

Advanced Camera for Surveys Exposure Time Calculator: II. Baseline Tests for the Ramp Filter Modes.

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ABSTRACT

The verification tests for the ACS Ramp Filter Exposure Time Calculator are presented. Our baseline suite of test cases includes one calculation for all filter modes with the same target, plus one subset for all kinds of targets through the same filter.

1. Introduction:

This is the second in a series of three ISRs (the first was ISR ACS-00-06 by Boffi et al.) where we summarize our testing of the Exposure Time Calculator (ETC) for ACS. Three interfaces to the ACS ETC are being developed; imaging, ramps and spectroscopic. Each interface consists of public and development versions for their supported modes. Once a complete set of testing has been carried out on the development version, the public version is updated and released. The public version web URL can be found at <http://garnet.stsci.edu/ACS/ETC/simulator.html>, where “*simulator*” is either “acs_ramp_etc”, “acs_img_etc” or “acs_spec_etc”.

2. Our baseline of exposures for the Ramp ETC:

In order to check the calculations for both CCD detectors and their ramp filters, we have created a baseline of exposures that spans the parameter space in two directions; we tested the ETC by keeping the spectral distribution fixed (flat spectrum) for all ramp filters, and also by keeping the filter fixed while varying the source spectral distributions. In Table 1, a subset of our test exposures are listed for the point source cases. The first six columns give the input parameters as detector, filter, source, normalization (in flux or magnitude), spectral distribution and exposure time. The filter column also contains the central wavelength of the filter bandpass used for the ramp filter. For example, filter fr914m#9000 indicates ramp filter fr914m where the wavelength of interest is 9000 Å. In the spectral

distribution column, “flat” indicates a constant flux distribution in $\text{erg sec}^{-1} \text{cm}^{-2} \text{Ang}^{-1}$.

“P. Law” indicates the power law spectrum of the form $F(\lambda) = \lambda^n$ (where the default $n = -1$). “BB” indicates a black body spectrum of Temperature 10,000 Kelvin. The O5V, B5V, G5V, M5V and M5I entries are Kurucz model atmospheres. GD71 and G191B2B are standard stars. A one second CRSplit=1 exposure was run in all cases so that counts and counts sec^{-1} have the same numerical value. Default values for gain (2), sky (average), and boxsize (5x5 for WFC and 9x9 for HRC) are used throughout. Non-default boxsizes were also tested and the results agreed exactly with those predicted by ensquared energy tables for the various boxsizes. The last four columns of Table 1 give the output results: signal to noise ratio (SNR), brightest pixel, total source, and sky, where the last three columns are in electrons, i.e. counts. The STSDAS synthetic photometry package (synphot) was then run to compare with the ETC output. The ACS ETC and synphot agreed to within roundoff error in all cases.

In addition to the subset of exposures in Table 1 we completely tested the remaining features of the ACS Ramp ETC. All remaining spectral distributions, including the Kurucz models, standard stars, non-stellar objects and the QSOs were tested successfully. Tests with various exposure times produced output which agreed with synphot. A user supplied spectrum of standard star GD71 was also tested. The exposure times computed by the ETC in order to reach our input SNR values were tested for the full baseline of exposures. This inverse type of test case is displayed for the fr388n filter in Table 1. The last WFC test case in Table 1 shows that the exposure time of one second is output when the same SNR of 3.1 is input to the ETC which we displayed in the first test case.

