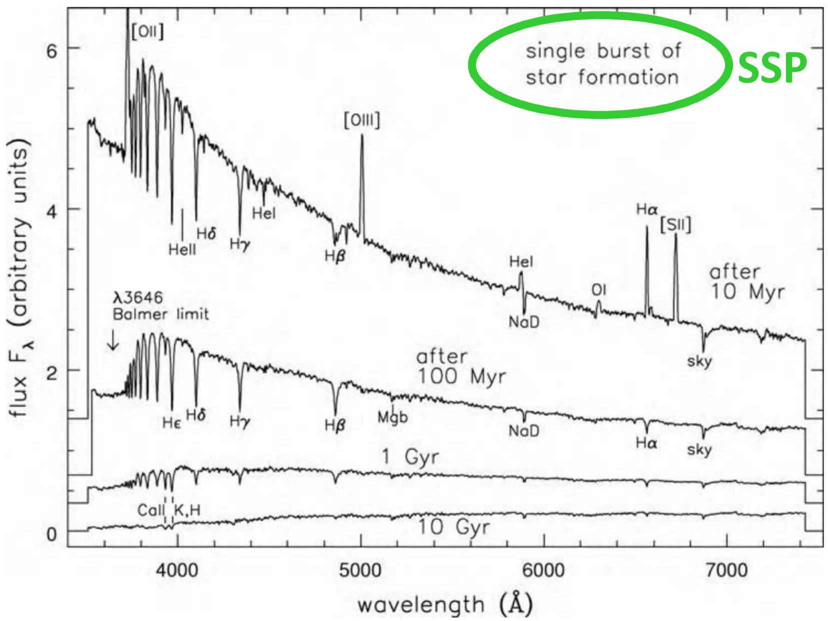
Galaxies as a Population III

ASTR 503/703

Population Synthesis Modeling

- Stellar Pop. Synth. (SPS)

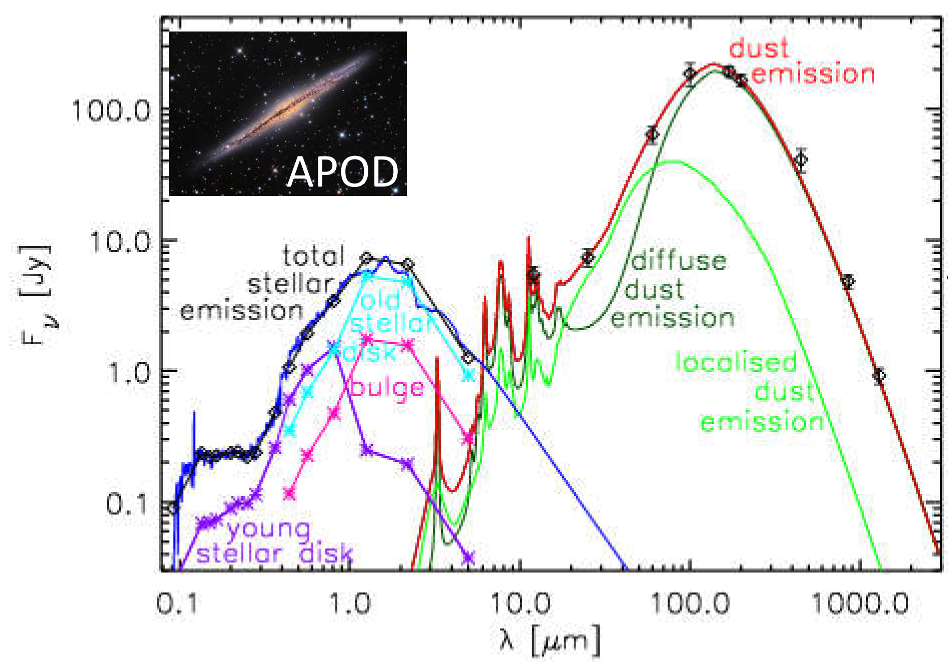


$$F_\lambda^{intrinsic} = \int_0^t SFR\,(t')F_\lambda^{SSP}(t - t', Z(t'))dt'$$

Inputs: initial mass function (IMF) of simple stellar population (SSP), star formation history (SFH), stellar evolution model code with stellar spectral library, [dust reddening model]

Outputs: spectra and filter fluxes (spectral energy distributions, "SEDs")

- Add-ons:
  - star-forming gas spectrum
  - chemical evolution
  - binary star evolution
  - AGN spectrum
  - dust *emission* spectrum



Popescu et al. 2011

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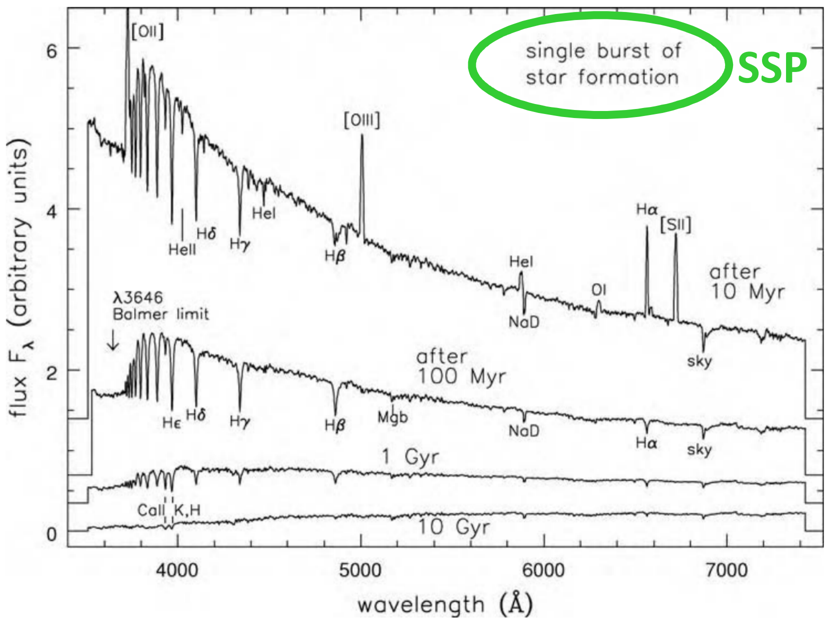

