Y-NBS: Probing the epoch of reionisation with the brightest distant LAEs

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1. The Epoch of Reionisation

Studying the **very early Universe** helps us to find our cosmic origins and to improve the models of **galaxy formation and evolution**. As the last major phase transition of hydrogen, the **epoch of reionisation** marks an important era in the history of the Universe, as the **neutral hydrogen** transformed into **ionised hydrogen**, yet there are many **open questions** and unknowns remaining.

- ❑ When did reionisation begin and end?
- ❑ What are the sources of reionisation?
- ❑ What can we learn about these sources?

Current evidence points towards **patchy reionisation** as a good model: reionisation began with the **brightest galaxies** with **bubbles** of ionised hydrogen **growing** around the sources, eventually **merging** into one another until the **entire IGM** consisted of **ionised hydrogen** [1]. Evidence for this can be seen from **different levels of ionisation across different fields** at the same redshifts.

Figure 1: Artist's impression of patchy reionisation - bubbles of ionised hydrogen growing around early galaxies (Credit: ESO/L. Calcada)

2. The Y-NBS Narrowband Survey in COSMOS

The Lyman-alpha (**Lyα**) emission line is an extremely useful **probe** into the **epoch of reionisation** as Lyα photons are sensitive to the **fraction of neutral hydrogen** in the IGM. Therefore, we set up the **widest** search yet for Lyα emitters (**LAEs**) **at z=7.7**, with observations of ~1deg^2 of the **COSMOS** field.

Y-NBS included both **deep** and **shallow** pointings, with exposure times of **24.1h and 7.4h** respectively.

