

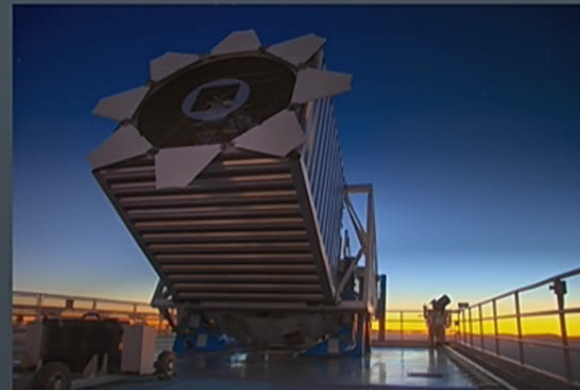
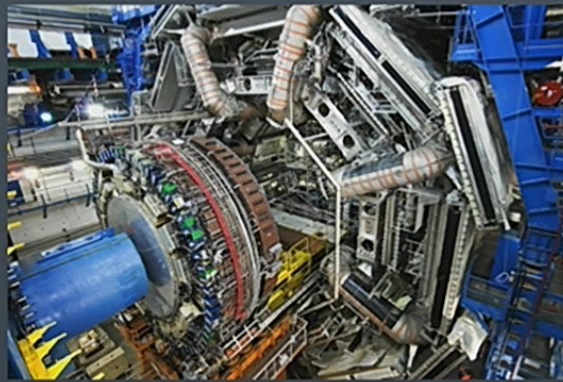
Title: Searching for the Dark Universe

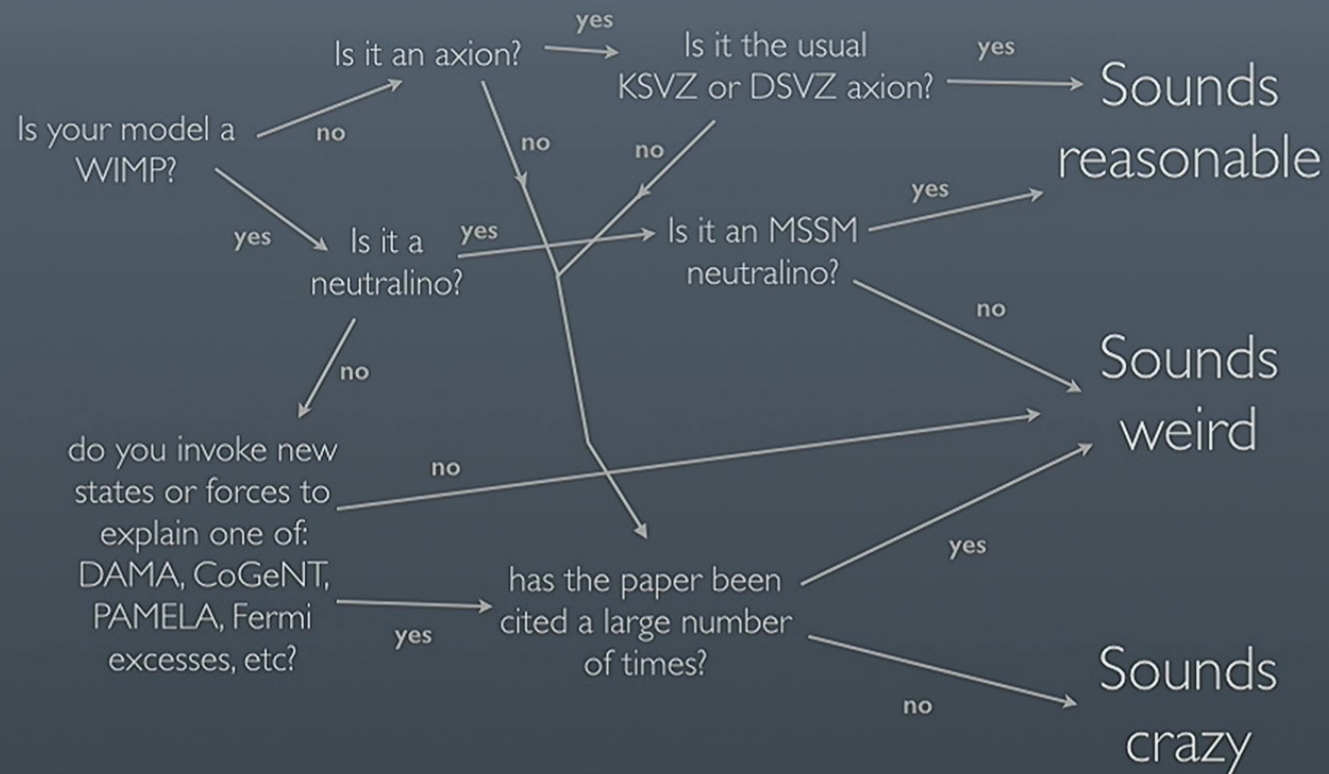
Date: Jun 23, 2015 11:10 AM

URL: <http://pirsa.org/15060041>

Abstract: For nearly a century, we have known that the majority of matter in the universe is not luminous. In the past few decades we have come to be certain that this matter is not only not luminous but not made out of any of the particle ever observed in a laboratory. I will describe the ongoing hunt for this matter and the prospects for the discovery in the next decade. I will further discuss recent claims the dark matter may have been discovered in various signals, and prospects for resolving these claims in the next few years. Finally I will touch on the idea of "dark forces," the idea of an expansive dark sector that is much greater than a single dark particle.

