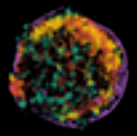

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Large Synoptic Survey Telescope

CoCo – Spectrophotometric Templates of Stripped Envelope Core Collapse Supernovae

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@UoS_SNe / @astro_berto

UoS-SNe

Rationale

- Stripped Envelope SNe (SESNe):
  - SNe Ib, IIb, Ic, broad line (BL)-Ic
- Existing stripped envelope SNe template sets
  - Small number of objects
  - Variable data quality
- Important for Classification and Simulation
- Recent releases have made more data available

Methods

- Unlike (relative) homogeneity of (normal) SNe Ia, CC SNe show great heterogeneity in:
  - Absolute Luminosity
  - Spectral Evolution
  - Light Curve Morphology
- ‘SNe Ia’-like method impractical

Methods

Approach used with SNe Ia:

- Create mean spectrum at a given epoch from large number of SNe
- Time series typically daily cadence
  - Additional sampling using linear interpolation
- Aligned to common phase (typically B-band max)

Approach

1. Assemble sample of SESNe – Spectra and Photometry
2. Fit light curves SN-by-SN, filter-by-filter
3. Mangle spectra (see eg. Hsiao et. al. 2007, Conley et. al. 2008)
   - Spline order is $N_{filters}+2$
4. Correct for MW extinction
5. Use adjusted spectra to generate spectrophotometry
6. Fit this synthetic data with LC function to cover all epochs
7. Preserve (normalised) z=0 template and mangling function
   - Use Luminosity Function to generate LCs currently Li et. al. 2011

Functional Form

$$f_K(t) = A\left[1 + B(t - t_1)^2\right] \frac{e^{-(t-t_0)/T_f}}{(1 + e^{-(t-t_0)/T_{r1}})(1 + e^{-(t-t_2)/T_{r2}})}$$

Flux in a given band ‘k’ at time t

- Normalisation, rise time, fall time

Similar parameterisation to that used

- Bazin et. al. 2009,
- Karpenka, Feroz & Hobson 2013

Data Sample

- 29 Stripped Envelope SNe, split into:
  - 12 SNe Ib
  - 9 SNe Ic
  - 6 SNe IIb
  - 2 SNe with intermediate classifications (Ib/c & II/Ib)
- $9 \leq N(\text{spectra}) \leq 59$
- 17/29 use data from the CfA sample (Modjaz et. al. 2014, Bianco et. al. 2014)

Data Sample

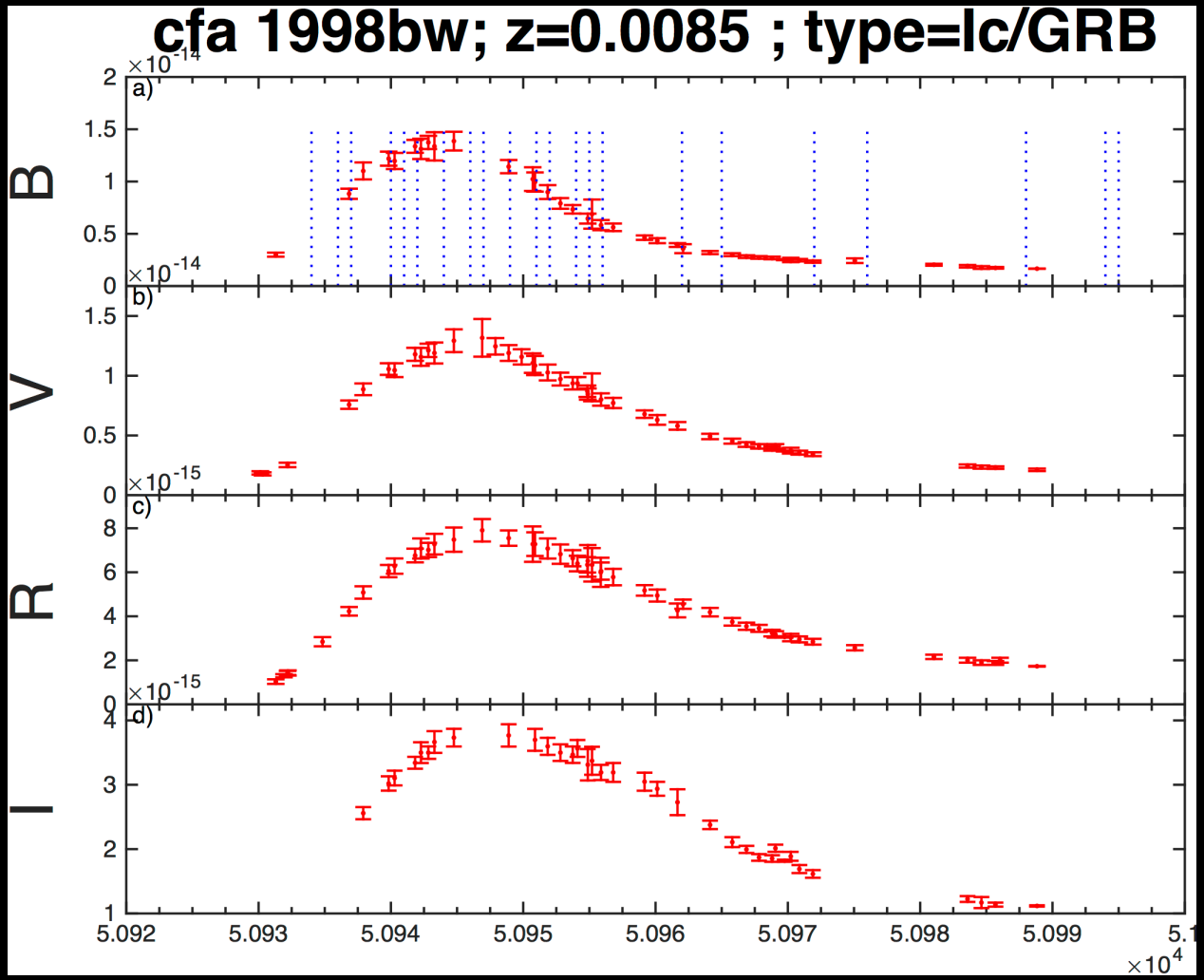
Selection cuts:

