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EXTENDED NEUTRAL HYDROGEN EMISSION IN THE NGC 5903/5898 BINARY ELLIPTICAL SYSTEM: EVIDENCE FOR A DOUBLE-GALAXY ACCRETION EVENT

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ABSTRACT

Neutral hydrogen observations made with the VLA are presented of the remarkable binary elliptical system NGC 5898/5903. NGC 5898 has been shown by Bertola and Bettoni to contain ionized gas which counter-rotates with respect to the stars suggesting that the gas has been acquired from outside the galaxy. Although no H I was detected from NGC 5898, extended emission, including long filaments, was found in and around the companion NGC 5903. The results suggest that NGC 5903 is currently undergoing a major accretion event which may be linked to a similar event which occurred at an earlier time in NGC 5898. Within NGC 5903 the H I is consistent with the early development of an accretion disk parallel to the minor axis of the optical isophotes. The kinematics of the gas and asymmetry of the H I distribution suggest that the accretion has occurred recently ($T = 2 \times 10^8$ yr) and the H I is not in a state of equilibrium with the potential of the galaxy. The infalling gas may also be responsible for the usual radio continuum emission which peaks near the center of NGC 5903 but extends outside the optical dimensions of the galaxy.

Subject headings: galaxies: individual (NGC 5898, NGC 5903) — galaxies: interactions — galaxies: interstellar matter

I. INTRODUCTION

Approximately 10% of the elliptical galaxies have been found to contain neutral hydrogen, but to date only a small number of these have been studied in detail (see Knapp 1987 for review.) As a result of these studies it is commonly believed that the neutral hydrogen is of an external origin rather than the result of stellar mass loss from within the galaxies. The strongest arguments for an external origin comes from the dynamics and distribution of the cool gas which is often strikingly different from the stellar properties of the host galaxy. For example, it is common to find H I emission in an external ring or disk, rotating rapidly and inclined at some arbitrary angle to the optical major or minor axis of the galaxy. In many cases the kinetic major axis of the H I does not align with that of the stars. In some cases the gas counter-rotates with respect to the stars (e.g., NGC 5898: Bertola and Bettoni 1988 and IC 2006: Schweizer, van Gorkom, and Seitzer 1989). The case of IC 2006 is interesting because the H I disk appears to join smoothly with an inner ionized ring or toroid, rotating in the same sense as the H I. The dynamical properties of such gaseous disks or rings are naturally explained in terms of infall from some external reservoir of mass and angular momentum rather than an internal source. Possible sources of such gas are intergalactic clouds, disrupted dwarf galaxies or tidally stripped disk galaxies. The elliptical galaxy NGC 1052 (van Gorkom *et al.* 1986) shows evidence for extended H I which may be tidal in origin and in at least one other case mass transfer from a gas-rich spiral would seem to be confirmed (NGC 5018, Kim *et al.* 1988). Similar evidence for infall by tidal disruption is found in the near environment of some SO galaxies (Sancisi *et al.* 1984; van Driel, Davies, and Appleton 1988).

In contrast to such cases, however, is another possible class of H I–rich ellipticals which do not show the hallmarks of accretion (e.g., NGC 2974, Kim *et al.* 1988; NGC 5666 and A1230+09, Lake, Schommer, and van Gorkom 1987; NGC 807, Dressel 1988). In these cases the cool gas may have been formed internally. It is still not clear, therefore, which mechanism is the most dominant process for the formation of a cool interstellar medium in elliptical galaxies.

In this paper we present H I observations of the binary elliptical system NGC 5898/5903. Taken together with previous optical data on NGC 5898 (Bertola and Bettoni 1988), the observations strongly suggest that *both* galaxies have undergone a major accretion event in the recent past. The galaxies, which are separated by 5.′2 ($\sim$2.7 optical D_{25} isophotal diameters) have similar systemic velocities, sizes, and optical luminosities (see Table 1). Both have been the subject of CCD photometry and color studies. NGC 5898 is the more optically unusual of the two galaxies. It shows significant isophotal twisting from the center to the outer isophotes (Jedrzejewski 1987) and contains a peculiar dust lane (Sparks *et al.* 1985). NGC 5898 is also detected as an extended X-ray source by Jones, Forman, and Tucker (1985). Perhaps the most remarkable aspect of NGC 5898 is the kinematic behavior of the ionized gas which (like IC 2006 above) counter-rotates with respect to the stars (Bertola and Bettoni 1988). In contrast, it is NGC 5903 which exhibits the remarkable radio properties discussed in this paper, whereas NGC 5898 is not detected down to the limits of our observations either in the H I line or in radio continuum. Throughout this paper we will assume a

TABLE 1

OPTICAL PROPERTIES OF THE NGC 5898/5903 SYSTEM

Name (1)	Velocity[a] (helio: km s^{-1}) (2)	Blue mag[b] B_T^0 (mag) (3)	Central Velocity[a] Dispersion (km s^{-1}) (4)	Diameter D_{25}[b] (5)	R_{25}[b] (6)
NGC 5898	2160[c]	11.91	230[c]	1.78	1.05
A1515	2340	...	127	0.56	1.45
NGC 5903	2519	11.76	235	1.99	1.15

[a] From Faber *et al.* 1989.
[b] From RC2.
[c] Data from Bertola and Bettoni 1988.

distance to the NGC 5903/5898 system of 24 Mpc. This distance is derived from the group velocity determined by Faber *et al.* (1989) from detailed modeling of the Hubble flow using a diameter velocity-dispersion relation for ellipticals. We assume a Hubble constant of 100 km s^{-1} Mpc^{-1}.

II. PREVIOUS RADIO OBSERVATIONS

NGC 5903 was first noted as a radio source by Disney and Wall (1977). Jenkins (1983) failed to detect NGC 5903 in H I at 21 cm with the Parkes 64 m radio telescope. Following observations by Sparks (1983) that both ellipticals were unusually red, the pair was observed and detected in the H I line with both the 76 m Lovell radio telescope at Jodrell Bank and later with the VLA (Appleton, Sparks, and Pedlar 1985).

III. THE OBSERVATIONS

The H I observations were made in two 6 hr tracks with 25 antennas in the C/D Hybrid of the VLA in 1984.[1] A preliminary H I surface density map of this current data was present ed by Appleton, Sparks, and Pedlar (1985). A total of 31 spectral-line channels were obtained across a 6.25 MHz bandwidth and the data was Hanning smoothed on-line yielding a velocity resolution of 41 km s^{-1}. Channel 0 is a broad-band pseudo-continuum channel. Amplitude and bandpass calibration was performed using the radio source 3C 286. Individual channel maps were obtained by Fourier transforming the visibility data using natural weights. The resulting telescope beam had a HPBW of 45.7 × 44.8 $arcsec^2$. After the channel maps had been made it was realized that a bright continuum source not associated with NGC 5903/5898 was producing strong sidelobe structure throughout the maps. In order to minimize the effects of this source on the interpretation of the channel maps the source was substracted from the uv data for all channels. This was achieved by CLEANing the channel 0 map in the region of the strong source. The CLEAN components resulting from this process were then subtracted from the uv data for each channel, and the maps were remade. This procedure successfully removed the major contribution of the bright continuum source from the maps. Further continuum subtraction was performed by first constructing a mean line-free continuum map by averaging maps at the extreme ends of the band. The continuum was then subtracted from each channel map in turn producing maps free of continuum emission.

