Boletim da Sociedade Astronômica Brasileira, **34**, no. 1, 69-70

A multizone chemical evolution model for the Milky Way bulge

O. Cavichia[1] & M. Mollá[2]

[1] Instituto de Física e Química, Universidade Federal de Itajubá, Av. BPS, 1303, 37500-903, Itajubá-MG, Brazil
e-mail: `cavichia@unifei.edu.br`

[2] Departamento de Investigación Básica, CIEMAT, Avda. Complutense 40, E-28040 Madrid, Spain
e-mail: `mercedes.molla@hotmail.es`

Abstract. In this work we developed a chemical evolution model taking into account the mass distribution in the bulge and disc to derive the radial dependence of the collapse time-scale in the Milky Way Galaxy. The results of the model were used to test a scenario where the bulge is formed assuming an inside-out growth scenario, where the accretion of metal-poor gas from the halo builds the spheroidal component and also the disc. The results suggest that the spread in α-ratios, as shown by the observational data at lower metallicities, may be the result of mixing stars from different radial locations within the bulge.

Resumo. Desenvolvemos um modelo de evolução química levando em conta a distribuição de massa no bojo e disco da Galáxia, para derivar a dependência radial da escala de tempo de colapso na Via Láctea. Os resultados do modelo foram utilizados para testar um cenário onde a componente esferoidal é formada de dentro para fora. Os resultados sugerem que o espalhamento das razões-α mostrado pelos dados em baixas metalicidades pode ser o resultado da mistura de estrelas originadas em diferentes regiões radiais do bojo.

Keywords. Galaxy: bulge – Galaxy: evolution – Galaxy: abundances – Stars: abundances

1. Introduction

Nowadays the Galactic bulge (GB) metallicity distribution function (MDF) can be traced for different regions within the bulge and can be used to constrain the bulge formation scenario. Observations have shown that the GB is composed of at least two components with different mean metallicities and possibly different spatial distribution and kinematics. Zoccali et al. (2017) have demonstrated that the two components present a different spatial distribution, with the metal poor population being more centrally concentrated. There is no consensus in the literature regarding if this result point to a GB formation scenario formed by a bar instability or if the the GB formed from a spheroidal collapse. In this regarding, chemical evolution models (CEM) are important tools to understand the formation and evolution of the components of the Milky Way Galaxy (MWG) and other galaxies in the universe. Precisely, one of the most important constraints for CEM is the MDF of a region, since it is sensible to the time-scale that the region was formed and can be useful to study the formation and evolution of the GB.

2. Description of the model and results

A chemical evolution model is proposed in this work taking into account the mass distributions in the Galactic bulge and disc, to derive the radial dependence of the time-scale in the MWG. The model is an update of our previous models: Mollá & Díaz (2005), Mollá et al. (2015) and Mollá et al. (2016). Since the infall rate depends on the time-scale in the chemical evolution model, the results of the model were used to test a scenario where the bulge is formed inside-out, where the accretion of metal-poor gas from the halo builds the spheroidal component and also the disc. The disc is divided in concentric rings each one 1 kpc wide and, in this new work, the bulge is divided in concentric spherical shells of 0.25 kpc, except for the central region, where a radius of 0.125 kpc is used instead. In the case of spiral galaxies, the central bulge brightness profile can be well described by a Sérsic function. By assuming that the mass distribution follows the light distribution, the bulge total mass can be calculated by integrating the brightness profile. This way, we will have the bulge mass as a function of the distance to the galactic centre. The collapse time-scales are computed following the prescriptions from Mollá et al. (2016) and it is obtained by imposing that after a Hubble time the system ends with a mass as observed.

We summarise some results that we have obtained in this work. The Galactic Centre (GC) region presents an intense star formation process and, consequently, the formation of a higher fraction of massive stars than in the other bulge regions at the early times. The model predicts that there is a radial [Fe/H] gradient within the bulge region. The MDF for each spherical region is shown in Fig. 1, represented by the [Fe/H] histograms. Since we only have a 2 D projection of the bulge MDF in the galactic longitude vs. galactic latitude plane, the comparison with the model may not be straightforward. The model predicts a wider MDF for the inner regions, while it starts to become increasingly narrower for the outer regions, a tendency also corroborated by the observational data. We are able to correctly predict the metallicity range in the MDF for each bulge radial region where the data are available, indicating that the obtained time-scales are probably correct. We are not able to reproduce the double peak of the MDFs, as shown by the observational data. In Fig. 2 we show the relative abundances for the [α/Fe] vs. [Fe/H] abundances. Overall, our model is able to reproduce the observational data. Interestingly, the model predicts different alpha ratios for each spherical region, the ratio being higher at the innermost regions and lower at the outermost regions, especially at low iron abundances. Higher α-ratios at low metallicities indicate a fast enrichment by massive stars, which explode as type II supernovae, that is a rapid formation of the stellar population. The results of Fig. 2 suggest that the spread in the α-ratios, as shown by the observational data at lower metallicities, may be the result of mixing stars from different radial locations within

