The Puoko-nui CCD Time Series Photometer

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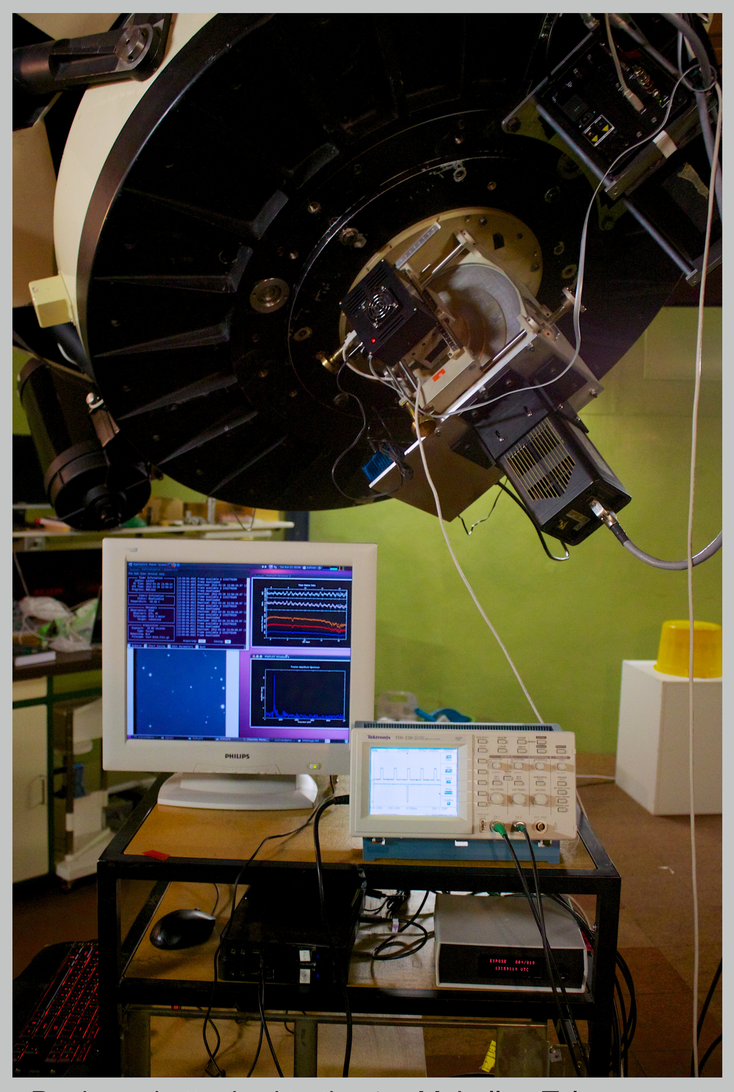
Instrument Overview

Puoko-nui is a precision time series photometer developed at Victoria University of Wellington, primarily for use with the 1m McLellan telescope at Mt John University Observatory (MJUO), Lake Tekapo, New Zealand. It has been operating in its current form since early 2011.

The initial design concept for the photometer was inspired by an earlier instrument (Argos) developed at the University of Texas in Austin. Puoko-nui features a modular design which replaces the parallel port timer dongle in Argos with a separate programmable hardware unit to provide a clean separation of timing and acquisition, and allow for much greater flexibility in operation.



Puoko-nui attached to the 1m McLellan Telescope at Mt John University Observatory, Lake Tekapo, NZ

