Dissecting the Red Sequence:

Star Formation Histories & Structural Evolution of Early Type Galaxies

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early type galaxy evolution

sCDM:

hierarchical formation
(small things form first)

mass assembly

present-day structure

"Downsizing":

massive galaxies are old, star formation moves to smaller galaxies

star formation history

current stellar population

How are these processes related?

zoo of ETG scaling laws

Early Type Galaxy (ETG) scaling laws:

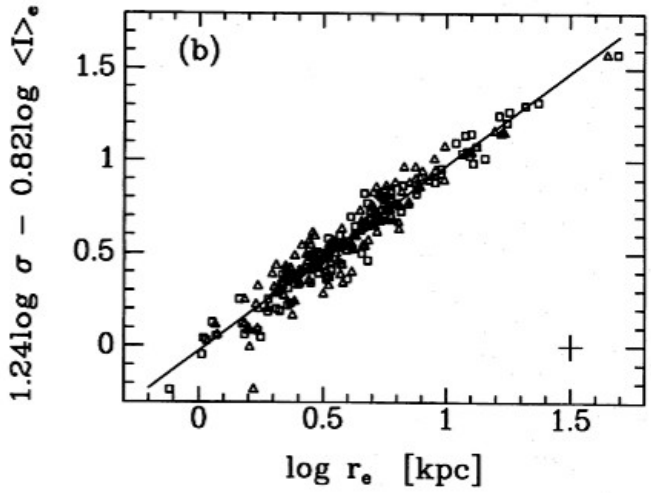
- Fundamental Plane
- Color - Magnitude
- Mg - v
- Metallicity - Luminosity
- M_*/L - L
- *etc…*

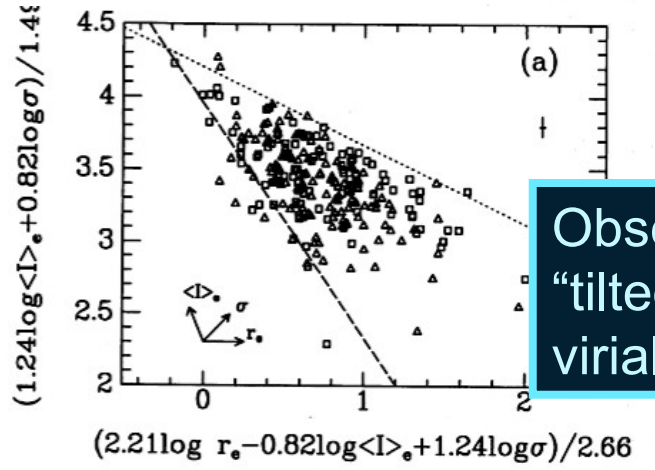
} structure vs. stellar populations

different projections of underlying relation → explore full parameter space

ETG structure: the fundamental plane

Jorgensen et al. (1996)





$R_e / v^{1.24} I_e^{-0.82}$

Definition:

$I_e / L / / R_e^2$

$L / R_e^2 I_e$

Virial Th^m:

$GM / R_e / / ^2$

M_{dyn} v $v^2 R_e$

If M / L = const.:

