The Dust Attenuation Law in Distant Galaxies: Evidence for Variation with Spectral Type

Kriek and Conroy, 2013

Introduction

- Dust
  - Energy balance in ISM
  - Cooling of gas
  - Star formation
- However!
  - Little knowledge about: grains type, distribution, dust to gas/dust to star ratio
  - Not included in theoretical models for galaxy evolution
- Must understand dust if we want to study stellar populations of galaxies

Introduction

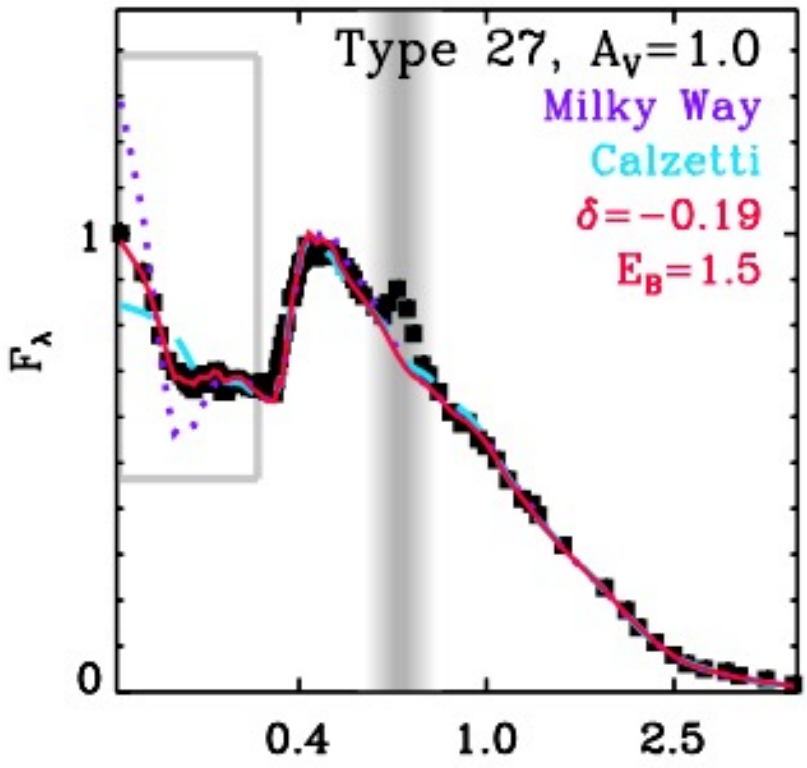
- Dust attenuation law not universal!
  - But that's usually how it's done
  - Uniform attenuation law (uniform screen)
- MW + LMC – 2175 Å feature
- 4/5 sight-lines to SMC + Calzetti empirical law for starburst galaxies -- do not show this feature
- Slope of attenuation curve shows variation among sight-lines and galaxies

Data

- Galaxy stellar light → dust attenuation curve
  - Wide wavelength coverage
  - Enough spectral resolution
- → NEWFIRM Medium-Band Survey (NMBS)
  - 0.5 deg^2 photometric survey in COSMOS and AEGIS fields
  - 5 custom designed medium-band near-IR filters
- + optical-to-MIR photometry

Data

- NMBS galaxies with redshift between 0.5 and 2.0 and S/N > 25
- Divide into 32 spectral classes
  - 22-455 galaxies in each class
- Composite SEDs
  - R $\lesssim$ 25
  - Hα (blended with NII, SII)
  - Blended OIII and Hβ
  - MgII, Balmer + 4000 Å break, dust absorption at 2175 Å



