

THE NONINTERACTING SPIRAL PAIR, NGC 450/UGC 807

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ABSTRACT

We have obtained rotation curves for the spiral galaxies NGC 450 and UGC 807 which appear as a close pair on the sky. From the shapes and amplitudes of the rotation curves we conclude that the two galaxies are widely separate in space with each galaxy at its Hubble distance. The systemic velocity of UGC 807 relative to the Local Group is $V_{LG} = 11,587 \text{ km s}^{-1}$; that of NGC 450 is only $V_{LG} = 1863 \text{ km s}^{-1}$. If UGC 807 were located as nearby as NGC 450, then it would have to be of extreme low luminosity ($M_B = -17$), with a predicted rotational velocity of $V_{rot} = 75 \text{ km s}^{-1}$, whereas we observe $V_{rot} = 211 \text{ km s}^{-1}$. Therefore, a nearby location is contradicted both by the morphology and by the observed rotational velocity. We conclude that the optical pair NGC 450/UGC 807 cannot properly be used as evidence for noncosmological redshifts.

Subject headings: galaxies: individual — galaxies: internal motions — galaxies: redshifts

I. INTRODUCTION

In recent papers, Arp (1980*b*, 1982*a*, *b*) has discussed M51-type galaxy pairs. Arp believes that the galaxies in these pairs are physically associated, even in cases where the difference between the systemic velocities of the two galaxies in each pair is large. An additional galaxy pair, NGC 450/UGC 807, has been identified by Arp to us (1980*a*; see also Arp 1982*b*) as one of the best cases in which the apparently interacting galaxies are each a well-defined spiral.

To investigate the possible association, we have measured the rotation curves of NGC 450 and UGC 807. We conclude:

1. The two galaxies are widely separated in space, with each galaxy at its Hubble distance. The systemic velocity of UGC 807 is $V_{LG} = 11,587 \text{ km s}^{-1}$, compared with only $V_{LG} = 1863 \text{ km s}^{-1}$ for NGC 450. This conclusion follows from the shapes and amplitudes of the rotation curves, which are sensitive to the galaxy mass distribution, and hence luminosity.

2. The shapes for both rotation curves are normal for isolated galaxies and exhibit none of the features observed in tidally interacting galaxies.

Hence there is no dynamical evidence for interaction of the two spirals. The details of the observations and analysis are discussed below.

II. OBSERVATIONS

A print of the NGC 450/UGC 807 pair, kindly made available by Arp, is shown in Figure 1. NGC 450 is a

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knotty-armed Sc spiral, viewed at an inclination of $36^\circ \pm 8^\circ$ to the line of sight. Its angular extent on the sky is 3.2×2.8 . Northeast of the nucleus, several giant H II regions are located near the line of sight to the Sb galaxy, UGC 807. The prominence of these knots was originally cited by Arp (1980*a*; see also Arp 1982) as evidence of the interaction.

UGC 807 subtends 1.1×0.5 on the sky, so its diameter is only about one-third that of NGC 450. Viewed at an angle of $65^\circ \pm 5^\circ$, it resembles a miniature M31. At the outset of our observing program, the systemic velocity of UGC 807 was unknown. On the sky, the centers of NGC 450 and UGC 807 are separated by about $80''$.

Long-slit spectra of the NGC 450/UGC 807 pair were obtained with the Ritchey-Chrétien spectrograph plus Carnegie two-stage image tube at the KPNO 4 m telescope. A record of the observations is given in Table 1. Velocities from H α emission lines on the plates were measured with a Mann two-dimensional measuring machine. Night sky OH lines crossing the plate served to define the wavelength scale and to map the geometrical distortions. Accurate OH wavelengths come from Brault and Hubbard (1981). For this observing run only, we used the Simmons spectrograph camera. Both the red response and the resolution were poorer than with the usual Singer camera. Even so, the forward and reverse measures at each point have a mean separation of only 16 km s^{-1} . The velocities on Figures 2 and 3 indicate a total scatter from two plates somewhat in excess of this.

