Another Look at the Cosmological Model of Omnès

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ABSTRACT The cosmological model of Roland Omnès was abandoned more than 30 years ago because it failed to show that coalescence was able to continue long enough to produce aggregations as large as the masses of galaxies. It was also determined that a universe containing antimatter galaxies is inconsistent with observations of cosmic annihilation radiation. This paper explores the implications of a simple assumption that suggests a reevaluation of those objections is needed.

***Index Terms*—cosmology, antimatter, CPT symmetry, black holes (SMBH, IMBH, PBH)**

I. INTRODUCTION

In 1969 Roland Omnès proposed a cosmological model with the goal of showing that the present universe is comprised of equal parts of matter and antimatter, in the form of matter galaxies mixed together with antimatter galaxies, which would be consistent with the law of baryon conservation [1]. Following the Radiation era, the initial state in the model was a close mixture of matter and antimatter plasma, separated by a Jordan surface, which is a simple closed curve in topology separating two different components, each of which is fully connected (no isolated elements)[2]. This state was referred to by Omnès, his coworkers and others, as an "emulsion". By about the mid-1970s, these efforts were abandoned because observations indicated that separation of the two kinds of matter on the scale of at least galactic clusters was needed to satisfy recent cosmic gamma radiation observations [3] and because the model was unable to demonstrate that coalescence could continue long enough so that the accumulations of matter, and of antimatter, could grow beyond about 4×10^{36} g [4] before coalescence ceased.

Cosmology has undergone a revolution since the 1970s with the introduction and refinement of concepts such as dark matter, dark energy, primordial and supermassive black holes, etc., so it is appropriate to reexamine the Omnès cosmological model. This paper takes a first look, and finds that a simple assumption can transform the Omnès model into one which appears to be far more compatible with observations of the cosmos.

II. THE COSMOS AS AN EMULSION

In chemistry, an emulsion consists of two immiscible fluids which resist dissolving into a single fluid because of Van der Waals forces. The two fluids can be forced to intermingle closely by vigorous shaking, which causes one component to form into separate globules, whereas the other component remains fully connected. Which component becomes globules, and which remains fully connected, depends on differences in surface tension and other characteristics such as chemical behavior and temperature. The globules are referred to as the dispersed phase and the other phase is called the dispersion medium. The resulting mixture is not stable and will separate over time, although stability can be extended by adding a suitable third component called an emulsifier. Under certain conditions, some emulsions can exist with reversed phases, so that when an equilibrium condition (such as temperature, pressure, or emulsifier concentration) is crossed the emulsion will "break", the dispersed phase becoming the dispersion medium and the dispersion medium becoming the dispersed phase.

Although matter and antimatter resist mixing for a different reason (they annihilate violently when they come together, increasing the temperature and pressure at any interface) the extension of the term "emulsion" to describe the intermixture of matter and antimatter is entirely appropriate. Indeed, because nuclear forces are involved instead of chemical ones, the close intermixing of the two kinds of matter could be characterized as a "super-emulsion". We begin by assuming that the emulsion described by Omnès actually behaved as an emulsion instead of remaining intermixed as globs of matter and separate globs of antimatter. If matter and antimatter have even a slight asymmetry of almost any kind; chemical, physical, or subatomic, it would be likely to cause the emulsive phases to break the same way everywhere in the Universe. Otherwise it would be a matter of chance, the two phases being reversed over vast adjacent regions of the universe.

Although immiscible liquids mixed together will separate over time if left undisturbed, the super-emulsion of the early cosmos as described by Omnès and others is anything but undisturbed, being flung away in all directions at close to the speed of light. So it is assumed here that the matter-antimatter emulsion mixture of Omnès, once formed into an emulsion, remained in that emulsive state for all of time, up to the present era. It is curious that neither Omnès, nor any of his collaborators, ever considered the possibility that the early "emulsion" might have actually behaved as an emulsion, i.e., one phase becoming dispersed in the other, which remains fully connected*. In the Omnès model all of the primordial antimatter not coalesced into globules, if any, would have ended up annihilating with normal matter, since virtually all of the galactic and intergalactic matter, in our region of today's universe, seems to be the normal variety [3], and the coalesced antimatter globs seem nowhere to be found.

Using these new concepts we next consider a scenario that might have transformed the early universe into the present universe, where the law of baryon conservation has been largely obeyed from the very beginning, and matter and antimatter are still present in equal or closely equal amounts. It seems possible that all of the surviving primordial antimatter is unobservable, not because it is separated from normal matter by immense distances, but because it is sequestered in isolated, condensed, massive objects.

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* Actually, Omnès did describe the emulsion as consisting of "a compact mass of matter surrounded by antimatter or vice versa", see [5], but only in context with his discussion of the possibility that quasars might be comprised of a mixture of antimatter and matter.

