Wide-field Infrared Survey Explorer (WISE)

Latent Image Characterization

Version 1.0

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Revision History

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12 July, 2009	1.0	Deborah Padgett	Initial Draft

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1 INTRODUCTION

1.1 Document Scope

1.2 Applicable Documents

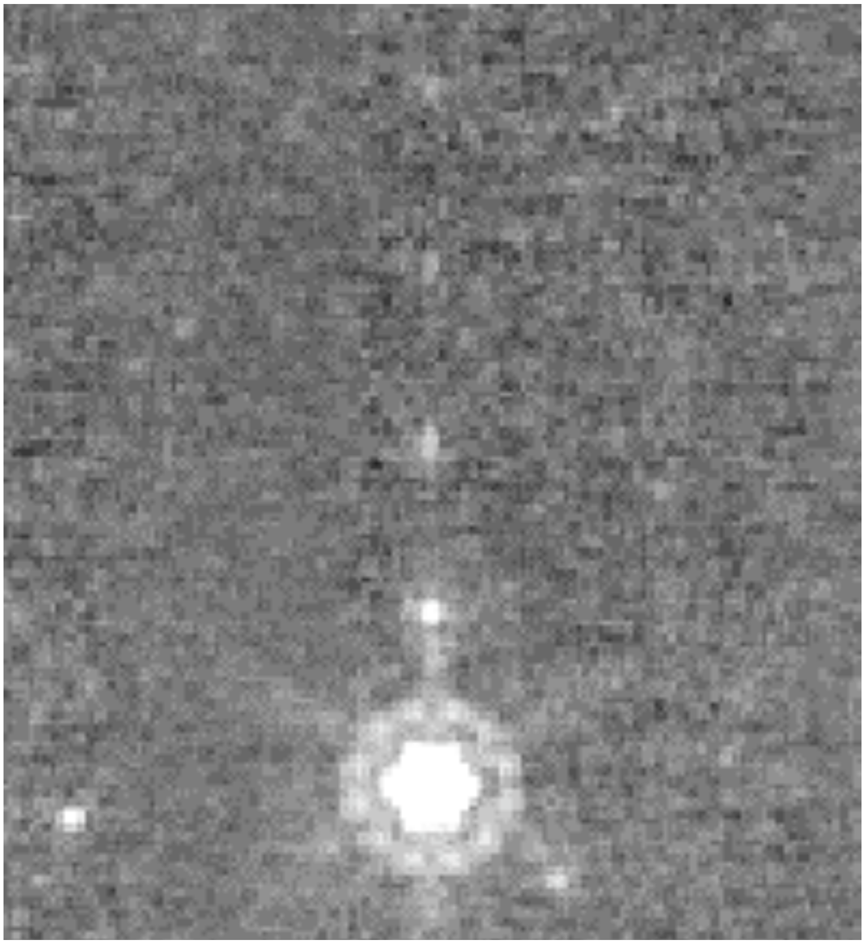
This plan conforms to the specifications in the following project documents:

- TBD

1.3 Acronyms

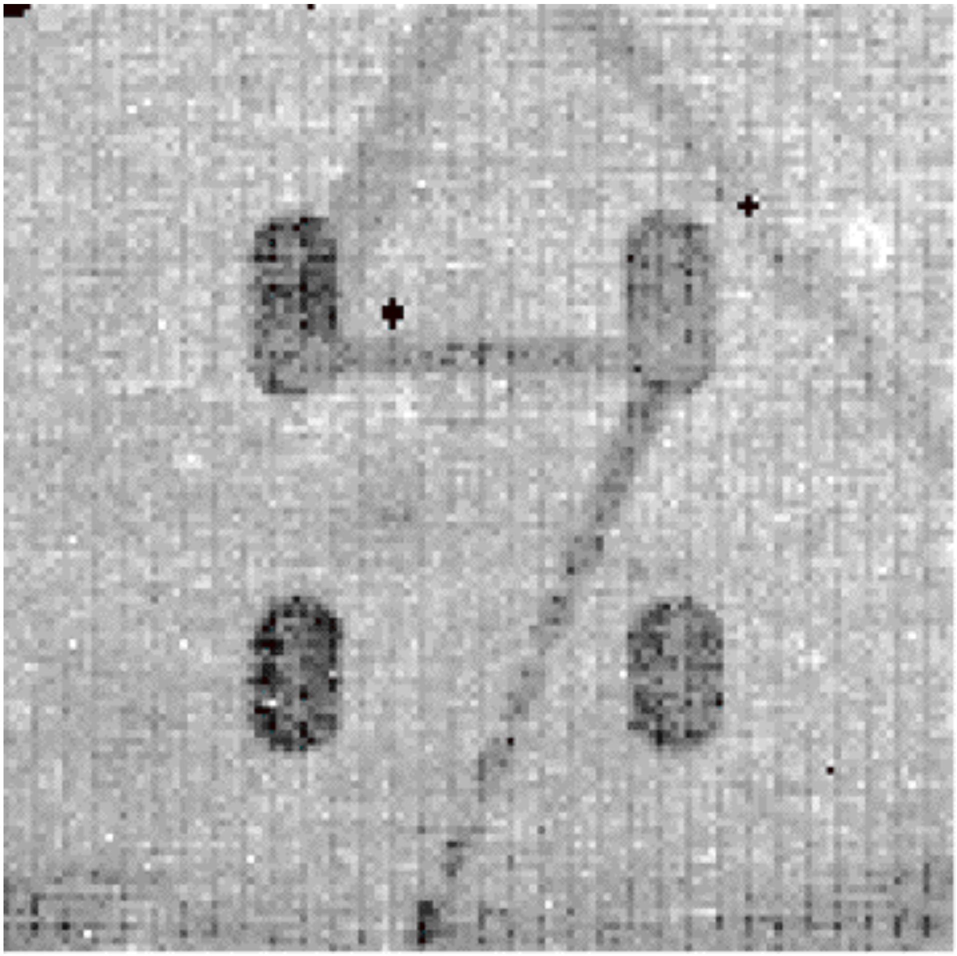
2 BACKGROUND

The WISE Si:As arrays will be used on orbit in 2009-2010 for a all-sky survey mission lasting from 6-13 months. During that time, these arrays will be in constant use at their bands of 12 and 23 microns, experiencing a wide range of input flux densities and varying radiation environment. Experience with the *Spitzer Space Telescope* MIPS 24 μm Si:As array indicates that long-term latent images can be a substantial problem for this type of array. The first type of latent seen on the MIPS-24 array is a bright residual image with a decay timescale of tens of seconds. This type of latent is illustrated in Figure 1. These latents start out at about 0.8% of the peak brightness of a point source. Characterized during ground



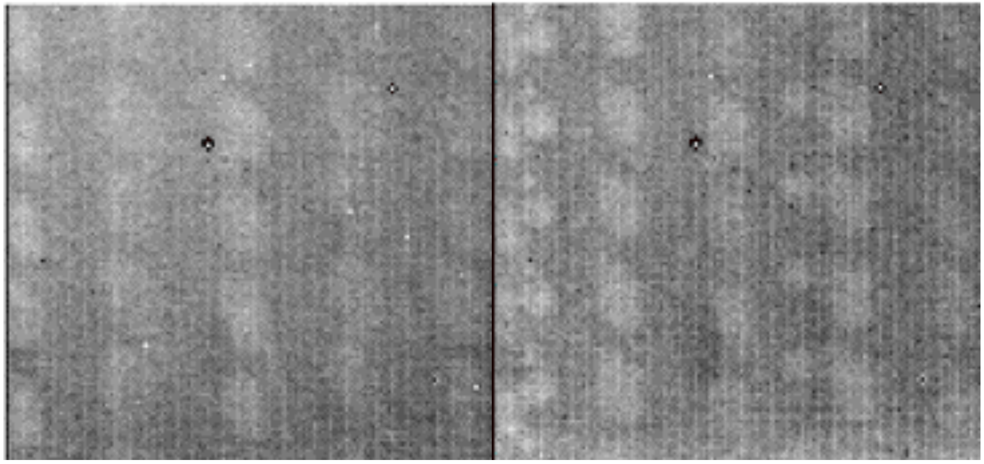
testing, this type of latent image artifact is known to appear more strongly at lower operating temperature. Since the WISE arrays will run at 7.0 K as opposed to the 5.0 K of the MIPS array, we expect the effect to diminish on WISE relative to MIPS. There does not seem to be a flux threshold for this type of latent in MIPS; it appears for all point sources, but may not be apparent for most due to the high zodi background for all fields on the sky. The MIPS instrument team has found that this type of latent decays with a timescale of ~10 sec.

