THE UNIVERSE

Mendel Sachs

The human race has understandably been fascinated over the ages with the universe. From the periods of ancient Greece and Asia, a primary pursuit has been the observations of the stars and planets of the night sky – the subject of astronomy – and the speculations to understand them.

Greek Astronomy[1]

In ancient Greece, about 2300 years ago, Aristotle argued that the Earth is at rest at the center of the universe, and all of the heavenly bodies are in rotation about it. In that period, Aristotle's idea was confirmed by the observations of the astronomer Ptolemy. This is the 'geocentric model' of the universe. A few centuries before Aristotle, Pythagoras speculated about the structure of the heavens, based on mathematical relations that he discovered. Some of these relations were found, in part, from his discovery of irrational numbers and the relations of the frequencies of vibration of a stretched string to the fractions of the length of the string under vibration. In this, Pythagoras saw a connection between physics and mathematics. That is, he reasoned that the discovery of mathematical relations must imply physical relations in the real world. [*Pythagoras did not personally record his own findings. They were recorded by his disciples – the 'School of Pythagoras'*]

Aristotle's teacher, Plato, also speculated about the distribution of stars, based on his idea of 'forms' and symmetry of the heavens. He argued that the stellar objects must be at the vertices of regular solids – these are geometrical forms that can be inscribed with their vertices on the surface of a sphere – which he assumed was the shape of space. (*These are the five regular solids: cube, tetrahedron, icosahedron, octahedron and dodecahedron*). Plato believed that the space of the universe must be spherical because the sphere is the most perfect of forms.

On the subject of the extent of space, Aristotle believed that it must be finite. He argued that the only logical reason for space to exist is that it must be there to occupy matter. From his observations, he deduced that the amount of matter in the universe is finite, thus he concluded that space must be finite.

Aristotle agreed with Plato that there are four primary elements - air, earth, fire and water. He then asserted that earth must be 'down'. He concluded that material objects would fall to Earth because their natural place is 'down'. [*One might see this assertion as Aristotle's law of gravity*].

Aristotle deduced that there is an absolute center of the universe. This is the location of our planet Earth. All other stellar objects must then be in circular motion about Earth, at the center of the universe (in agreement with Ptolemy's astronomical observations).

It should be mentioned that Plato's understanding of the heavens was qualitatively different from that of his pupil, Aristotle. Plato's view was abstract, based on the ideas that we form in our minds. The reality of the world must then be deduced by rational analyses from these impressions on our minds. On the other hand, Aristotle's view of the world was concrete – that the ways of the world is the way that we directly experience it. [*This difference in understanding the world is indicated in a painting of Raphael, ' School of Athens', in the*

Renaissance period. In this painting, Plato is seen pointing upwards to the heavens; Aristotle is seen pointing downwards, to Earth.]

As time progressed to the medieval times, the scholar of the Roman Catholic Church, Thomas Aquinas, argued that Aristotle's ideas of the universe were compatible with the Holy Scriptures. Thus the Christian Church adapted most of Aristotle's views as God's truth. An exception of disagreement was Aristotle's conclusion that there was no beginning of time. In contrast, the Church advocated, in accordance with the Biblical Scriptures, that there was a beginning of time, when God created the universe, *ab initio*. In the 15th century, contrary to the views of the Church, Copernicus discovered from his observations of the night sky that the Earth moves relative to the Sun – that Earth is not at the center of the universe! (*Thus, that the human being, residing on Earth, is not at the center of the universe!*) He theorized that the Sun is indeed at rest at the center of the universe, with all heavenly bodies (including Earth) revolving about it. This is the 'heliocentric model' of the universe.

Galileo's Physics[2]

In the 16th century that followed Copernicus, Galileo was the first astronomer to use the telescope, to magnify his observations of the heavens. He agreed with Copernicus that the Earth moves. But he argued further that motion, *per se*, is a subjective feature of our observations. Thus, from his understanding, it is just as true to say that the Sun moves relative to the Earth, *from the Earth's perspective*, as it is to say that the Earth moves relative to the Sun, *from the Sun's perspective*. It was his assertion that it is the physical law that binds the Earth and the Sun that must remain unchanged in form, independent of the perspective taken. This is called "Galileo's principle of relativity". It is a very important precursor for "Einstein's principle of relativity", that logically underlies his theory of general relativity, that was to come in 20th century physics. At the present stage of the history of physics, the latter is an important underlying law of the physics of the universe as a whole – the subject of cosmology.

