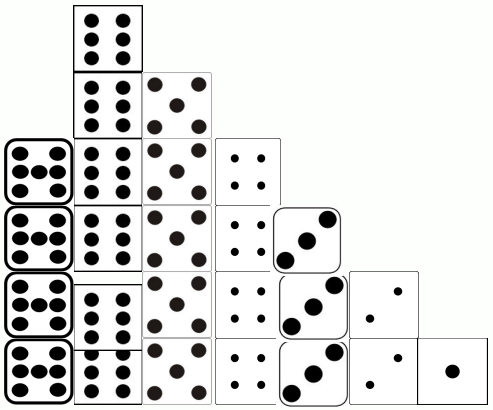
Variations of the stellar initial mass function in and between galaxies

Sami Dib

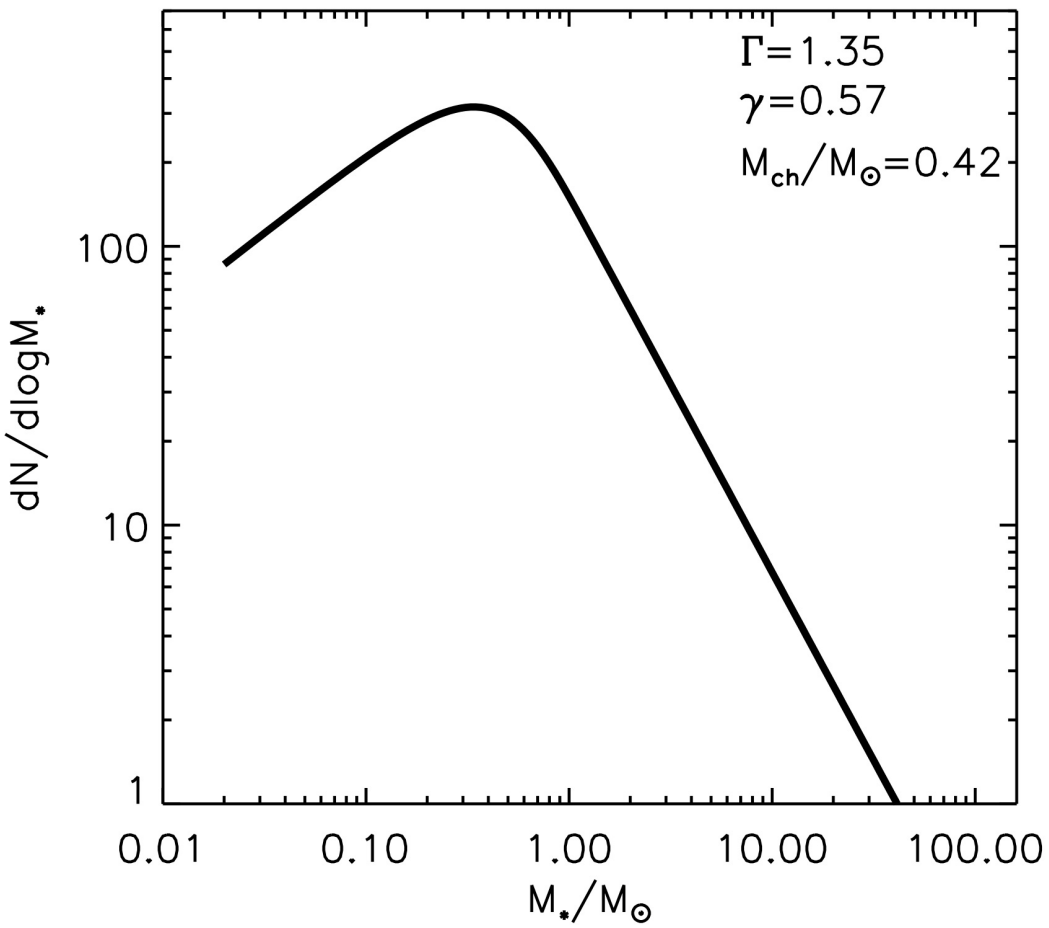
MPIA, Heidelberg



IMF clusters ≠ IGIMF (galactic) ≠ PDMF (galactic)

PDMF-The Galactic field

The local PDMF of the MW



$$\xi(\log M) = kM^{-\Gamma}\left\{1-\exp\left[-\left(\frac{M}{M_{ch}}\right)^{\gamma+\Gamma}\right]\right\}$$

Parravano+ (2011)

A time averaged Galactic IMF

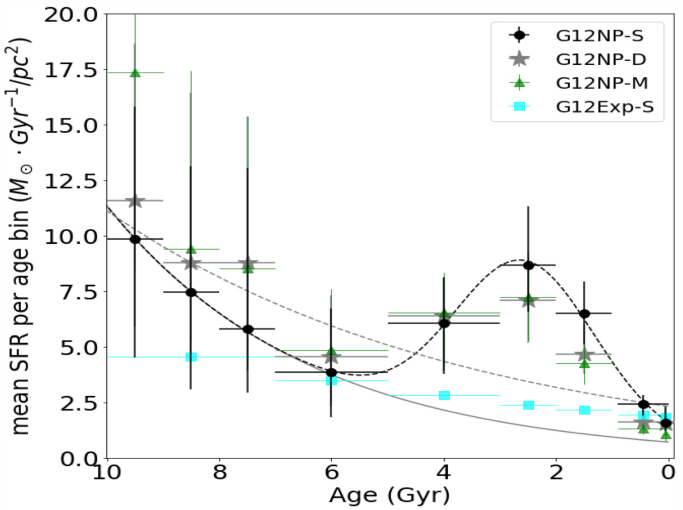
SFR → decaying exponential
Rybizki & Just (2015)
Mor et al. (2017, 2018)
Sollima et al. (2019)

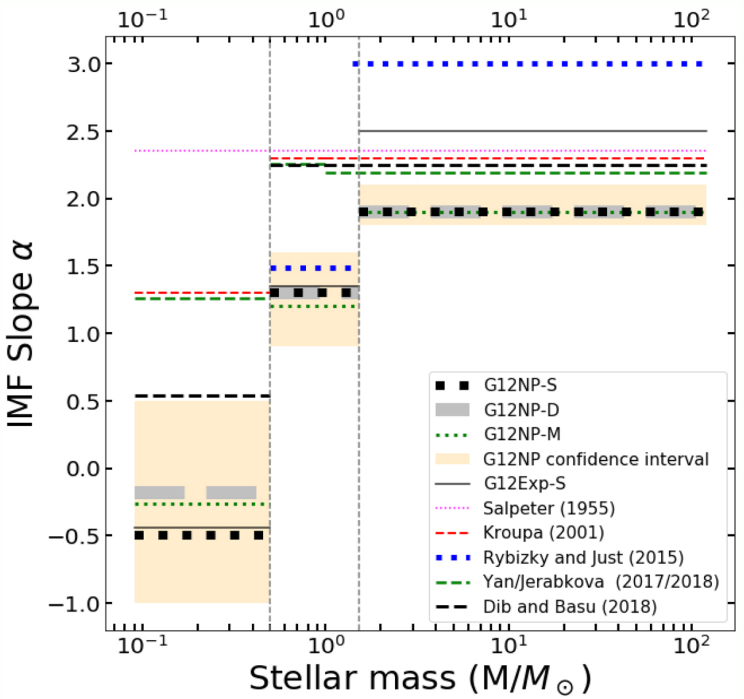
Mor et al. (2019): inferred both the shape of the time-averaged IMF, and of the SFH

