

# Advanced Camera for Surveys Exposure Time Calculator: I. Baseline Tests for the Broadband Imaging Modes.

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## ABSTRACT

*The verification tests for the Imaging Exposure Time Calculator for the Advanced Camera for Surveys 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.*

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## 1. Introduction:

A set of three ACS Exposure Time Calculator (ETC) are being developed, one for imaging, one for spectroscopy and one for ramps. They are created following the example of STIS (see Hack et al. 1997). There are two versions of each of the three ETCs: one for public use, and one for testing. Access is via the Web interface or via the host level with command-line input. Once a complete set of testing has been carried out on the development ETC, 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.html*” is one of the three calculators and “*simulator*” is either “*acs\_ramp\_etc*” or “*acs\_img\_etc*” or “*acs\_spec\_etc*”.

## 2. Our baseline of exposures for the Imaging ETC:

In order to check the calculations for all detectors and for all imaging elements, 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 filters, and also by keeping the filter fixed and varying the source spectral distributions. In Table 1, all exposures are listed for the point source case. The first six columns give the input parameters. They are detector, filter, source, normalization (in flux or magnitude), spectral distribution and exposure time, respectively. In the fifth column, i.e. the spectrum column,

flat indicates a constant flux distribution in  $\text{erg sec}^{-1} \text{cm}^{-2} \text{\AA}^{-1}$ , p. law the power law spectrum of the form  $F(\lambda) = \lambda^n$  (where the default  $n=-1$  is used) and BB a black body spectrum of Temperature = 10000 K. G5V is a Kurucz model atmosphere and GD71 is a standard star. A 1000 second exposure (CRSplit=2) was run in most cases to achieve at least  $\sim 100$  counts for the source; a one second exposure (CRSplit=1) was run in the brightest cases to avoid saturation of the CCD and a 100 second exposure was run for all SBC cases to achieve a  $S/N \sim 10$ . In Table 1, only GD71 with f150lp reaches the bright object limit (see Boffi & Bohlin 1999). Default gain and sky values were used (respectively, 2 and average). For Wide Field Channel and High Resolution Channel, the detector dark rate is  $2.78 \times 10^{-3} \text{ e}^- \text{ sec}^{-1} \text{ pix}^{-1}$  and the read noise is  $4.5 \text{ e}^- \text{ rms}$ ; for the Solar Blind Channel, the dark count is  $\sim 2.5 \times 10^{-4} \text{ counts sec}^{-1} \text{ pix}^{-1}$ . See also the ACS Handbook by Jedrzejewski et al. (2000). The calculations adopted the default square aperture values: 5x5, 9x9 and 15x15 pixels, respectively for WFC, HRC, and SBC. The four last columns, starting with column 7, give the main output results of the ETC: they are signal to noise ratio (SNR), brightest pixel, source and total sky. Source and sky are expressed in counts. The brightest pixel is in counts  $\text{sec}^{-1} \text{ pix}^{-1}$  for the SBC and in counts  $\text{pix}^{-1}$  for the CCDs.

**Table 1: Point Source Exposures:**

Detector	Filter	Source	Normal.	Spectrum	Exp. Time	SNR	Br.pixel	Sou.	Sky
wfc1	f435w	point	1.e-18	flat	1000	34.6	278	2167	677.7
wfc1	f475w	point	1.e-18	flat	1000	48.5	491	3831	1337
wfc1	f502n	point	1.e-18	flat	1000	3.8	18.4	133.4	48.2
wfc1	f550m	point	1.e-18	flat	1000	32.2	254	1986	731.5
wfc1	f555w	point	1.e-18	flat	1000	47.5	476	3729	1362
wfc1	f606w	point	1.e-18	flat	1000	80.8	1200	9527	3290
wfc1	f625w	point	1.e-18	flat	1000	63.9	786	6190	2117
wfc1	f658n	point	1.e-18	flat	1000	9.3	48.4	369.1	122.5
wfc1	f660n	point	1.e-18	flat	1000	3.9	18.9	137.7	46.02
wfc1	f775w	point	1.e-18	flat	1000	71.3	964	7281	2058
wfc1	f814w	point	1.e-18	flat	1000	87.8	1380	10550	2813
wfc1	f850lp	point	1.e-18	flat	1000	61.0	734	5346	1258
wfc1	f892n	point	1.e-18	flat	1000	12.0	68.3	492.8	120.2
wfc1	f555w	point	V=20	p. law	1	5.3	32.4	135	1.4
wfc1	f555w	point	V=20	BB	1	5.4	33.3	138.4	1.4