- SN must have observations in Bessel V
  - And at least one other band , in order to mangle spectra

- $N_{spectra} > 6$
  - At least one before V band max
  - One within 2 days of peak

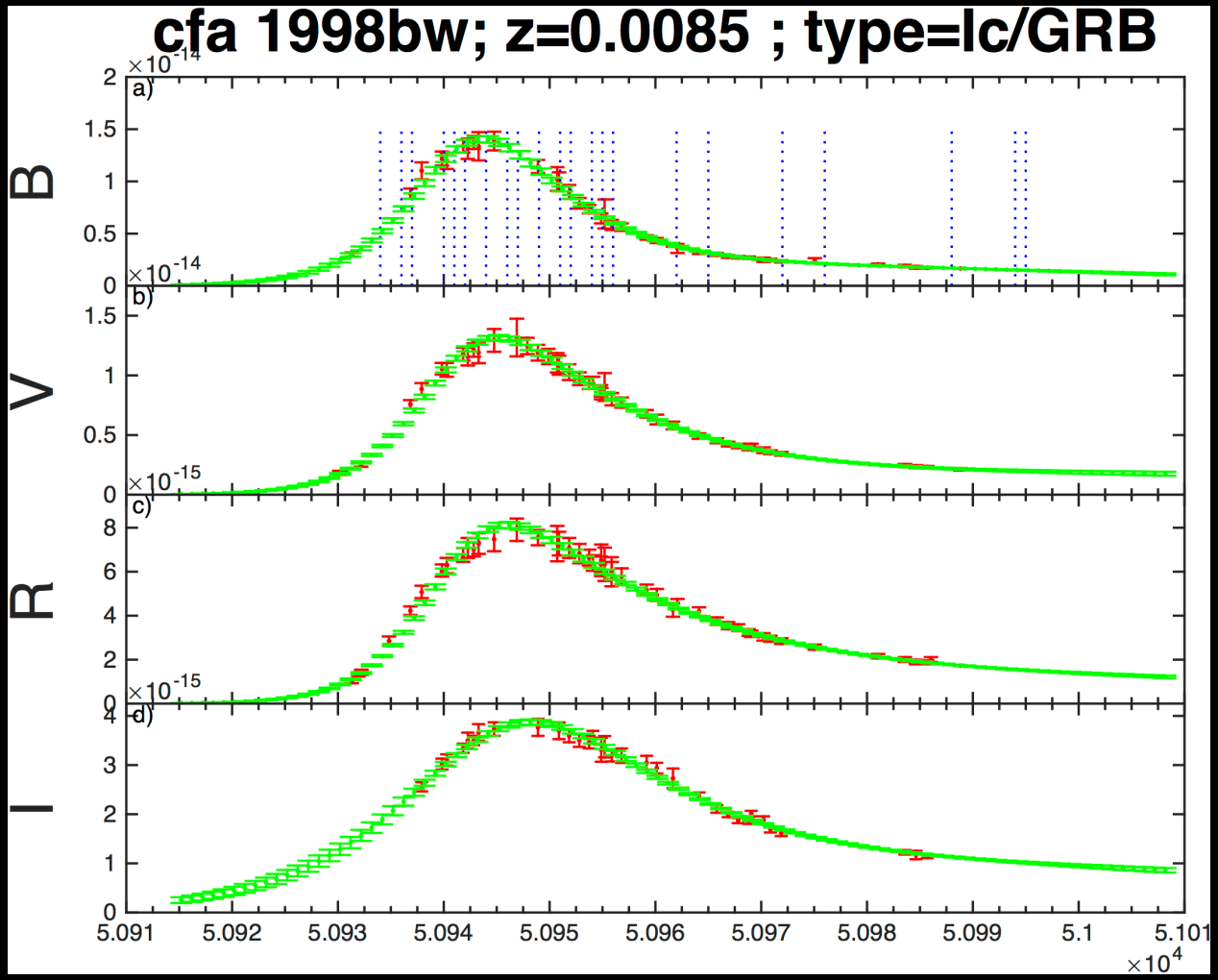
- N_{phot}(per band) > 9 (at $\tau < 50$)

