Radial Acceleration Relation of HI-rich Low Surface Brightness Galaxies

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ABSTRACT

We investigate the radial acceleration relation (RAR) in low surface brightness galaxies selected from the Arecibo Legacy Fast ALFA survey. We find that the dynamical acceleration $g_{\rm obs}$ and baryonic gravitational acceleration $g_{\rm bar}$ of the HI-rich low surface brightness galaxies still follow the universal RAR of typical late-type galaxies. The universal RAR signifies a consistent correlation between the distribution of baryonic matter and dark matter across galaxies with diverse morphologies and properties. Our findings suggest that the matter distributions in low surface brightness galaxies may indeed resemble that of general late-type galaxies. This implies that low surface brightness galaxies may not originate from dark matter halos with lower densities; instead, they may originate from the dark matter halos with high spins or form through feedback processes.

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

1 INTRODUCTION

Low surface brightness galaxies (LSBGs) constitute a special population of galaxies with central surface brightness at least one magnitude fainter than that of the sky background (i.e., *B*-band surface brightness ≥ 22.5 mag · arcsec^{-2}; Impey & Bothun 1997; Bothun et al. 1997). LSBGs have been observed to exhibit higher HI fractions (Du et al. 2015; He et al. 2020), lower star formation rates (Wyder et al. 2009; Rong et al. 2020b), and low metallicities (Kuzio de Naray et al. 2004). Also, they tend to appear in low-density environments (Pérez-Montaño & Cervantes Sodi 2019; Mo et al. 1994).

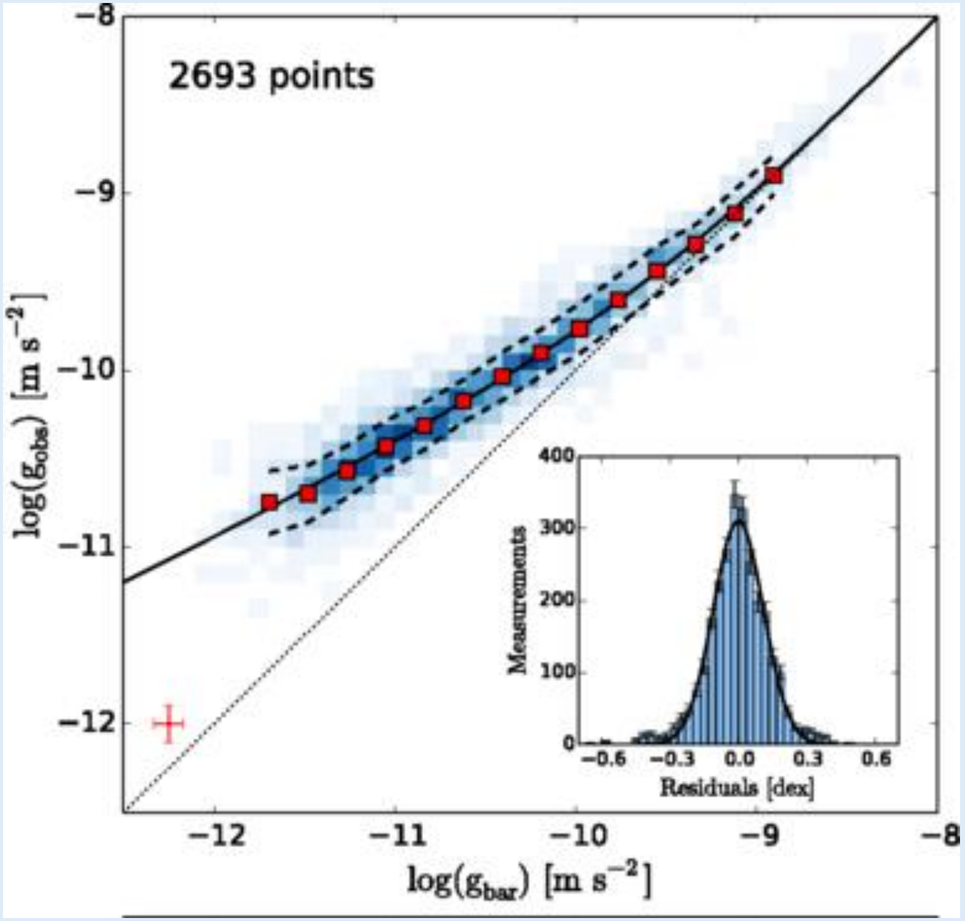
The distribution of dark matter and baryonic matter in LSBGs exhibits a high degree of diversity. Regarding the mass ratio of baryonic matter to dark matter, many studies have shown that the dynamics of LSBGs are dominated by dark matter (e.g. de Blok &

pathways. Therefore, understanding these differences is crucial for refining our current models of galaxy formation and evolution.

