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The H I and stellar mass bivariate distribution of centrals and satellites for all, late- and early-type local galaxies

A. R. Calette[1]★, Vladimir Avila-Reese[1], Aldo Rodríguez-Puebla[1], Claudia del P. Lagos[2,3] and Barbara Catinella[2,3]

[1] *Instituto de Astronomía, Universidad Nacional Autónoma de México, A. P. 70-264, 04510, Ciudad de México, México*
[2] *International Centre for Radio Astronomy Research (ICRAR), M468, University of Western Australia, 35 Stirling Hwy, Crawley, WA 6009, Australia.*
[3] *ARC Centre of Excellence for All Sky Astrophysics in 3 Dimensions (ASTRO 3D).*

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ABSTRACT

We characterise the conditional distributions of the H I gas-to-stellar mass ratio, $R_{\rm HI} \equiv M_{\rm HI}/M_*$, given the stellar mass, M_*, of local galaxies from $M_* \sim 10^7$ to 10^{12} $M_\odot$ separated into centrals and satellites as well as into late- and early-type galaxies (LTGs and ETGs, respectively). To do so, we use 1) the homogeneous "eXtended GALEX Arecibo SDSS Survey", xGASS(Catinella et al. 2018), by re-estimating their upper limits and taking into account them in our statistical analysis; and 2) the results from a large compilation of H I data reported in Calette et al. (2018). We use the $R_{\rm HI}$ conditional distributions combined with the Galaxy Stellar Mass Function to infer the bivariate $M_{\rm HI}$ and M_* distribution of all galaxies as well of the late/early-type and central/satellite subsamples and their combinations. Satellites are on average less H I gas-rich than centrals at low and intermediate masses, with

Ольгу Касьяновну – с Днем Рождения
и всех -
с Днем Космонавтики!!

Постановка задачи

- Как, уменьшив по возможности эффекты наблюдательной селекции, проследить влияние принадлежности галактики к системам галактик на относительную массу газа (HI), которая может быть не одинаковой для галактик ранних и поздних типов (ETGs and LTGs).
- The way to attempt to overcome the strong selection effects of blind HI radio surveys is to construct “well controlled” HI samples by means of radio follow-up observations of optically selected galaxy samples.
- Нужен также статистически корректный учет верхних оценок HI.

Распределение плотности вероятности относительной массы газа RHI=MHI/M* для галактик ранних и поздних типов (Catinella etal., 2018).

