HOMOGENEOUS STUDIES OF TRANSITING PLANETS

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Mass versus radius:

planets on the left, host stars on the right

Step 1: model the transit light curve

Fit a simple geometrical model to the data

I use the $_{\rm JKTEBOP}$ code



Light curve of WASP-2 (Southworth et al. 2009)

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Derived parameters:

Light curve of WASP-2 (Southworth et al. 2009)

 $P_{\rm orb}$ $k = r_{\rm b}/r_{\rm A}$ $r_{\rm A} = R_{\rm A}/a$ i

orbital period ratio of planet to star radius fractional radius of star inclination of the orbit

• Light curve: P_{orb} r_A k i

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- Radial velocities:
 - stellar velocity amplitude K_A
 - orbital eccentricity e

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- Spectral synthesis: stellar $T_{\rm eff}$ and $\left[\frac{\rm Fe}{\rm H}\right]$
- Interpolate in stellar models:
 - find best-fitting mass for the star
 - find most likely age for the system
- Get planet mass and radius
 - \Rightarrow surface gravity \Rightarrow atmosphere studies
 - $\Rightarrow\,$ density $\,\Rightarrow\,$ composition and core size
 - $\Rightarrow\,$ composition and core size $\,\Rightarrow\,$ formation scenario

Homogeneous studies of transiting planets

- Light curve fit: JKTEBOP
 - Limb darkening (five laws)
 - Contaminating light
 - Orbital eccentricity
 - Numerical integration (for long exposure times)
 - Statistical errors (Monte Carlo)
 - Correlated noise in the photometry (residual permutation)

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 - try five different theoretical models
 - also try eclipsing binary relations

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- Physical properties from extra constraint:
 - try five different theoretical models
 - also try eclipsing binary relations
- Now done 60 transiting systems
- Southworth (2008, 2009, 2010, 2011)
- TEPCat: http://www.astro.keele.ac.uk/~jkt/tepcat/

TEPCat – homogeneous studies

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TEPCat – all transiting planets

O TEPCat: Physical properties of transiting planets (without errorbars) - Opera U Opera P The Eclipsing Binar... x TEPCat: Physical p... x D John Southworth's ... x D Transiting extrasol... x - file://localhost/home/ikt/www/tepcat/allplanets-noerr.html Search with Google TEPCat: Physical properties of transiting planets without errorbars This table contains a summary of the physical properties for all known transiting extrasolar planetary systems, I include those systems for which a detailed study has been published in a refereed journal or on the arXiv preprint server. Most systems have been studied multiple times, so for these I select what I consider to be the best measurements. By necessity the results for many of the planetary systems have been assembled from multiple papers, so are not guaranteed to be internally consistent. I give a reference to the discovery paper and the paper from which most of the results were taken for each system. Click here for details of the quantities and their units Click here for a full table (includes errorbars for each quantity) Click here for the table in machine-readable CSV format Click here to return to the TEPCat main page Stellar properties Planetary properties Orbital Eccen-Semimir Teff [Fe/H] Mass Radius log(g) Density Mass Radius Gravity Density Equil Discovery Main recent (Msun) (Rsun) (cgs) System period tricity axis (AU) (K) (dex) (osun) (Miup) (Riup) (m/s2) (piup) temp reference reference 0.01564 5196 +0.31 0.02536 2008A+A...482L..178 0.02854 5696 1.018 0.907 1.362 41.5 1.066 1548 2008A+A 4821 21A 21.96 8.887 0.0855 2.96 0.884 19 0.0633 5080 . . .

