Gemini Integration Time Calculators

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SPE-C-G0076 Version 1.1; June 1998

Version History:
1.0 June 1998; first draft.
1.1 June 1998; following comments from Ted von Hippel and Joe Jensen.

1. Introduction

We describe the requirements and use of the Gemini instrument Integration Time Calculators (ITCs). The generic requirements are contained in the main sections of this document with specific instances for each instrument to be added, as they are developed, in the appendices.

The basic models followed are those employed by the STScI/HST and ESO/VLT integration time calculators but extended for spectroscopic applications. Examples of existing calculators can be found at the following URLs:

HST -

STIS (imaging): http://www.stsci.edu/ftp/instrument_news/STIS/ETC/stis_img_etc.html
STIS (spectroscopy): http://www.stsci.edu/ftp/instrument_news/STIS/ETC/stis_spec_etc.html
WFPC2: http://www.stsci.edu//ftp/instrument_news/WFPC2/Wfpc2_etc/wfpc2-etc.html
NICMOS:
http://www.stsci.edu/ftp/instrument_news/NICMOS/NICMOS_tools/NICMOS_etc_fast_2/nicmos_etc.html

SIRTF - various instruments
http://spider.ipac.caltech.edu/sirtf/sopt/

NOAO - IRAF task CCDtime
http://www.noao.edu/kpno/tools/ccdtime/ccdtime.html

ESO NTT - SUSI camera
http://web1.hq.eso.org/cgi-bin/dataflow/simulation/ntt/susi/exec/susiform?fmirror=65

2. Use of the Gemini Integration Time Calculators

The ITCs will be used by potential applicants, visiting and staff astronomers to estimate (a) the integration time require to obtain a particular signal-to-noise ratio and/or (b) the signal-to-noise ratio reached in a specified integration time. The calculators will therefore support proposal and observation preparation. They will be used both on-site and from remote sites, ideally via a web interface, and will be maintained by Gemini staff. In general it is to be expected that the data resulting from the ITC will be entered manually in (Phase I) proposals for telescope time (although future integration with the Gemini developed Phase I tool, and perhaps the Phase II Observing Tool, might be desirable).

The calculators should provide as realistic a model of the performance of the instrument as possible. The onus for this is on the external and Gemini instrument scientists to provide accurate input data (backgrounds, instrument throughput etc.) and calculation algorithms.

The calculation should take less than a few seconds to execute, by use of look-up tables if necessary. Thus detailed numerical simulations are not required or desired.

3. Generic User Input

The user interface must allow specification of the instrument configuration, source properties and other parameters via selection from a restricted set of options. Radio buttons, menu lists and numerical value text boxes are commonly used in existing calculators and are preferred.

The instrument configuration options will be specific to that instrument. See the appendices for details.

The user-selectable source properties and other parameters are more generic (i.e. they are re-usable by the ITCs for most if not all instruments) and include:

(a) Calculation mode: calculate S/N obtained in a specified time ("S/N mode") or the integration time required to achieve a requested S/N ("IntTime mode").

(b) Image profile: this is the spatial brightness distribution of the source. Initially it should be selectable from a simplified menu list, but ultimately must include an option for the profile to be generated by, or 'extracted' from, the Image Quality Estimator (IQE). The menu list should include:

   (i) Nominal point source. (The properties of this 'point' source, e.g. image size or encircled energy, would be specified in the web help pages).
   (ii) Extended source of user specified angular extent and central surface brightness with either (a) uniform surface brightness, (b) exponential surface brightness profile with specified scale length or (c) $R^{1/4}$ surface brightness profile with specified effective radius.
   (iii) Gaussian profile with user-specified FWHM (effectively a very simplified IQE).

(c) Source spectrum: this specifies the intrinsic spectrum of the source i.e. the flux density as a function of wavelength. The options must include:

   (i) Black body, at a user-specified temperature.
   (ii) Power law: $f(\lambda)\propto\lambda^{-\alpha}$, with user-specified power law index α.
   (iii) Stellar template spectra or atmosphere models, comprising a list of 10-20 spectra covering a range of spectral types and, if necessary, luminosity classes.
   (iv) Non-stellar models, including:

   - Emission line objects (planetary nebula and HII region).
   - Galaxies - normal (elliptical or spiral), at user specified redshift
   - Galaxies - active (Seyfert 1, Seyfert 2, or QSO)., at user specified redshift

The source spectra should be scalable by a user-specified normalization factor in several possible units:

- Magnitude in one of a number of recognized filter wavebands (e.g. UBVRIJHKLMNQ).
- Flux density at a specific wavelength (in nm or um) in either of the flux density units (i.e. per wavelength interval or per frequency interval).

either as the spatially integrated emission or as surface brightness (see 3b)ii)). [The former corresponds to the direct magnitude or flux density, the latter to these same properties per square arcsec of sky].

(v) A single (synthetic) emission line specified in terms of the integrated emission line flux (units of W/m**2), line width (units of km/s or micron), and continuum flux density (units of W/m**2/um or W/m**2/Hz or Jy or mag).

