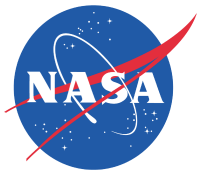

Kepler Data Release 24 Notes

Q0–Q17

KSCI-19064-002
Data Analysis Working Group (DAWG)
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April 2, 2015

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The correct citation for this document is: S. E. Thompson, J. M. Jenkins, D. A. Caldwell, T. Barclay, S. T. Bryson, C. J. Burke, J. R. Campbell, J. Catanzarite, J. L. Christiansen, B. D. Clarke, J. L. Coughlin, F. Girouard, M. R. Haas, K. Ibrahim, J. Li, S. D. McCauliff, R. L. Morris, F. R. Mullally, J. Rowe, A. Sabale, S. Seader, J. C. Smith, P. G. Tenenbaum, J. D. Twicken, and A. K. Uddin, 2015, Kepler Data Release 24 Notes (KSCI-19064-002).

Contents

A Introduction

These Data Release Notes provide information specific to the current reprocessing and re-export of Q0–Q17 data. The data products included in this data release include target pixel files, light curve files, FFIs, CBVs, ARP, Background, and Collateral files. This release marks the first time all the Kepler Mission Data has been processed consistently with the same version of the Kepler pipeline. See Tables 1 and 2 for a list of the reprocessed Kepler cadence data. See Table 3 for a list of the available FFIs.

Table 1: Contents of Data Release 24–Cadence Data, part 1

Q.m		First Cadence MJD midTime	Last Cadence MJD midTime	First Cadence UT midTime	Last Cadence UT midTime	Num CINs	Start CIN	End CIN
0	LC	54953.0382	54962.7441	02-May-2009 00:54:56	11-May-2009 17:51:31	476	568	1043
0	SC	54953.0283	54962.7540	02-May-2009 00:40:43	11-May-2009 18:05:44	14280	5500	19779
1	LC	54964.0110	54997.4812	13-May-2009 00:15:49	15-Jun-2009 11:32:57	1639	1105	2743
1	SC	54964.0011	54997.4911	13-May-2009 00:01:36	15-Jun-2009 11:47:11	49170	21610	70779
2	LC	55002.0175	55090.9649	20-Jun-2009 00:25:09	16-Sep-2009 23:09:29	4354	2965	7318
2.1	SCM1	55002.0076	55032.8003	20-Jun-2009 00:10:56	20-Jul-2009 19:12:30	45210	77410	122619
2.2	SCM2	55032.8215	55062.7969	20-Jul-2009 19:42:54	19-Aug-2009 19:07:29	44010	122650	166659
2.3	SCM3	55063.8601	55090.9748	20-Aug-2009 20:38:32	16-Sep-2009 23:23:42	39810	168220	208029
3	LC	55092.7222	55181.9966	18-Sep-2009 17:19:58	16-Dec-2009 23:55:06	4370	7404	11773
3.1	SCM1	55092.7123	55123.0555	18-Sep-2009 17:05:45	19-Oct-2009 01:19:58	44550	210580	255129
3.2	SCM2	55123.9144	55153.9511	19-Oct-2009 21:56:47	18-Nov-2009 22:49:38	44100	256390	300489
3.3	SCM3	55156.0156	55182.0065	21-Nov-2009 00:22:29	17-Dec-2009 00:09:19	38160	303520	341679
4	LC	55184.8777	55274.7038	19-Dec-2009 21:03:56	19-Mar-2010 16:53:31	4397	11914	16310
4.1	SCM1	55184.8679	55205.7421	19-Dec-2009 20:49:43	09-Jan-2010 17:48:41	30648	345880	376527
4.2	SCM2	55216.8056	55245.7389	20-Jan-2010 19:20:01	18-Feb-2010 17:43:58	42480	392770	435249
4.3	SCM3	55245.8009	55274.7137	18-Feb-2010 19:13:13	19-Mar-2010 17:07:44	42450	435340	477789
5	LC	55275.9912	55370.6600	20-Mar-2010 23:47:15	23-Jun-2010 15:50:26	4634	16373	21006
5.1	SCM1	55275.9813	55307.5096	20-Mar-2010 23:33:02	21-Apr-2010 12:13:53	46290	479650	525939
5.2	SCM2	55308.7772	55336.4028	22-Apr-2010 18:39:10	20-May-2010 09:39:57	40560	527800	568359
5.3	SCM3	55337.0982	55370.6699	21-May-2010 02:21:22	23-Jun-2010 16:04:39	49290	569380	618669
6	LC	55371.9473	55461.7939	24-Jun-2010 22:44:09	22-Sep-2010 19:03:09	4398	21069	25466
6.1	SCM1	55371.9375	55399.0317	24-Jun-2010 22:29:55	22-Jul-2010 00:45:41	39780	620530	660309
6.2	SCM2	55399.8702	55430.7855	22-Jul-2010 20:53:04	22-Aug-2010 18:51:11	45390	661540	706929
6.3	SCM3	55431.6853	55461.8037	23-Aug-2010 16:26:48	22-Sep-2010 19:17:22	44220	708250	752469
7	LC	55462.6725	55552.0491	23-Sep-2010 16:08:24	22-Dec-2010 01:10:41	4375	25509	29883
7.1	SCM1	55462.6626	55492.7811	23-Sep-2010 15:54:11	23-Oct-2010 18:44:45	44220	753730	797949
7.2	SCM2	55493.5378	55522.7367	24-Oct-2010 12:54:26	22-Nov-2010 17:40:54	42870	799060	841929
7.3	SCM3	55523.6161	55552.0590	23-Nov-2010 14:47:08	22-Dec-2010 01:24:54	41760	843220	884979
8	LC	55567.8647	55634.8460	06-Jan-2011 20:45:08	14-Mar-2011 20:18:16	3279	30657	33935
8.1	SCM1	55567.8548	55585.5496	06-Jan-2011 20:30:55	24-Jan-2011 13:11:27	25980	908170	934149
8.2	SCM2	55585.6116	55614.7084	24-Jan-2011 14:40:43	22-Feb-2011 17:00:02	42720	934240	976959
8.3	SCM3	55614.7703	55634.8559	22-Feb-2011 18:29:18	14-Mar-2011 20:32:29	29490	977050	1006539
9	LC	55641.016958	55738.423953	21-Mar-2011 00:24:25	26-Jun-2011 10:10:29	4768	34237	39004
9.1	SCM1	55641.007082	55677.419086	21-Mar-2011 00:10:11	26-Apr-2011 10:03:28	53460	1015570	1069029
9.2	SCM2	55678.114509	55706.618707	27-Apr-2011 02:44:53	25-May-2011 14:50:56	41850	1070050	1111899
9.3	SCM3	55707.252830	55738.433829	26-May-2011 06:04:04	26-Jun-2011 10:24:42	45780	1112830	1158609
10	LC	55739.343433	55832.765870	27-Jun-2011 08:14:32	28-Sep-2011 18:22:51	4573	39049	43621
10.1	SCM1	55739.333557	55769.452008	27-Jun-2011 08:00:19	27-Jul-2011 10:50:53	44220	1159930	1204149
10.2	SCM2	55770.290467	55801.737103	28-Jul-2011 06:58:16	28-Aug-2011 17:41:25	46170	1205380	1251549
10.3	SCM3	55802.575562	55832.775747	29-Aug-2011 13:48:48	28-Sep-2011 18:37:04	44340	1252780	1297119
11	LC	55833.7058	55930.8267	29-Sep-2011 16:56:19	04-Jan-2012 19:50:25	4754	43667	48420
11.1	SCM1	55833.6959	55864.7747	29-Sep-2011 16:42:06	30-Oct-2011 18:35:37	45630	1298470	1344099
11.2	SCM2	55865.5315	55895.7317	31-Oct-2011 12:45:18	30-Nov-2011 17:33:34	44340	1345210	1389549
11.3	SCM3	55896.6110	55930.8366	01-Dec-2011 14:39:48	04-Jan-2012 20:04:38	50250	1390840	1441089
12	LC	55931.9097	56014.5227	05-Jan-2012 21:49:54	28-Mar-2012 12:32:43	4044	48473	52516
12.1	SCM1	55931.8998	55958.4015	05-Jan-2012 21:35:41	01-Feb-2012 09:38:08	38910	1442650	1481559
12.2	SCM2	55959.1173	55986.4977	02-Feb-2012 02:48:58	29-Feb-2012 11:56:40	40200	1482610	1522809
12.3	SCM3	55987.3975	56014.5326	01-Mar-2012 09:32:20	28-Mar-2012 12:46:56	39840	1524130	1563969

Table 2: Contents of Data Release 24–Cadence Data, part 2

Q.m		First Cadence MJD midTime	Last Cadence MJD midTime	First Cadence UT midTime	Last Cadence UT midTime	Num CINs	Start CIN	End CIN
13	LC	56015.2379	56105.5544	29-Mar-2012 05:42:32	27-Jun-2012 13:18:20	4421	52551	56971
13.1	SCM1	56015.2280	56047.4920	29-Mar-2012 05:28:18	30-Apr-2012 11:48:26	47370	1564990	1612359
13.2	SCM2	56048.1874	56077.4272	01-May-2012 04:29:51	30-May-2012 10:15:10	42930	1613380	1656309
13.3	SCM3	56078.3270	56105.5643	31-May-2012 07:50:50	27-Jun-2012 13:32:34	39990	1657630	1697619
14	LC	56106.6374	56203.8196	28-Jun-2012 15:17:47	03-Oct-2012 19:40:10	4757	57024	61780
14.1	SCM1	56106.6275	56137.5020	28-Jun-2012 15:03:34	29-Jul-2012 12:02:49	45330	1699180	1744509
14.2	SCM2	56138.6469	56168.8062	30-Jul-2012 15:31:34	29-Aug-2012 19:20:59	44280	1746190	1790469
14.3	SCM3	56169.6651	56203.8294	30-Aug-2012 15:57:48	03-Oct-2012 19:54:23	50160	1791730	1841889
15	LC	56205.9855	56303.6377	05-Oct-2012 23:39:07	11-Jan-2013 15:18:15	4780	61886	66665
15.1	SCM1	56205.9756	56236.8093	05-Oct-2012 23:24:53	05-Nov-2012 19:25:19	45270	1845040	1890309
15.2	SCM2	56237.7703	56267.8887	06-Nov-2012 18:29:14	06-Dec-2012 21:19:47	44220	1891720	1935939
15.3	SCM3	56268.7272	56303.6476	07-Dec-2012 17:27:10	11-Jan-2013 15:32:29	51270	1937170	1988439
16	LC	56304.5980	56390.4600	12-Jan-2013 14:21:10	08-Apr-2013 11:02:28	4203	66712	70914
16.1	SCM1	56304.5882	56309.8185	12-Jan-2013 14:06:57	17-Jan-2013 19:38:37	7680	1989820	1997499
16.2	SCM2	56321.1598	56357.4697	29-Jan-2013 03:50:07	06-Mar-2013 11:16:17	53310	2014150	2067459
16.3	SCM3	56358.6146	56390.4699	07-Mar-2013 14:45:02	08-Apr-2013 11:16:41	46770	2069140	2115909
17	LC	56391.7269	56423.5012	09-Apr-2013 17:26:44	11-May-2013 12:01:39	1556	70976	72531
17.1	SCM1	56391.7170	56414.0911	09-Apr-2013 17:12:31	02-May-2013 02:11:14	32850	2117740	2150589
17.2	SCM2	56419.3024	56423.5110	07-May-2013 07:15:26	11-May-2013 12:15:52	6180	2158240	2164419

A.1 The SOC Pipeline for Q0–Q17

Data Release 24 was processed with the SOC Pipeline 9.2 (Jenkins *et al.*, 2010). For details on how Kepler processes the data through the front-end of the pipeline (modules CAL, PA, PDC), please see the Data Processing Handbook (Fanelli *et al.*, 2011). Notable changes and improvements to the pipeline are stated below.

A.1.1 Image Artifact Corrections

The pipeline was run with the Dynablack algorithm for the first time in this processing of the data. Dynablack is a module of the Kepler pipeline that accounts for instrument-induced artifacts when calibrating the data. Instrument-induced artifacts in the raw Kepler pixel data include time-varying crosstalk from the fine guidance sensor (FGS) clock signals, manifestations of drifting Moiré pattern as locally correlated non-stationary noise, and rolling bands in the images (see the Instrument Handbook, Van Cleve and Caldwell, 2009). These systematics find their way into the calibrated pixel time series and ultimately into the flux time series. The Kepler pipeline module Dynablack models the FGS crosstalk artifacts using a combination of raw science pixel data, full frame images, reverse-clocked pixel data and ancillary temperature data. The calibration module (CAL) uses the fitted Dynablack models to remove FGS crosstalk artifacts in the calibrated pixels by adjusting the black level correction per cadence.

Dynablack also detects and flags spatial regions and time intervals of strong time-varying black-level. These rolling band artifact (RBA) flags are produced on a per row per cadence basis by searching for transit signatures in the Dynablack fit residuals. The Photometric Analysis module (PA) generates per target per cadence data quality flags based on the Dynablack RBA flags. These flags are currently under evaluation and may be made available in a subsequent release of the data.

A.1.2 Propagation of Errors

The algorithm used by the CAL module to propagate the errors on the flux for each pixel and cadence was changed to improve its performance for stars that are highly variable on timescales of less than 12 hours.

