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Planetary Companions around Two Solar-Type Stars: HD 195019 and HD 217107[1]

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ABSTRACT. We have enlarged the sample of stars in the planet search at Lick Observatory. Doppler measurements of 82 new stars observed at Lick Observatory, with additional velocities from Keck Observatory, have revealed two new planet candidates. The G3 V/IV star, HD 195019, exhibits Keplerian velocity variations with a period of 18.27 days, an orbital eccentricity of 0.03 ± 0.03, and $M \sin i = 3.51$ $M_{\rm JUP}$. Based on a measurement of Ca II H and K emission, this star is chromospherically inactive. We estimate the metallicity of HD 195019 to be approximately solar from *ubvy* photometry. The second planet candidate was detected around HD 217107, a G7 V star. This star exhibits a 7.12 day Keplerian period with eccentricity 0.14 ± 0.05 and $M \sin i = 1.27$ $M_{\rm JUP}$. HD 217107 is also chromospherically inactive. The photometric metallicity is found to be $[{\rm Fe/H}] = +0.29 \pm 0.1$ dex. Given the relatively short orbital period, the absence of tidal spin-up in HD 217107 provides a theoretical constraint on the upper limit of the companion mass of less than 11 $M_{\rm JUP}$.

1. INTRODUCTION

In the past 3 yr, a dozen extrasolar planet candidates have been discovered around main-sequence stars using high-precision radial velocity measurements. All except one of these "planetary" companions has a derived mass ($M \sin i$) less than 5 times the mass of Jupiter. Only three of the companions have orbital periods longer than 1 yr. One unexpected result has been that the orbits for the "planets" appear to be both circular and eccentric. The theoretical interpretation of this observation is that the planets formed in dissipative circumstellar disks, followed by gravitational perturbations (see Lin, Bodenheimer, & Richardson 1996; Artymowicz 1997; Levinson, Lissauer, & Duncan 1998).

One of the first of the extrasolar "planets," 51 Peg (Mayor & Queloz 1995), was a surprise: a 0.5 $M_{\rm JUP}$ companion in a 4.2 day orbit. With the latest discovery of a planet in a 3.1 day orbit around HD 187123 (Butler et al. 1998) and the companion to τ Boo and υ And (Butler et al. 1997), there are now four of these very short period, 51 Peg–like systems. Models of tidal interactions between the star and planet (Terquem et al. 1998; Ford, Rasio, & Sills 1999; Marcy et al. 1997) provide timescales for circularization and spin-up of the stellar convective envelope and constrain the companion mass to the planetary regime for cases in which the orbital period is ~4 days or less.

A sample of 107 G–K main-sequence stars has been monitored since 1987 at Lick Observatory. A revision of the spectrograph optics in 1994 improved the internal radial velocity precision to 3 m s^{-1} for the brighter stars in this program. The Lick survey has identified "planetary" companions to 70 Vir, 47 UMa, 55 ρ Cnc, τ Boo, υ And, and GJ 876 (Marcy et al. 1998a) and has confirmed the discovery of planets around 51 Peg (Mayor & Queloz 1995) and ρ CrB (Noyes et al. 1997). A codiscovery of a companion to 16 Cyg B (Cochran et al. 1997) was also made with observations from Lick Observatory. The long-term nature of the Lick Observatory program and the high precision of the Doppler analysis should continue to provide information regarding low-amplitude, longer period companions.

In the past few months, 200 new stars have been added to the Lick project. The first goal in extending this planet-search program is to identify short-period companions to help characterize the planetary mass function and the orbits of such systems. These short-period systems test theories of tidal interactions between the host star and its companion and provide ideal targets for transit observations. An observation of a planet-transit would provide powerful corroboration regarding the nature of the planet candidates.

2. THE SECOND GENERATION LICK PROJECT

The selection criteria for the new sample stars were dictated by the fact that high S/N and an abundance of narrow spectral lines is required to achieve good velocity precision. Stars brighter than $V = 7.5$ with F7–K0 spectral type were selected

[1] Based on observations obtained at Lick Observatory, which is operated by the University of California, and on observations obtained at the W. M. Keck Observatory, which is operated jointly by the University of California and the California Institute of Technology.

