Antimatter, Galactic Nuclei and Theories of the Universe

The status of various charge symmetric cosmologies is reviewed. A theory of particle–antiparticle creation in galactic nuclei is outlined.

Speculation on the Nature of the Nuclei of Galaxies

THE usual view that only one type of matter exists predominantly in the universe can be considered to be related to the asymmetry of time imposed by the expansion of the universe. If we regard "particles" as going forward in time and "antiparticles" as going backward in time, a universe with both kinds of matter represented equally might well show no such asymmetry.

Yet this point of view raises a difficulty concerning the origin of matter. The baryon number is conserved in all known physical processes. Evidently, then, if the average baryon number density in the universe is not zero we must either seek a new as-yet-unknown physical process or we must suppose the universe to have been created at a particular moment of time with a non-zero baryon number. To big-bang cosmologists the former possibility seems unpalatable, and to steady-state cosmologists the latter possibility seems unpalatable. The present note suggests that perhaps both possibilities should be eschewed, in which case we must accept that the baryon number of the universe is zero.

Burbidge and I considered this possibility some 10 years ago[1]. We came to the conclusion that, while intergalactic matter at a density $\sim 10^{-29}$ g cm^{-3} might be a mixture of both types of matter without doing violence to observational data as it was then known, the stars and interstellar gas of particular galaxies had to be overwhelmingly of one type. Since this investigation, new data have shown that even an intergalactic mixture is not possible, otherwise annihilation γ-rays would exceed the observed flux by several orders of magnitude. These questions have been discussed in the accompanying article by Steigman. It is clear from Steigman's argument that other proposals[2,3] for a zero baryon number raise what seem to be insuperable difficulties.

There may be one possibility, however, that remains consistent with observation. We could have "particles" distributed in stars and interstellar gas, and "antiparticles" condensed as a compact nucleus at the galactic centre. The speculation is that pair creation occurs in the condensed nucleus, and that "particles" are then expelled away from the nucleus and "antiparticles" are retained at the nucleus. The roles of "particles" and "antiparticles" could be interchanged in different galaxies.

The immediate objection to this idea is that the gravitational masses of the compact nuclei of galaxies are usually less by at least an order of magnitude than the total mass of the surrounding stars, whereas we now require an equality of "particles" in the stars and "antiparticles" in the nucleus. This difficulty can be overcome in two ways. The nucleus may fragment through explosions such as we think occur in radio sources, and the fragments could be showered out into intergalactic space. Or the nucleus might radiate its gravitational mass. The recent observation of Weber[4] suggests that the nucleus of our own galaxy may be radiating gravitational energy at $\sim 10^{49}$ erg s^{-1}. Over $\sim 10^{17}$ s the energy total at this rate is $\sim 10^{66}$ erg, which is the rest mass of $\sim 5 \times 10^{11}$.

Startling new results in astronomy have been coming along at an increasing pace over the past decade. The trend has always been towards the view that highly condensed objects are the seat of extremely powerful energy processes. The present speculation has at least the advantage of suggesting a remarkable culmination to this trend. The difficulty in seeking for the spectacular, however, is that nature usually manages to be far more heterodox than we are capable of being.

FRED HOYLE

Institute of Theoretical Astronomy,
Cambridge.

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Antimatter and Cosmology

As Dirac first showed, when quantum mechanics and special relativity are combined, one is forced to conclude that particles come in pairs. The properties of the particles of these pairs obey certain rules of correspondence: the masses are equal, the electric charges (if any) are opposite, all quantum numbers are opposite. Most importantly, when the particles of the pair are brought together, they annihilate. Dirac's prediction has been overwhelmingly verified in laboratory experiments and it is accepted that to each particle there corresponds an antiparticle. Some particles, such as the photon or the neutral pion, are their own antiparticles, and these are called self-conjugate. Fortunately for us, the Earth and our solar system are all made of one kind of matter. One wonders, however, if on the metagalactic scale, nature has not exploited this symmetry in the laws of physics and created a universe which consists of equal numbers of particles and antiparticles.

Recently, there has been a revival of interest in charge symmetric cosmologies[1,2]. In such models, the universe is assumed to contain equal numbers of particles and antiparticles which are conveniently kept separated until they are needed to supply the energy for quasars, Seyfert galaxies, radio galaxies, and so on, through annihilation. Although such models are philosophically and aesthetically pleasing, there is at present no observational evidence to support them.

To detect antimatter in the universe, one has to wait until it meets up with ordinary matter and annihilates, then look for the annihilation products. The neutrinos will, for some time to come, be undetectable; the electrons and positrons will remain close to their regions of origin and can only be detected indirectly; the gamma rays provide us with the best chance of "observing" antimatter. Upper limits on, or observations of, gamma rays enable us to set limits on the amount of mixed matter