Type Ia supernova spectral features and applications to dust reddening and light-curve standardisation

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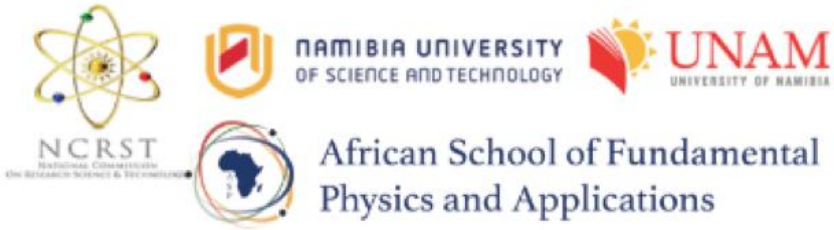

Outline

1. Dynamics of the Universe as implied from Type Ia supernova (SN Ia) data

2. Current SN Ia systematic uncertainty sources and potential solutions

3. Current research
   - Measurements of SN Ia spectral features at intermediate redshifts ($0.1 < z < 0.4$), as an alternative to standardising SN Ia light curves prior to their use in a cosmological analysis

What is a supernova?

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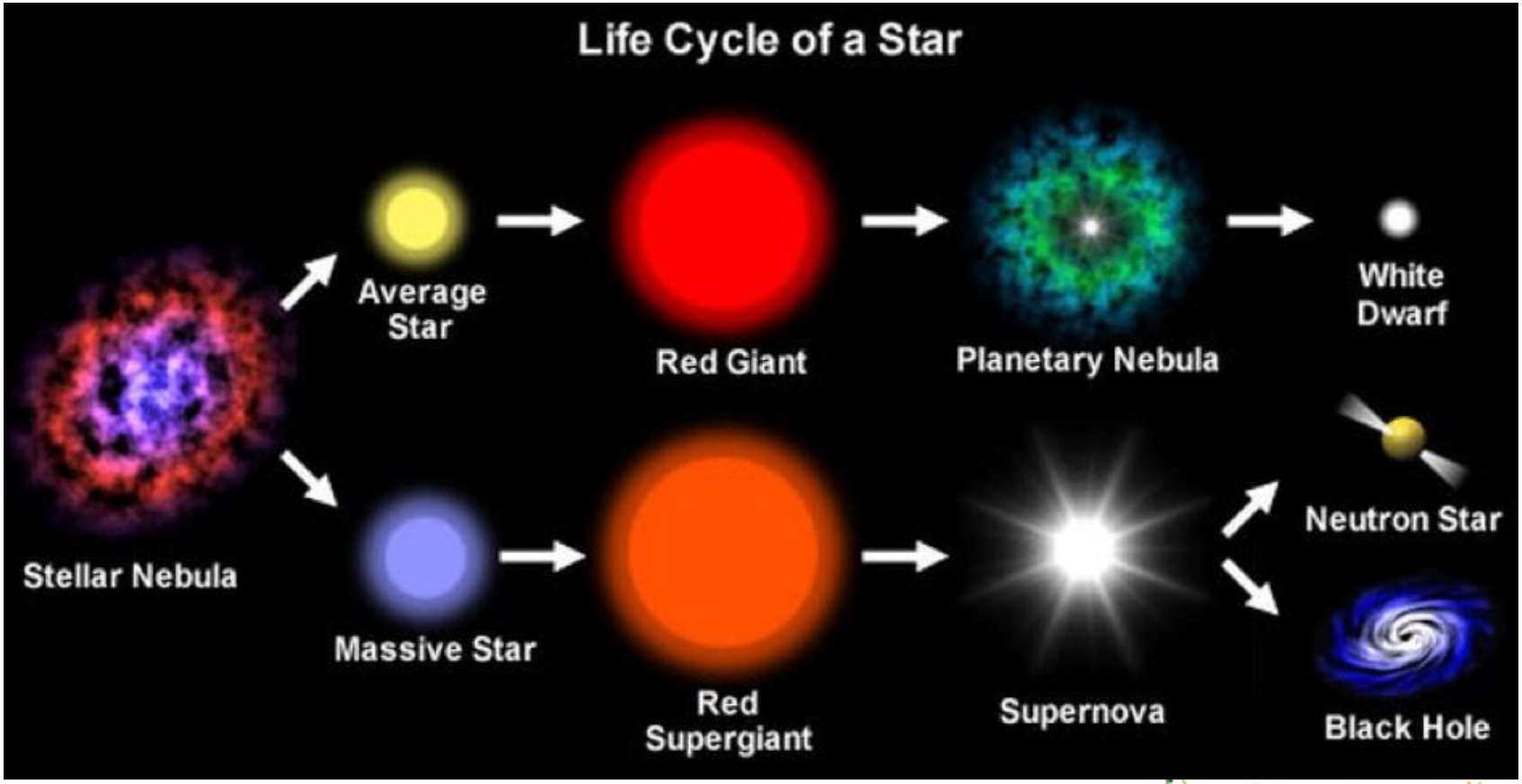


