On the star formation histories of bright IR galaxies at high z

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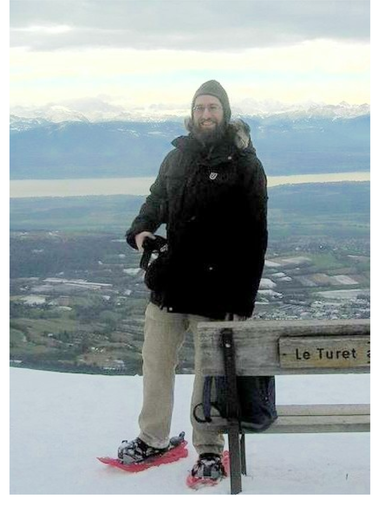

Introduction

We use a sample of IR-selected star-forming galaxies from GOODS-*Herschel* [3] to explore their star formation histories (SFHs), how the knowledge of their IR emission can be used as a constrain and how it affects the physical parameters of their stellar populations. In particular, we focus on the epoch around the peak of the cosmic SFH, in the redshift interval $z \sim 1-3$. As it is known, SED fitting can suffer from certain degeneracies, notably the age/extinction degeneracy in red/dusty galaxies. Constraining the extinction in the SED fits via the IR/UV ratio can break it, albeit with some caveats. We also produce nebular line emission predictions for our models, that can allow to further constrain them with the use of spectroscopic observations.

Methods

We use an updated version of the *Hyperz* photometric code [4], that includes nebular line emission to estimate the physical parameters of our sample and explore the following SFHs:

- exponentially declining, $\tau = [0.03{,}3]$ Gyr
- exponentially rising, $\tau = [0.03{,}3]$ Gyr
- delayed $\propto t/\tau^2 e^{-t/\tau}$, $\tau = [0.03{,}5]$ Gyr
- constant (CSFR)

Assuming energy conservation (star light absorbed by dust and re-emitted in the IR), our various models predict the IR luminosity $L_{\rm IR}$ and are confronted to the observed $L_{\rm IR}$.

Using the calibration described in [6] we estimate the extinction A_V needed for our models to match the observed IR/UV ratio in order to make fits that are consistent with the observations.

We use the redshift-parametrized main sequence (MS) calibration of [8] to derive distances from it, and explore who the different SFHs fare depending on whether the galaxies are on the MS or starbursts, and on redshift.

Conclusions

Beside the possible AGN contamination in $L_{\rm IR}$, there seem to be two main caveats that need caution in our approach:

- the detected rest-frame UV light may come from less obscured stars, not representative of the bulk of the dust emission, which can lead to an underestimate of the observed $L_{\rm IR}$. We observe this on the GOODS sample (Fig. 1), in particular for the brightest sources, for which a 2-component stellar population fit may be needed;
- the use of the observed $L_{\rm IR}$ can lead to the overestimation of the SFR, by e.g., making post-starbursts being interpreted as starburst (a detailed study can be found in [5]). We see this effect in our stellar population fits in most of the GOODS sample, where the $L_{\rm IR}/L_{\rm UV}$-imposed extinction models become more obscured (which is related to the previous point), and in order to compensate for the fit, have younger ages and stronger SFRs.

Some conclusions from our study:

1. Our single population, single extinction, varying SFH, including emission line treatment models fit well the bulk of the sample and allow to retrieve observables for sources up to $\log(L_{\rm IR}) \approx 12.5$. The most prefered model before fixing A_V is the declining SFH. Once we fix it via the IRX ratio, we note a shift towards more rising SFHs, without strong tendencies.
2. As also noted in [9], the higher we go in z, the UV-slopes get bluer for a given IRX.
3. The use of the observed $L_{\rm IR}/L_{\rm UV}$ ratio to constrain A_V proves very useful in breaking the age-extinction degeneracy that many of our red-sloped galaxies suffer from, and produces population models that are coherent with the observationally derived SFR estimates. This alone is not always sufficient to discriminate between SFHs, but in such cases the comparison of the emission line predictions to observed spectra can produce stronger diagnostics.
4. In the case of the Cosmic Eye, we can safely exclude rising or CSFR SFHs, based on the comparison of the predicted emission with the observed spectrum (Fig. 7, details in [1]). This approach should prove very useful in distinguishing similar sources in a post-starburst phase.

The sample being strongly luminosity-limited, we look forward in extending this work at lower luminosities, exploiting the *Herschel Lensing Survey*[2], presented in [1] on a small sample.

