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Space: The Expanse of Void

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Space is a conception of many aspects, and it has arisen – under various names, appellations, and descriptions – in different areas of cognition and knowledge: in cosmology, physics, mathematics, philosophy, psychology, and theology.

– Salomon Bochner

The Vast Stretch Beyond: ***Endless space is an illusion.***

Imagine voyaging in a rocket sailing indefinitely moving far above the clouds and into the distant expanse beyond. It takes you beyond Neptune and Pluto, crossing the Kuiper belt in the outskirts of our solar system where comets are swinging near their aphelions, far and still farther away amidst stars and more stars, and then even out of the periphery of our own galaxy, away from its billions of stars and zooming still more, passing millions of galaxies on the way. On and on you can go in your imagination, never encountering a stop sign that says, "Here endeth Space." As Lucretius would say[1], "the lively force of the mind breaks down all barriers, and makes its way far beyond the glittering walls of the Universe."

Infinity always baffles the mind, and here is a perplexing endlessness that strikes us as reasonable, prompting philosophers and lay people alike to conclude that space is limitless. Many ancient, medieval, and even modern thinkers imagined space to extend *ad infinitum*, as pure fantasy would suggest. But, in the modern view, physical space extends only as far as material galaxies have gushed forth, and this surely does not seem to be *ad infinitum*. Since galaxies appear to be advancing relentlessly every which way, space too is stretching itself to ever increasing dimensions. The cosmos, astronomers tell us, is like one gigantic balloon that is being continuously blown to larger and larger sizes. We seem to be living in an expanding universe. What irony that on our own planet we are gradually running out of Lebensraum!

Twentieth century astronomy has revealed that this is another illusion created by Nature, for physical space does not extend indefinitely. If it did, and stars were distributed uniformly in the heavens, then it would follow that the infinity of stars would light up the night sky as brightly

1 Lucretius, *De Rerum Natura*, i.73. *Vivida vis animi pervicit, et processit longe flammantia mœnia Mundi.*

as broad daylight. In earlier centuries astronomers reflected on this question, and concluded that there ought to be some distance beyond which there are no shining stars[2].

Space, a Stage for the Cosmic Show: *Space is where it all happens*.

The world is a long sequence of events mighty and meaningless, and on every conceivable scale. Space is the arena where all things happen. Take away space and there will be no place to put things in, hence no physical universe. Modifying Shakespeare[3], one might say that all of space is a stage, and all matter and movement merely players and acting. The grandest show of all (the universe) must and will in all likelihood continue, even if there is no terrestrial audience to observe and applaud. But such a world of mute matter *sans* measuring mind would not be pictured or expressed, conceived, experienced or explained the way it is by earthling-physicists. The universe would be like encyclopedias buried under the deep blue sea.

It is a chilling thought, a world without a human mind, ticking on for eons, without a receptacle for color or a response to beauty, or without rejoicing at fragrance, sound, or touch. We may be able to imagine *prakrti*, but not a science without *purusha*. Yet such a universe could well come to pass, as it once was before the emergence of consciousness on earth or elsewhere, if our current understandings of matter and energy and stellar life-spans are correct.

Some Older Views

Classical Indic thinkers spoke of *ákásha* which was one of the five primordial elements. It was the subtlest of them all, and was endowed with the special property of sound which would manifest itself only here and there. *Ákáshá* was the vast expanse, limitless and all-pervading. It was distinct from space and time. On the physical plane, it represented the dark sky above, intangible and unattainable, but at the esoteric level it represented a mystical void whose apprehension is what spiritual enlightenment is all about. To this day, in the sanctum sanctorum of the temple at Chidambaram, famous for its sublime icon of the Dancing Divine, there is a sacred sector where naught is present: that is the *ákásha*, the subtle symbol of spiritual effulgence[4].

Thinkers in ancient Greece considered space in different ways. There was the infinity of Anaximander, *apeiron* as he called it, which could have also been his view of space. Then there was the void of the Pythagoreans, referred to as *kenon*. Parmenides spoke of a Non-Being,

[2] This is the famous Olber's paradox mentioned in astronomy texts. See Edward Harrison, *Darkness at Night: A Riddle of the Universe*, Harvard University Press, Cambridge, MA, 1987.

