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Impact of gas flows on the metallicity of barred galaxies

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Abstract

The relative contribution of secular processes to galaxy evolution is a hot topic under an intense debate. Numerical simulations predict that bars represent a very important mechanism for triggering gas inflows that lead to central star formation and that change both, the gas-phase and stellar phase metallicities in the center of the galaxies. We present a comparative study of the gaseous and stellar metallicities in the center of galaxies with and without bars using a sample of SDSS galaxies. Contrary to some previous studies, we do not find any difference in the gaseous or stellar abundances of barred and unbarred galaxies. We discuss the origin of the discrepancies with previous results. The present analysis constitute a very important piece of information in our understanding of the importance of bars in building central bulges and, in general, in our understanding of secular processes in disk galaxies .

1 Introduction

Bars are important drivers of secular evolution because they redistribute material and angular momentum in the disk of the galaxies. This redistribution produces gas inflows to the center, where star formation may be triggered. Due to this enhanced star formation, simulations predict that barred galaxies should have higher central chemical abundances [9, 10]. Studies of the central star formation rates and gas-phase metallicities in barred and unbarred galaxies have yielded contradictory results with some authors finding the central metallicities of unbarred galaxies lower [6, 5], some higher [7], and some equal [13] to that of barred galaxies. The discrepancies may come from different sample selections, as it has been suggested that central accumulation of gas and the increase in the SFR density is only observed in early-type spiral galaxies [15, 14, 36, 17, 40]. On the other hand, only one study have compared the stellar metallicities of barred and unbarred galaxies, and it concentrated, only, on early type

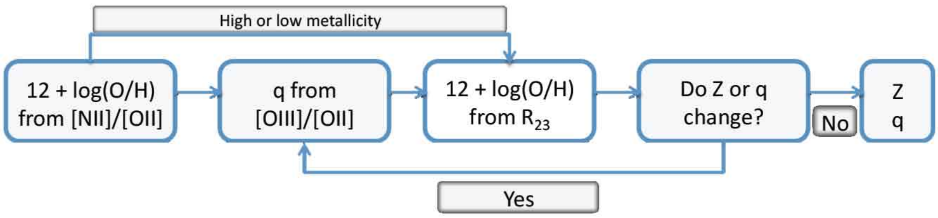

Figure 1: Scheme followed to calculate the metallicities of each individual galaxy. Each metallicity was iterated until convergence. The process was repeated 100 times for each galaxy varying the input data randomly following a gaussian distribution centered on the calculated value of each parameter.

galaxies [32]. The aim of the present work is to understand the role of bars in the evolution of disk galaxies by comparing central metallicities of the gaseous and stellar phases in a sample of barred and unbarred galaxies. This work is part of a long term project devoted to understand the role of bars in the evolution of disk galaxies.

2 Sample selection

We chose our sample from [30], which is a catalogue of about 14000 morphologically classified galaxies with spectroscopic redshifts up to 0.1 and brighter than 16 magnitude in the g-band. The morphological classification is done visually, using all SDSS photometric bands. The bar presence is also estimated visually, where strong bar corresponds to a galaxy in which the luminosity is dominated by the bar and weak bar corresponds to a galaxy in which the bar contains only a minor part of the total flux of the galaxy. The classification of weak bars implies the existence of a bar. If no bar is seen, the galaxy is catalogued as unbarred. This catalogue also contains the mass of the galaxy, obtained from [18].

To study disk galaxies, we chose galaxies with morphological T-type higher or equal than -2 (i.e., we excluded all elliptical galaxies but included S0). There is a bias due to the difficulty of observing bars in highly inclined galaxies. For that reason, we limited our sample to those galaxies with a ratio between the major and minor axis (b/a) higher than 0.4. We made sure that the bars can be observed with these parameters by a visual inspection of a representative subsample of the galaxies. Another reason to make this cut in the inclination was to minimise the disk contribution in the central fiber (3 arcsec). With this preliminary selection we obtained a sample of 1270 galaxies of which 931 are unbarred and 339 are barred.

3 Gas metallicity

We calculated the metallicity following the scheme in Fig. 1. The fluxes of the emission lines were taken from [31]. More details about the method can be found in [19]. This method can only be used on galaxies whose emission lines come from photoionization, not being valid on galaxies where the ionizing source is an AGN. We removed the galaxies with an AGN using a BPT diagram [1] comparing the observed line ratios [OIII]λ5007/Hβ and [NII]λ6584/Hα. We used the criterion in [18] to separate our galaxies.

