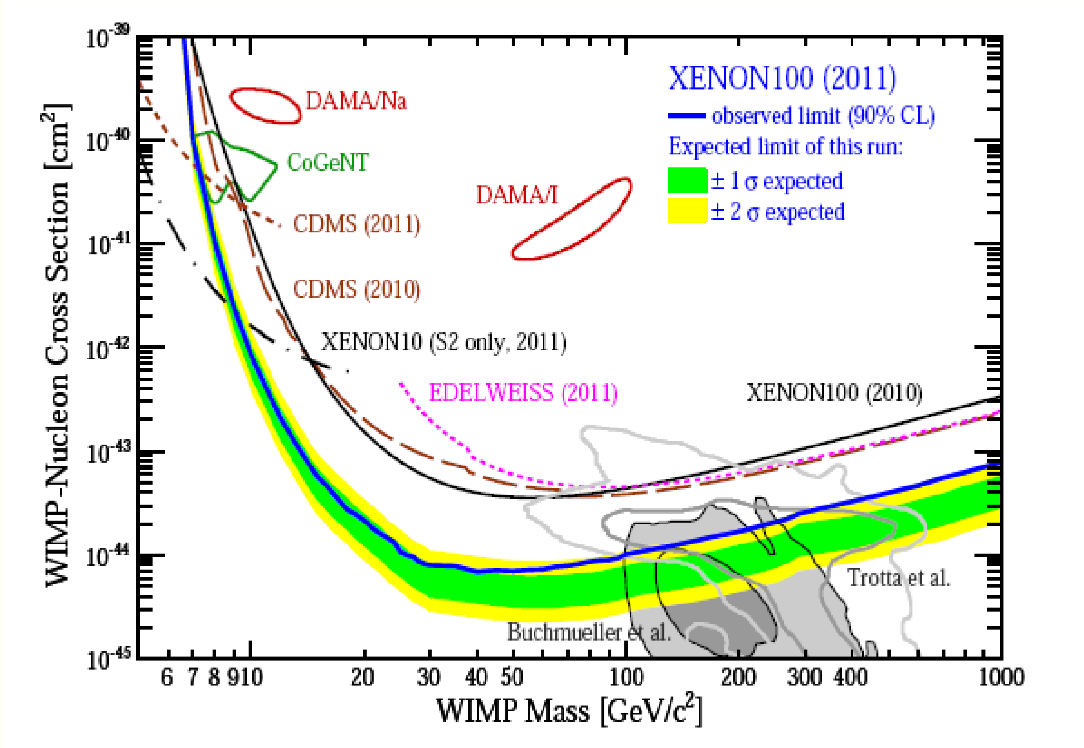
In the flat branch, the correct relic-density is obtained by adjusting μ so the right amount of higgsino/bino combination is obtained. As the neutralino becomes heavier, the higgsino fraction has to increase to maintain this balance. For this MHDM branch, $\sigma_{\rm SI}(\widetilde{Z}_1 p)$ asymptotes to a bit over 10^{-9} pb, right at the reach of projected DD searches. superCDMS, XENON-100, LUX

Ton-sized detectors essential for bino-like LSPs.1t-xenon WARP,..... noble element detectors

Targets using multiple nuclei can reveal multiple WIMP components.

THE EXPERIMENTAL SITUATION: NEUTRALINO NUCLEON SCATTERING

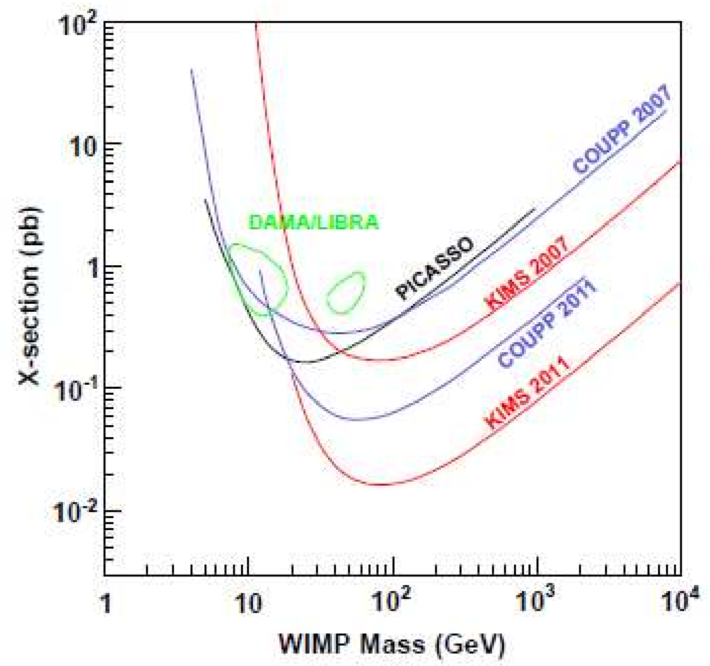


The XENON-100 experiment has probed the spin-independent direct detection cross section to a few $\times 10^{-8}$ pb level without seeing any sign of a signal.

Unless a signal is found soon, the mixed bino-higgsino branch will be experimentally excluded. We will have to look for a different type of DM candidate if we assume that the relic density is saturated by a single particle.

LUX taking data; liquid argon detectors coming on. Stay tuned!

THE EXPERIMENTAL SITUATION: SPIN-DEPENDENT SCATTERING



These experiments are not yet at the needed sensitivity, but projections show they will probe an interesting range, and can be complementary to the spin-independent signals.

The IceCube experiment probes down to 10^{-4} pb in a different way we will see later.

Presumably, you had noticed the islands on the spin-independent direct detection slide that I had shown earlier. This is where some experiments have claimed a signal for DM detection.

However, other experiments say that they exclude a signal in these regions. Whom should we believe?

I don't know. However, I strongly subscribe to the maxim: Extraordinary claims require extraordinary evidence.

Every experiment has potential issues that need to be understood.

CoGeNT (Ge) and CRESST ($CaWO_4$) have background issues.

CoGeNT has b/g that needs to be subtracted as there is no discriminator between the signal and the background.

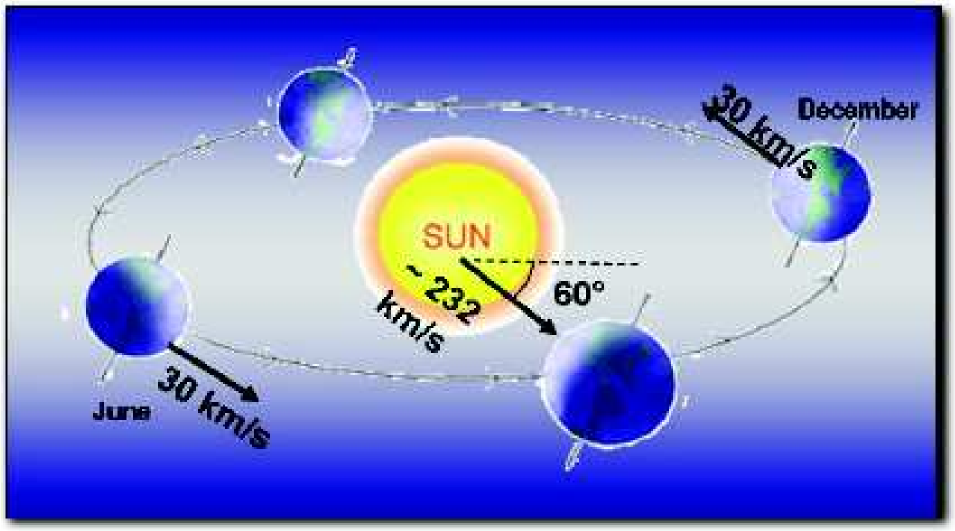
CRESST suffers from e/γ contamination as well as other issues.

No consistent region for fit.

I find it hard to be convinced that we are seeing anything real, but of course I may be missing the boat.

Modulation signal from dark matter

As the solar system moves through the galactic halo with the earth revolving around the sun, the "WIMP wind"' velocity must modulate between a minimum and a maximum because the earth's motion may have a component along/opposite to the direction of this "WIMP wind".

