Hot Subdwarf Stars and Related Objects
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SuperWASP Lightcurves of Subdwarf Stars

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Abstract. SuperWASP is a wide angle survey for transiting hot-Jupiter exoplanets around bright (V<13) solar-type stars. Lightcurves for millions of stars with a few thousand observations per star are available in the SuperWASP archive. We report the results of a search for periodic variable subdwarf stars in the data from the 2004 observing season. A Fourier transform of the SuperWASP lightcurve for Balloon 090100001 recovers the main pulsation frequency of this star. No new pulsators are found among the stars studied (about 200 objects). The binary sdB star HS 2333+3927 with a large reflection effect was recovered. We find that the hot subdwarf PG 1348+369 is variable with a period of 3.316days and a semi-amplitude of 13%. Follow-up spectroscopy shows that this variation is due to irradiation of a cool companion star in a binary system.

1. Introduction

SuperWASP is the UK's leading extra-solar planet transit survey. It uses two robotic observatories sited on La Palma and in South Africa to monitor the brightness of millions of stars (Pollacco et al. 2006). The principle aim of the project is to detect solar-type stars that show periodic dips in brightness of about 1% lasting a few hours every few days. This is the characteristic signal of a Jupiter-like planet in an edge-on orbit around a star, though there are other binary star systems that can mimic this phenomenon.

Each observatory has 8 cameras with 2k×2k CCD detectors on a single equatorial mount. Each camera has a field of view of $7.8° \times 7.8°$. The observing strategy is typically to repeatedly obtain pairs of 30 second exposures of selected fields. There are about 16 fields in each hemisphere, 6 to 8 of which are observed per night with a cadence of about 10 minutes. A dedicated pipeline has been written to reduce and analyse the images. The main products of the pipeline are synthetic aperture photometry for every star in each image using apertures with 3 different radii (21, 35 and 48 arcsec). The large pixel scale of the detectors (13.7 arcsec/pixel) means that blending between stars in the image can be a severe problem, particularly for fields at low galactic latitudes. Data were obtained over 6 months with 5 cameras on SuperWASP-North during 2004 without any filters in the system. Observations with both observatories using a 400–700nm bandpass filter have been on-going since mid-2006, generally with 8 cameras on both instruments. The system yields photometry accurate to 1% for stars as faint as 12th magnitude and accurate to 10% for stars as faint as 15th magnitude. Much of the noise is systematic errors ("red-noise") due to blending, focus variations and flat-fielding errors. Some of this red-noise can be removed using the Tamuz-algorithm (Tamuz et al. 2005) so that lightcurves suitable for transit detection are available for stars as faint as 13th magnitude.

For this study we used data from the 2004 observing season only, which contains 12,876,146,714 photometric measurements for 6,713,217 stars. We extracted the lightcurves from the database for all subdwarfs listed in the subdwarf database (Østensen 2006). Lightcurves with at least 500 observations were available for 146 sdB stars, 34 sdO stars and 19 stars classified only as "sd". There are a few thousand observations per star per camera in a typical lightcurve.

2. Balloon 090100001

We first investigated the lightcurve for the high amplitude pulsating sdB star Balloon 090100001 (Oreiro et al. 2004) to see whether SuperWASP is capable of detecting pulsating sdB stars. The lightcurve contains over 4000 useful observations with a baseline of 128 nights. The lightcurve folded on the principle frequency and the periodogram are shown in Fig. 1. The main pulsation frequency is clearly detected in the SuperWASP data. No other subdwarf stars in this study show a similar pulsation signal, which suggests that high amplitude pulsators like Balloon 090100001 are rare.

3. Known Binaries

We also looked for periodic signals in known binary sdB stars. Several sdB stars that are known SB1 binaries have good lightcurves but none show any coherent variability on the orbital period. The lack of a reflection effect suggests that the majority of the companions to these sdB stars are compact objects, probably white dwarfs (Maxted et al. 2002). By contrast, the sdB star HS2333+3927 is known to be a binary with an M-dwarf companion that shows a reflection effect with an amplitude of about 0.3 magnitudes (Heber et al. 2004). This reflection effect is clearly detected in the SuperWASP lightcurve shown in Fig. 2.

