TEMPLATES: Tests of NIRSpec Observing strategy, using SGAS1723
By Brian Welch, with contributions from Jane Rigby and Taylor Hutchison
for the TEMPLATES ERS team

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GOAL: To determine, for NIRSpec IFU observations, whether dedicated background observations and leakcal exposures are worth the extra observing time.

TL,DR: Do you need dedicated backgrounds? They're important if you want to measure the shape of the continuum; for continuum-subtracted line fluxes it won't make so much of a difference.
Do you need leakcals? Leakcals slightly reduced the noise, at a ~1% level. If you're tight on time and have decent S/N for your emission lines, you can probably skip them.

FINDINGS:

In order to help folks with their Cycle 2 proposals, I did this quick exercise to determine how necessary are dedicated background exposures and leakcal exposures, for NIRSpec IFU mode spectroscopy. For the TEMPLATES ERS program, each target was observed with the IFU, and had a corresponding background exposure with the instrument pointed to a blank patch of sky. Each target also had a "leakcal" exposure, wherein the IFU aperture and all of the mircoshutter array (MSA) shutters are closed. This is meant to measure the leakage through the MSA onto the NIRSpec detectors. In our proposal, we pointed out that JDox didn't know whether these calibrations were strictly needed; so we'd go find out, using real data, as part of our ERS program.

To investigate the impact of these background and leakcal exposures, I ran several iterations of the JWST Science Calibration Pipeline, using TEMPLATES custom steps and arguments. Note this version of the pipeline does not include either the built-in outlier_detection step, so some artifacts are to be expected. The first run was our standard reduction, which subtracts off both the background and leakcal data from the science exposures using the JWST calwebb_spec2 and calwebb_spec3 pipeline code. I then re-ran the pipeline with no background subtraction (NOBG), no leakcals (NOLEAK), and finally neither leakcals nor background subtraction (NOLEAK_NOBG).

I first simply looked at the different data cubes to see if there was an obvious difference. The only standout was a few additional artifacts in the NOLEAK_NOBG cubes (see Fig. 1)

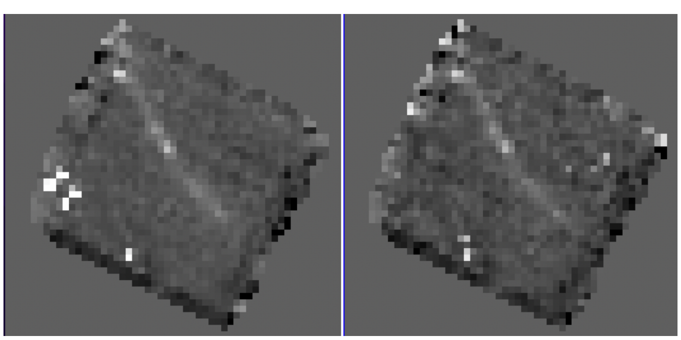
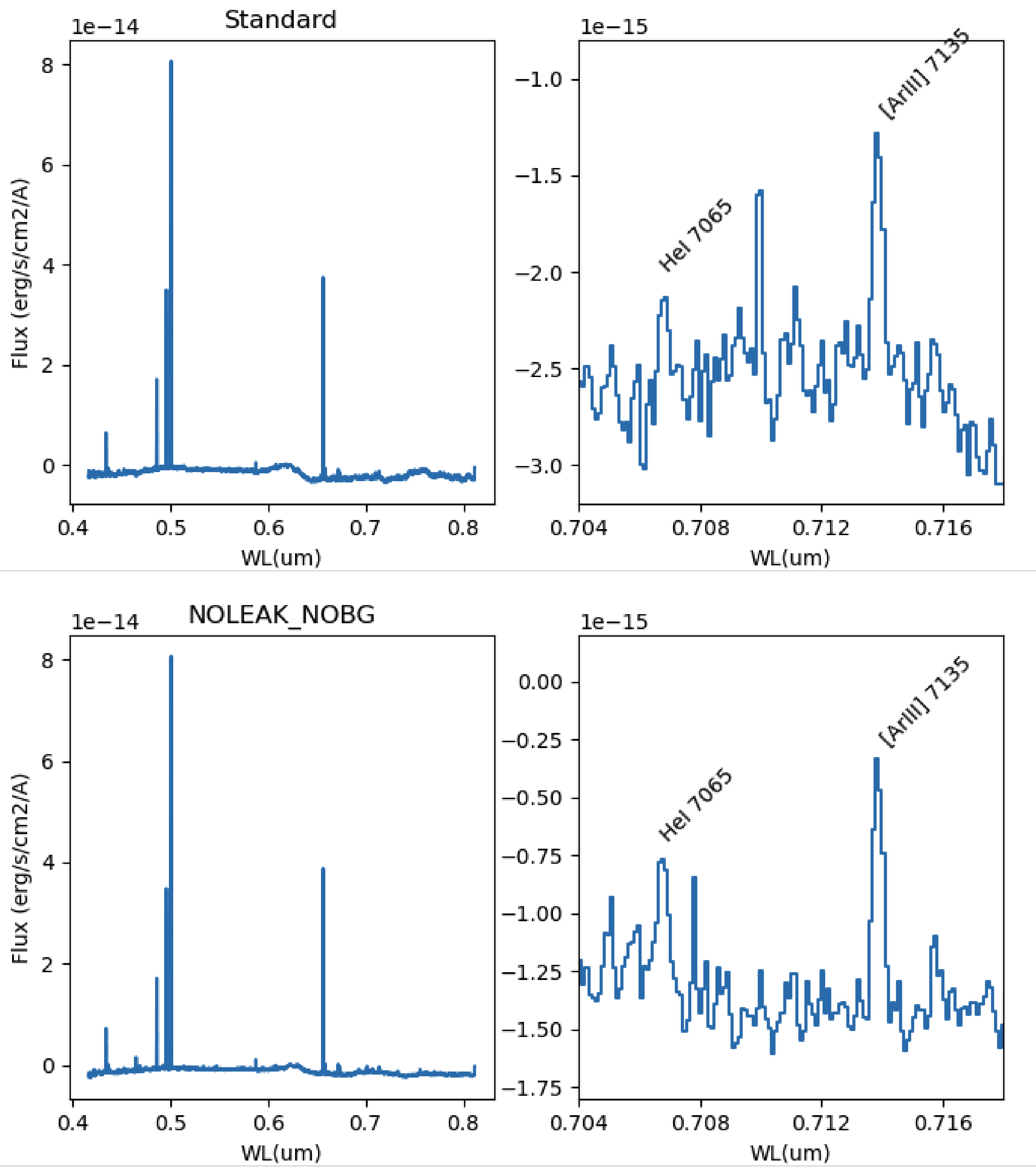