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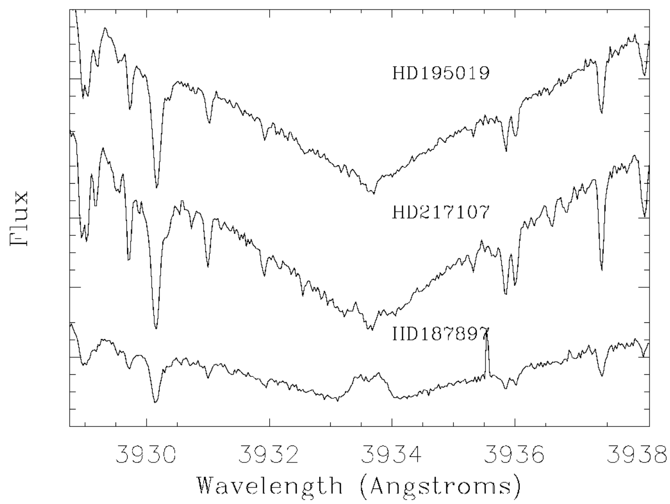

FIG. 1.—Spectral window centered on the Ca II K line at 3933.7 Å for HD 195019 (*top*), HD 217107 (*middle*), and HD 187897 (*bottom*). Core emission, indicating chromospheric activity, can be seen in HD 187897.

from the *Hipparcos* catalog, and their main-sequence status was confirmed using *Hipparcos* parallaxes to derive the absolute visual magnitude. This yielded a preliminary list of stars that were not already being observed in the Keck or Lick planet search programs.

The precise Doppler technique makes use of an iodine cell to impose a grid of sharp reference lines on the stellar spectrum. Also needed is a "template" observation of every sample star without iodine to serve as a reference. The Doppler analysis code later convolves this template spectrum with a Fourier transform spectrometer iodine observation to model subsequent observations of the star with iodine and thereby derive the spectrometer point-spread function and calibrate the wavelength (velocity) shift (Butler et al. 1996). High-quality template observations for the sample stars were obtained with HIRES (Vogt et al. 1994) at the Keck Observatory with $R =$ 87,000 and S/N of 300.

The Keck templates were immediately used to estimate $v \sin i$, measure Ca II H and K emission, and check for double lines in the spectra. High $v \sin i$ reduces the velocity precision that can ultimately be obtained, and a double-line spectrum precludes the Doppler analysis entirely. Core emission in the Ca II H and K lines is characterized by a pseudo–equivalent width, or *S* index, analogous to the Mount Wilson *HK* observations (Baliunas et al. 1998; Shirts & Marcy 1998). The *S* index is then transformed to $R'HK$, a ratio of the *HK* flux to the bolometric flux of the star. $R'HK$ is a good indicator of the level of chromospheric activity and a good predictor of the rotational period and the age of main-sequence stars (Noyes et al. 1984). Strong chromospheric activity is correlated with magnetic activity and motions in the photosphere of the star that can produce quasi-periodic radial velocity variations (Saar, Butler, & Marcy 1998; Marcy & Butler 1998; Butler et al. 1998), so low-amplitude velocity variations in active stars warrant caution.

After evaluating the template spectra, we ended up with 82 new sample stars that were accessible in July and August from Lick Observatory. In order to search all of these stars with a minimum expenditure of telescope time, we opted to take 2–5 minute exposures, which yielded S/N ~ 100 with typical velocity precisions of only 10–15 m s^{-1}. In retrospect, we believe this lower precision and limited sampling biased us against finding low-amplitude objects such as 51 Peg. We intend to continue monitoring these objects long term and with higher precision in the future to search for longer period and lower amplitude companions.

