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New Exposure Time Calculator for NICMOS (imaging): Features, Testing and Recommendations

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ABSTRACT

A new NICMOS ETC for imaging mode has been developed as part of the Astronomer's Proposal Toolkit (APT) project. This new tool fully updates the NICMOS performance for Cycles 11+, expands the funtionality of the previous ETC, providing the user more options, and homogenizes the non-instrument specific parameters (i.e. sky background, extinction laws) with other HST-ETCs. This report summarizes its main characteristics, and gives some recommendations to potential users. Details about the tool itself can be found in the documentation linked to the ETC user interface, which can be accessed from the NICMOS web site at STScI.

Introduction

Exposure Time Calculators (ETCs) are used to obtain estimates of exposure time for a given signal to noise ratio (SNR) (or vice versa) for a simulated observation with a given telescope/instrument configuration under some particular sky background conditions. This requires a proper characterization of the instrument and the sky backgrounds.

Two NICMOS ETCs have been supported at the STScI. A first tool was constructed by Skinner (1996), on the basis of pre-launch as well as early Cycle 7 throughput and quantum efficiency data. Some properties of the telescope and the instrument (e.g. thermal emission) were tuned to agree with the observations. Later, in preparation for the NIC-

MOS reactivation during SMOV3b, Sivaramakrishman (2000) developed a new ETC (here after CGI-ETC) which incorporated several improvements. For instance, it included a more fundamental model for the thermal emission, and it allowed the user to select the detector temperature, as well as the presence (or not) of the so-called 'dark current bump' (Boeker et al 2001). The exact characteristics of NICMOS under NCS (NICMOS Cooling System) operations were still unknown and users needed to estimate exposure times under a range of realistic possibilities. Details about the software architecture and user interface can be found in Sivaramakrishman (2000, 2001).

The CGI-ETC was tested versus Cycle 7 data by Sosey (2001). She concluded that the predicted and measured SNR agree in most of the cases within 10-20% , which is considered acceptable for this type of tool.

After the installation of the NCS, new data were collected and some properties of the instrument were more accurately characterized. For instance, no 'dark current bump' was present and the temperature of the detector could be actively maintained at an average value of 77.1 K (with small shifts of about 0.15 K peak-to-peak, due to orbital and telescope attitude variations). A new version of the CGI-ETC for Cycle 11+ was developed, which included part of the new instrument characteristics, as well as some further improvements. In particular, the changes in the CGI-ETC to support the post-NCS refurbishing included:

1- The detector temperature was fixed to 77.1K
2- The readout noise rate was updated to 26 e-/pix/sec for the three cameras.
3- The "dark current bump" option was removed
4- The linear component of the dark current was set to 0.3e-/s for all three cameras.

Furthermore, to support the cooling phase, the DQE temperature dependence model was modified to allow extrapolations at high T. However, this model is now disabled since the detector temperature (T) is fixed, although it could be in principle reactivated if needed. In addition, the following changes to improve background and thermal modeling were included:

5- The earthshine contribution to the background was included.
6- New tables for the zodiacal light were used. These models are described in Giavalisco et al. (WFC3 ISR 2002-12) .
7- The previous version used the same *etendue* for NIC1 and NIC3 as for NIC2. This has been corrected.
8- The emissivity of the primary and secondary mirrors was changed to 0.03 (instead of 0.045), and a "visible area" correction factor that was mistakenly being used was removed.

The most recent version of the CGI-ETC was not updated to include all the instrument parameters for Cycle 11+. Specifically, the saturation limits (which have been altered with respect to Cycle 7 as a consequence of the larger detector quantum efficiency after the installation of the NCS) were not updated.

New NICMOS ETC for the imaging mode

This tool is a web-based application that has been developed as part of the Astronomer's Proposal Toolkit (APT). It has been developed in Java with a new software architecture (Mclean et al. 2003), and includes several improvements with respect to the previous CGI version. In this section we describe the new basic architecture, as well as the new improvements.

