Stellar Subpopulations in bulges of MW-Like Galaxies

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Bulge of the MW

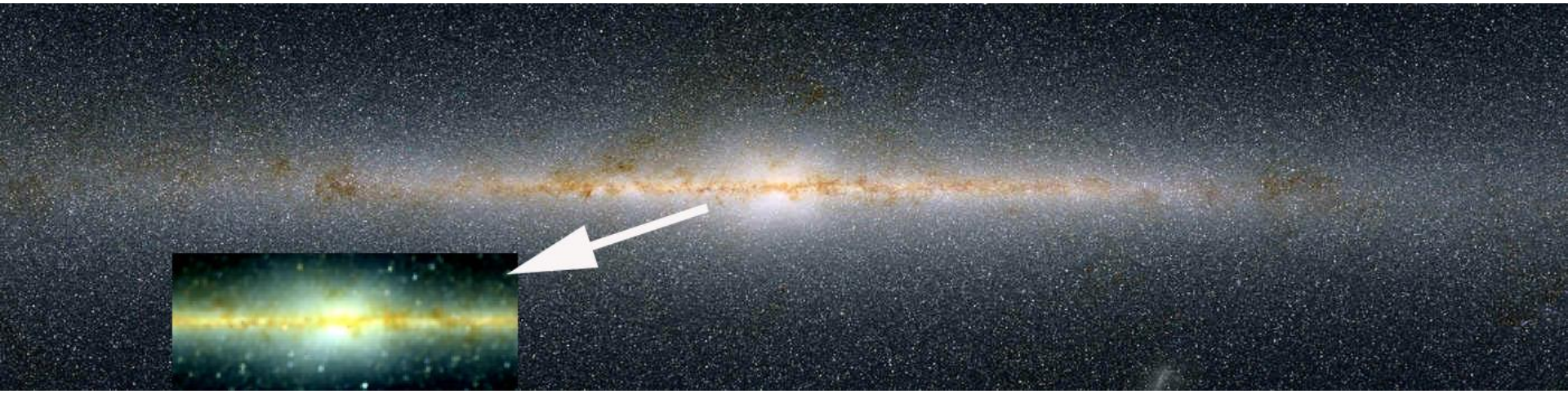

Image 2MASS

- Accesible in IR. Surveys 2MASS, VVV
- X – shape. Boxy/peanut. Vazquez+2014

Objectives

- Identify Milky-Way like Galaxies in the Multi-Dark simulations with tight constraints, using two different criteria combined. One of them regarding the cosmological build-up of its DM Halo and Local Group of galaxies, and the other regarding the barionic content and Morphology of the MW.

- Using the Semi-analytical galaxy formation model SAG, study the chemical properties of stellar subpopulations in Bulges of MW-like galaxies in order to understand the observed metallicity distributions and abundances of individual elements, and contribute to the understanding of the formation of the galactic bulge of the MW.

- Test the consecuences in the metallicity distributions and individual chemical abundances of bulges of MW-like galaxies and on its star fomation history, when applying a variable integrated initial mass function (IGIMF) in the model.

MW-Like galaxies selection

Mutch Criteria (2011, M11)

- To Be the most massive galaxy in the DM-Halo. In terms of the simulation, this translates to be the central galaxy of a FOF Halo.

- To have a stellar mass in the interval: $10^{10.5} < M\ [\ M_{\odot}\ ] < 10^{11.2}$. This condition is equivalent to the Galaxy Zoo criterium of galaxies like the MW/M31.

- To have an aproximate morpholoy of a Sb/c galaxy. This condition can be considered fullfilled if the ratio of luminosities (or diference of magnitud) between the bulge and and the whole galaxy is in the range $1{,}5 < M_{B\text{-}bulbo} - M_{B\text{-}total} < 2{,}6$, following a definition of de Vacouleurs (1986).

MW-Like galaxies selection

Criterium for Local Group (LG) analog systems, González (2014, G14)

- We look for pair of host galaxies that contain galaxies analog to the MW and M31, in which both members have masses in the range between $M_{200} = 10^{11} - 10^{13}$ and are separated by 0.5 to 1.3 Mpc.

- In order to select isolated pairs and avoid tripelts or larger groups, we difine a cuantitative criteria of isolation using a Force constrain

- We try to emulate the ausence of massive clusters of galaxies in the neighborhood of the LG. It is required that the halos of the sample don't have a neighbor halo with $M_{200} > 1{,}5 \times 10^{14}\ M_{\odot}$ between 12 Mpc. The values of mass and distance are lower than the real values of the Virgo Cluster.

MW-Like galaxies selection

Criterium for Local Group (LG) analog systems, González (2014, G14)

- Constraints in the galactocentric radial velocity , tangential velocity and separation of the pairs are imposed, based in results in the literature, but amplified errors are considered.

$$V_{\mathrm{RAD}} = -109{,}3 \pm 80 \ \mathrm{km\ s^{-1}}$$

$$V_{\mathrm{TAN}} < 65 \ \mathrm{km\ s^{-1}}$$

$$\Delta r = 770 \pm 100 \mathrm{kpc}$$

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1 Sigma : 125 pairs
2 Sigma : 1012 pairs
3 Sigma : 3159 pairs

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$$\Delta r = 770 \pm 100 \mathrm{kpc}$$

An alternative theory of variable IMF

TH-IGIMF (Top Heavy Integrated Galaxial Initial Mass Function)

Key Assumption : The stars are formed in embedded clusters (Lada & Lada 2003). The final distribution of stellar masses is a combination of all the stars ever formed in clusters.

Based in physically and observationally motivated axioms.

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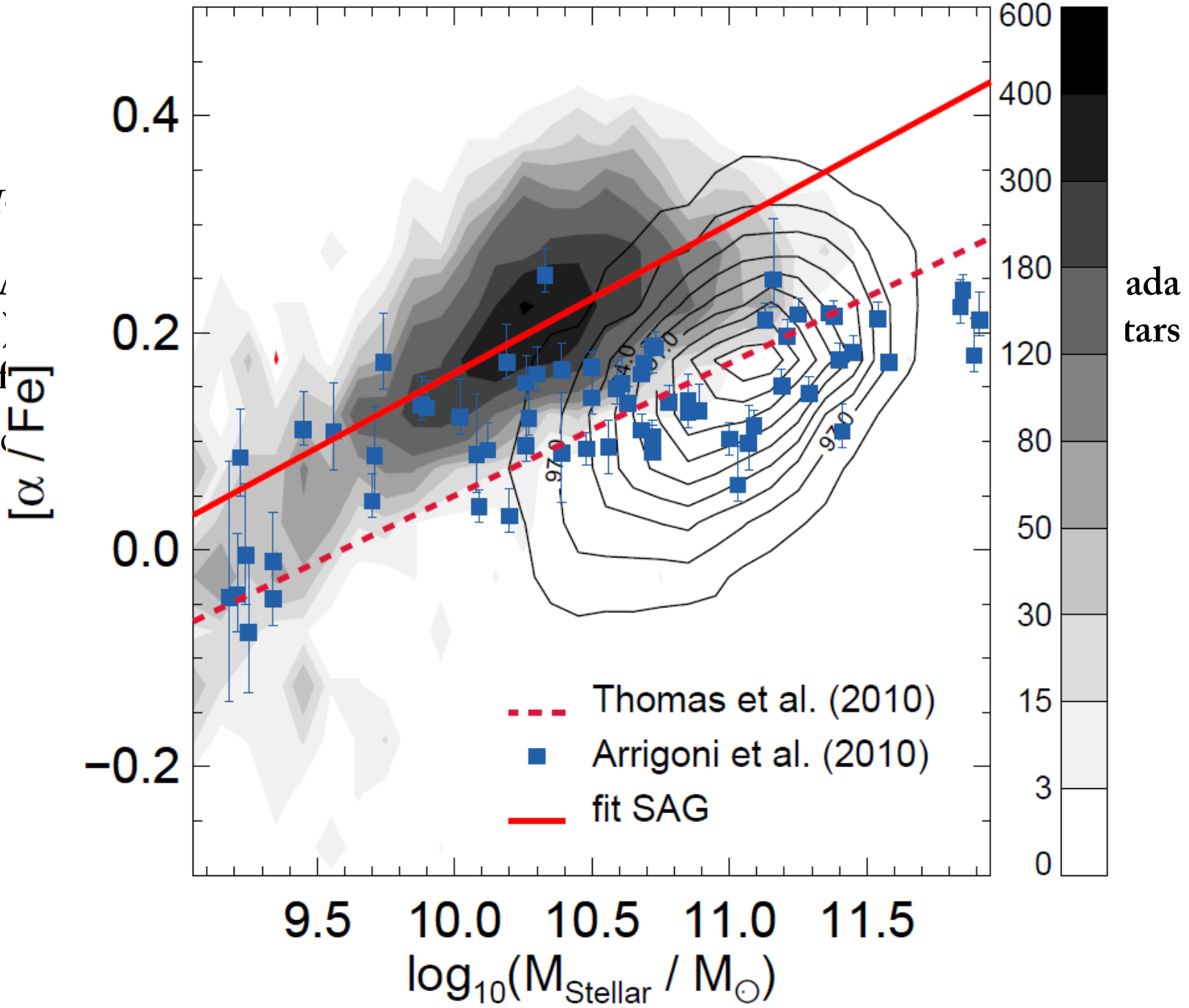

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1 – The IMF in the embedded clusters is the ``canonical``

$$\xi(m) = k \begin{cases} k' \left(\frac{m}{m_{\rm H}}\right)^{-\alpha_0} & , m_{\rm low} \leq m/M_\odot < m_{\rm H} \\ \left(\frac{m}{m_{\rm H}}\right)^{-\alpha_1} & , m_{\rm H} \leq m/M_\odot < m_0, \\ \left(\frac{m_0}{m_{\rm H}}\right)^{-\alpha_1} \left(\frac{m}{m_0}\right)^{-\alpha_2} & , m_0 \leq m/M_\odot < m_1, \\ \left(\frac{m_0}{m_{\rm H}}\right)^{-\alpha_1} \left(\frac{m_1}{m_0}\right)^{-\alpha_2} \left(\frac{m}{m_1}\right)^{-\alpha_3} & , m_1 \leq m/M_\odot \leq m_{\rm max}, \end{cases}$$

$$\begin{aligned} \alpha_0 &= +0.30 \quad , \quad m_{\rm low} = 0.01 \leqslant m/M_\odot < m_{\rm H} = 0.08, \\ \alpha_1 &= +1.30 \quad , \quad 0.08 \leqslant m/M_\odot < 0.50, \\ \alpha_2 &= +2.35 \quad , \quad 0.50 \leqslant m/M_\odot \leqslant 1.00, \\ \alpha_3 &= +2.35 \quad , \quad 1.00 \leqslant m/M_\odot \leqslant m_{\rm max}. \end{aligned}$$

