In this issue

A rare event for Earthlings

We reproduce on **pages 142–145** a selection of photographs obtained through 'internet' of one of the rarest events that took place in our solar system (between July 17 and 22). A comet actually crashed into Jupiter and the effects of the crash could be observed by the astronomers on earth and from our satellites. It was not a commoner garden comet but a shattered one with its fragments strung together in an exquisite heavenly chain. Each of the fragments hit Jupiter almost exactly at the time predicted. Unfortunately for us they hit Jupiter on its darker side, so that we on earth could not observe the actual impacts. But since Jupiter rotates (the Jovian day being only 10 hours long) the crash sights came into view within a few minutes of the impacts and the effects of the impact could also be studied.

Eugene and Carolyn Shoemaker of the Lowell observatory and an amateur astronomer David H. Levy discovered this comet for the first time on the night 24th March 1993. By the approved convention the comet was called 'Shoemaker-Levy 9 (1993e)' (SL9) (why not Shoemaker*s*-Levy 9 (1993e)!).

Comets usually go round the sun in an elliptical orbit and some of them as they move towards the sun break up. SL9 is quite unusual in that it is perhaps the only comet which has been *observed* to orbit Jupiter (although calculations indicate there could have been at least one more). In the first photographs the comet appeared squashed.

After careful computation, Brian Marsden predicted that this comet (SL9) would impact Jupiter in mid July 1994; and since then the comet has been the subject of intense study. The photographs from Kitt Peak revealed that the comet was really a shattered one with 21 fragments. The Hubble telescope photographed before and after it was 'repaired' showed these fragments very clearly—(proving also that the repair work had been done well). For identification purposes, each successive fragment is named after the alphabets A to W (I & O being omitted). The fragmentation must have taken place due to the tidal forces when the comet came closest to the Jupiter (called the perijove position after prehelion for conventional comets) on 7 July 1992. The length of the train of 'the string' in March 1993 was about half of the Earth–Moon distance (51 arcseconds angular length). It continuously expanded in length due to the differential orbital motion between the first and last fragments and on the day prior to the impact the length of the 'string pearls', as the astronomers affectionately called it, was about 25 times (i.e. about five million km long), the angular diameter being half that of the Moon.

Astronomers have speculated on whether there is previous evidence of a string of comet fragments hitting a planet. If such a succession of fragments hits a planet, the planet will show aligned chain craters or craters chain structures. Such crater chains have been observed on the satellites Callisto and Ganymede. The Moon too has a few examples of such crater chains.

Jupiter is now about 770 million kilometers from earth. As stated earlier, while one would not be able to observe the actual impact from the earth, one could see the effects of the impacts. The images taken by the Hubble telescope show that the fragments are between 1 and 4 km in size. The comet fragments will not affect Jupiter as a whole. The energy deposited by the comet fragments fall well short of the energy required to set off sustained thermonuclear fusion. As one astronomer remarked, it will be like sticking needles in an apple (but locally each needle does significant damage); when Jupiter rotates, the damage can be assessed.

It was predicted before the impact that each comet fragment would enter Jupiter at a speed of 60 km per second or 130 thousand miles per hour. Aerodynamic force will however overwhelm the material strength of the fragment and tear it apart. Five seconds after entering, the comet fragments would deposit their kinetic energy of around 10^{28} ergs (equivalent to around 200 thousand megatons of TNT) at 100–150 kilometers below the cloud layer. On impact, the hot gas at about 30,000 K resulting from (if the fragment is 1 km) the stopped comet will explode forming a fire ball similar to a nuclear explosion, but would be much larger. The visible fire ball may rise about 100 km at first say above the cloud top in this case. The fire ball will continue to rise, reaching a height of 1000 km before falling back. The splash will be heavily enriched with cometary volatiles such as water, ammonia, etc.

