Contribution Prospectives 2020

(Primordial) Black Holes

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Abstract:

With the discovery of gravitational waves by LIGO, black holes have regain interest in the recent years. In particular primordial black holes (PBHs), which originate from the very early Universe, may constitute (at least in part) dark matter. The possibility that dark matter is made of black holes is particularly appealing, and multi-messenger searches are important to probe this hypothesis. In addition, the study of black holes is of utmost interest since they may constitute portals to new physics and to quantum gravity.

After the discovery of gravitational waves (GWs) by LIGO and the observations of GW events involving black holes, the interest for black holes is growing. In particular, primordial black holes (PBHs), contrary to the stellar black holes created by a supernova, find their origin in the very early Universe [1]. In absence of signal for new physics at the LHC and in dark matter detection experiments, PBHs are now considered as potential candidates for dark matter [2,3]. Contrary to the stellar black holes, PBHs can have a large range of masses, from Planck mass to thousands of solar masses, which can be constrained by different experimental data (see figure below).

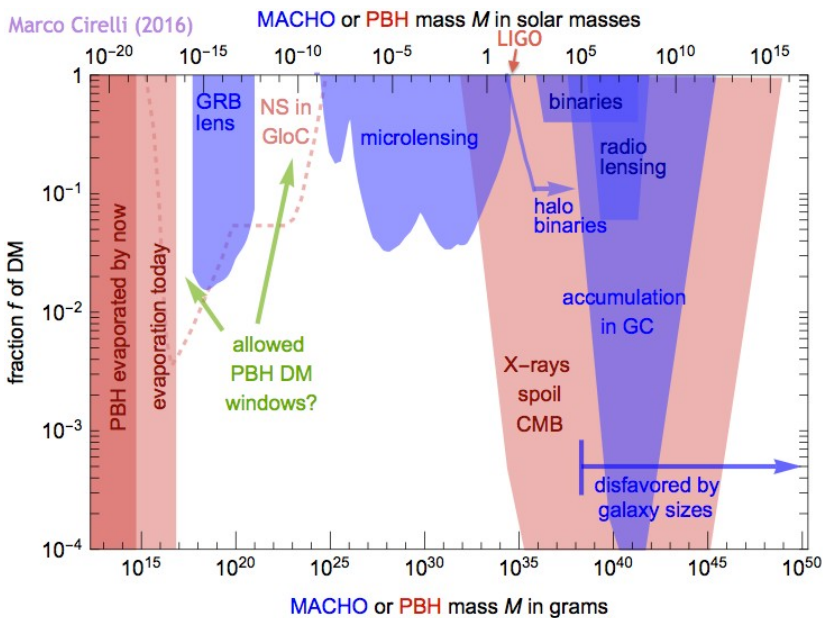

Figure: fraction of PBHs as dark matter, as a function of their mass. The colored regions correspond to different exclusions [2]. It was noted in [4] that PBH formation in clusters may strongly influence these constraints.

The study of primordial black holes, and more generally of black holes, is extremely important for the following aspects:

- gravity physics
  - tests of general relativity
  - nature of singularities, horizons, ...
  - links with wormholes, white holes, extradimensions, ...
  - links with quantum gravity
  - portal to new physics?

- quantum mechanics
  - Hawking radiation: emission of particles
  - physics at Planck scale

- astrophysics
  - formation mechanisms
  - nature of black holes

    - difference between neutrons stars and black holes

- cosmology (for primordial black holes)
    - candidate for dark matter
    - tests of formation mechanisms in the early Universe and of their relationship with particle symmetry and structure of its breaking at super high energies
    - relation with inflation

Studies of black holes can be based on different aspects:

- formal aspects
    - theories and models of black holes
    - information theory and thermodynamics
    - quantum gravity theories and consequences on black holes
    - string theory and consequences on black holes

- models and simulations
    - structure formation and evolution in presence of black holes
    - dynamical effects of PBHs on dwarf galaxies
    - formation of black holes
    - mergers of black holes

- cosmological and astrophysical searches
    - gravitational lensing
    - telescopes

- multi-messenger searches
    - gravitational waves
        - from mergers (LIGO, VIRGO)
        - from formation mechanisms (e-LISA, future experiments)
        - from Hawking radiation of PBHs

    - electromagnetic particles: electrons and positrons (e.g. Voyager-2, AMS-02, ...), antiprotons (AMS-02), photons (X-rays, gamma-rays, ...)
        - from Hawking radiation of PBHs
        - from accretion discs and asymmetric mergers

    - micro black holes at colliders

With this document we propose that IN2P3 gets more strongly involved on studies and searches for black holes.

References

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[3] M.Yu. Khlopov, Res. Astron. Astrophys. 10 (2010), 495-528 [arXiv:0801.0116].

[4] K. M. Belotsky et al., Eur. Phys. J. C79 (2019) 246 [arXiv:1807.06590].