The case for WIMP directional detection

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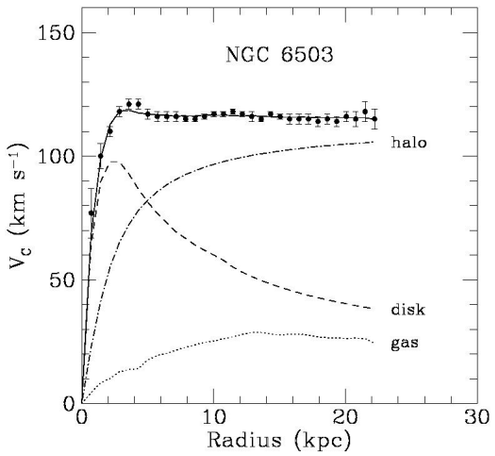
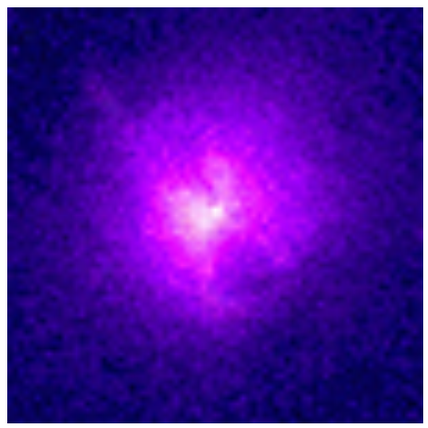
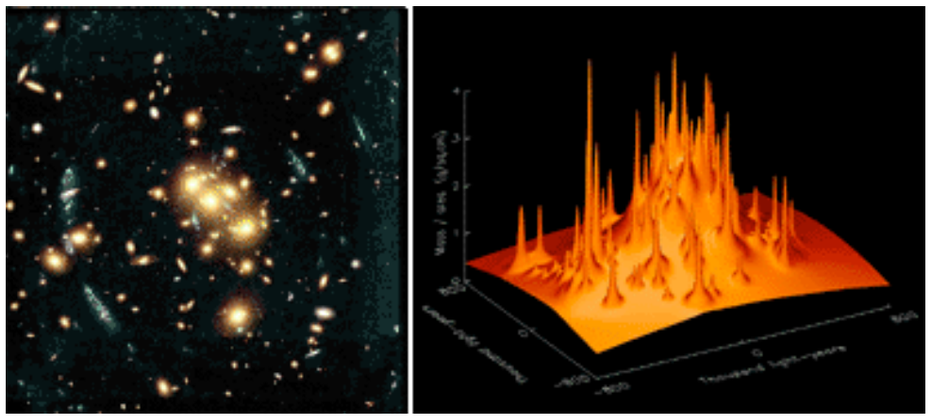
(attempting to channel J. D. Vergados, University of Ioannina, Greece....)