[1] The VLA of the National Radio Astronomy Observatory is operated by Associated Universities, Inc. under contract with the NSF.

The $\lambda = 20$ cm continuum map (see Fig. 7 below) was derived from the channel 0 data. The uv data was transformed into the map plane, CLEANed and a final map produced using the self-calibration technique (see Cornwell 1986). The resulting map had an effective half-power beam width of 30 × 30 $arcsec^2$.

IV. RESULTS

a) H I *Distribution*

In Figures 1*a* and 1*b* (Pl. 6) the integrated H I surface density map is presented. Extensive H I is seen associated with NGC 5903, but no emission down to a limit of $N(H) \leq 6 \times 10^{19}$ at cm^{-2} was detected in the direction of the companion NGC 5898. Integrating over the isophotal optical dimensions of NGC 5898 given in Table 1, the 3 σ upper limit to the H I mass of NGC 5898 is $1.5 \times 10^8 (100/H_0)^2 M_\odot$.

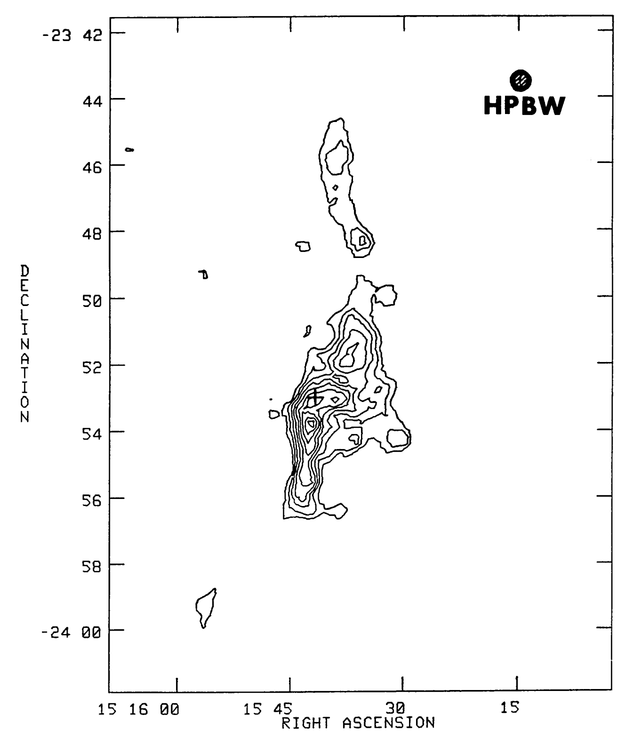

FIG. 1.—(*a*) The integrated H I surface density map of the NGC 5903/NGC 5898 field. The contour units are 0.6, 1.2, 1.7, 2.3, 2.9, 3.5, 4.1, 4.7, and 5.2×10^{20} at cm^{-2}.

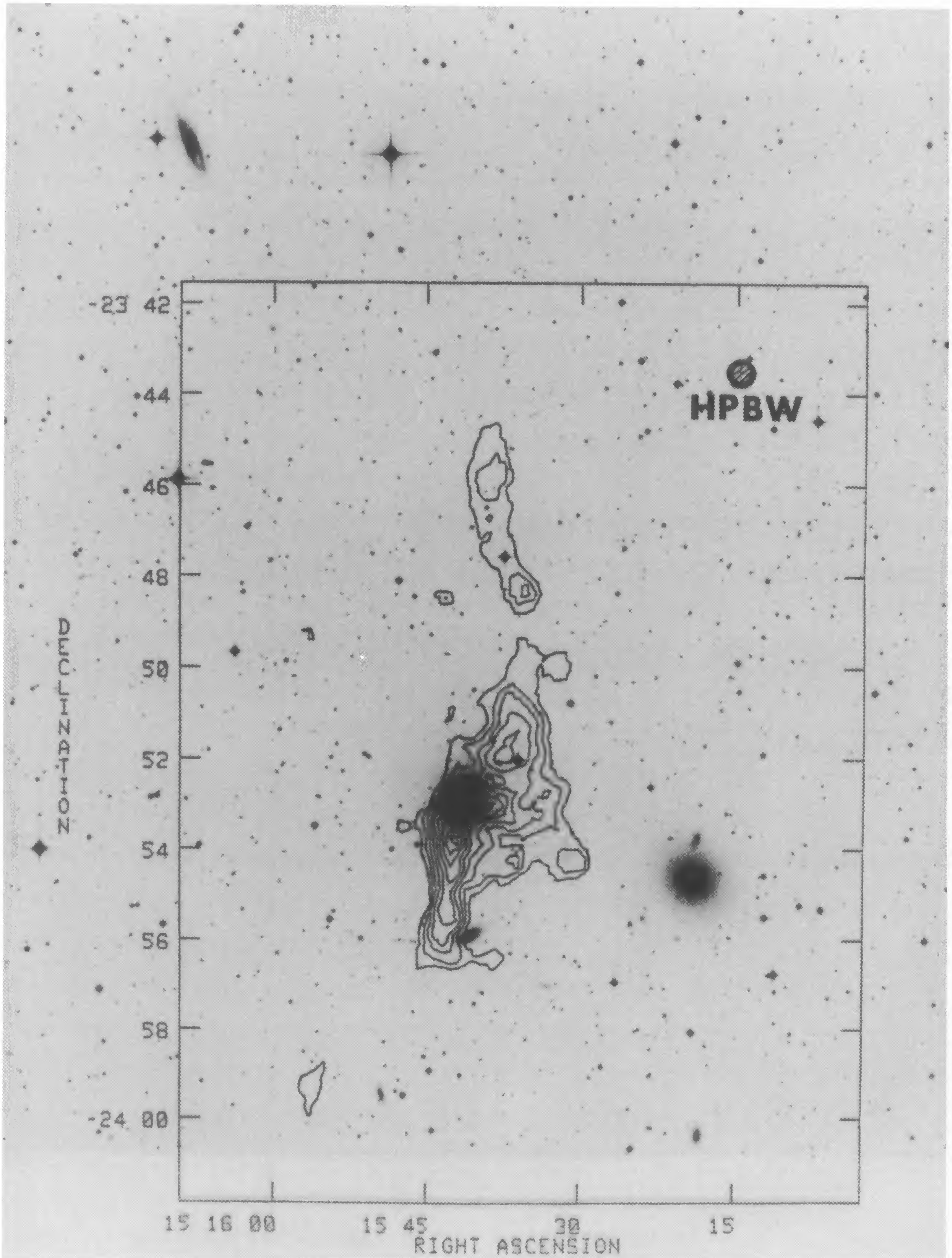

FIG. 1.—(*b*) Figure 1*a* superposed onto a print of the SERC-J survey plate of the region. The galaxy NGC 5903 lies to the east (*left*) and NGC 5898 to the west (*right*). The dwarf galaxy A1515 − 23 lies just to the south of NGC 5903.

