# REPORT ON THE 15th INTERNATIONAL COSMIC RAY CONFERENCE

The 15th International Cosmic Ray Conference organised by the Cosmic Ray Commission of the IUPAP was held at Plovdiv, Bulgaria, during Aug 13-26, 1977. A total of over 400 delegates participated in the Conference and contributed about 800 research papers. The proceedings in 9 volumes were distributed to the delegates when they registered for the Conference; two more volumes containing late papers, invited review talks and rapporteur summaries will be distributed after the Conference. The next Conference in this series will be held at Kyoto, Japan, in August 1979.

It is clear that in the limited space available we cannot summarise all that was presented at the Conference. We have therefore used our discretion in selecting areas which are of greater interest to astronomers rather than presenting a little of everything. Also, inspite of the fact that a number of papers in the field of X-ray astronomy were presented, we have not included them here because, though this field started as an activity of cosmic ray physicists, it has now moved closer to other astronomies.

## 1. Gamma Ray Astronomy

The spectral region which is of concern to us here extends from roughly about $10^7$ eV to $10^{15}$ eV. Two special advantages of astronomy in this window are first, the possibility of studying high-energy-transfer processes occuring in the cosmos, and second, the high degree of transparency of our Galaxy and the universe, to such gamma rays.

**Galactic gamma ray background :** It is now well established that in the few MeV to a few hundred MeV domain, there is anisotropic gamma ray background which is thought to be of extragalactic origin, superimposed on which there is a relatively bright component of galactic origin. Observations from the COS-B satellite launched in 1975 reported at this Conference (European collaboration) on the galactic background confirm and improve the earlier SAS-2 (launched in 1972) data and is given in Figure 1; here the longitude profile of the intensity of gamma rays of energy $>100$ MeV integrated over the latitude range $b < 6°$ is shown. Some of the peaks in this figure are identified with known sources; many more are likely to be identified when better instrumental resolutions are achieved. Furthermore, the shape of the energy spectrum of this background radiation clearly shows that, while at energies $>50$ MeV the decay of neutral pions dominate, below this energy contributions due to bremsstrahlung should be important. Such observations were also reported from a number of balloon experiments for limited parts of the sky.

A number of papers attempting to interpret these and other observations were reported. It is found that the longitudinal distribution of the gamma ray intensity along the galactic plane bears a close correlation with the molecular hydrogen distribution as inferred from CO studies. It is therefore seen immediately that gamma ray distribution in the Galaxy can be used to enlarge our understanding of matter distribution because gamma rays of energy $>$ 100 MeV are due mainly to the decay of neutral pions that result from nuclear collisions of energetic cosmic rays (C.R.) with ambient matter in interstellar space (I.S.). Many attempts to compare the observed galactic longitudinal and latitudinal gamma ray intensity distribution with other distributions such as non-thermal radio emission, neutral hydrogen, supernova remnants, different types of stars, etc. were also discussed. There were papers in which interpretations were sought for gamma rays of energy $<30$ MeV, assuming that they arise from bremsstrahlung of C.R. electrons interacting with I.S. matter. It is thus seen that I.S. matter is probed in both cases, by energetic nuclei in one and electrons in the other. Another process which is also being considered particularly for these lower energy gamma rays from the region of the galactic nucleus is inverse Compton scattering of relativistic electrons with starlight photons. However, we are still in search of interpretations which will provide internal consistency to all observations. It was also pointed out that improved detection of the background gamma rays leading to their detection from I.S. gas clouds could be a powerful source of information in this field.

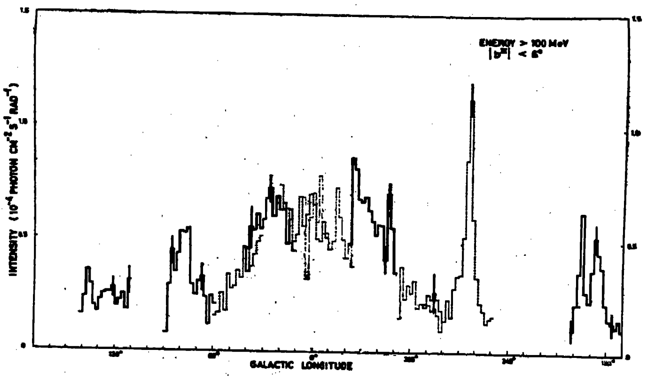


Fig. 1 : Intensity of the galactic gamma ray background.

