Electronic Activity from the Sun as a Signature of Dark Matter annihilation

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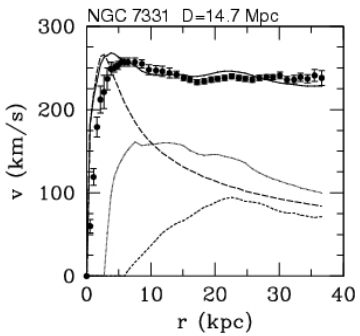
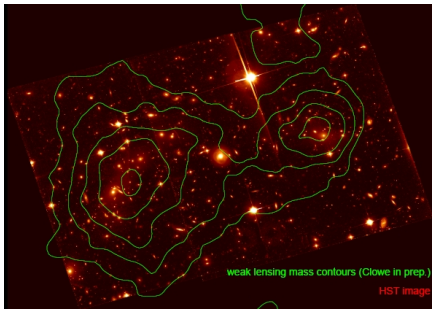
What is Dark Matter?

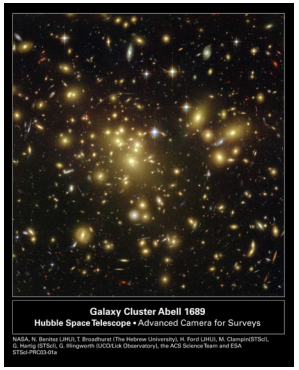
It gravitates and it is slow



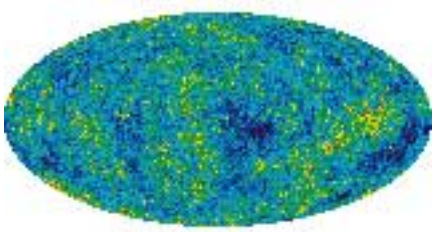
Rotation curves



Bullet Cluster



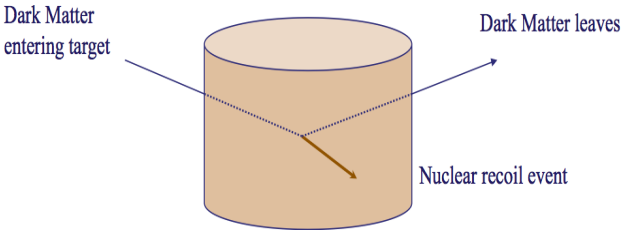
Lensing Effects



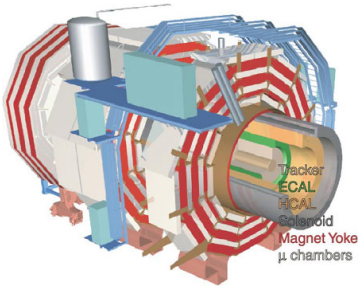
WMAP

But what else?