Table 1. Point Source Exposures

Detector	Filter	Source	Normal.	Spectrum	Exp time	SNR	Br. Pixel	Source	Sky
wfc1	fr388n#3880	point	1e-15	flat	1	3.1	18.5	75.6	0.01
wfc1	fr423n#4230	point	1e-15	flat	1	5.0	31.0	126	0.04
wfc1	fr462n#4620	point	1e-15	flat	1	6.9	44.0	180	0.07
wfc1	fr505n#5000	point	1e-15	flat	1	9.0	60.0	251	0.09
wfc1	fr551n#5500	point	1e-15	flat	1	10.0	69.0	288	0.10
wfc1	fr601n#6000	point	1e-15	flat	1	13.6	98.4	413	0.15
wfc1	fr656n#6500	point	1e-15	flat	1	16.5	128	530	0.18
wfc1	fr716n#7100	point	1e-15	flat	1	18.3	149	610	0.19
wfc1	fr782n#7900	point	1e-15	flat	1	20.2	175	703	0.19
wfc1	fr853n#8500	point	1e-15	flat	1	17.2	144	562	0.14
wfc1	fr931n#9300	point	1e-15	flat	1	14.4	118	445	0.10
wfc1	fr1016n#10000	point	1e-15	flat	1	9.2	69.8	255	0.05
wfc1	fr459m#4620	point	1e-15	flat	1	22.7	201	829	0.30
wfc1	fr647m#6470	point	1e-15	flat	1	41.5	514	2130	0.72
wfc1	fr914m#9000	point	1e-15	flat	1	61.1	1090	4180	1.03
wfc1	fr388n#3880	point	V=15	O5V	1	24.7	230	941	0.01
wfc1	fr388n#3880	point	V=15	B5V	1	20.5	176	719	0.01
wfc1	fr388n#3880	point	V=15	G5V	1	5.7	35.8	146	0.01
wfc1	fr388n#3880	point	V=15	M6V	1	1.2	6.98	28.5	0.01
wfc1	fr388n#3880	point	V=15	G5I	1	1.9	10.9	44.4	0.01
wfc1	fr388n#3880	point	NO	GD71	1	68.9	1270	5200	0.01
wfc1	fr388n#3880	point	NO	G191B2B	1	136	4650	19,000	0.01
wfc1	fr388n#3880	point	V=20	G5V	1	0.1	0.361	1.46	0.01
wfc1	fr388n#3880	point	V=20	BB	1	0.2	1.2	4.88	0.01
wfc1	fr388n#3880	point	V=20	P. Law	1	0.2	0.93	3.79	0.01
wfc1	fr388n#3880	point	1e-15	flat	0.99	3.1	18.3	74.7	0.01
hrc	fr388n#3880	point	1e-15	flat	1	2.1	10.9	89.3	0.02
hrc	fr505n#5050	point	1e-15	flat	1	4.5	23.4	195	0.07
hrc	fr656n#6560	point	1e-15	flat	1	7.4	40.1	328	0.10
hrc	fr459m#4590	point	1e-15	flat	1	13	75	618	0.20
hrc	fr388n#3880	point	V=15	O5V	1	21	136	1110	0.02

Detector	Filter	Source	Normal.	Spectrum	Exp time	SNR	Br. Pixel	Source	Sky
hrc	fr388n#3880	point	V=15	B5V	1	17	104	849	0.02
hrc	fr388n#3880	point	V=15	G5V	1	4.0	21	172	0.02
hrc	fr388n#3880	point	V=15	M6V	1	0.8	4.08	33.3	0.02
hrc	fr388n#3880	point	V=15	G5I	1	1.3	6.33	51.7	0.02
hrc	fr388n#3880	point	None	GD71	1	70	750	6200	0.02
hrc	fr388n#3880	point	None	G191B2B	1	145	2750	22,500	0.02
hrc	fr388n#3880	point	V=20	G5V	1	0.0	0.21	1.72	0.02
hrc	fr388n#3880	point	V=20	BB	1	0.1	0.71	5.77	0.02
hrc	fr388n#3880	point	V=20	P. Law	1	0.1	0.55	4.48	0.02

In Table 2 extended sources are considered. The table columns are the same as in Table 1, except all boxsizes are 2x2 pixels. All SNR calculations for extended sources use the 2x2 boxsize, since the source size is assumed to be larger than the ACS resolution. A CRSplit=1 was also used throughout. The “e. line” spectrum is an emission line.

