Artifact Analysis of DESC DIA Pipeline

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Artifact Analysis

We analyze subtraction artifacts detected from difference images produced by the DESC Difference Image Analysis (DIA) pipeline.

Dataset: DC2 Dataset, Run 2.2i, i band

Stack Version: v20.0.0

Software: dia_pipe

Template Image: deepCoadd

Science Image: calexp

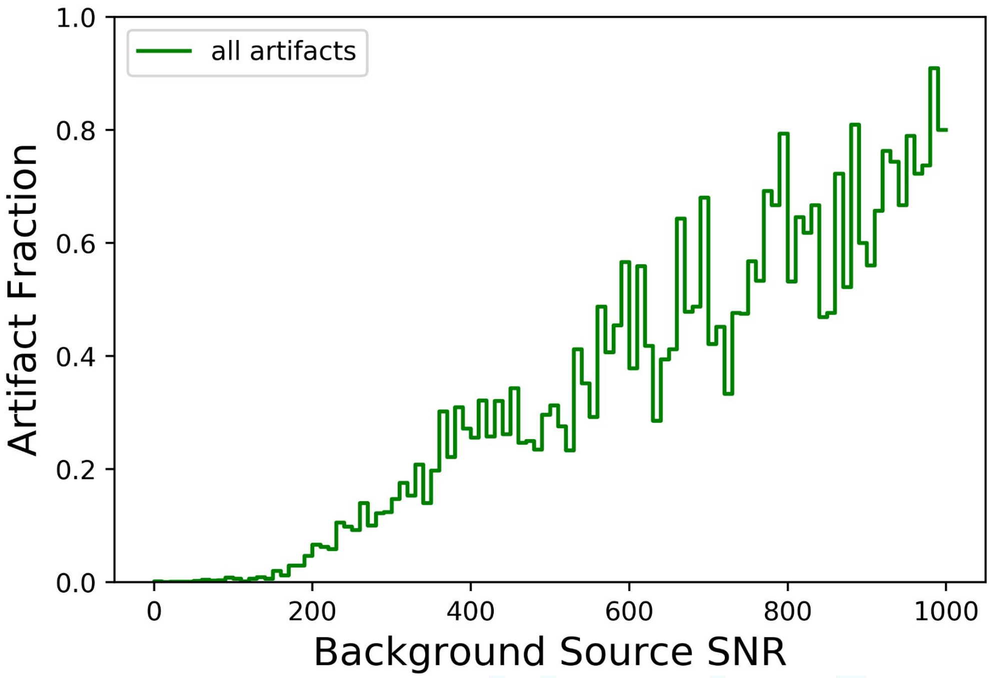
Subtraction Algorithm: Alard-Lupton (AL) algorithm

We choose 7 deepCoadds with patch id 00, 11, …, 66. For each deepCoadd, we select 10 calexp exposures which overlap with the coadd. We have 70 image pairs in total.

Artifact Fraction

For the detected artifacts, about 92.58 % of them are subtraction residuals of background sources. We match detected background sources from the calexp src catalog to the detected dia sources from the diaSrc catalog, and calculate the artifact fraction at different source SNR.

(173982 background sources in total)



Apply Base Flag Cut

We keep detections which have no following base flags be set. After applying these flags, we can still have 99.7% of true transients, which means these flags do not affect much of true transient detection.