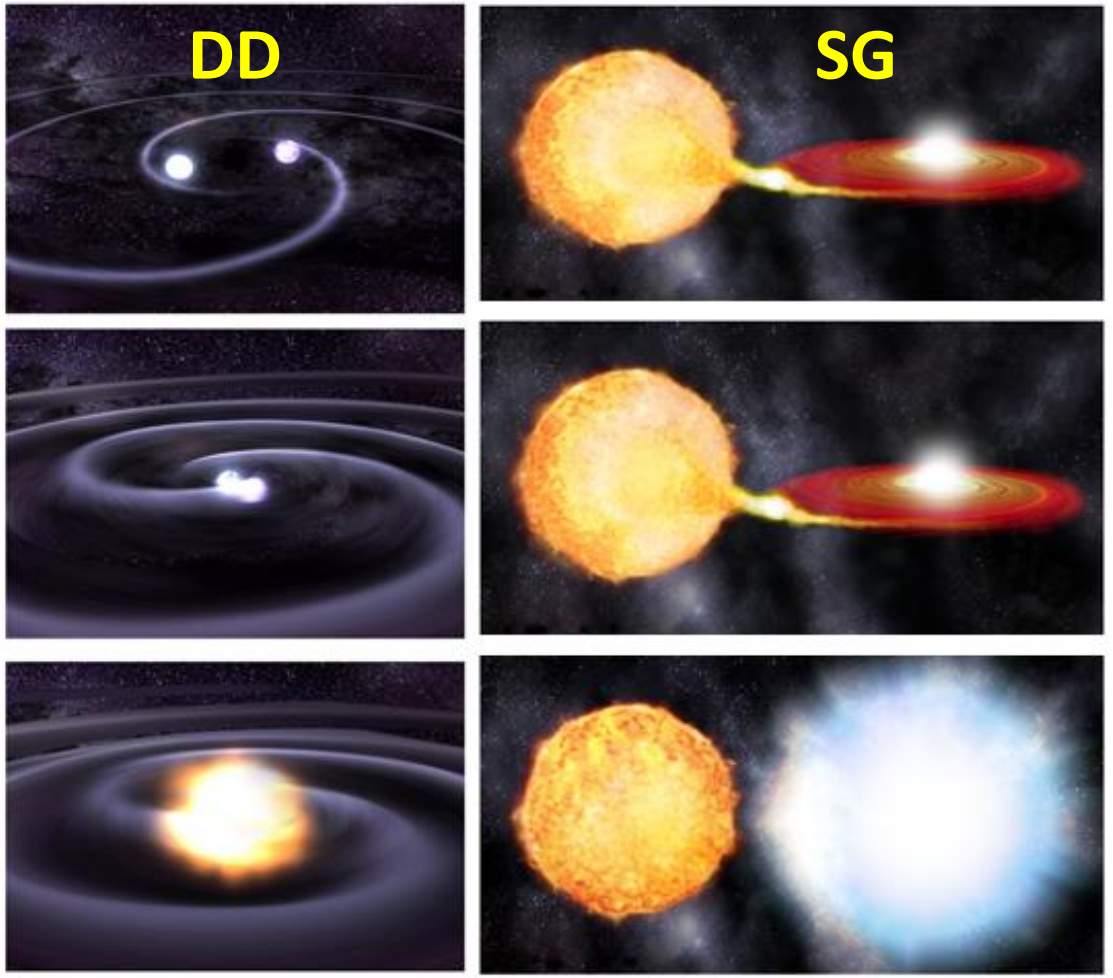
Background to SN Ia studies

1. Explosion mechanisms
   - Chandrasekhar limit,

   -> mass limit of 1.4$M_{\odot}$
   - Single-degenerate

   (SG) scenario
   - Double-degenerate

   (DD) scenario



Background to SN Ia studies *cont…*

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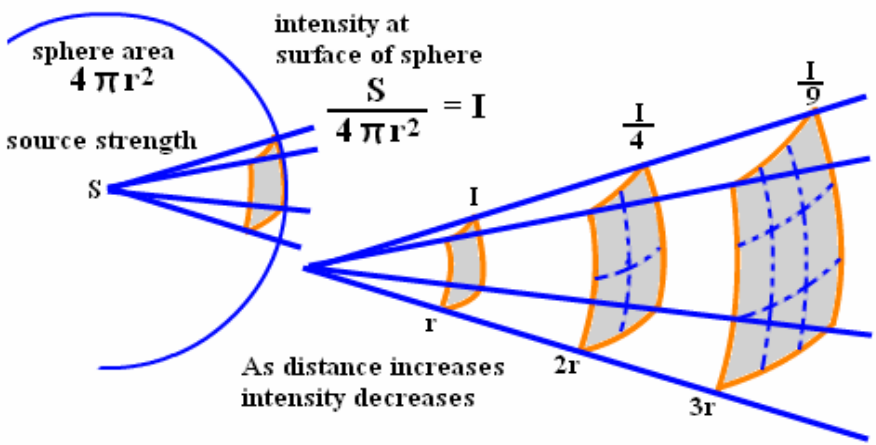
2. Distance determination

