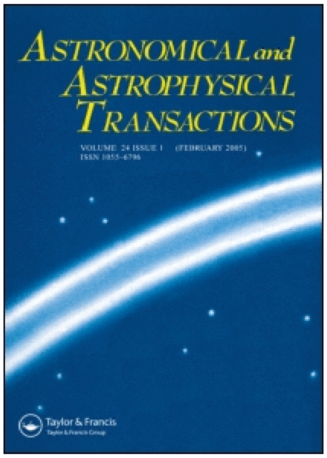

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

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Online Publication Date: 01 November 1996
To cite this Article: Gosachinskij, I. V. and Morozova, V. V. (1996) 'Statistical properties of interstellar HI clouds', Astronomical & Astrophysical Transactions, 11:3, 215 - 223
To link to this article: DOI: 10.1080/10556799608205468
URL: http://dx.doi.org/10.1080/10556799608205468

Astronomical and Astrophysical Transactions, 1996,
Vol. 11, pp. 215–223
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STATISTICAL PROPERTIES OF INTERSTELLAR HI CLOUDS

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(Received March 29, 1995)

We present results of the computation of the linear diameter, density and mass spectra for about 5000 HI clouds, which were found by their emission at 21 cm with RATAN-600 radio telescope in the region of $180° < l < 260°$ and $-15° < b < +15°$. The spectra were corrected for selection effects. The diameter spectrum has an approximately power-law shape with a spectral index of -3.0 ± 1. The density spectrum in the range from 1.0 to 500 cm^3 is not a power-law but has a maximum at n_H = 20–60 cm^3 depending on galactic latitude. The mass spectrum in the form of $M \cdot N(\log M)$ was obtained in the mass range from 0.6 to $2.5 \cdot 10^4 M_\odot$. It consists of at least three parts. In the range 2–600$M_\odot$ the spectrum has a spectral index of 0.8 ± 0.1. The second part, in the range 0.6–2$M_\odot$, has the spectral index of 3.0 ± 1, and the third part in the range from 600 to $2 \cdot 10^4 M_\odot$ has a spectral index of -0.7 ± 0.3. These data show that, in the middle mass range, the process of coalescence in cloud-cloud collisions predominates, but the clouds with low masses are evaporated probably due to the very hot ISM component. In the very high mass range the number of clouds may be decreased because of gravitational instability.

KEY WORDS Interstellar matter, HI clouds, mass spectra

1 INTRODUCTION

The distributions of cloud numbers in the particular ranges of mass, dimension and gas density obtained with observations give an opportunity to check some theoretical models of physical processes in the interstellar medium pertaining to cloud-cloud collisions and energy sources. However, there are only a few observational measurements of the mass spectra and, moreover, the majority of them are found from indirect measurements of cloud mass and therefore depend on simplifying assumptions (for example, the constant gas density is frequently accepted). The range of investigated masses is limited too, especially for low masses. Only in the papers of Crovisier (1981) and Gosachinskij (1989) the mass spectra were obtained down to 1.0 and $0.01 M_\odot$, respectively.

In this paper we present the results of our investigation of HI cloud distributions over their linear dimensions, gas densities and HI masses made on the basis of direct measurements of HI cloud parameters in emission at 21 cm with high angular resolution.

2 OBSERVATIONAL DATA AND REDUCTION

For our investigation, we took 29 cross-sections from the RATAN-600 HI Survey in the range of declinations from $-40°$ to $+30°$ and right ascension from 5^h to 10^h. This corresponds to a region in Galactic coordinates $180° < l < 260°$, $-15° < b < +15°$, that is the third Galactic quadrant.

The angular resolution of this Survey is $2'.4 \times 130'$, the velocity resolution is 6.3 km/s, the r.m.s. fluctuations of antenna temperature (T_a) are 0.25 K. Each cross-section consists of 78 drift curves obtained with 3.1 km/s velocity interval. A detailed description of equipment, technique and antenna parameters can be found in the paper of Venger *et al.* (1979).

