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NASA, ESA, M. Postman (STScI) & CLASH Team

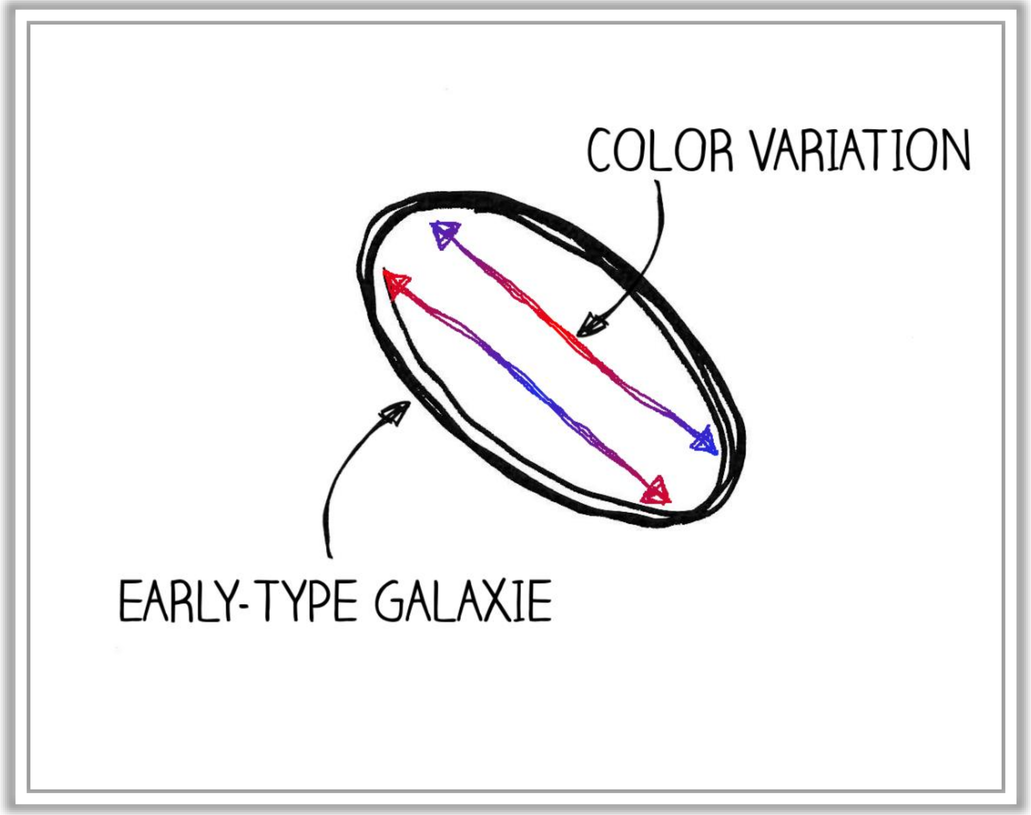
INTERNAL COLOR GRADIENTS AND DISTRIBUTIONS OF STELLAR POPULATIONS OF EARLY-TYPE GALAXIES IN THE CLASH MACS 1206 CLUSTER

V. Marian, B. Ziegler

Introduction, Data, Analysis,…

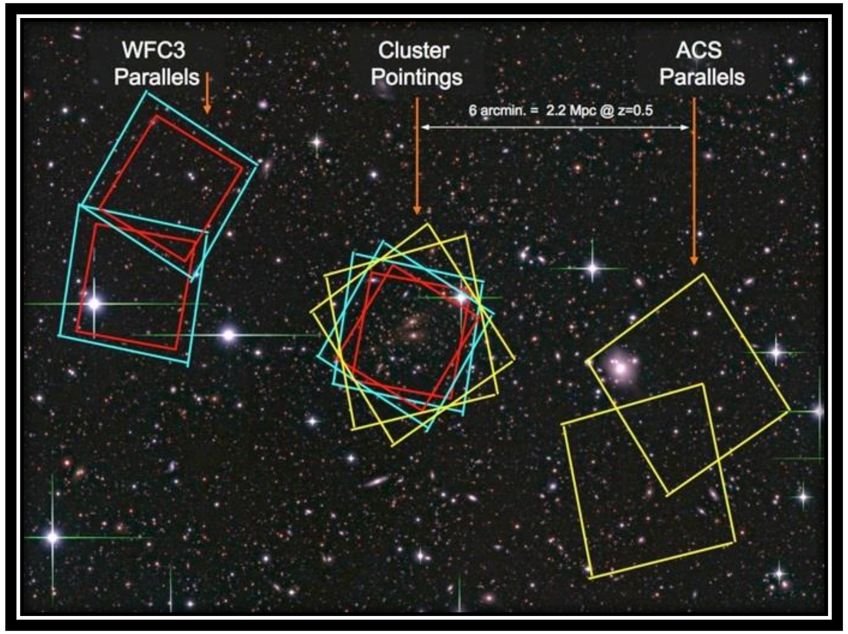
INTRODUCTION

- Evolution and mass assembly of **early-type** galaxies in clusters
- **Variation** in color = **variation** of stellar population
- Due to **age** and/or **metallicity**?
- → comparison with models: **constraints** on possible evolutionary scenarios



DATA

- **CLASH** (Postman et al., 2012):
  - „**C**luster **L**ensing **A**nd **S**upernova survey with **H**ubble“
  - 25 X-ray selected, massive clusters
  - 0.2 ≲ z ≲ 0.9
  - **16** HST bands (ACS, WFC3/UVIS/IR)
- **CLASH –VLT** (Rosati et al., 2014):
  - Spectroscopic follow-up for 13 clusters
  - 0.2 ≲ z ≲ 0.6
  - ~500 – 1000 members/cluster
- **MACS J1206.2-0847** at z ~ **0.44**



