HI Global Scaling Relations in the WISE-WHISP Survey

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ABSTRACT

We present the global scaling relations between the neutral atomic hydrogen gas, the stellar disk and the star forming disk in a sample of 228 nearby galaxies that are both spatially and spectrally resolved in HI line emission. We have used HI data from the Westerbork survey of HI in Irregular and Spiral galaxies (WHISP) and Mid Infrared (3.4 μm, 11.6 μm) data from the Wide-field Infrared Survey Explorer (WISE) survey, combining two datasets that are well-suited to such a study in terms of uniformity, resolution and sensitivity. We utilize a novel method of deriving scaling relations for quantities enclosed within the stellar disk rather than integrating over the HI disk and find the global scaling relations to be tighter when defined for enclosed quantities. We also present new HI intensity maps for the WHISP survey derived using a robust noise rejection technique along with corresponding velocity fields.

Key words: galaxies: ISM – galaxies: evolution – galaxies: star formation – galaxies: dwarf – galaxies: spiral

1 INTRODUCTION

The fundamental goal of astrophysical studies is a better understanding of the origins and evolution of our universe. Both theoretical and observational works are geared towards constructing a solid picture of the processes involved in the formation of cosmic structures. This involves pursuing accurate models of galaxy formation and evolution. Central to the evolution of galaxies is the process of star formation (SF) which must be properly accounted for in models of both chemical and physical evolution (e.g. Boissier & Prantzos 1999; Lia et al. 2002; Davé et al. 2017). This is because SF drives the consumption of gas in galaxies and the chemical and physical evolution of both the interstellar medium (ISM) and intergalactic medium (IGM) (de Blok et al. 2015).

found index N = 1.4±0.05 using a combination of $\Sigma_{\rm HI}$ and $\Sigma_{\rm H_2}$ for total gas surface density. However, over the years, different studies have found varying values of N. Most notably, it has been shown that the value of N is closer to 1.0 when the surface density of molecular hydrogen gas (as traced by CO) is used instead of the total gas surface density, especially in molecule-rich ISM conditions such as the central regions of star forming spiral galaxies (e.g. Wong & Blitz 2002; Bigiel et al. 2008; Leroy et al. 2013; Dessauges-Zavadsky et al. 2014). Studies such as Boissier et al. (2003); Bigiel et al. (2008); Schruba et al. (2011); Calzetti et al. (2018) have also shown that there is, at best, a nonlinear power law relationship between $\Sigma_{\rm HI+H_2}$ and Σ_{SFR} with a higher index N ≈ 2.0. This is attributed to the weak relationship between $\Sigma_{\rm HI}$ and Σ_{SFR}

The scaling of SF (measured in terms of star formation rate, SFR, and star formation efficiency, SFE) with other galaxy properties such as mass and mass surface density provides insights into how gas is utilized at difference epochs via collapse, accretion, ejection and recycling.

Наиболее известное соотношение: K-S law

$$\sum SFR = A\sum_g{}^N$$

N ~ 1 -2, имеет разные значения для HI, H_2, и $HI+H_2$.

SAMPLE AND DATA:

228 galaxies S0-Im

WHISP survey.

D = 5 – 30 Mpc, resolution 30’’. We derived new maps by employing a strict noise-rejection technique.

$$\Sigma_{HI}(M_\odot\ pc^{-2}) = \frac{N_{HI}}{1.248 \times 10^{20}} \cos i,$$

WISE catalogue.

