Robust source detection limits for *Chandra* observations

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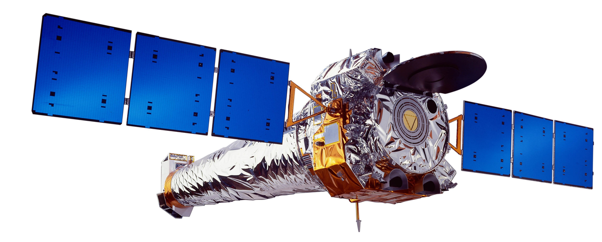


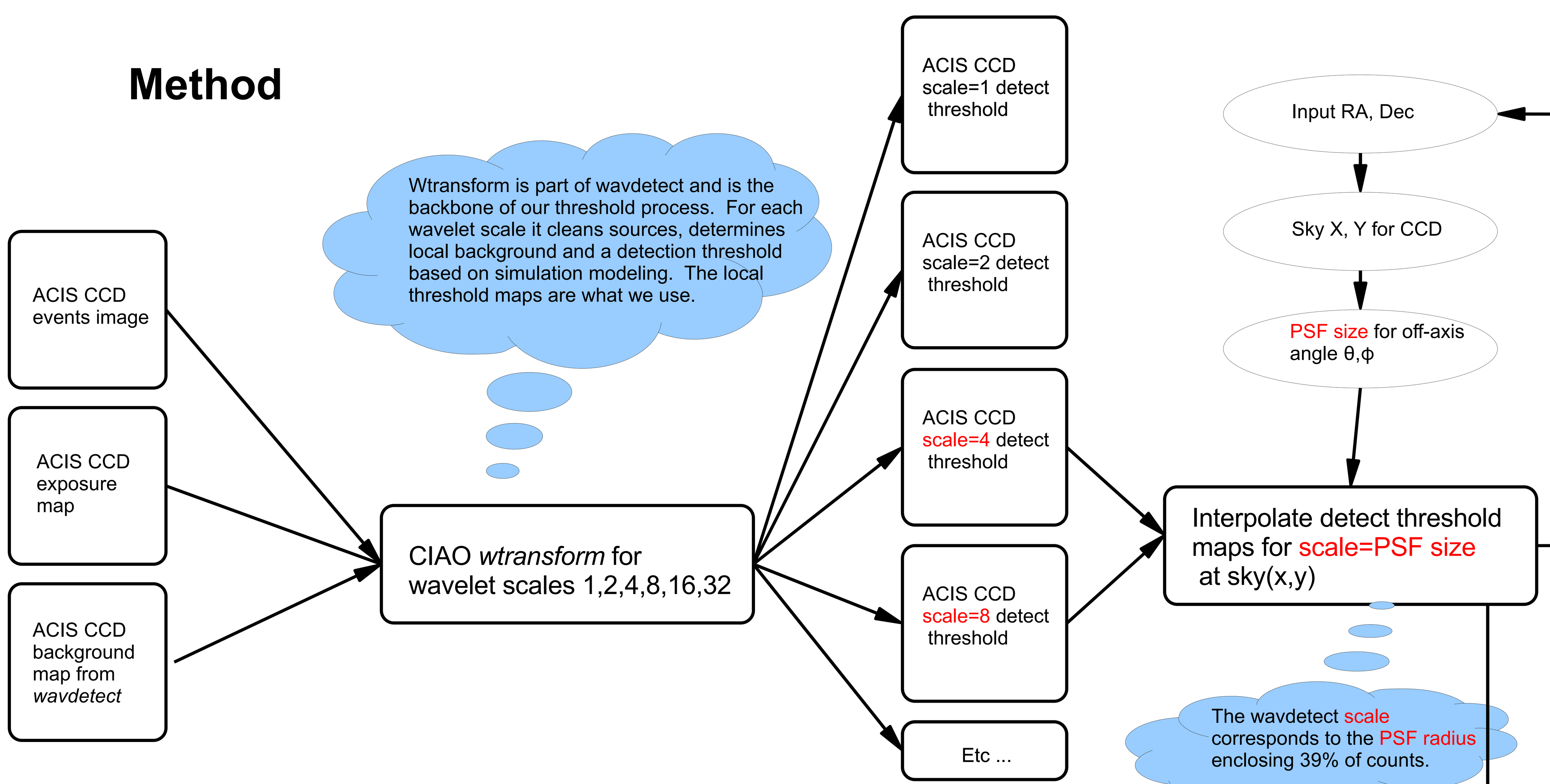
Abstract

We present a novel method for estimating the source detection limits in Chandra observations using the count threshold map produced by the CIAO wavdetect tool. This is particularly useful for multiwavelength analysis of X-ray non-detections at the position of prior sources, for instance known optically-selected AGN from the SDSS that are covered in the ChaMP survey. Because the Chandra PSF and detector characteristics are highly position dependent, a robust estimate of the detection limit at a particular location is not easily obtained. However, the CIAO wavdetect tool can produce a count threshold map at each wavelet scale that explicitly accounts for such effects. Taking advantage of a large body of source detection simulations previously done for the ChaMP effective area calculation, we derive an empirical correlation that uses the threshold map to predict the spatially dependent count limit at which 50% and 90% of sources are detected. We have verified this algorithm using the 2 Msec Chandra Deep Field South data.

Motivation

- **A robust estimate of flux upper limits is a key ingredient in the analysis of multi-wavelength survey data**.
- When correlating between different bands or surveys non-detections may be an significant population that should not be ignored.
- Upper limit estimation must account for the detection algorithm (e.g. wavdetect) and detailed spatial exposure, PSF and background dependence.
- This typically implies time-consuming Monte-Carlo simulations.
- Instead we have developed a method to use intermediate wavdetect outputs (detect threshold maps) as a proxy for Monte-Carlo limits.
- The Chandra Multiwavelength Project (ChaMP) now has a database of counts and flux detection limits on grid (10 arcsec spacing) covering over 300 obsids and 30 deg^2.

