Fake Source Experiment for Chandra ACIS Observations

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Abstract High spatial resolution Chandra X-ray observations have resolved many point sources in both galaxies and clusters of galaxies. The observed spatial distribution of these point sources suffer from incompleteness due to source locations, background variation, and source brightness. To investigate variations in completeness, we perform a large number of fake source experiments for Chandra ACIS observations using custom software called **XFAKE**. The detection probability is found to decrease with increasing off-axis angle (OAA), an angle measured from on-axis to the position of a source. The detection probability for point sources with net counts > 10 and OAA < 5 arcmin is found to be greater than 95%, with a slight dependence on background variation. We describe the simulation software **XFAKE** along with an accompanying software package **XPROCES** and discuss the detection probability and the count recovery rate for different background environments.

XPROCES

1. **Reduce new event 2 file** (http://cxc.harvard.edu/ciao/guides/acis_data.htm/)
2. **Clean flare events**
3. **Make exposure map & images**
4. **Perform X-ray photometry** (*wavdetect*, XAPPHOT)
5. **Accessory jobs** (Energy Conversion Factor, color grids etc)
6. **Compress the data**

Output of XPROCES is used in XFAKE

XFAKE

1. **Compute MARX correction factor** (http://space.mit.edu/CXC/MARX/)
2. **Generate the fake source list** (user-defined model)
3. **Run MARX to generate the fake source events**
4. **Group the fake sources to make an image**
5. **Make images to run *wavdetect***
6. **Perform X-ray photometry**
7. **Post photometry** (matching, detection probability etc)

XFAKE Simulation Result of Galaxy Clusters

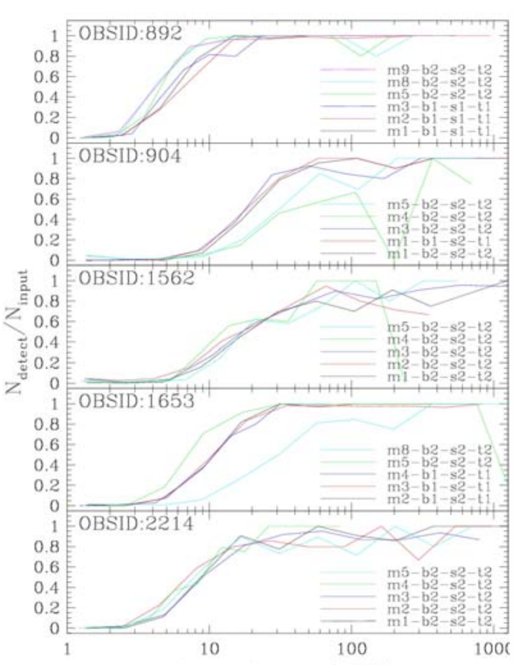

Table 1: Model description of **XFAKE** Simulations

obsid Detector Exp. Time	model	Description
892 ACIS-I 9 ksec	m1	standard model[1]
	m2	$\Gamma = 0.3$[2]
	m3	$\Gamma = 1.7$
	m5	$\beta_{2D}(r_c = 20'', \alpha = 1.0)$
	m8	xsub,pos=$\beta_{2D}(r_c = 20'', \alpha = 1.0)$
	m9	obs,pos=$\beta_{2D}(r_c = 20'', \alpha = 1.0)$
904 ACIS-I 38 ksec	m1	obs
	m3	xsub
	m4	xsub,$\beta_{2D}(r_c = 20'', \alpha = 1.0)$
	m5	xsub,$\beta_{2D}(r_c = 20'', \alpha = 1.0)$, overlap
1562 ACIS-S 70 ksec	m1	obs
	m2	standard model
	m3	$\Gamma = 0.3$
	m4	$\Gamma = 1.7$
	m5	xsub
1653 ACIS-I 70 ksec	m2	standard model
	m3	$\Gamma = 0.3$
	m4	$\Gamma = 1.7$
	m5	$\beta_{2D}(r_c = 20'', \alpha = 1.0)$
	m8	xsub,$\beta_{2D}(r_c = 20'', \alpha = 1.0)$
2214 ACIS-S 9 ksec	m1	obs
	m2	standard model
	m3	$\Gamma = 0.3$
	m4	$\Gamma = 1.7$
	m5	overlap[3]

[1] standard model: random distribution of source position, $\Gamma = 1$ for cumulative $log(N)-log(S)$ relation, fake sources are added on scaled blank sky event image, grouped not to be overlapped with each other.
[2] different from standard model only for $\Gamma = 0.3$ instead of 1.
[3] sources are allowed to overlap with each other.

Table 2: Binning, detection scales & thresholds

binning	scales	thresholds
b1 (1×1)	s1: "1 2 4 8 16 32 64"	t1: 10^{-6}
	s2: "1 2 4 8 16 32"	
b2 (2×2)	s1: "1 2 4 8 16 32"	t1,t2: $10^{-6}, 2 \times 10^{-6}$
	s2: "1 2 4 8 16"	

Fig. 6 **Detection probability of Chandra observations of galaxy clusters. Detail information of each model is described in Table1 & Table 2. Detection limit defined by the net count where the detection probability is 0.5, increases as exposure time increases due to the higher background noise for the deep exposure. Power-law index of log(N)-log(S) affects little on detection probability irrespective of exposure time and detector. Detection limit for model m8 of obsid=1653 is very high due to the high background of observed cluster image (sources are added on point source subtracted event image for this model).**

Acknowledgement: Algorithm to compute the energy conversion factor is based on XPIPE and an idea of MARX correction factor is kindly provided by ChaMP MARX simulations.

