AGN in Illustris

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Abstract

Theory predicts that galaxy mergers and interactions are among the primary triggers for Active Galactic Nuclei (AGN). Observational studies investigating this proposed connection find a mix of evidence supporting and contradicting this theory. It is unclear how secular processes could trigger the most luminous AGN, but evidence for merger-triggering is not completely clear. Using the IllustrisTNG project, we select AGN using a luminosity cut of $L_{bol} > 10^{44}$ ergs/s and analyse their merger history to determine if recent mergers could be the cause of the AGN activity. We use the SUBLINK merger trees to determine the time elapsed since the most recent merger. We find no correlation between merger mass ratio and AGN luminosity, and no clear trend between AGN luminosity and time elapsed since the most recent merger. We do, however, find that the brightest AGN are more likely to be found in host galaxies that have recently undergone a merger (minor or major) than galaxies, than less luminous AGN.

1 Introduction

Galaxy mergers play an important role in galaxy evolution, and are thought to be one of the driving mechanisms behind AGN activity. Numerous studies, both observational and theoretical, have found a variety of results on the presence or absence of a connection between AGN and mergers (Hopkins, Hernquist, Cox, Di Matteo, et al. 2006, Treister et al. 2012, Donley et al. 2018, Ellison et al. 2019). Some simulations note the difficulty in growing supermassive black holes without the use of mergers to ignite AGN activity by driving dust into an accretion disk (Dubois et al. 2016)

In particular, a recent study by Villforth et al. (2017) found no connection between major mergers and AGN for the highest luminosity AGN. They utilized a redshift range of $0.7 \geq z \geq 0.5$, and selected quasars with using a bolometric cutoff of $L_{bol} > 10^{45}$ ergs/s, as it is the presumed cutoff for merger-triggered AGN activity (Villforth et al. 2017).

2 Methodology

2.1 IllustrisTNG Project

IllustrisTNG are a series of magnetohydrodynamical cosmological galaxy formation simulations, beginning shortly after the Big Bang and ending at redshift z=0 (Nelson, Springel, et al. 2019). This study utilized the TNG100-2 run, (Pillepich et al. 2018, Springel et al. 2018, Nelson, Pillepich, et al. 2018, Naiman et al. 2018, Marinacci et al. 2018), the medium-resolution run of the simulation of a 100 Mpc side-length cube. TNG100 focuses on the same 'box' as the original Illustris simulations

2.2 Merger Trees

IllustrisTNG makes use of the SUBLINK algorithm (Rodriguez-Gomez et al. 2015) to construct merger trees. The SUBLINK merger trees were constructed by tracking the progenitor galaxies of a specific subhalo, and gathering all of the progenitors of the descendant into a tree (Rodriguez-Gomez et al. 2015). The merger trees were used to determine when the most recent merger occurred and whether it was a major or minor merger. Further details on the construction of the merger trees can be found in Rodriguez-Gomez et al. 2015.

2.3 AGN

Using snapshots 59 through 67, corresponding to a redshift range of $0.7 \leq z \leq 0.5$, we selected our AGN using a luminosity cut of $L_{bol} \geq 10^{44}$ ergs/s. Bolometric luminosities were calculated for each black hole in a given snapshot using the equation $L_{bol} = \epsilon c^2 \dot{M}$, with an assumed efficiency of $\epsilon = 0.1$. After an AGN was selected, its merger tree was investigated to determine the mass ratio of its most recent merger, as well as the snapshot number of that most recent merger. This snapshot number was then converted into an elapsed time from the snapshot at which the AGN was selected. We expect that if AGN activity is sparked by mergers, we should see it persist for approximately 0.25 Gyr after final coalescence (Hopkins, Hernquist, Cox, and Kereš 2008). Theory also suggests that AGN activity may be ignited ~ 1 Gyr before final coalescence, but these effects are not investigated here.

Our AGN sample consisted of 1540 AGN, spanning a luminosity range from $L_{bol} = 10^{44} - 10^{45.7}$ ergs/s. It is noteworthy that none of the AGN in TNG100 had a bolometric luminosity above $10^{45.7}$ ergs/s, and only a handful were above 10^{45} ergs/s, in contrast to observational studies such as Villforth et al (2017), which found several AGN with bolometric luminosities in excess of 10^{46}, even reaching up to 10^{47}.

