The Astrophysical Journal, 652:1694–1697, 2006 December 1

IMPACT OF STELLAR DYNAMICS ON THE FREQUENCY OF GIANT PLANETS IN CLOSE BINARIES

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Received 2006 June 27; accepted 2006 August 14

ABSTRACT

Hostile tidal forces may inhibit the formation of Jovian planets in binaries with semimajor axes of $\lesssim$50 AU, binaries that might be called "close" in this context. As an alternative to in situ planet formation, a binary can acquire a giant planet when one of its original members is replaced in a dynamical interaction with another star that hosts a planet. Simple scaling relations for the structure and evolution of star clusters, coupled with analytic arguments regarding binary-single and binary-binary scattering, indicate that dynamical processes can deposit Jovian planets in $<$1% of close binaries. If ongoing and future exoplanet surveys measure a much larger fraction, it may be that giant planets do somehow form frequently in such systems.

Subject headings: binaries: general — open clusters and associations: general — planetary systems — stellar dynamics

1. INTRODUCTION

Surveys using the Doppler technique have identified over 150 extrasolar planets in the last decade. The available data reveal important clues to the formation of giant planets around *single* stars (e.g., Marcy et al. 2005). Comparatively little is known about the population of *binary* star systems that harbor planets. Past planet searches have largely excluded known binaries with angular separations of $\lesssim 1''$, where blending of the two stellar spectra decreases the sensitivity to small velocity shifts. Roughly 30 planets have been detected around stars in binaries (Raghavan et al. 2006). Most of these binaries are very wide, although several have separations of $\lesssim$20 AU, small enough to challenge standard ideas on Jovian planet formation. Many more of these compact systems must be found before we can draw robust conclusions.

In an ongoing targeted search for planets in close, double-lined, spectroscopic binaries, Konacki (2005) discovered a "hot Jupiter" orbiting the outlying member of the hierarchical triple star HD 188753. The inner binary is sufficiently compact that its influence on the third star is essentially that of a point mass. What is intriguing about this system is that a disk around the planetary host star would be tidally truncated at a radius of only $\simeq$1 AU, perhaps leaving insufficient material to produce a Jovian-mass planet (Jang-Condell 2006). Broader questions of how a binary companion impacts planet formation have been explored in the literature.

If a protoplanetary disk is tidally truncated at $\lesssim$10 AU, stirring by the tidal field may prevent the growth of icy grains and planetesimals, as well as stabilize the disk against fragmentation (Nelson 2000; Thébault et al. 2004, 2006). In this case, neither the core-accretion scenario (e.g., Lissauer 1993) nor gravitational instability (e.g., Boss 2000) are accessible modes of giant planet formation. However, the tidal field might also trigger fragmentation of a marginally stable disk (Boss 2006). Whether or not giant planet formation is inhibited in close binaries remains an open problem.

These uncertainties are circumvented if one member of a close binary is divorced from its original companion and acquires a new partner star with a planet in tow. An example of such an event is an exchange interaction between a binary and a single star in a cluster environment. Pfahl (2005) and Portegies Zwart & McMillan (2005) proposed a form of this idea as a solution to the puzzle of HD 188753. Here we present a more general account of dynamical processes that deposit giant planets in binaries hostile to planet formation. We focus exclusively on encounters that mix a binary and a single star or two binaries. Higher order multiples are neglected here but deserve further attention in light of HD 188753.

We define "close binary" in § 2. An overview of binary scattering dynamics is given in § 3. Various aspects of star clusters are summarized in § 4. Ingredients from §§ 3 and 4 are combined in § 5 to estimate the frequency of giant planets in close binaries. In § 6, our results are discussed in the context of current exoplanet surveys.

2. OPERATIONAL DEFINITION OF A CLOSE BINARY

Here "close binary" refers to the influence of each star's gravity on the formation and dynamics of planets around its companion. Consider a binary with semimajor axis a, eccentricity e, and stellar masses M_1 and M_2, and define $q = M_1/M_2$ and $\mu = M_2/(M_1 + M_2)$. A disk around star 1 is tidally truncated at a radius (Pichardo et al. 2005)

$$R_t = \left[0.733 f_{\rm E}(q)\mu^{0.07}\right] a(1-e)^{1.2}, \tag{1}$$

where $f_{\rm E}(q) = 0.49[0.6 + q^{-2/3} \ln(1 + q^{1/3})]^{-1}$ is the Roche lobe function of Eggleton (1983). When $q = 0.1$–10 the bracketed quantity in equation (1) is $\simeq$0.15–0.36. We suppose that giant planets form only if $R_t \gtrsim 5$–10 AU and $a(1-e)^{1.2} \gtrsim$20–40 AU ($q \sim 1$). In practice, we define a close binary by $a < 50$ AU.

