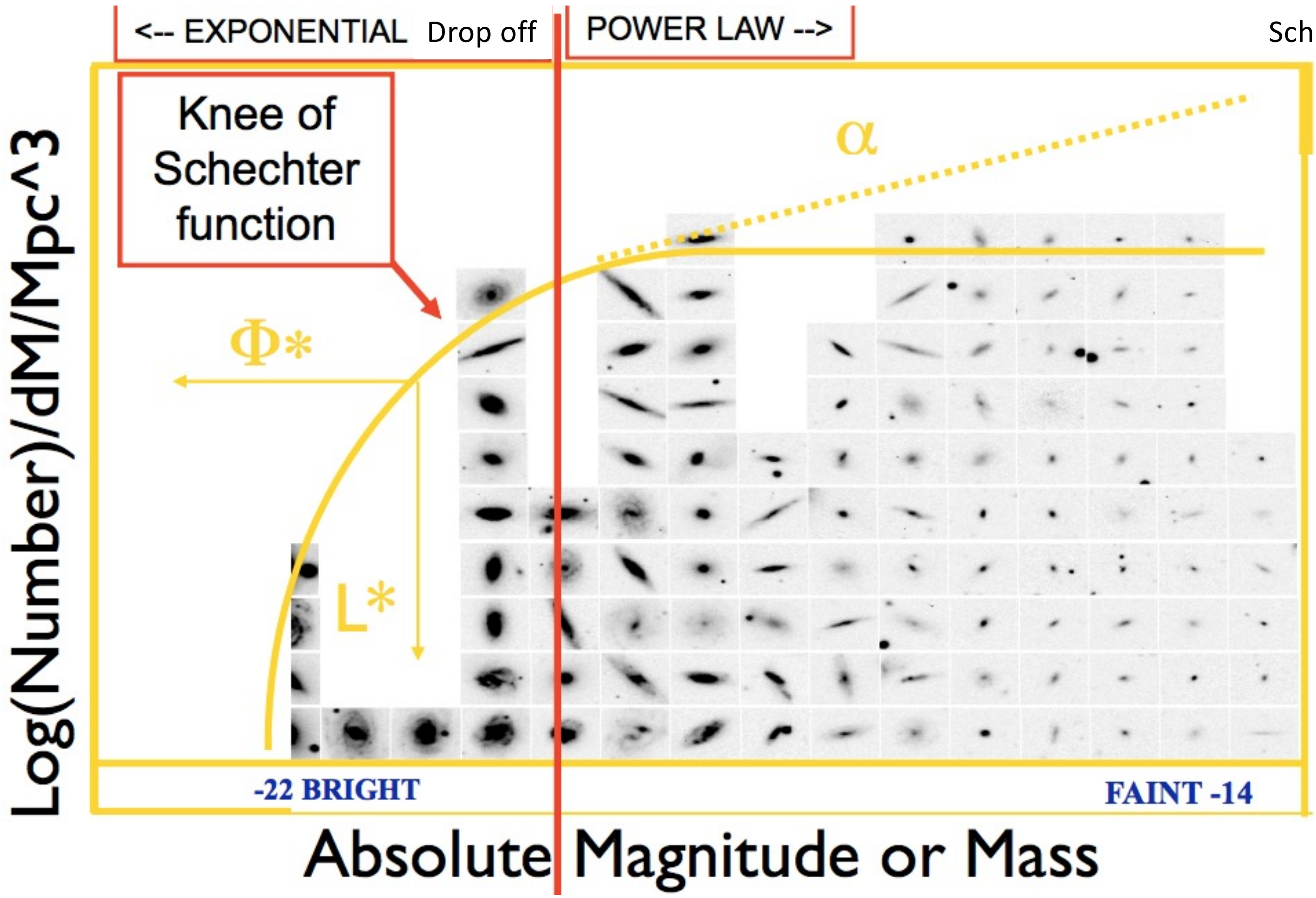
Luminosity Function

$$\Phi(L)dL = \frac{\text{number of stars with in L and L + dL}}{\text{volume probed}}.$$

$$n = \int_L^\infty \Phi(L')dL' \qquad L_{tot} = \int_L^\infty L'\Phi(L')dL'$$

Galaxy Luminosity Function: Schechter Fxn

Schechter 1976



Schechter Fxn (in terms of luminosity, L)

$$\Phi(L)dL = n_*\left(\frac{L}{L_*}\right)^{\alpha} e^{-(L/L_*)}\frac{dL}{L_*}$$

