国立天文台天文シミュレーションプロジェクト 成果報告書

研究課題名 Galactic Outflow Production of Multiphase Gas in the Circumgalactic Medium

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利用カテゴリ XC-B

Observations reveal the presence of numerous, compact, weak MgII absorbers with near to super-solar metallicities, often surrounded by more extended regions that produce CIV and/or OVI absorption in the circumgalactic medium (CGM) at large impact parameters from luminous galaxies. Their origin and nature remains unclear. Therefore, we used XC50 to run gas dynamical simulations of galactic outflows from a dwarf satellite galaxy with a halo mass of $5 \times 10^9\ M_{\odot}$,which is expected to arise in a larger L^* halo at z = 2, and study the gas interaction in the halo to test our hypothesis that invisible, satellite dwarf galaxies are responsible for producing such weak MgII absorbers.

We find that thin, filamentary weak MgII absorbers are produced in two phases: when 1) shocked core collapse supernovae (SNII) enriched gas eventually loses energy to descend toward expanding SNII enriched gas and gets shocked to cool (*phase 1*), and later, 2) an outflow driven by Type Ia supernovae (SNIa) shocks and sweeps pervading SNII enriched gas, which then cools (*phase 2*). The width of the filaments and fragments are ~100 pc, though the smallest ones cannot be resolved at 12.8 pc resolution. These MgII absorbers have $10-20\%$ of solar metallicity, and are continuously generated by shocks and cooling, though each cloud seems to survive only for ~ 60 Myr. They are also surrounded by larger CIV absorbers (0.5-1 kpc) that seem to survive longer. In addition, larger-scale (> kpc) CIV and OVI clouds are produced in both expanding and shocked SNII enriched gas, when photoionized by the UV metagalactic radiation at high redshift, and collisional ionization seems unimportant in production of these ions. Although higher ion clouds seem to cover a substantial fraction of the dwarf halo (> 50%), MgII clouds covers only $\sim 3-6\%$, much less than the observed estimate ($\sim 30\%$). Our simulation is limited to a single, instantaneous starburst in a small box where a substantial amount of metal-enriched gas that could produce both low and high ionization clouds leaves. Thus, we are not able to follow the further formation of higher metallicity MgII clouds through repeated cycles of *phase 1* and *phase 2* formation, beyond t ~240 Myr. Our simulation nonetheless highlights a possibility of galactic outflows producing multiphase gas, and future, more general simulation can estimate their global importance (our simulation plan for 2020).

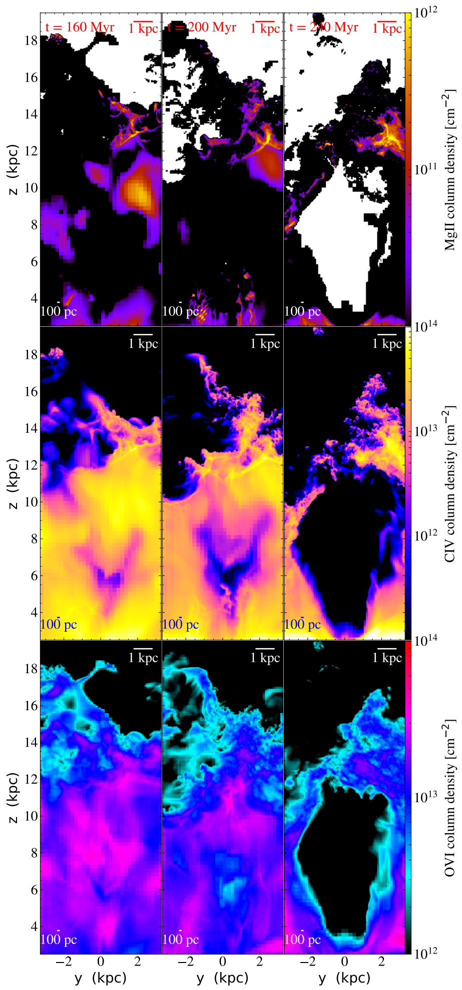

Figure 1. Projected MgII (top), CIV (middle), and OVI density (bottom) distributions at t=160 (left), 200 (middle), and 240 Myr (right), along x-axis in y-z plane.

We are currently writing a paper on the results to be submitted to the Astrophysical Journal by the end of May 2020.

