Lopsidedness in WHISP galaxies

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I INTRODUCTION

Both the stellar and gas distribution of galaxies are often characterised by asymmetries. This so-called lopsidedness is observed not only in the morphology of galaxies, but also in the kinematics. It has significant impact on the disc structure and its evolution, and it traces the disc formation history and the evolution of baryons in dark matter haloes. However, the origin of lopsidedness is still poorly understood. Possible scenarios include tidal interactions and minor mergers (e.g., Jog 1997, Zaritsky & Rix 1997), asymmetric gas accretion (Bournaud et al. 2005), but also an offset of the stellar disc in a halo potential (Mapelli et al. 2008).

Lopsidedness is particularly seen in the outer discs of more than 50% of the previously studied galaxies (e.g., Rix & Zaritsky 1995). However, most of these studies are based on optical/IR imaging. Therefore, we here present a new approach to study lopsidedness out to precedented large radii using deep HI maps.

II THE DATA

We investigate a large sample of nearby disc galaxies, observed within the Westerbork HI Survey of Irregular and SPiral Galaxies (WHISP). To combine reasonably high spatial resolution with a sufficiently high signal-to-noise, our analysis is based on data smoothed to 30"x30". Additionally, we apply two selection criteria:

(1) the galaxies need to have inclinations between 20° and 75°;
(2) the ratio of the HI diameter to the beam size has to be larger then 10.

Our final sample includes 70 galaxies covering a whole range of absolute *B* magnitudes and morphological types.

III ANALYSIS

Using GIPSY (Groningen Image Processing SYstem), two important steps were carried out:

(1) a tilted-ring analysis to determine the kinematic parameters of each galaxy (systemic velocity, centre coordinates, inclination, position angle, rotation velocity) and the parameter of the kinematic lopsidedness $\epsilon_{\rm kin}$;
(2) a harmonic decomposition to obtain the first normalised Fourier component A_1 as a measure of the morphological lopsidedness.

IV RESULTS

(a) Morphological lopsidedness

Previous studies showed that within the optical disc A_1 increases with radius. In contrast, we find here that only 20% of our sample galaxies show a steady increase in the morphological lopsidedness towards large radii (e.g., UGC 4173; see Fig. 1). In other galaxies, the value of A_1 scatters significantly with radius (e.g., UGC 7256). The phase typically remains constant indicating that lopsidedness is a global mode. We average A_1 for small and large radii (Fig. 2). Suprisingly, both distributions are comparable: most galaxies have a lopsidedness parameter below 0.2, only a few have higher values. Thus, while the lopsidedness is lower in the inner parts than beyond the optical disc (mean value of 0.11 in comparison to 0.15), the increase is not strong and the A_1 values seem to saturate beyond the optical disc.