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TABLE 2

H I PROPERTIES OF NGC 5898/5903

Name	Assumed Distance (Mpc)	Velocity Width $\Delta V_{1/2}$ (km s^{-1})	Systemic[a] Velocity $V_{\odot}$ (km s^{-1})	F_H ($\times 10^6$ $M_{\odot}$ Mpc^{-2})	M_H ($\times 10^8$ $L_{\odot}$)	L_B ($\times 10^{10}$ $L_{\odot}$)	M_H/L_B
NGC 5903............	24	280	2549 ± 20	0.78	4.5	2.13	0.02
NGC 5898............	24	...	...	≤0.26	≤1.5	1.91	≤0.008

[a] The systemic velocity was derived from the isovelocity map of Fig. 4 because of the very asymmetric distribution of H II.

The H I distribution associated with NGC 5903 is remarkable (see also Fig. 1*b*). In addition to the long filaments of H I extending to the north and south of the galaxy, there is strong extended emission from the galaxy itself. A total of 1.5×10^9 $M_{\odot}$ of H I was found over the entire structure of which 30% (4.5×10^8 $M_{\odot}$) is emitted from within the optical D_{25} dimensions[2] of NGC 5903. Some derived global properties of the galaxies are given in Table 2. The emission in the southern filament extends from the core of NGC 5903 to a point 2′.7 southward of the galaxy, in the direction of the dwarf galaxy A1515−23. However, no convincing H I emission is found directly associated with this dwarf. (The dwarf appears to be a member of the group; see Table 1). The northern filament extends from the west of NGC 5903 to the north, over an angular scale of 7′.2, which is $3.7 \times D_{25}$. At the assumed distance of 24 Mpc, the northern and southern filaments have projected linear scales of 50 and 19 kpc, respectively.

Within the galaxy, the strongest neutral hydrogen emission originates near the center and to the west of the nucleus where a bar or disk structure extends along a position angle of 100° (north through east). This strong emission is superposed on a broader emission region to the northwest which extends well outside the optical image of the galaxy and covers a total area of ~1.5 arcmin². The northern filament extends from the end of the barlike structure. The orientation of the bar is rotated by 30° to the position angle of the minor axis of NGC 5903 (measured by Jedrzejewski 1987 to be 70°). However, we will show that the integrated map is deceptive in that there are multiple velocity components present across the face of the galaxy. There is evidence for both a coherent structure rotating along the minor axis of NGC 5903 and additional extended emission with no particularly well defined position-velocity trend. There is also faint emission to the south-west of NGC 5903 at a level of $N_H = 1.2 \times 10^{20}$ at cm². This emission extends in the direction of the companion NGC 5898 and is the only structure that hints at a possible physical connection with NGC 5898.

We note that in the preliminary VLA map of Appleton *et al.* (1985) we did not detect emission from the body of NGC 5903. This was the result of an unfortunate coincidence between the spatial position of H I detected near the edge of the bandpass which completely subtracted in the map plane from emission near the band center during the continuum subtraction process. This line-splitting over much of the galaxy's optical extent and its unexpected velocity with respect to the optical velocity of the galaxy led us incorrectly to believe that no emission was present in that region. Clearly, Figure 1 of this paper rectifies this error. The implications of the large and complex velocity spread of the cool gas in this galaxy are discussed in § V.

[2] D_{25} = diameter at the 25 mag arcsec^{-2} isophote in the blue light derived from de Vaucouleurs, de Vaucouleurs, and Corwin (1976, hereafter RC2).

b) *Velocity Structure*

Figures 2*a*–2*n* show the set of line-containing channel maps covering the velocity range 2340–2885 km s^{-1}. We note that our observation covered a larger velocity spread, including the velocity of NGC 5898, but no H I was detected in these channels. The first contour level is approximately at the 2.5 σ level (i.e., 1 σ = 0.47 mJy beam^{-1}). The velocity structure of the filaments is relatively simple compared with that of the galaxy. The southern filament is observed to begin as a small spur of emission protruding from the optical center of NGC 5903 at a velocity of about 2370 km s^{-1} (Figs. 2*a*–2*b*) and at higher velocities (2510 km s^{-1}) the emission develops as a long, narrow filament extending over an angular scale of 4′ north/south (Figs. 2*c*–2*f*). At velocities in excess of 2510 km s^{-1} the southern filament abruptly disappears. The first hint of emission from the northern filament occurs at velocities around 2674 km s^{-1} (Fig. 2*i*) where a linear structure is observed in a north/south direction. The velocities increase toward NGC 5903 along the filament reaching a maximum of ~2840 km s^{-1} at a distance of 2′.1 from the galaxy where the velocities decrease again (Figs. 2*j*–2*m*). This is best seen in a schematic diagram of the emission features shown in Figure 3. The filament eventually blends with the extended emission to the northwest of NGC 5903 at velocities of ~2716 km s^{-1}. The intensity-weight mean isovelocity contours of the H I emission shown in Figure 4.

The velocity structure of the H I within the optical confines of NGC 5903 is complex. From Figure 2 it is clear that much clumpy emission is seen over the body of the elliptical galaxy. H I is observed over a range of velocities from 2380 to 2840 km s^{-1}. Although very extended in some channels, an overall trend of velocity with position is observed as is illustrated in Figure 3. The southern filament extends into the center of the NGC 5903 where the broadest H I line widths are observed (160 km s^{-1}, see Fig. 5). The velocity of the H I at the center of NGC 5903 is $V_{\odot}$ = 2549 km s^{-1}, a figure close to the optical systemic velocity of NGC 5903 determined from absorption line measurements (see Table 1). At higher velocities the H I emission centroid twists to follow the minor axis ($V_{\odot}$ = 2549–2716 km s^{-1}) for ~2′ where it again shifts north, eventually blending with the northern filament at ~2842 km s^{-1}. The overall impression is that of a highly disturbed system which, except for the very inner core region, does not appear to be in equilibrium with the potential. The marked asymmetry of the H I distribution and the anomalous velocities with respect to the systemic velocity support this picture. Figure 6 shows the

