Philip Massey: High Mass IMF

1995, 1998, 2011 (at least he's consistent)

Massey '95b

- Does high mass IMF depend on metalicitiy? – No
- Is there a limit to the most massive stars? – Not that we see
- Does birth of massive stars stop all star formation? - No
- Can you deduce the IMF from the LF if stars are born coeval? – Slightly, but No

Massey '98

- Large review of the same questions

Massey '11

- Short review of the same questions

Massey '95b

Observing OB stars in the Milky

- Observed 13 OB 'associations' (clusters) : photometry ~11k, spectroscopy ~300
- Binaries assumed to be identified or hopefully consistent
- Photometry + reddening parameter +bolometric corrections -> spectral type (?)
- Spectroscopy + spectral type -> distance (?) + brightness -> luminosity -> mass
- Comparison to follow to Large Magellanic Cloud (LMC) and the Small Magellanic Cloud (SMC)

Structure	Metallicitiy
Milky Way	z = 0.02
Large Magellanic Clouds	z = 0.008
Small Magellanic Clouds	z = 0.002

Massey '98

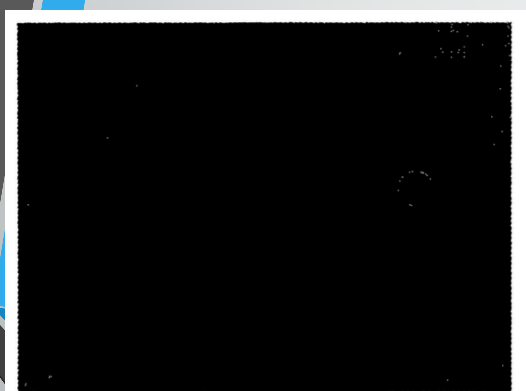
Challenges when identifying high mass stars

- High T_{eff} puts most light in far-UV, requiring highly significant bolometric corrections
  - Aging massive stars increase in visual magnitude
  - Are we looking at an older 80 $M_\odot$ or a younger 60 $M_\odot$?
  - Stellar winds and low surface gravity could greatly increase visual light!
- Sampling the Rayleigh-Jeans tail: Both T_{eff} = 50k and T_{eff} = 30k ZAMS stars have nearly the same UV light
  - Factor of 1.5 difference in masses of early and late type O stars very difficult to distinguish

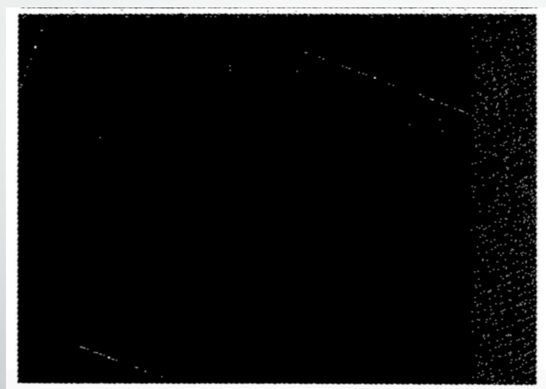
Massey '98

Improving Ability to Distinguish Objects

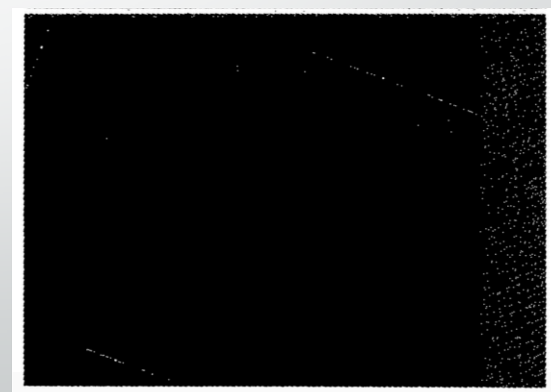
Figure 5. Three *U*-band images of the OB88/89 association in M 33. All three were "state of the art" in their day, and show the improvement that has taken place over the past 15 years.



CFHT plate ('81)



KPNO 2.1 m w/ RCA CCD ('86)



HST w/ WFPC2 CCD ('96)