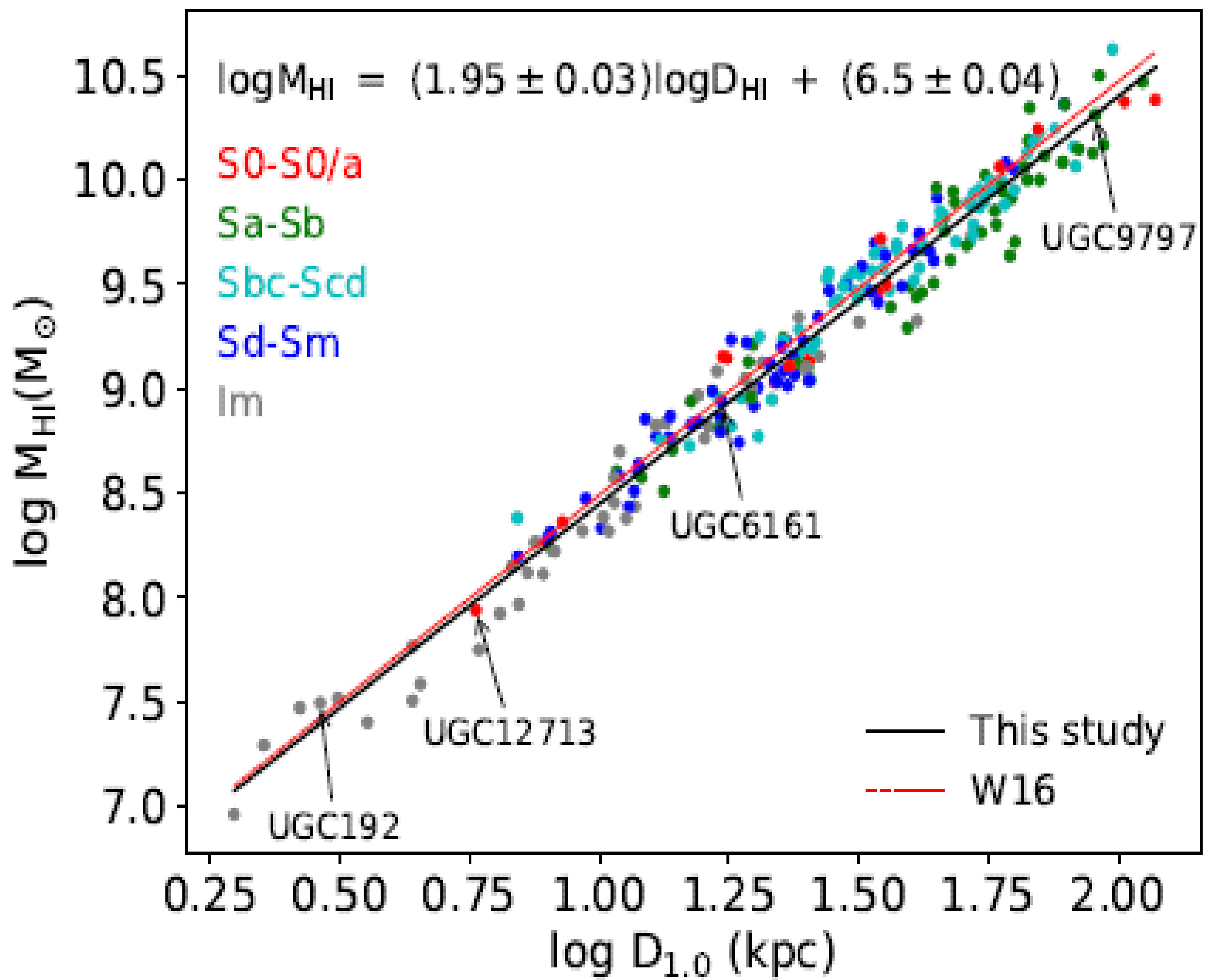
We calculated stellar masses for stellar disks from the W1 absolute magnitude. The stellar disks were defined as the region enclosed by the 1σ isophote (~ 23 mag arcsec2 in Vega units).

$$\log\ \Upsilon_*^{[3.4]} = -0.17 - 2.54(W1 - W2)$$

- SFR's were derived from the spectral luminosity, L, following the empirical relations of Cluver et al. (2017) who calibrated the WISE mid-IR to the total infrared luminosity;
- **log(SFR) = (-7.76± 0.15) + (0.889± 0.018) log(νL$_\nu$);**

Galaxies in close interactions or mergers as well as poor data and non-detections were excluded.

