Dear Members of the MIT Physics Community,

The announcement last February by the Laser Interferometer Gravitational-Wave Observatory (LIGO) of the first observation of gravitational waves was one of the greatest scientific events of all time. LIGO partners MIT and Caltech were featured at a press conference given by the National Science Foundation announcing the detection. It was followed by a panel discussion with MIT physics professors **Nergis Mavalvala** and **Matt Evans** and senior researcher **Erik Katsavounidis**. Back in Cambridge, MIT Kavli Director Prof. **Jackie Hewitt** and I hosted a lunch for 350 people to celebrate the event. A week later, LIGO co-founder Prof. **Rai Weiss** was joined by **Matt Evans**, Prof. **Ed Bertschinger** and LIGO researchers **Salvatore Vitale** and **Lisa Barsotti** in 26-100 for presentations and a Q&A with the MIT community. Finally, **Weiss** gave a special Physics Department Colloquium to a full house in 10-250. As I write this, LIGO is announcing more detections of gravitational waves.

LIGO's detection led to changes in my view of the universe. I have been searching for dark matter particles called Weakly Interacting Massive Particles (WIMPs) for 30 years. Our first experiment was in 1988 and since then a worldwide effort has led to an improvement of 10 billion in sensitivity to WIMPs. Starting in 1994, MIT has led the Alpha Magnetic Spectrometer (with Profs. **Sam Ting**, **Ulrich Becker** and **Paolo Zuccon**), which resides on the International Space Station (ISS) and looks for annihilation products of WIMPs. After a 15-year odyssey and four years of collecting data on the ISS, we still do not have a clear signal of WIMP annihilation. Theorists tell us dark matter could be another particle called the axion, predicted by Prof. **Frank Wilczek**, but a few excellent experiments have yet to turn up any signal.

A few years ago, I was expressing my frustration at not finding WIMPs, or axions, to Prof. **Paul Schechter** and he sent me a paper about a third possibility for dark matter: primordial black holes.

"Primordial" means the black holes would be produced before the production of matter, during the time of inflation, an idea put forth by Prof. **Alan Guth**. Primordial black holes are not theoretically popular because no one has a good idea of how to calculate them, but that does not mean they do not exist. **Schechter** and Prof. **Saul Rappaport** had made a series of optical and X-ray observations a few years ago of how matter in a galaxy between earth and a bright quasar distorts the image we see of the quasar and showed there would not be enough large black holes in galaxies

to account for dark matter. However, smaller black holes, with masses somewhere between a comet and the moon, would be a perfect way to account for dark matter.

Since then, I have been talking to **Guth** and Prof. **David Kaiser** about how to compute how many moon-mass black holes could have been produced during inflation. I am mainly thinking about how to detect such small black holes. Even though they weigh billions of tons, these black holes would be the size of the proton. They are so heavy, there would not be many of them floating around in the galaxy; they would not hit each other very often nor would they hit stars very often. In the entire age of the universe, it is unlikely that one would have hit the Earth! What makes them perfect dark matter also makes them very hard to find.

Our model of particle physics, the Standard Model, works really well, so explaining dark matter with WIMPs or axions means adding new particles to the model. However, primordial black holes would be explained by our other theory, gravity, so we would not have to add anything to our current model of particle physics. The problem of how gravity makes black holes in the early universe remains.

We believe that gravity and the Standard Model come from the same underlying theory that was present in the very early, hot universe. Our string theorists, Profs. **Wati Taylor**, **Barton Zwiebach** and **Hong Liu**, work on explaining how one theory became two as the universe evolved. Heady stuff.

Many faculty in our Department are looking for dark matter in other ways: **Christoph Paus** and **Markus Klute** at CERN; **Richard Milner** and I at Jefferson Lab; and **Kerstin Perez**, **Janet Conrad**, **Joe Formaggio** and **Lindley Winslow** are building new experiments at MIT. Where this all goes is anyone's guess; stay tuned.

With best regards,

Peter Fisher
Head, Department of Physics