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On the Luminosity Function of Galactic X-ray Sources

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Summary. The spatial and intensity distributions of X-ray sources in the UHURU catalogue are discussed, and luminosity functions are derived for $L > 10^{35}$ erg s^{-1} for the galactic disk and for the central region.

The fraction of the galactic X-ray background in the range 2–6 keV attributable to unresolved sources with the derived luminosity functions is found to be about 50%. In turn the limit imposed by the background on the density of X-ray sources with $L < 10^{35}$ erg s^{-1} is such that at most 10% of the UHURU sources with isotropic latitude distribution could belong to the Galaxy.

Considering the derived luminosity functions in relation to the three main groups of sources which can be distinguished in the sample covered by the survey of the UCRL group it is concluded that the disk sources belong to two main classes and the central sources to a third distinct class, distinguished by different properties of variability, temperature and luminosity.

Key words: X-ray sources – Galactic X-ray background

I. Introduction

Analysis of the UHURU catalogue of X-ray sources (Giacconi *et al.*, 1972) have shown that about half of the X-ray sources observed in the energy range from 2 keV to 6 keV can be located in our Galaxy, and that of these galactic sources there is a puzzling preponderance of the brightest sources in the longitudinal direction ±30° to the Galacitc Centre.

Although in early papers this effect has been attributed to the presence of the Sagittarius arm in this longitude sector (Gursky *et al.*, 1967; Fujimoto *et al.*, 1969; Oda and Matanoka, 1971), more recently it has been pointed out that there is probably a real clustering of sources around the Galactic Centre. This picture is derived both from the source counts (Salpeter, 1972; Gursky, 1972; Matilsky *et al.*, 1972) and from the lower limit imposed by the galactic X-ray background on the mean distance of the sources (Ryter, 1970; Setti and Woltjer, 1970).

Further evidence concerning this problem is discussed here. An analysis is made of the spatial and intensity distributions of the galactic sources, in order to derive luminosity functions for the central region and elsewhere. The fraction of the galactic background attributable to unresolved sources with this luminosity function is estimated. The limit imposed by the background on the density of X-ray sources of lower luminosity is considered.

The derived luminosity functions associated with different spatial distributions in the Galaxy are discussed in relation with the three main groups of sources which can be distinguished in the sample covered by the survey of Seward *et al.*, (1972), for which spectral measurements are available.

II. Criteria for Galactic Sources: *b* vs. *I* Distribution

In order to select galactic sources without a priori assumptions on the luminosity[1], it is useful to inspect the distribution of the sources in a diagram of galactic latitude b versus intensity I[2]. The analysis of Matilsky *et al.*, (1972) shows that the majority of galactic sources lie at $|b| < 20°$, and that most of the sources with $|b| > 20°$ are extragalactic. Applying this criterion of separation they estimate that the maximum contribution of extragalactic objects at low latitude is about 25%. In Fig. 1 is shown the distribution of b versus I for all sources with $|b| < 20°$. Should all galactic sources have a single luminosity, the higher intensity sources, being those nearest the Sun, should be observed with a wider latitude dispersion. There is no evidence for such a correlation between intensity and spread in latitude and one may deduce that there exists a spread in luminosity whose distribution, if approximated to a power law,

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[1] Here understood as the luminosity in the UHURU sensitivity range i.e. 2–6 keV. The integrated luminosity assuming a thermal bremsstrahlung spectrum as used by Seward *et al* (1972) will be called "total luminosity".

[2] For sources which show strong variability the maximum intensity has been used. This is correct for eclipsing binaries but not necessarily so for pulsed or flaring sources. Throughout the intensity is expressed in counts s^{-1} as measured by the UHURU instrument. This can be approximately converted to apparent luminosity in erg cm^{-2} s^{-1} in the 2–6 keV range multiplying by a factor of 1.7×10^{-11}. (Giacconi *et al.*, 1972).

