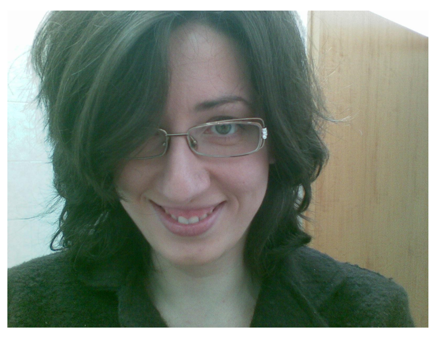
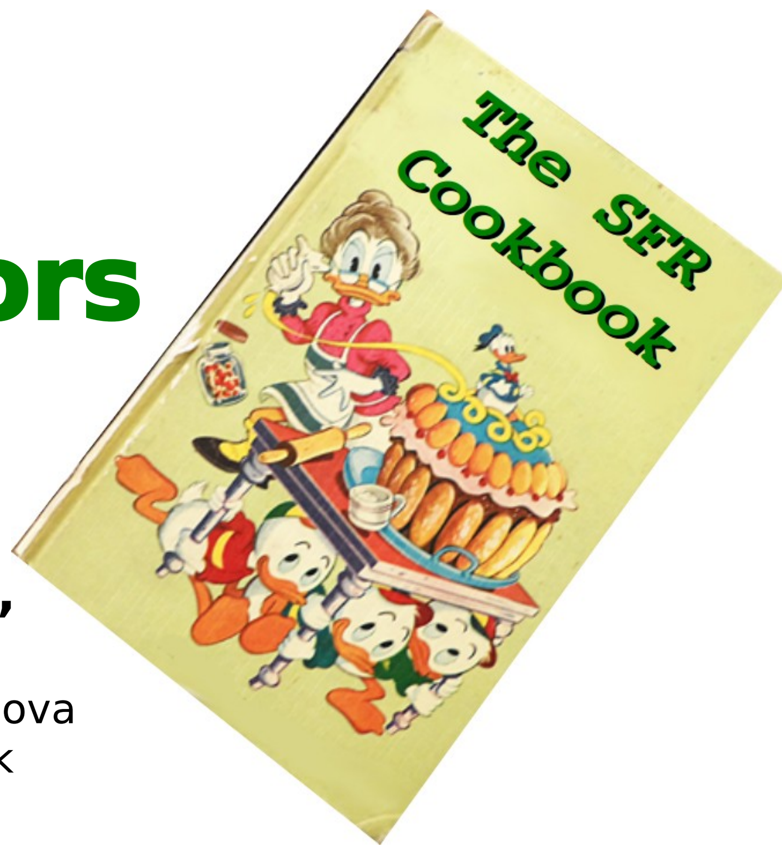
The SFR Cookbook at 1<z<3

New recipes for spectroscopic estimators

(*UV continuum & [OII]λ3727*)

Talia et al., 2014 A&A in preparation





Margherita Talia
margherita.talia2@unibo.it

M. Talia[1,3], A. Cimatti[1], L. Pozzetti[3], G. Rodighiero[2], C. Gruppioni[3], F. Pozzi[1], E. Daddi[4], C. Maraston[6], M. Mignoli[3], J. Kurk[5]

[1]Dipartimento di Fisica e Astronomia, Università di Bologna [2]Dipartimento di Fisica e Astronomia, Università di Padova
[3]INAF-Osservatorio Astronomico di Bologna [4]CEA-Saclay, DSM/Irfu/Service d'Astrophysique [5]Max Planck Institute für extraterrestrische Physic, Garching [6]Institute of Cosmology and Gravitation, Portsmouth

ABSTRACT

In this work we use a sample of galaxies at 1<z<3 drawn from the **GMASS** survey (Kurk+13) to study different SFR estimators. In particular, we concentrated mainly on two spectroscopic estimators (the UV luminosity and the [OII]λ3727 emission line) and the infra-red luminosity (L_{IR}). Using L_{IR} to calibrate the other two estimators, we were able to build a set of self-consistent SFR recipes.