Direct Detection

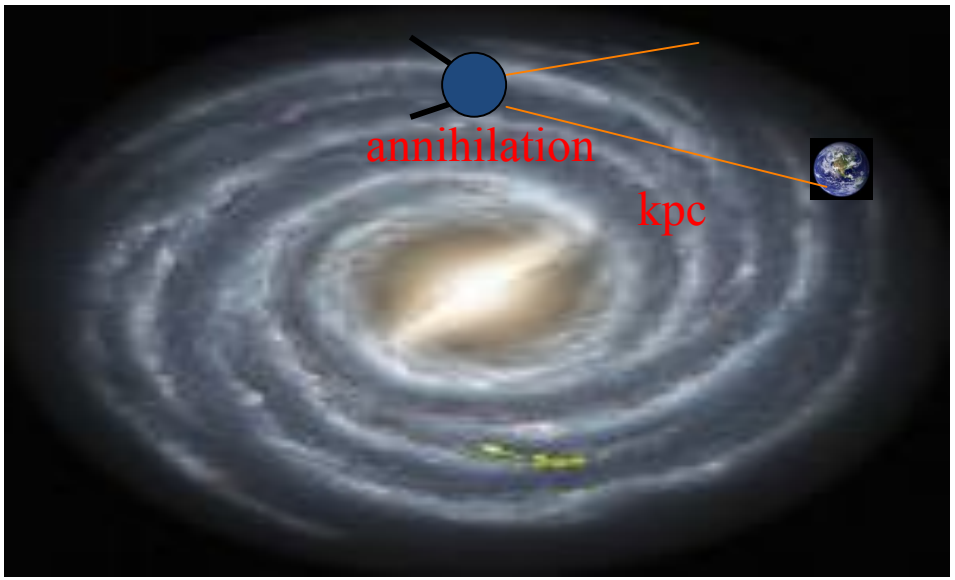


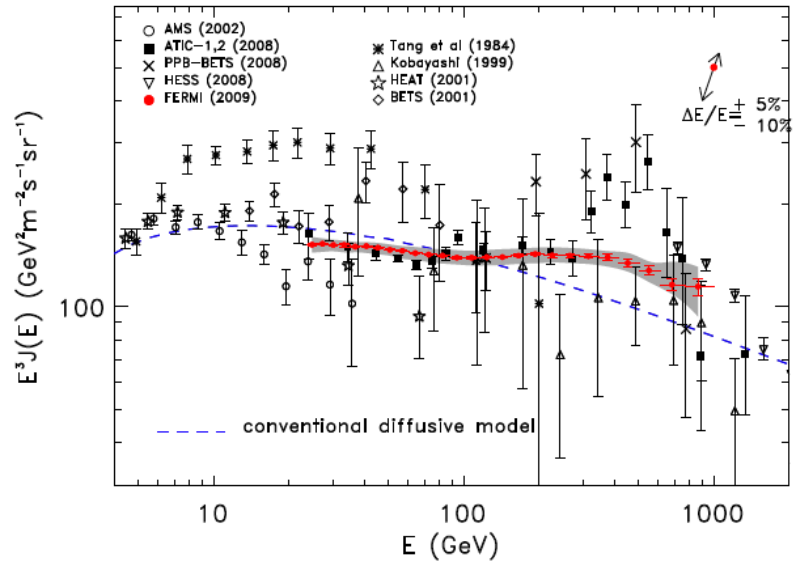
Direct Production

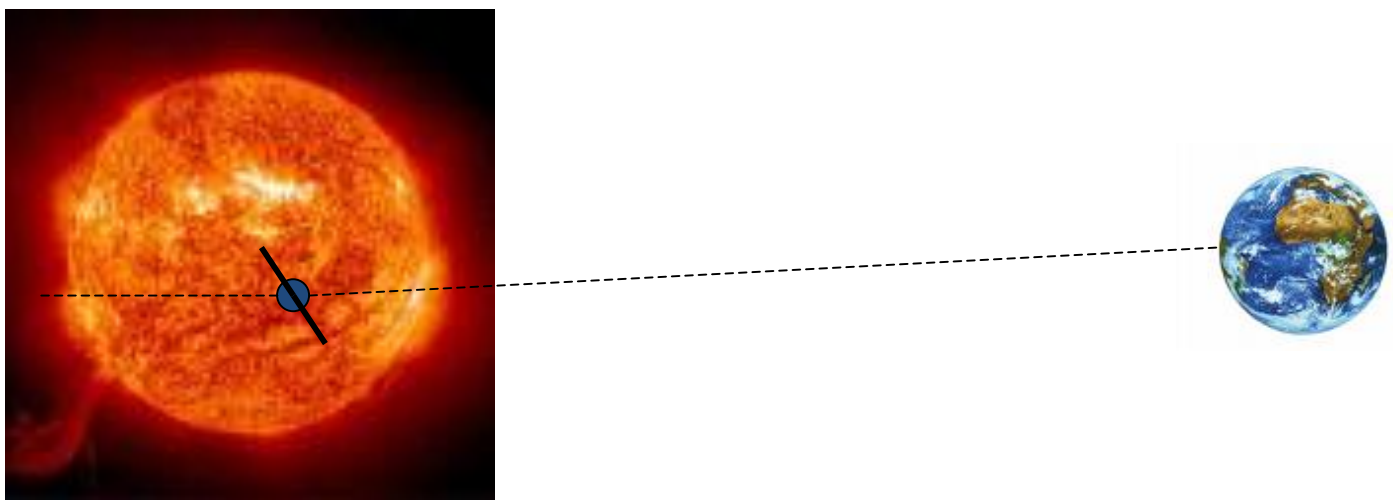


Indirect Detection

Dark Matter Annihilation

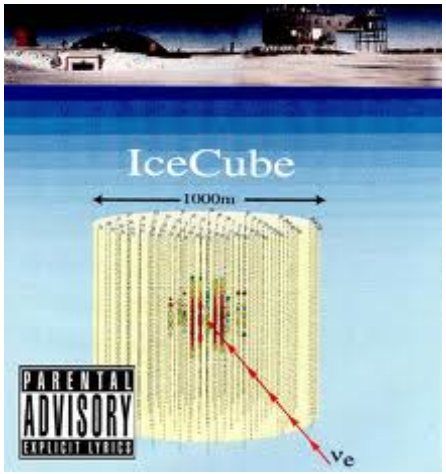


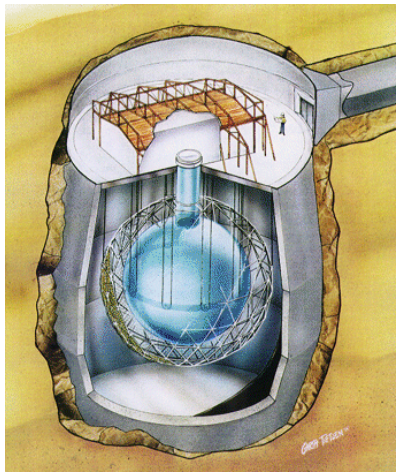




What can be observed?

