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# IC 3576: AN UNUSUAL SPIRAL GALAXY IN VIRGO

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## ABSTRACT

We have detected a weak, soft X-ray source in Virgo. If the positional information from our experiment is combined with that for the *Uhuru* source 2U 1231+7, the resulting error box of size 0.4 square degrees is centered on IC 3576, an unusual spiral galaxy. Several direct photographs of this galaxy have been obtained. We have observed neutral hydrogen emission at 21 cm from IC 3576, and have obtained upper limits on emission at 5, 1.4, and 0.43 GHz. The galaxy has an extraordinarily large ratio of H I to optical luminosity. Regardless of the identification of the X-ray source, the optical and radio data are difficult to reconcile.

## I. X-RAY OBSERVATIONS

The X-ray data reported in this *Letter* were obtained from rocket-borne argon-methane proportional counters equipped with Mylar windows, and sensitive to celestial X-rays in the 0.17–10 keV band. A complete description of the instrumentation and scan track of the rocket flight has appeared previously (Bowyer *et al.* 1970; Cruddace *et al.* 1972). During a scan maneuver of $0\overset{\circ}{.}34$ $s^{-1}$ between 3C 273 and Vir XR-1, the $3° \times 12°$ FWHM fan-beam detector observed a source in its 0.25-keV pulse-height channels. The counting rate in these channels during the transit of this source through the detector was 2.3 standard deviations above the background accumulated during the entire slow scan maneuver of duration 1 minute; the probability that this enhancement was due to a chance background fluctuation is 0.011. The source was not detected in the 1–10 keV channels of the detector, nor in any of the channels of the $1\overset{\circ}{.}6$ FWHM pencil beam detector also in the payload.

We have not previously reported this source because of the moderate statistical significance of the detection, and the fact that it was seen in only one detector. However, Giacconi *et al.* (1972) have recently reported detection of the source 2U1231+7 in the same region of Virgo. We have assumed this source to be identical to that observed during our flight, and combined the positional data from the two experiments to derive an improved location for the source. The result is remarkable and warrants comment at this time.

In figure 1 we present the scan track of our experiment, with the collimator pattern of the $1\overset{\circ}{.}6$ FWHM instrument projected against the celestial sphere. Also superposed is the error box for 2U 1231+7, of area 0.690 square degrees. We note that our failure to detect the source in the $1\overset{\circ}{.}6$ FWHM collimated detector, which, due to its small solid angle, has a much lower background counting rate than the fan-beam detector, is most reasonably interpreted as locating the source in the eastern half of the *Uhuru* satellite error slat. This combined error box has area 0.4 square degrees, with centroid at $\alpha = 12^h34^m$, $\delta = 7\overset{\circ}{.}0$ (equinox 1950). We note the galaxy IC 3576 has coordinates $\alpha = 12^h34^m05\overset{s}{.}4$; $\delta = 6°53'47''$. This identification has also tentatively been suggested by Giacconi *et al.* (1972) on the basis of the larger error box.

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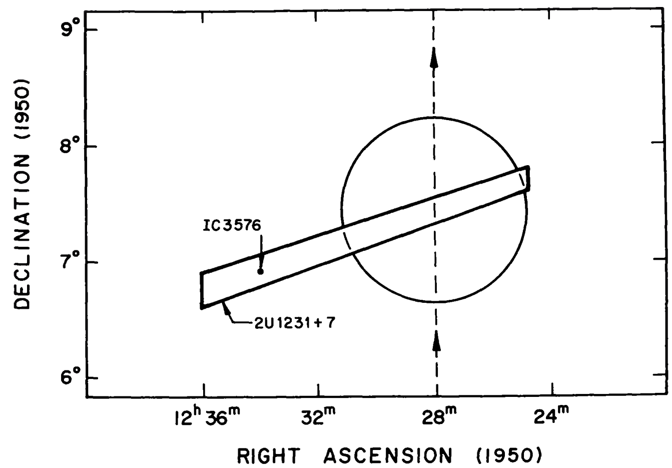


FIG. 1.—Scan track of the rocket experiment, with the projected beam pattern of the 1°.6 FWHM circulary collimated instrument, which did *not* detect the source. Also shown is the 90 percent confidence error box for the source 2U 1231+7 (Giacconi *et al.* 1972).

We do not have sufficient data to derive a spectrum for the X-ray source. However, we stress that our failure to detect the source at energies harder than 0.25 keV does not necessarily indicate that the intrinsic spectrum is a steep power law or due to thermal bremsstrahlung at $T \sim 2 \times 10^6$ ° K. A spectrum of the form $F = 0.45E^{-2.5}$ photons (cm$^2$ s keV)$^{-1}$ would cause the observed counting-rate at 0.25 keV in our detector, but be well beneath the background level in the 1–10 keV channels. This spectrum would also yield approximately 7 counts per second in the 2–6 keV band of the *Uhuru* detector, which is in fact the intensity reported by Giacconi *et al.*

## II. OPTICAL OBSERVATIONS

Due to the possible association of the X-ray source with IC 3576, we have initiated a program of optical observations of this galaxy. The photographic magnitude is given as 15.2 by Zwicky, Herzog, and Wild (1961). It also appears as No. 138 in a catalog of dwarf galaxies located on the *Palomar Sky Survey* (van den Bergh 1959). The *Sky Survey* prints show the object to be considerably better resolved on the blue plate, with several blue condensations and an overall diameter $\gtrsim 1'$.

