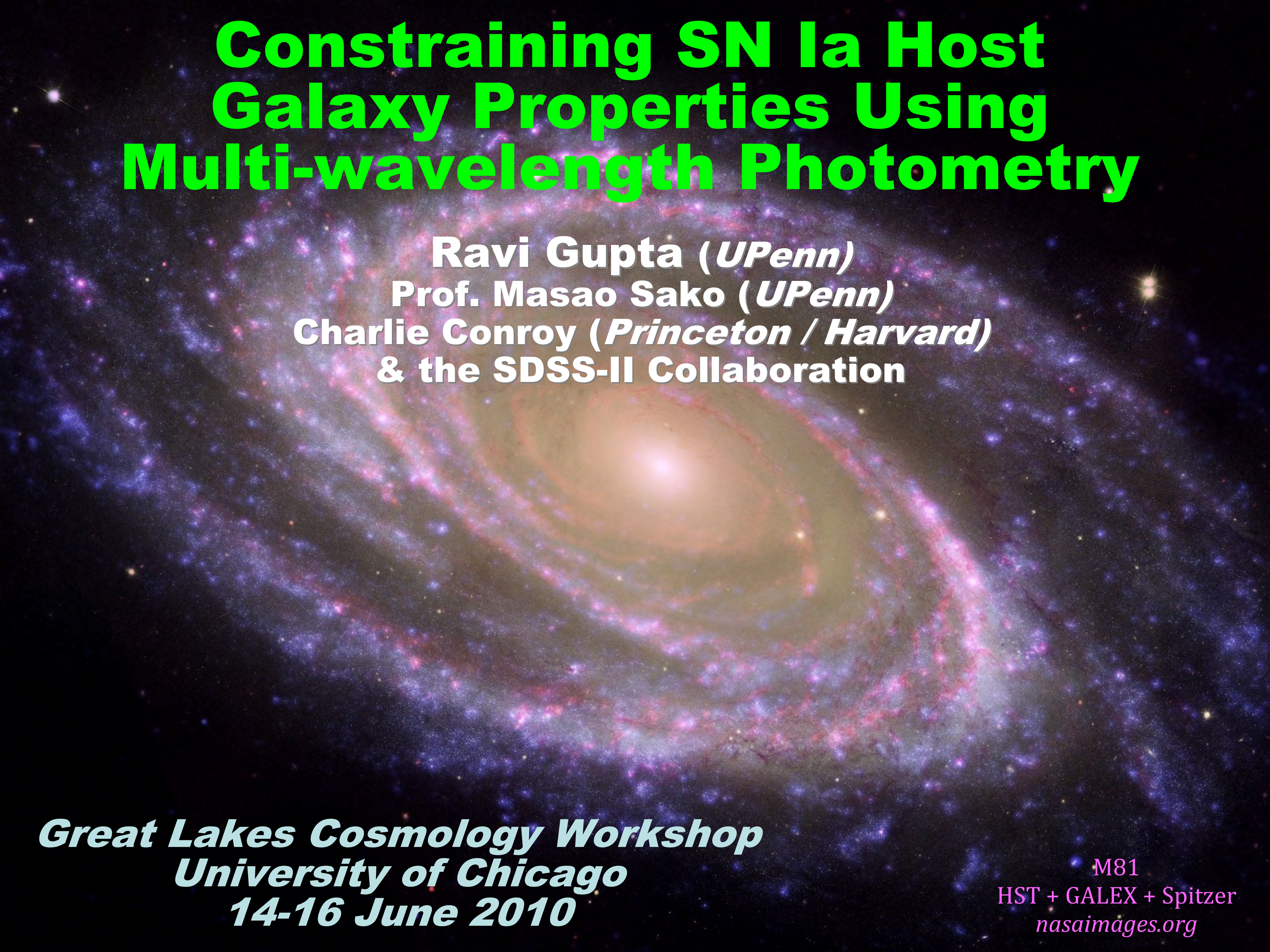
Constraining SN Ia Host Galaxy Properties Using Multi-wavelength Photometry

Ravi Gupta (*UPenn*)
Prof. Masao Sako (*UPenn*)
Charlie Conroy (*Princeton / Harvard*)
& the SDSS-II Collaboration



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M81
HST + GALEX + Spitzer
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The Goal