We used the 3 m Shane telescope with the Hamilton spectrograph (Vogt 1987) at Lick Observatory to obtain four to five observations of each of the new sample stars on 1998 July 9–11, July 30, 31, and August 1. Velocity dispersions greater than 3 σ were found in nine stars. A timely allocation of Keck telescope time made it possible to add these nine stars to the Keck planet search program and obtain high S/N spectra (~300) during seven of eight consecutive nights from September 12 to 19. The Keck observations showed that six of the nine candidates were not varying in short-period orbits; however, three of the candidates did show Keplerian-like velocity shifts. We then used the 0.6 m Coudé Auxiliary Telescope (CAT) at Lick Observatory to monitor these three stars on a nightly basis. Typically, a set of three half-hour CAT exposures were obtained within a 2 hr interval. Velocities determined within a 2 hr interval were averaged to form a single velocity measurement.

The Lick and Keck velocities each have independent, arbitrary velocity zero points. The relative zero point was determined by combining the two data sets and adjusting the velocity offset until the Keplerian fit yielded a minimum in the rms velocities. This exercise forced the Lick and Keck velocities to have the same zero point. After the Lick and Keck observations were combined, the velocity variations for two of the three candidates (HD 195019 and HD 217107) phased up nicely. In the case of the third candidate, HD 187897, the velocities did not phase up. Subsequent CAT observations revealed a departure from Keplerian velocity in the Lick data alone. The presence of moderate core emission in the Ca II H and K lines had raised suspicions regarding this star (Fig. 1, *bottom*). For HD 187897, we derive an *S* index of 0.286 and $\log R'HK = -4.5$. This level of chromospheric activity has been shown (Saar & Donahue 1997) to produce radial velocity variations with amplitudes between 30 and 50 m s^{-1}, and we therefore believe that the 36 m s^{-1} semiamplitude Doppler shifts observed in HD 187897 may originate from activity-related photospheric variations in the star.

3. OBSERVATIONS: HD 195019

HD 195019 (=HIP 100970) is spectral type G3 V/IV with $V = 6.87$, $B-V = 0.662$ from *Hipparcos* photometry (Perry-

TABLE 1
Radial Velocities for HD 195019

JD −2,450,000	RV (m s^{-1})	Telescope
1004.874	270.61	Shane
1006.883	146.82	Shane
1026.844	−11.26	Shane
1027.869	−70.12	Shane
1045.836	−34.42	Shane
1068.852	−222.53	Keck
1069.893	−185.77	Keck
1070.913	−106.85	Keck
1071.849	0.00	Keck
1072.837	92.42	Keck
1074.857	244.19	Keck
1075.795	292.32	Keck
1076.733	325.68	CAT
1077.802	262.04	CAT
1078.748	257.65	CAT
1079.786	174.90	CAT
1081.675	−3.40	CAT
1082.669	−79.72	CAT
1101.719	−150.00	CAT

man et al. 1997). Based on the spectral type, we assume a mass of 0.98 ± 0.06 $M_\odot$ (Lang 1992, p. 132). This star has a companion, ADS 13886B, that is fainter by 3 mag and separated by about 4″. The linear separation of the two components is about 150 AU, so this stellar companion has no impact on the velocities discussed here. The spectrum of HD 195019 is not contaminated by AC 13886B because this secondary star is relatively faint and the angular separation is sufficient to spatially resolve the two components.

Figure 1 (*top*) shows a spectral window centered on the Ca II K line for HD 195019. There is no apparent core emission, and the derived S value (0.189) implies a rotation period of 22 days, $\log R'HK = -4.85$, and log age = 9.5 yr. The spectral lines are narrow, which supports slow stellar rotation, and we measure a radial velocity of −93.1 ± 2 km s^{-1}. The space motions for this star are consistent with those of old disk stars. The *Hipparcos* parallax of 26.77 mas yields $M_V = 4.01$, about 0.7 mag brighter than expected for a ZAMS G3 star. There are two possible explanations that we cannot distinguish between at this time. If the Ca II H and K diagnostic is correct, then the star could be metal rich. We estimate that [Fe/H] ∼ + 0.30 could result in the observed shift from the ZAMS for this star. If HD 195019 is metal rich, it may be akin to τ Boo, which has [Fe/H] = +0.25 (Gonzalez 1998). However, this interpretation would require significant contamination of the *ubvy* photometry by the unresolved companion and seems unlikely given the relative faintness of the companion. Alternatively, the star may be slightly evolved with solar metallicity (from *ubv*y photometry), consistent with the luminosity classification and observed space motions. In either case, the chromospheric activity in this star is low, and we expect that activity-associated spots (see Butler et al. 1998) are an unlikely

