ABSTRACT

By analysing a sample of galaxies selected from the HI Parkes All Sky Survey (HIPASS) to contain more than 2.5 times their expected HI content based on their optical properties, we investigate what drives these HI eXtreme (HIX) galaxies to be so HI-rich. We model the H I kinematics with the *Ti*lted *Ri*ng *Fi*tting *C*ode TiRiFiC and compare the observed HIX galaxies to a control sample of galaxies from HIPASS as well as simulated galaxies built with the semi-analytic model DARK SAGE. We find that (1) H I discs in HIX galaxies are more likely to be warped and more likely to host H I arms and tails than in the control galaxies, (2) the average H I and average stellar column density of HIX galaxies is comparable to the control sample, (3) HIX galaxies have higher H I and baryonic specific angular momenta than control galaxies, (4) most HIX galaxies live in higher-spin haloes than most control galaxies. These results suggest that HIX galaxies are H I-rich because they can support more H I against gravitational instability due to their high specific angular momentum. The majority of the HIX galaxies inherits their high specific angular momentum from their halo. The H I content of HIX galaxies might be further increased by gas-rich minor mergers.

This paper is based on data obtained with the Australia Telescope Compact Array (ATCA) through the large program C 2705.

Key words: galaxies – evolution, galaxies – formation, galaxies – kinematics and dynamics, galaxies – ISM

1 INTRODUCTION

The gaseous and stellar content of galaxies is tightly related through the galactic gas cycle. Atomic hydrogen (H I) condenses to form molecular gas (H_2) clouds. These clouds are the birth places of stars. When comparing the amount of available H I to the current star formation rate in local galaxies, Kennicutt (1998) and Schiminovich et al. (2010) find that their H I reservoirs would be consumed within ≈ 2 Gyr. Hence, galaxies need to replenish their gas reservoir in order to remain active starformers in the future (Sancisi et al. 2008, Sánchez Almeida et al. 2014 and references therein).

Gas–rich mergers and smooth accretion from the circumgalactic medium are suggested as avenues for gas replenishment (White & Rees 1978). Observations of local galaxies do not find evidence for enough gas rich mergers to sustain star formation (Di Teodoro & Fraternali 2014; Sancisi et al. 2008; Sánchez Almeida et al. 2014). This leads to the the conclusion that smooth accretion is the dominant channel of gas accretion. This might be the reaccretion of gas previously ejected by feedback mechanisms together with pristine halo gas, which is dragged along (à la the "Galactic Fountain", see e. g. Oosterloo et al. 2007; Fraternali et al. 2011). Cosmological simulations suggest accretion occurs through the cooling of hot halo gas or through the delivery of cold gas through filaments (Birnboim & Dekel 2003; Kereš et al. 2005; Dekel & Birnboim 2006; van de Voort et al. 2011). In the local Universe, gas-phase metallicity gradients / inhomogeneities (Moran et al. 2012), warps (Roškar et al. 2010) and lopsided discs (Bournaud et al. 2005) may be interpreted as observations of cosmological accretion but may also result from tidal interactions with other galaxies.

The HALOGAS survey (Heald et al. 2011) has previously searched for signs of accretion in deep H I observations of nearby galaxies (distance < 11 Mpc). Through detailed modelling of the H I kinematics, the HALOGAS team has found a few high velocity clouds, thick H I discs, and warps in their samples galaxies (Gentile et al. 2013; Zschaechner et al. 2011, 2012; de Blok et al. 2014). In the Milky Way, high velocity clouds are thought to contribute to gas accretion (Putman et al. 2012). The thick disc component, which is usually lagging in rotation velocity with respect to the thin disc, is interpreted as a sign of the Galactic Fountain (Oosterloo et al. 2007; Fraternali et al. 2011). However, the total rate of detected H I accretion in the HALOGAS observations is not sufficient to fuel star formation in their sample galaxies (Heald 2015).

The H I eXtreme (HIX) galaxy survey examines a sample of H I-rich galaxies to understand how they accumulate and maintain their gas reservoirs. In Lutz et al. (2017), we found that HIX galaxies are less efficient at forming stars than a control sample. The most extreme galaxy in the HIX sample (ESO075-G006) has built its massive H I disc through a combination of a lower star formation efficiency ($\mathrm{SFE_{HI}} = \mathrm{SFR}/\mathrm{M_{HI}}$), due to a high specific baryonic angular momentum, and likely some accretion of pristine gas (as probed by gas-phase metallicity gradients).

So the gas-rich galaxies of the HIX survey are not necessarily gas-rich due to recent gas accretion but could also be inefficient at using their available gas for star formation. Simple models describing the H I based star formation efficiency ($\mathrm{SFE_{HI}} = \mathrm{SFR}/\mathrm{M_{HI}}$) find a strong dependence of the SFE on the stability of the disc (Wong et al. 2016). Maddox et al. (2015) suggests that the upper envelope of the stellar – H I mass relation at high stellar masses is defined by the halo spin parameter. That is galaxies with a high H I mass for their stellar mass tend to live in higher spin haloes. A high angular momentum can reduce the star formation efficiency in two ways: (1) accreted gas can not be transported to the denser, inner parts of the galaxy (Kim & Lee 2013; Forbes et al. 2014), where the star formation efficiency would be higher (Leroy et al. 2008); (2) the disc is stabilised against star formation (Toomre 1964; Obreschkow et al. 2016).

In this paper, we extend the analysis of the relation between the H I content and kinematic properties to the entire HIX sample and an accompanying control sample. We make use of observations of our sample galaxies with the Australia Telescope Compact Array (ATCA), which provide spatially resolved H I distributions and kinematics.

This article is structured as follow. In Sec. 2, we discuss the selection of the HIX and control samples and present the data used in this paper. In Sec. 3, we present the results of the analysis of H I kinematics and distribution. We then compare our results to the semi-analytic model DARK SAGE of galaxy evolution in Sec. 4. The results are discussed in Sec. 5. We then conclude in Sec. 6.

Throughout the paper we will assume a flat ΛCDM cosmology with the following cosmological parameters: $\mathrm{H_0} = 70.0\,\mathrm{km\,Mpc^{-1}\,s^{-1}}$, $\Omega_m = 0.3$. All velocities are used in the optical convention (cz).

2 SAMPLES AND DATA