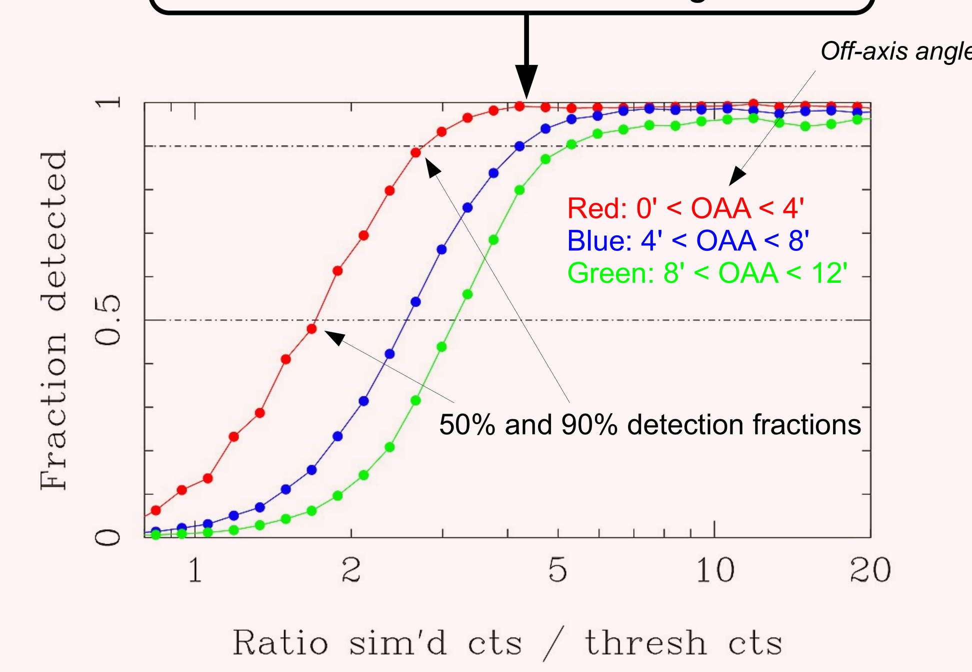
Method

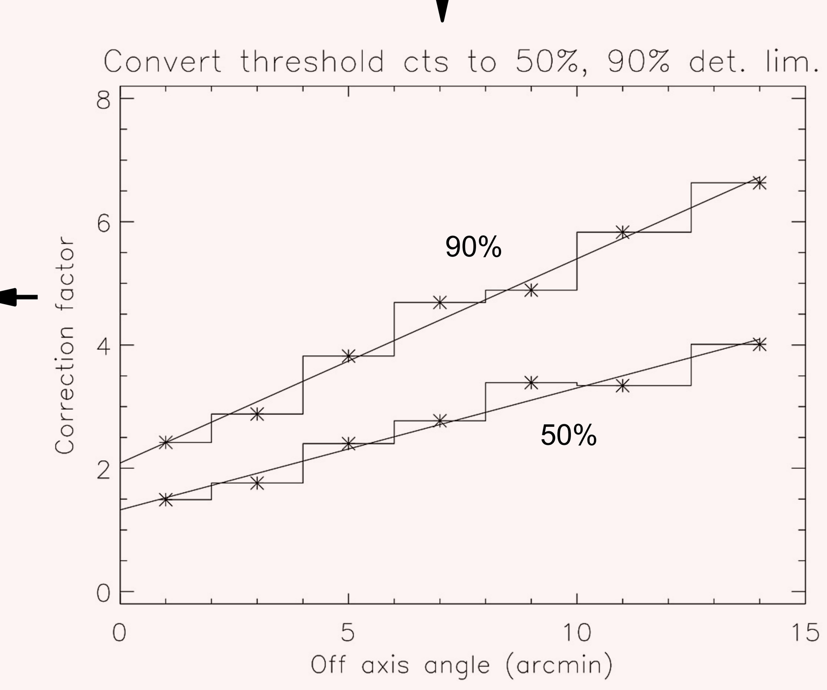


Calibration

60,000 simulated sources sparsely injected in ChaMP obsids:
[True Counts, Detected Counts, Position]

Plot the fraction of detected sources vs. (true_counts / detect_threshold) for different bins of off-axis angle



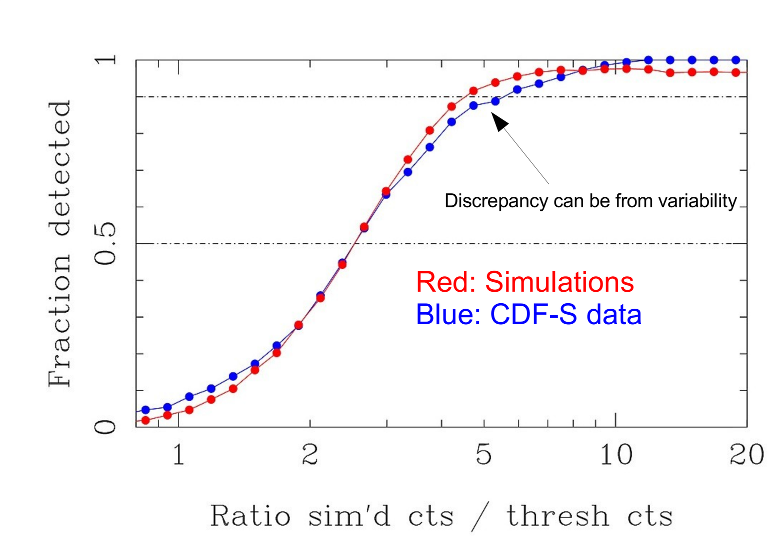


Now we have an empirical correction to account for the off-axis angle. Call this factor $C_{OAA}(\theta,f)$ where f = 50% or 90%.

