A Bottom-**Heavy** IMF in Massive Ellipticals

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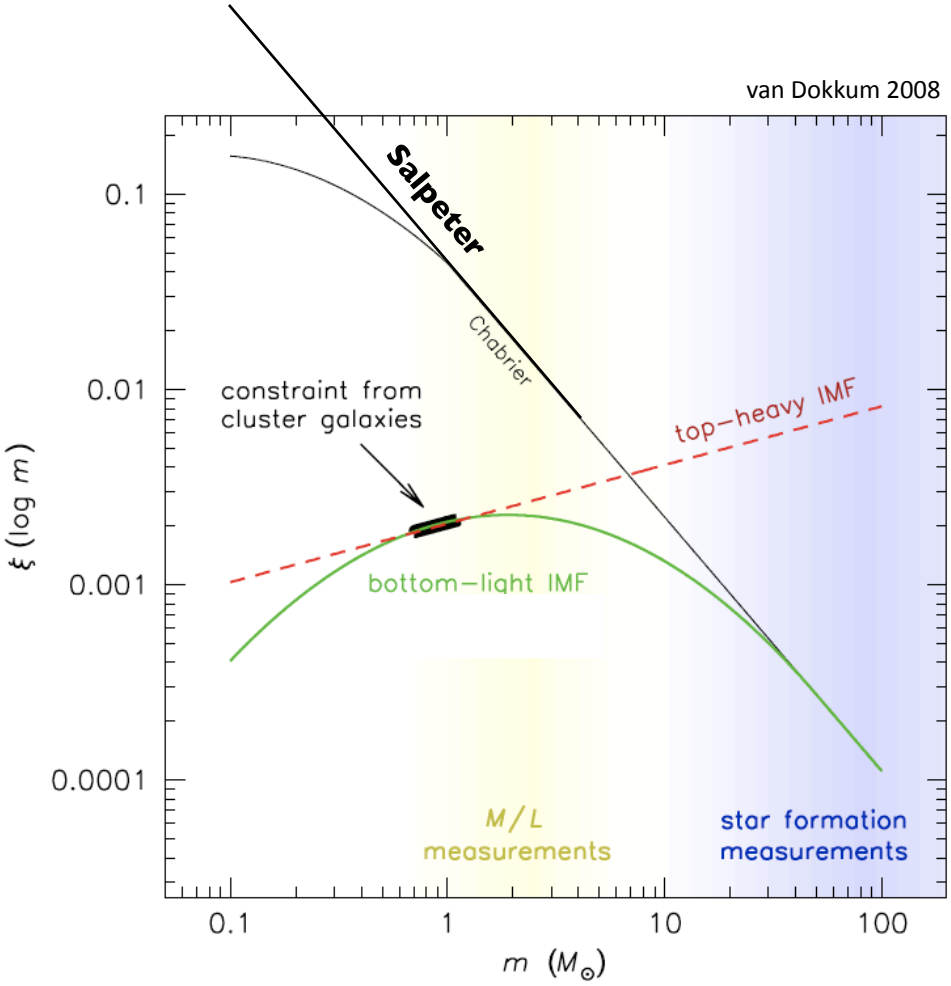
with Pieter van Dokkum (Yale)

IMF variation?



"Evidence" for a bottom-light IMF:

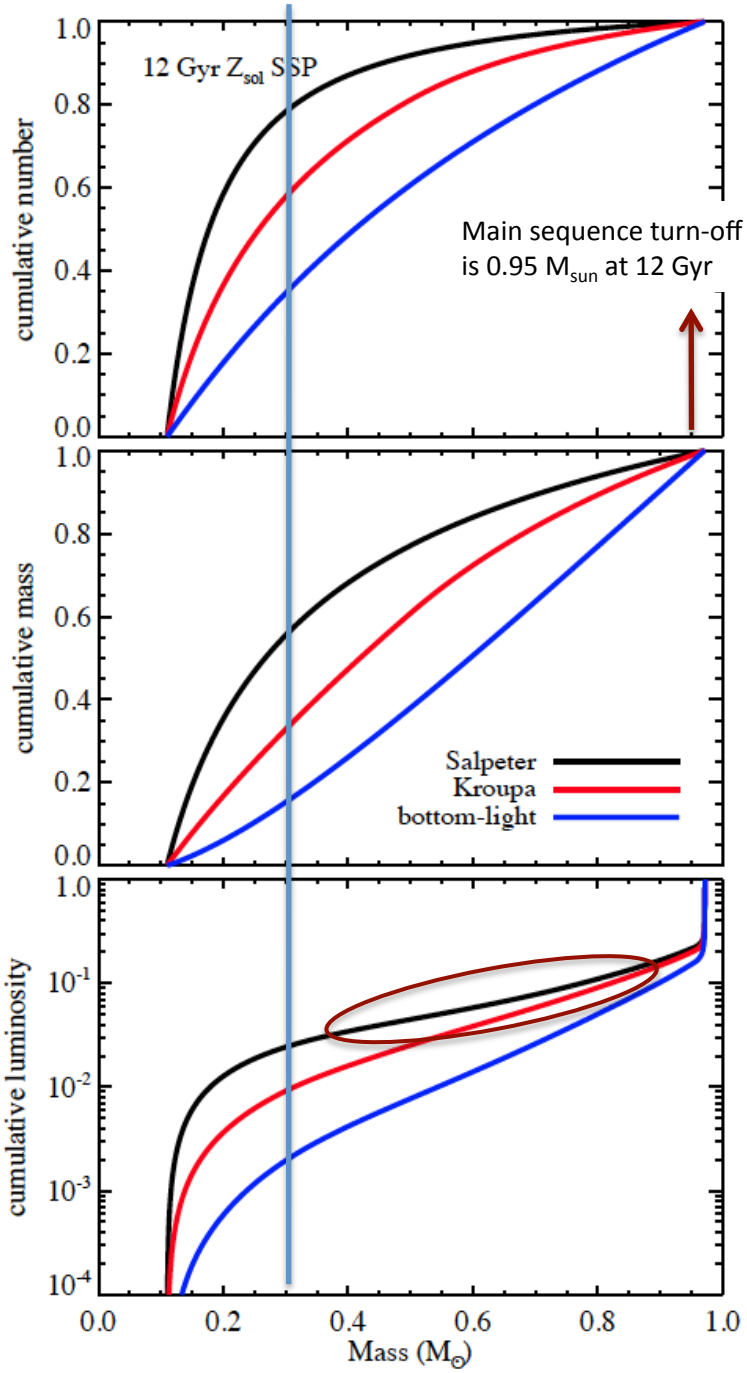
- Evolution in fundamental plane (van Dokkum 2008)
- Inconsistency between cosmic SF and stellar mass density evolution (Dave 2008)
- Submm galaxy counts (Baugh et al. 2005, C. Hayward this wokshop)
- Frequency of carbon-enhanced metal-poor stars (Lucatello et al. 2005, Tumlinson 2007)

→ ***Notice that these are all very indirect measures of the IMF!***

In contrast, there is no direct evidence (from star counts) for IMF variation (see review by Bastian et al. 2010)

Why the IMF matters

- If we are ever to directly detect low mass stars in unresolved galaxies, we will need spectro-photometric accuracy to ~1%
- The problem is even more daunting: how will we discriminate between ~0.2M_{sun} and ~0.7M_{sun} given that they are only ~1-5% perturbations?
  - i.e., the stellar content of galaxies is dominated by ~0.1-0.4 M_{sun} stars, so we really care about how many of *those* stars there are



