Radiative Transfer Modeling of Lyman Alpha Emitters

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We model $z=5.7$ Lyman Alpha Emitters (LAEs) by combining a state-of-the-art cosmological reionization simulation (Trac, Cen, & Loeb 2008) in a box of $(100\,\text{Mpc})^3$ with a Monte Carlo Ly$\alpha$ radiative transfer code (Zheng & Miralda-Escudé 2002).

Model Summary:
Radiative transfer in the circumgalactic and intergalactic environment (provided by the cosmological reionization simulation) is assumed to be the major factor in transforming the intrinsic Ly$\alpha$ emission to the observed emission.

Model Setups:
- Each LAE is located at the center of a dark matter halo.
- Ly$\alpha$ photons are initially emitted from a point source.
- Ly$\alpha$ luminosity is proportional to star formation rate.
- The initial Ly$\alpha$ spectrum follows a Gaussian profile with width determined by halo virial temperature.

Model Outputs:
- Ly$\alpha$ (narrow-band) image and spectra
- LAEs identified from the image following typical observational procedures
- Observational properties of LAEs (e.g., luminosity functions, clustering properties)

Main Results:
- Radiative transfer (resonant scattering) in the circumgalactic and intergalactic media leads to both spatial and frequency diffusion of Ly$\alpha$ photons.
- The Ly$\alpha$ emission from high-redshift starforming galaxies becomes extended and usually only the central, high surface brightness region can be observed.
- Radiative transfer leads to strong coupling between the observed Ly$\alpha$ emission and circumgalactic and intergalactic environment (density and velocity structures).
- At fixed intrinsic Ly$\alpha$ luminosity, the observed (apparent) Ly$\alpha$ luminosity has a broad distribution, reflecting the broad distribution of environment.

Highlight I: The simple model is able to provide natural explanations for an array of observed properties of LAEs.
Right: Images and spectra for a few LAEs in the model, which are similar to those of observed LAEs. Dotted curves are the intrinsic spectra. Black solid curves are the spectra after a full Ly$\alpha$ radiative transfer. Cyan solid curves are spectra with a simple treatment of the radiative transfer, which modifies the intrinsic spectra by $\exp(-t)$.

Highlight II: The model predicts extended Ly$\alpha$ emission around high-redshift starforming galaxies (LBGs or LAEs).

The prediction (Zheng et al. 2011b) starts to be verified or tested by latest observations (e.g., Steidel et al. 2011). The extended emission opens a new window to study the circumgalactic and intergalactic media.

Highlight III: The model predicts new effects in the clustering of LAEs caused by environment dependent Ly$\alpha$ radiative transfer.
- Enhancement (suppression) in the transverse (line-of-sight) fluctuation
- Anisotropic 3D clustering (prominent elongation along the line of sight)
- Scale-dependent bias

Left: The stacked narrowband Ly$\alpha$ image and surface brightness profile for high-redshift starforming galaxies in halos of mass $10^{10}$ $\text{M}_\odot$. The stacking suppresses the sky noise and can reveal the faint extended Ly$\alpha$ emission around these galaxies. At large radii, clustered sources start to contribute, leading to interesting features in the surface brightness profile. (Zheng et al. 2011b)

References: