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# A TRANSIT OF THE PLANET 51 Peg B?

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"We see it [a probable new planet] as Columbus saw America from the shores of Spain. Its movements have been felt, trembling along the far-reaching line of our analysis, with a certainty hardly inferior to that of ocular demonstration." – John Herschel, in a speech to the British [Astronomical] Association, 10 September 1846.†

Mayor & Queloz (1995) first announced that the solar-type star 51 Peg has a Jovian-mass planet with a 4.23 day orbital period. Their observations were confirmed by Marcy et al. (1997). Since this exciting discovery many people naturally have wondered if transits of the planet could be observed across the disk of the parent star. Guinan (1995) and, later, Henry et al. (1997) reported null events. They could not find evidence of transits. However, Henry et al. show only one, possibly two, averages-of-three data points in the transit window. Under the assumption that the planet has a zero-eccentricity orbit, has a size equal to 0.8 times that of Jupiter, and assuming that the star has a size 1.3 times that of the Sun and a mass of 1.0 $M_{\odot}$, we would expect a full transit to be 4.3 mmag deep, last for 4 hours, and be centered at phase 0.25 (see Henry et al. 1997). Any *reflection effect* at other phases, or an eclipse at phase 0.75, would change the light of the system less than 0.1 mmag (Charbonneau, Jha, & Noyes 1998). Incidentally, if the planet is 0.8 times the size of Jupiter, there will be full transits if the orbital inclination is within 6.3 degrees of $i = 90°$.

Guillot et al. (1996) modelled Jupiter-like planets and suggest that because 51 Peg A is 8.5 Gyr old (Edvardsson et al. 1993), 51 Peg B may actually be as large as 1.3 times that of Jupiter. In that case a transit of the planet could produce a dip in the light curve as deep as 11 mmag. This, of course, assumes that a Jovian planet so close to its parent star (0.051 AU) still has its thick atmosphere.

Zerbi and 16 coauthors (1999), of which I am one, recently published the results of a multi-longitude photometric campaign on the $\gamma$ Dor-type star BS 8799. The principal comparison star was HD 217715. The recommended check star was HD 218261. For reasons that I cannot quite recall, I decided to use a different check star, 51 Peg. This was two months *before* Mayor & Queloz announced the existence of the planet 51 Peg B. From 1210 Johnson V-band and Strömgren $v$-band measures of HD 218261 vs. HD 217715 over the course of 40 days Zerbi et al. conclude that both stars are constant. This allows us to investigate whether the 51 Peg vs. HD 217715 data show evidence of transits of 51 Peg B across its parent star.

†Quoted by Spencer Jones (1956). Of course, Herschel was referring to Neptune, which in fact was first seen by J. G. Galle and H. L. d'Arrest in Berlin 13 days later.

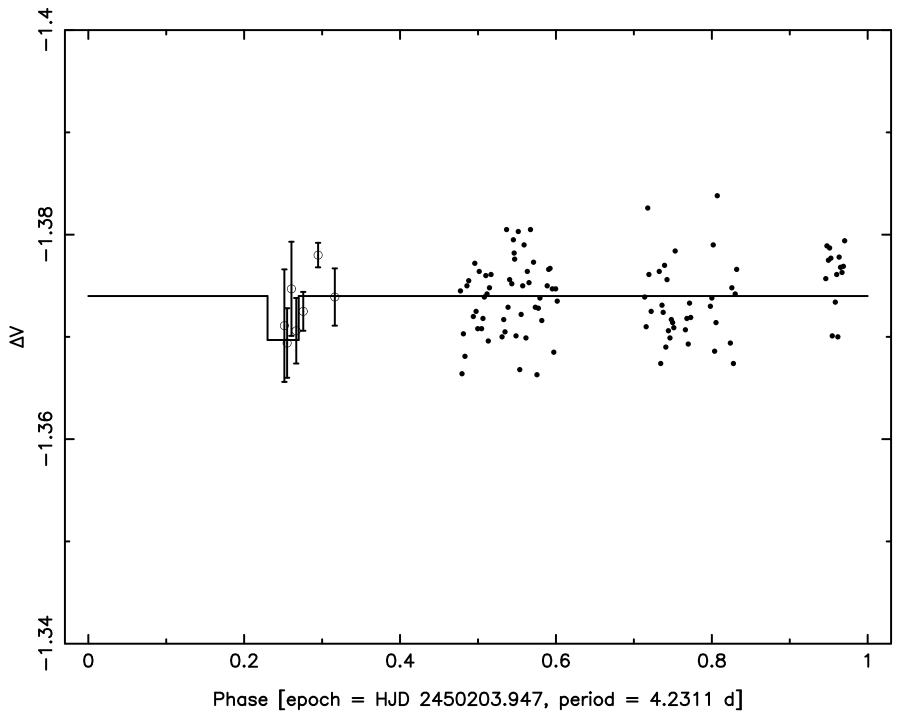


**Figure 1.** Differential measures of 51 Peg vs. HD 217715, obtained at Mauna Kea from 31 August to 6 September 1995 UT. The data are folded according the ephemeris of Marcy et al. (1997). Points without error bars are individual differential measures. Points with error bars are averages of 3 or 4 measures. A dip of 4.3 mmag is shown, corresponding to a full transit of a planet with $R = 0.8\,R_{Jup}$.

