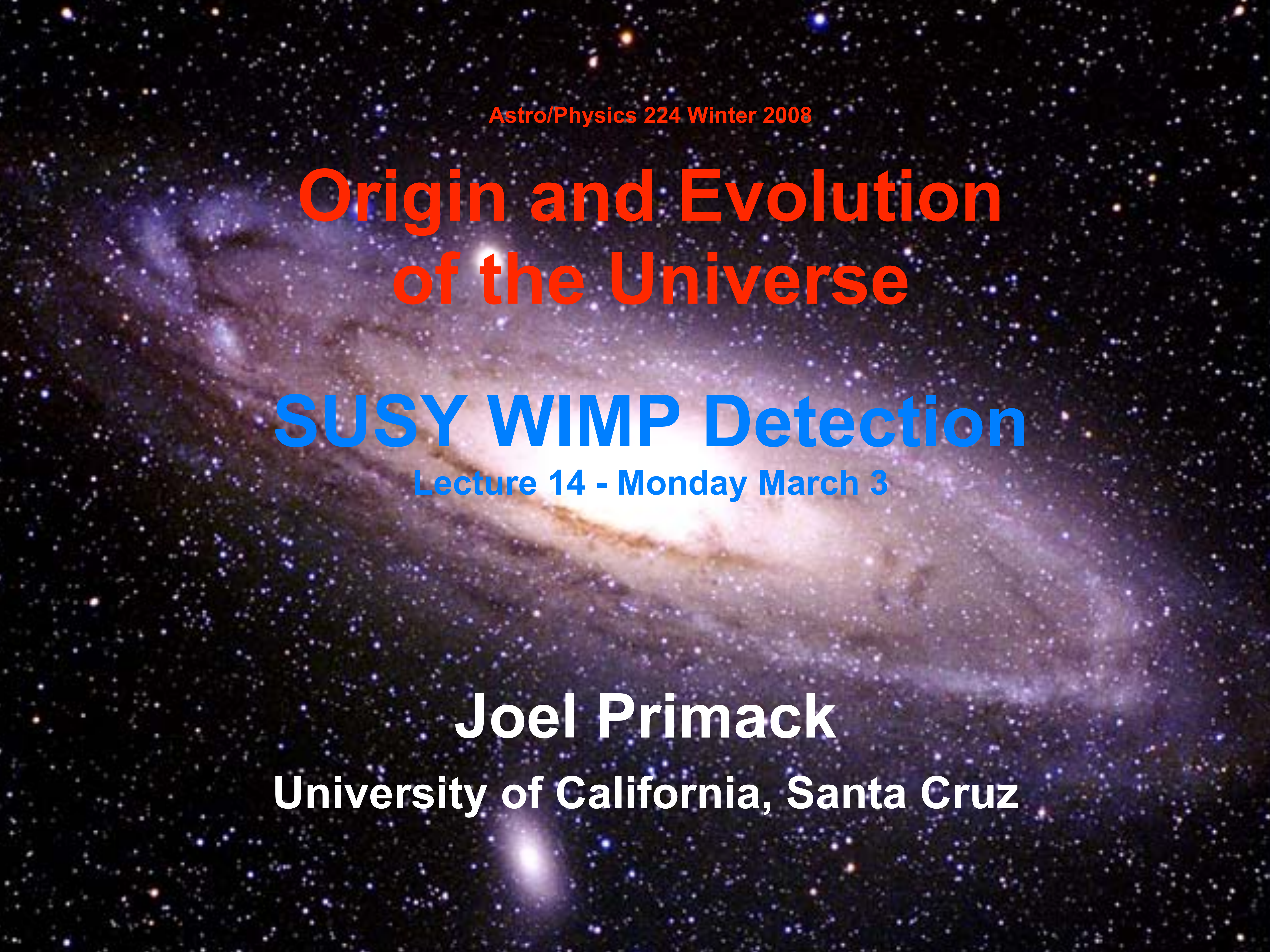


Astro/Physics 224 Winter 2008

Origin and Evolution of the Universe

SUSY WIMP Detection

Lecture 14 - Monday March 3

Joel Primack

University of California, Santa Cruz

Astro/Phys 224 Winter 2008 Term Project Topics

Term Project Reports will be Tuesday March 18 10 am-12 n, 2-5 pm

Brandon Anderson anderson@physics.ucsc.edu

Dark SUSY and Application to GLAST DM Annihilation Search

Zac Apte zapte@ucsc.edu

Galaxy Formation and Galaxy Morphology

Taylor Aune taune@ucsc.edu

Gamma Ray Burst Cosmology

Hal Cambier hcambier@ucsc.edu

Reionization and the End of the Dark Ages

Michael Dormody mdormody@ucsc.edu

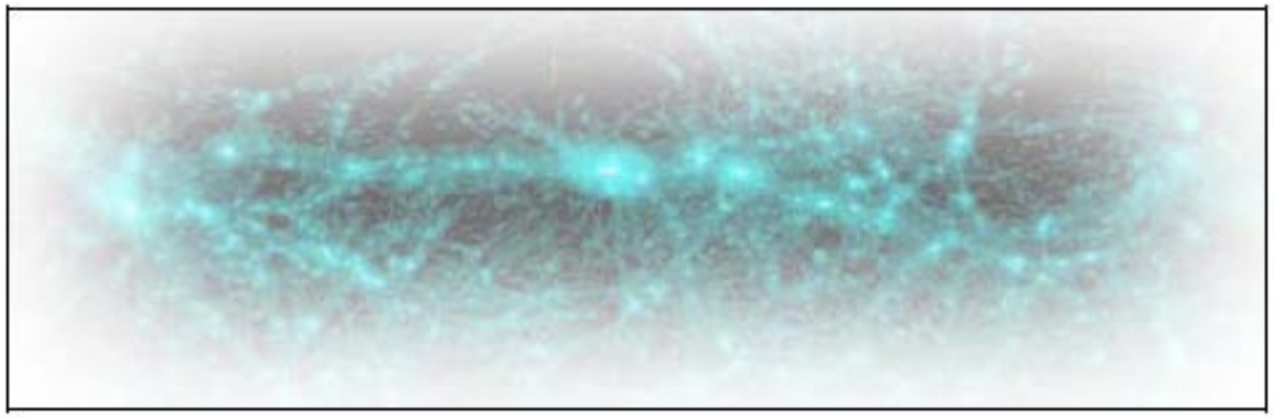
MOND and Other Alternatives to General Relativity

John Kehayias jkehayia@ucsc.edu

Holographic Cosmology

Camilla Penzo cpenzo@ucsc.edu

Measuring Dark Energy



8th UCLA Symposium on

Sources and Detection of Dark Matter and Dark Energy in the Universe

FEBRUARY 20-22, 2008 MARINA DEL REY MARRIOTT

TOPICS OF SESSIONS

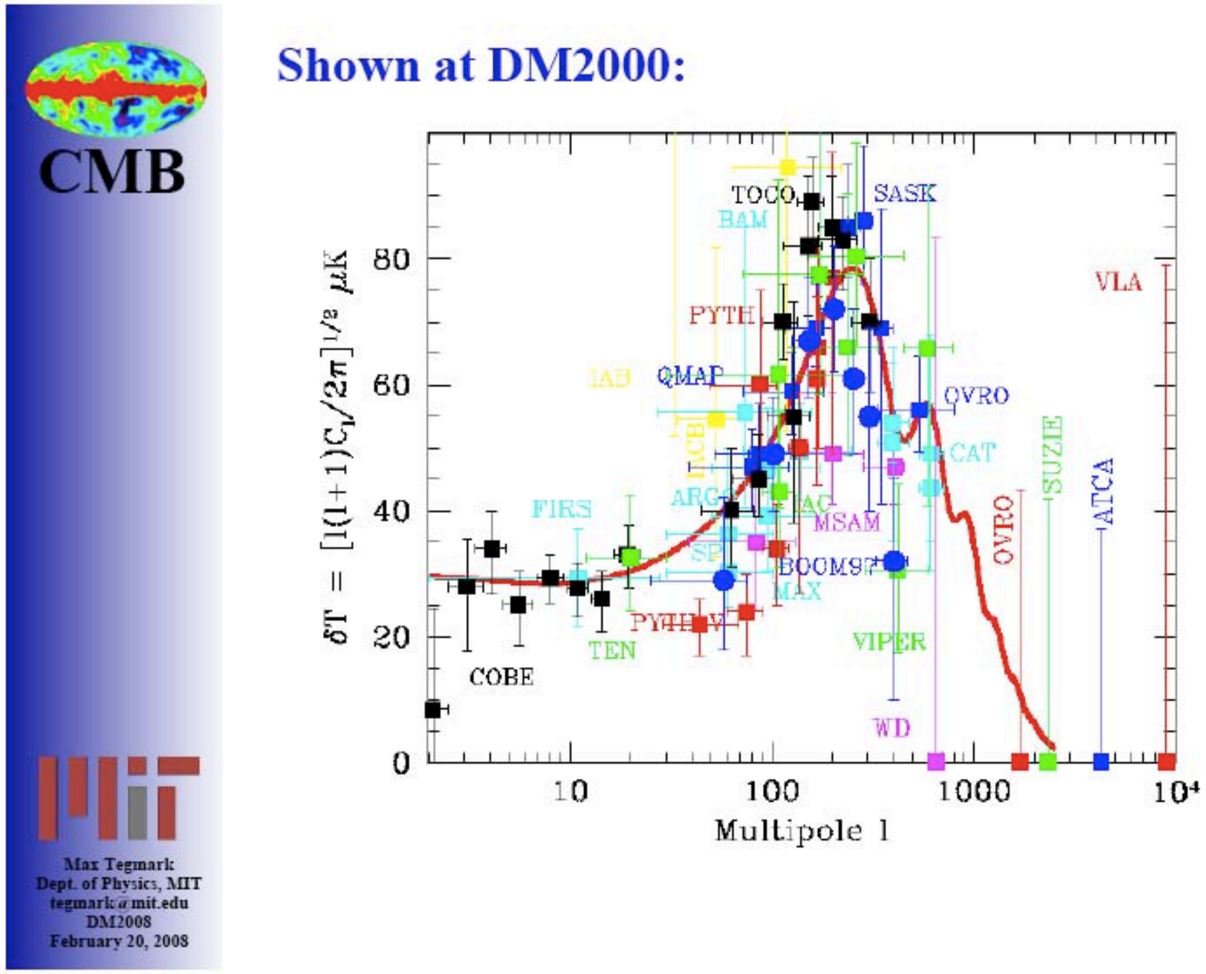
Precision cosmology and the dark universe
Current Observations on w
Large Telescopes and New Theory
Special Topic: Ten years of dark energy
Theories of dark energy and near term probes of w
Search for axions
Cold and warm dark matter models in the galaxy
Indirect search for dark matter
SUSY models of dark matter and direct search sensitivity
Direct and indirect search for dark matter results
Motivation for large detectors and plans for large detectors

FOCUS OF THIS PRESENTATION

Tegmark - CMB, SDSS, Redshifted 21cm
Roszkowski, Barger - SUSY WIMPS
Edsjö - WIMP Annihilation Internal Bremsstrahlung
Finkbeiner/Hooper - WMAP Haze
Mohapatra - New CDMS Limits on WIMPs
and brief reports on COUPP, LUX

MAX TEGMARK

CMB progress



Shown at DM2000:

CMB

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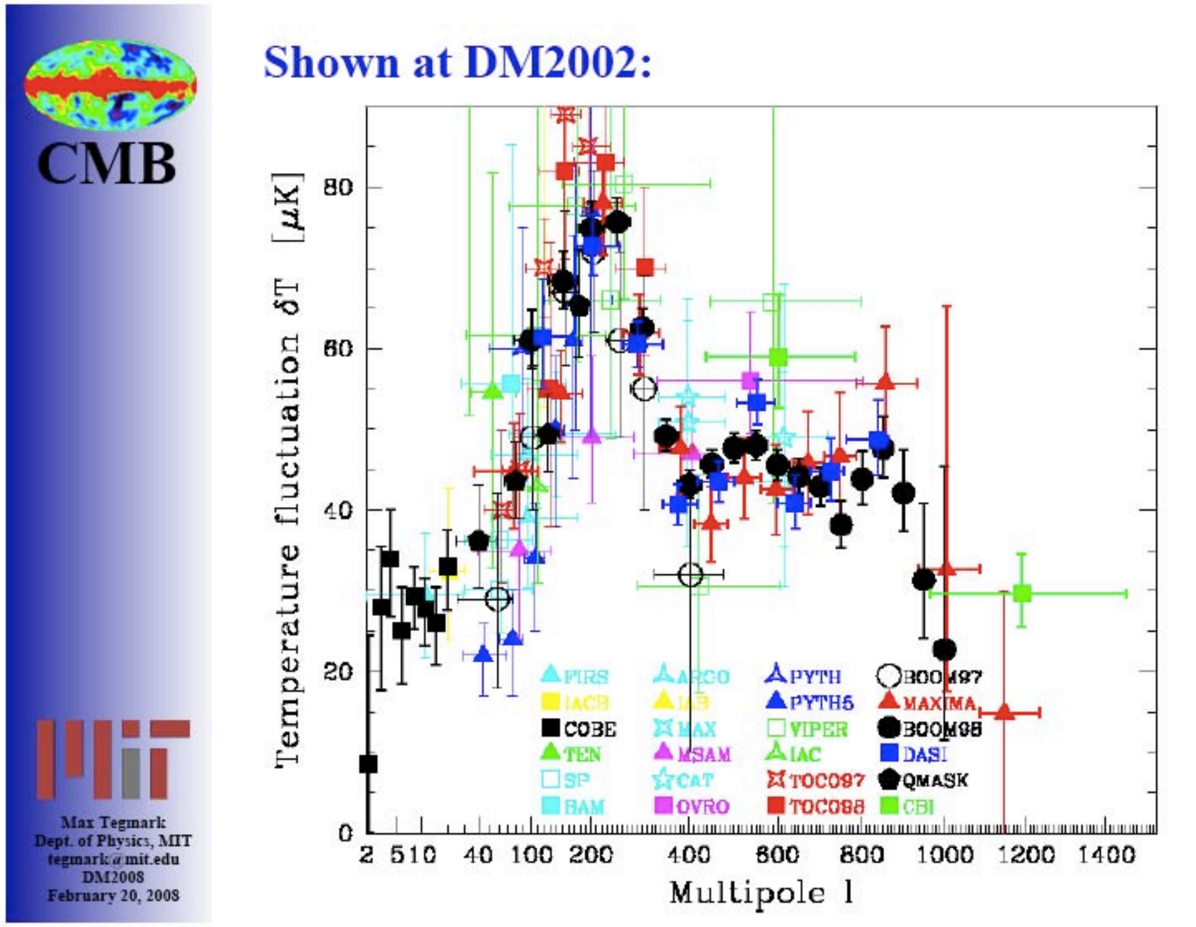
tegmark@mit.edu
DM2008
February 20, 2008



Shown at DM2002:

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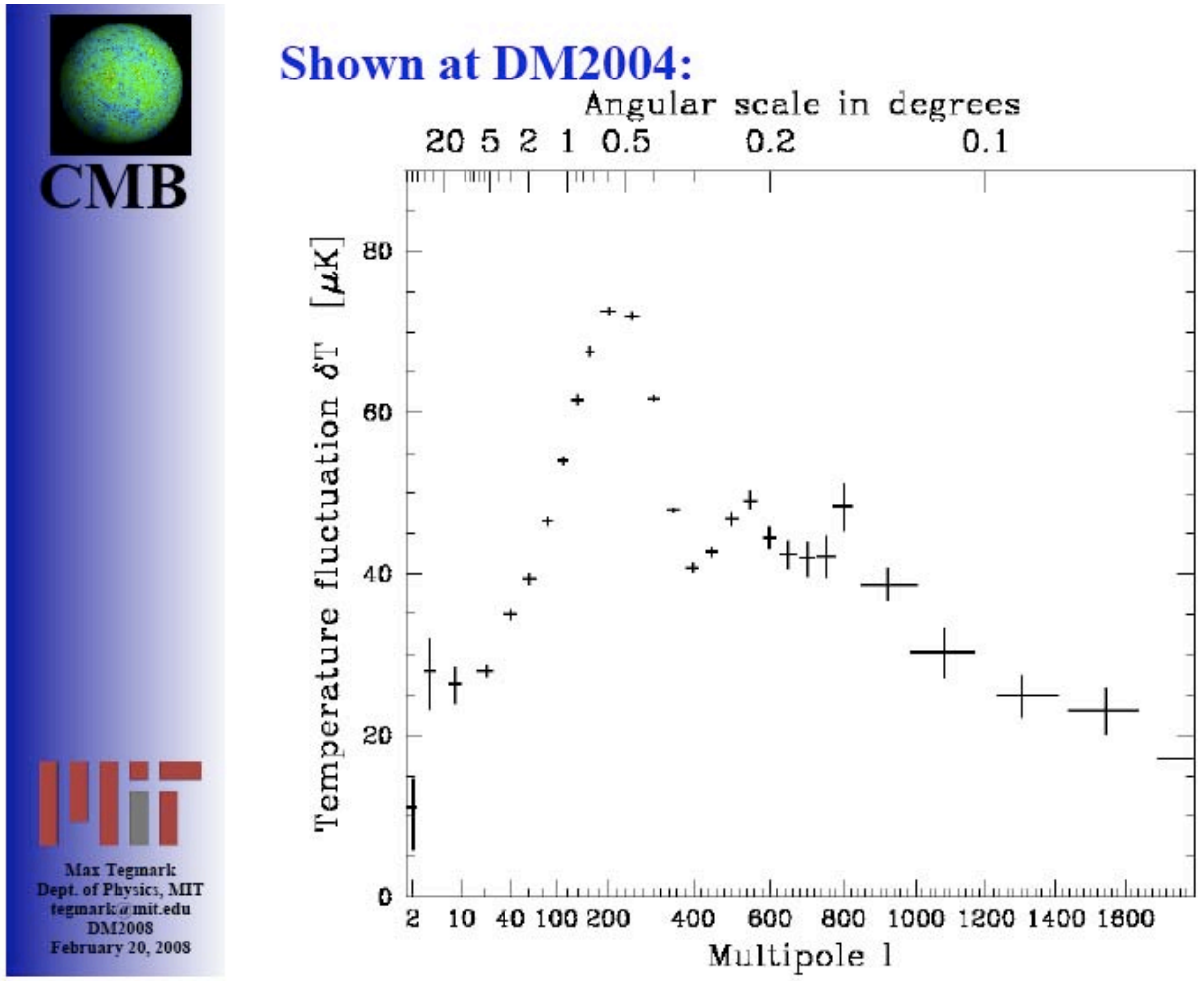

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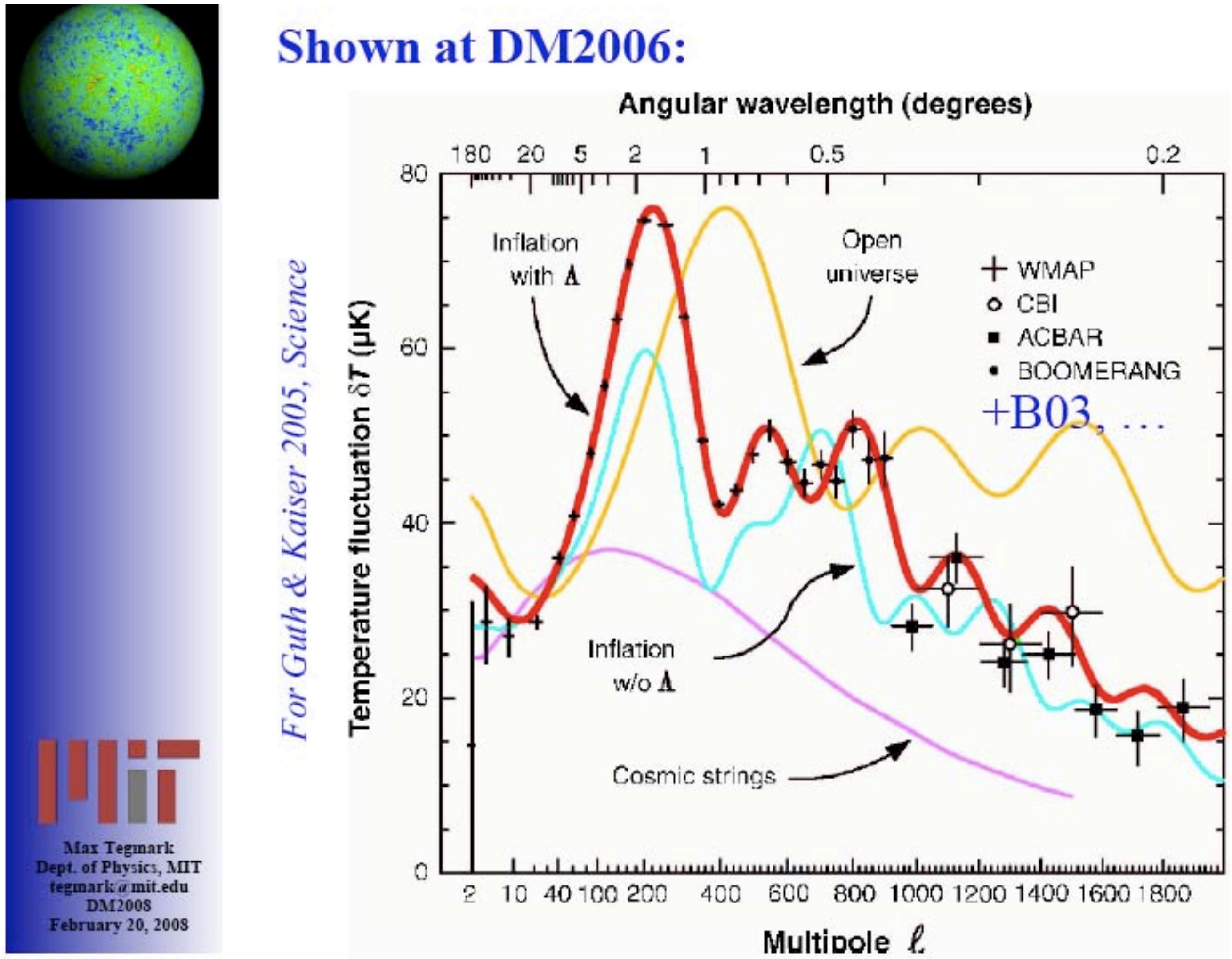

Shown at DM2006:

