

THE HI CONTENT OF NON-ISOLATED GALAXIES

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It seems obvious that the evolution of star formation rate and hence of gas content in galaxies strongly depends on their environment. It reveals itself in particular in enhanced star formation or even in a strong burst of activity of massive stars often observed in an interacting galaxies. Nevertheless it should be noted that the time scale for the gas to be exhausted in these galaxies is unknown even approximately. To clarify a role of surroundings in the evolution of disk galaxies we should compare the HI content of isolated and non-isolated galaxies otherwise similar by their properties.

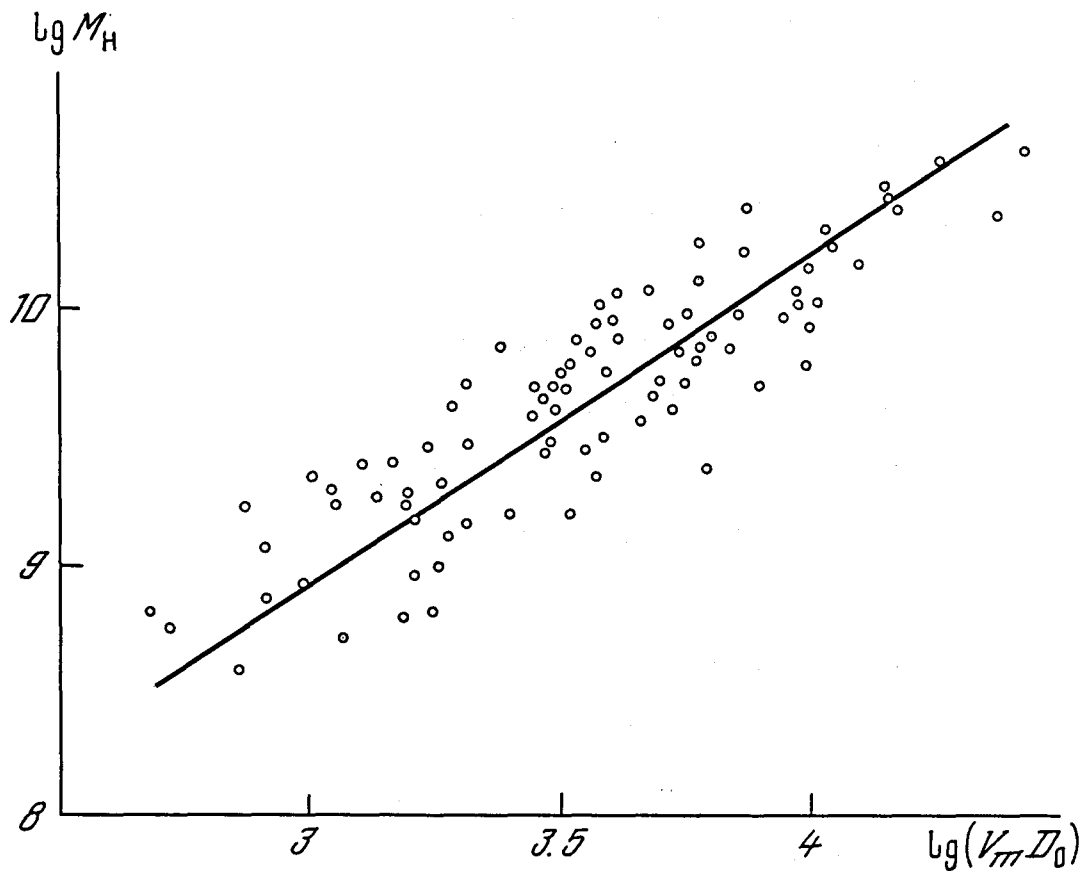
It was claimed elsewhere (see e.g., L. Bottinelli et al., 1982), that the isolated galaxies are probably richer in gas than others of the same morphological type (all references here and below are found in [1,2]). The main problem is to choose the right way to compare galaxies each with other. What should be taken as a "normal" amount of interstellar gas for a galaxy of a given type, mass or diameter?

