New and Improved Saturated Pixel Flagging for the ACS/WFC

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Abstract

Accurate characterization of the saturation level of the ACS/WFC CCD is crucial for proper flagging of affected pixels, which users and calibration routines require knowledge of. In this work, we present a new analysis of the saturation level that offers significant improvements and advantages over previously used methods. Unlike previous work, we measure the onset of saturation directly by identifying the precise charge level at which the brightest pixel of point sources begins to spill charge into neighboring pixels. This results in a sharp decrease in the fraction of charge contained in the central pixel, coupled with a sharp increase in the fraction of charge contained in neighboring pixels. Through this analysis, we find that the saturation level has a strong spatial dependence over the detector area and exhibits significant (± ∼ 6% about the mean) variations, in agreement with previous work. Despite this qualitative agreement, we find that the saturation level currently used in the CALACS calibration pipeline to flag affected pixels is much too high, causing it to routinely miss many clearly saturated pixels. When using our new saturation map to perform the flagging, we find visually superior results and as many as ∼ 15% more pixels being flagged as saturated in any given frame. We announce plans to implement our new saturation map into CALACS, and discuss extensions of this work.
1 Introduction

Accurate characterization of the saturation level of the ACS/WFC CCD is crucial for proper flagging of affected pixels, which users and calibration routines require knowledge of. In this context, saturation can be defined as the charge level (in electrons) above which a particular pixel loses its ability to linearly integrate more charge, and the pixel starts to spill some of the excess charge into its neighboring pixels (usually called ‘bleeding’ or ‘blooming’), discussed further in Section 2. This renders both the saturated pixels and all neighboring pixels suspect for calibration and science calculations at best, and completely unusable at worst.

Early ACS work on this topic was carried out by Gilliland (2004), who used characteristics of saturated star images to estimate the saturation level, though only indirectly. Following SM4, a new measurement of the saturation level was performed using photon transfer curve analysis (Golimowski et al., 2011), but the measured values were only accurate to within $\pm \sim 15\%$ due to relatively sparse sampling. Uncertainties that large in this measurement has evidently led to misbehaved saturation flagging (e.g. middle right column of Figure 5). Also, despite both previous analyses finding a position-dependent saturation level with significant variations ($\pm 6\%$ about the mean) over the detector area, only a single scalar threshold has ever been used for saturation flagging in the ACS/WFC calibration pipeline. In this work, we present a new analysis of the saturation level which offers improvements and advantages over both previous methods. We show that using our newly characterized saturation level, including its detector position dependence, provides superior saturated pixel flagging compared to the current uniform threshold. We discuss plans to implement the saturation map and flagging routine into the calibration pipeline (hereafter “CALACS”).

Note that there are two types of saturation discussed in the HST (and general CCD) literature and documentation (Ryon et al., 2019): analog-to-digital (A-to-D) converter saturation, and full-well saturation. In this work we are concerned only with full-well saturation, which can only occur for gain settings (header keyword CCDGAIN) of 1.4 and higher for the WFC CCD. However, since CCDGAIN=2 is the only currently supported setting, and the one used by the large majority of archival data, we restrict our analysis and results to images using CCDGAIN=2. We briefly discuss the impact on other gain settings in Section 3.2.

2 An Understanding and Definition of Saturation

We first examine a set of WFC pixels that we dub ‘super-hot’ pixels. These are a subset of ordinary hot pixels (Riess et al., 2002; Ogaz et al., 2015), with the added definition that their dark current is sufficiently high to cause them to be saturated in the typical WFC long darks ($\sim 1000\,$s); some have dark currents as high as $\sim 2000\,$ electrons per second, as measured from the WFC short darks ($\sim 8\,$s total dark time). Cutouts of a small region surrounding four of these super-hot pixels as seen in recent short and long super-darks (Lucas et al., 2018) are shown in Figure 1. At least a dozen of these super-hot pixels appear to be permanent (likely manufacturing defects) and are present in all WFC frames since ACS installation. In addition to those, as the detector has aged, there have been an increasing
Figure 1: Cutouts (21 × 41 pixels) of recent short (top row and colorbar) and long (bottom row and colorbar) superdarks centered on four ‘super-hot’ pixels (defined in the text), each located on a different quadrant of the full WFC frame. The source super-hot pixel (the location of which is first identified in the short darks) is indicated with a red cross, and the serial and parallel readout directions are indicated with the red arrows. Charge seen in pixels other than the source pixel result from various different effects: familiar vertical charge blooming in the column of the source pixel; CTE loss trails in both the serial and parallel directions opposite to readout; and a newly documented effect (presumably horizontal charge blooming) resulting in additional charge leaking into either or both columns flanking the central hot column.

