Correlations Between Hubble Residuals and Local Stellar Populations of Type Ia Supernovae

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The Big Question

Can using information about the local environment reduce systematic distance uncertainties in Type Ia supernovae?

Environmental Effects

Type Ia supernovae (SNIa) are excellent distance indicators, but their Hubble residuals show some correlation with host galaxy properties. Each individual SNIa has some variability, but these can be standardized. The two most popular light curve fitters take into account relationships like luminosity-decline rate and SNIa color. Research over the past several years is indicating that external variables seem to also contribute to SNIa variability. There are still uncertainties about how the host galaxy and the local environment influence the luminosity, color, and Hubble residuals of SNIa. There has been research that show the effects of host galaxy mass [1], global metallicity [2], and local H_α [3]

Data Collection

- SNIa selection, parameters, and cosmology from Campbell (spectroscopic and photometrically classified) [4]
- Local enviroment *ugriz* photometry form Holtzman Scene Modeling Photometry [5]
- Local stellar population model using Conroy's Flexible Stellar Population Synthesis (FSPS, [6, 7]) and Foreman-Mackey's pyFSPS [8]

Analysis

This analysis follows the work of Gupta [9] but rather then using the *ugriz* of the host from DR7 Stripe 82 co-added catalog we use the local values from Holtzman.

Stellar Population Model

The local stellar population is modeled by a four parameter "τ-model", where SFR $\propto e^{-t/\tau_{SF}}$.

- τ_{SF} – the e-folding timescale of star formation
- t_{SF} – the start time for star formation
- $\log(Z/Z_\odot)$ – the metalicity of the local stellar population
- τ_{dust} – the optical depth of the dust around starts older then 7 Gyr, younger stars have 3 times the optical depth

FSPS Parameters	Grid Values
τ_{SF} [Gyr]	0.1, 0.5, 1, 2, 3, 4, 6, 8, 10
t_{SF} [Gyr]	0, 1, 2, 3, 4, 5, 6, 7
$\log(Z/Z_\odot)$	-0.88, -0.59, -0.39, -0.20, 0, 0.20
τ_{dust}	0, 0.1, 0.3, 0.5, 1.0, 1.5

Table 1: FSPS Model Grid Parameters

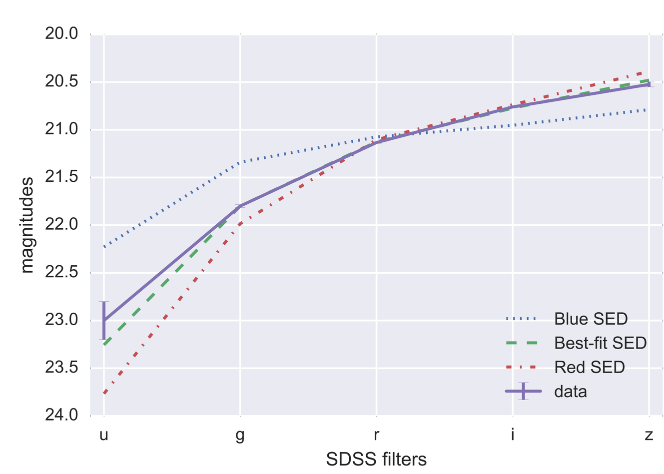

Figure 1: This figure shows the range of variability of models for SDSS SN6057 (SN 2005if).

Calculating Local Stellar Age

The "best-fit" model was selected as the one with the lowest χ^2. From this, we calculate the mass weighted age via:

$$\langle A\rangle_{\rm mass} = A_{SF} - \frac{\int_0^{A_{SF}} t\Psi(t)dt}{\int_0^{A_{SF}} \Psi(t)dt} \quad (1)$$

Where A_{SF} is the age of the universe at the given redshift minus t_{SF} and $\Psi(t)$ is the SFR as a function of time. Uncertainties were calculated by taking the RMS of the neighboring (in model space) ages scaled by probability of the fit. This results in the equation:

$$\sigma_{{\rm Age}_i} = \frac{e^{-5/2}}{e^{-\chi^2/2}}\sqrt{\langle \Delta {\rm Age}_i^2\rangle} \quad (2)$$

Local Properties Compared to Hubble Residual

The Hubble residuals were calculated using Campbell's ΛCDM best fit: $H_0 = 73.8$ km s^{-1} Mpc^{-1}, $\Omega_m = 0.24$. Figure 2 shows the results of the Hubble residual versus local stellar population age.

