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Neutral Hydrogen Observations and Computer Modelling of the Interacting Galaxies NGC 672–IC 1727

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Summary. A 2.6 × 2.4 arc min aperture synthesis study of the pair of galaxies NGC 672/IC 1727 has been made in the 21 cm emission line of neutral hydrogen. Total masses, hydrogen masses and related parameters have been derived for both objects. Continuum radiation associated with either galaxy has not been found. The observed essential features are strong displacements of H I centroids and velocity perturbations. These features suggest gravitational interaction. Also, less than 3% of the H I mass seems to pertain to a connection between the two galaxies. A computer model of tidal interaction fits the essential features revealed by the observations provided the H I surface density is ring-shaped rather than centrally-condensed.

Key words: galaxies – 21-cm line – interacting galaxies

I. Introduction

NGC 672 is a late type galaxy. It has been classified SBc by de Vaucouleurs et al. (1976) and Sc$^+$ by Holmberg (1958). IC 1727 is a nearby companion classified SBm and Ir I respectively by the same authors.

This system has been classified as interacting system VV 338 according to Vorontsov-Velyaminov (1968). Distances of 11.1 Mpc and 10.8 Mpc to the two galaxies have been determined by Sandage and Tammann (1974) from the size of H II regions. Here we adopt 11 Mpc as the distance to this pair. At 11 Mpc the distance between the centers of the two objects is 25 kpc projected on the sky.

These systems have been observed and included in several surveys, among them the investigation of the neutral hydrogen content of 30 galaxies by Rogstad et al. (1967) and the H I study of 46 Scd galaxies by Shostak (1975). In the optical domain Hodge (1969) has detected numerous H II regions in both objects.

The present study reports on high resolution neutral hydrogen observations of this system. These galaxies are close enough to be jointly in the field of view of the 27 m antennas used in this study and furthermore their optical images indicate some distortions which might be due to gravitational interaction. Therefore, these systems were included in an extragalactic neutral hydrogen survey carried out at the Owens Valley Radio Observatory (OVRO). The main thrust of the paper concerns the apparent detection of a dynamic interaction and its effect on the gas distribution and kinematics of the two galaxies.

The observations are described in Sect. II. The results are presented in Sect. III. Section IV contains a discussion on the total masses and the structure of the system. In Sect. V a model of the tidal interaction between the two galaxies is described and compared with the observations.

II. Observing and Reduction Procedure

The observations were carried out with the two elements interferometer of the OVRO in the 21 cm emission line of neutral hydrogen. The synthesized resolution was 2.6 arc min in the east-west direction and 2.4 arc min in the perpendicular direction (i.e. 8.3 kpc × 7.7 kpc at 11 Mpc). The field of view of the present observations was centered between the two galaxy centers at α (1950.0) = 1 h 45 min 2 s, δ (1950.0) = 27° 07′ 45″. The observing and reduction procedures were similar to those of Shostak (1971) and were described by Weliachew and Gottesman (1973).

A filterbank system of 23 channels each with a half-power width of 21.1 km s^{-1} and each separated by 21.1 km s^{-1} was used. Eight channels (from 168[1] to 231 km s^{-1} and from 569 to 632 km s^{-1}) were employed to provide an estimate of the visibility function of the continuum radiation. Vector subtraction then corrected the other 15 channels for continuum emission.

The observations were made at the OVRO between December, 1970 and September 1971. The interferometer was calibrated in amplitude and phase by frequent observations of the point source 3 C 48, whose flux density was taken to be 15.6 Jy. Because NGC 672 and IC 1727 were not the primary objects in a large observing program, the complete coverage of the Fourier Transform, or UV, plane, was not achieved. Figure 1 shows the coverage actually obtained after 46 hours of observation on this pair of galaxies. Although in Fig. 1, the maximum baselines in the east-west and north-south directions are nearly equal, the beamshape is slightly elliptical due to the fact that the shape of the (U, V) tracks is different along the two main directions.

Due to the incomplete coverage of the visibility plane, the synthesized beam pattern had large sidelobes. The largest ones were 20% of the main response. The effects of these sidelobes were removed by a "cleaning" procedure (Högbom, 1974) after Fourier inversion of the data. Owing to the low relative resolution on the individual channel maps, the source shapes were simple. Therefore, ambiguities due to sidelobes were very rare. These problems of confusion were examined in the manner described for the concomitant observations of M 82 (Gottesman and Weliachew, 1977) and NGC 253 (Combes et al., 1977). The effect of residual sidelobes after the cleaning procedure is lower than 5% of the source maxima on the single channel maps. This limit was easily estimated because

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1 All velocities are relative to the Sun