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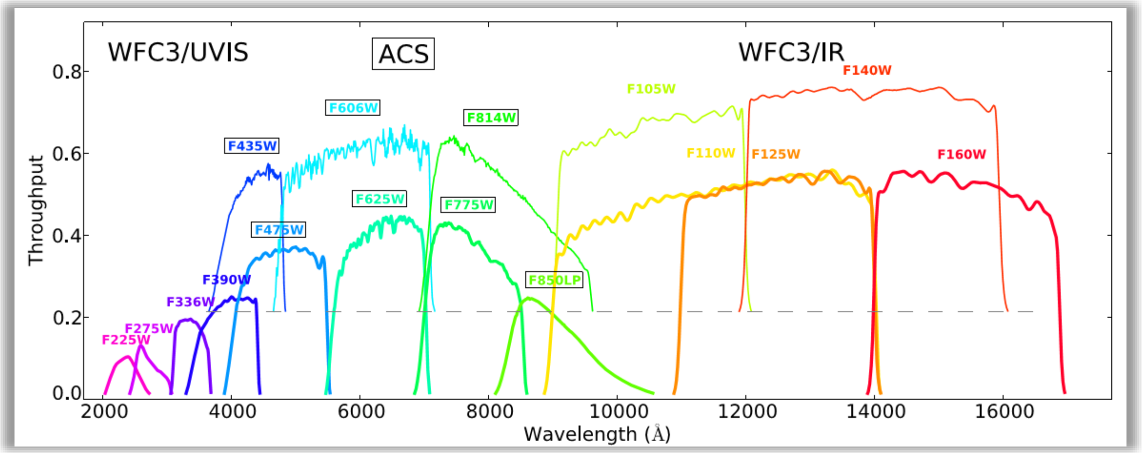
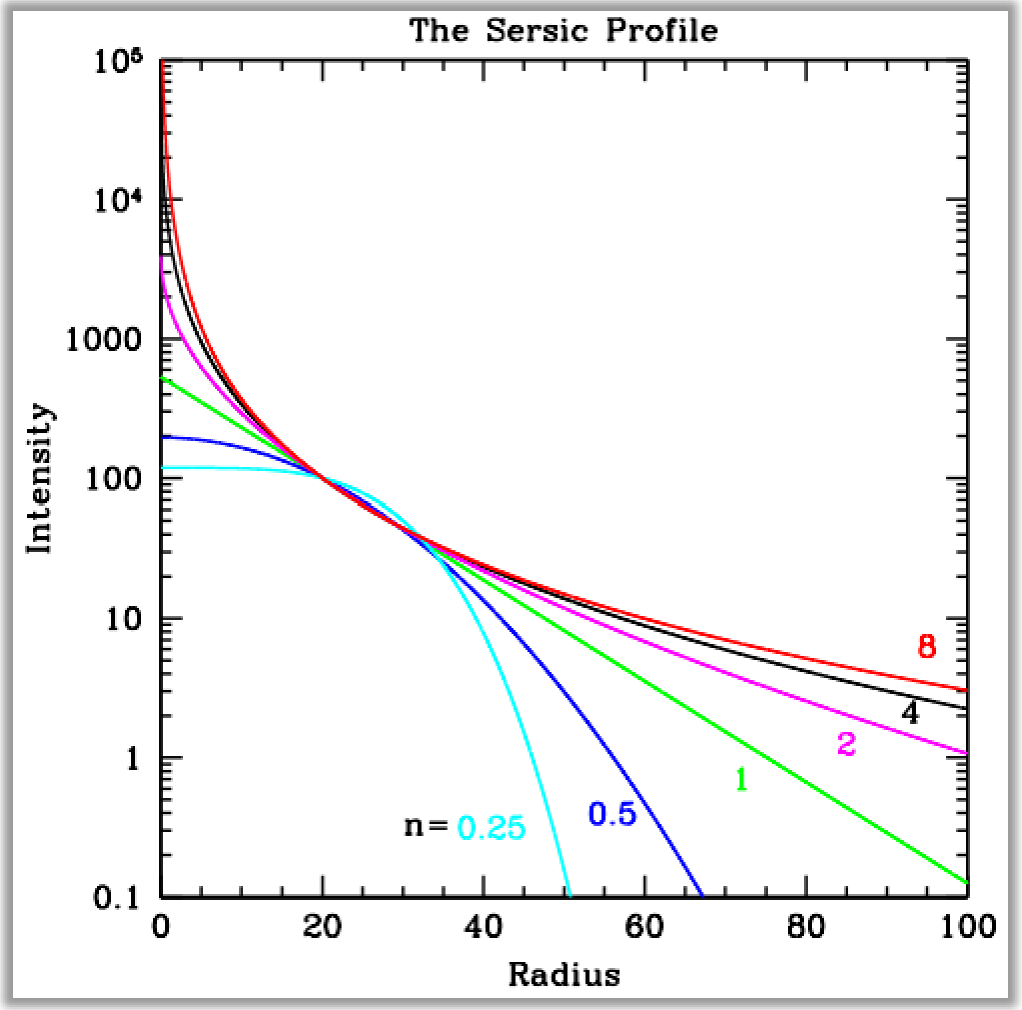


Postman et al., 2012

ANALYSIS

- **Simultaneous multi-band fitting of intensity profile**
- **MegaMorph** (Häußler et al., 2013)
- Based on Galapagos (Barden et al., 2012)
- Combining Source Extractor & Galfit(-M)
- Sérsic profile (early-type: $n > 2.5$)
- Increases S/N:
  - Lower mag-limit
  - Enhances stability
- One component fit



Peng et al., 2010

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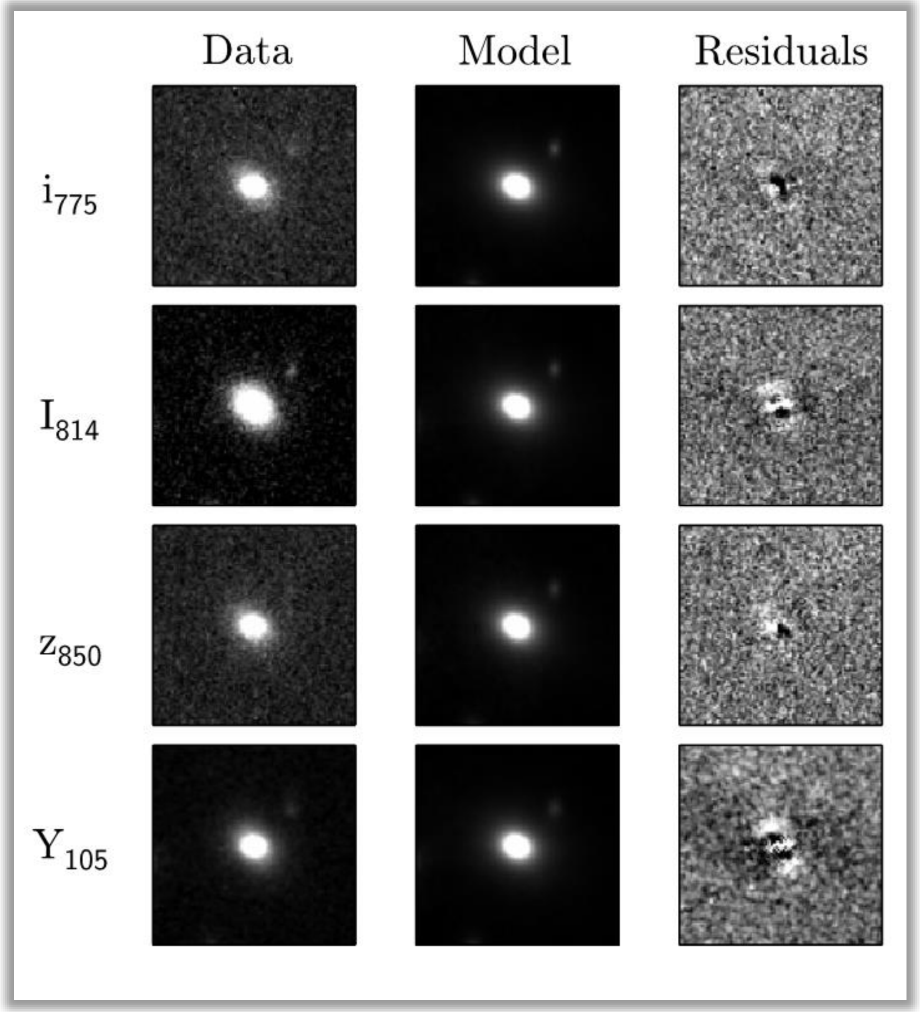