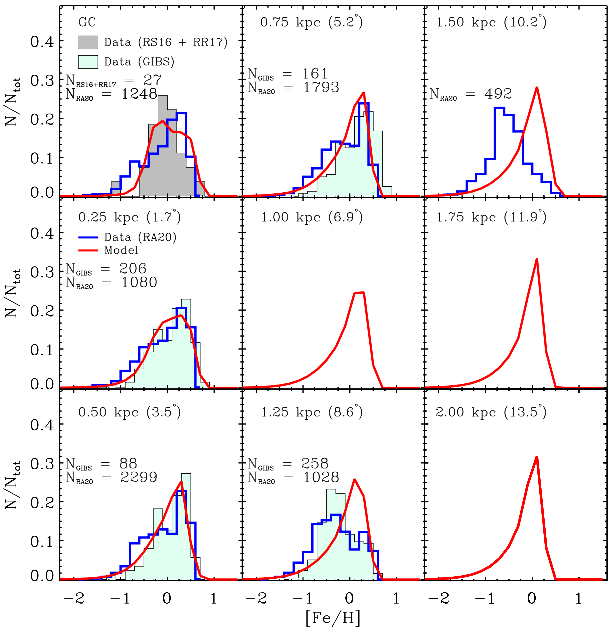

Figure 1. Fe/H] histograms for different regions in the GB (GC, 0.25, 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, and 2.0 kpc), as labeled in each panel. The theoretical MDFs represent those from giant GB stars, being the stellar abundances computed taking into account the stellar life-times from Padova isochrones. The data are from Zoccali et al. et al. (2017, GIBS), Ryde et al. et al. (2016, RS16), Rich et al. et al. (2017, RR17) and Rojas-Arriagada et al. et al. (2020, RA20). The number of stars to build the histograms are shown at the middle left of each panel where the observational data are plotted.

the bulge. For more details the reader is referred to Cavichia et al. (2022).

3. Conclusions

The conclusions of this work are the following ones:

- In this new model, a scenario is adopted where the bulge is formed inside-out in a multizone approach. The time-scales for the bulge formation are obtained from the radial mass distribution by imposing that at the end of the simulation the brightness profile is described by a Sérsic function.
- The metallicity distribution function (MDF), represented by the [Fe/H] histograms for each spherical region predicts a wider MDF for the inner regions and a narrower for the outer ones. The number of stars composing the metal poor (MP) population is higher in the central fields than the outer ones, in agreement with the data. At the same time, the fraction of metal rich (MR) stars increases towards the centre. Nonetheless, the positions of the peaks do not change considerably. The model predicts that there is a radial [Fe/H] gradient within the bulge.
- The model predicts a dependence with the spherical region for the α-ratio vs. metallicity. The results suggest that the spread of the data in this kind of plot might be the result of mixing stars from different radial regions. The differences are in the range of 0.05 to 0.08 dex, depending on the element, doing very difficult to detect them observationally considering the current uncertainties in the observational data.

Acknowledgements. FAPEMIG grant APQ-00915-18.

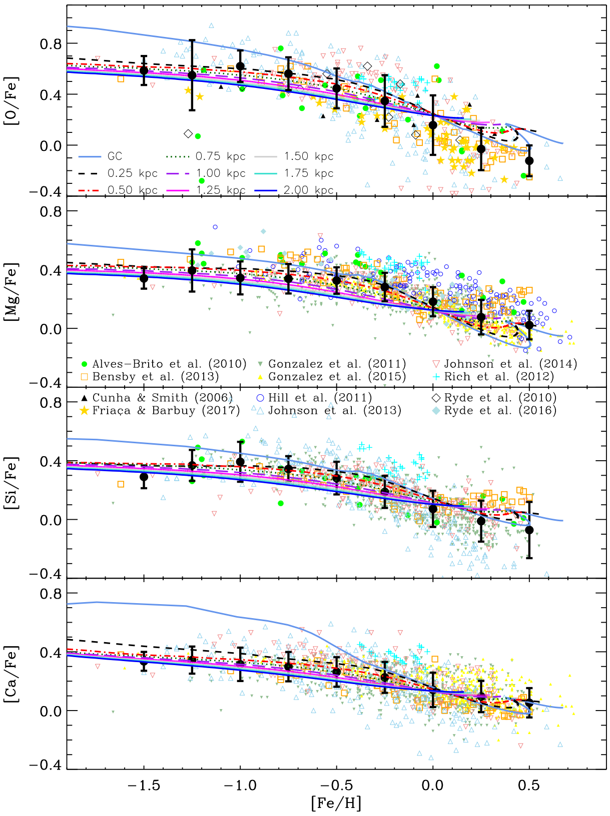

Figure 2. Comparison between the predictions of our model at different radial regions and the literature data for [α/Fe], where α stands for O, Mg, Si, and Ca, vs. [Fe/H]. The references for the bulge data are in the figure. The line codes of the models are as labeled in the first panel (from top to bottom). Black circles with error bars are the mean and standard deviation of the observational data for bins of 0.25 dex.

References

Cavichia, O., Mollá, M., & Baján, J. J. 2022, MNRAS, submitted
Mollá, M., & Díaz, A. I. 2005, MNRAS, 358, 521
Mollá, M., Cavichia, O., Gavilán, M., & Gibson, B. K. 2015, MNRAS, 451, 3693
Mollá, M., Díaz, Á. I., Gibson, B. K., Cavichia, O., & López-Sánchez, Á.-R. 2016, MNRAS, 462, 1329
Rich R. M., Ryde N., Thorsbro B., Fritz T. K., Schultheis M., Origlia L., Jönsson H., 2017, AJ, 154, 239. doi:10.3847/1538-3881/aa970a
Rojas-Arriagada A., Zasowski G., Schultheis M., Zoccali M., Hasselquist S., Chiappini C., Cohen R. E., et al., 2020, MNRAS, 499, 1037
Ryde N., Schultheis M., Grieco V., Matteucci F., Rich R. M., Uttenthaler S., 2016, AJ, 151, 1
Zoccali, M., Vasquez, S., Gonzalez, O. A., et al. 2017, A&A, 599, A12