Table 3: Contents of Data Release 24–Full Frame Images

Q	Class	Filename	UT Start	UT End
2	FFI	KPLR2009231194831	2009-08-19 19:19:05	2009-08-19 19:48:31
2	FFI	KPLR2009260000800	2009-09-16 23:38:34	2009-09-17 00:08:00
3	FFI	KPLR2009292020429	2009-10-19 01:35:04	2009-10-19 02:04:29
3	FFI	KPLR2009322233047	2009-11-18 23:01:21	2009-11-18 23:30:47
3	FFI	KPLR2009351005245	2009-12-17 00:23:19	2009-12-17 00:52:45
4	FFI	KPLR2010019225502	2010-01-19 22:25:37	2010-01-19 22:55:02
4	FFI	KPLR2010020005046	2010-01-20 00:21:21	2010-01-20 00:50:46
4	FFI	KPLR2010049182302	2010-02-18 17:53:37	2010-02-18 18:23:02
4	FFI	KPLR2010078174524	2010-03-19 17:15:58	2010-03-19 17:45:24
5	FFI	KPLR2010111125026	2010-04-21 12:21:01	2010-04-21 12:50:26
5	FFI	KPLR2010140101631	2010-05-20 09:47:06	2010-05-20 10:16:31
5	FFI	KPLR2010174164113	2010-06-23 16:11:48	2010-06-23 16:41:13
6	FFI	KPLR2010203012215	2010-07-22 00:52:49	2010-07-22 01:22:15
6	FFI	KPLR2010234192745	2010-08-22 18:58:19	2010-08-22 19:27:45
6	FFI	KPLR2010265195356	2010-09-22 19:24:31	2010-09-22 19:53:56
7	FFI	KPLR2010296192119	2010-10-23 18:51:53	2010-10-23 19:21:19
7	FFI	KPLR2010326181728	2010-11-22 17:48:03	2010-11-22 18:17:28
7	FFI	KPLR2010356020128	2010-12-22 01:32:03	2010-12-22 02:01:28
8	FFI	KPLR2011024134926	2011-01-24 13:20:01	2011-01-24 13:49:26
8	FFI	KPLR2011053174401	2011-02-22 17:14:35	2011-02-22 17:44:01
9	FFI	KPLR2011116104002	2011-04-26 10:10:37	2011-04-26 10:40:02
9	FFI	KPLR2011145152723	2011-05-25 14:57:58	2011-05-25 15:27:23
9	FFI	KPLR2011177110110	2011-06-26 10:31:44	2011-06-26 11:01:10
10	FFI	KPLR2011208112727	2011-07-27 10:58:01	2011-07-27 11:27:27
10	FFI	KPLR2011240181752	2011-08-28 17:48:27	2011-08-28 18:17:52
10	FFI	KPLR2011271191331	2011-09-28 18:44:06	2011-09-28 19:13:31
11	FFI	KPLR2011303191211	2011-10-30 18:42:45	2011-10-30 19:12:11
11	FFI	KPLR2011334181008	2011-11-30 17:40:43	2011-11-30 18:10:08
11	FFI	KPLR2012004204112	2012-01-04 20:11:47	2012-01-04 20:41:12
12	FFI	KPLR2012032101442	2012-02-01 09:45:16	2012-02-01 10:14:42
12	FFI	KPLR2012060123308	2012-02-29 12:03:42	2012-02-29 12:33:08
12	FFI	KPLR2012088132324	2012-03-28 12:53:58	2012-03-28 13:23:24
13	FFI	KPLR2012121122500	2012-04-30 11:55:30	2012-04-30 12:25:00
13	FFI	KPLR2012151105138	2012-05-30 10:22:12	2012-05-30 10:51:38
13	FFI	KPLR2012179140901	2012-06-27 13:39:35	2012-06-27 14:09:01
14	FFI	KPLR2012211123923	2012-07-29 12:09:58	2012-07-29 12:39:23
14	FFI	KPLR2012242195726	2012-08-29 19:28:01	2012-08-29 19:57:26
14	FFI	KPLR2012277203051	2012-10-03 20:01:25	2012-10-03 20:30:51
15	FFI	KPLR2012310200152	2012-11-05 19:32:27	2012-11-05 20:01:52
15	FFI	KPLR2012341215621	2012-12-06 21:26:56	2012-12-06 21:56:21
15	FFI	KPLR2013011160902	2013-01-11 15:39:37	2013-01-11 16:09:02
16	FFI	KPLR2013038133130	2013-02-07 13:02:05	2013-02-07 13:31:30
16	FFI	KPLR2013065115251	2013-03-06 11:23:26	2013-03-06 11:52:51
16	FFI	KPLR2013098115308	2013-04-08 11:23:43	2013-04-08 11:53:08

Note: The eight Q0 FFIs and the first Q2 FFI are no longer being reprocessed, see §A.1.7.

Under the old approach, under-sampling of the error estimates, and the consequent aliasing artifacts, resulted from only calculating the full propagation of uncertainties every ∼24 cadences and interpolating the results between these cadences. See §5.1.3 of the Data Characteristics Handbook (DCH, Christiansen *et al.*, 2013) for more details. In SOC 9.2 the reported errors for each cadence are a sum of the minimal error calculation (shot noise plus read noise) and an offset term to account for the extra error from the full propagation of errors. This offset is calculated by taking the mean of the difference between the full and the minimal error calculation across all cadences for which both were calculated. See Figure 1 for an example comparing the new and old methods of calculating the error for one pixel of a rapidly variable target.

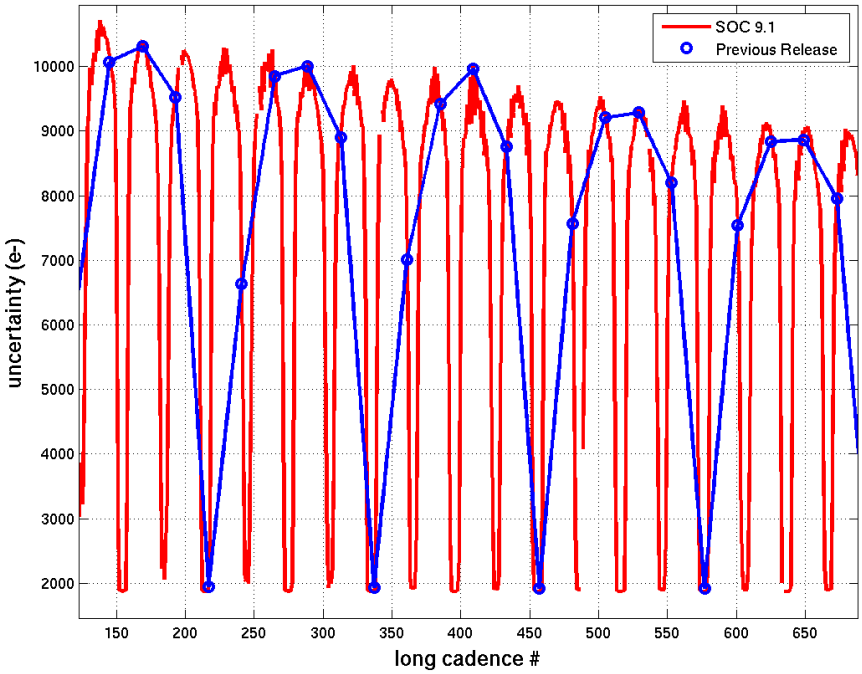


Figure 1: The error on the flux for one pixel plotted against relative, long-cadence number for a target that is highly variable on short timescales. The error calculated by a previous version of the pipeline is plotted in blue and the error calculated by the current SOC Pipeline 9.2 is plotted in red. The variability of the star is similar in shape and amplitude to the red line.

A.1.3 PDC Multi-scale MAP

The PDC (Presearch Data Conditioning) module of the pipeline has implemented multi-scale MAP (msMAP) for long cadence data. msMAP is a wavelet-based band-splitting framework for removing systematics from the light curves. It decomposes each light curve into three characteristic time-scales (or bands). This reduces the chance that an astrophysical signal will be accidentally removed and that systematic effects will be preserved. The Cotrending Basis Vectors (CBVs) are calculated separately for each band, which are then handled differently by PDC. The longest band ($\geq$ 1024 cadences, i.e., $\geq$21 days) performs a simple robust fit of the flux to the CBVs because it is difficult to distinguish between astrophysical signals and systematics on length scales similar in length to a quarter. The middle band performs a MAP fit. The shortest band ($<$ 4 cadences, i.e., $<$ 2 hours) simply preserves all signals and passes them to the output.

Multi-scale MAP does not always perform better than regular MAP. PDC therefore automatically compares the performance of msMAP to the regular MAP algorithm, and chooses the reduction with the better performance based on the total goodness metric calculated by PDC. Multi-scale MAP is preferred for approximately 90% of targets. The keywords in the headers of the FITS files indicate which PDC light curve was chosen for individual targets. For more information on this algorithm and how these affect the PDC light curves, see Smith *et al.* (2012) and Stumpe *et al.* (2012).

The CBVs for the different bands are not provided to the end user. The CBVs provided with this data release are calculated using regular MAP, as they have been in the past. See the KAM (Thompson and Fraquelli, 2014) for more details.

A.1.4 Application of MAP to SC Data

The pipeline applies a version of MAP, called quickMAP, to all short cadence light curves. quickMAP performs in much the same way as regular MAP does for long cadence light curves (Smith *et al.*, 2012). The primary difference arises from the small number of short cadence targets, making it impossible to construct useful basis vectors and priors directly from the short cadence targets. Instead, quickMAP interpolates the long cadence basis vectors to the short cadence exposure time and uses the prior information calculated for the target's long cadence light curve. As a result of the interpolation, no systematics with frequencies higher than the long cadence Nyquist frequency are removed (see DCH, Christiansen *et al.*, 2013, §5.12). There is also the potential that signals could be introduced above the long cadence Nyquist Frequency; however, Fourier analysis has shown this is not a significant problem.

Short cadence PDC light curves will be more similar to long cadence PDC light curves than in previous data releases. However, the algorithms and data sets are not identical, so there will be noticeable differences for individual targets. For example the long period attenuation discussed below occurs at shorter periods for short cadence data. Also, msMAP for long cadence data does a better job of removing Earth point recoveries.

A.1.5 PDC Keywords

The PDC keywords are now populated in the headers of all files. These include keywords to describe the PDC method, the 4 individual goodness metrics, the total goodness metric, and the sudden pixel sensitivity dropout keywords. For more information see the KAM (Thompson and Fraquelli, 2014).

A.1.6 PDC Protects Transits from Outlier Detection

PDC now protects known transits from incorrectly being identified as Sudden Pixel Sensitivity Dropouts (SPSDs) or other types of outliers. Cadences containing known transits and eclipses are computed using the epoch, period and duration of the events. No SPSDs or outliers are flagged during the known transits. This helps preserve transit depths and shapes from corruption by the SPSD and outlier correction algorithms. Note that this only affects transits known prior to running the pipeline. Identification of a transit as an outlier may still occur for transits not identified prior to the data processing.

A.1.7 WCS in the FFIs

The World Coordinate System (WCS) in the FFIs is now being calculated using the FFI (Full Frame Image) directly, instead of using the nearest, good, long-cadence WCS solution as done for previous releases of the data. Now, the WCS solution for each FFI is calculated in the same way as it is done for the cadence data, using a selection of bright stars across the field of view (see information on the motion polynomials in the DCH, Christiansen *et al.*, 2013; Twicken *et al.*, 2010).

The first 8 (golden) FFIs and the first Q2 FFI are non-standard in that they are not associated with a valid target table, which is necessary to calculate the position of the bright stars and derive motion polynomials. As a result, these 9 FFIs were not reprocessed and are not included in this data release (Table 3).

A.1.8 Barycentric Times

The export module (AR) of the pipeline exports all barycentric times in the TDB time system. See the DCH or DRN 20 for more information on how the time system was an issue for previous data releases. Now, the target pixel files all match the barycentric times in the light curve files. However, see §14.2 about the small error in the reported times for one cadence that occurred in Q14 because of a leap second.

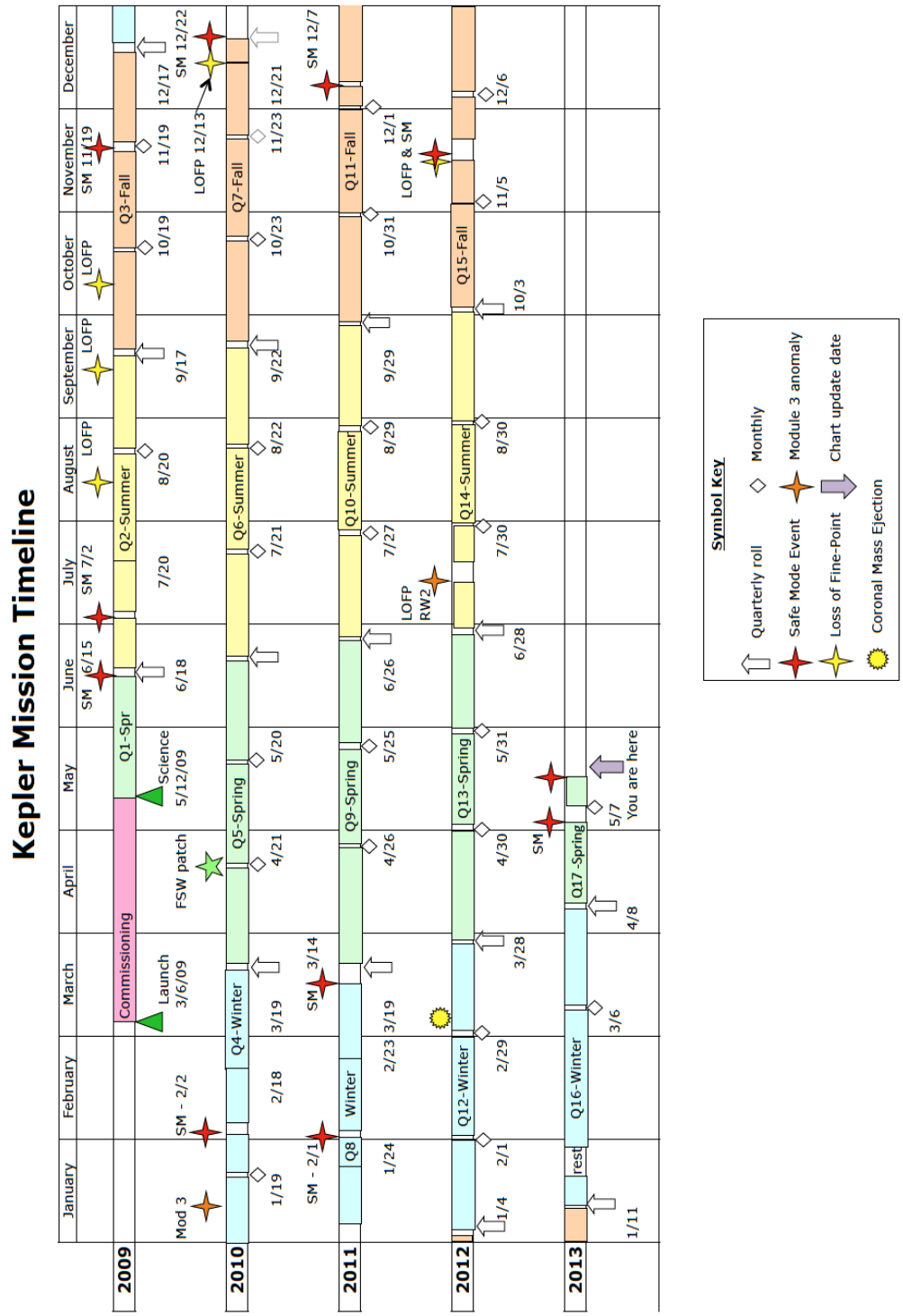
A.1.9 Anomalous Short-Cadence Data Near Gaps

Some short-cadence flux values can be anomalous if the adjacent or coincident long cadence has data quality bits 6, 9, 15 or 16 set (see Table 2.3 of the Kepler Archive Manual). This occurs because the long- and short-cadence data anomaly flags are handled inconsistently during pixel-level calibration (CAL), which permits bad long-cadence CCD bias levels to be interpolated for use in the calibration of adjacent or coincident short-cadence data. Though we have identified only one significant case of this anomaly, this effect could impact short-cadence data in or near other long-cadence data gaps. In this particular instance, the bad short-cadence data occur on either side of the Q8 safe mode in month 2. The SC flux values are incorrect by up to an order or magnitude for short-cadence indicies = 945895 – 945940 and 949840 – 949854.

