CCD Image Anomalies Caused by Unpainted Filter Edges, CCD Photo-Response Non-Uniformity and Mitigated CCD Residual Bulk Image Trap Leakage

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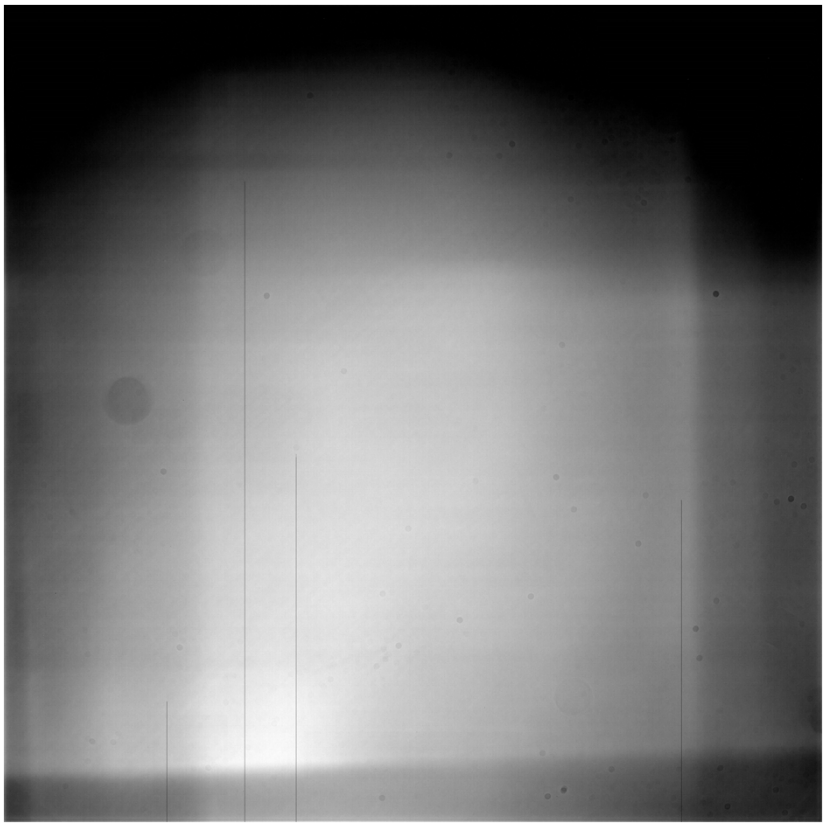
Key Points

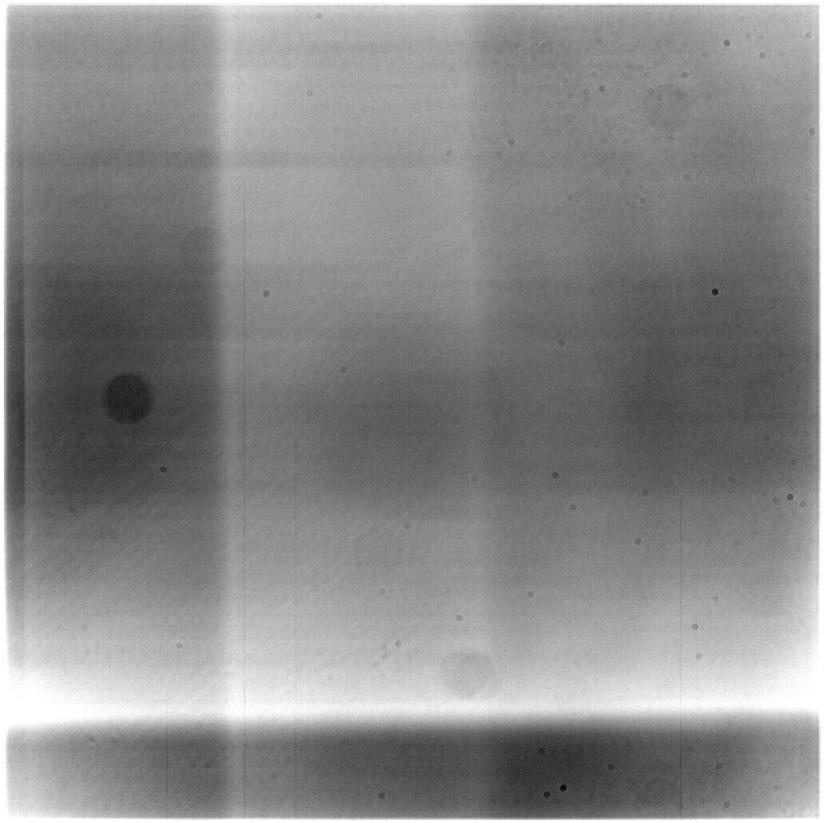
- Flats taken using CCDs and square filters with unpainted edges exhibit anomalies
  - Straight line ‘blocky-shadows’ and straight lines demarcating lighter versus darker regions appear in some flats
- Filter Edge Artifacts were eliminated by blackening edges of filters using a Testor’s brand Flat Black Enamel Pen
- Other artifacts are due to CCD Photoresponse non-uniformity and Mitigated Residual Bulk Image (RBI) Trap Leakage
- Proper calibration eliminates all artifacts except for filter edge artifacts, which are eliminated by edge painting

