PROCEEDINGS OF SCIENCE

The clumpy HI sub-structure of the Galactic Halo

Leonidas Dedes[*†]
RAIUB, Germany
E-mail: `ldedes@astro.uni-bonn.de`

Peter Kalberla
RAIUB, Germany
E-mail: `kalb@astro.uni-bonn.de`

Using the 100-m Effelberg Radio-Telescope and with the help of the new Leiden/Dwingeloo/Argentinian/Bonn(LAB) HI survey we detected a population of clumps in the outer parts of our Galaxy. These show a prominented two component structure with the cold component having $T_{Kin} < 700$K. The column density is of the ordrer of a few times 10^{19}cm^{-2}, the diameter is several tens of parsec and their mass is of the order of several hudred solar masses or even less. Due to the similarity of the physical parameters we have cocluded that we are proding clouds identical to the ones detected by Lockman(2002) in the inner Galaxy.

Baryons in Dark Matter Halos
5-9 October 2004
Novigrad, Croatia

PoS(BDMH2004)019

---

[*] Speaker.

[†] This work is supported by Graduiertenkolleg 787 “Galaxy groups as laboratories for baryonic and Dark Matter” and based on observations with the 100-m telescope of the MPIfR (Max-Planck-Institut für Radioastronomie) at Effelsberg.

Published by SISSA http://pos.sissa.it/

1. Introduction

The nature of the gaseous Galactic Halo remained unclear for many years. The existence of a quasi-static hot corona with a $T \sim 10^6$K was proposed by Spitzer 1956. The first observational evidence came with the detection of absorption lines in the spectra of very distant stars (Münch & Zirin, 1961). Later Lockman & Gehman(1991) found evidence for a local layer of halo gas extending to large z distances. Fluctuations in the absorption column densities from one direction to another suggested a patchy halo (Savage,Edgar & Diplas 1990, Diplas & Savage 1994). Compining the ROSAT and the Leiden/Dwingeloo(LDS) survey, more information about the halo layer was revealed (Pietz et. al 1998). From the soft X-Ray background a hot plasma with a scale height of 4kpc was derived and from the LDS survey a HI component with a large velocity dispersion and a scale hight of 4kpc, leading to the conclusion 50% of the halo gas mass exists as a hot plasma with $T \sim 10^{6.2}$K and 50% as HI with a low filling factor (Kalberla et. al 1998). The discovery of a population of Halo Clouds by Lockman(2003) using the GBT radio telescope gave the direct first evidence for the clumpy nature of the halo. A summary of the physical properties of these clumps is shown in table 1. Many of these clumps show a two phase structure of a cold and a underlying warm component. Galactic fountain have been proposed to explain such clumps.

V_{LRS} km s^{-1}	z kpc	T_L (K)	$\Delta\upsilon$ km s^{-1}	N_{Hi} $10^{19} cm^{-2}$	D pc	n cm^{-3}	M_{Hi} $M_\odot$
105 - 145	-0.6 - -1.2	0.4 - 2.7	5.4 - 26.3	0.7 - 6.3	19 - 35	0.1 - 0.9	12 - 290

Table 1: Summary of the properties of the Halo Clumps in the inner Galaxy.(Lockman, 2002)

