Dust and the measurement of star formation in galaxies

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Tracing star formation through the UV...

Not so simple to convert UV emission into SFR!

Multiple factors play a role:
- stellar populations (Z, rotation, binarity, atmospheres, etc.)
- IMF (shape, sampling)
- contamination (AGN, evolved stars, etc.)
- SFH
- etc.

And then, there is dust

M33/GALEX FUV+NUV
Dust is very efficient at absorbing UV photons.

New factors come into play:
- grain properties (composition, sizes, emissivity)
- attenuation curve (amplitude, shape)
- etc.
Dust heating from old stellar populations

Boquien, Buat, and Perret (2014)

Perret et al. (2014)

1 of 23 hydrodynamical simulations

FUV  NUV  U  TIR

Star formation rate [Msun/yr]

True  Lyman continuum

Boquien et al. (2019)

CIGALE (CODE INVESTIGATING GALAXIES EMISSION) THROUGH AN ENERGY BUDGET

Boquien, Buat, and Perret (2014)

Fraction due to old stars

Lyman continuum
To correct the UV for the dust we need to understand why and how $k_{IR}$ varies within and between galaxies. Combining $UV + IR$ has become popular to correct for the dust.

Hao et al. (2011) → $k_{24} = 3.89$  Liu et al. (2011) → $k_{24} = 6.0$

$L(\text{UV})_{\text{intrinsic}} = L(\text{UV})_{\text{observed}} + k_{IR} \times L(\text{IR})$

To correct the UV for the dust we need to understand why and how $k_{IR}$ varies within and between galaxies.
Towards adaptive hybrid SFR estimators

Subsample of 7 normal star-forming galaxies
Good spatial sampling: ~1 kpc/pixel, ~1300 pixels
Good wavelength sampling: FUV to 350 microns
Multi-wavelength modelling
Spatially resolved physical properties

Likelihood-weighted estimates of $A_{\text{FUV}}$, the stellar mass, and the SFR

NGC 628

NGC 1097

NGC 4321

NGC 5055
Spatially resolved $k_{IR}$

$$k_{IR} = \frac{L(\text{UV})_{\text{observed}}}{L(\text{IR})} \times \left[10^{A(\text{UV})/2.5}-1\right]$$
Variations of $k_{IR}$ with local physical properties
Parametrizing $k_{IR}$

Boquien et al. (2016)
Beyond nearby galaxies

GALEX-SDSS-WISE LEGACY CATALOG
Salim et al. (2016), Salim, Boquien & Lee (2018)

GSWLC
GALEX-SDSS-WISE LEGACY CATALOG
Salim, Lee, Proctor, de Carvalho, Downes, Boquien, Boughnet, Salim and Charlot

GSWLC contains physical properties of ~750,000 galaxies with 30% redshifts below 0.5 (0.5-1+z<0.3) and magnitude r<21.5.

GSWLC contains galaxies within GALEX Horizons, regardless of a UV detection, and belong to the Legacy Catalog.

There are two versions of the catalog: GSWLC 1 and GSWLC 2. GSWLC 2 is not just the update of GSWLC 1, it was produced in a different way. Both versions contain identical sources, but a different number of objects in the same catalog and they both cover identical photometry. In particular, the photometry from GSWLC contains numerous corrections, especially for the fluxing. The principal difference is that GSWLC 1 contains separate star formation rates (SFRs) from the UV-optical SED fitting method (R & Izotov) and from WISE 22 micrometers, whereas GSWLC 2 has more accurate SFRs from the UV-optical SED fitting.

GSWLC-1
GSWLC 1 is described in Salim et al. (2016) for 99% completeness, which is the same reference as the previous version.

http://pages.iu.edu/~salims/gswlc/

CIGALE (Core Investigating GALaxies Emission) THROUGH AN ENERGY BUDGET

CIGALE (Core Investigating GALaxies Emission) THROUGH AN ENERGY BUDGET

Version 2018.0

Leaves falling in the North
Birds singing in the south
Cigale is reborn

We have just released a new version of Cigale: This release is noteworthy in the history of Cigale, as it will allow you to break new ground and explore previously uncharted territories.

https://cigale.lam.fr/
Beyond nearby galaxies

Boquien & Salim (in prep.)

12773 low redshift star-forming galaxies

Boquien et al. (2016) relation for resolved galaxies

Salim, Boquien & Lee (2018)

Boquien & Salim (in prep.)
Conclusions

1. Measuring the SFR from the IR may seem easy, it is not so

2. Complex dust heating make monochromatic estimators imprecise

3. Standard hybrid estimators cannot account for the diversity of galaxies

4. Adaptive hybrid estimators improve the reliability of SFR in a simple way with just a near-IR band