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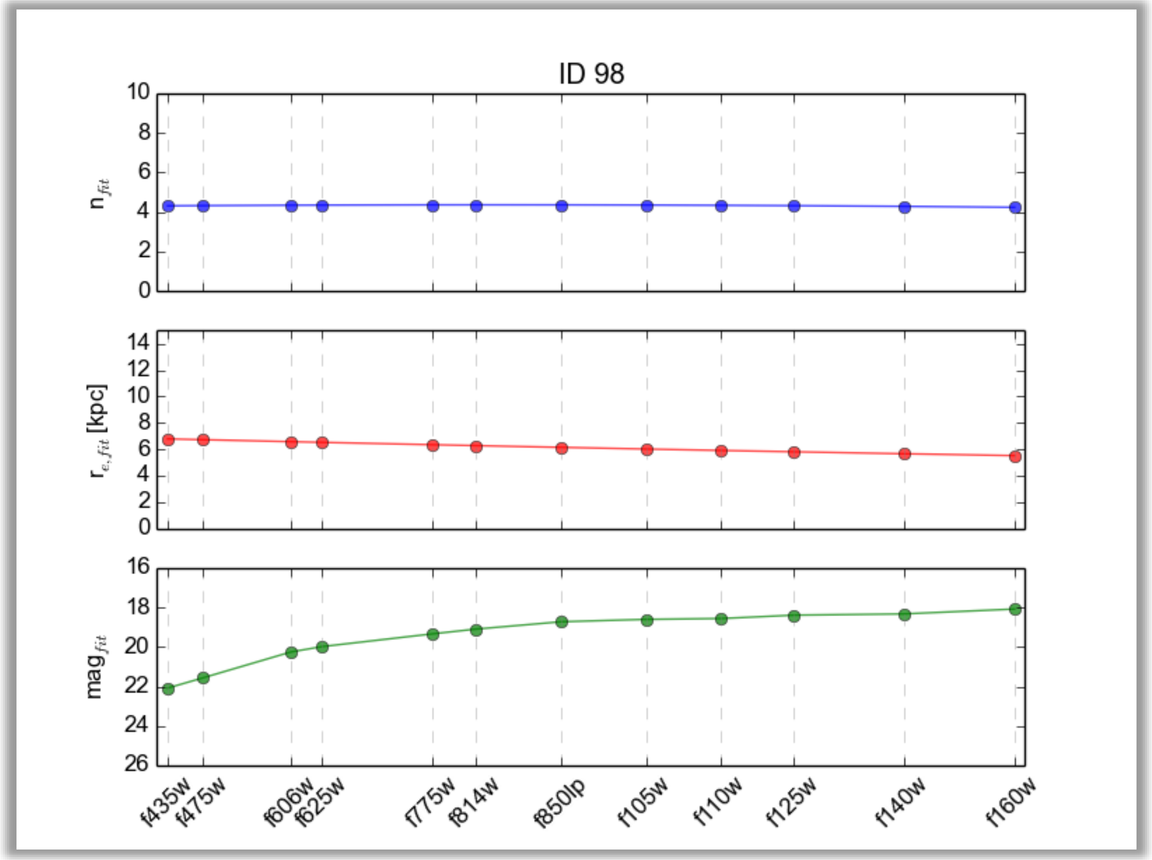
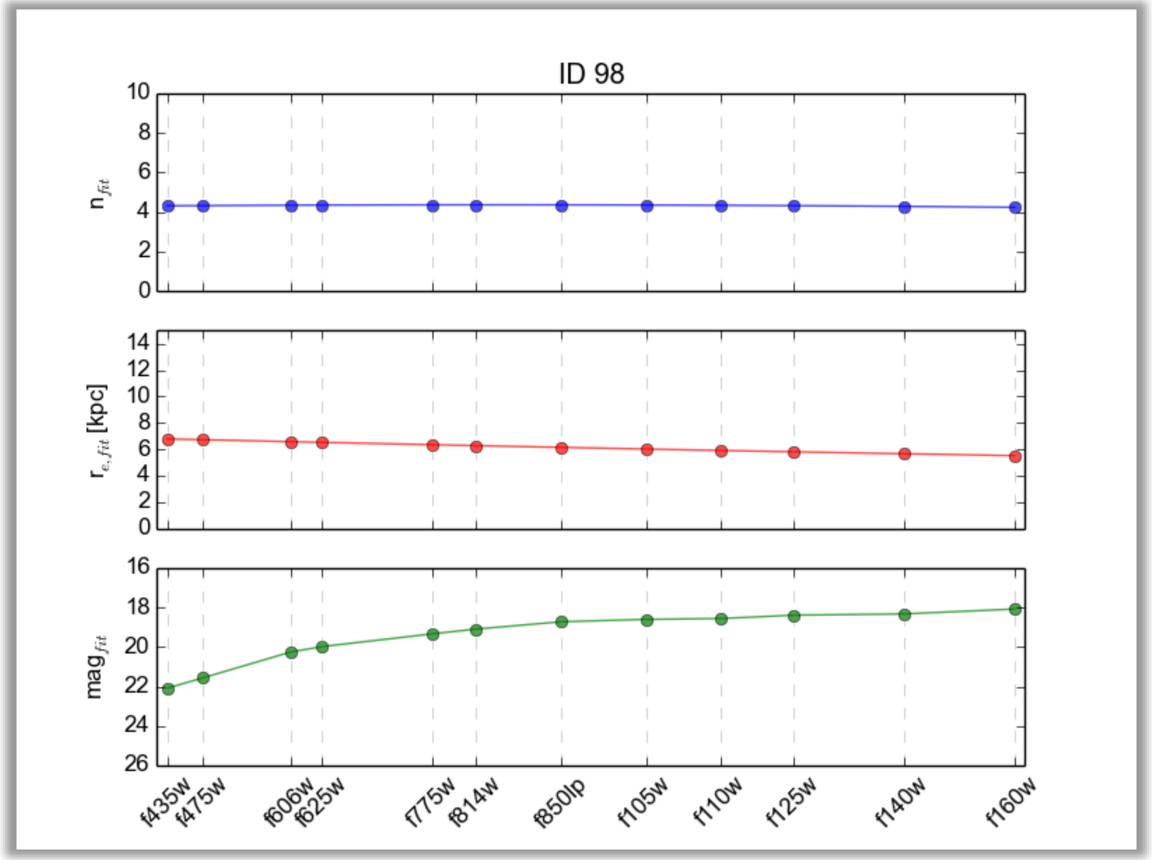