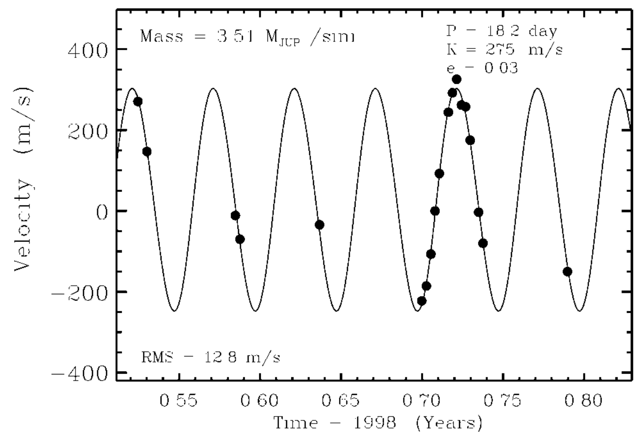

Fig. 2.—Combined Lick and Keck radial velocities for HD 195019. The solid line is the radial velocity curve from the best-fit orbital solution.

explanation for the observed Doppler shifts. Photometric observations of HD 195019 would provide additional discriminating evidence.

The spectral format at Lick Observatory includes the Li I resonance line at 6707.8 Å. The spectral resolution of the Hamilton spectrograph, $R = 50{,}000$, is sufficient to resolve the Li I line from an adjacent feature at 6707.45 Å. Three consecutive observations were co-added to build the S/N to 140. The composite spectrum was then used to derive $\log N(\mathrm{Li}) \leq 0.6$ in HD 195019. This lithium abundance was determined from a bilinear interpolation of a lithium curve of growth (Soderblom et al. 1993a) and is given on a scale where $\log N(\mathrm{H}) = 12.0$. The abundance determination assumes $T_{\mathrm{eff}} = 5600$ K (derived from a calibration to $B-V = 0.66$; Soderblom et al. 1993b) and an upper limit to the line equivalent width of 2.0 mÅ. Since the $B-V$ color is uncorrected for the unresolved stellar companion, the true temperature of the star may be hotter by almost 100 K. This would increase the upper limit in the derived lithium abundance to 0.8. For comparison, the abundance of lithium in the Sun is $\log N(\mathrm{Li}) \sim 1.0$.

Twelve velocity measurements for HD 195019 were obtained over a 4 month period at Lick Observatory and were combined with seven observations from Keck as previously described. To phase the Lick and Keck data, a velocity shift of −128 m s^{-1} was applied to all of the Keck velocities. The velocities (shifted to a common zero point), Julian date of observations, and the telescope used to obtain the velocites are listed in Table 1. In Table 1, the Shane telescope is the 3 m telescope at Lick Observatory, the Keck is the 10 m telescope, and the CAT is the 0.6 Coudé Auxiliary Telescope at Lick. A periodogram analysis reveals a strong peak at 18.27 days for the combined data set. The best-fit Keplerian is shown in Figure 2. The internal velocity errors from the S/N ∼ 100 observations with the 3 m Shane telescope at Lick were initially about 12.8 m s^{-1}. These were reduced to about 7 m s^{-1} by combining velocity measurements from three consecutive half-hour CAT obser-

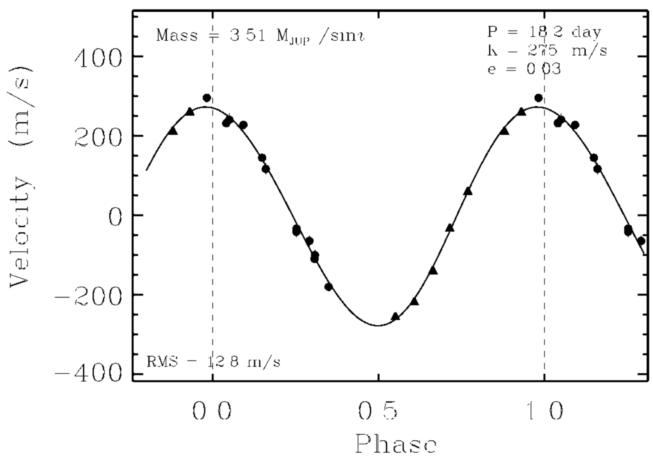

FIG. 3.—Combined Lick and Keck radial velocities plotted vs. orbital phase for HD 195019. The filled circles represent Lick observations, and the triangles represent Keck observations. The solid line is the radial velocity curve from the orbital solution for the combined data set.