L v M_{dyn}

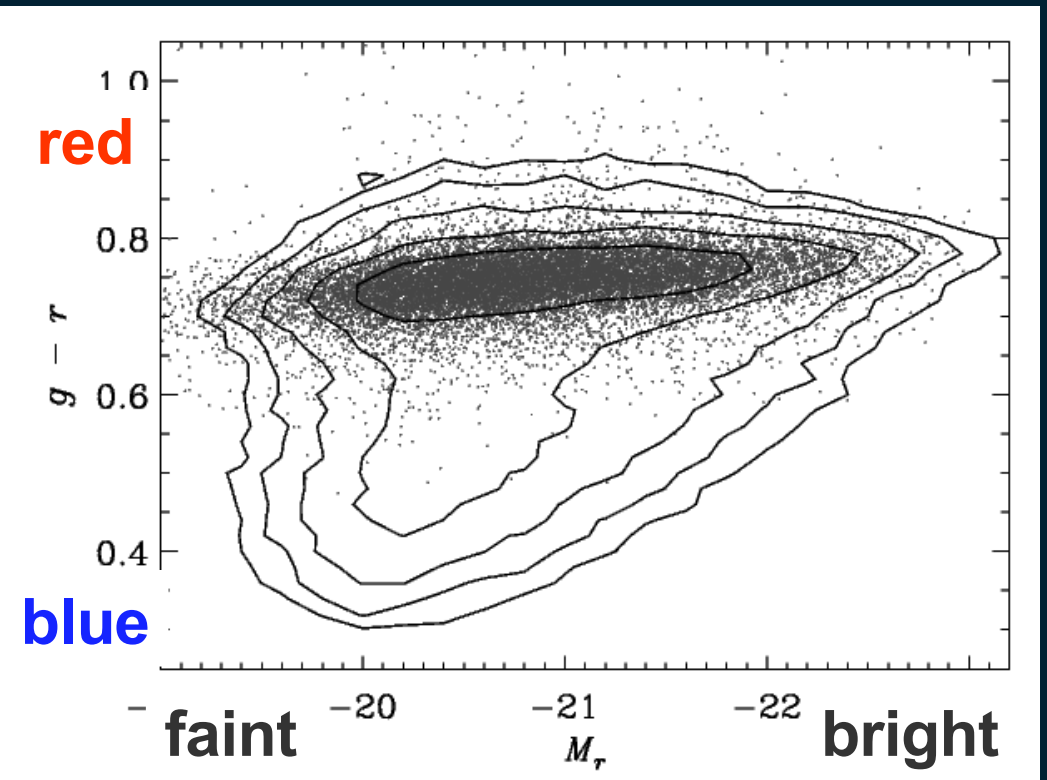
$R_e^2 I_e$ v $v^2 R_e$

$R_e / v^2 I_e^{-1}$

Observed FP is "tilted" from the virial plane

ETG stellar populations

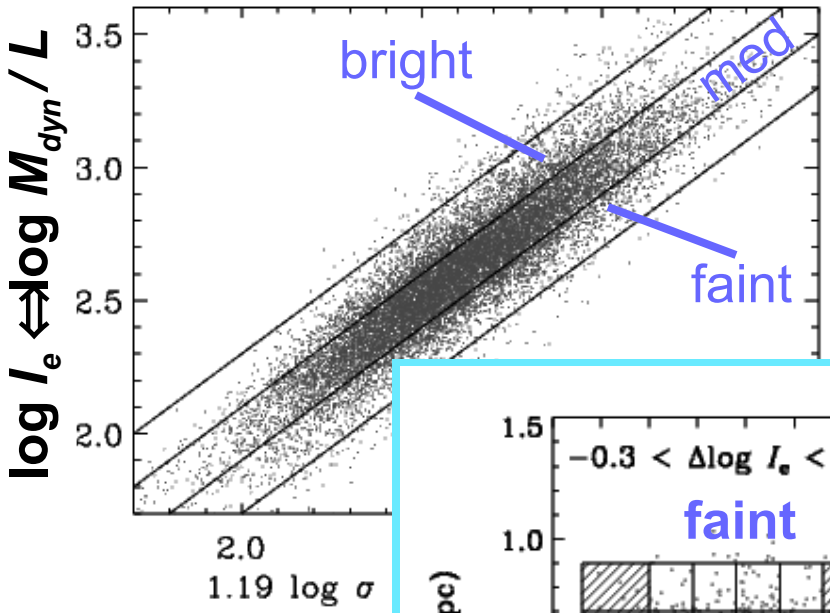
Our sample: ~16,000 SDSS early type galaxy spectra



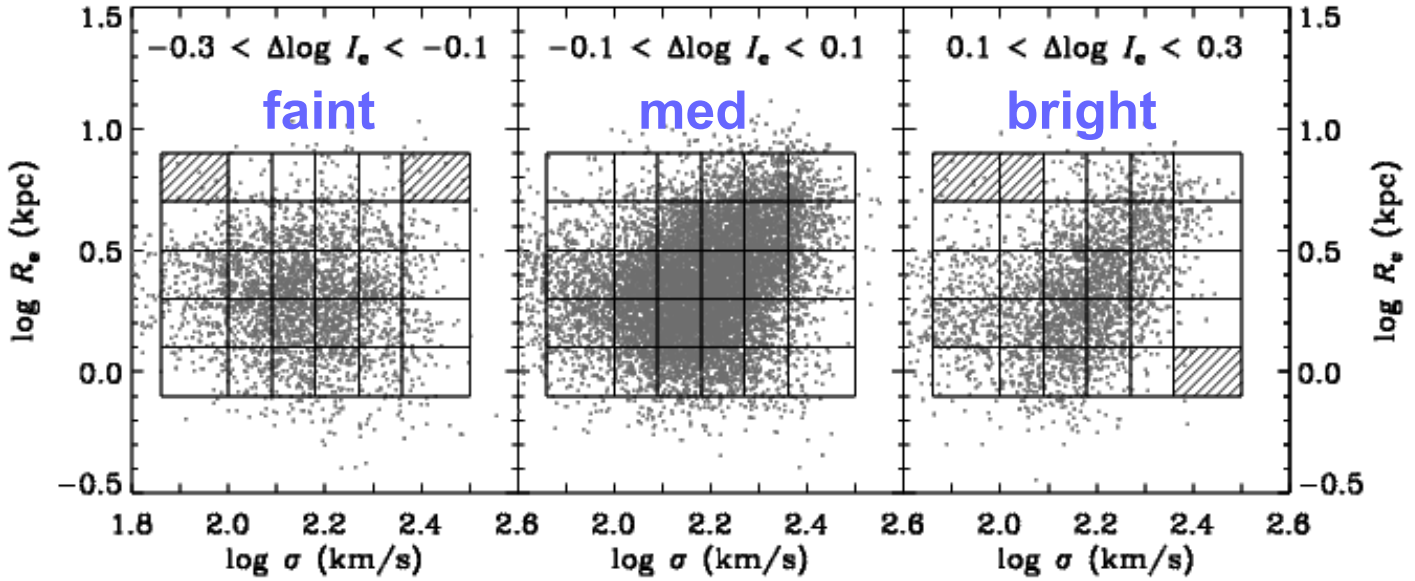
* $0.04 < z < 0.08$
* no emission
  (< 2v in Hv and [OII])
* concentrated light profile
  ($R_{90} / R_{50} > 2.5$)
* no color selection

