

# The Feb. 25, 2005 Opportunity For Follow-up Photometry to Check for Planetary Transits of HD 80606

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Among the 150-odd extrasolar planets that are currently known, HD 80606b certainly ranks among the most unusual. The discovery of the planet and its orbital solution were announced by the Geneva Observatory Planets Search Team in an April 04, 2001 ESO press release, and the radial velocities were later published and made available on CDS <sup>1</sup> by Naef et al (2001). With an orbital eccentricity  $e \sim 0.93$  HD 80606b is the most eccentric planet known. HD 80606 is accompanied by a visual binary companion, HD 80607. The projected separation of the components is  $\sim 2000AU$ . The stars have similar masses, sizes, and temperatures to the Sun, but they are enriched in metals by a factor of more than two relative to the Sun. Wu & Murray (2003) have suggested that HD 80606b's extreme eccentricity is the result of a three-body interaction between the planet and the two stars.

Using the Keck Telescope, the California-Carnegie Planet Search Team has made a number of high-precision radial velocity measurements of HD 80606 over the past three years. This set of measurements was communicated by Geoff Marcy (in advance of publication by Marcy et al. 2005). We have combined the Geneva and California-Carnegie velocities to produce an updated orbital model for the planet, and we have used the model to predict central transit times and uncertainty estimates for the transit ephemeris. The details of the orbital fit are given in Table 1, and the orbit itself is plotted in Figure 1. With the expanded data set, we confirm the original orbital fit, and refine the orbital parameters. For example, Naef et al. (2001) report  $P = 111.81 \pm 0.23$  d, whereas we obtain  $P = 111.419 \pm 0.004$  d. For the eccentricity, Naef et al (2001) obtain  $e = 0.927 \pm 0.012$ , whereas we find  $e = 0.938 \pm 0.002$ .

At periastron passage, the planet reaches a minimum distance from the star of only 0.29 AU ( $\sim 6$  stellar radii). The opportunity to observe the planet in transit occurs about 5.5 days after the periastron passage, when the planet is roughly 63 stellar radii from the star. For much of the orbital period, the planet is dawdling within the star's habitable zone, with an apocenter distance of 0.9 AU. The planet experiences intense tidal deformation during its brief close approaches to the star, and may be locked in a high-order spin-orbit resonance (analogous to the 3:2 spin-orbit resonance exhibited by the planet Mercury).

During the transit window, the planet's velocity vector has a significant component along the line of sight, generating a strikingly long transit duration (more than 17 hours in the case of a central transit). Indeed, if transits are occurring, the light curve will be measurably

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<sup>1</sup><ftp://cdsarc.u-strasbg.fr/pub/cats/J/A+A/375/L27/>

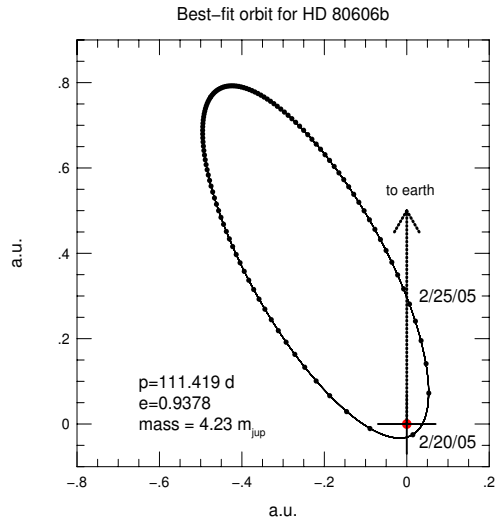


Figure 1: Orbital model for HD 80606b. The small black circles show the position of the planet at 1 day intervals, with periastron passage occurring at  $JD2353421.8779 \pm 0.05$  (2005 Feb 20 09:04 UT). The opportunity to observe transits occurs  $\sim 5$  days later as the planet crosses the line of sight from the star to the Earth.

asymmetric, as a result of the planet’s deceleration as it traverses the face of the star. The ingress and egress phases will last approximately 2 hours each.