BGM models

GAIA (structure & dynamics)
+
Apogee (chemical composition)

Dib & Basu (2018)

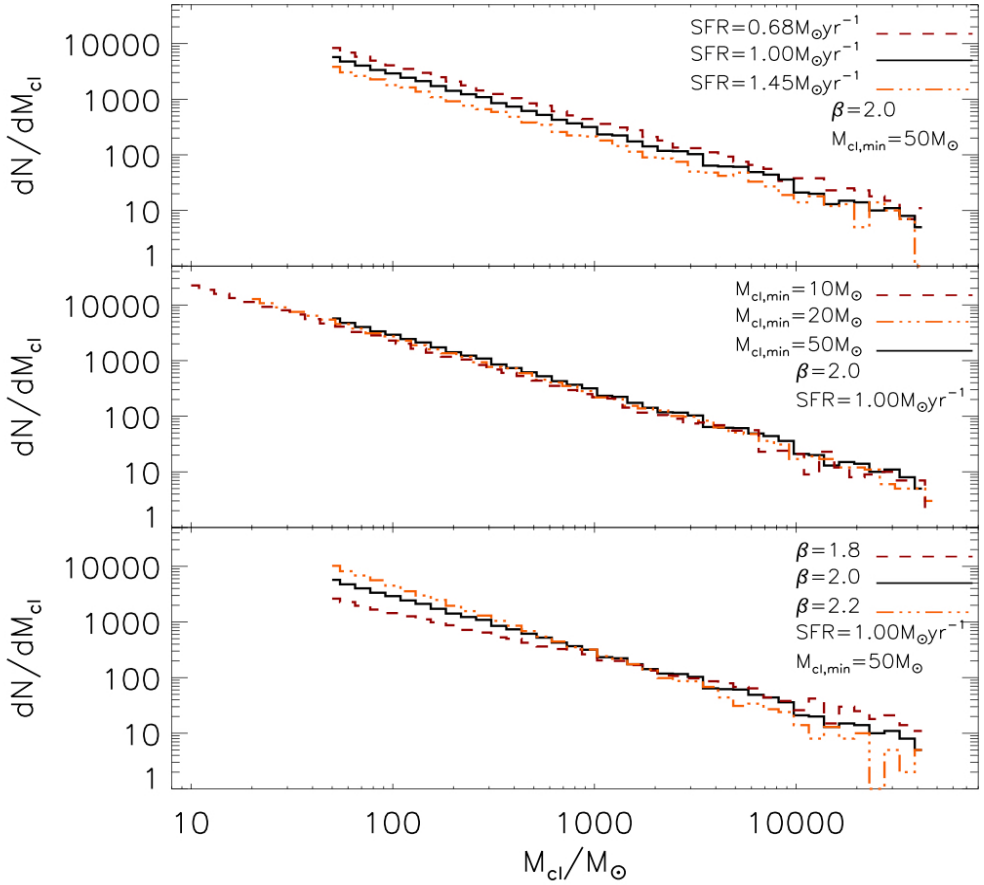




Clusters

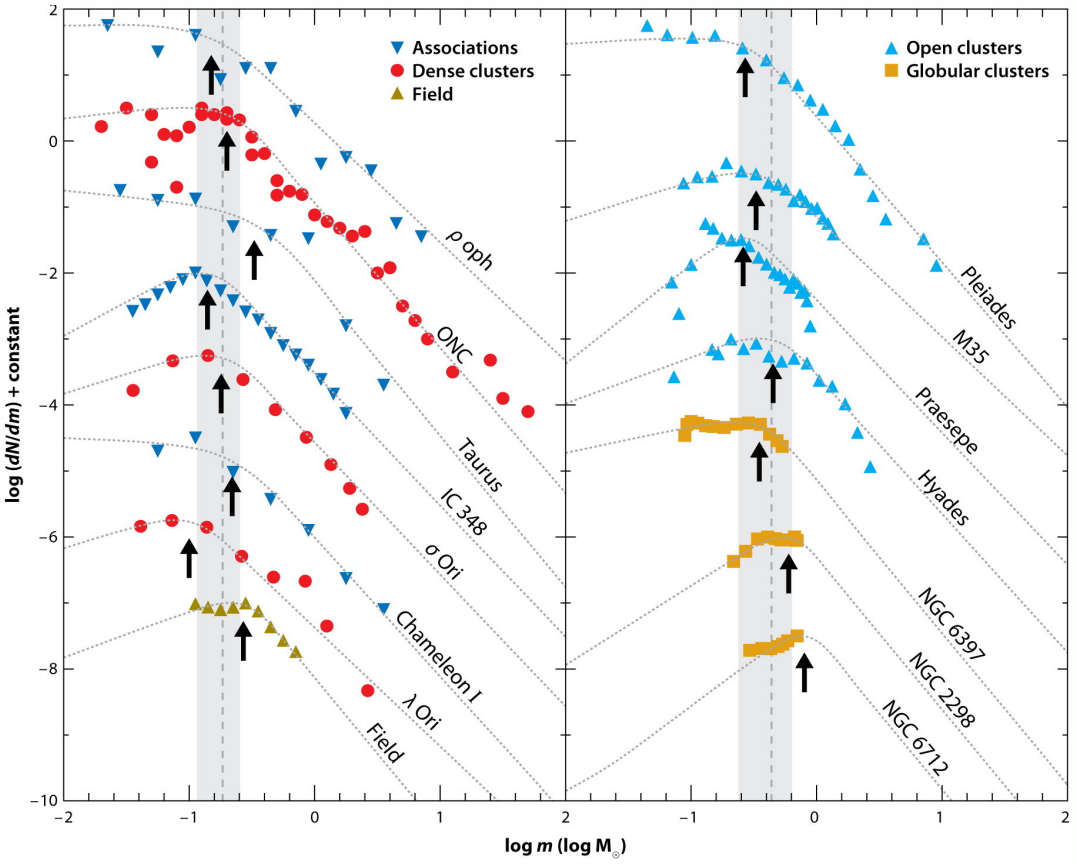
Statistics matters

The Milky Way forms ~10^4-10^5 clusters every 10-12 Myrs.