New Architecture: It relies heavily on the Synthetic Photometry (SYNPHOT) software package as its throughput calculator. SYNPHOT is part of the Space Telescope Science Data Analysis System (STSDAS) and is developed and maintained by the Science Software Branch (SSB) at STScI. STSDAS is an external package layered on the Image Reduction and Analysis Facility (IRAF) software package, which is developed and maintained by the National Optical Astronomy Observatory (NOAO). SYNPHOT provides the basic information to solve the SNR/Exposure-time equation, based on data from the Calibraton Data Base System (CDBS) at STScI.

Figure 1 below depicts the relationship between the ETC and SYNPHOT. The user first directs his/her web client to the ETC web server. The user then inputs instrument and exposure level parameters to the ETC input form that are then transmitted to the ETC application web server. The parameters are then packaged up as SYNPHOT request(s) and transmitted to the SYNPHOT server. The SYNPHOT response, which is a count rate in photons per second, is then retrieved by the ETC application and used in the final calculation and output report.

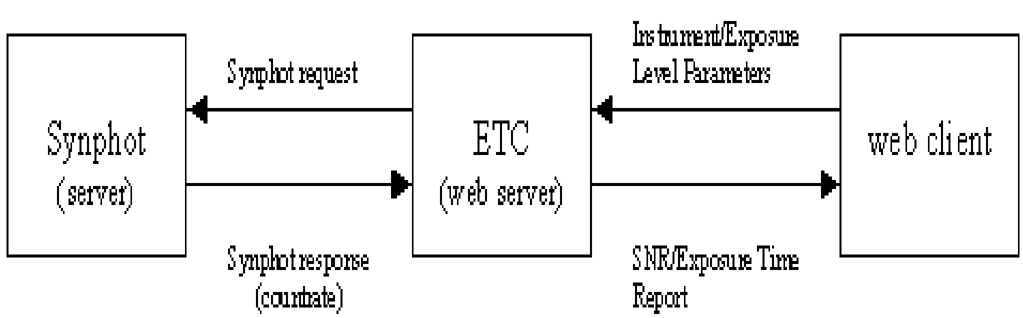

Figure 1- Basic structure of the new APT-ETC

New improvements:

From a NICMOS user’s perspective, the improvements implemented in this tool can be divided in the following four categories:

1) Full Cycle11+ instrument characterization

Apart from updated dark current, DQE, read noise, etc., already included in the previous CGI-ETC, the Cycle11+ saturation limits have also been implemented. (Saturation is said to be attained for the NICMOS detectors when 81% of the well depth is reached; see Shultz et al. 2003)

2) Comprehensive functionality

The new ETC offers more choices for the user to simulate NICMOS observations. In particular:

- For point sources, the calculations can be done at any user-selected circular aperture size. Apart from a set of pre-defined values, the user may request the value of his choice. In addition, the apertures can also be defined in terms of the percentage of encircled energy.
- For point sources, the ETC also gives an estimate of the "optimal S/N" (i.e. PSF-fitting method). The implementation of this option followed the model developed for the WFPC2 ETC (see Biretta, Lubin, et al. , 2002).
- The thermal model originally developed in C (Sivaramakrishnan et al. 2000) has been added to the SYNPHOT package in IRAF for easy maintenance and integration into the APT user tool. This model has been checked agaist Cycle11 data by Sosey et al. (2003), who found good agreement.
- It offers more choices for the spectral energy distributions. Now the user has the possibility to add upto three emission lines, use the Bruzual synthetic stellar spectra, redshift the input spectrum, and to select among more extinction laws.
- It offers more choices for the backgrounds, with the possibility of normalizing zodiacal and earth-shine fluxes independently at any desired value.

3) Homogenization of non instrument-specific parameters with other HST ETCs

This has been one of the generic goals of the APT-ETC project. Specifically, all HST APT-ETCs use now the same zodiacal and earthshine emission models (Giavalisco et al, 2003), as well as the extinction laws as other HST_ETCs (e.g. Boffi et al. 2003).

4) More accurate calculations

This is due to the fact that the fraction of encircled energy is obtained at the effective wavelength (i.e. convolving the intrumental response in wavelegth with the source spectral distribution), instead of at the pivot wavelength as in the CGI version.