TABLE 2
ORBITAL PARAMETERS

Parameter	HD 195019	HD 217107
P (days)	18.27 (0.14)	7.12 (0.02)
T_{max} (JD)[a]	2451072.16 (1.6)	2451067.42 (0.30)
e	0.03 (0.02)	0.14 (0.05)
ω (deg)[b]	250 (31)	19 (14)
K_1 (m s^{-1})	275.28 (5.0)	139.5 (4.1)
$a_1 \sin i$ (AU)	4.6×10^{-4}	9.0×10^{-5}
f_1 (m) ($M_\odot$)	3.94×10^{-8}	1.94×10^{-9}
$M_2 \sin i$ (M_{Jup})	3.51 (0.4)	1.27 (0.4)
Nobs[c]	19	21

[a] Time of velocity maximum.
[b] ω is poorly constrained for nearly circular orbits.
[c] Number of observations from both Lick and Keck. Velocities obtained within a 2 hr period at Lick are averaged values.

vations after this star was identified as a planet candidate. The Keck observations had S/N ∼ 300 with velocity errors of about 6 m s^{-1}. The internal velocity errors from Keck stem both from photon statistics (2 m s^{-1}) and systematic errors that are currently being investigated. Figure 3 shows a phased velocity plot containing all data for HD 195019. The triangles represent Keck observations, and the circles represent Lick observations. The best-fit Keplerian for the combined data yields an orbital period of 18.27 ± 0.14 days, a semiamplitude $K = 275 \pm 5$ m s^{-1}, and an eccentricity of 0.03 ± 0.03 with an rms to the fit of the Keplerian curve of 12.8 m s^{-1}. With our assumed mass of 0.98 $M_\odot$ for HD 195019, the orbital solution suggests a companion mass $M \sin i = 3.51 \pm 0.4$ M_{JUP}. The uncertainty in the mass of the companion is derived from the uncertainty in the stellar mass. The orbital elements for HD 195019 are summarized in Table 2.

4. OBSERVATIONS: HD 217107

The *Hipparcos* catalog lists a spectral classification of G8 IV for HD 217107 (=HR 8734, =HIP 113421) and $B-V = 0.744$. The apparent magnitude, $V = 6.17$, and *Hipparcos* parallax of 50.71 mas provide $M_V = 4.70$, about 0.7 mag above the zero-age main sequence (Lang 1992, p. 132). Our calibration of *ubvy* photometry suggests that this is a G7 V star with a metallicity [Fe/H] = 0.29 ± 0.1. Fine spectral analysis should be carried out for this star to verify the metallicity derived here. This higher metallicity would explain the position of this star on the color-magnitude diagram. For a solar metallicity G7 or G8 star, the mass estimate would be approximately 0.9 $M_\odot$. However, we estimate that the enhanced metallicity will result in a correction to the mass of the star of 0.1 $M_\odot$. We adopt an intermediate value of 0.96 ± 0.06 $M_\odot$ for HD 217107. The lack of emission in the Ca II H and K lines (Fig. 1, *middle*) implies that this star is chromospherically inactive. The measured S value (0.15) yields $P_{rot} = 39$ days, $\log R'HK = -5.0$, and log age = 9.89 yr. This star has disk motions similar to the Sun with an unusually low transverse velocity (<2 km s^{-1}) and a radial velocity of −14.0 ± 2 km s^{-1}.

The lithium abundance is also subsolar in this star. Three consecutive observations with composite S/N of 180 were used to set an upper limit in the equivalent width of Li I 6707.8 Å as 2 mÅ. Adopting $T_{eff} = 5360$ (calibrated to $B-V = 0.744$), we find $\log N(\mathrm{Li}) \leq 0.4$.