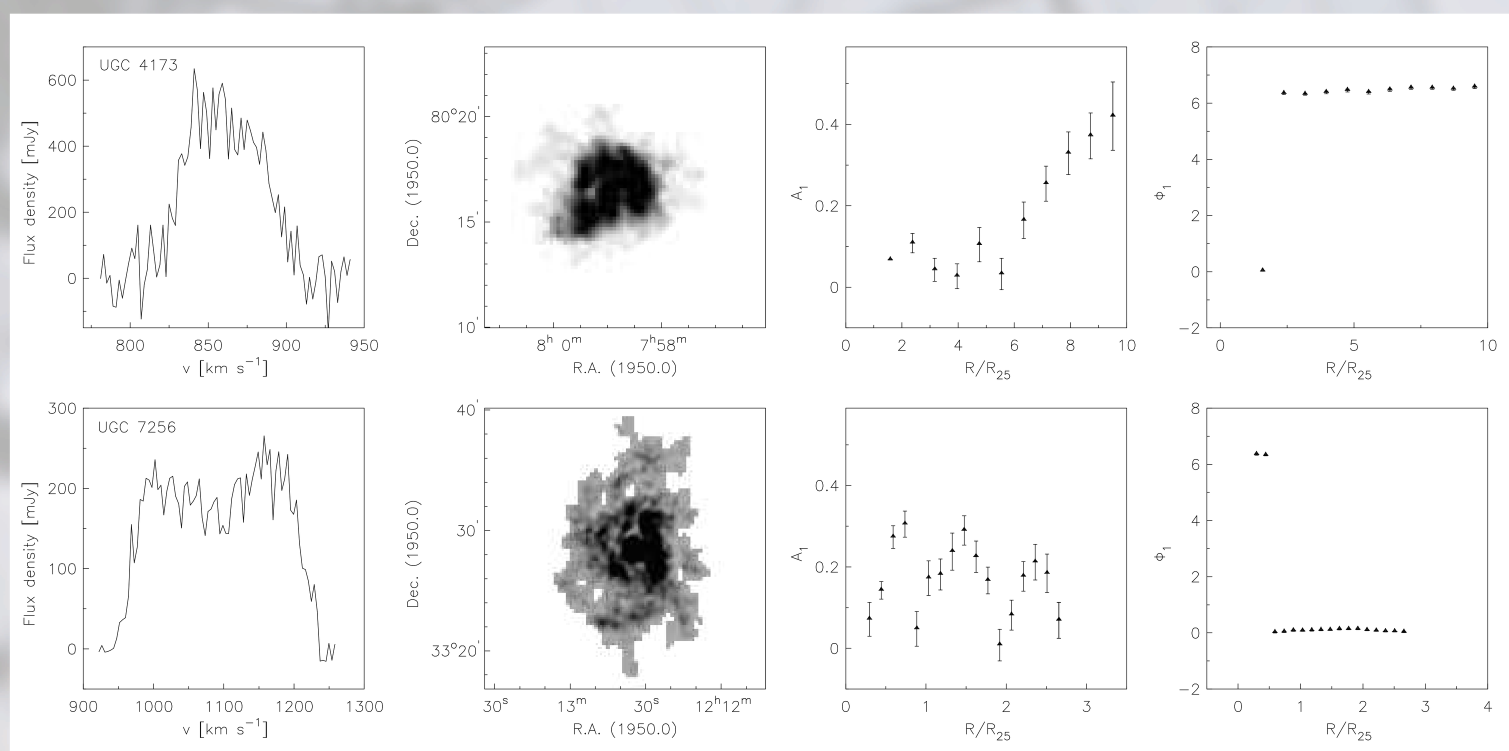

Fig. 1. From left to right: HI global profile, HI intensity map, the distribution of A_1 and the distribution of the phase ϕ_1 of two example galaxies.

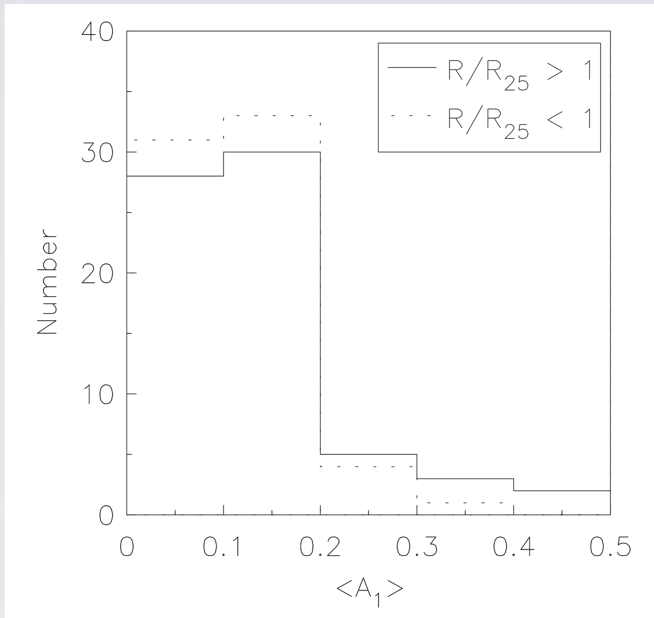

Fig. 2. The distribution of $< A_1 >$ for small and large radii.

(b) Lopsidedness vs. morphological type

We compare the morphological lopsidedness $< A_1 >$ of all sample galaxies averaged over large and small radii to the morphological type. The early-type spiral galaxies seem to be more strongly lopsided, especially in the outer radial regions. Since a tidal interaction drives a galaxy towards being an early-type, this high lopsidedness in early-type galaxies indicates that tidal encounters are the mechanism responsible for lopsidedness.