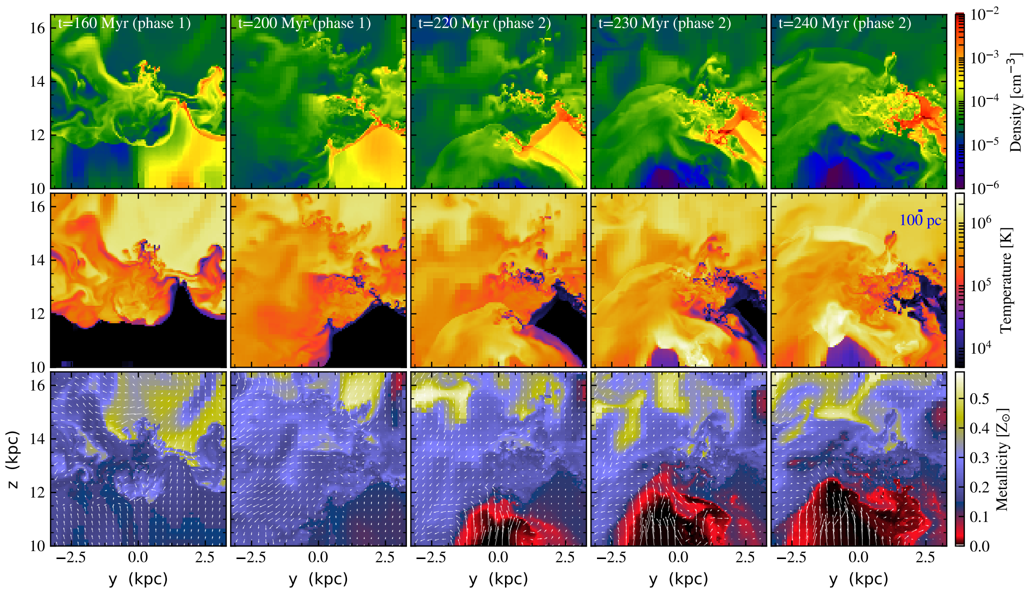

Figure 2. Sliced density (top), temperature (middle), and metallicity (bottom) distributions of cool, dense clouds at x=+1.42 kpc from the disk center in y-z plane at phase 1 (t=160 and 200 Myr) and phase 2 (t=220, 230, and 240 Myr) from left to right. Phase 1 formation begins when descending shocked SNII enriched gas collides with the expanding SNII enriched gas at the inner shock front, and phase 2 formation begins when SNIa driven outflow rams into the rest of the SNII enriched gas and the clouds made at phase 1.

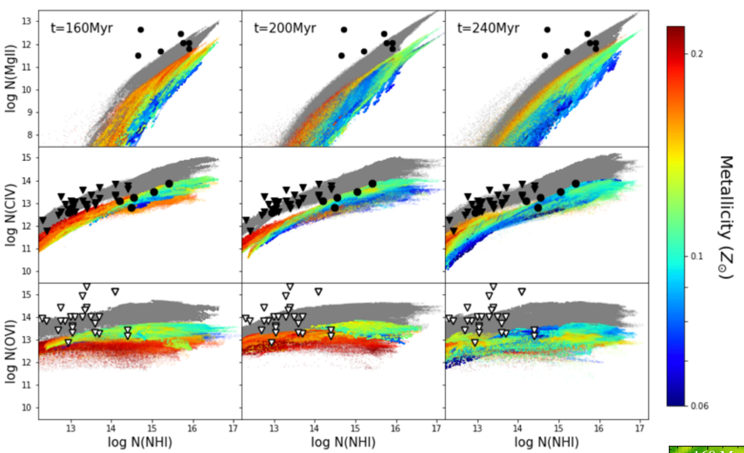

Figure 3. MgII (top row), CIV (middle row), and OVI (bottom row) versus HI column densities along each of the three cardinal axes at t=160 (left column), 200 (middle column), and 240 Myr (right column) with different colors indicating MgII, CIV, and OVI density-weighted metallicities, to be compared to the observed MgII/CIV clouds by (Misawa et al. 2008, circle) and the observed CIV/OVI observations by (Schaye et al. 2007, triangle). Note OVI and HI column densities by Schaye et al. (2007) are upperlimits (open triangle). Grey points indicate ions versus HI column density distributions expected when all the gas in our simulation is assumed to have solar metallicities.

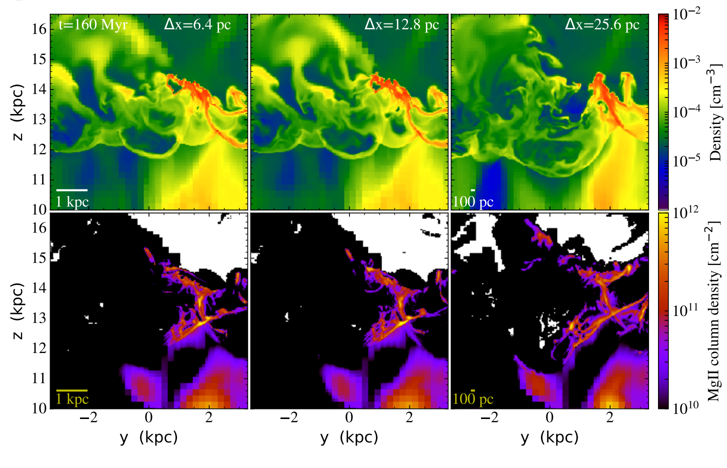

Figure 4. Sliced density distributions of cool, dense clouds resolved with highest resolutions of Δx = 6.4, 12.8 (our standard simulation), and 25.6 pc (from left to right) at x=+1.42 kpc from the disk center in y-z plane at phase 1 (t=160 Myr). The middle figure is the same as the rightmost figure in Figure 2.