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Generation-3 Direct Detection Dark Matter Experiments

Science

WIMPs/Dark sector direct detection

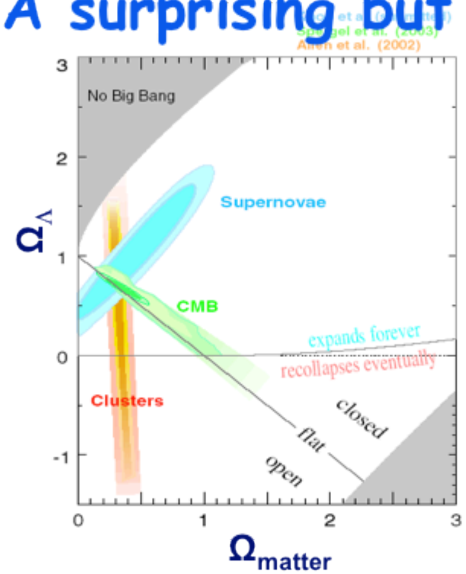
- Description: 2 G3 detectors led by the US
- Cost: 2 detectors for ≈ $150M
- Conclusion: absolutely central, advanced R&D phase (G2)

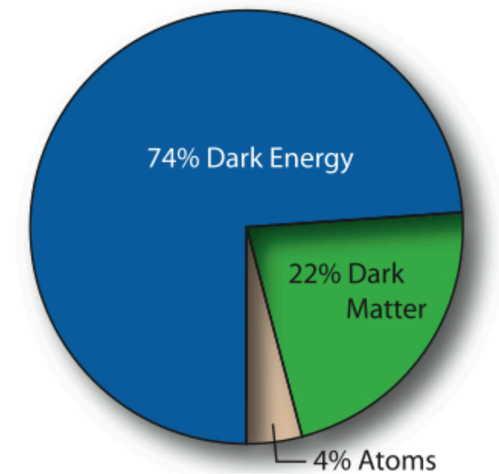
Axions

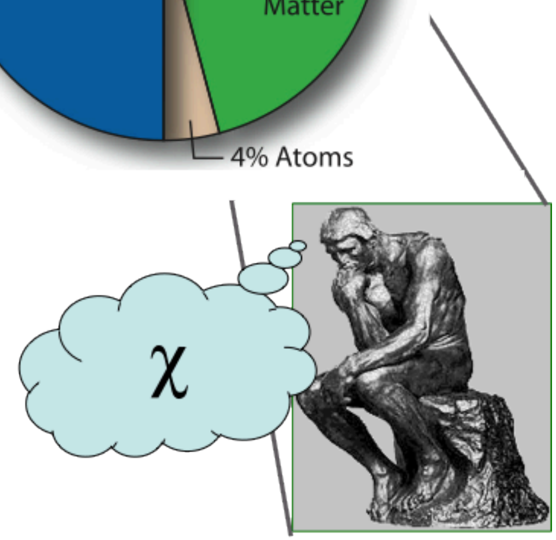
- Current G3 ideas but likely < $100M

The Mysteries of Cosmology

A surprising but consistent picture







The nature of dark matter is a central problem of cosmology!

≠ baryons

≠ light neutrinos

Is it made of particles produced in the early universe?

If yes: evidence for physics beyond standard model!

Tev scale or totally different origin?

Four Different Models

The old timers

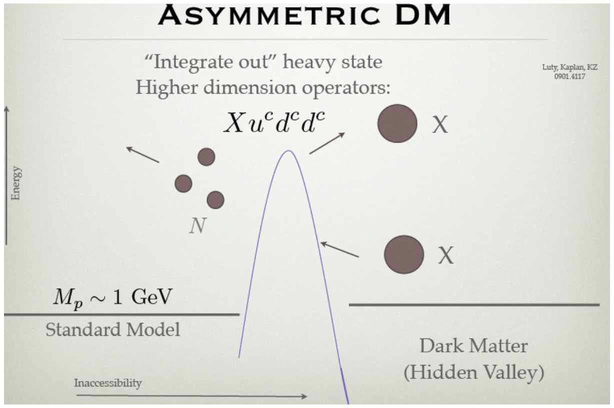
Axions:

May have to be combined

Dynamical restoration of CP invariance in QCD
although a lot of details glossed over, in particular $\theta \approx 1$ (time of inflation, impact of supersymmetry) + topological defects

WIMPs

Hierarchy problem in particle physics
Relic density for thermalized massive particles
although lot of parameters in MSSM,



Increasing Interest for:

A complex dark sector with self interaction

Symmetric (relic density) or asymmetric (if ≈same as matter => $M_\chi \approx 7$GeV)
Possibility of structure with a light mediator (e.g., dark photon)
But interaction with the standard sector ≈ arbitrary

Sterile neutrino

Right handed neutrino related to neutrino mass and baryogenesis
But scale is not fixed a priori (eV ≠ dark matter, keV or >100GeV)

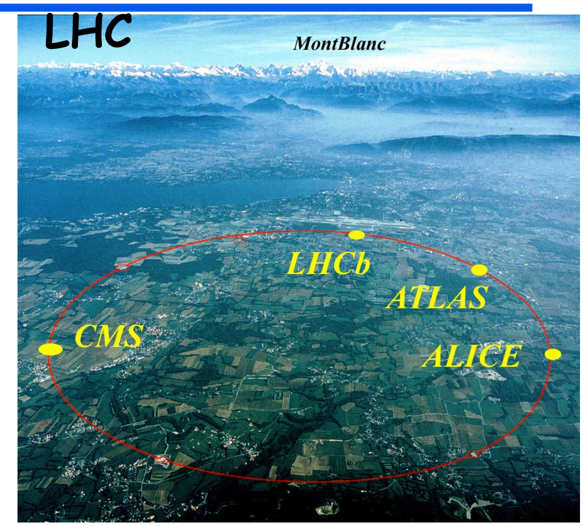
4 Complementary Approaches

Cosmological Observations

Planck

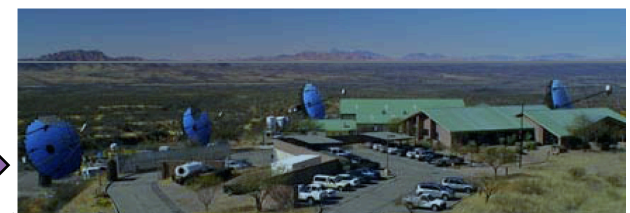
Keck telescopes

Dark Matter
Galactic Halo (simulation)



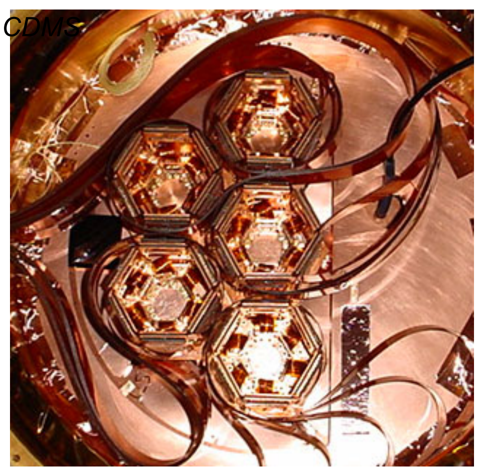
WIMP production on Earth

VERITAS, also HESS, Magic + IceCube (ν)



WIMP annihilation in the cosmos

Fermi/GLAST



WIMP scattering on Earth:e.g. CDMS, Xenon 100,etc.

Generation-3 Direct Detection Experiments

A summary of the US direct detection community discussions

DUSEL writing group -> on going Snowmass studies

Science

The direct detection of the scattering of dark matter particles in a terrestrial target would provide unambiguous proof that dark matter is made of particles and hint at its physical origin.

The 2011 NRC report "An Assessment of the Deep Underground Science and Engineering Laboratory" provided a strong endorsement: "The direct detection dark matter underground experiment is of paramount scientific importance and will address a crucial question upon whose answer the tenets of our understanding of the Universe depend".

Generation 2

either currently being built (Xenon1T, DEAP3600, XMASS 1 ton)

or in advanced R&D for selection by DOE and NSF in the coming year.

The results of these G2 experiments should be available in 2017–2020.

