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From haloes to galaxies - II. The fundamental relations in star formation and quenching

JING DOU,^{1,2} YINGJIE PENG,¹ ALVIO RENZINI,³ LUIS C. HO,^{1,2} FILIPPO MANNUCCI,⁴ EMANUELE DADDI,⁵ YU GAO,^{6,7} ROBERTO MAIOLINO,^{8,9} CHENGPENG ZHANG,^{1,2} QIUSHENG GU,^{10,11} DI LI,^{12,13} SIMON J. LILLY,¹⁴ AND FENG YUAN¹⁵

¹*Kavli Institute for Astronomy and Astrophysics, Peking University, 5 Yiheyuan Road, Beijing 100871, China*

²*Department of Astronomy, School of Physics, Peking University, 5 Yiheyuan Road, Beijing 100871, China*

³*INAF - Osservatorio Astronomico di Padova, Vicolo dell'Osservatorio 5, I-35122 Padova, Italy*

⁴*Istituto Nazionale di Astrofisica, Osservatorio Astrofisico di Arcetri, Largo Enrico Fermi 5, I-50125 Firenze, Italy*

⁵*AIM, CEA, CNRS, Université Paris-Saclay, Université Paris Diderot, Sorbonne Paris Cité, F-91191 Gif-sur-Yvette, France*

⁶*Purple Mountain Observatory & Key Laboratory for Radio Astronomy, Chinese Academy of Sciences, 10 Yuanhua Road, Nanjing 210033, PR China*

⁷*Department of Astronomy, Xiamen University, Xiamen, Fujian 361005, China*

⁸*Cavendish Laboratory, University of Cambridge, 19 J. J. Thomson Avenue, Cambridge CB3 0HE, UK*

⁹*Kavli Institute for Cosmology, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK*

¹⁰*School of Astronomy and Space Science, Nanjing University, Nanjing 210093, China.*

¹¹*Key Laboratory of Modern Astronomy and Astrophysics (Nanjing University), Ministry of Education, Nanjing 210093, China.*

¹²*CAS Key Laboratory of FAST, National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012, China*

¹³*School of Astronomy and Space Science, University of Chinese Academy of Sciences, Beijing 100049, China*

¹⁴*Department of Physics, ETH Zurich, Wolfgang-Pauli-Strasse 27, CH-8093 Zurich, Switzerland*

¹⁵*Key Laboratory for Research in Galaxies and Cosmology, Shanghai Astronomical Observatory, Chinese Academy of Sciences, 80 Nandan Road, Shanghai 200030, China*

