THE UNIVERSITY OF SYDNEY

Tania Barone
Matthew Colless, Francesco D'Eugenio
Nic Scott, Scott Croom

Australian National University

What Drives Stellar Population Evolution?

Barone et al. 2018: Gravitational Potential and Surface Density

01 INTRODUCTION

When it comes to galaxy properties, to an extent, everything correlates with everything. Stellar population parameters have been found to correlate with:

- Stellar mass
- Velocity dispersion
- Large scale environment
- Surface brightness
- Surface density

To identify the processes that drive stellar population evolution, we need to distinguish between fundamental (causal) relations, and what is the result of some other underlying trend, **because we assume tighter correlation suggests closer to causation.**

Our work builds on Franx et al. (2008) and Wake et al. (2012), arguing that the evolution of stellar populations is driven by physical parameters other than galaxy mass.

sami galaxy survey

We use a sample of 1380 galaxies including 625 morphologically-selected early-types.

The survey uses the Sydney-AAO Multi-object Integral-field (SAMI) instrument and the AAOmega spectrograph on the Anglo-Australian Telescope.

Our sample from internal release v0.9.1, has low redshifts ($z < 0.1$) and a broad range of stellar masses $10^7 < M_* < 10^{12}$.

Stellar population parameters were derived by Scott et al. (2017) from spectra integrated within 1 R_e, using the method of Lick indices with the single-burst stellar population models by Schiavon (2007) and Thomas et al. (2011).

02 ANALYSIS

We compare how the stellar population parameters *g-i* colour, metallicity, and age correlate with the galaxy properties mass M, gravitational potential $\Phi \sim M/R$, and surface mass density $\Sigma \sim M/R^2$.

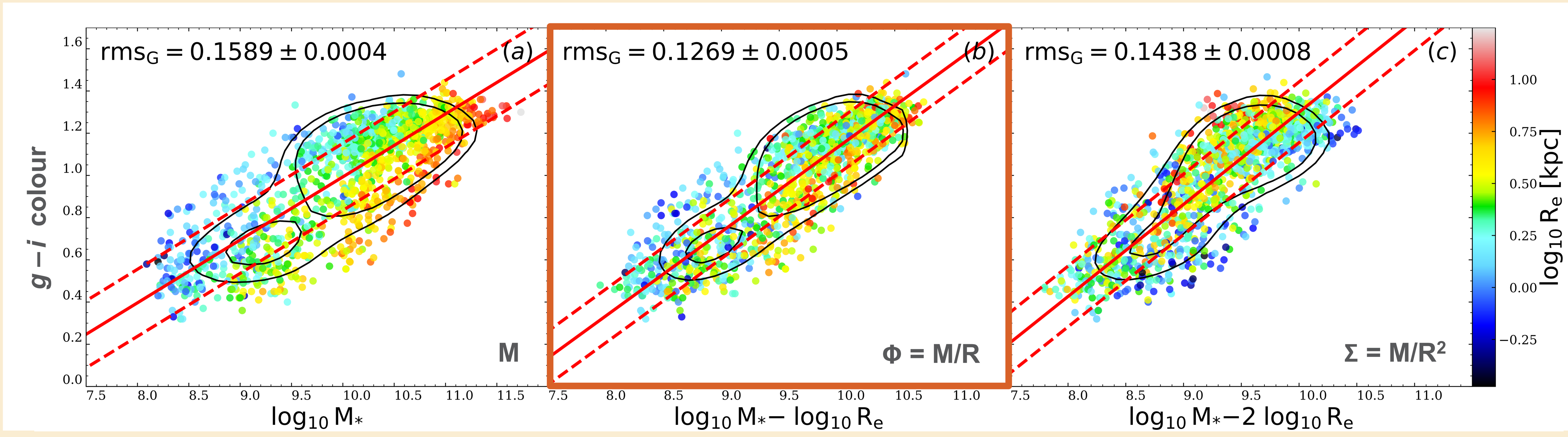
In determining the strength of a trend, we analyse both the overall scatter, and the observational uncertainty on the parameters, in order to compare the intrinsic scatter in each correlation.

