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MIGHTEE-HI: The radial acceleration relation with resolved stellar mass measurements

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ABSTRACT

The radial acceleration relation (RAR) is a fundamental relation linking baryonic and dark matter in galaxies by relating the observed acceleration derived from dynamics to the one estimated from the baryonic mass. This relation exhibits small scatter,

Выборка

Galaxy	z	$i_{\rm opt}$ [°]	$\log_{10}(M_\star/M_\odot)$	$\Upsilon_\star$ [$M_\odot/L_\odot$]
J095846.8+022051	0.00577	70	7.48 ± 0.08	0.33 ± 0.08
J095927.9+020025	0.01297	41	7.65 ± 0.10	0.35 ± 0.09
J100005.8+015440	0.00622	66	7.82 ± 0.06	0.53 ± 0.08
J095904.3+021516	0.02458	50	7.98 ± 0.08	0.36 ± 0.08
J100211.2+020118	0.02134	41	9.18 ± 0.09	0.38 ± 0.08
J100009.3+024247	0.03267	56	9.49 ± 0.09	0.37 ± 0.07
J100115.2+021823	0.02845	73	8.79 ± 0.09	0.32 ± 0.06
J095720.6+015507	0.03205	48	10.10 ± 0.07	0.36 ± 0.06
J100143.2+024109	0.04699	45	9.43 ± 0.09	0.34 ± 0.06
J100259.0+022035	0.04426	43	10.92 ± 0.10	0.37 ± 0.10
J100055.2+022344	0.04426	42	10.53 ± 0.08	0.57 ± 0.10
J095923.2+024137	0.04764	61	9.75 ± 0.10	0.37 ± 0.08
J100236.5+014836	0.04554	44	9.47 ± 0.12	0.24 ± 0.07
J100117.1+020337	0.06155	47	9.50 ± 0.09	0.34 ± 0.07
J100003.9+015253	0.06521	60	9.19 ± 0.09	0.30 ± 0.07
J095755.9+022608	0.07125	76	10.08 ± 0.10	0.39 ± 0.09
J100217.9+015124	0.06238	49	10.31 ± 0.12	0.29 ± 0.07
J100103.7+023053	0.07193	39	10.09 ± 0.10	0.30 ± 0.08
J095907.8+024213	0.07908	46	10.81 ± 0.07	0.38 ± 0.06

Table 1. Redshifts, optical inclinations, stellar masses, and total mass-to-light ratios in K_s −band for the galaxies in our sample. Stellar masses are derived from SED fitting using a delayed exponential star formation history (Mobasher et al. 2015), with uncertainties reflecting the posterior distributions obtained from BAGPIPES.

- MIGHTEE-HI: MeerKAT+COSMOS
- HI: Beam=12”
- Imaging: u(CFHT)+g… z(SUBARU)+JHK(Ultra VISTA)
- 19 галактик, i>20^o , z<0.08

Интерферометрия в 21 см: стандартный подход с 3DBarolo

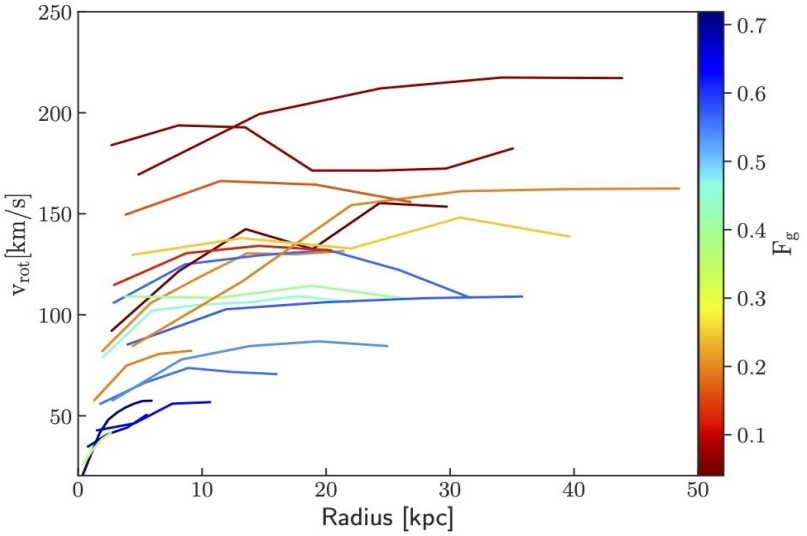


Figure 8. Rotation curves for our sample of galaxies, colour coded by their gas fraction, $F_g = M_{HI}/M_{bar}$.

