Forests of CNT to trap Dark Matter of our Galaxy

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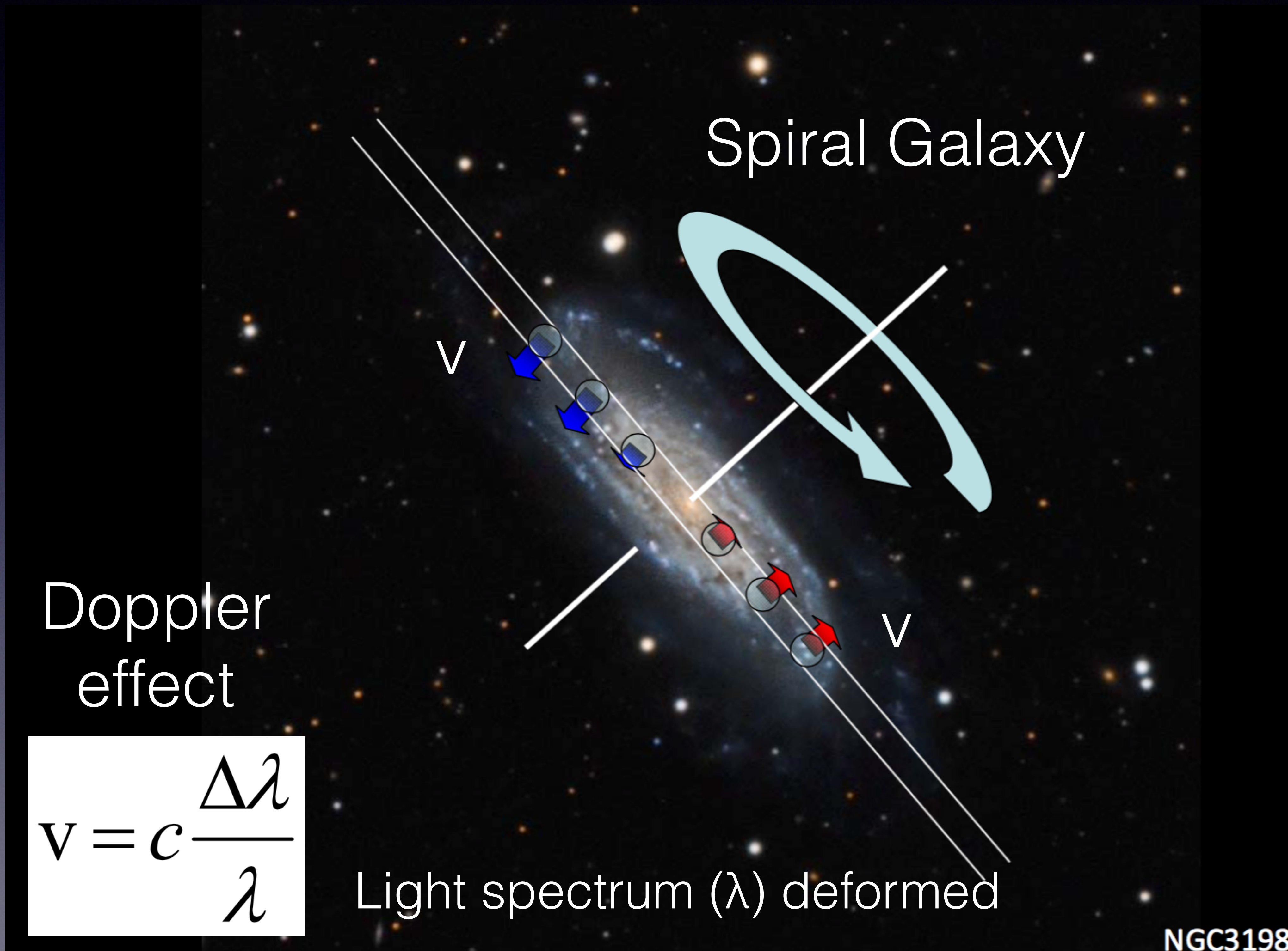
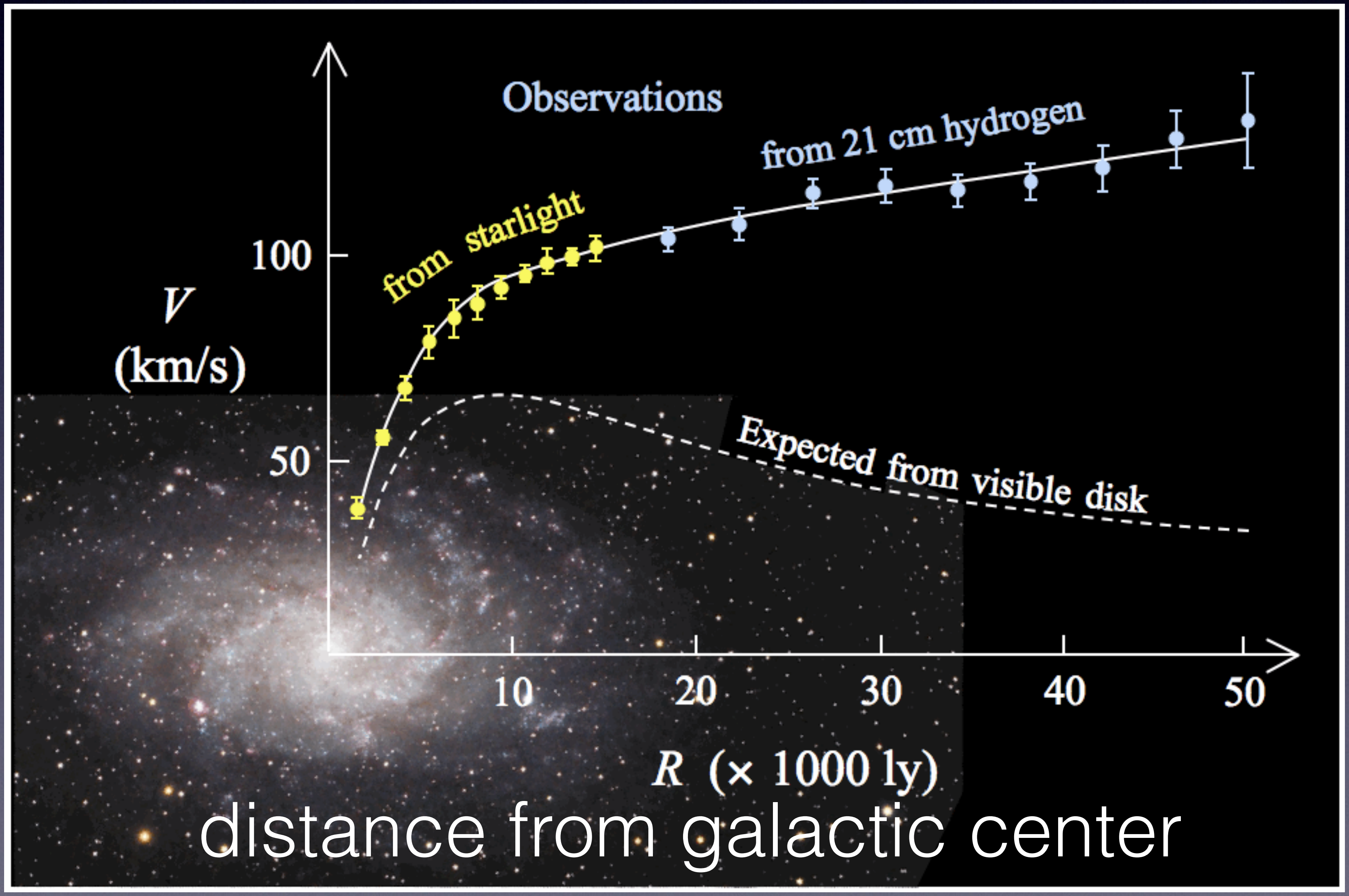
Stars velocity in a galaxy



Trouble: are some stars moving too fast ?!?



