High Velocity Clouds and the Local Group

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Abstract. It was proposed by Blitz et al. (1999) that High Velocity Clouds (HVCs) are remnants of Local Group formation and the average distance of HVCs is 1 Mpc, which is the result of a simple dynamical calculation leading to match the observed HVCs distributions. However, in this paper, we clearly show that fitting the observed HVCs distributions by a dynamical calculation cannot provide any constraints on the average distance of HVCs. With our choices of initial conditions, the observational results in Wakker & van Woerden (1991) are produced in our simulations for the models of both Galactic and extragalactic origins. Moreover, because Zwaan & Briggs (2000) reported that they failed to locate any extragalactic counterparts of the Local Group HVCs in a blind HI 21-cm survey of extragalactic groups, we propose to use “remnants of galactic disc formation” as the modification for the picture of “remnants of galaxy group formation” in Blitz et al. (1999) and thus reduce the possible average distances of HVCs to be about or less than a few hundred kpc.

1. Introduction

High Velocity Clouds (HVCs) are HI clouds at velocities incompatible with a simple model of Galactic rotation.

Most HI clouds are the tracers of the galactic discs for both the Galaxy and the extra-galaxies. The reason why HVCs are interesting is that they do not belong to the majority of the HI clouds in the Milky Way and therefore their nature and origins need to be understood.

The well-known proposed HVCs’ possible origins usually fall into two categories: (a) The Local Group Formation – the remnants of galaxy group formation, (b) Galactic Fountain – the material injected from the galactic disc ”after” the disc was formed. HVCs’ distances are the most important key parameters to understand their possible origins.

Blitz et al.(1999) argued that HVCs should be extragalactic because it is difficult to understand why HVCs would not be metal rich or how the vertical velocities could be so high in the Galactic Fountain context. Incidentally, their simulation, which seems to produce the observed HVCs’ distribution on the sky, suggested the mean HVC distance is about 1 Mpc.

On the other hand, Zwann & Briggs(2000) reported the result different form the hypothesis in Blitz et al. (1999). In a blind HI 21-cm survey of extragalactic group, they failed to locate any extragalactic counterparts of the Local Group HVCs.
2. The Simulations and Results

In order to solve this contradiction, we use N-body simulations to model the HVCs under the gravitational influence from the Milky Way and M31. We explore different initial conditions to check if the simulations can give constraints on the average distance of HVCs.

Different from what was tried in Blitz et al. (1999), we hope to link the observed quantities of each HVC to the simulational results even more closely. That is, we wish to reproduce the observed distributions as perfect as we can. In order to have an excellent guess for initial conditions, we plan to do the backward integration from the current positions and velocities of HVCs implied by the observational data.

The observational data in Wakker & van Woerden (1991) provides us the present Galactic longitude ($l$), Galactic latitude ($b$) and line-of-sight velocity ($v_{\text{los}}$) of each HVC but there is no information about the tangential velocity $v_t$ and Galactic-centre distance $R$ since they are more difficult to be determined. Therefore, we need to assign both the current values of $v_t$ and $R$ to each HVC is our simulations. The tangential velocity $v_t$ is always determined by a random number between 0 and 20 km/s and its direction on the tangential plane was chosen randomly.

Because the distances to HVCs are the most important quantities to be understood, we thus focus on this and plan to explore different range of Galactic-centre distance R: (a) The Model of Galactic Origins ($0 < R < 50$ kpc); (b) The Model of Extragalactic Origins ($560 < R < 760$ kpc); (c) The Mixed Model ($0 < R < 960$ kpc); (d) The Model of HVC Complexes, where many HVCs’ $R$ are assumed to be within the possible distance-intervals of known HVC Complexes studied in van Woerden et al. (1999), Wakker (2001), Wakker et al. (1998), Ryan et al. (1997), Tamanaha (1996), and also Wakker & van Woerden (1991).

We then do the backward integrations to get the initial conditions for the usual forward integrations. Both were performed for 11 Gyrs.

Figure 1-2 are our simulational results. Figure 1 is the $l-b$ plot and Figure 2 is the $l-v_{\text{los}}$ plot.

We found that most HVCs arrive the observed positions on the sky by the end of simulations. We also reproduce the observational HVC distribution on $l-v_{\text{los}}$ plane. Thus, general features of the observed HVC distribution on the sky and $l-v_{\text{los}}$ plane were reproduced though there are some deviations.

3. Conclusions

We found that most HVCs’ observational distribution on the sky ($l-b$ plane) and also $l-v_{\text{los}}$ plane can be produced for all our different models, including both Galactic origin and extragalactic origin models. Therefore, we conclude that fitting the observed HVCs distributions by a dynamical calculation cannot provide any constraints on the average distance of HVCs.

The mechanisms to produce HVCs of Galactic origins can be the galactic fountain model, stream of satellite galaxies (as the possible stream from Sagittarius dwarf galaxy in Figure 6 of Jiang & Binney 2000) and also remnants of galaxy group formation.
On the other hand, the mechanisms to produce HVCs of extragalactic origins can be only remnants of galaxy group formation unless these HVCs are all close to M31 and made by the mechanisms of Galactic origin but within M31.

It is easy to see that there will be no constraint on the distance at all if HVCs are the remnants of galaxy group formation and thus this suggestion seems to be able to explain the origins of most HVCs. Especially, if these HVCs have low-metallicity, other models of Galactic origins would be less attractive. Therefore, although one should keep in mind that it is always a correct concept that HVCs are multiple origins, the “remnants of galaxy group formation” is probably a good term to describe most HVCs when one has to make a choice.

However, Zwaan & Briggs (2000) make a point that there should not be so many HVCs in the intergalactic space as predicted by Blitz et al. (1999) and give the picture of “remnants of galaxy group formation” a difficult time.

Therefore, in order to resolve the contradiction between Blitz et al. (1999) and Zwaan & Briggs (2000), we propose that HVCs are “remnants of galactic disc formation” and reduce the possible average distances of HVCs to be about or less than a few hundred kpc.

This conclusion implied from our simulations completely agrees with recent observational results by Tufte et al. (2002), in which they observed $H\alpha$ lines of HVCs which are candidates for being at larger than average distance and found these clouds are in the Galactic halo and not distributed throughout the Local Group.

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Figure 1. The $l$–$b$ plots for all models, where circles are observational data from Wakker & van Woerden (1991) and cross-points are our simulative results: (a) The Model of Galactic Origins, (b) The Model of Extragalactic Origins, (c) The Mixed Model, (d) The Model of HVC Complexes.
Figure 2. The $l - v_{\text{los}}$ plots for all models, where circles are observational data from Wakker & van Woerden (1991) and cross-points are our simulative results: (a) The Model of Galactic Origins, (b) The Model of Extragalactic Origins, (c) The Mixed Model, (d) The Model of HVC Complexes. Please note that those cross-points with $|v_{\text{los}}| < 50$ km/s should be ignored since they do not satisfy the usual definition of HVCs.