THREE SCALE MODELS OF THE UNIVERSE

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The steady accumulation of evidence in the last seventy-five years that the structure of nature may be so foreign to our processes of thought that we can never uncover any meaningful objective truth about it does not totally destroy either the desire to make models of certain things in nature or the usefulness of models in certain instances.

Ghosts of 19th century concepts clank stubbornly and mechanically into the 20th century, and if they content themselves to be ghosts and do not attempt to trick us into reinstating them, we can afford them some tolerance and put them to occasional use.

A part of the belief that the universe should be governed by "common sense" laws capable of reasonably simple formulation, is the comfort of believing it also to be basically measurable. Just what we mean when we speak of measuring the universe is not clear enough to have any operational meaning. Even without the breakdown in concept at either end of the scale--the very small and the very large--there is a breakdown in our act of compassing such a range.

When I was a boy I wondered why no scale model of the universe had been undertaken by a museum or planetarium. Simple arithmetic shows why such a thing is impossible to build and almost impossible to imagine. When incomprehensibly large distances are reduced to moderate ones, previously moderate distances become incomprehensibly small.

Something can be accomplished, however, by building a model of the solar system, and then making a model of the model for inclusion of components outside the system, and finally a third reduction for the extremities.

A start can be made with the reduction of everything by a factor of one billion. We now have a model of the earth almost exactly one half inch in diameter and that of the moon a fat BB in orbit with a 16 inch radius. The sun, a four and a half foot sphere, is more than 160 yards away.

These sizes and distances, however impractical to house in a building, are easily conceivable, although the entire solar system in this scale begins to tax our powers if we wish to put in even the largest asteroids. Also, we should require taxi service to Pluto whose orbit has a four mile radius. Taxis are cheap and fast in imagination. What stops the model builder in his tracks is the inclusion of anything in the universe outside the solar system. In this scale of one to one billion, the nearest star is farther away than the distance around the Earth. So in a model that should furnish the visitor with a stout reading glass to view the moons of Mars, we find all stars except the sun so far away we not only can't visit them, but encounter difficulty imagining where they are placed since distances are as "astronomical" as if we had made no model at all.

The way around this is to make a model of the model. This second model is a further reduction of a million and finds Pluto's orbit about one quarter inch in radius. The sun's diameter is now 5.4×10^{-7} inch and can be pictured merely as a point of light. But where we might expect frequent points of light, again the almost overwhelming emptiness of the universe confronts us. Proxima Centauri, nearest companion of the sun, is 130 feet distant. Out beyond and in all directions the points of light glow at distances too great for our binocular vision to provide the guiding parallax which helps us comprehend the distance of most of the thing we view. The Milky Way Galaxy in this scale would sprawl in a void with a 600 mile diameter and with no dense part of it large enough to be comfortably visible to the unaided eye. The giant Antares would measure .002 inch. The Hercules Cluster with its more than 50,000 stars would be a little over half a mile in diameter and about 204 miles away from our dime-size solar system.

Now things are unwieldy again, so a model of this model is in order. The scale chosen for this one is one to 10^{21}. This represents another reduction by a factor of one million. Now the galaxy, 100,000 light years across, is pictured as a glowing pinwheel one yard in diameter. Here the idea of picturing the size of the billions of stellar masses in it or their possible satellites is meaningless. We must abandon worlds and suns and moons and consider only the will-o-the-wisp glow from our spiral-armed galaxy and others like it which are arranged in space in somewhat closer order relative to their size than are stars. The great wheel in Andromeda, M31, would be placed within 35 feet of ours. And stretching to distances of many miles, galaxies reach out in all directions with a random milling movement on which is imposed an ordered and accelerated recessive velocity from any point

center, and proportional to the distance. Light from our final model would crawl at a rate of .00038 inch per year, or an inch in about 2,800 years.

Suppose now that we have the magic ability to move much faster than this sluggish speed - that we are exempt from the limiting speed of light, and can make our way to some of the galaxies 10 to 50 miles from our own. Galaxies out there had shown a pronounce reddening. This is the combined effect of their atoms being in slower flux as a result of their velocities altering their space-time coordinate frames, (an effect of Special Relativity) - in other words, their natural clocks are keeping slower time than ours, and the Doppler effect is of their going away from us (compatible with Newtonian physics) as a train whistle sounding a fixed pitch seems to put out a lower pitch when the train is in motion away from us.