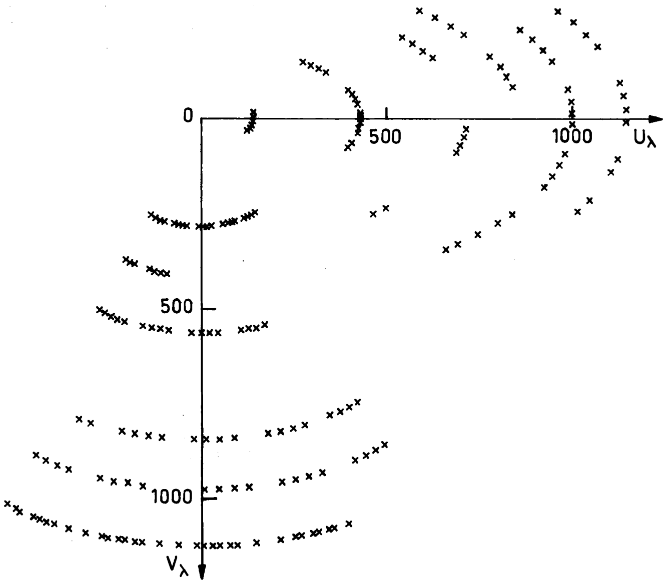

Fig. 1. Coverage of the *UV* plane of the present observations

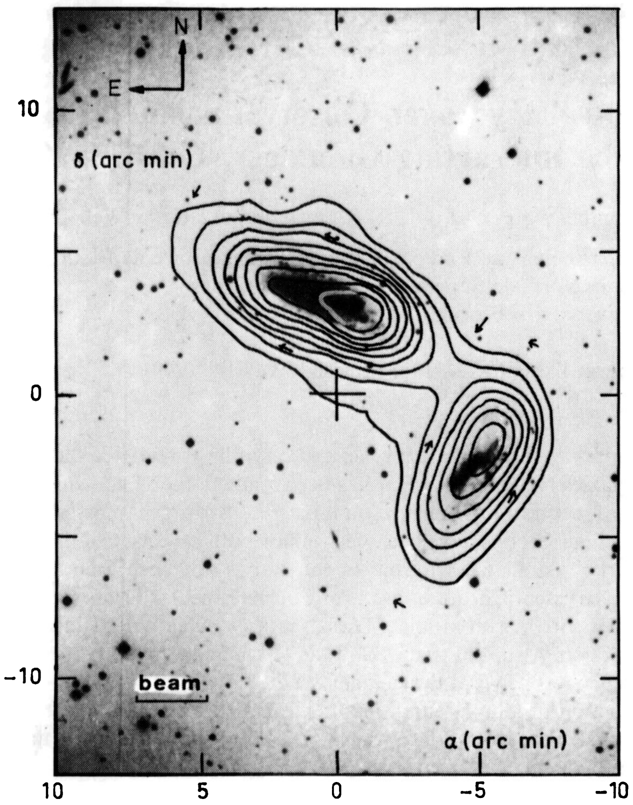

Fig. 3. Integrated H I map superposed on a blue print of the Palomar Sky Survey. Arrows show Holmberg dimensions. The cross shows the center of the field of view. One contour unit represents 2.1 10^{20} at cm^{-2} in the line of sight

the sources have rather simple structures on individual channel maps.

The final result of the reduction procedure was a set of fifteen single channel maps of line brightness temperature free of continuum radiation.

The channels range in velocity from 252 km s^{-1} to 548 km s^{-1}. These maps were restored for the primary beam pattern of the 27 m dishes. However this correction affects the signal-to-noise ratio on the maps. The *rms* uncertainties were estimated to be 0.6 K at the map center from regions of the maps showing no signal. This standard error takes random noise and ambiguities in the cleaning procedure into account. Owing to the main beam restoration the errors are higher away from the center (0.8 K r.m.s. at 10 arc min from the center of the field).

III. Results

A. Hydrogen Distribution

Figure 2 shows a sample of four single channel maps. The extreme line frequencies show a maximum brightness temperature of 3 K (252 km s^{-1}) and 1 K (548 km s^{-1}). The temperature in the single channel maps reaches a maximum of 15 K at 358 km s^{-1}. At three velocities (337, 358, 379 km s^{-1}) a connection is clearly seen between the two galaxies (see Fig. 2). In Fig. 3 the sum of the single channel maps is superposed on a reproduction of the blue print of the Palomar Sky Survey. Assuming a low optical depth, this map represents the beam smoothed H I column density projected on the sky. This summation of the fifteen single channel maps showing line radiation has been made applying a cut-off equal to the 1.5 r.m.s. uncertainty on the individual maps. The resulting un-

