Low-mass eclipsing binaries in TESS and CRÉME

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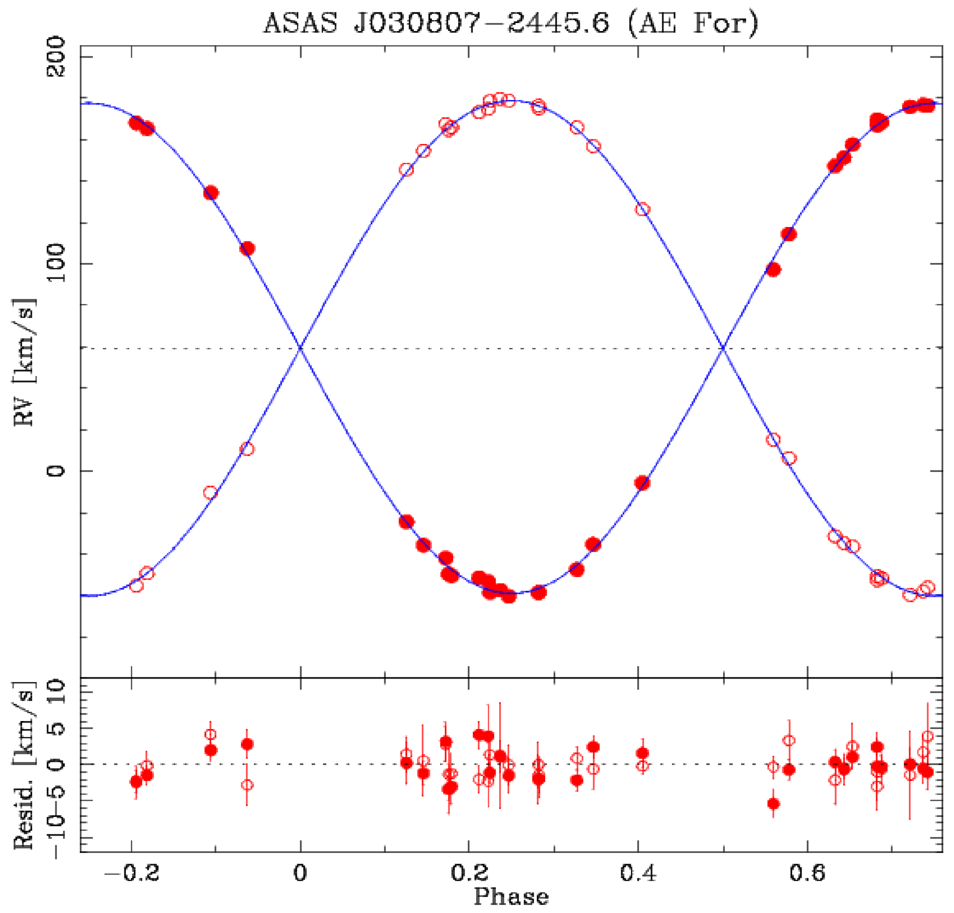
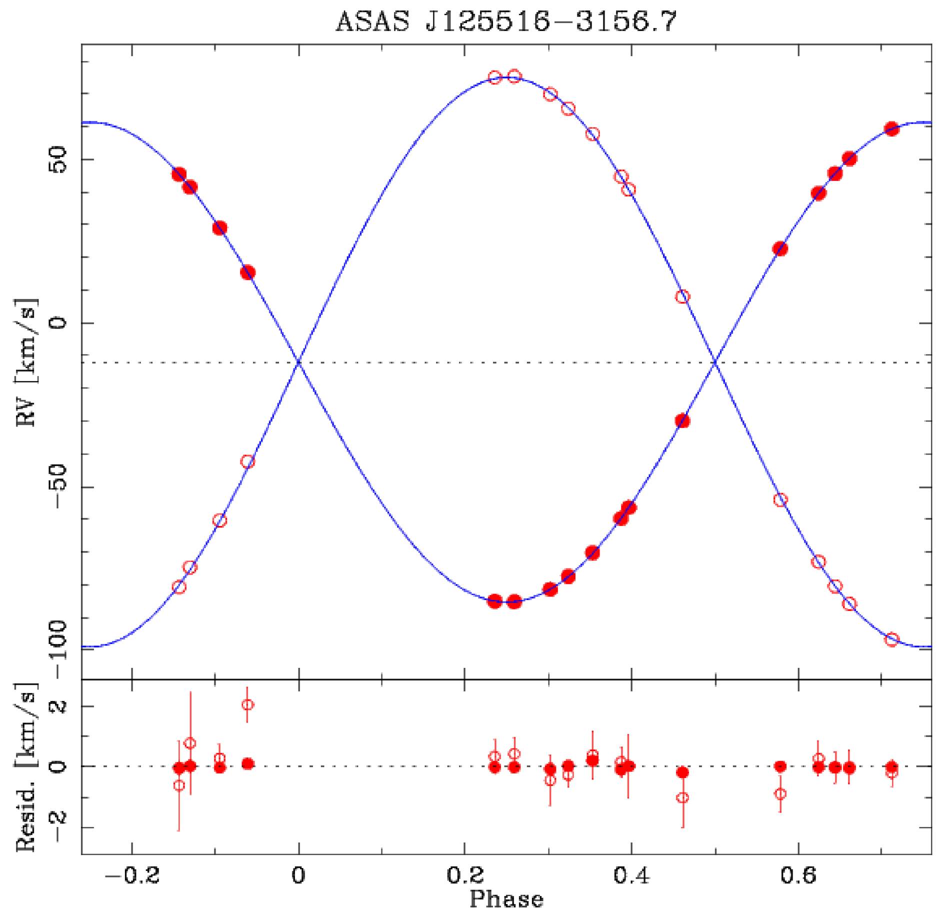
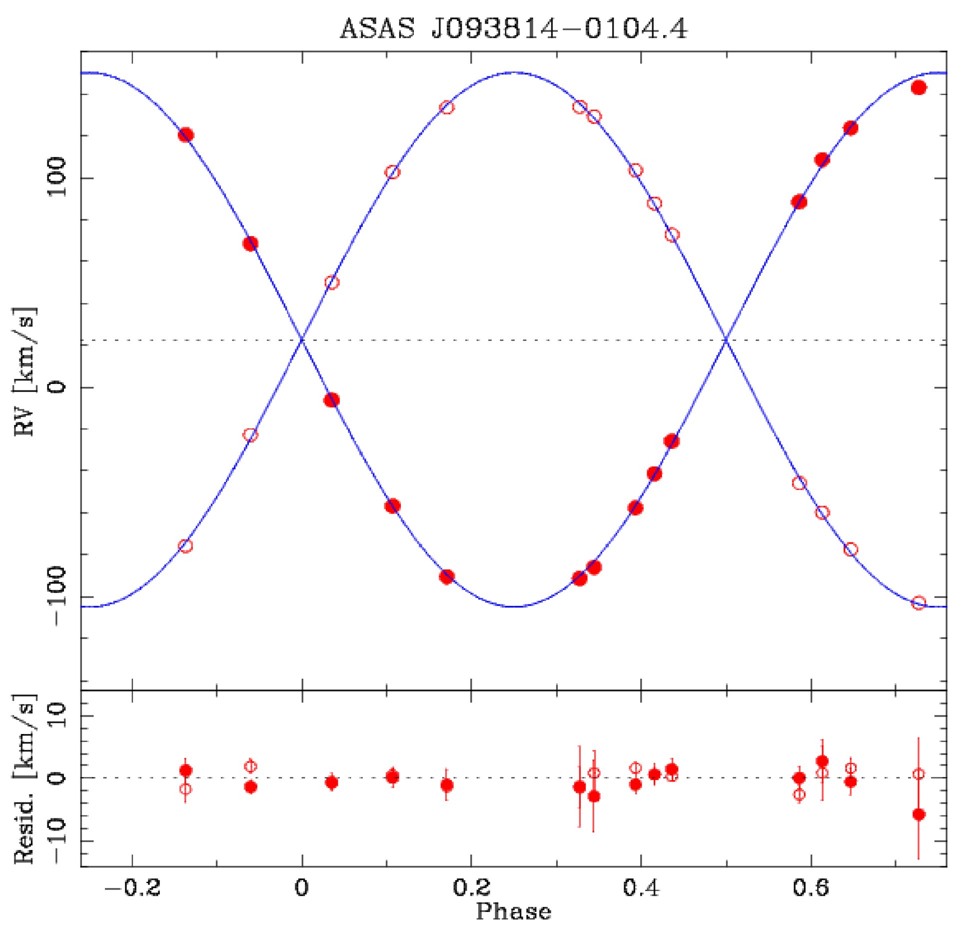
Magnetic fields in low-mass (<0.8 M$_\odot$) stars affect the fundamental stellar properties. In short-period, tidally locked binaries fast rotation of components strengthens the magnetic field through a form of a dynamo mechanism, enhances activity, and affects the observed radii and effective temperatures, which has been observed in low-mass detached eclipsing binaries (LMDEB) for decades. Several descriptions of this phenomenon have been proposed, but we lack good quality observational data and models of LMDEBs in order to validate or falsify them.

