GADGET-2 simulation for active galactic nuclei feedback in galaxy NGC 5252

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Abstract. We present a numerical simulation of active galactic nuclei (AGN) feedback in galaxy NGC 5252, while galaxy has gas, halo, disk, and bulge particles. We set up one bulge particle's mass to represent the black hole mass. According to the result from numerical simulation of active galactic nuclei feedback, we interpret that the gas provides some gas feedback at large distant approximately around 10 kpc. We generate initial condition, as known as IC file of the galaxy, including a stellar disk and gas particles following an exponential density profile. A dark matter halo and a stellar bulge follow a Dehnen density profile. GADGET-2 was used to calculate the distribution of particles in galaxy simulation, which is based on smoothed particle hydrodynamics method. Ultimately, we study the gas feedback of active galactic nuclei in the form of outflow gas with numerical simulations. From preliminary result show that the gas particles seem to evolve with time and concentrate on the later time near 5 to 10 kpc.

1. Introduction
AGNs are one of the most energetic sources in the universe. It is widely accepted that AGNs are powered by accretion of matter onto massive black holes (BH). Feedback from AGN is a key to understand galaxy evolution. The evidence of such feedback has been observed to interact with the intergalactic medium out to 10 kpc in projection from the AGN, suitable for studying the history of AGN [1].

NGC 5252 is a Seyfert 2 galaxy at a redshift z = 0.0228. NGC 5252 has long been perhaps the best-known example of an AGN with ionization cones. This edge-on S0 system (lenticular galaxy) has a half-spiral of dust. It is to study its nuclear kinematics and to determine the mass of its central BH. Its nucleus illuminates a well-defined biconical structure of ionized gas. The large angular extent of the ionized gas, distributed in a remarkable bicone extending more than 10 kpc from the nucleus [2], arguably provides a unique opportunity for investigating the above issues.

The paper is organized as follows. In section 2, we provide NGC 5252 properties. In section 3, we describe the simulation of NGC 5252 model. The results and discussion are described in section 4, and the conclusions and future work are provided in section 5.
2. NGC 5252 properties

NGC 5252 is a Seyfert 2 galaxy at a redshift \( z = 0.0228 \). The ellipticity is essentially constant at a value of 0.45 [3]. The total mass of gas; \( M_{H_2} = 4.7 \times 10^5 M_\odot \) [4], the BH mass; \( M_{BH} = 1.0^{+0.2}_{-0.4} \times 10^9 M_\odot \), the total mass of stellar bulge; \( M_{Bulge} = 2.4 \pm 0.9 \times 10^{11} M_\odot \) [5], the total mass of halo; \( M_{Halo} = 2.0 \times 10^{12} M_\odot \) [6] and the total mass of stellar disk; \( M_{Disk} = 3.2 \times 10^{10} M_\odot \) [7]. We use each value of the total mass to generate the IC for the NGC 5252 model.

3. Simulation

Our simulations use GAlaxies with Dark matter and Gas intEracT-2 (GADGET-2) [8] model, which is a freely available code for cosmological simulations following a collisionless fluid with the N-body method, and an ideal gas with smoothed particle hydrodynamics (SPH). GADGET-2 program was used to calculate the distribution of particles in galaxy simulation. The heating process in GADGET-2 is heating by photoionization has been applied in GADGET-2 [9]. In this work, we study kinetic feedback of the system. The BH feedback drives the mass of outflow gas. The initial conditions of the NGC 5252 model were generated using the codes galstep [10]. NGC 5252 model was simulated according to plausible NGC 5252 properties. We use cosmological parameter from Planck 2015 results XIII. For cosmological parameters [11], we use \( h = 0.6774 \), \( \Omega_m = 0.3089 \), \( \Omega_{\lambda} = 0.6911 \), and \( \Omega_k = 0.0486 \). This model has 4 types of particles (gas, halo, disk, and bulge). For each particle type (gas, halo, disk, and bulge) contain 250,000 particles. We set up one bulge particle’s mass to represent the black hole mass. The initial conditions for the NGC 5252 model have used a total of mass for each particle types in section 2. We use Dehnen profile and exponential profile for this model.

The dark matter halo and bulge component follow a Dehnen density profile [12]:

\[
\rho(r) = \frac{(3 - \gamma)M}{4\pi} \frac{a}{r^{\gamma}(r + a)^{4-\gamma}},
\]

where \( M \) is the total mass of the particle component and \( a \) is a scale factor. We use \( \gamma = 1 \).

The gas and the disk components follow an exponential profile [10]:

\[
\rho(R, z) = \frac{M}{4\pi R_d z_0} \exp\left(-\frac{R}{R_d}\right) \text{sech}^2\left(\frac{z}{z_0}\right),
\]

when \( R_d \) is radial scale and \( z_0 \) is vertical scale.

4. Results and discussion

The mass distribution was originally confined within 20 kpc and slowly evolves with time and reduces to have the mass confined within 15 kpc, as shown in figure 1.

![Figure 1](image-url)

Figure 1. Accumulative of gas’s mass as function of radius at t=0.0 Gyr (a), t=1.0 Gyr (b), and t=2.0 Gyr (c).
There is expansion behavior of the gas as seen by distance from the center of the boundary. The radius size is expanding to a larger distance specifically from 10 kpc to 30 kpc. The result also shows that the gas particles seem to have different distributions between the exponential distribution at the beginning and localized distribution in later time near 5 to 10 kpc, as shown by peak feature in figure 2. We got the result from figure 2 that system may not change after time = 1 Gyr.

![Figure 2. Number of gas's particles as function of radius at t=0.0 Gyr (a), t=1.0 Gyr (b), and t=2.0 Gyr (c).](image)

For small distance, the velocity starts with a very high value (750 km/s) and decrease to 600 km/s. At ten kpc the highest velocity (750 km/s) was found and drop to 600 km/s. At the boundary of approximately 50 kpc the velocity significantly drops from 550 km/s to 200 km/s. From figure 3, we found some gas particles far from the center more than 100 kpc. These results suggest that according to figure 2 the distribution of gas particles to larger distance could cause in the momentum loss, and consequently the drop of velocity.

![Figure 3. Evolution of gas's velocity profile at t=0.0 Gyr (a), t=1.0 Gyr (b), and t=2.0 Gyr (c).](image)

However, at 10 kpc, unlike figure 2, the velocity curve shows no evidence of the feedback. This implies that the feedback might affect more on the particle distribution, but not velocity. When compare the simulation with observation, this simulation does not provide some trends of gas feedback at a later time. From figure 2, feedback maybe appears on a small scale of time.

5. Conclusions
The result in figure 2, the gas particles seem to evolve with time and concentrate on the later time near 10 kpc. The velocity distribution of gas particles shows decreasing of velocity with distance could be caused by the momentum loss. This feedback might affect more on the particle distribution. The simulation may not be far enough to represent the feedback behavior properly.
because the resolution of simulation may not be enough and time step of the simulation is too far apart, but this work provides some result from simulation gas feedback of NGC 5252 near 10 kpc. In future work, we need to simulate this system in high-resolution simulation and use a small time step to study this simulation.

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