Exploring the treasure trove: PIRATE as a semi-robotic exoplanets winnower

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Introduction

The SuperWASP consortium (Pollacco et al 2006) has to date identified over 40,000 exoplanetary candidates, including 2,500 high priority targets. About 90% of these will eventually prove to be mimics (Street et al 2006) as seen in Figure 1, many of which are interesting in their own right.

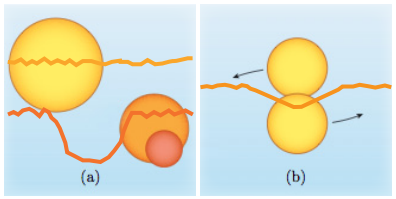

Figure 1. Two of the most common mimic types with characteristic lightcurves: (a) a star of constant brightness blended with an eclipsing binary (a blend); (b) a grazing eclipsing binary

To deal with such large quantities of candidates, a cost-effective follow-up procedure is required, to both broadly categorise all objects and identify the most interesting ones for further follow-up on expensive, high-demand telescopes (Haswell 2010).

In this context, we present PIRATE Mk II (Physics Innovations Robotic Astronomical Telescope Explorer) in its current role as a second stage exoplanetary candidate winnower.

PIRATE

Instrumentation:
The PIRATE facility houses a CDK 17" PlaneWave telescope (Fig 2) on a Paramount ME equatorial mount in a 3.5 m All-Sky Baader Planetarium robotic dome. The main imaging 4k x 4k SBIG STX-16803 CCD camera is equipped with Baader RGB, Cl & Hα filters and gives a 43' field of view. The facility achieves 60 second cadence, sub-percent photometric accuracy in the R-band for stars of 11th magnitude or brighter - sufficient for follow-up of SuperWASP targets.

Figure 2. PIRATE in it's clamshell dome. The telescope is a 17" f/6.8 PlaneWave Instruments Corrected Dall-Kirkham equipped with a 4k x 4k SBIG STX-16803 CCD as the main camera.

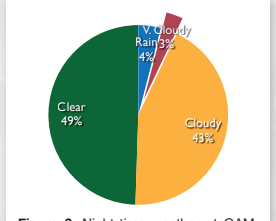

Figure 3. Night-time weather at OAM. Based on analysis of a year of weather data collected on site in 30 min intervals.

Location:
PIRATE is located at the Observatorio Astronómico de Mallorca (OAM) near Costix, Mallorca, at an altitude of 162 m. The observatory benefits from over 2,000 clear observing hours annually (Fig 3).

Observing modes:
All instruments can be controlled remotely from a personal computer or smartphone via either DC-3 Dream's ACP Browser Interface or a direct Virtual Network Computing (VNC) connection. Both solutions utilize reliable, commercial, off-the-shelf software discussed further in Holmes et al (2011).

Observations can be also conducted in a semi-robotic mode, requiring an observing plan to be submitted to the ACP Observatory Control software for execution. At a pre-specified time, ACP assumes control over the dome, the telescope mount and camera, and carries on observing for as long as required before closing down safely.

Reduction Pipeline

The reduction of data is performed by a semi-autonomous pipeline that makes use of IRAF and IDL routines. This is discussed in more detail in Holmes et al (2011). A summary of the steps used in this reduction is as follows:

- Low quality images are identified and removed manually.
- Bias, dark and flat field calibrations are performed.
- The frame that exhibits the highest standard deviation from the quartile of frames that have the lowest mean values is selected as a master frame. This can be manually overwritten.
- All sources above a 6σ threshold are identified within the master frame and a co-ordinate list is generated.
- A linear transformation is deduced and applied across all frames, generating a final co-ordinate list for all frames.
- Photometry is performed on all stars in order to generate raw lightcurves.
- Stars that contain photometry failures are removed from the data set. Likewise, any frames that exceed a predefined percentage number of failures are also removed.
- An optimal comparison lightcurve ensemble is determined, which is designed to minimize the RMS on a star by star basis.
- The final output is a set of normalised lightcurve plots for all the identified stars in the field of view.

Results

2012 Winnowing Campaign:
Out of 25 candidates, observed throughout January and February 2012, over 55% were identified as either mimics or potential planets:

- blends (e.g. Fig 4) 6
- grazing eclipsing binaries (e.g. Fig 5) 1
- potential exoplanets (e.g. Fig 6) 7

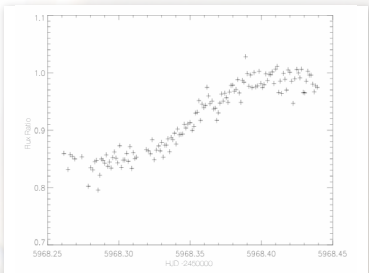

Figure 4. Lightcurve of a companion star to a candidate identified as a blend. Note the 15% depth of occultation.

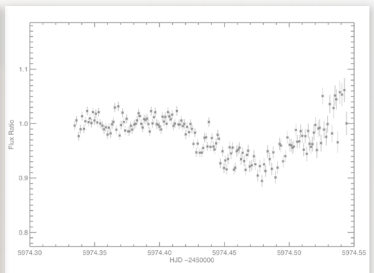

Figure 5. Lightcurve of a grazing eclipsing binary. Note the 10% depth of occultation and lack of a transit floor.

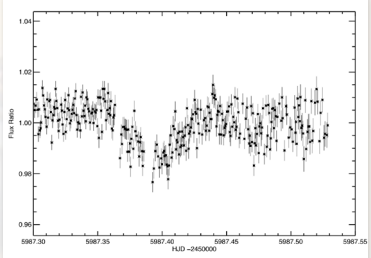

Figure 6. Lightcurve of a potential exoplanetary host star. Again, note the depth - here approx. 1.5%.

The remaining 11 objects could not be categorized due to low data quality (affected by adverse weather) and ephemeris drifts. Stars in the former group will be re-observed on the next occasion, further increasing the percentage of classified objects.

Transient Events:
PIRATE is particularly well suited for observations of transient events, utilising idle time between scheduled transits. In February 2012 this resulted in the successful follow-up confirmation of newly discovered comet (Fig 7) C/2012 B3 (La Sagra) - still at visual magnitude of 18 (Sanchez et al 2012).

During the same month, the routine search for novae as a part of a MPE/OU/OAM M31 monitoring collaboration, resulted in a discovery (Fig 8) in the south-western disk of the galaxy (Henze et al 2012).

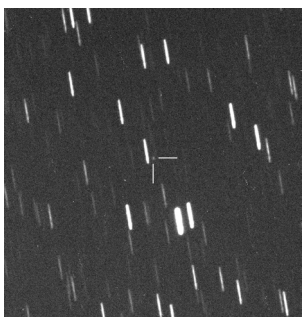

Figure 7. La Sagra against moving back -ground stars. 20x120 sec images in R.

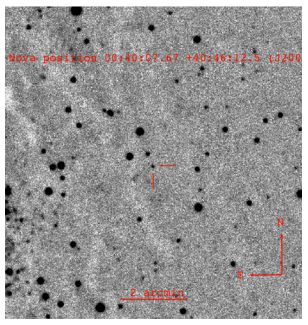

Figure 8. Nova in the south-western disk of M31 visible at 17.5 mag in R.

Conclusions

At the current rate of observations we expect to cover 150 candidates before 2013 and unambiguously classify about 65% of those. This in turn could yield up to 10 potential exoplanets.

Following the success of recent one-off observations (Fig 7 & 8) the PIRATE team is open to any discussions with regard to prospective collaborations.

References

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