We decided to concentrate on a well controlled spectroscopic sample, rich of ancillary data, in order to study the information that can be obtained directly from spectra, and derive relations about dust extinction corrections particularly useful in view of the large spectroscopic surveys that are currently on-going or will be carried out in the near future. The L_{IR}/L_{UV} ratio was used to calibrate the UV continuum slope β as an estimator of UV effective attenuation, in order to compute a correction to dust extinction to be applied to UV luminosities. We also find a correlation between attenuation and the rest-frame equivalent width (EW) of the [OII]λ3727 emission line. Such relation allows to derive an estimate of SFR, corrected for dust extinction, using solely spectral information from the [OII] line (luminosity and EW).

1. The multi-wavelength dataset

GMASS (*Galaxy Mass Assembly ultra-deep Spectroscopic Survey*) is an ESO VLT Large Program project based on data acquired using the FORS2 spectrograph. The sample is pure flux-limited with a limiting magnitude *mag(4.5μm)*<23.0 (AB).

The photometric catalogue of the GMASS survey was taken as parent sample. Only galaxies with a spectroscopic redshift 1<z<3 were selected, either from GMASS or from other public **ESO spectroscopic surveys**. The photometric information from U band to IRAC 8.0 μm band, in the GMASS photometric catalogue, was extended with four IR bands, from 24 to 160 μm, including data from the **PACS** instrument mounted on the **HERSCHEL** space observatory.

3. IR Luminosity

The total infrared luminosity (LIR) is defined as the integrated luminosity between 8-1000 μm. To derive LIR for the sources with at least two IR photometric points (i.e. 24 μm plus at least one Herschel band), we performed an SED fitting procedure, based on χ2 minimization, using the MAGPHYS code in its default configuration (da Cunha et al. 2008) and all the available photometric information, from U band to PACS data.

To improve the statistics of the sample, especially at low luminosities, LIR was computed also for those galaxies with a detection at 24 μm but no PACS data. We adopted the main sequence templates of Magdis (2012) to extrapolate LIR from the 24 μm flux densities. These templates, tested on the sub-sample of PACS-detected galaxies, provide LIR values that are highly consistent to those derived using all available IR data (mid- and far-IR), with no need of additional corrections.

The infrared luminosities were converted into SFR according to Kennicutt (1998). To this term, that represents the reprocessed light from new-born stars, we added another term to account for the unobscured UV light. We finally define $SFR_{IR+UV}=SFR_{IR}+SFR_{UV}$ as total SFR (obscured plus un-obscured).

