Applying Stellar Population Synthesis on Star Formation Rates of Galaxies

using Spectral Energy Density data

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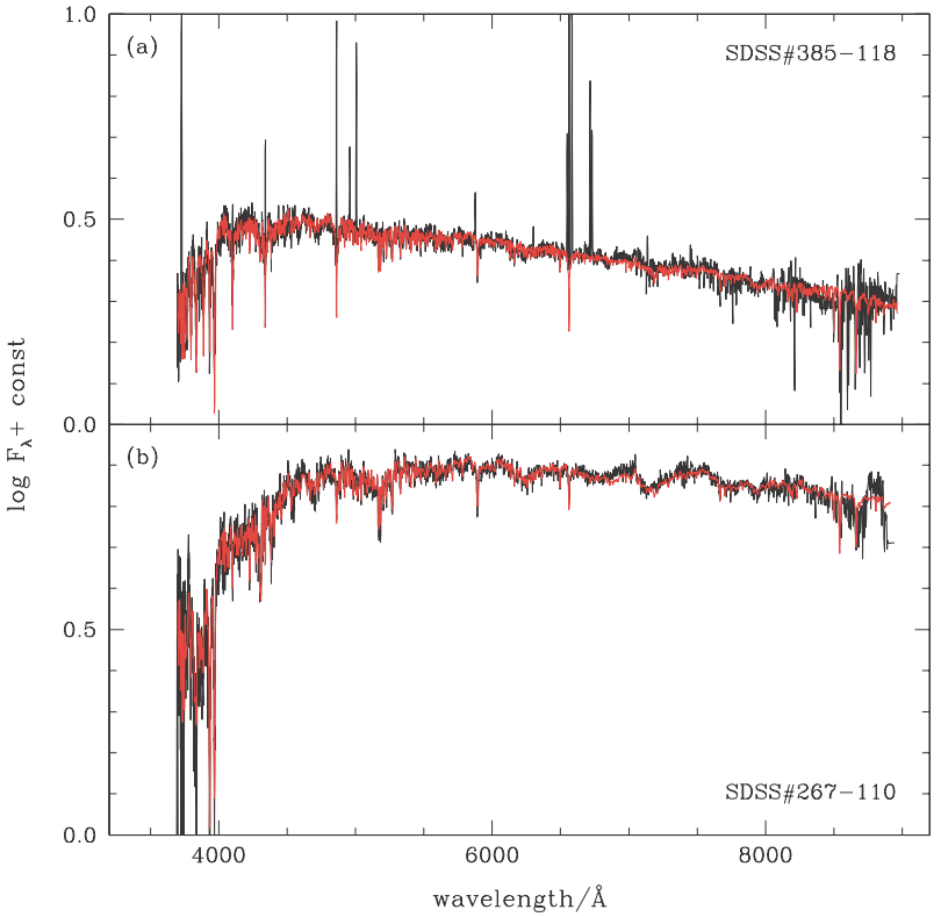
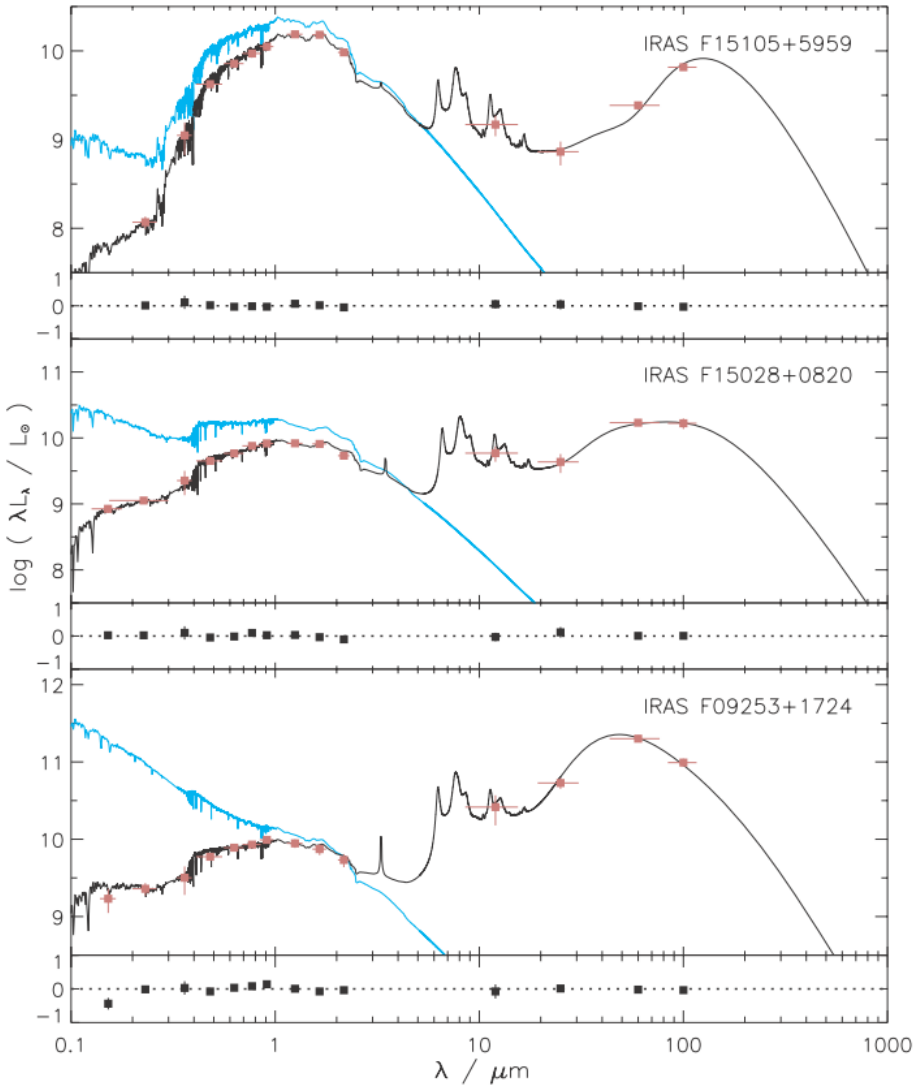
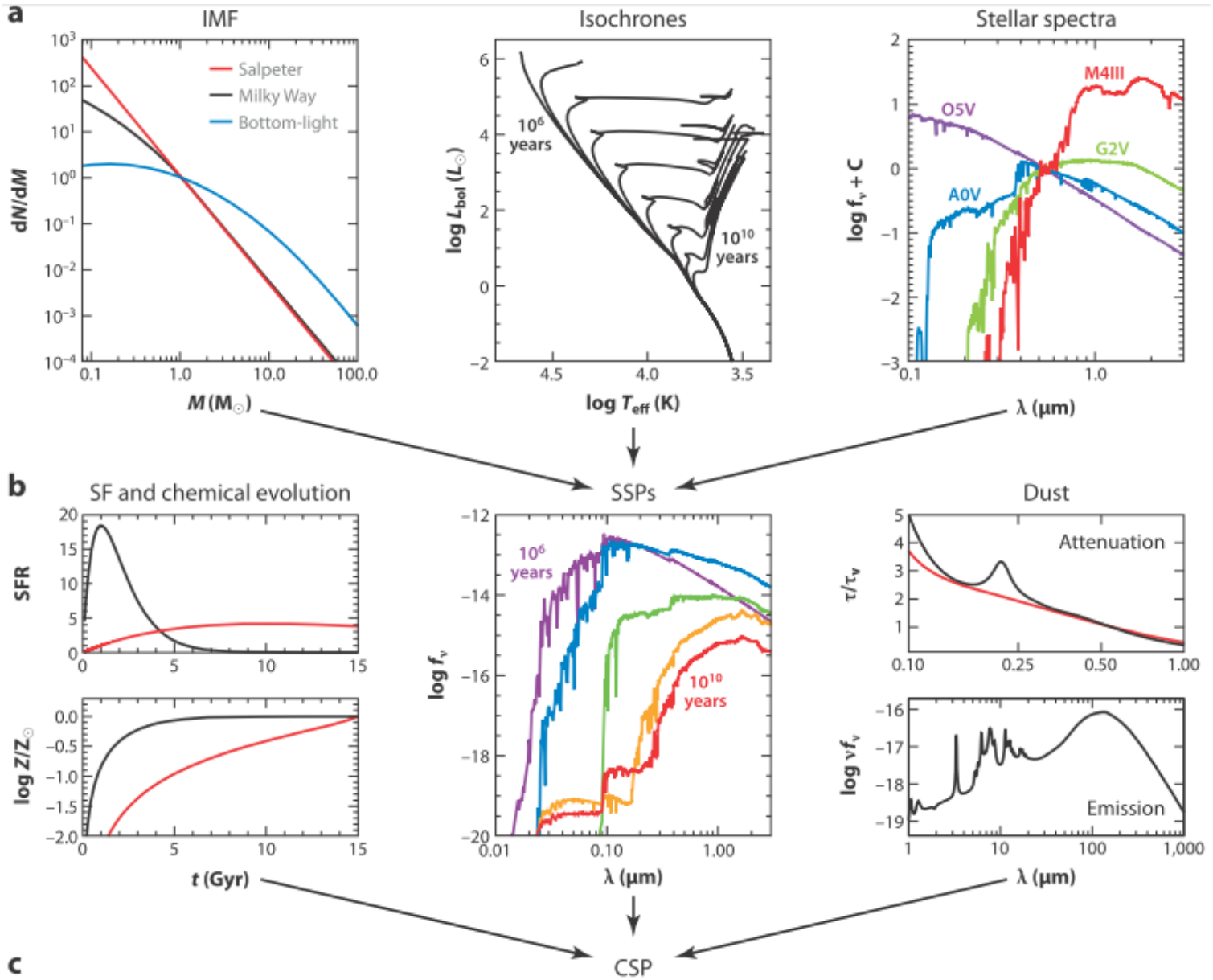
Galactic Astronomy Lecture, summer term 2018, Uni Bielefeld