Fourteen velocity measurements were obtained at Lick Observatory over the 4 month interval from 1988 July to October and were combined with seven observations from Keck. The internal velocity errors at Lick were initially 9.6 m s^{-1} and were later reduced to about 6 m s^{-1} by combining velocity measurements for three half-hour CAT observations obtained after HD 217107 was confirmed as a planet candidate at Keck. The internal velocity errors at Keck were about 6 m s^{-1}. The velocity offset between Keck and Lick data was found to be zero, and the velocities are listed in Table 3. A periodogram analysis of the combined velocities revealed a strong peak at 7.11 days. A Keplerian fit to the data, shown in Figure 4, yields the following orbital parameters: an orbital period of 7.12 ± 0.02 days, $K = 139.5 \pm 4.1$ m s^{-1}, and eccentricity = 0.14 ± 0.05 (see Table 2). The Keplerian fit had an rms = 14.6 m s^{-1}. The inferred companion mass, $M \sin i$, is 1.27 ± 0.4 M_{JUP}. The phased plot for the combined data sets is shown in Figure 5.

5. DISCUSSION

We have added nearly 200 new stars to the Lick planet search. In July and August, we observed 82 of these stars, and here we present two planet candidates around the chromospherically quiet G dwarfs, HD 195019 and HD 217107. The planet around HD 195019 has an orbital period of 18.27 days, similar to that of 55 Cnc ($P = 14.7$ days). The periodicity in

TABLE 3
RADIAL VELOCITIES FOR HD 217107

JD −2,450,000	RV (m s^{-1})	Telescope
1005.962	−76.55	Shane
1006.967	−68.69	Shane
1014.918	−29.73	Shane
1025.980	39.86	Shane
1027.941	−61.34	Shane
1049.811	−73.70	Shane
1068.860	54.01	Keck
1069.973	−41.24	Keck
1070.954	−49.35	Keck
1071.869	−6.99	Keck
1072.929	101.97	Keck
1074.870	195.79	Keck
1075.826	71.13	Keck
1076.800	−35.83	CAT
1077.872	−56.74	CAT
1078.817	0.00	CAT
1079.724	71.96	CAT
1079.859	92.17	CAT
1081.743	225.55	CAT
1100.756	35.90	CAT
1101.759	127.44	CAT

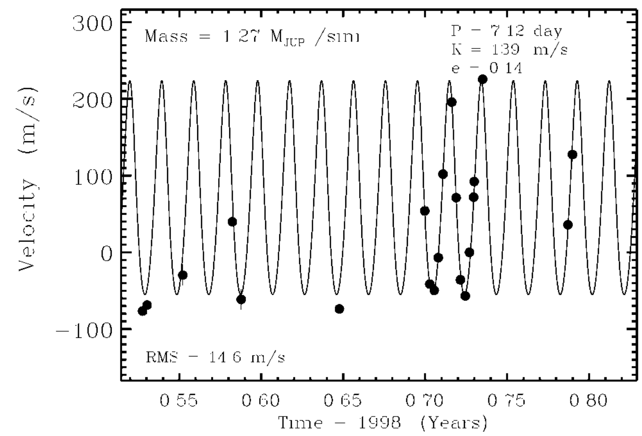

FIG. 4.—Combined Lick and Keck radial velocities for HD 217107. The solid line is the radial velocity curve from the orbital solution for the combined data set.

the radial velocities is similar to the rotation period (22 days) derived from a measure of the Ca II H and K emission. However, while astrophysical processes can mimic Keplerian velocity signals in chromospherically active stars with periodicities of a few days, we do not expect that modulation would occur in a chromospherically inactive star such as HD 195019. Photometric observations will provide an important diagnostic here. The orbital eccentricity of HD 195019 is 0.03 ± 0.03, and the companion mass, $M \sin i$, is 3.51 $M_{\rm JUP}$. The companion to HD 217107 has an orbital period of 7.12 days, an eccentricity of 0.14 ± 0.05, and $M \sin i = 1.27$ $M_{\rm JUP}$. Tidal effects are not expected to have circularized gas giants with orbital periods longer than a few days (Terquem et al. 1998; Ford et al. 1999; Marcy et al. 1997), so the nearly circular orbits derived for these two stars may be primordial.

