The “Light WIMPs” Saga

in Direct Dark Matter Detection

Graciela Gelmini - UCLA

PACIFIC, Gump Station, Moorea, Sept 15, 2015

- Prologe
- Setting the Stage
- The slow beginning
- The golden years
- Infidelity and murder
- Richness of the drama
- Will continue...

Subject is too vast for the time- so idiosyncratic choice of subjects. Citations disclaimer

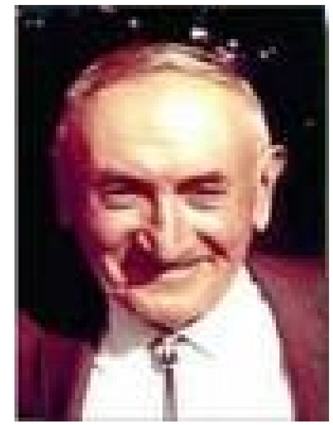
The DARK MATTER problem has been with us since 1930's,

name coined by Fritz Swicky in Helvetica Physica Acta Vol6 p.110-127, 1933

Die Rotverschiebung von extragalaktischen Nebeln

von **F. Zwicky.**

(16. II. 33.)



Inhaltsangabe. Diese Arbeit gibt eine Darstellung der wesentlichsten Merkmale extragalaktischer Nebel, sowie der Methoden, welche zur Erforschung derselben gedient haben. Insbesondere wird die sog. Rotverschiebung extragalaktischer Nebel eingehend diskutiert. Verschiedene Theorien, welche zur Erklärung dieses wichtigen Phänomens aufgestellt worden sind, werden kurz besprochen. Schliesslich wird angedeutet, inwiefern die Rotverschiebung für das Studium der durchdringenden Strahlung von Wichtigkeit zu werden verspricht.

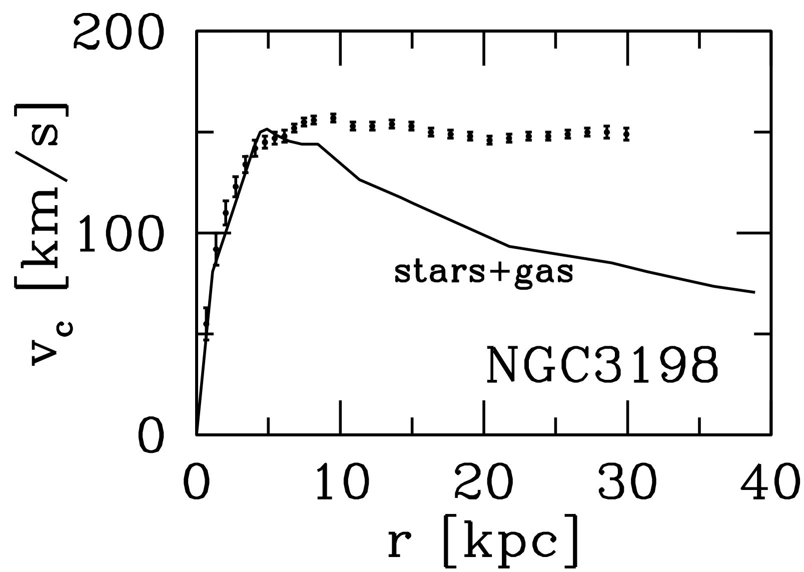
On page 122

gr/cm³. Es ist natürlich möglich, dass leuchtende plus **dunkle (kalte) Materie** zusammengenommen eine bedeutend höhere Dichte ergeben, und der Wert $\bar{\varrho} \sim 10^{-28}$ gr/cm³ erscheint daher nicht

Used the Virial theorem in the Coma Cluster: found its galaxies move too fast to remain bounded by the visible mass only. J. Ostriker: in the first 40 y his seminal 1937 paper had 10 citations!

Dark Matter rediscovered

In 1970's Vera Rubin found that the rotation curves of galaxies ARE FLAT!



$$\frac{GMm}{r^2} = m\frac{v^2}{r} \Rightarrow v = \sqrt{\frac{GM(r)}{r}}$$

$$v = const. \Rightarrow M(r) \sim r$$

even where there is no light!

1 pc = 3.2 ℓy

Dark Matter dominates in galaxies e.g. in NGC3198

$$M = 1.6 \times 10^{11} M_\odot (r/30 \text{ kpc})$$

$$M_{stars+gas} = 0.4 \times 10^{11} M_\odot$$

$$\frac{M}{M_{vis}} > 4$$

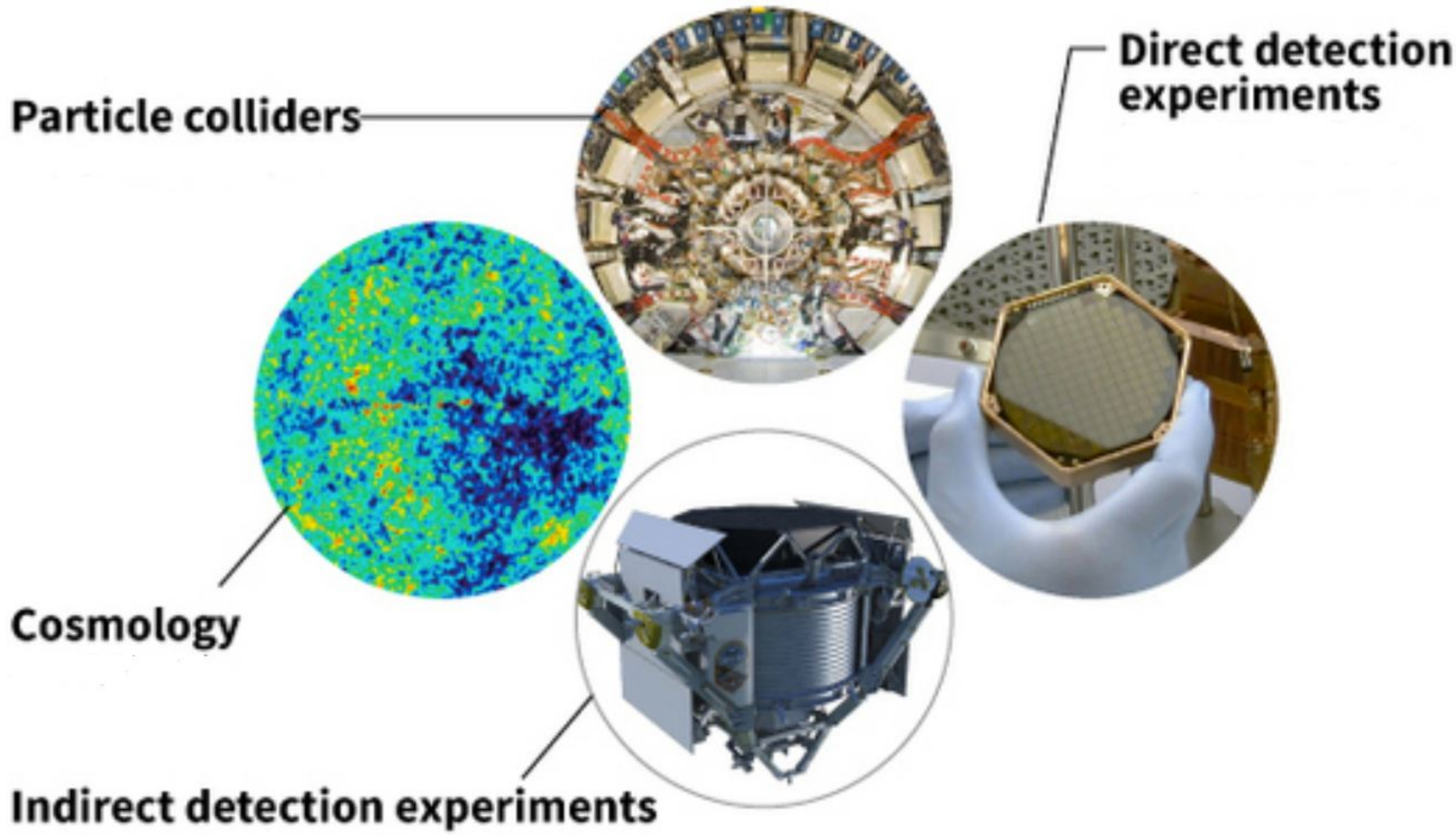
We are going to concentrate on the DM in the Dark Halo of our own galaxy

After 80 years, what we know about DM:

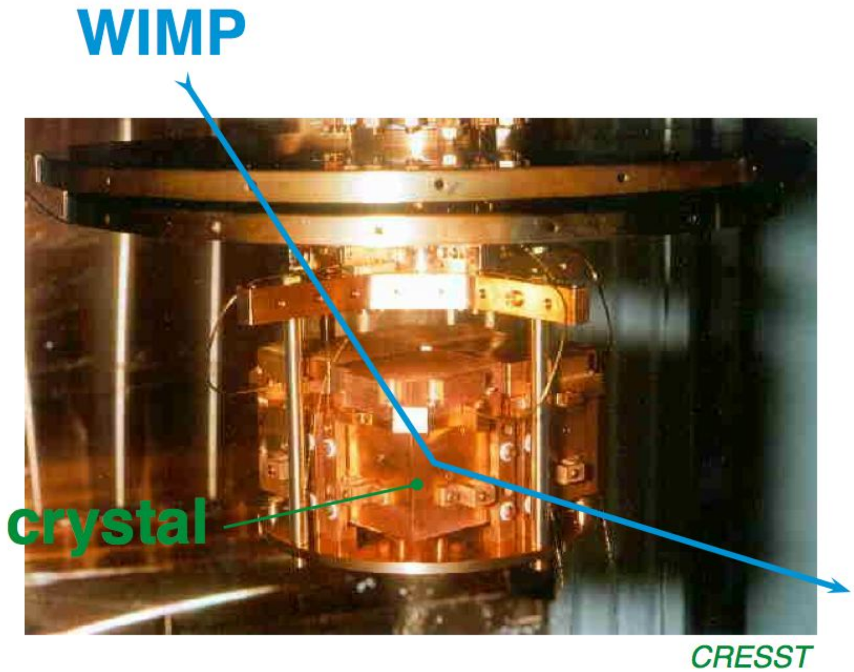
- **Dark matter and not MOND** (MOdified Newtonian Dynamics) because of the segregation of the dark and the visible matters in the "bullet cluster"

- **Stable** (or lifetime $>> t_U$)
- **Neutral, colorless** (or anyways not having any interaction detected so far but gravitational)
- **Non-dissipative** (but $< 10\%$ could be))
- With the **right relic abundance** $\leq \Omega_{DM} \simeq 0.27$
- 10^{-31} GeV $\leq$**mass**$\leq 10^{-7} M_{\odot}$ $=10^{50}$GeV (limits on MACHOS astro-ph/0607207)
  ("Fuzzy DM", boson Bohr radius= 1 kpc Hu, Barkana, Gruzinov, astro-ph/0003365)
  or 0.2-0.7 $\times 10^{-6}$ GeV$\leq$ mass (for particles which reached equilibrium - depending on boson-fermion and d.o.f. Tremaine-Gunn 1979; Madsen, astro-ph/0006074)
- **Self interactions with σ_{self}/m $\leq$0.1cm^2/g=0.7 barn/GeV**
  (from non-sphericity of galaxy and cluster halos) Peter et al 1208.3026
- **Cold or Warm, thus not included in the Standard Model of EP**...
  among other candidates are WIMPs (Weakly Interacting Massive Particles)

The Hunt for Dark Matter is multi-pronged involving ...