Dib et al. (2017)

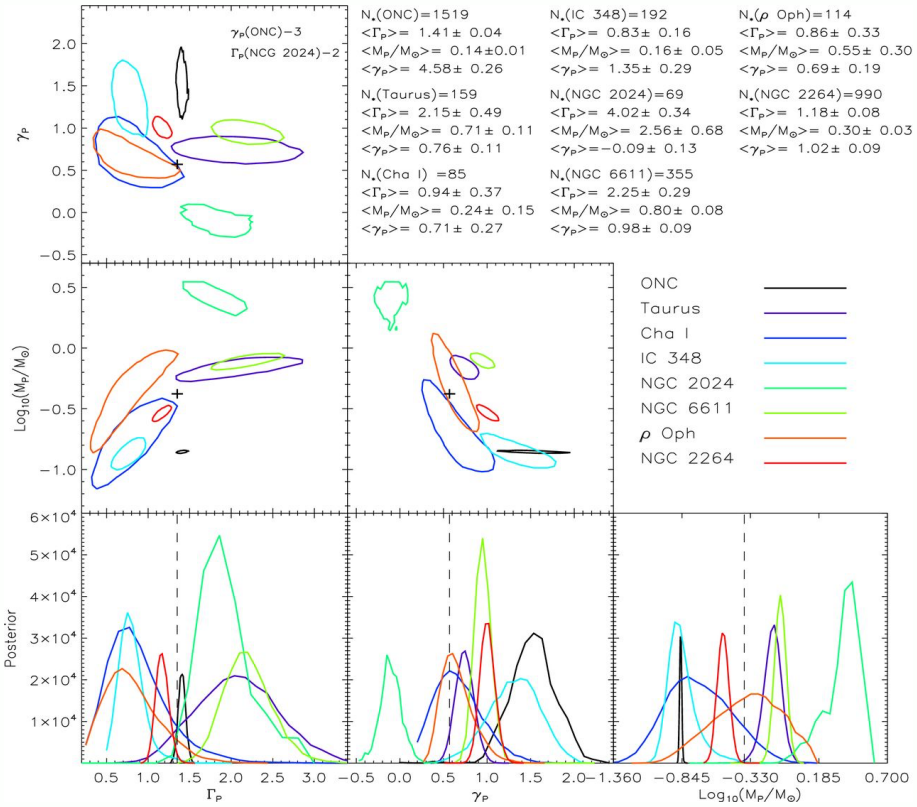
The IMF of stellar clusters



Bastian et al. (2010)

The IMF of stellar clusters

Evidence against universality



$$\xi(\log M) = kM^{-\Gamma}\left\{1-\exp\left[-\left(\frac{M}{M_{ch}}\right)^{\gamma+\Gamma}\right]\right\}$$

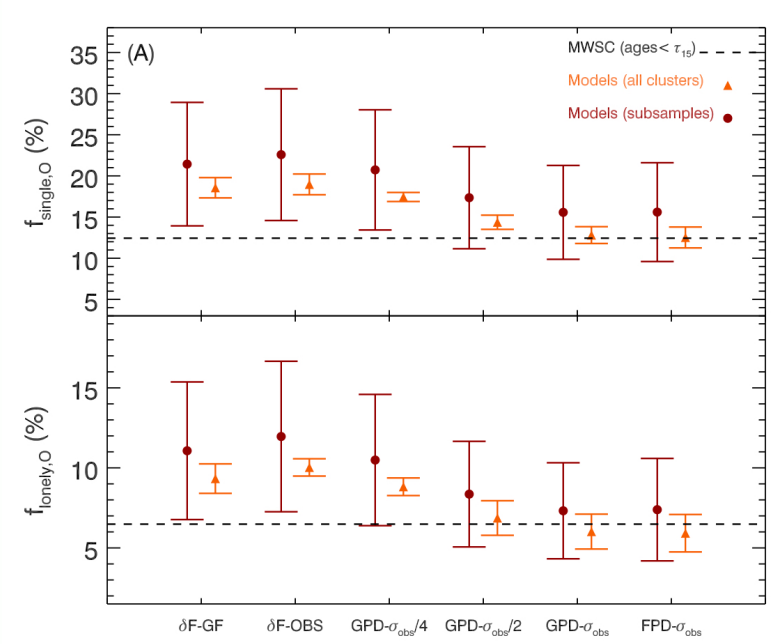
Dib 2014

The IMF of stellar clusters

Evidence against universality

Increasing width in parameter distributions

$$\sigma_{IMF} = \left(\sigma_{\Gamma_P} = 0.6, \sigma_{\gamma_P} = 0.25, \sigma_{M_P} = 0.27\right)$$



Dib+ (2017)

Libraries of synthetic clusters

- Random sample cluster masses from an ICLMF
- Radom sample an age for each cluster (from the age distrib. of observed clusters)
- Random sample stellar masses in each cluster (system stellar masses)
- assign a binarity probability for each cluster
- assign a mass ratio for each binary
- Correct for stellar evolution (i.e., remove evolved O stars at the assigned age of the cluster)
- Correct for ejected O stars
- Correct the total sample for completeness (based on the B stars content)

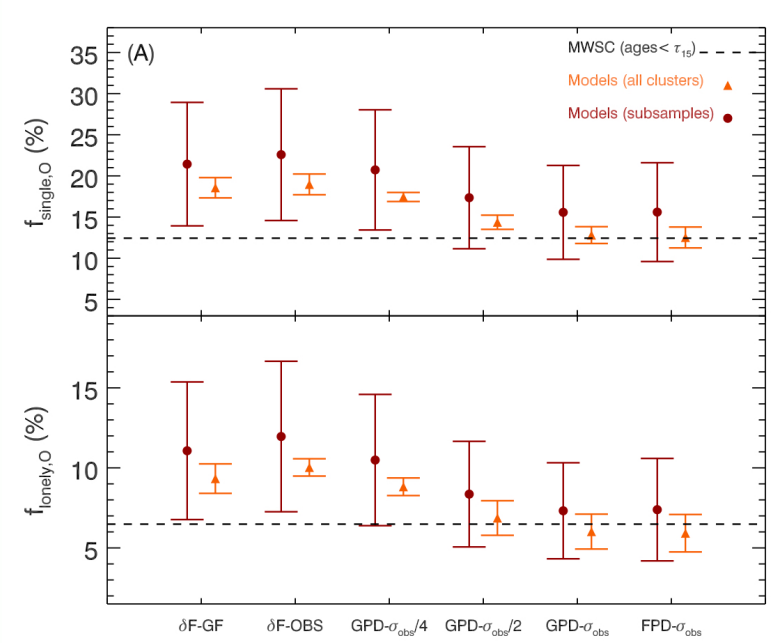
→ Measure the fractions of single and lonely O stars

