



Large Synoptic Survey Telescope

LSST Exposure Time Calculator

P. Gee (UCD), J.A. Tyson (UCD), P. Pinto (UA), Z. Ivezić (UW), D.K. Gilmore (SLAC), K.H. Cook (LLNL)

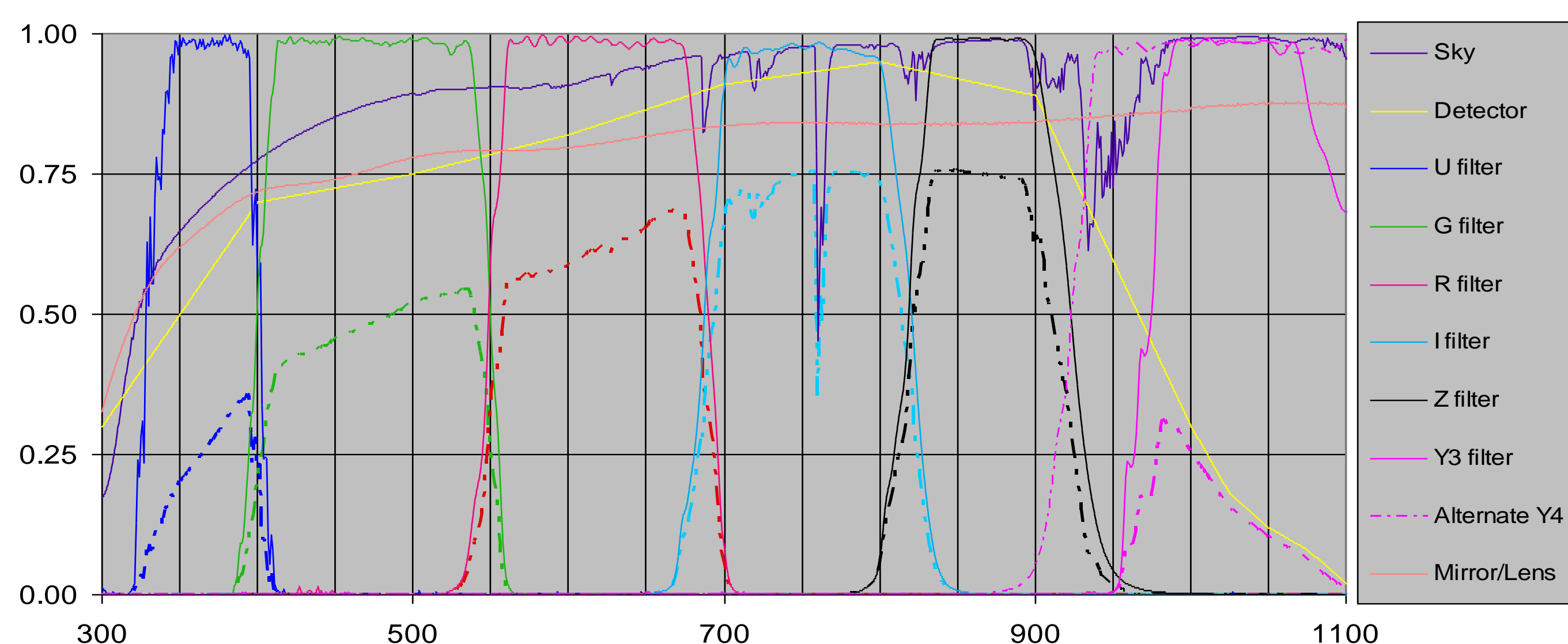
The LSST Exposure Time Calculator was developed to model the effects of LSST design changes on signal-to-noise ratio and survey depth. The ETC utilizes proposed LSST optical design, filter transmission, and CCD response, and incorporates a sky brightness model based on data taken at CTIO, UKIRT, and SDSS.

The Exposure Time Calculator allows the source spectral energy distribution, surface brightness profile, and redshift to be varied, and includes a library of stellar and extragalactic source spectra. Source and background spectra are modified for atmospheric effects and passed through the telescope and camera. The ETC uses the spectral curves to estimate both the signal-to-noise ratio for a single exposure, and the exposure time required to achieve a threshold signal-to-noise. The aperture for both background and source measurements can be specified, and an option for psf-weighted photometry is provided.

LSST Filters, Optics, and Camera Design

The ETC makes use of telescope design data supplied by the LSST Camera Team. The ETC combines sky absorption, telescope and camera optics, detector efficiency, and filter response to calculate the throughput of the system in each band.

The ETC has been used to study signal-to-noise for different filter designs: most recently alternative Y filter designs.

