Downloaded from rsta.royalsocietypublishing.org

Comparison of the Distributions of Galactic γ -Radiation and Radio Synchrotron Radiation [and Discussion]

C. G. T. Haslam, S. Kearsey, J. L. Osborne, S. Phillipps, H. Stoffel and A. W. Wolfendale

Phil. Trans. R. Soc. Lond. A 1981 **301**, 573-575
doi: 10.1098/rsta.1981.0135

Email alerting service Receive free email alerts when new articles cite this article - sign up in the box at the top right-hand corner of the article or click **here**

To subscribe to *Phil. Trans. R. Soc. Lond. A* go to: **http://rsta.royalsocietypublishing.org/subscriptions**

This journal is © 1981 The Royal Society

Downloaded from rsta.royalsocietypublishing.org

Phil. Trans. R. Soc. Lond. A **301**, 573–575 (1981)
Printed in Great Britain

Comparison of the distributions of galactic γ-radiation and radio synchrotron radiation

By C. G. T. Haslam†, S. Kearsey‡, J. L. Osborne‡,
S. Phillipps‡ and H. Stoffel†
† *Max-Planck-Institute for Radioastronomy, Auf dem Hügel* 69, *Bonn, F.R.G.*
‡ *Department of Physics, University of Durham, South Road, Durham DH*1 3*LE, U.K.*

We have used the new all-sky survey of continuum radio emission at 408 MHz of Haslam *et al.* (1981*a*, *b*) to compare the distribution of radio emission in a band along the galactic equator for $|b| < 20°$ with the COS-B γ-ray distribution of Mayer-Hasselwander *et al.* (1980). The radio survey has resolution with full width half-maximum (f.w.h.m.) of 51 arc min and the data are brightness temperatures at 20′ intervals in galactic coordinates. Such comparisons have been made before (see, for example, Jäkel *et al.* 1975; Paul *et al.* 1976; Higdon 1979) with earlier γ-ray data but this is the first in which the radio data have been in a form allowing a detailed comparison after convolution with the point spread function of the γ-ray detector.

At 408 MHz the radio continuum is predominantly synchrotron emission from electrons of a few gigaelectronvolts in the galactic magnetic field and is proportional to the product of the electron density and approximately the square of the field, B^2. Extended thermal emission contributes no more than a small percentage to the intensity at $b = 0°$ after convolution because its scale height is so much smaller than that of the synchrotron emission. Similarly, the discrete-source (HII region and supernova remnant) contribution to the convolved radio emission is very small with the exception of a few sources noted below. As mentioned in preceding papers at this meeting, the contribution of unresolved discrete sources to the γ-ray distribution is less certain, and the present comparison may give some constraints. In the interstellar medium, γ-rays of the order of 100 MeV energy are produced by bremsstrahlung of cosmic ray electrons of several hundred megaelectronvolts and from the decays of π^0-mesons from the interactions of cosmic ray nuclei of a few gigaelectronvolts on the gas. For a constant proton-to-electron ratio the γ-ray emissivity is then proportional to the product of the cosmic-ray and total gas densities. Our comparison therefore gives information on the relative distributions of B^2 and gas density. These may, of course, be dynamically related.

By taking into account the energy dependence of the half-power beam-width (h.p.b.w.) of the COS-B detector and by weighting according to the relative numbers of γ-rays of a given energy, a composite point spread function was obtained, having a f.w.h.m. of 3°, but a longer tail than a Gaussian, for the combined data from 70 MeV–5 GeV. This has been used to convolve the 408 MHz data, and to produce a contour map and the cuts and averages corresponding to those given by Mayer-Hassaelwander *et al.* (1980). Because of space limitations we give here only the average intensities along the galactic plane for $|b| < 5°$ (figure 1). Longitude and latitude cuts are given by Haslam *et al.* (1981*c*).

In figure 1 the γ-ray intensities are those after subtraction of instrumental and isotropic backgrounds, while the radio brightness temperatures have a 6 K extragalactic contribution removed. The normalization is arbitrary at 100 K $\equiv 1.25 \times 10^{-2}$ 'on-axis' count $s^{-1}\,sr^{-1}$. This

The Royal Society is collaborating with JSTOR to digitize, preserve, and extend access to
Philosophical Transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences.
www.jstor.org

Downloaded from rsta.royalsocietypublishing.org

makes the longitudinal cuts of the contour maps generally coincide to within 35° of the galactic centre. Some features in the longitude profiles can be discounted. There is no appreciable γ-ray emission corresponding to the Sag A complex at the galactic centre or the Cas A supernova remnant at $l = 112°$. The γ-peak at $l = 263.5°$ is from the Vela pulsar while the radio peak is from the supernova remnant. The agreement of the profiles in the Cyg X region ($l \approx 80°$) is partly fortuitous as the radio emission here is, exceptionally, largely thermal.