We want to find the 'best' correlations, which we define as having:

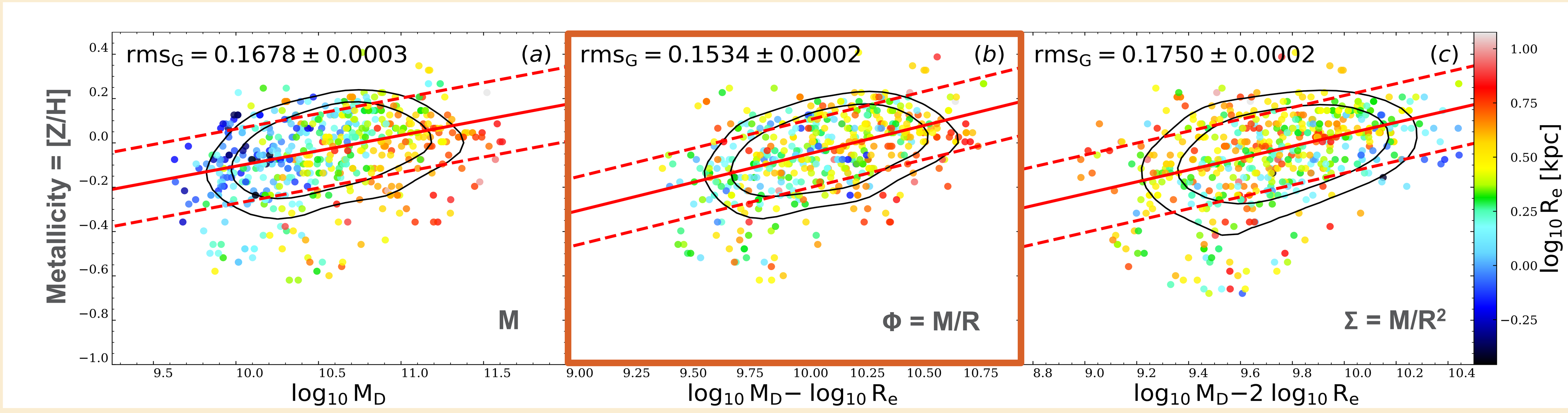
1. Lowest relative intrinsic scatter
2. Least residual trend with galaxy size

The data is modelled as a two-dimensional Gaussian, and log-linear relations are fit via maximum likelihood optimisation, followed by MCMC integration.

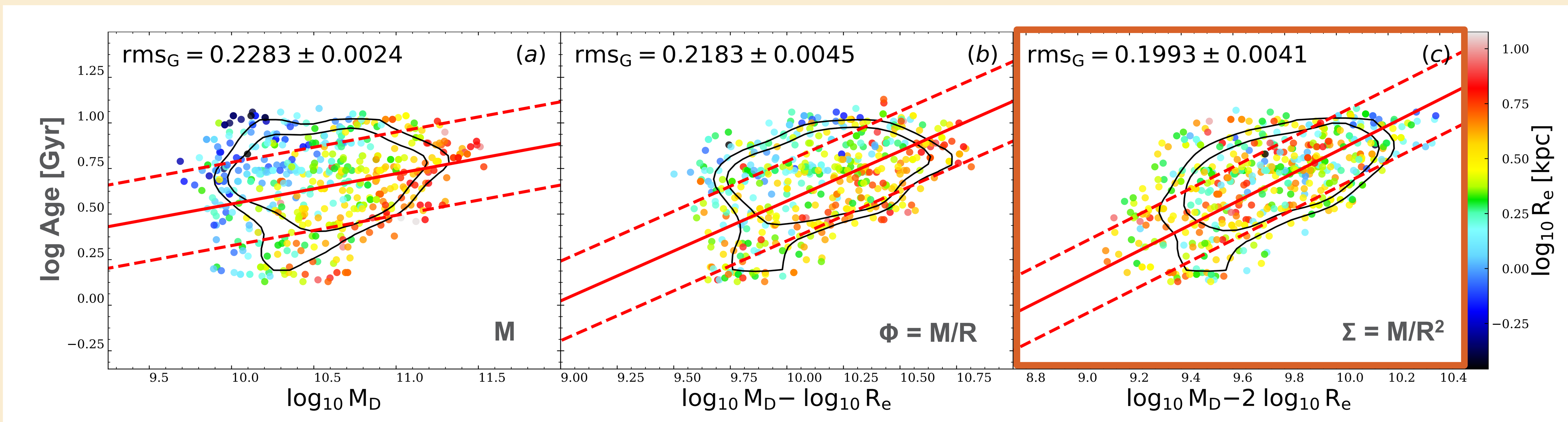
03 RESULTS



g-i colour as a function of (a) mass, (b) gravitational potential, and (c) surface mass density for all galaxy types. The two peaks in the distribution, corresponding to the red sequence and the blue cloud, are better aligned for *g-i* colour-Φ, and show the least residual trend with radius (indicated by the colour-map).