Observational evidence for dark matter



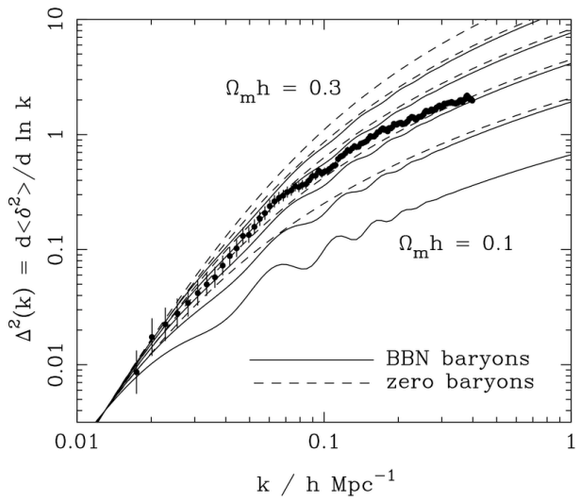


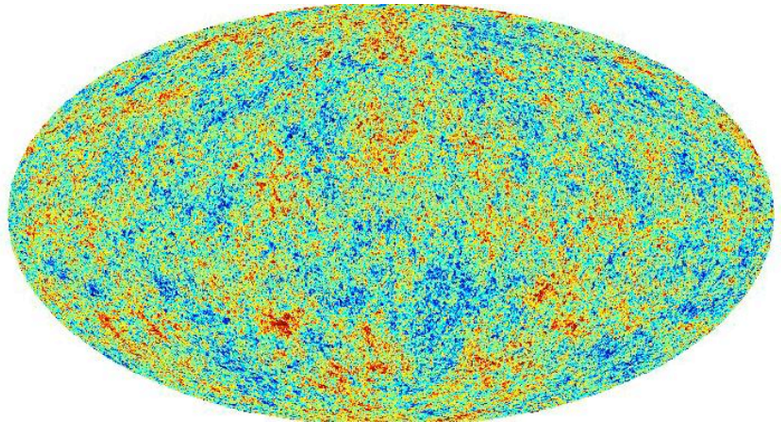


Lots of evidence for (non-baryonic cold) dark matter from diverse astronomical and cosmological observations

[galaxy rotation curves, galaxy clusters (galaxy velocities, X-ray gas, lensing), galaxy red-shift surveys, Cosmic Microwave Background]

assuming Newtonian gravity/GR is correct.

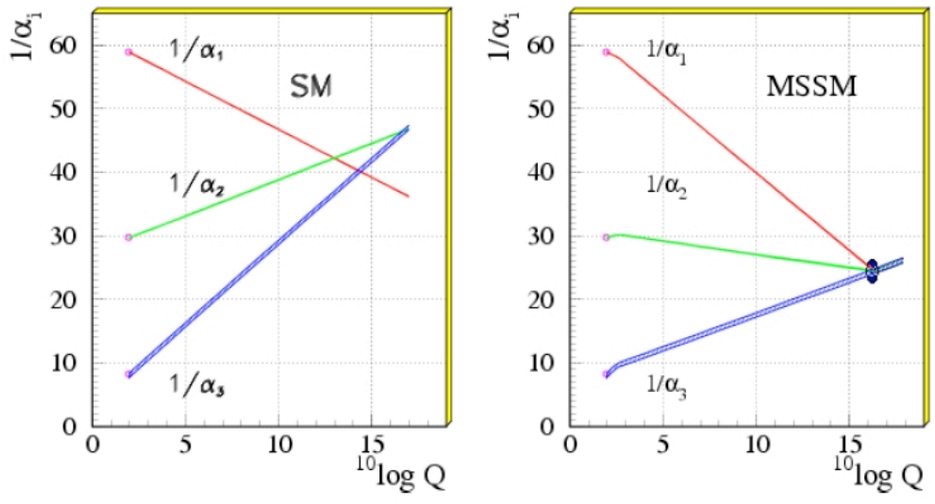




WIMPs

Generic motivation: Any Weakly Interacting Massive Particle in thermal equilibrium in the early Universe will have an interesting density today.

And Supersymmetry (motivated by gauge hierarchy problem,unification of coupling constants, string theory) provides us with a concrete, well motivated WIMP candidate in the form of the lightest neutralino (a mixture of the susy partners of the photon, the Z and the Higgs).



Other extensions of the standard model provide other plausible WIMP candidates (e.g. Universal Extra Dimensions and the Lightest Kaluza-Klein particle).

WIMP detection

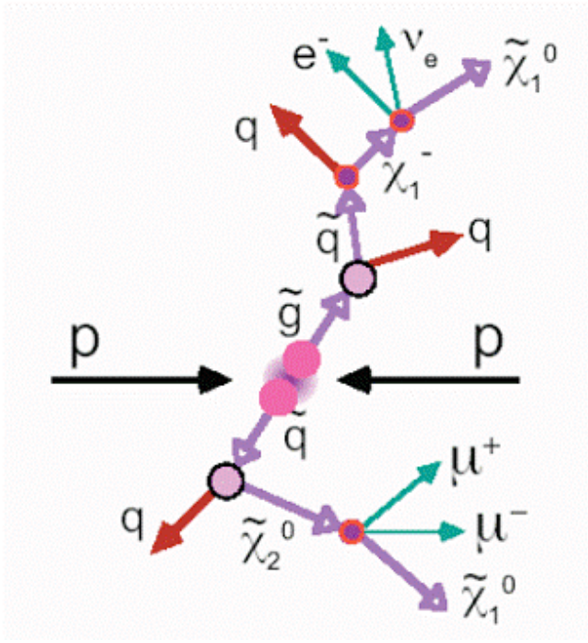
Particle Colliders (LHC)

In theory ‘generic’ signal: missing transverse energy.

In practice not quite that simple.....

In SUSY models characteristic event:

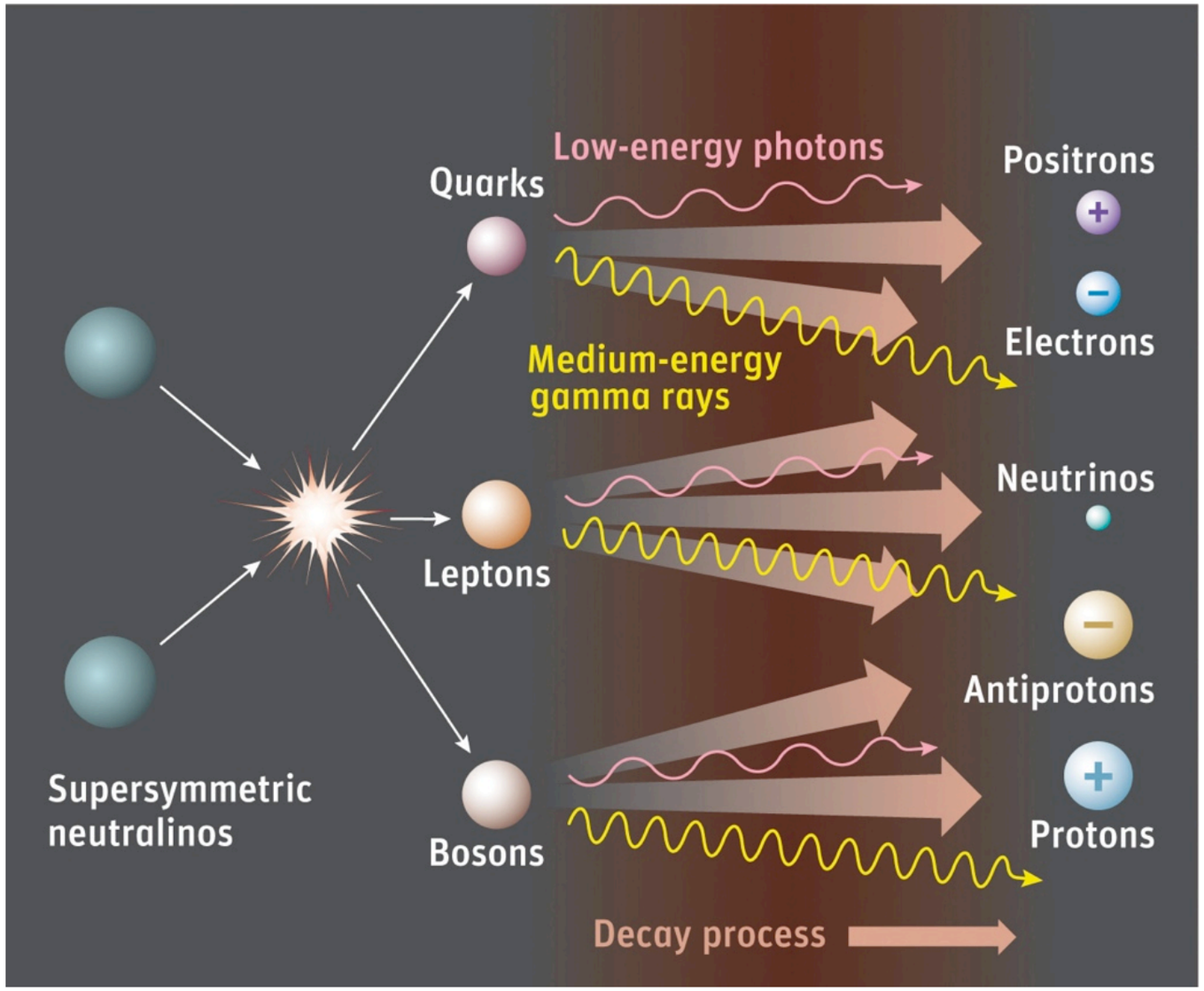
decay of gluinos and squarks into energetic quarks and leptons and invisible WIMPs