Many astronomical laboratories geared themselves to make observations of the impact of the fragments of SL9 on Jupiter and the consequent effects. Astronomers regularly report their findings through the International Astronomical Union Telegrams (IAUT) so that their community gets immediate information. Telegrams and circulars began pouring in. It was exciting to see them on the IAUT notice board of the Raman Research Institute. More than 20 telegrams came during this period and each contained observations made by 5 to 10 observatories. Simultaneously spectacular computer photographs of events observed by various laboratories also came in by 'internet' (we reproduce a few in this issue). Reading and seeing all these was more exciting than a one-day cricket match; excepting that the fire-works were much greater than what was expected. By reading these telegrams it was clear even to the layman that many questions remain to be answered. Why did the impact of fragment G photographed by the Keck telescope in Hawaii show so much of infrared emission—much brighter than Jupiter itself? What would be the energy deposited when these fragments impacted Jupiter? Is the estimated energy of the G fragments (3 km across) and A (1 km across) correspond to 6 million megatonnes and 200 thousand megatonnes of TNT? What is the average specific gravity of the SL9 comet? The fact that it fragmented, we are told, is a clear indication that it is a comet. However, if its composition is like that of other comets (ice) then why did not water and hydrogen reveal themselves in quantity. Is the detection of hydrogen sulphide, sulphur and carbon disulphide molecules any indication of atmospheric composition of Jupiter or were they products of the syntheses due to the collision? Why are the scars of the impacts so large and why did they glow for such a long time (30 to 40 hours) in the infrared and why did they appear black in the visible? Will the seismic waves studies give any information about the liquid hydrogen content of Jupiter? Why did each of the impacts behave so different from the other? What are the plumes that were detected by earth telescopes and the Hubble space telescope. When the dust literally settles down we will surely know much more about Jupiter and about comets in general and this comet in particular. We hope to have a comprehensive article by an expert.

It is gratifying that Indian astronomers too took an active part in this world exercise. The Indian Institute of Astrophysics (IAA) sent a study team to Leh. The Kavalur Vainu Bappu Telescope detected sharp brightness increase in the infrared (1.56 microns) when the fragment S impacted (see **page 141**). The Raman Research Institute observing team made observations with the 10.4 millimeter telescope at 86 GHz (3.5 mm wavelength) and looked at increase in the jovian continuum flux density. During the various impacts the increase ranged in intensity from 50% up to 400% over the normal radiation from Jupiter. These increases lasted from 3 seconds to 30 seconds. Amongst the IAU Telegrams received till we went to press, the one from RRI (Circular No. 6035) seems to be the first report of the measurements of the continuum flux of Jupiter at mm wavelengths when the comet fragments impacted. Thanks are due to R. Ramachandran and C. R. Ramachandra Rao of RRI for the help in obtaining the 'internet' pictures.

On 22nd of July 1994, R. K. Laxman, the internationally renowned cartoonist came to Raman Research Institute. Prof. Radhakrishnan explained to him the crash of the comet SL9 with Jupiter. Laxman drew a cartoon, which we have great pleasure in reproducing in this issue (see **page 146**).

S. R.

Global minimizers in quantum chemistry

Minimization of functions and functionals is an ubiquitous problem in different branches of science. In quantum chemical calculation of electronic structures, the extremization question arises as a natural consequence of Variation theorem. To obtain optimum wave functions for the ground and excited states, the usual difficulties in (a) characterizing minima, maxima and saddle points, (b) distinguishing local minima from the global minimum, and (c) determining the search directions in a multi-dimensional surface need to be surmounted.

The standard approach has been to use derivative-based methods. Increasingly, stochastic procedures such as the Simulated Annealing method in conjunction with the Metropolis Monte Carlo or the Molecular Dynamics strategy have been shown to be powerful alternatives. P. Dutta and S. P. Bhattacharyya review (**page 166**) the advantages and limitations of various methods used in minimizing the variational energy functional. Some representative applications are also discussed.

J. C.