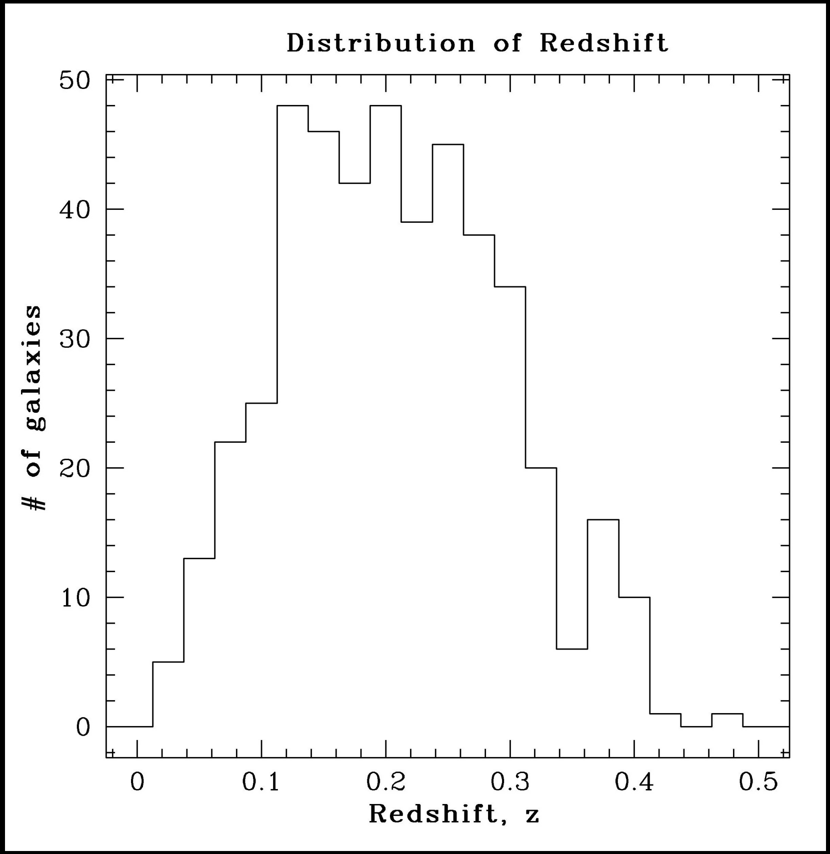
The progenitors of SNe Ia are not well-understood, so we would like to:

- Study physical properties of host galaxies (mass, star-formation rate, metallicity, dust) using archival multi-wavelength photometry. Future surveys (*LSST*, *DES*) will not have the resources to follow up all hosts, so it is useful to determine how well host properties can be constrained with photometry alone

- Correlate galaxy properties with SN properties to learn about the effect of environment on the progenitor star and its explosion