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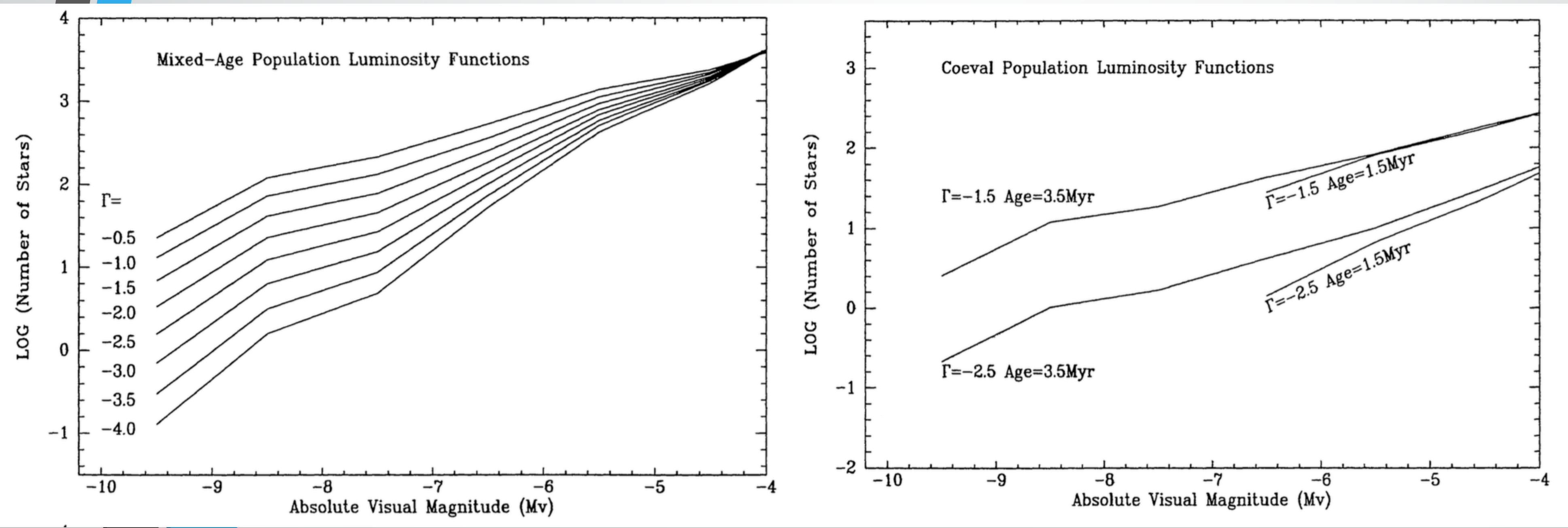
Luminosity Functions are Poor Indicators of IMF

Especially for mixed-age populations



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Age Spread of OB Associations in the MW

- Ages inferred from placing stars with spectra on HRD and matching them to modelled isochrones
- Spread of ages for stars M > 25 $M_\odot$: $\Delta\tau < 3$ Myr for most associations
- Large spreads in age could be observational bias from circumstellar envelopes, requires going back over old clusters with spectroscopy

- Presence of 5 $M_\odot$ and 10 $M_\odot$ stars (contraction times of 0.5-1.5 Myr) show that high mass star formation does <u>not</u> end all star formation
  - Could be true in some clusters where SN and stellar winds push out all star-forming gas, but not necessarily true everywhere
- Contrary to the idea that low mass stars must form first

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Limits to M_{up} in OB Associations in the MW

- Most massive stars in cluster's PDMF are an age effect from dying out
- Comparison to LMC and SMC show no dependence of metallicity on M_{up}
- "Radiation pressure on grains is not the limiting factor in how massive a star can be produced"

TABLE 5

Ages, IMF, and Stellar Densities

Association	$\mathrm{Age}_{>25\,\mathcal{M}_\odot}$ (Myr)	M_{up} ($\mathcal{M}_\odot$)	IMF Slope Γ	R_{GC} (kpc)	$N_{>10\,\mathcal{M}_\odot}$	$\rho_{>10\,\mathcal{M}_\odot}$ (10^4 kpc^{-2})
Milky Way						
NGC 6823	2–7	40	-1.3 ± 0.4	7.1	23	3.9
NGC 6871	2–5	40	-0.9 ± 0.4	7.6	11	1.7
NGC 6913	4–6	40	-1.1 ± 0.6	7.8	6	2.7
Berkely 86	2–3	40	-1.7 ± 0.4	7.8	10	4.2
NGC 7235	(6–11)	15	(-2.0)	9.4	11	1.8
NGC 7380	2	65	-1.7 ± 0.3	9.8	11	0.9
Cep OB5	2–4	30	-2.1 ± 0.6	9.9	6	0.8
IC 1805	1–3	100	-1.3 ± 0.2	9.8	24	1.9
NGC 1893	2–3	65	-1.6 ± 0.3	12.3	19	0.9
NGC 2244	1–3	70	-0.8 ± 0.3	9.7	12	1.4
NGC 6611	1–5	75	-0.7 ± 0.2	6.1	30	5.4
Cyg OB2.........	1–4	110	-0.9 ± 0.2	7.9	93	29.7
Tr 14/16	0–3	>120	-1.0 ± 0.2	7.7	82	9.4
Magellanic Clouds						
NGC 346	2–4	70	-1.3 ± 0.1	...	83	0.8
LH 9	1–5	55	-1.4 ± 0.2	...	84	3.5
LH 10	0–3	90	-1.1 ± 0.1	...	65	2.6
LH 58	2–4	50	-1.4 ± 0.2	...	66	1.5
LH 117/118......	1–3	100	-1.6 ± 0.2	...	40	0.5