Whether a planet forms in a binary or arrives there dynamically it has a maximum orbital radius $a_{p,\max}$ around its host star before it is stripped away. Holman & Wiegert (1999) mapped the range of stable planetary orbits as a function of e and μ. Their polynomial fit is matched to within 15% by

$$a_{p,\max} = [0.7 f_{\rm E}(q)] a(1-e)^{1.2}, \tag{2}$$

a function inspired by equation (1).

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3. FEW-BODY DYNAMICS

By assumption, all close binaries would be barren of Jovian planets if not for exchange interactions in their parent clusters. Before the exchange, the third star must be single or part of a binary wide enough to permit giant planet formation. Exchange is the most robust dynamical channel for generating close binaries with planets. Scattering rarely transforms a wide binary into a close binary, as discussed below. The main purpose of this section is to present exchange cross sections for binary-single and binary-binary scattering.

In binary-single scattering, a binary with semimajor axis a and component masses M_1 and M_2 approaches a single star of mass M_3 with a relative speed u at infinity. Let $M_{12} = M_1 + M_2$ and $M_{123} = M_1 + M_2 + M_3$; other combinations are defined analogously. The total system energy vanishes at a critical relative speed of $u_c = (G\tilde{M}/a)^{1/2}$, which has a value of $\simeq 3$ km s^{-1} when $\tilde{M} = 1\ M_\odot$ and $a = 100$ AU, where $\tilde{M} = M_1 M_2 M_{123}/M_3 M_{12}$ (e.g., Hut & Bahcall 1983). For a close binary in an open cluster, we expect $u \sim 1$ km s^{-1} (see § 4) and $u/u_c < 1$, implying that the total energy is negative and a binary must remain after the interaction. If M_3 passes within $\sim a$ from the binary barycenter, the binary may be strongly perturbed or have an exchange. The corresponding cross section is $\sim \Sigma_f = 2\pi a G M_{123} u^{-2}$, determined by gravitational focusing. When the masses are similar, a large fraction of such interactions result in exchange, so we write the binary-single exchange cross section as $\Sigma_{\rm bs} = \eta_{\rm bs}\Sigma_f$, where typically $\eta_{\rm bs}(M_1, M_2, M_3) \lesssim 1$ (see below).

Large differences between initial and final binary energies are suppressed by a probability factor $|\Delta E|^{-9/2}$, as shown analytically by Heggie (1975) and Heggie & Hut (1993). If M_3 replaces M_1 and a' is the new semimajor axis, then we expect $M_1 M_2/a' \sim M_2 M_3/a$ and $a'/a \sim M_3/M_1$. For $M_1 \sim M_2$, we have $\Sigma_{\rm bs} \sim \Sigma_f (M_3/M_{13})^{7/2} (M_{123}/M_{12})^{1/3}$, based on the analytic scaling relations of Heggie et al. (1996). Although $a'/a \ll 1$ is possible when $M_3/M_1 \ll 1$, exchange is inhibited by $(M_3/M_{13})^{7/2}$. When $M_3/M_1 \gg 1$, the chances of exchange and $a'/a \gg 1$ are enhanced, but $M_3/M_1 \gg 1$ is unlikely if M_3 is drawn from a stellar mass function such as $p(M_3) \propto M_3^{-2.3}$. Based on these arguments, we neglect the shrinkage of wide binaries and the expansion of close binaries.

A close binary is more likely to encounter a wide binary with semimajor axis $a_w > 50$ AU than a single star (for overviews of binary-binary scattering, see Mikkola 1983, 1984). The cross section for the two binaries to pass closer than $\sim a_w$ has the focusing value, $\sim 2\pi a_w G M_{1234} u^{-2}$, when $a_w \lesssim 10^3$ AU. When $a_w/a \simeq 1$ the probability is high for exchange of one star in the close binary with a star in the wide binary. As a_w/a increases, there is a decrease in the relative target area of the close binary and the fraction of encounters that result in exchange. In the limit $a_w/a \gg 1$, this fraction should scale as a/a_w, since a star in the wide system must approach within $\sim a$ of the close binary. Metastable hierarchical triples, which ultimately dissolve into a binary and single star (e.g., Mardling & Aarseth 2001), often result from binary-binary scattering, which may enhance the exchange fraction somewhat. We let $\Sigma_{\rm bb} = \eta_{\rm bb} 2\pi a G M_{1234} u^{-2}$, where $\eta_{\rm bb}$ depends on the masses and weakly on a. We expect $\eta_{\rm bb} \lesssim 5$ typically, but this must be checked numerically.

