CLOUD STRUCTURE OF INTERSTELLAR MATTER. OBSERVATIONAL PARAMETERS

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ABSTRACT. Parameters of 7600 HI clouds were determined on the base of HI RATAN-600 Survey in the second and third quadrants of galactic longitudes. The spectra of cloud linear diameters, HI densities and masses are obtained first for such huge population of clouds. Mass spectrum of HI clouds shows that, in middle mass range, the process of coalescence in cloud–cloud collisions predominates, but the clouds with low masses are probably evaporated due to the very hot ISM component. It is found that mean clouds linear diameters along Galactic plane are 2.5 times greater than in transverse direction. The relation between HI concentrations and cloud diameters is obtained in the f of $n_H \propto d^{-1.25\pm0.01}$ probably regardless of selec effects. It is shown that velocity dispersion does depend on cloud diameters, as distinct from molec clouds. It is found that 16% of HI clouds have syste tic velocity gradients across cloud disks that is ma due to clouds rotation. Mean clouds angular rotati velocity is about $5 \cdot 10^{-14} s^{-1}$ and observable quant of clouds with opposite directions of rotation are e within 5% in both galactic quadrants investigated

Key words: Interstellar matter, clouds, HI

1. Introduction

The characteristics of interstellar gas clouds main role in any theories of star formation. The d molecular cloud cores are probably immediate par of stars. However, the molecular clouds themse arise obviously from some structures of atomic c ponent of interstellar medium, because namely in the atomic gas may arise two-phase system: clouds and intercloud medium, namely neutral atomic clouds are able to increase their masses and densities due to inelastic collisions and rapid cooling. So the neutral atomic clouds may be named as "grand parents" of stars and their properties play genetic role for whole chain of matter transformations in the galaxies.

2. Equipment and methods

The RATAN-600 radio telescope has greatly high sensitivity to low contrast details of emission observed on the bright complex background. That's why we were able to create the unique database of HI clouds on the base of HI RATAN-600 Survey. The angular resolution of this Survey was $2.4' \times 130'$, velocity resolution was 6.3 km/s, r.m.s. fluctuations of antenna temperature (T_a) were 0.25 K. A detailed description of equipment, technique and antenna parameters can

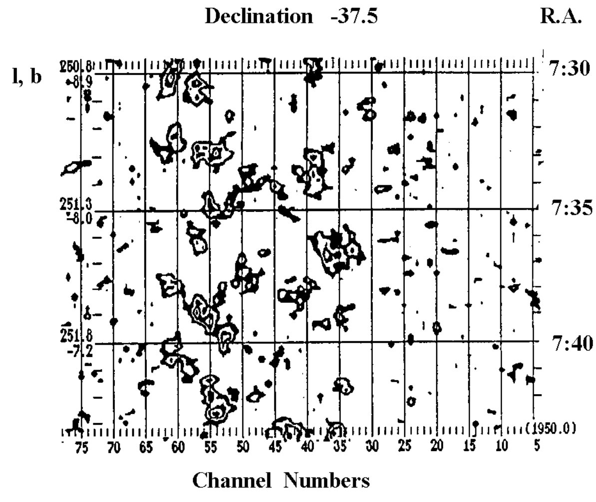

Figure 1: The HI details after removing of wide spread background emission.

In all drift curves of each cross-section the details of HI emission narrower than 0.5° were filtered with a simple second-order difference filter. Then the parameters of each details were determined with a help of a Gauss-analysis code and tabulated. For computing cloud distances, we accepted the Galactic rotation model of Kerr and Linden-Bell (1986) with $R_\odot$=8.5 kpc.

An example of HI details in function of right ascension and velocity (channel numbers) is represented on Fig. 1. About 1000 square degrees have been observed on the Sky, that correspond about 20 cubic kilo parsec at these regions of Galaxy.

All clouds with kinematical distances r ¡ 1.0 kpc were rejected because their relative distance errors are very high. Moreover, clouds with $T_a < 0.75$ K (3 times r.m.s. errors) and line widths $\Delta V < 6.3$ km/s were rejected too. Diameters, masses, gas densities and velocity dispersions of about 7600 HI clouds were determined in the second and third quadrants of galactic longitudes in $180° < l < 260°$, $-15° < b < +15°$ $100° < l < 150°$, $-10° < b < +10°$. Some selection effects were discovered and our statistic results were corrected for them.