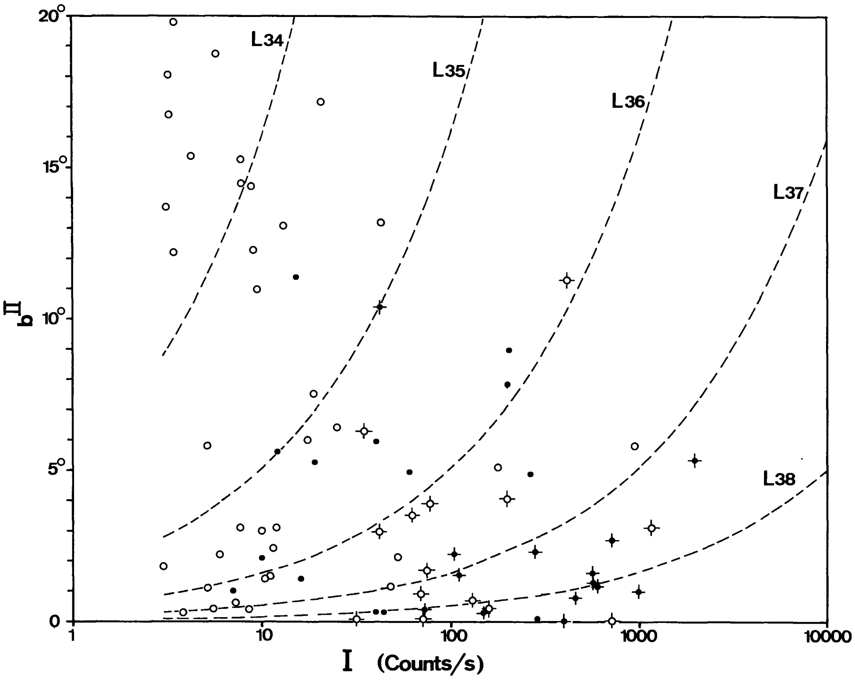

Fig. 1. Galactic latitude intensity plot for X-ray sources in the UHURU catalogue with $|b^{\mathrm{II}}| < 20°$. Full circles represent sources with galactic longitude $330° < l^{\mathrm{II}} < 30°$, empty circles represent sources outside this longitude interval. Crosses indicate sources for which variability has been observed. The curves represent the maximum latitude of sources of given luminosity L, distributed in a disk of half thickness $z = 200$ pc (L_n means $L = 10^n$ erg s^{-1})

$\frac{dN}{dL} = KL^{-\alpha}$, has $\alpha < 2$, for $L > 10^{35}$ erg s^{-1}. In choosing this analytic form for the luminosity function which will be used hereinafter we have been guided by the following considerations. Luminosity functions are often well represented by power laws (normal stars, galaxies in clusters), the observed intensity distribution (see Section IV) are well approximated by power laws and the power law is only a two parameter curve. In any case no great significance should be attributed to this analytic expression except that it gives the total number of galactic sources at various luminosities compatible with the UHURU catalogue.

The curves in the diagram corresponding to various luminosities, give the latitudes below which must fall all points corresponding to sources of that luminosity or greater, assuming a semi-thickness, z, of the galactic disk of 200 pc. It is seen from the figure that for $L > 10^{35}$ erg s^{-1} the solid angle for low intensities, where the contribution of extragalactic sources may be important, is small. With the extragalactic intensity distribution derived by Matilsky *et al.* (1972) we estimate that below the curve corresponding to $L = 10^{35}$ erg s^{-1} the maximum extragalactic contribution is of the order of 10%. In what follows we will treat separately the sources below and above the curve corresponding to $L = 10^{35}$ erg s^{-1} (or more generally $L/4\pi z^2 = 2.3 \times 10^{-8}$ erg cm^{-2} s^{-1}). The former may be called strong galactic sources (Section III and IV); the latter may comprise extragalactic and possibly weak galactic sources (Section V).

III. Distribution in Longitude

The first check on the homogeneity of the spatial distribution of the sources in the galaxy can be made by comparing the number of sources within $90° < l^{\mathrm{II}} < 270°$ (anticentre), $N_{ac} = 14 \pm 4$, with that within $270° < l^{\mathrm{II}} < 90°$ (centre), $N_c = 49 \pm 7$. Dividing by the relative galactic areas in the two sectors $A_{ac} = 38$ kpc^2 and $A_c = 314$ kpc^2, one obtains a "density" $n_c = 0.156 \pm 0.02$ sources kpc^{-2} for the centre and $n_{ac} = 0.37 \pm 0.10$ sources kpc^{-2} for the anticentre. The apparent lower density towards the centre could be attributed to the fact that the area of visibility for low luminosity sources is less than the total area. It can be easily shown that approximately

$$\frac{N_c/A_c}{N_{ac}/A_{ac}} \simeq \frac{N(L_c)}{N(L_{ac})} = \left(\frac{L_c}{L_{ac}}\right)^{-\alpha+1} \tag{1}$$

where L_c and L_{ac} are the lowest luminosities of sources that can be detected by UHURU in the whole area of the two sectors. From (1) an estimate of α can be derived.