$\mathrm{n}_* = 8 \times 10^{-3}h^3\ \mathrm{Mpc}^{-3}$ $\qquad L_* = 1.4 \times 10^{10} L_\odot$ $\qquad \alpha = -0.7$

Schechter Fxn (in terms of magnitude, M)

$$\Phi(M)dM = (0.4ln10)\phi_* 10^{0.4(M_*-M)(\alpha+1)} e^{-10^{0.4(M_*-M)}} dM$$

$\phi_* = 1.66 \pm 0.08 \times 10^{-2}h^3\mathrm{Mpc}^{-3}$ $\qquad \alpha = -0.81 \pm 0.04$ $\qquad \mathrm{M}^* = \mathrm{M}_k^* = -23.19 \pm 0.04 - 5\log(\mathrm{h})$

$h = H_0/(100\ \mathrm{km/s/Mpc})$. Where $H_0 = 70.4\ \mathrm{km/s/Mpc}$

Parameters from Smith+(2009 MNRAS 397, 868)
K band

Low Luminosities…

Blanton+2005 ApJ 631

$$\Phi(M) = 0.4 \ln 10 \, dM \, \exp\left[-10^{-0.4(M-M_*)}\right] \times \left[\phi_{*,1} 10^{-0.4(M-M_*)(\alpha_1+1)} + \phi_{*,2} 10^{-0.4(M-M_*)(\alpha_2+1)}\right]$$

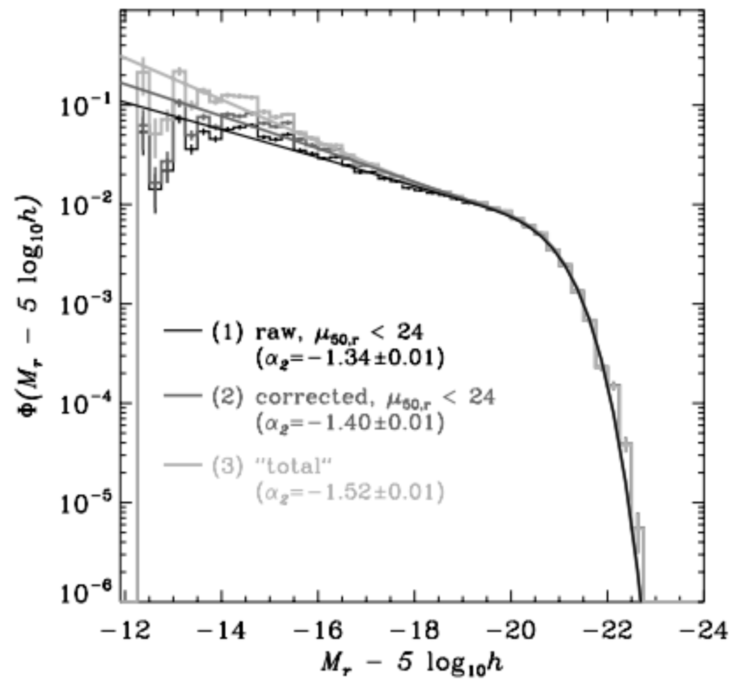


FIG. 7.—Luminosity function in the r band, calculated using the stepwise maximum likelihood method, with bins of width 0.25 mag. The black histogram indicates the minimal luminosity function, LF 1, for galaxies with $\mu_{50,r} < 24$, described in § 4.1, with no correction for surface brightness selection effects. The dark gray histogram indicates the luminosity function for galaxies with $\mu_{50,r} < 24$, corrected for surface brightness incompleteness. The light gray histogram represents an attempt to estimate how many galaxies there might be by using a simple model for the luminosity–surface brightness relationship. The values used in this plot are given in Table 2. The smooth curves are double Schechter function fits to each result, whose parameters are given in Table 3. All magnitudes here and elsewhere in the paper are K-corrected to rest-frame bandpasses and have no evolution correction applied.

Lab 2 Part A

- Luminosity fxns
- Numerical Integration
- Plotting

Mass Function: number of stars per mass bin $\Phi(M)$

If you know the relationship between star luminosity and mass, L(M), you can transform the luminosity function into a mass function.