TEPCat – observable quantities

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System 55 Cnc e CoRoT-1	Type TEP TEP	Right ascension 08 52 36.13 06 48 19.17	Declination +28 19 53.0 -03 06 07.8	V mag 5.95 13.6	Transit length (d) 0.0734 0.10439	Transit depth 0.045 % 2.3 %	Time of mid-transit 2455733.0087 ± 0.0012 2454524.6231 ± 0.0002	Orbital period (d) 0.7365449 ± 0.0000048 1.5089686 ± 0.0000012	Ephemeris reference 2012A+A539A28G 2009A+A506359G
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System 55 Cnc e CoRoT-1 CoRoT-2 CoRoT-3 CoRoT-4	Type TEP TEP TEP BD TEP BD	Right ascension 08 52 36.13 06 48 19.17 19 27 06.50 19 28 13.27 06 48 46.72 06 48 46.72	Declination +28 19 53.0 -03 06 07.8 +01 23 01.4 +00 07 18.6 -00 40 22.0	V mag 5.95 13.6 12.57 13.29 14.0	Transit length (d) 0.0734 0.10439 0.09446 0.153 0.184 0.137	Transit depth 0.045 % 2.3 % 3.2 % 0.25 % 1.3 %	Time of mid-transit 2455733.0087 ± 0.0012 2454524.6231 ± 0.0002 2454237.5355 ± 0.00021 2454238.13388 ± 0.00024 2454141.35416 ± 0.00059	Orbital period (d) 0.7365449 ± 0.0000048 1.508668 ± 0.000010 1.7429935 ± 0.000010 4.2567994 ± 0.0000035 9.20205 ± 0.00037 4.07376262 ± 0.00037	Ephemeris reference 2012A+A539A.28G 2009A+A506359G 2010A+A511A33G 2009A+A438A 2009A+A438A 2020A+A438A
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System 55 Cnc e CoRoT-1 CoRoT-2 CoRoT-3 CoRoT-4 CoRoT-5 CoRoT-6	Type TEP TEP TEP BD TEP BD TEP TEP	Right ascension 08 52 36.13 06 48 19.17 19 27 06.50 19 28 13.27 06 48 46.72 06 45 06.54 18 44 17.40 06 42 07.07	Declination +28 19 53.0 -03 06 07.8 +01 23 01.4 +00 07 18.6 -00 40 22.0 +00 48 54.9 +06 39 47.4	V mag 5.95 13.6 12.57 13.29 14.0 14.0 13.91	Transit length (d) 0.0734 0.10439 0.09446 0.153 0.184 0.117 0.170	Transit 0.045 % 2.3 % 3.2 % 0.25 % 1.3 % 1.4 % 1.5 %	Time of mid-transit 2455733.0087 ± 0.0012 2454237.53556 ± 0.0002 2454237.53556 ± 0.00021 2454283.13388 ± 0.00024 2454414.136415 ± 0.00002 2454400.18685 ± 0.00002 2454595.6144 ± 0.0002	Orbital period (d) 0.7365449 ± 0.000048 1.5089668 ± 0.000006 1.7429935 ± 0.000035 9.20205 ± 0.00037 4.0378962 ± 0.000037 8.886593 ± 0.00004 9.00205 ± 0.000019	Ephemeris reference 2012A+A59A28G 2009A+A506359G 2000A+A51A3G 2009A+A5059771 2008A+A40843A 2009A+A502218 2009A+A502218
System 55 Cnc e CoRoT-1 CoRoT-2 CoRoT-2 CoRoT-3 CoRoT-4 CoRoT-5 CoRoT-6 CoRoT-7 CoRoT-7	Type TEP TEP TEP BD TEP BD TEP TEP TEP TEP	Right ascension 08 52 36.13 06 48 19.17 19 27 06.50 19 28 13.27 06 48 46.72 06 45 06.54 18 44 17.40 06 43 49.47 19 32 3.24	Declination +28 19 53.0 -03 06 07.8 +01 23 01.4 +00 07 18.6 -00 40 22.0 +00 48 54.9 +06 39 47.4 -01 03 46.9	V mag 5.95 13.6 12.57 13.29 14.0 14.0 13.91 11.72	Transit length (d) 0.0734 0.10439 0.09446 0.153 0.184 0.117 0.170 0.0469 0.034	Transit depth 0.045 % 2.3 % 3.2 % 0.25 % 1.3 % 1.4 % 0.034 % 0.7 %	Time of mid-transit 2455733 0087 ± 0.0012 2454224 6231 ± 0.0002 2454297 35355 ± 0.00021 2454281 3454 ± 0.00029 2454280 (19885 ± 0.00029 24545495 0.144 ± 0.0002 2454599 0.009 ± 0.0015	Orbital period (d) 0.7365449 ± 0.000048 1.5089685 ± 0.000006 1.7429935 ± 0.000010 4.2557934 ± 0.000035 9.20205 ± 0.000037 9.20205 ± 0.000037 8.886593 ± 0.00004 0.853590 ± 0.00004 0.853590 ± 0.00005	Ephemeris reference 2012A+A539A286 2009A+A506359G 2010A+A511A36 2009A+A5063777 2008A+A488L43A 2009A+A506281R 2010A+A524147 2010A+A512A147