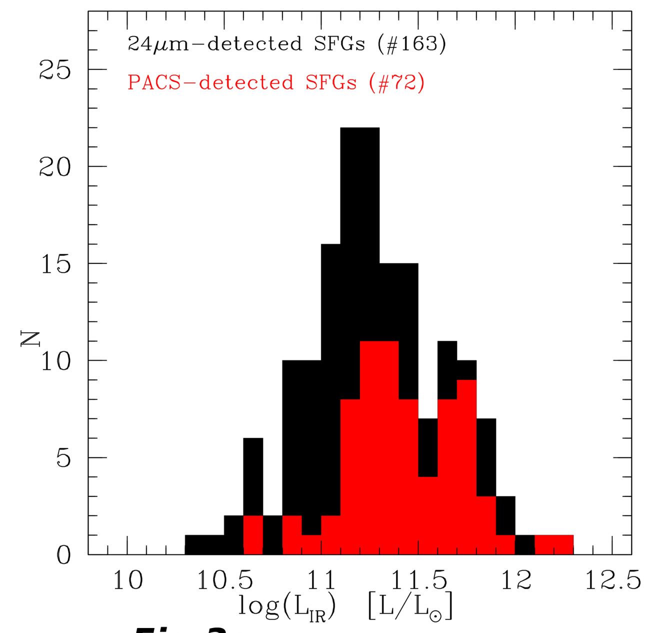


Fig.3a
LIR distribution

2. The selection of SFGs

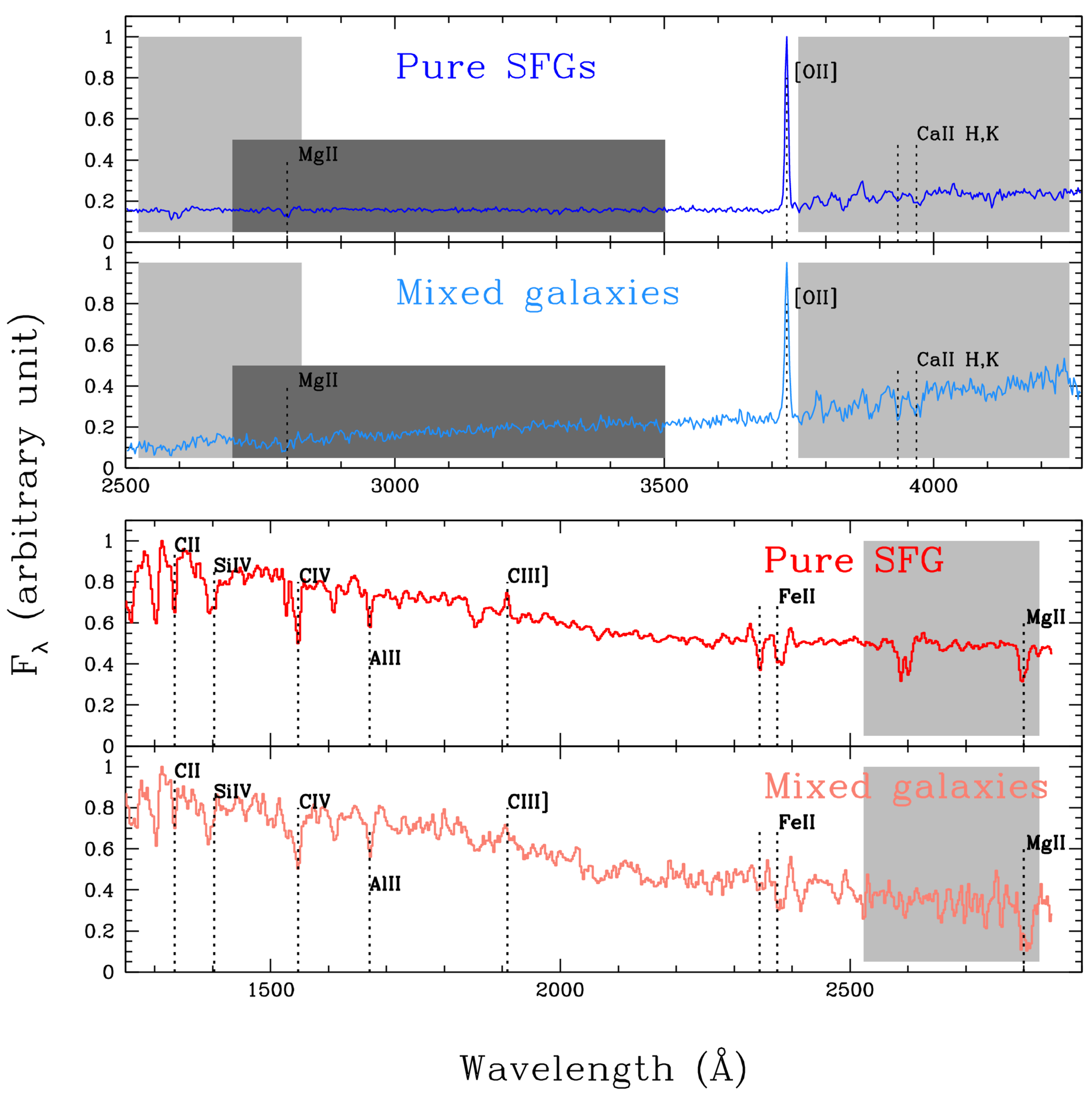


Fig.2a
From top to bottom: a) average spectrum of SFGs at 1<z<1.7; b) average spectrum of mixed galaxies at 1<z<1.7; c) average spectrum of SFGs at 1.4<z<3. d) average spectrum of mixed galaxies at 1.4<z<3.