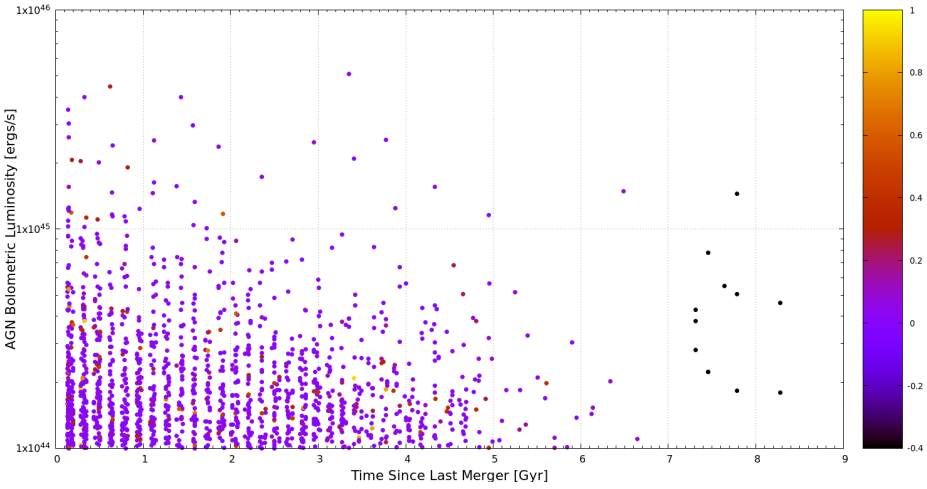

Figure 1: AGN plotted by luminosity and time since their most recent merger. The colorbar represents the merger mass ratio, with the minimum mass ratio set to 10^{-6}. Galaxies that have never undergone a merger are designated as having a mass ratio of -0.4, and the time since their last merger is listed as the age of the universe at the snapshot of AGN activity. Note that there appears to be little to no correlation between presence of an AGN and recent merger, as evidenced by the large number of AGN that have not undergone a merger within 1 Gyr of detection.

3 Results and Discussion

We find that the full luminosity range of our sample does not show a significant link between galaxies that have recently undergone a major merger and galaxies that host an AGN. As shown in figure 1, twelve of the AGN shown here have never undergone a merger, and of the highest luminosity AGN, only a few have undergone recent major mergers ($\mu_m \geq 0.3$). Additionally, even looking only at the AGN in host galaxies that have undergone a merger within the past gigayear, the majority of AGN across all luminosities have been only minor mergers, with no clear trend at either end of the luminosity spectrum.

Similarly, looking only at galaxies that have undergone a merger within the past gigayear, there still appears to be no connection between galaxies that have undergone a merger and AGN luminosity. Figure 2 shows that major mergers are found in all luminosity ranges, and even at the highest luminosities, galaxies are no more likely to be found in a major merger than a minor merger.

At the other side of the spectrum, if we instead investigate what fraction of AGN have been involved in a merger within the past 1 Gyr, we see a different picture begin to emerge. As demonstrated in figure 3, the highest luminosity AGN are more likely to be found in galaxies that have undergone a merger within the past 1 Gyr. Interestingly, however, AGN with luminosities between