Measured velocities from H α are listed in Table 2. For NGC 450, a central heliocentric velocity of $V = 1770 \pm 15 \text{ km s}^{-1}$ is adopted from the symmetry of the NE and SW rotation velocities. This corresponds to $V_{LG} = 1863 \text{ km s}^{-1}$ corrected for a solar motion of

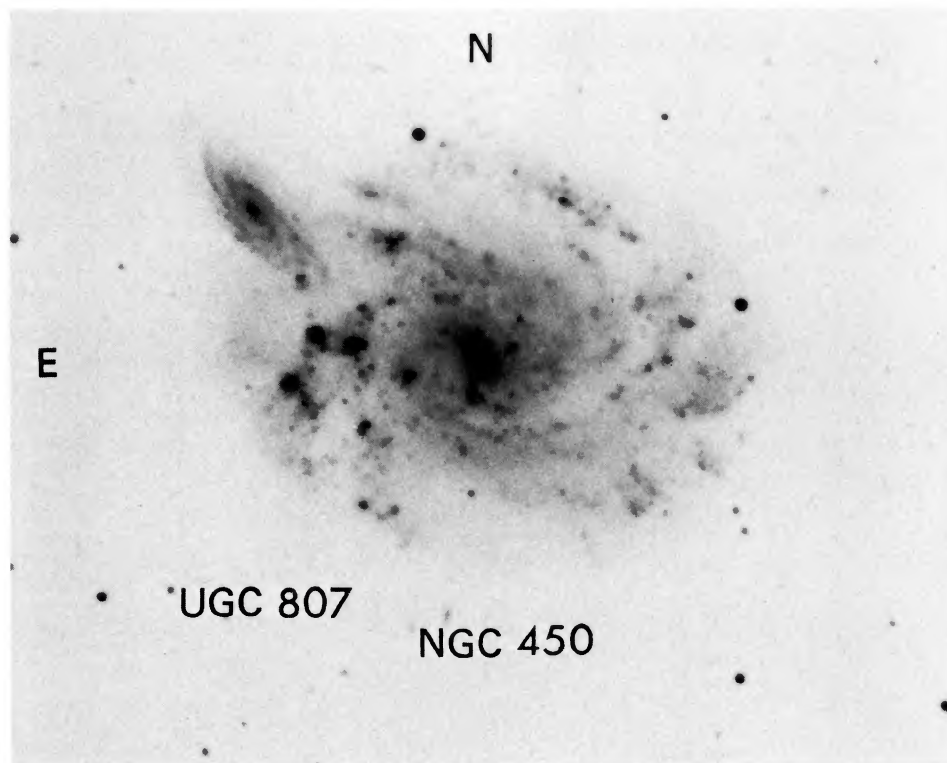


FIG. 1.—NGC 450 with UGC 807 to its NE, from a plate taken with the 4 m telescope and kindly made available by Dr. Arp. The separation of the nuclei of NGC 450 and UGC 807 is about $80''$.

TABLE 1
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Plate	Date (1980)	PA (deg)	Exposure (min)	Dispersion (\AA mm^{-1})	Locations
1804	Nov 12	82.4	136	22	NGC 450 major axis
1808	Nov 13	40.	130	44	UGC 807 major; NGC 450 SW
1813	Nov 14	40.	131	44	UGC 807 major; NGC 450 SW

$\Delta V = 300 \cos b \sin l$. With $H = 50 \text{ km s}^{-1} \text{ Mpc}^{-1}$ (adopted throughout), the distance is 37 Mpc. At this distance, $1'' = 181 \text{ pc}$. Tift (1982) reports $V_{\text{LG}} = 1841 \pm 50 \text{ km s}^{-1}$ from absorption lines. Velocities reflected about $V_{\text{LG}} = 1863 \text{ km s}^{-1}$ and deprojected into the plane of the galaxy, and the adopted hand-drawn rotation curve, are plotted in Figure 2. The principal uncertainty in the rotation curve arises from the small inclination of the galaxy, $i = 36^\circ$. Variations in the adopted viewing angle produce the changes indicated in the figure.

For UGC 807, heliocentric velocities are symmetrical about $V = 11,498 \text{ km s}^{-1}$ (plate 1808) and $V = 11,480 \text{ km s}^{-1}$ (plate 1813). A central velocity of $V = 11,489 \pm 15 \text{ km s}^{-1}$ is adopted. This corresponds to

$V_{\text{LG}} = 11,587 \text{ km s}^{-1}$ and a distance of 232 Mpc. Here $1'' = 1.12 \text{ kpc}$. Tift's (1982) velocity, $V_{\text{LG}} = 11,352 \pm 50 \text{ km s}^{-1}$, is in poor agreement. The observed velocities, reflected about the velocity of symmetry and deprojected into the plane, are plotted in Figure 3, along with the adopted rotation curves. The adopted curve is a hand-drawn curve through the measured velocities. The viewing angle of UGC 807 is sufficiently high, $i = 65^\circ$, so that the rotation velocity is relatively insensitive to the adopted inclination.

