Lopsided galaxies in TNG50

Silvio Varela-Lavin[1,2], Facundo Gomez[1,2], Patricia Tissera[3,4]
[1]Departamento de Física y Astronomía, Universidad de La Serena, Chile
[2]Instituto de Investigación Multidisciplinar en Ciencia y Tecnología, Universidad de La Serena
[3]Instituto de Astrofísica, Pontificia Universidad Católica, Chile
[4]Centro de Astro-Ingeniería, Pontificia Universidad Católica de Chile

Abstract

Many spiral galaxies show different asymmetric features on their morphology, such as warps, lopsidedness, polar rings, among others. In particular, a significant percentage of lopsided galaxies have been reported in previous research. These galaxies display a global non-axisymmetric mass distribution of type m=1. Currently, little attention has been paid to the origin of this asymmetric perturbation. Using the TNG50 simulations we study the formation of lopsided galaxies. We explore different mechanism for the formation of this perturbation. Interestingly, our results clearly shows a strong correlation between lopsidedness and stellar mass concentration. More concentrated galaxies are significantly less susceptible to this type of perturbation than their less concentrated counterparts.

Simulations and Methods

We use cosmological simulations from the Illustris TNG 50 project to characterize and analyze disk galaxies that display a non-axisymmetric global light distribution of type m=1, known as lopsided galaxies. We select galaxies embedded Milky Way mas halos, i.e. M_{200} between $10^{11.5}$ and $10^{12.5}$ $M_{\odot}$.The galaxies are required to have a disc-to-total mass ratio (D/T) greater than 0.5. This criteria gives us a total of 240 galaxies.

