Unevolved emission line galaxies with the LBT: from local galaxies to high-z

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Signs of very hard radiation fields

Deep spectra of several high redshift galaxies (z~ 7...9) show strong lines of highly ionized ions, like He II (e.g. Stark et al. 2015, 2017). Unfortunately, the objects are to faint to study the ionization source, ISM properties and their morphology.

Fortunately, there may candidates for lower redshift proxies, like Ultra-strong emission line galaxies (Kakazu et al. 2007, Hu et al. 2009) at z~0.5, exteme emission line galaxies at z~1.7 (Atek et al. 2012, van der Wel et al. 2012, „green peas" (e.g. Cardamone et al. 2009), and even „blueberries" (Yang et al. 2017) at quite low redshifts. Still, to be proxies of the highly ionized emitters at z~7, they should be nebular HeII emitters. Fortunately, such a sample can be generated based on SDSS DR7 (Shirazi & Brinchman 2012) and SDSS DR12 (Enders, Bomans, Langener 2017, in prep.). The galaxies which show no stellar HeII line from Wolf-Rayet stars are mostly very low-metallcity objects (log (O/H < 7.7) . As example, a stack from several SDSS-BOSS spectra of nebular He II emitters is shown in Fig.1 (Enders et al.).

One critical point of comparing these galaxies to the the high redshit one is to find the source of strong ionizing continuum, which could be very massive, very low metallicity stars, but also X-ray binaries, fast shocks, or even hidden AGN. Clearly high-quality spectroscopy is needed, hence we use **LBT / MODS**, supported by multi-wavelength data (HST; X-ray, radio-continuum) and photoionization and shock-ionization modelling..

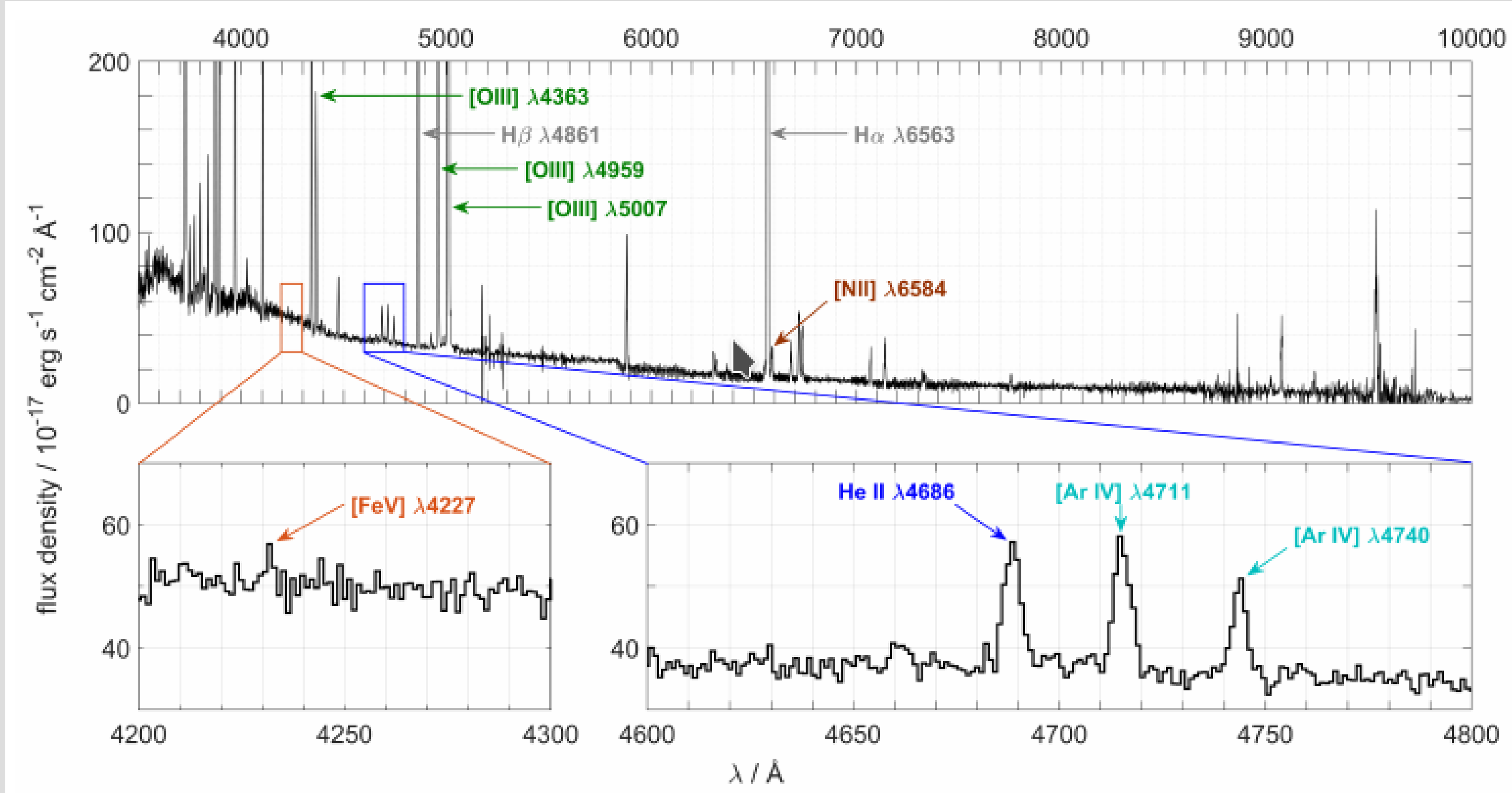
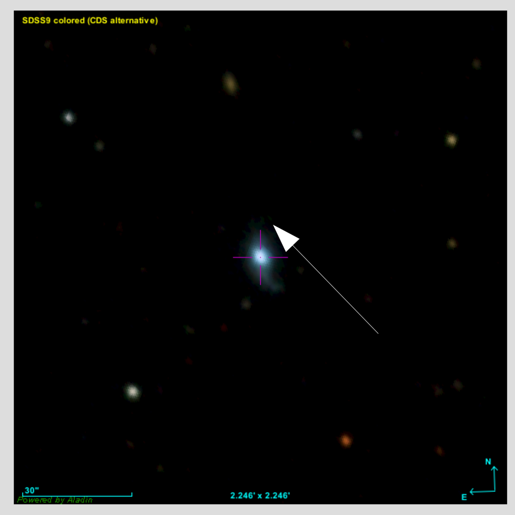


