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THE β PICTORIS MOVING GROUP

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ABSTRACT

Following the 1983 *IRAS* detection and subsequent imaging of its extensive dusty circumstellar disk, β Pictoris became the prototypical and most studied example of a potential forming planetary system. Here we report the identification of 17 star systems, each with one or more characteristics indicative of extreme youth, that are moving through space together with β Pic. This diverse set of ∼12 million yr old star systems, which includes a ∼35 Jupiter mass brown dwarf, and a wide assortment of dusty circumstellar disks, is the comoving, youthful group closest to Earth. Their unique combination of youth and proximity to Earth makes group members—many of which have masses similar to that of the Sun—prime candidates for imaging of warm planets and dusty circumstellar disks with ground- and space-based telescopes.

Subject headings: open clusters and associations: individual (β Pictoris) — stars: kinematics — stars: pre–main-sequence

1. INTRODUCTION

The past few years have seen the discovery of numerous massive extrasolar planets (Marcy, Cochran, & Mayor 2000). All have been detected indirectly, by virtue of their gravitational tug on the star about which they orbit. Only when planets are imaged directly will it be possible to measure their spectra and thus their compositions. Advances in astronomy from the ground, specifically, adaptive optics (AO; Beckers 1993), and the employment of an infrared camera on the *Hubble Space Telescope* (*HST*), now enable imaging detection of planets with masses comparable to that of Jupiter (Macintosh et al. 2001). A caveat is that such detections must be of thermal emission from young, warm planets rather than of reflected starlight from old, cold planets, such as Jupiter. At wavelengths near a few microns, thermal emission from a giant planet that is not older than a few tens of millions of years can be hundreds of times brighter than reflected starlight; the latter is still much too faint to be detected with any existing imaging system.

The giant planets of our solar system are 5–30 times more distant from the Sun than is Earth. Given the diffraction and instrumental scattered light properties of AO and of *HST*, imaging of solar system analogs requires finding stars within ∼40 pc of Earth not older than a few tens of millions of years. This is a challenging task, notwithstanding tremendous recent advances in the discovery of "young stars near Earth" (Jayawardhana & Greene 2001); indeed, until recently, few, if any, such stars had been identified.

An early suggestion that β Pictoris might be as young as 10 Myr (Jura et al. 1993) was "hard to swallow" because of the apparent isolation of β Pic in space. Then, Barrado y Navascués et al. (1999) found that the low-mass star systems GJ 799 and GJ 803 are moving through space together with β Pic. Hence, all three stars likely formed in proximity and at nearly the same time. Using standard techniques, Barrado y Navascués et al. (1999) estimated that GJ 799 and GJ 803, and thus β Pic, are 20 ± 10 million yr old.

It is a consensus that most stars, especially relatively massive ones such as β Pic, form in clusters or associations containing dozens to hundreds of members. These associations dissociate with time, but if β Pic is indeed as young as ∼20 Myr, then we would expect it to have comoving, coeval companions in addition to GJ 799 and GJ 803. Here we report the identification of 15 such companion systems (Table 1) where we define a "system" to contain a star with a *Hipparcos* catalog number. Four of these were found as part of our spectroscopic program at Siding Spring Observatory in New South Wales, Australia. The others were identified from data in the published literature sometimes augmented by our supplementary observations. The total number of stars plus brown dwarfs in Table 1 is 28.

2. OBSERVATIONS

At Siding Spring, we are in the midst of an extensive survey to identify young stars near Earth (I. Song, M. S. Bessell, & B. Zuckerman 2001, in preparation). We are using the double-beam grating spectrograph (DBS) and the echelle spectrograph on the two Nasmyth foci of the Australian National University's 2.3 m telescope. The red channel of the DBS covered the spectral range 6500–7450 Å at a measured resolution of 1.16 Å. The blue-beam data are discussed in I. Song et al. (2001, in preparation).