Example: SN1998bw



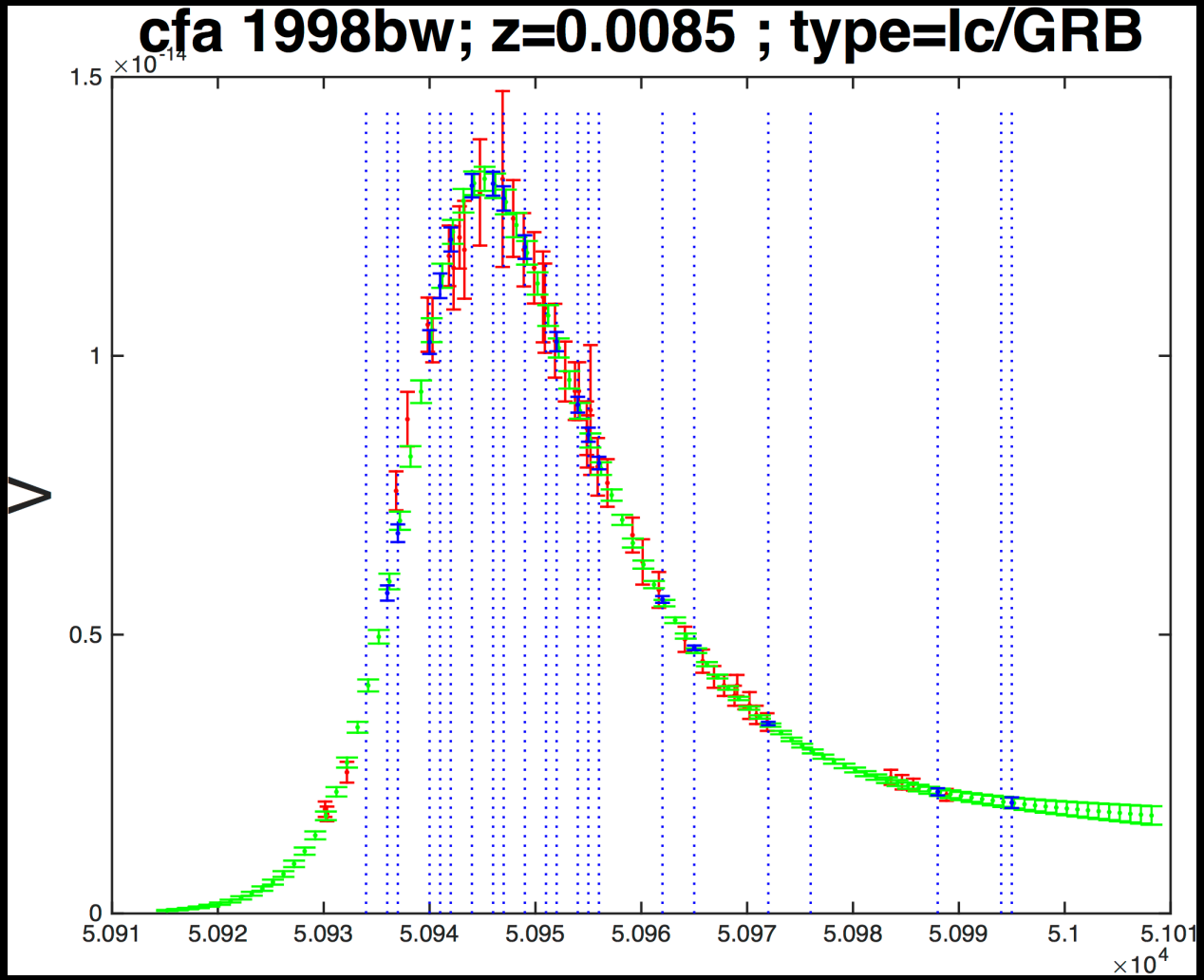
- CfA sample object
- Broad lined Ic
- BVRI (other bands also)
- Phase of Spectra shown in blue (top panel)

Example: SN1998bw



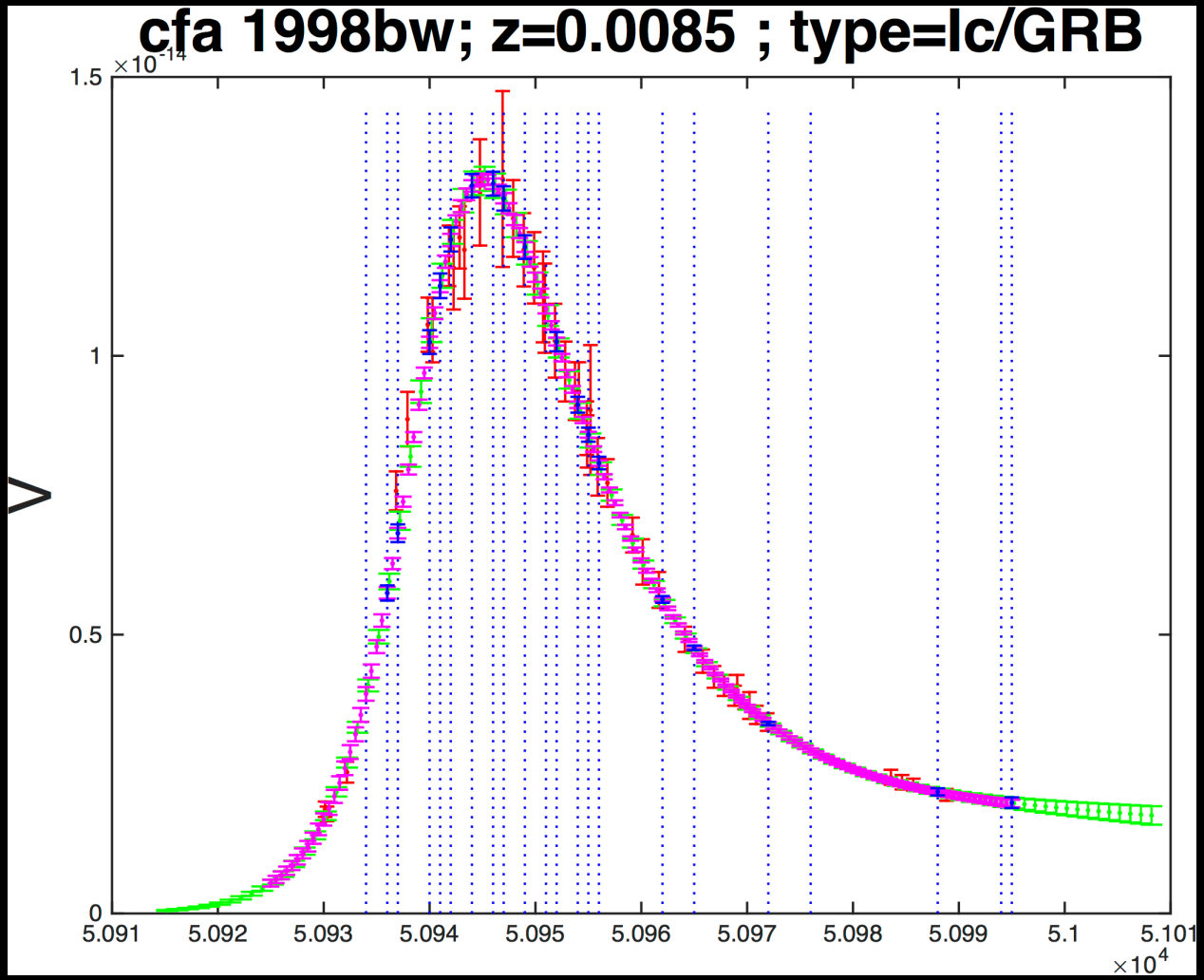
- Fit shown in green
- Uncertainties on fit propagated on through following steps
- Good fit to the data

