Light on dark matter

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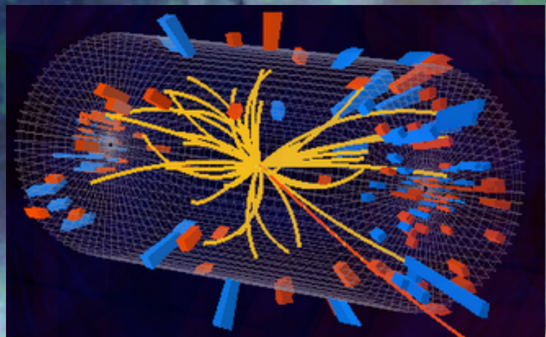


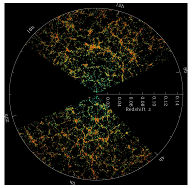
A dungeon horrible, on all sides round.
As one great furnace flamed;
yet from those flames
No light; but rather darkness visible …

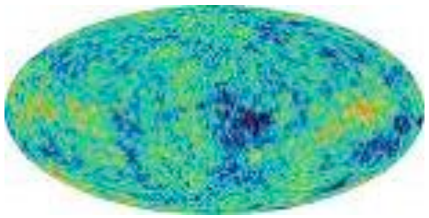
'Paradise Lost' – Milton

IoP Nuclear & Particle Physics Divisional Conference, Glasgow, 4-7 April 2011

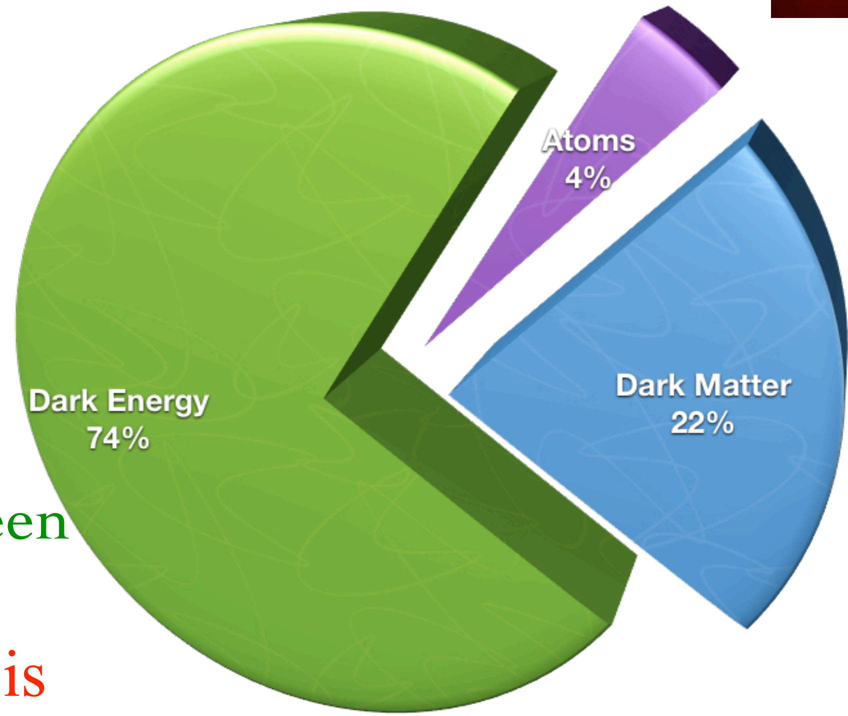
What is the world made of?

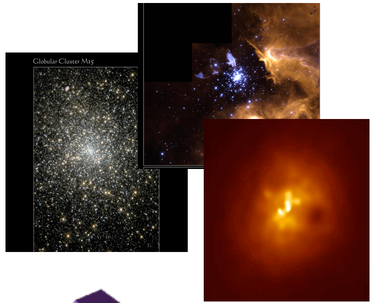
***Only* geometrical evidence:**
$\Lambda \sim O(H_0^2)$, $H_0 \sim 10^{-42}$ GeV
… dark energy is *inferred* from the 'cosmic sum rule':
$\Omega_m + \Omega_k + \Omega_\Lambda = 1$





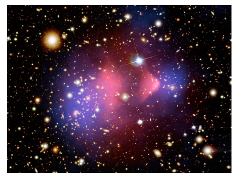
No significant *dynamical* evidence seen (e.g. 'late ISW effect')
…perhaps dark energy is faked by inhomogeneity?

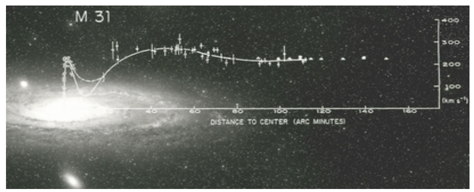




Baryons (but *no* antibaryons) … the stuff *we* are made of

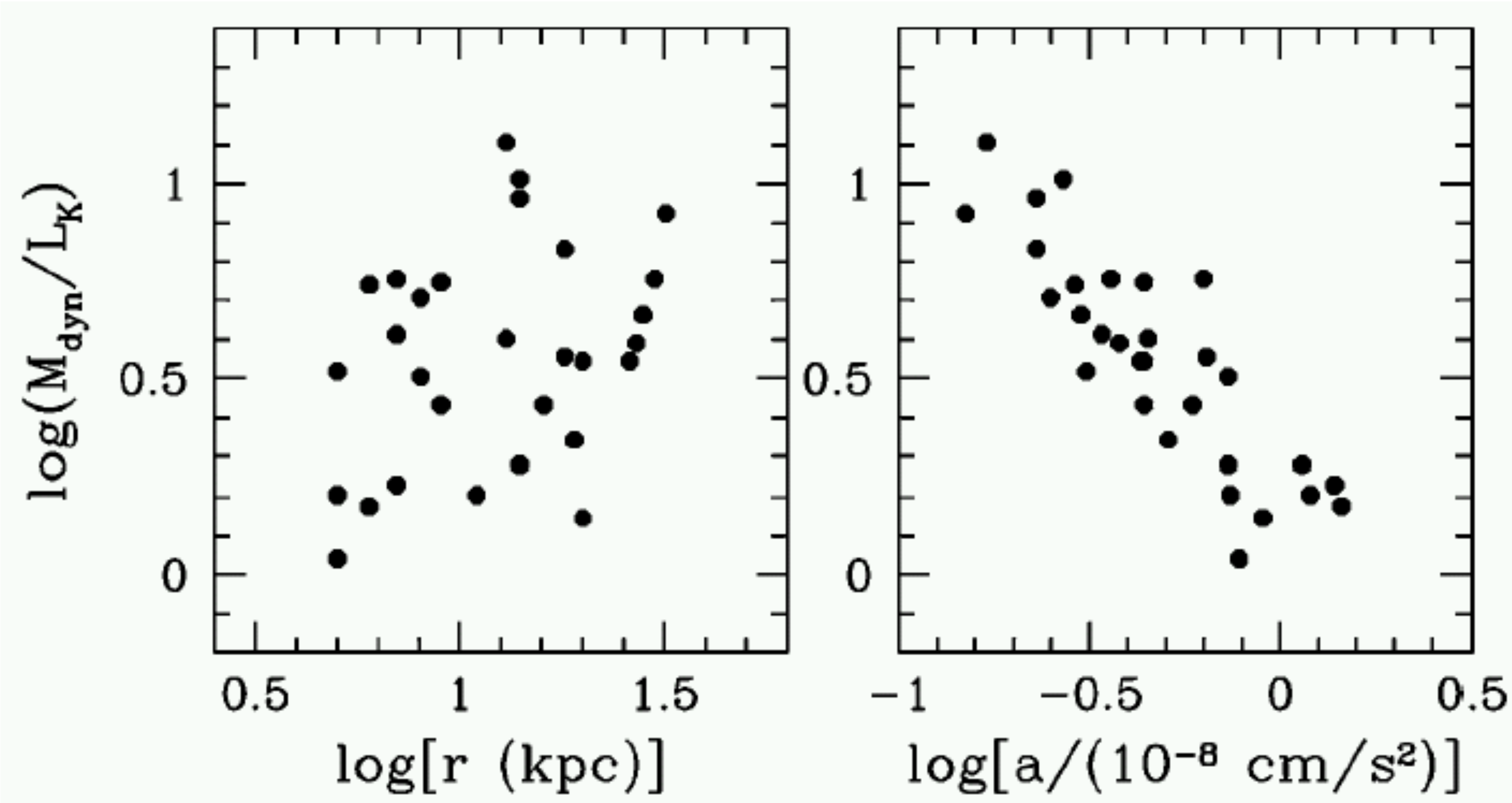
***Both* geometrical and dynamical evidence** (if GR is valid on all scales)





Dark matter seems to be required only where the test particle acceleration is low ($< a_0 \sim cH_0$) - it is *not* a scale-dependent effect

Milgrom (1983)

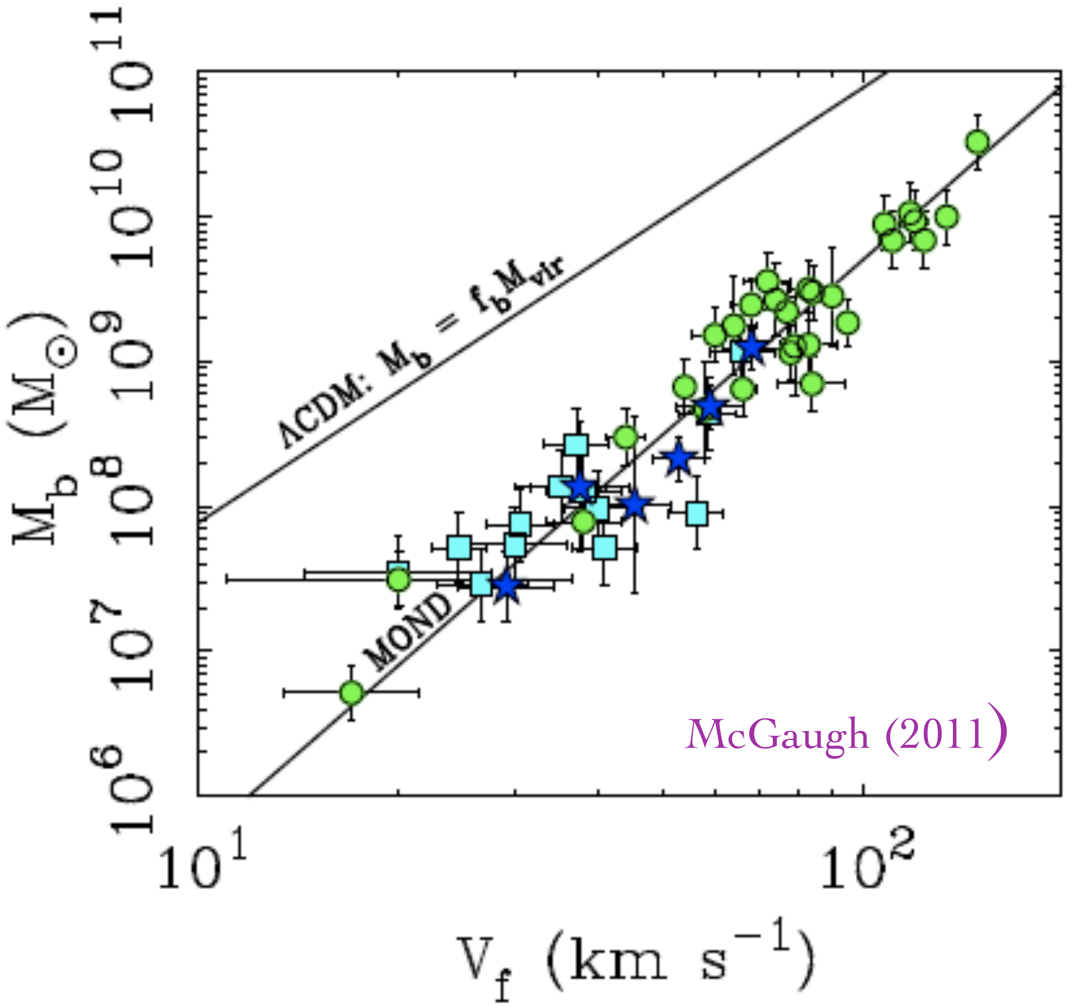


What if Newton's law is modified in weak fields?

$$F_{\rm N} \rightarrow \sqrt{\frac{GM}{r^2} a_0}$$

$$g_{r\rightarrow\infty} \rightarrow -\sqrt{MGa_0}\frac{\vec{r}}{r^2} + \mathcal{O}\left(\frac{1}{r^2}\right)$$

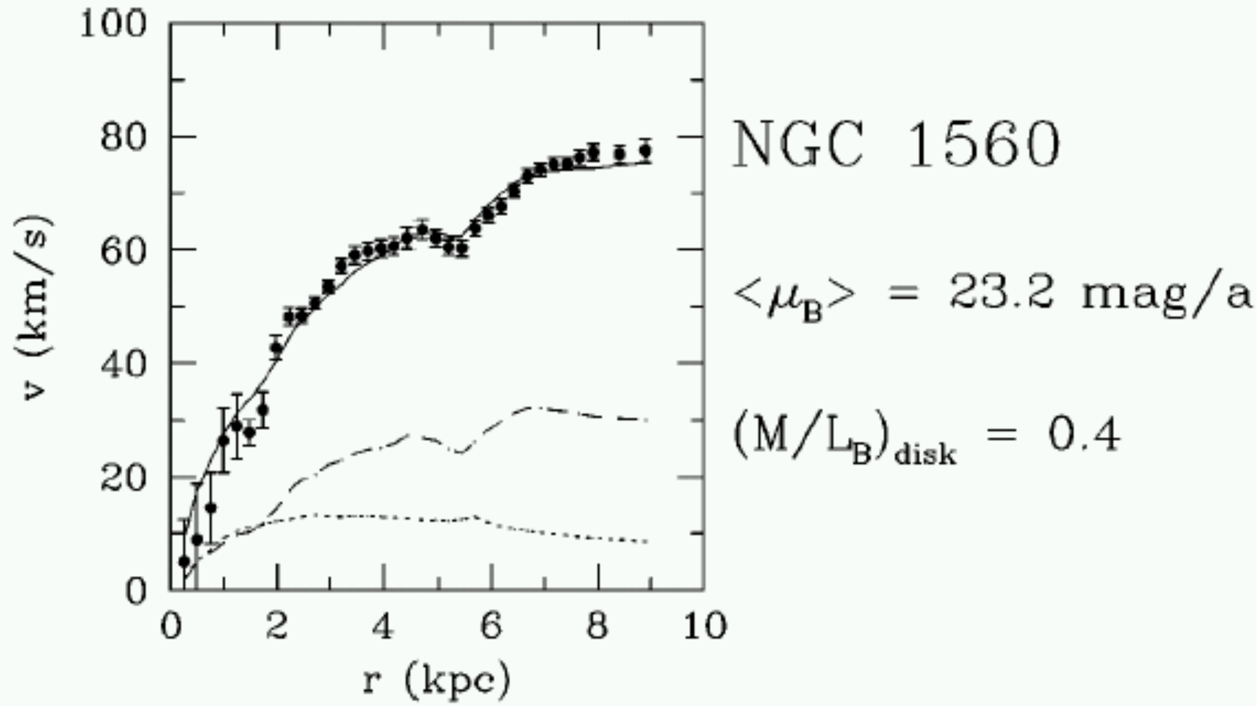
$$\frac{v^4}{r^2} = \frac{GM}{r^2} a_0 \quad \Rightarrow \quad M \propto v^4 \quad (\text{Tully–Fisher if } \frac{M}{L} = \text{const})$$

