Clarification of the Nature of the Galaxy CFC97 Cen 05

A. Bouchard, G. S. Da Costa and H. Jerjen
Research School of Astronomy & Astrophysics, Institute of Advanced Studies, Australian National University, Mt Stromlo Observatory, Cotter Road, Weston Creek, ACT 2611, Australia

bouchard, gdc, jerjen @mso.anu.edu.au

Received ___________________; accepted ___________________
ABSTRACT

The galaxy CFC97 Cen 05 has in the past been considered an HI-rich dwarf galaxy in the nearby Centaurus A group. We have used Australia Telescope Compact Array observations to show that the HI associated with CFC97 Cen 05 by Côté et al. (1997) is most likely a Galactic High Velocity Cloud that is centered $\sim 17'$ from the optical image of the galaxy. At the optical location of the galaxy, which is not that tabulated by Banks et al. (1999), there is no indication of the presence of HI for velocities less than the upper limit of the HIPASS survey at $\sim 12,500$ kms$^{-1}$. In addition, WFPC2 images of CFC97 Cen 05 obtained from the HST Archive reveal that this galaxy is in fact not a dwarf at all, but rather is a distant background spiral not associated with the Centaurus A group.

Subject headings: galaxies: dwarf — galaxies: individual (CFC97 Cen 05)
1. Introduction

The current paradigm for the formation of structure in the Universe (ΛCDM) envisages that relatively low-mass (∼ 10^7 M⊙, e.g. Mayer et al. 2002) dark matter halos form first from density fluctuations in the early Universe. These small-scale clumps of dark matter then merge in a hierarchical process to form larger structures. This model has revived interest in dwarf galaxies since such systems may well represent the closest present-day analogues to the products of the evolution of the initial dark matter halos. Dwarf galaxies are ubiquitous, being found in environments as diverse as rich clusters through to the general field. In many instances, the study of dwarf galaxies and the influence of environment on their evolution is based on observations of dwarfs in relatively nearby groups. The proximity of such systems allows the investigation of the properties of the dwarfs over a substantial range in luminosity, including systems approaching the absolute magnitude of all but the faintest of the Local Group dwarf population.

Frequently, the initial classification of a system as potential dwarf galaxy member of a group is done via visual inspection of Sky Survey films (e.g. Côté et al. 1997; Jerjen et al. 2000a). Such classification as a dwarf candidate is necessarily a subjective process: morphology of the image, surface brightness, extent of resolvable structure, etc, all play a role in the categorization process. Subsequent follow-up analyses necessarily require the census of dwarfs in a group to be as complete as possible. Consequently, confirmation of group membership needs to be carried forward for the dwarf candidates. This can come about via measurement of a radial velocity consistent with group membership, either

---

1Based in part on observations made with the NASA/ESA Hubble Space Telescope, obtained from the data archive at the Space Telescope Science Institute. STScI is operated by the Association of Universities for Research in Astronomy, Inc. under NASA contract NAS 5-26555.
through optical spectra or HI observations, or via a determination of a distance compatible with group membership obtained either directly from, for example, the tip of the red giant branch, or through surface brightness fluctuation techniques (e.g. Jerjen et al. 2000b).

In this paper we present a discussion of the galaxy CFC97 Cen 05. This galaxy was discovered and classified visually by Côté et al. (1997) as one of a number of potential dwarf irregular members of the Centaurus A group. This group lies at a distance of $\sim$3.5 Mpc, and as the name implies, has the unusual E galaxy Cen A (NGC 5128) as the dominant group member. Côté et al. (1997) sought to confirm group membership of their candidates through the measurement of radial velocities obtained with either the Parkes radio-telescope at 21 cm, and/or with the Siding Spring Observatory 2.3 m telescope at Hα. Although the heliocentric velocity for CFC97 Cen 05 given by Côté et al. (1997), $+122$ km$^{-1}$ obtained from HI observations, is more than 200 km$^{-1}$ lower than the next lowest velocity of the candidates with HI detections (ESO 383-G087)$^2$, Côté et al. (1997) classified CFC97 Cen 05 as a confirmed dwarf member of the Cen A group, and listed the total HI content as $1.6 \times 10^7 M_\odot$. Assuming membership in the Cen A group and using the photometry of Côté (1995) corrected for interstellar extinction but not absorption internal to the galaxy, the absolute blue magnitude of CFC97 Cen 05 is $M_B \approx -12.0$, yielding $M_{HI}/L_B \approx 1.7$ in solar units, a value typical of most dwarf irregulars (Warren et al. 2004).