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2 – The embedded clusters have their own mass distribution function

$$\xi_{\rm ecl}(M_{\rm ecl})\, dM_{\rm ecl} \propto M_{\rm ecl}^{-\beta}\, dM_{\rm ecl},$$

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3 – The mass of the most massive star in a cluster is a function of the cluster mass.

$$m_{\rm max} = m_{\rm max}(M_{\rm ecl})$$

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4 – There exists a relation between the star formation in galaxies and the mass of the most massive young embedded cluster.

$$M_{\rm ecl}^{\rm max}(SFR) = 8{,}5 \times 10^4\, SFR^{0,75}\, {\rm M}_\odot .$$

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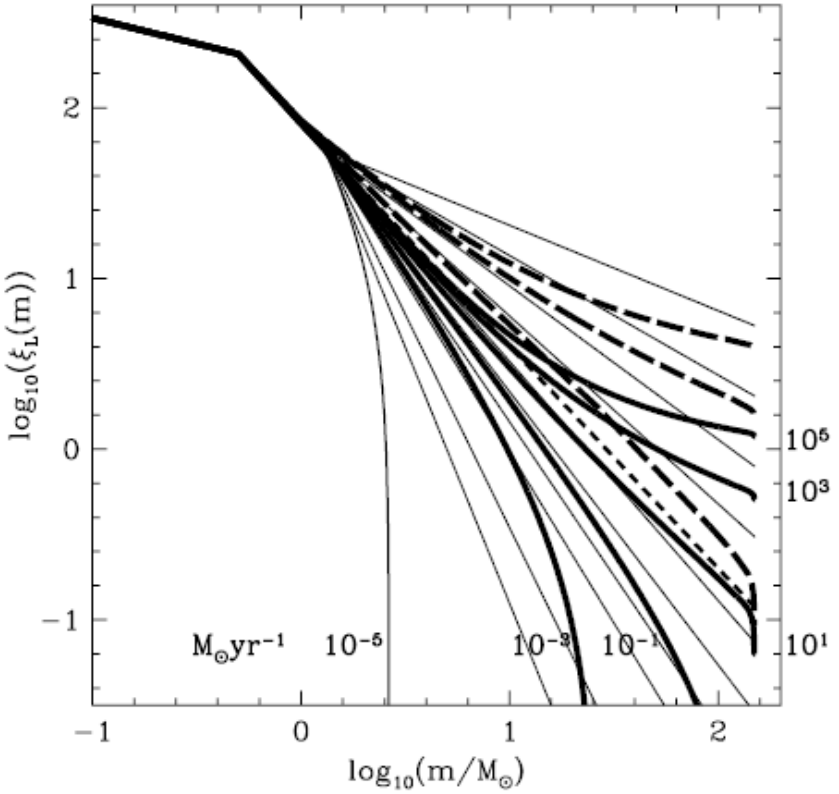
5 – When the level of star formation is high, the canonical IMF in each embedded cluster most massive than 10^6 solar mases changes the slope above 1.3 solar mases.

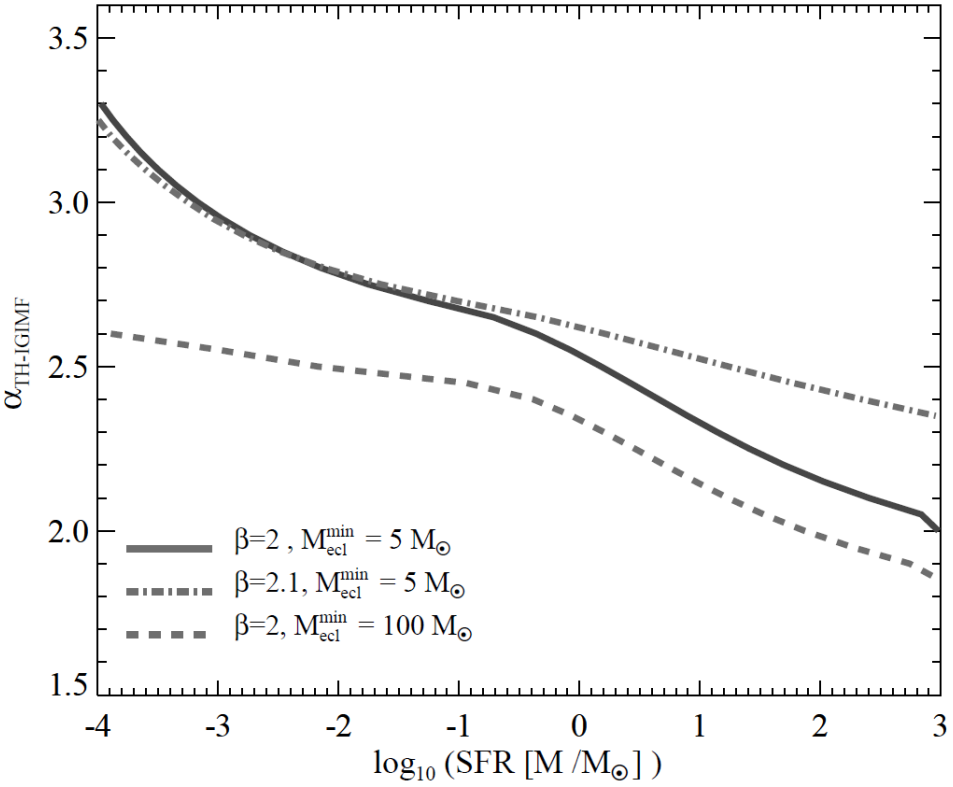
$$\alpha_3(M_{\rm ecl}) = -1{,}67 \times \log_{10}\left(\frac{M_{\rm ecl}}{10^6\,{\rm M}_\odot}\right) + 1{,}05.$$

An alternative theory of variable IMF

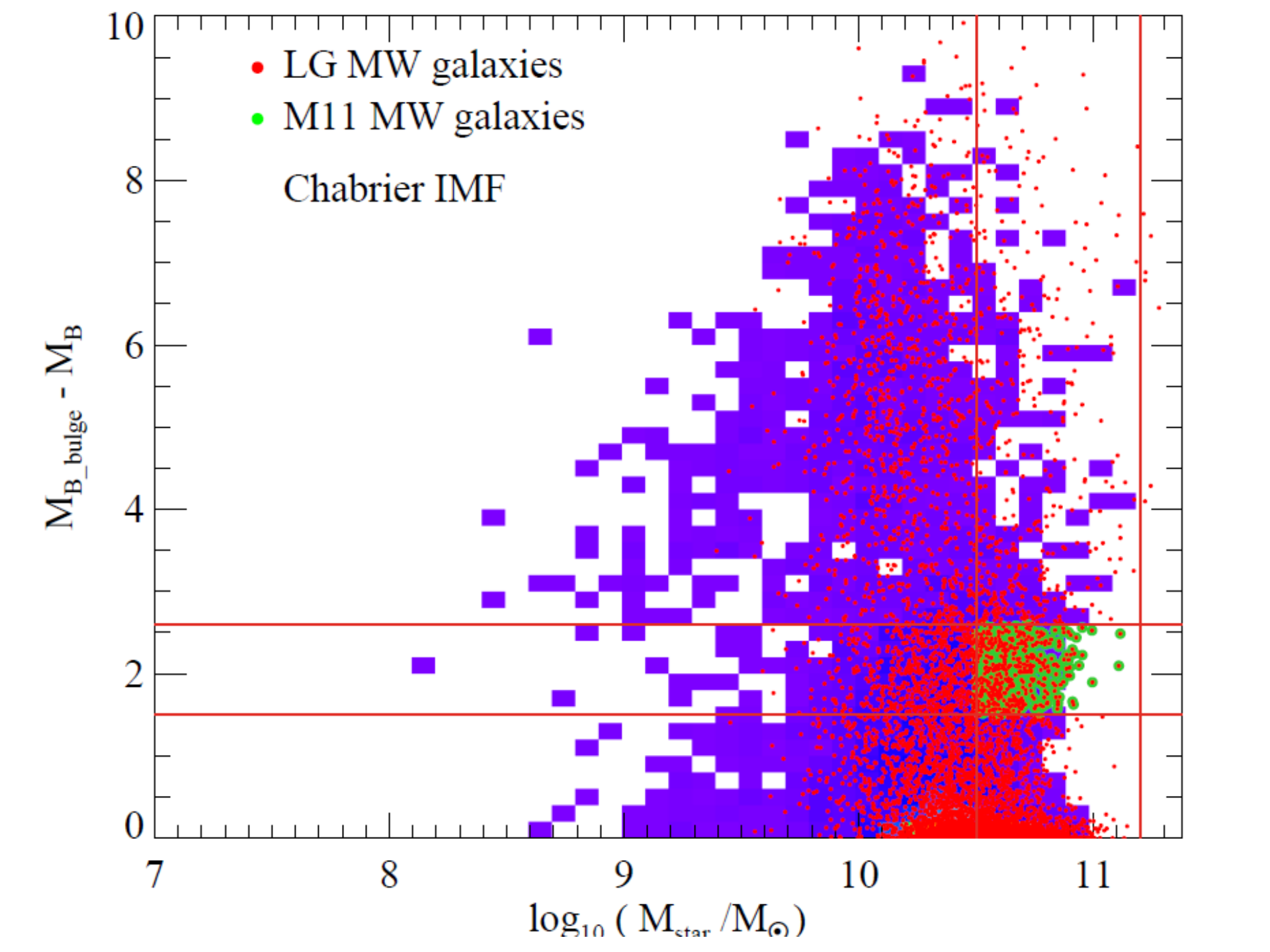
$$\xi_{\rm IGIMF}(m,t) = \int_{M_{\rm ecl}^{\rm min}}^{M_{\rm ecl}^{\rm max(SFR(t))}} \xi\left(m \leqslant m_{\rm max(M_{ecl})}\right) \xi_{\rm ecl}(M_{\rm ecl})\, dM_{\rm ecl},$$



Weidner+(2013)