Example: SN1998bw – V Band



- Fit (in green) to V-band photometry (in red)
- Extract spectrophotometry and associated uncertainties (blue)
- Note small size of uncertainties

Example: SN1998bw – V Band



- Consistency check – refit the new specphot
- Refit is shown in purple – consistent with original (green) fit to photometry – as expected

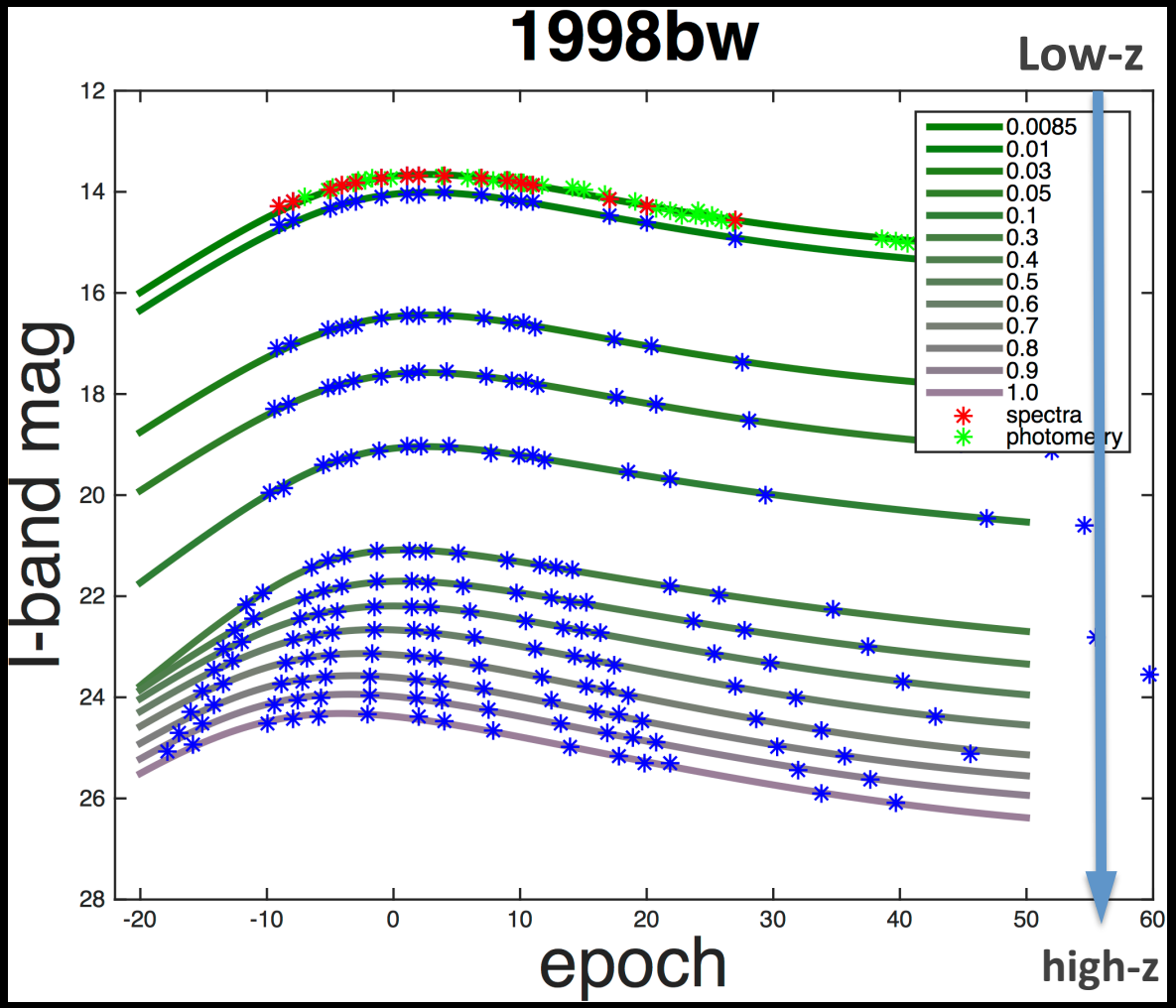
Example: SN1998bw – V Band

Once the spectra have been calibrated and mangled, light curves can be generated for other bands at other redshifts.