The HI mass-size relation

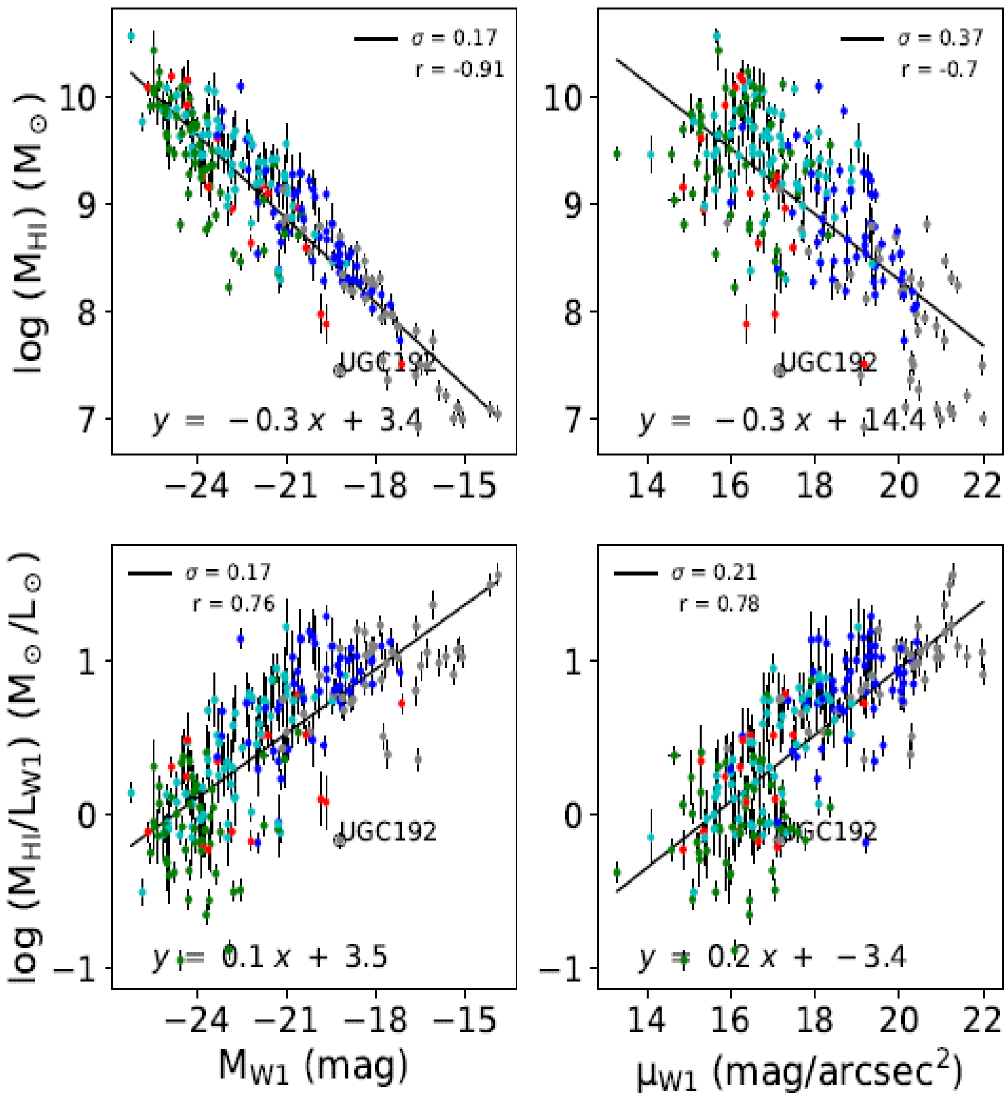


HI mass vs stellar luminosity

MHI – здесь не интегральная, а внутри звездного диска!
Красные точки – это S0-S0/a.

Scaling relations in our sample are in agreement with those of Verheijen & Sancisi (2001) taken from the Ursa major galaxy cluster.

