High redshift populations and rates

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Questions

- How do the progenitor stellar populations influence SN Ia properties?
- What are the consequences for SN Ia cosmology?

- Sub-luminous SN Ia rates

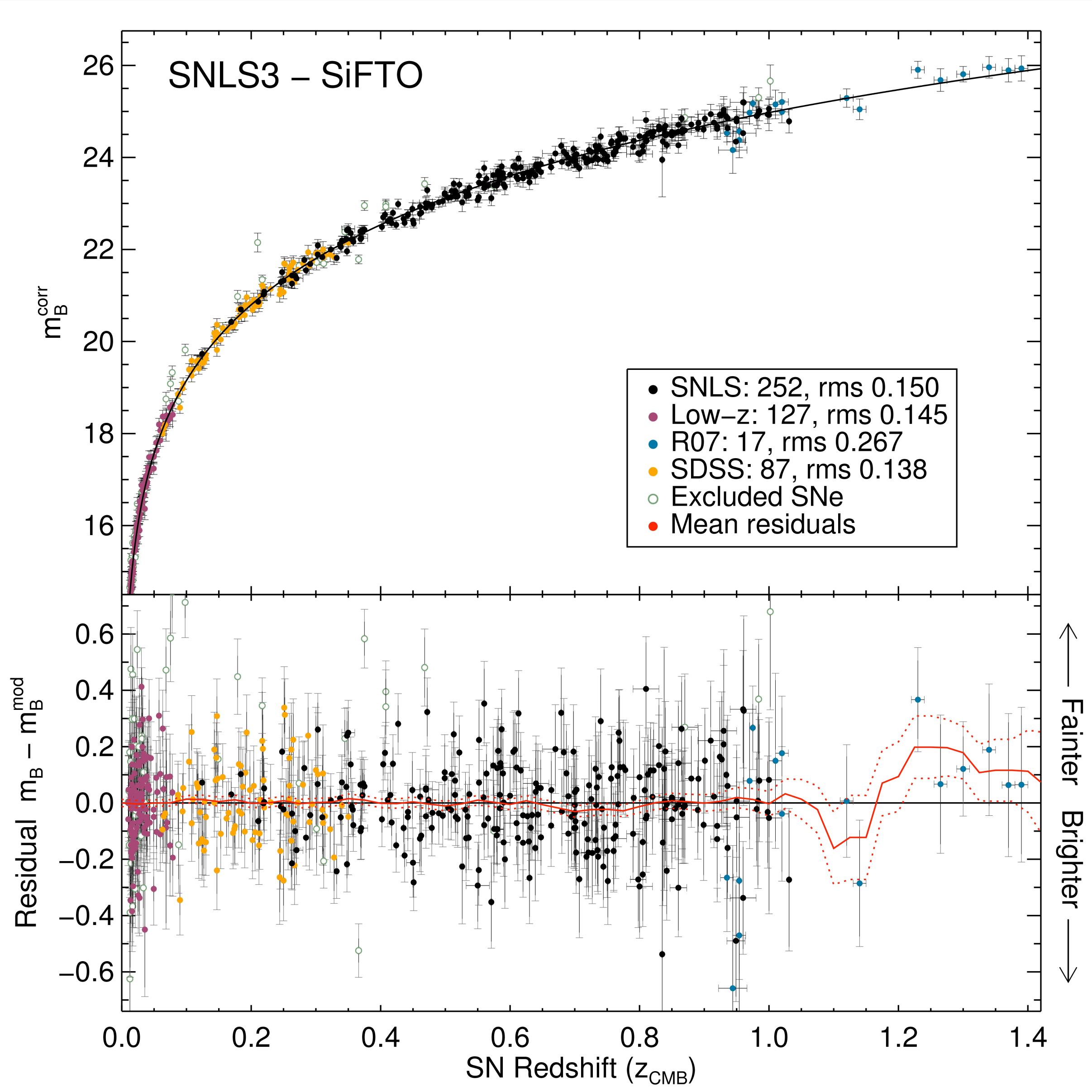
Cosmology: Standardising SNe Ia

- SN cosmology depends critically on empirical relations to decrease the scatter in SN peak luminosities
- Brighter have a) *wider, slower light curves*, and b) *bluer colours*
- Many techniques
  - *SALT, SiFTO, MLCS, BATM, Δm_{15}, …, …*
  - M_B – absolute magnitude for a s=1 c=0 SN *(Arbitrary definition)*
  - α – parameterises the stretch—luminosity relation
  - β – parameterises the colour—luminosity relation

$$\mu_B = m_B - M_B + \alpha(s-1) - \beta c$$

- Empirical, yet captures most of the variation in SN Ia properties
- Assumed to be universal (and therefore unevolving with redshift)

Typical Hubble Diagram



Typical sample sizes of 500 SNe Ia

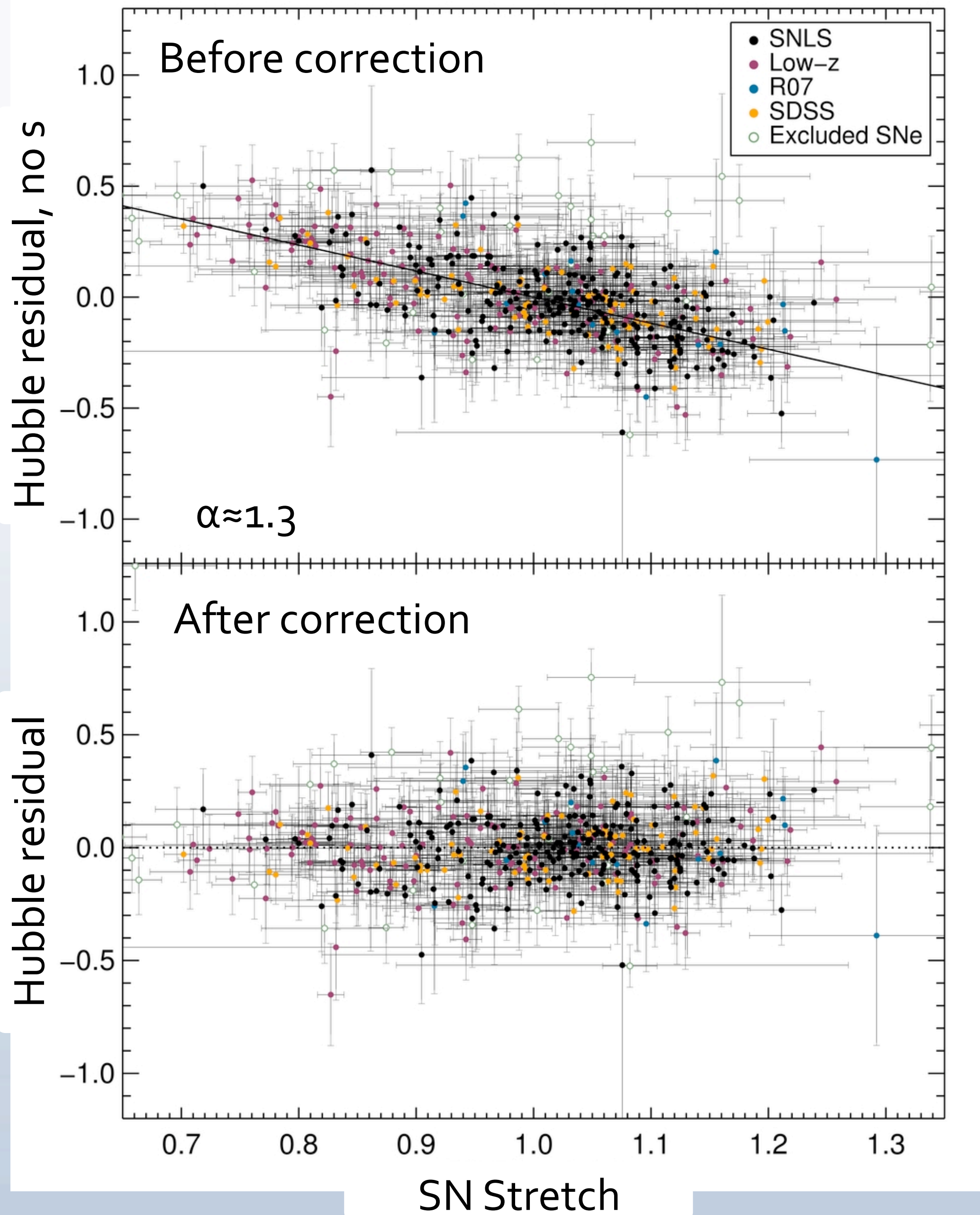
Typical rms is 0.14mag

Typical intrinsic error is 0.10mag

SN distances are generally accurate to 5-6%

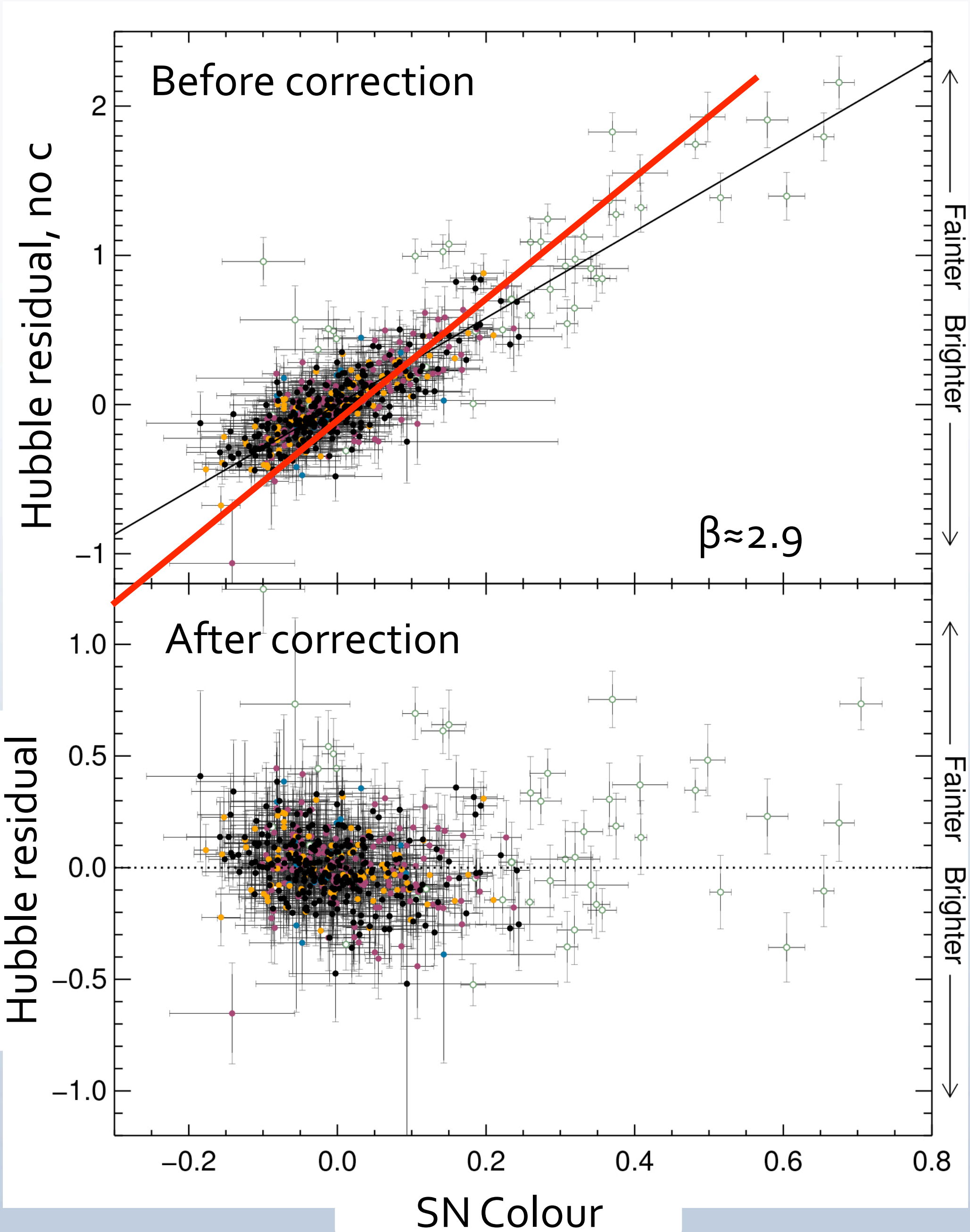
Therefore, any age or metallicity systematic is going to be subtle

