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Research Article

Nuclear Processes in Dark Interstellar Matter of H(0) Decrease the Hope of Migrating to Exoplanets

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It is still generally assumed that interstellar travel will be possible after purely technical development and thus that mankind can move to some suitable exoplanet when needed. However, recent research indicates this not to be the case, since interstellar space is filled with enough ultradense hydrogen H(0) as stable condensed dark matter (Holmlid, Astrophysical Journal 2018) to make interstellar space travel at the required and technically feasible relativistic velocities (Holmlid et al, Acta Astronautica 2020) almost impossible. H(0) can be observed to exist in space from the so-called extended red emission (ERE) features observed in space. A recent review (Holmlid et al., Physica Scripta 2019) describes the properties of H(0). H(0) gives nuclear processes emitting kaons and other particles, with kinetic energies even above 100 MeV after induction for example by fast particle (spaceship) impact. These high particle energies give radiative temperatures of 12000 K in collisions against a solid surface and will rapidly destroy any spaceship structure moving into the H(0) clouds at relativistic velocity. The importance of preserving our ecosystem is pointed out, since travel to suitable exoplanets may be impossible. The possibilities of instead clearing interstellar space from H(0) are discussed, eventually providing tunnels suitable for relativistic interstellar transport. Finding regions with low intensity of ERE could even be a way to identify space-cleaning activities and thus to locate earlier space-travelling civilizations.

1. Introduction

The focus of this contribution is on one aspect which is normally not seriously included in the discussions of future space probes and space travel, namely, that interstellar travel is not easily possible not even in principle or after considerable technical development. The problems of reaching relativistic velocities are likely to be solvable [1] by using nuclear annihilation reactions in ultradense hydrogen. The other side of the knowledge of ultradense hydrogen [2] is that it exists in space as well. The reason why interstellar travel is difficult is that space is not as empty as it may seem from a casual look but is filled with enough dark matter [3] in the form of condensed ultradense hydrogen H(0) to make interstellar space travel at the required relativistic velocities almost impossible.

Several other ideas for the dark matter in space [4] besides H(0) have been proposed, both in the form of new (exotic) nuclear particles (WIMPs) and in the form of dark solid bodies called MACHOs (MAssive Compact Halo Object) [5]. However, the most likely form is of course just more hydrogen, in condensed form as H(0) [2, 3]. This is also the only proposed form of "dark matter" for which spectroscopic signatures have been identified both in space and in the laboratory (so it was a dark matter only until the spectra were identified in Ref. [3]).

Ultradense hydrogen H(0) is condensed atomic hydrogen with a density up to 100-5000 kg per cubic centimeter [2, 3, 6, 7]. It has been studied in 55 scientific publications using several experimental methods and it was recently reviewed [2, 8]. It consists of extremely small (pm-sized) ultradense clusters or molecules. It is formed spontaneously from so-called Rydberg matter of hydrogen H(*l*) [9], and it is the most stable material known. It is stable for long times, days to months at or above room temperature even in the laboratory. It has been studied by a few groups using laser-based methods. In the laboratory, it is rapidly formed by catalytic processes using especially carbon surfaces and metal oxide-based catalysts [8, 10, 11] (in space, the processes taking place are uncatalyzed since the time scale is different (ky instead of minutes)). Such catalysts are active in hydrogen molecule splitting (dissociative adsorption), and several hydrogen active catalysts including pure metals have been used in the studies [6]. H(0) is concluded to exist in large amounts in space since it is the energetically and chemically most stable form of hydrogen [2, 12]. It is formed quite easily from atomic hydrogen, and hydrogen in space may have initially (primordially) existed in the form of H(0) (if such a concept as primordial is meaningful at all). The agreement between the rotational spectra of H(0) in the laboratory [7, 13] and the so-called extended red emission (ERE) spectra observed in space [14, 15] is good [3]. This agreement indicates that H(0) is abundant in space. Since H(0) does not interact with radiation or light otherwise and is condensed matter without any free hydrogen atoms, it cannot be observed by any atomic spectroscopy method neither in the visible nor in the radiofrequency range.

