ASTRONOMY

# Goddard Symposia

from Correspondents

THE Goddard Space Flight Center in Maryland was host recently to two international conferences: an X-ray astronomy symposium on April 27; and the first symposium and workshop devoted exclusively to gamma-ray astrophysics on April 27 to May 2.

## X-ray Astronomy

Goddard seemed an appropriate place for the X-ray astronomy symposium because it was the project management centre for the first Small Astronomy Satellite (Uhuru) which has provided such a wealth of data on X-ray astronomy and has stimulated not only ideas for other X-ray experiments, but also interest in related measurements in optical and radio astronomy.

The first speaker at the morning session was Dr R. Giacconi (American Science and Engineering), the principal investigator of SAS-1, who began by announcing the publication of the third *Uhuru X-ray Source Catalog*. In addition to this catalogue, now containing a total of 161 X-ray sources, the position uncertainties for many of the sources previously listed in the second Uhuru X-ray catalogue have been significantly reduced. He described the large class of objects observed, including the binary systems. It now seems that the X-ray star of such binary pairs is sometimes quite massive and releases very large amounts of energy, and this has led to speculation that these particular objects are black holes.

Dr E. Kellogg (American Science and Engineering) described information on X-ray objects not in the galactic plane. He noted that the study of large clusters with redshifts of about 3 which are detectable in X-rays could give very deep insight into the evolution of galaxies.

Dr L. Peterson (University of California) noted that the energy spectra of X-rays associated with binary objects are often rather flat to 30 or 40 keV, at which energy the spectrum is observed to steepen sharply. No conclusion was reached regarding the most probable cause of this change in spectral shape.

Dr G. Garmire (CalTech), who concentrated on the soft X-rays, pointed out that nearly all classes of X-ray emitting objects discovered at higher energies by Uhuru are observed in the soft X-ray region. In general, soft X-ray observations can assist in determining distances to X-ray objects attributed to interstellar absorption. In addition, said Dr Garmire, future spectral studies of binary objects should lead to a detailed knowledge of the gas flow in these systems.

The afternoon session was devoted to the correlation of X-ray data with radio and optical observations and their relation to theoretical models for the sources. Dr R. Hjellming (National Radio Astronomy Observatory) spoke on radio emission from X-ray stars, Dr W. Liller (Harvard University) discussed the optical characteristics of X-ray sources and Dr K. Davidson (Princeton University) considered some theoretical aspects of X-ray source models, particularly for binaries. Although Sco X-1 is the brightest X-ray star in the sky, observed in the optical and radio bands as well, and the first to be discovered, Dr Davidson concluded that it cannot be explained in terms of a simple binary model as used for other X-ray stars. Hercules X-1, the source which is most nearly understood, is clearly a member of a binary system. The optical companion for this X-ray source has been well studied and its variations traced back about eight years by examining old Harvard plates. Other point X-ray sources exhibit less well behaved variability but have significant radio counterparts. Variations in the radio and X-ray bands have been correlated for the black-hole candidate Cygnus X-1. On the other hand, it was pointed out that the most pronounced radio variability observed, that for Cygnus X-3, did not correspond to any comparable variations in the X-ray band.

## Gamma-ray Astrophysics

Important new results on the diffuse gamma-ray background as obtained by Apollo were presented by Drs L. Peterson (University of California, San Diego) and J. Trombka (NASA) and results obtained by SAS-II were presented by Dr D. Kniffen (NASA), who also reported observations of the galactic plane. The results from SAS-II confirm some important qualitative results first obtained by OSO-III that the Galaxy is an intense source of gamma radiation above 100 MeV and it stands out above the extragalactic background in this energy range. The spectrum is harder above 100 MeV than the gamma radiation seen at high galactic latitudes which is presumably extragalactic. The SAS-II results also indicate that the extragalactic (high galactic latitude) background spectrum is quite steep above 40 MeV.

Results from balloon observations by groups at the Max-Planck Institute and the US Naval Research Laboratory, reported by Dr G. Share (NRL), are consistent with the Apollo and SAS-II results which present a continuous observational spectrum from 300 keV up to 135 MeV. These data suggest a bulge in the gamma-ray spectrum above 1 MeV, in spite of background corrections which are of most importance below 4 MeV. This bulge has been interpreted as a new component of gamma radiation at energies above 1 MeV. This argument is even more important if the X-rays below 1 MeV are thermally produced and are falling off exponentially in energy above 100 keV as was suggested by Drs D. Schwartz (American Science and Engineering) and R. Cowsik (University of California, Berkeley). Problems with the thermal interpretation were discussed by Dr W. Kraushaar (University of Wisconsin).

The interpretation of the 1 MeV to 100 MeV bulge in the gamma-ray spectra was discussed by Dr F. Stecker (NASA), who concluded that the excess is most likely caused by matter/antimatter annihilation. The Apollo and SAS-II observational data present an excellent fit to the predicted annihilation spectrum up to 135 MeV. The matter/antimatter-symmetric cosmology was discussed by Drs R. Omnes (Laboratory of Theoretical and High Energy Physics, Orsay) and E. Schatzman and J. Puget (Paris Observatory, Meudon).

The exciting aspects of the matter/antimatter cosmology reported on by Drs Omnes, Schatzman, Puget and Stecker indicate that, in addition to implying baryon symmetry on a universal scale, it can explain such diverse phenomena as: the cosmic gamma-ray background spectrum; the ratio of photons to nucleons in the Universe of $\sim 10^9$; annihilation as the energy source for generation of large-scale turbulence leading to galaxy formation; and the consequent observed sizes, mean densities and rotational velocities of galaxies.

The galactic gamma-ray flux in the 100 MeV range seen by SAS-II and OSO-III indicates an increase in the direction of the galactic centre. The most likely implication is that there is a cosmic-ray gradient toward the galactic centre, as was pointed out in remarks by Professor A. Wolfendale (University of Durham) and in a communication by Dr V. Ginzburg (Lebedev Institute, Moscow).

Another interesting highlight of the meeting was the discussion of the 470 keV feature seen at the region of the galactic centre. Three interpretations of this feature were presented. Professor D. Clayton (Rice University), who discussed gamma-ray line emission, mentioned that it may be caused by lithium. Dr R. Ramaty (NASA) (who, with Dr D. Forrest (New Hampshire), discussed gamma rays from solar flares) suggested that this feature could be attributed to redshifted positron annihilation produced at the surface of neutron stars. (This has also been suggested by Guthrie and Tidemaru in *Nature Physical Science*, **241**, 77; 1973.) Dr M. Leventhal (Bell Laboratories) suggested that this feature may arise from a poorly resolved positronium annihilation spectrum.