Taking $L_c/L_{ac} \simeq (A_c/A_{ac})$ one has $\alpha = 1.4 \pm 0.1$. If the source distribution followed the mass distribution in the galaxy, a higher value of α would be obtained. This procedure can give only upper limits for α, since the source visibility towards the centre may be reduced by higher absorption and higher background, however it is interesting to note that the general distribution of galactic sources shows a deficiency at central longitudes with respect to the number expected if essentially all the sources had been seen.

IV. Distribution in Intensity

Turning now to consider the average intensity of the sources in various longitudinal sectors (Table 1) one finds that the average intensity is higher in the sector comprising the galactic centre than elsewhere. This cannot be accounted for by any spatial distribution if the mean luminosity is constant. In fact one would expect a lower mean intensity towards the galactic centre since the mean distance of the sources is higher. For $\alpha = 1.5$, and for a homogeneous distribution in the galaxy the mean intensity towards the centre should be a factor of 4 less than that in the anticentre, that is 40 counts s^{-1}, to be compared with the observed value of 244 counts s^{-1}. One is therefore led to consider separately the intensity distribution of sources in the sector comprising the galactic centre ($330° < l^{II} < 30°$) and elsewhere. The differential distribution is chosen in order to show statistically independent values. The contamination of extragalactic sources is estimated from the density of extragalactic sources given by Matilsky *et al.* (1972), to be less than 50% in the region $3 < I < 10$ c/s in the distribution for the disk, and negligible in comparison to statistical errors for the other points.

The distributions (Fig. 2 and Fig. 3) are clearly different. With a power law approximation:

$$\frac{dN}{dI} \simeq 52\, I^{-1.5} \quad \text{sources/(counts s}^{-1}\text{) outside the central sector} \tag{2}$$

Table 1. Variation of average intensity with longitude

Longitude sector	Average intensity $\bar{I}$(counts s^{-1})
$0 < l^{II} < 60°$ $300° < l^{II} < 0°$	244
$60° < l^{II} < 120°$ $240° < l^{II} < 300°$	131
$120° < l^{II} < 180°$ $180° < l^{II} < 240°$	158

and

$$\frac{dN}{dI} \simeq 2.6\, I^{-0.8} \quad \text{sources/(counts s}^{-1}\text{) in the central sector} \tag{3}$$

In Fig. 2 are drawn the expected intensity distributions for given luminosities all normalized to a number of sources $N_L = 10$. The full curves represent the distributions calculated on a purley geometrical basis (Appendix I). The dashed curves give an estimate of the distortion to be expected if one takes into account the reduction in intensity due to absorption in the interstellar gas (Appendix II). Folding in the intensity curves for single luminosities, uncorrected for absorption, one obtains for the region outside the central sector:

$$\left(\frac{dN}{dL}\right) = 3.4 \times 10^{+19} L^{-1.5} \text{ sources/(erg s}^{-1}\text{)} \quad (10^{35} < L < 10^{38} \text{ erg s}^{-1}) . \tag{4}$$

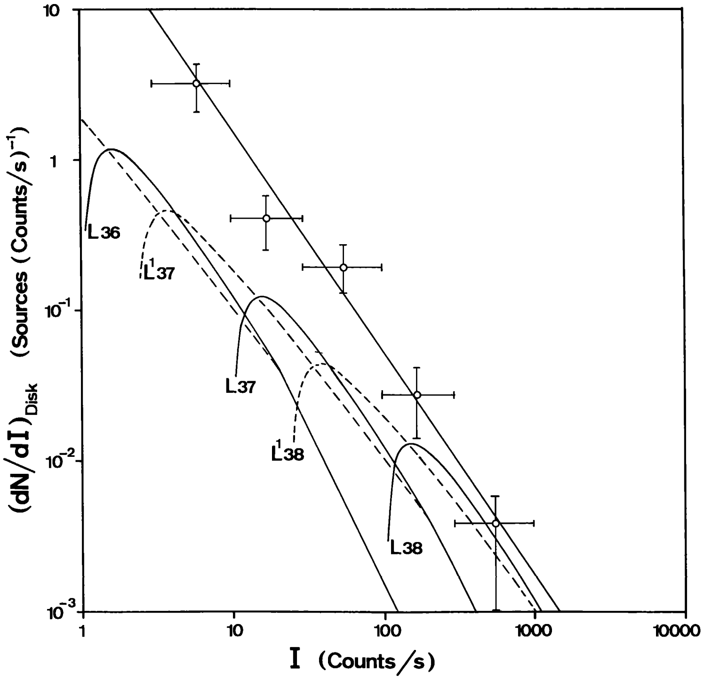

Fig. 2. Points represent the observed differential intensity distribution of X-ray sources outside the central region ($30° < l^{II} < 330°$) corrected for sky coverage. Errors are purely statistical. Solid curves represent the expected distribution for sources of fixed luminosity. Dotted curves show an estimate of the modifications introduced by absorption (see Table 3). All curves are normalized to a total number of 10 sources of the given luminosity in the Galaxy. The straight line represents the power law intensity distribution corresponding to the luminosity function given by Eq. (4)