For Guth & Kaiser 2005, Science

+B03, …

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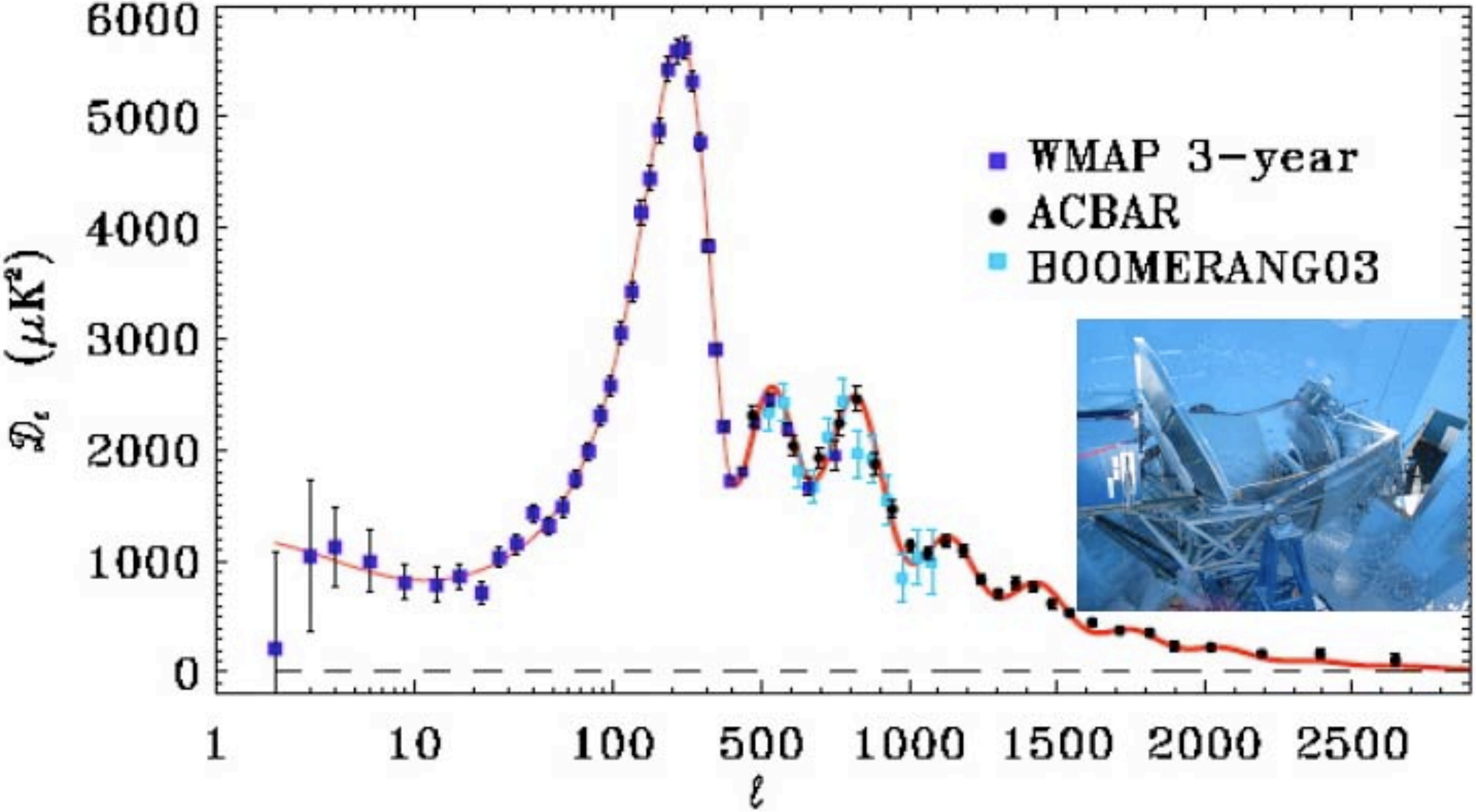
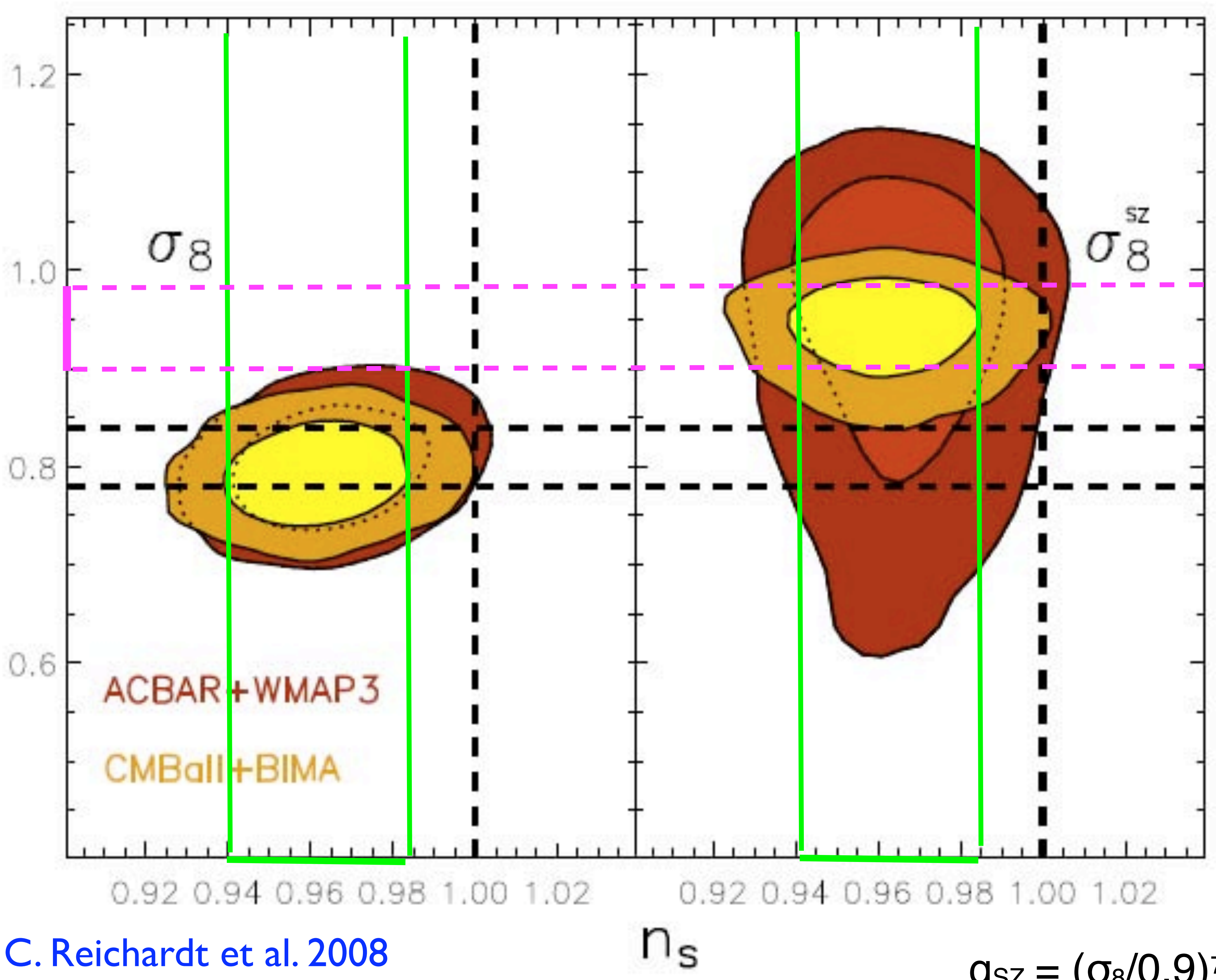
DM2008:

ACBAR = Arcminute Cosmology Bolometer Array Receiver at the South Pole



HIGH RESOLUTION CMB POWER SPECTRUM FROM THE COMPLETE ACBAR DATA SET.

Reichardt et al 2008, arXiv:0801.1491



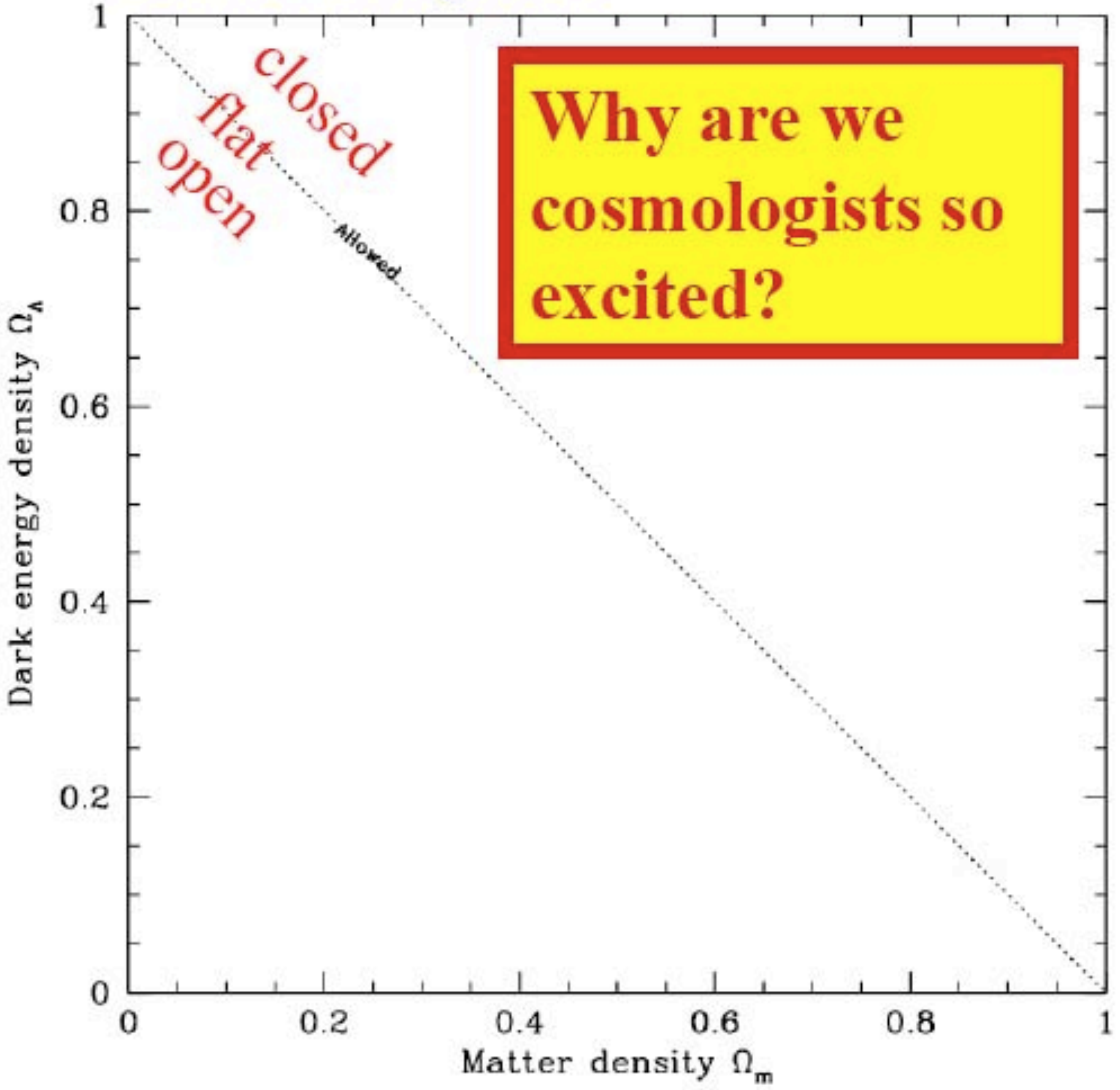
CMBall =
WMAP (TT+TE)
+DASI+VSA
+MAXIMA+CBI
+ACBAR (all TT)
MacTavish et al.06

ACBAR C. Reichardt et al. 2008

$$q_{SZ} = (\sigma_8/0.9)^7(\Omega_b h/0.029)^2$$

The one and two sigma contour intervals for **σ_8** determined from the primary anisotropy component of the CMB (left) with the value inferred from the SZ template transformation of qSZ into σ(SZ) (right), assuming a uniform prior measure in q_{SZ}. These panels also show visually the strength of the deviation of n_s from unity for the flat CDM model.

How flat is space?



Why are we cosmologists so excited?

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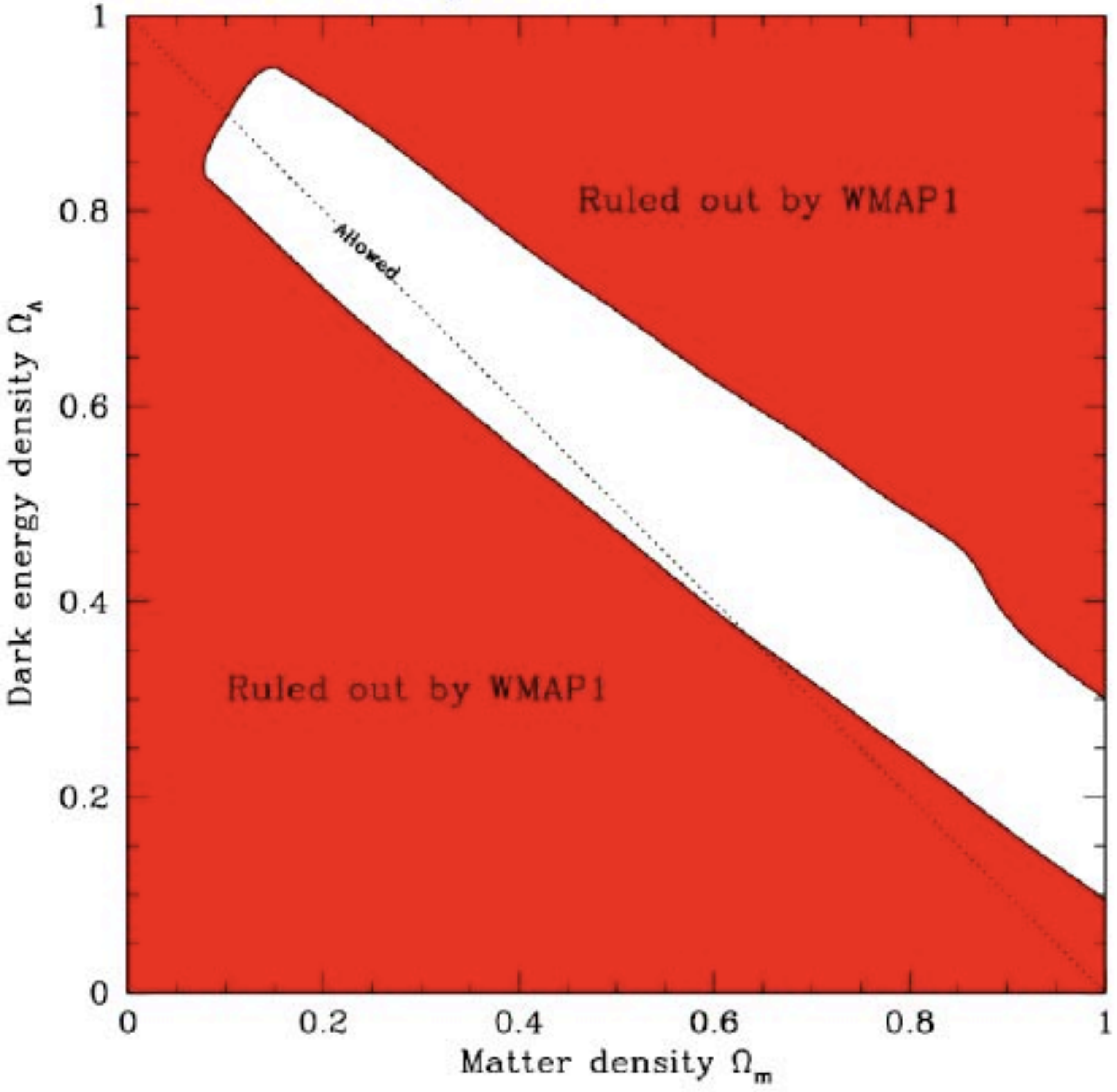
February 20, 2008

How flat is space?



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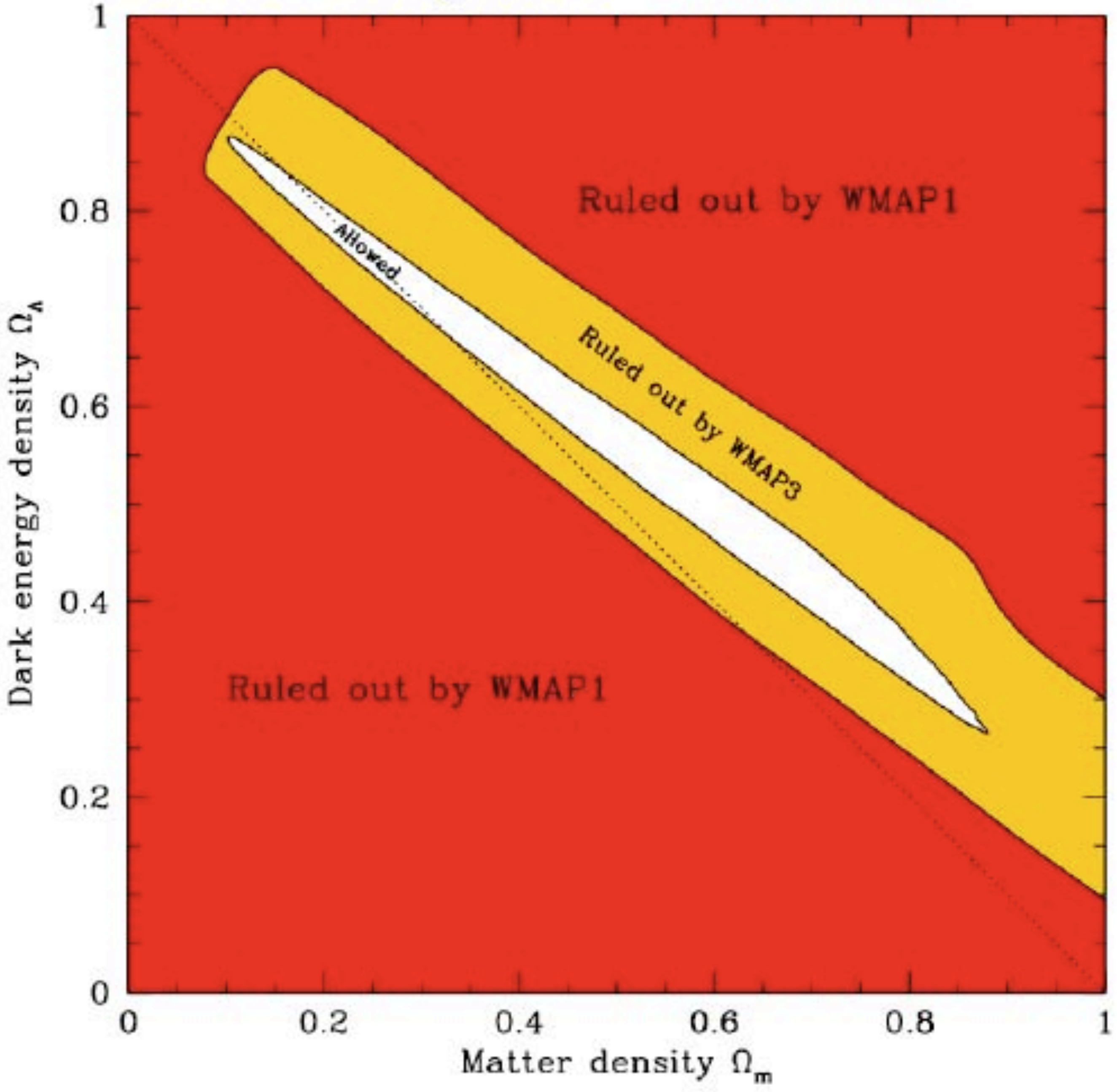
February 20, 2008

How flat is space? Somewhat.



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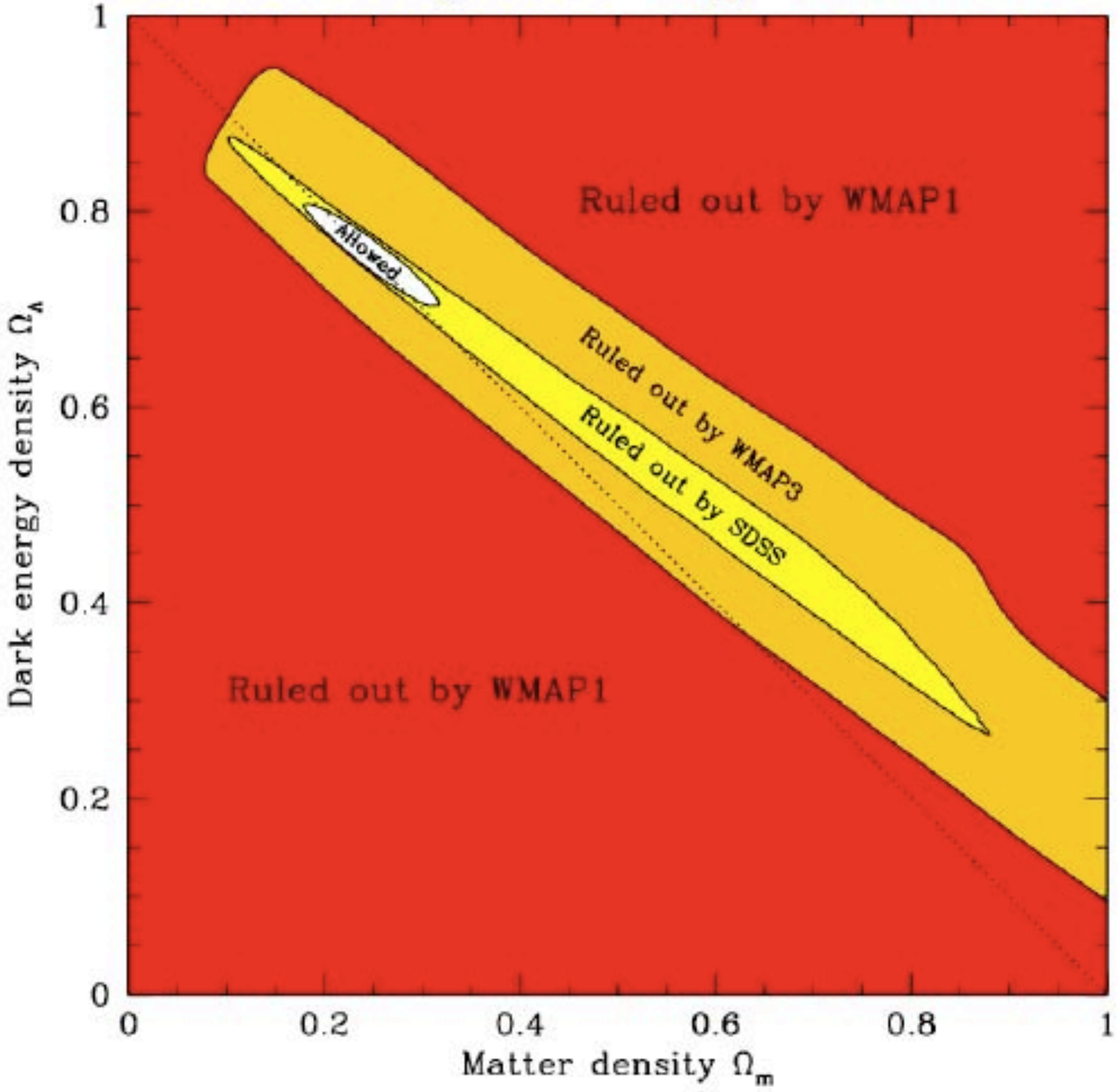
February 20, 2008

How flat is space? $\Omega_{tot}=1.003\pm0.010$



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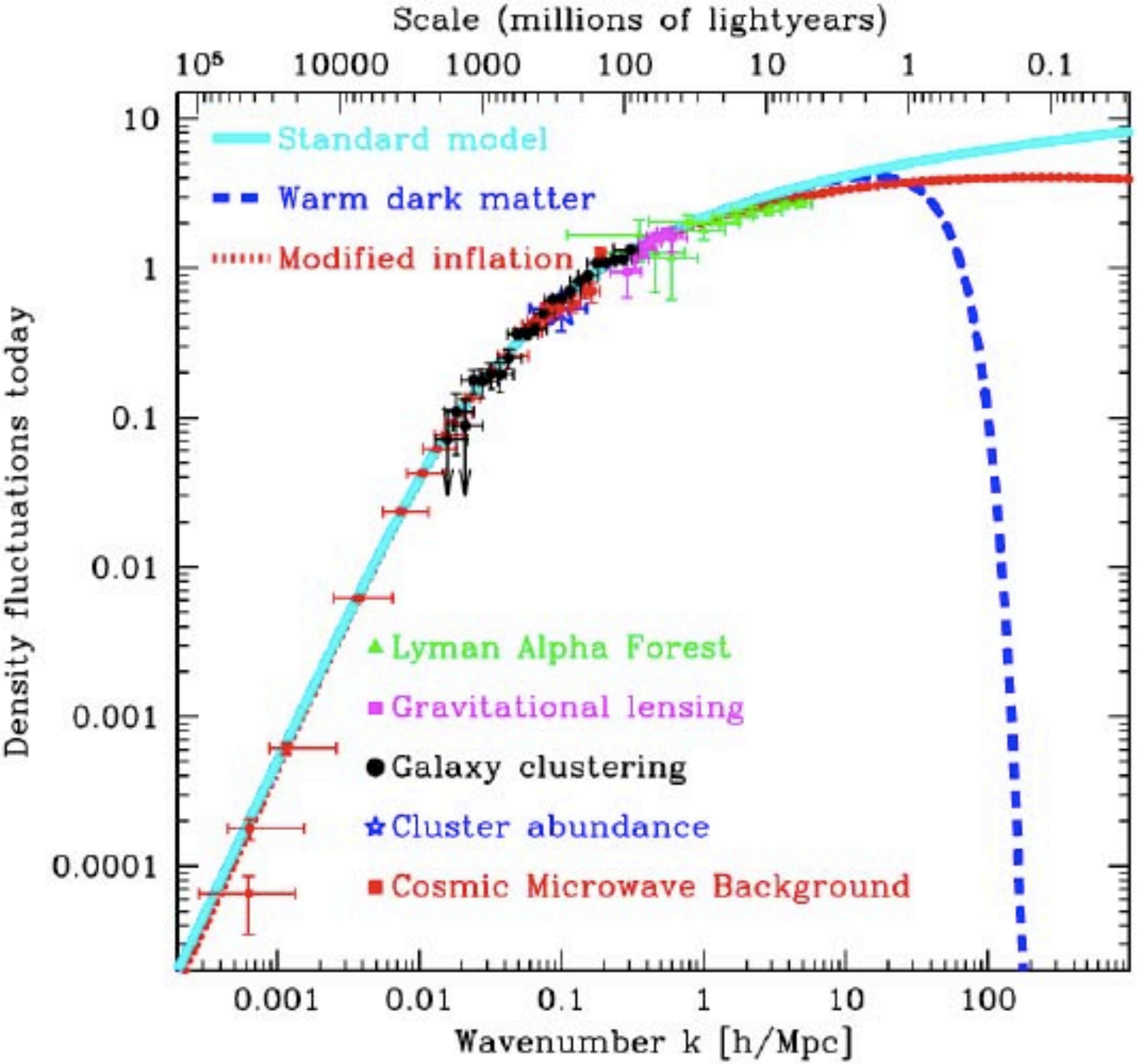
LSS



