

Monday, March 09, 2015

Of Relativity and the Other Man

by Tasneem Zehra Husain

Some time in 1919, or so the story goes, Sir Arthur Stanley Eddington was asked whether it was true that only three people in the world understood relativity. Apparently, he thought for a moment and then asked: "Who's the third?" Depending on your mood, that can either sound witty or just plain arrogant, but once you have read his beautiful exposition of the theory, it is difficult to say that reply was unjustified.

Eddington has gone down in history as the man who led the solar expedition to Principe, verified that starlight was indeed deflected by the Sun, just as Einstein had predicted, and hence "proved" the general theory of relativity. That is how he is known, but I think his true claim to fame lies in his deep and intimate understanding of an obscure theory, and the elegance with which he was able to convey his impressions to the public. Eddington had a rare gift for arranging ideas in such a logical and clear order that the progression begins to seem almost inevitable. When you reach the rather surprising conclusion at the end, even though part of you is stunned by the statement, another part is thinking "Well, of course. What else could it possibly be?"



Despite the fact that he was quite a prolific writer and lecturer, for some inexplicable reason his works are not nearly as well known as they deserve to be. Having such an incredible resource available to us, and yet never using it, seems to me a great shame. And so, since to celebrate the centennial of the general theory of relativity, I thought I would walk you through Einstein's (still) revolutionary ideas, with some help from relativity's Other Man.

In the hundred years worth of explanations and illustrations we have accumulated on the subject, there are some images that appear repeatedly, certain phrases that have been uttered so often, they have become cliches. Practically every account of relativity talks about space and time being elastic quantities which expand and contract based on the perspective of an observer; space-time is likened to a trampoline,

distorted, weighed down, by the presence of matter. While all this is true, and even important, I do not want to not belabor these points here; they have been stressed often enough in the literature. What I would like to do instead, is look past the (apparently counter intuitive) behavior of space and time, and - with a little help from Eddington - uncover the hidden motivation, the categorical imperative that compels them to act as they do.

In a brilliant lecture entitled '[The Theory of Relativity and its Influence on Scientific Thought](#)' Eddington begins by exposing the true nature of the intellectual obstacles we face when we attempt to grapple with the theory of relativity, and in so doing, he immediately cuts the problem down to size. We are reminded of the conundrum faced by our pre-Copernican ancestors. By insisting that the Earth occupied a uniquely privileged position, these people sentenced themselves to inhabit a universe where the heavenly bodies executed ridiculously convoluted maneuvers. In order to reproduce observations, our predecessors had to "fill the skies with spheres revolving upon spheres to bear the planets in their appointed orbits; and wheels were added to wheels until the music of the spheres seemed wellnigh drowned in a discord of whirling machinery."

Today, we scoff at that geocentric mindset and all the contortions people of old performed, in order to bend and reshape the universe so that they could stuff it into the little container they had shaped for it. All that was required to obliterate the need for that "cumbrous machinery of spheres and wheels" was to shift the origin of the measuring system from the Earth to the Sun, as Copernicus advocated. With a simple shift of perspective, the planetary orbits which had appeared to be extremely intricate paths, embellished with loops and nodes, were revealed to be mere ordinary ellipses.

It sounds obvious in hindsight, and we find ourselves wondering why any sane person would insist on adopting a viewpoint which introduces such unnecessary complications and is clearly unsuited to the problem at hand? But before we can congratulate ourselves on how far we have come, Eddington bursts the bubble. Our unease with relativity, he says, stems from a similar "terrestrial bias imported into [our conception of nature] by the limitation of our earthbound experience..." When we first come across the idea that the perception of time and space is subjective, most of us find it hard to swallow. It is completely counter intuitive, and flies in the face of everything experience has prepared us for. But our experience, Eddington reminds us, is solidly and (as of yet) uniquely terrestrial; there is only so far it can take us. It appears we do not fully escape the intellectual legacy of that centuries old geocentric point of view, until we espouse Einstein's relativity.

Before we explore the theory in detail, let's take a quick step back and look at science in broad brushstrokes. Why do we attempt to formulate theories in the first place? Why are certain statements enshrined as "laws of nature"? What sets them apart? Why are some laws thought to be more powerful than others?

We have a primal human urge to look for patterns, pay attention to repetitions, and arrange events into causal sequences. We are always seeking a structure, a framework that will bring some degree of predictability and order to the world; and that is precisely what science gives us. Observations are distilled into laws that capture the essence of what is shared by each individual instance. On the basis of these laws, we can then predict the behavior of a similar physical system in the future. A law derives its influence from the breadth of circumstances in which it is applicable. After all, a statement that holds true only in a very restricted set of cases, isn't much of a step up from a mere enumeration of facts! The wider the spectrum across which it reigns, the more powerful the law; the strength of a theory is a measure of the variety of situations it can encompass.