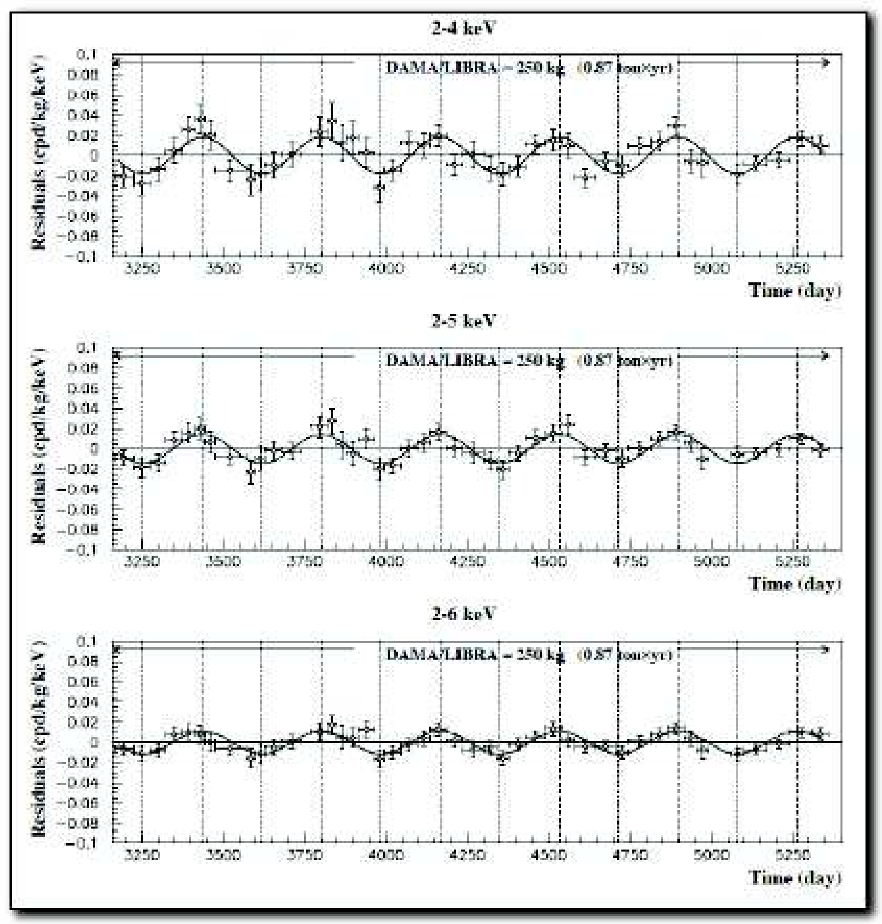


This means that the DM flux modulates with a period of one year.

Any DM signal should modulate with this same period, with a maximum in June, and a minimum in December. There is also a much smaller diurnal modulation.

The DAMA/LIBRA story

The DAMA/LIBRA experiment has claimed to see just such a modulation, and with the right phase! And, over a long period.



The data are truly impressive.

(CoGeNT have also claimed to see modulation albeit with lower statistics and the phase is not quite that expected from WIMP interpretation.)

However, lots of backgrounds do modulate between summer and winter.

There are also questions about the total rate versus modulation.

The hajjar crore question is not whether they are seeing a modulation as much as whether this modulation arises from the motion through a DM halo as opposed to a seasonal effect that we have not thought about.

Repeat DAMA in the southern hemisphere. DARK MATTER IN ICE

These difficulties have not held back theorists from "explaining" low mass DM.

Even if we drop the gaugino mass unification condition, it is not so simple to get the large $\sigma_{\rm SI}$ that is needed because dimensionally $\sigma \propto m^2/M^4_{\rm Weak}$.

People have also tried to to explain the "seemingly discrepant" regions in different experiments by invoking the freedom to allow different amplitudes for WIMP scattering from protons and neutrons, remembering that the proton/neutron composition is different in different nuclei, and the fact that the scattering is coherent.

- ⋆ ISOSPIN VIOLATING DARK MATTER (Only small isospin violating DM interactions in MSSM)

Of course, this does not explain discrepancy in experiments with the SAME nucleus.

INELASTIC DARK MATTER

Inelastic scattering of Dark matter was also proposed to explain why DAMA (Iodine) saw a signal, but CDMS (Ge) did not.

The idea was that the scattering matrix element dynamically favoured scattering to a slightly more massive DM particle than the WIMP, drastically changing the kinematics and so the minimum velocity of the WIMP for the scattering to be detected.

Recoil off a heavy nucleus was favoured, so signal from scattering of Iodine was argued to be present in DAMA but none off scattering of Ge in CDMS.

The XENON experiment spoiled this party by not seeing a signal...Xe is about as heavy as Iodine

Indirect Searches of Dark Matter

Dark matter clumps gravitationally and annihilates in these regions of concentration (if allowed to by its particle properties). The detection of its decay products is referred to as indirect detection of DM.

If these decay products cannot be produced at comparable rates from other processes, we will have a clean signature of DM.

Annihilation of DM possible if the DM particle is its own antiparticle; $e.g.$ the Majorana neutralino of the MSSM.

If the DM particle is different from its anti-particle, annihilation will not be possible unless the particles and antiparticles cohabit the same region.

Sources of Clumped DM: The centre of the Milky Way (dirty place); DM halo, Dwarf Spheroidal Galaxies, Sun,.....

Annihilation rate $\propto n^2$ (in contrast DD rate is $\propto n$.)

What do we detect?

- ⋆ Protons and anti-protons @ Pamela, Fermi, AMS02,...
- ⋆ electrons and positrons @ Pamela, Fermi, AMS02,...
- ⋆ photons Fermi, AMS02, Veritas, MAGIC, HAWC; WMAP, Planck
- ⋆ neutrinos @ Super-K, IceCube/DeepCore, ANTARES, KM3,...
- ⋆ Deuterons and anti-deuterons @ AMS02, GAPS

Particles are abundant but anti-particles are rare in today's Universe. So an excess of high energy anti-particles could have annihilations of heavy DM (or the decay of heavy DM) as the origin.

Charged particles bend in the magnetic field of our Galaxy so must come from within the Larmor radius. Electrons and positrons must be very local; less so for $\bar{p}$, $\overline{D}$. Photons and neutrinos from far away, including the Galactic Centre.

Neutral particles point to the source. This helps reduce background.

The Good Side of Gammas: Energy measured is energy at the source; monochromatic line signal can be very clean; Gamma's showered off from decays of many DM annihhilation products.

The Bad side of Gammas: Large continuum background because many things can produce gammas.

The Good side of Charged anti-particles; Limited backgrounds at high energy (but watch out for surprises! the tale of the e^+)

The Bad Side; Only nearby sources; energy lost in transit, propogation models have significant uncertainties, discriminating positrons and anti-protons.

Recall that the annihilation of Majorana fermions to positrons suppressed by $m_e^2/m_{\rm WIMP}^2$ in S-wave, and by v^2 in P-wave. In contrast, annihilation to $e^+e^-\gamma$ suppressed by just a factor α.

The Good side of νs: Come from long distances and point; this helps a lot with signal from the sun since neutrinos from nuclear reactions in the sun would necssarily be sub-GeV, while those from DM would have energy $\sim m_{\rm DM}$.

The Bad Side of ν: We detect the charged lepton produced by the charged current weak interaction in a neutrino telescope. Atmospheric neutrinos are an irreducible b/g. Looking at the sun or Galactic Centre helps.

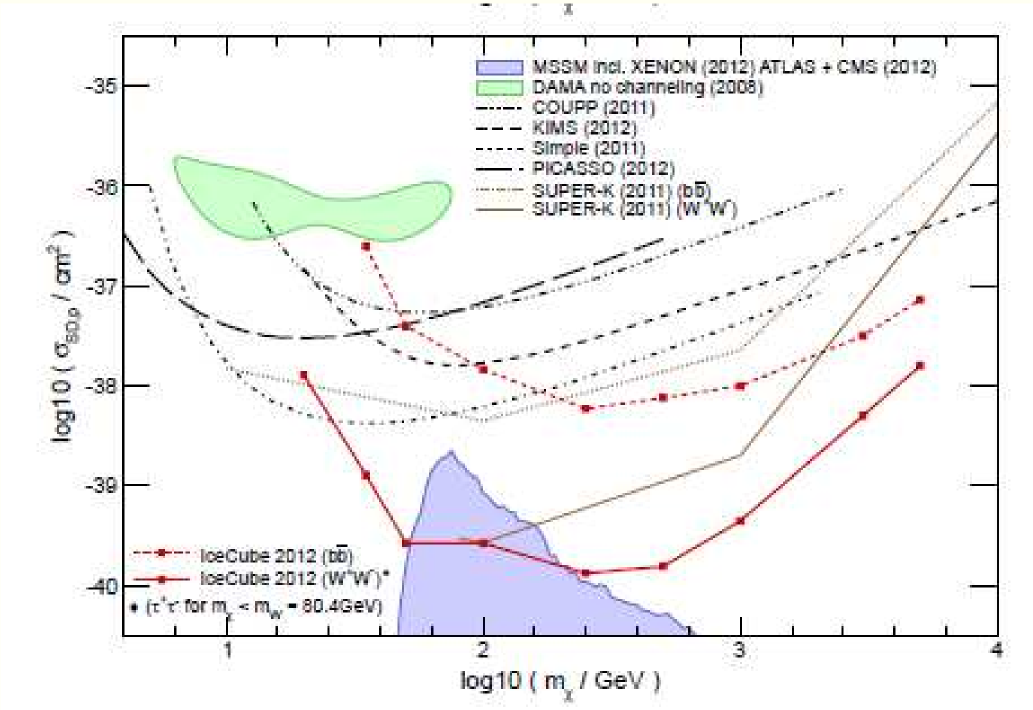
High energy neutrinos from the Sun

Dark Matter collisions with nuclei in the sun cause it to lose energy by elastic scattering. If the velocity falls below its escape velocity, it gets captured and accumulates in the core of the sun.