This work


LG MW galaxies
M11 MW galaxies
Chabrier IMF
$M_{B\_bulge} - M_B$
$\log_{10}(M_{star}/M_\odot)$
10
8
6
4
2
0
7
8
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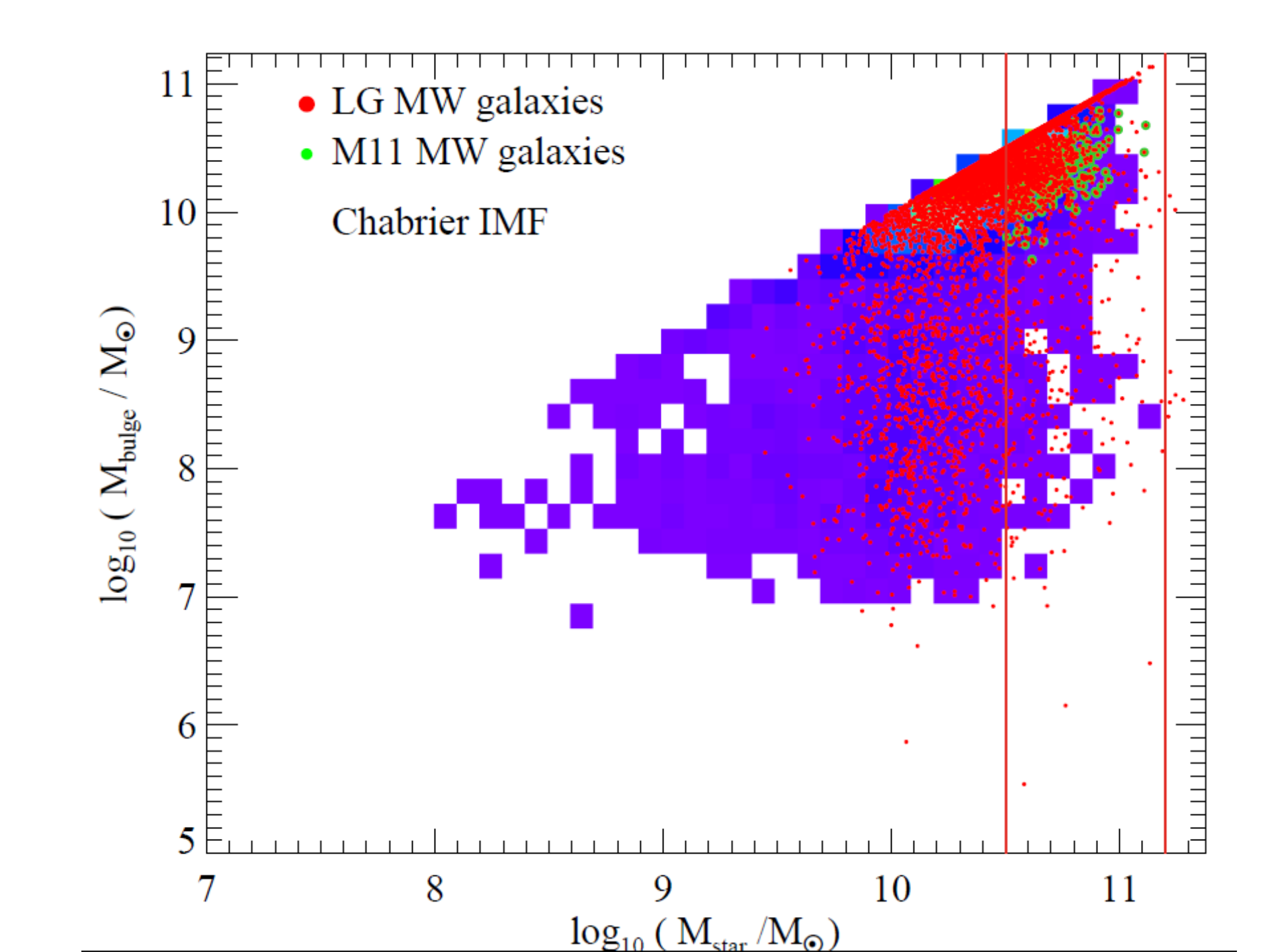
10
11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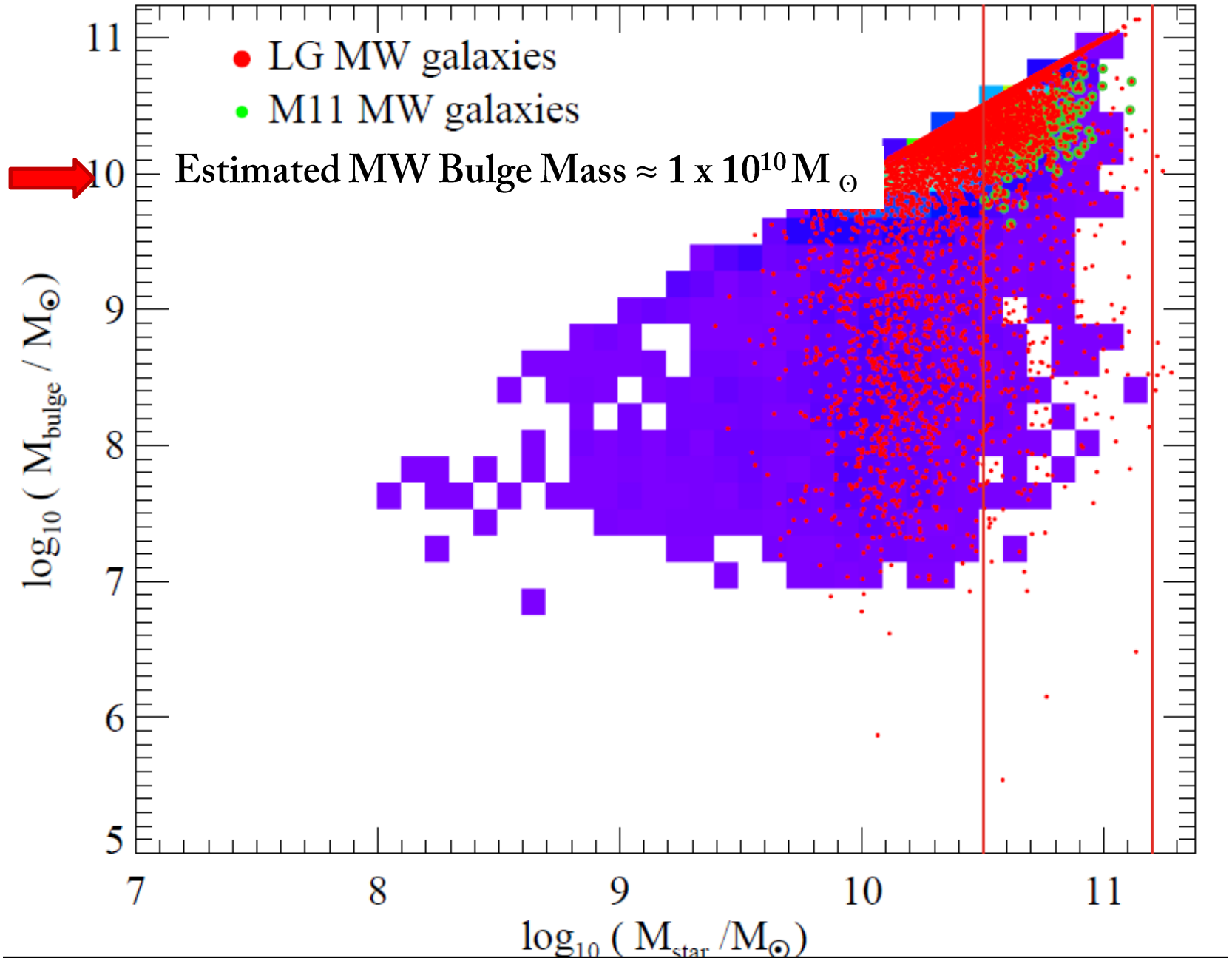
LG MW galaxies
M11 MW galaxies
Estimated MW Bulge Mass ≈ 1 x 10^10 M ⊙
log10 (Mbulge / M⊙)
log10 (Mstar /M⊙)
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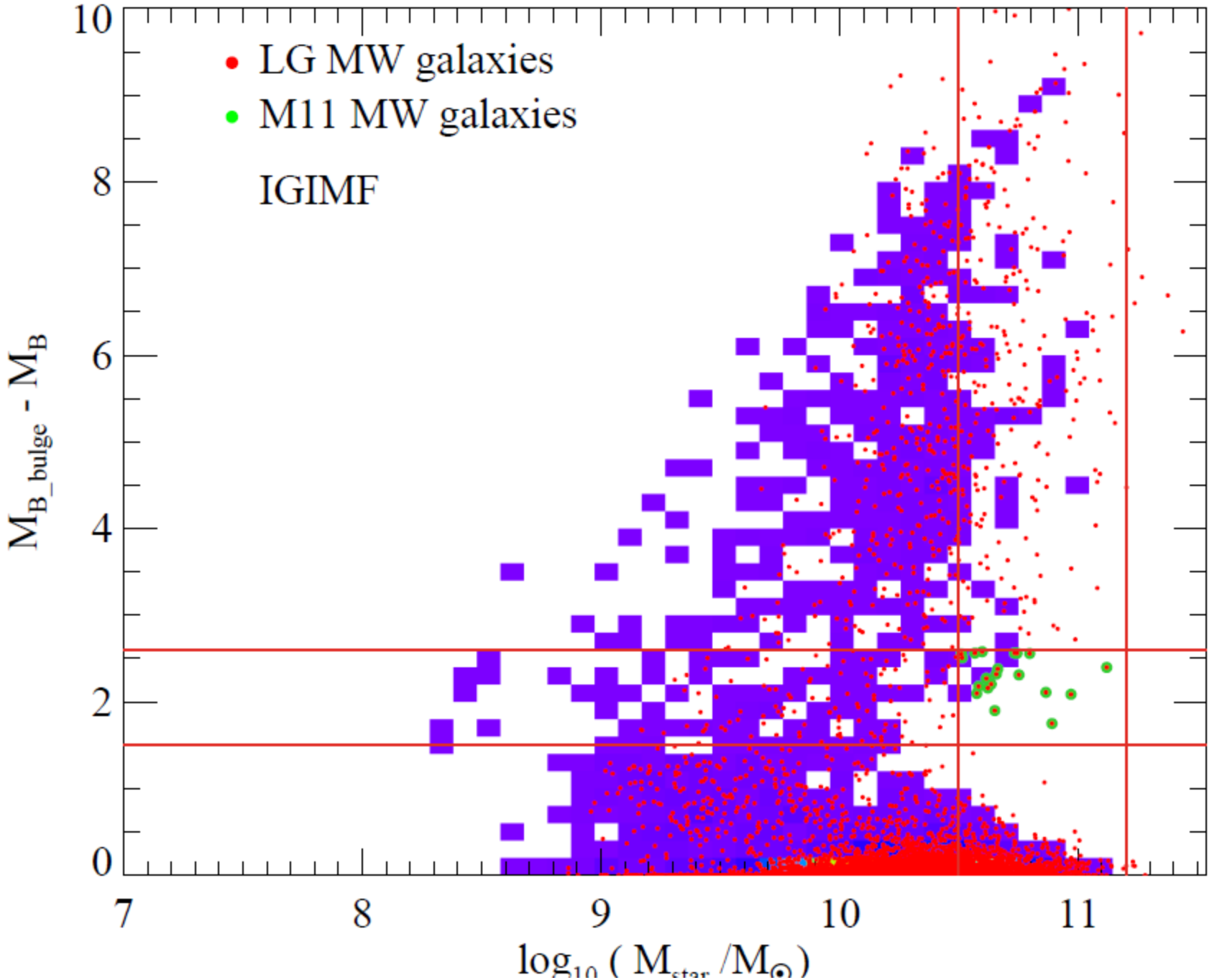
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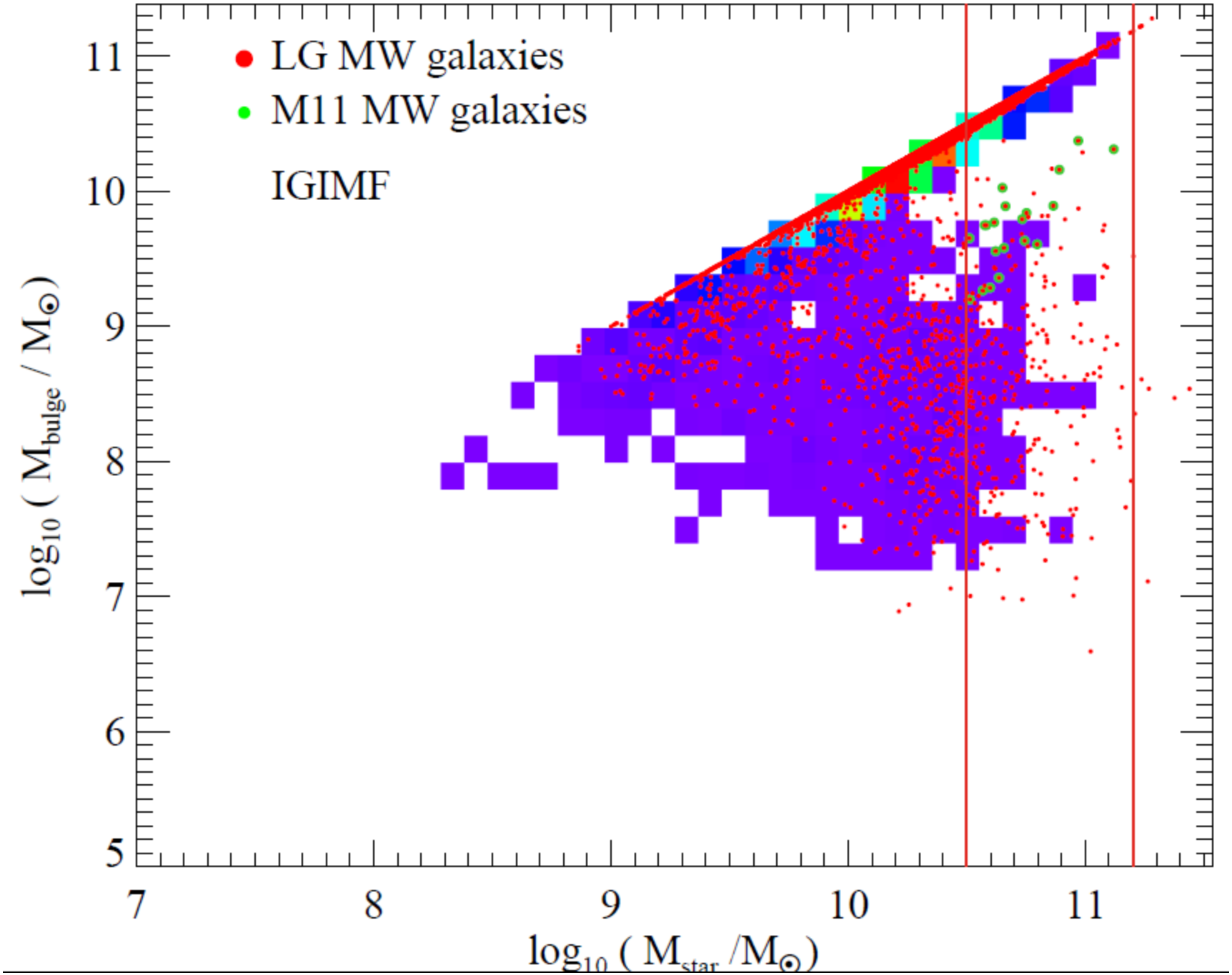
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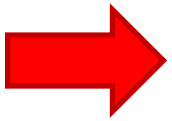
Stellar Subpopulations (SPs) in a semianalitical model

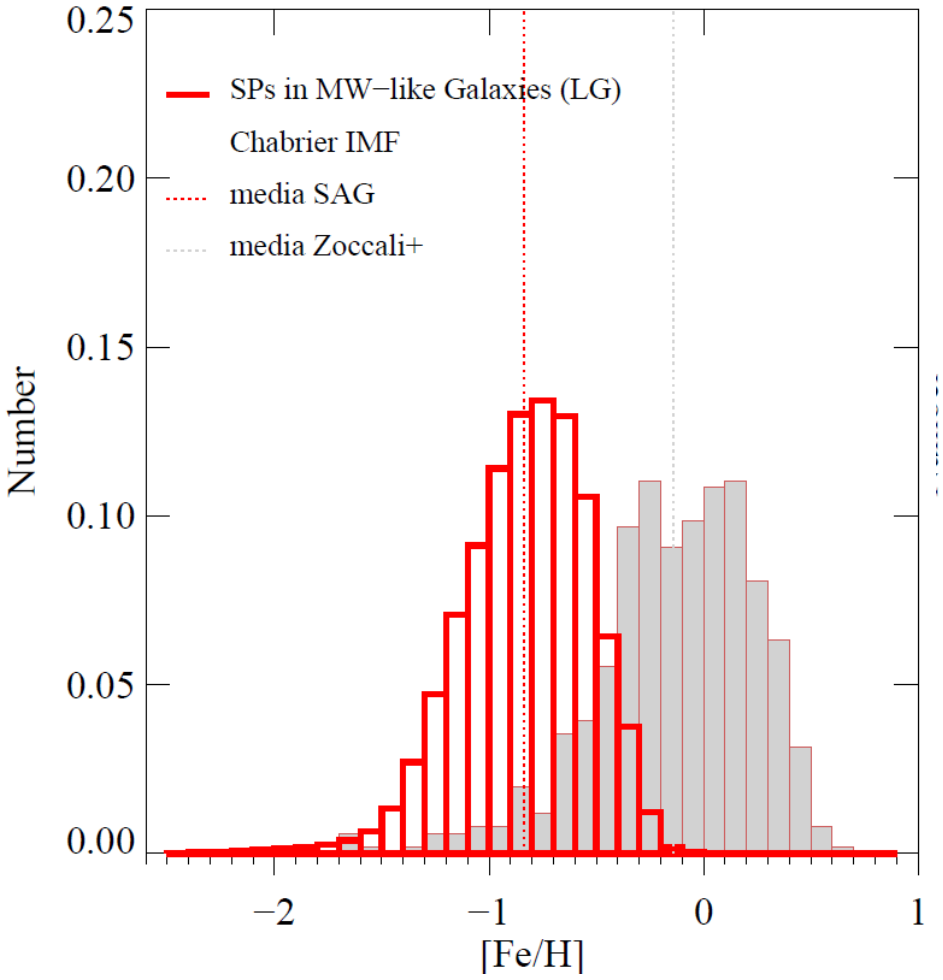
Basic assumption: Each event of star formation triggered during the evolution of the galaxy forms a stellar population distinguishable from the others by its chemical properties. («**Controlled chemical tagging**»)

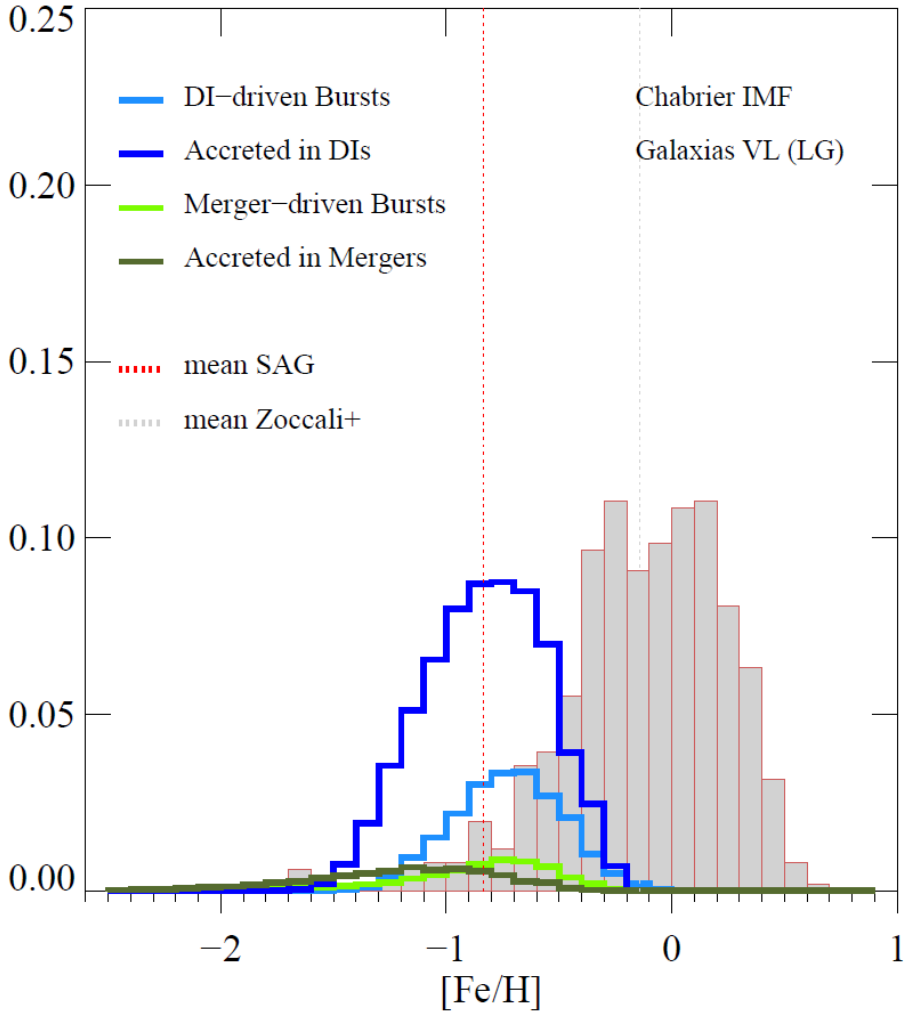
The mass and chemical properties of each star formation event are stored. Each process of star formation is considered separately. The information of the stellar subpopulations of the MW-type galaxies is stacked, in order to generate a statistically meaningfull number of SPs .

