

Metallicity evolution in mergers of disk galaxies with black holes

Antti Rantala and Peter H. Johansson

Department of Physics, University of Helsinki,
Gustaf Hällströmin katu 2a, 00560 Helsinki, Finland

antti.rantala@helsinki.fi

peter.johansson@helsinki.fi

Abstract. We use the TreeSPH simulation code Gadget-3 including a recently improved smoothed particle hydrodynamics (SPH) module, a detailed metallicity evolution model and sophisticated subresolution feedback models for supernovae and supermassive black holes in order to study the metallicity evolution in disk galaxy mergers. In addition, we examine the simulated morphology, star formation histories, metallicity gradients and kinematic properties of merging galaxies and merger remnants. We will compare our simulation results with observations of the early-type Centaurus A galaxy and the currently colliding Antennae galaxies.

Keywords. galaxies: abundances, galaxies: evolution, galaxies: formation, galaxies: interactions, methods: n-body simulations.

1. Introduction

A scenario has been put forward in which intermediate-mass, fast-rotating elliptical galaxies have been formed in mergers of disk galaxies (e.g. Naab *et al.* 2007, Johansson *et al.* 2009). The first galaxy interaction simulations by Toomre & Toomre (1972) contained only collisionless N-body particles. The development of SPH (see Monaghan 1992 for a review and e.g. Hu *et al.* 2014 for recent improvements) and computationally inexpensive gravitational force algorithms (e.g. the tree code) led eventually to modern galaxy merger codes such as Gadget (Springel 2005). Present-day simulations containing subresolution astrophysical models for gas and stellar metallicity, star formation, supernova feedback (Scannapieco *et al.* 2006) and supermassive black hole (SMBH) feedback (Springel *et al.* 2005, Choi *et al.* 2014) enable detailed comparisons with observations.

2. Metals in Merger Simulations

Following the approach of Johansson *et al.* (2009), we construct two disk galaxies consisting of a dark matter halo, a rotationally supported disk of gas and stars, and a central bulge. Both the bulge and halo component have Hernquist-like density profiles while the disk component is of an exponential form. We employ both random orbital geometries for large simulation samples and specific orbital geometries set to match observed galaxy mergers, such as the Antennae galaxies (Karl *et al.* 2010). We set the initial fractional abundances of 10 metal species (C, N, O, Ne, Mg, Si, S, Ca and Fe) in the following way. Observations indicate that a radial metallicity gradient exists in disk galaxies. We use dex units ($\text{dex} = 12 + \log_{10}(X/H)$) in which the radial abundance gradient is close to a linear form: $\text{dex}(r) = \text{dex}(r_0) + k(r - r_0)$, where r_0 is a scale radius and k is the negative metallicity gradient (Zaritsky *et al.* 1994, Kilian *et al.* 1994). The vertical abundance gradient is set in a similar way, motivated by observations from Ivezić *et al.* (2008). The ages of disk and bulge stars are initialized at $t = 0$ from an exponentially

decaying star formation rate ($\text{SFR} \propto \exp(-t/\tau)$) with $\tau = 1$ Gyr for bulge stars and $\tau = 4$ Gyr for disk stars. The interstellar medium is enriched during the simulation by Type Ia and II supernovae and winds of AGB stars with metal yields calculated by Iwamoto *et al.* (1999), Woosley & Weaver (1995) and Karakas (2010), respectively. Gas metallicity is smoothed using a metal diffusion technique between neighboring gas particles (Aumer *et al.* 2013).

3. Ongoing and Future Work

Currently (September 2014), the initial conditions of the merger simulations have been prepared and high-resolution simulations will be run in late 2014. We study especially the impact of SMBH feedback on the metallicity evolution in galaxy mergers, since previous studies have not considered both detailed metallicity evolution models and black holes at the same time. We also plan to study the triggering mechanisms of active galactic nuclei (AGN) in the aftermath of galaxy mergers as these systems with high BH accretion rates at high redshifts are possible quasar host galaxy candidates. We will produce simulated spectral energy distributions of quasar host galaxies using stellar population modelling techniques and compare the results with the observed properties of quasar host galaxies (Kotilainen *et al.* 2009).

References

- Aumer, M., White, S. D. M., Naab, T., & Scannapieco, C. 2013, *MNRAS*, 434, 3142
 Choi, E., Naab, T., Ostriker, J. P., Johansson, P. H., & Moster, B. P. 2014, *MNRAS*, 442, 440
 Hu, C.-Y., Naab, T., Walch, S., Moster, B. P., & Oser, L. 2014, *MNRAS*, 443, 1173
 Johansson, P. H., Naab, T., & Burkert, A. 2009a, *ApJ*, 690, 802
 Ivezić, Ž., Sesar, B., Jurić, M., *et al.* 2008, *ApJ*, 684, 287
 Iwamoto, K., Brachwitz, F., Nomoto, K., *et al.* 1999, *ApJS*, 125, 439
 Karakas, A. I. 2010, *MNRAS*, 403, 1413
 Karl, S. J., Naab, T., Johansson, P. H., *et al.* 2010, *ApJ*, 715, L88
 Kilian, J., Montenbruck, O., & Nissen, P. E. 1994, *A&A*, 284, 437
 Kotilainen, J. K., Falomo, R., Decarli, R., *et al.* 2009, *ApJ*, 703, 1663
 Monaghan, J. J. 1992, *ARA&A*, 30, 543
 Naab, T., Johansson, P. H., Ostriker, J. P., & Efstathiou, G. 2007, *ApJ*, 658, 710
 Scannapieco, C., Tissera, P. B., White, S. D. M., & Springel, V. 2006, *MNRAS*, 371, 1125
 Springel, V. 2005, *MNRAS*, 364, 1105
 Springel, V., Di Matteo, T., & Hernquist, L. 2005, *MNRAS*, 361, 776
 Toomre, A. & Toomre, J. 1972, *ApJ*, 178, 623
 Woosley, S. E. & Weaver, T. A. 1995, *ApJS*, 101, 181
 Zaritsky, D., Kennicutt, R. C., Jr., & Huchra, J. P. 1994, *ApJ*, 420, 87