spectra: $S / N \sim 20$ Å^{-1}

binning galaxies in the fp

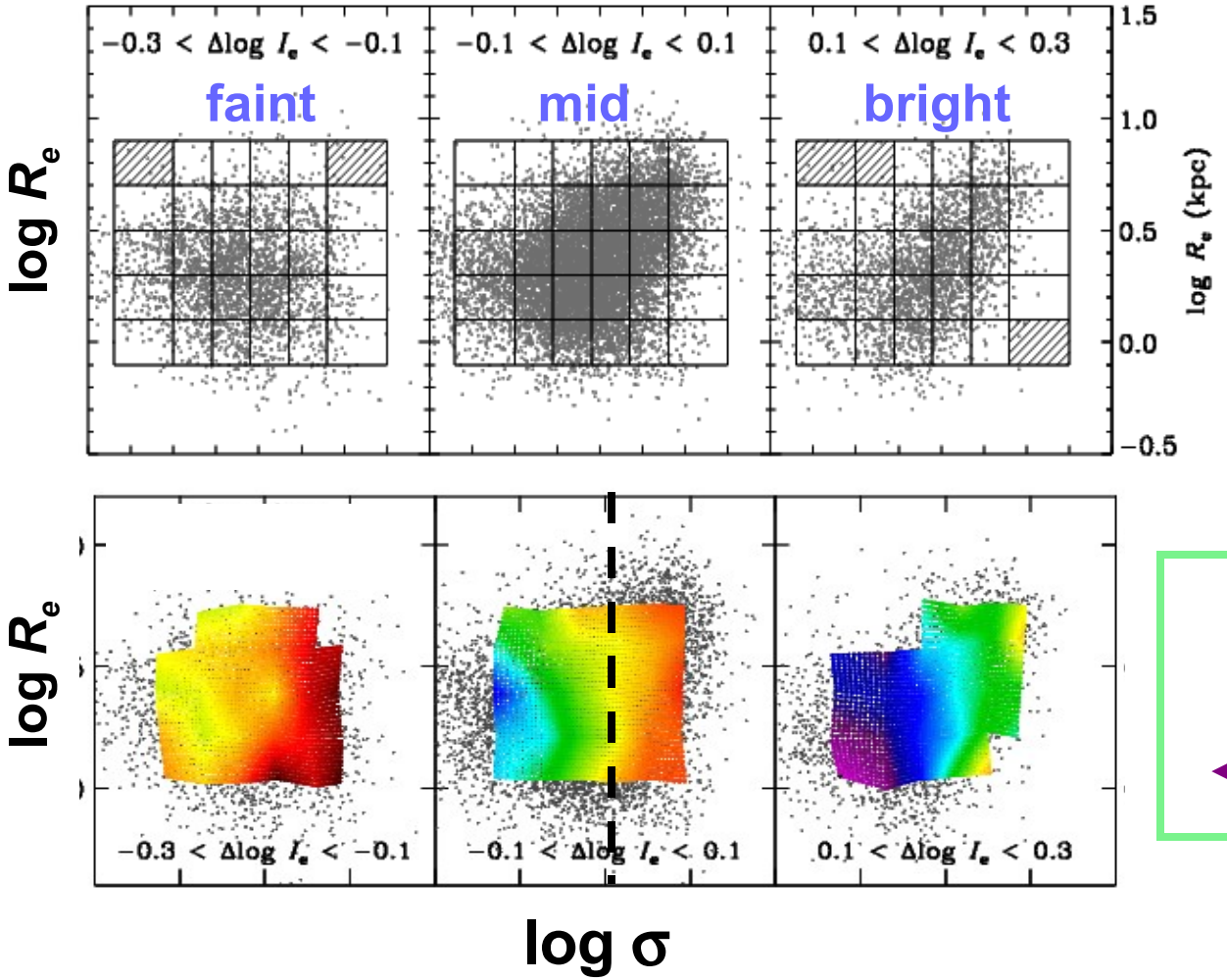


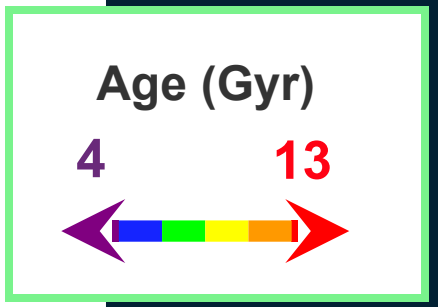
* sort galaxies into bins
* stack spectra of galaxies in each bin
* determine Age, [Fe/H], [Mg/Fe]



GG, Faber, & Schiavon (2008a, submitted to ApJ)

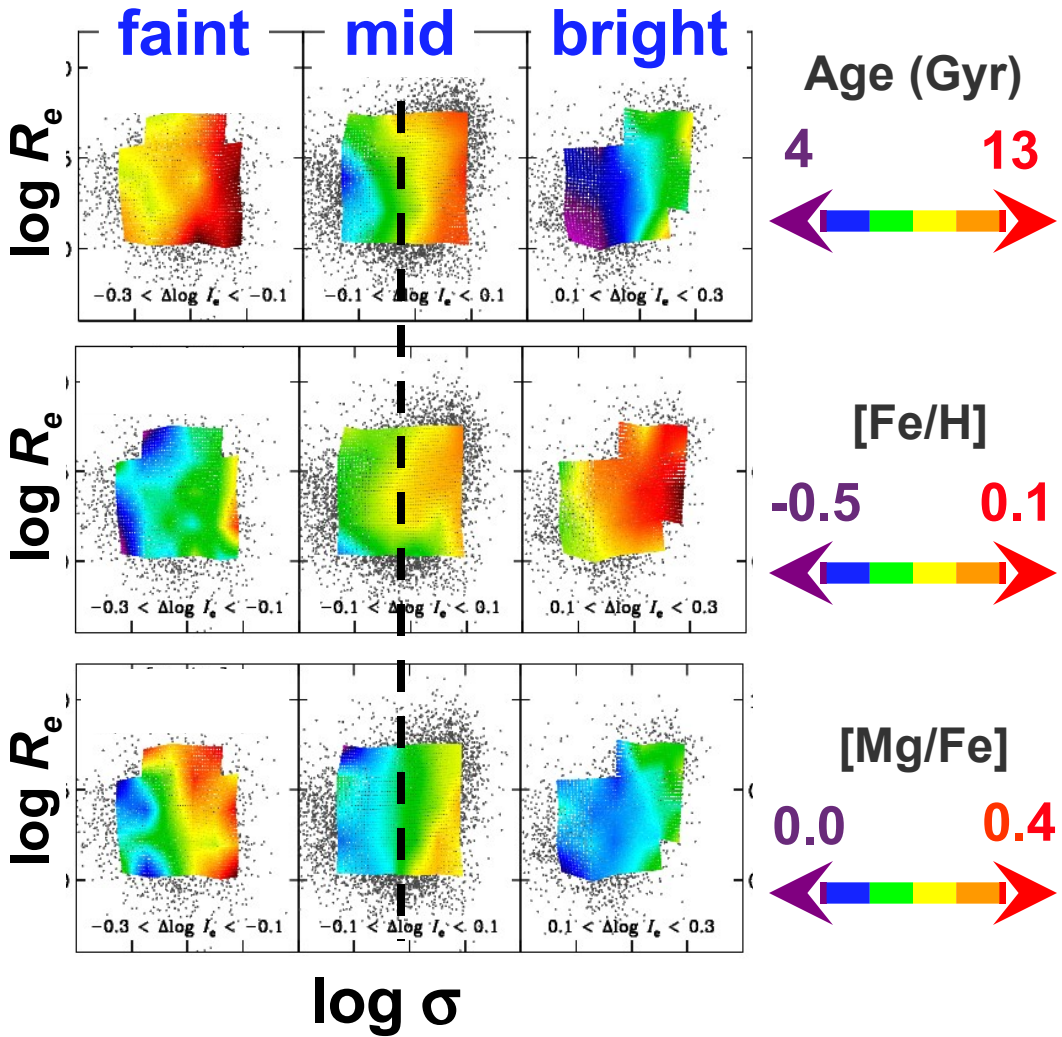
stellar populations across the fp





GG, Faber & Schiavon (2008a)