CFC97 Cen 05 is also mentioned in the blind HI survey of the Cen A group carried out by Banks et al. (1999) with the Parkes telescope and the multibeam focal plane array system (Barnes et al. 2001). Banks et al. (1999) listed an HI detection with a heliocentric velocity of 130 km$^{-1}$ that corresponded to an HI mass of $1.7 \times 10^7 M_\odot$ assuming membership in the Cen A group. These values agreed with those of Côté et al. (1997) for CFC97 Cen 05

$^2$Cen 05 is not plotted in the lower panel of Fig. 5 of Côté et al. (1997), as its $V_{LG}$, calculated using the definition employed by Côté et al. (1997), is $-166$ km$^{-1}$.
and consequently, Banks et al. (1999) assigned their HI detection to this object. However, Banks et al. (1999) apparently failed to notice that the position for the object they claimed as the detection of HI in CFC97 Cen 05 is in fact $\sim 17'$ from the location of the optical image of the galaxy.

As part of a larger project investigating the influence of environment on the evolution of dwarf galaxies, we are carrying out a study of the distribution of the HI in a number of dwarf galaxies in nearby groups, including the Cen A group. Local Group observations show that in low luminosity dwarfs, the gas can be centered on the optical component, offset from the center of the optical component, or perhaps even completely detached (e.g. Young & Lo 1997; St-Germain et al. 1999; Robishaw et al. 2002). While the Parkes telescope is adequate in most cases for detecting the presence of HI, given the small angular size of the target dwarfs, and the large beam size of that telescope ($\sim 15'$), higher spatial resolution observations are required to investigate the location of the neutral gas relative to the optical component. Consequently, we have employed the Australia Telescope Compact Array (ATCA) for our study. One of our targets was CFC97 Cen 05, which lies $\sim 7'$ ($\sim 7$ kpc in projection) from the luminous spiral NGC 4945 that has a Seyfert 2 nucleus. Our ATCA observations and subsequent follow-up using HST Archive data have revealed that not only is the HI detected by Côté et al. (1997) and Banks et al. (1999) not associated with CFC97 Cen 05, it is instead most likely a foreground Galactic High Velocity Cloud (HVC), but also the galaxy itself is background spiral and not a dwarf in the Cen A group.

The remainder of the paper is arranged as follows. In the following section we present and discuss our ATCA observations of CFC97 Cen 05, while in Sect. 3 we present an optical image of the galaxy obtained from HST Archive WFPC2 images. Our results are summarized in the final section.
2. Australia Telescope Compact Array Observations

CFC97 Cen 05 was observed with the ATCA on 24 Feb 2003. A full 12 hour integration was carried out using the 750D array configuration. The FULL_4_1024-128 correlator configuration was employed with a 4 MHz bandpass centered on 1420 MHz, yielding velocity coverage from $-315$ to $+528$ km$s^{-1}$ divided into 1024 channels, each of width 0.82 km$s^{-1}$. The primary beam has a FWHM of 33.6$'$ and it was centered at the CFC97 Cen 05 position as listed in Banks et al. (1999). The data were reduced using the MIRIAD package. The resulting cube has a circular beam 2$'$ in diameter and the velocity axis was binned to a channel spacing of 4.1 km$s^{-1}$.

Both Côté et al. (1997) and Banks et al. (1999) report the detection of HI at a heliocentric velocity of approximately 125 km$s^{-1}$. We show in Fig. 1 a map of the HI detected in our ATCA observations for the velocity range of 109 to 142 km$s^{-1}$. The map shows a relatively diffuse cloud $\sim$10$'$ in diameter, whose center is coincident with the position listed by Banks et al. (1999) for their claimed detection of HI in CFC97 Cen 05. The cloud has a mean heliocentric velocity of 124.7 km$s^{-1}$ with a velocity width $W_{20}$ of 36 km$s^{-1}$. These values are very similar to those given by Côté et al. (1997), 122 and 53 km$s^{-1}$, and by Banks et al. (1999), 130 and 46 km$s^{-1}$, respectively. The total flux from the cloud is 4.5 Jy km$s^{-1}$, which is somewhat less than the total fluxes given by Côté et al. (1997) and Banks et al. (1999), 5.5 and 5.9 Jy km$s^{-1}$, respectively. Such a discrepancy is not unexpected given our observations are with an interferometer rather than a single dish.

