MERGING STARS?

Evidence for period decrease in three SuperWASP eclipsing binaries

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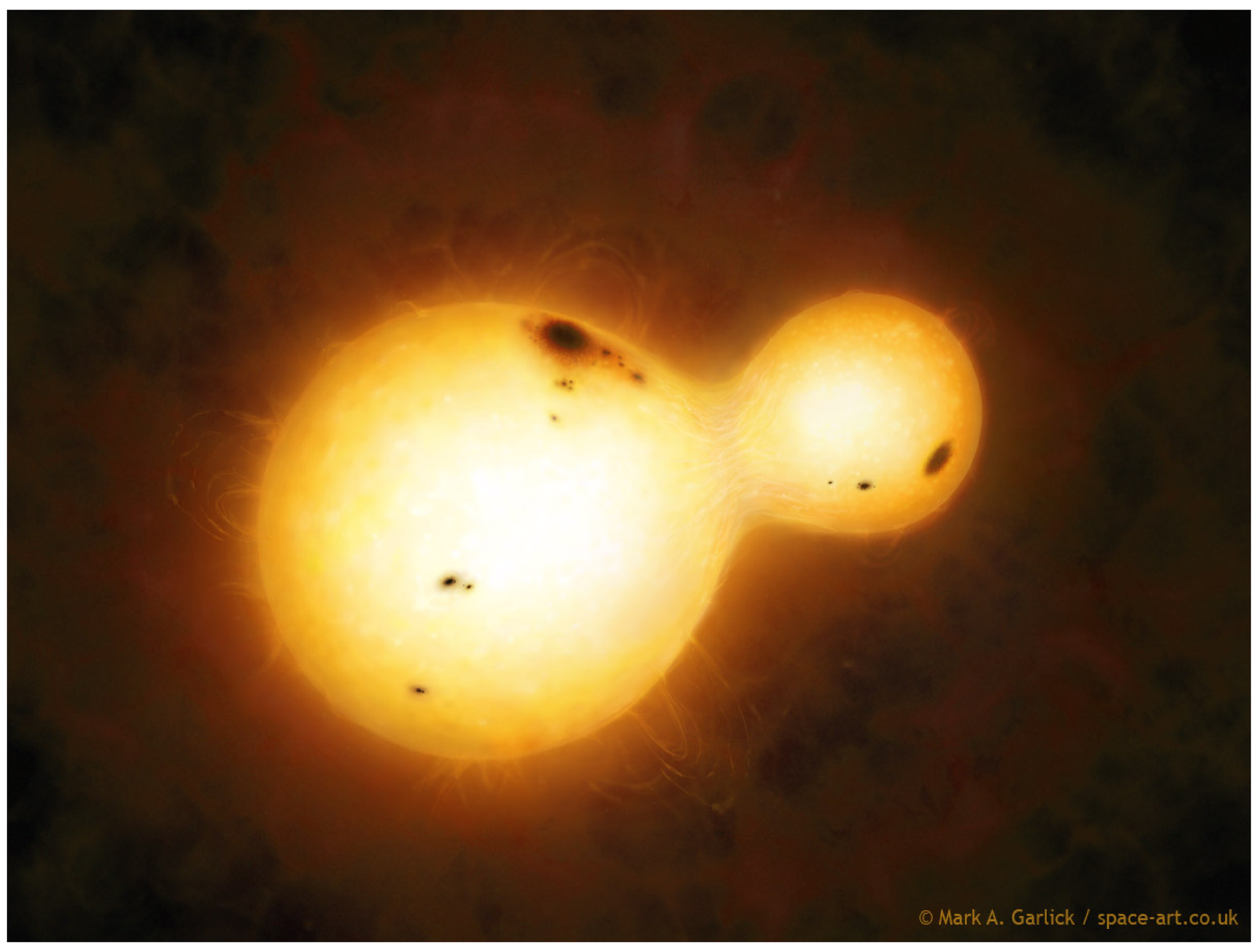

Figure 1. Artist's impression of W UMa binary system (used with permission of Mark Garlick)