stellar populations across the fp



Hv, <Fe>, Mg *b*

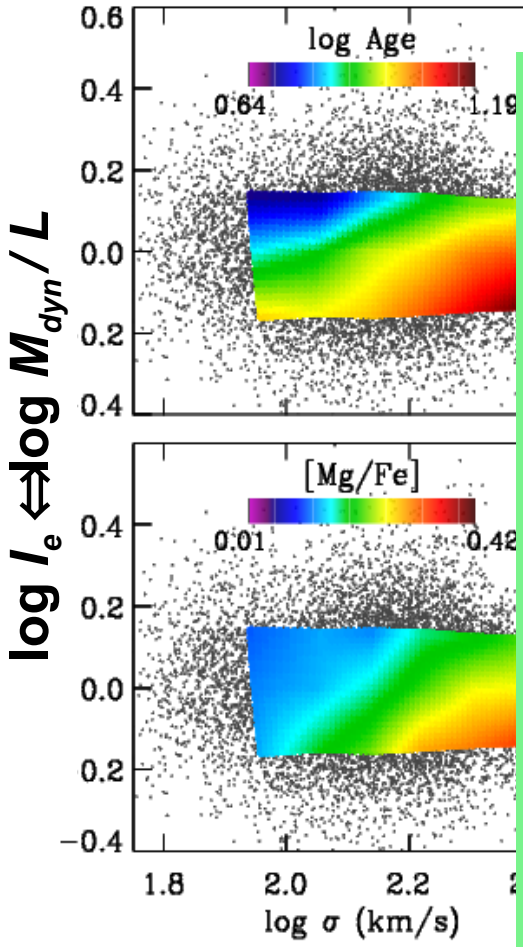
Age, [Fe/H], [Mg/Fe]

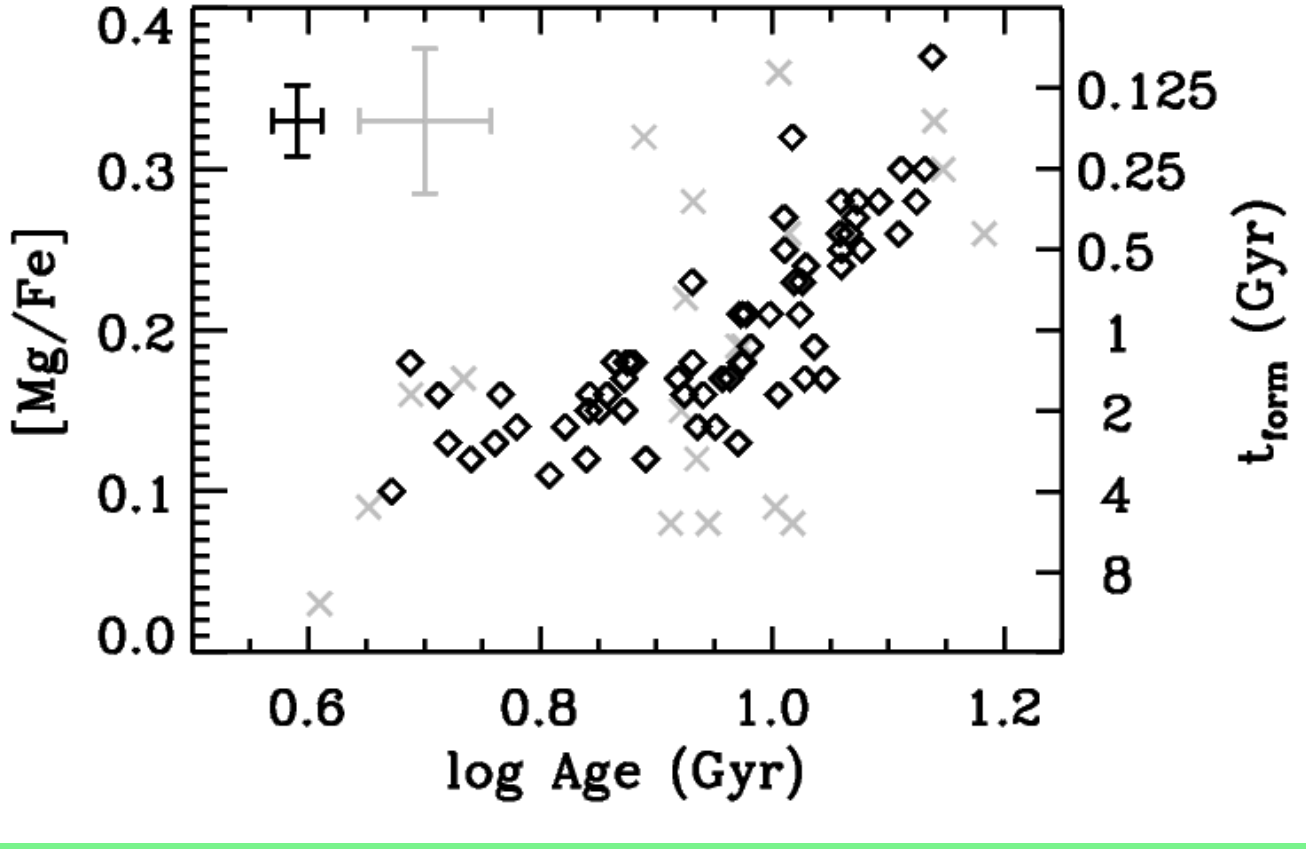
star formation history is independent of R_e

