Stellar Populations - Planning for the Next Decade
Proceedings IAU Symposium No. 262, 2009
Gustavo Bruzual & Stéphane Charlot, eds.

doi:10.1017/S1743921310002589

Resolved maps of stellar mass and SED of galaxies from optical/NIR imaging and SPS models

Stefano Zibetti[1], Stéphane Charlot[2] & Hans-Walter Rix[1]

[1]Max-Planck-Institut für Astronomie,
Königstuhl 17, 69117 Heidelberg, Germany
email: `zibetti@mpia.de`, `rix@mpia.de`

[2]Institut d'Astrophysique de Paris, CNRS, Université Pierre & Marie Curie,
98 bis Boulevard Arago, 75014 Paris, France
email: `charlot@iap.fr`

Abstract. We report on the method developed by Zibetti, Charlot & Rix (2009) to construct resolved stellar mass maps of galaxies from optical and NIR imaging. Accurate pixel-by-pixel colour information (specifically $g - i$ and $i - H$) is converted into stellar mass-to-light ratios with typical accuracy of 30%, based on median likelihoods derived from a Monte Carlo library of 50,000 stellar population synthesis models that include dust and updated TP-AGB phase prescriptions. Hence, surface mass densities are computed. In a pilot study, we analyze 9 galaxies spanning a broad range of morphologies. Among the main results, we find that: i) galaxies appear much smoother in stellar mass maps than at any optical or NIR wavelength; ii) total stellar mass estimates based on unresolved photometry are biased low with respect to the integral of resolved stellar mass maps, by up to 40%, due to dust obscured regions being under-represented in global colours; iii) within a galaxy, *on local scales* colours correlate with surface stellar mass density; iv) the slope and tightness of this correlation reflect/depend on the morphology of the galaxy.

Keywords. galaxies: general – galaxies: stellar content – galaxies: structure – galaxies: fundamental parameters – galaxies: photometry – techniques: photometric

---

1. Introduction

The key role of stellar mass to determine (or predict) the physical properties of present day galaxies has been established by a number of works since the last decade (e.g. Gavazzi *et al.* 1996; Scodeggio *et al.* 2002; Kauffmann *et al.* 2003). Indication has been provided that stellar mass density might be even more fundamental (Bell & de Jong 2000; Kauffmann *et al.* 2003). All these works, however, deal with *global* estimates of the stellar mass-to-light ratio, which is assumed to be uniform throughout a galaxy, contrary to what we should expect based on well known spatial variations of stellar population and dust properties. Hence, resolving the distribution of stellar mass is crucial to properly measure total stellar mass and mass density and to start investigating the structure and dynamics of galaxies in an unbiased way. Having access to the mass distribution also allows to address questions like: Is there any relation between *local* stellar mass density and the *local* SED and physical properties *within* a galaxy, similarly to the relations observed *globally*? If so, what does it tell us about the internal mechanisms of galaxy evolution?

With these goals and questions in mind, we have developed a new method to build stellar mass maps of galaxies (Zibetti, Charlot & Rix 2009, ZCR09 hereafter), which we review in this contribution (Sec. 2). We also present preliminary results on the colour-stellar mass density relation within galaxies for a small sample of different morphological types (Sec. 3).

2. From multi-band imaging to stellar mass

As described in ZCR09, our goal is to provide a computationally fast and observationally cheap method to obtain stellar mass maps. We express the surface stellar mass density at any given position (α, δ) of a galaxy as:

$$\Sigma_{M_*}(\alpha, \delta) = \Sigma_\lambda(\alpha, \delta)\Upsilon_\lambda(\alpha, \delta) \tag{2.1}$$

