A new era in the search for dark matter

-- JC84

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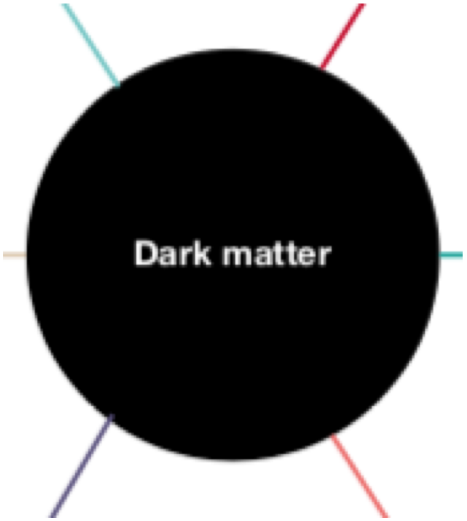
A Growing sense of “Crisis”

- In the dark-matter particle community

Absence of evidence for the most popular candidates

- Weakly interacting massive particles
- Axions
- Sterile neutrinos

- Our best hope of making progress on dark-matter problem
  - Diversifying the experimental effort
  - Incorporating astronomical surveys
  - Gravitational –wave observations

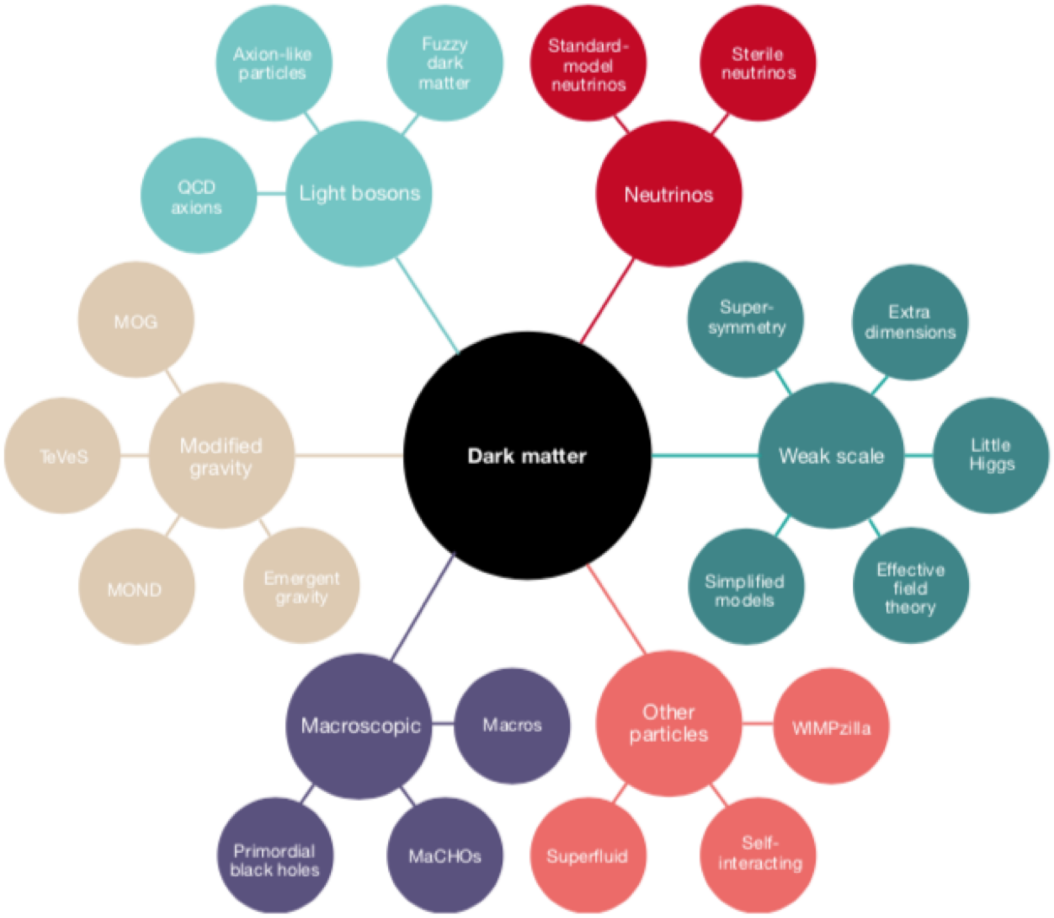


The fall of natural WIMP

- Proposed candidates for DM span 90 orders of magnitude in mass: from ultralight bosons to massive primordial black holes
- Weakly interacting massive particles (WIMPs) attracted most attention over the past 40 years : 10 GeV ~ 1 TeV
  - Produced naturally with the right relic abundance in the early Universe
  - Alleviating the infamous hierarchy problem
    (Higgs mass is the sum of a fundamental intrinsic value plus the correction terms)
  - Most of the parameter space of natural simple SUSY models is essentially ruled out.

Alternatives to natural WIMPs

- Non-natural WIMPs : 1 MeV ~ 100 TeV
- Axions: strong–CP in QCD
- Sterile neutrinos
- No stone left unturned



Probing DM with astronomical observations

- Departures from the lambda cold dark matter model (LSST, DESI, WFIRST)
- Self-interactions
  - Alleviate tensions between numerical simulations and observations at small cosmological scales
  - Cluster mergers and minor infalls – offset between galaxies and DM
- Substructures : cold, non-relativistic, free-steaming length << size of galaxies
  - Sub-dwarf galaxy dark structures in galactic haloes (E-ELT, DESI)
  - Search for perturbations induced by su—dwarf galaxy clumps on cold stellar streams (Gaia, LSST)

Gravitational wave portal

- Primordial black holes
  - Formed before Big Bang nucleosynthesis
- Constraints on modified gravity
  - Eliminate DM by modifying Einstein's theory of general relativity
- Black-hole environment
  - DM might manifest itself as a perturbation in the waveform of binary black holes.

The future

- A new era in the search for DM has begun with new guiding principle ‘no stone left unturned’:
  - Fuzz dark matter (10^{-22} eV) to primordial black holes (10 M_sun)
  - Fully exploit existing experimental facilities – most notably the LHC
  - Complete the search for WIMPs with direct-detection until reaches the neutrino floor