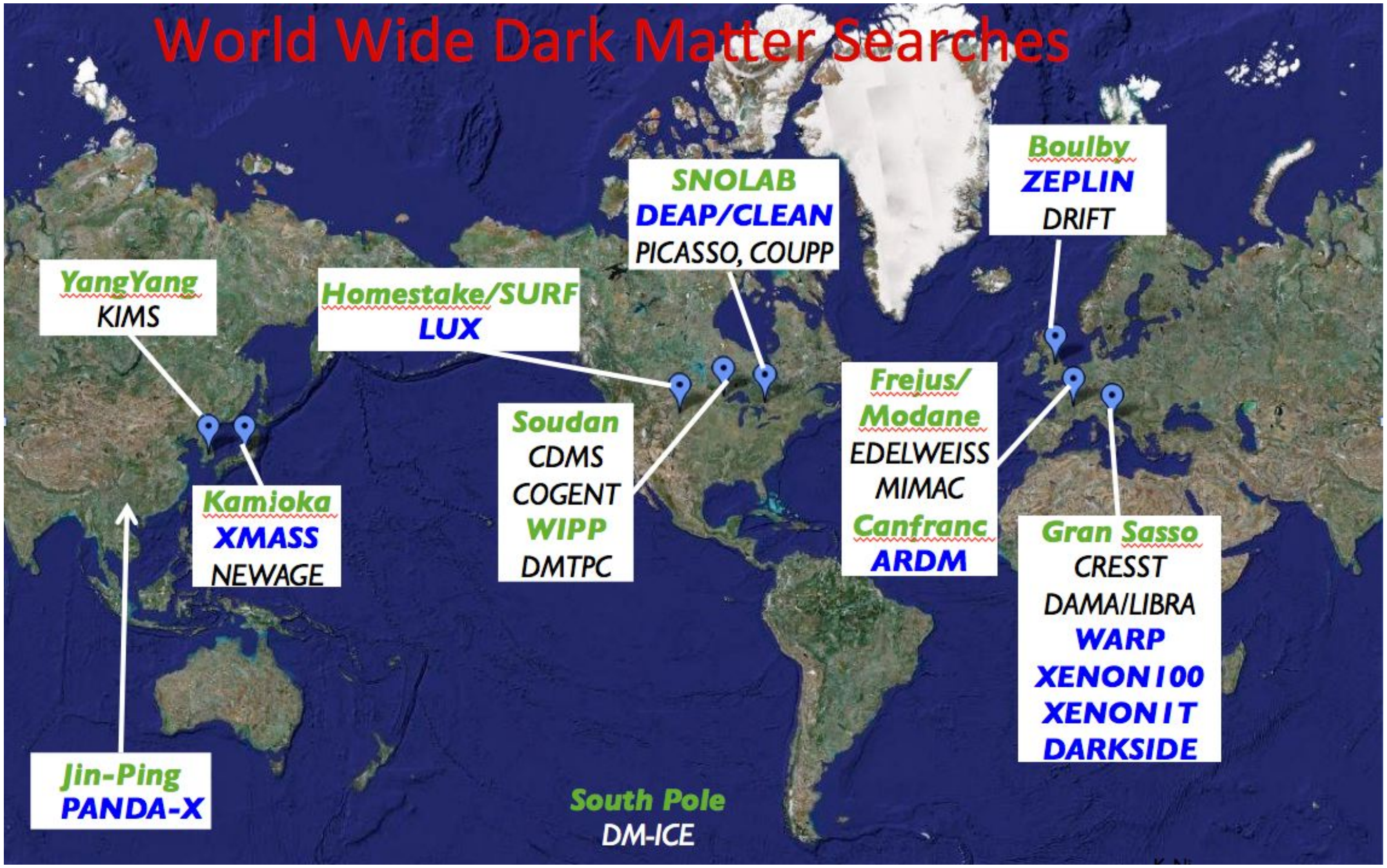


Direct DM Searches: look for energy deposited within a detector by the DM particles in the Dark Halo of the Milky Way. WIMP's interact coherently with nuclei



- Small $E_{Recoil} \leq 5$keV(m/10 GeV)
- Rate: typical... < 1 event/ 100 kg/day requires constant fight against backgrounds
- Single hits: single scatters, uniform through volume of detector
- Annual flux modulation (10 % effect)
- Most searches are non-directional but some in development are (try to measure the recoil direction)

Direct DM Searches: Many experiments!



Main Saga characters

DAMA (NaI), CoGeNT (Ge), CRESST II ($CaWO_4$) AND CDMS (Si) made potential detection claims.... pointing to WIMPs with m< 10 GeV.

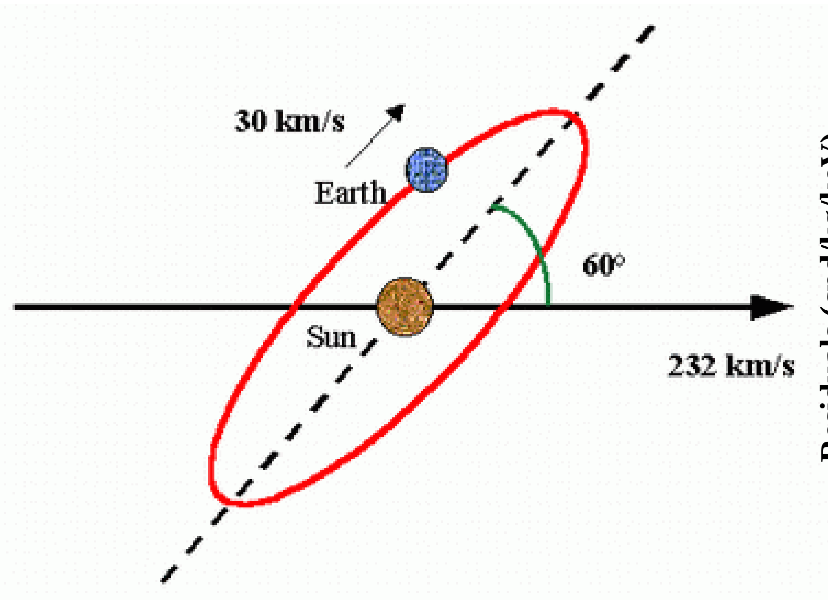
Are they DM signals or backgrounds?

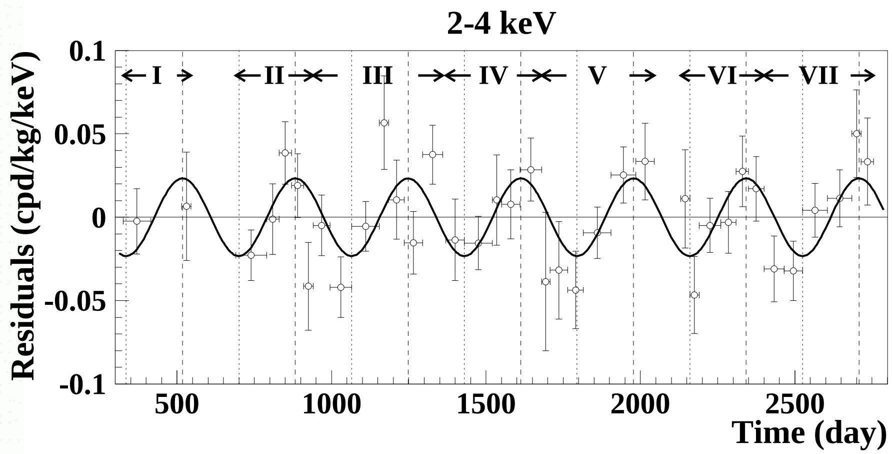
LUX (Xe) XENON 100 (Xe), XENON 10 (Xe), CDMS (Ge, Si), SUperCDMS, CDMSlite (Ge), SIMPLE (C_2ClF_5).... have upper bounds...

Assuming they are DM signals, can all signals and bounds be reconciled?
Some of them?

Setting the stage:

2002- Old DAMA/NaI: DM signal?



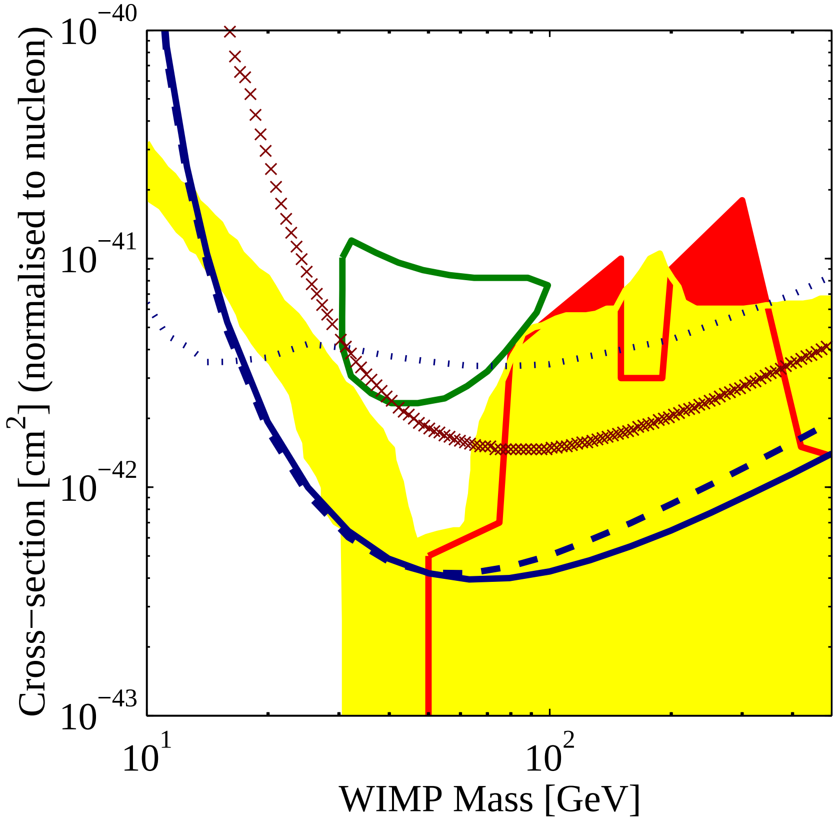


By 2002: 7 years of DAMA/NaI showed a 6σ modulation signal compatible with the Standard Halo Model.