Wt have obtained several direct photographs of IC 3576 at the 120-inch (305-cm) and Crossley reflectors of the Lick Observatory. One of these plates is reproduced in figure 2 (plate L3). This and other blue patches show no well-defined spiral-arm structure; however, patches and condensations are distributed in a nonrandom, spiral fashion. This distinctive morphology corresponds to the dwarf spiral of the second type discussed by van den Bergh (1959). The condensations are not as noticeable on 098 plates and thus cannot be H II regions; however, a 120-inch telescope plate shows the images to be distinctly nonstellar. This is also true of the brightest condensation near the center, which on the *Sky Survey* might be mistaken for a foreground star. We conclude these condensations are probably OB associations, with the possible exception of the central one which could represent a galactic nucleus.

## III. RADIO OBSERVATIONS

We have observed 21-cm emission due to neutral hydrogen in IC 3576 with the 140-foot (43-m) radio telescope of NRAO,[1] observing simultaneously with two

[1] Operated by Associated Universities, Inc., under contract with the National Science Foundation.

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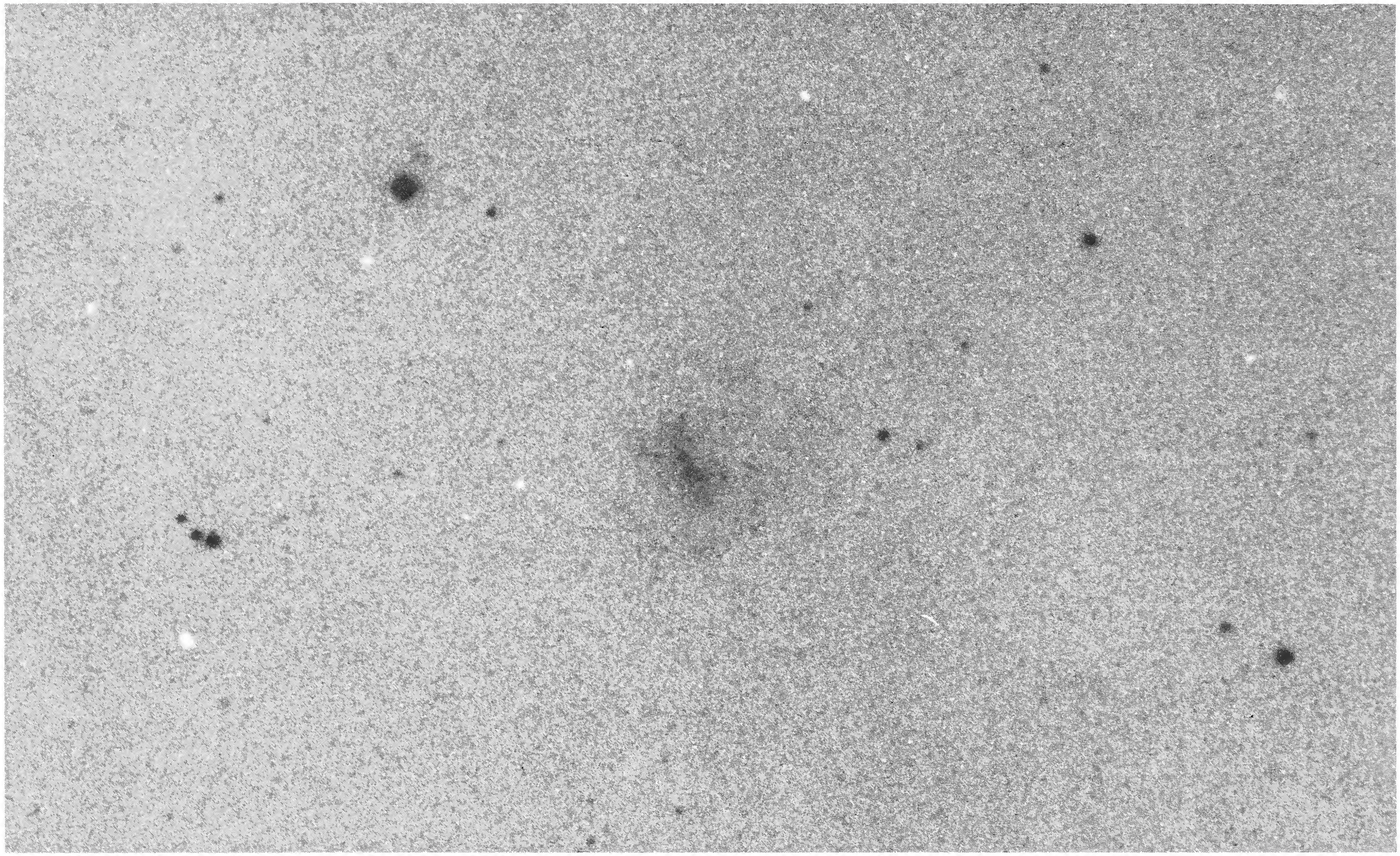

FIG. 2.—A 2-hour exposure of IC 3576 obtained at the Crossley reflector. The plate is an unfiltered nitrogen-baked IIIaJ. Scale of the print is 4″ per mm; original plate scale 40″ per mm. North is to the top, east to the left. Note the large number of condensations on the west side of the galaxy.