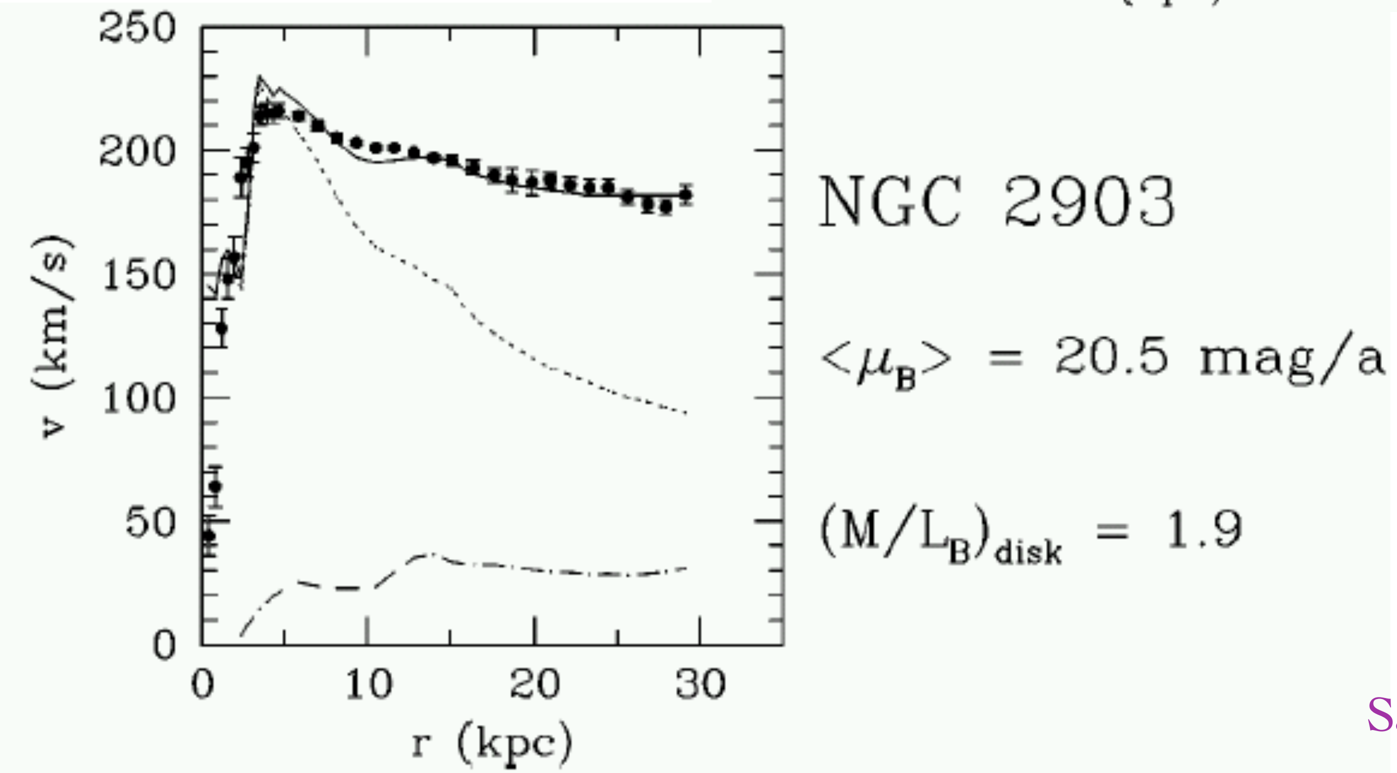


This is an impressive correlation which dark matter *cannot* explain

MOND fits galactic rotation curves with a_0=1.2x10^{-8} cm s^{-2}

… fitted M/L agrees well with expectation from stellar evolution

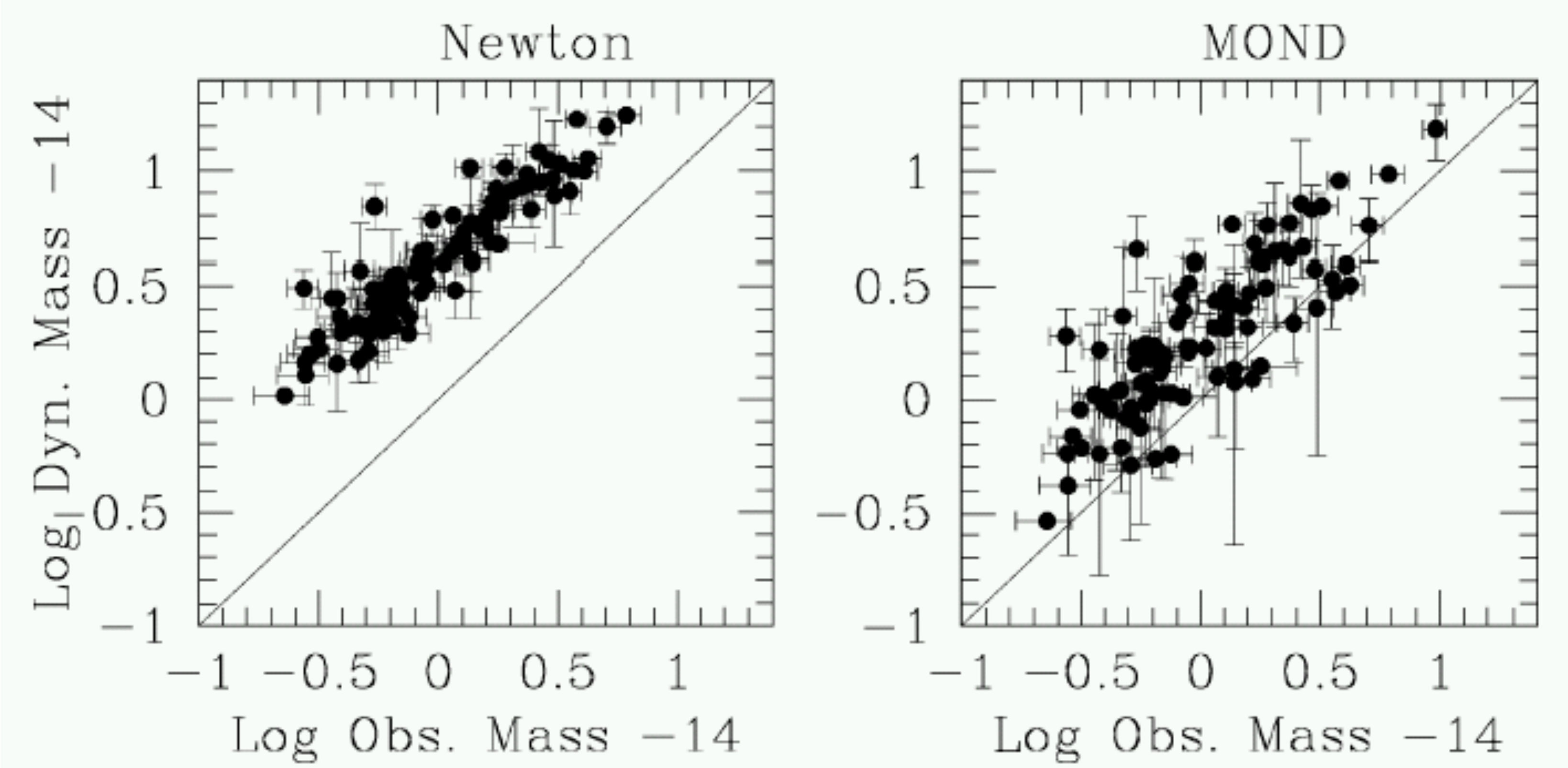




Features in the light profile are reproduced in the rotation curve!

Sanders & McGaugh (2002)

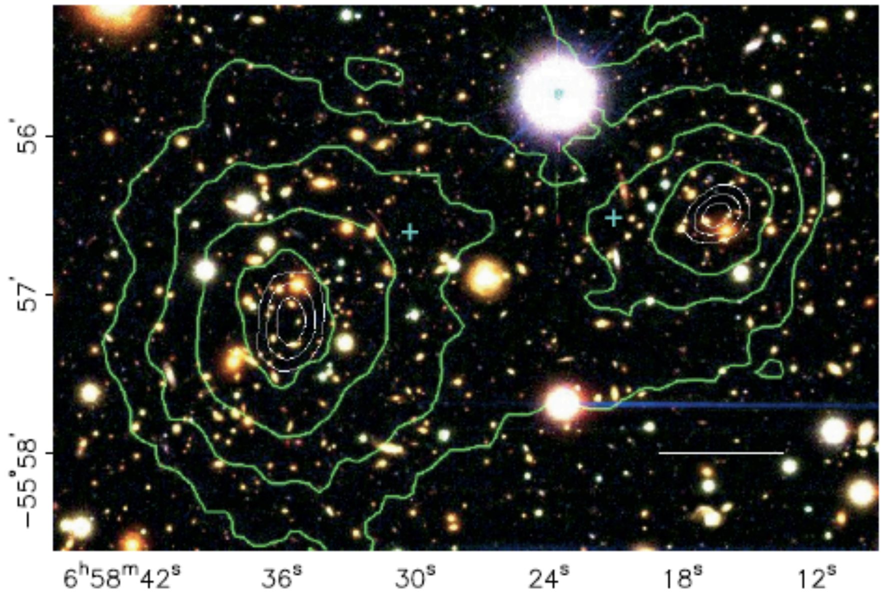
However MOND *fails* on the scale of clusters of galaxies



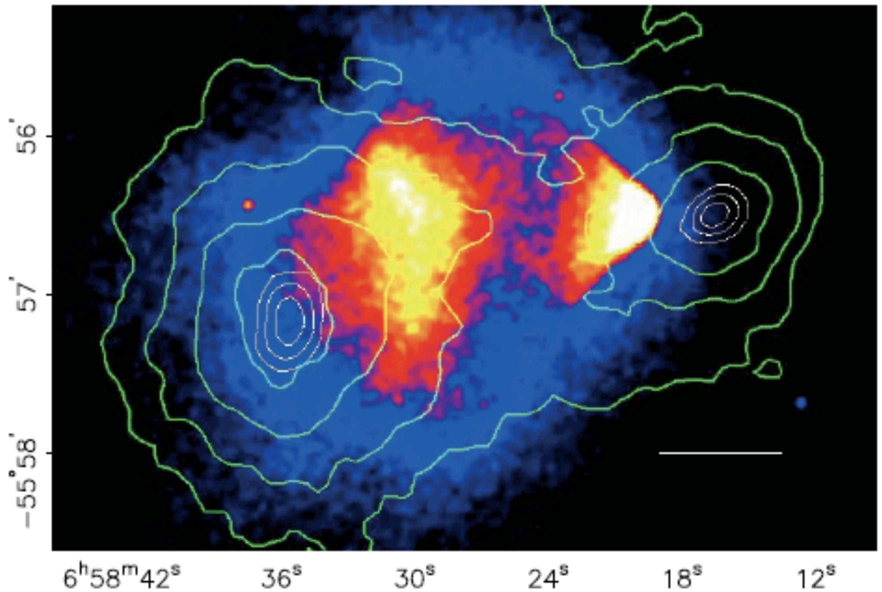
The "missing mass" *cannot* be accounted for entirely by invoking MOND … **dark matter *is* required** (vindicating the original proposal of Zwicky)

In the ‘bullet cluster’ the X-ray emitting **baryonic matter** is clearly *displaced* from the **dark matter** (the spatial distribution of which is inferred from gravitational lensing *assuming* GR)

… this seems to be convincing evidence for dark matter

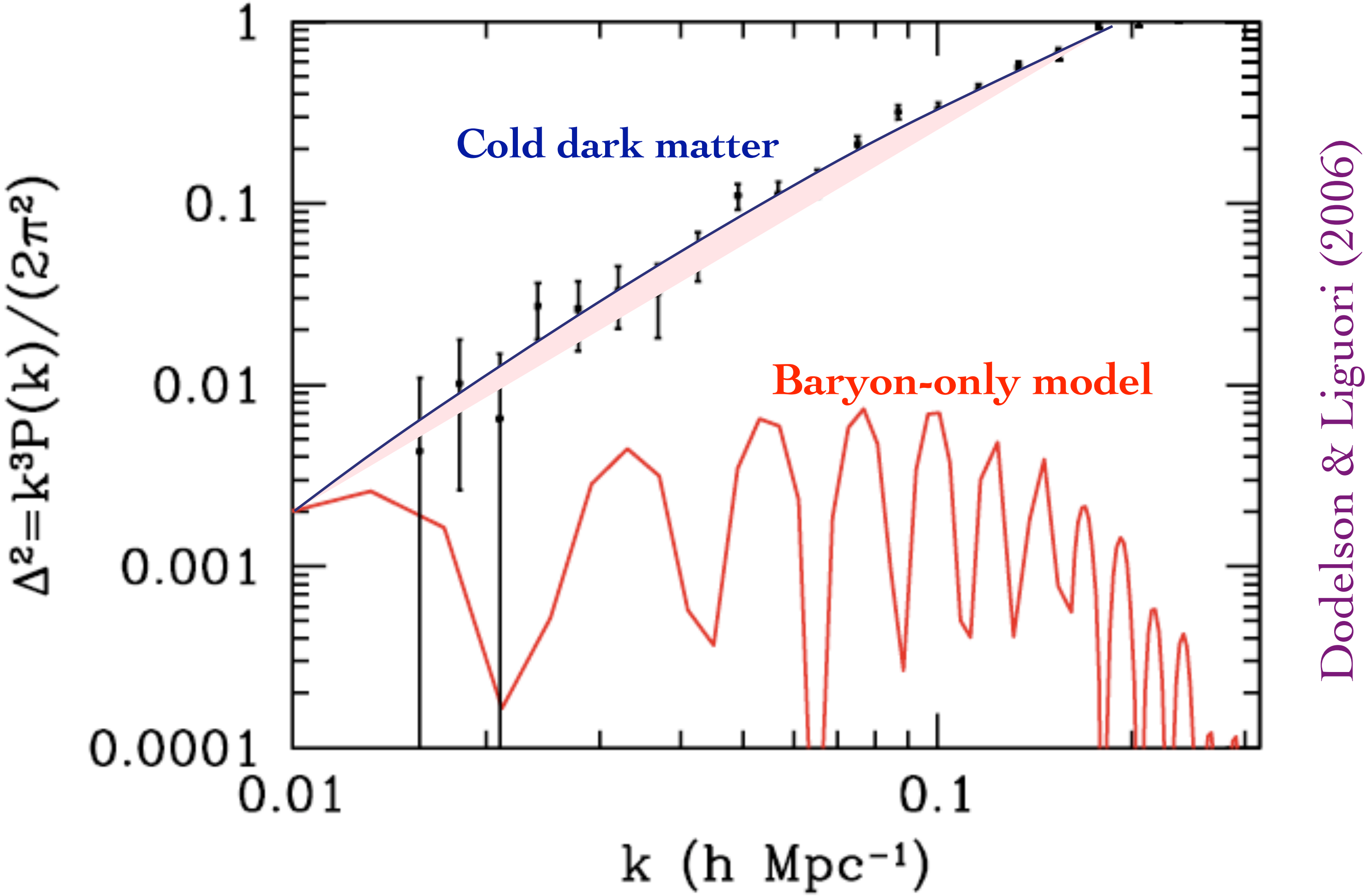


Clowe *et al* (2007)



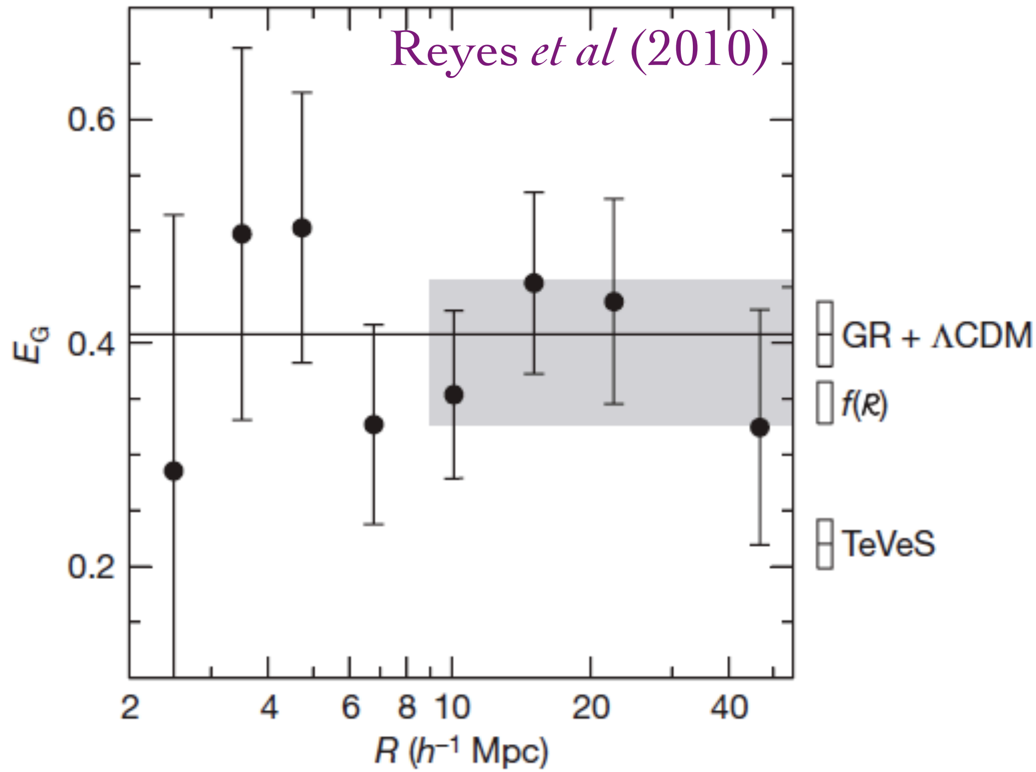
The *new* dynamics underlying MOND may, in principle, account for this, however no such compelling alternative to GR has been presented …

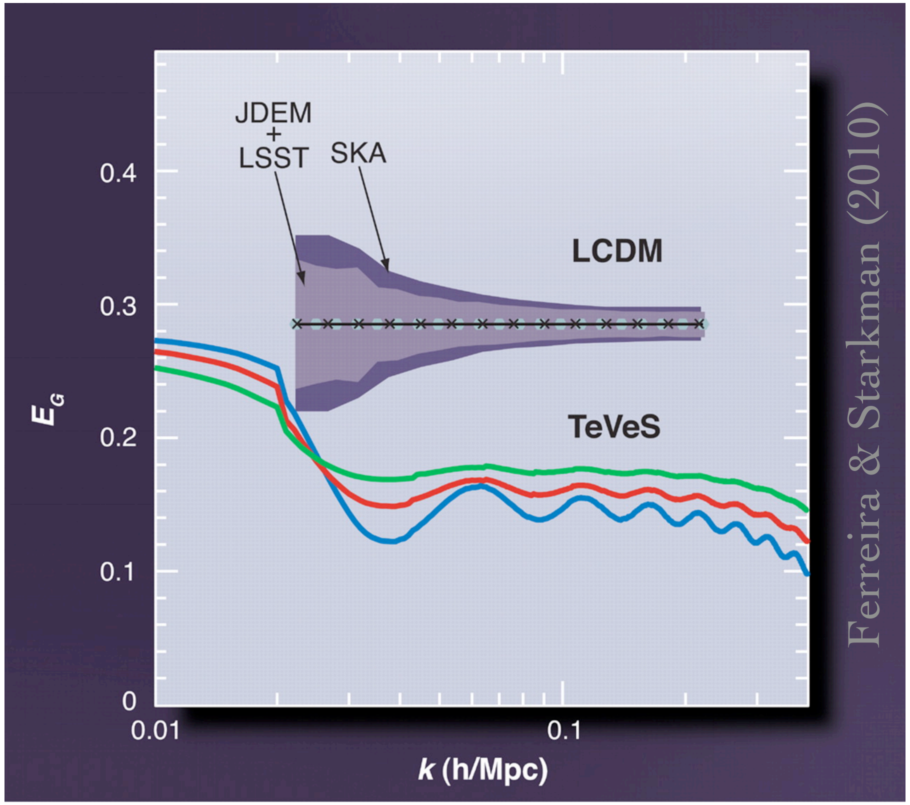
Moreover the observed large-scale structure *requires* $\Omega_m >> \Omega_B$ if it has resulted from the growth under gravity (GR) of small initial density fluctuations … which left their imprint on the CMB at last scattering



Detailed modelling of WMAP and 2dF/SDSS ⇒ $\Omega_m \sim 0.3$, $\Omega_B \sim 0.05$
… *No* MOND-like theory (e.g. TeVeS) can fit the data so well

Although *new* gravitational physics (underlying MOND) can in principle provide adequate growth of cosmological structure, there will always be an observable distinction – the 'gravitational slip' – between GR and the new theory

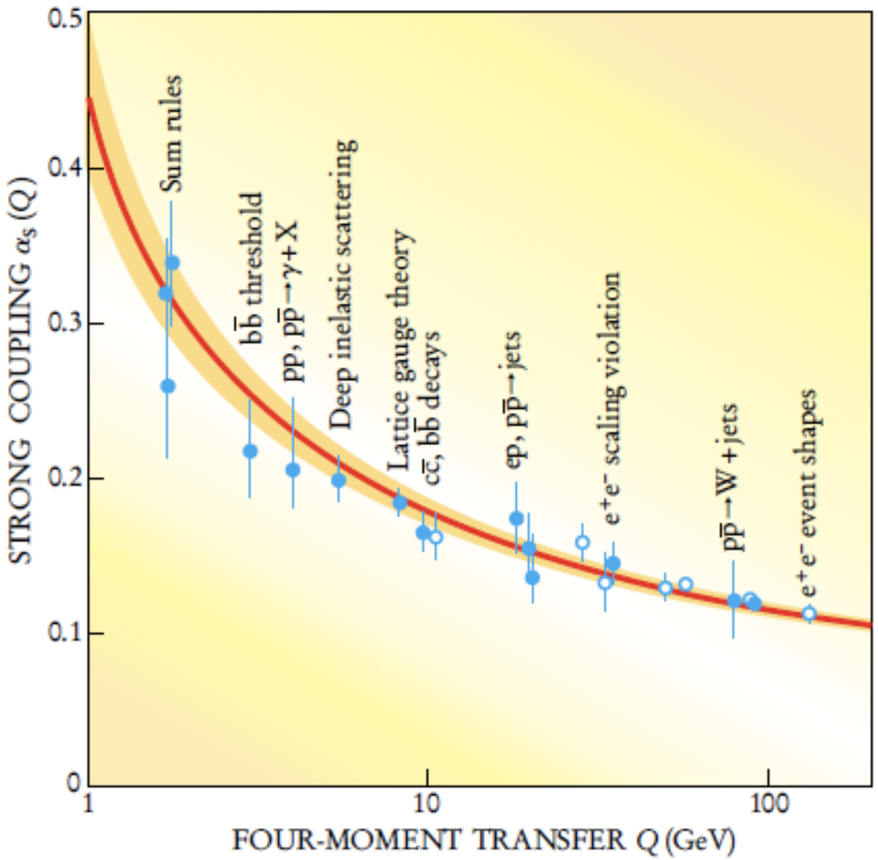


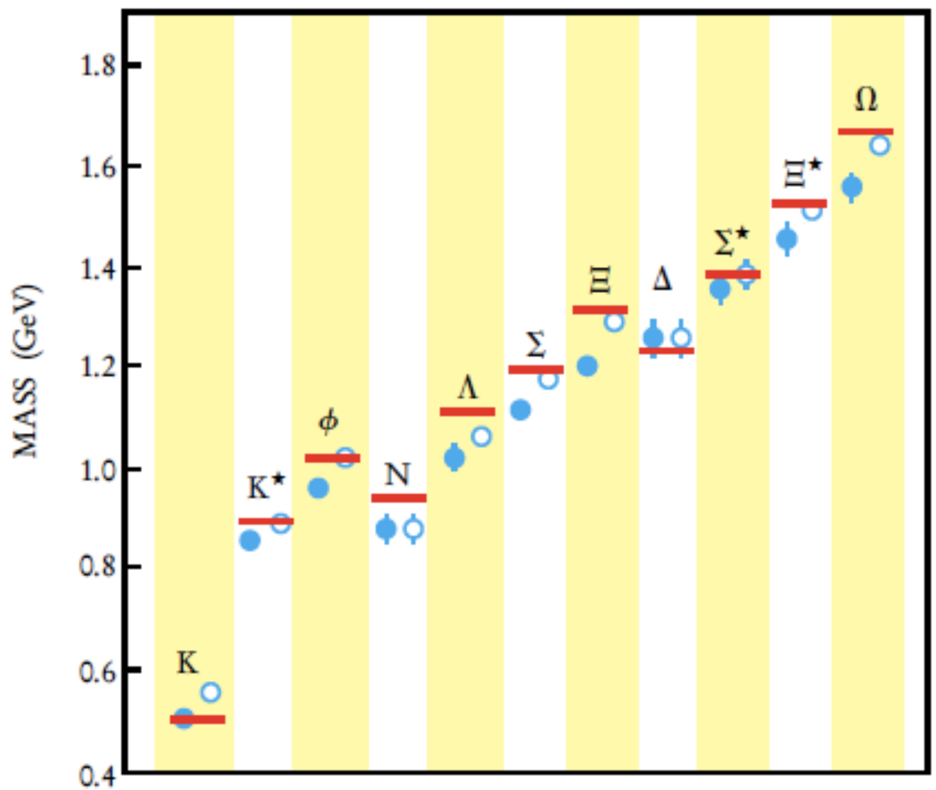


This can be tested through measurements of 'weak lensing' (shearing of galaxy shapes) and its cross-correlation with the galaxy density field

What *should* the world be made of ?