Eight orders of the echelle covered portions of the spectra between 5800 and 7230 Å but with rather large gaps between the orders. We focused our attention on orders that contained the Hα and lithium 6708 Å lines. In these orders, the measured resolution was 0.40 Å. Radial velocities were determined by cross-correlating target and standard spectra over five or six spectral orders. Projected rotational velocities (v sin i) were measured from a total of about 10 lines in the Li 6708 Å echelle order with a procedure similar to that described in Strassmeier et al. (1990). The DBS and echelle spectra, obtained in various ob-

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TABLE 1
THE β PICTORIS MOVING GROUP

HIP	Other Name	R.A.	Decl.	Spectral Type	Distance (pc)	V (mag)	$V-I_C$ [a]	$v \sin i$ (km s^{-1})	L_X/L_{bol} [b] ($\times 10^{-3}$)	(U, V, W)[c] (km s^{-1})	Notes
560 ……….	HR 9	00 06 50.0	−23 06 27	F2 IV	39.1	6.19	0.461	155	0.005	−11.2, −15.0, −10.1	1
21547 …….	51 Eri	04 37 36.1	−02 28 24	F0 V	29.8	5.22	0.342	95	…	−13.9, −16.0, −10.3	1, 2
	GJ 3305	04 37 37.3	−02 29 37	M0.5	29.8	10.59	1.90	…	3.2	…	2
23309 …….		05 00 47.1	−57 15 26	M0/1	26.3	10.01	1.79	11	0.3	−10.9, −15.4, −8.1	3
25486 …….	HD 35850	05 27 04.7	−11 54 03	F7	26.8	6.30	0.616	50	0.3	−10.3, −15.1, −8.0	4
27321 …….	β Pic	05 47 17.1	−51 04 00	A3 V	19.3	3.85	0.199	139	…	−10.8, −16.4, −8.9	1, 3
29964 …….	AO Men	06 18 28.2	−72 02 42	K6/7	38.5	9.77	1.34	13	1.3	−10.3, −15.2, −8.2	3
76629 …….	V343 Nor	15 38 57.6	−57 42 27	K0 V	39.8	8.14	0.93	11	0.6	−11.2, −15.7, −9.4	3
79881 …….	HR 6070	16 18 17.9	−28 36 50	A0	43.0	4.80	−0.01	30	…	−13.6, −16.8, −12.4	1
84586 …….	HD 155555A	17 17 25.5	−66 57 02	G5 IV	31.4	7.21	0.81	37	0.95	−10.6, −15.1, −8.2	5
	HD 155555B	17 17 25.5	−66 57 02	K0 IV/V	31.4	8.08	1.09	34	0.95	…	5
	HD 155555C	17 17 27.7	−66 57 00	M4.5	31.4	12.71	2.69	…	0.95	…	5
88399 …….	HD 164249	18 03 03.4	−51 38 56	F5 V	46.9	7.01	0.53	20	0.33	−7.3, −15.4, −8.8	3, 6
88726 …….	HR 6749	18 06 49.9	−43 25 30	A5 V	43.9	5.67	0.26	…	…	−11.4, −17.3, −10.0	1, 7
92024 …….	HD 172555	18 45 26.9	−64 52 15	A7	29.2	4.78	0.204	134	0.002	−10.9, −15.8, −8.8	1, 8
	CD −64°1208	18 45 36.9	−64 51 48	K7	29.2	9.54	1.545	$\gg$[d]	0.86	…	9
92680 …….	PZ Tel	18 53 05.9	−50 10 49	K0 Vp	49.7	8.25	0.85	63	0.77	−7.7, −16.6, −9.2	
95261 …….	HR 7329	19 22 51.2	−54 25 25	A0 Vn	47.7	5.05	0.04	$\gg$[d]	…	−10.8, −14.7, −7.7	1, 10
	HR 7329B	19 22 51.3	−54 25 29	M7/8 V	47.7	11.93[e]	…	…	…	…	
95270 …….	HD 181327	19 22 58.9	−54 32 16	F5.5	50.6	7.03	0.53	16	…	−10.1, −16.0, −8.8	10
102141 ……	GJ 799	20 41 51.0	−32 26 04	M4.5e	10.2	11.02	2.90	…	1.3	−9.6, −16.8, −11.1	7, 11
102409 ……	GJ 803	20 45 09.3	−31 20 24	M1e	9.9	8.81	2.10	9	1.4	−10.5, −16.6, −10.2	11, 12
103311 ……	HD 199143	20 55 47.7	−17 06 51	F8 V	47.7	7.34	0.62	120	0.45	−9.1, −14.7, −10.6	13
	BD −17°6128	20 56 02.7	−17 10 54	K7/M0	47.7	10.6	…	12	0.36	−9.0, −15.0, −10.8	13

NOTES.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds. (1) On A star zero-age main sequence (Jura et al. 1998). (2) Binary: listed *ROSAT* flux and L_X/L_{bol} are for the secondary. (3) See Table 2 for additional details. (4) See Tagliaferri et al. 1997, Mathioudakis & Mullan 1999, and Gagné et al. 1999 for additional details. See Silverstone 2000 for *Infrared Space Observatory* far-IR excess flux. (5) *ROSAT* X-ray flux (and thus L_X/L_{bol}) is for total of A + B + C; see Pasquini et al. 1991, Martin & Brandner 1995, Hatzes & Kürster 1999, and Strassmeier & Rice 2000 for additional details. (6) See Silverstone 2000 for *IRAS* excess flux. (7) Equal brightness binary; m_v is for each individual component. (8) See Coté 1987 and Mannings & Barlow 1998 for *IRAS* excess fluxes. (9) Spectral type is estimated from BVR_CI_C photometry (B. Shobbrook 2001, private communication); $V = 9.535$, $B-V = 1.189$, $V-R_C = 0.757$, and $V-I_C = 1.545$. A spectrum obtained by M. Buxton (2001, private communication) with the DBS shows strong Hα in emission (EW ∼ 2.2 Å), a strong Li 6708 Å feature (EW ∼ 580 mÅ), and fast rotation. The unusually strong Li for an ∼10 Myr old star may be due to the very fast rotation (Soderblom et al. 1993). (10) See Mannings & Barlow 1998 for *IRAS* excess fluxes. (11) See Barrado y Navascués et al. 1999 for additional details. (12) One of only two M-type stars not near a molecular cloud with *IRAS*-detected excess infrared emission (Song et al. 2001). (13) HD 199143 and BD −17°6128 are themselves both close unequal brightness binaries (D. Kaisler et al. 2001, in preparation), so this is a quadruple system; m_v is for the total of the primary and secondary at each named star.

[a] $V-I_C$ data are from many different sources (see I. Song, M. S. Bessell, & B. Zuckerman 2001, in preparation, for details).

[b] Ratio of X-ray luminosity (based on the *ROSAT All-Sky Survey* X-ray count rate) to total stellar luminosity.

[c] Based on averaged proper motions from PPM and *Hipparcos* catalogs. *UVW* are positive in the directions of the Galactic center, Galactic rotation, and the north Galactic pole. Errors in *UVW* are all smaller than 2.0 km s^{-1} in all components except for HIP 88399, 88726, and 92024, where poor radial velocity measurements result in errors, mainly in the U-component, of 3–5 km s^{-1}.

[d] $v \sin i \gtrsim 100$ km s^{-1}.

[e] H magnitude.

serving runs between 2001 January and June, were reduced and calibrated in IRAF. Additional details can be found in I. Song et al. (2001, in preparation).

With the echelle spectrograph, we measure stellar radial velocities, which, combined with proper motions and distances from the *Hipparcos* and Positions and Proper Motions (PPM) catalogs, yield Galactic three-dimensional space motions (*UVW*) with respect to the Sun. These measurements indicate that HIP 23309, 29964, 76629, and 88399 are comoving through space with β Pic (see Tables 1 and 2).