Dashed lines mark some spectral lines of interest.

Grey shaded regions indicate the wavelength intervals over which three continuum indices are defined: MgUV (2600-2900Å); C(29-30) (2900-3300Å); D4000 (3750-4250Å).

The parent spectroscopic catalogue was cleaned of passive objects and active galactic nuclei (AGNs). Galaxies with a passive-like spectrum were excluded based on their red continuum, metal absorption lines, absence of nebular emission lines. Galaxies with AGN spectral features (like broad emission lines) and/or an X-ray detection in the **Chandra 4Ms** catalogue and L_X>3x10^{42} erg/s were also excluded from the sample.

The validity of LIR as a SFR indicator relies on the assumption that young stellar populations heat the dust that than re-emits in the IR. However, there might be a non-negligible contribution of old stars to the dust heating, that grows with decreasing sSFR, leading to an overestimate of the true SFR when using LIR as sole estimator. We used three spectroscopic continuum indices (MgUV (Daddi+05); C(29-30) (Cimatti+08); D4000 (Bruzual+83)) to spot, and then exclude from the SFGs selection, all galaxies with some evidence of the possible presence of old stellar populations (called "mixed" galaxies).

The final sample counts ***279 star-forming galaxies***, whose spectra are characterized by strong [OII]λ3727 emission or strong inter-stellar absorption lines (depending on the redshift). Examples are shown in Fig.6. Two thirds of the galaxies in the sample have a detection in at least one IR photometric band.

Compared to the reference sample, the SFGs sample is probing galaxies with intermediate mass (median mass $M_\star=10^{9.8}M_\odot$), blue colours and high sSFR.

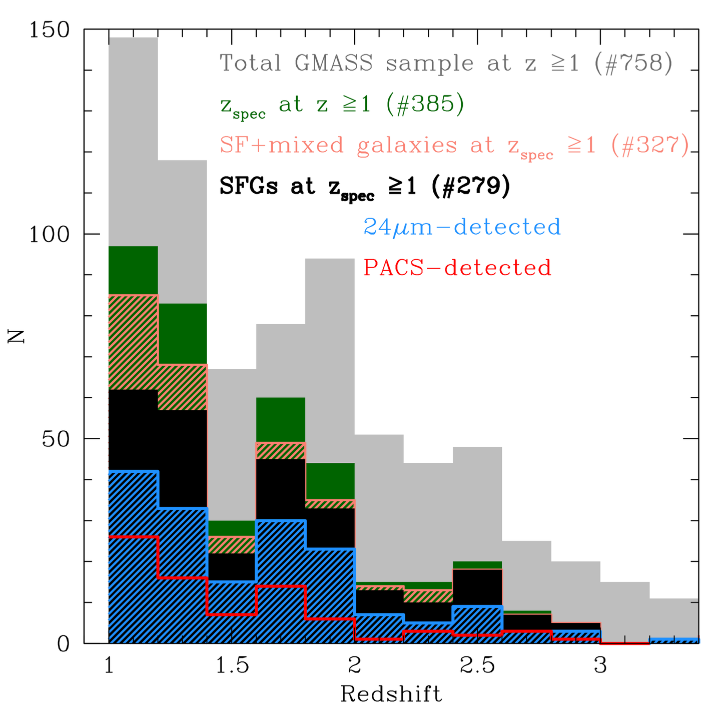


Fig.2b
Redshift distribution.