Введение: совершенно гениальное

1. INTRODUCTION

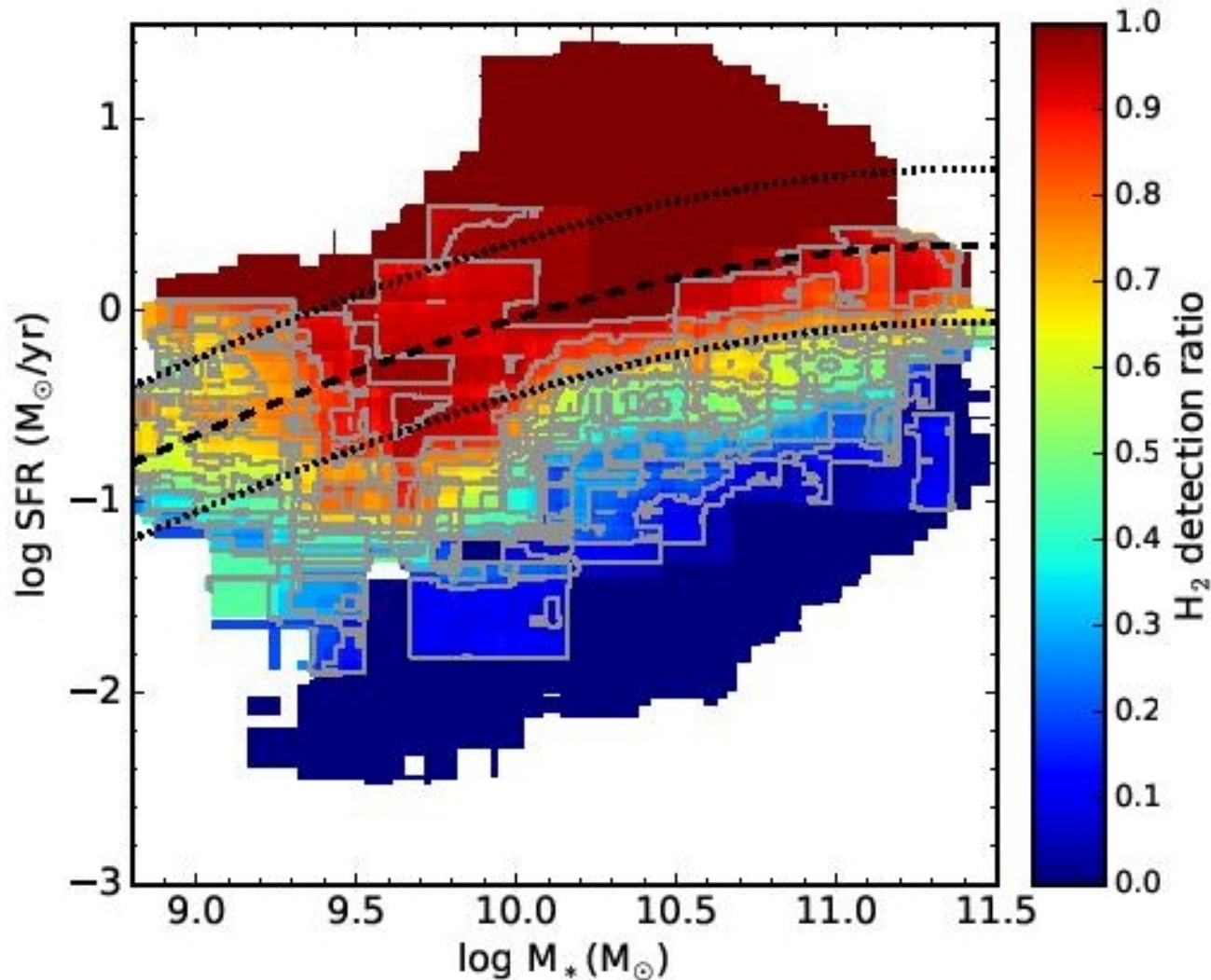
The assembly of the galaxy population across cosmic time can be mainly described by the star formation history (e.g., Lilly et al. 1996; Madau & Dickinson 2014 for a review), quenching history (e.g., Peng et al. 2010; Renzini 2016), merging history (e.g., Kauffmann et al. 1993; Conselice 2014 for a review), chemical enrichment history (e.g., Maiolino & Mannucci 2019 for a review) and angular momentum history (e.g., Peebles 1969; White 1984; Mo et al. 1998; Navarro & Steinmetz 2000; Renzini 2020; Peng & Renzini 2020). Stars are commonly believed to form in cold dense molecular clouds. Star formation rate (SFR) can be associated to the total available cold molecular gas mass (M_{H_2}) in the interstellar medium (ISM) of the galaxy via star formation efficiency (SFE) as $\text{SFR} = \text{SFE} \times M_{\text{H}_2}$. The SFE, or equivalently the gas depletion timescale τ ($\tau = 1/\text{SFE}$), describes how efficiently the galaxy can convert the available cold gas into stars.

In line with this effort, several key scaling relations have been identified. The first one is the star-forming main sequence (Brinchmann et al. 2004; Daddi et al. 2007; Elbaz et al. 2007, 2011; Noeske et al. 2007; Schiminovich et al. 2007; Franx et al. 2008; Peng et al. 2010; Whitaker et al. 2012, 2014; Speagle et al. 2014; Rodighiero et al. 2015; Renzini & Peng 2015; Schreiber et al. 2015; Popesso et al. 2019a,b), which describes the tight relation between SFR and stellar mass of the star-forming galaxies. The second one is the molecular gas main sequence (Barrera-Ballesteros et al. 2018; Tacconi et al. 2018; Lin et al. 2019; Barrera-Ballesteros et al. 2020), which describes the correlation between molecular gas mass and stellar mass. The third one is the so-called extended KS relation, which describes the correlation between SFR and the combination of gas mass and stellar mass (Dopita 1985; Dopita & Ryder 1994; Shi et al. 2011, 2018). There are also increasing interests and many efforts that have been made to study the combined 3D relation defined by M_* , SFR and M_{H_2} (Lin et al. 2019; Morselli et al. 2020; Ellison et al. 2020a,b).

