Preliminary Results from the PTF Orion Planet-Search Project

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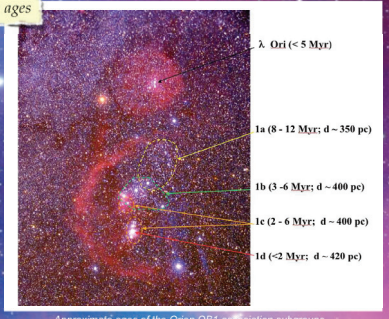
Background

The Palomar Transient Factory (PTF) is a new survey for astronomical transients being undertaken with the new wide-field CCD array installed on the Palomar 48" telescope in December 2008. The Orion project is an experiment that during its first year is focusing on a single pointing in the Orion star-forming region as part of the PTF survey. The project has been assigned 40 consecutive nights per year for three years 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 these young ages. Observations began in December 2009. Preliminary results based on a few hours from the night of December 19 are reported here.

- 12-CCD array, each 2048 by 4096 pixels.
- Total nominal 7.8 sq. deg. field, 1″ pixels.
- Search for young planets, and also provide unique data set for:
  - Eclipsing binary systems
  - Characterizing stellar activity/rotational periods
  - Previously unknown young stars in the Orion region.

Observations

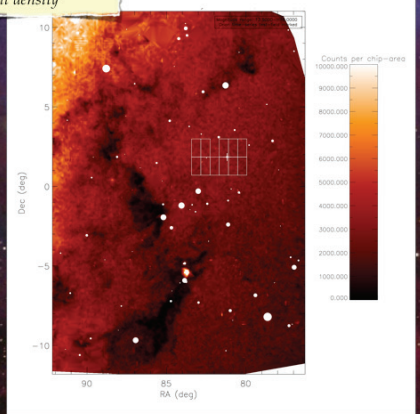
Orion ages



Approximate ages of the Orion OB1 association subgroups (reproduced from Bally, 2008)

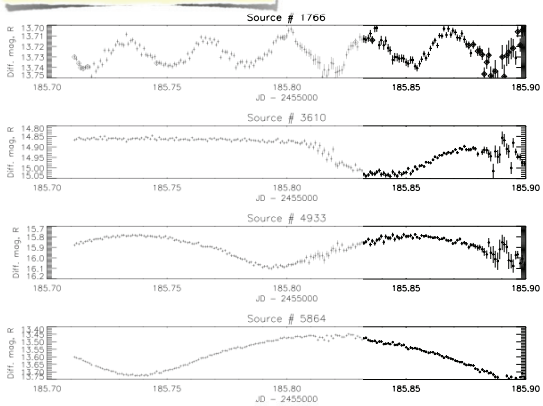
- Field is chosen centred on 25 Ori cluster:
  - Within 1a region (shown above) — matches 5—10Myr disk dissipation age.
  - Not overly reddened/attenuated.
  - Optimizes number sources without overcrowding.
  - Maximizes fraction of PMS stars (Briceño 2007).
- R band, 30s exposures.
- ~1m 20s cadence, for 40 nights.
- Observations began December 1 2009, currently ongoing.

Field location/Source count density



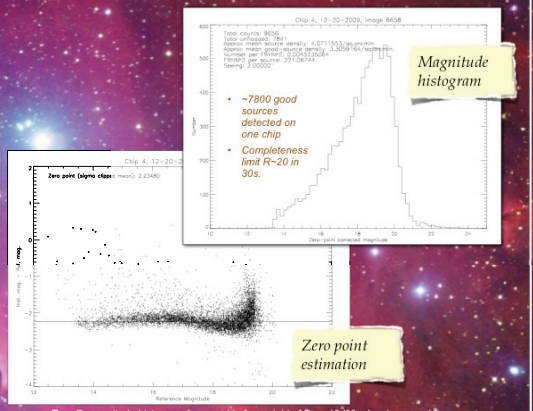
Location of PTF Orion field NW of Orion's belt (one dead chip is indicated as missing). Contours indicate stellar density for 13.5<Rmag<18.0, as obtained from a tiling of Orion with PTF in Feb. 2009.

