SCIENCE NEWS

INTERNATIONAL COLLOQUIUM ON BARYON NON-CONSERVATION (ICOBAN)

Does a proton decay? How do you go about measuring its lifetime? Can a neutron in vacuum become an *antineutron* after some time? What are the cosmic ray backgrounds one has to cope with in the deep-mine experiments? These were some of the exciting questions that were discussed in a 4-day meeting held at the Tata Institute of Fundamental Research, Bombay, in January this year. The meeting had been named ICOBAN to stand for International Colloquium on Baryon Non-Conservation. Out of the 80 delegates attending the meeting, 45 were from institutions inside India. The state of the art, both experimental and theoretical, was brought out vividly in 21 invited lectures and 14 contributed talks. Two sight-seeing trips were organised to Elephanta Caves near Bombay and the Kolar Gold Fields near Bangalore—the first perhaps to impress that the theme of unification was thought of much earlier in India and the other to the deepest level in the earth to witness how the implications of Grand Unified Theories (GUTS) are being studied.

The deliberations began with the welcoming remarks by B.V. Sreekantan, Director of TIFR, who spoke about the rich traditions set up by the Institute in the area of cosmic ray experimental work deep underground in the Kolar Gold mines in the past two decades. Jogesh Pati of Maryland University started out by giving a lucid account of how the conclusion that proton should be unstable was forced on him and Abdus Salam during 1972-73, while they were involved in their efforts to unify the particles and their forces. Grand unified theories propose to unify the electroweak force and the 'Colour' forces, and treat the quarks and leptons on the same footing. One has then the possibility that a quark can be transformed into a lepton, implying thereby the conversion of the three quarks of a proton into three leptons, leading to nonconservation of baryon number. An interesting prediction of the Pati-Salam scheme is the existence of 'mirror' fermions which are relatively stable and have masses in the range 20-200 GeV.

The theoretical estimates of the proton life time (τ_p) and the branching ratios in a variety of models of Baryon number violation were surveyed by Paul Langacker. The recently obtained small value of the QCD scale parameter $\Lambda = 160$ MeV is a bad news for SU(5) as it shortens the longevity of the proton to 3×10^{29} years. While the present errors in Λ leave τ_p uncertain by as much as a factor 100, it is also not difficult to decrease the theoretical estimate of τ_p by adding more Higgs of low mass. Whether the proton is free or bound, its life time seems to be roughly the same, according to the calculations reported by J. Arafune who considered the effects due to Fermi motion, pion absorption and scattering inside the nucleus. For the discussion of branching ratios, Virendra Singh presented a general phenomenological approach assuming an effective baryon-lepton vertex. Baryon non-conservation in unorthodox models such as GUT with 'garden', models with integer-charged quarks, and composite models with preons, comprised the theme of G. Rajasekaran's lively presentation.

It is generally held that supersymmetry, which treats the fermions and bosons on an equal footing, when combined with GUT would force the proton to be nearly stable ($\tau_p \sim 10^{45}$ years). This 'unexciting' conclusion of SUSY GUT can however be averted if the dimension-5 operators are made to dominate (instead of the Higgs, their fermionic partners are important). A night-marish possibility of SUSY GUT mentioned by D.V. Nanopoulos is that the proton would predominantly decay into $K^+\nu_\tau$ while all other modes have insignificant rates. This scenario was not appreciated by the experiments relying on back-to-back Cerenkov cones in water. There are many unresolved problems about SUSY; it is not clear how to break SUSY at 100 GeV, lots and lots of new particles—photinos, gluinos, Winos, Zinos, ... are required. R.N. Mohapatra while summarising the theoretical aspects referred to this field as a 'can of worms', but the SUSY enthusiasts promptly objected to such a comparison.

The dark matter in the universe, which could be as much as 30 times the luminous matter, may consist of a variety of light mass particles. Gary Steigman described how limits on the masses of these 'inos' can be placed by requiring that the inhomogeneities leading to the galaxy formation may not get damped out, etc.

Axions, which were invented to circumvent the strong CP violation, may easily be emitted in the stellar interiors. M. Yoshimura, who discussed the implications of the strong CP problem to baryon non-conservation, also mentioned the constraints that can be obtained by considering the energy loss due to axions on the cooling rates of stars. It is comforting to hear that the axion is completely harmless and it seems to be invisible even in astrophysics and cosmology!

On the experimental side, the world wide hunt for the signals of proton decay as well as the n-$\bar{n}$ oscillations were presented. With the exception of a few on-going experiments, most of the projects are in different stages of preparation. Clear-cut examples of proton decay are still elusive.