Выборка:

- xCOLD-GASS (eXtended CO-Legacy Database of GALEX-Arecibo SDSS Survey): 532 галактики с массой $> 10^9$
- IRAM, beam size 22", S/N>5.
- SFR – по сопоставлению UV(GALEX) vs MIR (WISE); → 330 галактик.
- Всех типов звездообразования: главная последовательность, starbursts, quenched.

Молекулярный газ есть почти везде!



Главная фишка

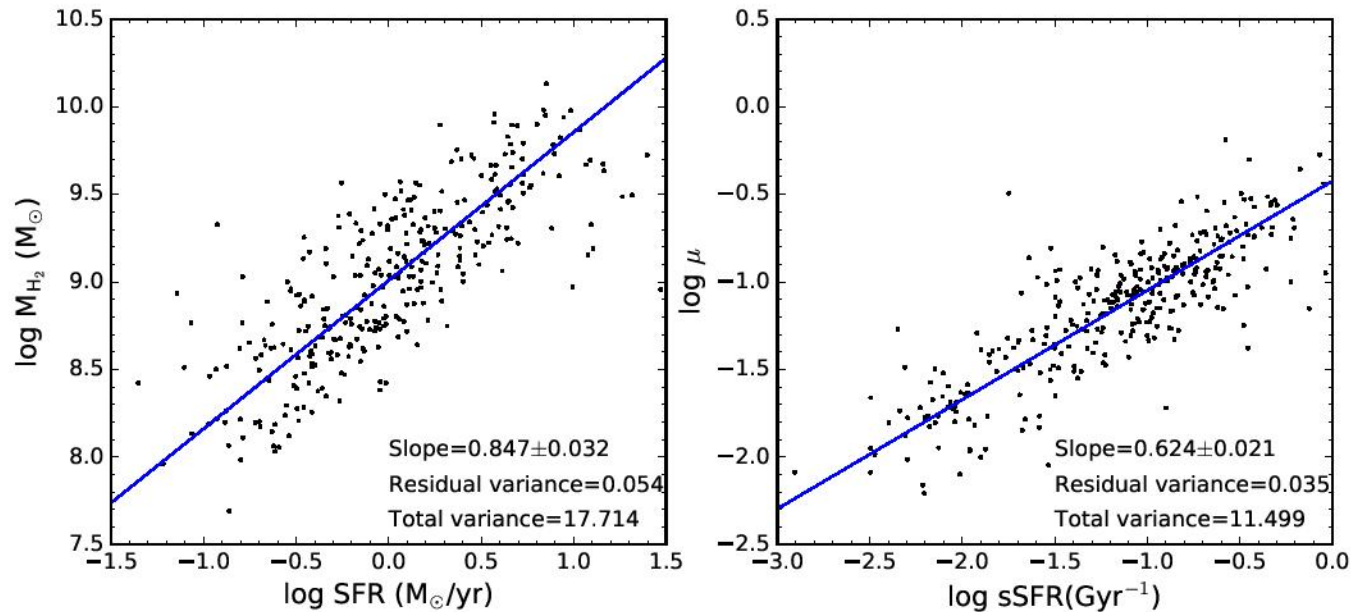


Figure 1. Comparison of the M_{H_2} -SFR relation (left) and μ -sSFR relation (right). Black dots are individual galaxies. The blue solid lines show the best fits to the data using ODR fitting method. The slope, residual variance and total variance of the best-fitting model are given in the legend.

Где разброс меньше, там и исходная зависимость!

Отчего велик разброс у исходного K-S? От диапазона масс!