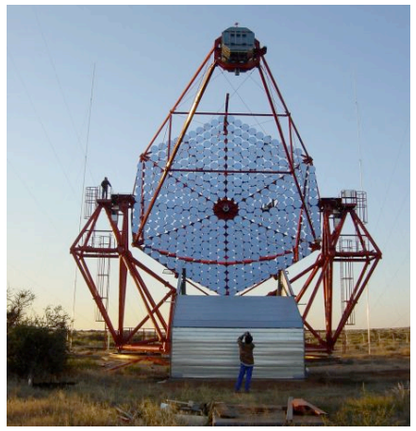


Collider production and detection of a WIMP-like particle would be very exciting, but wouldn’t demonstrate that the particles produced have lifetime greater than the age of the Universe and are the dark matter.

Indirect detection

Via products of annihilations, gamma-rays, positrons and anti-protons





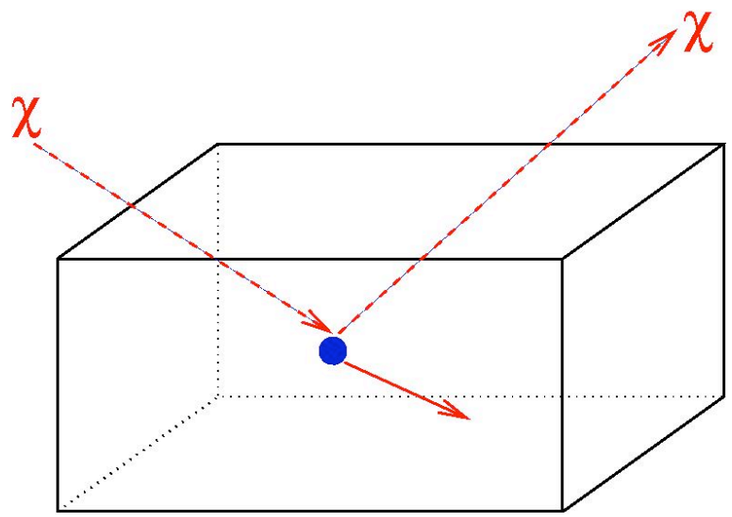
Event rates depend on WIMP distribution $\propto \rho^2$. Enhancement of rate w.r.t that produced by smooth halo, parameterised by boost factor.

Often need to distinguish WIMP annihilation from astrophysical backgrounds.

