Can Transients Comprise Stellar Population in Galaxy Clusters Constrain Fraction of PBHs in Dark Matter?

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Introduction

Primordial Blackholes (PBHs) formed in the very early universe due to matter overdensity are proposed to be one of the constituents of the mysterious **Dark Matter (DM)**. Motivated by the LIGO detection of many merger events comprising seed masses of ~**30 Solar Masses**, astronomers aroused their interest in searching for or constraining the abundance of PBHs of such mass in the universe, as these compact objects are expected to solely interact with matter though gravity, similar to what we expect for DM. One way to constrain the fraction of PBHs in such a mass window is through microlensing – PBHs' relatively high mass creates different microlensing signatures compared with solar mass microlenses.

In this work, we present a **NEW** method for possibly constraining the fraction of PBHs in DM, by considering the collective flux variability of lensed stellar populations due to the microlensing of **stellar and PBH microlenses**.

Methodology

To consider the collective flux variability of a lensed stellar population under microlensing, we construct a full-scale simulation by randomly sprinkling a sampled background stellar population on Microcaustics generated following a certain microlenses density and PBH fraction in DM. The simulation resolution reaches **~1AU per pixel** which allows us to safely assume each star can have its entire stellar atmosphere restrained within a pixel. All these stars are then ''moved'' by certain relative distances, as computed by considering the observation time cadence and the relative transverse velocity between the observer, galaxy cluster (the primary lens), the host galaxy of the star cluster, and individual stars in the star cluster.

We record the initial magnification corrected luminosity and compare it with the final magnification corrected luminosity to obtain the flux ratio of a stellar population between a certain observation epoch. A fraction of the simulation is presented in ***Figure 1***, where the red and blue dots represent stars before and after the movement. Some move from high magnification to low magnification and vice versa.

Results

Figure 1. Microcaustics and Stellar movement

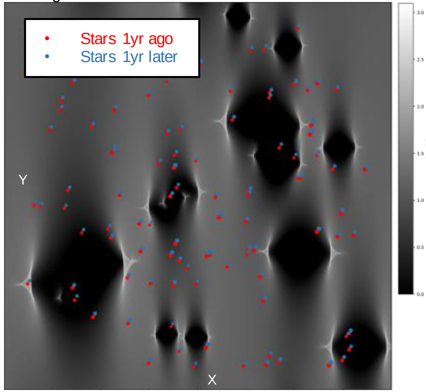


Figure 3. Transient detection probability vs Relative Motion

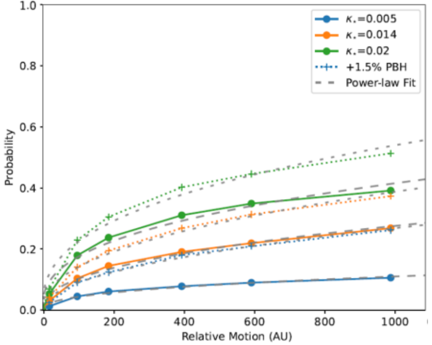
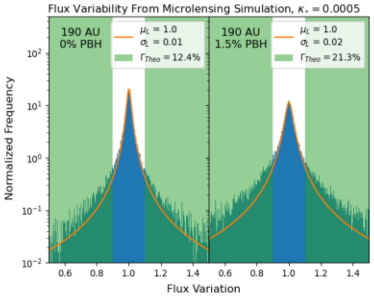


Figure 2. Flux Variability Histogram

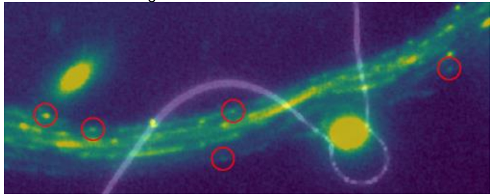


The simulation is repeated many times with different parameters to sample the distribution of allowed flux variability. A sample of the distribution is shown in ***Figure 2*** where we fit a Lorentzian distribution. We consider a detection threshold where any flux variation in the background stellar population of **more than 10%** (green band) can be detected by the telescope. The detection probability and the Lorentzian scaling parameter are plotted as a function of relative motion (which reflects the observation cadence, e.g.: 190 AU is equivalent to 330 days) in ***Figure 3***, where different colors refer to different effective surface stellar density (magnification times surface stellar density). The functions are in fact, good fits of power-laws (gray dashed lines), where we attempt to apply linear fit to the power-law parameters as a function of effective surface stellar density, the only parameter affecting the microlensing efficiency.

One can also tell that **considering 30 Solar Masses PBH taking up 1.5% of DM in the cluster can significantly boost the detection probability**. This fact allows us to compare our statistics with the detection rate of such transients to put constraints on the PBH fraction in DM.

Conclusion

Figure 4. Detected Transients



We compare the estimated transient detection rate that features young star clusters as simulated in this work with the actual observation from the **Flashlights Survey**. In particular, we selected the Dragon Arc in the cluster **Abell 370** which comprises many of such lensed stellar populations as in ***Figure 4***.

The number of transients detected that feature star clusters, if we assume that microlensing is the only source of flux variation, would be 5. With 32 such star clusters (of which some of them are counter-image of each other) in the Dragon Arc, we estimate the transient detection rate in 330 days to be **15.6%**. As a first-order approximation, we extrapolate the simulation result and constrain **the ~30 solar mass PBH fraction in DM to be below ~4.5% with a 3-sigma significance**.

Future Perspective

We opt to improve the simulation by extending the calculation from young stellar cluster to cluster with evolved stellar population and therefore increasing the pool for detecting such transients.

With more in-coming time domain extragalactic information coming in, we expect the course of this work to allow us to constrain the PBH fraction in DM to a further extent.

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