False Source Likelihood Thresholds, HRC

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Here is a brief outline of my suggested likelihood thresholds for HRC. They follow the ACIS guidelines in that they try to achieve < 0.1 false source per stack for the marginal-to-true threshold, and < 1 false source per stack for the false-to-marginal threshold. I further try to make the thresholds asymptote to flat likelihoods at both small and large radii, and to not wildly extrapolate for background counts values that I haven't looked at. Which brings up the point that there is a dependence upon *total background counts*, which I have measured at radii ≤ 18 arcmin. Below, I write this as an exposure times background per time per area. This rate should be estimated over an area as large as 18 arcmin radius, but I realize that there will be regions excluded for sources, bad pixels, therefore this is taken to be best estimate of average background per area over that size scale.

The basic form of the threshold likelihoods, $\mathcal{L}_x$, as a function of off axis angle, is given by a logistic function:

$$\log_{10} \mathcal{L}_x = \left(A_x + \frac{B_x - A_x}{(1 + \exp[-(a - C_x)/2])} \right) \quad , \tag{1}$$

where a is the off-axis angle in `arcmin` from the stack tangent point, and the x subscripts refer to the threshold in question ($fm \equiv$ false to marginal, $mt \equiv$ marginal to true). The function parameters are themselves functions of the background per square arcminute.

We define $l_b = \log_{10}(\sum_i \mathcal{B}_i * T_i)$, where T_i is the exposure time for each observation in the stack, and $\mathcal{B}_i$ is the background per square arcminute per second within the central 18 arcmin. The functional forms of the above parameters are:

$$A_x = A_{x1} + A_{x2}\, l_b \quad , \tag{2}$$

$$B_x = A_x + \frac{B_{x1}}{(1 + \exp[-B_{x2} * (l_b - B_{x3})])} \quad , \tag{3}$$

$$C_x = C_{x1} + C_{x2}\, l_b \quad . \tag{4}$$

For the false-to-marginal threshold, we have:

$$A_{fm1} = 0.6825 \ , \ A_{fm2} = 0.0711 \quad ; \tag{5}$$

$$B_{fm1} = 1.5219 \ , \ B_{fm2} = 5.2369 \ , \ B_{fm3} = 3.1628 \quad ; \tag{6}$$

$$C_{fm1} = 17.0781 \ , \ C_{fm2} = -1.8660 \quad . \tag{7}$$

For the marginal-to-true threshold, we have:

$$A_{mt1} = 0.8364 \ , \ A_{mt2} = 0.0561 \quad ; \tag{8}$$

$$B_{mt1} = 1.5197 \ , \ B_{mt2} = 7.5655 \ , \ B_{mt3} = 2.9419 \quad ; \tag{9}$$

$$C_{mt1} = 21.8523 \ , \ C_{mt2} = -3.2626 \quad . \tag{10}$$

Although the functional forms above were slighltly arbitrarily chosen (although they satisfy the desire to asymptote and not extrapolate wildly in regimes I haven't looked), the parameters were defined by fits to the data. 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 $< 1.8/6$, $< 1/6$, or $< 0.1/6$ false sources per stack in that bin.

These plots are then followed with figures that show how the fits behave as a function of off-axis angle and total background counts.