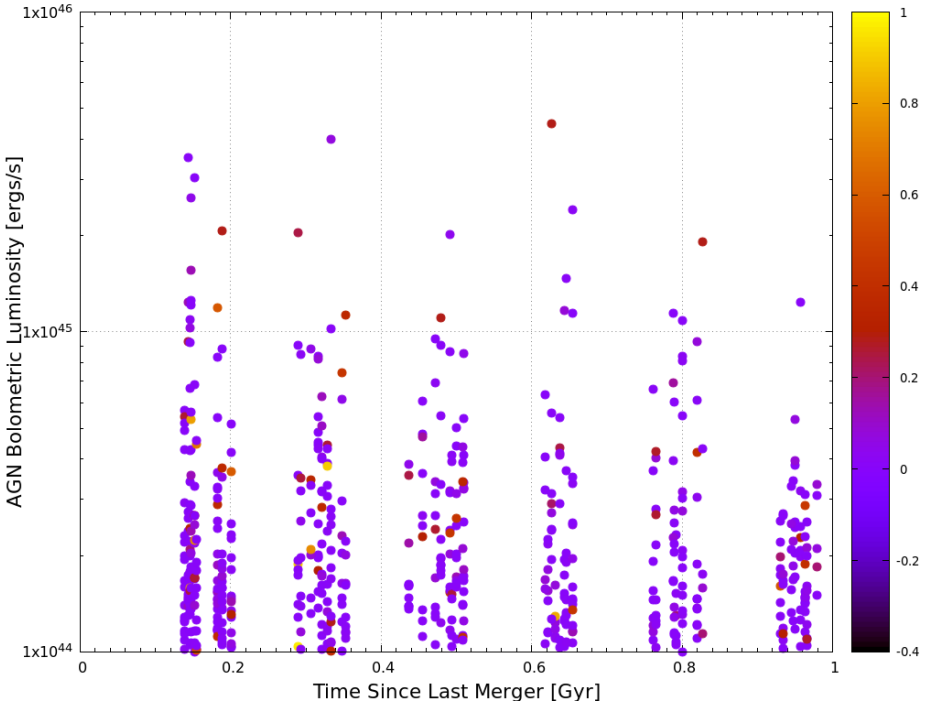

Figure 2: AGN plotted by luminosity and time elapsed since the most recent merger, with only the galaxies that have undergone a merger in the past 1 Gyr shown. The colorbar depicts the merger mass ratio, with the minimum mass ratio considered a merger as 10^{-6}. It can be seen that there is no discernible correlation between AGN bolometric luminosity and merger mass ratio, or between bolometric luminosity and time elapsed since final coalescence.

$7-8\times10^{44}$ ergs/s are very rarely seen in the aftermath of a merger. This finding is surprising and will need to be investigated further to be better understood.

4 Conclusions

We present a study of AGN in IllustrisTNG, comparing their bolometric luminosities to the time elapsed since final coalescence of the most recent galaxy merger. While comparing luminosity, time elapsed, and mass ratio of the most recent merger, we find no visible connection between mergers and AGN activity. However, when plotting the AGN bolometric luminosity against the fraction of AGN in that luminosity bin that have undergone a recent merger, we do find that the merger fraction is significantly higher for luminosities $L_{bol} \geq 8^44$ ergs/s, than it is for lower luminosities.

In fact, for these luminous AGN, we find that their host galaxies are more

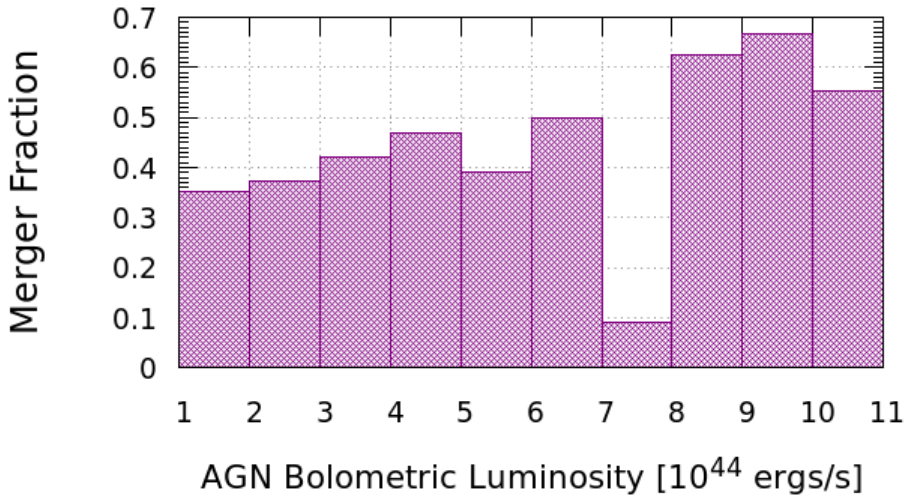

Figure 3: Fraction of AGN that have undergone a merger within the past 1 Gyr. Note that the highest luminosity AGN ($L_{bol} > 8 * 10^{44}$ergs/s) are more likely to be found in galaxies that have undergone a recent merger than to be found in quiescent galaxies.

likely to have undergone a recent merger than not. Further work will be needed to investigate the likelihood of AGN being found in the gigayear prior to final coalescence of the merging system, and to investigate properties of the host galaxies such as gas fractions and if the high luminosity AGN that appear to be caused by secular processes are simply found in more gas rich environments than their counterparts.

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