- Inverse square law



- Distance modulus

$$\mu = m - M = 5 \log_{10} \left(\frac{d}{10 \text{ pc}} \right)$$

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Background to SN Ia studies *cont…*

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3. Luminosity distance and cosmological parameters

- $$d_L(z') = \frac{c(1+z)}{H_0|\Omega_{\rm k}|^{-1/2}} \mathrm{sinn}\left\{|\Omega_{\rm k}|^{1/2} \int_0^{z'} \left[(1+z)^2(1+\Omega_{\rm M}z) - z(2+z)\Omega_\Lambda\right]^{-1/2} dz\right\}$$
- $$\mathrm{sinn}(x) = \begin{cases} \sin(x) & \text{if } \Omega_{\rm k} < 0, \\ \sinh(x) & \text{if } \Omega_{\rm k} > 0, \\ x & \text{if } \Omega_{\rm k} = 0. \end{cases}$$
- For a flat ΛCDM Universe, $\Omega_{\rm k} = 0$ and $\Omega_\Lambda = 1 - \Omega_M$

$$\Longrightarrow d_L(z') = (1+z)\frac{c}{H_0}\int_0^{z'} \frac{dz}{\sqrt{\Omega_{\rm M}(1+z')^3 + 1 - \Omega_{\rm M}}}$$

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Background to SN Ia studies *cont…*

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4. Distance modulus and cosmological parameter estimation

- $d_L(z') = (1+z)\frac{c}{H_0}\int_0^{z'} \frac{dz}{\sqrt{\Omega_{\rm M}(1+z)^3 + 1 - \Omega_{\rm M}}}$
- $\mu_{\Lambda{\rm CDM}} = 5\log_{10}\left(\frac{d_L(z, H_0, \Omega_{\rm M})}{10\ {\rm pc}}\right)$ theoretical μ
- $\mu_{obs} = m_B^* - M + \alpha x_1 - \beta c$ observed μ
- $\chi^2 = \frac{(\mu_B - \mu_{\Lambda{\rm CDM}})^2}{\sigma^2_{\mu_B} + \sigma^2_{int}}$

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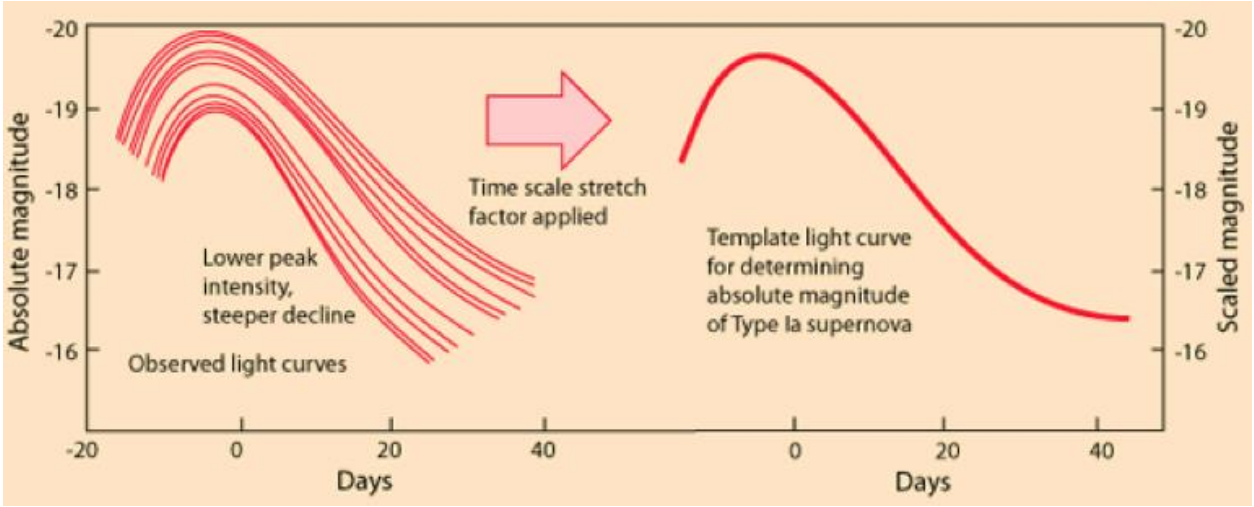
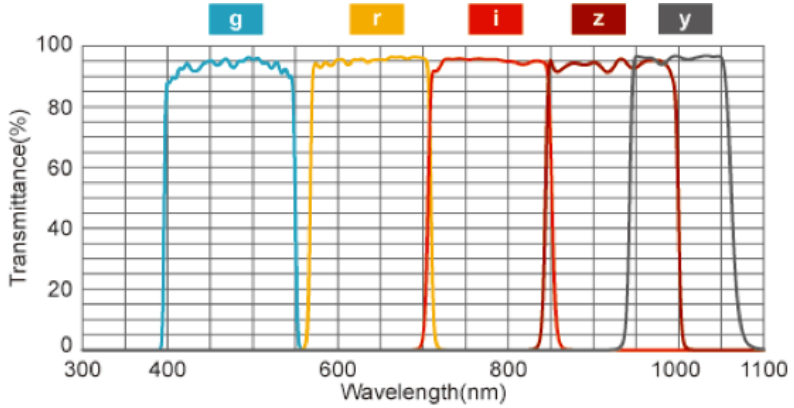
Background to SN Ia studies *cont…*

