Suggestions for False Source Likelihood Thresholds

Michael Nowak, MIT-CXC, Feb. 16, 2016

This is a very brief rundown of where I think we should go with the false-to-marginal, and marginal-to-true likelihood thresholds, with a few supporting figures. I will expand this with more figures while on the road, but wanted to get the basic results out first.

My suggestion is every bit as empirical as Ian's, and is much the same, with the addition that we add a time-dependence, and slightly tweak the numbers. Basically, I suggest we modify Ian's threshold as follows:

$$\mathcal{L}_x = N_x^d \left(A^d a^2 + B^d a + C^d \right) + max \left[S_x^d \log_{10} \left(\frac{T_{stack}}{10^4 \text{ sec}} \right), L_x^d - N_x^d C^d \right] \;, \tag{1}$$

where a is the off-axis angle (in `arcmin`) from the stack tangent point, the x subscripts refer to the threshold in question ($fm \equiv$ false to marginal, $mt \equiv$ marginal to true), and the d superscript refers to the main detector at the stack tangent point, i.e., ACIS-S, ACIS-I, or HRC. (For cases where ACIS-I and ACIS-S are mixed, I suggest that we adopt the slightly more conservative ACIS-S thresholds.)

Here are my current suggestions for ACIS-I:

$$N_{fm}^I = 1, N_{mt}^I = 2, A^I = 0.032, B^I = 0, C^I = 6.0, S_{fm}^I = S_{mt}^I = 4.6, \tag{2}$$

and for ACIS-S, we adopt

$$N_{fm}^S = 1, N_{mt}^S = 2, A^S = 0.08, B^S = 0, C^S = 3.6, S_{fm}^S = S_{mt}^S = 4.6 \;. \tag{3}$$

HRC values are To Be Determined.

The parameters L_x^d are there to make sure that the likelihood thresholds never go negative. I have not explored observations below 9 ksec, so for now I suggest we adopt something like $L_{fm}^I = L_{fm}^S = 1$ and $L_{mt}^I = L_{mt}^S = 2$. (We can play with these a bit, but the false source rate in even the 9 ksec threshold is *extremely* low.) In the simulations, there clearly is an exposure dependence to the false source rate, as well as a drift upward of the mean likelihood of falsely detected sources. This drift in mean likelihood, at most radii, was log-linear with exposure time, hence the addition of the time-dependent term.

As regards the false to marginal and marginal to true thresholds, the philosophy I adopted was to achieve approximately one false source per stack (false to marginal), or 0.1 false source per stack (marginal to true), with roughly equal contribution per 3 arcmin annulus. (Finding the cutoff likelihoods for 0.1 false source per stack was difficult — I would have to run a lot more simulations — so I extrapolated from 0.3 per stack.)

Note that although all the simulations showed a propensity for more false sources near the edges, there was nothing particularly "noteworthy" about the likelihoods near edges. Both false and real sources have slightly lower likelihoods (for a given off-axis angle) near edges. That is, the above thresholds are slightly more likely to discriminate against edge sources than non-edge sources, and I have not thought of anything more clever to distinguish false from real sources near an edge.

As regards the shapes I have chosen, they are slightly flatter than we currently use, at least for longer observations. In general, I have tried to either follow the shape of the mean likelihood vs. off-axis angle for blanksky simulations, or followed the shape of the likelihood that yields 1/6 of a source per stack per 3 arcmin bin (i.e., roughly 1 false source per stack). Neither is ideal, since there are unaccounted for area affects, and the occasional long tail in the detected source likelihood histograms. I fully admit that this has been done "by eye", rather than in a truly rigorous fashion. (The various plots I have done don't yield completely clean, self-similar results.) Also note that the factor of 2 between false to marginal and marginal to false is slightly less than the factor of 2.5 we use now. My best estimate of going from 1 false per stack to 0.1 false source per stack is that we don't have to be quite so harsh in the threshold. Plus, there is some

desire to not be too harsh concerning true low count sources (supporting figures for that will be added in a later update to this document).