number of temporary or newly-permanent super-hot pixels appearing in any given anneal cycle, with as many as ∼125 identified in some of the most recent (late 2019) darks. These pixels and their bleed trails are obviously a nuisance for science users of the instrument (e.g. Miles (2018)). However, they provide an extremely unique and useful opportunity to study saturation in-orbit, because: 1) all the charge originates from a single pixel, which allows us to study the properties of bled charge into neighboring pixels decoupled from charges from other sources; 2) they are not convolved with the PSF since the source of their charge originates in the detector and does not pass through optical elements; 3) the dark current is typically stable over long timescales; and 4) they appear in all dark and science frames, at identical pixel coordinates, meaning we can identify and study them with ease in tens of thousands of images across orders of magnitude in dark time and throughout the detector lifetime.

Making use of the last of those facts, we have plotted in Figure 2 the intensity of a representative super-hot pixel (blue scatter points), and the two immediately neighboring pixels in its column (red and green scatter points), as a function of dark time (integration
Figure 2: Intensity of a particular ‘super-hot’ pixel (blue scatter points), and its two nearest neighboring pixels in its column (red and green scatter points), as a function of dark time. The plotted scatter data are taken from a sample of over 40,000 individual WFC exposures spanning more than three orders of magnitude in dark time. The black solid line is a piecewise fit consisting of three linear functions fit to the central super-hot pixel data in log-log space; the three pieces are constrained to be continuous at the two breakpoints. The grey, vertical, dashed lines are plotted at the abscissa of the two fitted breakpoints, and are meant to delineate the three regimes of pixel behavior which we describe in the main text.

time of dark current, which is a sum of exposure time and additional time during which dark current may accumulate). The plotted measurements come from over 40,000 post-SM4 WFC (bias-subtracted) images, spanning integration times between $\sim 0.5\text{s}$ to $\sim 3,000\text{s}$. The aim of this figure is to illustrate the different regimes of charge accumulation. (The behavior of any of the other super-hot pixels and its neighbors is qualitatively the same.) The black solid line is a piecewise fit consisting of three linear functions fit to the super-hot pixel data in log-log space; the three pieces are constrained to be continuous at the two breakpoints. The grey, vertical, dashed lines are plotted at the abscissa of the two fitted breakpoints, and are meant to delineate the three regimes of charge-accumulation which we have identified: In the first regime, left of the first dashed line, the super-hot pixel integrates linearly (which appears curved in the plotted semi-log space), while its two neighboring pixels are consistent with the background level, as expected. Immediately right of the first dashed line, the super-hot pixel begins to bleed some, but not all, further accumulated charge into its neighboring pixels, causing the sudden increase in their intensity, and the sub-linear integration of the super-hot pixel; this behavior continues until the second dashed line. Finally, right of the second dashed line, the integration curve of the source pixel shallows once again to a vanishingly small slope, asymptotically approaching a charge level beyond which it cannot generally exceed\footnote{This ‘asymptotic’ or ‘maximum’ charge level that pixels seem to reach is an interesting and potentially important topic on its own. For example, we have found that this level is nearly constant within any given pixel column of the chip, and that this level can actually be exceeded under certain extreme circumstances. A full discussion of this topic is beyond the scope of this work.}.\footnote{This ‘asymptotic’ or ‘maximum’ charge level that pixels seem to reach is an interesting and potentially important topic on its own. For example, we have found that this level is nearly constant within any given pixel column of the chip, and that this level can actually be exceeded under certain extreme circumstances. A full discussion of this topic is beyond the scope of this work.}
The details of the pixel behavior observed in this figure (also see Fig. 3.9 of [Howell, 2006]) are applicable to all charge-accumulating pixels (i.e. not just ‘super-hot’ pixels) and guide us in deciding how we should define ‘saturation’ for practical purposes, and how we quantify the saturation onset. In the context of this work, we define the saturation level as the intensity of a charge-accumulating pixel at which bleeding begins (i.e. the intensity corresponding to the first dashed line in Figure 2 for that particular pixel), which we differentiate from the intensity that the pixel asymptotically approaches at even higher charge levels/integration times. Our goal then is to detect and measure the onset of this blooming and map it out over the WFC CCD area, as discussed in the following section. The details of the pixel behavior gleaned from Figure 2, coupled with the full saturation map which we produce in this work, are also crucial ingredients for accurate predictive modeling images of saturated sources, which we plan to develop in future work (Section 4).