M.G.K. Menon presented the latest results from TIFR-Osaka City University-Tokyo University collaboration experiment operating at a depth of 2300 metres (the deepest point in the current series of experiments) in the Kolar Gold Fields. The '3 candidate events' recorded in the first five months of operation are still considered as plausible examples of baryon nonconserving nucleon decay. The recent calibration runs at CERN on a proto-type 'NUSEX' detector (reported by E. Fiorini) substantiate the claim that these events have nothing to do with νinteractions. A recent event (the '4th one')recorded in the KGF detector with *its tracks fully confined* to the fiducial volume and with total energy around *1 GeV* was also discussed. Even though this event can be considered as an example of proton decay (eg. $p \to e^+\pi^0$, the track configurations are such that a ν-interaction may also simulate this event at a frequency of 1 in two to three years. Estimates on life-time based on these data, were quoted around 10^{31} years, an order of magnitude higher than the pre-1980 value. V. S. Narasimham discussed the cosmic ray background at the KGF depth and also presented a stringent lowe limit of 6×10^{30} years for the lifetime, in the context of Pati-Salam decay schemes($P \to 3\nu + \pi^+$ $n \to 3\nu + \pi^0$) as well as the supersymmetric GUTS discussed by Nanopoulos ($p \to \nu_t + K^+$ or $n \to \nu_t + K^0$)

From the other on-going experiments such as (*i*) the 30-ton experiment at Soudan mines, USA, (ii) the 300-ton Water Cerenkov detector at Homestake Mines, USA, and (iii) the 300-ton liquid scintillation detector in Baksan valley, USSR, a lower limit of 1-2 $\times 10^{30}$ years was obtained on the lifetime of protons. The latter two detectors (at Homestake and at Baksan valley) operating for over a year, were not originally designed for proton decay search; the results therefore constitute the ultimate capability in their present configuration. Ambitious new experiments with multi-kiloton detectors of high resolution are being planned by these and other groups. The outstanding examples are: the Giant Underground Detector (GUD) of 12·5 kilotons with neon flash chambers and resistive plate counters in the Gran Sasso tunnel in Italy, the 1·5 kiloton detector in the Gran Sasso tunnel in Italy, the 1·5 kiloton detector in the Frejus tunnel between Italy and France, the 1·4 kiloton liquid scintillator at Homestake mines and the Soudan II proposal for a kiloton detector using drift chambers. These experiments will have the necessary resolution to distinguish between different decay modes in view of the fine-grain sampling being built into the detectors.

Three experiments are getting ready for operation. The first one to start data-taking shortly is the NUSEX (Nucleon Stability Experiment) detector in Mont Blanc tunnel. Ettore Fiorini of the University of Milano discussed the calibration runs at CERN and the present status of preparation of the experiment. The biggest detector ever to be mounted underground, the Irvine-Michigan-Brookhaven 10-kiloton water tank, with 2400 phototubes, is scheduled for summer 1982, as described by J. Van der Velde of Michigan University. The Harvard-Purdue-Wisconsin experiment with 800 tons of water Cerenkov detector in the Silver King Mines at Utah, USA, was discussed by David Cline. A brief report on the experiment with the 3·0 kiloton water detector in Kamioka mines, Japan, by KEK-Tokyo collaboration was given by J. Arafune. Preliminary tests on the Cerenkov cones formed by charged particles were reported by Van der Velde and Arafune. The crucial full-scale measurements to establish the efficacy of such detectors in isolating the proton decay signals amidst the large cosmic ray background at these shallow depths are eagerly awaited.

The *first* result on n-$\bar{n}$ oscillation was reported by M. Baldo-Ceolin of the University of Padova. In an experiment conducted at the Grenoble reactor, no signals of antineutrons were recorded, with the result that the oscillation time has to be *greater than* 10^5 sec. This value is still about a factor of 100 smaller than the estimate obtained by noting that a neutron oscillating inside a nucleus will lead to the instability of the nucleus itself (at the level of about 10^{30} years). The status of the ambitious experiments with Trigga Mark II reactor at Pavia, Itlay, and at Oakridge, USA, was presented by S. P. Ratti and R. Wilson respectively. The ultimate sensitivity of these experiments is expected to be around 10^9 seconds, which should encompass most of the regions of oscillation time predicted by the protagonists of the left-right symmetric models.

Other topics touched upon at this meeting included (a) the search for primordial monopoles with masses heavier than 10^{15} GeV in the Baksan valley experiment by A.E. Chudakov of the Institute for Nuclear Sciences, Moscow, (b) the study of the neutrino oscillations with a water Cerenkov detector of a million tons either in deep lakes or ocean exposed to cosmic neutrinos (D.B. Cline of University of Wisconsin), and (c) the study of neutrino bursts lasting upto a second or so from the gravitational collapse of stars using the IMB detector (J. LoSecco of Caltech, USA).

