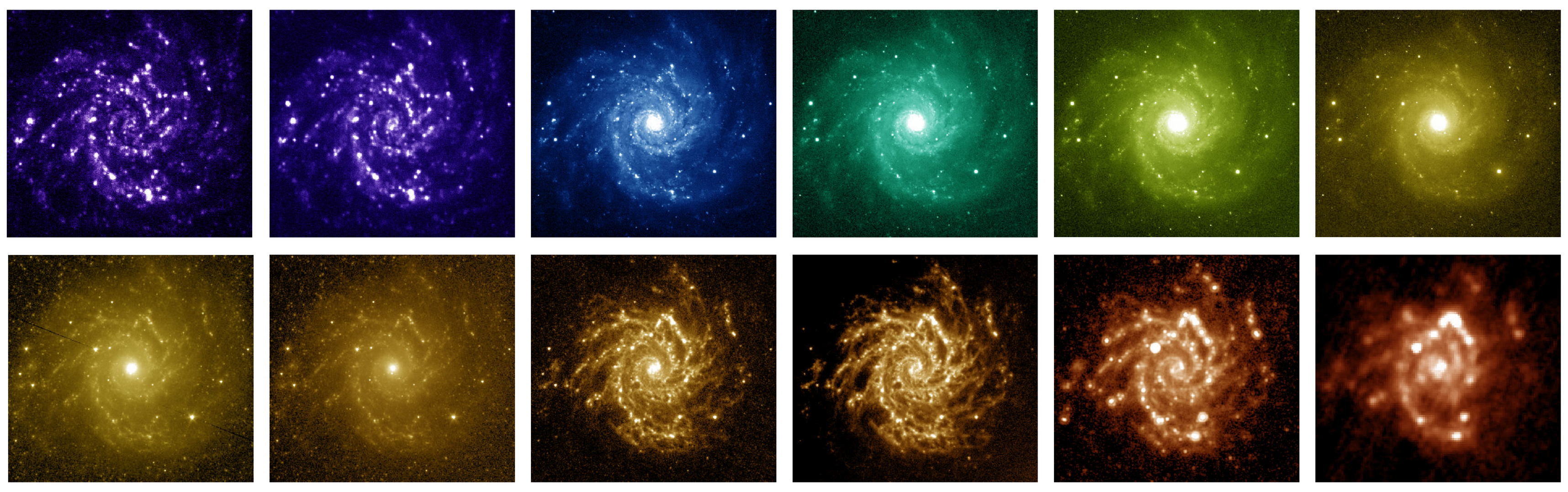
Non-parametric galaxy morphology from the far-UV to the far-IR