Examples
(non-edge blackened square filters)



Ha Flat

KAF16803



[SII] Flat

Source: Adrien Richardson

Edge Blackening

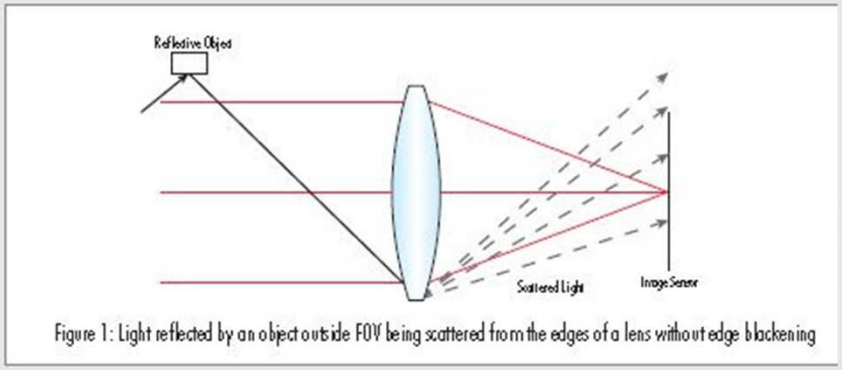


Figure 1: Light reflected by an object outside FOV being scattered from the edges of a lens without edge blackening

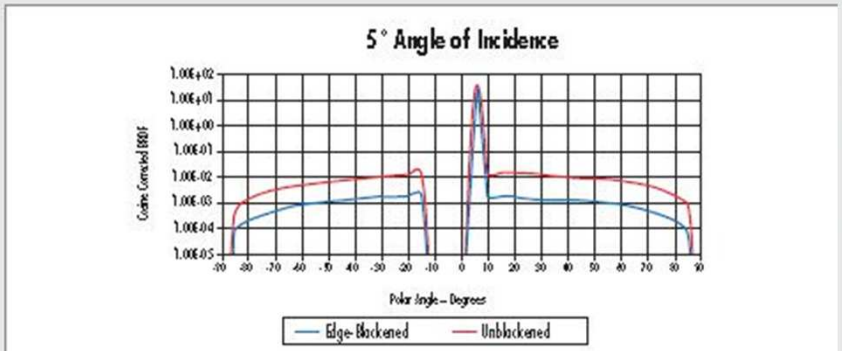
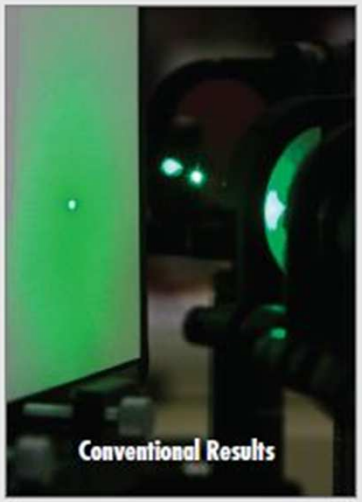


Figure 2: BRDF Plot of unblackened and blackened lenses



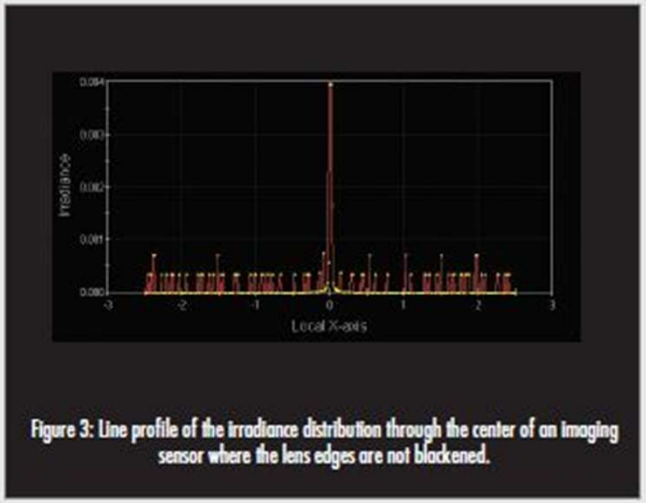


Figure 3: Line profile of the irradiance distribution through the center of an imaging sensor where the lens edges are not blackened.

