An Overview of Pileup

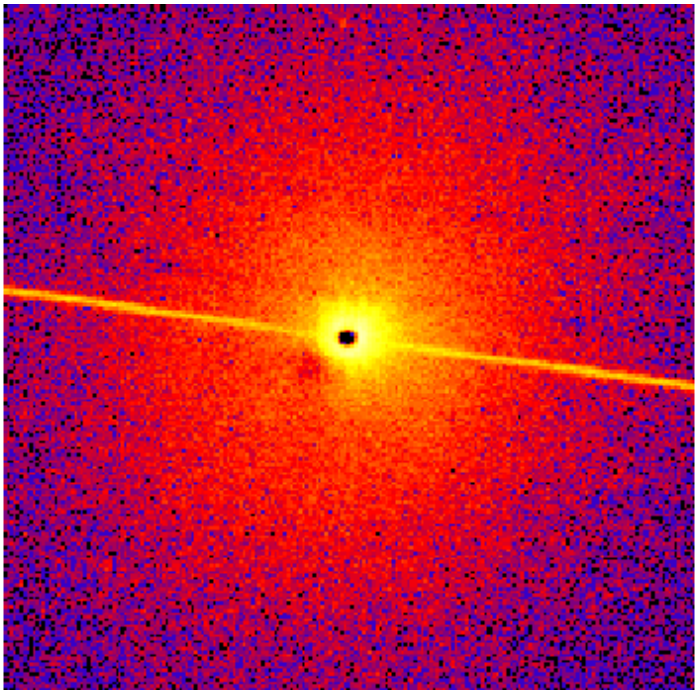
Return to: Why Index

The information in this why topic is taken from the Chandra ABC Guide to Pileup.

Pileup is a phenomenon that is inherent to CCD detectors, such as those that comprise the ACIS instrument on−board Chandra, which "under−sample" the mirror point spread function (PSF). Simply put, it occurs whenever two or more photons are detected as a single event, and thus it represents a loss of information from these events. The degree to which this information can be "recovered" is described below. Any corrections, however, are necessarily imperfect. Thus, it is often desirable to choose instrumental set−ups that minimize the occurrence of pileup.

The likelihood of pileup occurring is significant whenever source flux levels are high enough such that there is a reasonable probability of two or more photons arriving within the same detector region within a single ACIS frame integration time (or CCD row readout time, for continuous clocking mode). The charge from a single photon event is typically read out from a 3x3 pixel island; therefore, the relevant "detector region" referred to above is larger than a single pixel. Charge clouds from neighboring events can overlap and cause events centered several pixels away from each other to become piled; see Davis 2001 for a more thorough description.

The detected energy of a piled event is approximately equal to the sum of the energies of the individual photon events of which it is comprised. If the summed energy of the piled event exceeds the on−board spacecraft threshold (typically 15 keV), it is rejected by the spacecraft software. For sufficiently bright sources, this can lead to a visible "hole" in the source image, as seen in this image:



This is the 0th order image from an ACIS/HETG observation of a bright X−ray binary. Here, the count rate is sufficiently high that most piled events at the center of the PSF exceed the threshold energy and/or are assigned bad grades, yielding a hole in the image. In addition to the image hole caused by pileup, there is a readout streak (photons collected during the 41.04 msec required to transfer an image frame to the readout buffer), as well as asymmetry in the wings of the PSF. This latter effect is due to the effects of Charge Transfer Inefficiency (CTI), which similar to pileup, affects the grades of photon events. For CTI, photons closer to the chip readout (right side of the image) are less likely to have their grades migrate to bad values, and hence are less likely to be rejected.

Piled events also suffer from "grade migration". All events detected by ACIS are assigned grades based upon the shape of their charge cloud distributions in a 3x3 pixel island. These grades are used to determine whether the detected event is from a real photon or from a background event, such as a cosmic ray hit. As the number of photon events making up a piled event increases, it is more and more likely that the grade assigned to this piled event will "migrate" to a value inconsistent with a real photon. The piled event thus will be rejected either by spacecraft software or during subsequent analysis on the ground. This effect of grade migration also contributes to the detection hole illustrated in the figure above.

As a simple empirical description of this process of grade migration, one can assign a probability, alpha, that for each photon event beyond the first, the piled event retains a grade consistent with a real photon. Thus, in this simple model, the probability that a piled event is *retained* as a "real photon" is $\text{alpha}^{(N-1)}$, where N is the number of photons comprising the piled event. It is very important to note here that this is an empirical description of grade migration that has been found useful in some situations. As such, alpha is an uncalibrated quantity, and is likely unsuited for some applications. Grade migration is a complex phenomenon, which in reality will depend upon details of the detector, the incident spectrum, etc. We have found, however, that within the confines of our current understanding of the physics and calibration of the detector, more complex grade migration schemes are not yet warranted.

References

- Davis, J. E. 2001, ApJ, 562, 575

URL: http://cxc.harvard.edu/ciao3.4/why/pileup_intro.html
Last modified: 26 September 2006