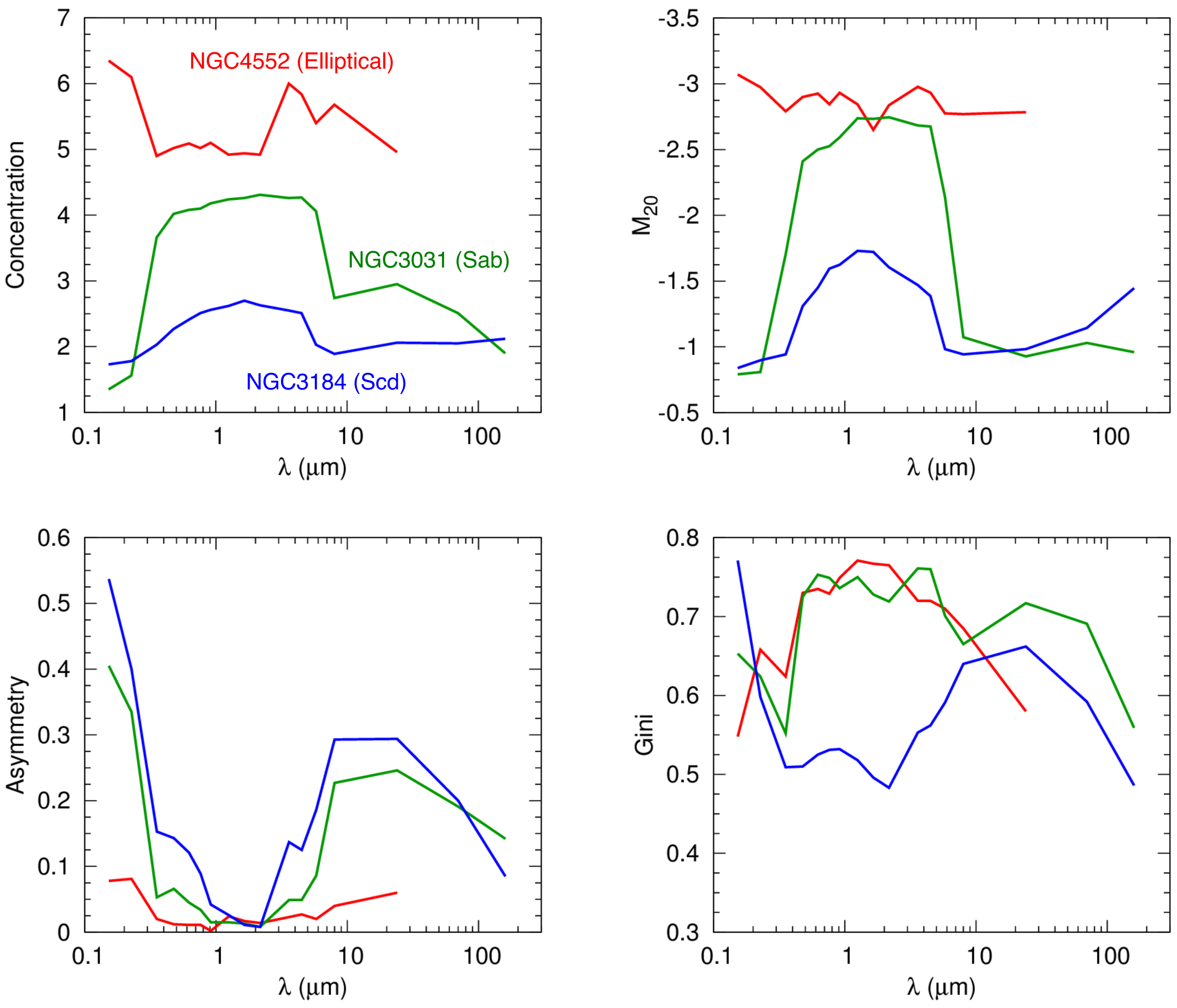
J. C. Muñoz-Mateos (ESO, jmunoz@eso.org), A. Gil de Paz, J. Zamorano, S. Boissier, D. A. Dale, P. G. Pérez-González,
J. Gallego, B. F. Madore, G. Bendo, A. Boselli, B. Buat, D. Calzetti, J. Moustakas & R. C. Kennicutt, Jr.

A panchromatic view of galaxies



The mechanisms governing the assembly and evolution of galaxies are encoded in their current morphologies. However, visual classification is impractical in modern surveys with many thousands of galaxies. Also, the classical Hubble types are not valid beyond the optical/near-IR bands, nor in high z galaxies. Non-parametric morphology estimators can overcome these limitations. In Muñoz-Mateos et al. (2009) we presented measurements of the concentration index, the second order moment, the asymmetry and the Gini coefficient for all 75 galaxies in the SINGS sample, in more than 20 photometric bands all the way from the far-UV to the far-IR. This constitutes an excellent local benchmark for morphology studies of galaxies at high z.