3 Saturation Map for the ACS/WFC

3.1 A Direct and Accurate Measurement of the Saturation Level

In order to measure the saturation level of a given pixel (or small group of pixels, assuming local variations are small) directly, we need to identify the charge level above which it starts to bleed charge into its neighboring pixels. For the case of individual super-hot pixels discussed in the previous section, we can rather easily fit/measure the saturation level in plots like Figure 2. However, there is not a dense enough sampling of these objects over the detector area for an accurate and high resolution map (though they provide a coarse check on the proper saturation map that we construct in this section). Instead, we will make use of a slightly different analysis which still captures the behavior of interest. In particular, for a large set of point sources (i.e. stars), we will plot the fraction of charge contained in their peak pixel as a function of the peak pixel intensity. Because of the excellent long-term stability of the ACS/WFC PSF, the reveals the saturation level as a sharp feature.

It may be instructive to elaborate on this approach: in the case of the super-hot pixels, assuming a background level of zero and other ideal conditions (e.g. no CTE losses, etc.), the total charge in a small region centered on the super-hot pixel is contributed entirely by that source pixel. Thus, for all charge levels below the saturation level, i.e. before the pixel starts blooming, the fraction of the total charge (within that small region) contained in the source pixel would be unity. As the integration continues above the saturation level, the source pixel will bleed some charge into neighboring pixels (Figure 2), resulting in a monotonic decrease in the fraction of total charge contained in the source pixel – a feature which we can identify in the relevant plot (e.g. Figure 3).

The concept is similar for images of astronomical sources convolved with the PSF: As the central (or any) pixel begins to bleed, the fraction of the total charge associated with that source contained in the particular pixel decreases. Crucially, since the PSF, which essentially encodes the fraction of charge/light contained in a given pixel, is independent of total brightness of the (unsaturated) source, we can use a heterogeneous sample of PSF-convolved images of point sources spanning a range of intensities as a proxy for a single source imaged at a range of exposure times. (Identifying the onset of saturation using this
Figure 3: Fraction of charge contained in the peak pixel vs. the peak pixel intensity for stars imaged within a particular small (128 × 128 pixels) region of the WFC CCD area. Top: Fractional charge level measured in background-subtracted images. Bottom: Fractional charge level measured in images with a constant background level added in, as described in the text. Black points are measurements from over 500 stars from ∼ 200 different images. Red and blue curves are a running median and polynomial fit of the data, respectively, and corresponding dashed lines running through their peaks. The abscissa of the two peaks are within 1% of each other, and we take their average value to be our estimate of the saturation level in this particular spatial bin. We automate this fitting and peak finding for all spatial bins over the detector area in order to map out the saturation level. This method provides the most direct and precise measurement of the saturation level out of any previously used methods.

method is in a sense the same as identifying the onset of PSF deviations.) An example of the relevant plot, for a certain small group of pixels on the WFC frame, is shown in Figure 3 and is described further below.

In order to use these principles to accurately map out the saturation level over the WFC CCD area, we need a large sample of sources with dense sampling in brightness near the saturation level and dense sampling in position on the detector. For this, we leverage the wealth of archival post-SM4 WFC data and perform the following procedure. First, we select an initial set of images consisting of over 200 individual F606W exposures of 47 Tuc (full list given in the Appendix) spanning a range of exposure times between ∼ 40 s to ∼ 1400 s. These particular images were chosen due to excellent spatial and brightness sampling. As mentioned in the Introduction, we use only full-frame images with gain=2. We obtain the raw images and run acscd on them in order to bias-subtract and convert the
science frames to units of electrons. We then run Source Extractor (SE; Bertin & Arnouts, 1996) on the science frames using mostly typical parameter values but slightly tweaked to optimize background subtraction and high fidelity source identification/measurement in these crowded stellar fields. Along with the default output parameters, we tell SE to include in the output catalogs, for each source: the coordinates of the peak pixel, the peak pixel value, the elongation, the FWHM, and the stellarity index.

