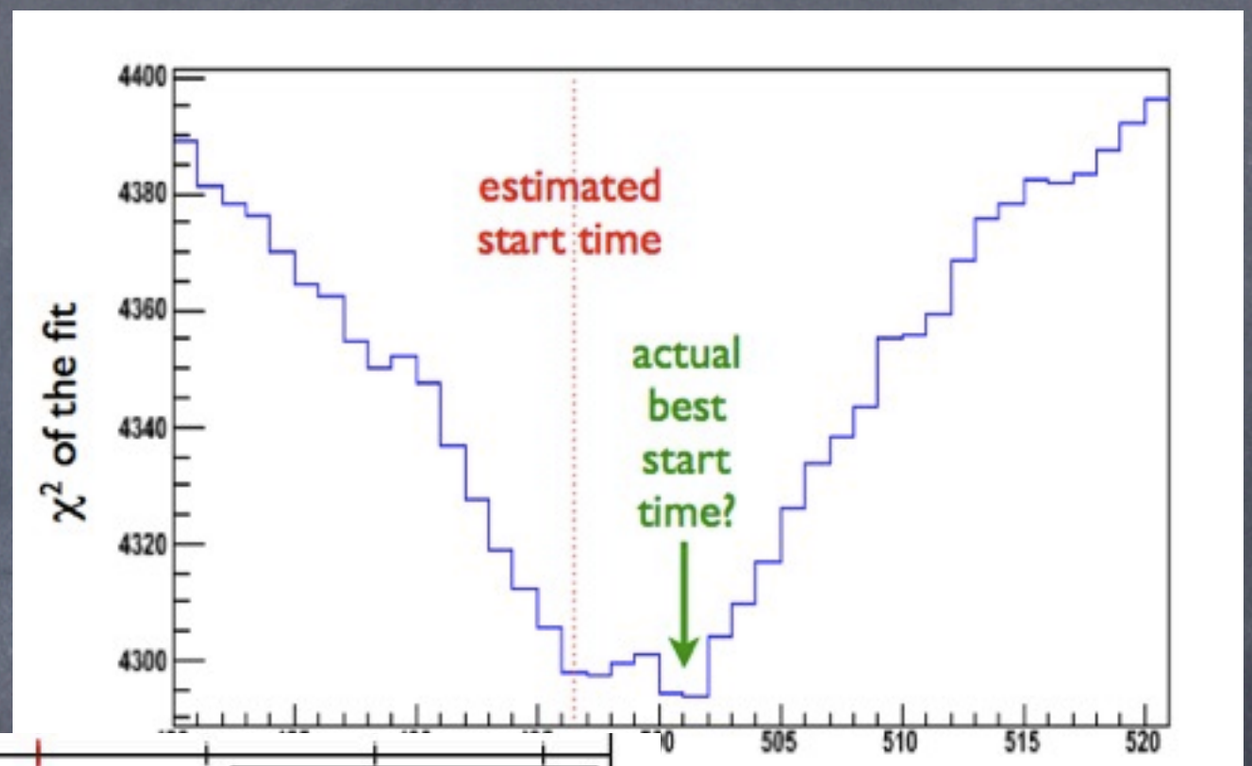
So what about that other event?

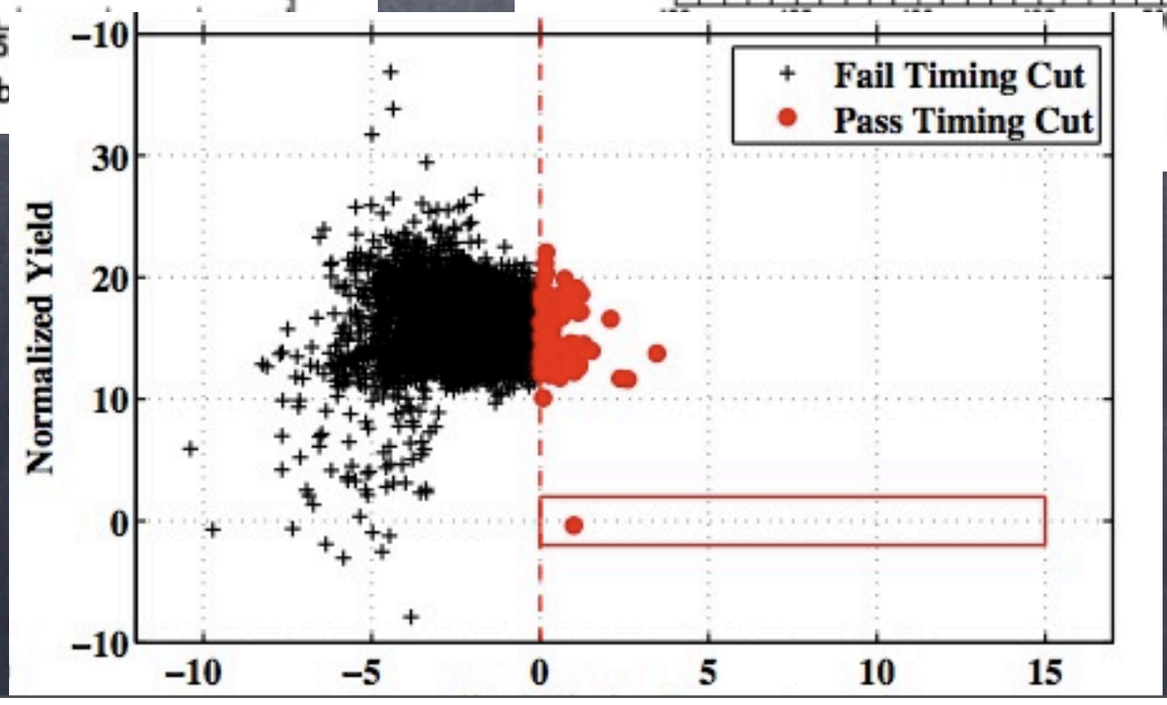




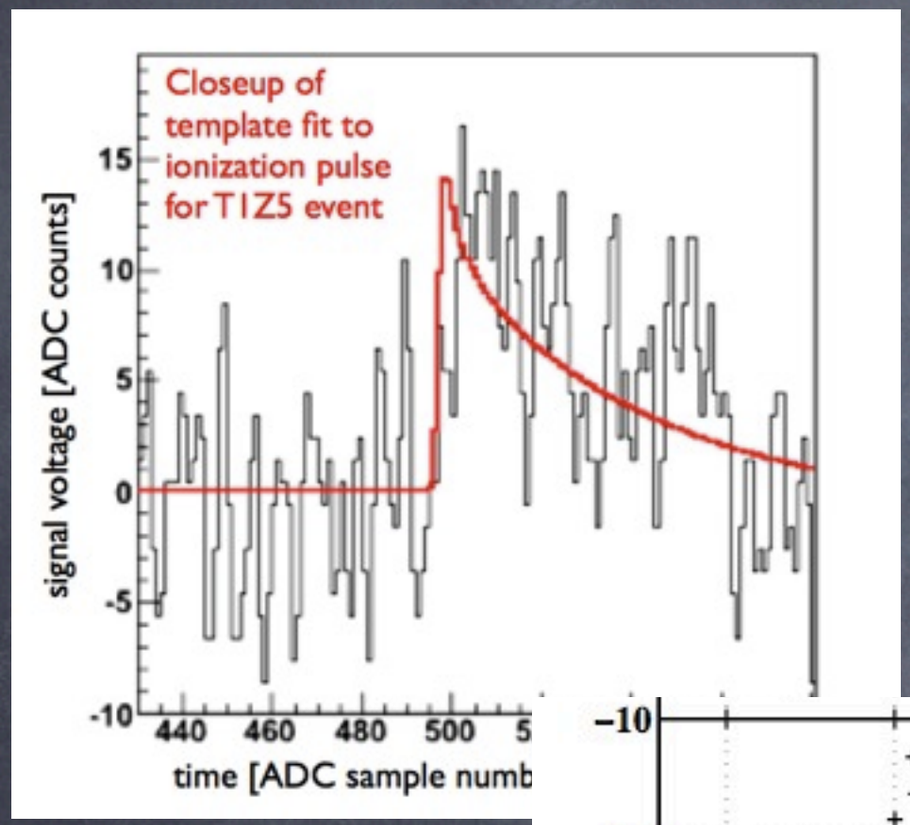
So what about that other event?

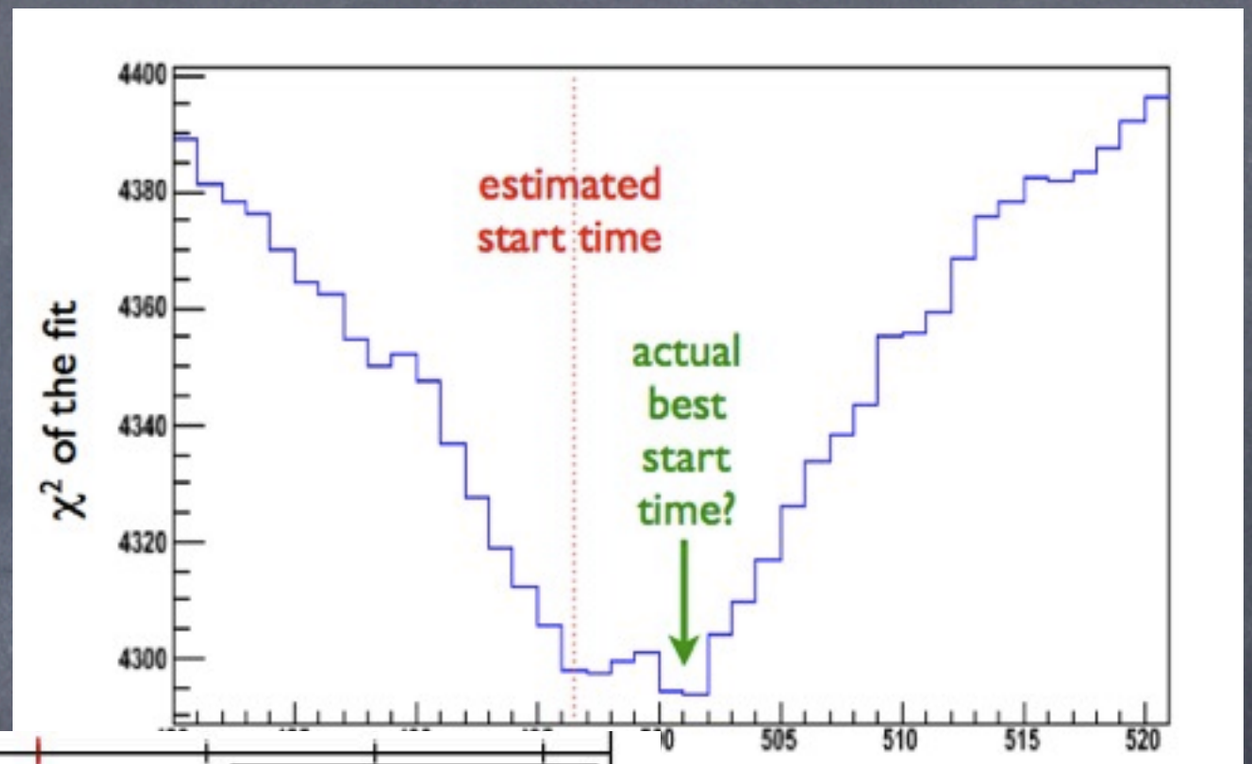


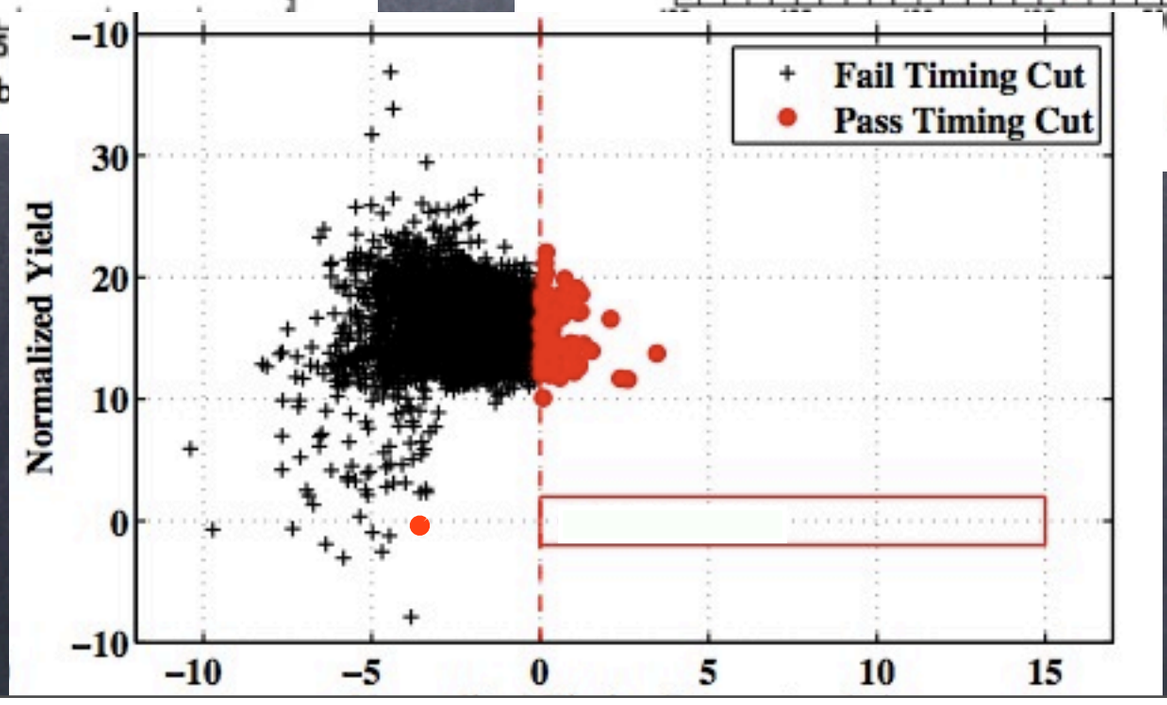




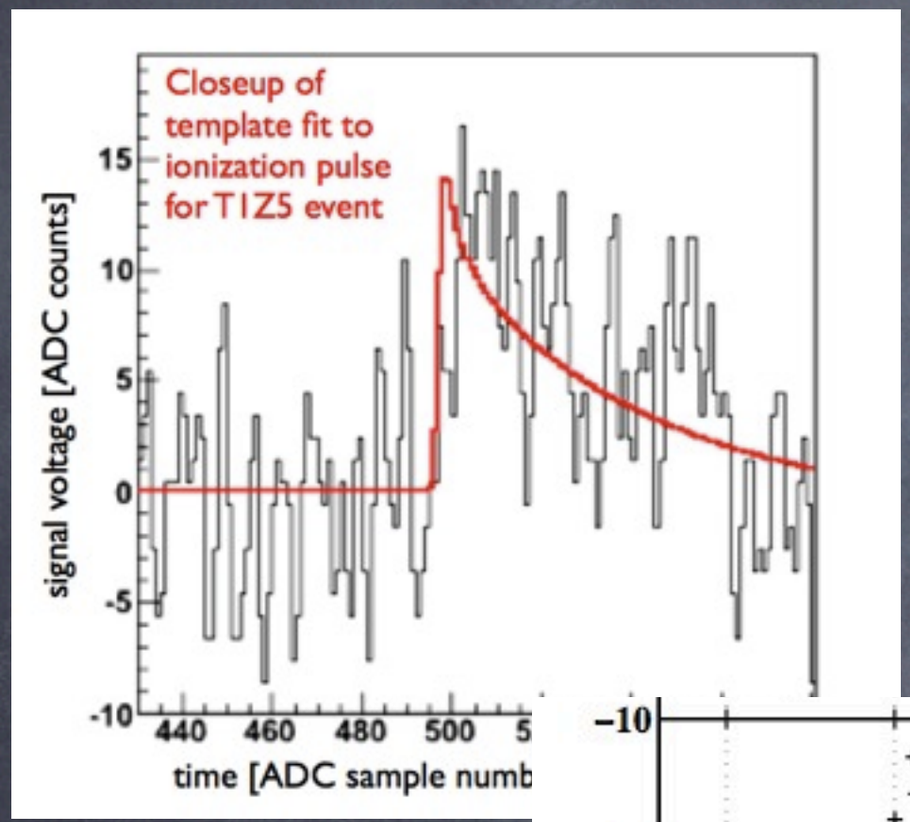
So what about that other event?

