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Filter Throughputs for WFC3 SYNPHOT Support

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ABSTRACT
To provide support for WFC3 in the SYNPHOT package, I have combined the measurements made of the WFC3 filters into a single throughput curve for each filter. Each filter was scanned twice, to characterize "in band" sensitivity and "out of band" sensitivity. The "out of band" measurements were typically done at much lower resolution than the "in band" measurements, which makes it difficult to combine these measurements when the throughput is changing rapidly in the region of overlap. Fortunately, this transition region from one type of measurement to another does not comprise a significant fraction of the integrated throughput of the filter, so in practice this mismatch in resolution should not affect the interpretation of photometric data or the prediction of count rates in the various observing modes. The purpose of this report is simply to record the details of how the distinct measurements for each filter were merged.

Background

The filters for the Wide Field Camera 3 (WFC3) were characterized by engineers at the Jet Propulsion Laboratory (JPL) and the Goddard Space Flight Center (GSFC). All of the IR filters were characterized at GSFC. Measurements of the UVIS filters dating from before 2003 were performed at JPL, while more recent measurements of the UVIS filters were performed at GSFC. The JPL and GSFC "in band" (IB) measurements were performed with a resolution that varied from filter to filter, using whatever was considered sufficient to capture the detailed throughput of each filter (given the narrow band filters can have a width as small as 1 nm). However, the "out of band" (OB) measurements done by GSFC were typically performed at approximately 1 nm resolution, while those done by JPL were typically performed at approximately 10 nm resolution. The low resolution of these OB measurements causes them to be discrepant with the IB measurements in the region of overlap (the near wings of the bandpass). The IB and OB measurements often disagree over wavelength ranges much wider than the resolution of the OB measurements, implying that both the IB and OB measurements suffer from large systematic errors due to saturation and nonlinearity issues when operating out of the nominal dynamic range of the measurement.

To combine these distinct measurements of the same filter, I generally truncated the IB measurements at a point where they became significantly noisy, and then concatenated the OB measurements at a point where those measurements were slowly varying. Although this could sometimes leave a small gap in the merged filter curve at the boundary between the IB and OB data, SYNPHOT interpolates the filter curve to a fine wavelength scale. I did not want to insert artificial data into such a gap, because the transmission curve should represent actual measurements. The low throughput and narrow wavelength range of these gaps means that they do not comprise a significant fraction of the integrated throughput under the filter curve; for example, significant gaps exist in the merged data for the F373N filter on the UVIS channel, but the throughput in these gap regions comprises 0.008% of the area integrated under the entire filter curve. Sometimes I included more of the noisy IB data, when it was available, if it looked like such noisy data would be preferable to a linear interpolation across the transition region from IB to OB data. In general, when there was a significant discrepancy between the IB and OB data spanning a wide wavelength range (i.e., beyond what can be attributed to differences in resolution), I trusted the measurements that were intended to characterize those wavelengths (i.e., I trusted the IB data when within the nominal bandpass and the OB data in the far wings of the bandpass).

Merged Data

So that observers and instrument scientists can have a record of how these merged filter transmission curves were created, I show in the following figures the IB and OB data for each filter in the region where those data were merged. The top panel of each figure shows the IB (*black*) and OB (*blue*) data on a linear scale. The OB data are plotted with a histogram style to demonstrate the coarse wavelength scale in the OB measurements. The middle panel of each figure shows these same data on a logarithmic scale, and indicates where the data were truncated to create the merged transmission curve (*vertical lines*). The bottom panel of each figure shows the final merged transmission data on a logarithmic scale. Like any plot with lines connecting the datapoints, the lines are plotted linearly even when the scale is logarithmic. Thus, when gaps are present in the merged data of the bottom panel, or when the OB wavelength spacing is very coarse, the straight lines connecting the datapoints are not the curves one would get if interpolating linearly in throughput. Table 1 lists the wavelengths where the truncations occur in the IB and OB data for each filter.

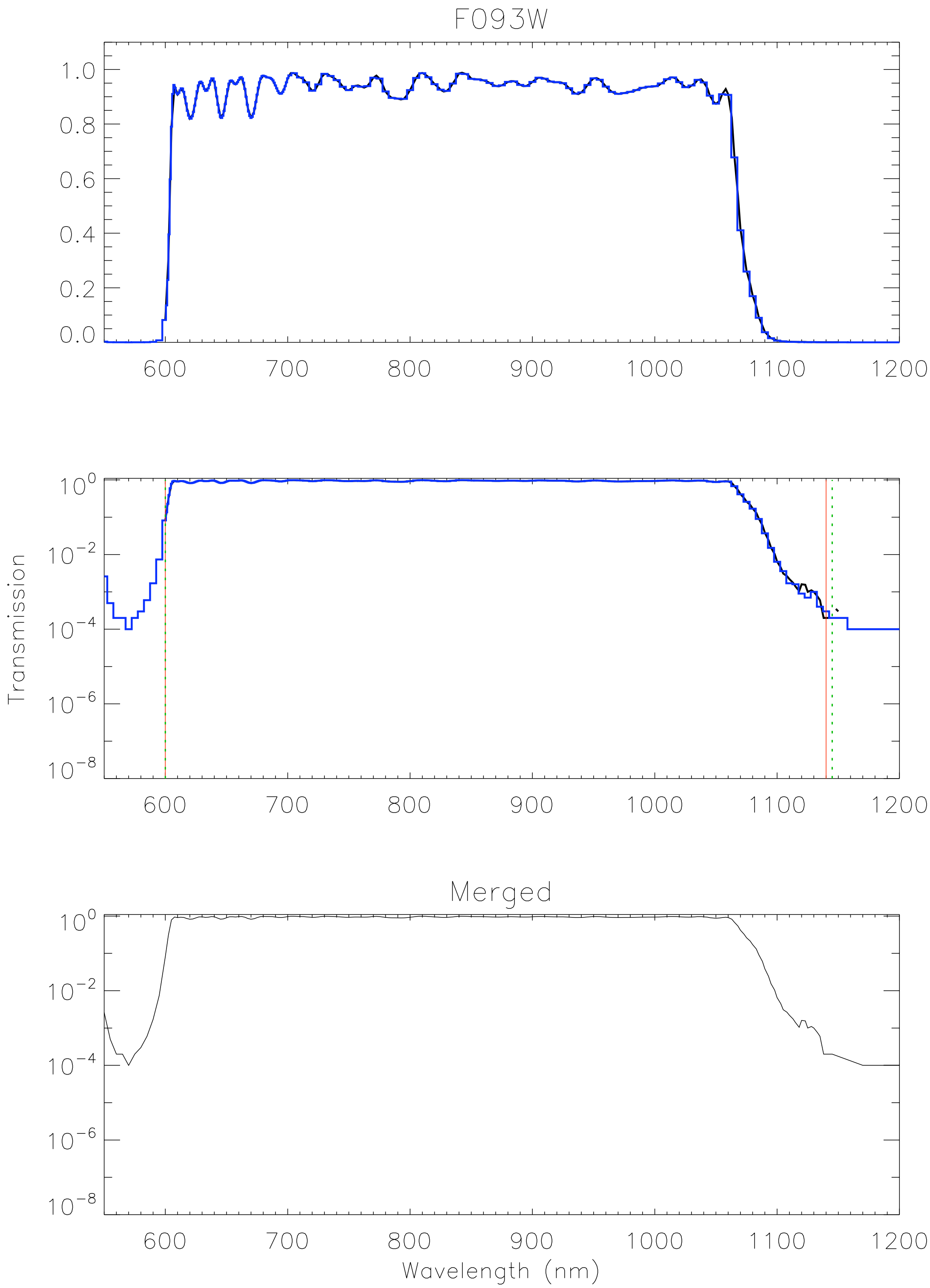

Figure 1. The merged data for IR/F093W. *Top panel:* IB measurements (*black curve*) and OB measurements (*blue histogram*) are shown on a linear scale. *Middle panel:* the same data on a logarithmic scale. Vertical lines mark where the IB data is truncated (*red solid lines*) and where the OB data begins (*green dotted lines*) when merging the two datasets. *Bottom panel:* the merged transmission curve, plotted on a logarithmic scale.

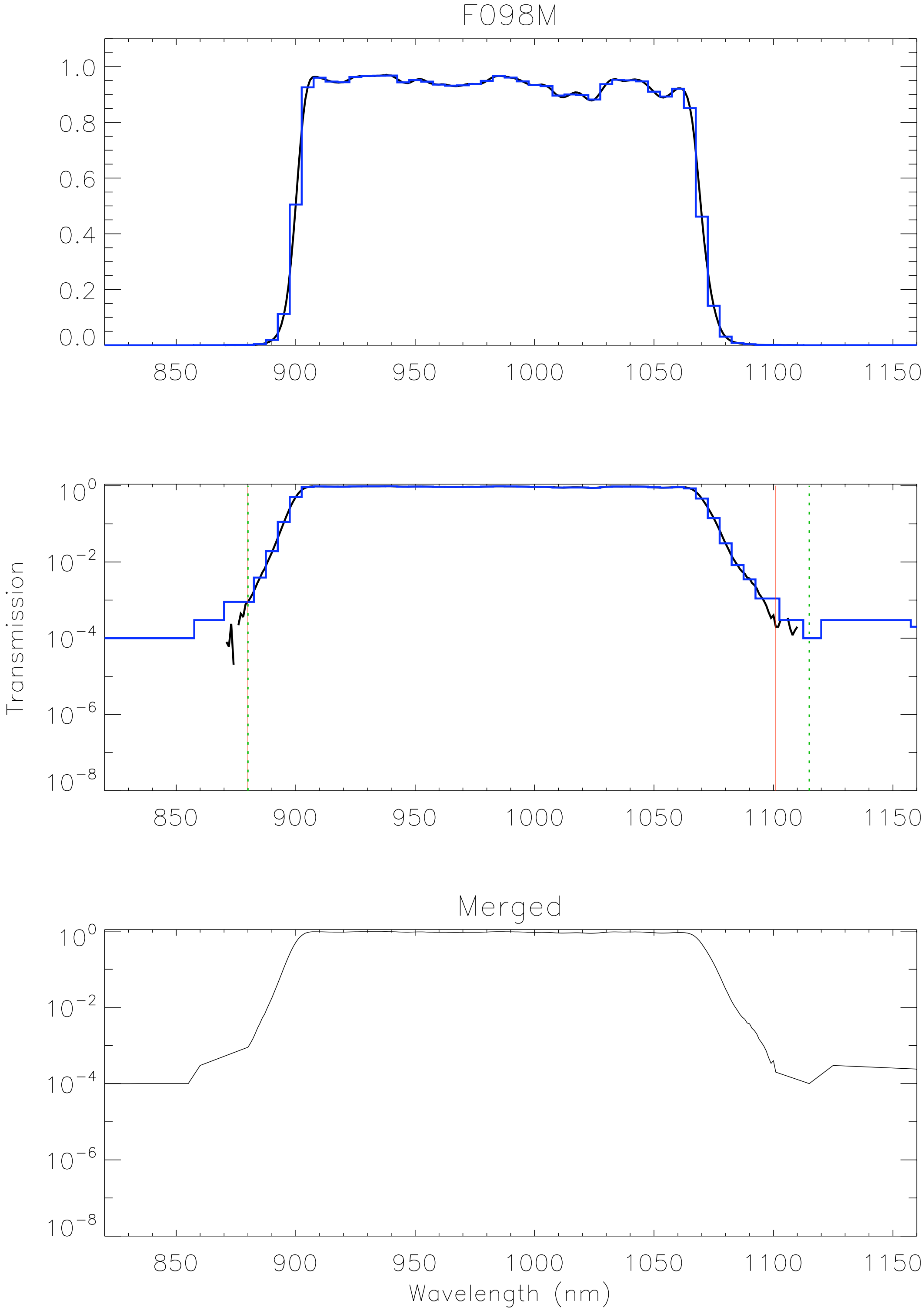

Figure 2: The same as in Figure 1, but for the IR/F098M filter.

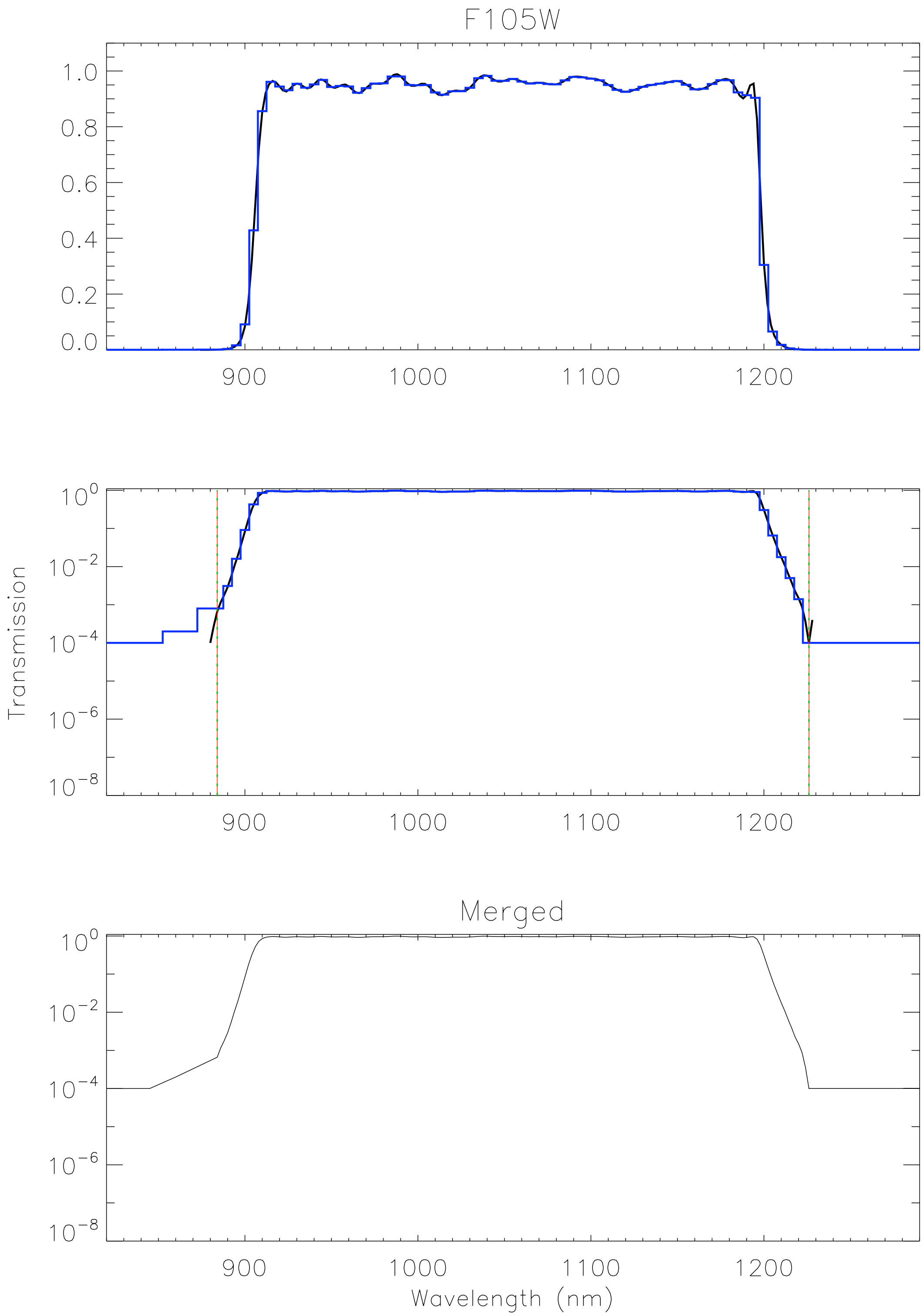

Figure 3: Same as in Figure 1, but for the IR/F105W filter.

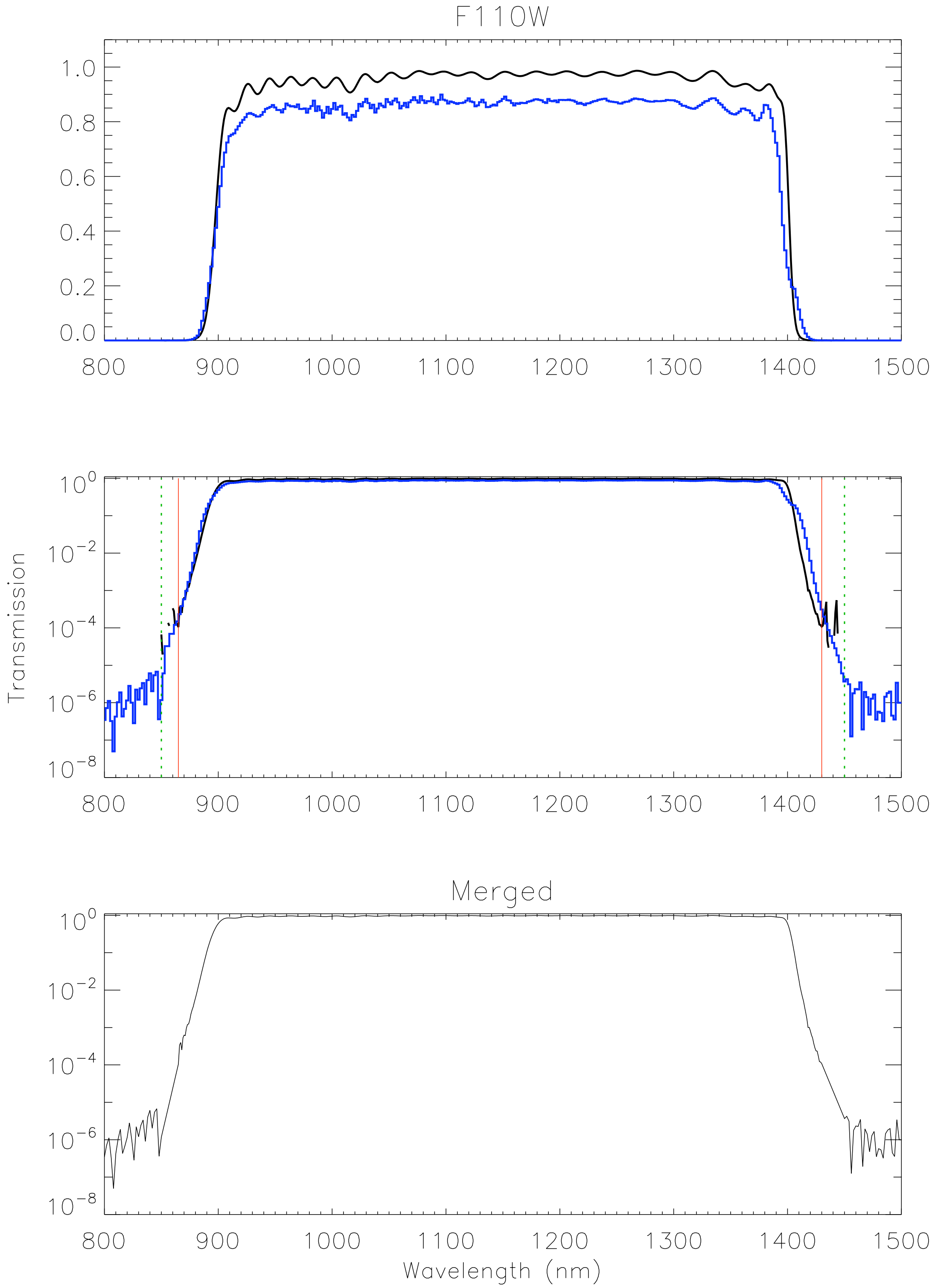

Figure 4: The same as in Figure 1, but for the IR/F110W filter.

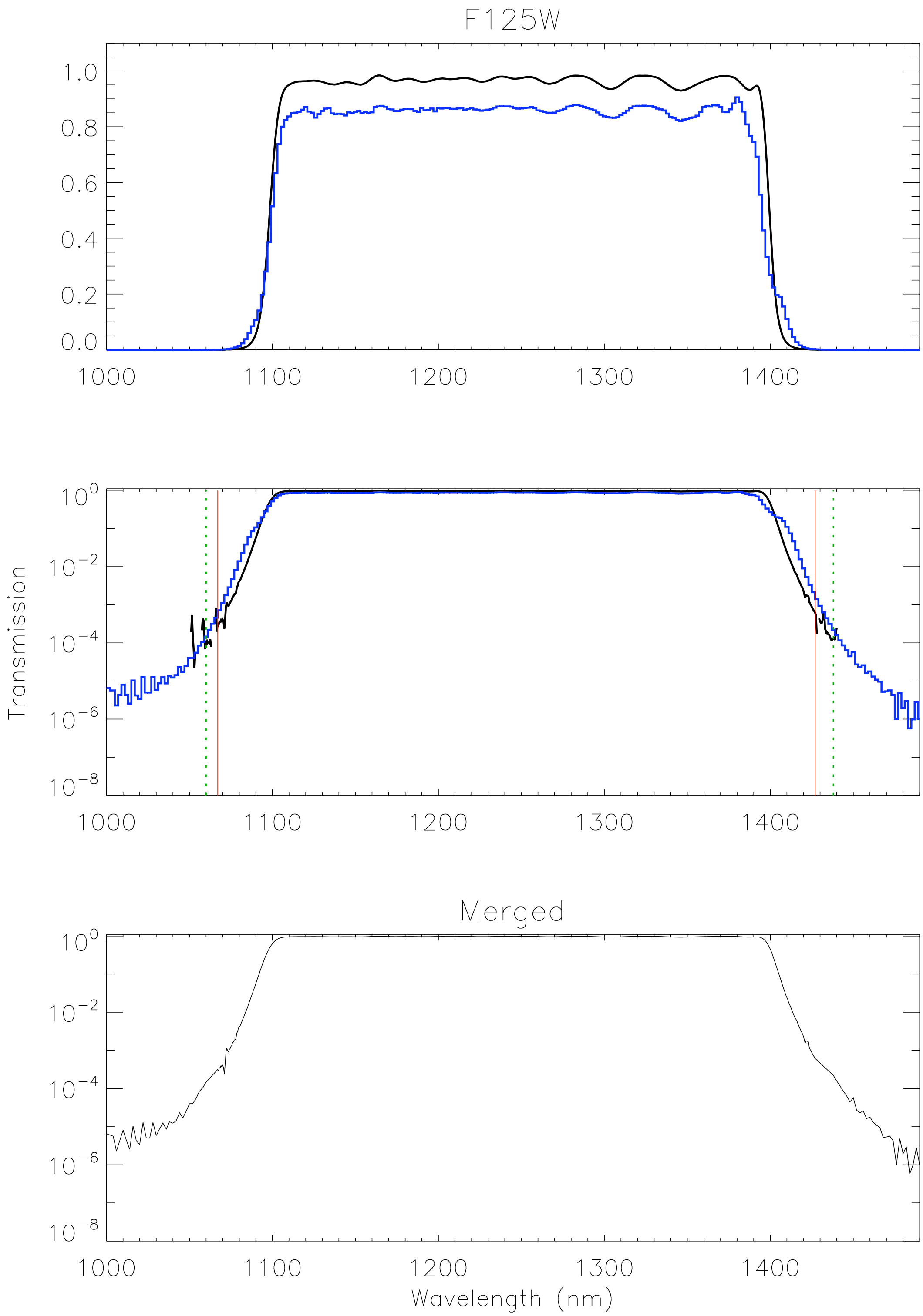

Figure 5: The same as in Figure 1, but for the IR/F125W filter.

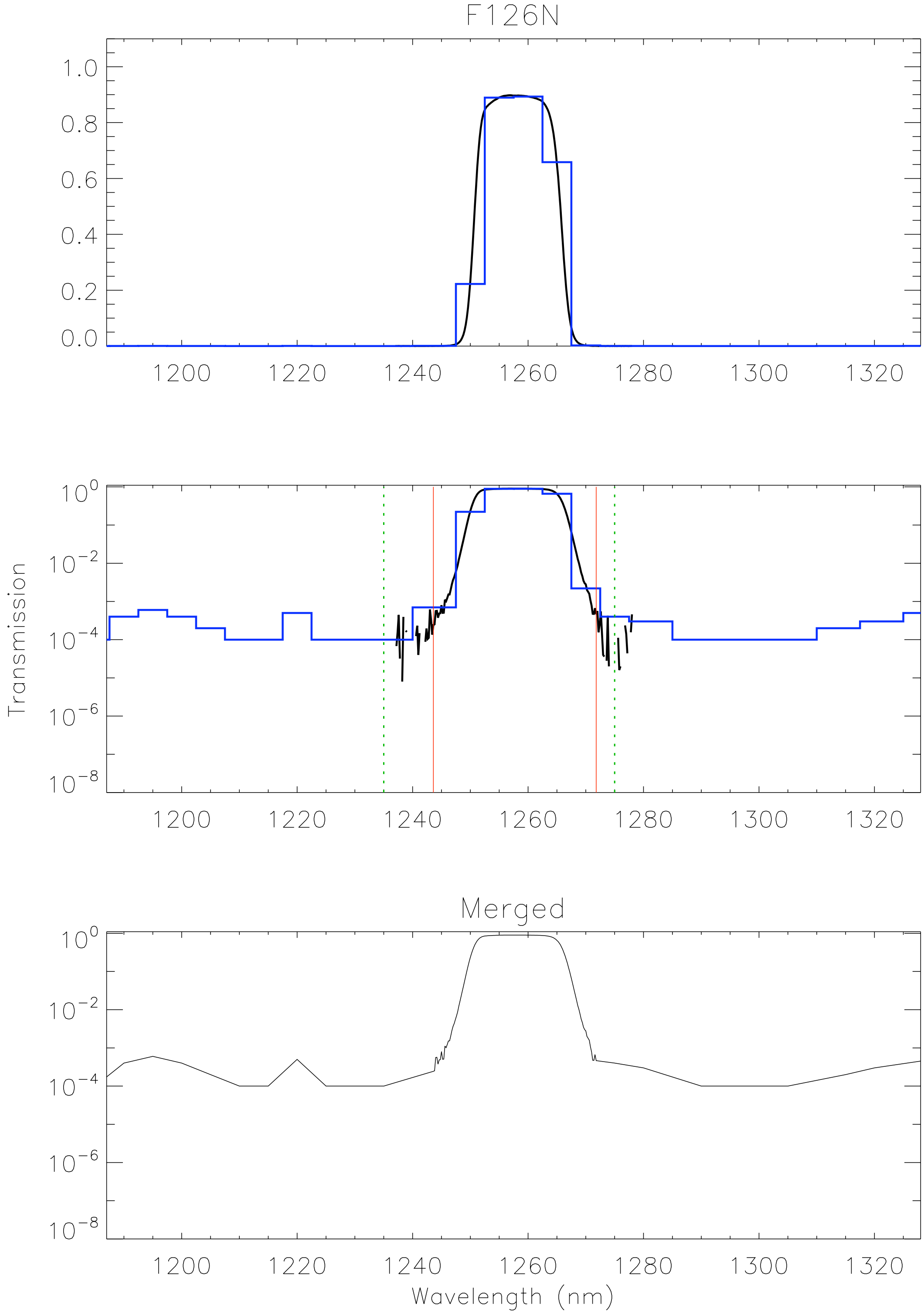

Figure 6: The same as in Figure 1, but for the IR/F126N filter.

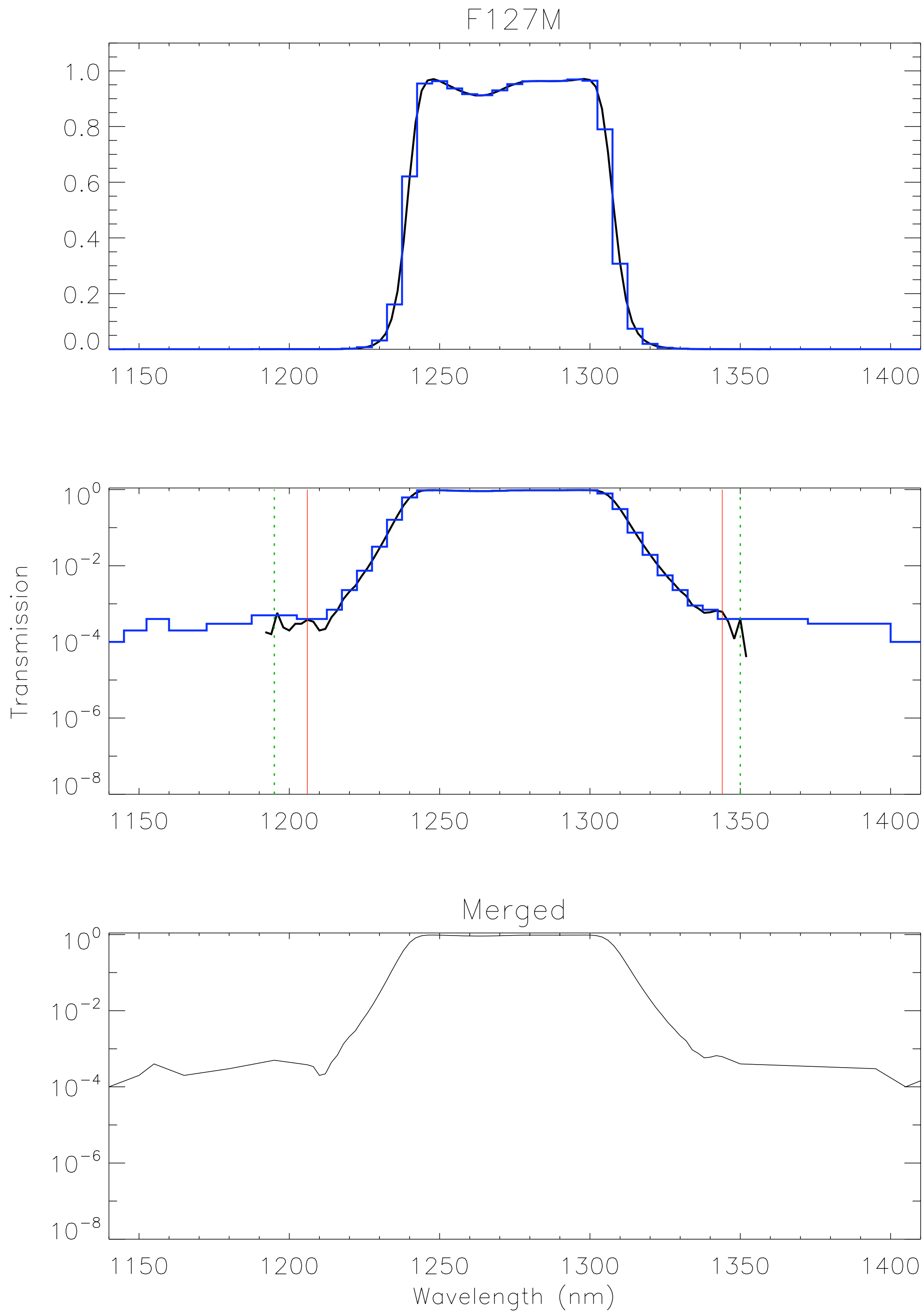

Figure 7: The same as in Figure 1, but for the IR/F127M filter.

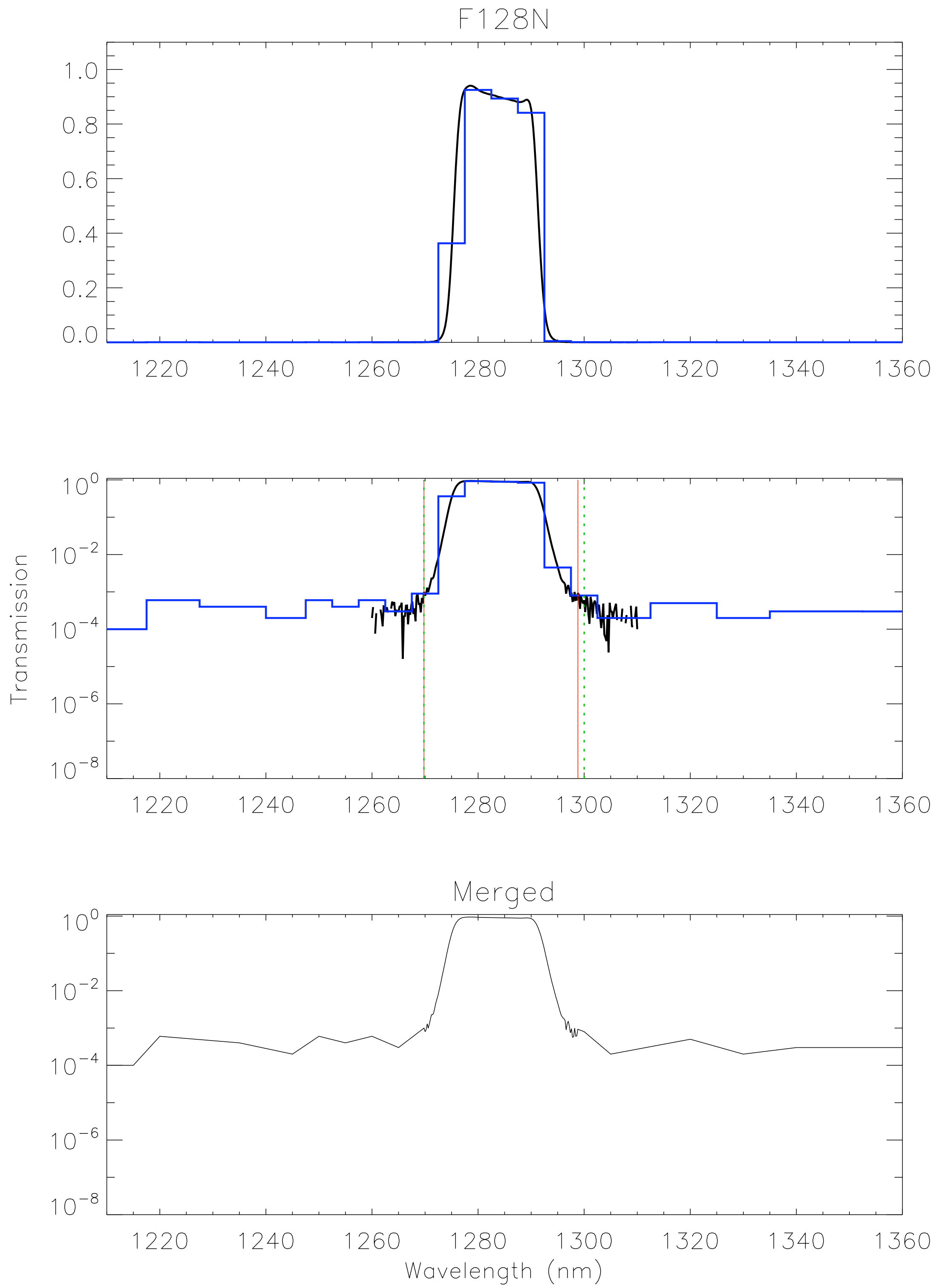

Figure 8: The same as in Figure 1, but for the IR/F128N filter.

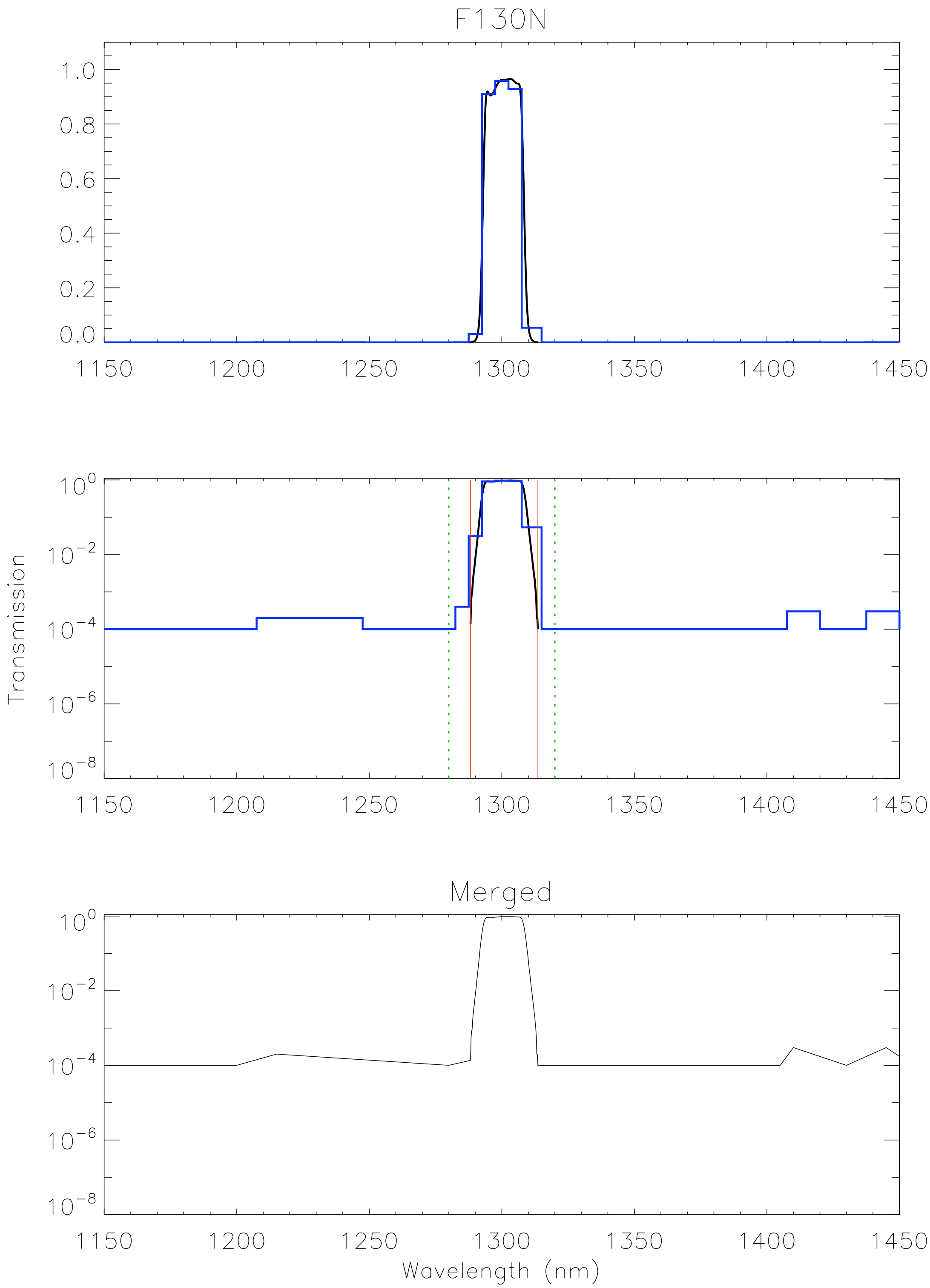

Figure 9: The same as in Figure 1, but for the IR/F130N filter.