Mass scale	Particle	Symmetry/ Quantum #	Stability	Production	Abundance
Λ_{QCD}	**Nucleons**	Baryon number	$\tau > 10^{33}$ yr (dim-6 OK)	'freeze-out' from thermal equilibrium	$\Omega_B \sim 10^{-10}$ *cf.* observed $\Omega_B \sim 0.05$





(Courtesey:Frank Wilczek)

What do we expect for the *symmetric* thermal relic abundance of baryons?

$$\dot{n} + 3Hn = -\langle\sigma v\rangle(n^2 - n_{\mathrm{T}}^2)$$

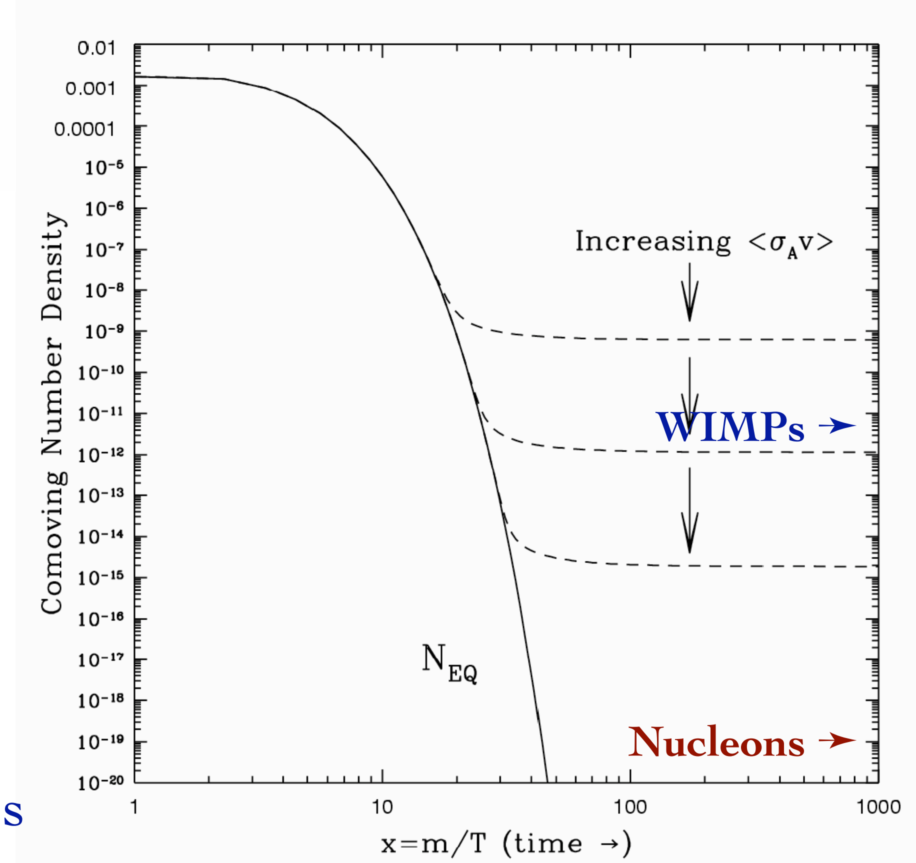
Chemical equilibrium is maintained as long as annihilation rate exceeds the Hubble expansion rate

'Freeze-out' occurs when annihilation rate:

$$\Gamma = n\sigma v \sim m_N^{3/2} T^{3/2} \mathrm{e}^{-m_N/T} \frac{1}{m_\pi^2}$$

becomes comparable to the expansion rate

$H \sim \dfrac{\sqrt{g}T^2}{M_{\mathrm{P}}}$ where $g \Rightarrow$ # relativistic species



i.e. freeze-out occurs at $T \sim \mathrm{m}_N/45$, with: $\dfrac{n_N}{n_\gamma} = \dfrac{n_{\bar{N}}}{n_\gamma} \sim 10^{-19}$

However the observed ratio is 10^9 times *bigger* for baryons, and there are *no* antibaryons, so we must invoke an **initial asymmetry**: $\dfrac{n_B - n_{\bar{B}}}{n_B + n_{\bar{B}}} \sim 10^{-9}$

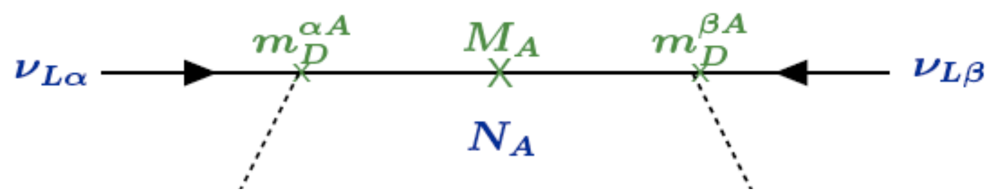
Sakharov conditions for baryogenesis:

1. Baryon number violation
2. C and CP violation
3. Departure for thermal equilibrium

Baryon number violation occurs even in the Standard Model through non-perturbative (sphaleron-mediated) processes … but CP-violation is *too weak* (also out-of-equilibrium conditions are not available since the electroweak symmetry breaking phase transition is in fact a 'cross-over')

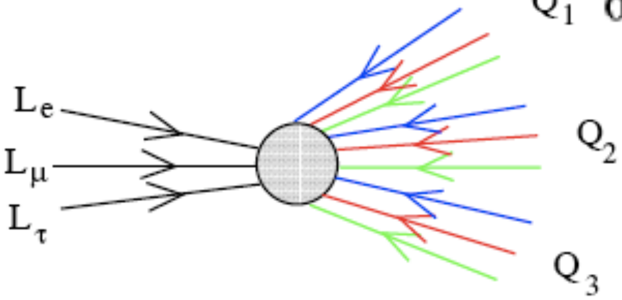
Thus the generation of the observed matter-antimatter asymmetry *requires* new BSM physics (could be related to neutrino masses … **possibly due to violation of lepton number → leptogenesis)**

'See-saw': $\mathcal{L} = \mathcal{L}_{SM} + \lambda^*_{\alpha J}\overline{\ell}_\alpha \cdot H N_J - \frac{1}{2}\overline{N_J} M_J N^c_J \qquad \lambda M^{-1}\lambda^{\mathrm{T}}\langle H^0\rangle^2 = [m_\nu]$



$\Delta m^2_{atm} = m^2_3 - m^2_2 \simeq 2.6 \times 10^{-3}\mathrm{eV}^2 \qquad \Delta m^2_\odot = m^2_2 - m^2_1 \simeq 7.9 \times 10^{-5}\mathrm{eV}^2$

Asymmetric baryonic matter



$$\partial_\mu j_i^\mu = \partial_\mu(\bar{\psi}^i \gamma^\mu \psi^i) = \frac{g^2}{8\pi} W^{a\mu\nu} \tilde{W}^a_{\mu\nu} \Rightarrow N^i(T) - N^j(T) = N_0^i - N_0^j$$

$$N^i(T) = c_i(m_i, T)\mu_i/T \quad + \quad \sum_i \mu_i = 0$$

$$\Rightarrow \quad N^i(T) = N_0^i - \frac{\sum_j N_0^j / c_j(m_j, T)}{\sum_j 1/c_j(m_j. T)}$$

Barr *et al* (1990)

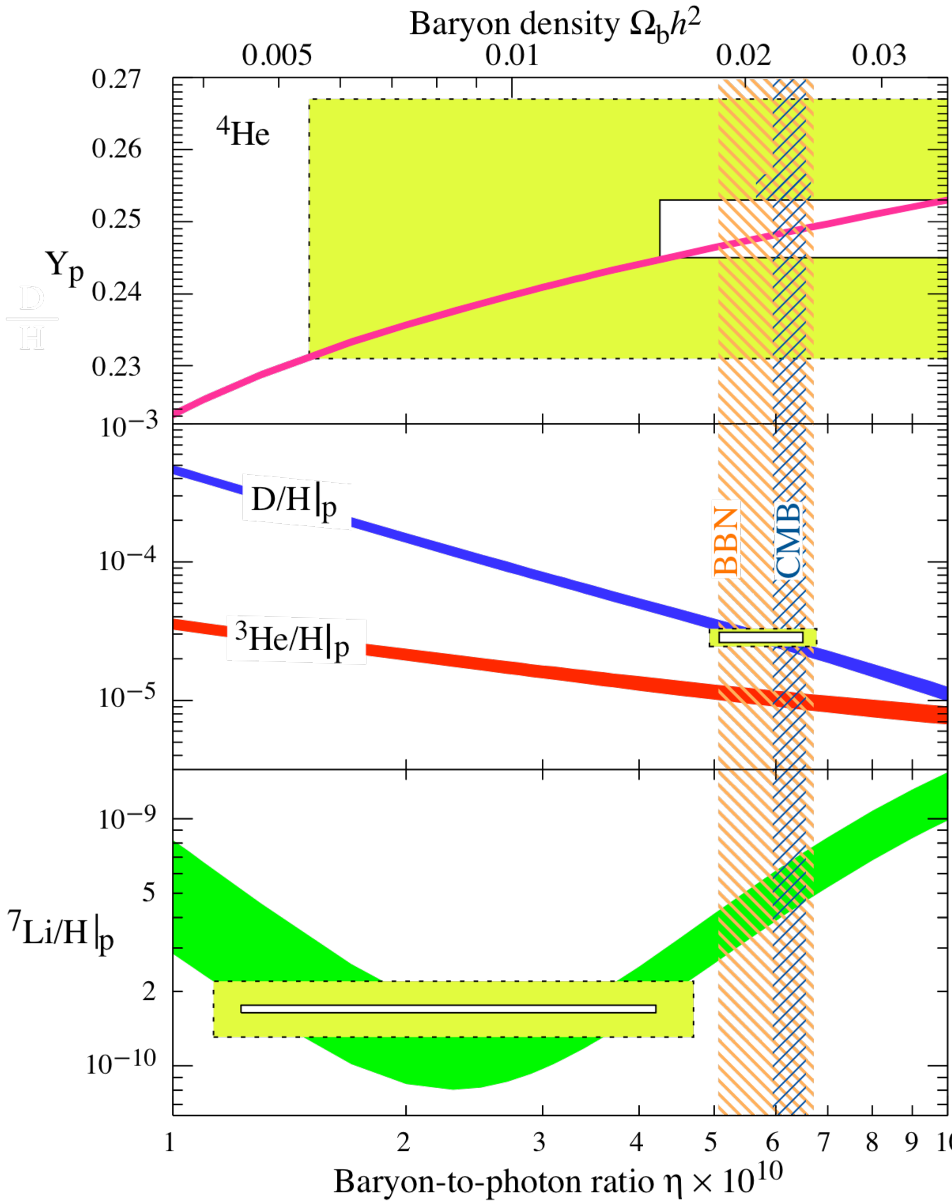
Any primordial lepton asymmetry (from the *out*-of-equilibrium decays of the right-handed *N*) would be redistributed by *B*+*L* violating processes (which *conserve B-L*) amongst *all* fermions which couple to the electroweak anomaly

Although **leptogenesis** is not directly testable experimentally (unless the lepton number violation occurs as low as the TeV scale), it is an elegant paradigm for the origin of baryons

… but in any case we accept that the only kind of matter which we *know* originated *non*-thermally in the early universe

Although vastly *overabundant* compared to the natural expectation, baryons ***cannot*** close the universe (BBN ✚ CMB concordance)

… the dark matter must therefore mainly be *non*-baryonic



Fields & Sarkar (Particle Data Group), 2010

The **Standard $SU(3)_c$ x $SU(2)_L$ x $U(1)_Y$ Model** provides an exact description of all *microphysics* (up to some high energy cut-off scale *M*)

Higgs mass divergence

$$\mathcal{L}_{\text{eff}} = M^4 + M^2\Phi^2 \quad m_H^2 \simeq \frac{h_t^2}{16\pi^2}\int_0^{M^2} \mathrm{d}k^2 = \frac{h_t^2}{16\pi^2}M^2$$ **super-renormalisable**

$$+ (D\Phi)^2 + \bar{\Psi} \not{D}\Psi + F^2 + \bar{\Psi}\Psi\Phi + \Phi^2$$ **renormalisable**

$$+ \frac{\bar{\Psi}\Psi\Phi\Phi}{M} + \frac{\bar{\Psi}\Psi\bar{\Psi}\Psi}{M^2} + \ldots$$ **non-renormalisable**

The effects of *new* physics beyond the SM (neutrino mass, nucleon decay, FCNC ...) → **non-renormalisable operators** suppressed by M^n … which 'decouple' as $M \to M_P$

But as *M* is raised, the effects of the **super-renormalisable operators** are *exacerbated*
Solution for 2nd term → 'softly broken' supersymmetry at *M* ~ 1 TeV (10^2 new parameters)

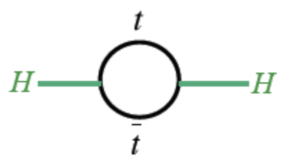
This suggests possible mechanisms for **baryogenesis**, candidates for **dark matter**, …
(as also do other proposed extensions of the SM, e.g. new dimensions @ TeV scale)

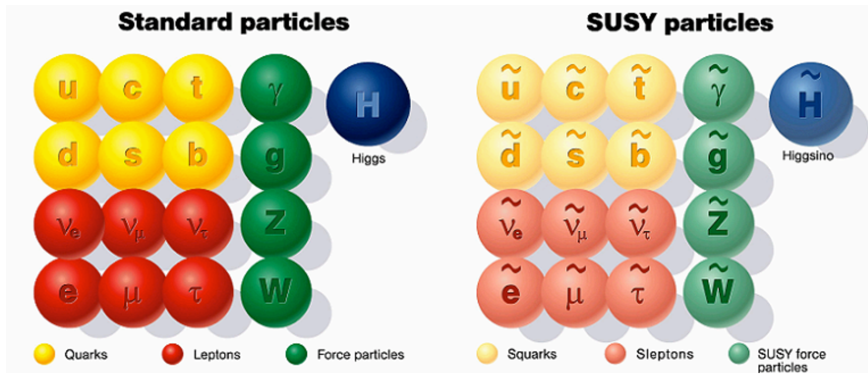
For example, the lightest supersymmetric particle (typically the neutralino χ), *if* protected against decay by *R*-parity, is a candidate for thermal dark matter

But if the Higgs is *composite* (as in **technicolor** models of **$SU(2)_L$ x $U(1)_Y$** breaking) then there is *no need* for supersymmetry … and light TC states can be dark matter

What *should* the world be made of ?