where $\Sigma_\lambda(\alpha, \delta)$ is the surface brightness in the chosen 'luminance' band of effective wavelength λ and $\Upsilon_\lambda(\alpha, \delta)$ is the corresponding effective M/L ratio. In turn, we want to express Υ_λ as a function of colour indexes. Despite the diversity of stellar population parameters and dust properties, if the luminance band and the colour indexes are appropriately chosen, the scatter of Υ_λ as a function of colour(s) can be reasonably small (e.g. Bell & de Jong 2001). We choose the H band (largely equivalent to J or K) as luminance band and we use $g-i$ and $i-H$ colour indexes to predict $\mathrm{M/L}_H$. This choice is supported by the fact that M/L variations in NIR are minimal with respect to shorter wavelengths, while these two colours are the best combination in terms of sensitivity and wavelength leverage. Based upon the 2007 version of the Bruzual & Charlot (2003) code, which implements updated prescriptions for the TP-AGB stellar evolutionary phase according to Marigo *et al.* (2008), we build a Monte Carlo library of 50,000 stellar population synthesis (SPS) models with a variety of star formation histories, both continuous and bursty, metallicities and dust attenuations á la Charlot & Fall (2000). In this way we mean to cover as uniformly as possible the parameter space occupied by individual regions in galaxies on scales of ≈ 100 pc, from old, metal-rich bulges/spheroids, to young spiral arms with different degrees of dust absorption. Then we bin the models in cells of 0.05×0.05 mag^2 in $g-i$ and $i-H$ and for each cell we consider the median $\mathrm{M/L}_H$. This look-up table is then used to assign the median-likelihood M/L to each pixel in a galaxy, depending on its colours. Our approach is therefore bayesian rather than frequentist and, as such, depends to some extent on the chosen prior distribution of models: a different choice of SFHs in particular can affect the M/L of the bluest stellar populations (see ZCR09 for a detailed discussion). We confirm (e.g. Maraston 2005) that the treatment of the TP-AGB phase in the SPS models has a great systematic impact on the resulting colours and M/L in NIR, but this is mainly limited to young/blue stellar populations. Apart from systematic effects, we find that the confidence half-range for the M/L is $\approx 30\%$ over most of the colour space, with the notable exception of the stellar populations with ages $\lesssim 1$ Gyr, where the stellar evolution is very rapid and results in larger ranges, up to a factor 2. The use of two colours is crucial to obtain such accurate estimates: by neglecting the dependence on $i-H$ one would easily over/under-estimate the M/L by a factor 2 to 3.†

To test our stellar mass mapping method we select a sample of 9 nearby galaxies, which are also part of the SINGS survey (Kennicutt *et al.* 2003) and for which optical SDSS imaging and medium-deep NIR imaging (either from GOLD Mine, Gavazzi *et al.* 2003, or UKIDSS, Lawrence *et al.* 2007) are available. The sample spans all range of morphologies, from ellipticals to late spirals. As fluxes and colours in individual pixels have to be accurate at few percent level in order for our method to work, it is necessary to pre-process the images to ensure that sufficiently high S/N can be reached also in the regions with surface brightness as low as 24-25 mag$_g$ arcsec^{-2}. This is done using

† In ZCR09 we show that using i-band and the $g-i$ colour as M/L predictor gives results that are in very good agreement with those based on $g-i-H$ in most cases, except in stellar populations dominated by a very young burst or with very large extinction.

https://doi.org/10.1017/S1743921310002589 Published online by Cambridge University Press

a newly developed adaptive smoothing code ADAPTSMOOTH (Zibetti in prep., ZCR09), which preserves the maximum spatial resolution compatible with the requested S/N.

Figure 1 shows the maps of effective M_*/L_{NIR} for the 9 galaxies of the sample. Earlier type galaxies have more uniform and higher M/L, on average. The young stellar populations that characterize spiral arms result in lower M/L ratios, which in turn decrease the spiral arm contrast. The resulting stellar mass maps reveal that the structure of spiral galaxies is significantly smoother than it appears at any optical or NIR wavelength. The

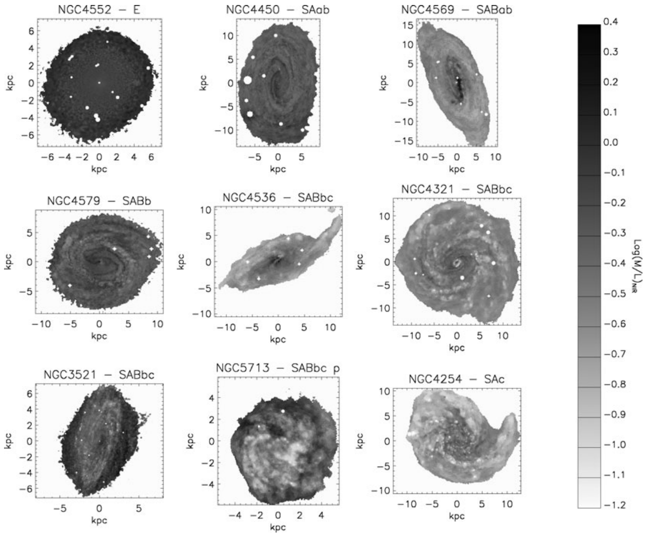

Figure 1. The maps of effective stellar mass to NIR light ratio of the 9 galaxies, sorted by morphological type, from Elliptical to Sc. Darker grey represents higher M/L, as given by the scale aside.

colour gradients, especially visible in spiral galaxies, result in M/L gradients, which in turn affect the structural parameters and make them differ from the ones derived from light distribution. In particular, the effective radius of spirals is smaller when the stellar mass distribution is used.

In Fig. 1 one can see lanes of much higher M/L (especially NGC4569 and NGC4536), which correspond to dust lanes. These regions can hide a significant amount of stellar mass, although the emerging light hardly affects the global luminosity and colours of the galaxy. As we show in ZCR09, this causes stellar masses obtained from global photometry to be biased low with respect to what one gets from integrating resolved stellar mass maps: the latter may miss up to 40% of the total stellar mass of a galaxy if dust obscured regions are very extended (as in NGC4569 and NGC4536).

3. Trends of colours with surface stellar mass density

Based on the analysis of the previous section, we study the correlation between colours (namely the optical $g - i$) and the surface stellar mass density *within* each galaxy. The distribution of pixels as a function of these two quantities are shown in Fig. 2, where the grey scale denotes the density of pixels. As a general result, we see that the colour positively correlates with surface stellar mass density: galaxies are redder in higher density regions. Although this holds for all galaxies, the slope and the dispersion of the correlation varies a lot along the morphological sequence. For a typical Elliptical galaxy the relation is very flat and very tight (consistent with a scatter due to photometric errors only).

https://doi.org/10.1017/S1743921310002589 Published online by Cambridge University Press

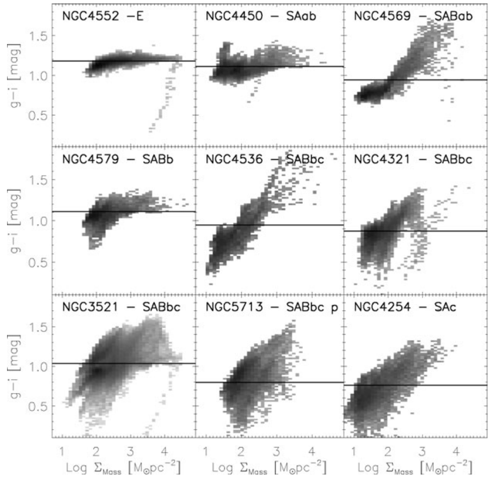

Figure 2. The distribution of pixels in the $g - i$ vs surface stellar mass density plane for the 9 galaxies: in grey scale the log of normalized number of pixels per cell. The horizontal line marks the global colour of the galaxy.

As we move to later types the colour-mass relation steepens, with low-density regions becoming increasingly bluer, while the highest density regions have roughly constant red colours. We can interpret this as a sign that star formation prefers low density and that the colour-morphology relation is mainly set by the relative weight of the younger stellar populations in the lower density regions with respect to the red high-density 'cores'. In addition, we see that the scatter around the mean relation increases going to later types, which have a more disomogeneous distribution of physical properties at given surface mass density. The presence of dust also increases the scatter, especially at high surface mass density. These preliminary results based on a small sample of only 9 galaxies will be put on a much more solid ground, both from the statistical and physical point of view, by the forthcoming analysis of a larger sample of galaxies for which multiwavelength observations, from UV to radio, are available.

References

Bell, E. F. & de Jong R. S. 2000, *MNRAS*, 312, 497
Bell, E. F. & de Jong R. S. 2001, *ApJ*, 550, 212
Bruzual, G. & Charlot, S. 2003, *MNRAS*, 344, 1000
Charlot, S. & Fall S. M. 2000, *ApJ*, 539, 718
Gavazzi, G., Boselli, A., Donati, A., Franzetti, P., & Scodeggio, M. 2003, *A&A*, 400, 451
Gavazzi, G., Pierini, D., & Boselli, A. 1996, *A&A*, 312, 397
Kauffmann, G. *et al.*, 2003, *MNRAS*, 341, 54
Kennicutt, Jr. R. C. *et al.* 2003, *PASP*, 115, 928
Lawrence, A. *et al.* 2007, *MNRAS*, 379, 1599
Maraston, C. 2005, *MNRAS*, 362, 799
Marigo, P., Girardi, L., Bressan, A., Groenewegen, M. A. T., Silva L., & Granato, G. L. 2008, *A&A*, 482, 883
Scodeggio, M., Gavazzi, G., Franzetti, P., Boselli, A., Zibetti, S., & Pierini, D. 2002, *A&A*, 384, 812
Zibetti, S., Charlot, S., & Rix, H.-W. 2009, *MNRAS* in press, ArXiv:0904.4252

https://doi.org/10.1017/S1743921310002589 Published online by Cambridge University Press