Stellar metallicity [Z/H] as a function of (a) mass, (b) gravitational potential, and (c) surface mass density for early-type galaxies. [Z/H]-Φ has the least scatter (lowest rms) and least residual trend with radius (shown by the colour-map).



Stellar age as a function of (a) mass, (b) gravitational potential, and (c) surface mass density for early-type galaxies. Age-Σ has the least scatter (lowest rms) and least residual trend with radius (shown by the colour-map).

From figures 1, 2, and 3 of Barone et al. (2018).

04 DISCUSSION

_g-i_ Colour ~ Potential

Whether analysed separately or together, both the red sequence and blue cloud are tighter and show less residual with galaxy size, compared to the mass relation.

Note: given [Z/H]~Φ and age~Σ, does the *g-i* colour~Φ relation indicate *g-i* colour is due more to metallicity than stellar age? See D'Eugenio et al. (in prep) for an in-depth study.

Metallicity ~ Potential

Proposed explanation: gravitational potential is the primary regulator of metallicity, via its relation to the gas escape velocity, meaning it originates with *in situ* star formation. Supporting evidence:

➔ [O/H]~ Φ for gas-phase metallicity in star-forming galaxies, (D'Eugenio et al. 2018).

➔There exists a tight radial trend between v_{escape} and line strength indices (Scott et al. 2009).

Simulations suggest relation is maintained in galaxy mergers (e.g. Boylan-Kolchin and Ma 2007):

➔Diffuse, low potential and low metallicity satellites are easily disrupted, and accrete their low metallicity material onto the host at large radii, hence decreasing the depth of hosts potential well and decreasing its metallicity (and vice-versa).

Age ~ Surface Density

Galaxy quiescence also correlates strongly with central surface density: e.g sSFR~Σ (Franx et al. 2008, Whitaker et al. 2017); Red fraction~Σ (Omand et al. 2014); D_n4000 break~Σ (Kauffman et al. 2013).

➔Are these observations all evidence of compactness-driven quenching mechanisms?

TAKE-HOME MESSAGE

Colour ~ Potential
M/R

Metallicity ~ Potential
M/R

Age ~ Surface Density
M/R²

05 SUMMARY

The well-established correlations between galaxy mass and stellar population properties are considered evidence for mass driving the evolution of the stellar population. However, for early-type galaxies we find that *g-i* colour and stellar metallicity [Z/H] correlate more strongly with gravitational potential Φ, rather than mass M, whereas age correlates best with surface density Σ.

Specifically, for our sample of 625 early-type galaxies from the SAMI Galaxy Survey, compared to correlations with mass, the colour-Φ, [Z/H]-Φ, and age-Σ relations show both smaller scatter and a lower residual trend with galaxy size.

These results lead us to make the following interpretations:

1. The colour–Φ diagram is a more precise tool for determining the developmental stage of the stellar population, rather than the conventional colour–mass diagram.
2. Gravitational potential is the primary regulator of global stellar metallicity, via its relation to the gas escape velocity.
3. We propose the following two mechanisms for the age relation with Σ:
   a. The age–Σ correlation arises as a result of compactness-driven quenching mechanisms; and/or
   b. as a fossil record of the $\Sigma_{SSFR} \sim \Sigma_{gas}$ relation in their disk-dominated progenitors.

Poster template from:
Frahna Karim (2014)
https://www.behance.net/karimfrahna

notes

⚠ See Barone et al. (2018) for further details.
⚠ Wait (im)patiently for companion paper (D'Eugenio et al. in prep) further analysing the colour relations.
⚠ See D'Eugenio et al. (2018) for a complementary study of gas-phase metallicity in star forming galaxies.

Tania M. Barone, PhD student
Australian National University
University of Sydney
tania.barone@anu.edu.au

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