Based on *ubvy* photometry, HD 195019 appears to have solar metallicity, and HD 217107 appears to be metal rich with [Fe/H] = +0.29. This lends some additional evidence favoring the suggestion that stars with close-in, gas giants may be metal rich relative to the general population of field stars (Gonzalez 1998). Fine spectral analysis of both stars is needed to confirm these results.

Figure 6 shows the distribution of detected planetary companions in a two-parameter plane of companion mass (in $M_{\rm JUP}$) and orbital period. The points representing HD 195019 and HD 217107 are labeled so that they may be more easily compared with the other extrasolar planet detections. Figure 6 also includes two planet detections, HD 168443 and HD 210277 (Marcy et al. 1998b), slightly in advance of publication because they add to the interpretation of this figure. Both of these soon-to-be announced planets have highly eccentric orbits that further highlight the observation that eccentric orbits are not uncommon. Orbits with eccentricities exceeding 0.20 are circled with an ellipse. The choice of a 0.2 eccentricity threshold is arbitrary; it was chosen because it marks cases in which the derived eccentricity clearly exceeds the uncertainty.

Also shown in Figure 6 are two radial velocity detectability curves. The detectability curves are based on Monte Carlo simulations that add Gaussian noise to the velocity curve of a test secondary mass with a given orbital period. For orbital periods longer than the extent of the radial velocity program, each phase of the velocity curve is tested. When the scatter in the velocity plus noise is detectable at the 95% confidence level by an *F*-ratio test, the secondary mass is deemed detectable. One of the curves demarcates the (small) regime in this two-

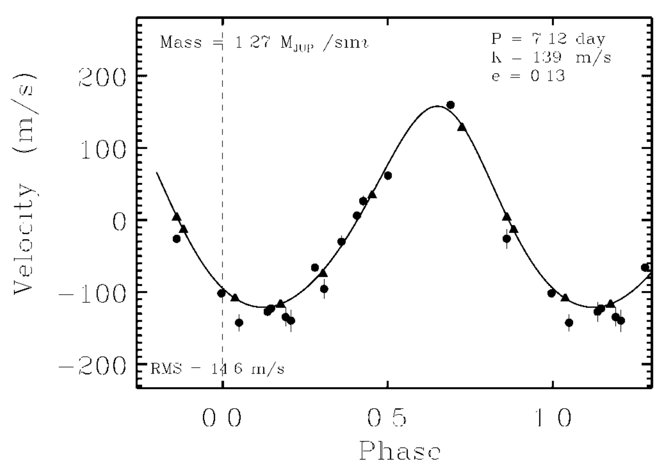

FIG. 5.—Combined Lick and Keck radial velocities for HD 217107, plotted vs. orbital phase. Filled circles are from Lick, and triangles come from Keck. The solid line is the radial velocity curve from the orbital solution.

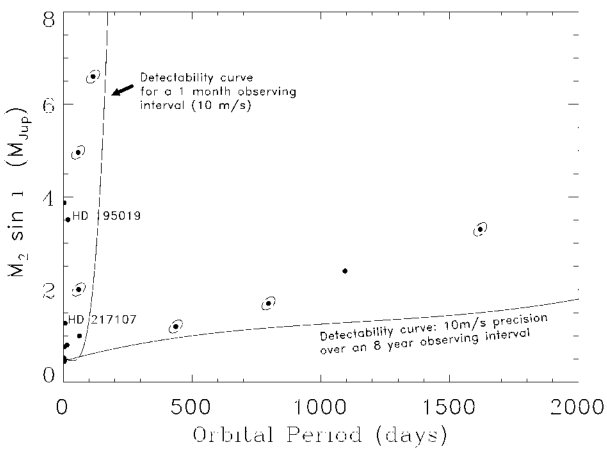

FIG. 6.—Detected planet companions from all surveys to date, including two soon-to-be announced planets (Marcy et al. 1998b). The planets in this paper, HD 195019 and HD 217107, are labeled. Orbital solutions with eccentricities greater than 0.20 are circled with ellipses. Two radial velocity detectability curves are plotted. The curve rising up to the left of the plot simulates a 1 month observing interval with five observations per star (similar to our campaign in July). Planets with orbital periods to the left of this curve could have been detected. The other curve models the detectability regime of the standard Lick planet search. It assumes an observing interval of 8 yr with four observations per year. Companions above this longer detectability curve could have been found in the sample of stars observed at Lick since 1987. Both curves assume a radial velocity precision of 10 m s^{-1}.