Solutions

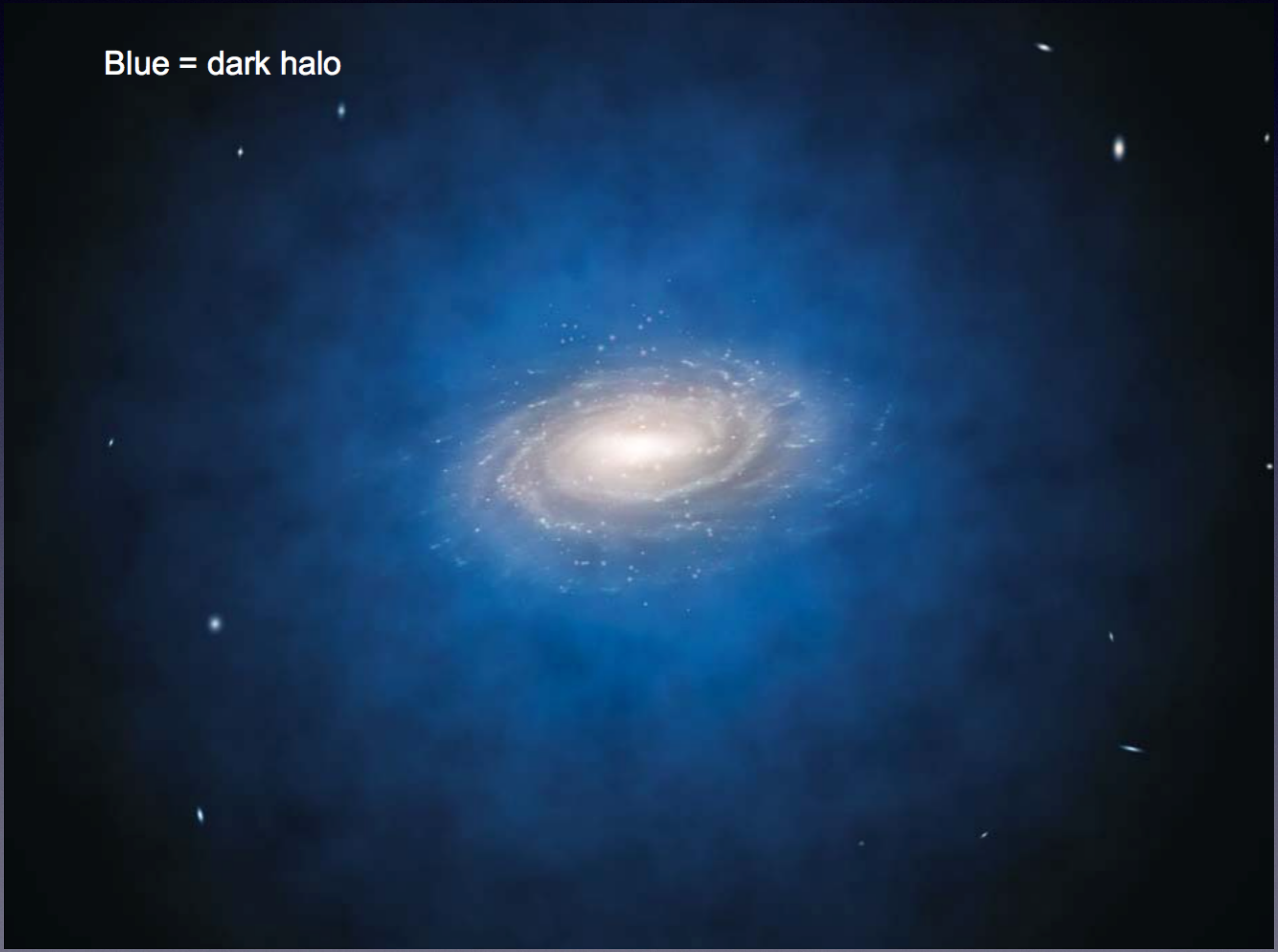
- **(I)** Most of a galaxy mass is contained in an **invisible spherical halo** with a radius larger than the "visible" radius with a **density ρ(r) ~1/r²**

$$M(<r) = \int_0^r 4\pi r^2 \rho(r)\,dr \propto r \longrightarrow v(r) = \sqrt{\frac{GM(<r)}{r}}$$ Constant !

- **(II)** Newton's gravity does not work in some extreme conditions (i.e. MOND theory)

The dark galactic halo

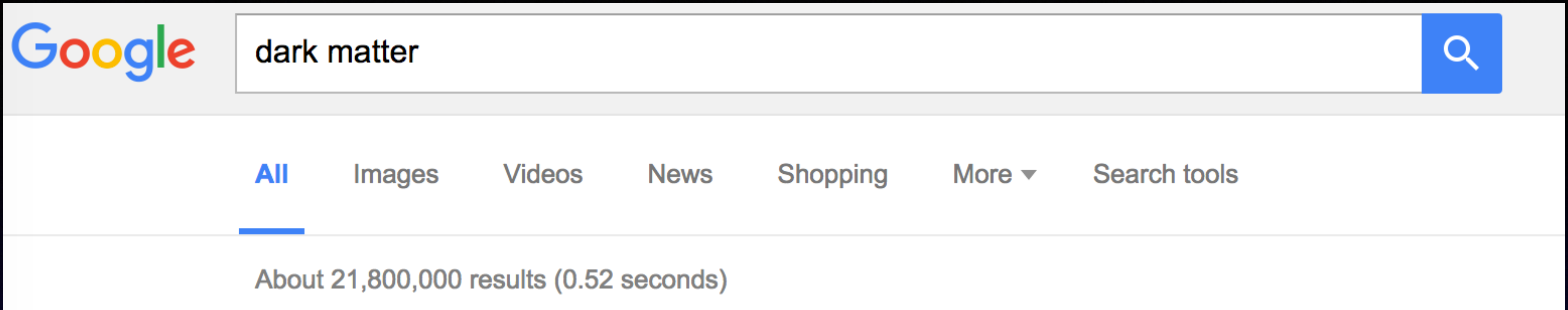
- As we imagine the halo

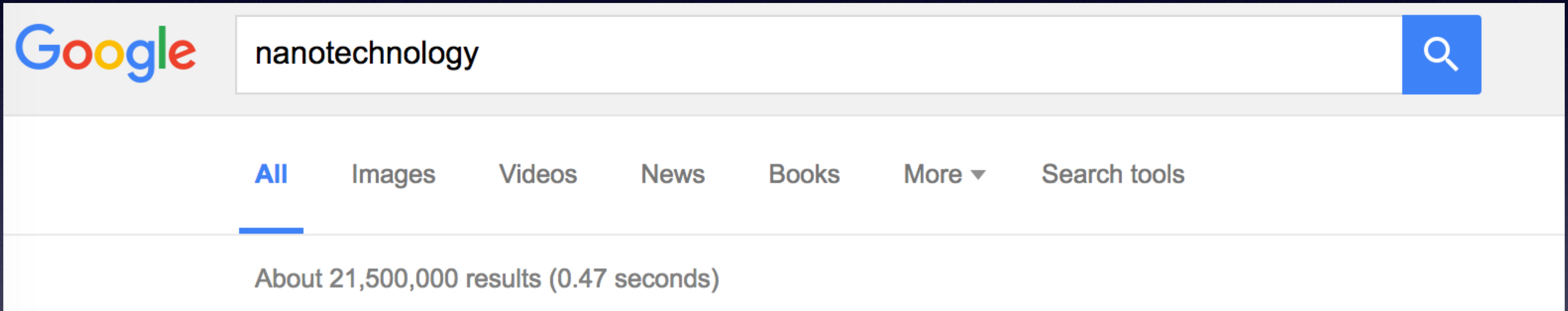


The question

Which is the nature of dark matter?

Certainly one of the most compelling
in fundamental physics
nowadays


Google
dark matter
All Images Videos News Shopping More Search tools
About 21,800,000 results (0.52 seconds)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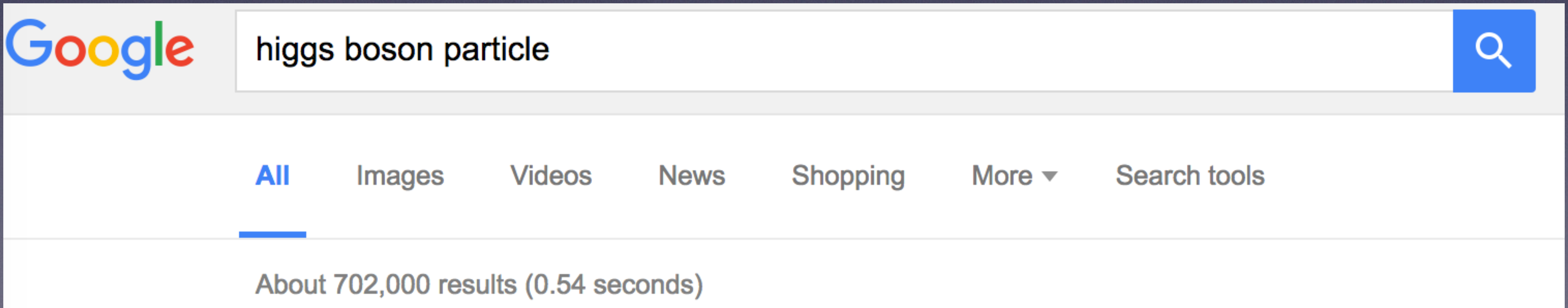
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higgs boson particle
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The WIMPs