2004-Old DAMA/NaI SI WIMPs?

Theoretical prejudice:
DAMA region cut at m= 25 GeV
(from 1997 until 2003)
was excluded in 2002 by Edelweiss
(brown crosses) and in 2004 by
CDMS-Soudan (blue).

Theoretical Prejudice:
limits were never shown below
m=10 GeV either!



Bottino et al. light neutralinos m >6 GeV

Baltz et al.

The slow beginning. . .
2005-Old DAMA SI WIMPs? Region compatible with all data!

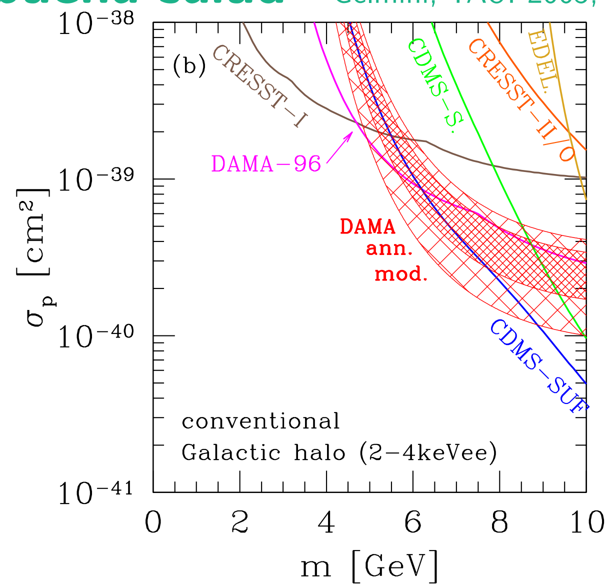
"DAMA dark matter detection compatible with other searches," Gelmini, Gondolo hep-ph/0405278; Gondolo Gelmini hep-ph/0504010

"Los muertos que vos matais gozan de buena salud" Gelmini, TAUP2005, Zaragoza

The bounds had never been extended to m< 10 GeV before.

Due to its Na, DAMA could see a signal that was under threshold for Ge in CDMS and EDELWEISS

Start of the "Light WIMP" saga!



Until 2010: the lone old main character- new antagonists

2008 DAMA/LIBRA

25 NaI (Tl) crystals of 9.5 kg each, 4y in LIBRA (11 years total),
0.83 ton $\times$ year, 8.2σ modulation signal (Gran Sasso) (Bernabei et al 0804.2741)

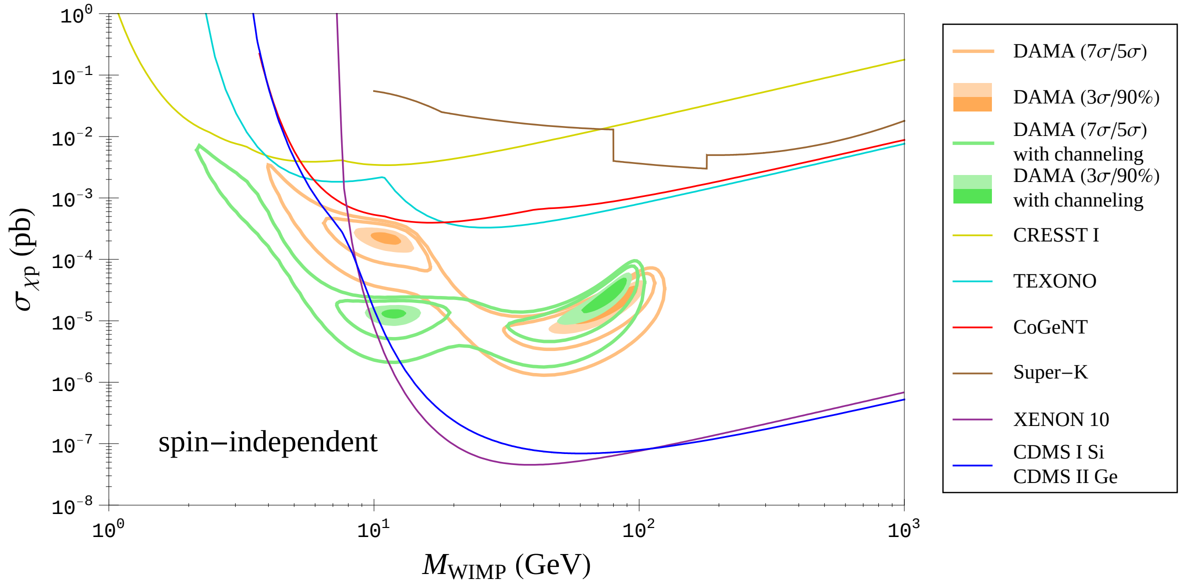
2010 DAMA/LIBRA

25 NaI (Tl) crystals of 9.5 kg each, 6y in LIBRA (13 years total),
1.17 ton $\times$ year, 8.9σ modulation signal.(Bernabei et al 1002.1028)

Negative searches: CoGeNT, CRESST-1, CDMS, XENON10, TEXONO...

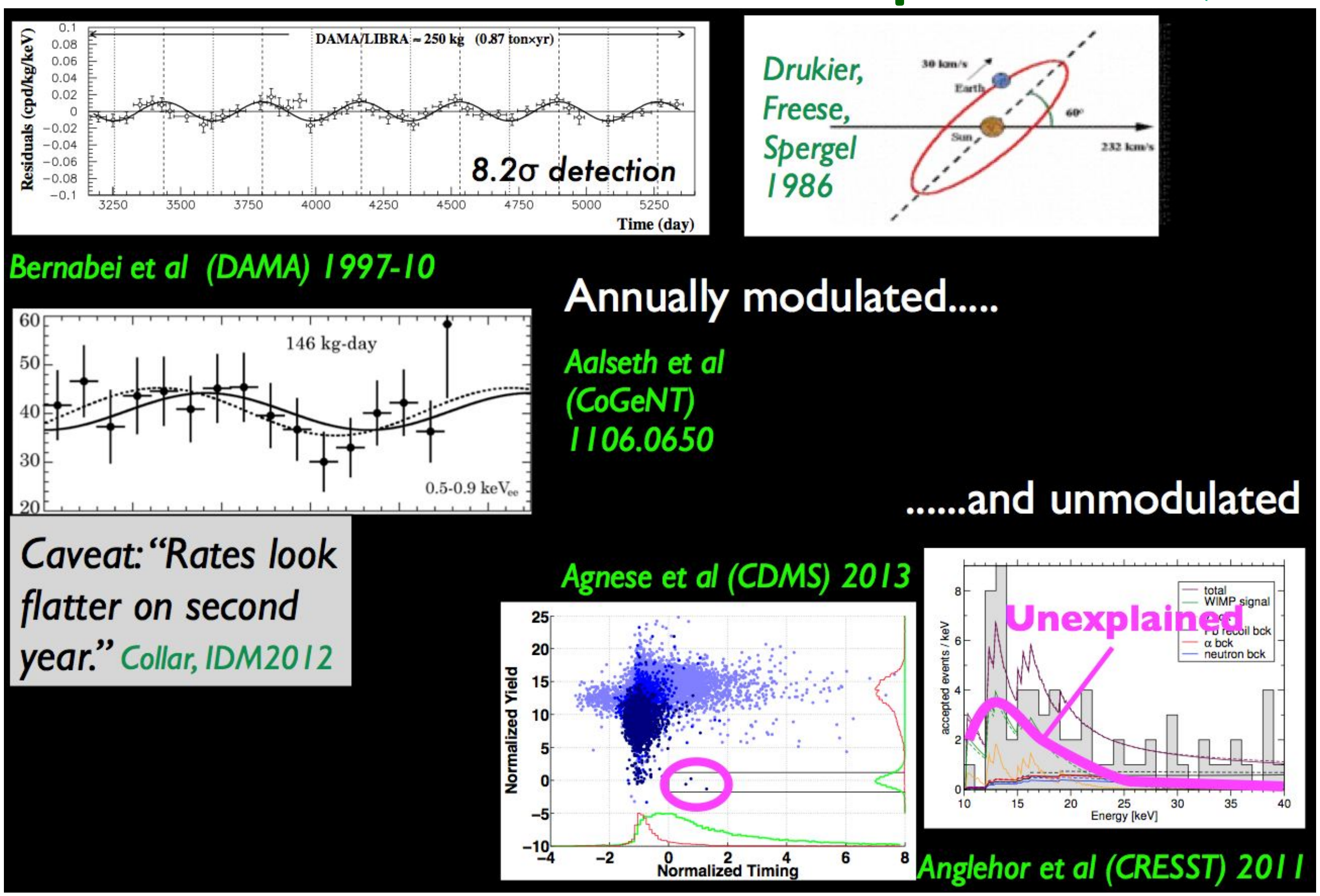
Upper limits: CoGeNT, CRESST, CDMS, XENON10, TEXONO...

