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# SDSS-IV MaNGA: the "G-dwarf problem" revisited

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This phenomenon can be most simply quantified by the cumulative metallicity distribution function (CMDF), which is just the total mass in stars in which the heavy element fraction is less than Z, M∗(< Z).

"closed box" model of chemical evolution:

$$M_*\,(<Z) = M_{\mathrm{gas},\,0}\left[1 - \exp\left(-Z/p\right)\right]$$

p is a parameter that defines the yield of heavy elements created by each generation of stars

"accreting box" model:

$$M_*\,(<Z) = -M_{\mathrm{gas}}\left[\ln\left(1 - Z/p\right)\right]$$

where $M_{\mathrm{gas}}$ is a constant

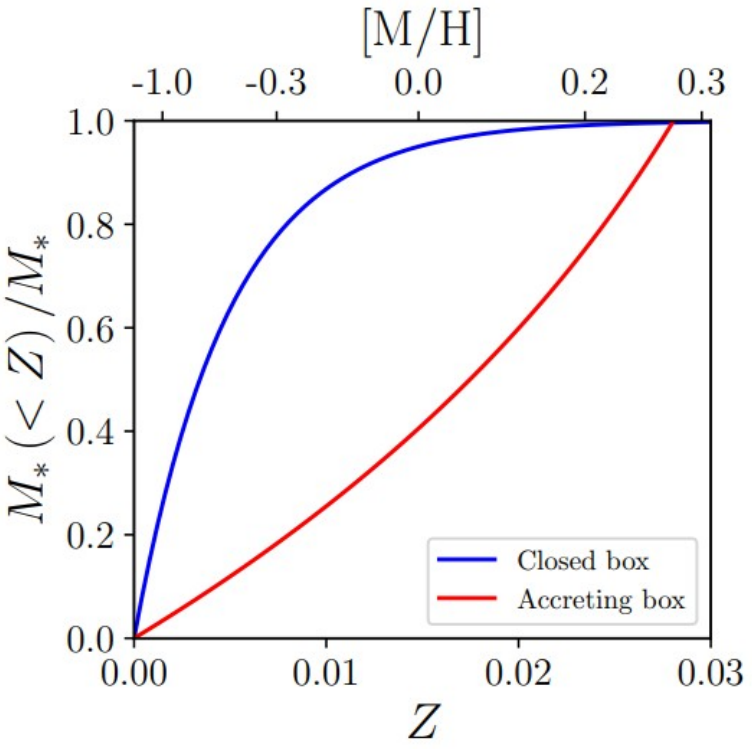
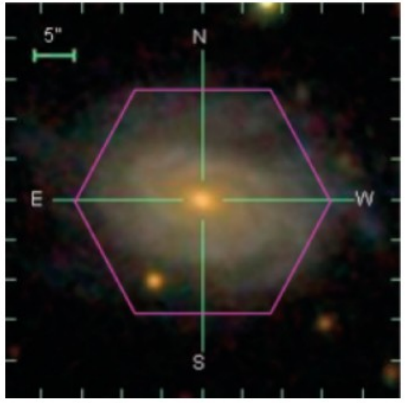


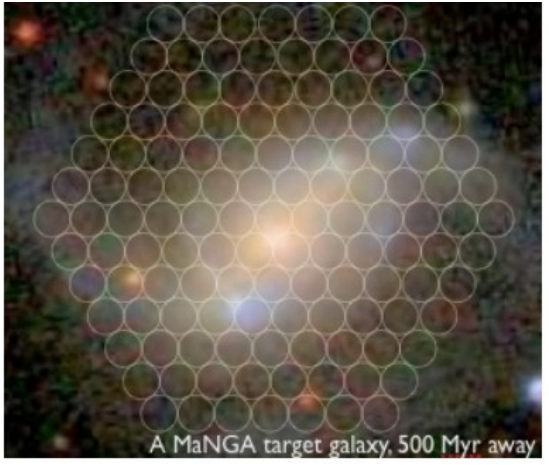

**Figure 1.** Simple model CMDFs showing the fractional mass of stars that have a metallicity less than $Z$ for a closed box (blue) and an accreting box (red). Characteristically, the yield $p$ of a generation of star formation is of order the value of Solar metallicity ($Z_\odot$ = 0.0148; Lodders 2019); for these models, we adopt yields of one-third $Z_\odot$ for the closed box, and three times $Z_\odot$ for the accreting box. These yield values are not physically motivated, but have been selected simply for illustrative purposes.