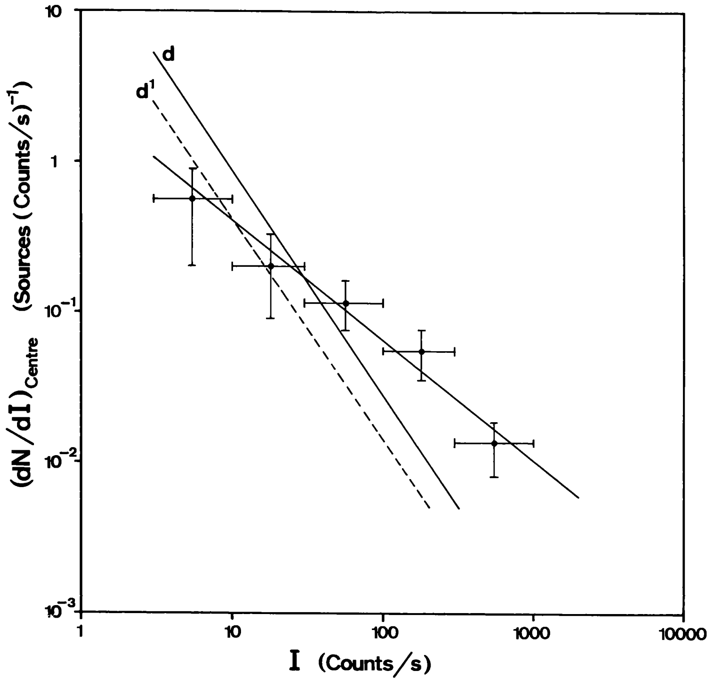

Fig. 3. Points are as in Fig. 2 for the central region ($330° < l^{II} < 30°$). Curve d represents the expected intensity distribution in the central region on the basis of the disk luminosity function. Curve d^1 shows an estimate of absorption. The flatter curve represents the intensity distribution corresponding to the luminosity function for the centre given by Eq. (5)

The spectral index is the same as that of the observed intensity distribution. If one takes into account the rough estimate of absorption represented by the dashed curves on Fig. 2, the coefficient of the power law in Eq. (4) could be increased by a factor of about 1.4.

With the derived luminosity function for the disk, one can calculate the intensity distribution expected in the central sector with and without absorption (Fig. 3). It is apparent that the observed distribution shows a deficiency in low intensity sources and an excess in high intensity sources compared to expectation. At $I < 10$ counts s^{-1} the number observed, corrected for coverage, is $N_{\rm obs} = 4$ while the expected number with and without absorption respectively is $N_{\rm exp} = 7$–14; at $I > 100$ counts s^{-1} $N_{\rm obs} = 20$, $N_{\rm exp} = 3$–5. Since the numbers involved are small, one cannot entirely exclude that the effect is due to statistical fluctuations. If however it is real, one is led to abandon the homogeneous model. In fact the deficiency of low intensity sources could be attributed to observational bias (confusion and higher background), but the excess in high intensity sources requires a density of luminous sources in the central sector higher than in the rest of the Galaxy. It is natural to relate the density enhancement with the central region of the Galaxy. However if this excess were simply related to the higher mass density in that region and the luminosity function were the same previously derived for the disk the expected number of sources with $30 < I < 100$ counts s^{-1} would be a factor of four greater than the observed number ($N_{\rm ex} = 24$, $N_{\rm obs} = 6$) which seems difficult to attribute to observational bias. Therefore we interpret the intensity distribution in the central sector as indicating the existence of a second population of X-ray sources with a luminosity function flatter than that of the first population, that may be called disk population, and with spatial distribution concentrated towards the centre of the galaxy. The spread in latitude $\Delta b^{II} \simeq 10°$ is smaller than that in longitude $\Delta l^{II} \simeq 30°$, suggesting a non spherical spatial distribution that may be similar to that of Novae or Planetary Nebulae.

