

Cool Side of Galaxy Evolution **at High Redshift**



Yoshi Taniguchi

Research Center for Space and Cosmic Evolution
Ehime University

**Not Paul Newman
but Yoshi Taniguchi**

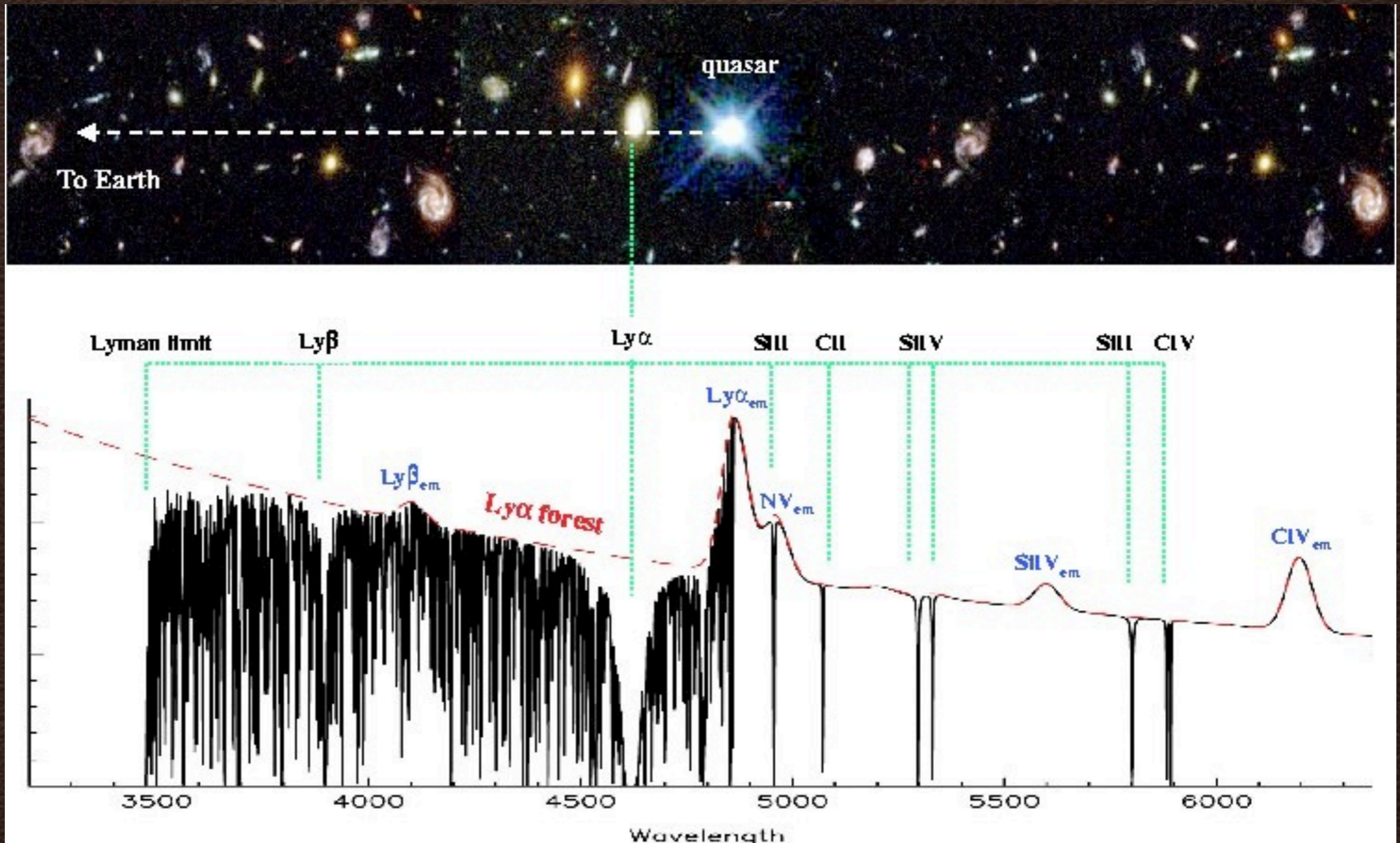
**Here is a galaxy
What will happen ?**

Not a hustler, but an astronomer !

A large, golden-yellow fireworks burst against a black background. The fireworks are in the center of the frame, radiating outwards in all directions. The text "A superwind occurs !" is overlaid on the fireworks in a bold, yellow, serif font.

A superwind occurs !