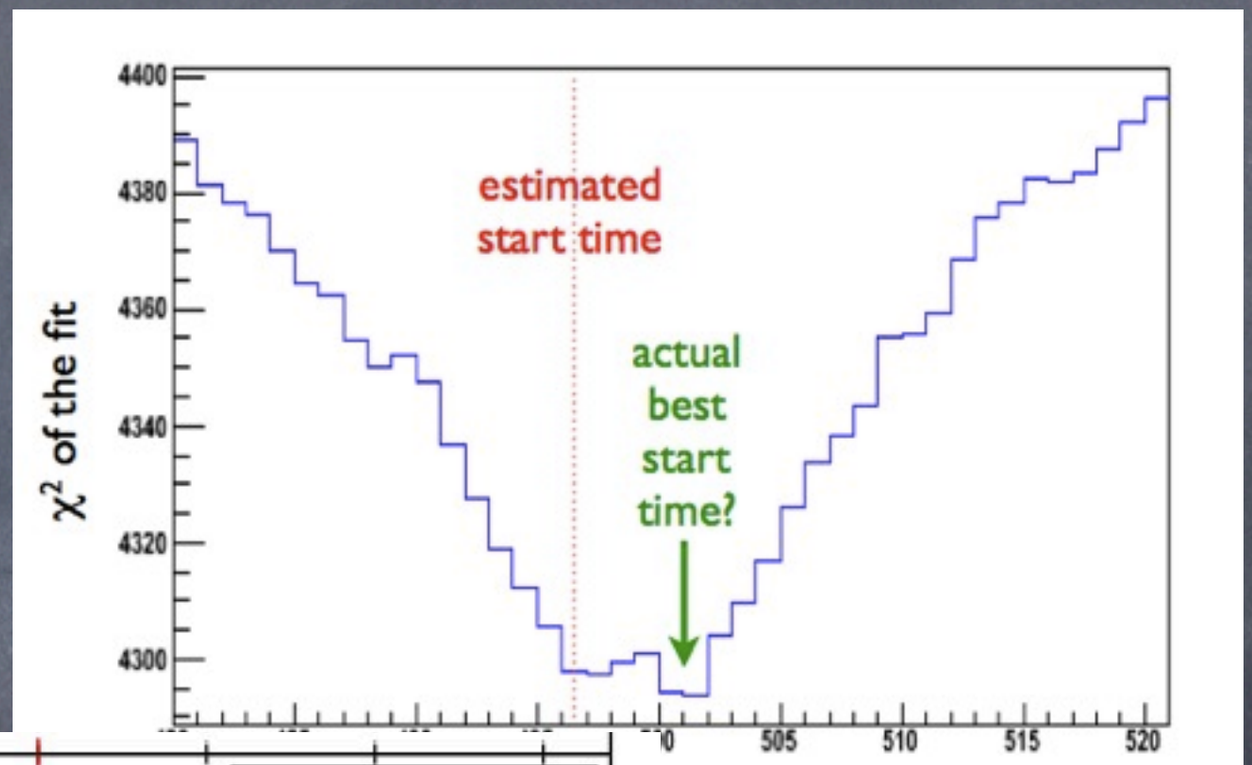


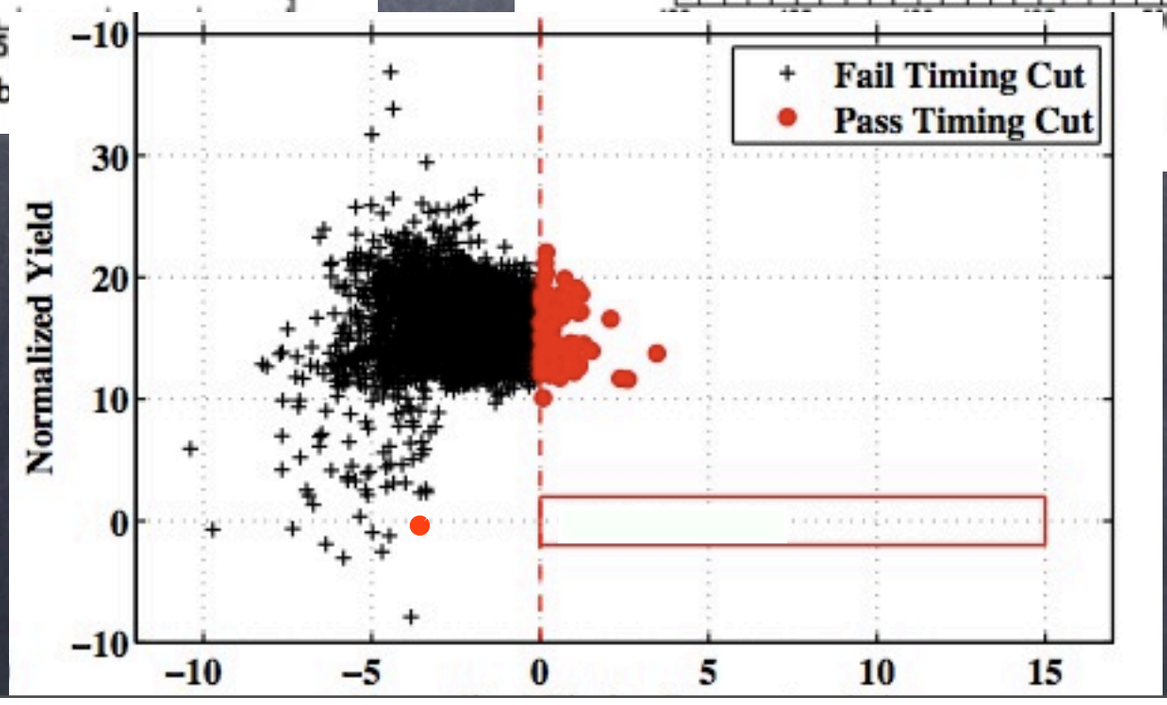




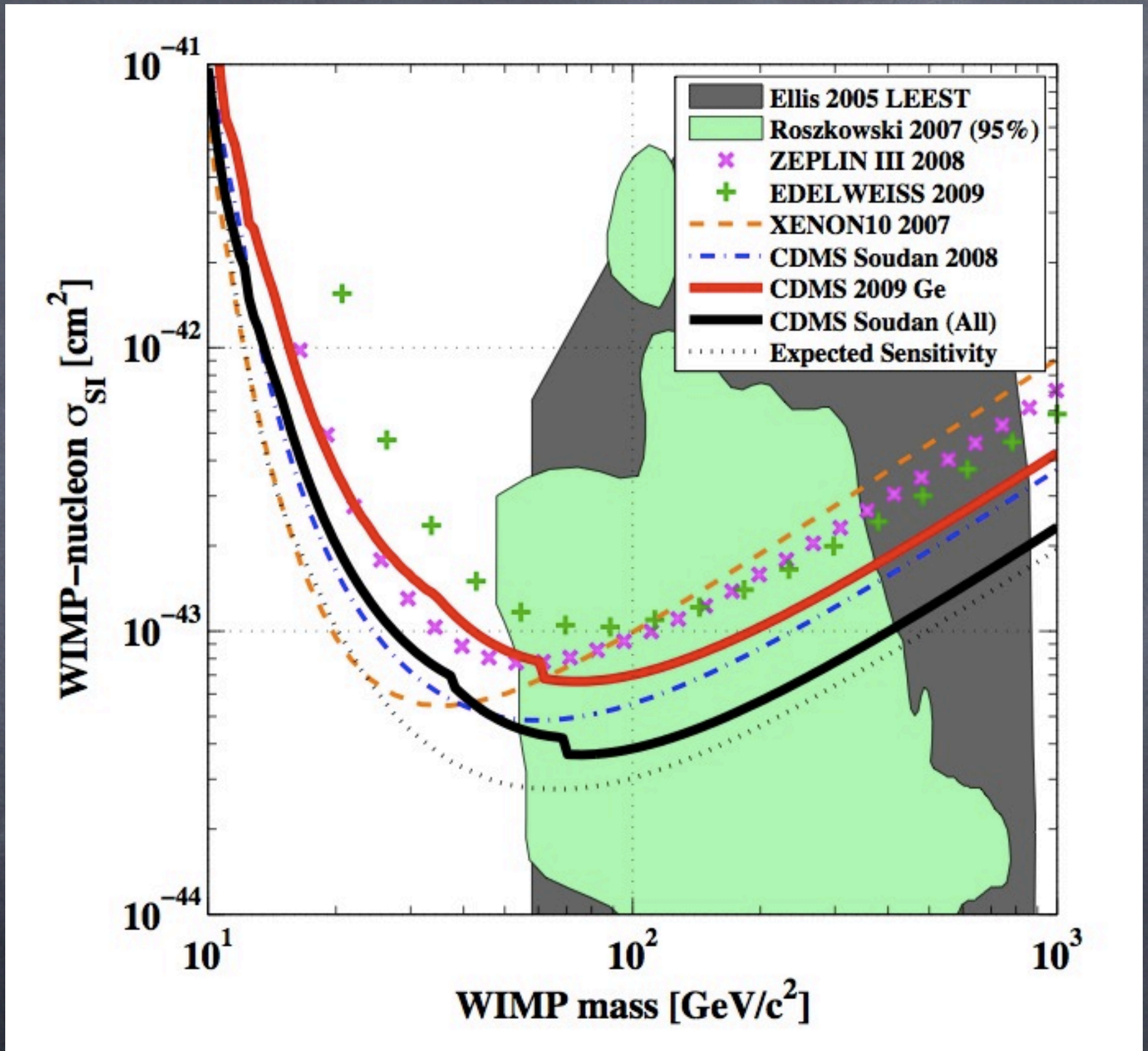
So what about that other event?