Fig. 1: Left: NOLEAK_NOBG data cube slice. Right: Standard data cube slice. Both displayed in DS9.

Next I extracted 1D spectra from each cube, using a mask highlighting the area created by T. Hutchison. This mask was created based on the signal-to-noise ratio of the bright [O III] λ5007 emission line. The resulting spectra are shown in Fig. 2.



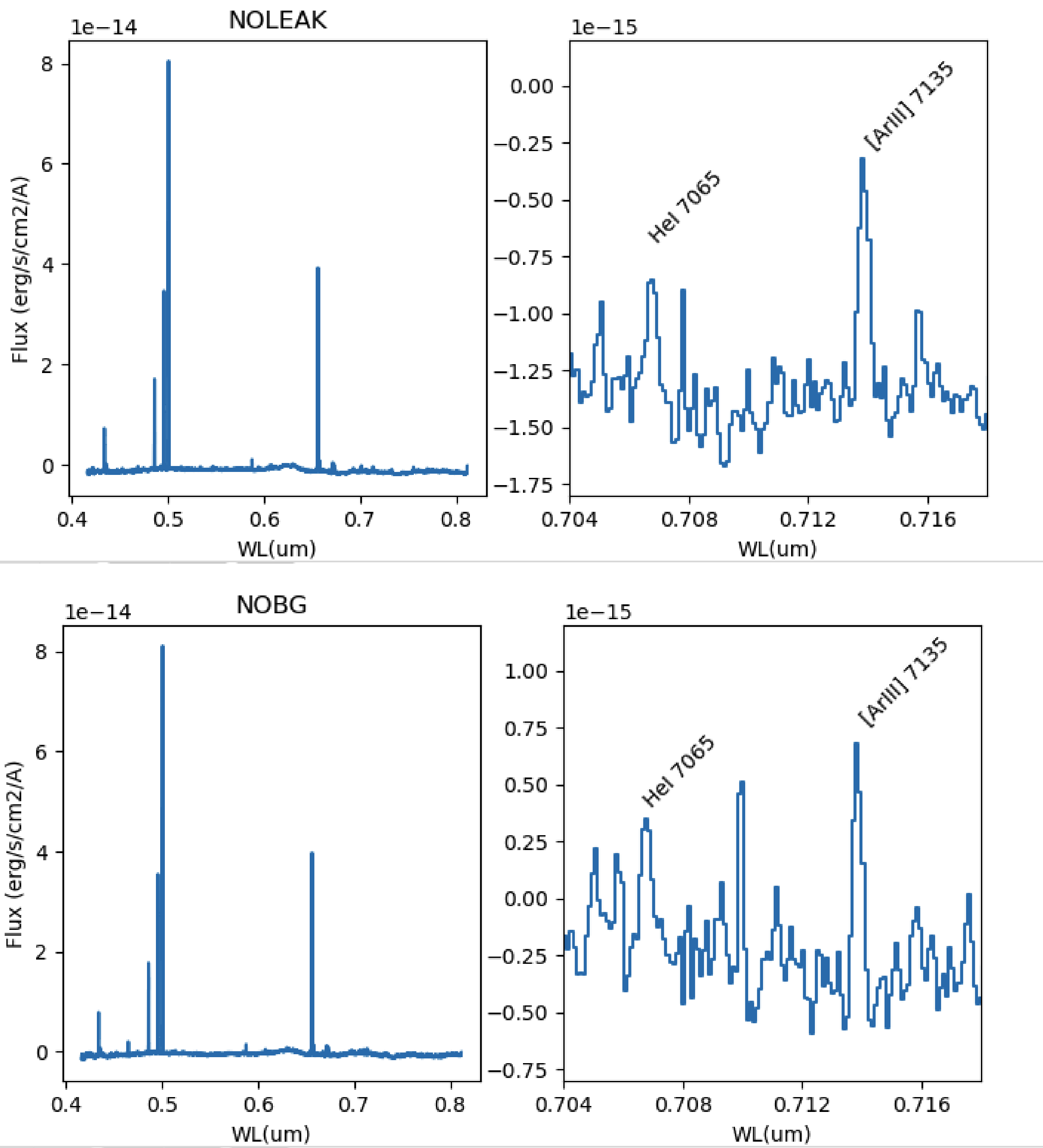


Fig. 2: Extracted 1D spectra from the various SGAS1723 reductions (all from the g140h grating). Left is the full spectrum, right is a cutout around a faint ArIII line and barely-detected HeI line.

First, a major caveat here. There is a lot I don't understand about these reductions, which use the pmap_1027 reference files. Why is most of the spectrum at negative flux? Why are the bright emission line peaks orders of magnitude brighter than seen in Rigby+2021 with HST? Something is weird overall, and I don't really know what is causing that. We think there's an error with the flux calibration, and have filed a helpdesk ticket.

But let's compare spectra anyway. The first thing to note is the [Ar III] line is quite clear in all the reductions. Woohoo! So if you get S/N >~ 5, the leakcals and background subtraction won't be much of an issue for your line fluxes, assuming you do a decent job of continuum-subtraction (and the continuum isn't all negative for some odd reason). The He I line is there in each reduction, but maybe a bit dicier without using both the leakcals and backgrounds. So if you really want to dig into the noise and find the faintest lines, these added steps might help a bit.

If the shape of the continuum is important to your science, the background subtraction becomes more important. In this test, not doing the background subtraction led to a slightly redder continuum overall. Also, perhaps obviously, the overall brightness of the continuum changes considerably before and after applying background subtraction, with differences as high as ~50%.

The last test here was to calculate the standard deviation of a known area of continuum within the spectrum to estimate the total noisiness of the data. I used a region between 5300 and 5500 Angstroms rest-frame, which did not have any detected lines. With all the bells and whistles, the standard deviation is ~1.15e-16. Meanwhile in the NOLEAK_NOBG case, the standard deviation is ~1.16e-16. So ~1% higher scatter.

One last important note here is that the SGAS1723 field does not have a lot of bright stars nearby, so there's not a whole lot of light shining on the MSA. If your observations put bright objects on the MSA, more light will get through the closed shutters. So crowded, bright fields may well need leak cals. We didn't test that in this high-latitude extragalactic observation.

Conclusions:

Ultimately, I'd say this exercise indicates that a dedicated background observation is probably necessary if you want to measure the shape of the continuum. And leak-cals may be necessary if you want to dig out the very faintest lines, or if you are working in a crowded, bright field. Otherwise, you could get away with skipping them.