The IMF of stellar clusters

Evidence against universality

Increasing width in parameter distributions

$$\sigma_{IMF} = \left(\sigma_{\Gamma_P} = 0.6, \sigma_{\gamma_P} = 0.25, \sigma_{M_P} = 0.27\right)$$



Dib+ (2017)

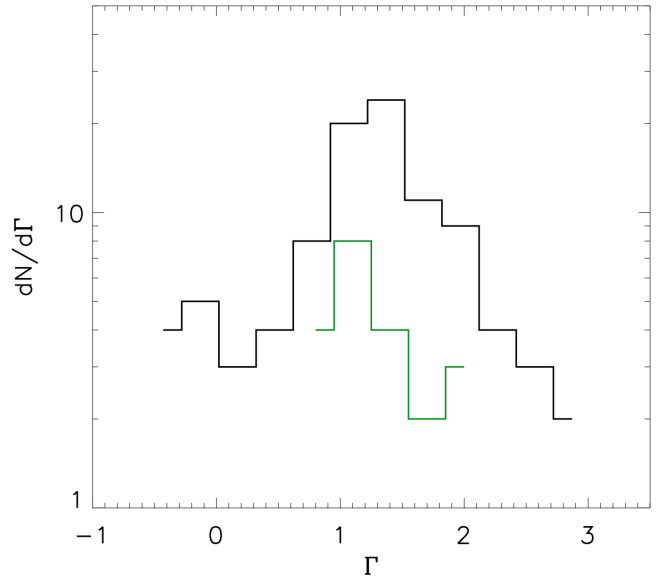
Libraries of synthetic clusters

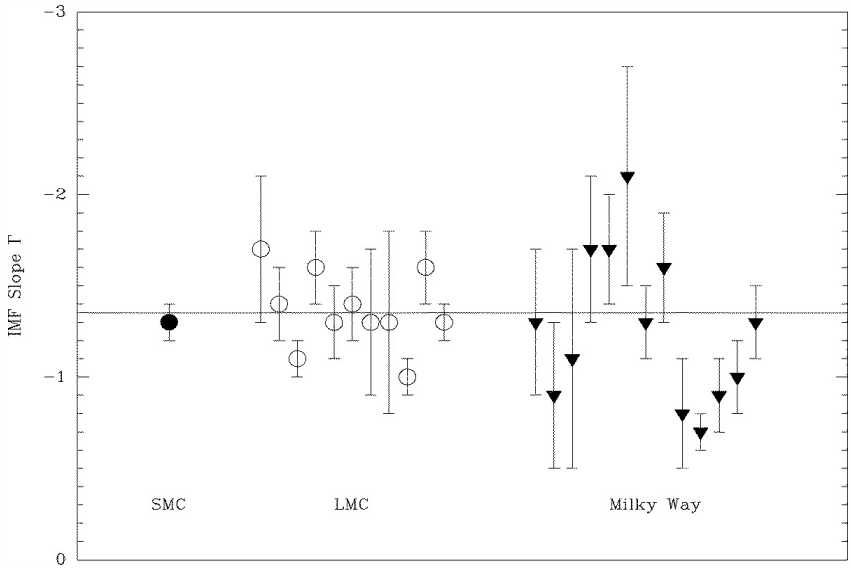
- Random sample cluster masses from an ICLMF
- Radom sample an age for each cluster (from the age distrib. of observed clusters)
- Random sample stellar masses in each cluster (system stellar masses)
- assign a binarity probability for each cluster
- assign a mass ratio for each binary
- Correct for stellar evolution (i.e., remove evolved O stars at the assigned age of the cluster)
- Correct for ejected O stars
- Correct the total sample for completeness (based on the B stars content)

→ Measure the fractions of single and lonely O stars

The IMF of stellar clusters

Evidence against universality





Lim et al. (2015),
Weisz et al. (2015)
Dib (in prep)

Massey 2003

The IGIMF- galaxy-wide IMF

The galaxy-integrated IMF: IGIMF

$$\Phi_{IGIMF}\left(M_*\right) = \int_0^{\infty} \varphi_{IMF}\left(M_*\right)\varsigma\left(M_{cl}\right)dM_{cl}$$

Weidner & Kroupa (2004),
++ several papers by Kroupa's group

The galaxy-integrated IMF: IGIMF

$$\Phi_{IGIMF}\left(M_*, SFR, [Fe/H]\right) = \int_{M_{cl,\min}}^{M_{cl,\max}(SFR)} \varphi_{IMF}\left(M_*, [Fe/H]\right) \varsigma\left(M_{cl}, SFR\right) dM_{cl}$$

SFR dependence: $M_{cl,max}$=F(SFR)

Metallicity dependence:

Γ=G([Fe/H])

γ=H([Fe/H])

The galaxy-integrated IMF with IMF variations

$$\Phi_{IGIMF}\left(M_*, SFR, [Fe/H]\right) = \int_{M_{cl,\min}}^{M_{cl,\max}(SFR)} \int_{\Gamma_{\min}}^{\Gamma_{\max}} \int_{\gamma_{\min}}^{\gamma_{\max}} \int_{M_{ch,\min}}^{M_{ch,mX}} P\left(M_{ch}\right) P\left(\gamma\right) P\left(\Gamma\right) \varphi_{IMF}\left(M_*, [Fe/H]\right) \varsigma\left(M_{cl}, SFR\right) dM_{cl} d\Gamma d\gamma$$

SFR dependence: $M_{cl,max}$=F(SFR)

SFR dependence: $M_{ch,}$=I(SFR) → **Inspired from simulations of Narayanan, Dave ++ (2012,2013)**

Metallicity dependence:
Γ=G([Fe/H])
γ=H([Fe/H])

Dib & Basu (2018)
Dib (2022)

IMF parameter distributions – Gaussian functions

$$P(\gamma) = \frac{1}{\sigma_\gamma \sqrt{2\pi}} \exp\left(-\frac{1}{2} \left(\frac{\gamma - \bar{\gamma}}{\sigma_\gamma} \right)^2 \right)$$