2. Ultradense Hydrogen H(0)

A review of H(0) was published [2] in 2019 and thus the description here is kept brief. The review was built on the 50 papers on H(0) published at that time. Since then, five more papers on H(0) have been published, among them a review of the production process [8]. Both ultradense protium p(0) and ultradense deuterium D(0) or d(0) are closely related to the lowest forms of ordinary Rydberg Matter (RM) [9, 16, 17] of the type H(1). These ultradense materials will both be named H(0) here. A possible quantum mechanical basis for d(0) was discussed by Winterberg [18, 19], suggesting the formation of d-d pair bonding by exchange forces as the crucial factor of its formation. Other theoretical descriptions based on the detailed experimental information available and on the theory for superfluids have been published [2, 6]. H(0) is observed experimentally to be superfluid at room temperature [20–22]. p(0) as well as d(0) is proposed to be a type-II superconductor even at elevated temperatures of a few hundred K from the observed Meissner effect in d(0) [23] and in p(0) [24]. Only hydrogen isotope atoms are expected to give an ultradense material form, since the inner atomic electrons prevent this formation for all other atoms but possibly for some doubly excited atoms like He^{**}. Such doubly excited atomic states give excellent agreement with the so-called diffuse interstellar bands DIBs observed in space [25, 26].

Ultradense hydrogen is of applied interest at present for energy production both in fusion reactors [27–29] and in annihilation reactors [30] and for relativistic rocket drives [1].

Ultradense hydrogen exists in many different objects in space for example in the Sun [31], interstellar space [3, 12] and probably also in giant planets and dwarf stars. The two ultradense materials p(0) and d(0) are slightly different also in structure [2]. They are the lowest energy forms of hydrogen, and they also form mixtures pd(0). Thus, H(0) will exist everywhere in space where hydrogen exists. The properties of H(0) and the higher hydrogen Rydberg matter levels H(*l*) [2] are thus of central importance for our understanding of the Universe [12]. H(0) has a density ten thousand times higher than the center of the Sun. The atoms released in H(0) in the laboratory by laser pulses giving Coulomb explosions (CE) have kinetic energy corresponding to at least 15 MK [20]. Recently, the proton solar wind was shown to agree well with the protons ejected by CE from p(0) [31]. The most important properties observed for H(0) have never been considered to be possible previously, namely, the short bond distances in the pm range and the strong bonds [2]. The H(0) clusters have dimensions down to a few pm as measured by time-of-flight [2], time-of-flight mass spectrometry, and rotational spectroscopy [7, 13]. This means that they will not absorb or scatter electromagnetic radiation with a wavelength longer than a few pm, and thus, that H(0) clusters will be invisible (dark) in any spectral range with a wavelength longer than typical gamma rays. Due to the strong interatomic bonding in H(0) with energy of the order of 1-2 keV, absorptions in the visible or UV ranges are unlikely. No stationary electronic excited states at intermediate energies exist in H(0). Rotational transitions however exist at energies of a few eV as mentioned above [7, 13]. The agreement with the ERE (extended red emission) features in interstellar space is good [3].

The bond energy in H(0) of at least 500 eV corresponds to a temperature of 5 MK. Thus, in any dense region in space where the temperature is lower than approximately 1 MK, ultradense hydrogen H(0) will be the dominant form of hydrogen. This means that this form of hydrogen will dominate even inside many stars. The formation of H(0) is spontaneous from higher hydrogen Rydberg matter (RM) states, for example by H(3) first falling down to H(1) [32], which is then spontaneously converted to H(0). The facile interconversion between D(1) and D(0) was indeed observed experimentally in real time [33]. This means that the stable state H(0) is easily reached by hydrogen in space at large enough densities or low enough temperatures <1 MK. Thus, large amounts of H(0) are proposed to exist in the Universe. Further below, it is concluded that almost all hydrogen in interstellar space is in the form H(0). Of course, if H_2 molecules at present dominate in some regions, the formation of H(0) there is slower and more complex, perhaps requiring solid surfaces like carbon surfaces which act as molecule dissociation catalysts. The processes involved in H(0) formation in the laboratory have recently been described in detail [8].

