Dark Matter

V. Direct and indirect searches of WIMP DM

Fabio Iocco

fabio.iocco.astro .AT. gmail.com

ICTP-SAIFR

IFT-UNESP

São Paulo

School on DM and neutrinos

ICTP-SAIFR, July 27, 2018

Most of the material in this classes can be found in standard book, above all the “Particle Dark Matter” one edited by G. Bertone. The class went on mostly at the blackboard, but I encourage you to look for the way more details classes of.

N. Bozorgnia (for direct detection) and F. Calore (for indirect).

The complete material can be found at this address

http://www.ictp-saifr.org/school-on-dark-matter-2/

I strongly encourage you to download and study them to have a broader view on the subject. Excellent exercises are suggested, and references available.

Of course, do not hesitate to contact me for any question you may have.

Outline of the DM lectures

- Why DM? (What do we see, is that with what we know, is there a problem between knowledge and new observations?)

- Is a “DM based framework” viable? How does it compare with observations?

- What class of (new) particles can fulfill the astrophysical and cosmological requirements? (Classes of models.)

- Let us have some practical examples of scenarios (model building : axions, SUSY WIMPs).

- How can we look for the very nature of these new particles? (Direct and indirect searches, colliders.)

A checklist of DM properties

1. *Does it match the appropriate relic density?*
2. *Is it cold?*
3. *Is it neutral?*
4. *Is it consistent with BBN?*
5. *Does it leave stellar evolution unchanged?*
6. *Is it compatible with constraints on self-interactions?*
7. *Is it consistent with direct DM searches?*
8. *Is it compatible with gamma-ray constraints?*
9. *Is it compatible with other astrophysical bounds?*
10. *Can it be probed experimentally?*

[Taoso et al., 2007]

