NASA satellite could reveal if primordial black holes are dark matter

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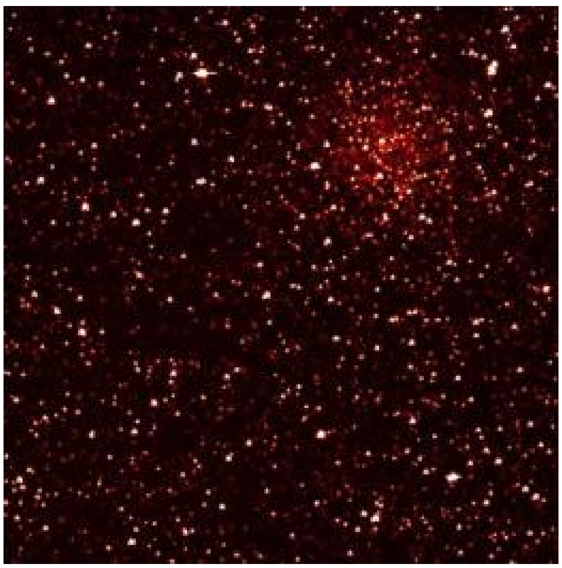

An image taken by Kepler of star cluster NGC 6791, which is located 13,000 light years from Earth. The image has been color-coded so that brighter stars appear white, and fainter stars, red. Image credit: NASA/Ames/JPL-Caltech

(PhysOrg.com) -- The primary objective of NASA's Kepler satellite, which was launched in March 2009 to orbit the Sun, is to search for Earth-like planets in a portion of the Milky Way galaxy. But now a team of physicists has proposed that Kepler could have a second appealing purpose: to either detect or rule out primordial black holes (PBHs) of a certain mass range as the primary constituent of dark matter.

The scientists, Kim Griest and Agnieszka Cieplak of the University of California, San Diego; Bhuvnesh Jain of the University of Pennsylvania; and Matthew Lehner of the University of Pennsylvania and Academia Sinica in Taipei, Taiwan, have published their study on using the Kepler satellite to detect PBH dark matter in a recent issue of *Physical Review Letters*.

“The nature of the dark matter is one of the biggest unsolved problems in all of science and so an answer would be extraordinary,” Griest told *PhysOrg.com*. “If it turns out to be primordial black holes, that will be totally fascinating and everyone will want to understand what happened in the early universe to create them. If nothing is found, then we eliminate much of a major contender, but it is not as exciting.”

As the scientists explain, PBHs have been considered as a candidate for dark matter since the 1970s. These black holes are thought to have formed during the early universe from density perturbations that may have resulted from a variety of factors, such as inflation, phase transitions, and possibly even the collapse of string loops. Because there is no single theory for how PBHs formed, scientists don’t know how massive they would be. However, previous experimental and theoretical work has eliminated most PBH masses, including almost the entire mass range from 10^{-18} to 10^{16} solar masses, the exception being the mass range between 10^{-13} and 10^{-7} solar masses. Scientists call these 5 orders of magnitude the “PBH dark matter window.”

In the current study, Griest and his coauthors think that Kepler data could potentially rule out a significant portion of this window. Currently, Kepler’s photometer is measuring the light intensity of stars – about 150,000 different stars every 30 minutes. When analyzing the data, scientists look for specific fluctuations in star light, or stellar flux, since a decrease could signal an Earth-sized planet transiting in front of the star.

In their study, the physicists have shown that Kepler's photometer could also be used to detect small amounts of gravitational lensing, or "microlensing," which is the bending of star light as it travels through nearby space. According to general relativity, the bending is due to the gravity of an invisible mass that acts like a "lens" and lies between the light source (star) and observer (satellite). This lens could be a PBH or another type of massive compact halo object (MACHO) as well as mini halos, all of which are dark matter candidates.

"PBHs are really just one form of MACHOs," Griest explained. "In the mass range we are sensitive to, I think PBHs are the most likely MACHO, but we won't really be able to tell if they were instead, say, non-topological soliton objects, which are another form of MACHO."

According to the scientists' calculations, Kepler could detect microlensing events caused by masses in the range between 5×10^{-10} and 10^{-4} solar masses, which means it could potentially rule out about 40% of the mass in the PBH dark matter window, if it doesn't detect anything. If it does detect microlensing events, then of course the implications would be much more exciting: PBHs could be dark matter.

"One never really expects to solve such a major problem that has defeated explanation for more than 50 years," Griest said. "So my skeptical scientist side says, most likely we'll rule out some parameter space. The searches for particle dark matter at LHC, etc., have so far come up empty handed, so I do think PBHs are becoming more likely as candidates."

Although other microlensing surveys have examined tens of millions of stars over periods of many years, the scientists explain that Kepler can, somewhat surprisingly, provide stronger limits on dark matter in this particular mass range than these earlier surveys. Kepler's advantages arise from the extreme precision of its photometer, which allows very small magnifications to be detected.

Griest and his coauthors have already begun looking at Kepler's data, which is publicly available. Analyzing the data will not be that simple, since it requires an understanding of the complex light curve data, understanding false positives and background events (such as stellar flares), and using strict selection criteria.

More information: Kim Griest, et al. "Microlensing of Kepler Stars as a Method of Detecting Primordial Black Hole Dark Matter." *Physical Review Letters* 107, 231101 (2011). DOI: 10.1103/PhysRevLett.107.231101

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