Max redshift typically depends on the how blue the spectral series goes

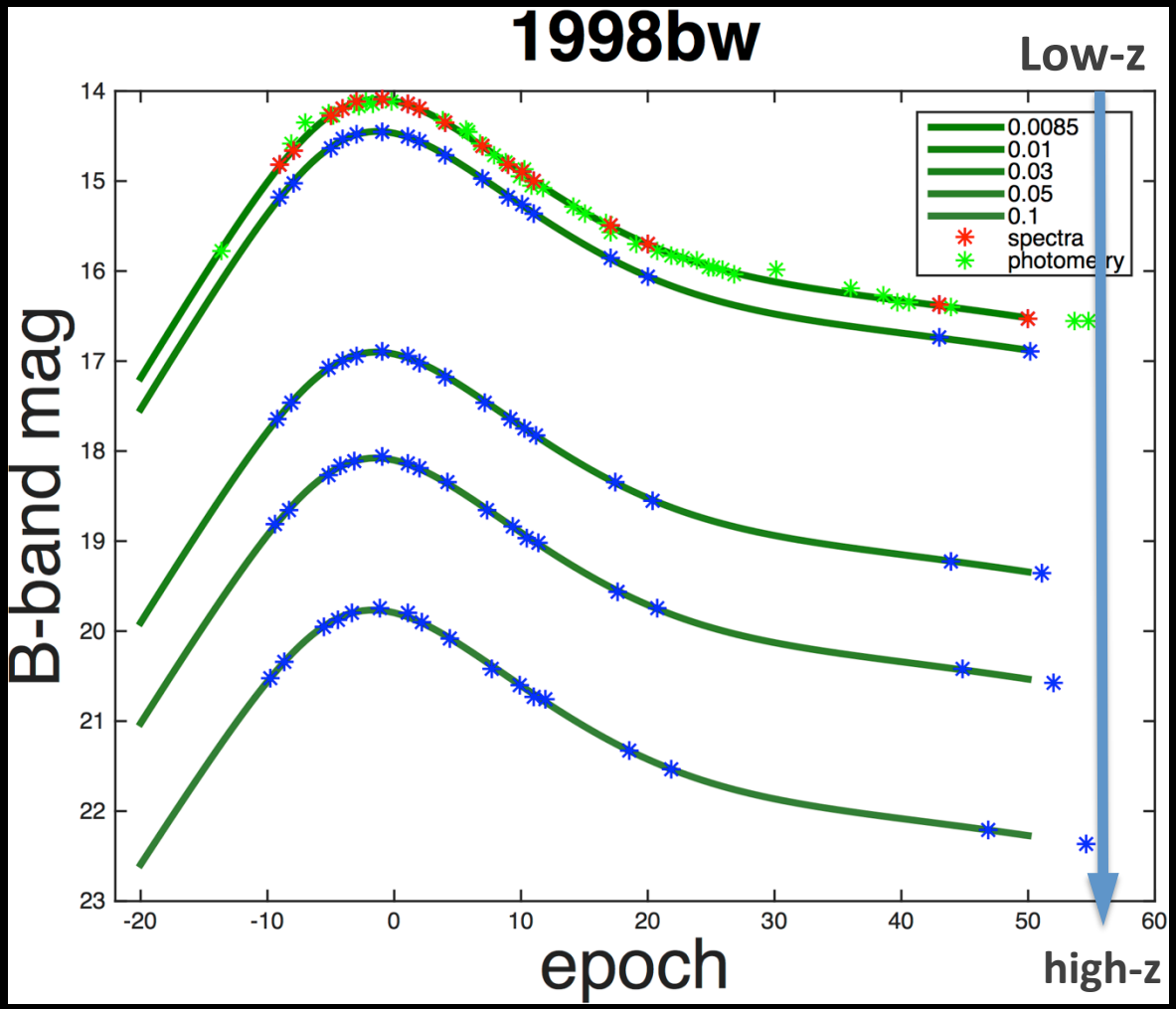
- Consistency check – refit the new specphot
- Refit is shown in purple – consistent with original (green) fit to photometry – as expected

