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The XXL Survey⋆
XIII. Baryon content of the bright cluster sample

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ABSTRACT

Traditionally, galaxy clusters have been expected to retain all the material accreted since their formation epoch. For this reason, their matter content should be representative of the Universe as a whole, and thus their baryon fraction should be close to the Universal baryon fraction Ω_b/Ω_m. We make use of the sample of the 100 brightest galaxy clusters discovered in the XXL Survey to investigate the fraction of baryons in the form of hot gas and stars in the cluster population. Since it spans a wide range of mass ($10^{13}-10^{15}M_\odot$) and redshift (0.05 – 1.1) and benefits from a large set of multiwavelength data, the XXL-100-GC sample is ideal for measuring the global baryon budget of massive halos. We measure the gas masses of the detected halos and use a mass–temperature relation directly calibrated using weak-lensing measurements for a subset of XXL clusters to estimate the halo mass. We find that the weak-lensing calibrated gas fraction of XXL-100-GC clusters is substantially lower than was found in previous studies using hydrostatic masses. Our best-fit relation between gas fraction and mass reads $f_{\rm gas,500}=0.055^{+0.007}_{-0.006}\left(M_{500}/10^{14}M_\odot\right)^{0.21^{+0.11}_{-0.10}}$. The baryon budget of galaxy clusters therefore falls short of the Universal baryon fraction by about a factor of two at $r_{\rm 500,MT}$. Our measurements require a hydrostatic bias $1-b=M_X/M_{\rm WL}=0.72^{+0.08}_{-0.07}$ to match the gas fraction obtained using lensing and hydrostatic equilibrium, which holds independently of the instrument considered. Comparing our gas fraction measurements with the expectations from numerical simulations, we find that our results favour an extreme feedback scheme in which a significant fraction of the baryons are expelled from the cores of halos. This model is, however, in contrast with the thermodynamical properties of observed halos, which might suggest that weak-lensing masses are overestimated. In light of these results, we note that a mass bias $1-b=0.58$ as required to reconcile *Planck* CMB and cluster counts should translate into an even lower baryon fraction, which poses a major challenge to our current understanding of galaxy clusters.

- Космология (ПЛАНК): барионы составляют 15% материи. Внутри галактик – дефицит DM, но в пределах вириального радиуса – дефицит барионов.
- Сколько барионов в скоплениях?
- Simulations (Sembolini etal 2015):

в скоплениях – “close to the universal value”.

XMM-NEWTON

The XXL is a large international multi-wavelength survey covering two 25 deg^2 areas, the natural development of the XMM-LSS pilot survey. It is the largest XMM project approved to date.
A first batch of XXL papers is due to appear in a XXL special issue of A&A ! (see PR). Contextually, since 15 Dec 2015 the XXL database will be **open for public access.**
See the "News" button for more details.
INAF IASF Milano has the responsibility to host the XXL Master catalogue database, as already done for XMM-LSS.

Исходные данные:

- XXL-100-GC
- -выборка из 100 скоплений XXL survey, z=0.05-1.1. Оценки T и L до R=300 kpc.

Для 38 скоплений – оценка массы по слабому линзированию. Они послужили для калибровки зависимости M-T до r

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$$M_{\rm gas}(< r) = \mu m_p \int_0^r n_{\rm gas}(r')\, 4\pi r'^2\, dr',$$