These galaxies have reached a sizeable fraction of the speed of light. Farther out from them there are others whose velocities are so high that all of their proper visible spectrum has slid down into the infra-red area. Also, these galaxies are fore-shortened in the direction of flight. If they are on edge, they become elliptical; if they are perpendicular to the direction of flight they are thinner, etc. It is as though Space itself were shrinking in one of its dimensions. The more it shrinks the more "time" it gives those objects robbed of that one coordinate of space. That is, their time seems slower than ours while we remain at home. It is simply that the distant galaxies are oriented differently in the space-time continuum - they are cutting it up into space and time in a different way. A curious thing happens when we go to them to observe them closely. The shrinking in the direction of flight stops, the pulse of their atomic clocks quickens to match ours, and even their recessive velocity vanishes because we have matched it. But looking back we find our home galaxy suffering the same symptoms we saw earlier in these distant galaxies; reddening and speeding away. Our new location now appears to be the center of the universe. So it is wherever we go.

At distances of just under seventy miles from us in what ever direction we go, galaxies are seen to be double their normal mass, and figuring time at half our value. Any part of any galaxy at that distance that weighed one ounce at rest relative to us would now weigh two ounces, and any clock there would require two of our hours to run off one hour of its own. Galaxies fitting into this great spherical wheel (and remember we are at the center) would also have lost exactly half of one dimension - a foot-rule laid along the direction of motion (always away from us) would be exactly six inches long. The speed of these galaxies is, in our model, .00033 inch per year.

This is a little over 86% of C and multiplied by 10^{21} (the factor of reduction in our final model) gives a velocity of about 161,000 miles per second. (The density is quadrupled since the volume is half and the mass doubled.) So as we consider galactic models farther than 70 miles, the effects rise steeply until soon there are no messages from out beyond a certain point. We do not "see" any galaxies more distant than 80 miles in the final model. The relativity effects are so pronounced that no radiation reaches us. These galaxies are completely flattened in their direction of flight - virtually two dimensional husks whose time is stopped by our reckoning.

At this point we can no longer assign meaning to the existence of these galaxies or any supposed to be farther away. They are completely two-dimensional. That is to say any finite stretch of time of theirs comprises eternity for us and there can be no communication or other interaction between them and us. The semantic content of such words as "reality" and "existence" requires an interaction of some kind to be meaningful. There is none here.

In one view of the universe, these conditions are not due to real motion on the part of the galaxies but to the nature of space at that distance. The tilt or orientation of matter that far removed would be analogous to the adjustment of the concept of up and down for two people at different places on the surface of the earth.

Thus the Universe would seem to be bounded by a formidable barrier --a condition of infinite mass and measuring rods of zero length: A sphere of finite diameter but with no surface; and a strain increasing outward and reaching infinite value at the "end" of the radius.

This is not the simple closed space of a three dimensional continuum curved into a fourth to make a sphere. If this were the case we might consider that a different component of our model existed at the same time. As we approached the limiting distance there would be an apparent increase in size of objects until at the antipodal point an object (the same object) would be seen wherever one looked, and all of its surface would be visible to an observer from his single viewing point. If the antipodal point of the universe for a given observer were, for example, inside a friend's skull (as would be the case if the two arranged themselves at maximum distance) then the observer by looking, let us say east, would see his friend's left ear, by looking north, the eyes and nose, by looking west the right ear and by looking south, the back of the head. Looking downward the soles of the feet, which would appear relatively the smallest part, being farthest away from the actual antipode.

Each would see the other in this way. The behavior of matter in such a space is such that as it moves outward along radii there is an expansion of lateral dimensions - that is the two dimensions perpendicular to the radius - racing off toward infinity as the surface is approached closely. There is not a real expansion but an indication of the reduction of space values in the neighborhood of the surface, on which all value vanishes, rendering the surface actually a single point. A two-dimensional analogy can show this if we imagine the surface of a sphere to be infinitely elastic and removable from the sphere. By putting a pinhole in the south pole and stretching the surface until it widens out, we can force it into a Euclidian plane. Now we have a flat disc. The north pole is the center of the circle and every point on the circumference is the same point - the South Pole. The behavior of flat objects on this kind of surface is analogous to our space above. They are found to be expanding and turning inside out.

But the Universe is not that simple. And before we give up model building because of galaxies that build up infinite mass and go out of existence, we should make some adjustments in time such as we made in space.

And here we find that just as space seems unnecessarily empty in the Universe, time seems to be extremely short. Our model now with the 36 inch home galaxy is a sphere (a very loose use of the word) probably not more than 160 miles in diameter. This is, you remember, in the scale of one to 20^{21}. Now we may apply this reduction factor to time and see how long things last.