Modern day Astronomy

In the 16th century, Galileo believed that the display of stars of the night sky, that we call the "Milky Way", is the entire universe. It was learned centuries after Galieo that the "Milky Way" is only one of its galaxies. A galaxy contains a very large number of stars; it is one of an infinitude of other galaxies of the universe. Our Sun is an average sized star among a very large number of constituent stars of the "Milky Way". It was discovered in the 19th century that "Milky Way" has a neighboring galaxy, called "Andromeda" that forms a binary system with "Milky Way".

With the present day high resolution instrumentation (such as the Hubble telescope) we have now gained a great deal more information about the night sky. There are exotic stellar objects, such as the pulsars and quasars. Pulsars are extremely dense, small stars that emit periodic bursts of radiation. Quasars are the most distant stellar objects we see, with enormous emitted radiant energy.

Recent high resolution telescopic observations reveal the shapes and dynamics of the galaxies. Most are 'pancake' shaped, bulging with their constituent stars at their centers. Most have spiral arms. Our own Sun is in one of the spiral arms of "Milky Way". Some of

the galaxies have the shape of ellipsoids. *[It has been my speculation that the galaxies behave like plasmas and that they therefore change their shapes during their natural pulsations. In this view, there is a possibility that there are continual transformations between the spiral and ellipsoidal shaped galaxies].*

It has been seen that the 'flat' spiral galaxies rotate about an axis that is perpendicular to their two-dimensional forms. It was originally thought that this rotation is due to the gravitational pull on them by their neighboring galaxies. But the masses of the galaxies are known as well as their mutual separations. It was then seen, using the approximation of Newtonian gravity, that the neighboring galaxies would be inadequate to cause the observed rotations of the galaxies. It was then speculated that there must be some invisible matter (to us) that permeates the universe that is responsible for the rotations of the galaxies. This unseen matter is called "dark matter". Candidates for this would be a dense sea of (non-zero mass) neutrinos and antineutrinos, or a dense sea of particle antiparticle pairs. Such electrically neutral matter couples gravitationally to other matter.

The Expansion of the Universe and the Hubble Law

In the 1920s Edwin Hubble discovered that the universe is expanding - the galaxies of the universe are moving away from each other at an accelerating rate. The empirical finding was that the speed of any galaxy relative to another, v, is linearly proportional to their mutual separation R, i.e., $v = HR$. The constant of proportionality, H, is called Hubble's constant. Its determination then allows us to extrapolate backwards in time to see when the expansion started – the 'big bang'. It turns out to be the order of 15 billion years ago.

Hubble's law was established from the Doppler shift of radiation emitted by one galaxy that is moving away from another. In the visible spectrum, the frequencies of monochromatic radiation of the emitting galaxy are then shifted toward the red end of the spectrum. Thus, it was Hubble's conclusion that all of the galaxies of the universe are moving away from all other galaxies – the universe is expanding.

This expansion does not mean that the universe as a whole is moving into empty space. There is no empty space outside of the universe – the universe is all that there is! What the expansion signifies is that, from any observer's view, the density of matter at any point in the universe is decreasing with respect to his or her time measure.

Extrapolating backwards in time, as we have indicated above, leads to the time when the density of matter was at a maximum and it was maximally unstable. This state led to a gigantic explosion - the 'big bang' – starting the presently observed expansion of the universe.

The question then rightly arises: How did all of the matter of the universe get into this state of maximal density and instability in the first place? To answer that this was the moment when God created the universe is unacceptable – it is a religious answer for a scientific question![3] The only scientific answer that I see is the following: Before the time of the 'big bang' to initiate the presently observed expansion, the matter of the universe was imploding under a dominating attractive gravitational force. Then, at an inflection point, the predominance of the attractive force changes to a predominance of a repulsive force, thereby changing the implosion into an explosion – leading to an expanding universe. In the course of the ensuing expansion of the universe, the matter becomes

sufficiently rarefied that the predominance of the repulsive force changes at an inflection point to a predominance of the attractive force once again. The matter of the universe then contracts with increasing density. The contraction reaches an inflection point once again when the implosion changes to an explosion and the contracting universe changes to an expanding universe, and so on *ad infinitum*. This is the "oscillating universe" cosmology.