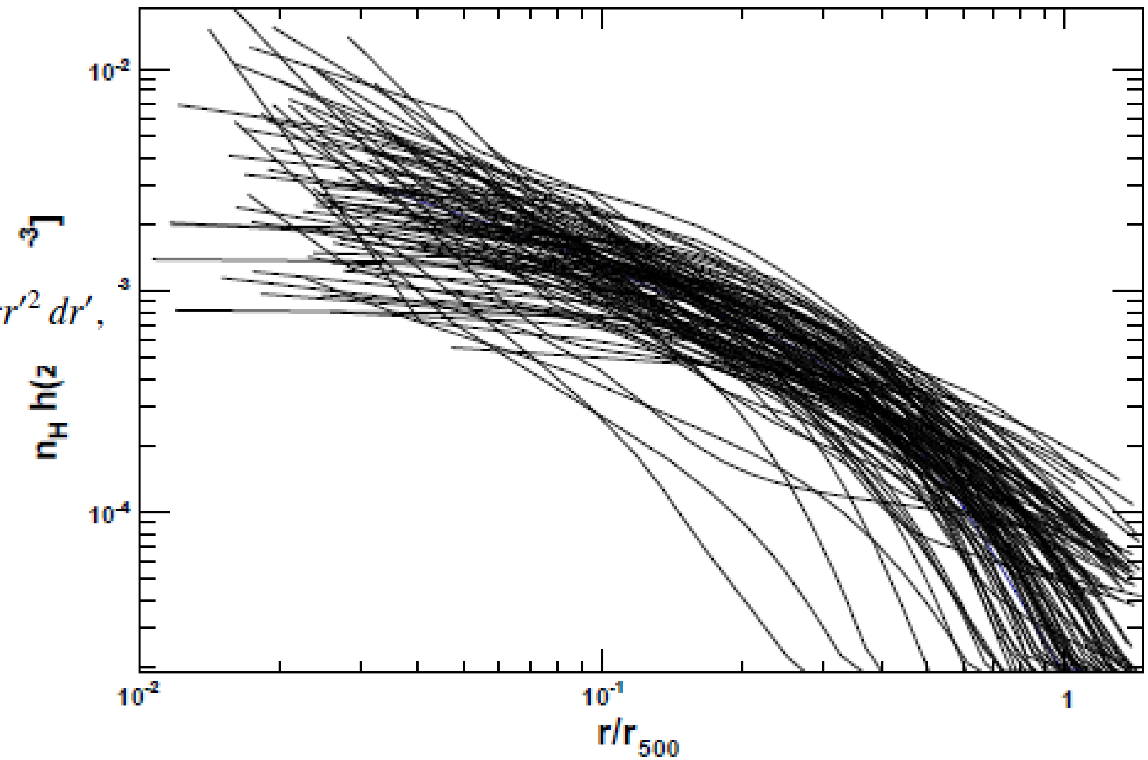


Fig. 1. Self-similarly scaled gas density profiles for the XXL-100-GC clusters.

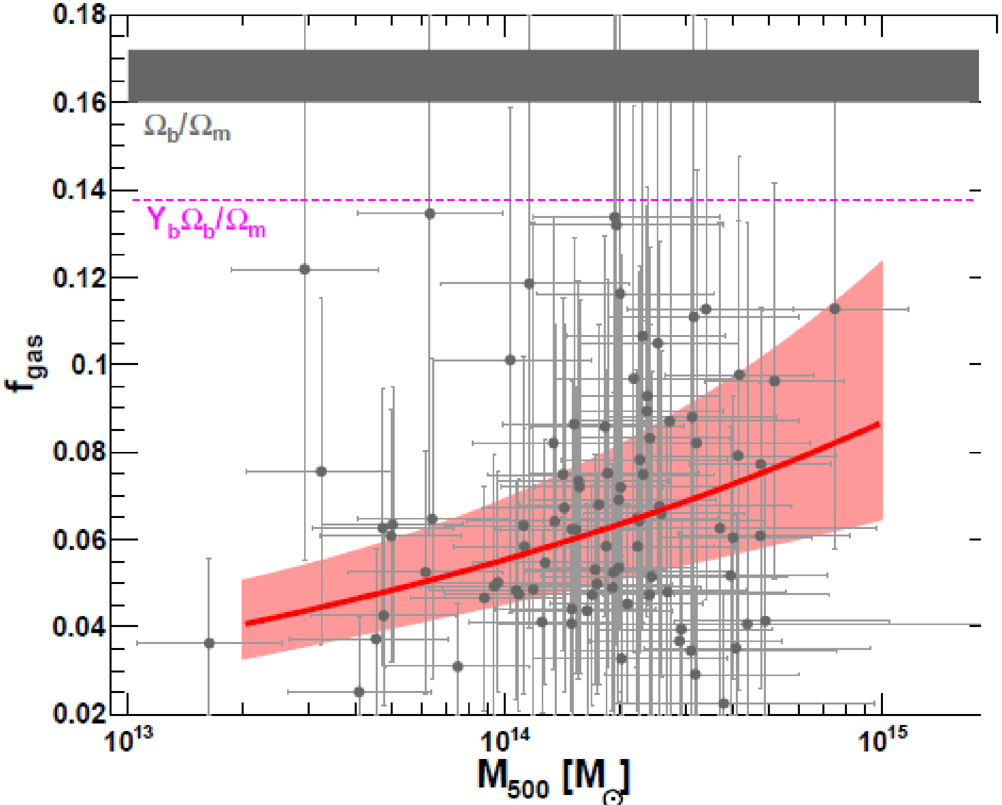
Масса звездного населения:

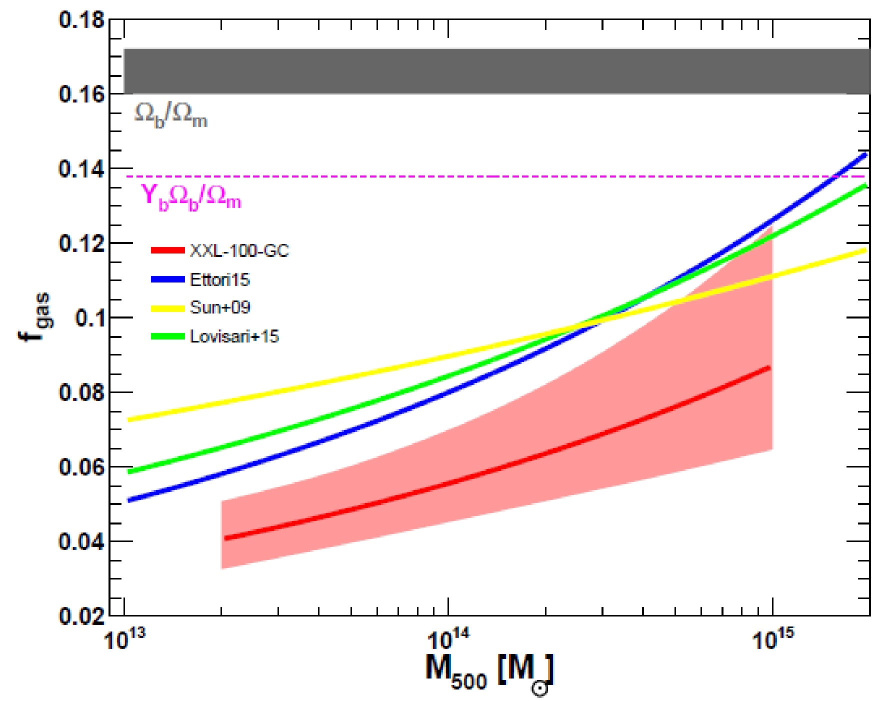
This sample is composed of deep optical photometry from the Canada-France-Hawaii Telescope Legacy Survey (CFHTLS, u; g; r; i; z) complemented by medium deep K-band photometry (KAB 22) from the WIRCam camera at CFHT.

Stellar masses are computed with the initial mass function (IMF) of Chabrier (2003) truncated at 0.1 and 100 M, and the stellar population synthesis templates from Bruzual & Charlot (2003).

Relation between gas fraction and halo mass within r500 for the XXL-100-GC sample. The red line and the red shaded area show the best-fit relation and its uncertainty.