THIS IS THE ERA OF LAMPPOSTS





A STRONG CP PROBLEM

$$\Theta G_{\mu\nu} \tilde{G}^{\mu\nu} \rightarrow \frac{a}{f_a} G_{\mu\nu} \tilde{G}^{\mu\nu}$$

idea \rightarrow make Θ a field

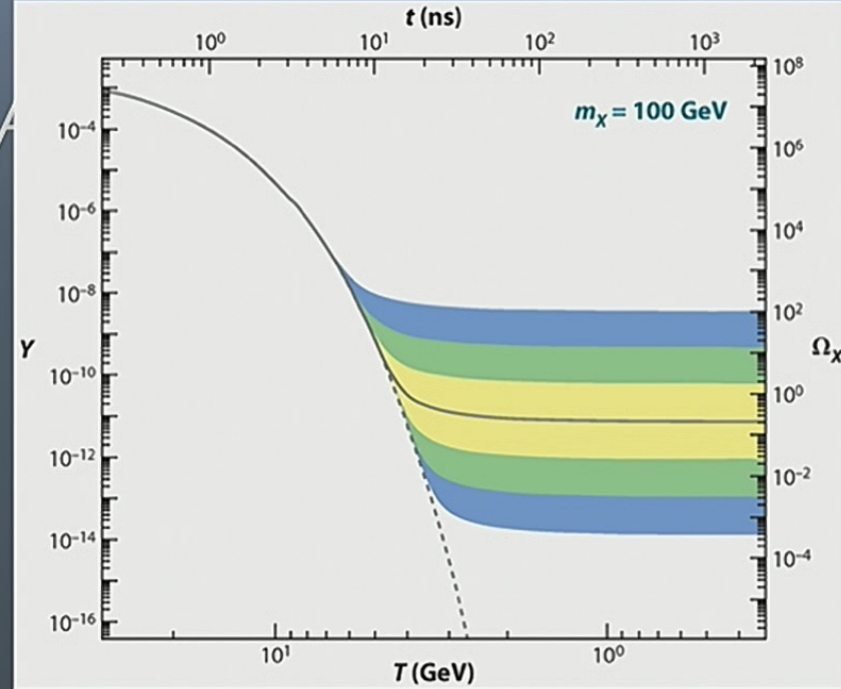
QCD effects generate potential that relaxes Θ (a) to 0

The axion acquires a mass $m_a \approx \frac{m_\pi f_\pi}{f_a} \approx 0.6 \text{ meV} \left(\frac{10^{10} \text{ GeV}}{f_a} \right)$

COUPLINGS TO OTHER MATTER

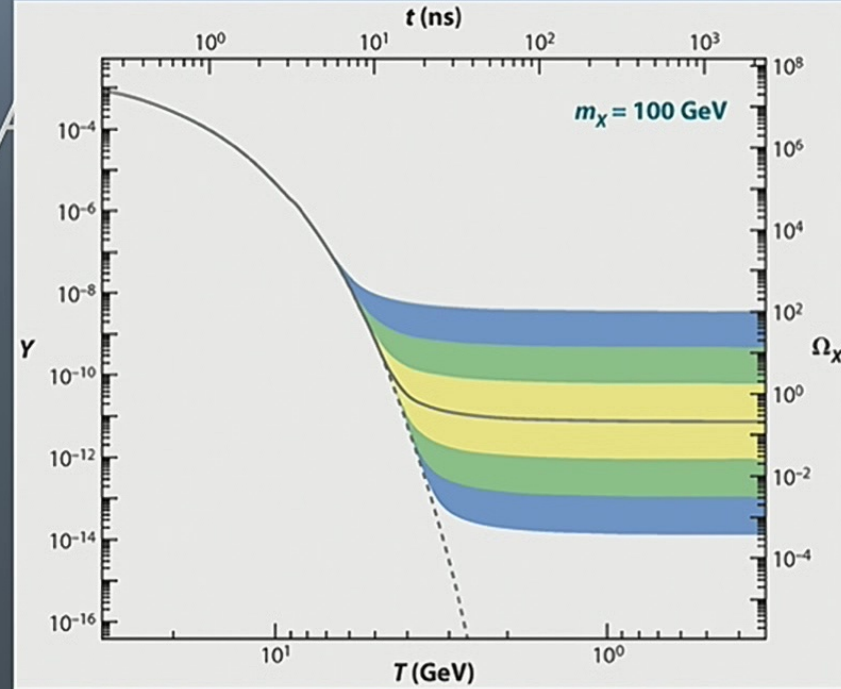
$$\frac{a}{f_a} G_{\mu\nu} \tilde{G}^{\mu\nu} \longrightarrow \frac{a}{f_a} F_{\mu\nu} \tilde{F}^{\mu\nu}$$





For a thermal relic, you learn precisely one number, namely the annihilation cross section