4. PG1348+369

We used the period-finding method described by Norton et al. (2007) to look for other binary subdwarfs showing a reflection effect in our sample. The only convincing example is the star PG1348+369, also shown in Fig. 2.

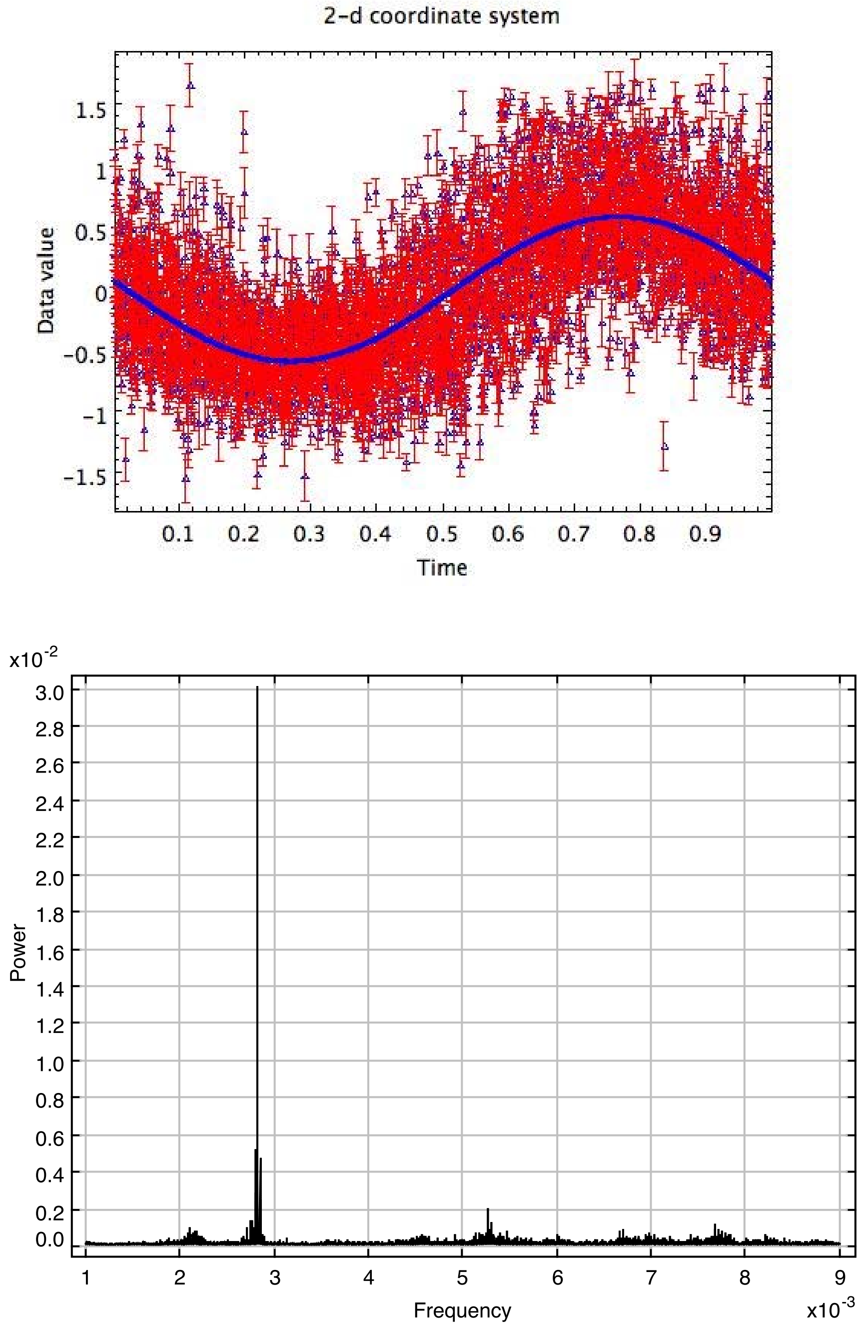

Figure 1. The SuperWASP lightcurve of Balloon 090100001 folded on the principle pulsation frequency (upper panel) and the periodogram of these data (lower panel)