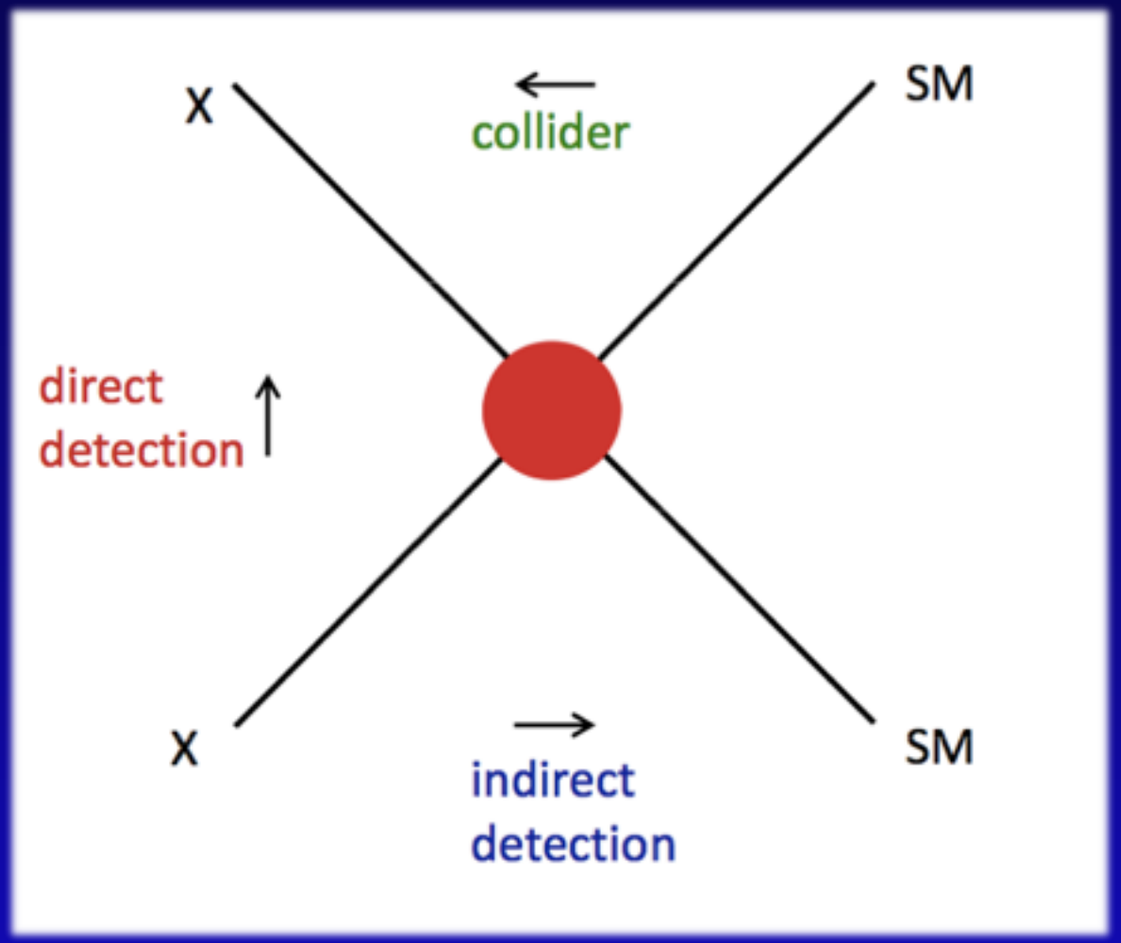
Direct and indirect searches of WIMP DM

complementary to colliders

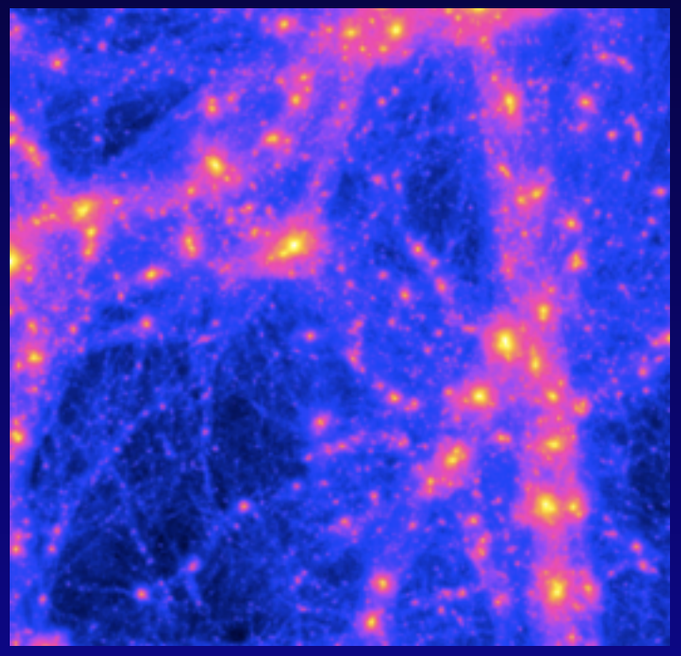
Direct detection:
DM scattering against nuclei, recoil

Indirect detection:
Annihilation in astrophysical envir.
Observation of SM products of annih.