Mass scale	Particle	Symmetry/ Quantum #	Stability	Production	Abundance
Λ_{QCD}	**Nucleons**	Baryon number	$\tau > 10^{33}$ yr (dim-6 OK)	~~‘freeze-out’ from thermal equilibrium~~ Asymmetric baryogenesis	$\Omega_B \sim 10^{-10}$ *cf.* observed $\Omega_B \sim 0.05$
$\Lambda_{Fermi} \sim G_F^{-1/2}$	Neutralino?	*R*-parity?	Violated? (matter parity adequate for *p* stability)	‘freeze-out’ from thermal equilibrium	$\Omega_{LSP} \sim 0.25$



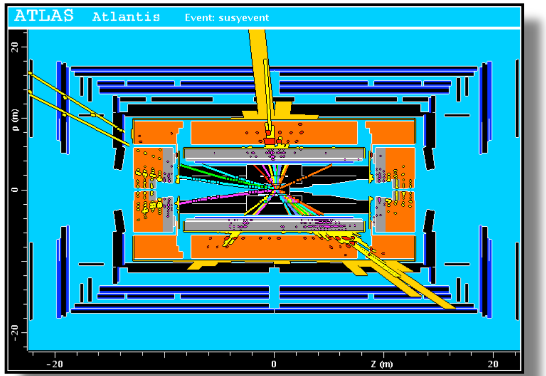


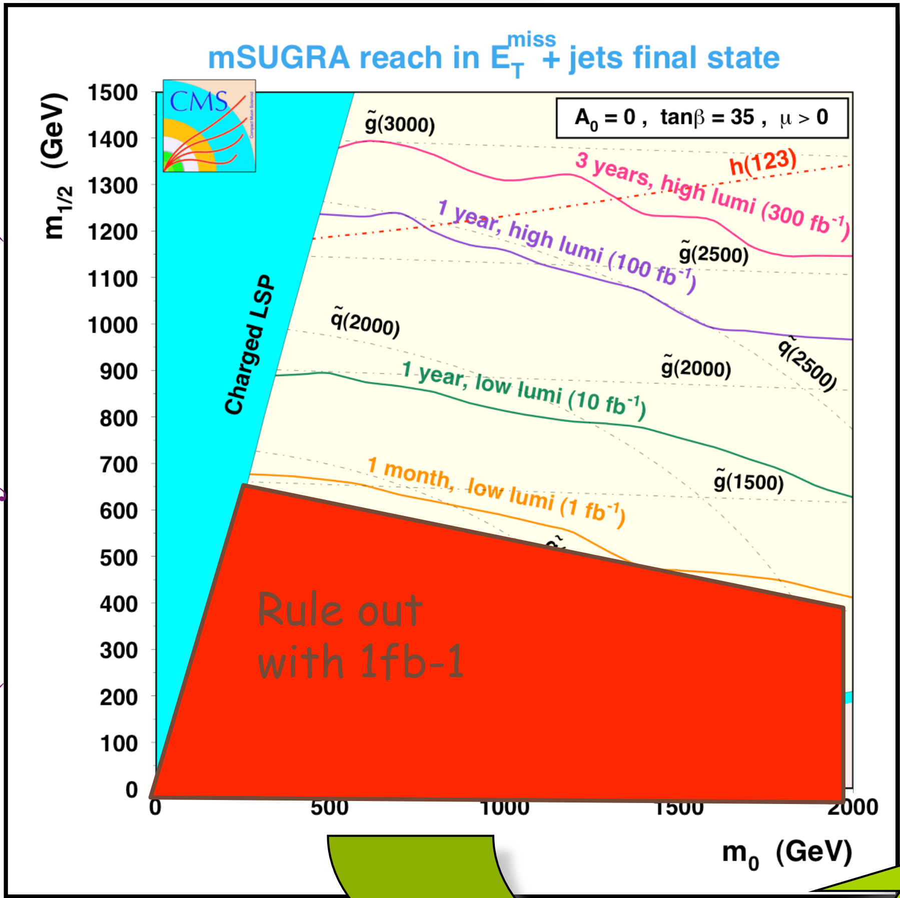
$$L^{SM}_{effective} \supset M_A A_\mu A^\mu + m_f \overline{f_L} f_R + M_H^2 |H|^2$$

For (softly broken) **supersymmetry** we have the ‘WIMP miracle’:

$$\Omega_\chi h^2 \simeq \frac{3 \times 10^{-27} \mathrm{cm}^{-3} \mathrm{s}^{-1}}{\langle \sigma_{\mathrm{ann}} v \rangle_{T=T_f}} \simeq 0.1 \quad , \text{ since } \langle \sigma_{\mathrm{ann}} v \rangle \sim \frac{g_\chi^4}{16\pi^2 m_\chi^2} \approx 3 \times 10^{-26} \mathrm{cm}^3 \mathrm{s}^{-1}$$

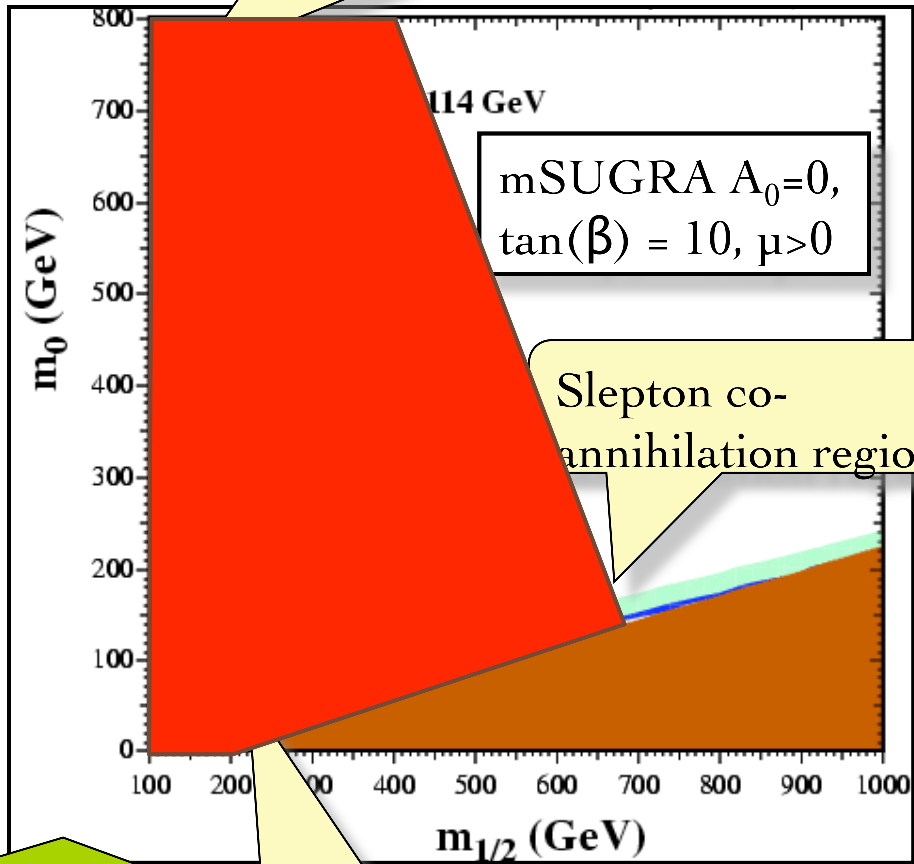
LHC reach for SUSY dark matter





(Courtesey: Alan Barr)

'Focus point' region:
annihilation to gauge bosons



Slepton co-annihilation region

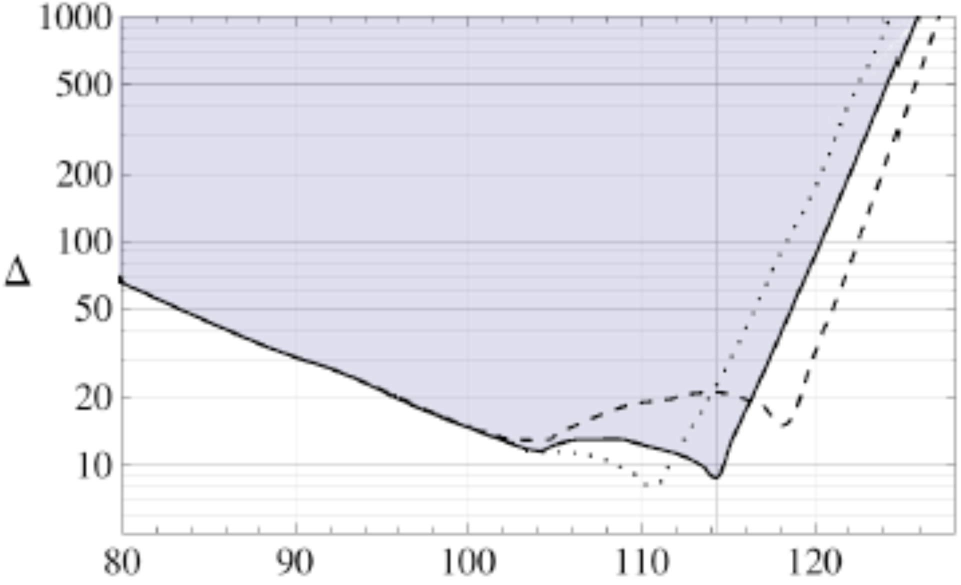
'Bulk' region:
t-channel slepton exchange

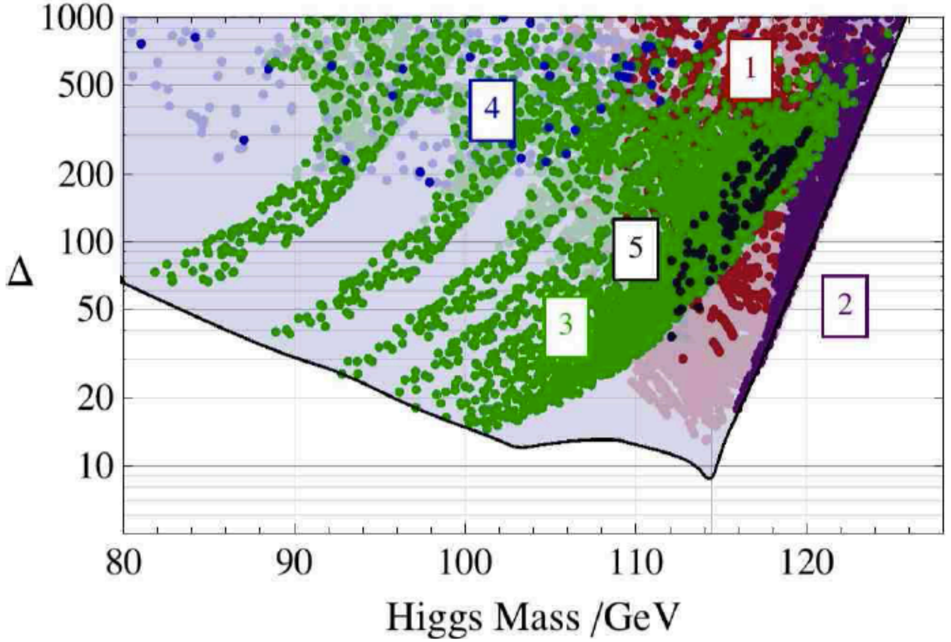
WMAP constraints

'Natural' parameter space in the CMSSM

Heavy sparticles → fine tuning of terms … with measure: $\Delta(a_i)=\left|\frac{a_i}{M_Z}\frac{\partial M_Z}{\partial a_i}\right|$

Castell, Ghilencea & Ross (2011)





Relic density unrestricted

SUSY particle masses

$3.20 < 10^4 \,\mathrm{Br}(b\to s\gamma) < 3.84$

$\mathrm{Br}(b\to\mu\mu) < 1.8\times 10^{-8}$

$\delta a_\mu < 292\times 10^{-11}$

$-0.0007 < \delta\rho < 0.0012$

$\Delta_{Min}=9,\quad m_h = 114\pm 2GeV$

Relic density restricted

1 h^0 resonant annihilation

2 $\tilde{h}$ t-channel exchange

3 $\tilde{\tau}$ co-annihilation

4 $\tilde{t}$ co-annihilation

• 5 A^0/H^0 resonant annihilation

$< 3\sigma$ WMAP: $\Delta_{Min}=18,\quad m_h = 115.9\pm 2GeV$

What *should* the world be made of ?

Mass scale	Particle	Symmetry/ Quantum #	Stability	Production	Abundance
Λ_{QCD}	**Nucleons**	Baryon number	$\tau > 10^{33}$ yr (dim-6 OK)	~~'Freeze-out' from thermal equilibrium~~ Asymmetric baryogenesis	$\Omega_B \sim 10^{-10}$ *cf.* observed $\Omega_B \sim 0.05$
$\Lambda_{Fermi} \sim G_F^{-1/2}$	Neutralino? Technibaryon?	R-parity? (walking) Technicolour	violated? □ $\tau \sim 10^{18}$ yr e^+ excess?!	'Freeze-out' from thermal equilibrium Asymmetric (like the *observed* baryons)	$\Omega_{LSP} \sim 0.25$ $\Omega_{TB} \sim 0.25$

A new particle would *share* in the *B/L* asymmetry if it is e.g. charged under a new global *U*(1) symmetry which has a mixed anomaly with *SU*(2) gauge symmetry

… this can *explain* the ratio of dark to baryonic matter!

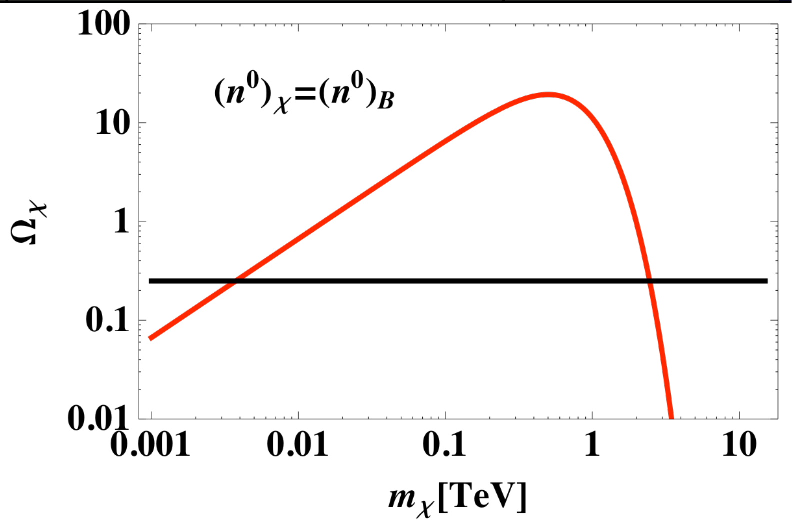
For example a TeV mass technibaryon would naturally have (Nussinov 1985):

$$\frac{\rho_{\rm DM}}{\rho_{\rm B}} \sim \frac{m_{\rm DM}}{m_{\rm B}} \left(\frac{m_{\rm DM}}{m_{\rm B}}\right)^{3/2} {\rm e}^{-m_{\rm DM}/T_{\rm sphaleron}} \simeq 5$$

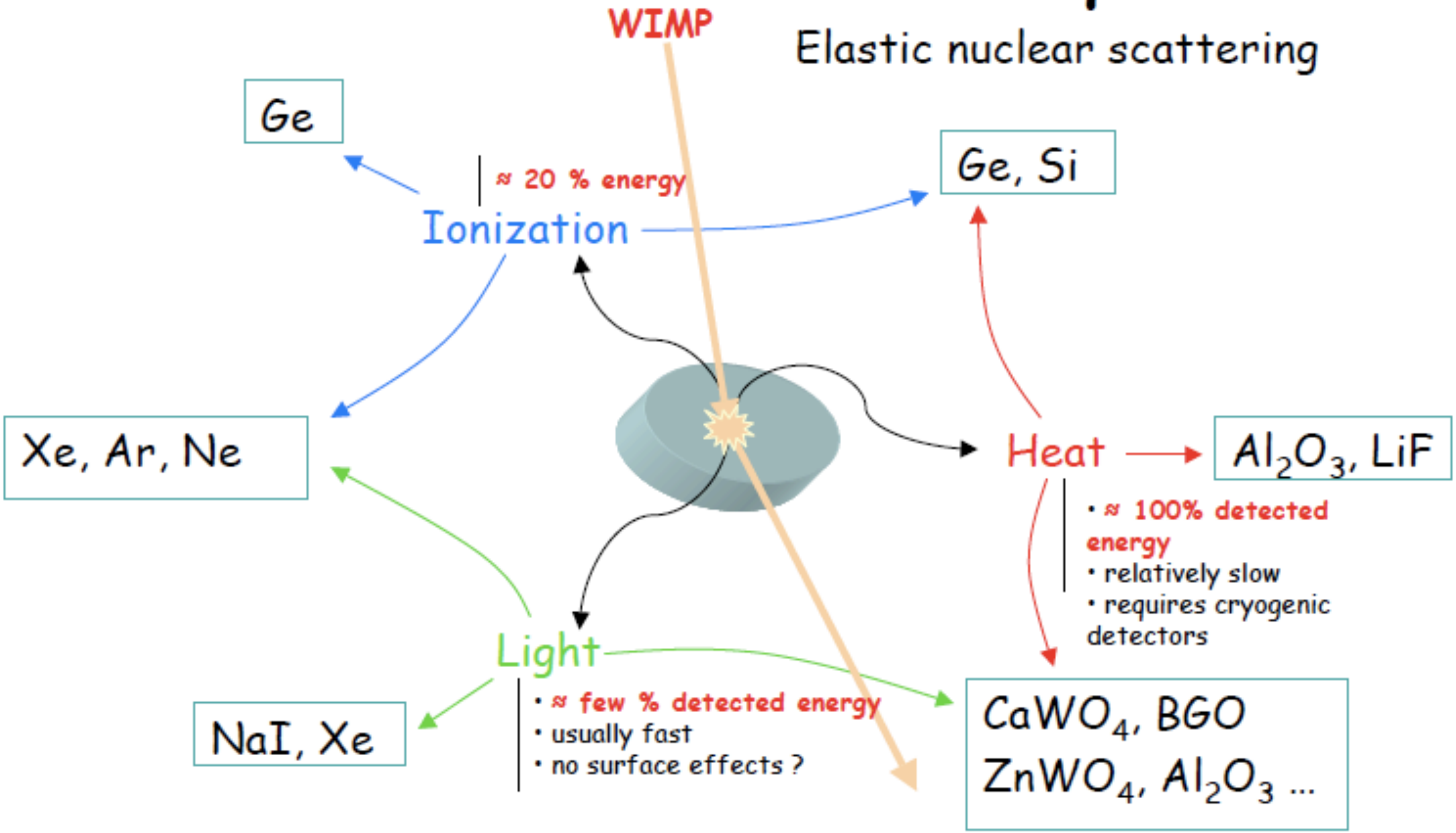
What *should* the world be made of ?