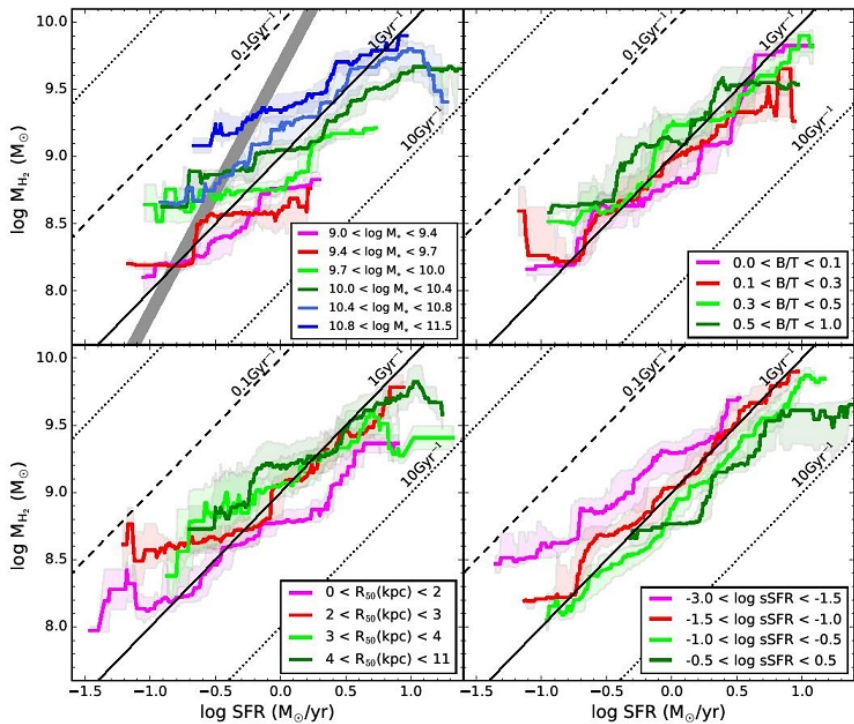


Figure 3. The average molecular gas mass as a function of SFR in different stellar mass, bulge-to-total ratio, effective radius and sSFR. The average values are calculated with a sliding box of 0.5 dex in SFR. Error bars on each line indicate the 32th and 68th percentile of the galaxy distribution. The black diagonal lines are the constant star formation efficiency in three different values. The thick gray line marks the CO detection ratio of ~80%. On the right hand side of the gray line, the average detection

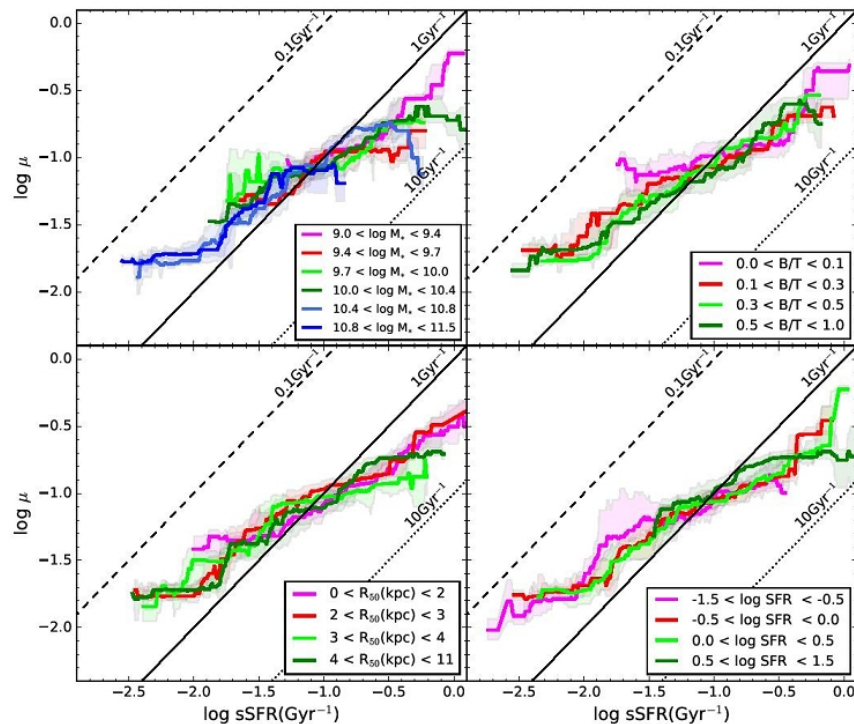


Figure 4. As for Figure 3, but for the μ -sSFR relation and the lower right panel is for different SFR bins. As discussed in the text and Appendix, for galaxies with $\log \text{sSFR} > -1.6 \text{ Gyr}^{-1}$, the average CO detection ratio is larger than 80%, where the results should be reliable.

