

H_I and O_{VI} 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 ($M_{\text{halo}} \sim 10^{10} M_{\odot}$) to Milky Way ($M_{\text{halo}} \sim 10^{12} M_{\odot}$) masses. We analyze the spatially-extended structures of emission lines from OVI and HI.

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 commonly.

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 of galaxies of the cosmological hydrodynamical simulation suite NIHAO (Wang et al. 2015) with observations, studied the covering fraction of dense HI, looked at the shape of the CGM and its chemical composition. The simulations have a good agreement with observations and show observers and modellers can compare with them in future studies.

However, the works mentioned above all relate to the absorption lines of HI and OVI, there are rare simulations comparing the emission lines of them with observations.

What is the advantage of emission 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. For each simulation, they predicted the emission from multiple metal lines including HI and OVI, and found more massive haloes are on average more UV-luminous and the UV metal line emission is primarily from collisionally ionized gas and strongly time variable. The high UV-luminous event correspond high star

formation and CIII, SiIII, CIV and SiIV should be detectable by current and upcoming integral field spectrographs such as the Multi Unit Spectroscopic Explorer (MUSE^{citation}).

In this paper we investigate the CGM OVI and HI emissivity distribution and shape in Numerical Investigation of a Hundred Astrophysical Objects, NIHAO (Wang et al. 2015) project. NIHAO project produced nearly 100 hydrodynamical, cosmological zoom-in galaxies across a range in mass from

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 HI 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 project (Wang et al. 2015). The halos to be re-simulated with baryons have been extracted from 3 different pure N-body simulations with a box size of 60, 20 and 15 h^{-1} Mpc respectively Dutton & 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

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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 sub-grid 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 ϵ_{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 $2R_{\text{vir}}$ to $200 \times 200 \times 200$ grids according SPH spline kernel (Monaghan & Lattanzio 1985):

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

The distribution of emissivities are then computed as a function of gas temperature and hydrogen number density on each grid by bi-linearly interpolating the grids of emissivities generated using CLOUDY (version and citation). The temperature of the grids are in the range $10^4 < T < 10^5 \text{ K}$ in intervals of $\Delta \log_{10} T = 0.1$ and hydrogen number densities are in the range $10^{-3} < n_H < 10^{-1} \text{ cm}^{-3}$ in intervals of $\Delta \log_{10} n_H = 0.1$. 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 $2R_{\text{vir}}$, 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

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

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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