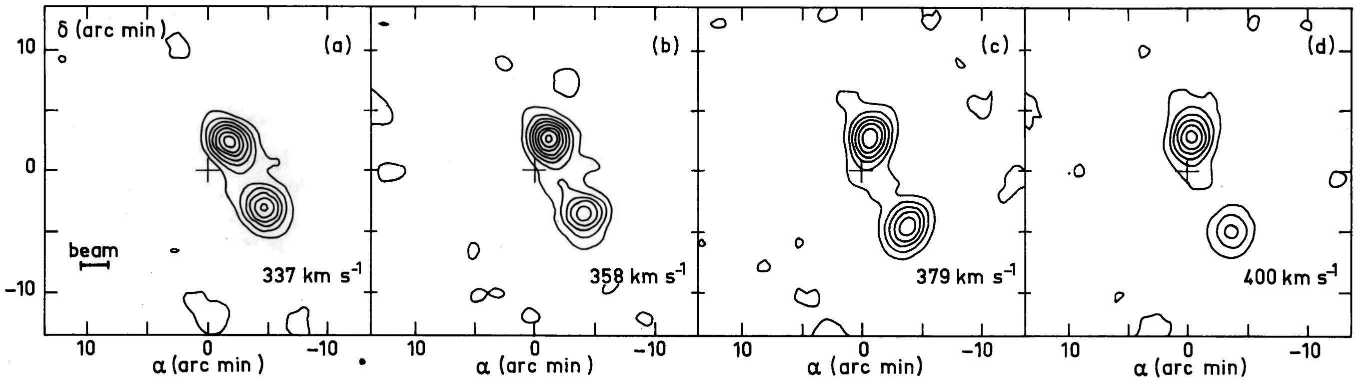

Fig. 2. Sample of four single channel maps at 337, 358, 379, 400 km s^{-1}. The field center was taken at $\alpha_{1950.0} = +01$ h 45 min 02 s and $\delta_{1950.0} = 27°07'45''$ and is shown by a cross on the figures. The contour unit is 2 K. The lowest contour level is 1 K

Table 1. Integral properties of NGC 672 and IC 1727

Parameters	NGC 672	IC 1727
α 1950[a]	$01^{h}\,45^{min}\,05.2^{s}$	$01^{h}\,44^{min}\,41.0^{s}$
δ 1950[a]	27° 11′ 07″	27° 05′ 06″
Morphological type	SBc 2[b] Sc^{+} 3[c]	SBm 2[b] IrI 3[c]
Adopted distance[d] (Mpc)	11	11
Inclination	67°	72°
Holmberg dimensions[c]	11′.3 × 4′.1	10′.2 × 3′.4
Luminosity L[e] ($10^{9}\,L_{pg\odot}$)	8.6	3.6
$M_{\mathrm{H_I}}$ ($10^{9}\,M_{\odot}$)	3.4	1.6
Total masses M_{T}[f] ($10^{9}\,M_{\odot}$)	38	20
$M_{\mathrm{H_I}}$ /Total mass[f]	0.09	0.08
M_{H} /L ($M_{\odot}/L_{\odot}$)	0.40	0.44
$M_{T}^{f}/L(M_{\odot}/L_{\odot})$	4.4	5.6
Systemic velocity/⊙	428 km s^{-1}	333 km s^{-1}

[a] Galloüet et al. (1973)
[b] G. de Vaucouleurs et al. (1976)
[c] E. Holmberg (1958)
[d] Sandage, A., Tammann, G.A. (1974)
[e] Corrected for galactic and internal absorption according to Sandage and Tammann (1974)
[f] See Table 3

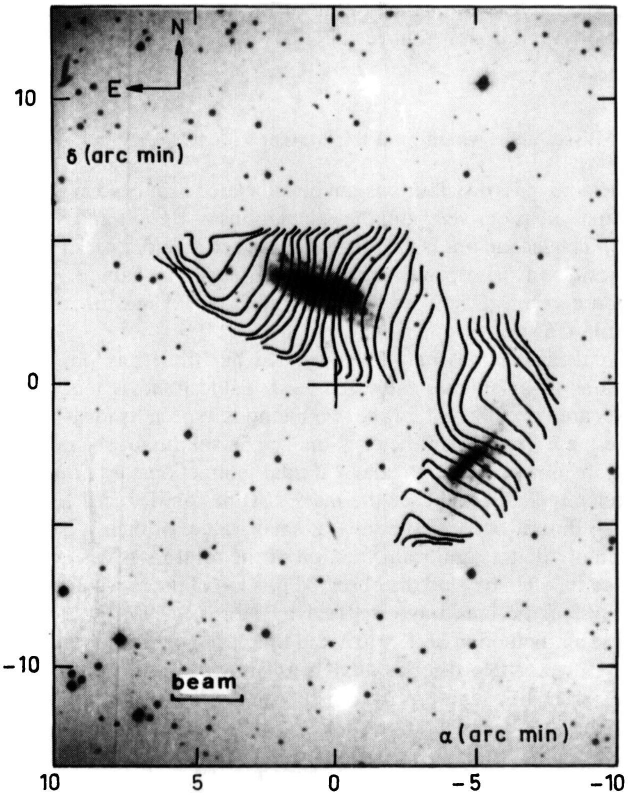

Fig. 4. Velocity field map superposed on the Palomar Sky Survey photograph, Contour values are indicated in Fig. 5. The cross shows the center of the field of view

certainty on the integrated map is 36 K km s^{-1} or 7.0 10^{19} at cm^{-2} in the line of sight when 10 channels have been integrated and 9 10^{19} at cm^{-2} when 15 channels have been taken. Due to the cut-off applied to the single channel maps the number of channels integrated varies from point to point.

For the system of the two galaxies an hydrogen mass of 5 $10^{9}\,M_{\odot}$ was found. The observed neutral gas of both galaxies lies within the Holmberg dimensions, listed in Table 1. The position angles of the H I distribution differ by less than 10° from the optical values. The only conspicuous difference between the H I and optical images is the significant shift of the H I peaks relative to the optical centers of symmetry. Indeed this displacement is 4.5 kpc and 3.5 kpc relative to the optical centers as determined by Gallouett et al. (1973). Small displacements of this kind occur quite frequently but in the present case they amount to 25 % of the Holmberg radius, a considerable effect. Although the connection or bridge between the two galaxies is more visible on individual maps (at 316, 337, 358, 379 km s^{-1}), it is also visible on the integrated map of Fig. 3.