Tests

The basic reference for testing this new tool has been the previous CGI-ETC. As commented above the CGI-ETC was tested against Cycle 7 data by Sosey (2001), who found a relatively good agreement between measured and predicted SNRs (i.e. within 20%). Provided that the CGI-ETC performed the SNR-t calculations only for the brightest pixel, the direct comparison APT versus CGI was only possible for that aperture. For a 1x1 pixel aperture, the APT-ETC SNR estimates for all cameras/filters combinations, when observing a point source of H=20, with a black body distribution of T=5500K and exposure time of 1000 sec (average earthshine, average zodiacal), were compared with the corresponding CGI predictions. Only for the cases for which the effective and the pivot wavelengths were rather different (e.g. F110W) the discrepancy was larger than 10%. To estimate the relative behavior in a poissonian regime, similar inputs but for H=20 were also compared for the wide filters. These comparisons yielded equally good agreement.

Therefore, the discrepancy between the tools was smaller than 10 % for most of the cases. Even though these are indeed small, they were understood in terms of the differences between both tools. However, apart from the discrepancies due to the differences between the pivot and effective wavelengths mentioned above, for some particular combinations the CGI and the APT disagree by more than 10%. Known cases are: NIC2 + F212N, NIC2 + F215N, NIC2 + F216N, NIC3 + F212N when the HST standard spectrum of G191B2B is selected.. After detailed analysis of these cases (V. Laider, private communication) it was found that the CGI-ETC was providing inaccurate answers, due to the order in which the operations were performed

Having secured the basic performance of the APT-ETC for a 1x1 aperture, the parameter space was then covered by selected cases with new apertures, spectral distributions, backgrounds, etc. Their results were analyzed on a case by case basis. For instance, all earthshine (shadow, average, high, extrahigh) and zodiacal (low, average, high) emission combinations were analized for Camera 3, F150W, H=23.5, and exposure time = 1000sec. The different spectral distributions (including only a subset of stellar models) , as well as the different extinction laws were tested with Camera 3, F110W, and H=20. Note that the combination of all the pre-defined input parameters imply more than 10^6 cases and, therefore, only a relatively small proportion of these possible cases (about 250) have been analyzed. However, as memtioned above, these should cover the complete parameter space.

This tool was offered to the community on November 2003, for the preparation of phase I proposals during Cycle 13. Prior to the submission deadline the NICMOS APT-ETC was used for about 2600 requests. No problems were reported.

Recommendations

Since new ETC offers more choices to the user, there may be some doubts about which selections should be made. In this section we provide some basic and general recommendations.

1-Optimal extraction calculation.

For point sources, the APT-ETC provides an estimate of the SNR when applying the optimal extraction method. This approach tends to give optimistic estimates for the SNR, and should not be used as a basis for requesting HST observation time by users who are not familiar with this method.

Although in general the 'optimal extraction method' gives the most optimistic results, this method assumes that the object is centered in the corner of a pixel (i.e. most conservative case, under this approach). Due to this fact, some calculations done for the brightest pixel (for which the PSF is well centered within the pixel) may give even more optimistic results. This is especially true for Camera 3 due to its larger pixel scale. However, note that the brightest pixel case is mainly used for saturation purposes and, therefore, the most conservative case here is when the PSF is well centered within the pixel.

2- Aperture selection

Unlike the previous CGI-ETC which performed all calculations in a 1x1 pixel aperture, the APT-ETC offers a large variety of options. In general, the default aperture (which is defined as a circular aperture containing 80% of the flux) should be an appropriate choice for most cases.

In order to compare the results when using a 1x1 and the 80% aperture, Figure 2 presents the ratio between the exposure times for two distinct cases ('bright' and 'faint' objects), in the three cameras. This figure shows clear that for bright objects, the 1x 1 aperture leads to longer exposure times than the 80% case (i.e. it provides the most conservative solution). However this is mainly motivated by the fact that the aperture collects relatively little flux from the source. Although this is also true for faint objects, in this case the 1x1 aperture has the advantage of significantly reducing the niose generated by the detector.

In general, the user should take into account that increasing the aperture size implies an increase in the detector and sky noise/background. In general, in a noise limited regime, the extraction region should be small. For bright object observations, for which poissonian noise from the source dominates, the apertures should be large to include most of the source's flux.