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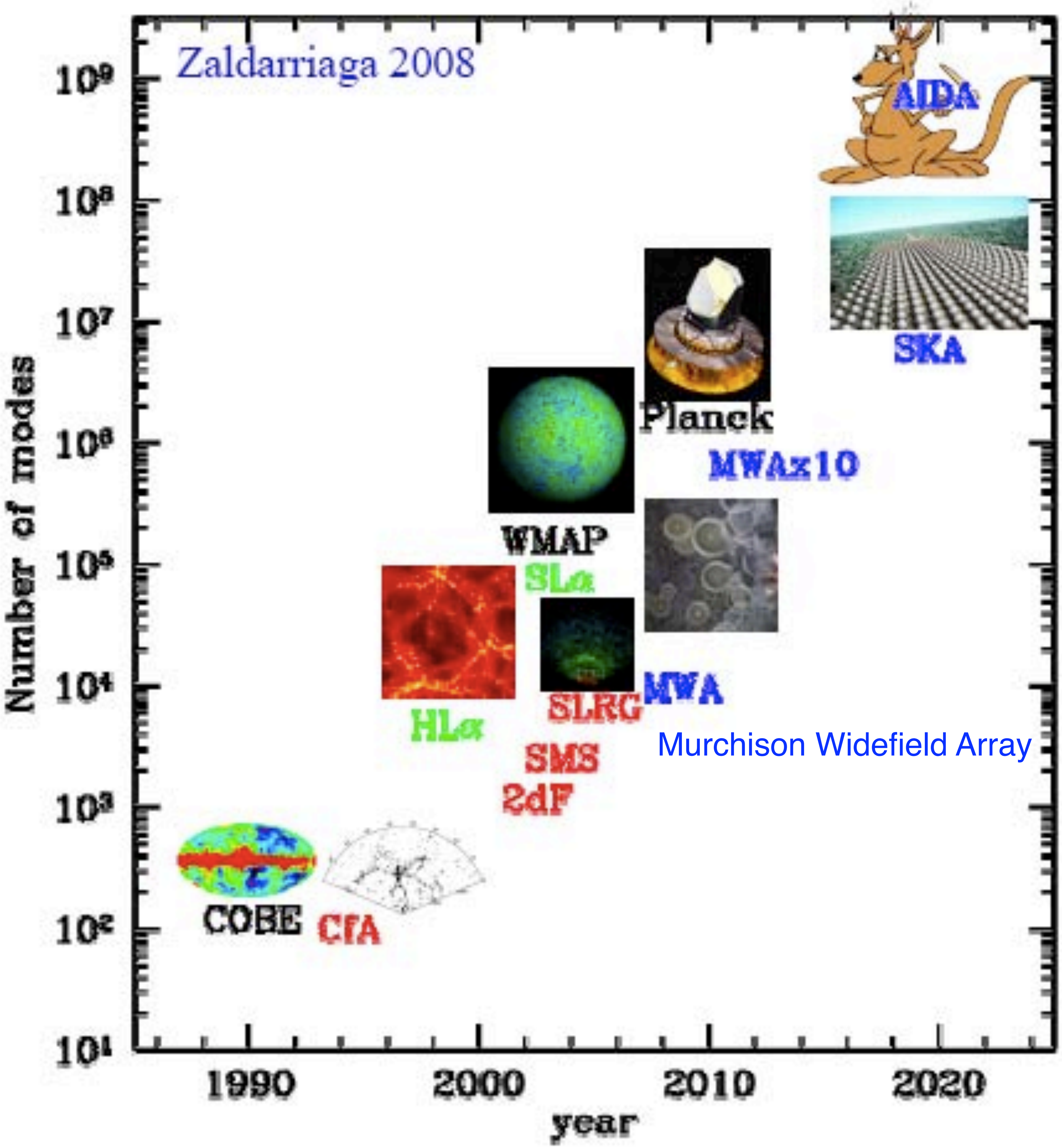


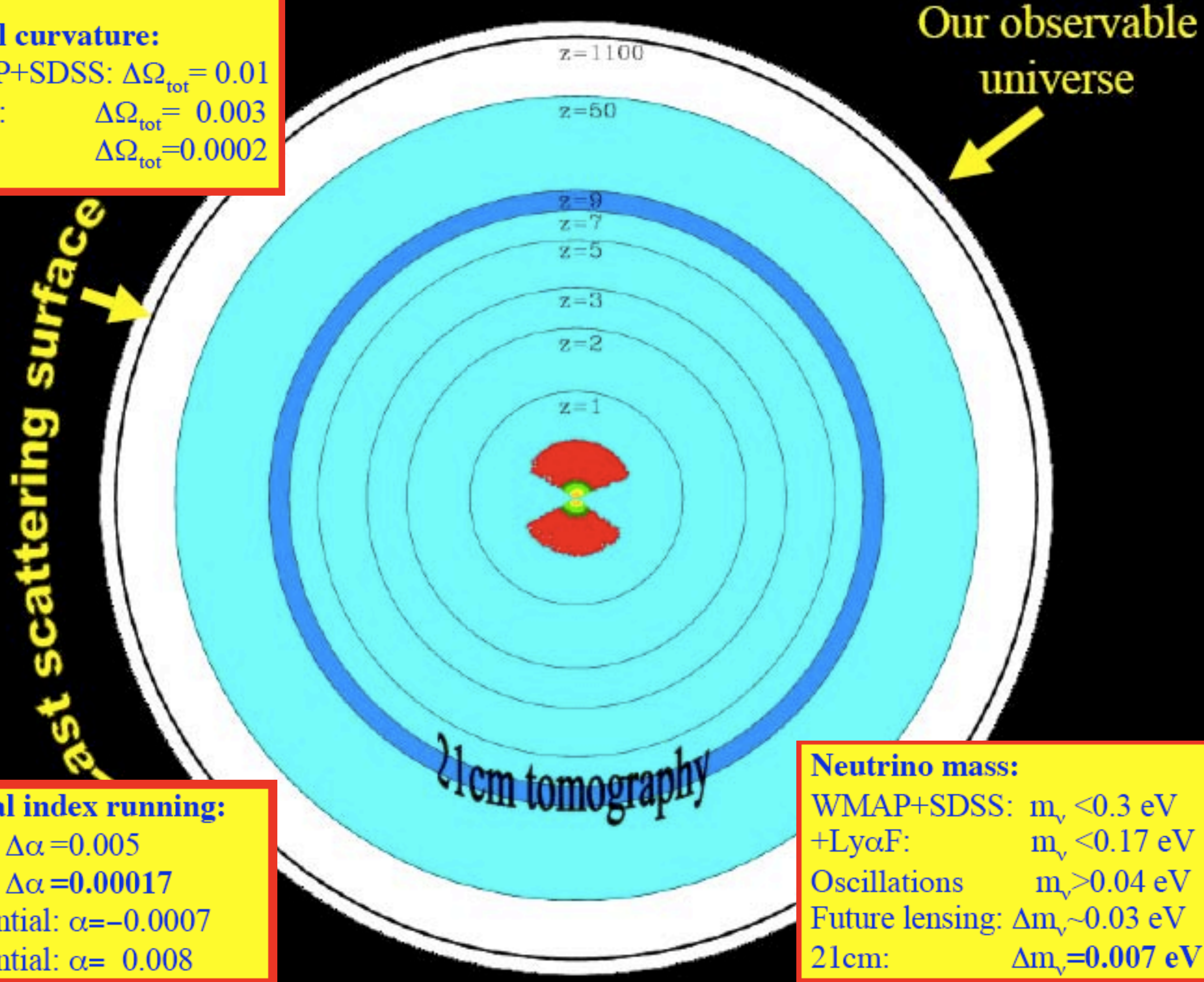
Murchison Widefield Array

Spatial curvature:

WMAP+SDSS: $\Delta\Omega_{tot} = 0.01$

Planck: $\Delta\Omega_{tot} = 0.003$

21cm: $\Delta\Omega_{tot} = 0.0002$



Spectral index running:

Planck: $\Delta\alpha = 0.005$

21cm: $\Delta\alpha =$ **0.00017**

ϕ^2-potential: $\alpha = -0.0007$

ϕ^4-potential: $\alpha = 0.008$

Neutrino mass:

WMAP+SDSS: $m_\nu < 0.3$ eV

+LyαF: $m_\nu < 0.17$ eV

Oscillations $m_\nu > 0.04$ eV

Future lensing: $\Delta m_\nu \sim 0.03$ eV

21cm: **$\Delta m_\nu = 0.007$ eV**

small scale issues

Joel Primack
UC Santa Cruz

Satellites

The discovery of many faint Local Group dwarf galaxies is consistent with ΛCDM predictions. Reionization, lensing, satellites, and Lyα forest data imply that WDM must be Tepid or Cooler.

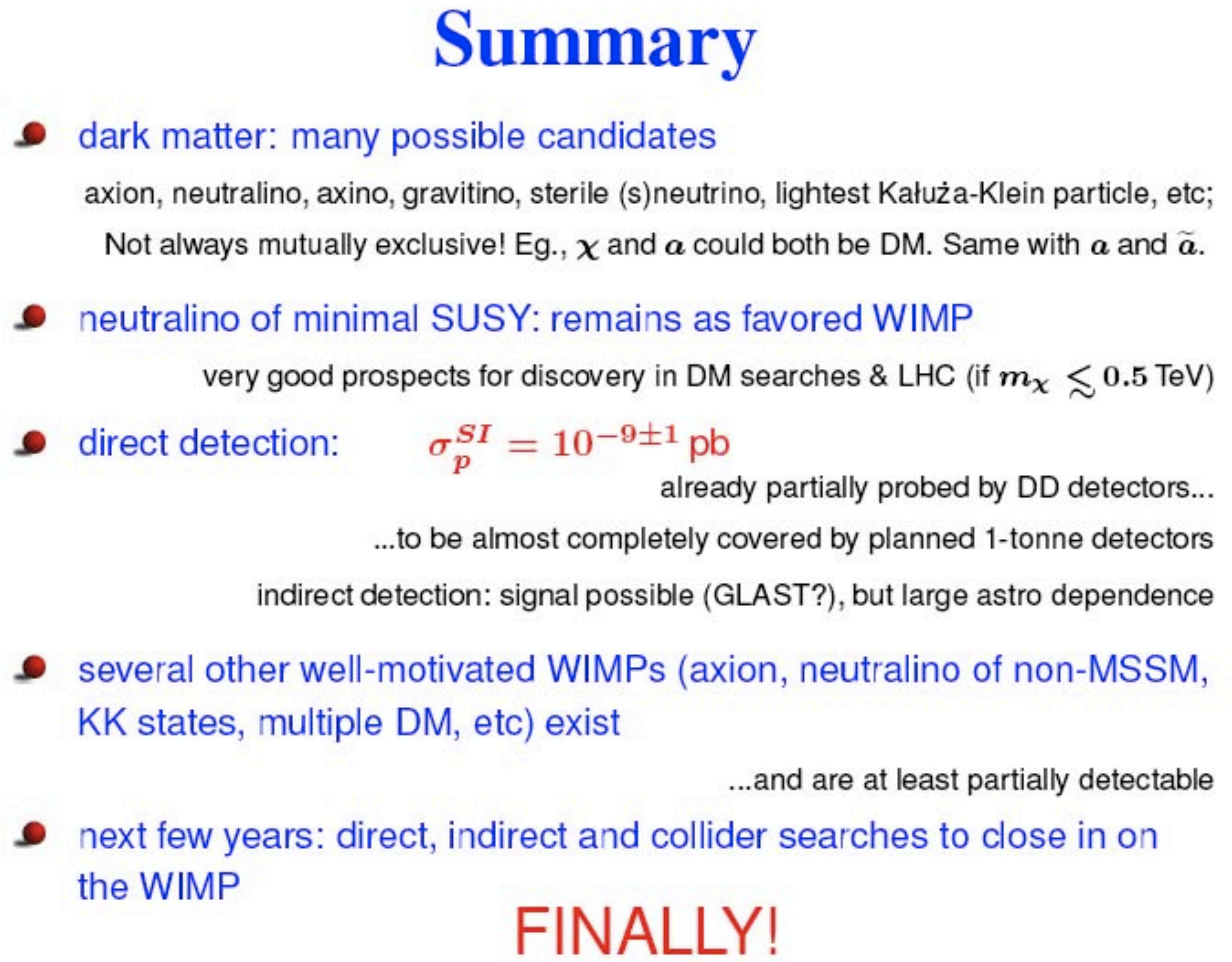
Cusps

The triaxial nature of dark matter halos plus observational biases suggest that observed velocity structure of LSB and dSpiral galaxies are consistent with cuspy ΛCDM halos.

Angular momentum

ΛCDM simulations are increasingly able to form realistic spiral galaxies, as resolution improves and feedback becomes more realistic.

Leszek Roszkowski



Summary

- dark matter: many possible candidates

  axion, neutralino, axino, gravitino, sterile (s)neutrino, lightest Kałuża-Klein particle, etc;

  Not always mutually exclusive! Eg., χ and a could both be DM. Same with a and $\widetilde{a}$.

- neutralino of minimal SUSY: remains as favored WIMP

  very good prospects for discovery in DM searches & LHC (if $m_\chi \lesssim 0.5$ TeV)

- direct detection: $\sigma_p^{SI} = 10^{-9\pm1}$ pb

  already partially probed by DD detectors...

  ...to be almost completely covered by planned 1-tonne detectors

  indirect detection: signal possible (GLAST?), but large astro dependence

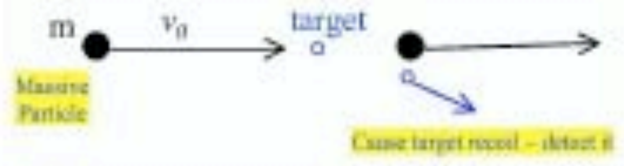
- several other well-motivated WIMPs (axion, neutralino of non-MSSM, KK states, multiple DM, etc) exist

  ...and are at least partially detectable

- next few years: direct, indirect and collider searches to close in on the WIMP

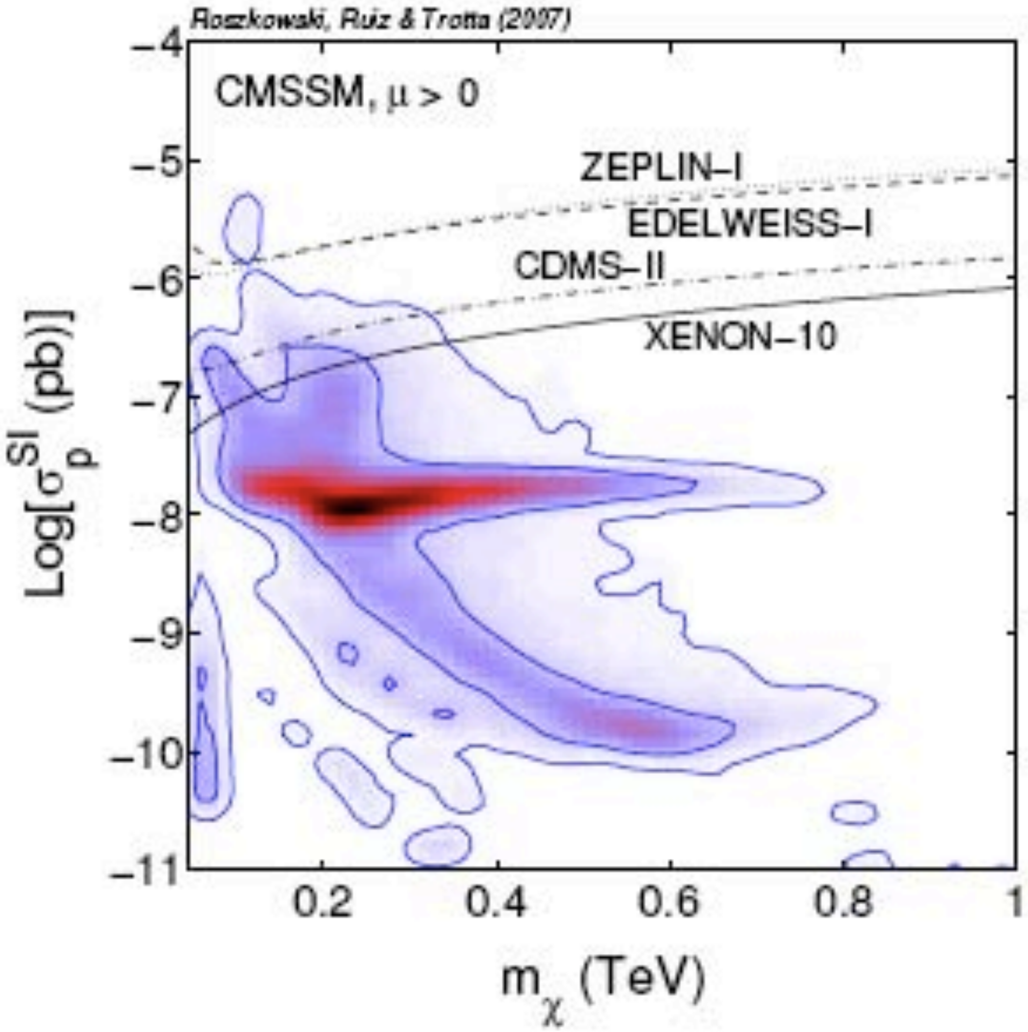
FINALLY!

CMSSM: Prospects for direct detection



CMSSM: Constrained MSSM

barn=10^{-24} cm^2, pb = 10^{-12} b = 10^{-40} m^2



Bayesian analysis, flat priors (MCMC)

XENON-10 (June 07): $\sigma_p^{SI} \lesssim 10^{-7}$ pb:

also CDMS–II, Zeplin–III (?)

⇒ already explore 68% region

(large $m_0 \gg m_{1/2}$ ⇒ heavy squarks) largely beyond LHC reach

ultimately: "1 tonne" detectors: $\sigma_p^{SI} \lesssim 10^{-10}$ pb

will cover all 68% region

internal (external): 68% (95%) region

most probable range: 10^{-8} pb $\lesssim \sigma_p^{SI} \lesssim 10^{-10}$ pb

partly outside of the LHC reach ($m_\chi \lesssim 0.4 - 0.5$ TeV)

⇒ direct detection: prospects look very good

Positron flux and PAMELA

- E_{e^+} from from DM annihilations
- propagate in interstellar magnetic field

$$K(\epsilon) = 2.1 \times 10^{28} \epsilon^{0.6} \mathrm{cm}^2\,\mathrm{sec}^{-1}$$

$$\epsilon = E_{e^+} / 1\,\mathrm{GeV}$$

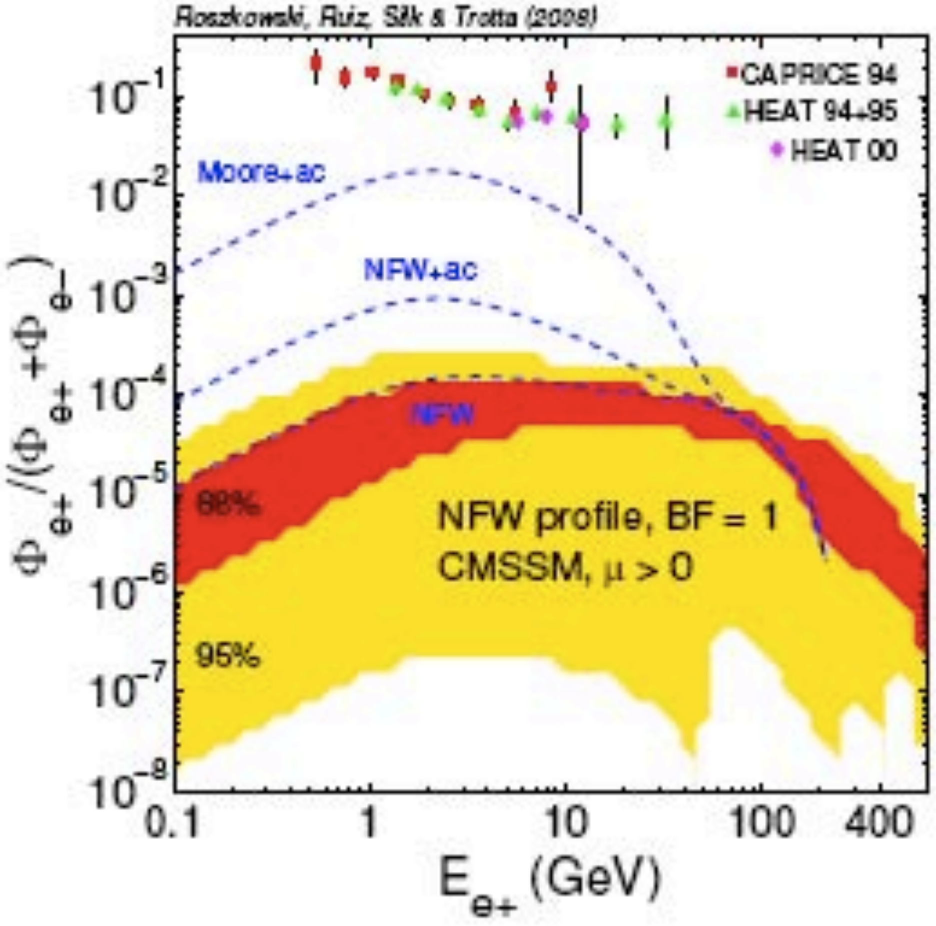
- much less halo model dependence
- loose energy via inverse Compton scattering

$$b(\epsilon) = \frac{\epsilon^2}{\tau_E} \approx 10^{-16} \epsilon^2\,\mathrm{sec}^{-1}$$

$$\tau_E = 10^{16}\,\mathrm{sec}^{-1}$$

- diffusion zone:
  infinite slab of height $L = 4\,\mathrm{kpc}$, free escape BC's

NFW + adiab. compression


Roszkowski, Ruiz, Silk & Trotta (2008)

$\Rightarrow$ CMSSM: prospects for PAMELA rather poor

(...unless extremely large boost factor, $\gtrsim 10^3$ for NFW)

true more generally in MSSM, (Baltz + Edsjo '98)

Dark Matter
and Terascale Physics

V. Barger

The Gold Standard: mSUGRA

- SUSY stabilizes radiative corrections to the Higgs mass and realizes GUT unification of electroweak and strong couplings
- Weird quantum numbers of particles explained by 16 representation of SO(10)

- mSUGRA: SUSY broken by gravity
  - predictive--small number of parameters: $m_0, m_{1/2}, A_0, \tan\beta, sign(\mu)$

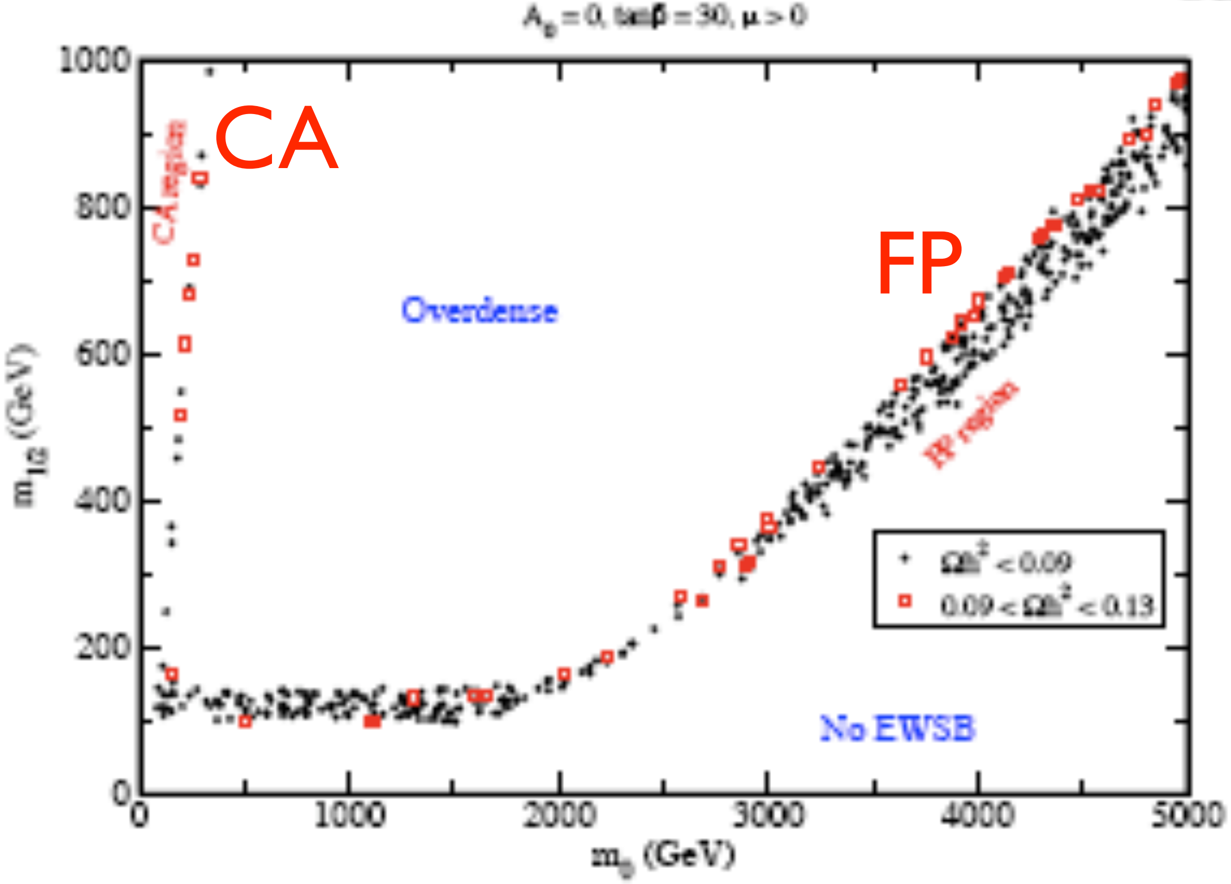
- Find well defined regions of parameter space consistent with the relic density from WMAP