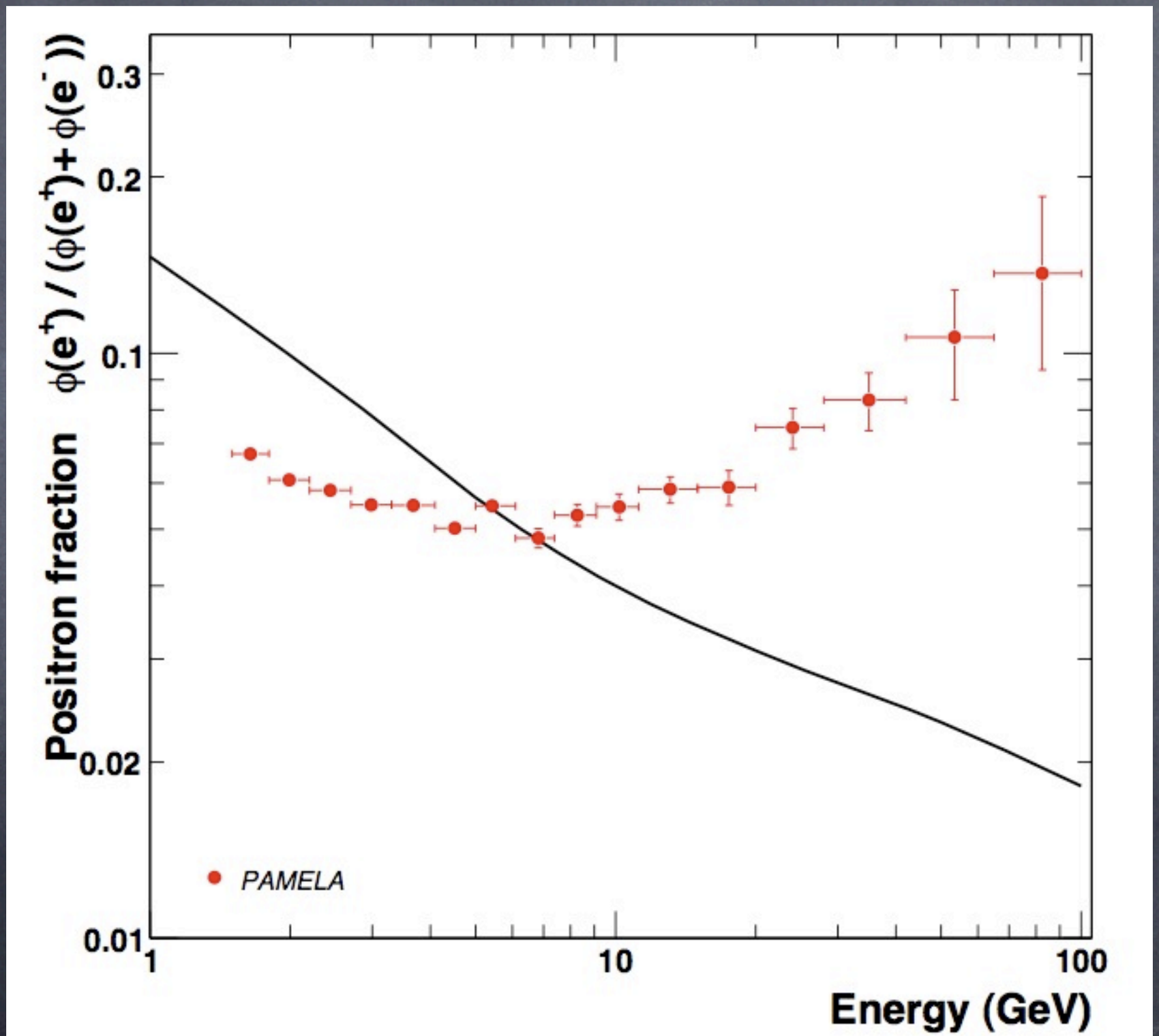


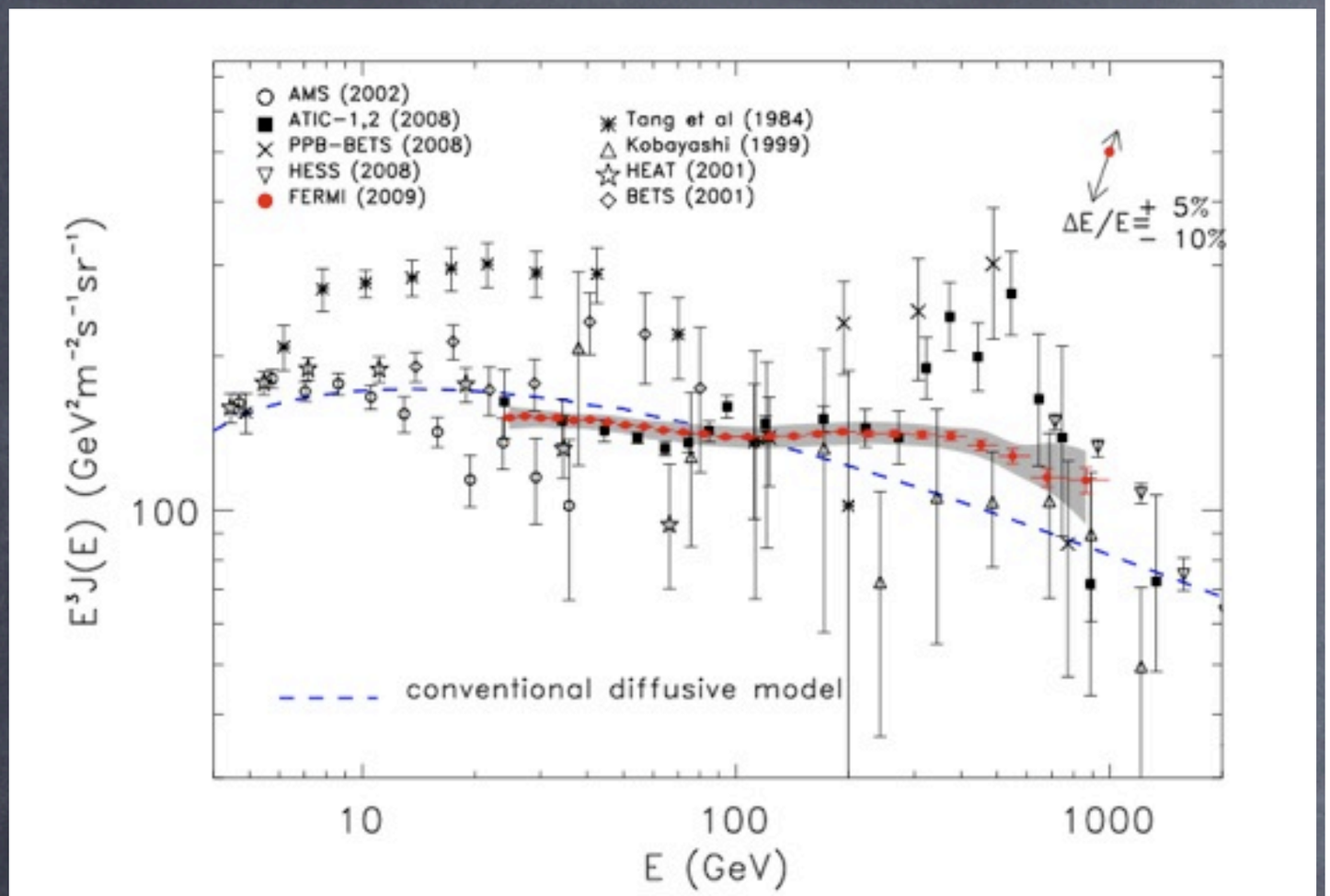
nb: just heuristic


Ellis 2005 LEEST
Roszkowski 2007 (95%)
ZEPLIN III 2008
EDELWEISS 2009
XENON10 2007
CDMS Soudan 2008
CDMS 2009 Ge
CDMS Soudan (All)
Expected Sensitivity
WIMP–nucleon σSI [cm2]
WIMP mass [GeV/c2]
10−41
10−42
10−43
10−44
101
102
103

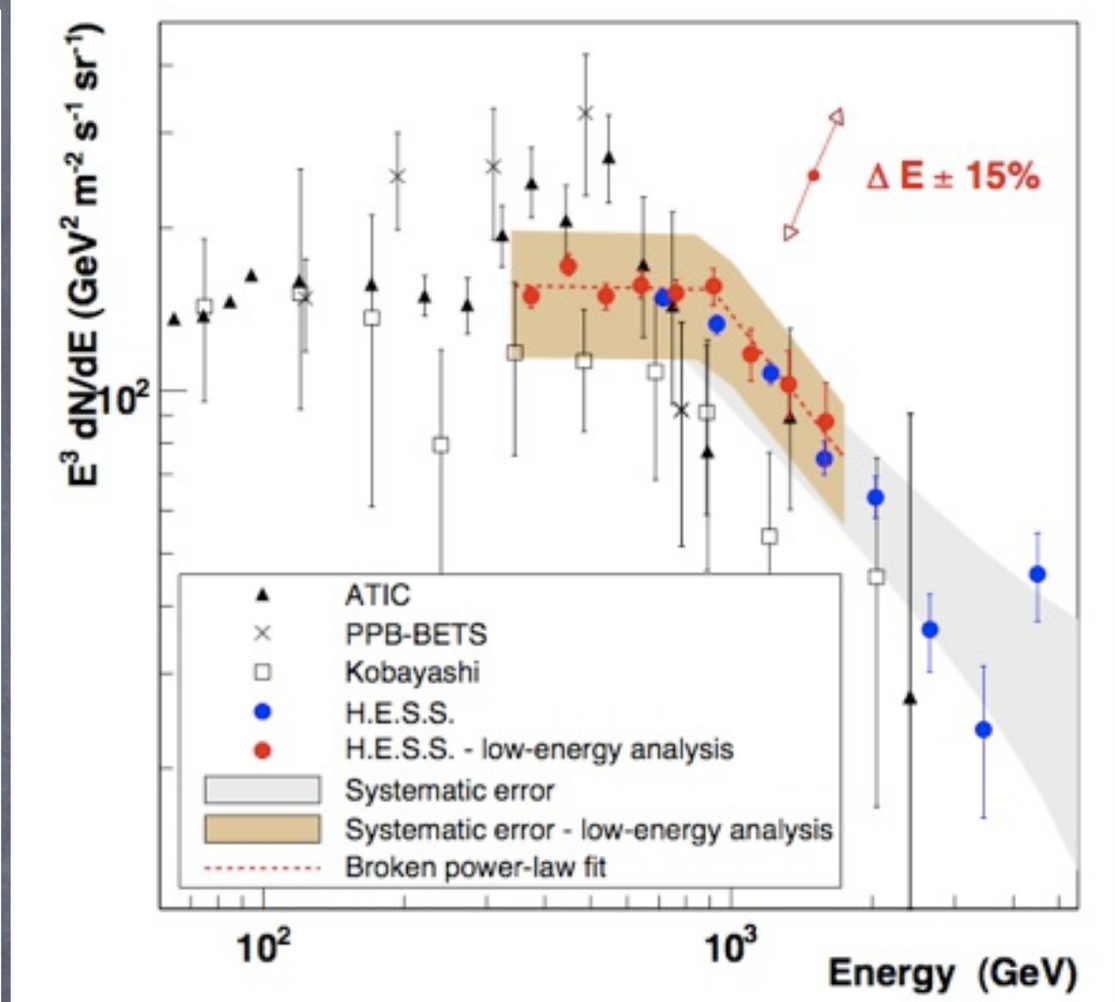
indirect = more data

- more data = more anomalies

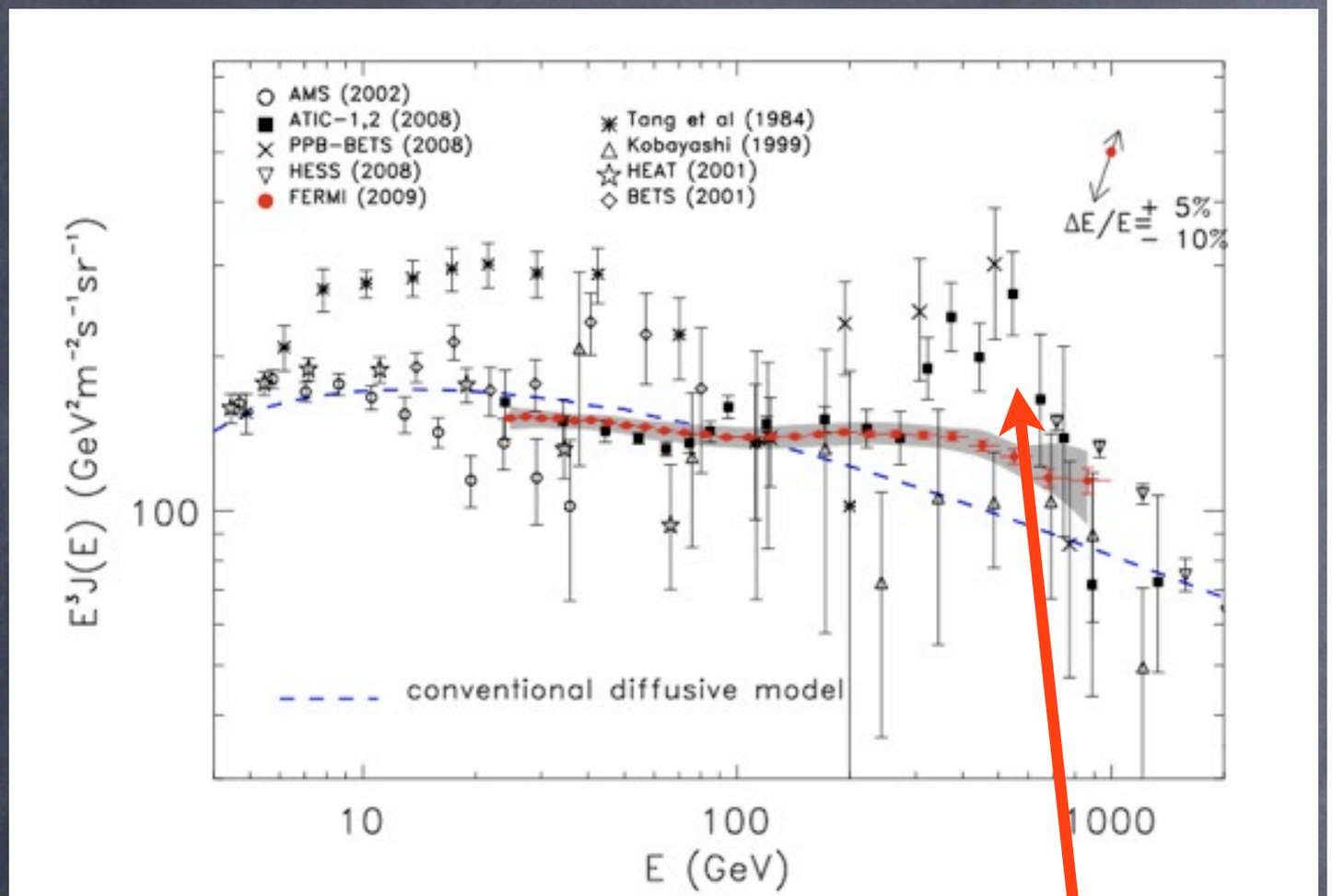

Positron fraction ϕ(e+) / (ϕ(e+)+ ϕ(e-))
0.3
0.2
0.1
0.02
0.01
1
10
100
Energy (GeV)
PAMELA