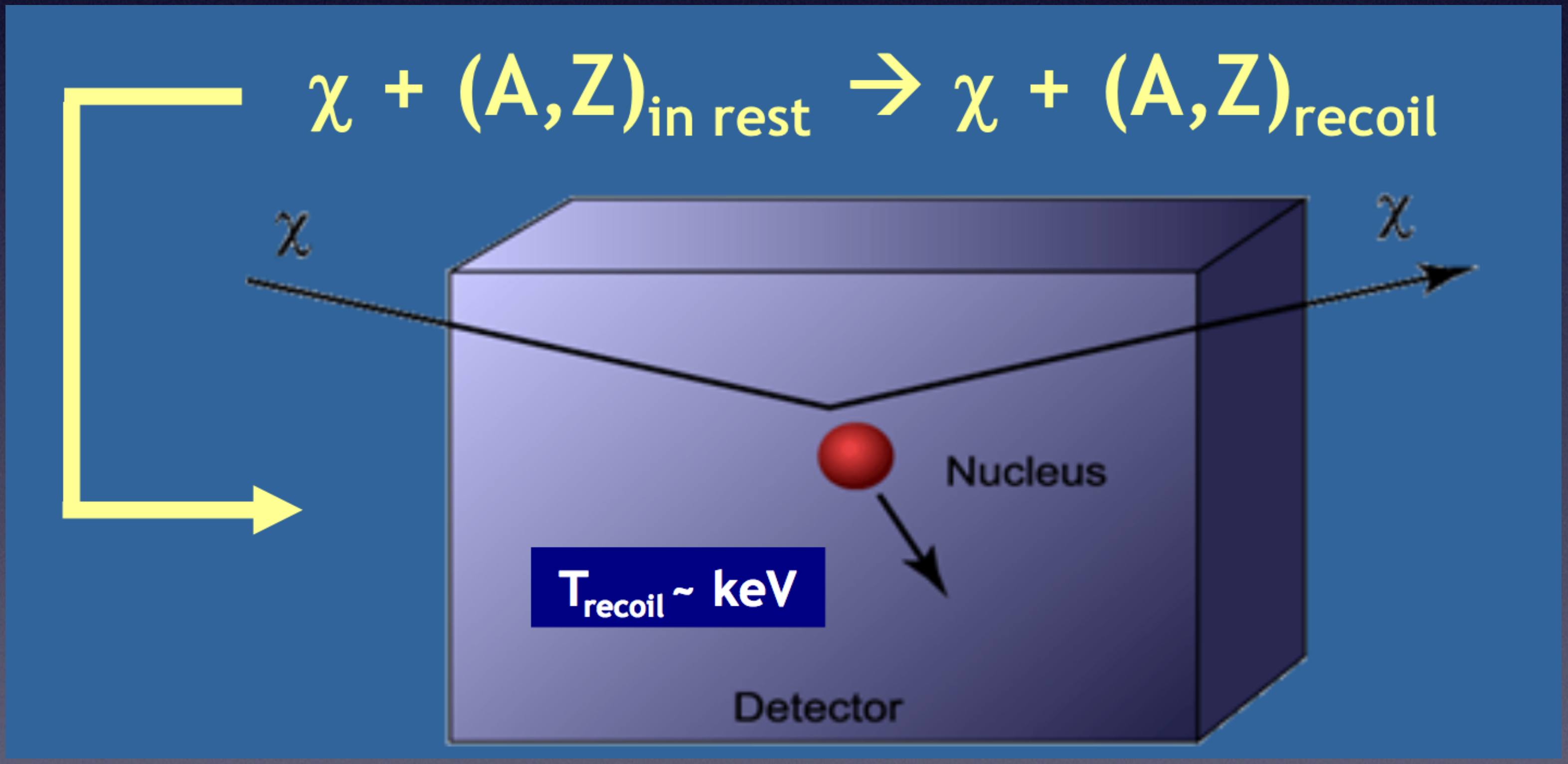
the most popular hypothesis

- It is a relic of the primordial universe
- It is made of stable particles
  (no decay to other particles)
- Relatively **heavy** (about 100 GeV)
- **Very little interaction** with ordinary matter
  (not much more than the neutrinos)

Weakly **I**nteracting **M**assive **P**articles

Can we see it ?

- No real clue on the interaction mechanism (i.e. the interaction lagrangian in a quantum field theory)
- But: $v_{WIMP} \sim 200$ km/s (as the stars)



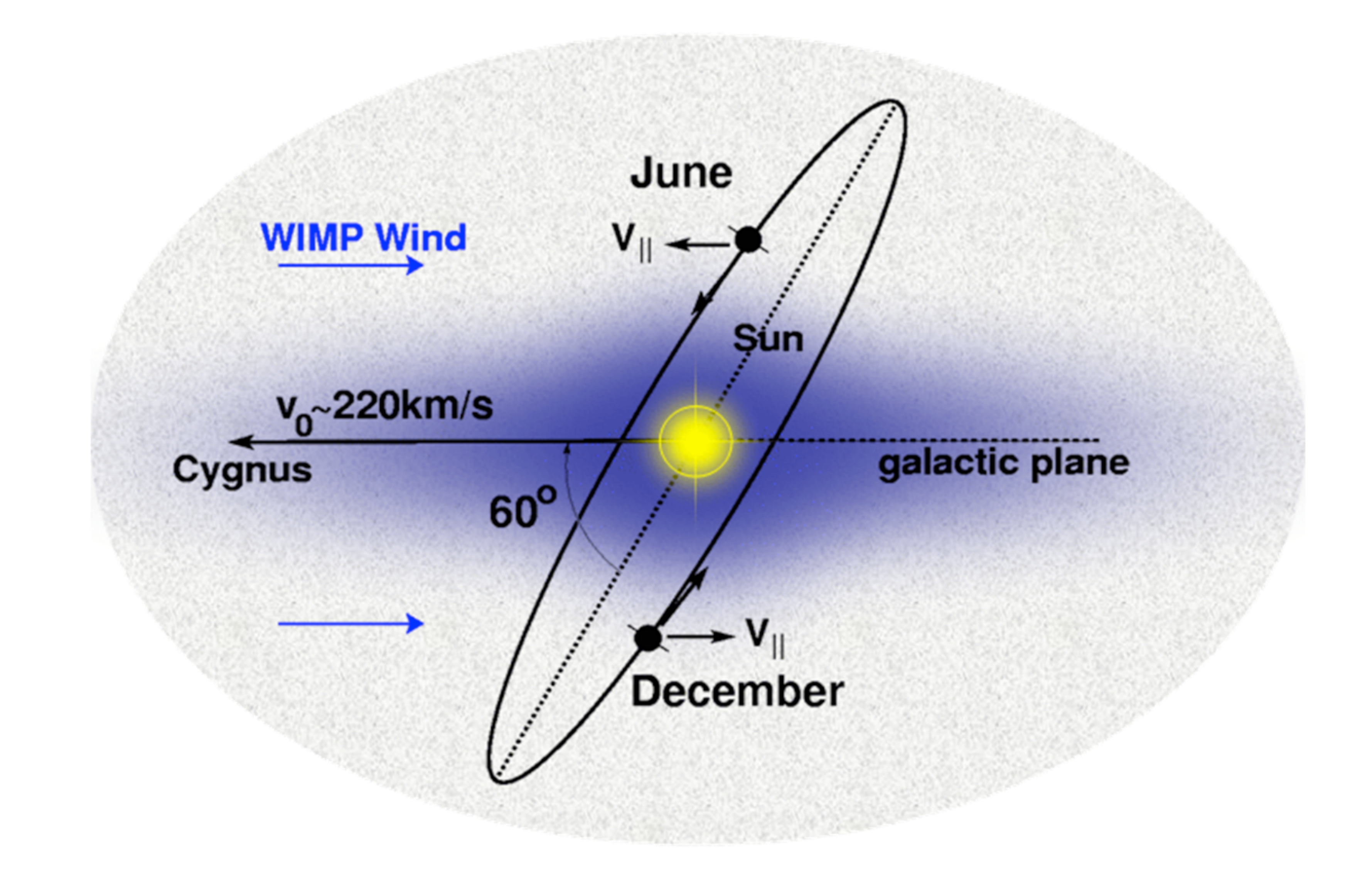
Non relativistic scattering of two similar masses.
Exp. signature: recoiling (nucleus) ion (and nothing else!)

