Thank for the invitation

ELECTROMAGNETIC

ACCELERATED

UNIVERSE

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1 References

P.H. Frampton,
Electromagnetic Accelerated Universe.
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See also:
P.H. Frampton,
Entropy (2022, in press).
arXiv:2202.04432[astro-ph.GA]

P.H. Frampton,
arXiv:2207.12408v1[astro-ph.CO]
Due to an archiving error v2 is an updated version of 2202.04432.
One must therefore select v1.

2 Introduction

The idea that the constituents of dark matter are primordial black holes (PBHs) is gaining momentum. Using entropy arguments, and assuming that the holographic entropy bound is saturated by PBHs led us in to introduce four tiers of PBHs according to their mass.

Adopting as the unit of mass the solar mass $M_{\odot} = 2 \times 10^{30}$kg. we define a mass exponent p by $M_{PBH} \equiv 10^{p} M_{\odot}$. In terms of p, the four tiers are defined with their corresponding acronyms as follows:

- Tier 1: PBHs with $p < 2$.
- Tier 2: PIMBHs with $2 < p < 5$ (IM $\equiv$ Intermediate Mass)
- Tier 3: PSMBHs with $5 < p < 11$ (SM $\equiv$ Supermassive)
- Tier 4: PEMBHs with $11 < p < 22$ (EM $\equiv$ Extremely Massive)

In the first several decades after the first proposal of PBHs in the 1960s, it was assumed that they were all in Tier 1. In fact it was assumed that $p \ll 0$ and that PBHs were not only much lighter than the Sun but also than the Earth or even than asteroids.

The idea that PBHs may be formed with higher masses than Tier 1 arose in the last few decades. For example, in 2010 it was shown that, at least mathematically, PBHs of arbitrarily large mass exponent p could be formed from arbitrarily large fluctuations and inhomogeneities.

Tier 2 PIMBHs with $2 < p < 5$ were suggested in 2015 as good candidates for the dark matter within galaxies such as the Milky Way. Within the Milky Way, a promising method for detection of PIMBHs is by microlensing, using as targets the stars in the Magallenic Clouds. At the time of writing, all attempts to find the relevant multi-year-duration microlensing light curves have proved to be inconclusive.

Tier 3 PSMBHs with $5 < p < 11$ include the supermassive black holes located at galactic centres. Of the known contents of the universe, these dominate by far the entropy of the universe by 15 orders of magnitude but still fall far short of the holographic entropy bound by another 20 orders of magnitude. This last was the motivation for introducing Tier 4.

Tier 4 PEMBHs with $11 < p < 22$ were the suggestion made in as the only known way to saturate the holographic entropy bound. We cut off Tier 4 at $p = 22$ only because $p = 23$ represents the total mass of the visible universe. A PBH with $p = 22$ may seem unlikely, but the dark matter is sufficiently mysterious that it is best to keep all possibilities open.

In the present talk we suggest a second argument to support the existence of Tier 4 which is related to the observed accelerated cosmological expansion.

3 Electrically charged PBHs

Kerr black holes are completely characterised by three parameters mass M, electric charge Q and spin S. In our previous discussions we have ignored S although it is to be expected that for a PEMBH the extremely high mass will be generally accompanied by a very large spin angular momentum.

We have tacitly assumed that $Q = 0$ as is normally done for astrophysical objects. This assumption has been recently queried for PBHs by astrophysicists.

In 2207.05829 (by Araya, Padilla, Rubio, Suredo, Mangano and Osorio)
four questions are addressed:

- (1) Are PBHs formed with non-zero electric charge Q?
- (2) Do PBHs retain this charge for at least the age of the universe?
- (3) Do the PBH charges all have the same sign?
- (4) Does the ratio Q/M of PBHs increase with increasing mass M?

Remarkably, the authors arrive at positive answers for all of these four questions, and these answers will be assumed in the following. For question (3) a common negative charge like the electron is favoured, although in what follows the sign of the PBH charges does not matter, as long as it is common. We shall focus on the very interesting positive answer to question (4).

We shall define a charge exponent q for PBHs by their charge Q being $Q = 10^q$ Coulombs. The relationship between q and the mass exponent p will be crucial and to suggest what this is we need to extrapolate the results in 2207.05829 about question (4) outside of their range of validity, to be justified only by our interesting conclusions.

Let us consider two identical PBHs both with mass $M = 10^p M_\odot$ and electric charge $Q = 10^q$C. Let the magnitudes of the gravitational attraction and Coulomb repulsion be F_g and F_E respectively. The ratio of these will be denoted by

$$\mathcal{R} \equiv \left(\frac{F_g}{F_E}\right). \qquad (1)$$

which scales as $(M^2/Q^2) \equiv 10^{2(p-q)}$.