**Gamma ray sources :** Though the identification of a number of celestial sources using balloon borne instruments has been claimed, it is only from the data of SAS-2 and COS-B that a significant list of convincing sources has been made. Two main weaknesses of even these observations are the poor directional resolution (2.5° above 100 MeV) and the limited statistics. Currently, features which have widths smaller than the instrumental resolution are ascribed as due to discrete sources. From such procedures adopted in the case of COS-B observations, a number of new sources were reported. Data from the COS-B satellite has also been used to study in detail the two previously identified gamma ray pulsars PSR 0531 + 21 (Crab pulsar) and PSR 0833—45 (Vela pulsar); both show very similar gamma ray light curves having two peaks of about equal intensity separated by 0.4 of the period. The pulsed fraction of gamma rays of energy $>$ 50 MeV is at least 78% in the former and consistent with 100% in the latter. As a result of their pulsar search PSR 1822-09 has been recognised to be a possible gamma ray emitter.

There is new interest to detect steady or pulsed gamma rays of energy $>$ 100 GeV from discrete sources.

In this connection, a group at the Tata Institute of Fundamental Research at Bombay has looked at 10 pulsars for pulsed emission at energies >500 GeV. The experiment is based on the detection of atmospheric Cerenkov radiation of the e.m. cascade produced by the gamma rays using 10 parabolic mirrors in suitable combinations of coincidence. The only two objects from which reasonably positive signals were obtained are PSR 0950+08 at 3.85 sigma level and PSR 0531+21 at 3.56 sigma level.

**Gama Ray Bursts :** Interest in the study of gamma ray bursts started with the discovery in 1973 of short duration bursts lasting for time scales of minutes or less at MeV energies from instruments carried by Vela satellites. So far about 40 events confirmed from instruments in more than one space craft have been recorded. Even so no burst source has yet been identified; even the question whether they are galactic or extragalactic is an open one. At this Conference two new events both recorded by balloon borne instruments were reported. A variety of experiments attempting to detect bursts of gamma rays of low and high energies expected to arise from explosive events such as supernova explosions and black hole evaporation were also described. This area is yet a no man's land but one can expect surprises and new discoveries in the years to come.

## 2. Elemental Abundances

The study of the elemental abundance in C.R., which has now been carried out for the last three decades, is a key problem that has led to a variety of vital information in the past on source abundance, cosmic ray propagation in space etc. But for a long time we have been handicapped by instruments with inadequate charge resolution and low abundance of important elements. Recently, however, the use of improved large area detectors operating in space for periods of even years have overcome much of these handicaps. An experiment reported at this Conference by the group at the University of Chicago has obtained the elemental abundance for nuclei with Z=14-28 at energies of 72-450 MeV/nucleon using a detector in the satellite IMP-8 with high resolution (Fig.2). From an analysis of their data, they are able to infer that the source abundances of Si, Ca, Fe and Ni derived by extrapolating the measured abundances back to the source are comparable to the solar system abundance.

About 5 years ago, it was discovered that the ratio of (Li + Be + B) nuclei to (C +O) nuclei decreased with energy roughly to the power -0.5. (We recall here that, in conformity with the near absence of Li, Be and B in the universal abundance, it is assmed in all C.R. studies that they are also absent at the C.R. sources. The Li, Be, B that are seen in the solar vicinity are "secondaries" produced in transit in collisions between heavier C.R. nuclei and I.S. matter). A similar trend has also been seen in the relative abundance of the universally rare elements Sc to Mn (Z=21-25) to that of Fe. This observation is now attractively interpreted to be due to the energy (or rigidity) dependent propagation of C.R. in space. At this Conference a number of papers were reported both on the observational and interpretational sides of the problem. But no significant improvement in the observational data has taken place in spite of its great importance to cosmic ray propagation studies.