Introduction – Spectral Energy Density (SED) data





Stellar Population Synthesis – The Construction Process



Stellar Population Synthesis – Combining the Components

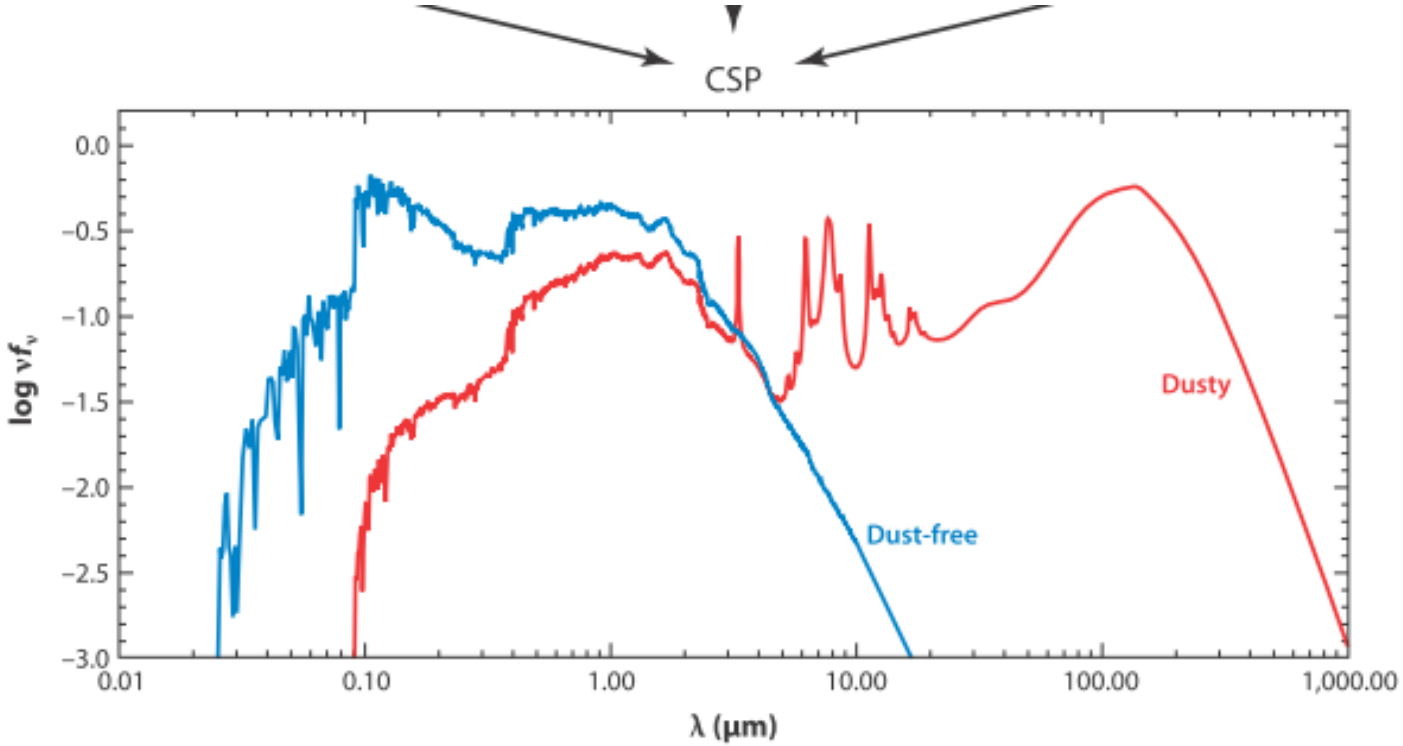
- Three basic components: isochrones, stellar spectra f_{star} and initial mass functions $\Phi(M)$ determine a *Simple Stellar Population* (SPS)

$$f_{SSP} = \int_{m_1}^{m_2(t)} \mathrm{dM}\ \Phi(M)\, f_{star}(T_{eff}, \log g(M)|t, Z)$$

- The *Composite Stellar Population* (CSP) of the galaxy is "built up" from SPS formed at different times:

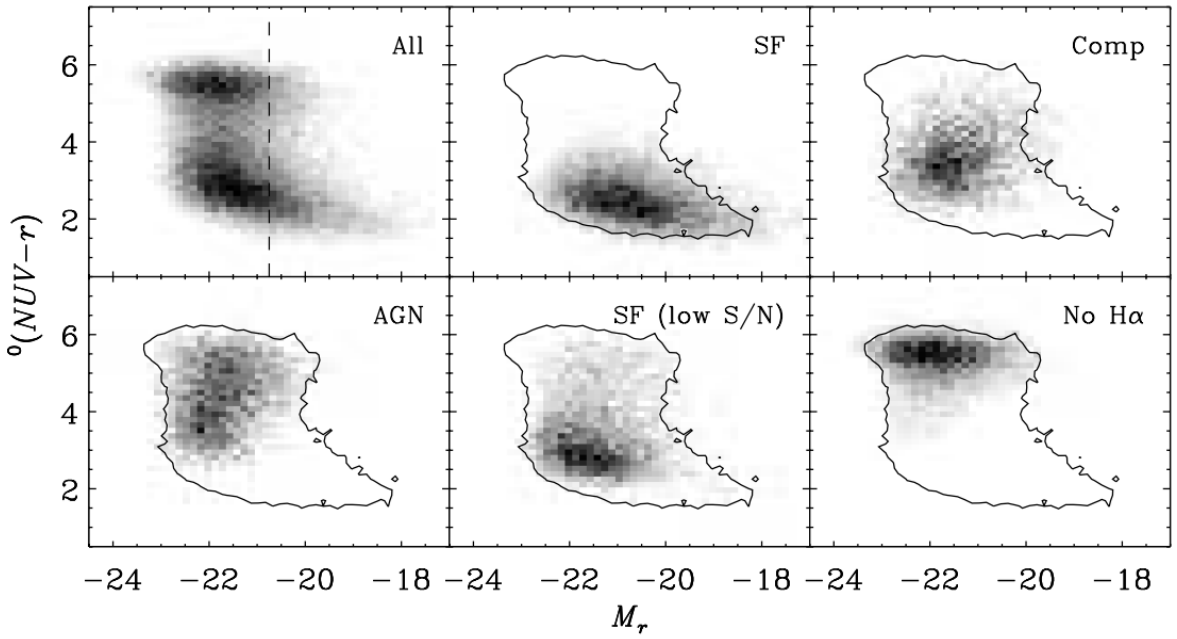
$$f_{CSP} = \int_{t'=0}^{t'=t} \mathrm{dt'} \int_{Z=0}^{Z_{max}} \mathrm{dZ}\ \mathrm{SFR}(t-t')\, P(Z, t-t')\, f_{SSP}(t', Z)\, \mathrm{e}^{-\tau_d(t')} + A\, f_d(t', Z)$$

Stellar Population Synthesis – The completed Model



- The Composite Stellar Population represents one completed model galaxy
- This model yields a theoretical spectral energy density for a given set of parameters (Mass-to-light ratio, (specific) star formation rate and history, metallicity, dust attenuation...)

(Salim, 2007) – the Data Sample



- Sample contains $\approx$ 50000 galaxies, $z \approx 1$, from *GALEX* and SDSS
- CMD shows a bimodal population

(Salim, 2007) – Aims and Method

- The strength of $\mathrm{H}\alpha$-emission is has previously been used with SPS as an indicator of SFR
- The authors want to show that SPS using various wavelengths, including UV, yields SFR results consistent with the $\mathrm{H}\alpha$-based methods

- The sample is categorised into galaxy classes by means of spectral line data and visualisation in a *BPT diagram*
- The SPS fitting is done with code from (Bruzual & Charlot, 2003)