Every desaturation cadence (data quality bit 6) potentially suffers from this anomaly, but these long cadences generally possess valid black values, so there is no significant impact on the associated short-cadence calibration. Generally speaking, users should be suspicious of short-cadence data that lie adjacent to gapped long-cadence data, but universally discarding all such short-cadence data is unwarranted.

A.2 Kepler Mission Timeline

The Figure shows the *Kepler* mission timeline for the entire mission.



B Data Quality in DRN 24

B.1 Evaluation of CDPP

To understand the overall performance of the pipeline, we show the Temporal Median (TM) of the CDPP time series as calculated by the TPS module for different versions of the SOC pipeline (Figure 2).

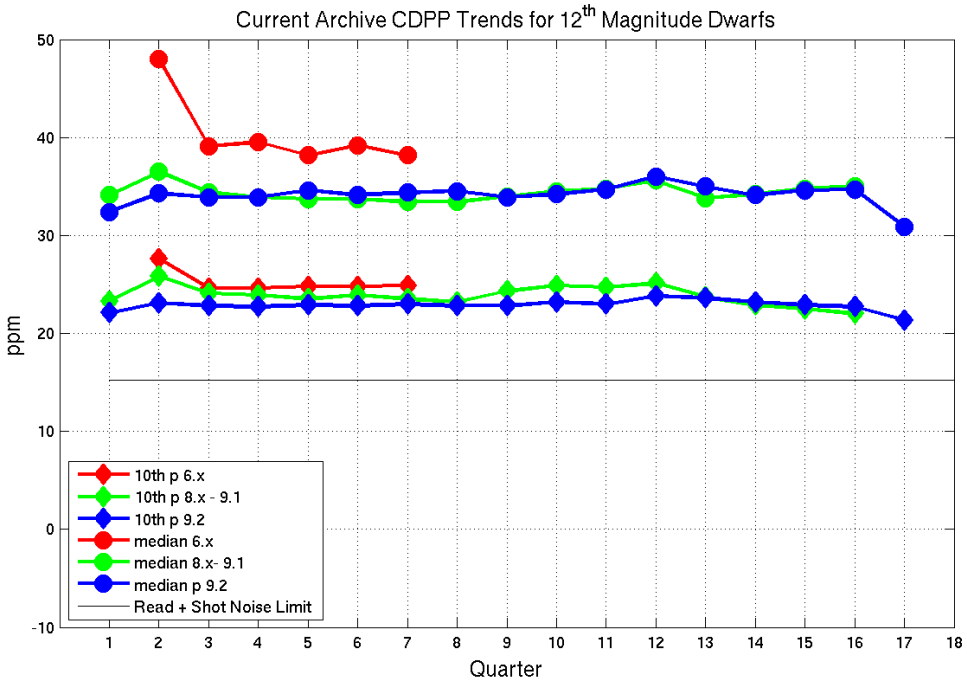


Figure 2: 6.5-h Temporal Median of the CDPP time series. The median (circles) and 10th percentile value (diamonds) for all dwarf stars between Kp=11.75–12.25 are given. The 6-h TMCDPPs have been divided by sqrt(13/12) = 1.041 to approximate 6.5-h TMCDPPs. The 6.x, 8.x and 9.x labels given in the legend refer to the version of the SOC pipeline used.

0 Q0 Notes

In this section we only discuss features of the data that are unique to Q0. For all other details about features present in the Kepler data, see the Data Characteristics Handbook (Christiansen *et al.*, 2013).

0.1 Summary of Data Anomalies

Certain cadences are flagged to indicate a possible reduction of quality. See the QUALITY and SAP_QUALITY columns of the target pixel and light curve files, respectively. Cadences with data anomalies that affect the entire focal plane are shown in the Figure below. The meaning of the flags are explained in the Data Characteristics Handbook (Christiansen *et al.*, 2013) and Archive Manual (Thompson and Fraquelli, 2014).

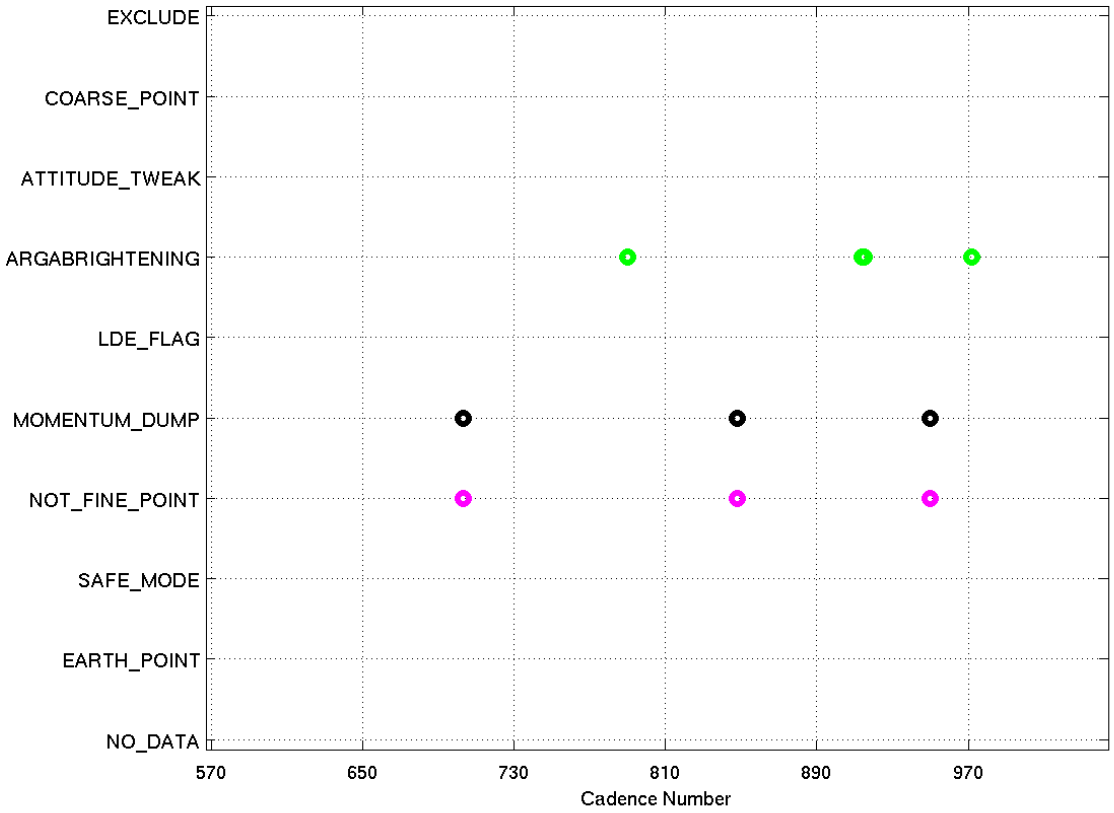


Figure 3: An overview of the location of the data anomalies flagged in Q0. ARGABRIGHTENING refers to cadences where the multiple-channel Argabrightening flag (flag 0x07, decimal value 64) was set.

0.2 No Events Unique to this Quarter

1 Q1 Notes

In this section we only discuss features of the data that are unique to Q1. For all other details about features present in the Kepler data, see the Data Characteristics Handbook (Christiansen *et al.*, 2013).

1.1 Summary of Data Anomalies

Certain cadences are flagged to indicate a possible reduction of quality. See the QUALITY and SAP_QUALITY columns of the target pixel and light curve files, respectively. Cadences with data anomalies that affect the entire focal plane are shown in the Figure below. The meaning of the flags are explained in the Data Characteristics Handbook (Christiansen *et al.*, 2013) and Archive Manual (Thompson and Fraquelli, 2014).

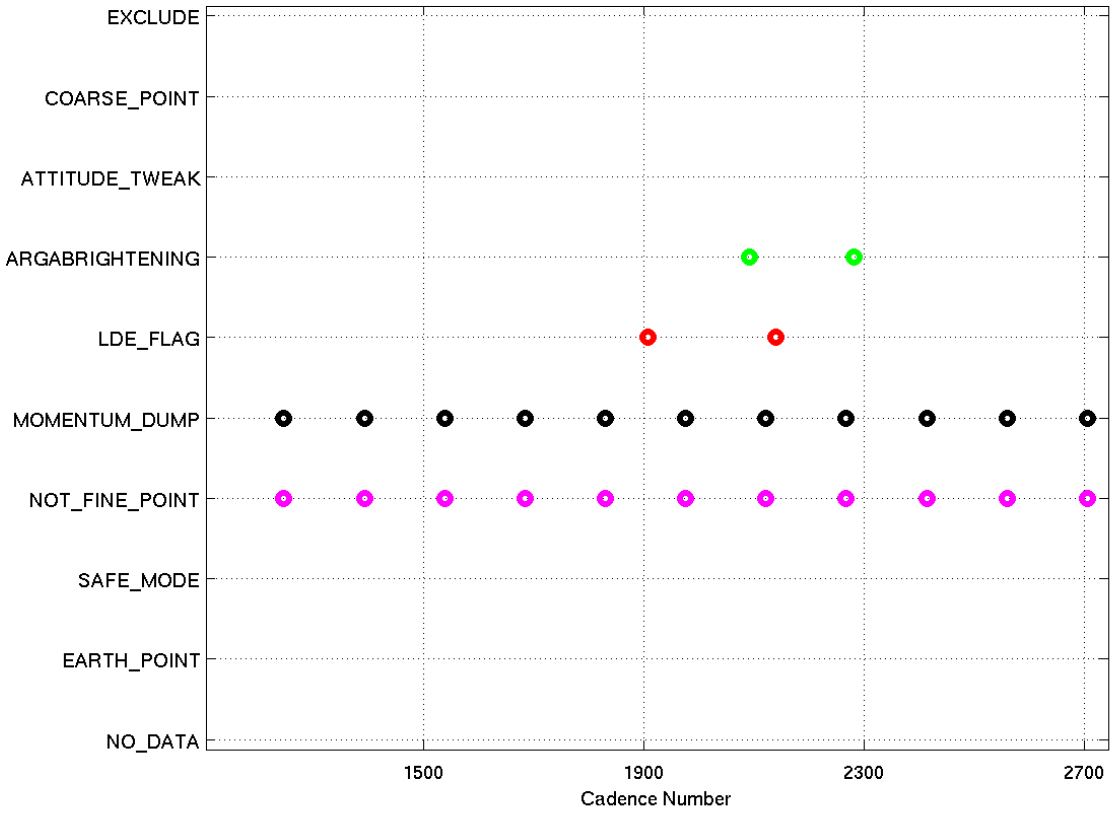


Figure 4: An overview of the location of the data anomalies flagged in Q1. ARGABRIGHTENING refers to cadences where the multiple-channel Argabrightening flag (flag 0x07, decimal value 64) was set.

1.2 No Events Unique to this Quarter

2 Q2 Notes

In this section we only discuss features of the data that are unique to Q2. For all other details about features present in the Kepler data, see the Data Characteristics Handbook (Christiansen *et al.*, 2013).

2.1 Summary of Data Anomalies

Certain cadences are flagged to indicate a possible reduction of quality. See the QUALITY and SAP_QUALITY columns of the target pixel and light curve files, respectively. Cadences with data anomalies that affect the entire focal plane are shown in the Figure below. The meaning of the flags are explained in the Data Characteristics Handbook (Christiansen *et al.*, 2013) and Archive Manual (Thompson and Fraquelli, 2014).

