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Constraining bar ages dependency on different stellar population models

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Abstract. The evolution of disc galaxies can be simplified in two phases scenario: when galaxies undergo interactions and, later on, internal evolution becomes significant. The transition between these scenarios remains an open question, but theoretical work and simulations suggest that a stellar bar can form when the disc is settled, driving the formation of internal structures. Determining the age of these bars is not straightforward, as they capture stars from the main disc, mixing populations and complicating age estimation. This project is based on the method presented in SÁ-FREITAS et al. (2023), which isolates these galaxy components using spectral fitting techniques to determine different stellar populations and to obtain the final age of the bar. Yet, the stellar population parameters derived depend directly on the stellar population models adopted in the spectral fitting, and the effect of choosing different models remains to be explored. In this work, the method by SA-FREITAS et al. will be applied to the same sample of galaxies from the TIMER survey, but adopting different stellar population models from the literature. It is known that different groups tailor models to different populations (e.g. star-bursting systems vs. intermediate and old ages) and we aim to quantify how this impacts the derived ages of the bars.

Resumo. A evolução das galáxias disco pode ser simplificada em um cenário de duas fases: inicialmente, quando as galáxias passam por interações, e, posteriormente, quando a evolução interna se torna dominante. A transição entre esses regimes ainda é uma questão em aberto, mas trabalhos teóricos e simulações sugerem que uma barra estelar pode se formar quando o disco já está assentado, impulsionando a formação de estruturas internas. Determinar a idade dessas barras não é trivial, pois elas capturam estrelas do disco principal, misturando populações estelares e dificultando a estimativa de idades. Este projeto baseia-se no método apresentado em de Sá-Freitas et al. (2023), que isola os diferentes componentes das galáxias por meio de técnicas de ajuste espectral, permitindo identificar distintas populações estelares e obter a idade final da barra. No entanto, os parâmetros de populações estelares derivados dependem diretamente dos modelos de populações estelares adotados no ajuste espectral, e o impacto da escolha de diferentes modelos ainda precisa ser explorado. Neste trabalho, o método de Sá-Freitas et al. será aplicado à mesma amostra de galáxias do levantamento TIMER, mas adotando diferentes modelos de populações estelares disponíveis na literatura. Sabe-se que diferentes grupos desenvolvem modelos otimizados para populações distintas (por exemplo, sistemas com intensa formação estelar versus populações de idades intermediárias e antigas), e buscamos quantificar como essas diferenças afetam as idades derivadas das barras.

Keywords. Galaxies: evolution – Galaxies: stellar content – Galaxies: structure

1. Introduction

In de Sá-Freitas et al. (2025), an observational estimate of bar ages was provided for a sample of nearby galaxies for the first time, offering an independent perspective on galaxy evolution and the properties of disc galaxies. A simplified overview of the methodology is presented in Fig. 1. This type of study is crucial for understanding the transition between dynamically maturing galaxies and the onset of bar-driven internal processes.

Figure 2 shows the results for the galaxies NGC 1300 and NGC 1433 for the MILES model. We are able to see the SFHs of the original nuclear disc region, of the representative SFH of the main disc, and of the nuclear disc with the representative SFH subtracted. The bottom panels show the moment of bar formation.

The results are consistent with high-redshift observational studies of the bar fraction beyond $z > 1$ and up to $z \leq 4$. From measuring bar ages, it is possible to trace how the bar fraction evolves over time and obtain, as well, insights on secular evolution, finding evidence on the growth of bars and their correlation with the quenching star formation in their host galaxies.

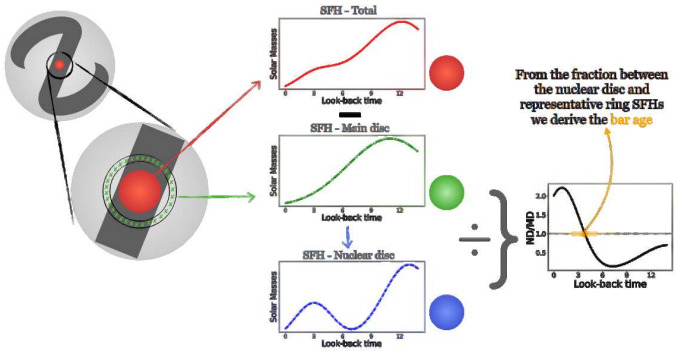

Figure 1. Illustration of the bar age measurement method presented in de Sá-Freitas et al. (2025). The SFH is derived from the original data of the nuclear disc (red) and of the representative ring regions (green), subtracting the main disc SFH from the original one, and the difference is considered the nuclear disc SFH (blue). Then, the ratio ND/MD is used to time the moment of bar formation (right plot, orange).