The hydrogen mass of each galaxy was computed within the lowest contour level in Fig. 3. This contour was roughly interpolated in the region between the two galaxies. We have considered all hydrogen external to this interpolated contour as pertaining to the bridge. This procedure does not lead to a significant error on the hydrogen masses of either galaxy. However, the estimate of the bridge mass may be in error by a factor of 2. In this way, hydrogen masses of 3.4 $10^{9}\,M_{\odot}$ and 1.6 $10^{9}\,M_{\odot}$ were found for NGC 672, IC 1727 respectively. Less than 3 % of the total hydrogen mass inside the whole system pertains to the bridge. No correction for inclination of galaxies has been applied to the hydrogen masses (Shostak, 1975).

A point source of 0.07 Jy intensity was detected in the 21 cm continuum. This source is situated 3′.2 north and 4′.2 east with respect to the center of the field. It does not appear to be associated with NGC 672 or IC 1727. The r.m.s. fluctuation of the continuum map is 0.2 K. No continuum radiation associated with either galaxy was found within this uncertainty.

B. *Velocity Field*

The determination of the radial velocity field is not simple because the observations give information about both the distribution and the kinematics of neutral hydrogen. Therefore, a velocity field model was built and will be described in the next section.

A first approximation to the velocity distribution is given by the profile center of gravity at each point on the sky. This "observed" velocity field is shown in Fig. 4 superposed on the blue Palomar Sky Survey photograph. Several striking kinematical features are apparent.

1. The velocity gradient in the optically visible part is roughly symmetrical in the central region of each galaxy and these central regions show no evidence for non-circular motion for the inner velocity curves are parallel to the minor axis.

2. The symmetry axis of the optical objects and of related velocity fields appear slightly different.

3. The isovelocity curve corresponding to the systemic velocity is shifted relative to the H I maxima, but it goes through the optical center of NGC 672. The "observed" systemic velocities are 425 km s^{-1} and 330 km s^{-1} respectively for NGC 672 and IC 1727. These values are close to the optical values (412, 362 km s^{-1}) quoted by de Vaucouleurs et al. (1976). The actual systemic velocity will be slightly different and must be refined by a model-fitting procedure. Indeed the "observed" systemic velocity is the mean of the central velocities weighted by the H I density across the beam pattern.

Table 2. Parameters of the model velocity field fitted to the data

	$n^\star$	$V^\star_{max}$ (km s^{-1})	$R^\star_{max}$ (arc min)	V_{Syst} (km s^{-1})	Major axis position angle (degree)	Inclination of galaxy on sky plane (degree)
NGC 672	2	110	5	428	72	67
IC 1727	0.5	70	5.5	333	150	72

$\star$ n, V_{max}, R_{max} are parameters from the Brandt and Scheer (1965) model rotation curve

The east feature of NGC 672 reveals a perturbation opposite to IC 1727 in the distortion of the isodensity curves.

C. Model Fitting for the Velocity Field

The velocity field was estimated using the method described by Weliachew and Gottesman (1973). In this method the beam shape is convolved with models of the hydrogen distribution and the velocity field. We have modified the original procedure in order to take into account the fact that the two galaxies are located in the field of view close to each other. The hydrogen distribution used in this model calculation was derived from the observed distribution by the deconvolution procedure of Bracewell and Roberts (1954). When calculating the model velocity field, a point in the sky was arbitrarily assigned to the galaxy whose center was on the same side of the perpendicular to the middle of the line joining the two galaxy centers. This criterion is consistent with the criterion used in separating the H I pertaining to either galaxy (see Sect. III A). The actual velocity field was found by using the model fitting procedure in two different ways. First, by an iterative method using the observed velocities on the major axis as a first guess for the rotation curve. Second, using the family of curves prepared by Brandt and Scheer (1965). The fit obtained is equally good for both methods. Table 2 shows the best fit for Brandt rotation curves. The result of the fit is shown in Fig. 5.

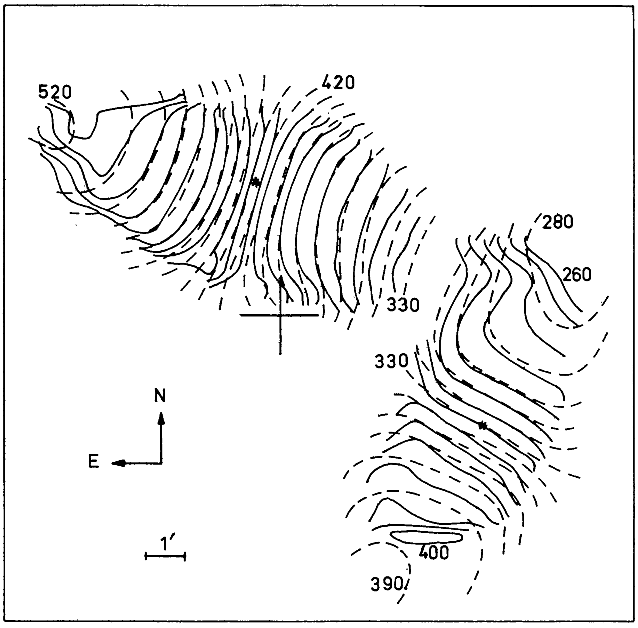

Fig. 5. Velocity model fitting using the Brandt and Scheer rotation curves (dotted line) superposed on the observed velocity field (full line). The cross shows the center of the field of view

