OG 2.7-10

COSMIC GAMMA RAYS FROM QUASARS

M.M. Lau and E.C.M. Young
Department of Physics
University of Hong Kong

ABSTRACT

The diffuse gamma radiation consists of the galactic and extragalactic components. The latter component is of special interest on account of its cosmological significance. Following the method recently proposed to estimate the gamma-ray flux from galaxy clusters (1), and the detection of gamma rays from the quasars 3C273 (2), we have used the data base of the SAS II satellite to estimate the contribution from quasars to the extragalactic gamma-ray flux. It is shown that quasars as a whole are significant gamma-ray contributors, the average gamma-ray flux per quasar in the energy range 35-100 MeV being $(1.3 \pm 0.9) \times 10^{-5}\ cm^{-2}s^{-1}sr^{-1}$.

1. Introduction   It is well-known from observational data, particularly those from the SAS-II (3) and COS-B (4) satellites, that the diffuse γ-radiation consists of two components. One component is associated with our Galaxy and it correlates well with tracers of galactic interstellar matter, e.g. atomic and molecular hydrogen. This component thus gives information about the distribution of cosmic rays in the Galaxy and their interactions with interstellar matter and photon fields. The other component is apparently isotropic and thought to be of extragalactic origin. As γ-radiation has been detected from extragalactic objects such as clusters (5) and quasars (2), it is apparent that some or all of the extragalactic γ-ray flux must come from discrete sources and their relative contributions to the total flux are yet to be determined. This determination will undoubtedly have very significant cosmological implications.

It is thus important to separate the extragalactic component from the total γ-ray flux. Thompson et. al. (6), using galaxy counts as a galactic matter tracer and the γ-ray data from the SAS-II, have estimated the total extragalactic diffuse γ-ray intensity to be $(5.5 \pm 1.3) \times 10^{-5}$ and $(1.3 \pm 0.5) \times 10^{-5}$ photons $cm^{-2}s^{-1}sr^{-1}$ for energies above 35 MeV and 100 MeV respectively. Houston, Wolfendale and Young (1) have used a similar method to obtain the contribution to the extragalactic γ-ray flux from rich clusters and they concluded that this contribution from clusters could be quite important. This method may prove to be potentially very useful in estimating the average contribution to the diffuse γ-radiation from various extragalactic objects. In this paper, we present results on the contribution from quasars.

2. The Method   Although COS-B data were used in detecting discrete sources such as the Perseus cluster (5) and the quasar 3C273 (2) the rather high and uncertain background makes the search for fainter objects impractical. Recourse was therefore made to the earlier results from SAS-II which in spite of the poor statistical accuracy had the advantage

of rather low background.

For a sample of a certain class of extragalactic objects, the aggregate flux of γ-rays, I_γ, from the directions of these objects can be estimated from the SAS-II data. If the galactic component which has been shown to correlate well with galaxy counts (6) is identified, the extragalactic component can be obtained.

The galaxy-count data have been taken from the Lick survey (7) which gives comprehensive tables of numbers of galaxies brighter than $m = 19.0$ per square degree and which covers the range $15^o < \ell < 240^o$ and $|b| > 15^o$. The total gas column density (8) is then

$$N_{HT} = 2.0 \times 10^{21} \log_{10}\left(\frac{75}{Ng}\right)$$

where Ng is the mean galaxy count per square degree.

A I_γ - N_{HT} plot should therefore allow the extragalactic component to be estimated.

3. Results The recent catalogue containing 1549 quasars given by Hewitt et. al. (9) was used to search for γ-ray flux. After excluding those quasars which lie outside the common coverage of the SAS-II and the Lick survey, a I_γ-N_{HT} plot of the sample has given a straight line which is not significantly different from the mean background derived using the range of ℓ and b of common coverage, except $|b| < 9.6^o$. This result seems to indicate that bearing in mind the present statistical limitation, quasars as a class are either not significant γ-ray contributors or on account of their vast distances from us, do not give a detectable γ-ray excess above the mean background with the present data.