Гидростатические оценки масс дают более низкие массы для скоплений (в среднем в 1.5 раза), а, след., более высокие значения $f_{gas.}$





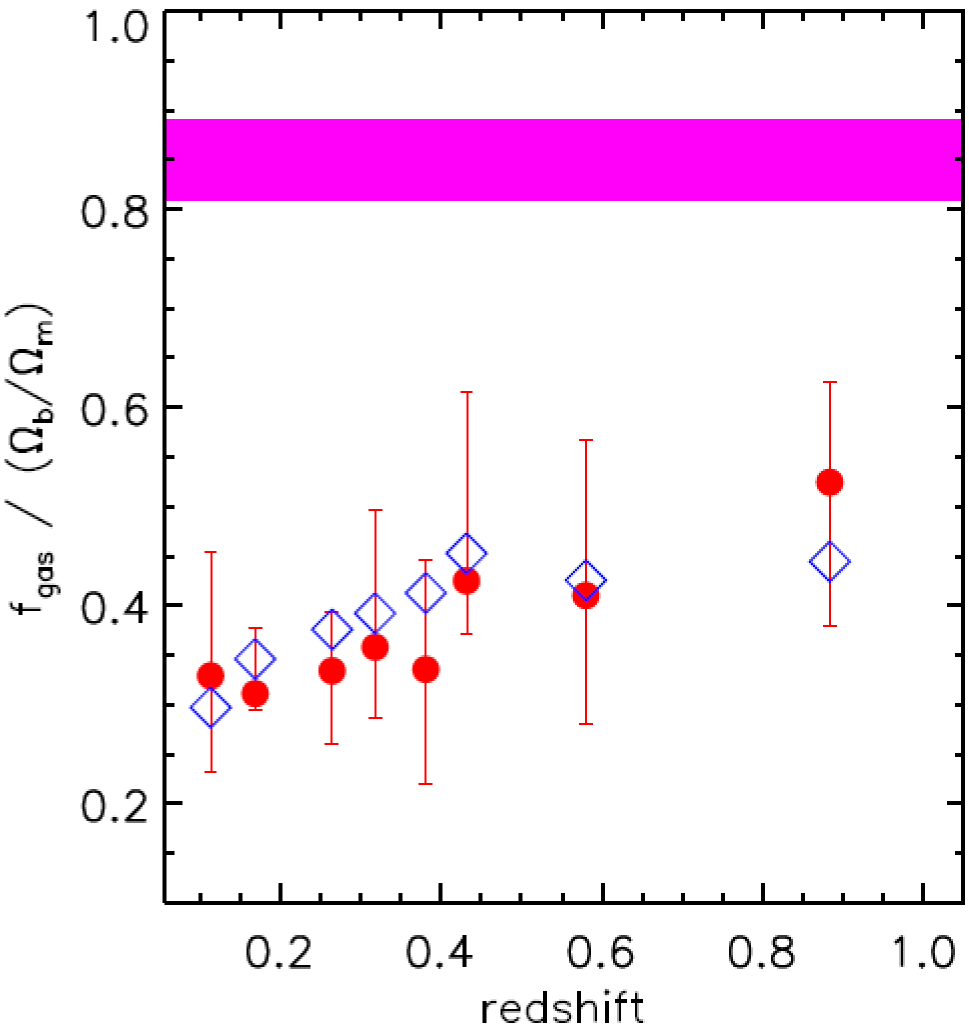


Fig. 5. Mean gas fraction and inter-quartile ranges (red points) for the XXL-100-GC clusters in eight redshift bins normalised to the Universal baryon fraction Ω_b/Ω_m. The blue diamonds show the gas fraction expected from Eq. 7 at the median mass of each redshift bin in our sample. The magenta shaded area shows the value expected at r_{500} from the simulations of Planelles et al. (2013).

