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A MULTI-FREQUENCY STUDY OF THE PECULIAR INTERACTING SYSTEM ARP 206

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I. INTRODUCTION

Arp 206 is a nearby (7.8 Mpc), relatively large ($7'.5 \times 2'.0$), and bright ($B_T^{b,i} = 11.07$) interacting system comprising unequal members: NGC 3432 and UGC 5983. A third anonymous galaxy, "Arp 206c", is visible in the field. (see Figure 1a) Vorontsov-Velyaminov (1959) included the NGC 3432-UGC 5983 pair in his *Atlas and Catalogue of Interacting Galaxies* (VV-11). On the other hand Arp (1966) interpreted the system as a galaxy with material ejected from the nucleus (Arp 206).

Bertola (1966, 1968, and priv. comm.) obtained long-slit spectra of the largest galaxy of the pair, NGC 3432. This showed strong non-circular motions that could be interpreted as an explosion in its nucleus. This work is in line with a similar study of another system, Arp 205 (Bertola *et al.* 1983, Noreau and Kronberg 1986, 1987). In this first case it was found that the non-circular radial velocities were caused by the 're-entry' of galactic material torn away by the interacting system.

In their seminal paper, Toomre and Toomre (1972) mentioned two striking consequences of interaction: (1) the spectacular distortion in the usually symmetric outer isophotes of a galaxy, and (2) the infall on the central part of the galaxy of material is no longer held in balance by the symmetric gravitational potential. These effects are present in a large number of system (Kennicutt 1990, this conference) However, detail case studies of individual galaxies are rare because for maximal usefulness they must involve an extensive array of observations at different wavelengths and using very different observational techniques.

We present here one such study and a preliminary discussion of the results. We used the VLA to perform a full synthesis map in the λ 21 cm line. In addition to these observations, we obtained VLA maps of the radio continuum at $\lambda\lambda$ 22, 18 and 6 cm. The radio maps are complemented with CCD images through B , V , and R broad-band filters and $H\alpha$, [S II], and [N II] interference filters obtained at the 1.6 meter telescope of the Mont Mégantic Observatory.

II. OBSERVATIONS AND DATA PROCESSING

A) Radio Observations

All radio data were taken with the NRAO Very Large Array in the 3 kilometre (“C”) configuration. For all observations 3C286 and 1128+385 were used as primary and secondary calibrators, respectively. Details of the line and continuum observations are given in Table I.

The visibilities at 1385 and 1470 MHz were combined together to produce a naturally weighted map. (Figure 1c) A uniform-weight map at 1635 MHz was also produced but is not displayed here. No polarisation was detected from the galaxy down to the noise level. The 4885 MHz map was also produced with natural weighting of the (u, v) data. (See Figure 1d.)

The $\lambda 21$ cm data for Arp 206 were obtained with full (u, v) track observations. We made a bandpass calibration based on 3C286 observations. Maps with both natural and uniform weightings of the (u, v) data were produced and the former was found more satisfactory. Line signals were found in 19 maps ranging from 446.2 to 756.7 km s^{-1} . We found it necessary to clean the line maps after subtracting a continuum map made of 12 channels in which no emission was found. The map noise was 0.54 millijansky beam^{-1} ; and the resolution was $22''.19 \times 17''.65$ at $P.A. = 87^\circ 8$.

TABLE I: Summary of Observations

ν_{eff} or λ_{eff}	$\Delta\nu$ or $\Delta\lambda$	T_{int}	date (y/m/d)	description
1.385 GHz	25 GHz	15.0 min.	83/03/06	21.6 cm continuum
1.385 GHz	25 GHz	50.0 min.	83/05/11	21.6 cm continuum
1.470 GHz	25 GHz	62.3 min.	83/05/11	20.4 cm continuum
1.635 GHz	25 GHz	16.7 min.	83/03/06	18.3 cm continuum
1.635 GHz	25 GHz	49.4 min.	83/05/11	18.3 cm continuum
4.885 GHz	50 GHz	10.3 min.	83/05/11	6.14 cm continuum
1.417 GHz	32×97.7 kHz	5.88 hrs	84/04/09	$\lambda 21$ cm line
4400 Å	~ 980 Å	1000 sec.	86/03/31	Johnson <i>B</i>
5500 Å	~ 890 Å	800 sec.	86/03/31	Johnson <i>V</i>
6400 Å	~ 800 Å	600 sec.	86/03/31	Kron-Cousins <i>R</i>
6577 Å	10 Å	2×2000 sec.	86/03/24	H α $\lambda 6563$ Å
6727 Å	50 Å	2000 sec.	86/03/31	[S II] $\lambda\lambda 6716, 6731$ Å
6002 Å	10 Å	2000 sec.	86/03/31	[N II] $\lambda 6583$ Å

B) Optical Observations

For the optical observations of Arp 206, the Cassegrain focus of the Mont Mégantic 1.6 meter telescope was equipped with a focal reducer, an inclinable filter holder and a CCD camera. Details of the observations are given in Table I. The usual processing step (debiasing, dark count removal, and flatfielding) were done using the IRAF CCDRED package. The latter steps of the processing were done using the AIPS software. Four stars from the HST Guide Star Catalog were used to orient the images relative to 1950.0 sky coordinates. A

crude B , and V calibration was made in the natural system of the CCD using published B and V magnitudes. In addition, $(B - V)$, $(V - R)$ and $(B - R)$ images were also produced. We subtracted the R image from the narrow bandwidth images to produce continuum-free $H\alpha$, $[S II]$, and $[N II]$ line images. The $H\alpha$ image is displayed in Figure 1b. The calibration of the the $H\alpha$, $[S II]$, and $[N II]$ images was made by using published spectrophotometric data of Stauffer (1982).