Massive targets

- Little interaction requires a lot of target nuclei to measure few events

XENON 1T at Laboratori Nazionali del Gran Sasso

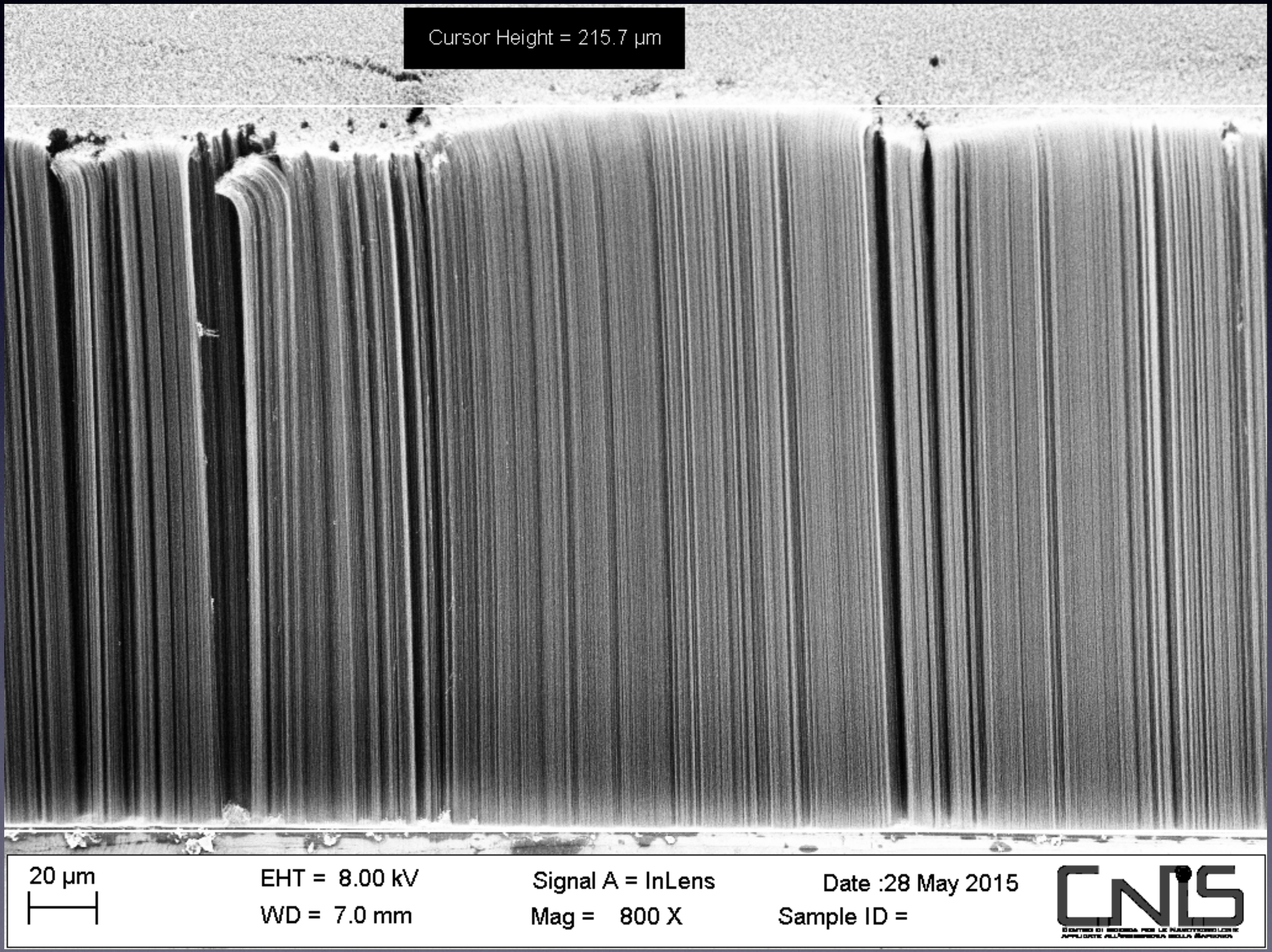
WIMP "wind"



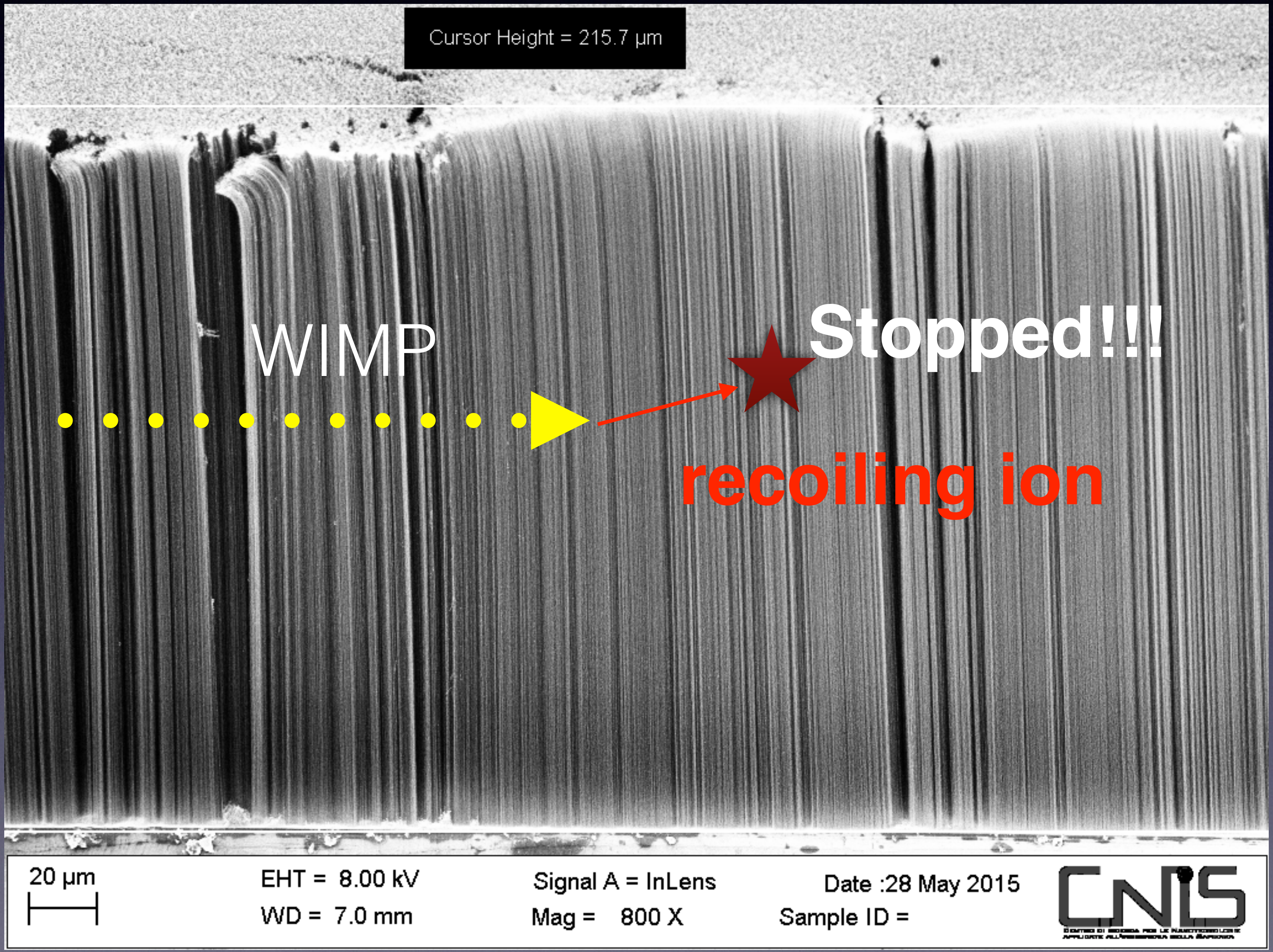
The Earth is moving with the Sun toward the Cygnus constellation

WIMPs are *apparently* moving like a *wind* towards us !
Can we see this wind ? can we measure the WIMPs direction?