Table 3. Masses adopted for NGC 672 and IC 1727 (in units of 10^9 $M_\odot$)

Galaxies	Masses inside a 5′ radius		Total masses extrapolated to infinite radius	
	Brandt Method	Nordsieck Method	Brandt Method	Nordsieck Method
NGC 672	36	28	83	38
IC 1727	16.5	16	230	20

IV. Masses and Dynamics of the System

Masses and mass distributions can be calculated using two methods. The first one is derived from the calculations of Brandt and Scheer (1965). The second one is the method described by Nordsieck (1973). The results of these computations are displayed in Table 3. There is good agreement between these two methods for masses inside a 5′ radius (16 kpc).

Total masses also may be calculated but these rely on extrapolations to an infinite radius. Indeed, Table 3 shows that these masses are very different for the two methods, especially for IC 1727 where the n Brandt parameter is small. The validity of such extrapolations is doubtful particularly if tidal interactions have affected the velocity field and hence the mass distribution deduced.

The Brandt curves, especially at small values of their n parameter, imply that a significant fraction of the total mass lies at very large radii, often beyond the observed portion of the rotation curve. This systematic bias was discussed by Nordsieck (1973) and we will use his method in Sect. V to avoid this strong radial dependence on n. However, Nordsieck's models assume a constant M/L ratio in the outer disk region; this may be equally unrealistic.

Using these observations and models, global relationships involving the mass, luminosity and hydrogen content of these systems can be calculated. These parameters and others of interest are given in Table 1 and are comparable to the results of Balkowski (1973) and Roberts (1975) for similar galactic types.

An estimate of the binding of this pair of galaxies can be made if we calculate the masses just sufficient to close the system

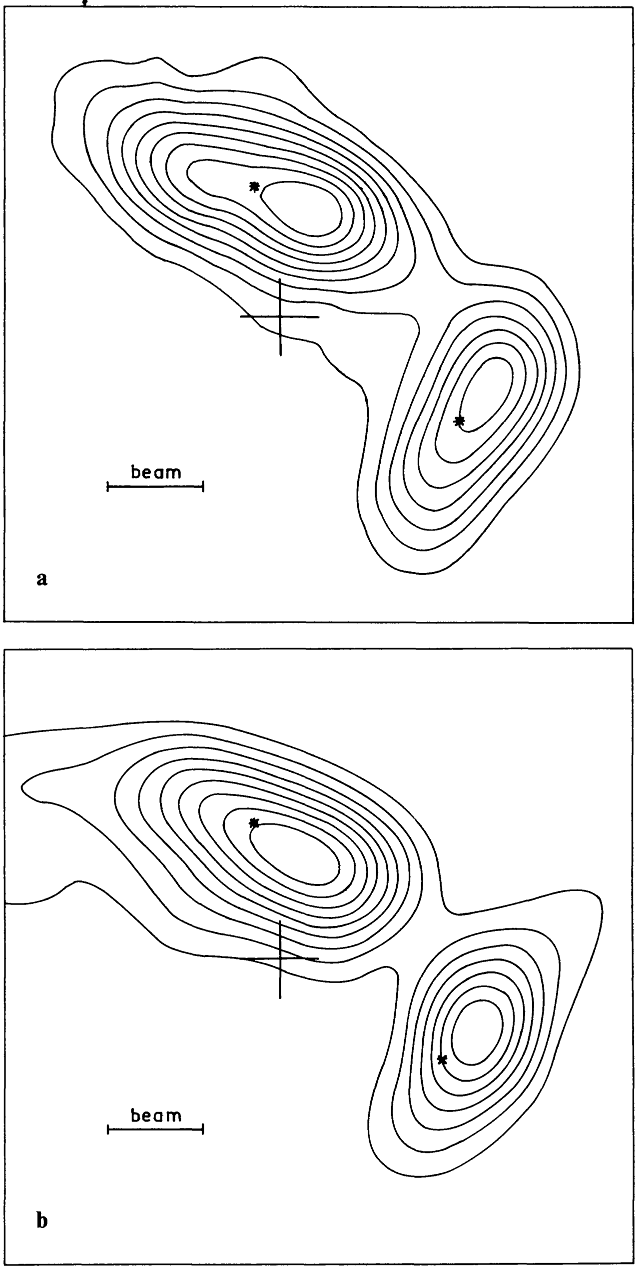

Fig. 6a. Isophotes of the integrated H I map. One contour unit represents 2.1 10^{20} at cm^{-2} in the line of sight; the field center is indicated by a cross $2' \times 2'$ long. **b** Same as **a** for our tidal interaction model