The second type of MIPS-24 latent is the so-called "dark latent" which appears in general following an exposure of the array to a source which saturates within the readout time of 0.5 sec. The effect starts out as a typical short-term bright latent which then evolves quickly into a depression in the zodi background of about 2% . This artifact has a time constant of 10 – 12 hours, seriously impacting subsequent images. Unfortunately, it is not totally clear as to whether this is a gain (multiplicative) or bias (additive) effect since only the image count rate (slope) is saved by the spacecraft. Either type of correction will cosmetically fix the images. In the above images, the dark latents were caused by a very bright point source (~1000 Jy at 24 microns) which was slewed onto the array, then observed in the small field photometry dither pattern with an exposure time of 3 sec. At this flux density level, even the constant readout mode of the array used during



slew registered damage from passing over this source. Since this type of latent requires a bright background to present on the array, it was not seen or characterized in MIPS ground testing.

In very high flux density cases when the dwell time of a source on the array is significant, a semi-permanent latent image can form on the array. In the following images, the MIPS-24 array is shown during a campaign in which bright sources were observed regularly over a week's time. The images are separated in time by several days. Bright latents are added to the array, but do not fade beyond the 0.5% of the background level. Fortunately, the artifacts are removed by a 20 K anneal. Obviously, without an anneal, the array would continue to collect such artifacts, potentially seriously compromising the calibration of the resultant images. Ground testing also did not reveal these sorts of latents since the array was not operated for days at a time following point source tests. During the WISE mission, the arrays will view the bright sources of the galactic plane twice per 1.5 hr orbit, as well as the 100 Jy Cat's Eye nebula at the North Ecliptic Pole. It therefore behooves the WISE team to thoroughly investigate mitigation techniques for long-term latents (i.e., annealing).



Annealing the MIPS-24 arrays removes latents and most evidence of radiation damage to pixels at the cost of short-term array stability and semi-permanent changes to the flat field. Ground tests on the MIPS-24 array showed that the response changes rapidly during the first 30 minutes following the anneal, then tapers off with about 0.5% change from 0.5 – 3 hr. However, low frequency components in the flat field are frequently modified by annealing. The response in the lower (first) 30 rows of the array is often depressed up to 2% by an anneal in mid-campaign, and this new flat field feature will persist until the end of campaign, requiring a new flat field to be applied for this time period. It is worth noting that the overall stability of the MIPS array is excellent in its central portion. Our repeatability standard has shown less than a 1% variation over the lifetime of the Spitzer mission thus far.

Based on the MIPS-24 experience, the following goals for WISE Si:As anneal testing seemed appropriate:

- Determine the array anneal recovery time in the presence of varying illumination levels. Does the array ever stabilize to its pre-anneal median? How long does it take to get within 0.5%? Does the detailed response pattern change after the anneal and at what level?

- Determine the efficacy of anneal removal of latent images (presuming that long-term latents do exist)? What is the efficacy of anneal removal of pixel radiation damage (hot, rogue, and depressed response pixels)?