Fig 1.: Stack of several SDSS-BOSS spectra of nebular HeII emitter (upper panel), and blow-ups of the spectral ranges of around the [Fe V] lines and the HeII and [Ar IV] lines. The HeII line is narrow and therefore nebular, without any broad emission lines of Wolf-Rayet stars, e.g. C III, C IV, N III, N IV. Strong lines of [Ar IV] and the tentative detection of [Fe V] further point at a hard ionizing continuum to be constrained by photoionization (and shock ionization) modelling.

Mrk 1434

The galaxy Mrk 1434 is especially interesting, being one of the closest members of the sample (z=0.0076) and already having some ancilliary HST and CHANDRA data. The MODS-1 spectrum not only shows the He II and other highly ionized lines, but the bright lines are spllit, indicating an outflow of ~300 km/s from the central knot.



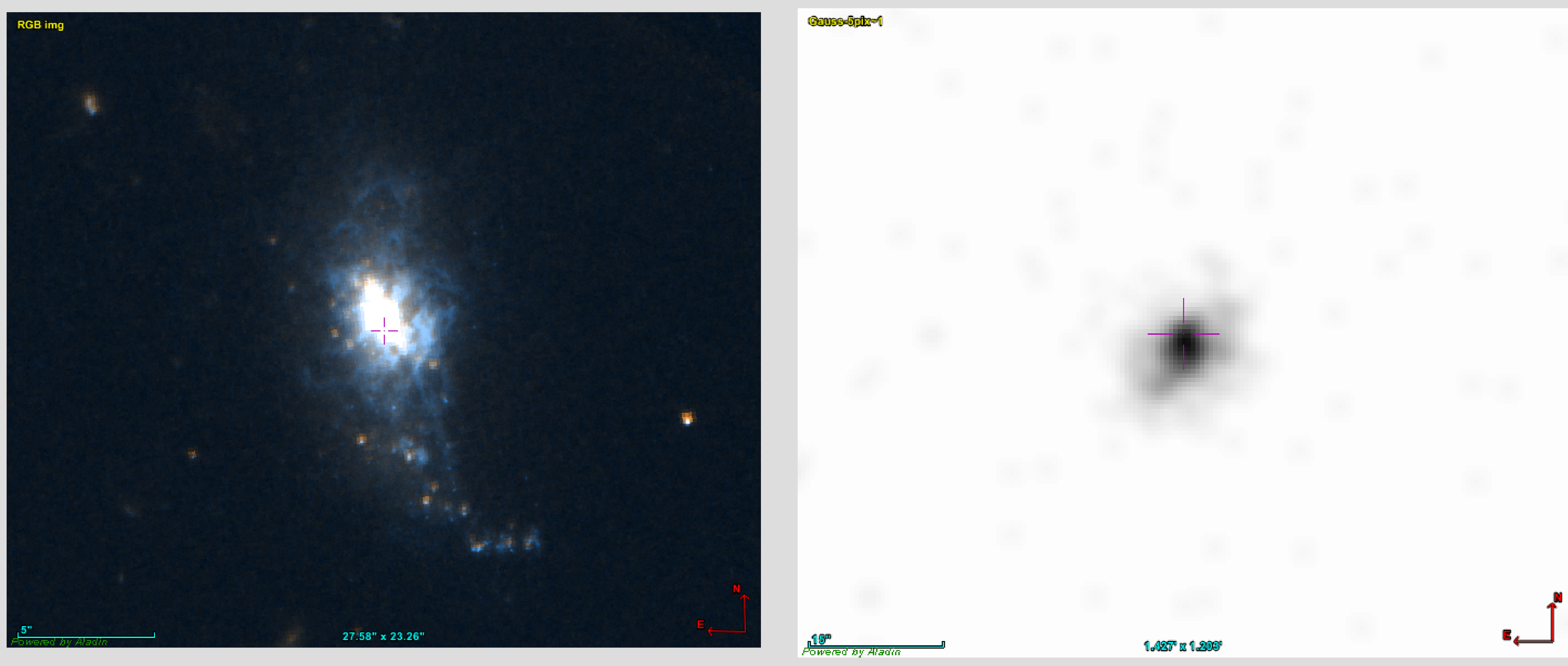


Fig 3.: left: HST WFC3 color image of Mrk 1434 (F606W blue, F110W red). Note the bright and complex filamentary morphology of the Hα emission (inside the F606W filter).
Right: CHANDRA X-ray image of Mrk 1434, showing a central knot and some possible diffuse halo. Since the galaxy was located far from the optical axis, careful modelling of the PSF is needed, before interpreting the halo. Still, a hard point-like source seem to be present at the core of Mrk 1434, either high-mass X-ray binaries, of maybe an accreting central supermassive black hole. On the other hand, no broad, AGN-like emission lines are detected in the MODS spectrum.