ANALYSIS

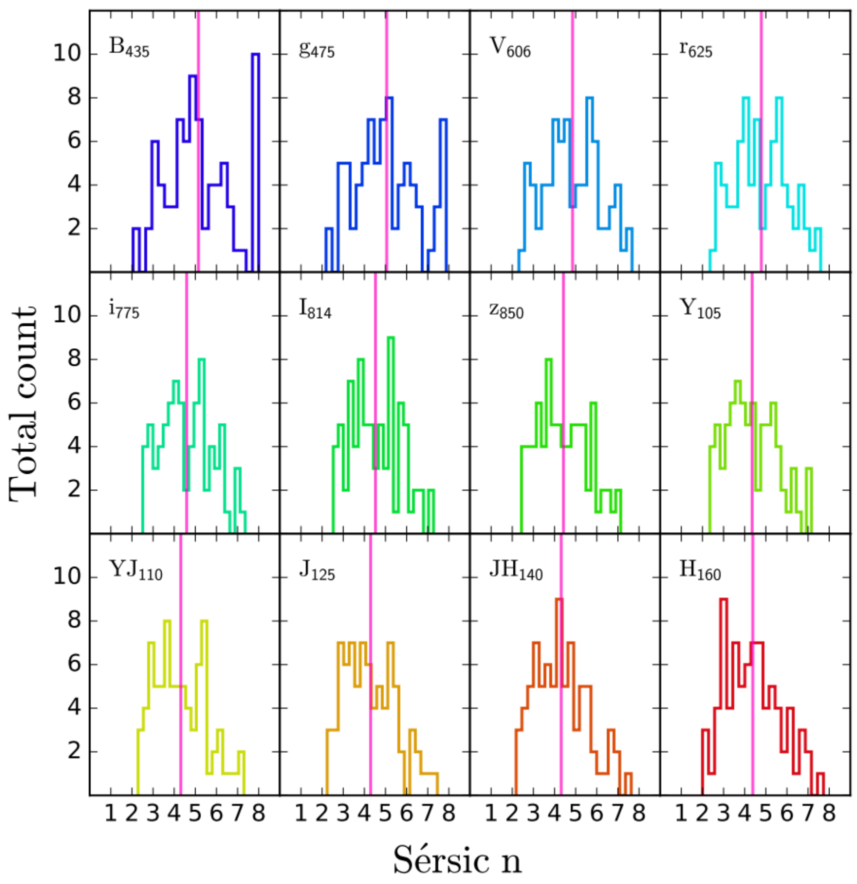
- 79 galaxies
- With $\mathbf{m_{tot}}$, Sérsic index $\mathbf{n}$ and effective radius $\mathbf{r_e}$ → surface brightness profiles
- → color profiles
- Logarithmic slope of profile → color gradient

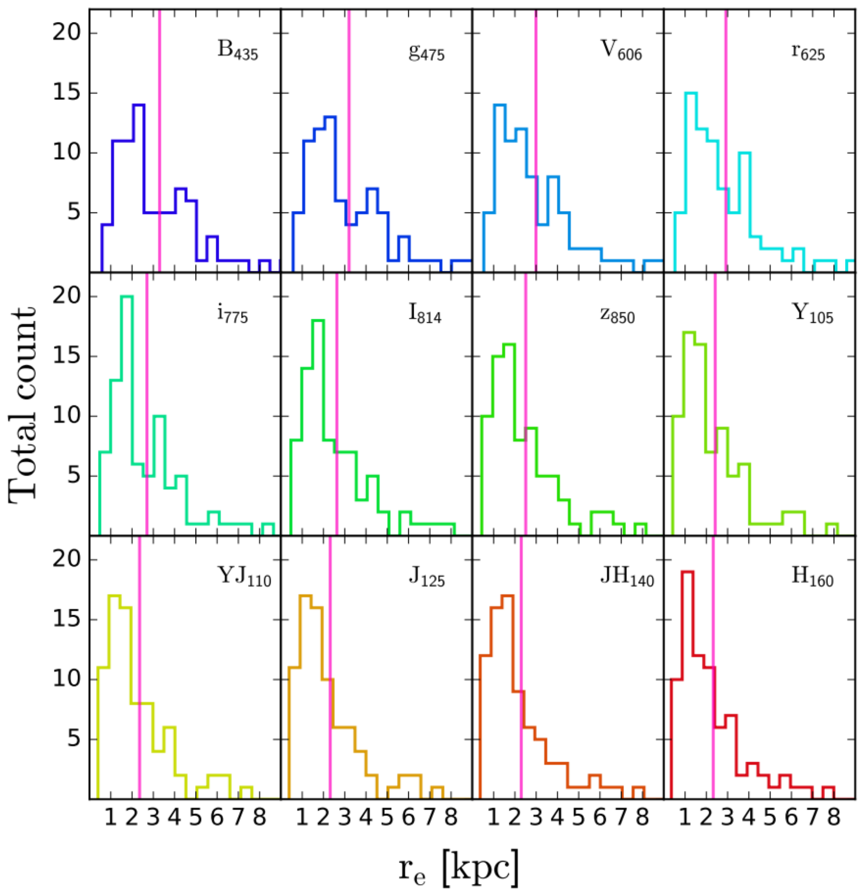
$$\nabla_{\lambda_2-\lambda_1} = \frac{\Delta\left[\mu_{\lambda_2}(R)-\mu_{\lambda_1}(R)\right]}{\Delta \log R}$$