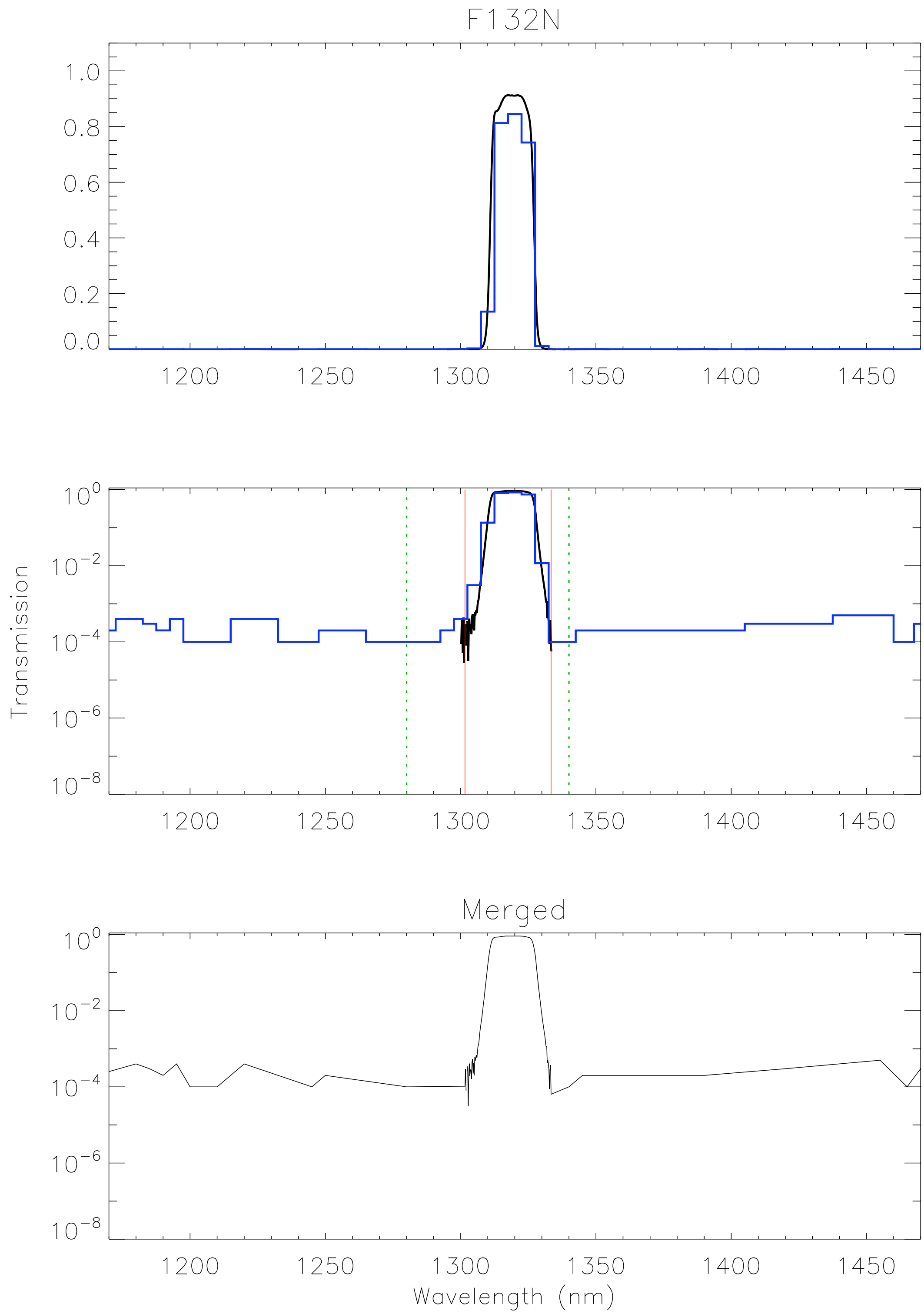

Figure 10: The same as in Figure 1, but for the IR/F132N filter.

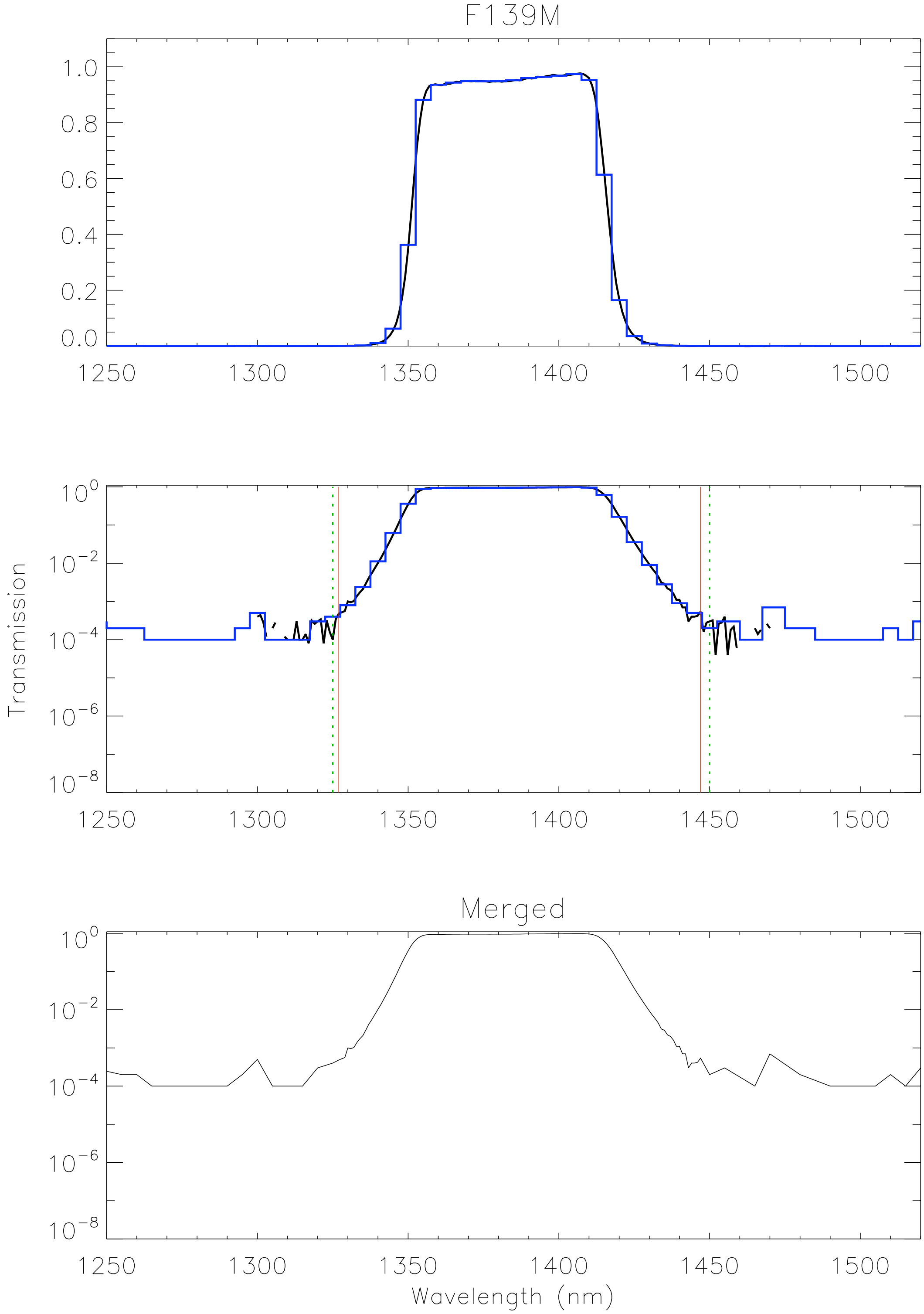

Figure 11: The same as in Figure 1, but for the IR/F139M filter.

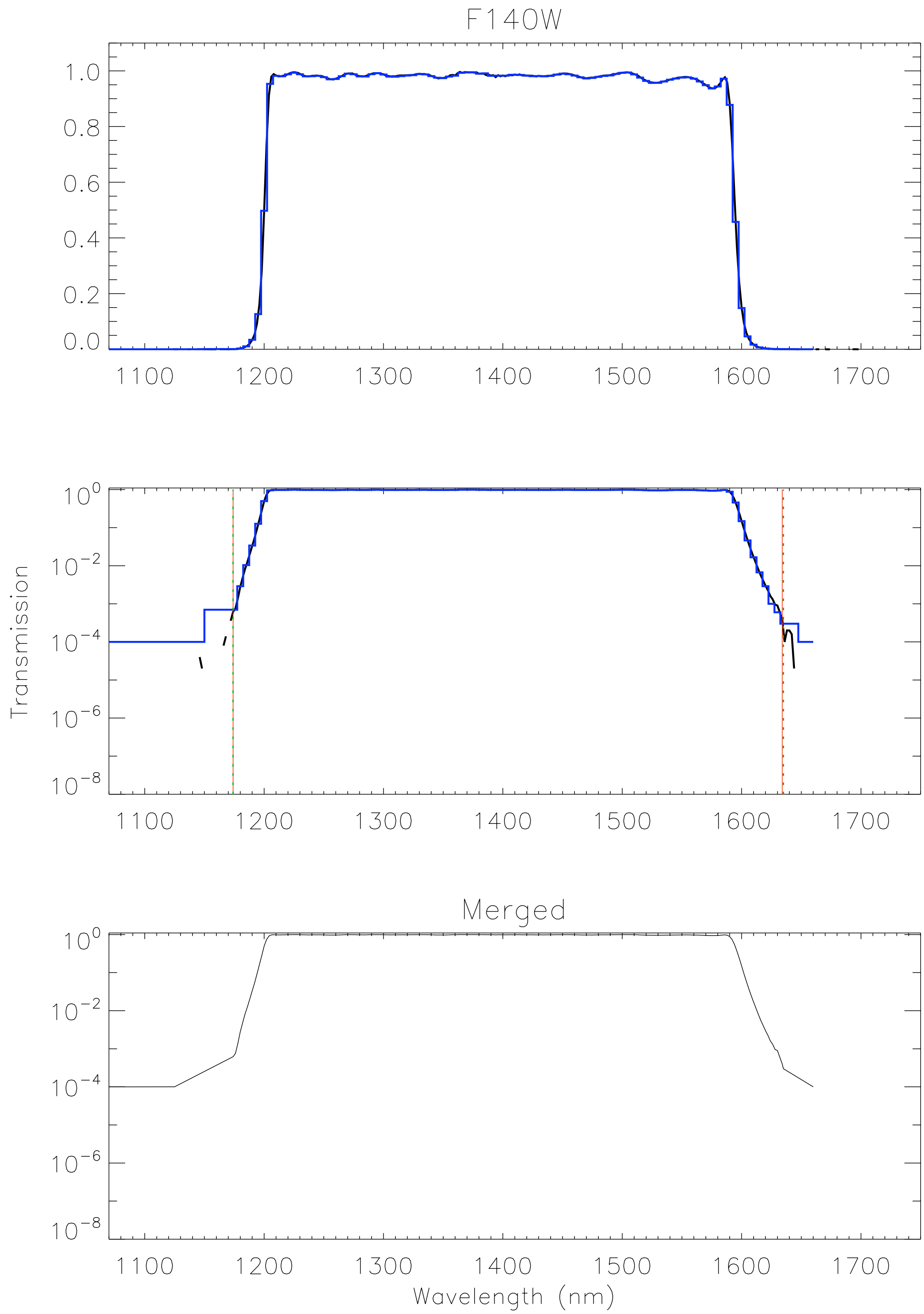

Figure 12: The same as in Figure 1, but for the IR/F140W filter.

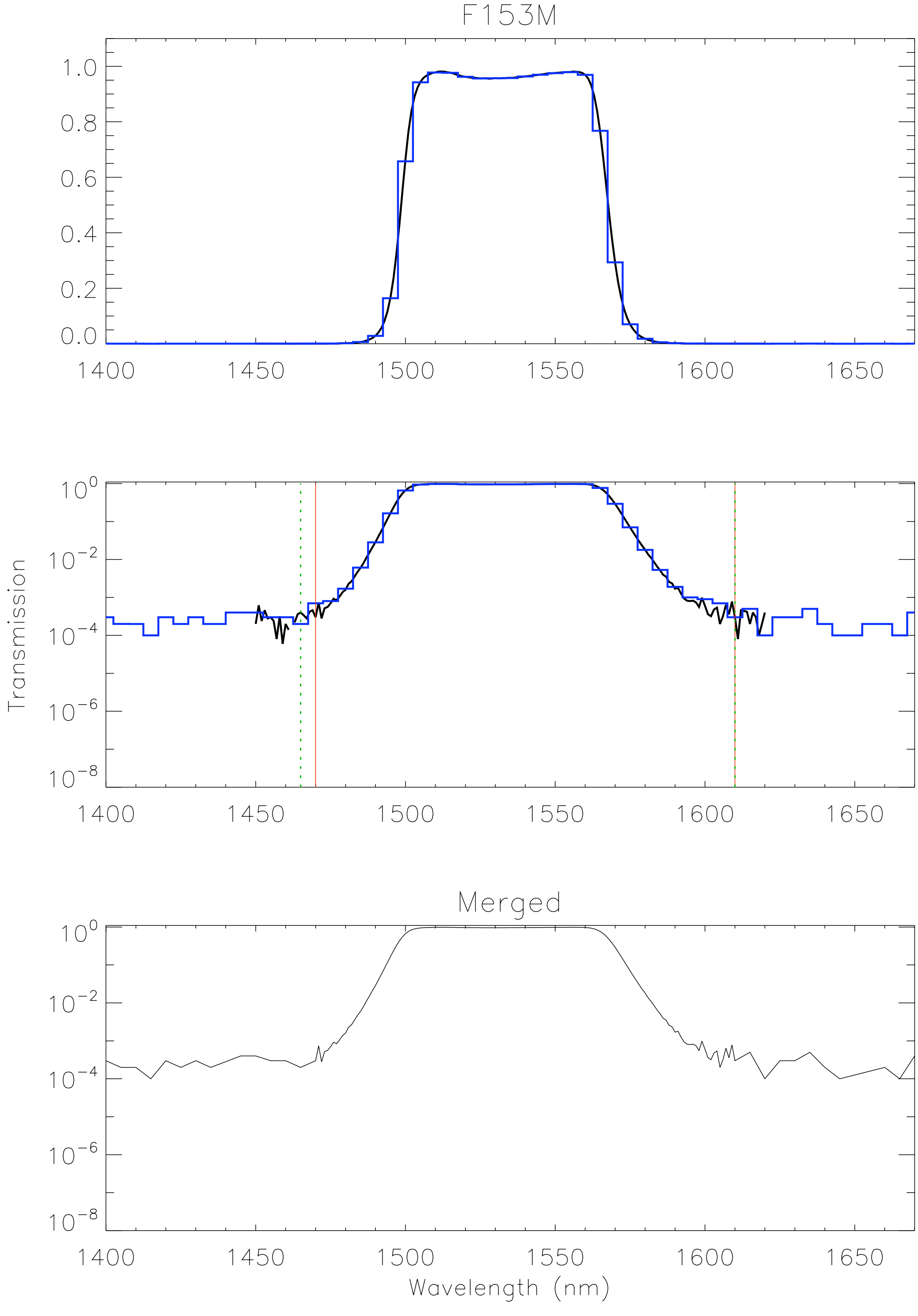

Figure 13: The same as in Figure 1, but for the IR/F153M filter.

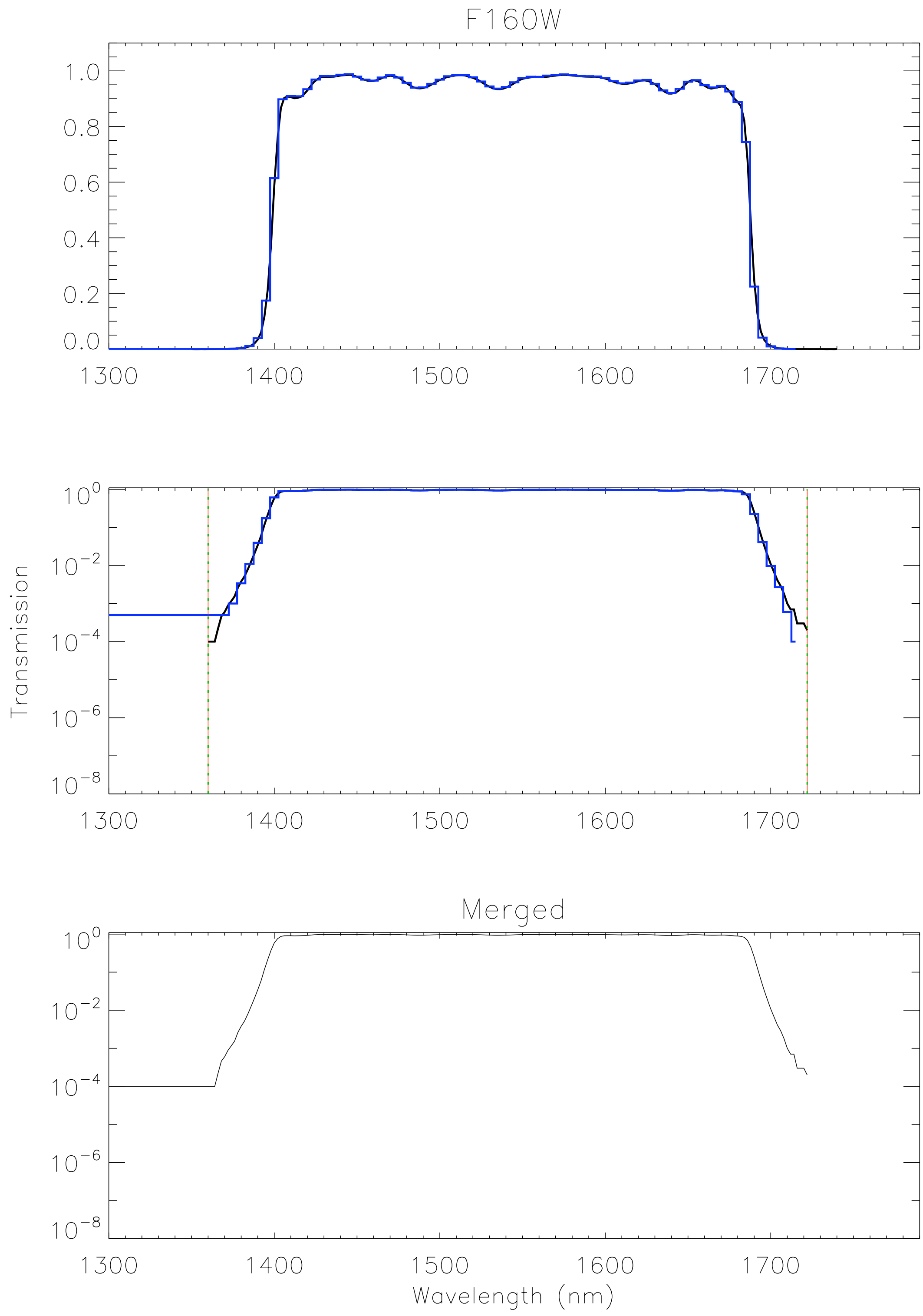

Figure 14: The same as in Figure 1, but for the IR/F160W filter.

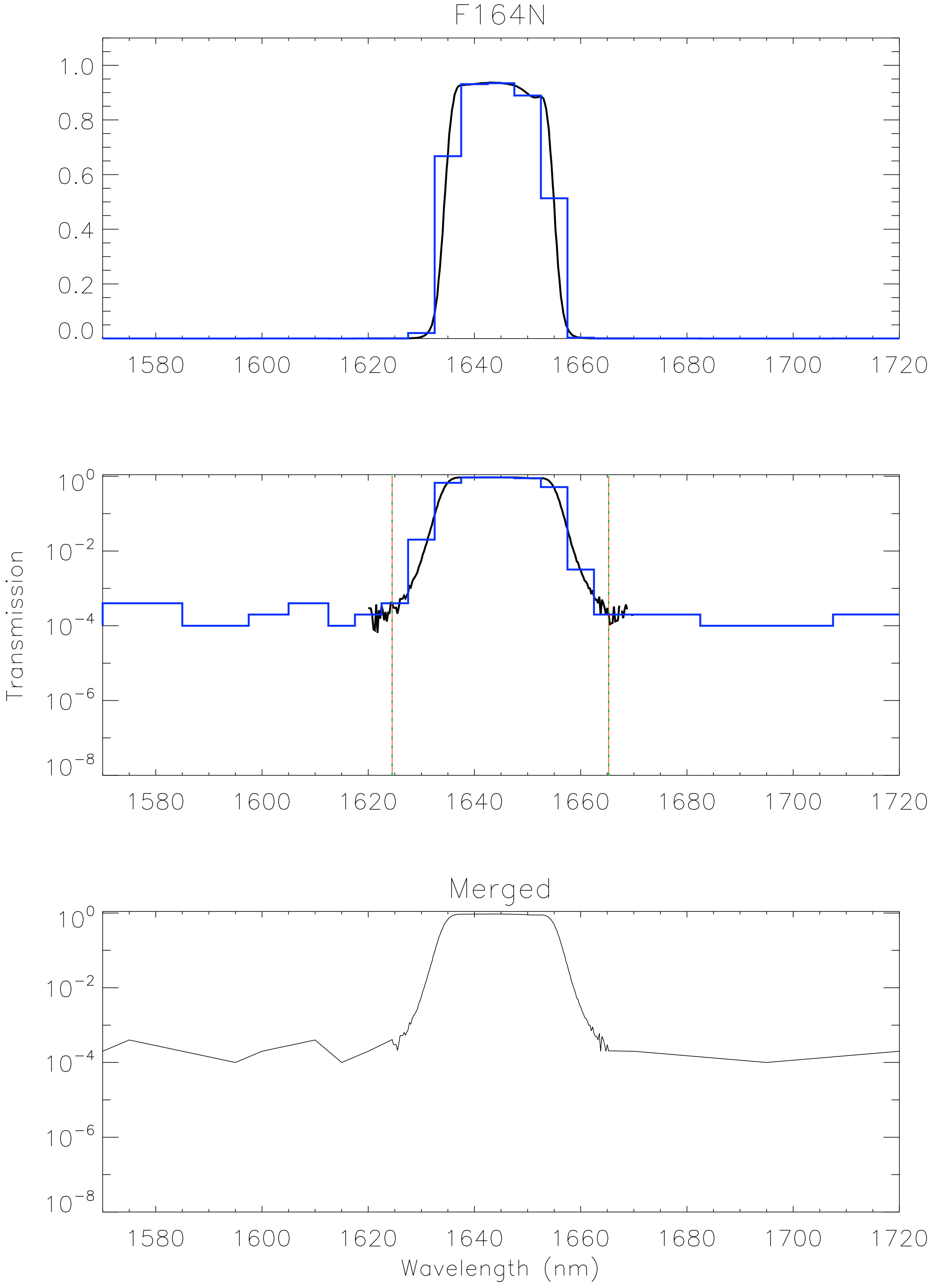

Figure 15: The same as in Figure 1, but for the IR/F164N filter.

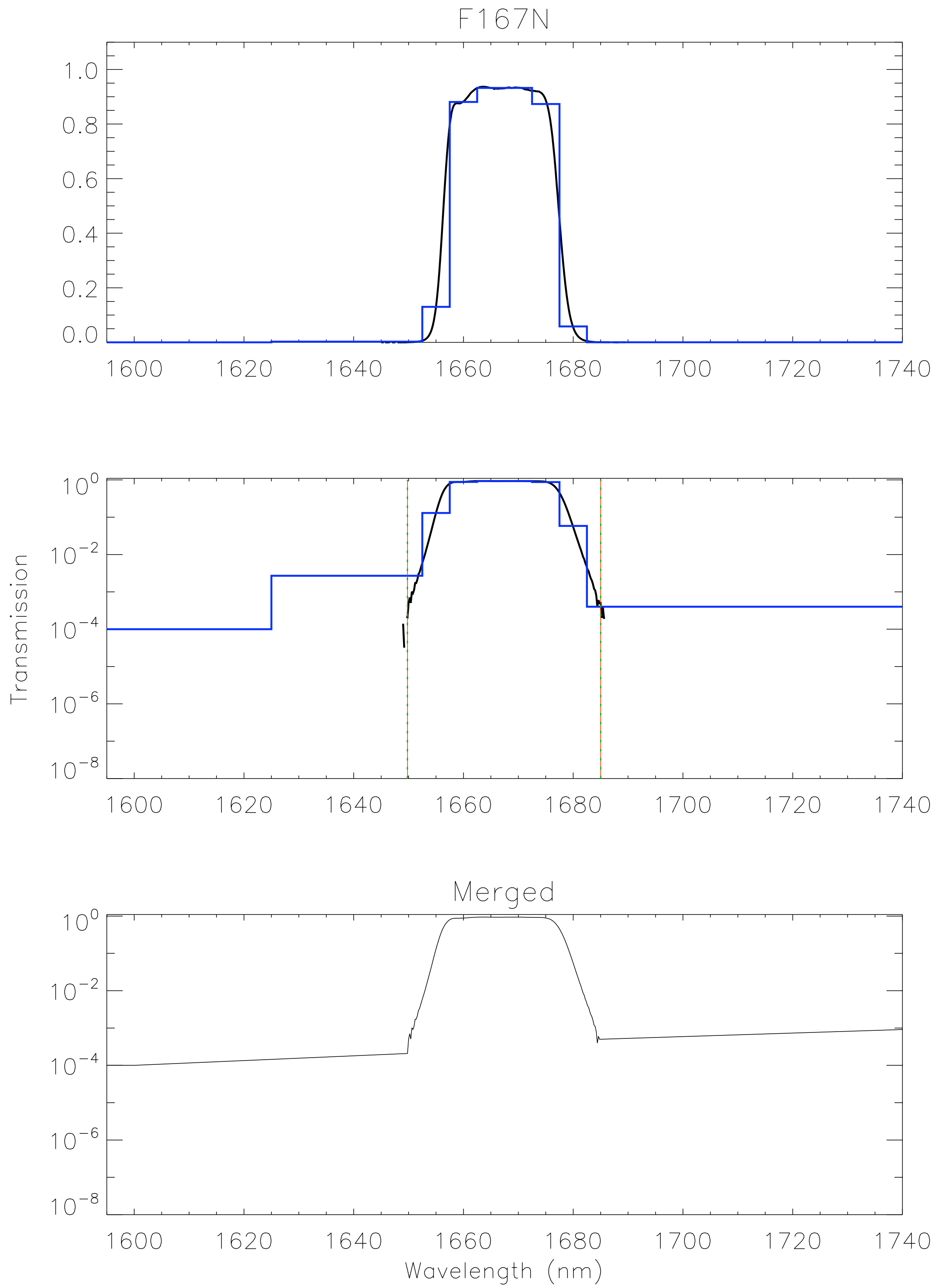

Figure 16: The same as in Figure 1, but for the IR/F167N filter.

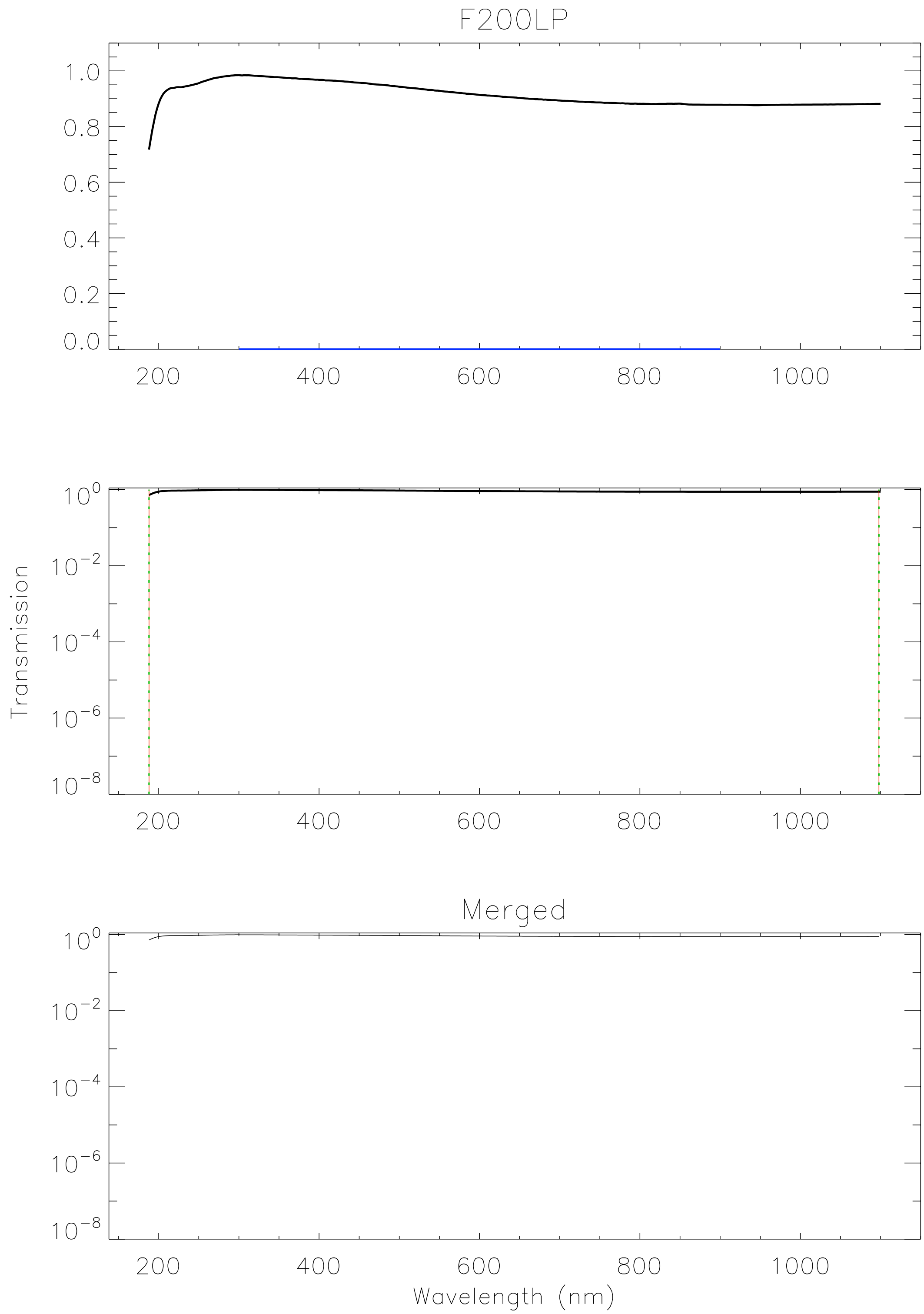

Figure 17: The same as in Figure 1, but for the UVIS/F200LP filter. There is no “out of band” measurement for this filter.

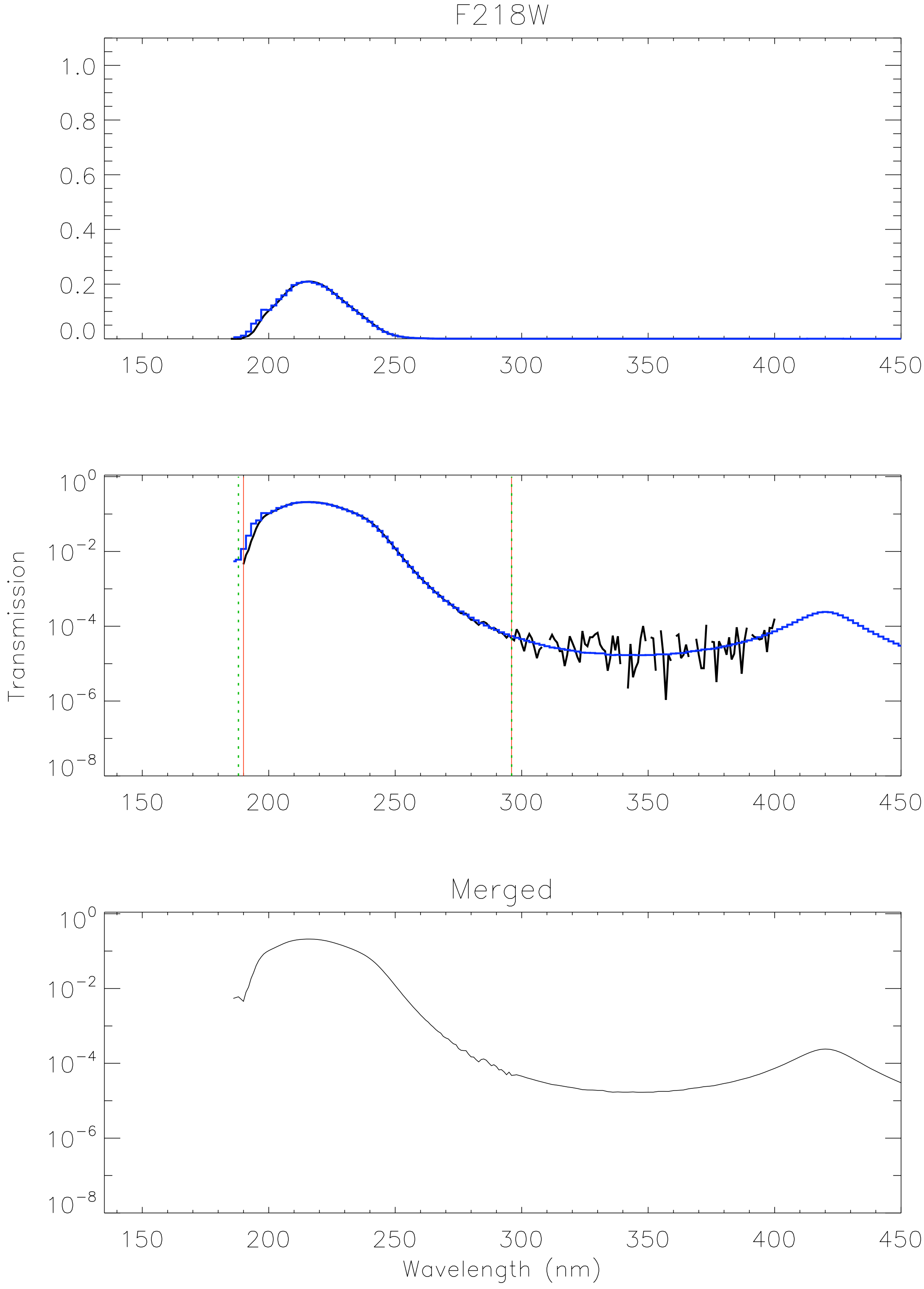

Figure 18: The same as in Figure 1, but for the UVIS/F218W filter.

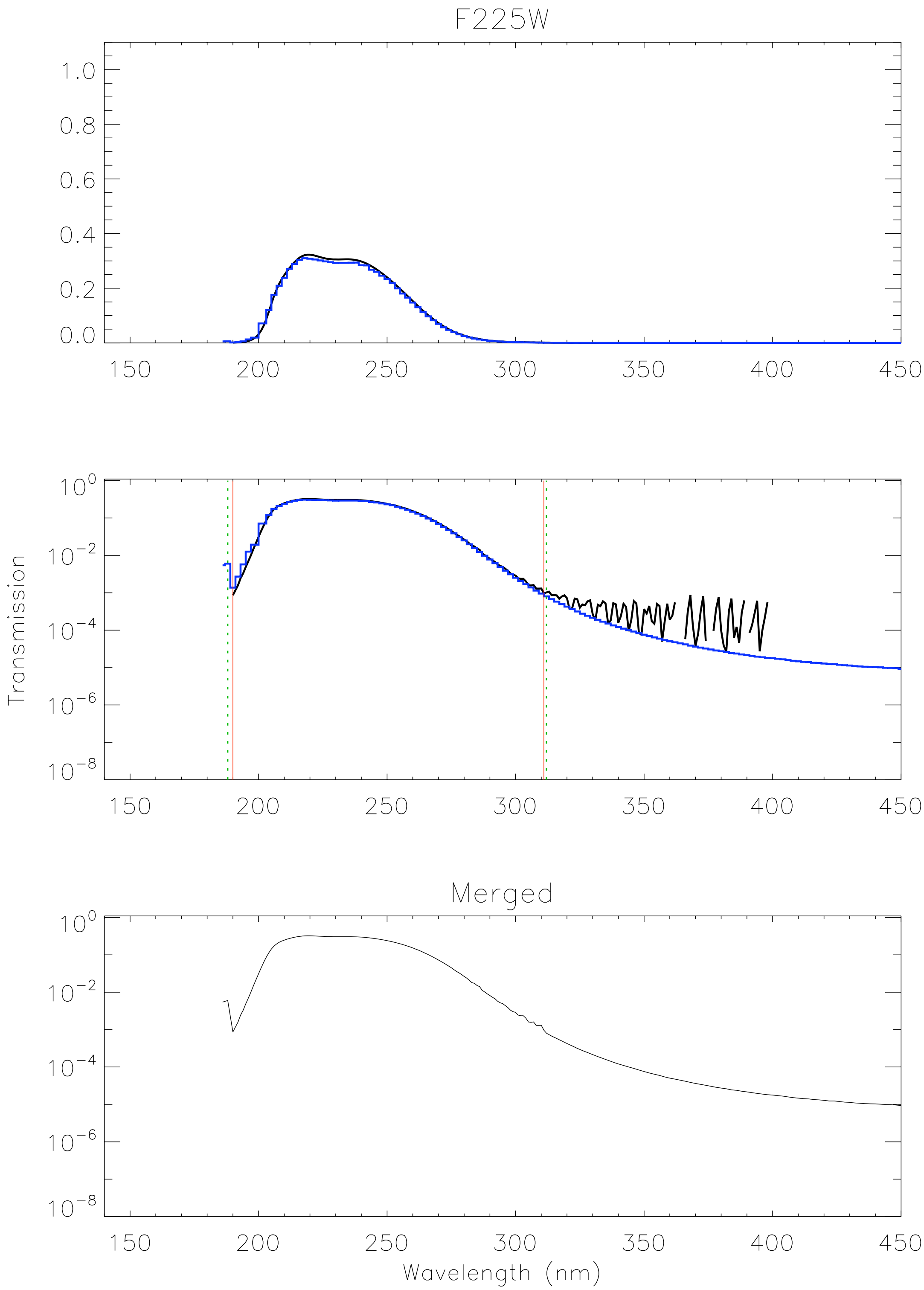

Figure 19: The same as in Figure 1, but for the UVIS/F225W filter.