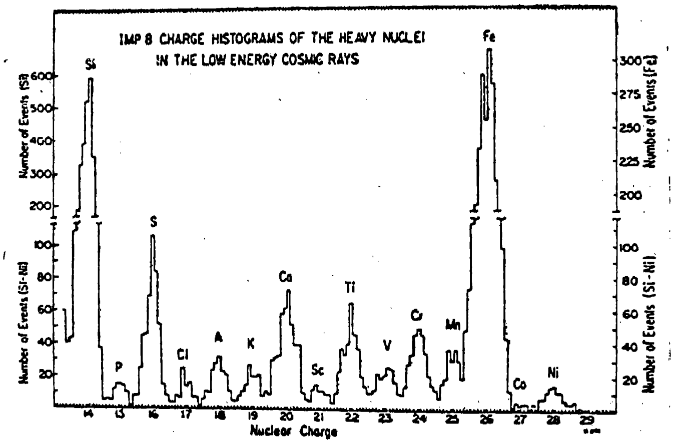


Fig. 2 : Charge histograms of the heavy nuclei in the low energy cosmic rays

Another related problem in these studies is the direct determination of the energy spectrum of individual nuclei extending hopefully to $10^{13}$ eV/ nucleon; this can then be joined with the spectra obtained at still higher energies from studies of extensive air showers they produce in the atmosphere. Existing measurements extend only upto about $10^{11}$ eV except in the case of protons and alpha particles which go upto almost $10^{12}$ eV. In the present Conference improved experiments were described to measure individual spectra upto a few times $10^{11}$ eV. Preliminary results were also presented by the Group at Johnson Space Centre from their super conducting magnet spectrometer on the energy spectrum of protons and helium nuclei between about 10 and 50 GeV based on $1.5 \times 10^5$ protons and $2 \times 10^4$ helium nuclei. Such high statistics experiments are capable of looking for deviations and structures in the power law nature of the spectra.

**Ultra heavy C.R.** Because of the extrême rarity of nuclei with Z > 30, work in this area has been possible only during recent years. However, large area and long exposure experiments using nuclear emulsions and special plastic films as detectors have already demonstrated that the elemental abundance extends at least upto the Pb region. One great importance of these studies is their potential to throw light on the details of the process of nucleosynthesis that is responsible for their production. At this Conference, preliminary results were reported from large area electronic detector systems, which can extend the charge spectrum to the heaviest elements. The first set of data going upto Z ≈ 80, though very crude, has sparked off considerable interest in calculations on explosive nucleosynthesis. A number of such attempts, notably by the Chicago Group, were presented at this Conference. They have examined the role of the r-process in the synthesis of elements and the uncertainties in nuclear physics inputs, namely a nuclear mass law and a β-rate formalism, which describe the very neutron rich nuclei that take part in the sr-process. They have also calculated the origin of nuclei of Z > 28 in supernova explosion of massive stars with M ≳100 M⊙ It is now believed that this approach can be sharpened when more reliable data become available in the elemental abundance of ultra heavy C.R.

## 3. Isotopic Composition

The importance of studying the existence of isotopes in the C.R. beam has been known for a long time. For example, in the case of radioactive nuclei (i) the "secondary $Be^{10}$ isotope which has a half life $t_{\frac{1}{2}} = 2 \times 10^6$ yrs can give information on the age of the cosmic rays; another isotope in this category is $Al^{26}$ with $t_{\frac{1}{2}} = 8 \times 10^5$ yrs; (ii) $Be^7$ isotope ($t_{\frac{1}{2}} = 52$ days) which decays by electron capture can give information on matter densities near accelerating regions; and (iii) $Ni^{56}$ ($t_{\frac{1}{2}}$, 6.1 days) and $Ti^{44}$ ($t_{\frac{1}{2}} = 47$ yrs) would prove to be source clocks to deduce time that elapses between nucleo-synthesis and C.R. acceleration. There is also considerable interest in studying stable isotopes such as $H^2$, $He^3$, $Li^7$, $C^{13}$, $N^{15}$, $O^{18}$, of Fe and a host of others which can give information of cosmological and astrophysical importance.