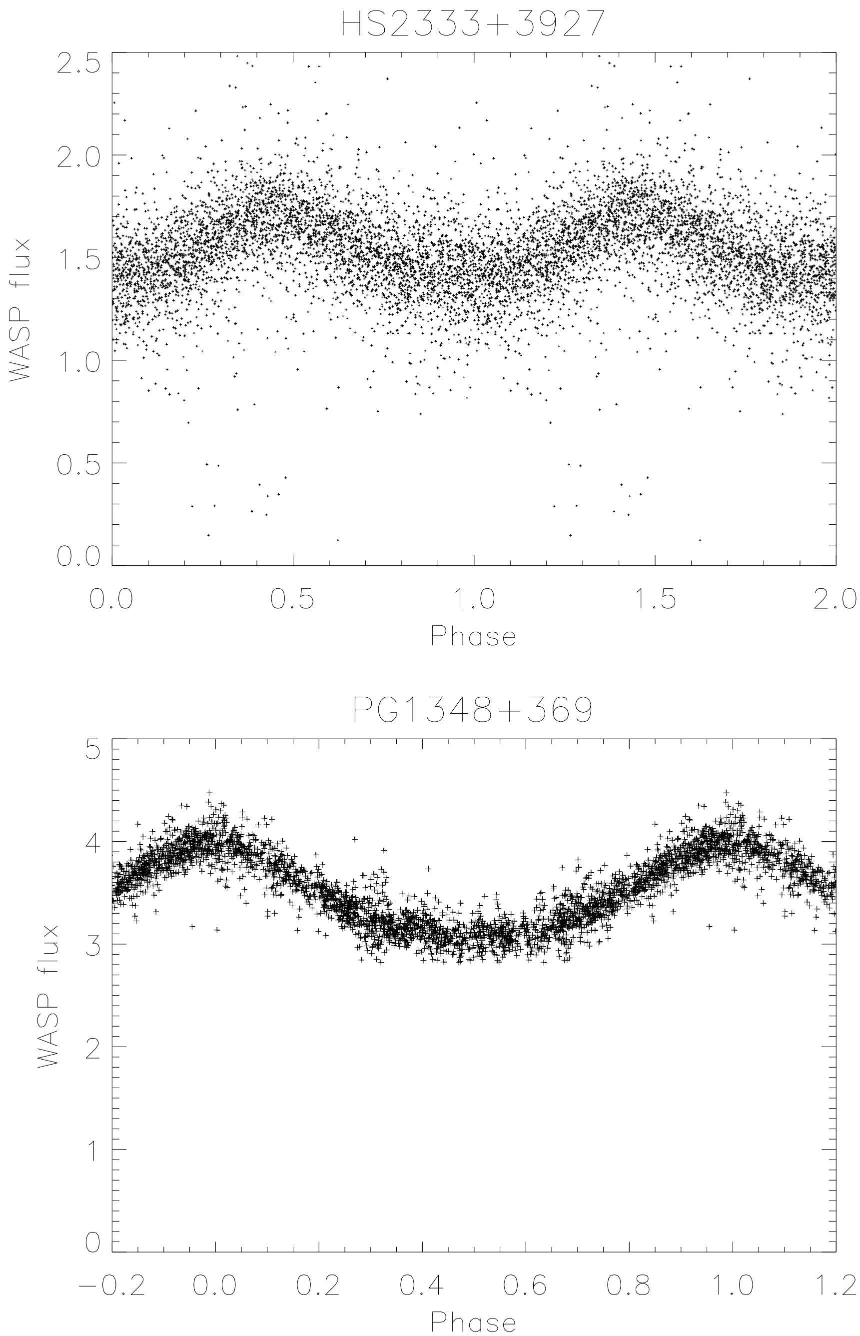

Figure 2. The SuperWASP lightcurves of HS2333+3927 (upper panel) and PG1348+369 (lower panel). The lightcurve of HS2333+3927 is folded on the orbital period using the ephemeris of Heber et al. (2004). The period of PG1348+369 determined from this lightcurve is 3.31637 days.