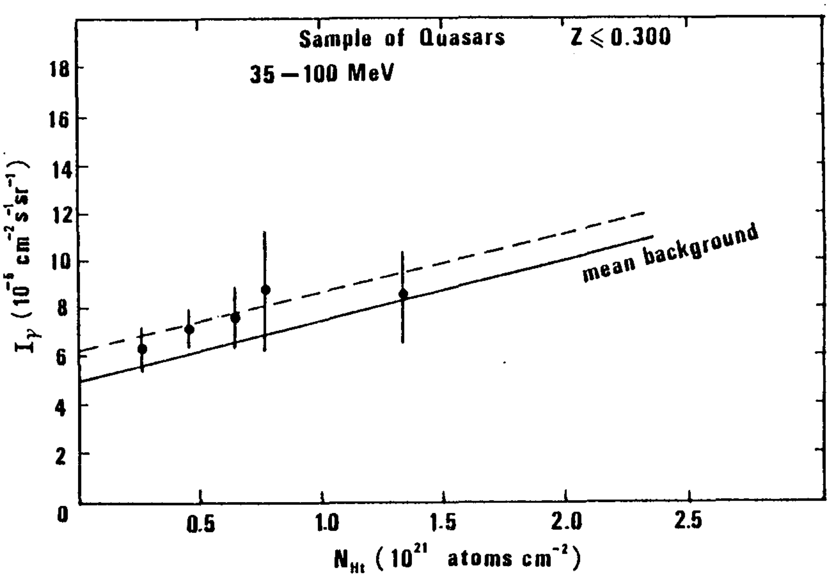

Fig.1 γ-ray intensity vs total gas column density (as derived from galaxy counts)

To resolve this question we further investigated special samples of quasars, viz. X-ray quasars, bright quasars and quasars with small redshifts ($z < 0.300$). The Hewitt et al. catalogue lists 36 X-ray quasars with 25 falling within the common coverage of the SAS-II and Lick survey. The Bright Quaser Survey (BQS) (10) consisting of 114 objects and the Burbidge catalogue (11) with 67 bright quasars gave a total of 91 bright quasars within the common coverage. Both samples have given I_γ - N_{HT} plots which are statistically not different from the mean background.

Quasars with small redshifts ($z < 0.300$) were then investigated. The catalogue gives a sample of 166 such quasers with 82 usable for the present analysis. The result is shown in Figure 1 for the energy range 35-100 MeV. There is clearly a contribution to the γ-ray flux from these quasars. The upper parallel line is the best fit to the quasar intensities and the lower line is the mean background derived as mentioned above. The difference between the two lines is then attributed to the contribution from quasars.

The average γ-ray intensity from quasars is found to be

$$I_Q(35\text{-}100\ \text{MeV}) = (1.3\pm0.9) \times 10^{-5}\ \text{cm}^{-2}\text{s}^{-1}\text{sr}^{-1}$$

For the energy range > 100 MeV only an upper limit (= $1.3 \times 10^{-5}\text{cm}^{-2}\text{s}^{-1}$ sr^{-1}) can be set in view of the very poor statistics. This result could imply that the average energy spectrum of quasars may steepen at energies around 100 MeV.

4. Discussion We have shown that there is indication that quasars as a whole might be significant contributors to the extragalactic γ-ray background. It also appears that quasars as γ-ray sources are mainly determined by their distances from us and are not related to their optical properties. The maximum redshift in our current sample corresponds to a distance ∿760 Mpc. From the distribution of redshifts in the sample the average luminosity is found to be

$$L_Q(35\text{-}100\ \text{MeV}) = (2.5\pm1.4) \times 10^{48}\ \text{ph.s}^{-1}$$

The total contribution of quasars to the extragalactic γ-ray flux in a non-evolving universe can be determined from the mean luminosity and the density of quasars. The spatial distribution of quasars is found to be non-uniform (12) and in the case of the local region, the non-uniformity appears to be more significant (13). The space density of quasars can be calculated from their redshifts and luminosity function. However, in view of the very low fluxes involved and the poor angular resolution of the detectors, we have assumed a uniform space density and arrived at a value of $0.21 \times 10^{-6}\ \text{Mpc}^{-3}$ in the small redshift range. Assuming no evolutionary effects, the universal flux due to quasars is then found to be $(3.5\pm1.9) \times 10^{-4}\ \text{cm}^{-2}\text{s}^{-1}$ in the 35-100 MeV energy range.

References

1. B.P. Houston, A.W. Wolfendale and E.C.M. Young (1984) J. Phys. G: Nucl. Phys. 10, L147.

2. G.F. Bignami et al. (1981) Astron. Astrophys. 93, 71.

3. C.E. Fichtel et al. (1978) NASA Tech. Memo. 79650

4. H.A. Mayer-Hasselwander et al. (1982) Astron.Astrophys. 105, 164.

5. A.W. Strong et al. (1983) Ap. J. 274, 549.

6. D.J. Thompson et al. (1982) Astron. Astrophys. 109, 352.

7. C.D. Shane et al. (1967) Publ. Lick. Obs. 22,

8. A.W. Strong et al. (1981) Phil. Trans. R. Soc. Lond. A301, 541.

9. A. Hewitt et al (1980) Ap. J. Suppl. Ser. 43, 57.

10. M. Schmidt et al. (1983) Ap. J. 269, 352.

11. G. Burbidge et al. (1979) Ap. J. Suppl. 40, No.3, 583.

12. M. Schmidt (1968) Ap. J. 151, 393.

13. Z. Junliang et al. (1983) Acta Astrophys. Sinica, 3, No.1, 1; A Halton (1984) Ap.J. 277, L27.