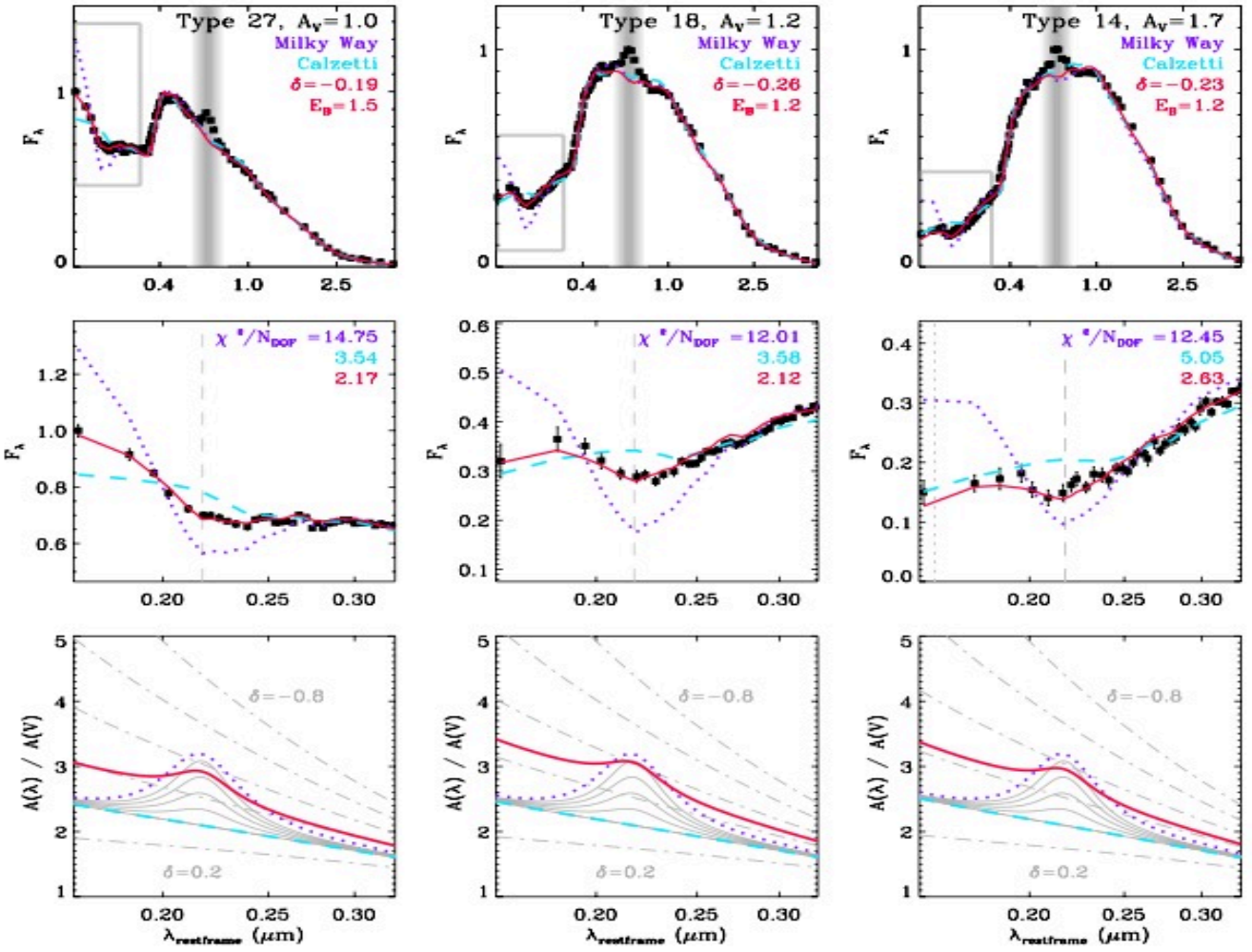
Constraining the Dust Attenuation Law

- Fit with FSPS models
  - Chabrier IMF
  - Exponentially declining SFH
- Dust models (uniform screen)
  - MW
  - Calzetti
  - Free dust model (Noll et al 2009)
    - $\lambda_0 = 2175\text{Å}$
    - $\Delta\lambda = 350\text{Å}$