The repulsive as well as the attractive gravitational force is an implicit feature of Einstein's theory of general relativity. This is in contrast with Newton's theory of universal gravitation, where the gravitational force is only attractive.

In Einstein's theory, the terms that play the role of force entail the 'affine connection' components of the curved spacetime. *These are not positive-definite*. That is, under some physical circumstances of sufficiently high matter density and relative speeds between interacting matter, the force of gravity would be repulsive. This would lead to the expanding universe. Then, under the conditions of more rarefied matter and low speeds between interacting matter, the force would be attractive. These features then lend themselves to the dynamics of the 'oscillating universe' cosmology, where, cyclically, expansion of the matter of the universe turns into contraction, and vice versa. This cosmological model is indeed compatible with Einstein's theory of general relativity. The single big bang model, where there is a absolute moment in time when the expansion starts, is not so. Most contemporary astrophysicists believe in the 'single big bang' cosmology.

It is interesting that the 'single big bang' cosmology entails an absolute time measure, referring to the beginning of the universe. But an absolute time measure (even on a cosmological, scale) is incompatible with the symmetry requirements of the theory of relativity. Here, the time measure, from any observer's reference frame, is relative to that frame. All that is 'absolute' in relativity theory are the forms of the laws of nature – they are independent of the reference frame in which they are expressed. This is the *principle of relativity*, which is the axiomatic basis of the theory of relativity.[4]

The Cosmological Future of the Human Race

On the controversy between the single big bang cosmology and the oscillating universe cosmology, it might be asked: What is the future of the human race according to these scenarios? According to the single big bang model, the universe will continue to expand, forever, monotonically. The stars will all eventually burn out their fuel and turn to cosmic dust. Before our Sun approaches this end, the human race will freeze out of existence and human bodies will disintegrate, joining the rest of the cosmic dust that makes up the entire, ever-expanding universe. In this scenario, it seems that the existence of the human race is an accident, forming over the relatively short time (compared with the time of evolution of the universe) when conditions were (temporarily) conducive to the formation of life systems.

According to the oscillating universe scenario, the expansion, in any given cycle, will change to a contraction of all of the matter of the universe. A time will then be reached when our species will heat up and vaporize out of existence, joining the 'soup' of all of the matter of the universe in a very dense state. This matter will then 'explode' once again in a 'big bang' – the beginning of a new cycle of expansion and later, contraction. Eventually, during the expansion, the matter of the universe will cool down and conditions will be ripe

once again for the formation of stars, planets and life forms. The human race will once again be generated on some of these planets, as it has happened in all previous cycles and will happen in all future cycles of an oscillating universe. In this view, then, the existence of the human race is cyclic and not an accident! It is, instead, a part of an underlying order, and just as old as the entire universe!

Olbers' Paradox

A problem for astronomy is the following: From the infinitude of stars of the universe, their emitted light (and other forms of radiation) has accumulated to infinite proportions over the time of evolution of the universe. Then why is the night sky dark? This is "Olbers' Paradox".

One answer given by the astrophysicists to resolve this paradox is the following: The frequencies of light (say in the visible spectrum) are decreased toward the red end of the spectrum, because of the expansion of the universe. This is the Doppler effect - it is because the emitter of this radiation is moving away from its absorber (detector). With the decrease of frequency Δf, of any 'photon' of light, there is a corresponding decrease of the energy of this light according to the Planck rule: $\Delta E = h\Delta f$. Thus, the expanding universe entails a steady decrease in the energy of emitted radiation from the stars, leading to our not absorbing the energy of most of this radiation.

I do not believe that this us a valid resolution of Olbers' paradox. For we must distinguish between what we (or any other 'absorbers' in the universe) "see", due to the relative motion of the emitters of the light in giving rise to the Doppler effect, on the one hand, and the intrinsic energy of this light, on the other hand. The latter is the *proper energy* of the light emitted by the stars – it is not affected by our observations of it! The conclusion must still be reached, with this view, that the total *intrinsic energy* of the emitted radiation from the infinite number of stars of the night sky must be infinitely large. Yet, the night sky is dark. Why is this so?