Observations indicate that giant planets orbit $\sim 10\%$ of single F, G, and K stars (Marcy et al. 2005). A similar fraction should apply to stars captured by close binaries in exchange encounters. Dynamics of the stars are usually little affected by a planet, but the planet's orbit may be disrupted. Let a_p denote the semimajor axis of the planetary orbit. Hut & Inagaki (1985) and Fregeau et al. (2004) estimate a cross section of $\simeq 2\Sigma_f (a_p/a)^{0.4}$ for two stars to pass within a distance a_p during a binary-single interaction with $M_1 = M_2 = M_3$ and $u/u_c \simeq 1$. Such an approach typically causes the planet to be ejected from the system, although there is a significant probability for it to become bound to the other star (Fregeau et al. 2006). If $a_p > 1$ AU there is a fair chance that the planet will be lost in an exchange encounter (see Laughlin & Adams 1998 for a related discussion). Even if the planet survives the few-body interaction, its orbit may not have long-term stability (see eq. [2]). We incorporate the fraction of stars with planets and the ejection probability by absorbing an ad hoc, constant factor $f_p \lesssim 0.1$ into $\Sigma_{\rm bs}$ and $\Sigma_{\rm bb}$ (see § 5).

4. STATISTICS OF CLUSTERS AND THEIR STARS

As many as 90% of all stars form in clusters with $\sim 10^2$–10^3 members (e.g., Lada & Lada 2003). Most clusters disintegrate in <100 Myr, releasing their stars into the Galaxy. Within 100 pc of the Sun, a volume containing most exoplanet discoveries, there are $\sim 10^5$ binaries contributed by thousands of clusters. We aim to determine the percentage of close binaries in this population that harbor giant planets as a result of dynamics. Since the solar neighborhood samples many stellar birth sites, our analysis can utilize the gross statistical properties of clusters, which we now summarize.

Infant clusters are embedded in gas and dust that dominate the system mass (Lada & Lada 2003). Embedded clusters (ECs) are easily disrupted if the diffuse material is expelled rapidly (e.g., Hills 1980). The EC phase lasts for $\lesssim 5$ Myr and coincides with the critical growth stages of giant planets (e.g., Lissauer 1993). Only $\lesssim 10\%$ of ECs survive to become classical open clusters (Lada & Lada 2003) but may lose more than half of their stars following gas expulsion (e.g., Boily & Kroupa 2003; Adams et al. 2006). Open clusters (OCs) are also subject to destructive processes, as reflected in their low median age of 200 Myr and the small fraction ($\simeq 2\%$) older than 1 Gyr (e.g., Wielen 1985).

For our purposes, a cluster is adequately described by four parameters: the number of stars N, radius r_h enclosing half of the cluster mass M_c (gas and stars), mean stellar density $n_h = 3N/8\pi r_h^3$ inside r_h, and characteristic stellar speed $\sigma = (GM_c/r_h)^{1/2}$. ECs have radii scattered about the trend $r_h({\rm EC}) \simeq N_2^{1/2}$ pc (Adams et al. 2006) and masses of $\simeq 3N\langle M\rangle$ for a 30% star formation efficiency, where $N_2 = N/100$ and $\langle M\rangle \simeq 0.5\ M_\odot$ is the mean stellar mass. We see that $n_h({\rm EC}) \simeq 10 N_2^{-1/2}$ pc^{-3} and $\sigma({\rm EC}) \simeq N_2^{1/4}$ km s^{-1}. OCs have $r_h({\rm OC}) \simeq 1$–5 pc with a weak dependence on N and cluster age. We use a fixed value of $r_h({\rm OC}) = 1$ pc, so that $n_h({\rm OC}) \simeq 10 N_2$ pc^{-3} and $\sigma({\rm OC}) \simeq 0.5 N_2^{1/2}$ km s^{-1}.

