Revealing the Light from Old Stars

Separating stars and dust in S^4G IRAC 3.6 and 4.5 µm images

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Abstract: The Spitzer Survey of Stellar Structure in Galaxies (S^4G) imaged 2352 nearby galaxies (D<40Mpc) in two IRAC bands: 3.6 and 4.5µm, an optimal window to trace stellar mass, as the emission is mainly coming from K and M type giants. However, as shown by Meidt *et al.* (2012), contamination from non-stellar sources (PAH, hot dust) can locally be significant in these bands, severely biasing the derived mass distributions in some regions. Here, we present an automatic application to the full S^4G sample of the method introduced in Meidt *et al.* (2012) to correct for that non-stellar emission, which is based on an Independent Component Analysis technique (ICA). Defining the best strategy to apply ICA to the whole S^4G sample has allowed us to obtain contaminant-free maps of the old stellar flux for ~1600 galaxies, which will become public soon. This is an extremely powerful tool for studies of stellar structure and secular evolution, as those dust-free images can be readily converted into stellar mass maps.

1.- Context

The *Spitzer* Survey of Stellar Structure in Galaxies (S^4G, Sheth *et al.* 2010) has imaged 2352 galaxies with the Infrared Array Camera (IRAC) in the 3.6 and 4.5µm bands still available within the post-cryogenic mission of the *Spitzer* Space Telescope. The selection of galaxies corresponds to a volume cut (d < 40Mpc), magnitude ($m_{B,corr}$ < 15.5mag) and size limit (D_{25} > 1'). Isophotal information and masks are, among other products, available as part of the S^4G pipeline.

At these near-infrared wavelengths, the emission is dominated by light from old stars, making it a good tracer of stellar mass. But additional non-stellar sources (3.3µm PAH feature, hot dust and PAH continuum) also appear and contribute a significant fraction of the light (as much as 30% of total), obscuring our view of the old stars. **To isolate the non-stellar emission from the old stellar light we have developed an automatic strategy to solve this problem, while retaining full 2D/structural information**. The present project is part of the European collaboration DAGAL (Detailed Anatomy of GALaxies), a joint effort of 6 research institutions with European funding (Marie Curie programme).

2.- ICA method

The technique is presented in Meidt et al. (2012), and the pipeline details are Our method is based on **Independent Component Analysis (ICA)** and relies exclusively on photometry from the 3.6 and 4.5µm bands available from S^4G, maximizing the statistical independence of the sources. With ICA we can separate the flux in each of *M* pixels observed in *N*=2 bands in to at most 2 independent sources, which allows us to **identify the dominant emission from old stars and separate it from secondary emission from dust** (Fig. 1).

We exclude:

- Galaxies with low average signal-to-noise (S/N < 10)
- Galaxies with [3.6]-[4.5]<0, consistent with old stellar colours (mainly ETGs)