*M is now mass

$$\Phi(M)dM = \Phi(L)\frac{dL(M)}{dM}dM$$

Stellar Mass to Light Relations L(M):

$$\frac{L}{L_\odot} \approx 0.23 \left(\frac{M}{M_\odot}\right)^{2.3} \qquad (M < 0.43 M_\odot)$$

$$\frac{L}{L_\odot} = \left(\frac{M}{M_\odot}\right)^{4} \qquad (0.43 M_\odot < M < 2 M_\odot)$$

$$\frac{L}{L_\odot} \approx 1.5 \left(\frac{M}{M_\odot}\right)^{3.5} \qquad (2 M_\odot < M < 20 M_\odot)$$

$$\frac{L}{L_\odot} \approx 3200 \frac{M}{M_\odot} \qquad (M > 20 M_\odot)$$

Luminosity Function for the Stellar Disk of the Milky Way

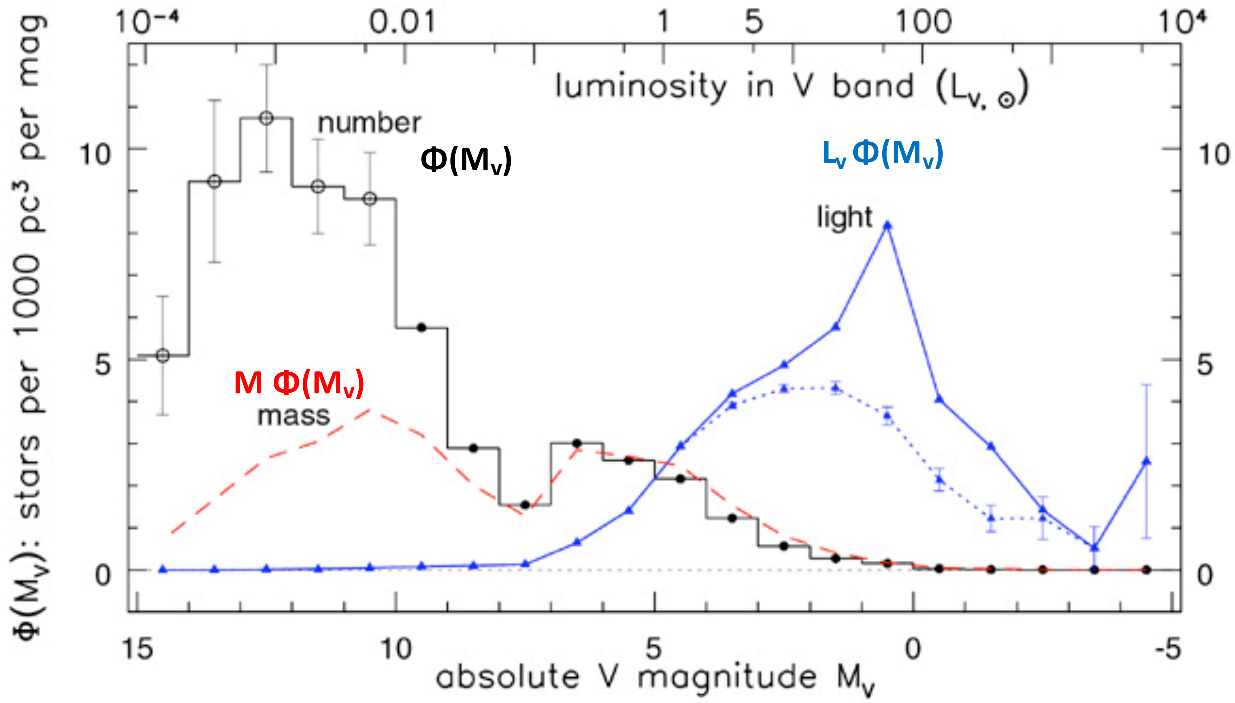


Fig 2.3 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

The histogram shows the luminosity function $\Phi(M_v)$ for nearby stars. Lines with triangles show $L_v\Phi(M_v)$, light from stars in each magnitude bin; the dotted curve is for main sequence stars alone, the solid curve for the total. The dashed curve gives $M\,\Phi_{MS}(M_v)$, the mass in main sequence stars. Units are $L_\odot$ or $M_\odot$ per 10 pc^3; vertical bars show uncertainty.