IR Luminosity as a Constrain on SED fitting

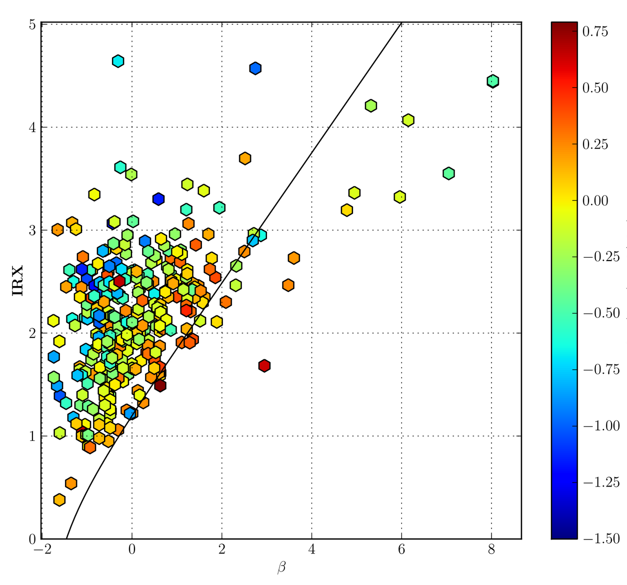

Figure 1: The IRX-β diagram for our sample. IRX is $\log(L_{\rm IR}/L_{\rm UV})$ and β is the UV-continuum slope as estimated by the SED fit. Here we show the results from the constant SFR models with the extinction as a free parameter, plotted against the Meurer relation [7]. The colorbar shows the predicted over observed IR luminosity ratio. The figure shows is us that the galaxies which mostly underpredict $L_{\rm IR}$ also have UV slopes that are "too blue" for their observed IRX ratio. This is suggestive of the UV spectrum being dominated by stars that are not as dust enshrouded as those who are responsible for the bulk of the IR emission.