Dark matter particles can also annihilate into Standard Model particles if they meet one another. We assume the sun is in a dynamic equilibrium in the sense the rate at which DM disappear due to annihilation is balanced by the rate at which they are captured.

In this sense, the neutrino event rate (if we observe the signal) would measure the DM capture rate.

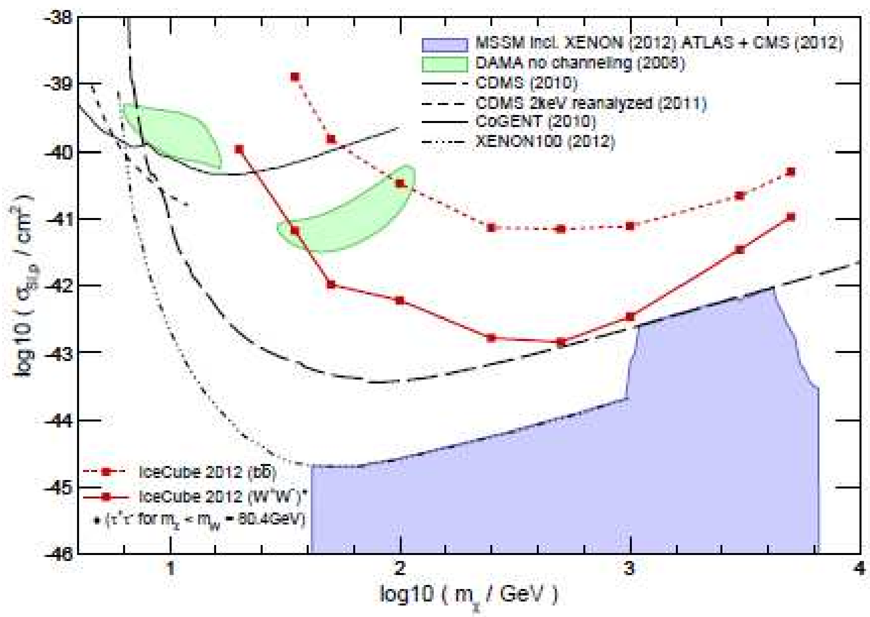
Since the sun is mostly hydrogen, the spin-dependent cross section p WIMP cross section can play a big role. Indeed, from a non-observation of a signal, experiments can bound this cross section. Kamiokande bound on sneutrinos (1998).



The IceCube Experiment (with the Deep Core extension) has the best limit on the spin-dependent neutralino-nucleon cross section to 10^{-4} pb arXiv:1212.4097

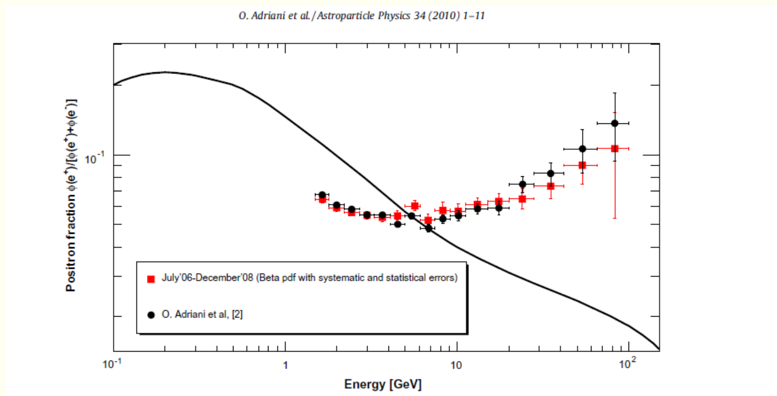
CAUTION: Limit sensitive to the model assumptions as it depends on WIMP coupling to nucleons AND neutrinos.

The IceCube experiment is less sensitive to the SI cross section than XENON100 or even CDMS whose results we had seen earlier.



Pamela, Fermi and AMS

We all know that there was a lot of excitement a few years back with the Pamela data showing an excess of positrons at high energy.

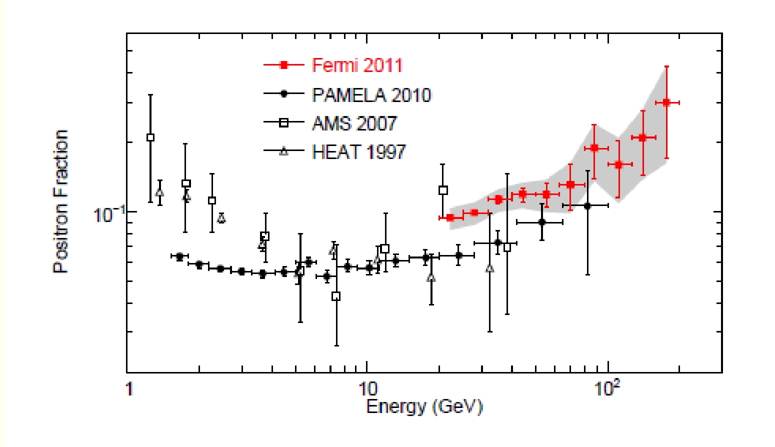


An excess of high energy positrons was also reported by a balloon experiment (ATIC) though it appears that their instrument was not calibrated at the highest energies where there were provocative spectral structures.

I will disregard the ATIC data

Key question: positron-proton discrimination (Greg Tarle)

The Fermi LAT also reports an excess in the positron fraction, and this excess continues beyond Pamela energy range



Are Fermi and Pamela data consistent?

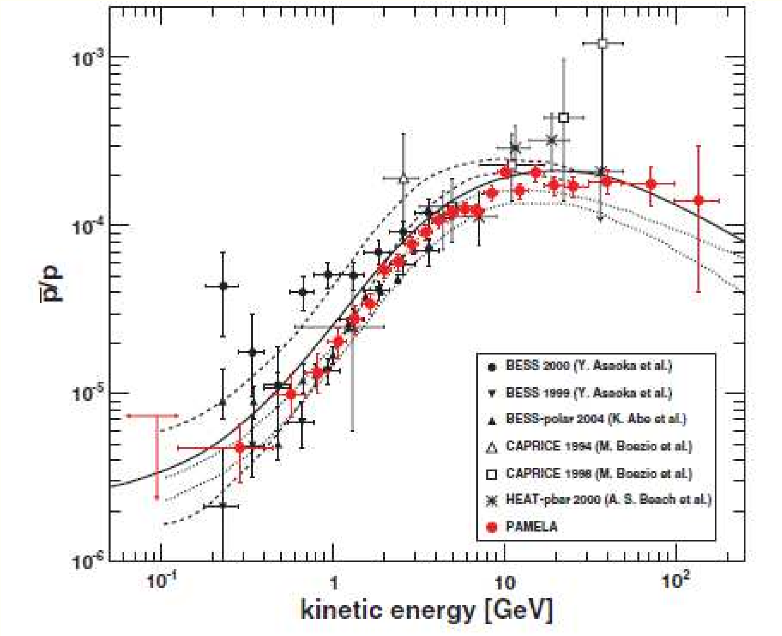
No matter what, if we believe there are high energy positrons, isn't it unbelievably exciting?

Many papers attributing this excess to dark matter annihilation to leptons. After all, WIMP annihilation would give such data!

But not all was rosy.

Things were not quite as expected.

⋆ Vanilla WIMP annihilation generically would give more anti-protons!



The anti-proton data were as expected, and fitted models with antiprotons created from high energy cosmic rays. No dark matter appeared to be needed!

So, we said, DM must be leptophilic. For reasons that we do not know, it does not couple to hadrons.