Savage, Gelmini, Gondolo and Freese, arXiv:0808.3607, JCAP 0904:010,2009



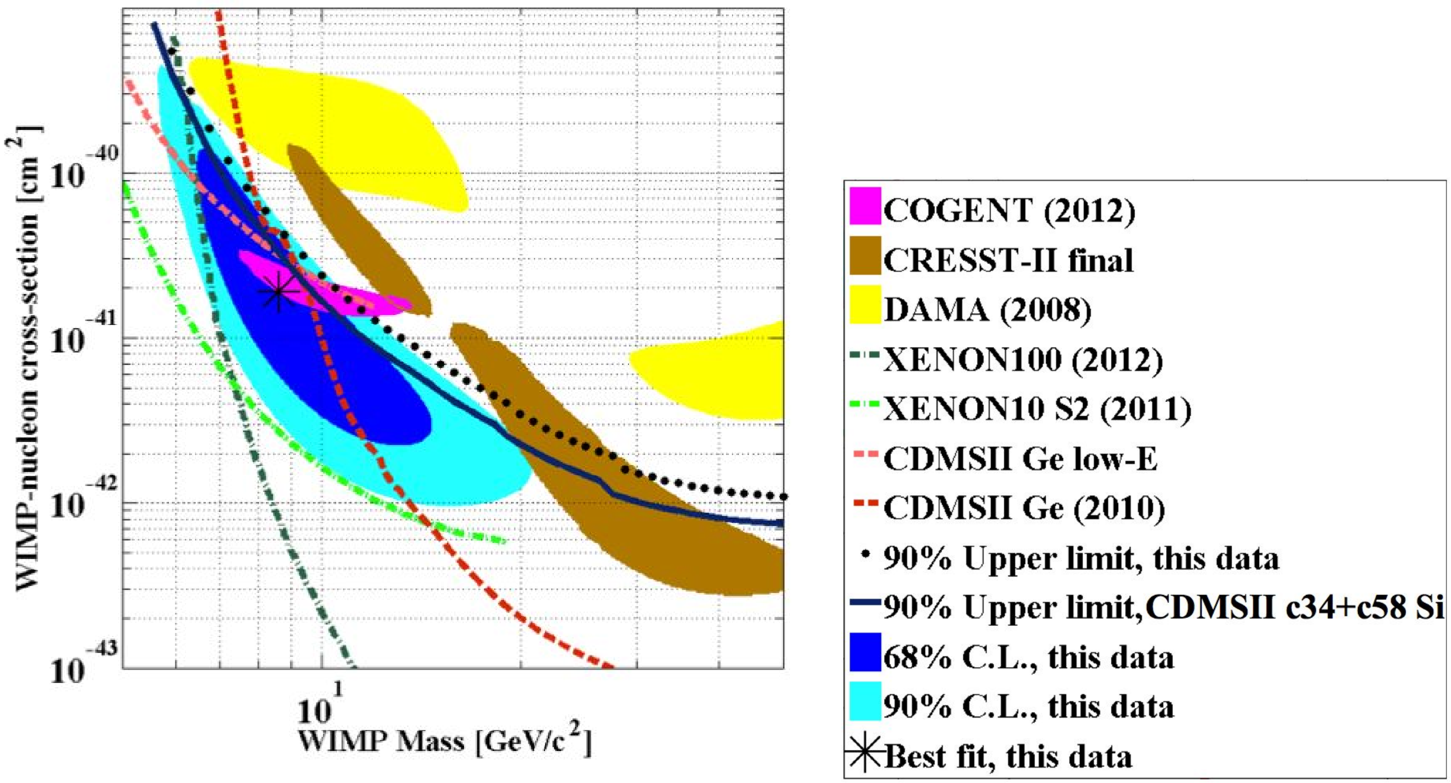
With the channeling fractions DAMA estimated in 2008 two distinct regions of light WIMPS $m \simeq$ 7-10 GeV with Na or channeled I recoils were a possible explanation- In 2010 understood that channeling is so small that is irrelevant for Direct Searches (Bozorgnia,GG. Gondolo 2010, Collar 2013 , KIMS)

2010-2013 Saga's golden years...
DM hints in four direct detection experiments (Fig. from P. Gondolo)



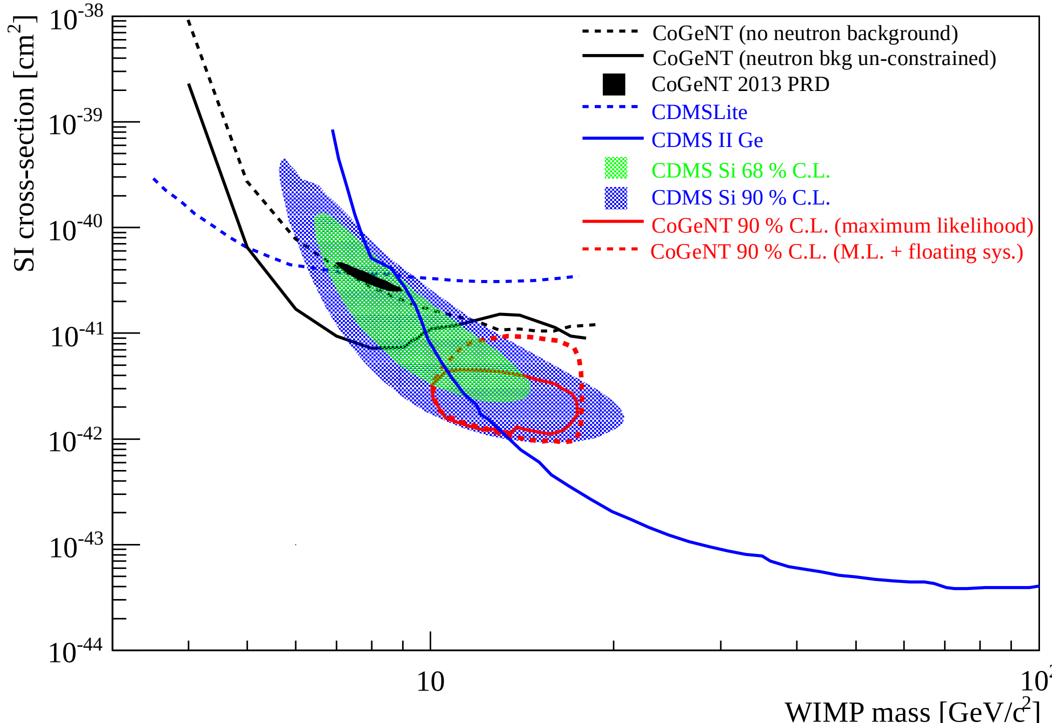
New role old character: CDMS Si 3 candidate events (April14, 2013)

140.23 kg-day from July 2007 to Sep. 2008 in 8 Si detectors, expected background events < 0.7 $(0.41^{+0.20+0.28}_{-0.08-0.24})$, i.e. 5.4% probability of being known backgrounds



The Saga continues with....

Weaker CoGeNT modulation 1401.3295 3.4y since 12-3-09
CoGeNT collaboration new data analyses 1401.6234



Only CDMS limits shown (in blue)

infidelity.... (Juan Collar is CoGeNT's leader)

Maximum Likelihood Signal Extraction Method Applied to 3.4 years of CoGeNT Data

C.E. Aalseth,[1] P.S. Barbeau,[2,*] J. Colaresi,[3] J.I. Collar,[2] J. Diaz Leon,[4] J.E. Fast,[1] N.E. Fields,[2] T.W. Hossbach,[1] A. Knecht,[4,†] M.S. Kos,[1,‡] M.G. Marino,[4,§] H.S. Miley,[1] M.L. Miller,[4,¶] J.L. Orrell,[1] and K.M. Yocum[3]
(CoGeNT Collaboration)

arXiv:1401.6234v1 24 Jan 2014

Maximum Likelihood Signal Extraction Method Applied to 3.4 years of CoGeNT Data

C.E. Aalseth,[1] P.S. Barbeau,[2,*] J. Colaresi,[3] J. Diaz Leon,[4] J.E. Fast,[1] T.W. Hossbach,[1] A. Knecht,[4,†] M.S. Kos,[1,‡] M.G. Marino,[4,§] H.S. Miley,[1] M.L. Miller,[4,¶] J.L. Orrell,[1] and K.M. Yocum[3]

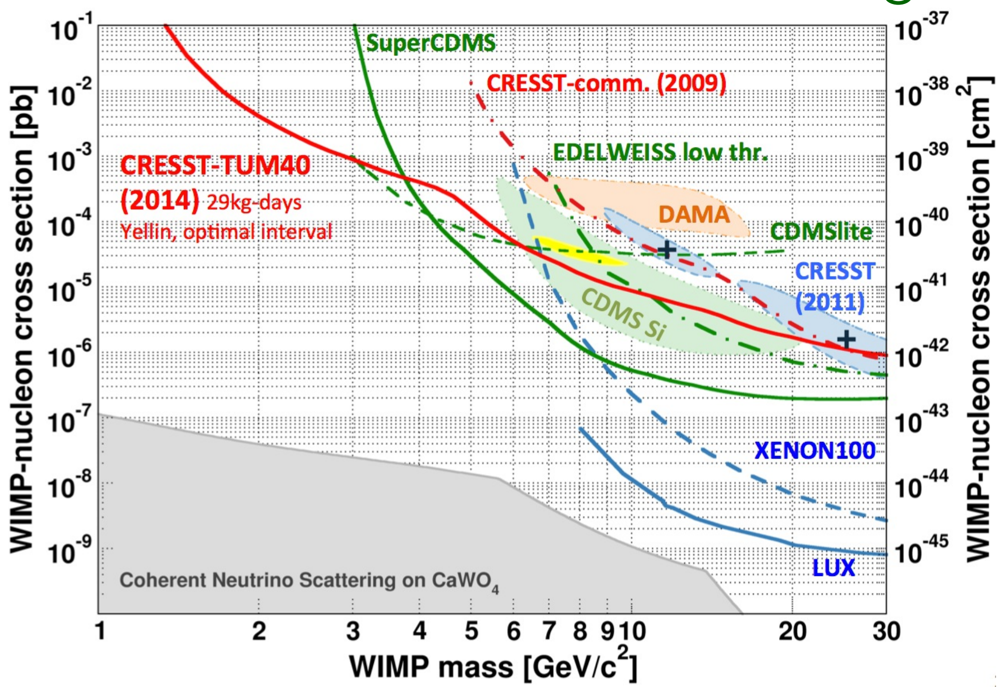
arXiv:1401.6234v2 27 Jan 2014

Matthew Bellis, Chris Kelso, Juan Collar and Nicole Fields independent analysis (IDM2014): "the fit gets worse when including WIMP component either as a Standard Halo or SGR like stream"

CoGeNT made public dataset and analysis done independently by J. Davis, C. McCabe and C. Boehm, 1405.0495: "preference for light dark matter in CoGeNT recoils at less than 1σ"

... and murder!

New CRESST-III results killed their own 2011 region 1407.3146



Most restrictive limits at present:

First LUX limits (Nov. 2013, 1310.8214)

Fiducial 118 kg of Xe- 85.3 days from April to Aug. 2013 (Sanford URF, South Dakota)

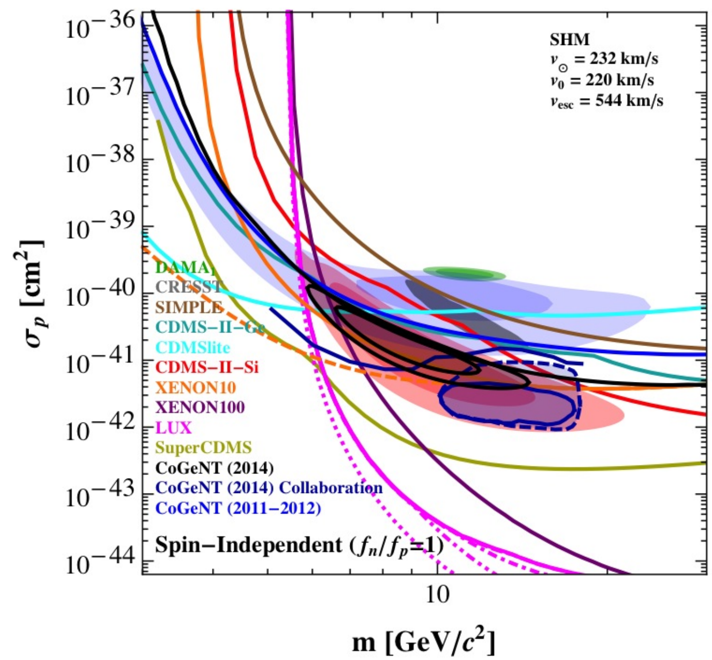
CDMSlite (Sept. 2013, 1309.3259- Fig from Dec. 2013)

0.6 kg of Ge- 10 days- part of SuperCDMS- very low threshold: 0.170 keVee (Soudan)

Super-CDMS new data 1402.7137

use 7 of 15 0.6kg Ge crystals, 577 kg-days, with threshold $\simeq 10$ keV (Soudan)

Our own analysis Del Nobile, Gelmini, Gondolo, Huh 1311.4247 & 1401.4508



All regions rejected by a combination of LUX and CDMSlite bound? BUT this is for elastic collisions and Spin Independent WIMP-nucleus interaction, equal coupling to n and p $f_n = f_p$ and assuming the Standard Halo Model!!!