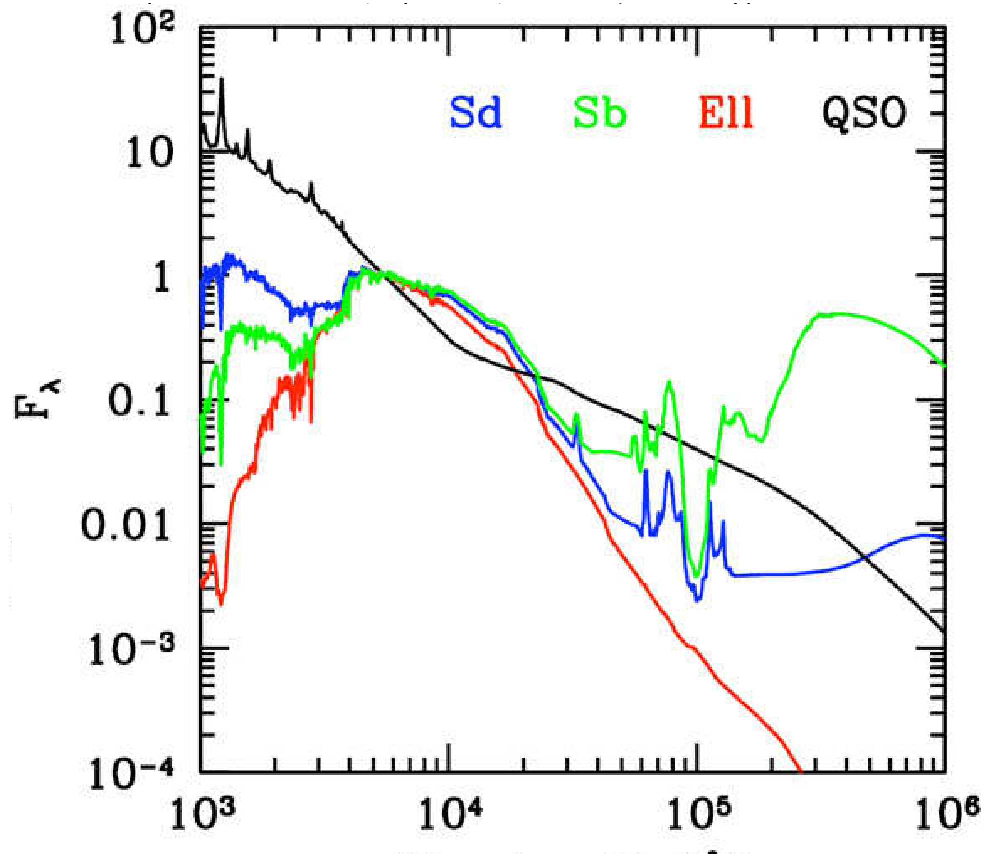

Polletta+ 2007

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  - star-forming gas spectrum
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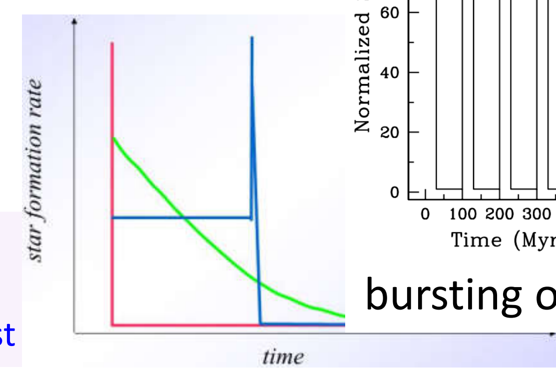
  - AGN spectrum
  - dust *emission* spectrum

What we learn (and don't learn) from SPS modeling

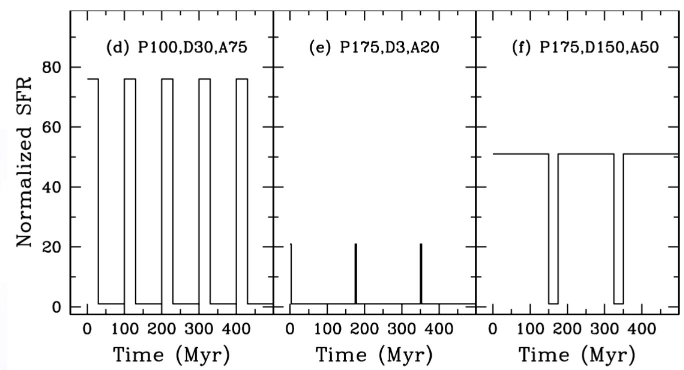
- SSP models: light-weighted ages, metallicities, dust reddenings, stellar M/Ls → optimal for globular clusters

- composite stellar pop (CSP) models: SFHs, stellar mass subcomponents, better age/Z/dust measurements

