Aristarchos RISE2: A Wide–Field Fast Imager for Exoplanet Transit Timing

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Abstract. The detection of exoplanets is currently of great topical interest in astronomy. The Rapid Imager for Surveys of Exoplanets 2 (RISE2) camera will be built for exoplanet studies and in particular for detection of transit timing variations (TTV) induced by the presence of a third body in the system. It will be identical to RISE which has been running successfully on the 2m Liverpool Telescope since 2008 but modified for the 2.3m ARISTARCHOS telescope. For TTV work the RISE/LT combination is regularly producing timings with accuracy \(< 10\) seconds making it the best suited instrument for this work. Furthermore, RISE2/AT has the added benefit of being located at a significantly different longitude to the LT/RISE on La Palma, hence extending the transit coverage.

1. Introduction

The detection of exoplanets is currently of great topical interest in astronomy. As technology and techniques progress the main emphasis is naturally moving towards the detection of low mass planets. These objects are difficult to detect by direct means and it is likely that we will have to wait for an ELT to image the first Earth analogue system. However, in the mean time, a number of techniques are being used to indirectly detect super–earth massed planets. For an eclipsing system, the idea of using timing residuals to infer the presence of a third, usually lower mass, body is not a new one, going back to the discovery of the outer planets of our own solar system. Recent calculations (Holman et al. 2005, Agol et al. 2005) show that a low mass planet moving in a resonance orbit can alter the transit times of a hot Jupiter planet by \(> 5\) sec for periods of 40 days or more. The SuperWASP surveys (Pollacco et al. 2006) are now the single largest source of transiting planets, the host stars of which typically have magnitudes in the range \(V \sim 8\)–12, with amplitudes of 5-20 mmag and durations of 1–3 hours (Cameron et al. 2007; Pollacco et al. 2008; Wilson et al. 2008; Anderson et al. 2008). For accu-
rate timing, it can be seen that photometry at the few milli–magnitude level is therefore required. Often signals such as this are dominated by systematic noise sources. One of the ways to help overcome this is to image as many comparison stars as possible with similar brightness to the target star. The stars themselves have target brightness that on a 2–m class telescope require exposure times of 1–10 seconds to obtain the required SNR for milli–mag photometry.

2. RISE

A British collaboration (Steele et al. 2008) produced the first RISE (Rapid Imager for Surveys of Exoplanets) instrument for the Liverpool Telescope with the prime science driver of obtaining high accuracy transit timing. RISE has recently been commissioned at the LT where it has been fully integrated into the robotic control system and is now in regular use. They decided to use a small frame transfer CCD combined with a field condensing system to achieve the combination of field of view and readout speed. The camera is an Andor DW435 model which uses an E2V CCD47–20 back illuminated, frame transfer CCD with 1024×1024 pixels (pixel size 13.0×13.0 microns). The RISE instrument itself uses a single filter (similar to V+R passband). Since commissioning in February 2008 RISE has obtained well over 100,000 astronomical images and the first results have already been published (Gibson et al. 2009).

3. RISE2

In order to understand the transit timing variation observations over many transits are necessary. Furthermore, the uncertainties of weather and telescope reliability mean that there are many advantages in having multiple RISE instruments. RISE2 will be similar to the original instrument but modified for the “Aristarchos” telescope (Fig. 1). The maximum field of view at the side port is 10 arcminutes and this will drive the field of view of the instrument. Using a similar frame transfer detector will result in a pixel size of ∼0.51″ which while ideal for observations of bright stars, may under sample the seeing in good weather. For integrations longer than ∼1.2 seconds there will effectively be no dead time between exposures.

3.1. Instrumentation

The mechanical design of the instrument was driven by the nature of the optics used (Figs. 2 & 3). The collimator lens has a 500mm focal length; this make the instrument too long to be stable without a fold mirror. The fold mirror brings the optical axis of the instrument along side the AGU of the telescope. A diagonal bar will be fitted spanning the length of the instrument to eliminate sag through the 90 degree fold. The bottom of the instrument will be clamped to lower part of the AGU to eliminate sway. Due to the physical size of the instrument in order not to add a lot of weight, it is decided to use Aluminum for its light weight and still strong tensile strength.
3.2. CCD system

Like RISE, the camera selected is an Andor DW435 model. This uses an E2V CCD47–20 back illuminated, frame transfer CCD which has $1024 \times 1024$ pixel light sensitive region. Each pixel is $13.0 \times 13.0$ microns. In direct imaging mode such a device would yield a field of view of $9 \times 9$ arcmin$^2$ with a pixel scale of $0.51''$ per pixel. The Andor device is a thermoelectrically cooled chip and has research grade noise characteristics when at its operating temperature of $-50$ $^\circ$C (RON $\sim$ 2.5 adu, low dark current, better than 1% linearity over its dynamic range etc).

3.3. Commissioning plan

The commissioning plan can be summarized as follows:

- 2009 July: Agreement (MOU) was signed by all parties
- 2009 August CCD has been ordered
- 2009 July - September: Instrument design completed (Mechanical Engineer and Computer programmer visited the telescope on site for final checks before staring the manufacture - Sept. 10th)
- 2009 October – 2010 Feb: Manufacture of all parties (mechanical, electronics, ccd) – Writing the appropriate software
- 2010 March-April: Commissioning of RISE2, testing period
- 2010 May: Starting Observing with RISE2

3.4. Concluding remarks

RISE2 is an instrument for the 2.3m ARISTARCHOS telescope, which will be designed, built and commissioned within 1 year of the initial agreement. Although work is still underway, having the first results from RISE (LT) it is clear that this project is sufficient to carry out the transit follow–up program and produce very good results. The collaboration between the two telescopes (2.3m AT and 2m LT) will increase the observation time since observations over many transits are necessary in order to understand better the transit timing variation. It is expected to increase the number of secondary planets to a sufficient number of planetary systems.

References

Figure 1.: The AGU of the Aristarchos telescope. RISE2 will be installed on the right side port (counter weights are currently there), opposite to the ATS spectrometer (left side port). The imaging CCD is on the side port between these two.

Figure 2.: Two different views of the mechanical layout of RISE2 (left: side view, right: angle view).

Figure 3.: A more detailed image of the mechanical design of RISE2.