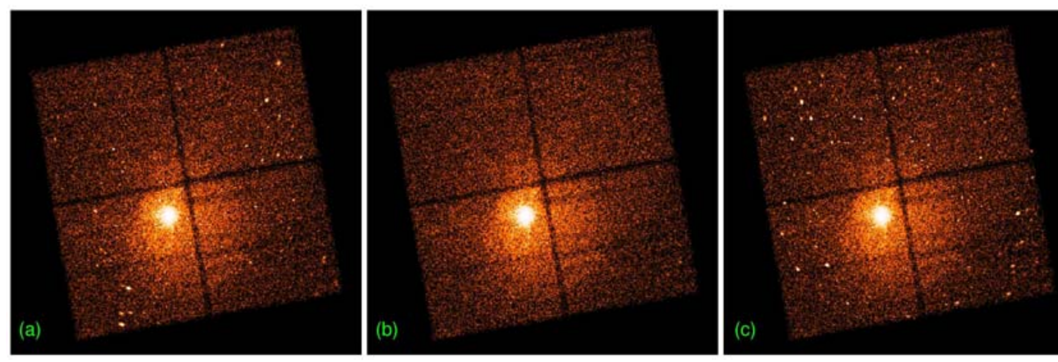

Fig. 1 **(a) Chandra ACIS observation of an elliptical galaxy NGC 1399 (XPROCES) (b) Point source subtracted event image (XSUBSTAR) (C) MARX generated fake sources added-on image (XFAKE)**

Performance of MARX Simulation

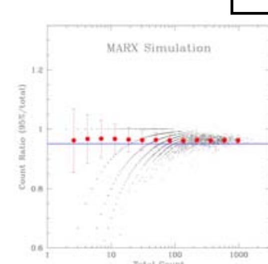

Fig. 2 **Number ratio of source events between R=95% of Encircled Energy Flux (EEF) of Point Spread Function (PSF) at E=1.5keV and total source events. The radius of 95% EEF of PSF is available at http://cxc.harvard.edu/cal/Hrma/psf/. Mean values (red circles) are very close to expected value (95%). The small difference (~1%) is mainly due to the choice of E=1.5keV to extract the radius of 95% EEF.**

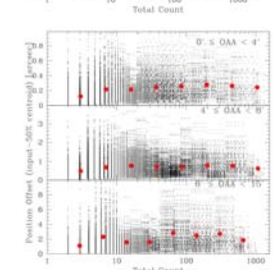

Fig. 3 **Offset between input MARX position and the centroid position of source events inside of R=50% EEF of PSF. The offset is as small as ~0.2 arcsec (~0.5px) for sources located around on-axis (top panel). For sources located at large off-axis angle (OAA~10 arcmin), the offset increases ~2 arcsec (note that the radius of 95% EEF of PSF at OAA~10 arcmin is ~13.5 arcsec).**

Photometry

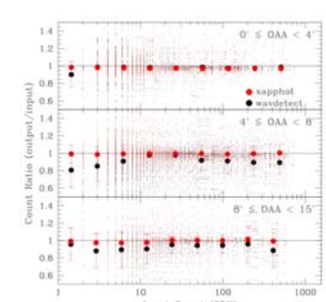

Fig. 4 **Comparisons of net counts of detected fake sources between *wavdetect* (black circles) and XAPPHOT (red circles). For sources located OAA<4 arcmin, both agree well with the input counts (top panel), while the net counts obtained with *wavdetect* for large OAA is clearly smaller than the input counts. Note that this underestimation of the net counts for *wavdetect* happens even for the brighter sources (2nd and 3rd panels).**

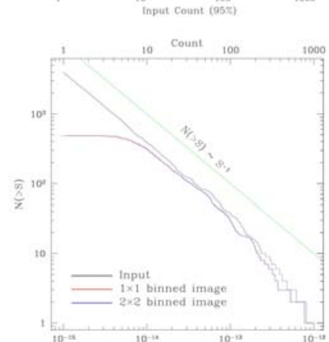

Fig. 5 **Source number count (cumulative log (N)-log(S)) plot of a sample run of XFAKE. Events of fake sources are added on a scaled blank sky event image. Input source list is generated by assuming power-law log(N)-log(S) (power index=1, green line) and fake sources are randomly distributed. Input fake sources are grouped not to be overlapped with each other in an image. The input source count does not follow the power-law at the brighter end due to the small number statistics. Source number counts for 2x2 binned image (blue line) agrees well with that of 1x1 binned image (red line). The CPU time to run *wavdetect* for a 2x2 binned image is ~10% of that of an 1x1 binned image.**

Example of XFAKE Output Plots

Left: Detection probability for given OAA bins (solid lines: number of sources, dashed lines with squares: detection probability). Detection probability is shown with red symbols and the false detection with blue symbols. **Center**: same as the left panel but as a function of OAA for given count bins. **Right**: Count recovery rate for *wavdetect* (black) and XAPPHOT (red) for given OAA bins.