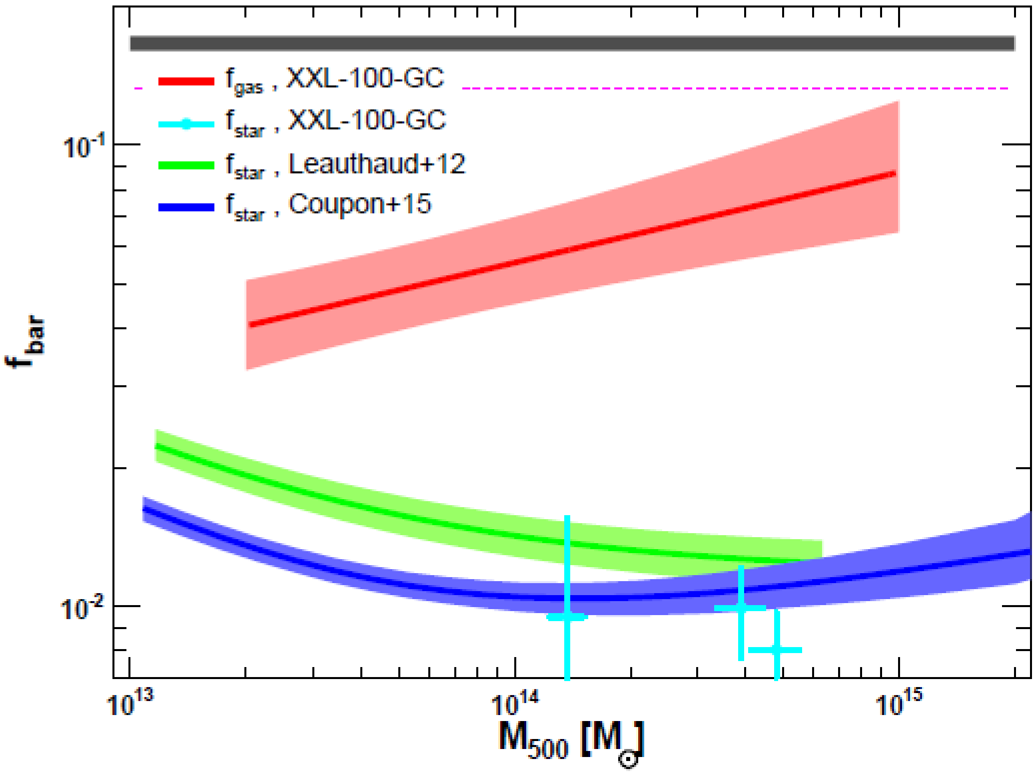


Fig. 7. Baryon fraction in the form of hot gas (red, this work) and stars. The cyan data points show the measurements obtained for the XXL-100-GC sample in three temperature bins (see Table 1), compared to literature measurements at different redshifts ($z \sim 0.3$, Leauthaud et al. (2012, green); $z \sim 0.8$, Coupon et al. (2015, blue)). The WMAP9 cosmic baryon fraction is displayed in the grey shaded area, whereas the dashed magenta line indicates the cosmic baryon fraction corrected by the depletion factor $Y_b = 0.85$ at r_{500} (Planelles et al. 2013).

Основные выводы

- Измерена масса рентгеновского газа в скоплениях в пределах r_{500}.. Показана ее тесная корреляция с температурой.
- Показано, что звезды составляют ~ 1% по массе.
- Доля барионов даже для массивных скоплений составляет $6.7 \pm 0.8\%$.
- Оценка доли газа к полной массе примерно вдвое ниже, чем это следует из космологии. Отток газа?