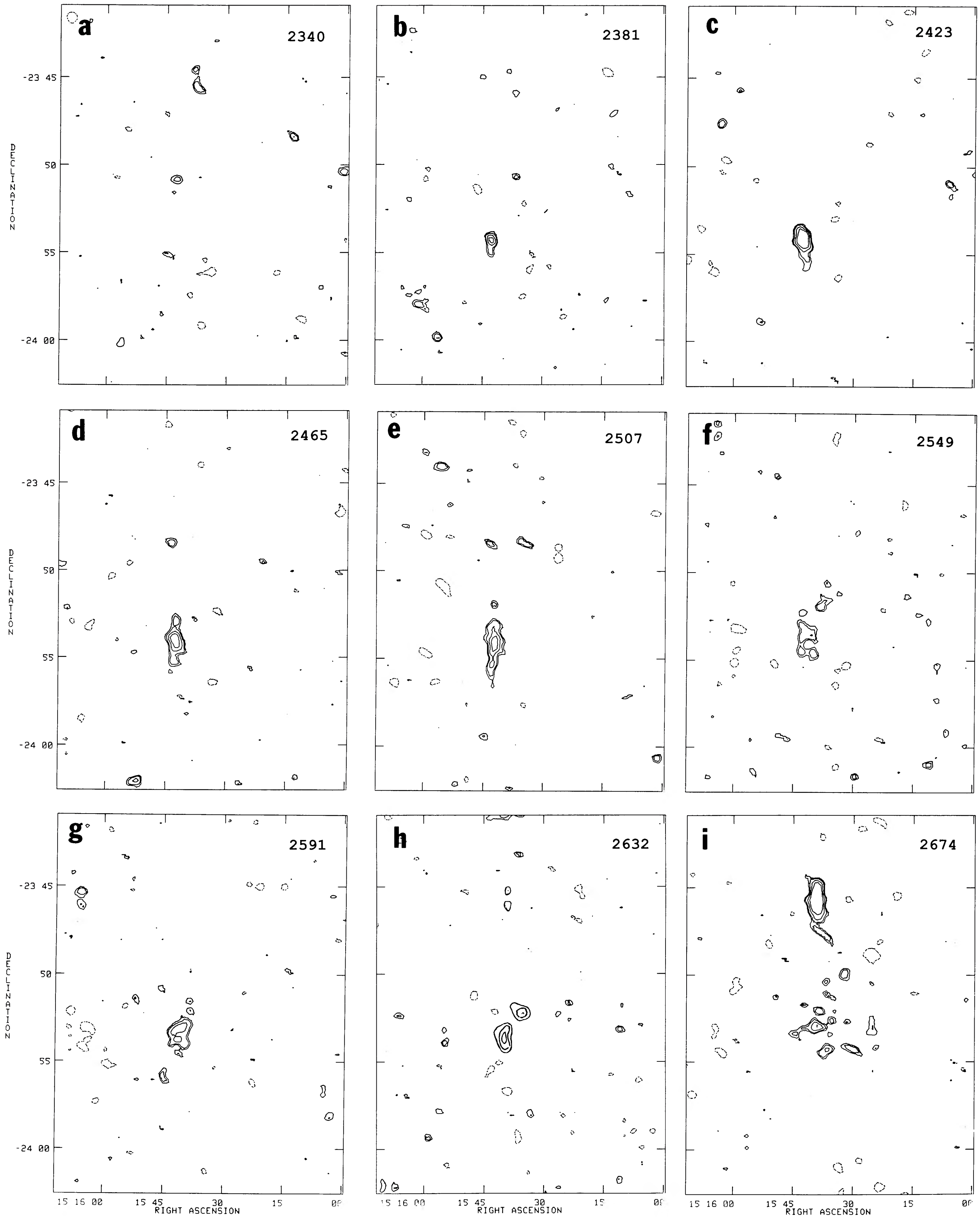

FIG. 2.—(*a–n*) H I channel maps covering the velocity range 2340–2885 km s^{-1}. Each channel (Figs. 2*a*–2*n*) covers a velocity range of 41 km s^{-1}. The contour levels are −1.1 (*dotted contours*), 1.1, 1.41, 1.88, 2.35, 4.70, 9.40, 11.75 mJy beam^{-1}. The first positive contour represents 2.5 times the rms noise in the maps.