However, as shown in Fig. 1, the center of the HI cloud is $\sim$17$'$ from the optical position of the galaxy. Assuming both the gas cloud and CFC97 Cen 05 are in the Cen A group at a distance of 3.5 Mpc, the diameter of the HI cloud would be approximately 10 kpc and the projected separation from the optical galaxy would be of order 17 kpc. Given that CFC97 Cen 05 has an optical diameter of $\sim$1 kpc if it is in the Cen A group, it would seem very
unlikely that such a large HI cloud is physically associated with CFC97 Cen 05, if both are at the distance of the Cen A group.

We are left then with two distinct questions. First, is the HI cloud actually associated with the Cen A group, and second, is there any evidence for HI at, or near, the optical position of CFC97 Cen 05 that might be associated with that system? As regards the first question, we note that inspection of the Digital Sky Survey shows no sign of any obvious optical counterpart at the location of the HI cloud, though interpretation of the DSS image is complicated by the fact that the bright star HD113314 ($V = 4.8$) lies on the sky only 1.8′ from the center of the HI cloud. Nevertheless, given the results of the HIPASS survey, which has revealed that isolated HI clouds beyond the Local Group without optical counterparts are extremely rare (Korabalski et al. 2004), it would seem rather unlikely that this cloud is associated with the Cen A group. Further, from our observations, the velocity of the Cloud relative to the Local Group (using the same definition as Côté et al. 1997) is $-163 \text{ km s}^{-1}$, which is $\sim 240 \text{ km s}^{-1}$ less than the velocity of the Cen A group member (ESO 383-G087) with the lowest velocity relative to the Local Group. As Fig. 5 of Côté et al. (1997) indicates, the bulk of the galaxies of the Cen A group have velocities relative to the Local Group in the range of 75 to 400 km s$^{-1}$. Consequently, we believe that the most likely interpretation of the HI cloud is that it is a Galactic HVC and thus not associated in any way with the Cen A group. The cloud is not listed in the HVC catalog of Putman et al. (2002) though this is not surprising, as with an area of $\sim 0.02 \text{ deg}^2$, it is below the resolution limit of that survey. The Putman et al. (2002) catalog, however, does list 8 HVCs within a 5 deg radius of the cloud. These clouds have $V_{LSR}$ velocities ranging from 90 to 210 km s$^{-1}$. Given that the $V_{LSR}$ of the HI cloud detected here is $\sim 120 \text{ km s}^{-1}$, our interpretation of the cloud as a HVC is plausible.

We turn now to the second question: whether there is any HI in the vicinity of the
optical image of CFC97 Cen 05. In Fig. 2 we show the ATCA spectrum for a $2' \times 2'$ region centered on the location of the optical image of CFC97 Cen 05. Aside from the Galactic HI detected at velocities near zero, there is no indication of the presence of any HI within the velocity range observed. This spectrum has an RMS of 5.7 mJy which converts to a $3\sigma$ upper limit on the mass of any HI present of $4 \times 10^3 [D/\text{Mpc}]^2 [\Delta V/\text{kms}^{-1}] \ M_\odot$, where $D$ is the distance and $\Delta V$ is the velocity width of the HI. At the distance of the Cen A group (3.5 Mpc) this limit is $7.4 \times 10^5 \ M_\odot$ for an assumed velocity width of 15 kms$^{-1}$.

It is of course conceivable that there may be HI associated with CFC97 Cen 05 that lies at velocities exceeding the upper limit of our ATCA observations (+528 kms$^{-1}$). To investigate this we show in Fig. 3, a HIPASS spectrum centered on the optical location of CFC97 Cen 05 for velocities between 0 and 2000 kms$^{-1}$. Given that the spatial resolution of the HIPASS data is $\sim15'$, it is not surprising that this spectrum also shows HI from the spiral galaxy NGC 4945 that lies nearby on the sky. HI from the HVC can also be identified at a velocity of $\sim120$ kms$^{-1}$. However, there are no indications of any other HI detections in this spectrum. Further, this result applies out to the upper velocity limit of the HIPASS data at $\sim12,500$ kms$^{-1}$. The typical RMS in HIPASS data is 13 mJy (Barnes et al. 2001) leading to a $3\sigma$ detection limit of $\sim10^4 [D/\text{Mpc}]^2 [\Delta V/\text{kms}^{-1}] \ M_\odot$. At the distance of the Cen A group and for a velocity dispersion of 15 kms$^{-1}$, this corresponds to a HI mass limit of $1.7\times10^6 \ M_\odot$. While further ATCA observations are required to definitely rule out the possibility of HI at the location of CFC97 Cen 05 which falls within the velocity range obscured by NGC 4945 in Fig. 3, it seems unlikely that there is any HI at this location, at least for velocities less than $\sim12,500$ kms$^{-1}$.
3. HST Archive Data

