Effects of Star Formation History on SFR Indicators: Insights from Nearby Dwarf Galaxies

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Outline

Introduction/Motivation
• star formation rate (SFR)
• and the star formation history (SFH)

Impact of SFH on measurements of SFR and stellar mass
• importance of resolved stars for SFH
• consistency of models with observed SED
• implications of SFH for SFR indicators
Many key results depend on accurate measures of SFR

e.g., The SFR density of the universe

Hopkins & Beacom 2006
SFR calibrations: connect fundamental observables (luminosity) to physical quantities

\[ \text{SFR}_T = \eta_{\lambda,T}(Z_*, \text{IMF}, \text{SFH} [, Z_{\text{gas}}, U_{\text{gas}}, f_{\text{esc}}]) \times L_{\lambda} \times 10^{0.4\hat{\text{A}}} \]

Population Synthesis Models  
Observed  
Dust Correction

All SFR calibrations are fundamentally based on SPS models

\[ \hat{\text{A}}: \text{effective attenuation} \]
\[ = \hat{\text{A}}(R_{\lambda}, p(\tau_V(t)), \Theta) \]
\[ T: \text{timescale over which SFR is averaged} \]
The TIR SFR Tracer

K98 assumptions: Bolometric Luminosity of 100Myr old constant SFR population (using an early version of BC03 and assuming Salpeter IMF) Assumes $\tau_V=\infty$

Usually, it is wrong twice:
1) galaxies are partially transparent and
2) stars older than 100-200 Myr can contribute to the IR (cirrus)

On Average these effects cancel out in the local universe (~half the IR is cirrus, and ~half the young starlight is unattenuated), but individual galaxies can be huge exceptions (transparent dwarfs like LMC and SMC, early type galaxies)

Caveats are in KE12 and K98! There are some strategies to address these (K09, Hao 11, Cortese 08, Leroy 12)
Connect fundamental observables (luminosity) to physical quantities.

Blanton et al. 2003, Brinchmann et al. 2004
The SFH connects variables across time

- It is a critical constraint on mechanisms of galaxy evolution
- It affects the conversion between physical properties and observables
- It is a significant source of uncertainty in population synthesis modeling of galaxies

Schiminovich et al. 2007
Variations in the SFH can be caused by, and encode:

- inflow/mergers/cooling (all masses)
- ‘feedback’: AGN (high mass), SNe+winds (all masses)
- stochasticity/CMF (low mass)
- interactions (see Geha+12 for SFH and dwarf environments)
SN Feedback: Hydrodynamic models of SFR in dwarf galaxies
‘self-regulated SFR’

e.g. Stinson et al. 2007
But the SFH of individual galaxies is exceedingly difficult to measure

SFH effects are often degenerate with dust attenuation and metallicity

constant metallicity, vary age+SFH
constant age, vary metallicity
But the SFH of individual galaxies is exceedingly difficult to measure

Smooth functions (T models) are usually assumed, possibly with ‘bursts’ of some form overlaid. Some measure of SFH is then derived from the SED itself, along with stellar mass and SFR.

Usually not bad for whole big galaxies. Breaks down for small galaxies or regions within galaxies (where the SFR varies on the timescale characteristic of your tracer, c.f. Gieles+08, Bastian+10)
Resolved stars offer a possibility to strongly constrain the SFH of nearby dwarf galaxies

Especially He-burning stars, which follow a luminosity-age relation

Weisz et al. 2008
The Derived SFHs

McQuinn et al. 2010
These SFHs can be used to determine the effect of realistic SFH on conversions between luminosity and SFR or $M_{\star}$

$$SFR_T = \eta_{\lambda, T}(Z_{\star}, \text{IMF}, \text{SFH}, [Z_{\text{gas}}]) \times L_\lambda \times 10^{0.4\Delta}$$
Use these SFHs as input to population synthesis codes.

HST image

HST CMD

‘Modeled’ luminosities (FSPS)

recovered SFH+extinction
Possible for nearby dwarfs with HST

~50 galaxies drawn from ANGST (Dalcanton et al.)

Distance < 4 Mpc

Observed with GALEX and Spitzer (Dale et al. 2009)

Very low metallicity
Very low dust attenuation

[Graph showing star formation rate vs. mass]
Comparison to observed SED

GALEX (UV)  SDSS (optical)  Spitzer IRAC (Near-infrared)

Supplemented by UBVR imaging of galaxies not covered by SDSS

Photometry within the HST footprint
Average ratio of predicted and observed luminosity at each wavelength

Error bars show the standard error on the mean at each wavelength

Using Flexible Stellar Population Synthesis models (Conroy 2010) for the prediction
The $L({\text{FUV}})/SFR$ Ratio \ i.e. $1/\eta$

There is scatter of a factor of two in this ratio

Uncertainty in SFR measured from UV

$\sigma_{\text{mod}} = 0.340$

$\sigma_{\text{obs}} = 0.330$

Johnson et al. 2013 submitted
Can we correct for this using observed galaxy colors?

dotted=K98
dashed=exponentials with $Z=0.2Z^\odot$
The fraction of unattenuated UV luminosity contributed by stars of different ages

Black circles are for constant SFR
see also Kennicutt & Evans 2012
Timescale of SF measured by UV emission ($\tau_{50}$)

Varies by 2 orders of magnitude for dwarfs

Dashed line = exponential decaying SF
Thank You

M. Seibert,
GALEX Science Team

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