E.g. variable sources — one night's data



Example variable sources obtained from preliminary differential photometry on data from the night of December 19 2009, spanning ~4.5hrs. Points marked with diamonds are flagged as questionable due to possible blending with nearby source found in USNO-B. Effects of clouds can be seen in the second half of the data set, particularly towards end.

Differential Photometry



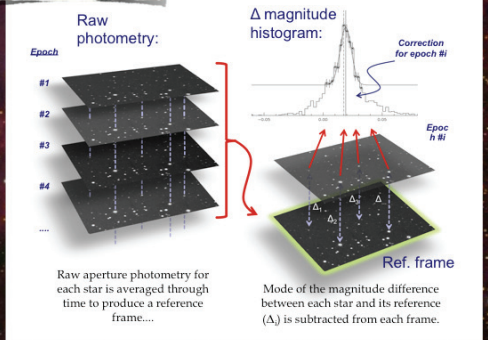
Top: *R-magnitude histogram for one chip from night of Dec. 19 '09, showing completeness.* ***Bottom***: *Zero-point determination — difference between DAOPHOT aperture photometry and USNO-B1.0 R magnitude, vs. R. Used for an initial photometry correction.*

Photometry procedure:

- **Image pre-processing/astrometry** using standard IPAC PTF pipeline.
- Standard **aperture photometry** – DAOPHOT.
- **Zero-point correction** in IDL referenced to USNO-B1.0 catalogue (above).
- **Source matching/differential photometry**: IDL.

Differential photometry is performed on the raw zero-point corrected photometry by further correcting each frame as a whole by the modal magnitude difference between itself and a mean reference frame (see below). This approach has the advantage of being very robust to outliers and variable stars.

Diff. photometry method

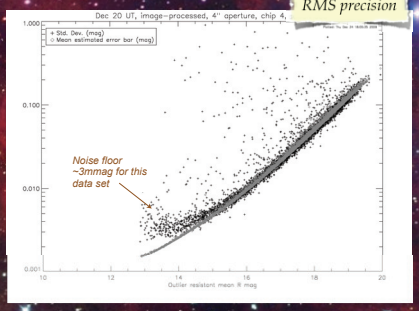


Raw aperture photometry for each star is averaged through time to produce a reference frame....

Mode of the magnitude difference between each star and its reference (Δ_i) is subtracted from each frame.

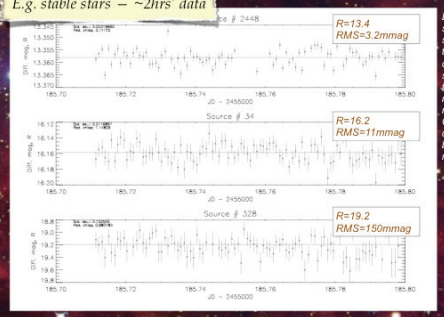
Preliminary Results

RMS precision



RMS magnitude variation after differential photometry correction vs. abs. magnitude from Dec. 19 '09, excluding cloudy data. The mean raw aperture-photometry error is overplotted (grey), giving an estimate of the theoretical best achievable precision.

E.g. stable stars — ~2hrs' data



Example stable stars from the same data set spanning the magnitude range. Cloudy data has been removed.

Summary

The results shown here represent some of the preliminary results from one of the 11 CCD chips, over a few hours from the night of December 19 2009. Numerous strongly variable sources are immediately obvious; the RMS vs. magnitude plot shows 1—2% photometry is achievable down to ~R=17, while the example stable stars shown underneath suggest no obvious systematic trends over the the course of ~2hrs.

- ~7,800 good sources detected on this chip => ~90,000 sources in total.
- Magnitude range 13 ≤ R ≤ 20.
- Preliminary differential precision ~3mmag at R~13—14, can likely be improved.
- Binning data points improves precision as expected, implying no severe systematics.
- Precision, source count, and magnitude range should all be sufficient to find a few young planets, assuming the same statistics as the current known exoplanet population.
- May also expect more planets from regular field stars in the PTF Orion field.

References

- *Bally, J., 2008, Handbook of Star Forming Regions, Volume I: The Northern Sky ASP Monograph Publications, Vol. 4. Edited by Bo Reipurth, p.45.*
- *Briceño, C., Hartmann, L., Hernández, J., Calvet, N., Vivas, A. K., Furesz, G., & Szentgyorgyi, A. 2007, ApJ, 661, 1119*