With the catalogs and images in hand, we then begin the saturation level analysis. We first combine all the SE catalogs into a single catalog and clean it from likely cosmic rays and extended sources by cutting on the FWHM (< 5 pixels), stellarity index (> 0.8), and elongation (< 5). Since we know that the saturation level varies over the frame (Gilliland, 2004), we bin the data by their image coordinates into bins 128 × 128 pixels large, a resolution which represents a balance between ensuring a reasonable sample size in each bin and not smoothing over too large of spatial scales. (This spatial binning assumes small local variations in the saturation level – this assumption is later confirmed by examining diagnostic error maps and using convergence testing.) For each bin, we can now generate a plot like Figure 3 (top).

However, it is at this point that we must address a subtlety in the analysis. When using properly background-subtracted images for these measurements (as in Figure 3 (top)), the fractional charge for peak pixels leftwards of the saturation level will be scattered about a constant value, with a somewhat gradual dropoff starting at the saturation level, as expected by the nature of the PSF. The shape of this trend is not very conducive to automated iden-

Figure 4: Map of the saturation level over the WFC frame. The plotted area corresponds to the entire WFC CCD detector area with the two chips concatenated at the center. Left: The saturation level directly measured in spatial bins as described in the text. Right: Smooth polynomial fit to Left, resized to the full resolution of WFC frames.
tification of the dropoff since it does not represent a clear extremum. Fortunately, we can employ a simple transformation to make this measurement easier. It is easy to convince oneself either analytically or using simulations that by adding a suitable constant 'background' to all the pixels from which the total charge of each source is measured (i.e. when measuring the quantity on the vertical axis of Figure 3 but NOT when measuring the quantity on the horizontal axis), the shape of the trend will steepen leftwards of the dropoff, resulting in the ordinate of the dropoff forming a clear peak without changing its abscissa. This makes it much easier to automate the identification of the saturation level by fitting the peak of the curve, as seen in the bottom panel of Figure 3. The value of the constant offset used can be tweaked by visually inspecting the relevant plot, ensuring that the desired behavior is achieved and that the relevant feature is preserved. We find that a large range of values works fine for this, and we settle somewhat arbitrarily on a value of \( \sim 8,000 \) electrons (\( \sim \frac{1}{10} \) of the typical saturation level) for this analysis.

For each spatial bin, we then make a plot like the bottom panel of Figure 3. The total charge of each source is measured within a \( 7 \times 7 \) pixel square aperture centered on the peak pixel. We fit the resulting scatter plot with a relatively low order polynomial (we find 8th order to work well) and, separately, smooth it with a median filter. We then find the peak pixel intensity corresponding to the maximum of the polynomial and the median-filtered signal, and we take their average intensity to be the saturation level for the given bin. For most bins, the two values agree to within a few per cent, but for a handful of bins, there may be large discrepancies, usually due to some large excursions of the polynomial fit near the boundaries of the fitting region or poor sampling of the data near the saturation level. We could inspect these bins by eye on a case-by-case basis and initialize the fit manually, but since it only affects a small number of bins, it is inconsequential since we next fit a low-order model to the whole map, which smoothes over these suspect bins. This smooth model is generated by splitting the resulting map (Figure 4 (left)) at the chip gap and fitting each separately with an 8th-order 2D polynomial (again, polynomial order chosen as an optimal value by eye). The two surfaces are then concatenated at the chip gap and the resulting image is resized (using sklearn.transform.resize) to the proper pixel dimensions of WFC frames, namely 4096 \( \times \) 4096 (Figure 4 (right)). The result of this final step is a map of the saturation level which can readily be used to flag saturated pixels in WFC science frames that have been processed with acscdd.

The mean saturation level over the whole map is \( \sim 77,400 \) electrons, with peak-to-peak variations of \( \pm \sim 5,000 \) electrons, or \( \pm \sim 6\% \), about the mean. For comparison, the value currently used in the pipeline for flagging saturated pixels is 44,450 DN (corresponding to \( \sim 84,500 \) electrons given typical bias levels at GAIN=2), which falls entirely outside the range of our map. The non-uniform structure of the variations does not seem to be strongly related to any other known structure inherent to the CCD, and arguably loosely resembles (qualitatively) the early result seen in Figure 4 of Gilliland (2004). We also find that the saturation level has remained constant throughout the post-SM4 lifetime of the detector, precluding the need for any time-dependent terms/corrections.
3.2 Resulting Improved Saturated Pixel Flagging and Implementation in the Pipeline