The corrected angular diameters and apparent magnitudes adopted for NGC 450 and UGC 807 are listed in Table 3. No published magnitude is available for UGC 807. Its magnitude is estimated from its surface area, assuming a mean surface brightness equal to that of

TABLE 2
MEASURED HELIOCENTRIC VELOCITIES IN NGC 450 AND UGC 807

y (arcsec)	V (km s ⁻¹)	y (arcsec)	V (km s ⁻¹)	y (arcsec)	V (km s ⁻¹)
NGC 450 Plate 1804, PA = 82°4		NGC 450 Plate 1808, PA = 40° (<i>cont.</i>)		UGC 807 Plate 1808, PA = 40° (<i>cont.</i>)	
NE -54.3	1678	94.0	1740	-2.0	11404
-51.0	1690	95.8	1742	-0.6	11428
-50.7	1683	98.2	1773	-0.2	11472
-46.8	1693	Plate 1813, PA = 40°		+1.6	11583
-42.1	1688			+1.8	11566
-40.0	1699			+4.0	11621
-39.6	1701	SW of 23.2	1675	+6.4	11641
-36.2	1719	UGC 807 24.8	1684	+8.6	11663
-35.8	1716	Nucleus 26.4	1693	+11.0	11662
-33.5	1727	42.4	1685	+13.4	11674
-16.6	1711	44.3	1691	+15.6	11645
-13.6	1711	46.6	1688	+18.2	11626
-10.4	1719	48.4	1693	+22.0	11684
-5.7	1724	50.6	1694	+24.4	11672
-2.7	1732	52.3	1707	+26.8	11678
-0.2	1744	54.5	1715	SW +29.2	11705
-0.1	1749	65.0	1708	Plate 1813, PA = 40°	
0	1748	67.7	1713		
+17.3	1846	69.6	1722		
+22.6	1837	70.1	1732		
+27.7	1847	72.7	1725		
+47.1	1840	82.3	1746	NE -22.7	11268
+49.9	1838	84.4	1745	-20.6	11264
+52.5	1831	86.6	1752	-18.5	11269
+74.5	1855	88.6	1744	-16.5	11280
+79.3	1852	90.7	1742	-14.4	11270
SW +84.5	1849	92.8	1741	-12.2	11297
		94.9	1746	-10.2	11312
		97.0	1743	-8.1	11323
		99.0	1755	-6.0	11338
		UGC 807 Plate 1808, PA = 40°		-1.8	11523
				+0.2	11537
				+0.8	11525
				+2.4	11588
SW of 47.1	1687			+4.5	11595
UGC 807 49.2	1710			+6.6	11625
Nucleus 51.3	1725	NE -23.6	11297	+8.6	11651
53.4	1729	-21.6	11288	+10.7	11670
55.5	1732	-19.5	11297	+12.8	11638
64.2	1717	-17.5	11302	+14.9	11632
66.4	1729	-15.4	11303	+17.0	11628
68.4	1724	-13.2	11300	+19.1	11648
70.2	1731	-11.1	11308	+21.2	11660
70.5	1726	-10.0	11335	+23.2	11666
72.6	1737	-7.0	11354	SW +25.3	11689
74.7	1718	-4.9	11387		
87.6	1767	-2.8	11397		

NGC 450. The results derived below do not depend critically on this magnitude.

III. DISCUSSION

Shapes and amplitudes of rotation curves serve as valuable diagnostics of the dynamical conditions of spiral galaxies. For a normal isolated galaxy, rotational velocities rise fairly rapidly over the first few kiloparsecs from

the nucleus, then rise slowly or remain constant thereafter across the galaxy. The shape and magnitude of the curve are clear indicators of the galaxy absolute magnitude (Rubin *et al.* 1982). For interacting galaxies, the rotation curves are often abnormal and indicative of tidal disturbances. We now use the derived rotation curves (Figs. 2 and 3) to estimate the absolute magnitudes, and to determine if the galaxies are so close in space that they can be interacting.