In all the drift curves of each cross-section the details of HI emission narrower than $0^\circ.5$ were filtered out with a simple second-order difference filter. Then the parameters of each detail (T_a, $\alpha_{\max}$ and $\Delta\alpha$) were determined with the help of a Gauss-analysis code and tabulated. If any detail was a blend of some narrower ones, this code separated them into individual components. After that each component found at any given velocity was compared with the ones at neighboring velocities. Under a certain restrictions on the velocity and T_a differences these velocity details are considered as a single cloud with particular velocity width (ΔV).

For computing cloud distances, we accepted the Galactic rotation model of Kerr and Lynden-Bell (1986) with $R_\odot = 8.5$ kpc. It is well known that kinematical distance errors are determined mainly by unknown cloud proper motions and systematic non-circular motions. So all clouds with $r < 1.0$ kpc were rejected because their relative distance errors are very high. Moreover, clouds with $T_a < 0.75$ K (3 times the r.m.s. error) and $\Delta V < 6.3$ km/s were also rejected. After that we have about 5000 clouds for which the physical parameters were computed.

The antenna temperatures of clouds were corrected for antenna losses, determined with the help of the observation of reference sources (Venger *et al.*, 1979), and cloud angular sizes were corrected for antenna smoothing. After that cloud parameters were computed as follows:

linear dimension	$d = 0.291 \cdot \theta \cdot r$ (pc),
integral intensity	$S = T_a \cdot \Delta V \cdot \eta_{\rm obs} \cdot 130'$ (K km/s arcmin^2),
HI mass	$M_H = 9.717 \times 10^{-4} \cdot S \cdot r^2 (M_\odot)$,
HI density	$n_H = 51.6 \cdot M_H / d^3$ (cm^{-3}).

These equations are applicable if the low optical depth of the HI clouds is assumed. For clouds having high brightness temperature, M_H and n_H were corrected assuming a kinetic temperature of 120 K. The estimated errors of these quantities are: 2.5 pc for size, 40% for integral intensity, up to a factor 3 for HI mass, and up to a factor of 1.5 for HI density.