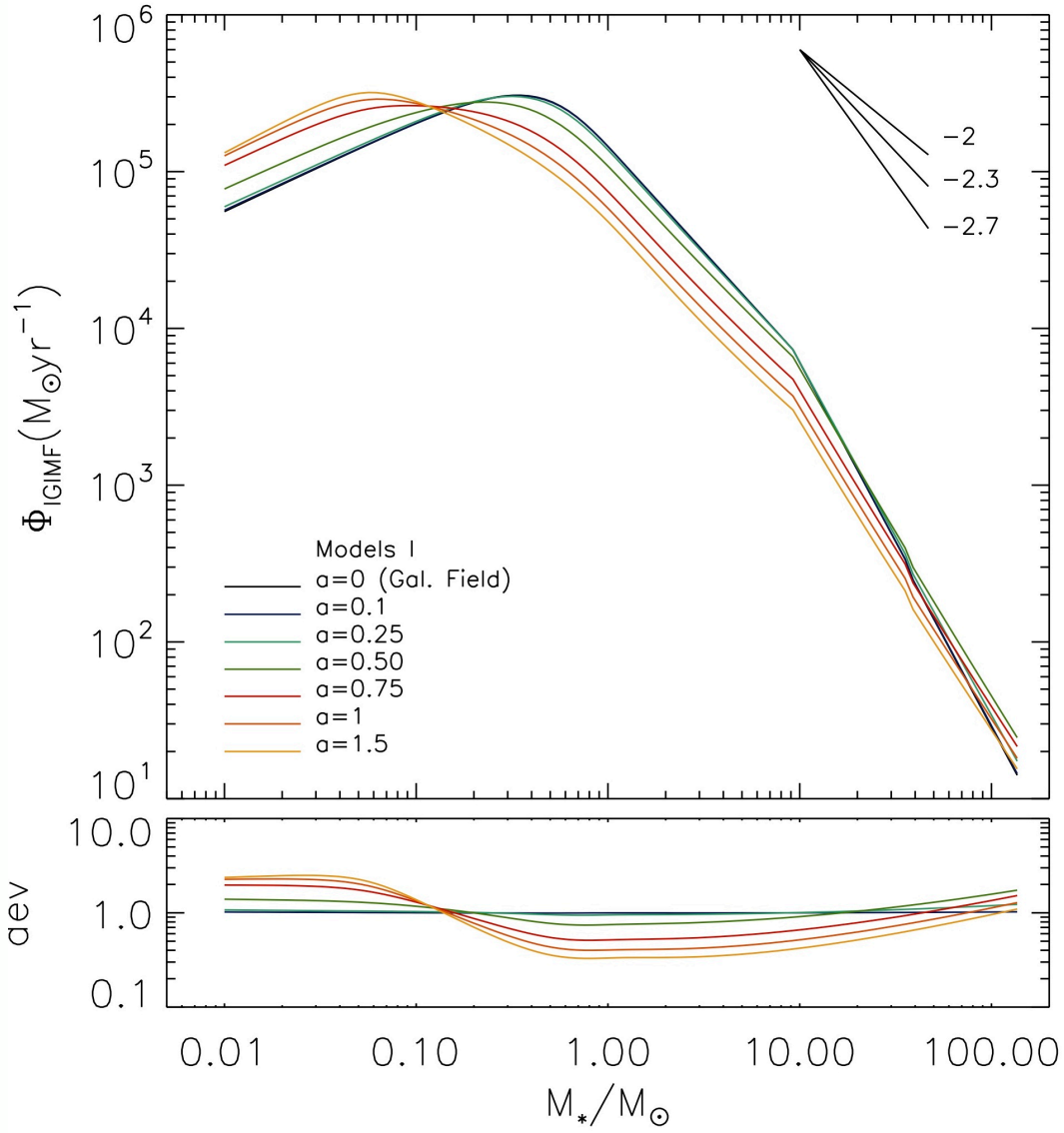
$$P(\Gamma) = \frac{1}{\sigma_\Gamma \sqrt{2\pi}} \exp\left(-\frac{1}{2} \left(\frac{\Gamma - \bar{\Gamma}}{\sigma_\Gamma} \right)^2 \right)$$

$$P(M_{ch}) = \frac{1}{\sigma_{M_{ch}} \sqrt{2\pi}} \exp\left(-\frac{1}{2} \left(\frac{M_{ch} - \overline{M_{ch}}}{\sigma_{M_{ch}}} \right)^2 \right)$$

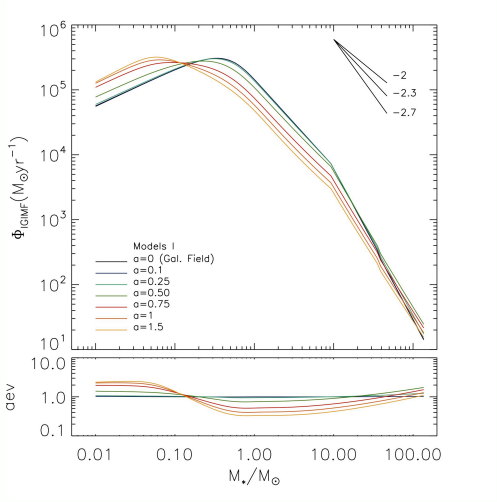
$$\sigma_\Gamma = a_\Gamma \sigma_{obs,\Gamma} \quad \sigma_\gamma = a_\gamma \sigma_{obs,\gamma} \quad \sigma_{M_{ch}} = a_{M_{ch}} \sigma_{obs,M_{ch}}$$