The toolbox of non-parametric morphology estimators



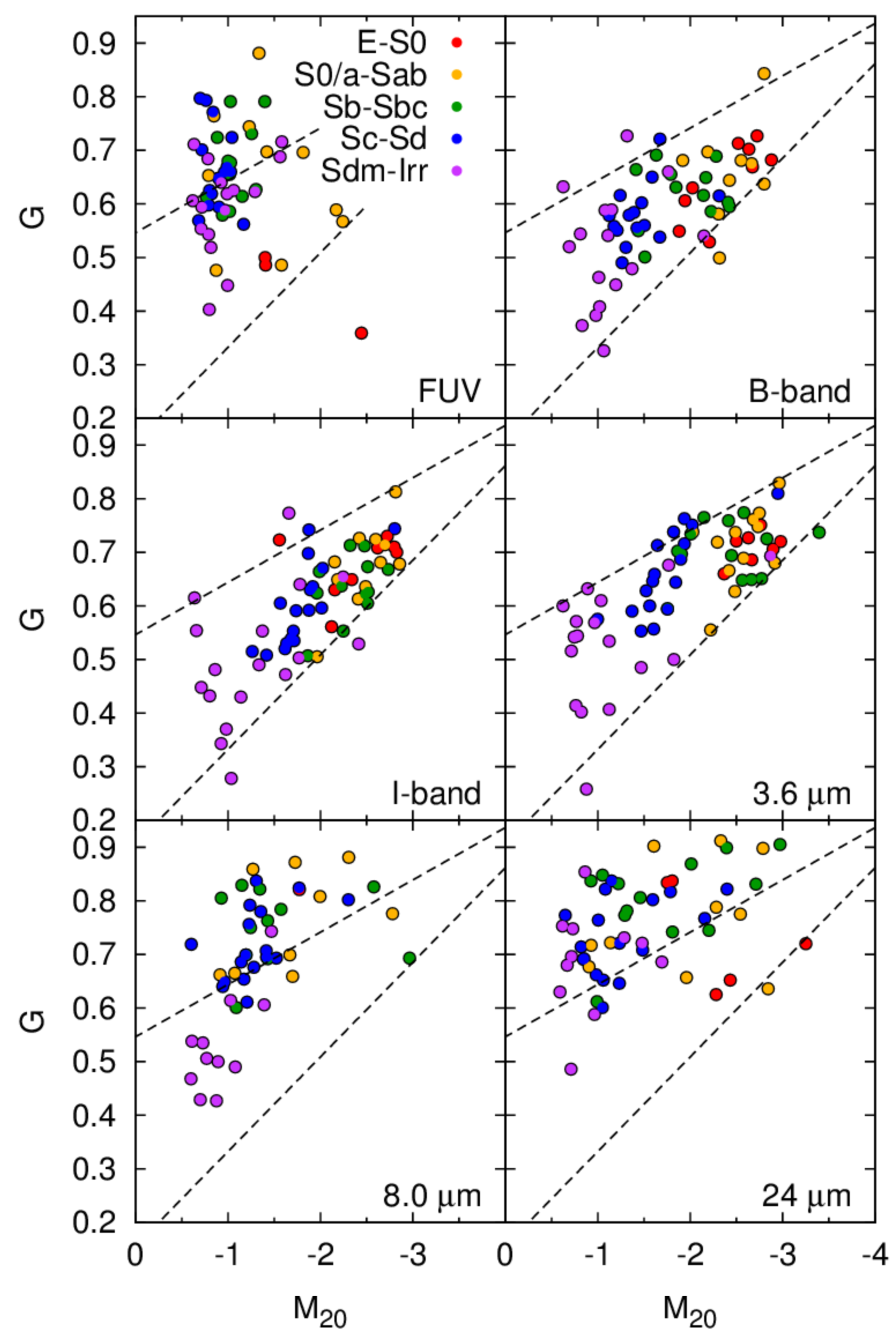
The **concentration index** compares the radii enclosing 20% and 80% of the total galaxy luminosity. Ellipticals exhibit a high concentration at all wavelengths. Spirals have low concentration in the UV, where the emission is dominated by recent star formation scattered throughout the disk. Redwards of the Balmer break the bulge shows up, rising the concentration index. This jump is more abrupt in early-type disks with prominent bulges than in late-type ones. The concentration drops again past ~5μm, where light is dominated by PAHs and dust at different temperatures.