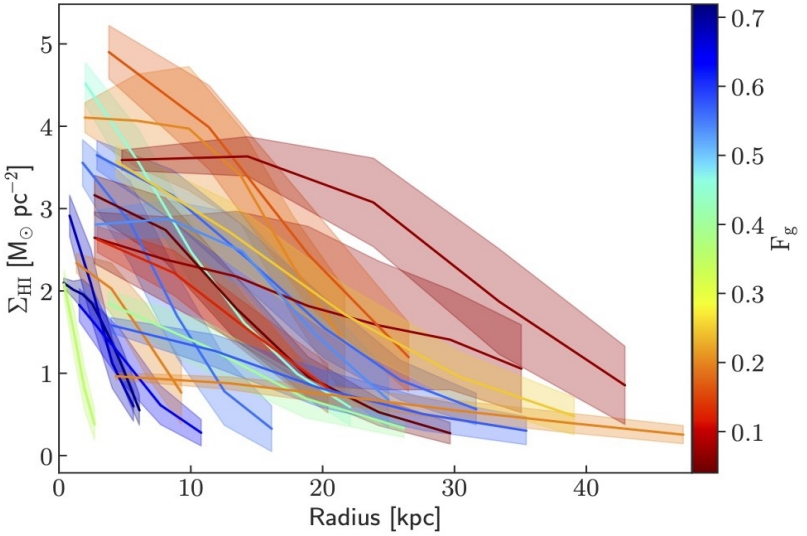


Figure 9. All HI radial surface densities derived using 3D BAROLO, colour coded by their gas fraction, $F_g = M_{HI}/M_{bar}$.

Фишка работы: радиальные изменения M/L по анализу SED

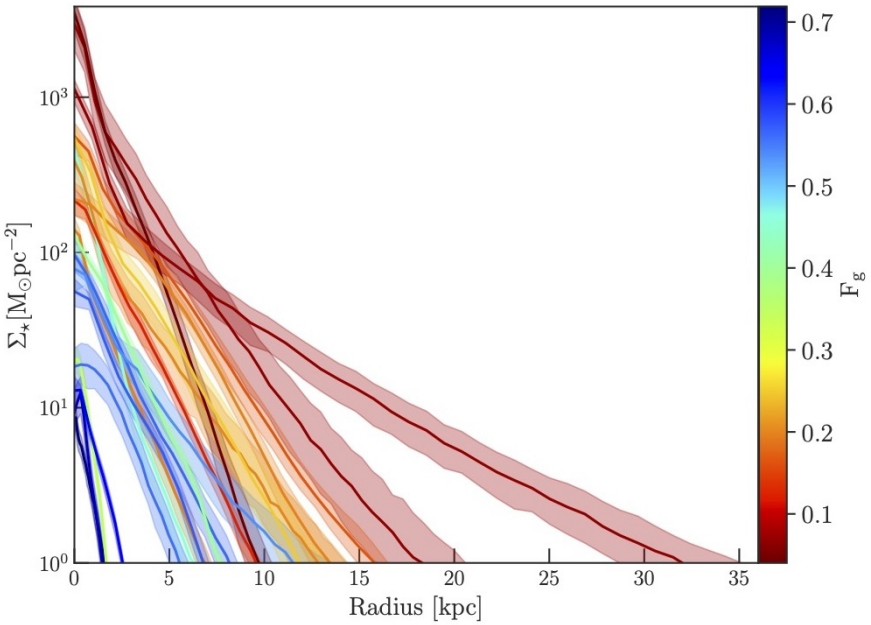


Figure 4. Resolved stellar surface mass densities for our sample of galaxies, colour coded by their gas fraction, $F_g = M_{HI}/M_{bar}$.