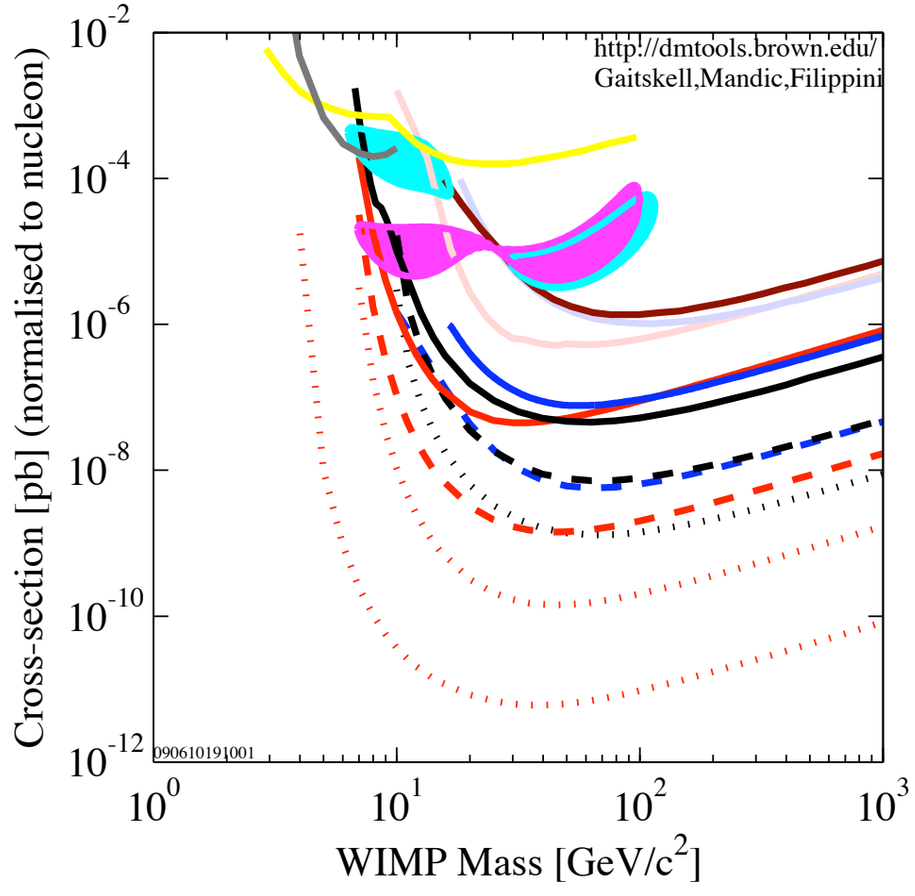
Direct detection

of WIMPs in the Milky Way halo via elastic scattering on detector nuclei in the lab.

$$\chi + N \rightarrow \chi + N$$



Current status:
(spin-independent cross-section)



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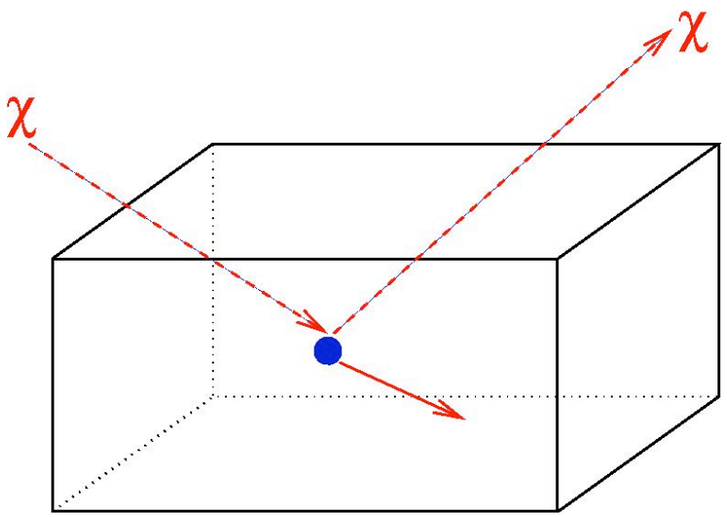