SFR relation is a collection and superposition of the M_{H_2} -SFR relations at different stellar masses, otherwise when the M_{H_2} -SFR relations at different stellar masses are

Схемка поясняет ЭТОТ тезис

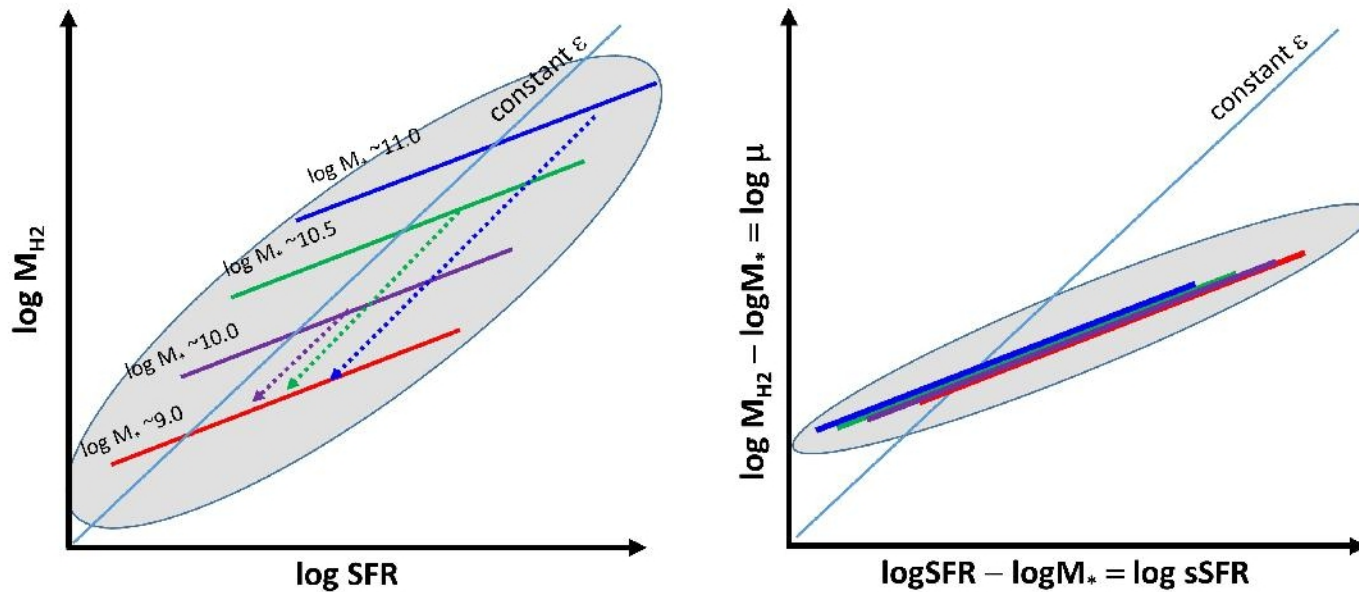


Figure 5. Illustration of the interrelationship between the M_{H_2} -SFR (i.e. the integrated KS law) and μ -SFR relation, and their dependence on stellar mass. The M_{H_2} -SFR relation can be transformed into the μ -SFR relation by shifting each galaxy by its $\log M_*$. For a given stellar mass bin (i.e. galaxies with similar M_*), the shift is the same. Therefore, when the M_{H_2} -SFR relation at a given stellar mass bin is transformed into the μ -SFR relation, it is shifted along the diagonal line (i.e. along the constant SFE line, as the shift is $-\log M_*$ in both x-axis and y-axis) and its slope remains unchanged. In other words, the intrinsic slope of the M_{H_2} -SFR relation (i.e. slope at a given stellar mass) is the same as the μ -SFR relation. The global M_{H_2} -SFR relation (shaded region in the left panel) is a collection and superposition of the M_{H_2} -SFR relations at different stellar

Уменьшаем разброс и у других шкалирующих зависимостей...