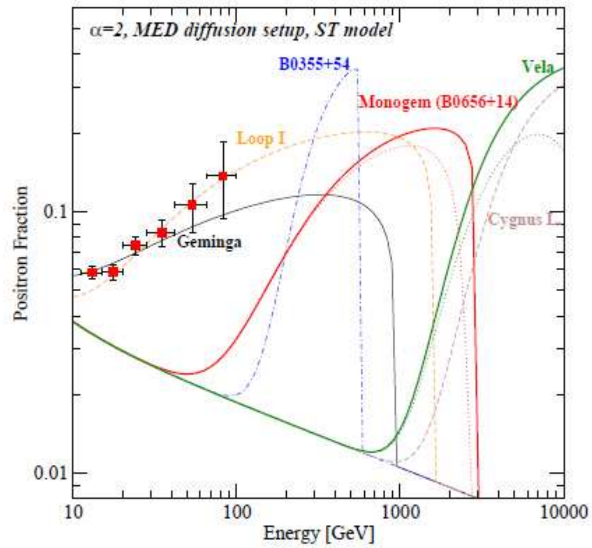
However, when we tried to do this, the numbers did not come out right. The annihilation cross section was too small.

This can be "fixed" by requiring a new attractive moderately long range force between DM particles. This causes non-relativistic particles to move closer together than if this force were absent, increasing the flux and hence the annihilation cross section. Sommerfeld enhancement.

We had to stand on our head to try and make things work, but it may be reasonable to suggest that the data were perhaps telling us something.

Note also that a particle interpretation of the high energy positron data imply there is a kinematic cut off on the positron energy, whose location and shape depend on the mass of the DM particle, whether it annihilates directly to positrons, or the positrons are secondaries, etc. We do not see such a cut-off yet, but it must be there.

The annihilating DM picture makes a nice story. However, there is another story to tell.



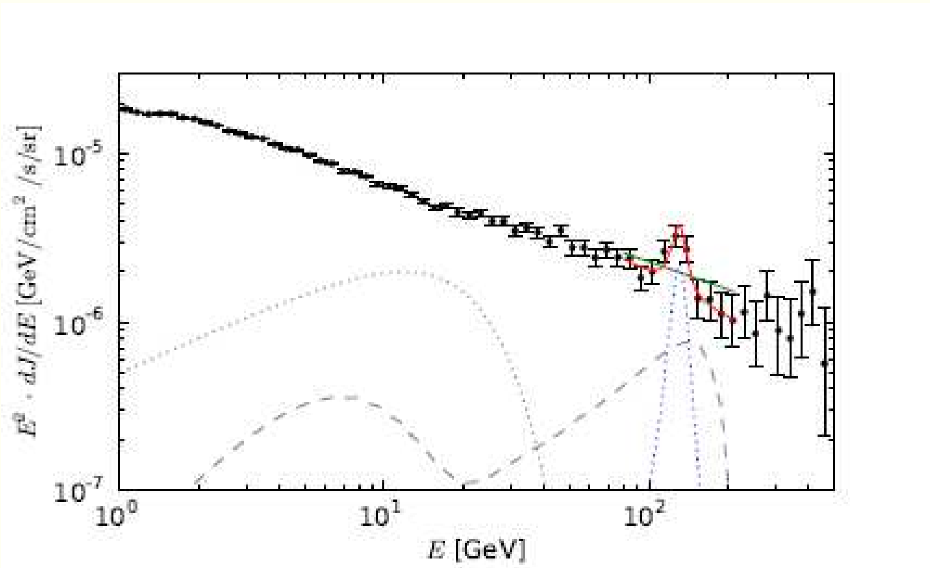
It appears that pulsars can also accelerate positrons to high energies.

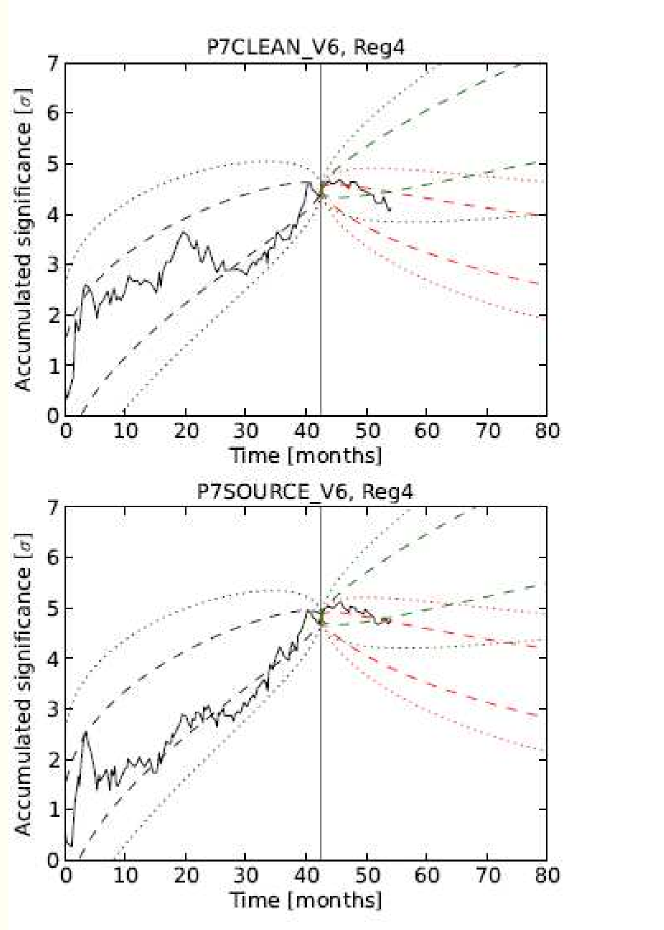
The way this works is electrons accelerated in the field of the pulsar synchrotron radiate. These high energy photons create e^+e^- pairs in the large magnetic field or by colliding with a thermal x-ray photon, and these positrons are what we see.

Anti-protons will not, I think, be created by this mechanism as these are composite.

ARE ANNIHILATION SIGNALS FROM ALL OTHER CHANNELS (OTHER THAN HIGH ENERGY PHOTONS) ABSENT? This is the crucial question.

A GAMMA RAY LINE AT 130 GeV? (Weniger)





Weniger's follow-up suggests that the significance of the 130 GeV line is reducing.

Fermi update

I heard from colleagues that the Fermi Collaboration at a talk at the Aspen physics workshop has suggested that the peak seen by Weiniger may be an artifact of the fact that the detection efficiency on either side of the peak position is lower than at the peak. (talk by Eric Charles)

Evidently they found a peak by studying the signal from the limb of the earth where you would not expect dark matter enhancement.

I do not know much more about this and can only refer you to Charles' talk. See also the talk by Whiteson at this meeting.

The bottom line is the gamma ray line may be dead.

GALACTIC CENTRE

There should be a huge concentration of DM at the galactic centre, so why not look for signals from there?

The DM density at the centre is probably not well understood. Simplest models with non-interacting DM gives cusps at the centre. Self interactions, should wipe out these cusps. Moreover, there should also be significant effects from including baryon density in this region.

THIS REGION IS DIFFICULT TO MODEL SO SIGNAL AS WELL AS BACKGROUND (ESPECIALLY PHOTON B/G) LIKELY HAS HIGH UNCERTAINTY

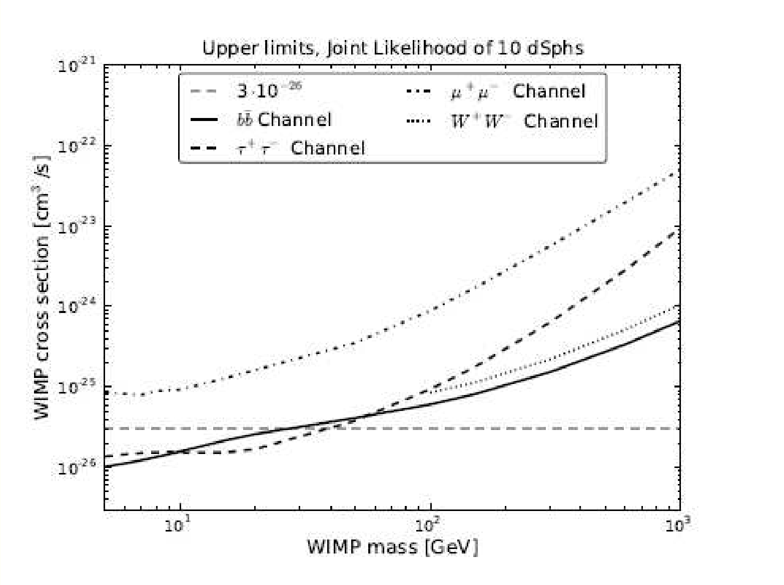
DWARF SPHEROIDAL GALAXIES

Since these are regions of concentrations of DM with relatively low baryon content, the problems associated with the galactic centre are ameliorated.

Indeed measured velocities of stars orbiting in these galaxies suggest the cusps are somewhat smoothed out. This points toward self-interactions of DM.

Why not study DM annihilation in dwarf galaxies? This is exactly what Fermi LAT did!

FERMI LIMITS FROM DWARF GALAXIES



Assumes S-wave annihilation and NFW profile.

Taken literally, it is a strike against very light DM, but number of ways out.

COLLIDER CONSTRAINTS

The idea is that essentially the same dynamics is responsible for:

- ⋆ Direct DM detection, X+SM $\rightarrow$ X+SM
- ⋆ Indirect DM detection, X+X $\rightarrow$ SM+SM
- ⋆ Collider search for DM via SM+SM $\rightarrow$ X+X

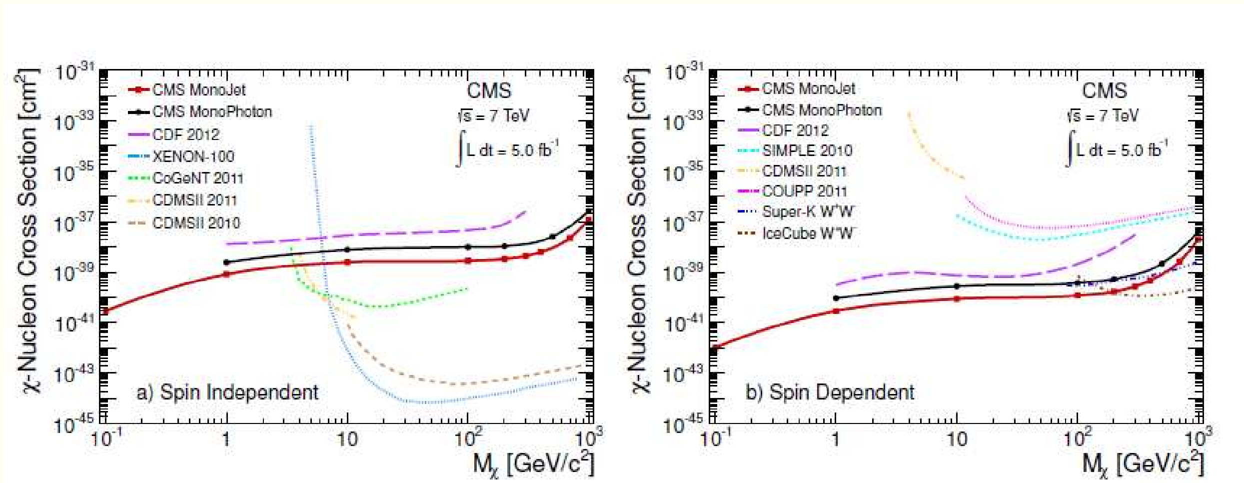
Of course, in the collider case, we'd see "nothing" and need gluon radiation for the signal to be seen as a monojet.

This is an interesting idea and advocates argue for the "model-independence" of this strategy, at least in the limit that the interactions between DM and the SM particles can be well approximated by contact operators..

Should of course not use the relic density constraint

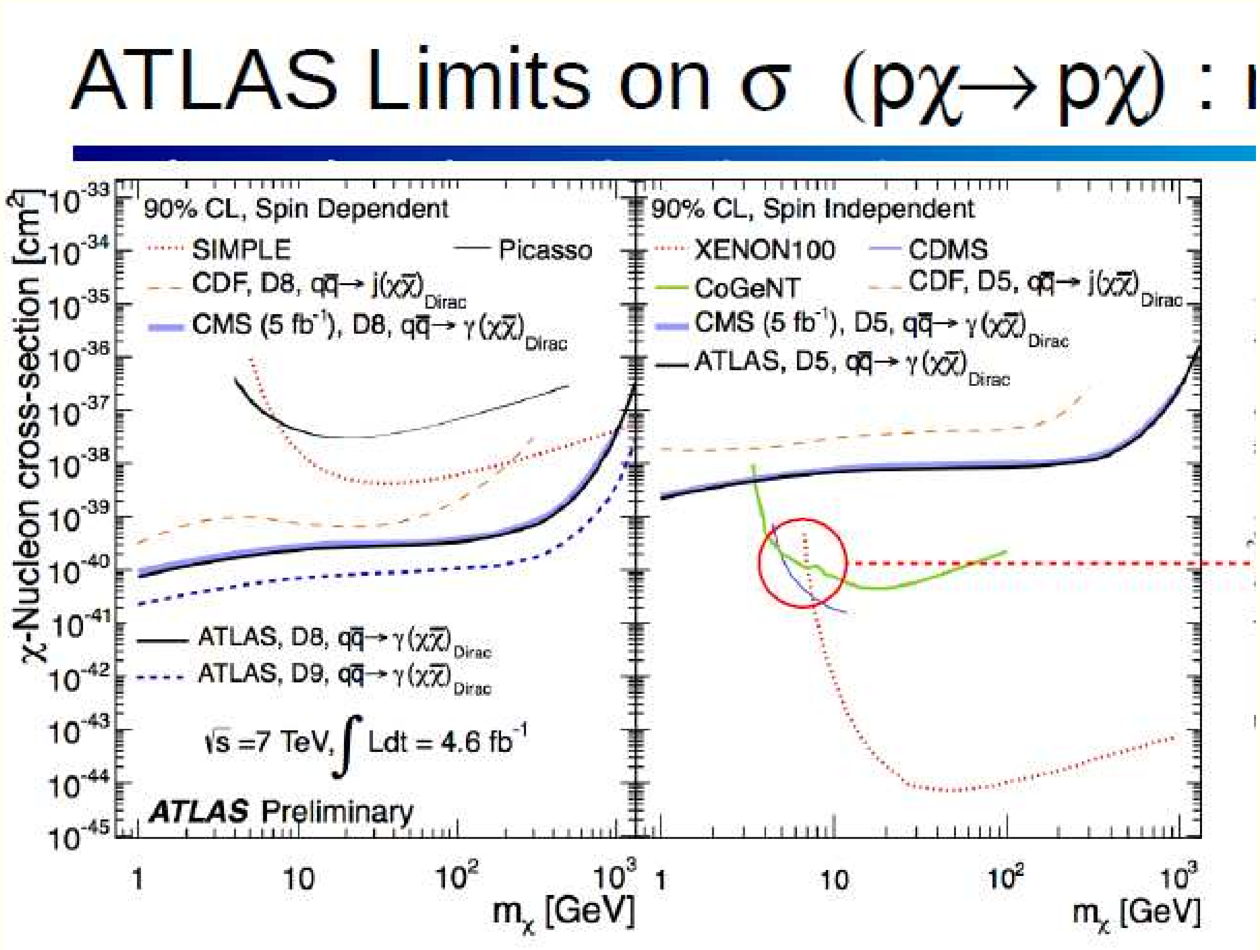
Experiments have used the non-observation of monojets to bound WIMP nucleon cross sections.

CMS limits on DM-nucleon scattering



In this analysis, the DM is assumed to be a Dirac fermion.

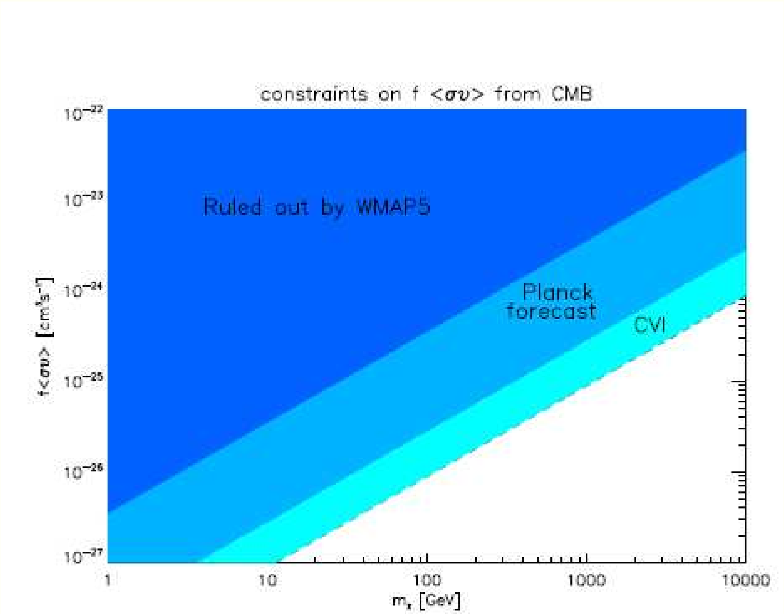
Very different kinematics, so are "form factor" effects relevant?



The Atlas collaboration has a similar analysis.

We have mentioned enhanced DM annihilation cross sections in the context of the Sommerfeld enhancement.

DM annihilation after electrons and protons have recombined to make atoms can potentially reionize the gas if a significant fraction of the annihilation energy is absorbed by the atoms. THIS CAN LEAVE AN IMPRINT ON THE ANISOTROPY AND POLARIZATION MEASUREMENTS OF WMAP. (arXiv:0905.0003)



Cross section enhancements at the level needed to explain the Pamela data are already limited by the WMAP data if the DM particle is light.