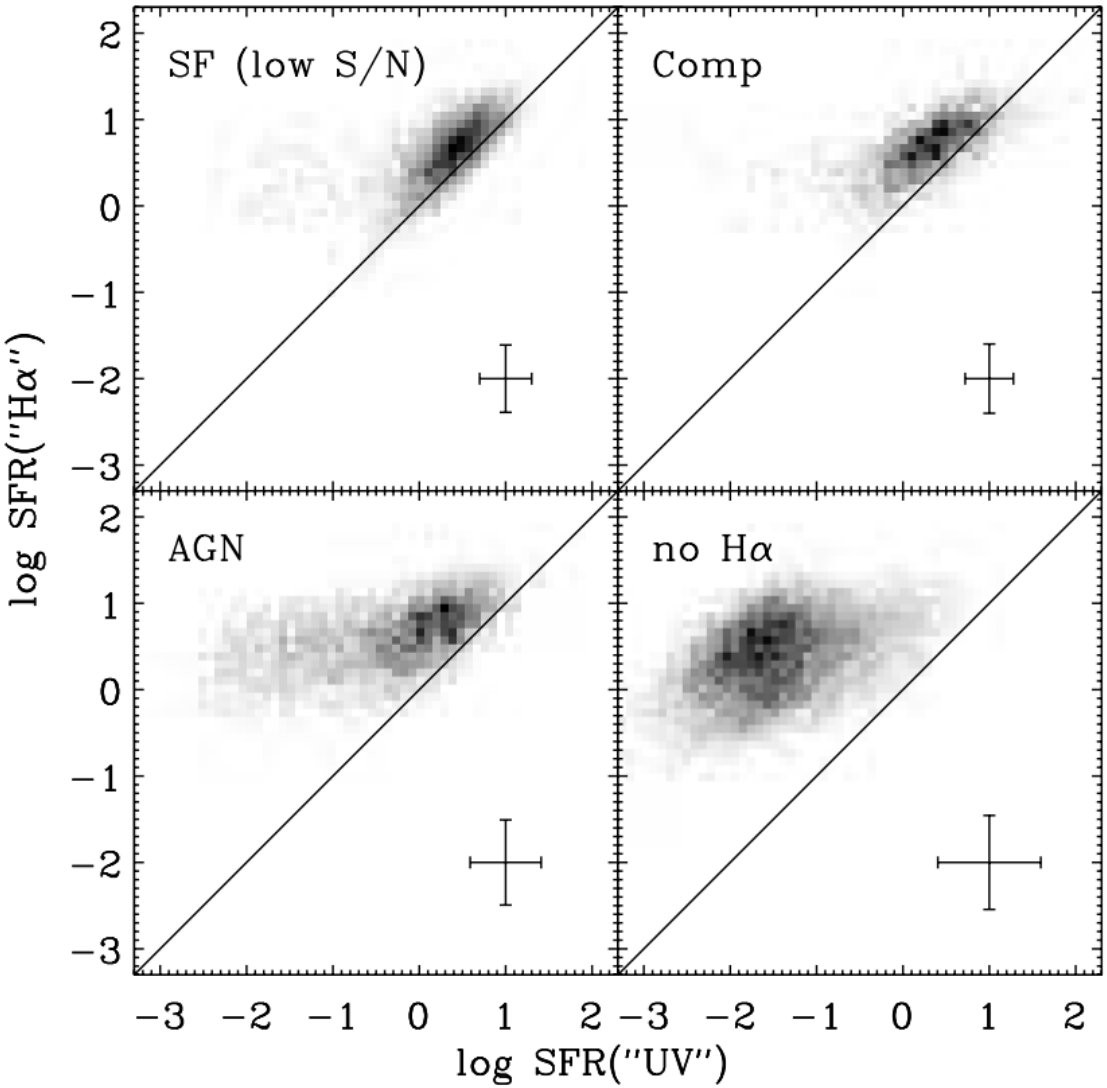
(Salim, 2007) – A bit of Detail about the Method

- 10^5 possible models are created, depending on redshift at least 78000 are used
- SED of a galaxy from the sample is fit to every one of the models
- χ^2 of a model is computed for the best *scale factor a* (the only parameter fit!) for each photometric passband

$$\chi_i^2 = \sum_{\mathrm{X=bands}} \left[\frac{F_{\mathrm{obs},X} - a_i \, F_{\mathrm{mod},X}}{\sigma(F_{\mathrm{obs},X})} \right]$$

- Those values are used to build a PDF for galaxy properties, defining a weight $w_i = \exp(-\chi_i^2/2)$ for a model's associated properties
- The final "measurement" of a property is its average from the PDF
- "Formal errors" are 1/4 of the PDF's 2.5-97.5 percentile range