(vi) User-supplied spectrum, entered as a file name with the file content being ASCII columns of wavelength and signal.

(d) Data processing extraction algorithm: user choice of “quick” or “optimum”. (These modes are tbd).

Although the sky background information can be thought of as generic, it pertains to specific instruments and will be described in the Appendices where relevant.

4. Generic User Output

(a) Imaging

The ITC for imaging instruments (including the imaging mode of combined imager/spectrometers) should generate and display the exposure time to obtain a requested S/N or the S/N reached in a specific integration time. (The choice of which is a user selection). In addition, regardless of the calculation mode, the limiting magnitude for a nominal point source (see 3(b)(i)) should be displayed as an indication of the depth to which the data extends.

For *S/N mode* and extended object profiles (see 3(b)(ii) and 3(b)(iii)), the S/N as a function of profile radius and, on the same radial scale, the brightness profile, should be calculated and displayed for a one-dimensional slice through the profile. [Ultimately we might wish to consider generating synthetic images of brightness and S/N analogous to the requirements for spectroscopic data in 4(b)].

Various additional values that are calculated as part of the processing should also be displayed. These include:

- Number of pixels (*N*) used for calculation (after binning if appropriate).
- Detector read noise (after non-destructive readout or binning, if appropriate) [electrons/pixel]
- Peak pixel value (source + background) [electrons]
- Background (sky + instrument) brightness [electrons/pixel]
- Total source signal integrated over *N* pixels [electrons]
- Total background (sky + instrument) integrated over *N* pixels [electrons]

In order to assess the relative noise contributions, the supplementary values generally should be displayed both for one exposure and for the entire integration (i.e. summed over all exposures).

(b) Spectroscopy

The ITC for spectroscopic instruments will be similar to those for the imagers, the principal difference being that they should generate and display the results graphically, as synthetic spectra. Many (all?) existing calculators approximate their calculations to an average spectroscopic element which can be inaccurate (by orders of magnitude) for the highly wavelength-dependent background of the far-red and near- and mid-IR.

The graphical output will depend on the calculation mode. In *S/N mode* the display should contain spectra (i.e. parameter as a function of wavelength) for all of the following parameters:

i. Input source model
ii. Source as modified by the instrument and atmosphere response
iii. Background (sky + instrument) emission
iv. S/N ratio

In *IntTime mode* the display should contain items (i - iii) above and:

v. Integration time required

Associated numerical information, such as the number of pixels used in the calculation, should also be displayed.

Appendices

The appendices contain instrument-specific information pertaining to the Instrument Time Calculators including details of the user inputs. The user-specified required sky background (e.g. sky continuum or OH brightness) and/or transparency (e.g. thin cirrus attenuation) should be specified in the same terms that appear in the Phase I and Observing Tool e.g. as a frequency of occurrence percentile.

Examples of information that must be included in the calculation are instrument throughput, linearity, saturation, and range A-to-D converter. One use of the latter would be for the ITC to warn users if an individual exposure time would put their object in the non-linear regime of the detector or saturate the A/D (which is often less than the full well of the device).

Appendix A: Acquisition Camera
Appendix B: tbd
Appendix C: tbd
Appendix D: tbd
Appendix E: tbd

Appendix A: Acquisition Camera

The Acquisition Camera (AcqCam) resides within the acquisition and guidance (A & G) unit and is thus more or less a permanent fixture on the telescope. Its principal function in its imaging role is to take images of the sky for target acquisition purposes. It will be used extensively during the commissioning phase for acquisition (pointing) and image quality measurements and, whilst it is not designed (or specified) to take scientific data, it may be also used at first light and perhaps occasionally during operations as a science imager.

The AcqCam is fed the telescope beam by a pick off mirror in the lowest module of the A & G unit. The AcqCam can be reconfigured remotely to fulfil its alternative role as the High Resolution Wavefront Sensor (HRWFS).

The AcqCam ITC will be the first to be developed and thus serves as a prototype for the other instrument ITCs.

Properties specific to the 'instrument' that will be set by the user are:

(1) Filter:
    Choice from (list of filters tbd).
(2) CCD configuration:
    (binning, number of exposures, exposure time, read-out mode (fast/slow?); need info on CCD controller capabilities)
(3) Sky background
    (e.g. choice of days from new moon?)

Static data that is required for the calculation includes [<u>specific information is required on all of these</u>]:

(1) Telescope throughput as a function of wavelength (essentially, coating curves for each mirror in the optical train: primary, secondary, AcqCam pick-off). This is generic and will be required by other ITCs. (May need to choose silver or aluminium coating as a user option).
(2) Instrument throughput (total throughput as a function of wavelength for the fixed optical train).
(3) Filter transmission data i.e. table of transmission *vs* wavelength for each filter (this is not strictly necessary if the sky background and throughputs are specified for each filter rather than as continuous functions that need to be integrated over).
(4) Sky background for each filter as a function of lunar phase.