Multiply by $C_{OAA}(\theta,f)$ to get detection threshold (counts) at RA, Dec

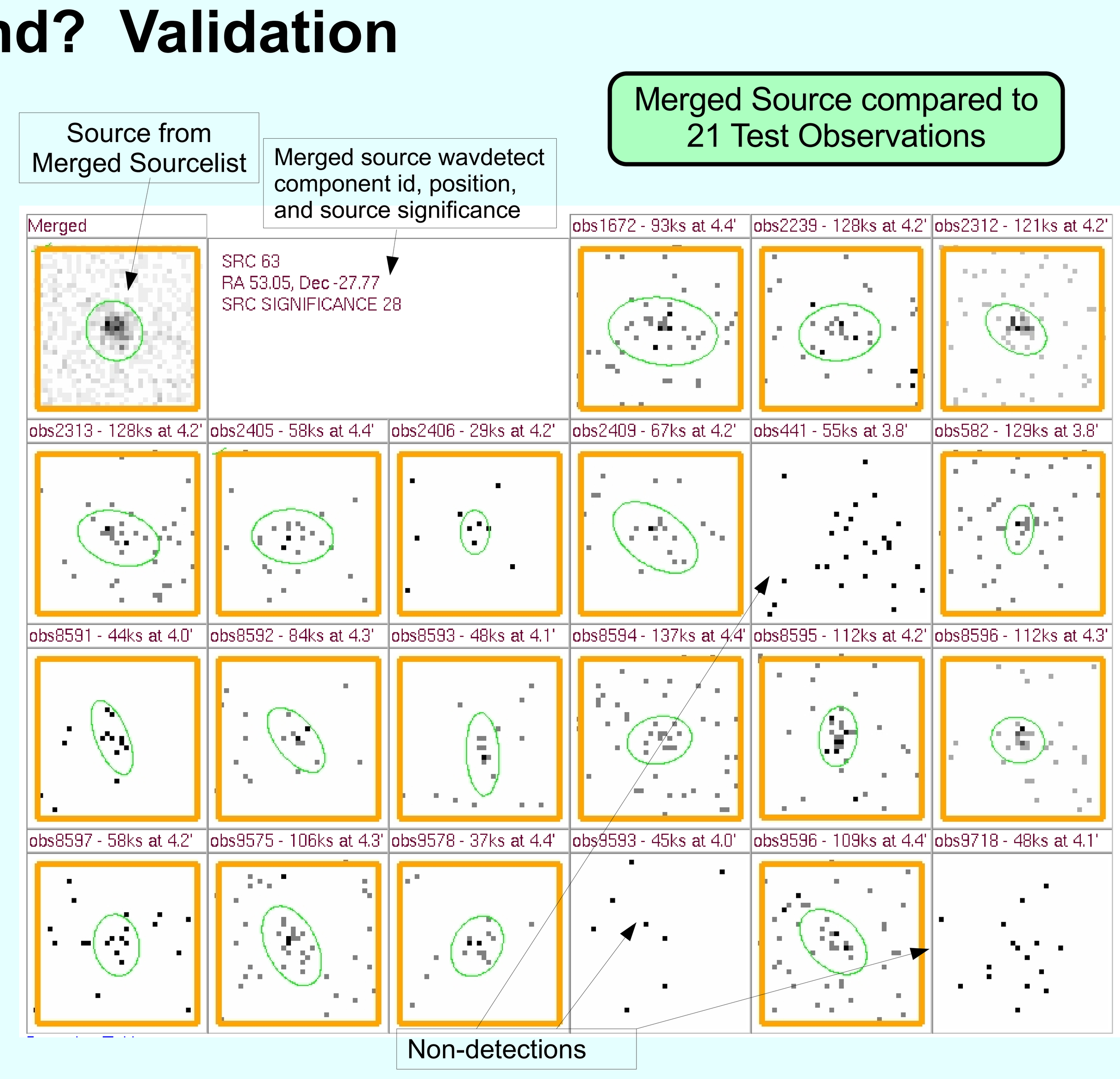
Convert to flux using your favorite model.

CDF-S results match simulations!



OK, but will it blend? Validation

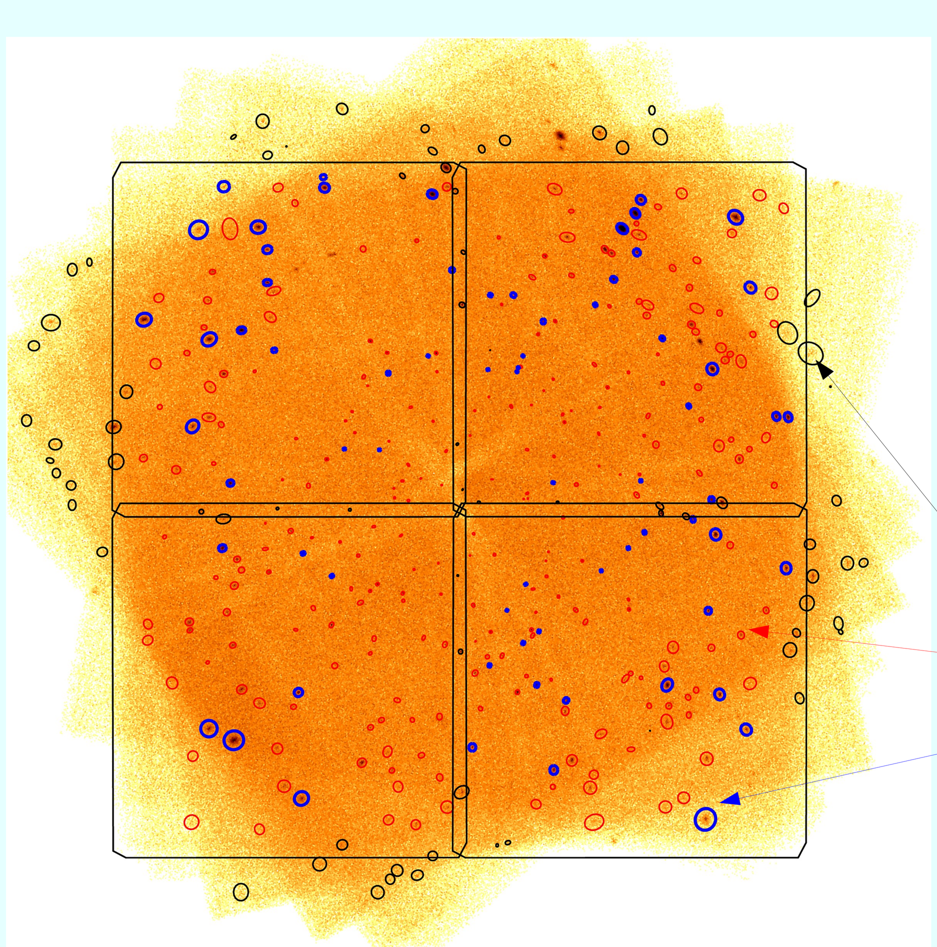
- We used the 1.8 Msec merged CDF-S to validate this method with real data.
- The merged CDF-S gives a list of "true" source count rates.
- The 21 individual CDF-S obsids of varying length can be considered as "realizations" of a Monte-Carlo detect experiment.
- The "simulated" input counts for a realization is the merged source counts scaled by exposure.
- A merged source may be detected in some, all, or none of the individual realizations (obsids). In the example to the right detections are marked with orange borders. The wavdetect regions are shown in green.



