The HST Exposure Time Calculators:
Estimating accurate observing times for HST Observations

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What is the ETC and how it works

The ETC is a web-base application (http://etc.stsci.edu) developed to assist Hubble Space Telescope observers in preparing their observations with any of the supported modes available at HST. The main purpose of the ETC is to calculate the Exposure time needed for observations requiring a given Signal-To-Noise ratio (SNR) and to also calculate the SNR for a simulated observation for a specified amount of time. These quantities are key for the preparation of proposals and observations during Phase I and Phase II of the proposing Cycle.

Currently the ETC provides support for all the active HST instruments:

- Advanced Camera for Surveys (ACS)
- Cosmic Origins Spectrograph (COS)
- Near Infrared Camera and Multi Object Spectrometer (NICMOS)
- Space Telescope Imaging Spectrograph (STIS)
- Wide Field Camera 3 (WFC3)

Figure 1a and 1b show specific observing modes for two different instruments. These ETC forms are intentionally separated into 6 well defined sections to allow HST observers and STScI instrument scientist to easily identify the relevant information that is needed in the calculations. As seen in Figure 1a-b, the same structure is maintained for all the ETC modes and instruments, making easier for HST users to plan observations for different HST instruments. In terms of the management of the software, it helps to track changes that are instrument dependent to those that affect all the instruments. For example, options available under 2., 3., 4., and 5. are shared by all the ETC modes, while sections 1. and 6. depend on the instrument in use and type of observation.

Although the exposure parameters (selection 2.) seem to be identical for all the instruments, the underlying calculations might vary slightly depending on the instrument, observing mode and sometime detector. The ETC handles these differences by subdividing the calculations in stages, making it easier to integrate these into the basic equations.

The ETC relies heavily on the Synthetic Photometry software package, *pysynphot*. *Pysynphot* is part of the Space Telescope Science Data Analysis System (STSDAS) and is developed and maintained by the Science Software Branch (SSB) at STScI. This package performs simulated photometry by computing the detected photons as a function of wavelength (and for spectrographs, detector bin) using a specified input spectrum and known throughput and detector quantum efficiency curves. The results are used by the ETC to compute exposure times and signal-to-noise ratios. Its predictions made by the *pysynphot* software rely on the throughput information for all the optical components of the instruments that are part of the Calibration Database System (CDBS) at STScI. This database contains not only the information regarding the sensitivity of the instrument components, but also about the thermal response of the infrared detector and a large number of available source spectra (HST Calibration tables, Catalogs, and Models). Figure 2 shows the flow of data between the Web interface, ETC and *pysynphot*. First the user inputs the observational parameters into the ETC web server. The parameters are then formatted by the ETC in a *pysynphot* request and submitted to the *pysynphot* package. The quantities calculated by *pysynphot* are the imaging and spectroscopic countrate, the thermal countrate for the IR detectors and the effective wavelength of an observation. The *pysynphot* response is retrieved by the ETC application and the count rate used for the calculation of the S/N and exposure time.

