Einstein's World and the Big Numbers Game

Cosmologies based on the 'hypothesis of the large numbers' will work according to Einstein's rules, even though Einstein never liked their consequences

BY DIETRICK E. THOMSEN

Physics is full of constants. These are the crucial numbers that appear in the laws and formulas and relate one fundamental quantity to another. For example, Newton's universal gravitational constant relates the size of a gravitational force to the masses of the bodies that generate it. Planck's constant relates the energy in a quantum of light to the frequency of its vibrations. The numbers of the fundamental constants are empirically determined to be such and such, and most physicists would say that is that.

For decades, however, there has been a thin gray line of philosophically minded physicists who insist that that is not that. There is, they say, a metaphysical significance to the numbers, and contemplating them can yield insights about the structure of the universe. Holy Scripture tells that His eye is on the sparrow and the the very hairs of our heads are numbered. If the number of hairs on a head is of cosmic significance, how much more so the number that determines how the galaxies approach one another or the number that keeps each atom emitting light according to its own kind? If they had had prophetic lectures on fundamental constants in acient Israel, Scripture might also tell us (as a prominent physicist has actually said) that God made the fine structure constant to be $^1/_{137}$ so that we would arise to worship Him. Otherwise physics and chemistry would have been different, and we would not be here.

The metaphysical significance of the fundamental constants is enhanced in the view of susceptible minds when one starts to play what is called the big numbers game. The game is played by making dimensionless ratios involving the fundamental constants. If one compares a length to a length, one gets a pure number that represents the ratio between them, likewise if one compares a force to a force. The big numbers game is played by taking a length belonging to the macrocosm, say the classical size of the universe (which is made up of fundamental constants) and comparing it to a microcosmic length, the classical "radius" of the electron. Or one can take electric force between proton and electron in a hydrogen atom and compare it to the gravitational force between them.

There are several ratios that form part of the big numbers game, all of which involve various multiplications and divisions of fundamental constants, and the striking fact about them is that they all come out to about the same number, 10^{40}, give or take a few powers of ten. (Since there are 40 powers of ten involved already, two or three more don't make much difference to a physicist. Whatever your friendly neighborhood schoolmarm may say, physics is far from being an exact science.) To the sort of mind already susceptible to the big number mystique, this coincidence of value seems more than fortuitous. One can start from it and spin cosmological models.

Cosmology, which is, properly stated, the history of the universe, gets into the big numbers game explicitly, because as most of the ratios are written, they involve a characteristic time, and it is typical of the way the game is played to consider that that time is the age of the universe. The age of the universe is always changing, and so the value of the big-number ratios is always changing, and that means that at least one of the constants that goes into the ratios is not constant at all. More than one choice has been tried for the variable—a few lead to rather bizarre theoretical results—but the traditional choice for a variable is the universal gravitational constant, which from now on will be designated by its usual symbol, G.

The choice of G is not entirely arbitrary. There are a lot of philosophical reasons apart from the big-numbers game for certain physicists to want G to vary. There has been a philosophical battle going on for at least 80 years in which Ernst Mach is the patron saint of the variable-G partisans and Albert Einstein the patron saint of the constant-G partisans. The variation usually desired is a gradual diminution of G as the universe ages, which amounts to a relative weakening of gravitational forces. There has been a good deal of observational and experimental work to try to determine whether it really does decrease, but so far the results don't satisfy everybody.

One can build cosmological models on the basis of variable G and the hypothesis that the big numbers have a cosmological meaning, and the most prominent living physicist who has done this is P. A. M. Dirac. But whoever makes such a cosmology runs full tilt into the Einsteinian orthodoxy with its insistence on a non-variable G. This is not a happy situation because Einstein's general relativity gives the space-time framework in which modern cosmological theories are supposed to work themselves out.

In the Aug. 11 NATURE, Ian W. Roxburgh of Queen Mary College of the University of London sets out to see whether there are cosmologies that accord with the big-number hypothesis that the relations among the fundamental constants are not fortuitous and are compatible with general relativity and work themselves out in what is called Robertson-Walker space-time, the space-time whose mathematical description is consistent with Einstein's equations. This appears to be a way of letting the big-numbers game into Einstein's world by the back door.

Roxburgh finds a family of such cosmological models, of which he cites five, two evolved by Dirac, one due to E. A. Milne, the "Steady State" model in which the density of matter in the universe stays the same in spite of the expansion, and a "Power Law" model. The models vary according to how the measurement of space-time distances and the Hubble constant vary with the age of the universe and other factors. All but the steady-state model have G decreasing as the universe ages. (In the steady-state model G is constant.) All but Dirac's first model have the amount of matter in the universe increasing with age—that is, new matter is continually created *ex nihilo*, a provision that gives orthodox big bang cosmologists the fits.

Can one say anthing observationally

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about any of these models? It is a parlous venture to try to say anything observable about any kind of cosmological models, let alone exotic ones like these, but models of this kind should affect at least two observables, the temperature history of the earth and the cosmic deceleration parameter, which is the rate at which the expansion of the universe is slowing down. The temperature of the earth should be affected (apart from any changes in the sun), because changes in *G* should change the force between earth and sun and alter the earth's orbit. The deceleration parameter should vary because changes in *G* alter the strength with which the galaxies pull on each other. With some uncertainties it is possible to figure out what the changes ought to be for each of the models Roxburgh cites, but unfortunately neither type of observation is yet precise enough to make a choice of model. In the case of the deceleration parameter we could be in for another half century of contention (after a half century already) before everyone is willing to agree on a number for it. Roxburgh's final sentence gives the present status of the whole proceeding: "Further restrictions have to be imposed on the theory before this class of solutions can be narrowed down to one model." □