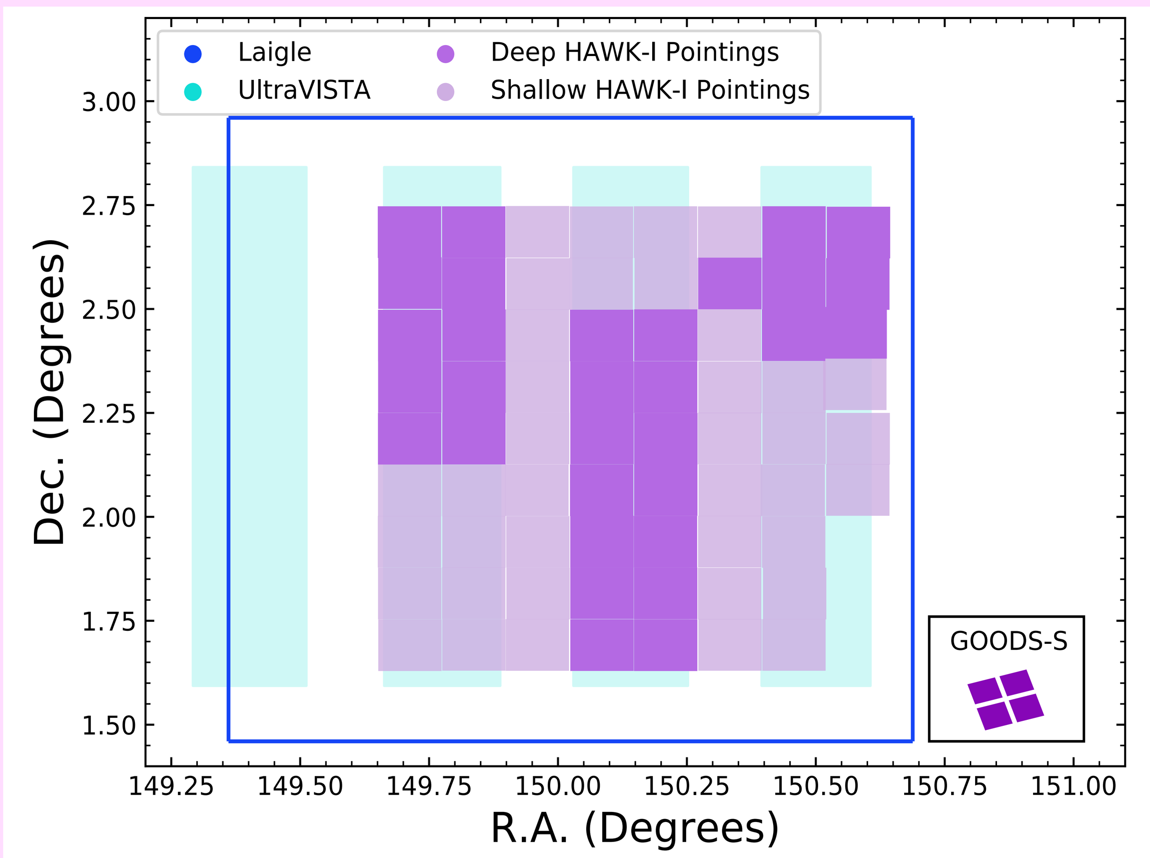

Figure 2: The footprint of this study, with deep pointings in darker purple, shallow pointings in lighter purple, and the GOODS-S data inset.

3. Y-NBS Continued

Y-NBS is an 'ultra-wide' Y band (**1.06um**) narrowband survey, using **HAWK-I** on the **Very Large Telescope** in the **COSMOS** field. Figure 3 shows the HAWK-I **NB1060** and the UltraVISTA Y and J band that we match to. We combine our wide COSMOS with an **extremely deep** HAWK-I pointing in the **GOODS-S** field, shown in Figure 2 [2].