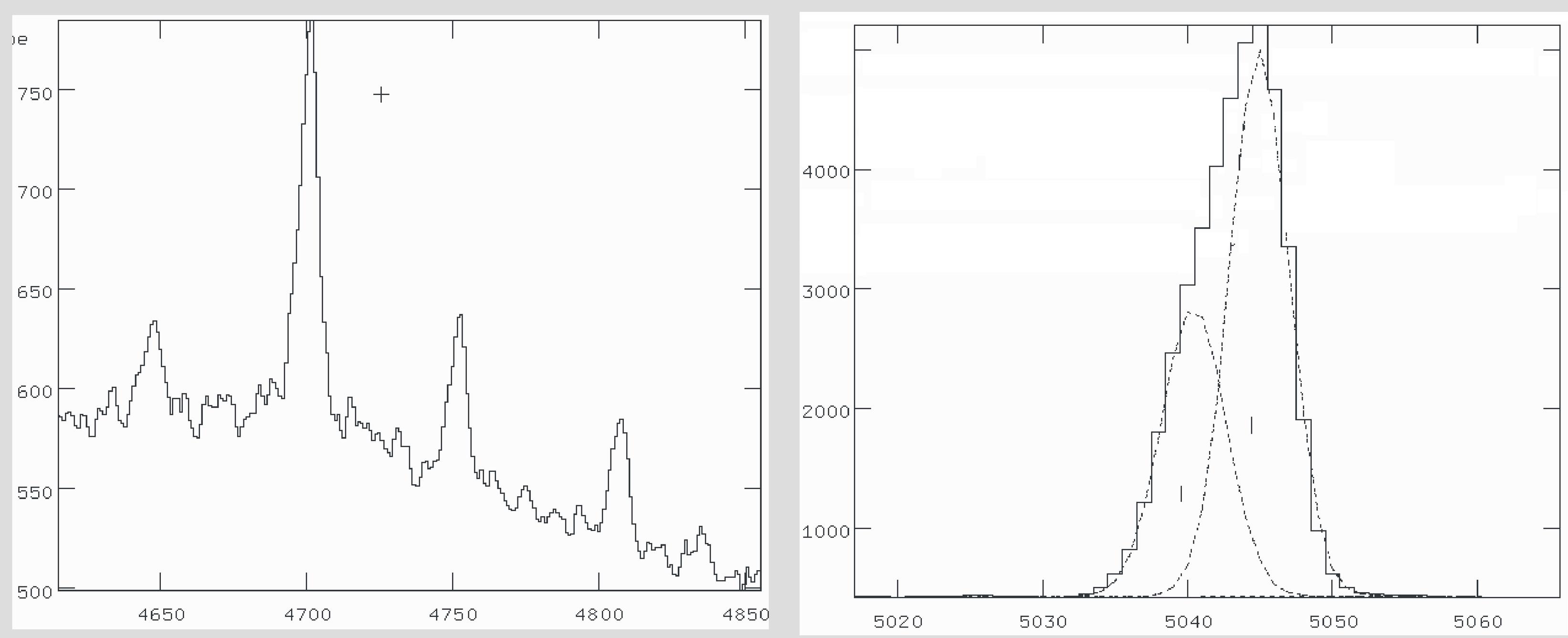


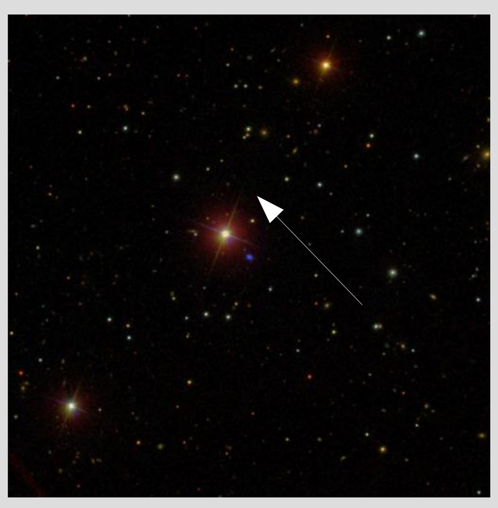
Fig 4.: Small subsections of MODS-1 spectrum of Mrk 1434. Again, strong, nebular HeII and other highly ionized lines are present (left panel). The strong lines appear to consist of two components (see fit of Hβ line in right panel), implying an expansion of the central region of 300 km/s, enough for strong shock ionization.