- Diversify the experimental effort: gravitational-wave interferometers and astronomical surveys
- New opportunities in extracting such information from the booming field of machine learning

Questions

Ryuta

Q. Around page 2, a topic of self-interaction between dark-matters is described

based on the comparison of simulation with the observation and we can find an expectation

value of its upper limit as:

" it is possible to set and upper limit on the velocity-independent, elastic

cross-sections sigma of self-interacting dark matter of mass m: sigma/m ~ 1 cm^{2}g^{-1}. "

I feel the order of this value might be close to that of normal nucleon's,

but if that is the case why that high value they are talking about ?

or is it possible that it's simply hard to see the difference of shapes if the number is small ?

Shan

In the sentence "Another very popular class of dark-matter candidate is that of axions and axion-like candidates." What's Axions? I am curious why it is called this name? And what's the relationship between axion and ‘strong-CP problem and "the neutron electric dipole moment"?

Yuhang

In self-interactions part, the paper says: "The observables in this case would be the offset between the galaxies and the dark matter (in addition to the offset between dark matter and gas) due to the possible non-collisional nature of dark matter, and the amount of ‘sloshing’ and ‘wobbling’ of galaxies around the center of the dark-matter halo."

How to explain the offset? What's the difference between the offset dark matter and gas and the offset between the galaxies and the dark matter?

Suyu

In Non-natural WIMPs part, it says 'the range of WIMP masses expand to encompass masses as low as around 1MeV or as high as around 100TeV'. Does it means non-natural WIMPs can cover the WIMPs' case?

Kai

Based on the fact of the fall of the natual WIMP, does the direct detecting experiments, such as PANDAX, CDEX in Jinping, still have a promising future? Could they still play important role in searching for the "alternatives to natural WIMP"?

Amit

Since Modified Newtonian Dynamics(MOND) theory has not succeeded exceptionally well except for the solution of galaxy rotation curve problem and almost have been ruled a decade ago, How can these theories be reconciled with observations by mimicking the behavior of cold dark matter on cosmological scales effectively and very precisely?