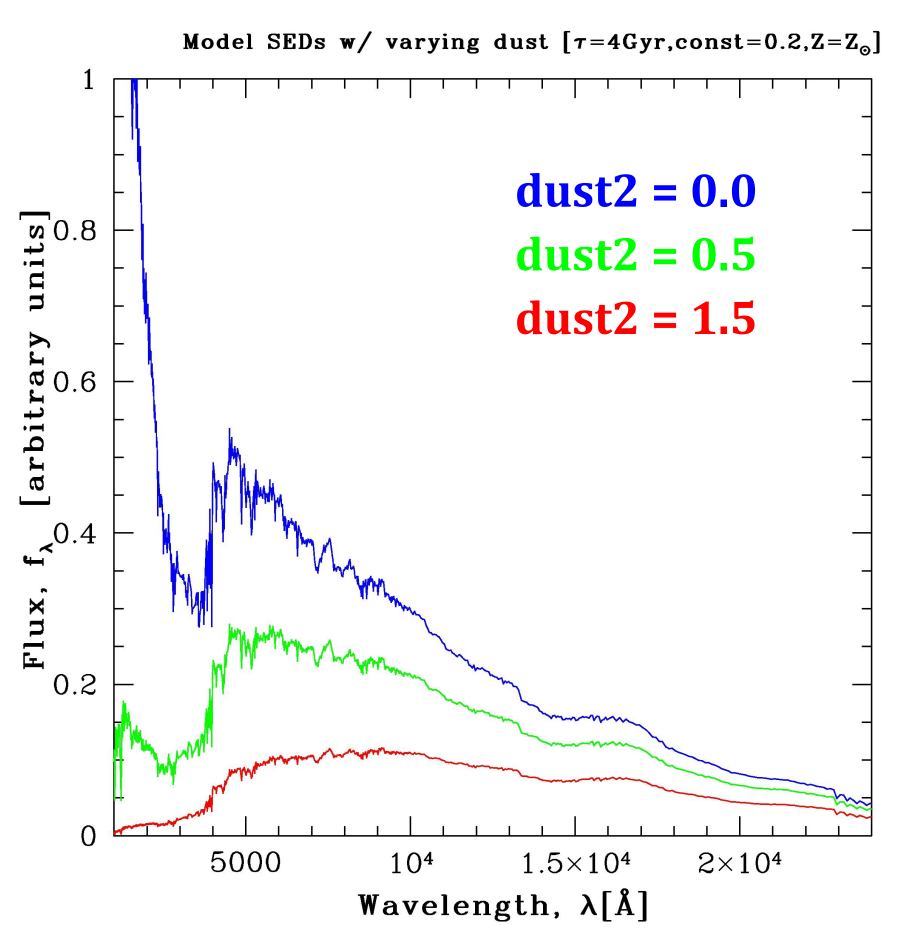
Data Sample

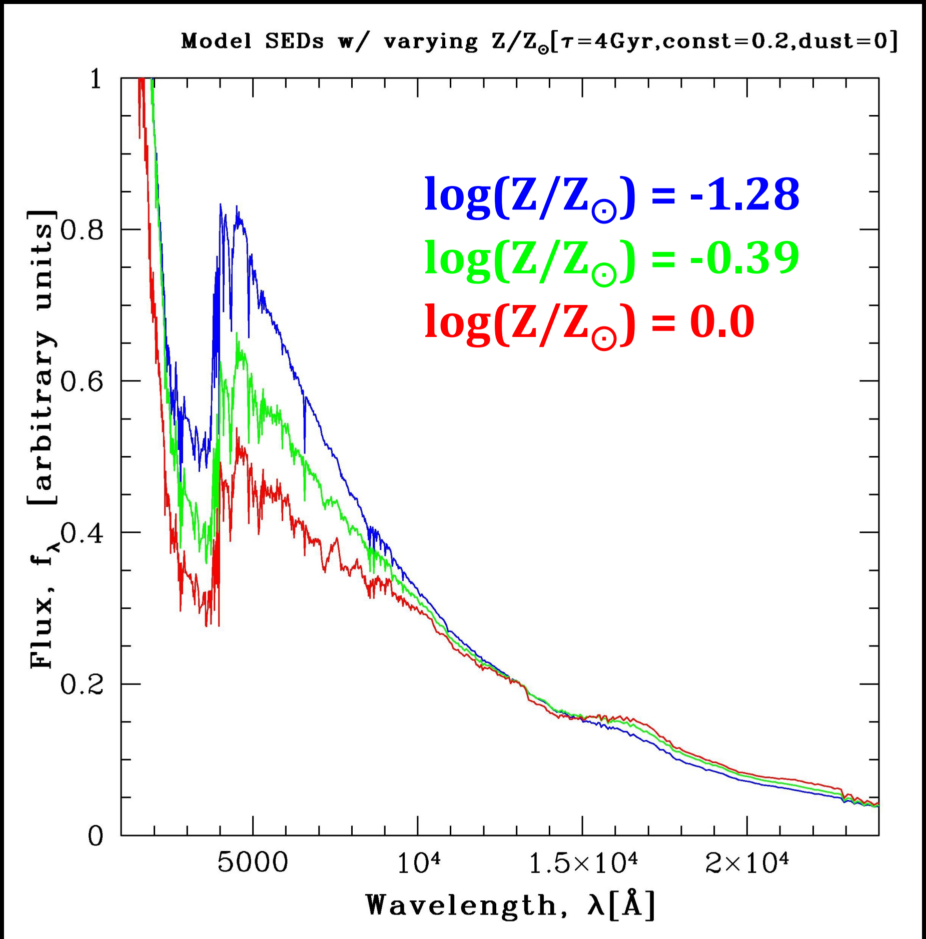
- 459 SDSS galaxies identified as hosts for the spectroscopically confirmed SNe Ia found in SDSS-II Supernova Survey [0.01 < z < 0.48] (*Frieman et al. 2008*)
- 272 of these 459 (~ 59%) have UKIDSS matches within a 5″ radius
- 192 (~ 42%) GALEX matches within a 5″ radius



GALEX [UV] + SDSS [optical] + UKIDSS [near-IR] photometry

The Effect of Dust & Metallicity





The addition of UV data helps constrain metallicity and SFR while near-IR data probes dust and older stellar populations

Method

- Generate grid of models parameterized by metallicity, dust, and star-formation history using **Flexible Stellar Population Synthesis** code of *Conroy, Gunn, & White 2009*

Minimum χ^2 grid search:

- For each galaxy, convert observed magnitudes to AB system, correct for MW extinction, then convert mags & corresponding errors to flux
- Perform χ^2 analysis, comparing data fluxes with each of the model fluxes
- Take the model with the smallest value of χ^2 to be the best-fit model

Model Fit Parameters

- Metallicity, *Z* (assumed constant for each model)
- Attenuation of old stellar light, *dust2*

Attenuation described by exp(-τ_λ(t)), where τ_λ(t) is the optical depth given by the 2-component dust model of Charlot & Fall (2000):

$$\tau_\lambda(t) \equiv \begin{cases} \tau_1(\lambda/5500\ \text{Å})^{-0.7} & t \leqslant 10^7\ \text{yr} \\ \tau_2(\lambda/5500\ \text{Å})^{-0.7} & t > 10^7\ \text{yr} \end{cases}$$

dust2

Also, fix *dust1* = 3×*dust2* (Kong et al. 2004)

- Decline rate of exponential component of SFR, τ
- Constant component of SFR, *C*

2-component τ + constant SFH:

$$\Psi(t) = \frac{(1-C)}{\tau}\frac{e^{-t/\tau}}{1-e^{-T_{univ}/\tau}} + \frac{C}{T_{univ}}$$