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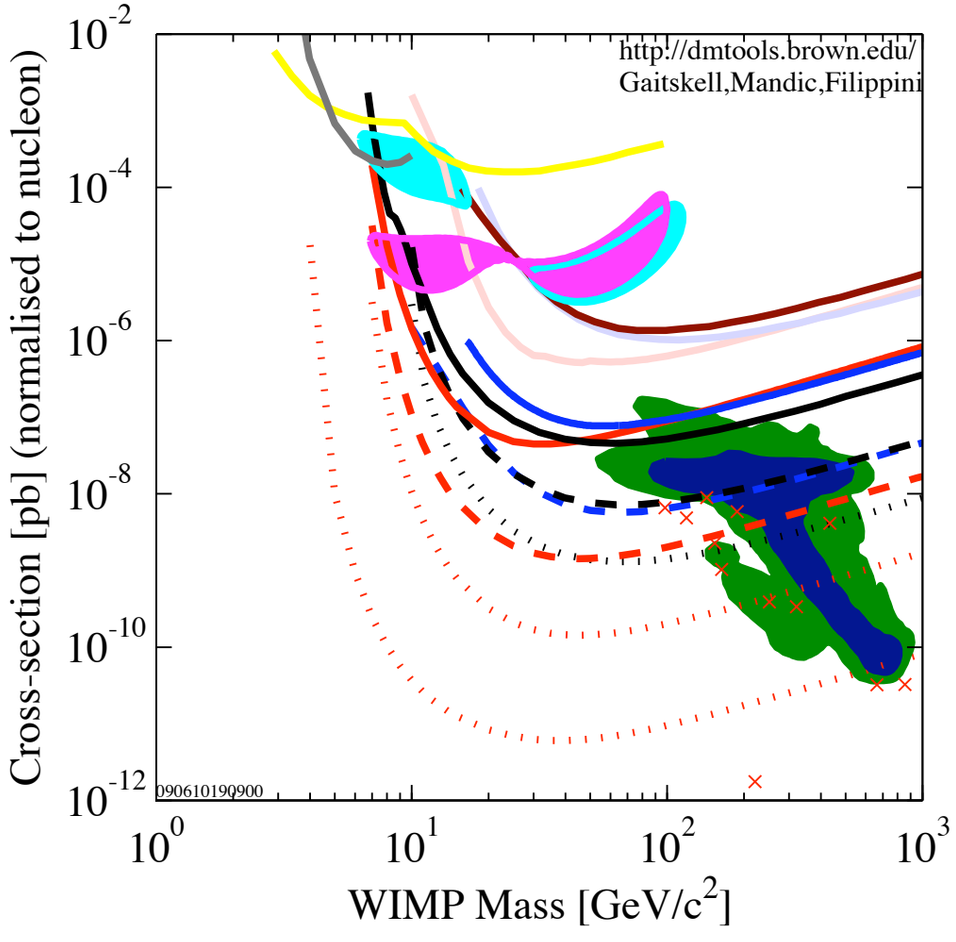
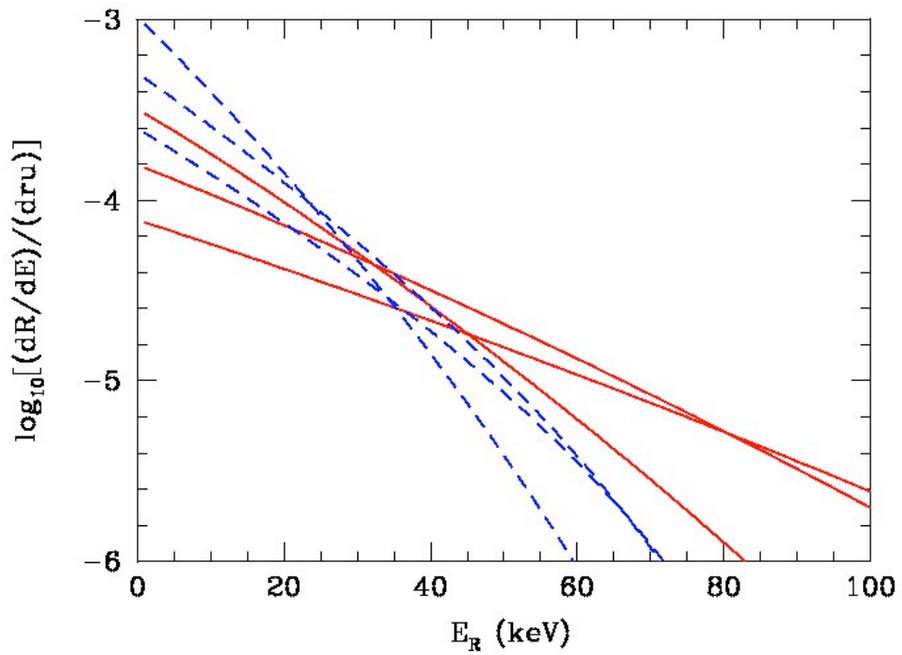