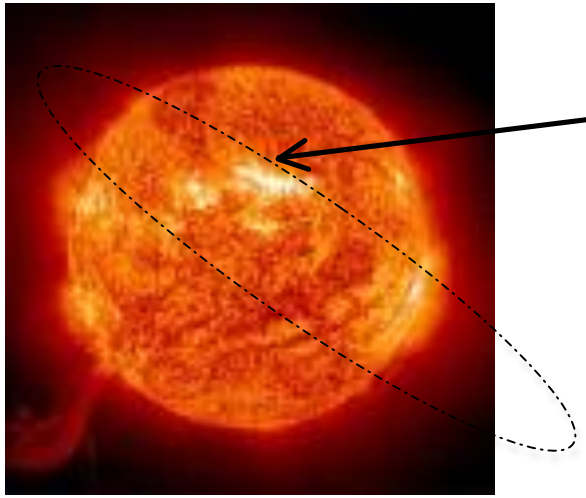
Traditionally the only possibility discussed is high-energy *neutrinos*





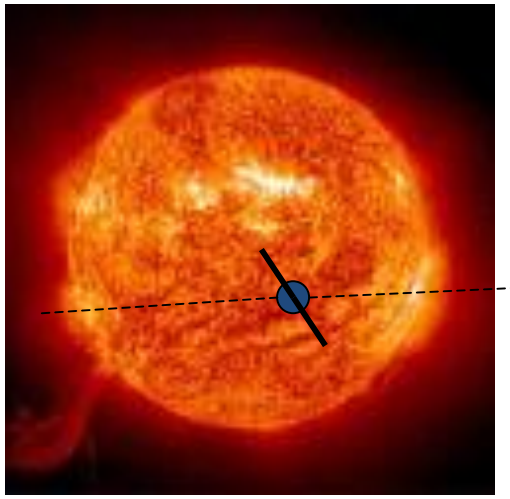
I will break with tradition and describe two other possibilities…

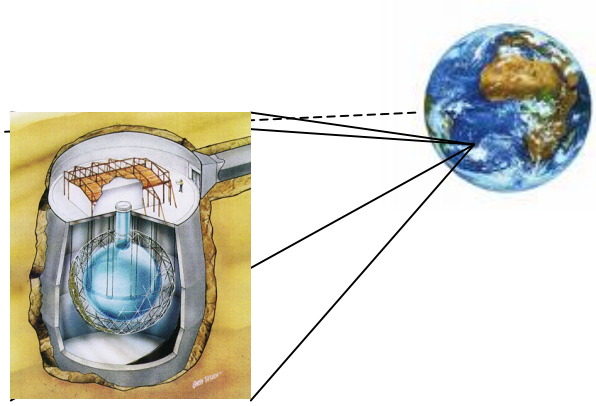
High Energy Neutrinos from the Sun



Dark matter collides with matter in the Sun and gets captured in a bound orbit.

After many collisions, dark matter settles in the center. If dense enough, it can annihilate. The only known particles that can escape are neutrinos





How to Compute Muon Flux

The computation can be separated into logically disjoint steps, as follows:

WIMP velocity distribution ✔

Capture Rate (DM/sec)