UGC192- outlier.
Причина;
Основная масса HI - за пределами звездного диска. Это



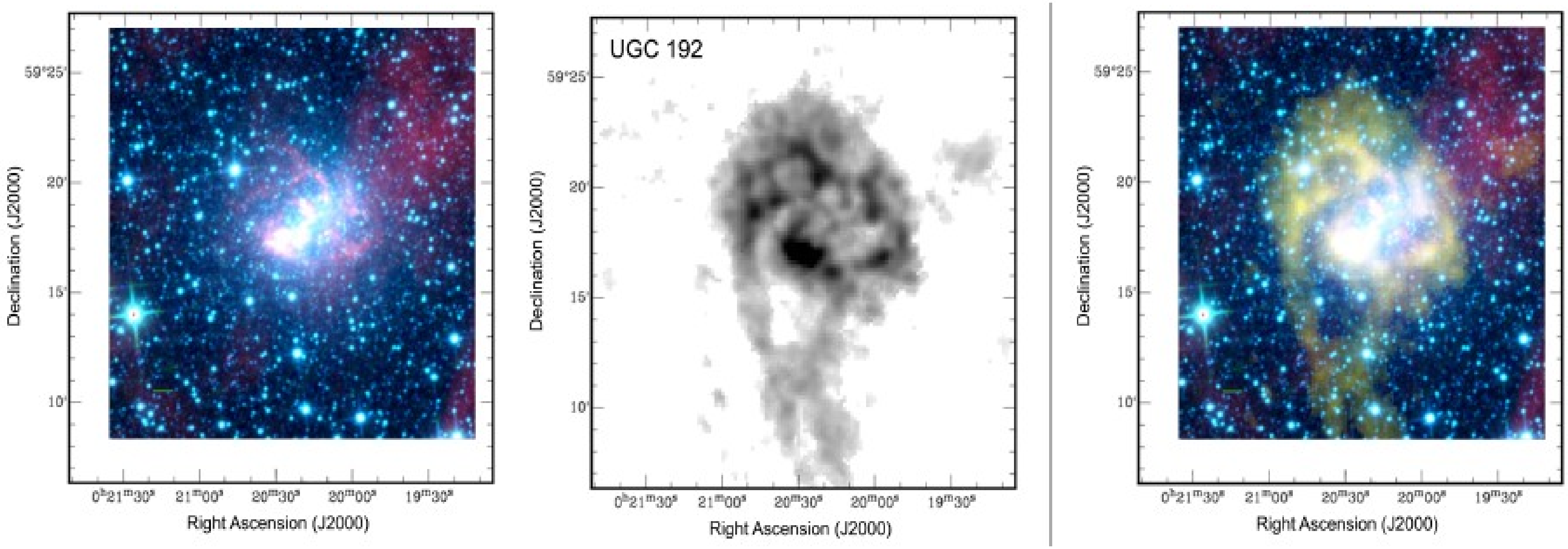


Figure 9. Star Formation and Gas Reservoir of UGC192. *Left*: A WISE three-color image of UGC192, with 3.4 μm (blue), 4.6 μm (cyan/green) and 11.6 μm (red). *Middle*: HI intensity distribution showing the disturbed morphology of UGC192 with a southern plume that has been suggested to be due to accretion of low column density primordial material (see Wilcots & Miller 1998; Namumba et al. 2019). Notice the spatial coincidence of the higher density HI clumps with the bright SF regions in the 11.6 μm emission. UGC192 is a star-bursting dwarf galaxy (a blue compact dwarf, BCD) in the local group. It has stellar mass $10^{8.6}M_\odot$ much higher than its gas mass ($10^{7.4}M_\odot$) and thus has a low gas fraction (0.06) that is similar to star forming spirals which place lower on the y-axis in the lower panels of Figure 8. Its absolute magnitude (stellar luminosity) is not atypical of the dwarfs in the sample (see left panels of Fig 8), but its surface brightness is exceptionally high (due to the starburst) and places it in the spiral-populated region in right panels of Figure 8. (see also Figure 13). *Right panel*: Combined HI and three-color WISE image showing the extent of the obscured star formation with respect to the HI disk. The green scale bar in the lower left corner shows an angular scale of 1 arcmin (0.2 kpc).