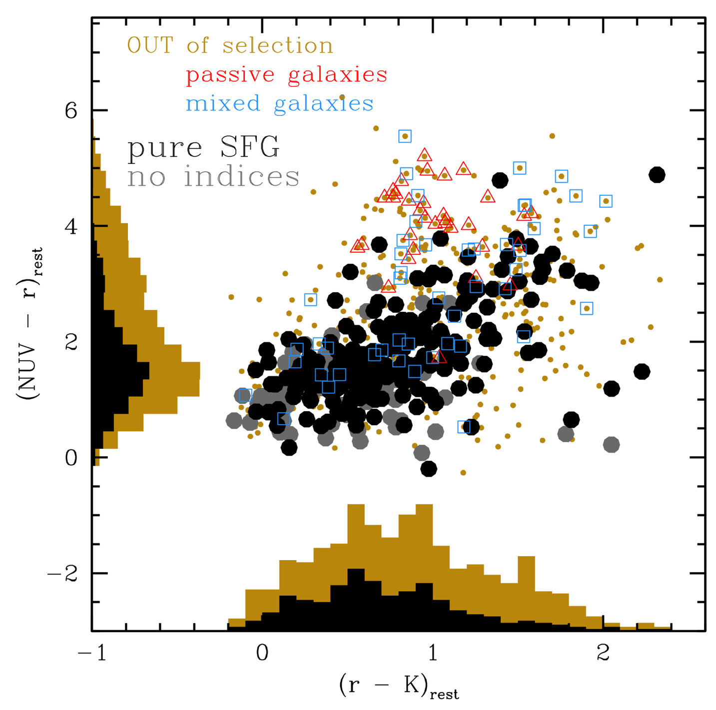


Fig.2c
Rest-frame (NUV-r)vs.(r-K) colour diagram.

4. SFR from UV luminosity and attenuation from UV continuum slope

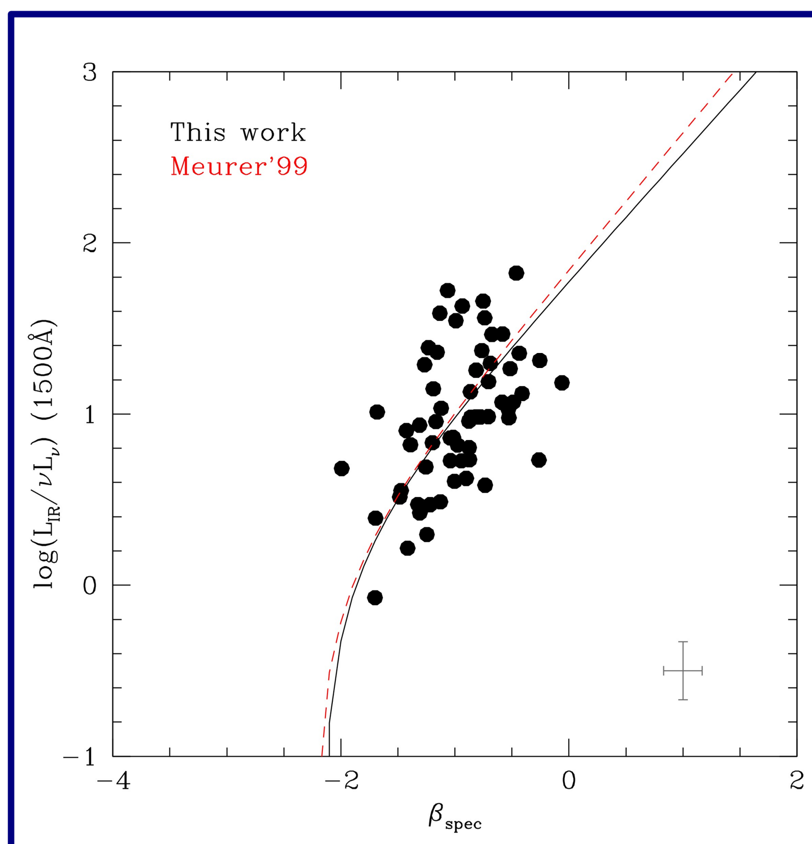


Fig.4a
LIR/LUV vs. β_{spec}.

In galaxies dominated by a young stellar population, the shape of the UV continuum can be fairly accurately approximated by a power law $F_\lambda \propto \lambda^\beta$, where F_λ is the observed flux and β is the UV continuum slope. Meurer+'99 found a correlation between β of local starburst galaxies and the ratio of their LIR over UV luminosity (LUV=νLν(1500Å)), not corrected for extinction. This ratio can be translated into attenuation. For the galaxies in our sample we derived a relation between β and *LIR/LUV* and we found it to be consistent with the Meurer one.