SSP
tau (closed box)
constant+quenching burst

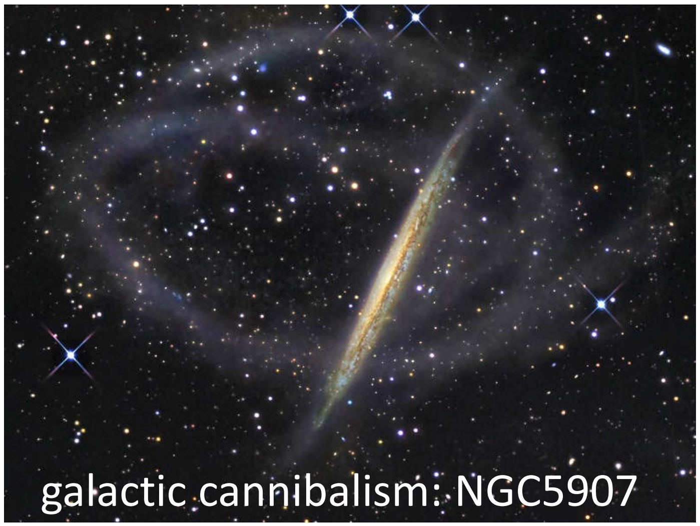


- Classic degeneracies
  - age-metallicity-reddening
  - mass vs. age of young population in CSP
- Spectra change slowly after ~1 Gyr
- Bayesian likelihood distributions superior to "best fits" for SPS modeling



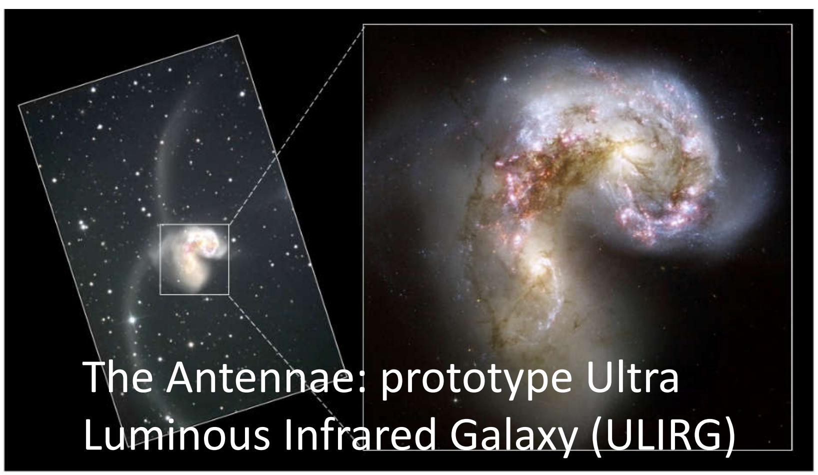
bursting or gasping, Weisz+ (2012)

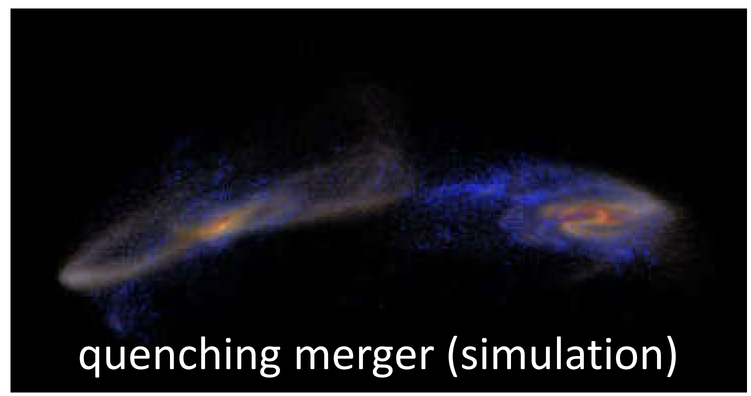
Hierarchical merging makes bursts of all sizes


galactic cannibalism: NGC5907

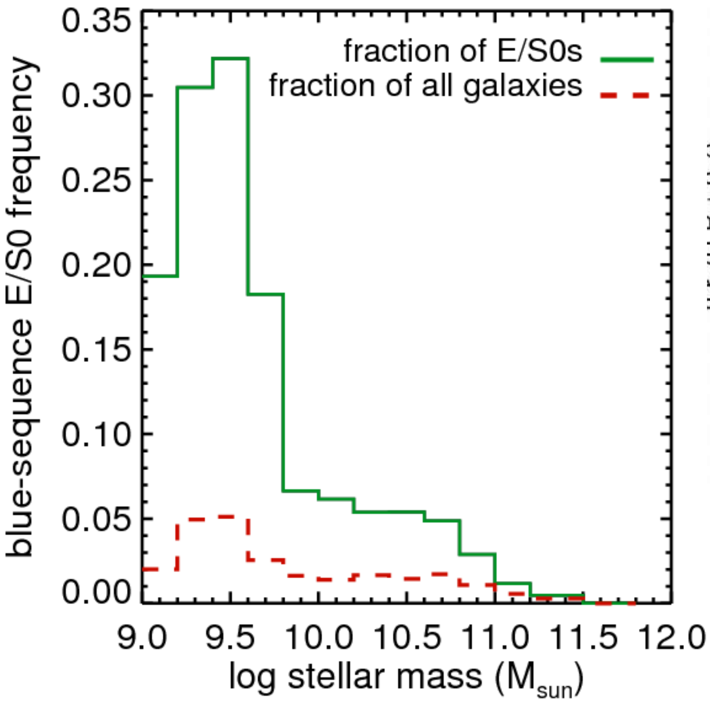
<u>gas</u> flows inward due to tidal forces & direct collision; $HI \rightarrow H_2$

1. new stars form in a huge burst
2. central concentration grows (young disky bulge!)
3. disk regrowth depends on availability of fresh gas

