Primordial Black Holes, Dark Matter and Gravitational Waves.

While the nature of dark matter is still a mystery, a viewable option is that it is composed of small-mass black holes, so called primordial black holes (PBH). This month's papers [1] and [2] explore the existence of PBHs with masses around $\mathbf{10^{-12}M_\odot}$ (solar masses) and point out that this possibility can thoroughly tested by the LISA experiment.

One of the big, still open questions in physics is the nature of dark matter. Observations from the velocity rotation of stars around a galaxy show that stars rotate much faster than expected from the visible mass and gravitational laws. Moreover, the observation of Cosmic Microwave Background fluctuations, of the universe's large scale structure and of the dynamics of colliding galaxy clusters also points towards the existence of a new form of matter that does not emit or absorb light and accounts for about 25% the energy of the Universe.

PBHs could account for all (or a significant part) of the dark matter of the universe. These are a hypothetical type of black hole that formed soon after the Big Bang when, after a period known as inflation, regions with a very large density compared to the average universe collapsed under their self gravitation. Since PBHs are not produced from stellar gravitational collapse, their masses can be much lower than regular black holes.

There are different theoretical scenarios for the creation of the initial overdense regions. Amongst the most common is that they were produced during the inflationary period. This is a very exciting possibility, as it connects the existence of PBHs with the production of gravitational waves, "ripples" in the fabric of space-time. These ripples would travel at the speed of light through the Universe, carrying with them information about their origin. In 2015, the first direct observation of gravitational waves was made from the merging of two $\sim 30M_\odot$ black holes by the LIGO and Virgo collaborations [3]. The detection of gravitational waves has not only opened a new window to explore the universe but also renewed the interest in PBHs as a candidate of dark matter.

The mass of a PBH can be related to the peak frequency of the gravitational waves. If the mass of the PBH happens to be around $10^{-12}M_\odot$, the frequency of the gravitational waves is around 3.4 mHz, where the Laser Interferometer Space Antenna (LISA) project [4] has the maximum sensitivity. LISA is a European Space Agency mission consisting of three spacecrafts, which relay a laser beam back and forth between each other, thereby constantly communicating their relative distance. Gravitational waves slightly change this distance and can therefore be measured. LISA is scheduled for launch in the early 2030s.

The serenpidity found in this paper is that for those PBH masses where LISA is most sensitive observational constraints on the existence of PBHs are absent. This can also be seen from Fig. 1, which shows the maximally allowed fraction PBHs can contribute to the total dark matter abundance according to several experimental constraints. LISA is able to either confirm or severely constrain the option, that dark matter is composed of PBHs with a mass around $\sim 10^{-12}M_\odot$, created from inflationary perturbations.

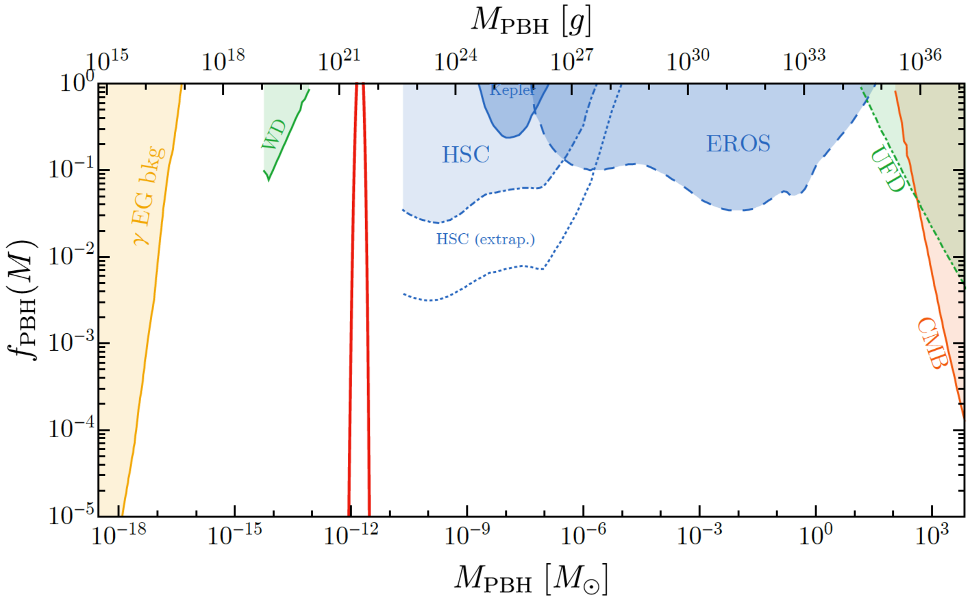

Figure 1: Current constraints on the fraction of dark matter in form of PBH masses. LISA will be sensitive to the gravitational waves produced by PBH of around $10^{-12} M_\odot$ (red band), testing the scenario where most of the dark matter comes in the form of PBHs.

References

[1] N. Bartolo, V. De Luca, G. Franciolini, M. Peloso, D. Racco and A. Riotto, arXiv:1810.12224 [astro-ph.CO].

[2] N. Bartolo, V. De Luca, G. Franciolini, M. Peloso and A. Riotto, arXiv:1810.12218 [astro-ph.CO].

[3] B. P. Abbott *et al.* [LIGO Scientific and Virgo Collaborations], Phys. Rev. Lett. **116** (2016) no.6, 061102 doi:10.1103/PhysRevLett.116.061102 [arXiv:1602.03837 [gr-qc]].

[4] H. Audley et al., [astro-ph.IM/1702.00786].