1. Introduction W UMa-type variables are contact binaries with low-mass main sequence components (Figure 1). Their light curves exhibit continuous variation associated with the ellipsoidal Roche-lobe-filling or overflowing components (Figure 2), and eclipses of similar depth due to a shared atmospheric envelope, concealing low massratios. Their orbital periods, typically of several hours, exhibit a lower limit around 0.2 days (illustrated by OGLE eclipsing binaries in Szymański et al. 2001, and ASAS objects in Paczyński et al. 2006). The reason for this period cut-off is uncertain (see e.g. Rucinski 1992, Stępień 2006 and Jiang et al. 2011) but it may be associated with a lower limit of primary mass and/or mass ratio, below which the stars rapidly inspiral and merge. Our research here followed up the identification of 53 W UMa candidates near the short-period limit by Norton et al. (2011), in SuperWASP archival data (see Pollacco et al. 2006 on the project in general), with the aim of confirming their periods and looking for evidence of period change, which might illuminate the short-period cut-off.

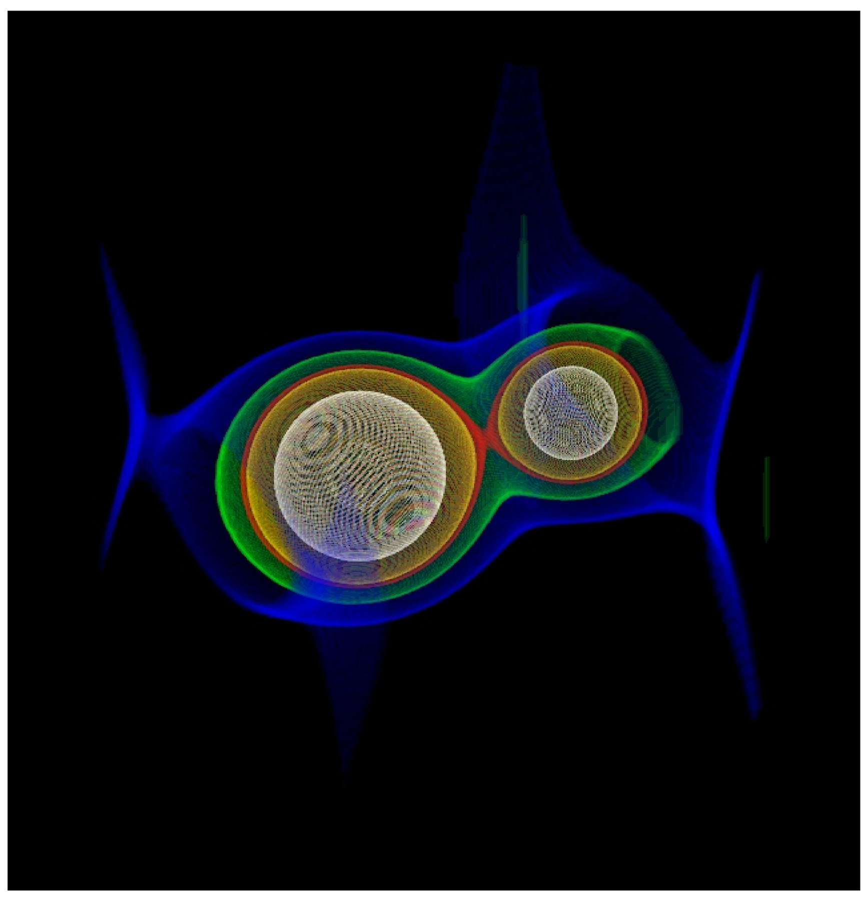

Figure 2. Roche equipotentials of close binaries with q = 0.38 (white and yellow surfaces represent detached configurations; red shows the critical Roche lobes; green and blue represent (over-)contact systems)

2. Method The periods of the 53 candidate eclipsing binaries were first checked using a custom-written 3-step IDL program. Individual nights of photometric data (see Figure 3) were fitted by a sinusoidal function using the Levenberg-Marquardt algorithm (Levenberg 1944; Marquardt 1963) to find a first approximation, which was then narrowed down using a Lomb-Scargle periodogram (Lomb 1976; Scargle 1982; Horne & Baliunas 1986), and finally determined to the nearest 0.01s by trial foldings of the full data set to minimize scatter in each of 100 bins. The consistency of these periods over the whole time of observation (up to 7 years) was then assessed using the standard tool of the *O-C* (observed minus calculated) diagram: the program selected a zero-point time of minimum (i.e. a primary or secondary eclipse) near the middle of each data set and calculated expected times of minima for all orbital cycles using the period found previously; the actual times of observed minima were then plotted against these, revealing variations in period as non-zero *O-C* values. Tests demonstrated that the program could correctly identify periods even in quite noisy data to 0.01 s accuracy, and detect linear period change to an accuracy of 0.1 s y^{-1}.