From *LIR/LUV* the effective attenuation A_{IRX} can be derived, to correct the UV luminosity:

$$\log(SFR_{tot})=\log(SFR_{UV})+0.4A_{IRX}$$

The relation linking β to A_{IRX} is:

$$A_{IRX} = 1.85 \times \beta_{spec} + 3.99$$

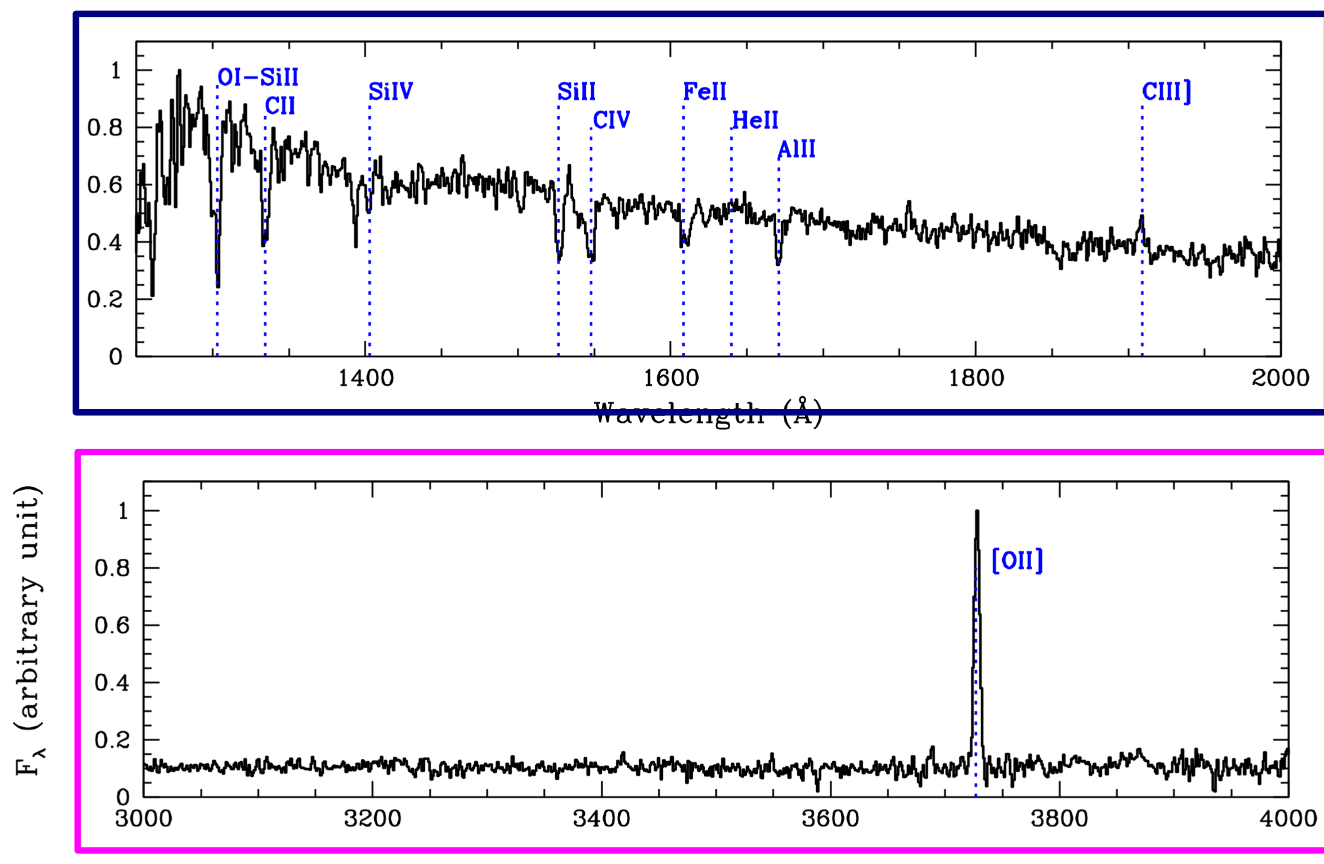


Fig.6
Examples of spectra of SFGs analyzed in this work.
Top: blue continuum and strong ISM absorption lines (1.4<z<3);
Bottom: strong [OII] emission line (1<z<1.6).