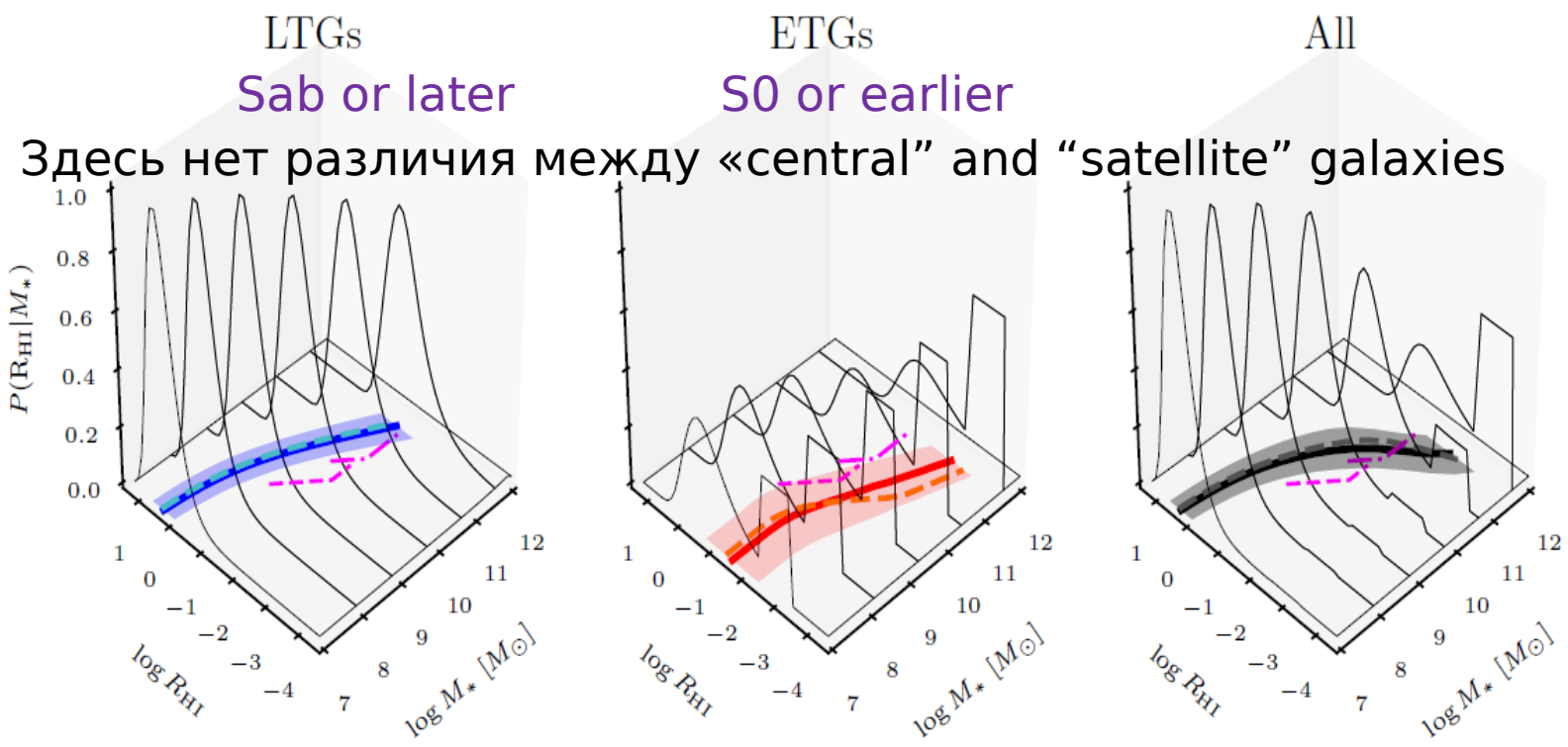

Figure 1. The R_{HI} gas conditional PDFs of LTGs, ETGs, and all galaxies as a function of M_* from Calette et al. (2018) and updated in Rodríguez-Puebla et al. (2020). In the projected log R_{HI}-log M_* planes, the logarithmic mean relations and their standard deviation are shown with thick solid lines and shaded areas, respectively. The dashed lines correspond to the medians instead of the logarithmic means. The magenta dashed and dot-dashed lines show the **xGASS** detection limits, see Section 2.

Предыстория вопроса

- Brown etal 2017: Спутники в более массивных гало имеют в среднем более низкое R=MHI/M* при данной M*.
- Stark et al 2016: эффект уменьшения R в системах галактик растет с увеличением массы гало, если $Mh>10^{12}$. Остается неясной ситуация с центральными галактиками и зависимость эффекта от морфологического типа.

Цель: рассмотреть отдельно содержание газа в “central” and “satellite” galaxies в интервале

$0.01 < z < 0.05$ and $10^9 M_s < M^* < 10^{11.5} M_s$.

Исходные данные:

- xGASS (eXtended GALEX Arecibo SDSS Survey; Catinella et al. 2018).
- xGASS is an homogeneously constructed HI (ALFALFA), ultraviolet (GALEX), and optical galaxy sample (SDSS) with well defined limits in RHI, M, and volume.
- Since this survey was constructed from SDSS, most of the galaxies can be separated into centrals and satellites making use of the Yang et al. (2007, 2012) halo-based group definition applied to SDSS.
- Approximately 30% of xGASS galaxies are classified as satellites in groups, 50% as isolated centrals, and 20% as centrals (the most massive member) in groups.

