A Microlensing Search for Primordial Black Holes in Dark Energy Survey Data

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Abstract: The search for dark matter is currently one of the most exciting fields in astronomy. One possible candidate for dark matter is primordial black holes, formed from density fluctuations at the beginning of the universe. We search for these black holes through microlensing events by creating light curves from stars in the Dark Energy Survey (DES). Microlensing occurs when a primordial black hole (lens) passes in front of a background star, briefly brightening the output from that star. This brightening, due to the increase in magnitude, becomes detectable. First, we must cut out galaxies from our sample of stars. We then vary key parameters involved in lensing to create potential light curves, and then compare them to light curves from actual events, as well as calculating errors. We then send off these curves for further analysis to determine if any real events occurred. We plan to create 10^6 light curves, due to the large amount of parameters being varied. If these primordial black holes are dark matter, we hope to eventually detect multiple events using the light curves we have created.

Motivation: In astronomy, we work with what we can see. Gravitational lensing in astronomy results when two astrophysical objects align to some degree in the sky. Depending on the mass of each of the objects, several types of lensing may occur. We are most interested in microlensing, which occurs when a massive object moves in front of a source, in our case a star in the Milky Way. When this occurs, we see a brightening of the background object due to the bent light around the foreground source. We use data from the Dark Energy Survey (DES) to look for this brightening and dimming of Milky Way stars, as it may be an indication of a primordial black hole in the foreground, a candidate for dark matter. We edit a currently existing code to create many microlensing light curves by varying many parameters. We will then send the light curves off for analysis.

Methods: Our project currently consists of several steps. First, learn the math behind the microlensing concept and become more familiar with Python and the code we are to edit. Second, edit the original code to take in actual data from the Dark Energy Survey. Finally, send the edited code to another physicist in Australia to analyze all the light curves we have created. We create our curves by varying the following parameters and using the following equations: \( t, u, v, M_{\text{lens}}, D_s, \) and \( x. \)

\[
A(t) = \frac{\alpha(\xi^2 - 2)}{\alpha(\xi^2 + 4)}
\]

Equation 1 calculates the total magnification of the source. We call this magnification “microlensing.”

\[
R_e(t) = 4.54\alpha \left( \frac{M_{\text{lens}}}{M_s} \right)^{1/2} \left( \frac{D_s}{D_{\text{lens}}} \right) \left( \frac{1 - \alpha^2}{\alpha^2} \right)^{1/2}
\]

Equation 2 calculates the Einstein radius, and Equation 3 calculates the closest the object gets to the lens, called the “impact parameter.”

In order to make use of these equations, we will need to create curves that vary every single input parameter by what we determine to be a reasonable amount. We will eventually vary the following parameters: \( t, u, v, M_{\text{lens}}, D_s \) and \( x. \) From the data we will input the initial magnitude of the pixel \( m_0, \) and the list of times that the pixel was observed.

Discussion: We had approximately 1000 pixels to look at. Each pixel has approximately 150,000 separate light sources that have magnitude measurements over different times. Some of these sources are stars, and some are galaxies. We also looked through five different bandpasses: g, r, i, z, and y. In the r-band, for pixel ID 11737, we found that 12,211 stars had an average magnitude of 20 or less, and the remaining 63,295 stars had a magnitude greater than 20. We expect to make approximately 600,000 light curves for every pixel, for each bandpass we decide to utilize. This accounts for the change in parameters. Our overarching result is the creation of a program to create light curves, and then successfully sending them off to be tested against actual microlensing events.

With more time or computing power, we may be able to refine and/or extend our parameters to smaller increments between values, or even extending their range. If no light curve matches are discovered in Australia, it may be a sign that primordial black holes are not the source of dark matter, or do not exist at all. However, if an event, or multiple events, are discovered, it could mean that primordial black holes are the source of missing mass in the universe, and will warrant much future study.

Discussion:

Methods:

Motivation:

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