Effects of Persistence on E2V Sensors and its Impacts on DC2 Data

John Banovetz, Yousuke Utsumi, Colin Slater

DMTN-276

Latest Revision: 2024-05-07

Abstract

In this technote, I describe the measurements and characterization of the persistence effect with the E2V sensors. I will also describe the process that I used to evaluate the effects persistence would have on the LSST survey. For this, I took persistence characterization values from electro-optical testing and modified raw DC2 images to include this model of persistence. I then ran the raw images through the DRP and analyzed the results. I found that the persistence adds a possibly non-negligible amount of flux to faint sources and can affect a significant amount of pixels.

Change Record

Version	Date	Description	Owner name
1	YYYY-MM-DD	Unreleased.	John Banovetz

Document source location: `https://github.com/lsst-dm/dmtn-276`

Contents

Effects of Persistence on E2V Sensors and its Impacts on DC2 Data

1 Electro-optical Measured Persistence
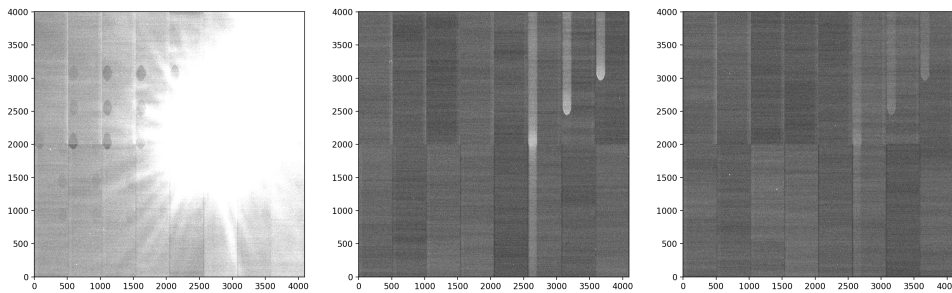
1.1 Definition and Run 5 Measurements

FIGURE 1: Example of peristence in Run 5 data. This figure shows the initial flash on the left most image (dataId shown as the title) and a portion of the subsquent darks images going from left to right. This particular flash has one of the three spots inbetween two amplifiers and you can see the trail starting at the spots and going all the way to the readout of each amplifier.

Persistence is a sensor level effect where charge gets trapped from one image and 'persists' into the next at some fraction of the original charge. Figure 1 shows an example of this from Run 5 data where three saturated spots ($> 10**5$ e-/pixel) persist into subsequent dark images. Persistence for LSSTCam was first found in Run 5 of electro-optical (EO) testing at SLAC from crosstalk measurements. Further investigation found that this effect only affected E2V sensors and that the persistence was only mitigated via integration time. Mitigation tests were done and found that while darks were able to release the trapped persistence charge, there were no signs of persistence in biases. One of the troublesome features of the persistence in the E2V sensors is the persistence trail. In addition to the persistence from the bright source, the pixels through which the source is transferred during readout also show persistence, leaving a trail from the source to the edge of the amplifier.

1.2 Run 6 Measurements

Following this discovery in Run 5, we tested and characterized the persistence further in Run 6a and 6b. This included using both a flat illumination to induce persistence as well as utilizing a pinhole filter to create saturated spots to measure the persistence.
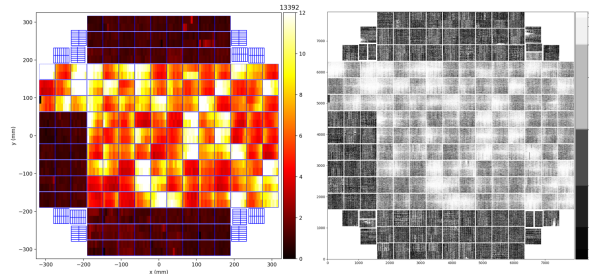
1.2.1 Flat Induced Persistence

FIGURE 2: Full focal plane images of the counts in the first dark image after a bright exposure for run 13392. The left shows the amplifier level average for all science sensors of the subsequent dark. The right shows a binned image of the dark image from RubinTV.