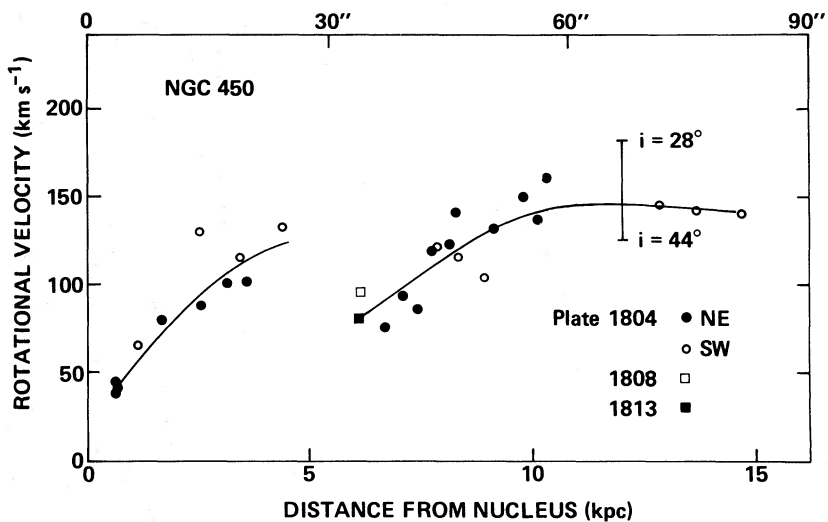


FIG. 2.—Rotational velocities in NGC 450 as a function of distance from the nucleus, from plate 1804. Velocities where plates 1808 and 1813 intersect the major axis of NGC 450 are indicated by squares. Inclination $i = 36^\circ$ is adopted; rotational velocities for other i are indicated. The adopted curve is a hand drawn curve through the measured velocities. Velocities are here not corrected for the relativistic Doppler term, $1/(1+z_0) = 0.994$.

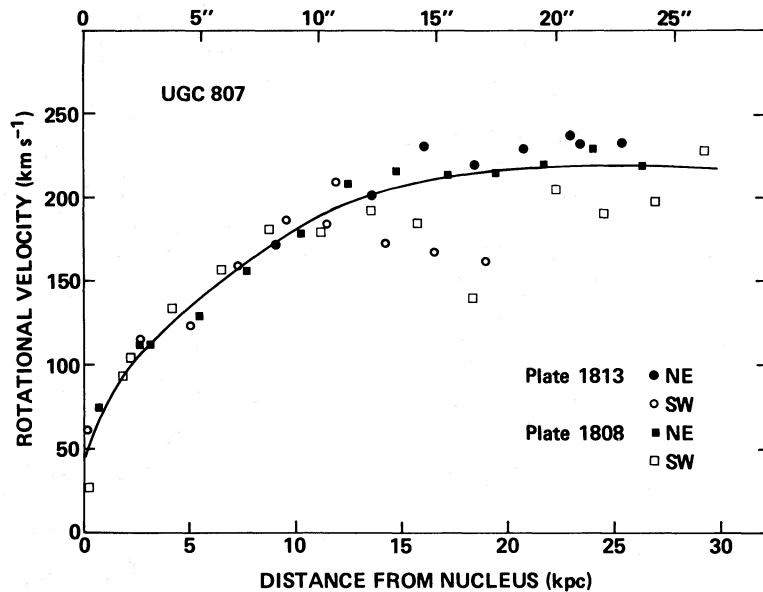


FIG. 3.—Rotational velocities in UGC 807, from plates 1808 and 1813. The low velocities in the SW are located in the region between arms one and two. The adopted curve is a hand drawn curve through the measured velocities. Velocities are here not corrected for the relativistic Doppler term, $1/(1+z_0) = 0.963$.

TABLE 3
ADOPTED PARAMETERS FOR NGC 450 AND UGC 807

Parameter	NGC 450	Source ^a	UGC 807	Source ^a
Class	Sb	1	S...; Sb,Sbc	6,2
V_{LG} (km s ⁻¹)	1863	2	11587	2
Distance (Mpc)	37.3	$H = 50$	232	$H = 50$
$V_{max}/(1+z_0)$	145 km s ⁻¹	2	211 km s ⁻¹	2
R_{25}	1:62	1	0:55	6
a/b	1.23	1	2.20	6
i	$36^\circ \pm 8^\circ$	2	$65^\circ \pm 5^\circ$	2
$R_{25}^{i,b}$	$1.60 = 17.4$ kpc	3	$0.52 = 34.9$ kpc	3
B_T (mag)	12.50	1	15.7	2
Δm_b (mag)	0	4	0	4
Δm_i (mag)	0.17	5	0.65	5
$m_c^{i,b}$ (mag)	12.3	...	15.0	...
M_B rotation curve	-20.6 ± 0.7	2	-21.6 ± 0.6	2
M_B at Hubble distance ...	-20.6		-21.8	