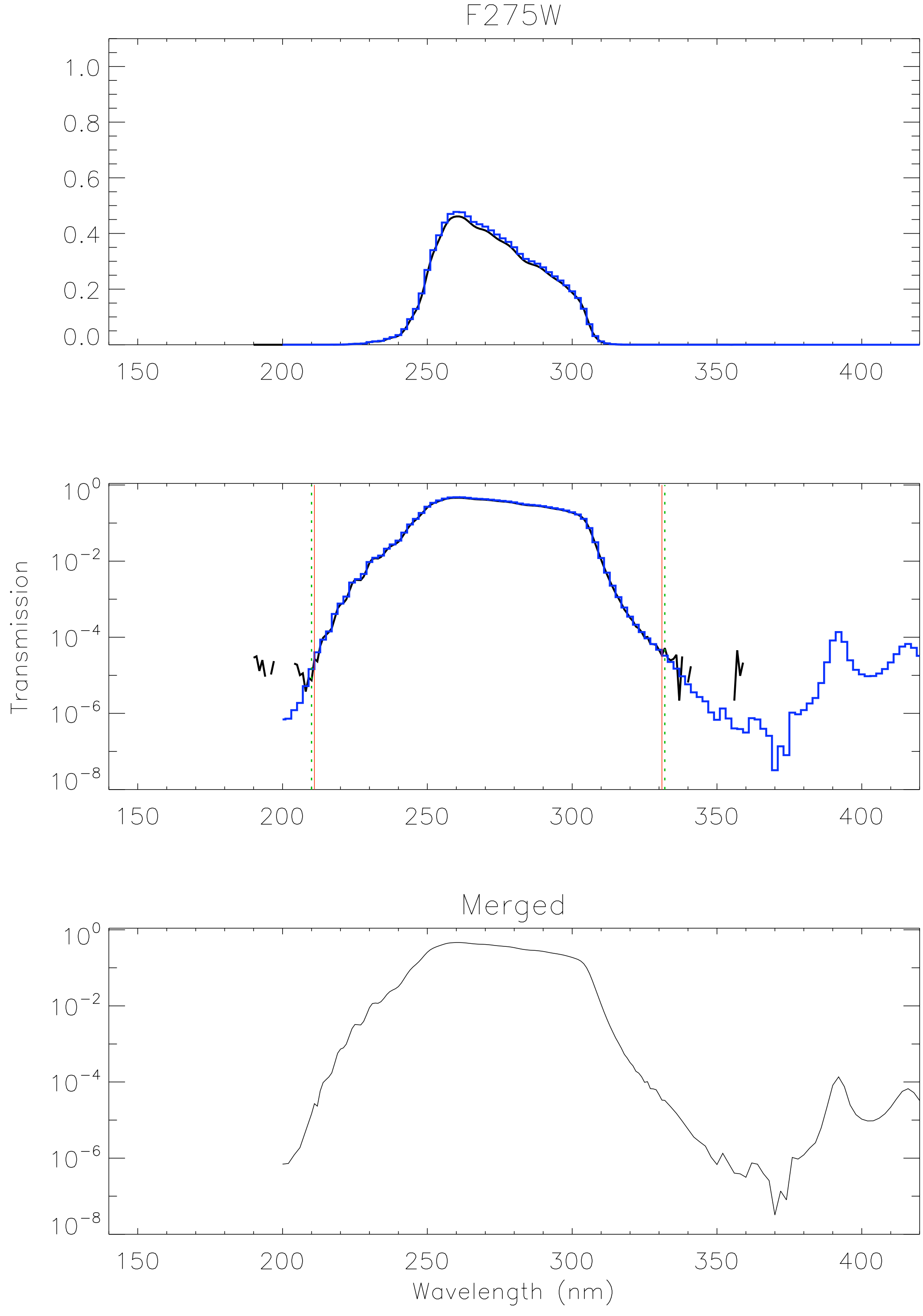

Figure 20: The same as in Figure 1, but for the UVIS/F275W filter.

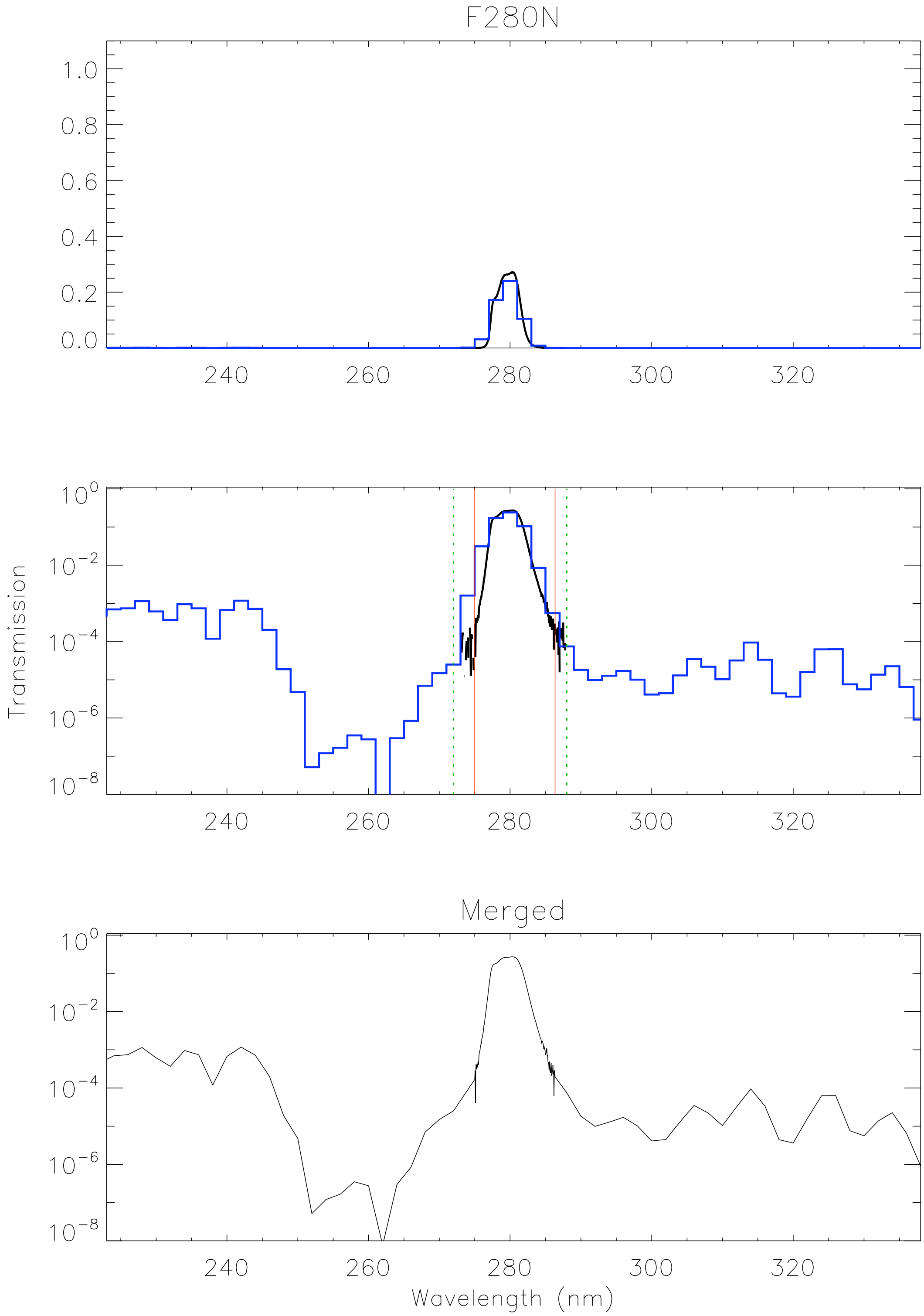

Figure 21: The same as in Figure 1, but for the UVIS/F280N filter.

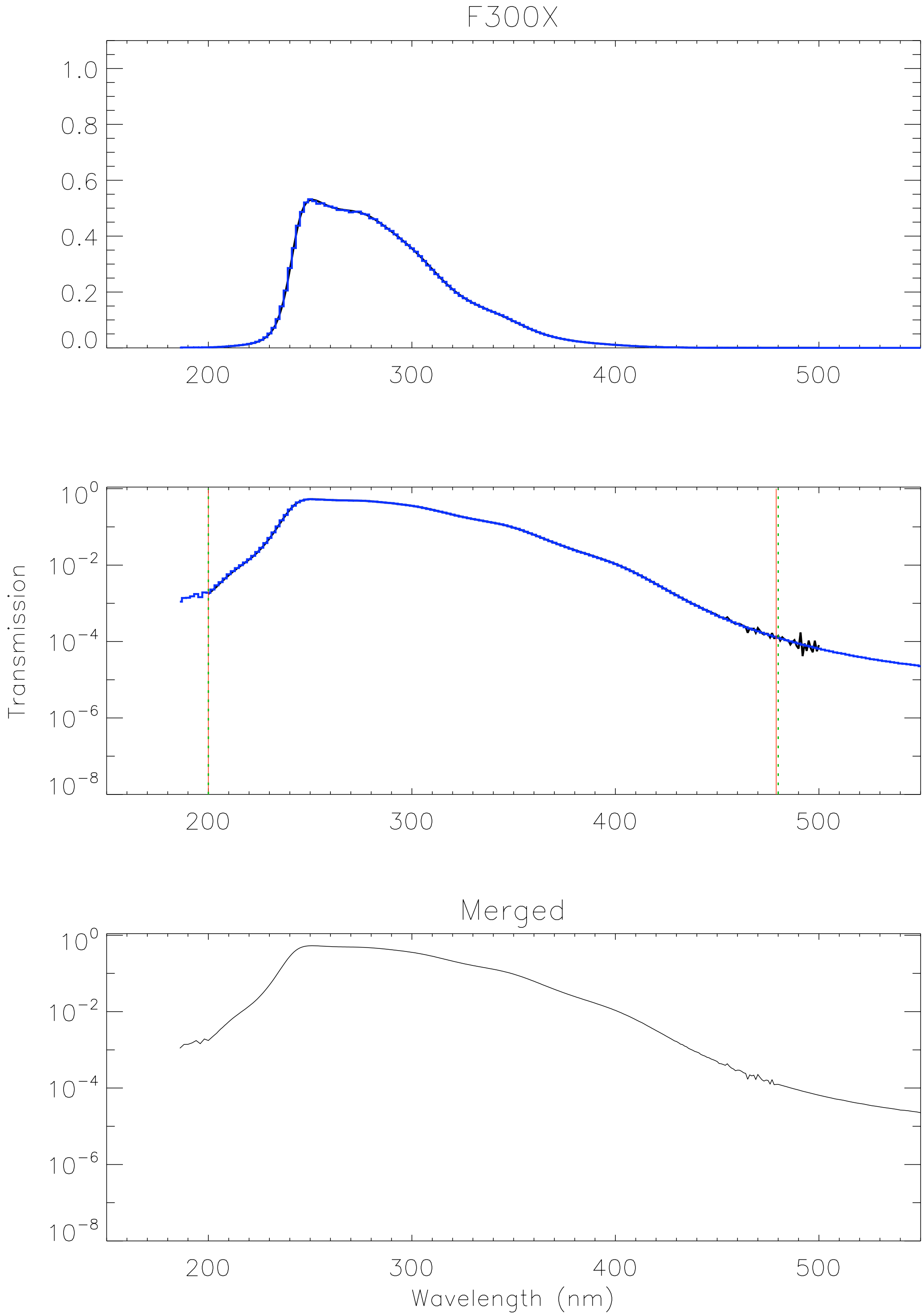

Figure 22: The same as in Figure 1, but for the UVIS/F300X filter.

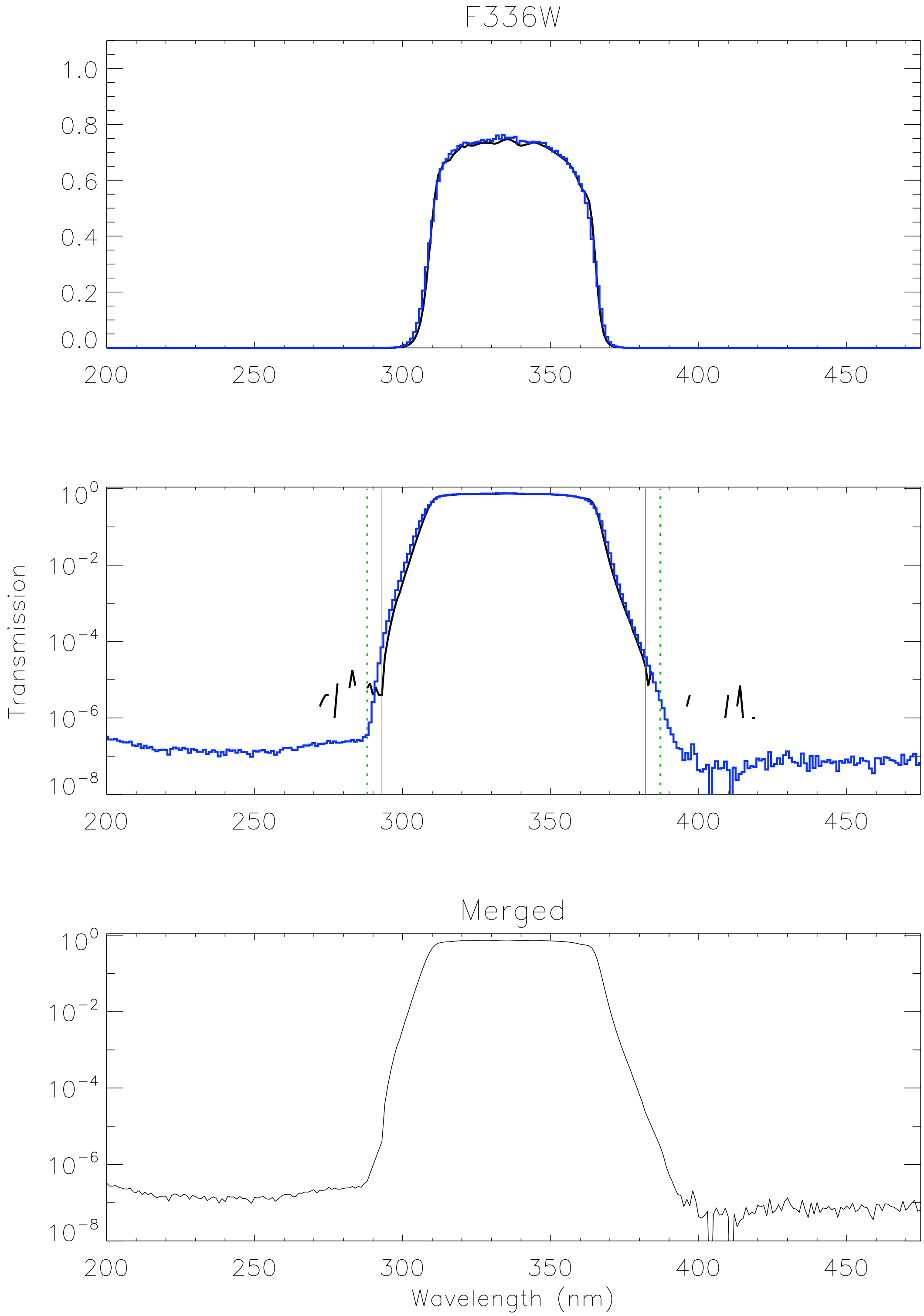

Figure 23: The same as in Figure 1, but for the UVIS/F336W filter.

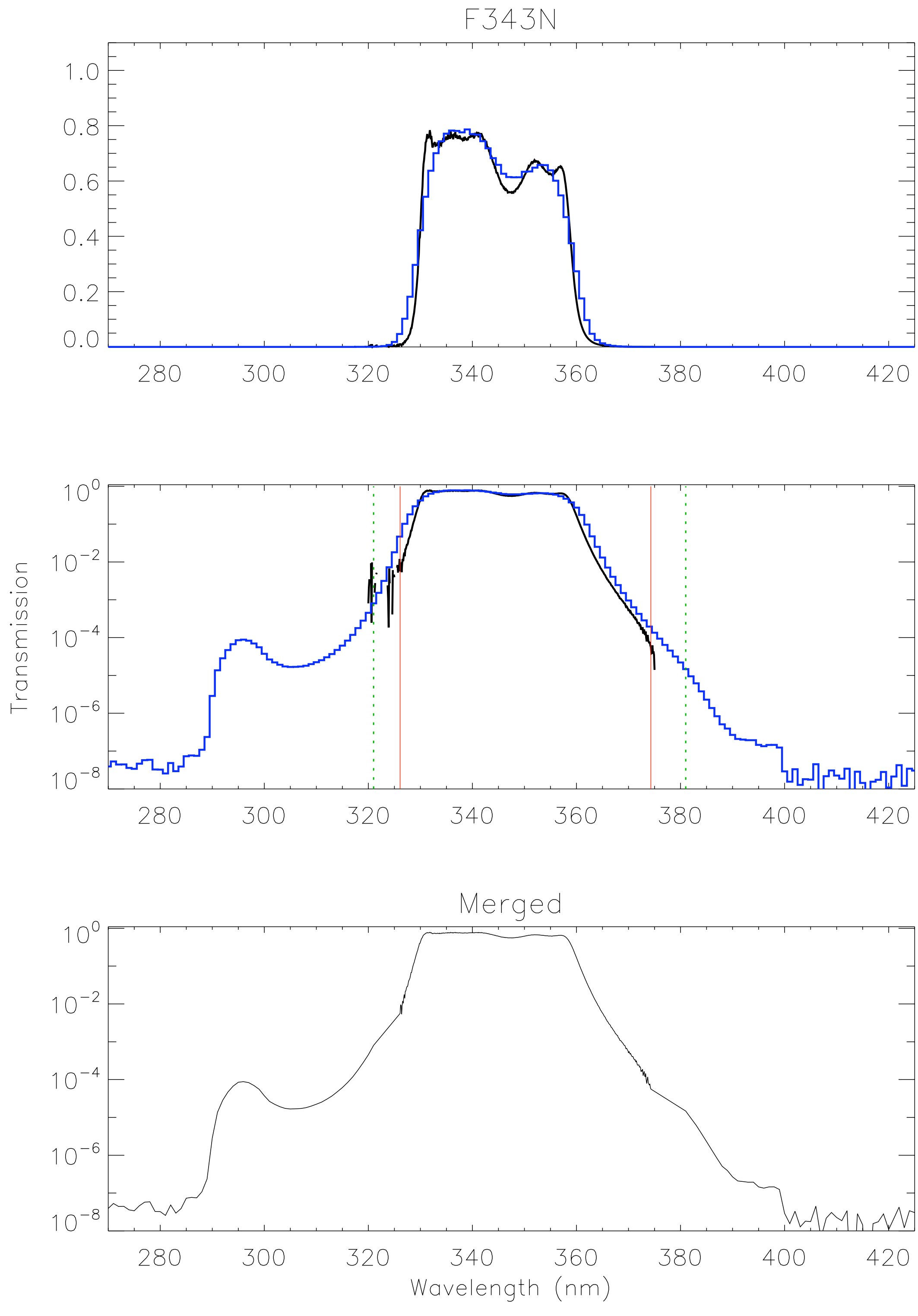

Figure 24: The same as in Figure 1, but for the UVIS/F343N filter.

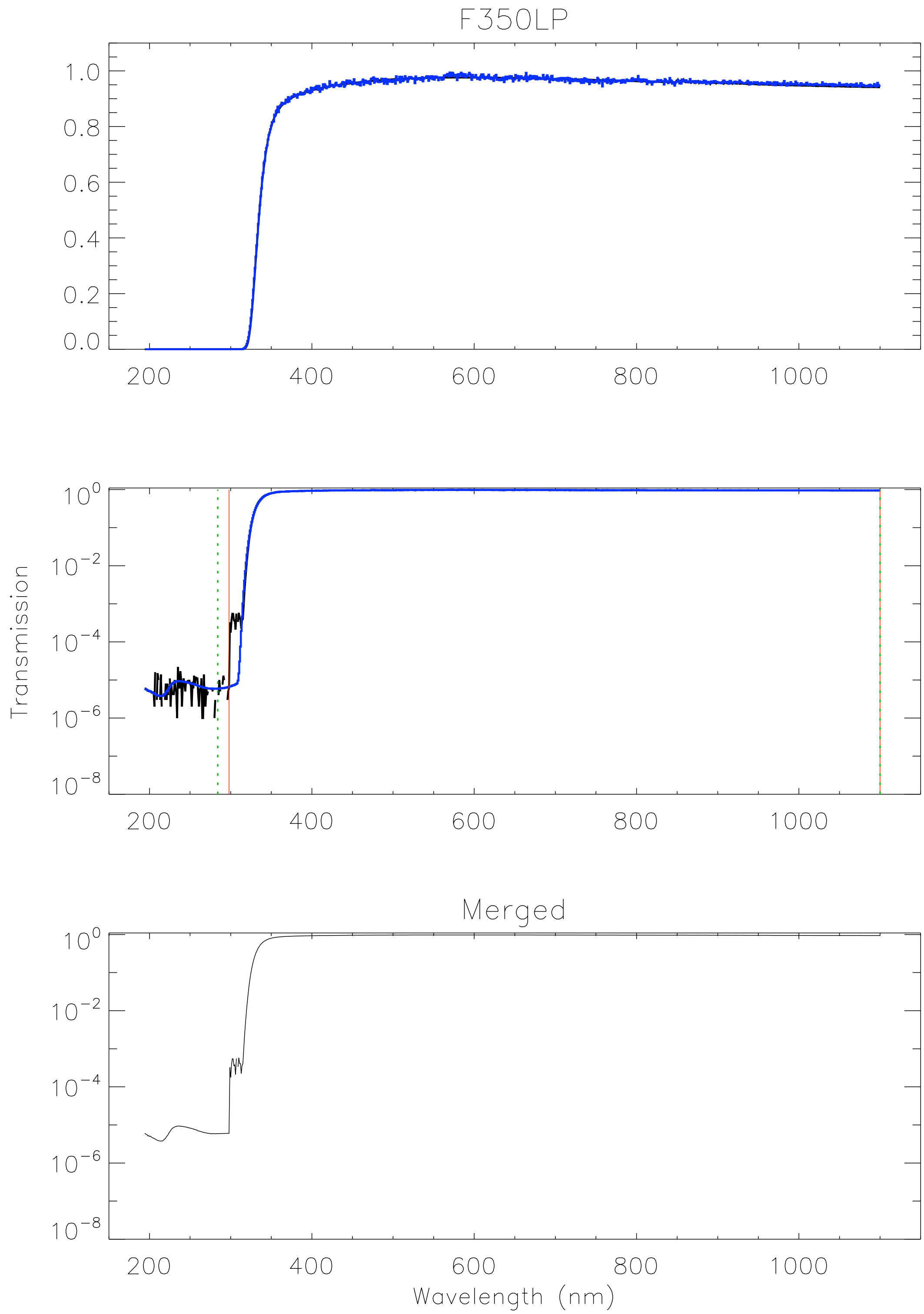

Figure 25: The same as in Figure 1, but for the UVIS/F350LP filter. The "knee" at 300 nm looks real, so the truncation point in the IB data was chosen to include this feature but exclude the noisy measurements immediately to the blue.

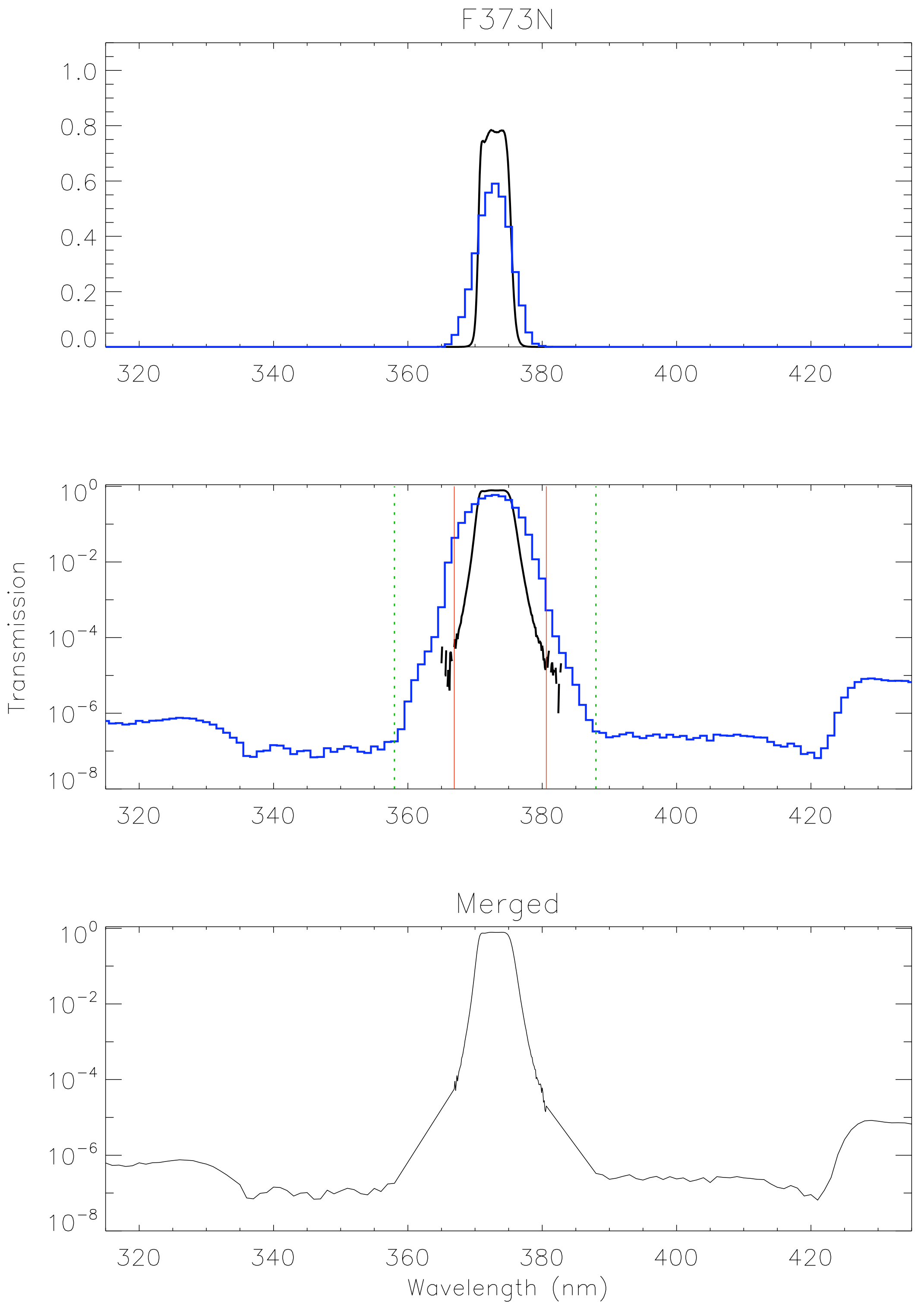

Figure 26: The same as in Figure 1, but for the UVIS/F373N filter. Although there are gaps in the merged data on each side of the bandpass (between the solid and dashed lines), if one linearly interpolates the data across these gaps, the area under the filter curve within the interpolated regions is less than 0.01% of the area under the entire filter curve.

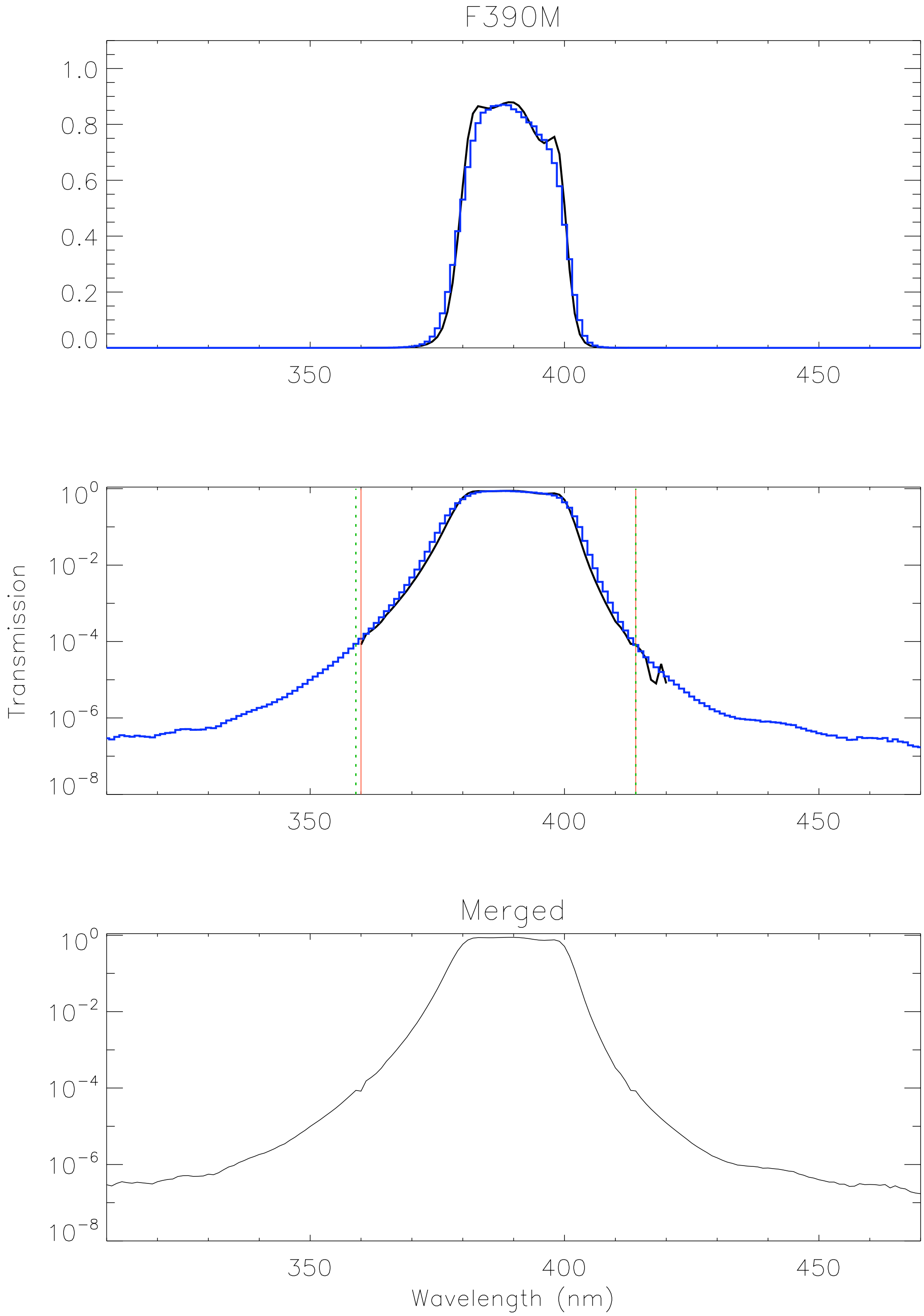

Figure 27: The same as in Figure 1, but for the UVIS/F390M filter.

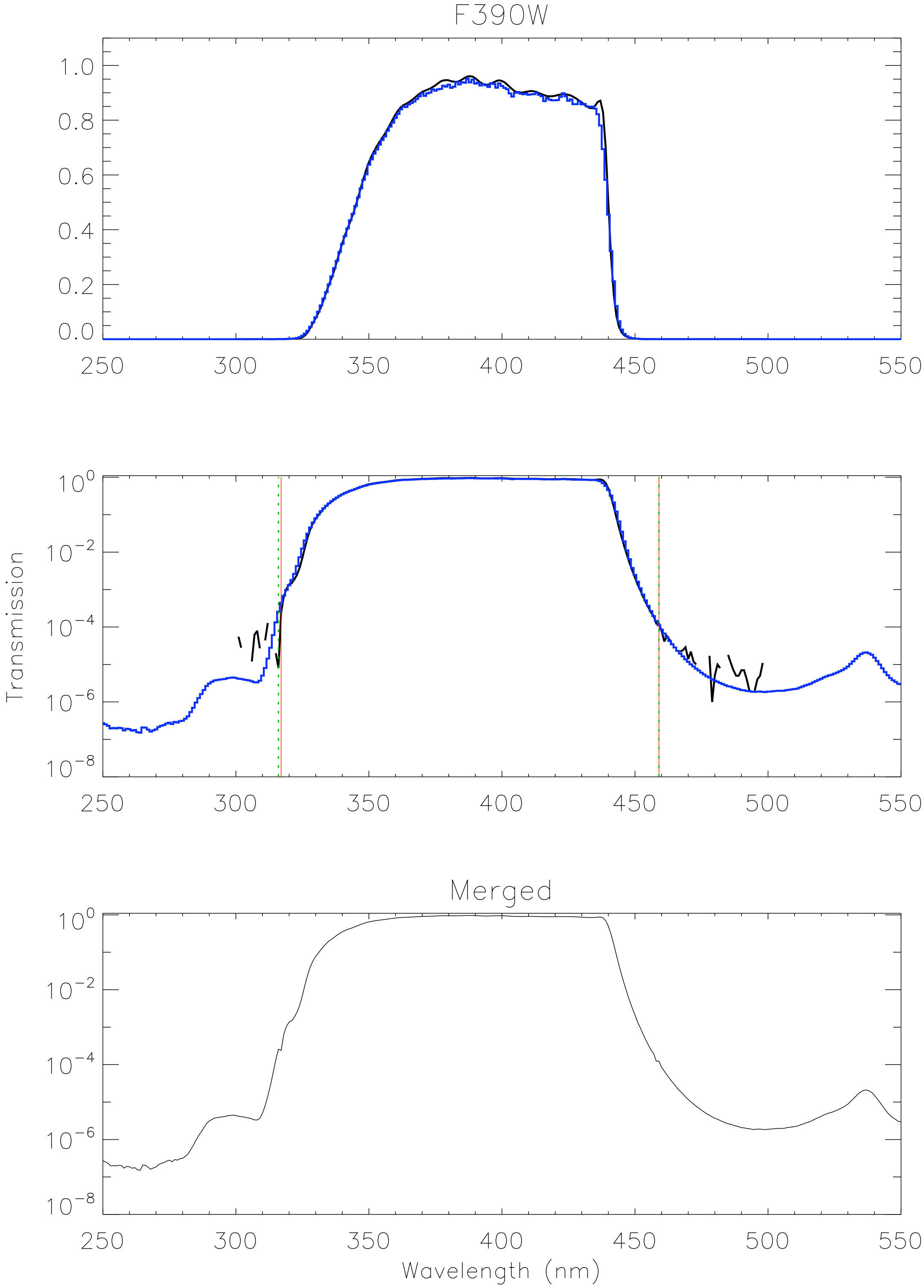

Figure 28: The same as in Figure 1, but for the UVIS/F390W filter.

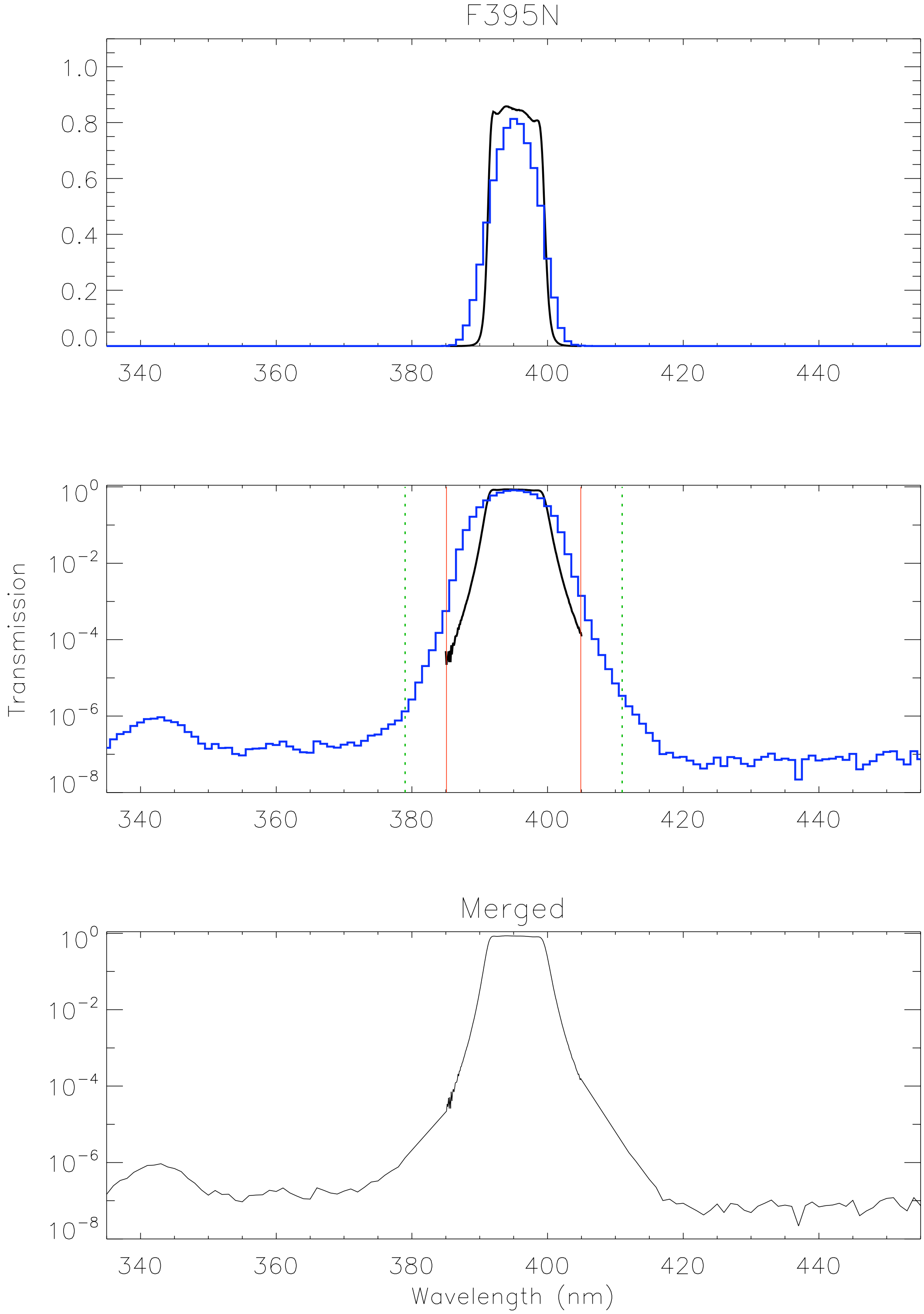

Figure 29: The same as in Figure 1, but for the UVIS/F395N filter.