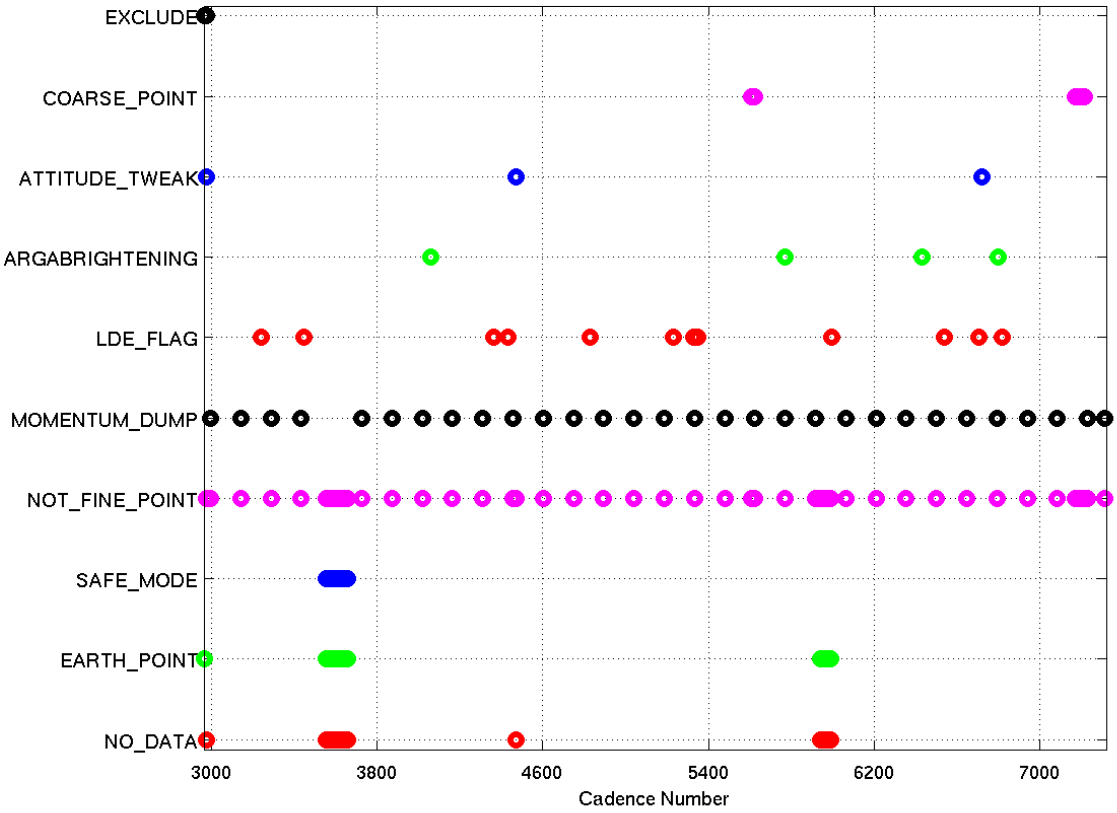


Figure 5: An overview of the location of the data anomalies flagged in Q2. ARGABRIGHTENING refers to cadences where the multiple-channel Argabrightening flag (flag 0x07, decimal value 64) was set.

2.2 Attitude Tweak

Since continued attitude drift invalidates target aperture definitions and leads to large photometric errors, small attitude adjustments were performed. In Q2 three attitude tweaks were performed with offsets of less than 0.05 pixels (Christiansen *et al.*, 2013).

2.3 Safe Mode

A safe mode occurred on 2009-07-02, in the middle of the first month of observations, causing a data gap.

3 Q3 Notes

In this section we only discuss features of the data that are unique to Q3. For all other details about features present in the Kepler data, see the Data Characteristics Handbook (Christiansen *et al.*, 2013).

3.1 Summary of Data Anomalies

Certain cadences are flagged to indicate a possible reduction of quality. See the QUALITY and SAP_QUALITY columns of the target pixel and light curve files, respectively. Cadences with data anomalies that affect the entire focal plane are shown in the Figure below. The meaning of the flags are explained in the Data Characteristics Handbook (Christiansen *et al.*, 2013) and Archive Manual (Thompson and Fraquelli, 2014).

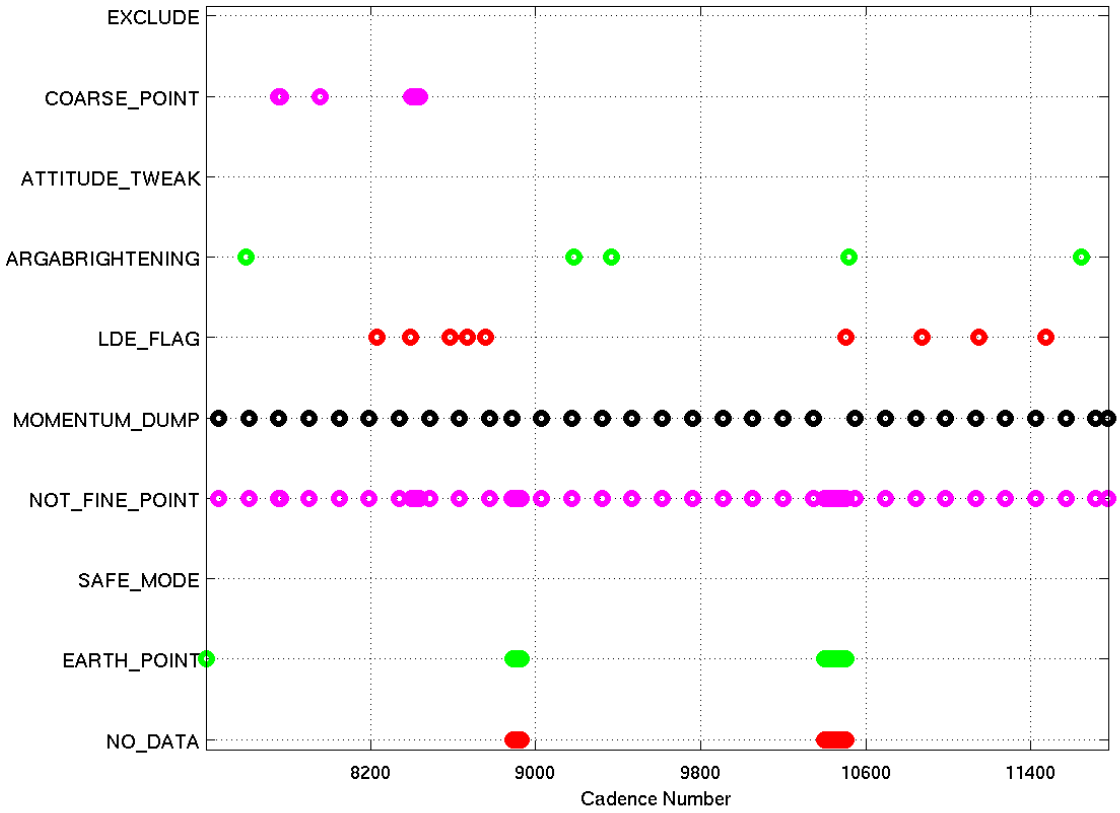


Figure 6: An overview of the location of the data anomalies flagged in Q3. ARGABRIGHTENING refers to cadences where the multiple-channel Argabrightening flag (flag 0x07, decimal value 64) was set.

3.2 No Events Unique to this Quarter

4 Q4 Notes

In this section we only discuss features of the data that are unique to Q4. For all other details about features present in the Kepler data, see the Data Characteristics Handbook (Christiansen *et al.*, 2013).

4.1 Summary of Data Anomalies

Certain cadences are flagged to indicate a possible reduction of quality. See the QUALITY and SAP_QUALITY columns of the target pixel and light curve files, respectively. Cadences with data anomalies that affect the entire focal plane are shown in the Figure below. The meaning of the flags are explained in the Data Characteristics Handbook (Christiansen *et al.*, 2013) and Archive Manual (Thompson and Fraquelli, 2014).

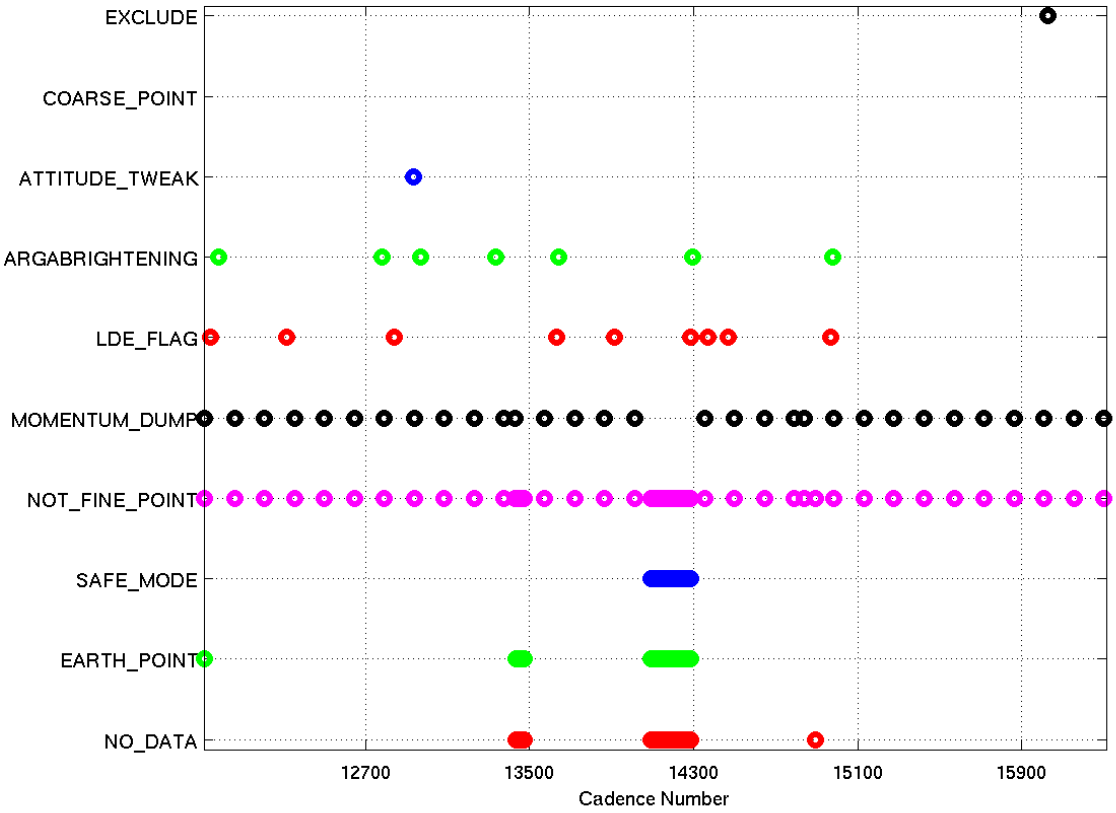


Figure 7: An overview of the location of the data anomalies flagged in Q4. ARGABRIGHTENING refers to cadences where the multiple-channel Argabrightening flag (flag 0x07, decimal value 64) was set.

4.2 Failure of Module 3

All 4 outputs of Module 3 failed at 17:52 UTC Jan 9, 2010 during LC CIN 12935. Reference pixels showed loss of stars and black levels decreased by 75 to 100 DN per frame. FFIs show no evidence of photons or electronically injected signals. The start of line ringing and FGS crosstalk are still present after the anomaly. The loss of the module led to consistent temperature drops within the LDE, telescope structure, Schmidt corrector, primary mirror, FPA modules, and acquisition/driver boards– which in turn affected photometry

and centroids across the full focal plane. The impact on science observations is that 20% of the FOV suffers a one-quarter data outage every year as Kepler performs its quarterly rolls. The cadence data sets for those targets on module three only contain cadences that occurred prior to the module failure.

5 Q5 Notes

In this section we only discuss features of the data that are unique to Q5. For all other details about features present in the Kepler data, see the Data Characteristics Handbook (Christiansen *et al.*, 2013).

5.1 Summary of Data Anomalies

Certain cadences are flagged to indicate a possible reduction of quality. See the QUALITY and SAP_QUALITY columns of the target pixel and light curve files, respectively. Cadences with data anomalies that affect the entire focal plane are shown in the Figure below. The meaning of the flags are explained in the Data Characteristics Handbook (Christiansen *et al.*, 2013) and Archive Manual (Thompson and Fraquelli, 2014).

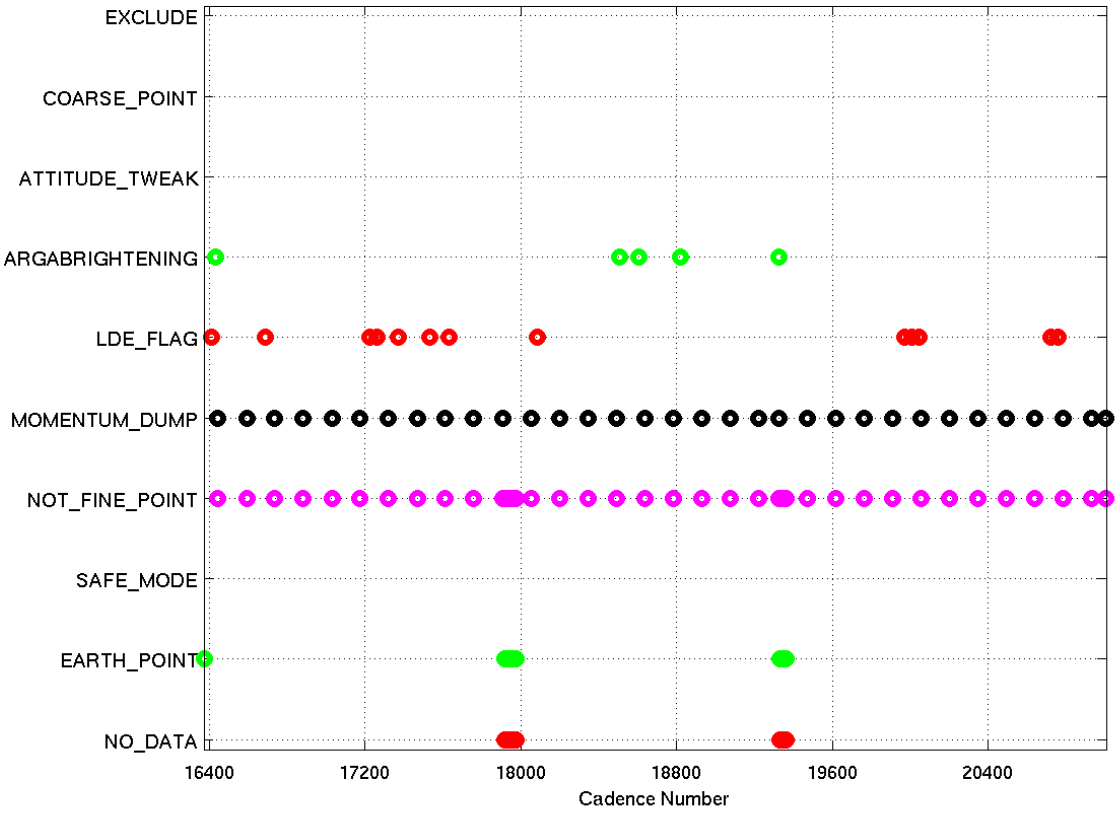


Figure 8: An overview of the location of the data anomalies flagged in Q5. ARGABRIGHTENING refers to cadences where the multiple-channel Argabrightening flag (flag 0x07, decimal value 64) was set.