The most interesting result on radioactive isotopes reported at this Conference relates to the high resolution work of the University of Chicago on Be isotopes of energy 30—120 MeV/n which has enabled them to attribute a C.R. lifetime of $1.5 \times 10^7$ yrs from the near absence of $Be^{10}$. This lifetime, when combined with the information on the amount of I.S. matter traversed of 6g $cm^{-2}$ as deduced from the abundance of "secondary" nuclei Li, Be and B, leads to a mean density for the medium of propagation of only about 0.2 atoms $cm^{-3}$ compared to the usual value of 1 atom $cm^{-3}$ attributed to I.S. medium. An understanding of this observation is yet to come.

As for stable isotopes, a number of papers were presented on isotopes of Li, N, C, O, Fe, etc. However it will take some more time before exciting results are obtained because of the current inadequacies like need for more improved mass resolution for high masses, corrections due to atmospheric secondaries in case of ballon experiments and effects due to C.R. propagation.

It is also important to mention here that in the interpretation of much of these observations, one needs a knowledge of cross sections for the production of the variety of isotopes from the large number of parent target nuclei in collision with protons and alpha particles as a function of energy. A large number of papers based on experiments and calculations to obtain such cross sections were also reported.

## 4. Electrons and Positrons

The importance of the study of the electron component stems from the consideration firstly that it permits us to relate its intensity and spectral shape with the galactic radio background they give rise to; and secondly because of their small mass, the associated synchrotron, bremsstrahlung and inverse Compton energy losses open possibilities to probe the I.S. magnetic field, matter distribution and photon field respectively. Further, since it is reasonable to assume that positrons are absent in galactic sources, their existence in C.R. will give us information on their secondary production in space mainly through the pi-mu-e decay chain and the propagation mechanisms operating on them.

Over the years, a large number of measurements have been made on electrons of energy between 10 and 500 GeV; however there have been serious contradictions between the observations of different groups. At this Conference, the Chicago Group presented results which they claim is based on a very careful and well calibrated experiment. Their results agree well with the early result of the Bombay Group at energies below 50 GeV but disagree at higher energies. The new results below 50 GeV presented by the Group at Johnson Space Center using their superconducting magnet spectrometer also agree with the Bombay results. Even so, the situation in this field is far from satisfactory, in spite of its great potential in C.R. astrophysics.

## 5. C.R. Sources, Acceleration and Propagation

Any model for the origin of cosmic rays to be acceptable should ultimately be able to account satisfactorily for such important quantities as the energetics (cosmic ray energy density is roughly 1 eV / $cm^{-3}$ in the Galaxy), the elemental and isotopic abundance, the energy spectra, the electron component and isotropy. At this Conference as many as about 100 papers were communicated in these areas. It is a reflection of not only the importance and competitiveness in this area, but also our ignorance of a variety of associated astrophysical quantities and processes which permit diverse approaches to be made for interpretation, speculation and conjectures.

A wide variety of celestial objects such as the galactic centre, pulsars, pre-mainsequence stars, supernova explosions and supernova remnants were reconsidered at this Conference as possible candidates of C.R. sources. While each one may explain some aspects of C.R., like for example the energetics, there is no single type of object which explains satisfactorily even a few of the important characteristics. The real situation however may be a hierarchy of sources which possibility was also discussed at this Conference. It is important to mention here that such attempts have been made in the past too.

One reason why progress in this area is slow is the fact that the source composition of C.R. gets modified because of a number of factors such as the type of acceleration processes that operate, and the effects due to C.R. propagation in the source region, the I.S. space and in the solar system. There were a large number of presentations on I.S. propagation as in previous Conferences. But there were three significant factors that were seriously included on this problem in the present Conference. We have already seen that the "secondary" nuclei such as Li, Be, B have an energy spectrum steeper than that of the "primary" nuclei such as C and O. This is now accepted as arising from a rigidity dependent leakage of particles from the region of C.R. confinement. The second arises from a recent development regarding the existence of the galactic halo. While during the 50's, the existence of a large galactic halo was strongly supported by the radioastronomers and hence used by C. R. physicists as a very attractive large (radius 15-20k pc) confinement volume of C.R., the radioastronomers themselves withdrew this support during subsequent years. But during the last 2 years or so, they have come again in support of a halo of intermediate size (a thickness of 10 kpc is now being talked about). The third new input is a lifetime of $\approx 10^7$ years for C.R. as deduced from studies of the flux of $Be^{10}$ nuclei. Diffusion models, copound diffusion models, closed galaxy models, disk models and disk-halo models were also discussed at this Conference. But it is difficult to say what significant progress we have made at this point.