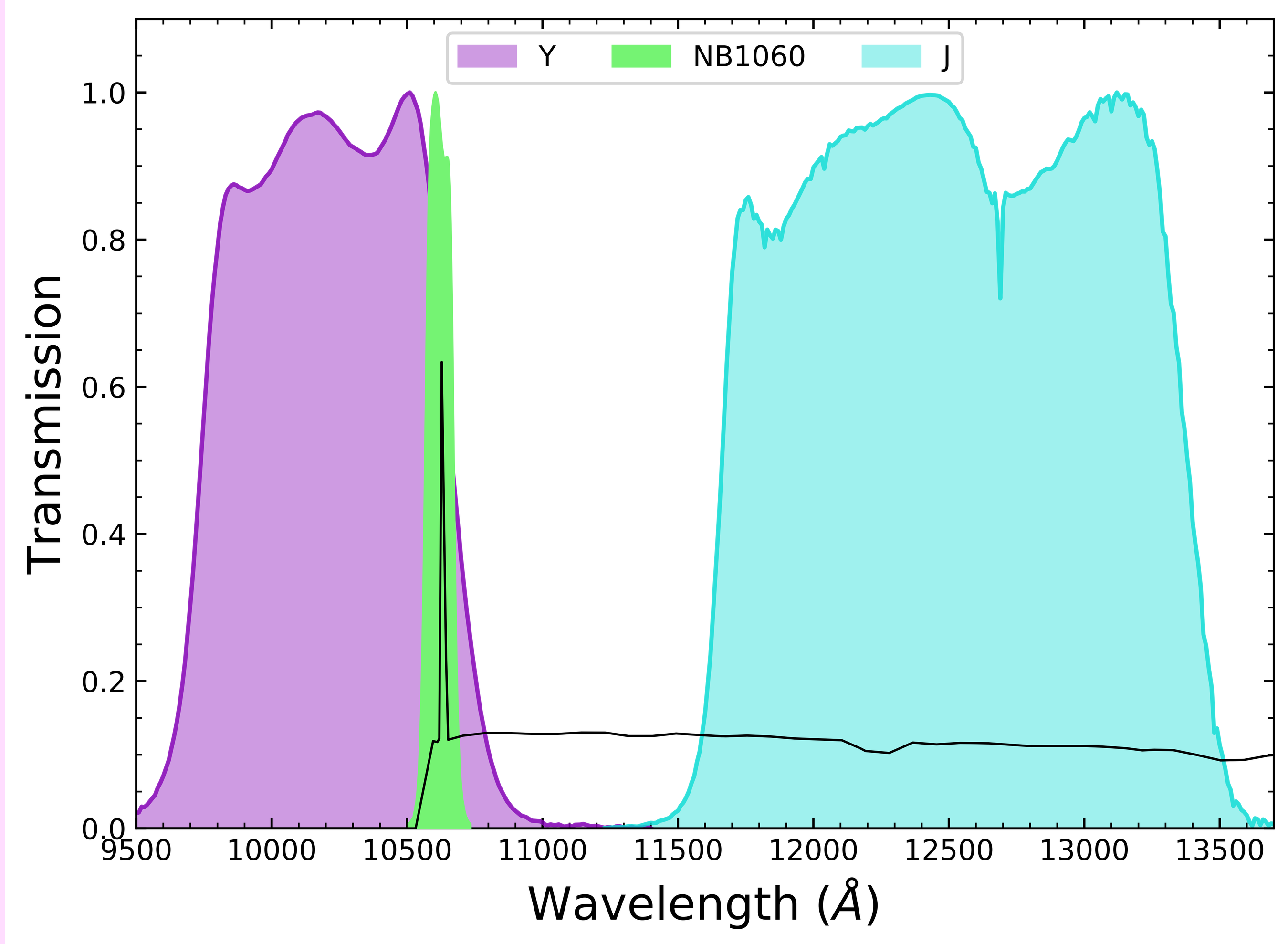

Figure 3: The HAWK-I NB1060 filter profile, alongside the VISTA Y and J filter profiles. In black is a z=7.7 LAE example spectrum.

Table 1 highlights the differences between the data for the COSMOS and GOODS-S fields: GOODS-S is only 1 pointing but it is significantly deeper, being able to observe especially faint Lyα luminosities.

	COSMOS	GOODS-S
No. HAWK-I Pointings	69	1
Area (deg^2)	0.8	0.014
Volume (Mpc^3)	~600,000	~9000
Lyα Luminosity (erg/s)	$10^{43.5}$	$10^{42.3}$

Table 1: Information about the two datasets in the COSMOS and GOODS-S fields.

Figure 3 also gives an example **z=7.7 LAE spectrum**, showing that it would be observed by an **excess in NB1060** compared to the Y and J. As well as LAEs, numerous other lower redshift **Hα, [OIII], Hb and [OII] emitters** will be observed meaning we will be able to compare the LFs for Hα, [OIII], Hb and [OII] with current results [3] – see Wade et al. in prep.

Y-NBS covers a **large proportion of the COSMOS field** and it marks the widest search yet for z=7.7 LAEs and **leads the way** for future surveys studying **large volumes at z > 7**. We hope to observe the brightest sources, and then continue this work with wider and deeper surveys to create the first large sample of z > 7 LAEs. Previous studies with **small volumes** have been **unsuccessful** in finding z=7.7 LAEs [2].

For more information about this work scan the QR code to **watch a conference talk about YNBS** - https://youtu.be/mx8lRf7WmPs

4. The Lyman-alpha Luminosity Function

The **Lyα luminosity function (LF)** is very well constrained up to z=6.6, but due to a **lack of ultra-wide narrowband surveys at z=7.7**, it remains **unconstrained deeper into the epoch of reionisation** and data is especially **lacking at the bright-end**. Our **Y-NBS** data will allow us to combine **ultra-faint** LAEs with the **brightest** LAEs to obtain the **best constraints** on the **z=7.7 Lyα LF** yet. Tilvi+2020 find sources to populate the bright end of the z=7.7 Lyα LF and we aim to add to this with more sources**.**