We shall suppose the Universe to have started with an explosion involving all of its matter, so we will gather everything together and pack it into a ball. We cannot decide what size ball because it did not know what size to be--it simply filled all space. And there we set it off. If we blink we will miss everything because stepping up time by a factor of 10^{21} means that 50 billion years will pass in .0016 second. The explosion and distribution of matter and energy to their present state, roughly 15 billion years, would be a fast strobe flash.

In a certain sense it may seem pointless to deal with time in a reduction ratio the same as that employed in building this last scale model of space and then considering it surprising or disappointing that Time itself is so very brief, but there is a connection between space and time, the main significance of which may lie in the fact that the separation of the two is conventional: that conscious entities demand that the continuum be split up into space and time to provide a three dimensional world that endures.

That time seems so brief and space so vast is more a commentary on us than on the Universe. Here again, life has built the world along lines of expediency. Our spectra of duration and extension are tiny fragments of cosmic totality, but they differ in magnitude from each other. Life appears to gulp great quantities of time while requiring relatively little space. A hint of this is found in the speed of light. One hundred and eighty six thousand miles is a gross length in human experience while a second is our shortest named unit of time. This equivalence is paralleled by the seemingly disproportionate ratio of matter to energy in $E=mc^2$. Here, vast amounts of energy (by standards based on our use of energy) are bound up in the substances we are made of. All the power companies in the world have produced only about pound of energy. All of the apparatus of our make-up is a long stringy business in space-time that requires only the feeblest impulses to power it. And Time runs out too fast for us if, in reducing the vastness of space to our grasp, we reduce the vastness of time proportionally.

We are free, of course, to set our time reduction at any ratio we wish. Take 5×10^{-13} for example. Now the cosmic drama will take place in two and a half hours, about the length of the average stage play counting intermissions - that is, 9,000 seconds. It is a strange play indeed. The theater itself and the audience come into being when it starts; and there will be no one to ring down the curtain when it ends. It must be viewed from the stage. There are no intermissions, and if there is a plot, we are too early in it to know what it is.

We will assume it began with the explosion. Raw energy at first writhes in a cramped and heavily curved enclosure. The enclosure is space itself. Note here that space by definition is not conceivable apart from matter. As time is the measure of events and time without events is meaningless, so space without matter is meaningless. (If energy in this primordial bomb did not behave as matter until a somewhat later time, the question of whether it occupied "space" at all prior to that moment is clouded by the question of whether there was any space to occupy.) At any rate, matter forms and the two lightest elements are forged in this ultimate crucible. After a minute or so, (in our adopted time scale) a cloud of gas expanding toward rarefaction builds outward and the intensity of radiation drops to be built up locally as stars form. Now heavier elements are synthesized as large stars compact their matter. Space continues to grow. The stars grow by sweeping up the heavy interstellar gas and haze and find themselves arranged in galaxies with the angular

momentum that gives many of them their spiral shape. In fifteen minutes, the "present" is passed. It might be interesting to look at geologic and historic time in passing it. Life has been on earth (which is somewhere among the tiny lights of the yard-wide spiral--if we point to it our fingertip will cover most of the stars which are given names) for about five minutes. Two minutes ago the giant reptiles of the Mesozoic appeared and died out 35 seconds before the end. All four glacial ages took place in the last two tenths of a second. History, from the first buildings of Babylon and Nippur to now, spans one thousandth of a second. James Jeans' simile of our studying the heavens for only "one tick of the astronomical clock" is applicable to a scale much larger than the one we are employing. Modern astronomy in this one is less than one hundred thousandth of a second old.

Galaxies on the "edge" of space - that is, distant and reddened enough to be nearly invisible, will move within minutes to beyond, and no light will come back from them. Galaxies near the center move much more slowly. Under the theory of continuous creation set forth by Hoyle and Bondi and Gold, we would watch for an hour or so and about the time we'd think that the Universe should be showing signs of emptying, we would see that other islands of stars are forming out of new clouds of newly crated hydrogen, replacing those lost by recession. This theory of course has been discredited in favor of the Big Bang Theory and so we should expect to see continued thining of the matter in the universe, unless it should prove there is enough total mass to halt the expansion and start a contraction which would end in "The Big Crunch".

Neither of these pictures will necessarily hold up under the fire of advancing cosmology, and our model suffers from not being able to exist all at the same time, nor to exist in a Euclidian space. In these respects model building must break down. Our use of it here is to suggest that model building can be employed within limits to help span the range of distances and times out of proportion with human habits of measurement. It can help show in the way we still understand things best, that, while an attitude of humility is indicated, there is justification for a kind of pride in the fact that we are, indeed, "citizens of no mean city."