Chapter 1

The Lord is subtle, but defies commonsense!

"The way that can be walked is not the perfect way, the word that can be said is not the perfect word"

-Lao Tse, c. 4th Century B.C.

Malcom, an American astrophysicist was peering into his computer screen carefully examining the tons of data beamed back by NASA's Gamma Ray Large Array Space Telescope, GLAST. This had been blasted off in mid 2008 to relay information on Gamma Rays being belched out from the deepest recesses of the universe. Was there a clue that could end the reign of Einstein's Special Theory of Relativity, a theory that had withstood a century of scrutiny?

A continent away, Jacob, a particle physicist in Europe was meticulously computing, using the equally voluminous data being churned out by the recently kick-started Large Hadron Collider (LHC), in CERN, Geneva. Was there a faint footprint of the Higgs particle that had been eluding detection for over four decades? Was the standard model of particle physics erected more than three decades earlier, the last word?

The year, 2010. Both the GLAST and the LHC are multi-billion dollar contraptions, the culmination of years of planning and labor, eagerly awaited for several years by physicists the world over. These would test two of the greatest intellectual theories fashioned out by the human mind in the last century of the millennium, the Theory of Relativity and Quantum Mechanics.

The story begins some 12000 years ago. The Earth was a frozen planet, much of it a freezing white sheet of ice. Human beings lived in caves and caverns, prowling and wandering like polar bears. They wore furs and used crude stone tools in their efforts to hunt down wild animals for food. But already the last of the great ice ages had begun to thaw and a new lifestyle was beginning to emerge. Agriculture. People now had to settle down in habitats to tend to their crops and domesticated animal herds.

As people looked around at the universe - the earth, sky and nature, in bewilderment, they discovered that oftentimes hostile nature could also be an ally in the struggle for survival. For example, they could use clubs or fire and later the wheel.

The advent of agriculture was a major departure in life style from the hunter gathering ways and days. People soon discovered that the drama in the heavens - the rising and setting of the sun, the phases of the moon and the progression of the seasons provided a clock cum calendar so essential for the new science of cultivation. Roughly, the starry sky was the dial of a clock, while the sun and moon were like the hands that indicate the passage of time.

The heavens threw up the different units of time. For instance the sun rises, sets and rises again. This gives birth to the 'day'. The moon passes through its various phases - from full moon through crescent moon back to full moon. This gives rise to the 'month'. Then, the sun appears to have another motion apart from rising and setting. This is a slow west to east drift through the stars. This means that exactly at sunset each day, we see different groups of stars or constellations as we call them, in the west. But after a year, we return to the same pattern of stars at sunset. These basic units of time were used for framing the earliest calendar, which guided ancient agricultural activity.

However as the precision of observations increased, crude calendars gave way to more precise ones in order to keep a track of the seasons, so essential for sowing, harvesting and other agricultural activities. Briefly, the problem which ancient man faced was the following. The month consisted of twenty nine and a half days, while the year consisted of three hundred and sixty five and one fourth days. So twelve months would be three hundred and fifty four days, some eleven days less than the true year. You might say, so what? But this difference of about eleven days would pile up. After about sixteen years, the difference would be about six months – and winter would be summer and summer in winter. A mess!

The ancient Indian calendar, perhaps the precursor of the Sumerian and later calendars overcame this mismatch by using a simple technique. As every three years of twelve months would lead to a shortfall of some thirty three days, an extra month was added every three years, a leap month.

Of course this scheme had to be tweaked even more to bring into step the month and the year.

The point is that the months are computed using the moon. This is very accurate because we can see the backdrop of stars when the moon is present in the sky. However the year is dictated by the sun – for instance the interval between the time when the length of the day (sunrise to sunset) exactly equals the length of the night to the next such occasion. All this happens at the vernal equinox. Similarly there is the autumnal equinox or the winter solstice signalling the longest night and the shortest day and the summer solstice where the opposite happens. It is the year which is important for agriculture, because it is so intimately connected with the seasons. What we are trying to do is to match the months of moon with the year of the sun. Small differences will have to be eliminated. For instance even if we add one extra month every three years, there is still a residual difference of a few days. Such a calendar is called a luni solar calendar and has been the hallmark of ancient agricultural civilizations.

However, one could just use the month as a unit and try to fit in the three hundred and sixty five and one fourth days of the year. Twelve months. This is essentially what has been done over the past two thousand years. Our modern calendar for instance manages to fit in three hundred and sixty five days within the twelve months. The one fourth day could be adjusted by having three years with three hundred and sixty five days and a fourth year, the leap year with an extra day. Again this broad scheme had to be fine tuned to make it precise.

As thought evolved, people began to try to understand and explain what they saw. In the process they built models, that is described new phenomena in terms of concepts or vocabulary they already knew. This is what every growing child does. The pattern has been going on ever since.

The earliest known model builders were the composers of the Rig Veda, several thousand years ago [1]. With amazing insights, they could guess that the apparently flat earth was actually round, describing the earth and sky as two bowls. They went on to describe the sun as a star of the daytime sky and even asked, how is it that though the sun is not bound it does not fall down? And so on and so on. This is an example of a pattern that has repeated itself over the ages: the breakthroughs have been counterintuitive, that is, have defied the apparent dictates of commonsense.