base_PixelFlags_flag_saturated

base_PixelFlags_flag_saturatedCenter

base_PixelFlags_flag_suspect

base_PixelFlags_flag_suspectCenter

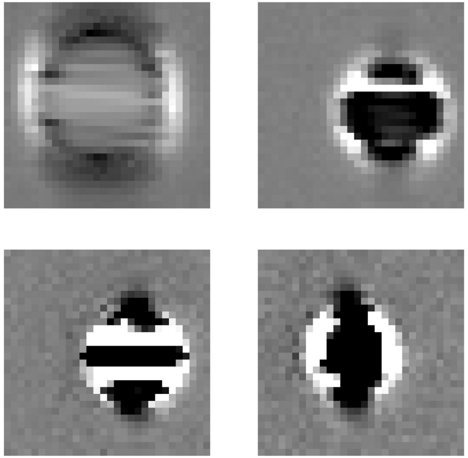
base_PixelFlags_flag_offimage

base_PixelFlags_flag_edge

base_PixelFlags_flag_bad

base_NaiveCentroid_flag

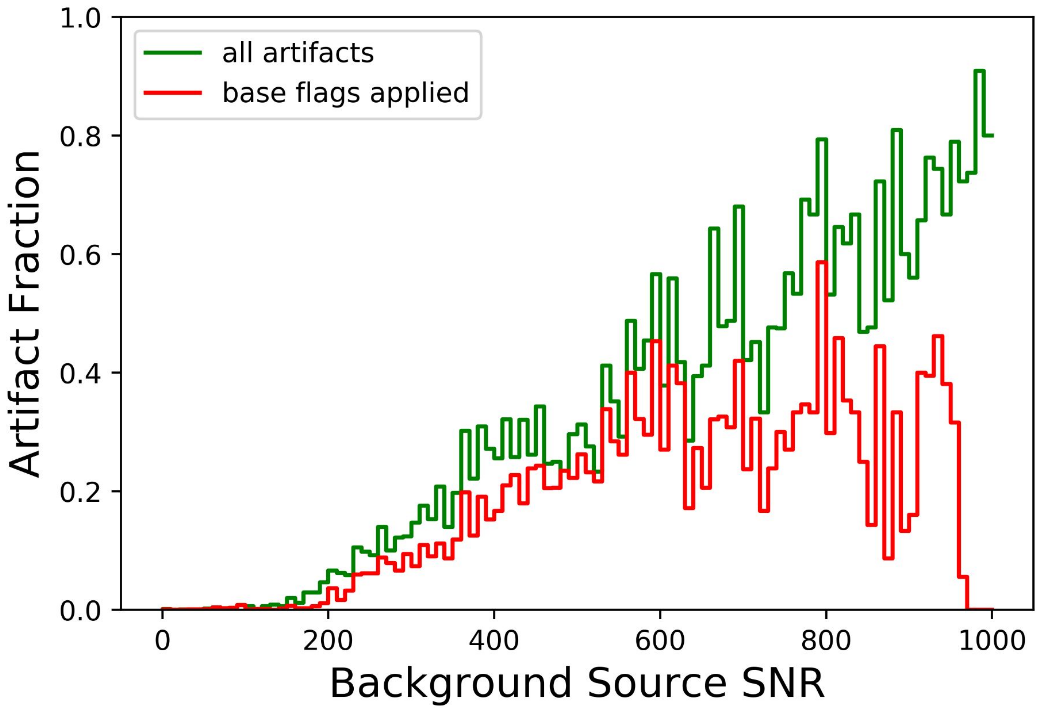
Saturation



Artifact Fraction

We have 2265 artifacts in total. After applying flag selection, we have 1134 artifacts. About 50% of artifacts can be removed by simply using base flag cut.

(173982 background sources in total)



PSF Full Width at Half Maximum (FWHM)

To study what causes subtraction artifacts, we split image pairs into three groups based on the difference between the calexp PSF fwhm and coadd PSF fwhm. We define the PSF ratio as,

$$\text{PSF Ratio } (r) = (\text{ Calexp FWHM} - \text{Coadd FWHM }) / \text{ Coadd FWHM}$$

The three groups are defined as

Group Name	PSF Ratio
Broad	$r >= 0$
Near	$-0.05 < r < 0$
Sharp	$r <= -0.05$

Artifact Morphology

Saturation Artifact: Saturation artifacts are artifacts which have saturation pixels, they can be easily removed by applying base flag cut.

Identified Dipole Artifact: Identified dipole artifacts are dipole artifacts which have dipole flags be set. Only a fraction of dipoles can be identified due to the detection threshold of the classification algorithm.

Remaining Artifact: Remaining artifacts have neither base flags or dipole flags be set. It includes dipoles, pixel correlation artifacts, and deconvolution artifacts.