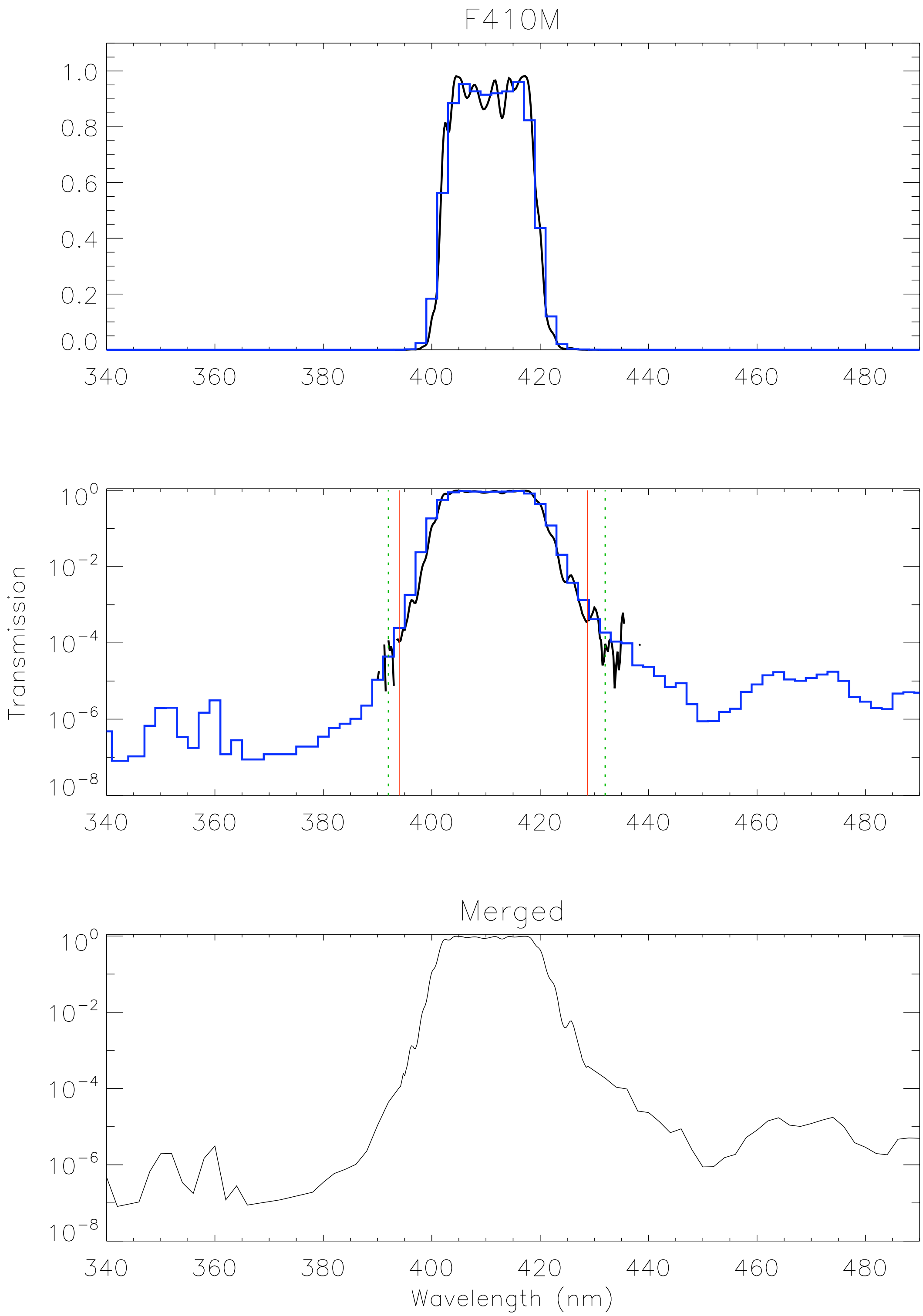

Figure 30: The same as in Figure 1, but for the UVIS/F410M filter.

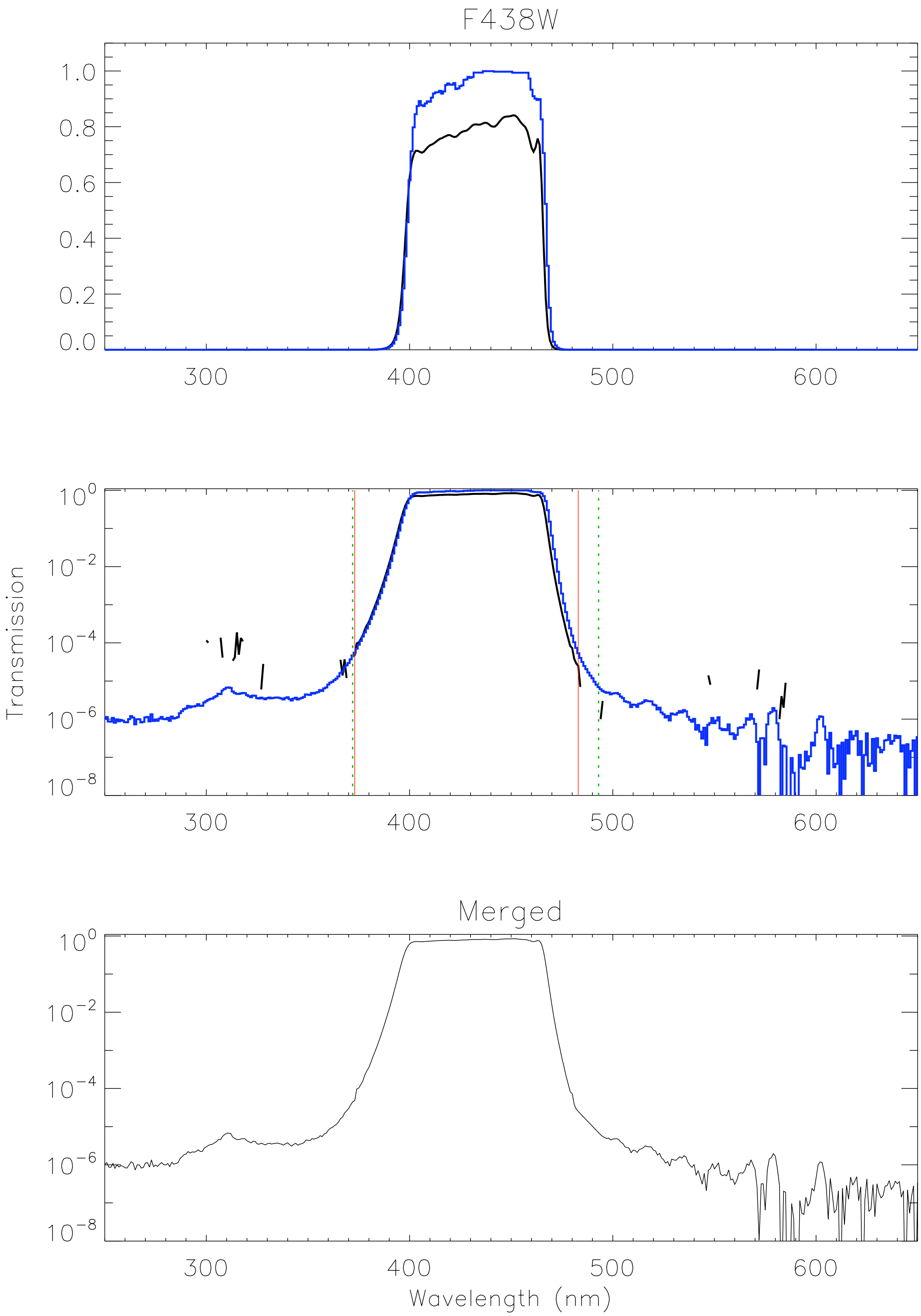

Figure 31: The same as in Figure 1, but for the UVIS/F438W filter.

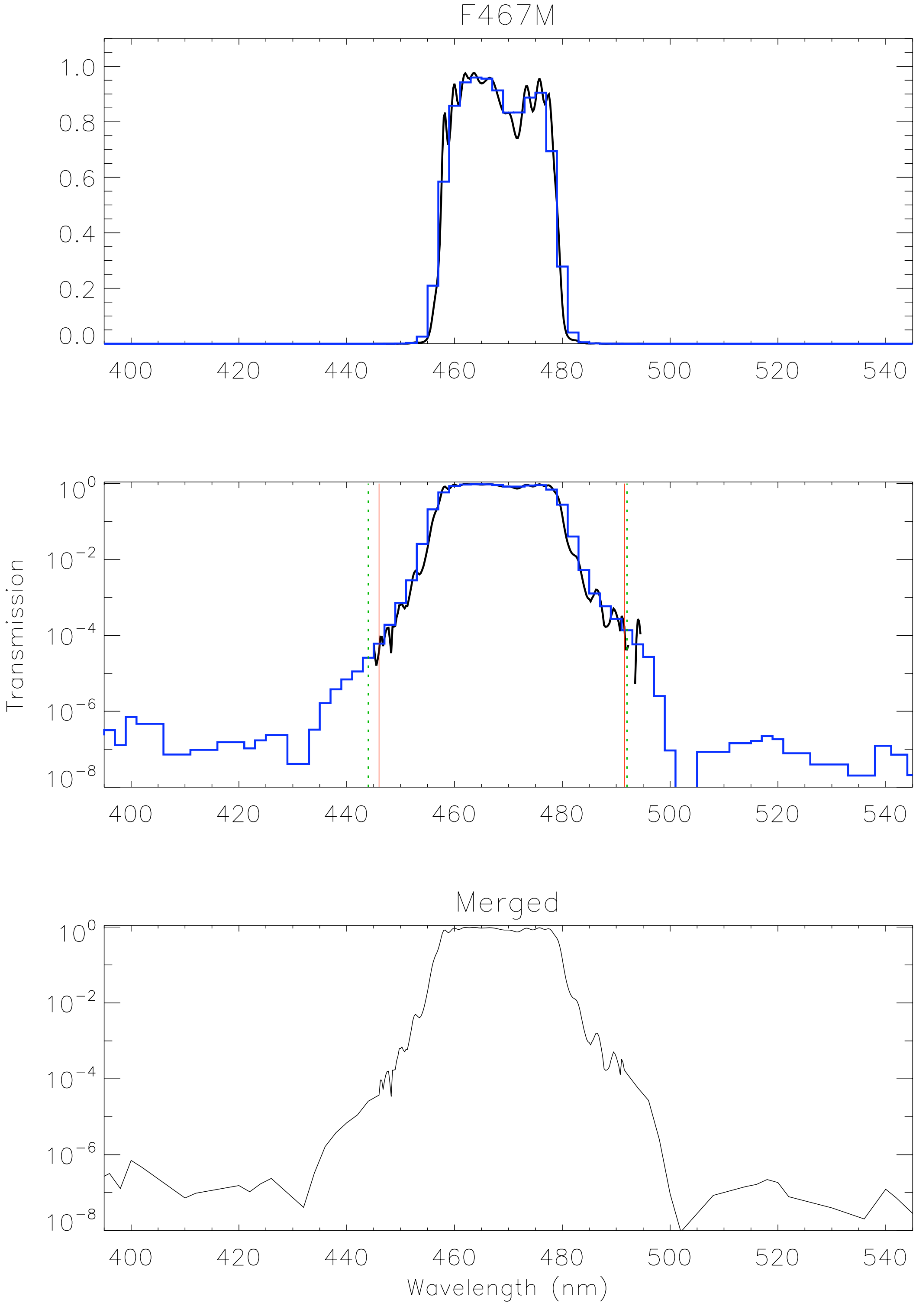

Figure 32: The same as in Figure 1, but for the UVIS/F467M filter.

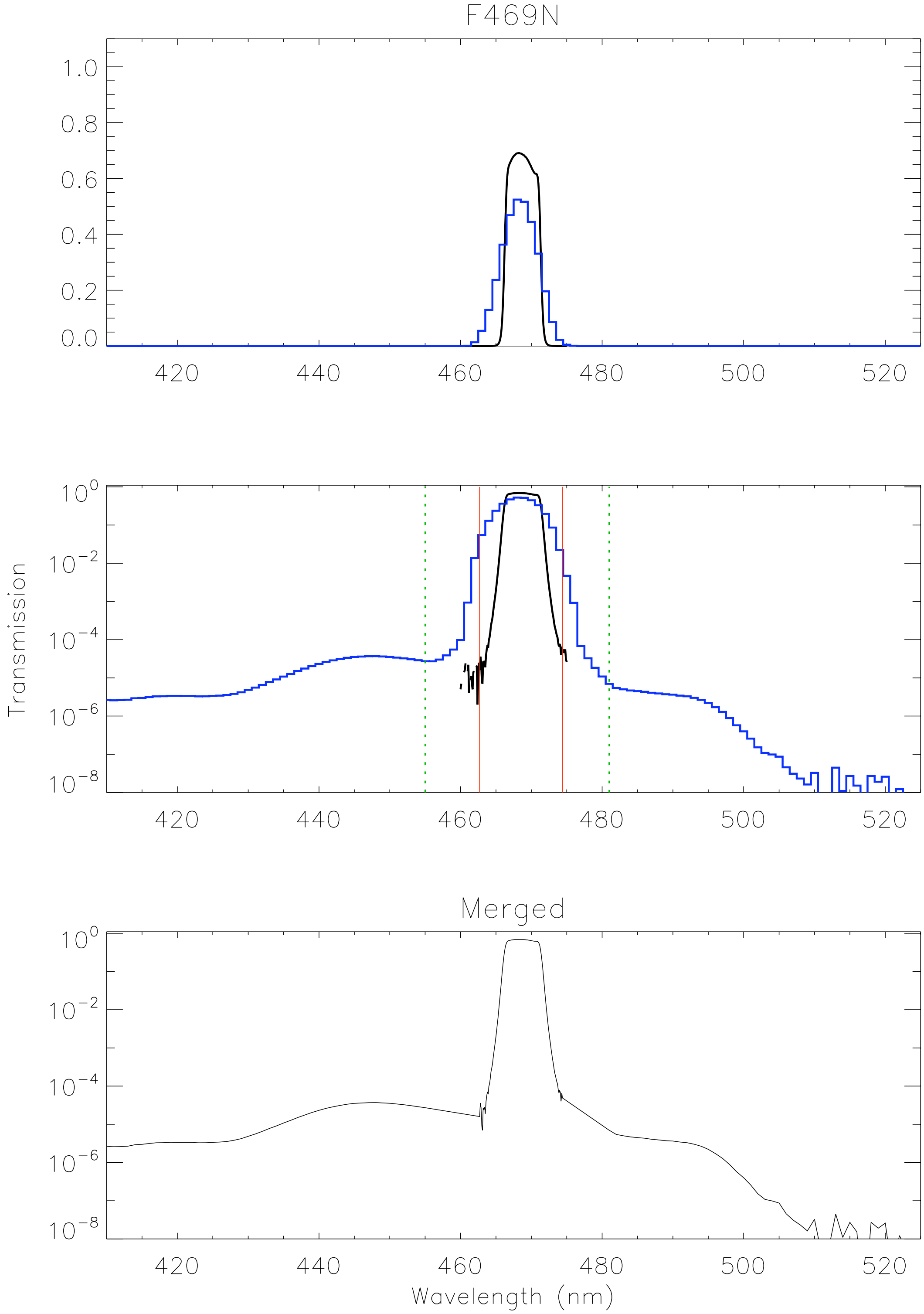

Figure 33: The same as in Figure 1, but for the UVIS/F469N filter.

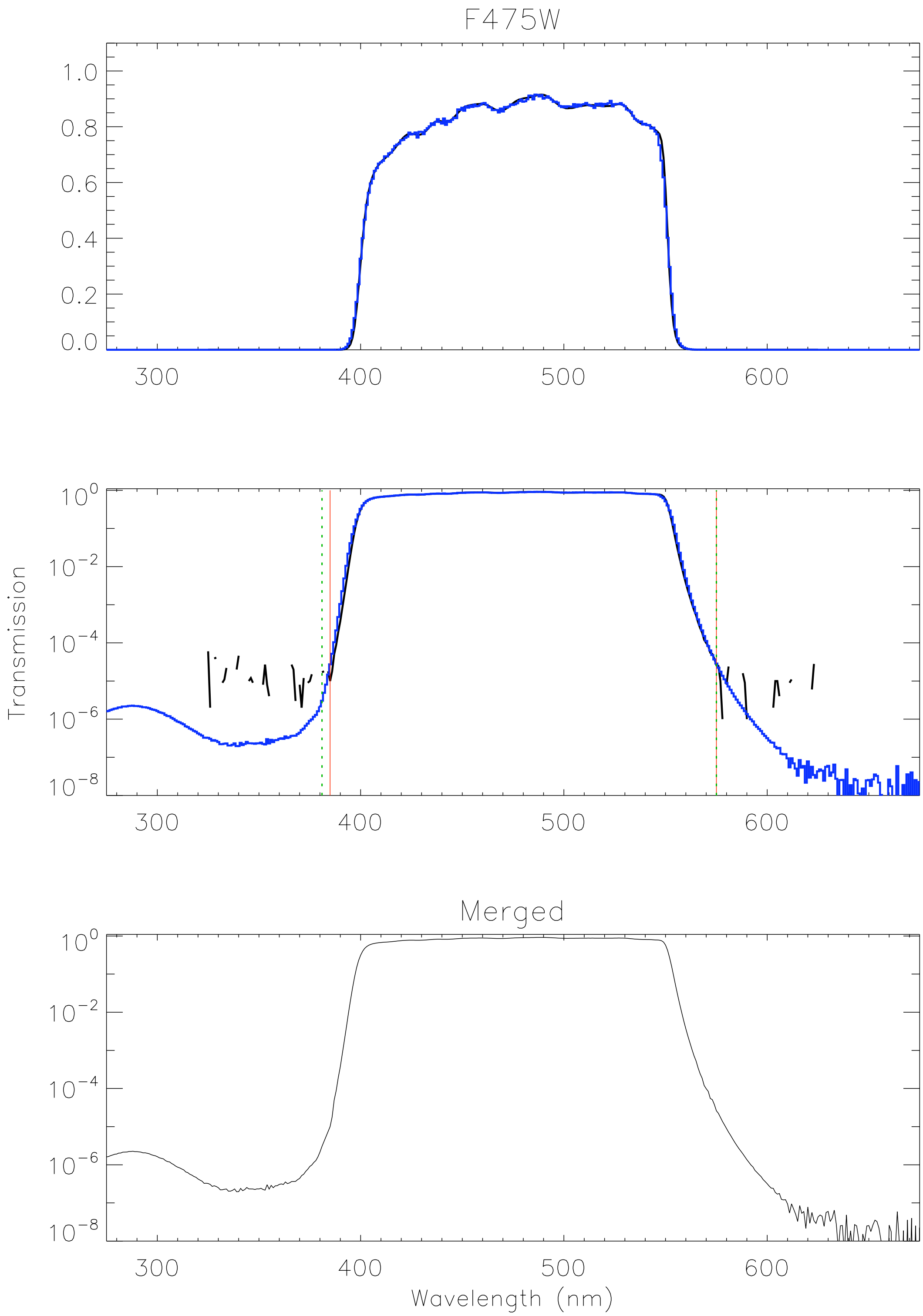

Figure 34: The same as in Figure 1, but for the UVIS/F475W filter.

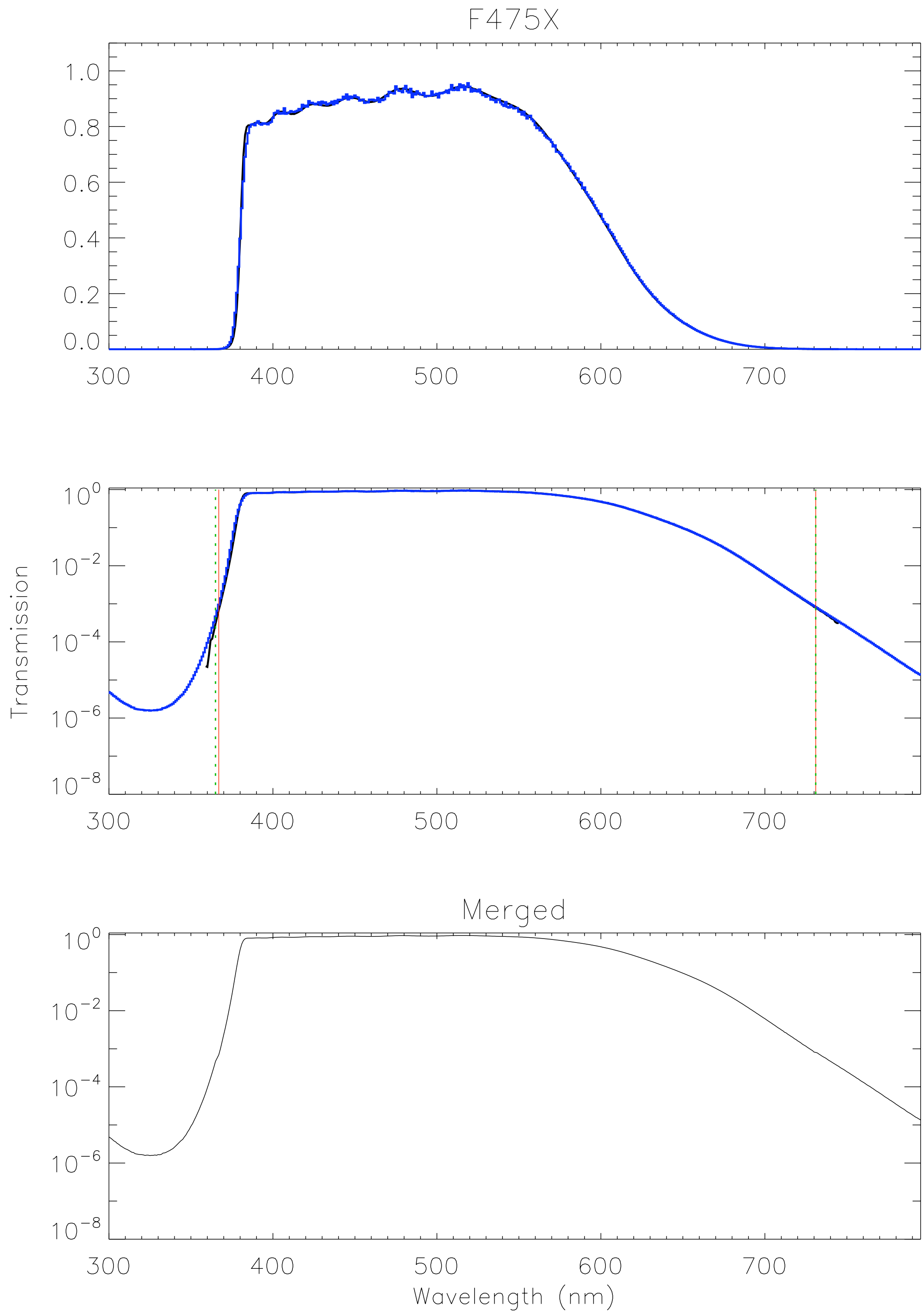

Figure 35: The same as in Figure 1, but for the UVIS/F475X filter.

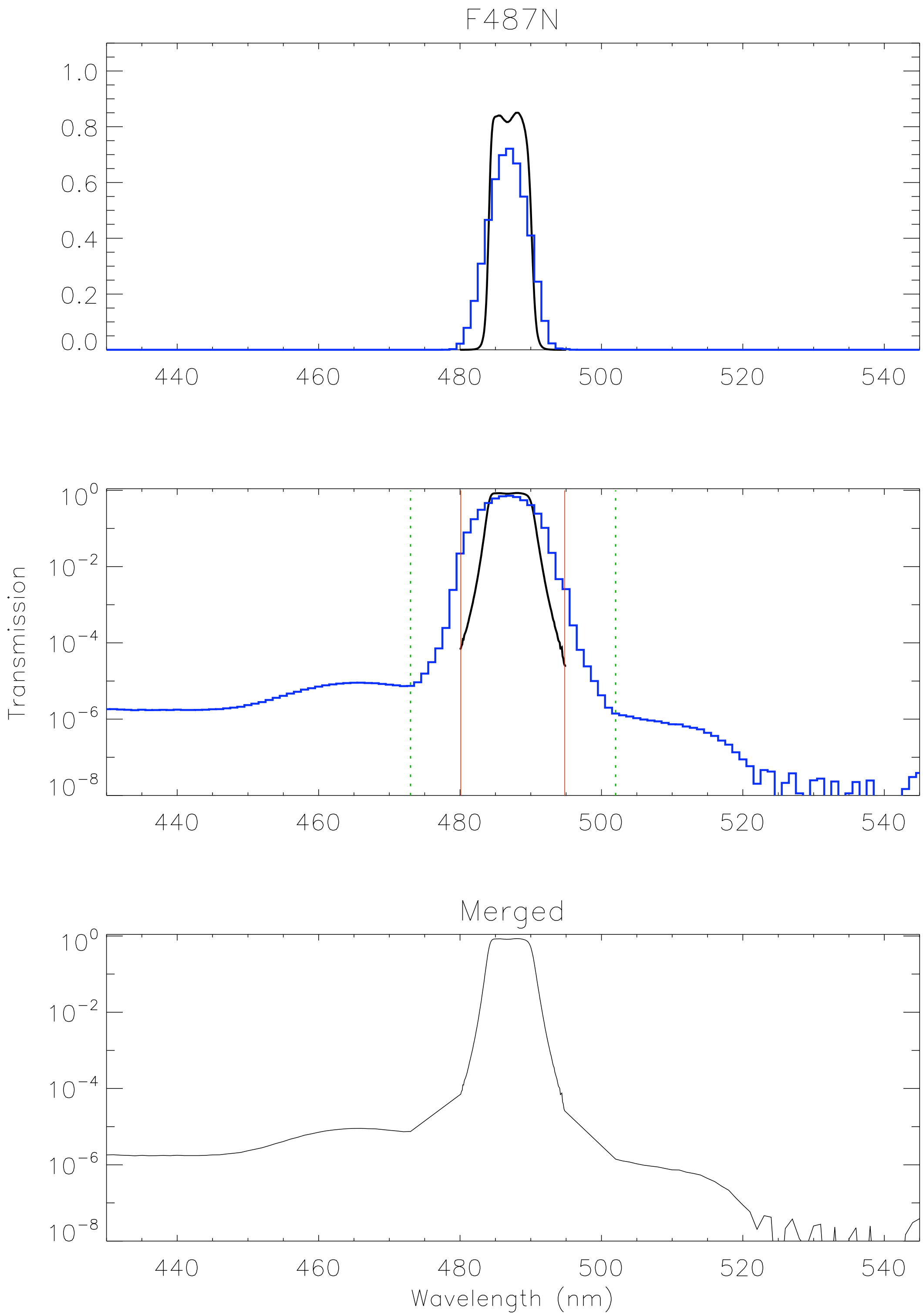

Figure 36: The same as in Figure 1, but for the UVIS/F487N filter.

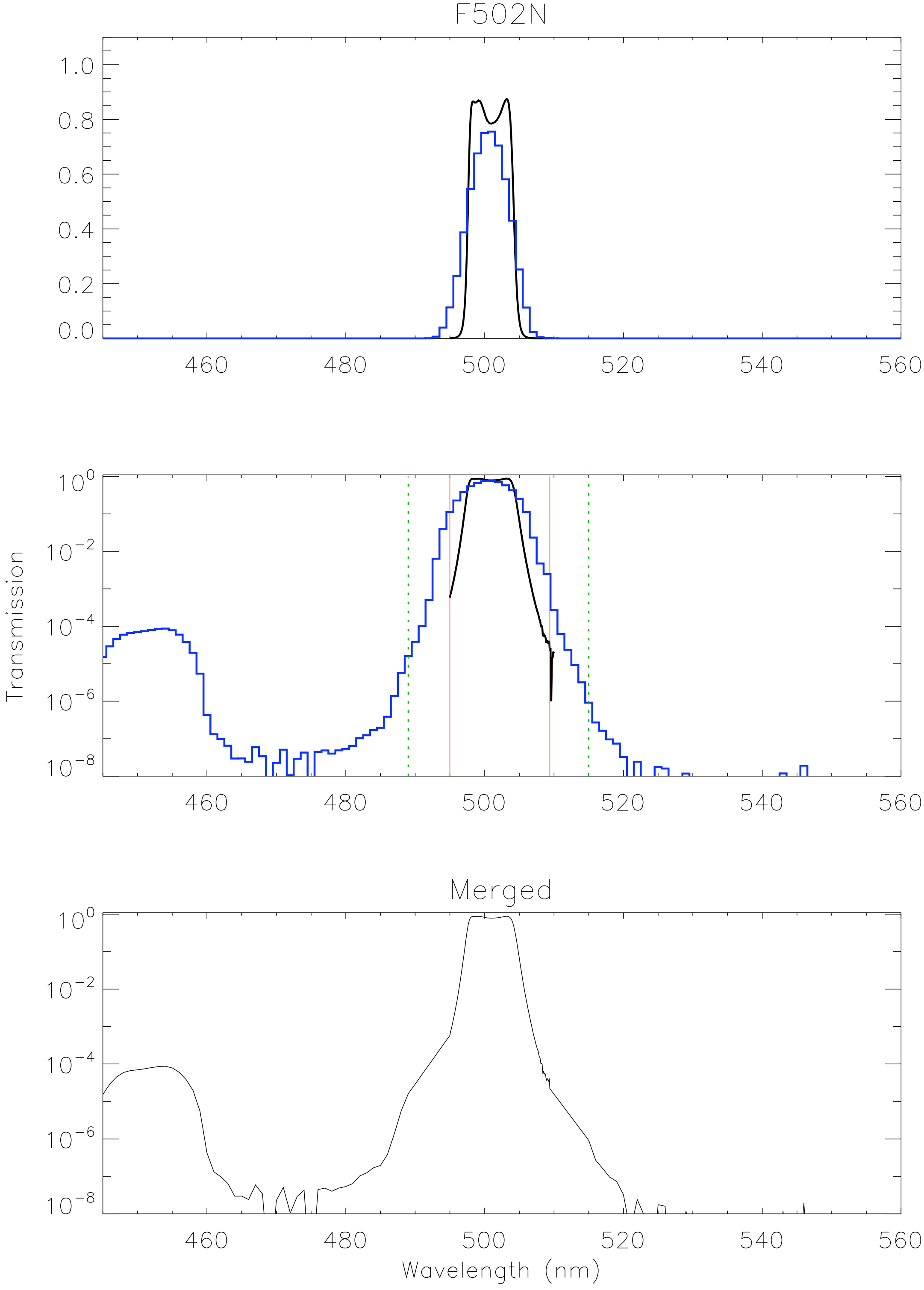

Figure 37: The same as in Figure 1, but for the UVIS/F502N filter.

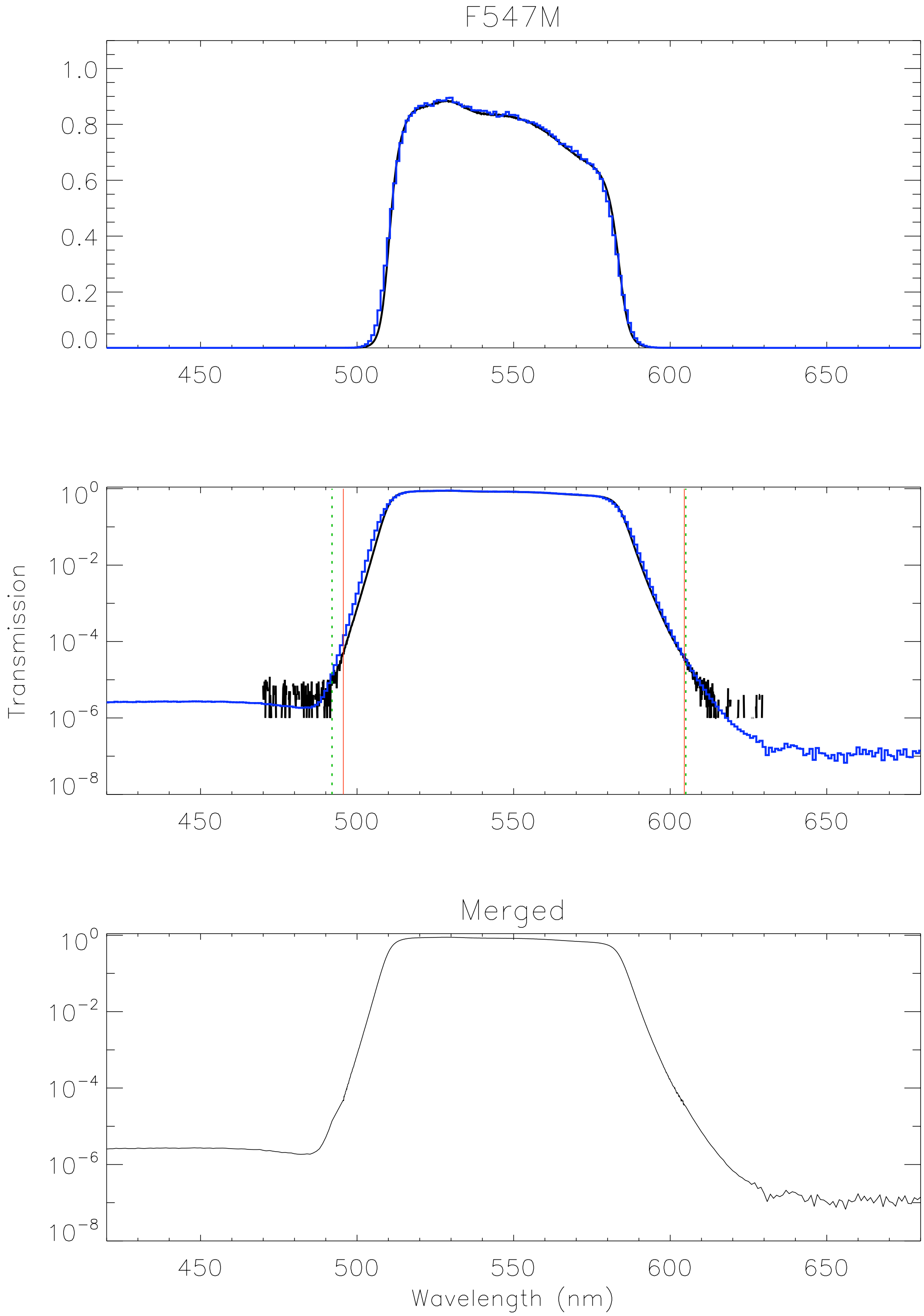

Figure 38: The same as in Figure 1, but for the UVIS/F547M filter.

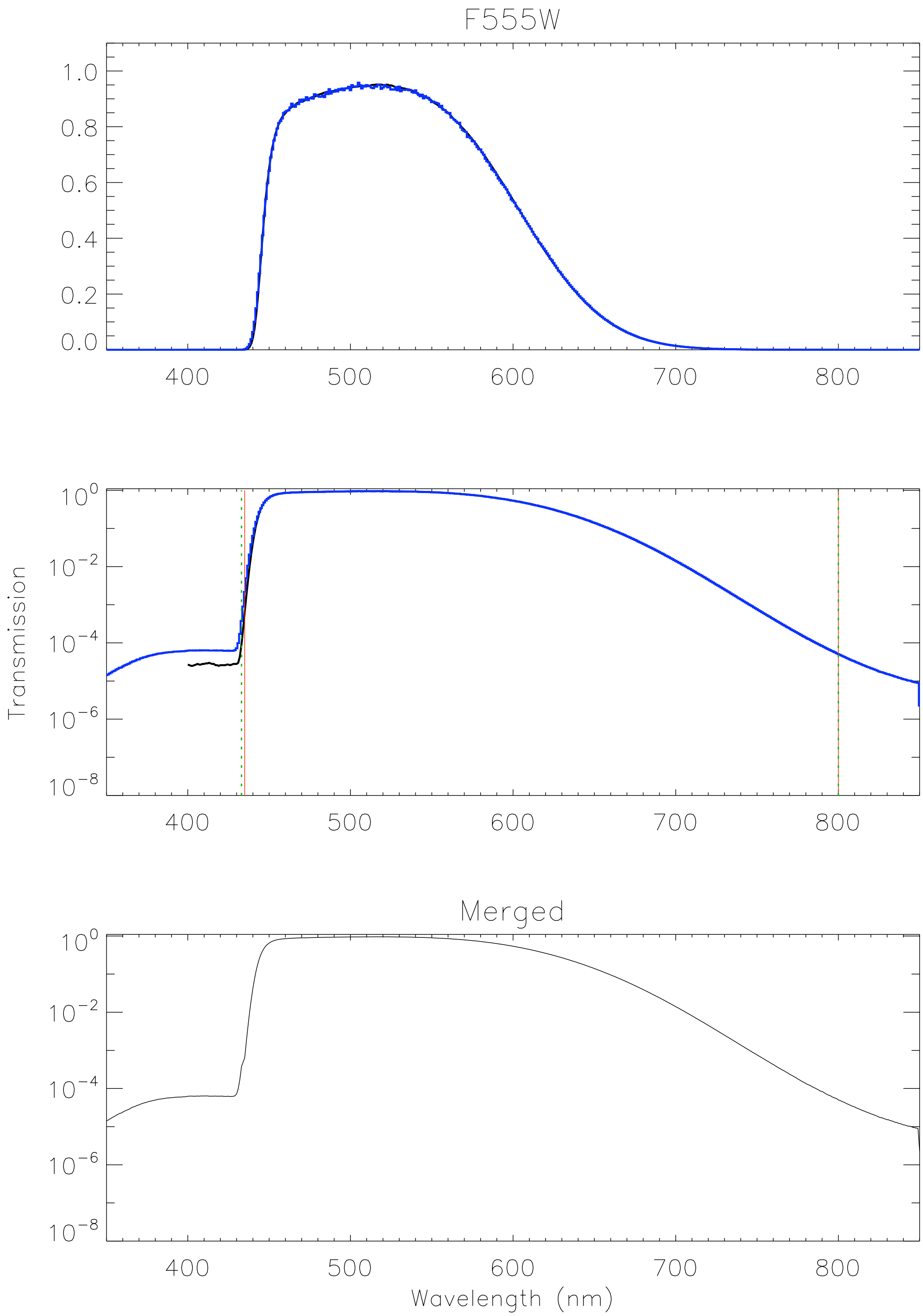

Figure 39: The same as in Figure 1, but for the UVIS/F555W filter.