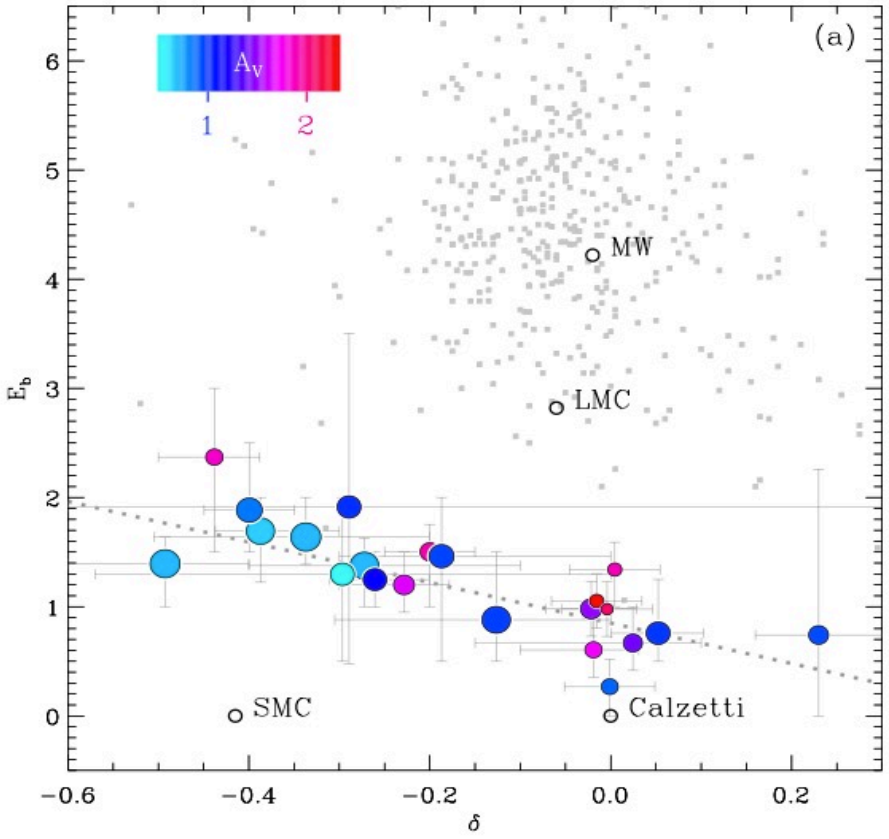
$$A(\lambda) = \frac{A_V}{4.05}(k'(\lambda) + D(\lambda))\left(\frac{\lambda}{\lambda_V}\right)^{\delta}$$

$$D(\lambda) = \frac{E_b(\lambda\,\Delta\lambda)^2}{(\lambda^2 - \lambda_0^2)^2 + (\lambda\,\Delta\lambda)^2}.$$

Constraining the Dust Attenuation Law



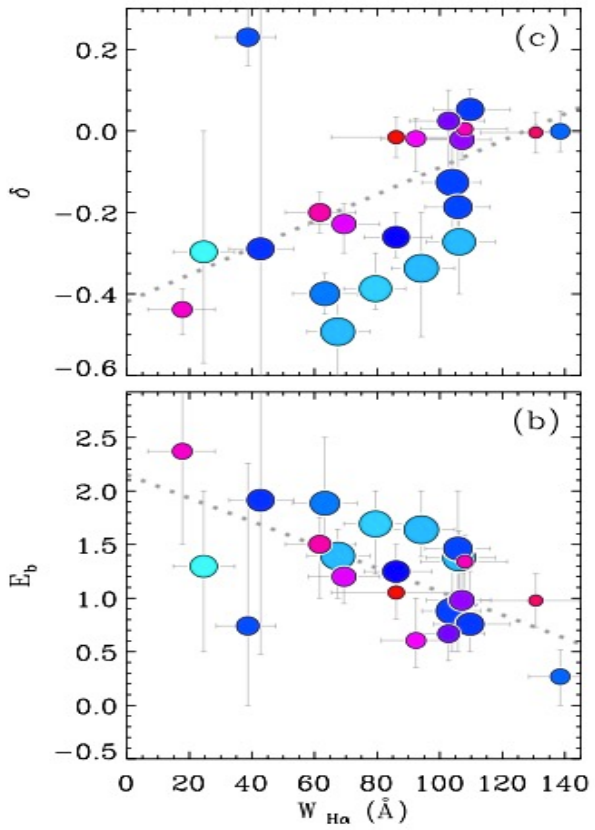
Correlations with Spectral Type



$$E_b = (0.85 \pm 0.09) - (1.9 \pm 0.4)\,\delta.$$

- Steeper attenuation curves have stronger UV bumps
- Shallower attenuation curves have weaker UV bumps