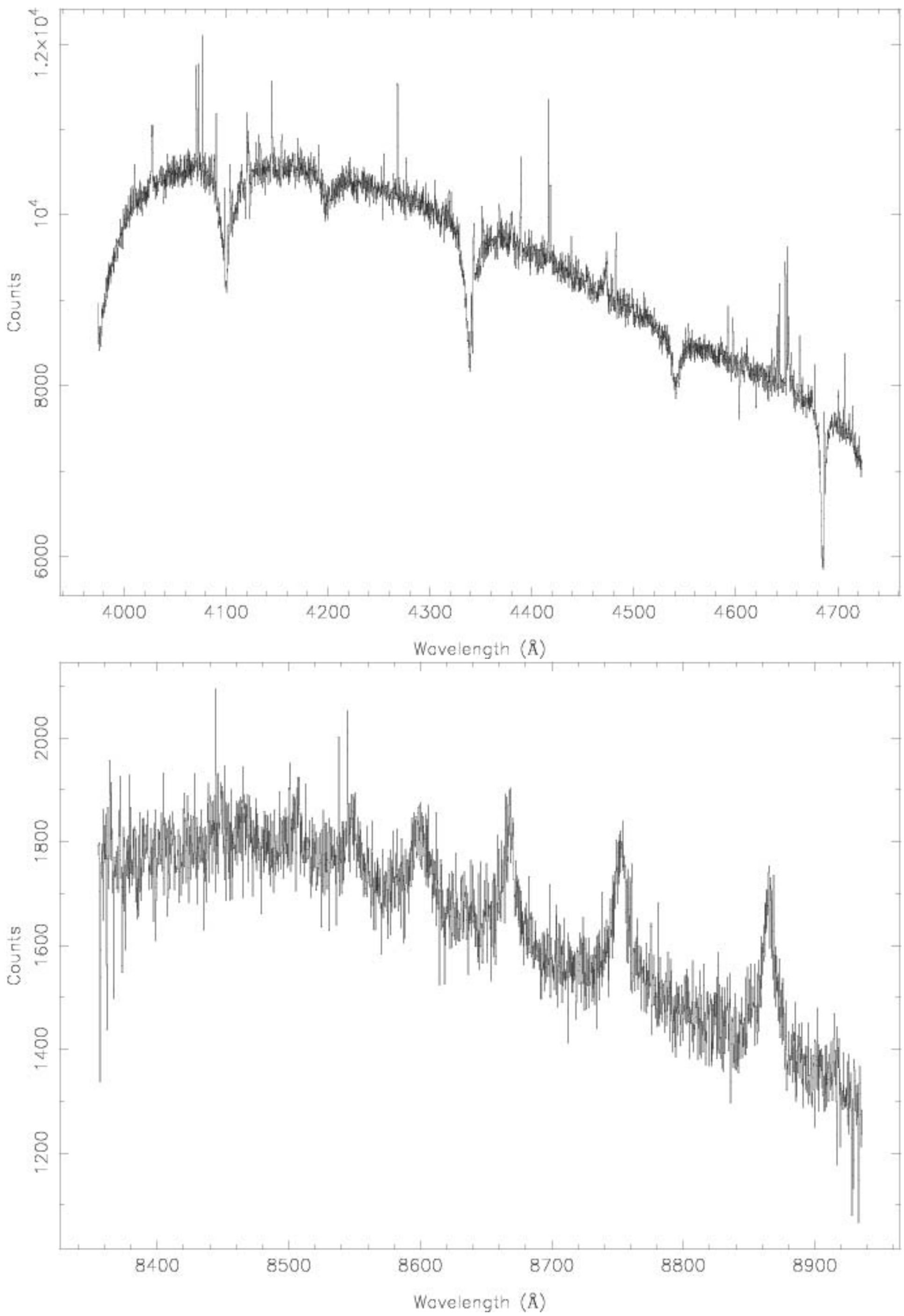

Figure 3. Spectra of PG1348+369 obtain with the ISIS spectrograph

We obtained 6 spectra on 3 nights of PG1348+369 using the Intermediate Dispersion Spectrograph on the 2.5m Isaac Newton Telescope and a single spectrum with the ISIS spectrograph on the 4.2m William Herschel Telescope. The ISIS spectra are shown in Fig. 3. The radial velocity of the emission lines apparent in the blue spectrum shows that they arise from the irradiated face of the cool companion star. The mass function derived from these emission lines is $0.27M_{\odot}$ (Fig. 4). The presence of the HeII 4686 line in the spectrum and the published optical photometry (Wesemael et al. 1992) suggest that the subdwarf dwarf is extremely hot ($\sim 100,000$ K). The broad emission lines in the red spectrum are Paschen emission lines and also originate from the cool companion.