- Do the previous quantities change with array temperature?

In order to answer these question adequately for the WISE mission, it is necessary to also determine the nature of latent images on the Si:As arrays. If no long-term latents are produced, the best course may well involve annealing infrequently to mitigate pixel radiation damage.

3 Latent Image Testing at Ames Research Center

Tests at the Ames Research Center in 2007 – 2009 used FPA#026 to monitor the effects of point-like sources and anneal cycles. Dark latents were seen for the cold blackbody source and bright latents were found when hotter blackbodies were used. All long-term latents were removed by 15 K anneals. (To be expanded).

The test plan for SDL based on the Ames results called for three stages of latent/anneal testing at SDL. First, bright point sources "at and near saturation" should be induced with the MIC2 collimator to check for the presence of long-term latents. It was unclear as to whether the array can be simultaneously exposed to a saturating point source and a flood illumination to simulate the zodi. If such latents are seen, an anneal should be applied to check the efficacy of latent removal. These tests will be performed with flow-through liquid He only. A post anneal response recovery test should be performed during environmental testing with solid hydrogen in the cryostat.

4 Latent Image Testing at Space Dynamics Lab

4.1 Design of Tests

The SDL document *Saturation, Latency, and Droop Test Procedures* dated October 6, 2008 describes a series of tests performed in the MIC-2 chamber at the SDL facility in Logan, Utah. Tests were performed on November 10 and 20, 2008. The test sequence consists of a several (4 – 5) frames in which the W3 and W4 stimulators provide an approximately uniform background illumination, introduction of a bright, extended source for one frames, then recording of the latent image residuals in the presence of the stimulator background. The position of the extended source is varies so that the time history of each latent can be traced separately. The flux density of a point source with peak brightness the same level as the extended source are shown in the following table:

Exposure ID	ND Filter	Aperture	W3 Peak Flux Density (Jy)	W4 Peak Flux Density (Jy)
SAT0001	ND5	ND3	0.056	0.12
SAT0002	ND5	ND2	1.1	0.4
SAT0003	ND5	ND1	9.5	32
SAT0004	ND5	Open	95	320
SAT0005	ND3	ND3	1.3	0.23
SAT0006	ND3	ND2	25	7.7
SAT0007	ND5	ND1	9.5	32
SAT0008	ND5	ND1	9.5	32
SAT0009	ND5	ND1	9.5	32
SAT0024	ND3	ND1	210	62
SAT0025	ND3	ND1	210	62
SAT0026, SAT0206	ND3	Open	2100	622
SAT0027, SAT0207	ND2	Open	42000	21000
SAT0208	ND1	Open	350000	160000

4.2 11/10/2008 Tests

Frame sets SAT0001 – SAT0038 were obtained during this test, which was limited by the dewar hold time of 8 hours. The tests began at 9:38 am and concluded by 3:05 pm, when an anneal sequence was started. The longest time history of about 5 hours was obtained for the latent introduced in SAT0004. Backgrounds were provided by the array stimulators, which have since become inoperative.

4.3 11/20/2008 Tests

Since the 11/10/2008 tests failed to introduce sources as bright as on-orbit targets such as Jupiter and Saturn, additional exposures of the same sorts were obtained on 11/20/2008. Frame sets SAT0206 – SAT0208 were obtain on that date, which included the brightest sources with a flight-like dwell time observed during the MIC-2 tests. The backgrounds for this source were provided by the scatter source. This provided much higher background levels than the 11/10 tests, confirming that the long-term latents produce a gain rather than bias offset effect.

