The Research Frontier

A Search for Stable Quarks

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A recent theoretical model (of the subatomic bits of matter called elementary particles) known as the "eightfold way" has led theoretical physicists to speculate that the so called "elementary particles" may be constructed from a set of six truly elementary particles. These particles called quarks would be the building blocks for elementary particles just as protons, neutrons, and electrons are the building blocks for atoms.

Quarks would have some unusual properties, the most notable of which is that their charge would be either one-third or two-thirds that of an electron or a proton. Many experiments have been performed (without success) by scientists using cosmic rays and large accelerators in an attempt to detect the production of such particles.

Considerations concerning the fundamental nature of quarks and their electric charge indicate that some of them must be stable. Therefore, if they exist, they should be found in conjunction with the other elements on the earth's surface. Some quarks would combine with electrons to form a new chemical element which we call "quarkogen." Quarkogen would most likely be found in the sea. We analyzed sea water and sea salt for quarkogen by optical spectroscopic methods. We were unable to detect any quarkogen and we conclude that there must be less than one quarkogen atom for every 100^{17} atoms of sea water. We also examined biological organisms from the sea (e.g., seaweed, oysters) for quarkogen. It is well known that such organisms tend to concentrate different elements from the sea. If quarkogen were among the elements concentrated, they would then be very rich sources for it. We found similar negative results for these organisms as for sea water.

Since quarks have third integral charges, macroscopic bodies containing quarks will have a net charge of one-third that of an electron that can never be neutralized unless, of course, the number of quarks in the body is some multiple of three. A particularly sensitive method of measuring the charge on a macroscopic object is the oil drop experiment used by Millikan to measure the charge of an electron. We have used a modified version of Millikan's experiment to search for quarks in oil drops. We did not detect them and can therefore conclude that the concentration of quarks in various natural oils is less than one quark in 10^{19} atoms.

Quasars as Protogalaxies

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If a galaxy of stars is born when two massive neutron stars collide, then a galaxy in its earliest stages should look like a quasar.

A galaxy is a collection of billions of stars arrayed along two spiral arms to look like a 4th-of-July pinwheel. Our star, the sun, is located far out on one of the spiral arms of our own galaxy, the Milky Way. A galaxy is so large that it takes thousands of years for light traveling 186 000 miles per second to cross a galaxy. The universe contains billions of such galaxies.

A quasar is a strange new object discovered by radio astronomy about eight years ago. It is seen as just a point of light, yet it radiates as much energy as a whole galaxy of stars. The light radiated by the atoms in a quasar becomes very red by the time it reaches the earth. This surprising *red shift* can be accounted for by assuming either that the light loses energy as it escapes the gravitational pull of the quasar or that quasars are all receding from the earth with very great velocities. Atoms on the earth, when they radiate light, radiate very definite pure colors; but the atoms in a quasar radiate a spread of colors. Quasars are apparently much hotter than most stars. These peculiar properties immediately attracted the attention of astronomers and physicists. The most amazing feature was discovered only after observing quasars for several years: The amount of light radiated varies with time. The time of variation can be from about a month to 10 years.

A neutron star is a giant ball of neutrons. A neutron is one of the particles which makes up the atomic nucleus. The proton is the other particle making up the atomic nucleus. The proton has a plus electric charge, while the neutron has no charge. Since the neutron is uncharged, there is the possibility that giant balls of such neutrons, or neutron stars, might actually exist. No one has even seen a neutron star, and it seems doubtful that anyone ever will. The reason that a neutron star will always be a *theory* rather than an observed *fact* is that a neutron star is very small. It need not be much bigger than the earth. It does not radiate much light because it is so small. If the neutron star is massive enough, the gravitational pull will also keep most of the light energy from escaping.

The present theory conceives of neutron stars with masses comparable to the mass of a galaxy. These massive neutron stars are postulated even though they appear to violate Einstein's general theory of relativity and to be contrary to some prior conjectures about neutron stars. When two such neutron stars first approach each other, the gravitational attraction between them will produce tidal bulges on the surfaces of the neutron stars. In these bulges, due to the decreased pressure, neutrons will turn into ordinary matter with a release of a vast amount of energy. Matter is then jetted from the surface of the neutron stars causing them to become captured and to circle each other. The calculated time for a revolution agrees with observed time variation in the amount of light radiated from quasars. The calculated amount of reddening of light, due to the gravitational pull of the neutron stars, also agrees with observations. The theory accounts qualitatively for the other observed features of quasars. As the neutron stars continue to jet away from each other, they leave ordinary matter behind to form the two spiral arms of a galaxy.

If galaxies are formed by collisions between massive neutron stars, then there must be enough neutron stars to maintain a constant number of galaxies, the rate at which galaxies are born equaling the rate at which they die. The number of neutron stars necessary to produce galaxies agrees with the number necessary to account for the observed fraction of mature galaxies which show evidence of having collided with a neutron star.

An Extension of the Second Law of Thermodynamics

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How is forward distinguished from backward in time? First, let us pour hot and cold water into a container—the resulting water will be warm. Can we reverse the process or go backward in time? Now let us pour the warm water back into the two containers. Can we restore the hot water to one and the cold water to the other? The second law of thermodynamics tells us which of the two above experiments is possible. The quantity called entropy makes this distinction. Those processes in which entropy increases can occur (hot and cold mixed to warm) whereas those in which entropy decreases (warm divided into hot and cold) do not occur. Entropy is the only quantity we know that distinguishes forward from backward in time. Entropy, as usually defined, requires the introduction of temperature (hot and cold).

What if there is no temperature? Can entropy and the second law be used? Let us consider a metallic automobile cylinder at absolute zero where there is *no* temperature. The above description of entropy cannot apply. We may fill the cylinder with light of a given color, say green. If the metal is a perfect mirror, the light will bounce around but will not change color or intensity. As the piston is inserted, the light will be compressed into a smaller volume. As the light is reflected from the moving piston, its frequency will be shifted and its wavelength shortened, ie., its color will change toward the blue. Since the energy of the light increases with the frequency, a push must be applied to the piston. As the piston is removed the light expands with reduced frequency (back toward the green color) and reduced energy, giving a push to the piston.

In the normal automobile the piston compresses the gases (gasoline vapor and air), ignition takes place and the hot gases expand, pushing on the piston. Equations relating gasoline air and temperature, making use of the second law, determine how much power may be delivered to the wheels.

The same equations can be used for our engine at absolute zero using light instead of gasoline. Temperature is not introduced, but we can discuss entropy and the power delivered. The quantity which replaces temperature in the conventional engine is the frequency of the light. We now have a new second law of thermodynamics that contains no reference to temperature but distinguishes forward from backward in time.

The Big Bang universe gives an illustration of the use of this law. Radio astronomers have recently found radio waves (a kind of light) that are the result of the original explosion and the fire ball created at the time of the Big Bang. The universe has been expanding ever since, and the original high frequency waves have become the present low frequency radio waves. If we go backward in time and recompress the radio waves, their frequency will increase to become visible light then ultraviolet light and so into the x-ray region corresponding to the original fire ball. Can the universe recompress or is it a one-way street where only expansion can occur? The new second law states that the entropy of the light and associated matter will be unchanged and that compression and expansion are both possible. Our best present guess is that the universe can oscillate, expanding, then contracting into a new fire ball, expanding again and so on and on forever.