Haro 11 and the Lyman continuum emission revisited

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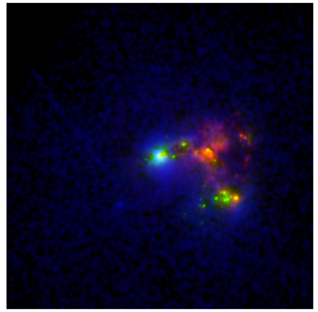

Fig.1: Haro 11 with Ly alpha emission seen in blue. A major part of the Ly alpha photons are emitted in the diffuse halo, but in the upper left knot direct leakage have been detected (Hayes et al. 2007).

Background

The contribution of star forming galaxies to the early stages of the cosmic reionization is still largely unknown. Due to the opacity of the intergalactic medium at earlier times, any direct detections have to be done at low and intermediate redshifts.
Few detections of galaxies leaking hydrogen ionizing photons have been made so far, and several of these have later been questioned. The local star forming galaxy Haro 11 is one such. It has been exhaustivly studied throughout the years, and is clearly undergoing a period of heavy star formation with its strong emission lines, blue colors, Wolf Rayet features and numerous super stellar clusters. It is also known to have a low content of neutral hydrogen, and was studied in the Lyman continuum (LyC) with FUSE (Far Ultraviolet Spectroscopic Explorer) by Bergvall et al. In 2006 these authors presented their results, where they found the escape fraction of LyC photons (fesc) to be 4-10 %. The same data were later re-analyzed by Grimes et al. 2007 where an upper bound of only 2 % was found. Also interesting in the context is the theoretical work in Hayes et al. 2007 where a predicted fesc of 9 % was found, closer to the original value by Bergvall et al., and the question still remains unsettled.

References:
Bergvall, N., Zackrisson, E., Andersson, B-G, et al. 2006, A&A 448, 513
Grimes, J.P., Heckman, T, Strickland, D, et al. 2007, ApJ 668, 891
Hayes, M., Östlin, G., Atek, H., et al. 2007, MNRAS 382, 1465
Grimes, J.P., Heckman, T., Aloisi, A., et al. 2009, ApJS 181, 272
Piskunov, N.E., Valenti, J.A., 2002, A&A 385, 1106

CALFUSE and the background subtraction

The pipeline of FUSE, CALFUSE, was not really designed for dealing with objects with very low photon counts (van Dixon 2007, private communication). This is also evident in several published works (e.g. Grimes et al. 2009) where the flux is negative for short wavelengths. The problem seem to lie in how the background is modeled, and is specifically problematic in the SiC 1A and 1B detector segments, where the spectrum lies on the steeply rising background at the edge (see Fig. 2). In this work we have used an approach different from what is used in the pipeline. The background of CALFUSE is constructed from scaling observations of a blank sky, where the one closest in time to the observations is used. Here, we instead select the two background models where the ratio between the maximum in the edge and the continuum level (of the 2D background images) are closest to the ratio in our science image, and interpolate between those. The advantage of this approach is that we can better use the shape of the background model close to the edge. The resulting background is then modeled by the "opt_filter_2d.pro" routine (Piskunov et al. 2002) and scaled according to the science image. For the 2A and 2B segments the spectra do not lie on the steep slope, and the modeling can be done directly from the science image. A comparison of the signal with the background overplotted for both the pipeline produced and our method can be seen in the figure below (pipeline left, our work right).

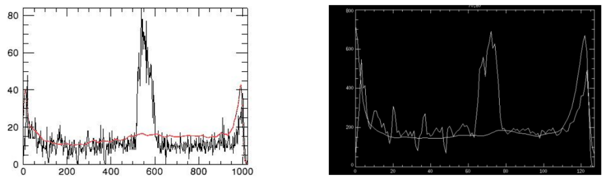

Fig. 2: Cross-section of the 2D spectrum for detector SiC 1B, summed over x-pixels at wavelengths corresponding to LyC leaking region. Left: Overplotted in red is the pipeline produced background. The signal is expected between pixels 48-112. Right: The background fit using our procedure overplotted on the signal, both rebinned by a factor of 8 compared to the left image. The signal is expected between pixels 6-14.

Preliminary results

At short wavelengths geocoronal emission is quite strong, especially during orbital day, and the lines lie close. To be on the safe side we avoid this problem by screening out all photons in regions marked as airglow regions, (automatically excluding all data below 920 Å) and only use the orbital night data. Even with these precautions both detector segments SiC 1B and SiC 2A show an excess in the 920-930 Å region, which is where the LyC of Haro 11 should be visible. The fluxes differ however, with preliminary value ~1.2 e-14 erg s-1 cm-2 Å-1 for the most problematic segment SiC 1B (figure below). The segment with a more stable background, SiC 2A, gives a flux of ~0.5 e-14 erg s-1 cm-2 Å-1. Thus, going by the more reliable SiC 2A, we arrive at a value lower than the Bergvall et al. 2006 result, but higher than the Grimes et al. 2007.

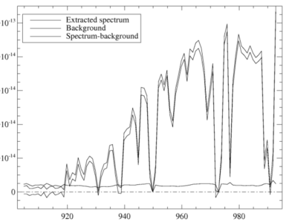

Fig. 3: 1D spectrum from the SiC 1B detector. All photons blow 920 Å are flagged as airglow photons, and are therefore discarded. The Lyman limit of Haro 11 is at 930 Å, a clear signal can be seen below this (Leitet et al. 2009, in prep.).