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Determining Whether Dark Matter is Entirely Primordial Black Holes with a Direct Detection DECam Microlensing Survey

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With LIGO's recent discovery of 30 solar mass ($\mathrm{M}_{\odot}$) black holes[1] and new theoretical arguments[2], we are now motivated to consider a dark matter candidate consisting entirely of primordial intermediate mass black holes formed less than one second after the Big Bang (IM MACHOs; 15-10^4 $\mathrm{M}_{\odot}$). Previous MACHO searches during the 1990's constrained the MACHO content of the universe for MACHO masses below 15 $\mathrm{M}_{\odot}$ (Figure 1). Meanwhile, the original CMB[3] and wide-binary[4] constraints from the 2000's appeared to rule out black hole dark matter above $2\mathrm{M}_{\odot}$; however, these constraints were reliant on complex and poorly constrained astrophysical assumptions. As these assumptions were explored in more detail[5,6], the window reopened between $30 < \mathrm{M}_{\mathrm{dark\ matter}} \lesssim 200\ \mathrm{M}_{\odot}$ but still with "order-of-magnitude" uncertainty due to necessary assumptions. The latest astrophysical constraint based on the stellar profile in dwarf galaxies[7], that presumably rules out black hole dark matter $> 20\ \mathrm{M}_{\odot}$, is also reliant on several astrophysical assumptions (a delta function MACHO mass function, no central massive black hole, and that the Eridanus II star cluster is at the center of the dwarf galaxy) which may be incorrect[8,9,10], and would cause the mass window to reopen.

Rather than attempt to address the various complex assumptions and associated systematics with these astrophysical probes, we propose to carry-out direct detection microlensing measurements of the intermediate mass MACHO population to determine if they comprise all of the dark matter.

Previous microlensing surveys were limited by image quality, analysis methods, and computational resources. Modern telescopes, instruments, and computing enable our parallactic microlensing detection method, which is ideal for the multi-year microlensing event timescales of intermediate mass MACHOs[1]. This is supported by a recent detection of a $9.6\mathrm{M}_{\odot}$ black hole[11]. By combining the parallactic[12] and astrometric[13] microlensing signals we can break the lensing mass-geometry degeneracy and make a precise measurement of individual black hole masses[14]. Thus, if primordial black holes make up dark matter, we will be measuring their "particle" properties, and the distribution of their masses will provide insight into the fundamental physics of the early universe. Furthermore, the parallactic microlensing signal enables dark matter mass constraints irrespective of the Einstein radius crossing time (i.e. mass), thus we can constrain all mass ranges $> 10\ \mathrm{M}_{\odot}$.

We propose a 5 year, 700 sq. deg., multi-band survey of the Galactic bulge with DECam (4 nights/month, 8 months/year, resulting in ~60 measurements/year of ~500 million stars). With this survey, we expect ~100 microlensing events by IM MACHOs. Importantly, this will also act as a bridge to the start of the LSST survey. LSST has potential to be the ideal survey for this science (with ~1000 expected microlensing events); however, microlensing is currently outside its current observing protocol. Additionally, current survey plan options, which only observe the Milky Way in the first year, will unnecessarily preclude microlensing dark matter science. It is pressing that we begin this effort now while there is still time to influence the LSST survey strategy.

By leveraging existing DOE investments in DECam & LSST (~$225M), LLNL data analysis computing efforts, FNAL computing efforts to reduce DECam data, and LLNL LDRD staff support ($150k one year LLNL feasibility study), this survey can be carried out with minimal additional investment by DOE. Additional DOE funds are only needed to support 2.5 postdoc FTE, two graduate students, one professor's summer salary, and travel for DECam survey observing runs to Chile.

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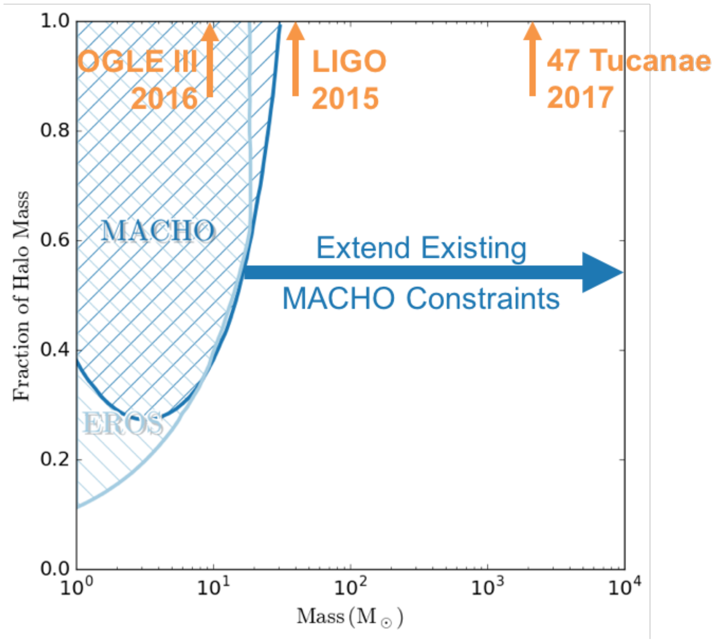

Figure 1: Existing constraints on the fraction of the mass in the MW halo that can be composed of IM MACHO dark matter. We seek to extend the existing MACHO microlensing constraint to higher masses. The masses of detected black holes are indicated in orange[1,9,11].

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