An excellent summary was given by Chudakov on the experimental topics discussed in ICOBAN. While taking note of the plausible evidence of nucleon decay presented at this meeting by the KGF group; he said that if the lifetime turns out to be larger than 10^{32} years or so, it will only be a matter of 'religious faith' as to whether protons decay or not.

The colloquium ended with the following quotation purported to be the last words of Lord Buddha-

"*All composite things decay. Strive diligently*"

There perhaps lies a message in it to the theorists and experimenters who assembled at ICOBAN.

The proceedings of the Colloquium are expected to appear soon as a special volume of Pramana (a journal of physics). Prof. E. Fiorini has announced that the second meeting in the ICOBAN series will be held in Frascati, Italy, on 10 January 1983.

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WORKSHOP ON GRAVITATION AND RELATIVISTIC ASTROPHYSICS, 18-20 JANUARY 1982, AHMEDABAD

The Workshop on gravitation and relativistic astrophysics held in January this year at the Physical Research Laboratory was jointly sponsored by the Physical Research Laboratory, the Raman Research Institute and the Tata Institute of Fundamental Research. The Workshop was also supported by the Indian National Science Academy and the University Grants Commission and was the first of its kind in the country. The participants consisted of experts in different fields (like general relativity, field theory, astrophysics, cosmology) and research workers and students from various institutes and universities. The Workshop consisted of invited lectures and discussions without any contributed papers. The deliberations were broadly classified into four sessions dealing with (i) gravitation as a gauge theory, (ii) gravitational collapse, supernovae and neutrons, (iii) accretion disk dynamics, and (iv) cosmology — quantum and classical.

The session on gravitation as a gauge theory consisted of lectures by N. Mukunda, P. Majumdar and T. Pradhan who dealt with aspects of Poincare gauge group, supergravity and long range spin-spin interactions respectively. Starting with the classical papers of Utiyama and Kibble, the lectures lucidly presented Lagrangian approach of gauge theory, reviewing the aspects of supergravity both from supersymmetry and superspace approach and pointed out the difficulty in understanding the role of torsion. An attempt was made to explain the novel feature of Tam and Happer's experiment indicating the attraction betweeen photon beams with parallel spins and repulsion between beams with antiparallel spins using a new set of transformations restoring only partial gauging of the Lorentz group.

The session on gravitation collapse, supernovae and neutrinos had five speakers: B. Banerjee, G. Srinivasan, C. V. Vishveshwara, S. V. Dhurandhar and B. R. Iyer. Here we had three surveys dealing with hydrodynamical collapse models of super novae, on the type of stellar remnant that most supernovae leave and on the general relativistic models of collapse. Some of the salient features that were brought out were: (a) the changes in adiabatic index governed by neutrino, (b) electron and nucleon degeneracy pressures, (c) the minimum mass limit of $7\,M_{\odot}$ for the progenitor to have an explosion, and (d) the Shapiro-Teukolsky adiabatic collapse model in which the collapse to a black hole can be followed accurately through a general relativistic hydrodynamical computer code. Iyer discussed the core-envelope models for collapsed objects presenting the methodology and indicating the mass limits for neutron stars obtained from these models. Dhurandhar spoke on the general relativistic effects on the neutrinos in gravitational collapse, using both the null geodesic and the massless Dirac equation on curved background geometry.

In the session on accretion disk dynamics, A. R. Prasanna and D. K. Chakraborty presented in detail the methodology and the results pertaining to the complete general relativistic analysis of structure and stability of disks around compact objects. In particular, they discussed the pressureless thin disk of charged fluid with self-consistent electromagnetic field and the structured thick disk of perfect fluid, on the background Schwarschild geometry and indicated the stability under different perturbations.

The final session on cosmology had five speakers, two on quantum and three on classical aspects. J. V. Narlikar and T. Padmanabhan discussed in detail the quantum conformal fluctuations near classical singularity, showing that the nonclassical paths with the same end conditions give rise to quantum effects and the Planck length could come as a natural cut-off for the scale factor as time approaches zero. An implication of their analysis seems to be that classical flat space vacuum is unstable against quantum fluctuations and as such the dynamical equations lead to creation of matter.

Speaking on classical cosmology, M. A. Melvin discussed briefly homogeneous axial and skew-axial cosmologies showing that the assumption of homogeneity leads to the synchronous form of the metrics for Bienchi cosmologies. P. C. Vaidya, considering rotating systems in cosmological background, presented some recent results concerning a solution of Einsteins equations having closed null geodesics interpreting it as *radiation-filled matter free* universe. A. K. Raychoudhury delivering the last lecture of the Workshop listed some outstanding problems in cosmology, particularly associated with the age of the universe.

Throughout the Workshop there were stimulating discussions which brought out many important, unsolved features of the various topics that were dealt with.

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