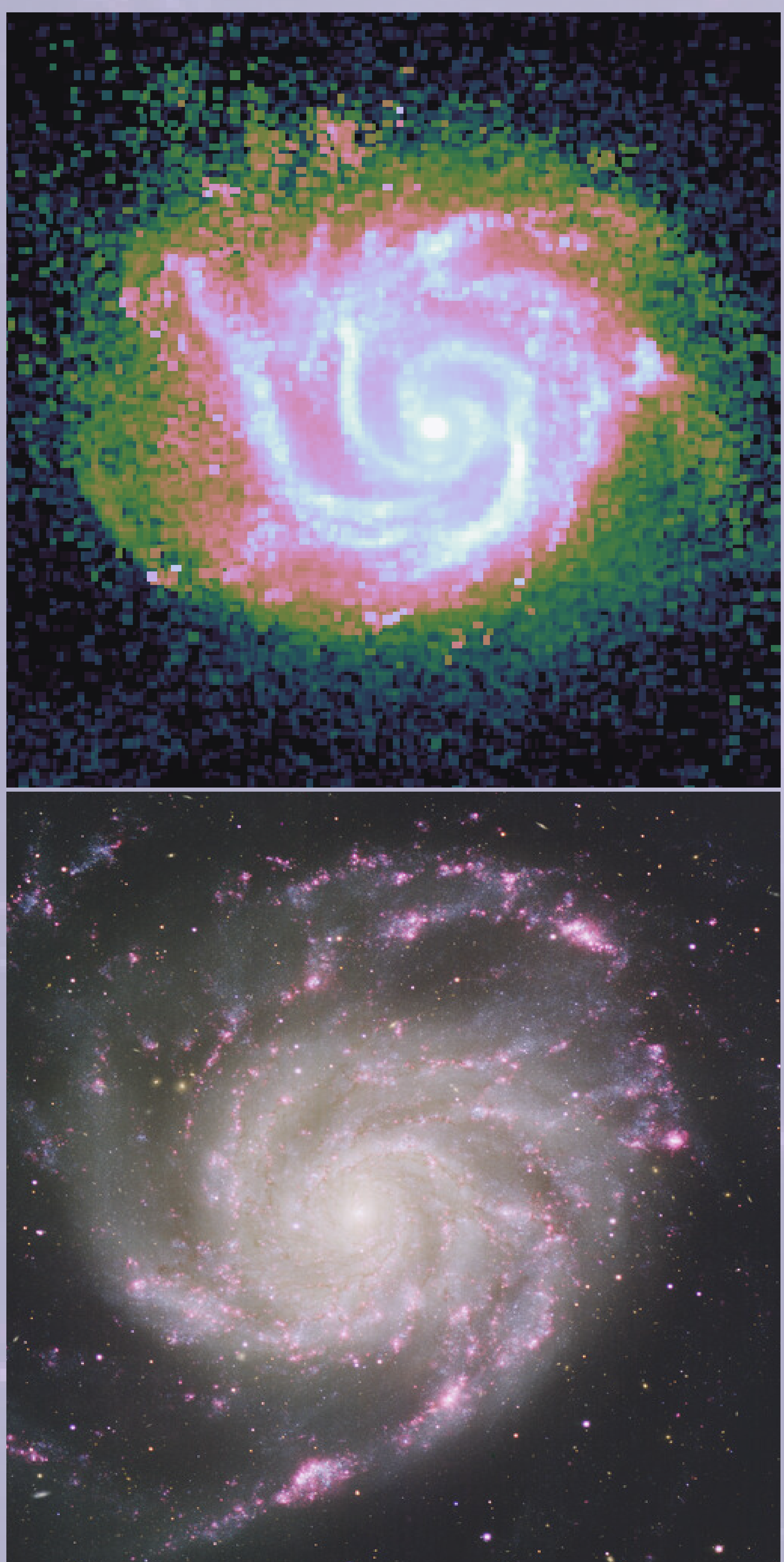
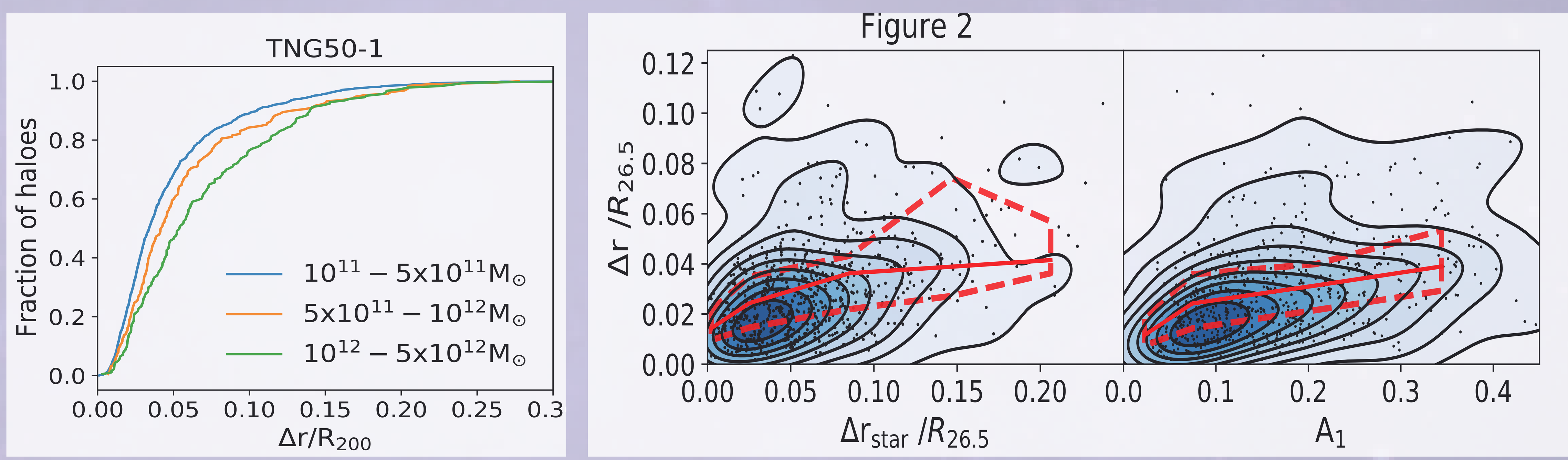


Figure 1: *In the bottom panel is M101, one of the most classic lopsided galaxies. The top panel is one of the most asymmetrical discs in our sample.*

Amplitude of the m=1 Fourier component. In order to quantify the asymmetry of the stellar disk we adopt the Fourier mode approach. The amplitude of the first Fourier mode, A_1, is calculated using concentric annulus of $0.1R_{26.5}$ width, from 0.4 to 1.2 $R_{26.5}$. Where $R_{26.5}$ is the optical radius in the V band.

Dark matter halo offset

It has been previously suggested that the origin of lopsided mode could be associated to a offset between the center of mass of DM halo and the galaxy center of density. In order to analyze this offset and compare them with A_1, we followed the analysis performed by Gao & White (2006). We calculate the offset of the center of mass of DM halo, r_{DM}, with respect to the position of the most bound particle, r_{core} as $\Delta r = r_{core} - r_{DM}$. Similarly we define the offset of the center of mass of the stellar disk as Δr_{star}. In **Figure 2 (left panel)**, we show the central halos cumulative distribution for three ranges of M_{200} as a function of Δr. Our results are consistent with those of Gao & White (2006) who shows that more massive halos tend to have larger asymmetries. In **Fig. 2. (right panel)** we compare the DM halo offset as a function of A_1 and Δr_{star} of each galaxy. We find a very weak correlation between the asymmetry of the DM halo and its stellar component. This suggest that DM halo offsets are not the main driver of lopsidedness. We also find that the correlation between lopsidedness and other mechanisms, such as satellite interactions and cold gas accretion, is not strong either.



