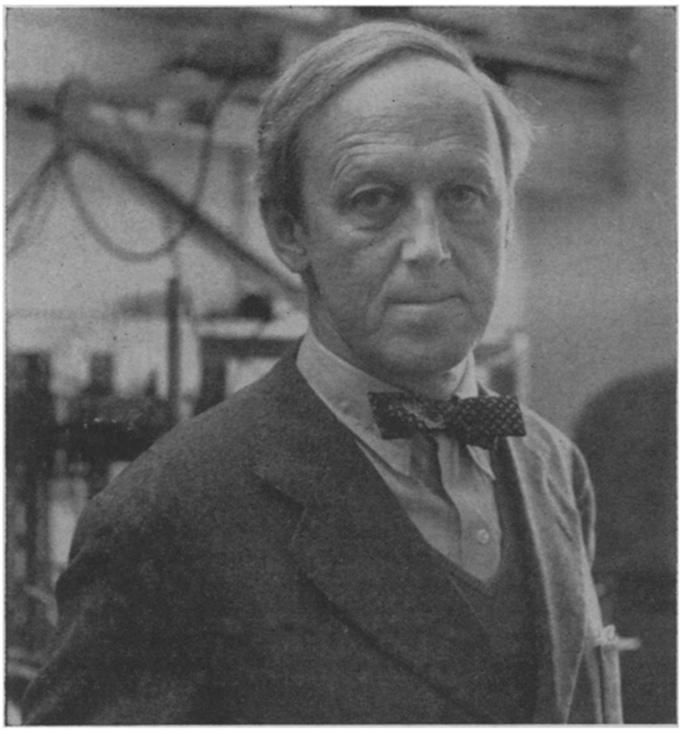
The universe's missing antimatter

Cosmologists trying to fit equal amounts of matter and antimatter into the universe find themselves in a dilemma



Bror Karlsson

Alfvén: For every star there's an antistar somewhere.

by Dietrick E. Thomsen

Cosmology and elementary particle physics occupy extreme ends of the scale of size. The one deals with the largest possible aggregation of matter; the other deals with the smallest distinguishable pieces.

Yet the two extremes come together more and more, both practically and philosophically. Not only must the cosmologists adopt the detection techniques of the particle physicists for such objects as celestial gamma rays and X-rays, but they must make their theories rhyme with those of the particle physicists.

Particle physics presents cosmological theories with a serious problem. The world of the particle physicist is symmetric and balanced between matter and antimatter; for every particle there is an antiparticle. But the currently most successful of cosmological theories simply ignores antimatter.

The cosmologists' dilemma is that observation seems to be knocking down theories designed to include an even balance of matter and antimatter; instead, it backs the so-called big bang theory, which has no such balance. But if they try to put matter-antimatter symmetry into the big bang as particle physics would require, they wind up with instant theoretical destruction of the universe at the beginning, before creation even had a chance.

Antimatter was brought into physical theory about 40 years ago by Dr. P. A. M. Dirac of Cambridge University, who was trying to apply the principles of special relativity theory to the behavior of subatomic particles. The particles will obey special relativity, he found, only if the world of ordinary matter is mirrored by a world of antimatter in which electric charge is reversed, left becomes right, and objects are capable of going backward in time. Each ordinary particle has, in this world, its mirror image, its antiparticle.

Dr. Dirac's theory provides—and particle experiments have always confirmed—that if any particle is created, its antiparticle comes along; if any particle vanishes, its antiparticle must be present to go too.

If a proton and an antiproton come together they will annihilate. That is, they both vanish, and the ultimate result is a burst of energy in the form of gamma rays. Conversely a properly energetic gamma ray sometimes creates a particle and its antiparticle. But creation comes only in pairs, never one side or the other alone.

If in these miniscule acts of creation in the laboratory, the matter-antimatter balance is always held, physicists reason, then why not in the gigantic act of creation that made the universe?

"There are very few physicists who claim explicitly that the universe is asymmetric in the sense that it contains ordinary matter but no antimatter," say Drs. Hannes Alfvén of the Swedish Royal Institute of Technology and Aina Elvius of Stockholm Observatory. "Most physicists seem to agree that there should be equal quantities of the two kinds."

