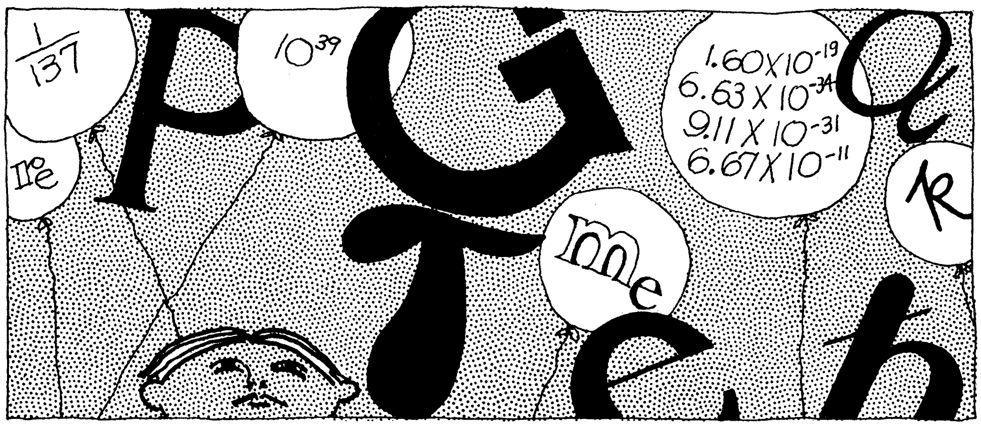
GRAVITY, THE BIG BANG AND THE NUMBERS GAME



Curious coincidences among large numbers inspire theorists

by Dietrick E. Thomsen

Physics is full of numbers. In fact a possible definition of physics is the attempt to put numbers on natural phenomena. (It's an imperialistic definition. Eventually it would include all science under physics. But let it stand.) Physical theorizing is an attempt to find relations among the numbers involved with a collection of phenomena, and no physical theory is really good unless it enables you to calculate numbers you do not know from those that you do. One of the ways of beginning to theorize, called dimensional analysis, is actually playing with numbers. The theorist takes the numbers involved with whatever phenomena he is considering and arranges them in ratios that yield dimensionless numbers that he hopes will illuminate the connections among the phenomena. The method has been especially fruitful in fluid dynamics, and that science is full of such dimensionless numbers, the Mach number, the Stokes number, the Reynolds number, and so on.

The most fascinating set of numbers is the most fundamental, the fundamental constants dealing with the basic forces of nature and the shape and history of the cosmos, such things as the Planck constant, the fine-structure constant, Newton's universal gravitational constant. Physicists want to know why these numbers are what they are and what the relationships among them have to do with the architecture of the universe.

Many good minds have exercised themselves on this field. Arthur Eddington was famous for it. P. A. M. Dirac has used 30 or 40 years of such cogitations to come up with a rather strange new unified field theory and cosmology (SN: 3/3/73, p. 138). Ralph A. Alpher of the General Electric Co., who was in at the creation of the big-bang theory, is interested in Dirac's formulation because it would leave the usual big-bang theory in very bad shape. Alpher has a countersuggestion that would save the big bang. He discussed the history and present state of these matters in a recent lecture at the National Bureau of Standards.

One has to be a mite careful in dealing with this subject of big numbers and cosmology. Many physicists will assert, sometimes with indignation, that there is nothing to it, it's just playing with pretty numbers. On the other hand some of its devotees wax mystic and psychic about it. Alpher opines that Eddington eventually went off the deep end about it, but he detects no such tendencies in Dirac. Dirac's theory is unusual, and as P. C. W. Davies remarks in reviewing it in NATURE, it contains things that will be unpalatable to the trendier cosmologists of the day, but what is unfashionable is not therefore to be condemned.

The way the numbers game is played in cosmology is to make ratios between fundamental data of the same kind, especially between one datum relating to the macroworld and one relating to the microworld. There are four or five such ratios that people play with, including such things as the classical dimension of the universe over the classical radius of the electron, and the ratio of the strength of the electromagnetic force between proton and electron in a hydrogen atom to the gravitational force between them. Alpher says he is not sure whether Dirac used dimensional analysis methods in formulating his theory. Dirac didn't write it down that way, but in his own lectures on the topic he has pointed out that at least one of these ratios, that of the electromagnetic to gravitational force, was important in his thinking.

One curious thing about all these ratios is that they all come to more or less the same number, 10^{39} or maybe 10^{40}. One must not be too picky about a factor of ten one way or the other in considering these numbers. One of the rules of the game, called Ginzburg's law of cosmic physics after the Soviet theorist V. L. Ginzburg, is that one is identical with ten.

Another curious fact is that when all the ratios are written down in the proper symbolism, it is seen that they all involve a characteristic time. Now if you are a theorist making a theory, what time do you choose to put in? What time is so fundamental in cosmology that you would dare put it in and hope that something that makes sense will come out? The age of the universe is a very important value, and that's what Dirac chose. It also happens that if you express the age of the universe in what Dirac calls atomic time units, it comes out to about 10^{40}, a fact that greatly enhances its appropriateness in Dirac's view. (One atomic time unit, or tempon, equals the time light takes to cross the classical radius of the electron, about 10^{-23} seconds.)

The age of the universe is a continually increasing quantity. The effect of throwing a variable in among this collection of ratios that might have been constants is to introduce variations where variations had not been expected. In the case of the ratio between

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organ from being rejected once it is transplanted. The organ recipient will also be injected with the enhancing antibody material to further increase the chances of organ acceptance.