Meanwhile, here are a few figures that I based my choices on. They show various slices on the likelihood, for blanksky simulations, as a function of off-axis angle. They show mean, median, and standard deviation for the detected likelihoods in 3 arcmin bins. They also show the likelihoods in each bin above which there is $< 1/6$ or $0.3/6$ false source per stack in that bin. There are also curves on these plots showing the existing threshold definitions (applicable to all exposure times), these newly suggested definitions applied to 10 ksec, and these newly suggested definitions applied to the exposure of these observations.
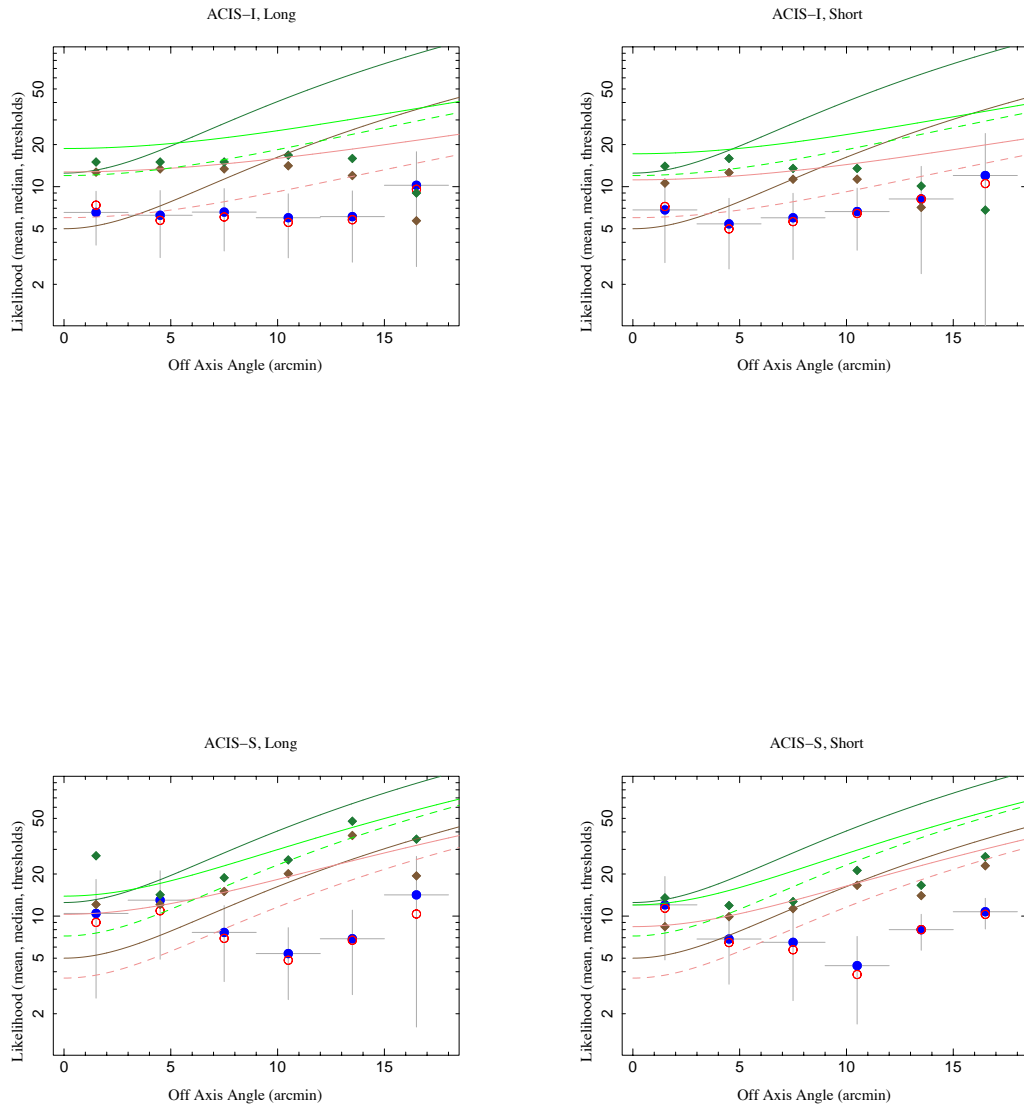
Figure 1: Blanksky Simulations. Brown and dark green lines are current thresholds, pink and light green lines are suggested (dashed is for 10 ksec). Brown and green diamonds are likelihood thresholds above which the false source rate is 1/6 or 0.3/6 per bin. Blue and red circles are the mean and median detected likelihood in each bin, and lines show standard deviation.