The derivation of the central luminosity function is subject to uncertainty in the subtraction of the disk component. From Fig. 3 one can see that it should account for the sources above 100 counts s^{-1}, while at lower intensity the disk contribution should be dominant even in the central sector. In order to calculate the intensity distribution with fixed luminosity for the second population of X-ray sources one should know the density gradient. Due to the small number of sources this cannot be derived from the available experimental data. However one expects the intensity distribution to have a maximum at intensities corresponding to locations close to the centre and to fall off for lower and heigher intensities. In this case, for the purpose of estimating roughly the luminosity function, the detailed shape of the intensity curve is irrelevant (see also Appendix I) and one can assume that all the sources are located at the Centre. With this approximation one obtains:

$$\left(\frac{dN}{dL}\right)_{\rm centre} = 2.3 \times 10^{-7}\, L^{-0.8}\ \text{sources/(erg s}^{-1}) \quad \text{for} \quad 10^{37} < L < 10^{38}\ \text{erg s}^{-1}\,. \tag{5}$$

Taking into account absorption the coefficient could be increased by a factor of 1.6.

V. Background and Low Luminosity Sources

The experimental information on the galactic X-ray background in the relevant energy range is resumed in Table 2. The energy spectrum ($E^{-2.8}$) and the angular width of the disk ($\Delta\theta \simeq 10^{-1}$ rad) given by Bleach *et al.* (1972) have been used for converting units.

If one calculates the contribution to the background at given longitude from sources with a power law luminosity function (see Appendix III), one obtains for $\alpha < 2$

$$\frac{\Delta\varphi_B}{\Delta l^{\mathrm{II}}} = \frac{Z\varepsilon(L_c)}{4\pi(2-\alpha)} = \frac{K L_c^{2-\alpha}}{8\pi A(2-\alpha)^2}$$

where $Z =$ half thickness of the galactic disk

$A =$ galactic disk area

$L_c = I_{\min} \times 4\pi R_g^2$

$I_{\min} =$ minimum detectable source intensity

$R_g =$ distance to the edge of the Galaxy for given longitude

$\varepsilon(L) = \int_0^L K L^{-\alpha+1} dL =$ galactic emissivity due to sources of luminosity less than L.

The background expected in a detector of the UHURU resolving power $I_{\min}$ from disk sources with the derived luminosity function is shown in Fig. 4 together with the experimental data. The centre sources having $L > 10^{36}$ erg s^{-1} at $R \sim 10$ kpc are essentially all resolved and do not contribute to the background.

The figure shows that the derived luminosity function is compatible with the upper limit imposed by the background. Unresolved sources of the type observed by UHURU can account for the background to within a factor of two. However some class of low luminosity sources ($L < 10^{35}$ erg s^{-1}) with density greater than the extrapolation of the luminosity function derived above for the higher luminosities may exist. The upper limit imposed by the background on such possible classes of sources is $\varrho L < 10^{26}$ erg s^{-1} pc^{-3}. The angular width $\Delta\theta \simeq 10^{-1}$ rad of the background at $l^{\mathrm{II}} \simeq 60°$ also says that the mean height of the sources above the plane should be about 200 pc.

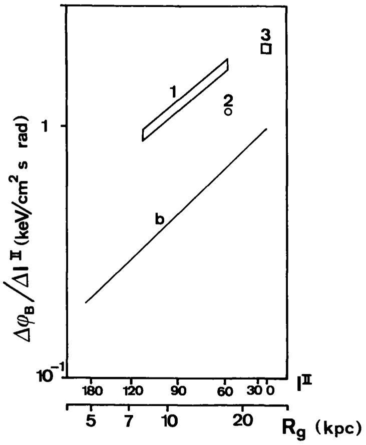

Fig. 4. Experimental data on the galactic background between (2–6) keV are compared with the background expected from unresolved sources with luminosity function given by Eq. (4). 1 Cooke and Griffiths, 1969, 2 Bleach *et al.*, 1972, 3 Gursky, 1972

Very low luminosity sources ($L < 4 \times 10^{32}$ erg/s) could appear in the UHURU catalogue with an isotropic distribution in latitude and so form part of the apparently extragalactic population. The maximum number of isotropic galactic sources that could appear in the UHURU catalogue will be given by

$$N \simeq \varrho \frac{4}{3} \pi \left(\frac{L}{4\pi I_{\min}} \right)^{3/2} .$$

With the limit imposed on ϱ by the background, $N \simeq 10$ for $L \sim 10^{32}$ erg s^{-1} and less for lower luminosities, that is of the order of 10% of the total number of low intensity isotropic sources actually observed corrected for sky coverage. It follows then that the great majority of such sources appearing in the catalogue are extragalactic.

