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Are the bars in IllustrisTNG waveband dependent?

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Abstract. The phenomenon of band-shifting due to redshift is expected when observing barred galaxies. However, recent research has identified that the same galactic bar can exhibit different properties when analyzed in different filters, even locally. To investigate whether the numerical model of galaxy formation in the Illustris TNG50 cosmological simulation captures this wavelength dependence, we used the hydrodynamic information from the simulation to generate mock images with the radiative transfer code SKIRT. These idealized images were processed by adding realistic noise, convolved with appropriate PSFs, and analyzed across filters ranging from optical (Johnson R and B) to infrared (Spitzer I1) and ultraviolet (GALEX FUV and NUV). As a proof of concept, we present two examples of barred galaxy subhalos in TNG50: one exhibiting the identified dependence and another that does not. These preliminary results, based on the comparison of two galaxies, show that in the subhalo where the phenomenon manifests, the bar gradually exhibits greater ellipticity and length as the filters become bluer; however, it becomes unidentifiable in the ultraviolet, a behavior also reported in astronomical observations. Furthermore, we verified that the mass acts as a deep infrared filter, even more extreme than Spitzer. Finally, the absence of the phenomenon in one of the galaxies suggests that specific properties of the host galaxy may inhibit or favor this dependence, highlighting the need for a statistical analysis with a larger sample as a future perspective.

Resumo. O fenômeno de band-shifting devido ao redshift é esperado na observação de galáxias barradas. No entanto, pesquisas recentes identificaram que uma mesma barra galáctica pode apresentar propriedades diferentes quando analisada em diferentes filtros, mesmo localmente. Para investigar se o modelo numérico de formação de galáxias da simulação cosmológica Illustris TNG50 captura essa dependência do comprimento de onda, utilizamos as informações hidrodinâmicas da simulação para gerar mock images com o código de transferência radiativa SKIRT. Essas imagens idealizadas foram processadas com adição de ruídos realistas, convoluídas com PSFs apropriadas e analisadas em filtros que abrangem do óptico (Johnson R e B), infravermelho (Spitzer I1) até o ultravioleta (GALEX FUV e NUV). Como prova de conceito apresentamos dois exemplos de subhalos de galáxias barradas na TNG50: um que exibe a dependência identificada e outro que não. Estes resultados preliminares, baseados na comparação de duas galáxias, mostram que no subhalo em que o fenômeno se manifesta, a barra apresenta gradualmente maior elipticidade e maior comprimento à medida que os filtros tornam-se mais azuis; entretanto, torna-se não identificável no ultravioleta, comportamento também relatado em observações astronômicas. Verificamos, ainda, que a massa se apresenta como um filtro infravermelho profundo, ainda mais extremo que o Spitzer. Por fim, a ausência do fenômeno em uma das galáxias indica que propriedades específicas da galáxia hospedeira podem inibir ou favorecer essa dependência, destacando a necessidade de uma análise estatística com uma amostra maior como perspectiva futura.

Keywords. Galaxies: structure – Galaxies: stellar content – Methods: numerical

1. Introduction

TNG50, part of the IllustrisTNG project (Nelson et al 2019), models complex physical processes on a cosmological scale. Using high-resolution gravo-magneto-hydrodynamic simulations via the moving-mesh AREPO code (Springel 2010), it operates within a flat ΛCDM cosmology and includes advanced galaxy formation physics. TNG50's high spatial resolution within a 50 Mpc^3 volume allows detailed studies of subhalo morphology, particularly of galactic bars, crucial for understanding galaxy dynamics. Recent studies (Rosas-Guevara 2022; Semczuk 2024) have explored the properties of barred galaxies.

Bar studies in IllustrisTNG generally rely on mass distribution, especially stars. However, comparisons with observational research, which uses light in various filters, are challenging. Thus, radiative transfer simulations (RT) are needed to model stellar emission across wavelengths and account for dust's effect on this emission.

This study aims to assess whether the wavelength dependence of galactic bars observed by Menéndez-Delmestre (2024) is also present in barred galaxies within the IllustrisTNG simulation.

2. Methods

The radiative transfer stage of our study, simulating stars in TNG50 galaxies as sources and modeling dust properties from subhalo gas, was conducted using the Monte Carlo RT code SKIRT 9 (Baes 2020). Using the Python Toolkit for SKIRT (PTS) library, we generated images in specific observational bands by applying appropriate transmission curves. For our analysis, we produced images in the Johnson R and B filters, Spitzer I1 in the infrared and GALEX FUV and NUV in the ultraviolet, which are available in Fig. 1. Additionally, we created FITS files of the simple mass distribution using only the TNG50 star particles, without processing them through SKIRT. These mass FITS files are treated as observational bands in our analysis.

Simulated images from SKIRT are typically idealized without noises. Following previous studies using and IllustrisTNG simulations (Gonçalves & Machado 2024), we introduced two key steps for synthetic realism: adding read and sky background noise, and convolving the images with a Point Spread Function (PSF).