Characterizing stellar asymmetries through time

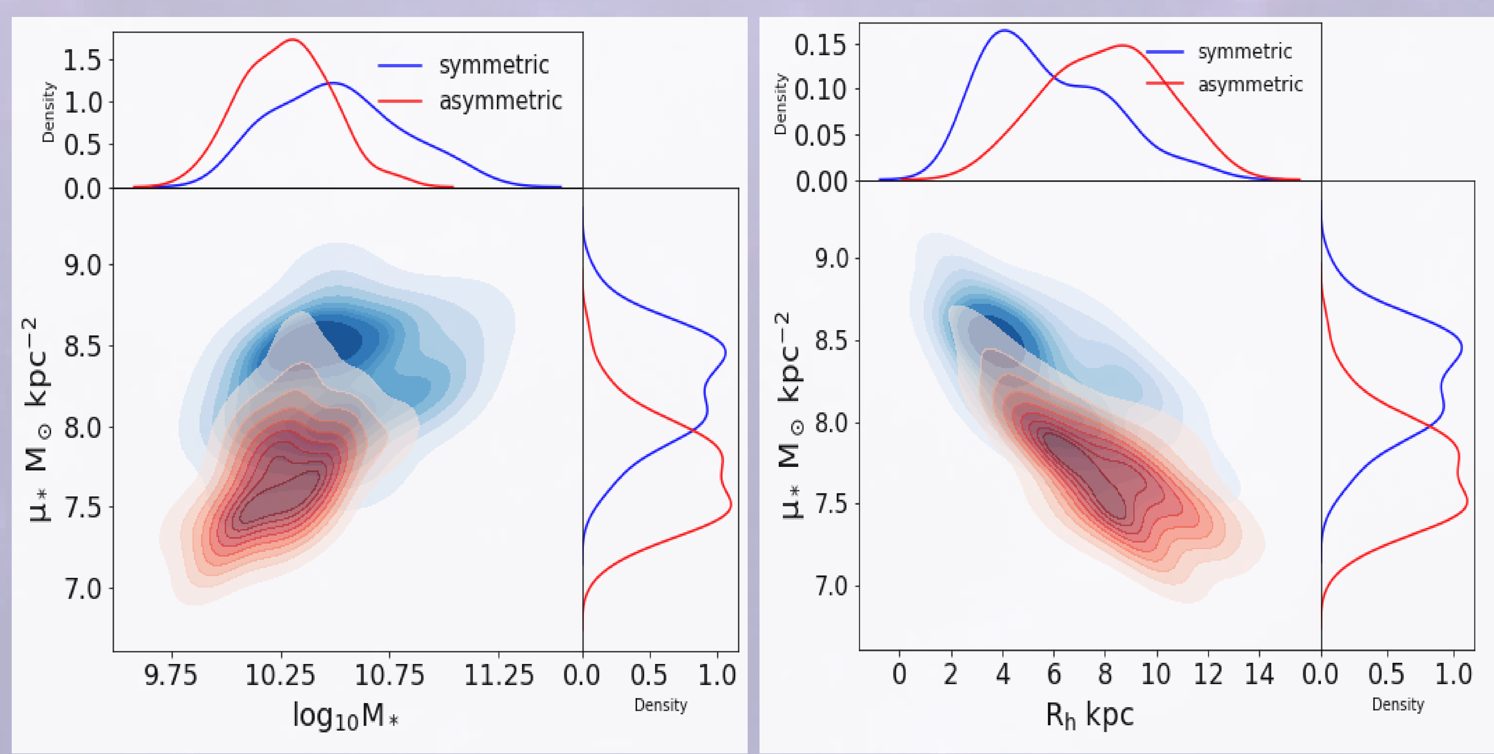


Figure 3

To understand the origin of lopsidedness, we select the 50% most symmetrical and asymmetric galaxies, and explore the space of central surface density $\mu*$, half mass radius, R_h, and the mass enclosed withing R_h, M_h. Asymmetric disks tend to have low concentration and also extended distribution (**Fig. 3**). **Fig. 4** shows the results of stacking M_h, R_h and $\mu*$ as a function of time, taking the last 7 Gyr. The most asymmetric galaxies tend to be less massive at all times, although both sample show a similar growth rate. However, the R_h of asymmetric galaxies grows significantly more rapidly on the the asymmetric objects. As a consequence of this, their stellar density drops significantly over time.