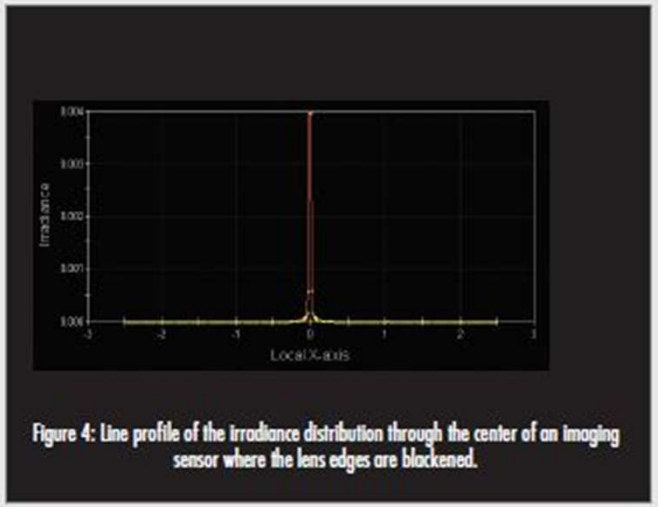


Figure 4: Line profile of the irradiance distribution through the center of an imaging sensor where the lens edges are blackened.

Source: Edmund Industrial Optics “Why Use Edge-Blackened Optics?”

Blackening the Edges

2549C Enamel Paint Marker Flat Black
by Testor Corp.

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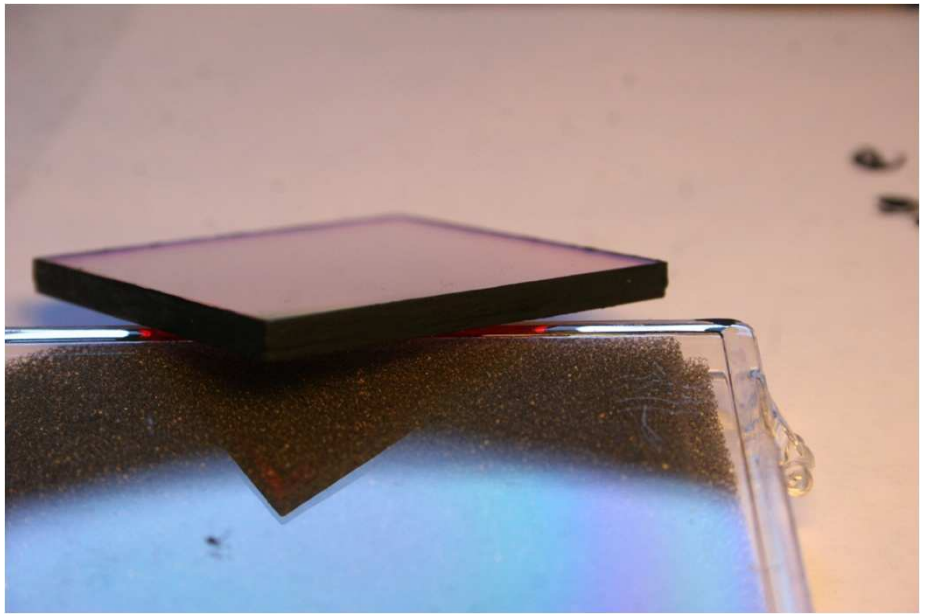
Price: $3.70

In Stock.
Ships from and sold by **Best Service Stores**.

Only 2 left in stock--order soon.

