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NEUTRAL HYDROGEN IN X-RAY CLUSTER GALAXIES: A1367

GUIDO L. CHINCARINI
University of Oklahoma and European Southern Observatory
R. GIOVANELLI
Arecibo Observatory[1]
M. HAYNES
National Radio Astronomy Observatory[2]
AND
P. FONTANELLI
Osservatorio di Arcetri, Firenze, and Arecibo Observatory
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ABSTRACT

21 cm observations of X-ray galaxies in the cluster A1367 show that the neutral hydrogen gas may coexist with the hot coronal X-ray gas. Such galaxies, however, are neutral hydrogen deficient.

Subject headings: galaxies: clusters of — radio sources: 21 cm radiation — X-rays: sources

I. INTRODUCTION

Bechtold *et al.* (1981) in an X-ray survey of the cluster A1367 detected 14 extended X-ray sources and 14 point X-ray sources. The extended sources have luminosities in the range 1.5–6.6 10^{41} ergs s^{-1} (passband 0.5–4.5 KeV) and define a galaxian corona. Two galaxies had been observed both in the X-ray and in our 21 cm line survey of the region Coma A1367 (Chincarini, Giovanelli, and Haynes 1981). Of these one is an X-ray source not detected in 21 cm, and the other a 21 cm source not detected in the X-ray.

It occurred to Giacconi, when he became aware of our work, that the X-ray emision may be incompatible with the presence of neutral hydrogen and vice versa, so that a better statistic would be need to confirm (or reject) the apparent anticorrelation. To this end we observed all the A1367 spiral galaxies which had been detected in the X-ray sample with the 305 m Arecibo dish in the 21 cm line. In this note we report on these observations.

II. OBSERVATIONS

Of the nine galaxies which have been identified with extended X-ray sources, four are ellipticals, and the rest have a morphological type later or equal to S0. These galaxies, a total of five, were observed in the 21 cm line. The observed galaxies are listed in Table 1.

The mode of observation and data reduction is the same as described in our previous work (Giovanelli, Hayes, and Chincarini 1982). It suffices here to mention that the spectral resolution is 32.063 KHz. The main beam half-power width is $3'.3 \pm 0'.1$, and its shape not far from the axis may be described by the square of a Bessel function of order zero. Because of the rather high surface density of galaxies in the observed region, we have, in two cases, beam confusion. Galaxy 8 is within the beam size of galaxy 6, and galaxy 9 is within the beam size of galaxy 7. A similar signal, at a lower flux level, is observed pointing the telescope at the coordinates of galaxy 8. For this reason and because galaxy 6 is brighter and bigger, we assume that the 21 cm emission originates in galaxy 6 (R.A. = 11:41:18.7, decl. = 20:03:12).

Somewhat more uncertain is the assignment of the radio signal between galaxies 7 and 9. We decided to assign the signal to galaxy 7 because this galaxy is 1 mag brighter.

Some of the galaxies listed in Table 1 are not X-ray sources and were observed to estimate confusion effects. The profiles of the detected galaxies are reproduced in Figure 1, and a brief discussion of the observed galaxies follows.

a) *Galaxy 1* ($11^h41^m26^s.3$, $20°03'36''$)

The centroid of the X-ray position is offset NE: $X(11^h41^m27^s.7$, $20°03'42''.8)$. The optical object, radio coordinates, consists of an Sb galaxy with a peculiar asymmetry (W of the center) which could be due to a