I believe that the resolution of Olbers' paradox comes from Faraday's interpretation of light, together with the theory of relativity. Faraday's interpretation of light is that it is a coupling between an electrically charged emitter and absorber, to effect their mutual interaction. Here, light is not a 'thing-in-itself', such as a collection of freely moving 'photons' that may fill (and light up!) the universe, independent of emitters and absorbers. Further, according to the theory of relativity, there is an interaction (a causal relation) between an emitter and absorber R cm away only if the absorber (say the eyes or instruments of an observer) is at a 'timelike' distance from the emitter, i.e. R is less than ct, where t is the total time it would take for light to traverse the distance R.[4] But most of the stars are at a 'spacelike' distance from us, that is, R is greater than ct. That is to say, we are too far from these stars to absorb their emitted light in the time t. In this case, most of the night sky must be dark to us, as we observe. This is my resolution of Olbers' paradox.

The Spiral Universe

It is usually assumed that the 'big bang' resulted in an expanding *isotropic* and *homogeneous* distribution of the matter of the universe. *There is no underlying reason to believe these assumptions.*

Indeed, astronomical observations of the night sky with high resolution instrumentation (such as the Hubble telescope) or even with the naked eye, reveals that the distribution of matter in the universe, the galaxies and other stellar configurations, is not isotropic or homogeneous. Galaxies cluster in some domains of the sky and not in other domains. Nor is the distribution of galaxies and other stellar matter the same in all directions of observation.

The question then arises: If the theory of general relativity is to provide a dynamical theory of the universe, as a closed system, are there solutions of its field equations that yield a non-isotropic and non-homogeneous matter distribution? In my research program, I have found that under reasonable approximations, there are solutions of the (generalized, quaternion form) of the general relativity field equations that represent a spiraling universe.[5] These solutions are the "Fresnel integrals". This dynamics is characterized by two inflection points, one where matter is maximally dense and there ensues an expansion of the matter of the universe, (the "big bang") and the second where the expanding matter has reached sufficient rarefaction that the expansion changes to a contraction. In the former phase, the gravitational forces are predominantly repulsive; in the latter phase, the predominant gravitational forces are attractive. Thus, from these solutions it is predicted that the universe continually expands and contracts in a spiral configuration, in cycles. If the presently estimated time since the last big bang, which is the order of 15 billion years, is approximately a half-cycle of the oscillating universe, it may be estimated that the period of a cycle is the order of 30 billion years. That is, every 30 billion years, from our time frame, there is another 'big bang'.

In this view, then, the universe is oscillating between expansion and contraction in spiral fashion. The matter of the universe is then neither isotropic not homogeneous, as it is believed to be in present day astrophysics. *The spiral configuration has many other appearances in other domains of Nature!*

In the foregoing analysis, the Hubble law is derived as a first approximation for a covariant law of the expansion and contraction of the universe. It is clear that the original expression of the Hubble law, $v = HR$, is not covariant. That is, any continuous spacetime transformation from the reference frame of an observer, where this law is seen to hold, to any other reference frame, would change its form. Nevertheless, this noncovariant form, that is empirically correct, is found to be an approximation for a truly covariant law of the dynamics of the matter of the universe. The spiral universe leads to this covariant law, in conformity with the theory of general relativity.

Matter and Antimatter in the Universe

An interesting question in contemporary elementary particle physics that may perhaps be resolved in the context of the spiral universe cosmology, is this: Why is it that most elementary particles in our region of the universe are matter, such as electrons and protons? The bulk matter that we experience, including our own bodies, are made up of composites of these particles, and their binding in terms of photon and neutrino fields.

We have detected in experimentation, from nuclear accelerators and in cosmic rays, antiparticles in our region of the universe, such as positrons (positively charged electrons) and antiprotons (negatively charged protons). But why is this antimatter not freely abundant in our region of the universe? A possible scenario that answers this question comes out of my research program that entails the spiral, oscillating universe cosmology.