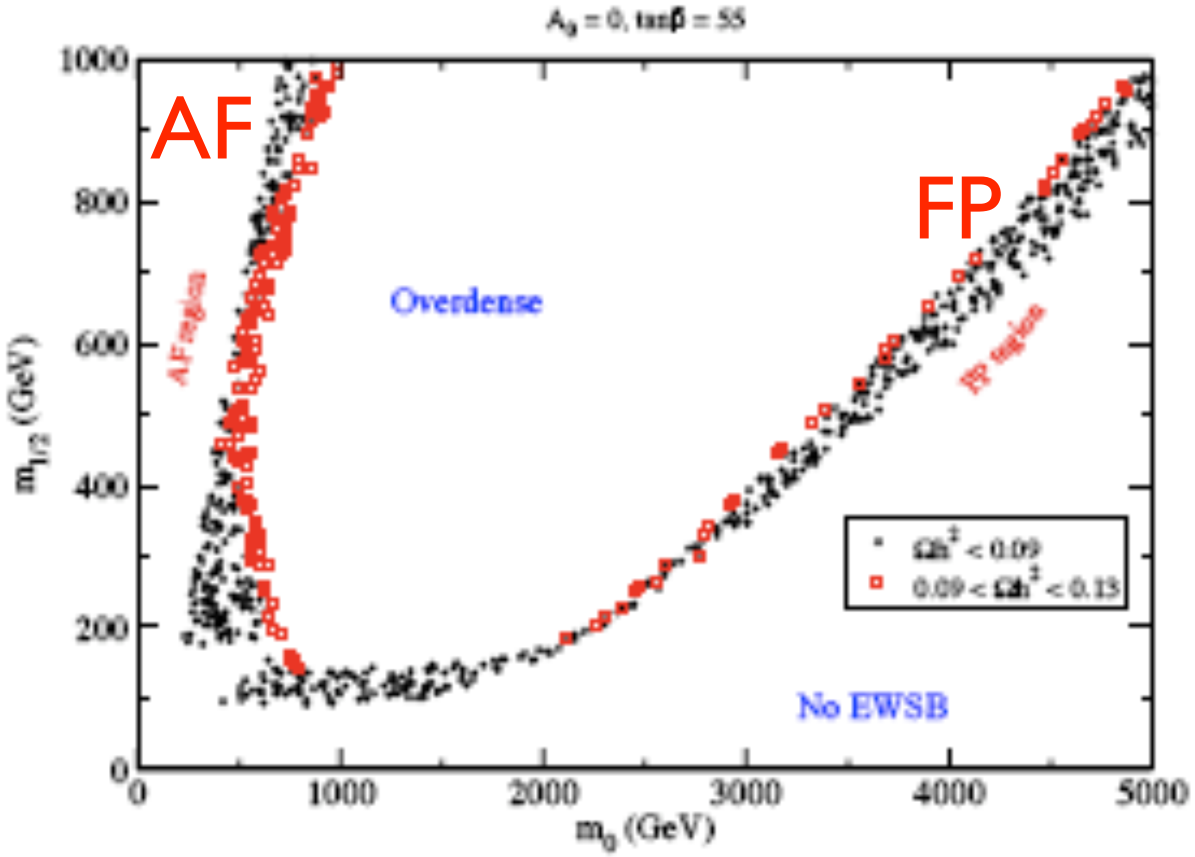
$$0.099 < \Omega_{DM} h^2 < 0.123 \ (2\sigma)$$

- DM is associated with EWSB
  - weak scale cross section naturally gives Ω_{CDM}

mSUGRA parameter space

- Representative regions in mSUGRA parameter space (red points fully account for $\Omega_{\rm CDM}$)





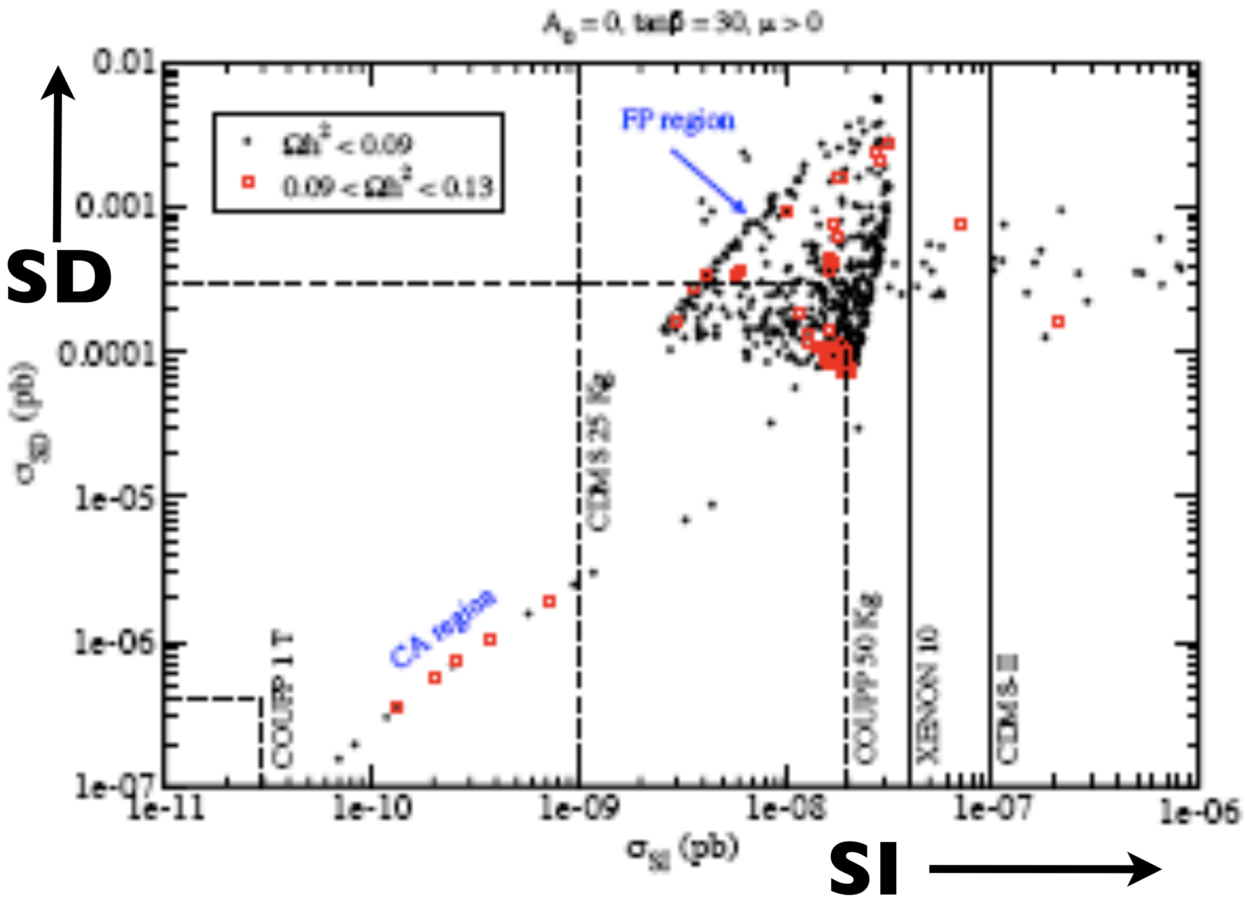
- Focus Point (FP) region: high mass scalar fermions

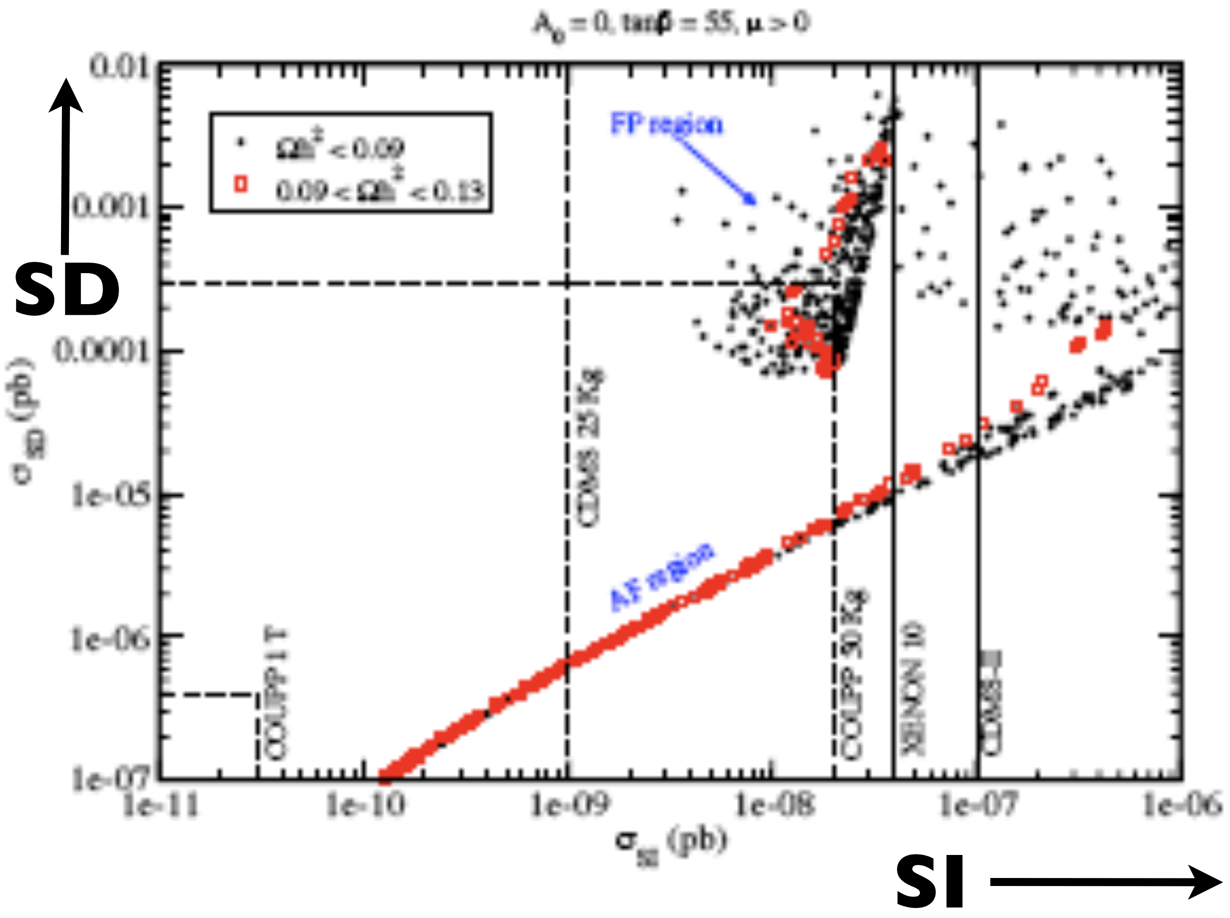
  Preferred by $b-\tau$ unification
  Solves SUSY FCNC and CP-violating problems

- A-funnel (AF) region: annihilation through CP-odd Higgs (A)
- $\tilde{\tau} - \chi_1^0$ coannihilation (CA) region
- Bulk region (BR) at low $m_0, m_{1/2}$ nearly excluded

Scattering rates in mSUGRA

- Different solutions to DM relic density populate different regions of σ_{SD} vs. σ_{SI} Spin Dependent vs. Spin Indenepdent





- FP region can be verified or disproved by both SD and SI measurements
- Detection in FP region would be of major significance for colliders (high mass scalars)

Conclusions

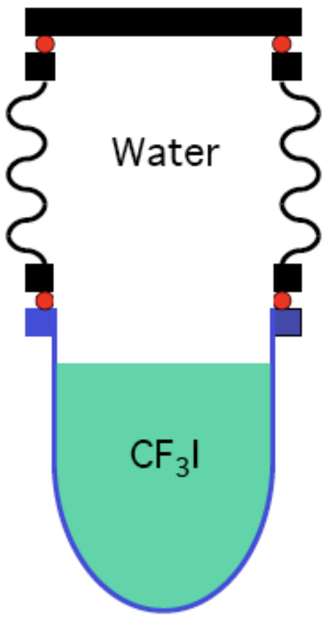
- Both LHC and direct detection experiments can discover WIMP dark matter and reveal its properties
- SD vs. SI cross section: an excellent DM model diagnostic
- Of all models, only the FP region of mSUGRA predicts large SD scattering:
  - SD due to large Higgsino asymmetry of Z-coupling
  - DM particle has mixed Higgsino-Bino composition
  - Large SD also necessary for significant DM capture by the Sun

Early Results from COUPP

Andrew Sonnenschein

Fermilab

Results from 2006 Run

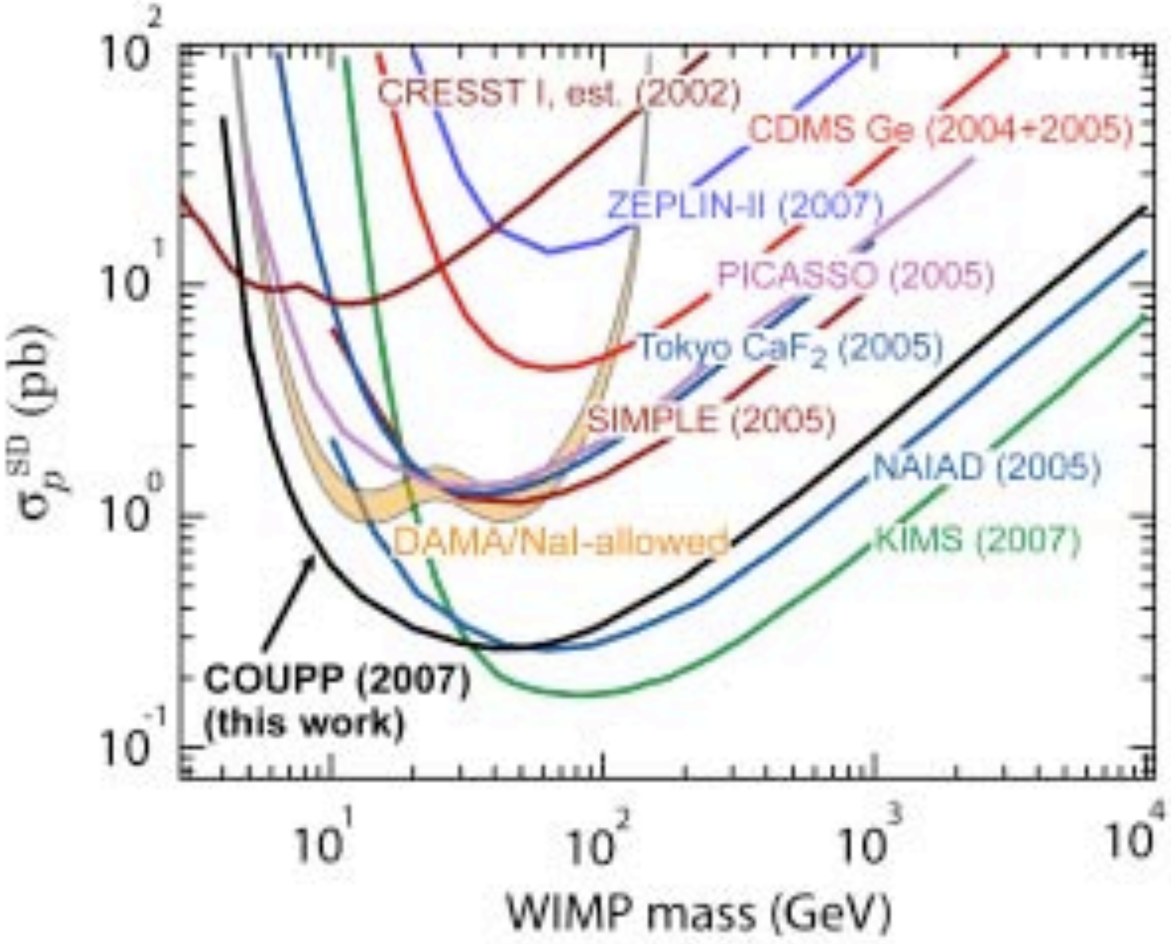


2 kg

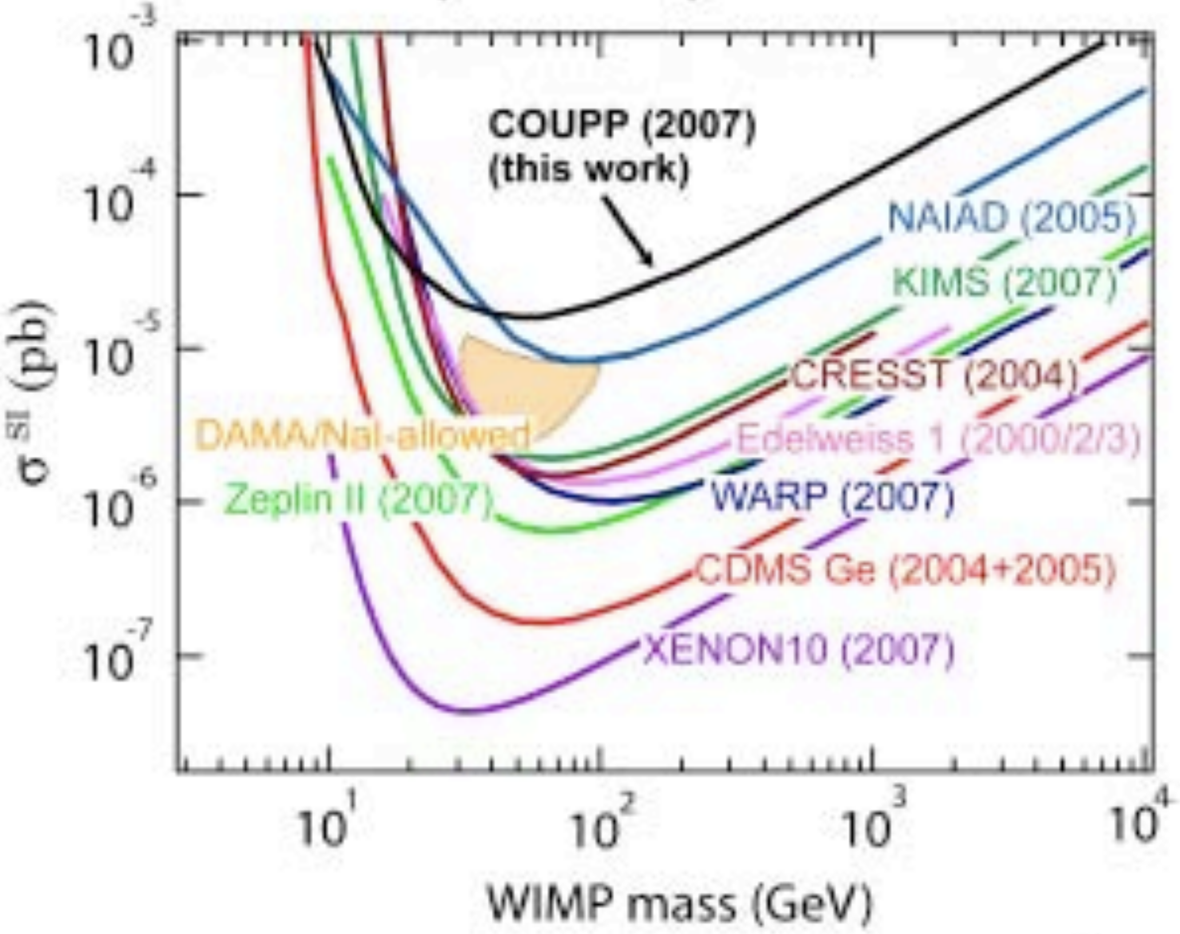
20 &
60 kg
in 2009

- We have competitive sensitivity for spin-dependent scattering, despite high radon background
- Now published, *Science, 319: 933-936 (2008).*

Spin-dependent



Spin-independent



New gamma ray contributions
to supersymmetric dark matter annihilations

Joakim Edsjö
Stockholm University
edsjo@physto.se

in collaboration with T. Bringmann and L. Bergström

arXiv: 0710.3169, JHEP 01 (2008) 049

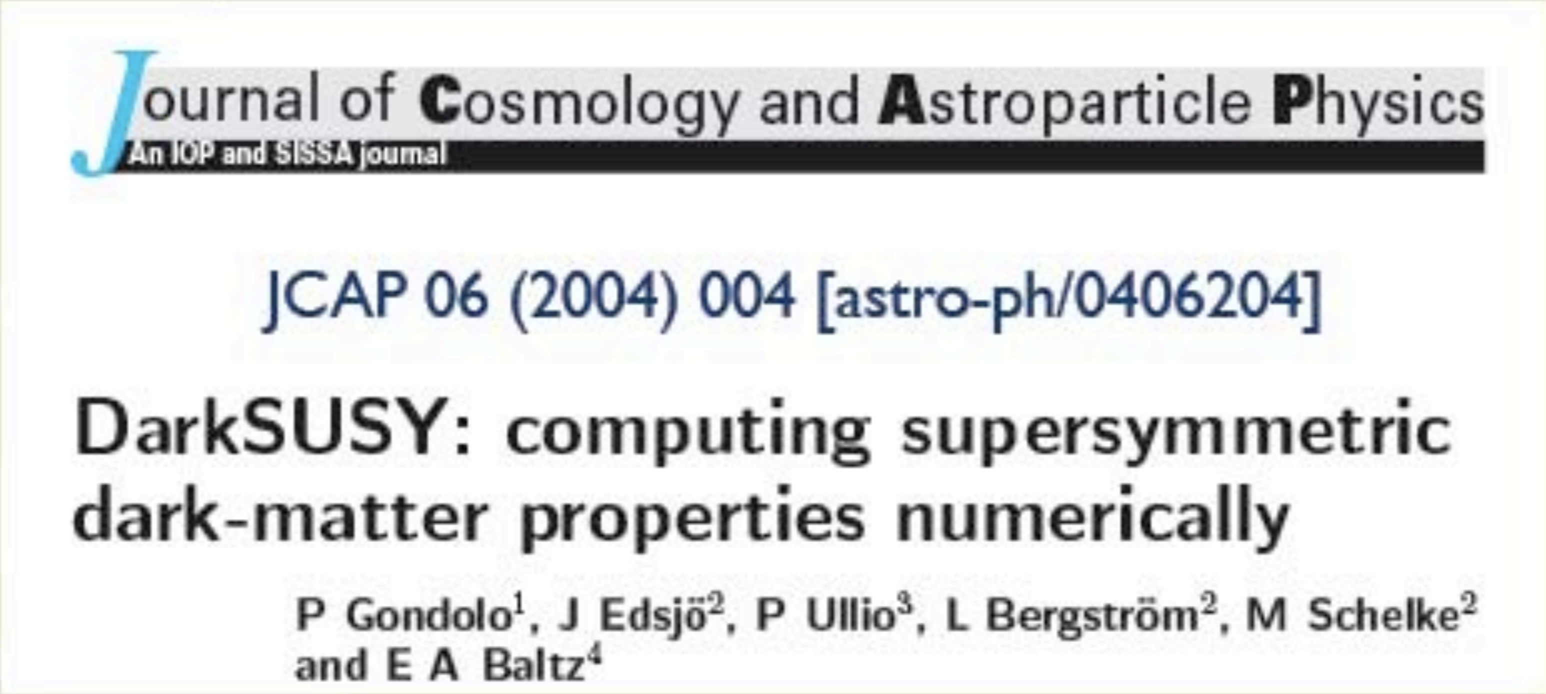
February ~~21~~ 22, 2008 @ DM08

Dark SUSY

P. Gondolo, J. Edsjö, P. Ullio,
L. Bergström, M. Schelke
and E.A. Baltz

4.2 coming soon!

Version 4.1 available now



Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal

JCAP 06 (2004) 004 [astro-ph/0406204]

DarkSUSY: computing supersymmetric dark-matter properties numerically

P Gondolo[1], J Edsjö[2], P Ullio[3], L Bergström[2], M Schelke[2] and E A Baltz[4]

- MSSM or mSUGRA
- Masses and couplings
- Relic density
- Lab constraints
- Rates: neutrino telescopes
- Rates: gamma rays
- Rates: antiprotons, positrons, antideuterons
- Rates: direct detection

www.physto.se/~edsjo/darksusy

Uses FeynHiggs, HDecay and Isasugra.
v4.2 will also use galprop and include final state radiation and neutrino oscillations.