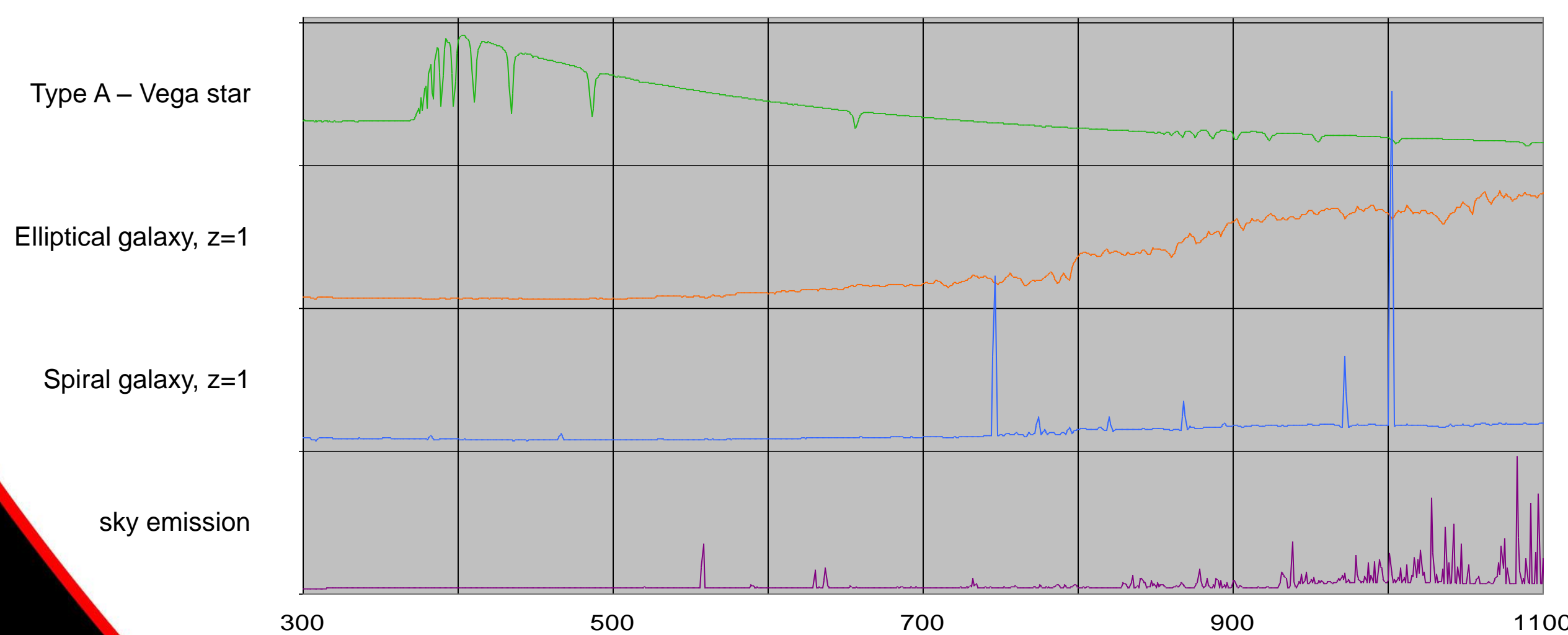


Source Specification

- Brightness or Surface Brightness
- Distribution (point, uniform surface, radial distributions)
- Redshift/velocity
- Spectral Energy Distribution

The ETC incorporates flux density curves for a variety of different sources. The source is shifted to the correct redshift and normalized to a selected brightness or surface brightness. The resulting flux density is combined with Sky Absorption, filter, optics, and detector curves to produce a photon count.

Sky brightness is also required to predict signal-to-noise. Sky emission data from the ESO UVES study² and the Gemini near infrared spectrum⁵ are used.



Total signal and noise counts incorporate the aperture of the telescope, the pixel area of the detector, dark current and read noise.

