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Supermassive black holes and dark halo from the Bose-condensed dark matter

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Most of the galaxies seem to harbor supermassive black holes (SMBH) of mass 10^{6-10} times the solar mass in their center. Recent many surveys on the galaxies deep in the sky reveal that such heavy SMBHs have already existed at the redshift 6-7. There have been quite a few research to explain the formation of many SMBH in such an early stage of the Universe. However, there is no definite settlement despite many efforts over forty years.

In this paper, we propose a coherent collapse of the wave formed from the Bose-condensed dark matter contrary to the previous approach of the baryon particle collapse. It is very natural to expect light bosons to form the quantum condensed state. They coherently collapse to form black holes as we demonstrate in this paper. We show that this is possible by using the Gross-Pitaevski equation with some approximations.

The point of the present study is not only the formation of SMBH but the systematic separation of the dark matter cloud into the central SMBH and the surrounding dark halo structure. Actually, the whole cloud collapses into SMBH if we forget the angular momentum. On the other hand, if we introduce the present amount of angular momentum, then no black hole can be formed. Both of them are far from observational situations. Therefore we consider the early stage of a galaxy when it was acquiring angular momentum by the tidal torque mechanism. We found, using typical observational values, that the mass ratio of the SMBH and the dark halo M(SMBH)/M(dark halo) is approximately 10^{-4 to -3}.

If we further consider the Axion case for the boson, the situation completely changes due to the attractive interaction though being quite tiny. We found that this attractive force just cancels the barrier formed by the angular momentum at the scale which is written in terms of the mass, the scattering length, and the gravitational constant only. This turns out to be the scale of several parsecs and the time scale for the SMBH formation to be about 10^8 years, well within the observational constraints. Furthermore, in this axion case, many smaller black holes, of mass 10^{2-5} solar masses, are forms as well on the outskirts of the galaxy. We found the scaling in the mass function of these black holes. The above scenario is compared with the recent experimental constraints on the axion properties.

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