Event rate: events/(kg of detector)/(keV of recoil energy)/day

$$\frac{dR}{dE_R} = \sum_T \int \frac{C_T}{M_T} \times \frac{d\sigma_T}{dE_R} \times n v f(\vec{v},t) d^3 v$$

- For a WIMP-nucleus contact differential cross section $d\sigma_T/dE_R = \sigma_T(E_R)\ M_T/2\mu_T^2 v^2$

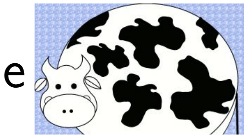
$$\frac{dR}{dE_R} = \sum_T \frac{\sigma_T(E_R)\rho}{2m\mu_T^2} \int_{v>v_{min}} \frac{f(\vec{v},t)}{v} d^3 v = \sum_T \frac{\sigma_T(E_R)}{2m\mu_T^2}\ \rho\eta(v_{min})$$

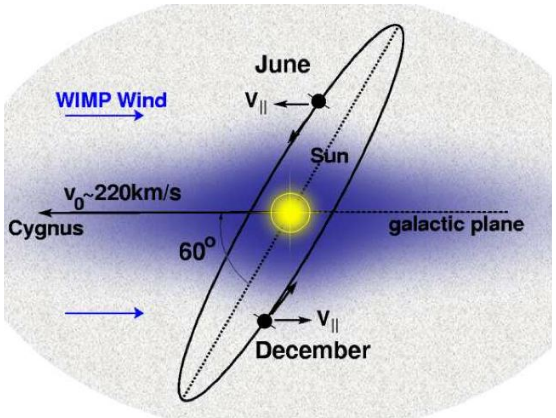
- T denotes each target nuclide (elements and isotopes)
- $\frac{C_T}{M_T}$= mass fraction × (Number of atoms per unit mass); $\mu_T = mM_T/(m + M_T)$
- For elastic scattering: $v_{min} = \sqrt{M_T E_R/2\mu_T^2}$ and E is the ion recoil energy .
- $\rho = nm$, $f(\vec{v},t)$: local DM density, $\vec{v}$ distribution depend on halo model
- e.g. for spin-independent (SI) interactions $\sigma_T(E_R) = \sigma_{T0} F^2(E_R)$ where

$$\sigma_{T0} = \left[Z + (A - Z)(f_n/f_p)\right]^2 (\mu_T^2/\mu_p^2)\sigma_p = A^2(\mu_T^2/\mu_p^2)\sigma_p$$

- spin-dependent (SD) $\sigma_T(E_R) = \frac{32\mu^2 G_F^2 (J_T+1)}{J_T}\left[\langle S_p\rangle a_p + \langle S_n\rangle a_n\right]^2$

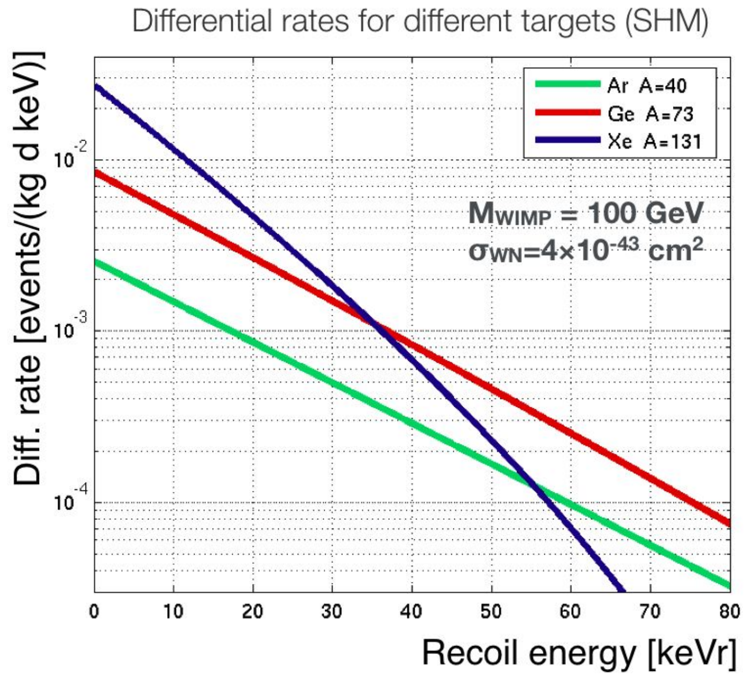
"Halo dependent" data comparison in the m, σ_p plane, given $\rho\eta(v_{min})$

Standard Halo Model (SHM) The  of halo models



- $\rho_{SHM} = 0.3^{+0.2}_{-0.1}$ GeV/cm^3
- $f(v,t)$: Maxwellian $\vec{v}$ distribution

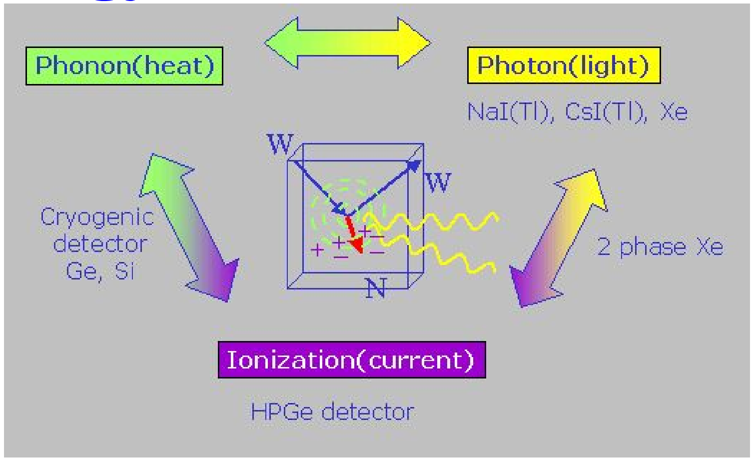
at rest with the Galaxy $v_\odot$ ≃220km/s (190 to 320km/s), v_{esc} ≃500-650km/s



ANNUAL MODULATION: max in May, min in Dec.(Drukier, Freese, Spergel 1986)

Local ρ, v, modulation phase/amplitude could be very different if Earth is within a DM clump or stream or there is a "Dark Disk". Other: anisotropies, velocity tails, debris flows...

But the recoil energy is not measured directly:

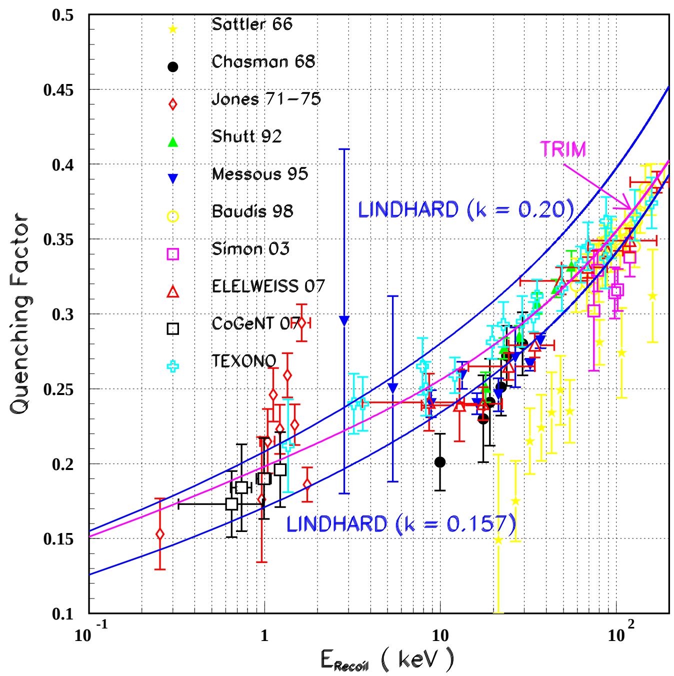


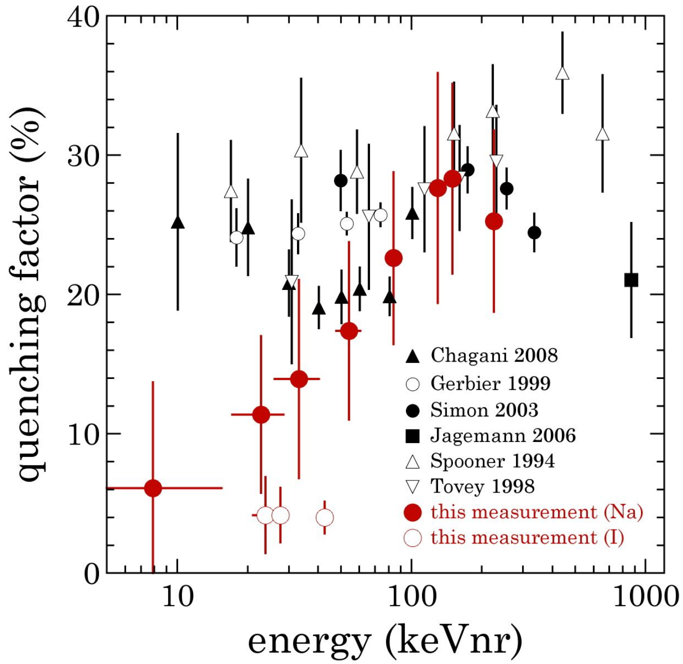
The differential rate in detected energy $E^{'}$(in keVee or number of PE)

$$\frac{dR}{dE^{'}} = \varepsilon(E^{'}) \int_0^{\infty} dE_R \sum_T C_T \, G_T(E_R, E^{'}) \frac{dR_T}{dE_R}$$