Correlations with Spectral Type

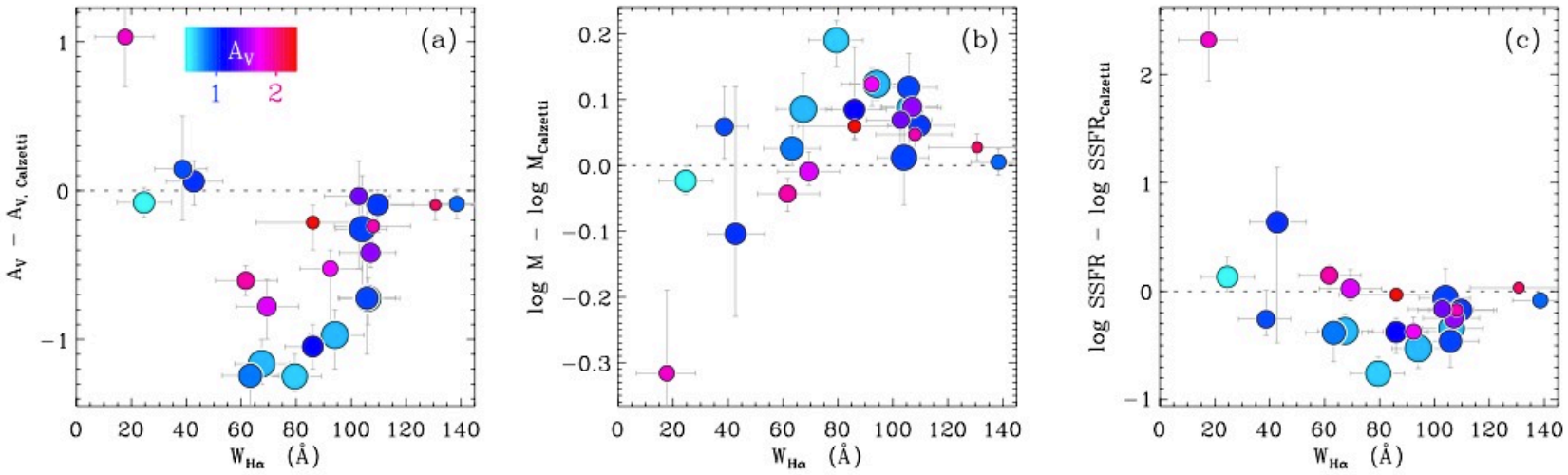


$$E_b = (2.2 \pm 0.3) - (1.1 \pm 0.3)\left(\frac{W_{\mathrm{H}\alpha}}{100\ \text{Å}}\right)$$

$$\delta = (0.33 \pm 0.04)\left(\frac{W_{\mathrm{H}\alpha}}{100\ \text{Å}}\right) - (0.41 \pm 0.04).$$

- Hα width → present to past star formation
  - Overestimated due to contamination NII, SII
- Higher Hα width have shallower attenuation curves with weaker UV bumps
  - Only outlier is SED type 8

Implications

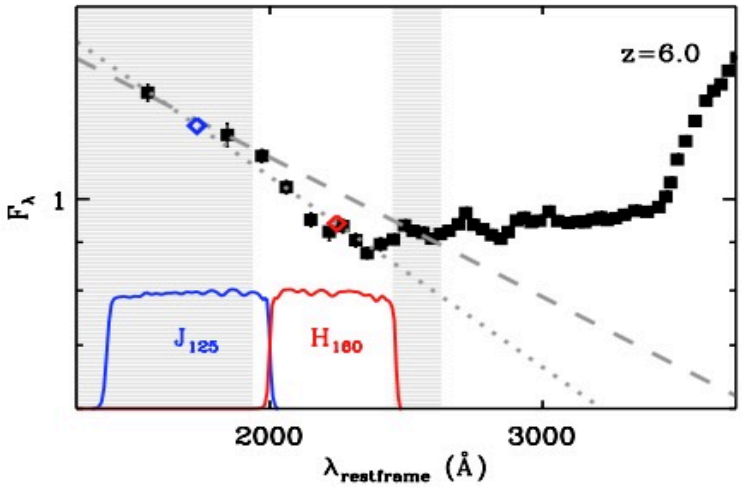


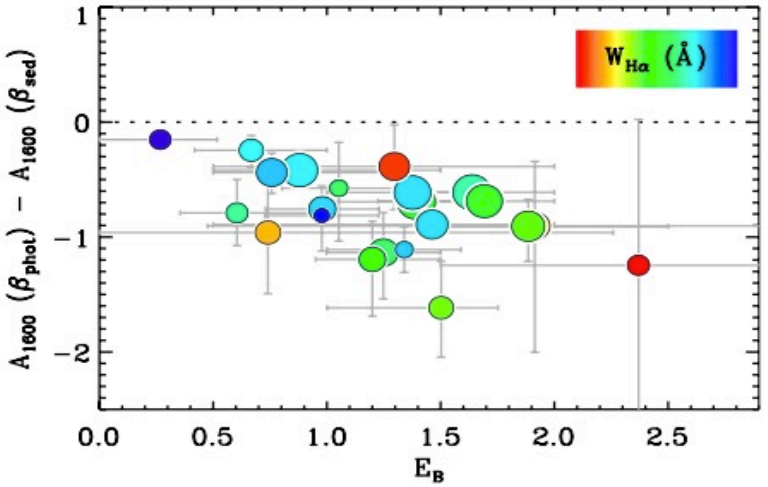
- Fixed dust law → systematic bias
- A_V, SFR overestimated for high Hα width

- Stellar mass underestimated
- SED type 12 exception
  - Poor fit by any SPS model!