System 55 Cnc e CoRoT-1 CoRoT-2 CoRoT-2 CoRoT-3 CoRoT-4 CoRoT-5 CoRoT-6 CoRoT-6 CoRoT-7 CoROT-7 COROT-7 COR	Type TEP TEP TEP BD TEP BD TEP TEP TEP TEP	Right ascension 08 52 36.13 06 48 19.17 19 27 06.50 19 28 13.27 06 48 46.72 06 48 46.72 06 43 06.54 18 44 17.40 06 43 49.47 19 26 21.24	Declination +28 19 53.0 -03 06 07.8 +01 23 01.4 +00 07 18.6 -004 0 22.0 +00 39 47.4 -01 03 46.9 +01 25 35.2 -02 12 55.2	V mag 5.95 13.6 12.57 13.29 14.0 14.0 14.0 13.91 11.72 14.76	Transit length (d) 0.0734 0.10439 0.09446 0.153 0.184 0.117 0.170 0.0469 0.114 0.237	Transit depth 0.045 % 2.3 % 3.2 % 0.25 % 1.3 % 1.4 % 1.5 % 0.034 % 0.7 %	Time of mid-transit 2455733 0087 ± 0.0012 245424 6231 ± 0.0002 245424 6231 ± 0.0002 245424 35456 ± 0.00021 24544303 13388 ± 0.00024 24544400 1985 ± 0.0002 2454595 6144 ± 0.0002 2454593 0540 ± 0.0015 2454293 0591 ± 0.0015	Orbital period (d) 0.7365449 ± 0.000048 1.5006968 ± 0.000010 4.2567964 ± 0.000010 4.2567964 ± 0.000010 9.20205 ± 0.00021 8.866593 ± 0.00001 0.653590 ± 0.00000 6.212381 ± 0.00005	Ephemeris reference 20124+A., 594,286 20094+A.,506,3506 20094+A.,506,3777 20084+A.,488L,43A 20094+A.,505,2818 20104+A.,512A.,14F 201240,1-748,181F 201240,1-748,181F 201240,1-748,181F
System 55 CnC e CoRoT-1 CoRoT-2 CoRoT-3 COROT-4 COROT-4 COROT-4 COROT-5 COROT-6 20RoT-7 ZOROT-8 ZOROT-9	Type TEP TEP TEP TEP TEP TEP TEP TEP TEP TEP	Right ascension 08 52 36.13 06 48 19.17 19 27 06.50 19 28 13.27 06 48 46.72 06 48 50.654 18 44 17.40 06 43 94.97 19 26 21.24 18 43 08.81	Declination +28 19 53.0 -03 06 07.8 +01 23 01.4 +00 07 18.6 -00 40 22.0 +06 39 47.4 -01 03 46.9 +01 25 35.2 +06 12 15.2	V mag 5.95 13.6 12.57 13.29 14.0 14.0 13.91 11.72 14.76 13.69	Transit length (d) 0.0734 0.10439 0.09446 0.153 0.184 0.117 0.0469 0.114 0.337	Transit 0.045 % 2.3 % 3.2 % 0.25 % 1.3 % 1.4 % 1.5 % 0.034 % 0.7 % 1.6 %	Time of mid-transit 2455733 0087 ± 0.0012 2454297.33556 ± 0.0002 2454297.33556 ± 0.0002 2454293.13840 ± 0.0002 2454403 1.9685 ± 0.0002 2454545 0.144 ± 0.0002 2454599.0709 ± 0.0015 2454293 0.3447 ± 0.0001	Orbital period (d) 0.7355449 ± 0.000048 1.5069685 ± 0.000016 1.7429953 ± 0.000015 2.42557944 ± 0.000037 4.0378962 ± 0.000031 8.886593 ± 0.00004 0.835590 ± 0.00004 0.633590 ± 0.00004 0.623281 ± 0.000037 95.2738 ± 0.00014	Ephemeris reference 2012A+A.,554,356 2009A+A.,514A,350 2009A+A.,506,3777 2009A+A.,488,33A 2009A+A.,488,33A 2009A+A.,488,34 2009A+A.,512A,14F 2012A+A.,512A,14F 2012A+A.,512A,14F 2012A+A.,512A,14F 2012A+A.,512A,14F 2012A+A.,512A,14F 2012A+A.,512A,14F 2012A+A.,512A,14F 2012A+A.,512A,14F 2012A+A.,512A,14F 2012A+A.,512A,14F 2012A+A.,512A,14F 2012A+A.,512A,14F 2012A+A.,512A,14F 2012A+A.,512A,14F 2012A+A.,514A,172A+A.,514A,174A,174A,174A,174A,174A,174A,174A,1