3. Selection effects

It is obvious that any statistical results are very sensitive to selection effects, arising due to limited possibilities of equipment and methods. The obvious selection effect is demonstrated in Fig. 2 where a dependance 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, sensitivity and methods of filtering employed.

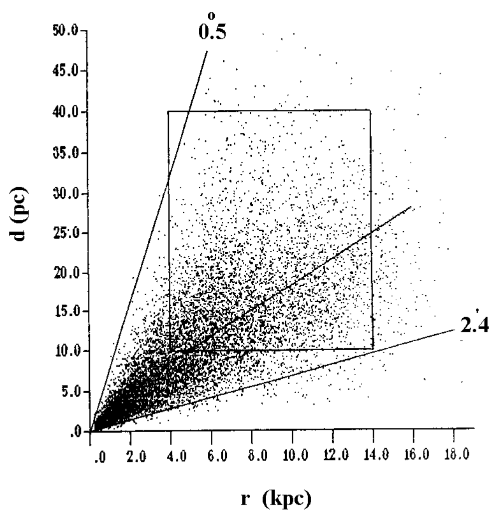

Figure 2: The diameters of HI clouds as a function of their distance. The inclined lines show the limitations of cloud survey.

We correct our cloud statistics for this effect by restriction of the ranges of d and r as shown in Fig. 2 by rectangle in which there is no dependence between d and r. The second method of correction supposes that characteristics of the cloud structure are uniform in the investigated regions of the Galaxy. So a number of cloud with particular diameter may be corrected. The first method may be applied to correlation dependances of parameters, but for spectra both methods can be applied.

The final estimates of measuring errors of the main cloud parameters are the next: linear dimension $\pm 1.0 pc$, integral intensity ±40%, HI density up to factor 1.5 and HI mass up to factor 3.

4. The spectra of parameters

It is obtained that maximum volume fraction occupied by HI clouds is $2 \cdot 10^{-4}$ in the Galactic plane and decreases with z. The mass density of the cloud component is about $8 \cdot 10^4 M_\odot$ kpc^{-3} in the plane and dec-

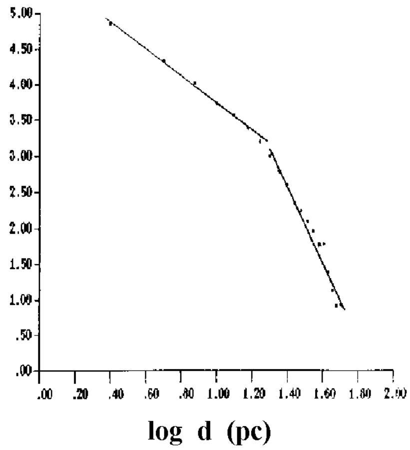

Figure 3: The diameters spectrum of HI clouds.

It is found that mean clouds linear diameters along Galactic plane are 2.5 times greater than in transverse direction. The cloud diameter spectrum (Fig. 3) has a bimodal power shape with spectral indexes of -1.9 ± 0.5 between 1 – 16 pc, and -3.9 ± 0.5 between 16 – 45 pc.

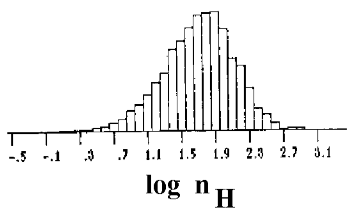

Figure 4: The distribution of HI cloud densities.

A HI gas density spectrum in the range of 1.0 to 400 cm^{-3} (Fig. 4) has not a power form, but it has a maximum at $n_H = 10 - 40$ cm^{-3} depending of galactic latitude. The lowest and highest density observed in the clouds are the very important parameters for theories of thermal instability and formation of molecules. These are about 1 cm^{-3} and about 400 cm^{-3} respectively. The first value shows that according to Suchkov and Shchekinov (1981) the rate of primary ionization of hydrogen is rather low at about $10^{-17} - -10^{-18} s^{-1}$ and abundance of heavy elements in the interstellar medium is close to the solar one.