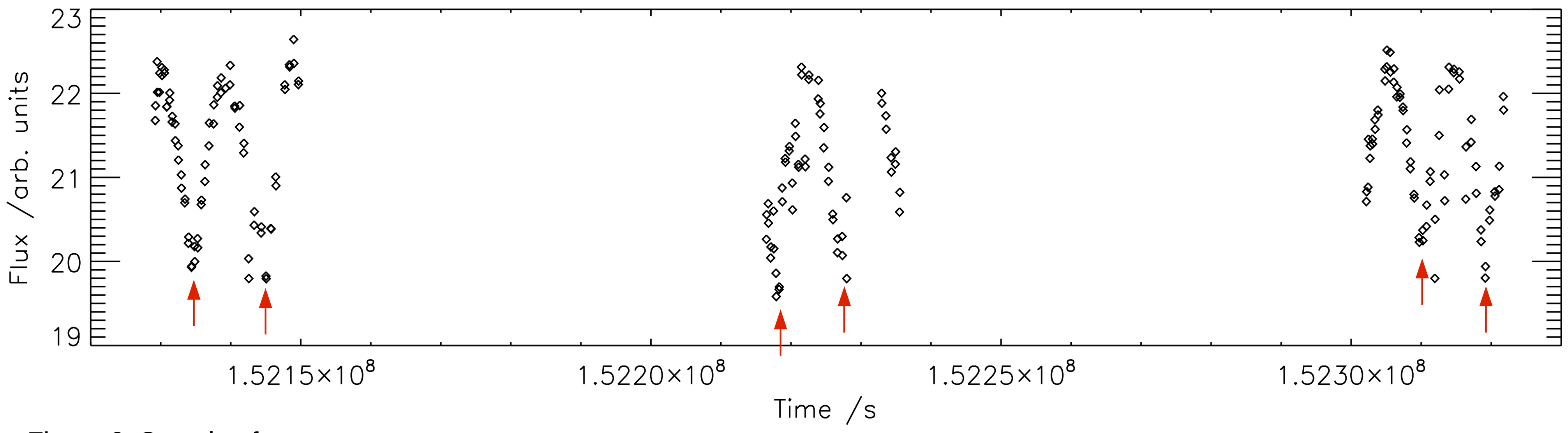

Figure 3. Sample of SuperWASP light curve data for 1SWASP J234401.81-212229.1 covering 3 nights (red arrows indicate approximate positions of primary and secondary eclipse minima each night)