Results

STRUCTURAL PARAMETERS



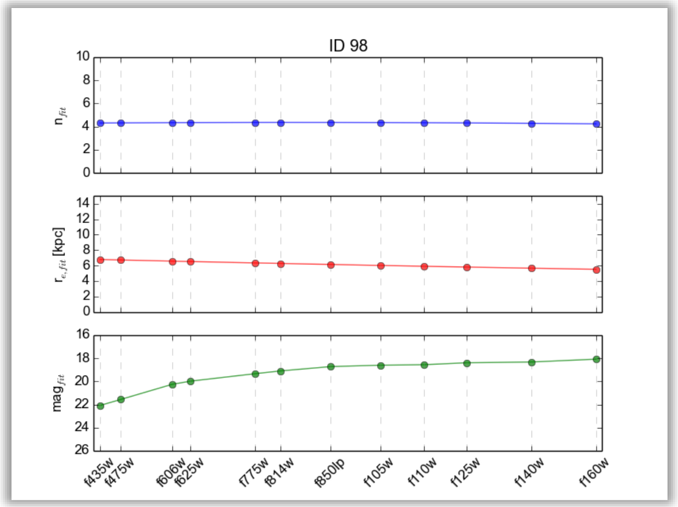


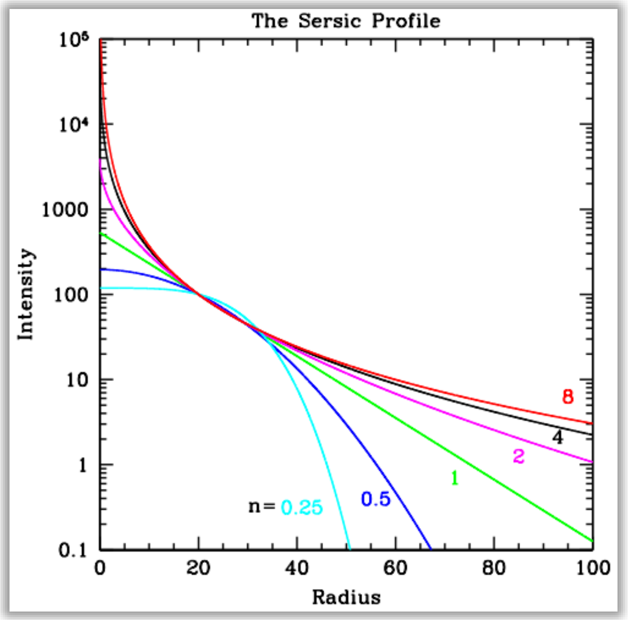
STRUCTURAL PARAMETERS

- $\mathbf{N} = \mathbf{n}_{H160}/\mathbf{n}_{r625}$
- $\mathbf{R} = \mathbf{r}_{e_{H,160}}/\mathbf{r}_{e_{r,625}}$
  - mean of ratios between $\mathbf{n}$ and $\mathbf{r_e}$ in $\mathbf{H_{160}}$ and $\mathbf{r_{625}}$
- $\mathbf{N < 1}$ → higher light concentration in bluer band
- $\mathbf{R < 1}$ → larger size in bluer band

$$\mathbf{N = 0.92 \pm 0.02}$$
$$\mathbf{R = 0.75 \pm 0.02}$$

- $\mathbf{n}$ constant, $\mathbf{r_e}$ decreases with wavelength
- → Indicates **negative** color gradient