GG, Faber & Schiavon (2008a)

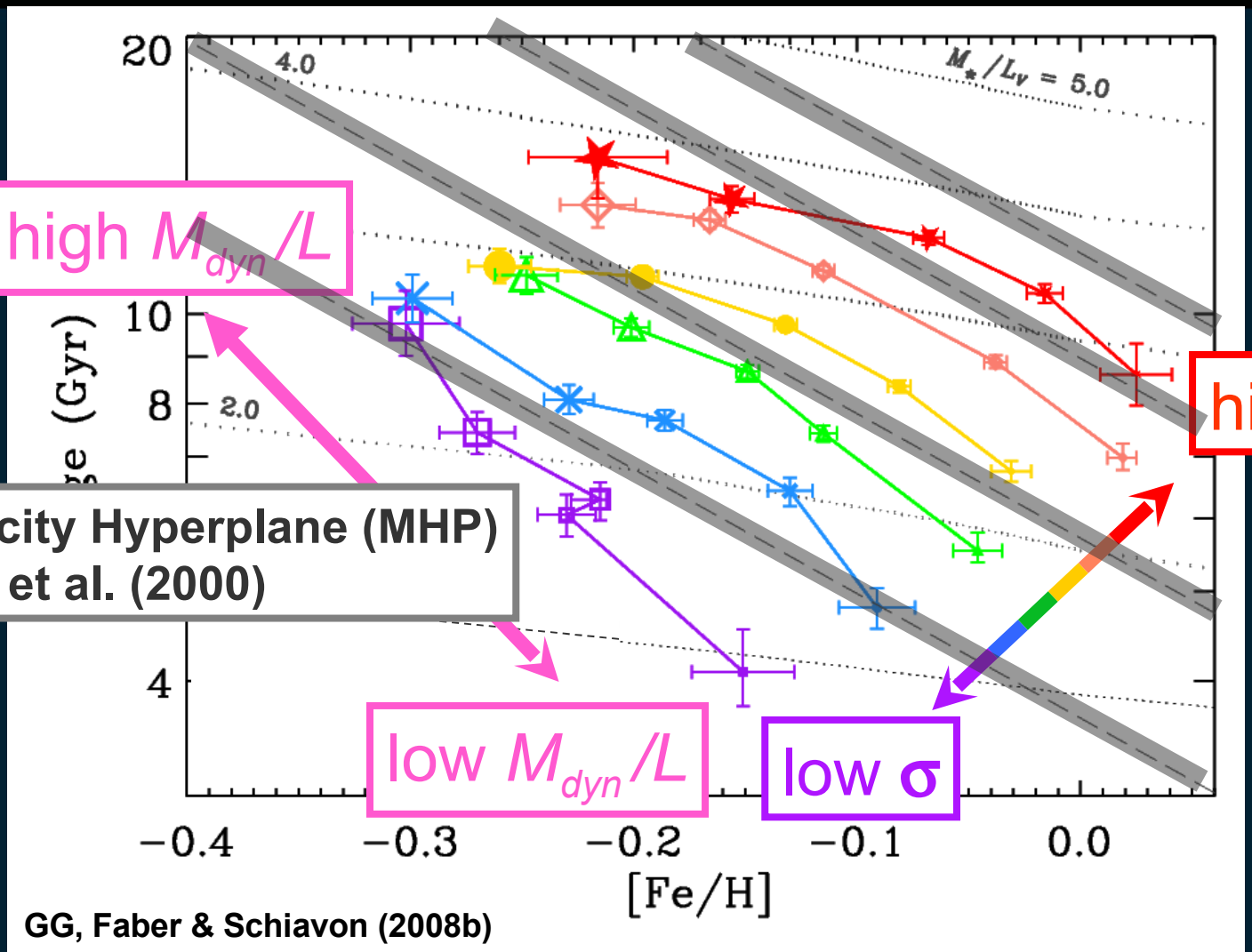
stellar populations across the fp

@ fixed v, galaxies





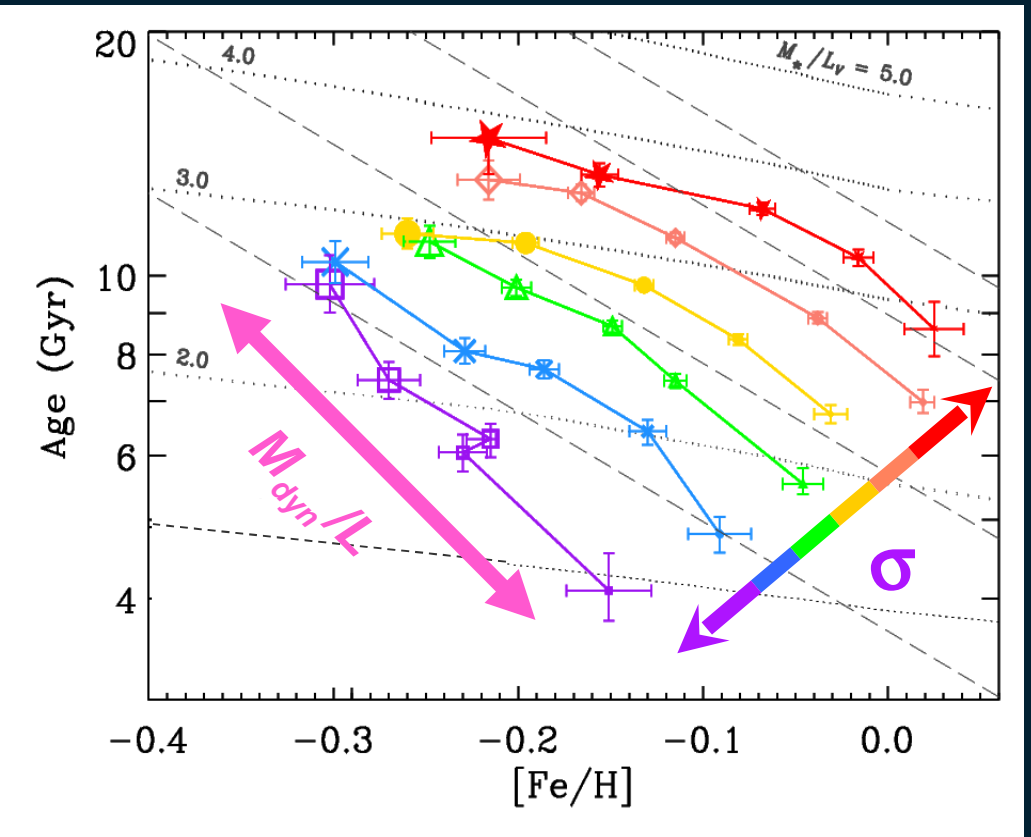