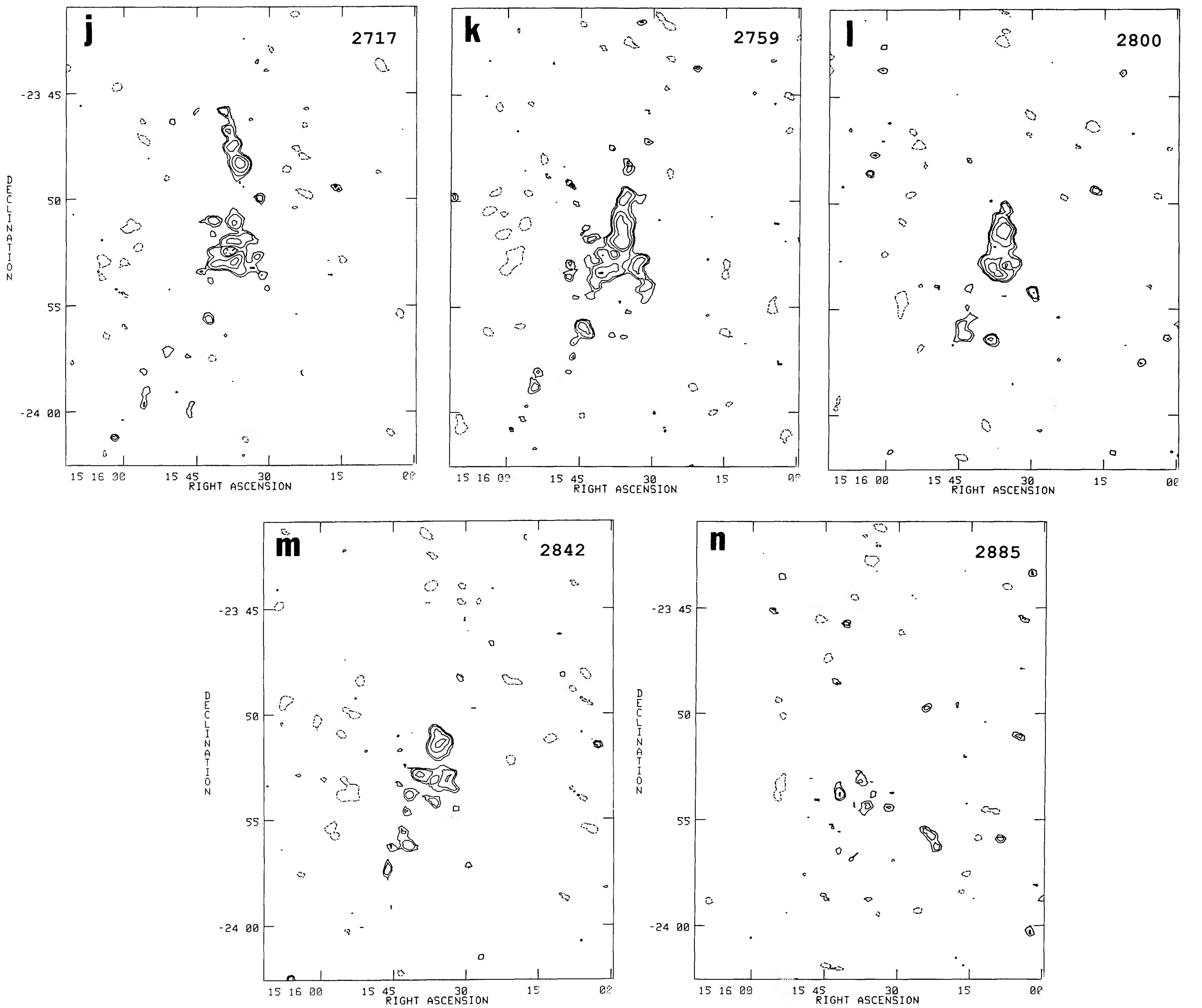

FIG. 2.—*Continued*

integrated H I spectrum of the gas considering only the gas within the inner 2′ surrounding the center of NGC 5903. This asymmetry with respect to the optical systemic velocity is further emphasized.

c) *Radio Continuum Emission*

Figures 7*a*–7*b* show the $\lambda = 20$ cm radio continuum map of NGC 5903 made with a spatial resolution of 30×30 arcsec^2 (see § III for details). The brightest emission (16 mJy beam^{-1}) comes from a barely resolved double radio source which lies $\sim 2''$ south of NGC 5903. The center of the double source has coordinates of R.A.(1950) = $15^{\mathrm{h}}15^{\mathrm{m}}41^{\mathrm{s}}$, and Decl.(1950) = 56°34′, and the two components are separated by 38″.5. Figure 7*b* (Plate 7) shows that the source is significantly offset from the dwarf companion galaxy A1515. The double morphology of the radio source and the lack of positional agreement with any bright objects suggest that it is a background radio galaxy or QSO, and we will not consider it further in this paper.

The majority of the flux comes from the extended source associated with NGC 5903 and has a peak of 8 mJy beam^{-1}. The brightest emission comes from within the optical dimensions of the galaxy but is by no means confined to the galaxy. Indeed, from Figure 7*b*, the emission can be seen to consist of an approximately elliptical shaped bright inner region which extends across and outside the main body of the galaxy and a more diffuse outer region which extends as far as 3′.3 to the southwest. The brightest emission comes from the center of NGC 5903 and is coincident with the region of highest column density of H I seen near the core of NGC 5903. However, apart from the center of NGC 5903, the radio continuum shows no other correlation with the H I distribution as can be seen from Figure 8, which shows both continuum and H I emission superposed. The radio continuum emission remains one of the most puzzling aspects of the present observations. In terms of

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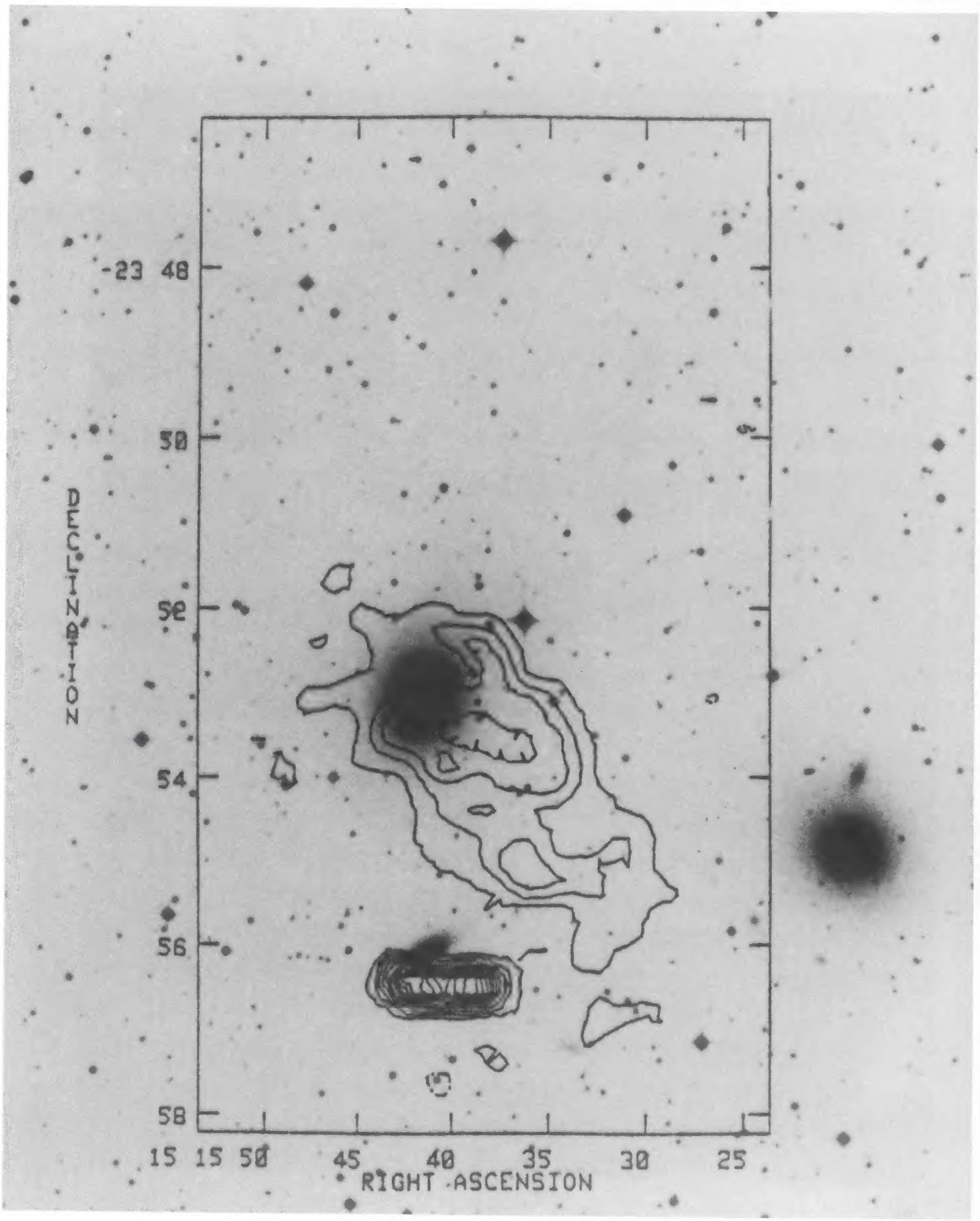