- C_T: mass fraction in target nuclide T;
- $\varepsilon(E^{'})$: counting efficiency or cut acceptance
- $G_T(E_R, E^{'})$: energy response function (includes the energy resolution $\sigma_E(E^{'})$ and the mean value $\langle E^{'} \rangle = E \, Q_T(E_R)$)

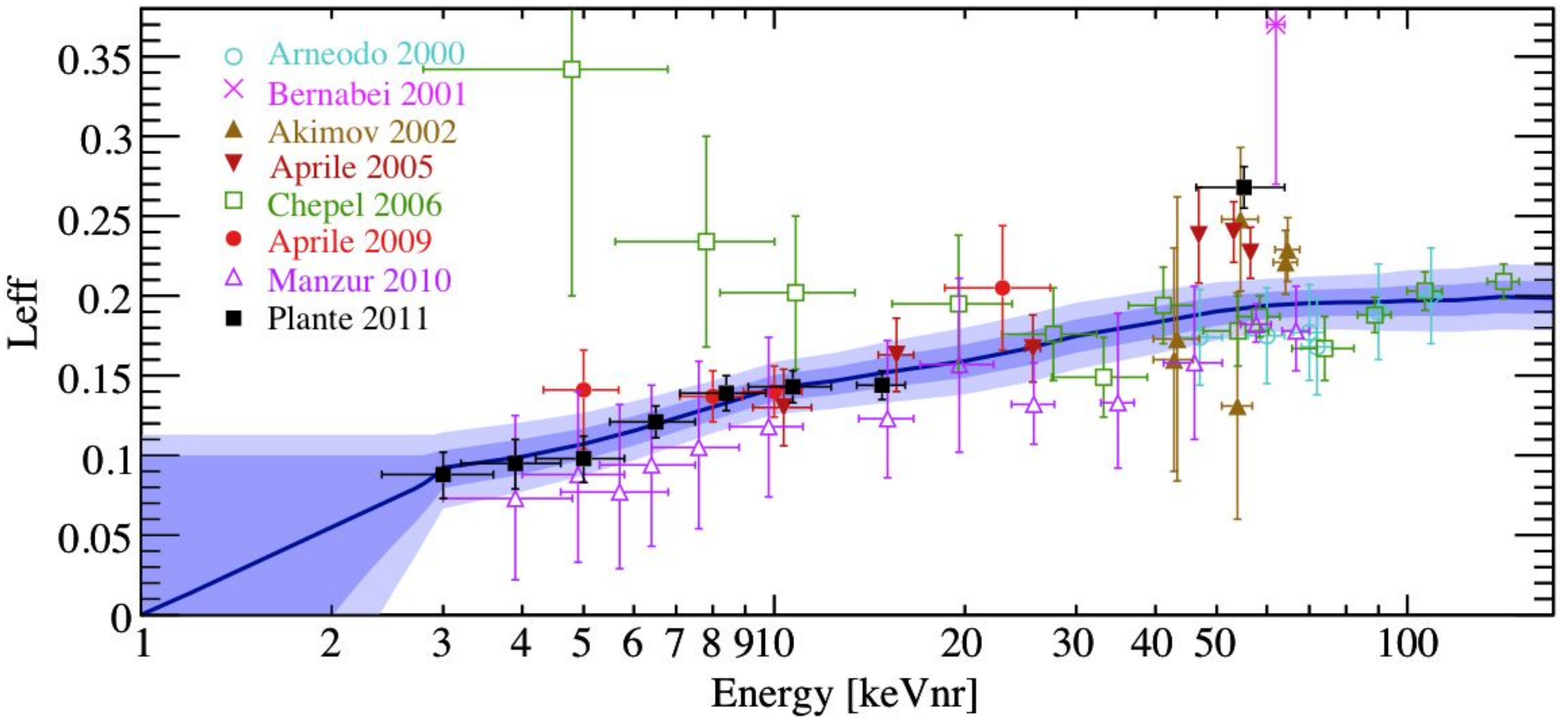
Large uncertainties in Q factors





Compilation of Q_{Ge} TEXONO 2007 and Q_{Na} Collar et al. 2013 measurements

Large uncertainties in L_{eff} of Xenon



The richness of the drama:

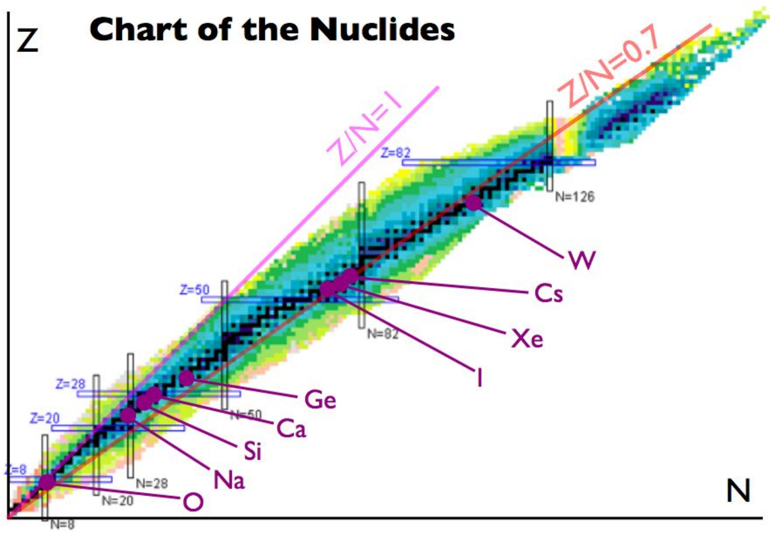
Rate= Detector response $\times$ DM particle model $\times$ Halo model,
thus large uncertainties in regions and bounds due to

- Detector response model: e.g. energy resolution, efficiency, fraction of energy deposited which is detectable, have large uncertainties at low E.
- Type of DM interaction: contact spin-indep. or dep.? With different couplings with p and n (i.e isospin violating-IV)? Magnetic moment interaction (MDM)? Milli-charged DM? anapole DM? resonant DM? Form factor DM? inelastic endothermic (iDM)? inelastic exothermic (ieDM)?
- Uncertainties in the Dark Halo model: anisotropies, DM clumps and streams, "debris flows", velocity tails, "dark disk", escape speed: make a **"Halo Independent data comparison"**
- Backgrounds: part, or all of the "DM signals" may be actually due to backgrounds? Modulation in DAMA due to CR muon-induced neutrons- but phase is not right- Jonathan Davis 1407.1052: muons + solar ν? (but see 1409.3185 and 1409.3516) We need ANDES!

Isospin conserving (IC) or violating (IV) light WIMP?

IV can make the coupling $\left[Z f_p + (A - Z) f_n\right] \simeq 0$ for $f_n/f_p \simeq -Z/N$, not exactly zero because of isotopic composition

Kurilov, Kamionkowski 2003; Giuliani 2005; Cotta et al 2009; Chang et al 2010; Kang et al 2010, Feng et al 2011...



$f_n/f_p \simeq -0.7$ disfavors mostly Xe
$f_n/f_p \simeq -0.8$ disfavors mostly Ge
(and changes the couplings of all other materials too)

Can have a rich "Dark Sector" similar to visible sector, with hidden gauge interactions and flavor Foot 2004, Huh at al 2008, Pospelov, Ritz, Voloshin 2008, Arkani-Hamed et al.,2009, Kaplan et al 0909.0753 and 1105.2073. . . "Atomic DM" Unbroken U'(1) hidden gauge symmetry that would give rise to bound states Goldberg Hall 1986; Feng, Kaplinghat, Tu 0905.3039; Ackerman 2009 DM must be asymmetric "Millicharged DM" with dark analogues of p, e, H coupled to a new U'(1) and "kinetic coupling"

$$\varepsilon F_{\mu\nu} F^{'\mu\nu}$$

Diagonalized gauge boson kinetic terms: em photon $A_\mu (J^\mu_{em} + \varepsilon g J^\mu_{dark})$ (g is U'(1) coupling). Need $\varepsilon \simeq 10^{-3}$, thus the DM acquires a millicharge $\varepsilon g = \varepsilon e$ under the usual e.m. Holdom 1986 , Burrage et al 0909.0649- Several versions too,

- γ mixed with massive dark vector boson that couples to the axial vector current of the DM D. E. Kaplan 0909.0753 1105.2073
- or γ mixed with massless dark vector boson $\gamma^{'}$ of the unbroken U(1) gauge symmetry Cline, Zuowei Liu, and Wei Xue 1201.4858

Dark Atoms may scatter elastically or inelastically depending of the choice of parameters e.g if the $\gamma^{'}$ gauge coupling is $\alpha^{'} = 0.06$ and $m_e = m_p \simeq 3$ GeV, the hyperfine splitting is 15 keV, and $\varepsilon = 10^{-2}$ gives the right cross section for explaining candidate DM events reported by CoGeNT.

Inelastic DM scattering

Tucker-Smith, Weiner 01 and 04; Chang, Kribs, Tucker-Smith, Weiner 08; March-Russel, McCabe, McCullough 08; Cui, Morrisey, Poland, Randall 09, many more. . .

In addition to the DM state χ with mass m_χ there is an excited state χ^* with mass m_{χ^*}

$$m_\chi - m_{\chi^*} = \delta$$

and inelastic scattering $\chi + N \to \chi^* + N$ dominates over elastic. Thus

$$v_{min}^{inel} = \left| \sqrt{\frac{ME_R}{2\mu^2}} + \frac{\delta}{\sqrt{2ME_R}} \right|$$

instead of $v_{min}^{el} = \sqrt{\frac{ME_R}{2\mu^2}}$

Inelastic Endothermic DM (iDM) i.e. Inelastic with $\delta > 0$

This was the initial idea. Favors heavy materials (I in DAMA over Ge in CDMS)

Inelastic Exothermic DM (ieDM) i.e. Inelastic with $\delta < 0$ Graham, Harnik, Rajendran, Saraswat 1004.0937 Favors light materials (Si in CDMS over Xe in LUX and XENON)

Small electromagnetic couplings

Magnetic (MDM) and Electric (EDM) Dipole Moment DM Pospelov & Veldhuis 2000, Sigurdson, Doran, Kurylov, Caldwell Kamionkowsky 2004, 2006, Maso, Mohanty, Rao 2009, Fortin, Tait 2012 many more

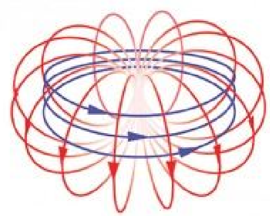
$$L = -(i/2)\bar{\psi}\sigma_{\mu\nu}(d_m + d_e\gamma_5)\psi F^{\mu\nu} \quad \rightarrow \quad H_{MDM} \sim d_m\vec{\sigma}.\vec{B}; \quad H_{EDM} \sim d_e\vec{\sigma}.\vec{E}$$