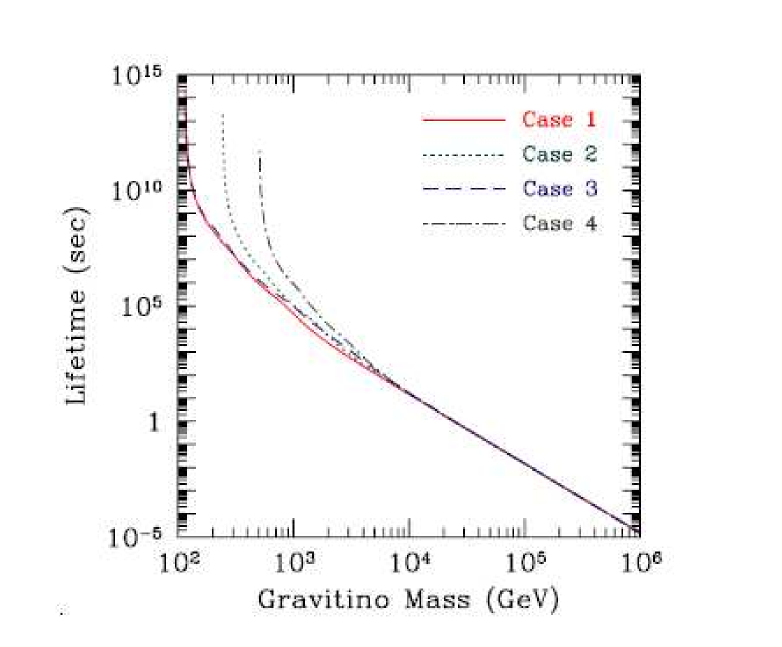
The Planck satellite will have sensitivity to $m_{\rm DM} \sim 50$ GeV (depending on the fraction of energy that contributes to ionization).

This is analogous to the more familiar injection of entropy that spoils nucleosynthesis; here, it distorts the relic radiation left over from the era of recombination.

Gravitinos and cosmology

Because they have very suppressed couplings, particle physicists never think about gravitinos. Unless these are extremely light, they are indeed irrelevant for particle physics experiments.

This is not the case in cosmology where time scales of the age of our Universe may be relevant.



Weak scale gravitinos decay with lifetimes of minutes. Their decay products might break up already formed nuclei, disrupting nucleosynthesis.

WHY DOES A LIGHT GRAVITINO MAKE A DIFFERENCE?

The dimensionless coupling for a decay $\tilde{P} \to P\tilde{G}$ is $\sim E/M_{\rm Pl}$.

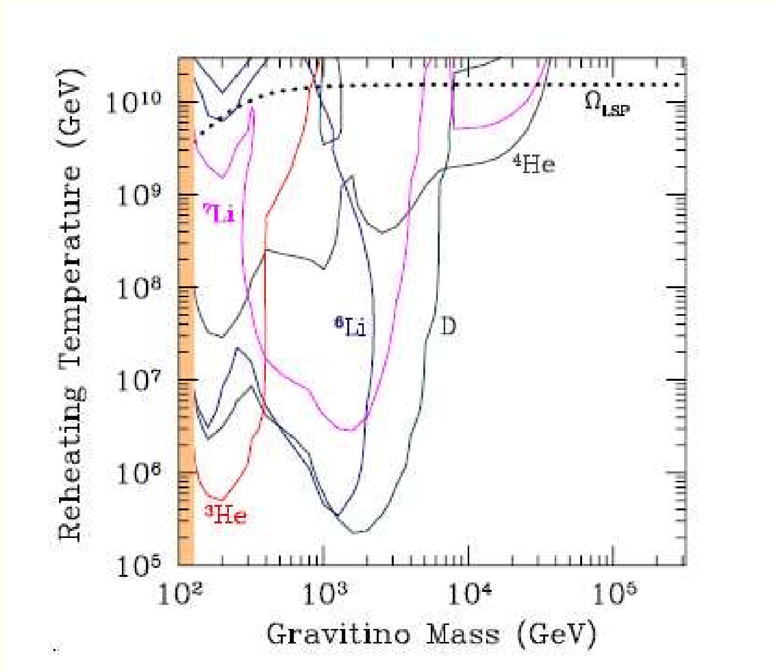
The gravitino gets a mass upon SUSY breaking, and develops longitudinal components by absorbing the Goldstino, in the same way that W-bosons develop longitudinal components after eating the Goldstone bosons.

Dimensionless coupling for this longitudinal component is $\frac{E}{M_{\rm Pl}} \times \frac{E}{m_{\tilde{G}}}$.

For $E \sim 100$ GeV, this is $\sim 10^{-6}\left(\frac{1\ {\rm eV}}{m_{\tilde{G}}}\right)$, or

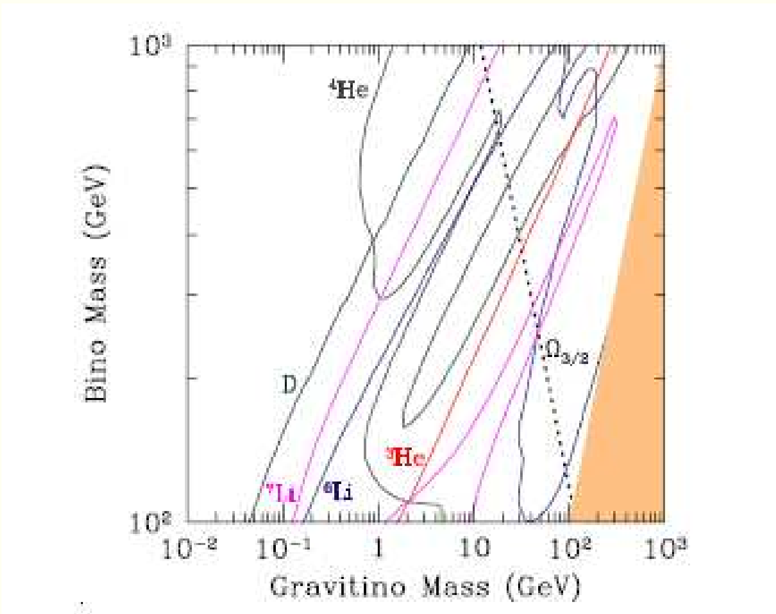
$$\tau(100\ {\rm GeV}) \sim 10^{-12}{\rm s} \times \left(\frac{m_{\tilde{G}}}{\rm eV}\right)^2.$$

This time scale is relevant to colliders.

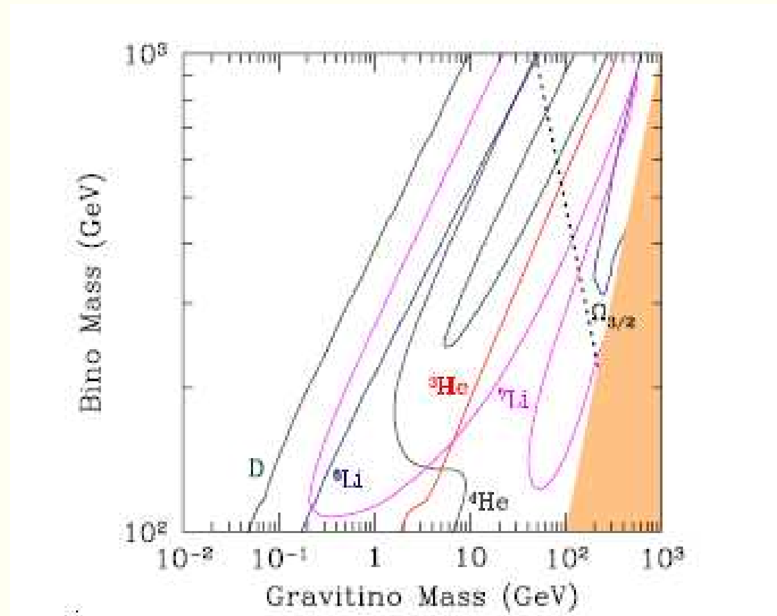


Decays of weak scale gravitinos indeed disrupt nucleosynthesis if gravitinos are produced by reheating after inflation. (Phys. Rev. D78 (2008) 065011.)

It does not help to make the gravitino stable because then the second lighest SUSY particle decays on similar time scales, and nucleosynthesis constraints again kick in.



NLSP in the bulk



NLSP in HB/FP or co-annihilation region

Suppose that we have been able to rig things so as not to run into trouble with nucleosynthesis and the gravitino is the DM.

Pre-inflation gravitinos are gone, but gravitinos can be produced during reheating with a thermal production density,

$$\Omega^{TP}_{\tilde{G}} h^2 \simeq 0.32 \left(\frac{10\ GeV}{m_{\tilde{G}}}\right) \left(\frac{m_{1/2}}{1\ \mathrm{TeV}}\right)^2 \left(\frac{T_R}{10^8\ \mathrm{GeV}}\right) .$$

These guys will be cold.

