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# Searching for Extrasolar Planets Using Transits

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**Abstract.**
The presence of an extrasolar planet can be revealed when it passes in front of its host star, reducing the star's apparent brightness by $\sim 1\%$. We are monitoring a large sample (of order $10^4$) of stars using our own 0.5 m telescope at Siding Spring Observatory, Australia, in search of such transiting planets.

## 1. Introduction

To date, over 100 planets have been found orbiting stars other than the Sun (Schneider 2002). Most of these planets were detected using the radial velocity method. An alternative used by an increasing number of teams is the transit method (see Horne 2002 for a review of ground-based transit search projects). This involves measuring the small decrease in apparent brightness (of order 1%) of the star, as the planet eclipses (or transits) it.

For a transiting planet, the detailed shape of the lightcurve (the star's brightness as a function of time) during the transit, along with radial velocity measurements from follow-up spectroscopy, can be used to estimate the planet's size, mass and orbital characteristics. If the host star is sufficiently bright, high-precision spectroscopic observations during the transit may reveal something about the chemical composition of the planet's atmosphere (e.g. Charbonneau et al. 2002; Webb & Wormleaton 2001).

## 2. The Automated Patrol Telescope search

We are searching for transiting extrasolar planets using the 0.5 m Automated Patrol Telescope (APT) at Siding Spring Observatory, Australia. The current CCD has a $2^\circ \times 3^\circ$ field of view and $9.4''$ pixels. For further technical details see Hidas et al. (2002). Regular observations for the project began in October, 2002. We observe a set of four fields over a period of about 3 months. We take

150-second exposures, cycling between the fields, resulting in a sampling rate of 4 images per field per hour. The fields were chosen to maximise the number of measurable stars while keeping airmasses low and avoiding bright stars which would saturate a significant fraction of the CCD.

For stars with $V \lesssim 14$ in our 150-second APT images, photometric precision is limited by systematic errors. The most significant of these is due to undersampling (the FWHM of a star in the image is $\sim 1.3$ pixels) coupled with intra-pixel variations (IPV) in the sensitivity of the CCD. A star centered on the more sensitive central part of a pixel appears $\sim 3\%$ brighter than the same star falling on the edge of a pixel. This constitutes a systematic error dependent on the star's position within a pixel (its *pixel phase*), and limits the precision of simple aperture photometry to $\sim 3\%$. Because the distribution of flux among the pixels in a star's image is also affected by IPV, astrometry also suffers from pixel phase errors.

In a set of images offset from each other by non-integer numbers of pixels (a *dithered* set), each star samples a range of pixel phases. Therefore, when measurements from these images are combined, the average values are less biased by IPV effects.

Anderson & King (2000, herein referred to as AK) have developed a new technique to deal with this problem. They define the *effective* point-spread function (ePSF) as the instrumental PSF convolved with the sensitivity function of a single pixel. A model of the ePSF can be constructed from a dithered set of images. Using this model, the effect of IPV on photometric (and astrometric) measurements is considerably reduced.

The algorithm described in AK was originally developed to perform high-precision astrometry on images from the Hubble Space Telescope's Wide-Field and Planetary Camera 2, which are also undersampled. The needs of our project differ in two important aspects. Firstly, because we are using a ground-based telescope, with atmospheric seeing and tracking errors, the PSF varies slightly from image to image. We therefore need to derive a PSF for each individual image from the image itself. This is possible once the accurate positions and magnitudes of the stars (unbiased by IPV effects) have been calculated by averaging measurements from a large, dithered set of images.

The second difference is that our project requires precise photometry, not astrometry. This places different demands on the PSF. Astrometry requires the model PSF to accurately describe the distribution of flux among the central pixels, as a function of the pixel phase. Photometry only requires knowledge of how the *total* flux within the central pixels varies with pixel phase. Because of this difference, we are able to derive the PSF using a simpler algorithm than that described in AK. Stars are first measured with a PSF assuming *no* intra-pixel variation. Comparing these measurements to the average values, their variation with pixel phase can be determined, and used as a constraint for the final model of the ePSF.

Using this modified algorithm, we can now measure stellar magnitudes to 1.5% precision down to $V \sim 14$ in a single 150-second image.

## References

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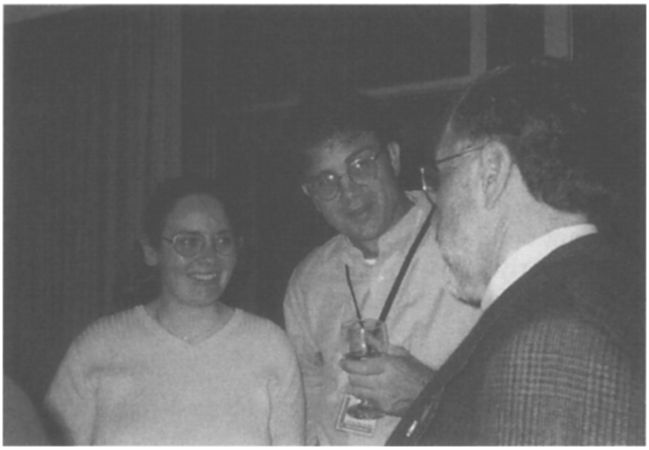

Charley Lineweaver & friends (*photo: Leesa Moore*)