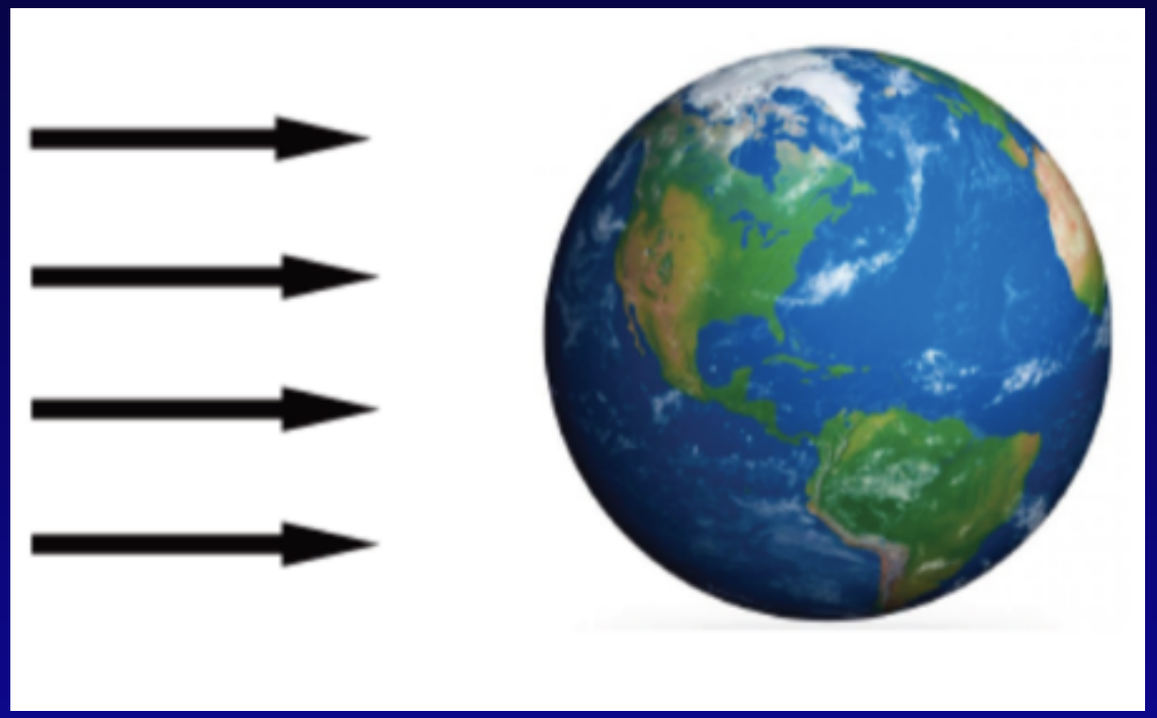
Production at LHC

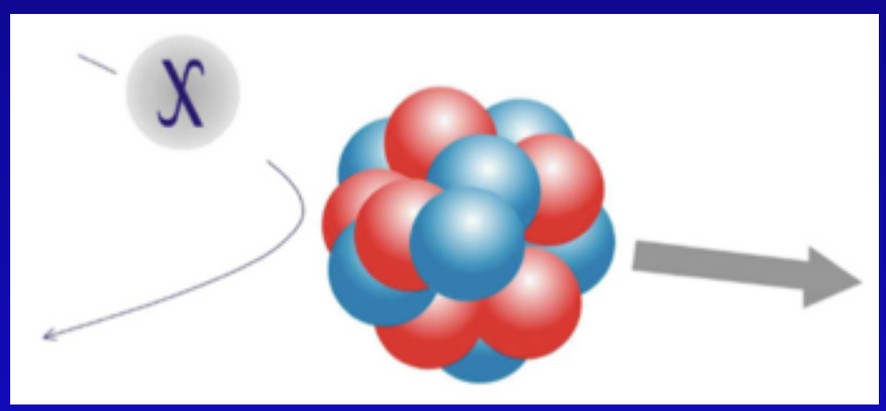


Direct DM searches



The DM cloud



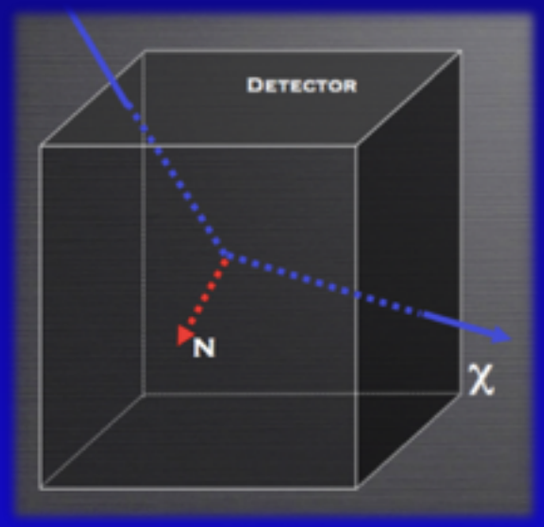


(Elastic) scatter of a DM particle over a nucleus induces recoil
Measure recoil in controlled environment: Lab on Earth (but also…)