4.4 Test Limitations

The SDL latent image tests were performed using a relatively extended (50 x 70 pixels in W4; 100 x 140 in W3) illuminating source. Both the illumination pattern and scattered light are not flight-like in nature. The illumination was introduced during approximately one frame using a cold blackbody source as a manual shutter. In some cases the illumination dwell time did not coincide with the frame exposure time, being initiated before or after the exposure began and ending either before the exposure ended or persisting into the following frame. Given the complex nature of the results, the grid of source illumination levels is rather sparse, with a large gap in knowledge in W4 for sources with illumination levels between 622 and 21000 Jy. The stimulator background proved to be highly non-uniform, both spatially and temporally. It was also much lower in magnitude than typical zodiacal backgrounds.

5 Summary of Test Results

5.1 Short-term Latents

The SDL MIC-2 latent tests are not ideal for determining the presence or absence of short-term latent images. A manual shutter was used to illuminate the arrays for a single exposure, so the effectiveness of closing the shutter before the next frame is problematic. Thus, the first frame after the illumination is not useful for determining the presence or absence of a short-term latent.

5.1.1 Hg-Cd-Te arrays

Although apparent residual images are present in the MIC-2 latent test initial post-illumination frames, we cannot determine whether they are due to shutter miscalculation or a very rapidly decaying short-term latent.

5.1.2 Si:As arrays

There is an initial short-term latent that appears to be present at all signal levels. The first frame after the illuminating frame has a latent present at < 3% of the peak flux (uncertain due to manual shutter operation). The second frame has a 0.4% latent. The decay time is ~3 sec. The functional form of the decay of brightness in W4 is:

$$F(t) = F_0 e^{-t/t_0} + B$$

where F_0 = initial brightness of pixel in source
t_0 = decay time = 3 sec
B = pixel background brightness without source + bias

5.2 Long-term Latents (Si:As arrays only)

The long term latent appears at some point between 7.7 and 32 Jy. It is a gain effect that increases the response by about 9% (in Band 4) in the pixels which exceed the threshold fluence. The strength of the latent does not seem to correlate in an obvious way with the brightness of the initial source between 3 and 320 Jy. It is very similar in strength over an order of magnitude in illuminating source flux density. There is no obvious decay in strength of this latent during the 5 hours. These latents are completely eliminated by 15K anneals of the arrays.

