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# Revealing Galactic scale bars with the help of Galaxy Zoo and ALFALFA

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**Abstract.** We use visual classifications of the brightest 250,000 galaxies in the Sloan Digital Sky Survey Main Galaxy Sample provided by citizen scientists via the Galaxy Zoo project (www.galaxyzoo.org, Lintott et al. 2008) to identify a sample of local disc galaxies with reliable bar identifications. These data, combined with information on the atomic gas content from the ALFALFA survey (Haynes et al. 2011) show that disc galaxies with higher gas content have lower bar fractions. We use a gas deficiency parameter to show that disc galaxies with more/less gas than expected for their stellar mass are less/more likely to host bars. Furthermore, we see that at a fixed gas content there is no residual correlation between bar fraction and stellar mass. We argue that this suggests previously observed correlations between galaxy colour/stellar mass and (strong) bar fraction (e.g. from the sample in Masters et al. 2011, and also see Nair & Abraham 2010) could be driven by the interaction between bars and the gas content of the disc, since more massive, optically redder disc galaxies are observed to have lower gas contents. Furthermore we see evidence that at a fixed gas content the global colours of barred galaxies are redder than those of unbarred galaxies. We suggest that this could be due to the exchange of angular momentum beyond co-rotation which might stop a replenishment of gas from external sources, and act as a source of feedback to temporarily halt or reduce the star formation in the outer parts of barred discs. These results (published as Masters et al. 2012) combined with those of Skibba et al. (2012), who use the same sample to show a clear (but subtle and complicated) environmental dependence of the bar fraction in disc galaxies, suggest that bars are intimately linked to the evolution of disc galaxies.

**Key words.** galaxies: evolution, galaxies: spiral, galaxies: fundamental parameters, galaxies: statistics, galaxies: structure, surveys, ISM: atoms, radio lines: galaxies

## 1. Introduction

Simulations and theoretical considerations suggest that gas content may play a vital role in controlling the ability of disc galaxies for form disc instabilities, particularly the strongest disc instabilities - or “strong bars” (see e.g. Friedli & Benz 1993, Athanassoula 2003, Berentzen et al. 2007, Heller et al. 2007, Combes 2008, Villa-Vargas et al. 2010 and very recently Athanssoula et al. 2012). In this work (pub-

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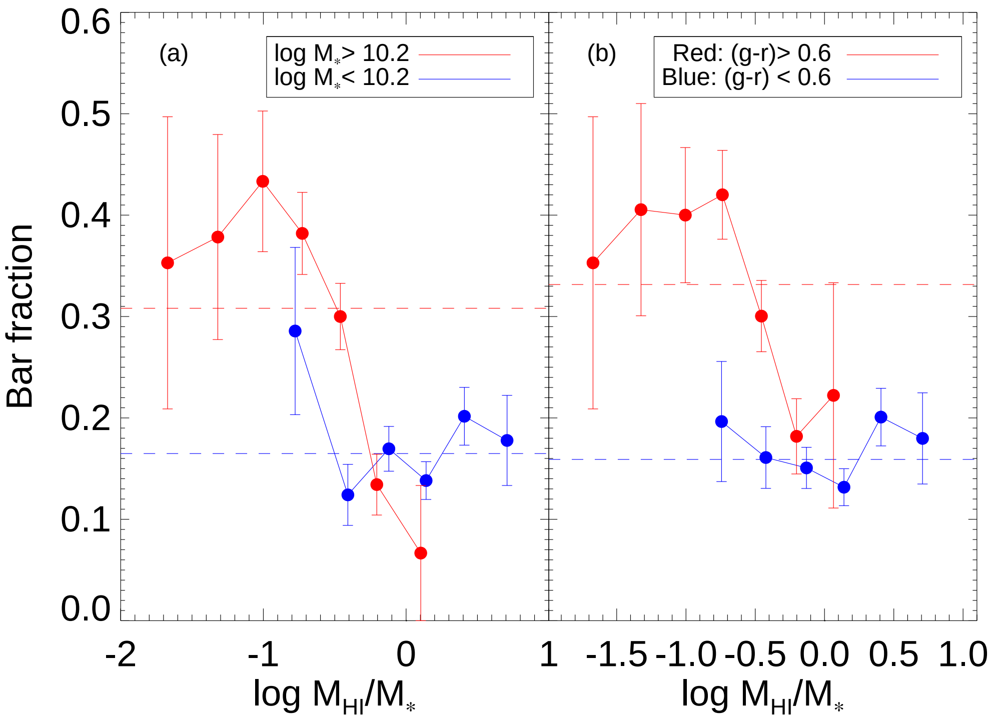


**Fig. 1.** The strong barfraction as a function of gas fraction for 2090 Galaxy Zoo galaxies detected in H I by ALFALFA split into two subgroups by either (a) stellar mass or (b) optical colour. The horizontal lines show the overall bar fraction for each subsample. We see that at a fixed gas fraction a redder disc galaxy is more likely to be found hosting a bar (or barred discs are redder), however, at a fixed gas fraction the stellar mass of the disc galaxy correlates less well with whether or not it hosts a bar. Reproduced from Figure 8 of Masters et al. (2012)

lished as Masters et al. 2012) we consider this question observationally by measuring the bar fraction of samples of disc galaxies with known atomic gas contents.

## 2. Sample

We use visual classifications of the brightest 250,000 galaxies in the Sloan Digital Sky Survey Main Galaxy Sample (Strauss et al. 2002) provided by citizen scientists via the Galaxy Zoo project (www.galaxyzoo.org, Lintott et al. 2008,2011) to identify a sample of local disc galaxies with reliable bar identifications ($N$ = 12956, see Masters et al. 2012 for details).

We cross match this sample with information on HI (atomic gas) detections in the first release of the ALFALFA survey (Arecibo Legacy Fast ALFA Survey; Giovanelli et al. 2005, Haynes et al. 2011) to make a sample of 2090 relatively face-on disc galaxies with bar identifications and HI (atomic hydrogen) gas measurements.

## 3. Summary of results

We use these data to show that disc galaxies with higher gas content have lower bar fractions (e.g. Figure 1 which is reproduced from Masters et al. 2012). We use a gas deficiency parameter to show that disc galaxies with more/less gas than expected for their stellar mass are less/more likely to host bars.

We see that at a fixed gas content there is little or no residual correlation between bar

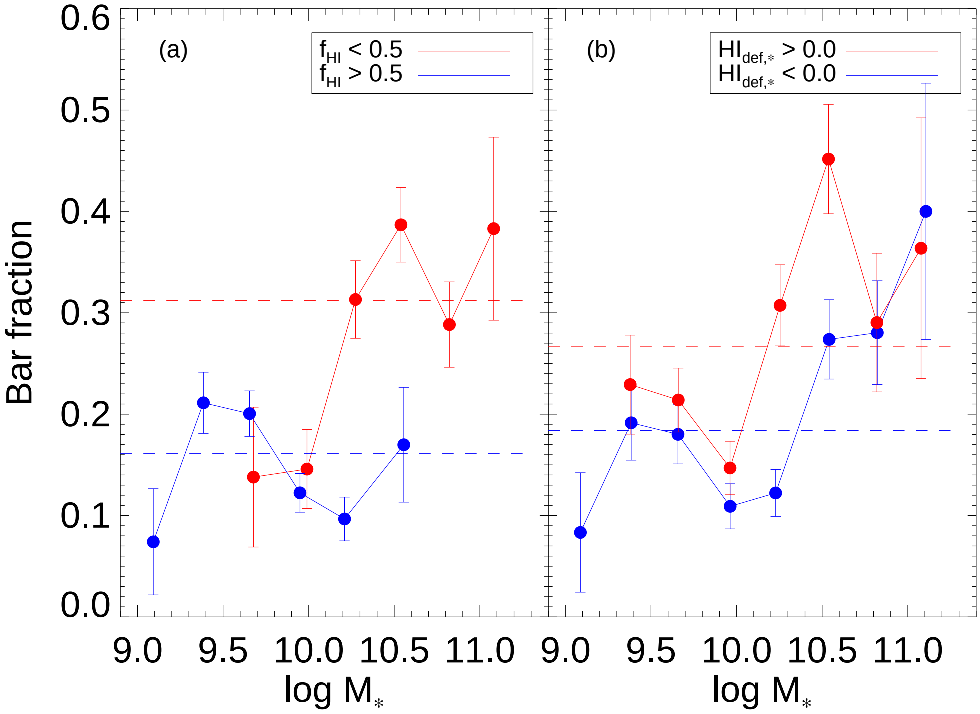


**Fig. 2.** The strong bar fraction as a function of stellar mass for 2090 Galaxy Zoo galaxies detected in HI by ALFALFA split into(a)gas-rich($f_{HI} > 0.5$) or gas-poor ($f_{HI} < 0.5$) galaxies; and (b) gas deficient (H $I_{def,\star} > 0.0$) or gas rich for mass (H $I_{def,\star} < 0.0$). The horizontal lines show the bar fraction for the whole of each subsample. Note that gas-poor galaxies fall out of our sample at the lowest stellar masses of our sample, while gas-rich massive galaxies are intrinsically very rare. We see that much of the correlation between bar fraction and stellar mass disappears when the sample is split into gas rich and gas poor. The biggest difference in bar fraction with gas content occurs in the intermediate-mass range (10 ¡ log (M?/M?) ¡ 10.7), while very (stellar) massive, or low-mass galaxies in our sample display no correlation between gas content and bar fraction. Reproduced from Figure 9 of Masters et al. (2012)

fraction and stellar mass (see left panel of Figure 2; also reproduced from Masters et al. 2012). We argue that this suggests previously observed correlations between galaxy colour/stellar mass and (strong) bar fraction (e.g. from the sample in Masters et al. 2011, and also see Nair & Abraham 2010) could be driven by the interaction between bars and the gas content of the disc, since more massive, optically redder disc galaxies are observed to have lower gas contents. We see evidence that at a fixed gas content the global colours of barred galaxies are redder than those of unbarred galaxies (Figure 1; right panel). We suggest that this could be due to the exchange of angular momentum beyond co-rotation which might stop a replenishment of gas from external sources, and act as a source of feedback to temporarily halt or reduce the star formation in the outer parts of barred discs.

These results (published as Masters et al. 2012) combined with those of Skibba et al. (2012), who use the same sample to show a clear (but subtle and complicated) environmental dependence of the bar fraction in disc galaxies, suggest that bars are intimately linked to the evolution of disc galaxies.

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