The PTF Orion Planet-Search: Early Results from the First Data Set

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Background

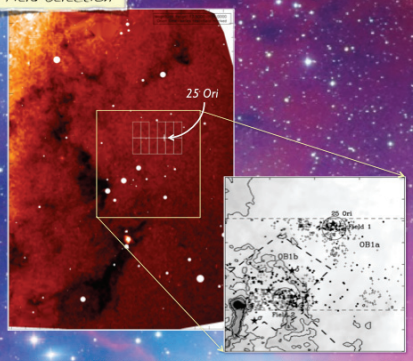
The PTF Orion project is a part of the Palomar Transient Factory (PTF), a survey for astronomical transients being undertaken with a dedicated wide-field 12-CCD array installed on the Palomar 48" telescope. The Orion project is an experiment that during its first year is focusing on a single pointing in the Orion star-forming region. The project has been assigned 40 consecutive nights per year for three years — the first 40 nights of which are now complete — to perform intensive time-series observations with the aim of detecting close-in, Jupiter-sized planets transiting young stars. Little is known about the distribution and frequency of planets around stars that are 1-100 Myr old - the time frame in which the giant planets are expected to form.

Our principal goal is to investigate the frequency of planets around stars at young ages. In addition, the observations will provide a unique data set to study a variety of stellar astrophysics, including eclipsing binary systems for testing star formation and evolution models; characterising stellar activity and rotational periods; and characterising previously unknown young stars in the Orion region.

At this point, light curves from two of the eleven functioning chips have been inspected by eye, and others spot checked. Here we present early example light curves from the initial inspection.

Observations

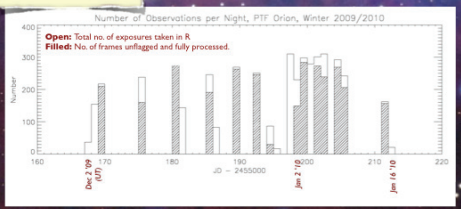
Field selection



***Left**: location of PTF Orion field NW of Orion's belt (one dead chip is indicated as missing). Background map indicates stellar density for 13.5<Rmag<18.0, as obtained from a tiling of Orion with PTF in Feb. 2009. **Inset (right):** small crosses and dots show clustering of classical and weak T-Tauri stars around 25 Ori (large labelled star), from Briceño et al. (2007).*

- Field centred on 25 Ori cluster:
  - Within Orion 1a region — matches 5-10Myr disk dissipation age.
  - Not overly reddened/attenuated.
  - Optimises number sources without overcrowding.
  - Maximises fraction of PMS stars

Data obtained

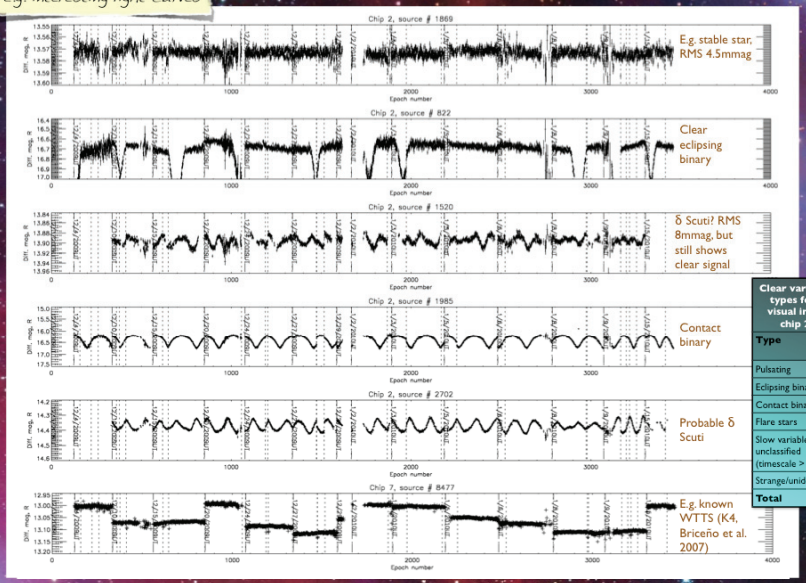


- 40 nights total allotted between Dec 1 '09 — Jan 15 '10
- R band, 30s exposures.
- ~70-90s cadence, continuous while airmass < 2.0
- 21 nights with weather allowing for observation.
- 14 nights of adequate quality currently processed (lack of cloud etc.)
- Additional nights likely can be processed, though most at lower precision.