Telescope Light Gathering and Noise Parameters

Effective aperture	6.5 m
Pixel scale	.2 arcsec
Dark current	.0015 e-/s
Read noise/pixel	5 e-

Variable Observing Conditions

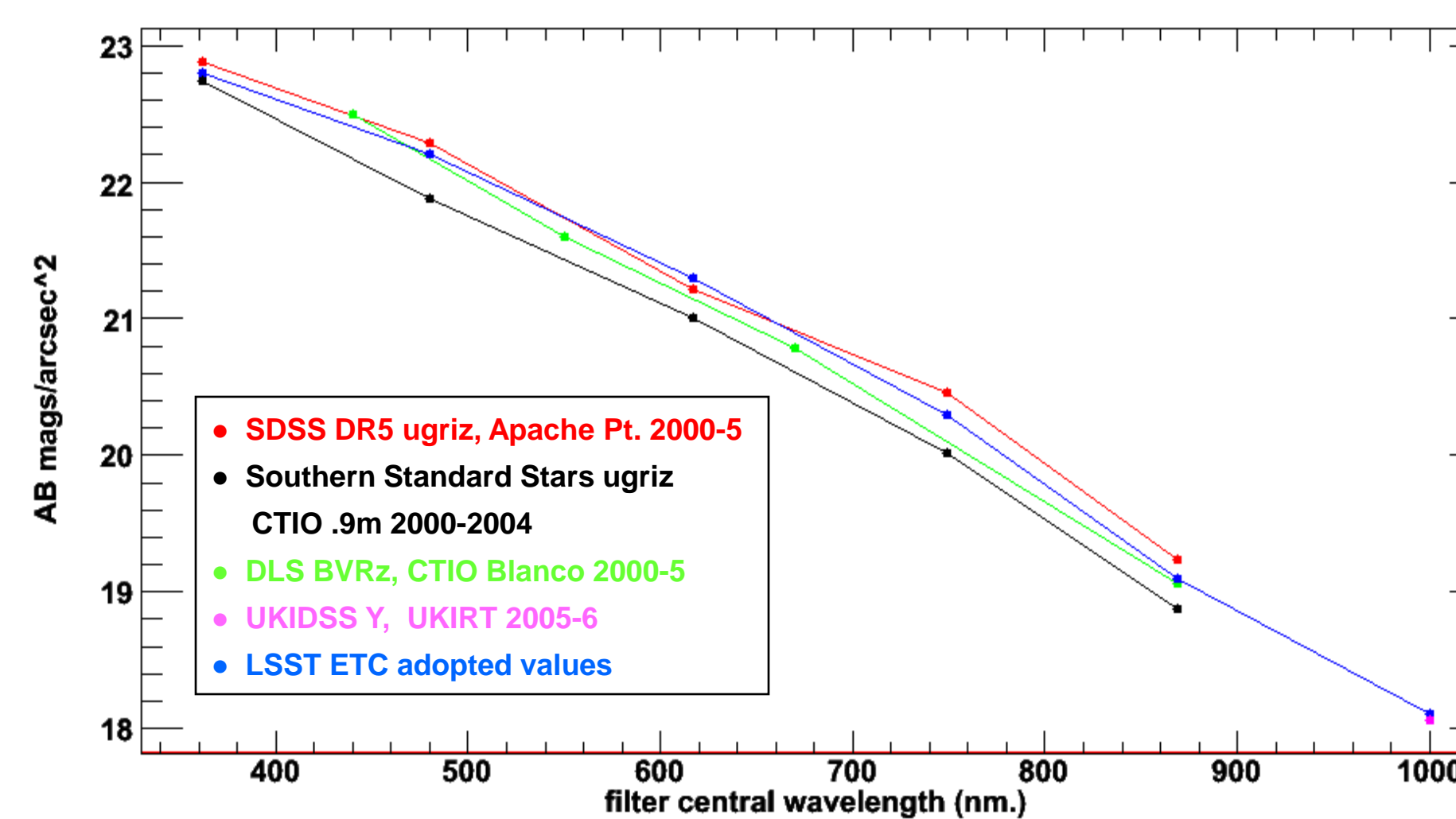
- Seeing (fwhm)
- Cloud Cover
- Lunar Elevation
- Airmass
- Lunar Phase Angle
- Moon/Observation Angle

Photometry and Signal-to-Noise Calculation Options

- Multiple exposures of a specified time and fraction of exposure on source
- Total SNR for n exposures or number of exposures required to achieve a specific SNR
- Fixed software aperture or the aperture which gives optimal SNR
- Counts within a specified aperture or PSF-weighted photometry

Study of Sky Emission for LSST

A study of Sky Brightness under moonless conditions was done using data from the Sloan Digital Sky Survey, the Deep Lens Survey, Southern Standard Stars, and UKIDSS. Dark sky average values were calculated by converting the sky brightness values to zenith, flux averaging, and converting back to AB magnitudes/arcsec².



