What MM=DM can't explain in cosmology?

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Neutron Oscillations: Appearance, Disappearance, and Baryogenesis (INT-17-69W)
National Institute for Nuclear Theory (INT)
University of Washington in Seattle, Washington, USA
October 23 - 27, 2017.

The subject and the title were suggested to me by the Organizers to play the role of the devil advocate.

However, in the process of preparation of this presentation I turned into the devil prosecutor.

But I like mirror matter and believe that the problems are solvable.

The assumed essential properties of mirror matter (MM), briefly:
"Mirror" usually implies symmetry, or at least some similarity, as if we look into the mirror. However, parity may be strongly non-conserved. Probably a better term is "shadow world".
The same particle content, but the particle properties may be different, though identical properties are allowed.
Two open questions:
1. How much the mirror sector is different from the usual one?
2. How strong can be interactions between "us" and mirror particles?

The universe us surely strongly asymmetric with respect to UM and MM, because BBN and CMB demand that our world cannot be equally populated by the usual and mirror particles, at least for particles with masses below MeV.

Extra species of relativistic matter are restricted by BBN and CMB.

Analysis of primordial ^{4}He results in

$$N_\nu^{(eff)} = 3.51 \pm 0.35 \ \ (68\% \ CL),$$

and the data on ^{2}H abundance gives

$$N_\nu^{(eff)} = 3.28 \pm 0.28.$$

According to the Planck measurements:

$$N_\nu^{(eff)} = 3.30 \pm 0.27.$$

($N_\nu^{(eff)} = 1$ supplies into the cosmic plasma the energy density equal to that of one neutrino species.)

The analysis of BBN and CMB do not contradict the canonical value $N_\nu^{(eff)} = 3.046$. However, it's intriguing that the central values of all measurements are noticeably above three. Maybe these data indicate the existence of light sterile neutrino or some other form of dark radiation, e.g. Mirror Matter.

Conclusion about the MM energy density: it could not exceed 10% of the total cosmological energy density at RD stage, after inflation.

Hence the universe heating after inflation must break mirror symmetry. Two competing assumptons for the driver of inflation:

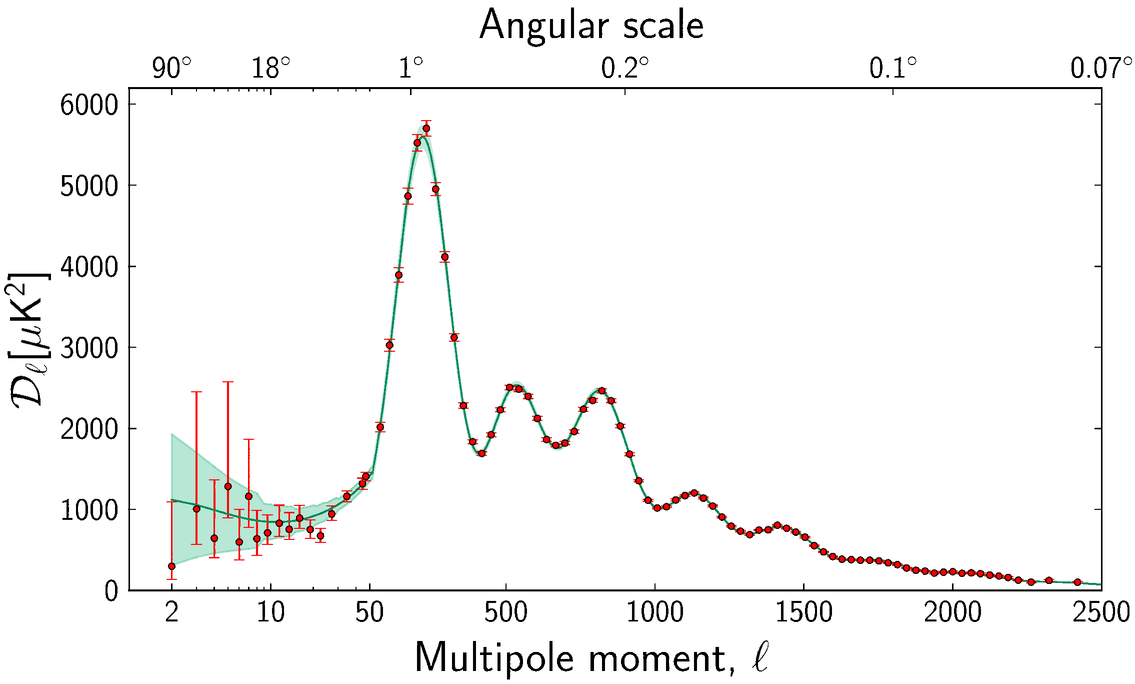
1) scalar field, inflaton, Φ;

2) curvature scalar in R^2 theory (Starobinsky). The latter became popular last years due to a strong upper limit on the primordial GWs.

At the end of inflation either Φ or R started to oscillate, producing particles and heating the universe (Big Bang).