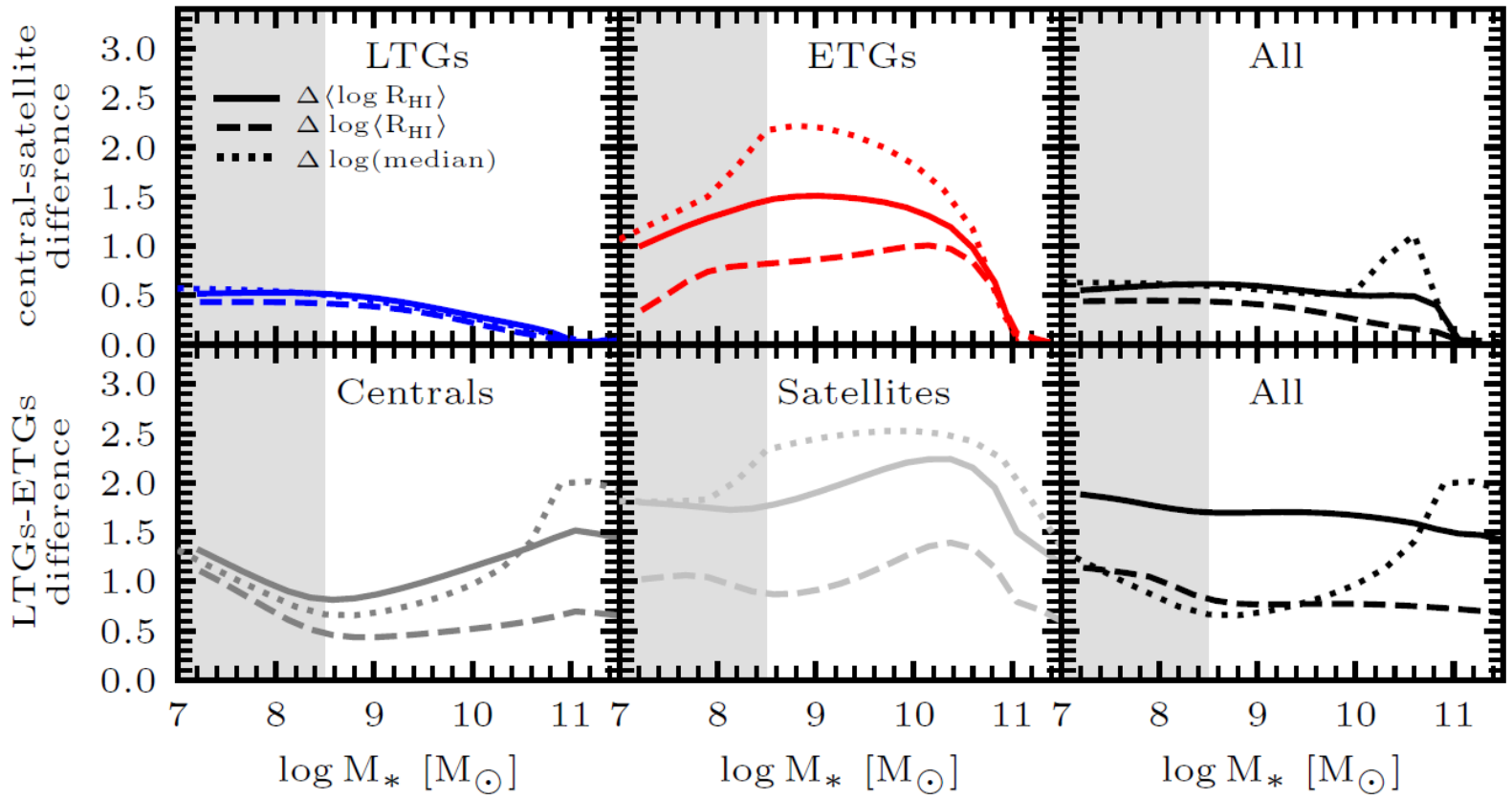

Figure 11. *Upper panels:* Relative differences (in dex) between the logarithmic means (solid line), arithmetic means (dashed line), and medians (dotted line) of centrals and satellites as a function of M_*. From left to right, these relative differences are shown for the LTG, ETG, and whole galaxy populations. In all the cases, centrals have higher H I gas contents than satellites, but at the largest masses, these differences become very small. *Lower panels:* As the upper panels but in this case the relative differences are between LTGs and ETGs for the central, satellite and whole galaxy population (from left to right, respectively). LTGs have much higher H I gas contents than ETGs at all masses. In both, upper and lower panels shaded gray areas indicate extrapolations to lower stellar masses of our empirically-constrained model for centrals and satellites.

У спутников содержание HI в среднем ниже, чем у центральных галактик
на 0.6-1 dex , хотя разброс значений , больше этой разности.