Properties of the Sun ✔

Dark Matter-nucleus interactions ✖

Annihilation cross-section ✔

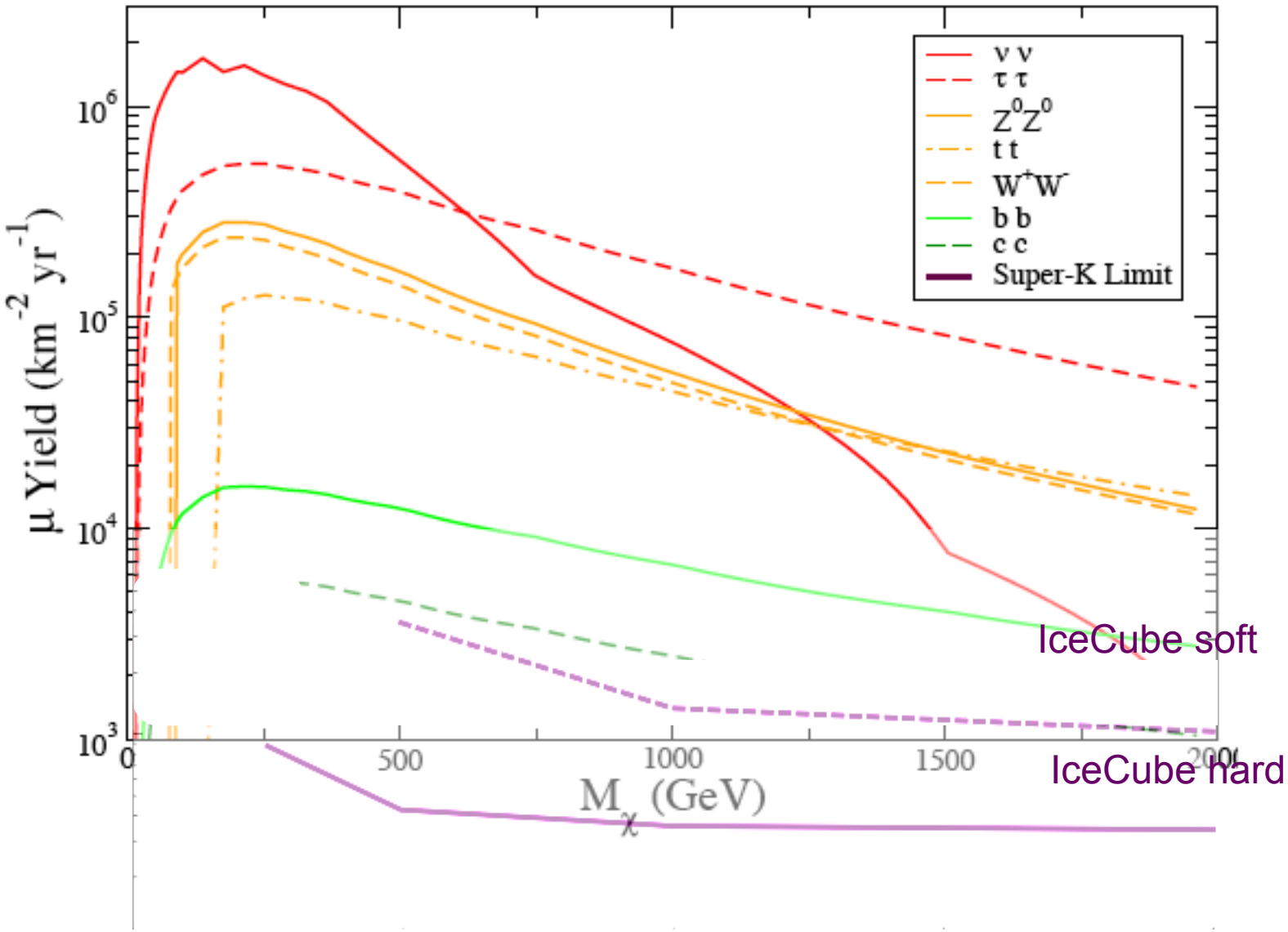
Annihilation Rate (Neutrinos/sec)

Annihilation products ✖

Muon Flux (muon/sec/area)

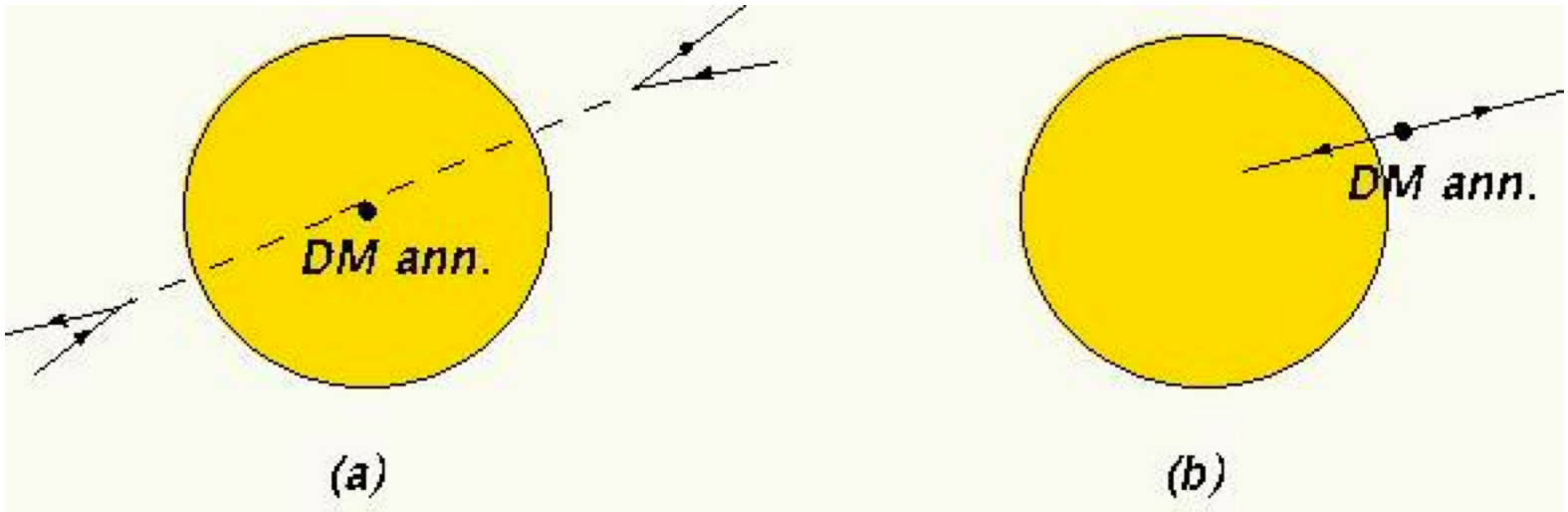
Many many things ✔

Bounds on Models of Dark Matter



Electronic Activity

If the annihilation is into light particles (muons, quarks, electrons, photons) it will be difficult to observe the resulting neutrinos. Some models of dark matter exhibit exactly such annihilations. Fortunately, they also offer a different way of probing this effect:

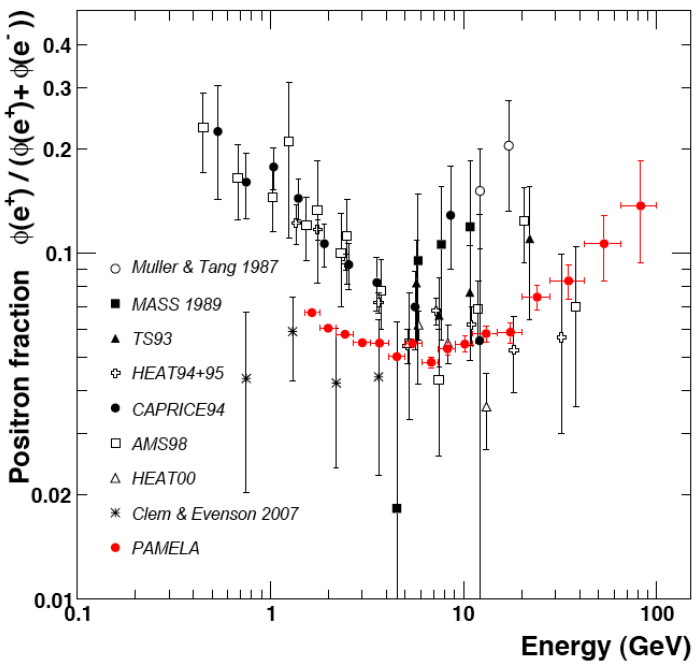


a) Annihilation into a new light state that escapes the sun and then decays.

b) Dark Matter does not accumulate in the center, annihilates *outside* the sun.

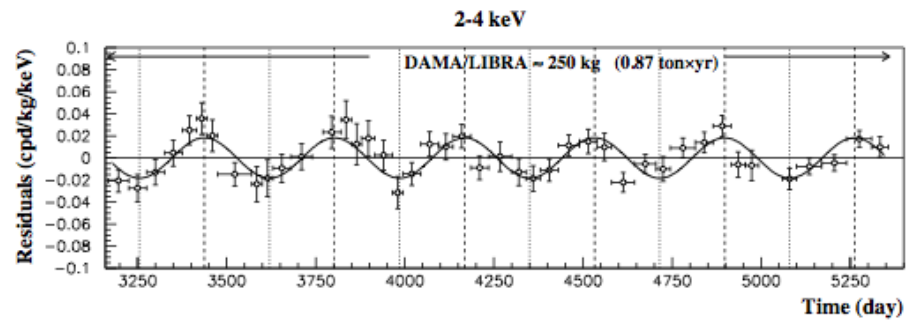
Motivation

New Light States

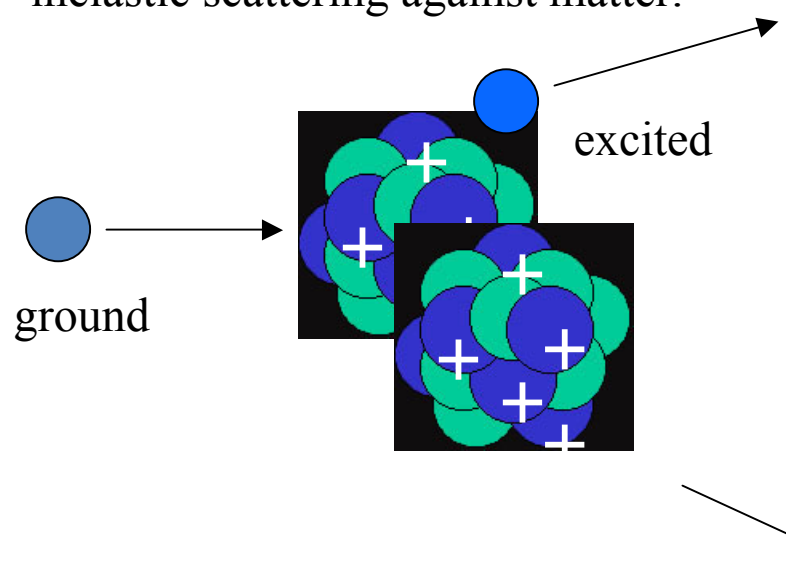


The excess observed by the PAMELA satellite motivated Dark Matter models where the annihilation is into light states which consequently decay into electrons, muons, and other light states.

