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MOPTOP: Multi-colour Optimised Optical Polarimeter

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Abstract. Polarimetric measurements are essential for the study of jetted sources associated with black holes, such as γ -ray bursts and blazars. The relativistic jets launched from regions close to the black hole are threaded with magnetic fields, which produce synchrotron emission, and can be studied with polarimetric measurements. The multi-colour, optimised, optical polarimeter (MOPTOP) is a multi-band imaging instrument designed for use on the Liverpool Telescope. By replacing the rotating polaroid with a half wave plate and beam splitter, the instrument utilises twice as much of the incoming beam of light from the telescope compared to its predecessor, Ringo3. MOPTOP also builds on the successful introduction of dichroic mirrors to perform simultaneous multi-waveband polarimetric and photometric analysis in Ringo3, and enhances the sensitivity of the instrument with sCMOS cameras to use all photons as efficiently as possible.

Keywords. polarization, instrumentation: polarimeters, techniques: polarimetric, etc.

1. Introduction

With the increase in demand for polarimetric observations using the Ringo3 polarimeter (Arnold et al. 2012), a new polarimeter has been designed to meet a list of requirements for an optimised instrument on the 2 metre, fully robotic and autonomous, Liverpool Telescope (Steele et al. 2004). These specifications include: maximum sensitivity, very low systematic errors ($<0.1\%$), rapid observations of variable or fading sources, measuring all sources in the widest possible field of view without prior identification or prior knowledge of source brightness, multi-wavelength polarimetric observations, readiness for response to transient triggers and best possible spatial resolution.

2. Overview

The fundamental difference between the optical design of Ringo3 and MOPTOP is the replacement of the rotating polaroid with a half-wave plate and wire-grid beam-splitter. This means that instead of $\sim 50\%$ light being discarded by the polaroid, the full beam is utilised, splitting the two polarisation states and directing them to separate detectors.

The detectors of choice are sCMOS cameras; they maintain the rapid readout (>100 frames per second) and ultra low read noise (<0.9 electrons) advantages of electron-multiplying charge-coupled devices (EMCCDs) but add greater sensitivity ($>70\%$ vs $\sim 40\%$ for EMCCDs; because EMCCDs have a charge multiplication noise component that effectively reduces the quantum efficiency by a factor of 2). In addition sCMOS detectors are available in much larger formats (~ 4 Mpix vs ~ 1 Mpix from EMCCDs) allowing the full 8 arcmin telescope field of view to be sampled at optimal (Nyquist sampled) resolution. MOPTOP will allow a throughput improvement from the Ringo3 value of $\sim 20\%$ to $\sim 60\%$ and a field of view improvement by a factor of 4. The

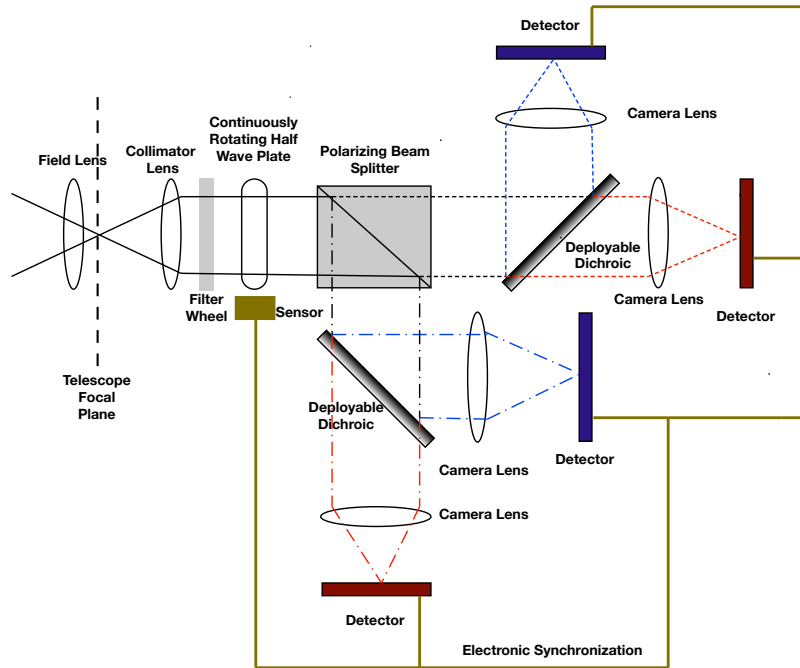


Figure 1: The two colour design of MOPTOP. The light from the telescope enters the instrument from the left where the unvignetted instrument field of view is increased by the field lens. The light enters a lens to collimate the light before passing through a filter wheel (for use in calibrating the instrument to standard sources). The polarisation of the beam is then modified by the continuously rotating half wave plate and is split to its ordinary and extraordinary beams by the beam splitter. The light is then directed through a deployable dichroic mirror and split to two electronically synchronous sCMOS detectors. If the dichroic mirrors are not deployed the instrument can record a more sensitive result in a broader wavelength range.

improved optical image quality from the use of better lenses, combined with the other improvements will give an increase in sensitivity of ~ 1.5 magnitudes (from $V=17.0$ to $V=18.5$ for 1% polarisation accuracy), which is equivalent to quadrupling the telescope size. This improvement reduces the exposure times required for polarimetric accuracy, and also vastly improves the number of sources available to the instrument; particularly optically detected γ -ray burst afterglows for which the Ringo series of instruments were designed (see Mundell et al. (2013) for example).

The optical design is shown in Figure 1. The instrument will be built for use on the Liverpool Telescope, however, the design will be made fully public domain, with the aim of encouraging copies to be placed on other (smaller) robotic facilities around the world such as the all sky network operated by LCOGT (<http://www.lcogt.net>).

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