(parabolic orbits). This condition is given by:

$$V \leqq \left(\frac{2G(M_{672}+M_{1727})}{r}\right)^{1/2}$$

where V is the relative orbital velocity between the two galaxies and r the distance between their centers. Assuming $M_{672} \sim 2M_{1727}$ following the results of Table 3 (Nordsieck's method), this yields:

$M_{672} \geqq 20\ 10^9\ M_\odot$

$M_{1727} \geqq 10\ 10^9\ M_\odot$

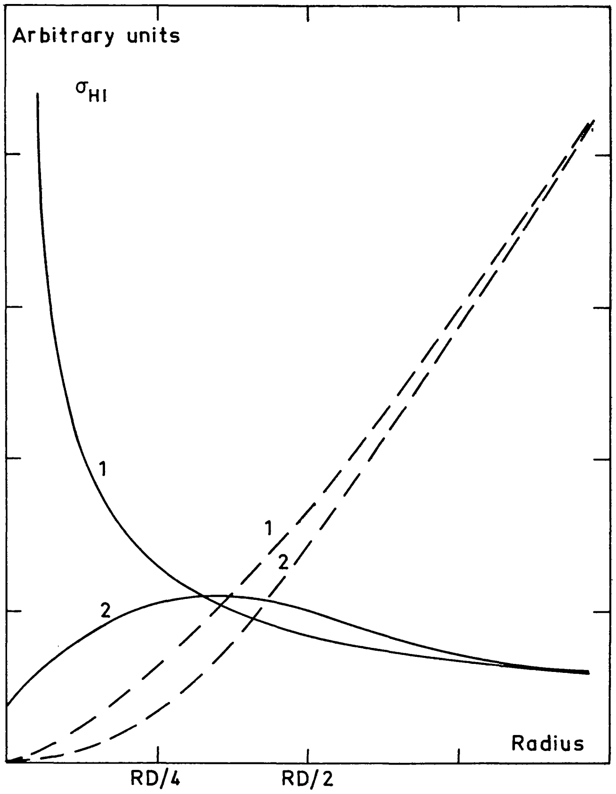

Fig. 7. Radial distribution of the H I surface densities used in our different models:
1) $\sigma \sim R^{-0.6}$
2) $\sigma \sim R^{-0.6} \sin^2(\pi R/RD) \exp(-2R/RD) + 0.3$

Dashed lines represent corresponding H I masses contained within a radius R

These numbers are close to the masses found (Table 3). Hence the system is probably bound unless projection effects on the relative separation and velocity are extremely large.

V. A Model Simulating the Tidal Interaction

We have attempted to interpret the morphology and dynamics of the neutral gas of this galaxy pair. The small projected distance between the two objects suggest a large gravitational interaction between them.

Our numerical model is based on the restricted three-body problem, since many geometrical and kinematical features of tidal interactions are reproduced by such a simple model (see e.g. Toomre and Toomre, 1972). We will not describe in detail the model, which is already presented by Combes (1978) but only the modifications that we have done to simulate this particular pair of galaxies (NGC 672 – IC 1727). Indeed, the H I observations do not show any spectacular tidal features in the outer parts of the galaxies (no tails or counter-arms) but the perturbation mainly concerns the center of each galaxy: the H I isophotes are highly asymmetric in that the center of gravity of the neutral gas is exceptionally displaced towards the companion, for both galaxies. This feature, together with the isovelocity contour disturbances, must be reproduced by the tidal model; it was thus felt necessary to introduce test-particles in the centre of the galaxies and not only at their periphery. More-

Table 4. Parameters of the model for tidal interaction
Elliptical Passage: $e=0.8$

	i'	ω	λ	i	PA	*nb* of particles	RD	n	A	M_T ($M_\odot$)
NGC 672	−24.0	50.0	117.0	247.0	72.0	1065	6′.04	4	3′.02	$4\ 10^{10}$
IC 1727	48.1	−169.9	50.8	265.0	140.0	500	3′.02	4	3′.40	$2\ 10^{10}$

i' inclination of the orbit plane of the companion relative to the spin plane
ω pericenter argument of the companion galaxy
λ viewing longitude in the sense of Toomre and Toomre (1972)
PA position angle of galaxy
RD extreme radius of the H I extent (before interaction)
A radial scale height of the total mass distribution (see Eq. 1)
n parameter of the mass function (see Eq. 1)

Minimal distance of approach $Q=3'.77=12.1$ kpc
Elapsed time since this minimal distance was reached: $3.1\ 10^8$ yr

over, if the true H I distribution is simulated, it is then possible to present the results of the model calculation in a form easily comparable to observations, i.e. isophotes and isovelocity contours.

H I *Distribution*

The observed hydrogen map (Fig. 6a) suggests a centrally peaked gas distribution, but since the H I beam is large relative to the galaxy sizes, this apparent centrally peaked distribution can be only an artifact of the resolution. Indeed, when deconvolved with the Bracewell and Roberts technique (1954) the H I map displays two peaks for NGC 672, as if there were an H I ring around the center. This deconvolution technique does not prove that this ring is real, it merely shows that this kind of distribution is compatible with the observations. From the observations only and with the present resolution it cannot be determined whether or not there is hydrogen in the center of galaxies. It should be noted here that in many galaxies observed in neutral hydrogen, there is a gas deficiency in the center.

