Scientific Research Publishing

Journal of High Energy Physics, Gravitation and Cosmology, 2023, 9, 438-444
https://www.scirp.org/journal/jhepgc
ISSN Online: 2380-4335
ISSN Print: 2380-4327

Why Don't Cold White Dwarfs Exist?

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How to cite this paper: Peng, Q.H. and Liu, J.J. (2023) Why Don't Cold White Dwarfs Exist? *Journal of High Energy Physics, Gravitation and Cosmology*, **9**, 438-444.
https://doi.org/10.4236/jhepgc.2023.92031

Received: December 20, 2022
Accepted: April 4, 2023
Published: April 7, 2023

Abstract

Why no late type M and much later type N white dwarfs with surface temperatures less than 3000 K had ever been observed? What are the heat sources of these later type white dwarfs? In this paper, we find that the energy source of white dwarfs is the nucleons decay catalyzed by magnetic monopoles.

Keywords

White Dwarfs, The Energy Source, Magnetic Monopoles

1. Introduction

White dwarfs (hereafter WDs) are dead stars, as well known, no thermal nuclear burning in their Interior. The effective temperatures of most of the white dwarfs are in the range of (5.5×10^3 - 4×10^4) K. Only few WDs have effective temperatures outside this range. Their spectral types corresponding to these WDs are from O to K. But one individual is for M type [1]. Why are the spectral types for most WDs above A (*i.e.*, O, A, B), but only are the F, G, K for few WDs? On the other hand, it is very interesting that the spectral types for few WDs, whose temperature are less than 3×10^3 K are later M, and N.

The temperature in the interiors of WDs is 10^6 K with total thermal energy less than 10^{47} ergs. The radius of WDs is about 10^4 km with surface temperature $T \approx 3\times10^3 \sim 4\times10^4\ \mathrm{K}$.

The radiation luminosity of WDs is

$$L_{\rm rad} = 4\pi R^2 \sigma T_{\rm eff}^4 \approx 7.1\times10^{30}\left(\frac{R}{10^4\ \mathrm{km}}\right)^2\left(\frac{T_{\rm eff}}{10^4\ \mathrm{K}}\right)^4, \tag{1}$$

where R is the radius of the star, and $\sigma = 5.6704\times10^{-5}\ \mathrm{ergs^{-1}\cdot cm^{-2}\cdot K^{-4}}$ is the radiation constant from Stefan's law. This surface temperature is defined in astronomy as the effective temperature $T_{\rm eff}$ by means of Stefan's law. For WDs with temperature 3×10^3 - 4×10^4 K, so that $L \approx 5.6 \times 10^{28} \sim 1.8 \times 10^{33}$ ergs^{-1}.

Since most of WDs have surface temperature - 10^4 K, we therefore adopt the typical surface temperatures of WDs as 10^4 K. The radiation luminosity of WDs is roughly $L_{\text{rad}} \approx 10^{31}$ ergs/s, so the typical cooling time scale of WDs is about 10^{16} s ≈ 3.3×10^8 Yr. In other words, WDs should cool down within 10^9 years, then why no late type M and type later N WDs with surface temperatures less than 3000 K had ever been observed? What are the heat sources of these later types WDs? Astronomers never discuss this question due to no given physical process to provide such heat source. The purpose of this article is to answer this question.

2. Astronomical Observational Evidence for the Existence of Magnetic Monopole

In the 1970s and 1980s, particle physicists were hotly discussing magnetic monopoles (MM) [2] [3] [4]. They think there might be a superheavy monopole (Its mass was estimated as $m_m \approx 10^{16} m_p$) with a magnetic charge $g_m = 3hc/(4\pi e) = 9.88 \times 10^{-8}$ G. Here g_m is the magnetic charge of a stable colorless monopole and m_m and m_p are masses of monopole and baryon, respectively.