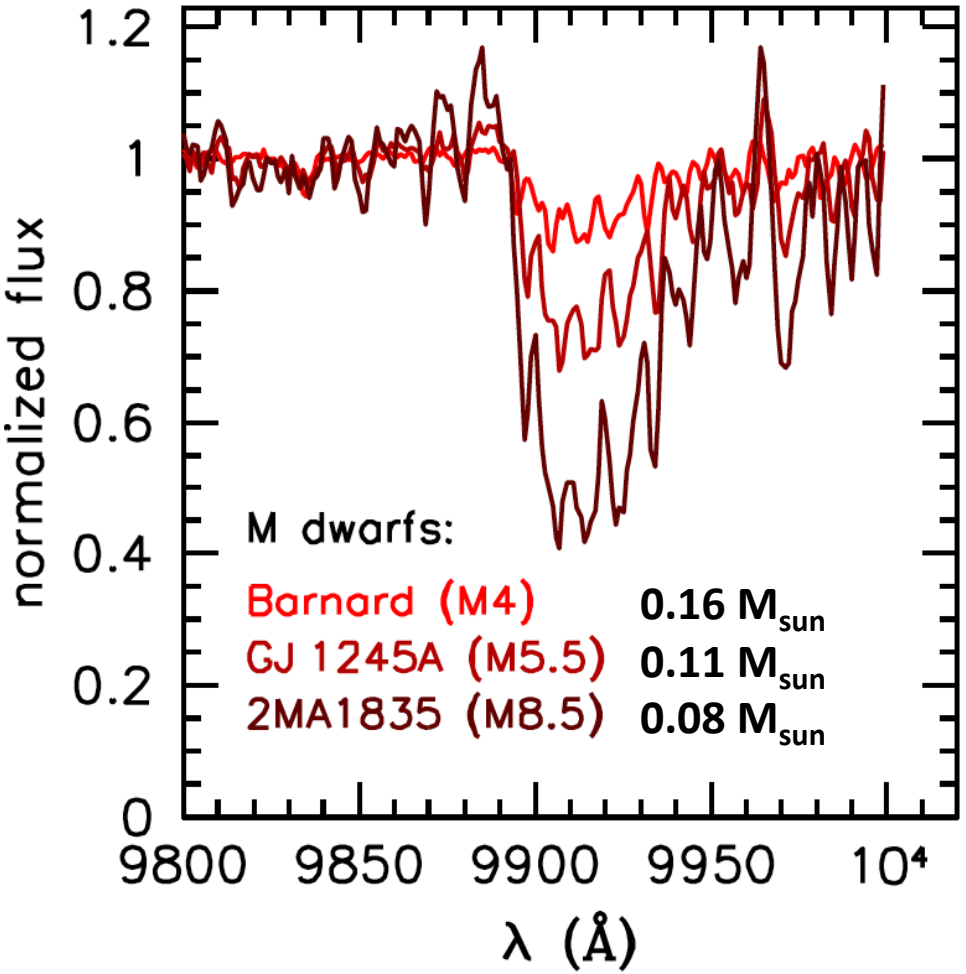
The Wing-Ford band

Wing-Ford band at ~9910A is a complex of FeH absorption features

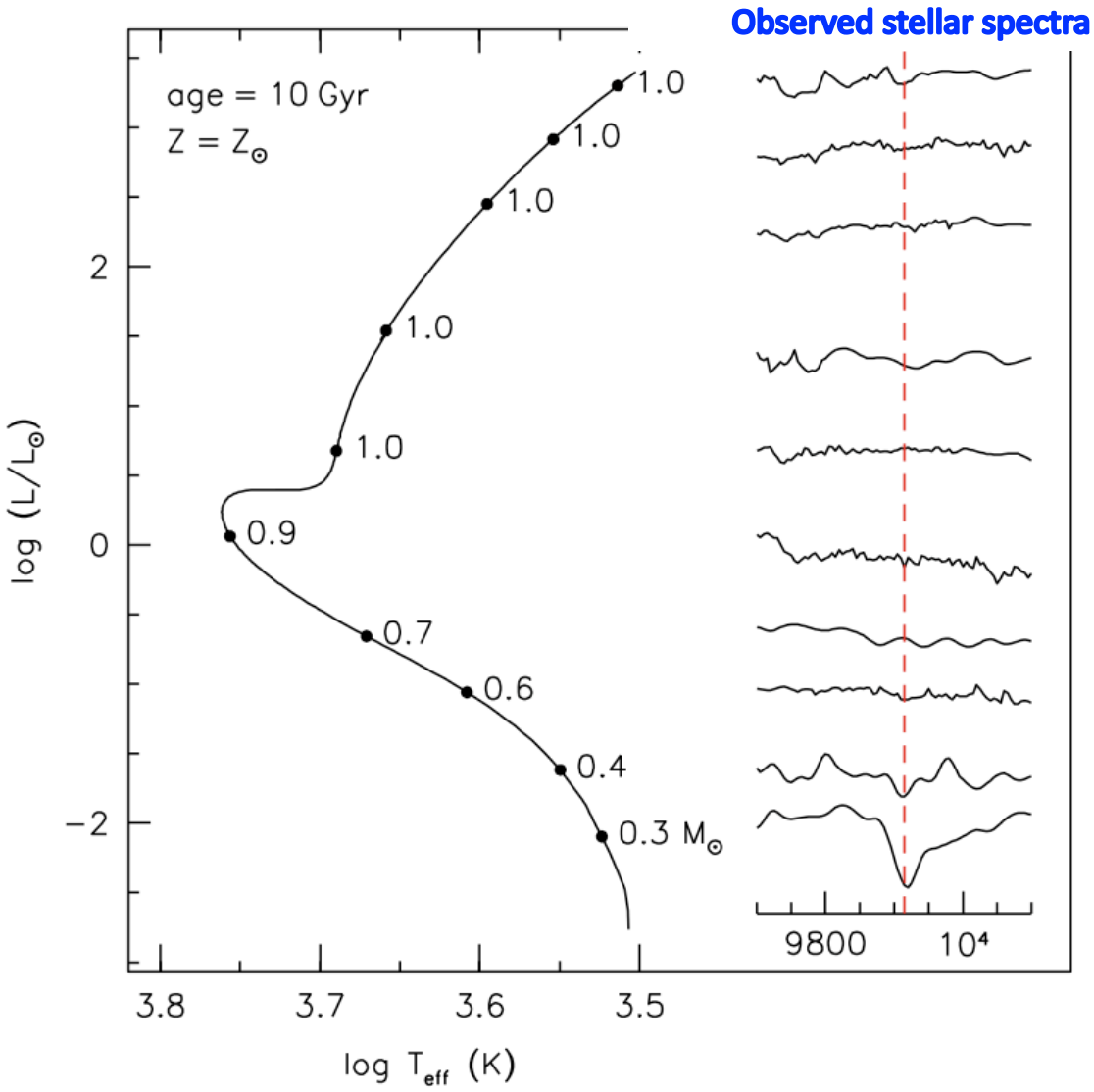
WFB has the desirable property that *it is strong in dwarfs and weak in giants*