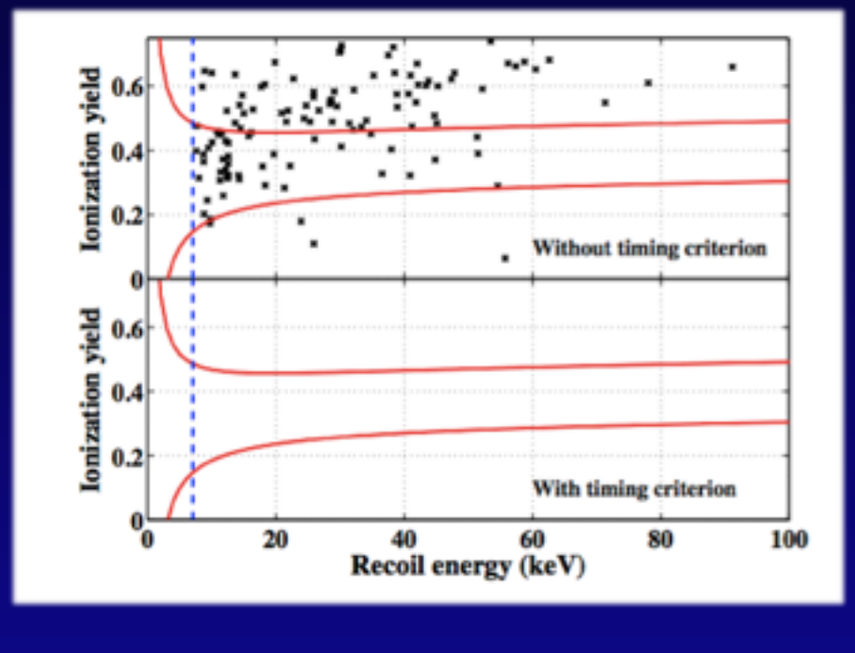
Direct Detection: principles and dependencies

A big mountain
(or a deep mine)