VI. The Physical Parameters of the Sources

From the preceding analysis, it seems clear that the spatial distribution of X-ray sources in the UHURU

Table 2. Experimental data on the galactic X-ray background in the energy range 2–10 keV

Authors	Longitude of observation	Energy range (keV)	Flux value given by the authors	Flux between 2–10 keV deduced assuming an E^{-3} spectrum and $\Delta\theta \simeq 10^{-1}$ rad
Cooke and Griffiths, 1969	$250 < l^{\mathrm{II}} < 300$	1.4–18	0.3.0.6 ph(cm^2 s rad)$^{-1}$	0.9–1.8 keV cm^{-2} s^{-1}
Bleach *et al.*, 1972	$l^{\mathrm{II}} \simeq 60°$	2–10	2.9 ph(cm^2 s sterad)$^{-1}$	1.1 keV cm^{-2} s^{-1}
Gursky, 1972	$l^{\mathrm{II}} \simeq 360°$	2–10	2 counts (s × 0.5°)$^{-1}$	2.1 keV cm^{-2} s^{-1}

catalogue can be explained in terms of a homogeneous population in a galactic disk of semi-height 200 pc with a rather flat luminosity distribution ($\propto L^{-1.5}$). However the intensity distribution of the sources in the central sector seems to indicate the existence of a second population concentrated towards the galactic centre with a flatter luminosity distribution ($\propto L^{-0.8}$).

Further evidence is required if one is to consider non-casual the predominance of high intensity sources in the central region.

Such evidence can be sought in the physical parameters of the sources. Apart from their intensity one can take into consideration their distance and hence luminosity, time variations, and temperature, if a thermal spectrum is assumed. This information can be derived for the limited number of sources of the survey by Seward *et al.* (1972). Their analysis depends on the interpretation of the observed low energy cut-offs as due to interstellar absorption. Although the variability of some cut-offs implies that there may be significant absorption at the source, comparison with optical extinction for identified sources shows that the interstellar absorption interpretation is in many cases acceptable (Reina and Tarenghi, 1973). Seward *et al.* distinguish three groups: "Supernova remnants", "nearby sources", and "far away" sources, and note that the "far away" sources (which are mainly situated in the central region) present a systematically higher luminosity than is found in the other two groups. They note that the average total luminosity of this group ($\bar{L}_t \simeq 4 \times 10^{38}$ erg s^{-1}) is close to that of the four sources detected in the Magellanic clouds ($\bar{L}_t \simeq 5 \times 10^{38}$ erg s^{-1}).

Considering in detail this high luminosity group we note that, apart from GCX which appears to be an extended source, all are highly variable and lie at more than 6 kpc from the Sun and within ±30° of the direction to the Galactic centre except Cir 1, which is close to the limit ($l^{\text{II}} = 322°$), Cyg × 3 which may owe its apparently high luminosity to a distance overestimated due to strong local absorption, and GX 13 + 1 which may be a supernova remnant (Pounds, 1972).

The six sources (GX 9 + 1, Cir 1, SCO 2, GX 17 + 2, GX 5 − 1 and Ara 1) seem to belong to a very homogeneous group, their total luminosities differ by less than a factor 5 and their kT values by less than a factor 2. The average kT of this group ($k\bar{T} = 4.2 \pm 0.35$ keV) is also close to that ($k\bar{T} = 5$ keV) of the sources in the Magellanic clouds. In fact, if one plots total luminosity against temperature (Fig. 5), the sources of the Magellanic clouds (whose distance, and hence luminosity, is relatively well determined) show a distinct anticorrelation and the average value of the galactic central sources is well aligned with the regression line.

Considering in turn the sources which belong to the "nearby" group (this means that they do not belong to the central region) one can note that they show a spread in temperature and luminosities much larger than the former group (variable sources in the central region).

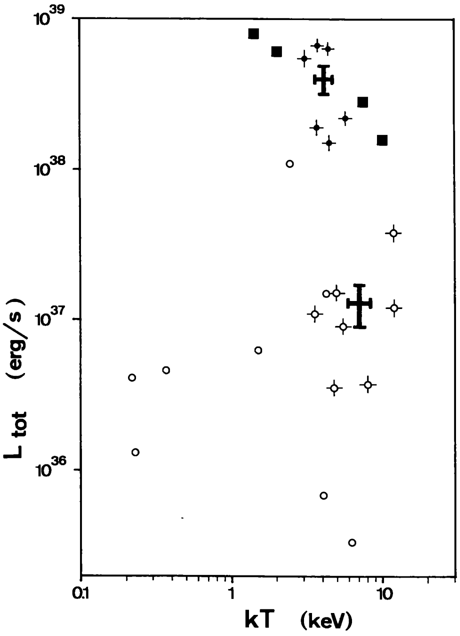

Fig. 5. Total luminosity-temperature plot for sources in the survey by Seward *et al.* (1972). ■ Sources in the Magellanic Clouds, ✦ Variable sources in the central region, ✧ Variable sources outside the central region, ✚ Mean values of the former groups, ○ Steady sources outside the central region