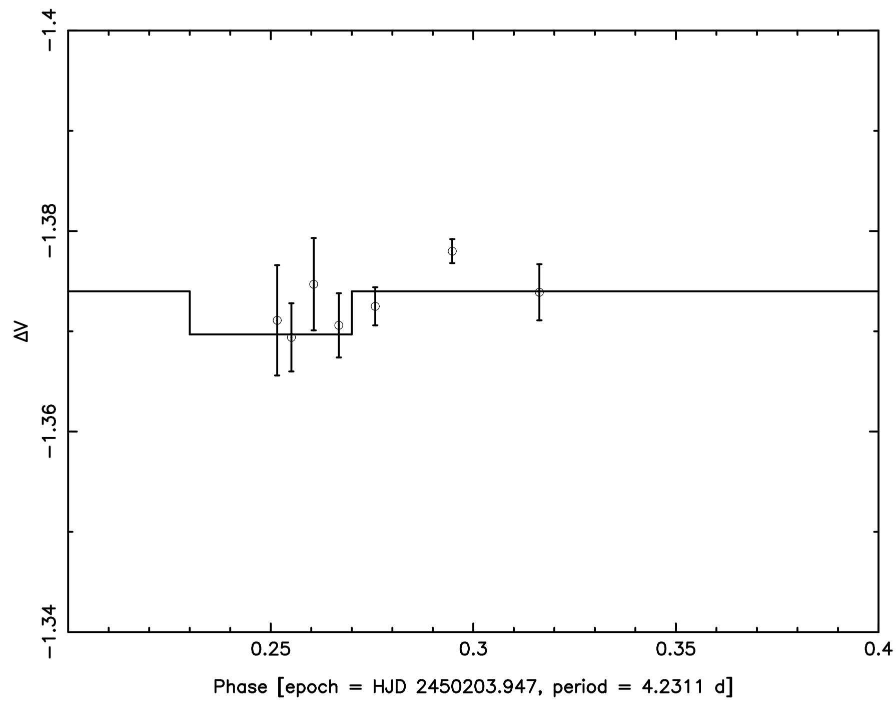


**Figure 2.** Data from Fig. 1, but only near the time of "inferior conjunction" of 51 Peg B.

Our observations were made with the University of Hawaii 0.6-m telescope at Mauna Kea from 31 August to 6 September 1995 UT, using an Optec SSP-5 photometer. The only night we observed near orbital phase 0.25 was 3 September 1995. From data on 6 of 7 nights we obtained 123 differential measurements under clear sky conditions with no tracking problems. Each "measurement" of a star was the result of two 30 second integrations. Each measurement of 51 Peg was bracketed by measurements of HD 217715. We linearly interpolated the comparison star counts by time for the calculation of the differential magnitude of 51 Peg, and made what we believe were appropriate differential extinction corrections. We added $\varepsilon_v \times \Delta(\mathrm{B}-\mathrm{V}) = -0.0253 \times 0.67 = -0.0170$ to all the data points to place them on the UBV system. Any systematic error in this color term has no bearing on the conclusions of this paper.

In Figure 1 we show the data folded according to the ephemeris of Marcy et al. (1997). We also show the predicted dip of 4.3 mmag centered at orbital phase 0.25 and lasting 4 hours. The dots in Fig. 1 are individual differential measures, and the points with error bars are averages of 3 or 4 differential measures. From 111 differential measures outside the transit window (phase 0.23 to 0.27) we find a mean differential magnitude of $\Delta\mathrm{V} = -1.3740 \pm 0.0004$. The internal error of a typical individual differential value is $\pm$ 3.8 mmag. Thus, an average of three measures should typically be accurate to $\pm$ 2.2 mmag.

In Figure 2 we show only the data near phase 0.25, when transits of the planet should occur, if in fact transits *do* occur. The first five points plotted are averages of three individual differential measures, and the last two points plotted are averages-of-four. Clearly, there is no 11 mmag dip. Thus, if Guillot et al. (1996) are correct, that 51 Peg B has $\mathrm{R} = 1.3\,\mathrm{R_{Jup}}$, full transits do not occur. If we average the 12 individual measures that occur in the transit window, we get $\Delta\mathrm{V} = -1.3714 \pm 0.0019$. Our data, taken at face value, indicate a dip of $2.6 \pm 1.9$ mmag. The probability of observing a 1.37-$\sigma$ *dip* at just the right phase corresponds to the area under *one* tail of the unit-area Gaussian distribution. A random sample of points, with errors distributed in a Gaussian manner, would show this dip with a probability of 0.085.

Our data are consistent with there being no transit, but the data are not inconsistent with a 4.3 mmag transit of a $0.8\,\mathrm{R_{Jup}}$ planet having been observed. Clearly more data are warranted. We should be encouraged that ground-based or satellite observations will sooner or later reveal transits of extra-solar planets.

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