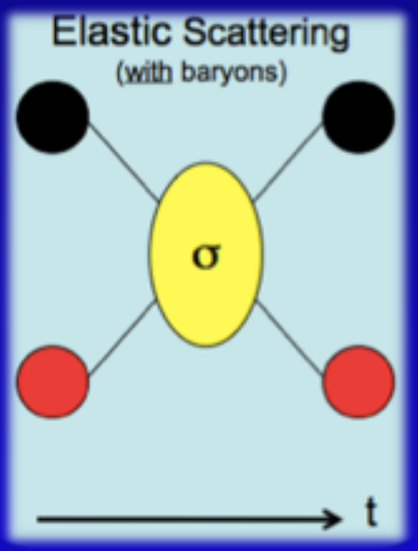
a relatively cheap detector



Your observed data

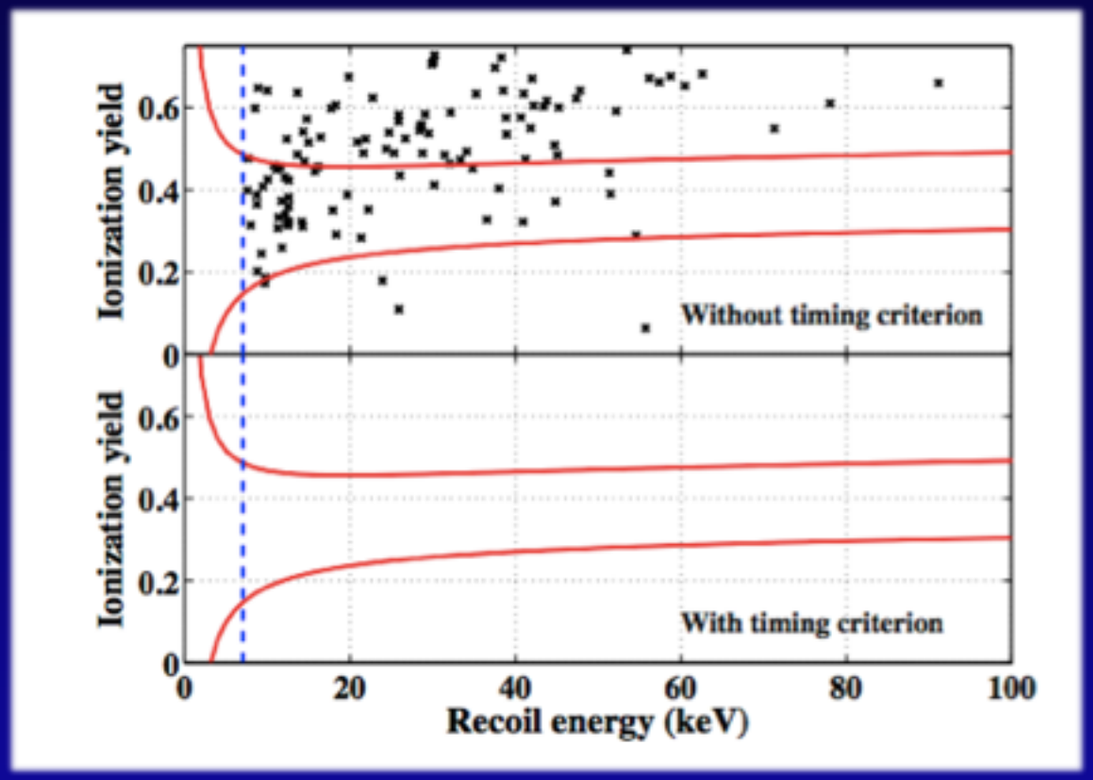


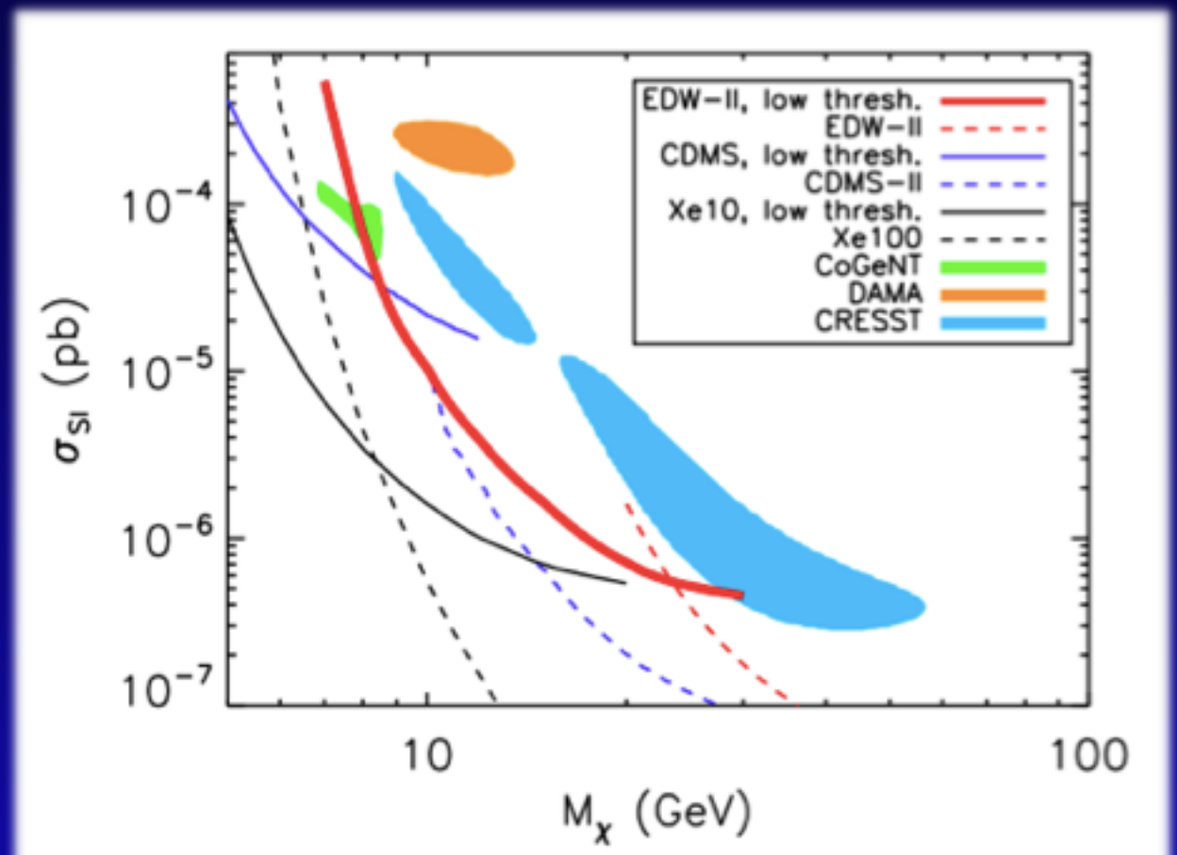
Your ticket to Stockholm



Direct Detection: principles and dependencies (to go…)