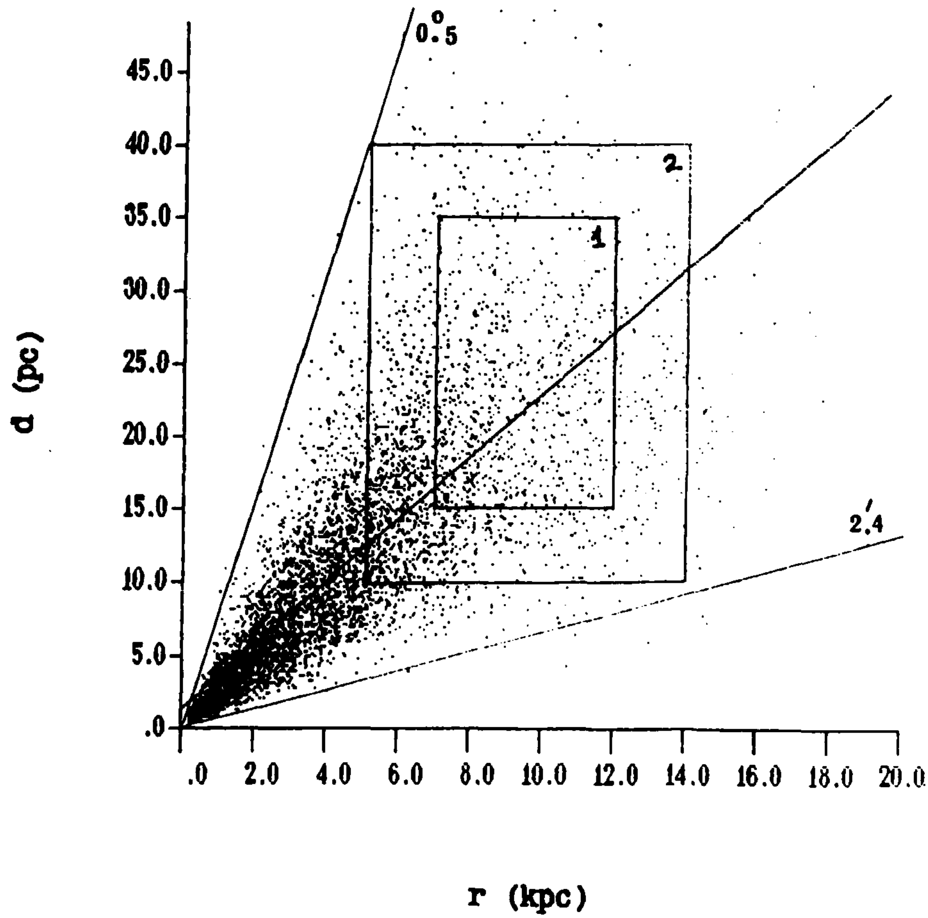


Figure 1 Linear dimension of HI clouds as a function of their distance. The inclined lines show the limitations of the cloud survey.

3 SELECTION EFFECTS

It is obvious that any statistical results are very sensitive to selection effects, arising due to limited possibilities of the equipment and methods. The limited resolving power of the equipment in angular coordinates and velocities leads to the presence a large number of unresolved objects (blends). It is reasonable to expect in that case some correlation between ΔV and $\eta_{\rm obs}$. However, the correlation coefficient between ΔV and $\eta_{\rm obs}$ in our material is lower than 0.1 and we can hope that the blends are absent.

The next selection effect is demonstrated in the Figure 1 where a dependence is presented between cloud linear diameters (d) and their distances (r). The inclined lines show our limits on the angular dimension of a cloud due to antenna resolution,

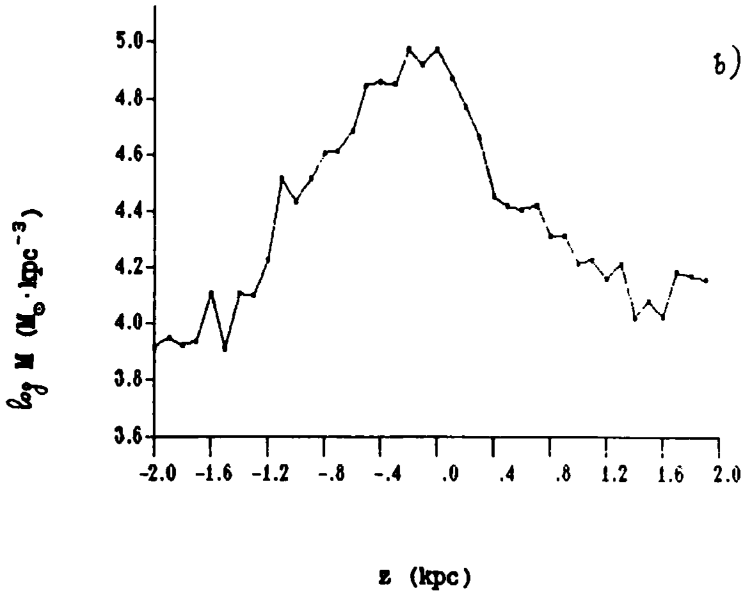


Figure 2 *a*, The relative volume occupied by clouds as a function of their z coordinates. *b*, The mass density of clouds as a function of the z coordinate.

sensitivity and methods employed. The resulting cloud statistics can be corrected for this effect in two ways. First, we may restrict our attention to narrower ranges of diameter and distance as shown in Figure 1 by rectangles in which there is no dependence between d and r. Second, a number of clouds with particular diameter can be corrected if we suppose that the characteristics of the cloud structure are uniform in the investigated region of the Galaxy. Such consideration can be applied to the estimates of HI mass and other parameters. The first method of correction can be applied to correlation dependences of the parameters, but for the spectra both methods can be applied.