Flat illuminated persistence measurements were taken during B and C protocol runs. The procedure for these measurements were to take a incredibly bright (3–4 times full well) flat followed by 15 second dark images. These images are then run through both cp_pipe and eo_pipe. This procedure is designed to induce the persistence, determine the level and then track its decay. Unfortunately this method does not allow us to measure the trail caused by the persistence as all the pixels are saturated.

One of the concerning discoveries with these measurements were the level of persistence was reaching as high as 10 ADU. Figure 2 shows an example of a focal plane plot displaying the per amp value of the first dark image after the flash as well as the actual dark image. This figure shows that not only are there large variations between E2V detectors, but also variations on the amplifier level.

One of the ways to lower or remove the persistence effect is to adjust the parallel swing voltages of the detector. This was tested and Figure 3 comapares the per amp plot between the nominal voltages and the slightly higher parallel clock swing voltages (-9.3 vs -9.0 V). This change did lower the persistence level but much less than what was expected (only 10%).
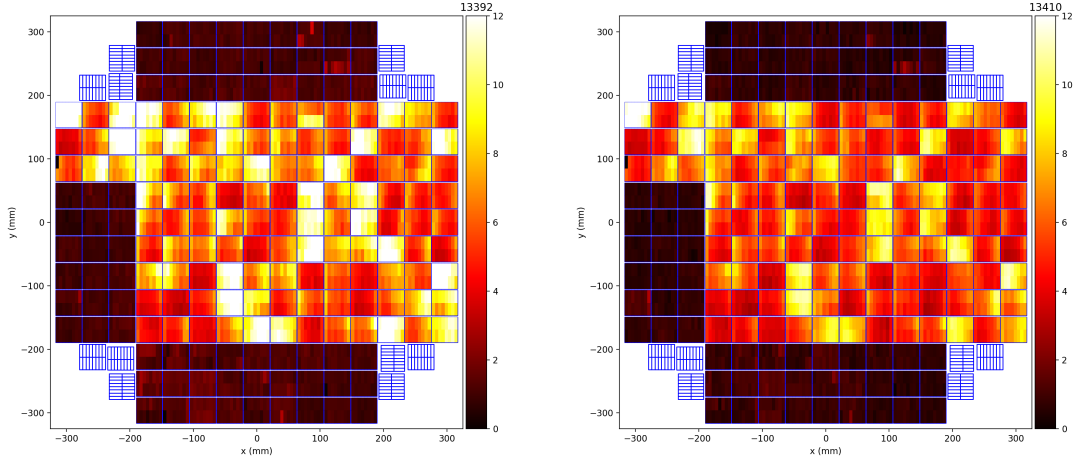
FIGURE 3: Full Focal plane images with amplifier level resoltuion comparing a subsequent dark image with nomial parallel clock swing voltages (left; Run 13392) and one with a slightly higher parallel clock swing voltage (right; Run 13410).

1.2.2 Spot Induced Persistence

During Run 6b, we utilized the pinhole filter to measure the persistence of the E2V sensors. The pinhole filter is positioned so that a small area of light hits one amplifier on each of the middle detectors on a raft. This means that we can only measure the persistence of 13 e2V detectors but we are able to get measurements across the focal plane. For these tests, we started with flashes from around 20 ke-/pixel below full well (100 ke-/pixel) and ramped to twice full well (200 ke-/pixel). After each flash, we take 10 dark images with 15 second integration times which we use to measure the persistence. These images are then overscan and bias corrected. Figure 4 shows an example of one of the saturated pixels (spot) and the subsquent dark image with persistence.

