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HIGH VELOCITY CLOUDS IN NEARBY DISK GALAXIES

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Introduction

Clouds of neutral hydrogen in our galaxy with $|v| > 100$ km s^{-1} cover approximately 10% of the sky to a limiting column density of 1×10^{18} cm^{-2} (Wakker 1990). These high velocity clouds (HVCs) may dominate the kinetic energy of neutral hydrogen in non-circular motion, and are an important though poorly understood component of galactic gas. It has been suggested that the HVCs can be reproduced by a combination of three phenomena: a galactic fountain driven by disk supernovae which would account for most of the HVCs (Bregman 1980), material tidally torn from the Magellanic Clouds (Giovanelli 1981), and an outer arm complex which is associated with the large scale structure of the warped galactic disk (Wakker 1990). We sought to detect HVCs in external galaxies in order to test the galactic fountain model.

Single-Dish Observations

We used the Arecibo 305 m telescope to observe 14 nearly face-on disk galaxies with no obvious companions and with HI profiles that are double-horned and well-behaved. Our goal was to determine whether the observational signature of HVCs, high velocity wings, is present in external galaxies. The observations were taken in April and September of 1991 with the dual-circular feed in a total-power mode, alternating five-minute ON-source scans with five-minute OFF scans. We obtained 40 ON-OFF pairs of NGC 5668 and reached an rms noise level of about 0.6 mJy per 2.1 km s^{-1} channel; 10-20 ON-OFF pairs were obtained for most of the other target galaxies.

We find high velocity wings, extending beyond the double-horned profiles, in 11 of 14 galaxies. The high velocity HI detected in the wings is from .5 to 3% of the total detected HI. Figure 1 shows the Arecibo profile of the Sd-galaxy NGC 5668, where the high velocity wings stretch from about 1470 to 1530 km s^{-1} on the blue side and from about 1660 to 1710 km s^{-1} on the red side. These features are confirmed in our Very Large Array (VLA) observations described below.

We developed simple disk galaxy models in order to better understand how high velocity gas from a warp or from HVCs produced by a galactic fountain affects the HI profiles. Galactic fountain HVCs were modeled as a component of galactic gas with a velocity dispersion of 50 km s^{-1}. The three galaxies without high velocity wings are well fit by models with neither a warp nor HVCs. Two of the galaxies with high velocity wings, NGC 765 and NGC 3344, are fit by models with moderate ($< 10°$) warps along the major axis and no HVCs. HVC models can produce the amount of high velocity gas but not the shape of the spectra. Models with HVCs and no warp are able to reproduce the spectra of the remaining nine galaxies. Models with just a warp are unable to reproduce the HI profiles of these galaxies. High velocity clouds make up 2 to 16% of the total HI in these models. The mass of *detected* high velocity material is a factor of 4 to 13 smaller because most of this high velocity material has the same line of sight velocity as quiescent disk HI (i.e., 1550 to 1610 km s^{-1} in Figure 1). In order to detect all the high velocity gas, we need observations with a synthesis telescope such as the VLA or the Westerbork Synthesis Radio Telescope (WSRT).

Synthesis Telescope Observations

We observed NGC 5668 with the VLA in D configuration for 24 hours in April of 1991 and obtained an rms noise level of 0.34 mJy beam^{-1} channel^{-1} for naturally weighted maps (FWHM= 1', channel width= 10.4 km s^{-1}). The highest velocity gas is not confined to an outer ring, as might be expected in a warped disk, but is distributed nonuniformly across the face of the galaxy. The VLA map reveals a much richer structure of HVCs not accessible to single-dish spectra (i.e., at velocities between the HI horns). From position-velocity diagrams, distinct HI complexes are evident at velocities considerably different from that of the underlying galaxy. Some HVCs extend 150 km s^{-1} away from the systemic velocity.

NGC 5668 does have a warp but the orientation of the warp is such that the affected material has a velocity *closer* to systemic over most of the face of the galaxy. The warp begins outside of the Arecibo beam and thus the warp material is at the wrong position and at the wrong velocity to be the high velocity gas that we detected with the Arecibo telescope. In addition, many of the HVCs seen in the position-velocity diagrams cannot be produced by a warp. We conclude that the high velocity material which we detect in NGC 5668 is not due to the warped disk.

Further VLA, WSRT, and optical observations will be used to test the galactic fountain model and will hopefully determine the nature, and mass, of the high velocity clouds in our own galaxy.

References

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Figure 1. Arecibo spectrum of NGC 5668.