THE SMALL SCATTER OF THE BARYONIC TULLY-FISHER RELATION

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ABSTRACT

In a ΛCDM cosmology, the baryonic Tully-Fisher relation (BTFR) is expected to show significant intrinsic scatter resulting from the mass-concentration relation of dark matter halos and the baryonic-to-halo mass ratio. We study the BTFR using a sample of 118 disc galaxies (spirals and irregulars) with data of the highest quality: extended H I rotation curves (tracing the outer velocity) and Spitzer photometry at 3.6 μm (tracing the stellar mass). Assuming that the stellar mass-to-light ratio (Υ_*) is nearly constant at 3.6 μm, we find that the scatter, slope, and normalization of the BTFR systematically vary with the adopted Υ_*. The observed scatter is minimized for $\Upsilon_* \gtrsim 0.5$ $M_\odot/L_\odot$, corresponding to nearly maximal discs in high-surface-brightness galaxies and BTFR slopes close to ~4. For any reasonable value of Υ_*, the intrinsic scatter is ~0.1 dex, below general ΛCDM expectations. The residuals show no correlations with galaxy structural parameters (radius or surface brightness), contrary to the predictions from some semi-analytic models of galaxy formation. These are fundamental issues for ΛCDM cosmology.

Subject headings: galaxies: kinematics and dynamics — galaxies: formation — galaxies: evolution — galaxies: spiral — galaxies: irregular — dark matter

1. INTRODUCTION

The baryonic Tully-Fisher relation (BTFR) links the rotation velocity of a galaxy to its total baryonic mass (M_b) and extends for 6 decades in M_b (McGaugh 2012). In a Λ cold dark matter (ΛCDM) cosmology, the BTFR must emerge from the complex process of galaxy formation, hence it is expected to show significant intrinsic scatter. Using a semi-analytic galaxy-formation model, Dutton (2012) predicts a *minimum* intrinsic scatter of ~0.15 dex along the BTFR (see also Di Cintio & Lelli 2015). The majority of this scatter comes from the mass-concentration relation of dark matter (DM) halos, which is largely independent of baryonic processes and well-constrained by cosmological DM-only simulations (Bullock et al. 2001). Hence the BTFR scatter provides a key test for ΛCDM.

The BTFR has been extensively studied using H I observations from radio interferometers (e.g., Verheijen 2001; Noordermeer & Verheijen 2007) and single-dish telescopes (e.g., Gurovich et al. 2010; Zaritsky et al. effects because rotation velocities from H I line-widths do not necessarily correspond to V_f (Verheijen 2001). Studies using H I line-widths generally reports shallower BTFR slopes (~3) than those using V_f (~4), leading to drastically different interpretations (Gurovich et al. 2010; McGaugh 2012). Studies based on Hα (Pizagno et al. 2007) or CO (Ho 2007) observations may present similar issues, since Hα and CO discs are typically less extended than H I discs and their maximum velocities may not be tracing V_f.

In this Letter, we investigate the BTFR using a sample of 118 galaxies with data of the highest quality: (i) extended H I rotation curves providing precise measurements of V_f, and (ii) Spitzer surface photometry at 3.6 μm providing the optimal tracer of the stellar mass.

2. DATA ANALYSIS

2.1. *Galaxy Sample*

This work is based on the SPARC (Spitzer Photome-

- BTF: численные космологические модели формирования галактик предсказывают внутренний разброс 0.15 dex (Dutton, 2012)

- Отобрано 118 галактик с наиболее длинными и надежными V(r) по HI и Spitzer photometry.

$$M_b = M_g + \Upsilon_* L_{[3.6]},$$

Our sample spans a large range in mass (10^8 <Mb < 10^{11}), size (0.3 < R_{eff} < 15 kpc), gas fraction (0.01 < fg <0.95), and morphology (S0 to Im). We are excluding merging and interacting galaxies,