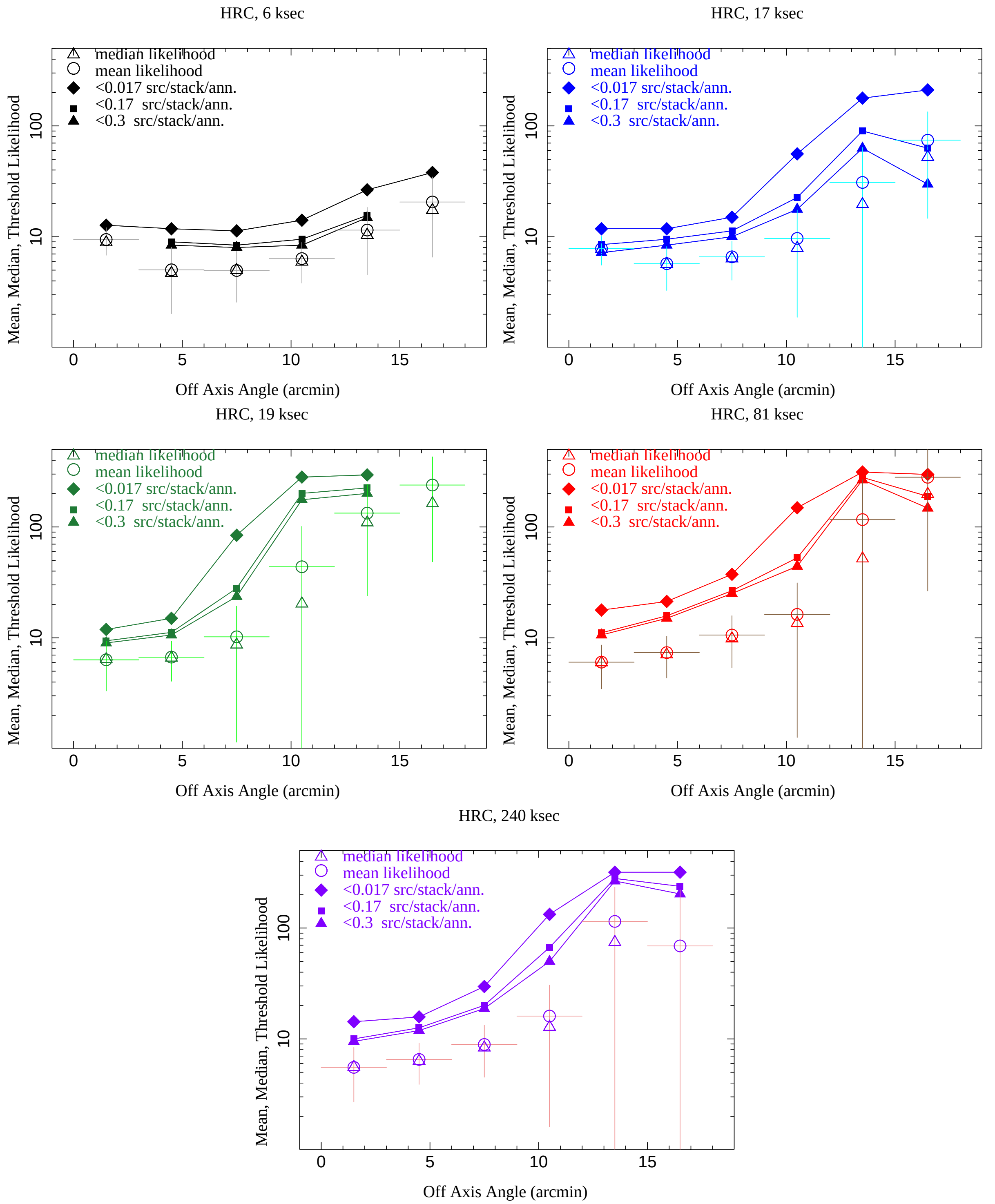

Figure 1: Source likelihoods derived from HRC simulations of varying exposures (and vastly different total background counts). Hollow triangles and circles are the median and mean likelihoods, respectively, in 3 arcmin annuli. Solid points (triangle, square, diamond) and lines are likelihood thresholds that achieve < 0.3, < 0.17, and < 0.017 false sources in each annulus per simulated observation. (I.e., they yield ≈ 2, 1, and 0.1 false sources per observation within the inner 18 arcmin.) In subsequent figures, for those simulations lacking data points in the first or last annuli (due to small number statistics), we've replicated the value from the next closest point.