Direct detection signals

i) Materials signal

Shape and normalisation (A^2)depend on mass of target nuclei:

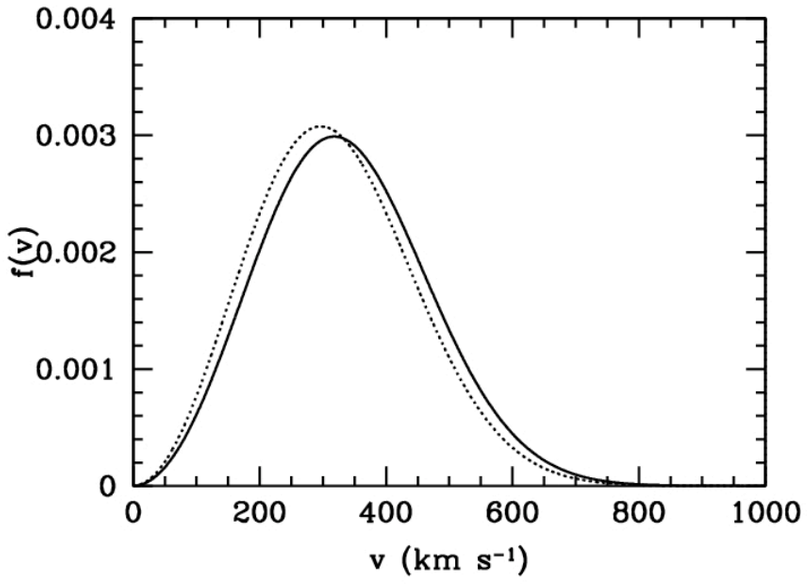


Ge and Xe m_χ = 50, 100, 200 GeV

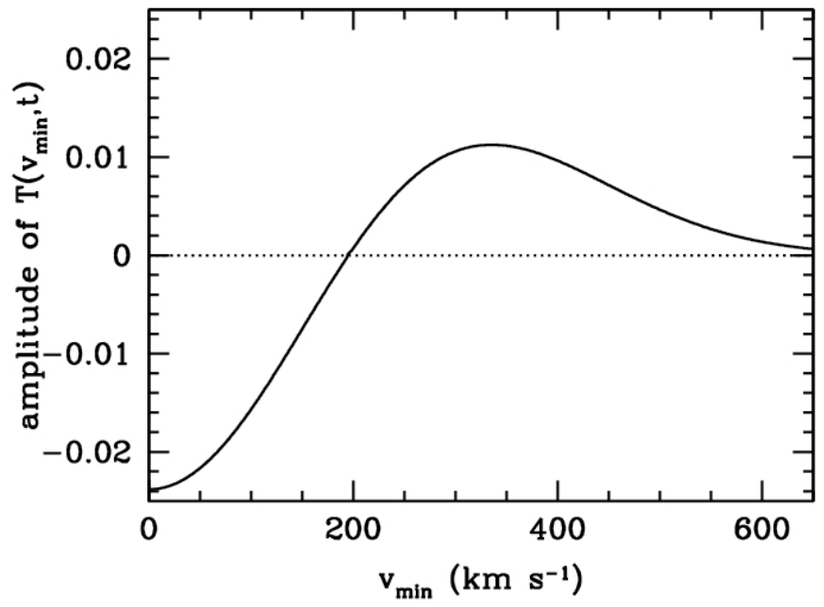
Need different targets in same background environment?