Pair Annihilation and Creation

From my research program, there is an exact solution of the nonlinear field equations for the particle antiparticle bound pair (electron-positron or proton-antiproton) that represents its true ground state.[6] The energy, linear momentum and angular momentum are all null for this state of the pair. Thus, when the particle and antiparticle are bound in this state, that is $2mc^2$ units of energy below the state where they would be free of each other, if this quantity of energy would be supplied to such a bound pair it would dissociate, giving rise to the appearance of a free particle and antiparticle. The former bound state, at null energy, would correspond to "pair annihilation" – but without actually annihilating the pair. It is still there, and capable of interacting gravitationally with other matter. (In this bound state, the pair would be invisible to an observer). The latter state of dissociation would correspond to "pair creation" – though without actually creating a pair from a vacuum! Also, in the ground state of the pair, its dynamics reveals two oppositely polarized currents, in a plane that it perpendicular to the direction of interaction with a detecting apparatus. This is precisely what is seen, and interpreted as the creation of two oppositely, circularly polarized photons when a pair is said to "annihilate".[7]

It was then concluded that there is no reason for there not to be a very dense gas of such pairs, in their ground states, in any region of the universe. It was found that the inertial mass of an elementary particle is indeed determined by such a dense gas of particle-antiparticle pairs – yielding, for a determined density value, the correct values of inertial masses of the electron and the muon.[8] Further, a sea of such bound pairs could serve as the 'dark matter' that permeates the universe, as evoked by the astrophysicists.

The Separation of Matter and Antimatter in the Universe

The scenario for the separation of matter from antimatter in the universe, at the inflection point where the expansion ensues (the 'big bang') is as follows: After the onset of the expansion phase of the oscillating universe, in the spiral motion of any given cycle, and after some cooling has taken place, the gravitational field of the universe delivers about 1 Mev units of energy to each of a number of electron pairs, that is, $2mc^2$ to dissociate them (out of a much larger number of such pairs) and 2 Gev ($2Mc^2$) to each of a number of proton pairs, to dissociate them (where m is the electron mass and M is the proton mass).

The released particles and antiparticles are then in rotational motion of the spiraling universe. The rotating particles and antiparticles, in a plane perpendicular to the axis of rotation of the universe, being oppositely charged, create magnetic fields parallel and antiparallel to the axis of rotation of the spiraling universe. Thus, there is a competition between the gravitational field of the matter of the universe, inducing particles and

antiparticles to move in a single rotational motion of the spiraling universe, and the magnetic fields separating the directions of motion of the particles and antiparticles. More particles than antiparticles will then move in one direction and more antiparticles than particles will move in the opposite direction. The matter and antimatter then become separated at the early stages of the expansion phases of each of the cycles of the oscillating universe.

Thus, certain regions of the universe become populated with mostly matter and other distant regions of the universe become populated with mostly antimatter. Future experimental studies of the distant regions of the universe may reveal the predominance of antimatter over matter in the formation of antimatter atoms and molecules, and the more complex structures made up of composites of antimatter. One may even speculate that (in the mode of science fiction!) there are human beings in those regions of the universe that are composed mainly of antimatter, living on planets and breathing the air that are composed of antimatter.

References

1. For a general discussion of Greek astronomy, see: A. C. Crombie, editor*, Scientific Change* (Heinmann, 1963); M. K. Munitz, editor, *Theories of the Universe* (The Free Press, 1957).
2. G. Galilei, *Dialogue Concerning the Two Chief World Systems* (University of California Press, 1976), transl. S. Drake.
3. A discussion of 'religious truth' versus 'scientific truth' is given in: M. Sachs, *Concepts of Modern Physics: The Haifa Lectures* (Imperial College Press, 2007), Chapter 1.
4. A discussion of the philosophy of relativity theory is given in: M. Sachs, *Relativity in our Time* (Taylor and Francis, 1993).
5. M. Sachs, *Quantum Mechanics and Gravity* (Springer, 2004).
6. M. Sachs, *Quantum Mechanics from General Relativity* (Reidel, 1986), Chapter 7.
7. C. S. Wu and I. Shaknov, *Physical Review* **77**, 136 (1950).
8. M. Sachs, *Nuovo Cimento* **7B**, 247 (1972); *Nuovo Cimento* **10B**, 339 (1972).