Studies suggest that the low-mass LSBGs may be failed L^* galaxies (van Dokkum et al. 2015a,b), or dwarf galaxies hosted in halos belonging to the high-end tail of the spin-distribution (Rong et al. 2017; Amorisco & Loeb 2016; Kim & Lee 2013). There are also studies suggesting that they were formed in low-density dark matter halos (Dekel & Silk 1986; McGaugh 1992; Mo et al. 1994). In addition, they may originate from early mergers (Wright et al. 2021) or stellar feedback processes (Chan et al. 2018) or tides (Rong et al. 2020a; Carleton et al. 2019) as well. As for high-mass LSBGs, their formation might due to mergers (Saburova et al. 2018; Zhu et al. 2023), two-stage process with external gas accretions (Saburova et al. 2021), or dynamical evolution originated from the bars (Noguchi

Началось все с работы Stacy S. McGaugh and Federico Lelli 2016

A universal law shows that the rotation of a disk galaxy is determined entirely by the visible matter it contains, even if the disk is mostly filled with dark matter.



Вопрос -куда лягут LSB?

Выборка LSB из ALFALFA-SDSS α.40 cross-matched catalogue.

- Incl.angle i> 45^0, SNR > 10,
- Отбрасывались single-peaked galaxies (where HI disks may be not extended enough)
- The final sample contains 127 high-quality LSBGs with double-horned HI lines, ensuring the most reliable results.
- For comparison, 207 high surface brightness galaxies (HSBGs, μ0B < 22.5 mag) with double-horned HI lines are also selected from our parent sample as the counterparts.

Массы

$$\Sigma_*(R) = \frac{M_*}{2\pi R_{d,*}^2} \exp(-\frac{R}{R_{d,*}}),$$

$$M_*/M_\odot = 0.45 L_{W1}/L_\odot,$$

$$\Sigma_g(R) = \frac{M_g}{2\pi R_{d,g}^2} \exp(-\frac{R}{R_{d,g}}),$$

$$\log(\frac{2R_{HI}}{kpc}) = (0.506 \pm 0.003)\log(\frac{M_{HI}}{M_\odot}) - (3.293 \pm 0.009).$$

$$g_{bar} = f(\frac{R}{2R_{d,*}})\frac{GM_*}{R^2} + f(\frac{R}{2R_{d,g}})\frac{GM_g}{R^2},$$