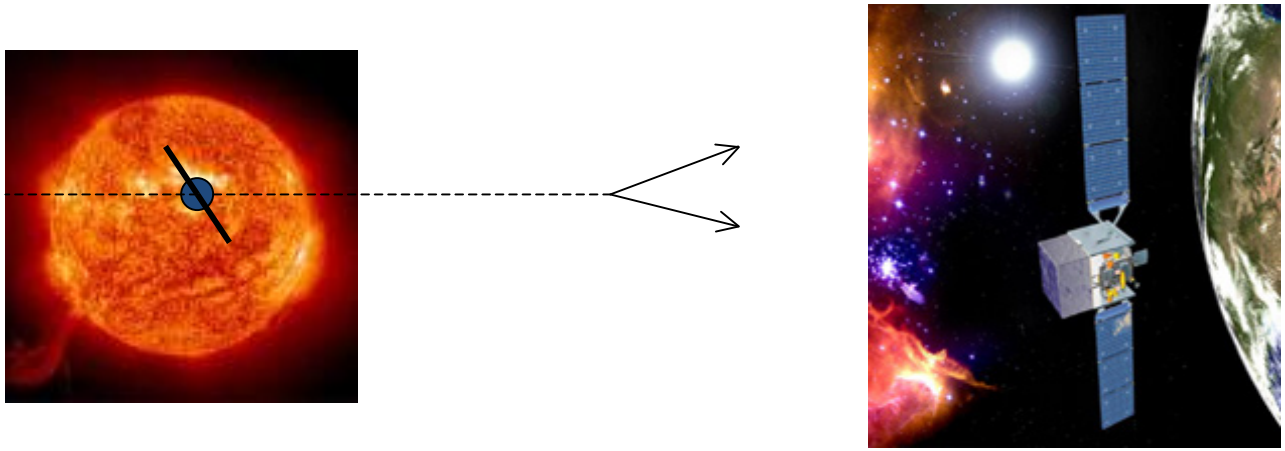
Inelastic Dark Matter



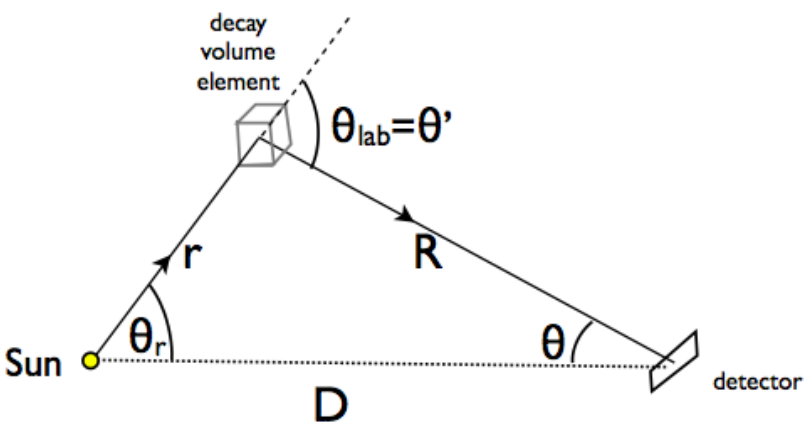
The signal observed by DAMA motivated Dark Matter models with inelastic scattering against matter.



Long-Lived States - Observation



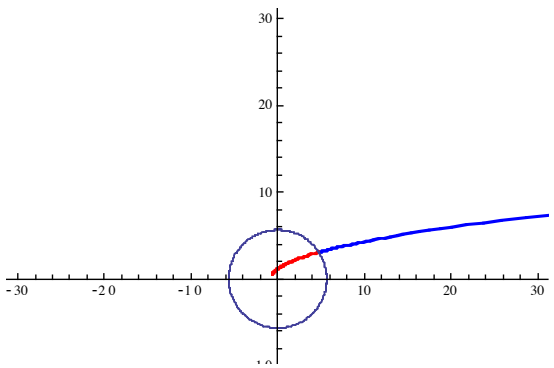
To get numerical predictions for the event rate at the detector one has to make some assumptions about the nature of the new state (lifetime and mass). Then a concrete prediction is possible,