If one considers among the "nearby" sources only those for which variability has been observed, the dispersion in temperature and luminosity is greatly reduced. However the mean luminosity of this subgroup $\bar{L} = (1.3 \pm 0.4) \times 10^{37}$ erg s^{-1} lower and the mean temperature, $k\bar{T} = 7.2 \pm 1.2$ keV is higher than those of the central sources.

The steady sources, despite their large dispersion in the diagram, tend to have smaller luminosities and temperature. The tendency for steady sources to have low luminosities can also be deduced from Fig. 1. At low intensities variability will be difficult to determine, but considering only sources of intensity greater than 40 counts/s, one can see that the steady sources lie on the average at higher latitudes than the variable sources.

VII. Conclusions

The information contained in the UHURU catalogue and the UCRL survey leads us to distinguish two main populations of X-ray sources, which we may call respectively the "disk" population and the "centre" population.

The "disk" population gives rise to the luminosity function of Eq. (4), can be considered to be distributed homogeneously throughout the galactic disk, and consists of sources of two classes:

(a) "Steady" sources with a wide spread of luminosity and kT value. Among these sources several supernova remnants have been identified, the X-ray emission being attributable to thermal bremsstrahlung in the majority of the cases, and in the case of the Crab Nebula to synchroton emission.

(b) Highly variable sources with an average luminosity $\bar{L}_t = (1.3 \pm 0.4) \times 10^{37}\,\mathrm{erg\,s^{-1}}$ and temperature $\overline{kT} = (7.2 \pm 1.2)\,\mathrm{keV}$. Among these sources binary systems have been identified. For these, and perhaps for the whole group, X-ray emission can arise from the accretion of a dense plasma by a compact object (neutron star or black hole).

With the luminosity function of this population, unresolved sources can account for about half of the galactic background emission.

A third class of very low luminosity X-ray sources ($L \simeq 10^{32}\,\mathrm{erg\,s^{-1}}$), responsible for the rest of the galactic background may exist, at present indistinguishable from the extragalactic sources. If it exists, this group cannot account for more than 10% of the isotropically distributed sources in the UHURU catalogue.

The "centre" population, responsible for the flatter luminosity function of Eq. (5), concentrated towards the central region of the galaxy, seems to consist of a single class of variable high luminosity sources with a relatively small spread in luminosity and kT value.

The average luminosity and kT values of this class are consistent with the values found for the sources of the Magellanic Clouds, for which there is an apparent anti-correlation between total luminosity and temperature. One of the Magellanic Cloud sources is a binary system. The total luminosity of these sources is close to the Eddington limit for stellar masses $M \simeq 1\,M_\odot$.

It is difficult at this stage to understand what physical processes are occurring in the objects belonging to the second population to produce this high luminosity group. If one assumes that the source of energy in all the variable sources is accretion, one needs to explain what are the essential differences between the populations leading to this group and the group of variable sources in the "disk" population. If one supposes that in both groups emission is taking place close to the Eddington limit, then one would deduce that accreting objects of higher mass are concentrated towards the Galactic Centre. Alternatively, one could attribute the difference in luminosity to an evolutionary condition which favours limiting conditions of accretion in the population most concentrated in the Central region.

Given the small number of objects involved, one cannot hope to obtain clearer understanding of this problem from arguments of a statistical nature. Further detailed observations of the individual sources and, where possible, identification of these sources with their counterparts in radio, infrared or optical emission are necessary.

Appendix I: Intensity Distributions

Intensity Distributions of Sources in a Homogeneous Flat Disk

Assuming that the sources are distributed in a disk of radius $R \simeq 15$ kpc and thickness $2z$, the number of sources with distance from the Sun less than r is: $N(<r) = 2z\varrho A(r)$ where ϱ is the uniform density of the sources, and $A(r)$ is the disk area within r, which has been calculated numerically. The differential dN/dI intensity distributions for a class of sources of given luminosity L can be approximately represented by:

1) Distribution in the entire disk

$$\left(\frac{dN}{dI}\right)_L \propto \begin{cases} I^{-2} & \text{for} \quad I > L/4\pi r_b^2 \\ I^{-1.7} & \text{for} \quad L/4\pi r_b^2 > I > L/4\pi r_0^2 \\ 0 & \text{elsewhere} \end{cases}$$

where $r_b \simeq 5$ kpc and where $r_0 \simeq 25$ kpc.