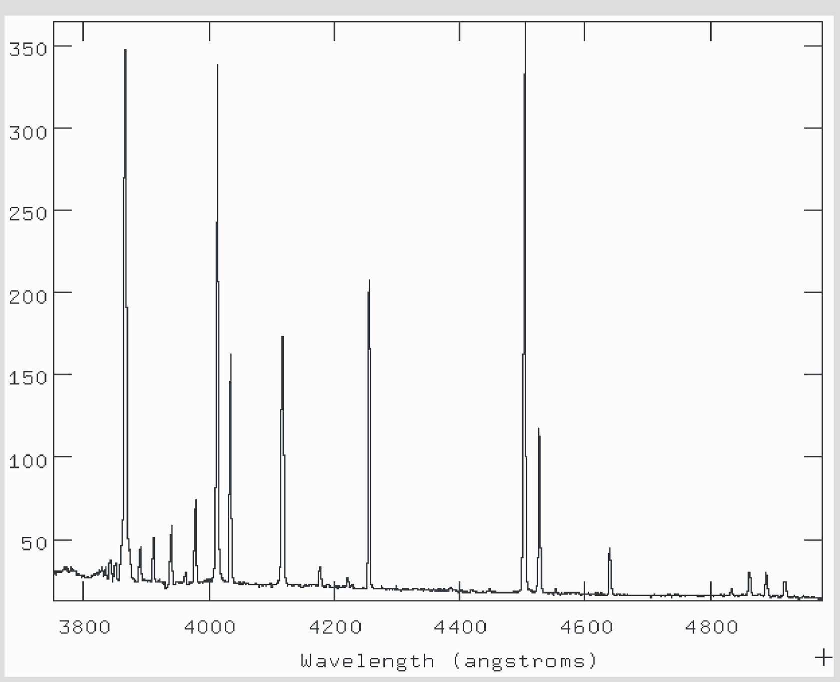
LBT MODS Observations

From the SDSS we derived a sample of nearby emission line galaxies, with nebular HeII emission based on (Shirazi & Brinchman 2012). This spring (Bochum GTO time during the LBTB blocks in February and May) we observed 5 galaxies with MODS1 and MODS2 in binocular mode.

SDSS 1545+0858

This is another galaxy from our MODS sample. It is more distant and signifcantly more luminous than Mrk 1434, and very compact (minor axis < 5 kpc). Also here very strong nebular lines of highly ionized ions are detected.





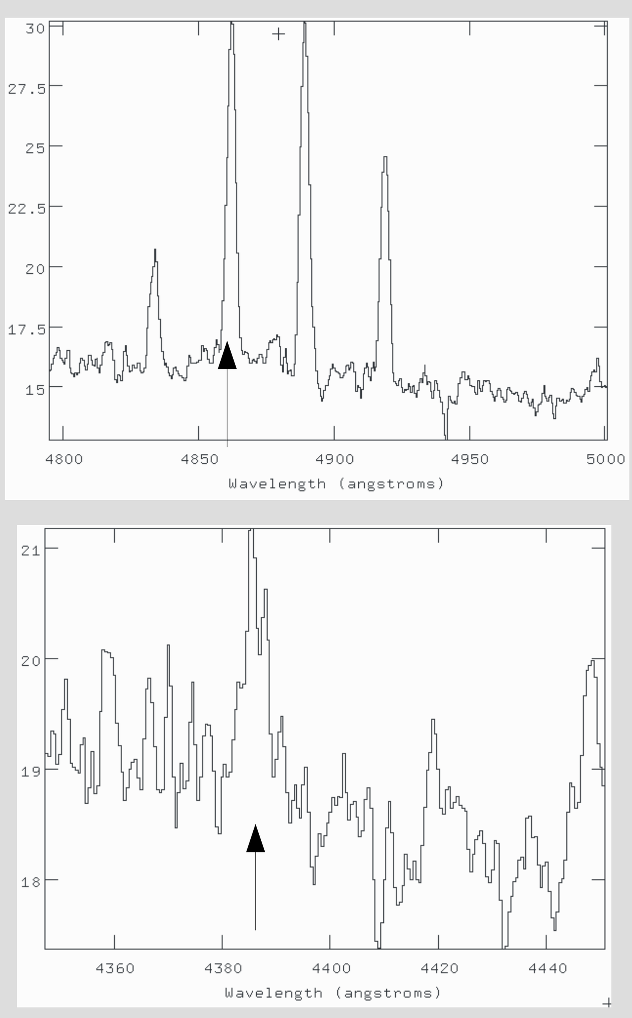


Fig 2.: Subset of a MODS-1 spectrum of SDSS 1545+0858 with blow-ups as in Fig. 1. Again, strong, nebular HeII (arrow in upper blow-up spectrum) and [Fe V] (arrow in lower blow-up spectrum) are detected.

Intermediate Redshifts

We also hunt for similar objects at intermediate redhifts (z~0.5) using LBC blue and red imaging (U & F972N20), and MODS MOS-spectroscopy follow-up. See the poster of Langener et al. on this part of the project.

Results

- Local proxies can help to understand better the highly ionized gas in z~7 galaxies
- Our recent LBT/MODS spectra provide handle for determining ionization mechanisms
- Multi-wavelenth data help to further disentangle the contributions of the different mechanisms, as the complex case of Mrk 1434 shows.
- LBT/LBC and LBT/MODS will be used to explore proxies out to intermediate redshifts (and probably beyond using LUCI)