Light-curve width correction



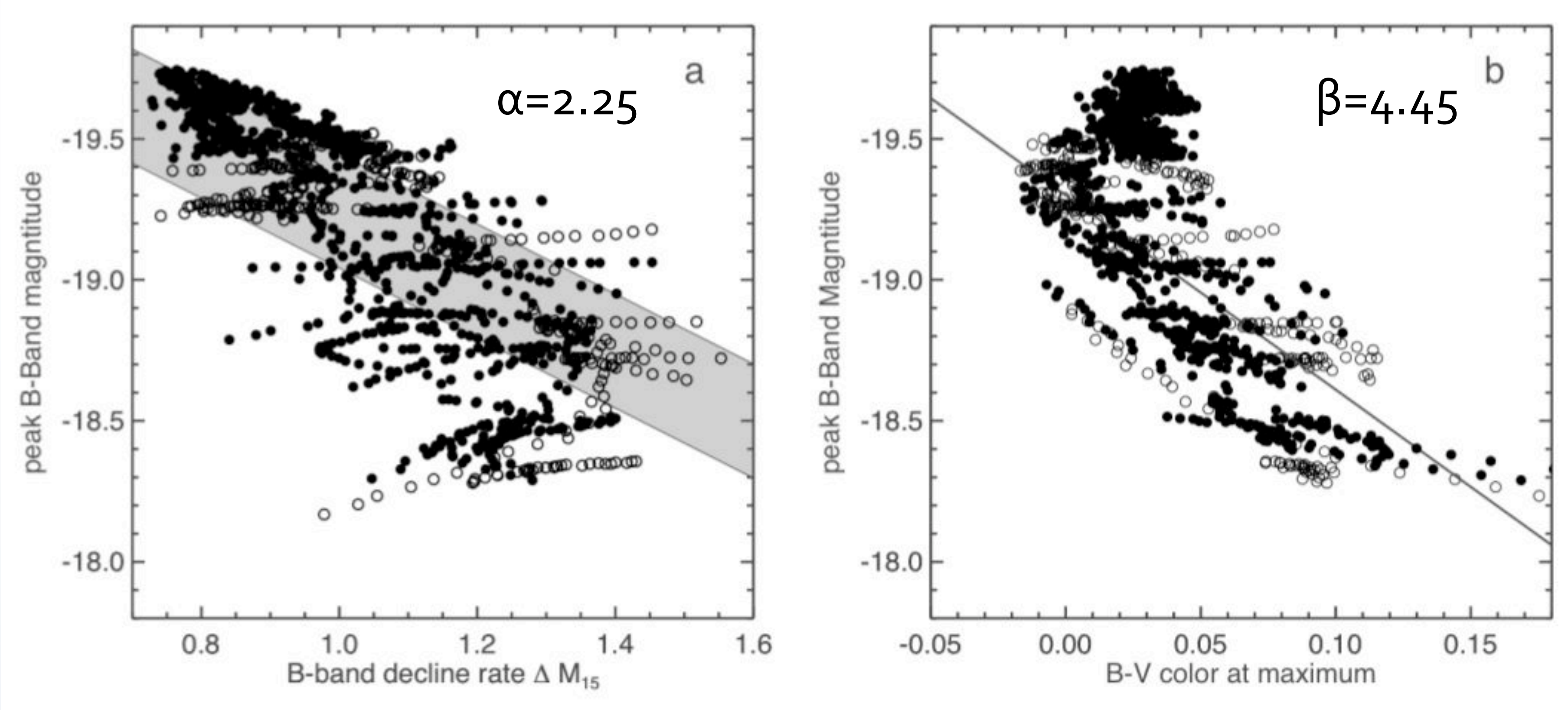
- Brighter SNe have wider, slower light curves
- Classic Phillips relation
- Almost certainly an intrinsic relationship
- Why should this be linear in magnitude (log) space?
- Should this be invariant with age or metallicity?

Colour correction



- Brighter SNe have bluer light curves
- Picture very confused
- Dust would give a linear relation in log/log space
- Slope, β, << 4.1 (MW dust)
- True for ALL light curve fitters
- *Mixture of external extinction and intrinsic relation?*
- *Properties of dust near SNe?*
- *Dust in MW is different to other galaxies?*

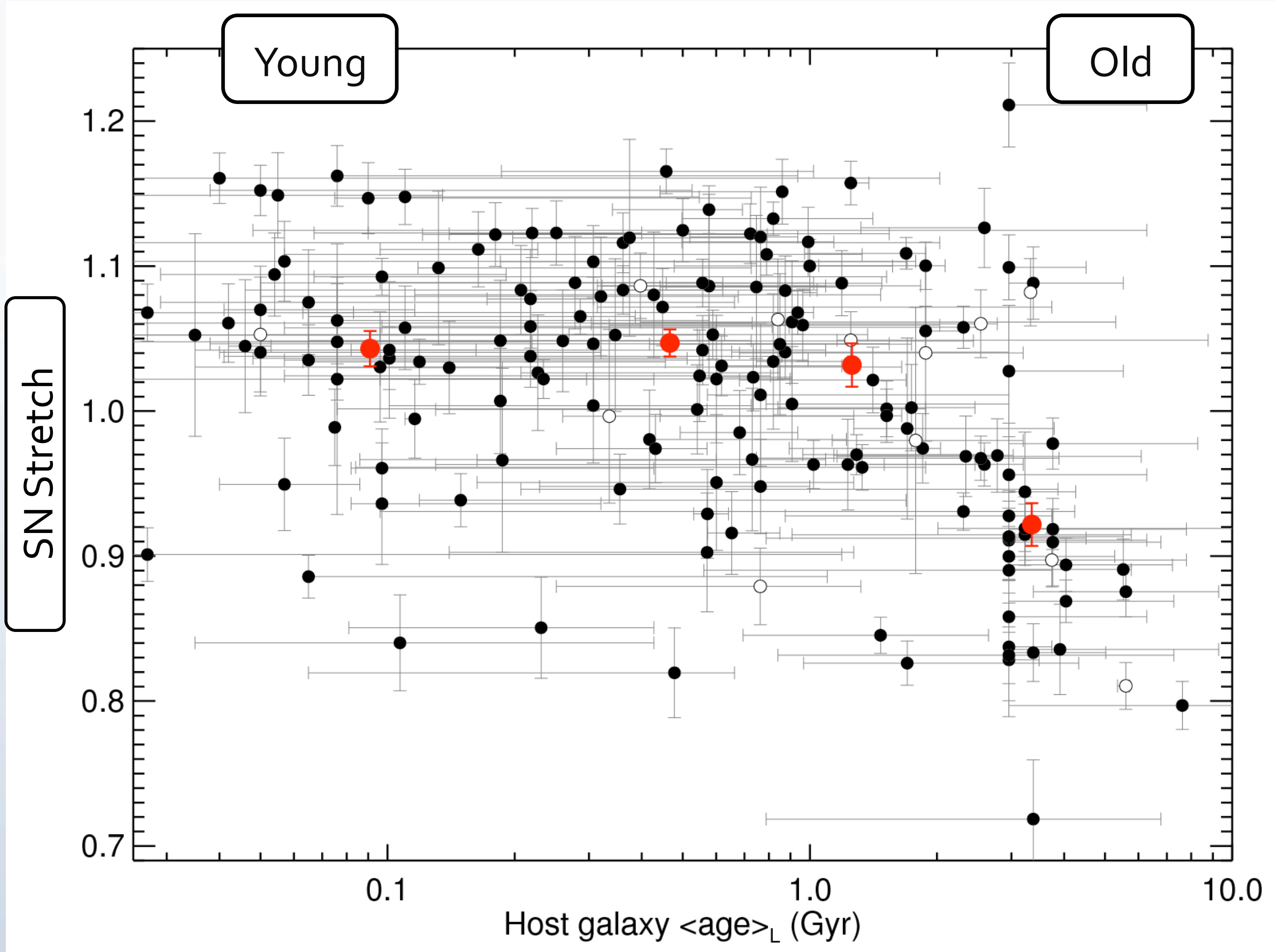
Theoretical predictions



- Models can reproduce sense and ~magnitude of the two relations
- An strong intrinsic colour—luminosity relationship is apparent