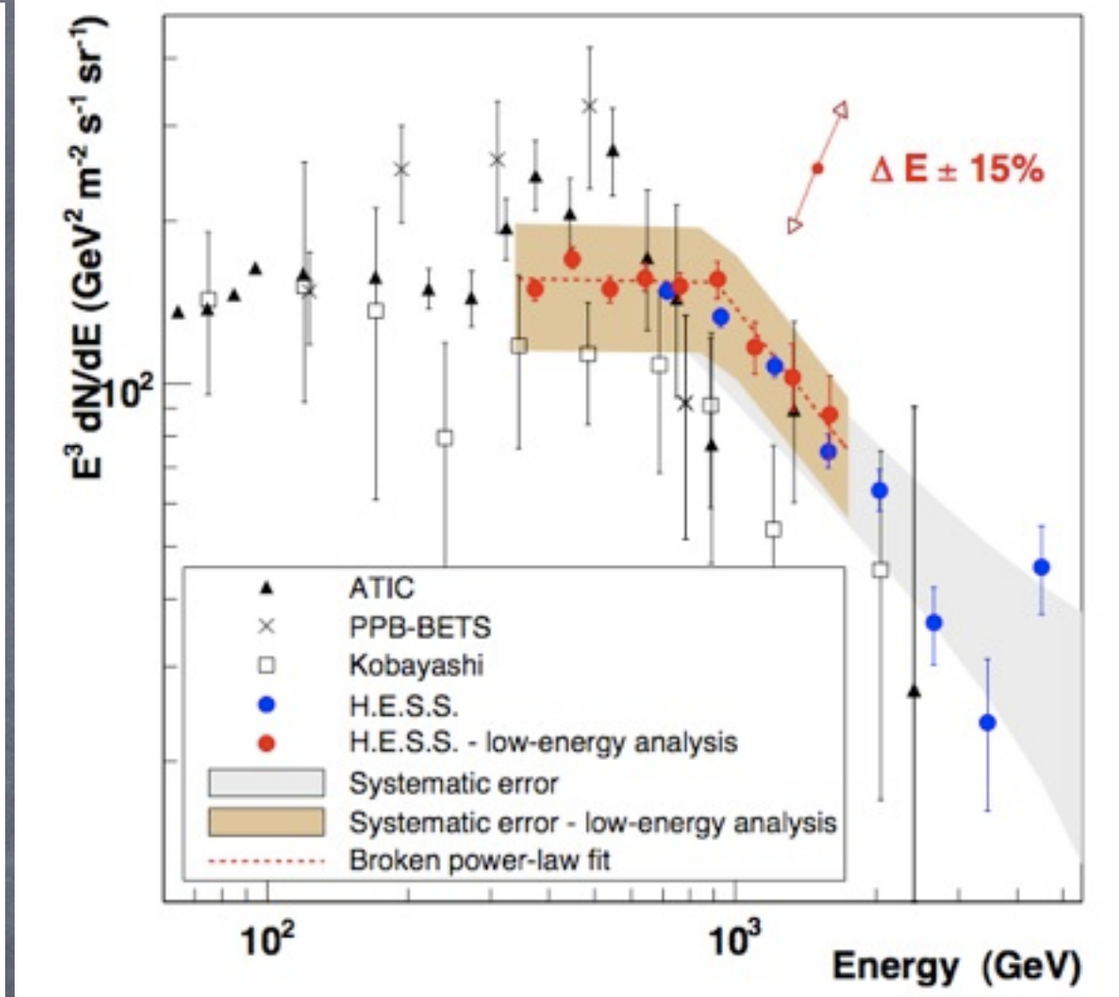
Fermi/LAT collaboration



HESS collaboration



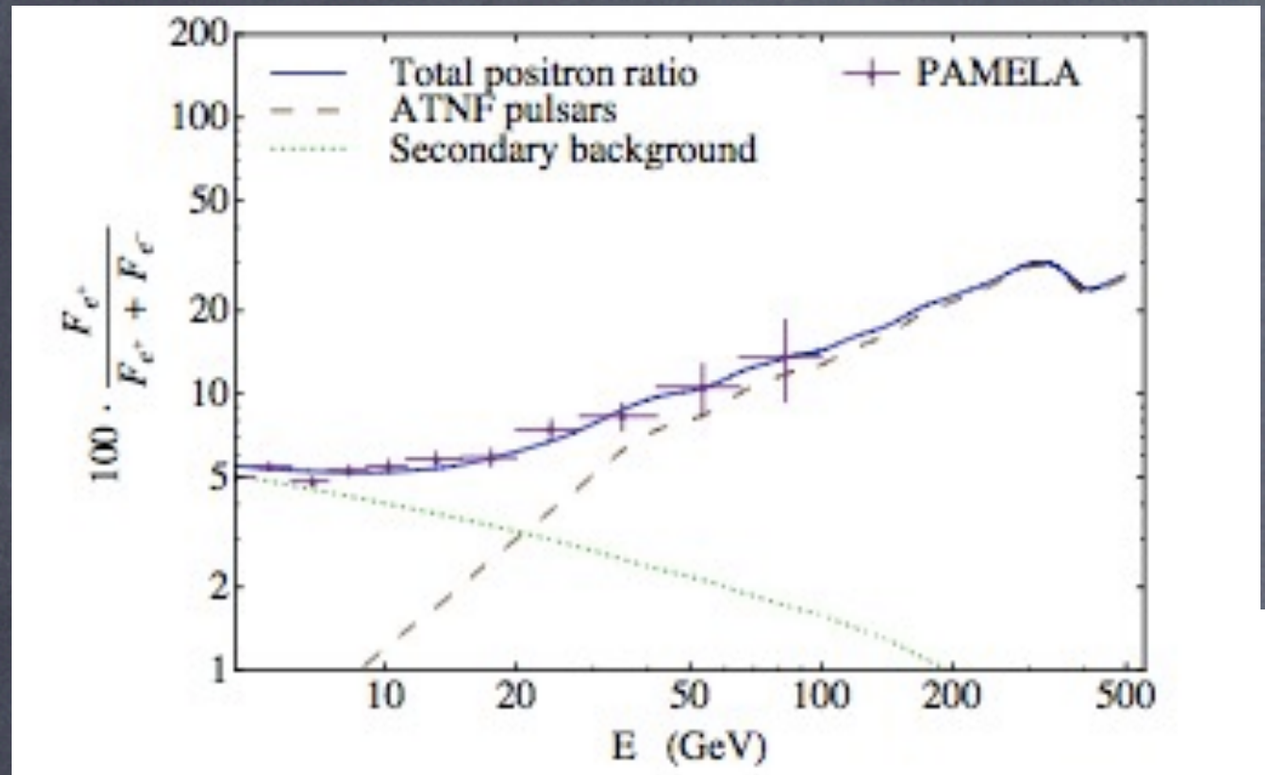
Fermi/LAT collaboration



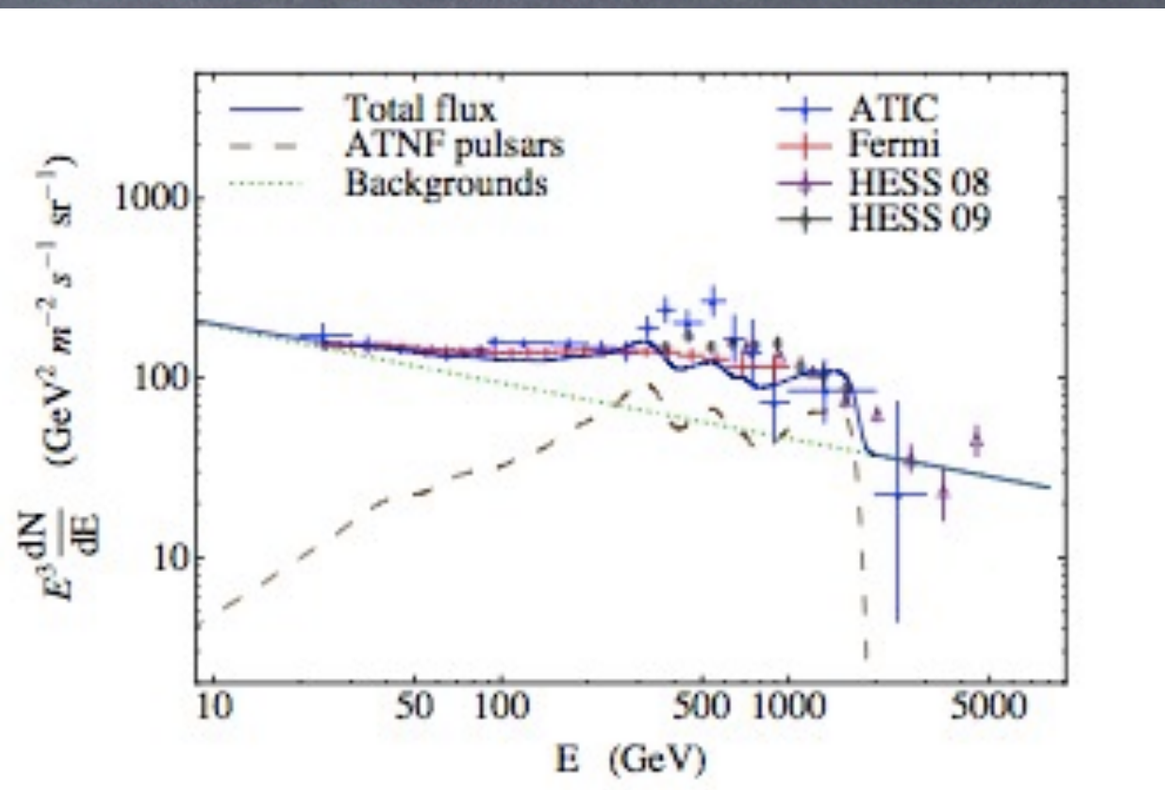
HESS collaboration

Psst, there's still ATIC!

Astrophysics?



Malyshev, Cholis, Gelfand, '09

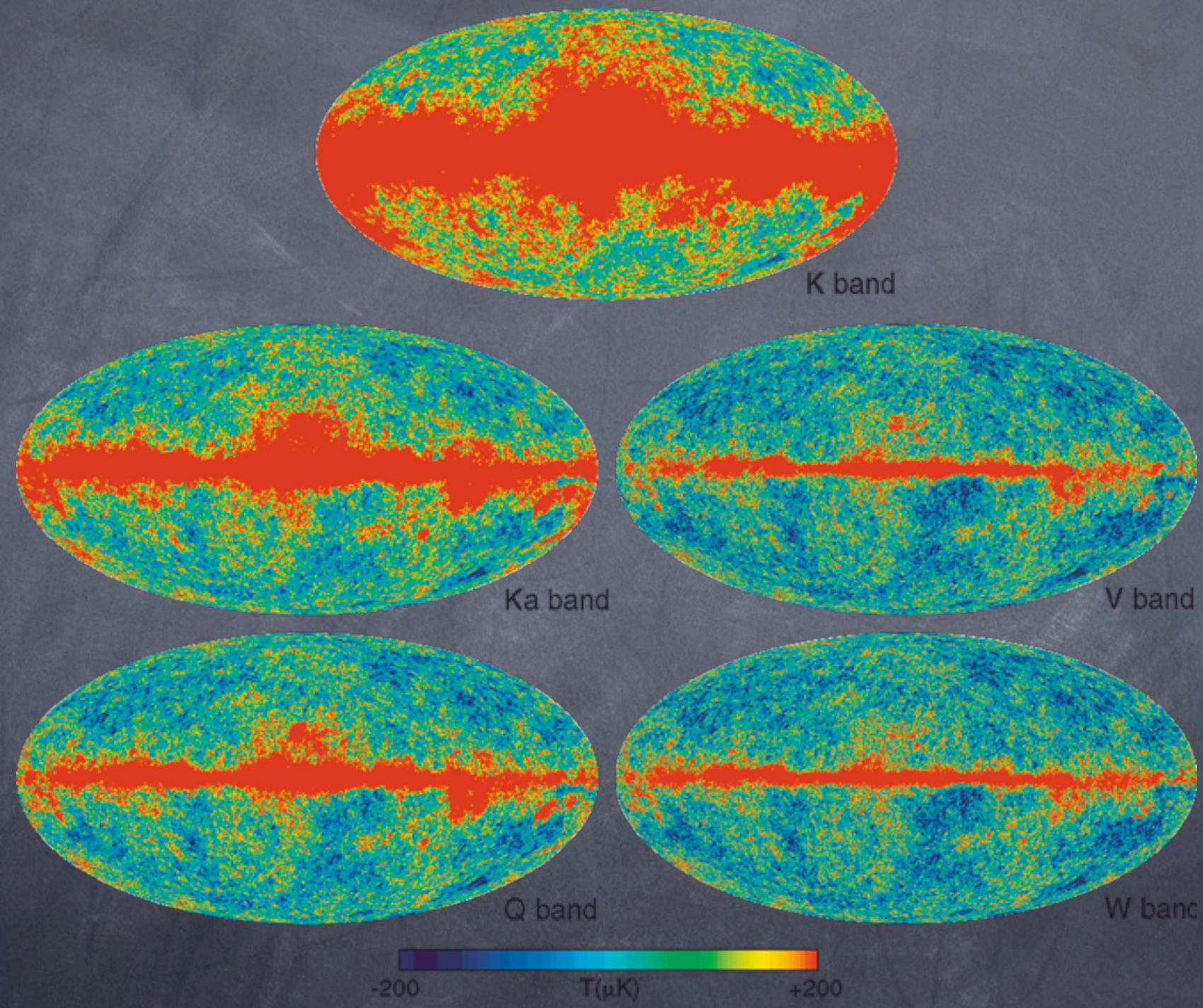


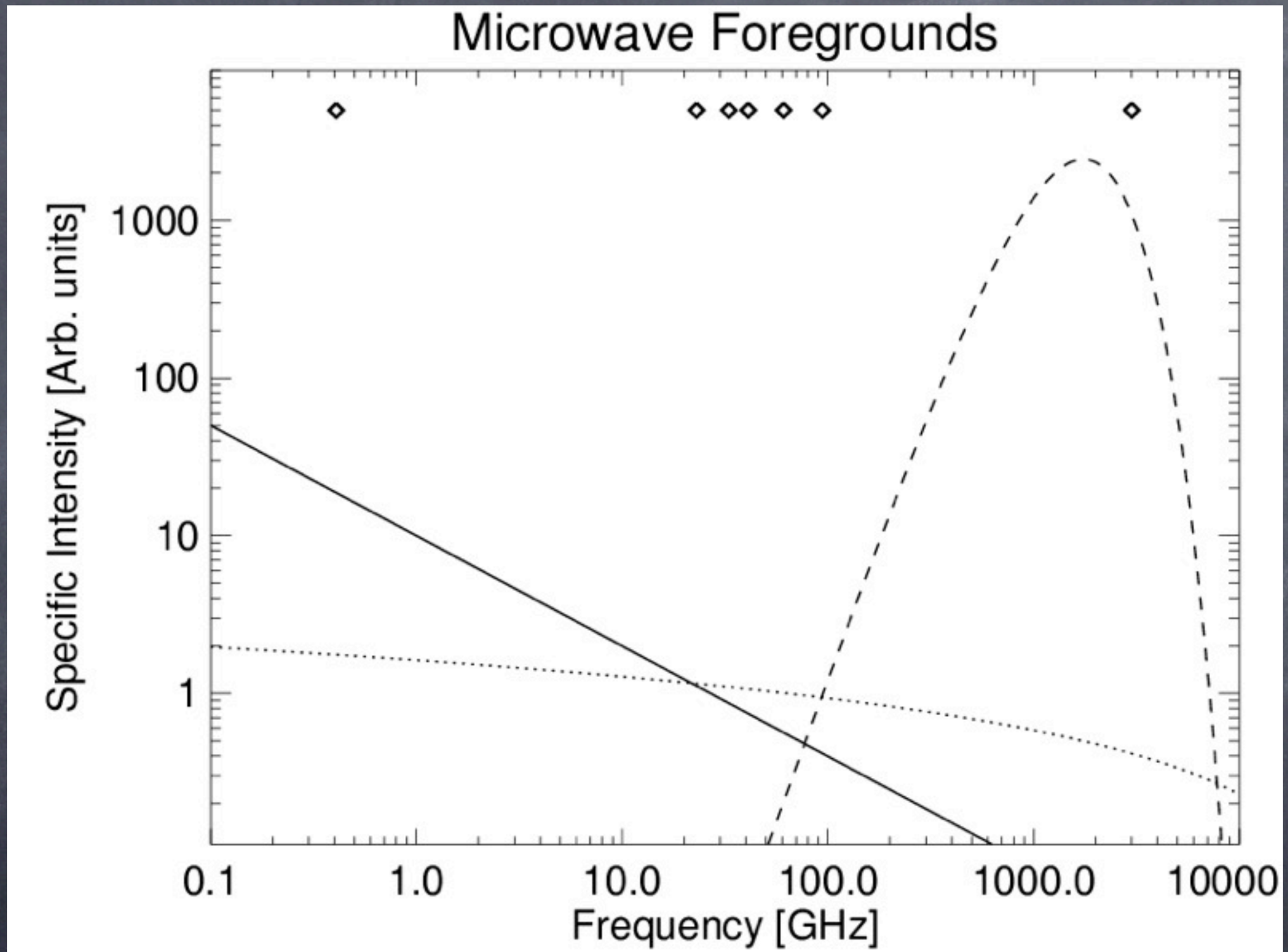
Aharonian, Atoyan, Volk '95; Hooper, Blasi, Serpico '08;Profumo '09...