parameter space in which planets could have been detected during our initial observations of new sample stars last July. It assumes an observing interval of 1 month with five evenly spaced observations per star, circular orbits, an average value for the inclination ($\pi/4$), and a velocity precision of 10 m s^{-1}. The second detectability curve makes the same assumptions but with an observing interval of 8 yr and four observations per star per year (typical of the original, ongoing Lick program). Given the distribution of detected companions in Figure 6, even the limited sampling of five observations over a 1 month interval appears to be fairly efficient sieve for planets in the new sample. However, analogs to 51 Peg with low-velocity amplitudes could have escaped detection with the velocity precision and sampling frequency employed here. It is interesting that the parameter space outside of the "1 month" detectability curve is not particularly rich in companions. Such companions could have been detected in the long-term project at Lick Observatory. The absence of brown dwarfs that would have been easily detected is also striking.

We derive $M \sin i$, rather than M, for the planet candidates. The question of whether these planets could actually be brown dwarfs or low-mass stars has been considered by Marcy & Butler (1996). Spectroscopic companions with $M \sin i =$ 5 M_{JUP} would have stellar masses (above 70 M_{JUP}) if the orbit were 4° or less from a face-on orientation. Statistically, this inclination will occur in about 0.2% of randomly oriented orbits. To estimate the probability that a planet candidate is actually a stellar companion, the 0.2% inclination probability must be multiplied by the probability that a star is a binary system with a low-mass companion in the relevant separation range. Integrating the mass and separation distribution (Duquennoy & Mayor 1991) suggests that about 8% of solar-type stars could have such a stellar companion. So, statistically, one in 6250 surveyed stars could disguise a stellar companion as a 5 M_{JUP} spectroscopic companion, but only a few hundred solar-type stars have been surveyed for these companions. Alternatively, a 5 M_{JUP} companion could be a 40 M_{JUP} brown dwarf. Since the mass function of brown dwarfs is unknown, we can set only an upper limit to this probability based on the low orbital inclination probability. However, there appears to be a vanishingly small number of companions with $M \sin i$ greater than 10 M_{JUP}, which suggests that brown dwarf companions to solar-type stars are rare (Mayor et al. 1999).

Additional constraints supporting the low-mass, planetary nature of these companions comes from models of tidal interactions between the star and planet. If the companion to HD 217107 were more massive than 11 M_{JUP}, it is expected that tidal torques would have spun up the convective envelope of the star to match the orbital period (Terquem et al. 1998). However the rotation period of the star is estimated to be 39 days (based on the Ca II H and K lines), while the orbital period is only 7.11 days.

The survey at Observatoire de Haute-Provence (Mayor & Queloz 1995) discovered 51 Peg in a survey of 140 solar-type stars. The original Lick project surveyed 107 stars, and 1.9% of those stars (τ Boo, υ And; Butler et al. 1997) were found to have companions with circularized orbits and periods of a few days. The 82 new Lick stars were observed 4–5 times over a 3 week interval with an initial precision of only 10 m s^{-1} in the hopes of identifying 51 Peg analogs. Neither of the planets presented in this paper qualifes as 51 Peg analogs as their orbital periods are too long. It is possible that there are no such systems in the sample that we have observed so far. However, we do not believe this is a conclusive result. In retrospect, we believe that the initial lower precision of 10 m s^{-1} and the small number of observations (four or five per star) was inadequate to detect the one or two low-amplitude, short-period systems that might still exist in the sample. We will continue to monitor these new additions to the Lick program long term and with higher Doppler precision.

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