ii) Annual modulation

Drukier, Freese & Spergel



WIMP 'standard' (Maxwellian) speed dist.
detector rest frame (summer and winter)



modulation amplitude

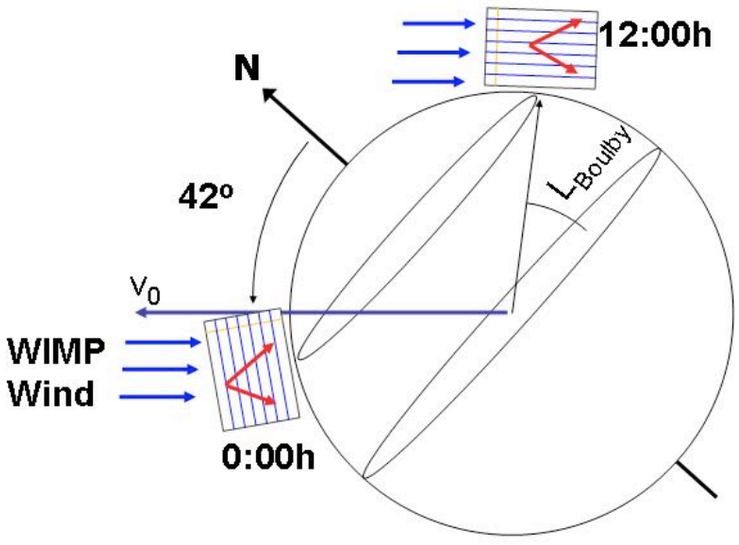
Signal ~ a few per-cent therefore need large exposure.

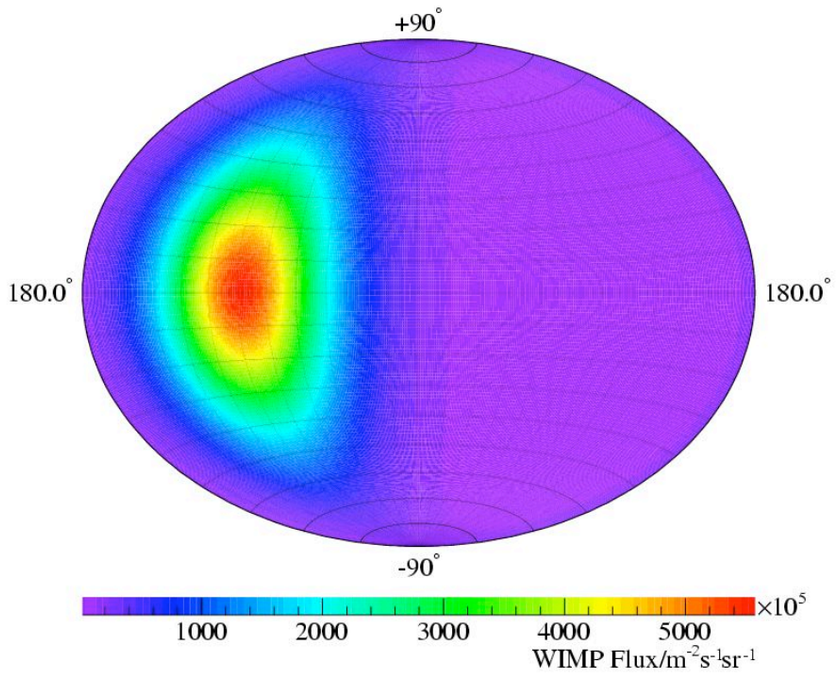
Details (e.g. phase & amplitude) depend somewhat on the local WIMP speed distribution.

How to demonstrate WIMP origin of modulation?

iii) Direction dependence

Spergel





Large rear-front asymmetry.

Direction of peak recoil rate in lab rotates over sidereal day (clear demonstration of Galactic origin of signal).

Potentially only O(10) events required to detect rear-front asymmetry.
Asymmetry not hugely sensitive to detail WIMP distribution.

BUT need detector which can measure recoil directions.

Summary

There's lots of observational evidence for dark matter, and WIMPs are a well motivated dark matter candidate.

For a robust detection of WIMPs we need a 'smoking gun' signal.

Directional dependence of event rate (rear-front asymmetry and variation of peak recoil direction over sidereal day) provides a potentially powerful signal.