FIG. 7.—(*b*) Figure 7*a* superposed on a print copy of the SERC-J plate of the region

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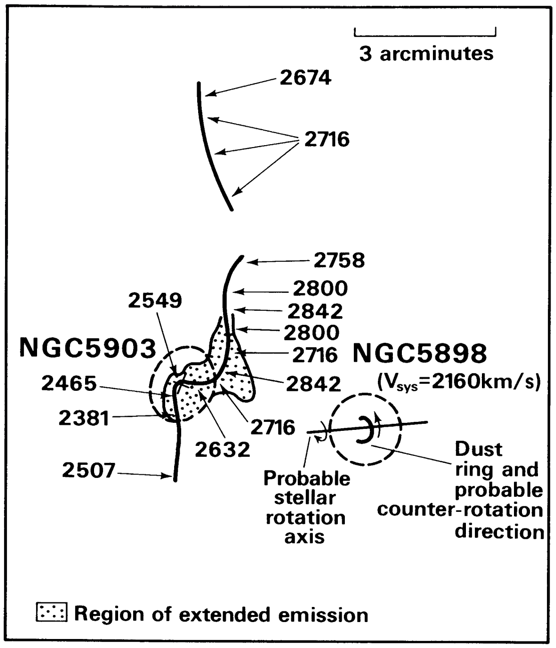

FIG. 3.—A schematic representation of the main H I ridge lines associated with NGC 5903. The dotted lines indicate the optical isophotal dimensions of the galaxy taken from RC2. For NGC 5903, the velocity of each region is indicated in km s^{-1}. We also show the likely sense of rotation for both the stars and ionized gas ring in NGC 5898 derived from the paper by Bertola and Bettoni (1988).

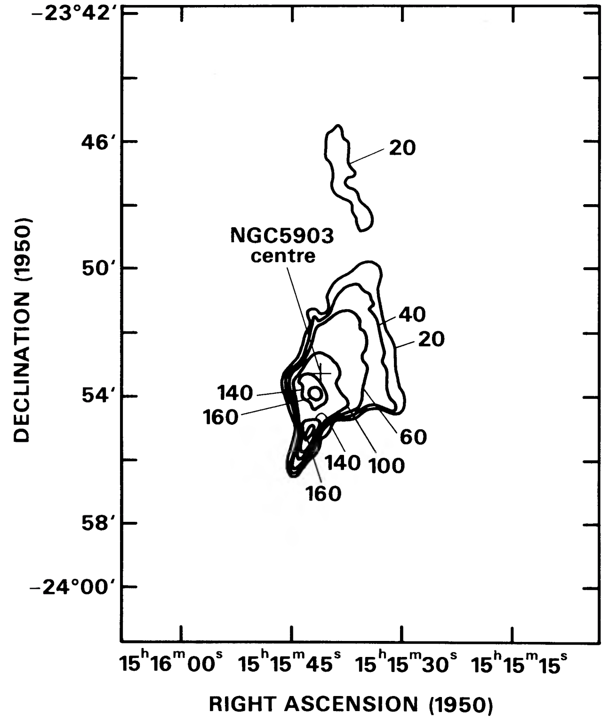

FIG. 5.—The velocity dispersion of the H I emission in km s^{-1}

morphology, the continuum emission is perhaps more similar to a head-tail cluster radio source than a normal elliptical galaxy in a small group. However, this picture is not consistent with the H I distribution (see below).

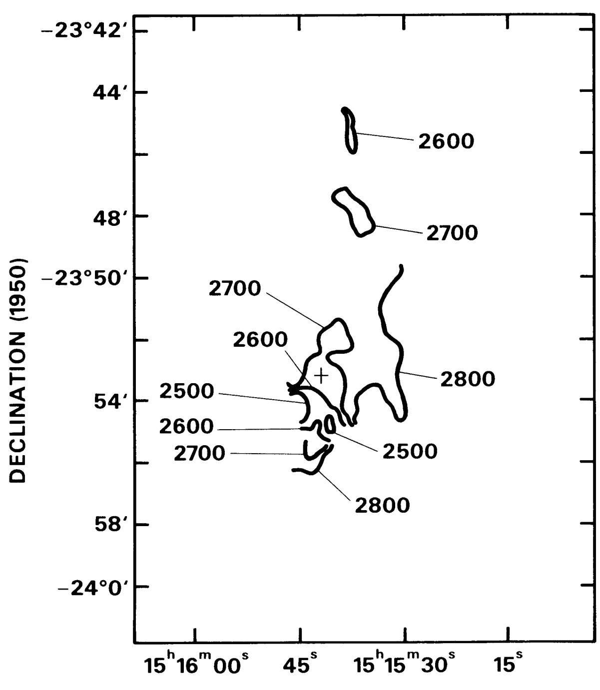

FIG. 4.—The intensity weighted mean velocity field of the neutral hydrogen distribution. Velocities are with respect to the Sun in km s^{-1}.

V. DISCUSSION

a) *Transient Nature of the Filaments*

The H I emission shows some of the characteristics of the filamentary emission found associated with interacting disk galaxies; gaseous counterparts to the tidal bridges and tails predicted by numerical models of interacting galaxies (Toomre and Toomre 1972). For example, long filaments of H I are typically found in tidally disturbed binary spirals (van der Hulst 1979; Haynes, Giovanelli, and Roberts 1979; Wevers *et al.* 1984; Haynes, Giovanelli, and Chincarini 1984) and spirals in groups (for example, Sancisi 1981; Appleton, Davies, and Stephenson 1981; Haynes, Giovanelli, and Chincarini 1984; Appleton and van der Hulst 1988). Filaments of H I are usually

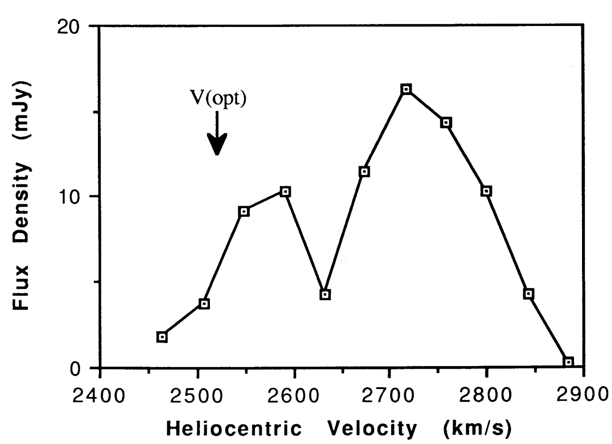

FIG. 6.—The integrated H I spectrum of NGC 5903. Only the emission which fell within a circle of diameter 2′ across centered on NGC 5903 was included in the integral.