# MaNGA

## Mapping Nearby Galaxies at APO (MaNGA)




The SDSS image of a galaxy observed by MaNGA; the pink hexagon shows the size of the MaNGA IFU




A MaNGA target galaxy, 500 Myr away

https://www.sdss.org/surveys/manga/

# Как отбирали галактики

- Galaxy Zoo 2 classifications are available for a total of 7330  MaNGA Product Launch galaxies
- from this sample, we first reject 58 galaxies which were flagged by GZ2 as obscured by a star or other artifact
- we then ensure each galaxy has a spiral morphology
- we retain only those which are oriented reasonably face-on (i>=60)
- we remove a further 166 galaxies that were flagged for poor data quality by the DRP* or had for any reason failed to produce the necessary DAP** data sets
- final sample contains 1475 face-on spiral galaxies. The galaxies in this final sample have a median redshift of z = 0.037

* Data Reduction Pipeline (DRP; Law et al. 2016),

** Data Analysis Pipeline  (DAP; Westfall et al. 2019; Belfiore et al. 2019)

# Фитирование спектров

- истории звездной эволюции восстанавливались с помощью STARLIGHT (full-spectrum stellar population fitting code)
- эмиссионные линии убирались с помощью MaNGA DAP
- Каждый спектр фитировался с помощью комбинации single stellar population E-MILES templates (из Vazdekis et al. (2016))
  - log(age/yr) = 7.85, 8.15, 8.45, 8.75, 9.05, 9.35, 9.65, 9.95, 10.25
  - [M/H] = −1.71, −1.31, −0.71, −0.40, +0.00, +0.22
- Для более молодых населений брались templates из (Asa’d et al. (2017))
  - log(age/yr) = 6.8, 6.9, 7.0, 7.2, 7.4, 7.6
  - [M/H] = −0.41, +0.00

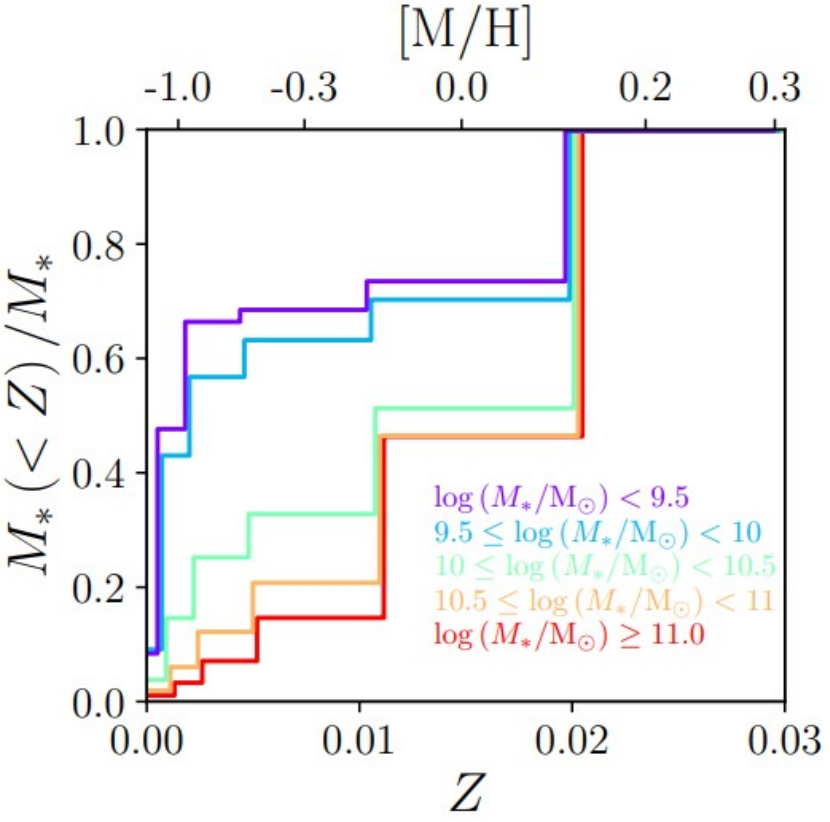



**Figure 2.** CMDFs for the spiral galaxies in the MaNGA sample, binned by stellar mass. The histograms show the median value for the CMDF within each mass bin, normalised by the total mass of each galaxy.

# Обсуждение

- Массивные галактики показывают недостаток маломассивных низкометалличных звезд. Маломассивные галактики – нет.
- Галактики, похожие на Млечный Путь, демонстрируют ту же проблему – недостаток низкометалличных G-карликов. Проблема решается, если модель “accreting box” эволюции верна
- Галактики с массой меньше, чем $10^{10}$ $M_{sun}$, хорошо описываются “closed box” моделями эволюции
- Полученные данные согласуются с тем, что в массивных галактиках большинство звезд сформировалось в короткий промежуток времени, а в маломассивных галактиках звезды формируются постепенно в течение времени, сравнимого с возрастом Вселенной, и вещество успевает хорошо перемешиваться.