Usage - Simulation



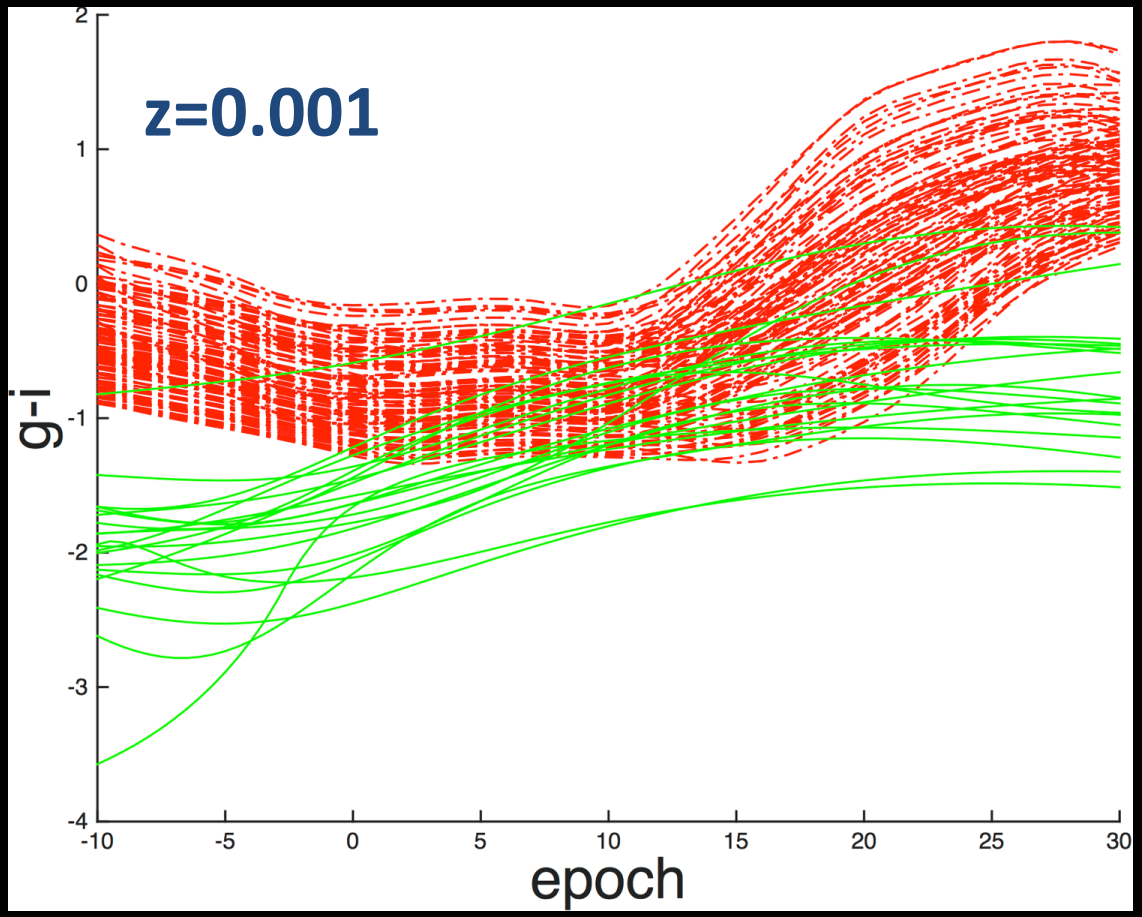
- Can take SN1998bw to z≈1.0 in I-band

Usage - Simulation



- Can take SN1998bw to z≈1.0 in I-band
- Only get to z≈0.1 in B-band
  - Need more UV data!

Usage – (Observed) Colour Evolution



- Use colour to discriminate between types.
- SALT2 SNe Ia templates shown in red.
- CC SESNe shown in green

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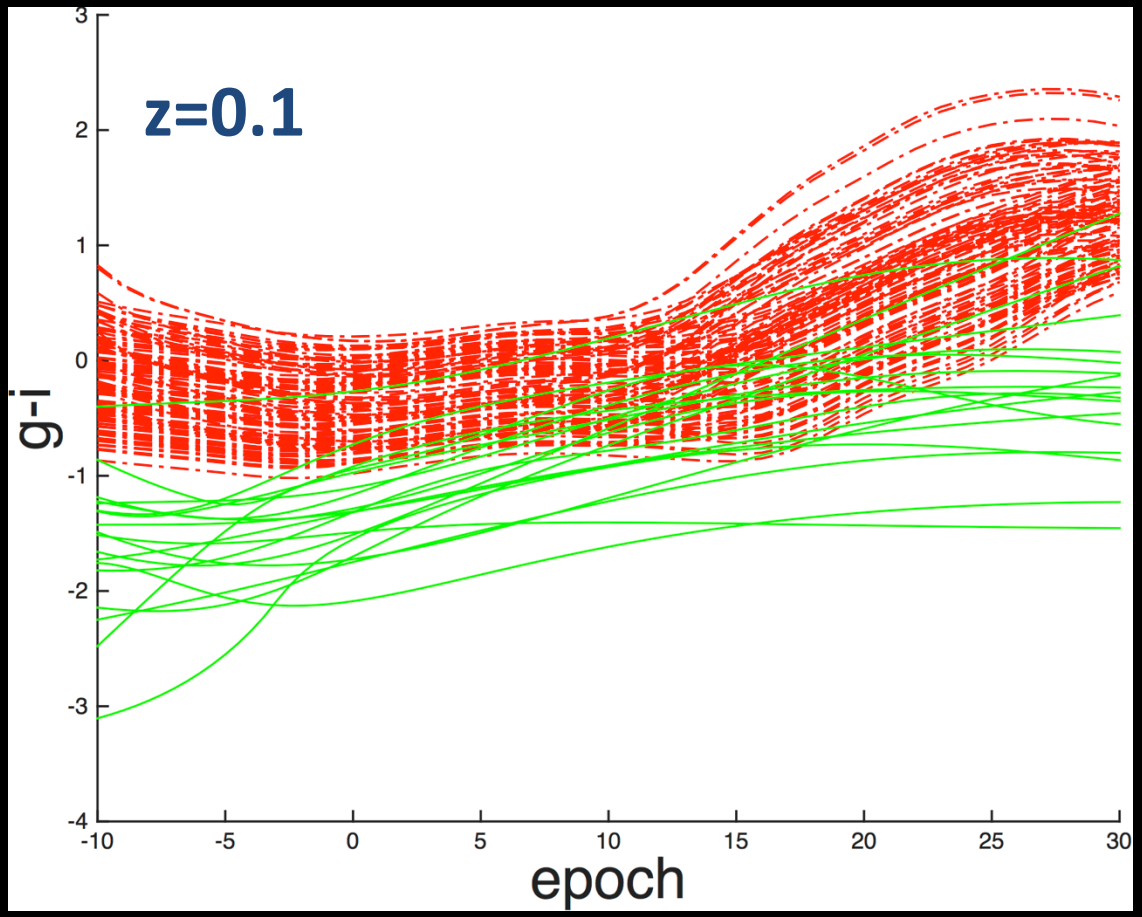