**Table 1: Point Source Exposures:**

Detector	Filter	Source	Normal.	Spectrum	Exp. Time	SNR	Br.pixel	Sou.	Sky
wfc1	f555w	point	NO	GD71	1	300	2.2e4	9.0e4	1.4
wfc1	f555w	point	V=20	G5V	1	5.3	32.3	134	1.4
hrc	f220w	point	1.e-18	flat	1000	3.2	14.5	196.3	27.5
hrc	f250w	point	1.e-18	flat	1000	6.2	26.8	391.4	66.9
hrc	f250w	point	NO	GD71	1	303.2	11900	9.4e4	0.1
hrc	f330w	point	1.e-18	flat	1000	10.5	44.0	681.6	66.3
hrc	f330w	point	NO	GD71	1	278.0	9780	7.9e4	0.1
hrc	f344n	point	1.e-18	flat	1000	1.1	5.6	67.4	7.3
hrc	f435w	point	1.e-18	flat	1000	23.8	115	1819	527.4
hrc	f475w	point	1.e-18	flat	1000	33.7	182	2897	966.6
hrc	f502n	point	1.e-18	flat	1000	1.7	7.6	99.9	34.6
hrc	f550m	point	1.e-18	flat	1000	18.6	85.8	1362	481.2
hrc	f555w	point	1.e-18	flat	1000	31.3	165	2633	922.7
hrc	f606w	point	1.e-18	flat	1000	57.3	386	6232	2075
hrc	f625w	point	1.e-18	flat	1000	41.5	242	3863	1280
hrc	f658n	point	1.e-18	flat	1000	3.6	15.5	222.6	71.9
hrc	f775w	point	1.e-18	flat	1000	38.6	238	3441	1013
hrc	f850lp	point	1.e-18	flat	1000	29.1	202	2351	679.5
hrc	f892n	point	1.e-18	flat	1000	3.8	20.5	231.5	66.7
hrc	f555w	point	20 V	p. law	1	2.3	11.5	95.6	0.9
hrc	f555w	point	20 V	BB	1	2.4	11.8	98.4	0.9
hrc	f555w	point	20 V	G5V	1	2.3	11.4	94.9	0.9
sbc	f122m	point	0.7e-16	flat	100	1.2	0.0	16.7	161.2
sbc	f115lp	point	0.7e-16	flat	100	10.2	0.9	367.4	919.9
sbc	f125lp	point	0.7e-16	flat	100	15.6	0.8	327.5	108.4
sbc	f140lp	point	0.7e-16	flat	100	14.7	0.5	223.4	2.5
sbc	f150lp	point	0.7e-16	flat	100	12.0	0.3	149.1	0.002
sbc	f165lp	point	0.7e-16	flat	100	7.2	0.1	56.8	0.001
sbc	f150lp	point	20 V	p. law	100	15.8	0.6	254.4	0.002
sbc	f150lp	point	20 V	BB	100	7.6	0.1	63.0	0.002
sbc	f150lp	point	NO	GD71	100	1682	6552	2.8e6	0.002

**Table 1: Point Source Exposures:**

Detector	Filter	Source	Normal.	Spectrum	Exp. Time	SNR	Br.pixel	Sou.	Sky
sbc	f150lp	point	20 V	O5V	100	70.2	11.4	4937	0.002

In Table 2 extended sources are considered. The table columns are the same as Table 1. In all CCD cases, a CRSplit=3 was used.