Why gamma rays?

- Rather high rates
- No attenuation (except from very close to dense sources)
- Point directly back to the source
- No diffusion model uncertainties as for charged particles
- There can be clear spectral signatures to look for

Annihilation to gamma rays

- **Monochromatic**
  At loop-level, annihilation can occur to

$$\gamma\gamma \quad \Rightarrow \quad E_\gamma = m_\chi$$

$$Z\gamma \quad \Rightarrow \quad E_\gamma = m_\chi - \frac{m_Z^2}{4m_\chi}$$

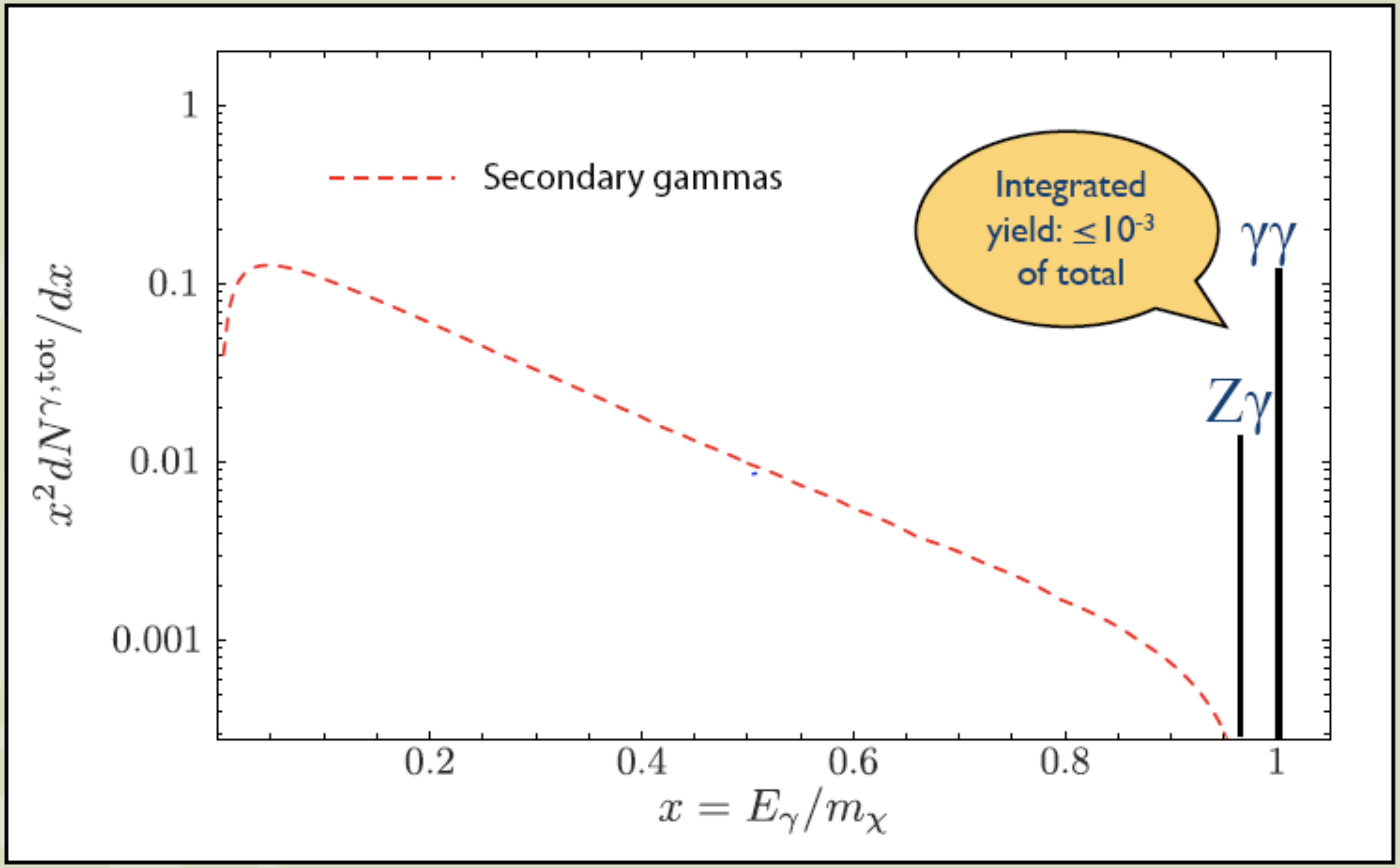
Features
- directionality – no propagation uncertainties
- low fluxes, but clear signature
- strong halo profile dependence

- **Continuous**
  WIMP annihilation can also produce a continuum of gamma rays

$$\chi\chi \to \cdots \to \pi^0 \to \gamma\gamma$$

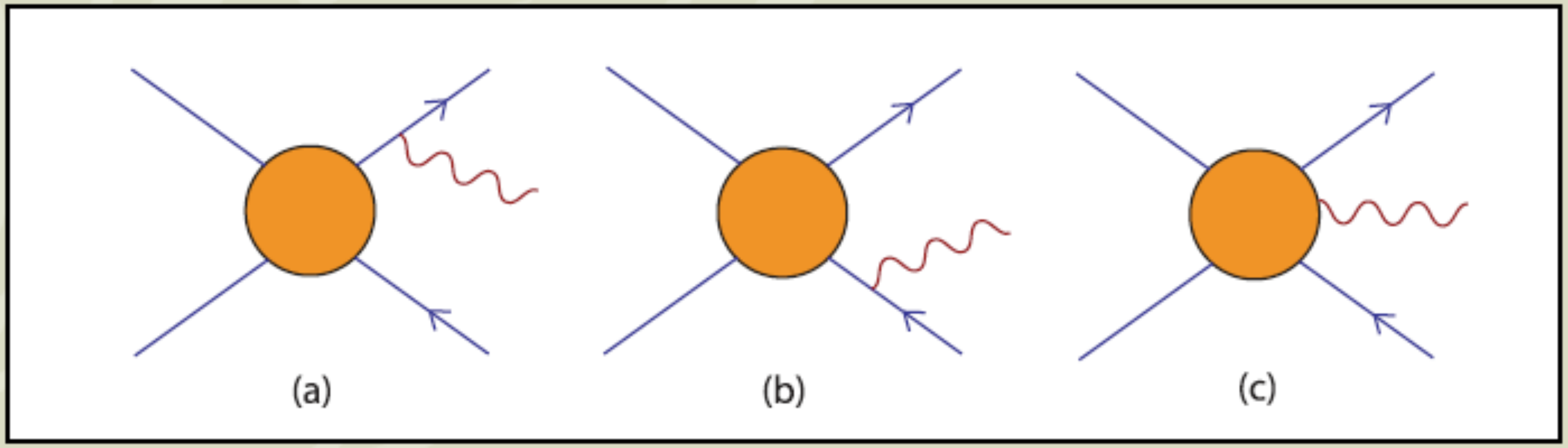
Features (compared to lines)
- lower energy
- more gammas / annihilation
- rather high fluxes
- not a very clear signature

Typical gamma ray spectrum

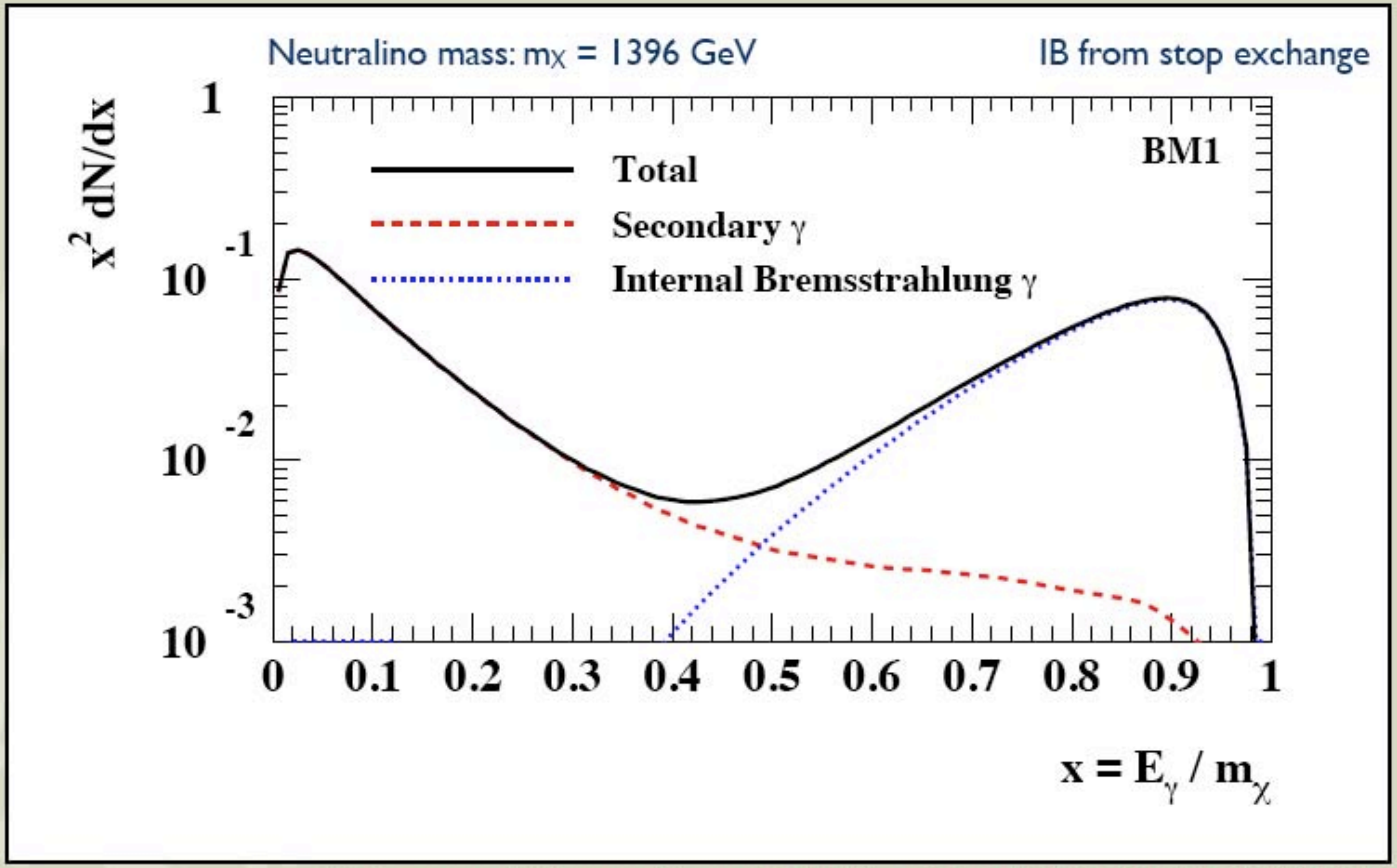


Internal Bremsstrahlung

- Whenever charged final states are present, photons can also be produced in internal bremsstrahlung processes



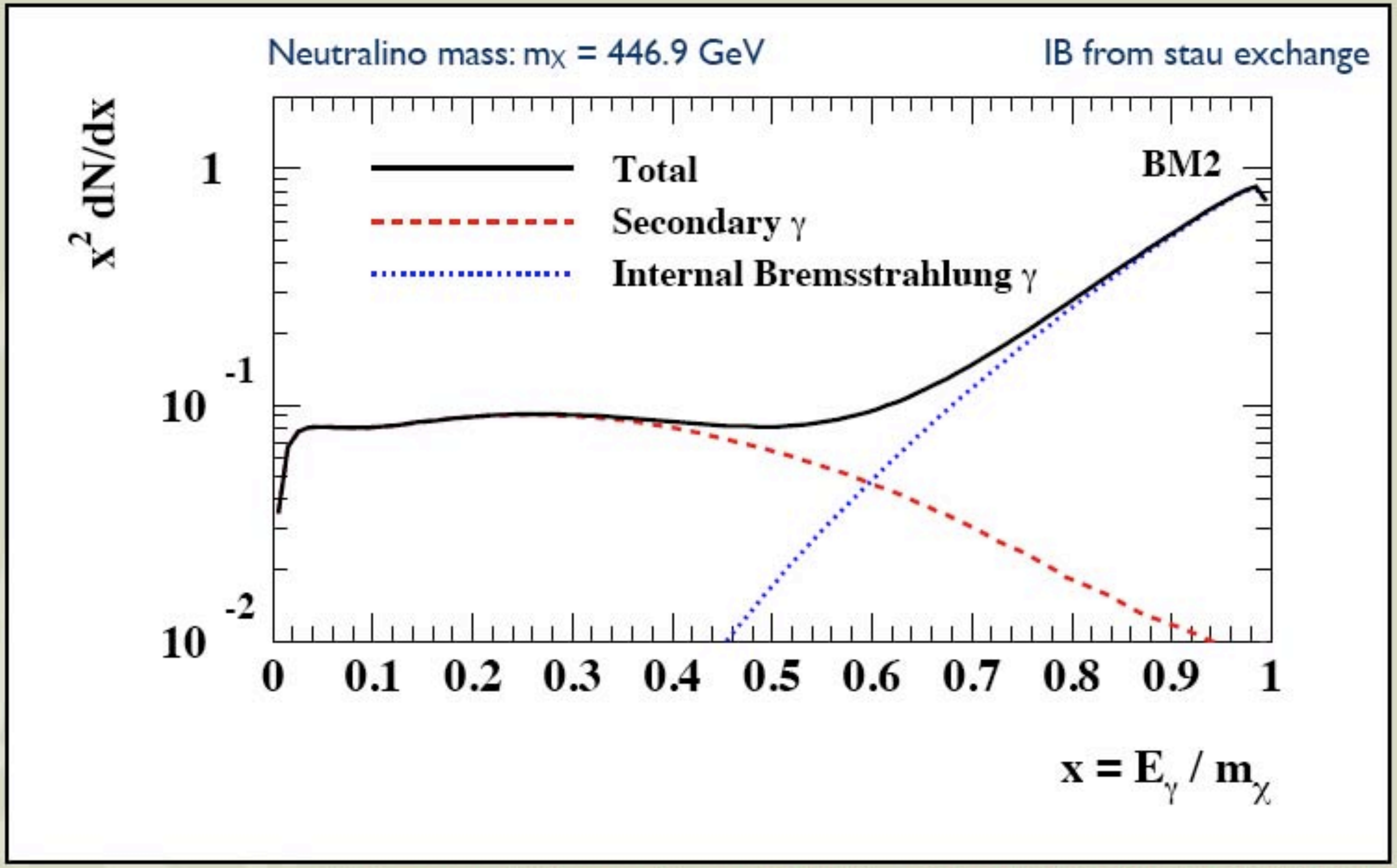
Gamma ray spectrum including IB photons I


Neutralino mass: m_χ = 1396 GeV

IB from stop exchange

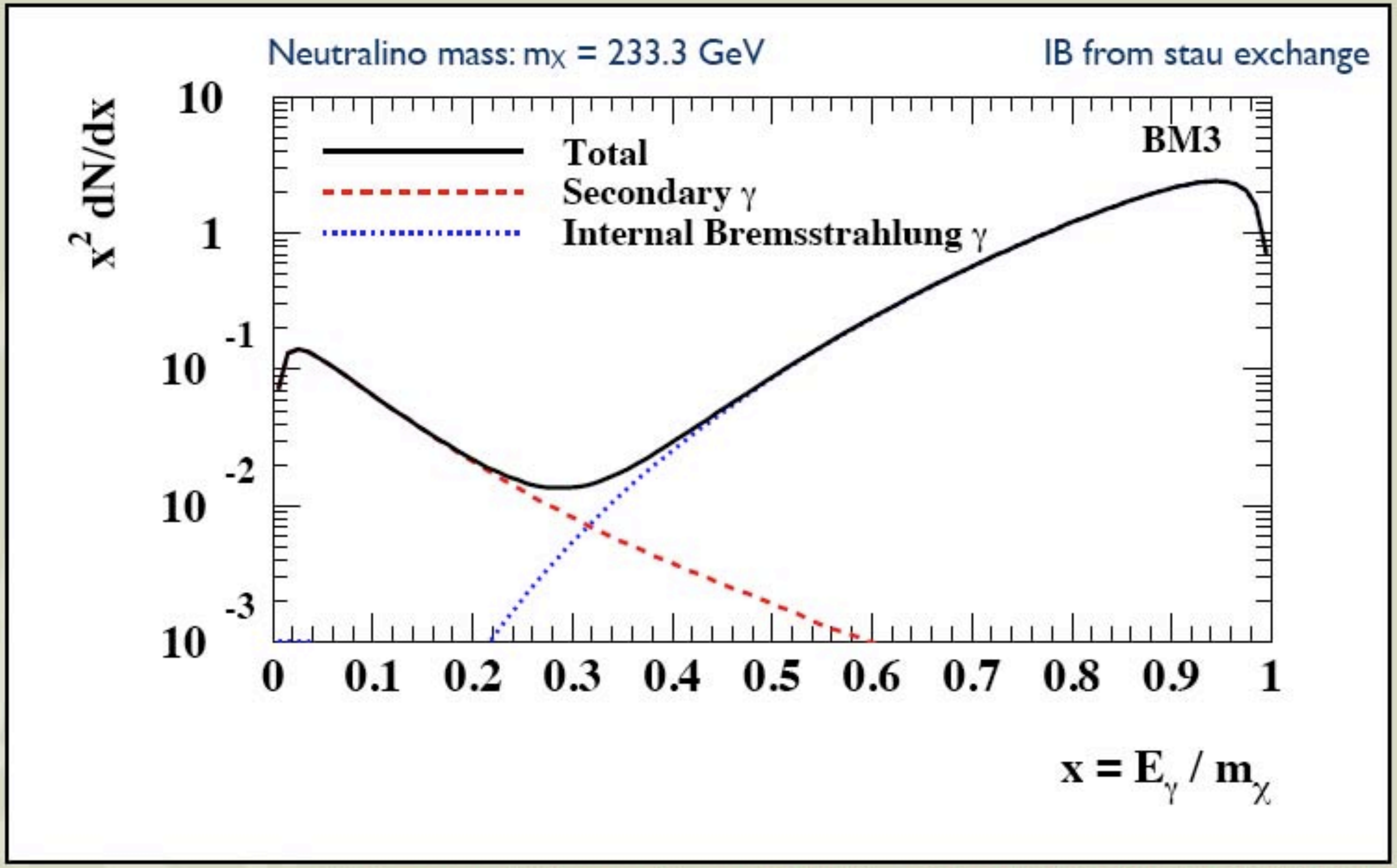
T. Bringmann, L. Bergström and J. Edsjö, arXiv: 0710.3169, JHEP 01 (2008) 049

Gamma ray spectrum including IB photons II



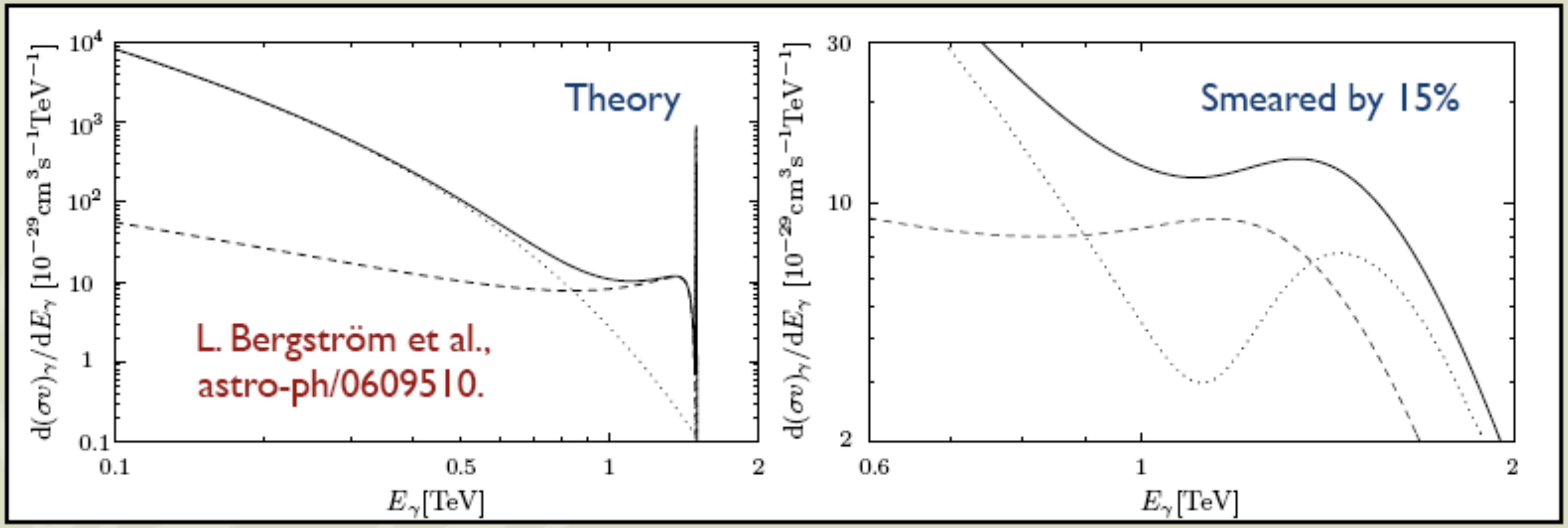
T. Bringmann, L. Bergström and J. Edsjö, arXiv: 0710.3169, JHEP 01 (2008) 049

Gamma ray spectrum including IB photons III



T. Bringmann, L. Bergström and J. Edsjö, arXiv: 0710.3169, JHEP 01 (2008) 049

Example of experimental smearing


Theory

Smeared by 15%

L. Bergström et al., astro-ph/0609510.

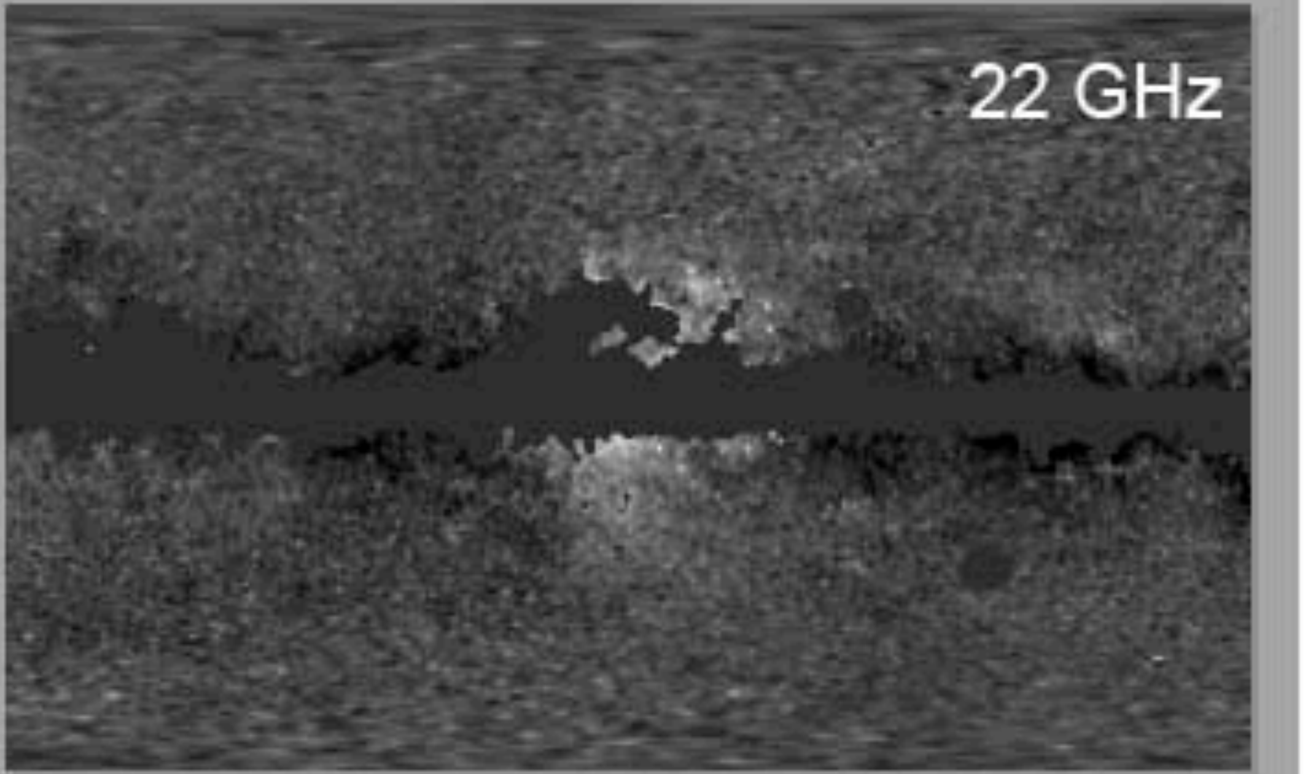
- W^+W^- channel via $\chi^\pm$ exchange