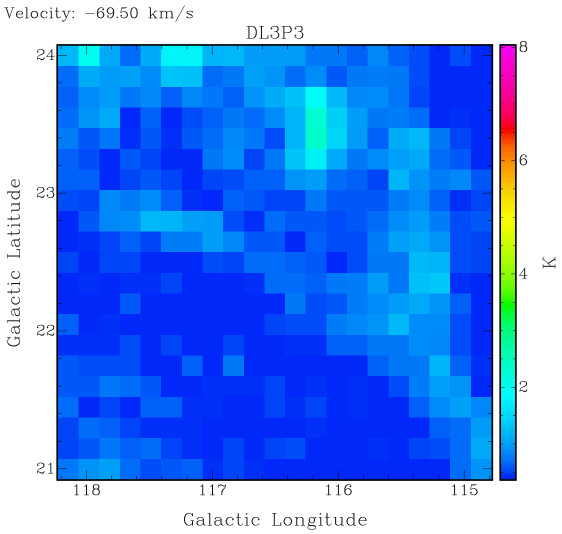
2. Our Project

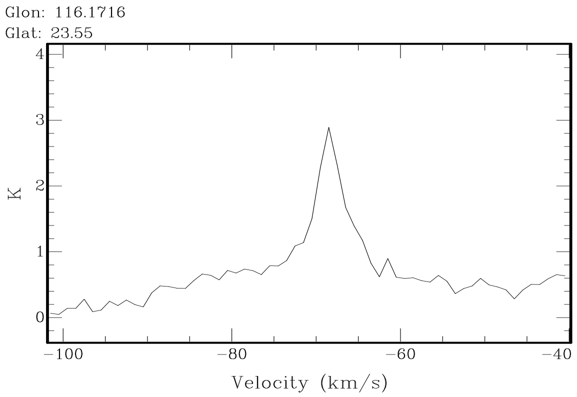
The nature of the gaseous Galactic Halo can be better understood by studying the halo substructure in the form of HI clumps. Their origin, galactic fountain and/or turbulent motion, and their properties can give us an insight about the physical processes in the halo. The aim of our project is to make an unbiased census of the halo HI clumps and to study their properties. We focus our observations to the outer part of the Galaxy. We use the 100-m Effelsberg with an angular resolution of 9' enough at least detect HI clumps. In our search we face two problems , the Halo emission is very faint and ,as mentioned, the filling factor of the HI phase is low ($< 10\%$). To overcome this we used the new LAB HI survey, which is a combination of the LDS and the Argentinian survey processed in Bonn (Kalberla, Burton et al. 2004) and a mass model of the Milky Way(Kalberla, 2003). From the model we derived the expected HI emission from disk and halo. Then we masked the emission from the disk thus we defined the phase-space of the HI halo. This template was used as a finding chart to choose the most interesting regions in the LAB survey to be probed with the 100m Effelsberg Radio-Telescope with higher resolution. It is important to note that the accuracy of the definition of the phase-space of the HI Halo depends on the quality of the model of the disk thus we had to take in account the large scale structure features of the Galactic HI emission(Dedes et. al, Extra Planar Gas Proceedings).

3. Observation, Data Analysis & Results

Using this model of the phase-space of the HI halo up to now 16 fields were selected covering an area of 9deg^2 each with Galactic Longtidute $0 < l < 180$ to be observed with the 100-m Effelsberg Radio-Telescope at 21cm. We observes maps with an angular resolution of 9' and a velocity resolution of 1.2 $\mathrm{km\,s^{-1}}$. The rms baseline noise is of the order of 0.15 K. Nine fields are completely mapped and we identified 20 possible candidates for Halo Clumps. Six of them have been re-observed, confirmed, and analyzed until now. For the analysis we derived kinematic distances from the Milky Way model. Using a two component Gaussian decomposition we extracted the line widths, area and intensity of the cold and the underlying warm component. The kinetic temperature is calculated from the line width using: $T_{kin} = 22 \cdot \Delta\upsilon^2$. Knowing the distance an upper limit for the diameter is given and so we can estimate the volume density $< n >$ and the pressure $\frac{P}{k}$.