We present high-precision light curves of several M- and K-type, active detached eclipsing binaries, recorded with 2-minute cadence by the *Transiting Exoplanet Survey Satellite* (TESS). Analysis of these curves, combined radial velocity (RV) data from literature and the CRÉME survey, allows to vastly improve the accuracy and precision of stellar parameters with respect to previous studies of these systems. Results for one previously unpublished DEB are also presented.





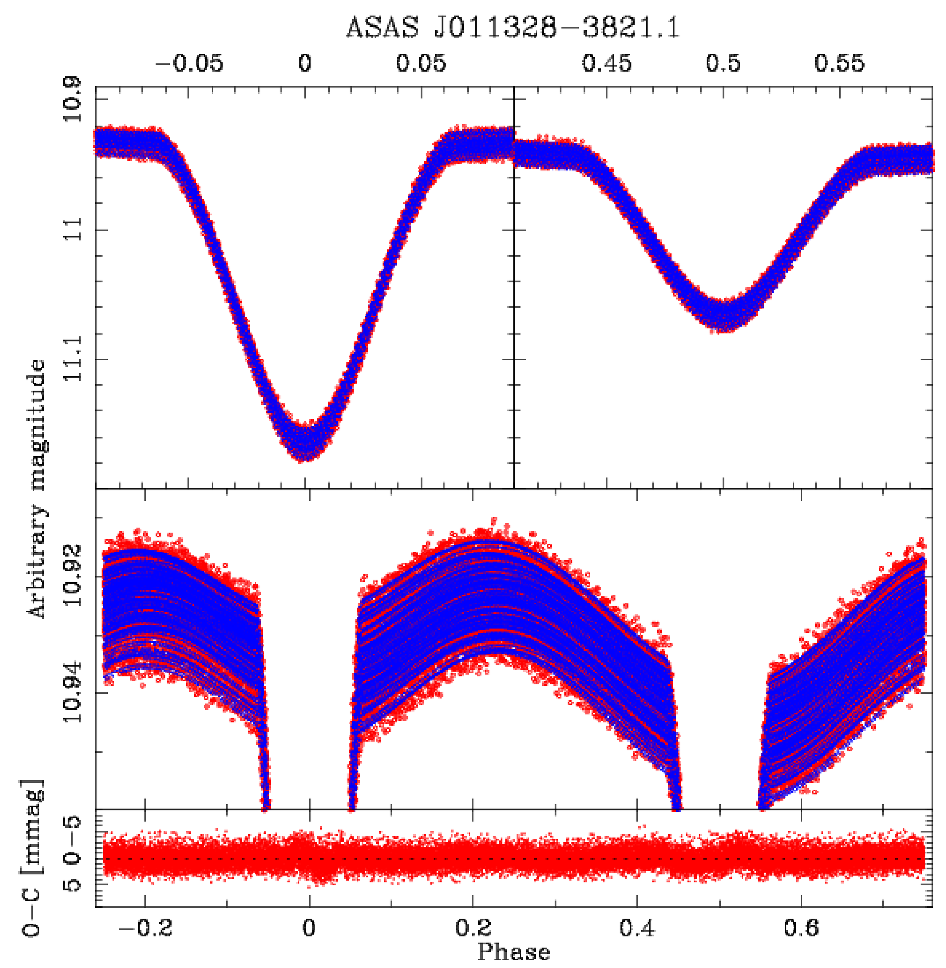


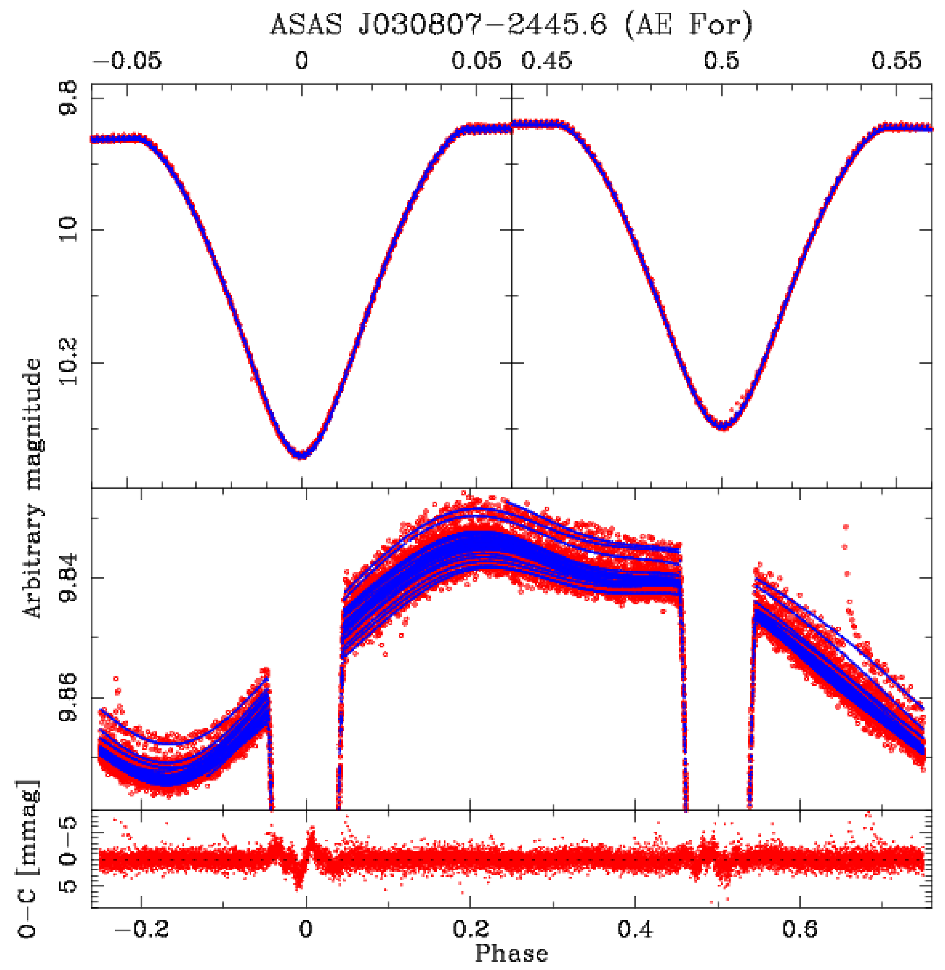
RADIAL VELOCITIES: RVs and orbital solutions of AK For and ASAS J011328-3821.1 remain unchanged with respect to the literature (Hełminiak et al. 2012, 2014). In three other cases we used our own CRÉME spectra obtained with CHIRON and CORALIE spectrographs, and calculated the RVs with the TODCOR method (Zucker & Mazeh 1994). Filled and open circles represent the primary and secondary component, respectively.