the metallicity hyperplane

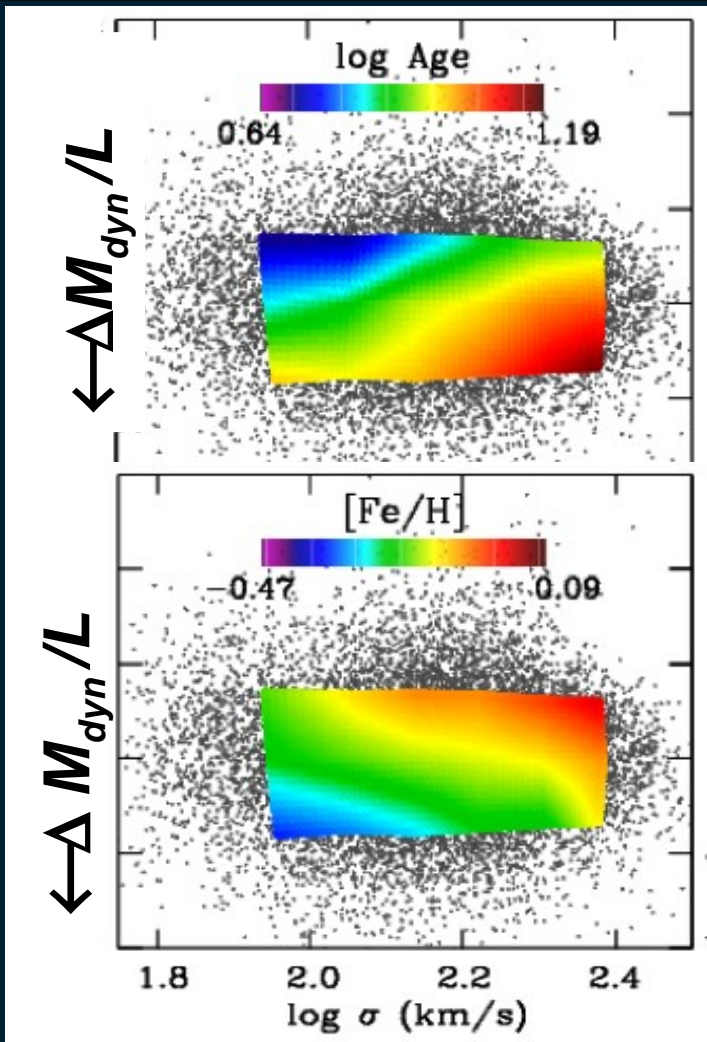


GG, Faber & Schiavon (2008b)

MHP maps onto FP X-section

(Age, [Fe/H]) $\longleftrightarrow$ (v , vM_{dyn}/L)