- In particular, it is very strong in very late-type dwarfs (>M5)

An ideal feature to constrain the low-mass IMF in unresolved galaxies (e.g., Carter et al. 86, Courture & Hardy 93, Schiavon et al. 97)



Synthesizing integrated light

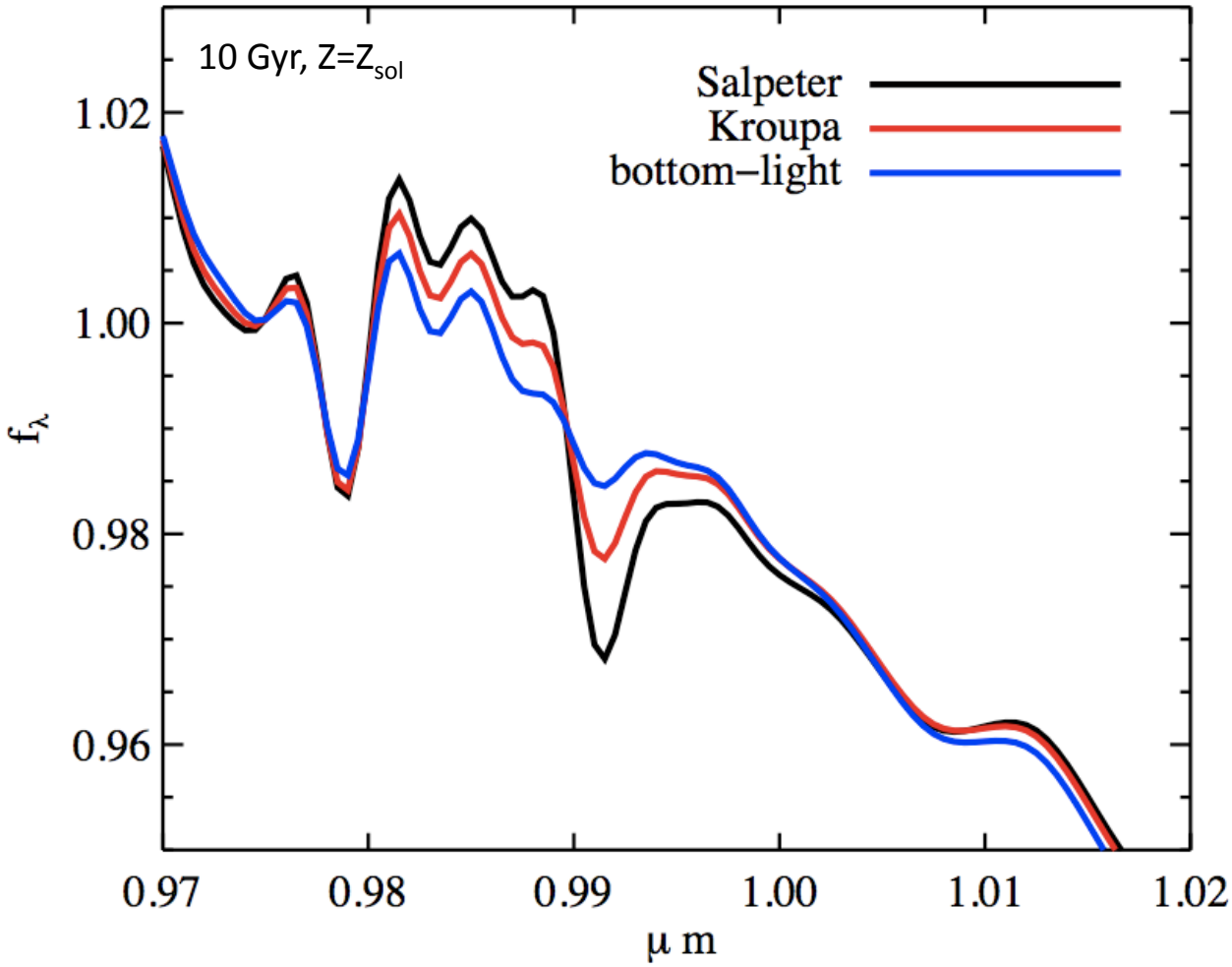


Probing the IMF in integrated light

As expected, requires relative flux calibration to better than 1% in the near-IR

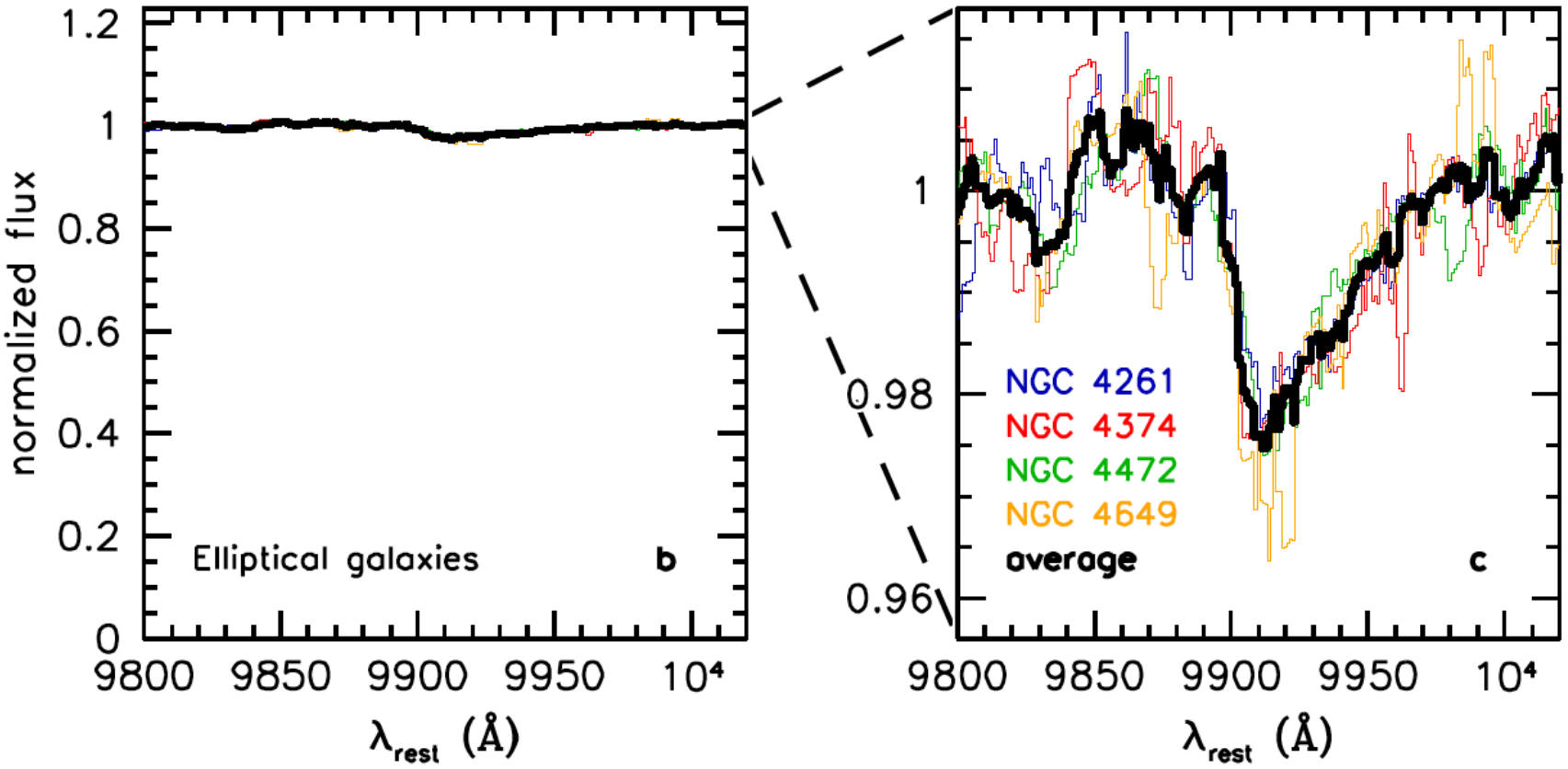
- This was *very* difficult until recent advances in CCD technology