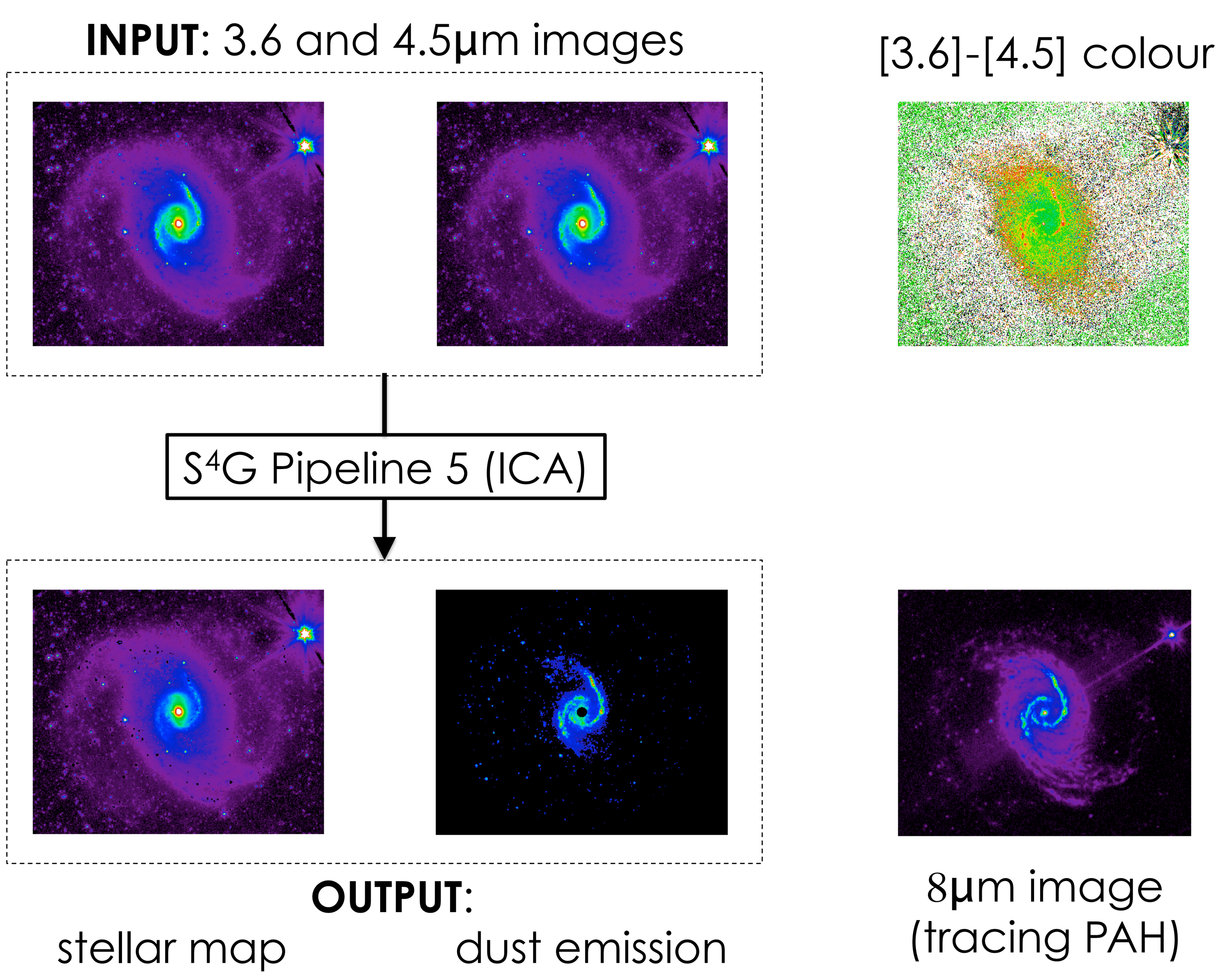

Fig.1. Schematic chart showing the input and output of our ICA-based pipeline, exemplified with NGC1566. For comparison, in the top-right, the original [3.6]-[4.5] colour map is shown: in these bands, the (old) stars that dominate the flux appear as [3.6]-[4.5]<0 (i.e. greenish colours), whereas dust contribution is always [3.6]-[4.5]>0 (yellow to red). In the bottom-right, the 8µm image is displayed for the same galaxy, showing good agreement between our 'dust map' and the PAH traced by 8µm, which is closely related to dust.

3.- Results

We have applied our pipeline to the entire S^4G sample, which covers the Hubble sequence. This has resulted in old stellar flux maps for more than 1600 galaxies, which can be easily converted to **stellar mass maps**, providing an important legacy dataset, which will be **publicly released**. In addition, our results allow us to perform a statistical analysis of the dust contribution to 3.6µm flux, exploring trends with Hubble types (Fig. 2 *left panel*) and specific star formation rates (SSFR, Fig. 2 *right panel*).