Dark Matter of Astrophysics?

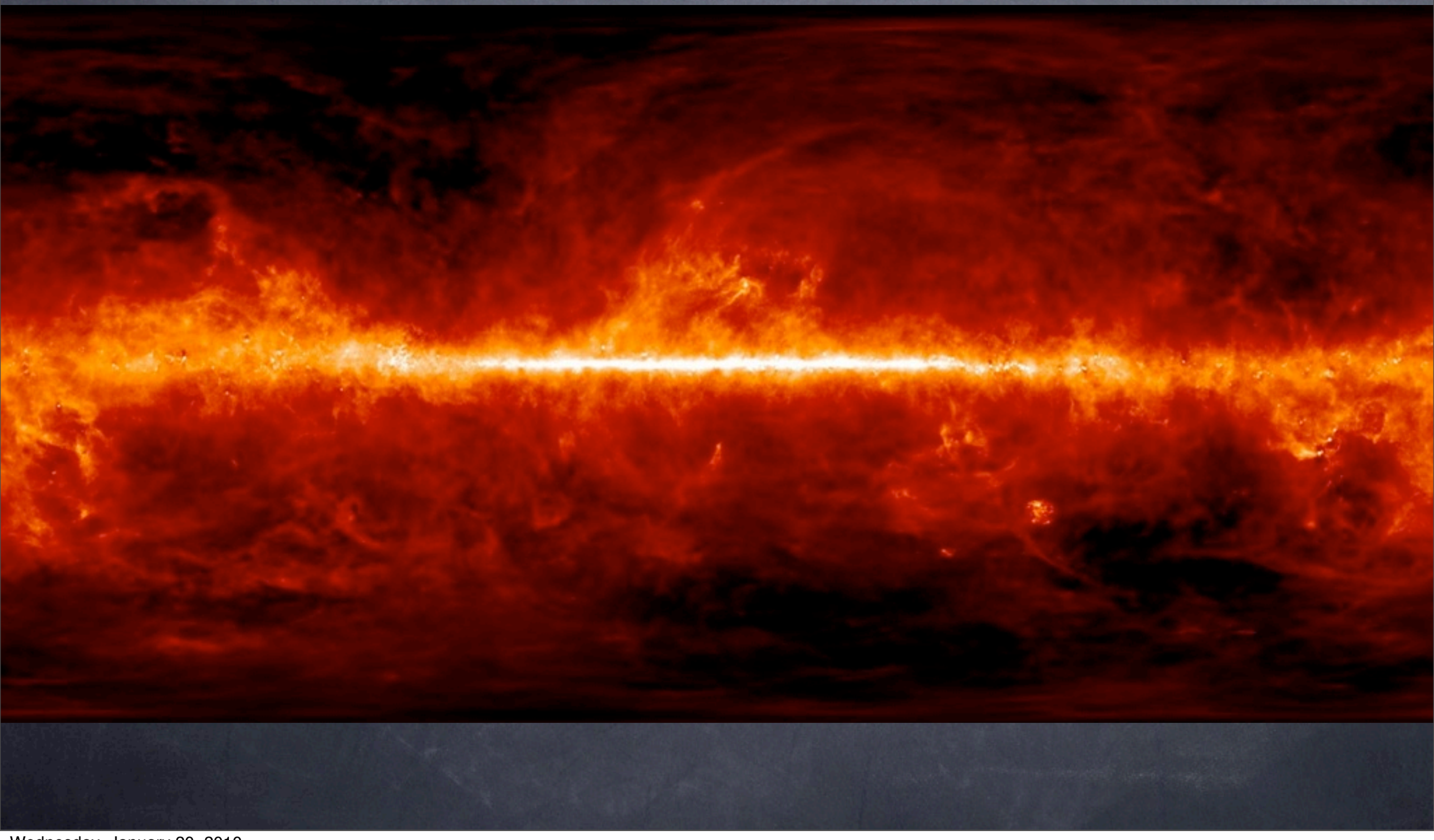
- Look in the galactic center

WMAP

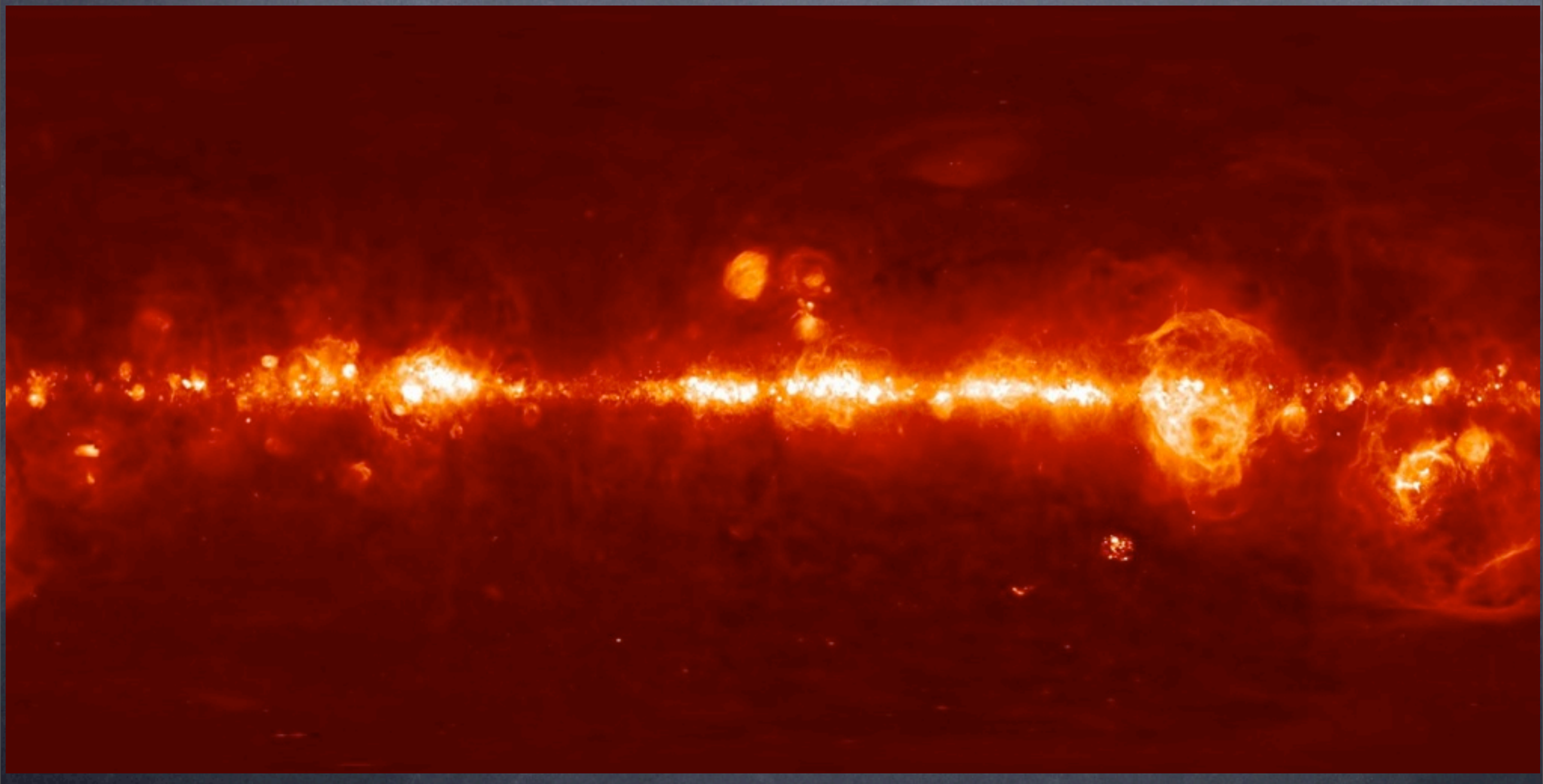



Microwave Foregrounds
Specific Intensity [Arb. units]
1000
100
10
1
0.1
1.0
10.0
100.0
1000.0
10000
Frequency [GHz]

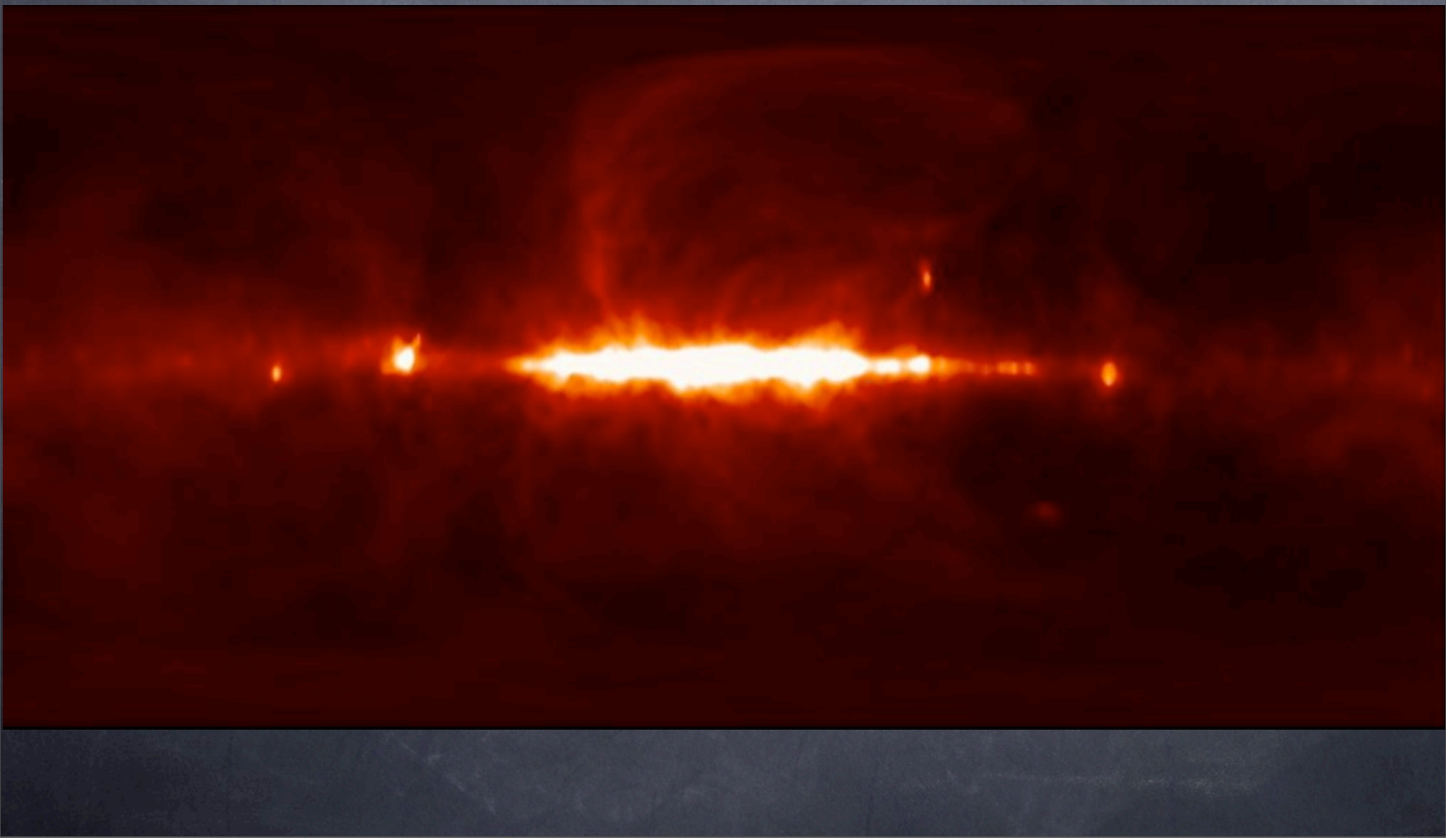
Interstellar Dust from IRAS, DIRBE (Finkbeiner et al. 1999)
Map extrapolated from 3 THz (100 micron) with FIRAS.



Ionized Gas from WHAM, SHASSA, VTSS (Finkbeiner 2003)
H-alpha emission measure goes as thermal bremsstrahlung.