Usually a mass of gas (or HI) is compared with a galaxy's total luminosity or with the square of its diameter. Mean values of hydrogen mass to luminosity (M_H/L) or to D^2 ratios for a given morphological type are used as reference points. But both of these ratios are characterized by large dispersion (especially

M_H/L) and may in turn depend on other parameters of galaxies, such as velocity of rotation or total luminosity, even within the same morphological type. On the other hand, galaxy morphology is subject to effects of interaction with neighbors which may be a source of systematic error in classification.

The idea we propose is to tie hydrogen mass M_H with kinematical parameters of galaxies, which are practically not subjected to evolution, namely with the specific angular momentum $V_m D_0$. Here V_m is maximal or asymptotic velocity of rotation, measured as half-width of the 21 cm HI line, corrected for inclination; D_0 - corrected optical diameter (according to RC 2-catalogue by G.de Vaucouleurs et al., 1976). The existence of an M_H - D_0 relation was noted by M. Abramian, D. Sedrakian (1985) and earlier--in a slightly different form--by A. Zasov (1974).

Fig. 1 plots the M_H data of a sample of isolated galaxies versus $V_m D_0$. All radio data were taken from M. Haynes and R. Giovanelli (1984). Galaxies of Sbc and later types which have a cosmological redshift $cz > 400$ km/s and a large angle of inclination $i > 45^\circ$ were considered; the Hubble constant was taken to be $H_0 = 75$ km/s/Mpc. A linear dependence stretches for at least two orders of magnitudes. In reality it goes even further. As preliminary results show, the inclusion of clumpy irregulars and blue dwarf galaxies, some of which have very low luminosity, prolongs this line without changing its slope up to four orders of M_H altogether.



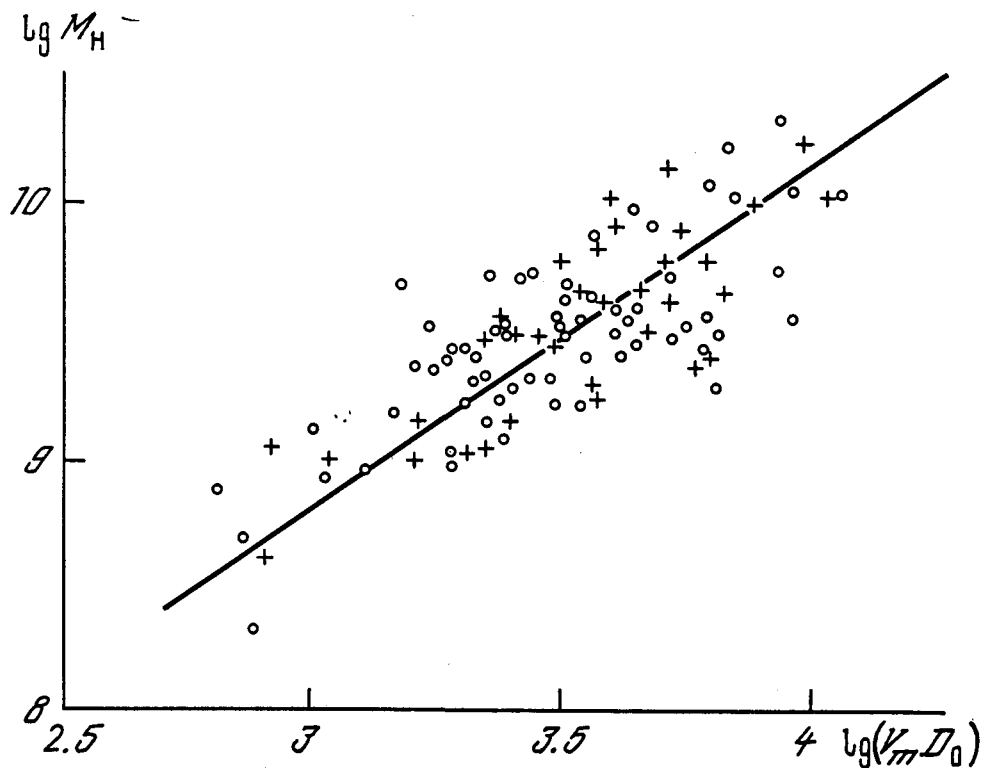
An advantage of the relationship we speak about is that it has a theoretical justification. There is an old idea proposed by W. Quirk (1972) that the local surface density of gas in disk galaxies is determined by a marginal gravitational stability condition of the gaseous layer. In the case of marginal stability a critical value of the surface density of gas is