5.2 No Events Unique to this Quarter

6 Q6 Notes

In this section we only discuss features of the data that are unique to Q6. For all other details about features present in the Kepler data, see the Data Characteristics Handbook (Christiansen *et al.*, 2013).

6.1 Summary of Data Anomalies

Certain cadences are flagged to indicate a possible reduction of quality. See the QUALITY and SAP_QUALITY columns of the target pixel and light curve files, respectively. Cadences with data anomalies that affect the entire focal plane are shown in the Figure below. The meaning of the flags are explained in the Data Characteristics Handbook (Christiansen *et al.*, 2013) and Archive Manual (Thompson and Fraquelli, 2014).

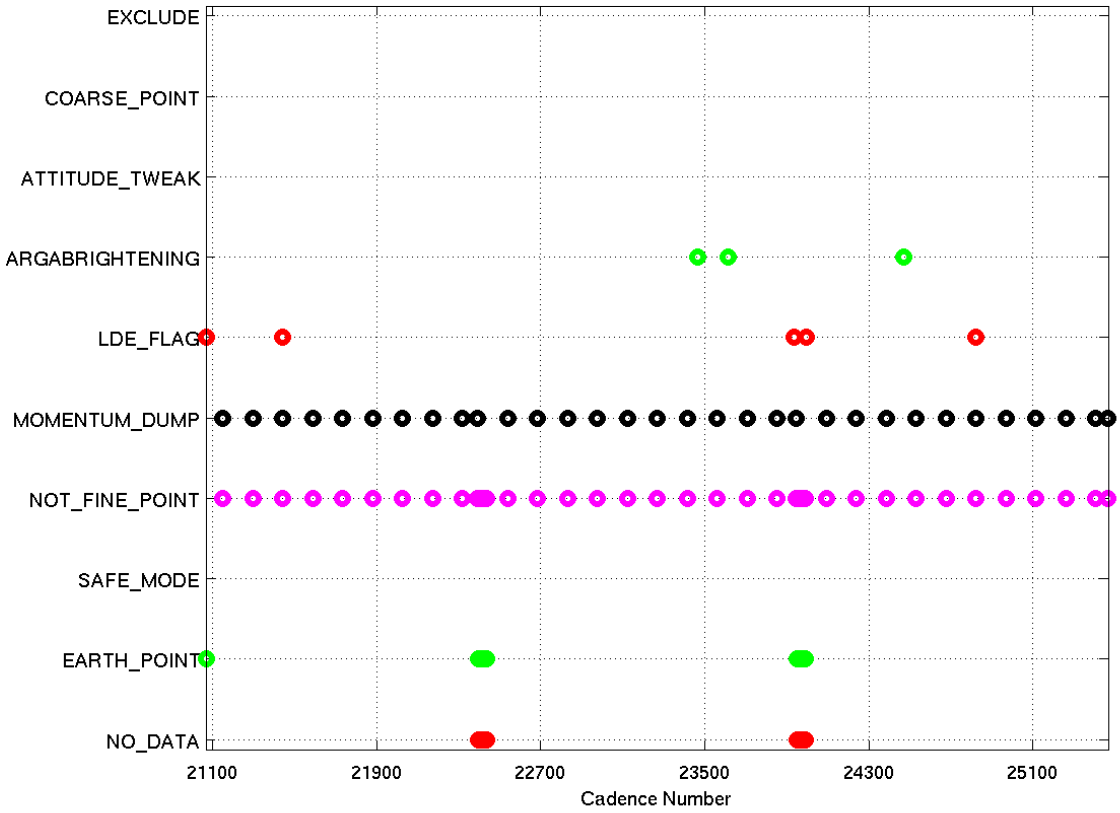


Figure 9: An overview of the location of the data anomalies flagged in Q6. ARGABRIGHTENING refers to cadences where the multiple-channel Argabrightening flag (flag 0x07, decimal value 64) was set.

6.2 No Events Unique to this Quarter

7 Q7 Notes

In this section we only discuss features of the data that are unique to Q7. For all other details about features present in the Kepler data, see the Data Characteristics Handbook (Christiansen *et al.*, 2013).

7.1 Summary of Data Anomalies

Certain cadences are flagged to indicate a possible reduction of quality. See the QUALITY and SAP_QUALITY columns of the target pixel and light curve files, respectively. Cadences with data anomalies that affect the entire focal plane are shown in the Figure below. The meaning of the flags are explained in the Data Characteristics Handbook (Christiansen *et al.*, 2013) and Archive Manual (Thompson and Fraquelli, 2014).

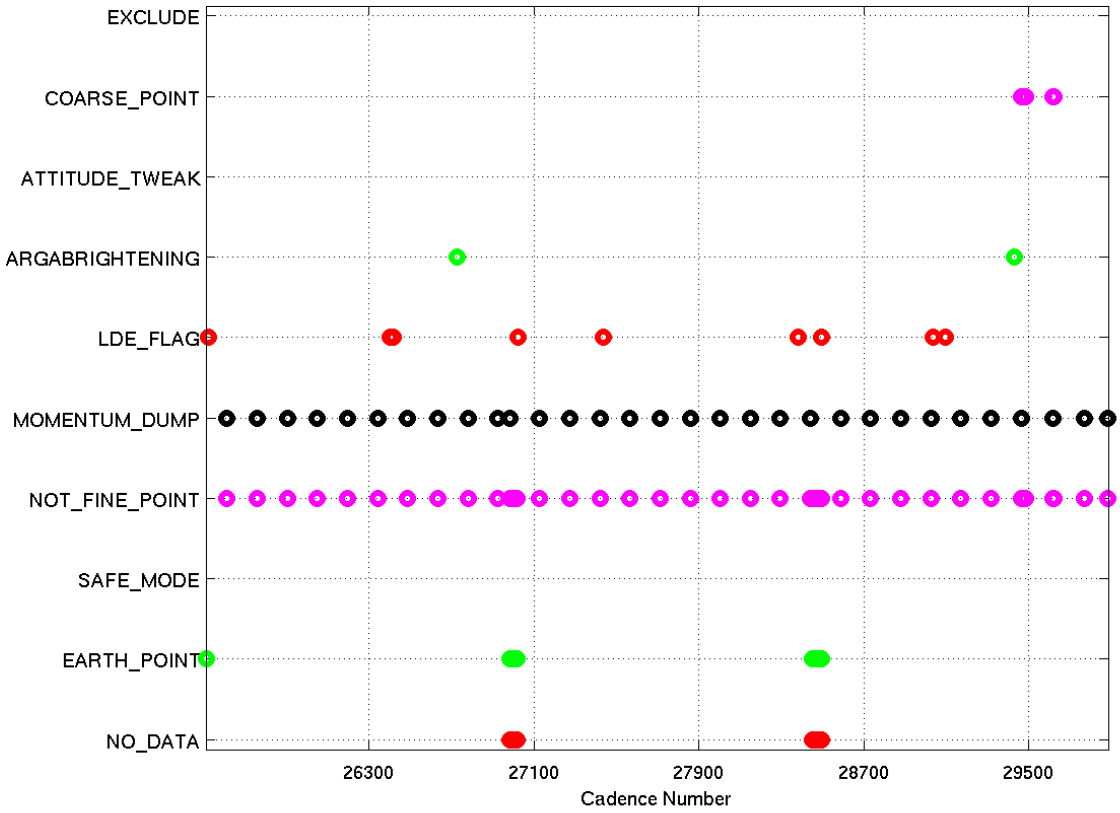


Figure 10: An overview of the location of the data anomalies flagged in Q7. ARGABRIGHTENING refers to cadences where the multiple-channel Argabrightening flag (flag 0x07, decimal value 64) was set.

7.2 No Events Unique to this Quarter

8 Q8 Notes

In this section we only discuss features of the data that are unique to Q8. For all other details about features present in the Kepler data, see the Data Characteristics Handbook (Christiansen *et al.*, 2013).

8.1 Summary of Data Anomalies

Certain cadences are flagged to indicate a possible reduction of quality. See the QUALITY and SAP_QUALITY columns of the target pixel and light curve files, respectively. Cadences with data anomalies that affect the entire focal plane are shown in the Figure below. The meaning of the flags are explained in the Data Characteristics Handbook (Christiansen *et al.*, 2013) and Archive Manual (Thompson and Fraquelli, 2014).

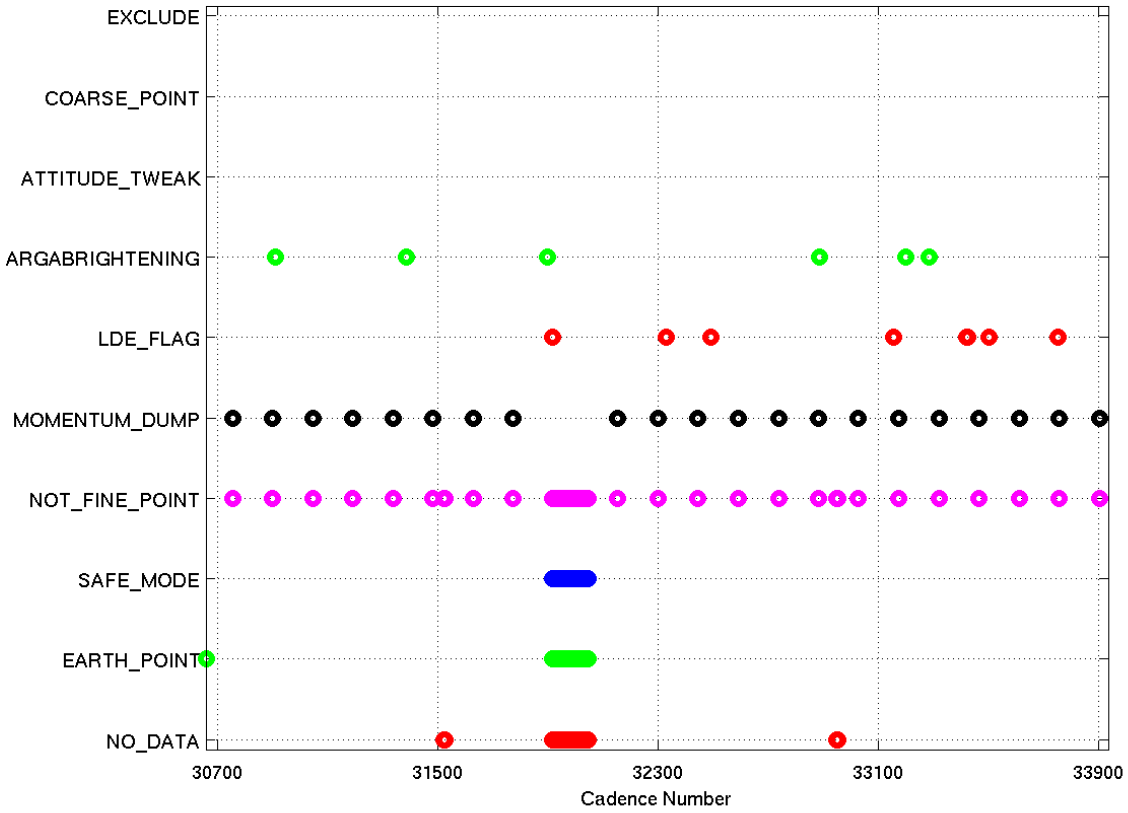


Figure 11: An overview of the location of the data anomalies flagged in Q8. ARGABRIGHTENING refers to cadences where the multiple-channel Argabrightening flag (flag 0x07, decimal value 64) was set.

8.2 Safe Mode

Three safe modes occurred in Q8 causing less data to be collected than originally scheduled. The first occurred shortly after the end of Q7 on 2010-12-22 and caused a delay in starting the Q8 observations. The second occurred on 2011-02-01, in the middle of the second month. See §A.1.9 regarding anomalous, unflagged SC data on either side of the second safe mode. The third occurred on 2011-03-14, causing Q8 to end prematurely.

9 Q9 Notes

In this section we only discuss features of the data that are unique to Q9. For all other details about features present in the Kepler data, see the Data Characteristics Handbook (Christiansen *et al.*, 2013).

9.1 Summary of Data Anomalies

Certain cadences are flagged to indicate a possible reduction of quality. See the QUALITY and SAP_QUALITY columns of the target pixel and light curve files, respectively. Cadences with data anomalies that affect the entire focal plane are shown in the Figure below. The meaning of the flags are explained in the Data Characteristics Handbook (Christiansen *et al.*, 2013) and Archive Manual (Thompson and Fraquelli, 2014).