As we will see over and over again, the universe is not what it appears to be. The answers may go against our intuition which is based on our experience. An example of an intuitive model of the universe would be that of the ancient Egyptians for whom the sky was a ceiling, supported at the extreme ends by mountains. It is difficult to break out of the intuitive mold. Such a departure is often forced upon us, due to the utter inadequacy of old concepts to describe new phenomena.

Perhaps the earliest model of what we today call microphysics or atomic or subatomic physics was proposed by the ancient Indian thinker Kanada who lived around the seventh century B.C. For him the universe was made up of ultimate sub constituents which were in perpetual vibration. Later, Greeks also had an atomic theory, which they may or may not have acquired from India. But there was a crucial difference. Their atoms were static. These concepts were brilliant, but they were much too counterintuitive, much too fanciful to be accepted wholeheartedly. How could smooth marble, for example, be composed of separate discrete bits? They remained on the fringes of speculation and philosophy for over two thousand years.

The insights of the Vedas were camouflaged in allegory and this oral tradition was lost over the millennia. Our legacy of modern science came from the more intuition and experience based Greeks who were expert geometers. They built up over a few centuries, an even more complex cosmic scheme in which the flat earth was at the center, surrounded by a series of transparent material spheres to which the various heavenly objects like the sun, moon, planets and stars were attached.

Why the material or crystalline spheres? Well, they were necessary, for, otherwise they would have had to explain why the moon doesn't crash down on to the earth, for example. Newton was not the first man to notice that the apple falls down!

These were spheres because Plato the Greek thinker, had preached that the circle (or sphere) was a perfect object, due to its total symmetry. Plato and his followers were obsessed with this notion of symmetry and perfection, with origins in geometry. His school, for example proclaimed that no one was allowed in, who did not know geometry. This legacy has come down over the ages – even Einstein swore by geometry. The moon is round, and so is the sun. In a perfect world therefore, everything had to be circular or spherical. The modern word "orbit" comes from the Greek word, orb, for circle. Furthermore these spheres would have to be rotating – otherwise how could we explain the heavenly drama such as the rising and setting of the stars.

As the observations sharpened, the above simple model, first put forward by Anaximenes around 500 B.C. needed modifications [2]. For instance the center of a sphere would not coincide exactly with the earth, but rather would be eccentric, that is, slightly away from it. Then the spheres themselves had to carry additional spheres called epicycles, themselves spinning and the objects were placed on top of the epicycles. Later, around 100 (A.D.), Ptolemy the Librarian of the Great Library of Alexandria compiled all this knowledge in two astronomical treatises only one of which, the great Astronomer or Al Magest survived. The Ptolemaic universe was a complicated tangle of such spheres and epicycles and epi-epicycles, undergoing complex circular motions. It was a geometrical wonder though. (Cf.Fig.1.1).

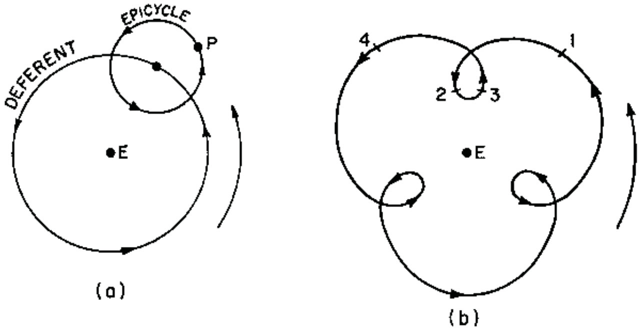

Fig. 1.1 Greek epicycles and effective motion

These basic ideas survived for nearly two thousand years, till the time of Copernicus. Nicolaus Copernicus was born in Torun, today in Poland, to a family dealing with copper. By the time he was forty, he settled down in Frauenberg, Germany. In the sixteenth century, in a commonsense defying leap of faith, he put the sun rather than the earth at the center, though much of the Greek baggage like transparent material spheres and the tangle of epicycles remained. Nevertheless it was a dramatic, even absurd idea. Imagine the solid earth with the trees and buildings hurtling through space! Another contra idea that was smuggled in was that the everywhere flat earth was actually round.

Though such contra ideas had been put forward by a Greek, Aristarchus, more than two thousand years before Copernicus, they were rejected even by the scholars. They argued decisively over the centuries that earth could not be traveling or rotating.

By now there had been a major development. Unfortunately the Greeks did not know of the positional system of notation and so their numbers were the clumsy so called Greek numerals. These were not amenable to algebraic computations. However the positional system of notation including the all important concept of zero were already well established in India over two thousand years earlier. No wonder that the ancient Indians were way ahead in computational techniques. For example Brahmagupta in the seventh century was already using second order differences in his interpolation formulas. So also Aryabhatta was using Trignometrical tables and computations around the same time. Moreover, calculus, an indispensable tool, was being used for planetary calculations at least six centuries before Newton [3].