4 Stellar metallicity

We calculated stellar metallicities performing a full spectral fitting technique with the code `STARLIGHT` [4] coupled with the MILES Single Stellar Populations library [38, 42]. The output of the code consists of a linear combination of single-stellar-populations (SSP) with a given age and metallicity that best fit the observed spectra. We obtained a mean metallicity for each galaxy averaging the metallicity of all the SSP weighting by their light contribution at 5400Å.

5 Results

In Fig. 2 (left panel) we show the gas-phase metallicity versus the mass of each galaxy for our sample of barred and unbarred galaxies, binning the points of individual galaxies into intervals of mass. The figure also shows a second order polynomial fit to the unbarred galaxies. In the right panel, we show the distance to this fit for the barred galaxies as a function of mass. Contrary to the recent study by [7], we do not find any significative difference between the central gas-phase metallicities of barred and unbarred galaxies. A Kolmogorov-Smirnov test of the residuals confirms this appreciation. The same result is obtained (figure not showed here) for the stellar metallicity.

As we mentioned in the introduction, the influence of the bar in the central parts of galaxies may depend on the morphological type. To check this, we repeated this analysis dividing the galaxies in two groups, a first group of galaxies with morphological types from S0 to Sb and a second group of galaxies between Sbc and Sm (Fig. 3). The absence of differences in the central gaseous metallicity of barred and unbarred galaxies seems to hold independently of the morphological type. The differences in the stellar metallicity are smaller than the error bars, but for early-type galaxies, the differences are systematically positive. This does not happen for late-type galaxies.

6 Comparison with previous results

There are some previous works comparing the metallicities of barred and unbarred galaxies. We used a large sample of galaxies with very restrictive conditions to avoid selection effects that may introduce a bias in the analysis. We wanted to minimize the errors, so we needed high quality measurements. We did this introducing a cut in the S/N, only taking into account galaxies with $S/N \geq 5$. We took the emission line fluxes from [31], which comprises all the galaxies in SDSS with $z \leq 0.1$, so we had measurements of the lines for all galaxies in our sample.

One of our aims with this job was trying to reproduce the results obtained by [7]. We

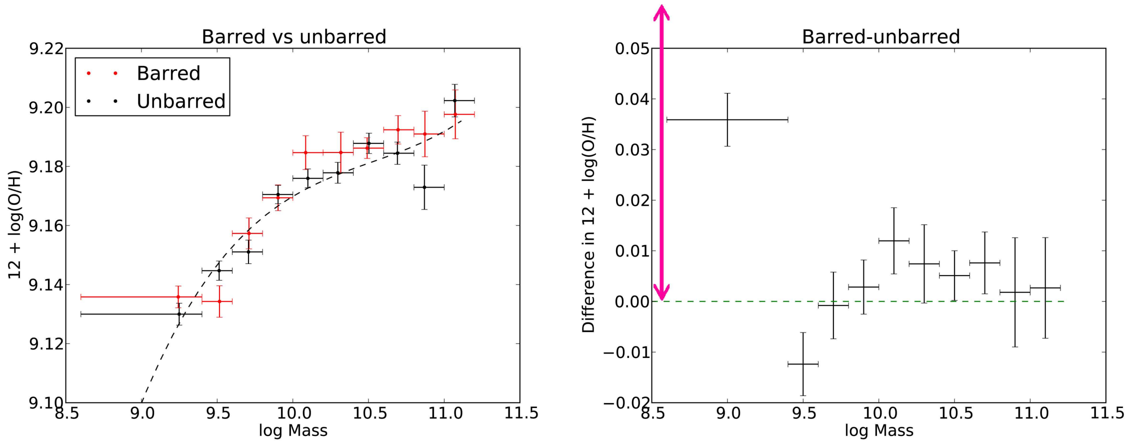

Figure 2: Binnings in mass for the galaxies. *Left panel:* galaxies binned in mass. Each point represents the mean metallicity in each bin, in the form log(O/H)+12. Error bars are the mean error in each bin. *Right panel:* the metallicity of the barred galaxies relative to the metallicity of the unbarred galaxies. The pink arrow represents the difference found by [7]. The horizontal error bars express the interval of mass taken for the bin. The vertical bars ilustrate the error in the mean (left panel) or in the difference (right panel).

followed the same methodology as they did, but introducing some changes. We took the emission line fluxes from [31], instead of MPA/JHU, as [7] did. Using [31] fluxes we did not find significant differences between the subsamples of barred and unbarred galaxies, even when our sample was compatible with [7].