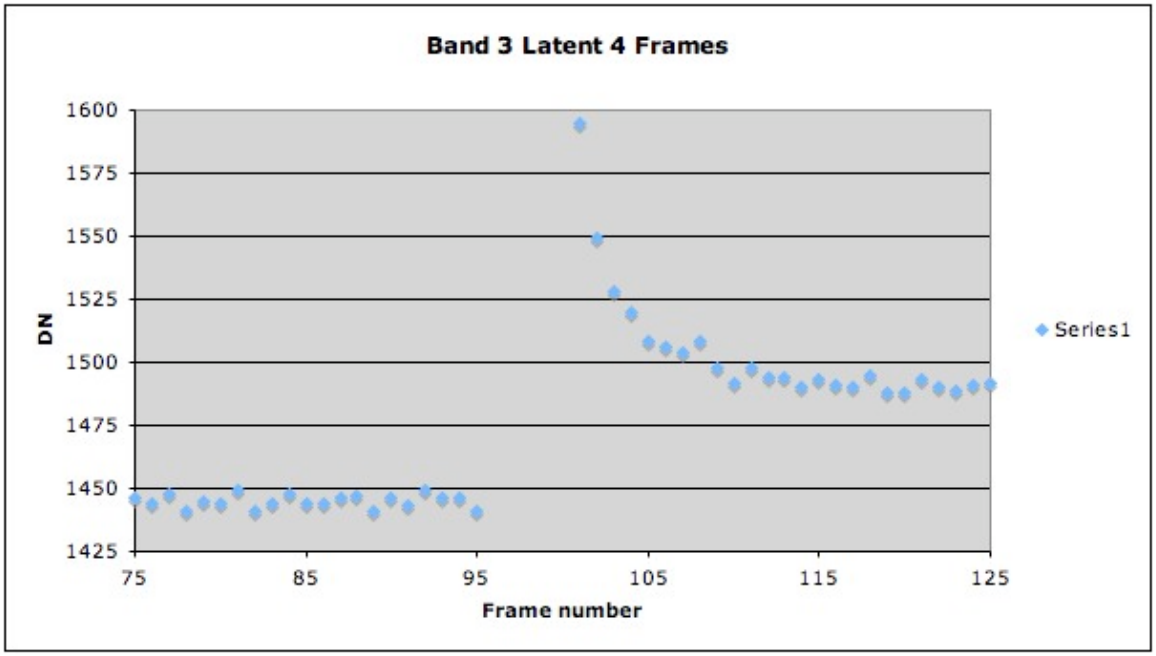


Figure 1. Latents in WISE Band 3 introduced by a 95 Jy equivalent source. The displacement between the values before frame 95 and after frame 115 is due to the long-term latent image of about 5% in gain. The exponential decay seen between frames 100 – 105 is due to a short-term latent.

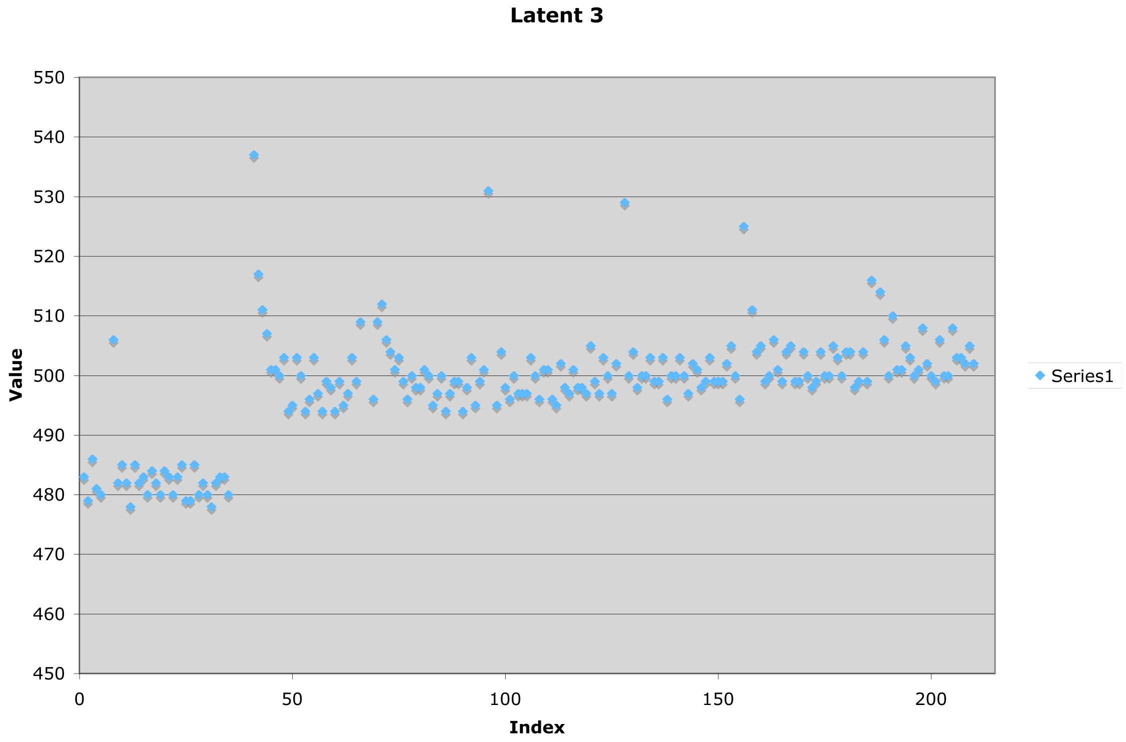


Figure 2. Long term latent image in WISE band 4 introduced by a 32 Jy equivalent source produces an offset in the light curve of about 9% in gain.