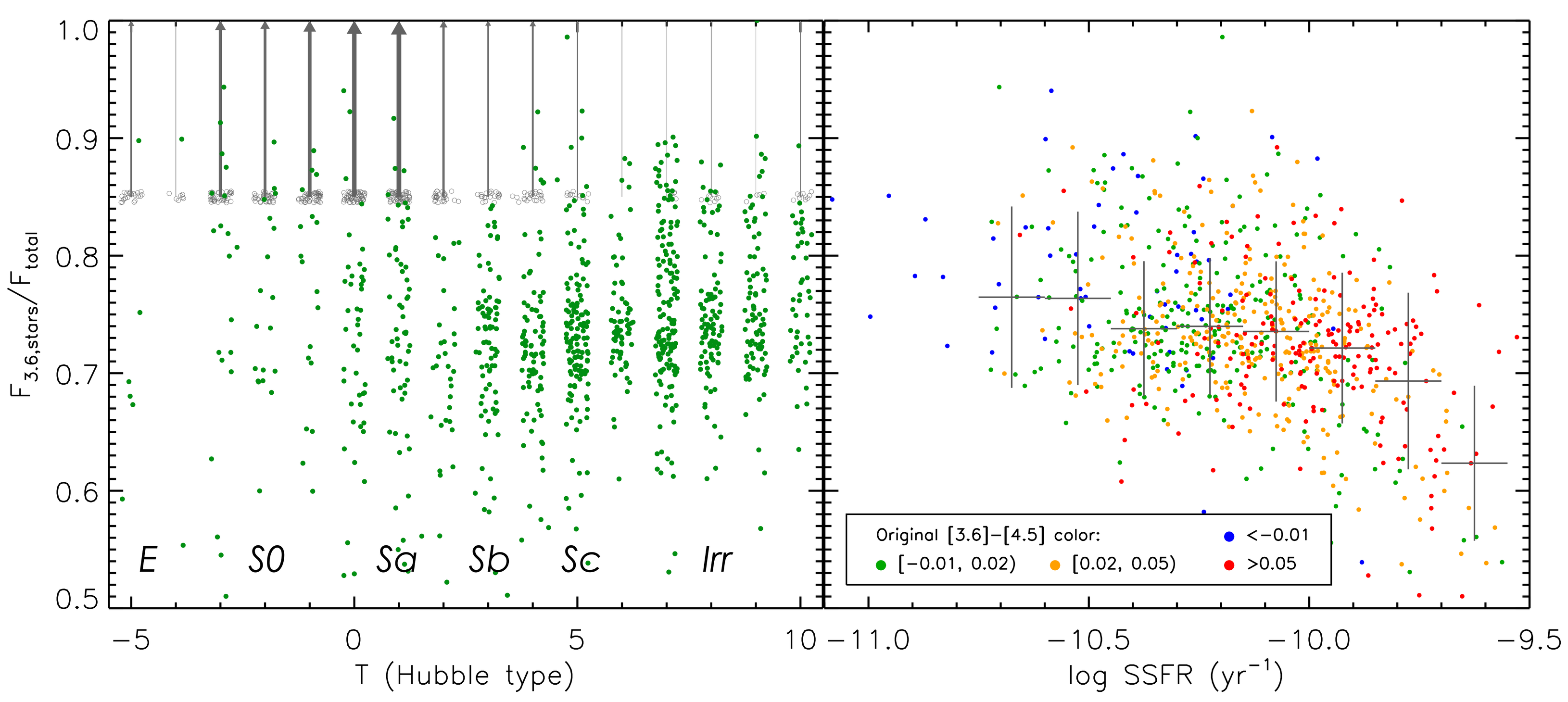

Fig.2 *Left*: stellar contribution to 3.6µm from our ICA separations. Each green point represents an S^4G galaxy to which ICA was applied; grey circles are galaxies with [3.6]-[4.5]<0 that were excluded from our pipeline. We estimate a conservative maximum dust contribution of 15% to total flux (represented as lower limits). *Right*: stellar flux fraction as a function of specific star formation rates (SSFR=SFR/Mass), calculated from IRSA 60 and 100µm fluxes; colour-coding reflects original IRAC colour of the galaxy, and superposed are running medians, which support the declining trend.

- **The amount of dust emission identified by ICA varies with Hubble type** (*left*), and can be up to 40%, with typical values ranging 20-30% for spiral galaxies.

This is probably the result of a dependence on SFR and stellar mass:

- Galaxies with **high specific star formation rates** (SSFR=SFR/Mass) are associated with the highest dust contributions (*right panel*).

- The global [3.6]-[4.5] colour is less predictive of the fractional contribution from dust (*right panel*); thus, **a method like ICA is required to identify it and produce reliable (old) stellar flux maps**.

Finally, Fig. 3 shows the effective M/L that stems from our ICA corrections, assuming a constant mass-to-light ratio once the dust has been removed. Meidt et al. (2014) showed that M/L=0.6 is a very good approximation for old stellar populations, with masses good up to ~0.1dex. The declining trend with original colour (similar to alternatives available from the literature) provides a first-order calibration which can be used in the absence of more information.