The stability of H(0) will be higher than for any other material, as understood from the description above. Only temperatures above the MK range will dissociate this material after it has been formed. Of course, fragmentation due to ionizing photons and fast particles always exists. The interaction with ionizing photons or fast-charged particles will mainly go through the loosely bound superconductive electrons in H(0) [2]. Also, the nuclear processes induced in H(0) by energetic photons and charged particles destroy this material. When the energy density of the radiation field is lower than that corresponding to 1 MK, the ultradense hydrogen phase should be stable. All implications of large densities of the superfluid and superconductive quantum material H(0) in space are certainly not yet clear [12].

One important fact which must be understood is the following fundamental point: measurements of the hydrogen density in space by spectroscopy like Lyman alpha or

21 cm radiation measurements do not observe the atoms in H(0). The hydrogen atoms in H(0) are bound in a condensed phase, and thus, their electrons are not in any normal atomic orbitals and do not give any atomic-type optical transitions. This type of effect of quenching of atomic spectra is apparent everywhere: for example, a piece of sodium metal does not show any atomic lines like yellow sodium D in reflection, emission, or absorption but is just metallic in appearance due to the conduction band electrons. More information about the spectroscopy of H(0) was given above. It may be clarifying to note that the ERE spectra mentioned as signatures of H(0) of course are not atomic but rotational spectra of two or more hydrogen atoms in the H(0) clusters [7, 13].

It is sometimes argued that dark matter cannot be baryonic since there are too few baryons in the universe: this argument seems to be based on alleged spectroscopy measurements of the density of hydrogen in space. Such measurements do not observe the hydrogen in the form of H(0) and can thus say nothing about the true amount of baryons in space. Other arguments based on nuclear synthesis in the Big Bang fall in the same trap: it is assumed that the correct atomic amounts in space can be observed by spectroscopy without taking into account that space is filled with condensed matter like ultradense hydrogen and ordinary Rydberg Matter [12]. As shown in that reference [12], the condensed matter H(0) has wide-ranging implications on the interpretation of galactic redshifts and the CMB and on many other cosmological problems. H(0) is both superfluid and superconductive below a few hundred K, and how this influences its behavior for example in the dark matter clouds surrounding galaxies is completely unknown since such large amounts of super matter have never been studied previously.

3. Nuclear Processes in H(0)

Laser-induced and spontaneous nuclear processes in ultradense hydrogen H(0) have been identified and studied in our laboratory [2, 30, 34–36]. Many of the nuclear processes take place [37] in the small clusters $H_3(0)$ and $H_4(0)$ depicted in Figure 1. The initial particles observed in the laboratory studies, as described in several publications [2, 30, 34–36], are both charged and neutral kaons each with a mass close to 0.5 mass units (490-500 MeV) and charged pions. These mesons are identified from their characteristic decay times. From two nucleons, one pair of kaons and two pairs of pions are ejected. The kaons each have kinetic energy close to 100 MeV [30]. The kaons decay to pions and muons [38–41], and the decay processes are quite complex [42–44]. The particles ejected by the nuclear processes are similar to those found in nucleon-antinucleon annihilation [45], so the processes observed are not ordinary nuclear fusion but a form of particle annihilation, similar to neutron+antineutron annihilation [30]. The final product particles after decay are electrons and positrons, each with a mass of only 511 keV [35]. These leptons may also annihilate to some degree, giving annihilation gamma photons. Some meson decay channels also end up as gamma photons [43, 44].

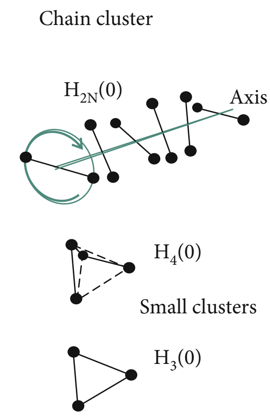

Figure 1: Most important shapes of H(0) clusters. The small clusters $H_3(0)$ and $H_4(0)$ are the ones in which the nuclear processes take place primarily [46]. The chain clusters $H_{2N}(0)$ have the special properties of forming a superfluid and superconductive phase [2, 37].

