Национальный исследовательский ядерный университет «МИФИ»
Кафедра физики элементарных частиц №40

Научная исследовательская работа студента на тему:

Effects of Dark Atom in Structure Formation

Работа студента 3-ого курса :Карни Мд Вейс Ал (Б19-102)

Руководитель проекта: проф. Хлопов М. Ю.

Москва 2021

Dark *O*He atoms

There is overwhelming evidence for the presence of a dark matter (DM) in the Universe , and together with most popular, but still elusive, weakly interacting massive particle (WIMP), there exist numerous theoretical models including axions, sterile neutrinos, primordial black hole, strongly interacting massive particles, and superweakly interacting particles. Even electromagnetically interacting massive particle (EIMP) candidates are possibly hidden in neutral atomlike states. Dark *O*He atoms, in which hypothetical −2 charged particles are bound with primordial He nuclei, occupy a special place on this list. Such models involve only one free parameter of new physics— the mass of −2 charged EIMPs—so many features of this type of dark matter can be described by the known nuclear and atomic physics.

Glashow's EIMP Model

In 2005, Glashow proposed a kind of EIMP model, according to which stable teraquarks ***U*** (of mass of the order of tera-electron-volts and of electric charge +2/3) form a ***UUU*** baryon bound with tera-electrons E of charge −1 in the neutral (***UUUEE***) atom.

$(\mathbf{HeE})^{+}$ ions

He formed in the big bang nucleosynthesis captures all the free E in positively charged $(\mathbf{HeE})^{+}$ ions, preventing a required suppression of the positively charged particles that can bind with electrons in atoms of anomalous hydrogen. In general, stable single charged EIMPs form anomalous hydrogen either directly binding with ordinary electrons (+1 charged EIMPs), or indirectly (−1 charged EIMPs) forming first +1 charge ion with primordial He and then anomalous hydrogen with ordinary electrons . Therefore, anomalous hydrogen overproduction excludes any significant amount of stable single charged EIMPs.

*O*He separation from plasma

In the early Universe when temperature fell below 1 keV, the rate of expansion started to exceed the rate of energy and momentum transfer from plasma to *O*He gas. As a result, *O*He decoupled from plasma and radiation and played the role of dark matter on the matter-dominated stage. The averaged baryonic density in the course of structure formation and in galaxies is sufficiently low, making baryonic matter at large scales transparent for *O*he.

*O*He does not follow the condensation

For that reason, in the period of formation of the first objects, *O*He does not follow the condensation of baryonic matter, so the *O*He model avoids constraints from the cosmic microwave background and formation of the first stars . In galaxies and galaxy clusters, *O*He behaves like collisionless gas, avoiding constraints from Bullet Cluster observations . Only dense matter objects like stars or planets are opaque for it. The protostellar cloud with the solar mass becomes opaque for *O*He.

Why *O*He are of special interest?

With the lack of evidence for WIMPs in direct and indirect searches for dark matter, the fields of study of possible dark matter physics should be strongly extended. Dark atoms of *O*He are of special interest in view of the minimal involvement of new physics in their properties. The hypothesis on stable double charged particle constituents of dark atoms sheds new light on the strategy of dark matter studies, offering a nontrivial explanation for the puzzles of direct and indirect dark matter searches.

Future Study.

Dark atoms like *O*He are nuclear interacting and lead to a specific type of scenario of large scale structure formation, which I plan to study further.