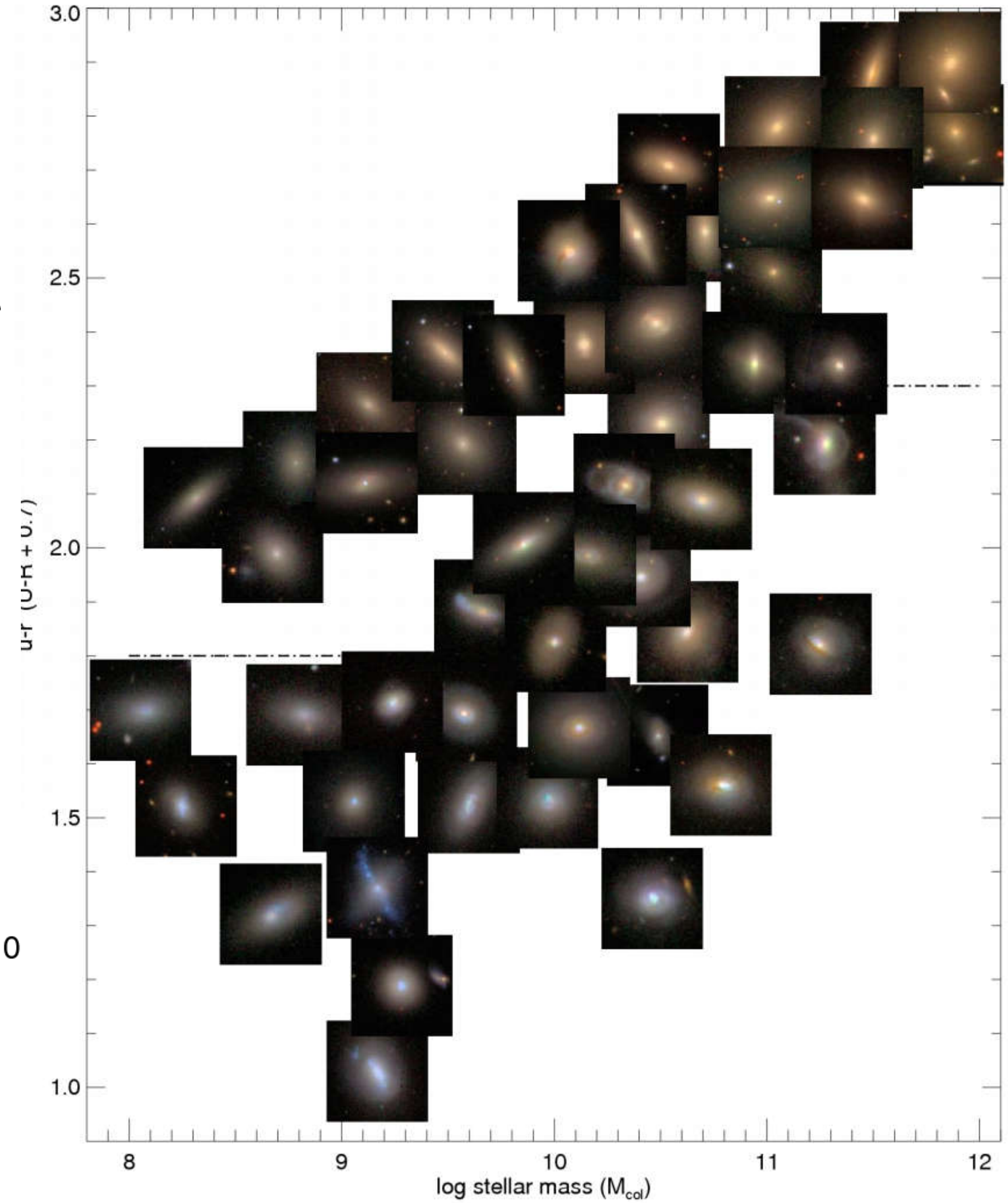

The Antennae: prototype Ultra Luminous Infrared Galaxy (ULIRG)


quenching merger (simulation)