The total energy released by these nuclear processes is roughly a factor of a hundred higher than that released by ordinary fusion [30]. The typical kinetic energy of the muons formed by the nuclear processes is >>100 MeV. This means that X-ray and gamma photons are also formed as secondary particles by the interaction of the fast, charged muons and mesons with matter. Low intensities of neutrons are also formed by muon capture and muon catalyzed fusion [27, 46].

4. Space Travel

Since ultradense hydrogen H(0) is the most stable and lowest energy form of hydrogen [2], it is obvious that this state will exist in space after several Gy of existence. The processes forming H(0) are known, and they are quite trivial well-known surface processes. In the lab, we have to work fast at the time scale of minutes thus a catalytic process is preferred [8], while in the universe, a time scale of the order of ky-My is enough. Thus, the reactions in space at a time scale of My can be 10^{11} times slower than in the lab, thus uncatalyzed. Since H(0) is the most strongly bound form of matter [2], the rate of destruction after its formation is very low [3, 12]. Further, it appears likely that H(0) was the primordial form of hydrogen in the Universe [3, 12], if such a description is possible at all without a Big Bang [12]. This indicates that most hydrogen in space is in the form of H(0). See further below in Section 5.

Future interstellar travel may be assumed to require relativistic velocities of the spaceships used for the transport. Of course, for robots and living organisms with long lifetimes a slower travel may also be of interest, but relativistic velocities can still be assumed to be required for many interstellar transports. When solid matter (spaceships) at high velocities collide with H(0), nuclear processes are initiated in H(0) similar to those initiated by the ns-pulsed quite weak lasers used in the H(0) laboratory studies [30–40]. This will give photons and mesons with typical energies of 100 MeV and a typical temperature of >>100 MK. No solid material can exist at such energy levels or temperatures not even H(0), so any spaceship structure will be destroyed rapidly. See further in the next subsection. The radiation from the nuclear processes in the form of gamma photons, mesons like kaons and pions, and leptons like muons, electrons, and positrons may damage both living organisms and any electronic devices like robots in a spaceship.

If it is possible to observe the extended clouds of H(0) for example from their ERE it may be possible to avoid them during the space flight. Since the information from the clouds cannot move faster than light and the spaceship moves close to the velocity of light, the detection and avoidance processes will be quite difficult. However, to instead methodically partially remove such clouds seems difficult but not impossible. One possibility could be to excite H(0) to higher Rydberg matter levels like H(1), which will not give nuclear processes in collisions. This will however require enormous amounts of energy, of the order of 500 eV per H atom or 10^4 J km^{-3} at the (low) average H(0) density calculated in the next section. The best approach to enable space travel seems however to be to use laser and ion beams on nonrelativistic cleaning spaceships to initiate the nuclear processes in H(0) and thus form essentially H(0)-free corridors (tunnels) between the star regions which are intended to have contact. This possibility may mean that in due time the effort of coming here from other star regions may be worth the resources needed for other civilizations. Maybe we will just need to prove that we are smart enough to survive to receive visitors from other civilizations. On the other hand, it is not a very useful method to use for exploration or migration.

5. Density of H(0) in Space and Energy Release

The density of H(0) in interstellar space is not directly measurable, since H(0) is dark matter. Its density may however be estimated roughly from the density of free H atoms observed outside the H(0). In the Physics Factbook 2019 [47], it is stated "The actual density of hydrogen as it exist in interstellar space is on the average of about 1 atom per cubic centimeter. In the extremes, as low as 0.1 atom per cubic centimeter has been found in the space between the spiral arms and as high as 1000 atoms per cubic centimeter are known to exist near the galactic core". In Wikipedia [48], it is stated: "The density of matter in the interstellar medium can vary considerably: the average is around 10^6 particles per m^3, but cold molecular clouds can hold 10^8–10^{12} per m^3."