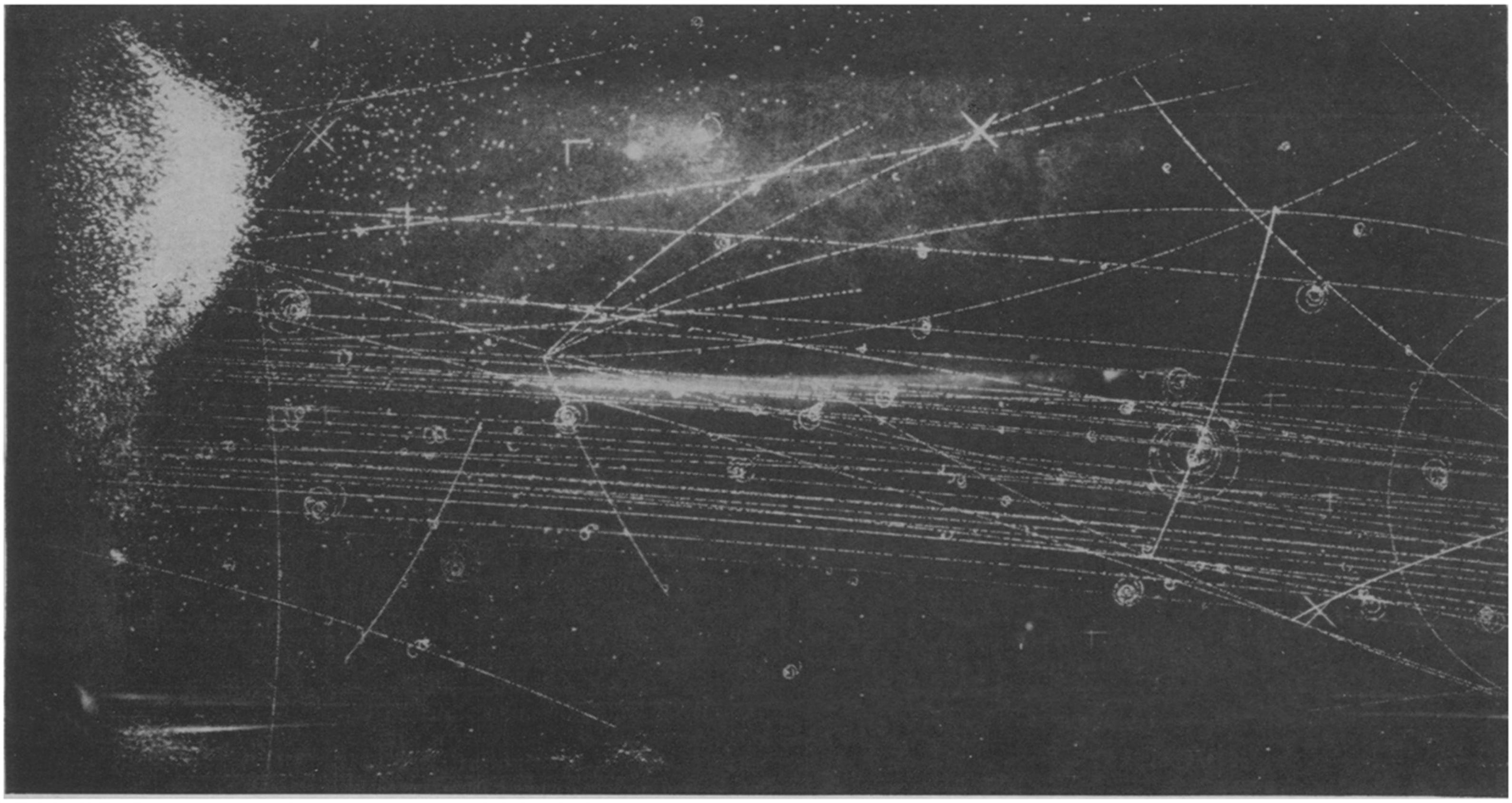
The problem then becomes twofold:

- Where in the universe ought antimatter to be put? There has to be some kind of segregation since whenever particle and antiparticle meet, they annihilate. If they were equally mixed, the universe would gradually become nothing but gamma rays.
- What should be done with the observational evidence that supports the so-called big-bang theory of cosmology? The big bang is the only cosmological theory that has any observational support, and in its current form it ignores antimatter.

To have a preponderance of matter throughout the universe would require postulating a new law of nature that would permit the universe to have been created so, giving a rule for the macrocosm different from that which applies to subatomic processes. "If we do not want to postulate any new laws of nature," say Drs. Alfvén and Elvius, "we have to assume that all the common particles are produced in pairs with antiparticles, by essentially the same kinds of processes as those we know from accelerator experiments."