In the primordial universe, the electromagnetic interaction between MM and plasma is so strong such that MM might gathered in the center of quasars and active galactic nuclei (AGN) during the collapsing process of the original giant nebulae, including at the collapsed core of the Galactic Center (GC). Due to the Rubakov-Callan (RC) effect [2] [4], MM may catalyze nucleon decay and is invoked as the energy source of quasars and AGN.

Based on a super-massive object infused with primordial MM, the super-massive object with MM (SMOMM) model is has been estimated in our paper [5] [6] [7] [8]. The fact that MM may catalyze nucleon decay (*i.e.*, RC effect) as predicated by the grand unified theory of particle physics is invoked as the energy source of quasars and active galactic nuclei. Recent study of this model revealed that the radius of the super-massive object located at the GC is much larger than its Schwarzschild radius. We proposed that the super-massive objects could be the source of high-energy gamma-ray radiation, although the emitted radiation may be mainly concentrated in the infrared.

Really, we detailed discussed this question as early since 1985 due to the fact that this is a very interesting question (see our paper [6]). We discussed the number of monopoles in stellar objects in the paper. We noted that the number of monopoles possibly contained in a stellar object is closely related to the initial physical condition in the primary cloud from which the object was born. For example, in the interior of a protostar (the number density of hydrogen atoms (10^2 - 10^4) cm^{-3} and temperature ≤ 10^2 K), the interaction of monopoles with neutral atoms is insignificant, and very few monopoles will be drawn by the neutral matter during the collapse of a primary cloud (molecular or neutral hydrogen). On the other hand, however, the huge primordial clouds (It collapses into quasars and AGNs) in the early universe were in a plasma state with high temperature 4 × 10^3 K. The interaction of monopoles with plasma is so strong that many monopoles will be drawn into the quasars and AGNs during their formation.

The SMOMM model is based on a super-massive object infused with primordial MM. However, it is believed today that, due to their immense mass, these monopoles could only have formed in the time interval between the Big Bang and inflation. Then, cosmic inflation would have diluted the monopole population so much that fewer than one would exist today within the observable Universe.

The model of SMOMM [6] suggested that an amount of MM stored up in the center of quasars and AGNs, including at the collapsed core of the GC during the collapsing process of the original giant nebulae in the primordial Universe because the electromagnetic interaction between magnetic monopoles and plasma was so strong. Due to the RC effect, nucleon decay may be catalyzed by MM, that is

$$pM \to e^{+}\pi^{0}M + \text{debris}(85\%), \tag{2}$$

$$pM \to e^{+}\mu^{\pm}M + \text{debris}(15\%) \tag{3}$$

In this model, the RC effect is invoked as the energy source. In the case of GC, the SMOMM is located at the center with the radius of about $8.1\times10^{15}\ \text{cm} \sim 1.2\times10^{4} R_s$ (R_s is its Schwarzschild radius). The total mass of the SMOMM in the GC is $4.6\times10^{6} M_{\odot}$) from the observed luminosity of SgrA^* (10^{37} ergs·s^{-1}). The gravitational effect around SMOMM in the GC is similar to the model of super-massive black holes. But the main energy source in the model of SMOMM is supplied by the RC effect rather than by the accretion of the black hotel model.

The main predictions of the model of SMOMM are as follows [6].

First, the production rate of positrons emitted from the SMOMM in the model is 6.5 × $10^{42} e^{+}$ s^{-1}. This prediction is confirmed by the observation [9], which reported that the measured 511 KeV line flux located at the GC at a distance of 8.5 kpc converts into an annihilation rate of (3.4 - 6.3) × 10^{42} s^{-1}. The observed flux is compatible with previous measurements [4] [10] that have been obtained using telescopes with small or moderate Field of view, yet it is on the low side when compared to OSSE measurements [9].

Second, high-energy gamma-ray radiation has energy higher than 0.5 MeV. The integrated energy of these radiations would be much greater than both the bolometric luminosity and the energy of positron annihilation line.

