Mon. Not. R. Astron. Soc. **356,** 955–957 (2005) doi:10.1111/j.1365-2966.2004.08511.x

An intriguing correlation between the masses and periods of the transiting planets

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Accepted 2004 October 12. Received 2004 September 9

ABSTRACT

We point out an intriguing relation between the masses of the transiting planets and their orbital periods. For the six currently known transiting planets, the data are consistent with a decreasing linear relation. The other known short-period planets, discovered through radial-velocity techniques, seem to agree with this relation. We briefly speculate about a tentative physical model to explain such a dependence.

Key words: planetary systems.

1 INTRODUCTION

The actual masses of most extrasolar planets are not known. Because radial-velocity data do not yield orbital inclinations, only minimum masses can be derived for those planets. Some information about the masses could be gained through *Hipparcos* astrometry (Pourbaix & Arenou 2001; Zucker & Mazeh 2001), but no definite masses. So far, the actual masses can be derived only for planets that exhibit transits, indicating orbital inclinations close to 90°. The first transiting planet to be discovered was HD 209458 (Charbonneau et al. 2000; Henry et al. 2000), after the radial-velocity modulation (Mazeh et al. 2000) indicated a minimum mass of about 0.7 Jupiter mass (M_J).

The next stage in the pursuit of knowledge of the actual planetary masses was the publication of the high-quality photometric data of OGLE (Udalski et al. 2002a,b, 2003), which yielded, especially after applying the BLS transit search algorithm (Kovács, Zucker & Mazeh 2002), more than 100 transit candidates. Follow-up radial-velocity observations confirmed that OGLE-TR-56 (Konacki et al. 2003; Torres et al. 2004), OGLE-TR-113 and OGLE-TR-132 (Bouchy et al. 2004) all have planetary companions, with masses of 1.45, 1.35 and 1.01 M_J, respectively.

In 2004 August three additional steps were taken in the saga of deriving the planetary masses, as follows.

(i) Superb photometry of OGLE-TR-132 improved its mass estimate to 1.19 M_J (Moutou et al. 2004).

(ii) One more OGLE candidate, OGLE-TR-111, was proven to harbour a planet with a mass of 0.5 M_J (Pont et al. 2004).

(iii) The first radial-velocity confirmation of planetary transit detection by a wide-field small telescope, TrES-1, was announced, with a mass of 0.75 M_J (Alonso et al. 2004).

Table 1 summarizes our present knowledge of the planetary masses known as of 2004 August 31. In this paper we present an intriguing correlation between the masses of the transiting planets and their periods, and discuss very briefly its possible implications.

2 THE MASS–PERIOD CORRELATION

Fig. 1 presents the six known planetary masses as a function of their periods, and their best linear fit. Despite the fact that we have only six points, the linearity of their positions in the diagram is intriguing. The probability to have their masses arranged as a monotonic (increasing or decreasing) function of their periods is $2/6! = 0.0028$, let alone having them appear on a straight line, within 1σ.

Obviously, any correlation between the masses of the short-period planets and their periods should also apply to the minimum masses of the other known short-period planets. We therefore plot in Fig. 2 the masses of all other planets with periods shorter than 5 d (from the Exoplanet Encyclopaedia, www.obspm.fr/encycl/catalog.html). We exclude only the planet around τ Boo (Butler et al. 1997), which is known to be in a binary system (Eggenberger, Udry & Mayor 2003), where the distant stellar M2 companion could have modified the planetary formation and evolution (Zucker & Mazeh 2002). For all these planets only the minimum mass is known. We therefore multiplied each planetary minimum mass by $4/\pi$, the reciprocal of the expected value of $\sin i$. We ignored the very recently discovered Neptune-sized planets, which probably are of a different nature and have a different formation and evolutionary history (Santos et al. 2004; McArthur et al. 2004; Butler et al. 2004).

Zucker & Mazeh (2002) have already found a correlation between planet masses and their orbital periods, manifested as a dearth of massive short-period planets. The relation suggested here applies to a small part of the mass–period diagram analyzed by Zucker & Mazeh. Therefore, it is probably related to other physical mechanisms. We find that the population of all the planets with periods shorter than 5 d is still consistent with the intriguing linear dependence found for the masses of the transiting planets, with admittedly some scatter.