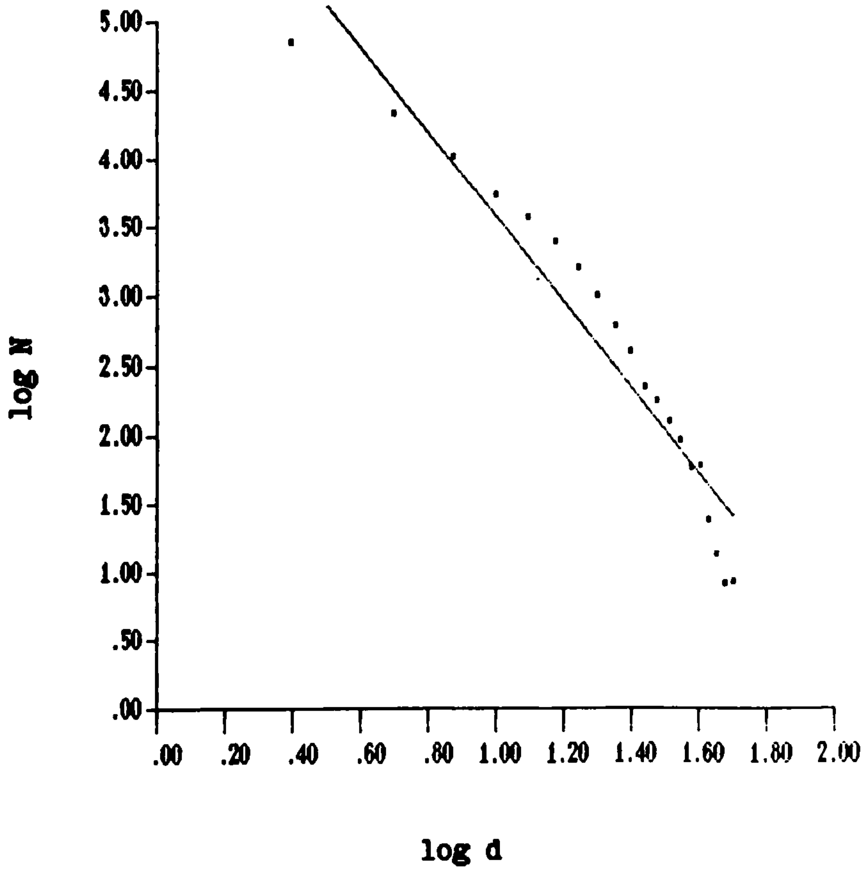
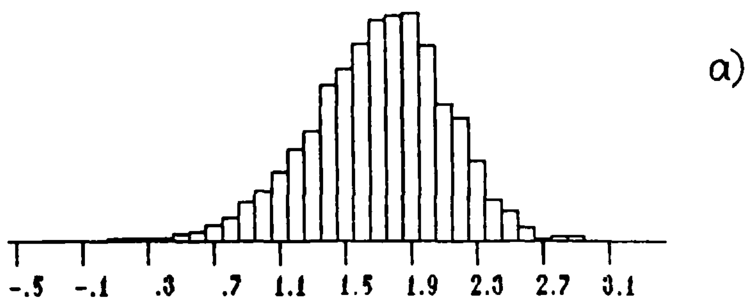


Figure 3 The number of clouds per unit interval in their diameter, corrected for selection effects.

4 RESULTS

The part of the volume occupied by HI clouds and their mass per unit volume are presented in Figure 2 as functions of the z-coordinate. It can be seen that the maximum volume fraction is 2×10^{-4} in the Galactic plane and decreases with z. The mass density of the cloud component is about $8 \times 10^4 M_\odot$ kpc^{-3} in the plane and decreases to $8 \times 10^3 M_\odot$ kpc^{-3} at large z.

The distribution of the number of clouds per unit interval in their diameter is presented in Figure 3 in logarithmic scales. The cloud numbers were corrected for the angular diameter selection effect with the help of the second method (see above). This distribution looks close to a power-law in the first approximation with an index of about −3.0 in the range of diameters from 2.5 to 50 pc. However, it is obvious that this dependence becomes steeper at larger masses.