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TABLE 1

OPTICAL PROPERTIES

Number	R.A. (1950)	decl. (1950)	Type	m_z	Size	L[a] ($10^{10}\ L_0$)	M[b]	V_0[c]	i	Notes[d]
1...........	$11^h41^m26^s.3$	20°03′36″	Sb	15.8	1′.05×0′.4	0.53	−20.44	4865	69	18
2...........	11 41 43.7	20 07 23	S0/Sa	14.5	0′.75×0′.55	1.20	−21.45	6382	44	23
3...........	11 42 10.2	20 02 03	S0	16.3	0′.45×0′.22	0.23	−19.52	6348	63	30
4...........	11 42 22.0	20 00 11	S0	16.4	0′.60×0′.60	0.21	−19.42	7809	0	point source[e]
5...........	11 42 13.5	20 04 16	Sb/Sa	13.8	1′.2×0′.6	1.40	−21.64	5390	61	35
6...........	11 42 18.7	20 03 12	Sc:	15.4	0′.80×0′.50	0.59	−20.43	8177	51	...
7...........	11 42 12.8	19 57 55	Sa	15.6	0′.52×0′.47	0.43	−20.22	4908	27	33
8...........	11 42 11.7	20 03 02	Sc:	15.9	0′.45×0′.35	...	...	8848:	...	[f]
9...........	11 42 10.7	19 58 27	Sc	16.7	0′.40×0′.40	...	...	...	...	[f]

[a] Assuming $\langle V_0 \rangle = 6700$ km s^{-1}, $H = 100$ km s^{-1} Mpc^{-1}.
[b] Assuming $\langle V_0 \rangle = 6700$ km s^{-1}, $H = 50$ km s^{-1} Mpc.
[c] Optical redshifts as listed in Bechtold *et al.* 1981.
[d] Number of galaxies according to the identification by Bechtold *et al.* 1981.
[e] Northern compact companion at $V_0 = 5962$, size = 0′.22×0′.19.
[f] Galaxies 8 and 9 are within the bean size of galaxies 6 and 7, respectively.

