A STATISTICAL STUDY OF THE CORRELATION OF GALACTIC SUPERNOVA REMNANTS AND SPIRAL ARMS

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Abstract: A statistical study of the correlation of Galactic supernova remnants with spiral arms and the disk is presented. SNR apparently have a larger radial scale length than disk stars. We estimate that only about 10 percent of the Galactic SNR have been detected.

1. Introduction

Based on statistical studies of external galaxies, our Galaxy is expected to produce Type I and Type II supernovae in closely equal number. There are as of this writing 162 known galactic SNRs. The basis for our investigation is the observation that SN II (and SN Ib) are tightly correlated with spiral galaxies. SN I (strictly speaking SN Ia) do not correlate with spiral arms, but are roughly of old disk population. We seek a method by which we can determine a correlation of SNR with spiral arms. For this preliminary exercise we use only information on the position of the SNR in Galactic coordinates, rather than uncertain distance estimates. As a test case, we compared the angular distribution of SNR and giant H II regions which are presumed to define the location of the spiral arms. To the eye there did seem to be a correlation.

2. Data base

The work of Milne and Downes and Clark and Caswell resulted in a catalogue of 125 SNR (Milne 1979). Van den Bergh (1983) presented a catalogue of 135 SNR in the Galaxy. Green (1984) gives a list of 145 SNRs. We have added some new SNRs, so the total number of SNRs is augmented to 153. In order to compare the distribution of giant H II regions and SNR, we used the catalogue of Georgelin and Georgelin (1976) and the list of H II regions in Blitz et al. (1982).

3. Monte Carlo simulation model

We have developed a quantitative approach to investigate the questions of the correlation of SNR with arm or disk populations. We use the observed angular distribution of SNR and giant H II regions to form a cumulative distribution with respect to galactic longitude. Two observed distributions can be compared and Kolmogorov-Smirnov statistics used to determine the probability that the two samples are not drawn from the same distribution. In addition, we have constructed Monte Carlo models in which sample objects are distributed in the spiral arms and galactic disk in a prescribed fashion. The correlation of these models with observed distributions can be used in conjunction with K-S statistics in an affirmative fashion to establish a figure of merit for the goodness of fit. The parameters of the Monte Carlo models, such as the opening angle of the spiral arms and the fraction of objects in the disk versus arm population can be varied to obtain the best fit to the observed distribution. We also study the effect of

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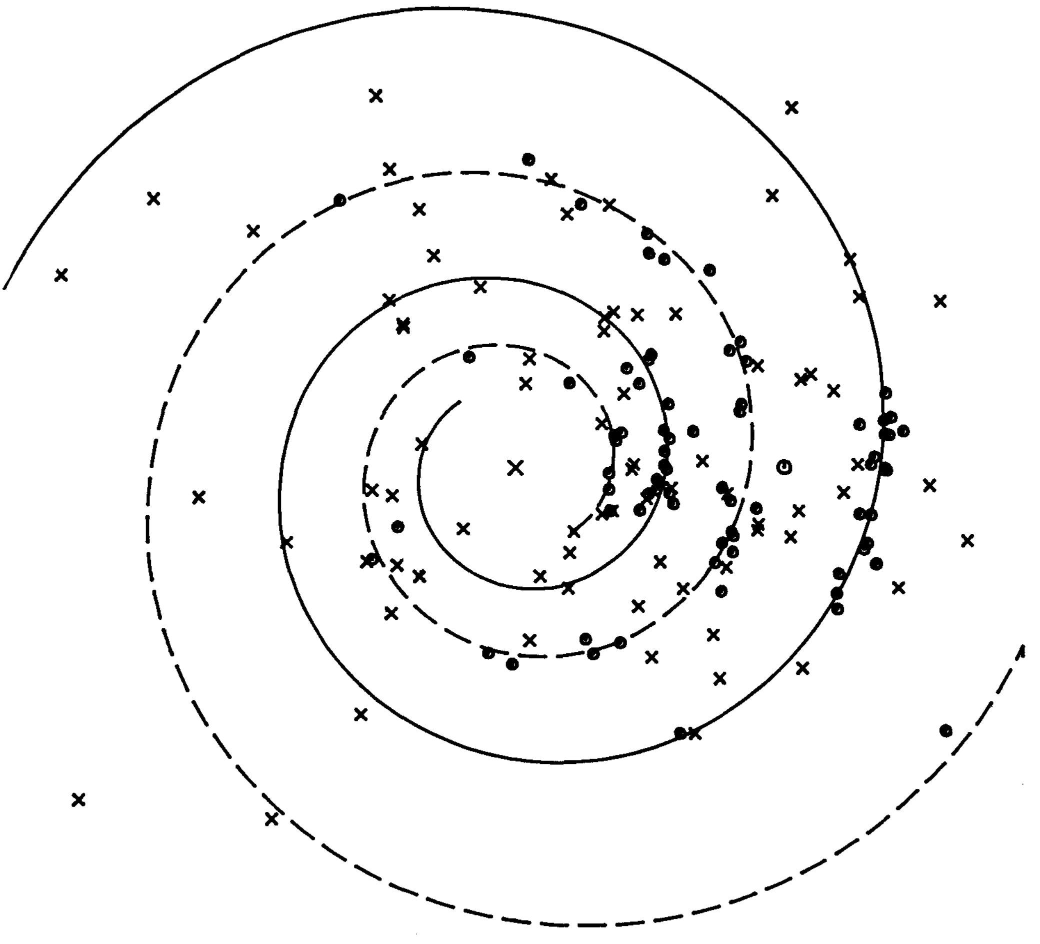

