

Refined Ephemeris for Four Hot Jupiters using Ground-Based and TESS Observations¹

© 2021 г. F. Davoudi^{1,2,3}, P. Mirshafie Khozani^{1,3}, E. Paki^{1,3},
M. Roshana^{1,3}, F. Hasheminasab³, A. Mazidabadi Farahani^{1,3},
F. Ahangarani Farahani^{1,3}, T. Farjadnia³, F. Nasrollahzadeh^{1,3},
S. Rezvanpanah³, S. M. Mousavi³, R. Foroughi³, A. Poro^{1,2,3*}, A. Ghalee^{3,4}

¹The International Occultation Timing Association Middle East section, Iran, info@iota-me.com

²Astronomy Department of the Raderon Lab., Burnaby, BC, Canada

³The Eight IOTA/ME Summer School of Astronomy, Tafresh University, Tafresh, Iran

⁴Department of Physics, Tafresh University, P.O. Box 39518-79611, Tafresh, Iran

Поступила в редакцию 28.04.2021 г.

После доработки 05.08.2021 г.; принята к публикации 05.08.2021 г.

WASP-12 b, WASP-33 b, WASP-36 b, and WASP-46 b are four transiting planetary systems which we have studied. These systems' light curves were derived from observations made by the Transiting Light Exoplanet Survey Satellite (TESS) and some ground-based telescopes. We used Exofast-v1 to model these light curves and calculate mid-transit times. Also, we plotted TTV diagrams for them using derived mid-transit times and those available within the literature. O-C analysis of these timings enables us to refine the linear ephemeris of four systems. We measured WASP-12's tidal quality factor based on adding TESS data as $Q'_* = (2.13 \pm 0.29) \times 10^5$. According to the analysis, the orbital period of the WASP-46 b system is increasing. The WASP-36 b and WASP-33 b systems have not shown any obvious quadratic trend in their TTV diagrams. The increase in their period is most likely due to inaccurate linear ephemeris that has increased over time. So, more observations are needed to evaluate whether or not there is an orbital decay in the WASP-36 b and WASP-33 b systems.

Keywords: planetary systems — planets and satellites: gaseous — planets techniques: photometric.

DOI: 10.31857/S0320010821090035

СПИСОК ЛИТЕРАТУРЫ

1. D. R. Anderson, A. Collier Cameron, M. Gillon, C. Hellier, E. Jehin, M. Lendl, P. F. L. Maxted, D. Queloz, et al., *Mon. Not. R. Astron. Soc.* **422**, 1988 (2012).
2. R. V. Baluev, E. N. Sokov, H. R. A. Jones, V. S. Shaidulin, I. A. Sokova, L. D. Nielsen, P. Benni, E. M. Schneiter, et al., *Mon. Not. R. Astron. Soc.* **490**, 1294 (2019).
3. L. Brát, S. Poddaný, O. Pejcha and M. Zejda, *ETD-Exoplanet Transit Database.* **435**, 443 (2010).
4. A. C. Cameron, E. Guenther, B. Smalley, I. McDonald, L. Hebb, J. Andersen, Th. Augusteijn, S. C. C. Barros, et al., *Mon. Not. R. Astron. Soc.* **407**, 507 (2010).
5. C. J. Campo, J. Harrington, R. A. Hardy, K. B. Stevenson, S. Nymeyer, D. Ragozzine, N. B. Lust, D. R. Anderson, et al., *Astrophys. J.* **727**, 125 (2011).
6. J. V. D. M. Cardoso, C. Hedges, M. Gully-Santiago, N. Saunders, A. M. Cody, T. Barclay, O. Hall, S. Sagar, et al., *ascl.* 1812 (2018).
7. A. Chakrabarty and S. Sengupta, *Astron. J.* **158**, 39 (2019).
8. T. Chan, M. Ingemyr, J. N. Winn, M. J. Holman, R. Sanchis-Ojeda, G. Esquerdo and Mark Everett, *Astron. J.* **141**, 179 (2011).
9. S. Ciceri, L. Mancini, J. Southworth, M. Lendl, J. Tregloan-Reed, R. Brahm, G. Chen, G. D'Agó, et al., *Mon. Not. R. Astron. Soc.* **456**, 990 (2016).
10. K. A. Collins, J. F. Kielkopf, K. G. Stassun and F. V. Hessman, *Astron. J.* **153**, 77 (2017).
11. K. A. Collins, J. F. Kielkopf, and K. G. Stassun, *Astron. J.* **153**, 78 (2017).
12. N. B. Cowan, P. Machalek, B. Croll, L. M. Shekhtman, A. Burrows, D. Deming, T. Greene and Joseph L. Hora, *Astrophys. J.* **747**, 82 (2012).
13. B. Croll, L. Albert, R. Jayawardhana, M. Cushing, C. Moutou, D. Lafreniere, J. A. Johnson,

*E-mail: iotamiddleeast@yahoo.com

¹Полный текст статьи публикуется в английской версии статьи (*Astronomy Letters*, V. 47, No. 9, 2021).