III. DISCUSSION

A) Arp 206 as a Pair of Galaxies

The CCD images show a well-developed bridge between NGC 3432 and UGC 5983. On the other hand, the complex $H I$ tails are not visible in the optical. In the total $H I$ map, the bridge is lost in a general envelope encompassing both galaxies. The “bridge” also appears to have some radio emission.

On the total $H I$ map the system is rather edge-on, far more than it would appear in optical wavelengths. UGC 5983 falls exactly in line with NGC 3432. The velocity of the centres of mass of NGC 3432 and UGC 5983 are 530 km s^{-1} and 630 km s^{-1} , respectively. In view of the considerable “damage” sustained by NGC 3432 and the apparent low mass of UGC 5983, it appears that the passage must have been at near parabolic speed, with a small pericentric distance and a very low inclination with respect to the disk of NGC 3432. The apparent distribution of $H I$ along the z axis of the galaxy could be accounted for by projection effects.

The tidal appendage found at higher velocities, which rises at a $P.A. \simeq 25^\circ$ west of the main body of the galaxy is probably the “tail”, the part of the tidal “damage” away from the perturbing companion. (see Figures 1a and b) The “bridge” may be rising north-east from the galaxy and then continue “under” to the south of the galaxy. The relative sizes of the appendages would indicate that the pericentre was crossed *recently*. Any further inferences about the collision parameters will need to await the results of detailed computational modelling of the interaction.

We now summarize the observational characteristics of the individual galaxies:

B) NGC 3432

The brightest isophotes of the galaxy show a wiggly line of “knots”. In the R image, the central region dominates the emission. The northeast part of the galaxy dominates in the $H\alpha$, $[S II]$, and $[N II]$ line maps and the 4885 MHz continuum map. (see Figure 1) The bluest ones are visible in the north-eastern part of the knot ridge. The peak of radio emission does not correspond with the nucleus but rather with the regions where the bluest knots are found. This region also corresponds with the local maxima of the $H\alpha$, and $[S II]$ maps. The radio emission observed is most probably due to star formation and supernova activity.

It is interesting to note that the main body of NGC 3432 was not disturbed by the interaction. The H I is concentrated into two maxima on either side of the optical "nucleus" itself does not appear to be prominent in the radio continuum at either "C" or "L" band.

It is interesting to note that the non-radial motions reported by Bertola (1966, 1968, and priv. comm.) were not reproduced in the H I line maps. (Noreau *et al.* 1990)

C) UGC 5983

Detailed examination of the H I line maps indicates that the location of the NE secondary maximum in the channel maps from 487.6 to 570.3 km s⁻¹ shifts with increasing velocity along a line at *P.A.* $\simeq 44^\circ$. This could be the rotation axis of UGC 5983. Some of the tidal material, especially in the NE, could perhaps have been part of UGC 5983 at some point.

The fact that both galaxies are found in a common H I envelope also suggests that material from NGC 3432 might have fallen toward its smaller companion. We suggest that actually, gas fell on the companion and triggered star formation. This scenario is supported by the discovery of continuum radio emission at 21.6 cm which is coincident with the H α emission seen in UGC 5983. (see Figures 1b and 1c.)

D) Arp 206c

Arp 206c was not detected in any of the radio continuum or optical interference filter images. Some H I emission appears in projection with Arp 206c, but they undoubtedly are extensions of the tidal features of NGC 3432. Arp 206c is most probably an unrelated background object.