Kasen et al. 2009

SN properties and environment



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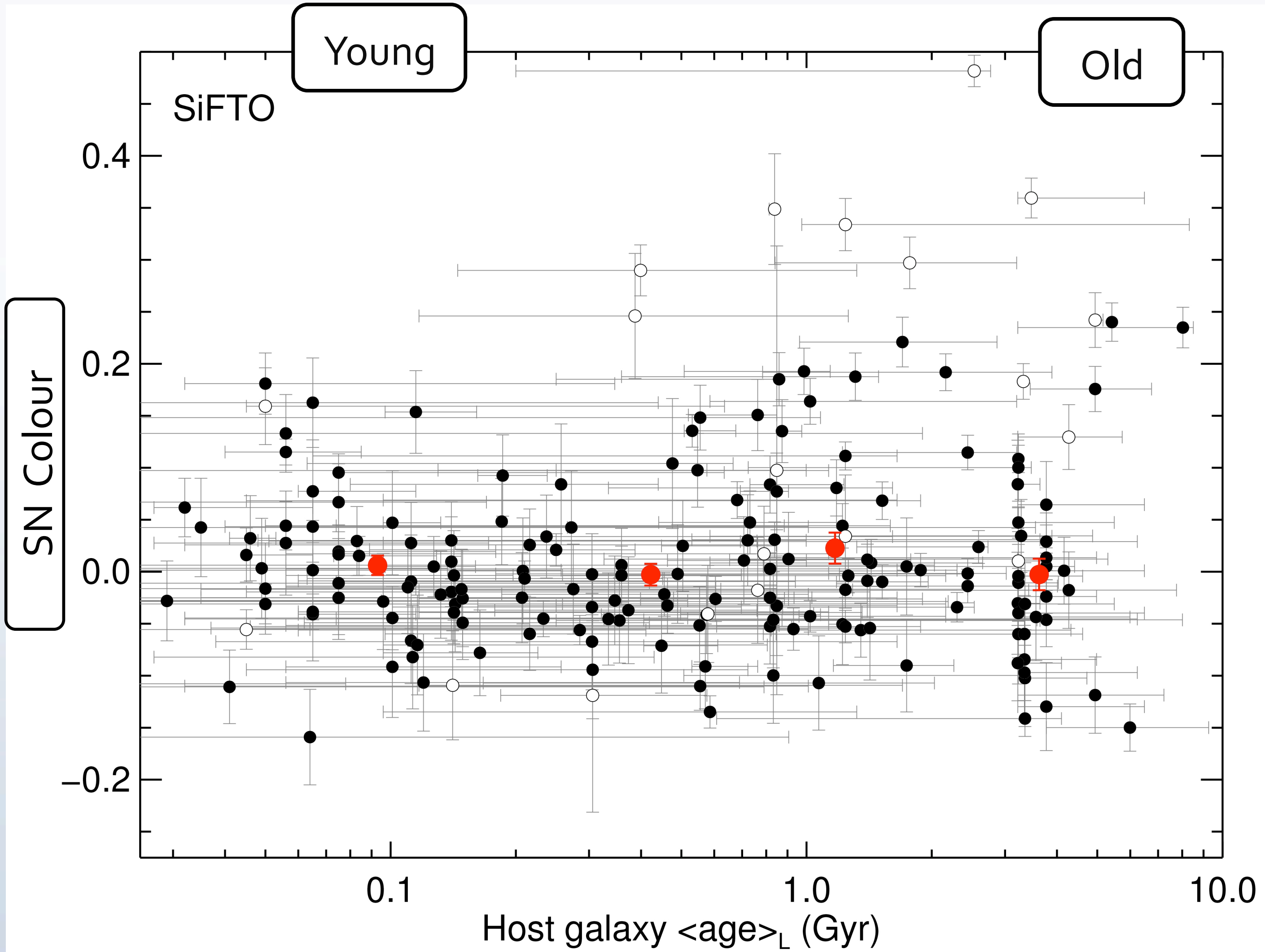
SN properties and environment



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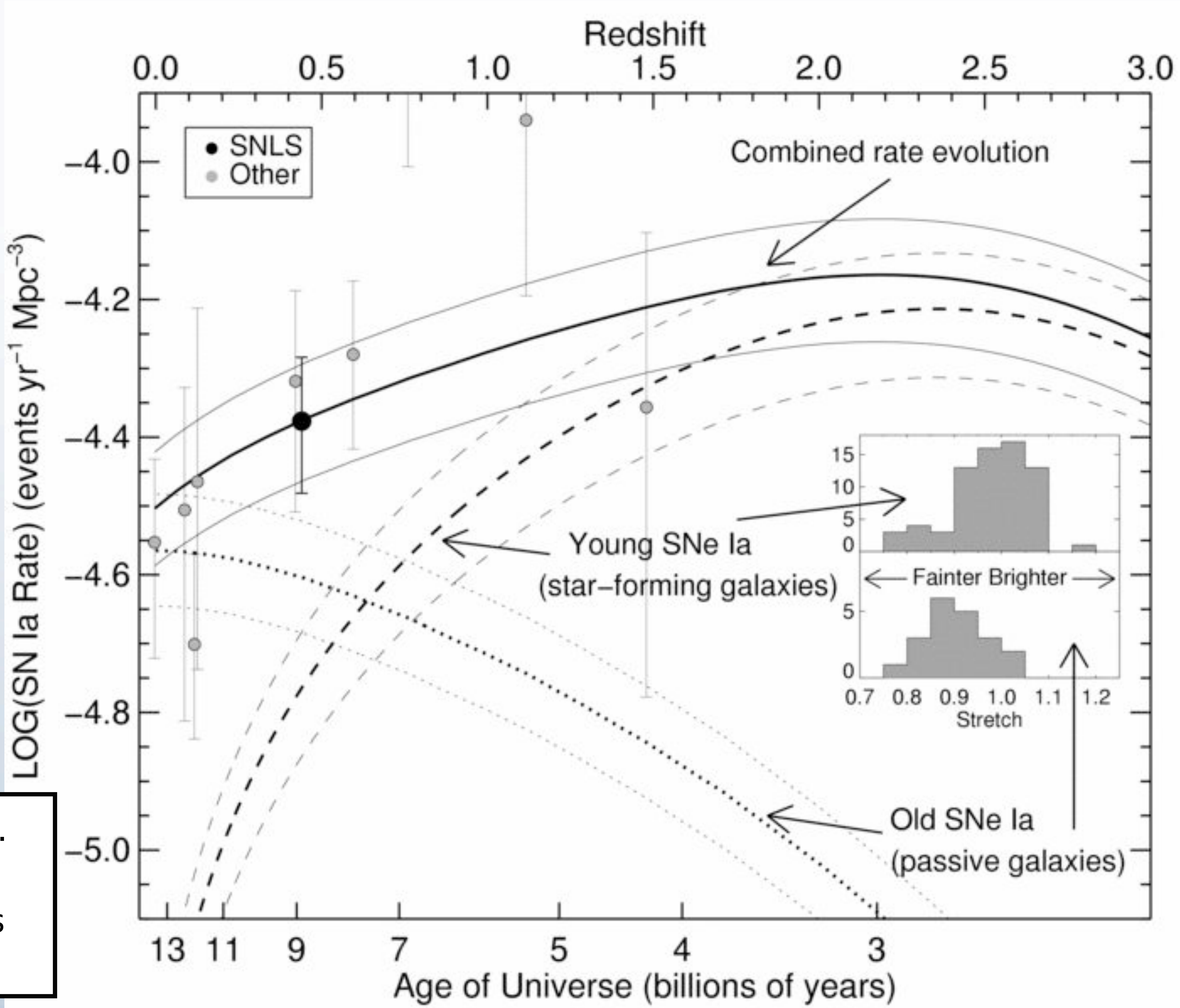
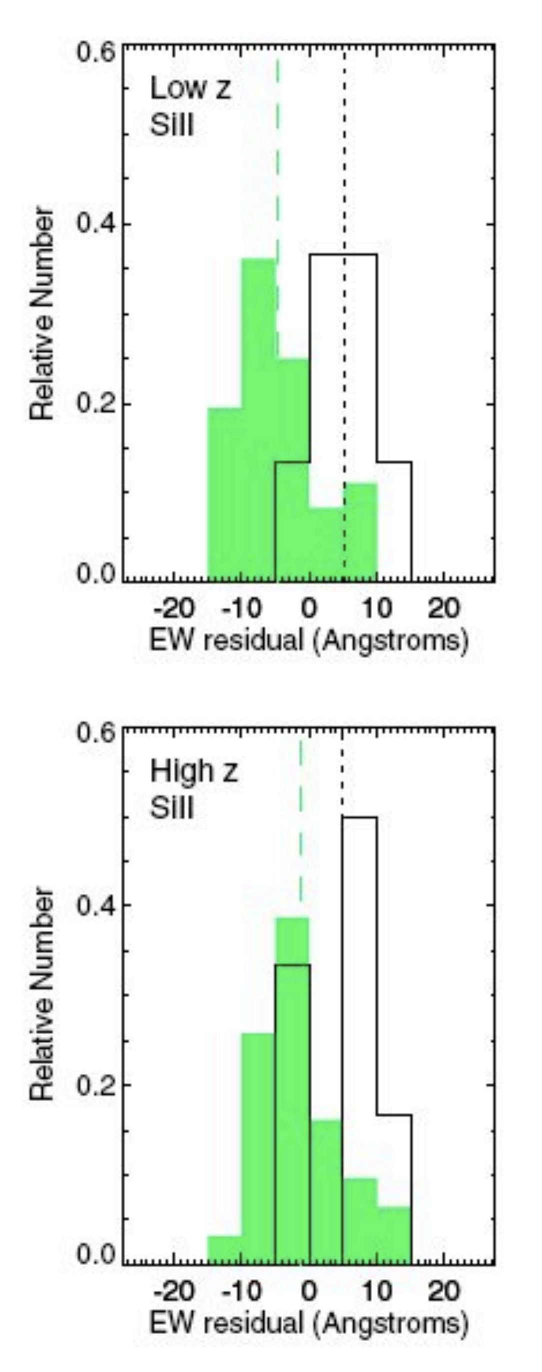
SN Ia mix evolves with redshift