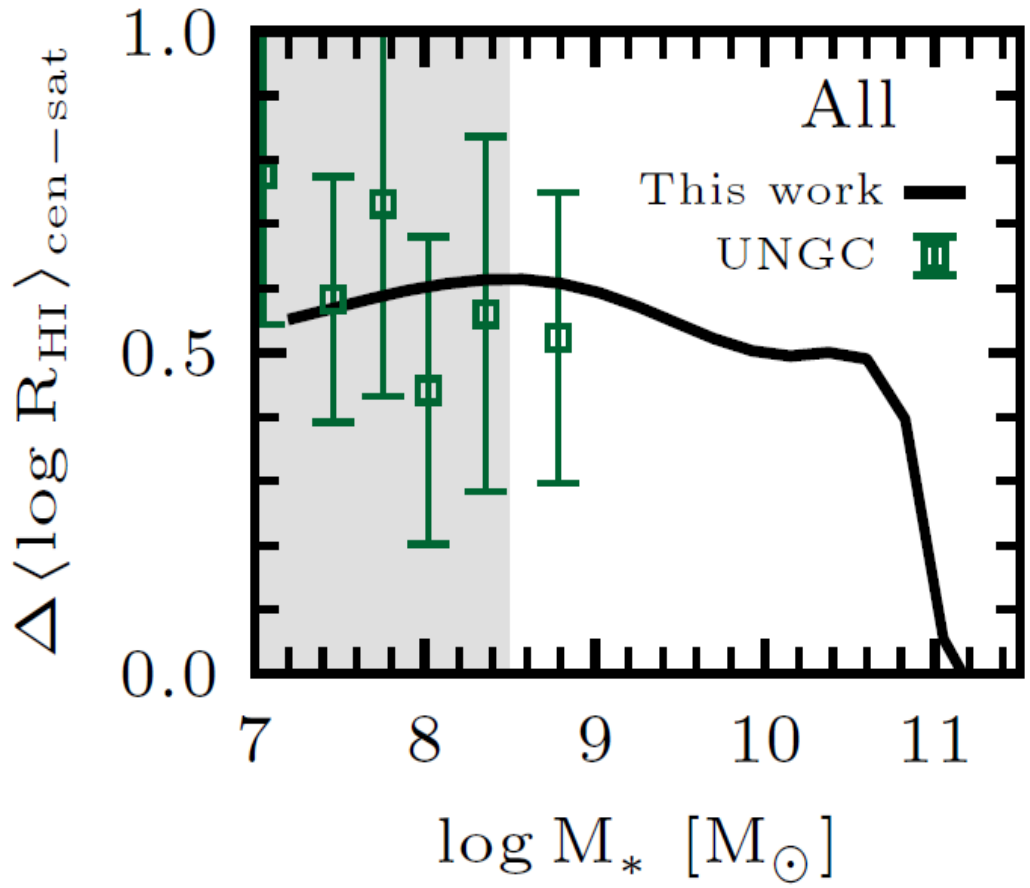

Figure 8. Difference of the logarithmic mean R_{HI} between central and satellite galaxies (in dex). The black solid line corresponds to this difference as a function of M_* from our results. Green squares with error bars are differences from the UNGC catalog for $M_* < 10^9$ $M_\odot$. Error bars result from propagating the errors of the mean of central and satellites in the given mass bins. The shaded gray area indicates the extrapolation to lower masses of our empirically-constrained model.