Synchrotron at 408 MHz (Haslam et al. 1982)



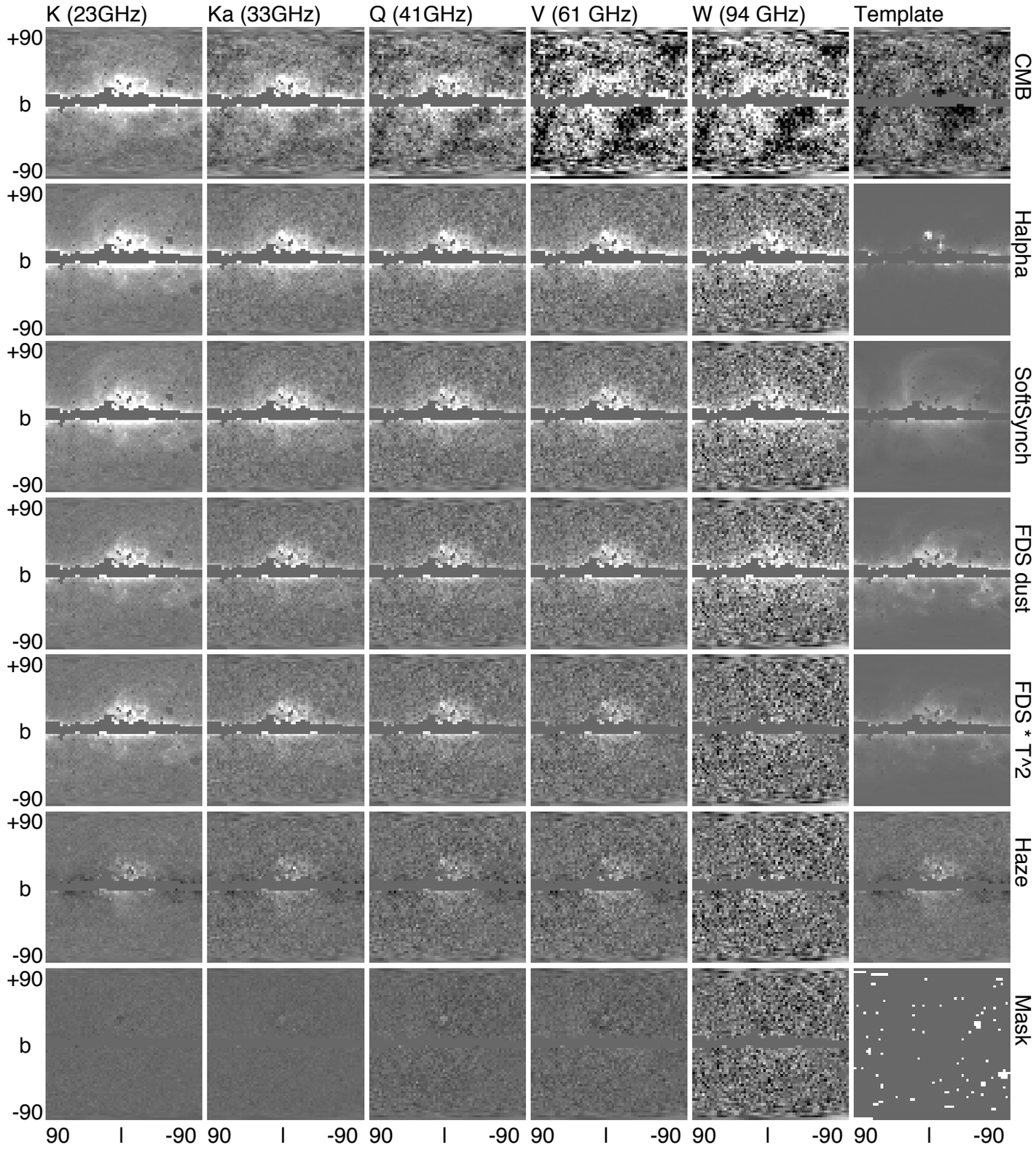
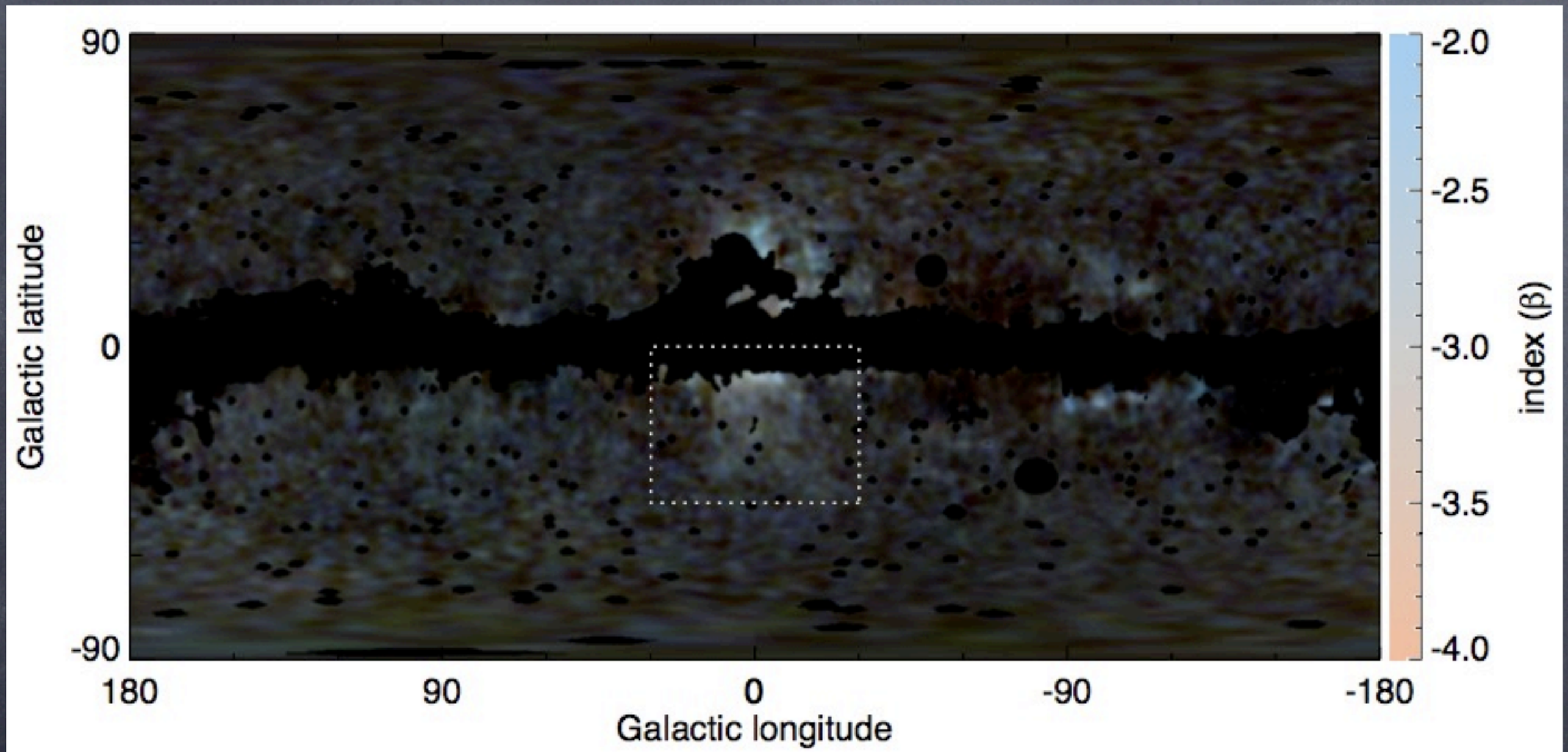


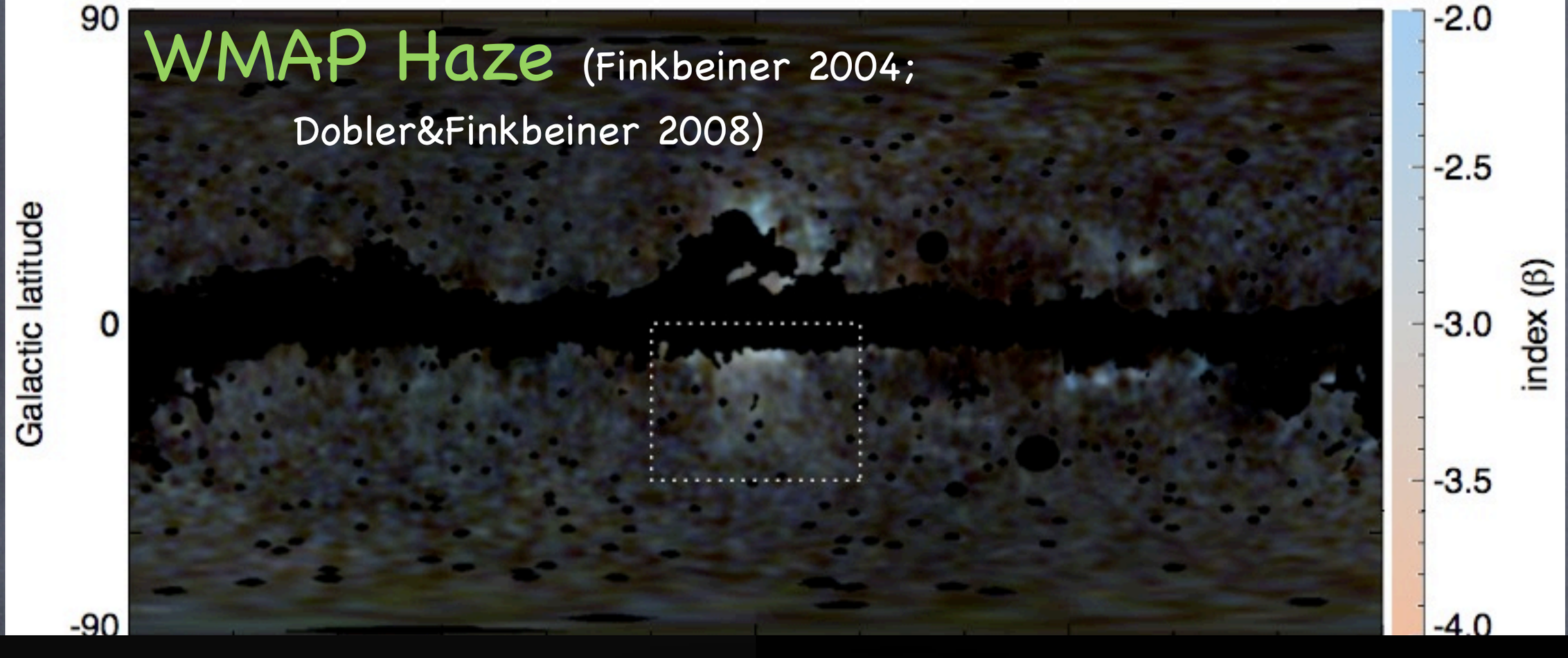
Fig. 1.— The WMAP foreground grid; see detailed discussion in §2.7.

Dobler and Finkbeiner ’08



Dobler and Finkbeiner '08

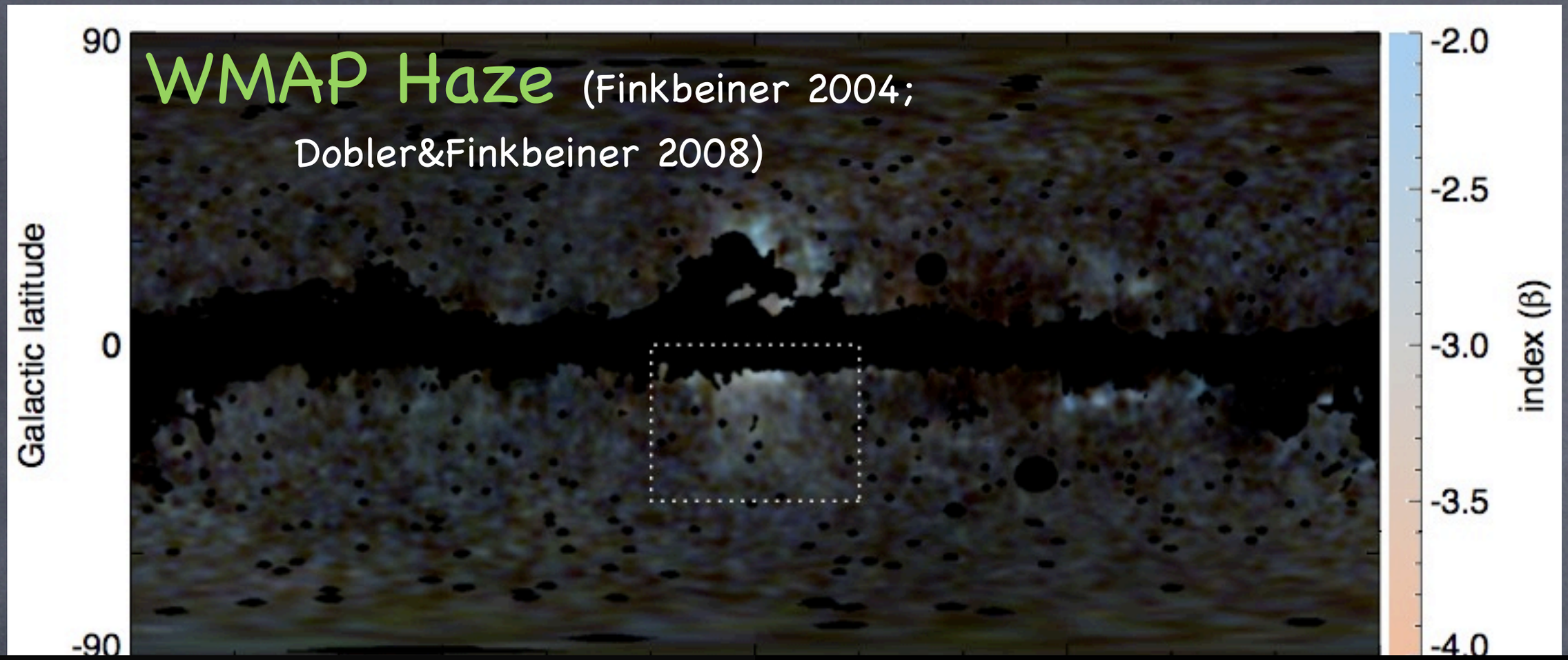
WMAP Haze (Finkbeiner 2004; Dobler&Finkbeiner 2008)



pulsars

dark matter

plots courtesy G. Dobler



Natural interpretation is of new source of 10+ GeV e+e- in galactic center, but with larger amplitude than locally