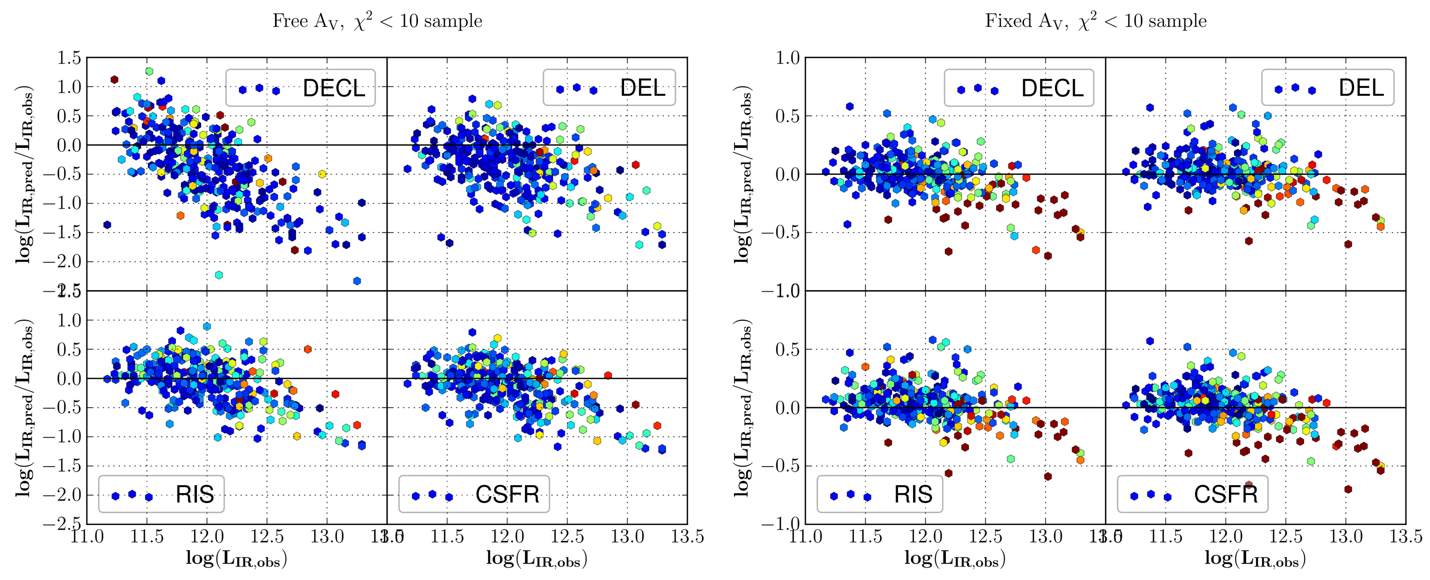

Figure 2: Predicted over observed $L_{\rm IR}$'s versus observed $L_{\rm IR}$ for the various SFHs for the unconstrained extinction fits (**left**) and the ones where A_V is fixed by the IRX ratio (**right**). Color indicates the χ^2_ν (dark blue is ≤ 0.5, dark red is ≥ 10). We can see that the brighter a galaxy is in the IR, the more the unconstrained fit tends to underestimate its extinction, especially when the SFR is allowed to decline (top panels). when the extinction is fixed, we can see the scatter is well reduced, and only some sources lying above $\log(L_{\rm IR}) \approx 12.5$ still can't match the observed luminosity, and have also low quality fits.

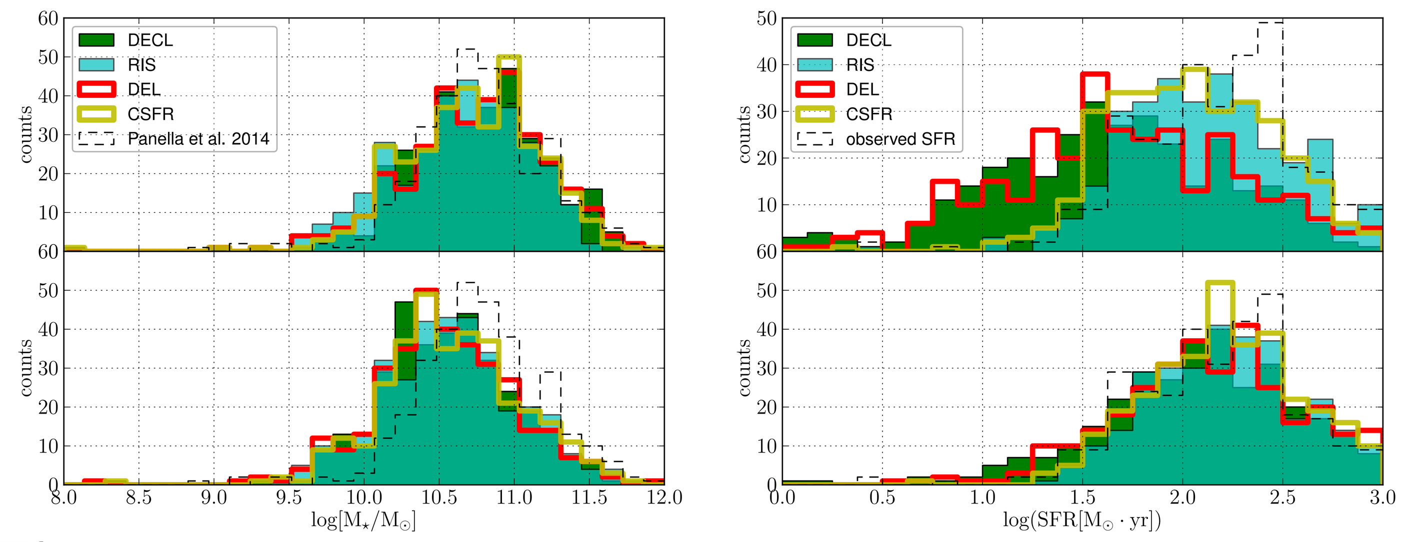

Figure 3: **Left:** Stellar mass distribution histogram, before (bottom) and after (top) fixing the extinction via $L_{\rm IR}/L_{\rm UV}$. We see that the stellar masses do not vary depending on SFH. When using the IRX ratio to impose the extinction in our models, the masses we yield are slightly smaller (~ 0.2 dex) **Right:** Same for the SED-derived SFRs. We see that the unconstrained fits tend to yield SFRs that are lower than the ones usually derived by the Kennicutt laws (dashed). The act of fixing the extinction allows to retrieve the observed SFRs, as by construction it produces the stellar population that matches the observation. This does not mean they are right, as discussed in the caveats.