Bulge 

- SPs accreted in mergers.
- SPs accreted in DIs.
- SPs formed in bursts due to mergers.
- SPs formed in bursts due to DIs.

Metallicity Distributions





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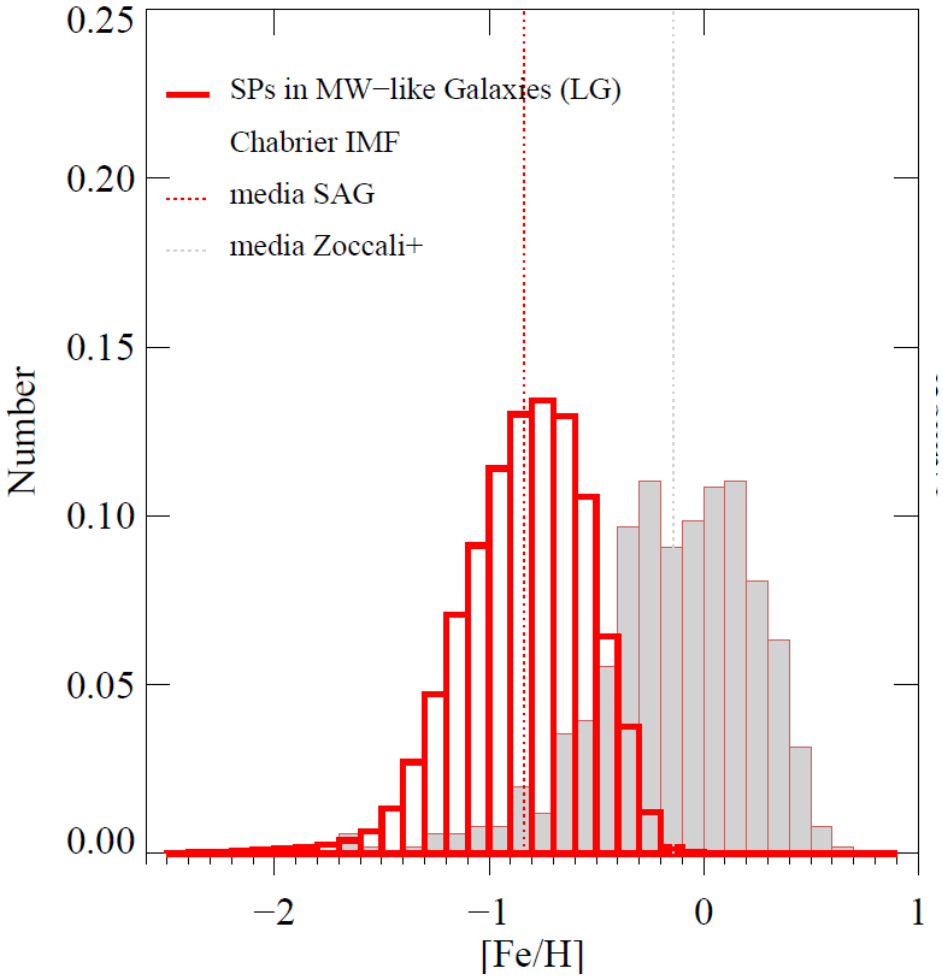
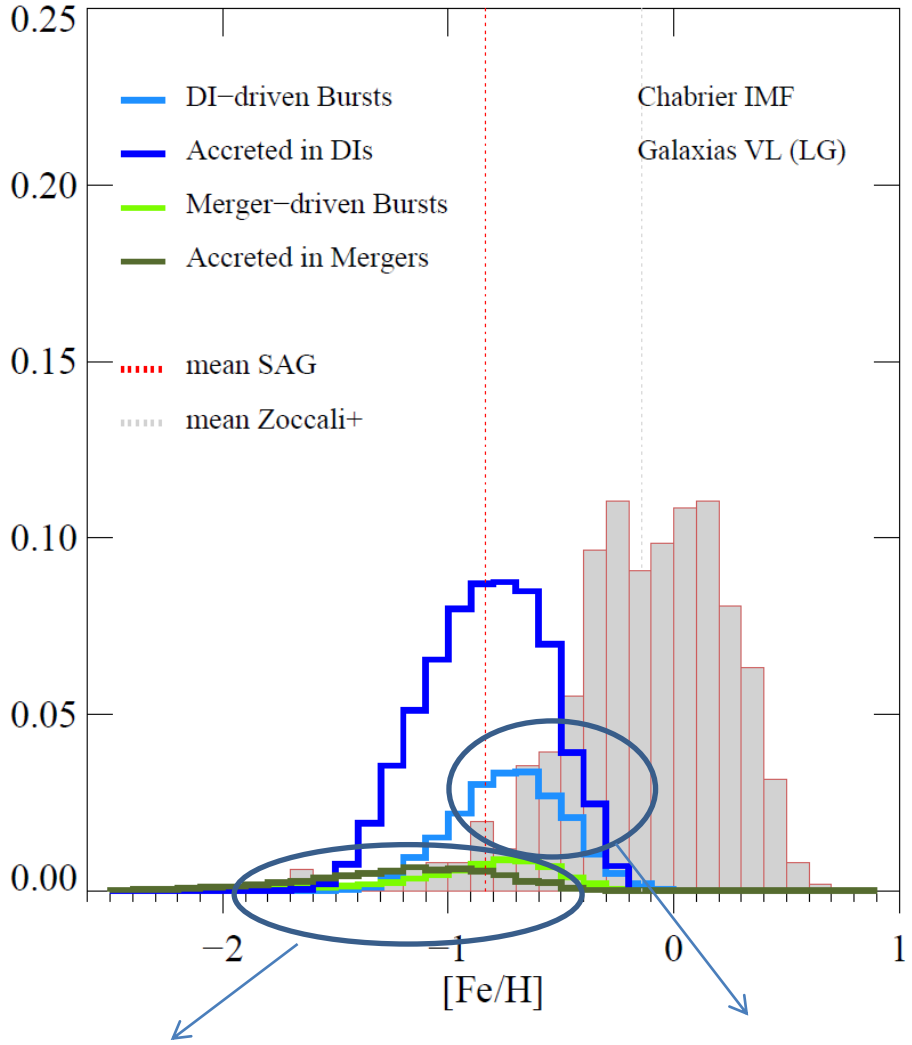
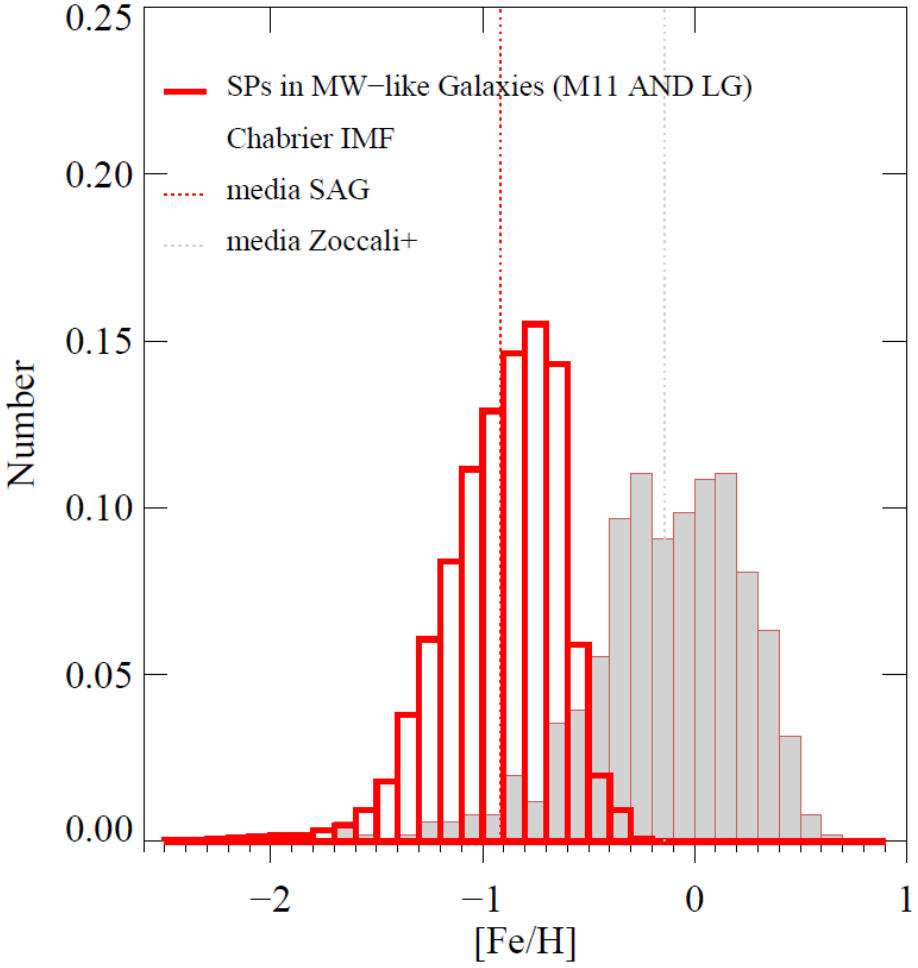