from this → to this

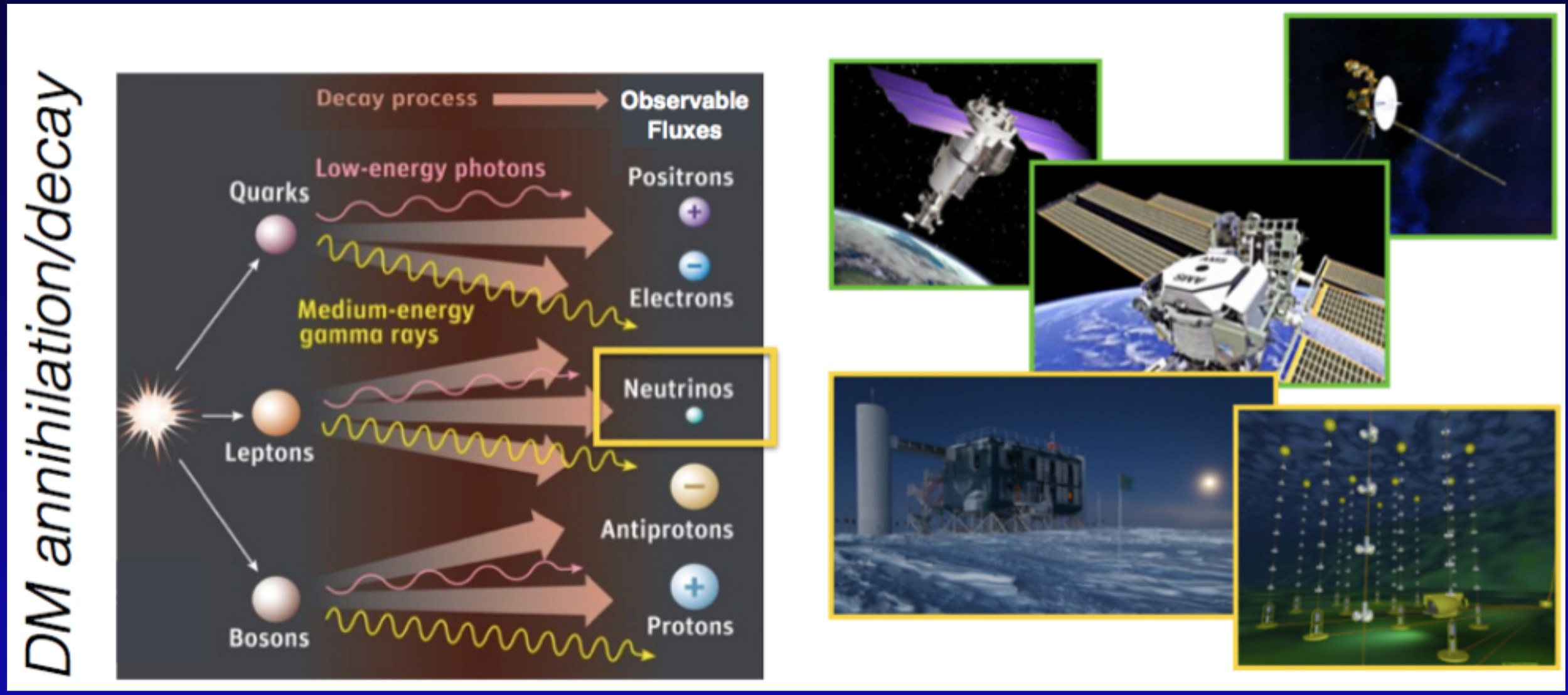




you need this

$$\frac{dR}{dE} \propto \frac{1}{\mu^2} \frac{\sigma_\chi}{m_\chi} \rho_0 \eta(v,t)$$

