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# Explanation of the Helium-3 problem

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## ABSTRACT

One of the tests of nucleosynthesis theory is the  ${}^3\text{He}$  abundance in the Galaxy.  ${}^3\text{He}^+$  is observed through its 3.46 cm hyperfine level in HII regions and the  ${}^3\text{He}/\text{H}$  ratio compares well with theory. Since  ${}^3\text{He}$  can be created or destroyed in nuclear reactions, one would expect that its abundance shows a trend with the amount of such reactions, so with distance to the Center of the Galaxy and with metallicity. Such trends are lacking in observations. This is explained by assuming that the HII clouds are recently formed out of the primordial micro brown dwarfs of earth mass predicted by gravitational hydrodynamics. If indeed existing, they would preserve their primordial  ${}^3\text{He}/\text{H}$  ratio and spread this when evaporating into HII clouds, independent of the location in the Galaxy.

In the development of the argument, it is also explained that wide binaries do not rule out the MACHO dark matter predicted by gravitational hydrodynamics, but are rather immersed as visible partners in Jeans clusters of dark micro brown dwarfs.

## 1 INTRODUCTION

Nucleosynthesis in the WMAP era is said to be a parameter-free theory, see e. g. Steigman (2007). With cosmology described by the Friedman-Lemaître-Robertson-Walker metric and the number of neutrino species known, accurate predictions can be made, ready for comparison with observations. We will discuss one of these tests, the one for  ${}^3\text{He}$ , that is in agreement with theory, but has a puzzling aspect.

## 2 THE HELIUM-3 PROBLEM

${}^3\text{He}$  is produced in nucleosynthesis and the observed abundance  ${}^3\text{He}/\text{H} \approx 1.0 \cdot 10^{-5}$  agrees with theory. But not all is well, so let us explain the way to observe it. The  ${}^3\text{He}$  nucleus consists of two protons and a neutron, so it has spin  $\frac{3}{2}$  or  $\frac{1}{2}$ . The singly ionized  ${}^3\text{He}^+$  contains one electron, thus the singlet spin- $\frac{1}{2}$  state brings an analogy with the neutral H-atom. Indeed, there is an analog of the 21-cm spin-flip transition, which occurs roughly at  $21/Z^2 = 21/4$  cm, more precisely at 3.46 cm. The emission by this transition line provides an observational signature of singly ionized  ${}^3\text{He}$  located in regions of ionized H gas (so-called HII regions) and in planetary nebulae that also contain ionized H and  ${}^3\text{He}$ .

HII regions have been created rather recently in the cosmic history (Rood et al. 1984, 2002; Bania et al. 2007), and are thus expected to reflect the chemical history of the surroundings.  ${}^3\text{He}$  can be created or destroyed in nuclear reactions. One would thus expect its local concentration in the Galaxy to depend on the amount of reactions that have taken place, a measure for which is the local metallicity. Since near the Center more reactions took place, there is a clear gradient in the metallicity, so one also expects a significantly higher  ${}^3\text{He}$  concentration near the Center than in the outskirts. But though observations show fluctuating concentrations, there is no statistical trend with distance or with metallicity. Specifically, low values of  ${}^3\text{He}/\text{H} \approx 1.0 \cdot 10^{-5}$  are observed at 4, 9, 10, 12 and 16 kpc from the Center, while up to two-three times higher values are observed in between (Rood et al. 2002).

The important point for the present paper is that the HII regions show no evidence for stellar  ${}^3\text{He}$  enrichment during the last 4.5 Gyr; the low values thus being found at any distance from the Center is called *the  ${}^3\text{He}$  problem* (Bania et al. 2007). This situation creates a paradox, since it calls for a delicate balance between creation and destruction *independent of the amount of reactions* (the metallicity). The relevant data indicate that the extra-mixing occurs in 90 to 95% of the low-mass stars (Charbonnel and Do Nascimento 1998; Charbonnel 1998). This is the best current solution to the “ ${}^3\text{He}$  Problem”. To

be compatible with this result, Galactic chemical evolution models (Tosi 2000) require that  $\sim 90\%$  of solar analog stars are non-producers of  ${}^3\text{He}$ . But the two best observed planetary nebulae do have higher concentration (Rood et al. 2002), and consequently should then both be members of the 10% class of stars that do produce  ${}^3\text{He}$  – which seems unlikely and actually looks to be an ad-hoc fix of the standard model. For a review of the current status of  ${}^3\text{He}$  evolution, see Romano et al. (2003).

