Science is Always Wrong, Eventually

The history of science is riddled with failure, from its beginnings in the days of Aristotle and the Greek philosophers, right up to the 21st century. The process of scientific enquiry begins with speculation about the nature and behavior of something (such as planetary motion). The scientist then develops specific ways to test whether the system being studied matches the theoretical behavior that is predicted by speculation. After comparing predicted results with experimental results, the scientist generally finds that they are different, maybe small differences, maybe large differences. The speculation is then modified to develop new predictions about the system behavior, and the process of experimental fact finding is repeated, hopefully with results that better fit the real world behavior. As you may know from your own experience, it is often difficult to get the right answer the first time, even if the guesses one makes are "educated".

There are some parts of the scientific culture that are not directly rooted in the scientific method described above. One very important philosophical tenet in science is that, if you have two different models of how things work (derived from the speculation), and both of these models match the real world system about equally well, then preference is given to the simpler of the two models. A very good example of this is the description of planetary motion from the history of Astronomy.

Planets look like stars in the night sky, but they have very different behavior from stars. The patterns of the stars appear to the human eye to be unchanging, whereas the planets move slowly relative to the fixed patterns of the stars. Both planets and stars appear to move across the sky during the course of a night, but the *relative* positions of the stars to each other don't change. Thus we have constellations of stars, groupings which resemble something familiar – Orion looks like a man, and the Big Dipper looks like a saucepan. Each new night shows a planet has moved a little bit relative to the group of stars where it is traveling. The Moon has similar and even more noticeable movement from night to night.

One of the oldest questions in science is "what makes the planets different from stars and why do they behave like they do?" Since it looks to us like all the stars, planets, Moon and Sun circle around the Earth, it was a logical thought to try to find a model which put the Earth at the center and all the other objects in motion around the Earth. This sort of model was considered to be correct for several thousand years, but it had problems accounting for the specific movement of the planets. You may know that Venus and Mercury never rise very high in the sky, whereas Mars, Jupiter, Saturn, the Moon and the Sun all pass overhead every day (or night).

Mercury and Venus' peculiar behavior caused early Astronomers to modify the theory that said *all* of the planets circle around the Earth continuously, and so they declared that Venus and Mercury do something a bit different that keeps them in their observed patterns. Everything is OK again, right? Well not quite.

People also observed that most of the time Mars, Jupiter and Saturn move in the same direction as the Sun and Moon, but sometimes, these three planets slow down, stop and then go the opposite direction for a few days or weeks. Then they slow down, stop and go forward again. This was difficult to reconcile with the theory that the planets go around the Earth in simple circles, so Ptolemy (Greek, about 200 B.C.) developed a new model of planetary behavior called *epicycles* which has the planets occasionally following a loop that takes them backwards (as observed). The loop was a smaller circle attached to the bigger circle that was the planet's primary orbit. Ptolemaic epicycles look like the designs you can draw with a spirograph toy, and indeed the geometrical ideas used by Ptolemy are the same basic ideas used to design the spirograph.

Ptolemy's model of planetary motion was accepted for about 1500 years, until Copernicus (Polish, 16th century A.D.) proposed the idea that the planets *don't* go around the Earth, but rather that they (including the Earth) go around the Sun. Only the Moon goes around the Earth. Copernicus' model explained why the planets sometimes *look* like they are going backwards. It is a simple result of having all the planets moving in concentric circles around the Sun, like cars in different lanes of a highway. You have had this experience if you have ever driven in a car and passed another car on the road. If you imagine that you are stationary, then it *appears* that the car you are passing is actually going backwards. You know of course that both cars are going forward, just at different speeds. When the two cars are planets that are millions of miles apart, and one looks like a tiny point of light while the other planet is the one you are standing on, then this effect is not easily perceived in a direct manner. So a great amount of scientific measurement, calculation and speculation is involved in trying to explain why planets behave as we observe them to do.

Copernicus' theory yielded a much simpler model than the Ptolemaic epicycles, even though both models matched the observed behavior of the planets equally well. The simpler model was preferred for philosophical reasons, and it turns out, after centuries of increasingly accurate observations, that a model similar to Copernicus' is correct. In modern times, we have sent robotic space probes to all the planets using the planetary model of Copernicus (modified of course, because it wasn't exactly right), and using the theory of Gravity proposed by Isaac Newton (England, 17th century A.D), which is also not quite right and has been modified by Einstein (Germany and USA, 20th century A.D.).

The principle of choosing the simpler of two scientific models is called Occam's Razor (William of Occam, England 14th century A.D.). The case of planetary motion is relatively simple, to us, looking back, but was quite difficult to develop by the scientists of the past. Modern science has many such puzzles to solve, and many different theoretical models of system behaviors. All theories are considered correct or incorrect (or partially correct) depending on how well their predictions match the results of experiments.

unfinished