Using these images, we are able to measure the persistence induced by the saturated pixels as well as the trail that follows. We then model the persistence decay using this function:

$$Counts = A * \exp(t/\tau) + c$$

where *Counts* are the average number of counts at the location of the spot in the following dark image, *t* is the time since flash, 15 seconds of which are with the CCDs integrating, τ is the decay constant and *A* and *c* are constants. Figure 5 shows an example of the decay of the
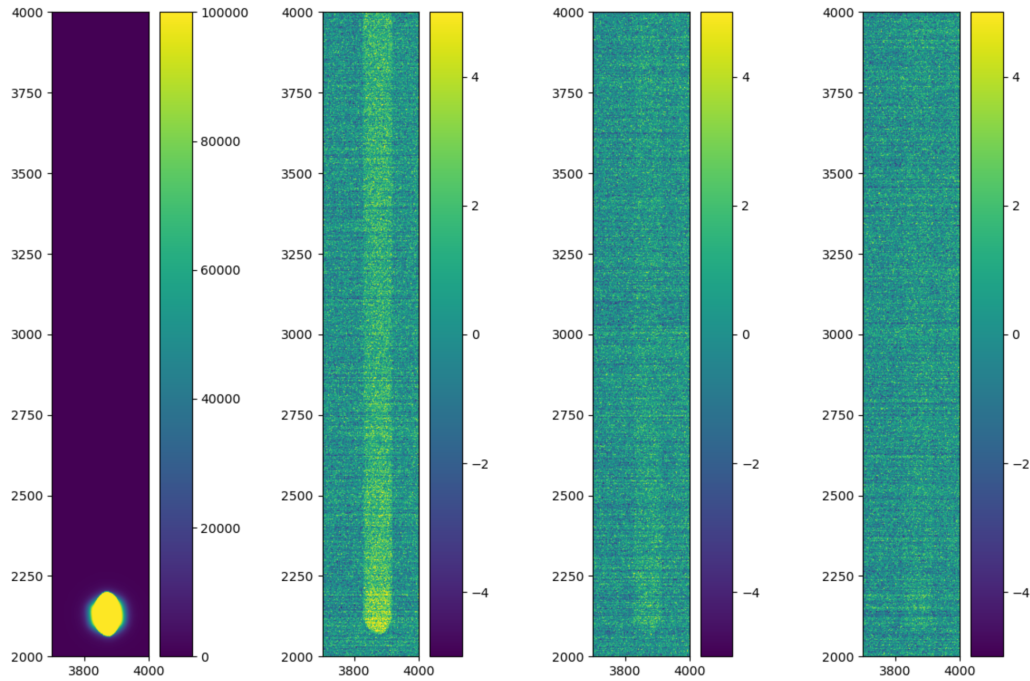
FIGURE 4: Similar to Figure 1 but with the pinhole filter. This shows the initial flash and the spot (left) and the dark images that followed.

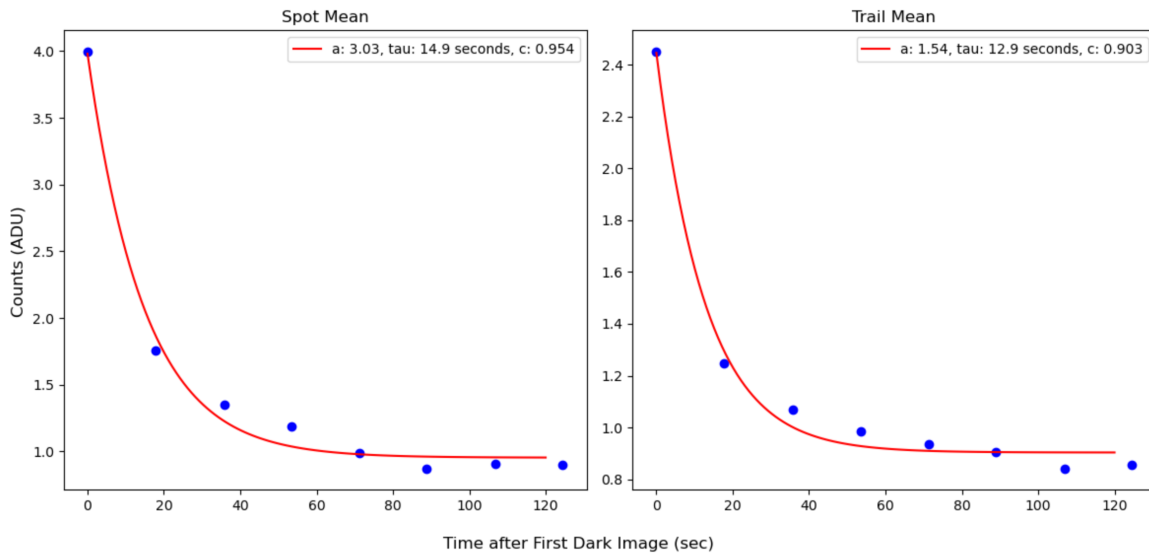both the spot and the trail and the corresponding model fit for one detector.