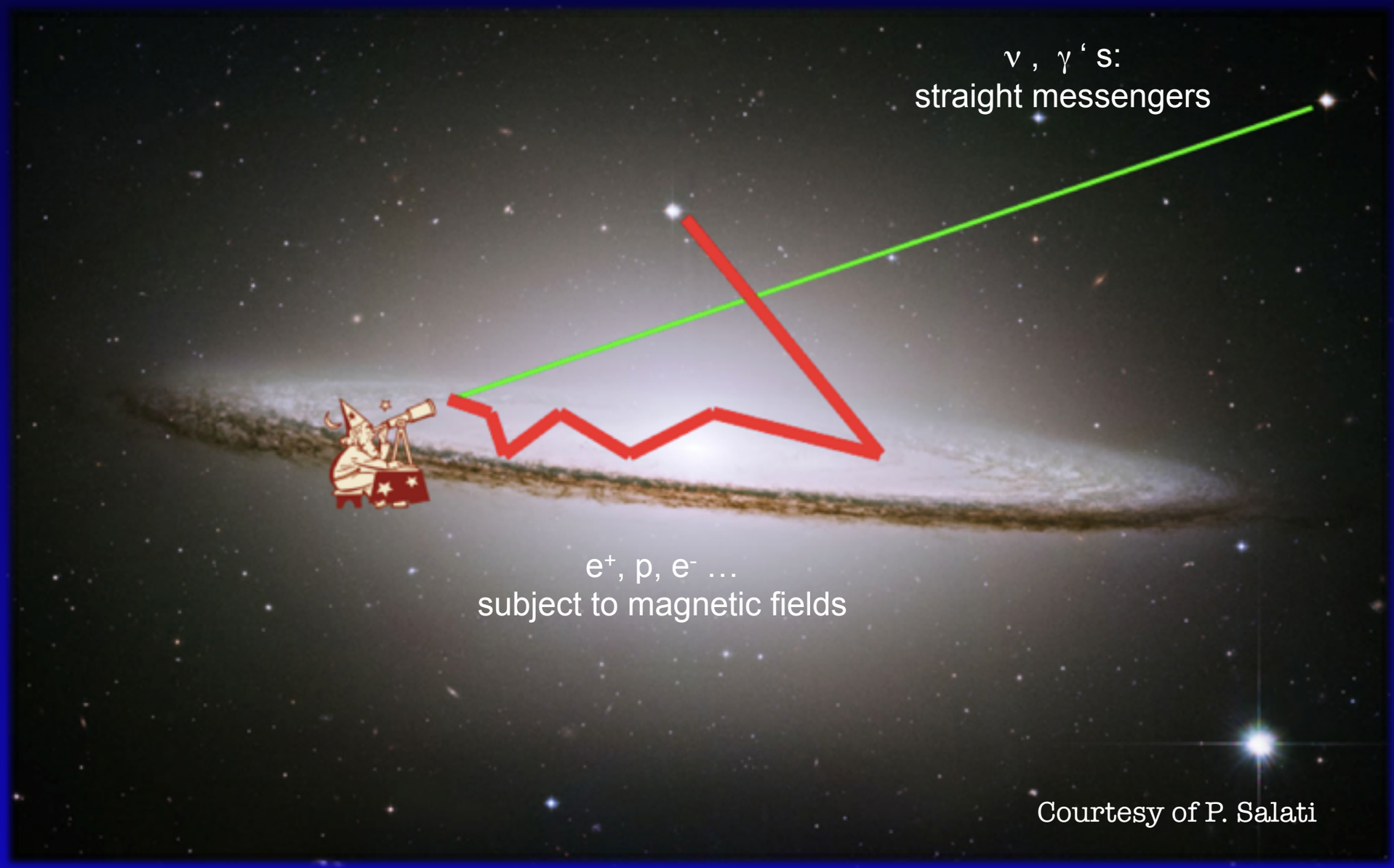
Indirect DM searches



Looking for byproducts of DM annihilation/decay into SM.
You need a lot of DM ➔ astrophysical (big) objects

Indirect Detection: principles and dependencies

$$\chi + \chi \to q\bar{q}, W^+W^-, \ldots \to \gamma, \bar{p}, \ \bar{D}, \ e^+ \ \& \ \nu's$$



$$F_i \propto \frac{1}{4\pi d^2} B_i \frac{\langle \sigma v \rangle}{m_\chi} \int \rho^2(r) dV$$

Indirect Detection: principles and dependencies

Galactic center, Dwarf Galaxies, Galactic Halo…
dependence on density structure
discovery (or constraints) subject to same uncertainty

$$F_i \propto \frac{1}{4\pi d^2} B_i \frac{\langle \sigma v \rangle}{m_\chi} \int \rho^2(r) dV$$

$$J_{annih} \propto \int_{los} \rho^2(r) dV$$

$$\Phi_{DM}(E) = \Phi_{PP}(E) \mathcal{J}$$