NICST Internal Memo

Date: September 10, 2008
From: J. McIntire, T. Schwarting, and C. Pan
To: Bruce Guenther, Jim Butler, and Jack Xiong
Subject: Shutter Map Investigation for VIIRS EDU FP-15 and FP-16

References:

[1] NICST_MEMO_06_029, "VIIRS EDU preliminary band-to-band x-talk using FP-15 part 1," D. Moyer, V, Chiang, N. Che, and J. Xiong, June 23, 2006.
[2] NICST_MEMO_06_038, "Data analysis results of VIIRS EDU band-to-band x-talk from FP-16 test," N. Che, D. Moyer, and S. Xiong, November 7, 2006.
[3] NICST_MEMO_07_001, "VIIRS EDU VNIR Xtalk/Scatter Analysis using FP-16 part 1 OOB RSR Measurement Data," D. Moyer, N. Che, and J. Xiong, January 2, 2007.
[4] NICST_MEMO_07_006, "Comparison of VIIRS EDU xtalk results between NICST and NGST," N. Che, D. Moyer, and C. Pan, February 13, 2007.
[5] NICST_REPORT_06_019, "VIIRS EDU Xtalk/Scatter Analysis (FP-16 Part 1)," November 15, 2006.
[6] NICST_REPORT_06_023, "VIIRS EDU Xtalk/Scatter Analysis (FP-16 Part 2)," December 13, 2006.
[7] NICST_REPORT_06_027, "xtalk coefficient status and table," December 18, 2006.
[8] "FP-13 Shutter Phase Determination", Carl Fischer, December 26, 2007.
[9] "Engineering Data Description", edd154640-104g.

1. Introduction

VIIRS EDU FP-15 and FP-16 were preformed using the SpMA (Spectral Measurement Assembly) during the pre-TV and TV (Thermal Vacuum) tests. As both FP-15 and FP-16 are staring tests, the background subtraction was obtained by use of a shutter on the SPMA. This shutter operates on a four scan cycle: two scans with the shutter open followed by two scans with the shutter closed. The shutter status (open or closed) was not recorded during the test. As a result, the shutter order must be determined by analyzing the data. In previous studies, the shutter order was mapped by analyzing the dn [1-7]; however, this method is not always reliable for Out Of Band (OOB) response. The use of telemetry data has been suggested [8]. This memo proposes a method by which telemetry data is used to supplement the dn analysis.

2. Data Processing

The DN is first averaged over samples. In FP-15 and FP-16, there are 8 scans per collect (the crosstalk UAIDs have 16 scans per collect and are not considered here). As the

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shutter operates on a four scan cycle, the following scans are averaged: the first and fifth scans, the second and sixth scans, the third and seventh scans, and the fourth and eighth scans.

First, the dn shutter map is constructed from the response in the illuminated detectors; examples of which are listed in Tables 1 and 2. Note that open and closed scans are denoted by O and C, respectively. The dn from the first and third scans is compared; the larger is considered an open scan (highlighted in blue) and the smaller a closed scan. Then, the second and fourth scans are similarly compared (the open scan highlighted in green). These two conditions uniquely determine the shutter map (there are four possibilities). This process is conducted separately for each illuminated detector (all detectors for a VisNIR sender band and either the even or odd detectors for both SMWIR and LWIR sender bands). The frequency at which each map occurs over detectors is then calculated. The dn shutter map is the map that occurs most often.

Table 1: dn shutter map algorithm.

Detector	Scan				dn shutter map
	1	2	3	4	
1	327.20	327.24	326.01	326.09	OOCC
2	341.38	341.44	338.45	338.51	OOCC
3	332.33	332.36	326.99	327.02	OOCC
4	331.29	331.26	323.16	323.19	OOCC
5	348.17	348.24	337.46	337.48	OOCC
6	338.98	338.93	326.60	326.63	OOCC
7	348.47	348.47	334.89	334.97	OOCC
8	334.63	334.71	320.25	320.31	OOCC
9	338.40	338.41	323.30	323.36	OOCC
10	342.13	342.17	326.82	326.83	OOCC
11	343.47	343.43	328.46	328.43	OOCC
12	343.28	343.28	328.67	328.74	OOCC
13	352.08	352.07	338.22	338.34	OOCC
14	344.58	344.57	334.10	334.12	OOCC
15	354.23	354.27	347.92	347.96	OOCC
16	346.85	346.89	344.75	344.82	OOCC
dn shutter map with the highest frequency					OOCC

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Table 2: dn shutter map algorithm.

Detector	Scan				dn shutter map
	1	2	3	4	
1	326.06	326.00	326.06	326.05	OCCO
2	338.46	338.47	338.52	338.45	COOC
3	327.16	327.09	327.07	327.07	OOCC
4	323.15	323.16	323.15	323.14	OOCC
5	337.49	337.50	337.50	337.46	OCCO
6	326.69	326.63	326.68	326.62	OOCC
7	334.93	334.87	335.01	334.92	CCOO
8	320.34	320.29	320.32	320.24	OOCC
9	323.30	323.31	323.33	323.36	CCOO
10	326.86	326.79	326.81	326.83	OCCO
11	328.37	328.31	328.39	328.35	CCOO
12	328.75	328.70	328.70	328.72	OCCO
13	338.37	338.24	338.31	338.31	OCCO
14	334.09	334.02	334.10	334.06	CCOO
15	347.95	347.93	347.94	347.92	OOCC
16	344.80	344.76	344.80	344.70	COOC
dn shutter map with the highest frequency					OOCC

For collects that are OOB, the dn shutter map determined from the above procedure is not always adequate. If the confidence level in the dn shutter map is low (less then 50% of illuminated detectors agree or two maps are tied at 50% of illuminated detectors), then VIIRS telemetry is used as a supplement. Tables 1 and 2 show the dn shutter map algorithm for collects with high and low confidence, respectively.

2.1 First telemetry map correction

The LRV extractor is used to acquire the absolute scan number, 'S_CP_SCAN_NUM' [9]. By determining the absolute scan number of the first and last scan of each collect, it is possible to determine the number of scans between collects.

Consider a situation in which there are three collects. The first and third collects have high confidence in the dn shutter map. The second does not. In this case, the number of scans between the first and second collects determines the shutter map for the second collect. This process is repeated to determine the shutter map of the third collect. The telemetry shutter map is then compared to the dn shutter map for the third collect. If they agree, the telemetry map is used for the second collect. If they do not agree, then either the shutter experienced a phase change or the dn shutter map was incorrect for the first or third collect. In this case, the dn shutter map is retained for the second collect.

This situation is outlined in Figure 1. In case 1, the telemetry shutter map was successful in determining the shutter map for the third collect (highlighted in blue). In case 2, the telemetry shutter map failed to determine the shutter map for the third collect (highlighted in red).

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Figure 1: first telemetry shutter map algorithm.

	collects	1		2		3
	confidence	high		low		high
	scans between collects		2		3	
case 1	telemetry shutter map	OOCC	OO	CCOO	CCO	OCCO
	dn shutter map	OOCC		CCOO		OCCO
case 2	telemetry shutter map	OOCC	OO	CCOO	CCO	OCCO
	dn shutter map	OOCC		CCOO		COOC

It is possible to apply the method described above to cases in which a series of collects with low confidence in the dn shutter map are bounded by collects with high confidence. This is referred to as telemetry map correction one.

2.2 Second telemetry map correction

In the event that the first telemetry correction fails, the approach is expanded. Now consider a situation in which there are five collects. The third collect has low confidence in the dn shutter map, but the remaining four collects have high confidence. Telemetry data is used to map the shutter from the first to the fifth collect. As before, the telemetry map and the dn shutter map for the fifth collect are compared. If they agree, the telemetry shutter map is used for the second, third, and fourth collects. If they do not agree, then either the shutter experienced a phase change or there was an error in the dn shutter map. In this case, the dn shutter map is retained for the second, third, and fourth collects.

This situation is outlined in Figure 2. Case 1 shows a successful application of the telemetry shutter map (highlighted in blue), and case 2 shows a telemetry shutter map that failed to determine the shutter map for the fifth collect (highlighted in red).

Figure 2: second telemetry shutter map algorithm.

	collects	1		2		3		4		5
	confidence	high		high		low		high		high
	scans between collects		2		3		1		2	
case 1	telemetry shutter map	OOCC	OO	CCOO	CCO	OCCO	O	CCOO	CC	OOCC
	dn shutter map	OOCC		CCOO		COOC		OCCO		OOCC
case 2	telemetry shutter map	OOCC	OO	CCOO	CCO	OCCO	O	CCOO	CC	OOCC
	dn shutter map	OOCC		CCOO		COOC		OCCO		COOC

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Again, it is possible to apply this method to cases in which a series of collects with low confidence in the dn shutter map are bounded by collects with high confidence. This is referred to as telemetry map correction two.

Note that this algorithm is predicated on the assumption that two phase changes in the shutter order which cancel each other do not occur between the collects with high confidence. The probability of this happening is low.

3. Analysis

3.1 VisNIR

The dn shutter map algorithm was applied to the VisNIR FP-16 OOB UAIDs listed in Table 3. This table also shows the sender band and total number of collects for each UAID, along with the number of collects where the dn shutter map has low confidence (less then 50% of illuminated detectors agree or two maps are tied at 50% of illuminated detectors). The next two columns show the number of collects where the shutter map remained underdetermined after the first and second telemetry corrections were applied, respectively.

The number of collects where the dn shutter map was uncertain in all VisNIR UAIDs was 14% of the total. The two telemetry corrections decrease the number of collects with low confidence to 5%. Of the remaining 59 underdetermined collects, about half were at the extremes of the tested wavelength range (last column in Table 3). These collects do not provide a bounded region to test the telemetry corrections; as a result, the dn shutter map was retained for these collects.

The dn shutter map was underdetermined more often for the I bands than for the M bands. Fifty-four percent of all underdetermined dn shutter maps were from the two I bands. The telemetry correction algorithm decreased the percentage of collects with low confidence from approximately 30% to 7%. By contrast, the number of underdetermined collects from the M bands declined from about 8% to 5%. The increased improvement in the I bands relative to the M bands is due to the large percentage of underdetermined collects at the extreme edge of the wavelength range for the M-bands.

In Figure 3, the crosstalk in band M6 is shown when I1 is illuminated. The upper graph shows the response using only the dn shutter map; the lower graph shows the response after incorporating the telemetry map corrections. Specific areas of improvement in the shutter map are highlighted by red ovals. There are two noticeable negative dips in Figure 3 (around 780 nm and 1100 nm) which are corrected.

The band I1 response also exhibited noticeable improvement after the telemetry corrections were implemented. Figure 4 shows the crosstalk received by band M5 with and without the telemetry corrections (upper and lower plots, respectively). Again, the improvement resulting from the telemetry corrections is highlighted in red.

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The improvement in the M bands is less noticeable, despite the number of underdetermined collects decreasing by half. Figure 5 shows a comparison of the crosstalk sent from M7 into M5 both before and after the telemetry correction algorithm was applied. M7 was chosen because it had the greatest improvement after application of the telemetry corrections. These results were typical for an M-band.

3.2 LWIR

The analysis here focuses on the FP-16 UAIDs for the LWIR listed in Table 4. This Table also lists the number of collects in each UAID along with the number of collects for which there was low confidence in the dn shutter map (less then 50% of illuminated detectors agree or two maps are tied at 50% of illuminated detectors). The number of collects whose shutter map remains underdetermined after use of the first and second telemetry map corrections is also listed.

The number of collects for which the dn shutter map has low confidence is between 2% (sender band I5) and 40% (sender band M15). The first telemetry map correction decreases the number of underdetermined collects by an average of 54%. The combination of the first and second telemetry map corrections decreases the number of underdetermined collects by an average of 71% for the LWIR. The use of both telemetry map corrections reduces the number of collects with low confidence from an average of 20% to 5% for the LWIR.

Figures 6 – 9 show the I5 subsample 1 (SS1) response for various LWIR sender bands. I5 was selected because its higher OOB signal highlights some of the underdetermined dn shutter map. Each figure plots the response determined from the dn shutter map in the upper graph and the response calculated using both telemetry map corrections in the lower graph.

Figure 6 shows the most improvement (sender band M15), while Figure 7 shows almost no change (sender band I5), as expected from Table 4. The telemetry map provided some improvement in sender bands M14 and M16A (Figures 8 and 9, respectively).

Figure 10 shows the response in band M14 from sender band M15. There is a large negative peak near 8500 nm in the upper graph (highlighted in red) that is corrected by the telemetry map algorithm.

Note that the extraneous peaks in Figures 6 – 10 are the possible result of the underdetermined shutter maps, but only when the shutter phase is two scans out of alignment with the true map. Underdetermined maps which are one or three scans out of alignment appear to have almost no response. In addition, some underdetermined maps actually coincide with the true map; for these cases there is no change in Figures 6 – 10 between the upper to lower graphs.

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It should be noted that up to 10% of collects in a given UAID have a shutter map that is still underdetermined even after use of VIIRS telemetry data. Further refinements of this method are in progress.

4. Summary

- The dn shutter map is not always adequate for the OOB response; up to 40% of collects in a given UAID have an underdetermined dn shutter map.
- The telemetry corrections compensate for approximately 62% and 73% of low confidence collects for the VisNIR and LWIR, respectively.
- Further refinements are in progress.

Acknowledgement

The sensor test data used in this document was provided by the SBRS testing team. Approaches for data acquisition and data reductions, as well as data extraction tools were also provided by the SBRS. We would like to thank the SBRS team for their support. The data analysis tools were developed by the NICST team, and we would like to extend our gratitude for their valued assistance.

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Table 2: Number of collects which are underdetermined after use of each method for the VisNIR.

Sender Band	UAID	Number of collects	Collects with low confidence	Telemtry map corretion 1	Telemtry map correction 2	Extreme of test range
M2	U2001718	128	17	8	8	2
M4	U2001723	122	7	6	6	2
M3	U2001733	123	9	8	8	0
I1	U2001740	141	59	11	6	6
I2	U2001744	142	25	14	14	4
M7	U2001749	137	11	1	1	1
M5	U2001754	123	11	9	9	8
M6	U2001761	130	12	2	2	2
M1	U2001783	124	8	5	5	5
	Totals	1170	159	64	59	30

Table 3: Number of collects which are underdetermined after use of each method for the LWIR.

Sender Band	UAID	Number of collects	Collects with low confidence	Telemtry map corretion 1	Telemtry map correction 2
I5	U2002603	243	6	2	2
M14	U2002589	235	56	25	16
M15	U2002592	216	85	43	20
M16A	U2002600	181	45	20	14
M16B	U2002596	215	20	11	5
	Totals	1090	212	101	57

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Figure 3: M6 response as a function of wavelength (nm) from sender band I1 (UAID U2001740).

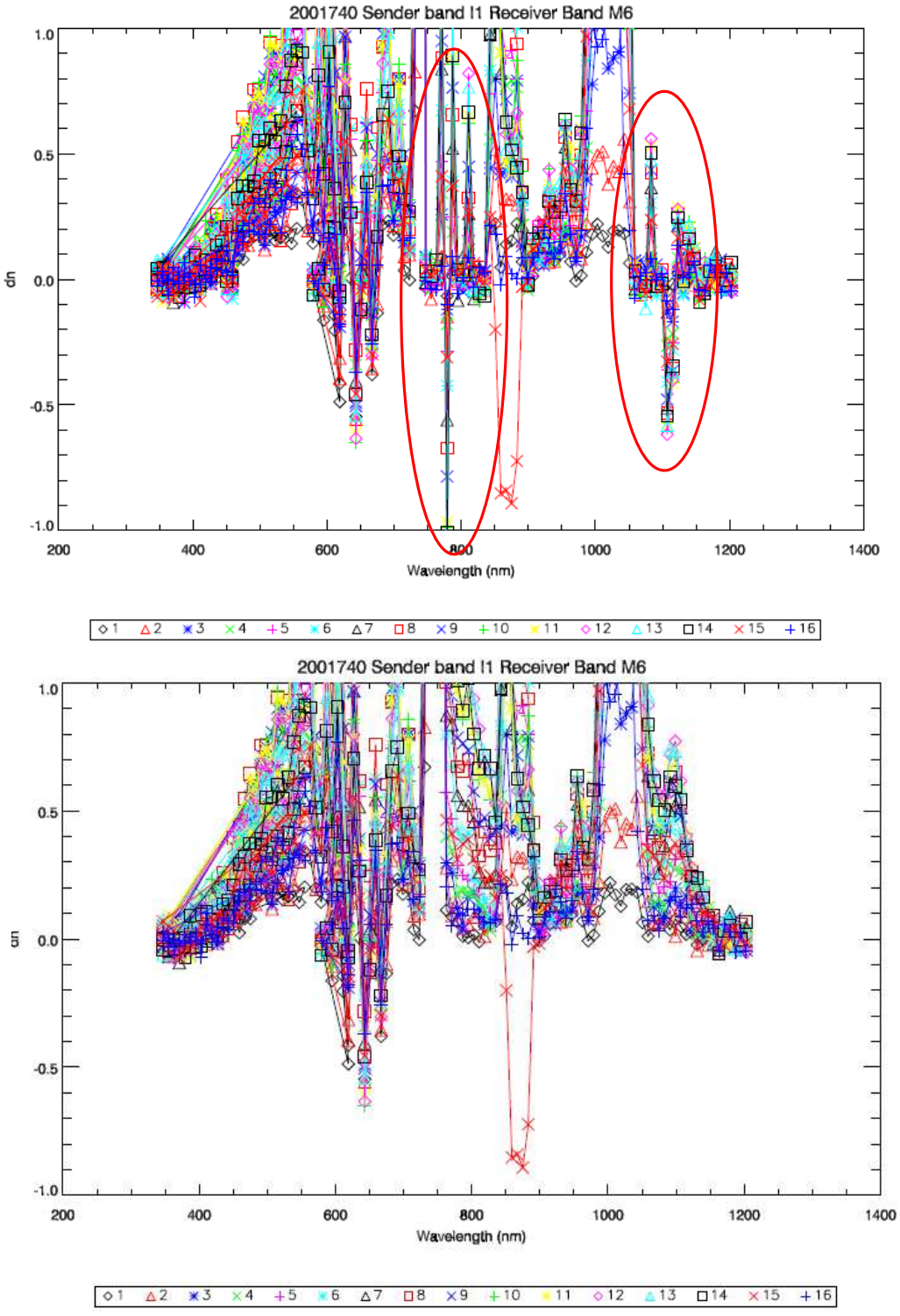

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Figure 4: M5 response as a function of wavelength (nm) from sender band I2 (UAID U2001744).

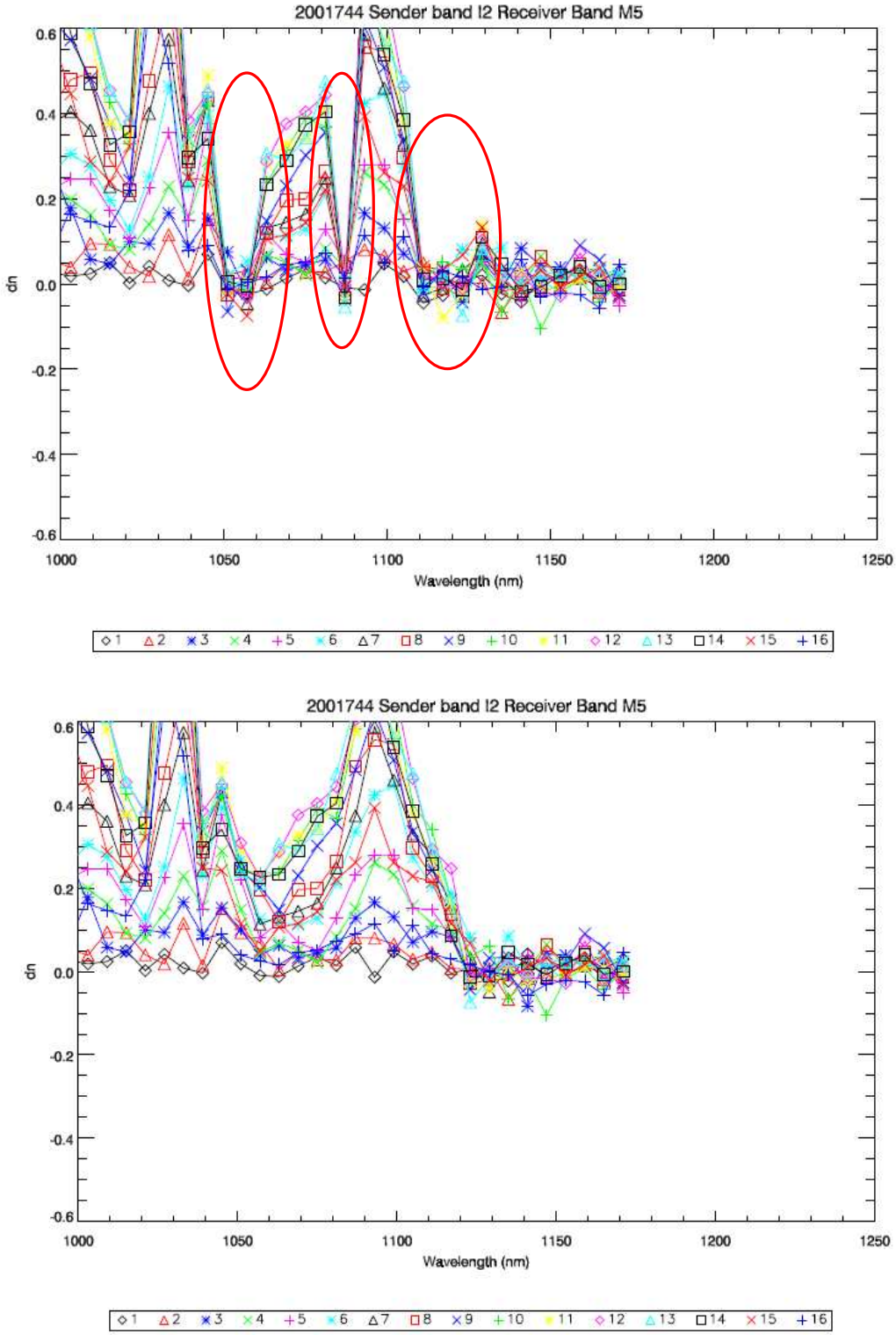

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Figure 5: M5 response as a function of wavelength (nm) from sender band M7 (UAID U2001749).

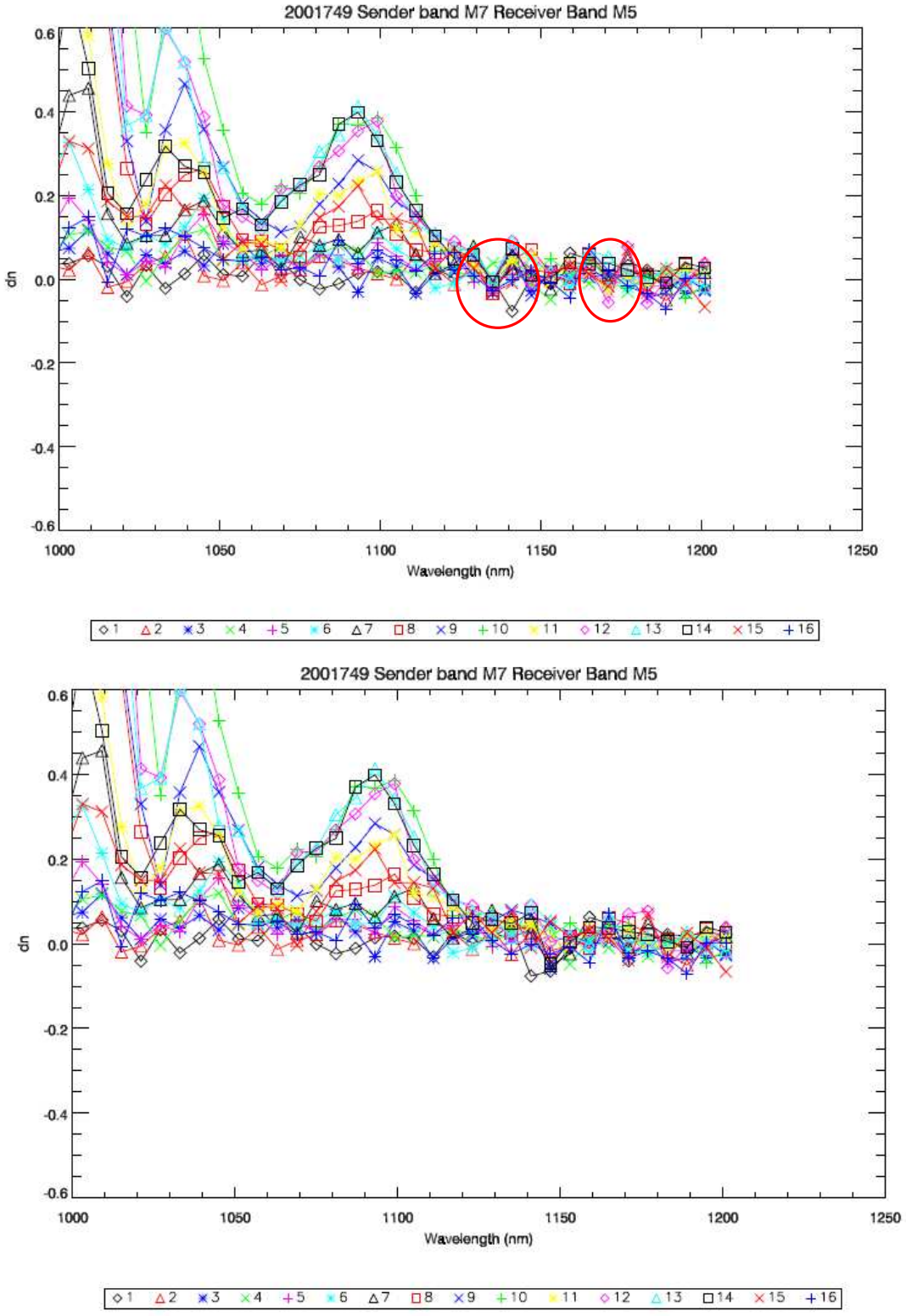

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Figure 6: I5 SS1 response as a function of wavelength (nm) from sender band M15 (UAID U2002592).

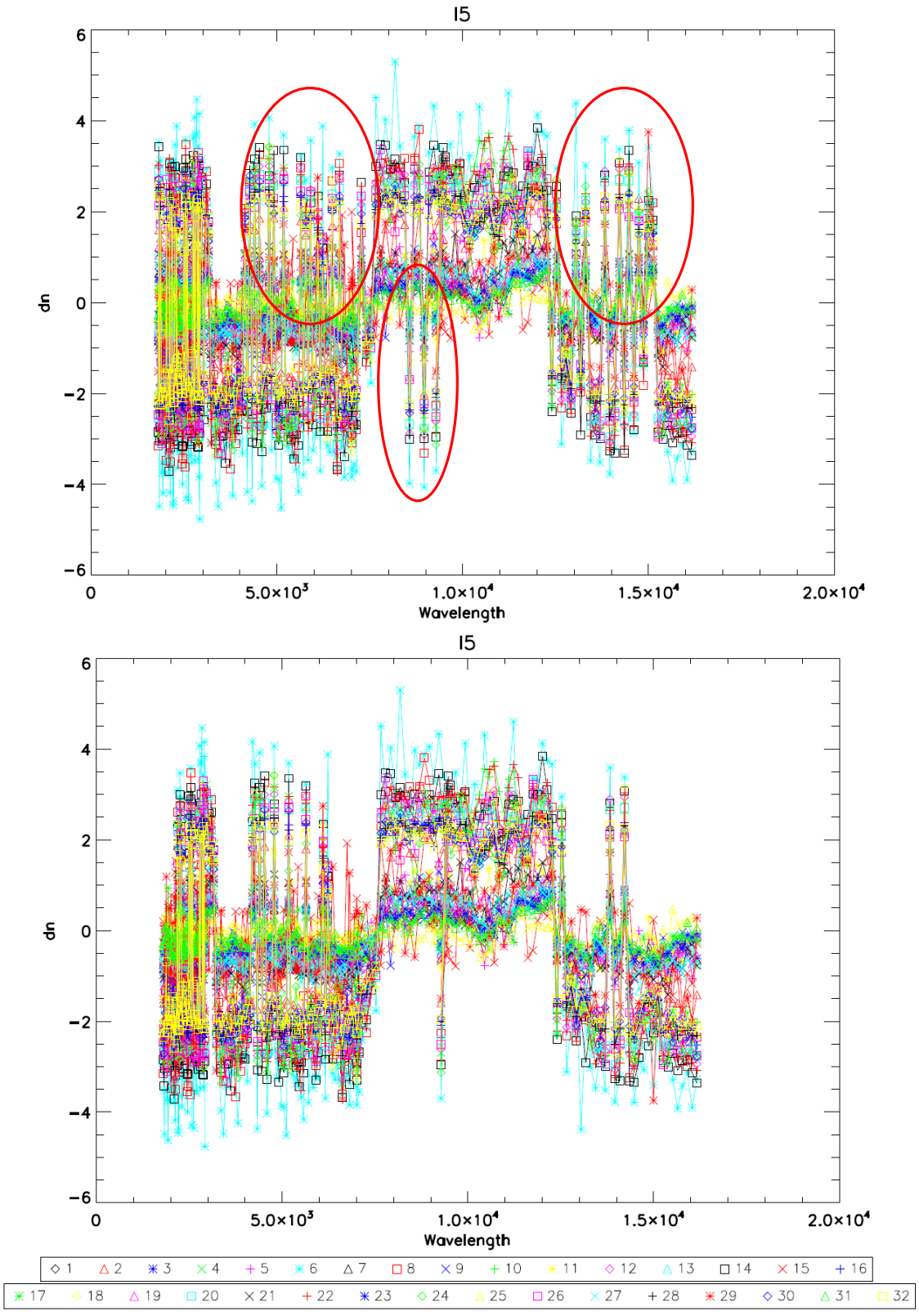

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Figure7: Sender band I5 SS1 response (UAID U2002603) as a function of wavelength (nm).

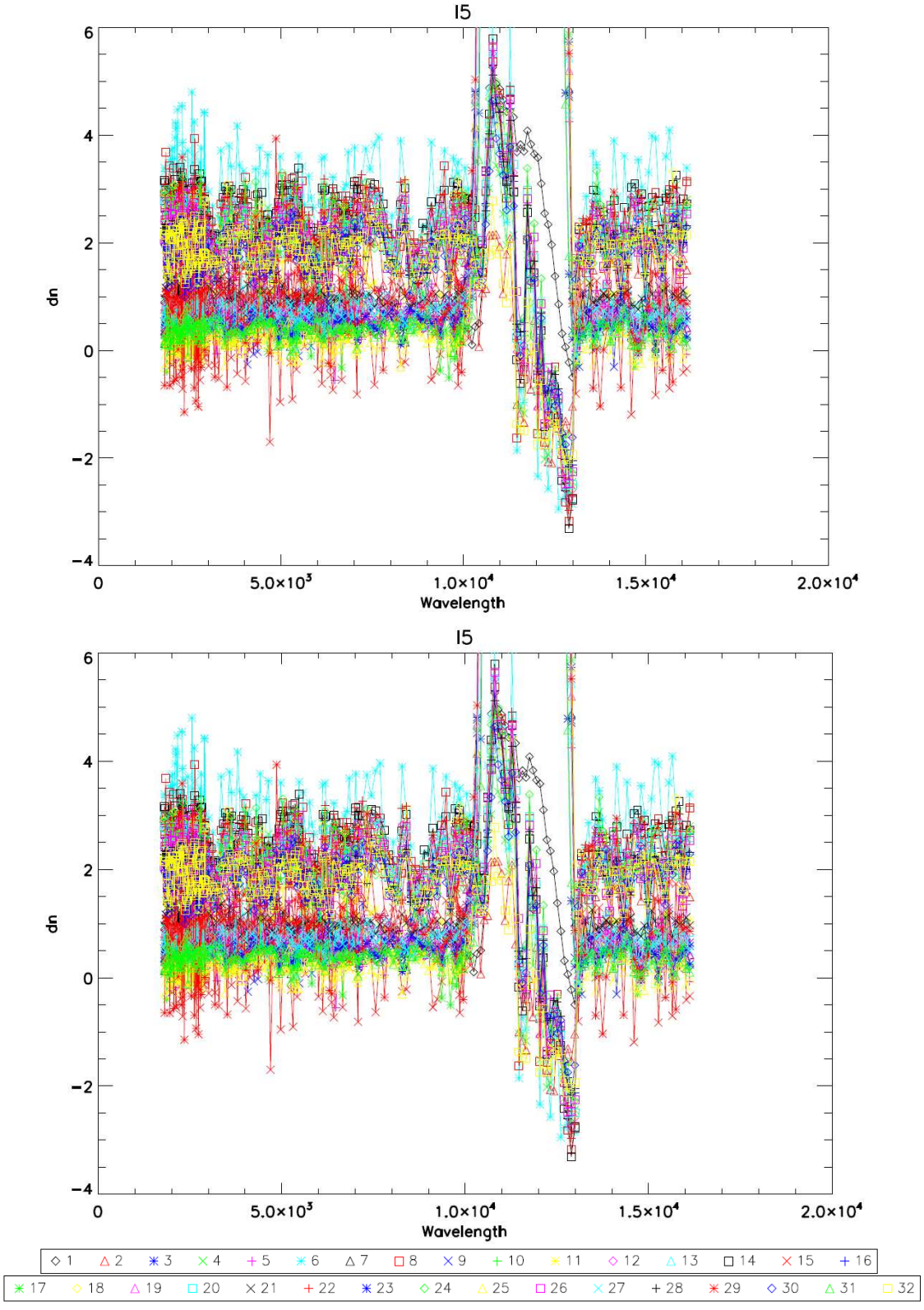

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Figure 8: I5 SS1 response as a function of wavelength (nm) from sender band M14 (UAID U2002589).

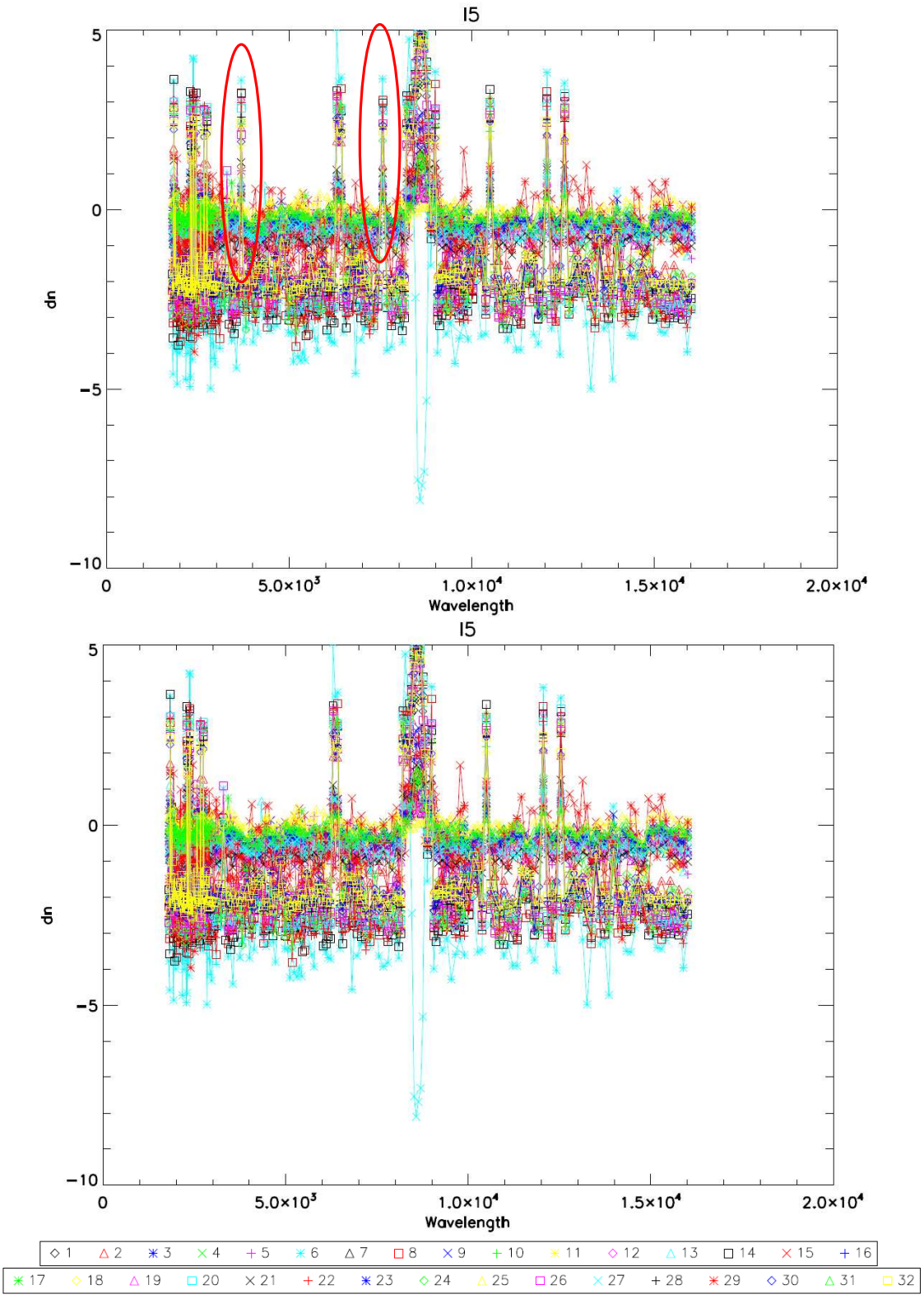

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Figure 9: I5 SS1 response as a function of wavelength (nm) from sender band M16A (UAID U2002600).

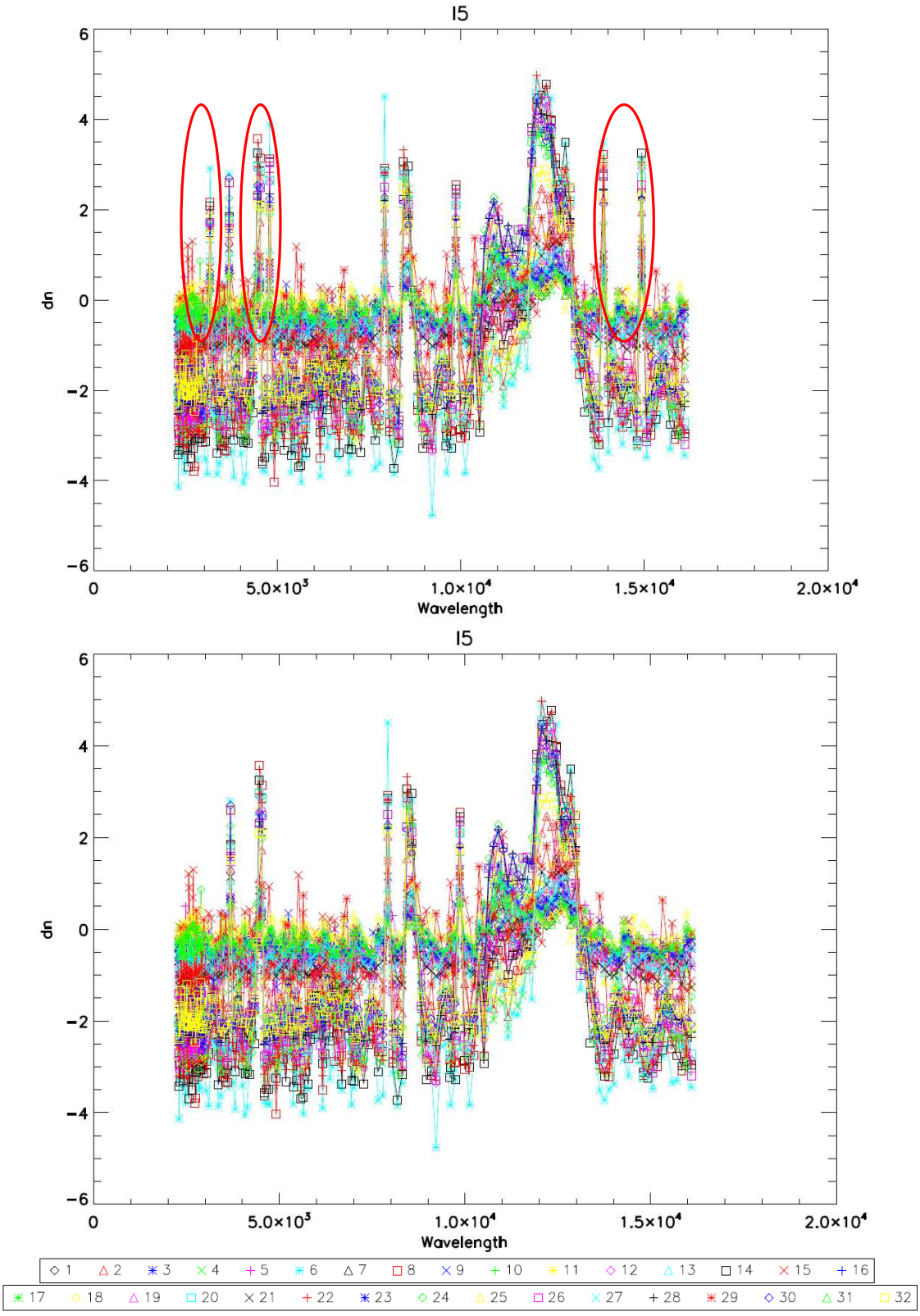

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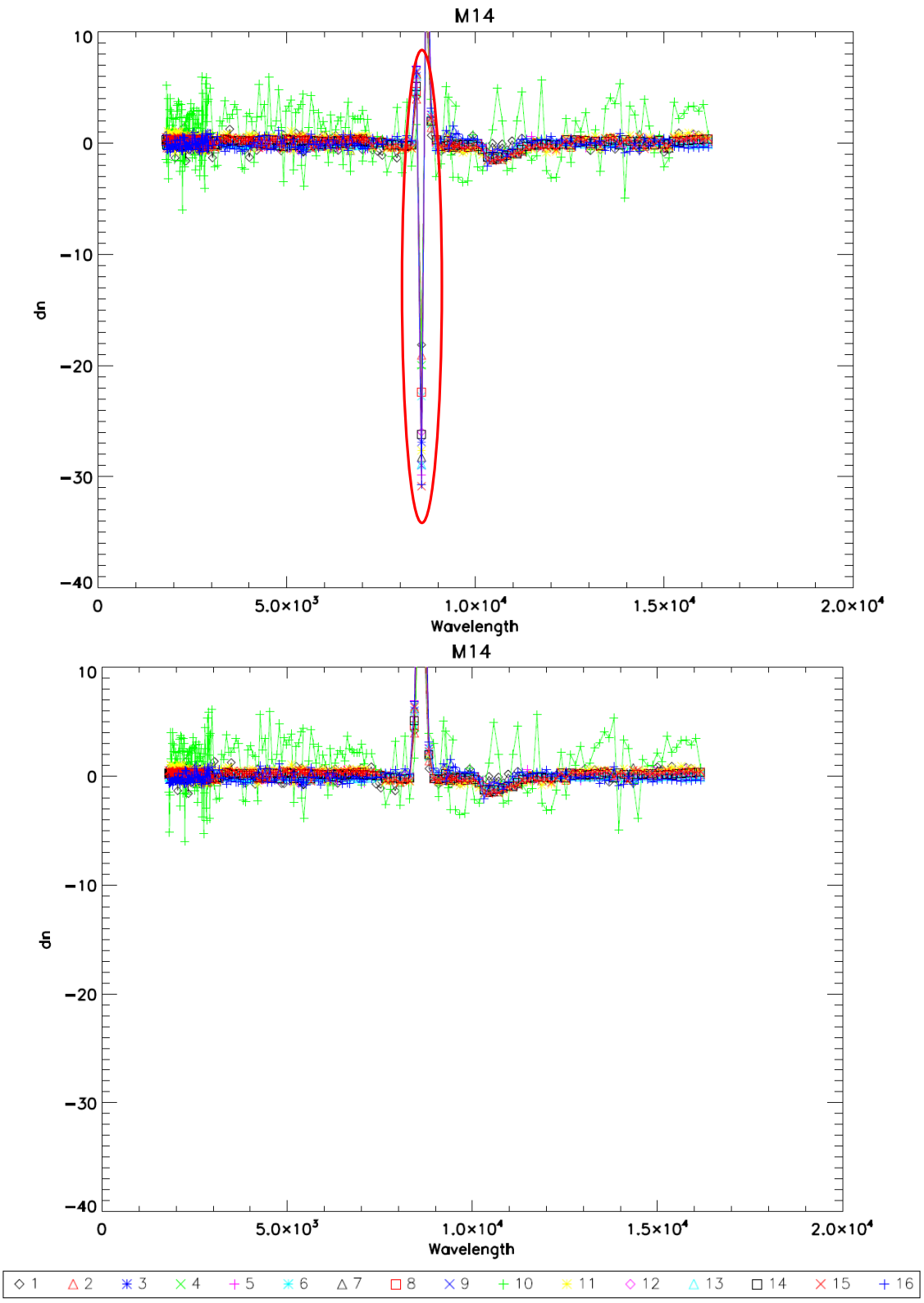
Figure 10: M14 response as a function of wavelength (nm) from sender band M15 (UAID U2002592).



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