We have thus tried to simulate two different kinds of H I distribution, both compatible with the observations and shown in Fig. 7. One such surface density law was similar in shape to the observed H I distribution (Fig. 6a), the other was simulating a ring of H I surface density.

Gravitational Potential

We have not used an extended component, or "halo", to fit the rotation curves of NGC 672 and IC 1727, since the observed rotation curves are not flat. In other words the observed hydrogen is all contained within the radius ($r_{\max}$) at which the rotational velocity is maximum. For the purpose of this model calculation a satisfactory representation of the total mass distribution was given by the following spherically symmetric function.

$$M(R)=M_{\mathrm{tot}}\frac{R^n}{R^n+A^n} \qquad (1)$$

where M_{tot} and A are respectively the total mass and radial scale length of the mass distribution. Half of the total mass is contained in a radius A. A and n have been adjusted to fit the observed rotation curve.

Geometrical Orbits

Since the H I map (Fig. 6a) does not appear very perturbed by the interaction in the outer regions of the galaxies, one can wonder whether the passage of the galaxies around each other is retrograde or direct, and whether the galaxies have interacted for a long time since their minimal distance of approach. We have tried both direct and retrograde passages, allowing an interaction time of the order of one galactic rotation or much less. The interaction was not strong enough in any retrograde passage to simulate the essential feature of the observations, i.e. the displacement of the hydrogen centroids towards each other. Even with a direct passage, the galaxies have to interact during at least $3\ 10^8$ yr to shows such a displacement.

All the parameters of the model giving the best fit to the observations are displayed in Table 4.

Discussion

Our model reproduces the essential features seen in the H I observations i.e. the displacement of the neutral gas centroid relative to the optical center for both galaxies, and the perturbation in the isovelocity contours in the north-east of NGC 672; this perturbation suggests a warping of the plane of this galaxy. Also the present model, in spite of the strength of the interaction, does not produce spectacular extensions of neutral gas, tails or counterarms, which is again consistent with the observations.

This interactive pattern (strong effect in the central rather than peripheral parts of galaxies) is easily explained by several properties of this pair of galaxies and by resolution effects. Indeed, for both NGC 672 and IC 1727, the neutral hydrogen has a small extension relative to that of the total mass. In other words the observed rotation curve is close to solid body rotation at all radii where H I is observed; this favors a central perturbation of the galaxies by their companion, since the less centrally condensed total masses yield less self attraction within each galaxy. Further the large beam size smoothes out the small features that could have formed in the outer parts of the galaxies, where only a small fraction of the neutral gas is involved. To illustrate this point, the result of our model before the convolution by the synthesized beam is plotted in Fig. 8b. Convolution of this picture by the synthesized beam does not show much perturbation due to the absence of long extended features.

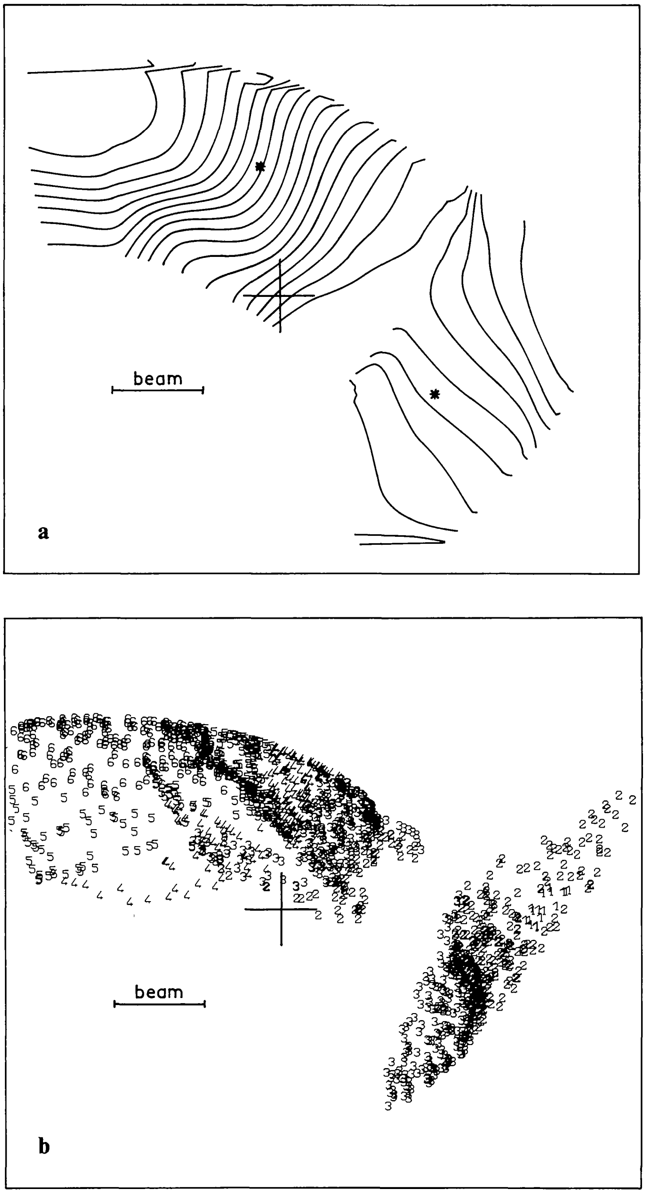

Fig. 8a. Isovelocity contours obtained from the model for the pair of galaxies (to be compared with the observed velocity field in Fig. 5). **b** Particle plot from our tidal model of the two galaxies NGC 672 and IC 1727. The minimal distance of approach between the galaxies was reached 3 10^8 yr ago. The passage is elliptical ($e=0.8$)