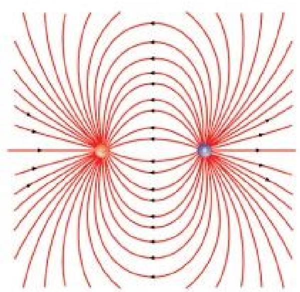
- For MDM, e.g. the cross section is (here $T =$ Target nucleus)

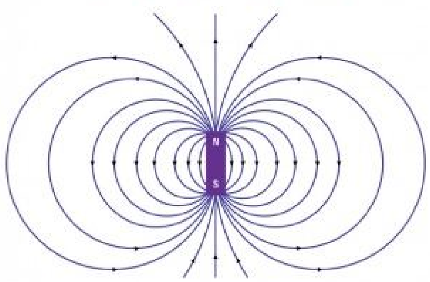
$$\frac{d\sigma_T}{dE_R} = \frac{\alpha d_m^2}{v^2}\left\{ Z_T^2 \frac{m_T}{2\mu_T^2}\left[\frac{v^2}{v_{min}^2} - \left(1 - \frac{\mu_T^2}{m^2}\right)\right] F_{SI,T}^2(E_R) + \frac{d_{mT}^2}{\mu_N^2}\frac{m_T}{m_p^2}\left(\frac{S_T+1}{3S_T}\right) F_{M,T}^2(E_R)\right\}$$

Dipole moments are zero for Majorana fermions (although transition moments are not) and the first non-zero moment is the

Small electromagnetic couplings







Anapole moment DM (ADM) Ho-Scherrer 1211.0503

First proposed by Zel dovich in Sov. Phys. JETP 6, 1184 (1958): particles could have anapole moment that breaks C and P, but preserves CP - first measured experimentally in Cesium-133: C. S. Wood et al, Science 275, 1759 (1997)

$$L = \frac{g}{\Lambda^2}\bar{\psi}\gamma^{\mu}\gamma_5\psi\partial^{\nu}F^{\mu\nu} \quad \rightarrow \quad H_{anapole}\vec{\sigma}\times\vec{B}$$

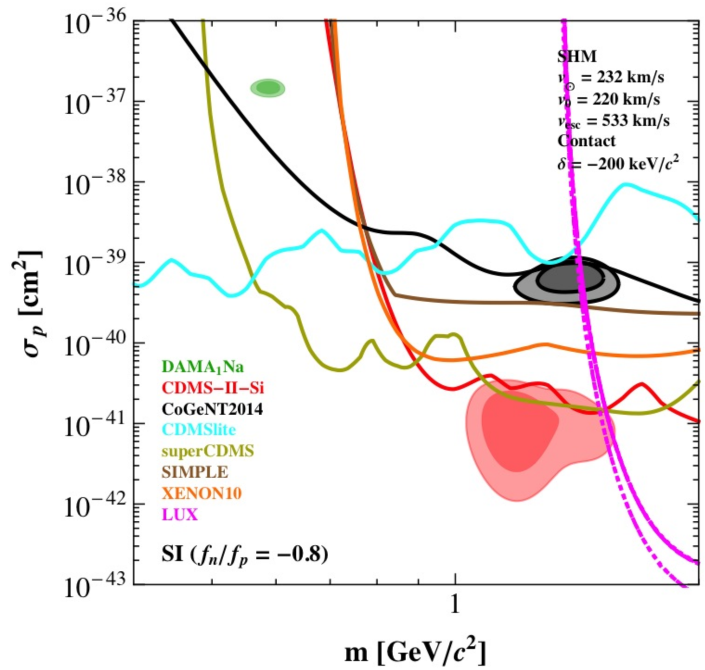
Annihilation is purely p-wave- $\sigma_{scattering} \sim \alpha Z^2 \mu_T v^2$, again two dominant terms in the differential cross sections.

Correct relic abundance and XENON bounds for 10MeV< m <80 GeV for 2.2 GeV< Λ < 340 GeV respect. $(g = 1)$.

Coupling cannot be with the em photon for $m \neq 0$- so use "kinetic mixing"

After considering many models: one can "save CDMS-Si" or "save DAMA" from all other bounds, but not both!

E.g. for CDMS-Si: Inelastic Exothermic SI "Ge-Phobic" DM Gelmini, Georgescu, Huh 1404.7484

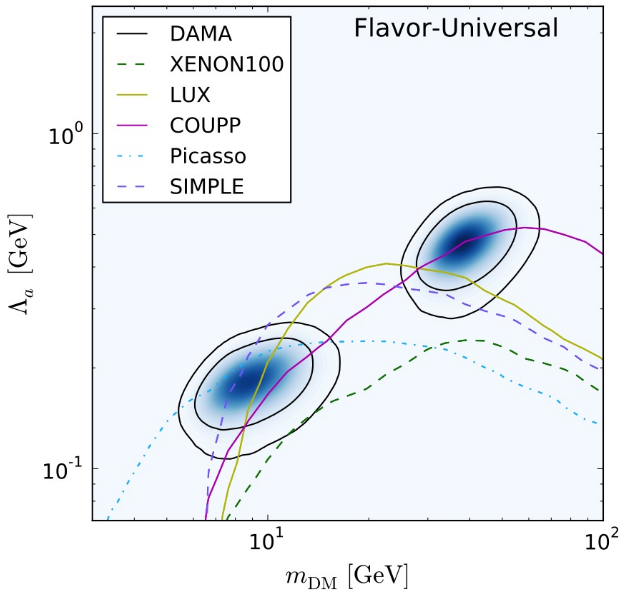


Exothermic $\delta = -200$ keV weakens Xe bounds, $f_n/f_p = -0.8$ weakens Ge bounds: CDMS-Si allowed by all bounds

E.g. for DAMA: spin dependent coupling mostly to p (Arina, Del Nobile, Panci, 1406.5542)

$$L_{eff} = \frac{1}{2\Lambda_a^2} \sum_{N=p,n} g_N \, \bar{\chi}\gamma^5\chi \, \bar{N}\gamma^5 N$$

Figure for $g_p/g_n = -16.4$



maybe plus exothermic scattering- but potential problem with indirect detection via neutrinos from the Sun Del Nobile,Gelmini, Georgescu, Huh in preparation

Halo Independent Data Comparison: Return to the recoil rate, in events/(kg of detector)/(keV of recoil energy)

$$\frac{dR}{dE_R} = \int \frac{N_T}{M_T} \times \frac{d\sigma}{dE_R} \times n v f(\vec{v}, t) d^3 v$$

- For a WIMP-nucleus contact interaction $d\sigma/dE_R = \sigma(E_R)\ M_T/2\mu^2 v^2$

$$\frac{dR}{dE_R} = N_T \frac{\sigma(E_R)\rho}{2m\mu^2} \int_{v>v_{min}} \frac{f(\vec{v}, t)}{v} d^3 v = N_T \frac{\sigma(E_R)}{2m\mu^2}\ \rho\eta(v_{min})$$

- $\frac{N_T}{M_T}$ = Avogadro's number per mol = Number of atoms per gram; $\mu = mM/(m+M)$
- For elastic scattering: $v_{min} = \sqrt{M_T E_R/2\mu^2}$ and E_R is the ion recoil energy .
- For inelastic scattering: $v_{min}^{inel} = \left|\sqrt{\frac{ME_R}{2\mu^2}} + \frac{\delta}{\sqrt{2ME_R}}\right|$

-$\rho = nm$, $f(\vec{v}, t)$: local DM density, $\vec{v}$ distribution, depend on the Dark Halo Model.

$\rho\eta(v_{min})$ **encodes all the halo dependence and is common to all experiments.**

"Halo independent" data comparison: transfer rate measurements and limits onto $\tilde{\eta}(v_{min}) \equiv \rho\eta/m$, in the plane v_{min}, $\tilde{\eta}$ (for fixed m)!

Halo independent analysis Initially developed for SI interactions, and with limitations to take into account the energy dependence of experimental efficiencies and response functions (Fox, Liu, Weiner 1011.1915; Frandsen et al 1111.0292)

Generalized to fully include efficiencies and response functions (Gondolo, GG 1202.6359)

and to ANY TYPE OF INTERACTIONS (Del Nobile, GG, Gondolo, Huh 1306.5273)

We write the expected rate over a detected energy interval $[E_1', E_2']$ for ANY interaction as

$$R_{[E_1',E_2']} = \int_0^\infty dv_{min}\, \mathscr{R}_{[E_1',E_2']}(v_{min})\, \tilde{\eta}(v_{min})$$

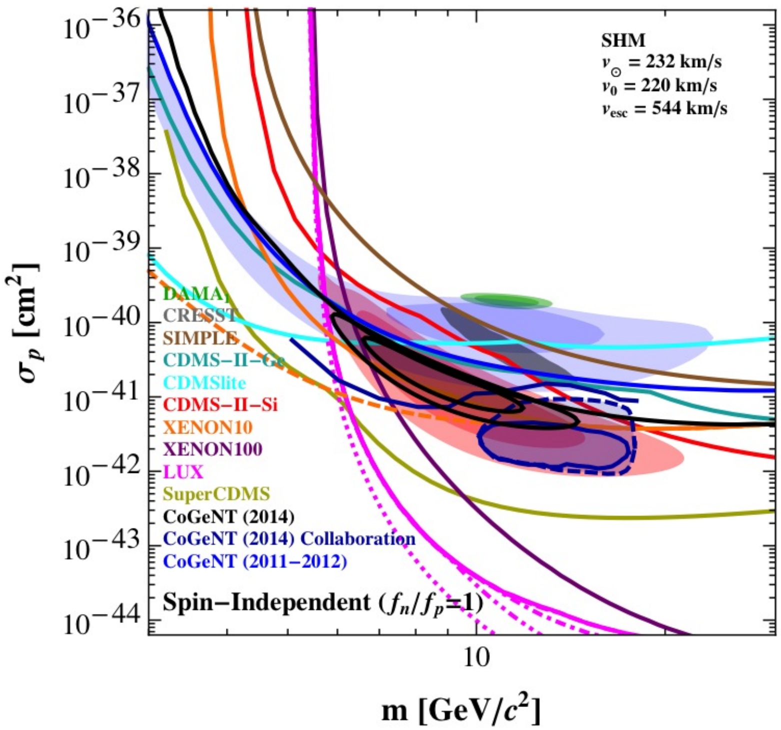
$\mathscr{R}_{[E_1',E_2']}$: experiment AND interaction dependent response function

