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An automatic identification of HI shells in the 2nd and 3rd Galactic Quadrants

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Abstract. We briefly discuss different methods used to identify HI shells in T_B datacubes. Then we give results for our automatic method applied to LDS and LAB HI surveys of the Milky Way (2nd and 3rd quadrants). We fit the radial distribution of HI shells (the exponential profile with the scale length of 3 kpc) and the size distribution (the power law with the index of 2.1). We compare the distribution of identified HI shells with HII regions and study the differences between identifications in the 2nd and 3rd quadrants.

Keywords. ISM: bubbles, methods: data analysis, Galaxy: structure

1. Introduction

HI shells are thoroughly studied in many galaxies, as described by E. Brinks and S. Stanimirovic in this volume. Originally, shells were discovered in the Milky Way Galaxy, which is probably not surprising. In recent years the studies, especially the statistical studies, are done mostly for shells in external galaxies. That might be expected. Our inside view gives us many advantages but also disadvantages. To study the whole Galaxy we need really an all-sky survey. The changing distance to objects makes objects with intrinsically the same dimensions have wildly different angular dimensions. Looking through the galactic disk means you encounter lots and lots of structures. And I do not even mention the problems with kinematical distances.

All that said I still do not think we should abandon the Milky Way and its shells. In this contribution I will give results of a study of shells in the 2nd and 3rd galactic quadrants. Before that I will describe a method used for their identification and since it is not a traditional way, I will also mention different approaches in dealing with the shell identification.

1.1. *Traditional by-eye approach*

The most obvious and historical approach to finding shells is looking at maps and localizing structures in individual velocity channels, probably with the help of velocity spectra. The main problem with that method is not that it is tedious and time-consuming, but that it is subjective and, in my opinion, dependent on the funny things like the observer's favourite colour and intensity scale. Nevertheless, it also has some pluses, like the ability of a human eye (or rather brain) connect disconnected features and disregard 'obviously' disconnected structures. This approach was used for the Milky Way shells by Heiles (1979), Heiles (1984), Hu (1981), and most recently by McClure-Griffiths, Dickey, Gaensler *et al.* (2002).

1.2. *Automatic identification*

An alternative method of identifying shells is some kind of an automatic search. The shell is somehow defined and the pattern is then searched for automatically in datacubes. One

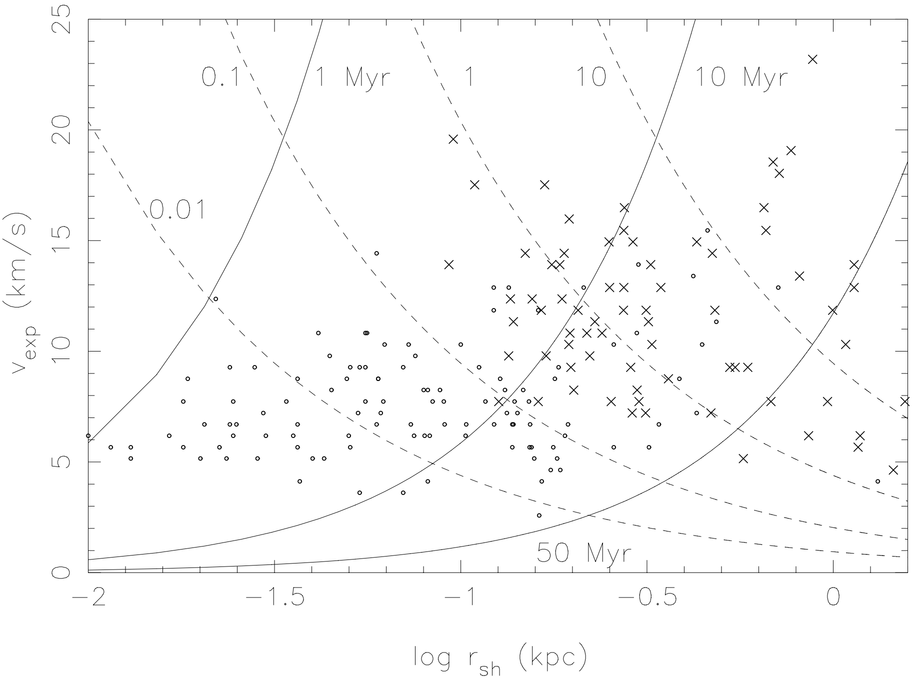

Figure 1. Radius vs expansion velocity of HI shells in the 2nd quadrant. Different symbols stand for different energies (circles $< 10^{51} erg$, crosses $> 10^{51} erg$). Overlaid are contours of constant luminosity and age.

way is to take numerical models of shells. This approach was taken by Thilker, Braun & Walterbos (1998); Mashchenko, Thilker & Braun (1999) and Mashchenko & St-Louis (2002), where (magneto)hydrodynamical and thin-shell models were used.

A different approach is used by Daigle, Joncas, Parizeau *et al.* (2003). They primarily study the velocity spectrum and search for the expanding pattern. Then they look at groups of pixels which contain the expansion and decide if the morphology corresponds to the HI shell.

Our approach (Ehlerová & Palouš (2005)) also differs. We primarily search for local holes in velocity maps and then study consecutive velocity channels and corresponding velocity spectra.

All mentioned methods are not perfect and the ISM is turbulent. Basically, with an automatic identification you have one of extremes: either your models are very restrictive and then you detect nothing or just a small part of real structures, or your models are lax and you have a high number of false identifications.

2. Identification of shells: HOLMES

The detailed description of the code HOLMES can be found in Ehlerová & Palouš (2005). As already told, we search for local minima in T_B velocity channels (step 1 in the procedure), connect them (step 2) and analyse their velocity spectra (step 3). Our method belongs to the type which is prone to find 'false detections': to get rid of them we use the analysis of the spectrum (e.g. step 3).