On the SFHs and Line Emission Predictions

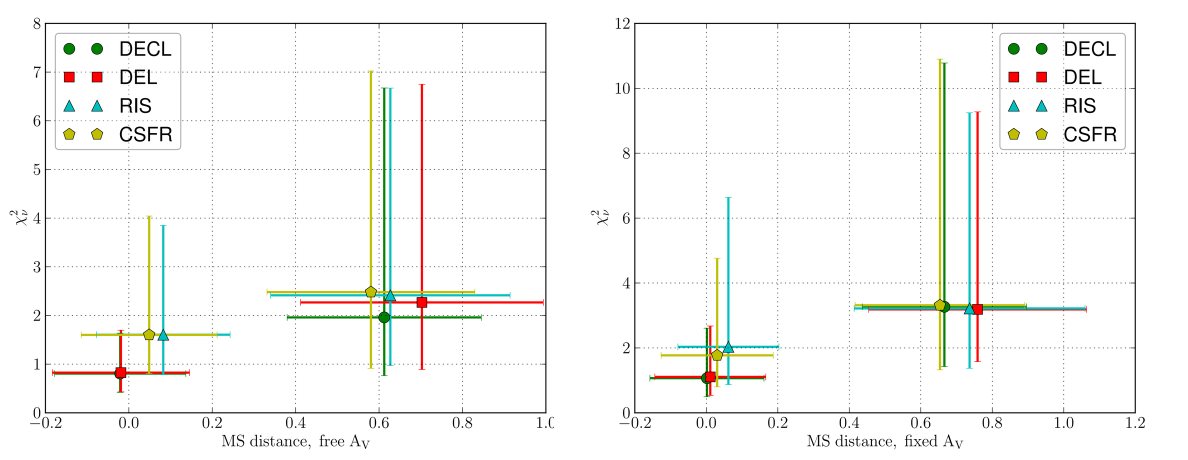

Figure 4: Plots showing the median χ^2_ν's for the "tight" MS sequence galaxies (within 0.2 dex of it), and the ones in starburst mode, for the different SFHs (**left** is with A_V as a free parameter, and **right** it's fixed). We see that the knowledge of $L_{\rm IR}$ does not have any particular effect here, and regardless of it, the declining and delayed models fit the photometry better, in the MS regime, and that there is no SFH preference in the SB mode. We also see that the sources in SB mode fit in general less well with our single population models.

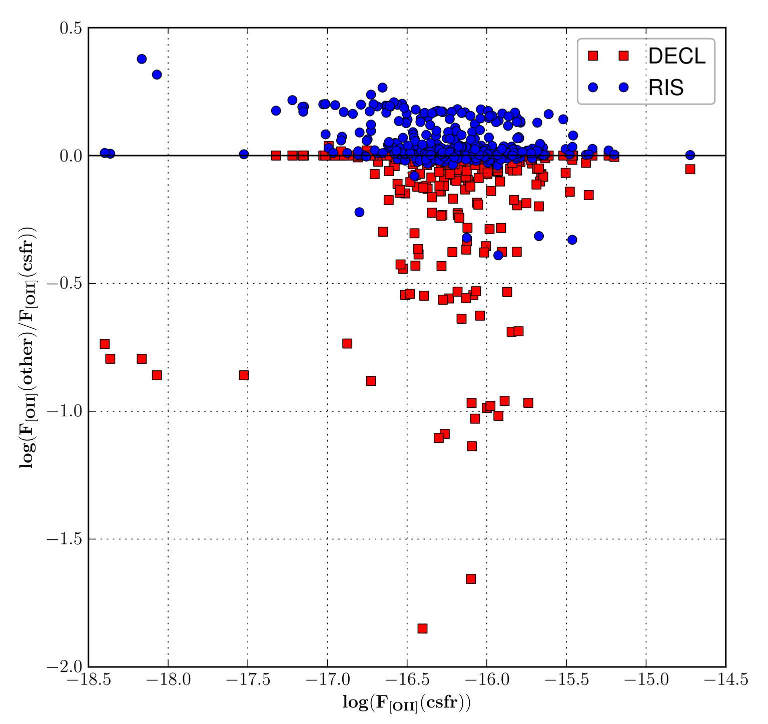

Figure 6: Plot comparing line emission flux predictions for two of our energy conserving models (declining and rising, normalized by the constant SFR model, and plotted against it). We can see that although by construction each source is fitted with the same IRX-inferred extinction, the emission lines - being that they are sensitive to smaller timescale variations of the SFR than the IR luminosity - can differ of ~ 0.4 dex or more for an important fraction of the sample, and can serve to discriminate between SFHs as we have shown for the Cosmic eye and cB58.