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Table 1. Periods and masses of the transiting planets.

Name	Period (d)	Mass (M_J)	Reference
OGLE-TR-56	1.2	1.45 ± 0.23	Torres et al. (2004)
OGLE-TR-113	1.43	1.35 ± 0.22	Moutou et al. (2004)
OGLE-TR-132	1.69	1.19 ± 0.13	Moutou et al. (2004)
TRes-1	3.03	0.75 ± 0.06	Alonso et al. (2004)
HD 209458	3.52	0.69 ± 0.05	Mazeh et al. (2000)
OGLE-TR-111	4.02	0.53 ± 0.11	Pont et al. (2004)

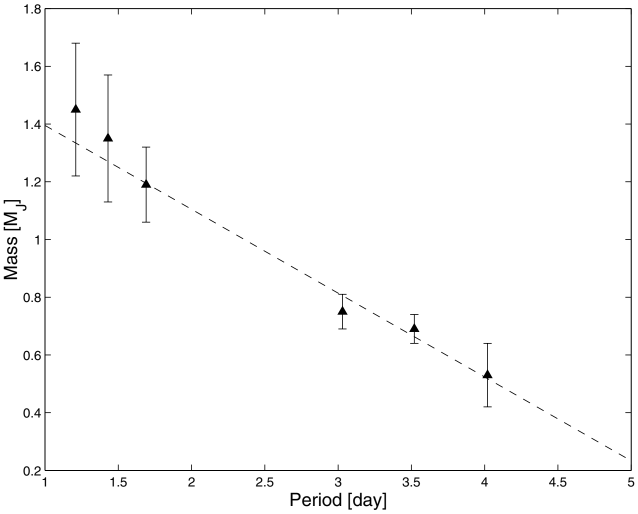

Figure 1. The masses of the transiting planets as a function of their periods. The line is the best linear fit.

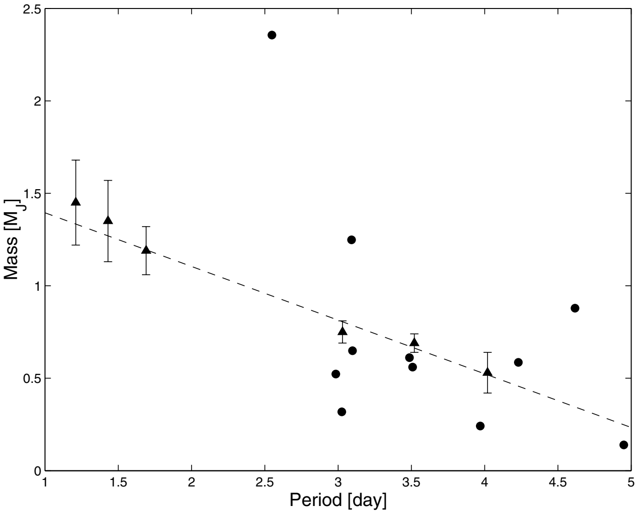

Figure 2. The mass–period diagram of the short-period planets. The filled circles are the minimum masses multiplied by $4/\pi$.

3 DISCUSSION

The suggested mass–period relation depicted in Figs 1 and 2 is based on small number statistics, and more points are certainly needed to establish its existence. The aim of this short paper is to attract the attention of the community to this intriguing relation and to initiate a fruitful discussion. Along this line, in what follows we speculate very briefly on the possible mechanism behind such an intriguing feature.

Very recently Baraffe et al. (2004) recalculated the evolutionary tracks of close-in giant planets, taking into account thermal evaporation caused by the XUV flux of the parent star (Lammer et al. 2003). They suggested that the orbital distance determines a critical mass, below which the evaporation time-scale becomes shorter than the thermal time-scale of the planet. For planets with initial masses below the critical mass, evaporation leads to a rapid expansion of the outer planetary layers, speeding up the evaporation process. Consequently, planets with masses below the critical mass do not survive. Such a process can cleanse the area in the mass–period diagram below the line that represents the critical mass.