Given that criterion, it makes sense that science strives towards proclamations that are grand, sweeping and context independent. But a detailed knowledge of the world comes through precise measurements, and measurement carries with it the implicit assumption of a system, a scale, an origin. We have to pick a frame of reference - a position and a state of motion to inhabit - from where we will make our measurements; and the instant we do that, we have subscribed to a limited, distorted, view of nature. From here on out, the particulars of what we behold will reflect our choice of frame. In Eddington's words, "wherever we pitch our camera, the photograph is necessarily a two-dimensional picture distorted according to the laws of perspective; it is never a true resemblance of the building itself."

Moreover, the actual view of two photographers, who shoot the same vista from separate angles, could vary widely. Each might pick up certain features of the landscape that are entirely invisible from the other's point of view. Because we are used to moving around in three dimensional space, we are not confounded by apparently different pictures of the same object; we recognize that both images are but facets of a greater whole.

A similar problem arises when two observers moving at distinct speeds, look out onto their surroundings. While both contemplate the same external universe, each experiences it differently; their individual perceptions of space and time are skewed by their motion so as to be out of sync. The principle is exactly the same as it was with the photographers - each observer slices space (or space-time) differently. But, because we cannot navigate our way in four dimensions with the same ease we exhibit in three, the two different perspectives of the moving observers seem contradictory to us, in a way that two photographs do not.

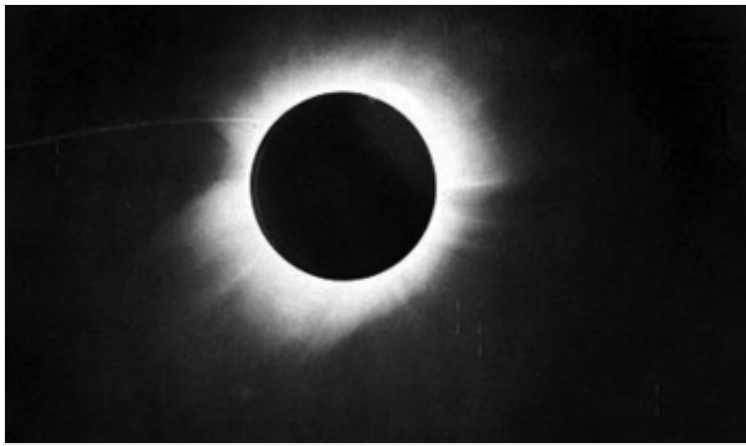
It is interesting, also, to notice that paradoxes arise only when the perspectives of these two observers (in relative motion) are compared. It is only when we attempt to reconcile both sets of observations that objects appear to "contract and expand as they are moved about, and the changes are concealed by an elaborate conspiracy in which all the quantities of nature - electrical, optical, mechanical, gravitational - have joined ... [and there is] a great complication of description which has no counterpart in anything

occurring in the external world." Neither sees any contradictions emerge in their own frame of reference, but *each* must concoct an elaborate scheme, where highly complicated processes are balanced just so, in order to explain (their personal perception of) the behavior of the *other* observer. Doesn't this remind you of the convoluted scheme that had to be made up to justify the motion of the planets for our pre-Copernican ancestors who insisted on placing the Earth at the origin of their coordinates?

In a situation such as this, where our experiences become frame dependent, what kinds of laws would truly be useful? A set of rules and principles that applies to the world as seen by one observer, might not be appropriate for another. It stands to reason that any scheme that is valid only in a certain frame would be limited by definition and hardly seems worthy of being called a law. On the other hand, suppose we could arrive at a statement that was agreed upon by all observers, regardless of their motion. If there was universal consensus, and no voice of dissent arose from any conceivable frame of reference, how vast a domain would this law rule over! How unprecedently powerful would it be!

The theory of relativity is a collection of just such a set of statements. Whether they stand still at a fixed point, or tilt their heads to look at the world from an angle; whether they cruise along at a fixed velocity, or change their speed continuously, whether they move in a straight line, or move along curved trajectories, Einstein's equations hold true for all observers. These "relations of simplicity" as Eddington calls them, link "events ... before they have been arbitrarily fitted into [a] frame." Being context independent, these statements do not stress numerical values (which necessarily depend on the choice of measuring system) but instead stress those relationships between physical quantities that are universal. These primordial decrees predate the selection of individual perspectives; they hold true before we slice the universe into frames of reference, and continue to apply afterwards.

This, to me, is the true reason that Einstein's theory deserves the exalted position that is accorded it. The particulars of exactly how space and time are warped for a particular observer, the specific shape acquired by spacetime as it curves around matter - those are details. The richness of the theory comes from no one single scenario, but the fact that it envelops an almost inexhaustible number of possibilities each with its own set of unique characteristics.



Perhaps it is a peculiarity of my own frame of reference, but it seems to me there's an interesting parallel between Eddington's eclipse expedition and his popular writing. In much the same way that he glimpsed the faint curve of starlight in a day made night, Eddington was one of the first to see the elegant framework of relativity and the ghosts of the gorgeous structures it could support. At a time when the brilliance of relativity was so dazzling that hardly anyone could bear to look straight at it, Eddington stood in front of us, to shield us from the glare; and in the friendly shadow he cast, dim traces of the theory slowly became visible.

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