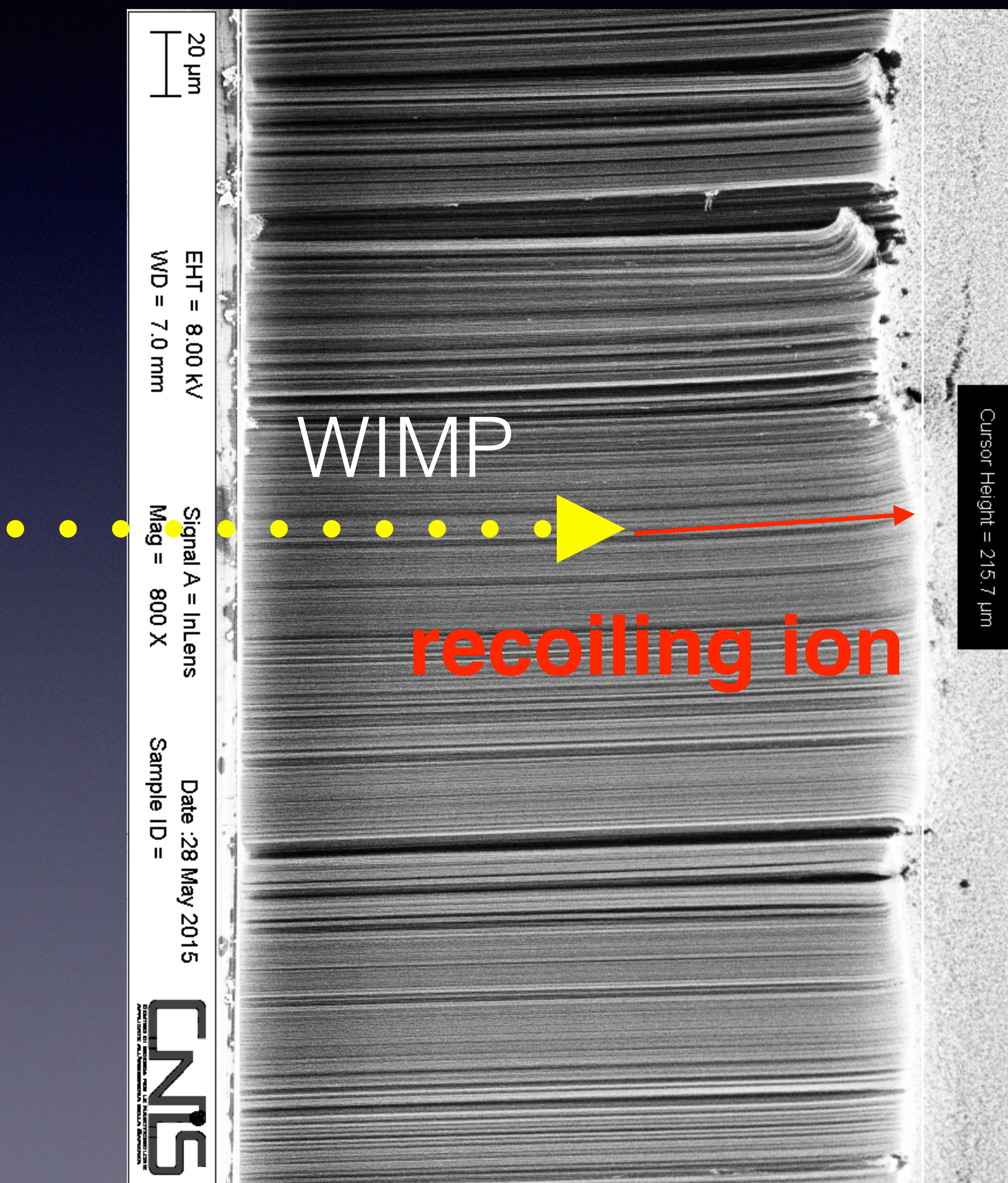
Anisotropic target: aligned CNT



WIMP in the forest



WIMP aligned with the CNT

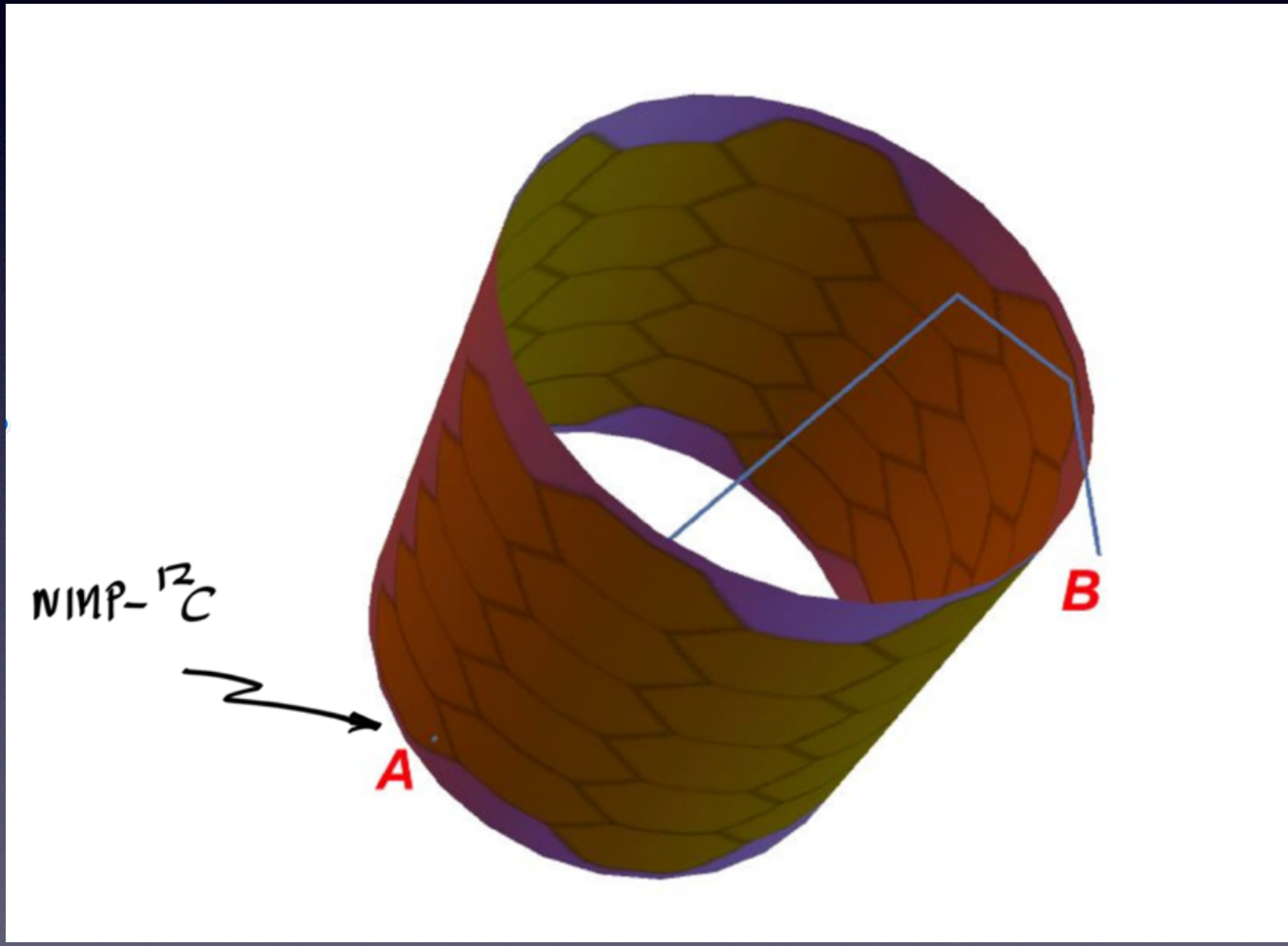


Trasmitted out of the forest

Detector of very slow (few KeV) C ions

Scattering on the CNT

- CNT are empty (electron mainly on the surface)
- Target nuclei on the surface
- Positively charged C ion is repelled by the CNT surface