5. SFR from [OII]λ3727 line

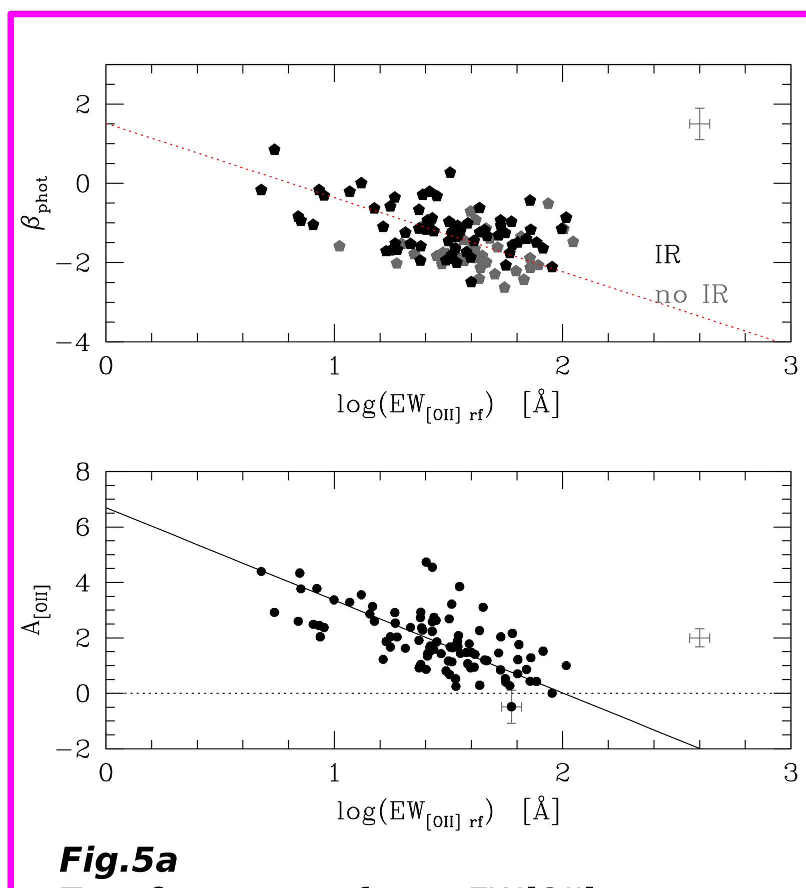


Fig.5a
Top: β_{phot} vs rest-frame EW[OII].
Bottom: $A_{[OII]}$ vs. rest-frame EW[OII].

The luminosity of the [OII] forbidden line can be calibrated empirically as a quantitative SFR tracer. However, the observed luminosities suffer from dust extinction and should be corrected for that. We found a relation between the UV continuum slope and the rest-frame equivalent width (EW) that motivated us to derive a direct relation between EW and attenuation, and obtain a self-consistent way of computing the dust corrected $SFR_{[OII]}$ from spectroscopic information alone.

Following the same formalism applied to UV luminosity, we used the IR luminosity to define an extinction correction to be applied to the [OII] flux:

$$\log(SFR_{tot})=\log(SFR_{[OII]})+0.4A_{[OII]}$$

We found an anti-correlation between $A_{[OII]}$ and the rest-frame equivalent width (EW) of the [OII] line:

$$A_{[OII]} = -3.34 \times \log(EW_{rest}) + 6.70$$

Selected bibliography: Arnouts+13, Balestra+10, Bouwens+12, Calzetti+94,+00,+01, Cimatti+08. daCunha+08, Daddi+04,+05, Elbaz+11, Kennicutt+98, Kurk+13, Lutz+11, Magdis+12, Meurer+99, Mignoli+05,+09, Nordon+13, Rodighiero+11,+14, Talia+12, Vanzella+08, Williams+09, Utomo+14, Xue+11