Bar length and ellipticity are commonly measured by fitting concentric ellipses to isophotes in the central regions of galaxies

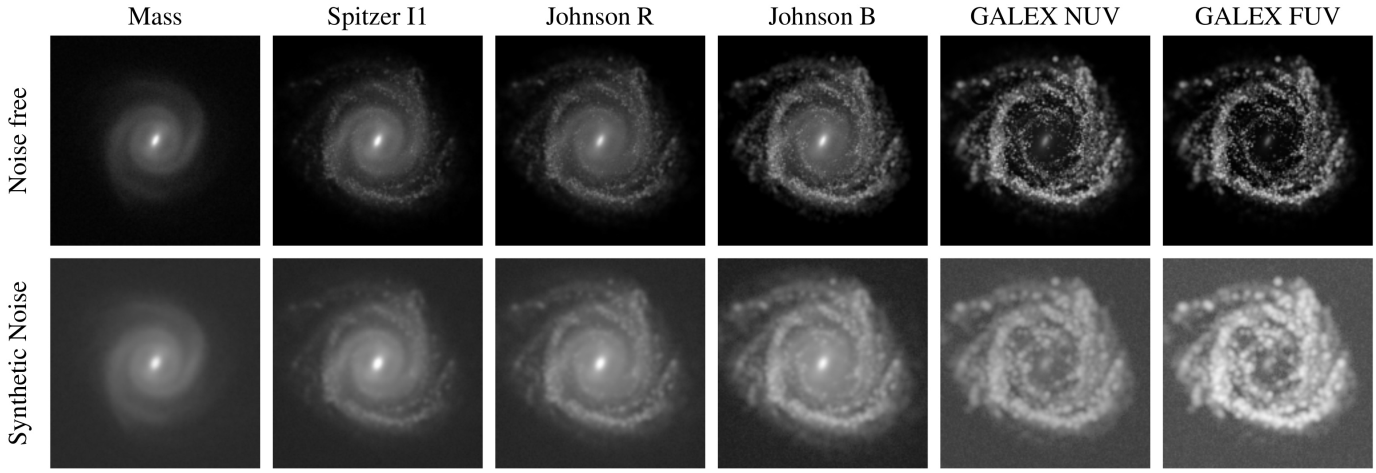

Figure 1. Comparison of mock images across our six observational bands. The top row shows noise-free images, while the bottom row includes synthetic noise and PSF. ID394621 at z = 0, with all images spanning 60 × 60 kpc and shown face-on.

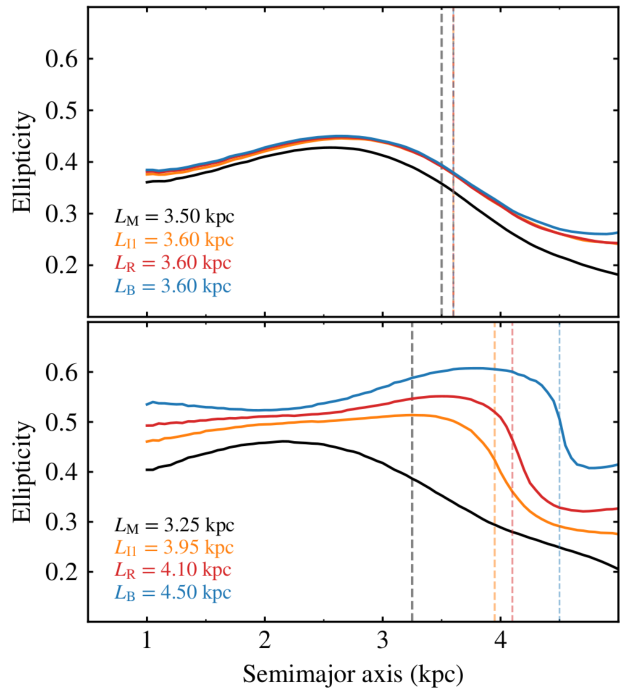

Figure 2. Ellipse-fit results for subhalos ID547844 (top panel) and ID566365 (bottom panel). Solid lines represent the results for Mass, Spitzer I1, Johnson R, and Johnson B, with dashed lines marking the bar length estimates in each band.

and identifying where ellipticity peaks and then drops, marking the bar end (Wozniak et al. 1995).

3. Results and Conclusion

The main results can be summarized as follows:

- The results show wavelength dependence of bar properties in the TNG50 simulation (Fig. 2).
- The simulated bars are monotonically more elliptical and longer in bluer filters.
- The bar could not be measured in UV bands, a limitation also reported in observational galaxies.
- The mass maps acts as a deep infrared filter, even more extreme than Spitzer.
- These findings are consistent with recent observational results, supporting the variation of galactic bar properties with wavelength.

The TNG50 simulation has shown the presence of wavelength dependence in its stellar population model, with realistic mock images serving as crucial links that bridge state-of-the-art galaxy formation models and observational astronomy. The fact that some subhalos do not exhibit this wavelength dependence suggests that this phenomenon is not merely a bias caused by variations in the flux distribution across filters, but rather a morphological property, highlighting the need for a statistical analysis with a larger sample as a future perspective.

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References

Camps, M. & Baes, P. 2020, A&C, 31, 100381
Gonçalves, G. F. & Machado, R. E. G. 2024, RNAAS, 8, 217
Menéndez-Delmestre, K. et al. 2024, MNRAS, 527, 11777
Nelson, D. et al. 2019, ComAC, 6, 2
Rosas-Guevara, Y. et al. 2022, MNRAS, 512, 5339
Semczuk, M., Dehnen, W., Schönrich, R. & Athanassoula, E. 2024, arXiv, arXiv:2407.11154
Springel, V. 2010, MNRAS, 401, 791
Wozniak, H., Friedli, D., Martinet, K., Martin, P. & Bratschi, P. 1995, A&AS, 111, 115