We have found that most of the discrepancies come from the source of the emission line fluxes. It is known that some hydrogen lines in MPA/JHU, are affected by systematic errors [11]. One of this lines is Hβ, which is related to dust extinction correction and the calculation of the metallicity (using the R_{23} calibration which includes the Hβ flux). This effect might lead to errors in the metallicity calculation. As this effect is systematic, it should affect to both barred and unbarred galaxies in the same way if there are no differences between barred and unbarred galaxies. It needs further investigation to study in detail the effects of Hβ on the metallicity. [31] gives measurements of the lines compatible with those given by the SDSS pipeline.

7 Summary

We present here a comparative study of the central metallicities using a sample of 1200 low-inclination galaxies obtained from the SDSS. We made a study of the metallicity from several points of view: nebular and stellar abundances. We did not find any clear differences in the central meallicity of barred and unbarred galaxies. We checked the influence of redshift on the results. The results are independent of redshift.

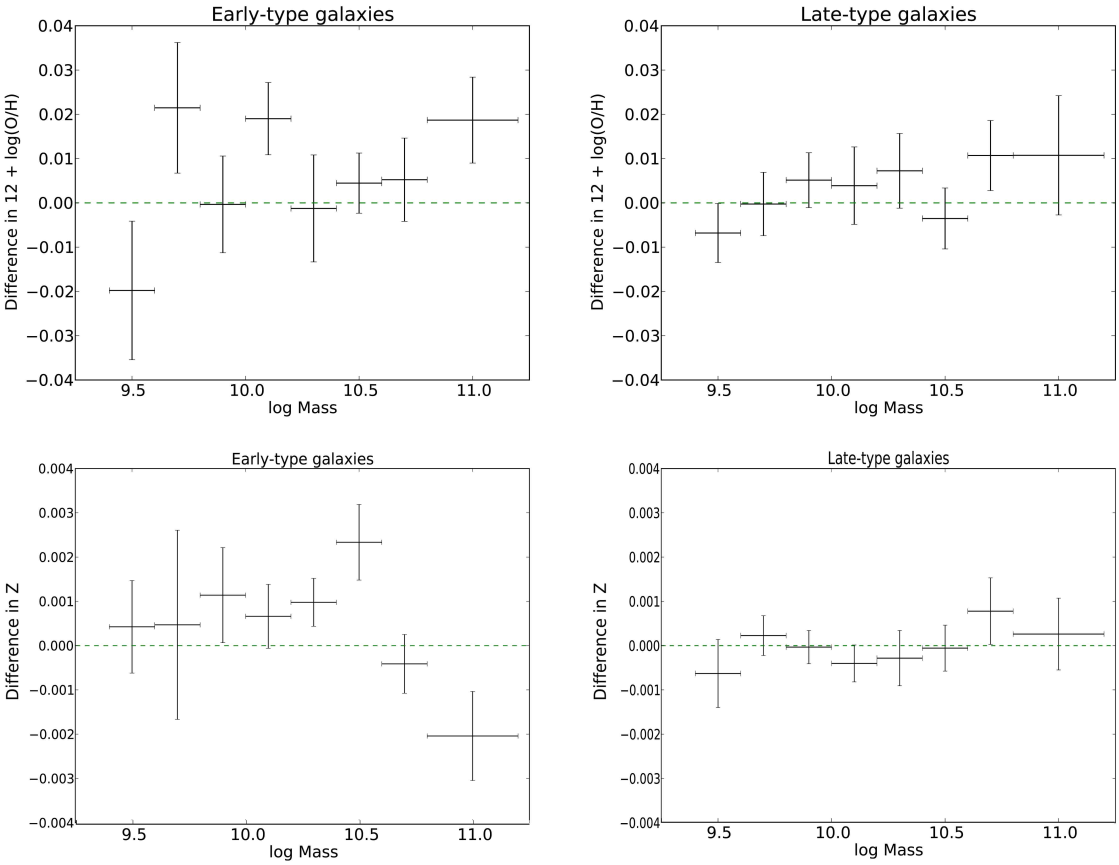

Figure 3: *Upper panels:* Difference in the gas-phase metallicity of barred to unbarred galaxies. We can find galaxies from S0 to Sb in the plot of the left panel, and galaxies from Sbc to Sm in the plot on the right panel. Error bars are again the interval of mass (horizontal), and the error in the mean. *Lower panels:* Same as above but for the stellar metallicities.

We use the same comparison techniques in the gaseous and stellar metallicity and extended the morphological range with respect to previous work. The differences found are smaller than the error bars, but there is a possible dependence of the difference in the stellar metallicity with the morphological type, being the early-type barred galaxies slightly more metal-rich than the unbarred. This trend reverts for late-type galaxies.

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