5. Light curve fitters
   - SALT, MCLS
   - SALT2
     - x_1, c (stretch, colour)



Current and future SN observational surveys

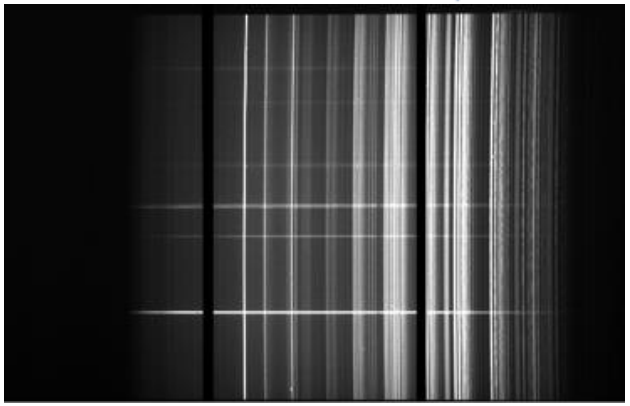
1. Current SN Surveys
   - Dark Energy Survey, PanSTARRS, SKyMapper, Palomar Transient Factory
2. Goals of DES SN Program
   - Constrain “w” to an accuracy of 1%
   - Obtain ~4000 high quality SN Ia light curves



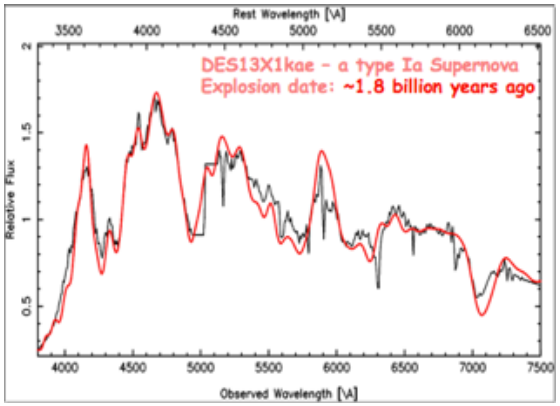
SALT DES SN follow-up spectroscopy

DES image

SALT



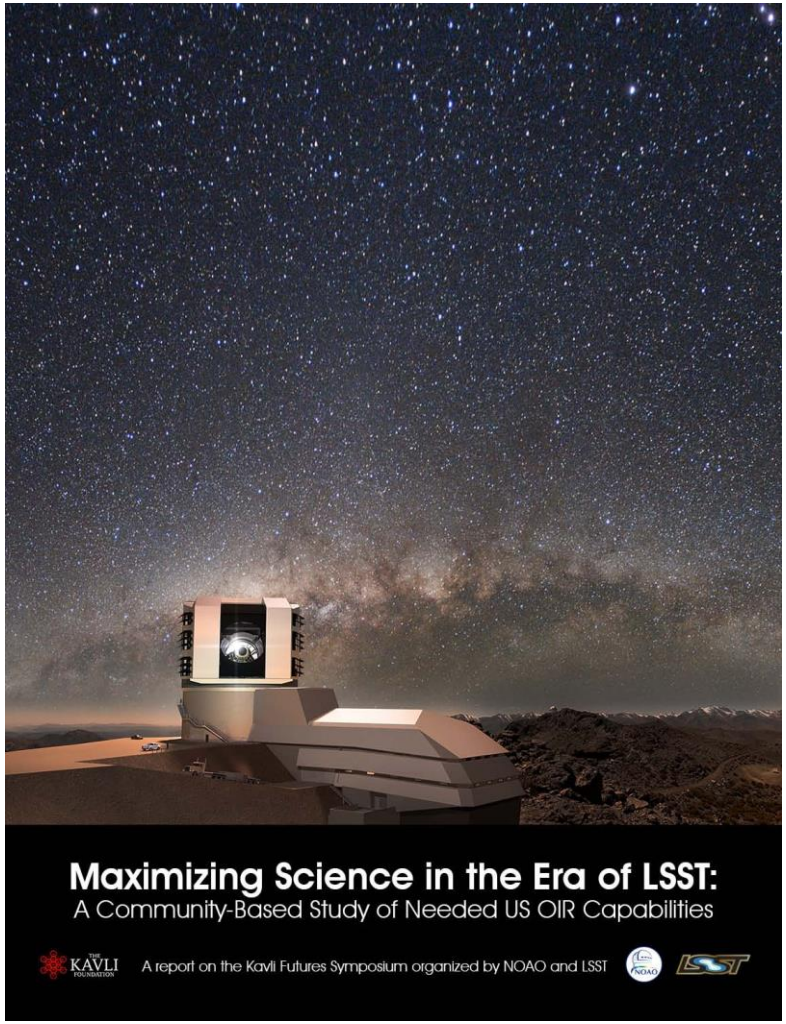
IRAF



Current and future SN observational surveys

2. Future SN observational Surveys - LSST

- 8.4m mirror
- 3200 megapixel camera
- 10 year survey of the entire southern sky
- 10^6 alerts -> 15 Terabytes of data ...every night!
- Science goals include understanding DM, DE
- Probes include SNe Ia, WL, etc.