Parameter Grid

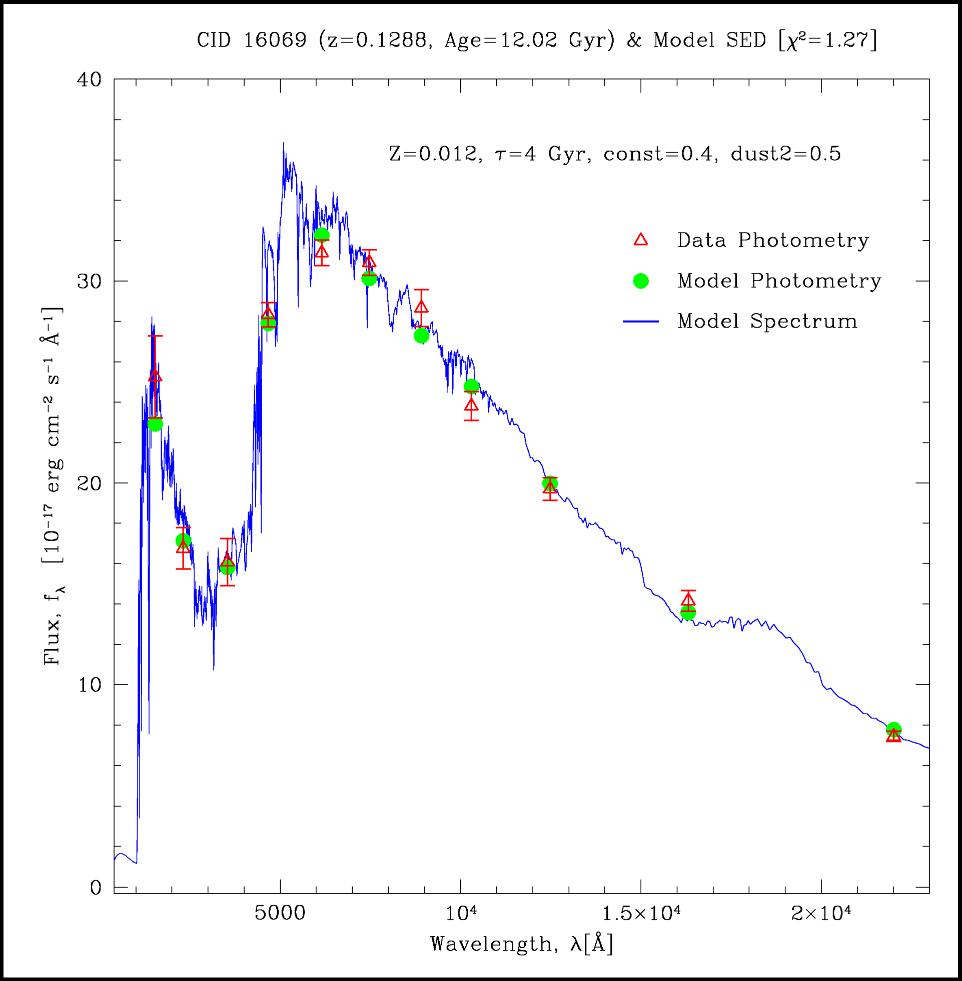
Z	0.001, 0.0025, 0.0049, 0.0077, 0.012, 0.019($\odot$), 0.03
τ (Gyr)	0.1, 0.5, 1, 2, 3, 4, 6, 8, 10
C	0.0, 0.2, 0.4, 0.6, 0.8, 1
dust2	0.0, 0.1, 0.3, 0.5, 1.0, 1.5