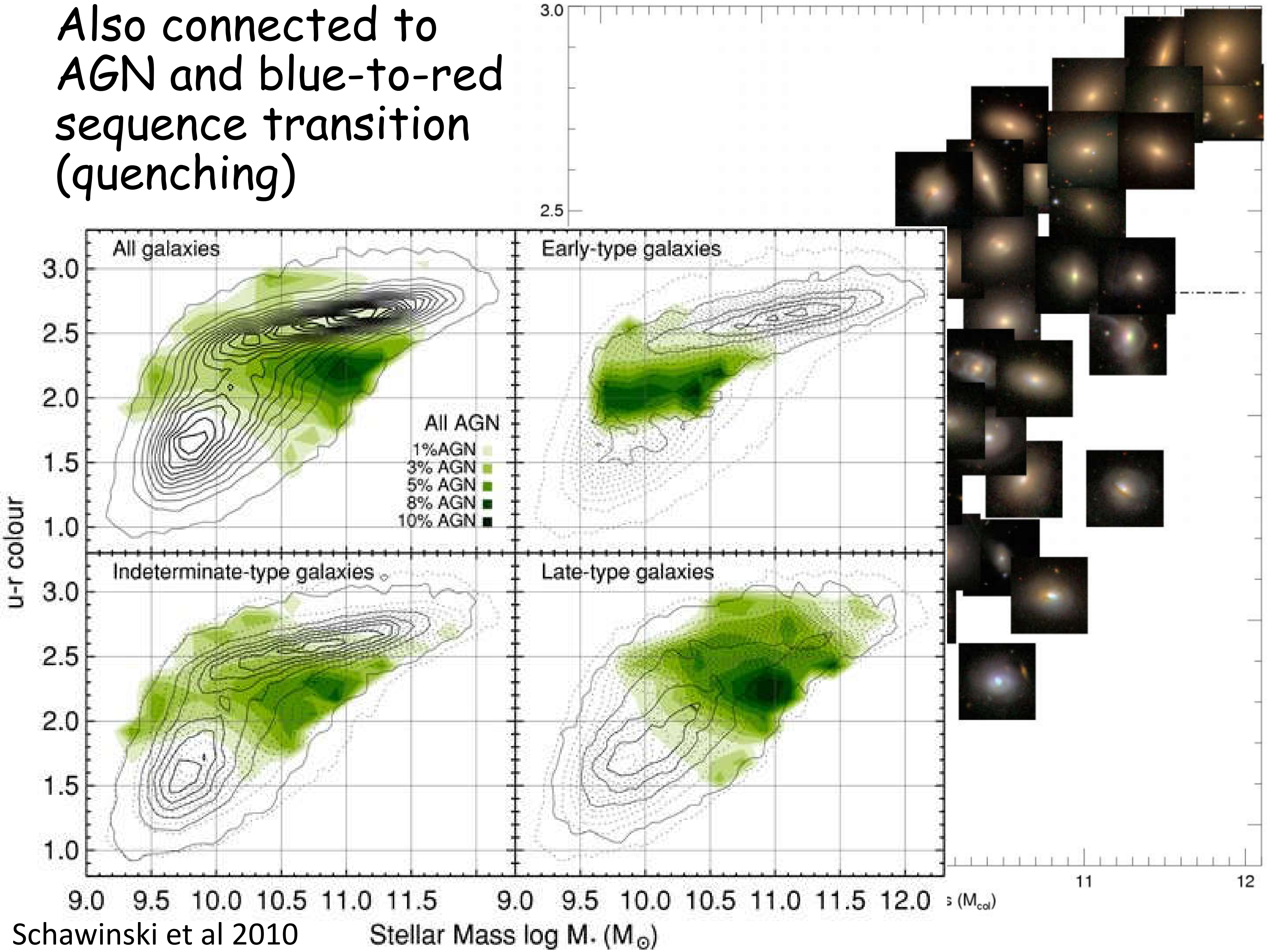
Below the gas-richness threshold mass, (pseudo)bulge building and post-merger disk regrowth



Kannappan et al. (2009);
see Stark et al. (2013) for
evidence of <u>gas</u> disk regrowth

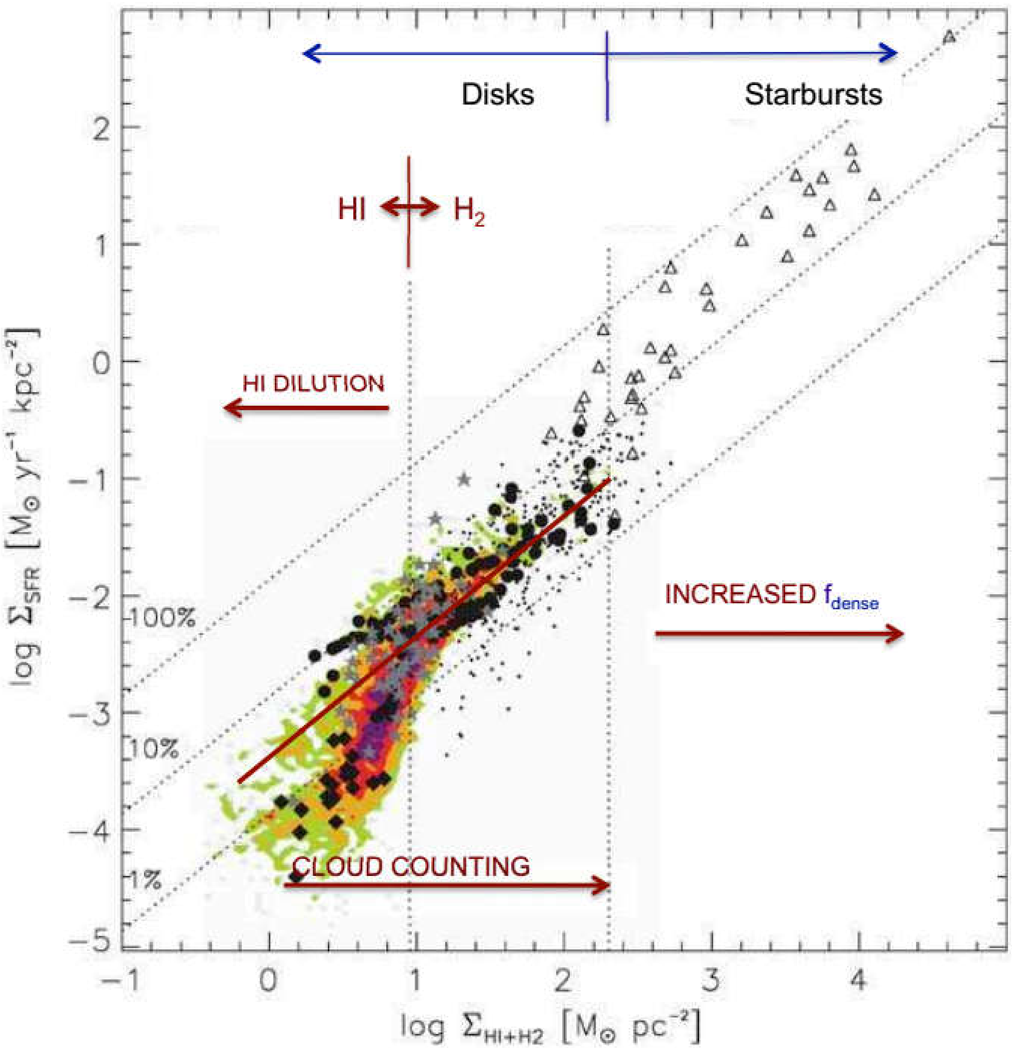


Also connected to AGN and blue-to-red sequence transition (quenching)