**Table 2: Extended Source Exposures:**

Detector	Filter	Source	Normal.	Spectrum	Exp. Time	SNR	Br.pix.	Sou.	Sky
wfc1	f555w	extended	V=22	flat	2000	14.2	79.1	490.6	435.8
wfc1	f555w,pol_v	extended	V=22	flat	2000	6.7	63.2	122	108.4
wfc1	f625w	extended	1.e-18	flat	2200	4.7	77.4	159.7	745.2
wfc1	f850lp	extended	1.e-18	flat	2200	5.2	51.6	152.2	442.9
hrc	f250w	extended	20.5 V	A1	3600	5.2	13	104	11.9
hrc	f330w	extended	1.e-17	flat	3600	4.5	11.7	88.1	11.8
sbc	f115lp	extended	1.5e-16	flat	1000	2.8	0.1	39.9	163.5
sbc	f125lp	extended	1.5e-16	flat	1000	4.7	0.0	35.4	19.3

### 3. Checking exposures by hand:

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

#### *Point Source:*

The ETC calculates what SNR and number of counts are achieved for a 1 sec exposure for a flat spectrum point source of flux  $1.5 \times 10^{-18} \text{ erg sec}^{-1} \text{ cm}^{-2} \text{ \AA}^{-1}$ , using the Wide Field Channel, and the filter f555w.

The flux is  $1.5 \times 10^{-18}$ , the sensitivity at 5500 is  $4.11 \times 10^{15}$  and the FWHM is 851 Å. For a 0.25 arsec box with  $\epsilon = 0.8337$ , the total counts from the star are approximately  $1.5 \times 10^{-18} * 4.11 \times 10^{15} * 851 * 0.8337 * 1 = 4.4$ . The more precise result obtained by the ETC, which integrates over the bandpass, is 5.6 counts for an 5x5px boxsize. The detector dark is calculated as  $25 * 0.00278 = 0.069$ , the read noise is equal to  $25 * 1 * (4.5^2) = 506.25$  (for CRSplit=1), and the sky background is 1.362. This value for the average sky is computed as one half the continuum high sky background of  $9.95 \times 10^{-18} \text{ erg sec}^{-1} \text{ cm}^{-2} \text{ \AA}^{-1}$

arcsec<sup>-2</sup> from Figure 6.1:  $0.5 * 9.95 \times 10^{-18} * 4.11 \times 10^{15} * (0.04945)^2 * 851 * 25 * 1 = 1.064$  electrons, or more precisely from the integral over wavelength in the ETC, 1.362 electrons. Since the brightest pixel contains 0.21 of the total source rate of 6.7 counts/sec (for a 101x101 boxsize), the rate for the central pixel is 1.4. By hand, the total source rate is 5.246 and, therefore, the rate for the central pixel is 1.1 within 20% of the more accurate value of the ETC. Finally, we apply the usual signal-to-noise ratio equation and obtain  $SNR = 5.6 / (5.6 + 1.362 + 506.25)^{0.5} = 0.2$ , which is what the ETC calculates.

### ***Extended Source:***

In Table 2, the ETC calculates SNR=14.2, the brightest pixel = 79.1, the source = 490.6 electrons and the sky =435.8, for a 2000 sec. exposure of a flat extended source of V=22 mag. arcsec<sup>-2</sup>, using the Wide Field Channel and the f555w filter. The flux of a V=22 mag. arcsec<sup>-2</sup> is  $6 \times 10^{-18}$ , the sensitivity is as above  $4.11 \times 10^{15}$  and the FWHM =851 Å. The calculations are performed over a 2x2px box and the total counts from the star are approximately  $6 \times 10^{-18} * 4.11 \times 10^{15} * 851 * 2000 * 4 * (0.04945 * 0.04945) = 410.4$  electrons, which is within 20% of the more accurate value of 490.6 calculated by the ETC integrating over the passband. In this calculation, the flux of the source, the sensitivity of the instrument at 5500 Å, and the area in arcsec<sup>2</sup> of 2x2 px on the detector are used. The hand calculation of 340 electrons from the sky is similar to previous example with the difference of the integration time and the number of pixels used.

## **4. Acknowledgements:**

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## **5. References:**

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