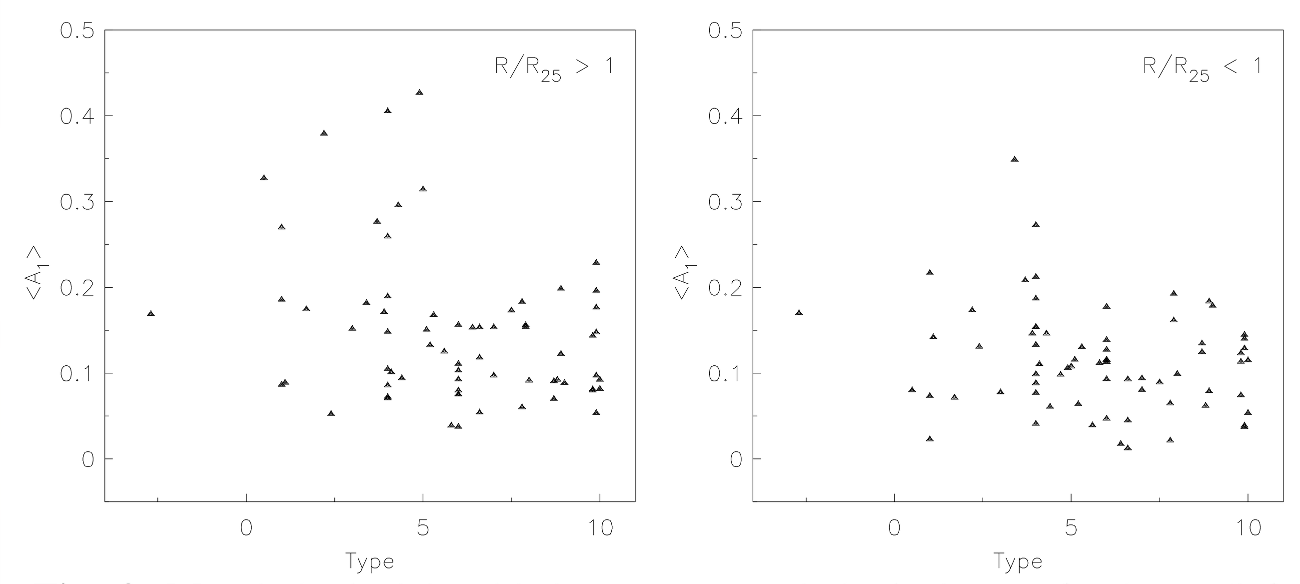

Fig. 3. Morphological lopsidedness vs. morphological type for large (left panel) and small (right panel) radii.

(c) The environment

We use the tidal parameter to quantify the effect of tidal forces (Bournaud et al. 2005):

$$T_{\rm p} = \log\left(\sum \frac{M_i}{M_0}\left(\frac{R_0}{D_i}\right)^3\right)$$

$M_{\rm i}$: mass of each companion
M_0: mass of the main galaxy
R_0: scale length
$D_{\rm i}$: distance of each companion from the main galaxy

We search for neighbours using the Tully Nearby Galaxies Catalogue (Tully & Fisher 1988) by only including companions within a radius of 2.5° and with measured radial velocities within 500 km/s. We find 31 galaxies to have between 1 and 15 companions.

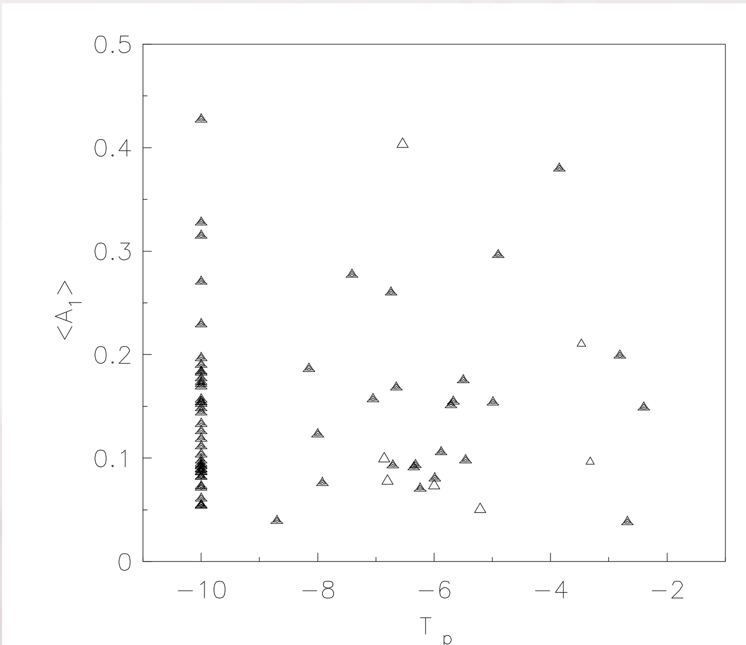

Fig. 4. $< A_1 >$ averaged over large radii vs. the tidal parameter $T_{\rm p}$.

The remaining 39 galaxies, for which no companion is known, are plotted with an assumed tidal parameter of -10. We do not find a correlation between lopsidedness and the environment. This result does not contradict the tidal origin of lopsidedness shown in Sect. (b), rather the above lack of correlation points to lopsidedness being long-lived.

V CONCLUSION

Using HI as a tracer, lopsidedness is measured to very large radii (several times the optical radius) in a sample of 70 WHISP galaxies. The amplitude of lopsidedness is shown to increase with radius within the optical radius, confirming earlier studies in the literature. Interestingly, the lopsidedness values saturate at large radii, which was not previously studied. The results from our work indicate that tidal encounters are the main mechanism responsible for the halo lopsidedness, to which the disc responds.

For more detailed information see van Eymeren et al. (2011a) and van Eymeren et al. (2011b).

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