HI Absorption-line systems in the Universe



(http://enki.phyast.pitt.edu/qso_abs.html)

HI Absorption-line systems in the Universe

Damped Ly α Absorption System:

$$\text{DLA} - N(\text{HI}) > 2 \times 10^{20} \text{ cm}^{-2}$$

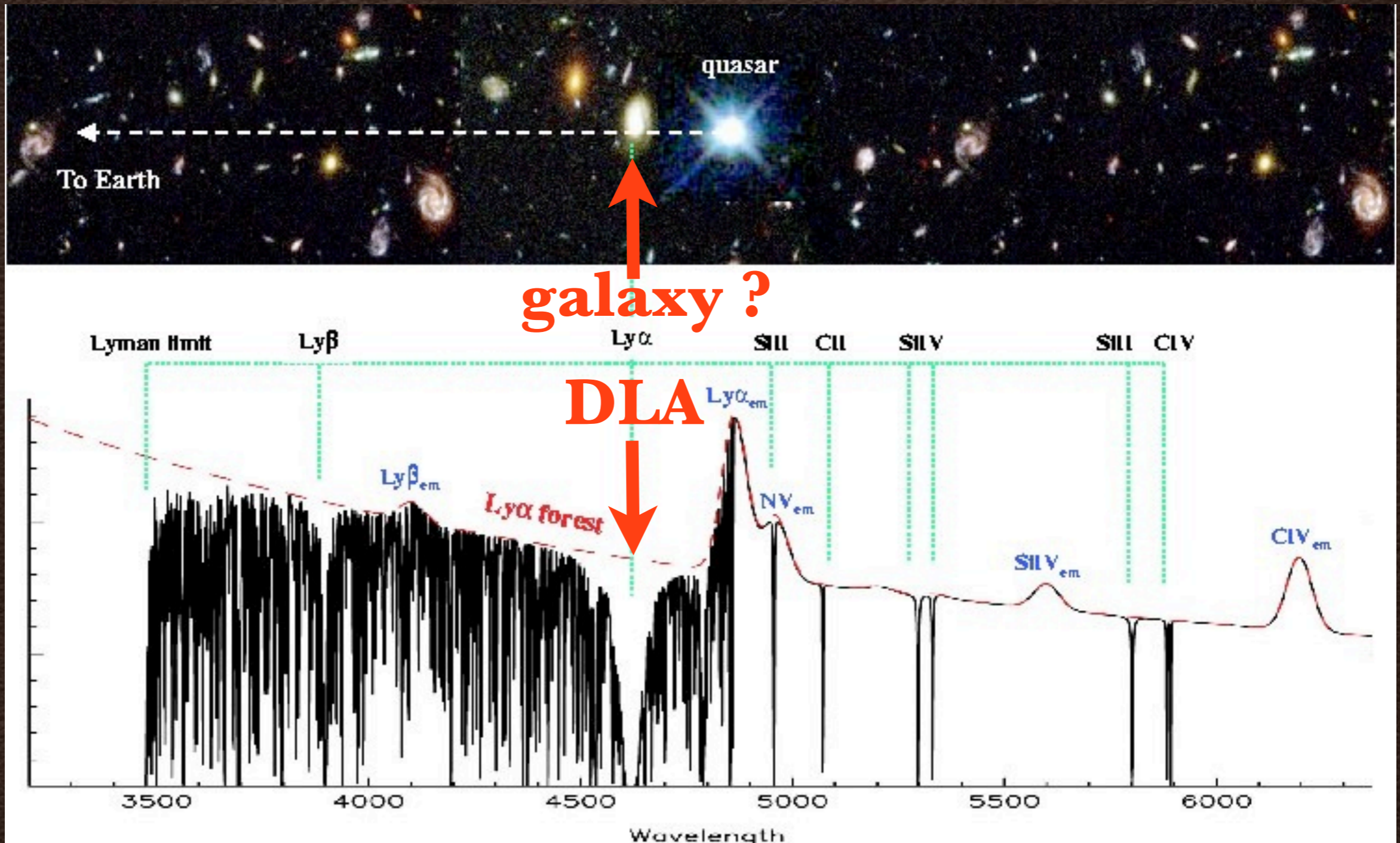
Lyman Limit Absorption System:

$$\text{LLS} - N(\text{HI}) \sim 10^{19} \text{ cm}^{-2}$$

Ly α Forests: $N(\text{HI}) < 10^{17} \text{ cm}^{-2}$

What are DLAs ?