Figure 1a

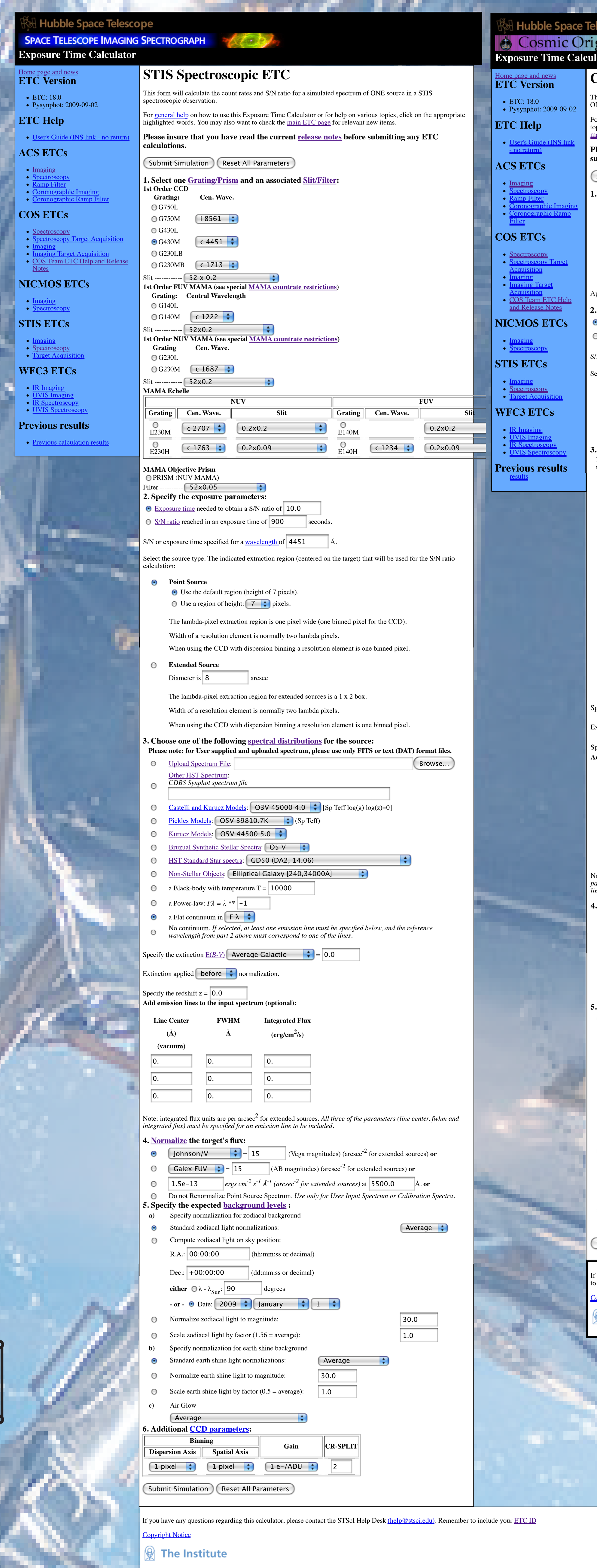


Figure 1b

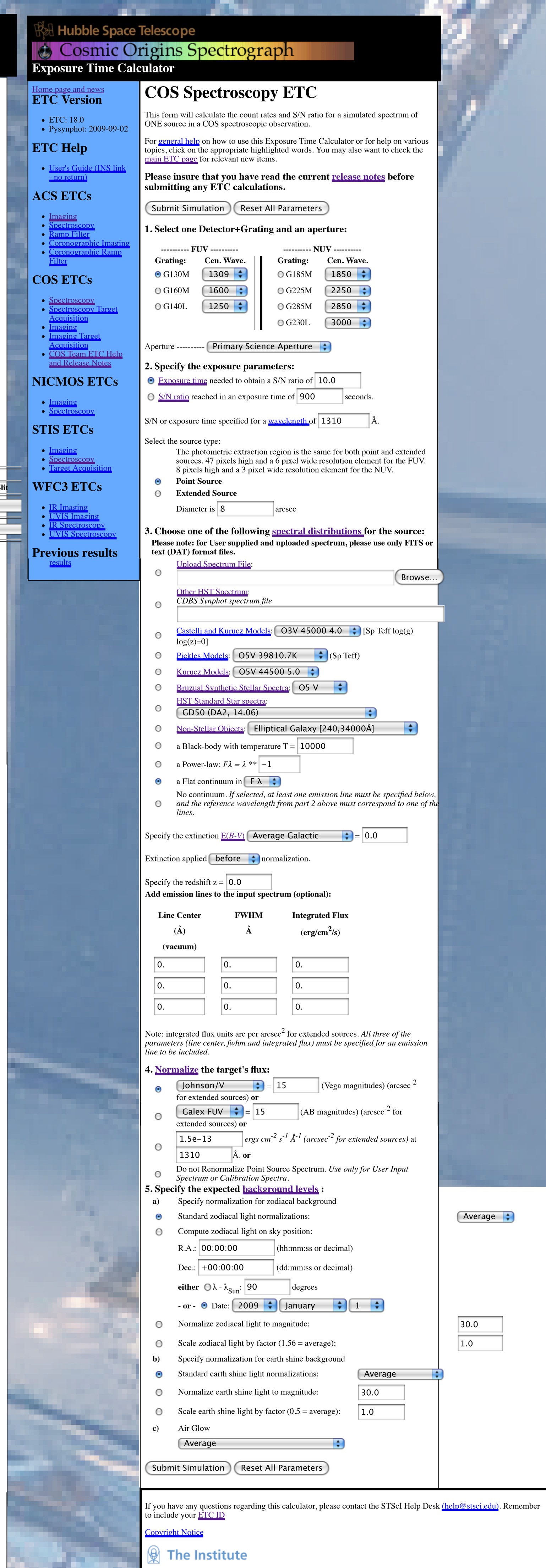
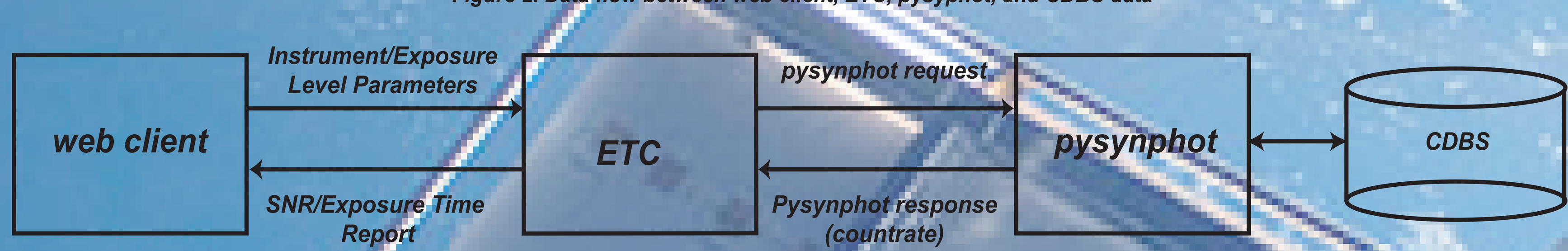