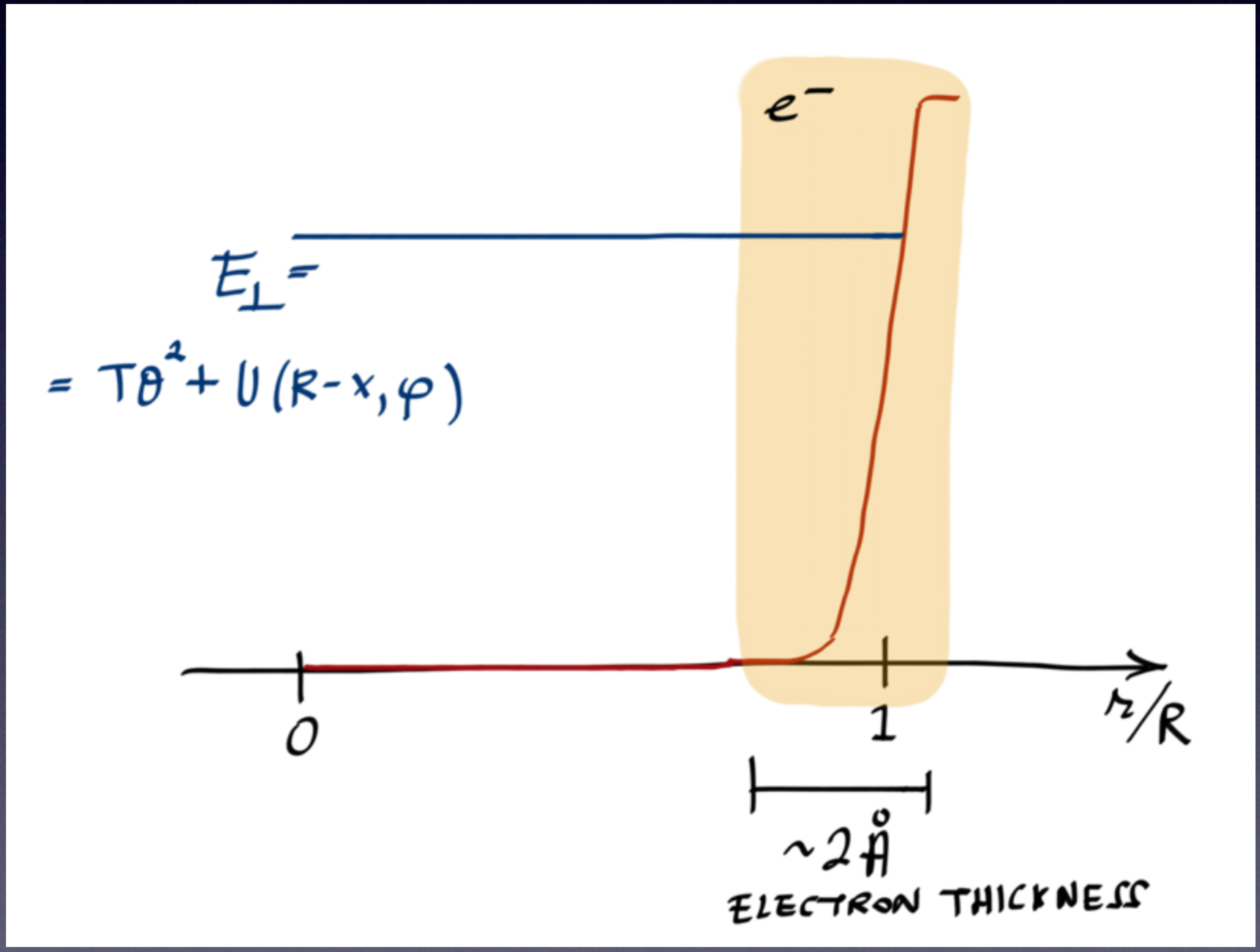


Carbon ion channeling

- Transverse energy is conserved

- Charged ***C*** ion scattered off the CNT are then "**channeled" in the CNT**

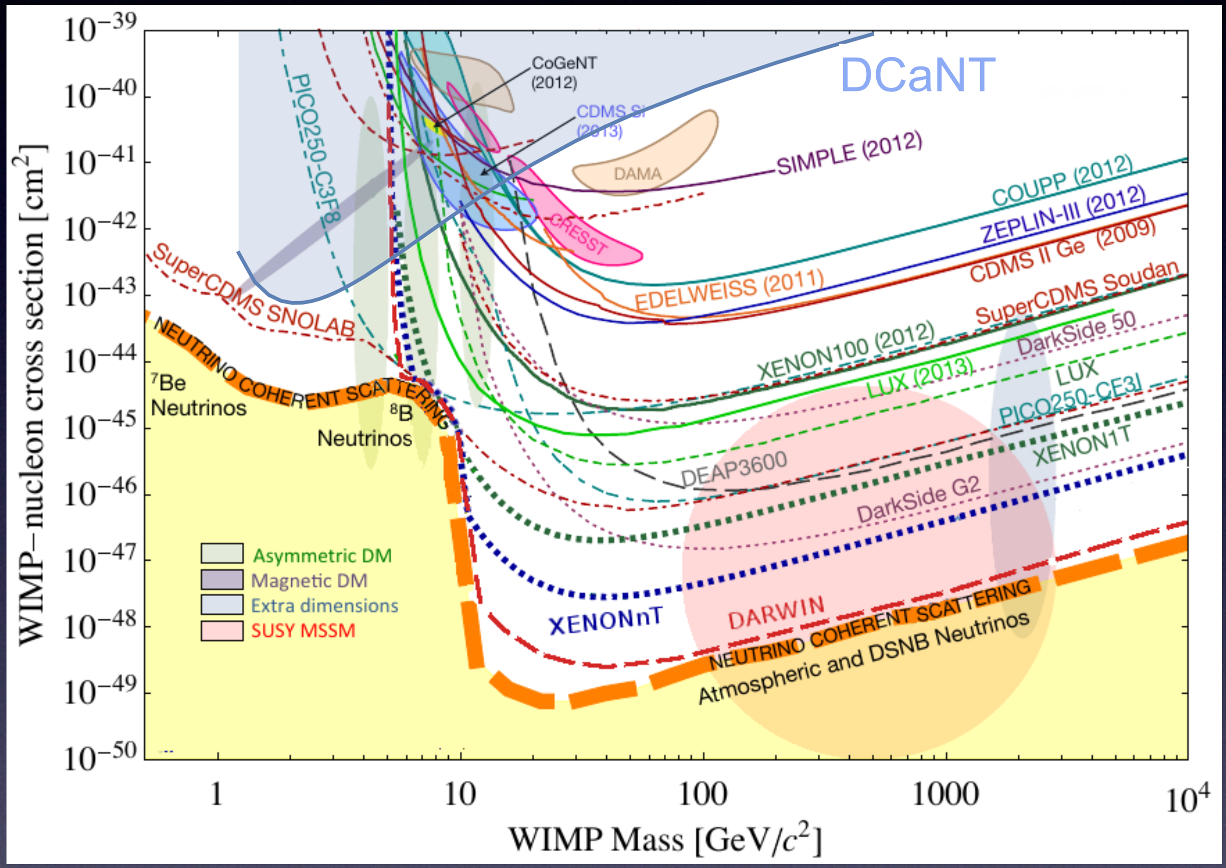
CNT effective potential well



Impact of CNT based detector

- 100 layers, 1 m² each.
- With compact readout, it can have a few m³ volume
- To be rotated tracking CYGNUS direction

Sensitivity for an exposure of 0.4 kgy



Demonstrating the C ion channeling in CNT arrays is the first step!

Experiment at INFN Laboratori Nazionali di Frascati using 400 MeV electrons scattering off the CNT C nuclei

To see the invisible

- Astrophysics and cosmolgy tell us invisible matter must fill the universe
- A lot of experimental efforts going on
  New detection scheme are needed
- CNT might be an **anisotropic target** to pin down the galactic **WIMP direction**
- Eventually we will need **~Kg target of aligned CNT!**
  Is anybody able to grow Kg of aligned CNT

More on this

- INFN Roma Seminars on Dark Matter detection
  - https://agenda.infn.it/conferenceDisplay.py?confId=7236
  - https://agenda.infn.it/conferenceDisplay.py?confId=7510
  - https://agenda.infn.it/conferenceDisplay.py?confId=7807
  - https://agenda.infn.it/conferenceDisplay.py?confId=9366

Bibliography

- **Directional Dark Matter Searches with Carbon Nanotubes** L.M. Capparelli (Rome U.), G. Cavoto (INFN, Rome), D. Mazzilli (Rome U.), A.D. Polosa (Rome U. & INFN, Rome). Dec 28, 2014. 7 pp. Published in **Phys.Dark Univ**. 9-10 (2015) 24-30, Erratum: **Phys.Dark Univ.** 11 (2016) 79-80

- **WIMP detection and slow ion dynamics in carbon nanotube arrays** G. Cavoto (INFN, Rome), E.N.M. Cirillo (Rome U., La Sapienza, Dip. di Energetica), F. Cocina (Rome U.), J. Ferretti (INFN, Rome & Rome U.), A.D. Polosa (Rome U. & INFN, Rome & CERN). Feb 9, 2016. 10 pp. e-Print: arXiv:1602.03216 **to appear in Eur.Phys.Jour. C**

Additional slides

Let’s go back to I.Newton!