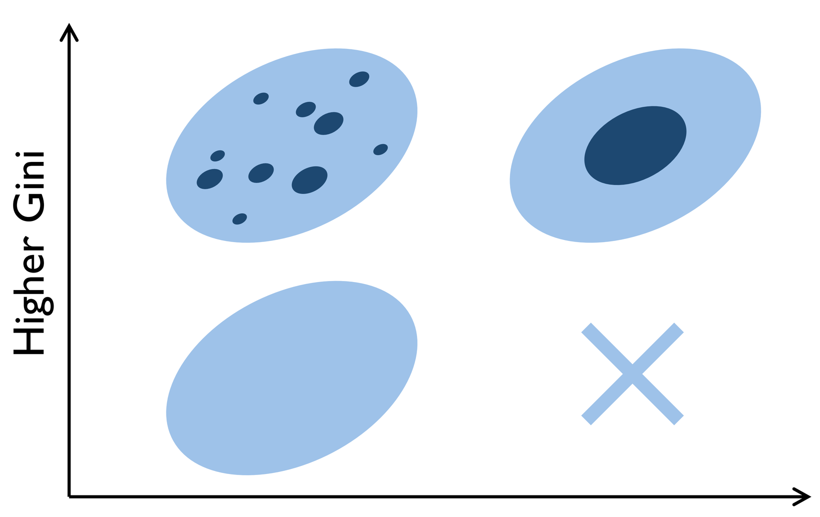
The **second order moment** of the brightest 20% of the pixels (M_{20}) also measures central light concentration. It is weighted by the distance squared, so it is more sensitive to the presence of bright regions at large galactocentric distances.

The **asymmetry** is measured by rotating the image of a galaxy by 180° and comparing it with the original, unrotated image. Elliptical galaxies are obviously highly symmetric at all wavelengths. Disks are quite asymmetric in the UV due to the clumpy distribution of young stars. The asymmetry decreases in the optical and near-IR, because the bulge and old stellar disk are smoother, but it rises again in the mid- and far-IR as dust is more irregularly distributed.

The **Gini coefficient** quantifies to what extent light is equally distributed among the pixels in an image, regardless of their spatial location. High values mean that most of the light is coming from just a few pixels, either in the central parts of the galaxy (as happens in ellipticals and the bulges of early-type disks) or in star-forming knots (mostly in late-type disks, especially in the UV and mid-IR). A low Gini coefficient implies that all pixels are more or less equally bright.