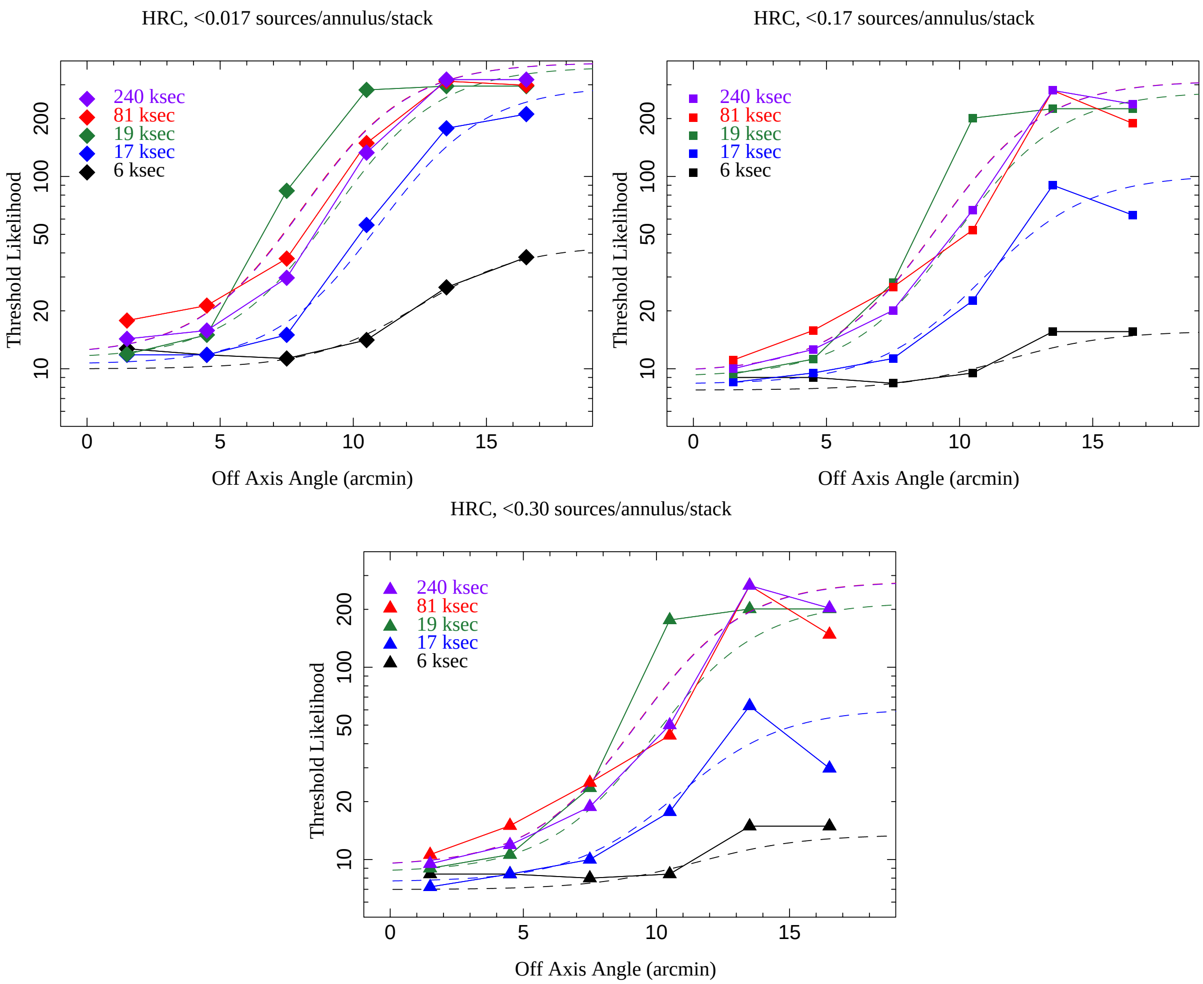

Figure 2: Source likelihood thresholds, as a function of off axis angle, with empirical description accounting for both off axis angle and background counts in the observation. Each color corresponds to a different simulation exposure (see Fig. 1).