Clearly, the critical mass gets smaller as the orbital distance gets larger. Therefore, such a mechanism can explain the feature seen in our diagram. Moreover, planets positioned on the suggested mass–period line might have suffered an increase of their radius because of the stellar heating, and would therefore be the easiest to detect by transit search. This might account for the fact that all the transiting planets are so close to the line in our diagram.

Obviously this speculation still has to be worked out. For example, it seems that planets with periods shorter than 5 d discovered by radial-velocity measurements also concentrate around our line, and their density above the line is low. To account for this we need to invoke another mechanism, as planets above the line apparently are not strongly affected by stellar heating. Furthermore, one still has to show why the critical mass would depend linearly on the orbital period. Moreover, one would think that the evaporation process should depend strongly on the stellar brightness, a feature which is not seen in the actual data of the short-period planets. It is also not clear why this effect is limited to planets with period shorter than 5 d. In short, we do not have any detailed model. We suggest that such a model should be worked out only when more planets in this range of periods are found, and the mass–period correlation better established.

ACKNOWLEDGMENTS

This work was supported by the Israeli Science Foundation through grant no. 03/233. SZ wishes to acknowledge support by the European RTN ‘The Origin of Planetary Systems’ (PLANETS, contract number HPRN-CT-2002-00308) in the form of a fellowship.

REFERENCES

Alonso R. et al., 2004, ApJ, 613, L153

Baraffe I., Selsis F., Chabrier G., Barman T. S., Allard F., Hauschildt P. H., Lammer H., 2004, A&A, 419, L13

Bouchy F., Pont F., Santos N. C., Melo C., Mayor M., Queloz D., Udry S., 2004, A&A, 421, L13

Butler R. P., Marcy G. W., Williams E., Hauser H., Shirts P., 1997, ApJ, 474, L115

Butler R. P., Vogt S. S., marcy G. W., Fischer D. A., Wright J. T., Henry G. W., Laughlin G., Lissauer J., 2004, astro-ph/0408587

Charbonneau D., Brown T. M., Latham D. W., Mayor M., 2000, ApJ, 529, L45

Eggenberger A., Udry S., Mayor M., 2003, in Deming D., Seager S., eds, ASP Conf. Ser. Vol. 294, Scientific Frontiers in Research on Extrasolar Planets. Astron. Soc. Pac., San Francisco, p. 43

Henry G. W., Marcy G. W., Butler R. P., Vogt S. S., 2000, ApJ, 529, L41

Konacki M., Torres G., Jha S., Sasselov D. D., 2003, Nat, 421, 507

Kovács G., Zucker S., Mazeh T., 2002, A&A, 391, 369

Lammer H., Selsis F., Ribas I., Guinan E. F., Bauer S. J., Weiss W. W., 2003, ApJ, 598, L121

Mazeh T. et al., 2000, ApJ, 532, L55

McArthur B. E. et al., 2004, ApJ, 614, L81

Moutou C., Pont F., Bouchy F., Mayor M., 2004, A&A

Pont F., Bouchy F., Queloz D., Santos N. C., Melo C., Mayor M., Udry S., 2004, A&A, 426, L15

Pourbaix D., Arenou F., 2001, A&A, 372, 935

Santos N. C. et al., 2004, A&A, 426, L19

Torres G., Konacki M., Sasselov D. D., Jha S., 2004, ApJ, 609, 1071

Udalski A. et al., 2002a, Acta Astron., 52, 1

Udalski A., Zebrun K., Szymanski M., Kubiak M., Soszynski I., Szewczyk O., Wyrzykowski L., Pietrzynski G., 2002b, Acta Astron., 52, 115

Udalski A., Pietrzynski G., Szymanski M., Kubiak M., Zebrun K., Soszynski I., Szewczyk O., Wyrzykowski L., 2003, Acta Astron., 53, 133

Zucker S., Mazeh T., 2001, ApJ, 562, 549

Zucker S., Mazeh T., 2002, ApJ, 568, L113

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