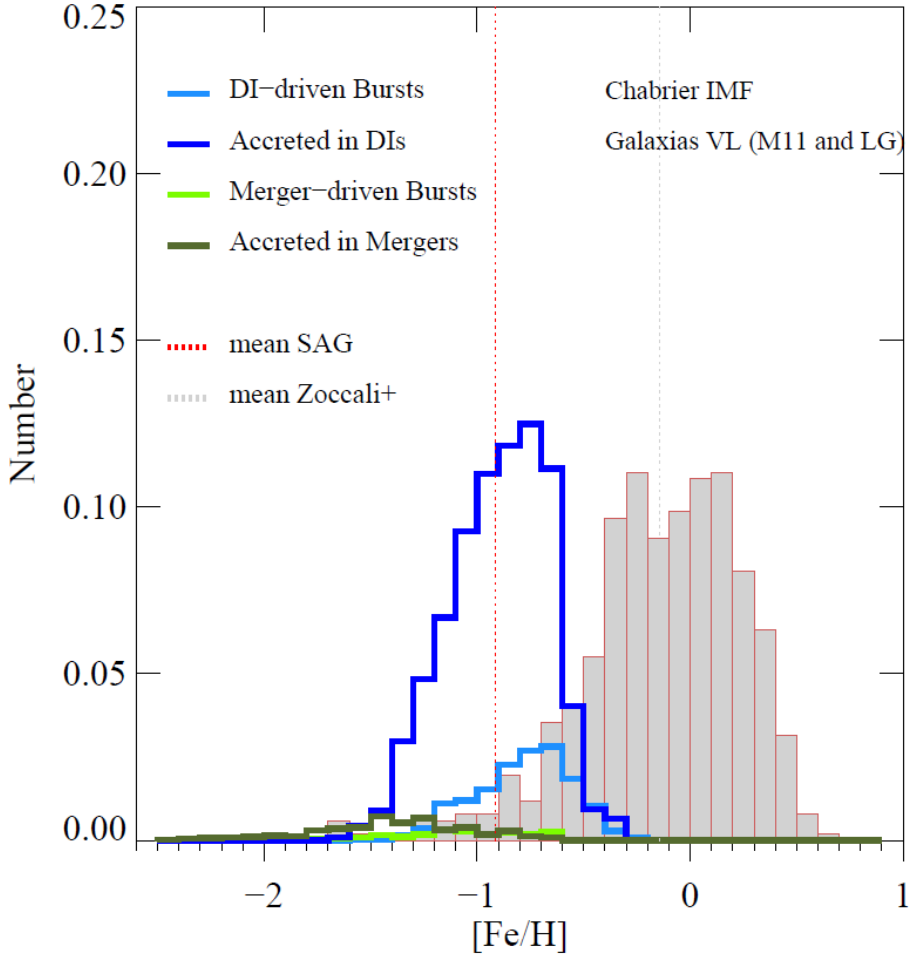


Low metallicity tail: Stars acreted in mergers!

SPs with higher [Fe/H] are originated in bursts due to DI's

Metallicity Distributions





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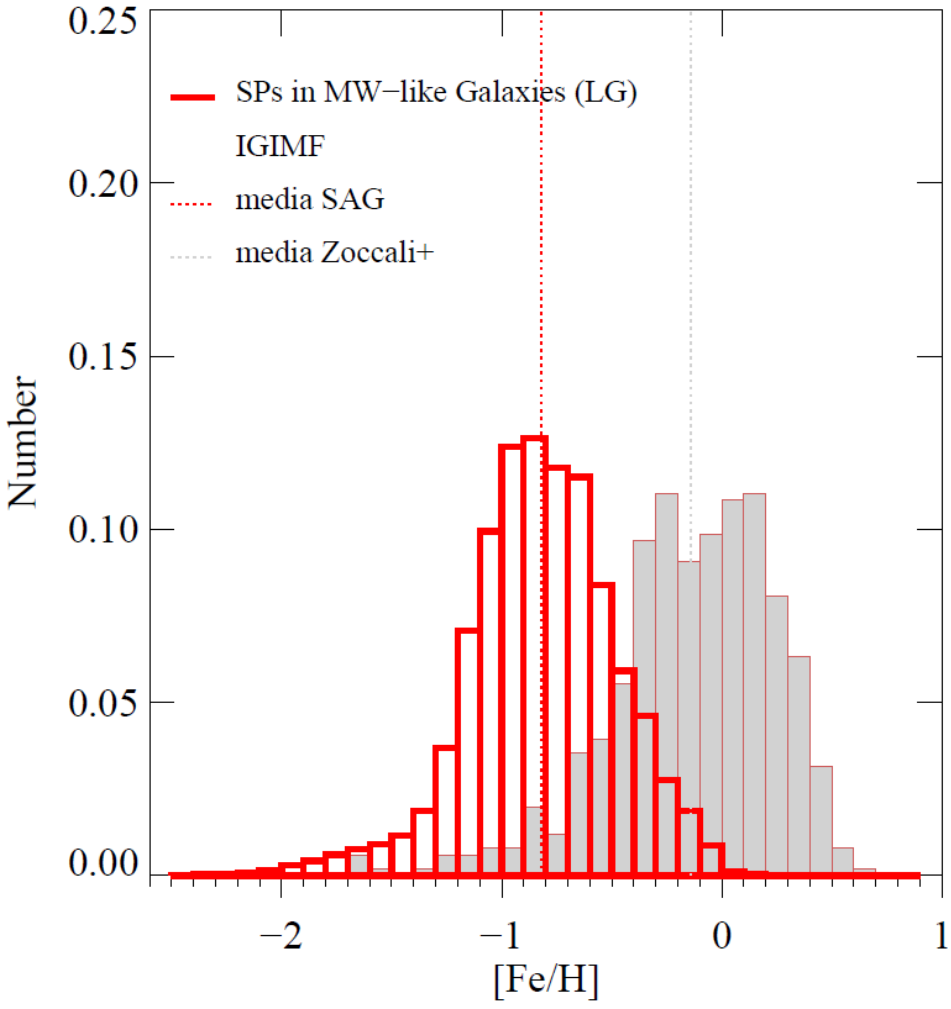
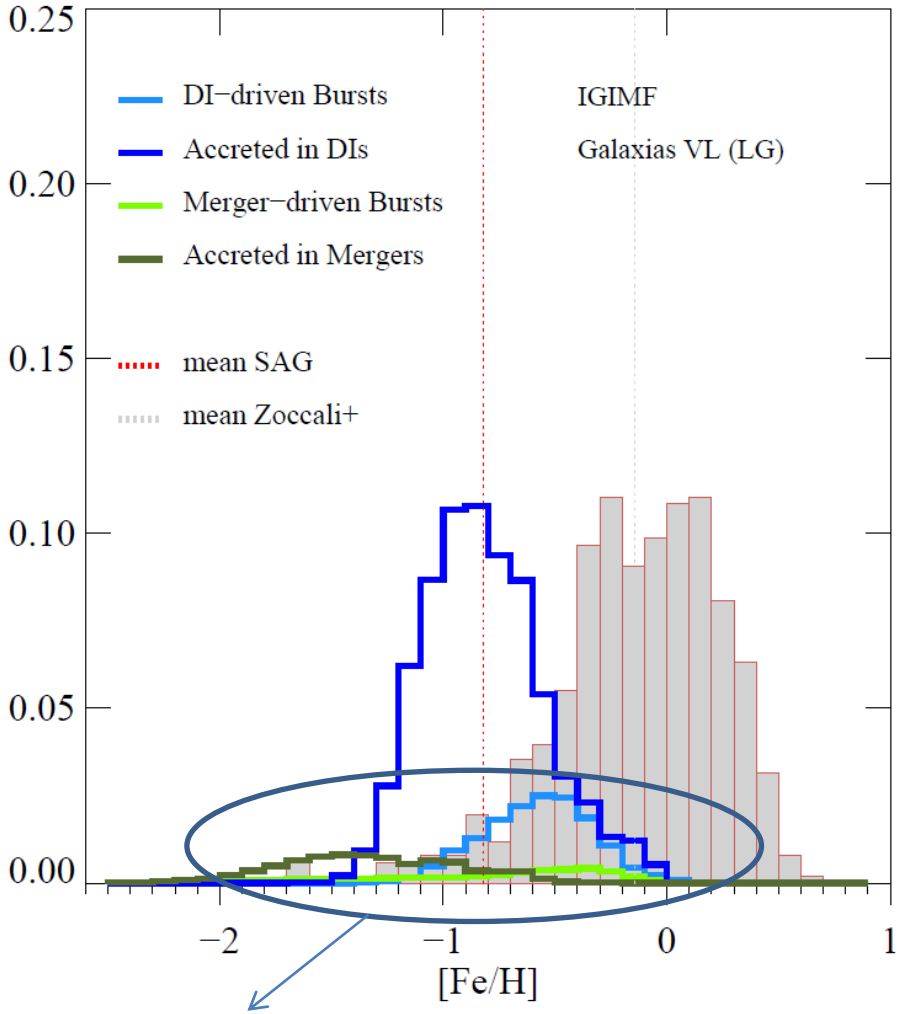


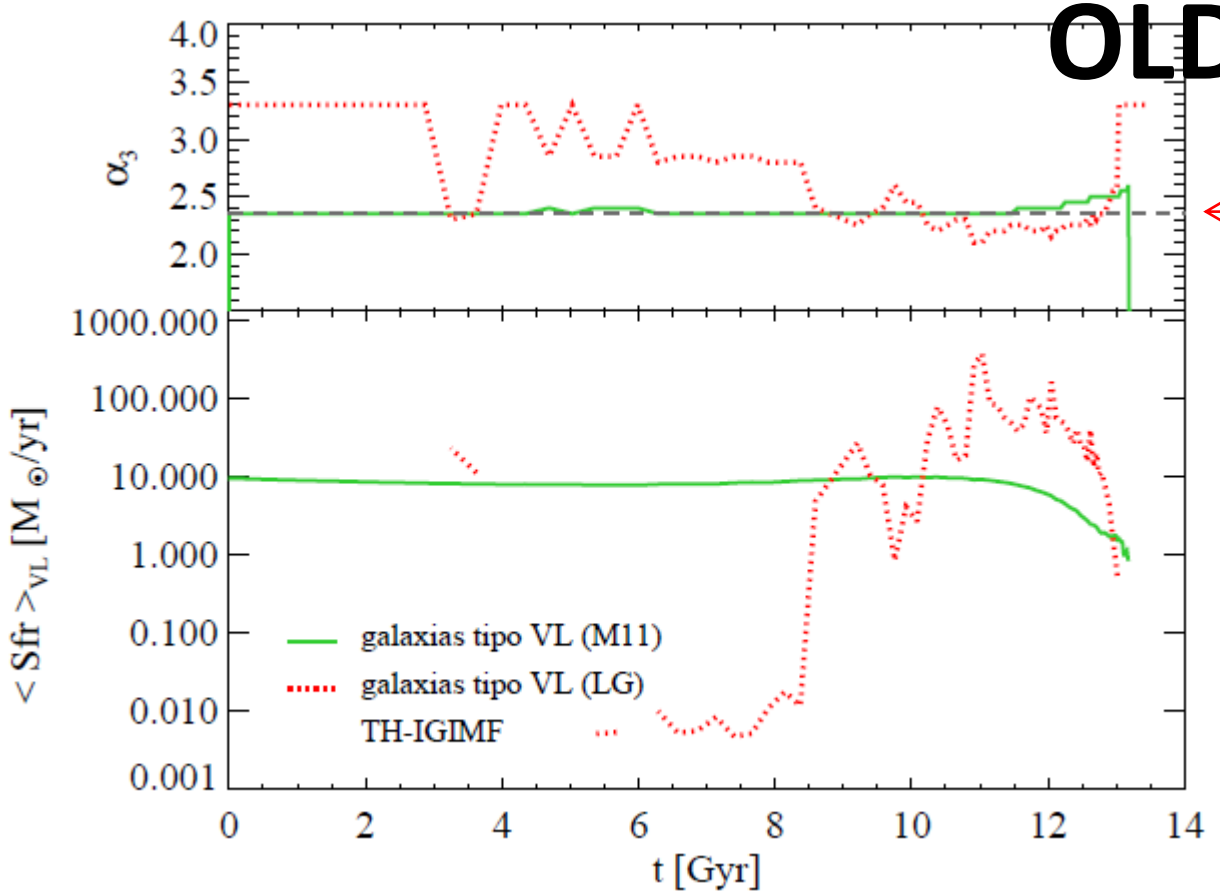


More clear features with IGIMF

Average Star Formation Histories of MW-like Galaxies

¿What is the origin of the differences between the MDs of SPs of MW-like galaxies selected by different methods?