5.2.1 Threshold

No long-term latents are detected in the tests for sources fainter than 10 Jy. A test was performed for a 7.7 Jy source which resulted in no long-term latent.

5.2.2 Dark Latents

Between 620 Jy and 21000 Jy in WISE Band 4, the long-term latent undergoes a qualitative change in character from a positive to a negative gain effect. The “dark latent” depresses the value of the background by up to 5% in the tests conducted at SDL on 11/20/2008. These latents are completely removed by a 15 K anneal.

5.3 Semi-permanent Latents

The focus probe and RSR tests used much higher illumination levels and dwell times on small portions of the W3 and W4 arrays. These introduced 1 – 2% bright latent images that persisted through all anneal cycles of the arrays over a period of more than 2 weeks. Complete thermal cycling of the arrays up to room temperature removed these latents.

6 Saturation Effects on WISE Arrays

6.1 Column pulldown

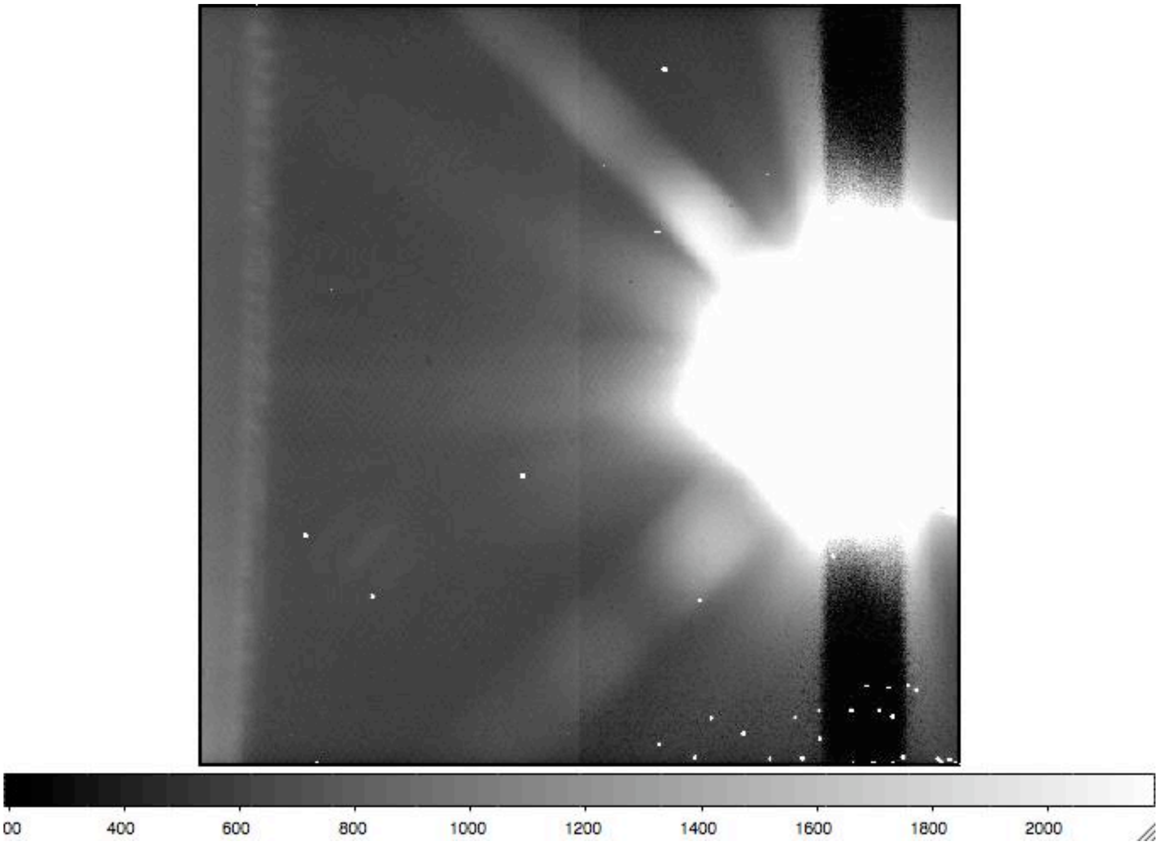


Figure 3. Column pulldown introduced by 320 Jy equivalent source in W4. Level of pulldown is bias of 256 DN.