### 3 MICRO BROWN DWARFS FROM GRAVITATIONAL HYDRODYNAMICS

Gravitational hydrodynamics is an approach that stresses the role of turbulence in cases of small viscosity (more precisely, large Reynolds number) and the possibility of viscous structure formation of turbulent flows on scales where the Reynolds number is low. It is well understood that at the transition from plasma to neutral gas (decoupling or recombination), the newly formed gas breaks up at the Jeans scale, forming Jeans clumps of some  $600,000 M_{\odot}$ . It was put forward by Gibson (1996) that the Jeans clumps themselves fragment at the viscous scale into objects of earth mass, turning the Jeans gas clumps into Jeans clusters of some  $2 \cdot 10^{11}$  micro brown dwarfs ( $\mu\text{BDs}$ ) of earth mass. The Galaxy is predicted to contain about two million Jeans clusters in its halo that make up the full Galactic dark matter (Nieuwenhuizen et al. 2010, Gibson 2011).

These objects are belong to the class called MACHOs (Massive Astrophysical Compact Halo Objects). They have been detected in quasar micro lensing (Schild 1996) and the observed signature has approximately equal positive and negative events (Schild 1999), uniquely indicating microlensing by a population at unit optical depth. However, in direct searches in front of the Magellanic clouds they have not been detected. Inspection of the literature in this field reveals that this low mass scale was covered only in one paper (Renault et al. 1998). This reports observations carried out in the early and mid nineties using a telescope of 40 cm in diameter. Later MACHO searches did not cover this mass range, so the controversy between the Schild detection and the Renault et al. non-detection was never resolved. It is planned to redo the MACHO search in front of the Magellanic clouds using a much larger telescope (Schild 2011). They will be searched in what is normally called cirrus dust clouds, but what could just be an agglomeration of dark Jeans clusters. One further indication for this bold assumption is that the temperature of “cirrus dust” is about 15 K (Veneziani et al. 2010), i. e., near the H triple point of 13.8 K. While cold dust theories have no explanation why the dust should minimally have this temperature, the required release of latent heat of these compact hydrogen clouds would then keep them long at this temperature, before finally freezing.

Analysis of wide binaries in the Galaxy halo has ruled out any MACHO dark matter component more heavy than  $43 M_{\odot}$  (Yoo et al. 2004). That this conclusion is somewhat too strong (Longhitano & Binggeli 2010), will be of little help in our situation. For a typical wide separation of the components, the major axis is of the order  $a = 18,000 \text{ AU} = 0.09 \text{ pc}$ . In our case the relevant MACHO objects for this application are the individual Jeans clusters of  $600,000 M_{\odot}$  and radius of 1.4 pc, so they would completely disrupt the binaries – if they were on their own. However, we now point out that these halo wide binaries - being much smaller than the Jeans clusters - must lie inside Jeans clusters themselves, as a result of which they must be much more stable than commonly expected. So we predict that these wide binaries have a center of mass motion of ca 200 km/s, a mutual speed of ca 20 km/s and are embedded in a baryonic dark matter matrix of ca  $600,000 M_{\odot}$ . These features can be tested. Clearly, stabilized inside Jeans clusters, wide binaries do not rule out the MACHO dark matter.