Main sequence

Ранние типы (более голубой ИК-цвет) имеют в среднем более низкий SFR. Причина: эволюция или наличие балджа?

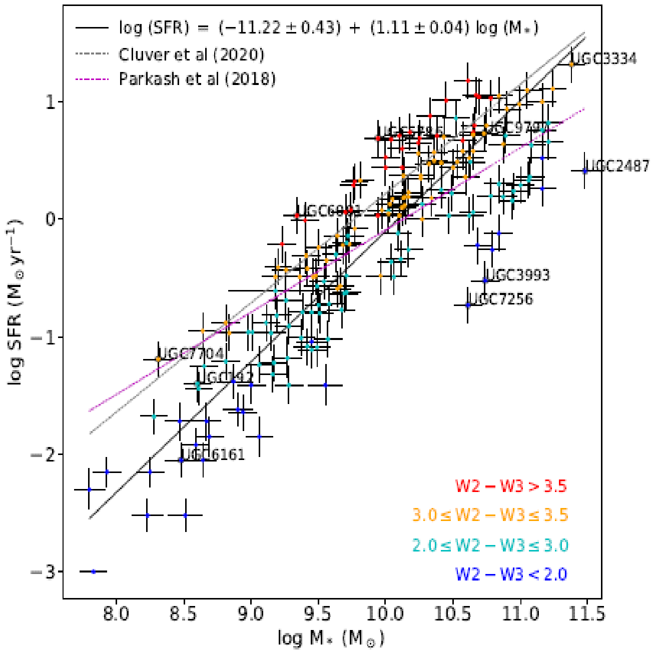
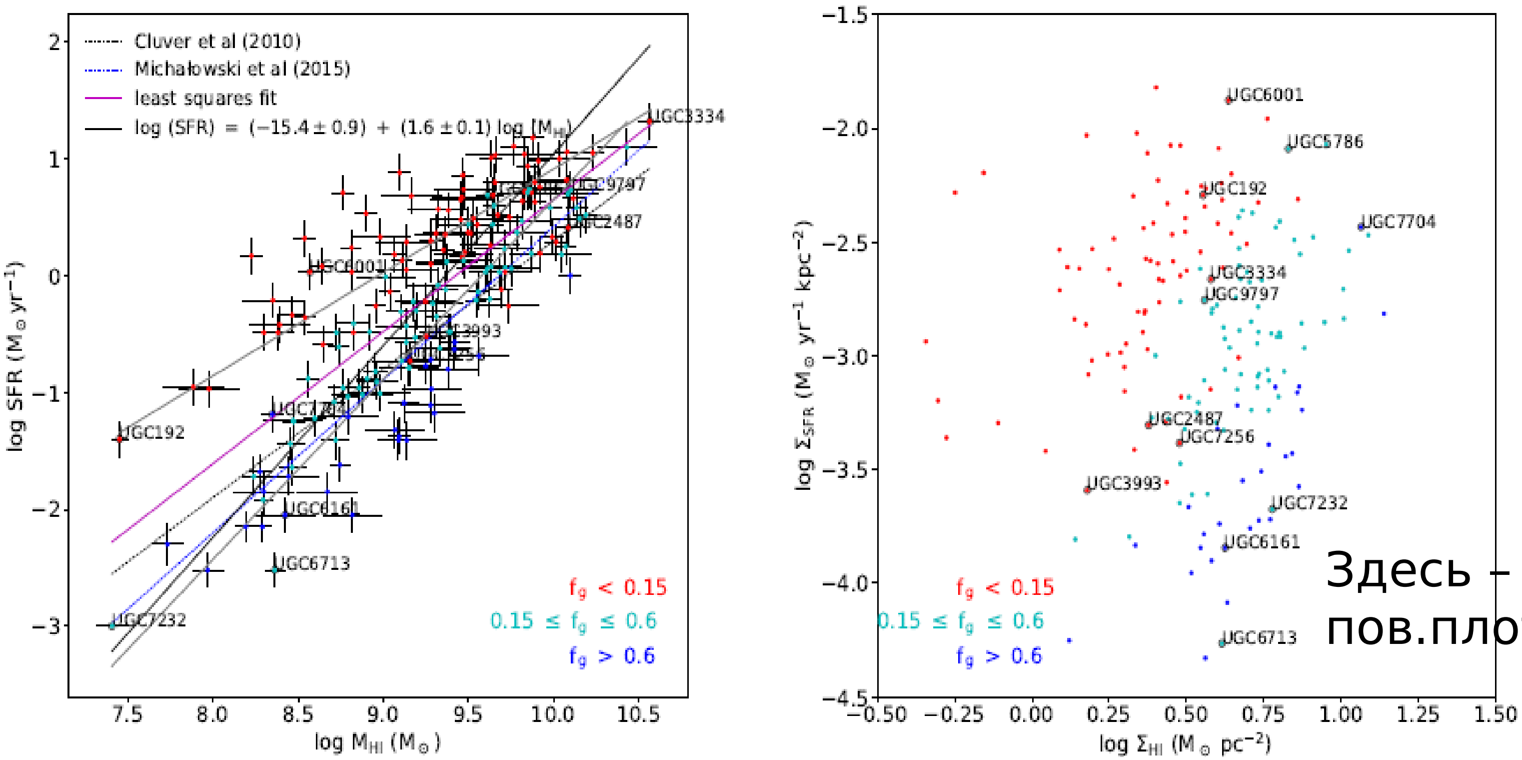