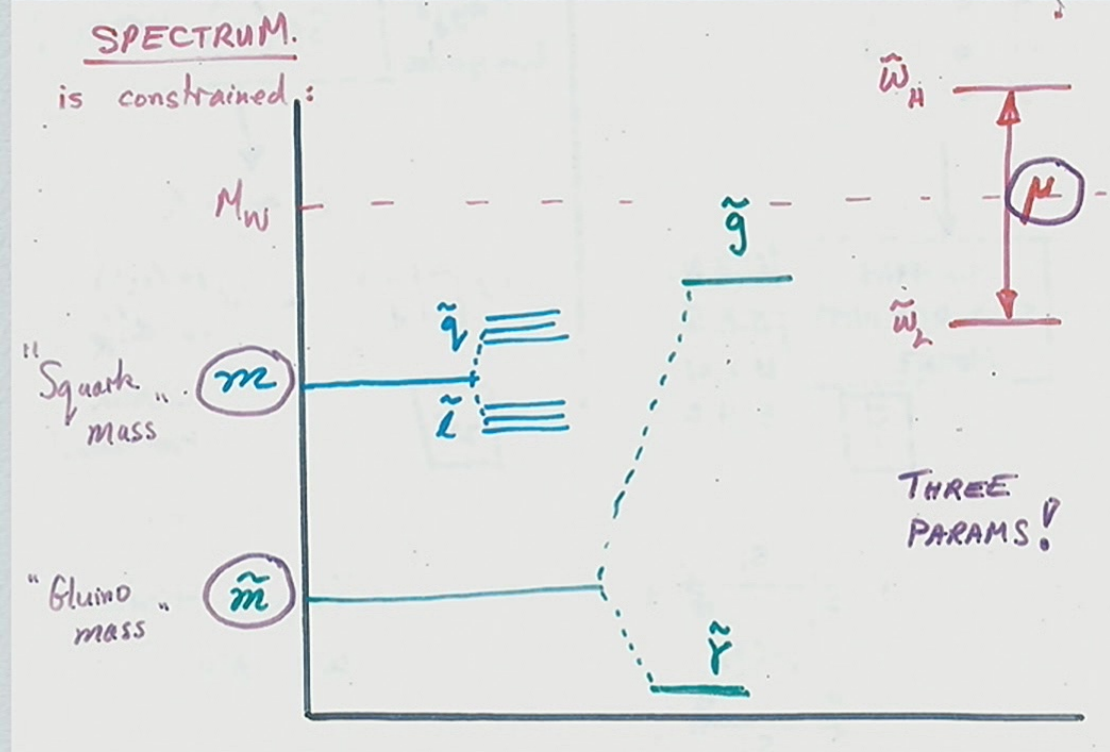
$$\begin{aligned} \langle \sigma v \rangle_{ann} &\approx 3 \times 10^{-26} \text{ cm}^3 \text{ sec}^{-1} \\ &\approx \frac{\alpha^2}{(200 \text{ GeV})^2} \end{aligned}$$



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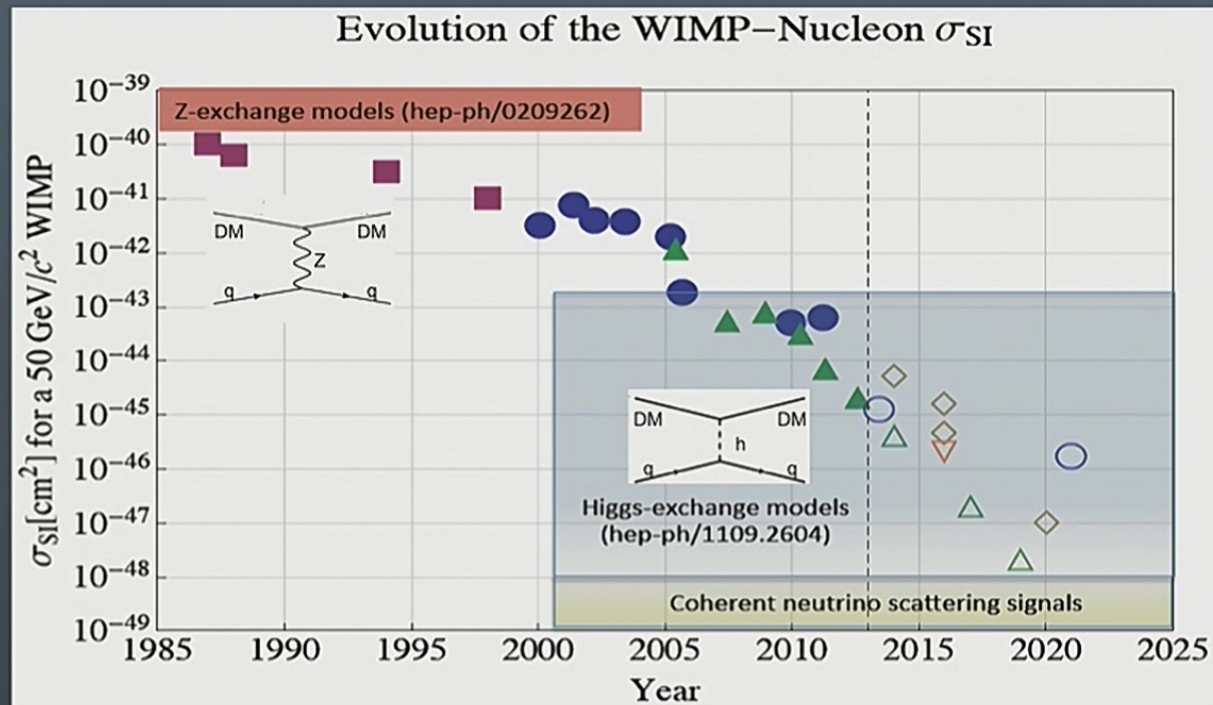
SUSY Spectrum, 1984