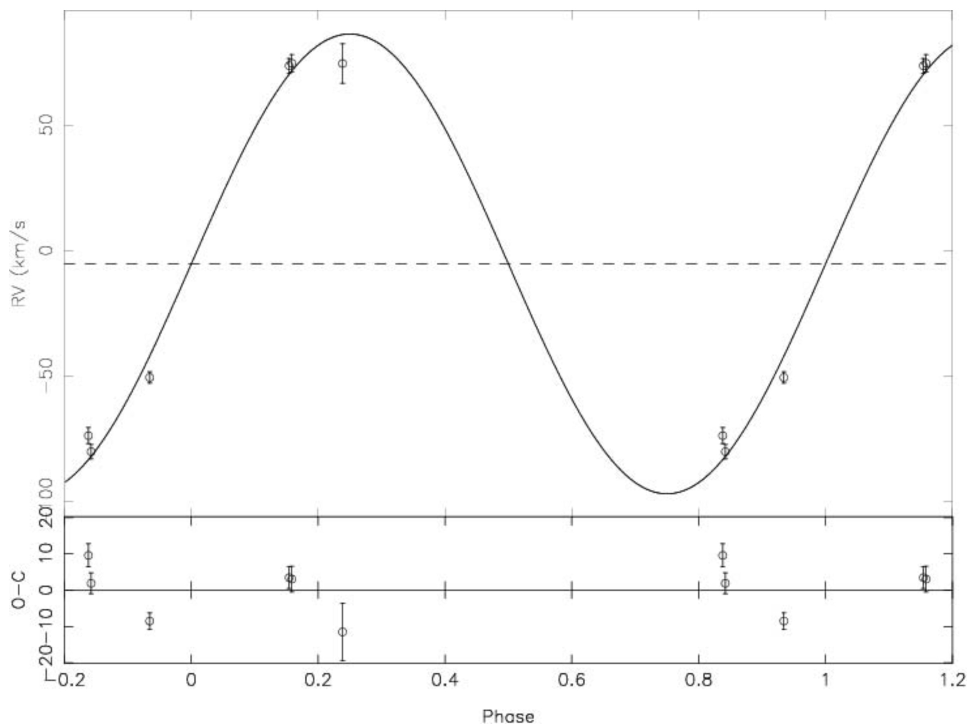

Figure 4. Radial velocities measured from the HeII 4686 emission lines in PG1348+369 plotted as a function of phase calculated from the SuperWASP lightcurve. A circular orbit fit by least-squared and residuals from this fit are also shown.

SuperWASP is clearly an extremely valuable resource for the study of variable stars, including sdB stars. There are now substantial datasets for millions of stars available covering both hemispheres from the 2006 and 2007 observing seasons. We plan to look for new variable subdwarfs stars in this large and growing dataset.

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