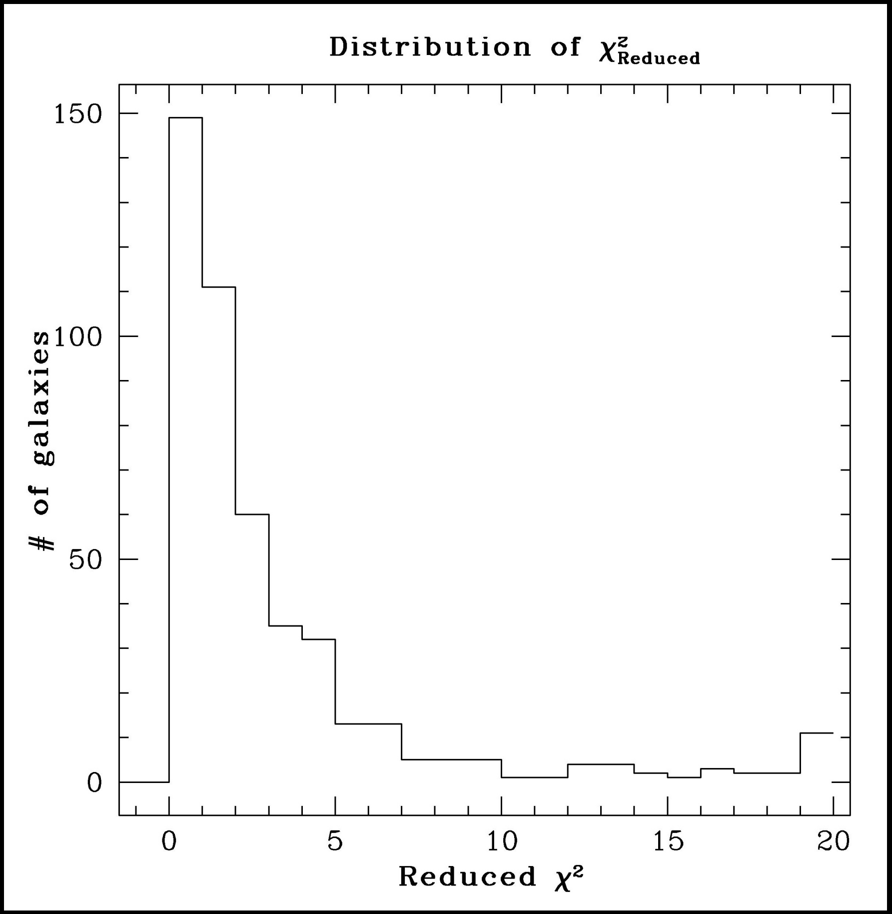
2268 MODELS

Some Important Assumptions

- IMF = Chabrier 2003
- WMAP5 Cosmology
- Padova isochrones
- BaSeL3.1 spectral library
- Fix age of galaxy = age of Universe at the redshift of the galaxy (star formation begins at $t = 0$)

(Some Preliminary) Results





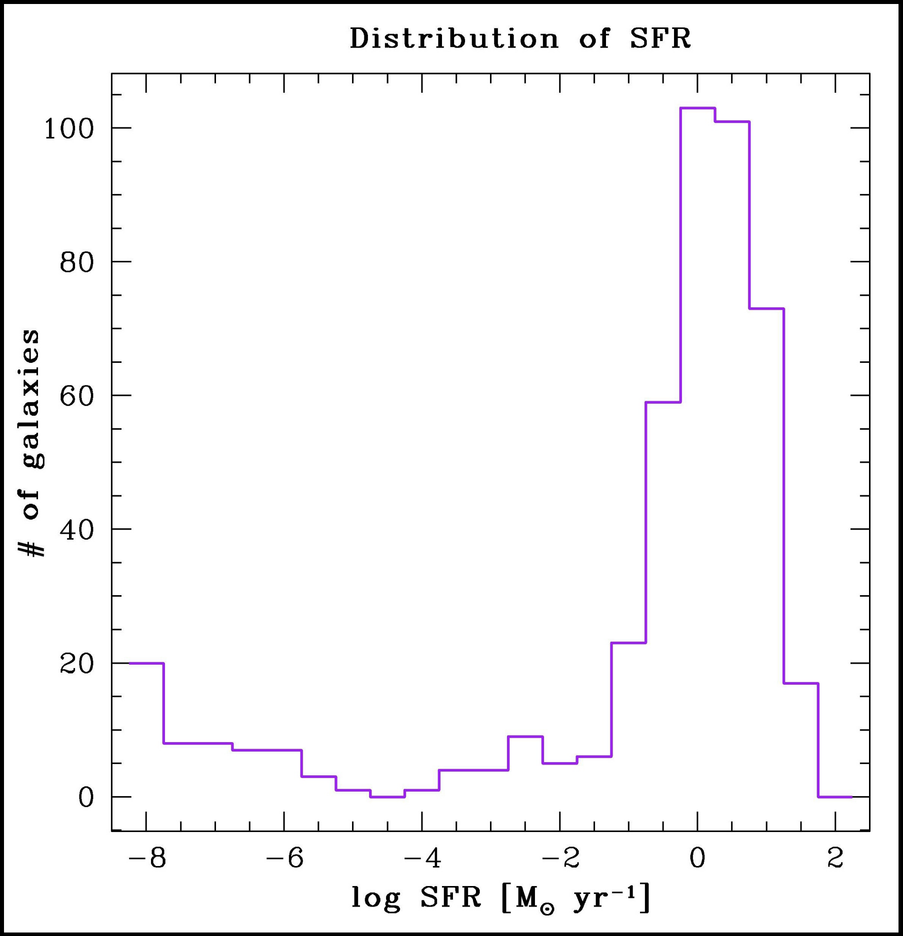
Derived Galaxy Properties

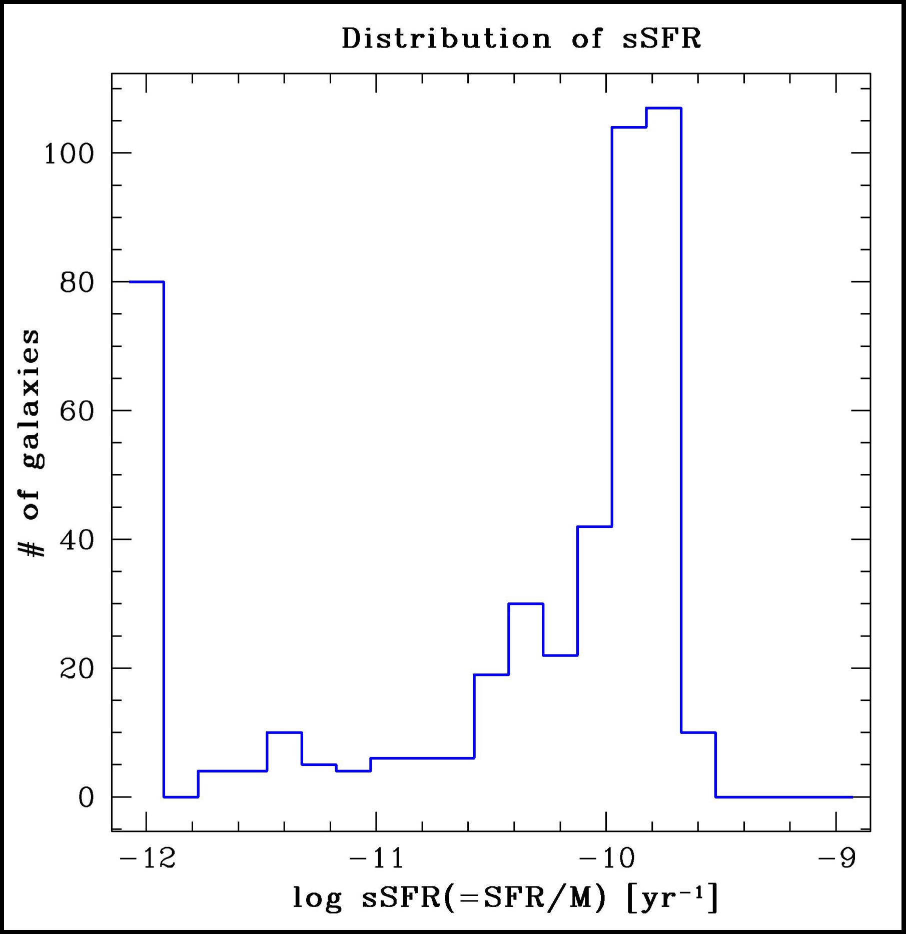
For each model we derive two galaxy properties:

- ***stellar mass*** – calculated by multiplying the luminosity in the *r* band by the mass-to-light ratio in the same band
- ***current average star-formation rate (SFR)*** – calculated by averaging the normalized SFH, $\Psi(t)$, over the past 10^8 years and converting into an absolute SFR (in $M_\odot$/yr) using the stellar mass

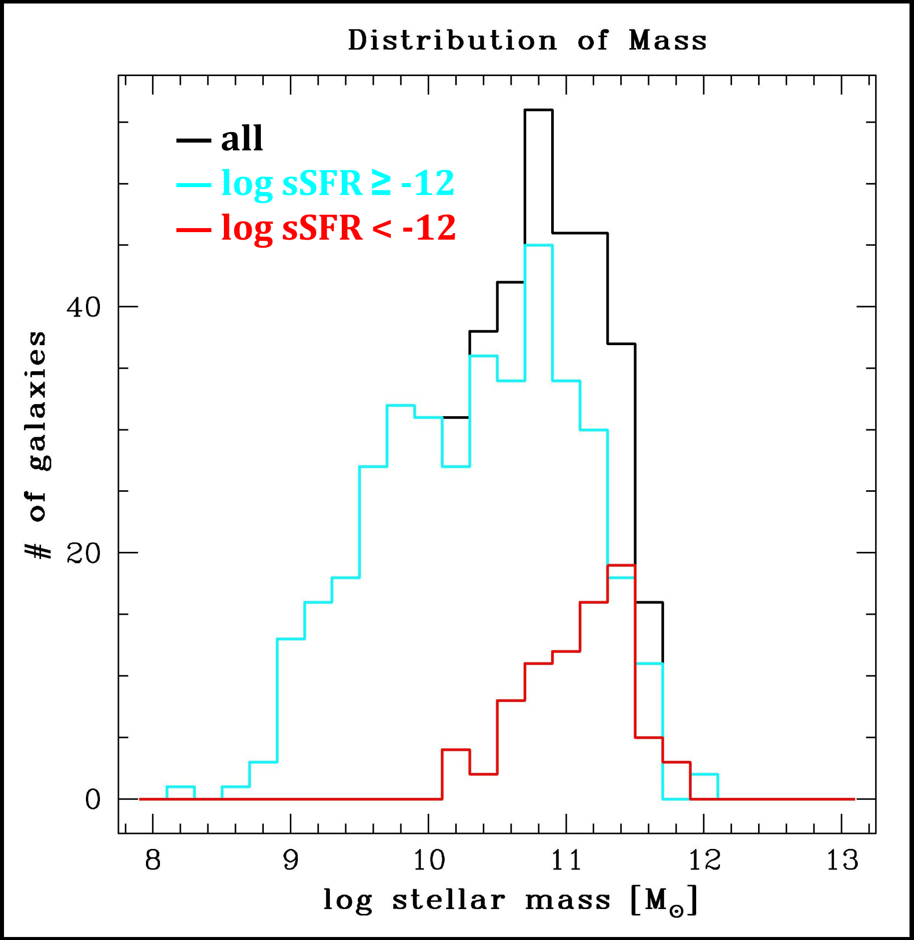
For each galaxy, we calculate the median mass & SFR and the corresponding uncertainties from the probability distribution obtained from likelihoods