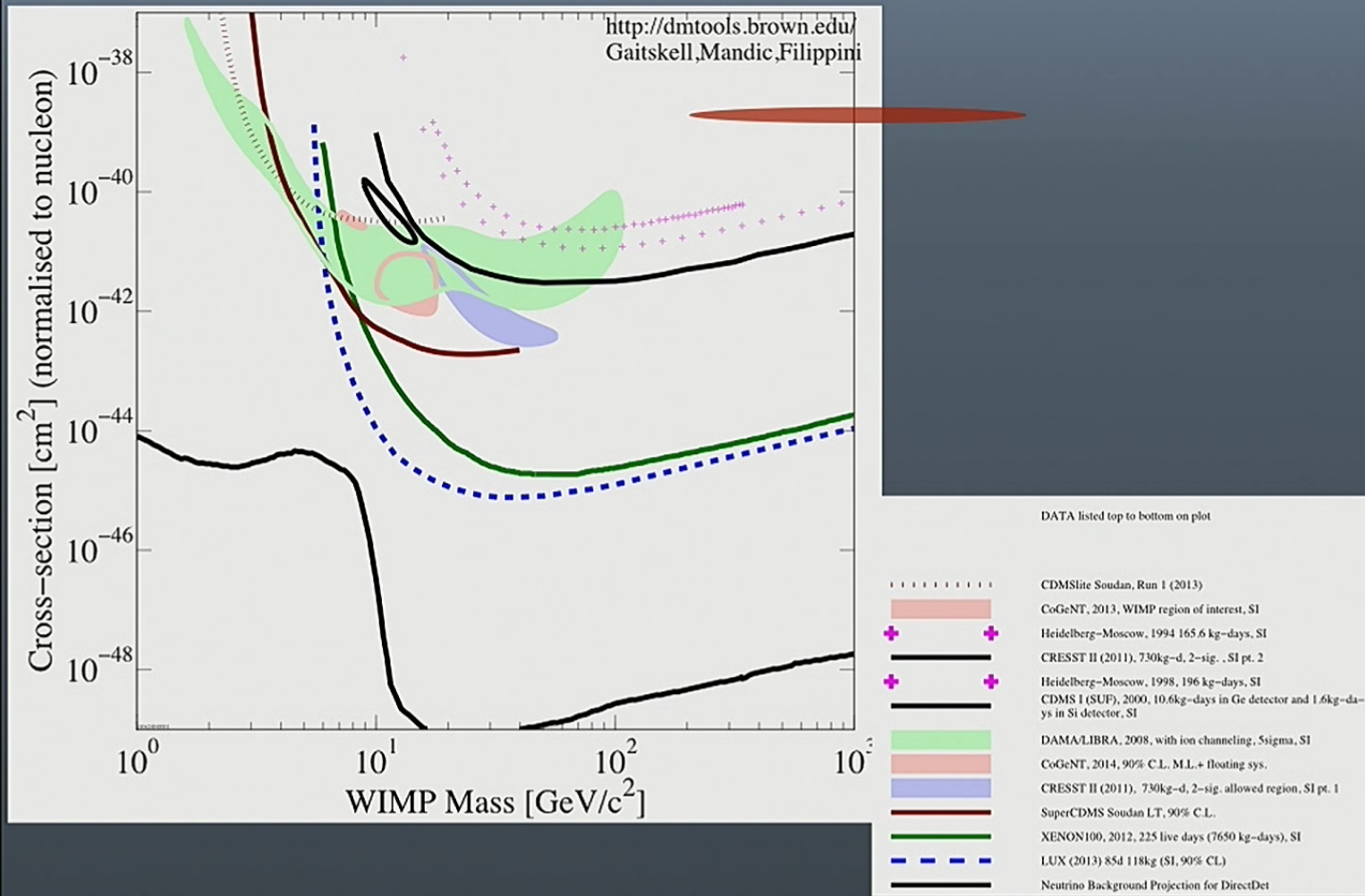
Lawrence Hall, Savasfest 2012
(cf Matt Reece talk LHCP2013)

- IMHO good to think generally about DM models because conventional wisdom on the weak scale has not proven itself reliable
- So, even if it is a WIMP, it needn't look or act as we anticipated
- Light WIMPs, very heavy WIMPs, hidden sector DM...