III. SUPERMASSIVE BLACK HOLES

Since the present universe appears to contain only normal matter, with little or no residual antimatter surviving annihilation, it is necessary to explain how the present universe came to consist entirely of normal matter. Consequently, examples of subatomic particle reactions that might have occurred in the early universe, violating CPT symmetry, have been searched for. In 1964 indirect evidence was found that the decay of the neutral K meson slightly violates CP symmetry, and more recently direct evidence of CP asymmetry has been found. This has encouraged cosmologists and particle physicists to believe that some as yet undiscovered particle reaction between matter and antimatter violates CPT symmetry to the extent that all primordial antimatter has been annihilated, leaving only the residual normal matter which is posited to constitute the entire baryon content of the present universe. Some physicists believe that CPT asymmetry has been "experimentally" proven by the very existence of our Universe [6]. However, a reaction which violates CPT symmetry has not yet been found and, if the conclusions of this paper are correct, may not even exist

One of the concepts introduced since the Omnès model was abandoned is that virtually every large galaxy in the universe contains a supermassive black hole (SMBH) with mass in the range of about 10^{6} to 10^{10} $M_{\odot}$. Cosmologists are puzzled by this, because no plausible scenario can be found to explain how such massive black holes could be formed by accretion within the lifetime of the universe. Treating the Omnès emulsion as a real emulsion, with antimatter as the dispersed phase, eliminates that problem, i.e., the antimatter globules could have coalesced to the mass of SMBHs, and even larger, shortly following the Big Bang, with no accretion needed.

Let us now consider what might have happened to the dispersed globs of antimatter as they evolved from the early universe. Ramani & Puget [4] showed that coalescence could only accumulate globular masses of about 2,000 $M_{\odot}$, before coalescence ceased. However, they assumed that individual globs of matter and antimatter coalesced separately, whereas in the emulsion model being considered here only the antimatter phase coalesced, so this objection needs to be reevaluated.

Shortly following their creation, individual globs of antimatter were surrounded by normal matter at extremely high pressure, temperature, and linear momentum [7]. The high pressure would act continuously to compress the antimatter into smaller and smaller volumes as long as significant amounts of normal matter remained in contact at the interface, leading eventually to isolated agglomerations of massive amounts of antimatter. Since the rate of normal matter impacting on the antimatter surface would decrease as the Universe expanded, but would never entirely go away, the natural endpoint would seem to be collapse of each sequestered glob of antimatter into a black hole.

The Big Bang is believed to have begun as pure radiation, which is rich in energy but possesses little momentum. With expansion and cooling, elementary particles began to form, and following their creation, each particle was accelerated by photon pressure to near the velocity of light and acquired an immense amount of linear momentum. At some point the Universe became turbulent, giving rise to huge amounts of angular momentum. If the period prior to the onset of turbulence lasted into the coalescence era, the angular momentum of each antimatter glob would have been very low, greatly enhancing the conditions for collapse into a black hole. Even if turbulence set in prior to the onset of coalescence, it is likely that angular momentum of the antimatter globules increased only slowly, still facilitating their collapse. It is proposed here that black holes comprised of antimatter, including SMBHs, have been present since very early in the formation of the universe and continue, in aggregate, to contain as much as half of the total baryonic mass of the universe. If this is correct, it seems doubtful that black holes ever form from normal matter by giant stars or by supernova explosions, so that all black holes in the universe may be primordial black holes (PBHs) comprised of antimatter.

The production of PBHs at the inception of the Universe has been considered seriously for many years, and was given a boost in credibility by the discovery a few years ago of what appear to be stellar size black holes that are only about 800 million years old [8].

IV. ACCRETION

It is known that some SMBHs in galactic halos undergo accretion, and doubtless all of them have undergone significant accretion in the past. Since we are considering that all of the SMBHs originally contained only antimatter, it is necessary to consider what happens when normal matter passes through the event horizon and into the SMBH. This situation cannot be addressed here if all SMBHs contain singularities, as many cosmologists believe. However, some cosmologists are deeply troubled by the concept of a material object which is described as having zero volume and containing a huge amount of mass at infinite density. Rabouski [9] recently reviewed the status of black hole theory and concluded that:

> "As a result we see that studies on the physical conditions of gravitational collapse are only beginning. New solutions, given in terms of physical observable quantities, do not close the gravitational collapse problem, but open new horizons for studies by both exact theory and numerical methods of General Relativity."

So it appears that the singularity concept is anything but certain, and since it is not subject to testing and verification, the author feels free to speculate on other models. Accordingly, a few statements of a conceptual nature will be made about the case where SMBHs do not contain singularities, but are more like supermassive (anti-)neutron stars with event horizons. For such SMBHs, small amounts of accreting dust and asteroids, on passing through the event horizon, would simply annihilate with the antimatter, producing subatomic particles, and ultimately, only photons and neutrinos. If larger rates of accretion occurred a Leidenfrost layer [10] would result, separating the normal matter from antimatter and limiting its rate of annihilation. If accretion then decreased gradually, annihilation of the normal matter would decrease to some rate which is at equilibrium with the accretion.

