REPORT ON THE SECOND INTERNATIONAL GAMMA RAY SYMPOSIUM

The Second International Gamma ray Symposium was held in Goddard Space Flight Center, Maryland, USA during June 2-4, 1976, under the title "The Structure and Content of the Galaxy and Galactic Rays." The Symposium was represented by a collection of astronomers working with meter wavelength photons to 10^{13} eV gamma rays, astrophysicists and cosmic ray physicists. The main emphasis of this symposium relates to the study of high energy astrophysical processes which are occurring in our Galaxy as they are revealed by gamma ray astronomy. This was accomplished through a series of invited talks followed by discussions, short presentation of new results not covered in the main talks, and remarks on controversial aspects. In this report, I have tried to summarize the new gamma ray results and to highlight some of the other topics which directly relate to the interpretation of these observational aspects.

The SAS-2 gamma ray observations have been analyzed with improved techniques and contour maps of the gamma ray sky, of energies above 100 MeV, were shown with an angular resolution of $\pm 2^\circ$ in galactic coordinates. Preliminary observations from the recently launched European gamma ray satellite COSB were also reported. The following are some of the important results obtained from these statellites.

(I) The latitude distribution towards the galactic center is broader than would be expected from the detector resolution. Two components, a narrow one with a detector resolution and a broader one with a Gaussian 1σ of of 6° to 7° are needed to give a good fit to the observation; the narrow component accounts for at least half the total radiation. COSB results confirm this finding with an additional information that at energies > 300 MeV, the latitude distribution has larger contribution from the narrow component. This information suggest that, perhaps, at energies < 300 MeV, gamma rays produced through processes other than the interaction of cosmic rays with matter are needed to understand the observation.

(II) The longitudinal distribution of gamma rays for latitudes within $\pm 10^\circ$ show structures. In the region of strong gamma ray emission towards the central region, five peaks stand out at longitudes 315°, 330°, 345°, 0° and 35°. These peaks are considered to be related to large scale structures in the Galaxy. However, not all the observed peaks can be understood at present on the basis of the known tangential directions to the inner spiral arms, or purely from the observed radial distribution of the CO molecules. In the region away from the galactic plane, four peaks are seen, out of which, two are identified with the Crab and Vela supernova remnants and the other two at longitudes 75° and 195° are not identified with known sources but are considered to be only localized sources. COSB observations are limited to a few regions of the Galaxy and are consistent with the above results.

(III) Four pulsars NP 0532, PSR 0833-45, PSR 1818-04 and PSR 1747-46 have been identified from the analysis of SAS-2 observations. The pulsed intensity from the Crab (NP 0532) is $(2.2\pm.7)\times 10^{-6}$ cm^{-2} s^{-1} above 100 MeV, and for the rest of the pulsars intensities of $(10.5\pm 2.4)\times 10^{-6}$ cm^{-2} s^{-1}, $(2.0\pm.5)\times 10^{-6}$ cm^{-2} s^{-1} and $(2.4 \pm.7\times 10^{-6}$ cm^{-2} s^{-1} respectively are seen above 35 MeV. Gamma ray pulses from the Crab are similar to those seen at x-ray, optical and radio wavelengths. The remaining pulsars seem to pulsate only in the radio and gamma ray regimes. In the case of Vela (PSR0833-45) double pulse is seen instead of a single pulse observed in the radio region; a delay of 13 milli-second is noticed between the radio and gamma ray pulses. COSB detected from the Vela pulsar an intensity nearly twice that observed by the SAS-2. This difference is attributed to a possible spin up of the pulsar. Further, the integral spectrum of gamma rays, from Vela in the energy region 50 to 1000 MeV is not a power law but closely resembles a π°-decay spectrum. This interesting observation from the COSB satellite would set useful constraints on the models of pulsed radiation from PSR 0833-45.

(IV) A new gamma ray source has been observed by these two satellites in the anticenter region close to the Crab. The flux enhancement as observed by SAS-2 is centered around $l=193^\circ$ and $b=4^\circ$, while that observed by COSB is centered around $l=195^\circ$ and $b=5^\circ$. This source is not identified in any other wavelengths. An analysis of the SAS-2 data suggests that this source pulsates with a period of about a minute, the data is also consistent with a possible increase in the period at the rate of 2.2×10^{-9}. The scheduled observation of this source by COSB will provide some valuable information in the near future.

One of the important parameters which is related to the observed gamma rays is the distribution of matter in the Galaxy. Considerable attention was given to this aspect in the symposium through a series of invited talks. The observed distribution of neutral hydrogen gives a good description of the spiral features in the Galaxy. However, its radial distribution in the galactic plane is different from other forms of matter. The amount of molecular hydrogen in the galaxy can be inferred from the observed CO molecules. In contrast to the observed neutral hydrogen, molecules are very abundant in the nuclear disk of the Galaxy. The density of molecules peaks again in the region of 4 to 6 kpc from the center and is clumpy. The density drops faster towards the outer regions of the Galaxy and its distribution perpendicular to the galactic plane is narrower than those exhibited by the atomic hydrogen. It is also interesting to note that the distribution of ionized hydrogen, supernova remnants and OB stars closely resemble that of molecules. The neutral hydrogen seems to be primarily a tracer of overall spiral gravitational potential where as the molecules, the young stars and the supernova remnants are considered to be the tracers of regions of strong compression associated with the spiral shock.