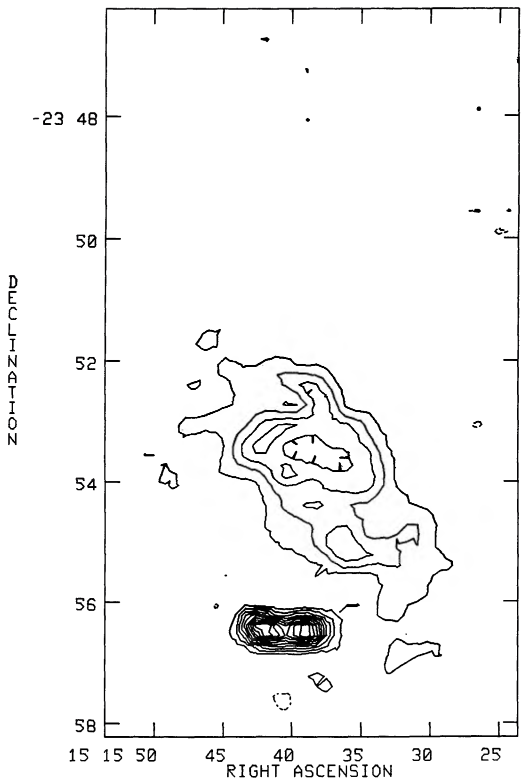

FIG. 7.—The radio continuum of the NGC 5903/5898 region. (*a*) Contour values, range from 2 mJy/beam for the lowest to 20 mJy beam^{-1} in intervals of 2 mJy beam^{-1}.

taken as an indicator of the presence of a dynamically cool component involved in a tidal interaction. However, neither NGC 5903 or 5898 could be described from their stellar distribution as being disk systems. They are classified as E2 and E0, respectively (RC2), and both have $R^{1/4}$ law luminosity profiles (Jedrezjewski 1987).

The H I distribution is in many ways similar to that seen near the elliptical galaxy NGC 1052 (van Gorkom *et al.* 1986). However, in the present case the gas is distributed much more asymmetrically relative to the optical galaxy and the filaments extend to larger distances. The H I over the face of NGC 5903 has, like NGC 1052, a preference to be orientated along the minor axis of the galaxy, and the extended emission shows a smoothly changing velocity gradient across most of the H I structure. As with NGC 1052, the more complicated kinematic behavior occurs inside the bright optical galaxy where noncircular motions may be present.

The filaments which extend to 50 kpc from the center of NGC 5903 to the north and 17 kpc to the south, provide the most compelling evidence for the recent capture of gas by accretion from some external source. It can be shown by a number of arguments that the filaments are probably transient. For example, by appealing to geometrical symmetry, the local velocity gradient in the filaments can be inverted to give a dynamical stretching time scale. For the northern plume the velocity gradient is ~ 22 km s^{-1} arcmin^{-1} over much of its length, corresponding to 3.1 km s^{-1} kpc^{-1}, and the value for the southern plume is 32 km s^{-1} kpc^{-1}, or 4.6 km s^{-1} kpc^{-1}. These figures imply time scales of 3.2×10^8 yr and 2.2×10^8 yr, respectively.

The straightness of the northern filament also provides another constraint on the age of the filament. If we assume (as a limiting case) that the clouds in the filament orbit the galaxy in approximately circular orbits, then the filament would "wrap-up" on a time scale given approximately by the orbital time scale of the innermost end of the filament. This time scale can be obtained by taking the distance to the inner filament and dividing by the velocity difference between the galaxy and the inner filament. The innermost point of the northern filament lies at a distance of 15 kpc from NGC 5903 and has a velocity difference of 323 km s^{-1}, implying a wrapping time scale of the filament of 3×10^8 yr. Given the uncertainty in the geometry and orbital motion of the filament, these time scales, although approximate, suggest that the plumes are transient structures.

b) Origin of the H I *in NGC 5903*

An important question to discuss is whether the H I we observe is actually physically associated with NGC 5903 or whether it is seen in projection against the galaxy. The H I may be a highly disrupted H I–rich LSB galaxy lying either in front of or behind NGC 5903. The main argument against such a chance alignment comes from a study of the kinematics of the gas. First, the systemic velocity of the gas seen near the center of NGC 5903 is ~ 2550 km s^{-1}, and this is in close agreement with the optical value of 2519 km s^{-1} given by Faber *et al.* (1989). Second, the H I line width is noticeably broader near the optical center, suggesting that some gas, at least, has been captured into the potential of the galaxy. Third, the ridge line of the brightest H I features shows a sudden change from a north-south orientation to an orientation essentially along the minor axis of NGC 5903 just near the center (see Fig. 3). These facts strongly suggest that the H I distribution is responding directly to the gravitational field of the galaxy and is not a chance projection against the optical image.

Because we do not have as yet, any dynamical information about the stars in NGC 5903, we cannot rule out completely an internal mechanism for the formation of cool gas. It is therefore possible that at least some of the gas seen over the body of the galaxy may have formed from the cooling of interstellar material shed by normal stellar mass-loss processes. On the other hand, we can see no reason to separate this material for the other very extensive gas which is found near NGC 5903, especially to the west. The huge extent of the filaments and the lack of detection of hot X-ray–emitting gas from this galaxy argues against cooling flows within NGC 5903.

c) A Double-Accretion Event?

The fact that both NGC 5903 and NGC 5898 show evidence for recent accretion is remarkable. Although the accretion in NGC 5903 is probably still occurring, it is likely that most of it has now ceased in NGC 5898. The minimum time that has elapsed since the presumed accretion event onto NGC 5898 will be of order a few rotation periods of the ionized ring. From the data given by Bertola and Bettoni (1988), the rotation period of the ring is in the range 5–8 $\times 10^7$ yr. Hence it is unlikely that accretion has occurred more recently than 2×10^8 yr ago. This time scale is comparable with the dynamical lifetime of the H I filaments. It is therefore possible that the accretion events for both galaxies are due to the same cause, probably the dumping of gas onto the elliptical binary system from a gas-rich galaxy either destroyed in the interaction (as suggested for H I structure seen near Arp 143 by Appleton *et*