In order to test our new saturation map, we use it to flag saturated pixels in a variety of science frames, including ones that were and were not used in the construction of the map. The flagging is done straightforwardly, just as it would be done in the calibration pipeline, using a simple logical comparison – in all pixels where the value of the science frame is greater than the value of the saturation map, the saturation flag is turned on. We can then compare the results of this flagging with the current pipeline flagging by inspecting the science frames and saturation masks side-by-side. Several examples of this comparison are shown in Figure 5, from which it is clear that our new saturation map delivers superior results. From a sample of about 100 random science frames, we find that our new flagging results in \(~5\%\) to \(~15\%\) more pixels being flagged as saturated in any given frame, with a mean of \(~9\%\) more, compared to the current flagging.

There are likely several reasons for the inferior and sometimes unexpected flagging of the current pipeline: The current pipeline does not account for the spatial variation of the saturation level over the detector area, instead using a single scalar threshold to check for saturation over the entire frame. The value of this threshold is also simply too high and often misses clearly saturated pixels belonging to extended saturation trails, or those forming the (less so, but still saturated) boundaries of saturated sources, or otherwise. Moreover, this threshold is in units of DN, and currently the flagging is done before bias-subtraction and conversion to units of electrons using the gain. We caution that this approach may be improper since the bias level is not constant between frames nor over the lifetime of the detector [Desjardins & Khandrika, 2019], and since the gain varies by as much as \(~9\%\) between the four CCD quadrants [Desjardins & Grogin, 2018].

Given the marked improvement of our new saturation flagging, the ACS instrument team is now taking steps to implement it into the calacs pipeline, including changing the order of operations in acscdd such that the saturation flagging happens after bias-subtraction and unit conversion. We hope to implement these updates into the pipeline in the near future.

Note: For gain settings lower than 2, full-well saturation cannot be automatically differentiated from A-to-D saturation using the methods of this work. Also, since gain settings other than 2 are not supported by the ACS team since shortly after post-SM4, and thus very few post-SM4 archival images using gain settings other than 2 exist, we plan to simply continue using a single scalar threshold for other gain settings unless indicated otherwise in future documentation.

4 Extensions and Topics for Future Work

4.1 Full Blooming Model and HDR Darks

The current pipeline dark subtraction has a shortcoming related to the ‘super-hot’ pixels: When calibrating science frames, since the intensity of the long superdarks are scaled up or down to match the exposure time of the science frame, frames with exposure times shorter than \(~1000\) s suffer from an oversubtraction of dark current in the pixels which form the
Figure 5: Visual comparison of several examples of our new saturated pixel flagging compared to the current pipeline flagging. These particular example cutouts were chosen to showcase several different types of situations where the current pipeline falls short. Left: Science image cutout. Middle left: Our new saturation flagging. Middle right: Current pipeline saturation flagging. Right: Difference between new and current saturation flagging, to guide the eye and highlight the current flagging shortcomings. All but the science frames are simply boolean images: 1 (white) where the saturation flag is on and 0 (black) where it is not.
bleed trail and their immediate neighbors in the superdarks, but which are not yet bled into in the science frame (see e.g. [Miles (2018)]). (The current pipeline also flags all the pixels in the bleed trail as hot pixels in the DQ arrays, even though only the central pixel is truly ‘hot’ in the sense that it is the source of the dark current.) The opposite issue occurs in science frames with exposure times larger than $\sim 1000$ s, which suffer from an undersubtraction of dark current in the pixels above and below the saturation trails. In order to properly subtract the dark current associated with the saturation trails of hot pixels, either darks would need to be taken at multiple intermediate exposure times, or the saturation trails would need to be modeled for a specific science frame exposure time. Since the former option is unviable, we turn to the latter option.

With our new saturation map, and a thorough understanding of the behavior of these hot pixels and how they bleed their charge, it should be possible to accurately model the structure and intensity of the dark current resulting from their saturation trails for any given exposure time. Following this work, we plan to develop this tool, and use it to create so-called “High Dynamic Range” darks, which will feature fully modeled saturated hot pixels and their bleed trails for any exposure times. A full blooming model as proposed would also be useful for simulating science images in which sources are expected to saturate. One might expect that the operating principle for this model should be as simple as spilling excess charge beyond saturation into the nearest available pixel in the column, which it is to first order. However, there is a slight complication, discussed in the following subsection.

