High velocity gas in external galaxies

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Abstract

Two nearby, nearly face-on spiral galaxies, M 101 and NGC 6946, observed in the HI with the WSRT as part of a program to search for high velocity gas in other galaxies, are used to illustrate the range of properties of high velocity gas in other galaxies found thusfar.

Introduction

The origin of the high velocity clouds in our Galaxy is still not well established. A fundamental problem with these high velocity clouds is the uncertainty in distance which makes it difficult to estimate the cloud masses and their spatial distribution. If the equivalent of the high velocity clouds can be found in other galaxies one would hope to acquire better insight into the origin of high velocity gas in galaxies, including our own. We therefore began a program of sensitive observations of four nearby spiral galaxies, using the Westerbork Synthesis Radio Telescope (WSRT) in search of high velocity gas features.

The first galaxy to be observed was M 101, where a large complex of high velocity gas was found (Van der Hulst and Sancisi, 1988), with velocities of up to 160 km/sec in excess of the rotation of the gas in the local disk and with a projected size of over 10 kpc. This gas is most likely moving in a direction perpendicular to the plane, coming out of the plane rather than falling in. The HI mass of this complex is about 2×10^8 $M_\odot$. The high velocity gas is connected with the gas in the disk and possibly related to large scale HI structures in the disk such as kinks in the spiral structure and holes in the HI distribution. Because of the one-sidedness and the large velocities involved it appears unlikely that stellar winds or supernova explosions could have driven this gas out of the disk. A more plausible explanation

seems that the high velocity gas is the result of infall of gas into the disk of M 101 as described by Tenorio-Tagle and Bodenheimer (1988).

Besides this HI with very high velocity with respect to the disk we also find several regions in M 101 with HI at intermediate velocities deviating by about 50 km/sec with respect to the rotation in the local gas layer, illustrating that the gas disk of M 101 is not very quiescent. These intermediate features have velocities that are either blue- or redshifted with respect to the rotation.

In contrast to the very high velocity gas discovered in M101 there are the now well known bubbles and shells in M 31 (e.g. Brinks and Bajaja, 1986), M 33 (Deul, 1988), LMC (e.g. Meaburn, 1980) and our galaxy (e.g. Heiles 1984). Their properties are at least two orders of magnitude lower than the properties of the high velocity gas in M 101. The involving energies and sizes of these phenomena are respectively about 10^{51}-10^{52} ergs and 0.1-1 kpc. The corresponding expansion velocities are of the order of 5-10 km/sec and hardly exceed 20 km/sec.

The first preliminary results on the second of our four survey galaxies, NGC 6946 have become available and show high velocity gas and hole/shell features which are intermediate between the HI shells in our Galaxy, M 33 , M 31 and the LMC on the one hand and the M 101 complex on the other hand. Here we briefly discuss some of the new features found in NGC 6946.

Results

From the WSRT observations we obtained maps at resolutions of 15″ (= 0.7 kpc for a distance of 10 Mpc), 30″ and 60″. The full resolution map shows no obvious velocity deviations. We did, however, find faint HI having excess velocities with respect to the gas in the disk in the 60″ data, but the precise connection with the disk is smeared out at this resolution. Therefore we used the 30″ data as a compromise between spatial resolution and sensitivity.

In NGC 6946 we found about 10 regions with velocities deviating by 50 to 80 km/sec from normal rotation. Most of these regions are spread throughout the disk and have either blueshifted or redshifted velocities with respect to the local rotation in the disk, but never show both. We discuss the two most striking features found at the north-western side in more detail below.

The first, in the northern inter-arm region, shows peculiar, redshifted velocities of about 50 km/sec with respect to the local disk. The redshifted velocity gas is located where the spiral arm bifurcates. Confusion with galactic foreground HI makes

it impossible to trace this gas further out to the east. The correspondence of features in the disk and the location of the redshifted gas suggests a causal relation, which could be similar to the high velocity gas of complex A in M 101 (Van der Hulst and Sancisi, 1988).

The other interesting region with peculiar velocities is associated with two HI holes. The innermost hole has a length of 5.5 kpc and an axial ratio of 3. The outer hole has a round shape and a diameter of 2 kpc.

The velocities at the edges of the inner elongated hole are blueshifted up to 60 km/sec with the highest velocities seen towards the hole centre, suggesting an expanding shell structure. The velocity deviations at the edges of the round hole are up to 100 km/sec but here no gas is detected towards the hole centre. The HI mass in this complex is about 1.2×10^7 $M_\odot$, not enough to fill the hole. The associated kinetic energy is of the order of 10^{53} ergs.

The gas complexes with the velocity deviations are not obviously associated with star forming regions such as giant HII regions or OB associations. Therefore, and because of the large kinetic energies required for producing these phenomena, it is difficult to produce these peculiar velocities with stellar winds or supernova explosions. An alternative explanation involves the infall of gas into the disk of NGC 6946 which drives a subsequent outflow of HI.

With only two galaxies studied in some detail it is not yet possible to make general statements about the presence of high velocity gas in other galaxies. Three more systems are being studied using the WSRT and the VLA. The phenomena observed in NGC 6946 and M 101 do suggest, however, the possible existence of a population of intermediate velocity structures in galaxies with quite a range of properties.

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