variations in M_{dyn}/L within R_e

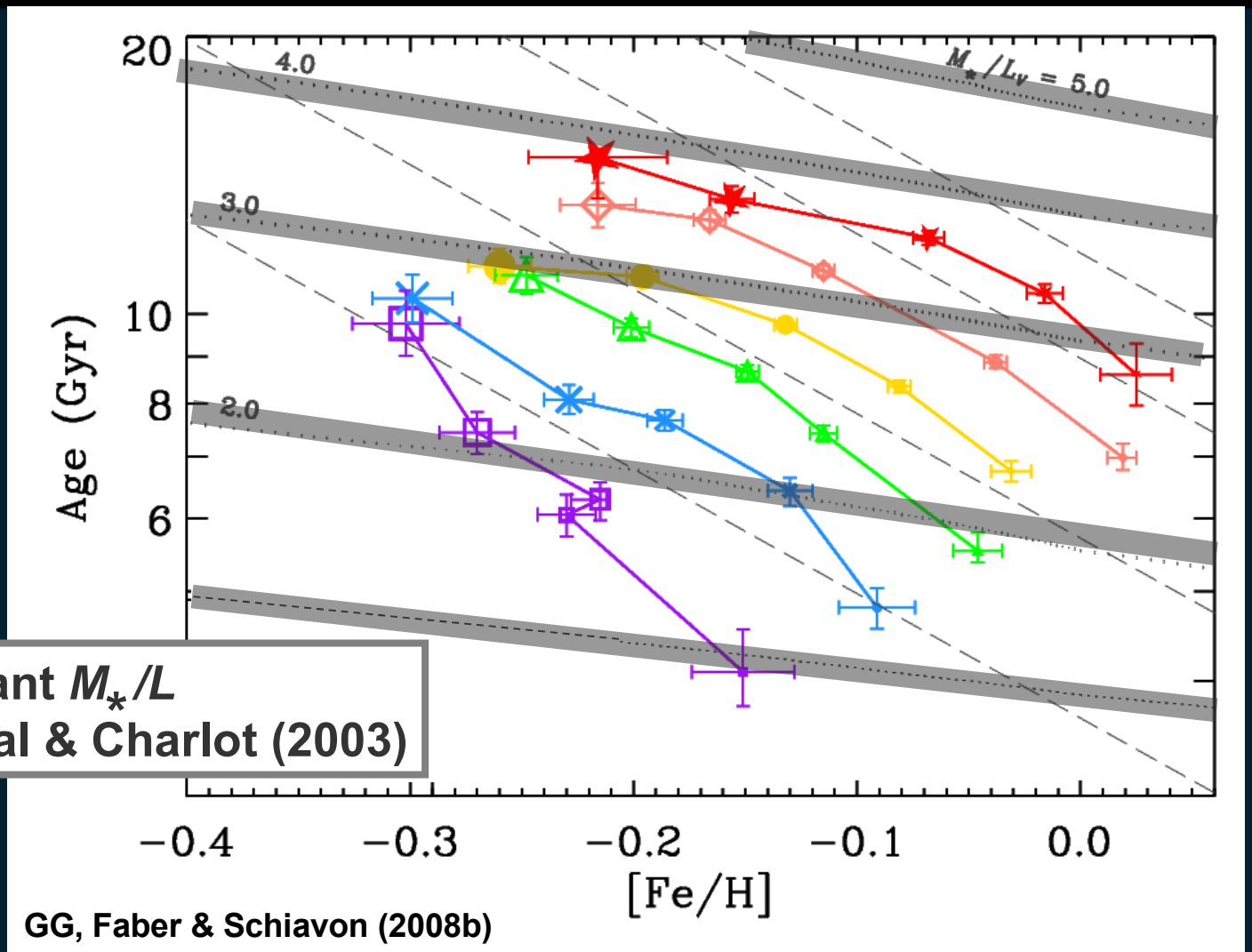
SLACS, SAURON

(cf. Bolton talk)

$$\frac{M_{dyn}}{L} = \cancel{\frac{M_{dyn}}{M_{tot}}} \times \underbrace{\frac{M_{tot}}{M_{\star,\mathrm{real}}}}_{\text{DM fraction}} \times \underbrace{\frac{M_{\star,\mathrm{real}}}{M_{\star,\mathrm{IMF}}}}_{\text{IMF}} \times \underbrace{\frac{M_{\star,\mathrm{IMF}}}{L}}_{\text{stellar population (age, } Z\text{)}}$$

dynamical mass estimator

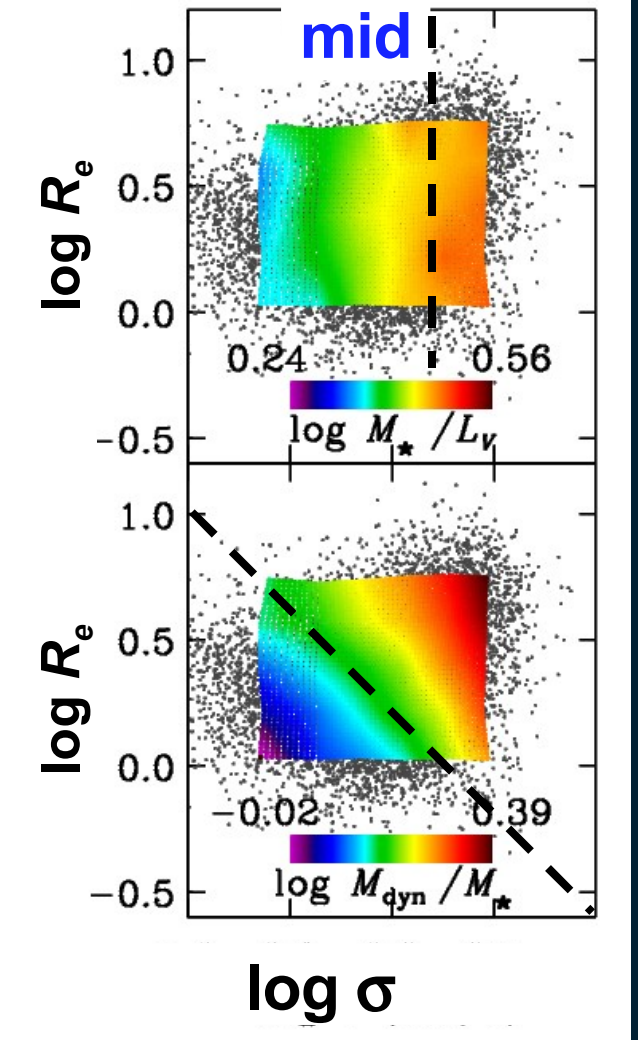
the metallicity hyperplane



constant M_*/L
Bruzual & Charlot (2003)

GG, Faber & Schiavon (2008b)