The natural unit of time for measuring changes in cluster structure is the half-mass relaxation time,

$$t_{\rm rh} \sim \left(\frac{r_h^3}{GM_c}\right)^{1/2} \frac{0.1N}{\ln N} \simeq 4\left(\frac{r_h}{1\ {\rm pc}}\right)^{3/2} N_2^{1/2}\ {\rm Myr}, \tag{3}$$

where we set $\ln N = 5$. The EC phase is so short ($\lesssim t_{\rm rh}$) that $r_h({\rm EC})$, $n_h({\rm EC})$, and $\sigma({\rm EC})$ change very little. An OC dissolves as relaxation drives stars across its tidal boundary; half of the stars escape in a time $T \sim 100 t_{\rm rh}$. Simulations show N dropping almost linearly, $N(t)/N(0) = 1 - t/2T$, where $N(0)$ is the number just after the EC phase (e.g., Terlevich 1987; Portegies Zwart et al. 2001). The function $T = 100 N_2^{1/2}(0)$ Myr is consistent with simulations and our kinematical scalings. This is an upper limit to the true half-life, since OC decay is hastened by encounters with molecular clouds (e.g., Wielen 1985). Binaries have little impact on the evolution of typical open clusters (e.g., Kroupa 1995b), unlike in dense globular clusters, where binaries can strongly modify the dynamics of core collapse.

An average of some combination of the above N-dependent functions over the cluster ensemble (see § 5) requires the differential N-distribution. For both ECs and young OCs the distribution is nearly $p(N) \propto N^{-2}$ for $N \sim 10^2$–10^3 (e.g., Elmegreen & Efremov 1997; Lada & Lada 2003; Adams et al. 2006). While the most massive known ECs have a few $\times 10^3$ stars, some old OCs probably had $\gtrsim 10^4$ stars initially (e.g., M67; Hurley et al. 2005). As a specific choice, we use the range $N = 10^2$–10^4 for both ECs and young OCs.

Stellar multiples in clusters must have proportions similar to those in the Galactic field, where $\simeq$50%, $\simeq$10%, and $\simeq$5% of stars are binary, triple, and quadruple, respectively (e.g., Duquennoy & Mayor 1991). Semimajor axes of field binaries span $\sim 10^{-2}$ to 10^4 AU and follow a lognormal distribution with a mean and variance of $\langle \log a(\mathrm{AU}) \rangle \simeq 1.5$ and $\sigma_{\log a} \simeq 1.5$ (e.g., Duquennoy & Mayor 1991). Over any small range in a, $p(a) \propto a^{-1}$ is a good approximation. The fraction of binaries that are close ($a \lesssim 50$ AU) is $f_{\rm cb} \simeq 0.5$. Cluster binary statistics evolve due to dynamical encounters, but this is evident mainly for systems with $a \gtrsim 10^3$ AU (e.g., Kroupa 1995a).

5. FRACTION OF CLOSE BINARIES WITH GIANT PLANETS

We now estimate the fraction of close binaries that acquire giant planets dynamically in clusters. First, we compute the rate for a close binary in a cluster to have a favorable interaction. Then the cumulative rate for all close binaries is integrated over the cluster lifetime. This number is averaged over all clusters, and the result is divided by the mean number of close binaries per cluster. Each step is detailed below for binary-single scattering. The binary-binary calculation is completely analogous, and only the final result is quoted. Note that we neglect interactions between binaries and stars in the Galactic disk after a cluster dissolves.

Imagine a close binary moving through a cluster of N stars. Near the target binary, singles and binaries have densities n_s and n_b, respectively. We let $n_s = f_s n$, $n_b = f_b n$, and $f_s + f_b = 1$ and assume that f_s and f_b are independent of N, t, and position within the cluster. We assume that all objects have a Maxwellian speed distribution with one-dimensional velocity dispersion σ. Relative speeds u then also follow a Maxwellian distribution, but with dispersion $\sqrt{2}\sigma$. The rate for the target binary to acquire a single star and its planet is

$$\begin{aligned} n_s \langle \Sigma_{\rm bs} u \rangle &= 2\sqrt{\pi} n_s f_p a G \langle \eta_{\rm bs} M_{123} \rangle \sigma^{-1} \\ &\simeq 7.5 \times 10^{-12} n_1 a_2 \sigma_0^{-1} \left(\frac{f_p}{0.1} \frac{\langle \eta_{\rm bs} M_{123} \rangle}{M_\odot} \right) \mathrm{yr}^{-1}, \quad (4) \end{aligned}$$

where $n_1 = n_s / 10\ \mathrm{pc}^{-3}$, $a_2 = a/100$ AU, $\sigma_0 = \sigma / 1\ \mathrm{km\ s}^{-1}$, and the angled brackets denote averages over u and M_3. If n_s and σ take their characteristic values for an open cluster (see § 4), we find that over the half-life T the planet-capture probability is $\sim 10^{-3} N_2 a_2$; such encounters are rare. Since $n_s \langle \Sigma_{\rm bs} u \rangle \propto a$, the a-distribution for close binaries that do acquire planets may be nearly flat if the primordial distribution is $\propto a^{-1}$.