Most of the observed gamma rays in the galactic plane are produced by interactions of cosmic rays with interstellar gas and one needs to know the distribution of cosmic rays in the Galaxy, apart from that of the gas. The birth of new stars influences the cosmic ray density distributions because of the possibility that particles are accelerated in the regions associated with violent stellar activities. In this regard, the density wave theory of the galactic spiral structure can predict regions of high compression in the Galaxy, where cloud complexes could conceivably undergo gravitational collapse. The theory suggests that the gas, which flows into the spiral potential field, gets compressed in the shock region and as the gas leaves the shock, it is decompressed. Strong shocks with narrow regions of high gas compression result when the unperturbed velocity component of the gas, W_{10}, normal to the spiral arm is larger than the sound speed, a, and weak shocks with broad regions of low gas compression result if $W_{10} < a$. In this picture it is reasonable to to expect large cosmic ray density to be assocaited with the compressed regions, where rapid star formation takes place, and therefore an enhancement production of gamma rays. Thus, high resolution gamma ray survey of the Galaxy will, in the future, throw light on the theoretical understanding of the spiral pattern of our Galaxy.

The following inferences could be made from the existing theories to explain the longitudinal profile of the gamma rays, which make use of the observed gas distribution in the Galaxy. Even though the observed peaks in the logitudinal profile are related to the tangential directions of the inner spiral arms, the correlation between the distribution of neutral hydrogen and the overall gamma ray intensity distribution is not very good. On the other hand, there exists a good correlation of the distributions of molecules, ionized hydrogen, supernova remnants and young stars, with the overall gamma ray intensity profile, whereas the observed gamma ray peaks cannot be fully explained on this basis. Thus it becomes clear that a proper understanding of the spiral structure, the gas distribution in the compressed regions, are necessary to fully explain the observed longitudinal profile of the gamma ray intensity. However, at this stage one cannot rule out the possibility that some of the variations could result from the distribution of unresolved gamma ray sources.

The distribution of non-thermal radio emission in the Galaxy is related to the cosmic ray electron intensity. The observed overall distribution of gamma ray is similar to that of the non-thermal radio emission. It was reported from a recent analysis of the backgound radio emission perpendicular to the galactic plane, that the radio emission is an extended one with a scale height of about 2 kpc, on which is superimposed a narrow disk component. The spectral index of the extended halo component is slightly steeper than that of the disk component. This observation is consistent with the hydrostatic equilibrium of the gas-field system perpendicular to the galactic plane and gives evidence to the existence of cosmic rays over a large volume in the halo. The observed broadening of the latitude distribution of gamma rays could then be explained as due to the contribution from the inverse compton scattering of radiation fields by cosmic ray electrons in the extended volume outside that gas disk. The energy spectrum of gamma ray at high latitudes would then be steeper than that at low latitudes.

To compliment the SAS-2 and COSB results, the existing data in the energy region 0.2 to 20 MeV and $> 10^{11}$ eV were reviewed. The low energy spectral data below 30 MeV over a broad region in the direction of galactic centre, seem to be consistent rather with gamma rays produced either through bremsstrahlung or inverse compton processes, than through π°-decay. However, below about 10 MeV, the existing data and upper limits are about an order of magnitude larger than the expected flux values and thus requiring higher sensitivity detectors than the existing ones for such studies. The observed nuclear line emission towards the galactic central region suggests the existence of a large amount of low energy cosmic ray nuclei. The gound based gamma ray astronomy at energies $> 10^{11}$ eV has begun yielding positive results and those with important astrophysical significance include, the pulsed emission from the Crab suggesting a flat spectrum, the variability of Cyg X-3 and the detection of extragalactic gamma ray source (Cen A).

Radiation mechanism and cosmic ray production from pulsar were discussed on the basis of the magnetospheric structure of pulsars. Ions leaving the polar cap could be accelerated to extremely high energy by electric field, and if they escape into interstellar space, they contribute to the cosmic ray flux. On the other hand, the accelerated electrons radiate in the curved magnetic field giving rise to ultra high energy gamma rays, and the consequent pair production of these gamma rays in the intense magnetic field leads to electron-photon cascades; the possible bunching of these secondary electrons could also radiate coherently. While this theory explains many of the observed properties of pulsars, it does not predict in detail the cosmic ray observations. Apart from this, some of the problems concerning the propagation and containment of cosmic rays in the Galaxy were brought out in this symposium.

It has become very clear that continued interest in the field of gamma ray observational astronomy, using sensitive and high resolution detectors, is needed to strengthen our understanding of the structure and dynamics of our Galaxy. In this context it was pointed out that with improved detectors, it is possible to observe gamma ray lines not only from sources but also in the diffuse radiation. The width and intensity of line emission in the diffuse radiation could reveal information on both the interstellar medium and low energy cosmic rays, while specific lines from super nova outbursts would provide clues to some aspects of nucleosynthesis. Far infrared observation of the galactic plane could also lead to a better understanding of the physics and conditions of interstellar dust and molecular clouds, as well as of their distribution in the Galaxy. A panel discussion at the close of this symposium was devoted to the future programs cover ing the above aspects.

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