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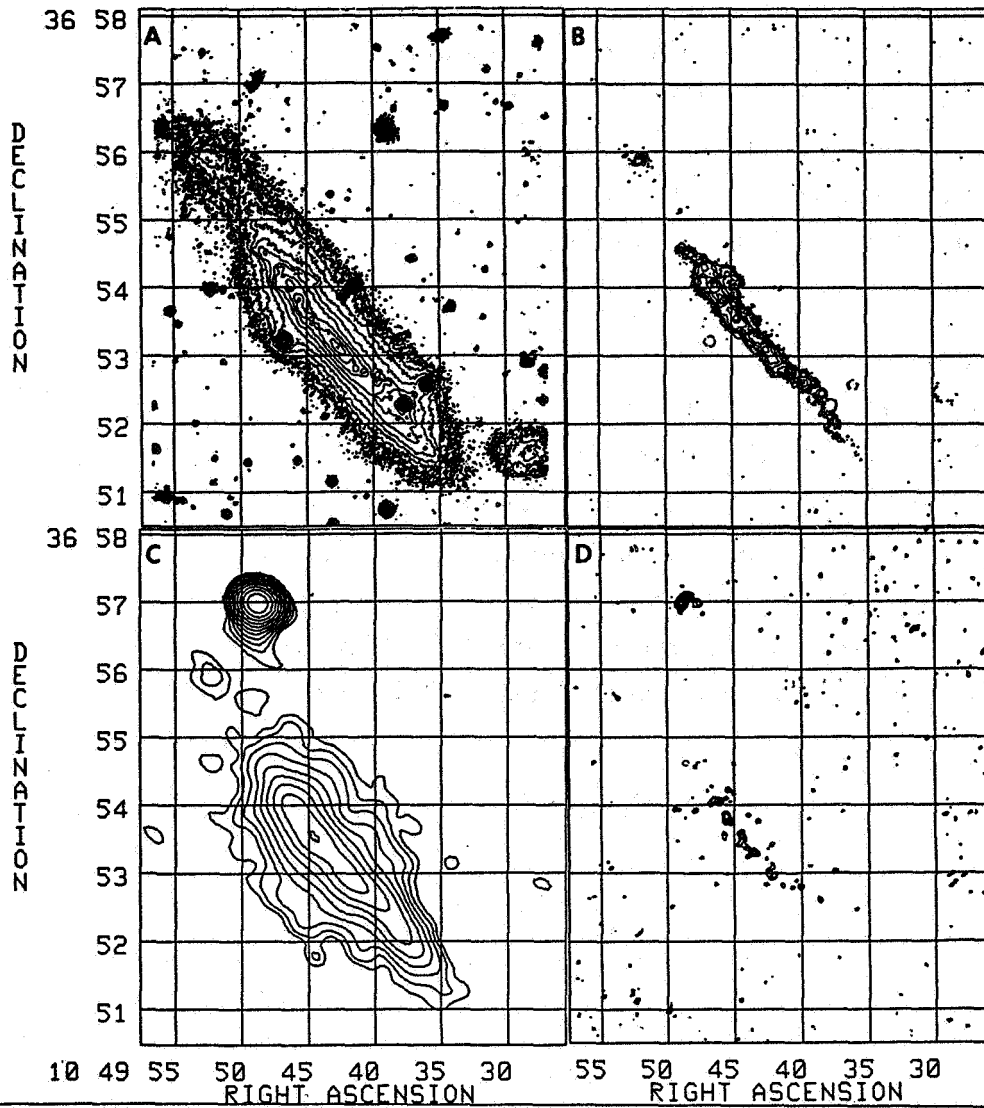


Figure 1 The many faces of Arp 206: (A) Red CCD image; (B) Continuum-free H α CCD image; (C) VLA map of the continuum emission at 21.6 cm. (D) VLA map of the radio continuum emission at 6.1 cm.

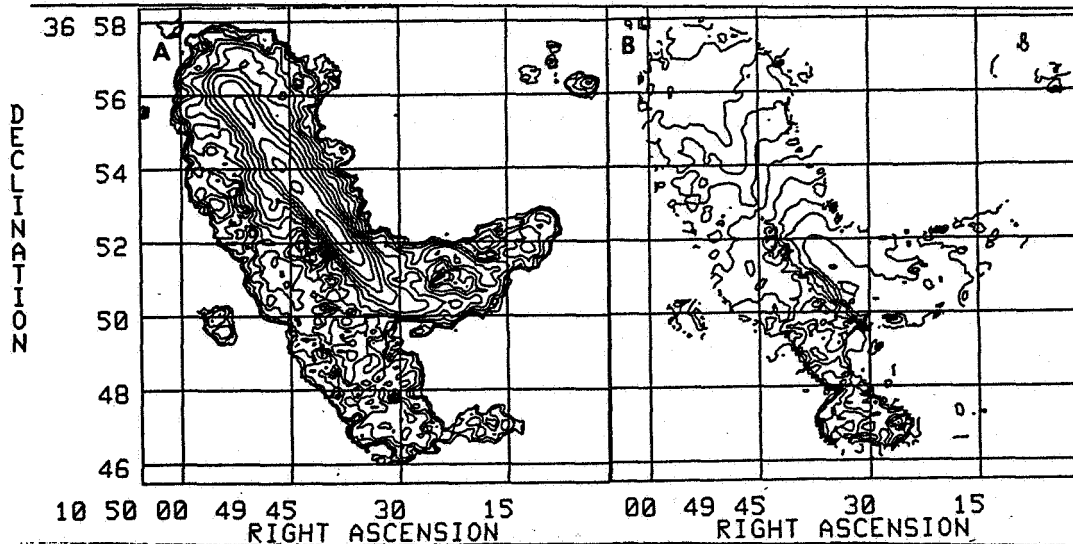


Figure 2 Arp 206 in the $\lambda 21$ cm line: (A) Total H I map; (B) Velocity map.