HI Observations of Dwarf Galaxies Out to a Distance of 50 Mpc

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Abstract

Here we report our preliminary findings from an HI search for dwarf galaxies in three environmentally distinct regions of the sky: a galactic void, a galactic cluster, and an interaction field. This study is sensitive at the 5σ level to hydrogen masses as low as $5x10^5$ $M_\odot$. We have made three possible detections of previously uncatalogued objects: one in the void field, and two in the cluster field. Reduction of the interaction field is in progress.

Introduction

It is argued that most dwarf systems are in a dormant state during which star formation does not occur, and have therefore gone undetected in optical surveys. In 1988, Tyson and Scalo published a paper in which they modeled star formation bursts in dwarf galaxies (1988, ApJ **329**, 618). Their luminosity function shows an increase in galaxy number as galaxy brightness decreases, and their most conservative space density was determined to be 10 dwarf galaxies/Mpc^3.

We have made VLA observations of three fields out to 50 Mpc. Using the Tyson and Scalo luminosity function and mass-radius relation, we find that there should be 8 to 10 dwarf galaxies within our detection limits for a single field. We should see 6 systems with hydrogen masses on the order of 10^6 $M_\odot$, and 2 to 4 systems with M_{HI} on the order of 10^7 $M_\odot$.

If the theory of biased galaxy formation is correct, then dwarf galaxies should also be more evenly distributed than more massive (and brighter) galaxies. We have therefore chosen to observe three environmentally distinct fields to investigate whether the space density of dwarf galaxies is location dependent.

Each field is centered on a known dwarf galaxy in a different environment. The first galaxy, UGC 10805, is located near the edge of the local void. If dwarf systems are evenly distributed, then they should also be found in the void.

The second galaxy, UGC 2014, is located near a spiral galaxy at the edge of a cluster. If the spatial density of dwarfs is inhomogeneous, there should be more than the predicted number of dwarf galaxies in this field, and there may be an enhancement at distances comparable to that of the cluster.

The last galaxy, M81 dwarf B, is was chosen to determine whether there is an enhancement of dwarfs in an area near a spiral that isn't in a cluster. Arguments have been made that dwarf systems form out of material that has been stripped off of spiral galaxies. The well known interaction of the M81/M82 system may provide much material for the formation of dwarfs.

Observations

We have made 21 cm observations at the VLA using the D array, with a field of view (HPBW) of 30′. We used a 64 channel spectrometer with a 12.5 MHz bandwidth and a channel separation of 195 kHz (41 km/s). Each of the three fields was observed at 2 independent frequencies for approximately 4 hours per frequency. The central frequency for the first set of observations was 1413 MHz (corresponding to a velocity of 1500 km/s) and the central frequency for the second set was 1401 MHz (4100 km/s). Each set of data was Hanning smoothed in velocity to remove the effects of "ringing" caused by Gibbs' phenomenon.

Void Field (UGC 10805): We have completed preliminary reduction of the data from both frequencies for this field. The velocity range for the reduced data is from 380 – 5376 km/s; this is a distance range of 3.80 – 53.76 Mpc (H_0=100 km/s/Mpc.) The total volume surveyed is 3.0 Mpc^3.

Low Redshift Data: These observations have a resolution of 90″, with a measured single-channel r.m.s. of 0.43 mJy for an unresolved point source. The velocity range for the reduced data is from 380 – 2754 km/s; this is a distance range of 3.80 – 27.54 Mpc. The total volume surveyed for this field is 0.42 Mpc^3. The minimum hydrogen mass for a 5σ detection ranges from $5.3x10^5$ $M_\odot$ at a distance of 3.80 Mpc to $2.8x10^7$ $M_\odot$ at a distance of 27.54 Mpc.

We have detected only UGC 10805 in this field. It is at a distance of 15.4 Mpc, has an observed peak column density (N_{HI}) of $5.0x10^{20}$ atoms/cm^2, and a hydrogen mass (M_{HI}) of $4.5x10^8$ $M_\odot$. This result is in agreement with Weinberg *et al* (1990, preprint) as they did not find any galaxies (with $M_{HI} \geq 10^8 M_\odot$) within their void fields.

High Redshift Data: These observations have a resolution of 70″, with a single-channel r.m.s. of 0.38 mJy. The velocity range covered for this set of data is 2960.7 – 5376.0 Mpc; or a distance range of 29.61 – 53.76 Mpc. The total volume surveyed is 2.58 Mpc^3. The minimum hydrogen mass for a 5σ detection ranges from $2.9x10^7$ $M_\odot$ at 29.61 Mpc to $9.6x10^7$ $M_\odot$ at 53.76 Mpc.

There is one possible detection in this field. The object is at a distance of 49.1 Mpc, has an observed peak column density of $5.8x10^{19}$ atoms/cm^2, and a hydrogen mass of $2.9x10^8$ $M_\odot$. This is a 4.9σ detection in M_{HI}.

Cluster Field (UGC 2014): Only the low redshift data set is currently available.

Low Redshift Data: The resolution for this field is 60″, and the measured single-channel r.m.s. is 0.60 mJy. The velocity range for this data set is 256.0 – 2754.4 km/s; or 2.56 – 27.54 Mpc. The corresponding volume covered is 0.42 Mpc^3. The minimum detectable hydrogen mass therefore ranges from $3.4x10^5$ $M_\odot$ at the minimum distance of 2.56 Mpc to $3.9x10^7$ $M_\odot$ at the maximum distance of 27.54 Mpc that is available for this data set.

In addition to UGC 2014, we may have detected two uncatalogued objects. UGC 2014 is at a distance of 5.45 Mpc, has $N_{HI} = 9.0x10^{20}$ atoms/cm^2, and has $M_{HI} = 4.3x10^7$ $M_\odot$. Object 1 is at a distance of 4.21 Mpc, has $N_{HI} = 8.5x10^{19}$ atoms/cm^2, and has $M_{HI} = 1.6x10^6$ $M_\odot$. This is a 4.7σ detection in M_{HI}. Object 2 is at 2.56 Mpc, has $N_{HI} = 2.0x10^{20}$ atoms/cm^2, and $M_{HI} = 9.7x10^5$ $M_\odot$. This is a 9.2σ detection in M_{HI}, but as its peak signal is in an end channel where the data quality is poor, this should be regarded with caution.

Interaction Field (M81 Dwarf B): Analysis is in progress.

Discussion

This work indicates that the homogeneity of the spatial density of dwarf galaxies as well as the number density assumed by Tyson and Scalo may be incorrect. We have found only one possible object in the void field, and two in the incompletely analyzed cluster field. Other recent work (Weinberg *et al*, 1990; and Briggs, 1990, AJ **100**) also indicates that Tyson and Scalo's number density is incorrect: it predicts too many small galaxies. However, the preliminary results of work in progress by Tyson (1992, private communication) suggest that up to 50% of galaxies with masses $\leq 10^7$ $M_\odot$ will become depleted of gas due to winds driven by star formation bursts. This would reduce the number of gas-rich galaxies, and thus lower the number we would be able to detect in HI.