A different perspective

At left is an image of the merged event file and its detected sources. Overplotted is the field of view during an example test observation, Obsid 2406, a 29ks observation. The source detection color code demonstrates how each merged source detection compares to the independent source detections of Obsid 2406. Of the 393 non-overlapping detections in the merged set vs Obsid 2406 there are:

- 69 matching detections
- 241 non-detections
- 83 merged detections off 2406 ACIS CCDs



Something to ponder

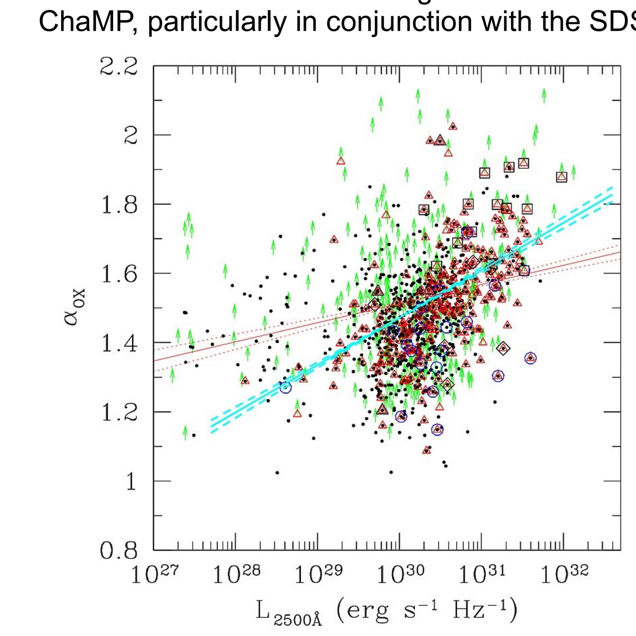
- In this method we calculate the number of counts required for a source to be detected in 90% of realizations.
- How does this compare to a traditional "90% upper limit"?
- And what does a "90% upper limit" mean anyway? See Kashyap poster here.

Acknowledgements

This work was supported by NASA contract NAS8-39073 .

ChaMP Science

Detection limits are now being used extensively for ChaMP, particularly in conjunction with the SDSS.



X-ray-to-optical SED slope α_{ox} vs. UV/optical luminosity for 1210 photometrically-selected SDSS QSOs analyzed by the Chandra Multiwavelength Project (ChaMP; Green et al. 2008). 72% of the QSOs are detected. Non-detections (green arrow lower limits to α_{ox} are flux upper limits from our xskycover table, based on analysis of the threshold maps as described in this poster. The resulting regression analysis (red line with dashed error bars) includes the effect of limits via Survival Analysis. The correlation is highly significant, but the slope is much flatter than recent analyses from more heterogeneous compilations (cyan line; Steffen et al. 2006).

Can I try this at home?

- Yes – **Powered by *yaxx*!**
- The processing is portably scripted in *yaxx* using perl, python, and CIAO.
- Please contact the author if interested.

http://cxc.harvard.edu/contrib/yaxx