§13. Metal Enrichment of Ly Alpha Clouds and Intergalactic Medium

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Recent observations have shown us that many Ly α clouds observed at redshift (z) ~ 3 are contaminated with metals. Associated CIV absorption lines indicate that these intergalactic clouds are likely to have about 1/100 solar metallicity ($Z_\odot$) (e.g. [1]). This puzzles us how such intergalactic clouds which do not associate with galaxies are metal-enriched at such high redshift, i.e. at early epoch of galaxy formation, since heavy elements must be synthesized in stars, i.e. in galaxies. We examine metal enrichment of the intergalactic medium (IGM) with galactic wind driven by supernova explosions, using 3D hydrodynamical simulations. Assuming UV background radiation given in Ref. [2], we obtain ion abundances of the IGM in ionization equilibrium. We use the CDM model of $(\Omega_0,\ h, \sigma_8)$=(1,0.5,1). The number of mesh cells and CDM particles is 128^3 and the simulation volume is $(20\mathrm{Mpc}/h)^3$. We perform the simulations from $1+z=50$ down to 1 [3, 4].

We find that at $z = 3$ only 12% of whole IGM volume has metallicity $Z > 10^{-2}Z_\odot$ and the intergalactic void region is metal free. The distribution of metallicity as well as CIV ions traces high matter density regions which are associated with galaxies (Fig.1). Simple model of galactic wind in the simulation is not sufficient to achieve metal enrichment of the whole IGM. The observations, however, do not necessarily require complete metal enrichment of the IGM. Primordial gas infall to potential wells of clusters of galaxies after metal production attenuates the metallicity there, resulting in too much low metallicity of intracluster gas (ICG), compared with the X-ray observations of the ICG at $z \approx 0$. This effect of attenuation would be weakened when we adopt smaller σ_8 which is reported by COBE observations because the main epoch of galaxy formation would be delayed.

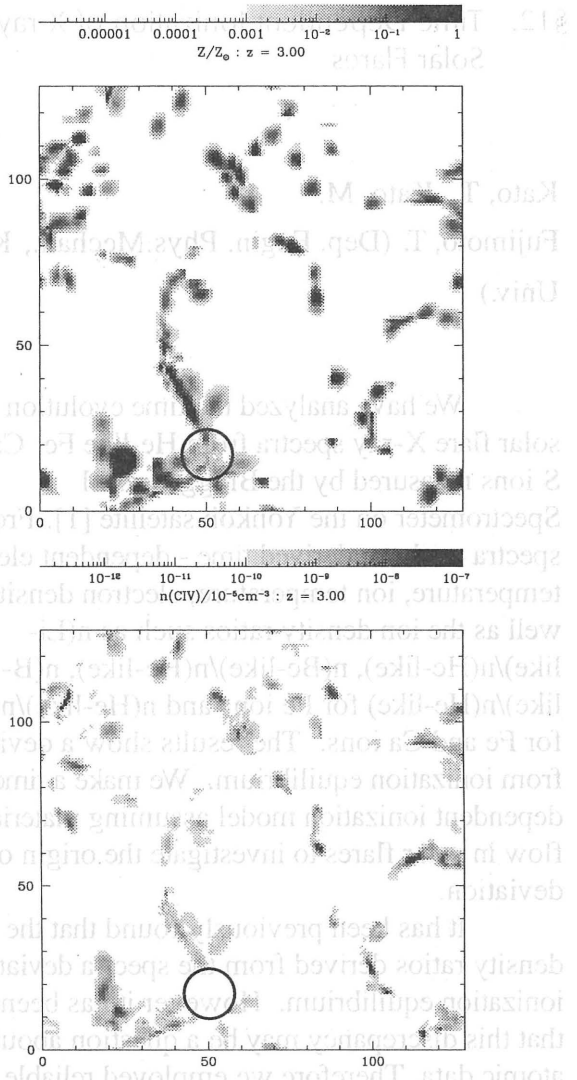

Figure 1: Upper panel: snapshot of metallicity distribution at $z = 3$ in a slice of $(20\mathrm{Mpc}/h)^2 \times 0.156\mathrm{Mpc}/h$. A region with low metallicity but high matter density appeared in the circled area. Lower panel: snapshot of CIV number density distribution at $z = 3$.

References

[1] Songaila A. & Cowie L. L., A.J.**112** (1996) 335.
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[3] Murakami, I. and Yamashita, K., in "Structure and Evolution of the intergalactic medium from QSO Absorption Line Systems" ed. by P.Ptitjean (Frontieres, 1997), p.77
[4] Yamashita, K. and Murakami, I. in Proceedings of Numerical Astrophysics (10-13 March, 1998, Tokyo) eds. by S.Miyama et al. (Kluwer, 1998), in press.