The Wing-Ford band in integrated light



Near-IR spectra of Virgo Es

- LRIS Keck spectra of the four most massive (σ>250 km/s) Virgo Es (excluding M87)
  only 12m exposure per galaxy
- Spectra extracted from central 4" = 350 pc at Virgo
- Relative flux calibration to better than 1%!
  S/N a factor of ~5 higher than previous measurements (Couture & Hardy)

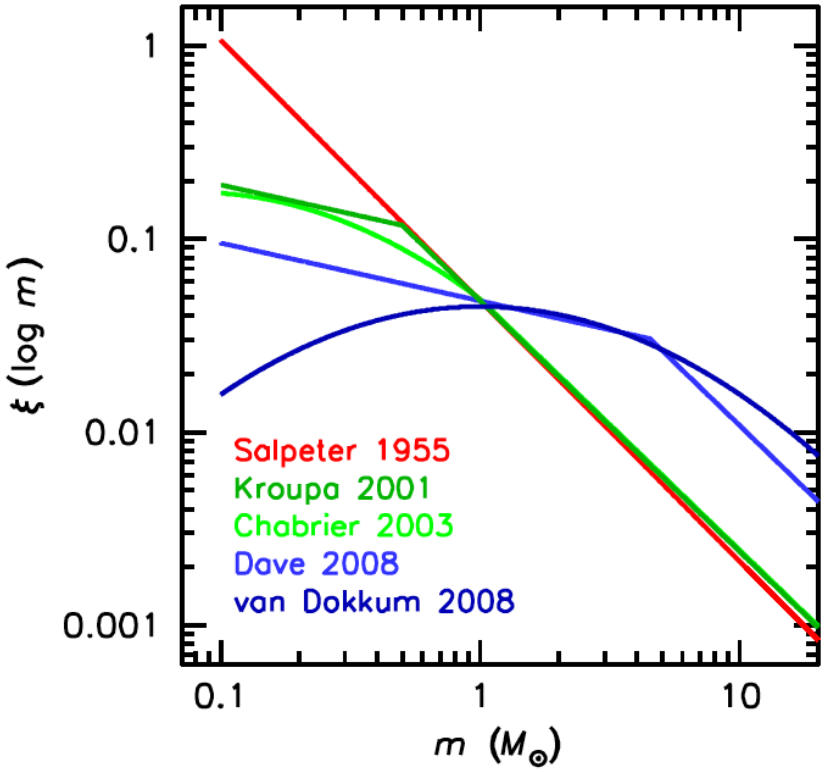


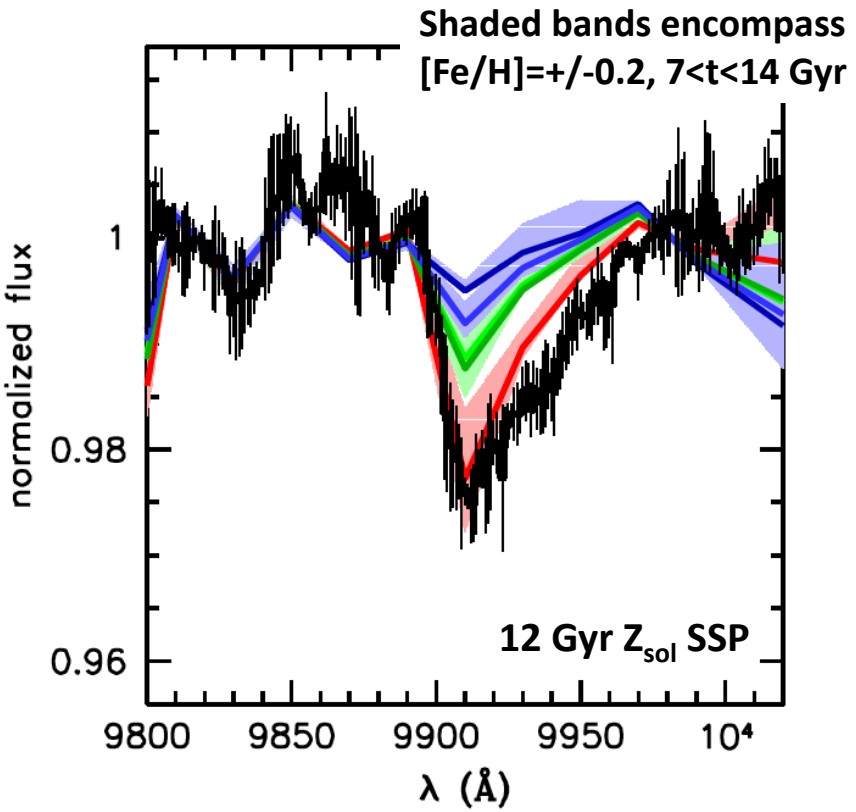
Spectral synthesis of the Wing-Ford band