(Salim, 2007) – Comparing Hα and UV methods



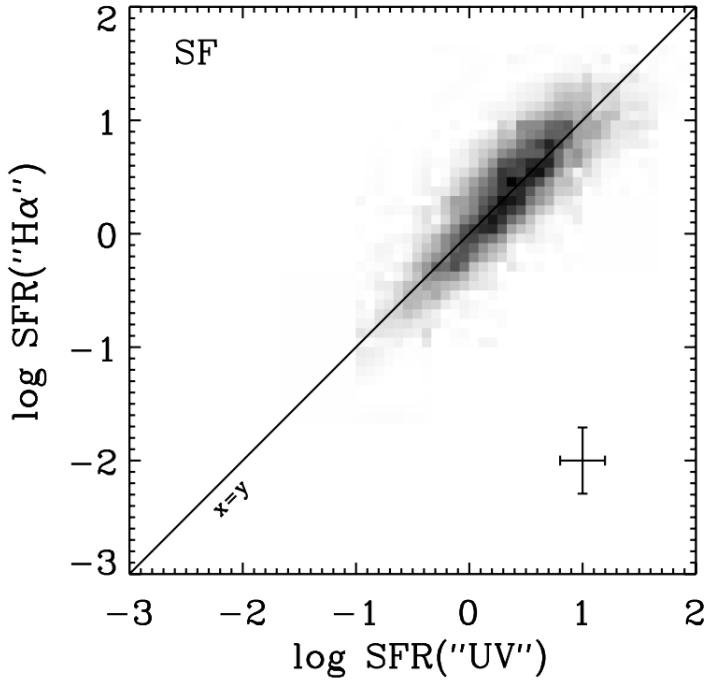
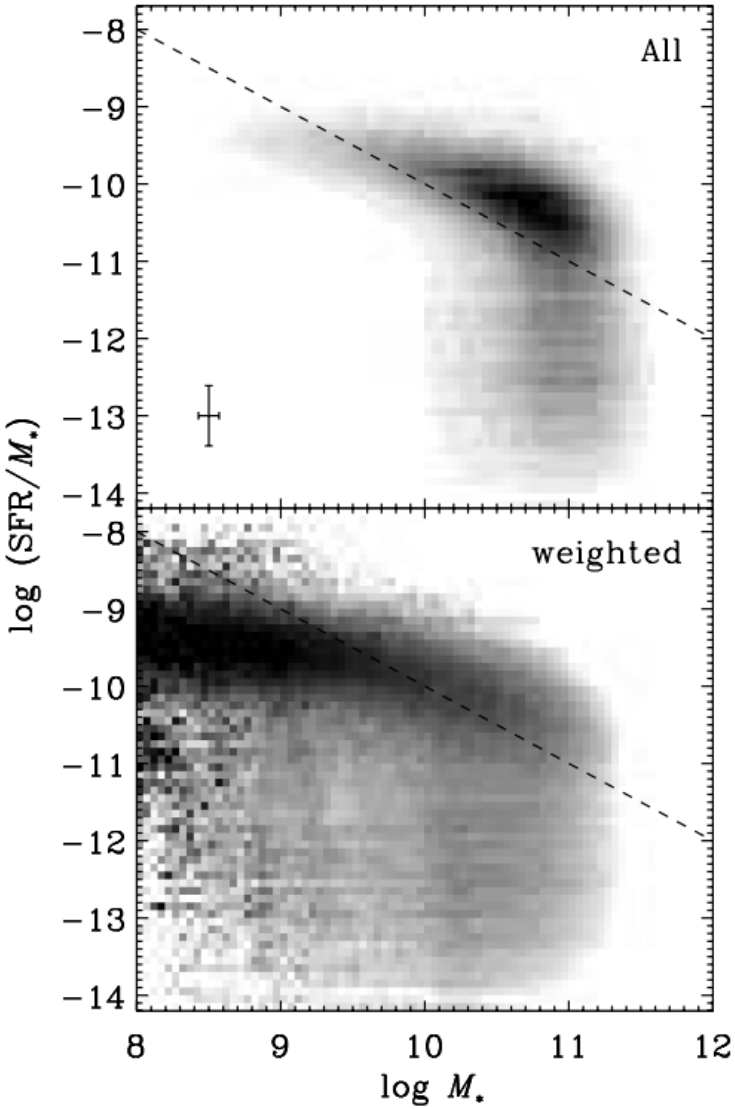


FIG. 6.—Comparison of B04 ("Hα") to our "UV" SFRs (both independently dust-corrected) for galaxies classified as star forming. The two compare very well on one-to-one basis. Also, the scatter is compatible with each measurement's errors.