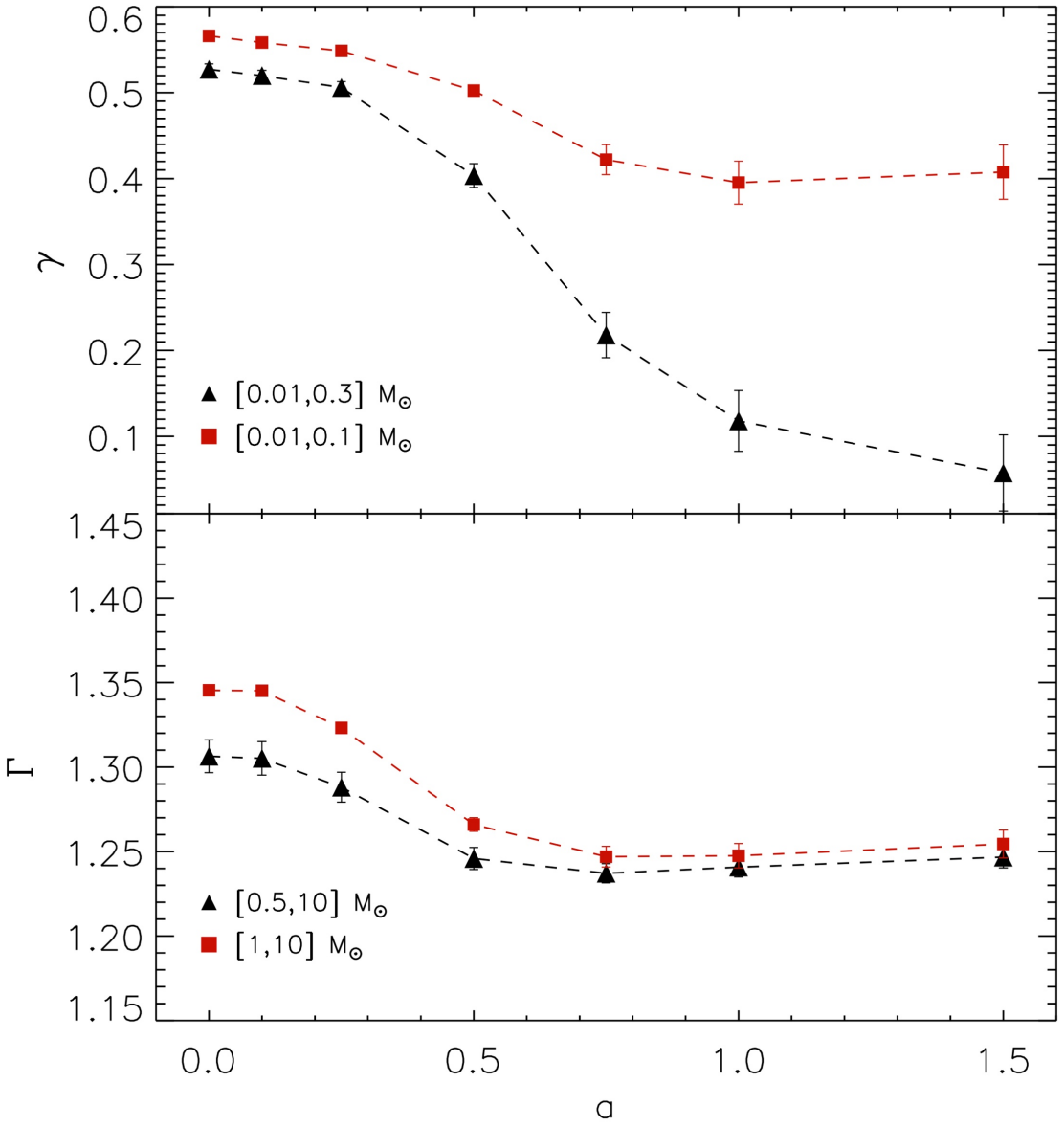
For simplicity, vary the a(s) in unison: $a_\gamma = a_\Gamma = a_{M_{ch}} = a$

