Connections between Anisotropic Gas Distribution and Lyman-Alpha Emission from LAEs

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Radiative Transfer: analytic solution or analytic setup

Great tool for understanding

plane-parallel

spherical symmetry

Gas Environment of Star-Forming Galaxies

Lyman-alpha photons from starforming galaxies (e.g., Lyman-alpha Emitters) experience resonant scatterings in the neutral gas of the circumgalactic and intergalactic media.

How would the anisotropic distribution of neutral gas affect the observational properties of Lyman-alpha emission?

How would we use the observed Lyman-alpha emission to probe the neutral gas?

Anisotropic Lyman-alpha Emission

Lyman-alpha emission from (analytic) anisotropic gas distribution

anisotropy in gas distribution: density and velocity
Density Gradient Case

Density Anisotropy
$$\Rightarrow$$ Lyman Alpha Emission Anisotropy

Flux

$N_{\text{HI}}=10^{19} \text{ cm}^{-2}$
Density Gradient Case

Lyman-alpha Equivalent Width Distribution

Model
Density Gradient Case

Ouchi et al. (2008)

Lyman-alpha Equivalent Width Distribution

Model

Observation
Velocity Gradient Case

Velocity Anisotropy

⇒ Lyman Alpha Emission Anisotropy
Velocity Gradient Case

Lyman-alpha Equivalent Width Distribution

Ouchi et al. (2008)
Anisotropic Lyman-alpha Emission

Relation between EW and Peak Offset

Model

Observation

Hashimoto et al. (2013)
Anisotropic Lyman-alpha Emission

Zheng & Wallace (2014)

Relation between Peak Offset (hard to observe) and Line Profile (easy to observe)

(Talks by Henry Childs and Anne Verhamme)
Anisotropic Lyman-alpha Emission

Relation between Peak Offset (hard to observe) and Line Profile (easy to observe)

(Talks by Henry Childs and Anne Verhamme)
Anisotropic Lyman-alpha Emission from Galaxies in Hydrodynamic Simulations


(also Shiyu Nie’s talk)
(Prehistoric) Diffuse Lyman-alpha Halos

HST images of a galaxy group at \( z = 2.81 \), and the sizes of damped Ly\( \alpha \) galaxies

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Third galaxy comprises two similarly compact components separated by 0.3 arcsec. The HST images and a new ground-based Ly\( \alpha \) image of the field provide evidence that the three galaxies are more extended in the light of Ly\( \alpha \) than in the continuum. Combined with the evidence from

Fynbo+2001

Ono, Ouchi, et al. 2010

401 \( z = 5.7 \) LAEs

207 \( z = 6.6 \) LAEs

To evaluate the aperture correction term for the two narrow bands, we measure fluxes for bright point sources in a series of apertures from 2” up to 6” with an interval of 0’1. Since we find that the fluxes level off for >5” apertures, we define

Hayashino+2004, 22 LBGs

Finkelstein et al. 2010

Figure 9. Measured light profiles from aperture photometry for the stack of our sample of three spectroscopically confirmed LAEs in blue and red for F658N and F775W, respectively. The lines, shaded and cross-hatched regions are the same as in Figure 7. Both stacks exhibit the same result as the individual objects—Ly\( \alpha \) emission appears more extended than the rest-frame UV continuum.

(A color version of this figure is available in the online journal.)
Diffuse Lyman-alpha Halos

Lake et al. 2015

(Talks by Floriane Leclercq and Kyoung-Soo Lee)

Wisotzki et al. 2016
Diffuse Lyman-alpha Halos

Stacked Lya Profile

Decomposition

Lake et al. 2015

(Talk by Lluis Mas-Ribas)
Diffuse Lyman-alpha Halos

Stacked Lya Profile

![Stacked Lya Profile graph](image)

Decomposition

![Decomposition graph](image)

Lake et al. 2015

(Talk by Lluis Mas-Ribas)
Diffuse Lyman-alpha Halos

Stacked Lya Profile

Stacked UV Profile

Lake et al. 2015
Anisotropic Lyman-alpha Emission from Galaxies in Hydrodynamic Simulations

viewing angle dependent column density

Wallace, ZZ, Sadoun, & Cen (in prep)
Anisotropic Lyman-alpha Emission from Galaxies in Hydrodynamic Simulations

viewing angle dependent Lyman-alpha flux

Wallace, ZZ, Sadoun, & Cen (in prep)
Anisotropic Lyman-alpha Emission from Galaxies in Hydrodynamic Simulations

flux distribution from randomly oriented galaxies

Wallace, ZZ, Sadoun, & Cen (in prep)
Anisotropic Lyman-alpha Emission from Galaxies in Hydrodynamic Simulations
Anisotropic Lyman-alpha Emission
from Galaxies in Hydrodynamic Simulations

Lyman-alpha EW distribution from anisotropic escape

Wallace, ZZ, Sadoun, & Cen (in prep)
Anisotropic Lyman-alpha Emission from Galaxies in Hydrodynamic Simulations

Lyman-alpha EW distribution: Model vs Observation

Wallace, ZZ, Sadoun, & Cen (in prep)
Summary

- Anisotropic gas distribution leads to anisotropic Lyman-alpha emission.
  - Radiative transfer calculations are performed for simple models of anisotropic Lyman-alpha emission.
  - The simple models are able to qualitatively reproduce some statistical trends seen in Lyman-alpha emission from star-forming galaxies (e.g., EW distribution and $EW-V_{\text{peak}}$ relation) and make interesting predictions (e.g., between $V_{\text{peak}}$ and line profile).
  - Lya RT modeling with simulated galaxies shows that Lya EW distribution can be largely explained by the anisotropic Lya emission.
  - The anisotropic Lyman-alpha emission could be one of the key factors in determining and in interpreting the observational properties of Lyman-alpha emission from star-