Relative mix of young+old evolves strongly with redshift

Mean stretch evolves with redshift

See Howell et al. (2007) for a detection of this effect





Si II EW versus host type

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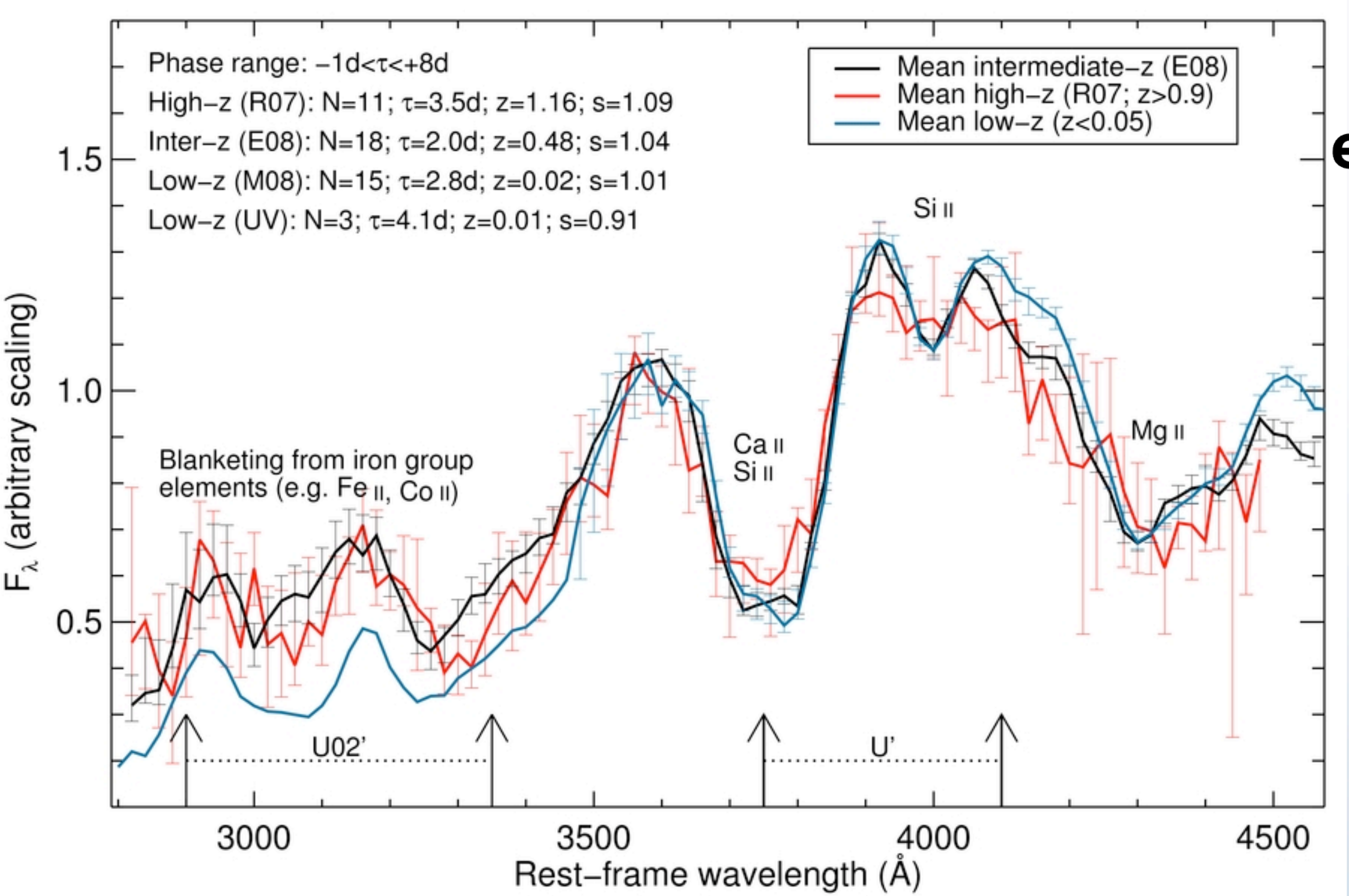
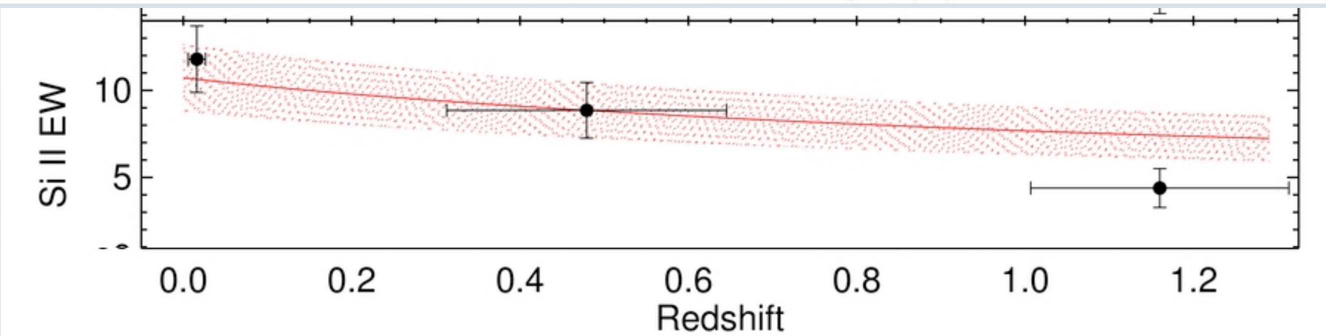
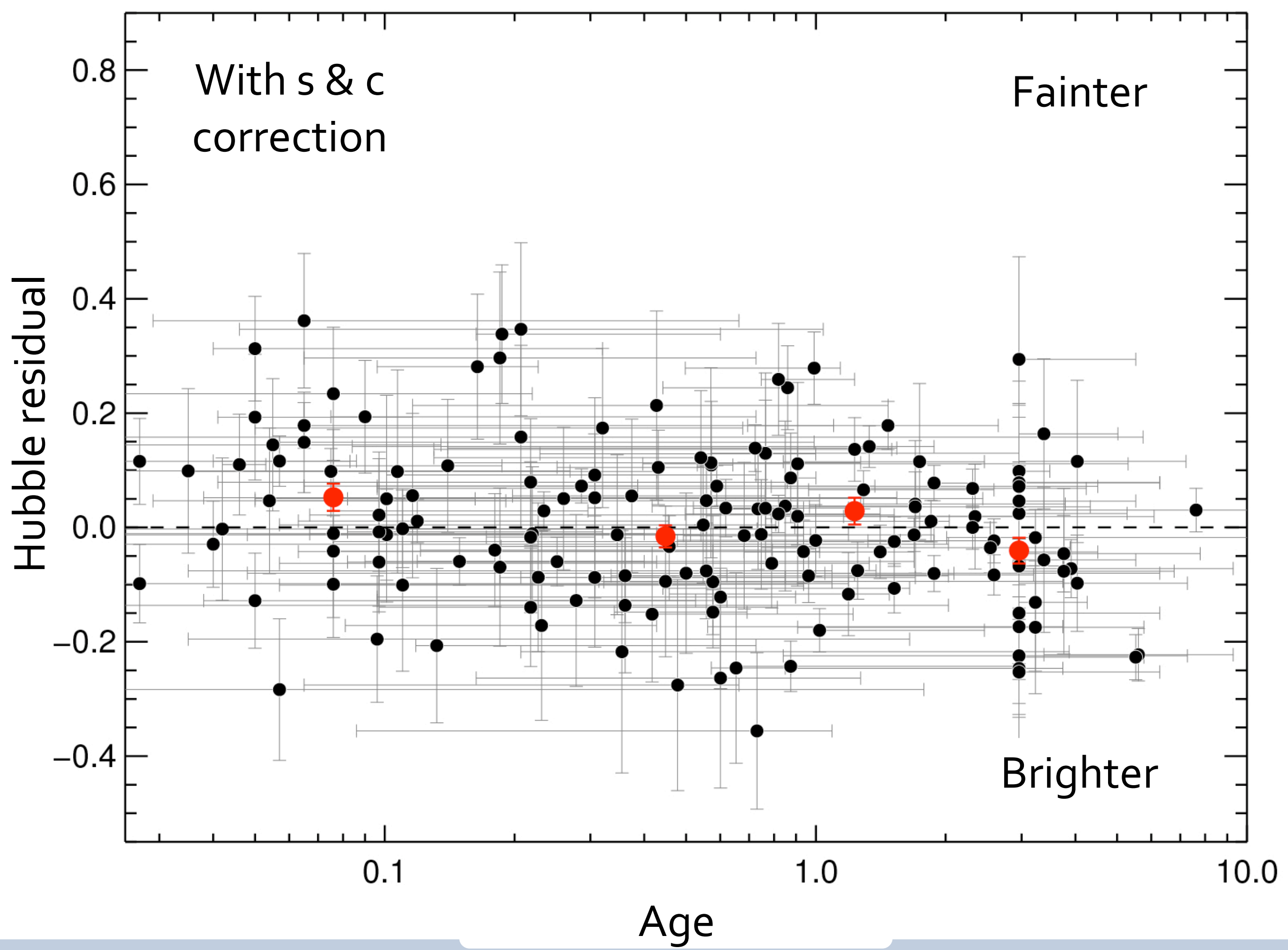
Spectral evolution?





Residuals versus galaxy properties

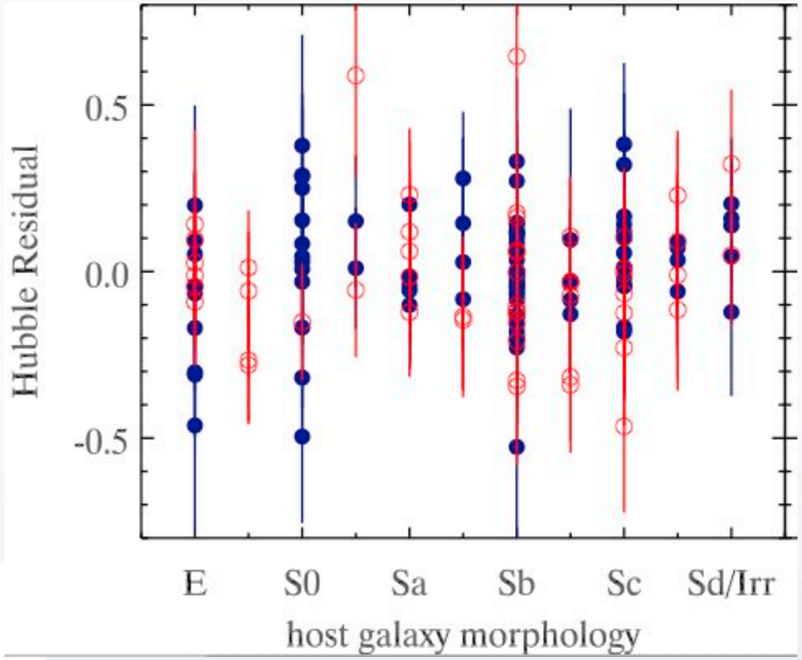
- Hubble residuals versus host galaxy SFR and host galaxy <age>$_L$
- After corrections, SNe in younger galaxies appear fainter, 0.05mag at ~2 – 2.5σ