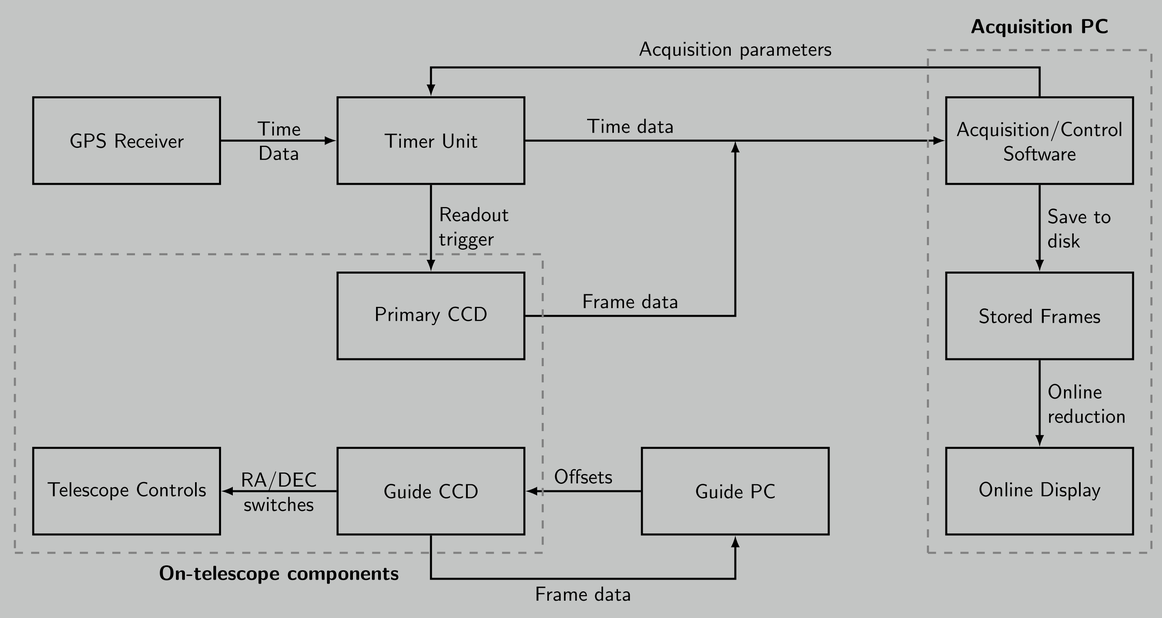
Detectors

Puoko-nui has two CCD detectors. The primary detector is a 1k $\times$ 1k pixel frame-transfer CCD that is part of a Princeton Instruments Micromax camera system. A smaller SBIG ST-402ME CCD is mounted in an offset guiding position with a 2D slide mechanism, which allows a bright star outside the main field of view to be imaged independently of the main detector for telescope autoguiding. Both detectors connect to their respective control PCs via USB.

The frame-transfer operation of the primary CCD effectively eliminates readout deadtime, allowing the system to be run without a shutter. At the maximum 1 MHz readout rate, full-resolution exposures as short as 2 seconds are possible. Faster rates can be achieved by binning pixels. The CCD is thermoelectrically cooled to -50°C to reduce thermal noise.

Our white dwarf observations use a broad blue band BG40 filter to reduce the sensitivity to red sky photons. The primary CCD is normally operated with 2 $\times$ 2 pixel binning and 100 kHz readout to minimize noise.

Paired with the MJUO 1m telescope at f/8, the primary field of view is 5.7 square arcminutes. When operated with 2 $\times$ 2 binning, the aggregate pixels each image a 0.66 square arcsecond region of the sky.



Block diagram illustrating the main components of the instrument

Timing

Exposure timing is controlled by a custom-built unit based around the ATmega1284p microcontroller. Timing information is received from an external GPS receiver via RS232 and a 1 Hz edge-aligned time pulse.

Camera readouts are triggered via a BNC cable connection, with a second connection used for monitoring the camera status. Communication with the acquisition PC is via USB.

The main timer firmware supports two external GPS units; the Trimble Thunderbolt, and an older Magellan OEM receiver. Support for additional GPS receivers can be added with minimal effort.

An alternative timer firmware provides a "high-speed" timing mode: the 1 Hz GPS time signal disciplines an internal timer, allowing sub-second exposures with a timing resolution of 10 ms.

Acquisition

The instrument control and online reduction software is run on a pair of compact "net-top" PCs situated adjacent to the telescope and controlled via a remote connection. One PC runs the acquisition and online reduction software in an Ubuntu GNU/Linux environment. The other runs the proprietary SBIG acquisition/autoguiding software in a Microsoft Windows environment.

The acquisition software provides facilities for setting image metadata (target name, observers, etc) and configuring run parameters such as exposure time and CCD temperature.

The software acts as a passive receiver once an acquisition run commences, tagging each frame with the GPS timestamp and image metadata. Frames are saved to disk as compressed FITS files.