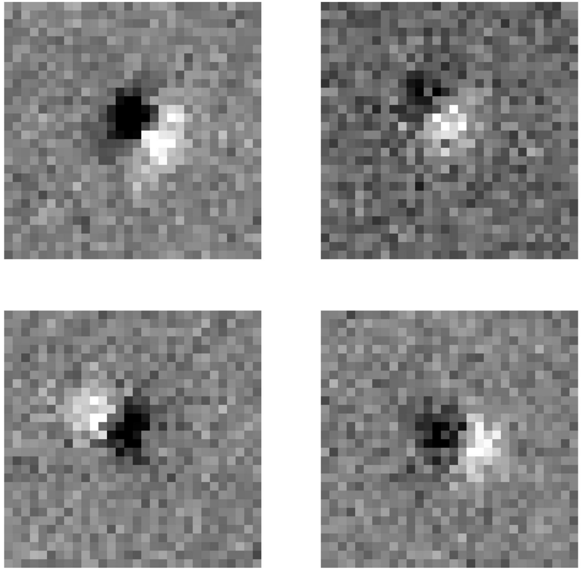
Fraction	Saturation	Identified Dipole	Remaining Artifact
Broad	44.47 %	18.91 %	36.62 %
Near	50.99 %	19.88 %	29.13 %
Sharp	53.48 %	20.68 %	25.84 %

Dipole Flag

The DIA pipeline provides an algorithm for dipole classification. For a detected source, it fits fluxes of negative and positive lobes using a joint-psf model. A detected source is classified as a dipole only if the quadrature sum of fitted pos/neg fluxes is above the minimum SNR threshold and the fitted fluxes weighted by the total flux are both smaller than the maximum threshold.

Since this algorithm depends on two selection thresholds, it is possible that a detection can visually appear as a dipole but cannot satisfy these criteria.

Dipole



Artifacts per Detector Rate

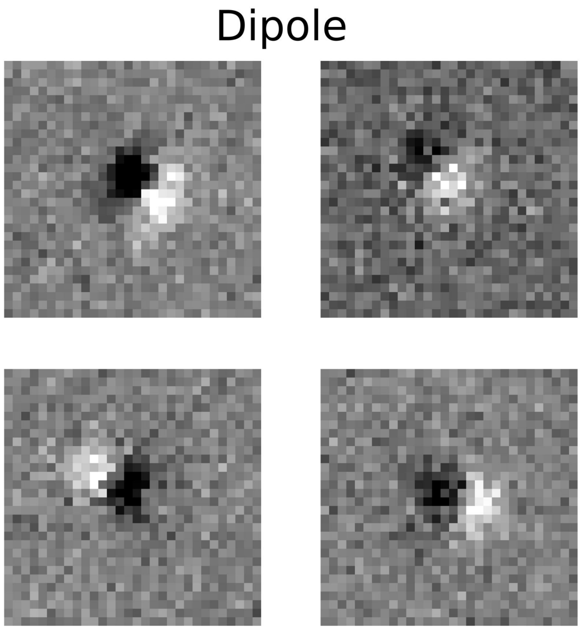
Since saturation artifacts can be removed by applying base flag cut, we focus only on identified dipole artifacts and remaining artifacts (1134 in total). The artifacts per detector rate of each group is shown below.

Group Name	Number of Image Pairs	Number of Artifacts	Artifacts per Detector
Broad	30	417	13.90
Near	16	249	15.56
Sharp	24	468	19.50

Dipole

Occurrence: Broad, Near, Sharp

Description: Dipoles can be caused through many processes, such as image registration, PSF variation, kernel fitting , resampling… Given the complexity of the origins of dipole artifacts, we propose to implement more flexible kernel bases (e.g. delta bases) with high spatial degree of freedom (DoF). Meanwhile, we need to keep track of the flux recovery when implementing new bases to avoid inaccurate flux measurement.



Pixel Covariance In the Difference Image

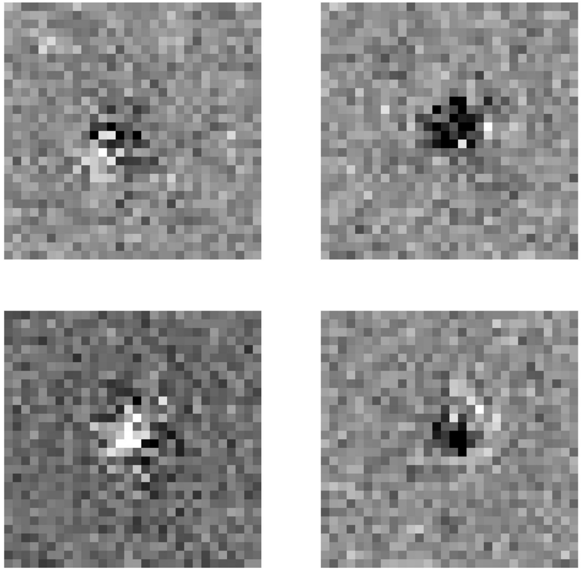
Occurrence: Broad, Near, Sharp

Description: Pixel correlation could be caused by image convolution. It can be reduced both globally and locally. The ZOGY algorithm suggests to normalize each frequency mode in the Fourier space. This can whiten the correlation of sky noise. In bright regions, we can apply a whitening filter to each detected stamp to diagonalize the covariance matrix. How to properly estimate the covariance matrix requires further work.

$$Z = \Sigma_X^{-\frac{1}{2}} X.$$

X: Random vector.
Σ_X: Covariance matrix of X.
Z: Whitened vector.