To calculate $(\mathcal{R})_{PBH}$, we may start from the well-known fact that for the electron and proton in a hydrogen atom,

$$(\mathcal{R})_{H-atom} = 10^{-39} \qquad (2)$$

and then scale by (M^2/Q^2) to obtain

$$(\mathcal{R})_{PBH} = 10^{-39}\left(\frac{M_{PBH}^2}{M_e M_p}\right)\left(\frac{e}{Q_{PBH}}\right)^2 \qquad (3)$$

Changing mass units to solar masses $M_\odot$, this becomes

$$(\mathcal{R})_{PBH} = 6.8 \times 10^{40+2(p-q)} \qquad (4)$$

To pass from Eq.(3) to Eq.(4) we used

- $M_e M_p = 470 MeV^2$
- $1 MeV^2 = 3.2 \times 10^{-60} kg^2$
- $1 kg^2 = 2.5 \times 10^{-61} M_\odot^2$
- $e^2 = 2.56 \times 10^{-38} C^2$

To use Eq.(4) we need a relationship between the mass exponent p and the charge exponent q. For this we extrapolate from the following results.

- $Q/M = 10^{-32}$ C/kg for $M = 10^{20}$ kg.
- $Q/M = 10^{-22}$ C/kg for $M = 10^{30}$ kg.

These results suggest an increase in Q/M with increasing M. It is irresistible to attempt an extrapolation beyond their domain of validity as follows

- $Q/M = 10^{m-52}$ C/kg for $M = 10^m$ kg.

This extrapolation to higher mass PBHs leads to the following relationship between q and p

$$q = 8 + 2p + \log 4 \tag{5}$$

Using Eq.(5) in Eq.(4), we display in Table 1 some examples of Tier 2, 3, 4 PBHs with $2 \leq p \leq 20$.

Table 1: Values of $\mathcal{R}$ and $\mathcal{R}^{-1}$ for PBHs with $M_{PBH} = 10^p M_\odot$ for various p. The value $q = (8 + 2p + log4)$ is used.

MASS $10^p M_\odot$	CHARGE 10^q C	$\mathcal{R} = F_g/F_E$ $=6.8 \times 10^{40+2(p-q)}$	$\mathcal{R}^{-1} = F_E/F_g$
p=2	$q = 12 + \log 4$	4.2×10^{19}	2.4×10^{-20}
p=5	$q = 18 + log4$	4.2×10^{13}	2.4×10^{-14}
p=8	$q = 24 + log4$	4.2×10^{7}	2.4×10^{-8}
p=11	$q = 30 + log4$	42	2.4×10^{-2}
p=14	$q = 36 + log4$	4.2×10^{-5}	2.4×10^{4}
p=17	$q = 42 + log4$	4.2×10^{-11}	2.4×10^{10}
p=20	$q = 48 + log4$	4.2×10^{-17}	2.4×10^{16}

The values displayed in Table 1 reveal the remarkable fact that as the PBH mass increases into the Tier 4 of PEMBHs the Coulomb repulsion begins to exceed the gravitational attraction somewhere between $p = 11$ and $p = 14$.

We can be more specific by solving $\mathcal{R} = 1$ and find $p = 11.8$. This implies that in the case of two PEMBHs each with, for example, one trillion solar masses the Coulomb repulsion is of comparable order of magnitude to the gravitational attraction and electromagnetic repulsion dominates gravitational attraction as the PEMBH mass further increases. This is counterintuitive only because astrophysical objects are usually assumed to carry negligible electric charge.

Electric charges for PEMBHS are large. Following from our formulas Eqs. (4) and (5) we list for a few notable cases what are the electric charges in Coulombs, together with the corresponding ratio ($\mathcal{R}^{-1}$) of the electromagnetic repulsion to the gravitational attraction for two identical PEMBHs.

- p=12 (one trillion solar masses) has $Q = -4 \times 10^{32}$ C
  and $\mathcal{R}^{-1} = 2.2$.
- p=18 (estimated mass of the Great Attractor) has $Q = -4 \times 10^{44}$ C
  and $\mathcal{R}^{-1} = 2.2 \times 10^{12}$.
- p=22 (the highest mass PEMBH considered) has $Q = -4 \times 10^{52}$ C
  and $\mathcal{R}^{-1} = 2.2 \times 10^{20}$

It has not escaped our attention that the electric repulsion between PEMBHS could provide an explanation for the observed cosmological acceleration.

4 Discussion

When the accelerating expansion of the universe was discovered in 1998, it surprised everyone. It was a monumental discovery which was counterintuitive. To provide a theoretical explanation for this discovery requires a comparably monumental explanation and any specific theory has an extremely small chance of being correct. We suspect that the present theory is no exception.

That being said, the present theory does have some redeeming qualities. The discovery of accelerated expansion was counterintuitive because the force of gravity is always attractive. Our present theory is counterintuitive because electromagnetic forces between astrophysical objects are generally infinitesimally small and negligible in astronomy and cosmology.

In the hydrogen atom the gravitational attraction between the proton and electron is completely negligible compared to the electromagnetic attraction. By contrast, in the Solar System the gravitational attraction dominates because the electric charges of the Sun and planets are negligibly small and the same is true for galaxies and clusters of galaxies.

In the present theory, the dark matter PBHs have extraordinary electromagnetic properties. For the first three tiers of PBHs, relevant to galaxies and clusters, gravitational attraction continues to dominate. For Tier 4 PBHs, however, which constitute the intergalactic and cosmological dark matter, as the PBH mass increases there is a tipping point at about one trillion solar masses beyond which, because of electric charges with a common sign, electromagnetic repulsion exceeds gravitational attraction. It is this electromagnetic repulsion which could explain the accelerated expansion of the universe.

It will be interesting to discover how the present theory stands up to more assiduous and sedulous study.

`Thank you for your attention`