Gini and light concentration



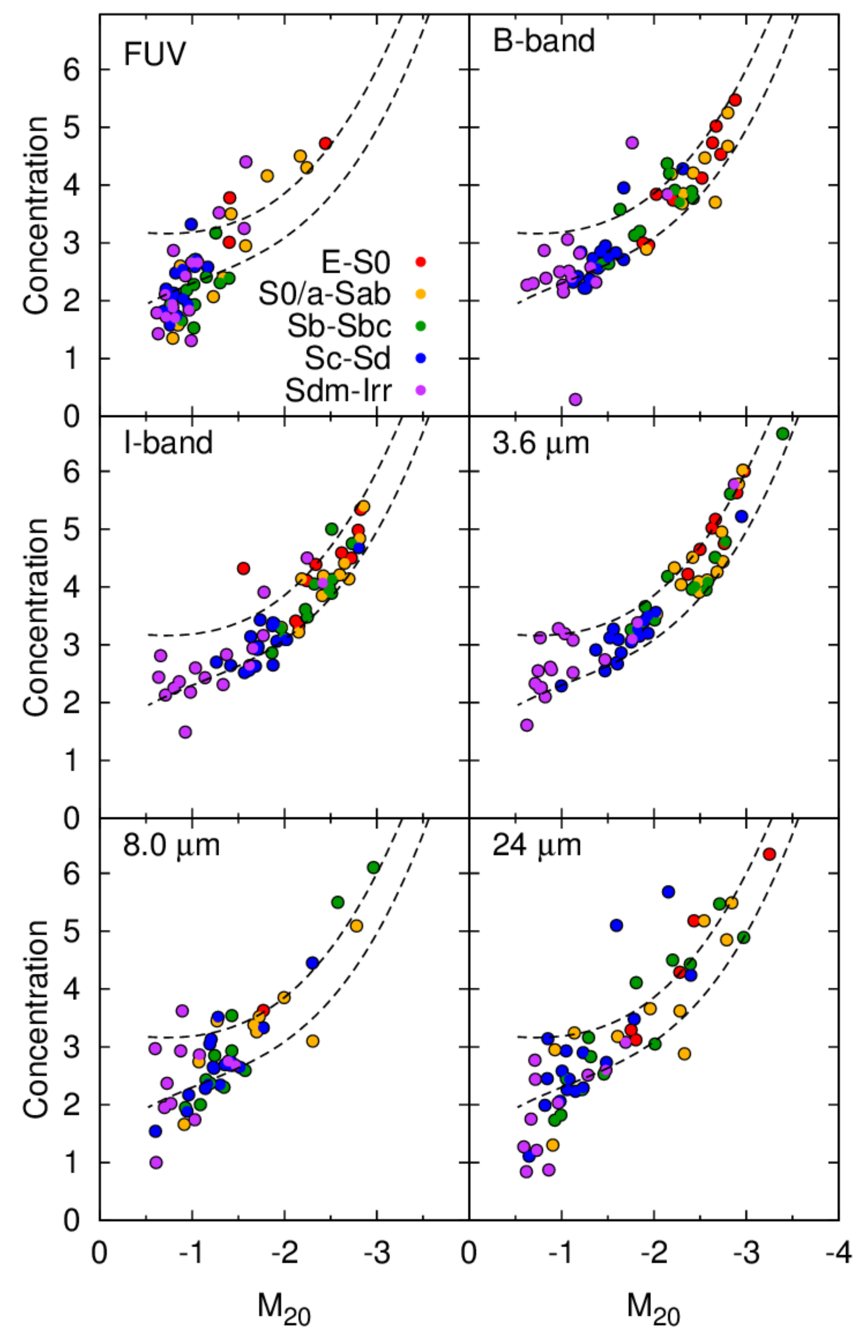


The Gini coefficient is highest when most of the galaxy light arises from a relatively small fraction of pixels, irrespectively of their spatial location within the galaxy. In the optical and near-IR regimes, those brightest pixels are preferentially located in the central bulge. Therefore, at these wavelengths the Gini coefficient is correlated with the concentration index and with M_{20}. Early-type galaxies with massive bulges have higher Gini and concentration values, as opposed to late-type galaxies where the light is more evenly distributed.

This correlation between Gini and light concentration breaks down in the UV and mid-IR. In these bands the brightest pixels are no longer found in the bulge. They are instead associated to star forming regions all over the disk. The Gini index can still be high, as most of the UV and mid-IR light comes from a few bright regions, but now the concentration will be low as these regions are spread out.

The combination of Gini and light concentration is therefore a very powerful morphology indicator.

Concentration index and M_{20}



Both the classical concentration index and the second order moment M_{20} quantify (in different ways) the fraction of the light coming from the central regions in galaxies. These parameters are therefore tightly correlated with each other in the optical and near-IR regimes. The trend has an "elbow" at M_{20} ~ -2, C ~ 3 that clearly separates Sc and later types from Sbc and earlier ones. The different slopes of this trend at both sides of the elbow can be attributed to progressive variations in the bulge-to-disk ratio across the Hubble sequence.

These two parameters are affected differently by discrete bright sources. Therefore, the tight correlation between them partially breaks down when moving into the UV and mid-IR.

References

This work: Muñoz-Mateos et al. (2009)

SINGS sample: Kennicutt et al. (2003)

Concentration: de Vaucouleurs (1977)
Kent (1985)

Second order moment: Lotz et al. (2004)

Gini index: Gini (1912)
Abraham et al. (2003)
Lotz et al. (2004)

Asymmetry: Schade 1995
Abraham et al. (1996)
Conselice et al. (2000)