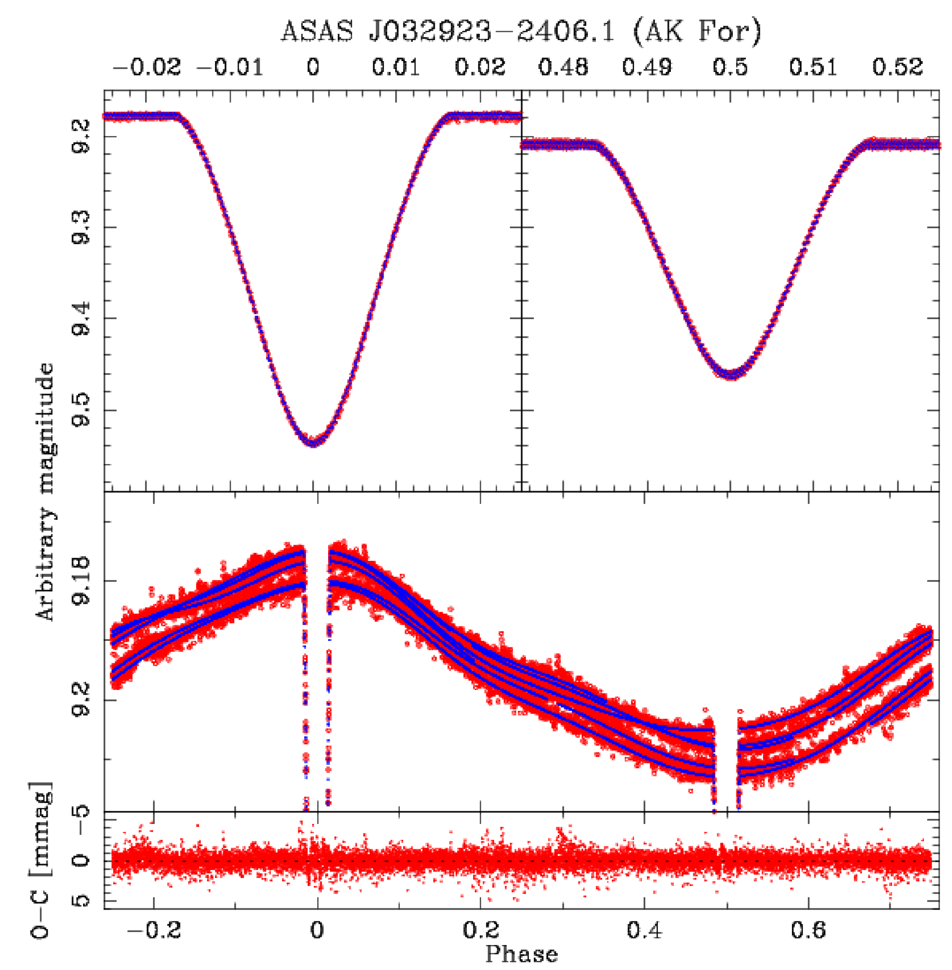
The CHIRON data for ASAS J093814-0104.4 were supplemented with measurements from Hełminiak et al. (2011). AE For was already described in Różyczka et al. (2013), but we did not use their data. ASAS J125516-3156.7 is a completely new system.

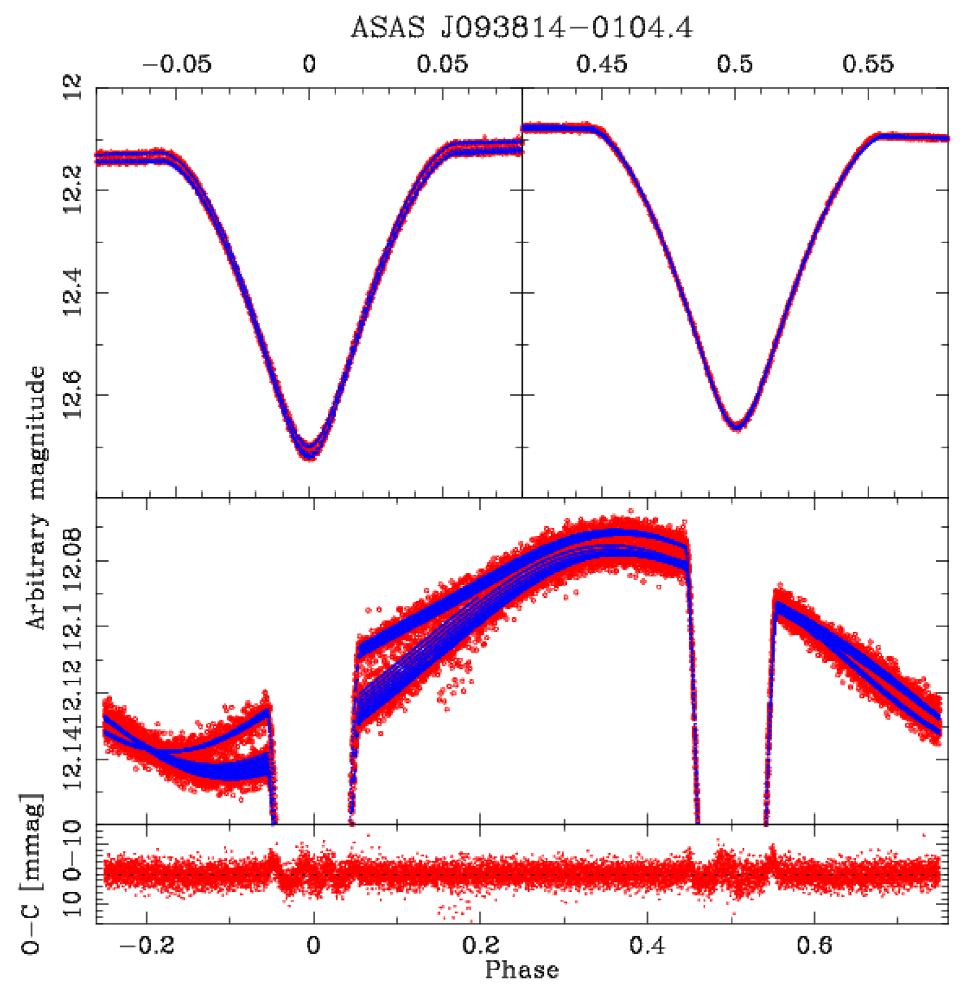
TARGETS: We selected one new and four previously published systems with component masses below 0.8M$_\odot$, and orbital periods shorter than 4 days. All systems are very active, with prominent spots and Hα emission lines. They were initially included into the Comprehensive Research with Échelles on the Most interesting Eclipsing binaries (CRÉME) project. Their 2-minute-cadence TESS photometry was obtained through Guest Investigator programs G011083, G022003, and G03028.

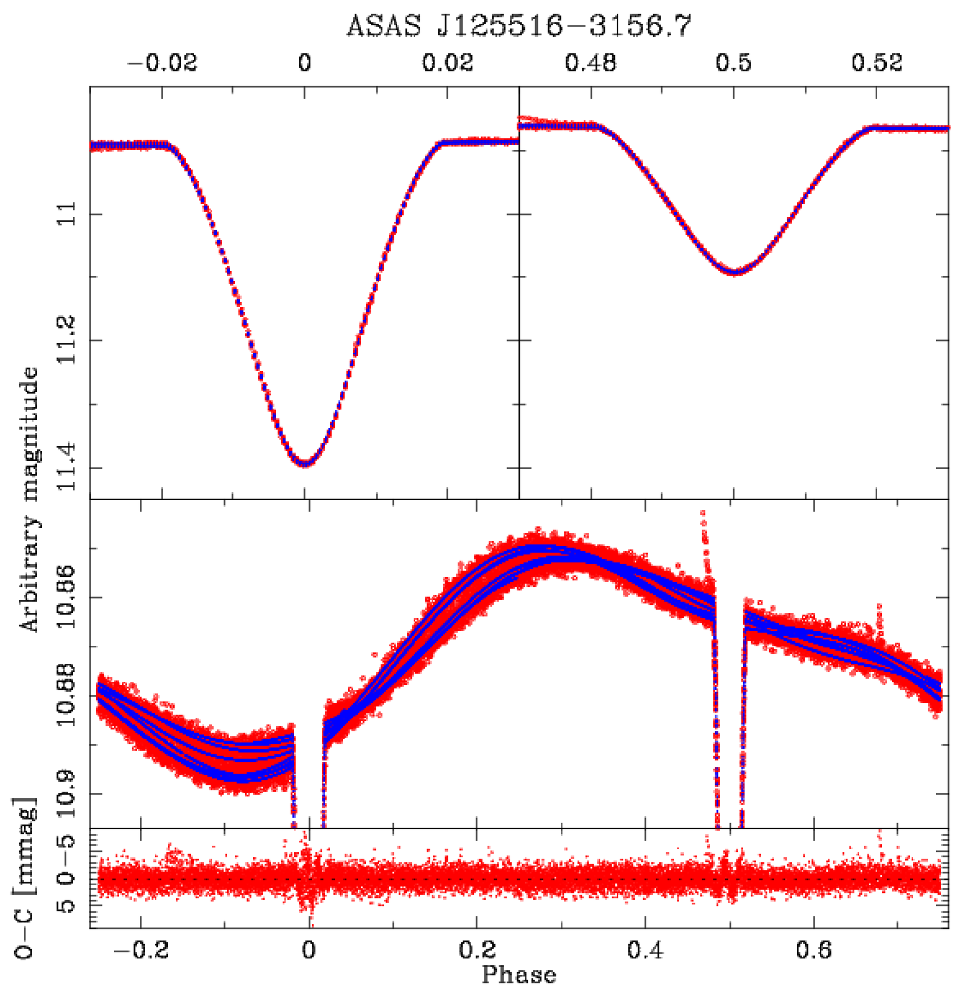
LC MODELLING: The TESS light curves were modelled with the JKTEBOP code v40 (Southworth et al. 2004). To account for the out-of-eclipse modulation coming from spots we applied (in JKTEBOP) a series of sine functions (up to four) and polynomials (up to fifth degree). Because the spot-originated variation may change in time quite rapidly, data were split into several (between 2 and 6) pieces, which were analyzed separately. Parameter errors for each piece were evaluated with a Monte-Carlo procedure. As the final values we adopted weighted averages, and to get final parameter uncertainties, we added in quadrature a median of individual piece errors and the *rms* of individual results.











RESULTS: Figures show TESS data (red) and JKTEBOP models (blue) phase-folded with orbital periods. Top rows are zooms on primary (left) and secondary (right) eclipses. Below are zooms on the out-of-eclipse (OOE) modulations. Bottom panels depict the residuals.

The variations in spot pattern, in time scales of single weeks, is the main difficulty in reaching good precision in radii. The behavior of residuals during the eclipses reflect the asymmetries and deviations of the shape of an eclipse from a "clean photosphere" case, and originate from spots on a surface of the eclipsed component.

Thanks to the TESS data, the uncertainty in radii is few times better than reported in literature, except for AK For (R_2/R_1 strongly correlated with third light). For J125516... all properties are derived with high precision.

ASAS ID	TIC	Sector	P [d]	K_1 [km/s]	K_2 [km/s]	I [deg]	M_1 [M$_\odot$]	M_2 [M$_\odot$]	R_1 [R$_\odot$]	R_2 [R$_\odot$]
011328-3821.1	183596242	2,3	0.44559604(18)	118.4(2.0)	162.9(3.3)	87.5(1.5)	0.597(28)	0.434(17)	0.607(12)	0.445(12)
030807-2445.6	88479623	4	0.918207(7)	118.3(5)	119.5(5)	87.8(1)	0.644(6)	0.638(6)	0.674(7)	0.617(10)
032923-2406.1	144539611	4	3.9809620(45)	70.47(3)	77.16(5)	87.37(7)	0.6959(10)	0.6356(7)	0.684(18)	0.628(20)
093814-0104.4	14307980	8	0.897420(2)	127.55(68)	127.62(97)	86.87(6)	0.775(12)	0.774(10)	0.774(6)	0.771(6)
125516-3156.7	103683084	10	3.0570393(44)	73.34(5)	87.00(15)	87.56(7)	0.7104(25)	0.5989(13)	0.669(4)	0.557(8)

References:
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- Pojmański G. 2002, AcA, 52, 397
- Różyczka M. et al. 2013, MNRAS, 429, 1840
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- Zucker S., Mazeh T., 1994, ApJ, 420, 806