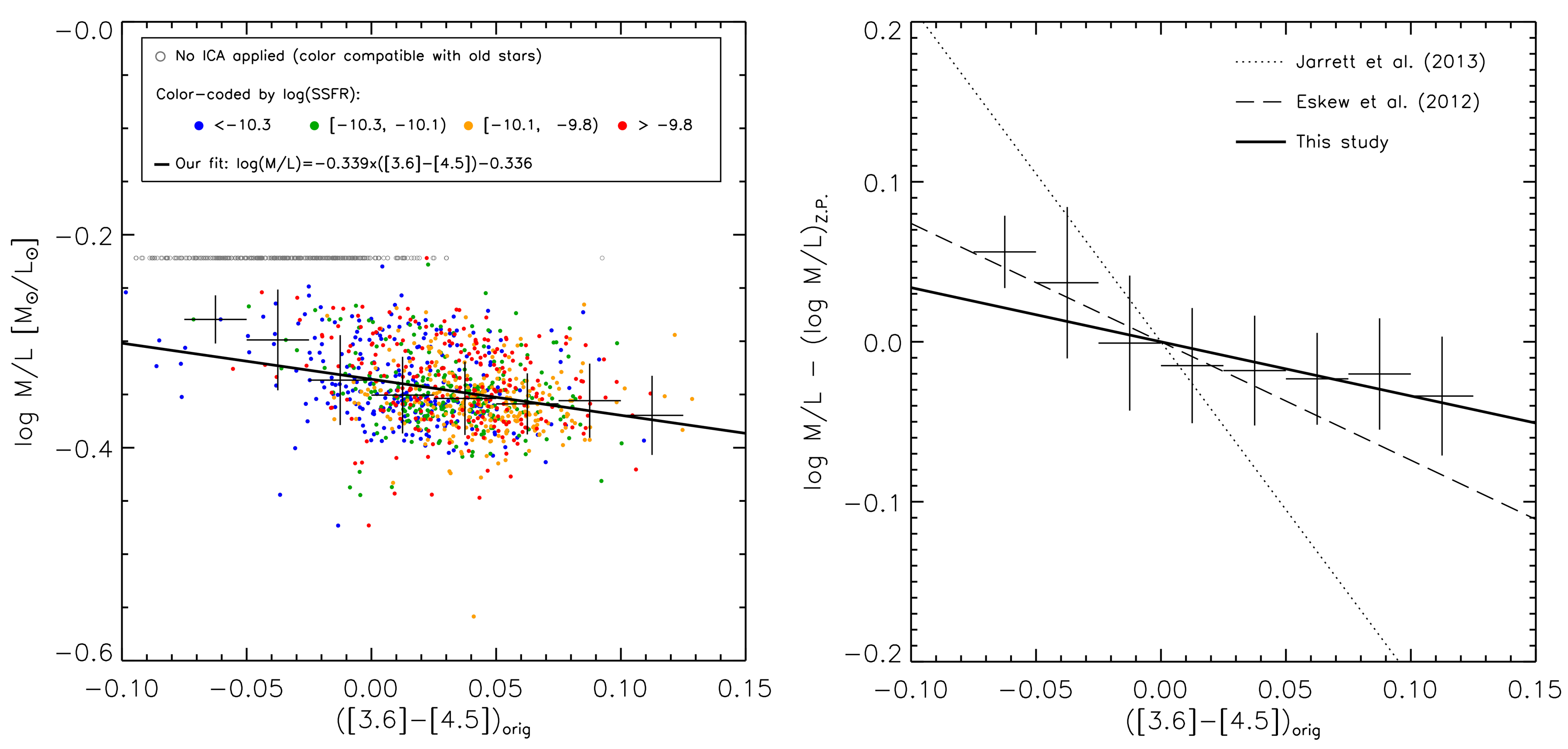

Fig.3. Our empirical mass-to-light ratio (M/L) reflects the variation due to the correction for dust emission, assuming a constant $M/L_{3.6}$=0.6 for old stellar populations (Meidt et al. 2014). I.e., this is the effective M/L that an observer should apply to the S^4G galaxies to obtain our final masses without any information about dust. Scatter is significant, but a declining trend is obvious: our fit shares the negative slope found by other authors, and compares reasonably well with the trend that Eskew+12 obtained based on the LMC (*right*).

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[2] We acknowledge financial support to the DAGAL network from the People Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme FP7/2007-2013/ under REA grant agreement number PITN-GA-2011-289313