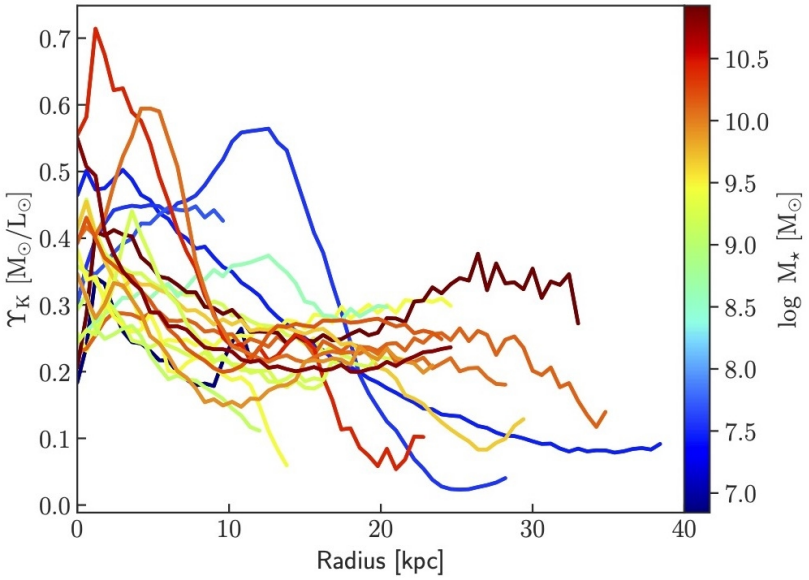
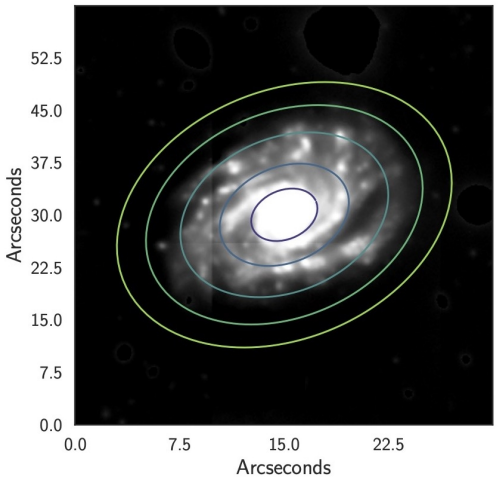


Figure 7. Mass-to-light ratio variations in K_s-band as a function of radius for all galaxies in our sample, colour coded by stellar mass. Unsurprisingly, the mass-to-light ratios are typically higher in the center, followed by a decrease and flattening at large