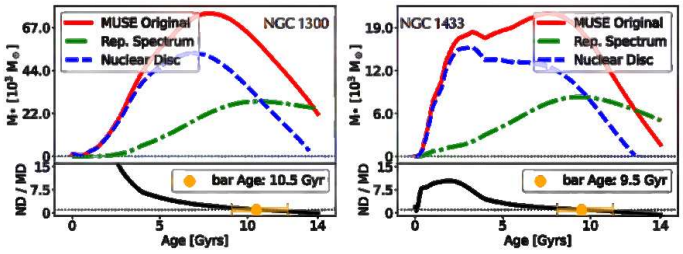

Figure 2. [Adapted from de Sá-Freitas et al. (2023)] Individual measurements of bar age of the low-SF sample, that is defined as the moment in which the SFH of the nuclear disc (dashed-blue line) overcomes the SFH of the main disc (dot-dashed-green line).

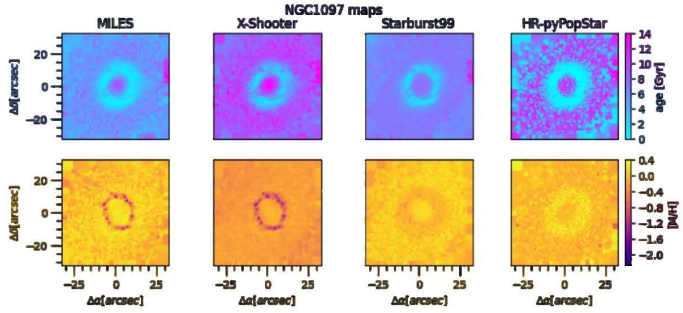

Figure 3. Maps of light-weighted ages and light-weighted [M/H] for NGC 1097. Each column displays the maps for fits with a different library of SSP models (MILES, X-Shooter, Starburst99, and HR-pyPopStar, respectively).

2. Motivation

Following Gonçalves, G., Coelho, P., TIMER collaboration (in prep) work, we will be employing stellar population models that are better suited for younger and mixed stellar populations.

As shown in Fig. 3, in that work, the star formation histories are considered in the age analysis; only the average age distribution is used, and it is not verified whether the shapes of the SFHs are the same.

The methodology was tested under various configurations to assess the effects of systematic errors. These tests included using different light profiles to build the underlying main disc, avoiding the collapse of the data cubes and instead deriving a mean SFH from the individual spaxels in the cube, and varying the pPXF regularisation error parameter. For the latter, it was verified that the systematic effect of employing different regularisations is limited to 0.5 Gyr.

It is also of interest to investigate other potential effects — for example, whether the shape of the SFHs varies, and whether such variation occurs consistently, in which case the mean ages obtained would remain unchanged.

3. Goals

The immediate goal is to systematically constrain how the bar ages, derived for the TIMER sample (de Sá-Freitas et al., 2025), depending on specific stellar population models. We will reproduce the analysis presented in de Sá-Freitas et al. (2023), but this time choosing four different models, MILES, X-shooter, Starburst 99, and a new one instead of HR-pyPopStar, still in

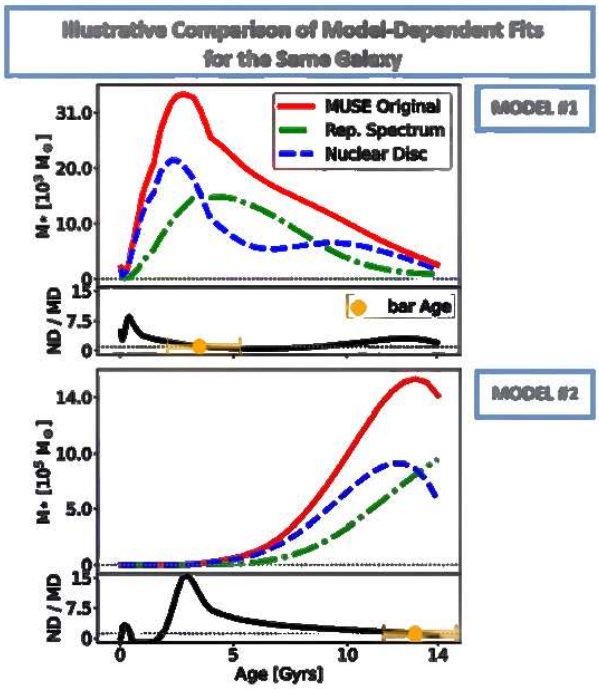

Figure 4. The figure shows a conceptual illustration of possible outcomes on the bar age derived from varying the stellar population models. This is a hypothetical bad scenario, where the models are not agreeing with each other.

preparation, to investigate possible differences in the shape of star formation histories, which could represent a limitation in this analysis. Figure 4 shows a schematic illustration on how our results could be if two models delivered totally unmatched bar ages.

Our results can be applied to various studies on unresolved stellar populations and will bring further understanding of spectral fitting techniques for different contexts.

The primary objective is to apply the entire analysis to the same pilot galaxy used in de Sá-Freitas et al., (2023), NGC 1433, obtaining meaningful results even before conclude the analysis for the entire TIMER sample.

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