The decay of the next to lightest super particle (NLSP) will also contribute to the gravitino density by an amount equal to the density of the thermally produced NLSP, scaled by the mass. These guys may be hot or warm, depending on the masses.

The gravitino is not detectable via the direct or indirect WIMP detection searches.

ALL IS NOT LOST, HOWEVER.

In such scenarios, however, unique collider signatures may be possible, depending on the nature of the NLSP.

- ⋆ Quasi-stable heavy charged sparticles.
- ⋆ Monitor decays of accumulated NLSPs trapped in surrounding tank of water (hep-ph/0409278). See also, hep-ph/0409248 and arXiv:0902.3754.

Axions as Cold DM

Axions are pseudo-Goldstone bosons that result from the breaking of Peceii-Quinn symmetry introduced to provide a solution to the so-called strong CP problem (Sourav Roy).

The axion field develops a potential at a temperature $\Lambda_{\rm QCD}$ giving the axion a teensy mass.

How then can axions be cold DM?

The field ϕ can be written as $\phi = ve^{\frac{ia(x)}{v}}$, where the phase field is the axion. Inflation makes ϕ uniform over the causal universe (I assume here that the PQ symmetry is broken before inflation), and any value of the field is as good as any other until the Universe cools to $T \sim \Lambda_{\rm QCD}$ (when the axion field develops a potential).

In general, it will not be at the minimum of the potential, and so will start to oscillate. The quanta are the axions. The axion mass $m_a \sim \Lambda_{\rm QCD}/f_a \sim 10^{-5}$ eV for $f_a \sim 10^{12}$ GeV.

The wavelength of the oscillations is the horizon size at $T \sim \Lambda_{\rm QCD}$, so the axion momentum is much smaller than its mass, and the axions are produced non-relativistically!

The typical value of $\Omega_a h^2 \sim \frac{1}{2}\left[\frac{6\times 10^{-6} eV}{m_a}\right]^{7/6} h^2$, but could be much smaller if the axion field value happened to be small at the time the field began to oscillate.

Axions may also be produced by other means, but these guys will not be cold.

Axions in SUSY Models

If we try and incorporate the Peccei-Quinn idea in a SUSY context, we cannot just have the axion, but have to introduce a complete super-multiplet. In addition to the axion we have a saxion (spin-zero) and an axino (spin half). The axino is a superparticle, and if it is lighter than the neutralino, the latter may decay to an axino and a photon/gluon.

These axinos inherit the number density of neutralinos, and
$$\Omega_{\tilde{a}} h^2 = \Omega_{\widetilde{Z}_1} h^2 \times \frac{m_{\tilde{a}}}{m_{\widetilde{Z}_1}}.$$

Axinos may also be produced by being emitted from particles in thermal equilibrium. Have to be careful these are not too abundant. Need the axinos too be very light. WHY SO LIGHT?

The main point that I am making is that models where the thermal neutralino DM density is too high are not *automatically excluded*.

Neutralino LSP with axion supermultiplet

We have seen that a bino-like particle does not annihilate sufficiently rapidly and so leads to too short-lived a Universe and too much DM.

Decay the bino or dilute the bino by having some other field decay to SM particles.

Can the saxion field do so? It appears that the answer is YES, but generically at the expense of having also decays to axions. This contradicts the WMAP bound on the number of sterile degrees of freedom. arXiv:1301.7428

(Howie Baer and his collaborators have done extensive studies of the cosmology of axion-saxion-axino-neutralino scenarios.)

If there are other long-lived heavy fields (not related to the axion), their decays to Standard Model particles may also dilute the neutralino density without violating the WMAP $N_{\rm Eff}$ constraint. However, these fields generically will also inject MSSM superpartners, so also repopulate the neutralino.

Naturalness and Dark Matter

We all know that LHC experiments have not discovered SUSY, but have pushed the mass scale for gluinos and first generation quarks to beyond 1 TeV.

This has led some to suggest that we ought to give up on SUSY as the solution to the fine tuning problem because if sparticles are so heavy, we still need significant cancellations to get the Z and Higgs boson masses where they are.

If the MSSM is valid in the sense of an effective field theory up to a very high scale, these cancellations are further exacerbated by large logarithms.

SUSY CERTAINLY AMELIORATES THE BIG FINE-TUNING PROBLEM.

A naturalness measure

Recall the electroweak symmetry breaking condition that fixes M_Z in the MSSM:

$$\frac{m_Z^2}{2} = \frac{m_{H_d}^2 - m_{H_u}^2 \tan^2\beta}{(\tan^2\beta - 1)} - \mu^2 \simeq -m_{H_u}^2 - \mu^2$$

Require no large cancellation among the various terms. This suggests that $\Delta_{\rm EW}$ defined to be the maximum of the ratio of each term to the LHS is a measure of fine-tuning.

In particular, μ^2 should not be hierarchically different from $M_Z^2/2$ in order not to be fine-tuned.

But how can $\Delta_{\rm EW}$ be a fine-tuning measure when this thing is all defined at the weak scale and does not know of the large logarithms?

Small $\Delta_{\rm EW}$ is a necessary (but may not be sufficient) condition for limited fine-tuning.

$\Delta_{\rm EW}$ may be the appropriate measure of naturalness in some high scale theory with this sparticle spectrum where the large logs automaticlly cancel against Lagrangian parameters. (This is not the forum to discuss fine-tuning.)

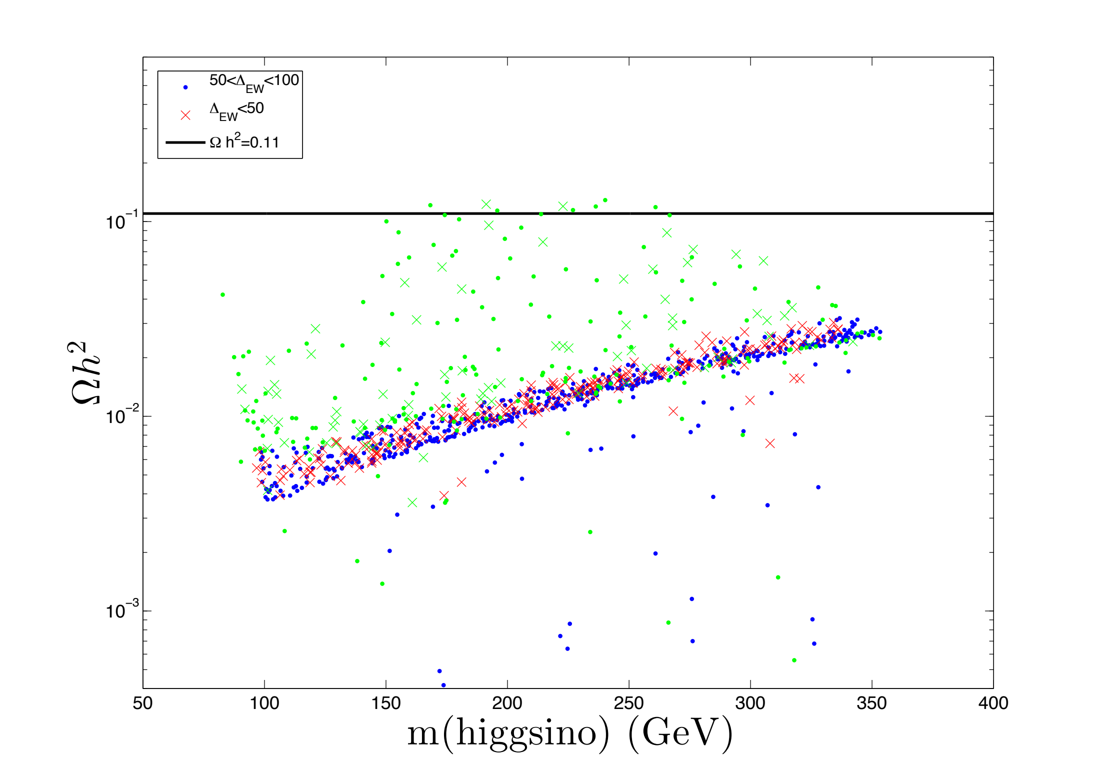
Naturalness considerations renew interest in light higgsino models, for which thermal relic DM is too small. Rest has to be made up by axions or something else. Making up underdensity seems readily possible as we just saw.

The interesting thing is that we can still say something about the detectability of this higgsino DM in these so-called radiative natural SUSY scenarios.

Same sign W pair production at the LHC is the hallmark of such scenarios is M_2 is not too large.