2) Distribution in the sector $330° < l < 30°$

$$\left(\frac{dN}{dI}\right)_L \propto \begin{cases} I^{-2} & \text{for} \quad I > L/4\pi r_0^2 \\ 0 & \text{elsewhere} \end{cases}$$

3) Distribution in the sector $30° < l < 330°$ (computed curves of this type are shown in Fig. 2)

$$\left(\frac{dN}{dI}\right)_L \propto \begin{cases} I^{-2} & \text{for} \quad I > L/4\pi r_b^2 \\ I^{-1.5} & \text{for} \quad L/4\pi r_b^2 > I > L/4\pi r_0^2 \\ 0 & \text{elsewhere} \end{cases}$$

Assuming a luminosity function $\frac{dN}{dL} = KL^{-\alpha}$, it is clear that if α is less than the index γ of the intensity distribution $\left(\frac{dN}{dI}\right)_L \div I^{-\gamma}$ of a single luminosity class, the intensity distribution integrated over luminosities will be of the form $\frac{dN}{dI} \div I^{-\alpha}$. Alternatively in the case $\alpha > \gamma$ one obtains that $\frac{dN}{dI} \div I^{-\gamma}$.

Appendix II: Estimate of Absorption Corrections to Source Intensity

The influence of absorption has been estimated as follows. In the absence of published detailed information on the response curve of the UHURU instrument, a constant efficiency was taken in the 2–6 keV energy range. The column density for various distances was estimated from data given by Seward *et al.* (1972). Finally the ratio of transmitted to emitted intensity in the energy interval 2–6 keV was computed by means of the cross section of Brown and Gould (1970), for thin bremsstrahlung spectra of various temperatures and for a power law of exponent $\alpha = -1$. Results are shown in Table 3.

Intensity distribution corrected for absorption are shown in Fig. 2 for various luminosities in the hypothesis that the mean height z of galactic X-ray sources

Table 3. Ratio of intensity transmitted by the interstellar medium I_t to intensity emitted by a source I_{em}, I_t/I_{em}(%), at various distances and for different spectra

Distance (kpc)	Columnar density X 10^{-22} at/cm^2	Cut-off energy (keV)	Temperature of a thin bremsstrahlung spectrum $kT=1$ keV	$kT=2$ keV	$kT=5$ keV	Power law spectral index $\alpha=-1$
7	3	2	60%	69%	75%	73%
10	8	3	30%	42%	50%	48%
16	13	3.5	20%	31%	39%	37%
20	17	4	13%	22%	30%	28%

is of the same order as that of the absorbing gas layer. For larger values of z the effects of absorption are reduced.

Appendix III: Galactic Background Due to Unresolved Sources

If a population of sources has a differential luminosity function $dN/dL=KL^{-\alpha}$, the background due to the integrated contribution of the sources observed by an instrument which can detect the minimum intensity $I_{\min}$ will be

$$\varphi_B=\int_0^{L_c} Ln(L)\,dL \int_{R_{\min}}^{R_g} \frac{dV}{4\pi r^2}$$

where $n(L)=\frac{1}{V}\frac{dN}{dL}$ (the distribution is assumed to be uniform in space)

$$R_{\min}=(L/4\pi I_{\min})^{1/2}$$

$R_g=$ distance to the galactic edge

$L_c=I_{\min}\,4\pi R_g^2.$

Approximating $dV=2z\Delta l^{\mathrm{II}}\,r\,dr$, which will be valid for $r\gg z$

$$\frac{\Delta\varphi_B}{\Delta l}=\frac{z}{4\pi}\int_0^{L_c} Ln(L)\ln\left(\frac{L_c}{L}\right)dL$$

$$=\frac{z}{4\pi}\left\{\left[\ln\left(\frac{L_c}{L}\right)\varepsilon(L)\right]_0^{L_c}+\int_0^{L_c}\varepsilon(L)\frac{1}{L}\,dL\right\}$$

where $\varepsilon(L)=\int_0^{L} Ln(L)\,dr$ is the galactic emissivity due to the considered sources up to the luminosity L.

For $\alpha<2$ one obtains

$$\frac{\Delta\varphi_B}{\Delta l}=\frac{z}{4\pi}\,\frac{\varepsilon(L_c)}{(2-\alpha)}.$$

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