- An IMF ***at least as steep as Salpeter*** (to ~0.1 M_{sun}) is required to fit the WFB strength for the stacked spectrum of four massive Virgo Es

  Spectral models from "Flexible SPS" (Conroy et al. 2009)

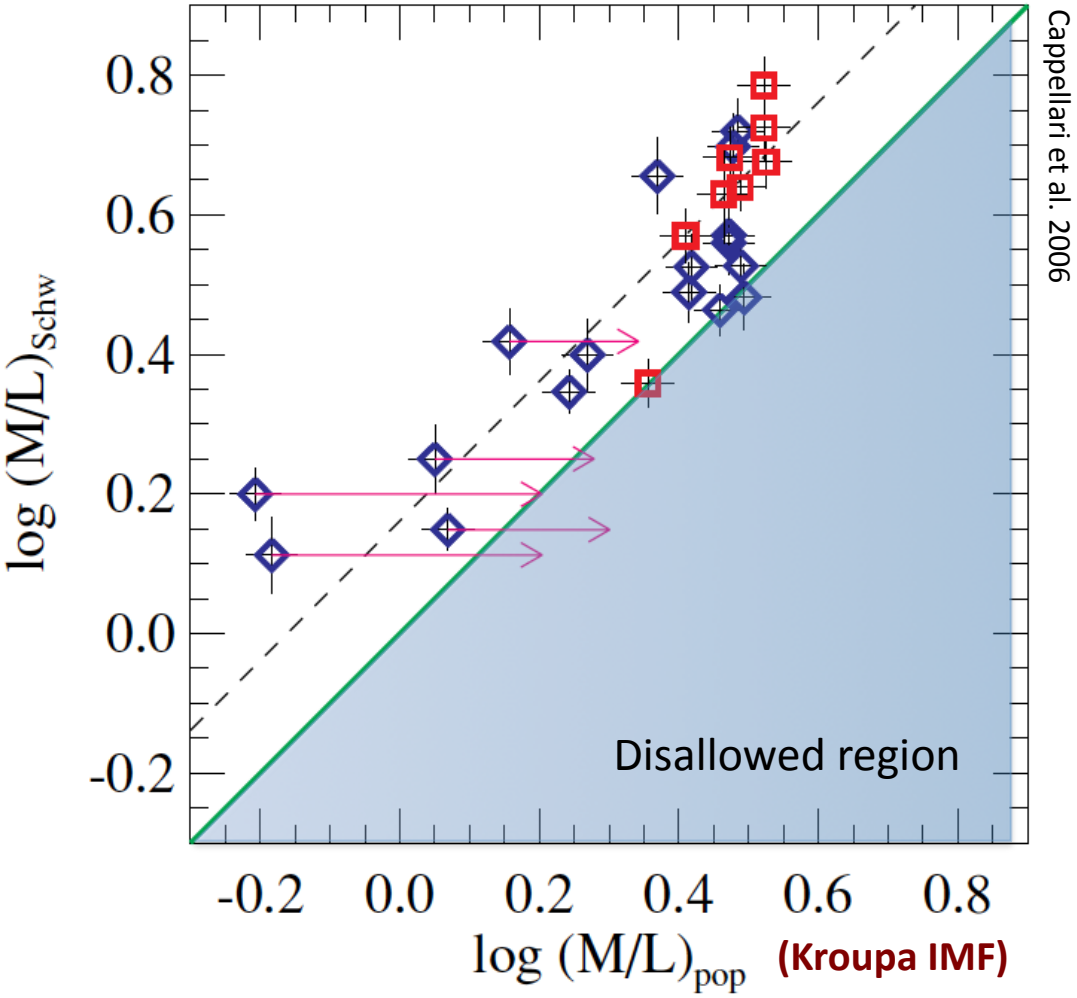
- Very strong evidence for ***a non-universal IMF***





In Context: I

- SAURON IFU spectra have provided accurate, Schwarzschild model-based dynamical masses of local Ellipticals
- Comparison to stellar pop-based masses has lead to the broad-brush conclusion that Salpeter IMFs are disfavored
- In fact, Salpeter IMFs are consistent with the dynamical masses for the slow-rotators
  - ✓ Our sample of Virgo Es are slow-rotators
  - ✓ Different IMFs for slow and fast rotators?