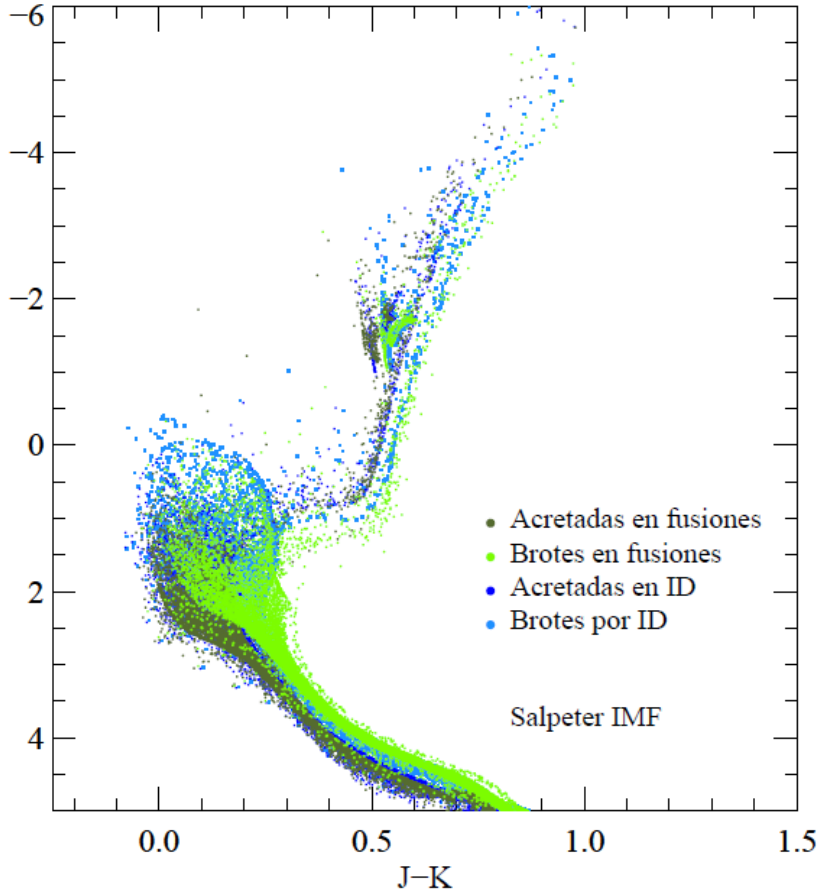
OLD PLOT



Salpeter Slope

Photometric metallicity distributions

- Existence of a metallicity gradient in latitude in the bulge. Stars with lower metallicities towards the galactic plane.
- Larger density of stars near the plane.
- Selected Fields for spectroscopic observations are homogenously distributed.



Posible BIAS towards lower metallicities in Spectroscopic distributions.

Z (z)

SFR (z)

IAC- STAR

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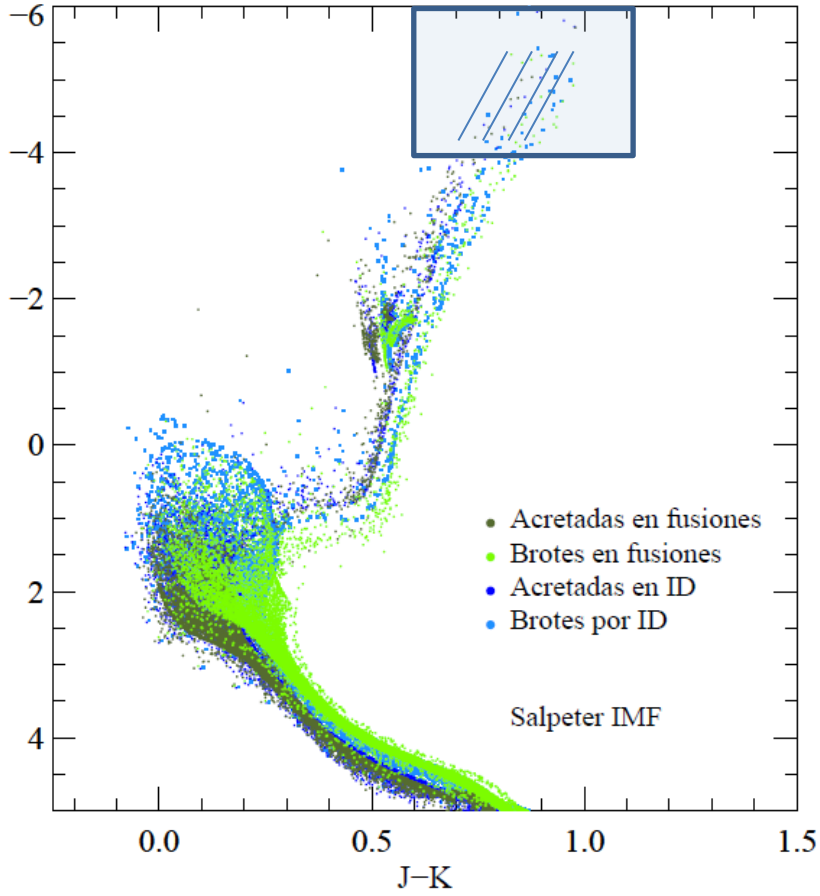

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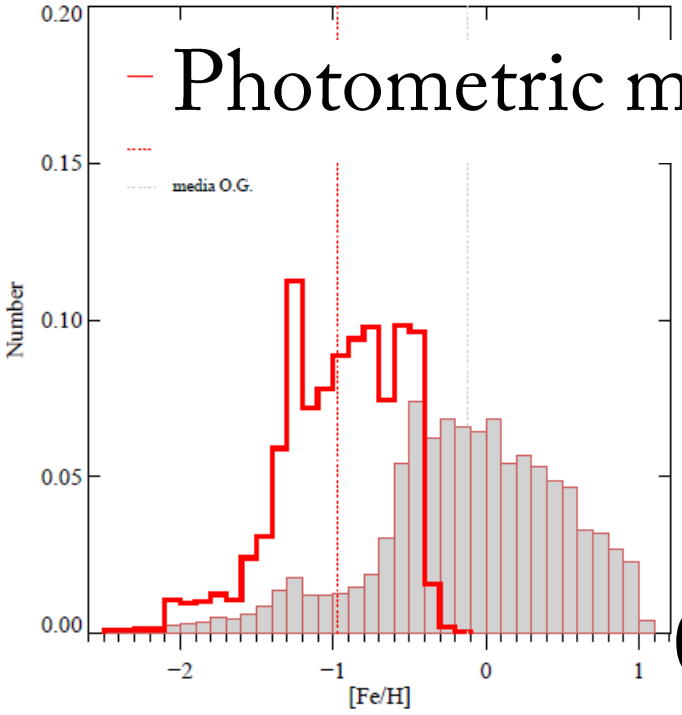

