Galactic Outflow Production of Multiphase Gas in the Circumgalactic Medium

Akimi Fujita

Shinshu University

1. Project Purpose

Observations at intermediate redshifts reveal the presence of numerous, compact, weak MgII absorbers with near to super-solar metallicities, often surrounded by extended regions that produce CIV and/or OVI absorption, in the circumgalactic medium at large impact parameters from luminous galaxies. Their origin and nature remains unclear. The project purpose was to test our hypothesis that undetected, satellite dwarf galaxies are responsible for producing some of these weak MgII absorbers, using gas dynamical simulations of galactic outflows from a dwarf galaxy with a halo mass of $4 \times 10^9 M_\odot$, as might be falling into a larger L* halo at z=2.

2. Results

We find that thin, filamentary, weak MgII absorbers (<100 pc) are produced in two stages: 1) when shocked core collapse supernova (SNII) enriched gas descending in a galactic fountain gets shock compressed by upward flows driven by subsequent SNIIs and cools (phase 1), and later, 2) during an outflow driven by Type Ia supernovae that shocks and sweeps up pervasive SNII-enriched gas, which then cools (phase 2). The MgII absorbers in our simulations are continuously generated for >150 Myr by shocks and cooling with moderate metallicity 0.1-0.2 $Z_\odot$, but low column density $< 10^{12}$ cm^{-2}. They are also surrounded by larger (0.5-1 kpc) CIV absorbers that seem to survive longer. Larger-scale (>1 kpc) CIV and OVI clouds are also

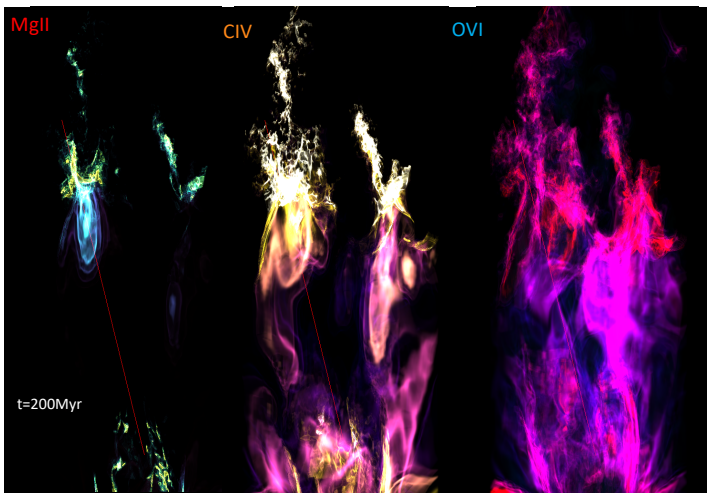

Figure 1: 3D visualization of MgII (*left*), CIV (*middle*), and OVI (*right*) ion distributions in a dwarf galaxy at z=2, t =200 Myr after the onset of an instantaneous starburst. The outflow is first driven by SNII with an average mechanical luminosity of 3×10^{42} erg s^{-1} lasting for 40 Myr, then by SNIa with an average mechanical luminosity two orders of magnitude lower.

produced in both expanding and shocked SNII-enriched gas. Observable ion distributions from our models appear well-converged at our standard resolution (12.8 pc). Our simulation highlights the possibility of dwarf galactic outflows producing highly enriched multiphase gas.

３．Roles of the MCRP and its significance

We used Oakforest-PACS to complete some of the simulations presented in our published paper.

４．Future plan

We will study several cycles of *phase 1 & phase 2* formation of clumps and filaments in mass-loaded outflows due to repeated starbursts from a dwarf satellite galaxy embedded in denser, high-pressure gas of its host halo. Thus, we continue to model the effects of repeated SNII & SNIa explosions driving outflows in the same dwarf galaxy at $z = 2$ with $M_{halo} = 4 \times 10^9 M_\odot$ and $R_{vir} = 17.5$ kpc (Fujita et al. 2021), but 1) with repeated starbursts every 200 Myr for 1Gyr, 2) placed in CGM of characteristic haloes expected to collapse from ΛCDM density perturbations as 1-2σ peaks, 3) assuming the dwarf galaxy is moving through the host halo with v=100 km/s and 200 km/s. We will use the adaptive mesh refinement hydrodynamics code ENZO (Bryan et al.1). Our simulation box has dimensions (6.5536, 6.5536, 32.768) kpc initially with (32, 32, 160) cells. We use 4 refinement levels resulting in a highest resolution of 12.8 pc with an aim to resolve structures expected to form out of gas with $n \approx 10^{-2} cm^{-3}$ in the presence of the metagalactic background radiation at z=2.

５．Publications and conference presentations

(1) Journal papers

"Origin of Weak MgII and Higher Ionization Absorption Lines in Outflows from Intermediate-redshift Dwarf Galaxies", Akimi Fujita, Toru Misawa, Jane C Charlton, Avery Meiksin & Mordecai-Mark Mac Low, The Astrophysical Journal, 909(2):157-174 2021 (March)

(2) Presentations

"Origin of Weak MgII and Higher Ionization Absorption Lines in Outflows from Intermediate-redshift Dwarf Galaxies", Akimi Fujita, Toru Misawa, Jane C Charlton, Avery Meiksin & Mordecai-Mark Mac Low, **令和2年度国立天文台** CfCA **ユーザーズミーティングプログラム**

(3) Others

Supercomputer	Use	Allocated resources*	
		Initial resources	Additional resources
Cygnus	No		
Oakforest-PACS	Yes	32,527	
*in units of node-hour product			