Figure 2. Data flow between web client, ETC, pysyphot, and CDBS data



The results of the calculation are displayed to a web page and saved in a file for future reference. For example, to recall previous calculation results or to plot or show a table of the input spectrum, instrument throughput, or detected counts or signal-to-noise as a function of wavelength. An example of the output of a run for an ACS observing configuration as well as that for a COS spectroscopic observation is given in Figure 3a and 3b, respectively.

The ETC output gives detailed information on the counts rates that are due to the source and background, the selection of parameters for the source and instrument, as well as other relevant information to the instrument and mode used. The output information is separated in sections which are common to all the instruments and modes. However, detailed information and instrument configuration information will change from instrument to instrument and also with detectors.

Other capabilities of the ETCs are:

- option for user-supplied input spectra
- calculation of optimal S/N as would be obtained by PSF fitting
- inclusion of instrument-specific effects. For example, NICMOS spectroscopy simulations include the degradation in the spectral purity due to the line spread function.
- verification that user-supplied wavelengths fall within instrumental range
- bright-limit checks

Support for new instruments.

The last HST Servicing Mission added two new instruments: Wide Field Camera 3 (WFC3) and Cosmic Origins Spectrograph (COS). Adding support for WFC3 was relatively strightforward since the similarities between the two channels covered by WFC3 detectors with ACS (for the UV) and NICMOS (for the IR) made it possible to implement support for the WFC3 modes with few changes. The main differences between these ETC are the instrument specific parameters. Other differences have to do with the extraction box size and shape, and the way in with the size of the extraction box and size are indicated.

The design of the COS detectors, on the ther hand, possed significan challenges for the ETC developers. The FUV channel is a photon counter with 2 segments that can operate independently and that have a 9 mm gap in between. The NUV channel creates a three spectrum stripes for the science data with a gap of 3.70 mm between them. Because of this the ETC needed also to provide with:

- the count rate and global count rate that accounts for the sensitivity of the segments or stripes and the gap between them
- validate the input wavelength for the grating-central wavelength combination
- specify the global and maximum local count rates on each channel

Since the FUV channel is regularly used in time tag mode the ETC also estimates the buffer time. Furthermore, due to the vulnerability of photo multiplier detectors to damage, the ETC needs to calculate various total count rates for segments and stripes and the corresponding maximum observed count rates within the segments or stripes, and appropriate buffer time values. When these exceed or are close to exceed global or local limits for the detectors, these are clearly flagged by the software as shown in Figure 3b.