Conclusions

- Gamma rays from dark matter annihilation can have distinct spectral features, either from the monochromatic lines or from internal bremsstrahlung effects
- Searches with e.g. GLAST (launch May 16) and Air Cherenkov Telescopes will be very interesting

Dark Matter in the WMAP Sky

- In 2004, Doug Finkbeiner suggested that the WMAP Haze could be synchtrotron from electrons/positrons produced in dark matter annihilations in the inner galaxy (astro-ph/0409027)



- In particular, he noted that:

1) Assuming an NFW profile, a WIMP mass of 100 GeV and an annihilation cross section of 3×10^{-26} cm^3/s, the total power in dark matter annihilations in the inner 3 kpc of the Milky Way is
$\sim1.2\times10^{39}$ GeV/sec

2) The total power of the WMAP Haze is between
0.7×10^{39} and 3×10^{39} GeV/sec

Dan Hooper - *Dark Matter Annihilations in the WMAP Sky*

Dark Matter in the WMAP Sky

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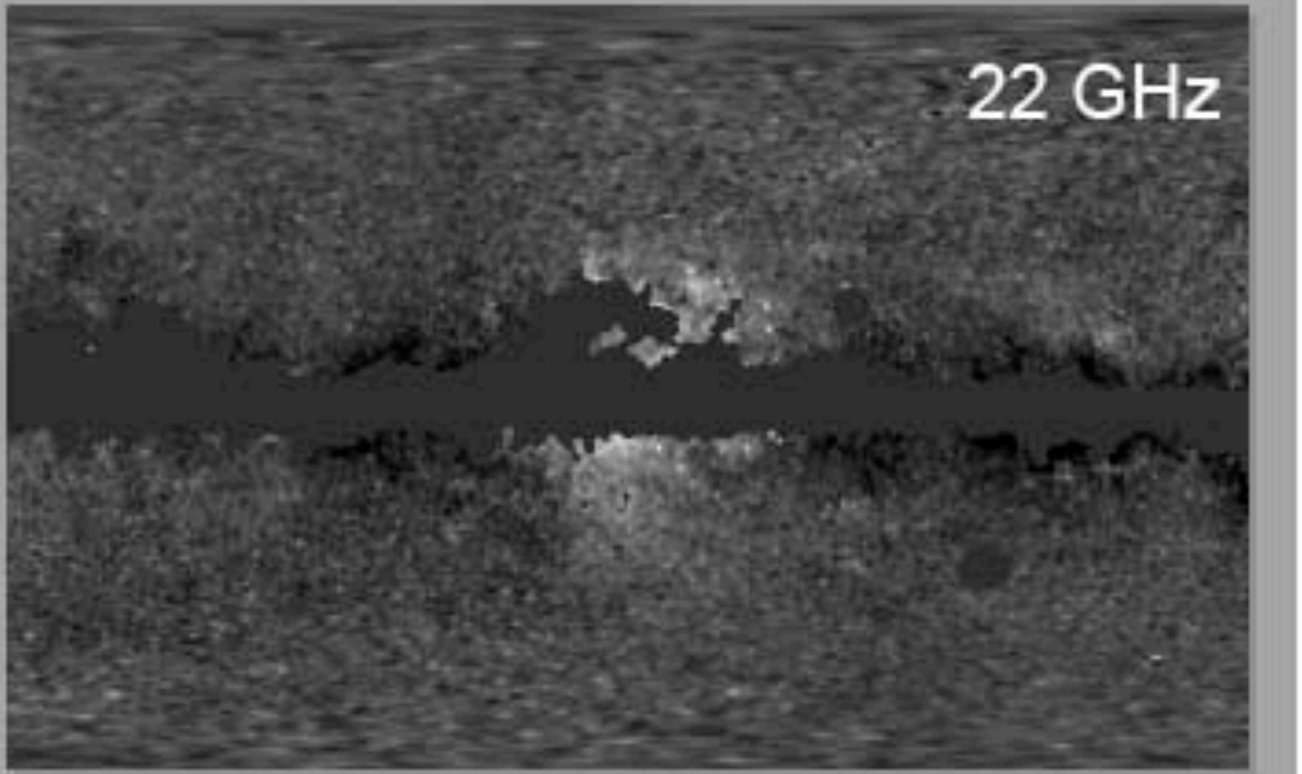


- In particular, he noted that:

1) Assuming an NFW profile, a WIMP mass of 100 GeV and an annihilation cross section of 3×10^{-26} cm^3/s, the total power in dark matter annihilations in the inner 2 kpc of the Milky Way is

$\sim 1.2\times10^{39}$ GeV/sec

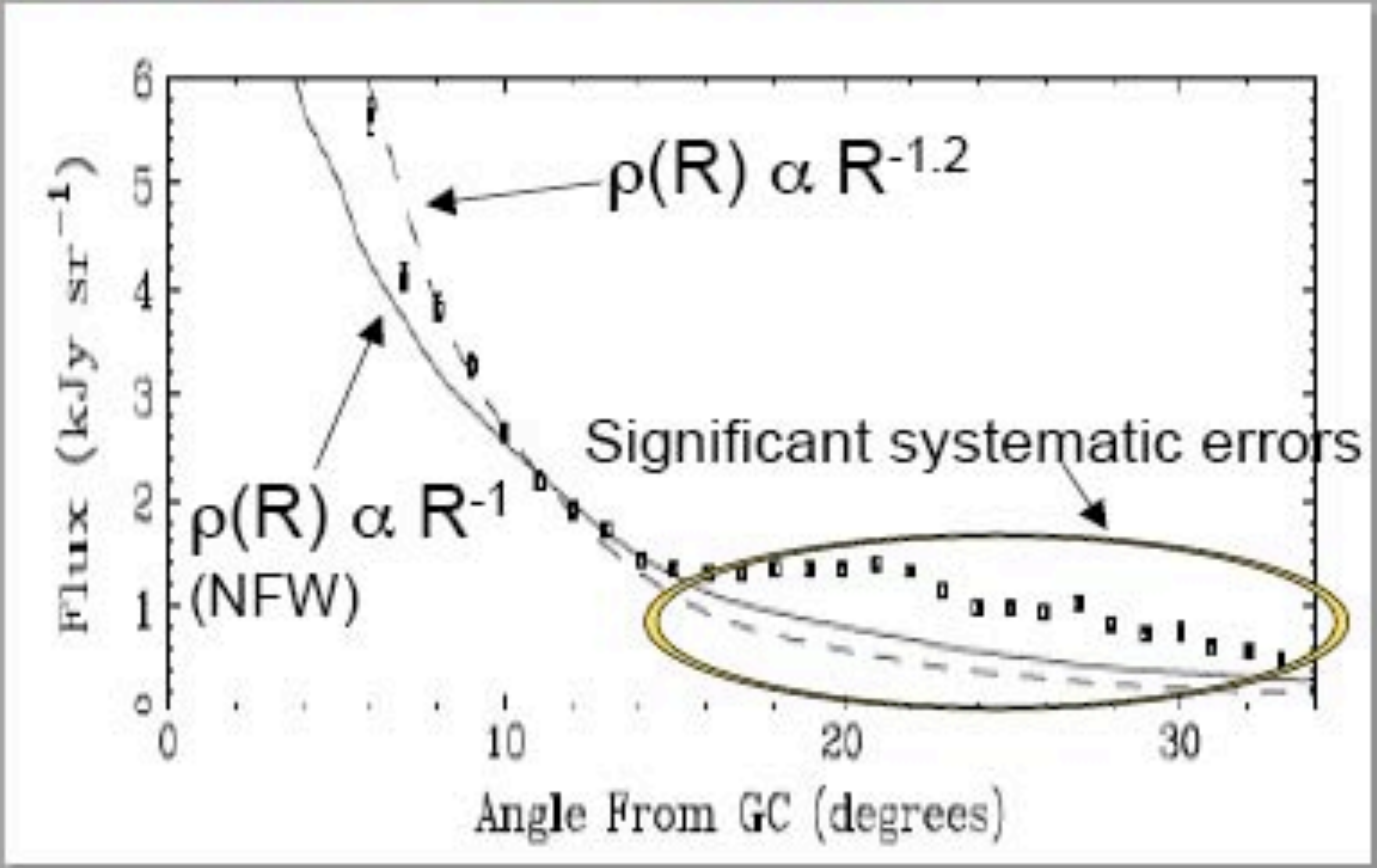
Coincidence?

2) The total power of the WMAP Haze is between

0.7×10^{39} and 3×10^{39} GeV/sec

Fitting The Haze To The Dark Matter Halo Profile

- When the effects of diffusion are accounted for, we find that an NFW halo profile ($\rho\ \alpha\ R^{-1}$) under produces the WMAP haze at small angles
- Angular distribution of the haze matches that found for a profile, with $\rho\ \alpha\ R^{-1.2}$

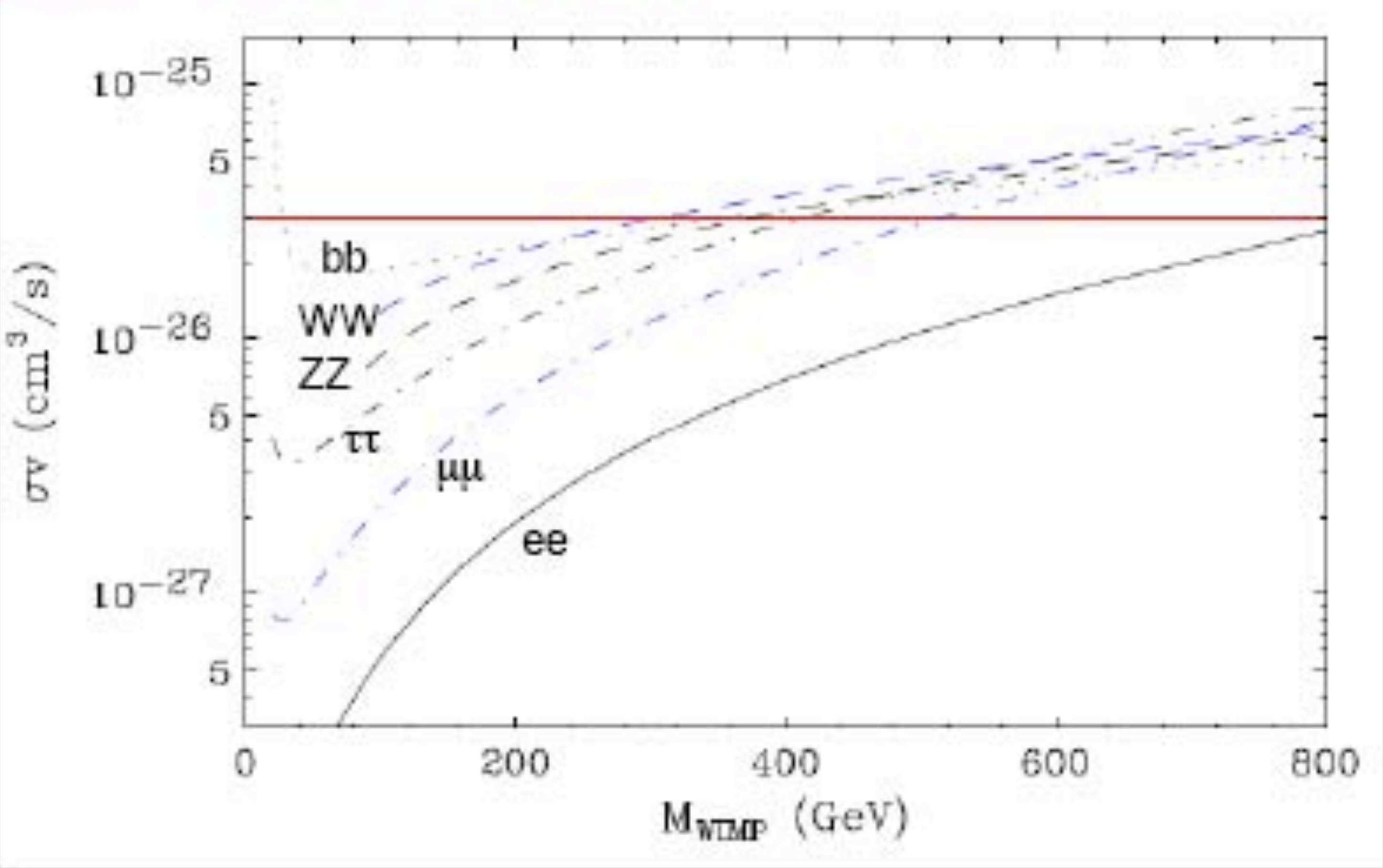


- Although the precise result of this fit depends on the diffusion parameters adopted (magnetic fields, starlight density, etc.), the approximate result (slope of -1.1 to -1.3) is fairly robust

Hooper, G. Dobler and D. Finkbeiner, PRD, arXiv:0705.3655

The Dark Matter Annihilation Cross Section

- For a given annihilation mode, diffusion parameters and halo profile, we can calculate the annihilation cross section needed to normalize to the observed intensity of the WMAP Haze



- For a typical 100-1000 GeV WIMP, the annihilation cross section needed is within a factor of 2-3 of the value needed to generate the density of dark matter thermally (3×10^{-26} cm^3/s)

- ***No boost factors are required!***

Hooper, G. Dobler and D. Finkbeiner, PRD, arXiv:0705.3655

The remarkable match of the WMAP Haze to the signal expected from Dark Matter

The Haze is consistent with dark matter annihilations with the following characteristics:

1. A dark matter distribution with $\rho \propto R^{-1.2}$ in the inner kiloparsecs of our galaxy
2. A dark matter particle with a ~100 GeV to several TeV mass, and that annihilates to typical channels (heavy fermions, gauge bosons, etc.)
3. An annihilation cross section within a factor of a few of $3\text{x}10^{-26}$ cm^3/s (the value required of a thermal relic)

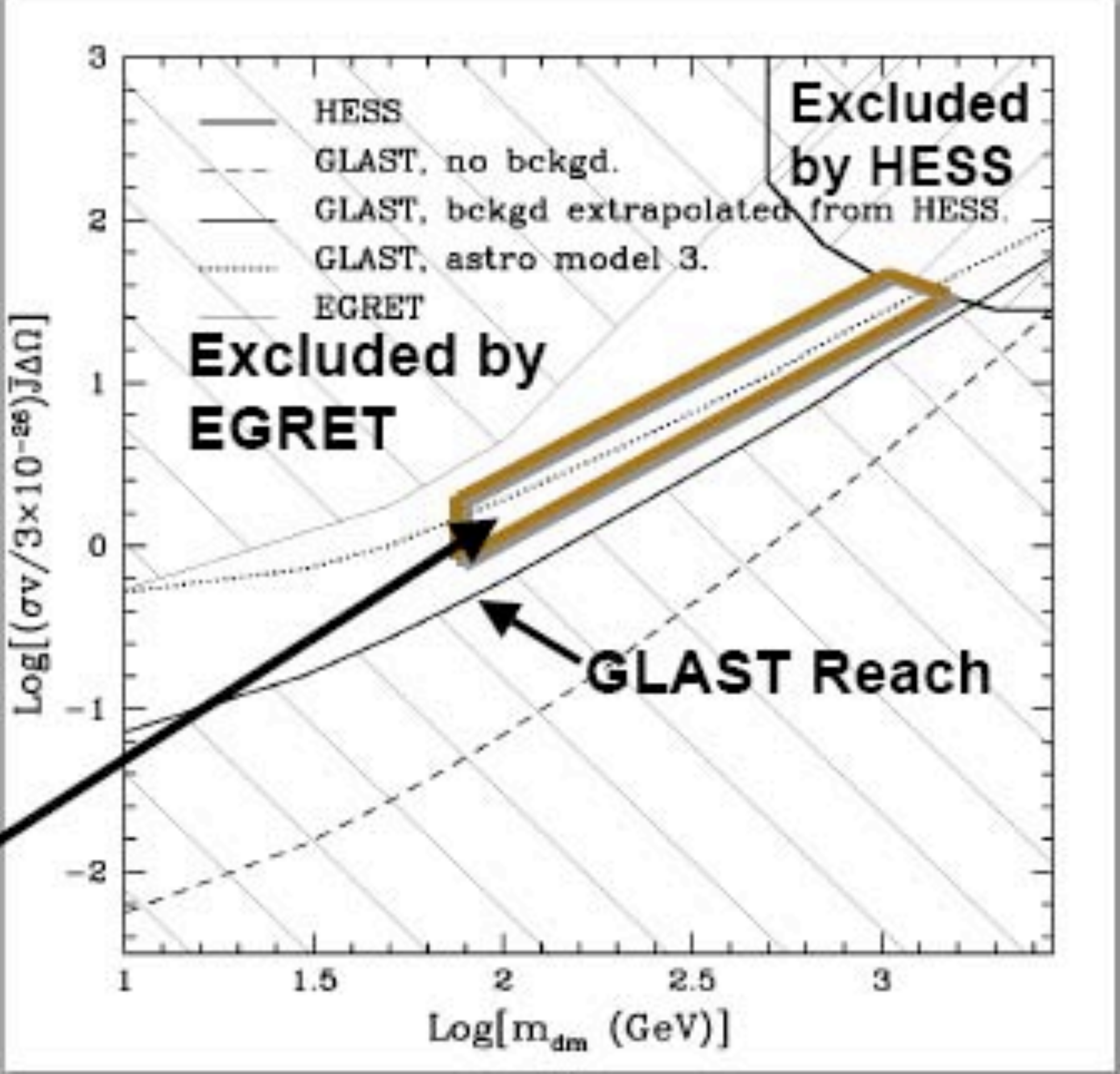
A completely vanilla dark matter scenario!

Hooper, G. Dobler and D. Finkbeiner, PRD, arXiv:0705.3655

Gamma-Rays From The Galactic Center

- GLAST will extend the region of the cross section-mass plane excluded by EGRET and HESS considerably

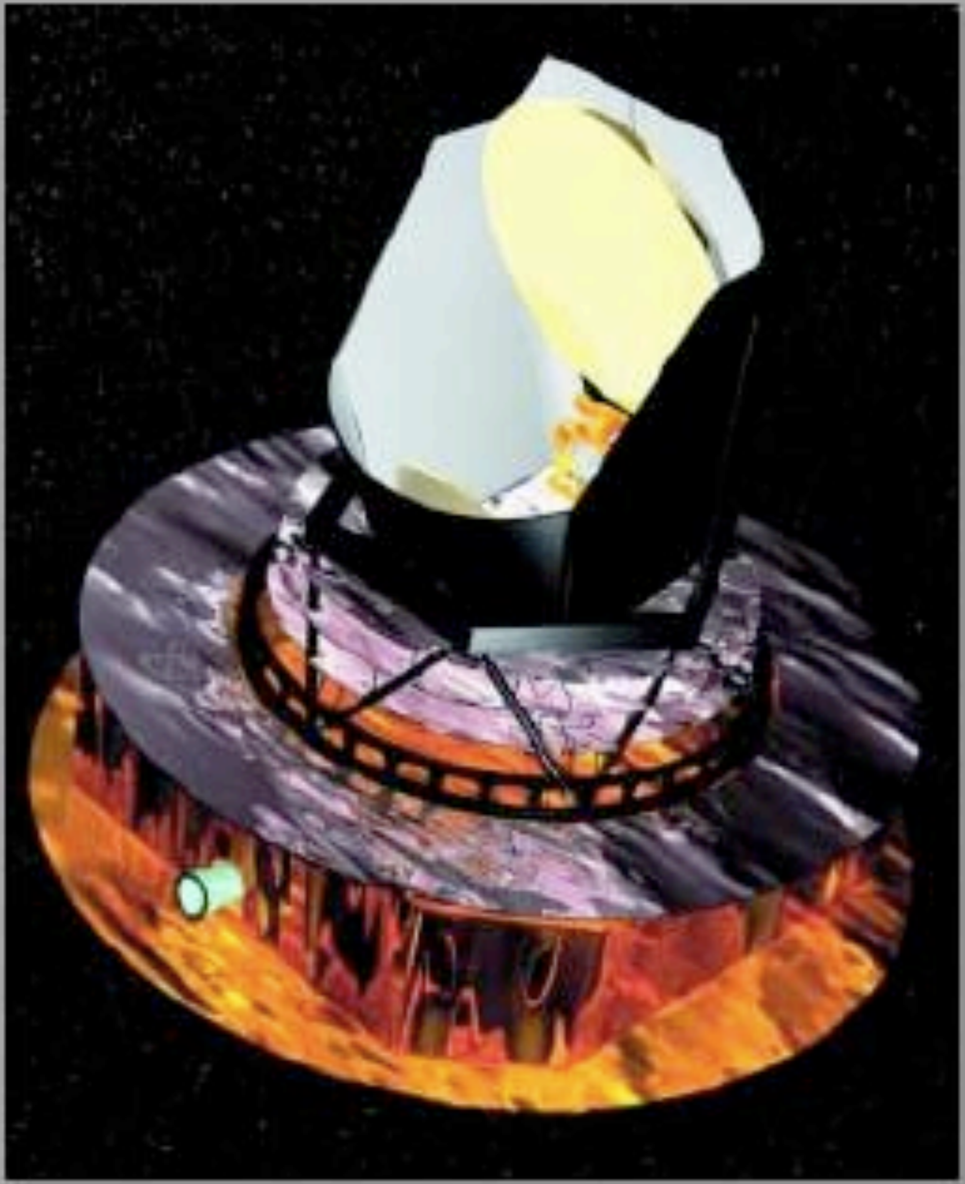
- If we normalize the annihilation rate to that needed to generate the observed intensity of the WMAP Haze, we find that the gamma ray flux is within the reach of GLAST



Range Predicted By the WMAP Haze

Hooper and G. Zaharijas, PRD, hep-ph/0603540

The WMAP Haze In Light Of Planck



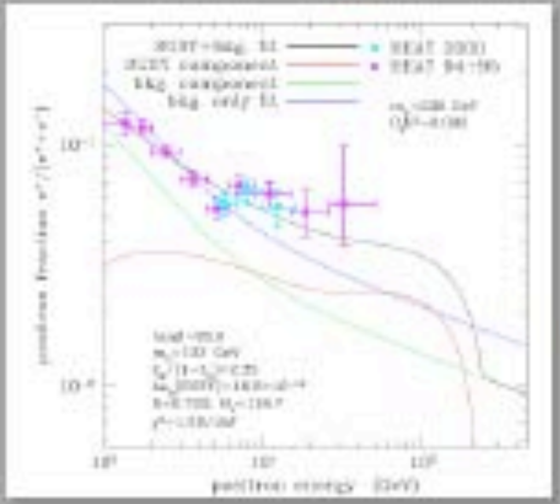
Planck (launch in 2008) will represent a major step forward from WMAP:

- Improved frequency coverage
- Improved angular resolution

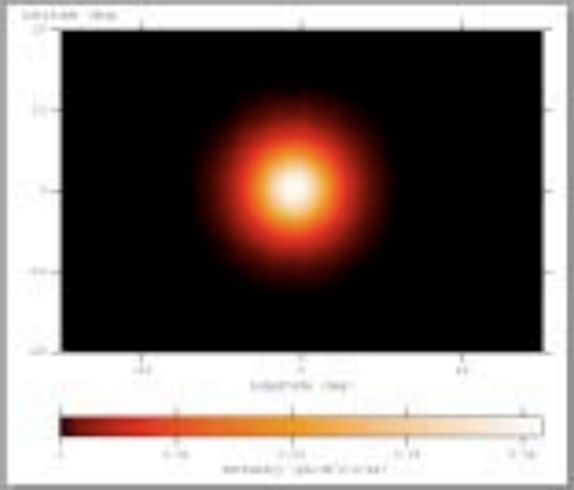
- At frequencies above ~100 GHz, all foregrounds other than emission from thermal dust are negligible; subtracting one foreground rather than the several (3 or 4) required at WMAP frequencies will enable for a much more robust confirmation of the hard synchrotron origin of the Haze
- Systematic uncertainties are expected to be reduced by more than an order of magnitude relative to WMAP

What About Other Claims of Evidence For Dark Matter Annihilation?