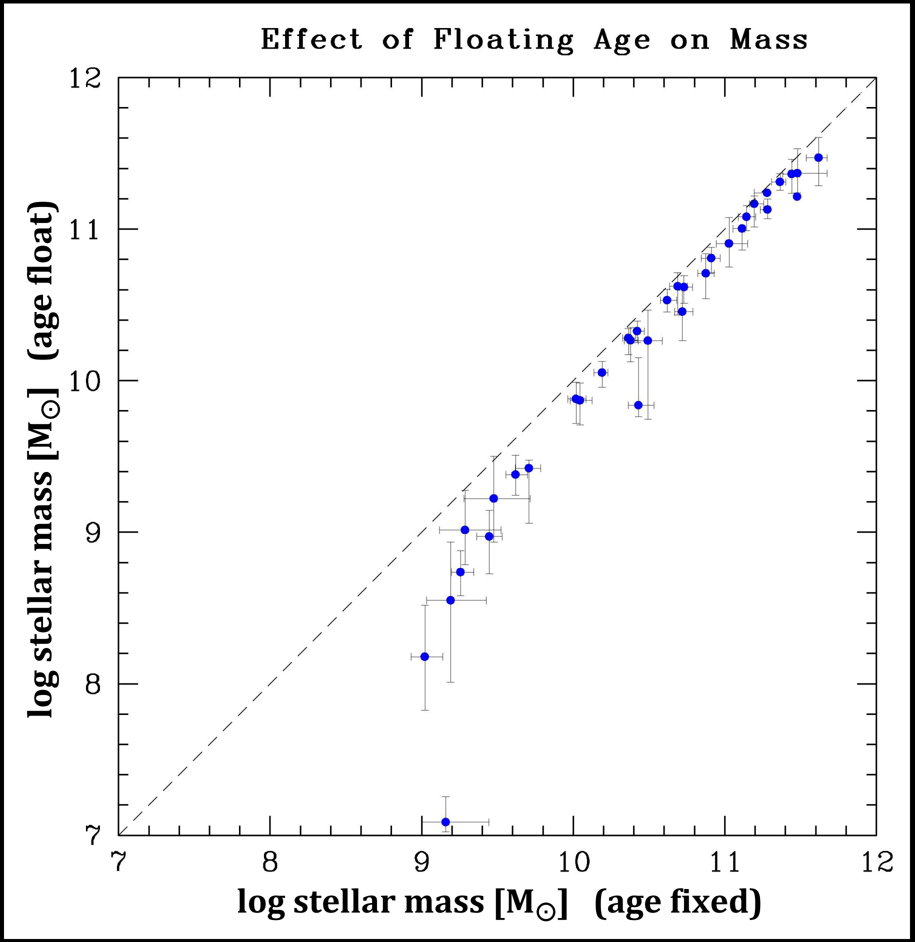
Star-Formation Rate





Stellar Mass

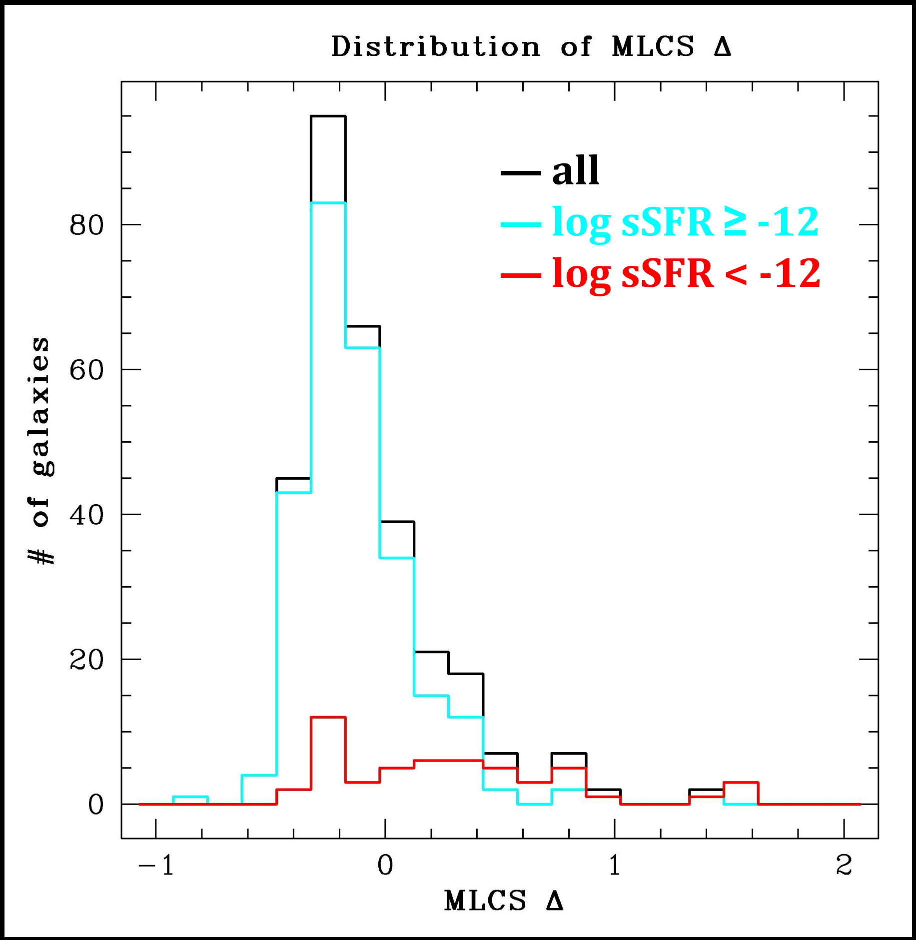




SN Ia Properties

- Used multicolor light-curve shape method MLCS2k2 (*Jha et al. 2007*) to obtain SN Ia properties such as:
  - Δ : particular SN's under- or overluminosity (smaller Δ means intrinsically brighter SN)
  - μ : distance modulus
  - A_V : host galaxy extinction
- Look for correlations between host galaxy properties and SNe Ia properties
- If observed variations in SNe Ia are due to environmental factors or systematics, it would have important implications for cosmology and the use of SNe Ia as "standard candles"

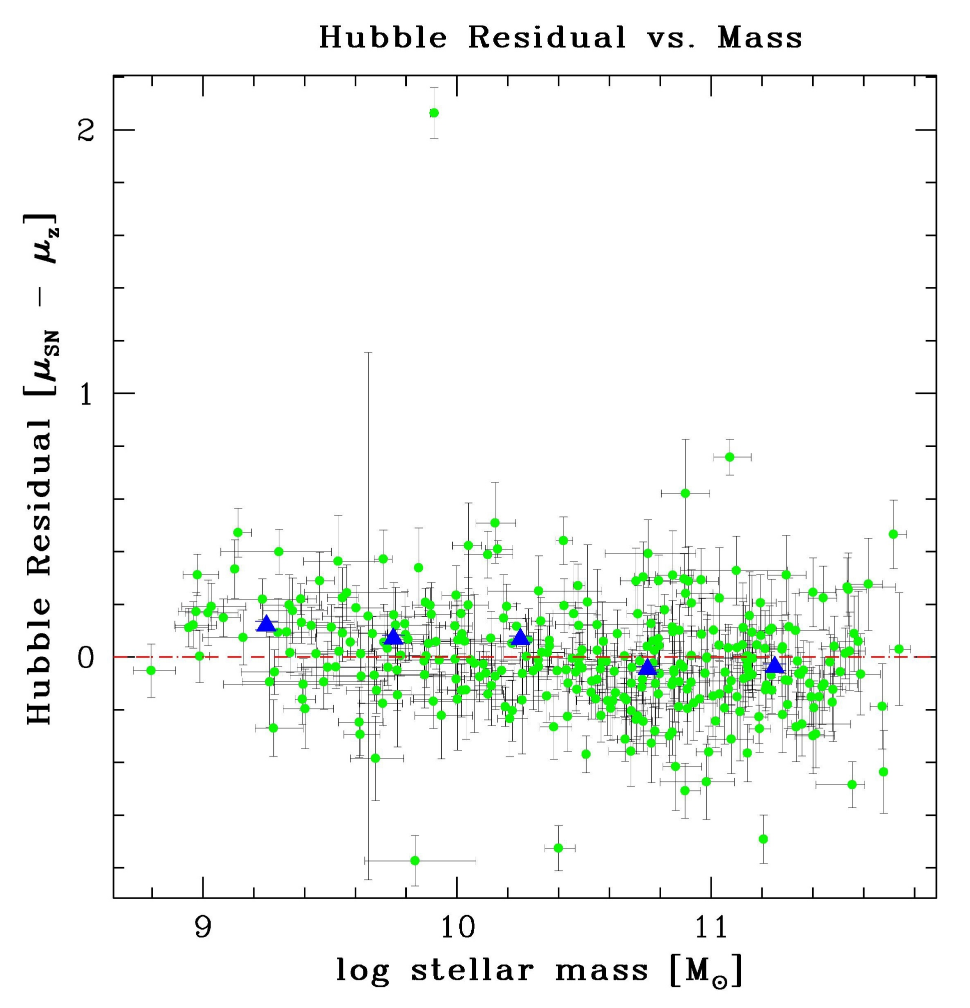
MLCS Fit Results



Some evidence that supports the trend that fainter SNe favor passive hosts, while brighter SNe favor star-forming hosts (*Hamuy et al. 1995, 2000; Gallagher et al. 2005; Sullivan et al. 2006*)

Intrinsically Brighter SN Ia

SN Ia Properties vs. Galaxy Properties



We also find evidence that more massive galaxies seem to host brighter SNe after light-curve correction (*Kelly et al. 2010; Sullivan et al. 2010; Lampeitl et al. 2010*)

HR > 0 indicates SN is fainter *after* light-curve correction

Future Work

- Fit for galaxy age
- Continue searching for SN-galaxy correlations
- Analyze sample of field galaxies for comparison
- Use available spectra to better constrain SFR and metallicity

Selected References

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