# Paschen Star Formation History of the Universe with HiZELS

In the past 5 Gyr

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## ABSTRACT

The most fundamental observational properties that need to be determined to obtain a comprehensive understanding of the physical processes of galaxy formation and evolution are the cosmic star formation history of the Universe and the volume-averaged star formation rate as a function of epoch. However, determining these quantities with high accuracy alone is insufficient for our understanding of galaxy formation and evolution: understanding the nature and properties of the star-forming galaxies is also essential. The High-redshift Emission Line Survey (HiZELS) is a successful panoramic extragalactic survey which uses the narrow-band technique (in the J, H and K bands) to search for emission line galaxies and primarily targets Hα emitters at z = 0.84, 1.47 and 2.23. The narrow-band K ($NB_K$) filter is also sensitive to Paschen−α, Paschen−β and Paschen−γ line emitters at z = 0.13, 0.66 and 0.95, respectively. The lines from the Paschen series of the hydrogen atom are infra-red lines and therefore ~ dust-independent star-formation tracers, hence interesting. Preliminary results of the spectroscopic follow-up the $NB_K$ line emitters are presented in this poster.

## 1. HiZELS

HiZELS is using the WFCAM instrument on the United Kingdom Infrared Telescope (UKIRT). The survey aims at detecting emission line galaxies over the redshift range z = 0 − 9 using a set of narrow-band filters in the J, H and K bands and covers an area of ~ 7 deg² of the extragalactic sky. There are a multitude of emission lines (and consequently, emission line galaxies at several redshifts) which can be detected in the narrow-band filters.

HiZELS primarily aims at using Hα emitters to measure the star-formation history of the Universe across the peak of star- formation (z ~ 1 − 2), investigate the environment in which star-forming galaxies reside, study the epoch of re-ionisation using the highest redshift detected galaxies, and compare the star-formation properties of the Hα-selected galaxies with the corresponding information obtained using studies at other wavelengths.

Emission line objects are selected based on their narrow-band excess flux, i.e., depending on the significance of their broad-band minus narrow-band (BB − NB) colour as they will have (BB − NB) > 0 (see Figure 1 for an example).

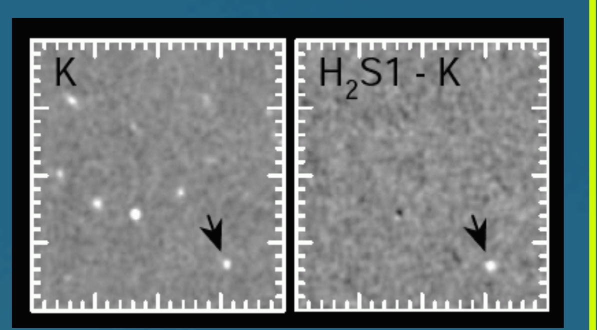


Fig. 1 - Narrow-band excess object selected form $NB_K$ imaging.

HiZELS has measured the Hα luminosity function and shown that the star-formation rate density measured in a consistent manner with the Hα line seems to rise up to z ~ 1 and then flatten out to z ~ 2.2 (see Figure 2) [Geach et al. 2008, Sobral et al. 2009a, 2011b].

