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Ram pressure effects on the color evolution of a galaxy

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Abstract. The color index of a galaxy can be related to its age and dynamical history, being directly influenced by the stellar populations within its medium. We aim to understand how external interactions can alter the color of a galaxy, such as ram pressure stripping. To achieve this, a series of *N*-body simulations was conducted, using the Flexible Stellar Population Synthesis (FSPS) code to obtain color information for each stellar population generated. Comparisons were made between an isolated galaxy and the same galaxy evolved inside a wind tunnel. Current results suggest that color changes significantly between simulations, mostly due to higher star formation rate induced by ram pressure.

Resumo. O índice de cor de uma galáxia pode ser relacionada à sua idade e ao seu histórico dinâmico, sendo diretamente influenciada pelas populações estelares do meio intergalático. Procuramos entender como interações externas podem alterar a cor de uma galáxia por meio de ram pressure. Para isso, uma série de simulações de *N*-corpos foi conduzida, usando o código Flexible Stellar Population Synthesis (FSPS) para obter as informações de cor para cada população estelar gerada. Comparações foram feitas entre uma galáxia isolada e a mesma galáxia evoluída dentro de um túnel de vento. Resultados atuais sugerem que a cor muda significativamente entre as simulações, em boa parte devido à maior formação estelar induzida pela ram pressure.

Keywords. Galaxies: clusters – Galaxies: clusters: intracluster medium – Galaxies: evolution

1. Introduction

It is know that the environment can affect galaxy evolution, being the main factor contributing to gas stripping from a disc galaxy when it traverses the intracluster medium (ICM) (Gunn & Gott 1972).

Numerical simulations have extensively been employed to study numerous properties of galaxies inside the ICM, such as star formation rate and gas stripping rate (Kronberger et al 2008; Steinhauser et al 2012), morphology (Tonnesen & Bryan 2009) and the importance of galaxy quenching in color (Steinhauser, Schindler & Springel 2016), also using wind-tunnels to understand gas mixing and the influence of specific trajectories (Tonnesen 2019).

With this study we aim to analyze how color can be affected by ram pressure stripping, while using a wind tunnel environment, which makes possible to better control most variables.

2. Simulation Setup

For all simulations a modified version of the Arepo code was used. Arepo is an astrophysical *N*-body simulation code that uses an adaptive moving mesh for hydrodynamical interactions (Weinberger, Springel, & Pakmor 2020).

The initial galaxy was generated with the Python3 version of galstep (Ruggiero & Lima Neto 2017), using parameters set to create a late-type galaxy roughly similar to the Milky Way in size and mass. These parameters are specified in Tab. 1 for the dark matter and stellar bulge halo profile, which used a Hernquist (1990) density profile:

$$\rho(r) = \frac{M}{2\pi}\frac{a}{r(r+a)^3} \tag{1}$$

where M is the total mass of the profile a is a scale lenght, and Tab. 2 for the stellar and gas disk using a exponential profile:

$$\rho(R,z) = \frac{M}{4\pi R'^2 z'}\exp\left(-\frac{R}{R'}\right)\operatorname{sech}^2\left(\frac{z}{z'}\right) \tag{2}$$

Table 1. Parameters used for the dark matter halo and bulge density profiles.

	M ($M_\odot$)	a (kpc)
Halo	10^{12}	47
Bulge	2×10^{10}	1.5

Table 2. Parameters used for the stellar and gas disk density profiles.

	M ($M_\odot$)	R' (kpc)	z' (kpc)
Stellar disk	5×10^{10}	3.5	0.7
Gas disk	2×10^{10}	3.5	0.245

where M is also the total mass and R' and z' are scale lengths related to the extension of the disk in radius and thickness, respectively. This galaxy was then relaxed for 1 Gyr.

Two simulations were then performed: one featuring the relaxed galaxy in isolation and another where the same galaxy was placed within a gas box. This gas box had uniform density $\rho = 2.32\times10^{-28}\,\mathrm{g\,cm^{-3}}$ acting like a wind tunnel with periodic boundaries and relative velocity of $750\,\mathrm{km\,s^{-1}}$.

In order to obtain color indexes the FSPS (Flexible Stellar Population Synthesis) code is then applied, considering each star particle as a simple stellar population (Conroy et al. 2021; Conroy & Gunn 2010), in a similar way to what was done in Steinhauser, Schindler & Springel (2016) and Nelson et al. (2018), generating magnitudes from population age and metallicity. As an approximation the age and metallicity of the particles composing the disk and the bulge were chosen to be 7 Gyr and 1 solar metallicity in both simulations.