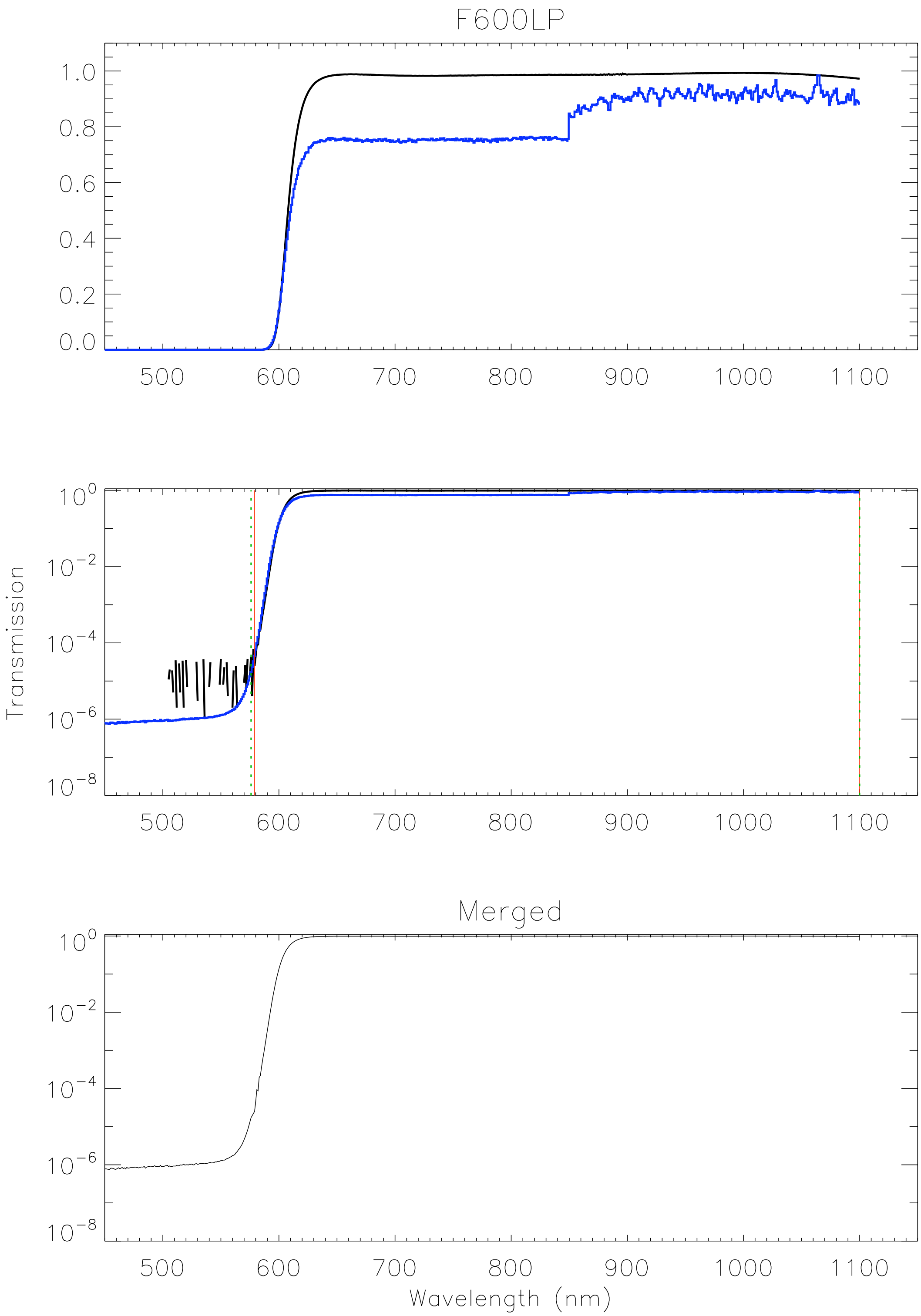

Figure 40: The same as in Figure 1, but for the UVIS/F600LP filter.

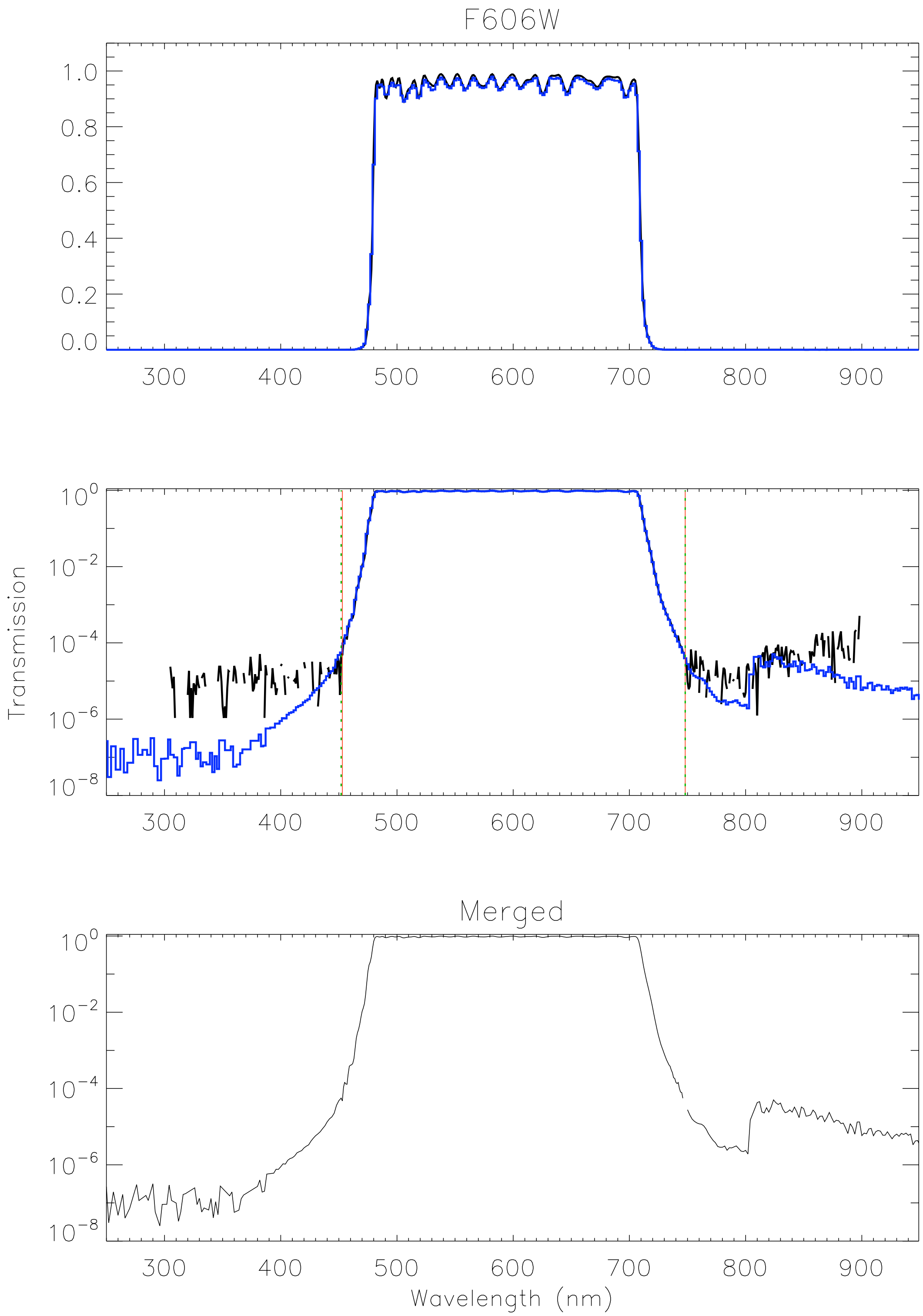

Figure 41: The same as in Figure 1, but for the UVIS/F606W filter.

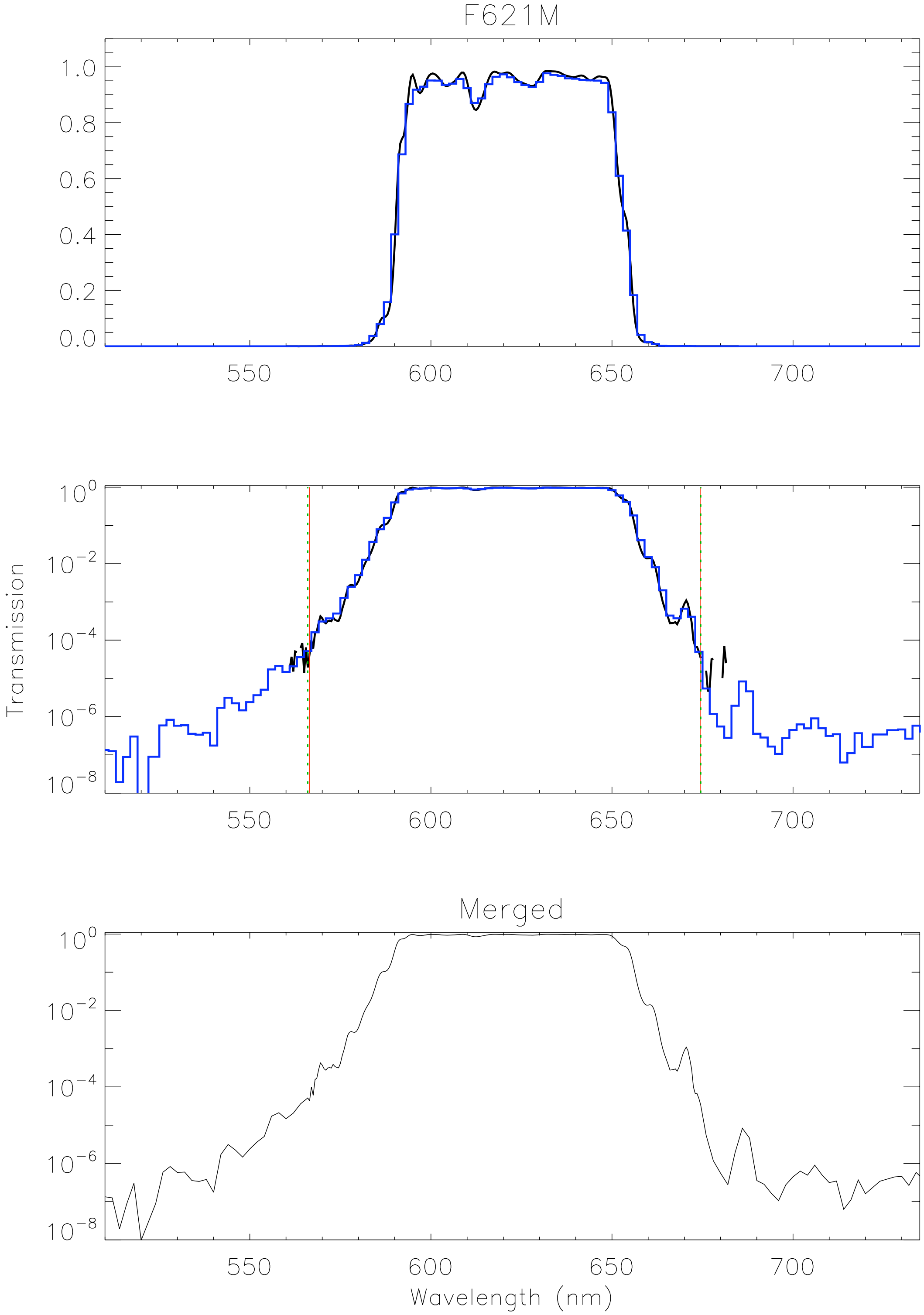

Figure 42: The same as in Figure 1, but for the UVIS/F621M filter.

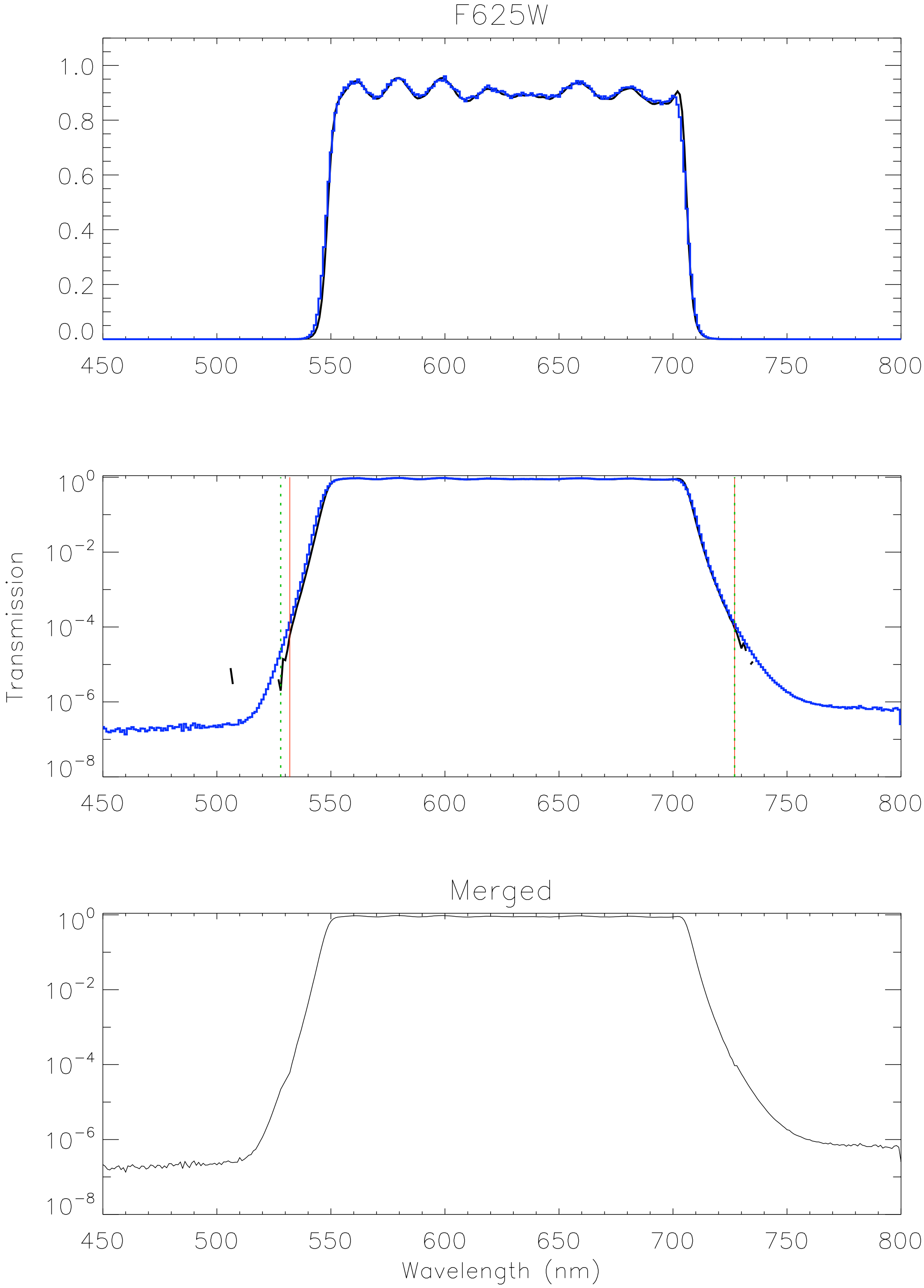

Figure 43: The same as in Figure 1, but for the UVIS/F625W filter.

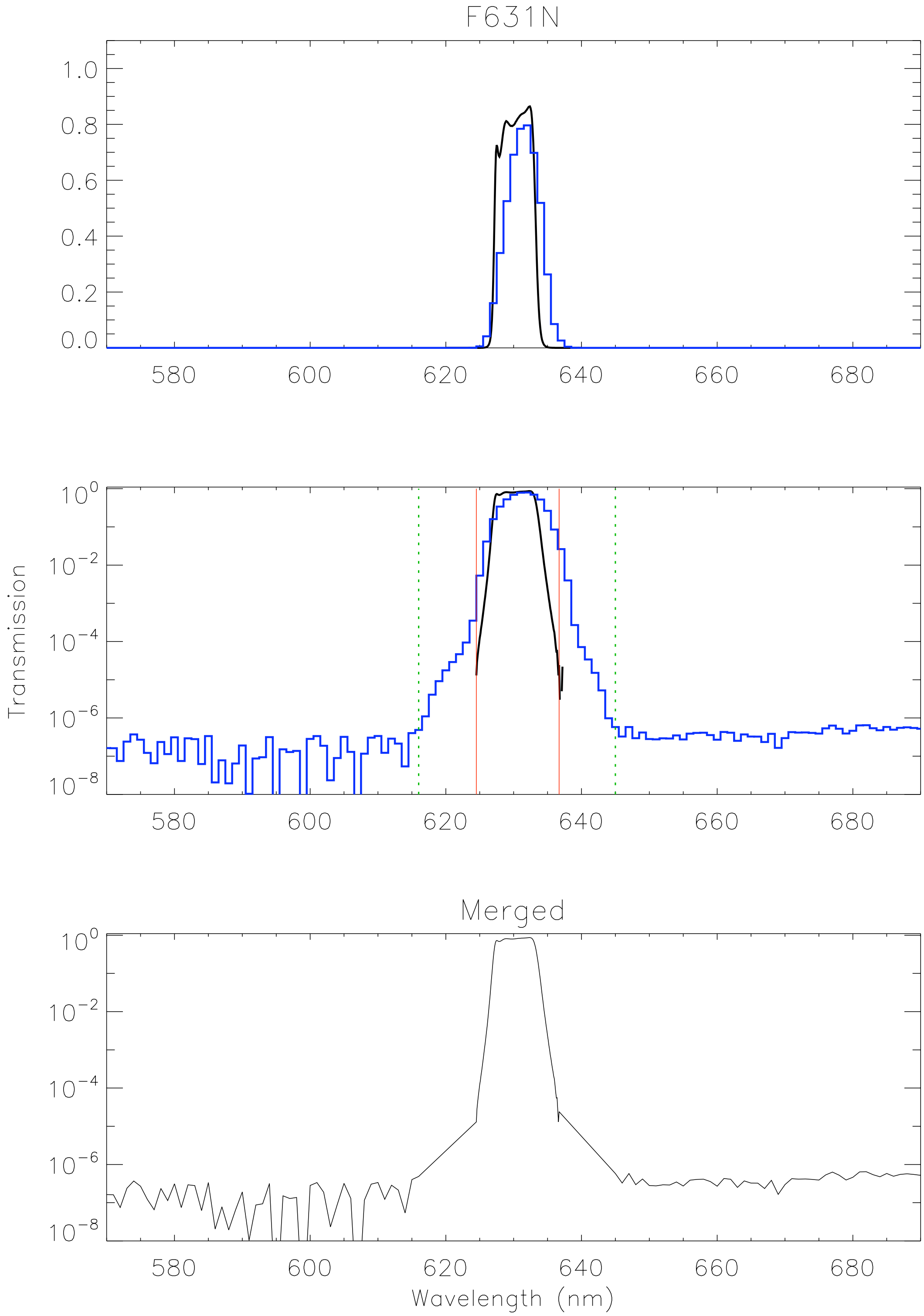

Figure 44: The same as in Figure 1, but for the UVIS/F631N filter.

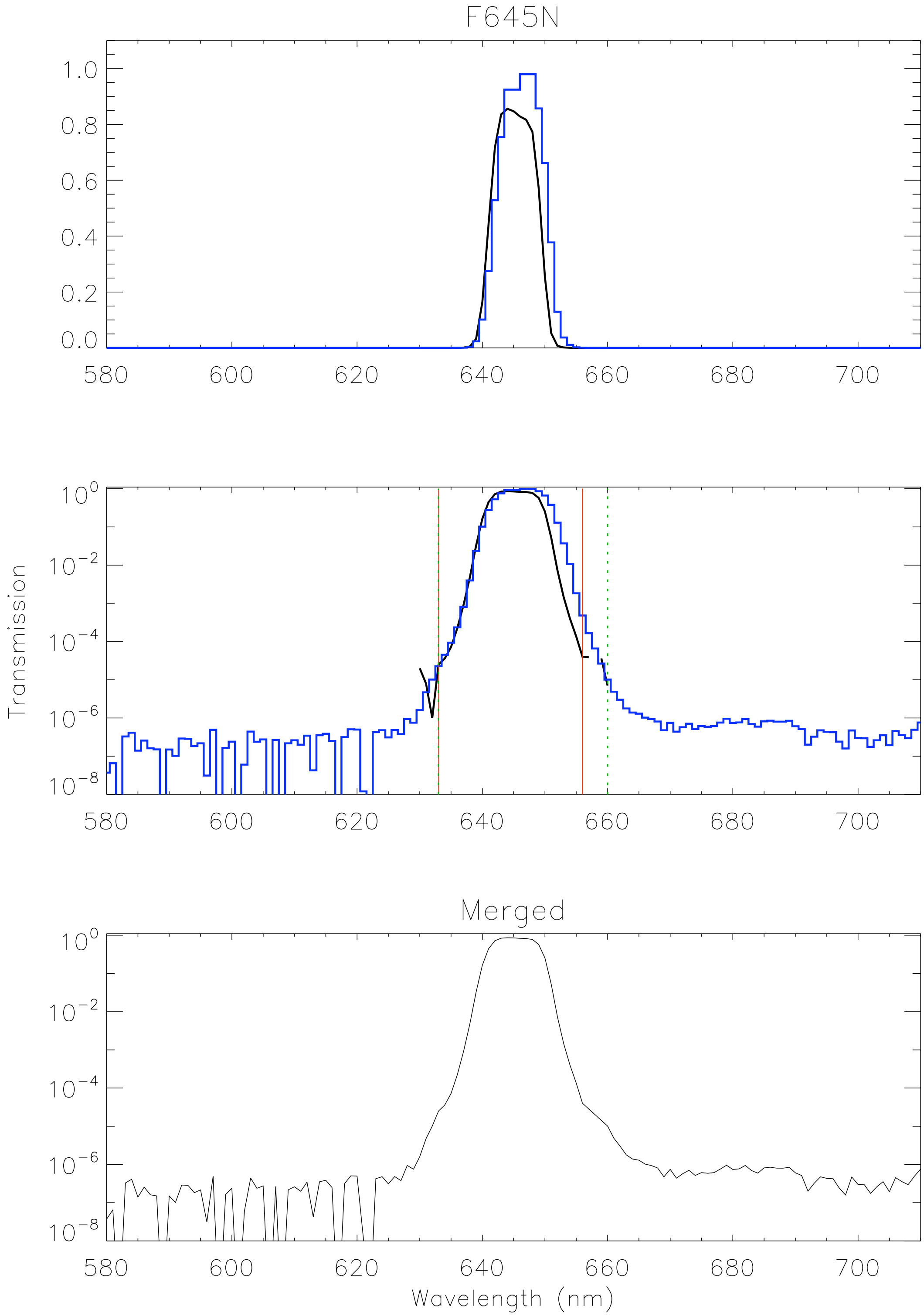

Figure 45: The same as in Figure 1, but for the UVIS/F645N filter.

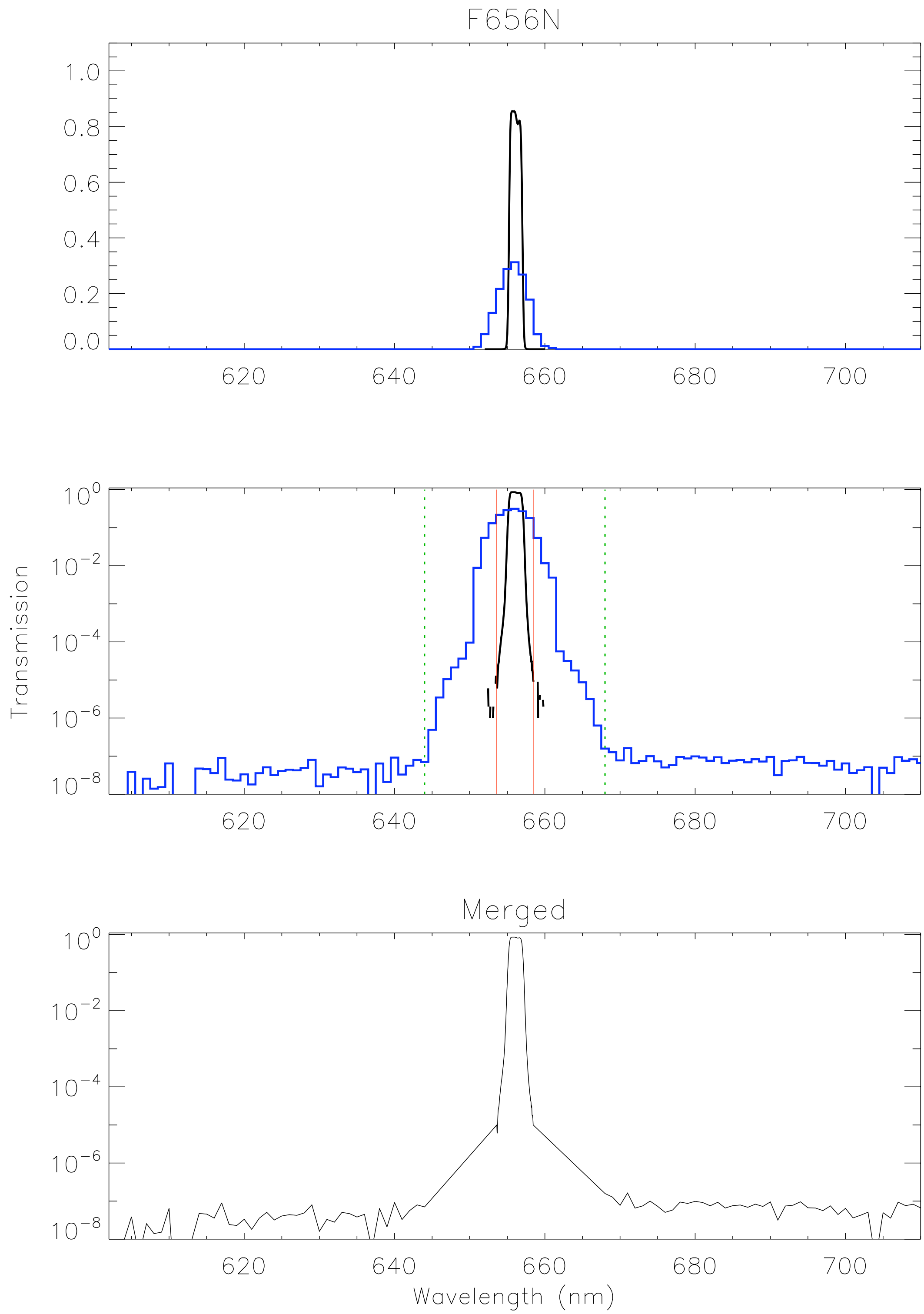

Figure 46: The same as in Figure 1, but for the UVIS/F656N filter.

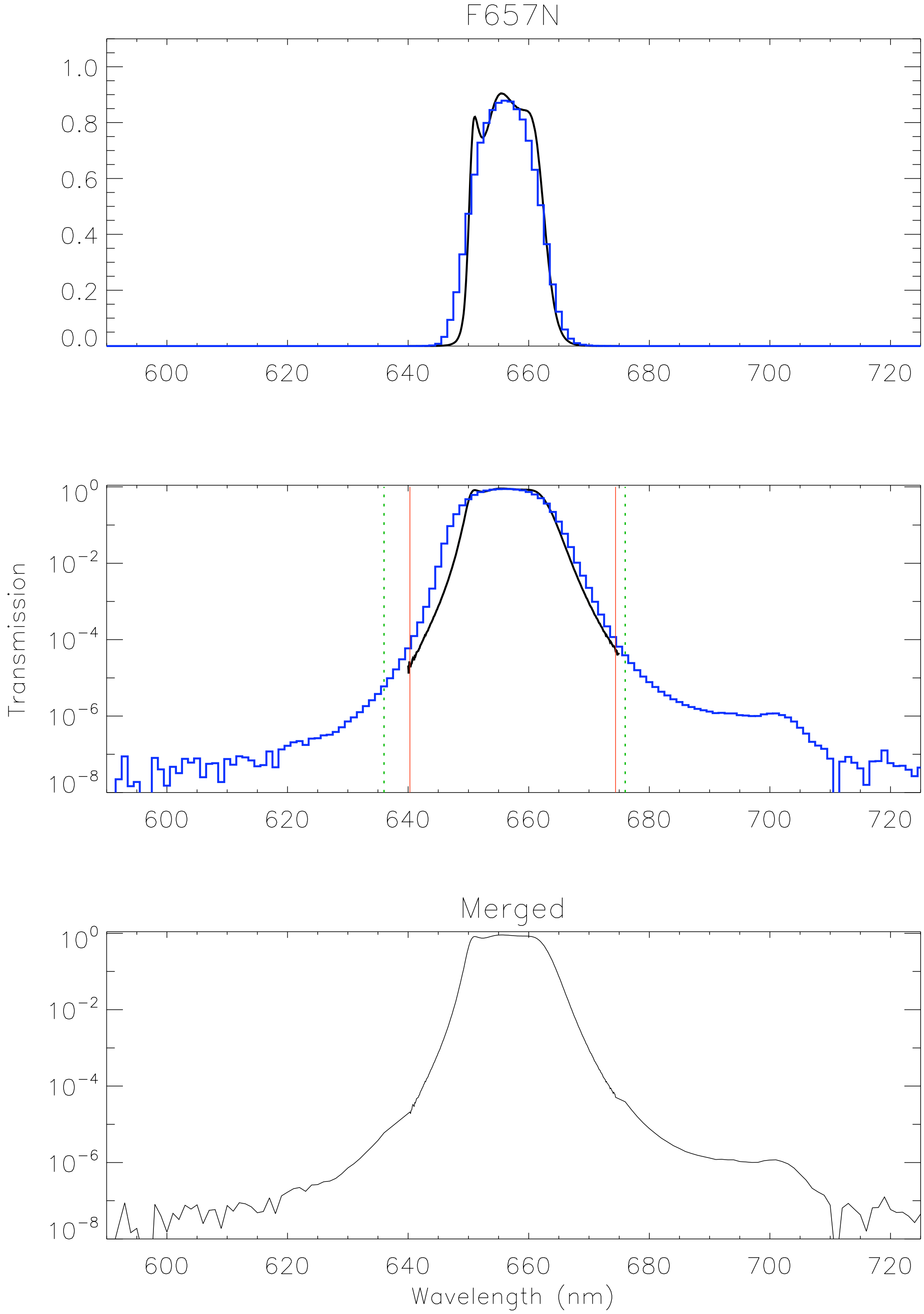

Figure 47: The same as in Figure 1, but for the UVIS/F657N filter.

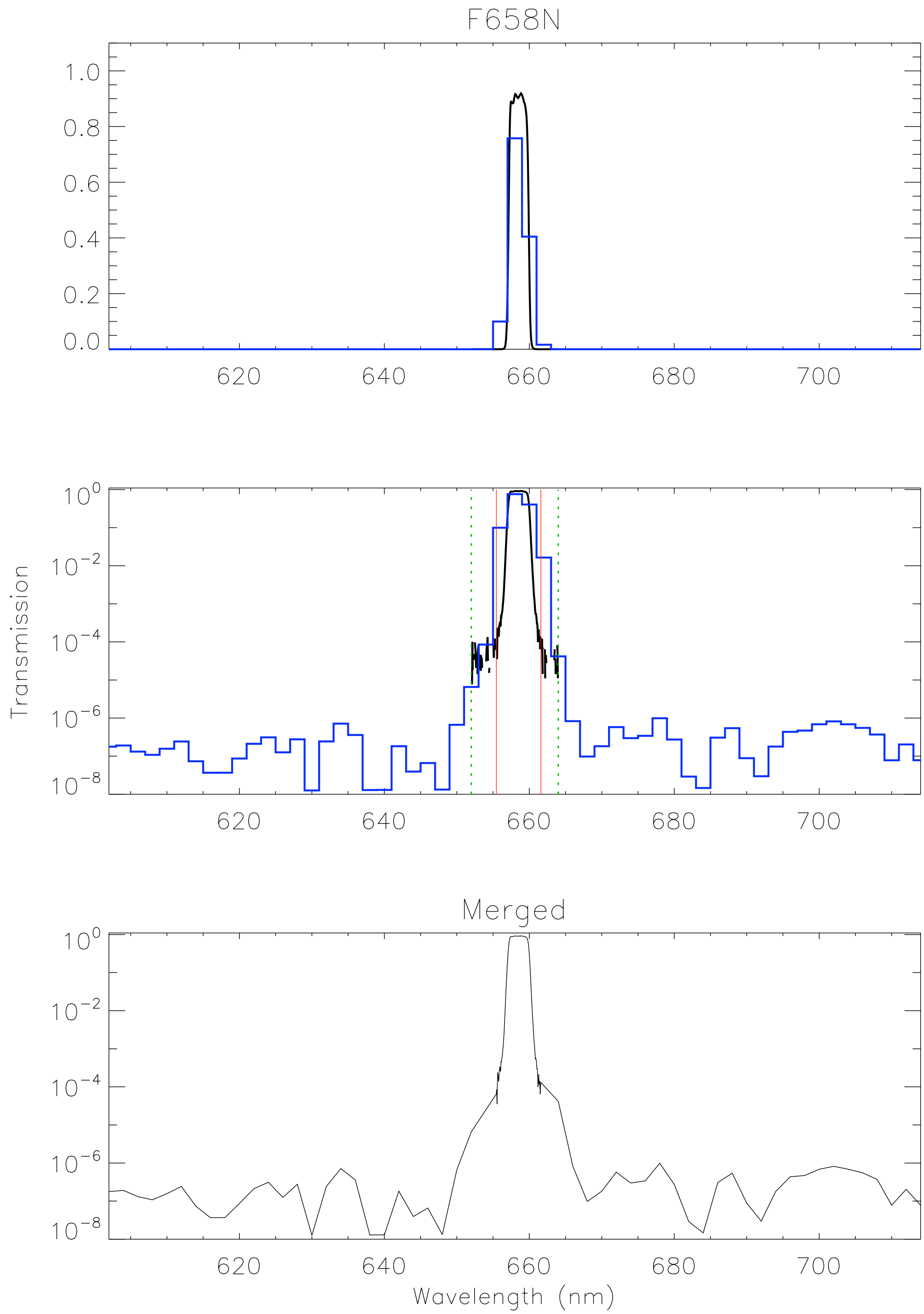

Figure 48: The same as in Figure 1, but for the UVIS/F658N filter.

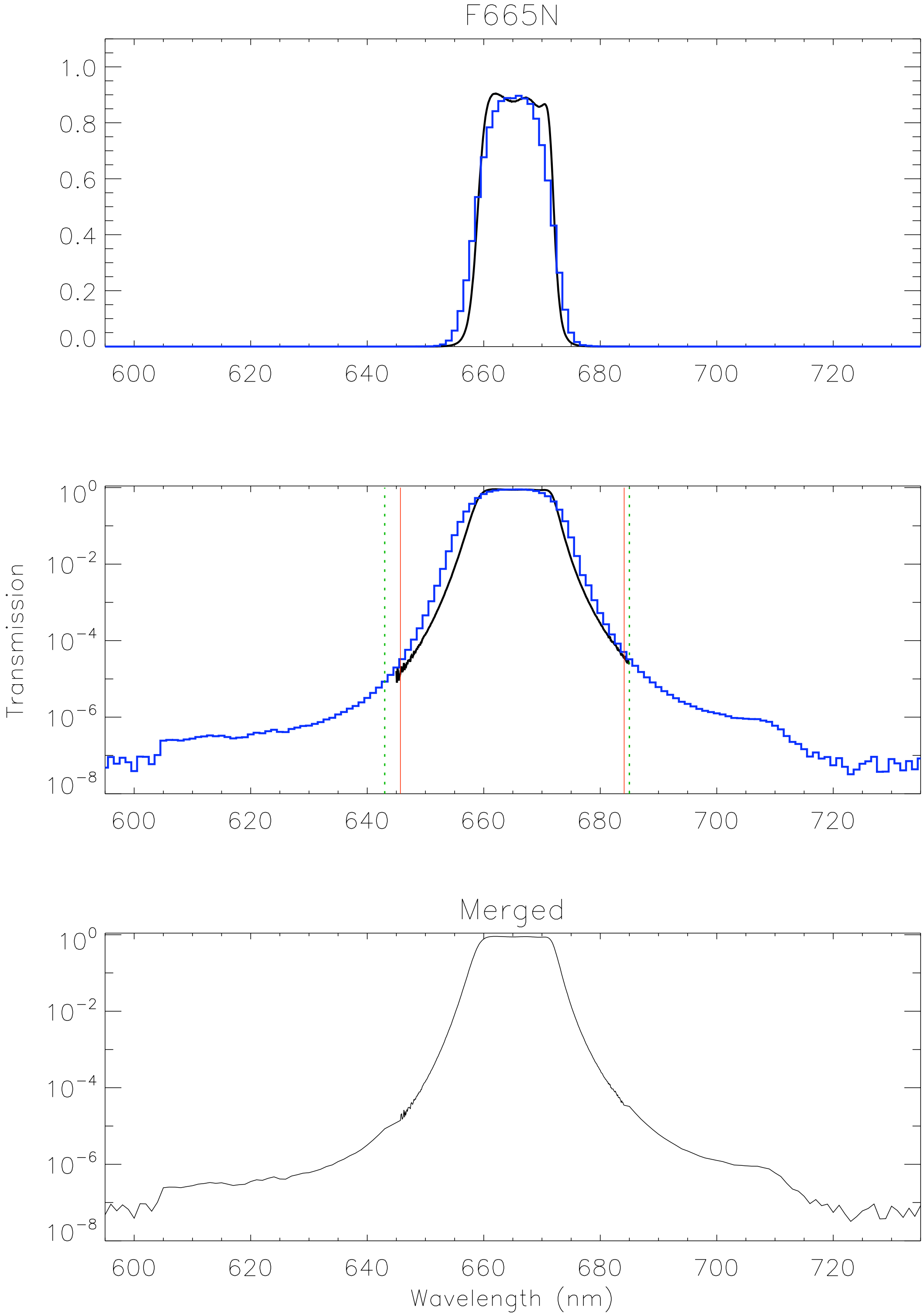

Figure 49: The same as in Figure 1, but for the UVIS/F665N filter.

