matters arising

Association of young supernova remnants with γ-ray sources

MY original argument[1] that there are statistically unlikely coincidences of compact supernova remnants (SNRs) with the COS-B γ-ray sources[2] has been weakened by the recent discovery[3] that one of the remnants classed as compact is not. The argument was based on the frequency of SNR 'hits' with the COS-B error boxes. A more rigorous study of the overlap between these two distributions can be carried out by calculating for each SNR the chi-squared value

$$\chi^2 \equiv (\Delta l/\sigma_l)^2 + (\Delta b/\sigma_b)^2$$

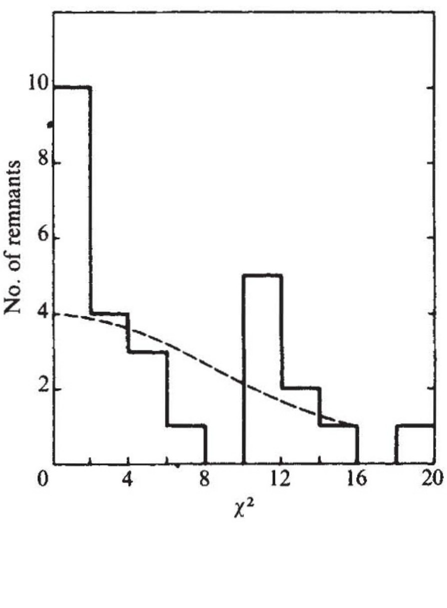
where Δl and Δb are the differences in galactic longitude and latitude to the nearest γ-ray source and σ_l and σ_b are the respective standard deviations in the γ-ray source position. If σ_l and σ_b are equal to one another then χ^2 is the angular distance squared to the centre of the nearest γ-ray error box in units of the one-dimensional variance.

I have calculated χ^2 for each of the 51 SNR from the list of Ilovaisky and Lequeux[4] which lie in the four regions surveyed in the COS-B observations. It is assumed that the errors quoted by the COS-B group are single standard deviations. (Application of the χ^2 formula to the two sources whose positions are known precisely, the Vela and Crab pulsars, gives χ^2 values of 0.56 and 2.1, which are reasonable for a χ^2 with two degrees of freedom. If, however, the error boxes are interpreted as being at the 90% confidence level, then these χ^2 values would increase by a factor of ~4, indicating that the Crab position had an improbably large error associated with it.) With this assumption regarding the errors the probability that a source is actually found inside its own error box, 1σ on a side, is only 46%, and therefore the original analysis in terms of a hit or a miss of the error box is too restrictive.

The distribution of χ^2 for the 27 SNR with χ^2 values less than 20 is shown in Fig. 1. The dashed curve is the prediction of a Monte Carlo simulation assuming randomly distributed SNR. [The parameters of the distributions used in the Monte Carlo calculation were derived from an analysis of the 51 SNR. The latitude distribution was assumed to be gaussian with widths (σ) of 0.9° and 2.3° for the regions towards and away from the galactic centre respectively. The longitude distribution was assumed uniform with a width of 40° except for the region near Cygnus in which the width was restricted to 69° to 94° to simulate the observed SNR clustering in this region.] The Monte Carlo calculation predicts 15.4 SNR with χ^2 values in the range of 4 to 20 in good agreement with the 13 observed to fall in this range. However, in the range from 0 to 2 the Monte Carlo calculation predicts slightly less than 4, whereas 10 are observed. The probability of a fluctuation of 10 or greater when the expected number is 4, is less than 1% on the basis of Poisson statistics. Therefore, the distribution suggests a statistically significant association of some (perhaps 6) of the remnants with some of the COS-B sources.

The 10 remnants (numbered according to the list of Ilovaisky and Lequeux) and their possible COS-B counterparts are: 40 with CG75+0, 42 with CG78+1, 65 with CG189+1, 87 with CG312−1, 93, 95, and 96 with CG327−0, and 99, 100, and 101 with CG333+0. The average diameter of these 10 remnants is 19.9±2.0 pc whereas the remaining 41 have an average diameter of 30.3±2.5 pc so that there seems to be a significantly smaller diameter associated with those remnants which are near enough to γ-ray sources that there may be an identification. The age of a 'typical' SNR remnant as calculated from the Sedov relation quoted in my original paper for a diameter of 19.9 pc is 5,200 yr. Therefore, the suggestion advanced in the original analysis that there was an association of youthful SNR with some of the COS-B sources seems to be borne out in this more detailed analysis.

Fig. 1 The distribution of SNR relative to the COS-B γ-ray sources. χ^2 is the sum of the squares of the latitude and longitude deviations of a SNR relative to the nearest γ-ray source. The dashed line gives the prediction of a Monte Carlo simulation assuming randomly distributed SNR. The excess of remnants in the first bin has a probability of less than 1% by chance.



Of course this does not definitively prove anything, as we could be seeing statistical fluctuations, albeit improbable ones. The eventual decision on these possible associations must await future high resolution radio, X-ray, and γ-ray observations.

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Were Archaean continental geothermal gradients much steeper than today?

BURKE AND KIDD[1] have suggested that the scarcity of 'minimum-melting' granites in the Archaean Superior Province of Canada shows that temperatures at the base of the Archaean sialic crust (35 km depth) did not generally exceed 800 °C. From this they deduce a surface geothermal gradient of less than 23 °C km^{-1} compared with 17 °C km^{-1} in such regions today. Although their suggestion for Archaean temperatures at 35 km depth is confirmed by *P–T* determinations on Archaean granulites (summarised in ref. 2) their calculation of the geothermal gradient does not comply with conductive properties and distribution of heat producing elements within the Earth. Their calculation merely divides 800 °C by 35 km, assuming constant thermal conductivity, total absence of heat producing elements in the crust and constant geothermal gradient in the crust[3]. Such an extrapolation bears no relationship to a natural steady state geotherm and cannot be used

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