3. Results and Analysis

In Fig. 1 the dynamical evolution of the simulated galaxies is shown. The galaxy inside the wind tunnel (lower panels) quickly

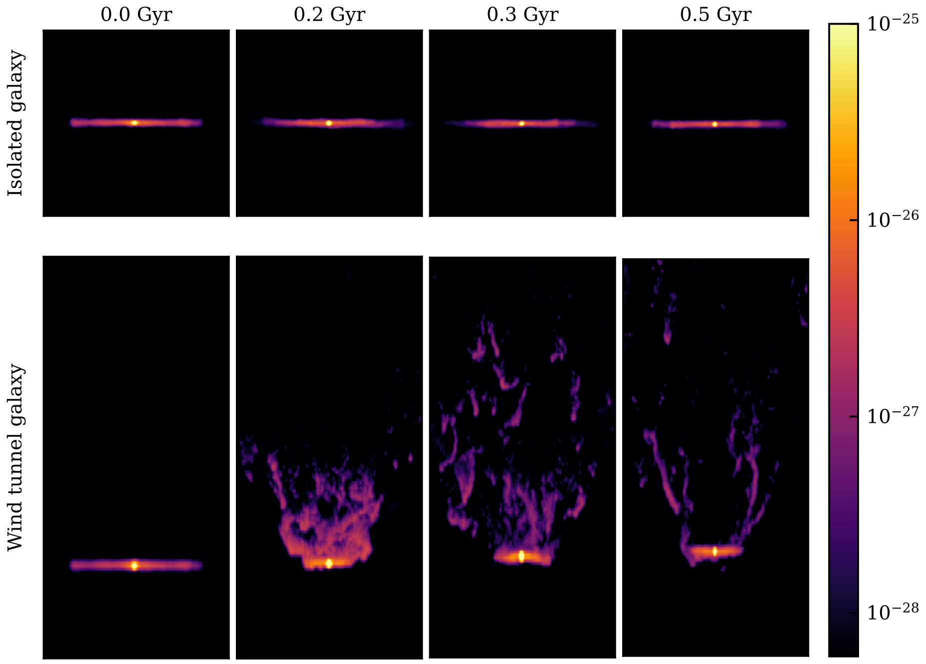

FIGURE 1. Gas density maps of both galaxies seen edge on. The lower panels show the galaxy that crosses gas, while the upper ones show the isolated galaxy. Upper maps are 60 kpc×60 kpc, while lower ones are 60 kpc×150 kpc.

develops tails and loses its gas due to ram pressure, also having its gas disk truncated.

The first panel of Fig. 2 displays the color evolution of both galaxies, where the isolated galaxy color index constantly increases over time. Due to the ram pressure there is also a higher star formation rate (second panel of Fig. 2) in the wind tunnel galaxy, strongly contributing to the lower index in comparison to the isolated galaxy, since younger populations are bluer.

4. Conclusions

Results show that the galaxy affected by ram pressure maintains a lower color index g-r, being bluer than its counterpart in isolation. It also has a higher star formation rate caused by ram pressure, contributing to the lower color index directly influenced by younger stellar populations.

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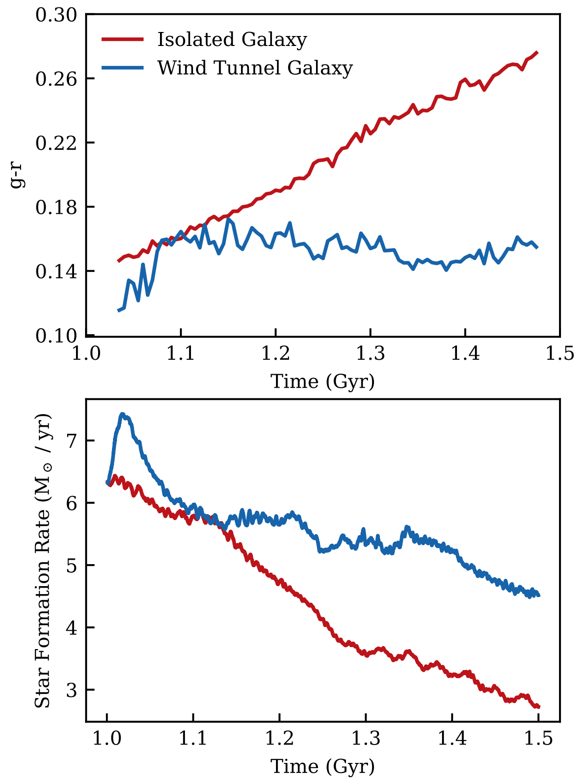

FIGURE 2. Color index g-r in SDSS filters and total star formation rate in each simulation, respectively.

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