Mass scale	Particle	Symmetry/ Quantum #	Stability	Production	Abundance
Λ_{QCD}	**Nucleons**	Baryon number	$\tau > 10^{33}$ yr (dim-6 OK)	~~'Freeze-out' from thermal equilibrium~~ Asymmetric baryogenesis (how?)	$\Omega_B \sim 10^{-10}$ *cf.* observed $\Omega_B \sim 0.05$
$\Lambda_{QCD'} \sim 5\Lambda_{QCD}$	**Dark baryon**	$U(1)_{DB}$	?	Asymmetric (like the *observed* baryons)	$\Omega_{DB} \sim 0.25$
$\Lambda_{Fermi} \sim G_F^{-1/2}$	Neutralino? Technibaryon?	R-parity? (walking) Technicolour	violated? $\tau \sim 10^{18}$ yr e^+ excess?!	'Freeze-out' from thermal equilibrium Asymmetric (like the *observed* baryons)	$\Omega_{LSP} \sim 0.25$ $\Omega_{TB} \sim 0.25$

For ~5 GeV mass the required abundance is *even* more natural (Gelmini *et al* 1987) and there are candidate particles in *hidden* sectors (Kaplan 1992, Hooper *et al* 2005, Kaplan *et al* 2009, Kribs *et al* 2009, Sannino & Zwicky 2010, An *et al* 2010, Cohen *et al* 2010, Frandsen *et al* 2011) with characteristic collider signatures …



Direct detection techniques



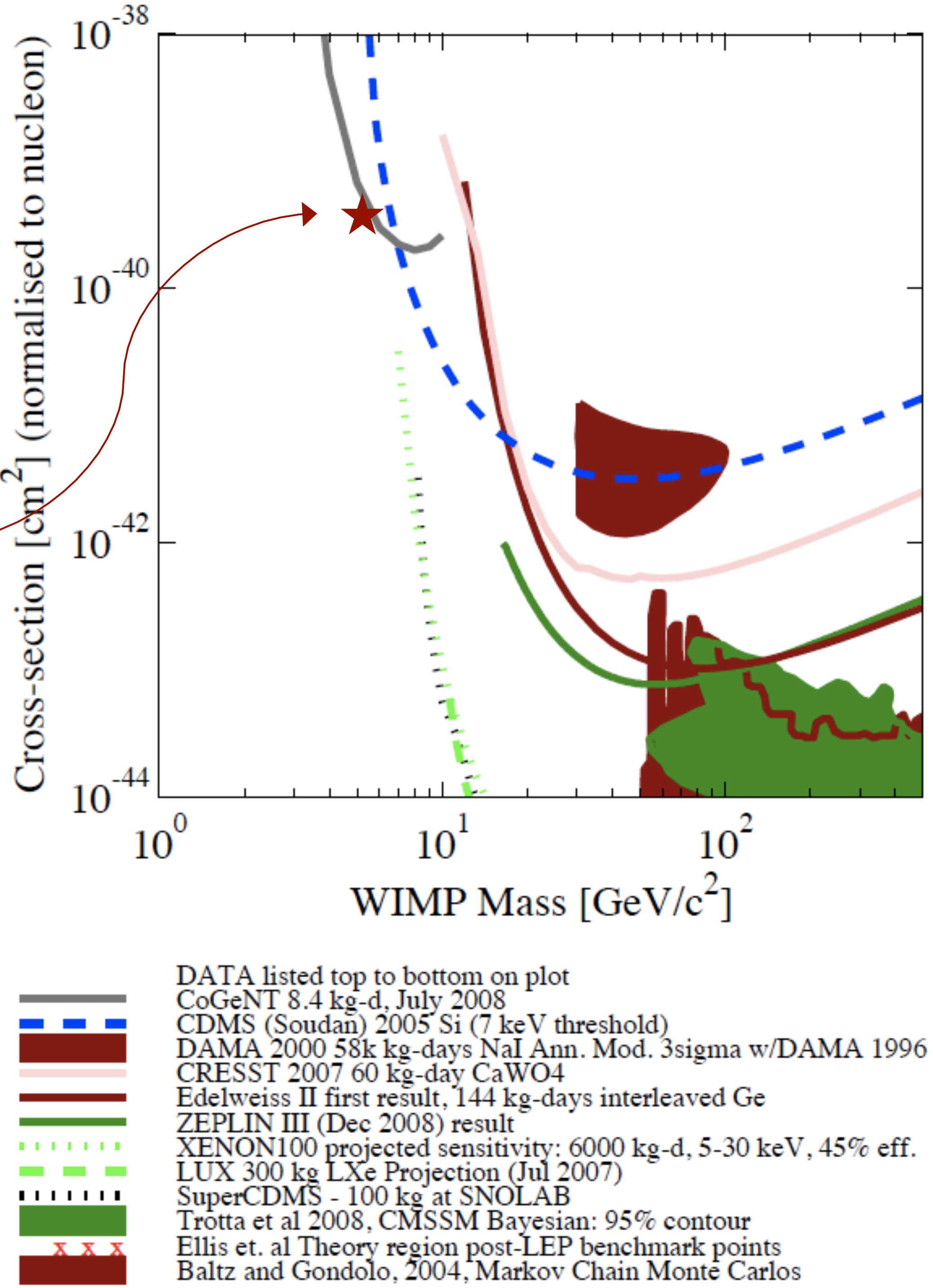
(Drukier & Stodolsky 1984; Goodman & Witten 1985)

No detection so far … upper limits (~10^{-43} cm^2) on scattering cross-section of ~100 GeV WIMPs, assuming local halo dark matter density ~ 0.3 GeV cm^{-3}

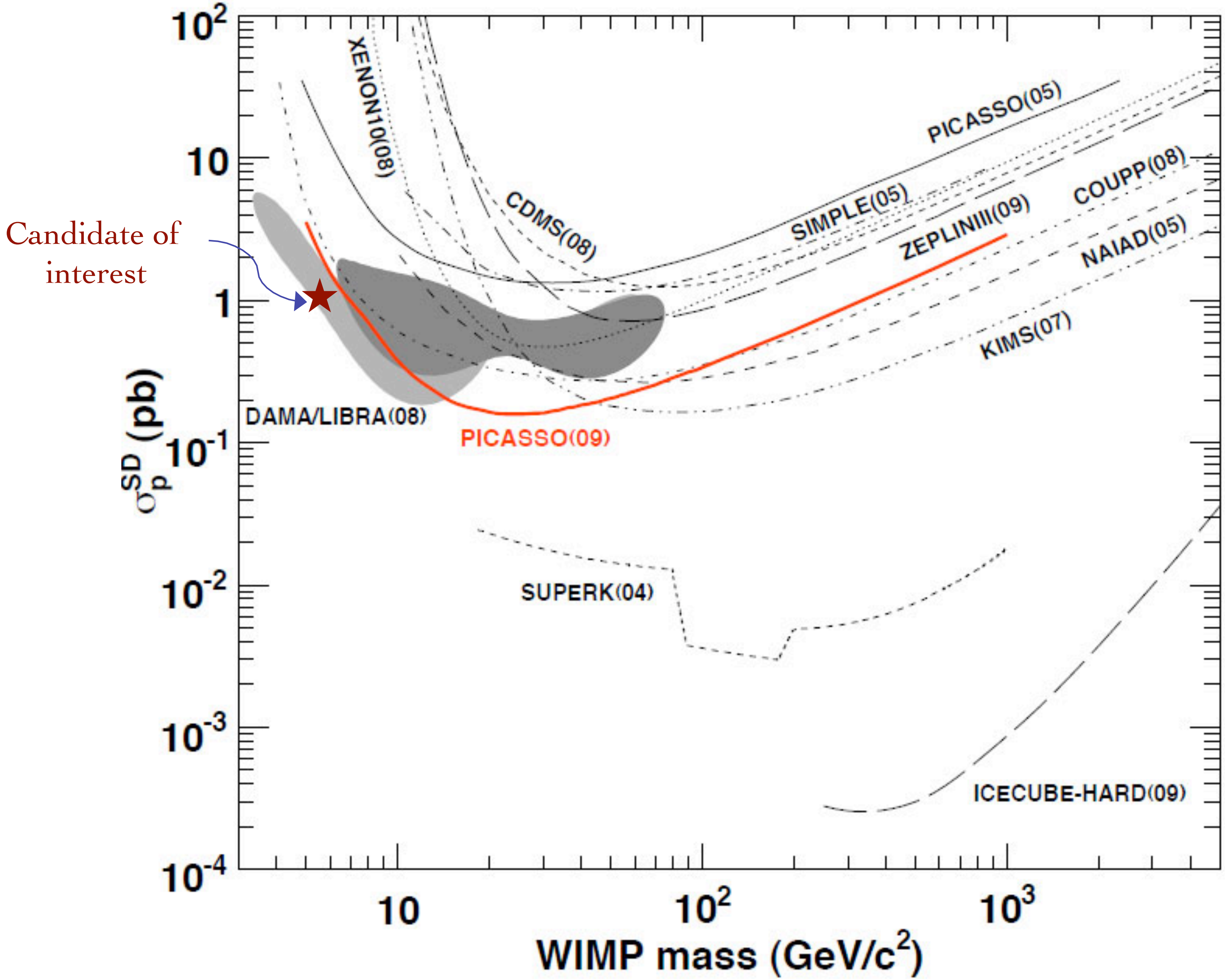
Experiments to directly detect dark matter through nuclear recoil are optimised for heavy WIMPs (motivated by SUSY) … they have little sensitivity for low mass particles ⇒ O(keV) recoil energy

A ~5 GeV dark matter particle may have gone undetected even if its interaction cross-section is as high as $\sim 10^{-40}$-10^{-39} cm^2

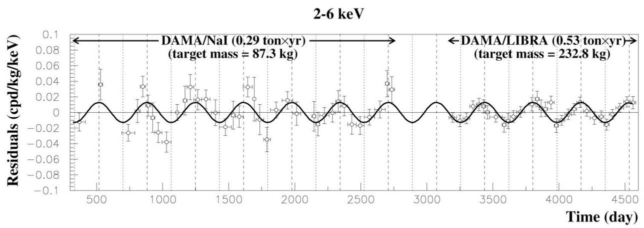
To detect such particles will require *low* threshold detectors

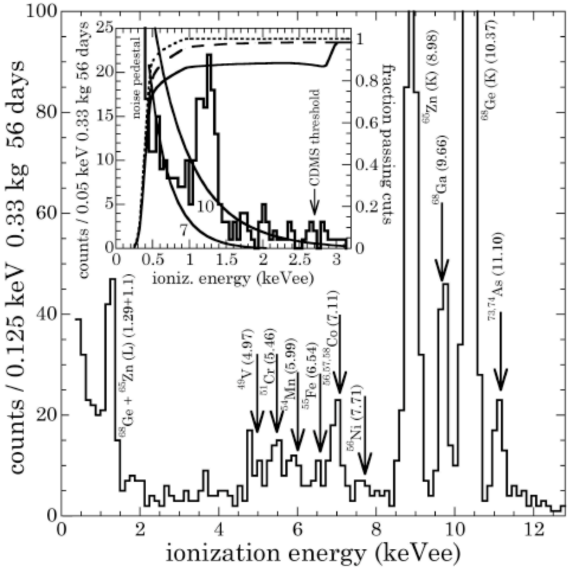


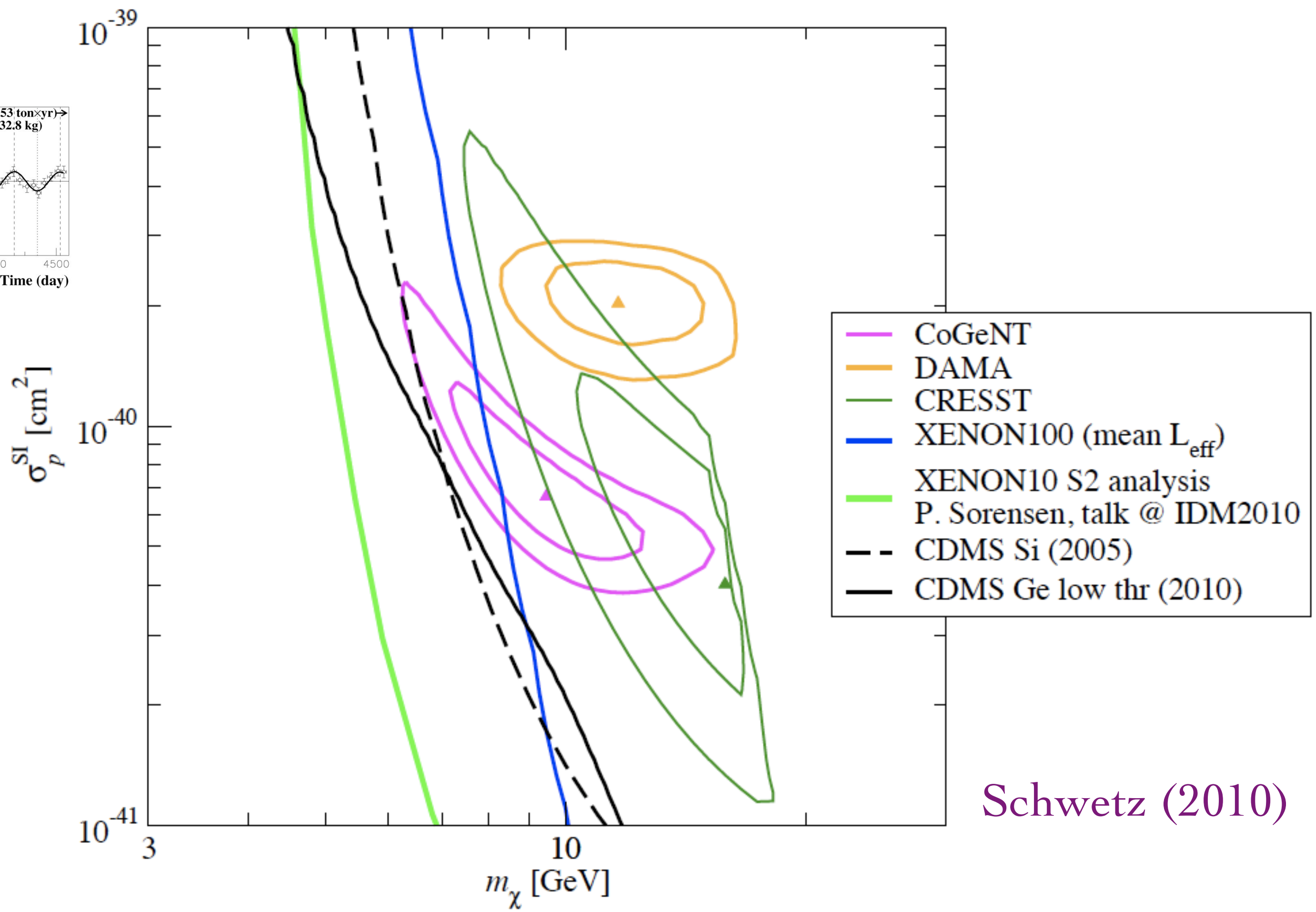
The spin *dependent* DM-nucleon cross-section can be as high as 10^{-36} cm^2



Some experiments (CoGeNT, DAMA, ...) have reported *possible* signals for ~5-10 GeV mass dark matter with $\sigma_{SI} \sim 10^{-40}$-$10^{-39}$ cm^2!

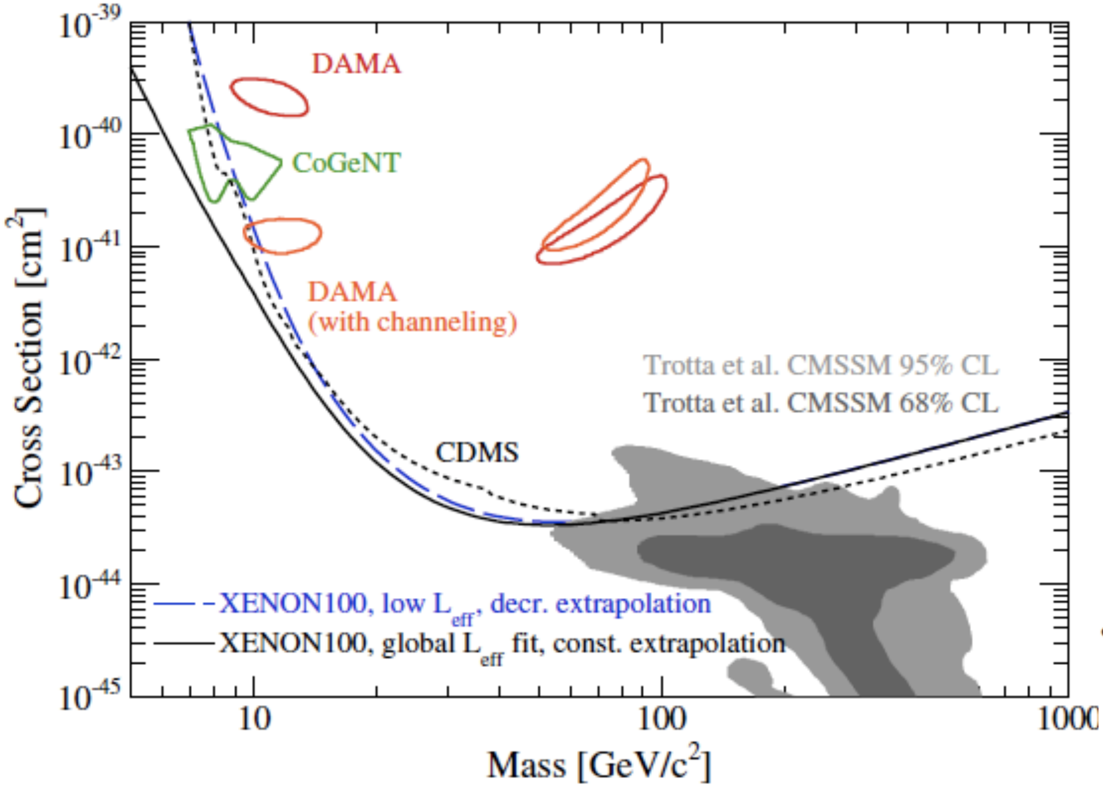


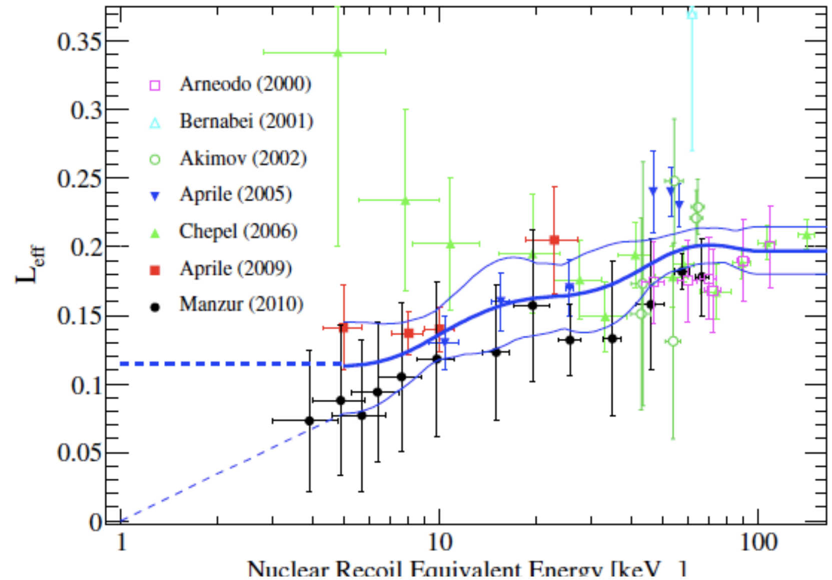


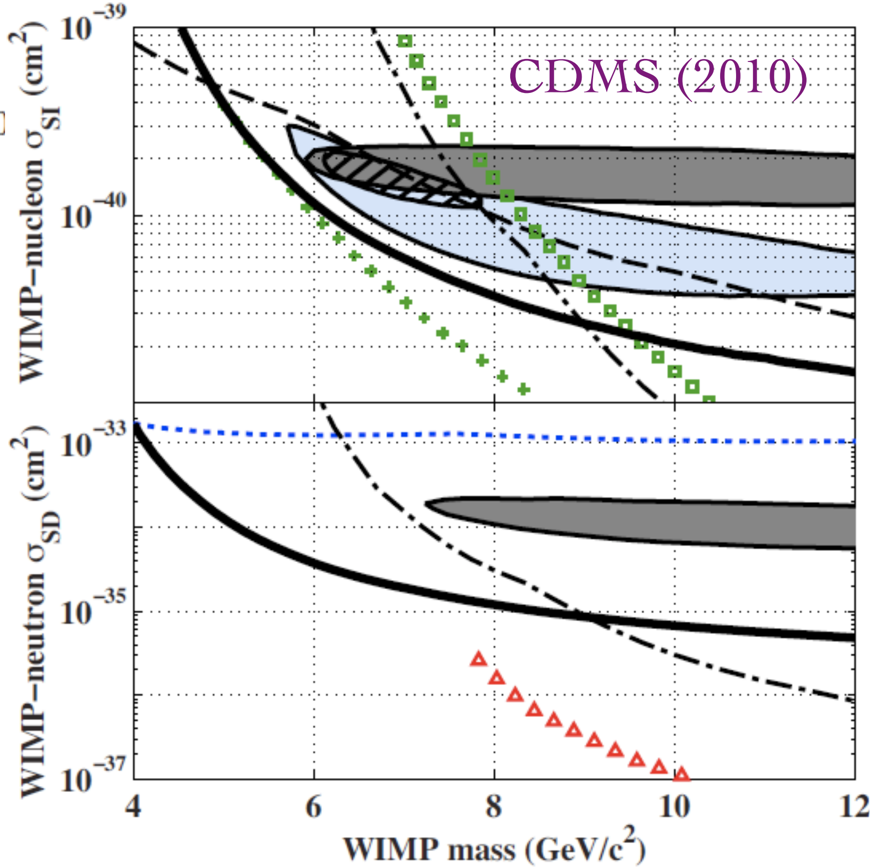


Schwetz (2010)

Efforts are currently underway to test these claims with *low threshold* detectors (XENON, CCDs ...)



