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Fully degenerate fermionic dark matter in the cluster-center and black hole

Tadashi Nakajima and Masahiro Morikawa†

National Astronomical Observatory of Japan, Osawa 2-21-1, Mitaka, 181-8588, Japan

† Department of Physics, Ochanomizu University, 2-1-1 Otsuka, Bunkyo, Tokyo, 112-8610, Japan

hiro@phys.ocha.ac.jp

Abstract. We propose degenerate fermionic dark matter to explain the flat-top density profile of the cluster A1689 recently observed.

1. Introduction

Recent observation of the mass concentration in the cluster A1689 is too high and the density profile seems to be flat-top type [1], which cannot be well fitted by the standard NFW form [2]. Further there are several other clusters which seem to have flat-top density profile at their central regions. This general property motivates us to explore any universal mechanism which supports the flat-top density profile at the cluster centers. It is obvious that the density profile is dominated by unknown dark matter. Although we don't know any of its properties, we would like to consider ubiquitous mechanism which is capable of explaining the prevailing density profiles in the universe.

Thus in this report, we would like to propose a degenerate structure [3] of some light fermion for the core of galaxy clusters. This condensation mechanism is free from interactions between dark matter particles and is directly related to the heart of quantum mechanics.

2. Structures formed by degenerate fermions

Fermion gas can degenerate if thermal de Broglie wave length $\left(2\pi\hbar^2/(mkT)\right)^{1/2}$ exceeds the mean separation of particles $kT < 2\pi\hbar^2 n^{2/3}/m$. This structure has the characteristic density $\rho = m^4 c^3/\hbar^3$. The critical mass beyond which the fermion gas forms black hole is given by $M_{critical} \approx m_{pl}^3/m^2$,where $m_{pl} = (\hbar c/G)^{1/2} = 2.18\times 10^{-5}\mathrm{gr}$ is the Plank mass. For a typical example, characteristic mass of the white dwarves and neutron stars are almost the solar mass. This degenerate structure is general and requires no interaction (Figure 1). The detail structure should be analyzed by the relativistic state equation and the theory of general relativity (TOV equation[4]).

3. Structures formed by degenerate fermions

In order to explain the mass concentration of the cluster A1689, we suppose a model in which the inner region is described by the degenerate fermion and the outer region by the phenomenological NFW profile. Especially assuming dynamical equilibrium, we introduce the equivalent effective equation of state, which can be described by the polylog function. The fit of the model to the observations (Figure 2) deduces the fermion mass $m = 0.16[\mathrm{eV}]$, which suggests a possibility of neutrino [5]. The detail is found in our recent paper [6].

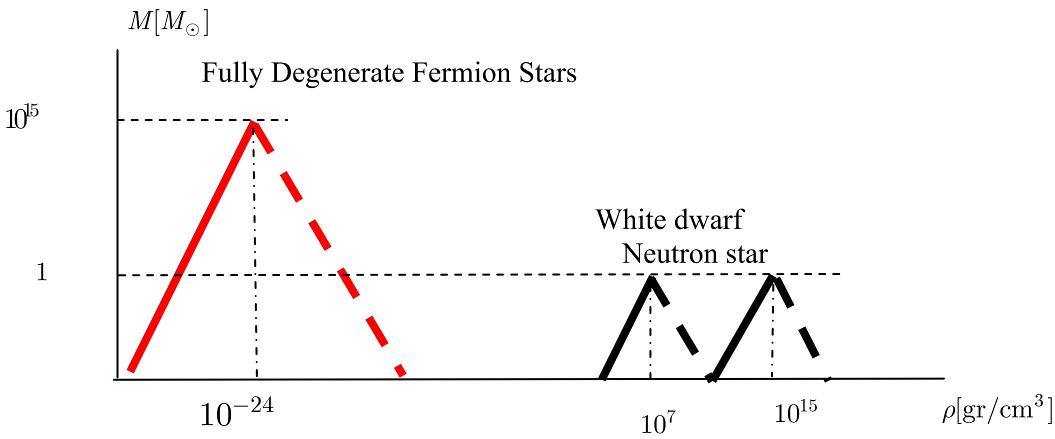

Figure 1 Schematic diagram of the equilibrium mass-density relation for degenerate fermions. Black lines represent white dwarves and neutron stars, and red lines represent our model. They are all similar. Solid part and the broken part of the lines represent stable and unstable equilibrium, respectively.

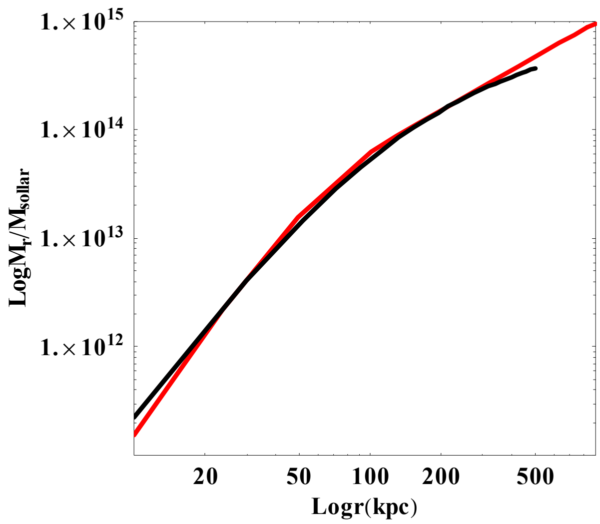

Figure 2. The black solid line is a best fit for A1689 observations, and the red solid line is our model NFW+FDFS. We obtain the fermion mass $m = 0.16[\mathrm{eV}]$ if $g = 3$ (Majorana).

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