Figure 11. Relation between SFR and stellar mass for 180 galaxies detected in W3. The plot is color coded by the W2-W3 color where blue, cyan, orange and red represent W2-W3 ≤ 2, ≤ 3.0, ≤ 3.5 and, ≥ 3.5 respectively. The W2-W3 is an indicator of the dust content but also follows the morphologies such that low star forming early-types have bluer colors while the high star forming intermediate spirals have redder colors (we have followed the color-code convention of Cluver et al. 2017). The solid black line is a maximum likelihood fit to the data. For a given mass range, the main sequence line marks a separation between early-types and late-types.

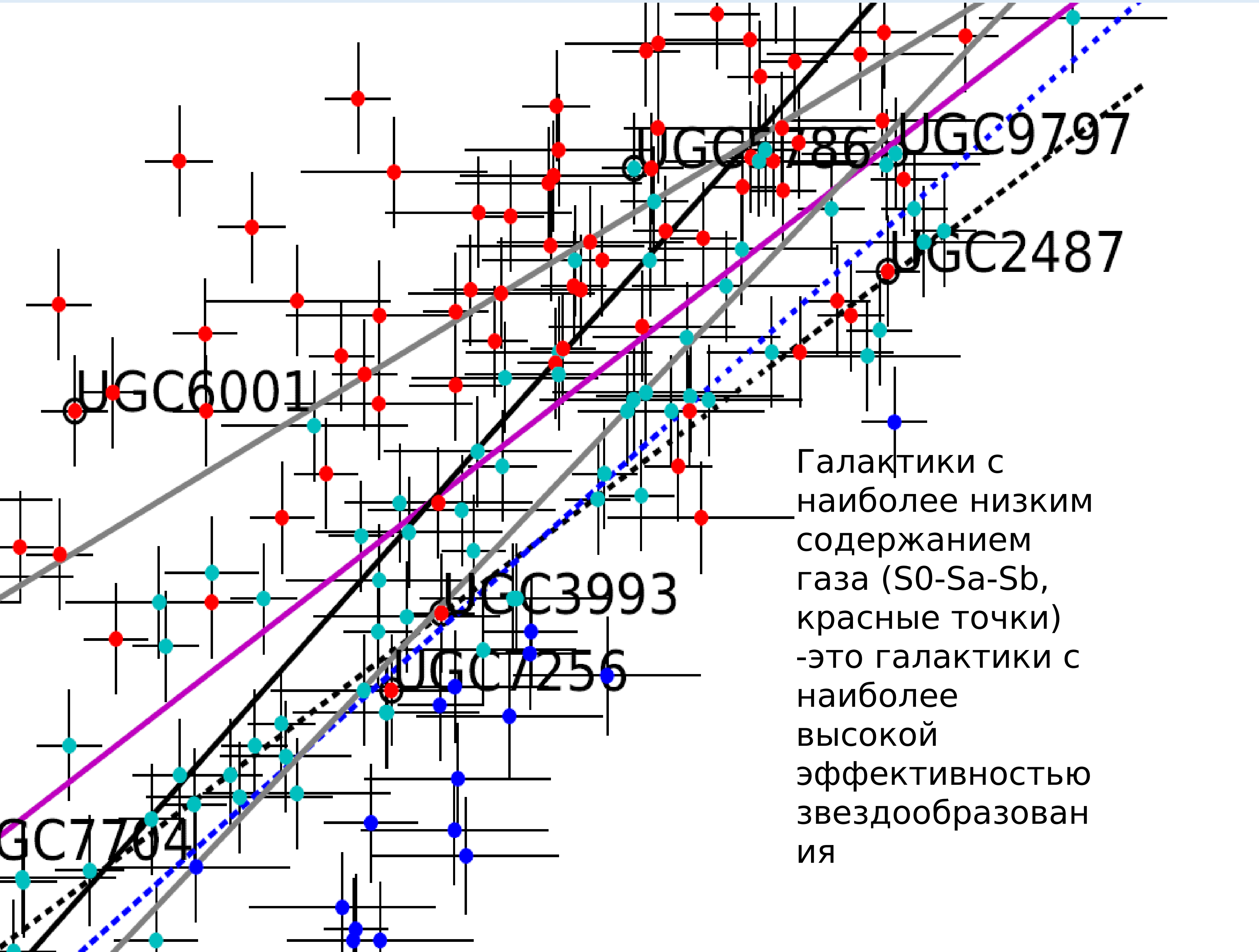
Star formation rate vs HI mass



Здесь – интеграль
пов.плотность HI.

тики с более низким содержанием газа имеют сравнительно более высоки

Figure 13. *Left panel*: Star formation rate versus atomic gas mass. The HI masses were derived from gas enclosed within the stellar disk defined by the 1σ isophote in the W1 images ($\sim$23 mag arcsec^{-2} in Vega units). The points are color-coded by gas fraction (f_g = MHI/M_*) such that red represents $f_g \leq 0.15$, cyan for $0.15 \leq f_g \leq 0.6$ and blue for $f_g > 0.6$. The color code highlights a 'green valley' and apparent red and blue sequences (fit by the two thin gray lines - discussed in the