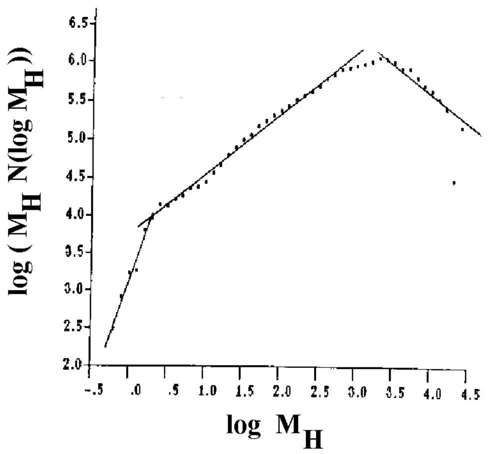

Figure 5: The mass spectrum oh HI clouds.

The mass spectrum in the form of M·N(log M) was obtained in the mass range of 0.6 to 2.5·10^4 M$_\odot$ (Fig. 5). It consists of at least three parts. In the range of 2 to 600 M$_\odot$ the spectrum has a spectral index of 0.8 ± 0.1, in the range of 0.6 to 2 M$_\odot$ the spectral index is 3.0 ± 1 , and in the range of 600 to 2·10^4 M$_\odot$ the spectral index is –0.7 ± 0.3. A theoretical computation of mass spectra for colliding clouds was made by Cheeze 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 collision. Clouds with low masses may be evaporated probably due to very hot ISM component. In the very high mass range the number of neutral gas clouds may be decreased because of gravitational instability or/and molecularization.

5. The relations between cloud parameters

There are wellknown empirical power-law scaling relation for internal velocity dispersion, Δv, gas particle density, n and cloud diameter d and mass M, first pointed by Larson (1981) for population of molecular clouds. These relation is generally interpreted as evidence for mechanical equilibrium in self-gravity, turbulent molecular clouds. For lower density atomic (HI) clouds self-gravitation is unessential and Fleck (1996) supposed phenomenological model of compressible turbulence. It is interesting to note however that there is dozen papers on investigation of the scaling relation in molecular clouds but only one - for atomic clouds.

The relation between HI concentrations and cloud diameters presented in Fig. 6 for more than 7700 clouds. The linear regression give the dependence in the form of $n_H \propto d^{-1.25 \pm 0.01}$ regardless of selection effects. The correlation coefficient between *log* n_H and *log d* is equal –0.87. This is nearly the same as obtained by many authors (see Falgarone, Puget, 1986, Vasquez-Semadeny et al. 1997) for molecular clouds. Fleck (1996) has shown that for atomic clouds $\rho \propto d^{-3\alpha}$, where α is a measure of the degree of compression at each level of compressible turbulence. So our data give $\alpha = 0.42$, that is about 2.5 times greater than from Fleck(1996).

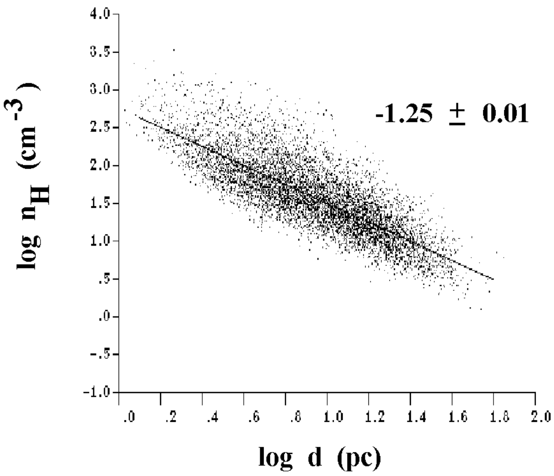

Figure 6: Relation between HI clouds diameters and densities.

It is shown that other important dependence – velocity dispersion versus cloud diameters, that is well defined for molecular clouds in the form of $\Delta v \propto d^{-0.4}$ – is completely absent in the case of HI clouds with large significance level (see Fig. 7, where instead of velocity dispersion half widths of observable emission profiles are presented). Probably this is due to negligible role of intrinsic turbulence in the HI clouds but may be that atomic and molecular clouds represent distinct populations