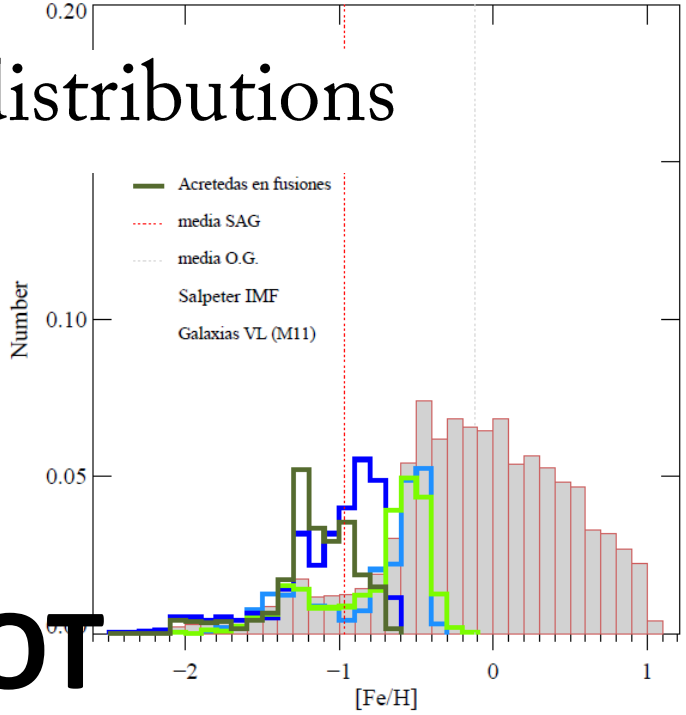

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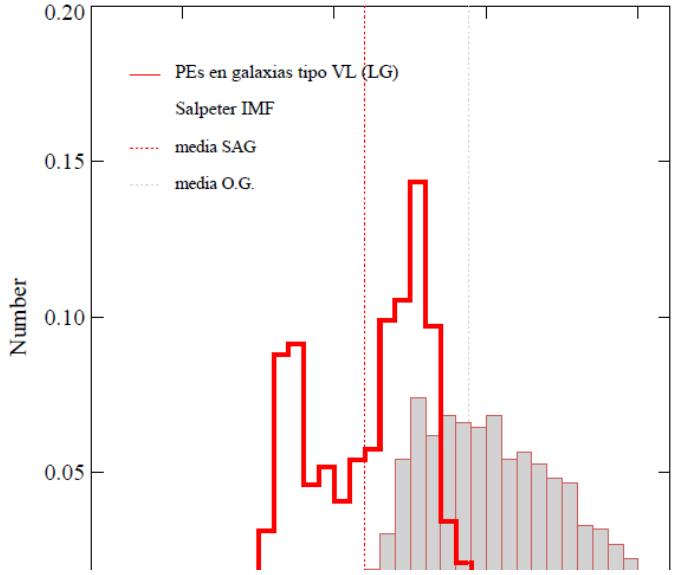
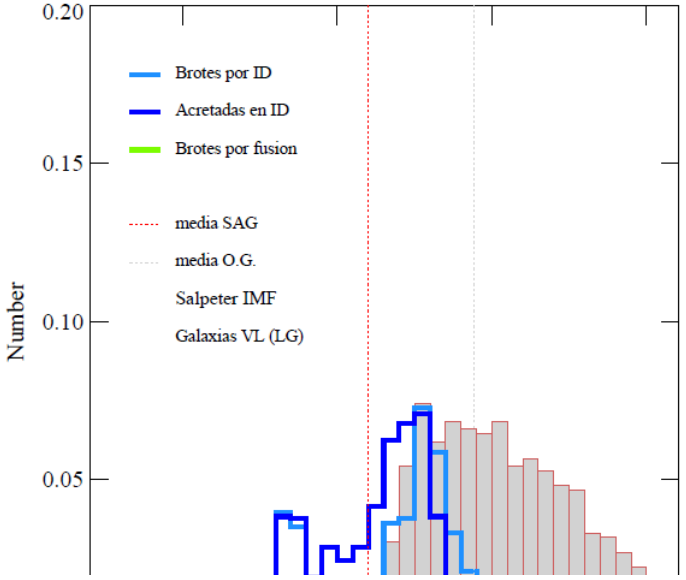
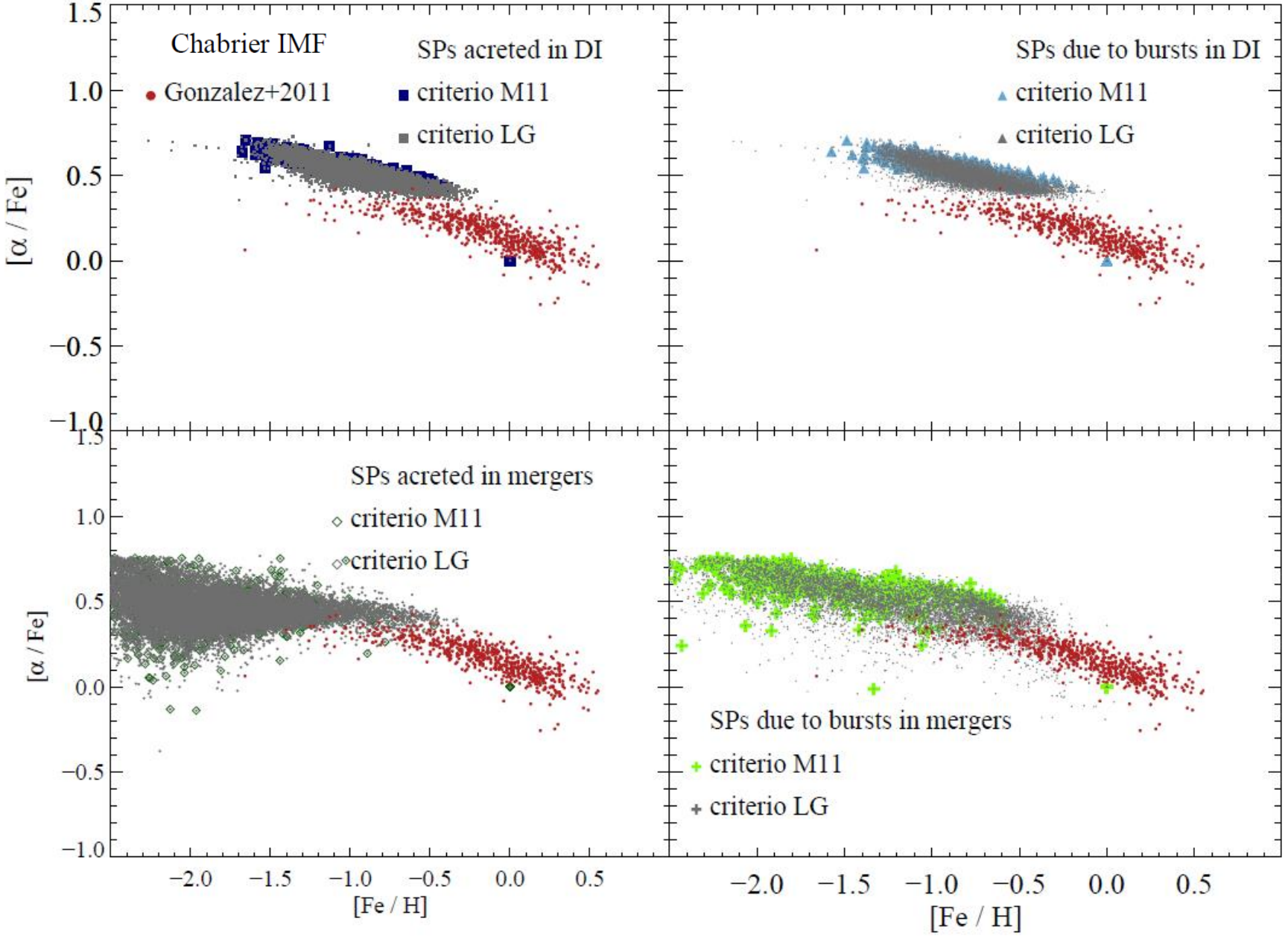




There is no difference between MDs with different selection criteria of MW-like galaxies.
Limitations of the observational method or assumptions in the IAC-STAR.

Abundance ratios [α/Fe] of SPs of bulges



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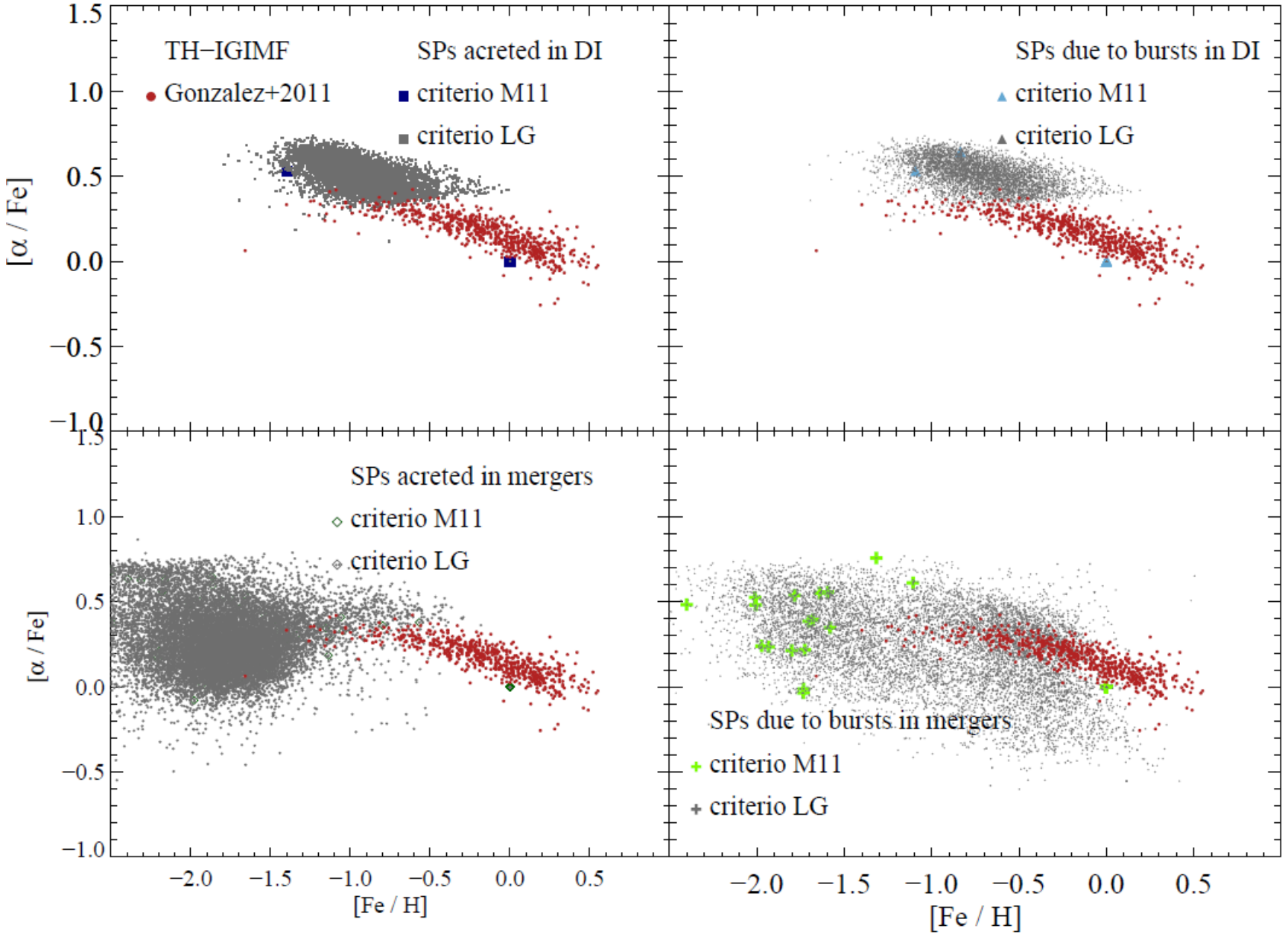

Conclusions

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We study the bulges of galaxies with equivalent caracteristics to the MW, which were selected by two differente criteria sets. One of them considers the observed photometric properties of the Bulge of the MW and the other considers the membership of the galaxies to systems that are analogs to the Local Group of Galaxies (Gonzalez+14). We evaluate the impact of a Chabrier IMF and a TH-IGIMF caracterized by $M_{\rm minecl}$ = $5M_{\odot}$ y b = 2 in the chemical properties of the stellar subpopulations.

We draw the following conclusions:

- We can decode the metallicity distributions of a galaxy Component. SPs of bulges in MW-tyoe galaxies with higher metallicity are originated in bursts due to events of Disc Instabilities.
- The Alpha element ratios to [Fe/H] show the same behavior than the observations.
- Looking forward to analize the SPs of the Stellar Halo of MW like galaxies, and its sattelites.