- A. S. Bonomo, M. Deleuil, J. Fortney, et al., *Astrophys. J.* **802**, 28 (2015).
14. I. J. Crossfield, T. Barman, B. M. Hansen, I. Tanaka and T. Kodama, *Astrophys. J.* **760**, 140 (2012).
15. F. Davoudi, S. J. Jafarzadeh, A. Poro, O. Basturk, S. Mesforoush, A. F. Harandi, M. J. Gozarandi, Z. Z. Mehrjardi, et al., *New Astron.* **76**, 101305 (2020).
16. D. Deming, H. Knutson, J. Kammer, B. J. Fulton, J. Ingalls, S. Carey, A. Burrows, J. J. Fortney, et al., *Astrophys. J.* **805**, 132 (2015).
17. N. Madhusudhan, H. A. Knutson, J. Harrington, J. Blečić, S. Nymeyer, et al., *Astrophys. J.* **754**, 106 (2012).
18. J. Eastman, R. Siverd, and B. S. Gaudi, *Publ. Astron. Soc. Pac.* **122**, 935 (2010).
19. J. Eastman, B. S. Gaudi and E. Agol, *Publ. Astron. Soc. Pac.* **125**, 83 (2013).
20. R. Essick and N. N. Weinberg, *Astrophys. J.* **816**, 18 (2015).
21. B. J. Fulton, A. Shporer, J. N. Winn, M. J. Holman, A. Pál, and J. Z. Gazak, *Astron. J.* **142**, 84 (2011).
22. D. Föhring, V. S. Dhillon, N. Madhusudhan, T. R. Marsh, C. M. Copperwheat, S. P. Littlefair and R. W. Wilson, *Mon. Not. R. Astron. Soc.* **435**, 2268 (2013).
23. P. Gajdoš and Š. Parimucha, In 50th Conference on Variable Stars Research. 71 (2019).
24. L. Hebb, A. Collier-Cameron, B. Loeillet, D. Pollacco, G. Hébrard, R. A. Street, F. Bouchy, H. C. Stempels, et al., *Astrophys. J.* **693**, 1920 (2009).
25. E. Herrero, J. C. Morales, I. Ribas and R. Naves, *Astron. Astrophys.* **526**, 10 (2011).
26. L. Iorio, *Astrophys. Space Sci.* **331**, 485 (2011).
27. M. C. Johnson, W. D. Cochran, A. C. Cameron and D. Bayliss, *Astrophys. J., Lett.* **810**, 23 (2015).
28. G. Kovács, T. Kovács, J. D. Hartman, G. Á. Bakos, A. Bieryla, D. Latham, R. W. Noyes, Zs. Regály, G. A. Esquerdo, et al., *Astron. Astrophys.* **553**, 44 (2013).
29. L. Kreidberg, M. R. Line, J. L. Bean, K. B. Stevenson, J. M. Désert, N. Madhusudhan, J. J. Fortney, J. K. Barstow, et al., *Astrophys. J.* **814**, 66 (2015).
30. Y. Lin and G. I. Ogilvie, *Mon. Not. R. Astron. Soc.* **468**, 1387 (2017).
31. G. Maciejewski, D. Dimitrov, M. Fernández, A. Sota, G. Nowak, J. Ohlert, G. Nikolov, L. Bukowiecki, et al., *Astron. Astrophys.* **588**, 6 (2016).
32. G. Maciejewski, D. Dimitrov, M. Seeliger, St. Raetz, L. Bukowiecki, M. Kitze, R. Errmann, G. Nowak, et al., *Astron. Astrophys.* **551**, 108 (2013).
33. G. Maciejewski, R. Errmann, M. Seeliger, I. Spaleniak and R. Neuhäuser, *Astron. Astrophys.* **528**, 65 (2011).
34. G. Maciejewski, M. Fernández, F. Aceituno, S. Martín-Ruiz, J. Ohlert, D. Dimitrov, K. Szyszka, C. von Essen, et al., arXiv preprint arXiv:1812.02438 (2018).
35. G. Maciejewski, A. Niedzielski, E. Villaver, M. Konacki, and R. K. Pawłaszek, *Astrophys. J.* **889**, 54 (2020).
36. L. Mancini, J. Kemmer, J. Southworth, K. Bott, P. Mollière, S. Ciceri, G. Chen, Th. Henning, et al., *Mon. Not. R. Astron. Soc.* **459**, 1393 (2016).
37. A. M. Mandell, K. Haynes, E. Sinukoff, N. Madhusudhan, A. Burrows and D. Deming, *Astrophys. J.* **779**, 128 (2013).
38. I. McDonald and E. Kerins, *Mon. Not. R. Astron. Soc.: Lett.* **477**, 21 (2018).
39. A. A. Neath and J. E. Cavanaugh, *Wiley Interdisciplinary Reviews: Computational Statistics.* **4**, 199 (2012).
40. K. C. Patra, J. N. Winn, M. J. Holman, M. Gillon, A. Burdanov, E. Jehin, L. Delrez, F. J. Pozuelos, et al., *Astron. J.* **159**, 150 (2020).
41. K. C. Patra, J. N. Winn, M. J. Holman, K. C. Patra, S. Vissapragada, M. M. Zhang, M. J. Holman, A. Shporer, et al., *Astron. J.* **154**, 4 (2017).
42. R. Petrucci, E. Jofre, L. V. Ferrero, V. Cuneo, L. Saker, F. Lovos, M. Gomez and P. Mauas, *Mon. Not. R. Astron. Soc.* **473**, 5126 (2018).
43. S. Poddany, L. Brátand and O. Pejcha, *New Astronomy.* **15**, 297 (2010).
44. D. L. Pollacco, I. Skillen, A. C. Cameron, D. J. Christian, C. Hellier, J. Irwin, T. A. Lister, R. A. Street, et al., *Publ. Astron. Soc. Pac.* **118**, 1407 (2006).
45. G. R. Ricker, J. N. Winn, R. Vanderspek, D. W. Latham, G. Á. Bakos, J. L. Bean, Z. K. Berta-Thompson, T. M. Brown, et al., *Journal of Astronomical Telescopes, Instruments, and Systems.* **1**, 014003 (2014).
46. T. P. Robitaille, E. J. Tollerud, P. Greenfield, M. Droettboom, E. Bray, T. Aldcroft, M. Davis, A. Ginsburg, et al., *Astron. Astrophys.* **558**, 33 (2013).
47. P. V. Sada, D. Deming, D. E. Jennings, B. K. Jackson, C. M. Hamilton, J. Fraine, S. W. Peterson, F. Haase, et al., *Publ. Astron. Soc. Pac.* **124**, 212 (2012).
48. J. Salvatier, T. V. Wiecki and C. Fonnesbeck, *PeerJ Computer Science.* **2**, 55 (2016).
49. A. M. S. Smith, D. R. Anderson, A. C. Cameron, M. Gillon, C. Hellier, M. Lendl, P. F. L. Maxted, D. Queloz, et al., *Astron. J.* **143**, 81 (2012).
50. J. Southworth, M. Dominik, U. G. Jørgensen, M. I. Andersen, V. Bozza, M. J. Burgdorf, G. D'Agó, S. Dib, et al., *Mon. Not. R. Astron. Soc.* **490**, 4230 (2019).