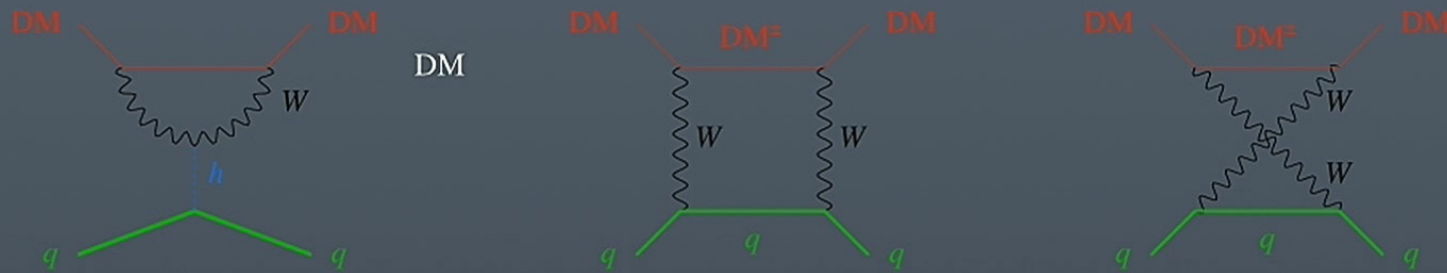
SO WHAT ABOUT THE SEARCH FOR WIMPS?