One would expect that the fragmentation of the Jeans cloud has been seen in numerics. When Truelove et al. (1997) noticed instabilities in their simulations, they dismissed them as unphysical and built in Jeans filters to remove them. Recently instabilities at the  $10^{-3} - 10^{-4} M_{\odot}$  level were observed in the simulation of the first stars in turbulent gas clouds (Clark et al. 2011): the gas first fragments and then the fragments aggregate to form the stars. The authors carefully explain how the gas can cool, namely grace to the formation of molecular hydrogen ( $\text{H}_2$ ) with help of a small fraction of free electrons still present, so that heat can be radiated away through  $\text{H}_2$  levels. This allows the gas to cool locally after which it can fragment. Though the authors did not carefully sort out what would be the minimal fragmentation scale, their fragmentation at the  $10^{-3} - 10^{-4} M_{\odot}$  level is a already strong support for the gravitational hydrodynamics picture and indeed points towards its predicted earth mass MACHOs.

Nuclear synthesis attributes enough matter for the  $\mu\text{BDs}$ . About 4.5% of the critical density of the Universe is baryonic. At best 0.5 % is luminous, and some 2–3% is observed in X-ray gas. The *missing baryon problem* refers to the fact that most of the baryons are unaccounted for, about 60% is missing at cosmic scales; an inventory of baryons in and around the Milky Way reveals at best 25% of the expected baryons. Though they are believed to be located in unobserved relatively cool X-ray clouds, this need not be the full or the only explanation. Indeed, the missing dark baryons may be locked up in  $\mu\text{BDs}$ . Radiation from what is commonly called “cold cirrus clouds” or “cold cirrus dust” is observed to have a temperature of 15 K (Veneziani et al. 2010), or, more generally, temperatures between 40 K and 15 K (Amblard et al. 2010). Dust models have no explanation for the minimum of 15 K. But the radiation may actually arise from the thermal atmospheres of  $\mu\text{BDs}$  (Nieuwenhuizen et al. 2010). The fact that H has a critical point at 33 K and a triple point at 13.8 K coincides with many observations of “cold dust” temperatures by the Herschel telescope between 15 and 40 K, with the lower values condensing near 15 K, see Figures 2 and 3 of Amblard et al. (2010).

The picture of baryonic dark matter locked up in  $\mu\text{BDs}$  grouped in – mostly – dark Jeans clusters (JCs) explains another,

not often mentioned problem: *the missing Jeans clusters problem*. Indeed, it is agreed that after the decoupling all gas fragments in Jeans clumps, but where are they now? Gravitational hydrodynamics asserts that they just constitute the halo dark matter of galaxies.

From the point of view of galactic structures there is a lot of support for the picture of Jeans clouds consisting of micro brown dwarfs. Galactic rotation curves flatten when the ca  $2 \cdot 10^6$  JCs of the Galaxy have an isothermal distribution  $\rho(r) \approx v^2/2\pi Gr^2$ , where  $v$  is the velocity dispersion, about 200 km/s for Jeans clusters in the Galaxy and 20 km/s for  $\mu$ BDs inside a Jeans cluster. The Tully-Fisher and Faber-Jackson relations follow if one assumes that star formation arises when JCs heat each others mBDs by tidal forces when they come within a certain radius of each other, which brings the proportionality  $Luminosity \sim \# \text{ stars} \sim \int d^3r \rho^2(r) \sim v^4/R_*$  for some characteristic radius  $R_*$  (Nieuwenhuizen et al. 2009).

In galaxy merging the observed young globular clusters may not or not only appear due to tidal disruption, and its unknown star formation process, but also due to tidal heating of the mBDs, which expand and can form stars millions of years after the merging process has taken place (Nieuwenhuizen et al. 2010). Thus the galaxy merging process can transform, along the merging path, dark Jeans clusters in situ in the observed bright young globular clusters.

Mysterious radio events were reported by Ofek et al. (2010). They are frequent (1000/square degree/year), radio loud ( $> 1\text{Jy}$ ), and have neither a precursor nor a follow up, and have no detectable counterparts in the infrared, visible or X-ray spectrum. Within isothermal modeling, they have been connected to merging of  $\mu$ BDs inside Jeans clusters, and the event duration of more than half an hour to several days allowed to estimate their radius as  $3 \times (\text{the duration in days}) \times (\text{the solar radius})$  (Nieuwenhuizen et al. 2010).