Initial Mass Function: $\xi(M)$

$$\boxed{\xi(M)dM = \xi_0 (M/M_\odot)^{-\alpha} \frac{dM}{M_\odot}}$$

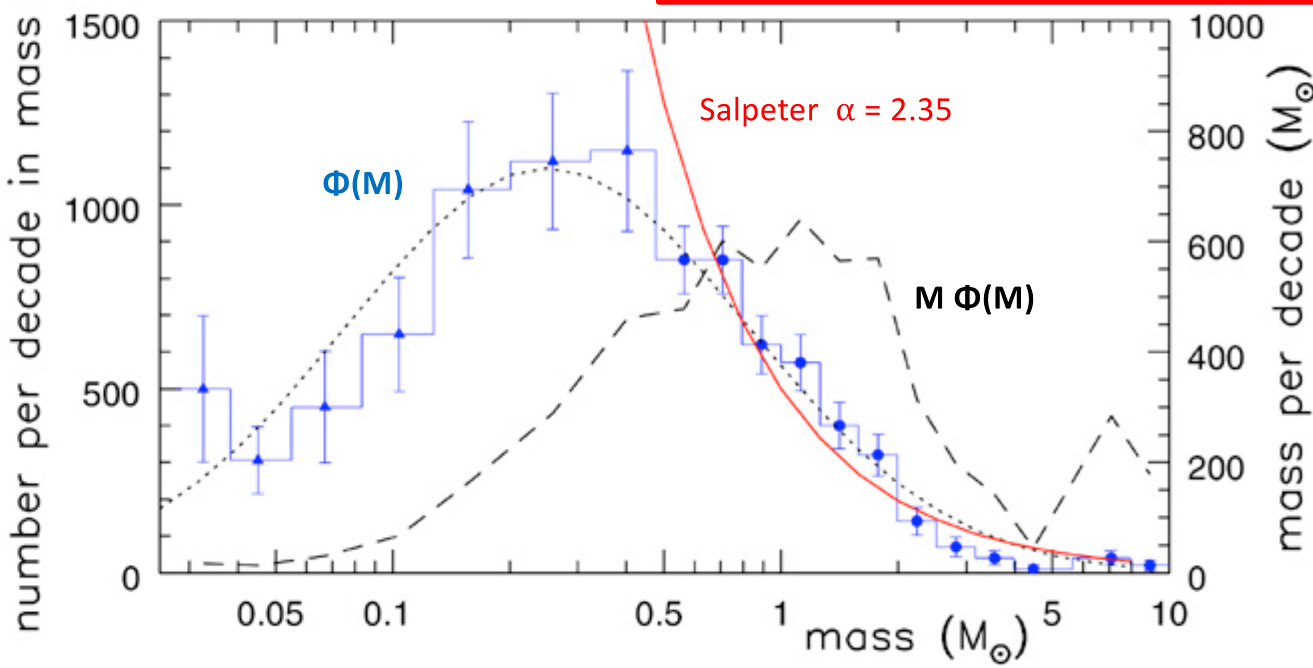
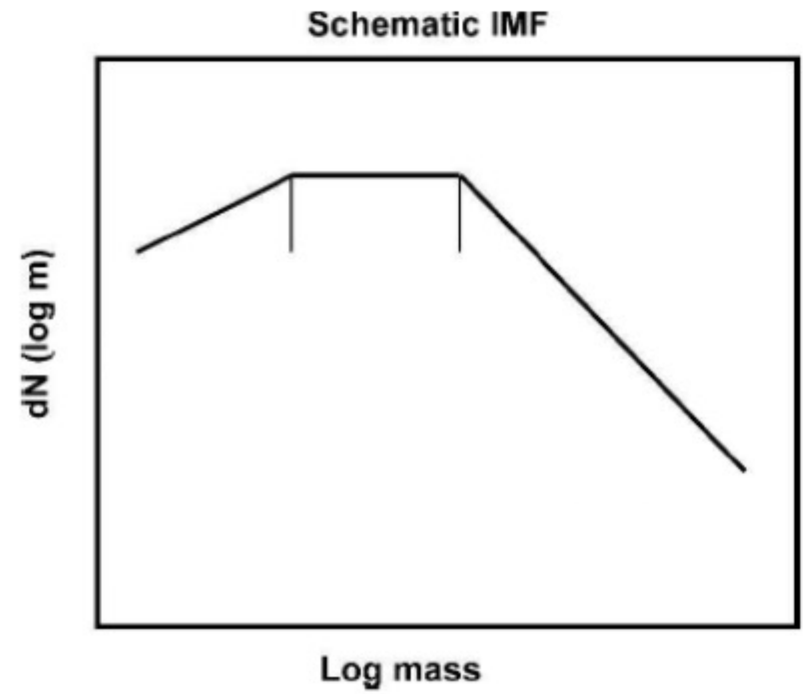
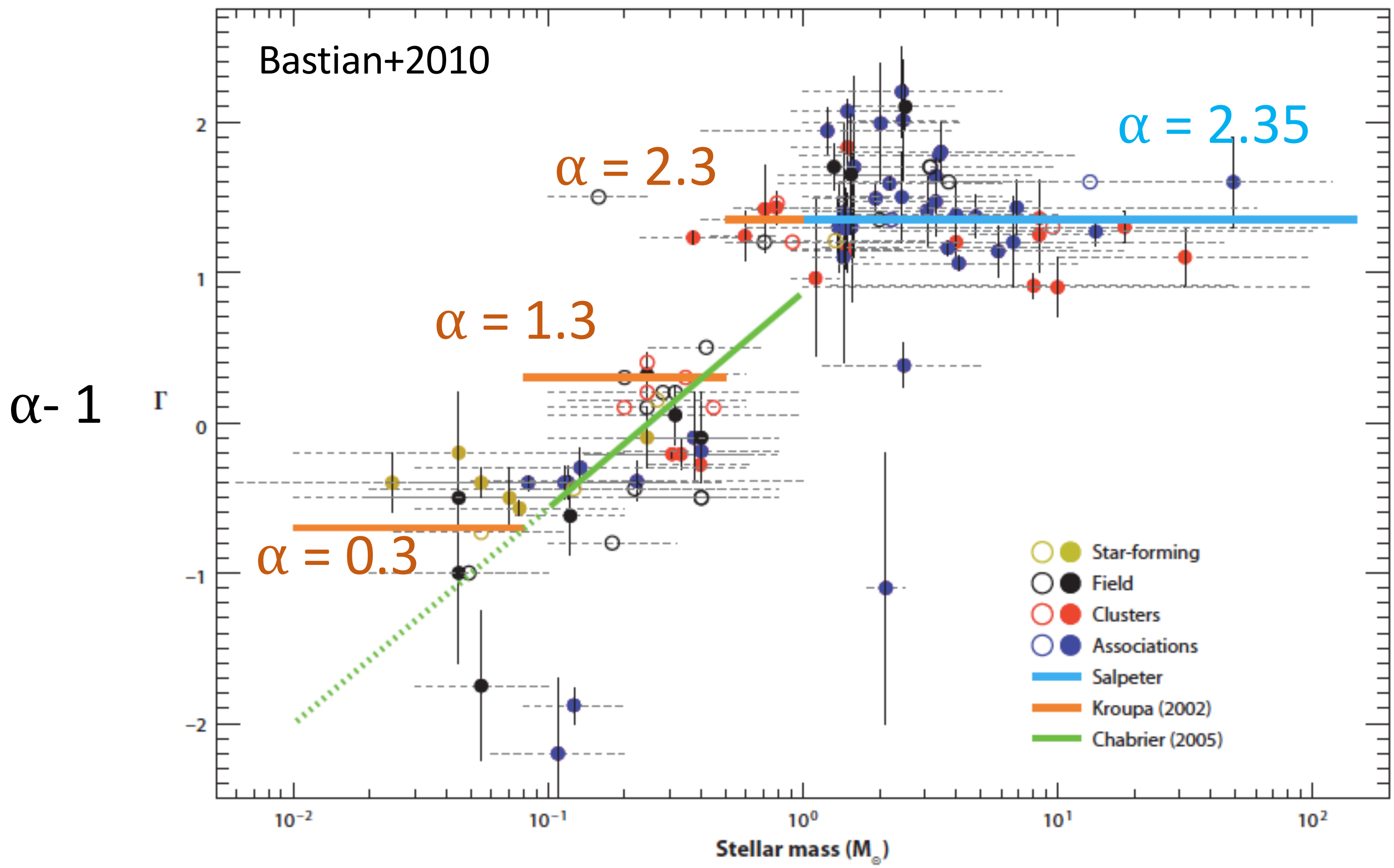


Fig 2.5 (E. Moreau) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

Masses of stars in the Pleiades cluster: the blue line/triangles is the mass function (# stars per mass bin), the dotted curve is a lognormal function. The dashed line shows the **mass distribution**: stars near 0.25 $M_\odot$ are most numerous, but those of (1-2)$M_\odot$ account for most of the cluster's mass, so Salpeter doesn't do a bad job.