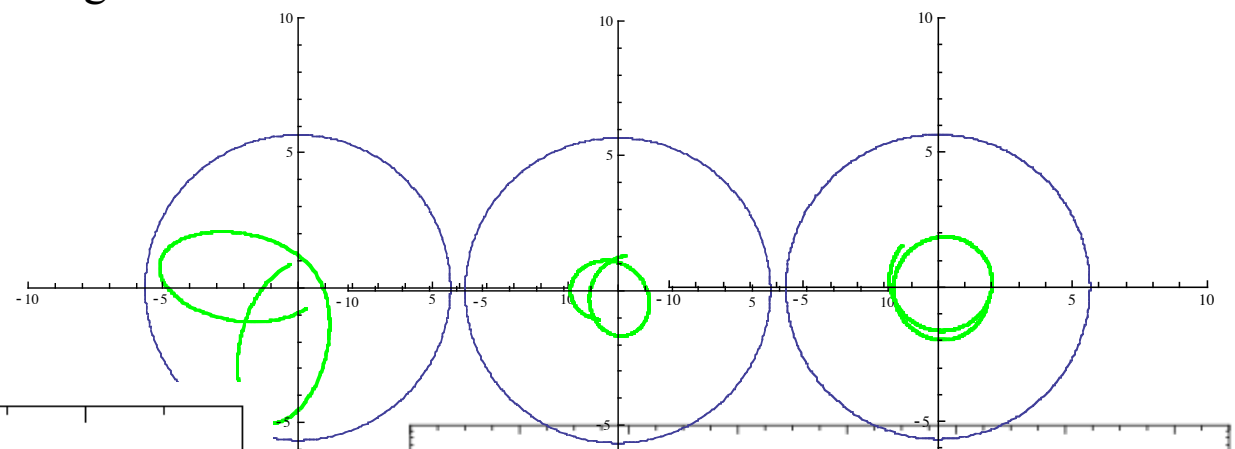


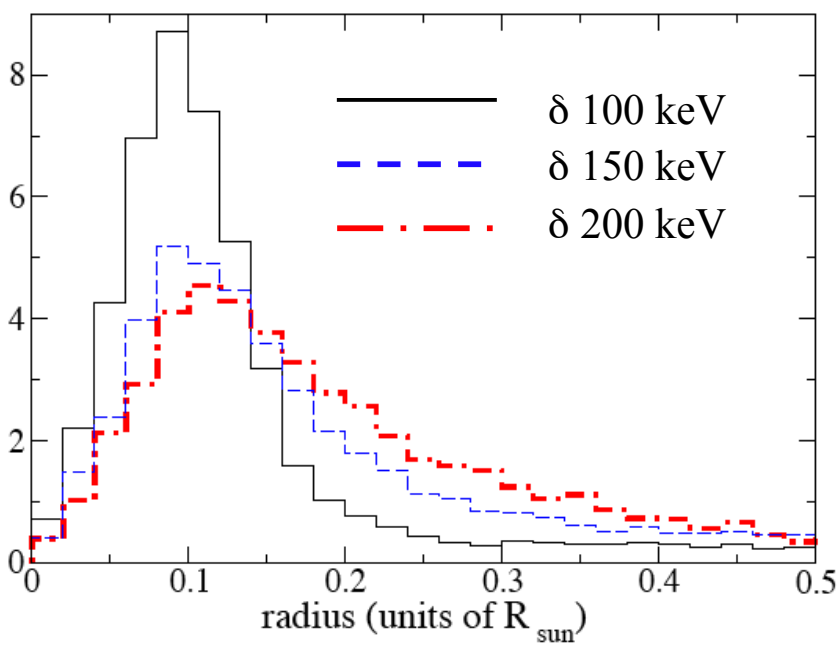
$$\frac{d\dot{N}_{det}}{d\cos\theta dAdx} = \frac{C_\odot}{4\pi LD}\frac{1+\beta}{2\beta\sin\theta}e^{-r/L} \times \frac{\gamma\beta x}{\sqrt{(1-x)(x-x_{min})}}\Theta(x_{max}-x),$$

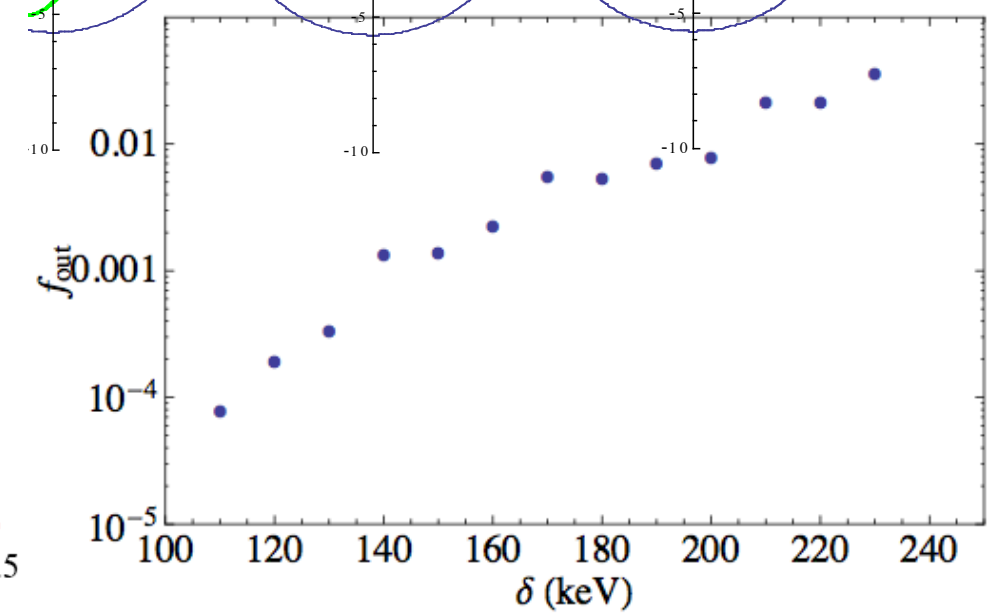
Annihilation Outside the Sun

If Dark Matter scatters inelastically, it can only scatter a few times before it loses enough energy and can no longer scatter.