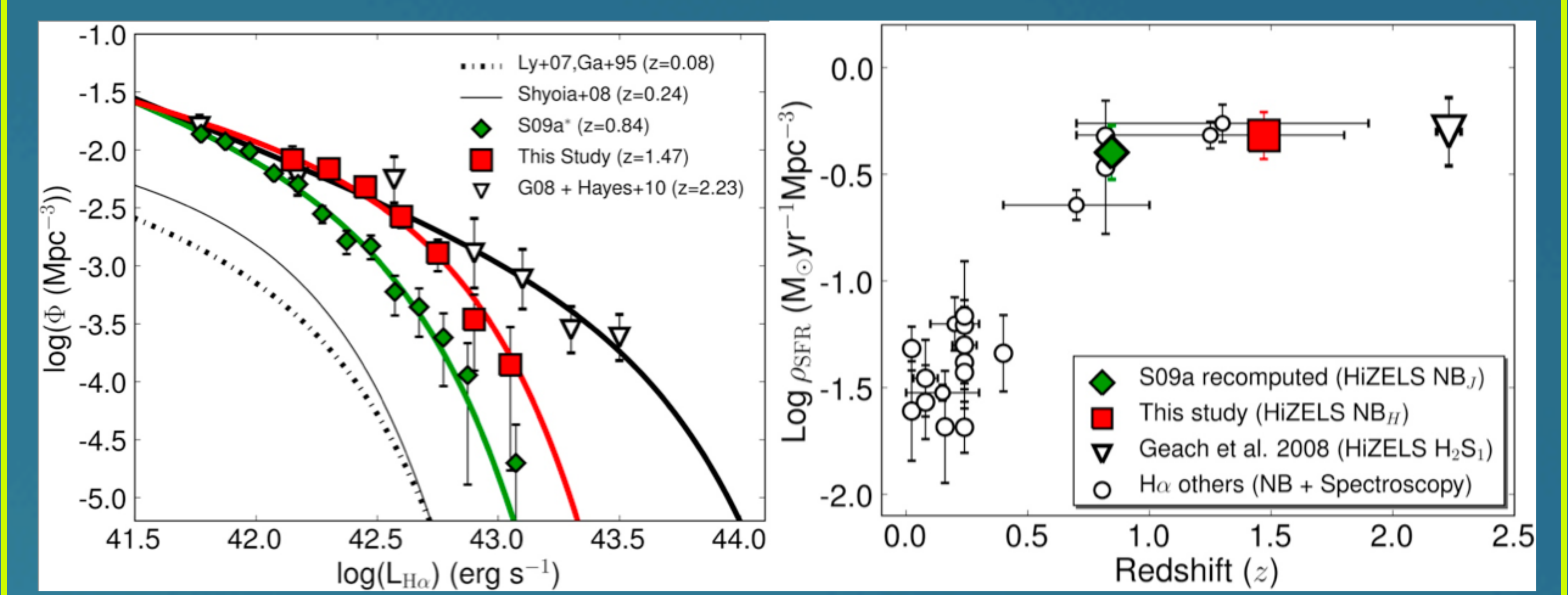


Fig. 2 - *Left*: Hα Luminosity function from HizELS and other surveys. *Right*: Evolution of the star-formation rate density as a function of redshift based on Hα.

Other major HiZELS results have included:

- Morphologies: disks dominate the sample for low star-formation rates, whereas for higher luminosities irregulars and mergers predominate [Sobral et al. 2009a].
- Clustering: is a strong function of Hα luminosity; galaxies at the same $L_{H\alpha}/L^*_{H\alpha}$ reside in similar dark matter halos at all redshifts [Sobral et al. 2010].
- Mass and Environment: mass-downsizing is seen to already be in place at z = 0.84; whilst star-forming galaxies also avoid the most dense environments at z ~ 1 [Sobral et al. 2011a].
- Dust: the relationship between dust attenuation and star-formation rate evolves out to z ~ 1.5 [Garn et al. 2010, Sobral et al. 2011b].

## 2. Paschen Emitters

Using the narrow-band technique with HiZELS, one can detect not only the Hα line, but any emission line. In fact, in the narrow-band K over 50% of the emitters are non-Hα line emitters, of which a considerable number is thought to be Paschen emitters (Paα at z = 0.13, Paβ at z = 0.66 and Paγ at z = 0.95). These emitters can then be used to probe the low-to-medium redshift (z ~ 0 − 1) end of the cosmic star-forming population, in a dust-independent manner (see Figure 3).

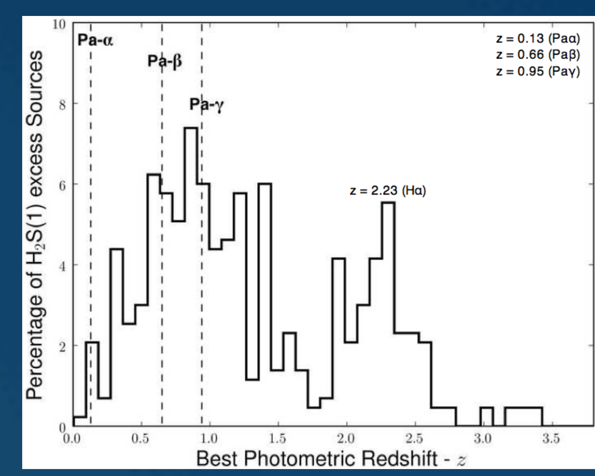


Fig. 3 - Best photometric redshift. In the COSMOS field, photometric redhshifts are of high quality.

## 3. Spectroscopic Follow-up

Firstly, the aim is to produce samples of high redshift Paschen emitters, with which it will be possible to test the star-formation rate density calculations and investigate galaxy properties in a way which is not biased by dust-extinction. Spectroscopic follow-up of the non-Hα emitters is used to investigate the practicality of using these to derive for the first time a star-formation rate history based on Paschen lines, study their sensitivity, calibration, the accuracy and completeness of the photometric redshift selection, identify AGN within the sample and measure dust-extinction.

In order to investigate the reliability of the photometric redshift selection spectroscopic redshifts are needed. To serve such a purpose one may use:

- Literature spectroscopic redshifts (eg: zCOSMOS)
- Follow-up observations:
  - ⋆ generic HiZELS follow-up with the VIsible MultiObject Spectrograph (VIMOS),
  - ⋆ dedicated Paschen candidates targeting with AAOmega.

Spectroscopy for the non-Hα emitters using the AAOmega instrument (a high-multiplex spectrograph) on the Anglo-Australian Telescope and VIMOS has been obtained. These observations may also detect other emitters at low redshift.

Figure 4 shows preliminary results from AAOmega spectroscopy. For the majority of the identified Paschen emitters (for an example see Figure 4, right panel), the photometric and the spectroscopic redshift agree well (see Figure 4, left panel). The few outliers also shown in Figure 4 (left panel) are robust and indicate cases where the photometric redshifts are inaccurate, probably due to the strong emission lines. Work on completing the data analysis of this data set is still on-going.

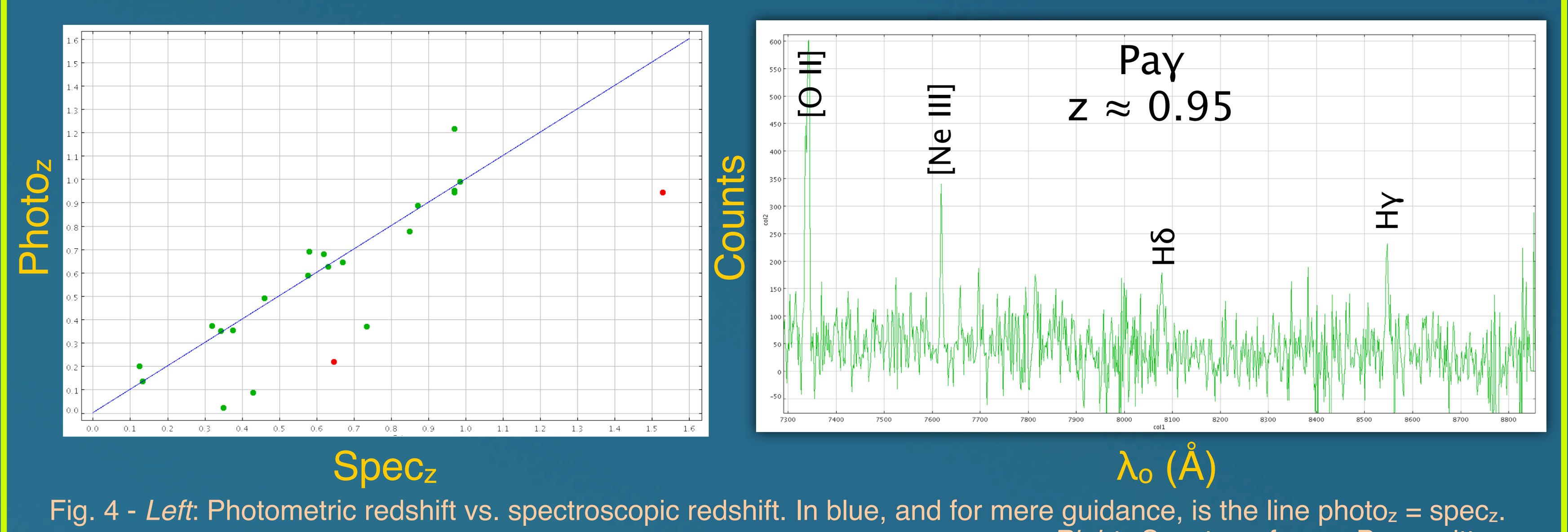


Fig. 4 - *Left*: Photometric redshift vs. spectroscopic redshift. In blue, and for mere guidance, is the line $photo_z = spec_z$. *Right*: Spectrum from a Paγ emitter.

The combined observations of both the AAOmega and the VIMOS coupled with literature data will provide a statistically significant sample of Paschen emitters in the low-to-medium redshift range.

## 4. Future Work

Future work with the narrow-band imaging comprises studying the nature of star-forming galaxies, using a wealth of multi-wavelength data sets, and the role of the environment in the star-formation activity. Further- more, the first robust sample of star-forming galaxies at high redshifts (z > 7) is to be obtained using narrow-band filters on the new VISTA telescope, just at the formation epoch of the first galaxies and the re-ionisation of the Universe. Finally, the observational results will be applied to strongly constrain galaxy formation and evolution models.

## References

Garn, T.; et al., 2010, MNRAS, 402
Geach, J.; et al., 2008, MNRAS, 388
Sobral et al. 2011a, MNRAS 411
Sobral, D.; et al., 2009a, MNRAS, 398
Sobral, D.; et al., 2010, MNRAS, 398
Sobral, D.; et al., 2011b, *in prep*.

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