Finally, it is worth pointing that the galactic background gamma ray studies are poised to make a significant contribution in propagation problems, because the spatial distribution of such energetic gamma rays arises essentially as a product of C.R. intensity and matter density in the Galaxy along the line of sight. A few papers highlighting such possibilities were also presented at this Conference.

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## ROUND TABLE CONFERENCE ON 'TRAINING REQUIREMENTS OF ASTRONOMERS IN INDIA'

At the invitation of the Centre of Advanced Study in Astronomy (CASA), a representative group of Indian astronomers from various astronomical institutes and universities in India met in the Astronomy Department of Osmania University between December 27-30 to discuss the 'Training Requirements of Astronomers in India'.

The conference was inaugurated by Professor V.R. Srinivasan, Principal, University College of Science, O.U. on the morning of December 27, 1977. The Current Teaching Programmes in the Indian Universities were reviewed in the afternoon. The morning of December 28 was devoted to the consideration of the Requirements of Astronomical Institutes as put forward by the delegates from such institutes. The whole of December 29 was utilized in the discussion of Required Teaching Programmes and Contents of Syllabii. The Osmania University syllabii for the proposed (i) Two-year M.Sc. course in Astronomy and Astrophysics, (ii) The one year Post M.Sc. Diploma course in Astrophysics and Space Science and (iii) The M. Phil course were scrutinised thoroughly on the morning of December 30. The deliberations of the conference were summarised at the same session through a series of recommendatory resolutions which are given below :—

### Resolution No. 1

Considering that Astronomy is a part of the cultural heritage of humanity from the most ancient to the most modern times and taking into account the fact that the subject of Astronomy was very well developed in ancient times in India while it has been neglected during the last several decades, it is recommended that Astronomy should be included in the curriculum of Colleges and Universities as well as in those of High Schools and Higher Secondary Schools, which is the practice in most foreign countries. The inclusion of Astronomy in the Physics curriculum of the higher secondary stage by the NCERT is a right step in this direction, which is appreciated by this conference.

### Resolution No. 2

As the subject of Astronomy and Astrophysics has grown tremendously since the beginning of this century, it should form a separate discipline with an independent Department in at least a few Universities spread out in different parts of India—besides Osmania University which already has a separate Astronomy Department. As man-power needs of observatories, research institutes, teaching departments, planetaria etc., is estimated to be 20-25 per year for the next 5-10 years, these Universities should take up teaching of Astronomy at M.Sc. and post M.Sc. level and the UGC should support them with financial help for staff and equipment.

### Resolution No. 3

It is desirable that Astronomy should be taught as one of the subjects in the Physical Sciences group at undergraduate level in all Universities as a separate subject on par with other subjects like Physics, Mathematics, etc. In the meanwhile, the subject of Astronomy should be introduced as a part of Physics or Mathematics in B.Sc/B.Sc. honours courses and also as a specialization in Physics and Mathematics at M.Sc. level. As a beginning in this direction, one or two courses of Astronomy should be included in the Physics and Mathematics curriculum of B.Sc. and M.Sc. The UGC should give adequate support for these innovations by the Universities.

### Resolution No. 4

Due to the paucity of qualified staff to teach Astronomy at undergraduate and school level, CASA and other institutions should conduct separate Summer Schools : (i) for college and University teachers of Physics and Mathematics and (ii) for High School and Higher Secondary Teachers of Science, to acquaint them with important topics in Astronomy.

### Resolution No. 5

As books and teaching materials in Astronomy are not available in India, the senior Astronomers are urged to write suitable books of school, undergraduate and post-graduate standards and the observatories are requested to prepare suitable teaching materials and laboratory exercises which will be useful for them.

### Resolution No. 6

Since every institution cannot afford to have a good library in Astronomy and material on Astronomical education, a clearing house should be set-up, for instance, to start with at CAS in Astronomy, Hyderabad so that other centres may get from this clearing house on loan or otherwise this mateiral and the UGC should provide a special fund for this purpose.

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