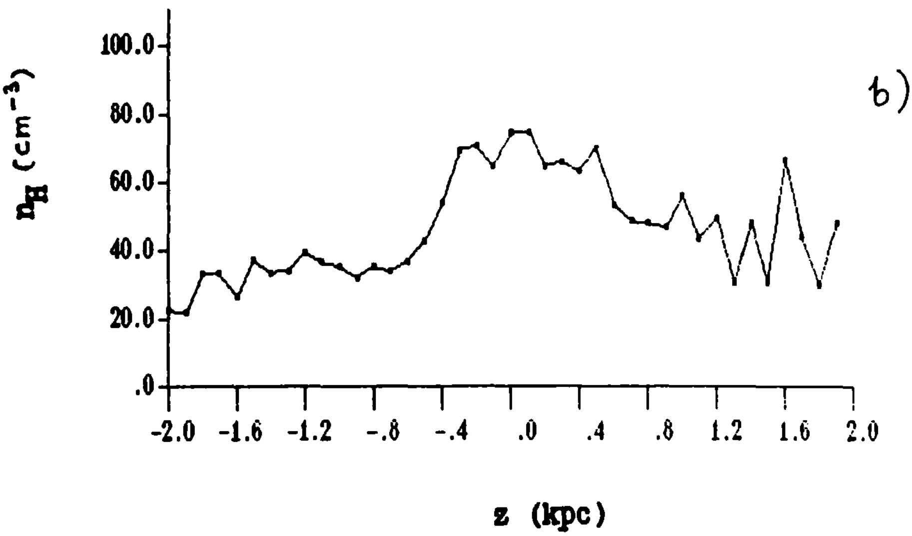


Figure 4 *a*, The number of clouds per unit interval in log n_H. *b*, The mean cloud n_H versus the z coordinate.

The distribution of cloud number per unit interval in log n_H and the mean n_H as a function of z are presented in Figure 4. The mean HI density is about 60 cm^{-3} in the Galactic plane and decreases to 25 cm^{-3} at large z. The largest and lowest HI densities are important parameters: these are 500 and 1 cm^{-3}, respectively.

And finally, the HI mass spectrum of the clouds is presented in Figure 5. For convenience of comparing our data with theoretical ones, this spectrum is presented in the form of $M \cdot N(\log M)$, that is the mass of the cloud component per unit interval of log M. The usual differential spectrum $N(M)$ can be otained from