Schawinski et al 2010

Gas content and star formation rate (SFR): the Kennicutt-Schmidt relation (global & "resolved")



"resolved" = kpc/sub-kpc

K-S breaks down on <few 100pc scales (separation of H_2 gas fuel from young stars)

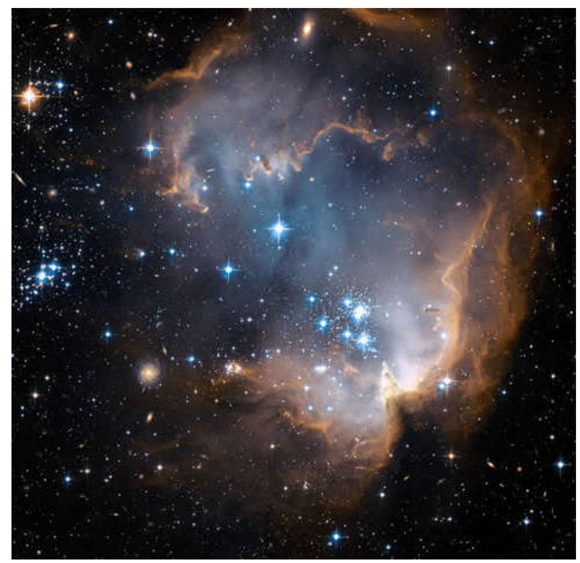


Figure adapted from Bigiel et al. (2008) by Lada (2014)

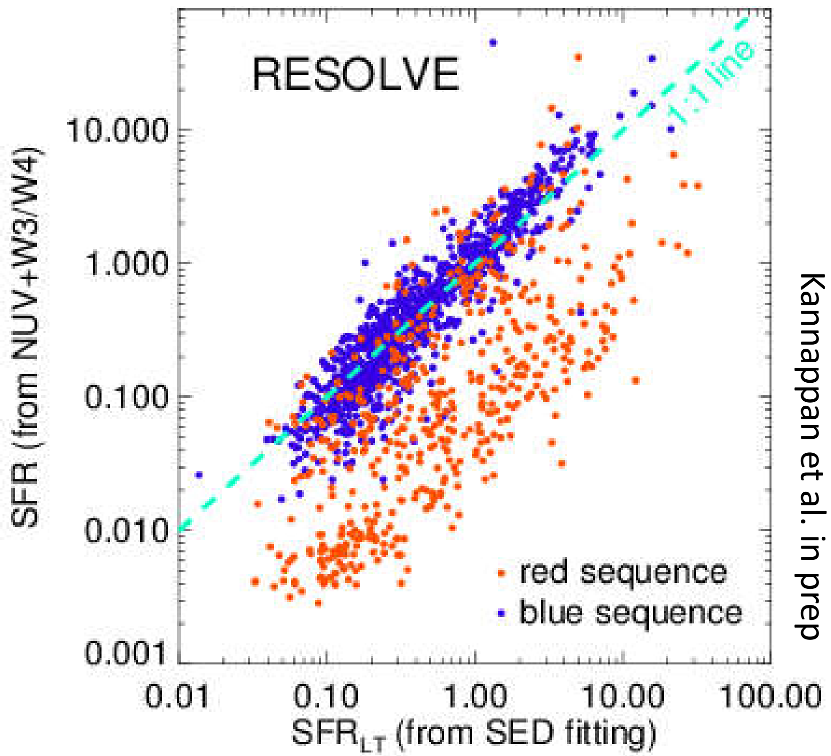
Star formation rates have implicit timescales and modeling assumptions

Measures of SFR

- **Hα** – sensitive to 5-10 Myr timescales, sensitive to extinction (Paschen α faint)
- **[OII] 3727** – similar timescales to Hα, more sensitive to extinction, also metallicity (reverse effect! higher O/H ➔ better cooling ➔ [OII] down)
- **UV flux** – sensitive to 10-100+Myr timescales, subject to extinction, calibrated w/ stellar population models
- **Far-IR flux** – no extinction, dust heated by young stars & old stars >~100 Myr
- **Radio continuum (1-6 GHz)** – no extinction, emission from relativistic electrons accelerated in supernovae, delayed timescales of 3-30 Myr

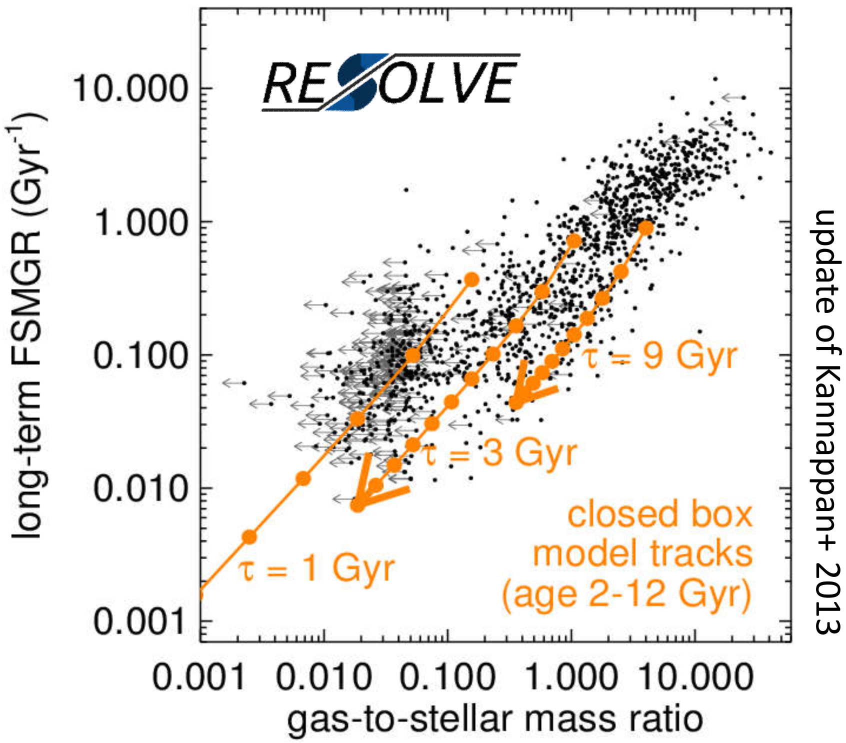
Notes:

- All methods trace massive, short-lived stars so are sensitive to IMF
- By default SFRs are assumed to be short term (SPS modeling is used to infer a Gyr-timescale SFR below)

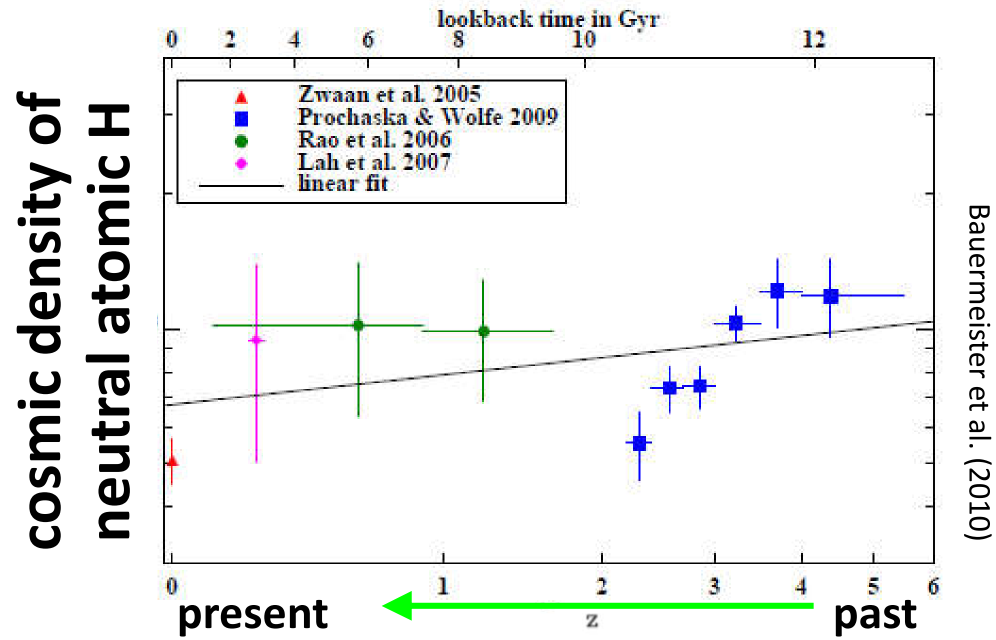


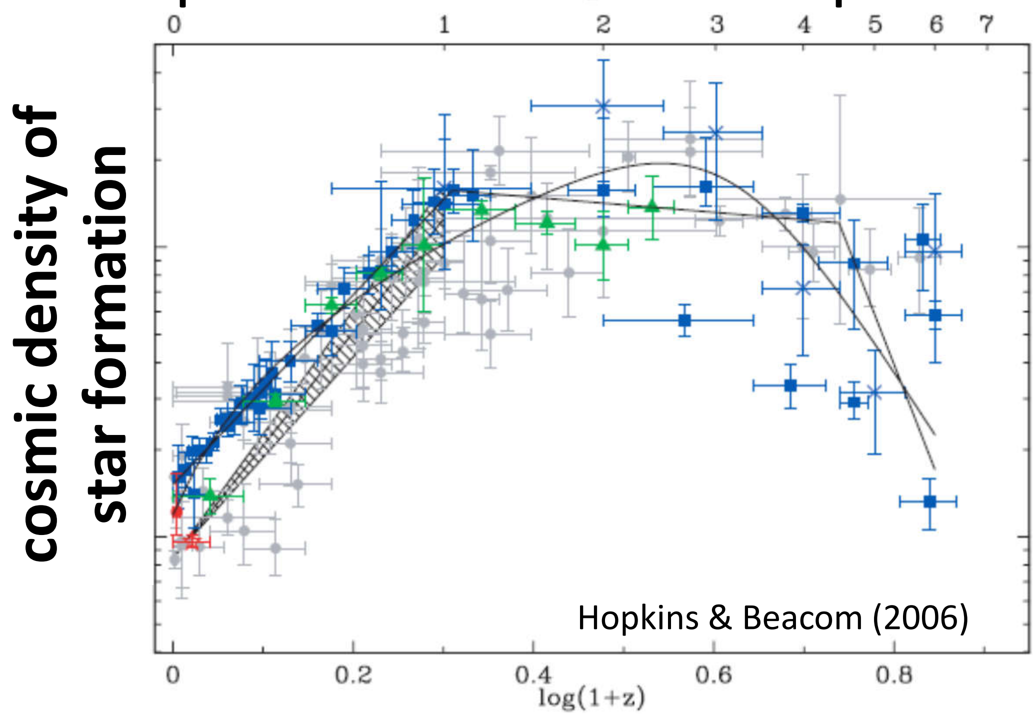
Kannappan et al. in prep

Evidence of cosmic gas accretion on longer timescales



Fractional stellar mass growth rate (stellar mass formed in last Gyr/formed in all previous Gyr) tracks *current* HI gas content → dwarfs not closed boxes!