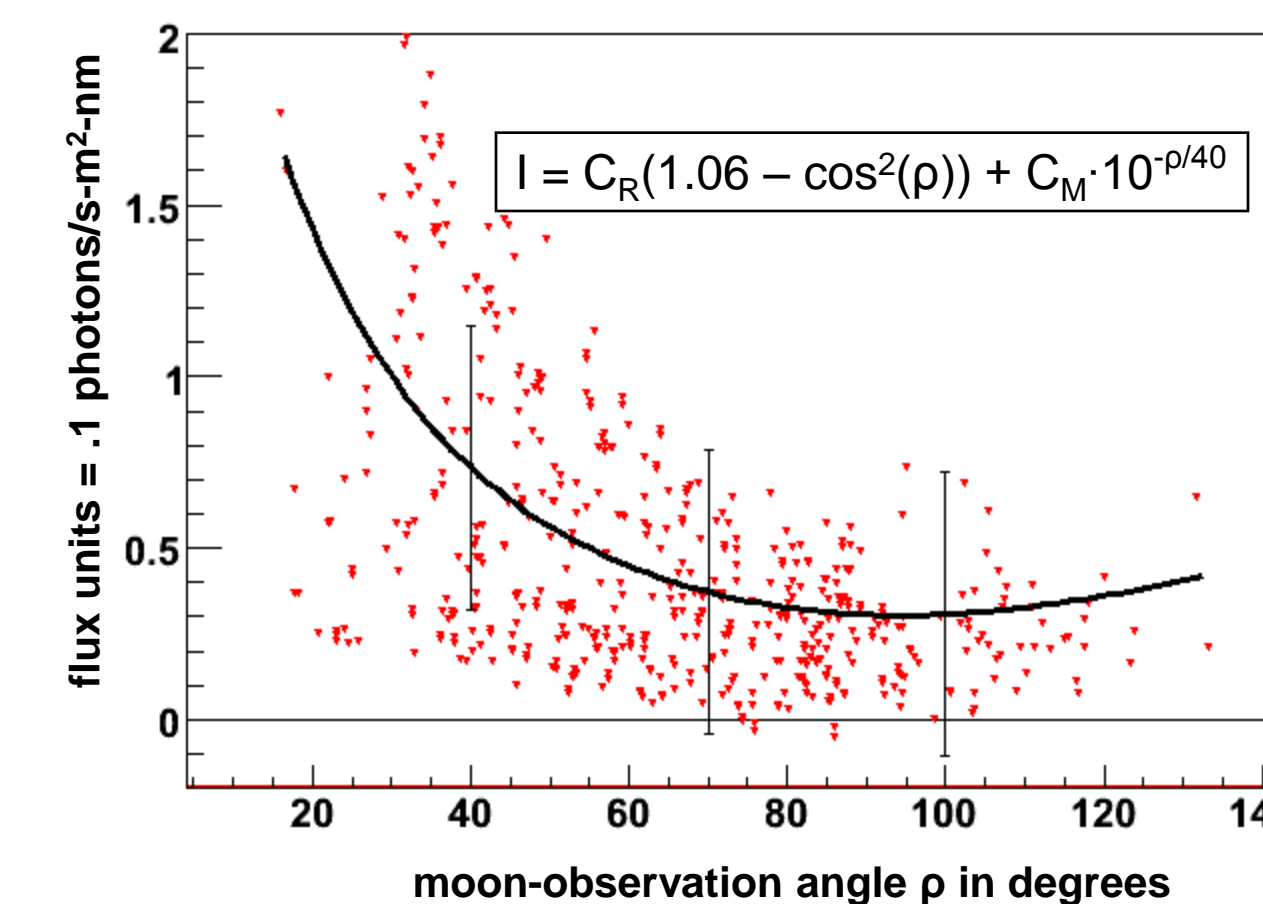
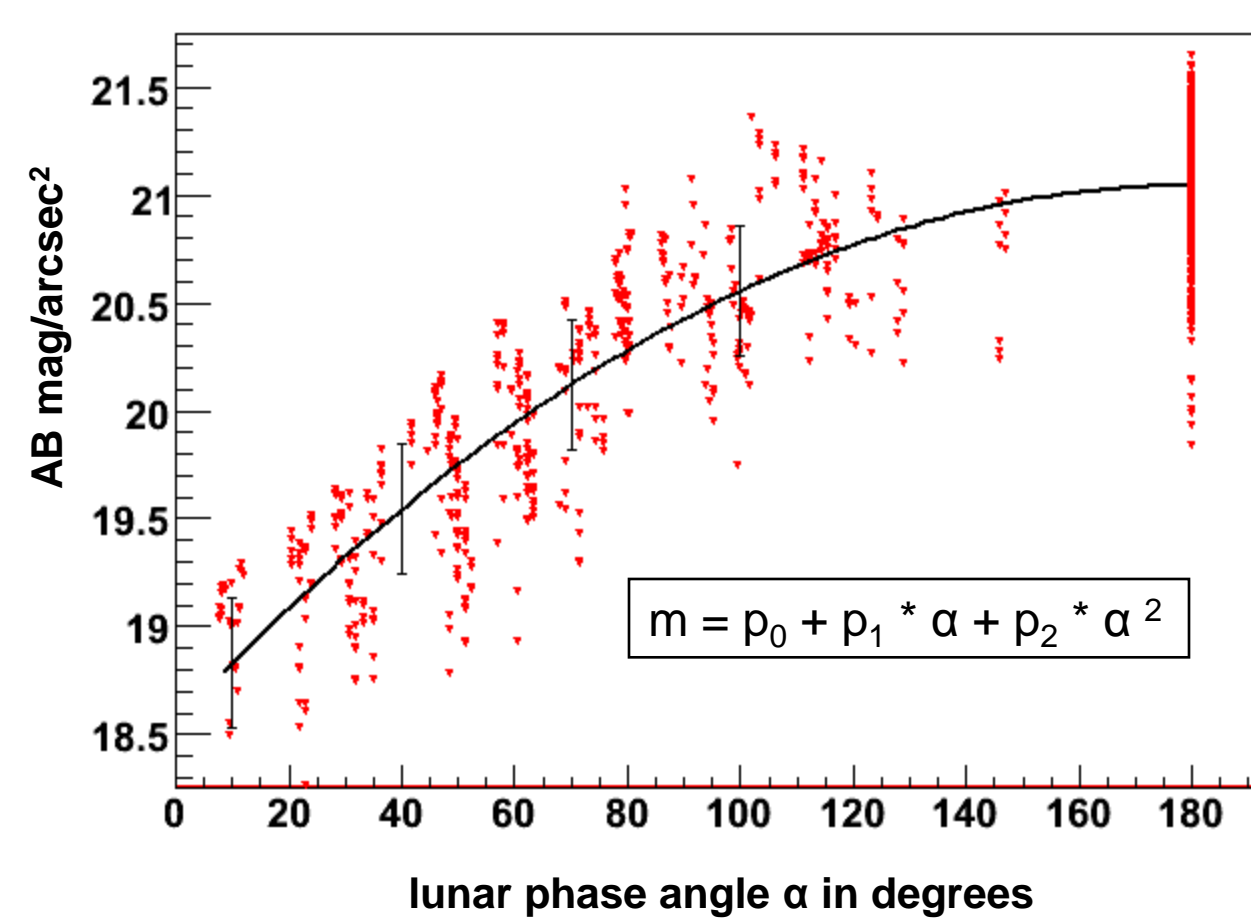
The values adopted for the ETC were based primarily on SDSS and DLS measurements.