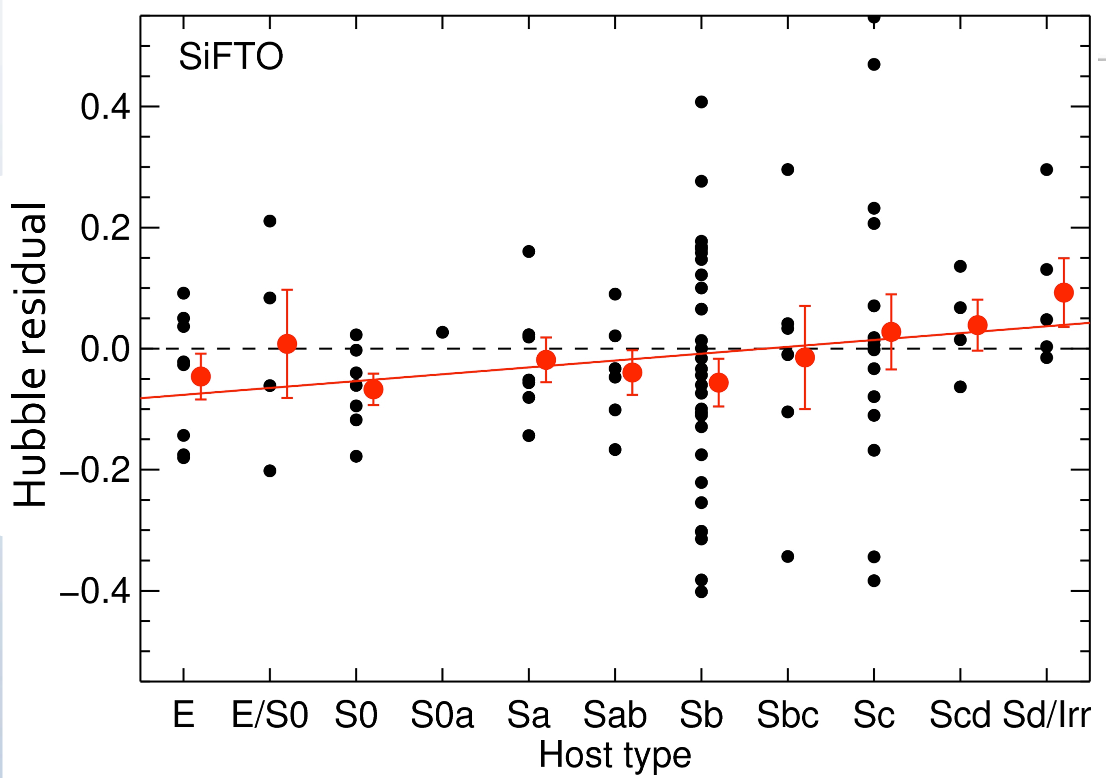


SNLS data and fixed cosmological model

Hicken et al.

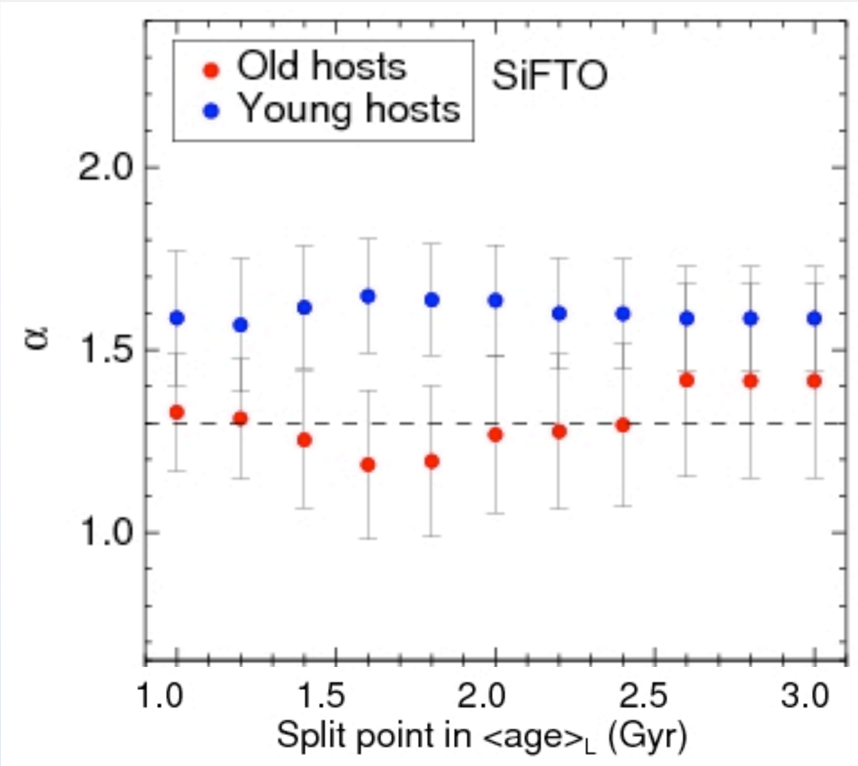
- Hicken et al. observed a similar ≈2σ effect in a new low-z sample
- Similar weak trends seen with all light curve fitters (right, SALT; below, SiFTO)