The theory of star formation that has always been inconclusive, strongly benefits from the principle that star (and larger planet) formation arises from aggregations of  $\mu$ BDs (Gibson and Schild 2011). The *iron planet core problem* acknowledges that metallic iron planet cores, like in the earth, are difficult to explain, since iron is mostly observed in oxides, both on earth and in intergalactic space. But primordial  $\mu$ BDs with hot H atmospheres as massive as the Earth, can collect intergalactic chemicals C, N, O, S, P, Si etc. of the first supernovae as well as nickel and iron oxides as gravitational “vacuum cleaners”, while the initially hot, moist, H atmospheres are all too eager to reduce the oxides for making molten iron-nickel cores under molten rock oceans until the water oceans condense at 2 million years at critical temperature 647 K (Gibson, Schild & Wickramasinghe 2011). Iron cores are then explained from repeatedly merging iron cores with molten rock layers in the frictional accretions of the  $\mu$ BDs to form larger and larger planets and finally stars (Nieuwenhuizen et al. 2010).

A relation between globular clusters and black holes was discussed (Nieuwenhuizen et al. 2010) and will be expanded elsewhere, in particular in connection with role of Jeans clusters in solving the so-called last parsec problem in black hole merging processes.

Nowadays galaxies are observed at redshifts basically up to  $z = 10$ . This being considered before the reionization era, they should not be visible but immersed in H clouds, so that many unobserved weak galaxies are invoked, which should ionize the gas and create a “pencil of visibility” in our direction. The galaxy UDFy-38135539 was established to have redshift  $z = 8.55$ , so we see light that it emitted 600 million years after the big bang (Lehnert et al. 2010). The authors say in the abstract that a significant contribution from other, probably fainter galaxies nearby, is needed to explain its visibility. This is a *deus ex machina*, an ad hoc argument to save the standard theory.  $\mu$ BDs, on the other hand, offer a more obvious explanation: the hydrogen is locked up in condensed objects, so most of the space is empty and transparent (Nieuwenhuizen et al. 2010, Gibson 2011).

One observes that the amount of dust and the rate of star formation had a peak at redshift  $z \sim 2$  and are smaller in recent times. This higher amount of dust content in massive galaxies at higher redshift is difficult to explain in standard dust evolution models (Dunne et al. 2010). But it finds an easy explanation if one accepts that the “dust” radiation is produced by the atmospheres of  $\mu$ BDs. In the course of time, they are more and more used up because they coagulate to form heavier objects and stars. Consequently, less fuel for star formation is ultimately available and less  $\mu$ BD outer surface exists to emit “dust” radiation.

#### 4 THE ANSWER TO THE HELIUM-3 PROBLEM

Within gravitational hydrodynamics it is natural to identify the HII clouds with partly or fully evaporated Jeans clusters, in which a large fraction of the  $\mu$ BDs, if not all, evaporated by heating in a strong star forming region. In such a case the  $\mu$ BDs of a Jeans cluster can expand into a gas cloud. Though they would have swept up metals produced by super novae, there would have been little  $^3\text{He}$  in the interstellar medium, so they would have kept the primordial  $^3\text{He}$  content up to then. Thus it would not change when they evaporated into HII clouds, so the primordial value would appear independent of their location in the Galaxy and independent of the local metallicity, which explains the  $^3\text{He}$  problem.

The most massive and largest HII region in the Local Group is the region 30 Doradus in the Large Magellanic Cloud. It has been carefully studied recently (Lopez et al 2008). In addition to a large ionized gas mass  $\sim 8 \cdot 10^5 M_\odot$  (Kennicutt 1984), the 30 Doradus nebula also has  $\sim 10^6 M_\odot$  of CO (Johansson et al. 1998). This HII mass is approximately the mass of

a single Jeans cluster, supporting the just mentioned gravitational hydrodynamics picture, while the CO content exhibits a large metallicity.

In conclusion, in gravitational hydrodynamics many problems, like the 15 K cold dust temperature, the visibility of early galaxies and the  $^3\text{He}$  problem, find a simple explanation.

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