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?
Early Type Galaxy (ETG) scaling laws:

- Fundamental Plane
- Color - Magnitude
- 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)

Definition:

\[ \frac{I_e}{L} \propto \frac{R_e}{R_e}^2 \]

\[ \frac{L}{R_e^2 I_e} \]

Virial Thm:

\[ \frac{GM}{R_e} \propto v^2 \]

\[ M_{dyn} \propto v^2 R_e \]

If \( M/L = \text{const.} \):

\[ L \propto M_{dyn} \]

\[ R_e^2 I_e \propto v^2 R_e \]

\[ R_e \propto v^2 I_e^{-1} \]

Observed FP is “tilted” from the virial plane

\[ \frac{R_e}{v^{1.24}} I_e \propto -0.82 \]
ETG stellar populations

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

- $0.04 < z < 0.08$
- no emission ($< 2\nu$ in H\textsc{v} and [O\textsc{ii}])
- concentrated light profile ($R_{90}/R_{50} > 2.5$)
- no color selection

spectra: $S/N \sim 20\ \text{Å}^{-1}$
Binning galaxies in the fp

- Sort galaxies into bins
- Stack spectra of galaxies in each bin
- Determine Age, [Fe/H], [Mg/Fe]

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

\[ \log \frac{L}{e} \equiv \log \frac{M_{\text{dyn}}}{L} \]

• younger ages
• higher $\left[ \text{Fe} / \text{H} \right]$
• lower $\left[ \text{Mg} / \text{Fe} \right]$
• longer duration star formation
the metallicity hyperplane

Metallicity Hyperplane (MHP)
Trager et al. (2000)

high $M_{\text{dyn}}/L$
low $M_{\text{dyn}}/L$

high $\sigma$
low $\sigma$
MHP maps onto FP X-section

\[(\text{Age, [Fe/H]}) \leftrightarrow (v, v M_{\text{dyn}} / L)\]
variations in $M_{\text{dyn}}/L$ within $R_e$

\[
\frac{M_{\text{dyn}}}{L} = \frac{M_{\text{dyn}}}{M_{\text{tot}}} \times \frac{M_{\text{tot}}}{M_{\text{real}}} \times \frac{M_{\star,\text{IMF}}}{L}
\]

- Dynamical mass estimator
- DM fraction
- IMF
- Stellar population (age, Z)

SLACS, SAURON
(cf. Bolton talk)
the metallicity hyperplane

constant $M_\star/L$
Bruzual & Charlot (2003)

GG, Faber & Schiavon (2008b)
two tilts of the FP

Stellar Population: $M_*/L$

residual tilt:

Dark Matter, IMF: $M_{dyn}/M_*$

GG & Faber (2008)
$M_*/L$ vs. $M_{dyn}/L$

GG, Faber, & Schiavon (2008b)
variations in $M_{dyn}/L$ within $R_e$

$$\frac{M_{dyn}}{L} = \frac{M_{dyn}}{M_{tot}} \times \frac{M_{\star, real}}{M_{\star, IMF}} \times \frac{L}{L_{DM fraction}}$$

SLACS, SAURON
(cf. Bolton talk)

dynamical mass estimator

not enough

stellar population (age, Z)
• 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
Cappellari et al. (2006) - IFU data, dynamical models
Bolton et al. (2007) - strong lensing