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Article

Is Asteroid 33 Polyhymnia a Dark Matter (DM) Degenerate Object?

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Abstract: Polyhymnia (33 Polyhymnia) is a main belt asteroid in our solar system with a diameter around 54km. The density of asteroid 33 Polyhymnia, located in the main asteroid belt is calculated to be 75g/cc. Researchers have speculated the possibility that Polyhymnia could be composed of high-density superheavy elements near atomic number 164. Here we propose that Polyhymnia could be an asteroid composed of degenerate Dark Matter (DM) and there could be many such asteroids in our solar system (this is following our earlier work suggesting Planet Nine could be such an object).

Keywords: 33 Polyhymnia; dark matter; superheavy elements; compact object

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1. Introduction

In the main asteroid belt between Mars and Jupiter lies an asteroid known as 33 Polyhymnia. Researchers led by Johann Rafelski of the University of Arizona, have discovered that this asteroid's density is significantly higher than that of ordinary objects (Polyhymnia has a density of about 75 g/cm^3) [1] and they refer to these objects as compact ultra-dense objects, or CUDOs. These astronomical objects have their mass density higher than that of osmium, the densest metal (Z=76). Oganesson, with atomic number 118, is the element with highest Z ever created in a laboratory [2]. It is the element that tops the periodic table. All isotopes of these elements have been found to be highly unstable. Elements above atomic number 118 are only in the realm of theory. Using a basic atomic model i.e., the Thomas-Fermi model, the group came to the conclusion that superheavy elements might reside in 33 Polyhymnia. Around atomic number 164, or what the researchers refer to as a "island of nuclear stability," these "new" elements would be stable. They discovered that the density of elements with atomic numbers close to 164 have a density range from 36 to 68.4 grams per cubic centimetre. Here we propose an alternate model to explain the anomalously high density of Polyhymnia 33. We consider it to be made up of DM particles in a degenerate state.

2. DM Compact Objects

We had mentioned in our recent paper [3] that one reason we haven't detected DM particles could be that DM at high redshifts could form primordial objects composed completely of DM particles. Such dark matter objects may exist now, having evolved during the early epochs of the cosmos when the local DM density was far higher. Indeed we had proposed sometime back that the intriguing Planet Nine [4] in our solar system could indeed be such an object composed of degenerate DM particles. Considering the low non-thermal energies of these dark matter particles that make up the gravitationally bound object, we can consider the degeneracy pressure to be dominant.

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3. Mass, Radius, and Density of compact objects

The typical mass of such objects, made up mostly of DM particles of mass m_D, is given as [5]

$$M = \frac{{M_{Pl}}^3}{{m_D}^2} \qquad (1)$$

Here M_{Pl} is the Planck mass. The discovery of excess gamma-rays from the galactic centre [6], which is linked to the decay of 60 GeV DM particles, is currently of some interest [7]. This DM particle mass is also supported by other findings (such as the DAMA experiment, among others) [8]. Using m_D = 60 GeV, we get the mass of the compact object as 10^{29} g, about the mass of Neptune. In our earlier paper [3] we had proposed the composition of Planet Nine to be completely degenerate DM and that this may explain the negative results of the searches for the hypothetical planet.

Such objects, if composed primarily of DM particles, would not radiate at any wavelength and would not show up in the routine observational searches. Additionally, we calculated (Sivaram et al. 2016) that there might be a single such object in the volume of solar system. Therefore, there may be 10^{15} of these objects in our galaxy. The mass 10^{29} g represents the upper bound of these objects. In theory, there may be DM objects with a broad range of masses (asteroid to planetary) [9]; the upper bound is provided by Equation (1).

These degenerate objects have a density that increases with the square of their mass. Their radius is determined by:

$$R = \frac{92\hbar^2}{G m_D^{8/3} M^{1/3}} \qquad (2)$$

Table 1 gives the mass and size of such DM objects. The usual homologous law, $M^{1/3}R$ = constant, implies that density of these objects scales as M^2.

Table 1. Mass, size and density of DM objects for 60 GeV DM particles..

M(in g)	R (in cm)	ρ_{DMO}(g/cc)
10^{29}	1.5×10^{4}	7×10^{15}
10^{28}	3.2×10^{4}	7.3×10^{13}
10^{27}	7×10^{4}	6.98×10^{11}
10^{26}	1.5×10^{5}	7×10^{9}
10^{25}	3.2×10^{5}	7.3×10^{7}
10^{24}	7×10^{5}	6.98×10^{5}
10^{23}	1.5×10^{6}	7×10^{3}
10^{22}	3.2×10^{6}	**73.07***
10^{21}	7×10^{6}	0.7
10^{20}	1.5×10^{7}	7×10^{-3}
10^{19}	3.2×10^{7}	7.3×10^{-5}
10^{18}	7×10^{7}	6.98×10^{-7}
10^{17}	1.5×10^{8}	7.09×10^{-9}
10^{16}	3.2×10^{8}	7.3×10^{-11}
10^{15}	7×10^{8}	6.98×10^{-13}
10^{14}	1.5×10^{9}	7.09×10^{-15}

*this corresponds to the observed density of Polyhymnia.

4. Conclusions

The asteroid 33 Polyhymnia is 34 mile wide (5×10^6 cm). From table 1 it is found that an object of asteroid mass (10^{22} g) can have a radius of 3.2×10^6 cm and the density of such objects will be 73 g/cc, very close to the one observed for the asteroid (75 g/cc). This could be a very valid explanation for the high density of the observed asteroid. There could be other asteroids with similar mass range and density. There could be other asteroid range masses (from Table 1) with similar high densities and

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these objects could be present in our solar system. Here we don't have to consider the presence of very high atomic number elements as invoked in [1] to explain the high density.

Data Availability Statement: No Data associated in the manuscript.

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