Dark Matter

V. Direct and indirect searches of WIMP DM

Fabio Iocco

fabio.iocco.astro@at.gmail.com

ICTP-SAIFR
IFT-UNESP
São Paulo
Most of the material in this class 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 detailed 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

(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)

Your observed data

Your ticket to Stockholm

a relatively cheap detector

Elastic Scattering
(with baryons)
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

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

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

\( \nu, \gamma \): straight messengers

\( e^+, p, e^- \): subject to magnetic fields

Courtesy of P. Salati
Indirect Detection: principles and dependencies

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

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

\[ J_{\text{annih}} \propto \int_{\text{los}} \rho^2(r) dV \]

\[ \Phi_{DM}(E) = \Phi_{PP}(E') J \]