The first clump of the sample has (l,b)=(116,23.5) and can be seen in left figure. It is situated in the top of the figure and has an angular diameter of 18'. The clump seems to be surrounded/embedded in a broader,warmer filamentary structure which connects it also with other cold clumps. The spectrum of the clump can be seen in diagram at the right. A cold component can been seen clearly with a line width of 3.05 $\mathrm{km\,s^{-1}}$corresponding to a kinetic temperature of 300K. The underline broad component,which is more difficult to discern and has a large uncertainty has a line width of 17 $\mathrm{km\,s^{-1}}$corresponding to a kinetic temperature of 6000 K. The intensity of the warm component is also half of the intensity of the cold component. The column density is $N = 1.05 \cdot 10^{19}\mathrm{cm}^-2$. The clump lies in the outer galaxy at R=13kpc and z=3kpc. For a diameter of 30pc the volume density is n=0.13 cm^{-3} and the mass is M=80M$_\odot$. Finally the pressure is $\frac{P}{k}$=26K$\cdot$cm^{-2}, a lower limit due to the uncertainty in the diameter of the clump. In case the clump is stable it probably due to the confinement from the ambient medium.





Generally for the six clumps the range of values for the radial velocity is -85 $\mathrm{km\,s^{-1}} < V_{LSR} < -44\mathrm{km\,s^{-1}}$meaning that according to our model they are in the outer galaxy with R>13kpc and z<5 kpc. All of them show very narrow lines, line widths $\Delta\upsilon$<6$\mathrm{km\,s^{-1}}$, which means that the temperature is less than 800K. Column densities range between $0.5 \cdot 10^{19}\mathrm{cm}^-2 < \mathrm{N_{HI}} < 3.5 \cdot 10^{19}\mathrm{cm}^-2$

leading to volumes densities of the order of $< n >= 0.3\mathrm{cm}^{-3}$. Finally the mass of each clump is of the order of $100\mathrm{M}_{\odot}$.As we can see our clumps share similar properties with the HI clumps found in the inner galaxy. The only difference being the location which has a significant impact on their origin. Due to angular momentum conservation considerations the Halo clumps in the outer galaxy have very low probability to originate from the Galactic fountain phenomenon, a most probable cause is the large turbulent motion in the Halo of the Galaxy or probably a combination of both.

4. Summary & future work

In this paper we describe the first results regarding the detection of Halo Clouds in the outer Galaxy. Up to now 20 possible candidates were detected, six of them are already confirmed showing similar properties as clouds on the inner Galaxy. These discoveries can help us gain a better understanding of the Halo nature. It is already mentioned quite a few times that their origin is connected with phenomena like the galactic fountain or the turbulent motions. But also we can gain information about the ISM in the halo, for example the equilibrium of a two phases structures is very sensitive to the metal content of the ISM, dust is important to heat the gas and carbon is needed for the cooling of the denser phase(Wolfire, 1995). To reach a statistical significant number to study their properties we will continue to probe more regions for clumps. High resolution observation with interferometers are also needed to resolve interaction with the ambient medium, the substructure of the clumps and determine with high accuracy parameters like the temperature and pressure. Measure of the metalicity will help us determine if there is a connection with the HVC, and maybe give us a hint regarding the origin of the material which constitutes them.

References

[1] Diplas, A. & Savage, B. D. 1994, ApJS, 93, 211

[2] Kalberla, P. M. W., Westphalen, G., Mebold, U., Hartmann, D., & Burton, W. B. 1998, A&A, 332, L61

[3] Kalberla, P. M. W. 2003, ApJ, 588, 805

[4] Kalberla, P. M. W., Burton, W. B. et al. 2004 A&A, submitted

[5] Lockman, F. J. & Gehman, C. S. 1991, ApJ, 382, 182

[6] Lockman, F. J. 2002, ApJL, 580, L47

[7] Münch, G. & Zirin, H. 1961, ApJ, 133, 11

[8] Pietz, J., Kerp, J., Kalberla, P. M. W., Burton, W. B., Hartmann, D., & Mebold, U. 1998, A&A, 332, 55

[9] Savage, B. D., Edgar, R. J., & Diplas, A. 1990, ApJ, 361, 107

[10] Spitzer, L. J. 1956, ApJ, 124, 20

[11] Wolfire, M. G., Hollenbach, D., McKee, C. F., Tielens, A. G. G. M., & Bakes, E. L. O. 1995, ApJ, 443, 152