pulsars

good fit for DM explanation

dark matter

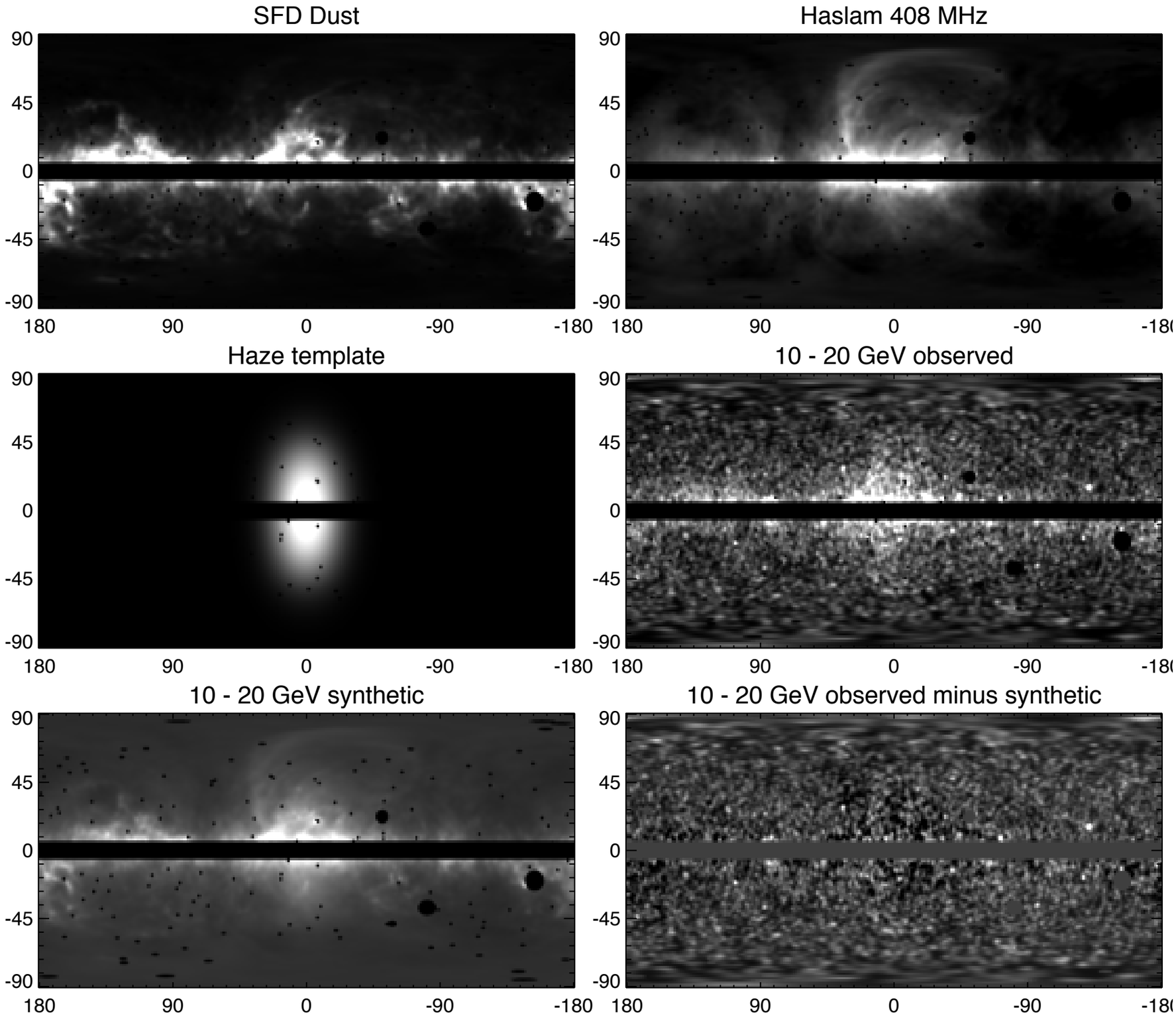
plots courtesy G. Dobler

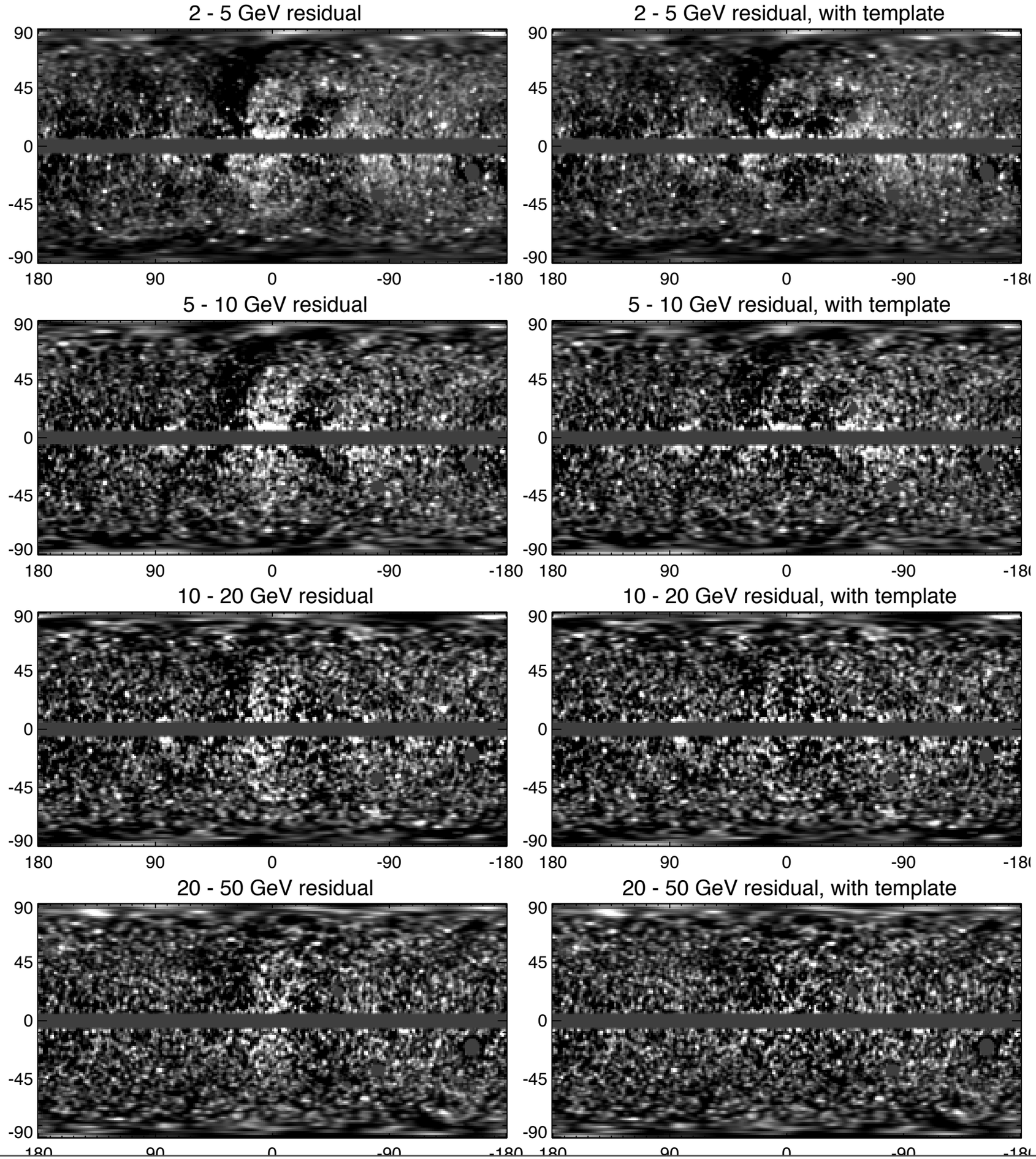
Fermi ICS

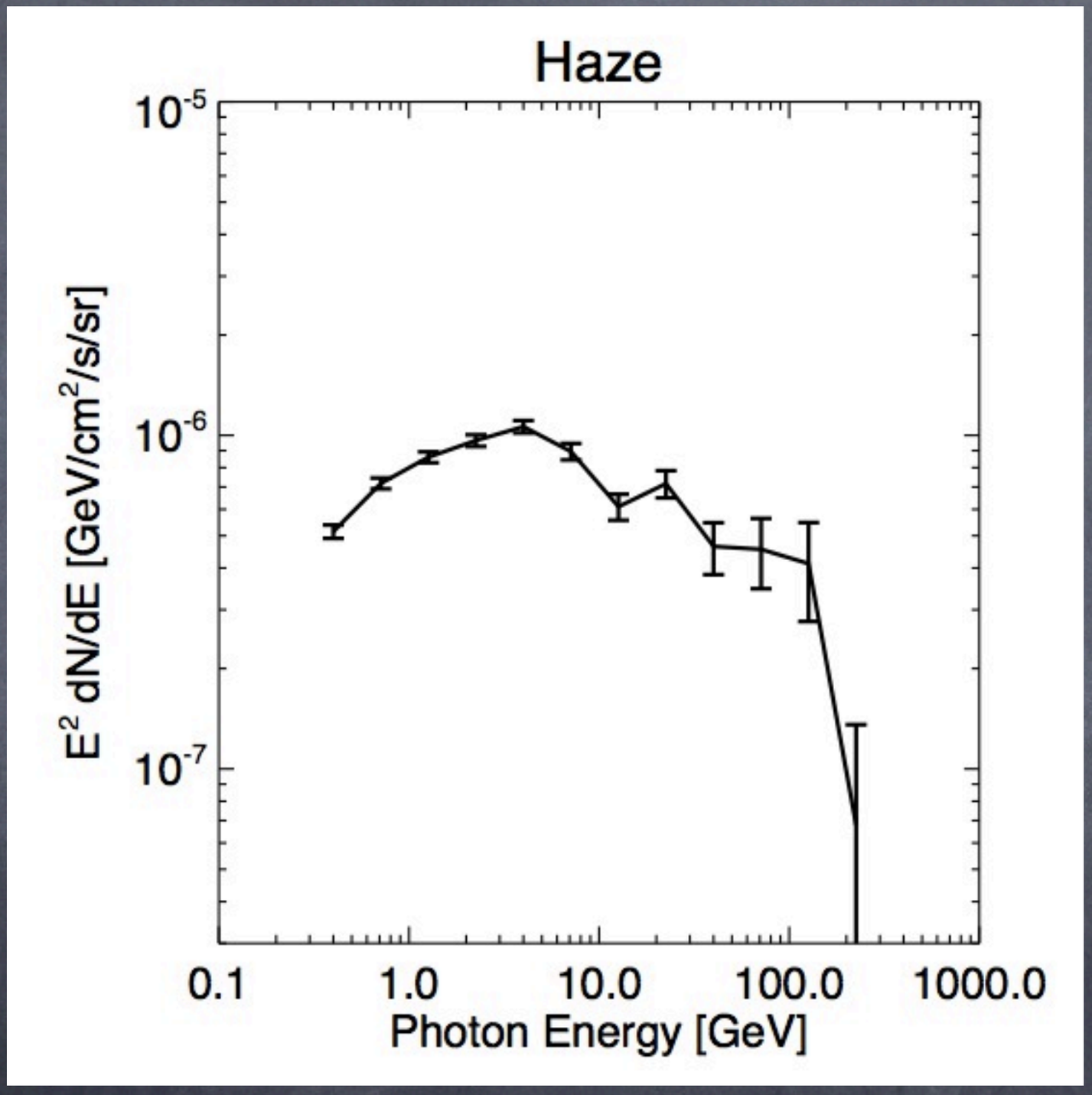
In the inner galaxy, high energy e+e- convert energy to synchrotron radiation (WMAP haze) **and inverse-compton scattered photons**

Inner galaxy can be studied: pions trace gas and dust; "soft" ICS seen in low energy microwaves; can do a regression for those gamma rays and find residual

Fermi ICS


SFD Dust
Haslam 408 MHz
Haze template
10 - 20 GeV observed
10 - 20 GeV synthetic
10 - 20 GeV observed minus synthetic
90
45
0
-45
-90
180
90
0
-90
-180


2 - 5 GeV residual
2 - 5 GeV residual, with template
5 - 10 GeV residual
5 - 10 GeV residual, with template
10 - 20 GeV residual
10 - 20 GeV residual, with template
20 - 50 GeV residual
20 - 50 GeV residual, with template
90
45
0
-45
-90
180
90
0
-90
-180


Haze
10^{-5}
10^{-6}
10^{-7}
E^2 dN/dE [GeV/cm^2/s/sr]
0.1
1.0
10.0
100.0
1000.0
Photon Energy [GeV]

WMAP & Fermi "Haze"

Finkbeiner, '03; Dobler & Finkbeiner '07; Dobler et al '09

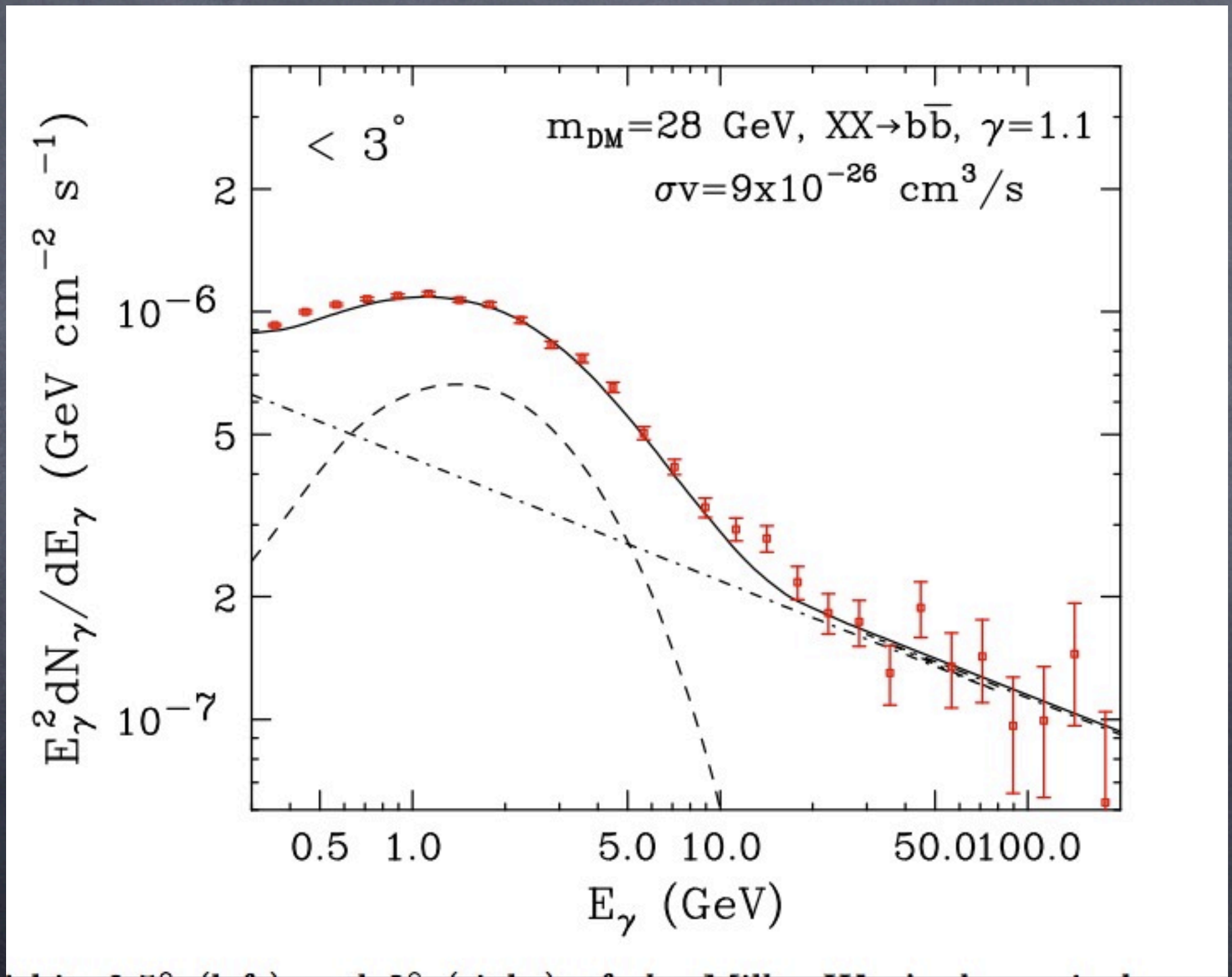
- "Hard" spectrum of microwave radiation
- Consistent with high energy (10-100 GeV) electrons and positrons synchrotron radiating in galactic magnetic field
- New Fermi data seem to indicate excess gammas - if ICS it will confirm electronic interpretation
- PLANCK will extend the frequency range and definitively test this interpretation

Cosmic Summary

- A variety of pieces of evidence point to new sources of high energy (10-1000 GeV) positrons and electrons
- Pulsars could possibly explain local excesses (PAMELA), but not sources in galactic center
- Dark matter?