Table 2. Extended Source Exposures

Detector	Filter	Source	Normal	Spectrum	Exp time	SNR	Br. Pixel	Source	Sky
wfc1	fr388n#3880	extended	V=22	flat	1000	0.5	4.60	5.07	2.18
wfc1	fr388n#3880	extended	1.e-15	e. line	1	0.0	0.005	0.01	0.002
wfc1	fr459m#4590	extended	V=22	flat	1000	3.9	28.1	53.9	47.3
wfc1	fr388n#3880	extended	1.e-15	flat	1000	28.6	230	905	2.18
hrc	fr459m#4590	extended	V=22	flat	1000	1.10	8.48	12.2	10.7
hrc	fr388n#3880	extended	1.e-15	flat	1000	15.6	82.1	316	0.8

3. Checking exposures by hand:

In the following, we present our hand calculations to check the ETC output for one extended continuum source and one extended emission line source. More examples are in Chapter 6 of the ACS Handbook along with the documentation for our equations.

Extended Continuum Source:

In Table 2, the ETC calculates SNR=0.5, the brightest pixel = 4.60, the source = 5.07 electrons and the sky = 2.18 for a 1000 second exposure of a flat extended source of V=22 mag. arcsec⁻² using the Wide Field Channel and the fr388n ramp filter. The flux of a V=22 mag. arcsec⁻² source is 6×10^{-18} , the sensitivity of the filter is 1.01519×10^{15} and the

FWHM=87.558. The calculations are performed over a 2x2 pixel box. The total counts from the extended source is approximately $1.01519 \times 10^{15} * 6 \times 10^{18} * 4 * (0.04945 * 0.04945) * 87.558 * 1000 = 5.2$ electrons which is 2% from the more accurate value of 5.1 calculated by the ETC integrating over the passband. This integration over the 87.558 Å passband is responsible for most of the 2% error. An error greater than 10% would be cause for concern. The dark rate is $1000 * 2.78 \times 10^{-4} = 11$, while the brightest pixel is $0.25 * (5.2 + 2.2 + 11) = 4.6$ which agree with the ETC.

Extended Emission Line Source:

In Table 2, the ETC calculates what number of counts are achieved for a 1 sec exposure for an emission line at 3880 Å of specific intensity $1. \times 10^{-15}$ erg sec⁻¹ cm⁻² arcsec⁻², using the Wide Field Channel and the fr388n ramp filter, in the case of an extended source (CRSsplit=1). The sensitivity is calculated as $S_{3880} = 2.27 \times 10^{12} * T_{3880} * 3880 = 1 \times 10^{15}$, where 2.27×10^{12} is a constant, T_{3880} is the system throughput at the wavelength of 3880 Å, and 3880 is the wavelength. The counts per pixel in the line are simply given by the product of specific intensity, sensitivity and WFC pixel size squared (0.049^2). The value that we obtain is 0.0024, that multiplied by 4 pixels (which is the number of pixels used by the ETC for the calculation of the S/N) gives 9.8×10^{-3} which is 1% from the ETC value of 9.9×10^{-3} . Since the emission line source calculation does not calculate over an 87.5 Å passband like the previous extended source calculation, it avoids that error and should be within ~1% of the ETC value. The detector dark is equal to $2.78 \times 10^{-3} * 4 = 0.011$, like the ETC. The average sky value is calculated as one half the continuum high sky background of 5×10^{-18} erg sec⁻¹ cm⁻² Å⁻¹ arcsec⁻², from Figure 6.1: $0.5 * 5 \times 10^{-18} * 1 \times 10^{15} * (0.049)^2 * 4 * 86.62 * 1 = 0.002$, which is also the value calculated by the ETC. The brightest pixel contains 0.25 of the total source, sky, and dark rate: $0.25 * (0.0099 + 0.002 + 0.011) = 0.0057$, which agrees with the ETC value of 0.0054. Finally, we apply the usual signal-to-noise ratio equation and obtain $SNR = 9.9 \times 10^{-3} / (9.9 \times 10^{-3} + 0.002 + 0.011 + 81)^{0.5} = 0.001$, which is what the ETC calculates.

4. References

Boffi F.R., Bohlin R.C. & Shaw R.A. 2000, Advanced Camera for Surveys Exposure Time Calculator: I. Baseline Test for Broadband Imaging Modes, ISR ACS-00-06 (Baltimore: STScI).

Jedrzejewski, R., et al. 2000, ACS Instrument Handbook, version 1.0, (Baltimore: STScI).