In the eighth century the founder of Baghdad Khalif Al Mansoor invited Indian scholars, and one in particular, Kanka of Ujjain in Central India acquainted the Arabs with not only the decimal system but also Brahmagupta's computational techniques. The decimal system itself reached Europe through Spain as late as the twelfth/thirteenth century. Two mathematicians, Fibonacci and later Abelard of Bath learnt of this new technique and it soon caught on. Copernicus [4] and later astronomers were armed with this new and powerful tool of mathematics.

But the bold work of Copernicus did not go far enough. Early in the seventeenth century, Kepler a young German scholar, noticed that the Copernican model differed from observation by just a whisker, eight minutes of arc, for the orbit of Mars. Kepler had inherited the meticulous observations of his mentor Tycho Brahe [5], and a lesser mortal would have put down this minor discrepancy to an error in observation. On the contrary, Kepler was convinced that the observations were correct and that the discrepancy pointed to a reformation of Astronomy, as he put it.

Kepler in another counterintuitive leap of faith proposed his first two laws of planetary motion in 1609. Some years later the third law followed. Crucially the orbits were ellipses. This went blatantly against Plato's picture of perfection that had survived two thousand years. With a single ellipse Kepler could wipe out the minute discrepancy between theory and observation, for the planet Mars. There were different ellipses too for other planets. The tangle of crystalline material spheres which had withstood two millennia of scrutiny, finally came crashing down. (Cf.Fig.1.2).

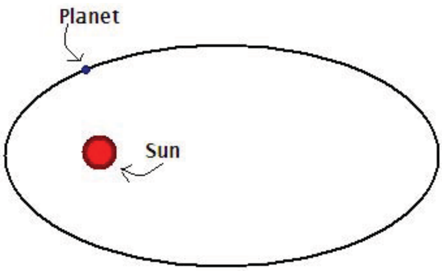

Fig. 1.2 An elliptic orbit

Kepler's third law related the sizes of the orbits of the planets to the time taken by the planets to go round the sun couched in a precise mathematical language. Indeed this was the beginning of modern science.

In hindsight, what the Greeks had tried to do was, approximate a simple ellipse by a series of complicated "perfect" circles. The larger implication of this minute correction was this: The ellipses destroyed the crystal spheres holding up the sun, moon, planets and the stars. And – the age old question once again returned to haunt. Why don't the moon, the planets and so forth crash down?

This question was answered by the brilliant British scientist, Sir Isaac Newton. He first crafted the laws of mechanics which were based on ideas developed a little earlier by the Italian scholar Galilei Galileo. Next he introduced his Theory of Gravitation. Kepler's purely observational laws could now be explained from theory.

Newton's answer to the age old puzzle was actually opposite to what we might naively expect. There was no counterbalancing force to halt the planets from plumetting down. Such a force, as we will see, came from

Einstein much later. Rather it was the attractive gravitational force which held aloft these objects in their orbits! How could that be?
First we should realize that for thousands of years people had taken it for granted that a force was needed only to move an object. Even Aristotle the famous Greek had said so. On the contrary Galileo and Newton noticed that without any force an object could be stationary or it could even move with uniform speed. A force was needed only to change the speed or direction of motion. This was the content of Newton's law of inertia.
So, let us consider the moon going round the earth for example. If suddenly the gravitational force was switched off, what would happen? Rather than plummet, the moon would rush off in a straight line at a tangent to its orbit. This is similar to what happens when a stone whirling at the end of a string is suddenly released (Cf.Fig.1.3). The attractive gravitational force would actually tug at the moon, pull it in and barely keeping it in its orbit.

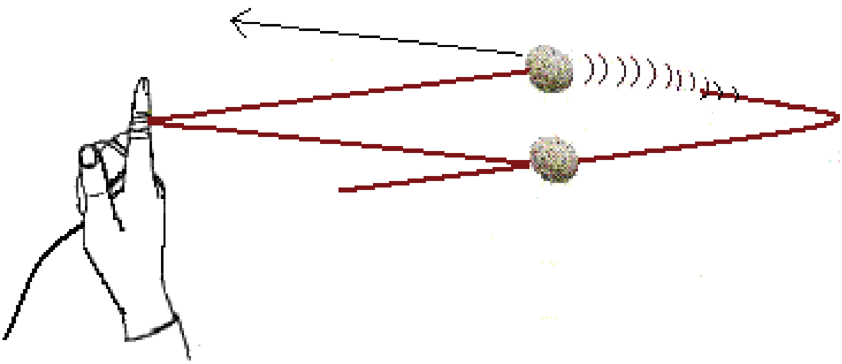

Fig. 1.3 The stone tends to rush off along the tangent if the string snaps

The beautiful edifice of Newtonian mechanics which demolished the Greek crystal palaces dominated the scientific scene for a few centuries - less than a tenth of the life of the Greek model itself. There was an absolute space, while time was separate. Space was a container a platform on which actors like matter, force and energy played their roles. Time too was absolute. The present moment "now", meant the same for a person on the street or an extragalactic being. A meter or a second were universal. All this is, of course "commonsense". Albert Einstein would say, the Lord is subtle, but he is not malicious. The Lord though defies "commonsense" as we will discover.