

FOR GENERAL RELATIVITY, IS THE PROOF IN THE PULSAR?

The binary radio pulsar PSR 1913+16, as discussed by Daniel Kleppner (April 1993, page 9), is indeed a fascinating lab for new physics, but it cannot yet be regarded simply as a verification of general relativity.

The field equations $G^{\mu\nu} = KT^{\mu\nu}$ yield the metric $g_{\mu\nu}$ for a given mass distribution. In the case of the essentially spherically symmetric Sun, the mass distribution is especially simple and yields a simple $g_{\mu\nu}$ (the Schwarzschild metric). Nearby "particles," such as planets, do not alter the metric too badly, and thus the motions of the particles may be obtained quite accurately from the geodesic equation.

In the case of two massive stars, general relativity is inadequate. Albert Einstein, Leopold Infeld and Banesh Hoffmann¹ looked at this type of problem in 1938 and 1940, and in 1943 Peter Bergmann² wrote, "A genuine 2 body problem, that of a double star, for instance, can be treated only by precarious methods of approximation which are not based on a rigorous theory."

More currently, binary stars are analyzed using post-Newtonian approximations, and the modern references are Thibault Damour and N. Deruelle's papers³ of 1985 and 1986, in the former of which they say, "The two-body problem in general relativity is more complicated; because of the nonlinear hyperbolic structure of Einstein's field equations one is not sure of the 'good' boundary conditions at infinity so that the problem is not even well posed."

Finally, we note that the power law in radiation damping comes purely from the quadrupole nature of the source. Any theory of gravity would predict this quadrupole nature, as the dipole moment of any mass distribution (about the center of mass) is zero. The coefficient in the power-law damping formula depends on orbital parameters that are computed *assuming* general relativity. Hence the result is difficult to accept as a test of the very theory that it assumes!

The results of Joseph Taylor's

painstaking work on PSR 1913+16 over almost two decades are beautiful and obviously closely related to general relativity. But we must not exuberantly say that "general relativity has been verified" until the *extensions* of Einstein's theory have been accepted. To our knowledge that has not occurred.

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TAYLOR AND DAMOUR REPLY: Tarun Biswas and J. David Nightingale obviously read Daniel Kleppner's Reference Frame piece, and they appear to have read some relativity, but there's little evidence that they have read the experimental papers on binary-pulsar timing experiments¹ or the other extensive works exploring their theoretical significance.² Computational methods within Einstein's theory have come a long way since 1943: The equations of motion for two massive stars, including the effect of gravitational-radiation damping, are now well established in general relativity³ and have been worked out in a number of alternative theories as well. It is emphatically *not* the case that any theory of gravity must predict that the leading term in an expression for gravitational-radiation damping is quadrupolar. Gravitational self-energy can cause the appearance of a dipole contribution in the radiation damping as well as modify other (nonradiative) terms in the equations of motion. Only in general relativity are the effects of gravitational self-energy fully "effaced" away in the orbital dynamics.

No circular reasoning is involved in the interpretation of the timing observations of pulsar PSR

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B1913+16. Orbital parameters of the system are determined in a purely phenomenological way, without assuming any specific theory of gravity. The combination of phenomenological parameters can then be compared with the predictions of any specific relativistic theory of gravity, such as general relativity. The key point is that timing observations give access to more phenomenological parameters than the number of independent dynamical degrees of freedom. This redundancy allows one to extract one or more tests of any theory of gravitation. In this way Einstein's theory passes several independent tests, including the crucial one involving radiation damping effects—currently at the 0.3% level—thereby verifying the predicted existence, quadrupolar nature and propagation speed of gravitational waves.

We have no reason to think that general relativity necessarily comprises the last valid words to be written about gravity, not least because the theory is not perturbatively quantizable. Perhaps most importantly, binary-pulsar timing experiments offer a means of probing the nature of gravity under strong-field conditions that do not exist anywhere within the solar system. With such experimental tools, large regions of gravitational "theory space" can be summarily rejected. In the future, one might even hope to isolate a region in which the "true" theory of gravity departs from general relativity. In the meantime, Einstein's theory of gravity remains the best thing going in the nonquantum regime, in full accord with all high-precision experimental tests, including gravitational-radiation losses from binary pulsar systems.

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New Data Advance Retarded Forces

We read with great interest the Search and Discovery story "New Evidence Confirms Old Predictions of Retarded Forces," by Barbara Goss Levi (April 1993, page 18). We wish to mention two other kinds of experiments that are very pertinent to the issue of retardation. One experiment was a pioneering study by Ed Sabisky and Charles Anderson,¹ who demonstrated that liquid helium films possess a thickness dependence on gas pressure that agrees remarkably well with the retardation theory of Igor E. Dzyaloshinskii, Evgenii M. Lifshitz and Lev P. Pitaevskii² (although more recent data are not so consistent). The second experiment is an ongoing project in the group of Thomas Greytak and Daniel Kleppner.³ This experiment measures the sticking at ultralow energy of a hydrogen atom to a cold liquid He surface. Calculations⁴ indicate that the sticking coefficient is reduced by a factor of two when retardation is taken into account! The latest data⁵ are consistent with this prediction. We are optimistic therefore about the prospect for further experimental validation of this fundamental concept.

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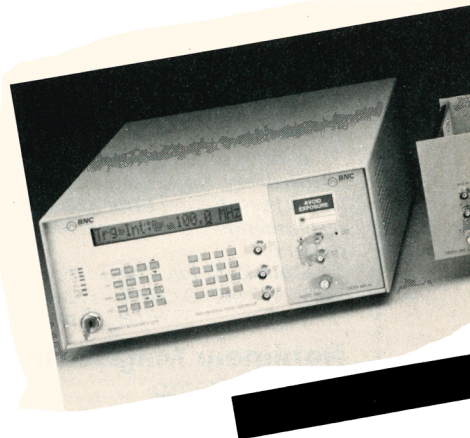
NASA, Congress and Gomory's 'Goals'

Much of what Ralph Gomory says about Federally funded science in his article "Goals for the Federal Role in Science and Technology" (May 1993, page 42) is indisputable, but his comments on "the huge bill the government pays NASA" call for a personal reply on some specific points.

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