論文の内容の要旨

Oscillon Formation and 21cm Forest by Ultra-Light Axion-like Particle

（非常に軽いアクシオンによるオシロン形成と21cm線を用いた観測）

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While the cosmological constant and cold dark matter (ΛCDM) model succeeds in explaining the large scale structure of the universe, it contains astrophysical problems on small scales around kpc, which represents the excess of the matter density in numerical simulations. Ultra-Light Axion-like Particle (ULAP) generated from the dimensional reduction in string theory is one of the famous solutions to these problems. This is because the cosmological structure below its de Broglie wavelength, which corresponds to the relevant scale $\sim$ kpc if the ULAP mass is about $m \simeq 10^{-22}$ eV, are smeared out by its quantum pressure. When such a light scalar particle oscillates with an $\mathcal{O}(1)$ amplitude in a potential shallower than quadratic, the large fluctuations produced by parametric resonance can create localized dense objects, oscillons. Because of their longevity due to the approximate conservation of the adiabatic invariant, they can survive up to the recent universe around redshift $z \sim \mathcal{O}(10)$. One of the methods to probe the matter structure below the scale Mpc is 21cm line, which is generated from the energy difference due to the hyperfine splitting by the interaction between the electron and proton spins in neutral hydrogen.

In this thesis, we examine the possibility to detect ULAP oscillons by the 21cm forest, which is the consecutive absorption of the 21cm line by dark matter mini-halos. First, to precisely estimate the effect of oscillons on the matter structure, we derive the analytical formula of the oscillon power spectrum and confirm that it reproduces our simulation results. Then, using these values, we calculate the number of intersections of a background source with mini-halos depending on the optical depth. We find that the oscillons can enhance the number of 21cm line absorption when the ULAP mass is smaller than 10^{-19} eV and the fraction of ULAP to dark matter is much larger than 10^{-2} in the case of a monodromy type potential. These results are also applicable to any other scalar potentials that produce long-lived oscillons.