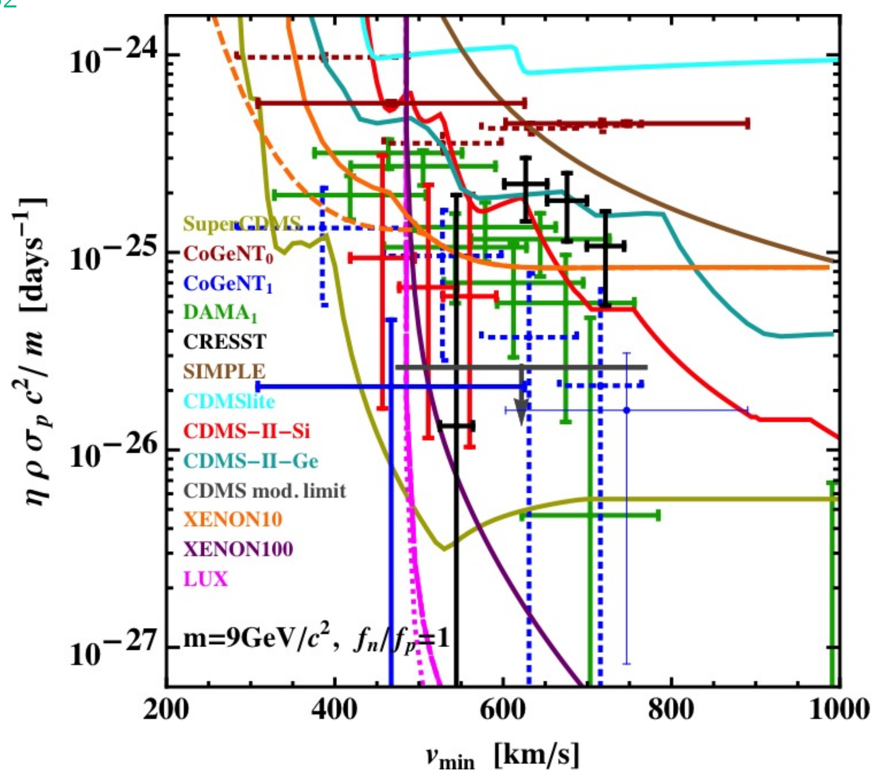
We then map in v_{min} space all rate measurements and bounds on

$$\tilde{\eta}(v_{min}, t) = \frac{\rho\sigma_{ref}}{m} \int_{v_{min}}^\infty dv\, \frac{f(\vec{v}, t)}{v} d^3v \simeq \widetilde{\eta}^0 + \widetilde{\eta}^1 \cos(\omega t - t_0)$$

Halo Dependent vs Independent comparison for SI IC

Del Nobile, Gelmini, Gondolo, Huh 1304.6183, 1311.4247, 1405.5582

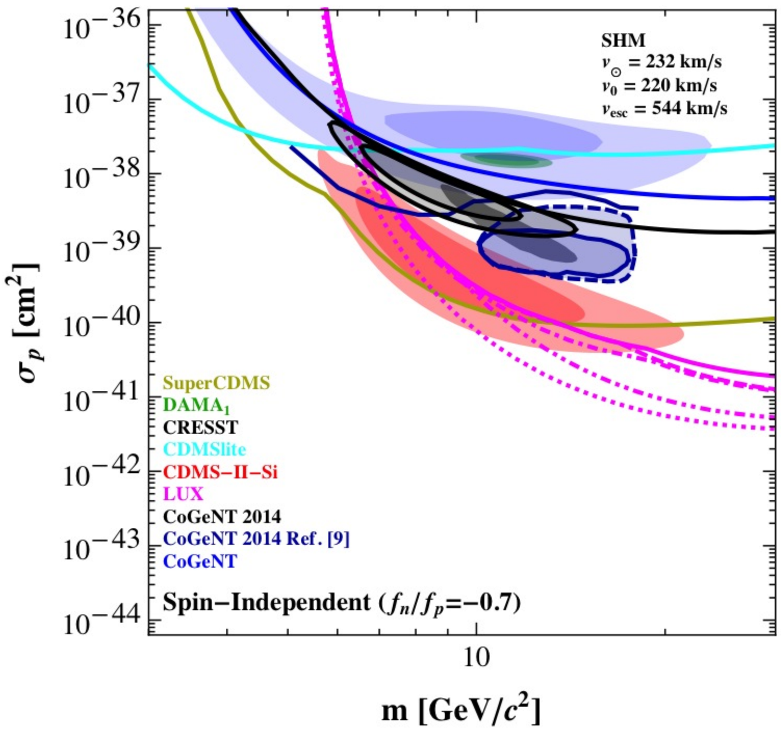


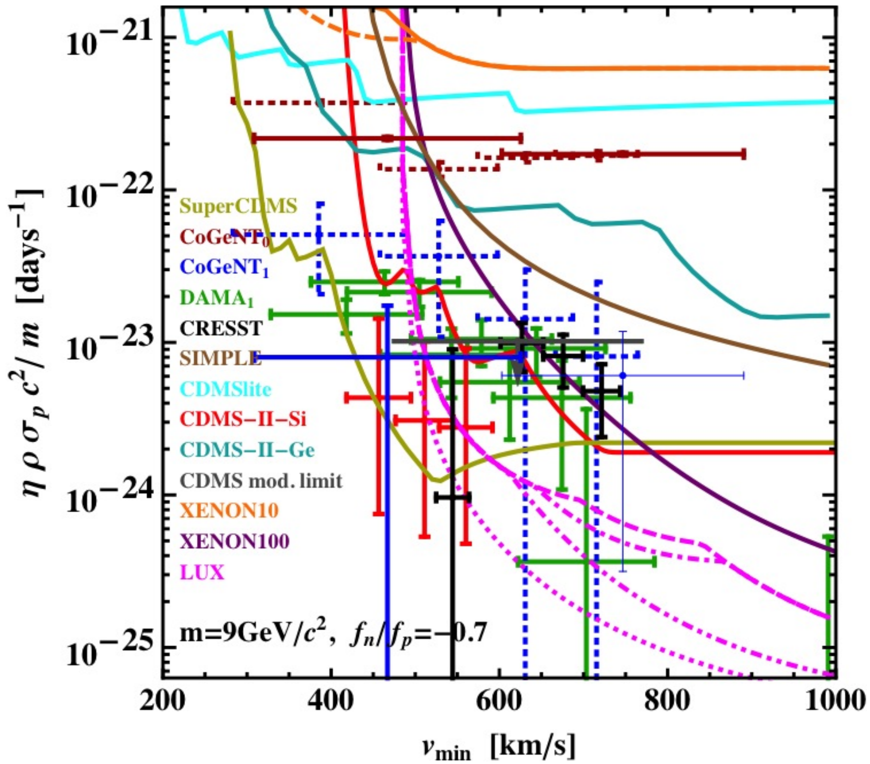


LEFT: CDMS-SI and CoGeNT regions overlap. RIGHT: $m = 9$GeV. CDMS-Si rate is small for CoGeNT/DAMA mod.(but CoGeNT annual mod. amplitude is compatible with zero at $\simeq 1\sigma$, assuming the best fit phase of DAMA)- New SuperCDMS limit rejects regions in both analyses.

Halo Dependent vs Independent comparison for SI IV

Del Nobile, Gelmini, Gondolo, Huh

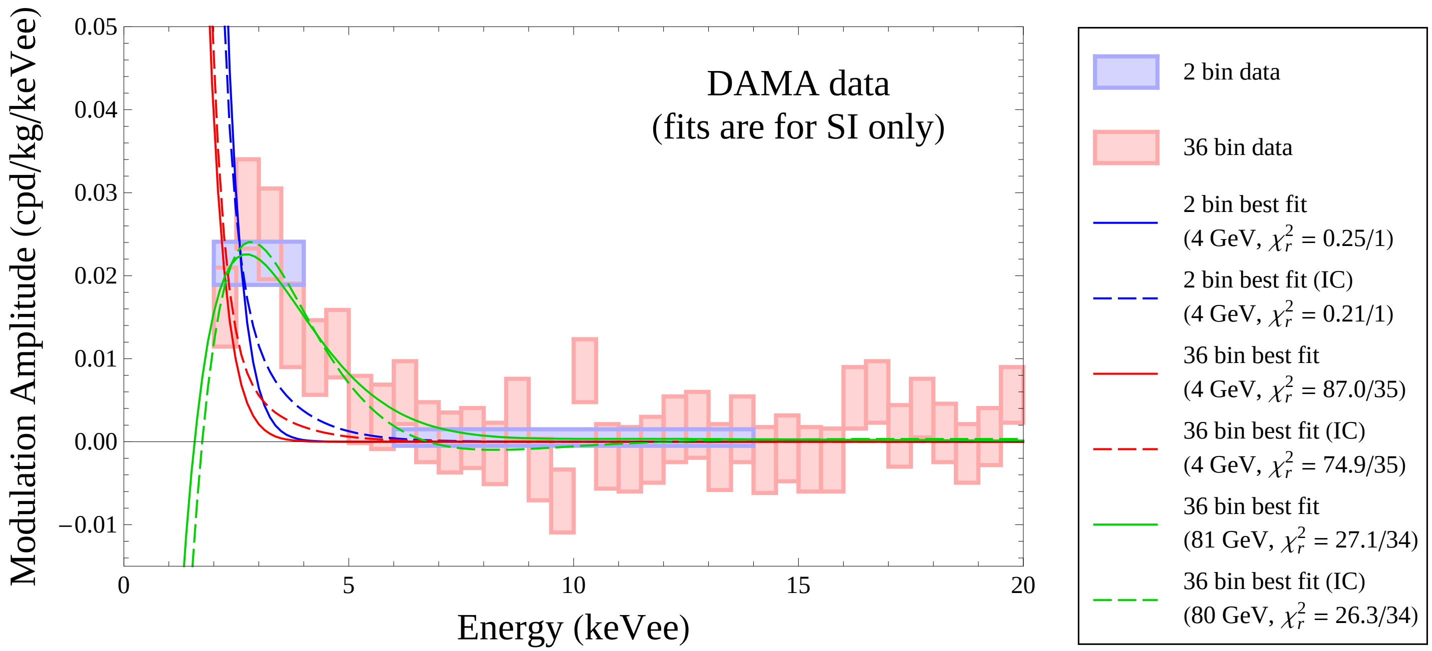




Both: CDMS-Si rate small for CoGeNT/DAMA mod.(but CoGeNT annual mod. amplitude is compatible with zero at $\simeq 1\sigma$, assuming the best fit phase of DAMA)- New SuperCDMS limit very important in this case!

To be continued...in 2015 lower DAMA/LIBRA threshold

(fig. from Savage,Gelmini, Gondolo and Freese 0808.3607)



NOTICE: 1st bin lower than 2nd/3rd implies that HEAVY WIMPs (e.g. m =81GeV)fit data better than LIGHT WIMPs (e.g. m =4GeV) DAMA/LIBRA is now taking 5y of data with lower threshold (1 keVee instead of 2keVee)!