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HI and OVI Emission from the Circum-Galactic Medium with a large sample of cosmological hydrodynamical simulations

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ABSTRACT

We use the NIHAO galaxy formation simulations to study ultra-violet (UV) emission from circum-galactic medium (CGM) in galaxies ranging from dwarf ($M_{\rm halo} \sim 10^{10}{\rm M}_\odot$) to Milky Way ($M_{\rm halo} \sim 10^{12}{\rm M}_\odot$) masses. We analyze the spatially-extended structures of emission lines from OVI and Lyα.

Key words: galaxies: evolution – galaxies: formation – galaxies: dwarf – galaxies: spiral – methods: numerical – cosmology: theory

1 INTRODUCTION

Why the CGM is important

The hot and cold gas phases were indicated by OVI and HI ions in observation commomly.

What can we gain from HI and OVI in CGM

Gutcke et al. (2016) compared the column density profiles of OVI and HI in CGM with observations.

What is the advantage of emssion line of HI and OVI

Sravan et al. (2015) studied ultra-violet (UV) metal line emission from the CGM of high-redshift ($z = 2-4$) galaxies using cosmological simulations from the Feedback in Realistic Environments (FIRE) project.

This paper is organized as follows: The cosmological hydrodynamical simulations and the methodology for computing metal line emission are briefly described in §2; In §3 we present the results including the Lyα and OVI emission map, surface brightness and luminosity evolutions of all galaxies in NIHAO sample; §4 gives discussion and summary of our results.

2 METHODOLOGY

2.1 Simulations

The simulations studied in this work are from the NIHAO (Numerical Investigation of a Hundred Astrophysical Objects) project (Wang et al. 2015). The halos to be resimulated with baryons have been extracted from 3 different pure N-body simulations with a box size of 60, 20 and 15 h^{-1} Mpc respectivelyDutton & Macciò (2014). All halos across the whole mass range with typically a million dark matter particles inside the virial radius of the target halo at redshift $z = 0$. We adopted the latest compilation of cosmological parameters from the Planck satellite (the Planck Collaboration et al. 2014).

We use the SPH hydrodynamics code GASOLINE (Wadsley et al. 2004), with a revised treatment of hydrodynamics as described in Keller et al. (2014). The code includes a subgrid model for turbulent mixing of metal and energy (Wadsley et al. 2008), heating and cooling include photoelectric heating of dust grains, ultraviolet (UV) heating and ionization and cooling due to hydrogen, helium and metals (Shen et al. 2010). The star formation and feedback modeling follows what was used in the MaGICC simulations (Stinson et al. 2013). There are two small changes in NIHAO simulations: The change in number of neighbors and the new combination of softening length and particle mass means the threshold for star formation increased from 9.3 to 10.3 cm^{-3}, the increase of pre-SN feedback efficiency $\epsilon_{\rm ESF}$, from 0.1 to 0.13. The more detail on star formation and feedback modeling can be found in Wang et al. (2015).

2.2 Emissivity Calculation

We first assign the hydrogen number densities and temperatures of all gas particles inside $2R_{\rm vir}$ to $200 \times 200 \times 200$ grids

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according SPH spline kernel (Monaghan & Lattanzio 1985):

$$W(r,h) = \frac{8}{\pi h^3} \begin{cases} 1 - 6\left(\frac{r}{h}\right)^2 + 6\left(\frac{r}{h}\right)^3, & 0 \leqslant \frac{r}{h} \leqslant \frac{1}{2}, \\ 2\left(1 - \frac{r}{h}\right)^3, & \frac{1}{2} < \frac{r}{h} \leqslant 1, \\ 0, & \frac{r}{h} > 1. \end{cases} \quad (1)$$

The distribution of emissivities are then computed as a function of gas temperature and hydroden number density on each grid by bi-linearly interplating the grids of emissivities generated using CLOUDY (**version and citation**). The temperature of the grids are in the range ?? $< T <$??K in intervals of $\Delta \log_{10} T =$?.?? and hydrogen number densities are in the range ?? $< n_H <$??cm^{-3} in intervals of $\Delta \log_{10} n_H =$??. The grids are computed at redshift z = 0 assuming gas is of solar metallicity, optical thin and **blabla**.

To compute the HI neutral fraction, like (Gutcke et al. 2016), we used the self-shielding approximation presented in (Rahmati et al. 2013). **say more detail about it**. Contrastly, To compute the OVI, the self-shielding approximation is not necessary to consider. **reason**

2.3 Luminosity Calculation

In order to estimate the evolution of total OVI and HI luminosities inside $2R_{\rm vir}$, we employ the grids of emissivities computed since z=4 to present to evaluate the evolution of luminosities of all galaxies in NIHAO sample from particle data directly. The method is similar to the one used by (Sravan et al. 2015), the OVI and HI luminosities of each gas particle are calculated as

$$L = \epsilon_{\odot}(z, n_H, T)\left(\frac{m_{gas}}{\rho_{gas}}\right)\left(\frac{Z_{gas}}{Z_{\odot}}\right), \quad (2)$$

where m_{gas}, ρ_{gas} and Z_{gas} are the mass, density and metallicity of the gas particle, and $\epsilon_{\odot}(z, n_H, T)$ is the emissivity interpolated bi-linearly from pre-computed grids of emissivities with given redshift, hydrogen number density and temperature.

3 RESULTS

3.1 OVI and HI Emissivity Maps and Radial Profile

3.2 Evolution of Luminosities

4 SUMMARY

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