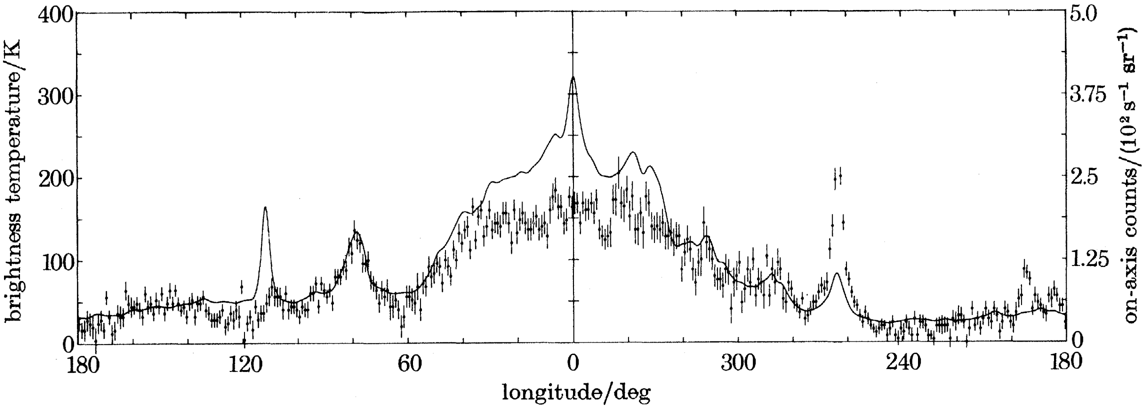

FIGURE 1. The variation with galactic longitude of the intensities of 70 MeV–5 GeV γ-rays, and the convolved 408 MHz radio emission averaged over $|b| < 5°$. Line and left-hand scale: radio. Points (with errors) and right-hand scale: average γ-ray intensities in 1° longitude bins.

Comparison of the latitude profiles shows that the synchrotron emission is much broader in extent than the γ-radiation for all longitudes except $145° < l < 175°$. In the inner parts of the Galaxy the true width of the γ-emission is not resolved, as would be expected for production in the interstellar gas. The differing latitude distributions partly account for the relative deficit of γ-rays along the inner half of the galactic plane in figure 1. There are similarities in the longitude profiles. The steps at 285°, 310°, and 330°, evidence of spiral structure, are reproduced in both while there are no steps in either between 40° and 60°. Both have broad minima around 240°.

The latitude profiles show that in three dimensions the γ-ray and synchrotron emissivities are not proportional, but the question arises whether there is overall proportionality in the galactic plane. We have derived (Phillipps *et al.* 1981) the distribution of synchrotron emissivity in the plane from the full resolution profile by an unfolding technique. A regular component of the galactic magnetic field, following the direction of galactic rotation, of about the same strength as the irregular component, is required. The γ-ray profile predicted, by assuming that the emissivity in the plane mirrors the synchrotron emissivity but that its scale height is that of the gas, gives a reasonable fit overall to that observed. The relative enhancement of the synchrotron profile within 35° of the galactic centre would be due to the regular component of the field being viewed perpendicularly, as the line of sight approaches $l = 0°$. The two emissivities can therefore be in approximately constant ratio although there does seem to be more structure in the γ-ray emission even after statistical fluctuations are taken into account. The implication is that B^2 is proportional to gas density but only on some suitably large scale, and in the plane of the Galaxy. If, on the other hand, the emission were dominated by discrete sources their number density would have to follow closely the product of cosmic ray density and B^2.

Downloaded from rsta.royalsocietypublishing.org

REFERENCES (Haslam *et al.*)

Jäkel, C. E., Nissen, P., Schlickeiser, R. & Thielheim, K. O. 1975 *Proc. 14th Int. C.R. Conf., Munich*, vol. 12, p. 417.

Haslam, C. G. T., Klein, U., Salter, C. J., Stoffel, H., Wilson, W. E., Cleary, M. N., Cooke, D. J. & Thomasson, P. 1981*a* *Astron. Astrophys.* (In the press.)

Haslam, C. G. T., Salter, C. J., Stoffel, H. & Wilson, W. E. 1981*b* *Astron. Astrophys. Suppl.* (In the press.)

Haslam, C. G. T., Kearsey, S., Osborne, J. L., Phillipps, S. & Stoffel, H. 1981*c* *Nature, Lond.* **289**, 470.

Higdon, J. C. 1979 *Astrophys. J.* **232**, 113.

Mayer-Hasselwander, H. A., Bennett, K., Bignami, G. F., Buccheri, R., D'Amico, N., Hermsen, W., Kanbach, G., Lebrun, F., Lichti, G. G., Masnou, J. L., Paul, J. A., Pinkau, K., Scarsi, L., Swanenburg, B. N. & Wills, R. D. 1980 *Ann. N.Y. Acad. Sci.* **336**, 211.

Paul, J., Cassé, M. & Cesarsky, C. J. 1976 *Astrophys. J.* **207**, 62.

Phillipps, S., Kearsey, S., Osborne, J. L., Haslam, C. G. T. & Stoffel, H. 1981 *Astron. Astrophys.* (In the press.)

Discussion

A. W. WOLFENDALE, F.R.S. (*Physics Department, The University, Science Laboratories, South Road, Durham DH*1 3*LE, U.K.*). Are the relative strengths of the smooth and random components of the interstellar magnetic field known with any accuracy? Has the relative strength much effect on your results?

J. L. OSBORNE. Of the various methods by which the ratio of random to regular field strengths, R, can be estimated, that giving the best qualitative value uses the pulsar rotation measures. Manchester & Taylor (1977), using a subset of the 62 rotation measures available, deduced a longitudinal field of 0.17 ± 0.03 nT and $R \approx 1$. Thomson & Nelson (1980) analysed the same data in terms of a model field with more free parameters and obtained 0.35 ± 0.03 nT and $1 < R < 4$. These results refer to the local region, within 3 kpc. Phillipps *et al.* (1981, see reference above) show that $R \gtrsim 1$ is preferred for the Galaxy as a whole in order best to account for the distribution of synchrotron emission along the galactic plane. The explanation of the differing forms of the γ-ray and synchrotron profiles in terms of a geometrical effect requires $R \lesssim 2$.

References

Manchester, R. N. & Taylor, J. H. 1977 *Pulsars*. San Francisco: W. H. Freeman & Co.

Thomson, R. C. & Nelson, A. H. 1980 *Mon. Not. R. astr. Soc.* **191**, 863.