HI Absorption-line systems in the Universe



(http://enki.phyast.pitt.edu/qso_abs.html)

Lesson

$$r = 5 \text{ kpc} \quad \& \quad M(\text{HI}) = 10^9 M_{\text{sun}}$$

$$V \sim 2 \times 10^{67} \text{ cm}^3$$



a spherical
galaxy

$$\mathcal{N}(\text{HI}) = M(\text{HI}) / m_{\text{p}} \\ \sim 1 \times 10^{66} \text{ atoms}$$

$$n(\text{HI}) = \mathcal{N}(\text{HI}) / V \\ \sim 0.05 \text{ cm}^{-3}$$

$$N(\text{HI}) = n(\text{HI}) \times 2r \\ \sim 3 \times 10^{21} \text{ cm}^{-2}$$

Oh, DLAs must be galaxies !

Predictions of galaxy models for DLAs

*1. Impact parameters should be
less than several kpc*

*2. We could easily identify a galaxy
as a counterpart*

However

Observational properties of DLAs
are **far from the predictions**

*1. Impact parameters are large
up to several 100 kpc*

*2. Detection rate of counterparts is
only 10 %*

(e.g., Wolfe+06, ARAA, 43, 861)

Something wrong !

Another



option

Superwind Model for DLAs

(Taniguchi & Shioya, 00, ApJ, 532, L13 [TS00]; 01, ApJ, 547, 146 [TS01])

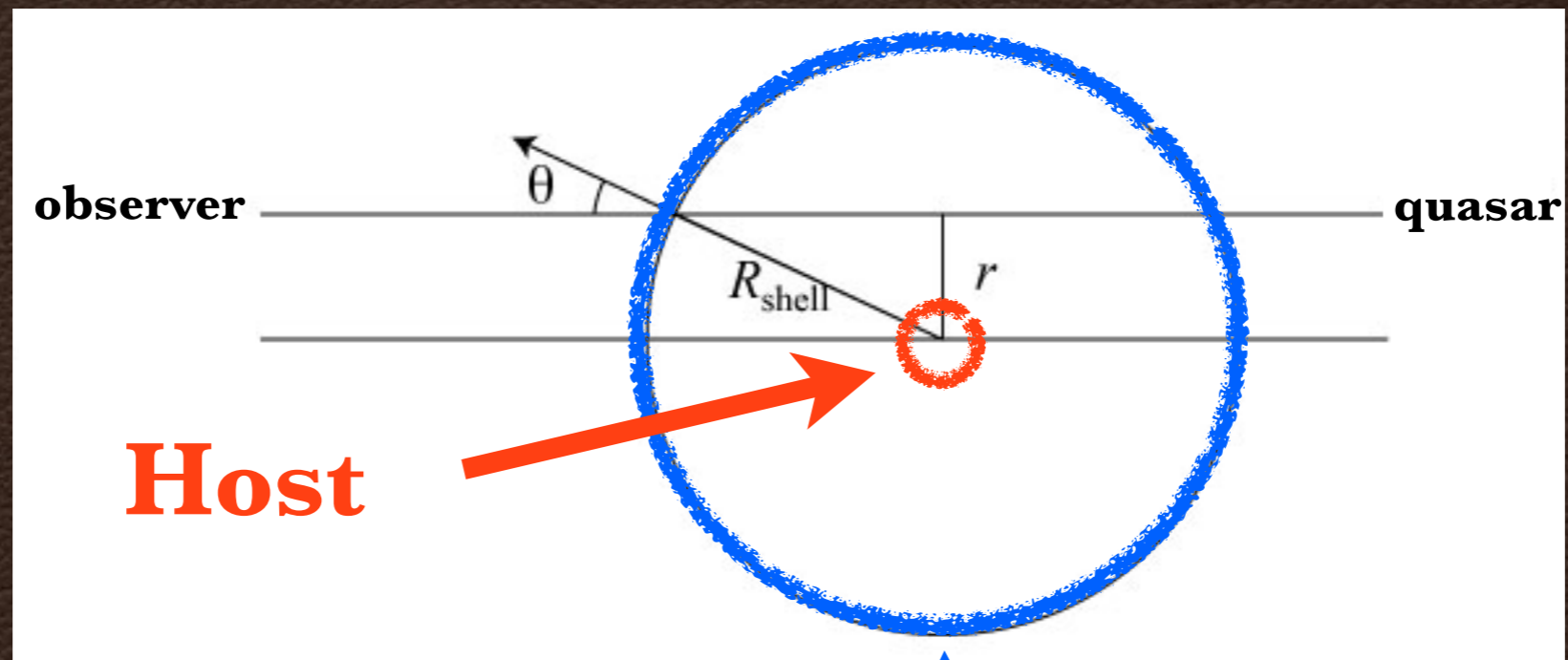
Originally, proposed to explain

1. Origin of **Ly α blobs** (TS00)
2. Origin of **chain galaxies** (TS01)

But, also explains origin of DLAs

Superwind Model for DLAs

(Taniguchi & Shioya, 00, ApJ, 532, L13 [TS00]; 01, ApJ, 547, 146 [TS01])