Hufnagel and Chung are also working on ways to solve cross-species rejection between organ and recipient in hopes that animal organs might eventually be used for human transplants. "Of the various approaches we are taking to the rejection problem," Hufnagel says, "this one has the greatest potential. But it is also the most difficult."

Monaco is taking a different tack in trying to solve the rejection problem —injecting bone marrow from the organ donor into the patient to receive the organ. His rationale is that bone marrow, which is rich in HL-A antigens, should stimulate blocking antibody action in the prospective organ receipient. Thus, when the patient receives the organ, his enhancing antibodies will already be primed to help protect the foreign organ. Monaco has obtained encouraging results with this approach in mice and dogs. He is now ready to try it with patients.

Monaco also looks forward to the day where enough HL-A antigens have been purified that they can be taken from an organ donor and injected into the prospective organ recipient. The would-be recipient would then make blocking antibodies against the antigens. The blocking antibodies would help protect the foreign organ upon implantation.

Robert J. Sharbaugh and his immunology colleagues at the Medical University of South Carolina in Charleston are trying to solve the rejection problem by working with large animals. They are looking for the transplantation antigens in sheep that correspond to the HL-A's in people. They will then coat a column with these antigens, insert a tube into the sheep's thoracic duct and circulate the sheep's lymph through the column in hopes that any lymphocytes in the lymph that have a predilection for transplantation antigens will stick to the antigens on the column. Once the sheep's body is cleared of lymphocytes that attack transplantation antigens, the sheep should be ready for an organ transplant, presumably with no rejection problem.

"Our approach is promising," Sharbaugh asserts, "but it's tough because few investigators are using this approach. In other words, we have little or no past experience to call on."

Still other investigators, such as Stanley G. Nathenson of the Albert Einstein College of Medicine in New York City, believe that a better understanding of the chemistry of transplant antigens should lead to ways of preventing organ rejection. Certainly progress is being made toward this end. But so far evidence is more provocative than gratifying. For instance, HL-A antigens are now known to share certain chemical sequences with antibodies and to be coded by genes that lie near genes that code for various immunological activities. Such evidence suggests that transplantation antigens may have some yet unidentified immunological function. This would be bizarre since they themselves provoke immunological reactions.

Certainly the problems of organ transplantation are many, and finding solutions to these problems is time-consuming and costly. But the clinicians and investigators who are dedicating their lives to furthering transplantation are convinced that the answers will come. "We haven't scratched the potential of transplants yet," declares Amos.

Meanwhile, they have the satisfaction of knowing that they are extending the lives of thousands of patients for a few precious months, or even years. A prime example of a patient who is profiting from transplant teams' efforts is Richard Cope of Patchogue, N.Y. Four years ago Cope received a new heart from Shumway and his team. Cope is alive today, working as an engineer for the Grumann Aerospace Corp., swimming in a pool he built himself and enjoying a full sex life. The latter he attributes "to having a 17-year-old heart with 49 years of experience." ☐

. . . Gravity

the electromagnetic and gravitational forces it comes down to a very important dilemma: Either you make Newton's universal gravitational constant a variable and admit that the strength of gravity may vary with time or you make the amount of electric charge carried by the electron (and every other charged elementary particle) be a variable.

In spite of—or maybe because of—the havoc that it would wreak in electrodynamic theory, the late George Gamow suggested that we should make the electron charge vary. He was promptly shot down by observers, who pointed out that if the electron charge had been different in past aeons, the spectrum of the light we receive from distant bodies (which was emitted millions and billions of years ago) should be different from the spectrum we receive from nearby bodies. It isn't.

Dirac's choice is to make gravity vary. This is something that the usual big-bang theory will not admit, nor will it admit some of Dirac's other conclusions such as continual creation of new matter. And this makes Alpher want to answer.

The answer depends on the critical time you choose. Is there a critical time that is important enough to merit trial in the context and that will make constants constant again? Alpher suggests what big-bang cosmologists call the crossover time. In the beginning, they say, the universe was dominated by radiation, that is, photons and neutrinos. In this the Biblical intuition was exactly correct: Light came first; all else followed. Gradually radiation begat matter, and eventually matter came to dominate. The time when the universe switched from a majority of radiation to a majority of matter is the crossover time. It happened once and for all. Its value—about 1 million years after the big bang—is constant so it will render the constants constant again.

Does it merit inclusion in the august company of the big numbers? Alpher thinks yes. It is a moment very significant in the history of the universe. A lot of interesting thermodynamics and fluid dynamics went on then, and those are both fundamental parts of physics. It may also be the time the galaxies started to form.

Another suggestion, not original with Alpher, depends on a belief in an oscillating universe. Granting that, there will be a time when the universe reaches its maximum extension and starts to collapse back. That number is also a constant and might also fix things up. At this point Alpher does not present a detailed cosmology or field theory based on either of these suggestions, but that too may come.

Meanwhile the question of changing gravity is becoming an observational one. Changing, specifically weakening, gravity is not unique with Dirac, but is contained in other recent cosmological theories. It was, however, rejected by Einstein, and the debate is decades old. Now a number of observers and experimenters are trying to settle it.

One of them, Thomas C. Van Flandern of the Naval Observatory, brings evidence he says shows a weakening, and his latest figures tend to favor Dirac more than the other current theories (SN: 8/24-31/74, p. 116). I. I. Shapiro of the Massachusetts Institute of Technology has been using radar astronomy to try to get a precise knowledge of the gravitational constant and its possible changes. His latest results would indicate a minute strengthening of gravity over time, but the error margin is bigger than the figure itself so the result is still very inconclusive. It may be some time before precise and generally accepted observational figures are available. Meanwhile the cosmic game of the big numbers continues. ☐