**Merger trees**

Galaxies often evolve together with neighboring galaxies. This complexity makes it challenging to trace the history and evolution of galaxies. A helpful tool to understand the evolution and formation is merger trees which portray and explain dark matter haloes’ hierarchical mass assembly and evolution [1] [30]. Halo merger trees are the backbone of galaxy formation and evolution modelling [90], and are especially central in SAMs [89], [88], [87].

Merger trees are usually built using two steps. The first step is to analyze each time-step output to locate dark matter collapsed structures, haloes, and halo catalogs. After that is completed, haloes are connected across different time-steps which provide the merger history (merger tree) of the haloes [2] [3].

There are multiple ways to construct merger trees, the most popular method is based on high resolution dark matter only (N-body) simulations. This method manages to produce realistic evolutionary history of haloes and can produce multiple merger trees at the same time. This, however, comes with the cost of being computationally expensive and require long runs. [30], [135], [132], [129], [128], [127], [126], [125], (Kauffmann et al., 1999; Hatton et al., 2003; De Lucia et al., 2004; Croton et al., 2006; Bower et al., 2006; Guo et al., 2011; Lee et al., 2014). [2]

Another simple but fairly effective method to produce halo merger trees that is based on Monte Carlo simulations (Kauffmann & White 1993; Kauffmann et al. 1993; Cole et al. 1994) and extended Press-Schechter formalism (Bond et al. 1991). This method can only construct one merger tree at a time which often is inconsistent with simulations (Jiang & van den Bosch 2014). Even though the downside of this method is well known, it is still described as especially reliable for hierarchical universe mass history descriptions and efficient both in terms of speed and quality results with high mass resolution.[30], [133], [123], [122], [122], [121], [120] (Lacey & Cole 1993; Somerville & Primack 1999; Cole et al. 2000; Somerville et al. 2008; Benson & Bower 2010; Ricciardelli & Franceschini 2010).

Other methods like cosmological N-body simulations rely heavily on complex clustering algorithms to find haloes and build trees and have mass resolution limit which can make it challenging to identify substructures for halo finders while being computationally expensive. [119], [118], [117], [116], [115], [114] (Knebe et al. 2011; Avila et al. 2014; Gómez et al. 2022; Muldrew et al. 2011; Onions et al. 2013; Elahi et al. 2013).

In other words, there exists multiple methods for merger tree constructions that produces decent results, but these methods are computationally intensive, rely on complex algorithms, produce inconsistent constructions, or can only produce one tree at a time.

The main issue with the different methods of producing halo merger trees is that they produce different results since the methods care about distinctive patterns and structures. Different merger tree building algorithms have different errors and inconsistencies which yield dissimilar results and generate distinct halo growth histories. [3] When applying merger trees to SAMs, the differences between them can alter the galaxy properties and results of the SAM [125]. Simply put, different merger tree algorithms can create merger trees that are significantly different, even though they come from the same halo catalog [30]. This is what Robles et al. (2022) focuses on in their paper, where they analyze two different merger tree builder algorithms [3]. Srisawat et al. (2013) did a more comprehensive project regarding merger tree construction algorithms and their difference. They compared 10 different merger tree construction algorithms and applied the generated merger trees to the same simulations. The results indicated an uncomfortable quantity of inconsistency and differences [86]. This is an occurring result that have been examined and research [117] [118], [125]. Since SAM are sensitive to the differences in merger tree constructions, it is crucial to use consistent and well-constructed merger trees in SAMs [117].

Since SAMs are sensitive to the differences in merger trees that occurs from the choice of merger tree construction algorithms, it is important to understand the merger trees before they are applied as input for galaxy formation models [125].