Third, the radial magnetic field at the surface of the SMOMM is estimated to be $H(R)$ - (20 - 100) G. This prediction is just confirmed by the observation the observation in 2013, which indicate that there is a dynamically important Magnetic field near the GC [11]. In particular, at $r = 0.12$ pc, the lower limit of the outward radial magnetic field near the GC is

$$B \ge \frac{8RM}{66.960\ \mathrm{cm}^{-2}} \left(\frac{n^0}{26\ \mathrm{cm}^{-3}} \right)^{-1} \mathrm{mG}, \tag{4}$$

where n^0 is the number density of electrons there, and *RM* denotes the measurement of the Faraday rotation near the GC. The lower limit of the observed data is in agreement with the prediction 3 in the model of SMOMM because the magnetic field strength decreases as the inverse square of the distance from the source and has $B \approx (10 \sim 50)\,\mathrm{mG}$ at $r = 0.12\ \mathrm{pc}$. Up to now no other physical mechanism can produce this strong radial magnetic field [7].

Fourth, the strong radial magnetic field of the high-speed rotating SMOMM transforms a strong electric field for a distant observer in the rest frame. A variety of produced particles (e^{+}, $\mu^{\pm}$, $^{\pm}$) would be accelerated by the strong electric field to very high energy, say $E_\gamma \sim 10^{21}\ \mathrm{eV}$ or greater. We predict that these could just be the observed ultra-high-energy cosmic rays which have an initial energy of several hundred MeV produced from the SMOMM.

Finally, the surface temperature of the SMOMM is derived to be about 120 K and the corresponding spectrum peak of the thermal radiation is at 10^{13} Hz in the sub-millimeter wavelength regime. A review paper [12] pointed out that the radio flux density S_γ from the GC shows a flat-to-inverted spectrum. *i.e.*, it raised slowly with frequency of the power peaking around 10^{12} Hz in the sub-mm band. The observed power peak is in agreement basically with the prediction 5 in the model of SMOMM.

The agreement of the predictions of our model of the SMOMM with three newly recent astrophysical observations quantitatively or basically issues the signals or evidences for existence of magnetic monopoles. We are looking forward to seeing more astrophysical observation which will meet the predictions of our model.

According to the evidences for existence of magnetic monopoles, it shows that the RC effect (*i.e.* the magnetic monopole may catalyze nucleon decay) may be a reasonable energy source of celestial bodies.

Generally speaking, stars are formed in the massive neutral hydrogen cloud via Jeans gravitational instability. The interaction between MMs with neutral hydrogen atoms is so weak that few MMs can fall towards the central region following gravitational collapse of the neutral hydrogen cloud and they are neglected. But some MMs may be contained in the interiors of stars now. These MMs were mainly captured from space during their life time after their formation.

The total number of MMs captured from space by stars after their formation may be estimated to be [5]

$$N_{m(\mathrm{tot})} = 4\pi R^2 t\phi \approx 2\times 10^{27} \left(\frac{\phi}{\phi^{\mathrm{up}}} \right) \left(\frac{R}{R_\odot} \right)^2 \left(\frac{t}{10^9\ \mathrm{Yr}} \right), \tag{5}$$

where *t* are the radius and the age of the star. ϕ is flux of MM in the space. Its upper limit (ϕ^{up}) is given by Parker. (1970) [3], $\phi_{\mathrm{P}}^{\mathrm{up}} \approx 10^{-16}\ \mathrm{cm}^{-2} \cdot \mathrm{s}^{-2} \cdot \mathrm{Sr}^{-1}$. However, a revised of the upper limit is $\phi_{\mathrm{K}}^{\mathrm{up}} \approx 10^{-12}\ \mathrm{cm}^{-2} \cdot \mathrm{s}^{-2} \cdot \mathrm{Sr}^{-1}$ given by Knodlseder *et al.* (2003) [13].