^aSOURCE.—(1) de Vaucouleurs, de Vaucouleurs, and Corwin 1976. (2) This work. (3) $\log R_{25}^{i,b} = \log R_{25} - 0.07 \log a/b - \log [1 - (m_b/3.35)]$ (Rubin *et al.* 1982). (4) Burstein and Heiles 1982; galactic latitude = -63° . (5) $\Delta m_i = 1.9 \log (a/b)$; Rubin *et al.* 1982 (6) Nilson

We discuss first the companion galaxy. UGC 807 appears to be a fairly normal Sb or Sbc spiral. Its southwest structure is viewed through the outer regions of NGC 450 (see Fig. 1). The rotation velocities rise monotonically, except for the dip near $17''$ SW. These low velocities correspond to the interarm region between SW arms one and two. Low velocities between arms are characteristic of some Sb's and Sc's (Rubin, Ford, and Thonnard 1980). The maximum rotational velocity, $V_{max} = 211$ km s⁻¹, or 219 km s⁻¹ uncorrected for the relativistic Doppler shift, $V/(1+z_0)$, identifies UGC 807 as a fairly luminous spiral.

In Figure 4 we show synthetic rotation curves for Sb galaxies of various absolute magnitudes. These curves have been formed from the rotation curves of all of the Sb galaxies we have observed, by using velocities from all of the 23 galaxies at successive fractional radii. They represent very smoothed descriptions of rotation curves. Details of the formation procedure are discussed elsewhere (Thonnard, Rubin, and Ford 1981; Thonnard and Rubin 1981). Along the relatively flat portion of each synthetic rotation curve, the 1σ dispersion is about 0.6 or 0.7 mag.

Matched against the Sb synthetic rotation curves, the absolute magnitude of NGC 807 is about $M_B(\text{Sb}) = -21.3$. When matched with the corresponding set of Sc curves, $M_B(\text{Sc}) = -22.3$, so that $M_B(\text{Sbc}) = -21.8$. We adopt $M_B = -21.6 \pm 0.6$ as a reasonable range for M_B based on the morphological type and rotational properties. This determination of absolute magnitude is, of course, independent of the distance of the galaxy. Placed at its Hubble distance, $D = 232$ Mpc, with $M_B = -21.6$, UGC 807 would appear as $m = 15.2$, which is well within the range of its estimated magnitude. If, instead,

UGC 807 were located as close as NGC 450, $D = 37$ Mpc, then it would appear enormously bright, $m = 11.2$, which it clearly does not. Or stated another way, for UGC 807 to be both close and appear faint ($m \sim 15$), its absolute magnitude would have to be extremely low, $M_B = -17.8$. Because its rotation curve, and indeed its morphology, identify it as a normal high-luminosity Sb or Sbc, there can be little doubt that UGC 807 is located at its Hubble distance.

NGC 450 has a rotation curve which is notable for the discontinuity and velocity minimum between the first and second arms ($r \sim 5$ kpc). However, such discontinuities and velocity falls of 30 to 50 km s⁻¹ are observed in perhaps 20–30% of the Sc galaxies we have observed (Rubin, Ford, and Thonnard 1980, Fig. 4). Of these 21 Sc galaxies, at least five (NGC 801, 1087, 2998, 4321, and UGC 2885) show discontinuities and velocity minima between arms on both sides of the nucleus. A few others show a similar effect of smaller amplitude. We conclude that the shape of the rotation curve of NGC 450 is sufficiently normal to rule out a tidal interaction.

From the shape and amplitude ($V_{max} = 145$ km s⁻¹) of the rotation curve, the absolute magnitude of NGC 450 is $M_B = -20.6$ when matched to the set of synthetic Sc curves. Allowing for a total possible range in inclination of 28° to 44° produces a spread in M_B from -20.0 to -21.6 . With $M_B = -20.6 \pm 0.7$ and a Hubble distance of 37 Mpc, NGC 450 will appear as $m_c = 12.3 \pm 0.7$. This value is just as observed. Hence NGC 450 is a moderately low luminosity Sc galaxy, more than 6 times closer to us than UGC 807.