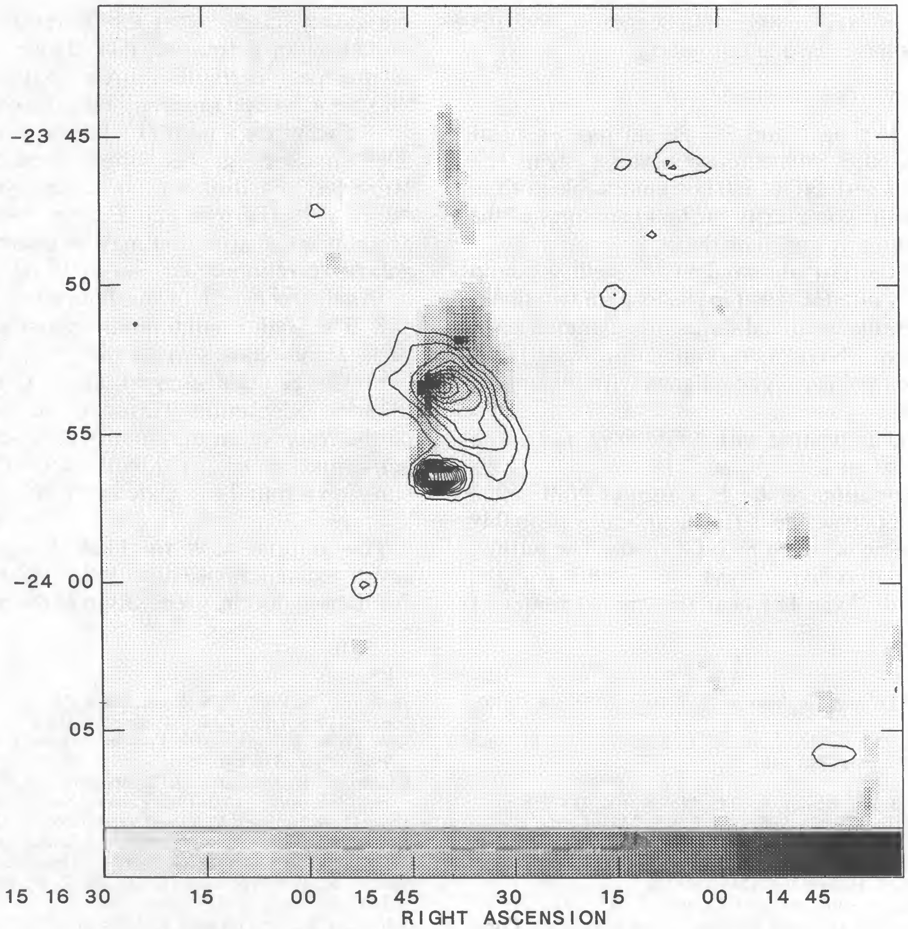

FIG. 8.—The radio continuum $\lambda = 20$ cm map (contours) superposed on a (gray scale) representation of the integrated H I emission. Radio-continuum emission contour levels are 4, 8, 12, 16, 20, 24, 32, and 36 mJy beam^{-1}. In the construction of the radio continuum map, the CLEAN components were convolved with a Gaussian of HPBW $= 50 \times 50$ arcsec^2 to emphasize the extended structure.

al. 1987*a*, *b*) or the less damaging tidal stripping of gas from another group member. The problem with the latter suggestion is that very few large spiral companions are seen near either galaxy. NGC 5903 has a slightly larger companion A1515+23, which lies beyond the tip of the southern H I plume. This galaxy is a potential remnant of a tidally disrupted donar galaxy. However, one might expect that a galaxy so strongly disrupted would have already merged with one of the elliptical galaxies by the action of tidal friction. The lack of a detectable H II signal from A1515−23 also argues against this being the original source of the accreting gas, since in most simulations of tidal interaction, the lower mass galaxy usually retains some of its particles, albeit in elliptical orbits (e.g., Toomre and Toomre 1972).

A more likely donor of the gas is the more substantial galaxy ESO 514−0050 of unknown redshift seen on Figure 1*b* ~16′ to the northeast of NGC 5903 at position R.A.(1950) = $15^h16^m09^s$, Decl.(1950) = −23°38′7″. This edge-on disk galaxy has its major axis orientated along a position-angle which points to within 1′ of the center of NGC 5903! The galaxy looks slightly disturbed and contains a tilted dust-lane and could well be the source of the accreted gas. The galaxy is too far from the center of the primary beam in the current VLA observations, and so nothing is known about its kinematics.

d) Origin of the Extended Radio-Continuum Emission

The one-sided extensive radio emission from NGC 5903 would be notable even in the absence of the very extended H I emission from this system. One-sided radio structures of this kind are usually found associated with galaxies in rich clusters, where either ram-pressure effects or buoyancy effects lead to one or more tails associated with the interaction of relativistic plasma from the galaxy with the ICM. It is known that NGC 5898 has a hot tenuous X-ray–emitting halo around it (Jones, Forman, and Tucker 1985), and it could be argued that NGC 5903 is orbiting within the outer parts of this halo, providing some analogy with an X-ray–emitting cluster. However, such a picture is not consistent with the structure of the H I filaments, which would also be expected to be acted upon by ram-pressure from the gaseous halo of NGC 5898. The very different distribution between the H I and the radio continuum (Fig. 8) does not support a head-tail radio source model.

It is more plausible that the extended radio emission may be the result of an outburst of nuclear activity in NGC 5903. Such activity may have produced the one-sided radio structure. The minimum time since such an outburst would be the light-travel time across the emission region which corresponds to ~90,000 yr. It is possible that the outburst may be linked to the accretion of the gas onto NGC 5903. However, no similar radio emission is detected from NGC 5898, again suggesting that the main accretion process has ceased in this galaxy.

VI. CONCLUSIONS

We present neutral hydrogen and $\lambda = 20$ cm radio continuum data for the NGC 5903/5898 elliptical binary system. The H I structure associated with NGC 5903 is remarkable both in its large extent and in the complexity of the kinematics of the gas. From the observation we conclude that:

1. The majority of the H I observed in the field is found *outside* the optical body of NGC 5903 in the form of two linear filaments and considerable extended emission asymmetrically distributed with respect to NGC 5903. Only 30% of the H I is found within the galaxy and is roughly aligned with the optical minor axis of NGC 5903.

2. No H I was found associated with NGC 5898 down to a limit of $N_{\rm H} \leq 6 \times 10^{19}$ at cm^{-2}.

3. The general distribution of the H I around NGC 5903 suggests that the present structure is transient and is probably gas in the process of being accreted by NGC 5903. The settling of the H I onto the minor axis of the NGC 5903 and the broader velocity spread of the H I near the optical center of the galaxy suggest that the accretion has already led to the formation of a rotating disk. However, the rather scattered asymmetric distribution further out from the galaxy suggests that the accretion process is far from complete.

4. Except for a faint H I extension in the direction of NGC 5989, no cool gas is found connecting the two galaxies. However, the discovery of counter-rotating ionized gas in NGC 5898 (Bertola and Bettoni 1988) also suggests recent accretion. The accretion may be related to a common double-galaxy accretion event $\sim 3 \times 10^8$ yr ago, an event in which both galaxies have had gas dumped on them from outside.

5. The radio continuum emission from NGC 5903 is unusual for a galaxy in a loose group. It shows a tail extending over a large scale, comparable to that of the H I but with a different orientation. This extensive $\lambda = 20$ cm emission may be the result of an outburst of radio-emitting plasma from an active nucleus, triggered by the accretion of the H I. No similar emission is found associated with NGC 5898.

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