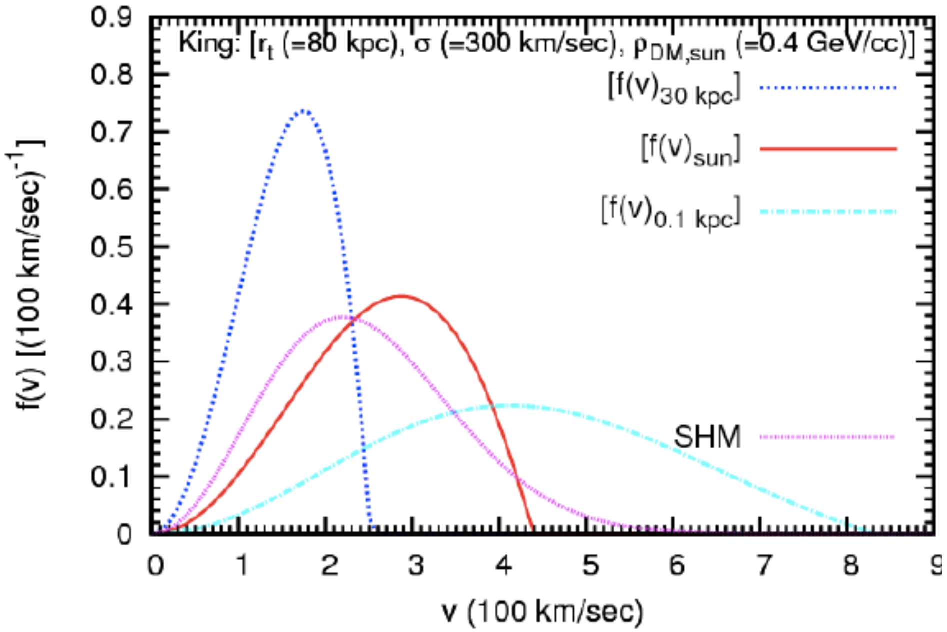


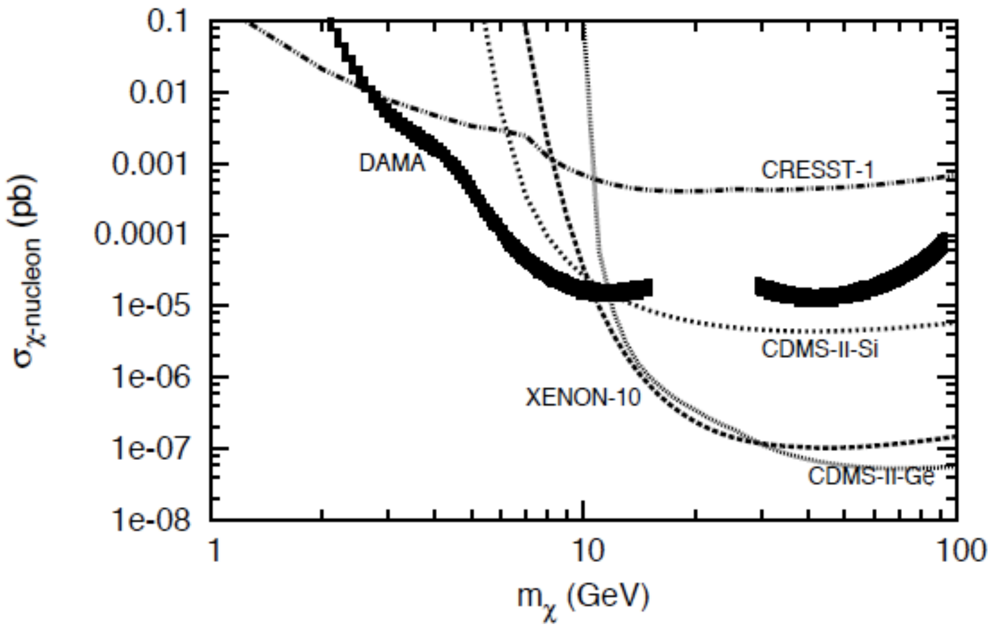


Xenon-100 has *ruled out* CoGeNT and DAMA … although their bounds are subject to large uncertainties in the scintillation light yield at low threshold

However CDMS-II too does *not* confirm CoGeNT and DAMA claims

However all exclusion limits are sensitive to the *assumed* velocity distribution of dark matter in the Galaxy … e.g. a *non*-Maxwellian distribution (determined self-consistently, taking into account the effect of baryons) changes the picture considerably (Chaudhury, Bhattacharjee & Cowsik, 2010)

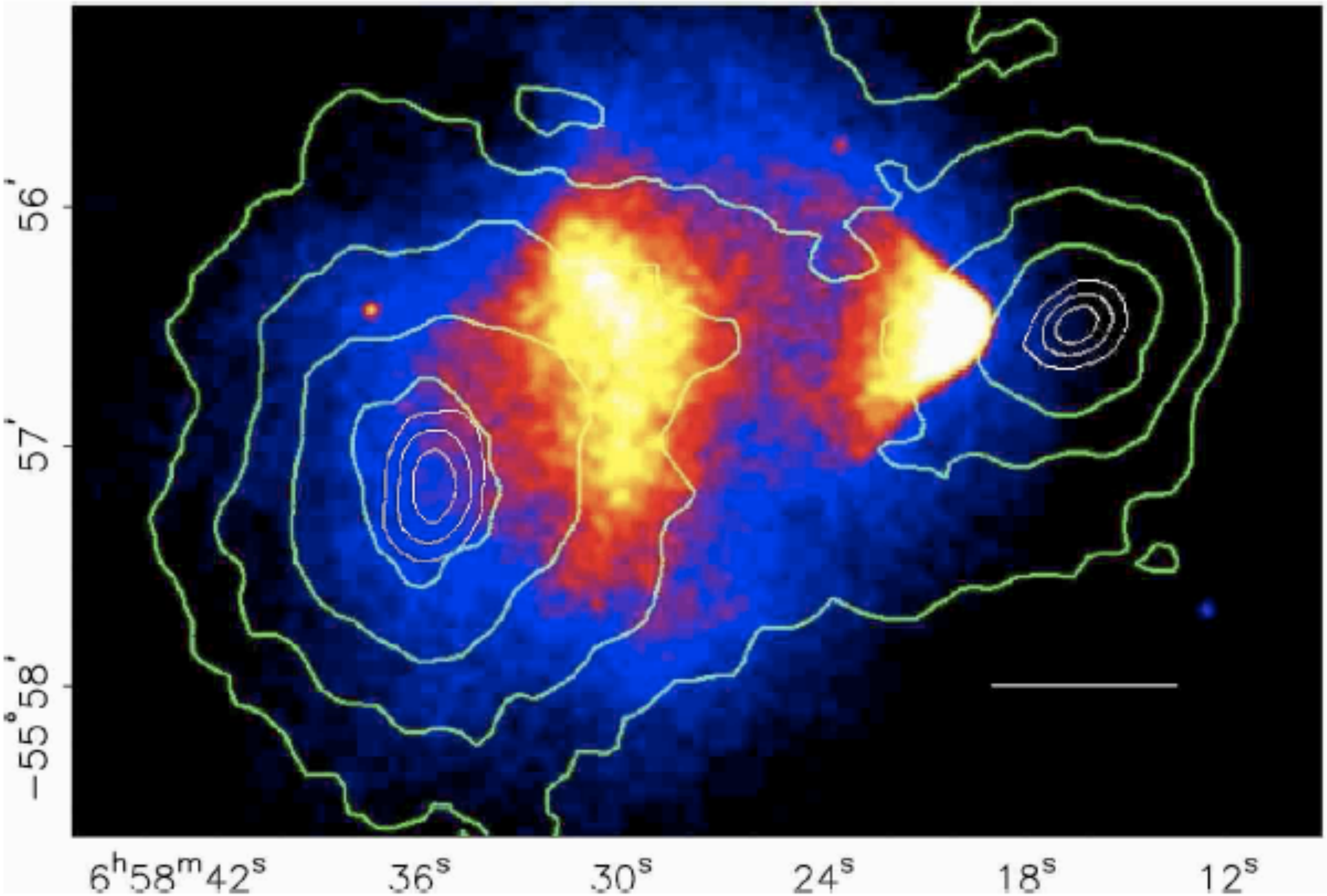




Moreover the escape velocity from the Galaxy and even the Sun's orbital velocity are not known very accurately and the local density of dark matter is uncertain by at least a factor of ~2 … varying these parameters alters the limits

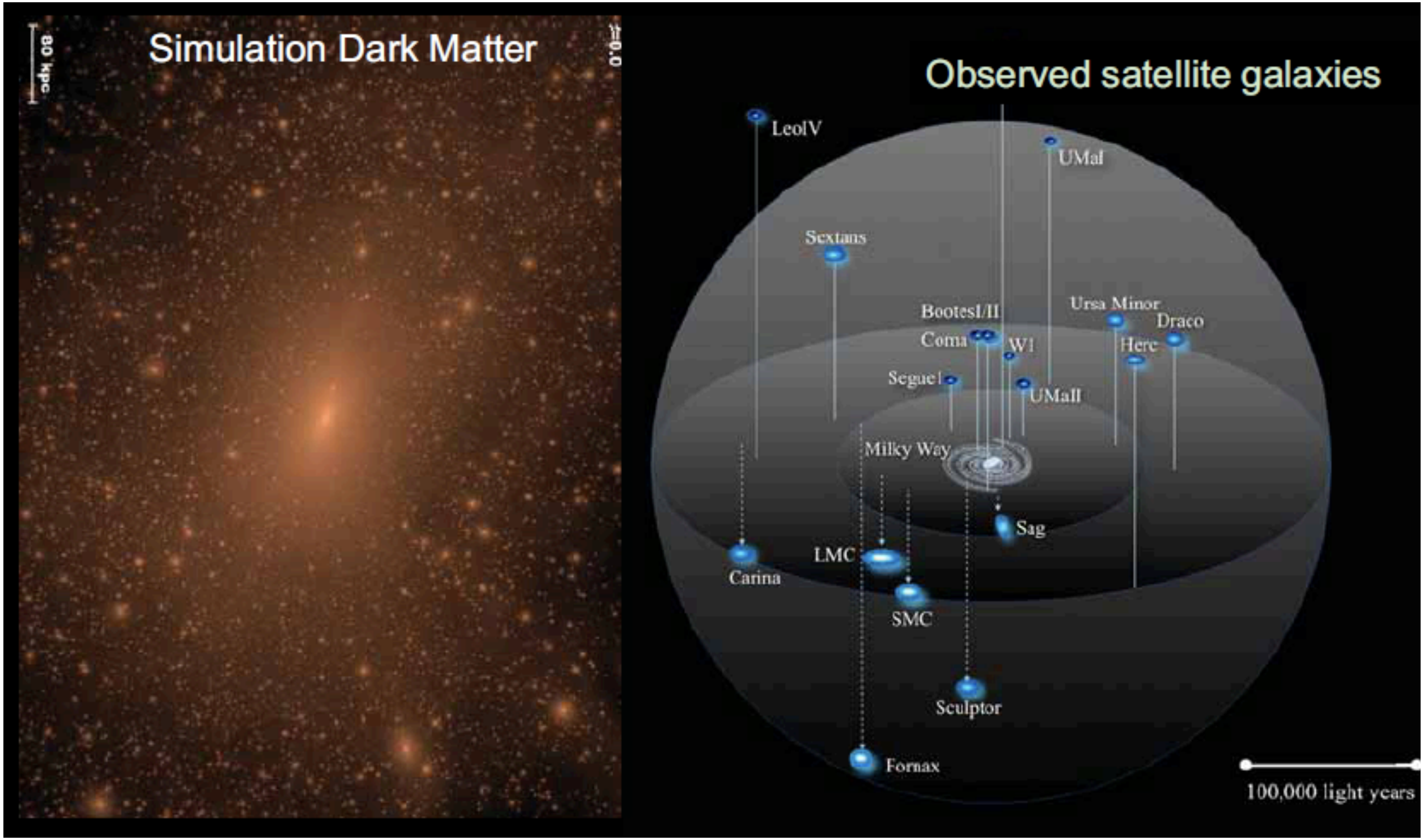
Expect improved measurements from *GAIA* (2012)

ADM particles would be naturally **self-interacting** with a typical cross-section: $\sigma_{\chi\chi} \sim \sigma_{nn} (m_n/m_\chi)^2$, where $\sigma_{nn} \sim 10^{-23}$ cm^2



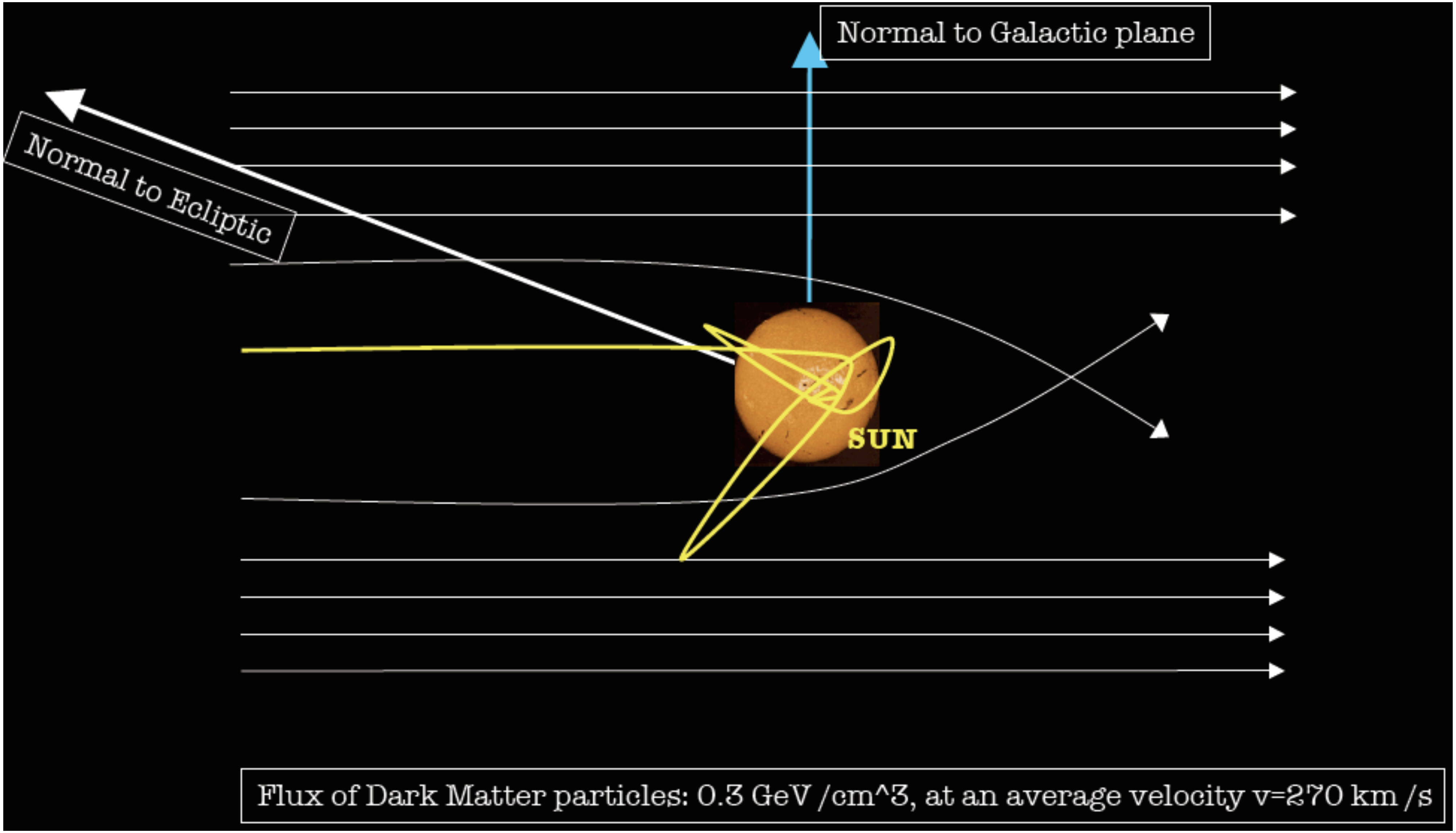
… well below the bound of $2\text{x}10^{-24}$ cm^2/GeV from the 'Bullet cluster'

Self-interacting dark matter (Spergel & Steinhardt 2000) can reduce the excessive substructure seen in simulations of *collisionless* dark matter …



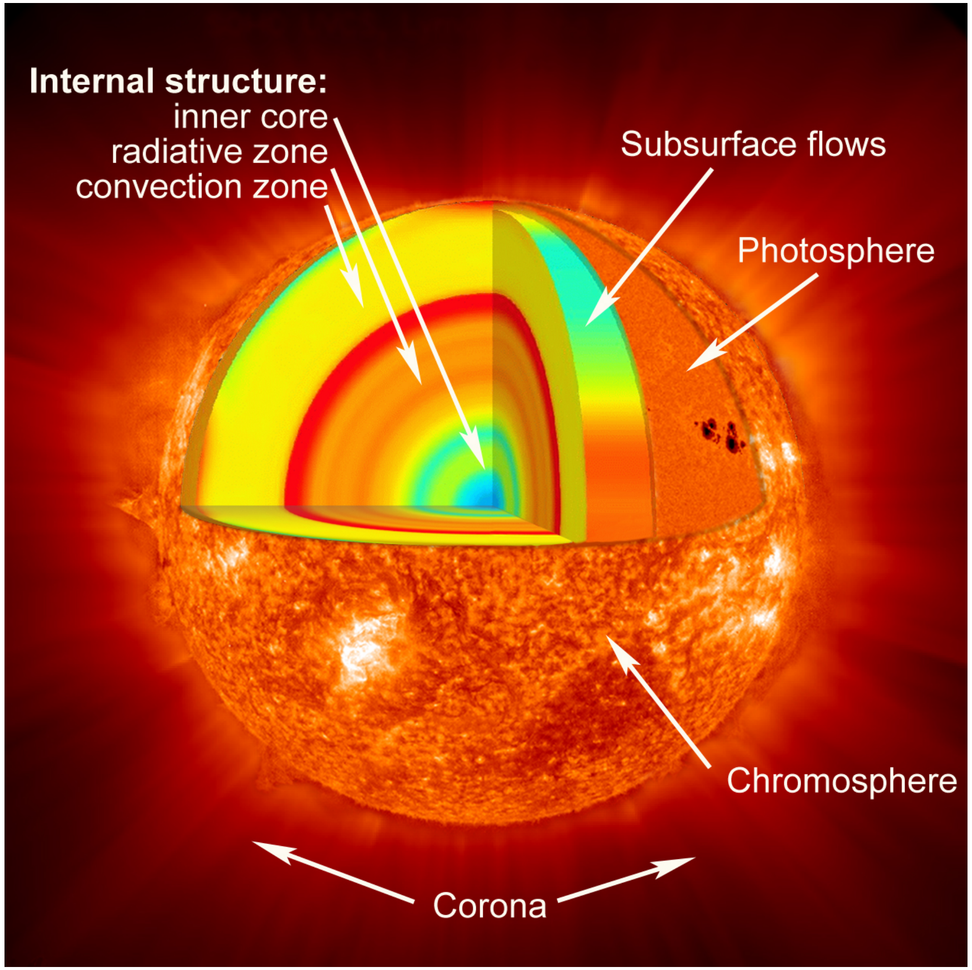
e.g. the Milky Way has only ~25 dwarf galaxies, while $>10^3$ are expected (not all are expected to be luminous, nevertheless there *is* a problem)