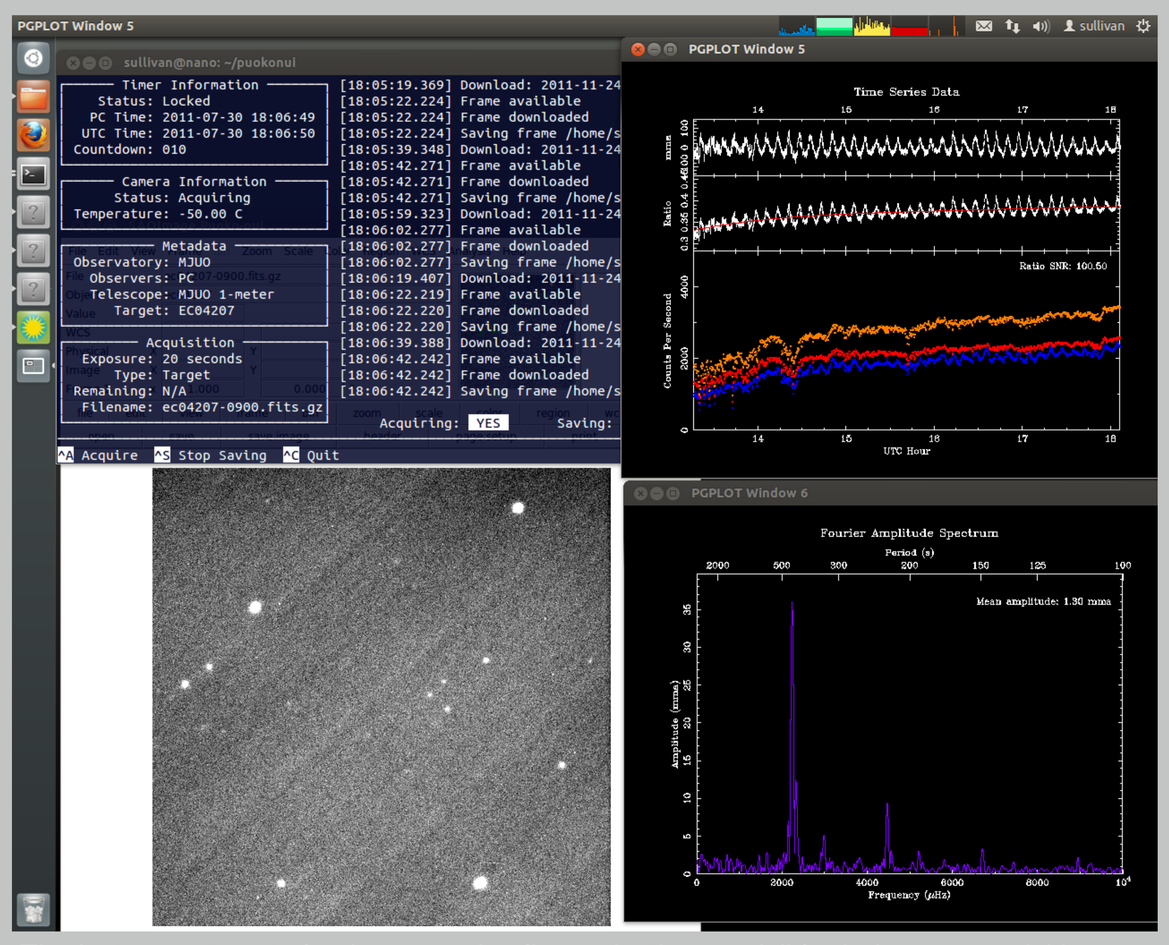
Online Reduction

We have also created a software package for online reduction and analysis of Puoko-nui data, called `tsreduce`.

`tsreduce` performs aperture photometry on selected target and comparison stars. The intrinsic variation in the target star (measured in milli-modulation amplitudes; 10 mma = 1% change) is determined by taking the ratio of the target and comparison intensities, then subtracting a low-order polynomial fit to remove any residual long-period effects.

Frames are processed immediately after acquisition, producing an up to date graphical display of the raw lightcurves for each star, and a lightcurve and Fourier amplitude spectrum of the intrinsic target intensity.

Offline analysis functionality includes routines for optimizing aperture size, BJD timestamp corrections, and Fourier analysis techniques including prewhitening.



The instrument control software and online reduction as visible during an acquisition run

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