A note on Gravitational Waves

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As a young research student back in the mid-seventies, attending a Manchester astronomy conference, I heard Prof Rod Drever from Glasgow talk about the possibility of detecting gravitational waves using laser interferometers - just one of a number of way-out ideas being discussed at the time. This one, however, seemed just about feasible, and as I found myself waiting for a bus to the railway station with Prof Drever, I took the opportunity to question him about the proposal. It was a discussion that stayed in my mind - not only because Prof Drever was more than willing to spend time talking to a student he had never met before, but his enthusiasm for the idea overflowed. He did not know whether it would work. There were many, many orders of magnitude in instrument sensitivity to climb, and though he was sure that they would manage factors of a few million - could they do a billion or even more if necessary? He was going to bet his career on the idea and it would be the major technical challenge for which his experience had prepared him.

It paid off on 14th September 2015, forty years after my encounter with Prof Drever. To those with some connections in astronomy the announcement was not so much of a surprise. Not only had rumours been circulating for some time, the theoretical studies had made it clear that something would be very wrong with our understanding of relativity if we did *not* see any gravitational waves with Advanced LIGO. (Hence, in a way, a negative result after a year or two of operation would have had even more profound implications for physics.)

What was astounding about this event was its clarity. In science we are used to the first hints of a new discovery coming from measurements barely above the noise level. This was a shout! Of course they still had to check carefully, just to be sure that one of the many potential disturbing effects had not somehow created a signal looking exactly like the waves from a black-hole merger. (They also inject simulated false signals into the system to validate the data analysis flow. Could it be one of those accidentally overlooked? No!)

What we could not have anticipated forty years ago was the capacity of modern computers to simulate extreme events, such as the merger of two black holes. Einstein's field equations are elegant and simple in concept, and notoriously difficult to manipulate mathematically. Few exact analytical solution have been found, and back in the mid-1970s numerical simulation of a time-evolving solution of ten simultaneous non-linear second-order differential equations was as far over the horizon as, for example, building detectors to measure gravitational waves. Both are still extreme technical challenges.

The significance of the discovery announced on 11 February 2016 is that the combination of experimental virtuosity and theoretical simulation tells us more than we might have hoped so many years ago. The chirp detected by LIGO can be almost precisely lined up with the expectation of the interaction of two almost equal size black holes with a combined mass of 65 times the Sun. The amplitude of the signal then tells us the distance to the event. So, not only do we have the detection – itself a triumph, we also have data of profound astronomical significance: the first observation of a black hole merger, something unlikely to be seen by any other means.

For the past century astronomy has been in a process of continuous revolution. Every time a new window on the sky opens we have had surprises that have had major impacts on our world-view – most recently with the discovery that most of the mass and energy in the universe is invisible to electromagnetic waves. Well, it does interact with gravity! Who knows where the view from this latest window will take us?

There will undoubtedly be a Nobel Prize associated with this discovery. I hope Ron Drever gets a share, and I hope that he is able to understand, for he now suffers from Alzheimer's and may not appreciate his long-delayed triumph.

Michael McEllin

Astronomy PhD Student 1973-76.