(Salim, 2007) – Results for specific SFR



(Salim, 2007) – specific SFR results by Galaxy Class

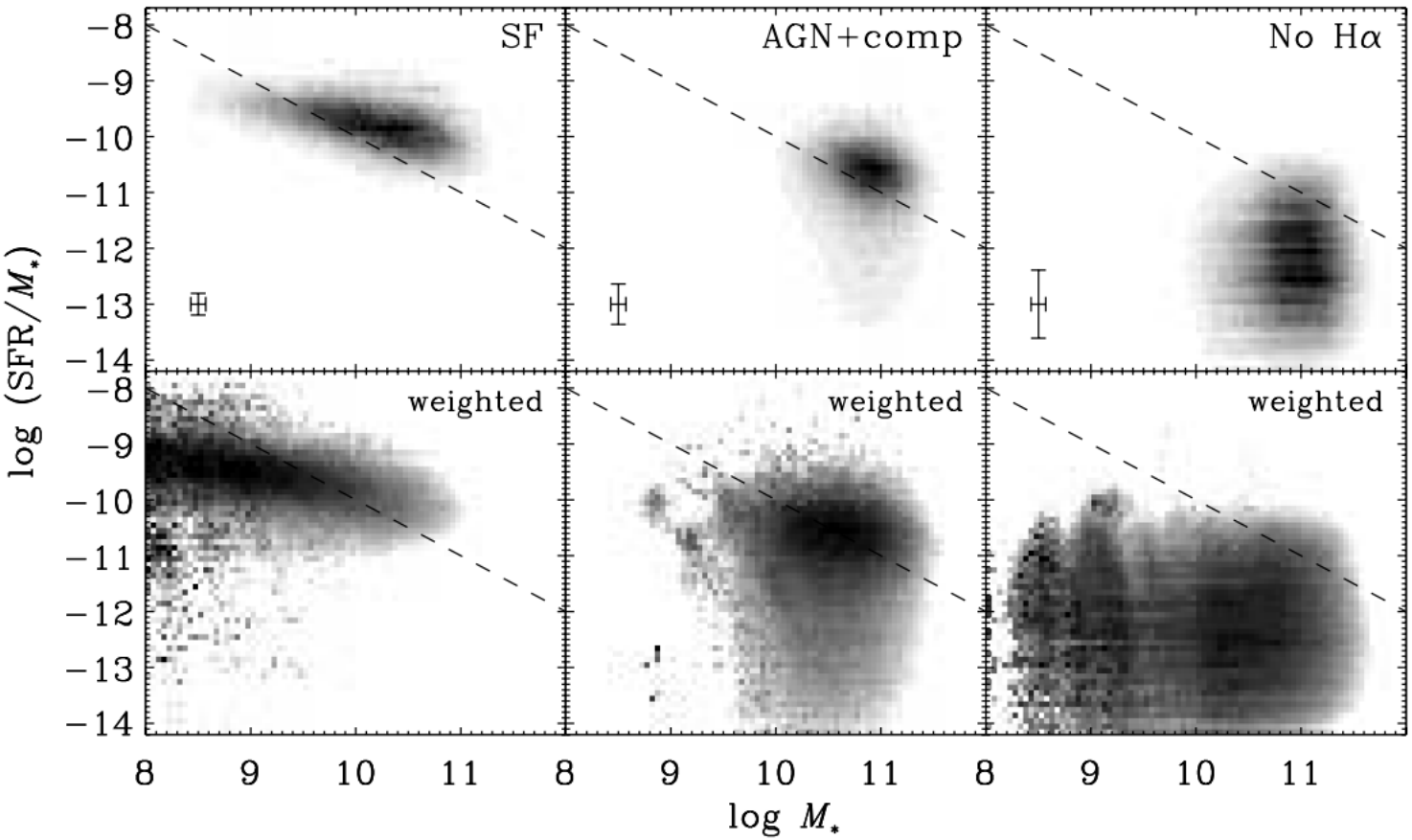


FIG. 17.—Dependence of the specific SFR on the stellar mass for different classes of galaxies. Star-forming (*left panels*); galaxies with AGNs (*middle panels*); and galaxies without Hα detection (*right panels*) all occupy distinct regions of the parameter space, indicating different SF histories. SF galaxies form a narrow sequence. AGNs have intermediate specific SFRs, and are predominantly high mass. Galaxies without Hα, mostly red-sequence galaxies, have low specific SFRs. The dashed lines shows the reference SFR of 1 $M_\odot \mathrm{yr}^{-1}$. The bottom panel shows values weighted by $V_{\max}$. Uneven behavior at low masses is because of small number of galaxies (or no galaxies) in those mass bins.