TEPCat – Rossiter-McLaughlin

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+ -> 2 File://localhost/home/jkt/www/tepcat/rossiter.html				Search with Google
TEPCat: Rossit	er-McL	aughlin effect.	observations of tra	nsiting planets
This table catalogues the Rossiter-McLaughlin effects measur measurements) but can be obtained photometrically, by anal	ed for knowr ysis of starsp	n (published) transiting extr lot crossing events during	asolar planets. This effect is normally o transits.	bserved spectroscopically (usually via radial velocity
All known Rossiter-McLaughlin measurements are included. N but it is worthwhile checking the literature to be sure.	lany systems	s have multiple measureme	nts, often resulting from the same data	. In these cases the most recent is normally the most reliable
The Rossiter-McLaughlin effect was originally predicted by Ho was subsequently described and clearly demonstrated by Ro	lt (1893) and ssiter (1924)	i observed (but not definitiv for β Lyrae and McLaughin	ely) in the eclipsing binary star systems (1924) for $β$ Persei. The designation "P	s & Librae (Schlesinger 1910) and \ Tauri (Schlesinger 1916). It iossiter-McLaughlin effect" arose from the latter two papers.
Click here for details of the quantities and their units Click here for the table in machine-readable ASCII format Click here for the table in machine-readable CSV format Click here to return to the TEPCat main page				
	System	λ (degrees)	Reference	
	CoRoT-1	77 ± 11	Pont et al. (2010)	
	CoRoT-2	7.2 ± 4.5 4.0 + 6.1 - 5.9	Bouchy et al. (2008) Gillon et al. (2010)	
	CoRoT-3	37.6 + 10.0 - 22.3	Triaud et al. (2009)	
		prograde	Gandolfi et al. (2010)	
	CoRoT-18	-10 ± 20	Hébrard et al. (2011)	
		-52 + 27 - 22	Guenther et al. (2011)	
	HAT-P-1	3.7 ± 2.1	Johnson et al. (2008)	
	HAT-P-2	1.2 ± 13.4 $0.2 \pm 12.2 \pm 12.5$	Winn et al. (2007) Loeilet et al. (2008)	
	HAT-P-4	-4.9 ± 11.9	Winn et al. (2011)	0