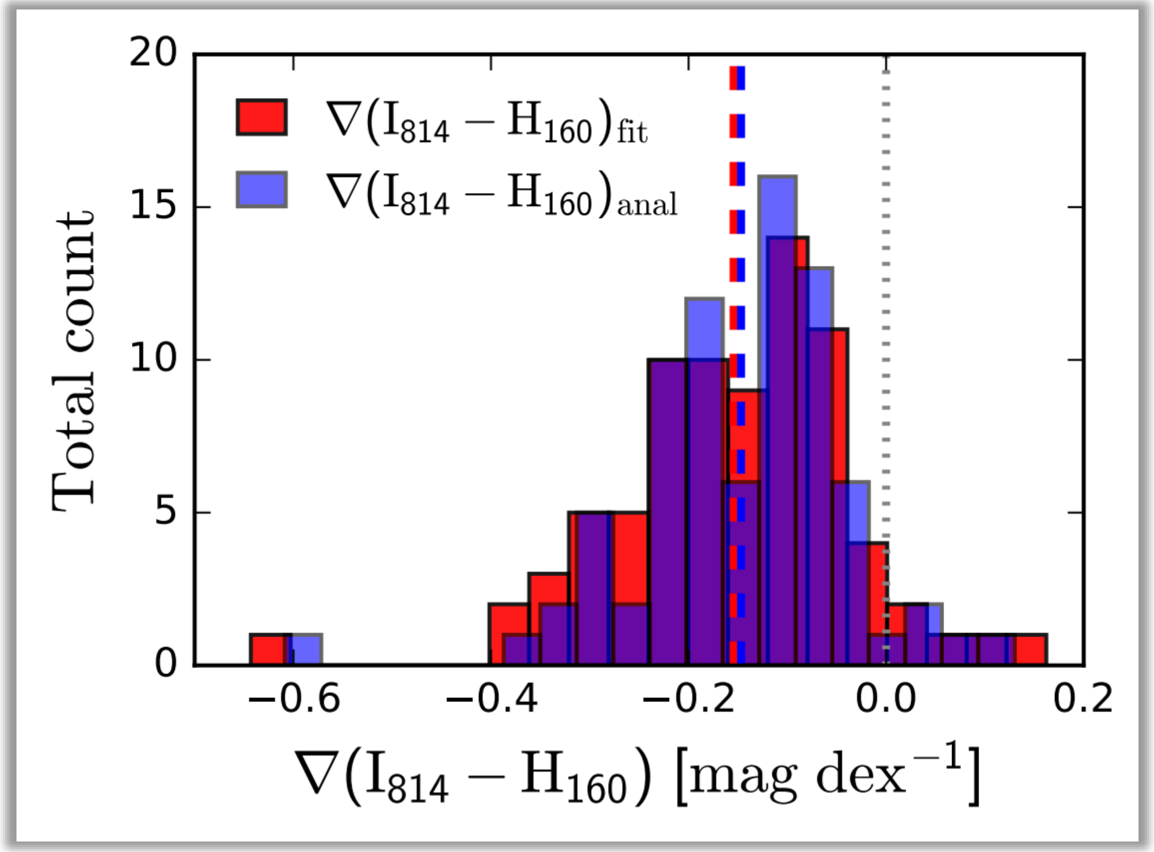
Peng et al., 2010

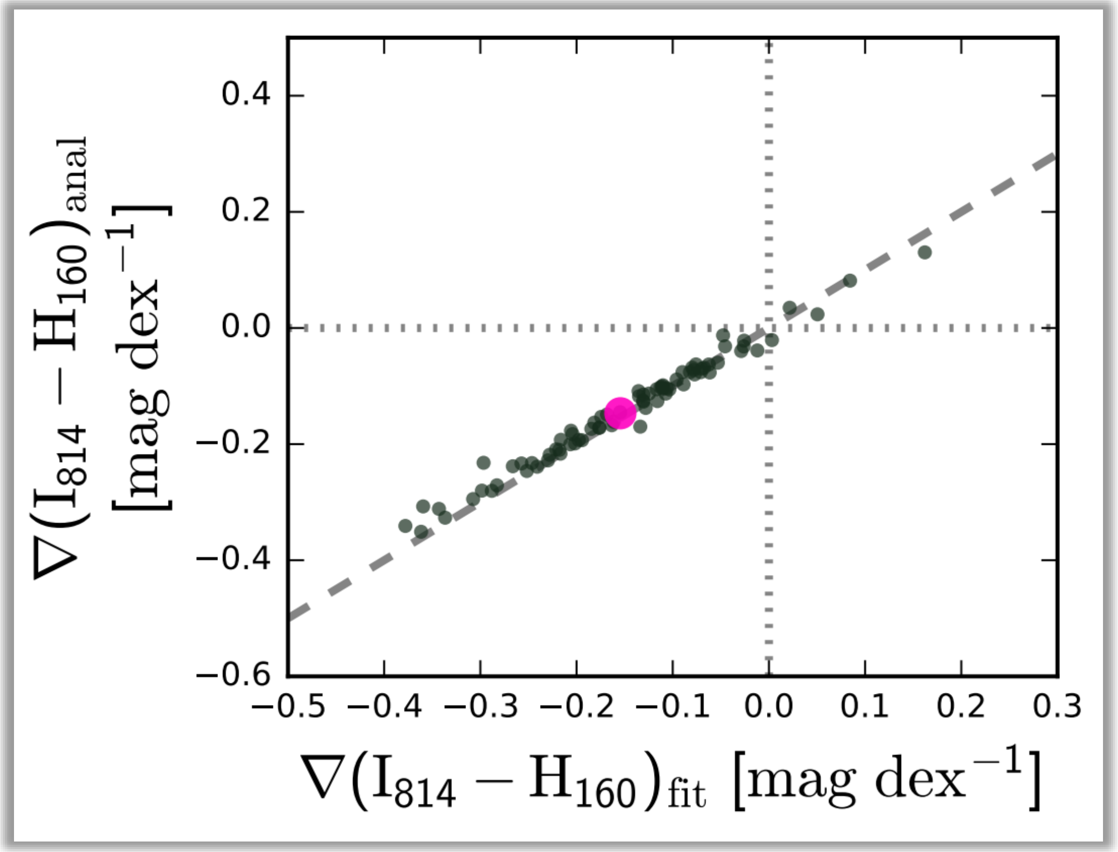
COLOR GRADIENTS

- **$0.1 - 2r_e$**
- Two different methods:
  - LSQ fit to color profile
  - ‚Analytical approach' (La Barbera et al. (2002))
- Four colors:
  - $\mathbf{g_{475} - I_{814}} \sim \mathrm{U - V}$
  - $\mathbf{r_{625} - Y_{105}} \sim \mathrm{B - I}$
  - $\mathbf{I_{814} - H_{160}} \sim \mathrm{V - Y}$
  - $\mathbf{Y_{105} - H_{160}} \sim \mathrm{I - Y}$

Color	$\nabla_{\mathrm{mean,fit}}$ [mag dex^{-1}]	$\nabla_{\mathrm{mean,anal}}$ [mag dex^{-1}]
$\mathbf{g_{475} - I_{814}}$	-0.17 ± 0.08	-0.12 ± 0.08
$\mathbf{r_{625} - Y_{105}}$	-0.18 ± 0.08	-0.15 ± 0.08
$\mathbf{I_{814} - H_{160}}$	-0.15 ± 0.12	-0.15 ± 0.11
$\mathbf{Y_{105} - H_{160}}$	-0.07 ± 0.09	-0.07 ± 0.09

COLOR GRADIENTS





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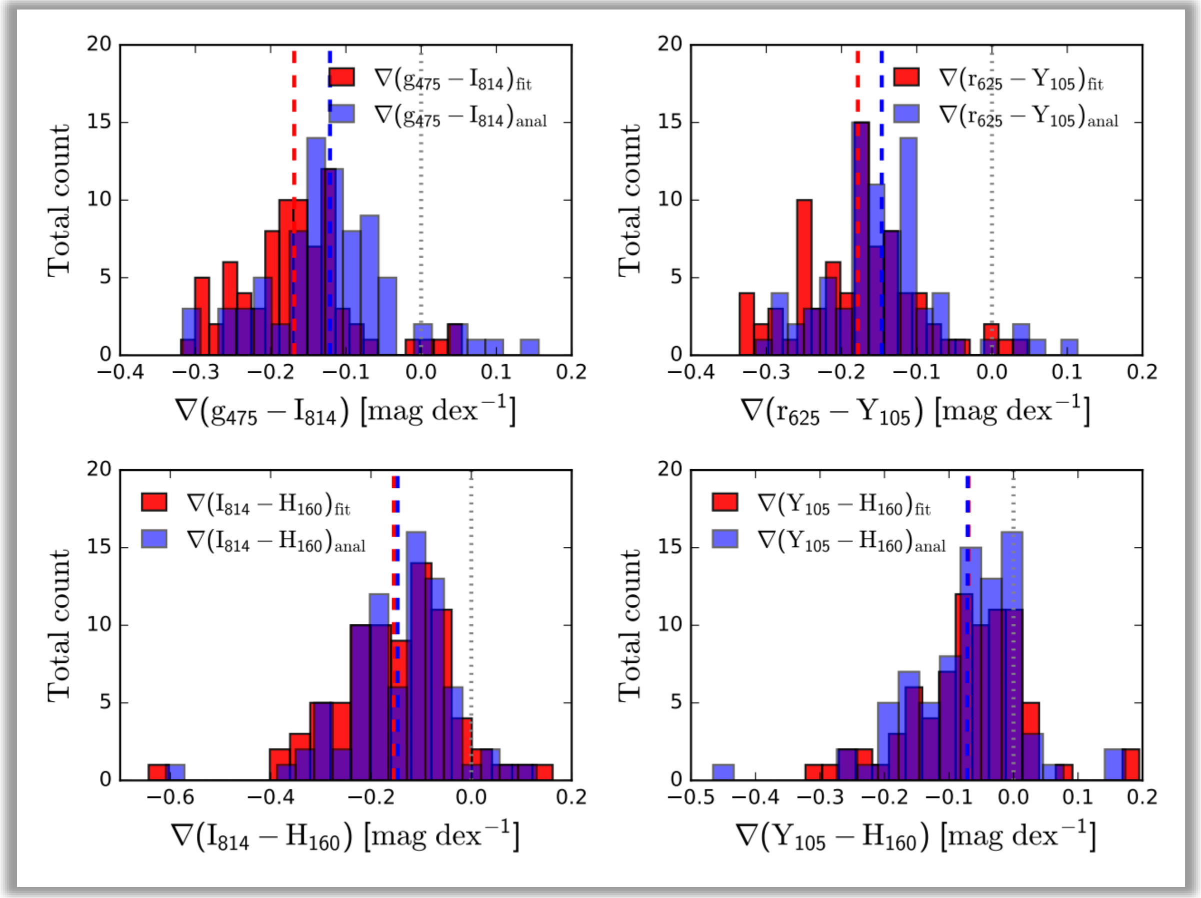