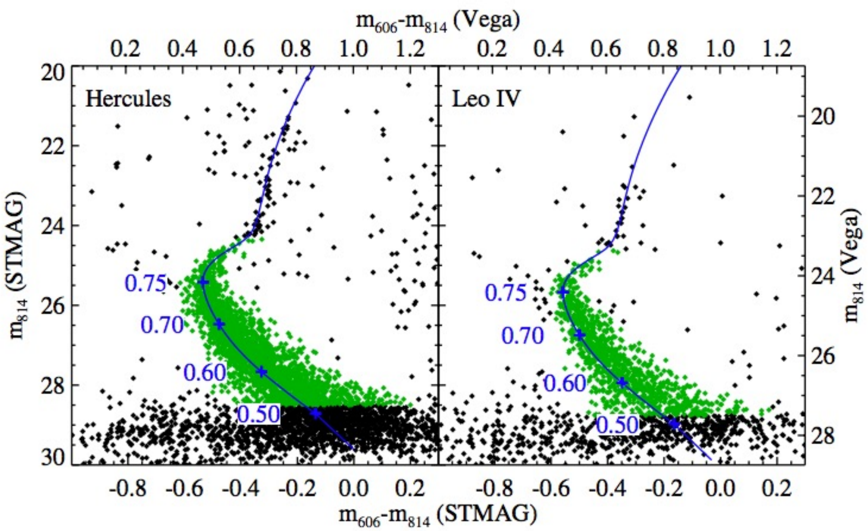
Why is the IMF ~ log normal?




Bastian+2010
α = 2.35
α = 2.3
α = 1.3
α = 0.3
α- 1
Γ
2
1
0
−1
−2
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
Stellar mass ($M_\odot$)
Star-forming
Field
Clusters
Associations
Salpeter
Kroupa (2002)
Chabrier (2005)

Geha+2013

Is the IMF slope at ~1 Msun actually universal?