text) with a few outliers. Our maximum likelihood best fit (solid black line) is shown together with the lines of Cluver et al. (2010) and Michałowski et al. (2015). *Right panel*: Mean star formation rate surface density versus HI surface density for the sub-sample. The surface densities were averaged over the entire stellar disk defined by the 1σ isophote in the W1 images. The plot is color coded by gas fraction (f_g = MHI/M_*) such that red represents $f_g \leq 0.15$, cyan for $0.15 \leq f_g \leq 0.6$ and blue for $f_g > 0.6$. There is no correlation observed between the Σ_{HI} and Σ_{SFR} at these global scales.


UGC6001
UGC9797
UGC2487
UGC3993
UGC7256
Галактики с
наиболее низким
содержанием
газа (S0-Sa-Sb,
красные точки)
-это галактики с
наиболее
высокой
эффективностью
звездообразован
ия

Основные выводы

- Подтверждается примерное постоянство усредненной пов.плотности HI.
- Использование MHI enclosed within the stellar disk позволяет уменьшить дисперсию точек по сравнению с «when total integrated masses are used»
- Гл.последовательность SF имеет наклон ~ 1, однако есть сегрегация галактик по ИК цвету (фактически – по содержанию газа). Более ранние типы, а также наиболее массивные галактики – в среднем ниже MS (quenching, gas stripping or mergers??).
- Положение на диаграмме SFR-MHI различно для галактик с разным содержанием газа.