51. K. B. Stevenson, J. L. Bean, A. Seifahrt, J. M. Désert, N. Madhusudhan, M. Bergmann, L. Kreidberg, D. Homeier et al., *Astron. J.* **147**, 161 (2014).
52. J. D. Turner, K. A. Pearson, L. I. Biddle, B. M. Smart, R. T. Zellem, J. K. Teske, K. K. Hardegree-Ullman, C. C. Griffith, et al., *Mon. Not. R. Astron. Soc.* **459**, 789 (2016).
53. C. von Essen, S. Czesla, U. Wolter, M. Breger, E. Herrero, M. Mallonn, I. Ribas, K. G. Strassmeier, et al., *Astron. Astrophys.* **561**, 48 (2014).
54. C. von Essen, M. Mallonn, C. C. Borre, V. Antoci, K. G. Stassun, S. Khalafinejad and G. Tautvaivsiene, arXiv preprint arXiv:2004.10767 (2020).
55. J. N. Winn, M. J. Holman, G. Torres, P. McCullough, C. Johns-Krull, D. W. Latham, A. Shporer, T. Mazeh, et al., *Astrophys. J.* **683**, 1076 (2008).
56. S. W. Yee, J. N. Winn, H. A. Knutson, K. C. Patra, S. Vissapragada, M. M. Zhang, M. J. Holman, A. Shporer, et al., *Astrophys. J., Lett.* **888**, 5 (2019).
57. G. Zhou, D. D. R. Bayliss, L. Kedziora-Chudczer, C. G. Tinney, J. Bailey, G. Salter and J. Rodriguez, *Mon. Not. R. Astron. Soc.* **454**, 3002 (2015).