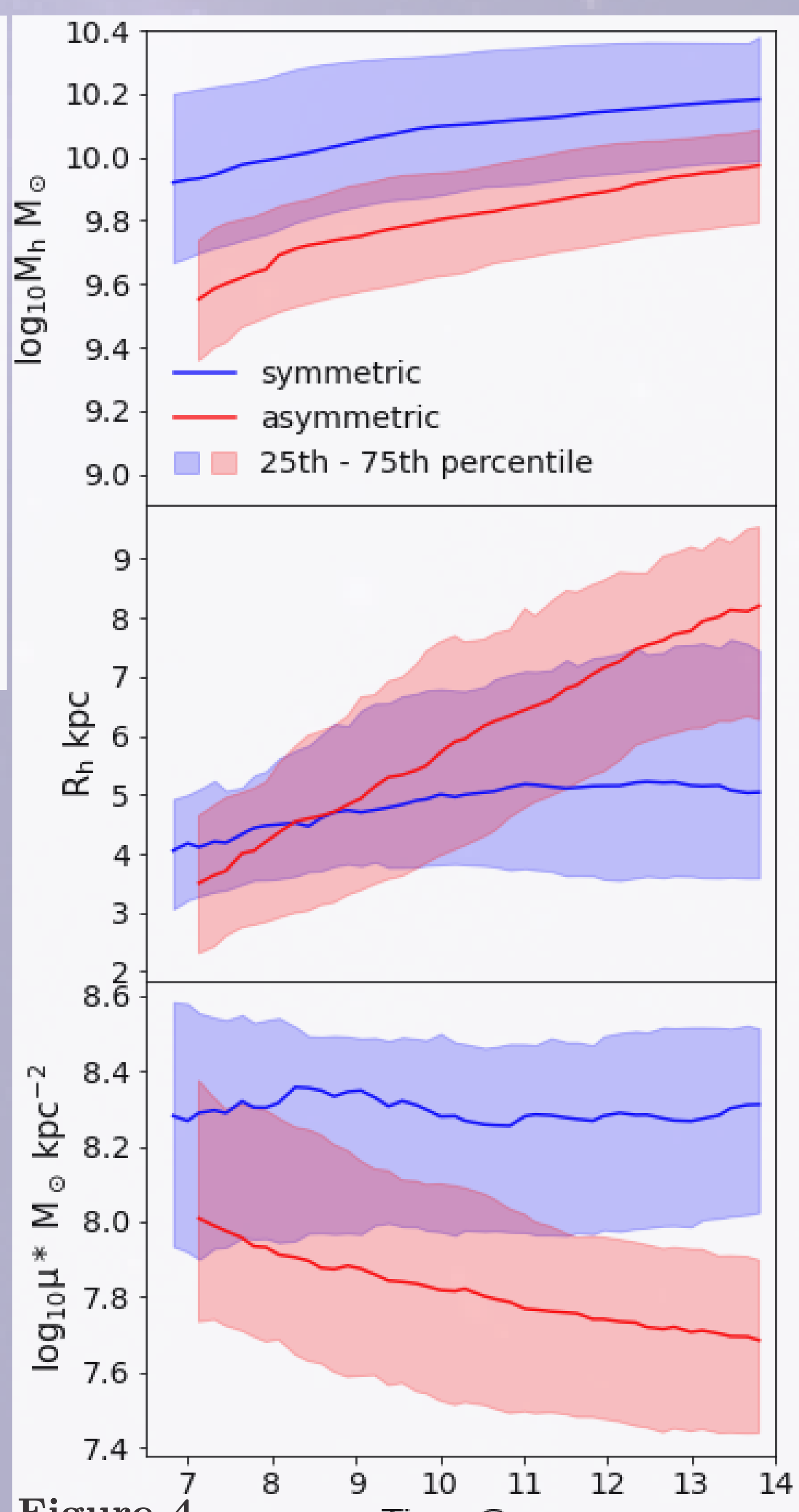


Figure 4

Conclusion

- The correlation between offset in DM halos and asymmetry parameters, such as, A_1 and Δr_{star} is not strong. Similar results are found for other mechanisms as interaction and gas accretion.
- Our sample show a clear relation lopsidedness and galaxy mass distribution. Less asymmetric galaxies have a more concentrated stellar mass distribution than their more asymmetric counterparts.
- Generally, our study, suggest that the high asymmetries galaxies have a prolonged interaction with the environment, in addition to being discs that are not very self-gravitating.

Acknowledgements

SVL acknowledges financial support from the ULS through the "Beca Doctoral". FAG and SVL acknowledges financial support from CONICYT through the project FONDECYT Regular Nr. 1211370. FAG acknowledge funding from the Max Planck Society through a Partner Group grant.