Integration of $n_s \langle \Sigma_{\rm bs} u \rangle$ over all close binaries and the cluster lifetime gives the total number of planet captures from binary-single exchange encounters:

$$\begin{aligned} N_{\rm bs} &= \int dt \int dV\, n_b n_s \langle\langle \Sigma_{\rm bs} u \rangle\rangle \\ &= 2\sqrt{\pi} f_s f_b f_p G \langle\langle a \eta_{\rm bs} M_{123} \rangle\rangle \int dt\, \sigma^{-1} \int dV\, n^2, \quad (5) \end{aligned}$$

where dV is a volume element, n_b is the local number density of binaries (close and wide), and double brackets denote averages over u, the M_i, and a for the close binaries. Among close binaries, the mean a is $\sim$10 AU. The volume integral picks out the formal mean density: $\int dV\, n^2 = \int dN\, n \equiv N \langle n \rangle$. Density profiles appropriate for open clusters have $\langle n \rangle \simeq n_h$; we equate these two densities.

The approximate scaling relations in § 4 allow us to evaluate $N_{\rm bs}$ for ECs and OCs. We assume that the EC phase lasts 10^7 yr and has fixed N, which gives

$$N_{\rm bs}(\mathrm{EC}) \simeq 0.0002 N_2^{1/4} \left(\frac{f_s}{0.5} \frac{f_b}{0.5} \frac{f_p}{0.1} \frac{\langle\langle a \eta_{\rm bs} M_{123} \rangle\rangle}{10\ \mathrm{AU}\ M_\odot} \right). \quad (6)$$

If the number of open-cluster stars drops linearly in time (see § 4), integration over the full lifetime $2T$ gives

$$N_{\rm bs}(\mathrm{OC}) \simeq 0.003 N_2^2 \left(\frac{f_s}{0.5} \frac{f_b}{0.5} \frac{f_p}{0.1} \frac{\langle\langle a \eta_{\rm bs} M_{123} \rangle\rangle}{10\ \mathrm{AU}\ M_\odot} \right), \quad (7)$$

where $N_2 = N(0)/100$. For the fraction $f_{\rm OC} \lesssim 0.1$ of newly minted clusters that are destined to be open, the early embedded phase yields only a small correction to $N_{\rm bs}$.

Each cluster disperses $f_b f_{\rm cb} N$ close binaries into the Galaxy. Using $p(N)$ in § 4, we sum $N_{\rm bs}$ over an ensemble of clusters and divide by the total number of close binaries to obtain the fraction of all close binaries that acquire a planet via binary-single exchange:

$$\begin{aligned} F_{\rm bs} &\simeq \frac{f_{\rm OC} \langle N_{\rm bs}(\mathrm{OC}) \rangle + (1 - f_{\rm OC}) \langle N_{\rm bs}(\mathrm{EC}) \rangle}{f_b f_{\rm cb} \langle N \rangle} \\ &\simeq 0.0003 \left(\frac{f_{\rm OC}}{0.1} \frac{0.5}{f_{\rm cb}} \frac{f_s}{0.5} \frac{f_p}{0.1} \frac{\langle\langle a \eta_{\rm bs} M_{123} \rangle\rangle}{10\ \mathrm{AU}\ M_\odot} \right), \quad (8) \end{aligned}$$

where the overall contribution from ECs is negligible. For binary-binary scattering, we replace n_s and $\Sigma_{\rm bs}$ with n_b and $\Sigma_{\rm bb}$ in equation (5) and estimate

$$F_{\rm bb} \simeq 0.0003 \left(\frac{f_{\rm OC}}{0.1} \frac{0.5}{f_{\rm cb}} \frac{f_b}{0.5} \frac{f_p}{0.1} \frac{\langle\langle a \eta_{\rm bb} M_{1234} \rangle\rangle}{10\ \mathrm{AU}\ M_\odot} \right), \quad (9)$$

where we expect $\langle\langle a \eta_{\rm bb} M_{1234} \rangle\rangle \lesssim 100$ AU $M_\odot$ (see § 3).