The Southern Standard Stars data taken with the CTIO .9m telescope is known to be bright by .2-.4 mags.⁴

Sky emission value is quoted for zenith, at the elevation of the telescope.

Modeling the Effect of Scattered Lunar Light

The contribution of scattered lunar light to sky brightness was studied using moonlit observations from the Southern Standard Stars and UKIDSS. Our model extends the V band model of Krisciunas & Schaefer² to the SDSS ugriz and UKIDSS Y systems. The model parameters are lunar elevation, phase angle, airmass, and moon-observation angle.



Acknowledgements

- The baseline Java servlet used to create the ETC was taken from the Gemini ITC⁵. Thanks to Phil Puxley and Brian Walls.
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- Sloan Digital Sky Survey data from Apache Point, March 1999-June 2005, provided by Zjelko Ivezić.
- WSA UKIDSS data from UKIRT, May 2005-July 2006, provided by Nigel Hambly.
- K.H. Cook's work performed under the auspices of the U.S. DOE by LLNL under Contract DE-AC52-07NA273447.

References

- D.K. Gilmore, design data on the LSST Camera from the LSST Document Archive (2007).
- R. W. Hanuschikz, A flux-calibrated, high-resolution atlas of optical sky emission from UVES, A&A 407, 1157-1164 (2003).
- Krisciunas and Schaefer, A Model of the Brightness of Moonlight, PASP 103, 1033-1039 (1991).
- Krisciunas and Semler, Optical sky brightness at cerro toloolo inter-american observatory from 1992 to 2006, PASP 119, 687-696 (2007).
- Gemini Integration Time Calculator at <http://gemini.fcaglp.unlp.edu.ar/sciops/instruments/itc/Help/ITChelp.html>

Visit the LSST ETC at http://www.lsst.org/Science/for_scientists.shtml

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