$$(\Sigma_g)_c = c_s \kappa / \pi G \times f(c_s, \Omega, \Omega') .$$

Here c_s is the sound velocity (or velocity dispersion of gas) which is usually about 10 km/s, κ is the epicyclic frequency,

$f(v, \Omega, \Omega')$ is a function of local kinematical parameters equal to unity for radial perturbations (Goldreich-Lynden-Bell criterion) and is a little less than unity for the more general case, when non-radial perturbations are taken into account (Morozov's criterion).

A qualitative comparison of $(\sigma_g)_c$ with the observed gas density distribution $\sigma_g(r)$ in spiral galaxies have been undertaken by A. Zasov and A. Morozov (1985), A. Zasov and S. Simakov (1988), and R. Kennicutt (preprint, 1989). In all of these papers good agreement is found between these quantities for gas-rich late-type spirals over a large range of radius. The surface density of gas in early-type galaxies is in most cases well below its critical value, so they are not considered.



Here we don't care much about the precise value of $f(v, \Omega, \Omega')$. What is essential for us is that for the fixed c_g the critical gas density should be proportional to $\kappa(r)$, and hence to $\Omega(r)$, or to V_m/r (the shapes of $V(r)$ -curves in galaxies are taken to be flat or at least similar). Then the mass of gas within the optical diameter D_0 , which includes most of the gas in a galaxy, should be equal to

$$M_g \sim 2\pi \int_0^{D_0/2} \kappa(r) dr \sim V_m D_0,$$

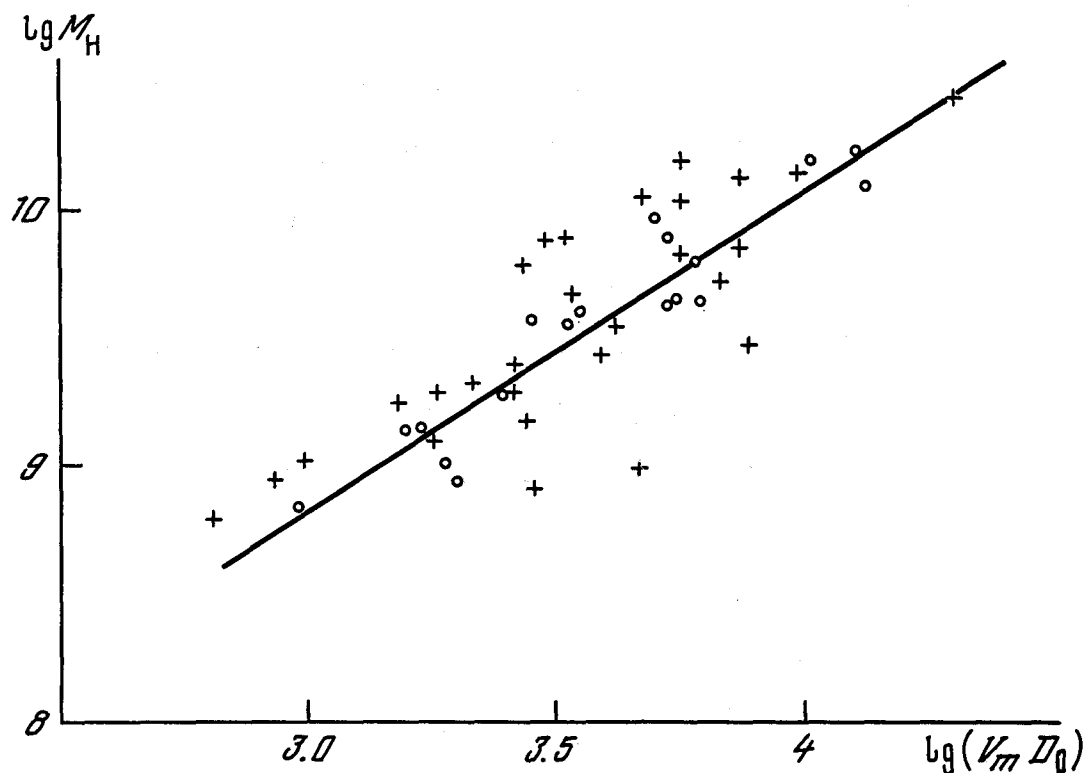
which is the very relation we observe for M_H .