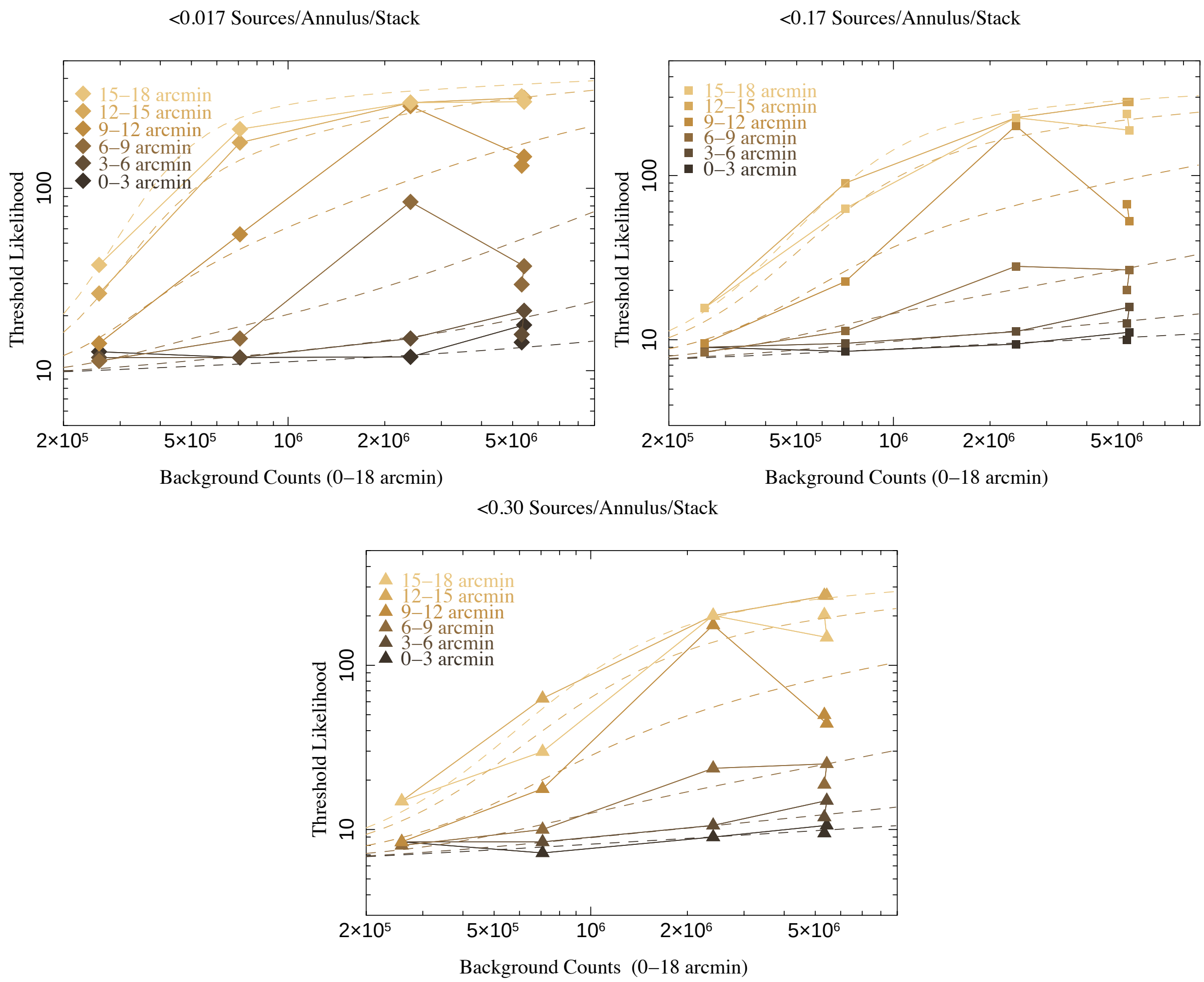

Figure 3: Source likelihood thresholds, as a function of total background counts within 18 arcmin, with empirical description accounting for both off axis angle and background counts in the observation. Each shade corresponds to a different annulus off axis angle.