Effects of IMF variations in clusters on the IGIMF

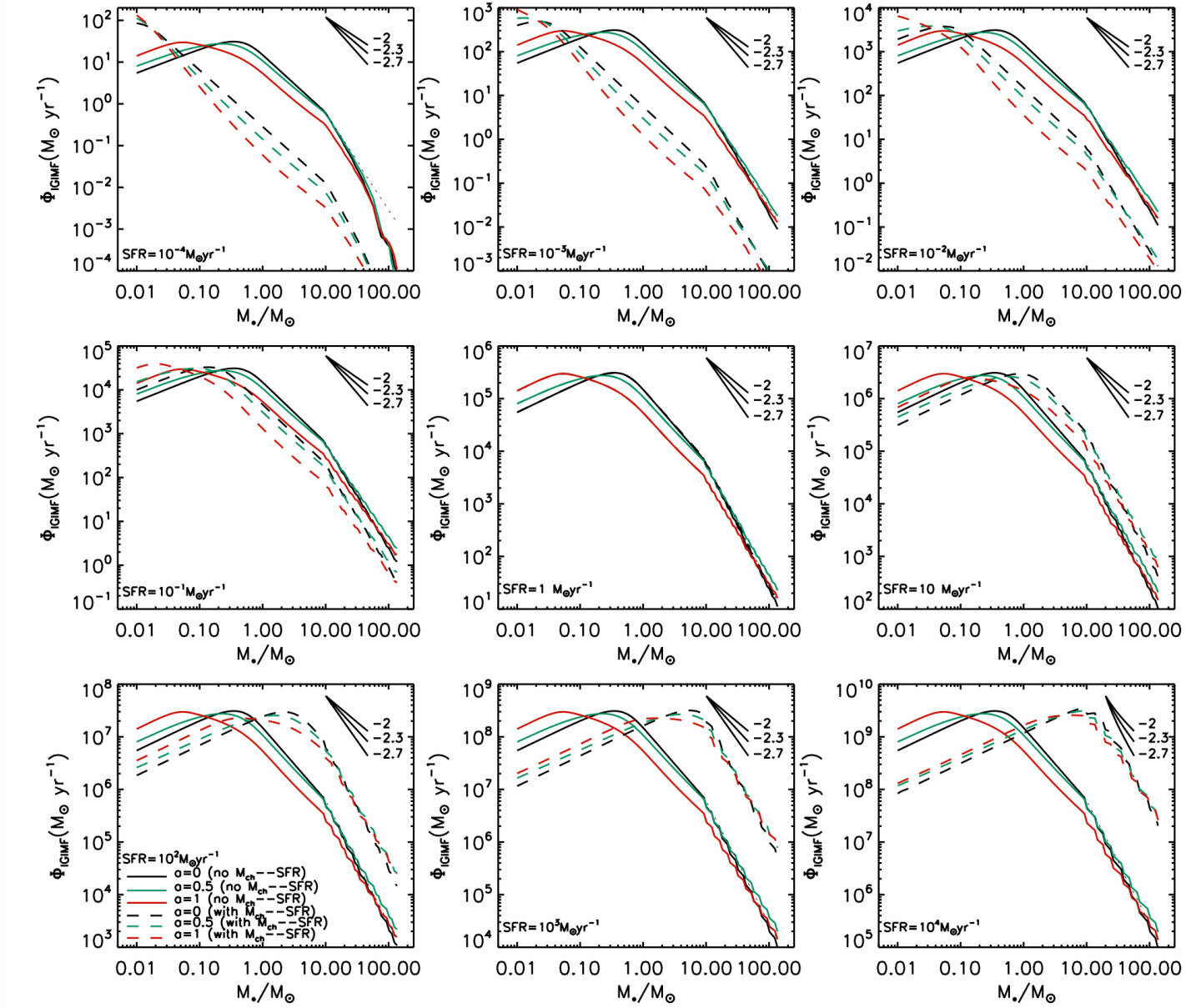


Effects of IMF variations in clusters on the IGIMF

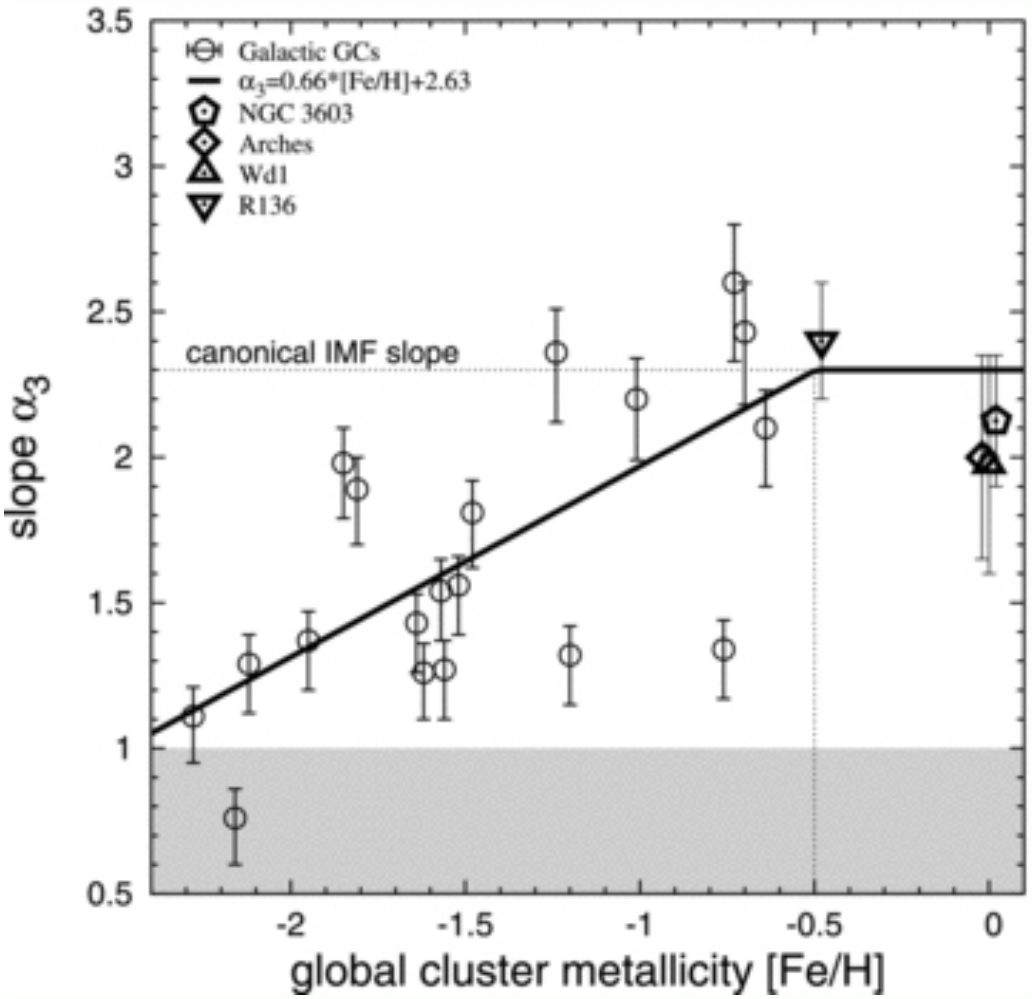


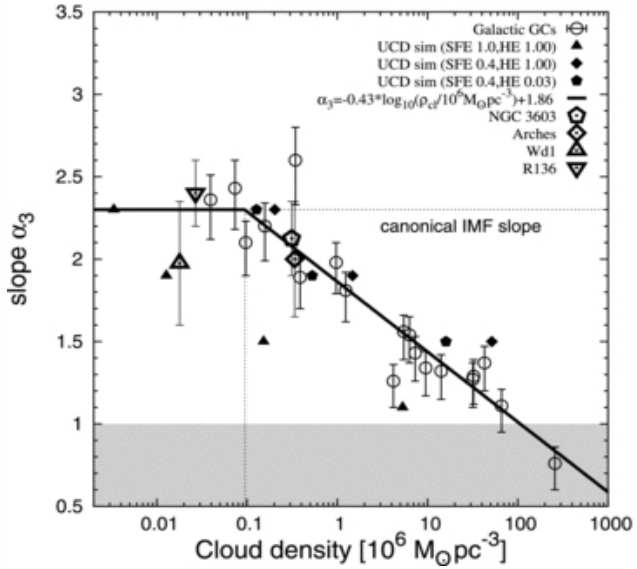


Effects of IMF variations in clusters on the IGIMF



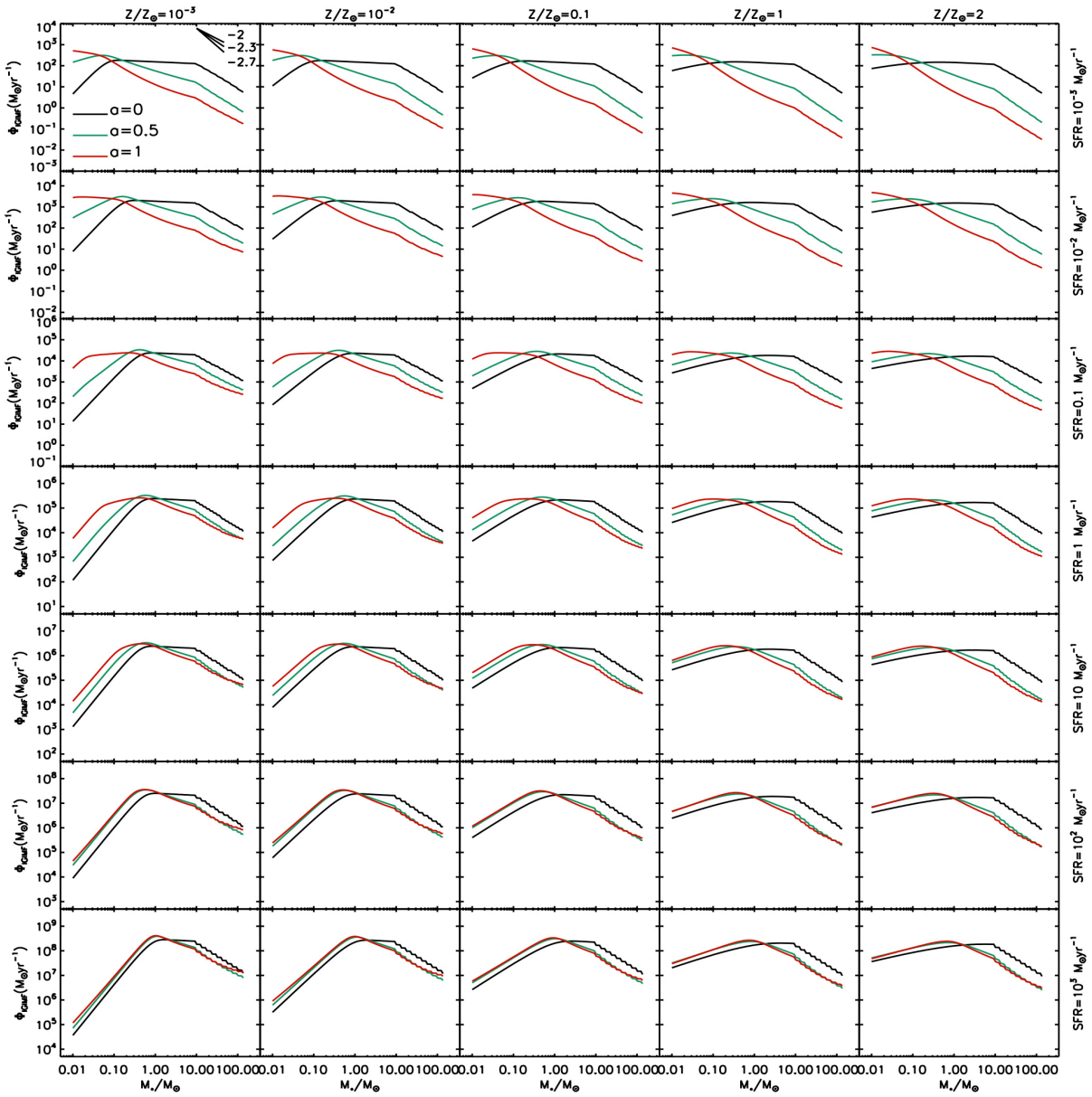
Metallicity dependence



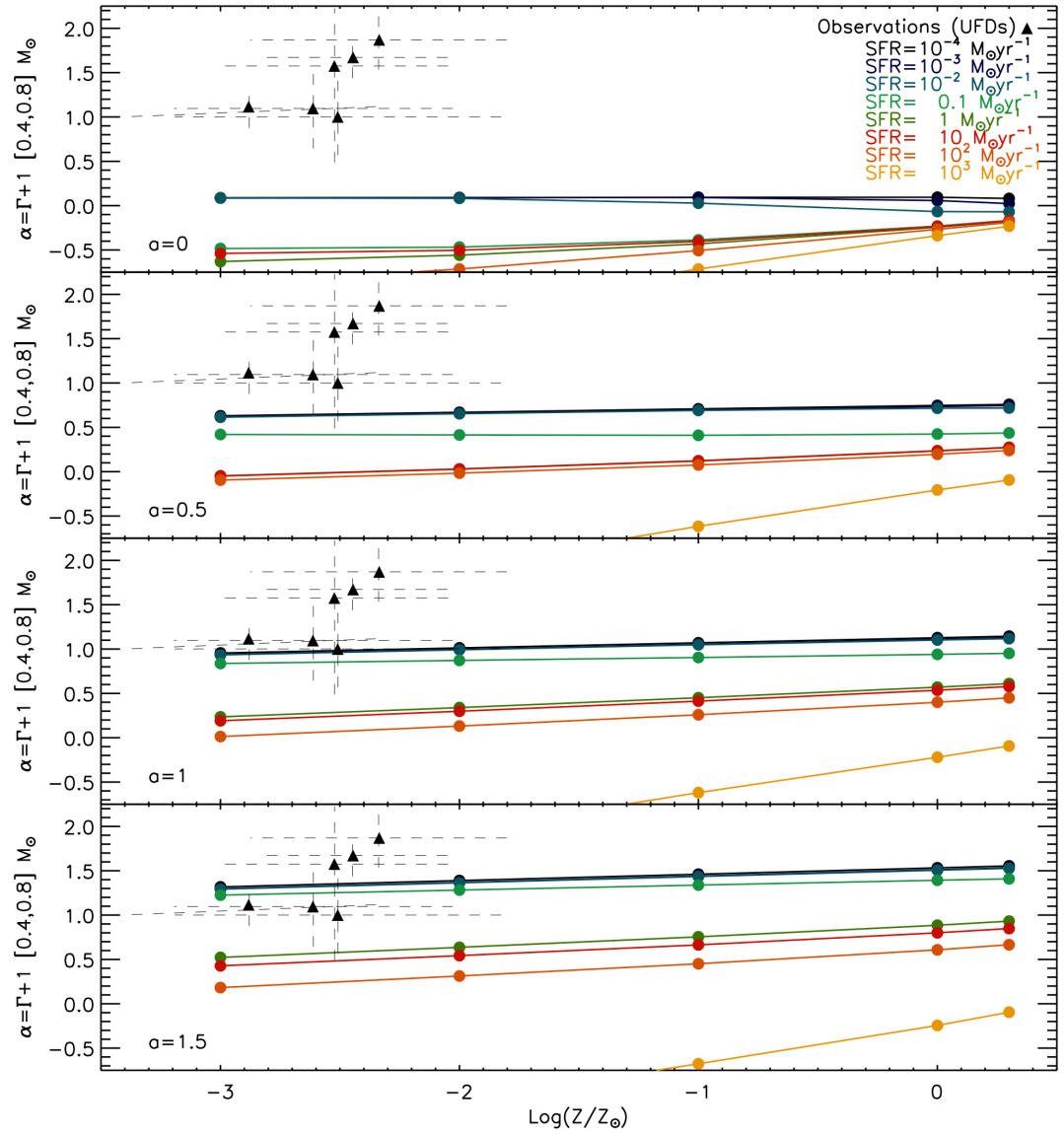


Marks et al. (2012)

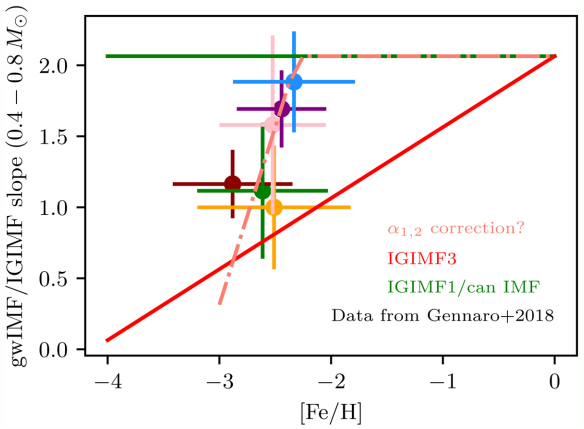
Grid in Metallicity-SFR



Comparison to observations - UFDs



Dib (2022)



Jerabkoba+ 18

Some conclusions

- Variations of the IMF in Galactic clusters
  - Level of variation $\sigma_{IMF} = \left(\sigma_{\Gamma_P} = 0.6, \sigma_{\gamma_P} = 0.25, \sigma_{M_P} = 0.27\right)$
  - Necessity to measure variations in and outside the MW

- Accounting for IMF variation is necessary to fit the IGIMF/PDMF of Ultra-faint dwarfs …and probably for all galaxies at all epochs

- Should have consequences for gas dynamics and chemical enrichement

- Next step: calculate galactic PDMFs