Now we can compare isolated and non-isolated galaxies putting them on the $M_H - V_m D_0$ diagram. Figure 2 plots the data for the sample of the so-called "best observed galaxies" from Bottinelli et al. (1982). This sample includes galaxies with the most accurately determined parameters. Only late-type spirals Sbc-Sd are taken. The regression line in Figure 2 is transferred from a similar diagram for isolated galaxies (see Figure 1). There is no noticeable difference between these galaxies.

The sample of the "best observed galaxies" is not homogeneous by itself: it includes single galaxies as well as galaxies in groups or pairs. Those galaxies which are members of systems or have close companions are marked by crosses. The difference between these two subsamples appears to be negligible: for the same angular momentum the mean $\overline{\Delta \lg M_H} = 0.01 \pm 0.05$.

To compare interacting and non-interacting galaxies in another way we have used HI measurements obtained by Davis and

Seaquist (1983). They have observed interacting galaxies along with the galaxies of Catalogue of Isolated Galaxies by V. Karachentseva. Again we restricted ourselves to late types of galaxies with $i > 45^\circ$. Nearby systems with $cz < 1000$ km/s were excluded. Only those interacting galaxies were considered for which an individual estimates of fluxes and widths of HI line were available. A diagram $M_H - V_m D_0$ for these galaxies is shown in Figure 3 (crosses refer to interacting galaxies).



The mean difference between M_H of interacting and non-interacting galaxies with the same angular momentum appears to be small again: $\overline{\Delta \lg M_H} = 0.05 \pm 0.06$, although the dispersion is probably larger for interacting galaxies.

Thus we come to the conclusion that there are no systematic differences between HI content in isolated and non-isolated late-type galaxies: in spite of the differences of star formation rates their hydrogen mass is determined by slowly evolving kinematic parameters of the disk. Enhanced star formation in interacting galaxies, if it lasts long enough, must have an initial mass function enriched in massive stars in order not to significantly reduce the supply of gas.

Certainly these conclusions are not valid for galaxies which are members of rich clusters such as Virgo or Coma, where HI-deficiency really exists, possibly due to the interaction of interstellar HI with hot intergalactic gas.

The main results of this work were published in the following papers:

(1) A. V. Zasov, T. V. Rubtsova. Letters in Astron. J. (Russian), 1989, v. 15, p. 118.

(2) A. V. Zasov, S. G. Simakov. Astrofizika (in Russian), 1988, v. 29, p. 190.

DISCUSSION

Roberts: Your HI mass versus angular momentum is closely related to the two Tully-Fisher relations, luminosity versus rotational velocity and luminosity versus size (radius). Since HI mass is closely related to luminosity the question arises as to what or which is fundamental among these interrelations. What is your view?

Zasov: I think that the fundamental relation concerning the total mass of gas is the dependence $M_{\text{gas}} \sim V_m D_0$. It has nothing to do with luminosity, so you can't get it from Tully-Fisher relations, but if you take into account the existence of the nearly linear dependence between velocity of rotation V_m and diameter D_0 of galaxies, it is easy to show that a well known approximate constancy of surface gas density stems from this fundamental dependence. So kinematic properties of late-type galaxies appear to be of the greatest importance.