If the second point is correct, then the antimatter has to be somewhere. Dr. Alfvén has done a good deal of work on this point. Years ago he suggested that the universe was separated into galaxies and antigalaxies or even into groups of galaxies, metagalaxies, and antimetagalaxies (SN: 1/21/67, p. 64). Now he and Dr. Elvius think that matter and antimatter may be mixed in each galaxy.

The center of a galaxy in their view could be a mixture of particles and antiparticles. In the beginning of its his-



Brookhaven National Laboratory

Matter equals antimatter in bubble chamber creations. In the universe the same balance ought to be evident.

tory, a galaxy is almost all center, a compact cloud of matter and antimatter. Annihilations take place in the cloud at a great rate, producing extremely large amounts of energy. The Swedish scientists suggest that this is what a quasar is, a galaxy at the beginning of its history radiating energy derived from matter-antimatter annihilations.

As the galaxy ages, matter and antimatter separate, possibly urged in opposite directions by magnetic fields. Outside the center, regions of segregated matter and antimatter grow up. The center, depleted of material, slowly burns down. Meanwhile in the outer regions stars and antistars form.

There is no way to tell stars from antistars by looking. Both matter and antimatter give off light, and the light does not tell which one it comes from. But, says Dr. Gary Steigman of Cambridge University, there is a possible observational check on the Alfvén theory. That is by looking for the gamma rays produced by the annihilations in galactic centers.

But the observed flux of gamma rays is too low, says Dr. Steigman, to have come from clouds of matter and antimatter as large as Dr. Alfvén would like to have.

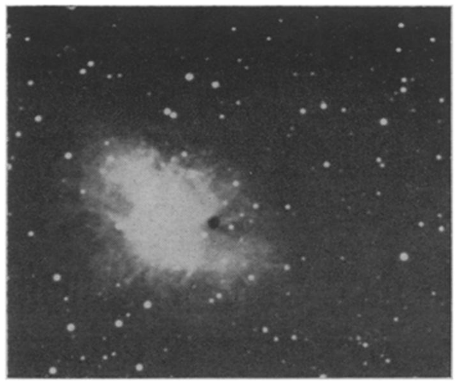
The observed gamma ray flux also shoots down, at least in one form, the so-called steady-state cosmology proposed by Dr. Fred Hoyle of Cambridge University and others. Dr. Hoyle and his associates have been concerned that the expansion of the universe would gradually spread the matter in it thinner and thinner. For various reasons they want to avoid this thinning.

So they have proposed a theory in which new matter is continually created to compensate for the expansion. But this creation, too, must be in particle-antiparticle pairs. If such creation happens at an equal rate in all parts of space, as the original steady-state theory proposes, then, says Dr. Steigman, we should see 10,000 times as much gamma radiation from our galaxy as we do.

Dr. Hoyle counters by suggesting that perhaps the creation does not take place all over. It may be concentrated in the centers of galaxies, and these may be permeated or surrounded by a material that absorbs gamma rays so that we do not see them. Dr. Steigman judges that unless the creation events are hidden in such a manner, steady-state theory and matter-antimatter symmetry are as incompatible as are the big bang and symmetry.

But if the creation events are hidden, there is no observational test of the steady-state theory.

If steady state is still raw theory, the big-bang proposition has some verification of its own; it has passed at least one observational test. The theory proposes that the expansion of the universe began with the explosion of a compact cosmic fireball about 10 billion years ago. The explosion would have generated a lot of radiation and some of it should still be floating around the universe in the form of radio waves, representing a residual temperature of three degrees above absolute zero. Such



U.S. Naval Observatory

Crab nebula: matter or antimatter?

radiation has been found and is regarded by many astronomers as a support of the theory (SN: 6/22/68, p. 577), whether or not it contradicts the particle-antiparticle theory.

One who has done a lot of work with the big-bang theory, Dr. Robert H. Dicke of Princeton University, says that the contradiction can be avoided by postulating some mechanism to separate matter and antimatter in the big bang before the annihilation could have happened. Dr. Steigman also suggests this as an out, but neither he nor Dr. Dicke have any guesses about the nature of a mechanism that could do it.

So, says Dr. Dicke, "I'm inclined to agree that the universe is asymmetric if we had a big bang." His other suggestion is that conditions in the big bang were so extreme that their like is never seen in the laboratory, and that those conditions did in fact violate the laws of particle physics. □