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independent 50° K systems in orthogonal linear polarization. The technique used was that of total-power spectroscopy, described by Gordon (1970). The observation consisted of a comparison spectrum, obtained by a 20-minute integration about 14° west of IC 3576, followed by a 20-minute observation of the source. The resulting velocity profile is shown in figure 3; the peak signal occurs at a velocity of 1080 km $s^{-1}$ with respect to the local standard of rest. The velocity and spatial location of this galaxy suggest membership in the Virgo cluster. If we assume a Hubble constant $H = 50$ km $s^{-1}$ $Mpc^{-1}$, the integral of the velocity profile yields a total mass of H I in IC 3576 of $M_{\rm H\,I} = 1.8 \times 10^9\, M_\odot$.

We have searched unsuccessfully for nonthermal radio emission from IC 3576. Observations at the 300-foot (91-m) telescope of NRAO have yielded upper limits of 0.06 and 0.1 f.u. at 5 and 1.4 GHz, respectively. We have also observed IC 3576 at the 1000-foot (305-m) radio telescope of the National Atmospheric and Ionosphere Center, Arecibo, yielding an upper limit of 0.1 f.u. at 430 MHz.

## IV. DISCUSSION

Roberts (1969) has shown that the ratio of neutral-hydrogen content to optical luminosity, a distance-independent quantity, is very well correlated with morphological type. His survey yields average values for

$$\frac{M_{\rm H\,I}/M_\odot}{(L_0/L_\odot)_{\rm pg}}$$

of 0.40 ± 0.06 for Sc galaxies, and 0.79 ± 0.08 for irregular galaxies. The few dwarf galaxies measured tend to yield slightly larger values, the largest being 1.36 for Sex A. From the present work on IC 3576 we derive for this ratio the extraordinary value of 3.1. Even if the photographic magnitude for IC 3576 were incorrect by 1.6 mag, the ratio would still exceed that of Local Group dwarfs such as IC 1613 (Roberts 1969).

This value is difficult to reconcile with the data at our disposal. The high gas-to-luminosity ratio argues strongly that IC 3576 is a dwarf galaxy. The distinctive morphology discussed earlier also supports this argument. However, figure 2 shows easily discernible structure extending for at least 2'.4 in diameter. If IC 3576 is at the distance indicated by its 21-cm velocity profile, again assuming $H = 50$ km $s^{-1}$ $Mpc^{-1}$, then its linear diameter is 15.1 kpc—certainly too large for a dwarf galaxy (cf. Hodge 1971).

We note the resemblance of IC 3576 to the two compact blue galaxies I Zw 18 and II Zw 40, discussed by Sargent and Searle (1970), Chamaraux, Heidmann, and Lauqué (1970), and Searle and Sargent (1972). All three of these blue objects have very high ratios of neutral hydrogen to optical luminosity, and narrow velocity profiles at 21 cm.

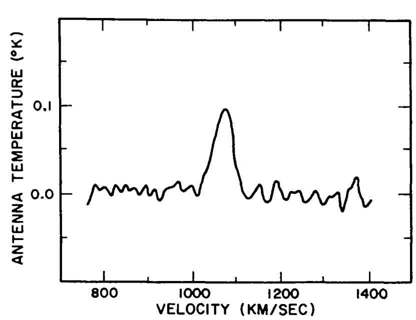


FIG. 3.—Portion of the 21-cm velocity profile of IC 3576 as observed with the 140-foot telescope of NRAO.

The optical morphology of IC 3576, however, is quite different. Searle and Sargent conclude that I Zw 18 and II Zw 40 are either very young or else objects in which star formation is proceeding quite abnormally. If IC 3576 is indeed a member of this class, then a small distance, in disagreement with the velocity, is also indicated.

The evidence at this time that the X-ray source in Virgo corresponds to IC 3576 is positional only. However, all such weak high-latitude sources have in the past proved to be extragalactic. If improved positional information indicates that IC 3576 is the X-ray source discussed here, the discrepancy with the radio observations will be further accentuated. The velocity of this galaxy indicates that it is at a distance which implies an enormous intrinsic X-ray luminosity, quite incompatible with the total lack of nonthermal radio emission reported here. One possibility is that IC 3576 is the first example of a new type of X-ray galaxy, similar to that discussed by Murray *et al.* (1972).

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