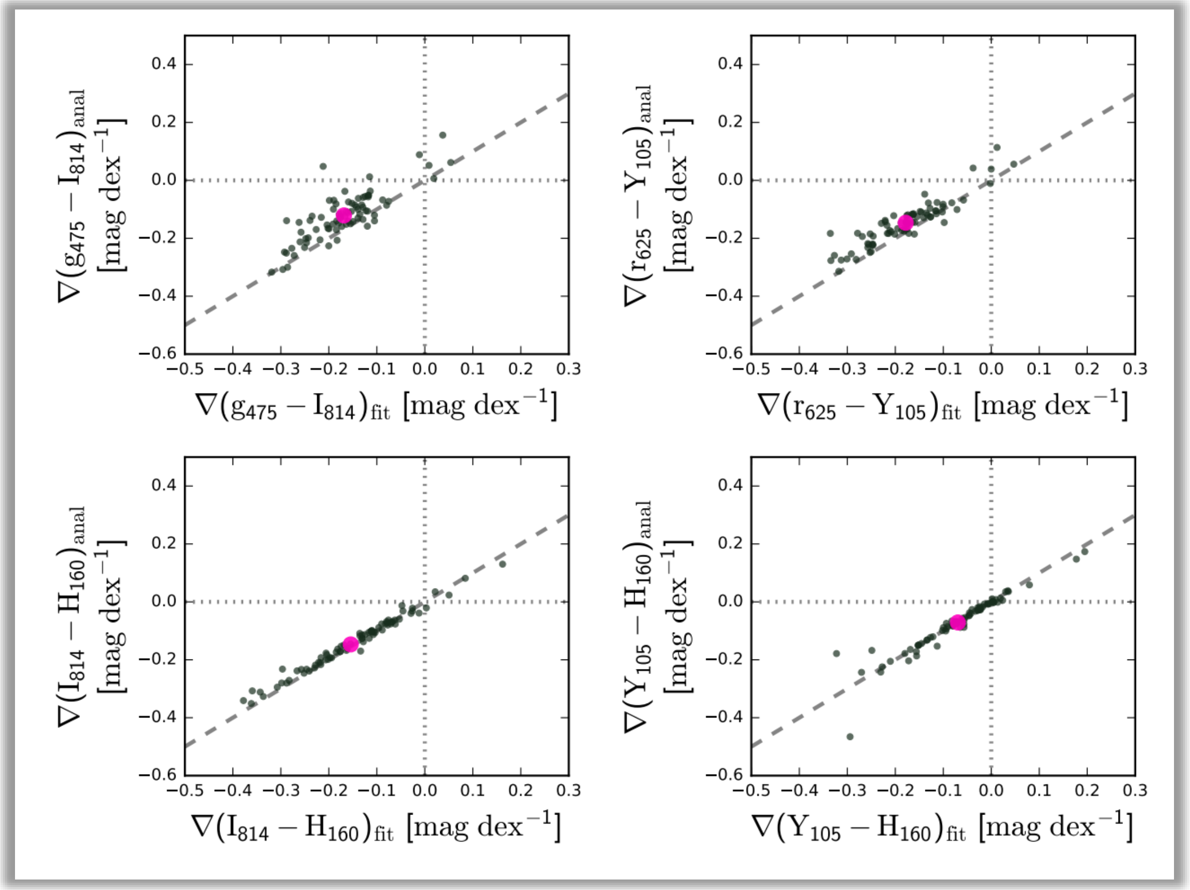

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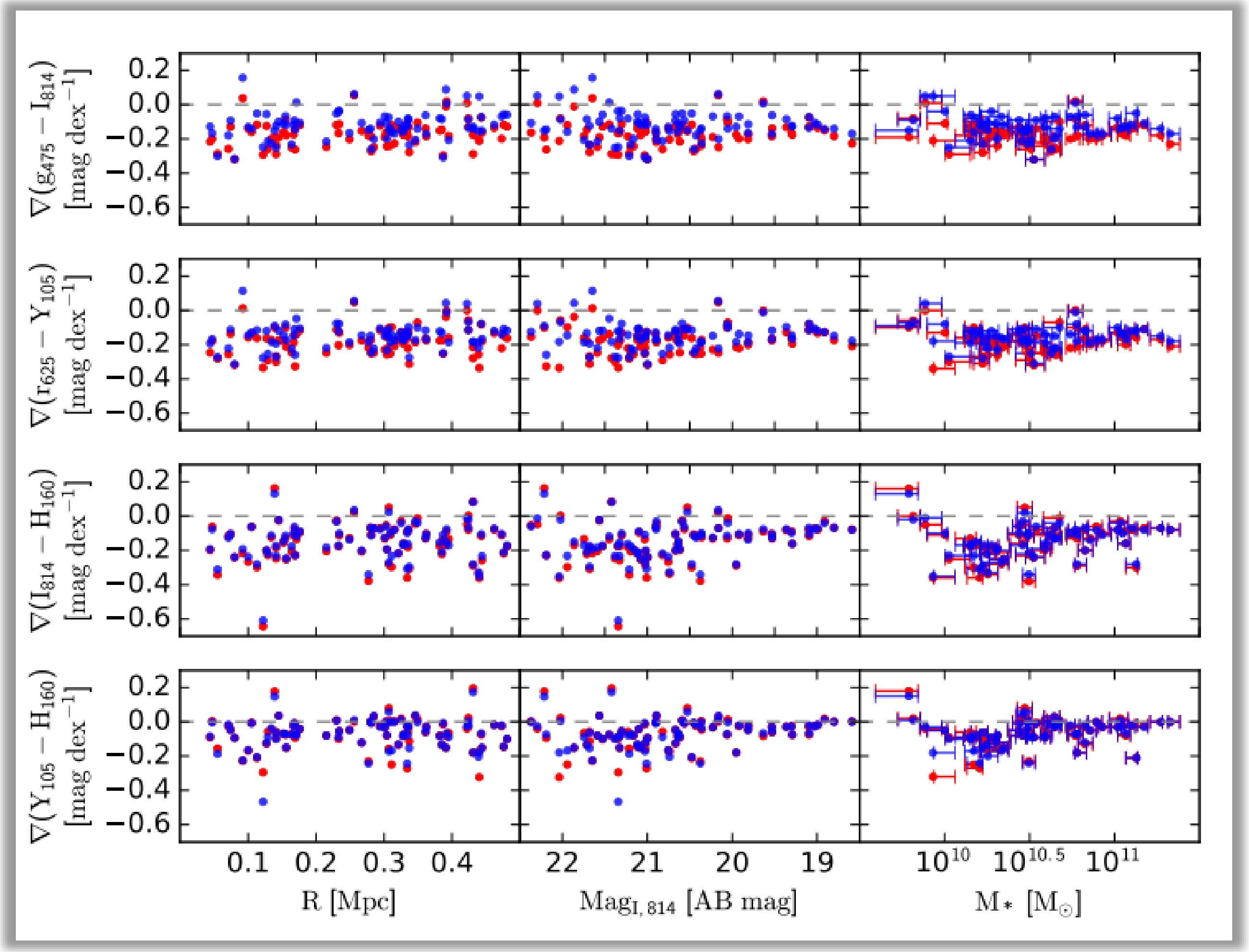
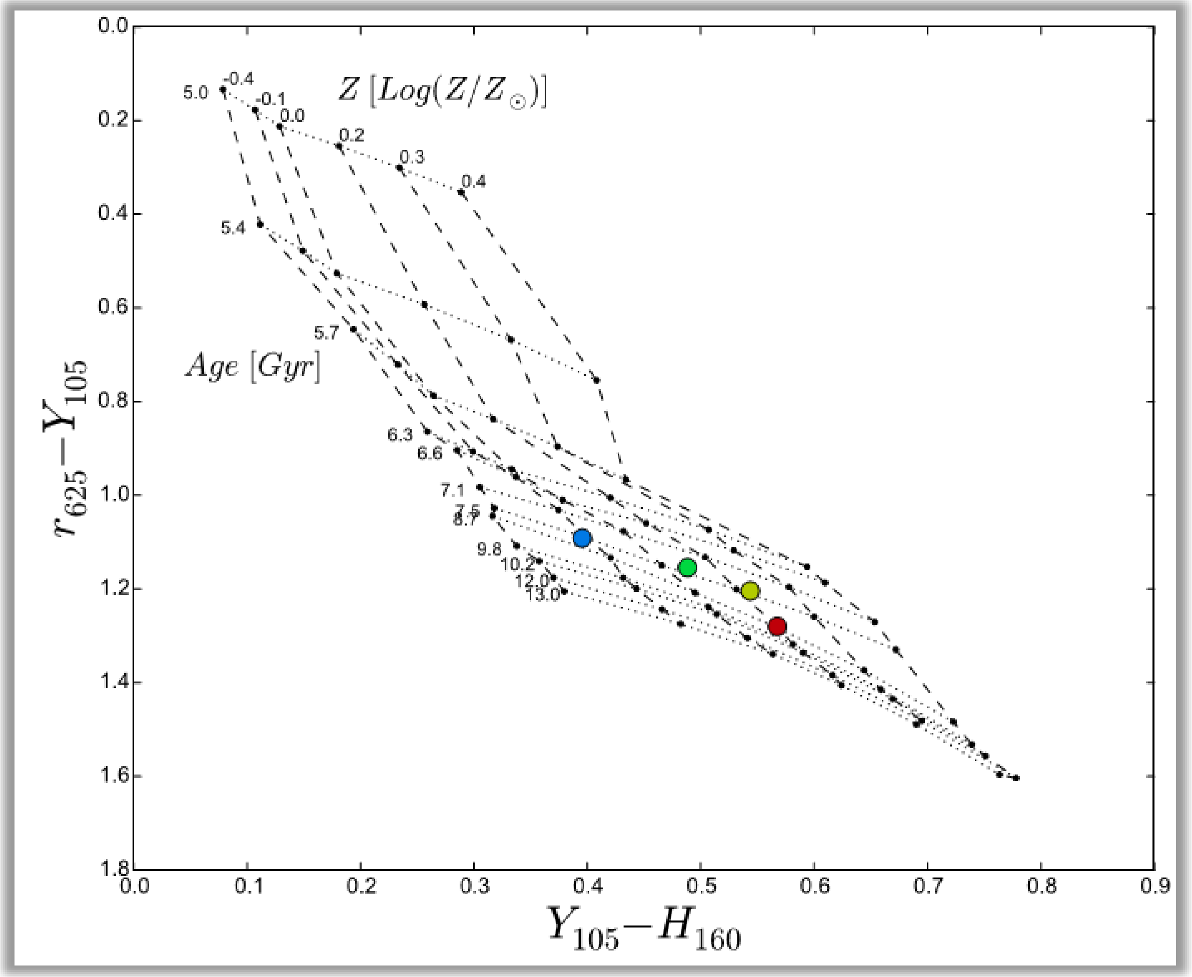