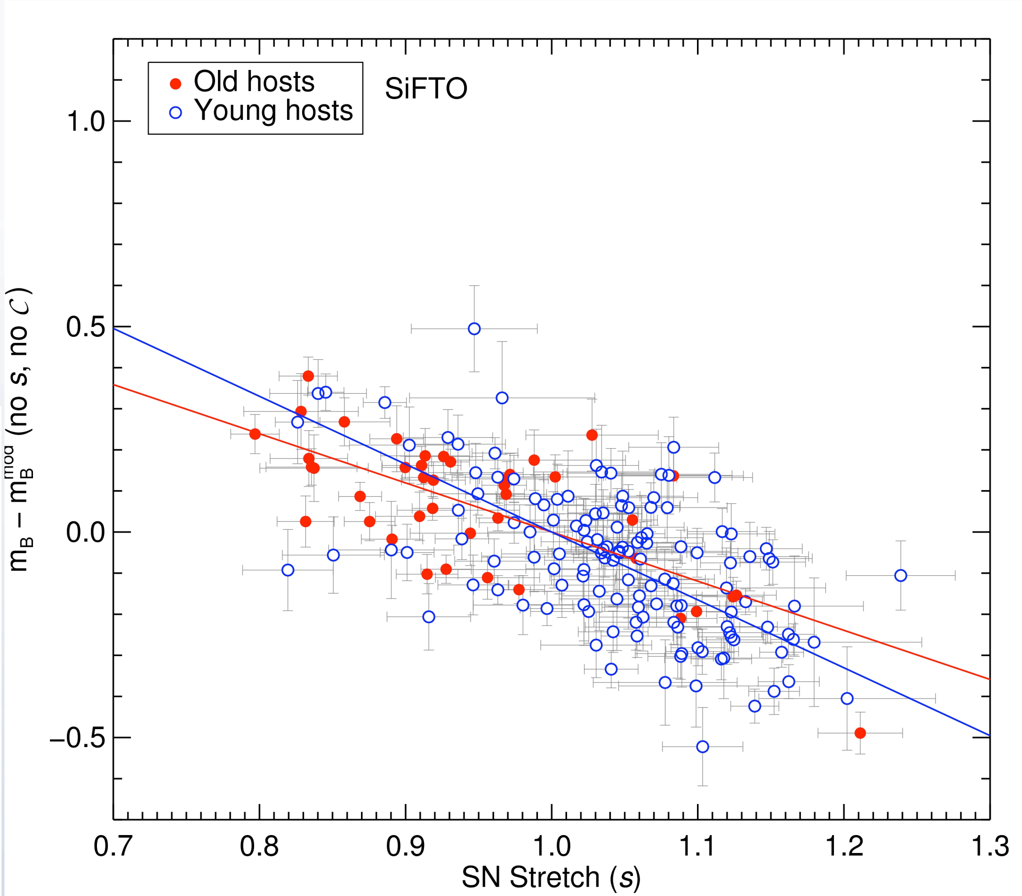




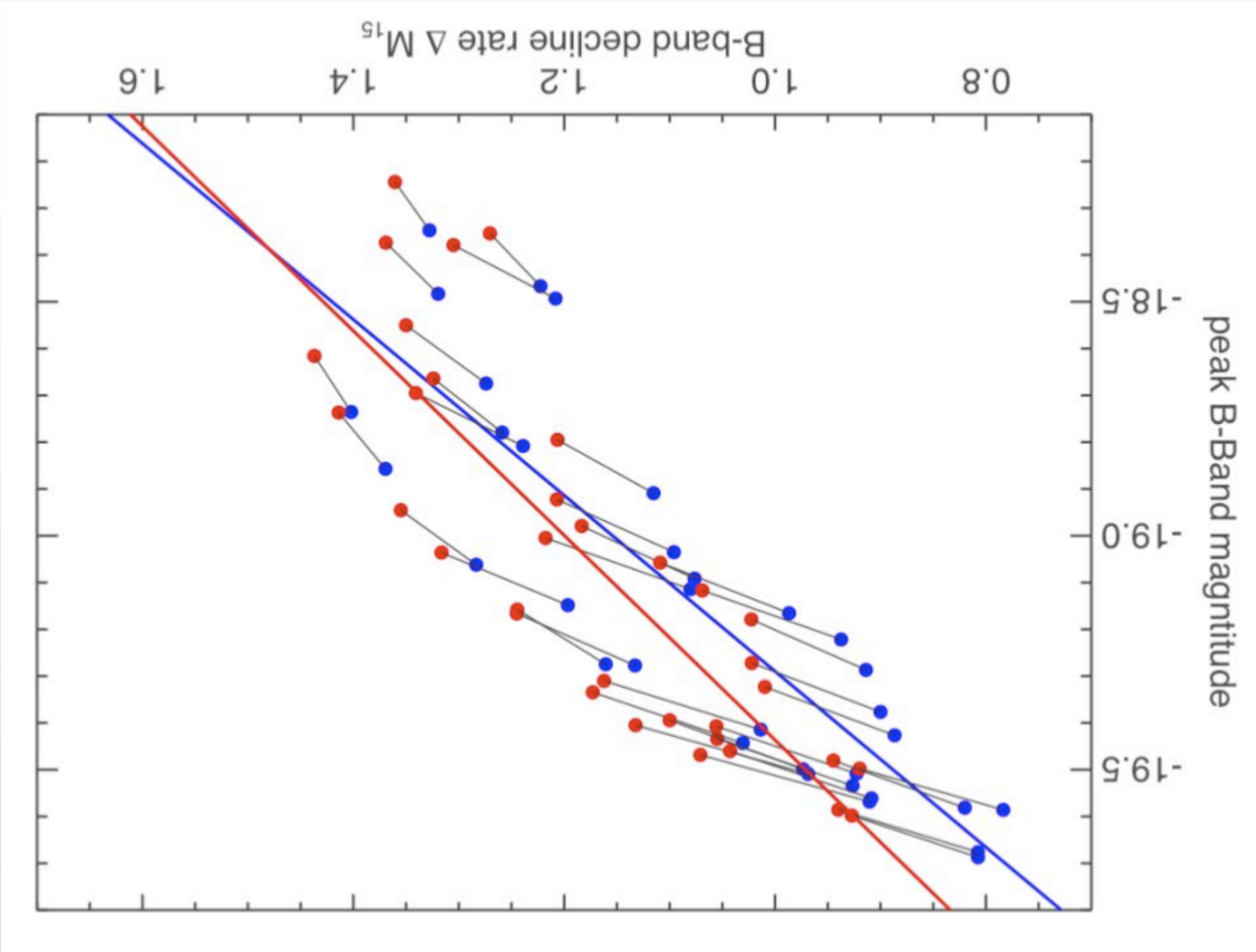
Stretch relation

Slope of stretch corrections appear similar across environments





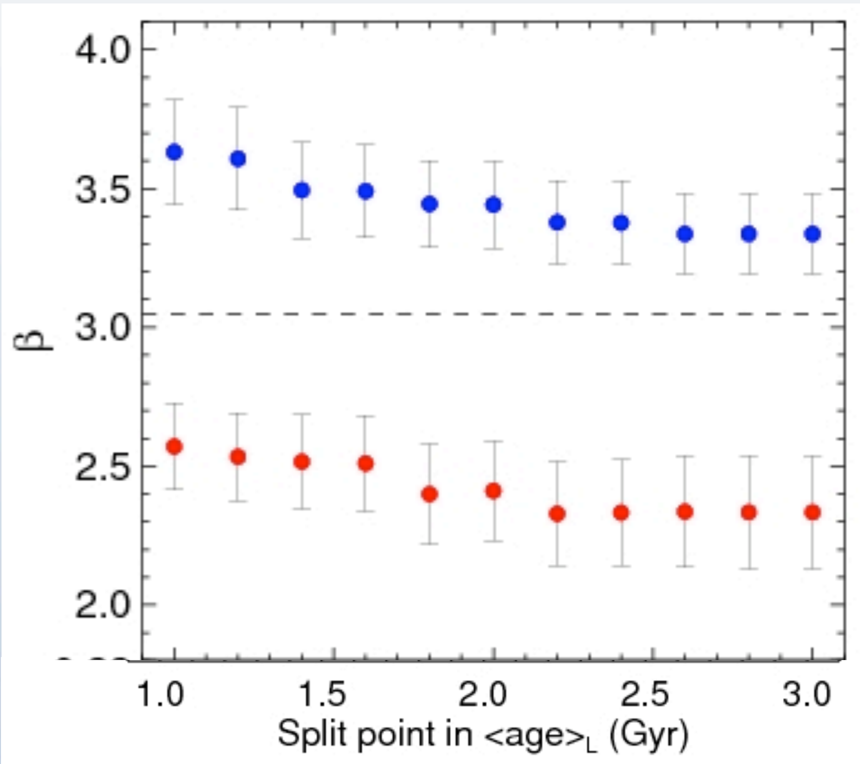
Compare to theory

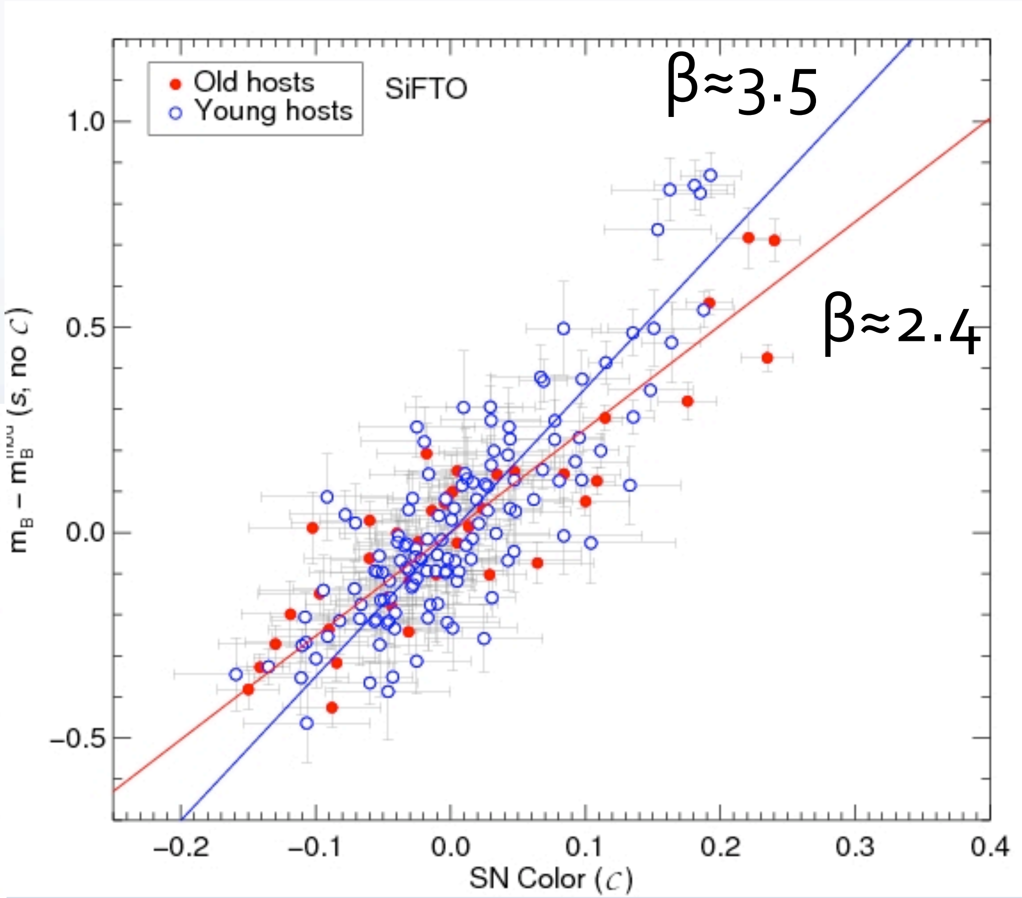


- Red – high metallicity
- Blue – low metallicity

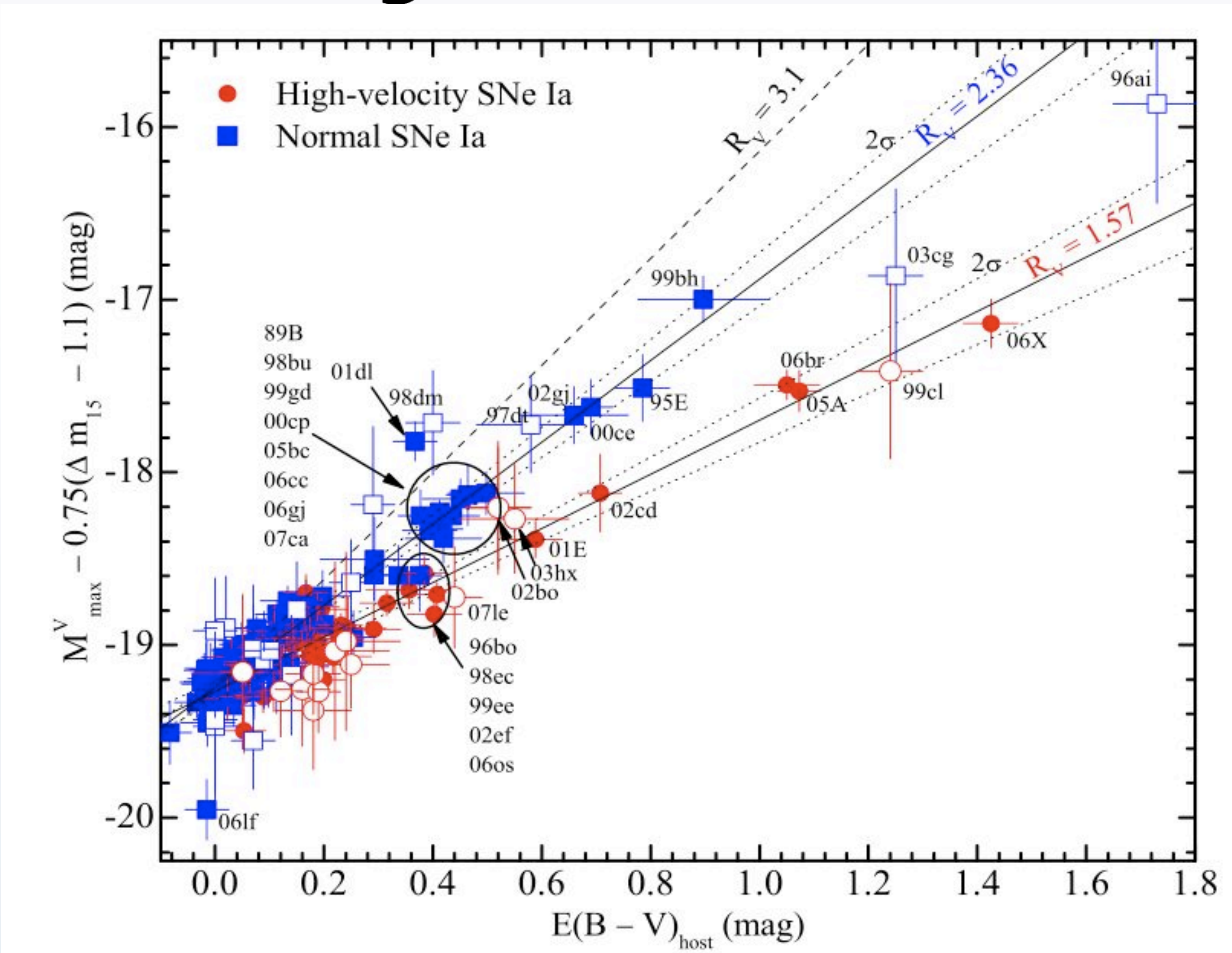
Colour relation

- Some evidence for larger β in younger galaxies
- Note strong colour relation in old, passive galaxies