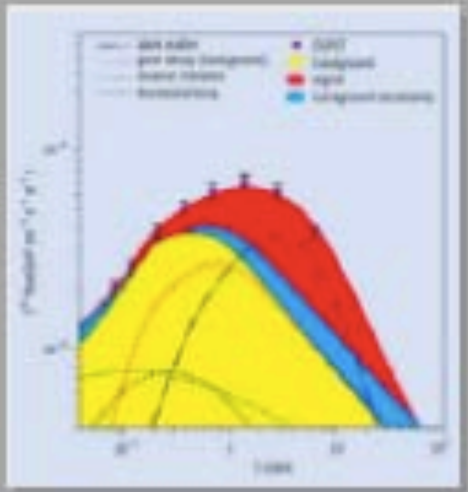
- The HEAT positron excess



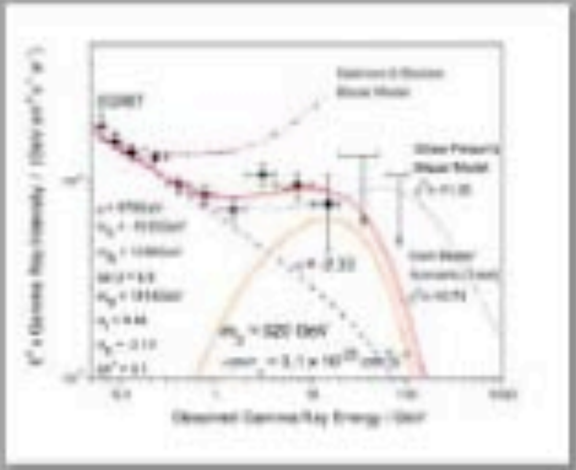
- 511 keV emission from the galactic bulge



- EGRET's galactic gamma ray spectrum



- EGRET's extragalactic gamma ray spectrum



Dan Hooper - *Dark Matter Annihilations in the WMAP Sky*

Signal	Required Particle Physics	Required Astrophysics
WMAP Haze	100 GeV to multi-TeV WIMP, ~3x10^{-26} cm^{3}/s annihilation cross section	Cusped halo profile, standard diffusion, no boost factors
HEAT Positron Excess	50-1000 GeV WIMP; Either large (non-thermal) annihilation cross section OR …	Large boost factor (50 or more)
INTEGRAL 511 keV Emission	~MeV particle, p-wave annihilator with ~3x10^{-26} cm^{3}/s annihilation cross section	Mildly cusped halo profile
EGRET Diffuse Galactic	~50-300 GeV WIMP; Either large (non-thermal) annihilation cross section OR …	Large boost factors; two massive rings of dark matter in the galactic plane; non-standard, highly convective diffusion model
EGRET Diffuse Extragalactic	~500 GeV WIMP; Either large (non-thermal) annihilation cross section OR …	Large boost factors/highly cusped profiles; Conflict with Milky Way unless Galactic Center is exceptional

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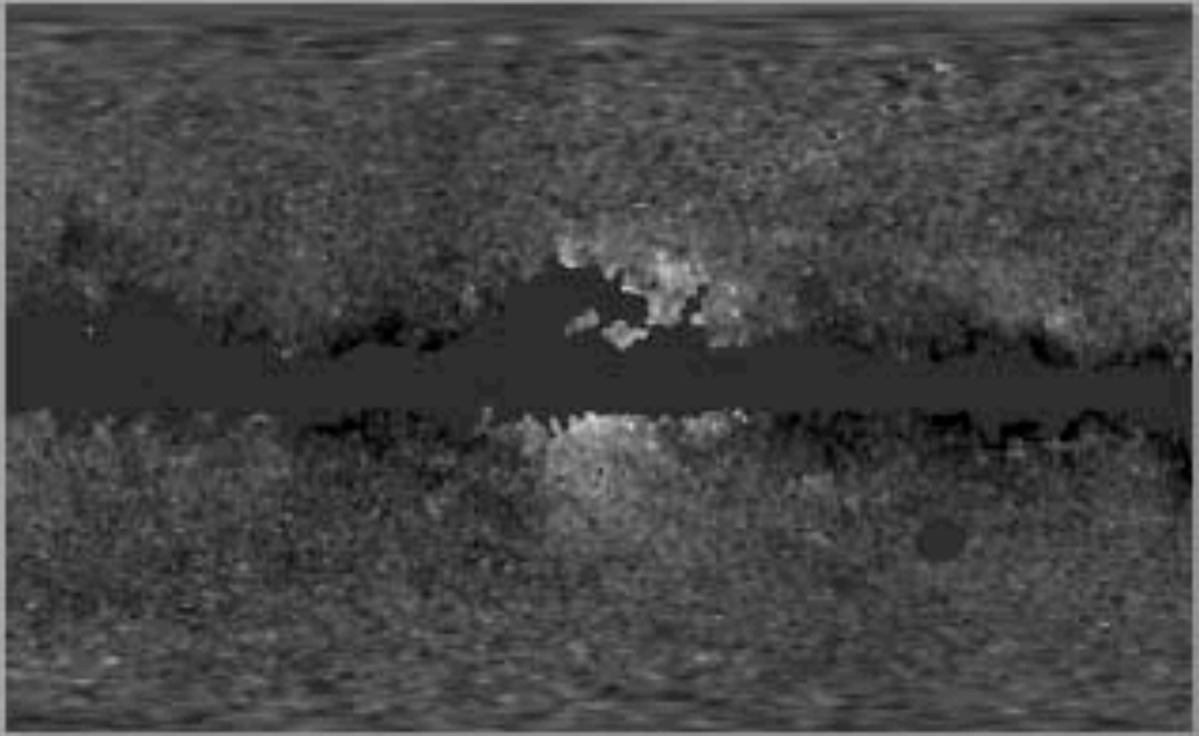
Dan Hooper - *Dark Matter Annihilations in the WMAP Sky*

Conclusions

- WMAP data, after the subtraction of known foregrounds, contains an excess from the region around the center of the Milky Way - The “WMAP Haze”



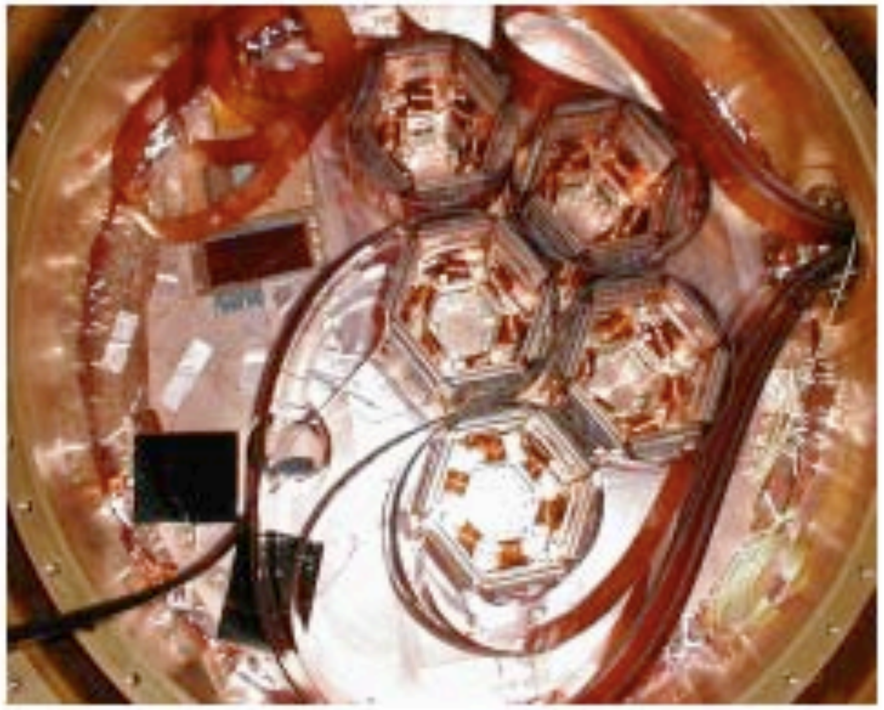
- Consistent with synchrotron emission from energetic electrons/positrons from dark matter annihilations with:
  - A cusped halo profile
  - A 100-1000 GeV WIMP
  - An annihilation cross section within a factor of 2-3 of the value required of a thermal relic (~3×10^{-26} cm^3/s)

A completely vanilla dark matter scenario!

First CDMS 5-Tower Results

Rupak Mahapatra
UC Santa Barbara

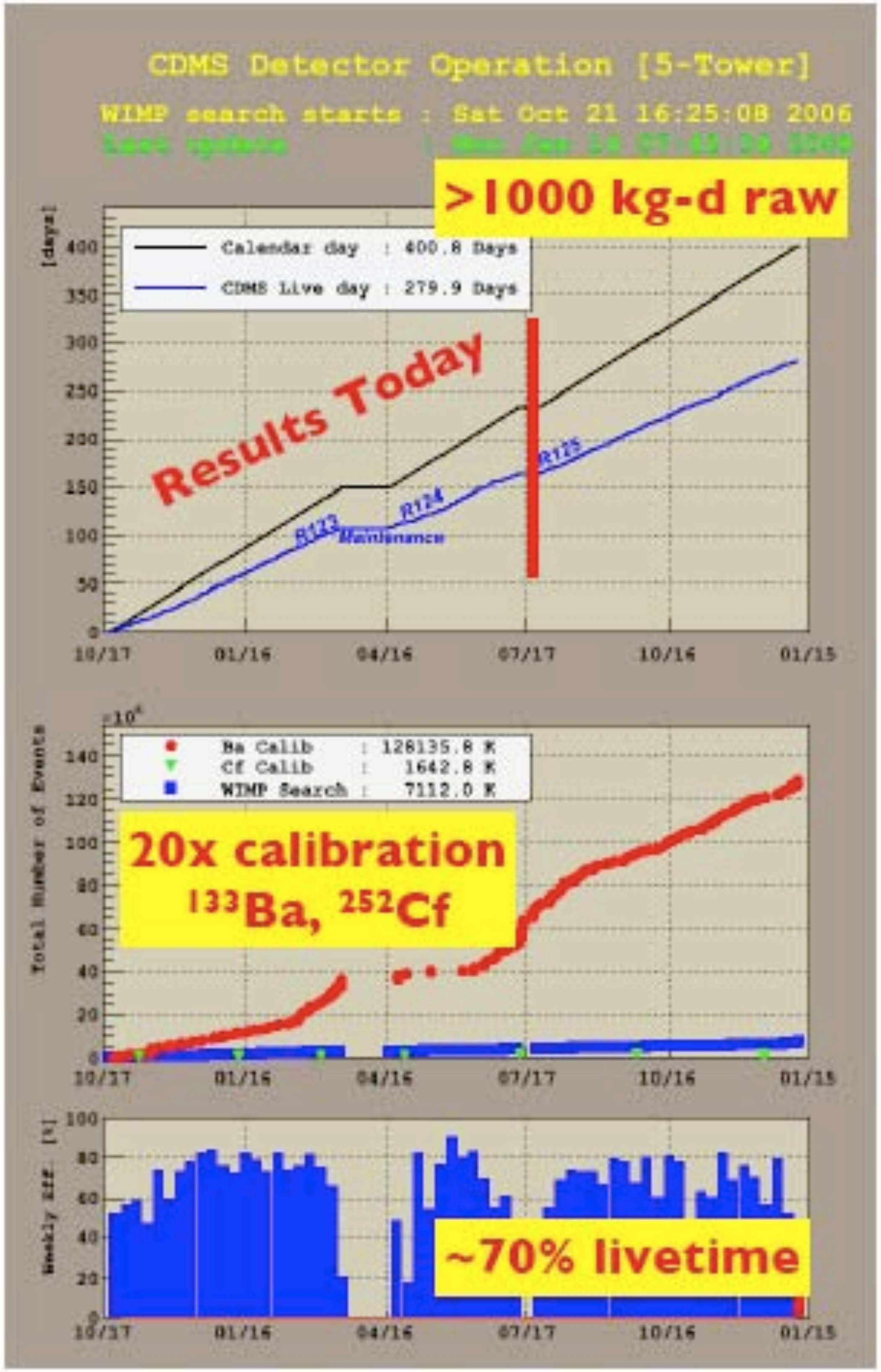
For the CDMS Collaboration



Improvements Since Last Run

- More Detectors (5 Towers, 30 Detectors)
  - Newer Towers have 2-3X Lower β Background from Radon
- More stable Cryogenics. Cryocooler
- DAQ: 10X Faster (100 Hz) Calibration Speed. Acquire Huge Calibration Sample: 20x exposure
- Enhanced Online & Offline Data Quality Monitoring
- Improved Analysis Pipeline

Five Tower Status



Three successful **5-T** data runs so far:

- Run 123 (10/21-3/21): **430 kg-d** Ge (raw)
- Run 124 (4/20-7/16): **224 kg-d** Ge (raw)
- Run 125 (7/21-1/09): **465 kg-d** Ge (raw)
- Run 126 (1/17-date): **ongoing**

>10x the 2-Tower exposure so far!

We have analyzed Run 123+124 Data

~Double exposure waiting to be analyzed

Neutron Background Estimate

Cosmogenic

8 Vetoed Nuclear Recoil Multiples observed

No vetoed singles observed

Use MC predicted singles/multiples ratio and vetoed to unvetoed ratio

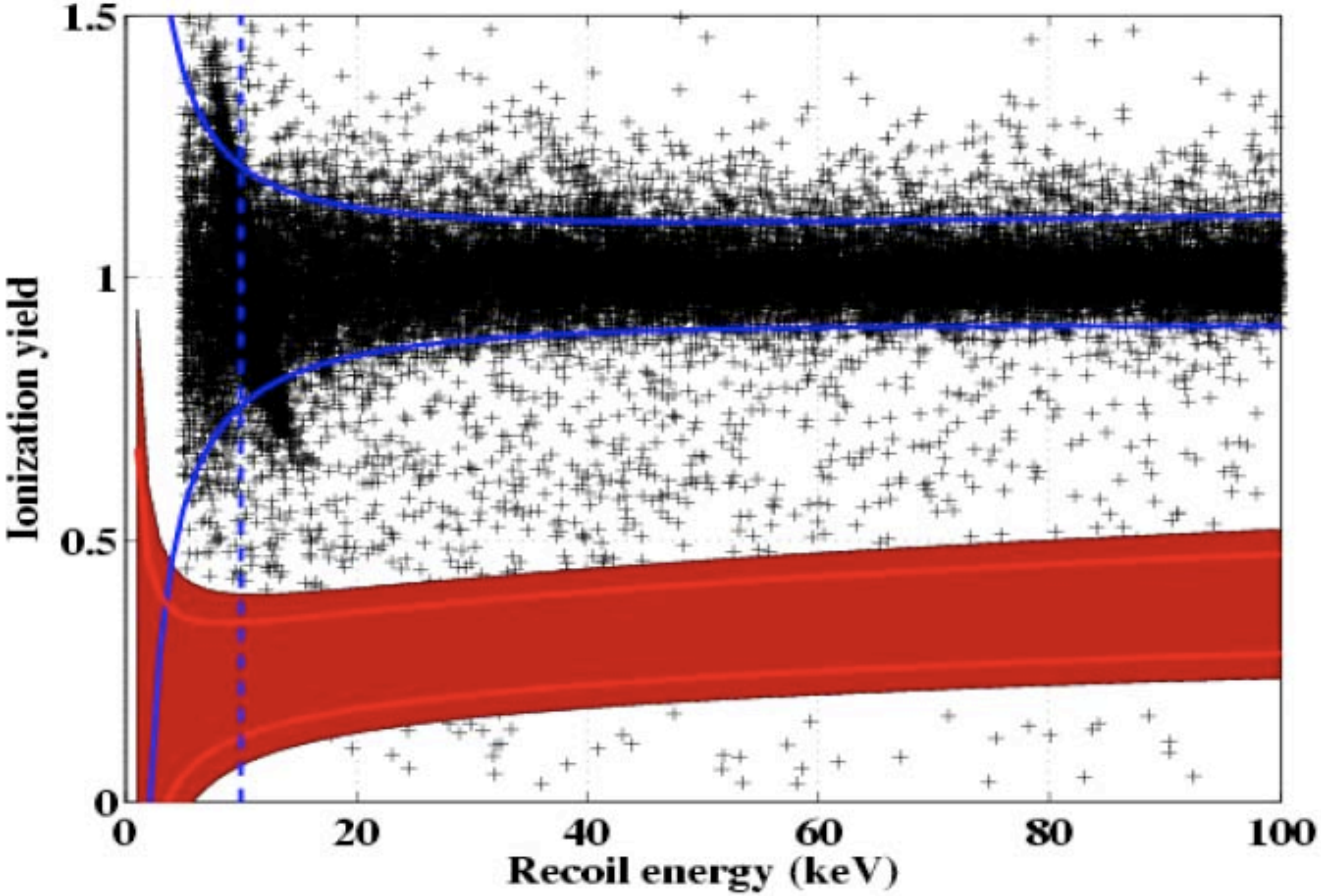
Expect <0.1 Unvetoed Neutron background

Fission/alpha-N

- Fission Neutron < 0.1 from Pb counting
- Alpha-N < 0.03 from Uranium in Poly

Expect Total Neutron background <0.2 events

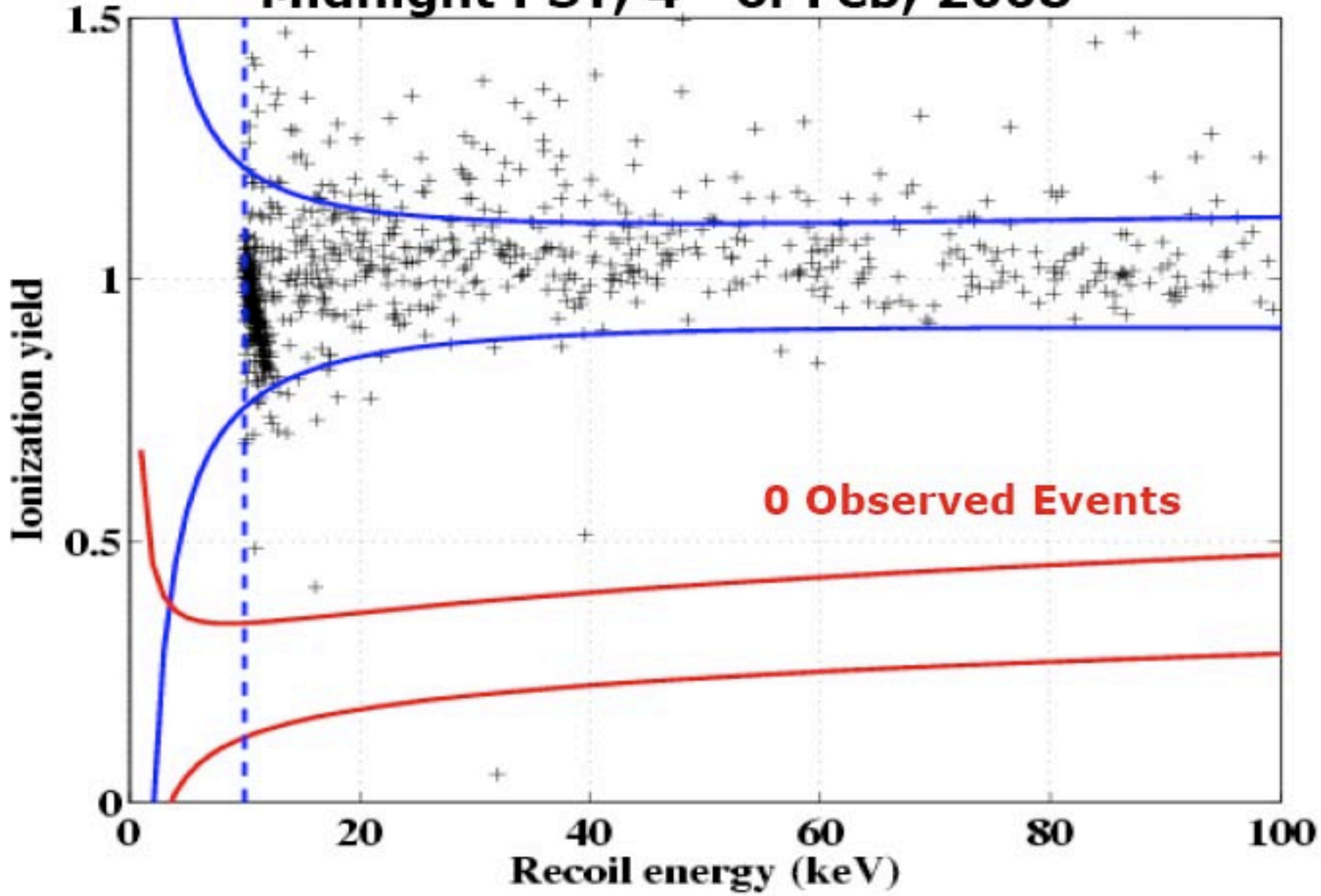
The WIMP Search Data: Ge



All cuts set and frozen! Predict 77 ± 15 single scatters in NR

Open The Box: Surface Event Cut

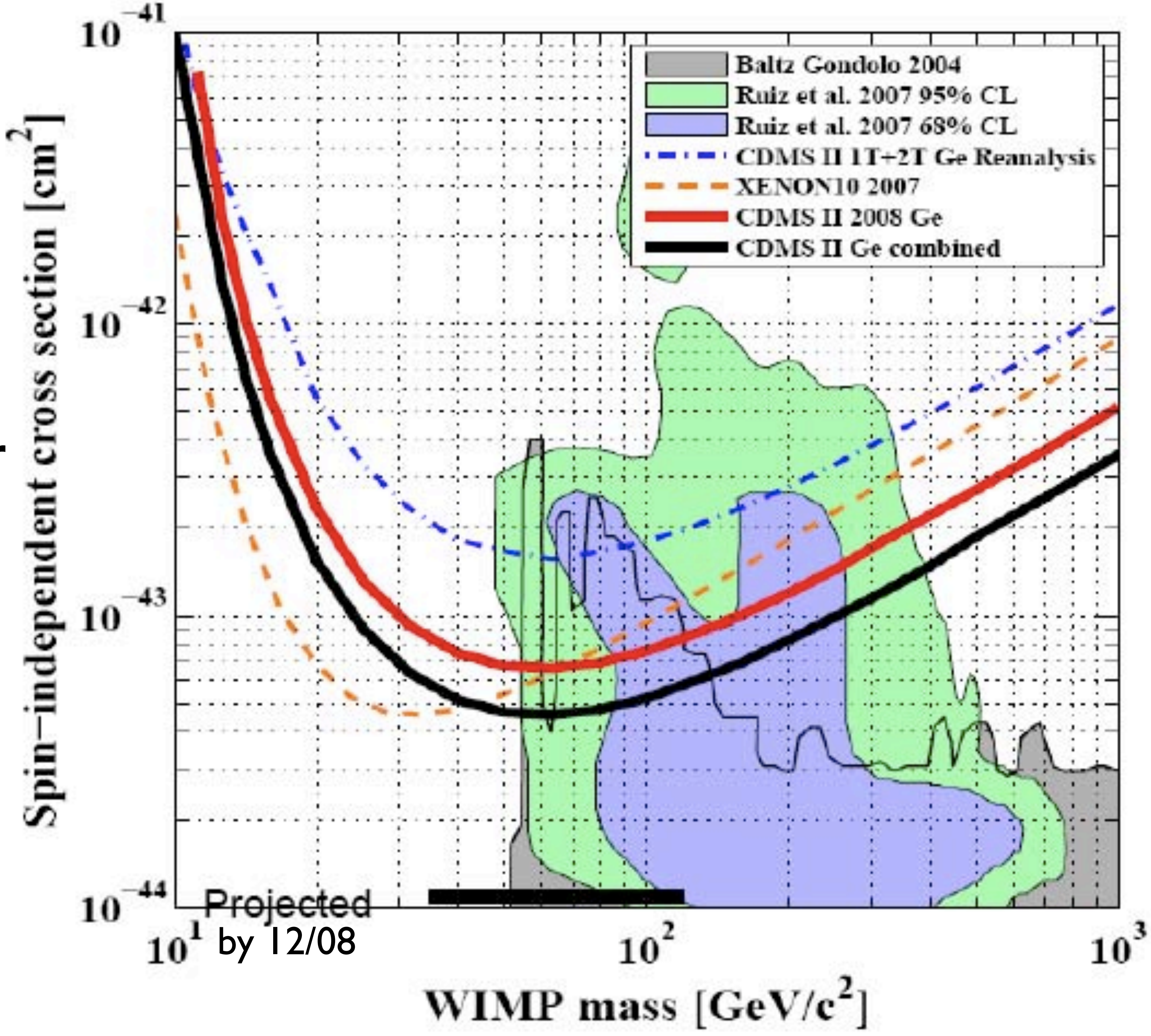
Midnight PST, 4th of Feb, 2008



Expected Background: 0.6 ± 0.5 surface events and < 0.2 neutrons

Spin-Independent Exclusion Limit

First
CDMS
5-Tower
Results



Reanalysis result from 1T+2T Data available in W. Ogburn's (Stanford) Thesis

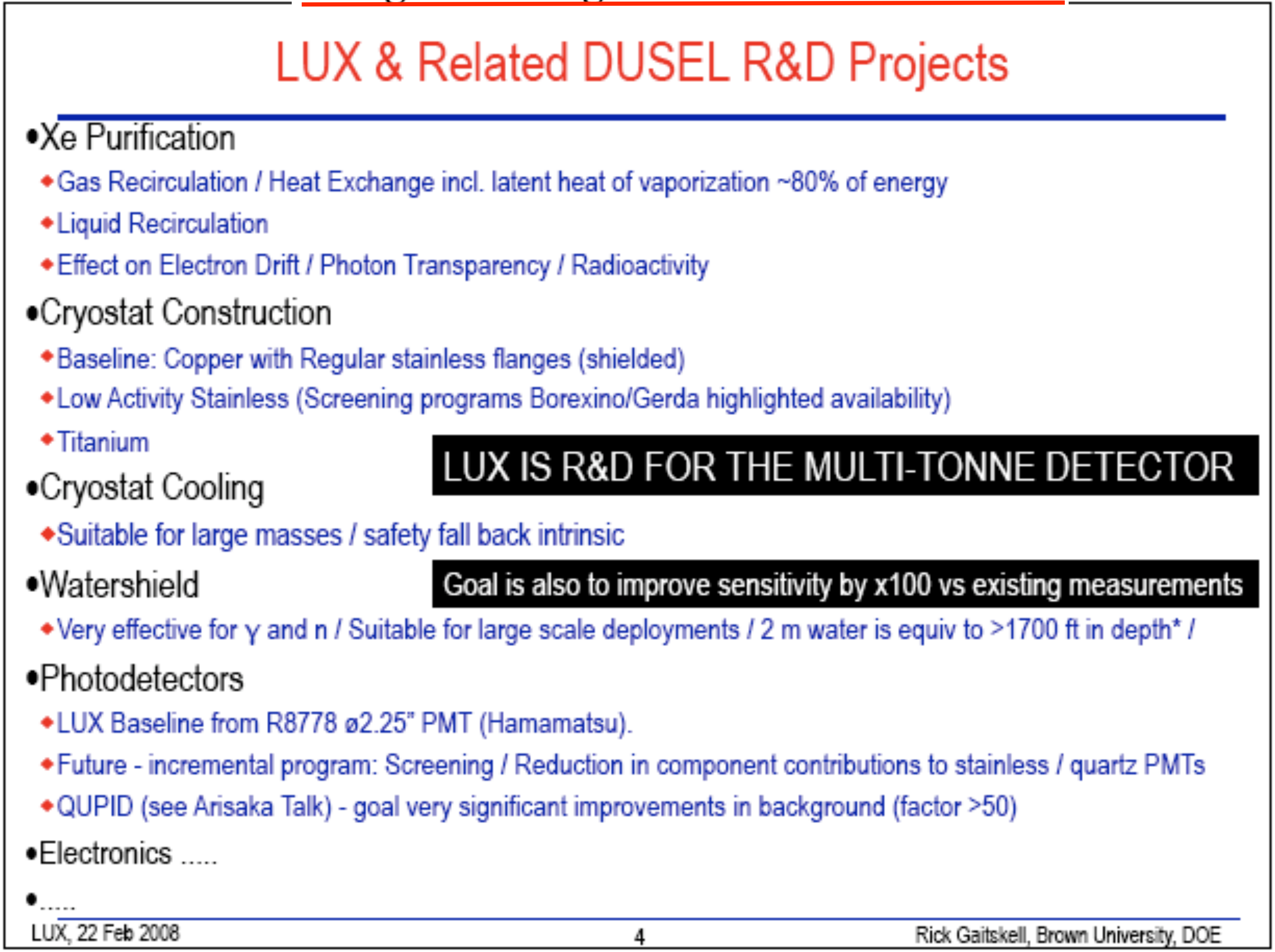
Conclusions

- **Zero Events Observed!**
- Best Spin Independent limit above 40GeV/c^2 of WIMP Mass
- ~ Twice the exposure of current analysis waiting in analysis pipeline. Double again by end 2008
- Will surpass target sensitivity of 2 x 10^{-44}cm^2
- Preprint in next hour @ http://cdms.berkeley.edu/ and on arxiv Monday morning