In equilibrium, the density n_0 bound in H(0) relative to the density n_H of free H atoms is

$$n_0 = n_\mathrm{H} \exp\,(E_b/k_B T), \quad (1)$$

where E_b is the bond energy in H(0) of the order of 500 eV, k_B is the Boltzmann constant, and T is the temperature in space, here assumed to be of the order of 100 K. Thus, n_0 is a very large number of the order of $\exp(10^4)$, which means that almost all hydrogen is in the form of H(0). Of course, departures from thermal equilibrium may exist for example close to stars, but this should be close to the average over a large volume of space. Very conservatively assuming a small value of $n_0 = 10^5\, n_\mathrm{H}$ gives then of the order of 10^5 atoms H(0) cm^{-3} on average, but dense clouds could be many orders of magnitude denser. At a velocity of 0.5 c, each unit area of 1 cm^2 of a spaceship moves through a large volume per second. If each H atom gives off 500 MeV due to the nuclear processes as found in the experiments, the power density becomes 100 kW cm^{-2}. This corresponds to a radiating surface temperature of 12000 K: thus, all solid material moving close to the velocity of light will melt and evaporate when it moves into a cloud of H(0). A cooling machine with the unlikely capacity of 100 kW cm^{-2} is needed to be helpful for travel at 0.5 c. A lower velocity will of course help to reduce the heat load. At 0.05 c the energy load will still be 10 kW cm^{-2}, corresponding to 6800 K, which is not much of an improvement. At 0.005 c, the heating in thin clouds should be possible to handle. A long and sharp nose of the spaceship could decrease the heat load somewhat. The density of H(0) is here estimated very conservatively and may thus be much higher at equilibrium, giving much higher energy from the nuclear processes.

6. Implications of Clean Space

The observation of really clean regions in space, for example with low ERE emission (this emission being a signature of H(0)) in space as shown in [3], could be a way to observe locations where space travel is possible and even where other space travelers exist or have existed. However, it is not known how fast any tunnels through H(0) will be wiped out by thermal motion or by motion of the stars. With tunnel diameters of a few astronomical units which may be the minimum needed for safe navigation and passage, the thermal time for wiping them out is of the order of 1 ky, if they are not maintained. Probably much larger regions are required for detection at a distance. This may seem to be too much of a science-fiction approach but the alternative to this, with humanity losing hope of long-time survival due to eternal isolation is not very attractive but a likely result of H(0) as dark matter in space.

7. Conclusions

From the known properties of ultradense hydrogen H(0), it is concluded that any spaceship structure will be destroyed by the high temperature and high particle radiation created by the nuclear processes initiated in H(0) by any attempt to move with relativistic velocity through this type of matter. It is concluded as previously that H(0) is abundant in space, both from its known energetic and bonding properties (being the chemically most stable and energetically lowest form of hydrogen) and also from the agreement of its rotational emission spectra in the laboratory with the ERE (extended red emissions) features which are observed almost everywhere in space [3]. Thus, we will be unable to easily travel through interstellar space. We have to accept that we may be eternally confined to our small solar system and that humanity may be unable to make physical contact with other civilizations. With this knowledge about the problems of space travel, it is even more important that we keep Earth in good health and do not lock our resources into moving humanity to other planetary systems, which has recently been suggested even by serious scientists [49] It is likely that such efforts would lead to no more than really dead ends.

On the other hand, finding really empty parts of interstellar space with no ERE and thus without H(0) may give us a clue to where space travelling civilizations have cleaned away the H(0) to form regions useful for safe interstellar travel at relativistic velocities. If such civilizations still exist is of course unknown, and it will be difficult to determine this in a short time. However, this type of search for space travelling civilizations could be an important complementary approach to the searches for electromagnetic signatures performed today (for example by SETI (Search for extraterrestrial intelligence)). Long-distance space expeditions at velocities suitable for robot travel may become feasible within a reasonable time using for example a novel annihilation-based space-propulsion drive [1]. The common science-fiction idea of travelling at velocities above the speed of light by moving in hyperspace may be just science fiction but may be worth pursuing since travel in physical space is difficult. We can of course hope that other civilizations in due time will contact us, if we prove that we are smart enough to survive on Earth.

Conflicts of Interest

No conflict of interests exists.

Authors' Contributions

All aspects of this publication are due to LH.

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