$$f(y) = 4y^3[I_0(y)K_0(y) - I_1(y)K_1(y)],$$

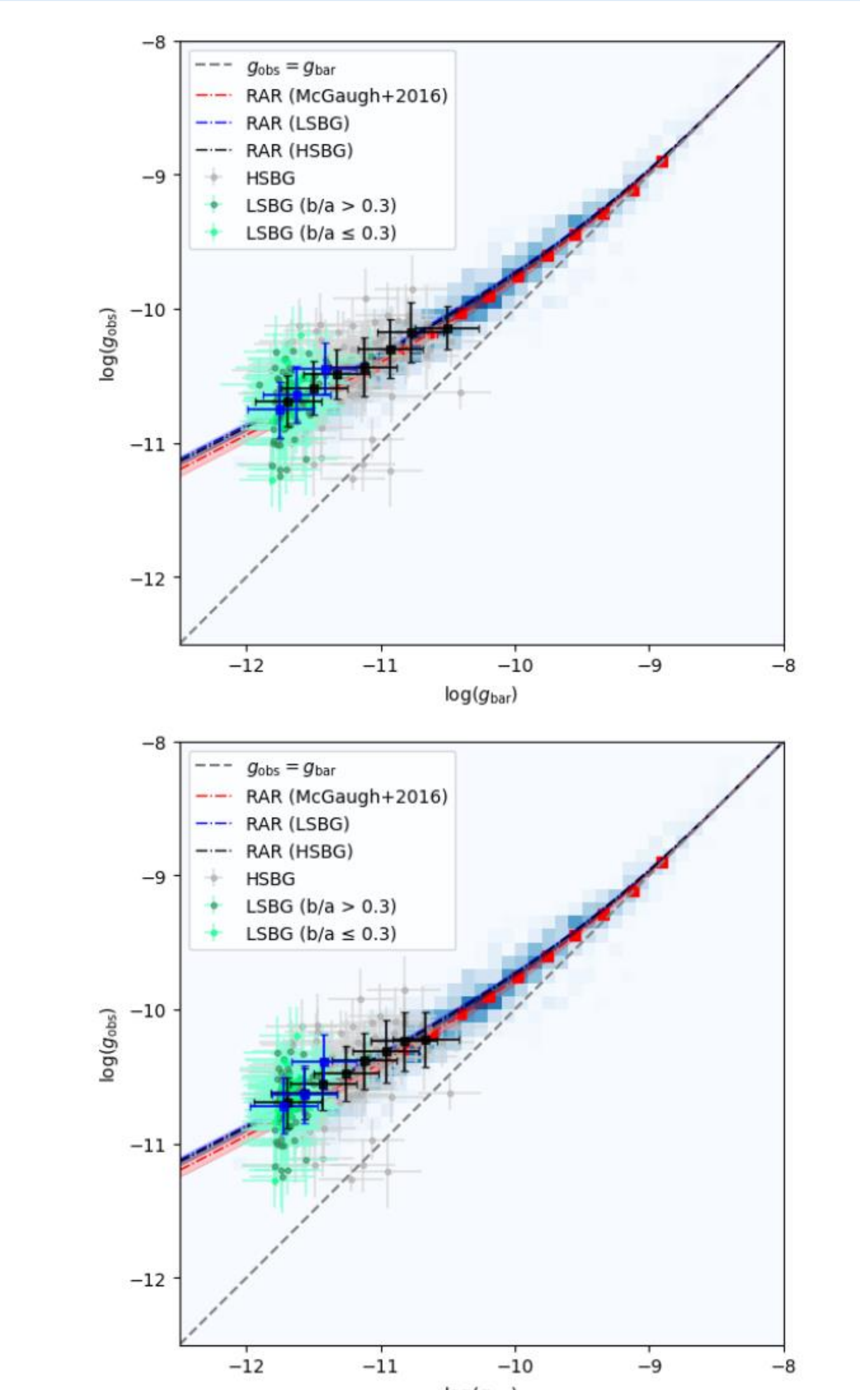
Скорости вращения

$$v_{rot} = \frac{W_{20}}{2\sin i},$$

$$g_{obs} = \frac{v_{rot}^2}{R},$$

- The upper panel: stars and gas are assumed to be distributed in standard thin disks, respectively.
- The lower panel: stars and gas are assumed to distribute in uniform spheres, respectively.

- Голубые квадратики – LSB (binned)
- Красные квадратики – HSB from Lelli etal, 2917
- Серые квадратики - our control sample (HSB)



Выводы

- LSBGs conform to the universal RAR found in typical late-type galaxies. Our results indicate that the distributions of dark matter and baryonic matter may still correlate with each other in LSBGs and that the mass distributions of the majority of LSBG may be similar to those of ordinary late-type galaxies.
- Есть три основных версии происхождения LSB:

1. Low surface brightness of disk galaxies may stem from their formation within dark matter halos characterized by lower densities postulated (e.g. McGaugh 1992; Dekel & Silk 1986);

2. LSBGs may originate from high spin dark matter halos (e.g. Kim&Lee 2013; Mo et al. 1998)

3. LSBGs may be influenced by feedback processes (Ludlowet al. 2017).

Исключается первый вариант: (при нормальном моменте вращения диска он будет сильнее сконцентрирован к центру галактики, чем гало, поэтому изменится соотношение между ускорениями).