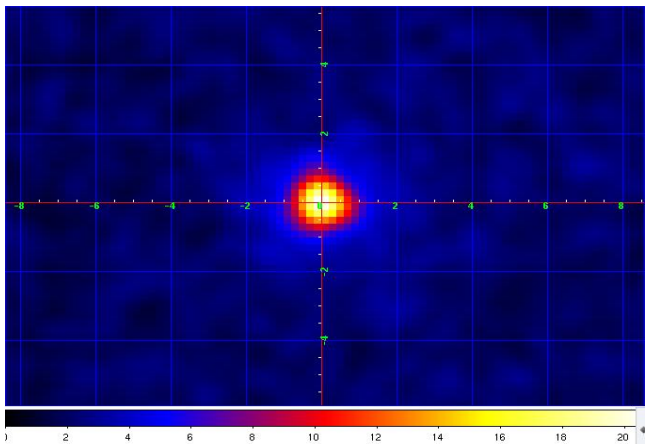




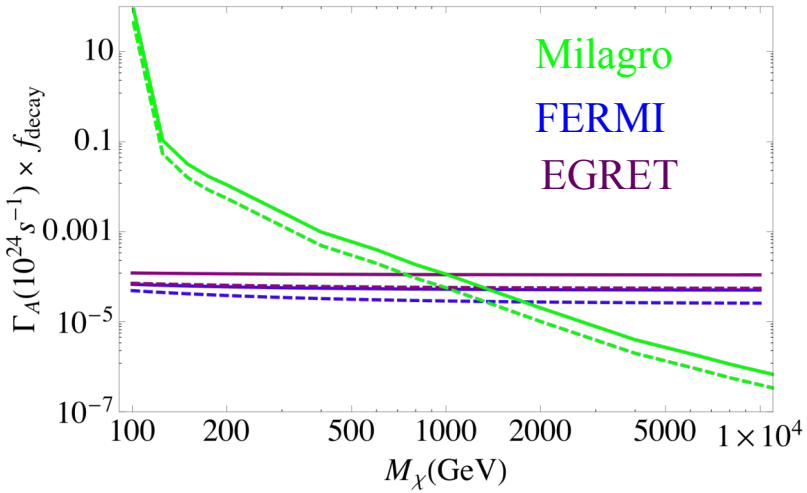


Constraints

FERMI and other observatories have looked for such effects. So far, no excess has been observed.



Giglietto for FERMi



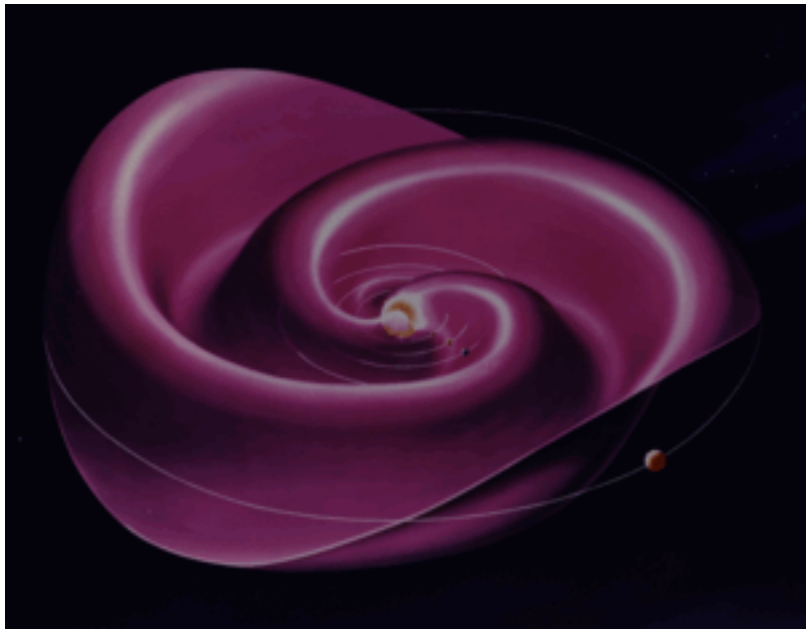
These constraints arise from the gamma rays associated with any high energy electronic activity. It will be interesting to search for electrons directly.

How to look for it?

Well, look at the Sun, but can define

$$A_{\mathrm{dn}} = d\Phi^e/dE|_{\mathrm{day}} - d\Phi^e/dE|_{\mathrm{night}}$$

Also, the magnetic fields may result in a distorted shape,



The Parker spiral

Conclusions

- We really do not know what dark matter is except that it gravitates.
- We should try to cast as wide a net as possible and hope for something to show up.
- High energy electronic activity from the Sun is such a striking signal, that although it is highly speculative, it is nevertheless worth looking for.