If an extremely large amount of accretion were to occur in a short time, such as dozens or hundreds of stars, a Leidenfrost shell would likely form just inside the event horizon, separating the two kinds of matter and limiting the annihilation rate. Eventually, annihilation would then proceed to completion and the Leidenfrost shell would dissipate. If we imagine that very rapid accretion continues for a long time, the amount of normal matter in the outer shell would grow, increasing the pressure of the Leidenfrost shell and increasing its kinetic temperature toward 350 MeV, it seems unavoidable that an instability of some kind would have to occur eventually, causing pressure relief by bipolar ejection of the outer shell of matter. This ejected matter would be normal matter, not antimatter, and ejection would continue until an equilibrium state is reached, or (more likely, once begun) until all of the normal matter is either ejected or annihilated. This, of course, is a result that can account for active galaxies, quasars, and blazars, which are now understood to be the same phenomena except for the viewing angle; edge on for active galactic nuclei, oblique angle for quasars, and in-line with the ejected flow for blazars. The above scenario cannot occur with SMBHs as they are understood by most physicists, because such objects are thought to be unable to eject matter, or even radiation (other than Hawking radiation). However, a black hole with kinetic temperature as high as 350 MeV has not been studied, and so it cannot be shown at the present time that such a scenario is impossible under such conditions.

V. AN ACCOUNTING OF THE MASSES

It is now well established that all galaxies with a massive bulge component harbor a central SMBH within the mass range of 10^6 $M_\odot$ to 10^{10} $M_\odot$, and it is becoming apparent that intermediate mass black holes (IMBHs) with mass 10^2 $M_\odot$ to 10^5 $M_\odot$ are associated with many, if not all, globular clusters [11]. Also, several authors have noted that the largest SMBH masses inferred from quasars exceed the largest equivalent dispersions found in local galaxies, implying that the maximum mass of galaxy bulge SMBHs must be > 10^{10} $M_\odot$ [12], indicating that PBH masses exceeded 10^{10} $M_\odot$. Jahnke and Macciò [13] question the SMBH mass-dispersion relationship and also suggest that SMBHs can have masses larger than 10^{10} $M_\odot$. Therefore, it seems that PBHs may have been produced over a wide range of masses, and the cosmology presented here has not been evaluated to establish whether or not there is a mechanism which would provide a natural upper limit to their size. These and other observations and findings seem to open up the possibility that the total amount of baryonic mass in black holes is equal to the amount of total baryonic mass in our Universe, as suggested by van der Marel [14] for IMBHs alone.

The plausibility of a matter-antimatter symmetric universe can be illustrated by showing numerically how it might be possible for our own galaxy to have B = 0, as follows: The observable mass of the Milky Way is ~ 6 x10^{11} $M_\odot$, so if is to have B = 0 the total mass of (unobservable) antimatter black holes must also be about 6 x10^{11} $M_\odot$. Even if every IMBH in the galaxy has a mass of the upper bound of the defined mass (10^5 $M_\odot$) the number of IMBHs required to make B = 0 is 6 x 10^6, which would seem to make it very unlikely that IMBHs are a significant source of the Milky Way's antimatter mass, since less than 200 galactic clusters are believed to reside in our galaxy. The prospects of showing that SMBHs are responsible for the amount of antimatter in the galaxy appear to be much better.

For example, if our galaxy were to contain a single SMBH with mass of 6 x10^{11} $M_\odot$, then B = 0 and the problem would be solved. Similarly with 10 SMBHs, each with mass 6 x10^{10} $M_\odot$, or 100 SMBHs with mass 6 x10^{9} $M_\odot$, or 1,000 SMBHs with 6 x10^{8} $M_\odot$. The absence of observable effects in the disk of the galaxy can be accounted for if, as with globular clusters in the Milky Way, the black holes that make B = 0 for the Milky Way mostly orbit the galaxy at large distances, away from any significant amount of visible galactic matter which might indicate their presence.

If there are hundreds or thousands of SMBHs orbiting the Milky Way, their orbits are probably close to where the putative dark matter is supposed to lie, at about twice the radius of the outermost spiral. The possibility that 6 x 10^{11} solar masses in orbit around the galaxy can account for its flat rotation curve needs to be evaluated, bearing in mind that, if the universe is asymmetric it is even possible that it may contain far more baryonic antimatter than baryonic normal matter, rather than vice-versa as has been thought.

VI. CONCLUSIONS

Roland Omnès, with the assistance of a few others, developed a matter-symmetric cosmology from its initial state as an emulsion of closely mixed matter and antimatter, and tried to show that coalescence would produce galaxy size agglomerations of matter mixed in with galaxy size agglomerations of antimatter. It is concluded here that the effort may have failed primarily because the emulsion was not treated in the model as an emulsion, but rather as a simple mixture of two dispersed phases, one comprised of normal matter and the second comprised of antimatter. However, this is not the behavior that an emulsion exhibits, since emulsions always comprise a fully connected dispersion medium, and a second component of condensed globules dispersed in the medium.

The simple expedient of assuming that the emulsion described by Omnès actually behaved as an emulsion creates an entirely new cosmological model which eliminates the problem in the original model posed by the absence of annihilation radiation, and also seems to have the potential to provide a far more accurate description of the observed universe.

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