6.2 Dark ring

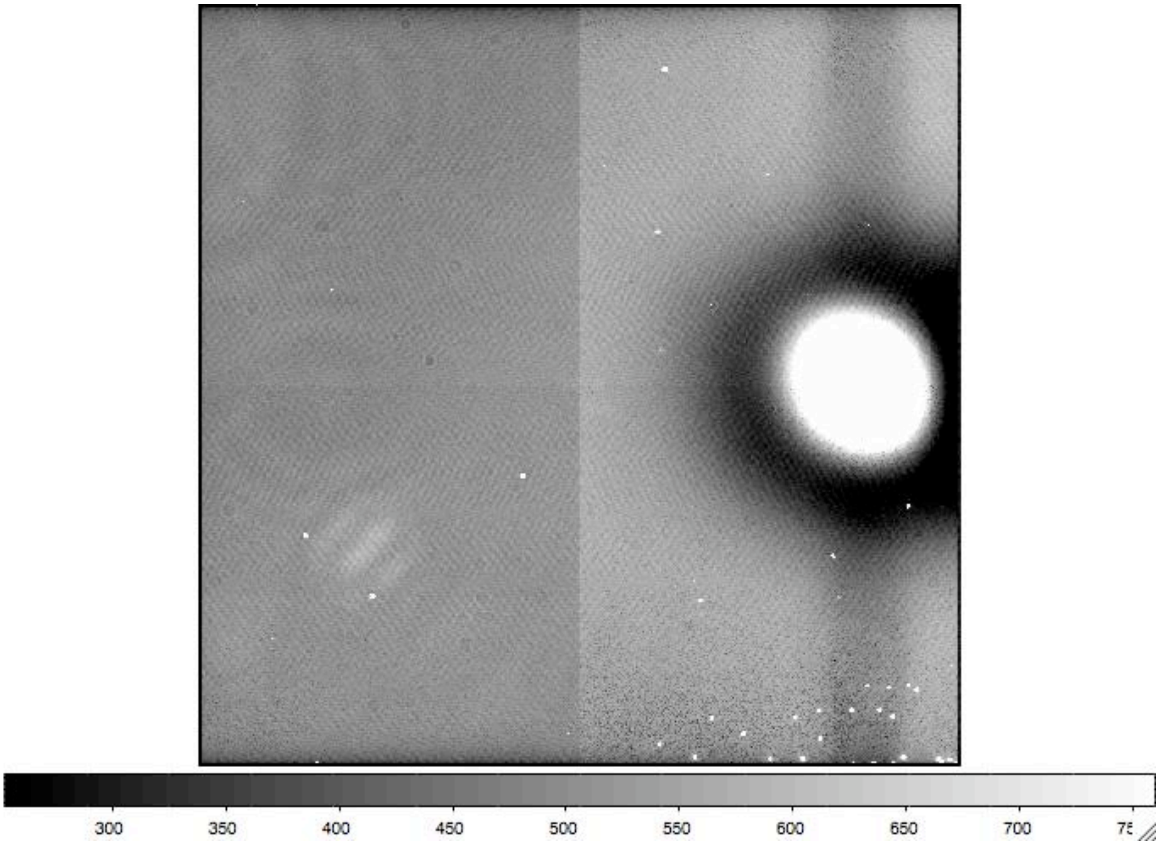


Figure 4. Dark ring persisting two frames after a 320 Jy equivalent source in W4. Level of dark ring is below the bias in some positions

6.3 Nonlinear quadrant droop

TBD