(Salim, 2007) – Galaxies with and without AGN / SF

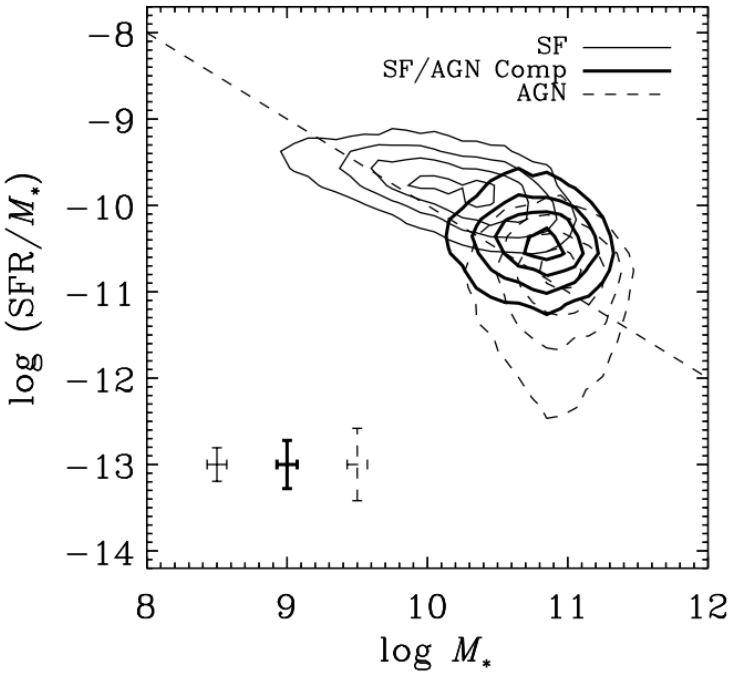
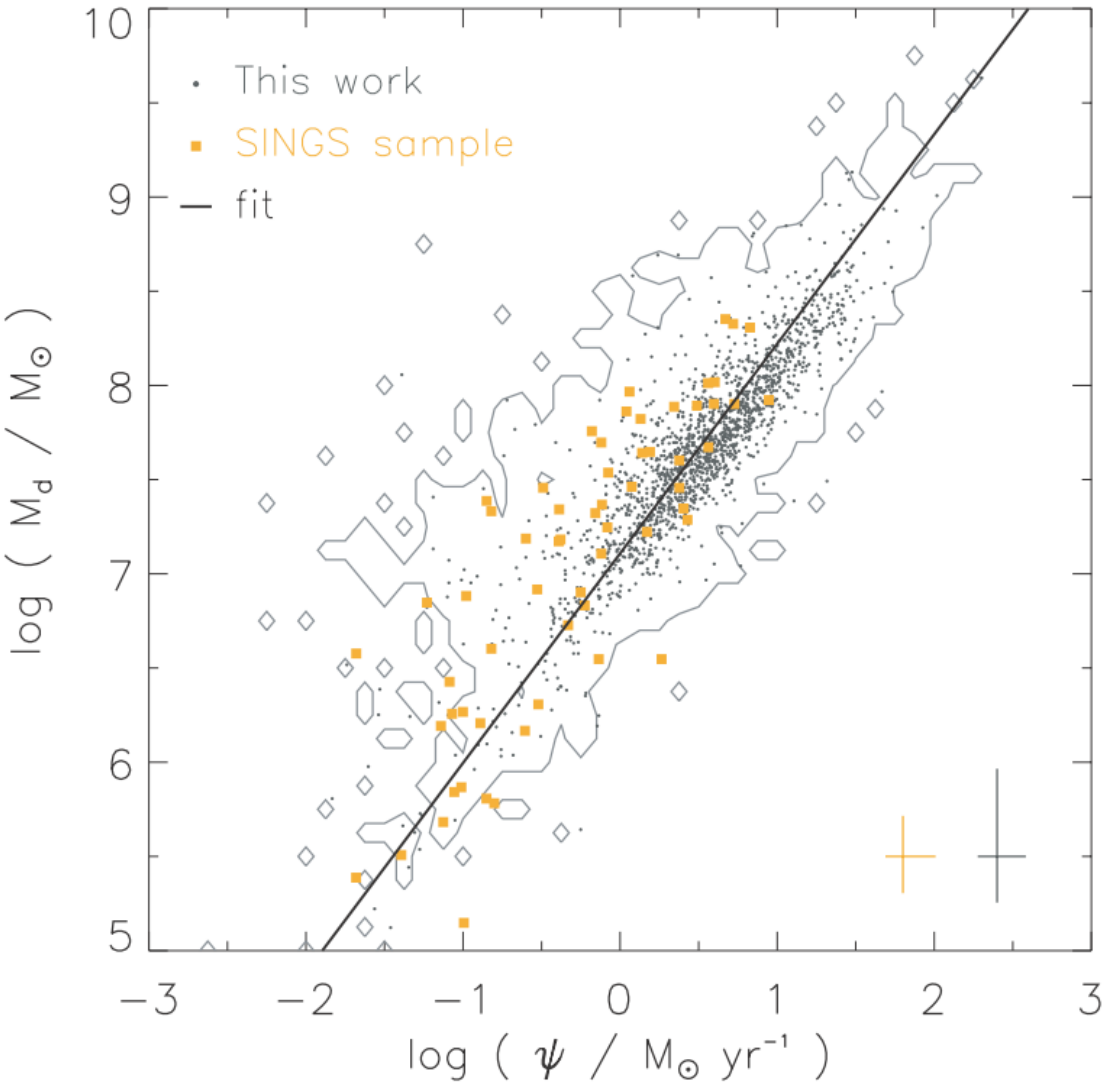


FIG. 18.—Specific SFR and mass of star forming, and of galaxies hosting AGNs. We plot density contours for normal SF galaxies having no AGNs (*thin solid contours*), of SF/AGN composites (*bold solid contours*), and of "pure" AGNs (*dashed contours*). The SF/AGN composite class (bottom part of the AGN branch in BPT diagram) bridges normal SF galaxies and the AGNs lying on the top part of the AGN branch. Contours of unweighted distribution encompass 10%, 30%, 50%, and 70% of objects, i.e., their composite PDF densities.

- Separation of galaxies containing AGN into ones with SF and ones without
- Contour plots of these subpopulations encourage bolder guesses:
  - Star forming galaxies with AGN are positioned as a "bridge"
  - Comparison with other findings: relationship between strong AGN and fading star formation?

Correlation of SFR and Dust Mass (da Cunha, 2010)



- Contour: distribution for the full sample
- Grey points: 1658 highest SNR galaxies
- Properties estimated by PDF **median**, formal (percentile-based) errors

$$M_d = (1.28 \pm 0.02) \times 10^7 \cdot \left(\frac{\psi}{M_\odot\, yr^{-1}} \right)^{1.11 \pm 0.01} M_\odot$$

Conclusions

- SPS constructs the spectral energy distribution of model galaxies from theory
- To that end, the contributions of "generations" of stars are added up

- To fit data, observed SED is compared with a huge library of SPS constructs (10^5), this yields estimates for galaxy properties

- Obvious: model dependency, a **lot** of assumptions
- Nevertheless: the technique produces estimates of SFR that are consistent between different fitting schemes and allow guesses at the relation of SFR and other galaxy properties