Early Results

E.g. interesting light curves

Selection of interesting sources selected by visual inspection, plotted against exposure number. Vertical lines mark discontinuities in the data.



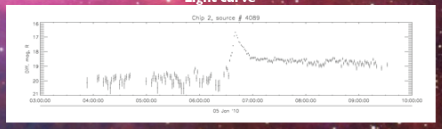
Clear variable light curve types found by initial visual inspection from chip 2 (out of 11)

Type	No. found
Pulsating	3
Eclipsing binary	3
Contact binary	1
Flare stars	4
Slow variables, so far unclassified (timescale >1d)	21, inc. 4 w/ flares
Strange/unidentified	3
Total	**35**

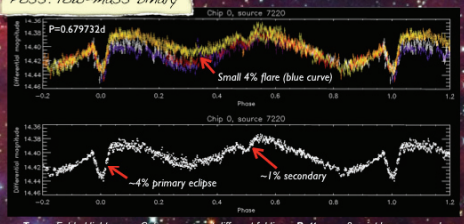
A strong flare

- 3mag rise over ~10min
- 2MASS JHK suggests M giant — unlikely for flare. Poss. flare from secondary in a binary system?

Light curve



Poss. low-mass binary



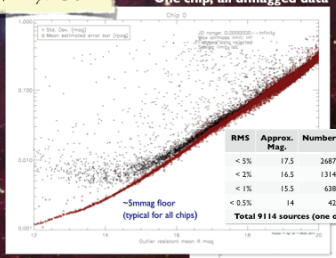
*Top — Folded light curve. Colors represent different foldings; **Bottom** — 3-point box-averaged after folding. Error bars removed for clarity.*

- 2MASS JHK ⇒ ~K5 giant or M0 dwarf (M0 more likely)
- M0 dwarf distance consistent w/ Orion ⇒ may be young.
- Out-of-eclipse variation suggests spotted primary or hotspots.
- M0 dwarf with later secondary? Poss. brown dwarf?

Discussion

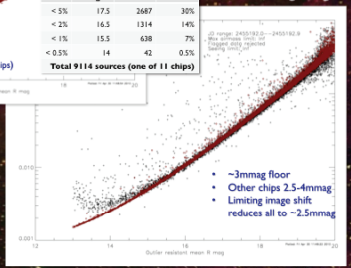
RMS precision

One chip, all unflagged data



RMS	Approx. Mag.	Number	Fraction
< 5%	17.5	2687	30%
< 2%	16.5	1314	14%
< 1%	15.5	638	7%
< 0.5%	14	42	0.5%
Total 9114 sources (one of 11 chips)			

Same, single night



RMS versus magnitude for one chip, unflagged data for whole 40 night run (above), and for cloudless data from a single good night (right). Red points indicate photon +readout+background noise level; black points indicate source RMS.

Summary

The results shown here represent some of the initial findings from differential photometry of the full Orion data set from Winter 2009/2010. The detection of the 1% secondary eclipse shown above (equivalent to the eclipse depth of a Jupiter-sized planet orbiting a Solar-like star) demonstrates the precision should be adequate for finding planets.

- ~10,000 sources per chip implies ~100,000 total light curves
- Mag. range ~13.5 ≤ R ≤ 20
- Precision <2% over whole run down to R~16.5
- Current noise floor ~3mmag on good quality data
- ~35 clear variables found by eye on one chip suggests ~300-400 such variables will result from the data.
- Next steps:
  - Detrending: slow linear systematic trends seen on some chips owing to technical issues with detector; should be manageable with detrending.
  - Periodogram analysis - find observing window function, aliases, search for stellar rotation periods and periodic variables etc.
  - Begin planet transit search of all light curves.

References

Briceño, C., Hartmann, L., Hernández, J., Calvet, N., Vivas, A. K., Furesz, G., & Szentgyorgyi, A. 2007, ApJ, 661, 1119

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