The Sun has been accreting dark matter particles for ~4.6 x 10^9 yr as it orbits around the Galaxy … these will orbit *inside* affecting energy transport



The flux of Solar neutrinos is *very* sensitive to the core temperature and can thus be affected (Faulkner *et al* 1985, Press & Spergel 1985, Gould 1987)

The particle mass must be ~5-10 GeV to have an effect on energy transport
(too light and they 'evaporate', too heavy and their orbits do not extend out far enough)



Dark matter forms thermal core within the star with $r_{th} \sim \left[\frac{9kT}{8\pi G\rho_c m_\chi}\right]^{1/2}$

For the Sun and 5 GeV DM, this is ~ 4 x 10^9 cm (orbit period ~ 10^4 s)

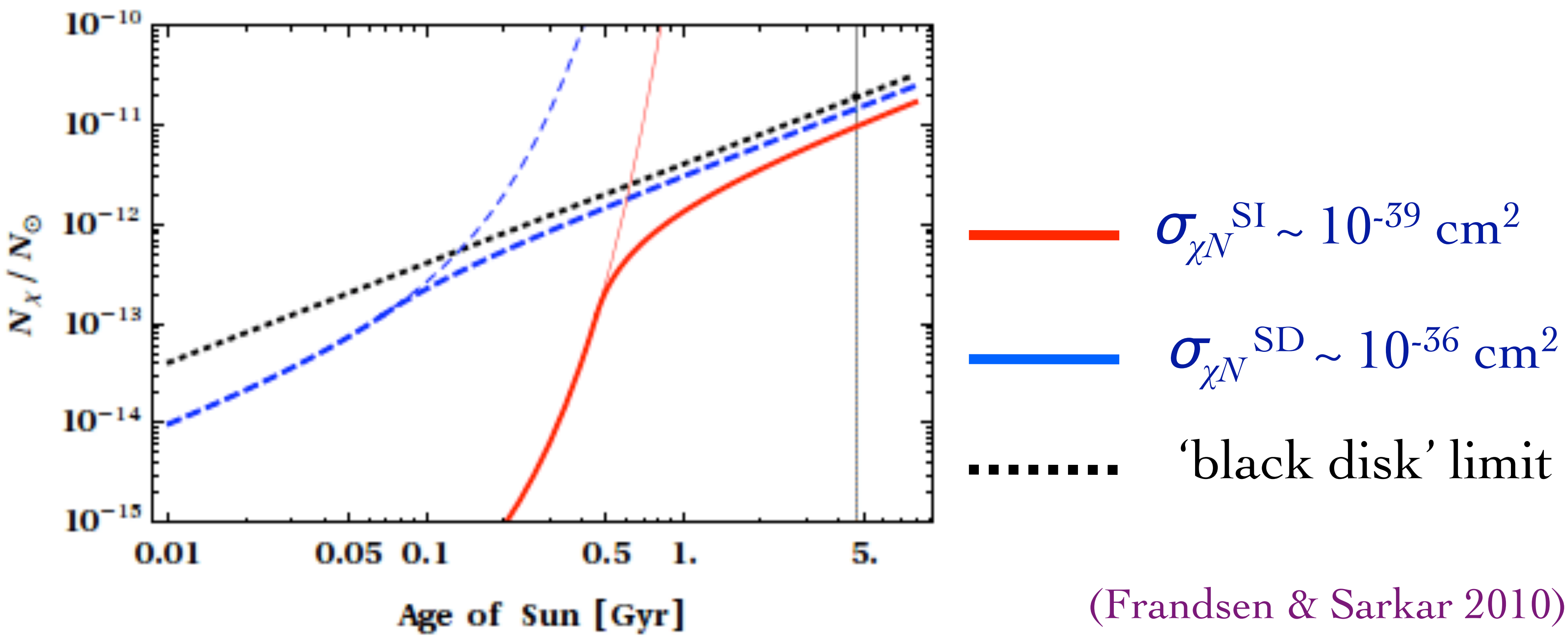
… compare with Solar radius ~7x10^{10} cm (thermal diffusion time ~10^{15} s)

Self-interactions will *increase* capture rate in the Sun (Zentner 2009)

The abundance of *asymmetric* dark matter is not depleted by annihilation … so grows exponentially (until geometric limit set by Solar radius)

$$\frac{dN_\chi}{dt} = C_{\chi N} + C_{\chi\chi} N_\chi \quad \Rightarrow \quad N_\chi(t) = \frac{C_{\chi\mathcal{N}}}{C_{\chi\chi}} \left(e^{C_{\chi\chi} t} - 1\right)$$

Self-capture rate: $C_{\chi\chi} = \sqrt{\frac{3}{2}}\, \rho_{\rm local}\, s_\chi\, \frac{v^2_{\rm esc}(R_\odot)}{\bar{v}}\, \langle\phi\rangle\, \frac{\mathrm{erf}(\eta)}{\eta}$

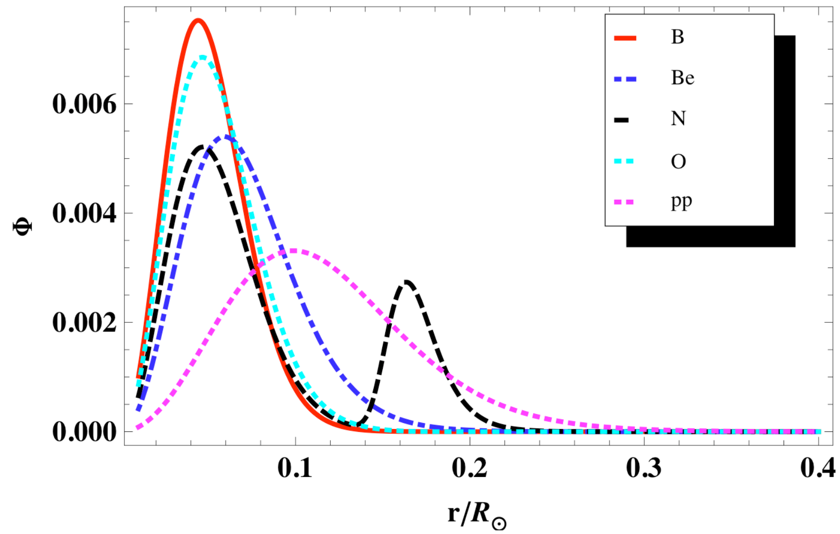


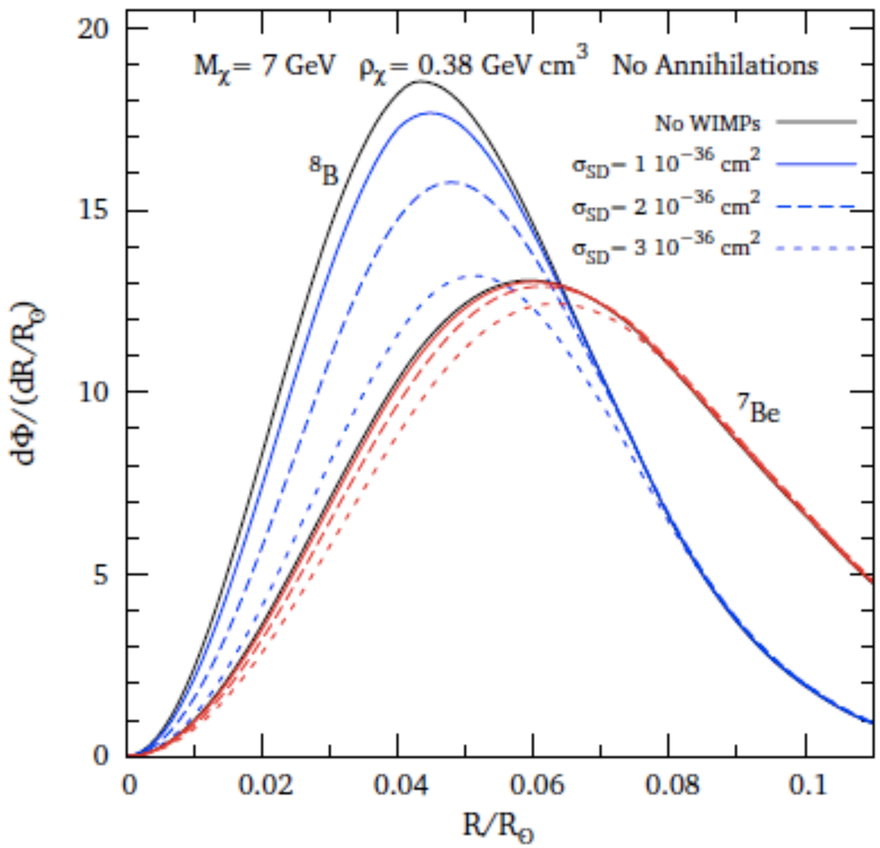
(Frandsen & Sarkar 2010)

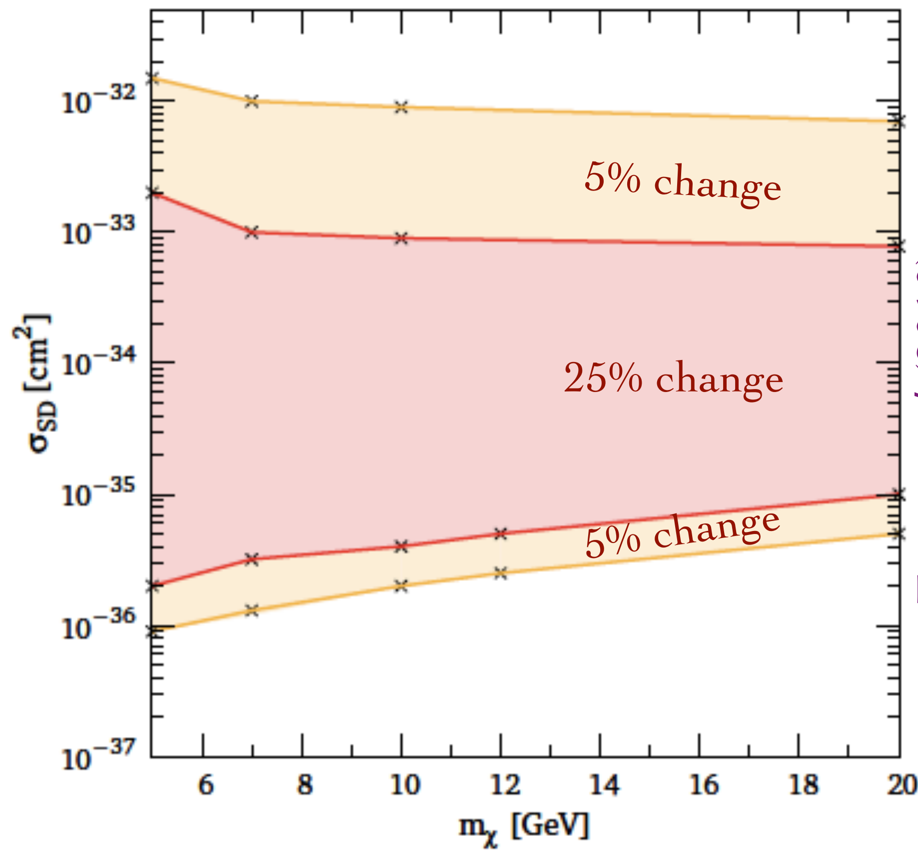
ADM will transport heat in the Sun:

$$L_\chi \sim 4 \times 10^{12} L_\odot \frac{N_\chi}{N_\odot} \frac{\sigma_{\chi N}}{\sigma_\odot} \sqrt{\frac{m_N}{m_\chi}}$$

Modification of the luminosity profile will *reduce* low energy neutrino fluxes: … this is testable by Borexino & SNO$^+$

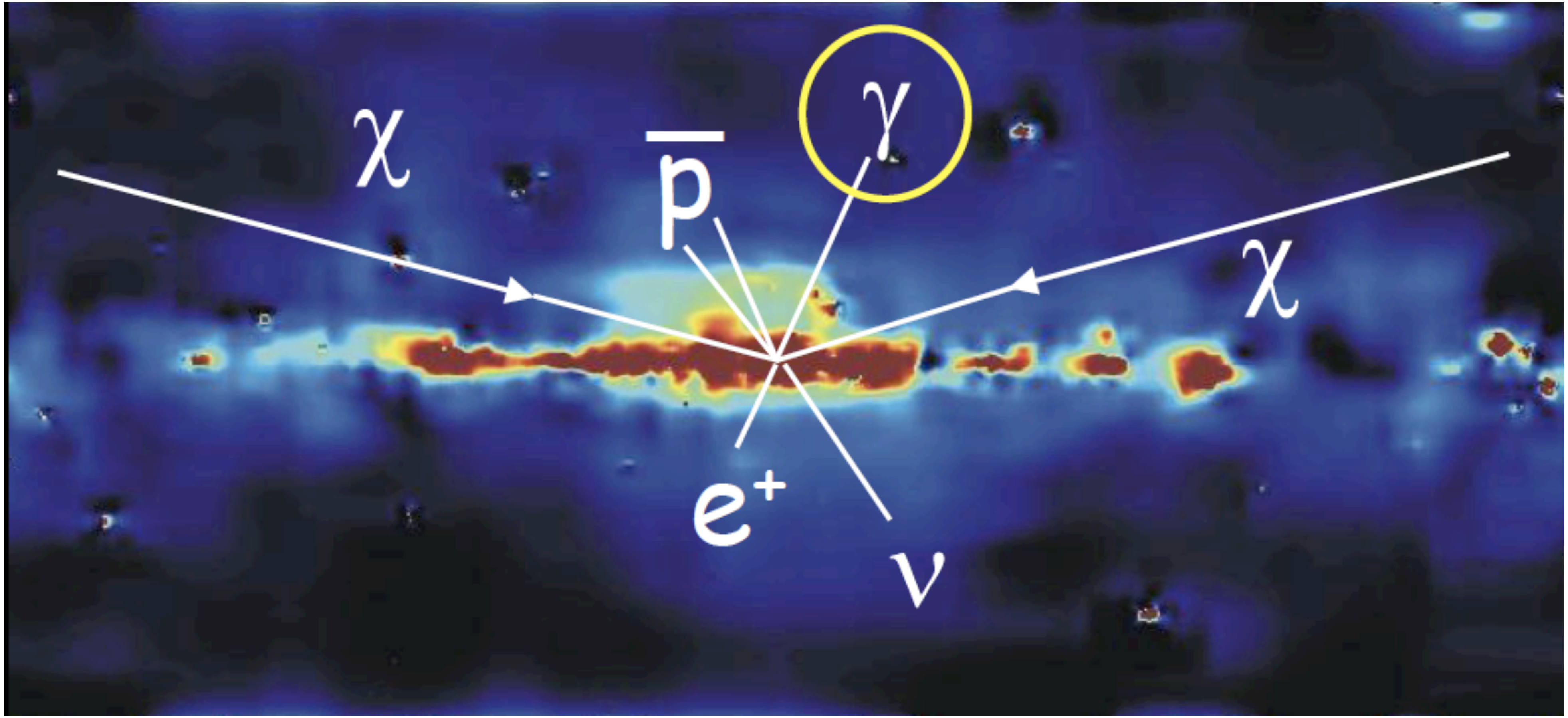






Taoso *et al* (2010)

Many techniques for indirect detection … and many claims!



The *PAMELA* 'excess' (e^+), *Fermi* 'excess' ($e^+ + e^-$), *WMAP* 'haze' (radio), … have all been ascribed to dark matter annihilations or decays

These probe dark matter *elsewhere* in the Galaxy so usefully complement direct detection experiments … but have other systematic uncertainties

The *PAMELA* ‘anomaly’

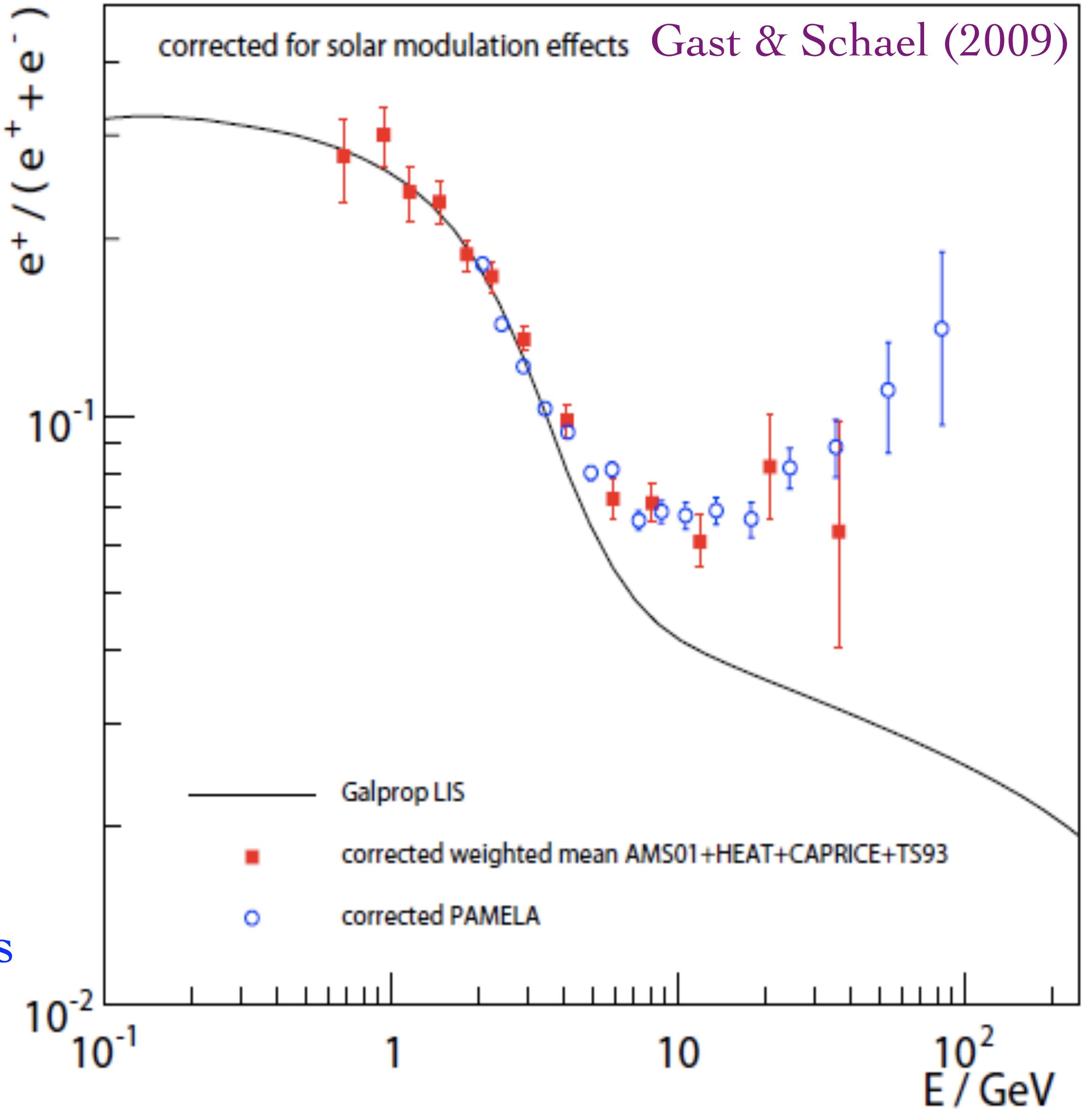
PAMELA has measured the positron fraction:

$$\frac{\phi_{e^+}}{\phi_{e^+} + \phi_{e^-}}$$

Anomaly ⇒ excess above ‘astrophysical background’

Widely attributed to dark matter annihilations/decays … fits the spectral shape!

However predicted amplitude typically ~10-10^4 too *small* … while ‘boost factor’ due to clumping of dark matter is less than a factor of ~2-10

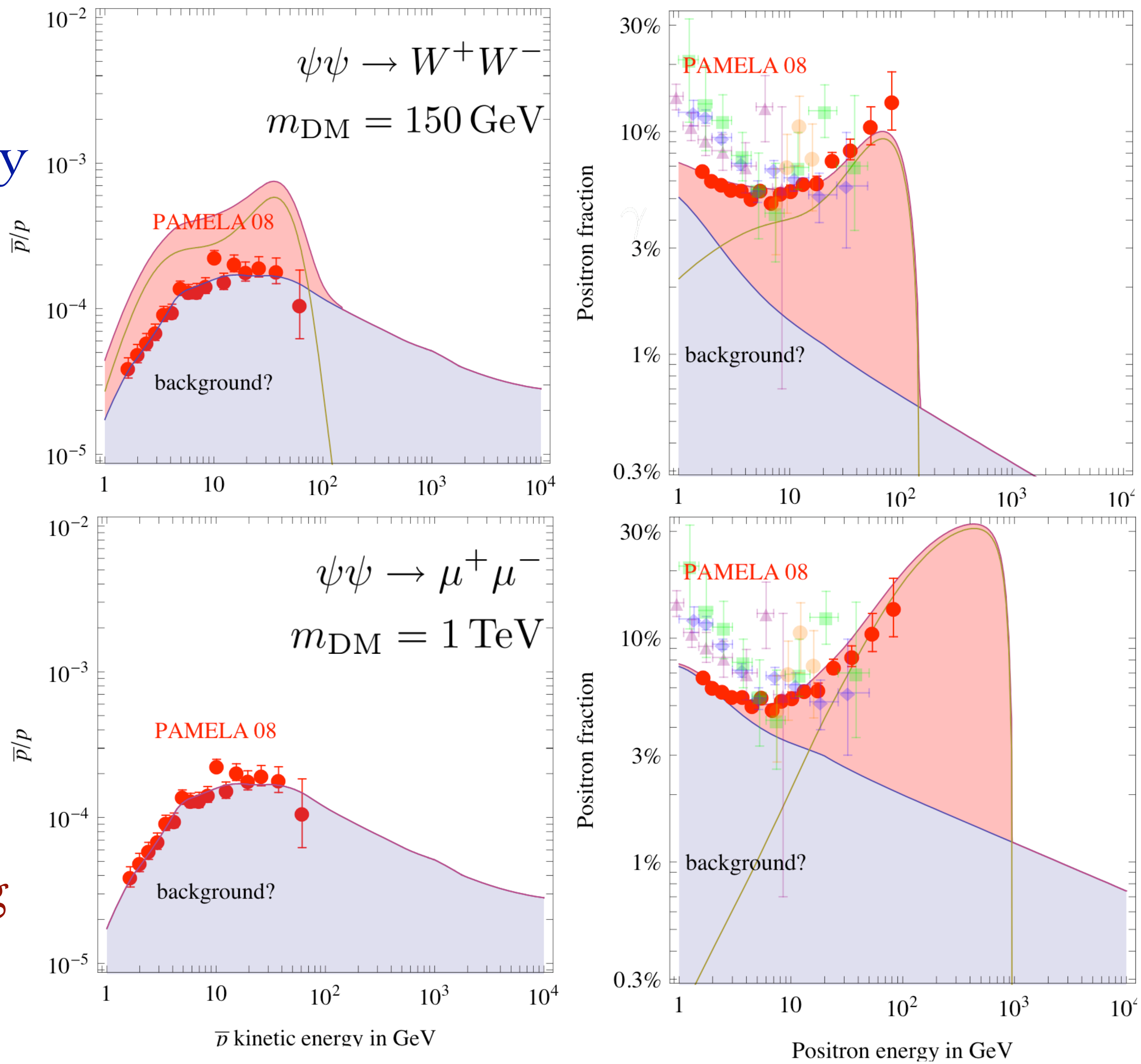


Moreover the observed antiproton flux is *consistent* with the background expectation (from standard cosmic ray propagation in the Galaxy)

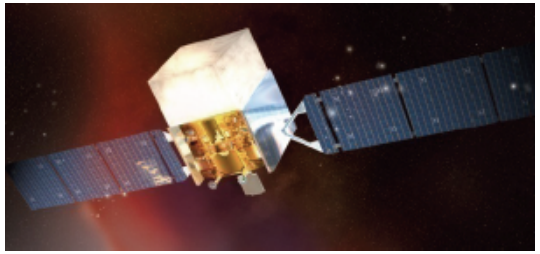
This makes dark matter rather unlikely to explain the *PAMELA* anomaly

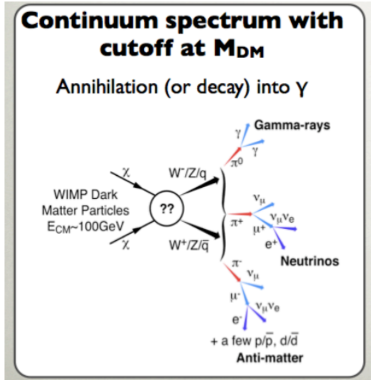
Can fit with DM decay or annihilation only if DM particles are 'leptophilic'

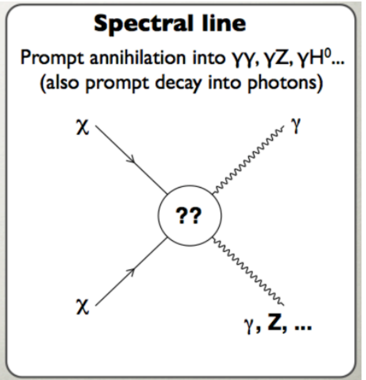
… but such models are increasingly being constrained by *Fermi*

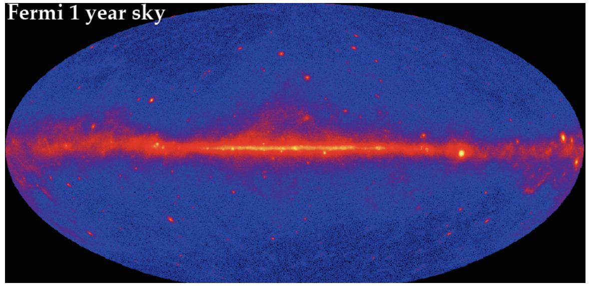


Cirelli *et al* (2009)







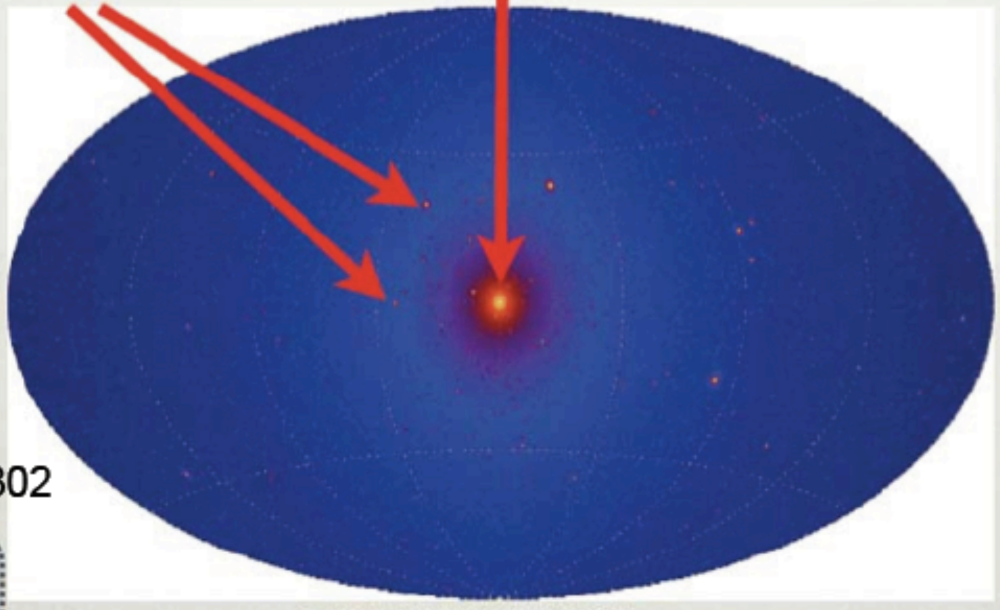


Satellites:
Low background and good source ID, but low statistics

Galactic center:
Good statistics but source confusion/diffuse background

Milky Way halo:
Large statistics but diffuse background

2010, ApJ, 712, 147



All-sky map of gamma rays from DM annihilation arXiv:0908.0195 (based on Via Lactea II simulation)

And electrons!

2010, PRL 104, 091302

2010, JCAP, 04, 014

Spectral lines:
No astrophysical uncertainties, good source id, but low statistics

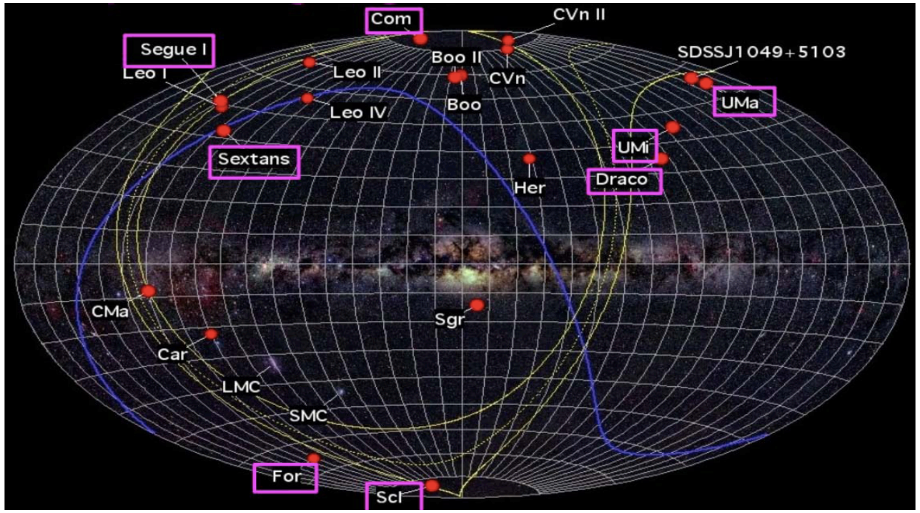
Galaxy clusters:
Low background but low statistics

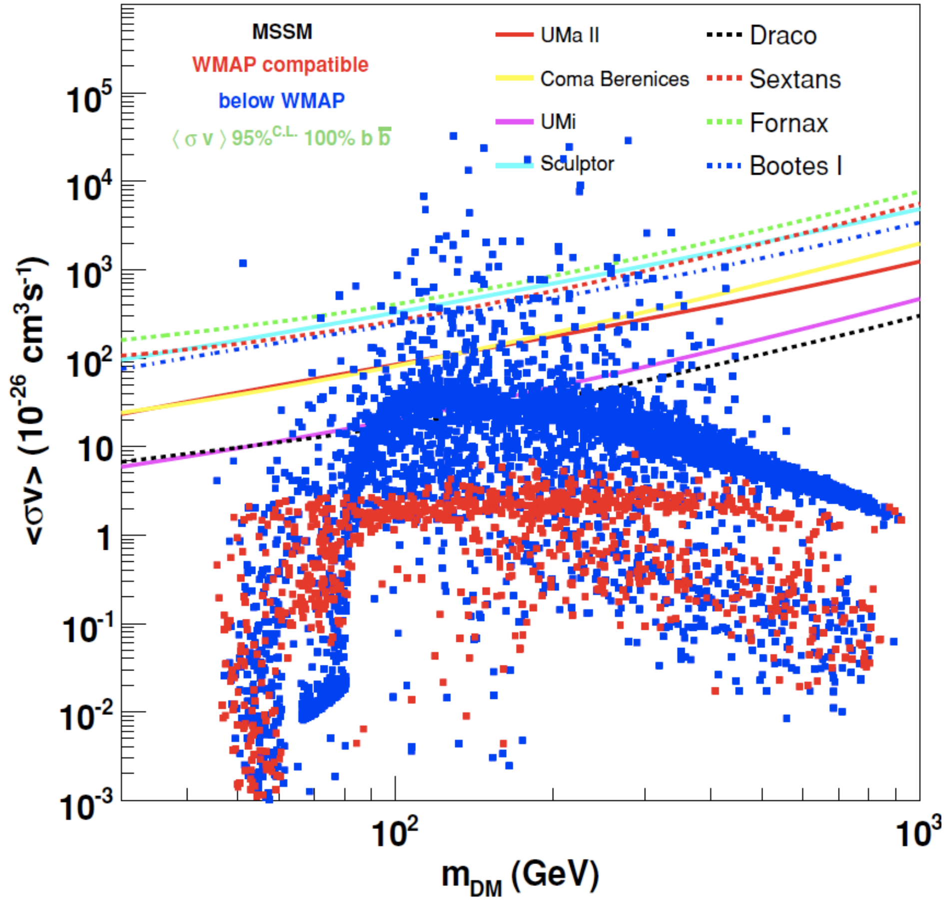
2010, JCAP, 05, 025

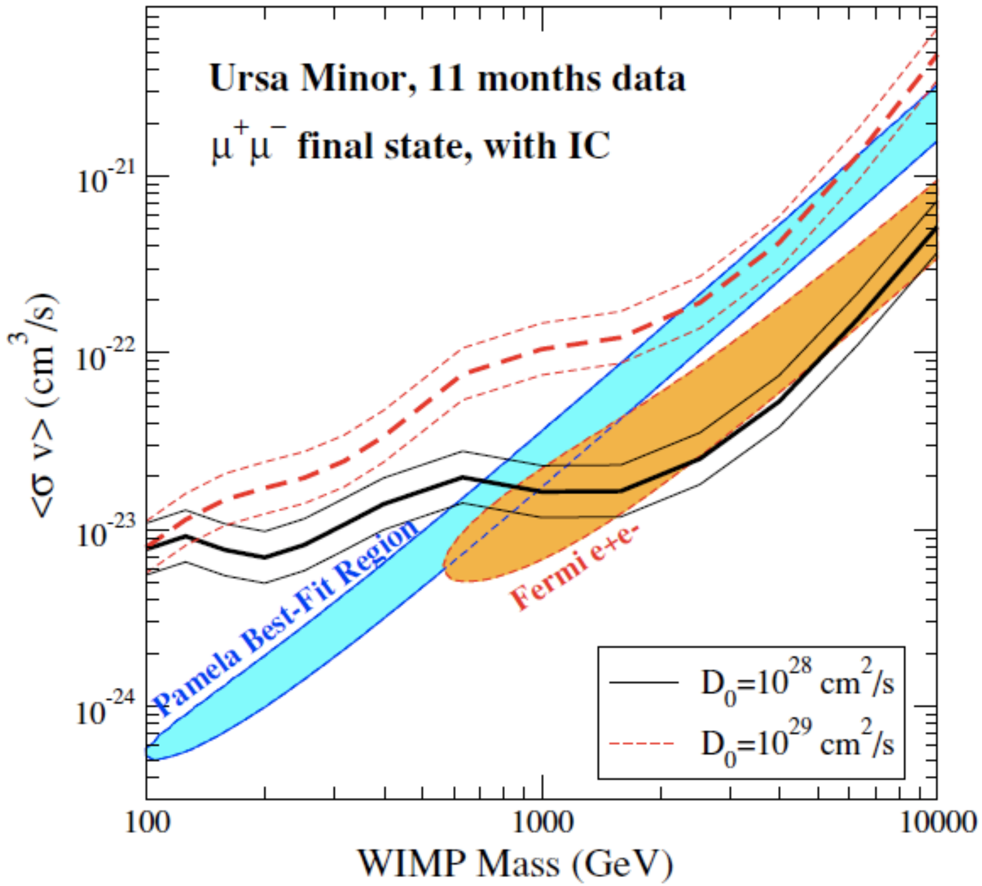
Extragalactic:
Large statistics, but astrophysics, galactic diffuse background

Pre-launch sensitivities published in Baltz et al., 2008, JCAP 0807:013 [astro-ph/0806.2911]

Sensitivity to the annihilation signal from dSphs is however *very* dependent on how the dark matter distribution is modelled … cored halos would reduce the signal by ~10^2-10^3 *cf.* cusps







What *should* the world be made of ?

Mass scale	Lightest stable particle	Symmetry/ Quantum #	Stability ensured?	Production	Abundance
Λ_{QCD}	Nucleons	Baryon number	$\tau > 10^{33}$ yr	'Freeze-out' from thermal equilibrium Asymmetric baryogenesis (how?)	$\Omega_B \sim 10^{-10}$ *cf.* observed $\Omega_B \sim 0.05$
$\Lambda_{QCD'} \sim 5\Lambda_{QCD}$	Dark baryon	$U(1)_{DB}$	?	Asymmetric (like the *observed* baryons)	$\Omega_{DB} \sim 0.3$
$\Lambda_{Fermi} \sim G_F^{-1/2}$	Neutralino?	R-parity?	violated?	'freeze-out' from thermal equilibrium	$\Omega_{LSP} \sim 0.3$
	Technibaryon?	(walking) Technicolour	$\tau \sim 10^{18}$ yr	Asymmetric (like the observed baryons)	$\Omega_{TB} \sim 0.3$
$\Lambda_{hidden\ sector} \sim (\Lambda_F M_P)^{1/2}$	Crypton? hidden valley?	Discrete (model-dependent)	$\tau \gtrsim 10^{18}$ yr	Varying gravitational field during inflation	$\Omega_X \sim 0.3?$
$\Lambda_{see\text{-}saw} \sim \Lambda_{Fermi}^2/\Lambda_{B-L}$	Neutrinos	Lepton number	Stable	Thermal (like CMB)	$\Omega_\nu > 0.003$
M_{string} M_{Planck}	Kaluza-Klein states?	?	?	?	?
	Axions	Peccei-Quinn	stable	Field oscillations	$\Omega_a \gg 1$!

No definite indication from theory…
must decide by experiment!

Summary

Experimental situation reminiscent of search for temperature fluctuations in the CMB in the '80s … there were clear theoretical predictions but only upper limits on detection (on verge of causing crisis for theory)
Finally breakthrough that transformed cosmology!

The theoretical expectations for dark matter are not as clear (being based on BSM physics) but there are many experimental approaches and interesting complementarities between them

There are bound to be some false alarms but it is a reasonable expectation that the nature of dark matter will be clarified soon experimentally