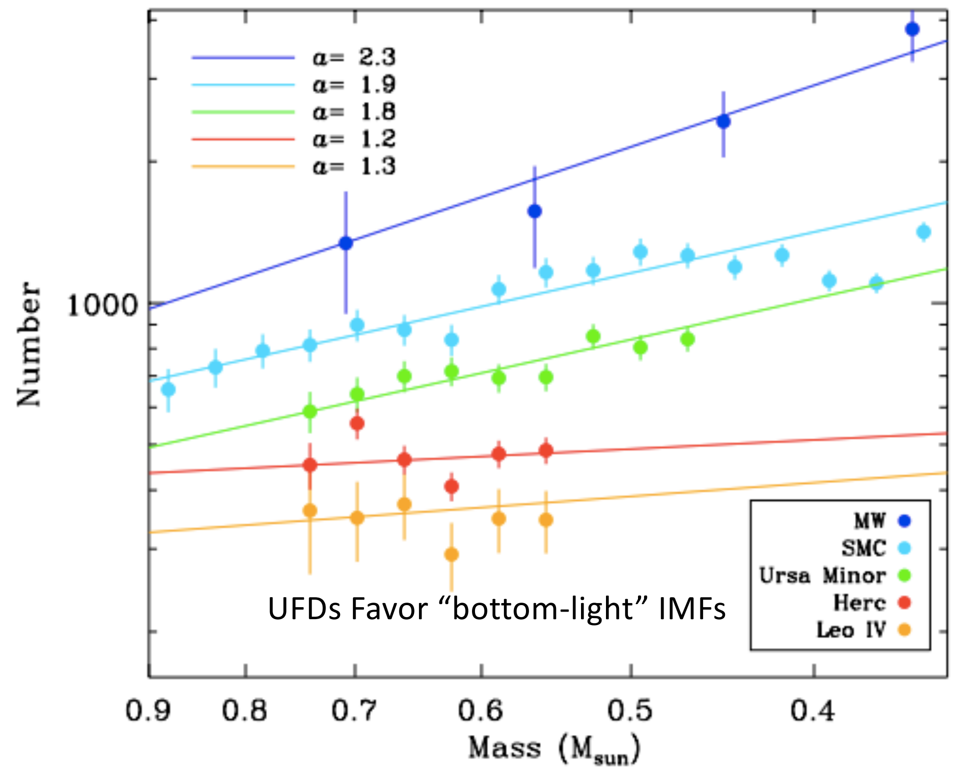
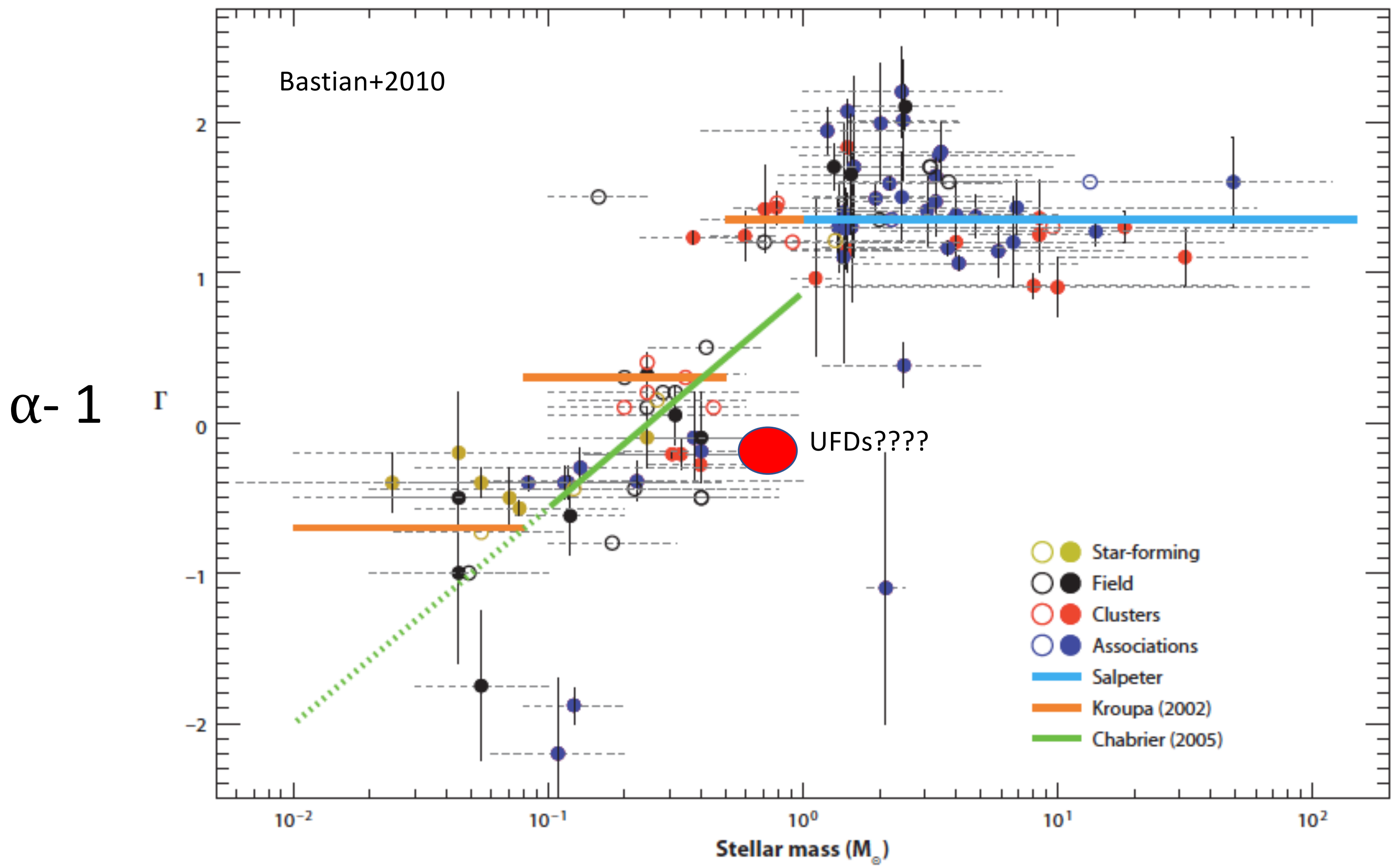