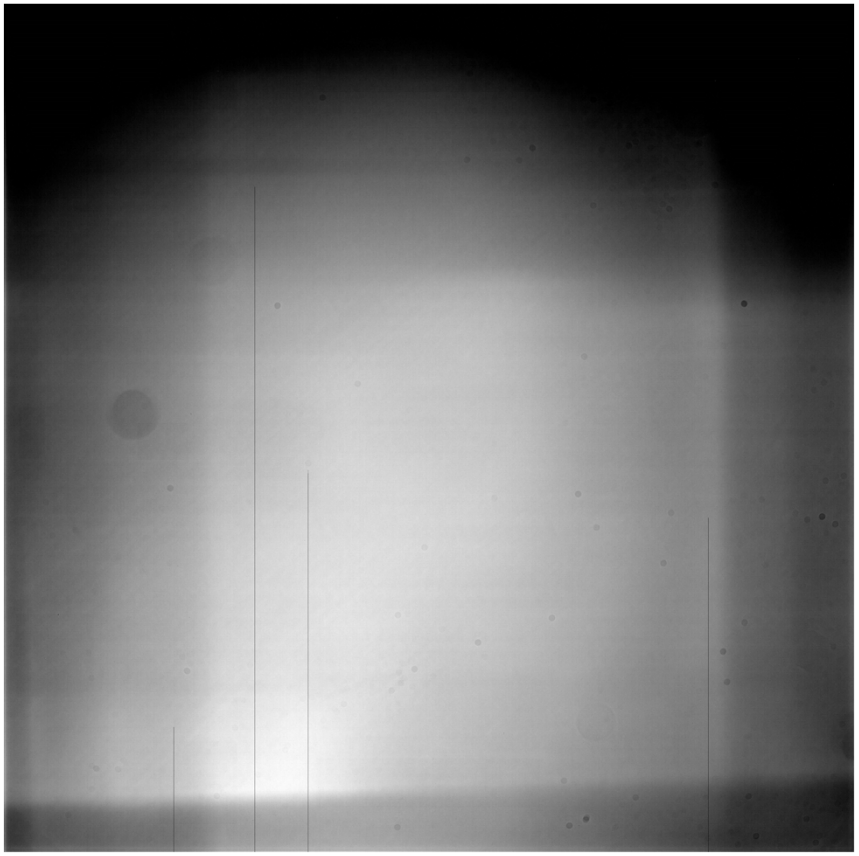
4 new from $3.70

Source: Amazon.com



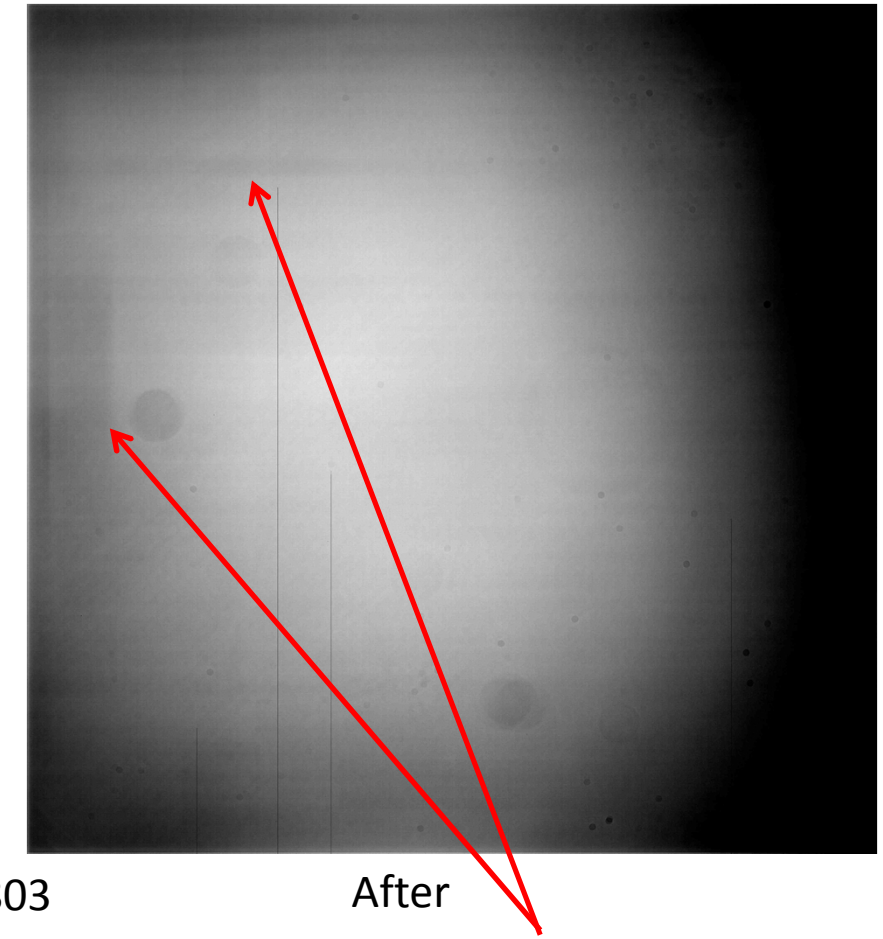
Source: Adrien Richardson

Before/After Edge Blackening



Before

KAF16803



After

Remaining anomalies are discussed next

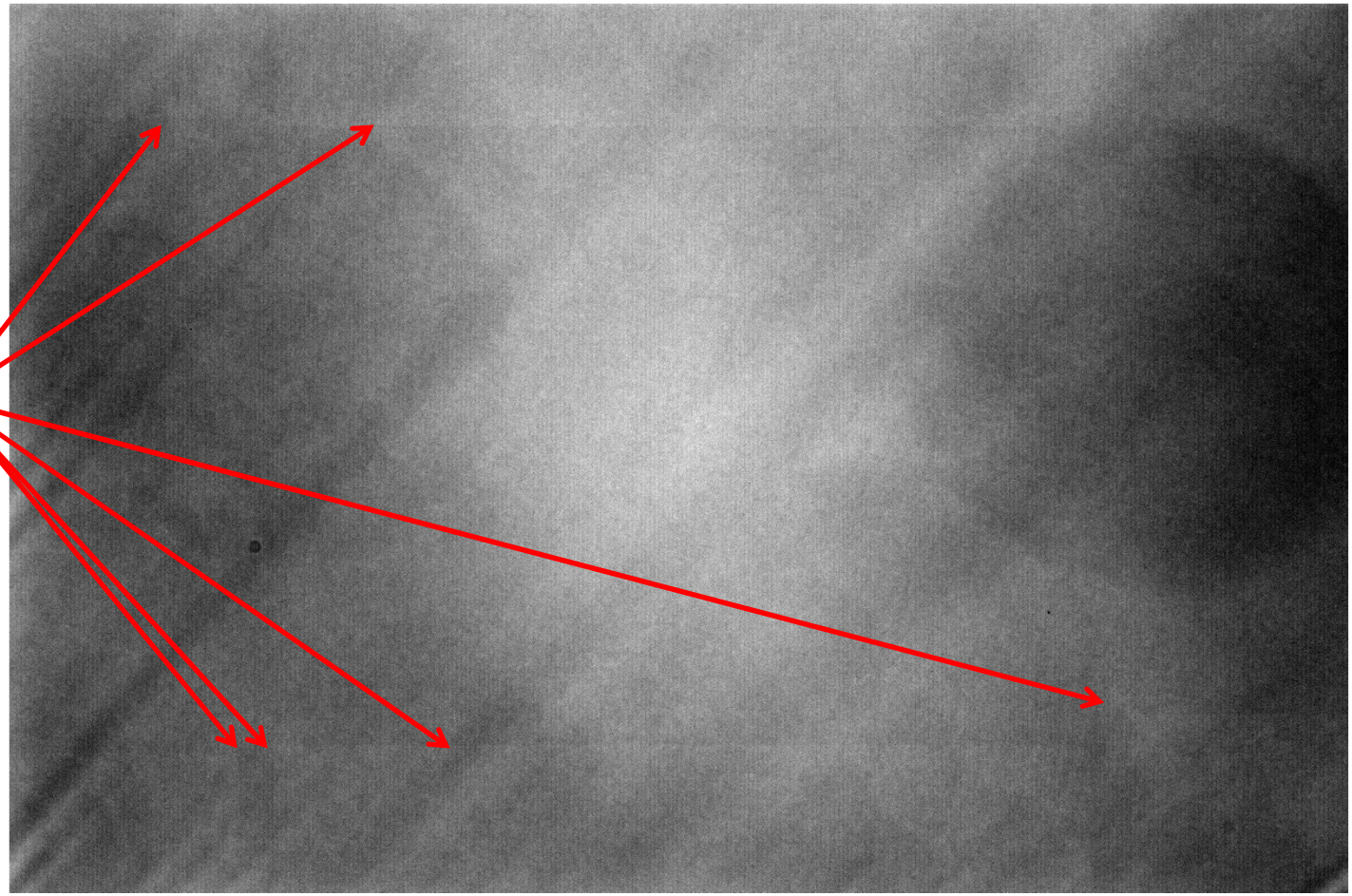
Source: Adrien Richardson

PRNU Anomalies

- Fabrication processes for CCDs use photolithography for making required structures on the silicon wafer
- The wafers are coated with a photosensitive thin film, exposed via a photomask and then processed creating the CCD's circuitry on the silicon wafer
- The photomasks are made using an electron-beam with a finite spot size.
- Minor variations in line widths on the photomask arise from the finite spot size and the need for the beam to "snap to grid" to cut the design features
  - The features to be etched may not lie perfectly on Ebeam boundaries
  - This causes dimensional variation in the resulting etched features on the photomask
- These result in linewidth variations on the CCD that cause some pixels to be slightly larger than others
- This leads to visible artifacts in images arising from Photo Response Non Uniformity (PRNU), an important CCD performance specification
- These artifacts are completely removed by proper flat fielding