Wang et al. HV SNe Ia

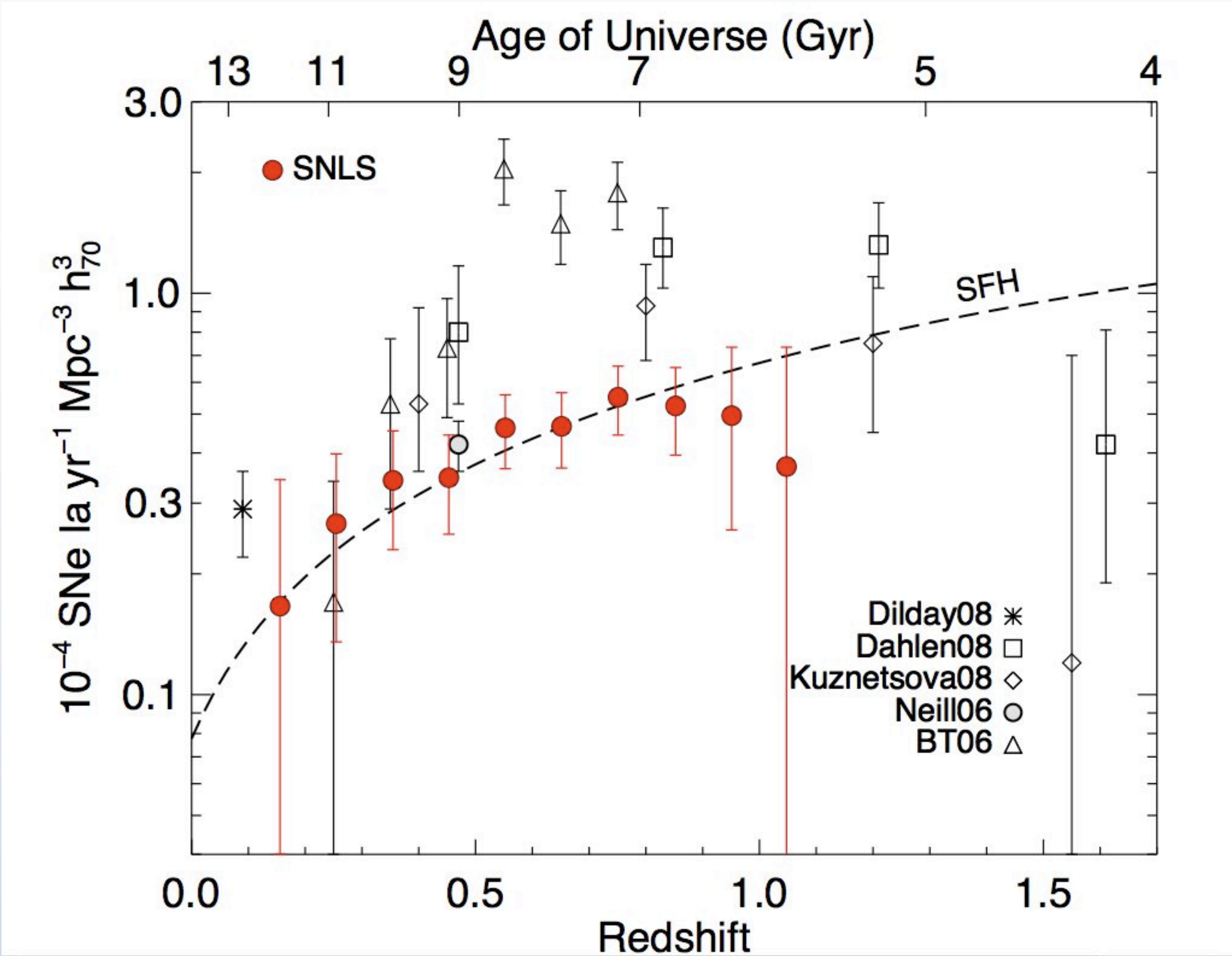


- High-velocity Si 6355 SNe show smaller R_V

Standardisaton Summary

- Tests for the cosmological effects of “two components” are non-trivial – supplementary host information is required
- Some evidence for differences in nuisance parameters
- Not clear whether this is a property of:
    - The SNe (e.g., two progenitors)?
    - The galaxies and environments (e.g., dust)?
    - The light-curve fitting techniques?

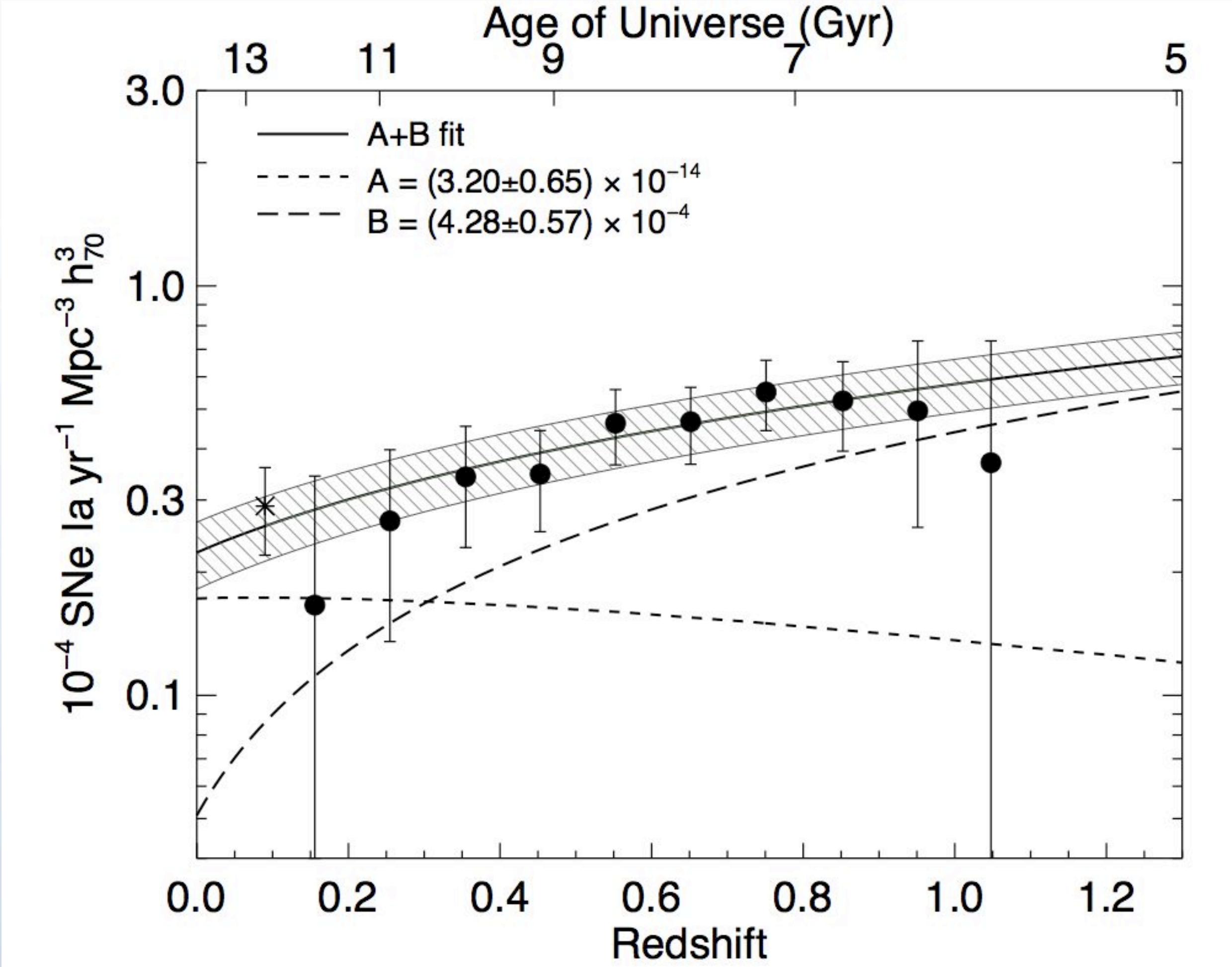
SN Ia rates



- Normal SN Ia rates (0.8<s<1.25)

Perrett et al. (2009)

SN Ia rates



- "A+B" fit, inc. z~0 SDSS data point

Perrett et al. (2009)

Sub-luminous SN Ia rates

- Sub-luminous – up to 2mags fainter
- Narrow, fast, redder light curves (*see poster by S. Gonzalez*)
- Ti II and enhanced Si II in spectra; classical example SN1991bg
- Usually found in old stellar populations

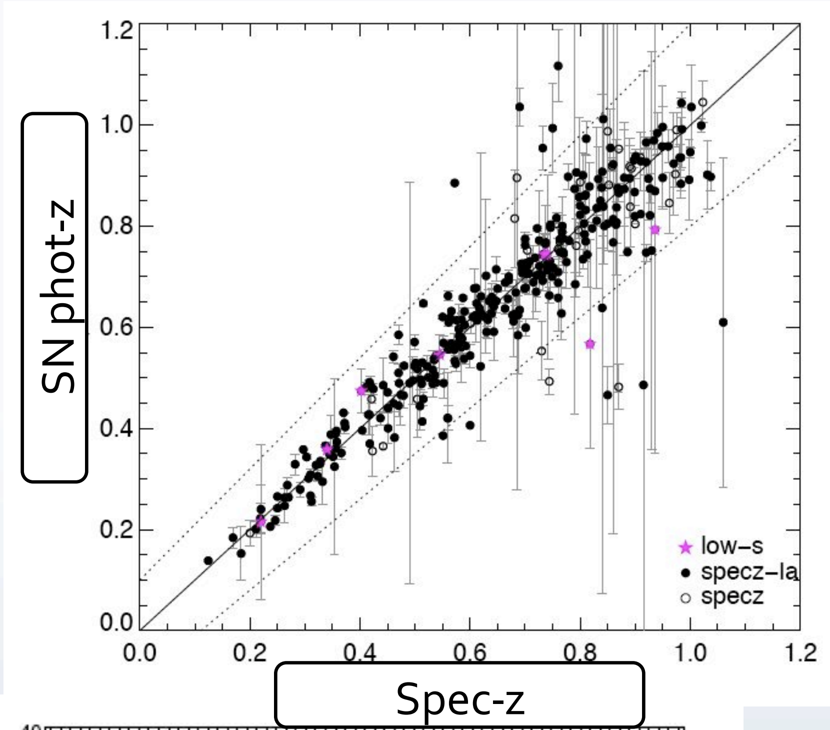
- Not yet located at z>~0.1:
  - Too faint to find? Too faint to spectroscopically confirm?
  - Don't exist – delay time too long? Different progenitors?