Cappellari et al. 2006

In Context: II

1. Bottom-heavy IMF implies that IMF cannot explain fundamental plane evolution
   - need to re-interpret van Dokkum 2008

2. Structural + chemical properties of SDSS Es (Graves & Faber)
   - Variable IMF disfavored by Graves & Faber
   - Galaxies with σ>250 km/s not included in their analysis. Perhaps bottom-heavy IMFs restricted to the very most massive Es?

3. Dynamical + stellar pop constraints (Auger, Treu et al.)
   - Use weak+strong lensing, velocity dispersions, and stellar pop to constrain IMF
   - Data seem to favor Salpeter-like IMFs, though modeling is complicated

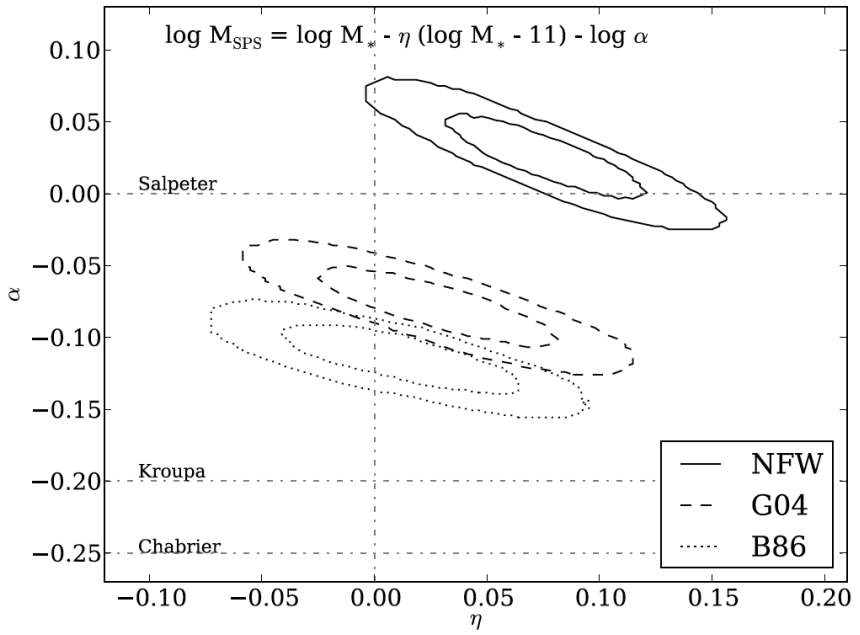
Graves & Faber 2010

Table 4
The Effects of Variable IMFs

	$M_\star/M_{\star,IMF}$ $(M_\odot/M_\odot)$	$\Delta \log I_e$ $(L_\odot\ \mathrm{pc}^{-2})$	[Mg/Fe] (dex)	[Fe/H] (dex)	[Mg/H] (dex)
Observed*	+	−	+	−	−
More very high-mass stars	+	−	+	+	+
More very low-mass stars	+	−	none	−	−

Note. —
*Assuming all variation is due to IMF differences, i.e., $M_{dyn}/M_\star = const.$

Auger et al. 2010



Summary

- The Wing-Ford band provides the most direct constraint on the low-mass end of the IMF, second only to direct star counts
  - Thanks to new red-sensitive CCDs, we are now able to achieve <1% relative flux calibration in the near-IR
  - This allows us to differentiate between Salpeter and Chabrier/Kroupa IMFs in unresolved stellar populations
- Data on 4 massive Virgo Es ***strongly favors an IMF at least as steep as Salpeter*** at M<0.4 M_{sun}
  - The IMF is not universal

- NOAO proposal accepted to target many more Es in Virgo and Coma
  - Radial variation in WFB, variation with stellar age, abundance patterns, σ, etc.
- Measurements of WFB in conjunction with stellar population parameters and dynamical mass estimates will allow the most robust distinction between stars and dark matter within ellipticals