Figure 1 - The radial distribution is given for a Monte Carlo model containing 152 sample SNR with SH = 7.0 kpc, SE = 5.0 kpc, D_O = 3.0 kpc and i = -8°. Half the points are in the exponential disk, half distributed along the assumed two-armed logarithmic spiral. The cumulative angle distribution of such a model distribution gives a reasonable representation of that corresponding to the observed SNR.

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selection effects, if the surface brightness of SNR falls below a threshold for detectability (as $1/r^2$). We calculated the following distributions:

(a) The distribution of SN in an exponential galactic disk with coordinates given by the radial distance from the galactic center, R, and the angle with respect to the line of centers to the Sun, θ. A selection effect function was used to bias against distant supernovae.

(b) For the distribution of SNR along the spiral arms, we first assumed that the SNR were uniformly distributed per unit length along the spiral arms, then calculated the corresponding R and θ. We also required a decrease in probability density along the arms according to the exponential law used for the disk population. We also spread the points in a Gaussian distribution laterally to the arms so that they were not infinitesimally thin. A selection effect function was added in the same fashion as for the disk models.

In order to reduce numerical fluctuations each Monte Carlo model is run to produce 500 sample points. Each such model is then run 20 times and the results are averaged to produce the angular distribution to be compared with the observational data.

4. Kolmogorov-Smirnov Two-Sample Test of SNR, Giant H II regions, and Monte Carlo models

The Kolmogorov-Smirnov two-sample test (K-S Test) is a test of whether two independent samples have been drawn from the same population. The two-tailed test is sensitive to any kind of difference in distributions from which the two samples were drawn.

Table 1 gives the probability that the sample of 150 SNR is similar to the Monte Carlo models. The parameters are as follows: SH = 7.0 is the radial scale length in the disk, SE = 5.0 is the scale length of the $1/r^2$ selection effect, D_O = 3.0 is the radius of the selection free circle around the solar neighborhood, f is the fraction of the SNR in the spiral arms, and i is the opening angle of the model two-armed spiral. The probability of positive correlation is maximum for i ~ -8°, characteristic of spiral arms, and for f ~ 0.5, as expected. Figure 1 shows a representative radial distribution for a Monte Carlo model

Table 1
150 SNR vs. Models

SH = 7.0 SE = 5.0 D_O = 3.0

f	i=-8.9	-8.45	-8.2	-8.0	-7.8	-7.6	-7.4
0.0	0.64	0.64	0.64	0.64	0.64	0.64	0.64
0.1	0.69	0.73	0.73	0.73	0.73	0.69	0.65
0.2	0.73	0.76	0.76	0.78	0.75	0.73	0.69
0.3	0.78	0.86	0.86	0.85	0.84	0.75	0.70
0.4	0.76	0.84	0.86	0.90	0.87	0.80	0.73
0.5	0.69	0.78	0.84	0.90	0.89	0.82	0.70
0.6	0.55	0.69	0.75	0.84	0.91	0.76	0.73
0.7	0.45	0.60	0.69	0.80	0.82	0.65	0.62
0.8	0.38	0.54	0.61	0.74	0.73	0.49	0.46
0.9	0.30	0.47	0.59	0.70	0.63	0.40	0.35
1.0	0.24	0.45	0.49	0.65	0.50	0.29	0.25

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with these parameters.

The K-S test shows that the observed samples of SNR and giant H II regions are not, in fact, highly correlated. The H II regions do seem to have a radial scale length ~ 3.5 kpc in the solar neighborhood. For the SNR, however, the probability of positive correlation decreases significantly for a radial scale length of 3.5 kpc, typical of the stellar disk. This suggests that the SNR in the sample are not distributed radially with the same scale length as the stellar disk and that SNR are not concentrated in an inner ring. More effort is underway to examine the impact of selection effects on this tentative conclusion. The Monte Carlo models that reproduce the observed distribution moderately well suggest that the Galaxy contains $\gtrsim$ 1200 SNR, and that only ~ 10 percent have thus been detected.

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