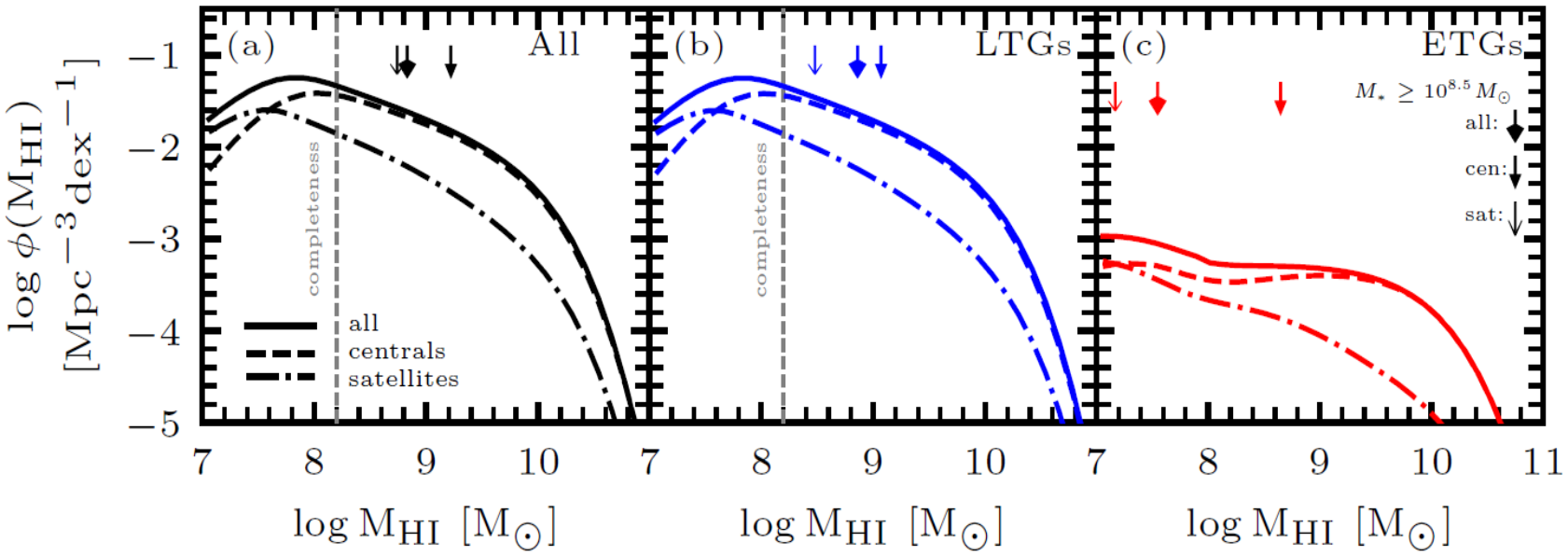

Figure 10. *Panel (a):* H I MF for all, central and satellite galaxies when integrating the bivariate M_* and $M_{\rm HI}$ distributions over M_*. The shaded green area represent extrapolations for the H I MF of all galaxies. *Panel (b):* As panel (a) but only for LTGs. *Panel (c):* As panel (a) but only for ETGs. Downward arrows indicate the H I masses corresponding to $M_* \sim 10^{8.5}$, the mass below which our model for centrals and satellites are extrapolations. The vertical dashed lines indicate the completeness limits of our H I MFs. Due to the low H I-to-stellar mass ratio of ETGs, note that the H I completeness limit is below 10^7 $\mathrm{M_\odot}$.

“Satellites” не вносят большого вклада в общее содержание

- Quantitatively, the central and satellite HI distributions are different at the 95% or higher level (p <0.05) for M <3 10^{10} Ms in all the cases. For larger masses, the differences are smaller and both centrals and satellites are consistent with being drawn from the same distribution of HI gas content.
- Уменьшение HI в спутниках (напр., из-за ram pressure) не обязательно сопровождается переходом от LTG к ETG.

There is evidence that perhaps low-mass disks can be transformed into S0 gas-poor galaxies when they fall into clusters of galaxies, while the formation of massive S0 galaxies seems to be more related to high-redshift dissipational processes (Fraser-McKelvie et al. 2018, and more references therein).

Основные выводы

- For LTGs, satellites have on average less HI than centrals. Up to M ~10^9 Ms, the relative difference is 0.5 dex and all the gas-rich dwarf LTGs are centrals. For higher masses, this relative difference decreases up to M ~3 10^{10} Ms, above which there is no difference between centrals and satellites.
- For ETGs, the bivariate distributions for centrals and satellites differ more than for LTGs, satellites being on average more devoid of HI than centrals up to M ~5 10^{10} M. However, a fraction of satellite ETGs has RHI values close to those of central ETGs.

- Overall, our results show that the difference in the RHI and M* distribution between late- and early-type galaxies is significantly larger than between central and satellite galaxies. This suggests that the HI gas content of galaxies depends more on their internal nature, that is, whether they are of late or early type morphology, than on external conditions associated to whether the galaxy is central or satellite.
- Иными словами, морфологическое различие между галактиками непосредственно не связано с тем, являются они “centrals” либо “satellites”.

К сожалению, рез-ты трудно физически интерпретировать, поскольку -

- не делается различия между E и S0;
- не делается различия между различными масштабами групп (между парами, бедными группами и богатыми скоплениями), а одиночная галактика относится к “centrals” как и галактика в центре скопления.