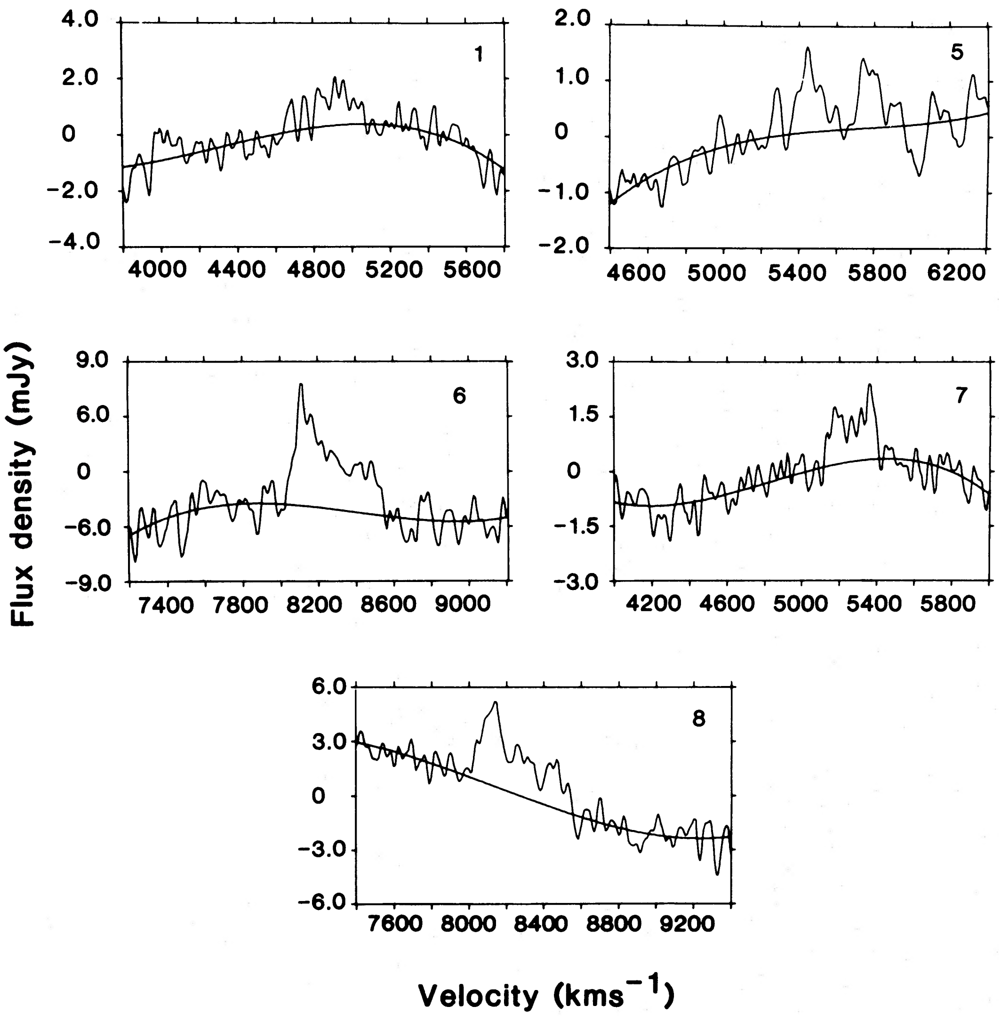

FIG. 1.—21 cm profiles of detected galaxies

very bright H II region. The asymmetry may be due to tidal forces caused by the SW companion which is at a distance of ~ 38".2.

b) Galaxy 2 ($11^h41^m43^s.7$, 20°07′23″)

The X-ray source $X(11^h41^m42^s.0$, 20°06′48".8) is centered NW of the optical object. The galaxy shows a very faint and extended spiral arm. The two companions (SE) are at a distance of 69″ and 104″, respectively. A bar may be present.

c) Galaxy 3 ($11^h42^m10^s.2$, 20°02′03″)

The X-ray source is located at $X(11^h42^m10^s.2$, 20°02′05".5) and practically coincides with a rather inconspicuous lenticular galaxy. Galaxy 8 is within the beam size at a distance of ~ 57″. The galaxy is probably part of the group dominated by the galaxy ($11^h42^m13^s.5$, 20°04′16″) discussed below.

d) Galaxy 4 ($11^h42^m22^s.0$, 20°00′11″)

An X-ray point source $X(11^h42^m22^s.0$, 20°00′10".9) is identified with the lenticular face on galaxy.

e) Galaxy 5 ($11^h42^m13^s.5$, 20°04′16″)

The center of the X-ray source $X(11^h42^m13^s.0$, 20°04′42".6) is located between the bright Sa galaxy and a faint north companion (distance ~ 45″). The galaxy is the brightest object of a group of five galaxies. Part of this group are galaxies 6 and 8 (Table 1 and below) which have been observed even if they are not X-ray sources because (1) They are within the beam size of the brightest galaxy; however, the redshift of N.6 is higher. (2) They show morphological peculiarities (H II regions and disruption) which may be indicative of the presence of neutral hydrogen. The region of this group is characteristic of the presence of "intragroup" gas which seems to be spread all over. The SE companion shows signs of activity.

f) Galaxy 6 ($11^h42^m18^s.7$, 20°03′12″)

This galaxy is not an X-ray source, but it is part of the group discussed above at a distance of ~ 105″ from galaxy 5. Its peculiar morphology is indicative of violent activity, and various bright H II regions are present.

g) Galaxy 7 ($11^h42^m12^s.8$, 19°57′55″)

This is the brightest galaxy of a pair separated by ~ 45″. The center of the X-ray source $X(11^h42^m12^s.8$, 19°58′15".0) is north of the galaxy and SE of its companion, galaxy 9. The companion is ~ 1 mag fainter, its morphological type Sc. The identification is uncertain due to beam confusion. Note, however, that the deficiency parameter would increase somewhat if both galaxies emit in the 21 cm line and would only slightly decrease if the flux is due to the companion since the variations in morphological type and luminosity almost cancel out.

In summary, we detect two bona fide extended ray sources, galaxies 1 and 5. For both we measure a large hydrogen deficiency. The three nondetected galaxies allow lower limits which are consistent with deficiency. In one case, galaxy 4, the redshift is uncertain.

III. DISCUSSION

The present observations show that (*a*) high temperature coronal gas may coexist with cold H I gas; (*b*) when both states are detected (hot and cold), the neutral hydrogen is underabundant by a rather large factor (5 to 10).