The conclusion is clear. Based solely on the shapes of their rotation curves plus their apparent magnitudes,

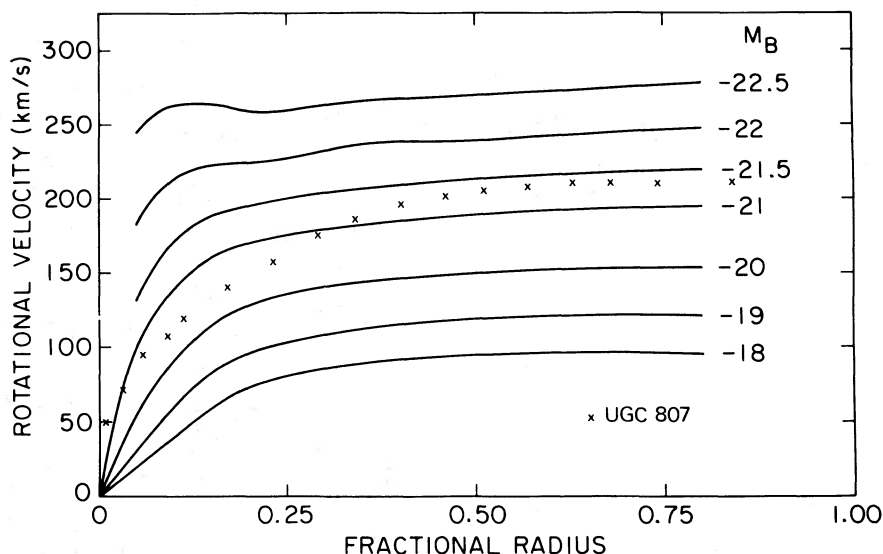


FIG. 4.—Rotational velocities in UGC 807 (*crosses*), as a function of the fractional isophotal radius, superposed on the set of synthetic rotation curves for 23 Sb galaxies. Such curves (Thonnard and Rubin 1981) show rotation velocities for galaxies of successive absolute magnitudes (using $H = 50 \text{ km s}^{-1} \text{ Mpc}^{-1}$), and permit the assignment of an absolute magnitude from a rotation curve. All velocities are here corrected for the relativistic Doppler effect.

NGC 450 and UGC 807 are well separated in space, each located at the Hubble distance implied by their very different velocities.

Moreover, there is yet another diagnostic for tidally interacting galaxies. In several interacting systems which we are studying, rotation curves are not of the flat or slightly rising normal variety. Instead, velocities in the outer regions fall steeply to zero or even below. Because we have studied only a few such systems, we do not yet know how widespread this characteristic is. Regardless, the detection of such rotation curves becomes a valuable indicator of a tidal interaction. Figure 5 shows an interacting system, the double NGC 2207/IC 2163 (Peterson, Rubin, and Ford 1984). Morphologically, these galaxies are more like the NGC 450/UGC 807 pair than any other spiral pair we have observed. As the figure illustrates, in the region of overlap of the two galaxies west of the nucleus of IC 2163, the velocities are confused. And in the outer regions of both galaxies, rotational velocities fall to the central velocity at large radial distances. In NGC 2207, velocities decrease faster than $1/r^{1/2}$ with increasing radial distance. Velocities decreasing faster than Keplerian cannot arise from a simple spheroidal mass distribution whose density decreases with increasing radial distance. Instead, they are the signature of a more complicated dynamical situation. They may indicate a non-axisymmetric mass distribution, a significant mass in an outer ring, or unstable, noncircular orbits. Such dynamical circumstances would not be unexpected in tidally interacting galaxies.

Very few other interacting disk systems have been studied. But neither M51/NGC 5195 (Goad, de Veny,

and Goad 1979) nor NGC 4038/4039 (Rubin and Ford 1970) exhibits normal flat rotation curves. In NGC 7252, velocities in the two merging gas disks (Schweizer 1982) also decrease to zero following the initial rise. For NGC 450 and UGC 807, the normal shapes of the rotation curves offer no evidence that a dynamical interaction is taking place.