Massey '95b

The IMF of the Milky Way

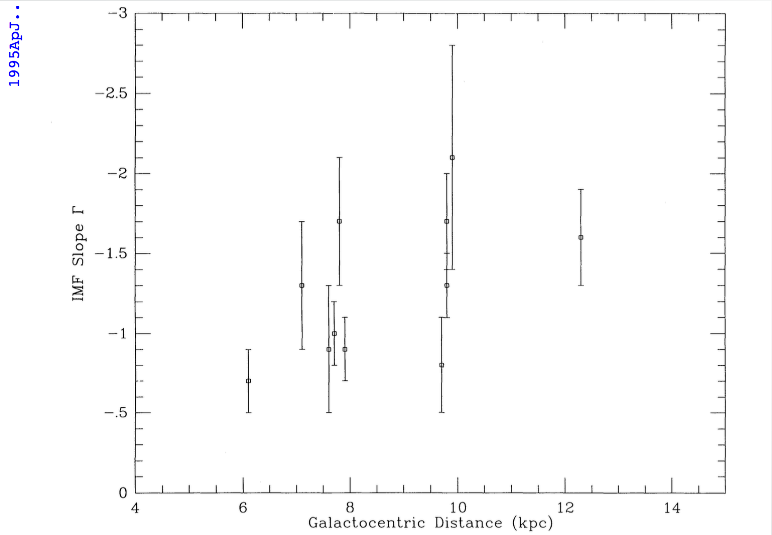


FIG. 6.—The IMF slope Γ plotted as a function of galactocentric distance for each association. No trend is apparent.

Take <u>that</u> Garmany et al. '82!

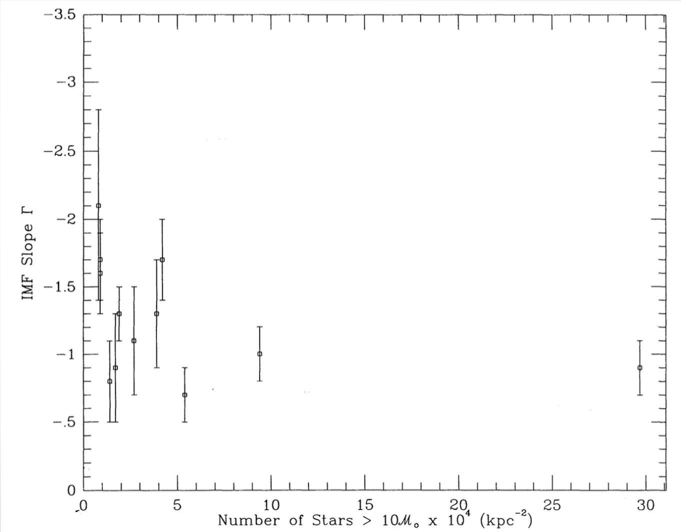


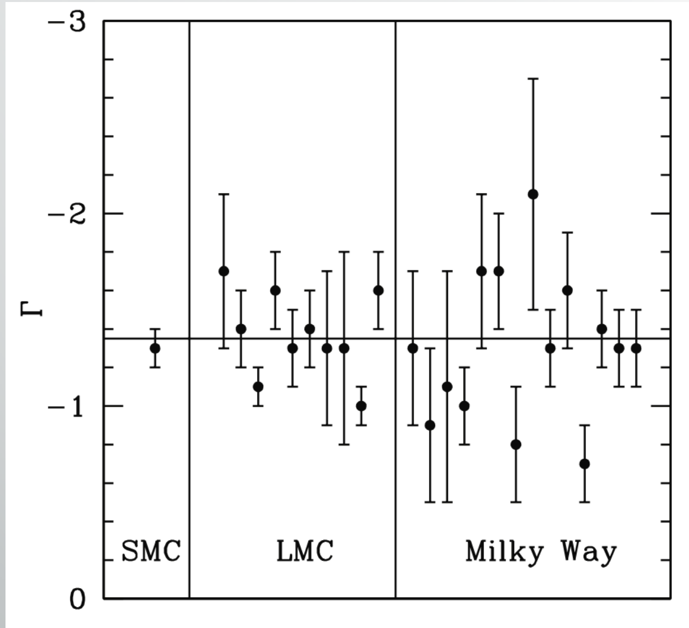
FIG. 7.—The IMF slope Γ is plotted as a function of the surface density of stars. No trend is apparent.

And that Massey et al. '95!

"Although the values of Γ cover a range from -0.7 to -2.0, we are more struck by the consistency in the values rather than the range."

Massey '95b

The IMF of the Milky Way compared to MC



Data from: Massey ('98), Slesnick et al. ('02)
and Massey & Hunter ('98)

Finally, we answer the question posed at the beginning of this paper: does the slope of the IMF depend upon metallicity? Table 5 summarizes the values for the IMF slopes found in the Magellanic Clouds, and it is clear that there is considerable overlap with those of the Milky Way. The weighted average of the IMF slopes of the Milky Way is -1.1 ± 0.1 (standard deviation of the mean); that of the Magellanic Clouds is -1.3 ± 0.1. *Thus to within our ability to measure the IMF, there is no difference in the slope of the IMF between the metallicities of the Milky Way and the Clouds.*

Massey '11

"Having a number of pieces of indirect, weak evidence doesn't prove the variability of the upper end of the IMF or that 150 $M_\odot$ is the upper mass limit, any more than anecdotal stories prove the existence of UFOs and cosmic vortexes. They may be fun to believe in, but one has to look at the evidence critically."