The ratio of the hot gas kinetic energy to the galaxian gravitational energy is of $\sim 3/2\ kTl/GM_\mu H$, where l is the scale length of the hot gas. For galaxies 1 and 5, using $T \approx 3 \times 10^7$ K and $M \approx 5 \times 10^{11}\ M_\odot$ (see Table 2 with $h \approx 0.5$), we have, assuming gravitational confinement, $l \approx 10^4$ pc. This compares with a Holmberg radius of $\sim 6 \times 10^4$ pc (1'.7) and a neutral hydrogen statistical diameter of $\sim 5 \times 10^4$ pc (1'.3). The model for the H I distribution assumes that 70% of total H I mass is contained within 1.2 times the UGC diameter (H diameter = 1.2 × UGC major axis). The observed extension of the X-ray is about the same, viz., $\sim 10^4$ pc (according to Bechtold *et al.*, 1'.4 diameter for galaxy 1 and 1'.2 diameter for galaxy 5). A hot shell at $\sim 3 \times 10^4$ pc from the center of the galaxies is unstable toward formation of galaxian winds, and this is in agreement with the fact that the hot gas is observed at a distance which is ~ 5 times larger than the scale height demanded for gravitational confinement.

Our model is therefore one of semiconfinement with a strong galaxian wind. At very large radii the intracluster gas and the ram pressure may partly confine and sweep the outermost shells.

The X-ray observations coupled to the 21 cm data show that the total amount of gas is what we statistically expect for these morphological types. In the X-ray sources, however, the hot gas is overabundant and the H I largely deficient. This is indicative of a model where the neutral hydrogen evaporates in the corona (conduction) and the corona is partly affected by sweeping. We note, however, that an extended X-ray source has been detected also in four elliptical galaxies.

We do not answer the question why some galaxies have a strong X-ray corona and others do not. The X-ray galaxies seem not to have apparent morphological characteristics, suggesting a particular mechanism capable to heat the coronal gas. As suggested by Bechtold *et al.* (1981), the corona visibility may be a consequence of the compression suffered by the coronal gas in regions of higher densities. Naturally a larger sample is desirable to better understand the X-ray versus radio properties.

TABLE 2

21 CENTIMETER PROPERTIES

Number	$V_{21,\odot}$[a] (km s^{-1})	W_{21} (km s^{-1})	rms (mJy)	$\int Jy\,dv$ (Jy km s^{-1})	hM_H[b] ($10^{10}\,M_\odot$)	hM_T ($10^{12}\,M_\odot$)	M_H/L	hM_H/M_T ($\times 10^{-1}$)	$h^{-1}M_T/L$	Def.	L_X (erg s^{-1})
1	4857	416	0.46	1.04	0.06	0.19	0.10	0.32	36	+0.072	6.2×10^{41}
2	(5000)	...	0.37	< 0.28	< 0.03	...	...	...	...	> +0.36	1.5×10^{41}
3	(5000)	...	0.70	< 0.57	< 0.06	...	...	...	...	> −0.33	4.6×10^{41}
4	(5000)[c]	...	0.55	< 0.11	< 0.01	...	...	...	...	> +0.67	[d]
5	5595	470	0.36	1.03	0.03	0.32	0.02	0.09	23	+ 1.08	2.9×10^{41}
6	8290	496[e]	0.85	1.02	0.18	0.62	0.10	0.29	104	−0.12	[f]
7	5256	281[g]	0.35	1.02	0.04	0.26	0.08	0.15	59	+0.30	6.5×10^{41}

[a]Velocity in parentheses refers to the center of the passband when the galaxy is not detected.
[b]All the parameters have been computed using $\langle V_0 \rangle = 6700$ km s^{-1}.
[c]Redshift off band?
[d]Point source.
[e]Detected also when observing galaxy 8.
[f]Not detected.
[g]Detected also when observing galaxy 9.

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GUIDO CHINCARINI: Department of Physics and Astronomy, University of Oklahoma, Norman, OK 73019

PAOLO FONTANELLI: Osservatorio di Arcetri, Largo Enrico Fermi, 5, Firenze, Italy

RICCARDO GIOVANELLI: Arecibo Observatory, PO Box 995, Arecibo, PR 00612

MARTHA P. HAYNES: NRAO, PO Box 2, Green Bank, WV 24922