In the face of these two tests, we can reach no other conclusion except that the two galaxies are widely separated in space. However, if one were to insist that UGC 807 is located at the near distance and physically associated with NGC 450, the following problems would arise:

1. UGC 807 would then be of extremely low ($M_B = -17$) luminosity, with an expected rotational velocity of about 75 km s^{-1} . This is contradicted both by its observed rotational velocity, $V_{\text{rot}} = 211 \text{ km s}^{-1}$, and by its morphology (van den Bergh 1960).

2. Tidal interactions are known to induce bursts of star formation (Larson and Tinsley 1978) which enhance the blue luminosity of the galaxies. The large H II knots in NGC 450 are such regions, according to Arp (1980*a*). Yet if nearby, UGC 807 is 4 mag too faint (i.e., 6 or 7 σ from the mean) for its rotational velocities, rather than too bright.

We conclude that all of the evidence indicates that NGC 450 and UGC 807 are not physically associated.

IV. CONCLUSIONS

For many years, Arp and his collaborators have identified a variety of pairs of objects which appear close

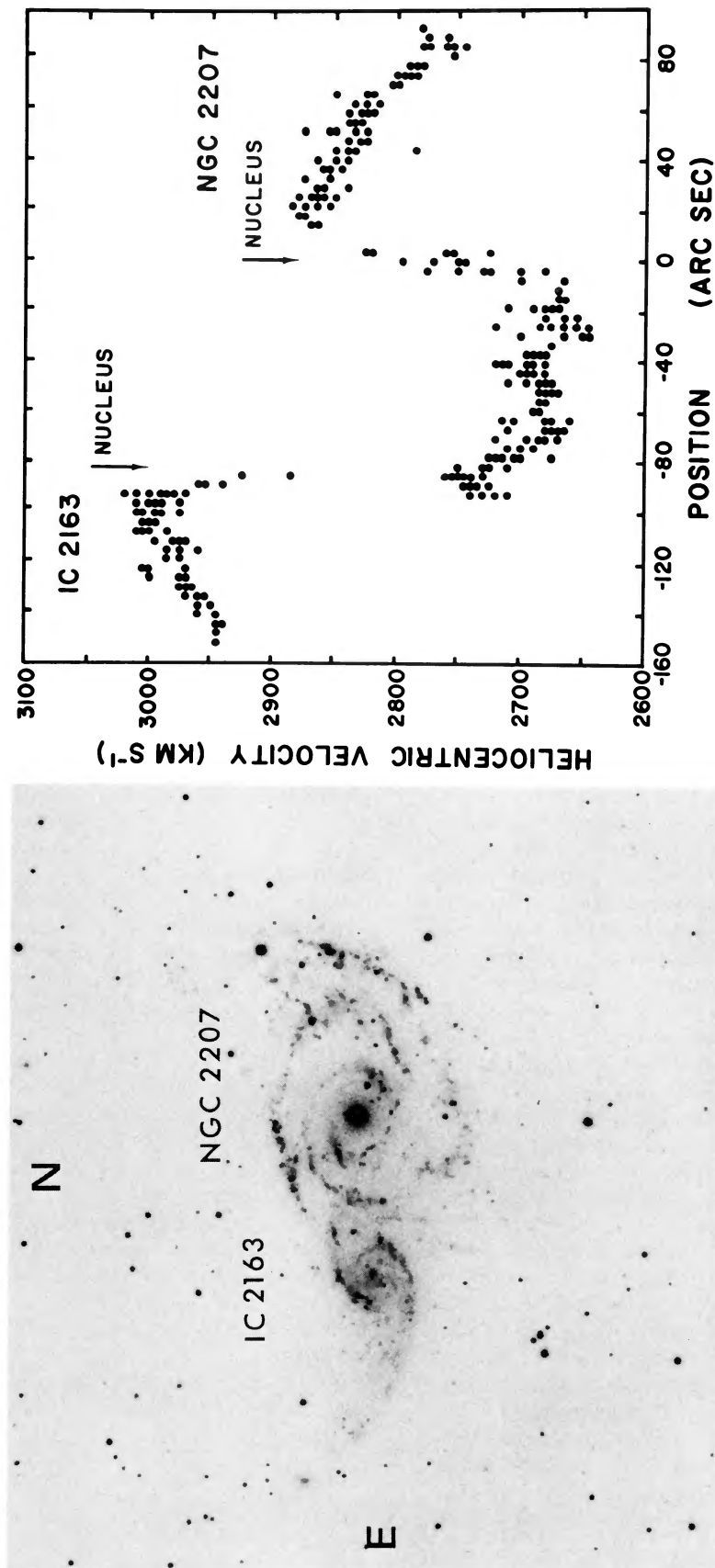


FIG. 5.— *Left*, IC 2163 (east) and NGC 2207 (west) from an $H\alpha$ photograph taken at the 4 m Kitt Peak prime focus, 098-04 plate plus $\lambda 6650 \text{ \AA}$ filter; exposure 50 min. The separation of the nuclei of IC 2163 and NGC 2207 is about $80''$. *Right*, observed velocities in IC 2163 and NGC 2207 as a function of nuclear distance, along the line joining the two nuclei, $PA = 97^\circ$. Note the decrease in rotational velocity with increasing nuclear distance in the disks of both galaxies.

together on the sky, but which exhibit very different ("discrepant") redshifts. Sometimes these pairs consist of two QSOs, sometimes of one galaxy and one QSO, and sometimes of two galaxies. In such cases, Arp has argued that the objects are physically associated, and that their association is evidence for noncosmological redshifts. Generally, it is difficult to apply quantitative tests to locate the objects in space. But for spiral galaxies, present knowledge of average rotational properties now makes it possible to assign an absolute magnitude based on the shape of the rotation curve and to decide if there is dynamical evidence of a tidal interaction.