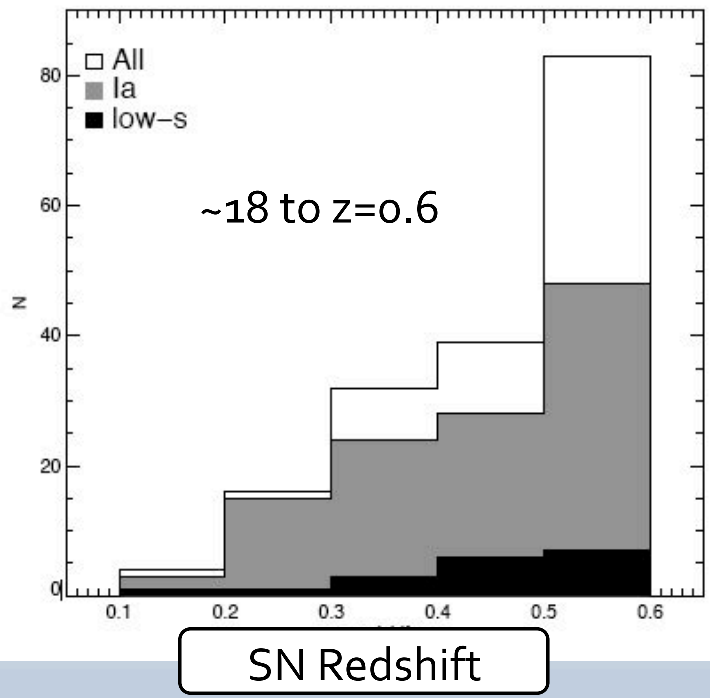
- Defined here as s<0.8 (typically not used in cosmology)
- Search in SNLS data and identify photometrically

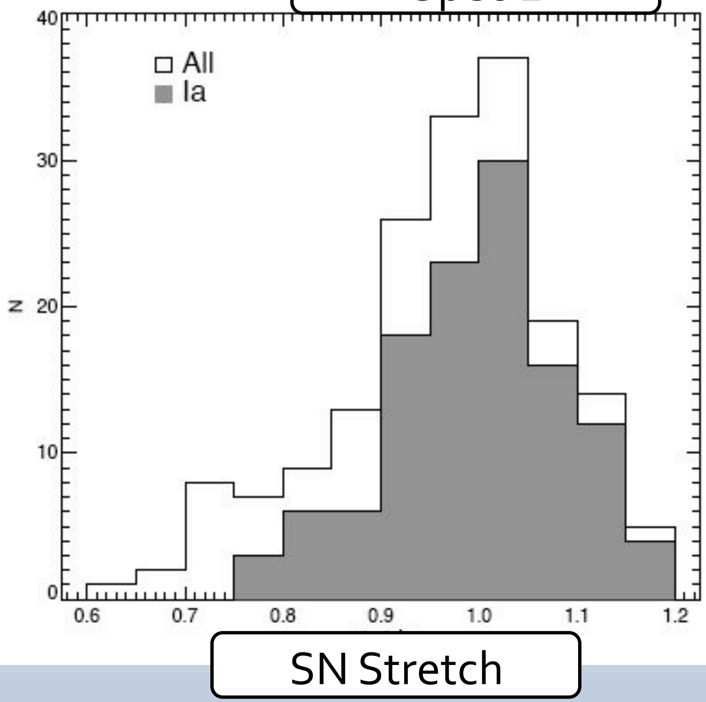
Gonzalez-Gaitan et al., in prep

Redshift and stretch histograms

- Redshifts show excellent agreement
- Many low-s SNe identified at high-z

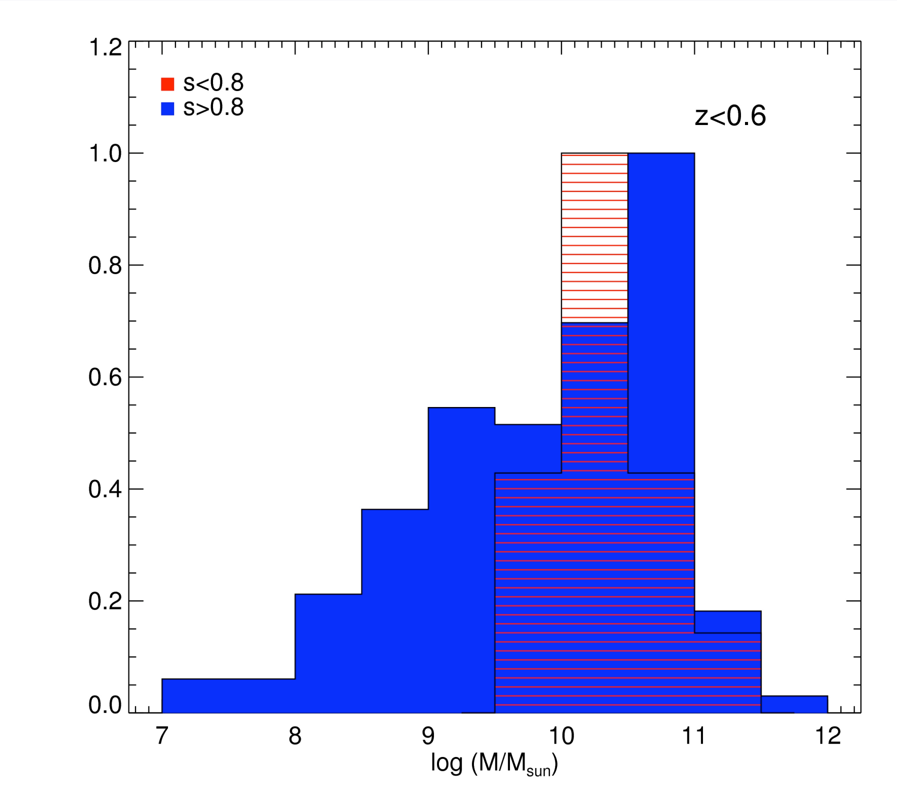


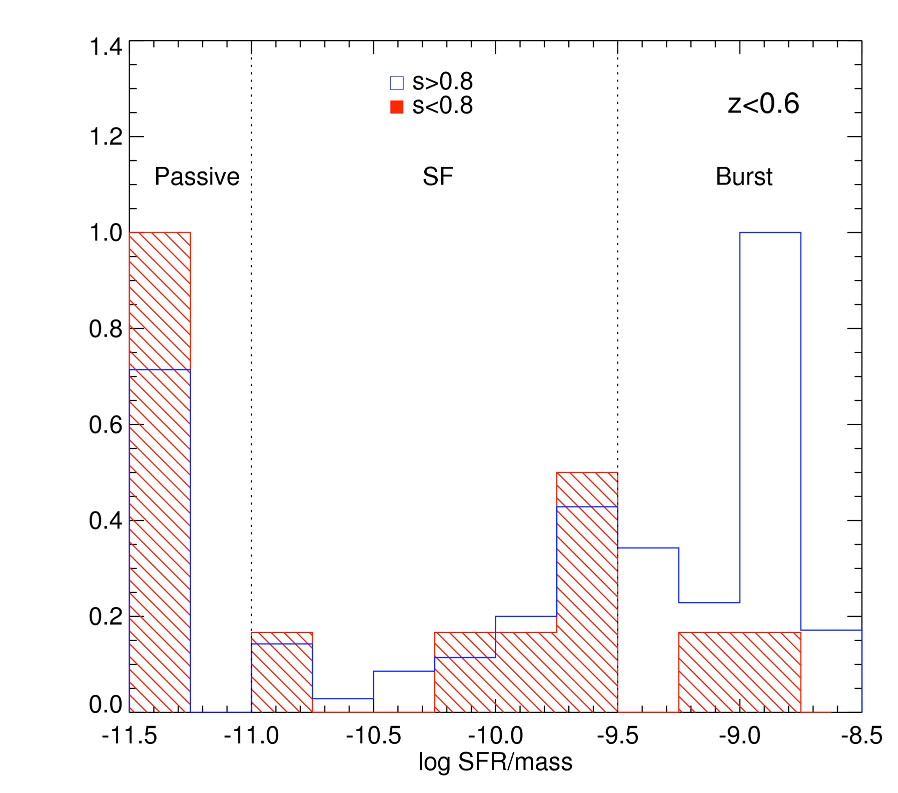




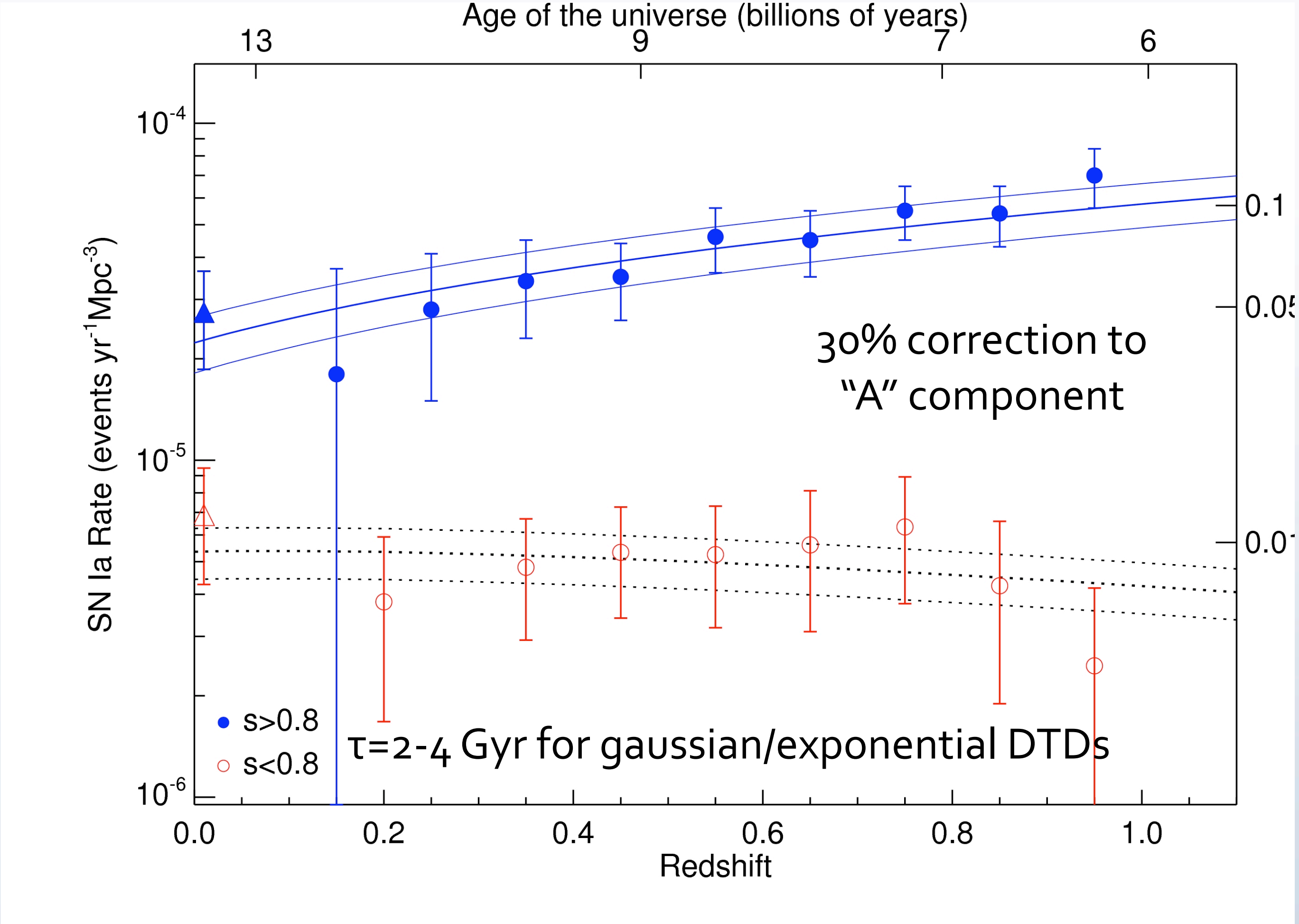
Hosts of sub-luminous SN Ia

Hosts tend to be high mass and low (zero) specific SFR (as expected)





Sub-luminous SN Ia rates



- Sub-luminous (s<0.8) rate evolution

Gonzalez-Gaitan et al., in prep