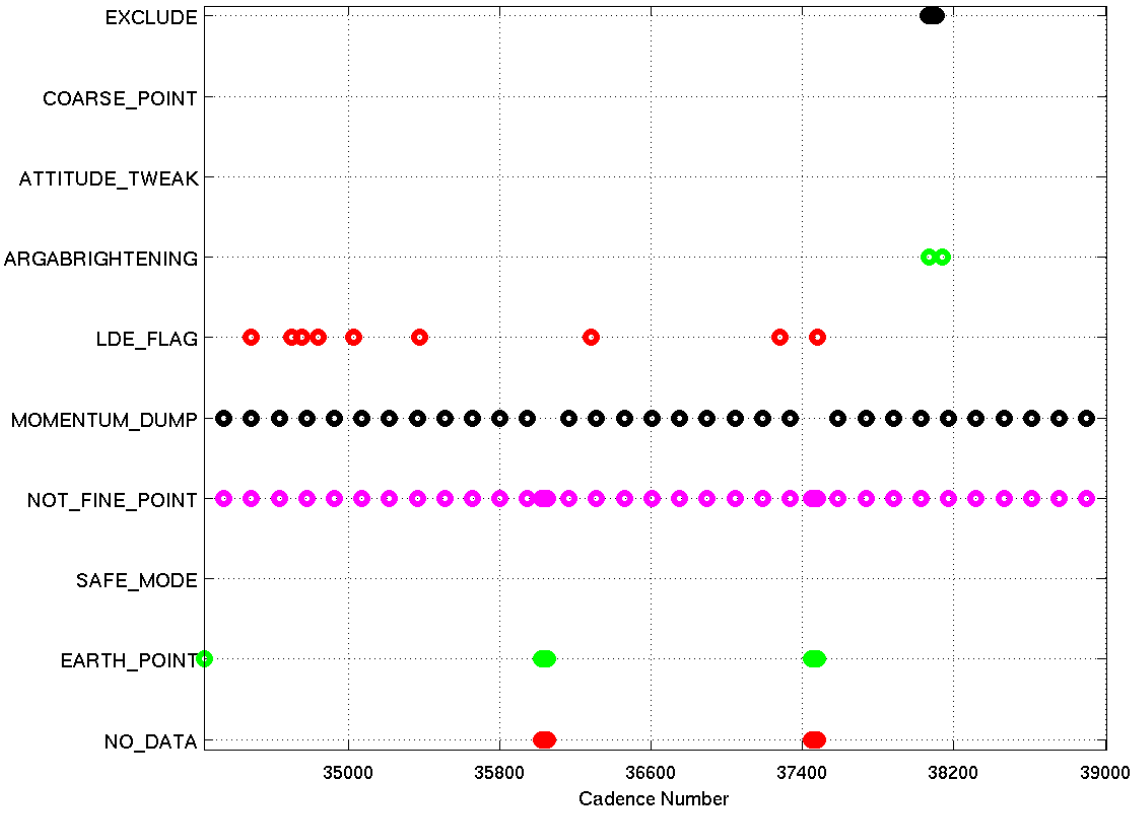


Figure 12: An overview of the location of the data anomalies flagged in Q9. ARGABRIGHTENING refers to cadences where the multiple-channel Argabrightening flag (flag 0x07, decimal value 64) was set.

9.2 Safe Mode before Q9

As mentioned in section §8.2, a Safe Mode occurred on 2011-03-14, before the beginning of Q9. It has no apparent impact on the Q9 data.

9.3 LDE Out of Sync

During Q9 the Local Detector Electronics (LDE) became out of sync after the second Earth-point. This resulted in the first 30 short cadences not being processed; only raw pixel data exists for these cadences. This is the first instance of this anomaly.

10 Q10 Notes

In this section we only discuss features of the data that are unique to Q10. For all other details about features present in the Kepler data, see the Data Characteristics Handbook (Christiansen *et al.*, 2013).

10.1 Summary of Data Anomalies

Certain cadences are flagged to indicate a possible reduction of quality. See the QUALITY and SAP_QUALITY columns of the target pixel and light curve files, respectively. Cadences with data anomalies that affect the entire focal plane are shown in the Figure below. The meaning of the flags are explained in the Data Characteristics Handbook (Christiansen *et al.*, 2013) and Archive Manual (Thompson and Fraquelli, 2014).

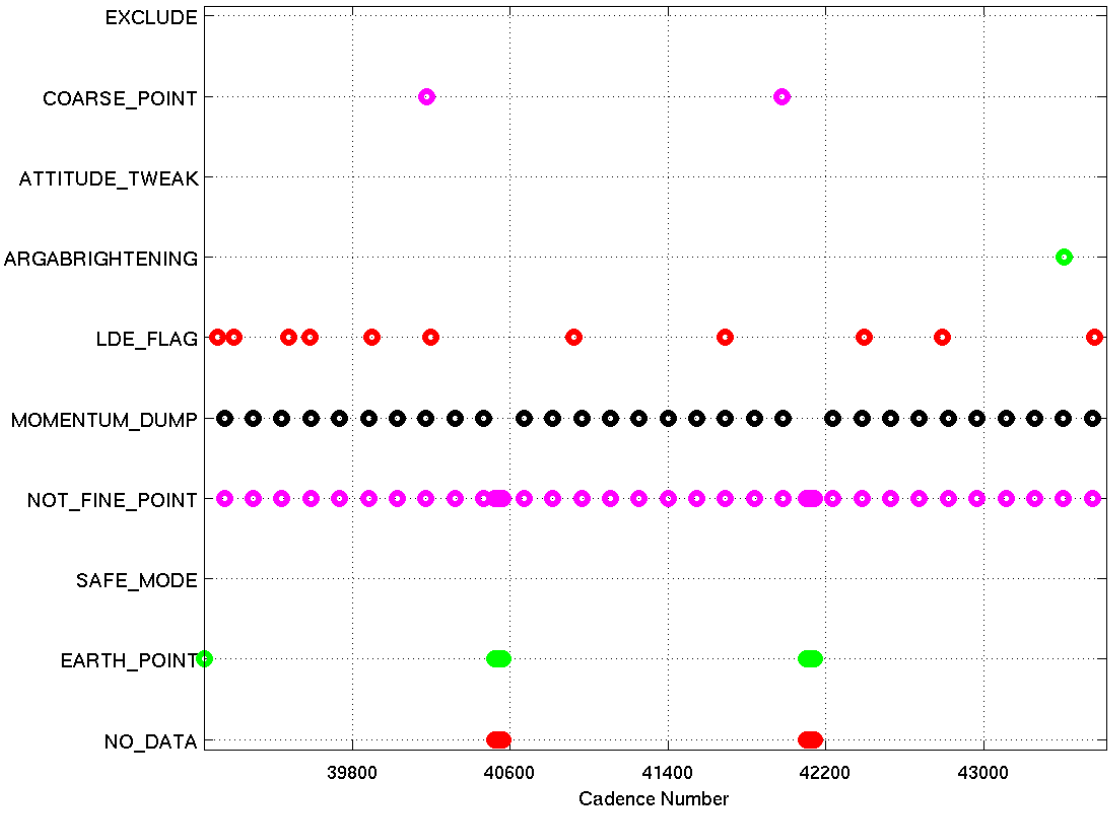


Figure 13: An overview of the location of the data anomalies flagged in Q10. ARGABRIGHTENING refers to cadences where the multiple-channel Argabrightening flag (flag 0x07, decimal value 64) was set.

10.2 No Events Unique to this Quarter

11 Q11 Notes

In this section we only discuss features of the data that are unique to Q11. For all other details about features present in the Kepler data, see the Data Characteristics Handbook (Christiansen *et al.*, 2013).

11.1 Summary of Data Anomalies

Certain cadences are flagged to indicate a possible reduction of quality. See the QUALITY and SAP_QUALITY columns of the target pixel and light curve files, respectively. Cadences with data anomalies that affect the entire focal plane are shown in the Figure below. The meaning of the flags are explained in the Data Characteristics Handbook (Christiansen *et al.*, 2013) and Archive Manual (Thompson and Fraquelli, 2014).

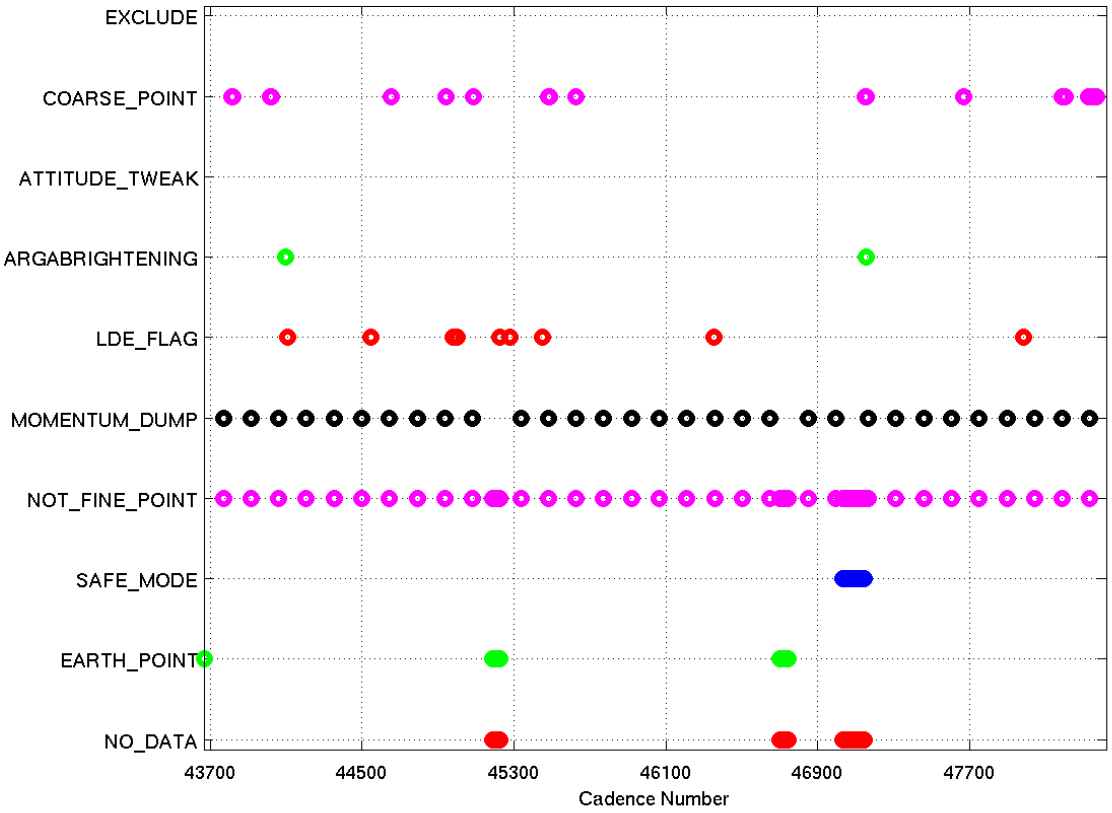


Figure 14: An overview of the location of the data anomalies flagged in Q11. ARGABRIGHTENING refers to cadences where the multiple-channel Argabrightening flag (flag 0x07, decimal value 64) was set.

11.2 No Events Unique to this Quarter

12 Q12 Notes

In this section we only discuss features of the data that are unique to Q12. For all other details about features present in the Kepler data, see the Data Characteristics Handbook (Christiansen *et al.*, 2013).

12.1 Summary of Data Anomalies

Certain cadences are flagged to indicate a possible reduction of quality. See the QUALITY and SAP_QUALITY columns of the target pixel and light curve files, respectively. Cadences with data anomalies that affect the entire focal plane are shown in the Figure below. The meaning of the flags are explained in the Data Characteristics Handbook (Christiansen *et al.*, 2013) and Archive Manual (Thompson and Fraquelli, 2014).

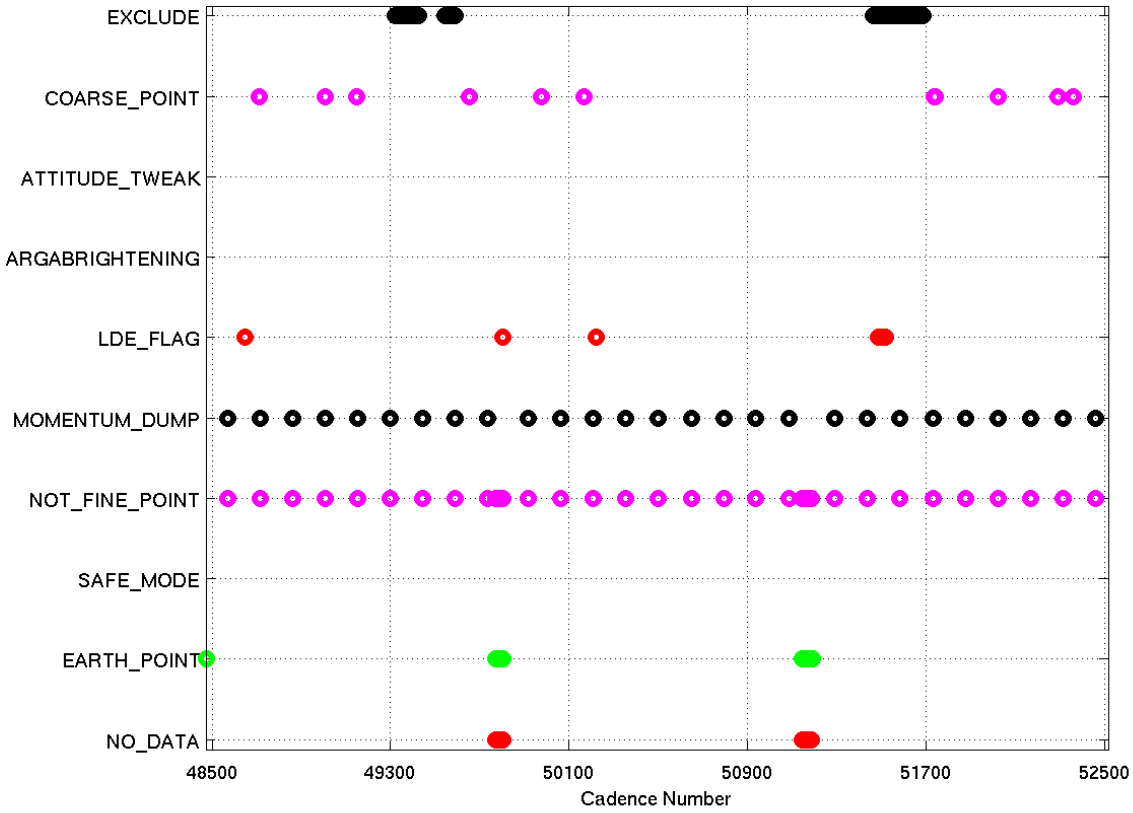


Figure 15: An overview of the location of the data anomalies flagged in Q12. ARGABRIGHTENING refers to cadences where the multiple-channel Argabrightening flag (flag 0x07, decimal value 64) was set.