[3] In *As You Like it* (Act. ii, sc.7. l. 139–140.]: All the world's a stage. And all the men and women merely players.

[4] For details see D M Bose *et al*., *A Concise History of Science in India*, p.460 *et seq*., Indian National Science Academy, 1971.

to mi on in his terminology, which the later Democritus took as the void where his atoms swam. Plato spoke of *chora,* a space which once emerged in the grand, and then gelled into *topos,* the space we experience today[5]. Aristotle interpreted them as global and local spaces, comparing them to a country and a region in it. He said[6], "Place is what is motionless: it is rather the whole river that is place, because as a whole it is motionless."

The Indic notion of the *ákásha* had its parallels in Western thought also. The ancient Greeks called it *aiqhr,* which came through Latin into English as *aether*. In ancient Greek mythology this aether was personified, born of Erebus and Nyx who originated from Chaos, the pre-universe. Like the Hindu *ákásha,* the aether too stood for the blue sky which had been taken as the world beyond our terrestrial abode. This idea persisted in different forms in the worldviews of the ages, for space was for long conceived as a supersubtle substance, existing everywhere and at all times.

In the early phase of the scientific revolution, Descartes formulated analytical geometry, which mapped space on a sheet of paper so as to track down figures and relationships mathematically. He spoke of the three dimensions of space. He was geometrizing space, and spatializing geometry. At the same time, Descartes was also bringing to the fore the *continuity* of space: an idea that is crucial in the mathematical description of space[7]. Descartes transformed the passive emptiness of the *aether* into an entity with mechanical properties. He imagined vortices in the aether, the sun itself being smack in the middle of a gigantic central vortex in the universe. The existence of such an immaterial substratum was taken quite seriously by physicists in their views on the propagation of light.

The concept of an *absolute space* is both intuitive and ancient. Even as ships sail and fish move in the vast ocean-body, one can imagine a static expansive sea of space wherein all movements occur. In his classic work that was to pave the way for the science of mechanics, Newton reaffirmed this idea[8] in a famous *scholium*: "Absolute space, in its own nature, without regard to anything external, remains always similar and immovable." The sheer all-pervasiveness of space led Newton and others to see in it the divine principle, for is not God also omnipresent? Henry More explicitly noted[9] the many parallels between space and the Supreme Being: One, simple, immovable, eternal, existing by itself, incorruptible, etc.

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[5] For selections from their writings, see Walter Kaufmann, *Philosophic Classics: Thales to Ockham*, Prentice Hall, London, 1968

[6] Aristotle, *Physics*, Book IV.

[7] E Slowik, *Cartesian Spacetime*, Kluwer, Dordrecht, 2002.

[8] Isaac Newton, *Philosophiae naturalis principia mathematica* (1687), Scholium II, Cambridge, 1972.

[9] Sharon Lichtenstein, *Henry More: The Rational Theology of a Cambridge Platonist*, Harvard University Press, Cambridge, 1962.

Immanuel Kant looked upon space (and time) from another perspective. He held that space is a mere adjustment by the human mind of the sense data that are incessantly impinging upon it. For him, space was a form in which our external sense-experiences are ordered in the brain. From Kant's point of view, space (and time) have no objective existence; they are created by our sense perceptions. In other words, our impressions of space are just that: impressions. All we understand about space are relations[10].

Homogeneity and Isotropy

It is one thing to study the world in our vicinity and another to make statements about the world at large. But the scientific spirit is intent upon formulating world-pictures that are universal. It is convinced that the laws of physics that we discover here must be valid way out there, anywhere and everywhere in the universe: on the moon as in a distant galaxy millions of light years away. Physics is persuaded (or at least it assumes) that the laws governing the world are the same for no matter whom and no matter where.

