UNIVERSITEIT VAN AMSTERDAM

Probing New Physics Underground. Promotor is prof. dr. M.P. Decowski
T.D.P. Edwards

Summary

A physicists job generally takes two forms: attempting to find signs of a new phenomena, or trying to explain the long list of existing unexplained phenomena. This thesis sits at the boundary, taking ideas from one side and applying them to the other, hoping to succeed in understanding something new, or finding solutions to long standing mysteries.

Throughout our daily lives we interact with the *stuff* that makes up the world around us. This stuff, the atoms that make up our bodies and everything throughout the Universe, is called *matter*. Strangely, measurements of how the Universe moves and evolves have led physicists to believe that there is a lot of extra stuff that we cannot see, *dark matter*. There just isn't enough visible matter to explain amount of gravity we see acting on stars, galaxies, and beyond.

This dark matter has been a mystery to physicists for decades. Many think its a new type of particle, the building blocks normal matter, although this has never been proven. Unfortunately, searching for dark matter is extremely difficult by its very nature. The fact that we haven't seen it already means that it must interact with normal matter so rarely that it has no effect on the Earth. In fact, by tracking the motions of stars close to Earth we can predict the amount of dark matter close by. It turns out that there is so much dark matter that almost 10,000 particles pass through your body every second! Luckily we can use this abundance to search for dark matter here on Earth. By building detectors deep underground its possible to look for the tiny traces of energy that dark matter might release when one of these rare events occurs.

To interpret the data from one of these experiments is a arduous task. Since the number of times these interactions will happen is so low, just by chance we might see only one but we could also see more. If we want to make a discovery and claim we truly have seen dark matter, its imperative that we are absolutely certain that these *events* are caused by dark matter. Chapter 4 is about exactly this topic. How can we be sure that a detector will be sensitive enough to find the evidence we need? We

developed the necessary techniques to answer these questions in an efficient way. In Chapter 5 we went further, calculating whether future experiments will be able to not only *detect* the dark matter but learn about its nature, thus revealing its secrets. Unfortunately, future experimental setups will be unlikely to learn all there is to know about dark matter therefore further experimental tests may be required.

We then turned, in Chapter 6, to a new way to detect these minute energy deposits; using ancient rocks from below the surface of the Earth. By searching for abnormalities in the rocks structure, we can search for the historic evidence of dark matter passing through the Earth. We showed that these *paleo-detectors* could be the most sensitive dark matter detectors to date, and they lie just under our feet.

Finally in Chapter 7 we turned to another set of mysterious particles, known as *neutrinos*. These fundamental particles are not well understood but known to play huge roles in many astrophysical settings. The explosions that happen at the end of a stars life, called supernovae, would look completely different if it were not for neutrinos. Like dark matter, they are all around us, harmlessly zooming through the Earth. We showed that paleo-detectors could find the neutrinos from these supernovae explosions in our own galaxy. If a supernova went off close enough to Earth in its history, the radiation from the explosion could seriously damage our atmosphere, potentially causing mass extinction events. We showed that paleo-detectors would record evidence for one of these events within them, providing evidence for how life evolved on Earth.