**shocked cool shell
formed by a superwind**

Properties of shocked cool shell - 1

(Taniguchi & Shioya, 00, ApJ, 532, L13 [TS00]; 01, ApJ, 547, 146 [TS01])

Initial starburst in L^* galaxy at $z=5$
→ Superwind causes shocked shell

$T_{\text{shell}} = 2.1 \text{ Gyr}$ ($z_{\text{shell}} = 1.6$) ← cooling time

$R_{\text{shell}} = 160 \text{ kpc}$ (large impact parameter)

$N(\text{HI})_{\text{shell}} = 1.5 \times 10^{20} \text{ cm}^{-2}$ (good for DLAs)

$Z_{\text{shell}} = 4 \times 10^{-4}$ (note that $Z_{\text{IGM}} = 2 \times 10^{-4}$)

Chemical abundance pattern:

Type II SNe driven

~ consistent with that in DLAs

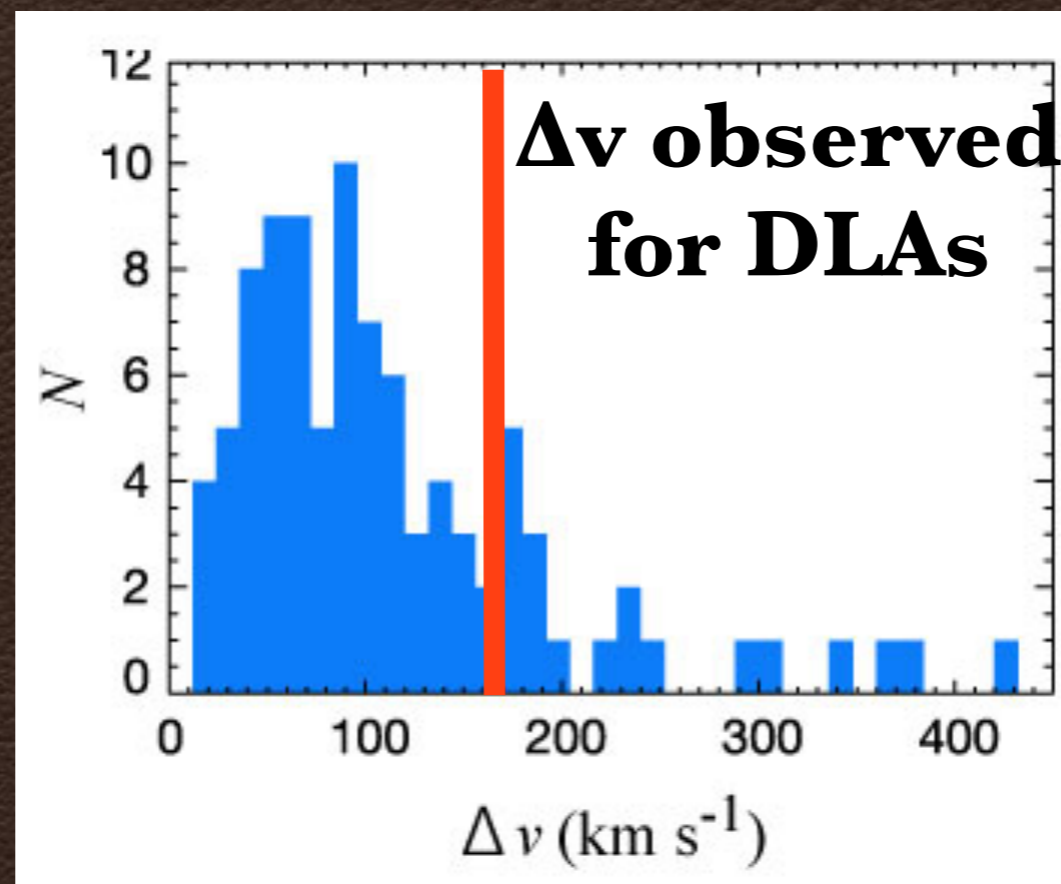
(a flat universe with $\Omega_m=0.3$, $\Omega_\Lambda=0.7$, & $h = 0.7$)