No obvious correlations of color gradients with:

- Cluster-centric distance
- Total magnitude
- Stellar mass

STELLAR POPULATIONS

- Simple Stellar Population models
  - (Bruzual & Charlot, 2003)
- Chabrier IMF
- Breaking age-Z-degeneracy
- Compared colors at **0.1, 0.5, 1** and **$2r_e$**
- **B − I** vs. **I − Y**



STELLAR POPULATIONS

Parameter	$0.1r_e$	$0.5r_e$	$1r_e$	$2r_e$
Age [Gyr]	11.5 ± 0.3	11.2 ± 0.3	10.1 ± 0.3	10.1 ± 0.3
Z [$\log(Z/Z_\odot)$]	0.2 ± 0.03	0.1 ± 0.02	0.0 ± 0.02	0.0 ± 0.02

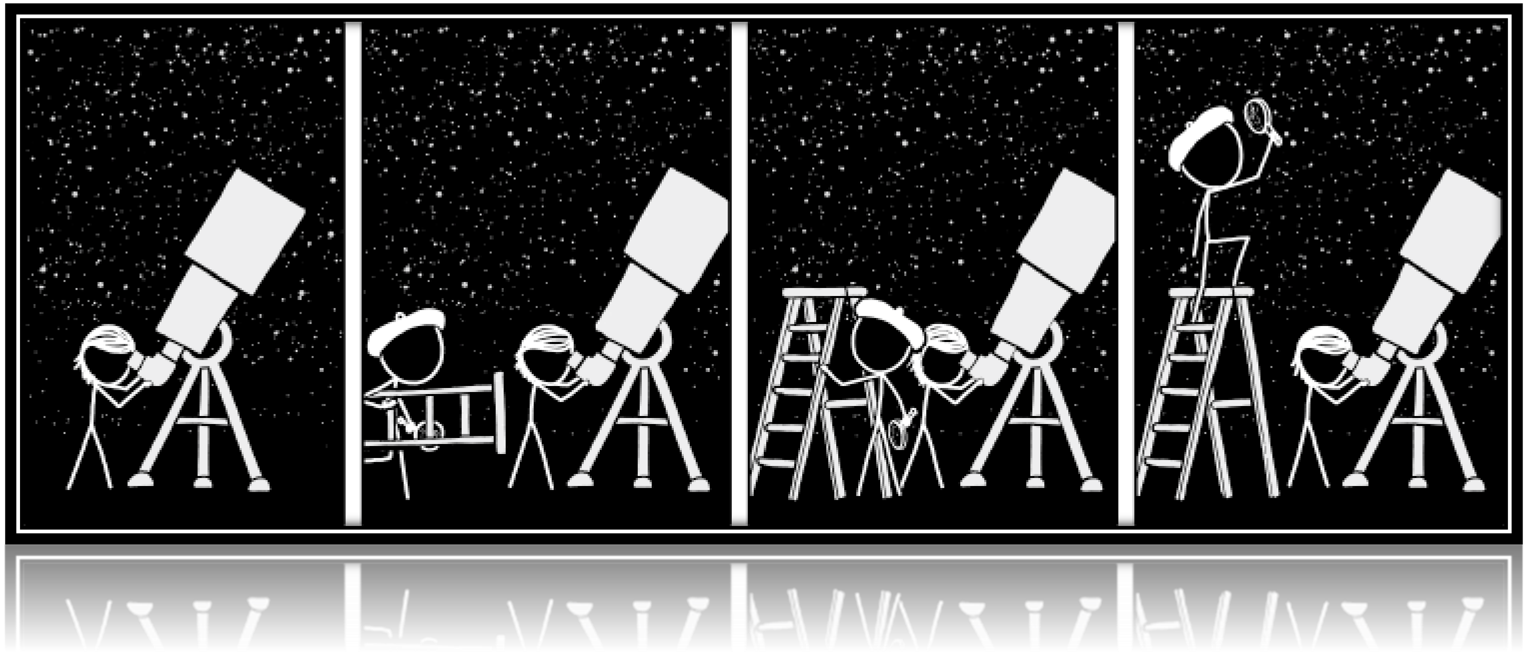
- Decrease in age and metallicity with radius

→ both, age and metallicity have effect on observed color gradients

Summary

SUMMARY

- $\mathbf{r_e} \sim$ **25%** smaller in $\mathbf{H_{160}}$ than in $\mathbf{r_{625}}$ → indicating **negative** color gradients
- $\mathbf{n}$ appears **constant** over same wavelength range
- **Color gradients on average negative**
- **No correlation** of gradients with cluster-centric distance, total magnitude or stellar mass
- **Age** and **metallicity** are **drivers** for color gradients
- Inside-out growth of early-type galaxies plausible evolution scenario



Xkcd.com