radii, where the surface brightness exponentially decreases.

Примеры


Arcseconds
Arcseconds
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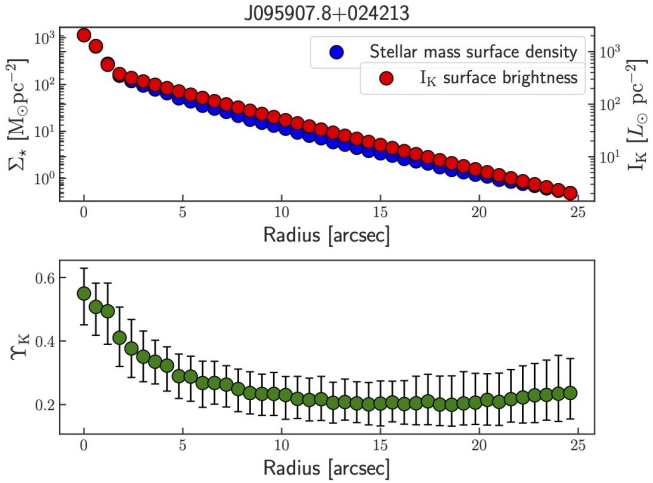
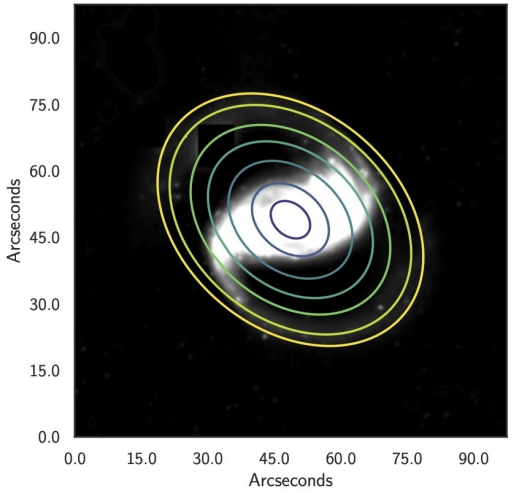
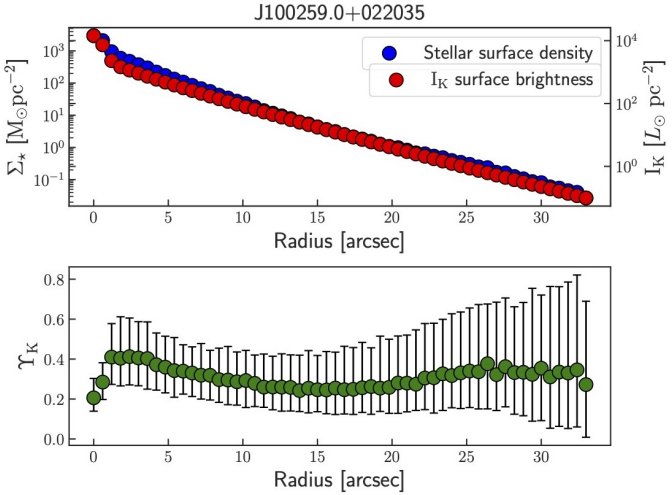
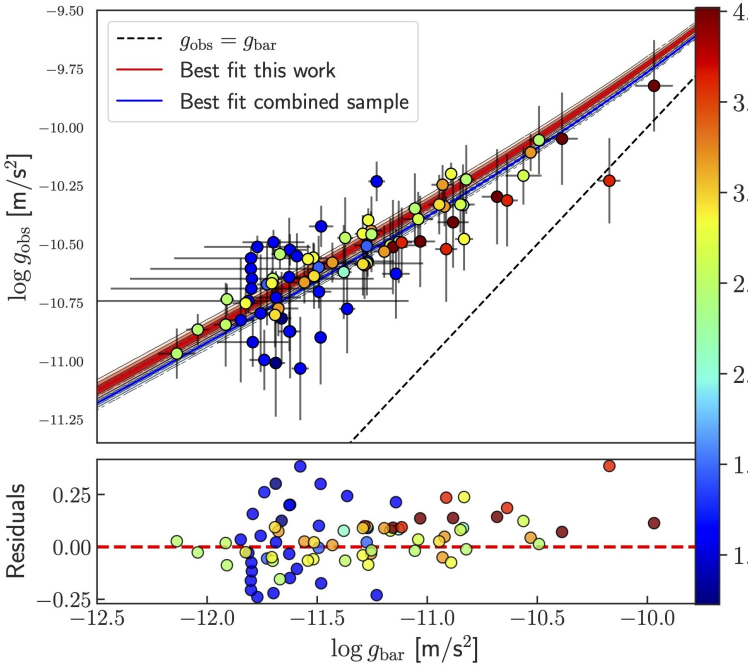
7.5
15.0
22.5
30.0
37.5
45.0
52.5