Other Astrophysics

Goodenough, Hooper



2.5 keV from Willman-I

Kusenko, Loewenstein

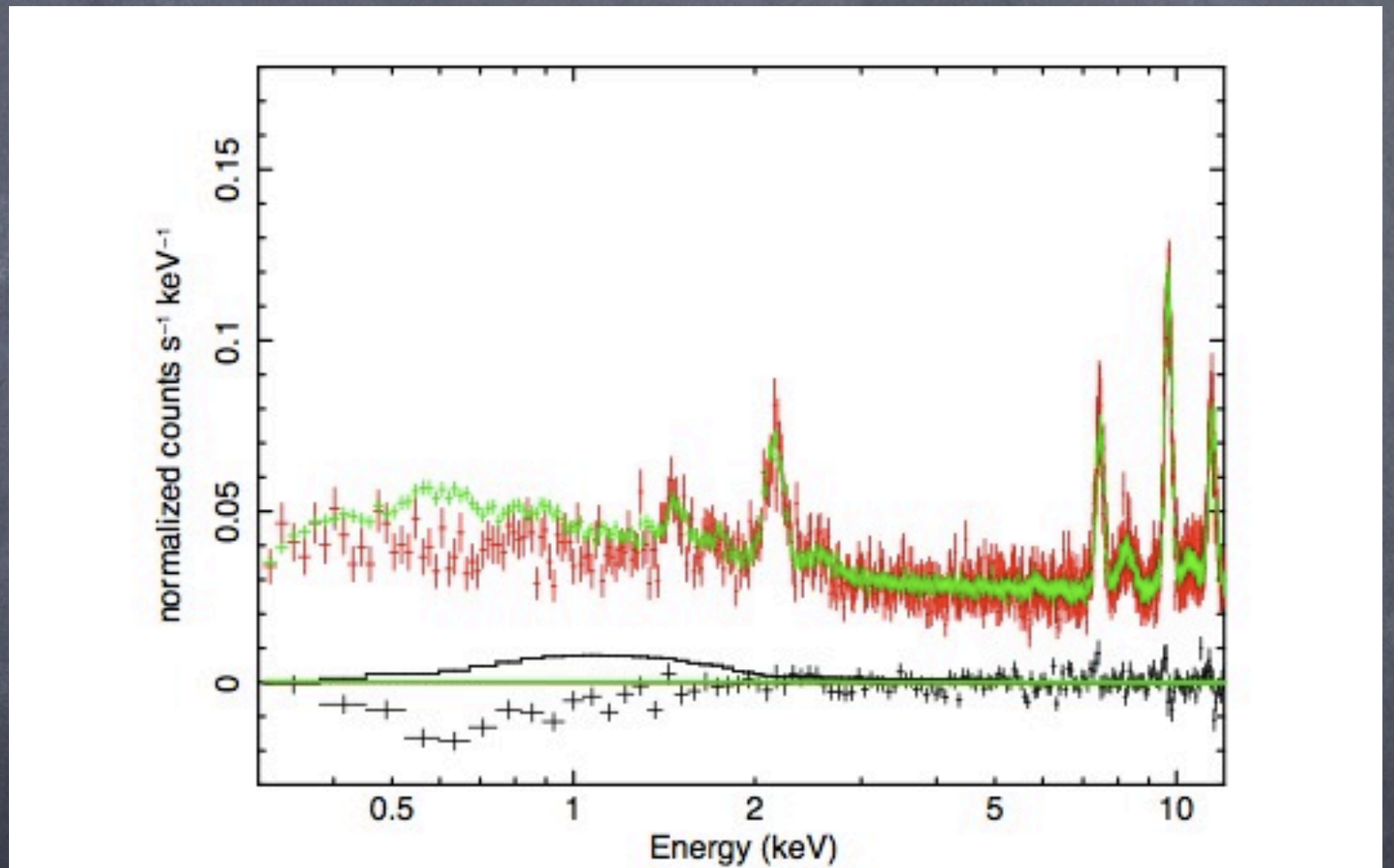
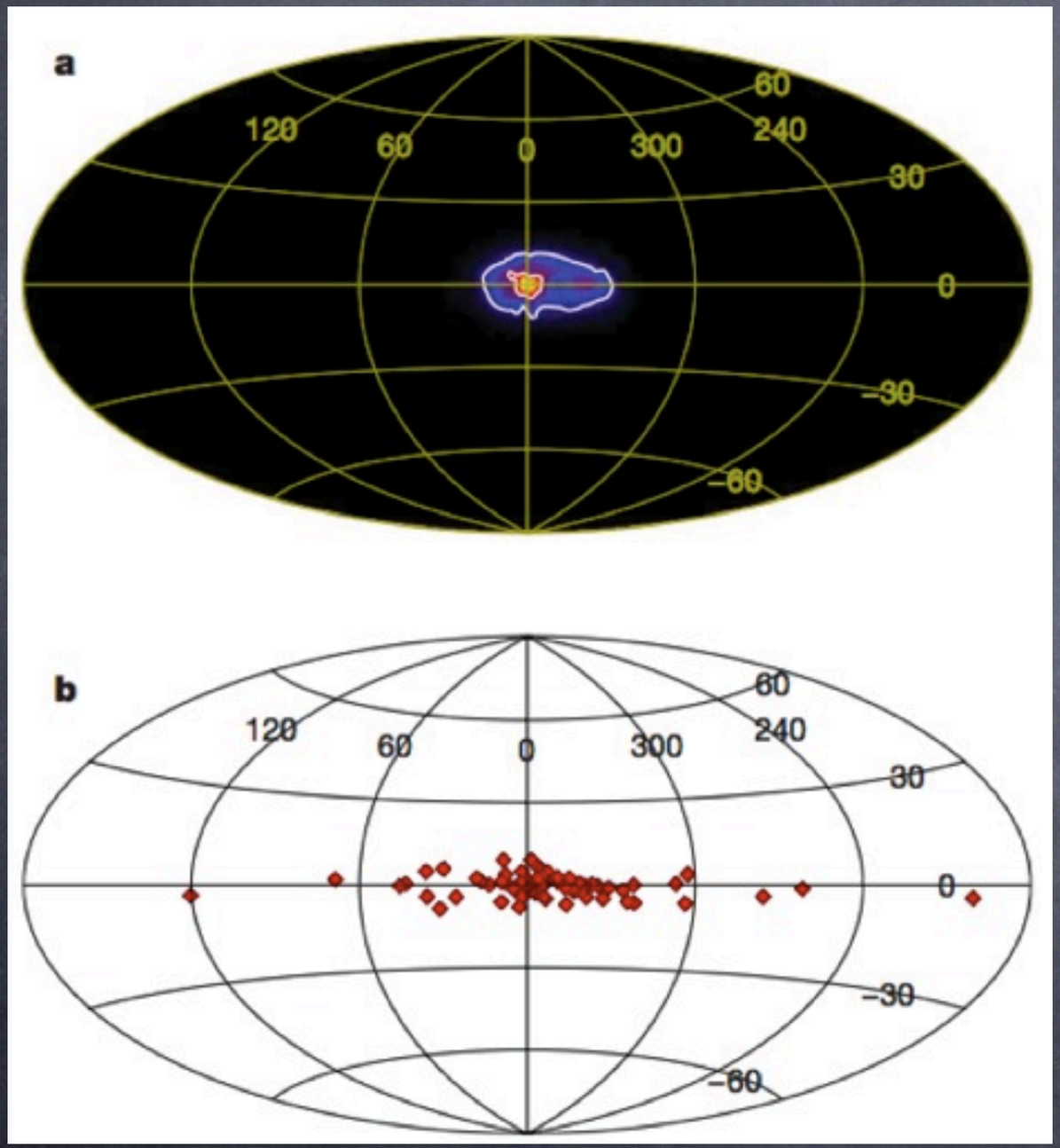


Fig. 2.— Total (red), SB (green), and SB-subtracted (black) spectra. The histogram is the best-fit GXB+CXB model to the *PB-subtracted* spectrum of Figure 1b. The SB results in an oversubtraction below 2 keV.

Instrumental effect? (Boyarsky et al)

INTEGRAL



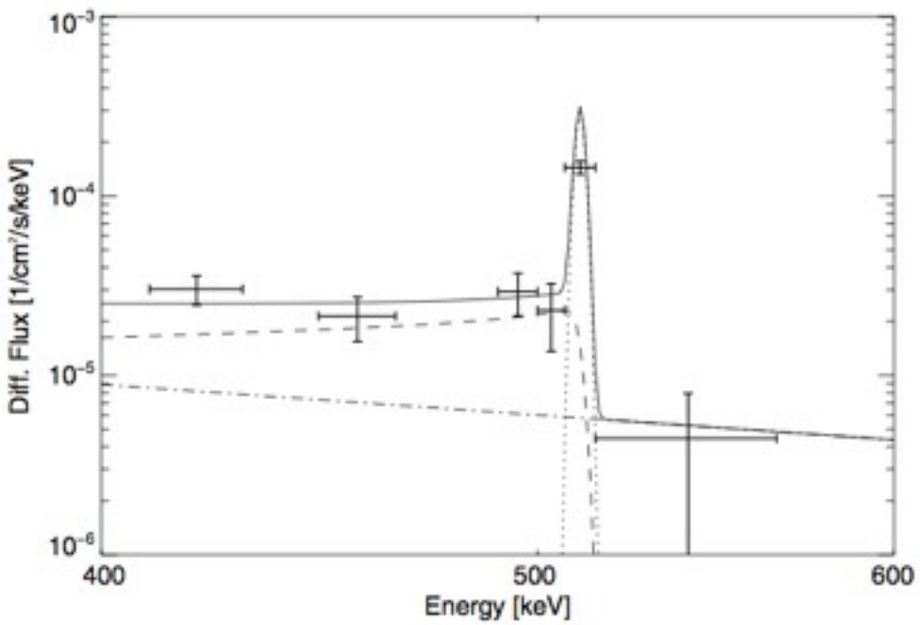


Fig. 2. A fit of the SPI result for the diffuse emission from the GC region ($|l|, |b| \leq 16°$) obtained with a spatial model consisting of an 8° *FWHM* Gaussian bulge and a CO disk. In the fit a diagonal response was assumed. The spectral components are: 511 keV line (dotted), Ps continuum (dashes), and power-law continuum (dash-dots). The summed models are indicated by the solid line. Details of the fitting procedure are given in the text.

LMXB's having some trouble: Private communcation: P. Ubertini

Caveat emptor

- Most of these are almost certainly not signs of new physics
- One can spend a lot of time trying to figure out anomalies

Caveat odior*

*My Latin is out of date and my Wheelock is at home

Caveat odior*

- Even wrong anomalies motivate new phenomenology and models!

*My Latin is out of date and my Wheelock is at home

Caveat odior*

- Even wrong anomalies motivate new phenomenology and models!
- In our discussion of hints and anomalies, we all have a tendency to become "haters"

*My Latin is out of date and my Wheelock is at home

Caveat odior*

- Even wrong anomalies motivate new phenomenology and models!
- In our discussion of hints and anomalies, we all have a tendency to become "haters"
- Two types: active hater, passive hater

*My Latin is out of date and my Wheelock is at home

Caveat odior*

- Even wrong anomalies motivate new phenomenology and models!
- In our discussion of hints and anomalies, we all have a tendency to become "haters"
- Two types: active hater, passive hater
- Both are dangerous!

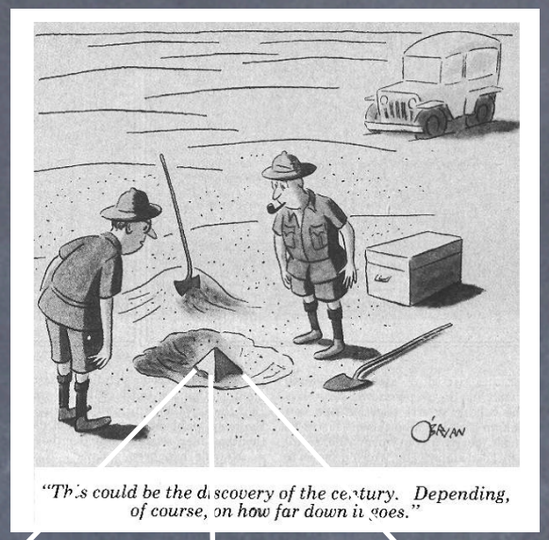
*My Latin is out of date and my Wheelock is at home

Caveat odior*

- Even wrong anomalies motivate new phenomenology and models!
- In our discussion of hints and anomalies, we all have a tendency to become "haters"
- Two types: active hater, passive hater
- Both are dangerous!
- Be a skeptic, not a hater - maybe they can't all be right, but ~~surely~~ ~~likely~~ possibly one is!

*My Latin is out of date and my Wheelock is at home

Who knows what we'll find...



DAMA

PAMELA

g-2/EWPT

?

funky WIMPs

cool SUSY

dark forces