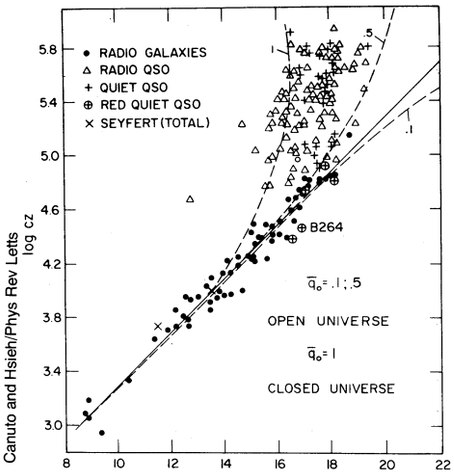
Open Universe With Two Time Standards

Argument over the shape of the universe has embroiled cosmologists ever since they found out it could have a shape. It is of physical, philosophic and maybe theological interest to know whether the curvature of space returns upon itself and is closed or whether it bends ever outward to endless openness. The data from which observers attempt to determine the space curvature are the Doppler shifts (redshifts) of the light from distant galaxies and quasars, which are taken to represent the distances of those objects, and their apparent and intrinsic brightnesses. The way the amount of attenuation that occurs in going from intrinsic to apparent brightness is related to the distance depends in its turn on the value of the space curvature. Observers arrange the data in graphs called Hubble diagrams in the hope that a clear trend can be seen in the observation of thousands of objects.

The clarity of the trend can be argued. There is some doubt about the actual intrinsic luminosity of objects millions or billions of light-years away, but even when that is agreed on, the curves on a standard Hubble diagram that correspond to open and closed universes are so close together that a trend is hard to distinguish within the limits of experimental error and theoretical argument in the data.

In the March 17 PHYSICAL REVIEW LETTERS V.M. Canuto and S.-H. Hsieh of the NASA Goddard Institute for Space Studies in New York set forth a method for getting some distance between those curves, enough to enable them to decide for an open universe, which is rather the unpopular side of the question right now. They get there by dropping an implicit but basic assumption from the usual cosmological procedure. In the end it amounts to a fairly radical recension of the theory, but they claim the implicit permission of Albert Einstein for doing so.

The main content of the theory of general relativity is in the so-called Einstein equations, which relate the curvature of space-time to the usual dynamical quantities (masses of bodies, energies, momenta, etc.) of the physical field theory. The geometrical side of the Einstein equations has always been regarded as complete, but the dynamic side was suspect even to Einstein himself. He called it a makeshift and wrote that it was "a condensation of all those things whose comprehension in the sense of a field theory is still problematic." One of the difficulties read out by Canuto and Hsieh is that "measurements of gravitational phenomena depend on the dynamical units used." In the particular case they wish to put, the relevant dynamical units are those used for measuring time.



Hubble diagram with power-law relation between time standards.

Canuto and Hsieh point out that there are now two physically independent ways of measuring time, in their words: the gravitational and the atomic. Gravitational time measurement is based on rotations or orbital motions of astronomical bodies under the influence of gravity. Since 1955 atomic clocks have been available. These depend on phenomena inside atoms that are not determined by gravity.

In the context of a general relativistic theory there is no perfect external standard with which these two experimental methods of measuring time can be compared. They must be compared with each other. It seems to be a silent assumption of standard cosmological procedure that gravitational and atomic time are the same and have been throughout the history of the universe. Canuto and Hsieh point out that all we know for sure is the relationship between them at the moment as it has been determined from measurements of the gravitational redshift of light emitted by certain atoms. That says nothing about the past. Canuto and Hsieh propose that the relationship has been a varying one.

If that is true, it means the relationship among redshift, distance and luminosity has to be treated very carefully. Redshift is an atomic quantity nestled among gravitational ones. Any formula involving it is thus sensitive to the change in the relation between the two units of time, and this will become especially pronounced in the cases of the most distant objects because the light from them was emitted billions of years ago when the difference from the present time relationship might be quite pronounced.

There is nothing to specify what the relationship between gravitational time and atomic time might be, but Canuto and Hsieh follow a standard practice of physicists facing such an unknown situation by putting in for a trial the so-called power-law relation, which is both simple and found in many natural phenomena. Calculating on this basis, they find that the criteria for different universal curvatures are separated much more sharply than they are by the standard cosmological procedure (up to 13 times as much in the case of one curve). They think the choice should be an open universe.

A change in computational procedure can produce this result. The next question is whether there is any warrant for thinking such a varying relation between gravitational and atomic time really exists. Canuto and Hsieh cite the records of the moon's orbital motion, in particular the variation due to tidal interactions between the earth and the moon. This change has been monitored by gravitational time for centuries and by atomic time for 25 years. Comparing the two they find a difference that they call significant, and it goes in the same direction as their trial power law. So they conclude there is reason to think these things might be. □

Lead-soldered cans: A serious hazard?

Do not eat food coming out of lead-soldered cans — the most common type available — because of the high degree of lead contamination that enters food from the solder. In fact, lead-soldered cans should be eliminated immediately "because they constitute a major source of lead in foods." Or so charge Dorothy M. Settle and Clair C. Patterson, a team of California Institute of Technology scientists whose work on lead in tuna and other products is reported in the March 14 SCIENCE.

The provocative report states that "half the lead in the American diet probably originates from lead-soldered cans, since these containers contaminate their contents about tenfold and canned foods comprise about 20 percent of the diet." Both the authors and other scientists point out that if this is true, the health hazard is "not negligible."

The Caltech team carried out their studies in lead-free, ultra-clean laboratories designed to study moon-rock samples, and used the most accurate technique available. Owing to the ubiquity of lead pollution, exhaustive precautions were taken to eliminate industrial lead pollutants from the samples during preparation and analysis. What Settle and Patterson found was that contamination that takes place during butchering, canning