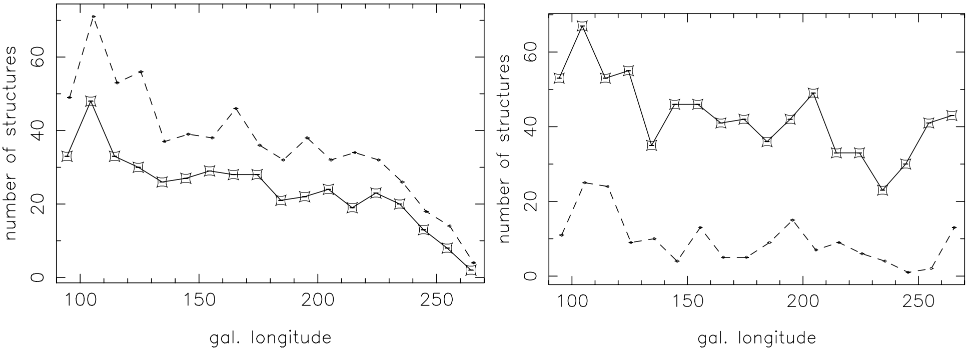

Figure 2. *Left:* number of HI shells in LDS as a function of galactic longitude. Solid line corresponds to the full step 3 in the identification, dashed line to the reduced step 3. *Right:* number of HI shells in the LAB survey (reduced step 3, solid line) and HII regions (dashed line) as a function of longitude.

2.1. *Results for the 2nd Quadrant and LDS*

We applied our searching code HOLMES on the Leiden-Dwingeloo HI survey (Hartmann & Burton (1997)), which covers about 80 % of the sky, in which we identified 628 shells.

For the structures in the 2nd quadrant (fully observed by Hartmann & Burton (1997) and no distance ambiguity) we fitted the exponential radial distribution and found that the radial scale length is about 3 kpc, in agreement with the scale length of the stellar disk.

We also studied the size distribution of shells in the 2nd quadrant using the analysis of Oey & Clarke (1997). We found the power-law index of $\alpha = 2.1$ which is quite shallow but corresponding to values derived for several external galaxies (M31, M33, LMC, SMC, HoII).

The $r - v_{exp}$ diagram for shells in the 2nd quadrant is shown in figure 1. Radii of detected structures range from ~ 10 *pc* to ~ 1.5 kpc, expansion velocities are between 4 km s^{-1} (an artificial limit set by HOLMES) and ~ 20 km s^{-1}.

2.2. *Application on the LAB survey*

Recently, we began applying our HOLMES code on the LAB all-sky HI survey (Kalberla *et al.* (2005)). So far, we were able to process the 2nd and 3rd quadrants. Step 3 of the procedure (the analysis of the spectra, see above) did not behave quite satisfactorily, therefore we exchange it for the time being by a reduced condition: the identified structure must have $\Delta v_{exp} \geqslant 4$ km s^{-1}. Compared to the full step 3 this increases the number of detections by about 1/2.

Figure 2 (left) shows the number of HI shells as a function of the galactic longitude for the LDS shells using the full and reduced step 3. Absolute numbers differ but the profile is the same. Figure 2 (right) shows the number of HI shells identified in the LAB survey and a number of HII regions from Paladini *et al.* (2003). There are about 3-4 shells for one HII region, but profiles agree well with each other. The discrepancy between profiles of LDS shells and LAB shells in the 3rd quadrant is caused by the fact that the LDS survey does not fully cover this region.

There is a notable difference between numbers of HI shells in the 2nd and 3rd quadrants (as well as HII regions). This is probably caused by the presence of the spiral structure which is dominant in the 2nd quadrant. As studied by McClure-Griffiths, Dickey, Gaensler *et al.* (2002), HI shells prefer interarm regions and avoid arms. This seems to be the case for our identifications as well, even though the absolute number increases with the presence of the spiral structure.

3. Summary

We have briefly summarized advantages and disadvantages of two approaches towards the identification of shells: the traditional 'by-eye' approach and the automatic methods. We then showed results based on one of the automatic searching codes applied to the LDS (Leiden/Dwingeloo HI survey) and to LAB (Leiden/Argentina/Bonn) HI survey. LDS results were used to estimate the radial profile of HI shells (the exponential with the scale length of 3 kpc) and the size distribution (the power law with the index of 2.1). For the LAB shells differences are shown between 2nd and 3rd quadrants; these differences are connected to the spiral structure.

Acknowledgements

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Discussion

MAC LOW: It's remarkable that you also showed a positive slope to the R-v relationship for your shells, like Stanimirovic did for the SMC. Yet, we certainly don't think there was a recent single burst of star formation in the Milky Way, so that cannot be the explanation. Something else must be going on to give a positive slope, rather than the negative one predicted by Oey from standard bubble theory.

EHLEROVÁ: I agree. This kind of R-v diagram seems to be quite frequent among galaxies.

TOTH: What are the velocity limits of your survey? In other term, what is the age limit for the expanding shells?

EHLEROVÁ: There is an artificial lower limit of 4 km s^{-1}.

HEYER: What is the fraction of mass contained within the shells?

EHLEROVÁ: We didn't make precise calculations but the rough estimate is 5–10 % for the outer Galaxy ($R \sim 11$ kpc) and the thickness of the disk of 1–2 kpc.

DEHARVENG: Do you have some statistical results about the morphology of your shells? (spherical shells, half-shells? rings ...?)

EHLEROVÁ: The only morphological quantity we have studied so far is the prolongation of shells in the b direction. The average value of $\frac{\Delta b}{\Delta l cos(b)}$ is 0.8, 70 % of shells are elongated in the l direction rather than in the b one.