Examples of Photomask-Induced PRNU Artifacts

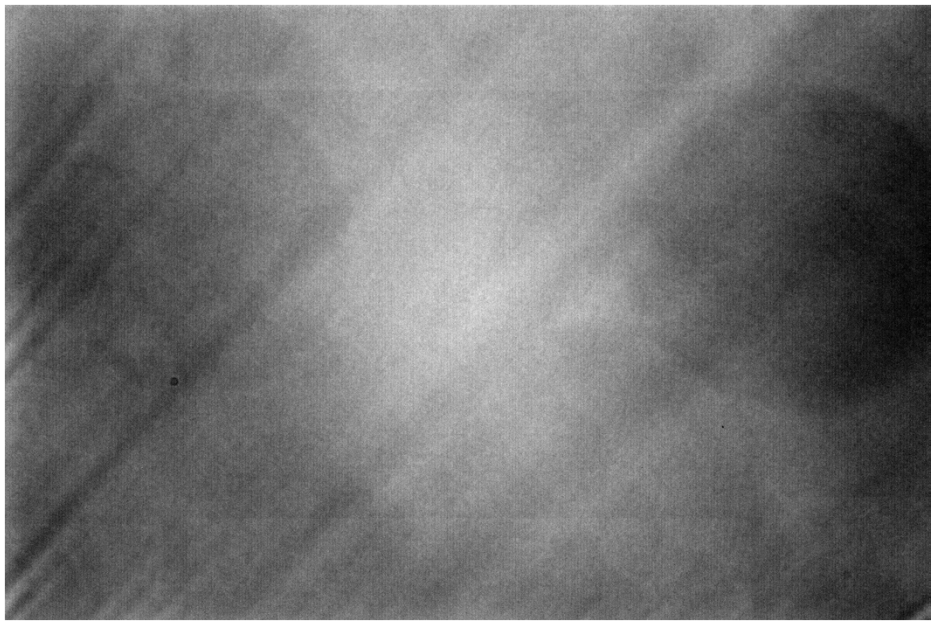
Caused by photomask linewidth variation



KAF3200ME Halpha flat using 50mm ROUND filter

Source: Crisp

Multiple PRNU Artifacts
(all are removable by flat-fielding)



KAF3200ME Halpha flat
using 50mm ROUND filter

KAF3200ME [OIII] flat using
50mm ROUND filter

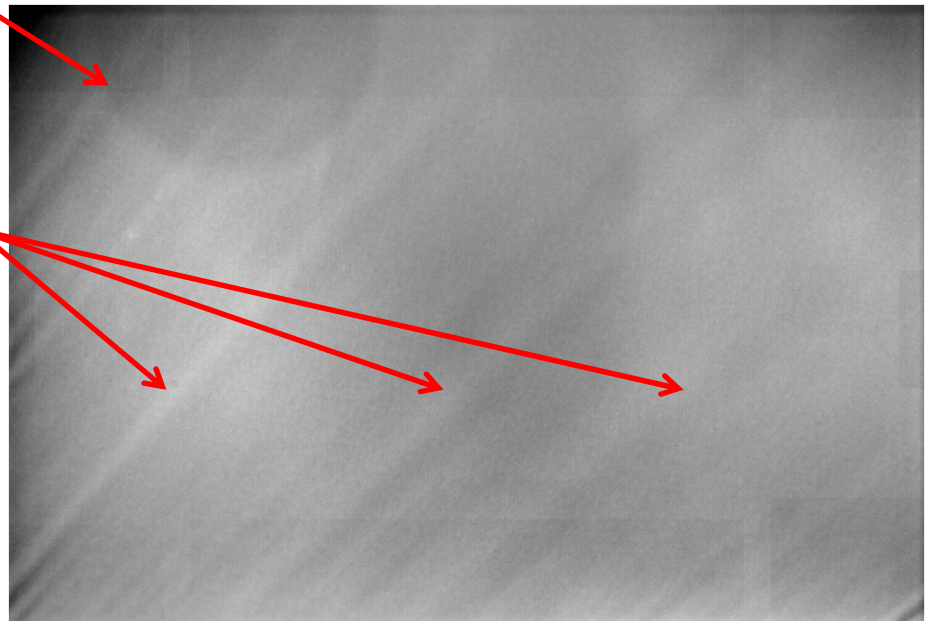
Note the photomask-induced artifacts are identical
(the blocky shapes with straight edges oriented horiz and vert)
NOT CAUSED BY FILTER EDGES

Source: Crisp

Non Photomask Artifacts (all are removable by flat-fielding)

Dust Mote on filter

Wafer Polishing Artifacts (in silicon wafers prior to CCD fabrication steps) cause CCD Photo-Response Non-Uniformity