Large Underground Xenon detector

- Noble gas two phase technology is mature (proven by ZEPLIN II and XENON10).
- The LUX collaboration is firmly in place (10-Inst. 57-Mem).
- Detector design has matured. Construction can begin immediately (some started/completed).
- Full 350kg Xenon in hand.
- All PMTs needed manufactured (120+16)
- Cryostat, prototype components, sub-systems are being assembled.
- Homestake is projecting initial occupancy in late 2008. Deployment can begin at that point.
- With funds in place, physics data can start as early as End of 2008.

Large Underground Xenon detector



LUX & Related DUSEL R&D Projects

- Xe Purification
  - Gas Recirculation / Heat Exchange incl. latent heat of vaporization ~80% of energy
  - Liquid Recirculation
  - Effect on Electron Drift / Photon Transparency / Radioactivity
- Cryostat Construction
  - Baseline: Copper with Regular stainless flanges (shielded)
  - Low Activity Stainless (Screening programs Borexino/Gerda highlighted availability)
  - Titanium
- Cryostat Cooling
  - Suitable for large masses / safety fall back intrinsic
- Watershield
  - Very effective for γ and n / Suitable for large scale deployments / 2 m water is equiv to >1700 ft in depth* /
- Photodetectors
  - LUX Baseline from R8778 ø2.25" PMT (Hamamatsu).
  - Future - incremental program: Screening / Reduction in component contributions to stainless / quartz PMTs
  - QUPID (see Arisaka Talk) - goal very significant improvements in background (factor >50)
- Electronics .....
- .....

LUX IS R&D FOR THE MULTI-TONNE DETECTOR

Goal is also to improve sensitivity by x100 vs existing measurements

LUX, 22 Feb 2008 4 Rick Gaitskell, Brown University, DOE

Large Underground Xenon detector

LUX Goals

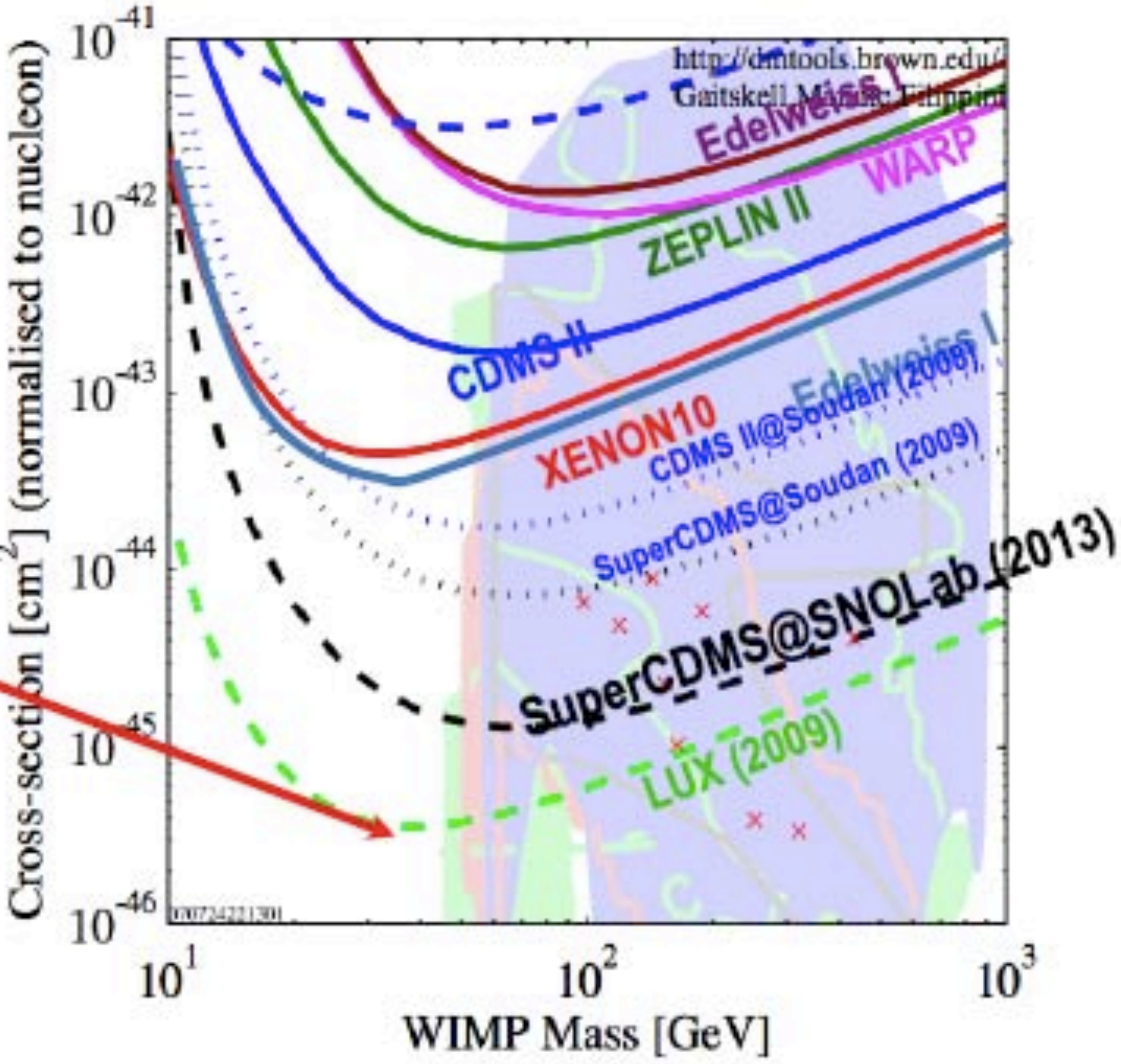
- 99.3 – 99.9% Electron Recoil background rejection for 50% Neutron Recoil acceptance, in the range 5 keVr < E < 25 keV

- $\gamma + \beta$ rate < 8×10^{-4} events/kg/keVee/day with 99.4% rejection (conservative)

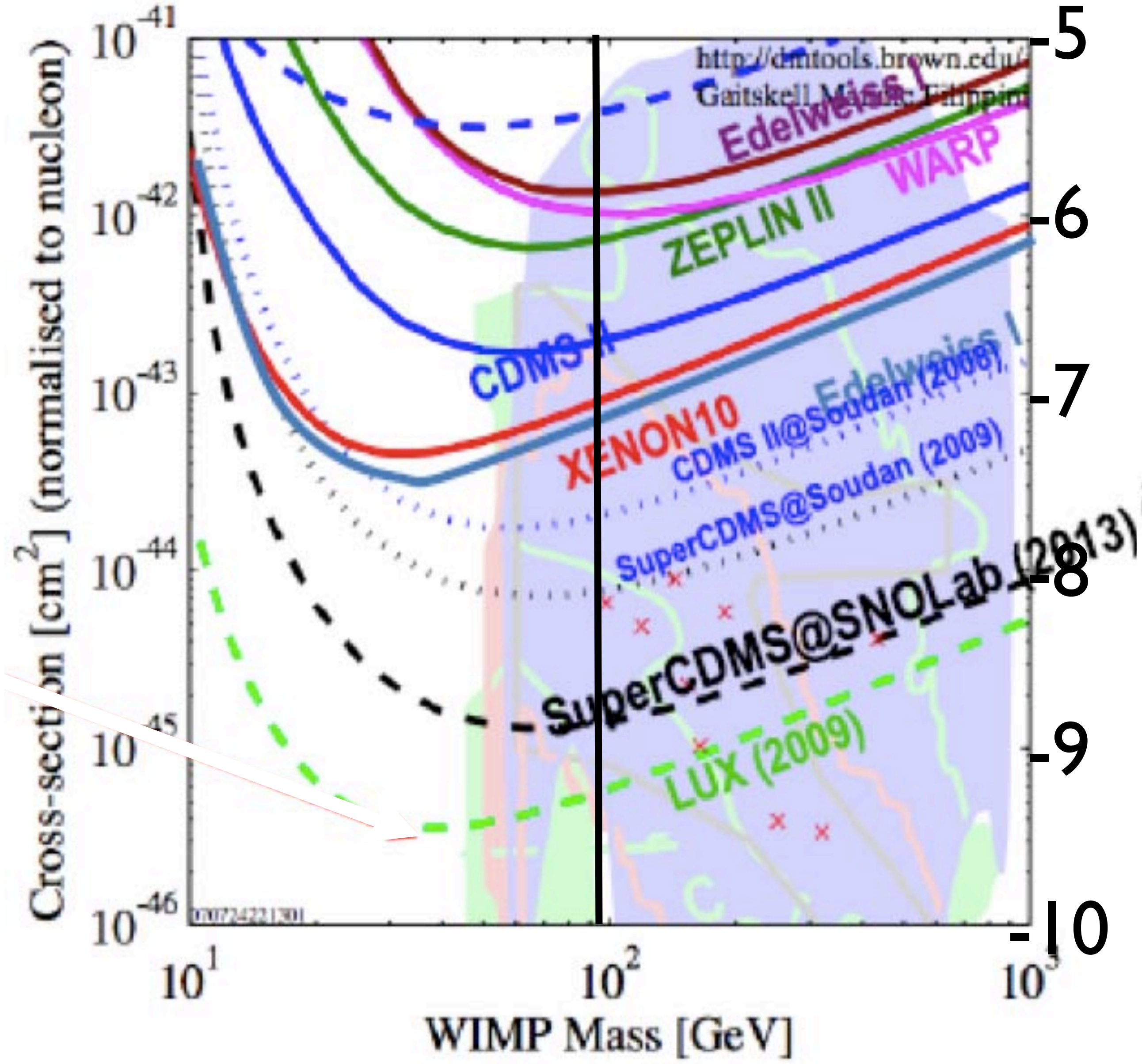
- 10 month run w/ 50% NR acceptance (net 15,000 kg-days)

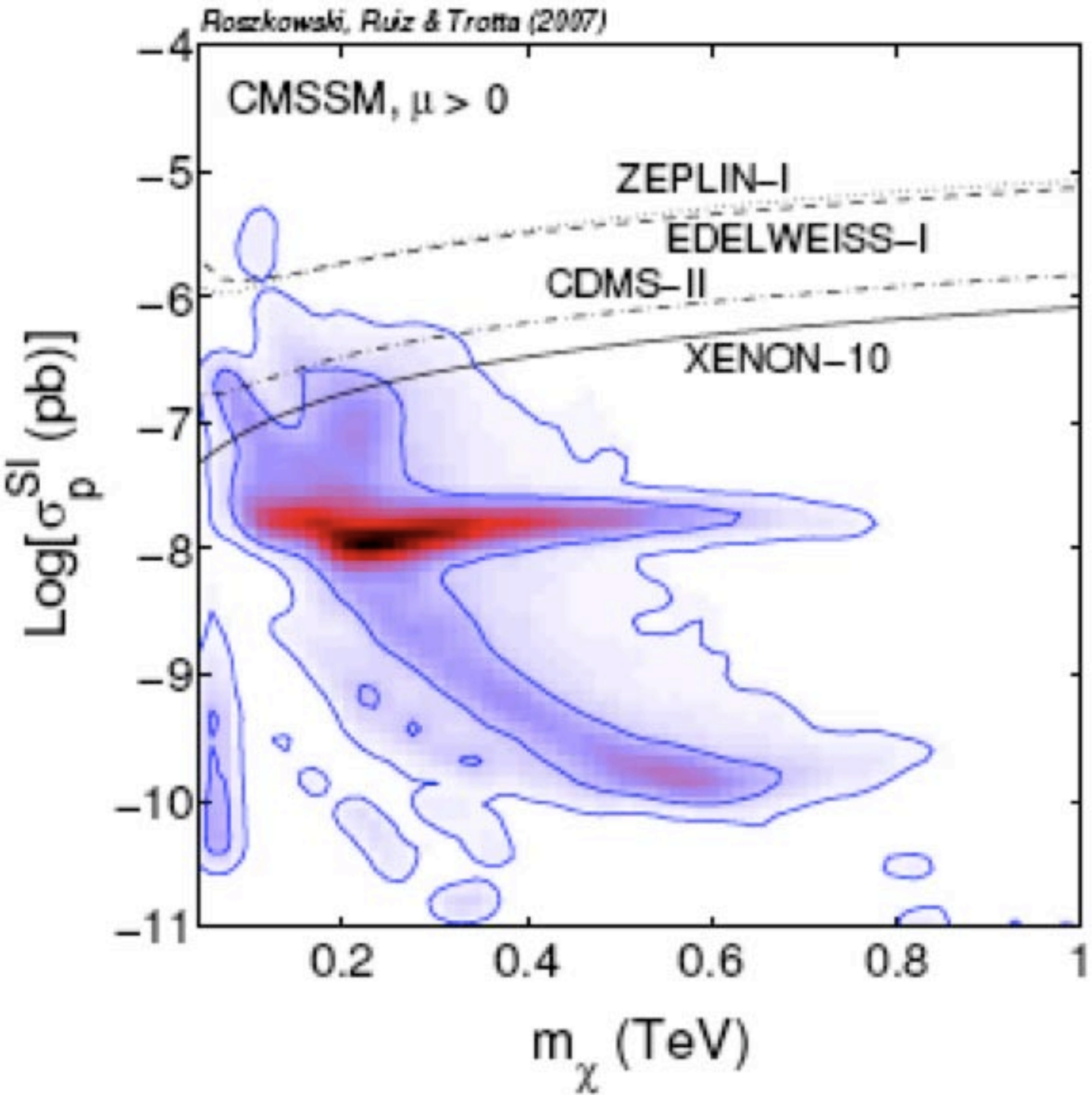
- DM reach $\sigma \sim 4 \times 10^{-46}$ cm²

(Equivalent to an event rate of ~0.4/100kg/month in 100kg fiducial)



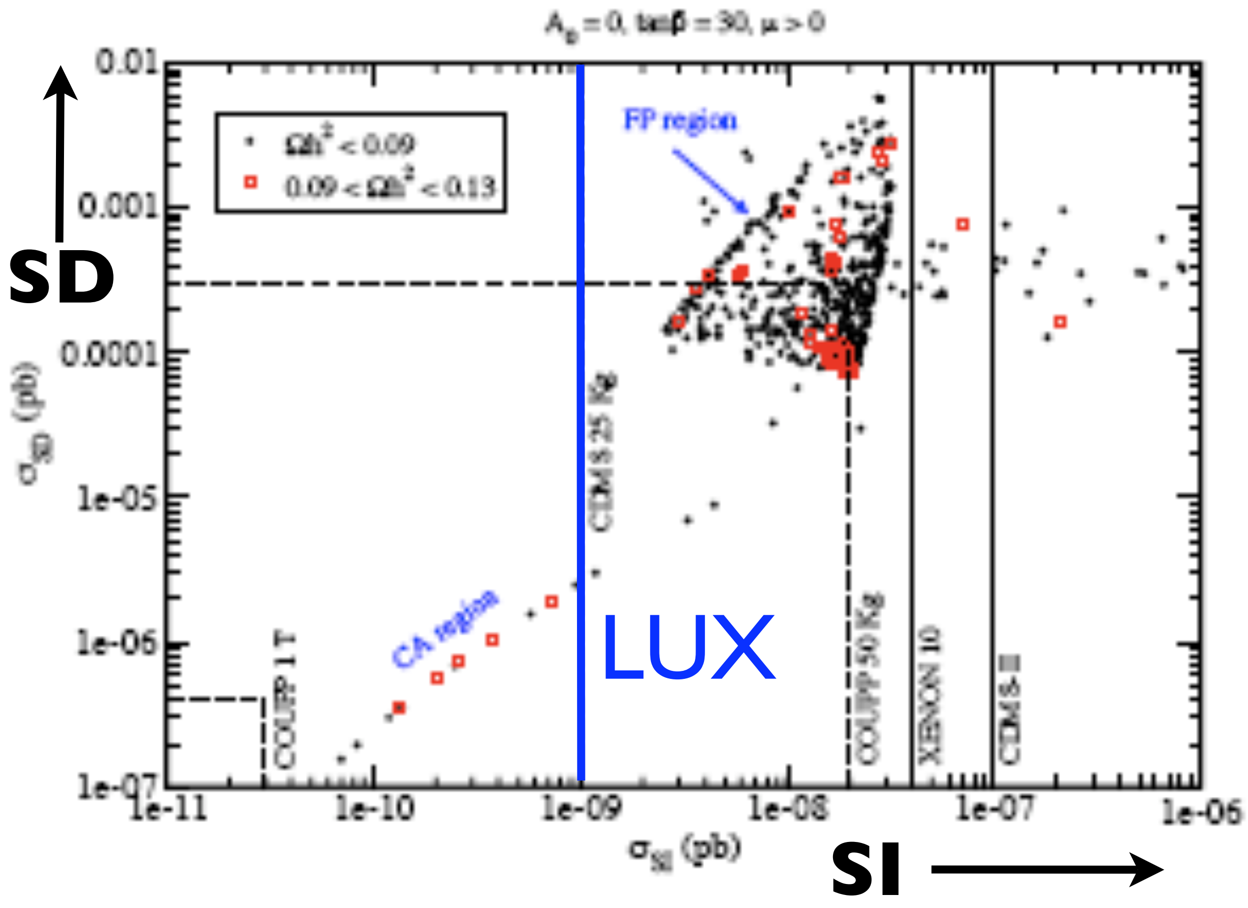
By ~2009 Direct Detection could probe most of the CMSSM and mSUGRA WIMP parameter space!

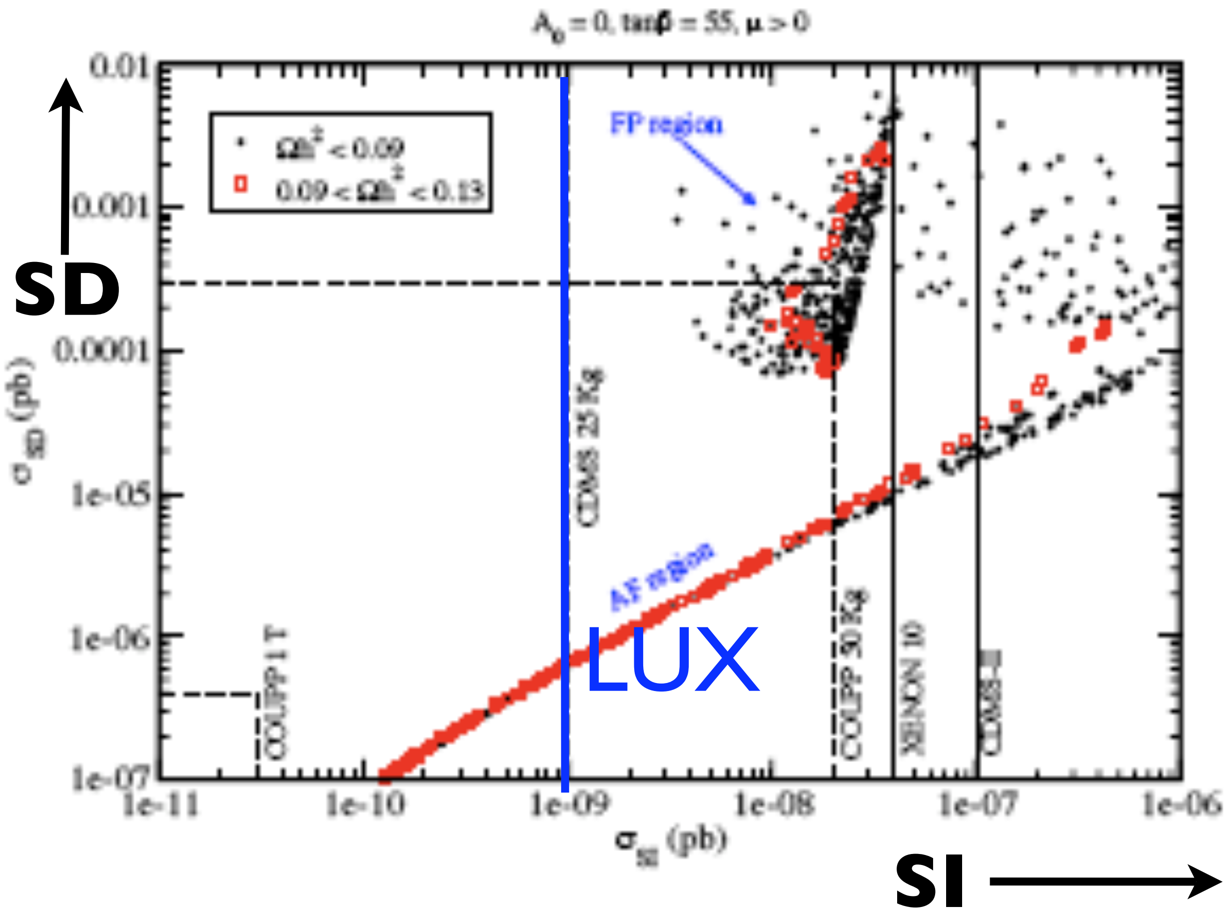




Scattering rates in mSUGRA

- Different solutions to DM relic density populate different regions of σ_{SD} vs. σ_{SI} Spin Dependent vs. Spin Indenepdent





- FP region can be verified or disproved by both SD and SI measurements
- Detection in FP region would be of major significance for colliders (high mass scalars)

With many upcoming experiments

Large Hadron Collider
PLANCK
GLAST and larger ACTs
Direct Detection
    Spin Independent - CDMS-II, XENON50, LUX
    Spin Dependent - COUPP, PICASSO

the next two years could be extremely exciting!

Four roads to dark matter: *catch it, infer it, make it, weigh it*

Direct:

Production:

Indirect:

GLAST launch
scheduled for
May 16 2008

Gravitational:

Planck launch
scheduled for
~ July 31 2008

21 cm
tomography
coming

Max Tegmark