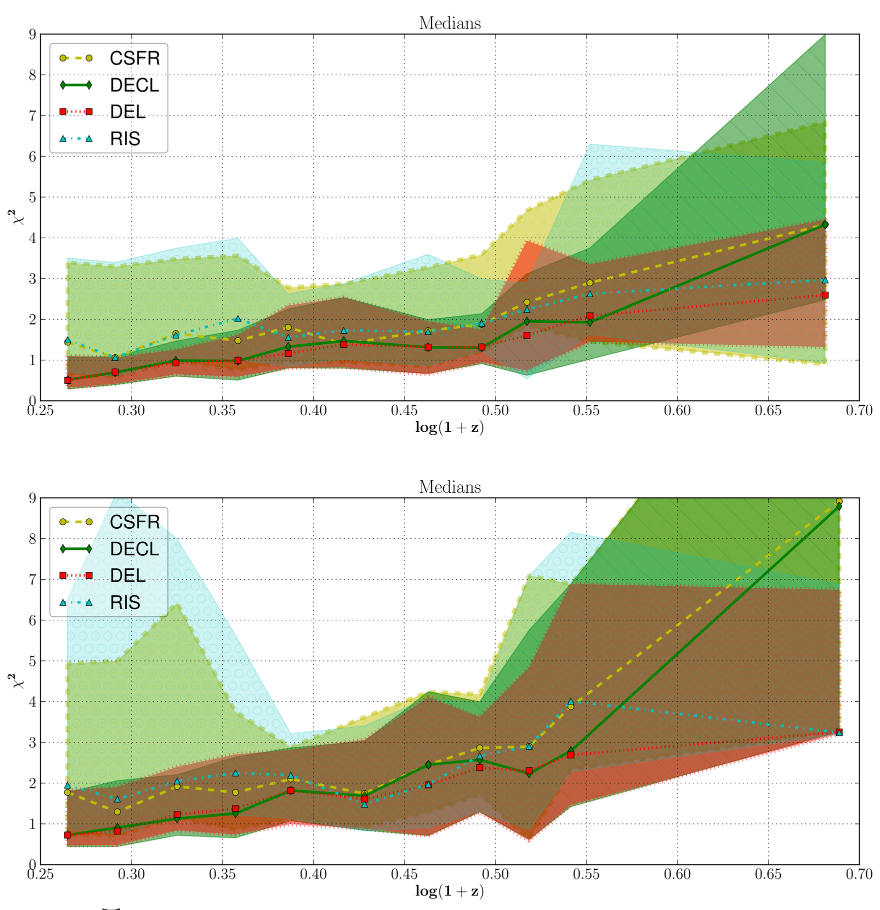

Figure 5: Similar SFH comparison, only here the sources are binned per redshift, for a subsample of sources close to the MS. Here, the evolution is very interesting, although the sample is small on the high-z end, and $L_{\rm IR}$-limited. There is a change in preference in the SFHs between before and after z$\sim$ 1.5 ($\log(1+z) \sim$ 0.4), and the contrast becomes stronger with constraining the extinction (bottom). At high z, SFHs that allow for the SFR to rise are best fitting the sources, whereas at lower z it's the declining SFHs that work best, reflecting the cosmic SFH.

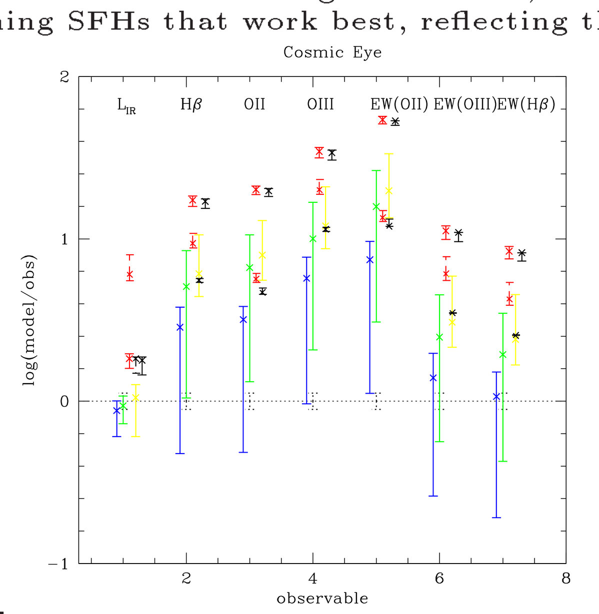

Figure 7: Figure from **Sklias et al. 2014, A&A, vol. 561, 149**. Predicted $L_{\rm IR}$ and nebular lines are confronted to the observations for all our models, and only the declining SFHs with increased nebular extinction can account well for all of them (in blue).

Acknowledgements

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