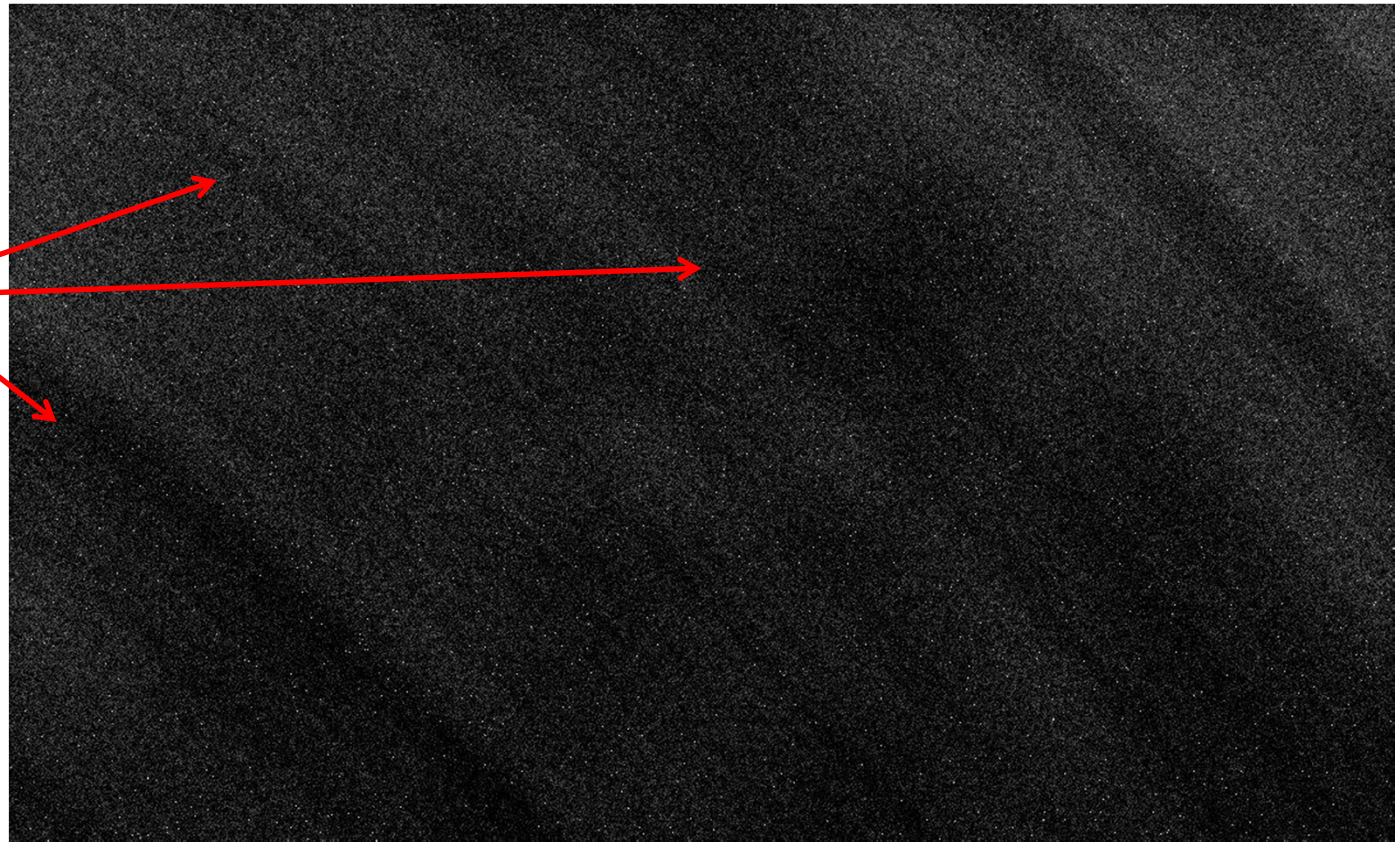


KAF3200ME [OIII] flat using 50mm ROUND filter

Source: Crisp

Dark Signal Non-Uniformity (DSNU) For RBI Mitigated Camera

DSNU component caused by non-uniform RBI Trap distribution (removed by dark-subtraction)

