“Exploring the Dark Universe” 2017
Dark Matter: a long standing question

Some history
The dark matter question
Where are we, where are we going
Introduction

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Queen’s University
EDU2017 – July 22th 2017
Some personal notes

• 1979 my first Rencontres de Moriond in Alps
  – great spirit and combination of working and winter sport

• 2013 ICISE in Vietnam
  – a dream which came to life

• 2017 Dark Matter at ICISE
  – an old idea which took form in 2017
  – a strong competition with TAUP at SNOLAB

• Myself
  – in the Direct Detection field for 30ish years
  – now in Canada for projects at SNOLAB
non luminous matter $\leq$ ?? M or G ?? $\Rightarrow$ change GR

$V^2 \propto GM/r$
Vera Rubin in 1970’s measured galaxy rotation curves: Inspired by F Zwicky work in the 1930’s

“We have peered into a new world and have seen that it is more mysterious and more complex than we had imagined. Still more mysteries of the universe remain hidden. Their discovery awaits the adventurous scientists of the future. I like it this way.”

Fritz Zwicky in the 1930’s, noticed that galaxies were gathered in clusters and that galaxies were moving too fast within clusters => Need « Dunkle Materie »
Same observations for most galaxies, here Andromeda.
“Between” stars and galaxies, in the dark parts, was discovered in 1964 the 3K cosmic microwave background, imprint of the Big Bang.
Dark matter not only in galaxies – also in the whole Universe
Cosmology “concordance model” reproduces well data

Remarquable coincidence between the model (curve) and the data (points)

Strong theoretical motivations that Dark Matter is made of particles
The particles of ordinary matter

Atoms
Molecules

The atom

Proton
Neutrons

Electrons

Photon
Neutrinos
Elementary Particles described in the Standard Model
no Dark Matter => need to go “beyond”

No particle for Dark Matter in Standard Model

+ many more models
...
Producing Dark Matter particles at LHC at CERN??

Large Hadron Collider ready to search for dark matter once again after 2-year reboot

Sanjit Dutt | Sunday, March 15 2015
Tracking the Dark Matter particles, flying in the sky?

Particles of DM

Us: sun + earth

Milky Way

Halo
Wimp « indirect » detection: detect products of annihilation of DM particles

Annihilation:
- in Sun, Earth: $\gamma$
- in (clumpy) halo: $\gamma$, $p$, $e^+$, $D$
- in galactic center or dense regions: $\gamma$

Space, on ground experiments
“Direct detection” of Dark Matter: playing billiard with Dark Matter particles and nuclei.

- Liquid Xenon
- Spherical gaseous detector
- Instrumentation conduits
- Water tank
- Gadolinium-loaded liquid scintillator veto
- 488 photomultiplier tubes (PMTs)
- 7 tonne liquid xenon time-projection chamber
- Additional 180 xenon “skin” PMTs

Germanium detectors

Very tiny and rare expected signals
Going underground to protect from cosmic rays

Also underground labs in
Europe (4 labs)
US (2 labs)
Japan
China
India
Australia
soon in South America
...

SNOLAB
Sudbury Canada
Will EDU2017 bring new lights on Dark Matter?

- Dark Matter has not yet been identified
- Here and now is EDU2017
- 75 participants
- 60 presentations on
  - Theories, models
  - Indirect detection of Dark Matter
  - Direct Detection of Dark Matter
  - Dark Matter production at accelerators (LHC, e+e-, fixed target…)
  - …
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- We are going to learn …