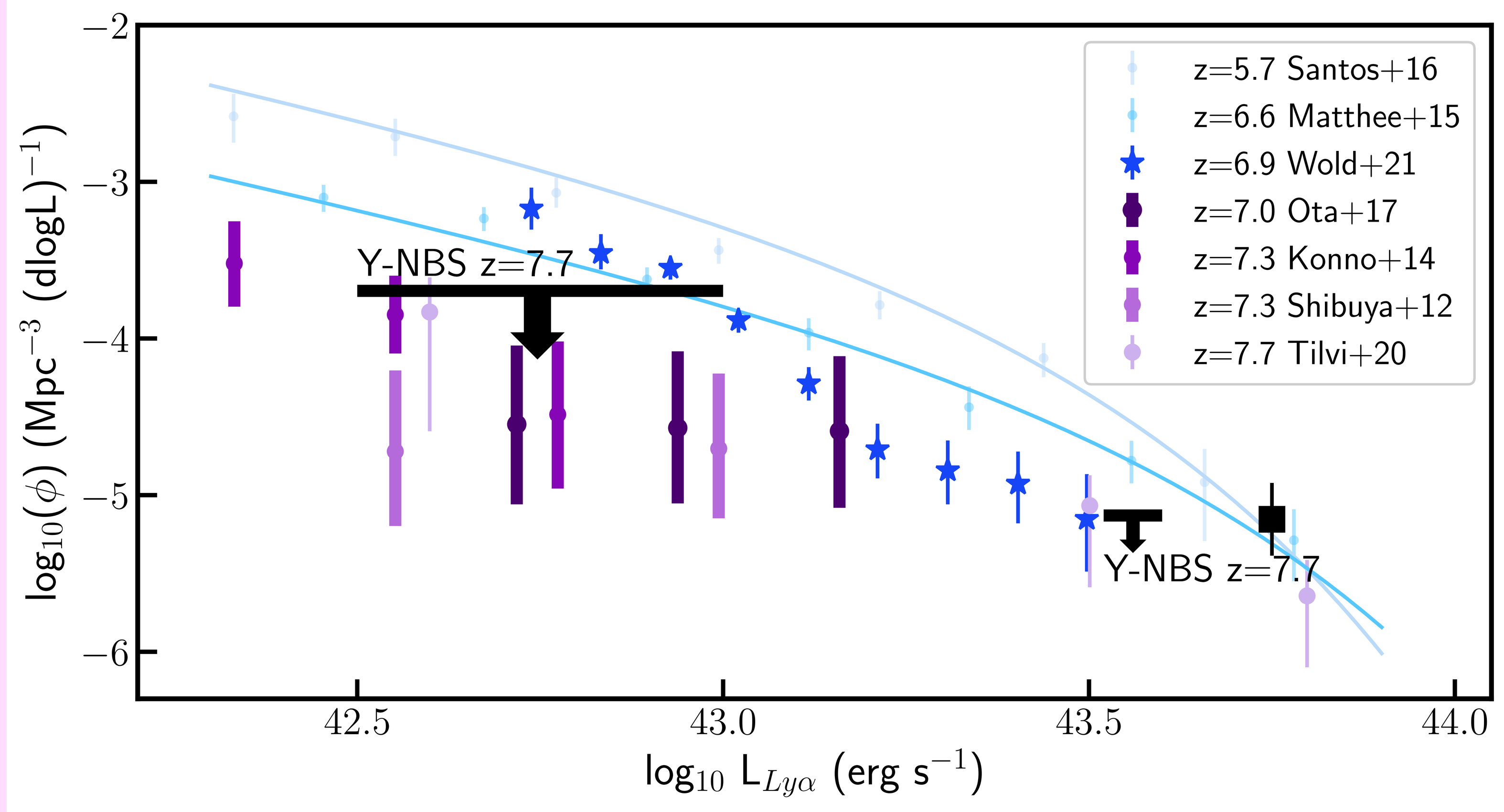

Figure 4: The current best Lyα luminosity function from z=5.7 to z=7.7, including our constraints (black lines) and our preliminary results (black square).

Early analysis shows **2 possible z=7.7 LAEs** in our COSMOS data, shown on Figure 4 as the black square, but this is preliminary work currently. The black lines show the constraints from **volume and luminosities probed** by the Y-NBS survey. We are **greatly constricting** the possible z=7.7 Lyα LF and we can hopefully spectroscopically **confirm the detections** of these mysterious z=7.7 LAEs. Also, the intermediate luminosity region (log Lyα lum = 43.0 – 43.5) is yet to be constrained or fully studied, despite it being possible with current telescopes. **The need for more wide and deep surveys has never been greater as they can currently unlock many of the secrets of the epoch of reionisation.**

5. Summary

Y-NBS is the **largest ultra-wide HAWKI/VLT narrowband survey** yet to be carried out in order to search for **z = 7.7 LAEs in the epoch of reionisation**. We **constrain the z=7.7 Lyα luminosity** and potentially find 2 LAEs in our COSMOS data. Also, the numerous **Hα, [OII] and [OIII] emitters** at intermediate redshifts, will be fully explored in **Wade et al. in prep.**

References

[1] – Santos S., Sobral D., Matthee J., 2016, MNRAS, 463, 1678
[2] – Clement B., et al., 2012, A&A, 538, A66
[3] - Khostovan A. A., et al., 2020, MNRAS, 493, 3966