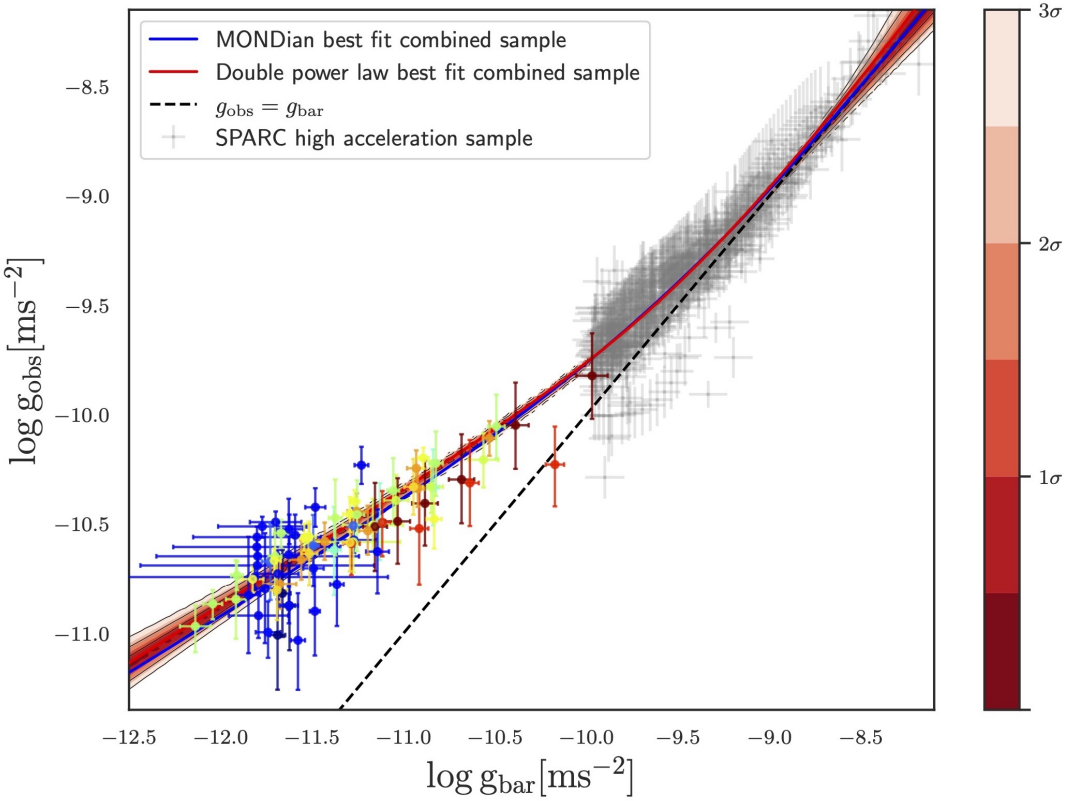

J095907.8+024213
Stellar mass surface density
I_K surface brightness
$\Sigma_\star$ [$M_\odot pc^{-2}$]
I_K [$L_\odot$ pc^{-2}]
Radius [arcsec]
Υ_K
Radius [arcsec]


Arcseconds
Arcseconds
0.0
15.0
30.0
45.0
60.0
75.0
90.0


J100259.0+022035
Stellar surface density
I_K surface brightness
$\Sigma_\star$ [$M_\odot pc^{-2}$]
I_K [$L_\odot$ pc^{-2}]
Radius [arcsec]
Υ_K
Radius [arcsec]

RAR


$g_{obs} = g_{bar}$
Best fit this work
Best fit combined sample
$\log g_{obs}$ [m/s^2]
Residuals
$\log g_{bar}$ [m/s^2]


MONDian best fit combined sample
Double power law best fit combined sample
$g_{obs} = g_{bar}$
SPARC high acceleration sample
$\log g_{obs}[ms^{-2}]$
$\log g_{bar}[ms^{-2}]$
3σ
2σ
1σ

Аппроксимация: общий двухкомпонентный степенной закон и…

The MOND-inspired functional form (McGaugh et al. 2016) is described by the following equation:

$$g_{obs} = F(g_{bar}) = \frac{g_{bar}}{1 - e^{-\sqrt{g_{bar}/a_0}}}, \qquad (12)$$

Результаты

Table 3. Best-fit acceleration scale (a_0) and intrinsic scatter (σ_{int}) of the RAR under different $\Upsilon_\star$ assumptions, obtained using RoxY. Results are shown for both our sample and the combined dataset including high acceleration SPARC galaxies. The first row shows the values including the molecular gas corrections (fiducial case), while the second row presents results without this correction.

Υ_K assumption	a_0 [10^{-10} m s^{-2}]	Intrinsic Scatter [dex]
Varying $\Upsilon_K^{\rm fiducial}$	1.69 ± 0.13	0.045 ± 0.022
Varying $\Upsilon_K^{\rm no\,mol}$	2.06 ± 0.15	0.038 ± 0.021
Fixed $\Upsilon_K = 0.6$	1.08 ± 0.09	0.06 ± 0.02
Radial average Υ_K	1.47 ± 0.13	0.09 ± 0.02
SPARC RAR	1.15 ± 0.02	0.082 ± 0.003
Combined sample	1.32 ± 0.13	0.064 ± 0.007

We adopted uniform priors for $\log_{10}(a_0)$ between -15 and 5, and for the intrinsic scatter between 0 and 3 dex. Running RoxY with 700 warm-up steps and 5000 samples (ample to ensure convergence), we recovered a best-fit value of the acceleration scale $a_0 = (1.69 \pm 0.13) \times 10^{-10}$ ms^{-2} and an intrinsic scatter of 0.045 ± 0.022 dex. This is significantly smaller than the 0.12 dex total scatter reported by Lelli et al. (2017) for SPARC galaxies, and consistent with more recent estimates of the intrinsic scatter (Li et al. 2018; Chae et al. 2021, 2022; Desmond 2023), although we note the small dynamic range in $g_{\rm bar}$ for our sample.

We also perform a joint fit using our sample combined with the SPARC RAR data at high accelerations (above our highest value for $\log_{10}(g_{\rm bar})$) for which we impose a quality cut to include only galaxies with inclinations greater than 30 degrees. Running RoxY on this combined dataset yields a best-fit acceleration scale of $a_0 = (1.32 \pm 0.13) \times 10^{-10}$ ms^{-2} and an intrinsic scatter of

Подтверждение фундаментальности RAR