12.2 Data Loss and Detector Changes from Coronal Mass Ejections

Data quality during Q12 was affected by three coronal mass ejections (CMEs). Cadences impacted by the CMEs were marked with the Manual Exclude flag (0x09, decimal 256) in the SAP_QUALITY column of the light curve files (and the QUALITY column in the target pixel files). Users are strongly discouraged from using the data collected during these events.

During these CMEs, the flux of charged particles from the sun impacting the spacecraft increased by many orders of magnitude causing an increase in measured dark current and the"cosmic ray" count. The fine guidance sensors were also impacted, so the pointing of the spacecraft deviated from the nominal value by many milli-pixels.

Users should note that the detector underwent some long-term changes after the CMEs. These effects are particularly noticeable after the third, and most powerful, CME. In particular:

- The dark current rose slightly. This increase does not materially affect data quality.
- A small number of pixels show a pronounced drop in sensitivity after the largest CME. When a target star falls on one or more of these pixels, the mean measured flux will be lower after the CME than before. In the majority of such cases, the pixel-sensitivity dropout corrector in PDC is unable to correct for these discontinuities because of the intervening gapped cadences. PDC can only correct global systematic errors and thus these sensitivity dropouts cannot be dealt with effectively by the algorithm. Hence, PDC fails to correct most of them and often introduces additional low-frequency artifacts into the light curve (see Figure 16).

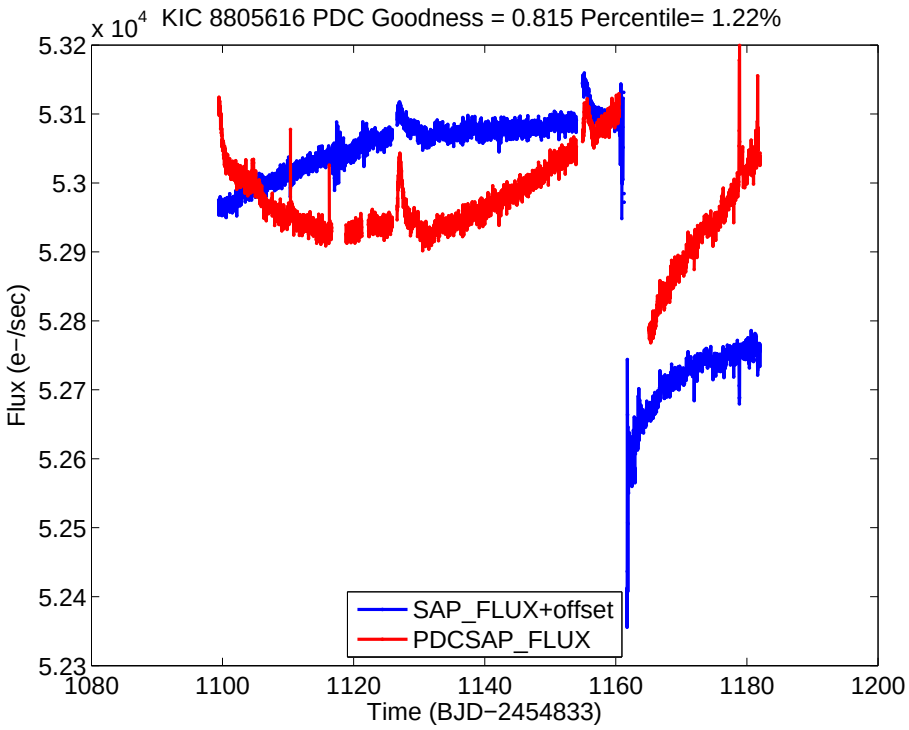


Figure 16: Flux time series showing a discontinuity that can happen after the CME. The blue and red curves show the PA and PDC light curves, respectively. Notice that since the SPSD detector does not attempt to correct the discontinuities following the CME, PDC introduces a long term trend into the data.

13 Q13 Notes

In this section we only discuss features of the data that are unique to Q13. For all other details about features present in the Kepler data, see the Data Characteristics Handbook (Christiansen *et al.*, 2013).

13.1 Summary of Data Anomalies

Certain cadences are flagged to indicate a possible reduction of quality. See the QUALITY and SAP_QUALITY columns of the target pixel and light curve files, respectively. Cadences with data anomalies that affect the entire focal plane are shown in the Figure below. The meaning of the flags are explained in the Data Characteristics Handbook (Christiansen *et al.*, 2013) and Archive Manual (Thompson and Fraquelli, 2014).

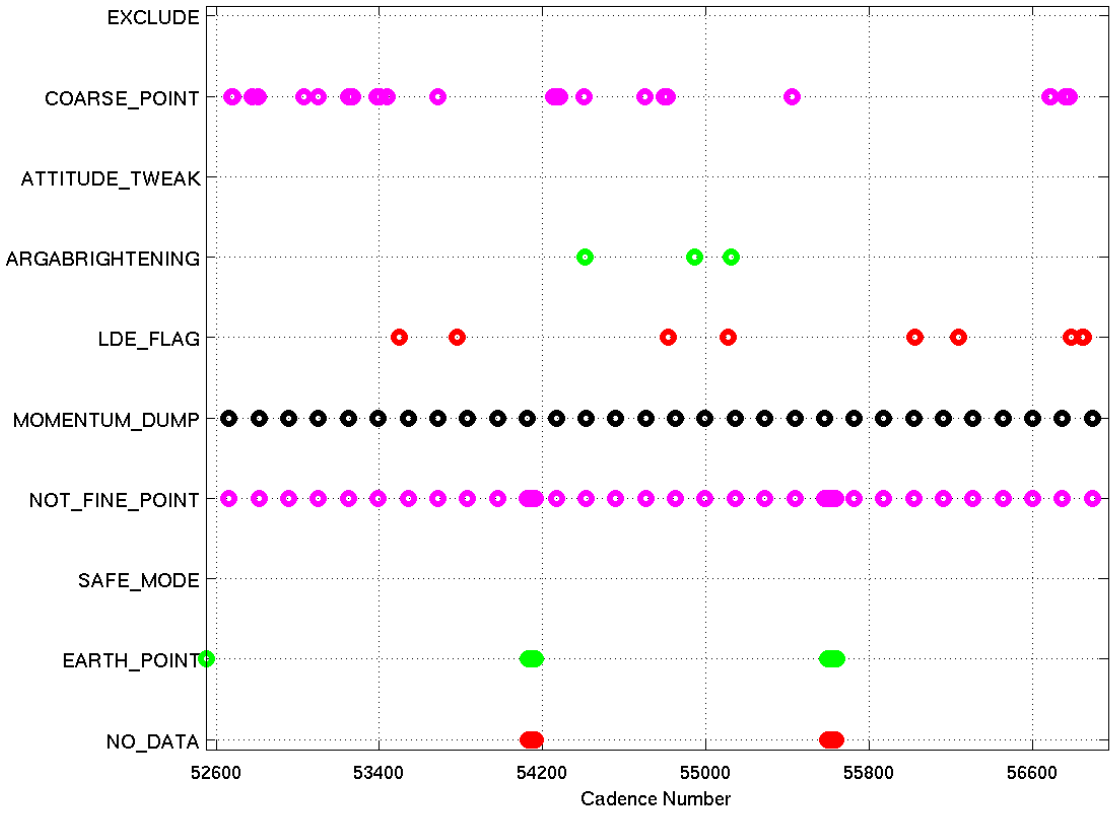


Figure 17: An overview of the location of the data anomalies flagged in Q13. ARGABRIGHTENING refers to cadences where the multiple-channel Argabrightening flag (flag 0x07, decimal value 64) was set.

13.2 Reaction Wheel Zero Crossings

A software change on the spacecraft was implemented that prevents the reaction wheel velocities from crossing zero. This is the cause for the absence of cadences with the zero-crossing flag (QUALITY flag 0x05, decimal value 16) being set in Q13 and all subsequent quarters.

14 Q14 Notes

In this section we only discuss features of the data that are unique to Q14. For all other details about features present in the Kepler data, see the Data Characteristics Handbook (Christiansen *et al.*, 2013).

14.1 Summary of Data Anomalies

Certain cadences are flagged to indicate a possible reduction of quality. See the QUALITY and SAP_QUALITY columns of the target pixel and light curve files, respectively. Cadences with data anomalies that affect the entire focal plane are shown in the Figure below. The meaning of the flags are explained in the Data Characteristics Handbook (Christiansen *et al.*, 2013) and Archive Manual (Thompson and Fraquelli, 2014).

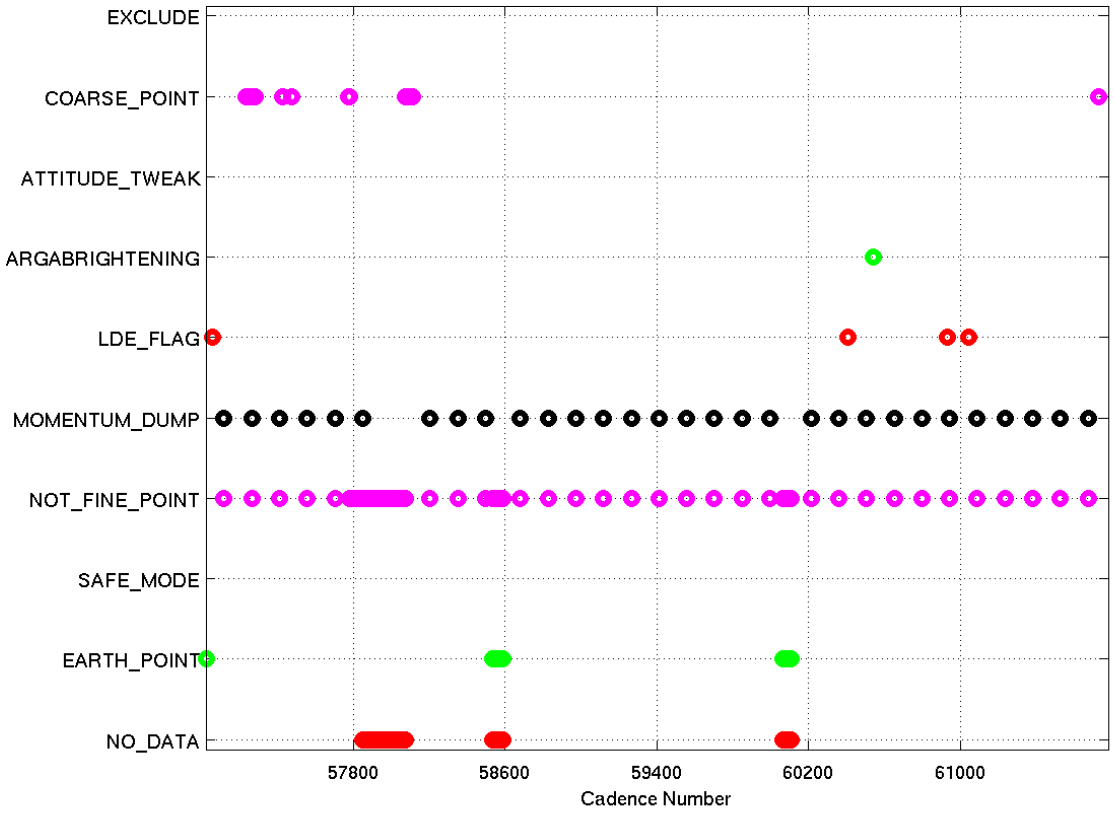


Figure 18: An overview of the location of the data anomalies flagged in Q14. ARGABRIGHTENING refers to cadences where the multiple-channel Argabrightening flag (flag 0x07, decimal value 64) was set.

14.2 The Leap Second Cadence

During Q14, a leap second was applied to Coordinated Universal Time (UTC). The start time reported to the SOC for the cadence containing the leap second (CIN 57140) was incorrect, causing the mid-exposure time (MJD and BKJD times) for this cadence to be misreported in all FITS files. The error is on the order of one second. The times reported for all other cadences are expected to be correct. Note, the exposure time for CIN 57140 is the same as all other cadences.

14.3 Reaction Wheel Failure

Kepler lost reaction wheel 2 due to excess friction on 2012-07-14 (MJD 56122) and returned to science data collection using three reaction wheels on 2012-07-20 (MJD 56128). The intervening six days of data has been excluded, as is normally the case for coarse point data. This change in attitude control occurred midway through Q14 month 1. However, Kepler's performance on three wheels appears nominal, so the three- and four-wheel data have been processed and exported as usual (i.e., by month for short-cadence and by quarter for long-cadence).

14.4 Missing Short Cadence Flags

A small number of short cadences were not marked as COARSE_POINT during the reaction wheel failure. These cadences are not suitable for science, and should be removed before analyzing short cadence data. The affected short cadences range from 1721709 to 1731878, or MJD 56121.975 to 56128.902.

14.5 Coronal Mass Ejection

The spacecraft was effected by a small Coronal Mass Ejection on 2012-06-25, in the first month of Q14 data. The effects can be seen for an approximately 16-hour period, from long cadences 57519 to 57551, in the collateral data and in the background flux time series. Data quality was not degraded to the point of flagging or exclusion.

15 Q15 Notes

In this section we only discuss features of the data that are unique to Q15. For all other details about features present in the Kepler data, see the Data Characteristics Handbook (Christiansen *et al.*, 2013).

15.1 Summary of Data Anomalies

Certain cadences are flagged to indicate a possible reduction of quality. See the QUALITY and SAP_QUALITY columns of the target pixel and light curve files, respectively. Cadences with data anomalies that affect the entire focal plane are shown in the Figure below. The meaning of the flags are explained in the Data Characteristics Handbook (Christiansen *et al.*, 2013) and Archive Manual (Thompson and Fraquelli, 2014).