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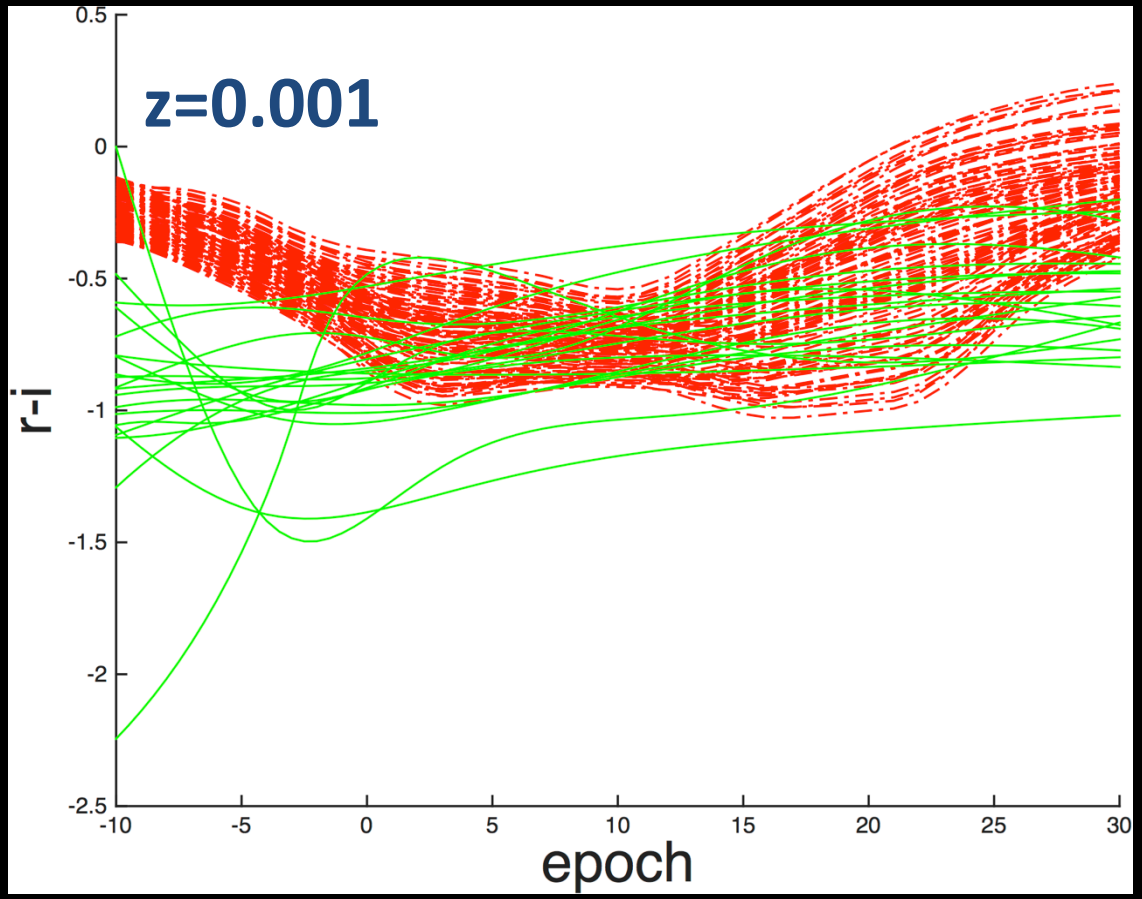

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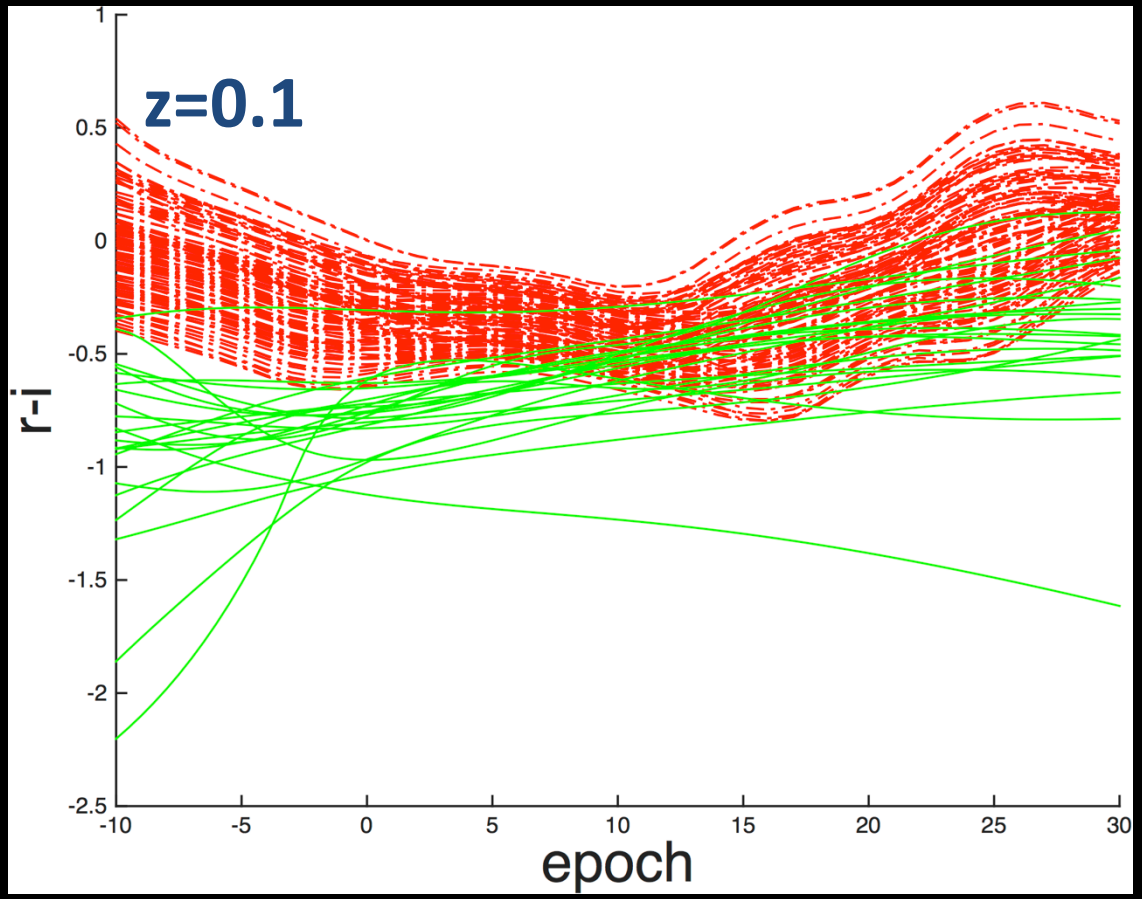