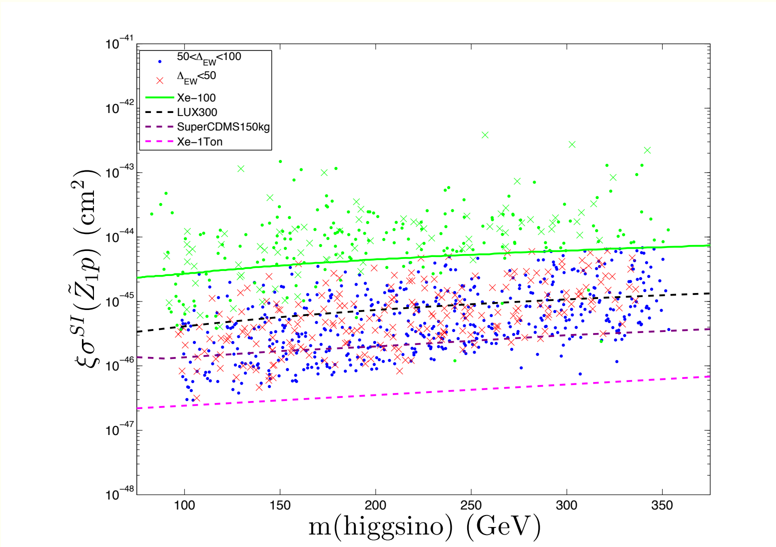
An e^+e^- collider with $\sqrt{s} \geq |\mu|$ will be a higgsino factory and should definitively test such a scenario.

Prospects for DM detection in RNS models

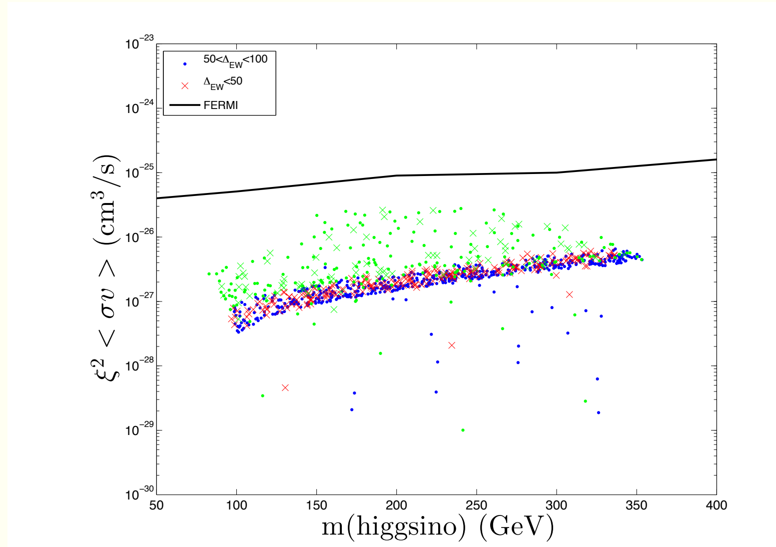


DM density falls short of measured relic density (by a factor $\xi \sim 5 - 25$) because higgsinos can annihilate efficiently in the early Universe.

Direct Detecton



Fermi Constraint



Notice the scaling on the vertical axis!

Because the bino and wino masses are bounded by fine-tuning considerations, μ/M_1 is not totally arbitrary, and prospects for detection not bad at all.

LHC Agenda for 2013-2020

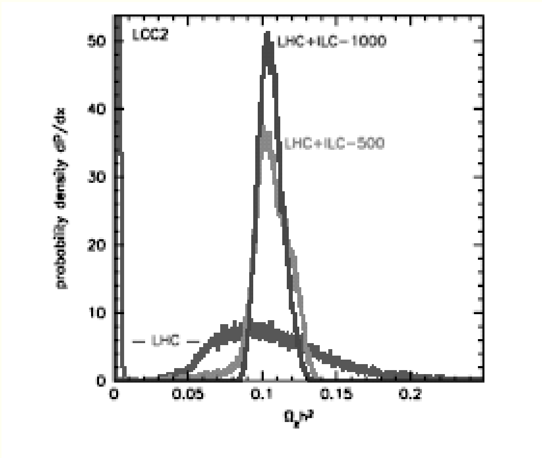
- ⋆ Establish a clear New Physics signal at the LHC.
- ⋆ Make the case it is SUSY. The case will be circumstantial.
- ⋆ Rates vs. mass. Strong vs. EW $\Longrightarrow$ Q. Nos.
- ⋆ Same sign dileptons+jet+$E_T^{\rm miss}$ signal $\Longrightarrow$ strongly interacting Majorana particles. ($N(\ell^+\ell^+)$ vs. $N(\ell^-\ell^-)$)
- ⋆ Cascade decays evidence of charginos and neutralinos?
- ⋆ Clean trileptons as evidence of charginos and neutralinos.
- ⋆ Quiter SS dileptons as a signature of low μ models?
- ⋆ Spin and Mass Measurements (multiple techniques by many groups.)

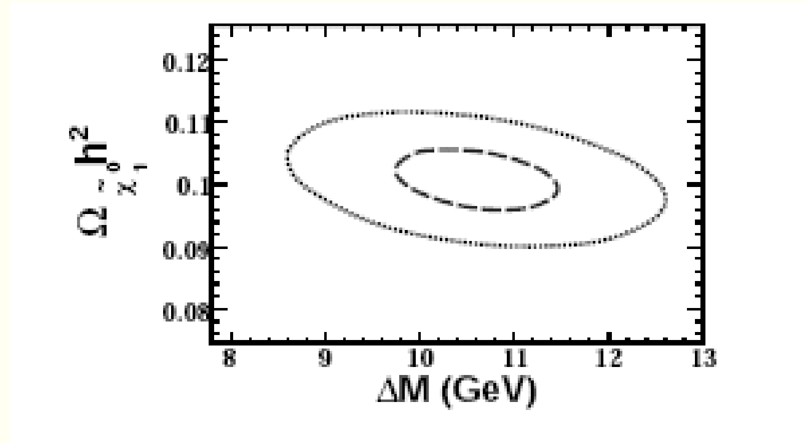
BUILD A CONSISTENT PICTURE.

In the next several years, we hope there will be a lot of new data as we have many beautiful experiments running/coming on.

- ⋆ LHC, Direction WIMP detection searches: superCDMS, XENON100, COUPP, LUX larger noble gas/liquid detectors....
  Indirect detection: IceCube, AMS-2, FERMI-LAT,......
- ⋆ Probes of flavour physics in the b and c meson systems....also at the LHC. Must also probe lepton flavour violation. REMEMBER THAT WE DO NOT UNDERSTAND FLAVOUR CONSERVATION IN THE SUSY CONTEXT. Even if flavour violation is only in the Yukawa sector, KM matrix may not completely encode it!
- ⋆ We do not understand the goodness of CP in the SUSY context. Push experiments in meson systems to see if we can break the KM tyranny. Probe neutron and electron EDMs.
- ⋆ Axion searches *e.g.* ADMX for the mixed axion-axino DM scenarios most recently being promoted by the Oklahoma gang.
- ⋆ Planck Satellite, Probes of acceleration of the Universe

The distinction between particle type and cosmology type will be fuzzy as plots like these may exist with real data!





XENON-100 excluded, $m_{\tilde{g}} \simeq 850$ GeV, heavy $\tilde{q}$

Baltz, Battaglia, Peskin, Wizansky.

LHC excluded, $m_{\tilde{g}}, m_{\tilde{g}} \simeq 750 - 850$ GeV

Arnowitt et al.

See also, Nojiri, Polesello and Tovey; Bertone et al (degeneracy removal).

It is remarkable that determinations at the LHC can get the right order of magnitude for $\Omega_{\widetilde{Z}_1}$. An "absurd answer" would make axion/axino DM guys happy! Is this analysis possible for LHC- and XENON100-safe points?

This may well be one of two ways to know DM consists of a single component. A peaked plot like this (with real data) would truly be a consumation of the HEP-Cosmology union.

CONCLUSIONS

- ⋆ WE ARE ENTERING A DECADE OF NEW OPPORTUNITIES WITH THE ADVENT OF THE LHC AND OF MANY FACILITIES THAT WILL ALLOW US TO STUDY STUFF FROM THE SKY.
- ⋆ PARTICLE PHYSICS AND COSMOLOGY WILL BE INTER-RELATED AT AN UNPRECEDENTED LEVEL.
- ⋆ I DO NOT KNOW WHAT NATURE HAS IN STORE FOR US, BUT WE MUST LOOK TO SEE WHAT WE FIND.
- ⋆ WE HOPE THAT OUR EXPERIMENTAL COLLEAGUES WILL TELL US SOMETHING NEW (AND ALSO TRUE) SOON!!!!