- Luminosity (and age) of a star
  -> directly related to the mass of the star

- Total “visible” mass of a galaxy up to a radius r:
  M(<r) ~ r³

Star velocity at distance *r*

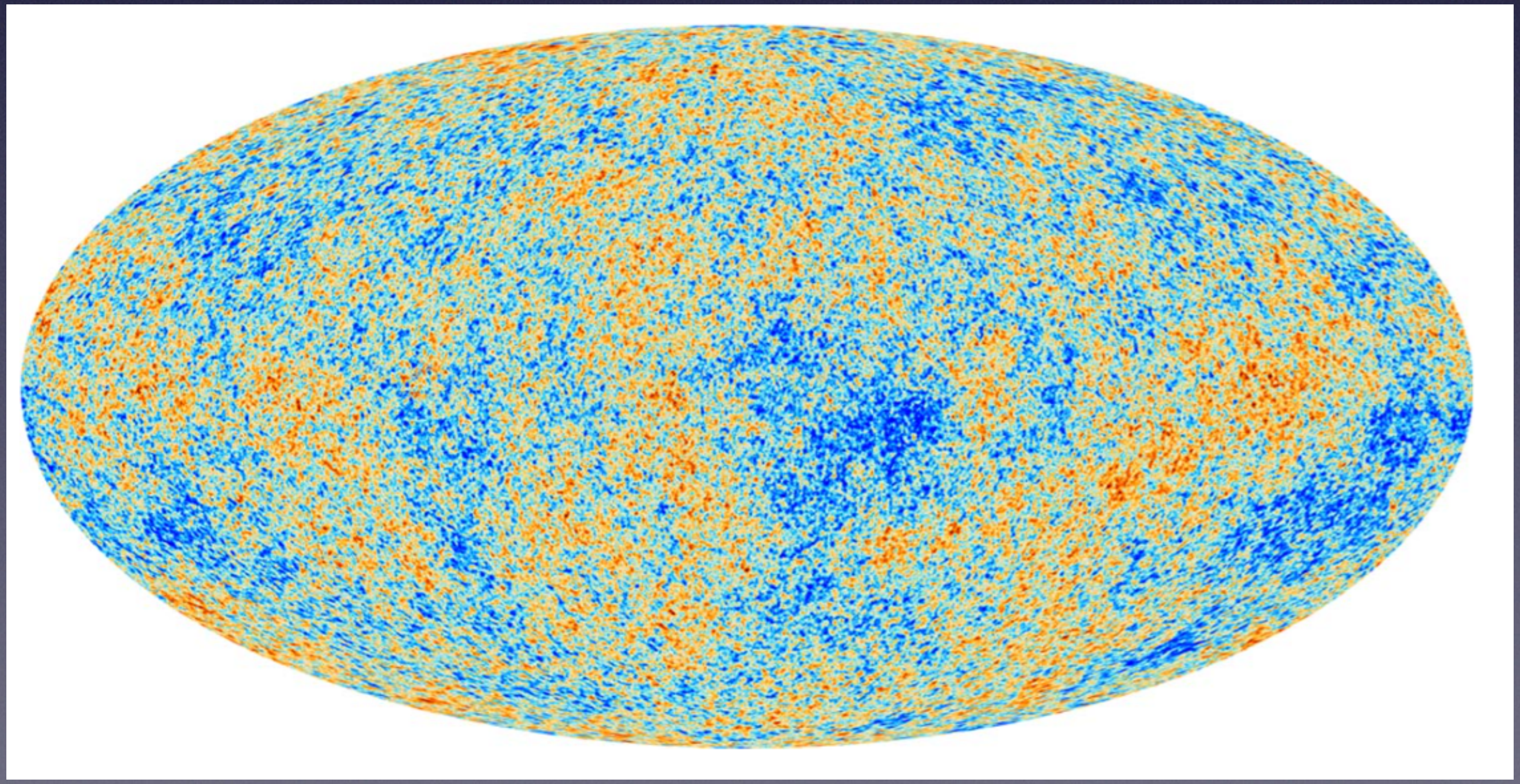
$$v = \sqrt{\frac{GM(<r)}{r}}$$

assuming uniform density

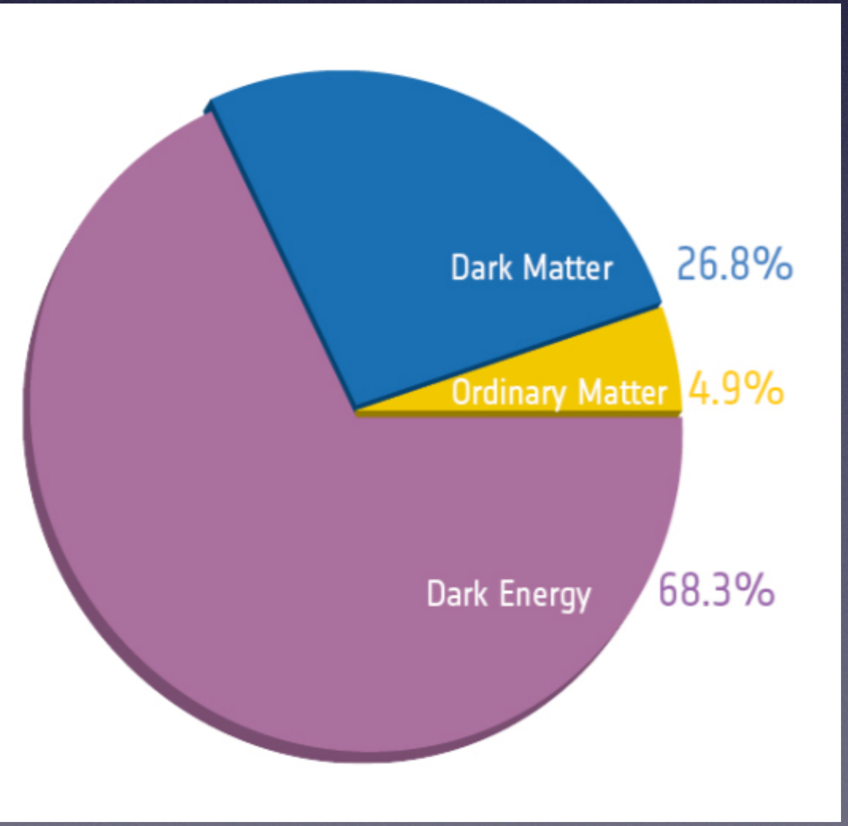
We know that stars are made of ordinary matter (“baryons”)

Other evidences

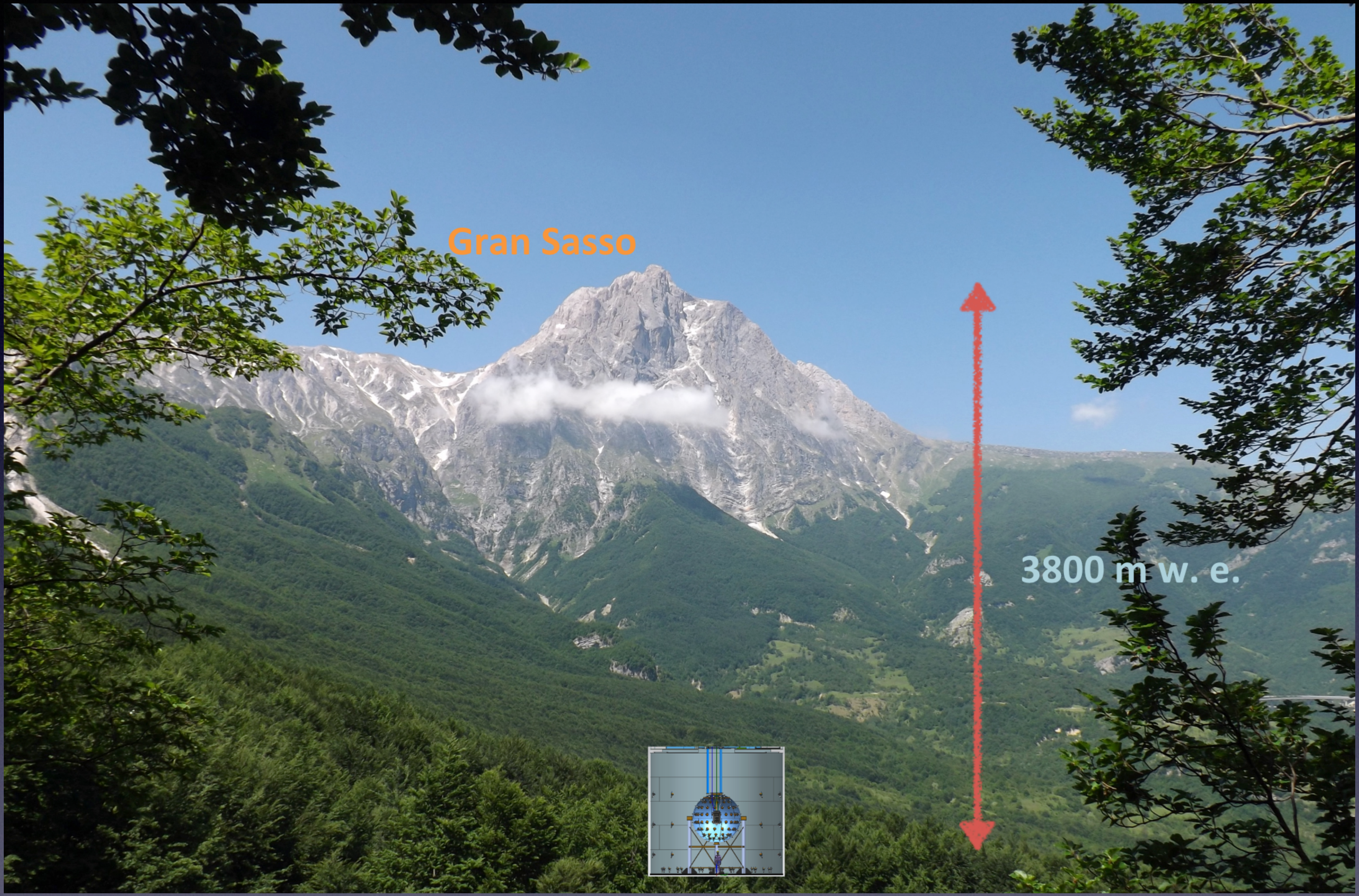
- Gravitational lensing, galaxy cluster, cosmic microwave background anisotropy