Sure, there will be local variations. Martians (if any) can see more than one moon, and creatures (if any) in a multiple star system experience permanent daylight from the thousands of luminaries surrounding them. There are galaxies here and there, strewn all over, like ink spots on a white sheet, or mini-mounds on a flat meadow. Leaving aside clustered clumps, the large-scale features of the universe will be the same everywhere, just as a cup of water from anywhere in the ocean will not vary from place to place. Space, we say, is *homogeneous*.

Next consider the universe along any direction. We see some constellations along one direction, yet others along another. But again, the overall aspect of space is the same along all directions. It is like standing in the snow-white of Arctic wilderness or the scorching Saharan sand and looking every which way. It all looks the same north and south, east and west. The same is true from any spot in space. We look in every direction, and there is no significant difference in the panorama. The universe, we say, is *isotropic*, and so is space.

This view, or compelling assumption, by which the universe preserves common features from no matter where is known as the *cosmological principle*. In a homogeneous and isotropic universe, only three things are possible: the universe remains static, it expands uniformly, or it contracts uniformly.

There are three possibilities for such a homogeneous and isotropic universe: It can remain static, like gas in a closed bottle, with the same constant density all through time; it can be expanding,

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[10] John Randolph Lucas, *Space, Time and Causality*.

somewhat like a balloon that is being blown; or it can be contracting like a collapsing balloon. It is for observational astronomers to find out what exactly is happening.

Space in Current Physics: *Einstein revolutionized our concept of space*.

The notion of an absolute cosmically stationary space may be appealing to the meditating mind, but there is no practical way of detecting it. During the last decades of the 19th century, experimental physicists contrived sophisticated arrangements to put into evidence a static universe-sea in which celestial bodies voyaged, but to no avail [11]. Physics was forced to conclude that there is no such thing as *absolute* space.

When we work out the consequences of abandoning absolutes, we are led to a concept of space (and time) that is jolting to our intuitive apprehension of perceived reality. The most famous theory of twentieth century physics, namely, the special theory of relativity, is the mathematical exploration of the key idea of the non-existence of an absolute frame of reference, and interpretations of the resulting formulas.

The relativity of space implies, among other things, that the physical dimensions of bodies are not *intrinsically* determined. When we speak of the *length of a rod*, for example, we are unconsciously meaning the length relative to a system of reference. The special theory of relativity reveals that the same length, measured by someone with respect to whom the rod is moving, will be quite different. It will, in principle, appear to be shorter.

Moreover, the theory of Special Relativity also discovered that space and time are intrinsically intertwines forming what is known as (Minkowski's) space-time continuum.

Strange this may sound, and certainly contrary to what one would expect, but physicists have amassed ample evidence for believing in *length contraction*. However, this length contraction becomes measurably significant and consequential only when motions are very, very fast. And by *very, very, fast* we do not mean fast as a supersonic plane or rocket, or even fast as orbiting planets which zoom with speeds like a few kilometers a second. Here we are talking about speeds of the order of millions of kilometers a second: unimaginable speeds, almost approaching the speed of light. All the atrociously absurd implications of the theory of relativity – implications which turn topsy-turvy our common-sense notions of space and time – have been amply verified by serious and sophisticated experiments.

[11] A A Michelson and A Morley 1887 ––. On the Relative Motion of the Earth and the Luminiferous Ether. *American Journal of Science*, Vol.34, pp.333–345, 1887.

Geometrical Space: ***Space may be viewed as a collection of geometrical points*.**

Any simple line, short or long, is made up of countless points. It is useful to define such a collection of points as a space. A line may be bent or unbent, so the space in question could be curved or uncurved. We call them *Euclidean* or *non-Euclidean*.

Then again, since any point on a line can be located by specifying just one number (its distance along one or the opposite direction from a fixed point on the line) we say that this linear space is one-dimensional. If we consider the aggregate of points on the circumference of a circle, we have another example of a one-dimensional, curved (non-Euclidean) space, except that this space has no end-points. It is therefore described as *unbounded*, unlike the open line which is *bounded*. The line and circumference of the circle are also *finite*: their measure is not limitless.