R^2-version is excluded, since gravity is equally well coupled to all forms of energy, while the creation of MM must be subdominant.
Φ may have different strength of coupling to MM and the usual matter (UM), so the creation of MM would be suppressed w.r.t. UM.
Gravitational particle production operates also in Φ-scenario but it is weaker than the heating by the Φ decay.
So if 'in mirror matter we trust", we must reject R^2 inflation and choose the version which allows for mirror symmetry breaking and does not predict too high level of GWs

Planck: $\Omega_b h^2 = 0.02205 \pm 0.00028$.
Helium-4: $\Omega_b h^2 = 0.0234 \pm 0.0019$
Deuterium $\Omega_b h^2 = 0.02202 \pm 0.00045$,
NB: the BBN measurements are sensitive to cosmology of the very early universe with the age $t \sim (1-200)$ sec, while CMB presents information about the universe about 100 000 years old. Before accurate CMB data, Ω_b was "measured" by primordial deuterium - "baryometer". Now CMB does it better by the ratio of the peak heights and the photon diffusion length.



Spectrum of angular fluctuations of CMB by Planck. Green area is the cosmic variance

Can it be that $N_\nu^{(eff)}$ and $\Omega_b h^2$ determined from BBN and CMB would have different values? Or even from the two features of CMB: ratio of the heights of the neighboring peaks and the diffusion length?

Yes, it is but the effect may be induced by the ordinary matter, e.g. by sterile neutrinos.

Comment: relativistic species at BBN $g_* = 10.75$, includes nu, gamma, and electron-positron pairs, while CMB feels only neutrinos and n_B/n_γ.

Secondary heating of MM through interaction with the usual thermal bath, e.g. $e + \gamma \to e + \tilde{\gamma}$. Abundant mirror photons at $T \gtrsim m_e$ are not created if their coupling to the usual electrons is strongly bounded from above:

$$\tilde{\alpha}_e < 10^{-20}.$$

The coupling of mirror photons to quarks is two orders of magnitude weaker, $\alpha_q < 10^{-18}$.
The coupling of the usual γ to MM, which is colder than the normal matter, can be restricted by the absence of any distortion of the frequency spectrum of CMB at the level 10^{-4}.
No other limits???

MM and the universe structure.

Problems with the standard ΛCDM.

1. Missing satellites: CDM predicts an order of magnitude more galactic satellites than observed.
2. Destruction of galactic disk: Even if the number of the satellites is reduced by star formation winds, many smaller tightly bound DM systems would survive and destroy galactic disk by gravitational heating.

3. Central cusps: singularity in galactic centers, $\rho_{DM} \sim r^{-N}$, N=1-2, while flat profile is observed.

4. Excessive angular momentum: CDM predicts much smaller galactic angular momentum than observed.

Possible solutions:

1. Insufficient accuracy of numerical ~~stimulation~~ simulation.

2. Dissipative and self-interacting DM (e.g. mirror). Seems to work in the opposite direction.

3. WDM, or better, a mixture of WDM and CDM.

One more piece of data against dissipative DM: galactic haloes are much larger than galaxies.

Problem of cosmic conspiracy:

$\Omega_{\mathrm{DM}}(0.25) \sim \Omega_{\mathrm{DE}}(0.7) \sim \Omega_{\mathrm{B}}(0.05)$

or even stronger:

$\Omega_{\mathrm{CDM}} \sim \Omega_{\mathrm{WDM}} \sim \Omega_{\mathrm{DE}} \sim \Omega_{\mathrm{B}}$

WHY?

We need generation of baryon asymmetry and creation of DM by the same or related mechanism.

Can MM help to solve this problem?

For example similar magnitudes of the baryon asymmetries and higher masses of mirror baryons suggest natural explanation of the conspiracy between the visible and dark matter (asymmetric DM).

More about differences between UM and MM.

1. $T_{MM} < T_{UM}$.

2. The non-observed CUSPs in galaxies, created by cooler MM and due to emission of dark radiation should be more pronounced than CUSP in the standard CDM cosmology.

If MDM is in the form of stellar-like stellar-like objects they would distort star morion in the galactic center, or mimic effects of the central SMBH.

Maybe MDM is warm?

3. Galactic haloes are much larger than galaxies, while MM leads to more compact halos.

6. Adiabatic density perturbations created by inflaton are the same for all forms of matter::

$$\delta\rho_j/\rho_j = const$$

Hence the density fluctuations of mirror baryons are larger than in the standard case.
7. Different recombination temperature of MM and UM. Higher or lower?
Different diffusion(Silk) damping scale prior to the mirror recombination.
8. Spectrum of the angular fluctuations of MCMB with larger $\delta\rho_B$
May be not essential. But the structure formation depends upon the diffusion damping scale and on the Jeans wave length of the ionized and neutral (mirror hydrogen).

Verdict:

To be issued by the GRAND JURY.

THE (HAPPY?) END