Our study of the dwarf galaxies of the Cen A group makes use, wherever possible, of HST Archive data to, for example, determine distances from the \( I \) magnitude of the tip of the red giant branch (cf. Karachentsev et al. 2002). Consequently, we investigated whether the HST Archive contained any data for CFC97 Cen 05. Fortunately, this galaxy was included in the field-of-view of a series of images taken with the WFPC2 camera on 25 March 1998 as a pure parallel observation (program 7909). The data comprise four exposures taken through the \( F606W \) filter (wide-V) with exposure times of 260, 500, 500 and 700 seconds, respectively. CFC97 Cen 05 is located on the WF2 CCD in each image.

The processed data frames for the three longer exposure images were downloaded from the Archive and combined using standard techniques (cf. Da Costa et al. 2002). The resulting image of CFC97 Cen 05 is shown in Fig. 4. It is immediately evident from this image that CFC97 Cen 05 is not a dwarf galaxy at all; rather it is an almost face-on spiral galaxy that is presumably located well beyond the Cen A group. On this image the disk of the galaxy is traceable out to a diameter of \( \sim 60'' \) and numerous likely HII regions are evident. An optical spectrum should then be able to readily detect H\( \alpha \) emission from this galaxy and thus determine its redshift. At the present time we can only note that the lack of any HI detection at the location of this galaxy in the HIPASS survey suggests that the redshift exceeds \( \sim 12,500 \text{ kms}^{-1} \), the limit of that survey.

4. Conclusions

We have used HI observations with the Australia Telescope Compact Array and HST Archive data to clarify the nature of the galaxy CFC97 Cen 05, reputedly a relatively gas-rich dwarf in the nearby Cen A group. The HI observations reveal that the gas
previously associated with this galaxy is instead a Galactic High Velocity Cloud centered some $\sim 17'$ from the optical image of CFC97 Cen 05. No gas is detected at the optical location of the galaxy for redshifts less than $\sim 12,500 \text{ km s}^{-1}$. HST WFPC2 observations then reveal that CFC97 Cen 05 is not a dwarf member of the Cen A group at all, rather it is a distant almost face-on spiral galaxy. While mistaken identifications of this type are presumably not common, it is a salutary lesson that group membership of apparently low luminosity small galaxies generally needs confirmation via a number of techniques in order to be certain of group membership.

This research has been supported in part by funds from the Australian Research Council through Discovery Project grant DP0343156. The Digitized Sky Survey was produced at the Space Telescope Science Institute under U.S. Government grant NAG W-2166. The images of these surveys are based on photographic data obtained using the Oschin Schmidt Telescope on Palomar Mountain and the UK Schmidt Telescope. The plates were processed into the present compressed digital form with the permission of these institutions.
REFERENCES


This manuscript was prepared with the AAS \LaTeX macros v5.2.
Fig. 1.— An HI intensity map from the ATCA observations for the velocity range 109 to 142 km s$^{-1}$. The column density levels are 0.5, 1.0, 1.5, 2.0 and 2.5 x 10$^{19}$ cm$^{-2}$. This gas cloud is that detected with the Parkes telescope by Côté et al. (1997) and Banks et al. (1999), and associated by them with CFC97 Cen 05. However, the plus symbol to the North-East of the HI cloud marks the location of the optical image of CFC97 Cen 05. The symbol is 2' x 2' in size and encompasses the optical extent of the galaxy. The ~17 kpc separation between the optical image of the galaxy and the HI cloud, if both are at the distance of the Cen A.
Fig. 2.— A HI spectrum from the ATCA observations for a 2' × 2' region centered on the optical image of CFC97 Cen 05. The RMS of this spectrum is 5.7mJy. Aside from the Galactic HI near zero velocity, there is no indication of any HI at this location within this velocity interval.
Fig. 3.— The HIPASS spectrum at the optical location of CFC97 Cen 05. The lower spatial resolution of the HIPASS data results in contamination from the nearby spiral galaxy NGC 4945. HI from the HVC can also be identified at a velocity of $\sim 120 \text{ km s}^{-1}$. No other HI detections are evident.
Fig. 4.— An image of the galaxy CFC97 Cen 05 generated from three HST WFPC2 images in the $F606W$ (wide-V) filter. The $1.2' \times 1.2'$ field of the WF2 CCD is shown. The galaxy is evidently a background spiral rather than a dwarf member of the Cen A group.