FIGURE 5: The decay of the persistence with consecutive dark images. The blue points are the measured average counts of the spot (left) and trail (right). The red line shows the model fit with the parameters shown in the upper right.

Figure 6 shows the values for A and τ for all measured e2v detectors and all exposures that showed persistence. This figure shows that while τ is roughly the same for all images (between 10–20 seconds), the amplitude of the effect changes. There also is a relationship between flashtime/the brightest of the spot and the persistence measured signal.
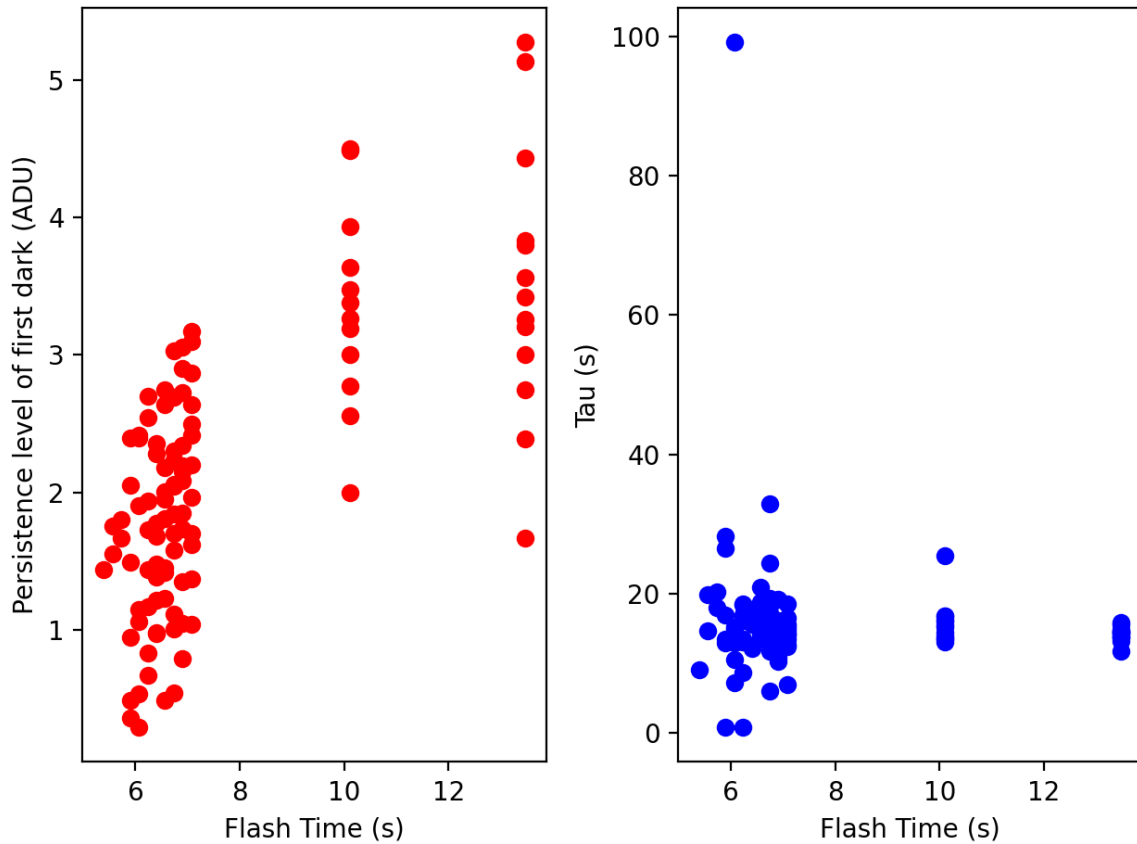