Properties of shocked cool shell - 2

(Taniguchi & Shioya, 00, ApJ, 532, L13 [TS00]; 01, ApJ, 547, 146 [TS01])

Shell width: $\Delta R_{\text{shell}} \sim 24$ kpc

Velocity dispersion: $\Delta v_{\text{shell}} \sim \mathbf{160}$ km s⁻¹



(Wolfe+06, ARAA, 43, 861)

Predictions of Superwind Model for DLAs

(Taniguchi & Shioya, 00, ApJ, 532, L13 [TS00]; 01, ApJ, 547, 146 [TS01])

1. $N(\text{HI})$ is okay
2. Large impact parameters
Also, explains small values
3. Metallicity is consistent
4. Abundance pattern is consistent
5. Velocity dispersion is consistent

&

Since host galaxies evolved passively, $R \sim 28$
they are too faint to be detected.

Everything is fine !!!

Let's go to DLAs with ALMA



Ideal case for SHOCKED SHELL

[CII] mapping of **proximate** DLA of
SDSS J124020.91+145535.6 @ $z = 3.1$

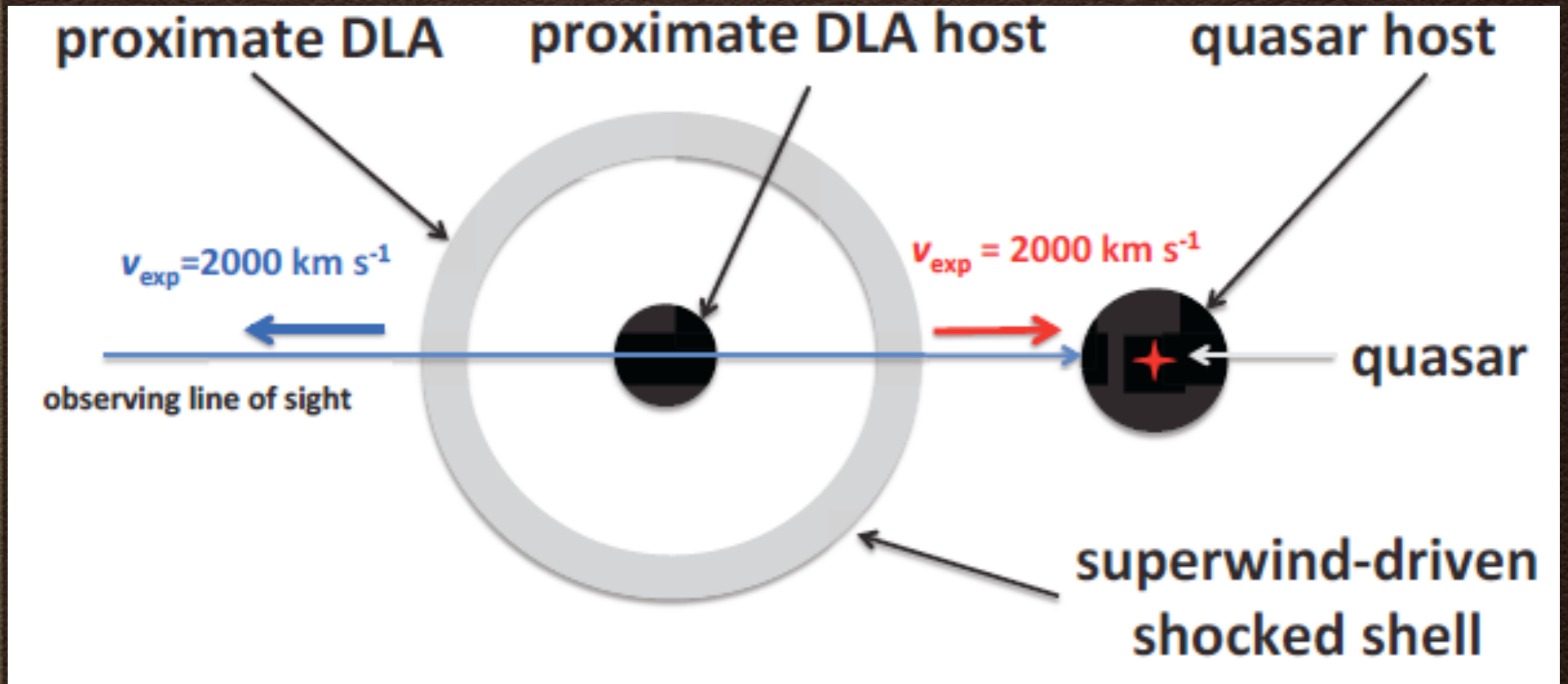


YOSHIAKI TANIGUCHI

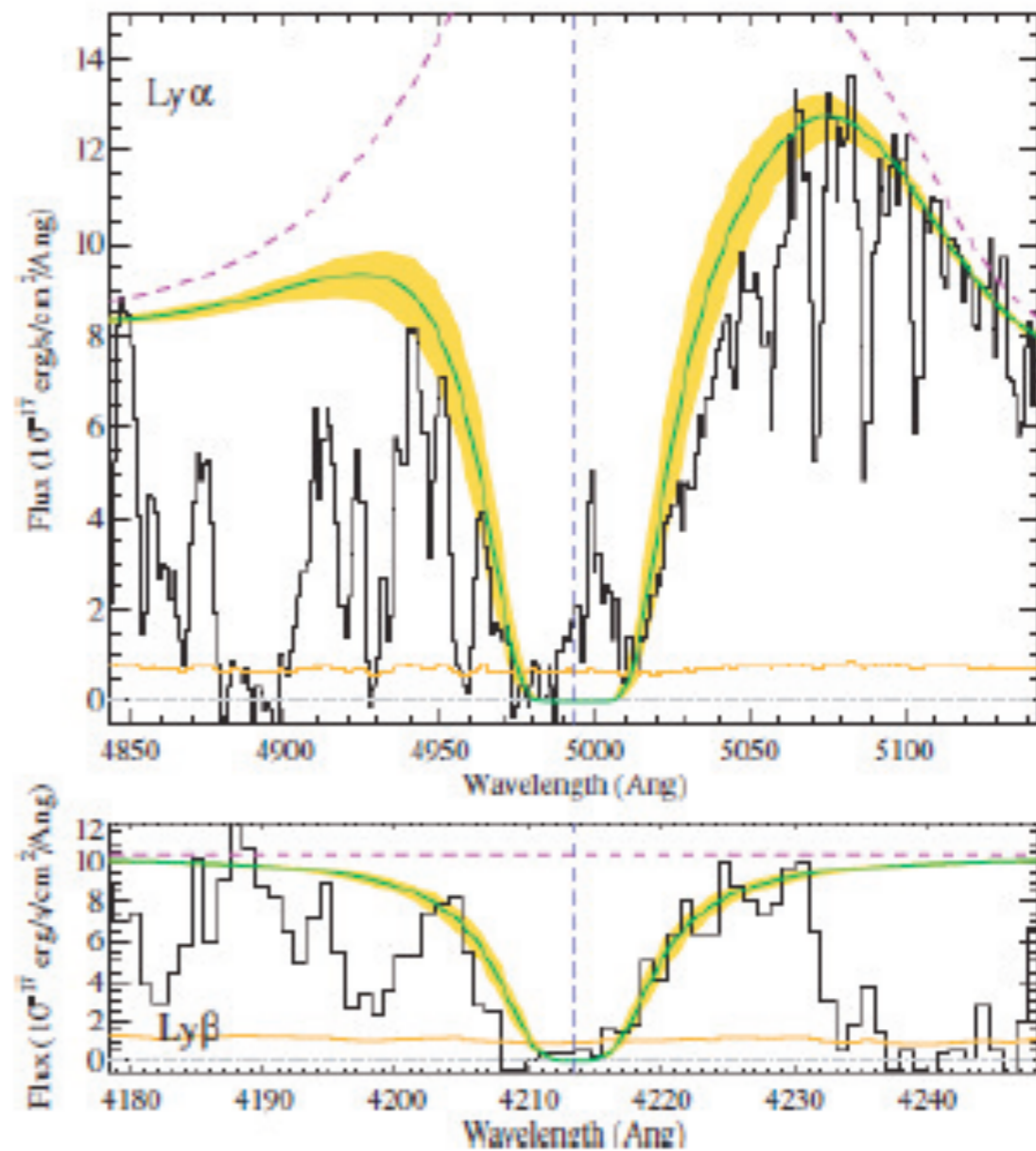
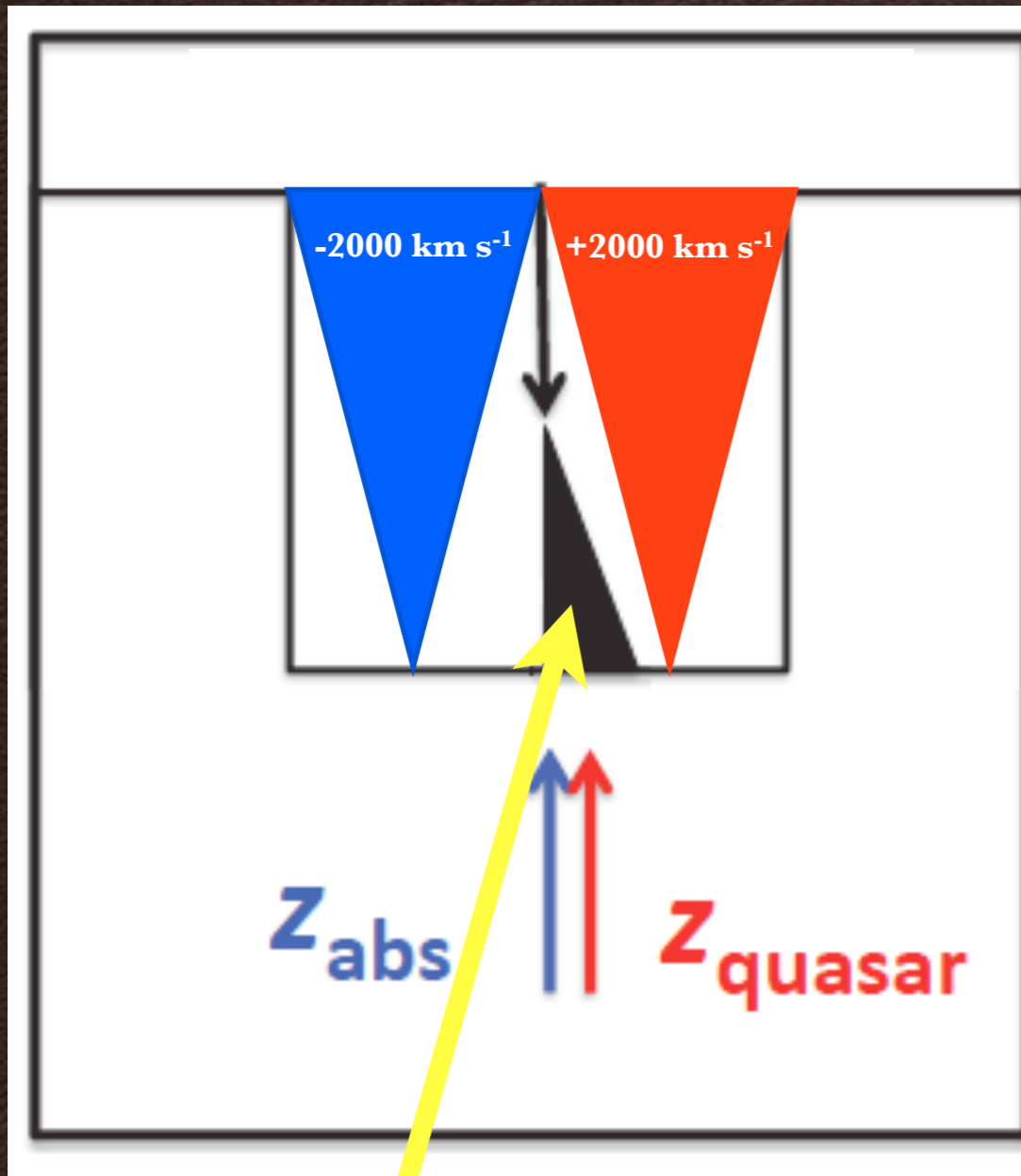
2013.1.00227.S