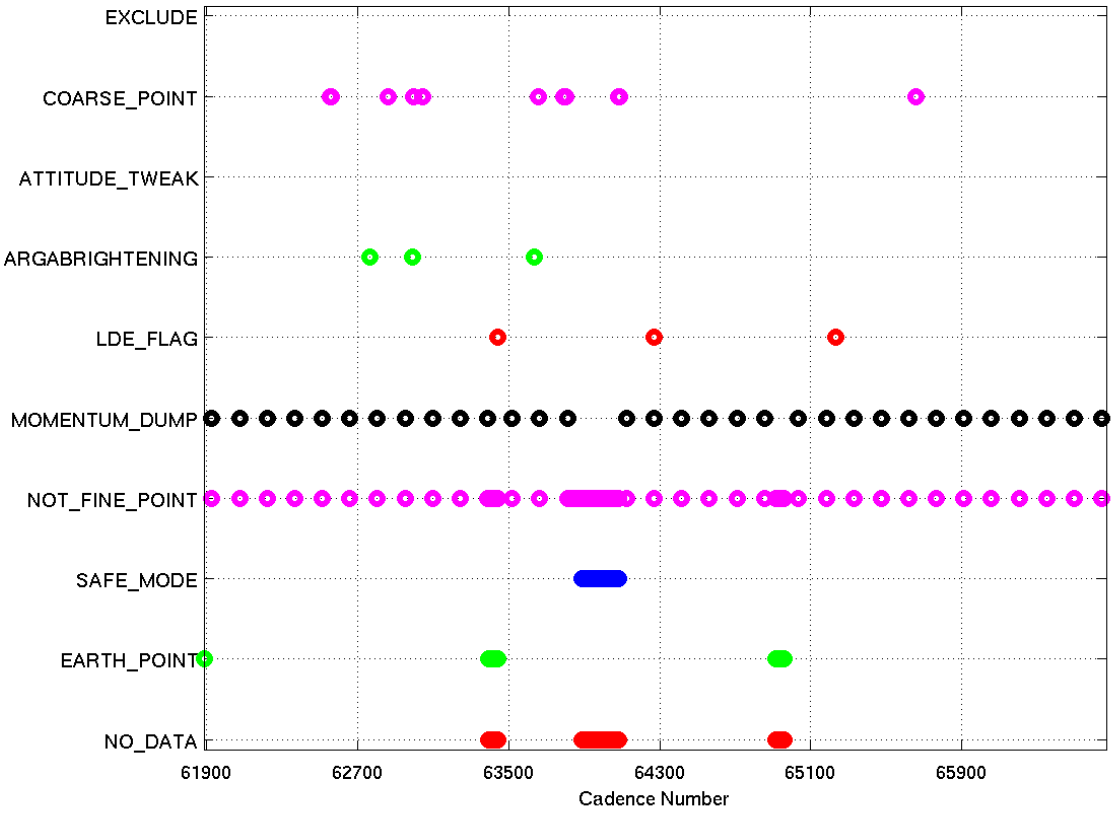


Figure 19: An overview of the location of the data anomalies flagged in Q15. ARGABRIGHTENING refers to cadences where the multiple-channel Argabrightening flag (flag 0x07, decimal value 64) was set.

15.2 No Events Unique to this Quarter

16 Q16 Notes

In this section we only discuss features of the data that are unique to Q16. For all other details about features present in the Kepler data, see the Data Characteristics Handbook (Christiansen *et al.*, 2013).

16.1 Summary of Data Anomalies

Certain cadences are flagged to indicate a possible reduction of quality. See the QUALITY and SAP_QUALITY columns of the target pixel and light curve files, respectively. Cadences with data anomalies that affect the entire focal plane are shown in the Figure below. The meaning of the flags are explained in the Data Characteristics Handbook (Christiansen *et al.*, 2013) and Archive Manual (Thompson and Fraquelli, 2014).

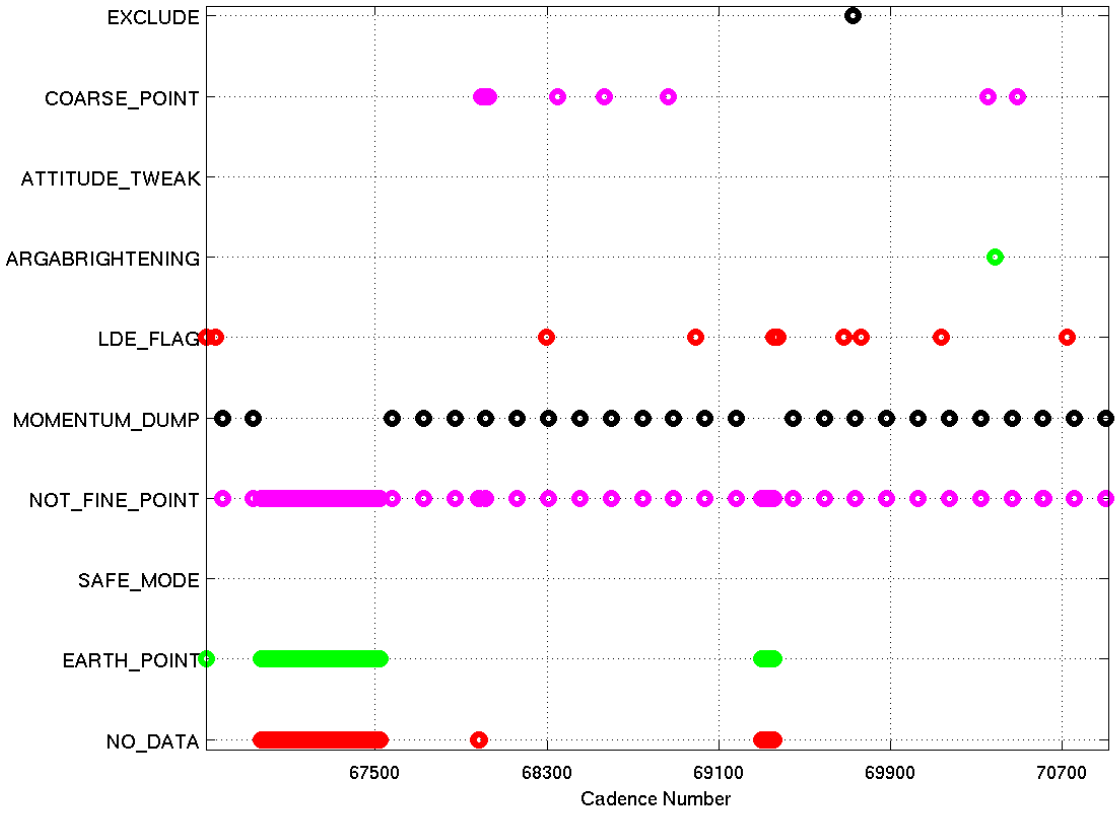


Figure 20: An overview of the location of the data anomalies flagged in Q16. ARGABRIGHTENING refers to cadences where the multiple-channel Argabrightening flag (flag 0x07, decimal value 64) was set.

16.2 Reaction Wheel 4

Reaction wheel 4 suffered a temporary increase in friction between approximately CIN 67920 and 68100, which coincided with a slight degradation in pointing stability. Although a cursory analysis did not show any loss of data quality during this time, we have marked cadences 67996 and 68010–68013 as COARSE_POINT (see Figure 20) because they crossed our 0.5 millipixel pointing-deviation threshold. Users should be suspicious of unusual events in their light curves during this time.

16.3 Resting the Spacecraft

Because of a detected increase in the amount of torque required to spin one of the three remaining reaction wheels, Kepler opted to place the spacecraft in a "wheel rest" safe mode for a period of 11.3 days. Resting the wheels provided an opportunity to redistribute internal lubricant in the reaction wheels and hopefully cause the friction levels to return to normal. The rest started on January 17, 2013 (CIN 66968) and ended on January 29, 2013 (CIN 67522). No data was collected during this rest.

Following the rest, the target tables for month two were loaded and CIN 67523 marks the beginning of the second month of observations for Q16. The result is a short, first month of data, lasting only 5.2 days, and a somewhat longer, second month of data, lasting 36.3 days. At the normal monthly gap (February 2, 2013), the science collection was paused for 1.5 hours to collect an FFI for Q16.

16.4 Thermal Changes Following the Spacecraft Rest

The centroid offsets measured by the PA portion of the pipeline showed a rapid change in position in the few weeks following an eleven-day rest of the spacecraft (January 17 to 29, 2013). Because the rest occurred at a non-science attitude, the telescope underwent extensive thermal changes during this time. The unusually large centroid deviations which occurred upon return to science data collection are a result of the re-equilibration that occurred once science attitude was restored. This is confirmed by measurements of the temperatures of the primary mirror, Schmidt corrector, LDE central acquisition board, and Driver board, which all show a thermal settling that is correlated with the unusual centroid measurements. Users may notice an increase in systematic errors due to the thermal and pointing changes during this period, similar to what is observed at the start of a quarter or a return from safe-mode.

16.5 Solar Weather

There were a number of small solar flares during this quarter. Small flares increase the observed dark current so their effect is most noticeable for faint targets. Stronger flares can reduce pointing accuracy, and therefore affect the photometry of all stars, by interfering with the Fine Guidance Sensors. We marked a single cadence (CIN 69724) with the EXCLUDE flag due to the effect of a solar flare on spacecraft pointing. A number of cadences immediately before and after this cadence also show elevated dark current, but these have smaller pointing excursions.

17 Q17 Notes

In this section we only discuss features of the data that are unique to Q17. For all other details about features present in the Kepler data, see the Data Characteristics Handbook (Christiansen *et al.*, 2013).

17.1 Summary of Data Anomalies

Certain cadences are flagged to indicate a possible reduction of quality. See the QUALITY and SAP_QUALITY columns of the target pixel and light curve files, respectively. Cadences with data anomalies that affect the entire focal plane are shown in the Figure below. The meaning of the flags are explained in the Data Characteristics Handbook (Christiansen *et al.*, 2013) and Archive Manual (Thompson and Fraquelli, 2014).

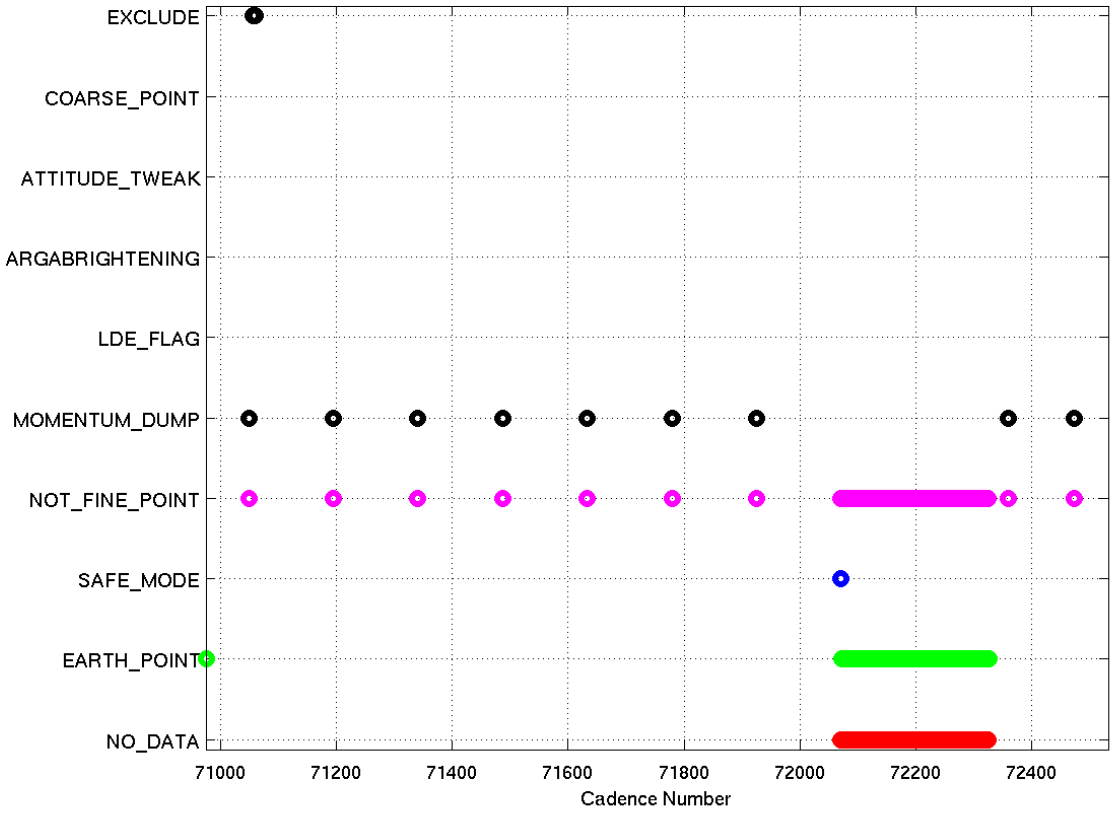


Figure 21: An overview of the location of the data anomalies flagged in Q17. ARGABRIGHTENING refers to cadences where the multiple-channel Argabrightening flag (flag 0x07, decimal value 64) was set.

17.2 Solar Flare

The sun emitted a series of X-ray flares on and around CIN 71058 in month 1 of Q17. Cadences 71056 to 71060 were gapped with the EXCLUDE flag to indicate that this data is of bad quality. However, the dark current remained elevated for several hours after the peak of the event, and users may notice degraded quality, especially for fainter stars.

17.3 PDC Corrected Short Cadence Data

As discussed in §5.15 of the Data Characteristics Handbook (Christiansen *et al.*, 2013), PDC attenuates signals with timescales longer than approximately one third the quarter duration. For Q17, this timescale is shorter than normal, ∼7-10 days, instead of the typical ∼20 days for full-length quarters.

In short cadence, MAP is applied on a monthly basis. Since Q17M2 is only a week long, signals with timescales longer than a few days are removed. Short cadence data for this month should not be used to examine phenomena with timescales of days or longer.

17.4 Final Data Set Collected

The second month of Q17 was terminated by a safe mode event. After the spacecraft was commanded to return to science attitude, reaction wheel 4 failed and the spacecraft returned to safe mode. Extensive analysis concluded that neither of the two failed wheels could be recovered. With only two wheels, it is not possible to point at the Kepler field for the purpose of collecting high precision photometry. No futher data will be collected for the original Kepler Mission; but a re-purposed mission, known as *K2*, is using the *Kepler* spacecraft to look at fields along the ecliptic and began on 2014-03-12 (Howell *et al.*, 2014).

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