Acknowledgements

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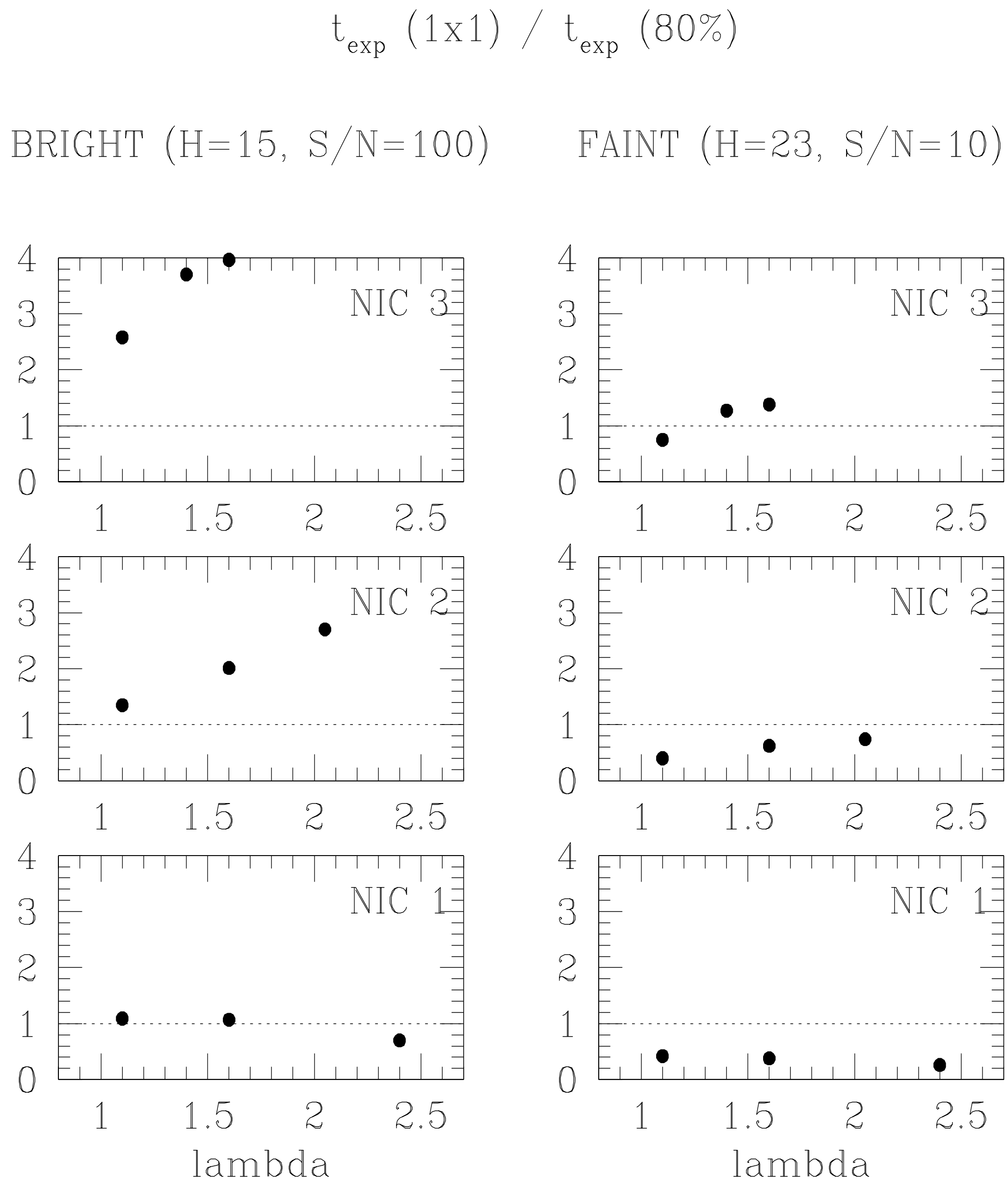

Figure 2. Ratio of the exposure time estimates for a 1x1 pixel aperture, and for a circular aperture containing 80% of the flux.