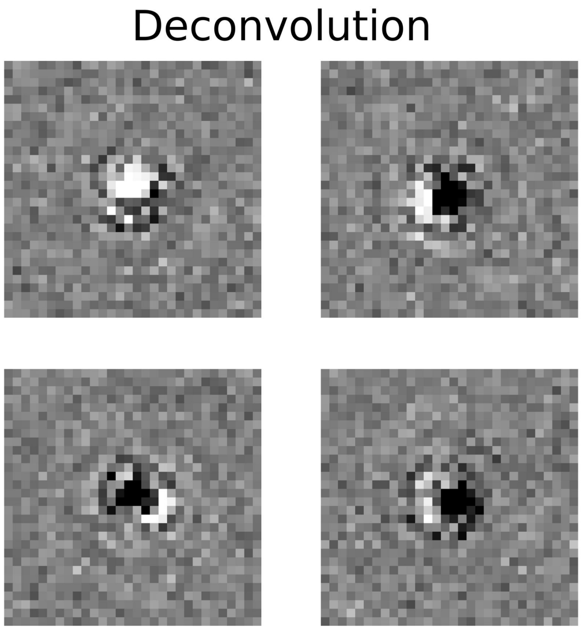
Pixel Correlation



Deconvolution

Occurrence: Near, Sharp

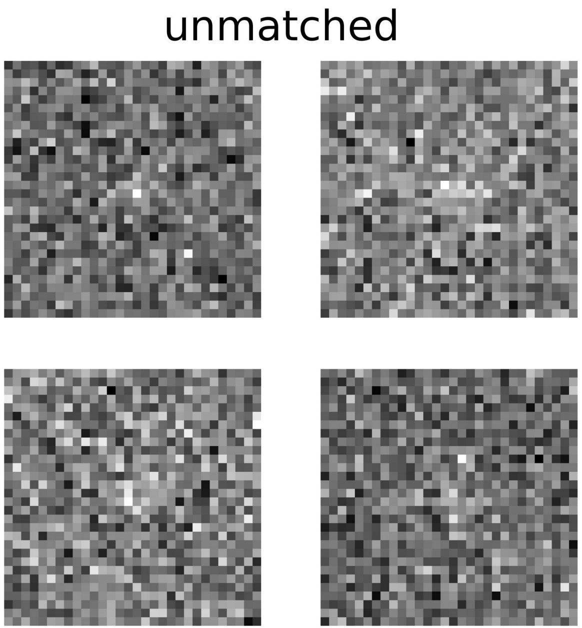
Description: Deconvolution artifacts can be found when the calexp PSF is sharper than the coadd PSF. It usually comes with a ring pattern. To remove it, we can either convolve the calexp exposure to the template, or pre-convolve the calexp exposure before kernel matching. Both methods add correlations between pixels. We need to include the non-diagonal covariance matrix to get the "optimal" kernel solution.



Unmatched Artifacts

Occurrence: Broad, Near, Sharp

Description: Unmatched artifacts are detections which cannot be matched to background sources. They are caused by statistical fluctuations of sky background noise.



Conclusion

1. Most of detected artifacts are subtraction residuals of background sources. The distribution of artifacts fraction increase with the background source SNR. Applying base flag cut can reduce more than 50 % of artifacts.
2. We break image pairs into three groups based on the PSF FWHM difference between the calexp exposure and the coadd exposure. The artifacts per detector rate increases as the FWHM difference decreases.
3. We study origins of different types of artifacts and explored possible methods to remove these artifacts. A more flexible matching kernel with high spatial DoF can be useful to remove dipoles. Pre-convolution or convolving calexp to deppCoadd are possible methods to avoid deconvolution. Tracking pixel covariance and applying whitening methods are helpful to reduce pixel correlations.

Thank You !