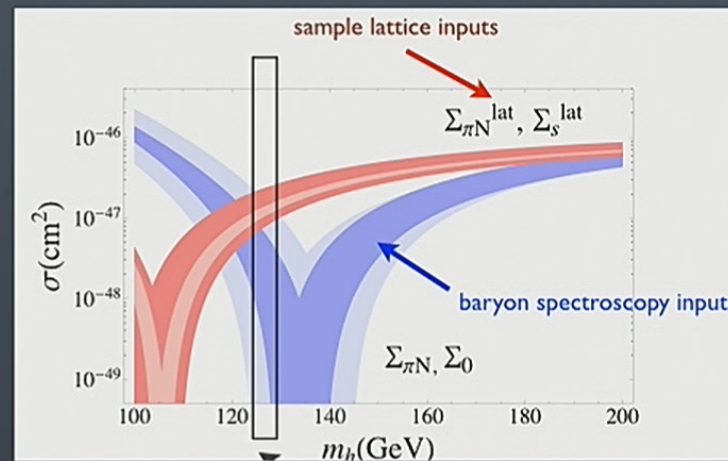
slide from J Feng

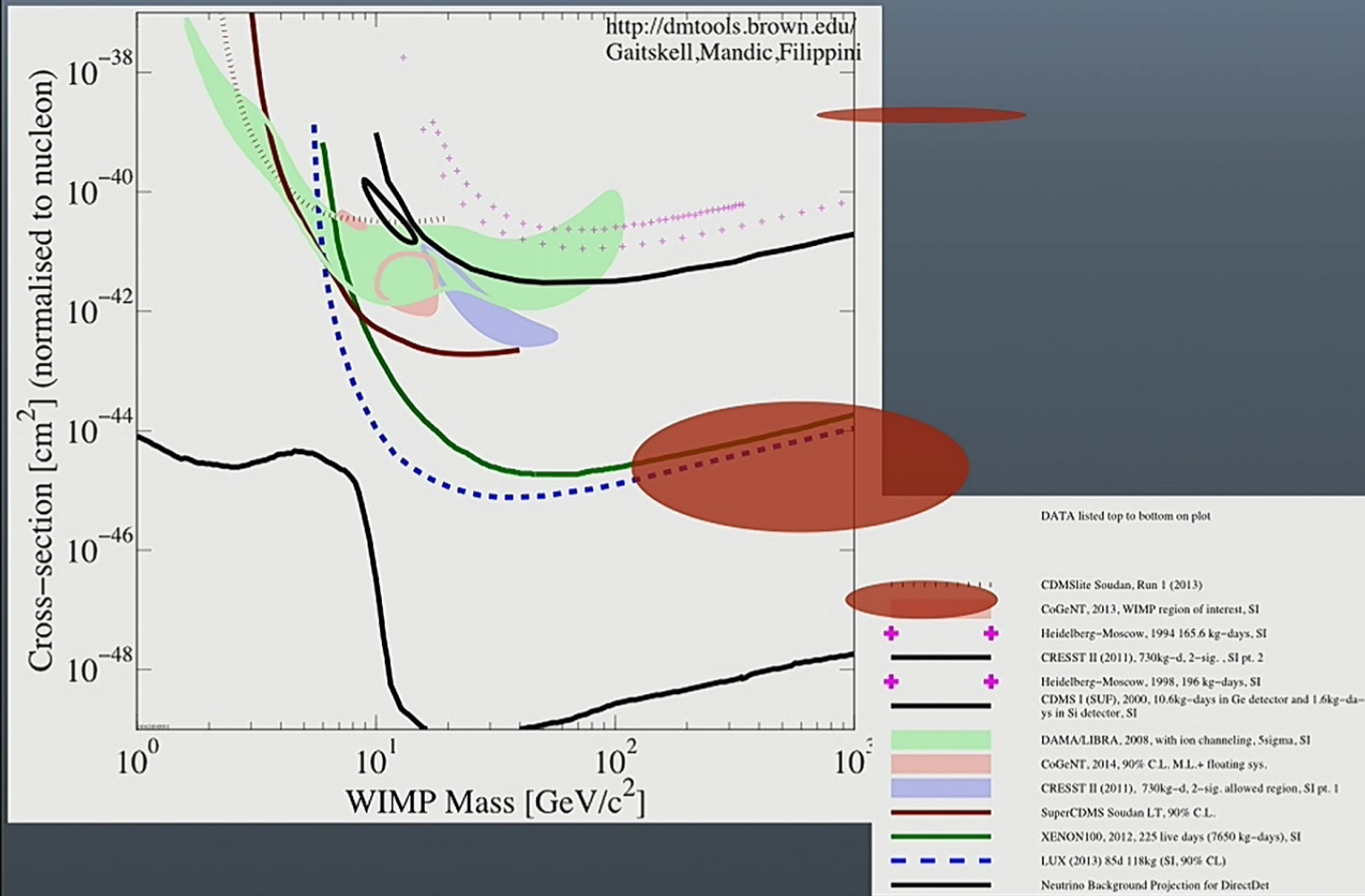


MAJORANA TRIPLET: LOOP MEDIATED



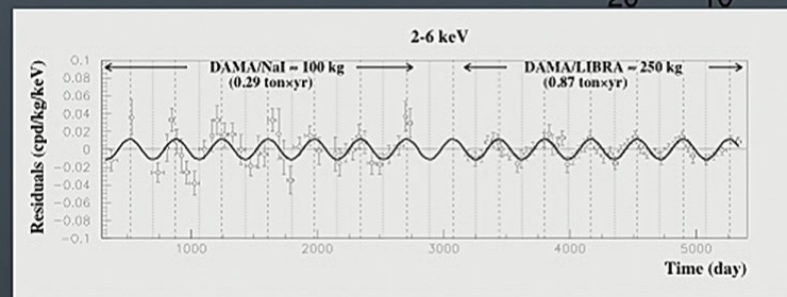
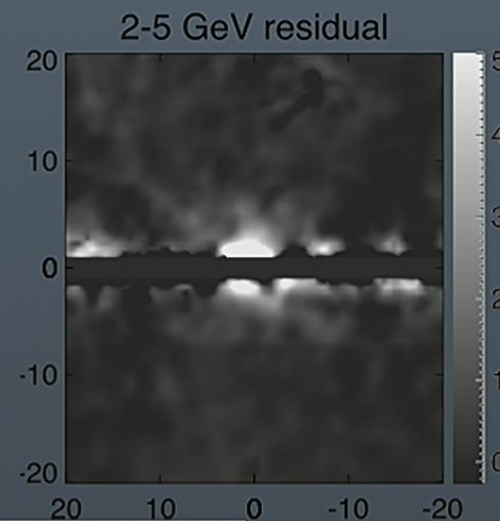
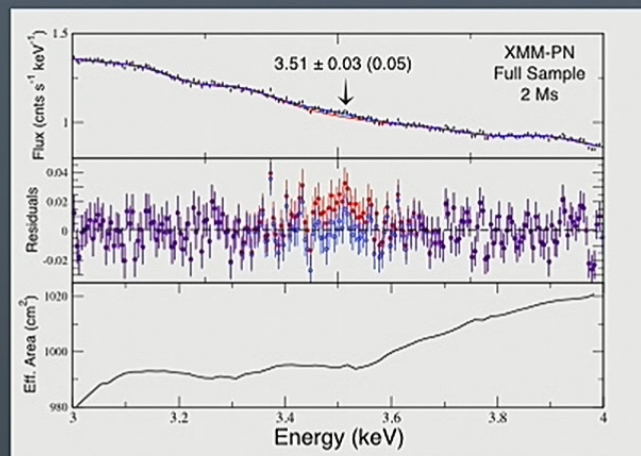
Hill + Solon '13;
Hill + Solon '14





- This era will answer the question: does the dark matter couple at $O(0.1-0.01)$ to the Higgs boson
- But perfectly plausible WIMPs can have very weak nucleon interactions

HAVE WE FOUND DARK MATTER ALREADY?



A LINE AT 3.55(ish) KeV

DETECTION OF AN UNIDENTIFIED EMISSION LINE IN THE STACKED X-RAY SPECTRUM OF GALAXY CLUSTERS

ESRA BULBUL^{1,2}, MAXIM MARKEVITCH², ADAM FOSTER¹, RANDALL K. SMITH¹, MICHAEL LOEWENSTEIN², AND SCOTT W. RANDALL¹

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Submitted to ApJ, 2014 February 10

An unidentified line in X-ray spectra of the Andromeda galaxy and Perseus galaxy cluster

A. Boyarsky¹, O. Ruchayskiy², D. Iakubovskiy^{3,4} and J. Franse^{1,5}

¹Instituut-Lorentz for Theoretical Physics, Universiteit Leiden, Niels Bohrweg 2, Leiden, The Netherlands