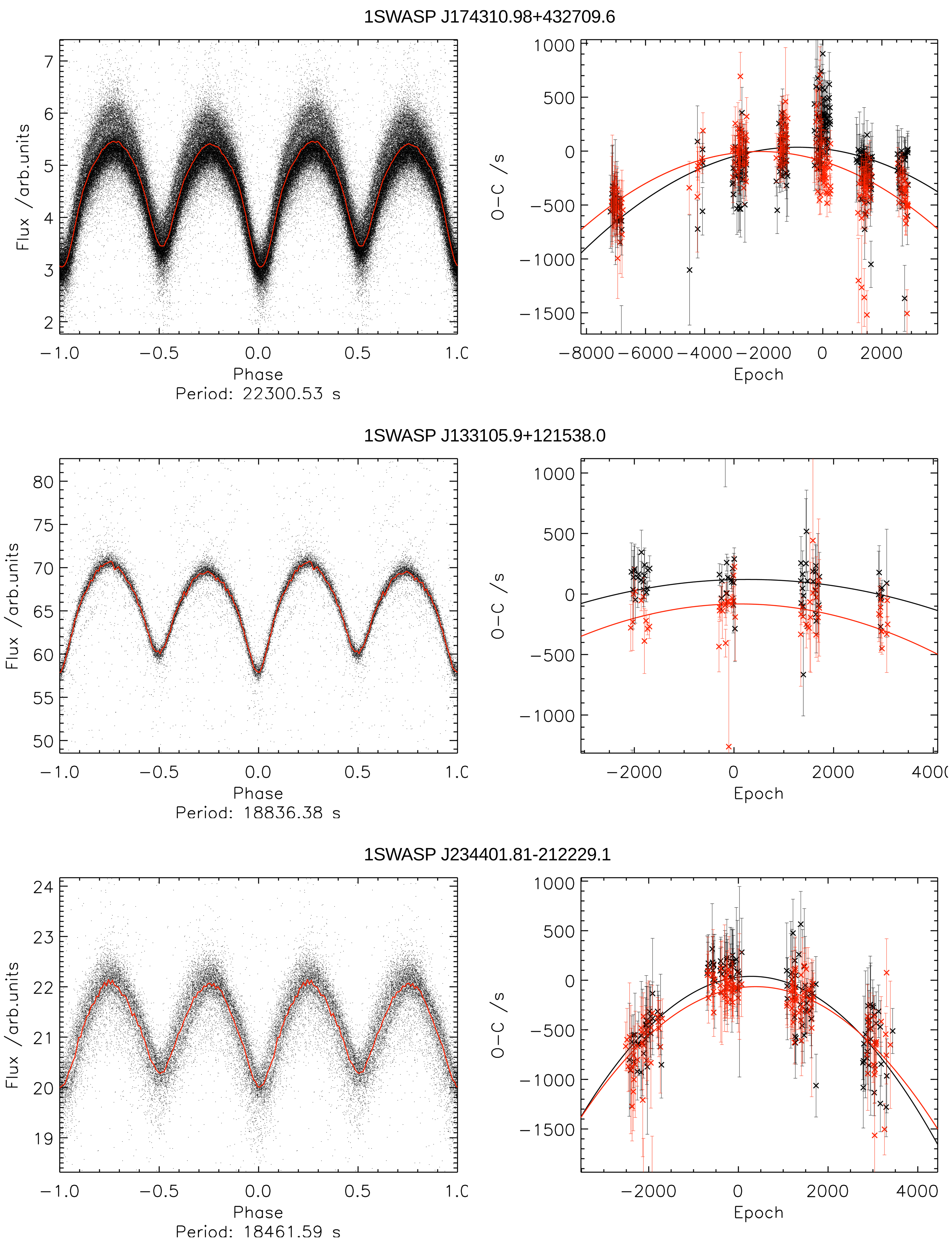

Figure 4. Lightcurves for 3 objects folded at determined periods (left) with O-C diagrams showing period decrease (right)

3. Results and Discussion The periods found for 44 of the 53 objects confirmed those in Norton et al. (2011) to 4 or 5 s.f., but periods approximately 1/8 longer were found for 9 objects, producing a total range between 16643.64 s (1SWASP J022050.85+332047.6 = GSC 2314-0530) and 22593.53 s i.e. about 0.19-0.26 d. Period change could not be investigated for one object due to lack of data, while another object's data proved to have been contaminated by a nearby star and was excluded from further analysis. Of the remaining 51 objects, 17 showed marginal evidence for period change (at ≥ 1 σ) which might be expected by chance alone, but in 3 of these the change was significant at more than 5 σ (Figure 4). These objects showed apparent period decreases during the time of observation of -0.055 s y^{-1}, -0.075 s y^{-1} and -0.313 s y^{-1}, implying merger timescales no greater than ~400000, 250000 and 60000 years respectively.

Preliminary modelling of these 3 objects' light curves using PHOEBE software (Prša & Zwitter 2005, built upon the code of Wilson & Devinney 1971) gave possible sets of stellar parameters (in the absence of radial velocities, semi-major axis could not be determined, so a range of physically plausible values were considered). Using these, the likelihood of several astrophysical causes for the observed rates of period change were considered (equations given in e.g. Hilditch 2001, Kolb 2010). Magnetic braking and gravitational wave radiation both produce effects several orders of magnitude too small; the most likely physical mechanism is therefore unstable mass transfer between primary and secondary components, and/or unstable mass and angular momentum loss from the systems.

4. Conclusion We have confirmed that the 53 objects identified in Norton et al. (2011) provide a useful sample of probable W UMa-type eclipsing binaries close to the short-period limit. We also found evidence for 3 objects undergoing significant period decrease, at rates best explained by unstable mass transfer/loss. If these rapid period decreases continue, in objects already close to the period limit, it is plausible that the components will merge on a relatively short timescale. They constitute potentially rare examples of binary systems caught in a moment of transition. We plan to obtain spectroscopic measurements for them to allow more precise stellar modelling in future, and to apply the methods described here to further SuperWASP variables.

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