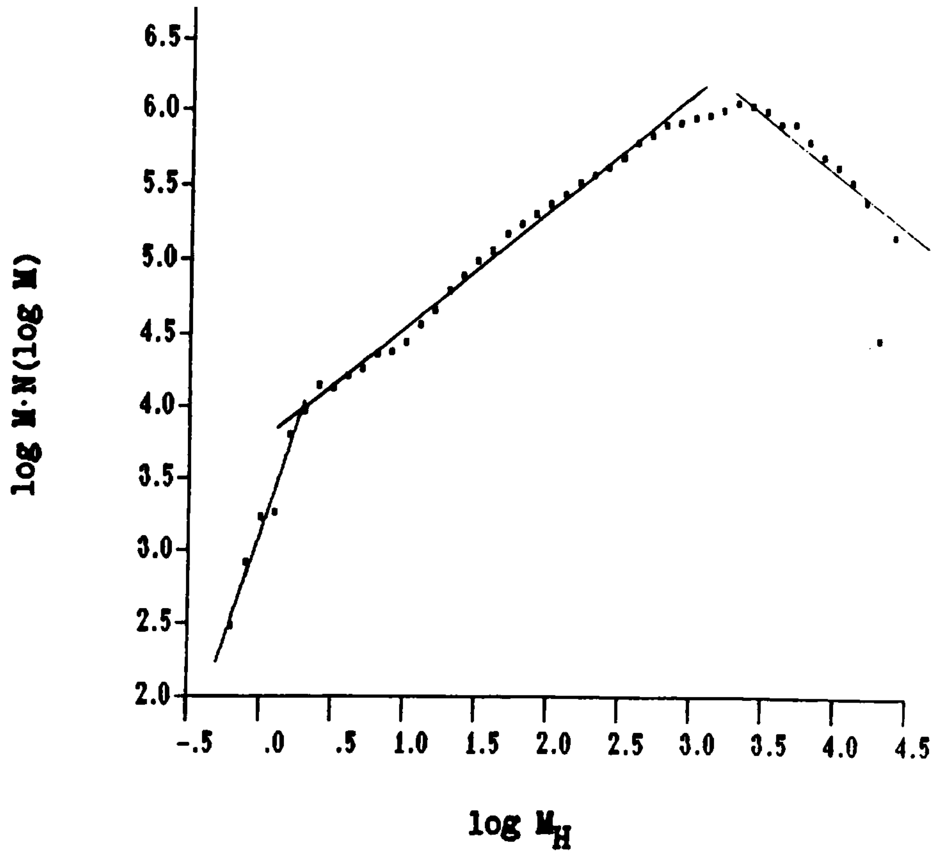


Figure 5 The mass spectrum of HI clouds. Straight lines show the linear regression of points in three selected mass intervals.

$$M^2 \cdot N(M) = M \cdot N(\log M).$$

It can be seen that this spectrum can be divided into at least three parts. In the intermediate mass range from 2 to $600 M_\odot$, it has a spectral index of 0.8 ± 0.1. In the region of low masses it becomes steeper with a spectral index of 3.0 ± 1. In the region of large mass between 600 and $2.5 \times 10^4 M_\odot$, the spectral index is -0.7 ± 0.3.

Concerning any correlation between cloud parameters, the selection effects mentioned above make them very doubtful. For example, there is a correlation between n_H and M_H obtained for all the clouds with the correlation coefficient of -0.7. However, this dependence completely disappears when computation is made inside the rectangles shown in Figure 1. On the other hand, a well-defined dependence of n_H on d ($n_H \propto d^{-1.1}$) with the correlation coefficient of -0.87 does not disappear after all the methods to correct for the selection effects have been applied. Therefore, this correlation may be real.

5 DISCUSSION

It is interesting to compare our results with those of other observers and with theoretical considerations. Dimension spectra of interstellar clouds were obtained by Knude (1981) using interstellar absorption and by Gosachinskij (1989) using HI clouds seen in the absorption line. They have obtained the spectral indices of −2.5 and −1.5, respectively. Note that the ranges of diameters in these investigations are diffarent and differ from ours. It can be seen in Figure 3 that the diameter spectrum is curved, so in the range of large diameters it becames steeper. Therefore our estimate of the index does not contradict the results of Knude (1981) and Gosachinskij (1989).

Our mean HI density looks rather high, a more common value is about 25 cm^{-3}. It is difficult to explain this fact. The minimum observed density is about 1 cm^{-3}, and with assumed kinetic temperature 120 K this gives the so-called minimum critical pressure in the clouds of about 120 K cm^{-3}. This is nearly the same as obtained by Gosachinskij (1989) and, according to Suchkov and Shchekinov (1981), shows that the rate of primary ionization of hydrogen is rather low at about 10^{-17}–10^{-18} s^{-1} and the abundance of heavy elements in the interstellar medium is close to the solar one. Our maximum observed density differs from that of Gosachinskij (1989) only by a factor of two.

It is interesting to note that the mass spectrum obtained here is close to that of Gosachinskij (1989) in spite of a rather different population of clouds considered in these two investigations. The other data compiled by Clifford (1985) are different from ours. A theoretical computation of mass spectra for colliding clouds was made by Chieze and Lazareff (1980). They show that a rather high spectral index of 0.8 can occur only if the processes of coalescence dominate in the cloud-cloud collisions. For the low-mass range, Chieze and Lazareff (1980) show that in the framework of the model of McKee and Ostriker (1977) there must be evaporation of clouds due to the hot gas phase. Our data confirm this conclusion. Concerning the steep decrease in the cloud number at masses greater than $600 M_\odot$, the gravitational instability can be important at that mass and clouds disappear from view at 21 cm.

Acknowledgements

The authors are grateful to N. A. Yudaeva, M. E. Makrosova, Z. A. Alferova and T. V. Monastyreva for their great help in observations and reduction of the RATAN-600 HI Survey.

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