Generation 3=follow up to positive or negative results

- If particle dark matter has been discovered in G2 direct detection, large statistics => mass, cross section, link to galaxy, halo velocity distribution
- Characterization of a signal seen at LHC or in indirect detection
- Increase sensitivity as much as possible if nothing has been seen so far

  Eventually limited by solar or atmospheric neutrinos ≈ 10^{-48} cm^2/nucleon (scalar)

Possible shifts of paradigms: e.g., simple WIMPs to a complex dark sector

G3 DD detectors in the US

Lessons learnt in the last few years

Recent theory developments have increased the likely range of dark matter particle masses and suggested that the phenomenology (e.g., dependence on the target nucleus) may be more complex than for the "vanilla" WIMP scenarios.

Worldwide, we may then need significantly more than two Generation-3 detectors (as was assumed before).

Ideally:

- Several technologies with complementary capabilities
- Different susceptibility to background.
- Enough sensitivity overlap to have at least a second experiment able to cross-check any claim.

US Goals

Maximize the return on our scientific investment:

- Breadth of our reach
- Cross checks
- Reduction of technological risk of experiments at the forefront of background control

Maintain our historical leadership,

- We have led the technology development (thanks to NSF and DOE support)
- About 40% of the community worldwide

=> US should lead the development of at least two such detectors (in single collaboration or in separate experiments)

Operation in early 2020's=> selection process initiated in ≈ 5 years and construction decisions in ≈ 8 years.

Collaboration, Funding, Cost

Collaboration

G2 down selection -> reorganization of the collaborations.

Likely consolidation of the efforts worldwide ->significant foreign contribution if the decision process in the US is effective and timely.

but it is easy to loose leadership through delays in decision and funding

US community has the technological knowledge and the scientific strength to take responsibility of two detectors.

Costs

Engineering studies made in the context of DUSEL indicated a cost on the order of $100M per Generation-3 detector, leading to a total of ~$200M for two detectors (with contingency). Foreign participation may decrease this number by ~30%.

If we need to excavate a new cavity: an additional investment of $50M to $200M (to be amortized over the duration of the facility).

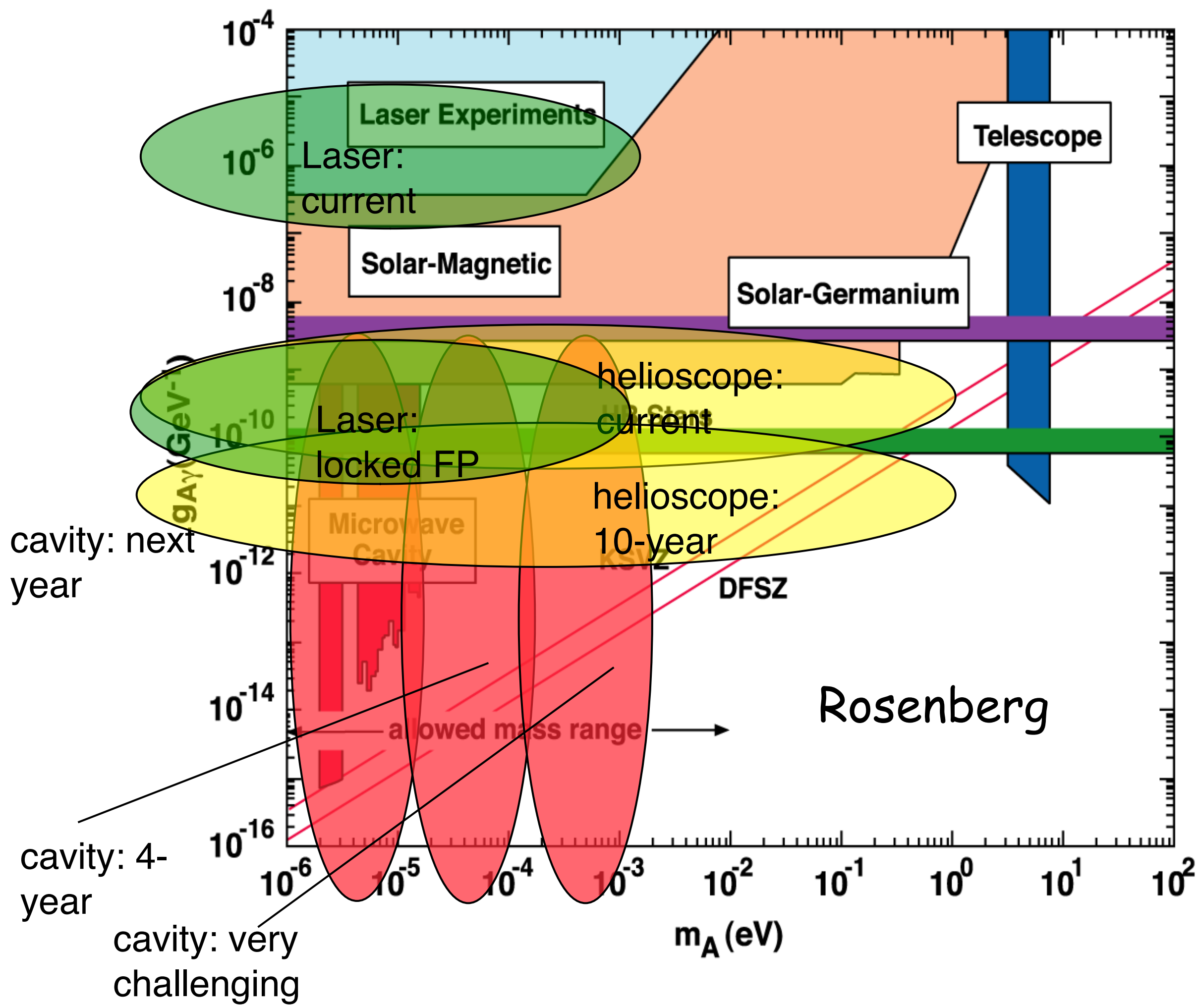
Plan for ≈ $150M for direct detection (in ≈ 8 years)