It is unfortunate that the longitude of periastron,  $\varpi = 300.2^\circ$ , is not favorably oriented for a high a-priori transit probability. The chance that transits are occurring is  $\mathcal{P} \sim 1.7\%$ . (Had it been the case that  $\varpi \sim 90^\circ$ , the transit probability would be  $\mathcal{P} \sim 17\%$ ). Using the planetary structure models of Bodenheimer, Laughlin & Lin (2003), we estimate a planetary radius of  $R_{\text{pl}} = 1.08R_{\text{JUP}}$ , implying a central transit depth of order 1.3%.

An estimate of the uncertainty in the time of central transit was obtained by using the Bootstrap Monte Carlo procedure (see, e.g., Press et al 1992) to generate synthetic radial velocity data sets. By repeatedly fitting to these synthetic data sets, a distribution of central transit times is created. This distribution of transit times indicates that the central transit can potentially occur as much as one day before or after the nominal predicted time of 2005 Feb 25 19:39 UT. Given that the transit duration can be of order 17 hours, we therefore recommend intense photometric monitoring of the star during the four-day window centered on 2005 Feb 25 19:39 UT.

To summarize, it must be stressed that the a-priori probability of observing HD 80606b in transit is low. It is important, however, to determine whether transits of this extremely interesting planet are occurring. The long transit duration, combined with the measurable asymmetry in the light curve, would allow for an unprecedentedly accurate characterization of a strange world orbiting another star.

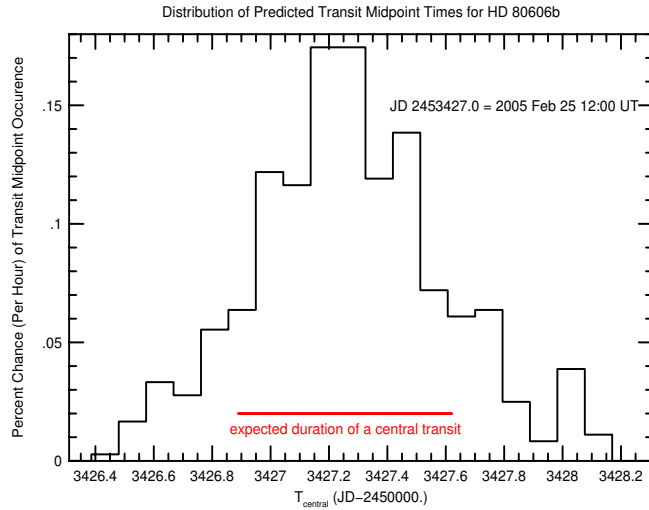


Figure 2: Histogram showing central transit times computed using 1-planet Keplerian fits to the combined Swiss and Keck radial velocity data, combined with a bootstrap Monte-Carlo method to compute transit times. The peak probability for observing a transit of HD 80606 b occurs at Jan 01, 2005 (UT). The uncertainties in the orbital solutions to the radial velocity data lead to a total computed spread of  $\sim 2$  d in the possible central transit times, with an estimated  $1\text{-}\sigma$  uncertainty of 0.35 d. The situation is complicated by the long  $\sim 18$  hr hour duration of a central transit. Note that if the planetary inclination is  $i < 90^\circ$ , then the transit duration will be shorter than the maximum. Continuous photometric coverage during the full two days to either side of the best-fit central transit time is therefore required in order to definitively confirm or rule out the presence of transits. Furthermore, because individual observers will be able to catch only an ingress or an egress, it is important to have multiple light curves.

**Table 1: Stellar and Planetary Properties of the HD 80606 system**

Parameter	HD 80606 b
Orbital Period	$111.419 \pm 0.004$ d
Time of Periastron Passage	$\text{JD } 2453421.878 \pm 0.05$
eccentricity	$0.9378 \pm 0.002$
inclination (assumed)	$90.0^\circ$
$\varpi$	$300.2^\circ \pm 0.52^\circ$
Planet Mass	$4.23 \pm 0.05 M_{\text{JUP}}$
Transit Probability	1.7%
Predicted Planetary Radius	$1.08 R_{\text{JUP}}$
Predicted Transit Epoch	$\text{JD } 2453427.32 \pm 0.4$
Predicted Central Transit Depth	1.34%
Predicted Central Transit Duration	17.33 hours
Right Ascension	09 23
Declination	+50 36
Stellar V mag	8.93
Stellar B mag	9.65

### References

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- Naef, D., et al. 2001, *Astronomy and Astrophysics*, **375**, L27.
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