8. A SEARCH FOR HIGH-ENERGY γ-RAYS FROM QUASI-STELLAR AND OTHER SOURCES

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(Presented at the meeting by J. V. Jelley)

The Čerenkov technique (1, 2) for studying extensive cosmic-ray showers produced in the atmosphere by high-energy primary cosmic radiation, has been used to set upper limits to the flux of γ-rays from three of the known quasi-stellar objects, from the Crab Nebula, and from one magnetic variable star.

Without discussing the technique in detail, it should be mentioned that the characteristics of Čerenkov radiation from large showers are such that with the existing light-collecting equipment of physical area $\sim 10^4$ cm^2, it is possible to detect showers over an effective area of $\sim 10^9$ cm^2 with an angular resolution on the celestial sphere of $\sim 2°$. The observations were carried out by University College, Dublin, at an exceptionally dark site in the Wicklow mountains, with equipment developed at A.E.R.E., Harwell. With this apparatus, at this site, it was possible to detect showers produced by the normal charged-particle primary radiation, at a rate of $\sim$ 100 min^{-1} at the zenith, which corresponds to a primary energy threshold of $E_0 = 5 \cdot 10^{12}$ eV. In this energy region the technique has no rival for searches for γ-rays from selected possible 'point sources', such γ-rays also producing showers of a similar nature. There are, however, severe technical and operational limitations to its extension to lower energies; it would seem nevertheless that it might be possible to lower the energy threshold by about one order of magnitude.

The results of the observations, which have already been announced elsewhere (3), are shown in the table below.

Source	*Type*	*Total counts on the source*	*Total counts off the source*	*a*	*b*	*c*	*d*	*e*	*f*	*g*
Crab Nebula	Supernova	1985	2009	22	8	12	2	1×10^{-10}	—	5×10^{35}
3C 147	Q.S.R.S.	6554	6325	28	20	8	0	1×10^{-10}	0·04	5×10^{47}
3C 196	Q.S.R.S.	2372	2368	8	3	5	0	5×10^{-11}	0·95	3×10^{47}
3C 273	Q.S.R.S.	648	646	7	5	2	0	3×10^{-10}	0·95	3×10^{47}
53 Cam	Mag. Var.	306	289	2	1	1	0	5×10^{-10}	0·49	—
All sources		11865	11637	67	37	28	2	—	—	—
All except 3C 147		5311	5312	39	17	20	2	—	—	—

(*a*) The total number of comparisons carried out on each source.
(*b*) The number of runs which gave a positive effect.
(*c*) The number of runs which gave a negative effect.
(*d*) The number of runs which gave equal counts on and off.
(*e*) The upper limit flux of γ-rays in quanta/cm^2 sec, at the Earth, which is compatible, at the 0·5 per cent level, with the observed figures.
(*f*) The probability based on a χ^2 test that the observed figures are compatible with zero flux of γ-rays.
(*g*) The upper limit to the energy flux at the source, in ergs/sec, for γ-rays of energy greater than 5×10^{12} eV, assuming a power law spectrum with integral exponent $-1{\cdot}5$.

These results are compatible with a zero flux of γ-rays from the five objects investigated, although the effect from 3C 147 is approaching statistical significance, especially when we consider that a positive effect appeared on 20 out of 28 runs.

At present there is, however, some concern with 3C 147 about possible effects of atmospheric scintillations in stray light from the bright star α Aur, although this lies 2·5° outside the geometrical field of view of the equipment. Possible effects of changes in sensitivity of the equipment with changes in its orientation in the Earth's magnetic field are also being considered, though preliminary tests indicate these effects are negligible. The work will be continued this coming winter.

We appreciate that the estimated fluxes at the sources, for the three quasi-stellar objects, column g, are about one order of magnitude higher than the optical and radio fluxes from these sources (4), and that it would be unlikely for the bulk of the emission to appear in the form of such high-energies.

It has recently been pointed out (5) that photon-photon pair production may be a significant absorption mechanism, by which high-energy γ-rays from remote extra-galactic objects may be lost by collisions with intergalactic optical photons. G. R. Burbidge (private discussion) has however pointed out to me that the intergalactic photon flux assumed by Nikishov is too high, at 0·1 eV cm^{-3}, probably by two orders of magnitude.

Nevertheless I would like to suggest tentatively that such γ-rays, if not absorbed in intergalactic space, may be absorbed near their source of origin, where high optical photon (or possibly X-ray) fluxes may exist, at levels high enough to compensate for the much smaller interaction lengths.

The apparent absence of γ-rays from the Crab Nebula is consistent with earlier observations by Chudakov (6) using the same technique.

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9. CONCLUSION

G. C. McVittie

DISCUSSION

R. Minkowski. I would like to emphasize that it would be very difficult, because of the large difference in luminosities (about 5 magnitudes) to detect the galaxy around a quasi-stellar radio source.

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