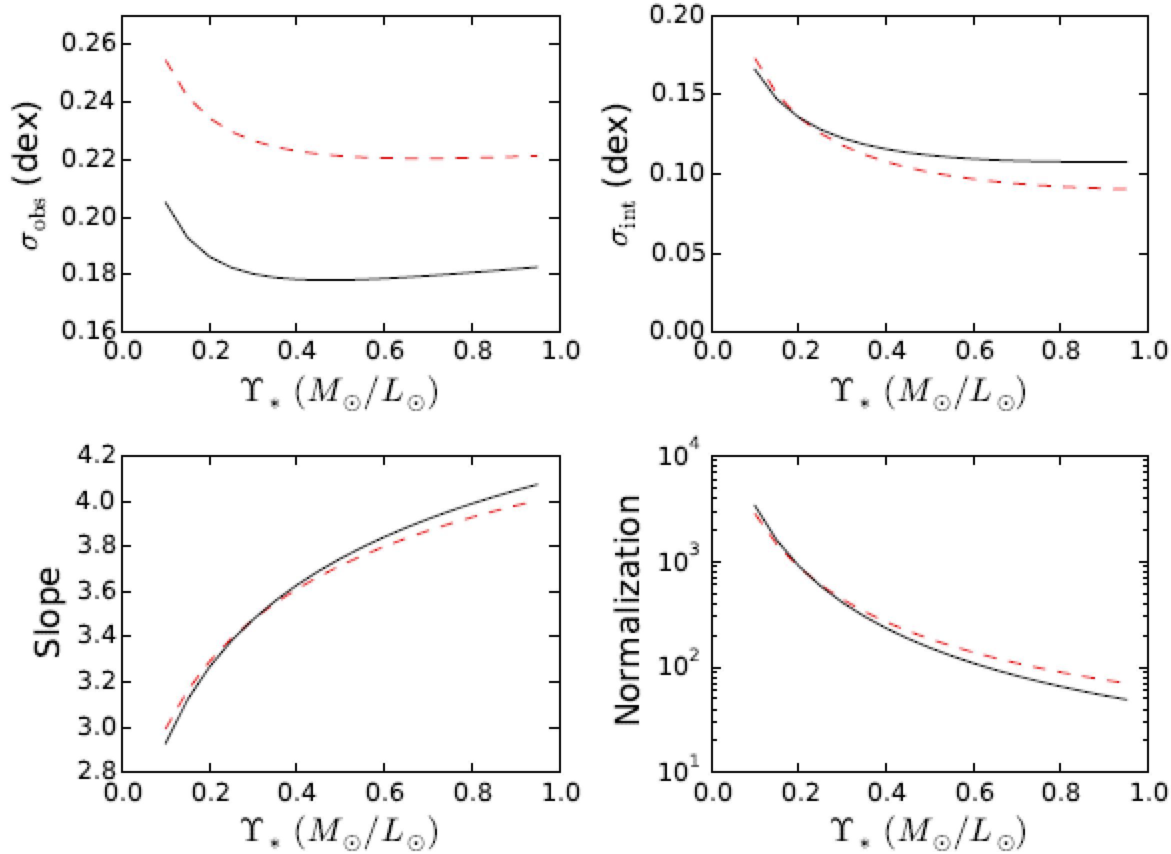

FIG. 1.— The properties of the BTFR as a function of Υ_*: observed scatter (top-left), intrinsic scatter (top-right), slope (bottom-left), and normalization (bottom-right). Dashed and solid lines show results for the total and accurate-distance samples, respectively.