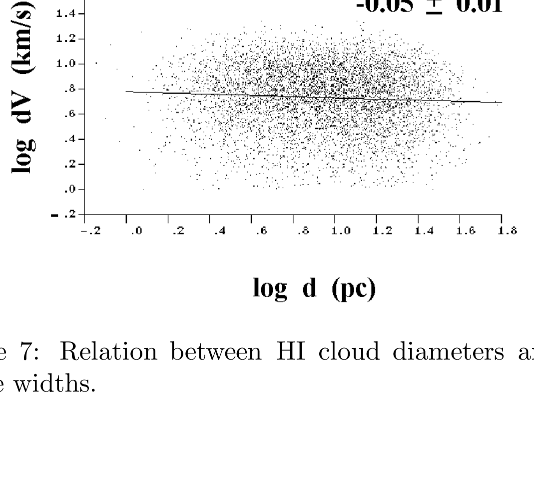

Figure 7: Relation between HI cloud diameters and profile widths.

6. The rotation of the HI clouds

It has been found that 16% of HI clouds have significant systematic velocity gradients across cloud disks that may be due to rotation of clouds (Fig. 8). This phenomenon may explain rather high velocity widths of HI line profiles in the observable clouds. These gradients have been approximated by straight lines and for those objects, where values of slope were greater than 3 times r.m.s., angular rotational velocities were determined. The mean value of clouds angular rotational velocity obtained with these gradients is about $5 \cdot 10^{-14}$ s^{-1}.

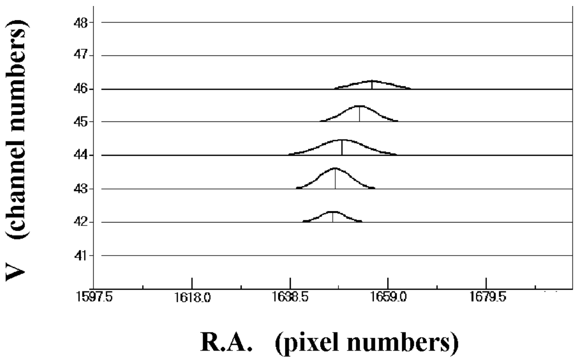

Figure 8: R.A. of maximum cloud emission in function of channel number.

The distribution of absolute values of rotational velocities is presented on the Fig. 9. It may be seen that the range of values is rather narrow. This may be due to some methodical restriction (selection effects) therefore the mean value of rotational velocities is only tentative. With these data mean rotational energy of clouds is about 10^{48} ergs, that is comparable to the

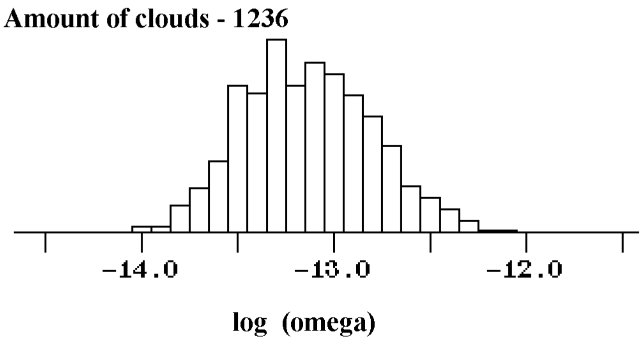

Figure 9: Distribution of measured cloud angular velocities.

Finally, observable quantities of clouds with opposite directions of rotation are equal within 5% in both galactic quadrants investigated.

It is interesting to note that in the recent paper of Phillips (1999) some results on rotation of molecular clouds are reported. Part of them corresponds to our results on atomic clouds, in particular, that part of clouds with rotation is very large and that directions of rotation axes are mainly arbitrarily.

7. Concluding remarks

High angular resolution and high sensitivity of the RATAN–600 to low contrast details of emission allowed us to create the unique collection of HI cloud parameters in the Second and Third Galactic Quadrants. It is now not necessary to use so-called "standard cloud" for computation of any theoretical models. It is possible to use our results in the straightforward manner for further investigation like Khersonsky (1997) who try to connect the interstellar gas cloud mass spectrum with stellar mass spectrum in star-forming regions.

These results are published in the next paper: Gosachinskij I.V., 1989, Pisma v A.Zh. **15**, 788, Gosachinskij I.V. and Morozova V.V., 1996, Astron. Astrophys. Transactions, **11**, 215, and will be published in Gosachinskij I.V., Morozova V.V., 1999, Astron. Zh. (in press).

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