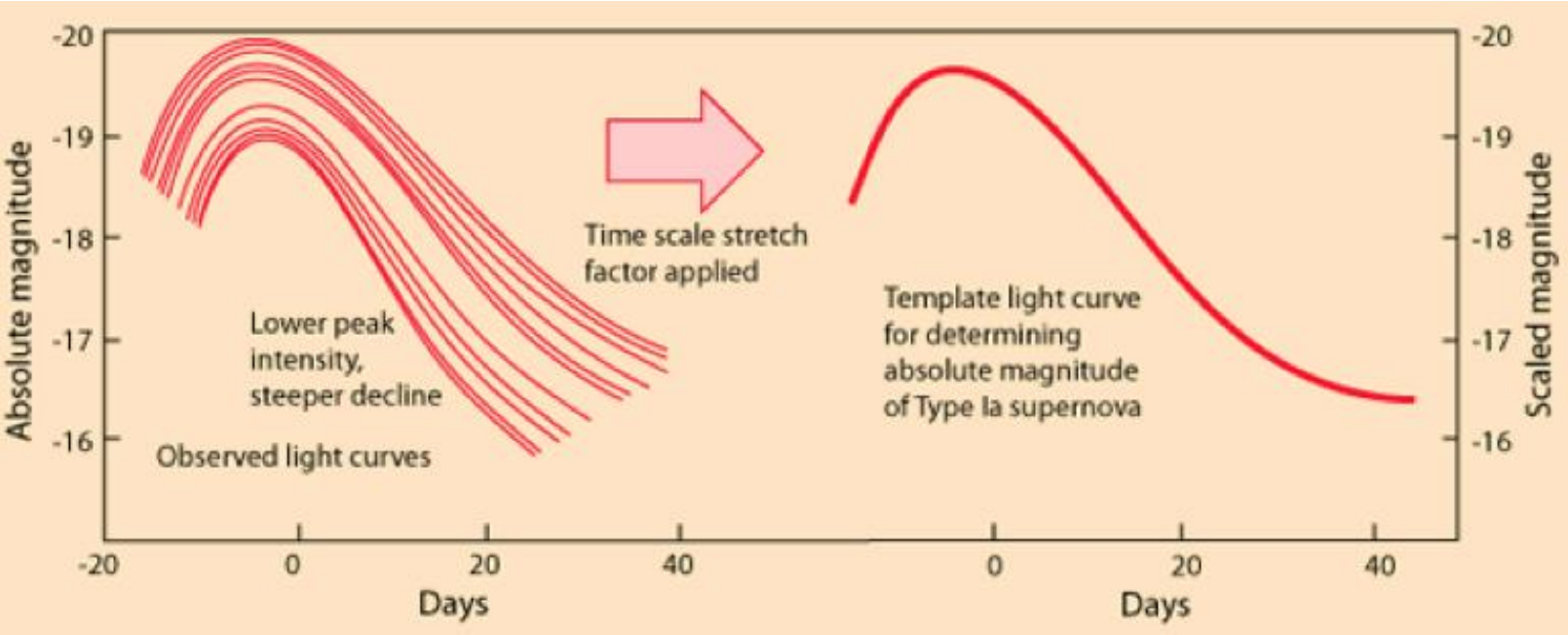


SN Ia systematics and potential solutions

1. Extinction and reddening of SN Ia light

SN Ia systematics and potential solutions

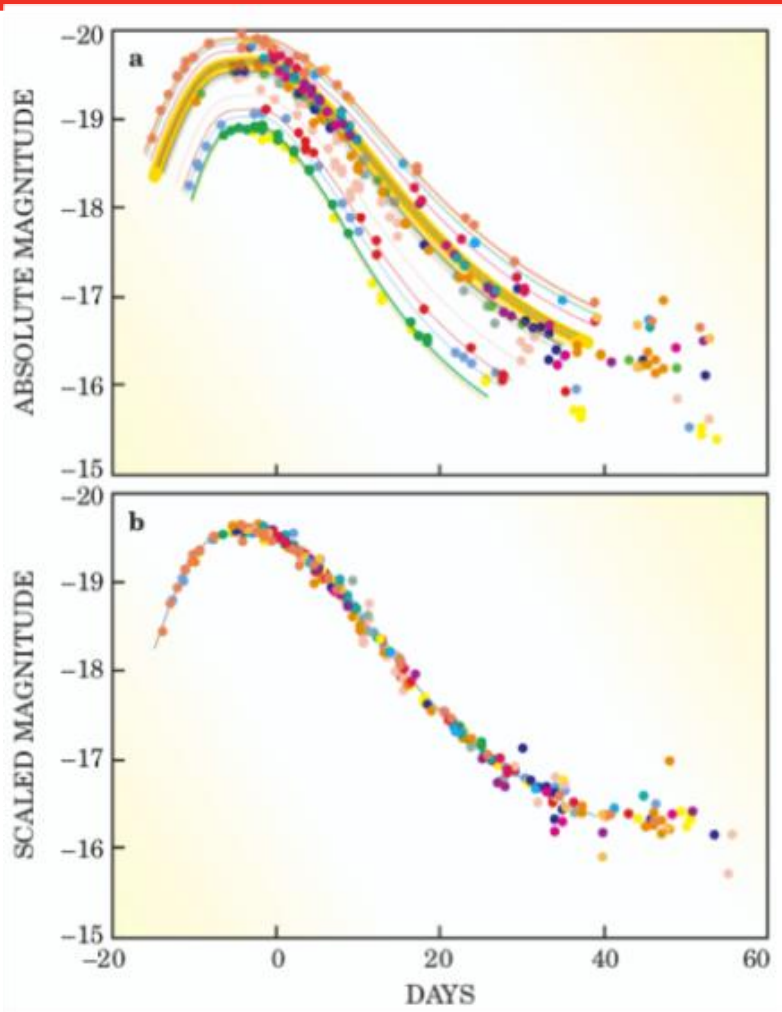
1. Extinction and reddening of SN Ia light
2. Are the SN Ia intrinsic effects due to extinction and reddening or are they due to explosion physics?