We may extend these ideas to points on a plane to generate a two-dimensional space which again may be Euclidean or not. The surface of a flat table is a finite, two-dimensional, bounded, Euclidean space; whereas that of a ball is an example of a finite, two-dimensional, unbounded, non-Euclidean space. All the points making up the *body* of a cube constitute a finite, bounded, three-dimensional Euclidean space.

Can we envision a three-dimensional curved space? Here is a challenge to the image-making prowess of the human mind. Try as we may, we cannot *picture* a world where three-dimensional physical space suffers a curvature. The reason is simple: For curved space of any dimension we need a space which is at least one dimension higher into which it can possibly curve. That is why we need a sheet of paper of two dimensions to draw a curved line, and a three dimensional space (which has volume) to accommodate the surface of a ball. But where is the fourth dimension into which our three-dimensional space can curve? We are limited in our imagery.

Another note on technical terminology: the measurable features of short distances in a space are said to be given by its *metric*. The metric of flat (uncurved) space is said to be Euclidean. Curved spaces have other kinds of metric, depending on the nature of their curvature. A closed curved space is said to have Riemannian metric.

Physical Space is Non-Euclidean

Interstellar space up there appears to be three-dimensional, Euclidean, unbounded, and infinite. But twentieth century physics has revealed that it is neither Euclidean nor unbounded, nor infinite for that matter. The deeper we probe into the nature of perceived reality, the stranger we find its roots to be.

The vast three-dimensional space which is the abode of stars and galaxies where chunks of matter are drifting silently at random is non-Euclidean. Its curvature is wrought by the massive bodies it harbors. Not unlike a sheet of stretched rubber that sags downwards in the vicinity of a heavy load on it, three-dimensional space suffers a kink in the neighborhood of massive stars. The immense masses of the countless galaxies cause physical space to curve into a bounded whole which is how our universe seems to be! The curvature of space at any point is a measure of how much matter is present in the region.

The curvature of space follows from Einstein's theory of General Relativity. This is not simply mathematical poetry. It is physical enough to be subjected to experimental check. It implies that the path of light – assumed since ages to be rectilinear – would perforce be curved in the vicinity of a massive body like our sun. This would imply apparent changes in the known positions of stars when viewed during a solar eclipse. So scientific expeditions were dispatched to Brazil and elsewhere for observing a memorable solar eclipse which came to pass on May 29, 1919. As A N Whitehead described it[12], when the observational confirmation of Einstein's theory of General Relativity was announced in the hallowed hall of the Royal Society of London, "the whole atmosphere was exactly like that of the Greek Drama... There was dramatic quality in the staging: the traditional ceremonial, and in the background the picture of Newton to remind us that the greatest of scientific generalizations was now, after more than two centuries, to receive its first modification".

Macro- and Micro-Space

Aside from the technicalities involved, the notion of space in the worldview of current physics is not uniquely determined. There are, in fact, three levels at which space becomes relevant in 20th century physics, and in each instance the picture is slightly different. Depending on how we view it, space reveals varying aspects of itself.

First there is the space at our level of description and calculation. This is the *classical space* where that you and I stay and survive, like the other things we see around. This is the space wherein tops spin and projectiles zoom, the space of common sense and high school physics. This too is the space that presents itself to astronomers when they compute the orbits of planets and comets, and to explorers when they speed in space ships.

Then there is the space of the microcosm, or *quantum space*. This space is determined by the laws of Special Relativity and quantum field theory. It is in many ways very different from the

[12] Alfred North Whitehead, *Science and the Modern World* (New York, 1948 ed.) p.15. For further details, see V V Raman, Relativity in the Early Twenties: Many-sided Reactions to a Great Theory, *Indian Journal of History of Science*, Vol.7, No.2, p.1006, 1972.

inert vacuous space of everyday experience. Here, as was mentioned, strange things happen, like the fleeting emergence and vanishing of peculiar particles. What is more, this space could very well be just one manifestation of something more complex and curled that undergirds the world. Theorists have worked out esoteric mathematics which interpret our space to have ten dimensions, six of them squeezed into imperceptible minuteness.