FIGURE 6: The relationship between the duration of the LED flash (a proxy for the brightness of a saturated source) and amplitude (left) and tau (right) for the spot. Each point represents the measured tau and amplitude values of a single sensor from a single exposure that displayed persistence. The amplitude appears to be dependent on the flash time, while tau is invariant and is consistently between 10–20 seconds.

2 Effect of Persistence on DC2 Data

Though studies are currently being done to minimize or elminate persistence amplitude, both through hardware and processing, one of the next steps is to see how much persistence will affect LSST photometric measurements. To study these effects, we used DESC DC2 data and assume that the persistence will affect all saturated pixels with the characteristics of a τ of 15

seconds and an amplitude of 5 ADU. We set *c* to zero in this case as there should be no offset with DC2 data. These numbers are derived from the pinhole data, which we feel will better represent on-sky data. As most of the characterization has been with the spot and not the trail, we use 5 different models to determine the impact of the trail: assume the trail carries with it 100%, 75%, 50%, 25%, and 0% of the spot persistence level. We only used one of the e2V detectors at random (detector number 88/R21-S21) for this analysis and then assume that this detector is representative of the other e2V detectors. We also only utilize single-visit images with 30 second exposures to mimic what the effect would be as images would be coming from the observatory.

2.1 Affected Pixel Counts

One of the first studies we did was to look at the number of affected by persistence during a simulated night of observing. To do this, we utilized the 1000 `calexp` images from DC2 dataset. We sorted these images by exposure number in order to apply the persistence as if it was a normal night of observing. For each individual image, we first apply a running list of persisted pixels following the equation as described above. For this list, we only included persistence that had a signal strength greater than 1 ADU, as below this value is reaching the level of the bias noise. After this, we identify the saturated pixels in the image and mapped these pixels, as well as then creating a trail from the saturated pixels to the readout of the amplifier. We then repeat this procedure for all 1000 images. Table 2.1shows the average number of affected pixels in a single image in each of the trail models.

% of Spot in Trail	>3 ADU (10^{-4})	>1 ADU (10^{-4})	>0.1 ADU (10^{-4})	>0.01 ADU (10^{-4})
100	5.85	5.85	11.7	23.4
75	5.85	5.85	11.7	17.5
50	0.0216	5.85	11.7	17.5
25	0.0216	5.85	11.7	17.5
0	0.0216	3.91	7.81	11.7

TABLE 1: Table showing the average about of pixels in persistence-affected regions above ceratin ADU levels. The numbers are then normalized to fraction of total CCD pixels affected. We compare with different trail levels.

2.2 Persistence Induced Flux Effects on Objects

Another possible metric to gauge the impact of persistence is the object measurements. For this study, we created a new dataset type called $raw\_modified$. This dataset type takes the raw file and adds the persistence model as described above utilizing the previous images. For this

study, we utilized a small subset of the DC2 dataset (68 images) and the latest reprocessing using the latest verison of the Data Release Pipeline (DRP). We then run the $raw\_modified$ images through the isr, $characterizeImage$, and $calibrate$ steps of the DRP.