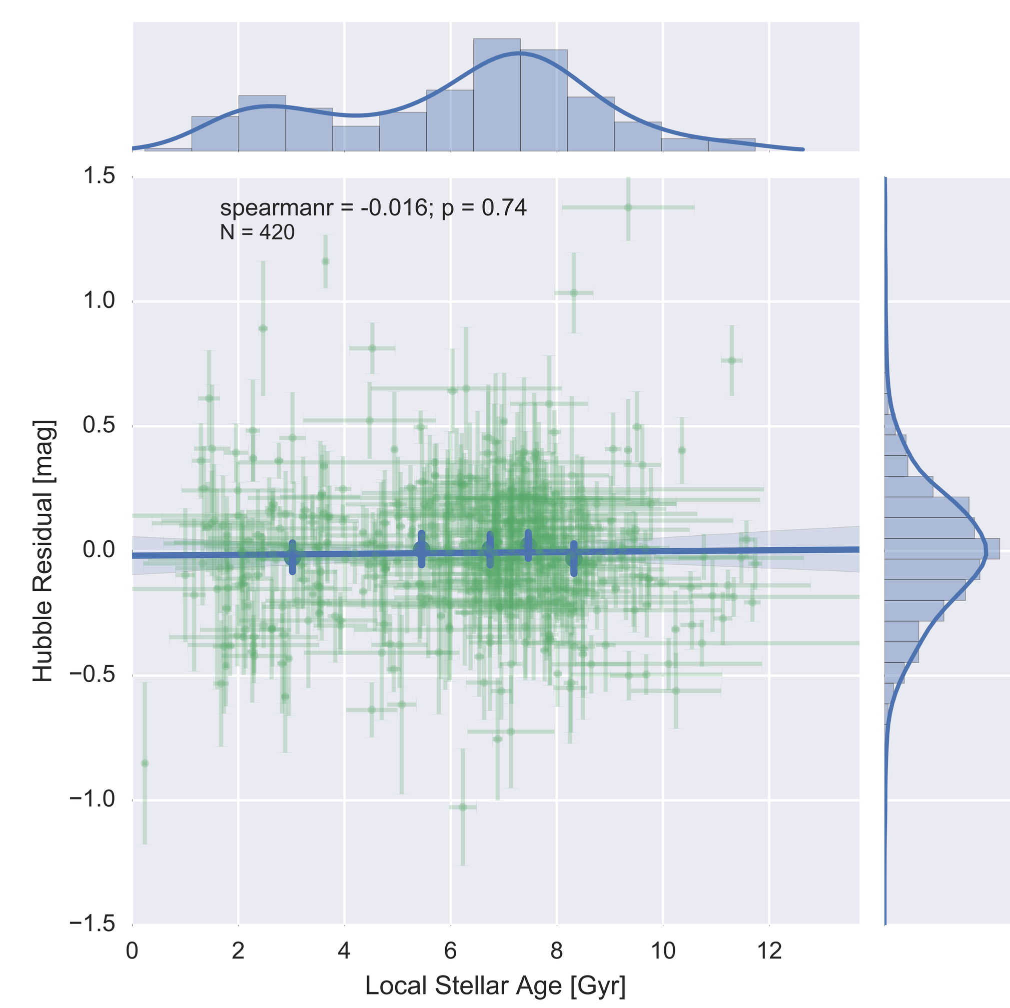

Figure 2: A linear fit (blue line) was performed to look for a correlation between Hubble residual and local stellar age. Five binned points (blue) are plotted on top of the complete data set ($N = 420$, green) to guide the eye.

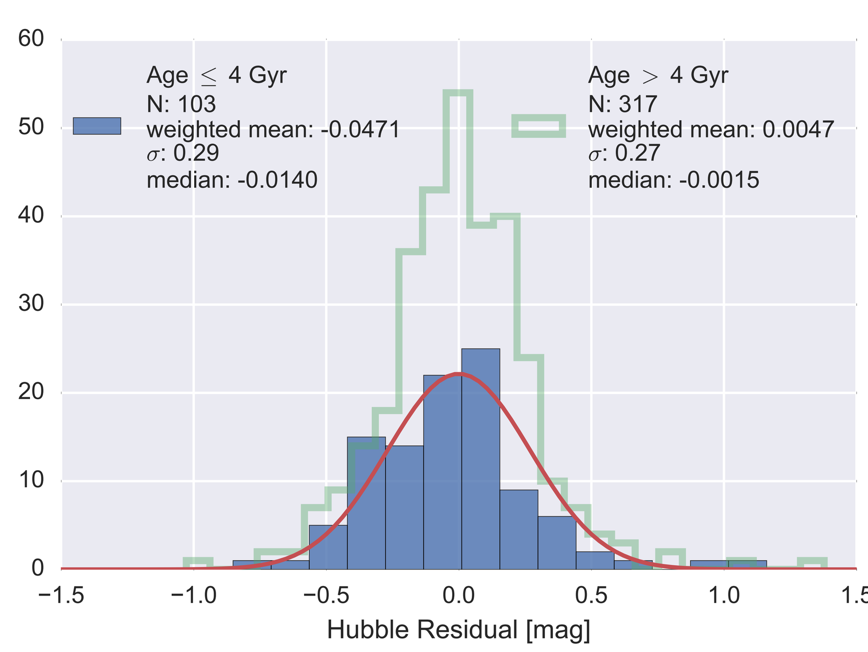

Figure 3: The distributions of the Hubble residuals split by age. The old population (> 4 Gyr) has a strong Gaussian shape. The young population (≤ 4 Gyr) does not appear to have a Gaussian shape but rather a positive skew. The plotted Gaussian (red line) is centered at 0 with the same σ as the old population.

Preliminary Results

- The local environments divide into two ages: a "young" stellar population with ages less than 4 Gyr and an older population.
- There is no clear trend of Hubble residual with local stellar age.
- The young population appears to have a non-Gaussian distribution of Hubble residual that may suggest a mix of progenitors similar to Rigault [3].
- There appears to be a difference between local age and global age, Gupta [9] does not have a bimodal global age distribution.

What is Next

Investigate differences and similarities between global host parameters and local environment parameters, specifically age distribution. Also investigate a mixed progenitor model to explain the non-Gaussian Hubble residuals of the young stellar population.

References

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