Finally, there is *cosmological space*: the very big space where huge chunks of matter and very long stretches of time come into play. In the analysis of this cosmic space General Relativity takes over. Here space has measurable curvature, kinks, warps and all. This space is totally closed or open perhaps: as yet, astronomers do not have data enough to say which, for it all depends on how much matter there is in the world at large. As noted earlier, if indeed, as it seems to be the case, galaxies are receding with increasing speeds due to dark energy or whatever other cause, then eventually all galaxies beyond our own will no longer be within our observational range.

The Extremes of Space: *The span of space from the very small and the very large is inconceivably impressive.*

Assuming you have very sharp eyes, how small an object can you see? Perhaps the tenth part of a millimeter. Surely there are objects much smaller than that. There is a whole world of living entities whose dimensions are minute compared to the millimeter. The smallest bacteria are barely a fraction of a micron across, and viruses are no bigger.

But even these specks of life are made up of multi-millions of molecules, so when we descend to molecular levels, we enter a whole new realm of smallness. Molecular sizes are of the order of 10^{-10} m. Atoms are smaller still, but even they are spread out in their tiny space, extending to some 10^{-12} m. The core of the atom, the nucleus, is still smaller, its radius being of the order of 10^{-14} m. These are unimaginably minute dimensions. But such are the features of the deep-down roots of perceived reality, as revealed by physics. More remarkable still, microcosmic entities dance impeccably to the tune of precise physical laws, never missing a step: as if trained in a most perfect school.

Objects we ordinarily handle range in size from a few centimeters to a few meters. We can see large lakes and landscapes, mountains and meadows, extending to a few kilometers. There are asteroids hurtling through space, mammoth rocks a few kilometers wide, and then the moon and the earth, other planets and satellites with diameters of the order of thousands of kilometers. Our sun is huge compared to these, bulging to almost a million and a half kilometers, but then there are stars in high heaven that are thousands of times larger even than our sun. If extensions are what we are trying to imagine, consider the distance of the sun from us: about 150 million kilometers. But the radius of our solar system is immensely large: Pluto is more than three and a half billion kilometers away from the sun!

Then there are stars trillions of kilometers from the sun, and again sizes become staggering. Our solar system is a citizen of the vast Milky Way which includes billions of other stars. The diameter of the Milky Way has been estimated to be about 10^{18} kilometers. The closest galaxy is ten times as far as the size of our galaxy. Taking into account all the galaxies observed and from other considerations, astronomers aver that our universe extends to some 10^{23} kilometers, a number that is more easily written down than visualized.

Such is the stupendous range of sizes structuring space: from microcosmic minuteness to intergalactic separations and the cosmic stretch. All of this is mind-boggling, but enormously more impressive is the fact that the human mind that has fathomed so much of the mystery.

Three-dimensionality of Space: ***The three-dimensionality of space causes many things to happen*.**

We live in a space of three spatial dimensions. One may wonder why this is so, and if this has any observational consequences. It turns out that the inverse square law of gravitation would be impossible if space had more or less dimensions. Carrying this result into the microcosm where electrons revolve around nuclei because they are subject to the Coulomb inverse square law, it has been shown that the stability of atoms, and therefore of all matter, depends on the three-dimensionality of space. It has also been established that in a space with an even number of dimensions, the behavior of waves would be very different, and would result in a very different kind of world.

It was argued by Gerald Whitrow that a three-dimensional space is a necessary condition for the evolution of human beings. Indeed there are reasons to believe that if there were spaces of higher dimensions the fundamental constants would no longer be constants, but changing ever so slowly[13]. In more recent theories in fundamental physics, the considerations of spatial three-dimensionality have become quite complex.

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[13] For a non-technical discussion of these questions, see John D Barrow, *The Constants of Nature: The Numbers that encode the Deepest Secrets of the Universe*, Vintage Press, New York, Ch.10, 2002.

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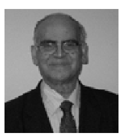

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