Abstract: Our Portable Occultation, Eclipse, and Transit Systems (POETS; Souza et al. 2006, PASP 118, 1550) have been successfully employed for multiple stellar occultation observations: (i) four systems obtained data in South America during the 2005 July 11 occultation of 3C13.2 (2UAC 26295718) by Charon (Guilbis et al. 2006, Nature 439, 48); (ii) four systems obtained data in Australia during the 2006 June 12 occultation of P384.2 (2UAC 263936859) by Pluto (Elliott et al. 2007, AJ 134, 1), and (iii) three systems were utilized in the Southwestern U.S. for the 2007 March 18 occultation of P445.2 (2UAC 25823784) by Pluto (Pasachoff et al. 2007 & Person et al. 2007, this meeting).

Pluto and Charon have apparent V magnitudes of ~14 and ~16, and the stars for these events had UCAC magnitudes of 14.99 to 15.25. These events were bright enough to check for and correct faint signal-to-noise ratios (SNRs) at cadences between 2 and 10 Hz by using “conventional” camera modes. POETS also possesses electron-multiplying (EM) readout modes, which we have not yet employed for occultation observations because conventional modes have been more adequate. Here, we present an exploration of conventional versus EM mode as applied to observations of stellar occultations by faint objects. In particular, we are interested in the performance of the KBO-03 system (KBOs) in the EM mode. Although dependent on specifics of the occultation, telescope, and instrument, we find that electronic readout can be utilized to provide data of high SNR for KBO occultation observations.

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Overview: Conventional vs. Electron-Multiplying (EM)

The POETS camera, an Andor iXon (e2v CCD97), has two modes: conventional and electron-multiplying (EM). Conventional mode operates like a standard charge-transfer CCD. In EM mode, charge is moved through an additional multiplication register, where it is amplified prior to the e-/ADU conversion in the standard output amplifier (see Elliott et al. 2005). While the EM process effectively increases signal without increasing read noise, the increased EM noise is due to the dynamic range being limited at high gains (see Figure 1), and an excess noise factor is incurred due to impact ionization statistics (see Figure 3), and (ii) spurious (or clock-induced) charge becomes a significant factor.

SNR Regimes

This plot shows the SNR as a function of signal for three different regimes, relative to an ideal, noiseless detector. The blue line of “conventional” represents data taken in the conventional mode. This blue “EM" line represents data that are read out through the electron-multiplying register. The red “EM photon counting” curve represents data collected in the EM mode and analyzed using a photon-counting technique (i.e., histogram method). Optimal modes for the given signal levels are as follows: conventional ~ 5; EM ~ 20 – 25; EM photon counting ~ 25. The transition between EM and conventional is dependent on read noise. Here, we have assumed POETS’ read noise of 6 e⁻ for conventional (1 MHz) and 60 e⁻ (110 e⁻).

Occultation SNR: Conventional vs. EM

This graph compares the EM gain and conventional sets of data as a function of signal-to-noise ratio. For a given level of signal, the EM mode requires significantly lower signal-to-noise ratio than the conventional mode in order to obtain an acceptable level of SNR. This is particularly true at low signals, where the EM mode can provide a significant improvement in signal-to-noise ratio. For example, at a signal-to-noise ratio of 10, the conventional mode requires 200 e⁻, while the EM mode requires only 5 e⁻. This improvement is due to the increased sensitivity of the EM mode, which is able to detect weaker signals than the conventional mode. Additionally, the EM mode is more tolerant of noise, as it can handle a wider range of signal-to-noise ratios. This allows for more accurate measurements of faint objects, even in the presence of significant background noise.

Conclusions

- With occultations with POETS iXon cameras (e2v CCD97), the optimal EM gain setting is a few tens to a few hundreds of 1 e⁻. This is in agreement with previous studies that have shown that EM mode is superior to conventional mode for faint occultation stars.

- Theoretical, EM mode should return higher SNRs than conventional for stellar occultations of faint stars by faint objects. The theoretical magnitudes depend on many factors for POETS on the IRTF with 1 e⁻ exposures. Our results indicate that EM mode will perform better than conventional for KBO occultations with star magnitudes fainter than approximately 15.5.

- Time-series photometry of a star near the detectability limit (~0.1 s exposures of a 13 mag. star on a 0.6-m telescope; taken in the manner of an occultation observation), demonstrates that EM mode returns higher SNR for a faint star in practice.

References