High Velocity Clouds

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1. Introduction

Clouds of HI gas are with local standard of rest velocities upwards of 100 km/s were discovered 40 years ago (Wakker 2004) and remain some of more enigmatic phenomena in the skies. A number of theories abound as to the nature of the High Velocity Clouds (HVCs). HVCs are suggested to have formed through tidal interactions with neighbouring galaxies to the Milky Way or through the outflow and inflow of gas from the disc. One dissenting view is that HVCs are extragalactic in location and form the building blocks of galaxies. The different perspectives are summarised below, along with the supporting evidence for each.

2. HVCs as Local Objects

2.1 HIPASS

From 1997 the Parkes Radiotelescope performed a near complete survey of HI sources in the Southern Sky using a multibeam instrument (Staveley-Smith 1997). Previous HVC cloud surveys had been performed in the Northern Hemisphere by the Leiden-Dwingeloo and in the Southern Hemisphere by the 30 metre instrument at Villa Elisa in Argentina (Putman & Gibson 1999). The superior resolution of HIPASS revealed fine-scale structure in existing clouds (Putman & Gibson 1999) and increasing the number of observed clouds by almost 2000 (Putman et al. 2002)

2.2 Tidal Interactions

On the basis of early results from HIPASS Putman and Gibson (1999) suggested that many HVCs are part of the local Milky Way galaxy and its immediate neighbours. They observed a continuous stream of HI between the Milky Way and the Magellanic Clouds (the Leading Arm) and behind the Clouds (the Magellanic Stream). These streams of gas are a predicted feature of models of tidal interactions between the Magellanic Clouds and the Milky Way (Putman & Gibson 1999).

Putman and Gibson further suggested that other clouds not associated directly with the tidal interaction of the Milky Way with the Magellanic Clouds may be related to the emission of HI from the Milky Way by supernova, past tidal interactions and disruptions. The filamentary structures observed in these clouds may be due to extended galactic magnetic fields. However, Putman and Gibson caution that not alll observed HVCs may be local structures and highlight the need for further inspection of the clouds' properties.

2.3 The Galactic Fountain

Shapiro and Field (1976) developed the Galactic Fountain model in which clouds of hot gas from superbubbles (caused, say, by regions of O and B star formation) blows into the galactic halo before falling back into the plane. Wakker (2004) suggests that this is another potential sources lower velocity HVCs, or Intermediate-Velocity Clouds.

3. Galactic Building Blocks

3.1 Low Mass Halos

Blitz et al. (1999) have espoused an alternative hypothesis on the nature of HVCs. They contend that HVCs are the missing low mass halos predicted by many hierarchical galactic formation models. They would be the remnants of galaxy formation, regions where the density is low enough that UV radiation pressure will prevent star formation.

3.2 Supporting Evidence

The following evidence is cited by Blitz et al. (1999) to support their conclusions:

- Most of the observed HVCs are found away from the galactic plane.
- The one major HVC that does lie in the plane ("Complex H") has a sizable velocity difference with that of the galactic rotation without displaying signs of shocked gas.
- Three-body simulations representing the Milky Way, M31 (the Andromeda Galaxy) and an HVC as the test particle give reasonably close results to observations, including filamentary structures connecting the galaxies.

3.3 Predictions

The low mass halo hypothesis allows Blitz et al to make testable predictions as to the nature of HVCs.

- HVCs should have very low metallicities in comparison with the Sun due to the lack of star formation.
- HVCs should have low internal pressure.
- Other galaxies should have HVC analogues.
- H-alpha emissions of HVCs should be greater than or equal to those of the Magellanic Stream if they are local objects or much less than this in the extragalactic realm.

4. Observational and Theoretical Evidence

4.1 Observational Support for HVCs as Low Mass Halos

In their 1999 paper Blitz et al. provide some references to observational support for their low mass halo HVC predictions, including observations of low metallicity in Complex C by Wakker et al (1999), and low densities within clouds. At the time of publication of their paper, clear results were also awaited for their final prediction, that of H-alpha measurements.

Blitz et al. list possible HVC analogues around other galaxies, but state the need for further observations. Using the Australia Telescope Compact Array and Parkes Telescope Pisano et al. (2004) attempted to detect HVCs around three other galaxy groups similar to the Local Group. While dwarf galaxies were detected, no HVC analgoues were observed. Similar results had been obtained by Zwaan et al. (1997) and Zwaan (2001), throwing doubt on Blitz et al.'s conclusions.

4.2 Compact HVCs Appear to be Local

Maloney and Putman (2003) consider the class of Compact HVCs (CHVCs), which show some properties of dwarf galaxies and are the best candidates for extragalactic objects. However, their model suggests that CHVCs would require unrealistically high dark to normal matter mass ratios leading to spectral line widths far in excess of observations. The implication is that CHVCs are associated with the Galactic halo.

4.3 Interactions with the Magellanic Clouds

In his review of recent HVC research, Wakker (2004) finds that there is strong evidence from kinematic, and metallicity observations, as well as theoretical models, that the Magellanic Stream is of tidal origin. Theoretical modelling by Olano further suggests

that many HVCs are the result of tidal interactions between the Small and Large Magellanic Clouds about 570 Myr ago.

5. Conclusions

While some observations have been interpreted to support the hypothesis that HVCs are the missing low mass halos required by hierarchical galaxy formation models, it appears that the majority of evidence supports a local origin. Sources suggested for HVCs have included tidal interactions between the Milky Way and Magellanic Clouds, as well as outflows of gas from the disc of the galaxy. From observations made and theoretical modelling it appears likely that both mechanisms may feature, although most do not entirely that some clouds may indeed be extragalactic.

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