two tilts of the FP



Stellar Population: $M_\star/L$ s s

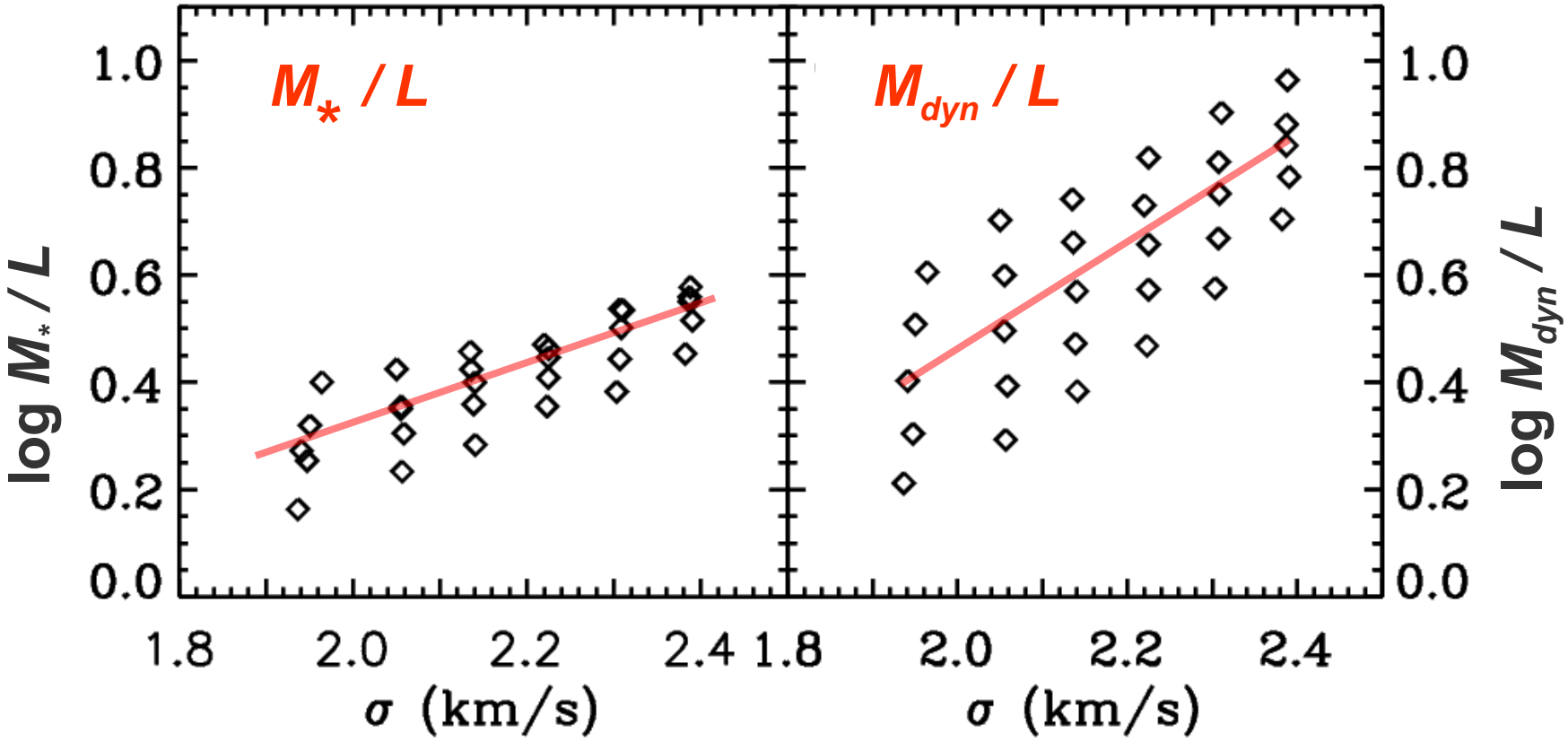
residual tilt:

Dark Matter, IMF: $M_{dyn}/M_\star$ s s^2 R_e n M_{dyn}

GG & Faber (2008)

$M_\star/L$ vs. M_{dyn}/L

GG, Faber, & Schiavon (2008b)



variations in M_{dyn}/L within R_e

SLACS, SAURON

(cf. Bolton talk)

not enough

$$\frac{M_{dyn}}{L} = \cancel{\frac{M_{dyn}}{M_{tot}}} \times \frac{M_{tot}}{M_{\star,real}} \times \frac{M_{\star,real}}{M_{\star,IMF}} \times \frac{M_{\star,IMF}}{L}$$

dynamical mass estimator

DM fraction

IMF

stellar population (age, Z)

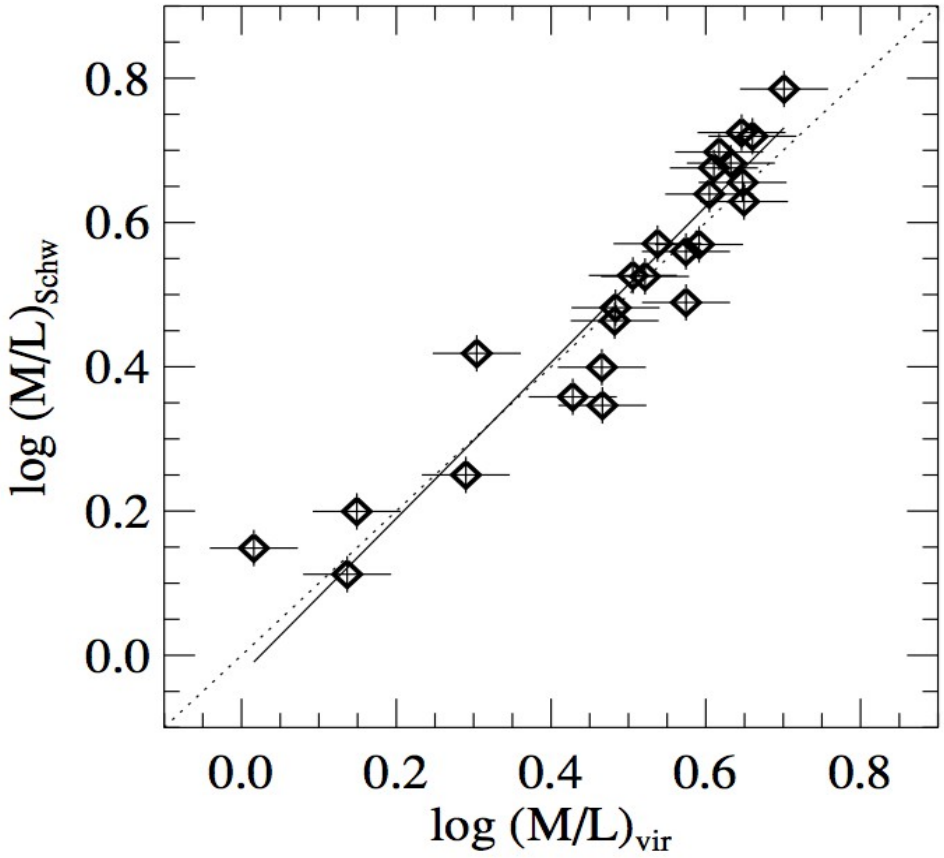
conclusions

- We have mapped stellar population properties in 3-D FP space
- ETG star formation histories = 2-D parameter space (variations with v and with M_{dyn}/L)
- 2-D family of star formation histories = X-section of FP
- Stellar population effects cannot account for observed tilt of the FP, or the observed thickness of the FP

→ variations in the IMF or central DM fraction required

dynamical mass estimator

Cappellari et al. (2006) - IFU data, dynamical models



Bolton et al. (2007) - strong lensing