Implications

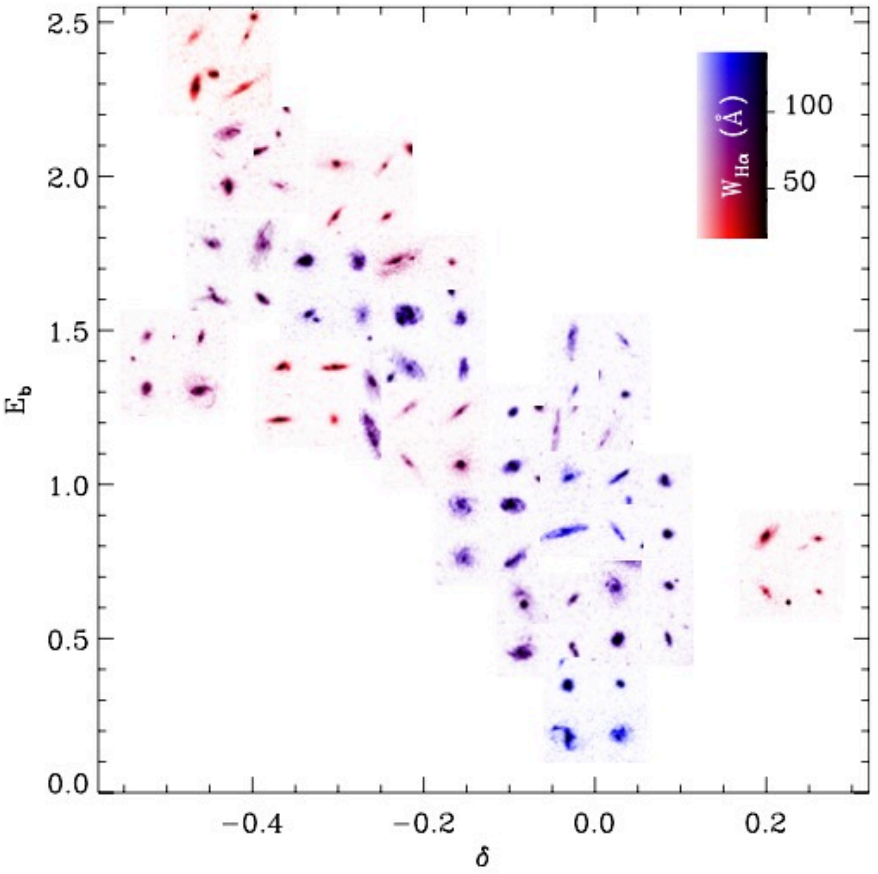
- How does UV bump affect UV slope ($F_\lambda \sim \lambda^\beta$) measurement?
- Dust feature → underestimate dust correction → underestimate SFR
- Stronger dust features → larger bias





Discussion

- Two-component dust model
  - All stars attenuated by ISM
  - Young stars also attenuated b dust in birth clouds
- This predicts variation with galaxy inclination
  - Low Hα width/Edge-on have steeper curves and stronger bumps
  - High Hα width/face-on have shallower curves and weaker bumps



But!

- Stacking SEDs of similar type is a weakness!
  - Could be combining different attenuation curves
- Wavelength coverage is not the same for all redshifts
- Only look at attenuated light (no re-emitted)
  - Future work here

Summary

- FSPS with different attenuation curves → fit composite SEDs
- MW + Calzetti are poor fit for almost all cases
- UV bump strongly correlates to slope
  - Steeper slopes have stronger bumps
- Shape of dust curve correlates with Hα width
  - Higher Hα width have shallower curves and weaker bumps
- Average law has UV bump ~25% MW bump and slope between SMC and MW
- Two-component dust model
  - Edge-on have steeper curves and stronger bumps