Max Alexander: Photographer

DARK MATTER

How close are we to a direct detection?













Motivation

Early evidence for Dark Matter 1: Look at Galaxy clusters 2. Observe motion

3: Apply laws of physics that we know

4: Deduce that there is more mass than visible







Comparison of the rotation curves calculated by all the methods discusted (assuming $R_0 = 7.0$ kpc and $\Theta_0 = 200$ km s⁻¹).





Take a slice and compare with observation....



Courtesy C Frenk

Conclusions of all this...

The Constituents of the Universe



SUSY

- Gauge hierarchy
- Unification of coupling constants
- Connection to string theory



In most models the Lightest Supersymmetric Particle (which is usually the lightest neutralino, a mixture of the SUSY partners of the photon, the Z and the Higgs) is stable (R parity is conserved) and is a good CDM candidate.

The WIMP Miracle

Weak Annihilations result in exactly the right WDM

- WIMPs produced in Big Bang through e.g. e⁺+e⁻ → χ x̄
- While T > 2mχ number density comparable to e⁻, γ...
- Number decreases due to $\chi \overline{\chi}$ annihilations
- Cease annihilating when mean time between annihilations > t_{universe}
- Weak cross sections match suspiciously well to present number density





The Challenge

WIMP-like DM hypothesis...

 Earth should be passing through a halo of weakly interacting massive particles



We search for the rare collisions of WIMPs with normal matter here on Earth.

Basic method

Make a device that should see *nothing* from normal physics

And see if there's anything still there...

Experimental Method...

<u>WIMP detection techniques and DM</u> <u>experiments around the world</u>



DAMA LIBRA XMASS CLEAN ANAIS KIMS

<u>WIMP scattering rates prediction for</u> <u>three targets: Ge, LXe and LAr</u>

For 50 GeV/c² (near the peak of direct-search sensitivity)

For 500 GeV/ c^2 (in the centre of the favoured MSSM param. space)

Integral spectra for 500 GeV/c² WIMP with σ_{si} =1E-9 pb



1.E+02 canonical isothermal halo Maxwellian velocity distribution vy=220 km/s, vg=240 km/s, vm=600 km/s, local DM density pur0.3 GeV/c²/cm² 20 12 events above threshold 1.E+01 3.2 1.E+00 xenon (1 tonne) argon (5 tonnes) germanium (0.1 tonne) 1.E-01 20 0 40 60 80 100 threshold recoil energy, keV

1-tonne xenon target proves to be the most attractive !

Discrimination principles



We can tell neutrons (WIMPs) from gamma and beta backgrounds

A typical experiment...

Go to a very dark place



Now, let's take a trip underground

ZEPLIN III at the Boulby mine

Neutron shield - 30 cm of hydrocarbon



Design



Two-phase Noble liquid method



Discrimination plots

By plotting S2/S1 vs S1 we can separate neutron (WIMP-like) from gamma/beta events

S2/S1

Gamma-rays

Elastic neutrons



Detector calibration



Combined data from runs with ¹³⁷Cs (red) and AmBe (blue) sources. Separation of NR and ER bands is very clear. 40 keV line from neutron inelastic scattering is clearly visible on the ER band.

Discrimination Power



Slicing with 1 keV bin and fitting with skew-normal function:





Take data for a few months, and analyse...



Recent results





"Consistent with zero at 90% CL"

CDMS vs DAMA & iDM



FIG. 5: The shaded green region represents WIMP masses and mass splittings for which there exists a cross section compatible with the DAMA/LIBRA [24] modulation spectrum at 90% C. L. under the inelastic dark matter interpretation [23]. Excluded regions for CDMS II (solid-black hatched) and XENON10 [27] (red-dashed hatched) were calculated in this work using the Optimum Interval Method. (Color online.)

Future

ZEPLIN III Upgrade PMTs

Installation of ultra Low-Background PMTs (reduction in radioactivity 30 times)



Ready to start the Second Science Run



ZEPLIN III Veto

Gd-loaded slabs around ZIII detector

Veto barrel section full assembly



ZEPLIN III Second Science Run Projected limit after 1 year



Back to the Question...

"How close are we to a direct detection?"

• Exciting 'hint' from final run of CDMS-II

 Exciting 'hints' from excesses of e⁻ and e⁺ in satellite data (but excesses so far reasonably explained as pulsars)

> Prospects of SUSY from LHC (but 2 years until >7 TeV [CERN Bulletin])

> > ZEPLIN-III SSR has significant science reach

• XENON100 has significant science reach • XMASS has significant science reach

Answer: ...Perhaps very close!

But... STFC shambles

- ZEPLIN-III, 6 months funding (till July 31).
- PPAN: "In the current financial circumstances, PPAN recommended that provision for funding be made for a UK role in a single dark matter project. PPAN would await the outcome of the PPRP review of Lux-Zeplin and Eureca before making a decision on which project that should be." [deliberations document of 4/12/2010, STFC]
- LUX-ZEPLIN and EURECA PPRP submissions stopped...

Some negotiations still ongoing...

"How close are we to a direct

detection?"

Close! But 'we' might not be part of it...

(despite world-leading results, high international rating, established programme, significant past investment, British leadership, major successful outreach programme, etc, etc...