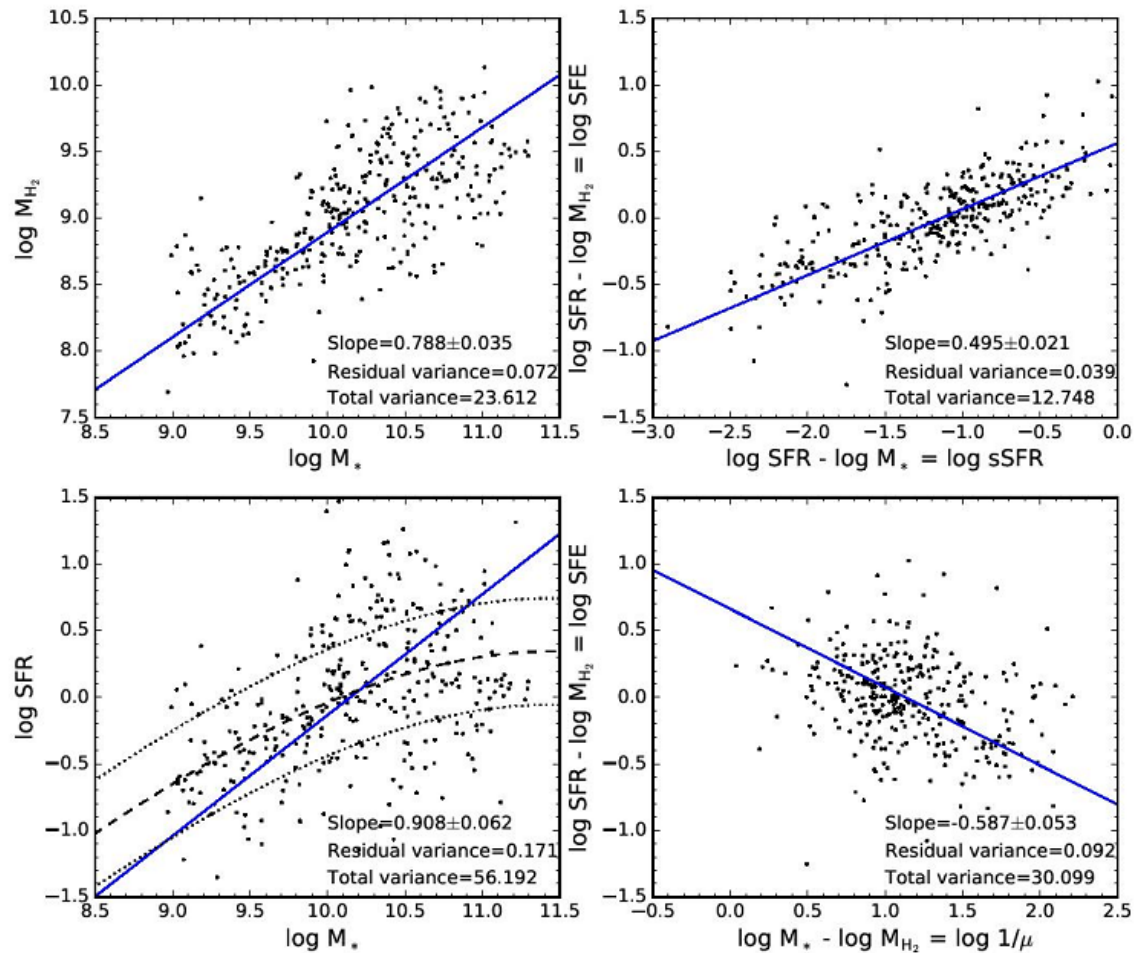
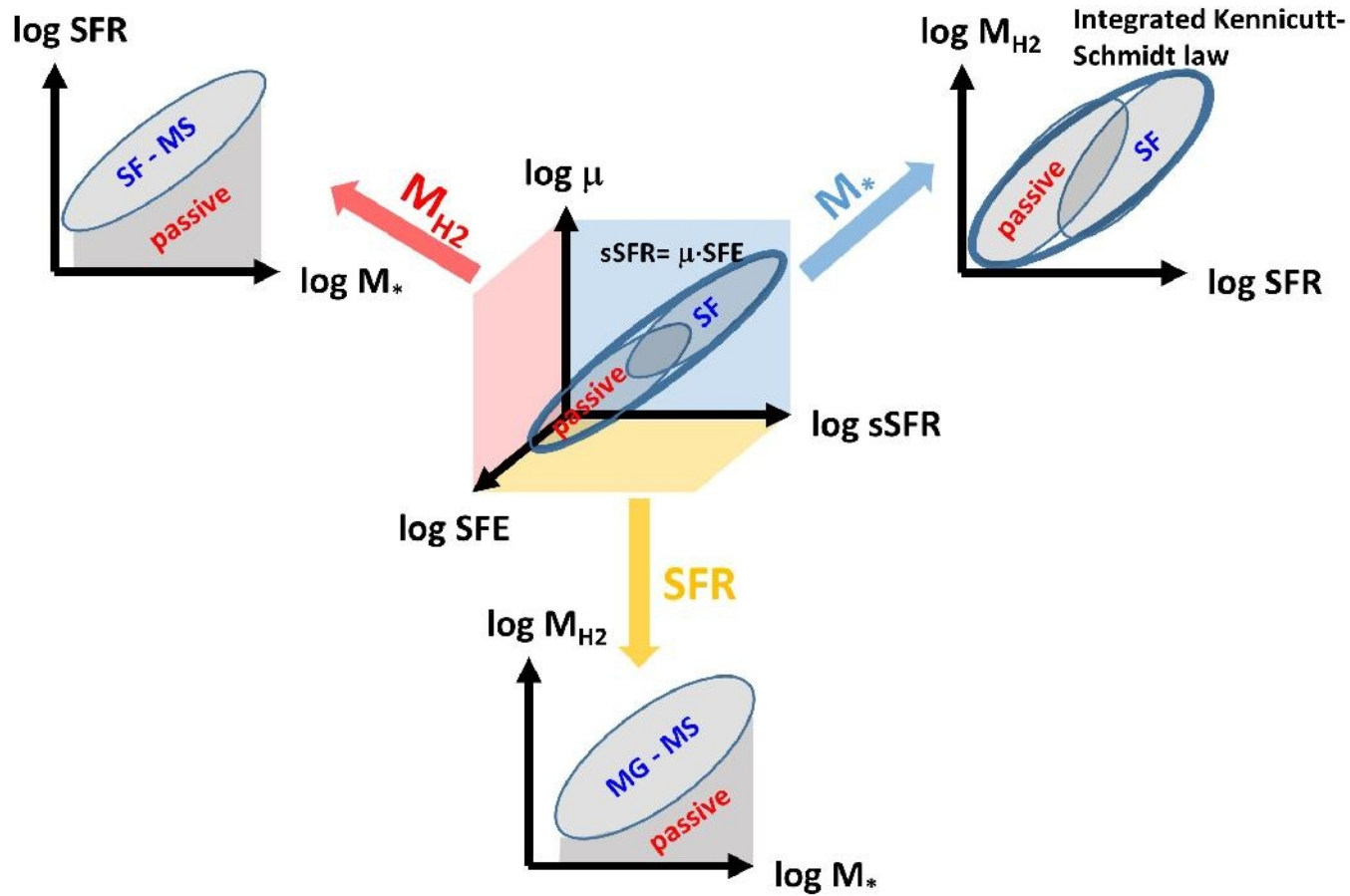


Figure 6. Comparison of the M_{H_2} - M_* relation (upper left) and SFE-sSFR relation (upper right); SFR- M_* relation (bottom left) and SFE- $1/\mu$ relation (bottom right). Black dots are individual galaxies. The blue solid lines show the best fits to the data using ODR fitting method. The slope, residual variance and total variance of the best-fitting model are given in the legend. The dashed line indicates the position of the star-forming main sequence defined in [Saintonge et al. \(2016\)](#). The dotted lines indicate ± 0.4 dex scatter around the main sequence.

...и приходим к FFR!



Fundamental Formation Relation