Figure 3a. Output for WFC3 Imaging ETC

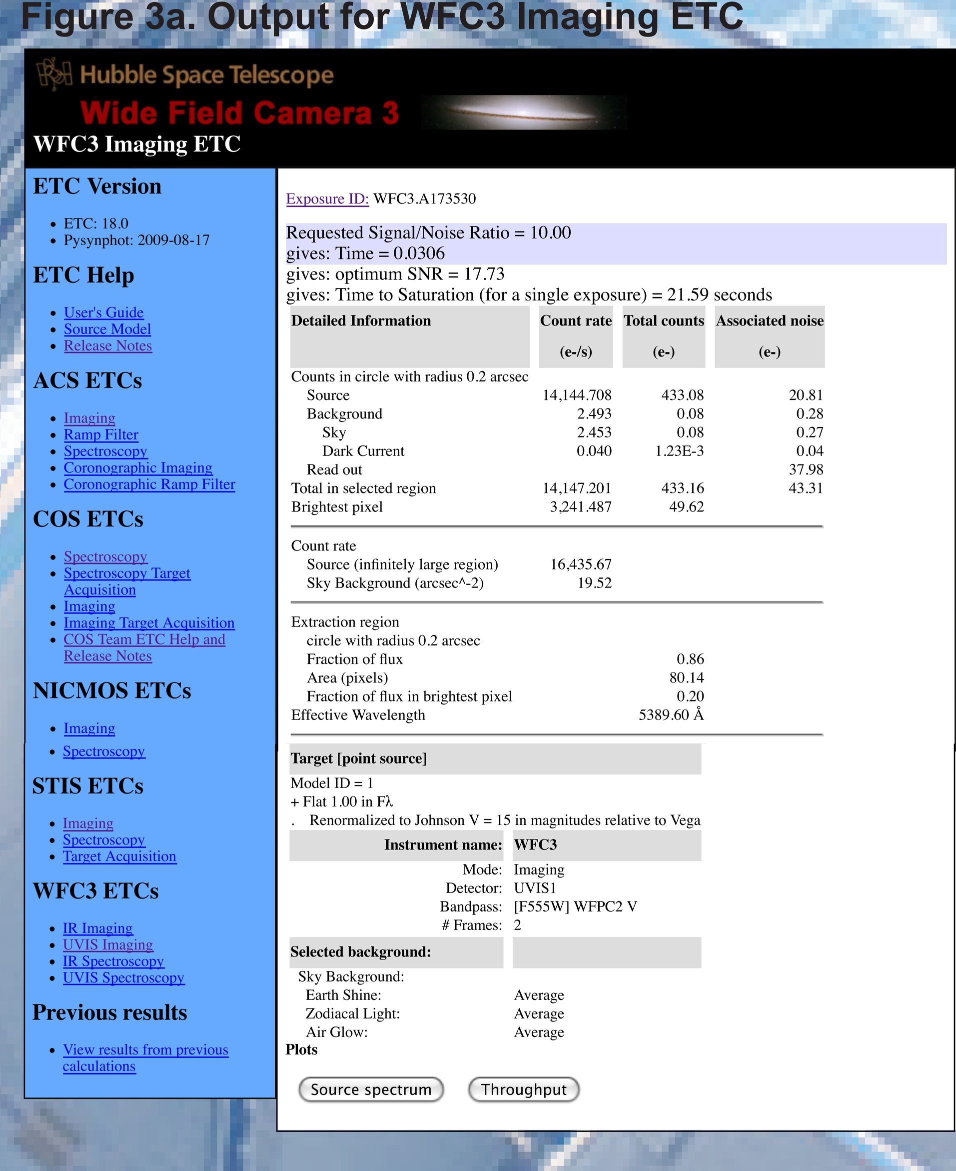
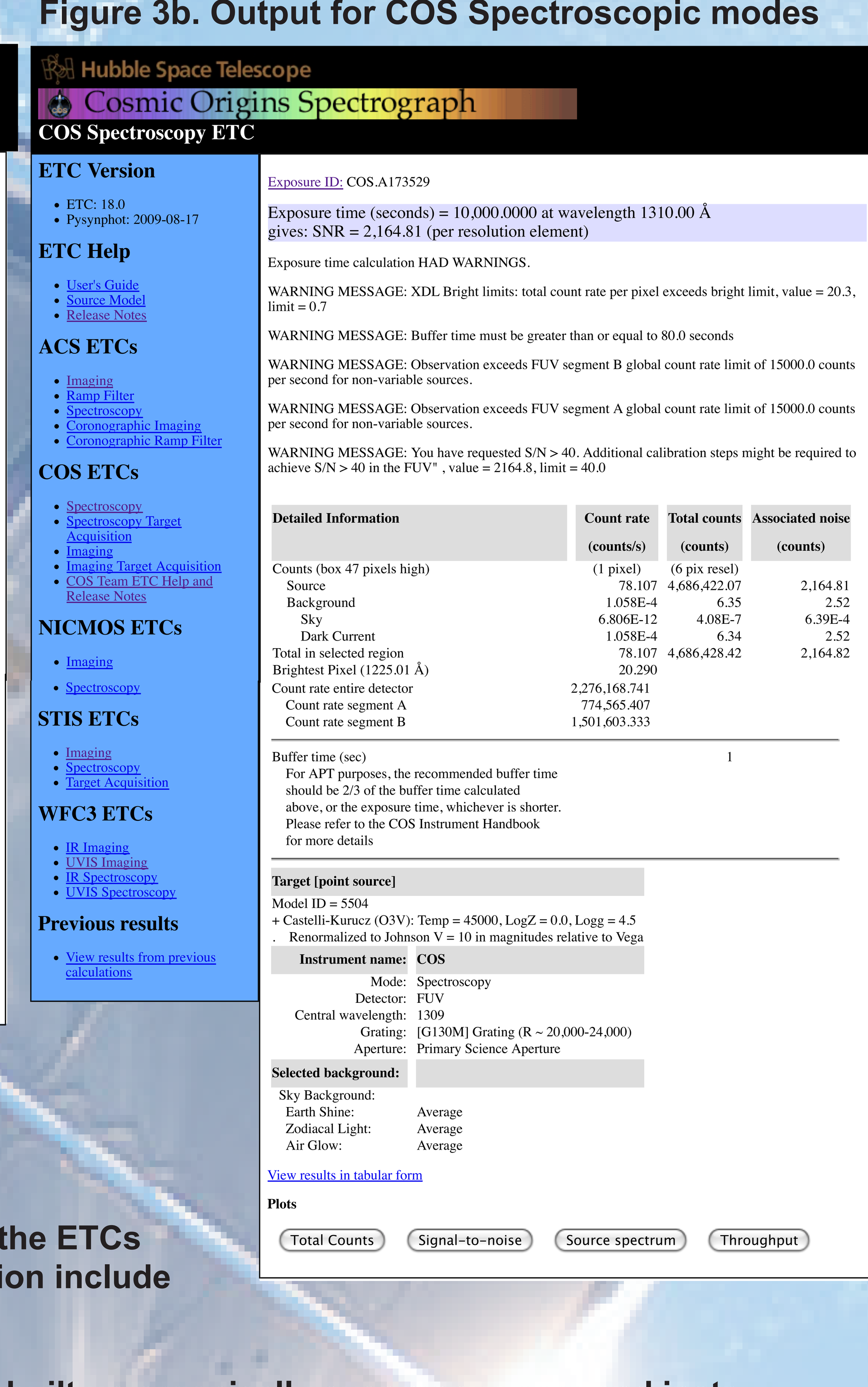


Figure 3b. Output for COS Spectroscopic modes



PYETC

Recently STScI has started an effort to rewrite the ETCs in Python. The reasons for this re-implementation include the following goals:

- Streamlining the code and data that has been built up organically over many years and instrments.
- Permitting better integration with many of the new STScI science software tools that are being written in Python, for example, *pysynphot*, a Python re-implementation of SYNPHOT.
- Making some of the underlying components for the ETC available for other science purposesthat would be distributed as part of STScI science calibration and analysis software, for example, background models and signal-to-noise calculations. The ETC computational engine will eventually be distributed with the rest of the science software.
- Anticipating JWST ETC development needs.

The re-implementation will also make possible some other capabilities not yet possible, such as scripting ETCs from Python for batch use and perhaps drive the web version of the ETC from a Python script running on a user's computer.

The new ETCs will retain much of the same web user interface as the existing ETCs so users should not find much difference in how they use the ETCs. The ability to recall past calculations, plot them, and have access to the tabular results will remain.