The "star forming main sequence"

skeptic's view:

DECODING THE STAR-FORMING MAIN SEQUENCE OR:
HOW I LEARNED TO STOP WORRYING AND LOVE THE CENTRAL LIMIT THEOREM

DANIEL D. KELSON
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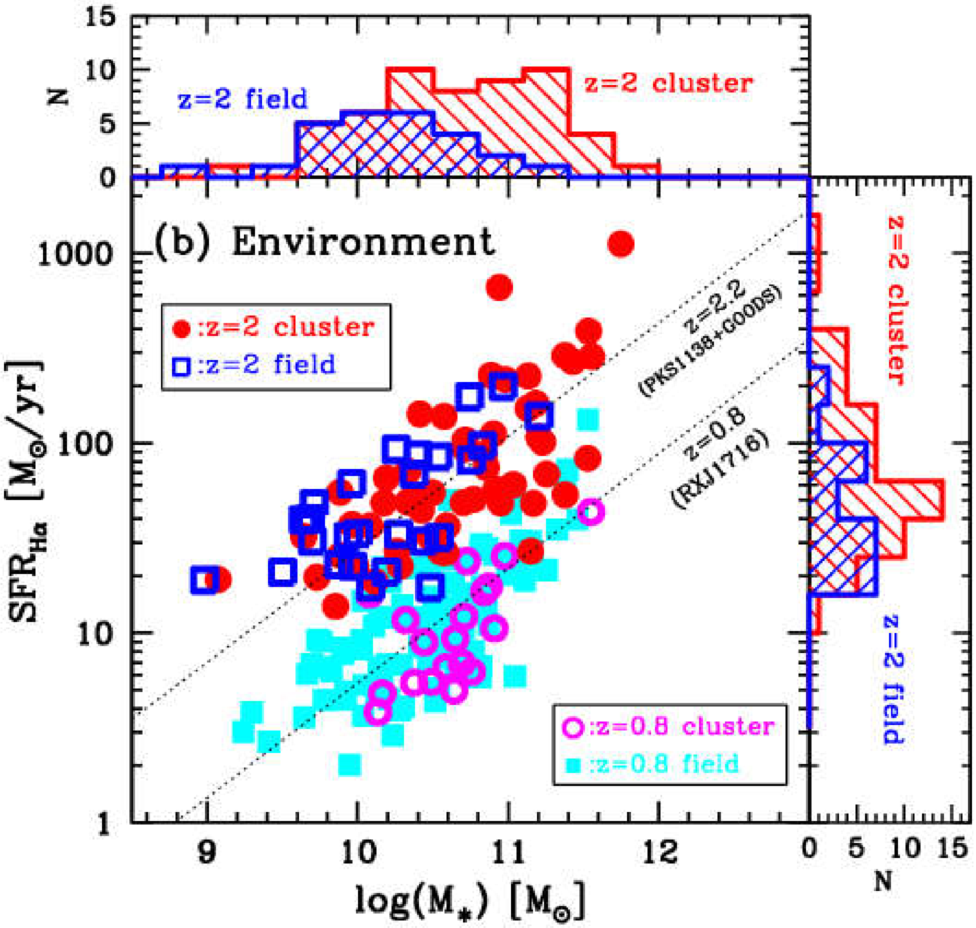
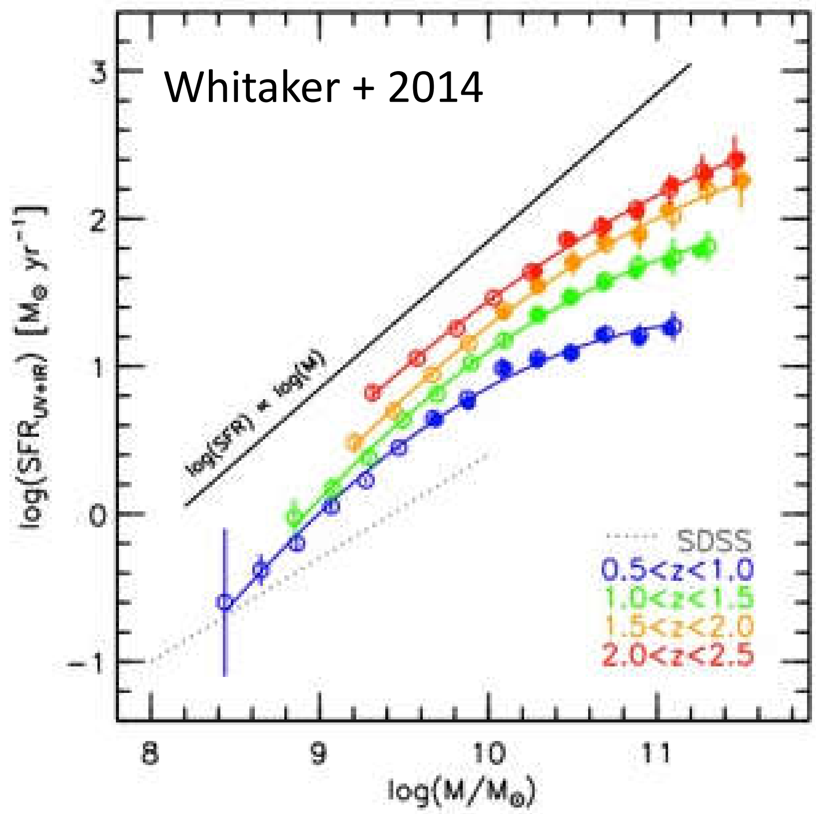
(Draft June 23, 2014)



Koyama + 2013



derivative-integral relation:
astrophysics is in the scatter…