PROJECT TITLE:	ALMA Detection of a Superwind-Driven Shocked Shell Associated with the Proximate DLA of SDSS J124020.91+145535.6 at $z=3.1$				
PRINCIPAL INVESTIGATOR NAME:	Yoshiaki Taniguchi		PROJECT CODE:	2013.1.00227.S	
SCIENCE CATEGORY:	Cosmology and the High Redshift Universe	ESTIMATED 12M TIME:	1.4 h	ESTIMATED ACA TIME:	5.6 h
CO-PI NAME(S): (Large Proposals only)					
CO-INVESTIGATOR NAME(S):	Yuichi Matsuda; Nobunari Kashikawa; Tohru Nagao; Masaru Kajisawa; Masakazu Kobayashi; Yasuhiro Shioya; Katsuhiko Murata; Kartik Sheth				
EXECUTIVE SHARES[%]:	NA :	0	STUDENT PROJECT? (Yes/No)	No	
	EU :	0	RESUBMISSION? (Yes/No)	No	
	EA :	100			
	CL :	0			
	OTHER :	0			

Proximate DLA of SDSS J124020.91+145535.6 @ $z = 3.1$



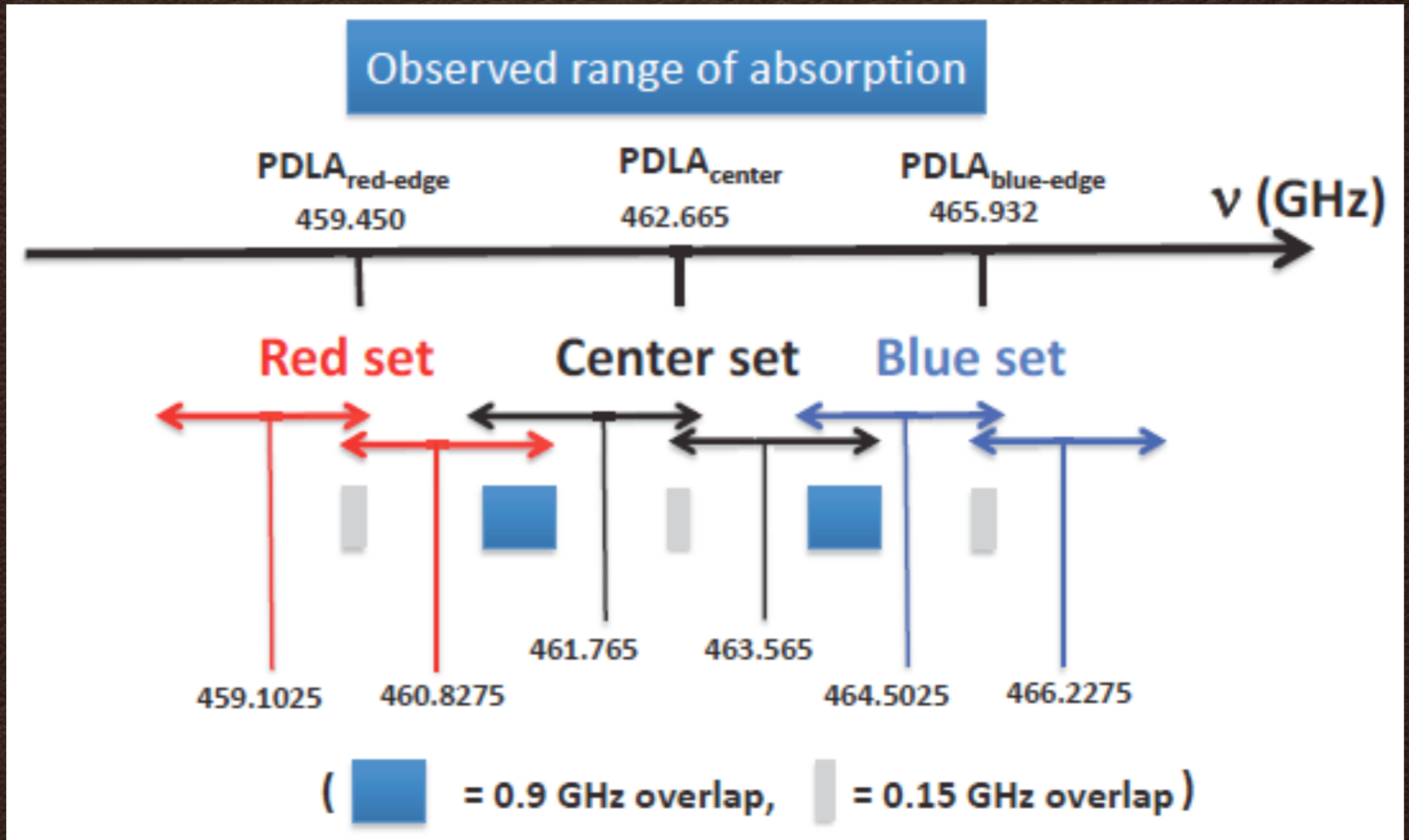
Superwind model for **Proximate** DLA of SDSS J124020.91+145535.6 @ $z = 3.1$



**Not Ly α emission
but undamped part of continuum**

(Hennami+ 09, ApJ, 693, L49)

Observational Strategy



A large, golden firework exploding against a black background. The firework consists of numerous thin, golden streaks radiating outwards from a central point, creating a starburst effect. The text is centered over the firework.

**We will see
a fantastic firework
at high redshift**