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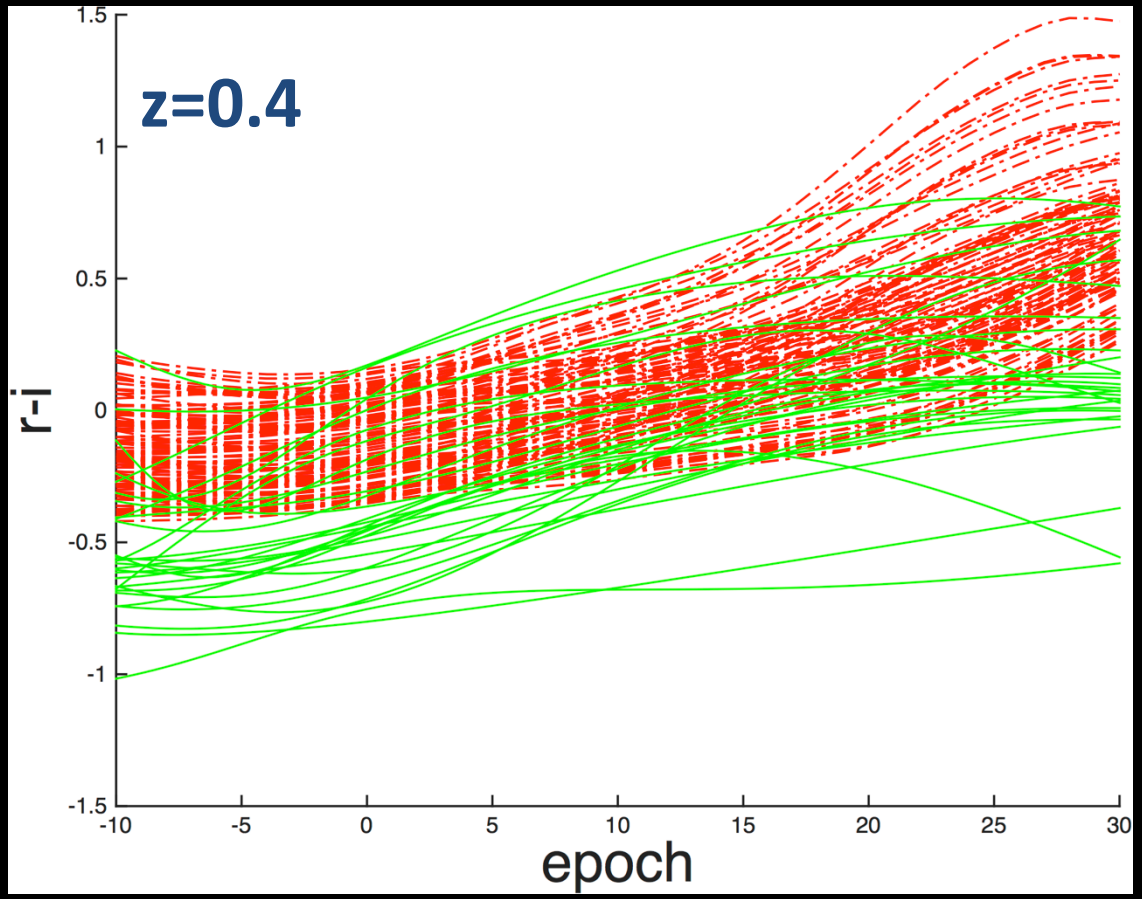

- Use colour to discriminate between types.
- SALT2 SNe Ia templates shown in red.
- CC SESNe shown in green

In Summary…

- Github:
  - github.com/SzymonPrajs/CoCo
  - Development is active and ongoing!
  - Looking for volunteers
- Priorities:
  - Speed – Currently slow, implement faster operation
  - Flexibility – add more templates
  - Python frontend
  - UV data
  - Luminosity Functions

In Summary…

- Light curve Fitter coupled with mangling of spectra = spectrophotometric data at any redshift
- No need for k-correction
- Full uncertainty propagation
- Refit provides smooth LC template
- 29 SNe
- Good for ‘one off objects’
- Paper in prep
- What does the community want in terms of output/end product?
  - How to best apply and integrate?

Questions?