OBSERVING TIME PROPOSAL — Gemini Observatory – Semester 2027A

Probing the Epoch of Reionization: Spectroscopy of Lyα Emitters at $z > 6.5$

Principal Investigator:	Dr. Elena Vance (IfA, Hawaii)	**Telescope:**	Gemini North (8.1m)
Co-Investigators:	M. Thorne (UCSC), S. Jenkins (NOIRLab)	**Instrument:**	GMOS-N
Proposal Category:	Standard Joint / Dark Time	**Time Req:**	4 Nights (18.3 Hours)

Abstract

We propose to perform deep optical spectroscopy of a sample of six candidate Lyα emitting galaxies (LAEs) at redshifts $6.5 < z < 6.8$ discovered in the deep fields of the Subaru Hyper Suprime-Cam (HSC) survey. Our primary goal is to confirm their redshifts via the detection of the asymmetric Lyα emission line and to characterize their line profiles and equivalent widths. These observations will provide critical constraints on the neutral fraction of the intergalactic medium (IGM) at the tail end of the cosmic reionization epoch. By targeting objects with existing deep multi-band photometry, we will relate the spectroscopically determined Lyα escape fraction to the underlying stellar population properties (mass, age, and dust content). We request 4 nights (18.3 hours total including overheads) with GMOS-N in queue mode, using the R400 grating to achieve a spectral resolution of $R \sim 1900$, sufficient to resolve the characteristic red-asymmetric profile of Lyα and exclude low-redshift interlopers.

1 Scientific Justification

The transition of the intergalactic medium (IGM) from a neutral state to a fully ionized state—the Epoch of Reionization (EoR)—is a major milestone in cosmic history [1]. Current constraints from cosmic microwave background (CMB) optical depth and high-redshift quasar absorption spectra suggest that reionization was largely complete by $z \sim 6$. However, the detailed topology and timeline of this process remain poorly constrained. High-redshift Lyα emitting galaxies (LAEs) serve as sensitive probes of the IGM state because the resonant scattering of Lyα photons by neutral hydrogen suppresses the observed line flux [2].

Measuring the evolution of the Lyα spatial density and the line profile shape at $z > 6.5$ provides a direct measure of the IGM neutral fraction (x_{HI}) [3]. Recent surveys have identified a significant population of candidate LAEs at these epochs, but spectroscopic confirmation is required to confirm their high-redshift nature and break the degeneracy between intrinsic line profile evolution and IGM absorption [4].

Our target sample consists of six robust candidate LAEs at $z \approx 6.6$ selected from the Subaru HSC Ultra-Deep Survey [5]. These targets have been clean-selected using narrow-band imaging ($NB921$) and deep broadband data (g, r, i, z, y), which minimizes the risk of low-redshift contaminants such as [O II] emitters at $z \approx 1.5$.

The primary scientific objectives of this proposal are:

1. **Redshift Confirmation and Spatial Distribution:** Confirm the redshifts of six candidates to map the three-dimensional clustering of galaxies at the end of the EoR.

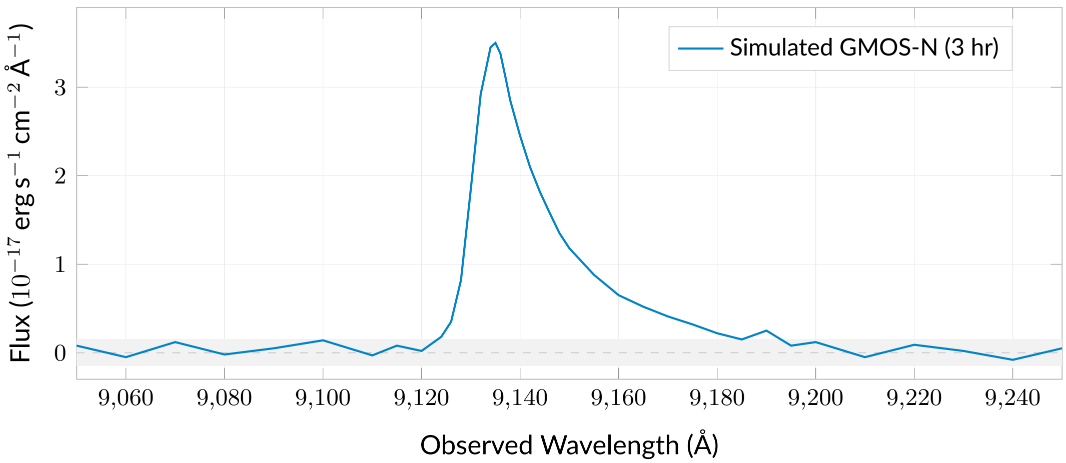

Figure 1: Simulated 3-hour GMOS-N spectrum of our primary target, HSC-LAE-J123408+010522 (blue curve), showing the predicted asymmetric Lyα profile at $z = 6.512$. The gray shaded region represents the 1σ sensitivity limit. The characteristic sharp blue cutoff and extended red wing are clearly resolvable at $R \sim 1900$, enabling a precise determination of the redshift and line asymmetry.