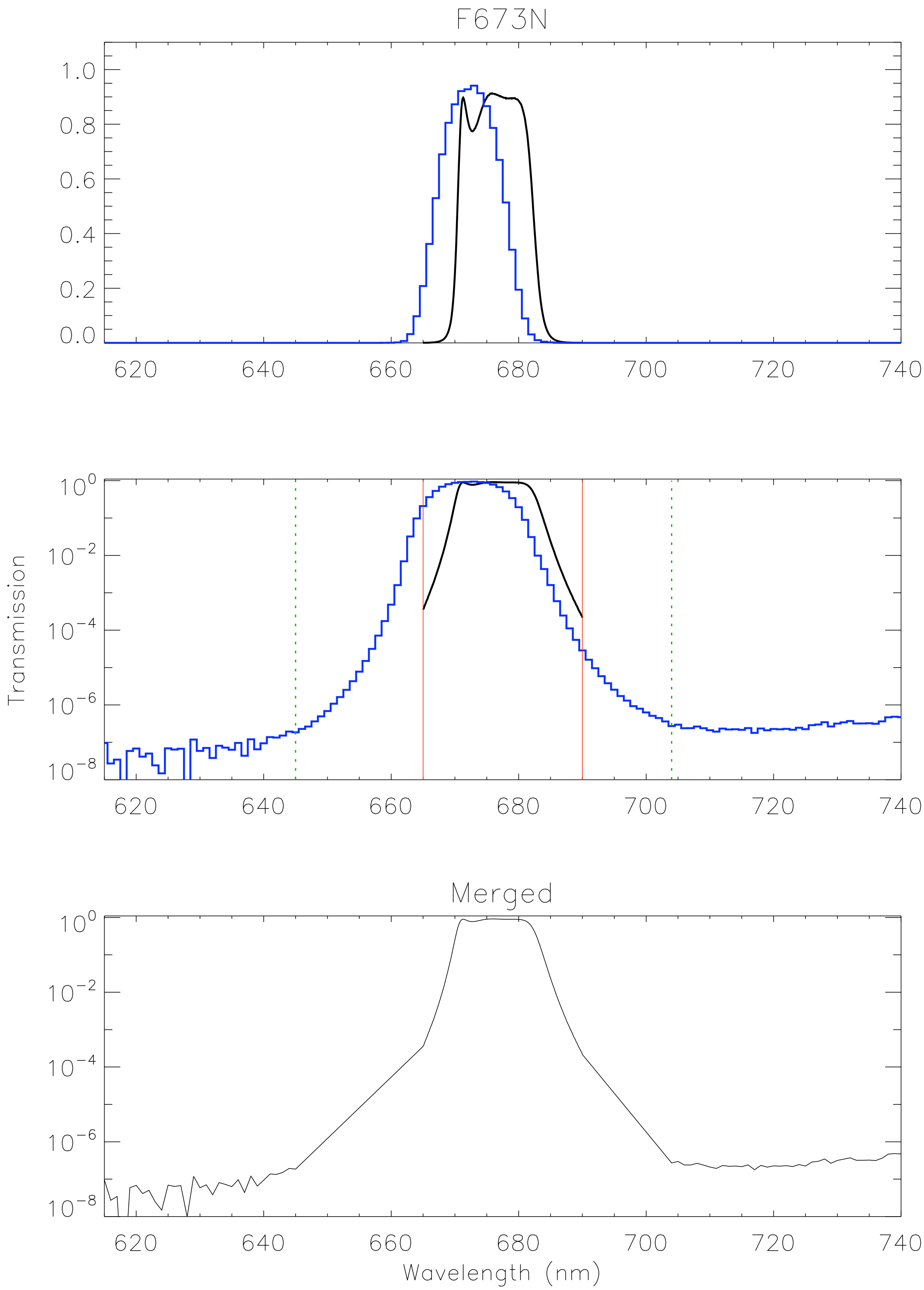

Figure 50: The same as in Figure 1, but for the UVIS/F673N filter. The OB data appear to be offset in wavelength. Given the slowly varying response in the far wings of this filter, if this is a wavelength error, it should not cause problems in the merged filter curve, but if these OB data actually belong to another filter, that could be a problem if that filter's OB response is very different from that of the flight F673N. The OB data do not look like those of FQ672N or FQ674N.

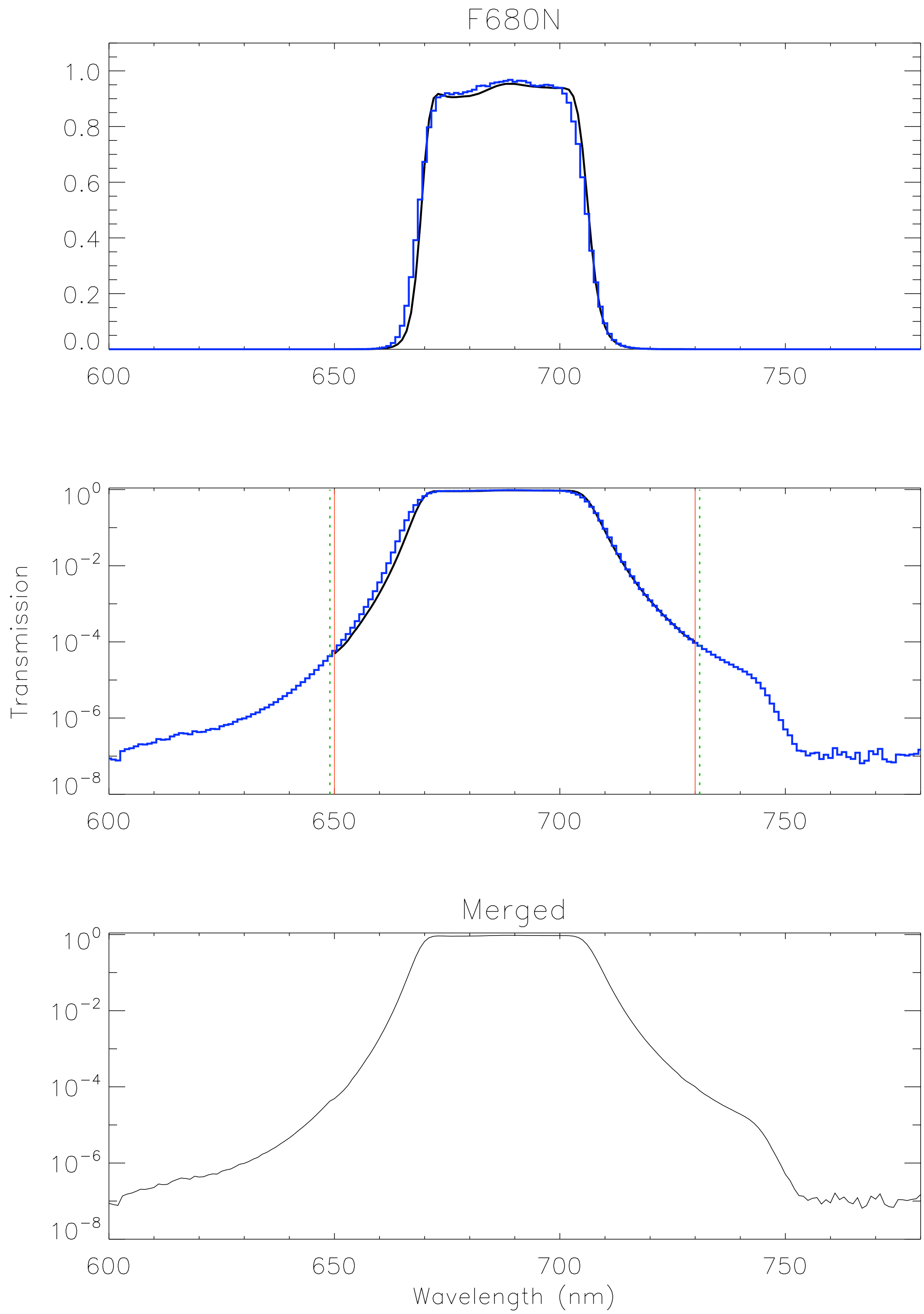

Figure 51: The same as in Figure 1, but for the UVIS/F680N filter.

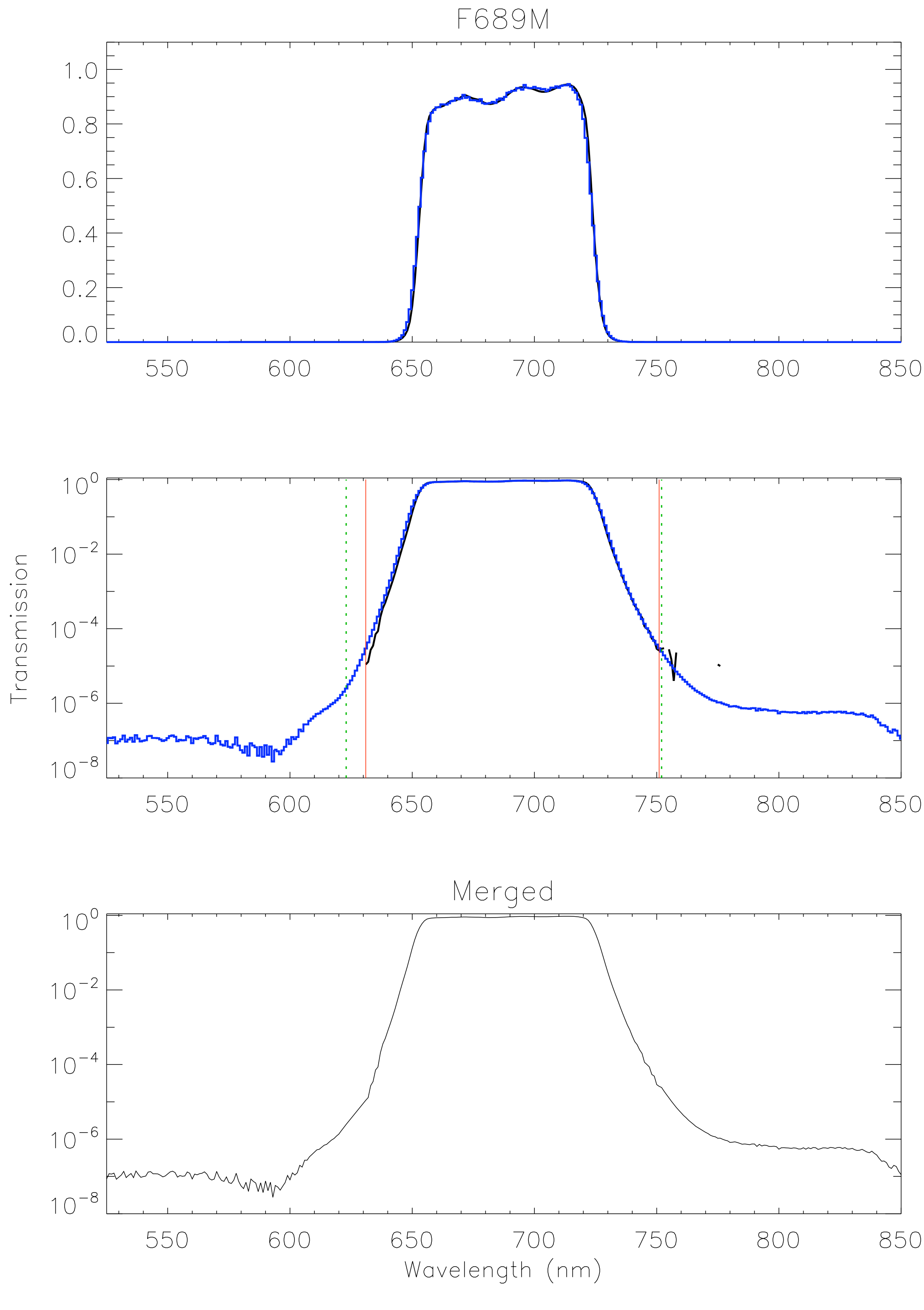

Figure 52: The same as in Figure 1, but for the UVIS/F689M filter.

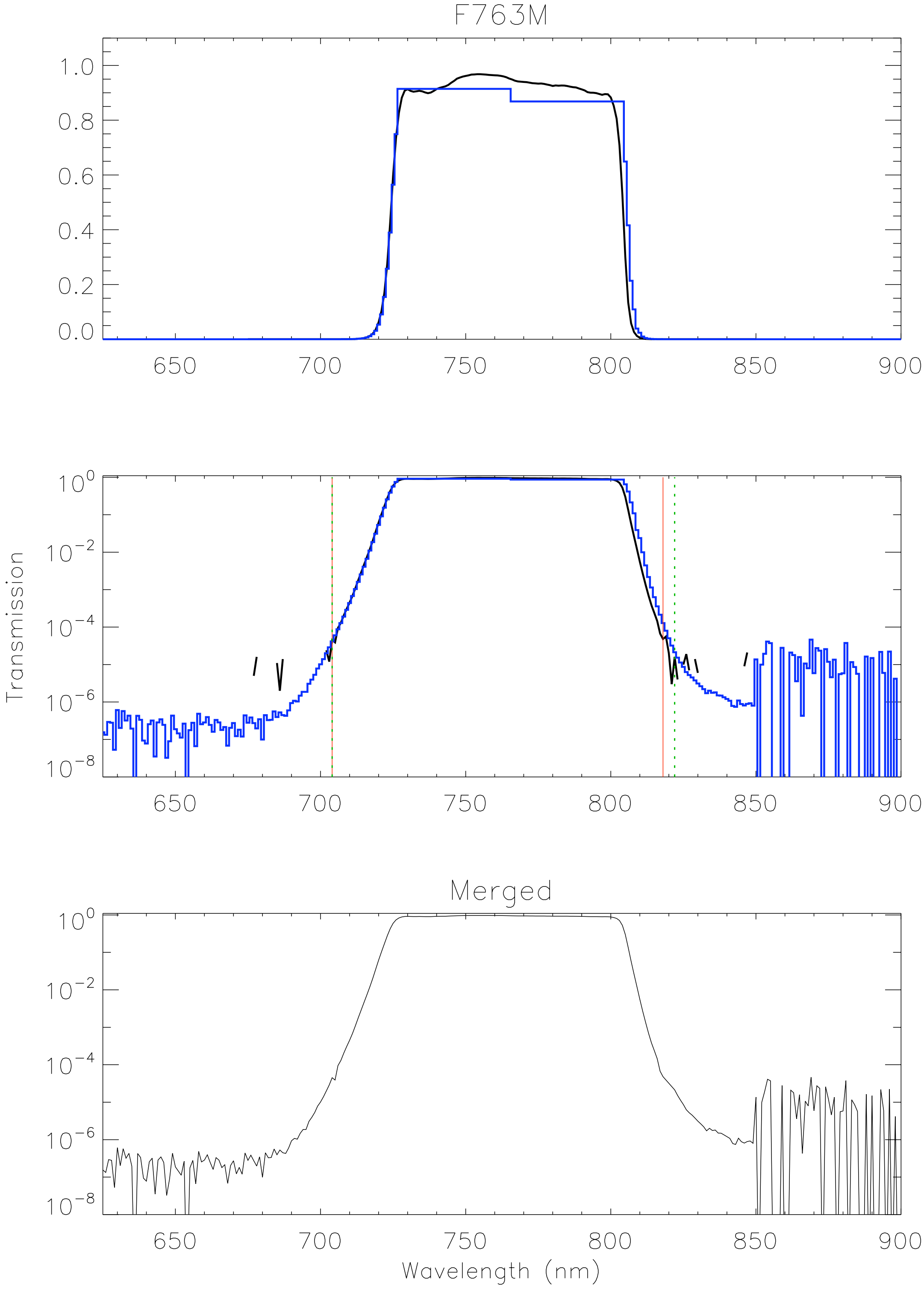

Figure 53: The same as in Figure 1, but for the UVIS/F763M filter.

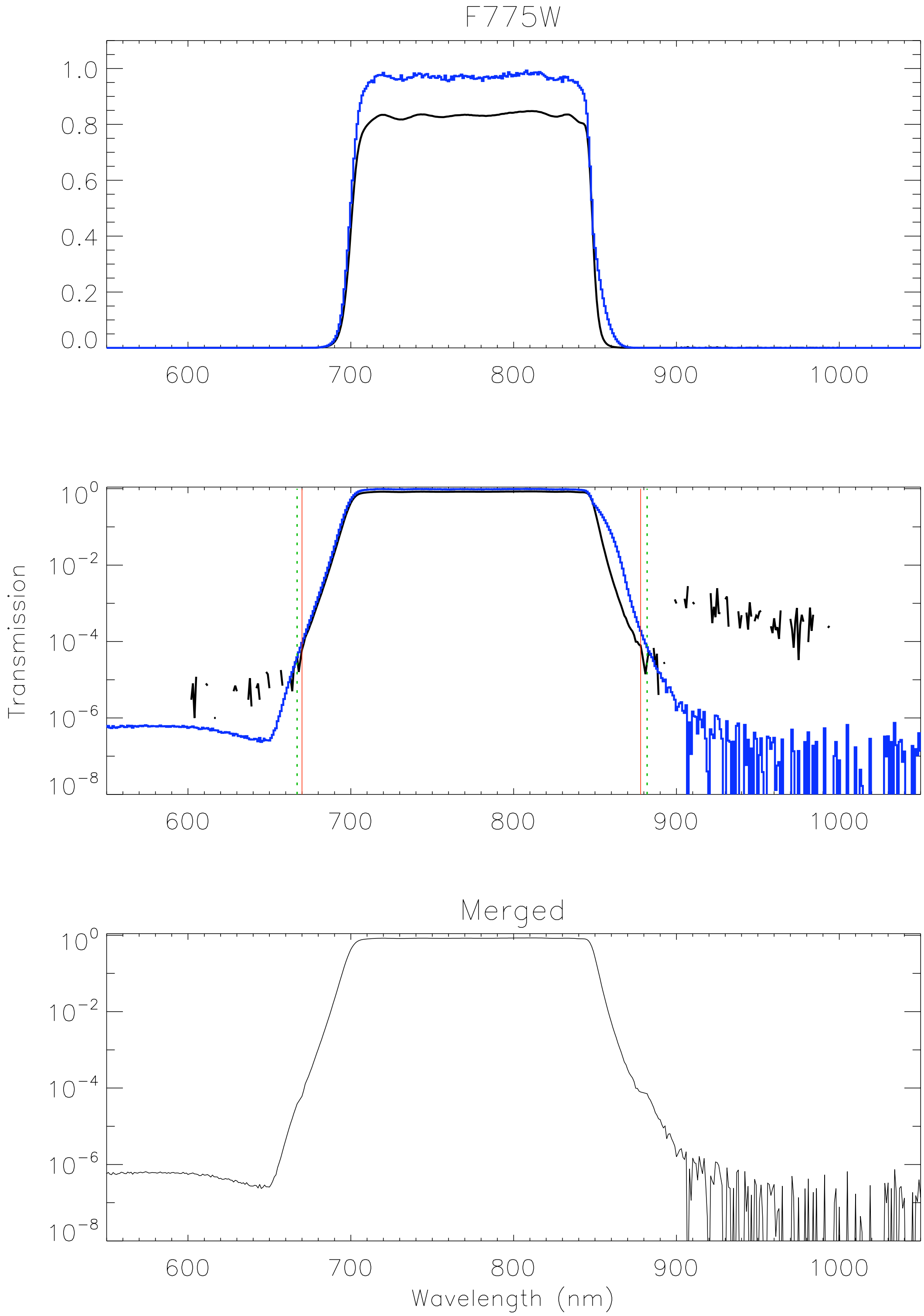

Figure 54: The same as in Figure 1, but for the UVIS/F775W filter. This filter demonstrates how the mismatch between the IB and OB data can go beyond what can be explained with varying resolution. The IB data is 10% lower than the OB over the 700-850 nm range (top panel), while the OB is 10-1000x lower than the IB in the wings (middle panel), likely due to non-linearity and saturation issues when operating out of the nominal range of each measurement.

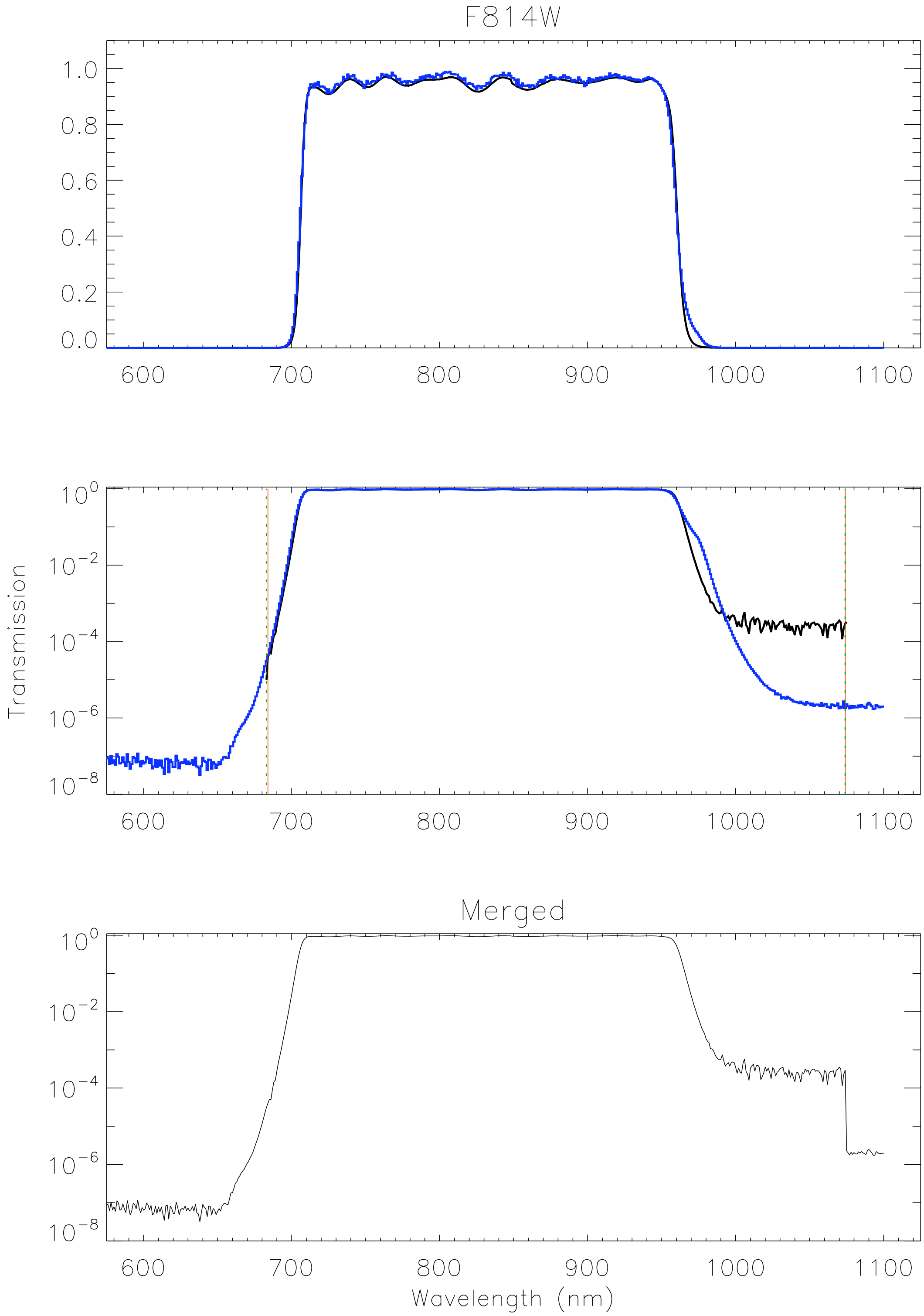

Figure 55: The same as in Figure 1, but for the UVIS/F814W filter.

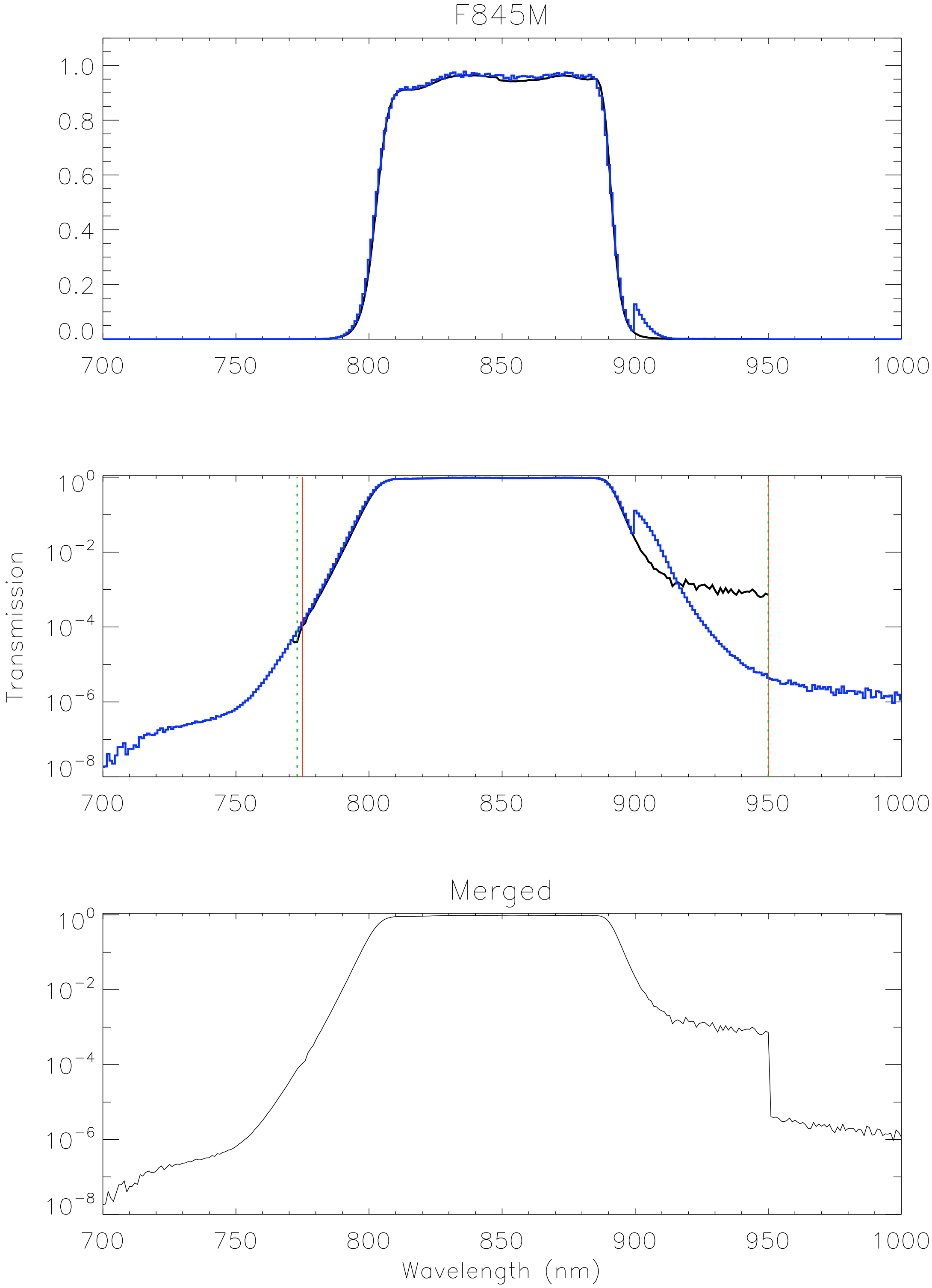

Figure 56: The same as in Figure 1, but for the UVIS/F845M filter.

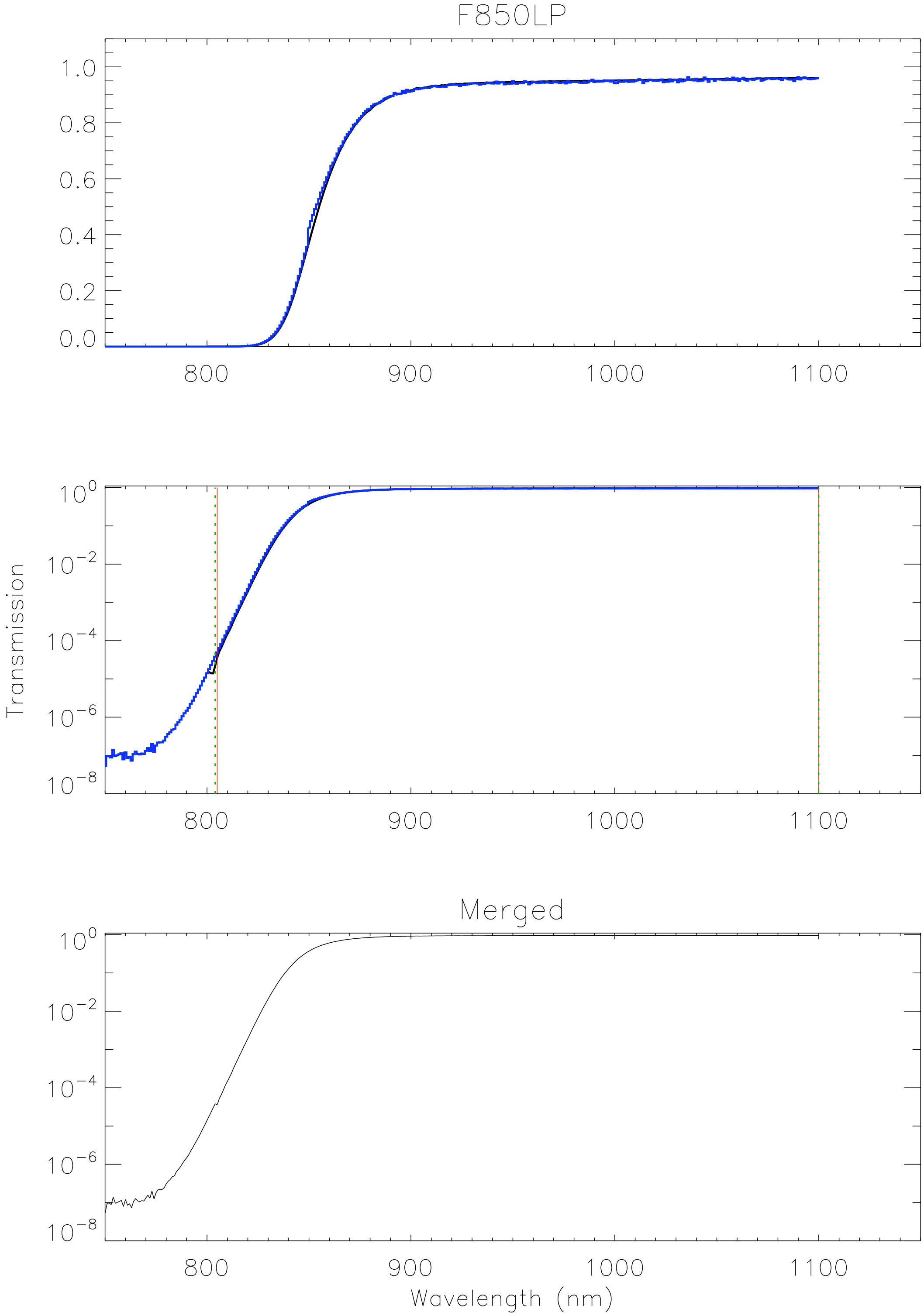

Figure 57: The same as in Figure 1, but for the UVIS/F850LP filter.

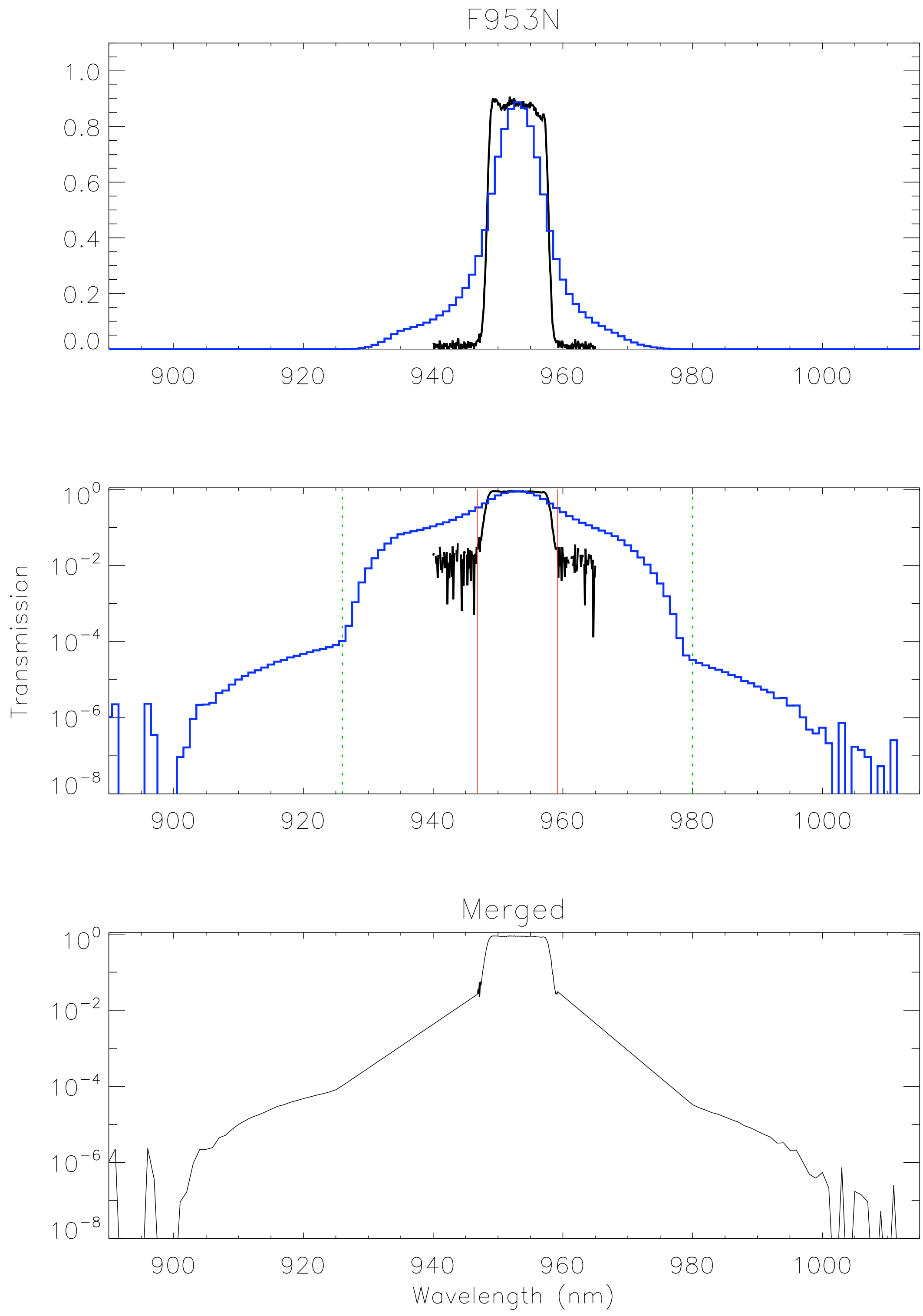

Figure 58: The same as in Figure 1, but for the UVIS/F953N filter.

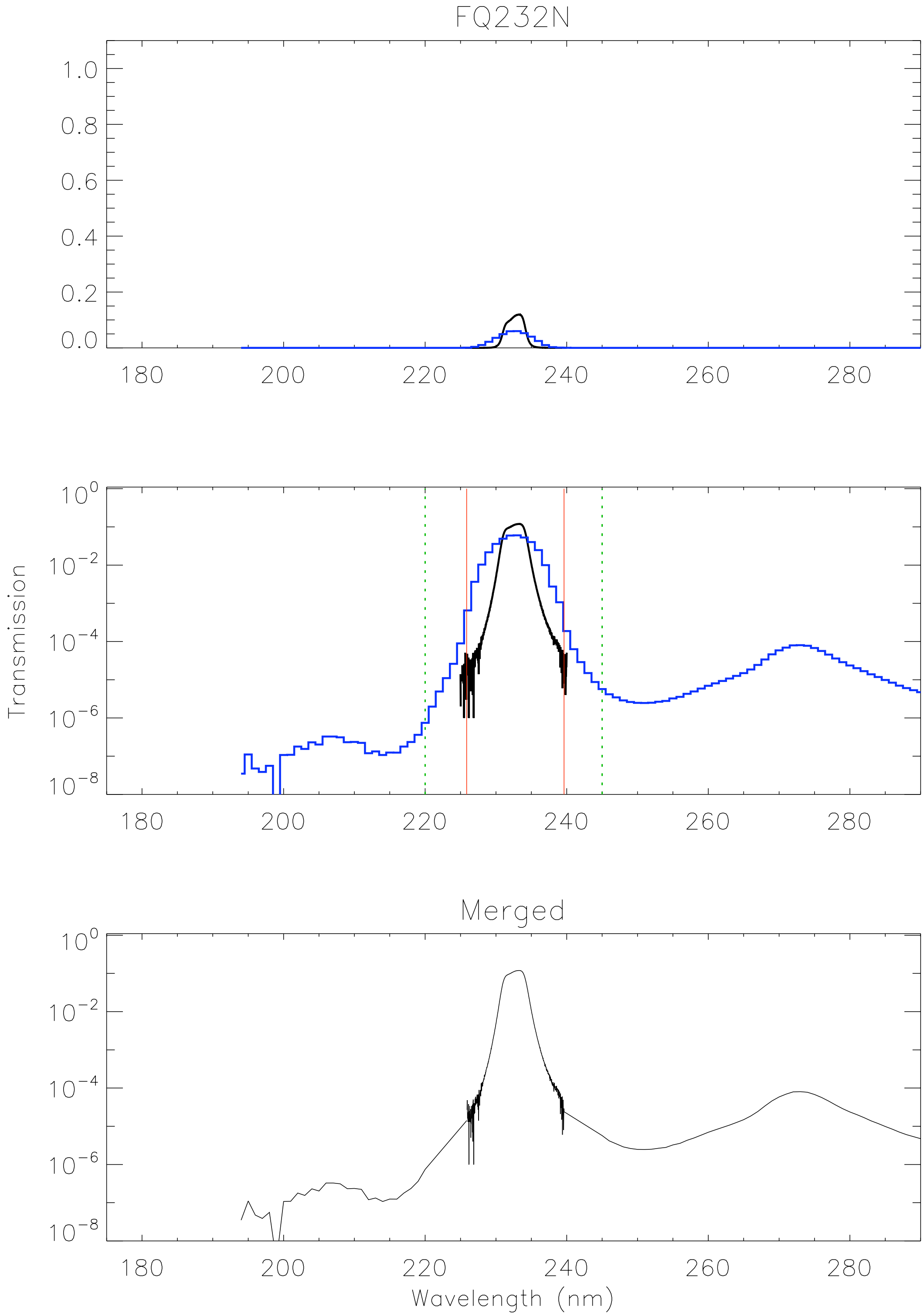

Figure 59: The same as in Figure 1, but for the UVIS/FQ232N filter.

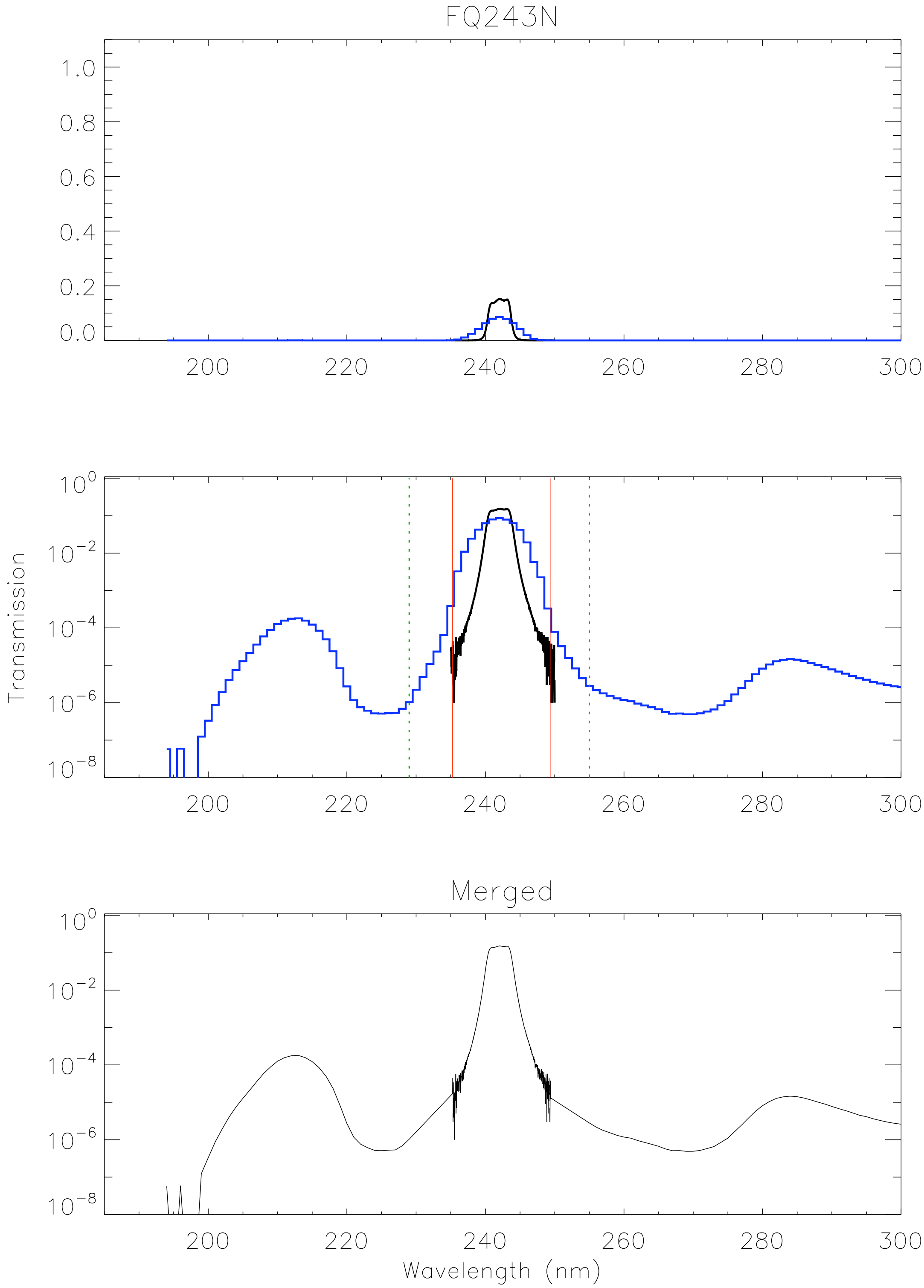

Figure 60: The same as in Figure 1, but for the UVIS/FQ243N filter.

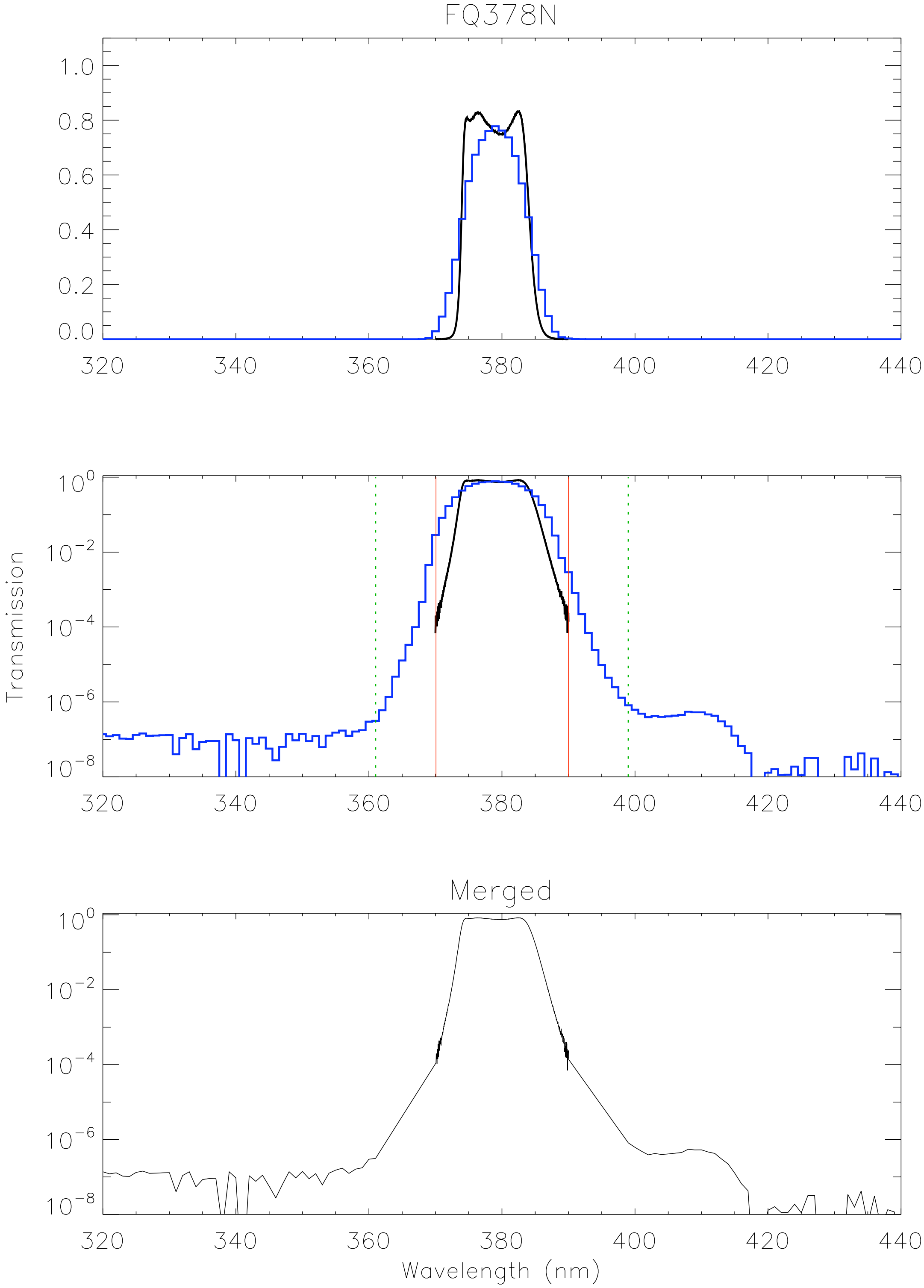

Figure 61: The same as in Figure 1, but for the UVIS/FQ378N filter.

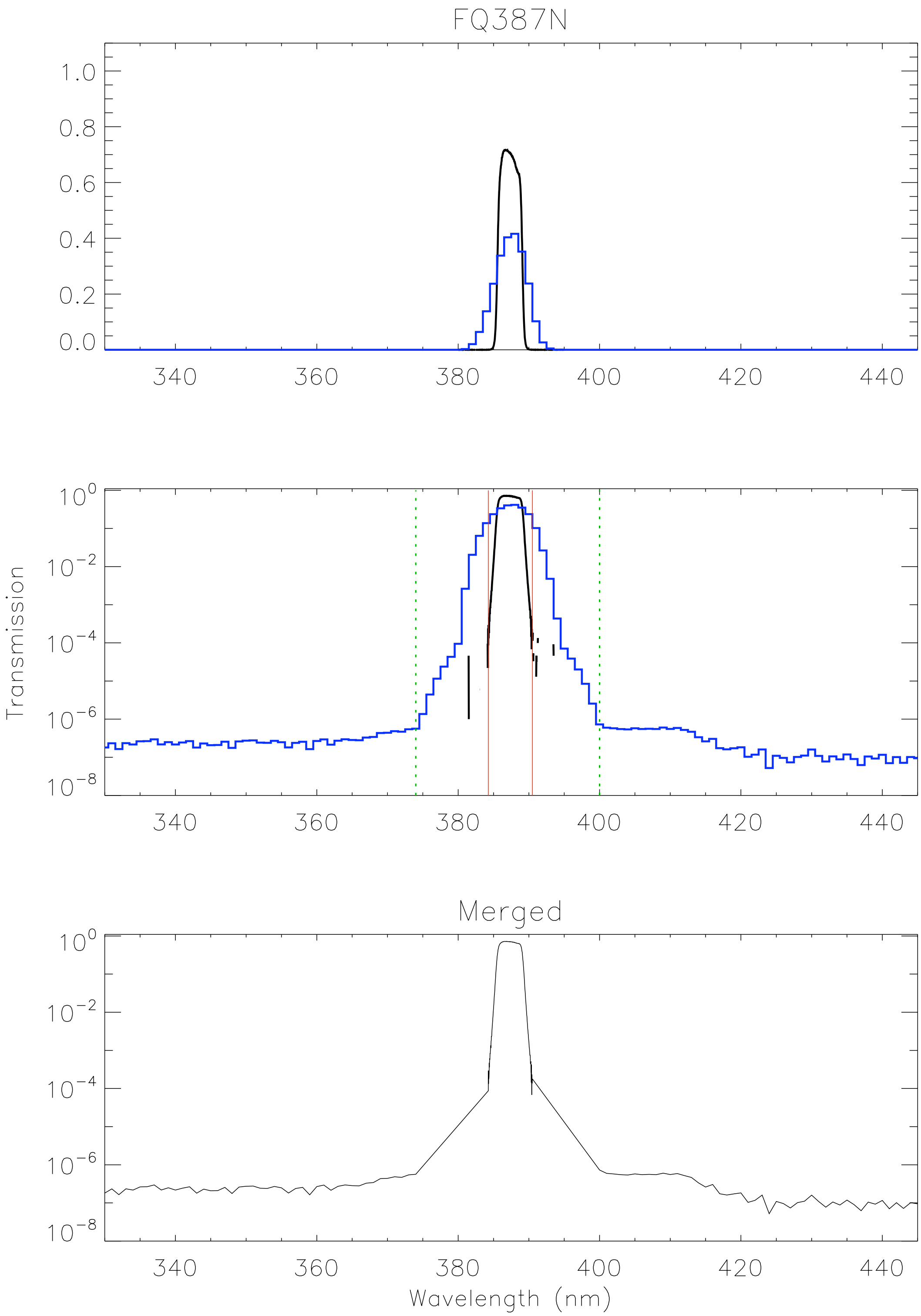

Figure 62: The same as in Figure 1, but for the UVIS/FQ387N filter.

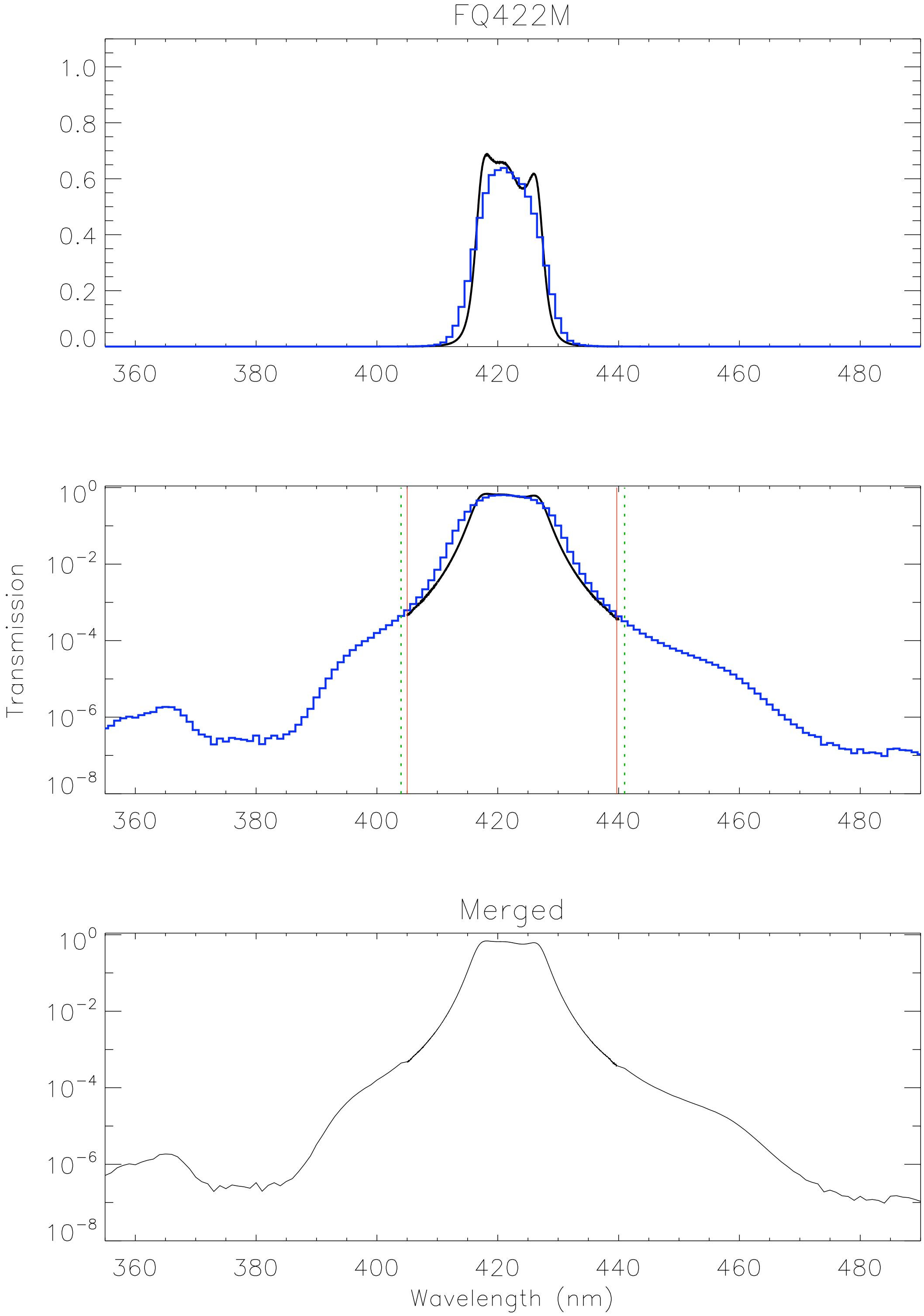

Figure 63: The same as in Figure 1, but for the UVIS/FQ422M filter.

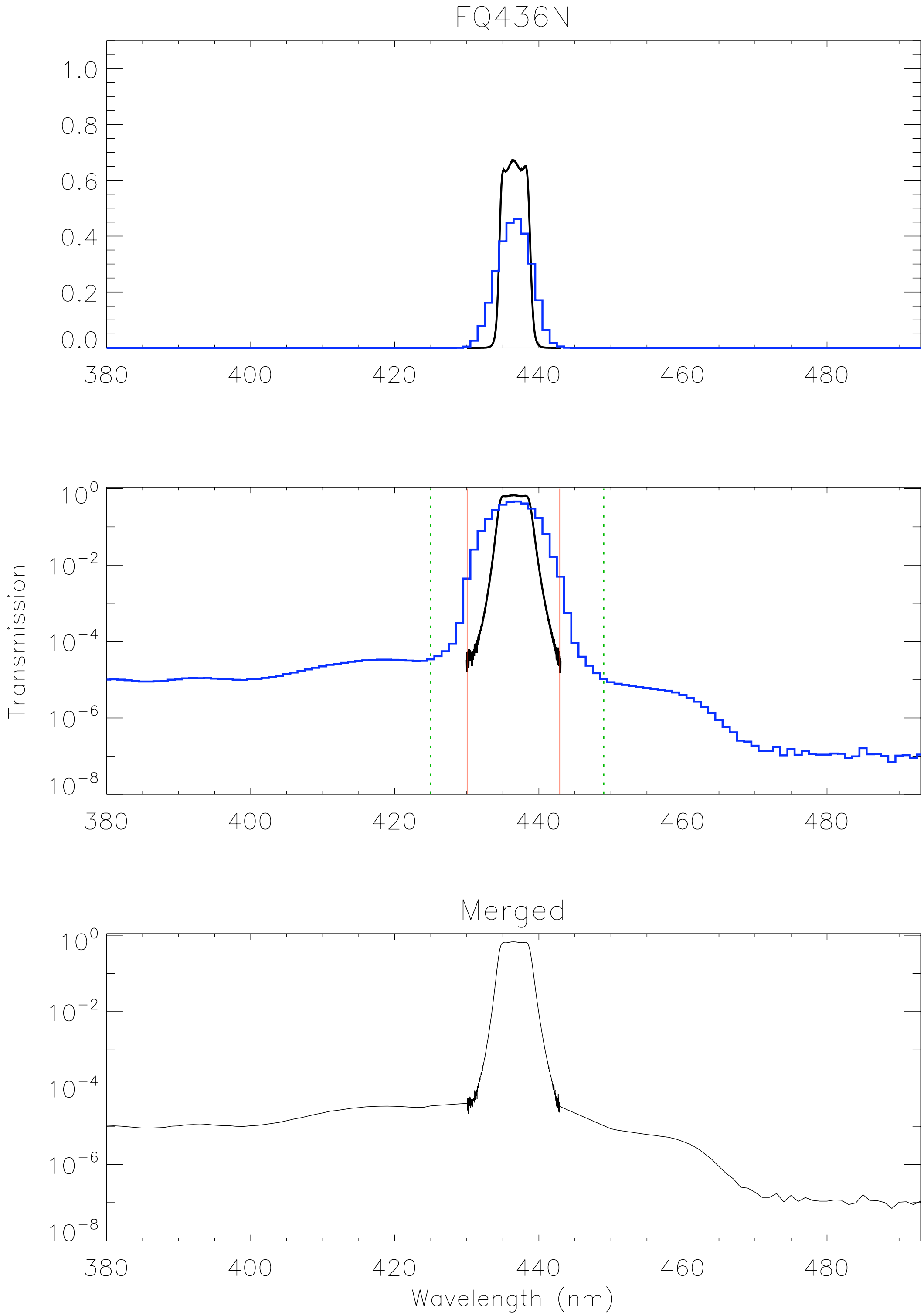

Figure 64: The same as in Figure 1, but for the UVIS/FQ436N filter.

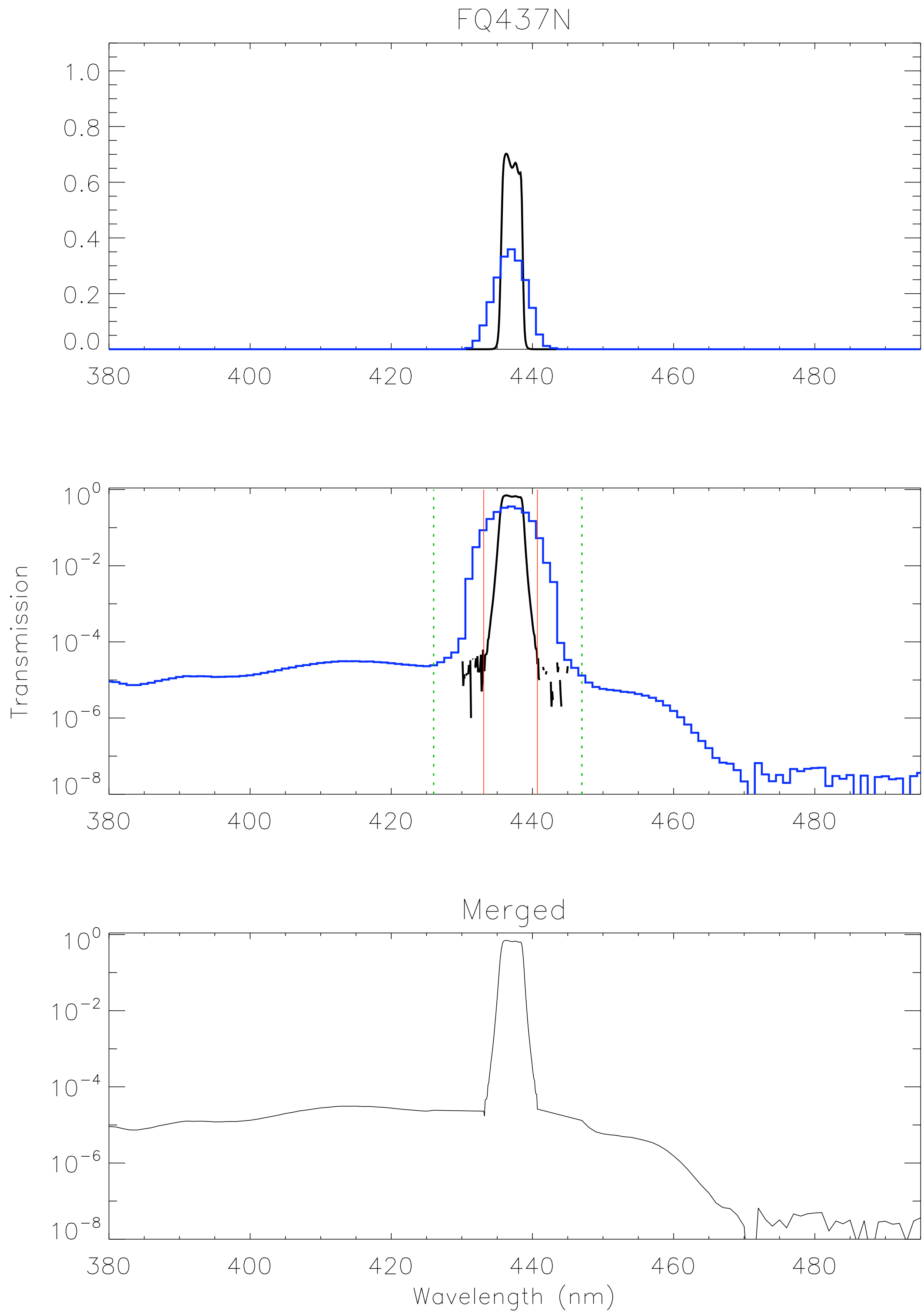

Figure 65: The same as in Figure 1, but for the UVIS/FQ437N filter.

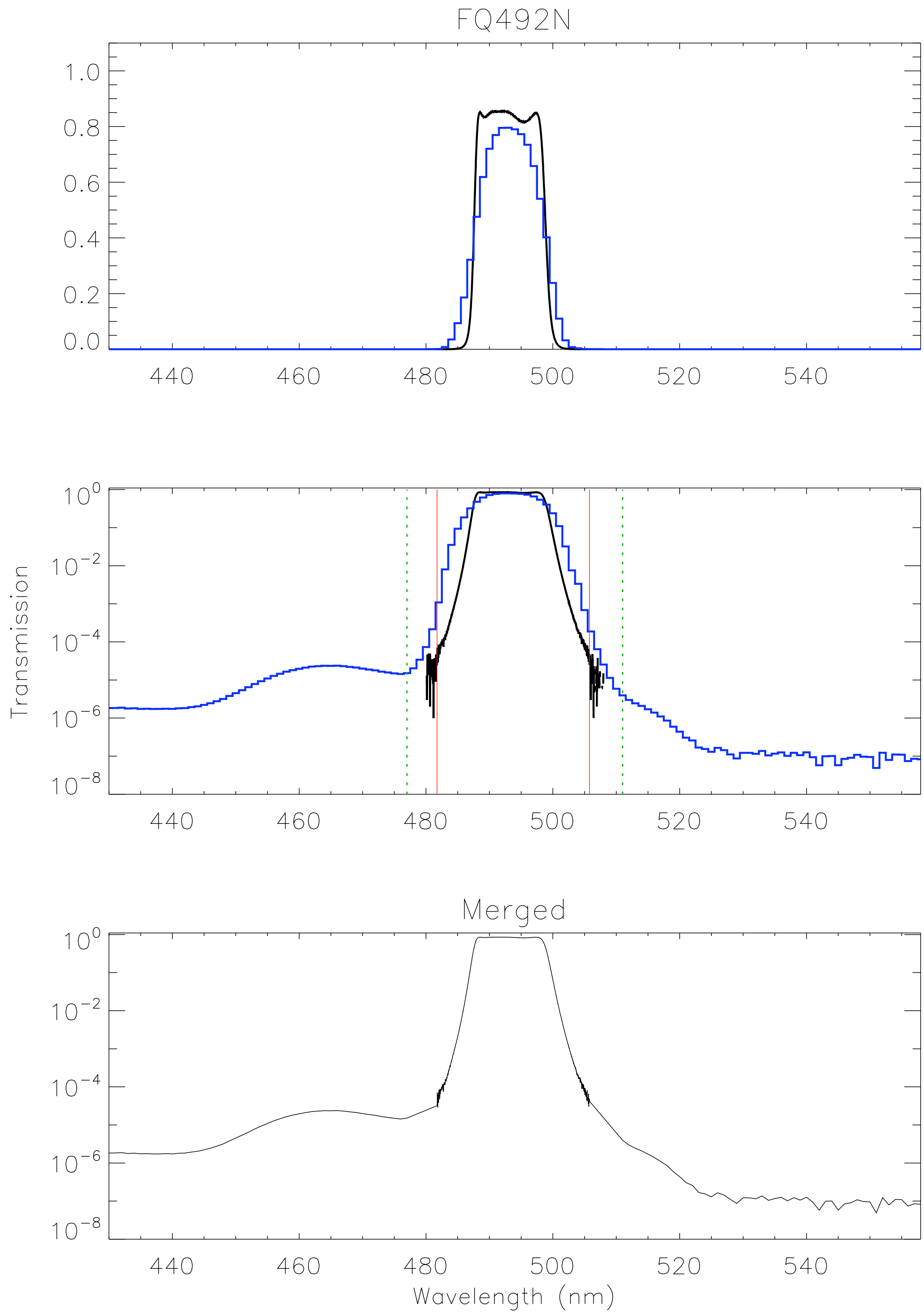

Figure 66: The same as in Figure 1, but for the UVIS/FQ492N filter.

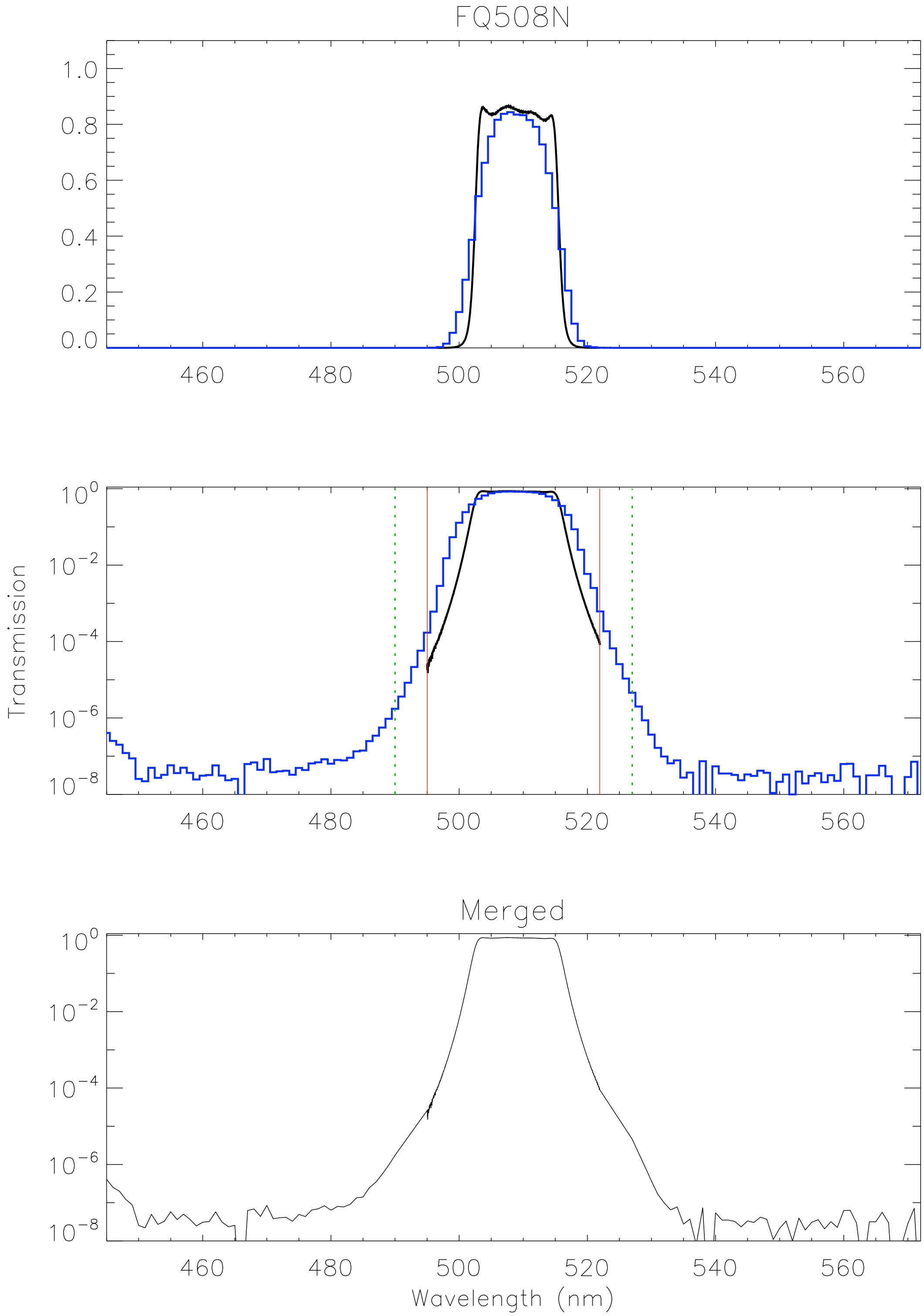

Figure 67: The same as in Figure 1, but for the UVIS/FQ508N filter.

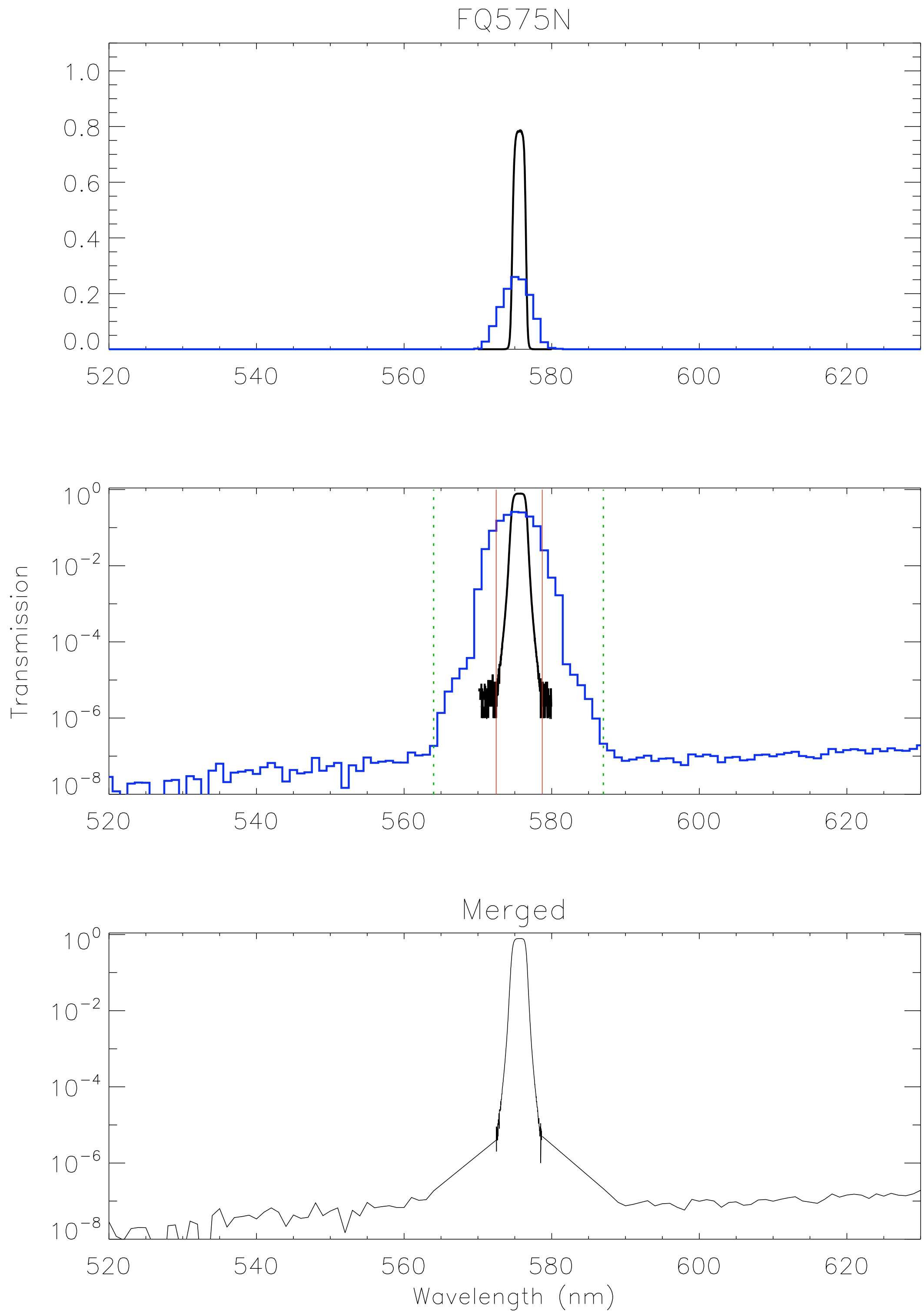

Figure 68: The same as in Figure 1, but for the UVIS/FQ575N filter.

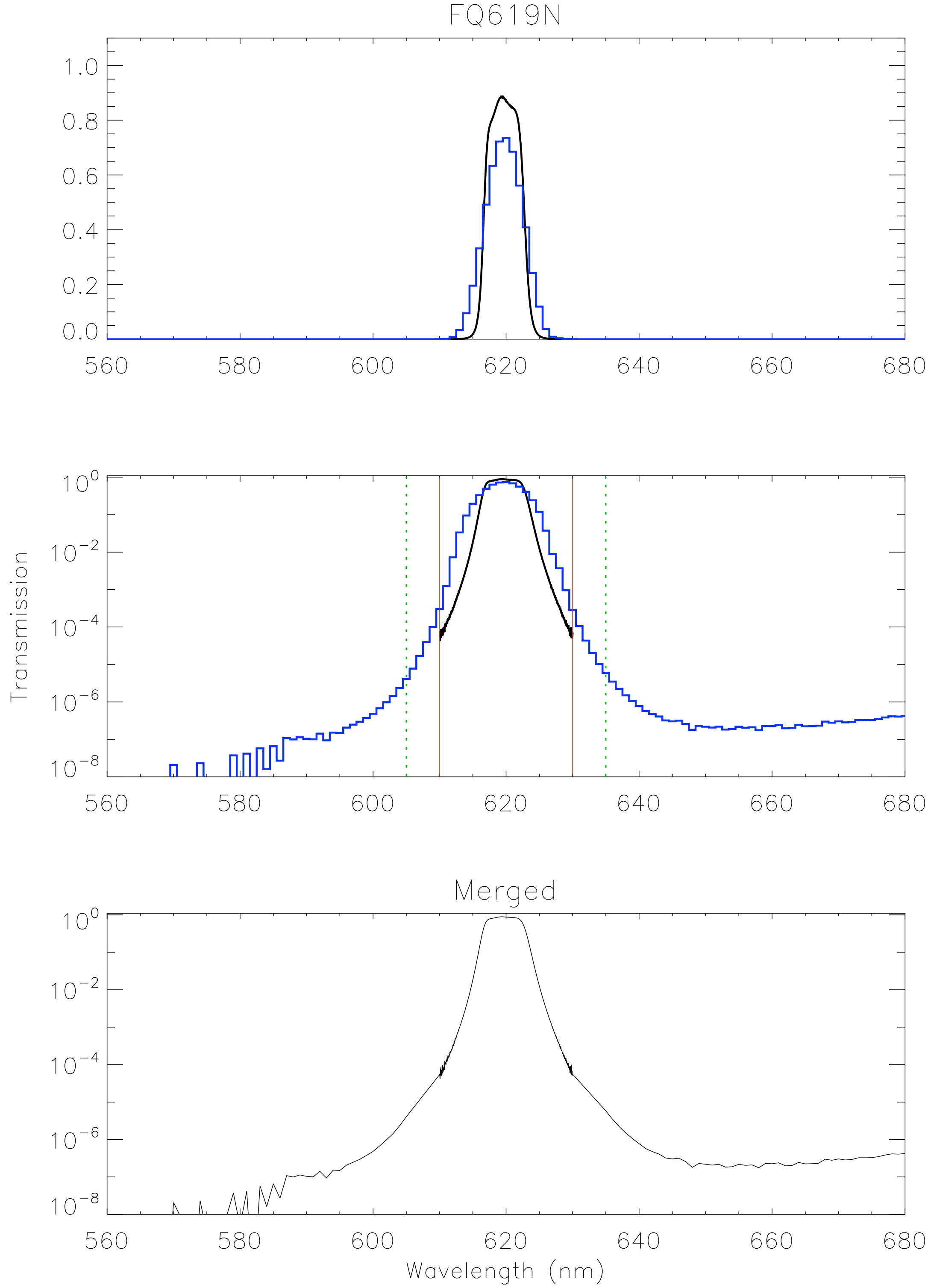

Figure 69: The same as in Figure 1, but for the UVIS/FQ619N filter.

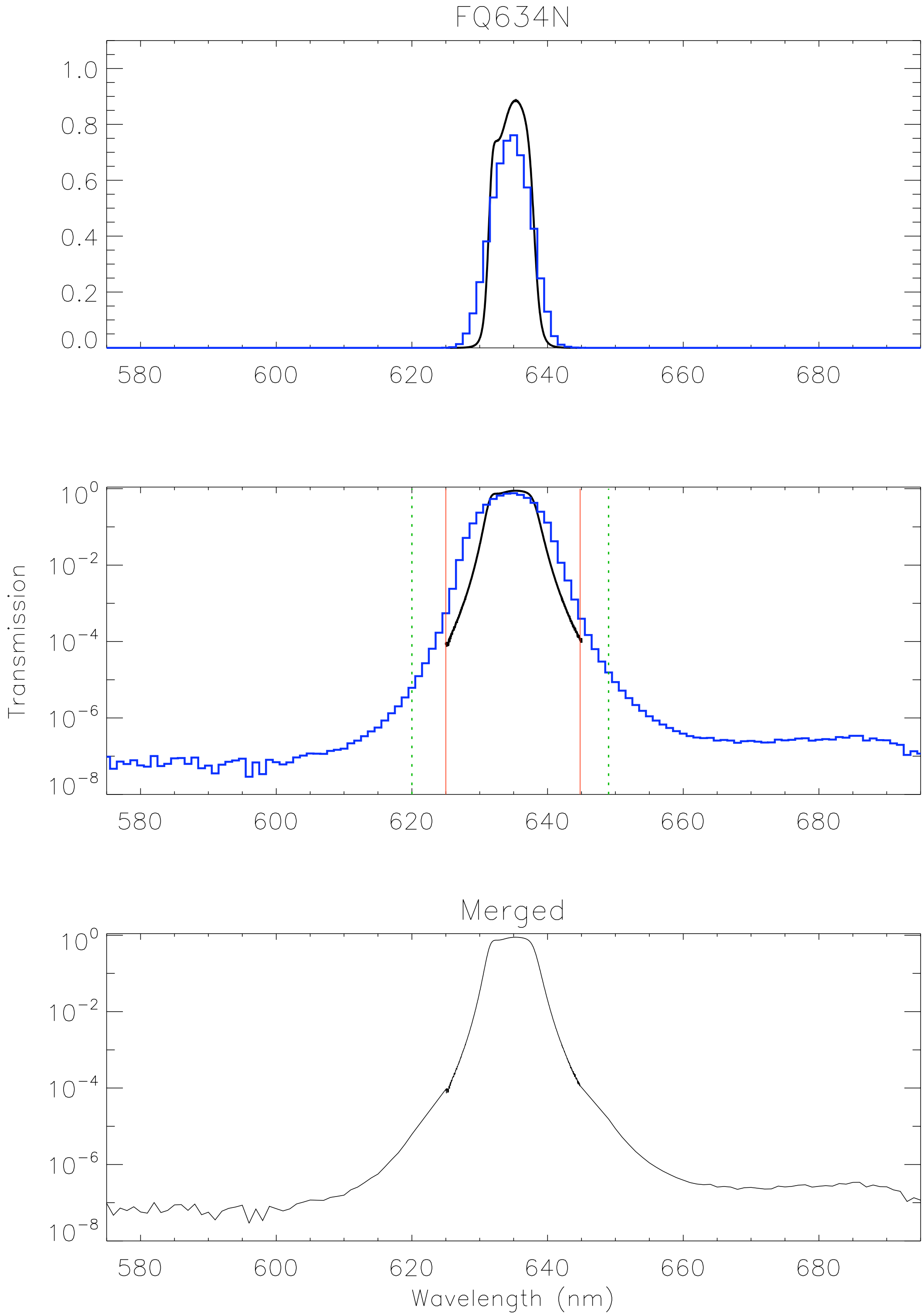

Figure 70: The same as in Figure 1, but for the UVIS/FQ634N filter.

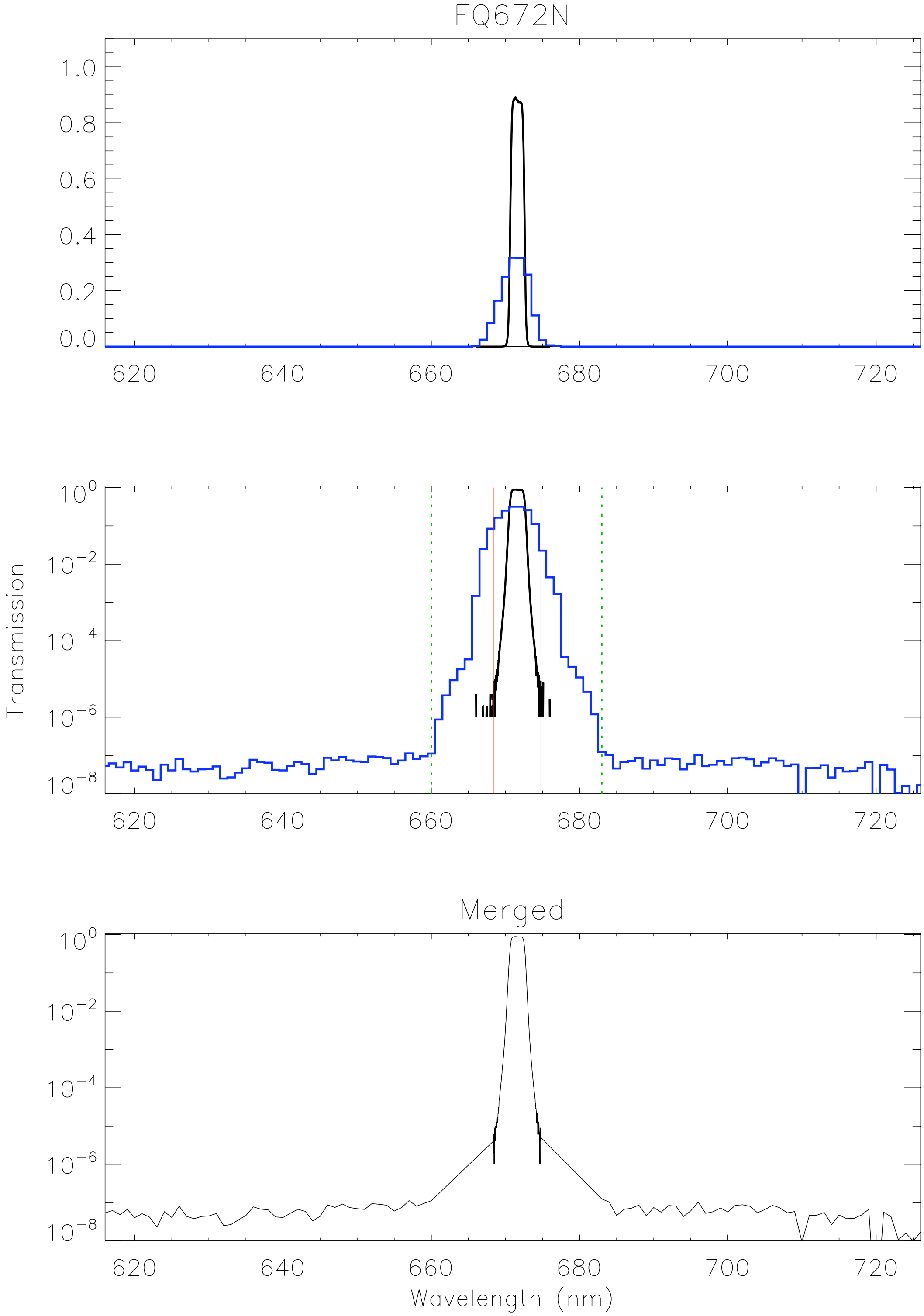

Figure 71: The same as in Figure 1, but for the UVIS/FQ672N filter.

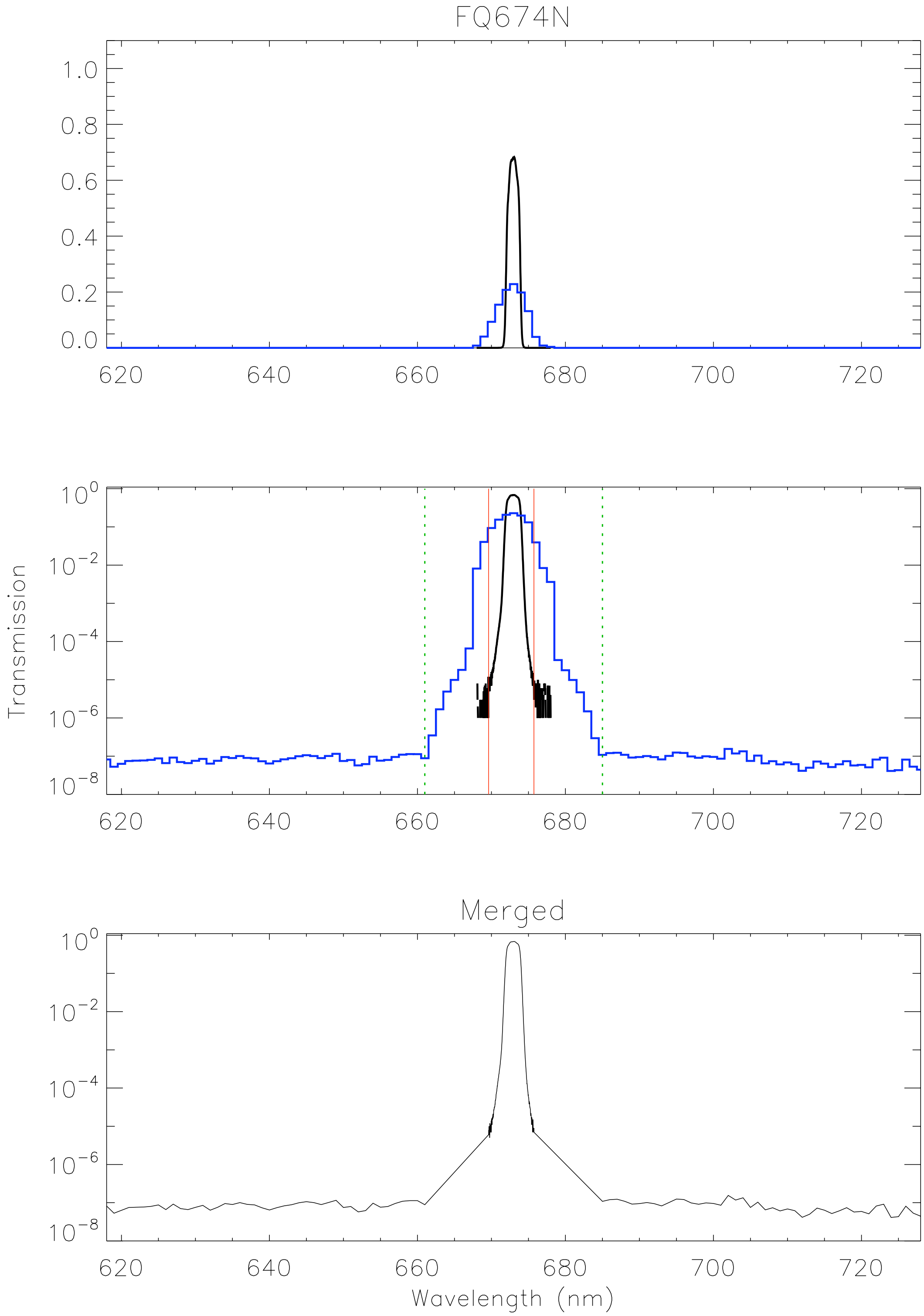

Figure 72: The same as in Figure 1, but for the UVIS/FQ674N filter.

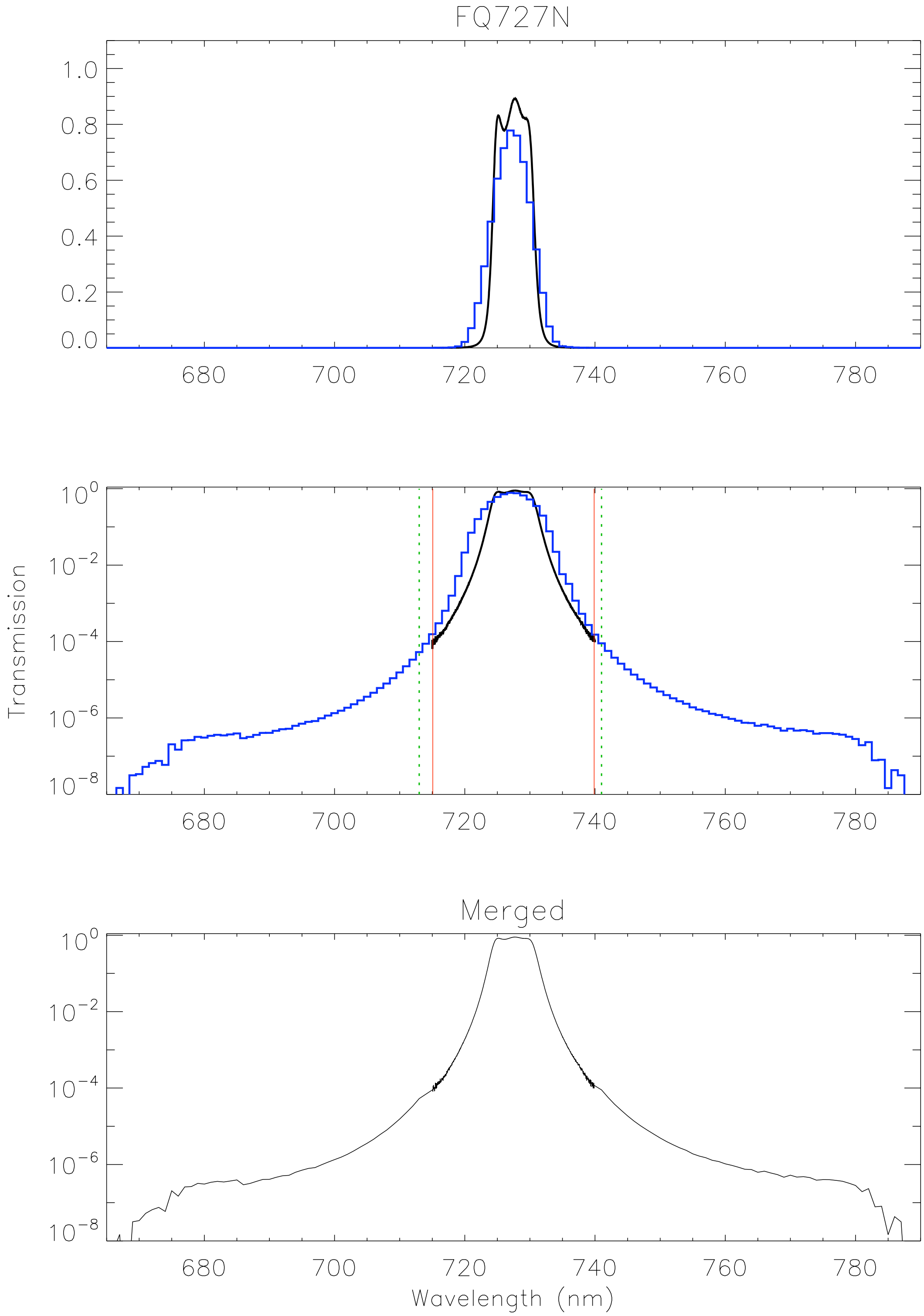

Figure 73: The same as in Figure 1, but for the UVIS/FQ727N filter.

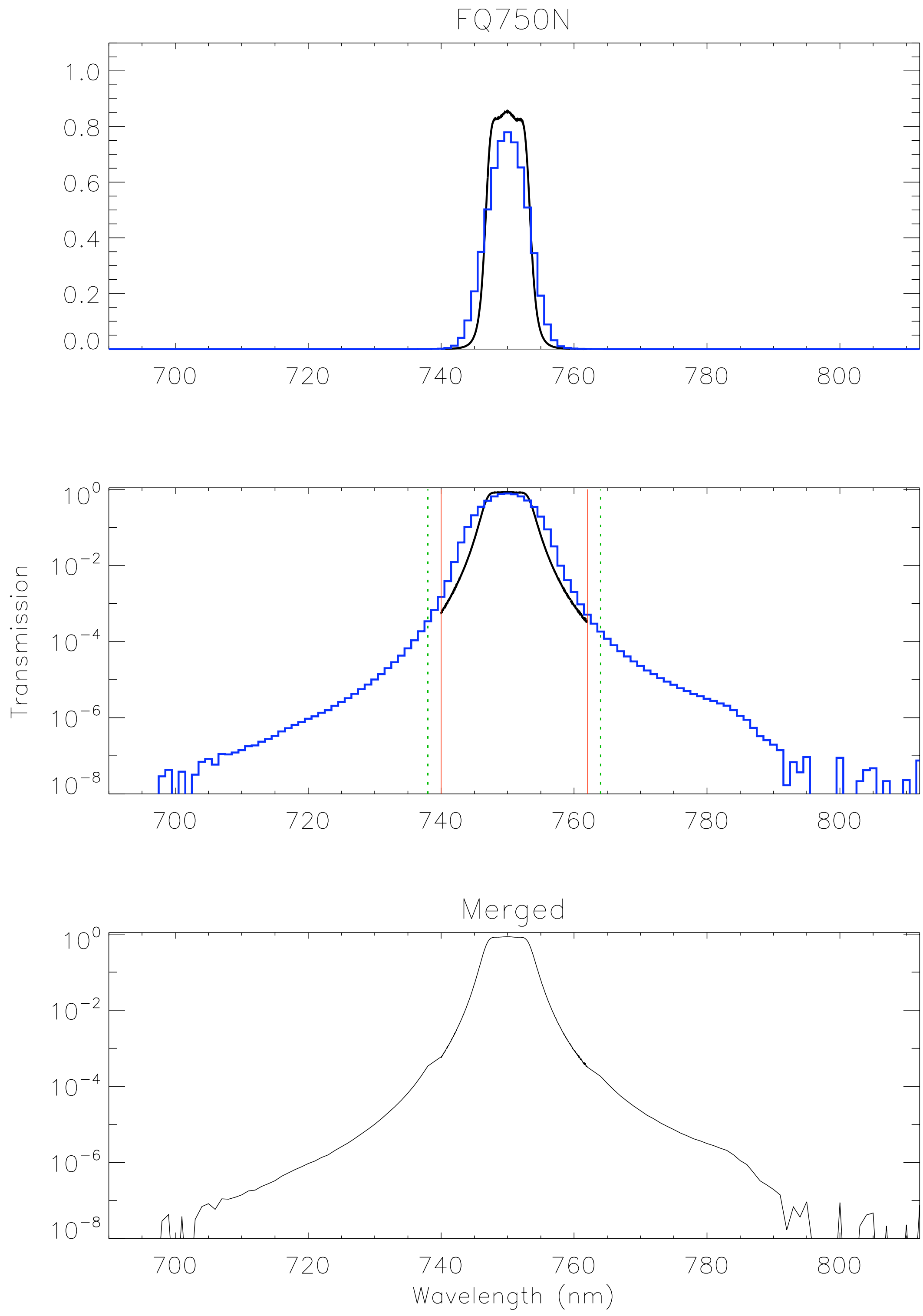

Figure 74: The same as in Figure 1, but for the UVIS/FQ750N filter.

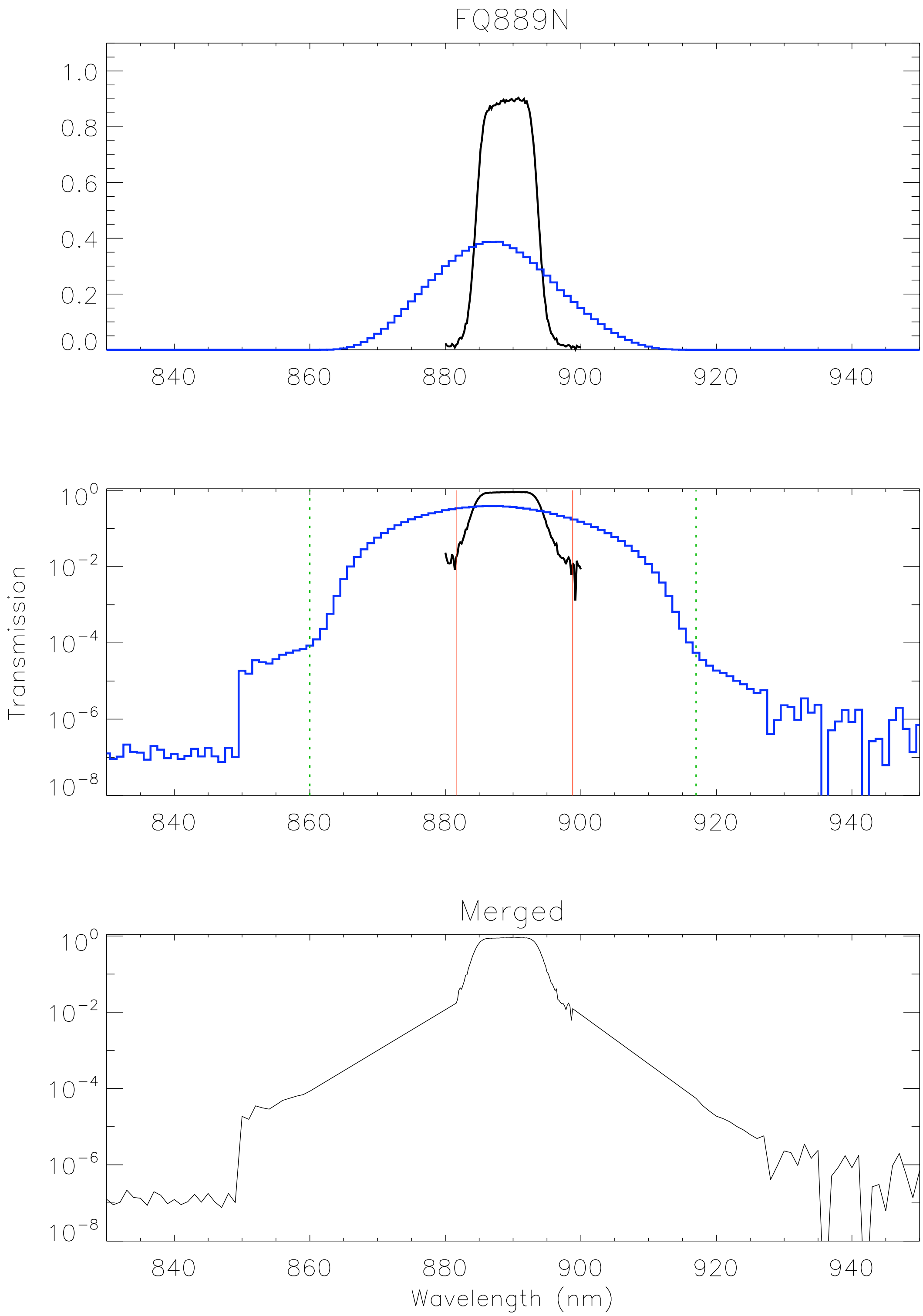

Figure 75: The same as in Figure 1, but for the UVIS/FQ889N filter.

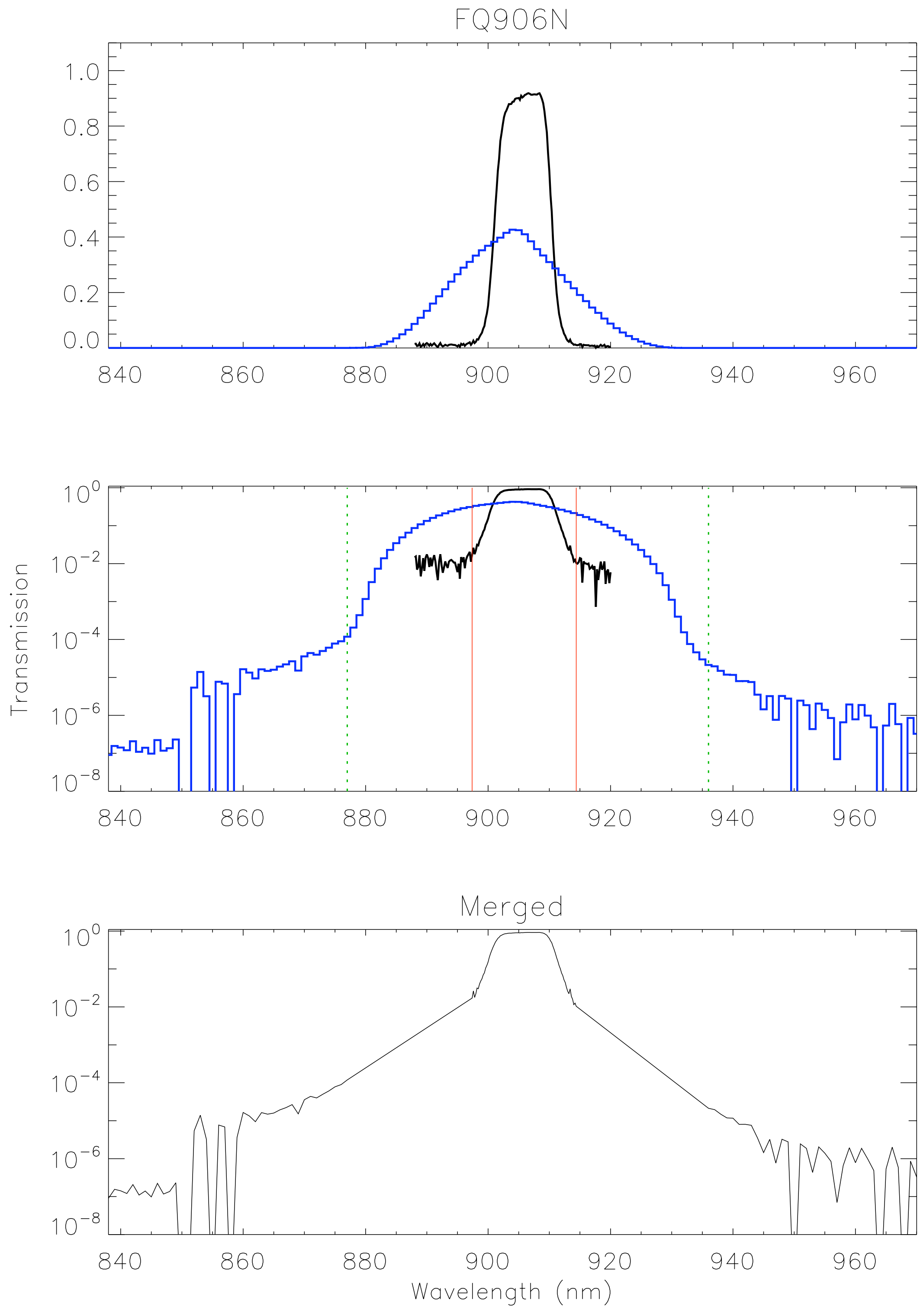

Figure 76: The same as in Figure 1, but for the UVIS/FQ906N filter.

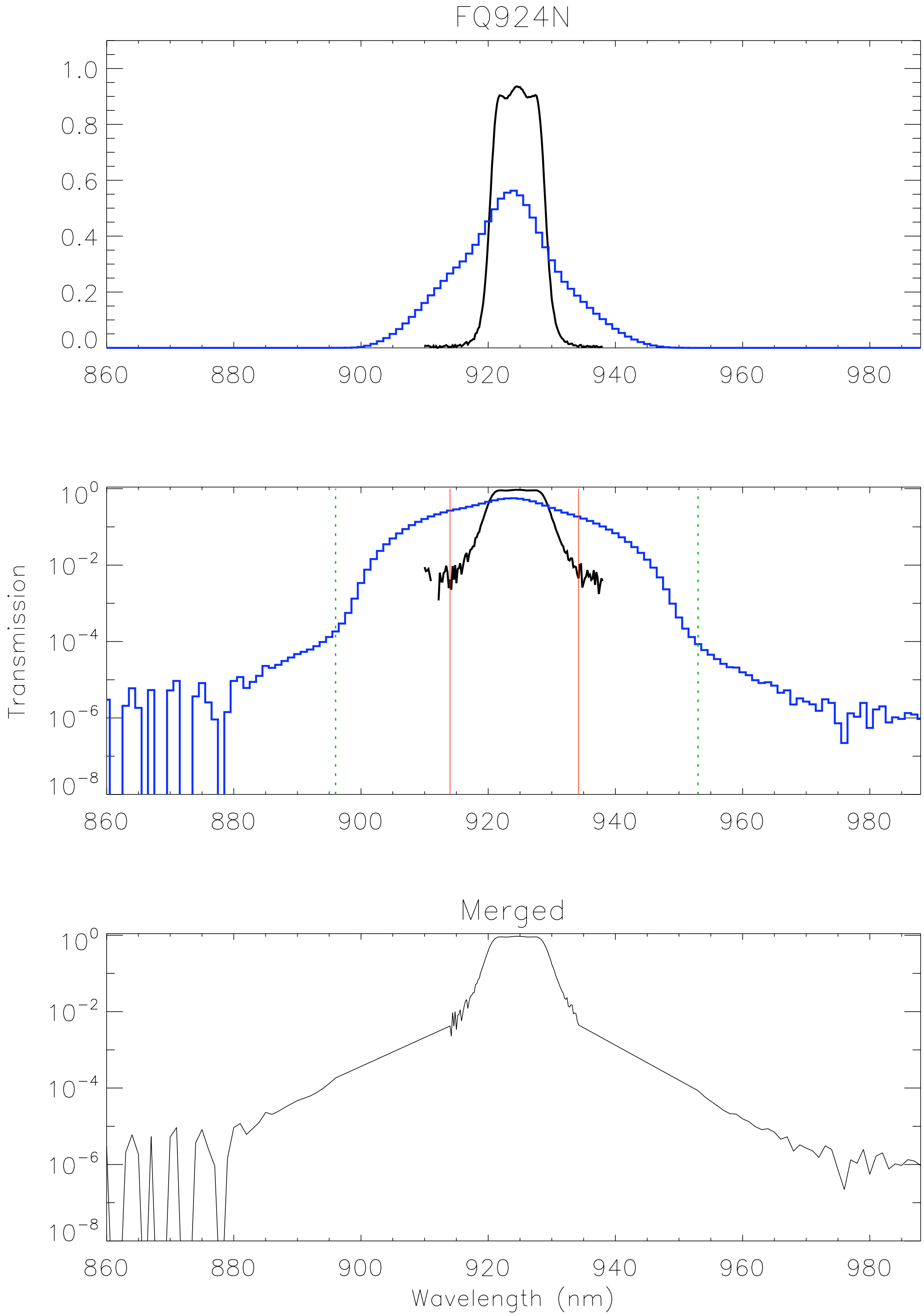

Figure 77: The same as in Figure 1, but for the UVIS/FQ924N filter.

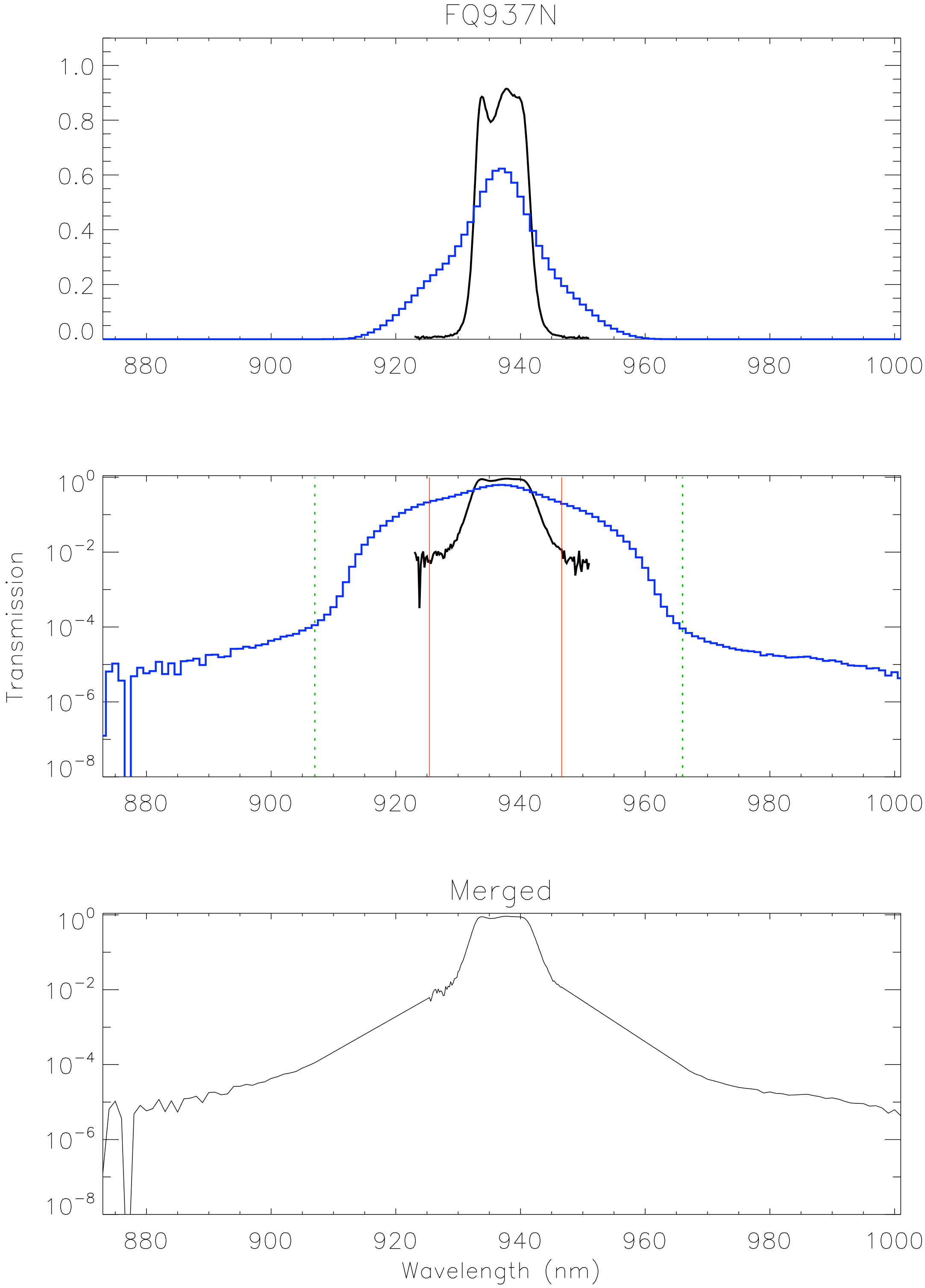

Figure 78: The same as in Figure 1, but for the UVIS/FQ937N filter.

Table 1: Truncation Points for IB and OB Data Merging

Filter	IB red cutoff (nm)	OB red start (nm)	IB blue cut-off (nm)	OB blue start (nm)
F093W	1140	1145	600	600
F098M	1101	1115	880	880
F105W	1226	1226	884	884
F110W	1430	1450	865	850
F125W	1427	1438	1067	1060
F126N	1272	1275	1244	1235
F127M	1344	1350	1206	1195
F128N	1299	1300	1270	1270
F130N	1314	1320	1288	1280
F132N	1333	1340	1302	1280
F139M	1447	1450	1327	1325
F140W	1634	1634	1174	1174
F153M	1610	1610	1470	1465
F160W	1722	1722	1360	1360
F164N	1665	1665	1625	1625
F167N	1685	1685	1650	1650
F200LP	1098	N/A	188	N/A
F218W	296	296	190	188
F225W	311	312	190	188
F275W	331	332	211	210
F280N	286	288	275	272
F300X	479	480	200	200

Filter	IB red cutoff (nm)	OB red start (nm)	IB blue cut-off (nm)	OB blue start (nm)
F336W	382	387	293	288
F343N	374	381	326	321
F350LP	1100	1100	298	284
F373N	381	388	367	358
F390M	414	414	360	359
F390W	459	459	317	316
F395N	405	411	385	379
F410M	429	432	394	392
F438W	483	493	373	372
F467M	492	492	446	444
F469N	474	481	463	455
F475W	575	575	385	381
F475X	731	731	367	365
F487N	495	502	480	473
F502N	509	515	495	489
F547M	605	605	496	492
F555W	800	800	435	433
F600LP	1100	1100	579	576
F606W	748	748	453	452
F621M	675	675	567	566
F625W	727	727	532	528
F631N	637	645	625	616
F645N	656	660	633	633

Filter	IB red cutoff (nm)	OB red start (nm)	IB blue cut-off (nm)	OB blue start (nm)
F656N	658	668	654	644
F657N	674	676	640	636
F658N	662	664	655	652
F665N	684	685	646	643
F673N	690	704	665	645
F680N	730	731	650	649
F689M	751	752	631	623
F763M	818	822	704	704
F775W	878	882	670	667
F814W	1074	1074	684	683
F845M	950	950	775	773
F850LP	1100	1100	805	804
F953N	959	980	947	926
FQ232N	240	245	226	220
FQ243N	249	255	235	229
FQ378N	390	399	370	361
FQ387N	391	400	384	374
FQ422M	440	441	405	404
FQ436N	443	449	430	425
FQ437N	441	447	433	426
FQ492N	506	511	482	477
FQ508N	522	527	495	490
FQ575N	579	587	572	564

Filter	IB red cutoff (nm)	OB red start (nm)	IB blue cut-off (nm)	OB blue start (nm)
FQ619N	630	635	610	605
FQ634N	645	649	625	620
FQ672N	675	683	668	660
FQ674N	676	685	670	661
FQ727N	740	741	715	713
FQ750N	762	764	740	738
FQ889N	899	917	882	860
FQ906N	914	936	897	877
FQ924N	934	953	914	896
FQ937N	947	966	925	907

Acknowledgements

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