### 4.2 Possible Horizontal Blooming

The reader may have noticed a curious feature in the image cutouts from the long darks in Figure 1 – in addition to the familiar saturation blooming trail seen in the column of the source pixel, there also appears to be noticeable charge in the neighboring pixels one column over in either direction. Some excess charge in the adjacent column on the side opposite to readout is expected due to serial CTE losses, which are small (Anderson & Bedin, 2010), but currently uncorrected for. However, the charge observed in the column on the other side, which is often much brighter than the CTE loss trail, is unexpected and newly documented as of this work. This effect, which has evidently been present for the entire lifetime of the detector, is also readily seen in science images of saturated stars (though it is harder to isolate due to nearby charge from any other sources), where the effect can clearly appear on both sides of the saturation trail, and can span multiple columns. (For reference, a similar effect is not observed in WFC3/UVIS images, though this comparison may be inconsequential because the two imagers use CCDs with different characteristics and manufactured by different companies.) Our suspicion is that this excess charge is the result of charge bleeding in the horizontal (serial) direction, though the conventional wisdom suggests that this should not occur (Janesick, 2001). Another possibility is that this is related to charge diffusion (Krist, 2003), or perhaps that this charge could be bleeding during readout (i.e. due to some issue with the serial register) rather than during integration. Regardless of its nature, we have spent significant effort studying the phenonomenon in WFC images, which has resulted in a significant, but as of yet incomplete, characterization of it. We plan to discuss this topic in detail in future work, but suffice it to say for the moment that the ways in which this effect manifests and behaves are considerably unlike familiar vertical blooming,
and defies the straightforward modeling that successfully quantifies WFC vertical blooming.

4.3 Pre-SM4 Analysis

The results presented in this work apply only to post-SM4 WFC data. There may be reason to suspect that the saturation levels were different pre-SM4 due to the different readout electronics and settings used. In the future we plan to carry out this analysis for pre-SM4 data.

5 Summary

The current ACS/WFC calibration pipeline’s saturated pixel flagging routine produces somewhat unsatisfactory and unexpected results, failing to identify many clearly saturated pixels. We have developed and deployed a new method for measuring the position-dependent saturation level of the ACS/WFC CCD (and in principle, any CCD). This method, which offers both a more direct and more precise measurement compared to the previously used methods, operates by identifying pixels which are just beginning to bleed charge into their neighboring pixels. We leverage a large sample of post-SM4 archival image data in order to achieve a high precision measurement of this effect, and map the saturation level across the CCDs. We find that our resulting map of the saturation level provides results significantly superior to the current pipeline flagging, and we plan to implement it into the calibration pipeline in the near future. Several related issues yet remain unsolved, and we plan to explore them in future work.

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This research made use of: NumPy (Van Der Walt et al., 2011), SciPy (Virtanen et al., 2019), matplotlib (Hunter, 2007), Astropy (Price-Whelan et al., 2018), and Scikit-learn (McKinney, 2010).

References


Appendix

List of ACS/WFC datasets used in this work:
ja9702spq, ja9702srq, ja9702sxq, ja9702szq, ja9702t5q, ja9702t7q, ja9bw2a4q, ja9bw2a5q, ja9bw2a7q, ja9bw2abq, ja9bw2adq, ja9bw2adq, ja9bw2yko, ja9bw2yldq, ja9bw2zfq, ja9bw2zhq, ja9bw2zjq, ja9bw2zsq, ja9bw2zuq, ja9bw2zwq, jb6v01diq, jb6v01dkq, jb6v01e0q, jb6v01e5q, jb6v01ekq, jb6v02x7q, jb6v02xbq, jb6v02xhq, jb6v02xmq, jb6v02zuq, jb6v03h4q, jb6v03h4q, jb6v03h4q, jb6v03i7q, jb6v03i7q, jb6v03imq, jb6v04a4q, jb6v04a4q, jb6v04a9q, jb6v04a9q, jb6v04aoq, jb6v04aoq, jb6v04ztq, jb6v04xq, jb6v06bzm, jb6v06c3q, jb6v06c3q, jb6v06c3q, jb6v06ceq, jb6v06csq, jb6v06csq, jb6v07wmq,