We have analyzed the rotational velocities of the apparent galaxy pair NGC 450/UGC 807. From the normal forms of their rotation curves, the galaxies are identified as relatively isolated field galaxies. Their velocities show none of the characteristics sometimes

seen in dynamically interacting galaxies. Moreover, when compared with synthetic rotation curves for Sb and Sc galaxies, the rotation curve for each galaxy indicates an absolute magnitude consistent with the observed magnitude only when each galaxy is placed at its Hubble distance. Thus the low-luminosity NGC 450 ($V_{LG} = 1863$ km s⁻¹, distance = 37 Mpc, $M_B = -20.6$) is widely separated in space from the higher luminosity UGC 807 ($V_{LG} = 11,587$ km s⁻¹, distance = 232 Mpc, $M_B = -21.6$). We conclude that NGC 450 and UGC 807 are not interacting, and the pair cannot properly be used as evidence for noncosmological redshifts.

We thank Dr. Arp for identifying the NGC 450/UGC 807 pair as one worthy of study, and for supplying the photograph, Dr. Esther Hu for assisting with the observations, and Drs. Arp, David Koo, and François Schweizer for valuable comments on the manuscript.

REFERENCES

- Arp, H. 1980*a*, private communication.
 ———. 1980*b*, *Ap. J.*, **239**, 469.
 ———. 1982*a*, *Ap. J.*, **256**, 54.
 ———. 1982*b*, *Ap. J.*, **263**, 54.
 Brault, J., and Hubbard, R. 1981, private communication.
 Burstein, D., and Heiles, C. 1982, *A. J.*, **87**, 1165.
 de Vaucouleurs, G., de Vaucouleurs, A., and Corwin, H. G. 1976, *Second Reference Catalogue of Bright Galaxies* (Austin: University of Texas Press).
 Goad, J. W., De Veny, J., and Goad, L. E. 1979, *Ap. J. Suppl.*, **39**, 439.
 Larson, R. B., and Tinsley, B. M. 1978, *Ap. J.*, **219**, 40.
 Nilson, P. 1973, *Uppsala General Catalogue of Galaxies* (Uppsala Obs. Ann., Vol. 6).
 Peterson, C. J., Rubin, V. C., and Ford, W. K., Jr. 1984, in preparation.
 Rubin, V. C., and Ford, W. K., Jr. 1970, *Ap. J.*, **160**, 801.
 Rubin, V. C., Ford, W. K., Jr., and Thonnard, N. 1980, *Ap. J.*, **238**, 471.
 Rubin, V. C., Ford, W. K., Jr., Thonnard, N., and Burstein, D. 1982, *Ap. J.*, **261**, 439.
 Schweizer, F. 1982, *Ap. J.*, **252**, 455.
 Thonnard, N., and Rubin, V. C. 1981, *Carnegie Yrbk.*, **80**, 551.
 Thonnard, N., Rubin, V. C., and Ford, W. K., Jr. 1981, *Bull. AAS*, **13**, 507.
 Tifft, W. G. 1982, *Ap. J. Suppl.*, **50**, 319.
 van den Bergh, S. 1960, *Ap. J.*, **131**, 558.

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