2. **Line Profile Analysis:** Measure the asymmetry parameter and velocity width of the Lyα line. The shape of the red wing is highly sensitive to the presence of an expanding neutral envelope, allowing us to model the local ionization bubbles.
3. **IGM Neutral Fraction:** Constrain the volume-averaged neutral fraction x_{HI} at $z \approx 6.6$ by comparing our measured Lyα spatial density and equivalent width distribution with empirical models of IGM attenuation.

2 Technical Justification

2.1 Observations and Instrument Configuration

We request the use of the Gemini Multi-Object Spectrograph (GMOS-N) on the Gemini North telescope in long-slit mode. To observe the Lyα emission line (expected at $\lambda \approx 9120$–9240 Å for our target sample), we will use the **R400_G5305** grating centered at 915 nm. We will pair this with the **GG455** order-sorting filter to block second-order contamination. A slit width of $1.0''$ will be used, matching the median seeing conditions at Maunakea in the optical ($0.75''$–$0.85''$). This setup yields a spectral resolution of $R \approx 1918$ at 915 nm, corresponding to a velocity resolution of $\Delta v \approx 156$ km s^{-1}. This is sufficient to resolve the expected asymmetric profile of the Lyα line (FWHM ~ 250 km s^{-1}) and distinguish it from low-redshift interlopers such as [O II] doublets ($\lambda\lambda 3726, 3729$) which would appear resolved at this resolution.

To minimize the impact of hot pixels and cosmic rays, we will employ a standard dithering pattern, offset by $\pm 5''$ along the slit between individual exposures. The detector will be binned 2×2 in both spatial and spectral directions to maximize the S/N ratio in the faint line wing.

2.2 Requested Time & Feasibility

We have utilized the GMOS Integration Time Calculator (ITC) to estimate the required exposure times. Our target selection is based on the narrow-band NB921 magnitudes, which range from 24.8 to 25.4 mag (corresponding to Lyα line fluxes of $F_{\mathrm{Ly}\alpha} \approx 1.2\text{–}2.0 \times 10^{-17}$ erg s^{-1} cm^{-2}).

For our faintest target ($m_{\mathrm{NB921}} \approx 25.4$), the ITC indicates that an on-source integration time of 3.0 hours (six 30-minute exposures) under 70%-ile image quality (seeing $\leq 0.85''$), 50%-ile cloud cover (clear), and dark sky conditions (dark time) will yield an integrated line S/N of ≈ 6.5. This is sufficient for robust line profile fitting and asymmetric parameter measurement. For the brighter targets in our sample, we will achieve S/N ≈ 10 in the same integration time.

Our sample consists of 6 targets. With an on-source integration time of 2.5 to 3.0 hours per target, the total on-source time is 14.5 hours. We calculate the total telescope time including overheads as follows:

- **On-source integration:** 14.5 hours (6 targets $\times 2.4$ hours average).
- **Acquisition overhead:** 1.8 hours total (6×18 minutes per target, using offset-star alignment).
- **Readout and grating overhead:** 2.0 hours total (4 minutes per exposure, 30 exposures).

This results in a total requested time of **18.3 hours** (equivalent to approximately 2.3 nights of classical time, but requested as 18.3 hours of queue time to optimize execution under matching weather constraints). We request scheduling in queue mode under conditions: Image Quality < 70%, Cloud Cover < 50%, Sky Brightness = Dark.

3 Target List

The primary target sample consists of six candidate Lyα emitters selected from the Subaru Hyper Suprime-Cam (HSC) Ultra-Deep survey fields. The coordinates, V-magnitudes (all targets are extremely faint in the optical and require blind offset acquisition), integration times, and execution priorities are summarized in Table 1.

Table 1: Target list for the proposed GMOS-N spectroscopic observations.

Target	RA (J2000)	Dec (J2000)	V-mag	Exp. time	Priority
HSC-LAE-J123408+010522	12:34:08.52	+01:05:22.4	> 27.5	2.5 hr	P1
HSC-LAE-J123519+010844	12:35:19.11	+01:08:44.2	> 27.5	3.0 hr	P1
HSC-LAE-J123602+011210	12:36:02.04	+01:12:10.8	> 27.5	2.5 hr	P1
HSC-LAE-J123445+010315	12:34:45.18	+01:03:15.1	> 27.5	3.0 hr	P2
HSC-LAE-J123550+011502	12:35:50.88	+01:15:02.6	> 27.5	3.0 hr	P2
HSC-LAE-J123611+010158	12:36:11.75	+01:01:58.3	> 27.5	3.0 hr	P2

References

[1] Fan, X., Carilli, C. L., & Keating, B. 2006, ARA&A, 44, 415

[2] Ouchi, M., Shimasaku, K., Furusawa, H., et al. 2010, ApJ, 723, 869

[3] Stark, D. P., Ellis, R. S., Chiu, K., et al. 2010, MNRAS, 408, 1628
[4] Konno, A., Ouchi, M., Shibuya, T., et al. 2018, PASJ, 70, S16
[5] Harikane, Y., Ono, Y., Ouchi, M., et al. 2022, ApJS, 259, 20