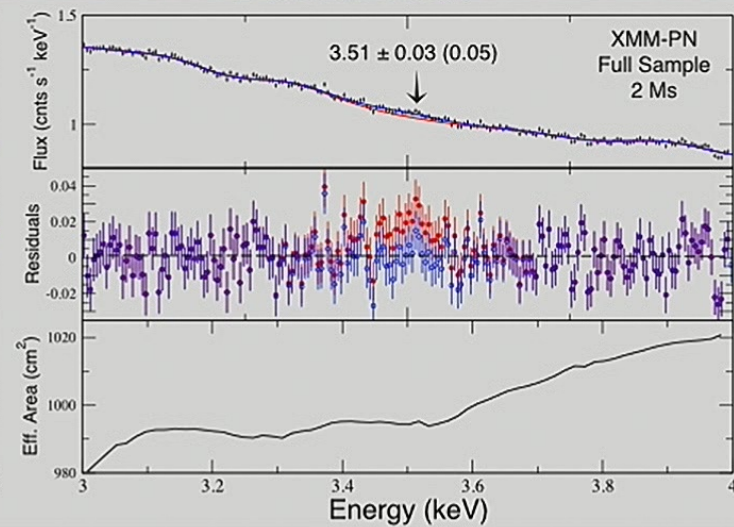
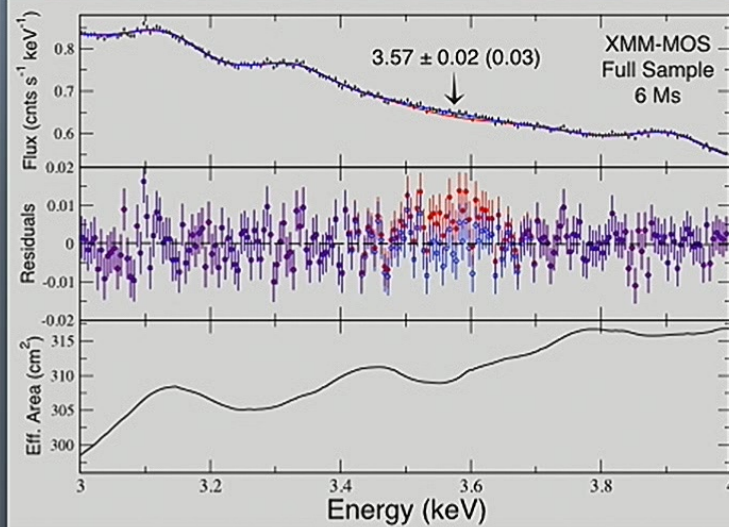
²Ecole Polytechnique Fédérale de Lausanne, FSB/ITP/LPPC, BSP, CH-1015, Lausanne, Switzerland

³Bogolyubov Institute of Theoretical Physics, Metrologichna Str. 14-b, 03680, Kyiv, Ukraine

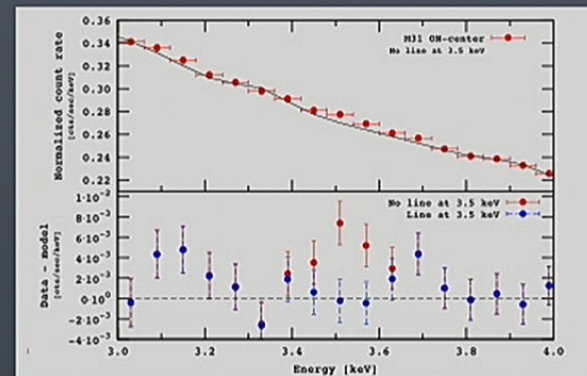
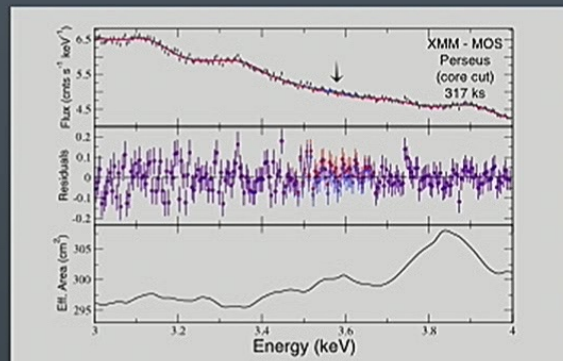
⁴National University "Kyiv-Mohyla Academy", Skovorody Str. 2, 04070, Kyiv, Ukraine

⁵Leiden Observatory, Leiden University, Niels Bohrweg 2, Leiden, The Netherlands

Bulbul et al



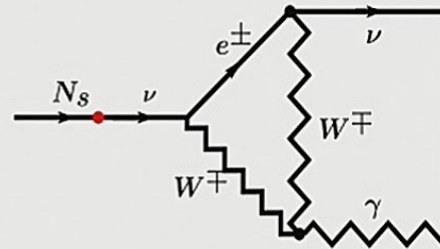
Boyarsky et al



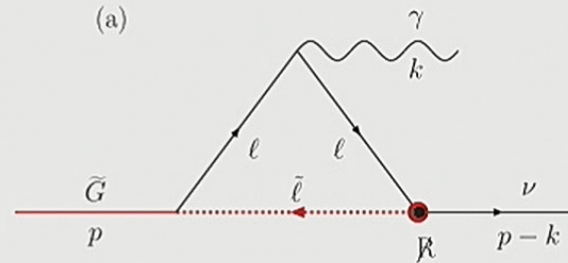
Passes the Toro test

DECAYING DARK MATTER

- Sterile neutrino $N \rightarrow \nu + \gamma$



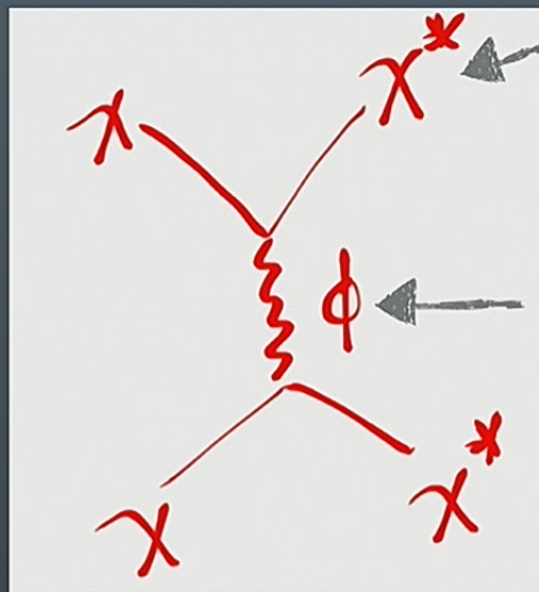
- R-parity violating gravitino
 $\tilde{g} \rightarrow \nu + \gamma$



- Also R-parity violating axino, ...
- For bosonic DM axions (or axion-like particles) would decay $a \rightarrow \gamma\gamma$

from talk by Ruchayskiy, April 2014

A NEW FORCE



Dark matter

Dark force carrier

maybe look for this?

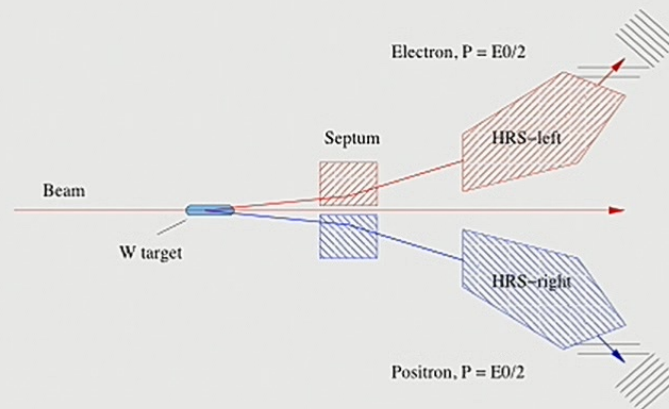
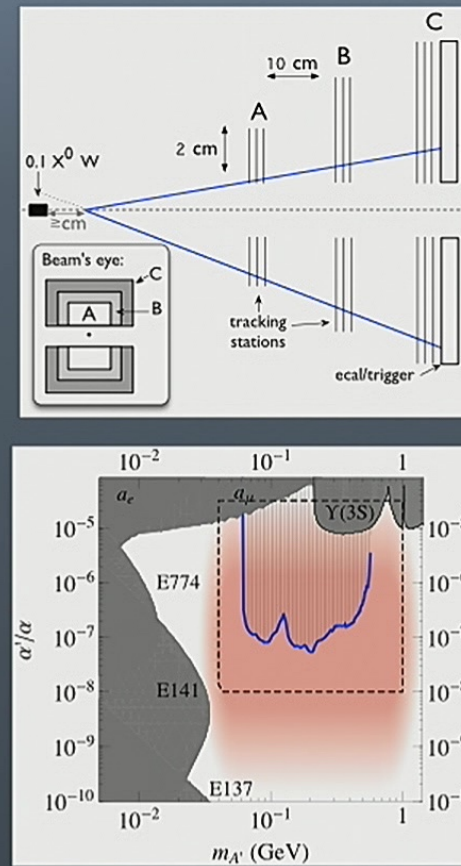


FIG. 5: The layout of the experimental setup — see text for details.

Bjorken, Essig, Schuster, Toro



APEX, HPS, Darklight... - searches for new physics at the $\leq \text{GeV}$ scale


Figure 1 is a log-log plot showing the electron-to-proton mass ratio ϵ (y-axis) versus the magnetic field strength mA'/GeV (x-axis). The x-axis ranges from 0.01 to 0.1, and the y-axis ranges from 10^{-5} to 10^{-1} . The plot is divided into several regions: a central white region, a grey region with a cross-hatch pattern, a dark grey region, and an orange region. A dashed line with an arrow points to a region labeled 'C' within the white area. Two sets of closed loops are shown: a red dotted one and a purple solid one, both centered around the 'C' region.

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THIS IS A STORY OF LAMP POSTS



THE SEARCH FOR DARK MATTER

- 
- Finding dark matter is hard because it's dark and we don't know what it is
 - In this era, we will learn important qualitative results about dark matter, whether or not it is found
 - We have many well motivated lamp posts being pursued, and there are tremendous prospects in the coming decade
 - But it may be that the lamp post that best illuminates dark matter is still unconsidered