It is well known that white dwarfs evolve from red giants with mass less than $8M_{\odot}$. Due to the radius of the red giants being much large than one of their predecessors: $R_{\mathrm{RG}} \approx 10^{3} \sim 10^{4} R_{\odot}$. The magnetic monopole content of the trapping accumulation set is mainly from the red giant phase. It equal to

$$N_m = 4\pi R^2 t\phi = 2\times 10^{33}\left(\frac{\phi}{\phi_{\mathrm{K}}^{\mathrm{up}}}\right)\left(\frac{R_{\mathrm{RG}}}{10^{3} R_{\odot}}\right)^{2}\left(\frac{t_{\mathrm{RG}}}{10^{9}\ \mathrm{Yr}}\right), \tag{6}$$

where t_{RG} is the lifetime of red giant star. These captured super-massive MMs accumulate at the deep interior of the stellar core.

3. The RC Luminosity from the Central Region of WDs

The total luminosity generated by the nucleon decay induced by MMs in the central region of the star may be estimated as follows [5]

$$L_m \approx \frac{4\pi}{3} r_c^3 n_m n_B^c c\langle\sigma_m\beta_{\mathrm{T}}\rangle = N_m n_B^c c\langle\sigma_m\beta_{\mathrm{T}}\rangle m_B c^2, \tag{7}$$

where r_c, and n_m, n_B are the radius of the stellar central region, the number density of MMs and nucleons, respectively. $\beta = v_{\mathrm{T}}/c$ is the thermal velocity of the nucleon at the center of the star divided by the speed of light.

We can also express the total luminosity due to RC effect by

$$L_m = 3\times 10^{41}\left(\frac{n_B^c}{10^{32}\ \mathrm{cm}^{-3}}\right)\left(\frac{\langle\sigma_m\beta_{\mathrm{T}}\rangle}{10^{-27}\ \mathrm{cm}^2}\right)\left(\frac{\phi}{\phi_{\mathrm{K}}^{\mathrm{up}}}\right)\left(\frac{m_B c^2}{1\,\mathrm{GeV}}\right)\left(\frac{R_{\mathrm{RG}}}{R_{\odot}}\right)^{2}\left(\frac{t_{\mathrm{RG}}}{10^{9}\ \mathrm{Yr}}\right). \tag{8}$$

Or can written by

$$L_m = 3\times 10^{41}\xi\left(\frac{\rho_B^c}{10^{8}\ \mathrm{g}\cdot\mathrm{cm}^{-3}}\right)\left(\frac{R_{\mathrm{RG}}}{R_{\odot}}\right)^{2}\left(\frac{t_{\mathrm{RG}}}{10^{9}\ \mathrm{Yr}}\right), \tag{9}$$

where

$$\xi = \left(\frac{\phi}{\phi_{\mathrm{K}}^{\mathrm{up}}}\right)\left(\frac{\langle\sigma_m\beta_{\mathrm{T}}\rangle}{10^{-27}\ \mathrm{cm}^2}\right). \tag{10}$$

In Equations (8) and (9), n_B^c, and ρ_B^c are the baryon number density and baryon mass density of WDs, respectively, and as often as not, $n_B^c = N_A \rho_B^c/\mu_e$, which is about 10^{31} - 10^{33} cm^3 in WDs. For the WDs, the range of their luminosity is $L \approx 5.6\times 10^{28} \sim 1.8\times 10^{33}\ \mathrm{ergs/s}$. We may got the luminosity range as long as the parameter $\xi \approx 10^{-7} \sim 10^{-2}$.

4. Concluding Remark

The energy source of WDs is the RC effect. That is the nucleons decay catalyzed by MM.

Acknowledgements

This work was supported in part by the National Natural Science Foundation of

China under grants 11965010, 11565020, and the Natural Science Foundation of Hainan Province under grant 2019RC239, 118MS071, 114012 and the Counterpart Foundation of Sanya under grant 2016PT43, 2019PT76, the Special Foundation of Science and Technology Cooperation for Advanced Academy and Regional of Sanya under grant 2016YD28, the Scientific Research Starting Foundation for 515 Talented Project of Hainan Tropical Ocean University under grant RHDRC201701.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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