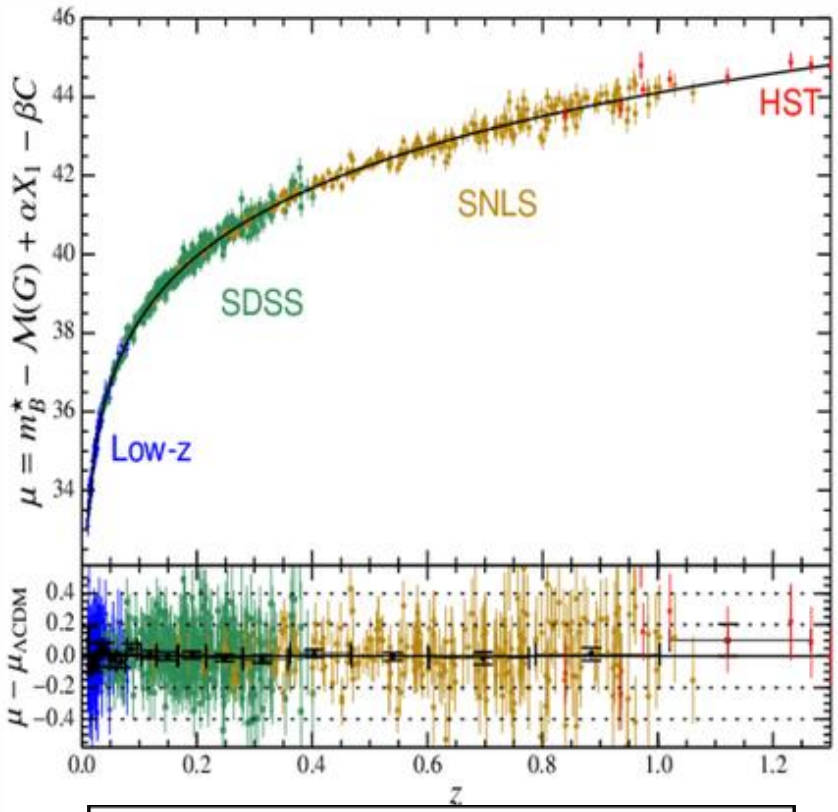


SN Ia systematics and potential solutions

1. Extinction and reddening of SN Ia light
2. Are the SN Ia intrinsic effects due to extincting and reddening or explosion physics?
3. Possible solutions to reducing the observed scatter in SN Ia absolute magnitudes