Absolutely central science

In advanced R&D phase. The G2 experiments= basic demonstration + additional R&D for better sensitivity, lower thresholds

R&D for directional detectors needed but unlikely to be part of G3.

Axions

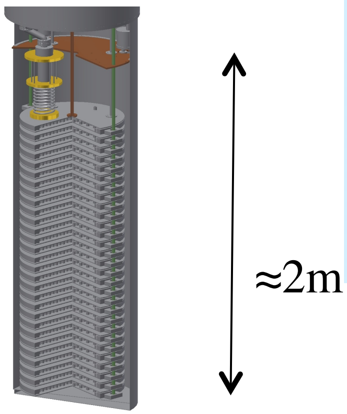


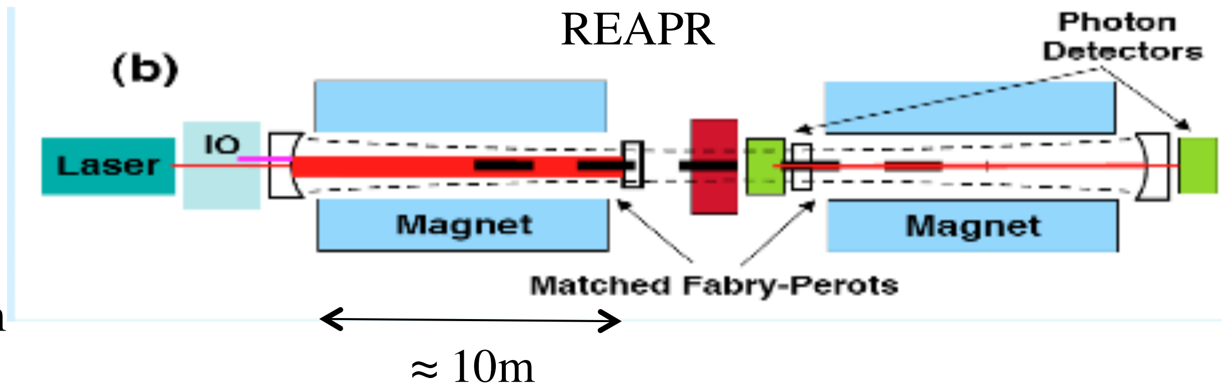
3 directions

- Cosmological axions with RF cavities
- Solar axions
- Light-through the wall experiments

G3 plans

ADMX G3 HF cavity





IAXO magnet may be > $100M

But, according to Rosenberg,

" realistically, the G3 axion program will come in below $100M"