

# Cold and Warm Dark Matter Particles in the Mirror Model with Massive Mirror Photon

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One of a promising asymmetric dark matter model is the mirror model, where the gauge group is doubled the standard model (SM) gauge group, i.e.  $SU(3)_1 \otimes SU(3)_2 \otimes SU(2)_L \otimes SU(2)_R \otimes U(1)_{Y1} \otimes U(1)_{Y2}$ , and the particles content consist of the ordinary (o) SM particles (plus the right handed neutrinos) and their parity mirror (m) partners. To this model I add a singlet scalar  $\phi_e$  and its mirror partner  $\phi_E$ , whose quantum numbers are the same as the singlet right handed electron and its m-partner. The kinetic mixing of the abelian gauge bosons has been ignored, and the particles are assumed to be separated and thermally decoupled into o- and m-sectors after the electroweak symmetry breaking. A general scalar potential which is invariant under the gauge group and the parity mirror symmetry, can have parameters that allows the  $\phi_E$  to have a non zero VEV, while the  $\phi_e$  remains with zero VEV. As consequences of this, several phenomena can take place: 1. The  $SU(2)$ -doublet scalar (which is the usual SM Higgs) and its m-partner can have non-zeros and unequal VEVs; 2. Mirror photon will gain mass, with its mass naturally in the order of neutral weak boson mass; 3. Unlike its mirror partner, since  $\phi_e$  has zero VEV, it will decay slowly after decoupled from thermal equilibrium, thus producing more entropy in the o-sector than in the m-sector, and making the temperature of o-sector higher than the m-sector. This gives an escape to the BBN constraint for this model; 4. There are mixings among six types of particles, the o- and m-singlet neutrinos, the o- and m-doublet neutrinos, and the m-singlet and m-doublet electrons. One of the consequence of this mixing is the m-doublet electron will be lighter than the o-electron, and can have mass in the keV order, thus they may be the keV sterile neutrinos.

Assuming the VEVs of the usual SM Higgs and its m-partner are of the same order, the asymmetric part of m-baryons will contribute to the energy density approximately the same as the o-baryon energy density  $\Omega_B$ , and they are forming the cold dark matter part of the model. The symmetric part of m-baryons will annihilates into m-mesons which eventually will decay into m-electrons and m-neutrinos. The m-electrons cannot annihilate into m-photons, and its abundance is comparable to the o-photons. But since m-electron mass is of the keV order, they can contribute to the remaining part of the dark energy density as a warm dark matter with  $\Omega \approx 4\Omega_B$ .

## Summary

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