SN Ia systematics and potential solutions

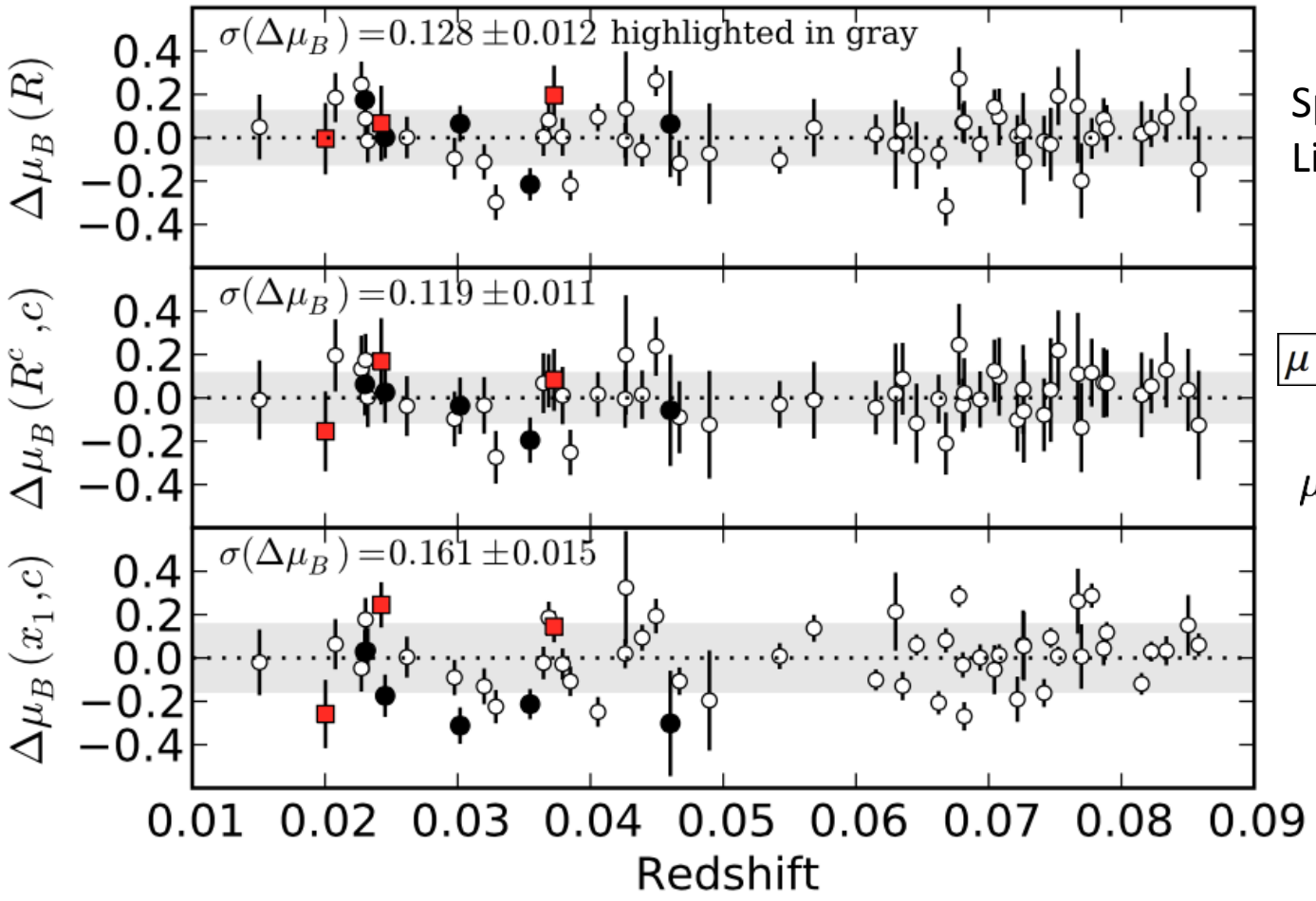




$$\mu = m_B - M + \alpha x_1 - \beta c$$

$$\mu = m_B - M + \alpha x_1 - \beta c + \gamma \mathcal{S}$$

SN Ia systematics and potential solutions



Spectral Adaptive Lightcurve Template 2

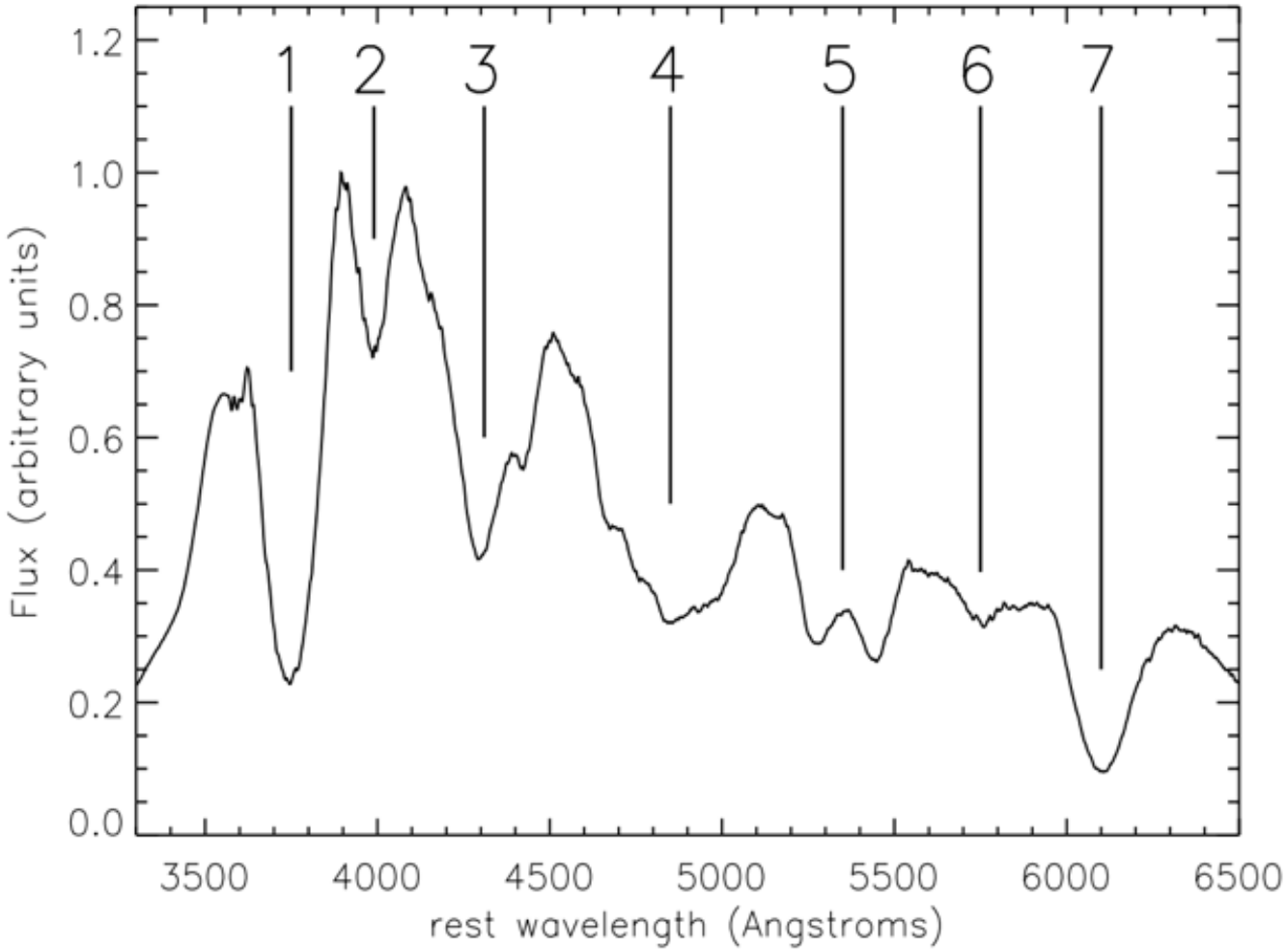
x_1, c

$$\mu = m_B - M + \alpha x_1 - \beta c$$

$$\mu = m_B^* - M' + \gamma \mathcal{R}$$

$$\mathcal{R}_{642/443}$$

SN Ia systematics and potential solutions



Example of a SN spectrum

Current research: Measurements of SN Ia spectral features

1. Measurements of SN Ia spectral features at intermediate redshifts ($0.1 < z < 0.4$)

2. SN Ia spectra are sourced from public SN databases, such as SUSPECT and Asiago Supernova Catalogue

3. Literature on similar measurements at low redshift, i.e. $z < 0.1$: Bailey et al. (2009), Chotard et al. (2011)

Thanks for listening!

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Questions?

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