Each particle is represented by a number which gives its velocity according to the following:

9 $622.9\ \mathrm{km\,s^{-1}} \leqq V$
8 $574.2\ \mathrm{km\,s^{-1}} \leqq V < 622.9\ \mathrm{km\,s^{-1}}$
7 $525.4\ \mathrm{km\,s^{-1}} \leqq V < 574.2\ \mathrm{km\,s^{-1}}$
6 $476.7\ \mathrm{km\,s^{-1}} \leqq V < 525.4\ \mathrm{km\,s^{-1}}$
5 $428\ \mathrm{km\,s^{-1}} \leqq V < 476.7\ \mathrm{km\,s^{-1}}$
4 $379.3\ \mathrm{km\,s^{-1}} \leqq V < 428\ \mathrm{km\,s^{-1}}$
3 $330.6\ \mathrm{km\,s^{-1}} \leqq V < 379.3\ \mathrm{km\,s^{-1}}$
2 $281.8\ \mathrm{km\,s^{-1}} \leqq V < 330.6\ \mathrm{km\,s^{-1}}$
1 $233.1\ \mathrm{km\,s^{-1}} \leqq V < 281.8\ \mathrm{km\,s^{-1}}$
0 $V < 233.1\ \mathrm{km\,s^{-1}}$

The H I radial distribution for both galaxies has turned out to be a very critical parameter of the model. For our first model, which was centrally peaked, no displacement of neutral hydrogen centroids was obtained; this is easily explained, since tidal forces act much more on extended objects. With our second model, where the maximal H I surface density occurs inside a ring, the required H I displacement never obtains if the maximum is too close to the center. Also, if the maximum is too remote from the center, the H I density is too high in the outer parts of the galaxies which yields too much perturbation on the outside. The upper limit to the ring density contrast relative to the center and outer parts of the H I distribution is set by the fact that no irregularity must be visible in the convolved map. Therefore, the tidal interaction model allows the precise determination of the true H I distribution: the centers are definitely deficient in neutral hydrogen by a factor of 2–3 relative to the maximum density, which occurs in both galaxies at a radius a little smaller than half the total H I extent (Fig. 7).

From the observations, the system is almost certainly bound (see Sect. IV), and the orbital eccentricity cannot be greater than 1.0. For the best fit presented in Figs. 6b and 8, we have chosen an elliptical passage with eccentricity $e=0.8$; this parameter is not very critical and a parabolic passage might also have been possible. At any rate, the eccentricity of the orbit is likely to vary throughout the encounter, since energy from orbital motion is lost to internal motions and perturbations in each galaxy. Then, the choice of an elliptic orbit does not mean that the two galaxies have already encountered each other but at least that future encounters are to be expected.

Is the perturbation of the isovelocity contours at the north-east of NGC 672 due to a warp of the plane of this galaxy? A model has the advantage that one can change the point of view of the observer. We have inclined NGC 672 to make an edge-on view of it: in this projection, there are a few particles *under* the plane of NGC 672 in the nord-east region, which were pulled out by the companion, but the isovelocity contours are regular and not distorted upward. This suggests that, in the actual view, the velocities are weighted by the hydrogen concentration of a spiral arm essentially lying in the plane. This arm is formed by the interaction modelled here. The observed H I map could also contain the same bias, since a spiral arm is seen in the same position and orientation in the optical picture. Hence, this model does not lead to an actual warp of the plane of NGC 672. The velocity distortions seen in the observations and reproduced by the model rather appear as an artifact of geometry and resolution.

VI. Conclusion

The present observations of the galaxies NGC 672 and IC 1727 essentially show distortions of the hydrogen distribution of both galaxies in their central parts. Also the isovelocity contours of NGC 672 appear disturbed on one side of that galaxy. These features are reproduced by a tidal interaction model between the two galaxies.

To obtain these features, the interaction between the two galaxies must be strong: short minimal distance of approach, direct passage with small inclination, small pericenter argument (the pericenter argument $\omega=0°$ means that the closest approach occurs at the same time as the passage across the plane of the victim galaxy) and relatively large duration of the interaction (about one rotation for the galaxy NGC 672).

This strong interaction however, does not perturb too much the outer parts of the galaxies, and this may be due to the relatively small H I extent. Also the low relative resolution smoothes out all small features.

A strong interaction seems in agreement with the relatively large perturbations that can be seen in photographs of the galaxy IC 1727, since the star component is more difficult to perturb than the gas.

Our model, not only reproduces the observations, but also allows the determination of the H I radial distribution: the latter is not centrally peaked as suggested by the convolved H I map, but consists of a ring around a gas deficient center.

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