The fraction of all close binaries that capture giant planets is $F_{\rm ex} = F_{\rm bs} + F_{\rm bb} \lesssim 10^{-3}$ if the above parameters take their plausible fiducial values. Reasonable variations in our adopted scaling relations or more accurate cross sections might yield $F_{\rm ex} \sim 10^{-2}$. Small values of $F_{\rm ex}$ result from the relative rarity of suitable exchange encounters in open clusters (see the text below eq. [4]). For future theoretical work, we recommend a systematic study of few-body interactions including planets in order to obtain better cross sections. Complementary N-body simulations of clusters with binaries and planets would stringently test of our assertions.

6. COMPARISON TO OBSERVATIONS

Raghavan et al. (2006; see also Eggenberger et al. 2004) find that $\simeq$30 of $\simeq$130 exoplanet host stars have binary companions, most with separations of 10^2–10^4 AU. Only five systems (see Table 1) are candidate close binaries; two are technically triples. The objects in Table 1 were observed in different surveys, each with different criteria to select targets. This makes it difficult to empirically estimate the fraction, F, of close binaries with giant planets. Given that $\simeq$3000 stars have been searched for planets,

TABLE 1

Close Binaries with Planets

Object	a (AU)	e[a]	M_1/M_2[b]	R_t (AU)	Refs.
HD 188753[c]	12.3	0.50	1.06/1.63	1.3	1
γ Cep	18.5	0.36	1.59/0.34	3.6	2, 3
GJ 86[d]	~20	...	0.7/1.0	~5	4, 5, 6
HD 41004[e]	~20	...	0.7/0.4	~6	7
HD 196885	~25	...	1.3/0.6	~7	8

[a] When no eccentricity is given, only the projected binary separation is known.
[b] Planetary host mass divided by companion mass.
[c] The secondary is a binary with semimajor axis 0.67 AU.
[d] The secondary is a white dwarf of mass $\simeq 0.5\ M_\odot$. To estimate R_t, we assumed an original companion mass of 1 $M_\odot$.
[e] The secondary is orbited by a brown dwarf with a 1.3 day period.

References.—(1) Konacki 2005; (2) Campbell et al. 1988; (3) Hatzes et al. 2003; (4) Queloz et al. 2000; (5) Mugrauer & Neuhäuser 2005; (6) Lagrange et al. 2006; (7) Zucker et al. 2004; (8) Chauvin et al. 2006.

the vast majority of which are not close binaries, the expectation is that $F \gg 0.1\%$.

Known spectroscopic binaries with angular separations of $\lesssim 1''$–$2''$ have been largely overlooked in Doppler surveys. HD 41004, HD 196885, GJ 86, and γ Cep have relatively large angular separations of $\simeq 0''.5$, $\simeq 0''.7$, $\simeq 1''$, and $2''$, respectively. Perhaps more importantly, the secondary stars in these systems are sufficiently faint that the primary's spectrum is not greatly contaminated. The serious selection effects against discovering giant planets in close binaries strengthen the notion that $F \gg 0.1\%$.

We note that $F \sim 1\%$ is consistent with the discovery of a planet in HD 188753 by Konacki (2005), who has so far conducted a cursory analysis of $\simeq 100$ binaries. A similar fraction follows from the limited Campbell et al. (1988) survey of 16 stars that ultimately led to the detection of a planet in γ Cep (Hatzes et al. 2003). Our preferred value for the contribution to F from dynamics is $\sim 0.1\%$. If future surveys verify that $F \sim 1\%$, this may signal that giant planets do form in close binaries, despite the seemingly unfavorable conditions.

Several exoplanet searches that specifically target close binaries are now underway. Konacki's spectroscopic survey includes $\simeq 100$ known binaries with projected separations of 10–60 AU and distances of 30–300 pc. The Palomar High-precision Astrometric Search for Exoplanet Systems (PHASES; Lane & Muterspaugh 2004; Muterspaugh et al. 2005) at the Palomar Testbed Interferometer (Colavita et al. 1999) aims to monitor $\simeq 50$ visual binaries, 16 of which also belong to Konacki's radial-velocity sample. Udry et al. (2004) report on the first steps in a campaign to spectroscopically search for planets in $\simeq 100$ single-line spectroscopic binaries with 2–50 yr periods ($a \simeq$ 2–15 AU).

We thank Phil Arras and the referee, John Chambers, for valuable comments and Maciej Konacki for providing details on his survey. E. P. was supported by NSF grant PHY 99-07949. M. M. was supported by the Michelson Graduate Fellowship and NASA grant NNG05GJ58G issued through the *Terrestrial Planet Finder* Foundation Science Program. M. M. appreciates the hospitality of the KITP during the week in which this work began.

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