

## RECORD OF PLANETARY EVOLUTION IN TINY SEA SHELLS

Nature has its own ingenuous ways of keeping its evolutionary records, some of which remain well preserved for long periods of time. Much knowledge about terrestrial climate, early history of the solar system and the earth has come from the study of fossils present in sedimentary formations, meteoritic grains etc.

Some species like shells grow every day and these diurnal increments accumulate layer by layer. Under the influence of lunar tidal cycle, special accumulations or discontinuities occur every month and thus it is possible, for example, to determine number of days in a month. Old fossils, dated by independent methods, can thus reveal time variations in these parameters and serve as palaeontological clocks. Since earth's rotational period is significantly modified by the lunar tides, its variation has profound implications on the orbital evolution of the Earth-moon system. Such a possibility was realised in early 1960's with the work of J. W. Wells where he suggested that certain corals show daily increments within annual growth clusters. With the help of high resolution microscopy, this has developed into an important area of research. A series of articles appearing in "Growth Rhythms and History of the Earth's Rotation" edited by G. D. Rosenberg and S. K. Runcorn (Wiley, 1975) describe a large numbers of attempts which bear on the earth's rotation based on study of marine shells.

For a reliable study, well preserved samples containing continuous records are required. These are rare and a search for better fossils has continued over the years. Recently Kahn and Pompea (*Nature*, 275, 606, 1978) have reported growth rhythms in nautiloids, a small sea shell which floats in the ocean. As nautilus grows, coiling its shell in the shape of a spiral, it incorporates two kinds of periodic structures. One is the daily secretion of calcium carbonate on the outer shell at the aperture resulting in a growth line, and the other is septation, i.e., formation of chambers as the animal abandons one part of the shell to stay in the other. The numbers of growth lines per chamber length in modern nautiloid, as counted by Kahn and Pompea is  $30 \pm 2$ , close to the lunar month of 29.53 days. In old nautiloids dated to be formed 420 m.y. ago, the growth lines are only 9 per chamber. If our understanding of the growth of nautiloid shell is correct, this would mean that lunar month has increased from a 9 day period 420 m.y. ago to 29.5 days now. This work further shows that the increase in number of days per month is not linear but was slower 225 m.y. ago when the continents were not separated yet.

The moon is receding about 5.8 cm every year as can be determined from a study of ancient lunar eclipses. The sea fossils give a value about 17 times as large for the past 70 m.y. If both these data are to be consistent a change in the recession rate has to be invoked.

The geologic evidence suggests three stages in the evolution of the earth-moon system. First, when water

was not present in liquid form on the earth's surface, the lunar orbit evolved slowly due only to tides in the solid Earth and the moon. Next the moon receded slowly because the sea was deep and dissipated little energy. Then about 600 m.y. ago, when the continents emerged, the last stage began and lunar recession proceeded more rapidly. The nautiloid data, though limited much in time, support the recent trend in recession of the lunar orbit.

Although, the Nautiloid data cannot be considered conclusive, they do indicate the fascinating microworld of the fossils which may help us understand some major events of our planetary system in the remote past, which is otherwise difficult to infer even from direct studies of lunar samples.

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## BINARY PULSAR AND GENERAL RELATIVITY

A few years ago the attention of relativists was drawn to a likely testing site for the predictions of general relativity, which lies well beyond the usual sites provided in our Solar System. In a paper published in the *Astrophysical Journal Letters* [195, 51, (1975)], R. A. Hulse and J. H. Taylor pointed out that observations of the binary pulsar PSR 1913 + 16 indicated a precession of

the periastron at a rate of  $\dot{\omega} \simeq 4.2$  deg/yr. Until then the only such measurement available had been the classical observation for planet Mercury, whose periastron (after the effects of other planets have been accounted for) advances at a rate of about 43 arc sec per 100 yr! The large value for the advance of the periastron in the Hulse-Taylor binary is due to the large eccentricity of the orbit and the larger strength of the gravitational field.

In a recent work presented at the Texas Symposium in Munich and also published in *Nature* (277, 437, 1979), J. H. Taylor, L.A. Fowler and P.M. McCulloch have carried the observations of PSR 1913 + 16 much further and have come up with more striking results which provide further support for Einstein's general relativity. Among other things their results may be looked upon as a first (albeit indirect) indication of the existence of gravitational radiation.

These results arise from pulse time measurements of nearly 1000 observations over 4.1 years, years, at frequencies of  $\sim 430$  and 1410 MHz at the 1000 foot dish at Arecibo. Various corrections have to be made to the pulse arrival times including geographic variations, dispersion in the interstellar medium etc. The pulse arrival data is then used to obtain the thirteen orbital parameters of the binary system. These parameters were then used to place strong constraints

on the masses of the two stars. The 'best fit' for the masses seems, according to the authors, to be  $(1.39 \pm 0.15)M_{\odot}$  and  $(1.44 \pm 0.15)M_{\odot}$ . The observed periastron

shift  $\dot{\omega} = 4.226 \pm 0.002$  deg/yr can then be explained entirely as the general relativistic effect. Since the stars are compact (most probably neutron) stars, the tidal effects are not going to be important. It may be remarked that since some of the orbital parameters had not been known before, Hulse and Taylor (op cit) could not argue whether the observed  $\dot{\omega}$  was explained by general relativity.

Another interesting aspect of these observations is the rate of decrease of orbital period:  $P_b = - (8.64 \pm 0.02) \times 10^{-12}$ . Why should the period decrease? The reason provided by general relativity is that a binary star system has changing quadrupole moment and hence radiates energy. Because of this, the orbit changes and the period decreases. The authors point out that the observed result is consistent with this interpretation. They also mention that theories of gravity which predict dipole gravitational radiation are in disagreement with the observations. They also rule out Rosen's suggestion that gravitational waves are time-symmetric and do not transport energy.

Finally, the authors point out another test of general relativity, namely, the spin orbit coupling, which should cause the pulsar spin axis to precess at a rate of  $\sim 1$  deg/yr. The pulsar shows a double-peaked pulse shape, which is probably caused by the rotation through our line of sight of a hollow cone of beamed emission. As the spin axis precesses, we should expect to see different sections through the radiation beam, probably accompanied by changes in pulse width and/or shape. Such an effect has been seen, although a quantitative estimate of the result cannot yet be made.

It is remarkable that a single object should combine so many different tests of general relativity. Whether 'no other' interpretation of these observations is viable still remains to be carefully investigated. Nevertheless, the ease with which general relativity can account for the data will go a long way towards boosting confidence in the theory. These observations also indicate that thanks to radical improvements in technology the 'weakness' of gravity need no longer pose a major obstacle towards testing theories of this type.

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## REPORT ON EINSTEIN CENTENARY SYMPOSIUM AT AHMEDABAD

Einstein Centenary Symposium which was held in Ahmedabad from 29th January—3rd February, 1979, sponsored by Physical Research Laboratory, Space Applications Centre, Gujarat University, Ahmedabad, Tata Institute of Fundamental Research, Bombay, Raman Research Institute and the Indian Institute of Science, Bangalore along with the Indian Association for General Relativity and Gravitation, was a great success with over two hundred participants amongst whom fifteen were from abroad. The Symposium in a way reflected the true spirit of Einstein's own concept of unity of nature by bringing in scholars in different aspects of Physics like Relativity, Astrophysics, field theory and foundations of Quantum Mechanics and Statistical Mechanics, fields in which Einstein's contributions have been fundamental.

Prof. J. V. Narlikar in his inaugural lecture spoke on the philosophical foundations of Einstein's theories particularly of Relativity. He emphasized on the creative genius of Einstein and on his process of thinking. After briefly indicating the ideas of special relativity he talked about the transition to general relativity and eventually considered the solution of two body problem in general relativity. Prof. Ted Newman, from Pittsburg gave an overview of research in Relativity, since Einstein (a biased view in fact as he called it) broadly outlining the new developments in understanding solutions of Einstein's equations using the modern differential geometry on the one hand and the study of gravitational radiation, asymptotics and black hole physics on the other. As he pointed out, in spite of many developments there has been no breakthrough in attempts to quantise gravity. However, Hawking's attempts of Euclidean quantum gravity with gravitational instantons and Penrose's theory of twistors seem to be more promising lines in this direction. Speaking on his personal work during recent years, Prof. Newman elaborated on the theory of H-spaces (solutions of Einstein's vacuum equations on complex manifolds) highlighting their structure and some plausible arguments for studying them.

Prof. A. Papapetrou of Institut Henri Poincare, Paris, speaking on problems of gravitational radiation gave an appraisal of recent trends in theoretical research in this field particularly in connection with radiation in a two body system. Prof. J. Pachner described his new method of numerical integration for a spherically symmetric collapse which he found to be accurate and stable as compared with some analytical results of the similar problem. His conclusion was that for any non-uniform spherically symmetric distribution with monotonically decreasing density the collapse is highly non-uniform.

One of the most outstanding problems of general relativity had been the famous positive mass conjecture. As is well known, the singularity theorems require for their validity the positivity of energy. Dr. D. Brill of University of Maryland reviewed this problem and he described his proof of the conjecture in the case of asymptotically flat spacetime as one can define a unique total energy only for such a system.