Mass of the Universe



INFN LNGS



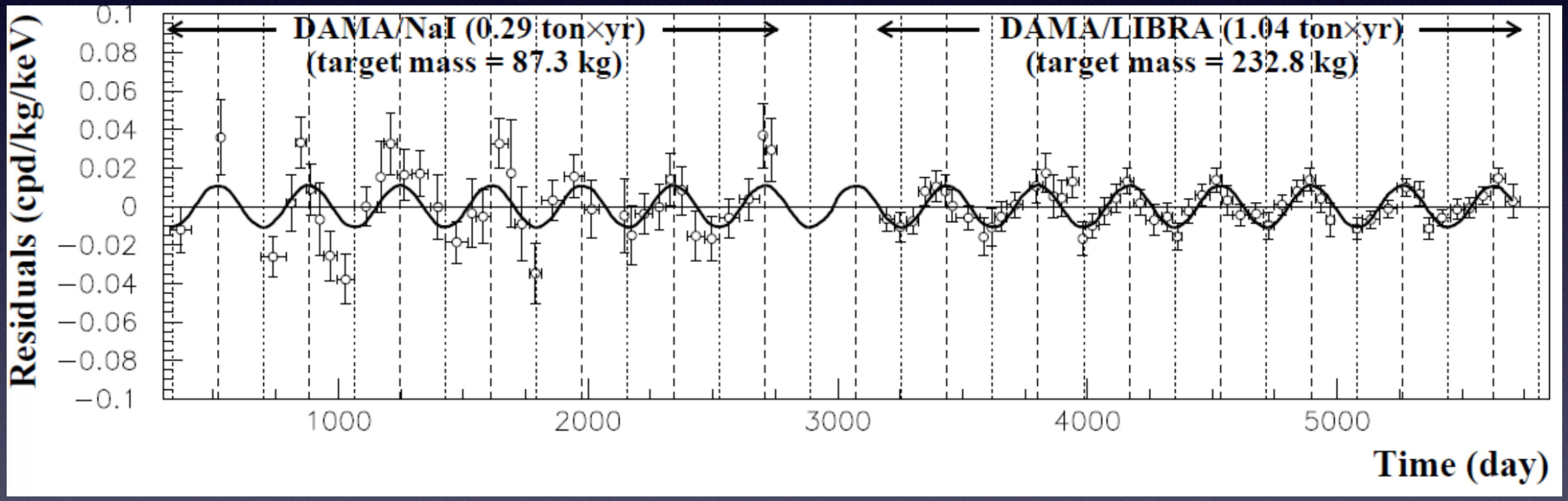
- Mountain rocks screen the labs from cosmic ray induced background events

Radiopurity

- Detector materials can contain tiny amounts of radionuclides: they can easily mimic the WIMP induced ion recoil

Did we see it? DAMA

- Ion recoils detected with CsI(Tl) crystals (scintillation light)
- Rate of the detected recoils as a function of the day (during several years)

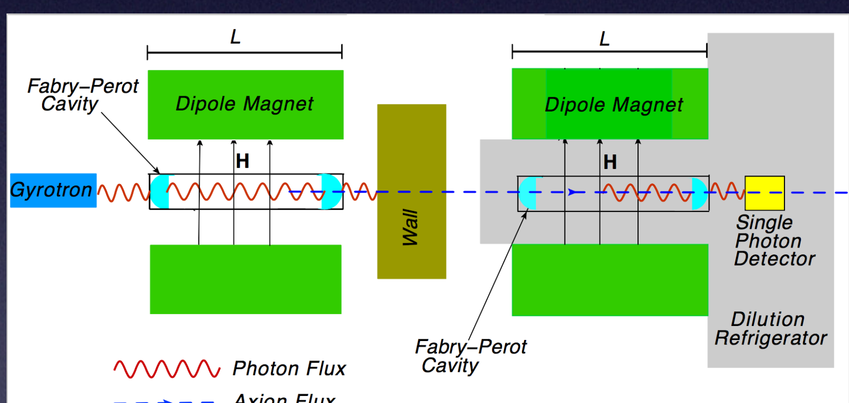


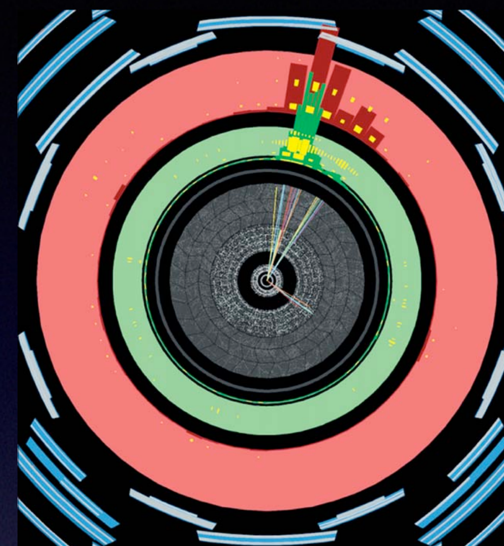
Annual modulation!

Are those really WIMP induce ion recoils ?
No other experiment (out of many!) confirmed this yet.

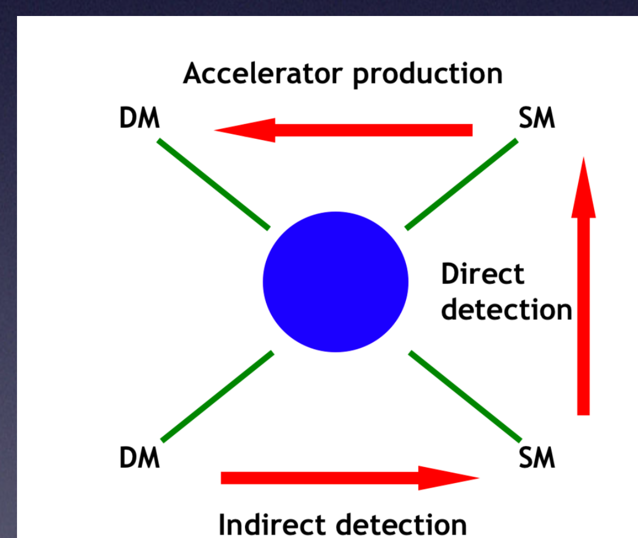
Other hypotheses, other experiments

Axions
(light-shining-thru-wall)

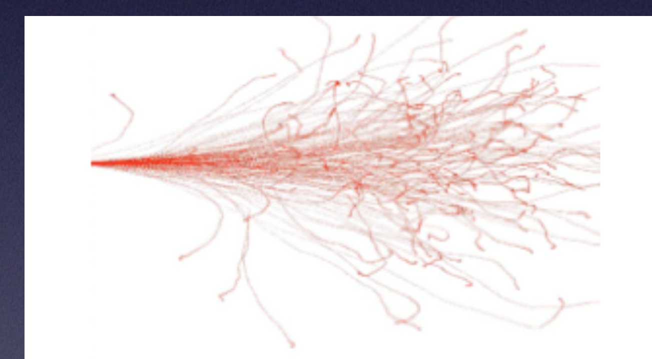


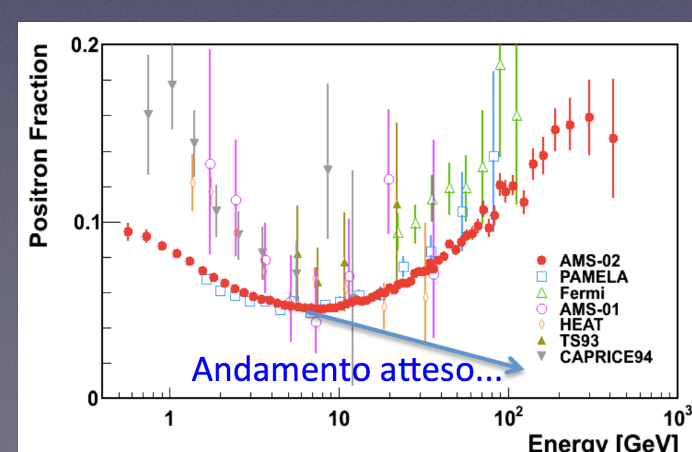


LHC monojet



ion recoil
in gas





Cosmic ray
anti-matter