Stellar populations and chemical evolution in SAMS S.C. Trager (Kapteyn) R.S. Somerville (STScI) M. Arrigoni (Kapteyn)



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Motivation

- Use semi-analytic models as tools to understand stellar population results
 - What do stellar population ages represent?
 - What does archaeological downsizing mean?
 - What physics are required to understand the chemical composition of galaxies?
- Note: I'm not a believer, I'm a user.





Stellar populations in galaxies: a brief review



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How can we measure the ages of galaxies?

Colours don't help!

- at least not for old galaxies
- Why not?
 - Colours come from red giant branch and main sequence
 - <u>Degenerate</u> to changes in age and composition!



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How can we break this degeneracy?



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 Metal lines arise from coolest stars: RGB & lower MS (invisible at optical wavelengths)





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How can we break this degeneracy?

- Metal lines arise from coolest stars: RGB & lower MS (invisible at optical wavelengths)
- Balmer lines of H arise from *hottest* stars (cooler than mid-B): main-sequence turn-off (MSTO)
 - *nonlinearly* sensitive to temperature





- We can predict line strengths and compare to observed galaxies
- Note inconsistency between stellar populations using different metal-line strengths!
 - due to $[\alpha/Fe]\neq 0$ in massive early-type galaxies
 - α-elements include Mg, Si, Na, S, and other even-numbered elements
 - reflects SNell/SNela ratio





 Can separate out [α/Fe] effect from age and metallicity by combining indexes cleverly (González93, Thomas +03)





There's a problem, though...

 Late bursts of star formation (RSF=residual star formation) make Hβ ages *much* younger than 'true' mass-weighted ages (see Trager+00, Serra & Trager07): we refer to the Hβ ages as SSP-equivalent ages

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Our SAMS: Somerville+ 2008 and Arrigoni+ 2008



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- Somerville+08: extension of Somerville & Primack99 and Somerville+01 SAMS
- Major improvements:
 - more realistic merger models based on Robertson +06 and Cox+08
 - 'bright' AGN feedback mode based on Hopkins+07 which drive (super)winds
 - 'radio' AGN feedback mode based on Bondi accretion (like Croton+06)



- Arrigoni+08 (in prep.): extends Somerville+08 to include realistic chemical evolution model (cf. Nagashima+04,05)
 - based on classic method of Tinsley80, Matteucci & Gibson95 (and many others)
 - includes SN la!
 - can track up to 19 separate elements, including Fe-peak and α-elements
 - Karakas & Lattanzio07 + Woosley & Weaver95 + Nomoto +97 yields, no modifications
 - allows for changes in IMF and in fraction of binaries that explode as SN Ia
- Trager+08 (in prep.): extends Somerville+08 to produce line strengths (extension of Arrigoni+08 models in progress)



What can we learn about stellar populations from SAMS?



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Cluster galaxies: general properties

- Built 20 realizations (mock catalogues) of Coma cluster-sized halos
 - selected early-types (based on B/T)
- Note 'downsizing' in age as fn. of mass and mass-metallicity relation for early-types



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Stellar populations of cluster galaxies



 Compute line strengths of model galaxies, then SSPequivalent ages and metallicities



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Stellar populations of cluster galaxies



 Compute line strengths of model galaxies, then SSPequivalent ages and metallicities



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'Downsizing' in SSP-equivalent age stronger than in mass-weighted age



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- 'Downsizing' in SSP-equivalent age stronger than in mass-weighted age
- SSP-equivalent age poorly correlated with mass- and light-weighted ages



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 SSP-equivalent ages do **not** correlate with time of last (major) merger or time when some fraction of stars were formed...



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- SSP-equivalent ages do **not** correlate with time of last (major) merger or time when some fraction of stars were formed...
- ...but with birthrate of stars in last 0.1-2 Gyr





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 SSP-equivalent metallicity is basically equivalent to mass- or light-weighted metallicity



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- SSP-equivalent metallicity is basically equivalent to mass- or light-weighted metallicity
- But mass-metallicity slope is wrong (zero-point, too)!



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- SSP-equivalent metallicity is basically equivalent to mass- or light-weighted metallicity
- But mass-metallicity slope is wrong (zero-point, too)!
 - problem with satellites



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- Use Arrigoni+08 GCEenhanced SAMs
- Follow centrals, not satellites
 - compare with *field* galaxies



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- Use Arrigoni+08 GCEenhanced SAMs
- Follow centrals, not satellites
 - compare with *field* galaxies
- Need to flatten IMF and lower SN la fraction to match observations



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Conclusions

- SAMS provide powerful tool for calibrating and understanding observations
 - wealth of information about evolution of stellar populations when analysed like the data
- SSP-equivalent age not equivalent to mass- or lightweighted age but SSP-equivalent metallicity is good metallicity tracer
 - archaeological downsizing overestimates true downsizing
 - may need flatter IMFs and lower SN Ia fractions in early-type galaxies than in Milky Way



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- still problems, of course...
 - satellite galaxies have problems
 - mass-metallicity relation wrong
 - need other physics in satellites!
 - stronger feedback? different star formation? something else?