Figure 4. Stellar mass functions for the five galaxies in which the IMF has been measured via direct star counts: the Milky Way (blue; Bochanski et al. 2010), the SMC (light blue; Kalirai et al. 2013), Ursa Minor dSph (green; Wyse et al. 2002), Leo IV (yellow; this work) and Hercules (red; this work). Except for Hercules, the vertical normalization is arbitrary. For reference, the published power law slopes are shown for each dataset, normalized at 0.75 $M_{\odot}$. We note that a power law slope of $\alpha = 1$ is a flat line in this log–log plot. The UFD galaxies show noticeably flatter mass functions in this mass range.



Bastian+2010
α- 1
Γ
2
1
0
−1
−2
UFDs????
Star-forming
Field
Clusters
Associations
Salpeter
Kroupa (2002)
Chabrier (2005)
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
Stellar mass ($M_{\odot}$)

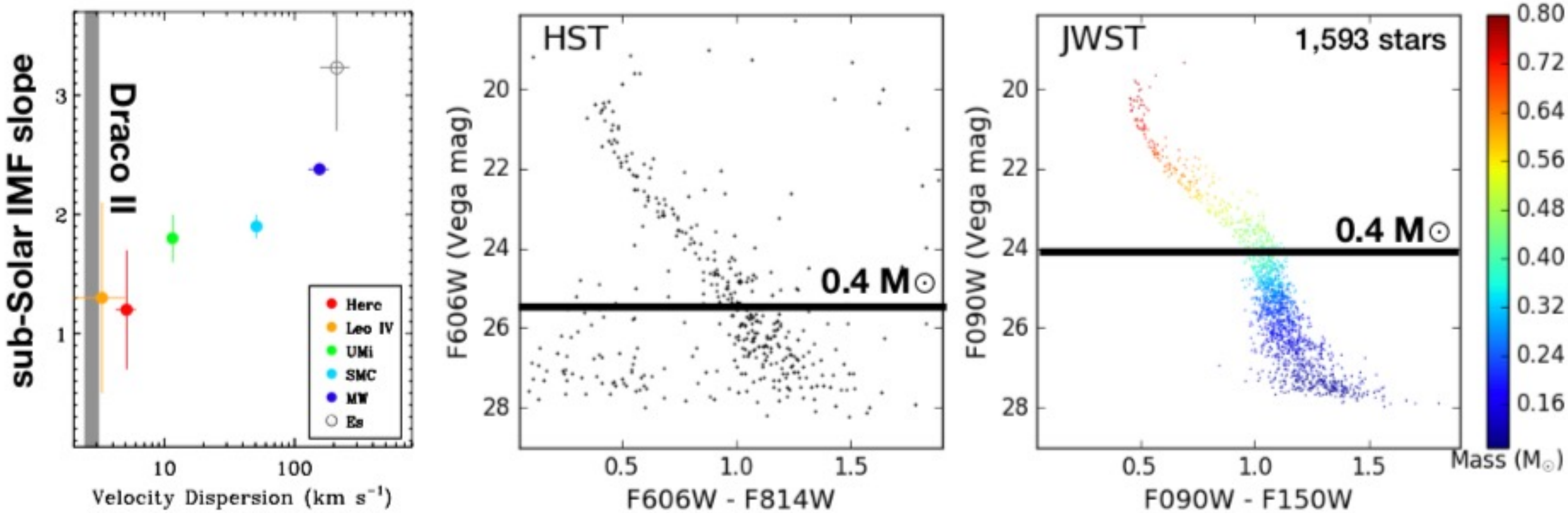


FIGURE 3: **Left–**A plot showing that galaxies with lower velocity dispersions tend to have 'bottom-light' sub-Solar IMF slopes as measured from resolved stars (Geha et al. 2013; Kalirai et al. 2013). **Middle & Right–** The *HST*-based CMD and a simulated *JWST* CMD of Draco II. The horizontal line indicates equivalent stellar masses. The sub-Solar IMF slopes of Hercules and Leo IV were measured from similarly deep *HST* data. The increased depth of our Draco II data will provide for the most secure extragalactic sub-Solar IMF measurement to date.