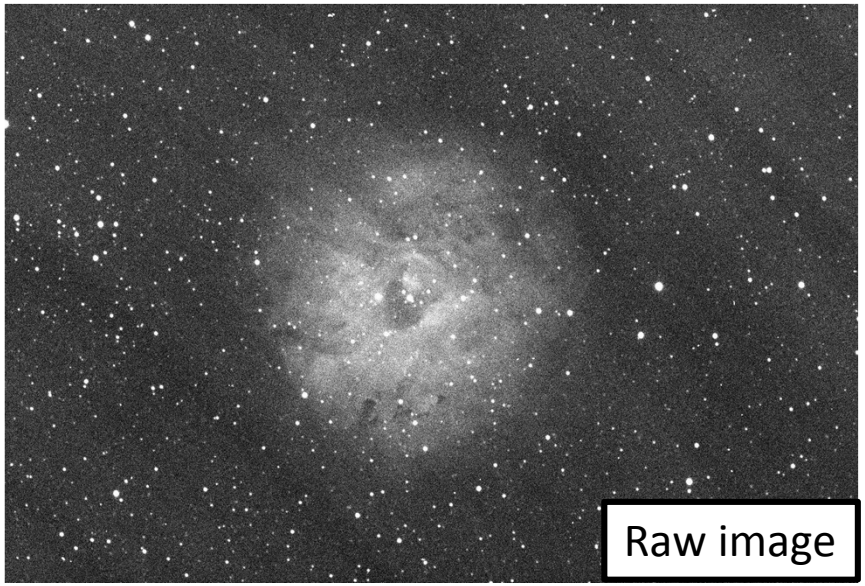


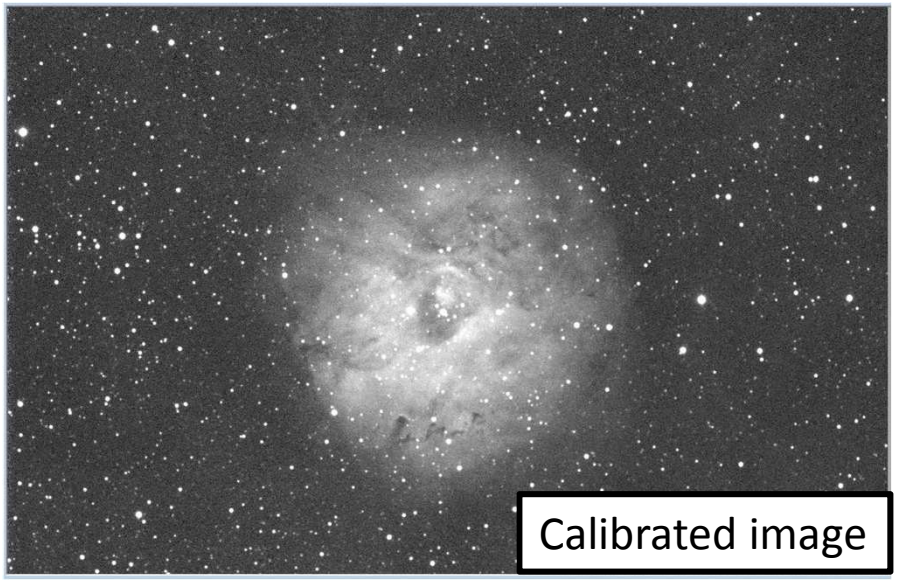
KAF3200ME Dark

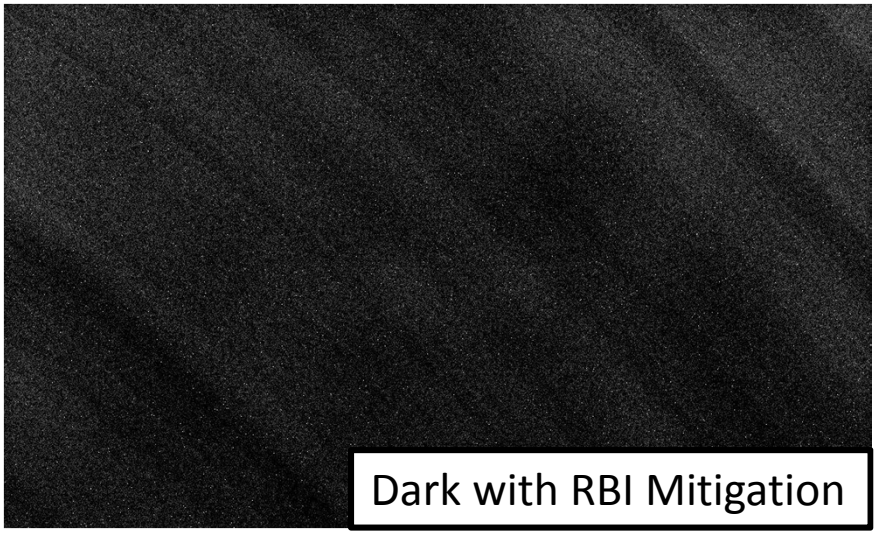
Classic DSNU “Dark Spikes” (salt and pepper features) (removed by dark-subtraction)

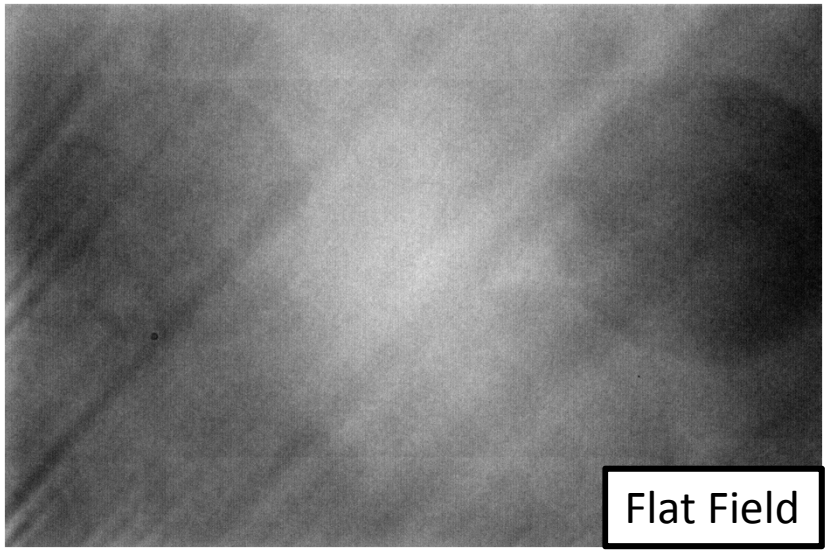
Source: Crisp

Before/After Calibration









Source: Crisp