Problems and solutions in deriving the log$N$-log$S$ of sources detected in PSPC images with a wavelet-transform algorithm

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1. The zero-order log$N$-log$S$

We study the problem of recovering the true flux distribution of point X-ray sources in the sky from a list of detections in ROSAT PSPC images. We describe a few problems in the derivation of the log$N$-log$S$ that we are able to solve, as well as those that could not be solved using PSPC data.

As a source-detection algorithm we use the wavelet-transform algorithm of Damiani et al. (1997a,b), extensively tested to work well even in the outer parts of PSPC images, where the PSF is degraded. Using the same method, we produce a sensitivity map for each observation, yielding the limiting count rate for point-source detection throughout the field of view (FOV).

In order to test our ability to recover the input log$N$-log$S$, we apply our method to simulated PSPC images, including spatial exposure variations (from exposure map), and the detailed PSF (from Hasinger et al. 1993a); the input log$N$-log$S$ was taken equal to that derived by Hasinger et al. (1993b). For an application to real PSPC data, see Sciortino et al. (this volume).

The zero-order log$N$-log$S$ is derived, as usually, computing from the sensitivity map a sensitivity histogram, reading from it the explored area corresponding to the flux of each detected source, and building the cumulative distribution of detected source density vs. apparent flux. Since we are using detections from the *full* PSPC FOV the source statistics is much improved at the highest fluxes (detectable in the whole FOV).

The lowest flux reached with this approach is about $\log f_x = -14.2$ (ergs sec^{-1} cm^{-2}) for $T_{exp} = 30$ ks. At these fluxes, the log$N$-log$S$ is dominated by sources detected in the very inner part of the FOV, most sensitive because of the small PSF width and larger effective area.

1.1. The corrected log$N$-log$S$

Correction for sub-threshold sources: In a number of cases, sources are detected with a count rate *lower* than the nominal limit for point-source detection. Upon careful examination, it turns out that these sources are real, not spurious, and they are detected despite their low flux because they appear *smaller than the local PSF* (and the corresponding limiting flux is accordingly lower). This is due to the limited photon statistics, yielding not only an indeterminacy on source flux but also on source apparent size; our wavelet algorithm allows us nevertheless to both detect these sources and assign them the correct flux, since it is a multi-scale approach. Therefore, the sub-threshold sources must be included in the log$N$-log$S$ derivation (we have verified that excluding them yields very incorrect results).

In order to assign to these sources an 'effective' sensitive area, we make use of the detection efficiency curves derived by Damiani et al. (1997b), that allow us to estimate the probability η that a source below threshold will be detected, as a function of the ratio $r = \frac{\text{source rate}}{\text{limiting rate}}$. Using η as an area correction factor, we obtain a better agreement between derived and input log$N$-log$S$ at low fluxes. Moreover, we reach now a minimum flux $\log f_x \sim -14.5$, *a factor of 2 below the zero-order* log$N$-log$S$, *with the same* T_{exp}, thanks to the good calibration of our detection algorithm.

Correction for source area: When the total area occupied by detected sources is not small compared to the total imaged area, an additional correction becomes relevant. The area occupied by a given source is defined in terms of the radius below which a second source cannot be resolved from the former, because of the finite PSF width. Thus, weak sources cannot be detected in the area occupied by all stronger sources, thereby reducing the effective area at the lower fluxes. This correction depends on the number and position of all detections in an image that are stronger than the source being considered, and of course it becomes more relevant for crowded fields. Applying this correction to the log$N$-log$S$ derived from our 30 ks simulations yields an even better agreement at the lowest fluxes.

1.2. The hard problem: confusion

As soon as the PSPC images become crowded with respect to spatial resolution, source confusion becomes important, as already discussed by Hasinger et al. (1993b). The log$N$-log$S$ derived with a *direct* method becomes distorted, and it is very difficult to correct for this effect. We checked that confusion effects start to distort the derived log$N$-log$S$ as soon as the spatial density of detections exceeds the value $(dN/dA)_{lim} \sim 0.03/\pi\sigma^2_{PSF}$. Above this limit, our direct method cannot be used, and other indirect methods may be more appropriate.

References

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