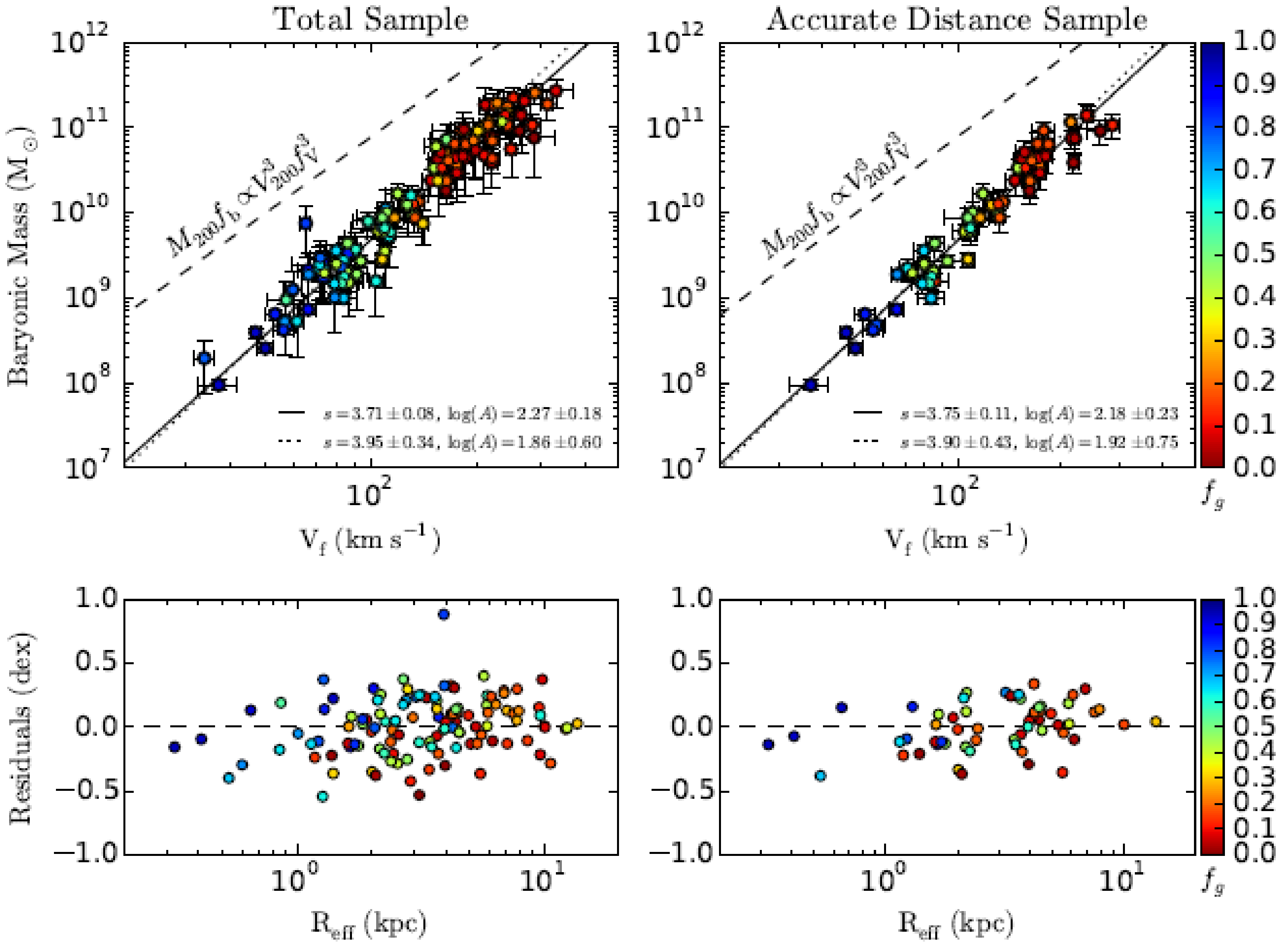

FIG. 2.— *Top panels*: BTFR adopting $\Upsilon_* = 0.5\ M_\odot/L_\odot$. Galaxies are color-coded by $f_g = M_g/M_b$. Solid lines show error-weighted fits. Dotted lines show fits weighted by f_g^2, increasing the importance of gas-dominated galaxies. The dashed line shows the ΛCDM initial condition with $f_V = 1$ and $f_b = 0.17$ (the cosmic value). *Bottom panels*: residuals from the error-weighted fits versus the galaxy effective radius. The outlier is UGC 7125, which has an unusually high correction for Virgocentric infall and lies near the region where the infall solution is triple-valued. If we consider only the correction for Local Group motion, UGC 7125 lies on the BTFR within the scatter.

Основные выводы

- При M/L ≥0.5 разброс на BTF- диаграмме (0.11 dex) ниже ожидаемого для ΛCDM-модели.

- The BTFR is an open issue for the current cosmological model: the stochastic process of galaxy formation needs to reproduce a global relation with little (if any) intrinsic scatter and no dependence on galaxy structural parameters.