Figure 7 shows an example image of an object comparing the two $calexp$ images from raw and $raw\_modified$. While the persistence is small enough that is extremely difficult to find by eye, the small boost in signal can affect photometric measurements of objects. Using these 68 images, we measured the differences in magnitude of objects centered in the persistence-affected regions. Figure 8 shows the difference in magnitude using both the an aperture flux and PSF flux.
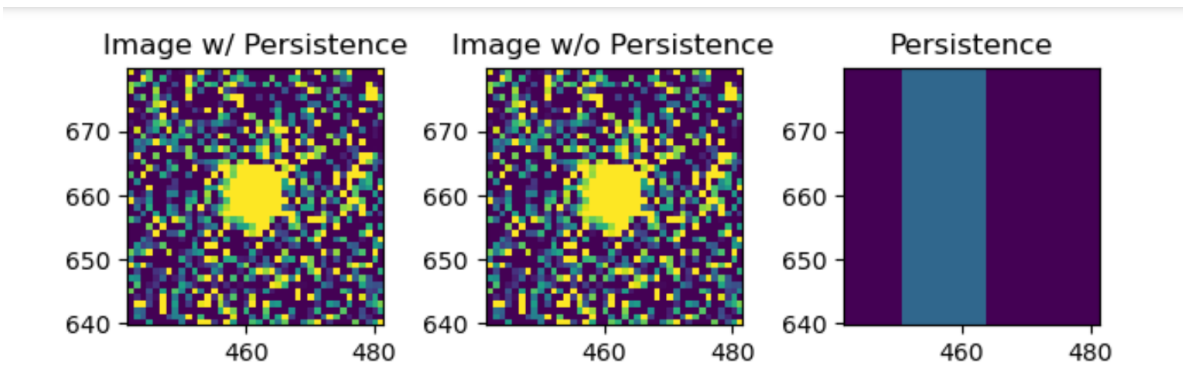

FIGURE 7: A zoomed in object that shows the persistence-affected image (left), the original image (middle) and the subtraction between the two to highlight the persistence (right).
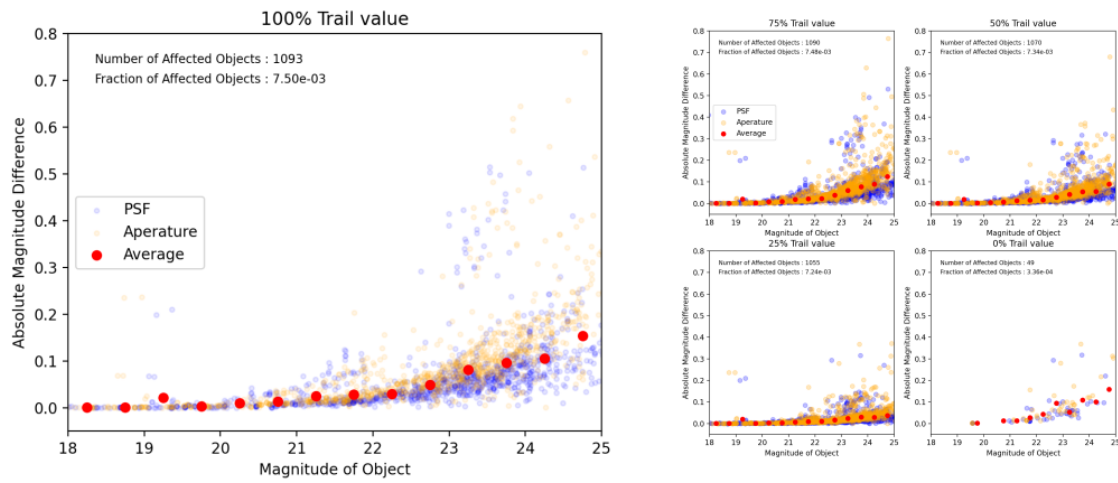
FIGURE 8:   The changes of magnitude of objects in persistence-affected regions for all five trail regimes, highlighting the 100% case on the left and the other models on the right. In the blue are the changes in magnitude using the calculated PSF, the changes in magnitude using an aperture (orange), and the average changes in the PSF magnitudes for every 0.5 mag (red) Also included is the number of objects affected as well as the fraction of objects affected vs total objects. These plots only look at magnitudes up to 25th mag. There are sources at magnitudes >25 mag but 25th magnitude is the magnitude limit of single exposures.