3. DISCUSSION

We considered ∼22,000 stars whose space motion can be calculated from data that exist in the literature, specifically, stars with measured radial velocities and with *Hipparcos* parallaxes. We searched for stars within 50 pc of Earth whose *UVW* velocity components are each within a few kilometers per second of those of β Pic. We further winnowed down this list by demanding that a star have at least one strong signpost of extreme youth. For stars listed in Table 1, these signs include (1) a large L_X/L_{bol} for GJ 3305, HIP 23309, 25486, 29964, 76629, 84586, 88399, 92680, 102141, 102409, and 103311, BD −17°6128, and CD −64°1208; (2) large $v \sin i$ (rapid rotation) for HIP 23309, 25486, 29964, 76629, 84586, 88399, 92680, 102409, and 103311, BD −17°6128, and CD −64°1208; (3) large lithium abundance for HIP 23309, 29964, 76629, 92680, and 102409, BD −17°6128, and CD −64°1208; (4) Hα in emission or filled in for HIP 23309, 29964, 92680, 102141, and 102409; (5) An A or early F dwarf on the zero-age main sequence for HIP 560, 21547, 27321, 79881, 88726, 92024, and 95261; (6) optical variability for HIP 29964, 76629, 84586, 92680, 102141, 102409, 103311, and BD −17°6128; (7) excess mid- or far-IR emission for HIP 25486, 27321, 88399, 92024, 95261, 95270, and 102409; and (8) for low-mass stars, a location well above the main sequence on a color-magnitude diagram (Fig. 1).

All 18 star systems that survived this procedure—"the β Pic moving group"—lie in the southern hemisphere (Table 1), notwithstanding that most of the 22,000 stars are located in the northern hemisphere. The average distance from Earth of the Table 1 systems is ∼35 pc. Because of the 50 pc cutoff in our sample selection and the fact that all Table 1 stars lie on one side of the sky, it is possible that members of the moving group remain to be identified at southern declinations beyond 50 pc.

TABLE 2
MEASURED AND DERIVED QUANTITIES[a]

Quantity	HIP 23309	HIP 29964[b] (HD 45081)	HIP 76629 (HD 139084)	HIP 88399 (HD 164249)	β Pic (HIP 27321)
$\mu_{\mathrm{R.A.}}$ (mas yr^{-1}):					
PPM	35	−11	−51	6.6	9.4
Hipparcos	36	−8	−53	3.5	4.7
$\mu_{\mathrm{decl.}}$ (mas yr^{-1}):					
PPM	76	75	−97	−93	79
Hipparcos	73	71	−106	−86	82
Radial velocity (km s^{-1})	17.8 ± 0.8	15.0 ± 1.0	0.5 ± 0.9	0.1 ± 3.0	20.2 ± 0.4
T_{eff} (K)	3810	4288	5250	6420	8500
$B-V$	1.421	1.11	0.82	0.458	0.171
V	10.01	9.77	8.06	7.01	3.85
$V-I_C$	1.79	1.34	0.93	…	0.18
J	…	7.55	…	…	3.55
H	…	6.99	…	…	3.47
K	…	6.81	…	…	3.49
Li 6708 EW (mÅ)[c]	294	357	261	92	…
Hα EW (Å)[d]	−0.81	−0.65	0.49	1.46	−
ROSAT (counts s^{-1})	0.33	1.03	1.42	0.15	…

[a] Radial velocity, Li, and Hα EWs for HIP 23309, 29964, and 76629 are from our echelle spectra; $B-V$, V, $V-I_C$ for HIP 23309 and 29964 are from L. Berdnikov (2001, private communication); J, H, and K for HIP 29964 are from the Two Micron All Sky Survey catalog; radial velocity for β Pic is from Barrado y Navascués et al. 1999. Colors and V for HIP 76629 are from Cutispoto et al. 1999.

[b] Cutispoto et al. 1999 list a set of measurements for HIP 29964; radial velocity $= 16.2 \pm 0.7$ km s^{-1}, $v \sin i = 17 \pm 2$ km s^{-1}, $(B-V) = 1.13$, $V = 9.80$, and $(V-I_C) = 1.32$. Average radial velocity of our value, 15.0 km s^{-1}, and Cutispoto et al.'s was used to calculate (U, V, W).

[c] Measured lithium equivalent widths corrected for the contribution of an Fe I λ6707.44 line. Corrections are 25, 19, 13, and 6 mÅ for HIP 23309, 29964, 76629, and 88399, respectively (Soderblom et al. 1993).

[d] Line core equivalent widths of Hα. The minus sign indicates emission.

Other known kinematically related associations of nearby young stars include Tucana/Horologium at 45 pc (Zuckerman & Webb 2000; Torres et al. 2000; Stelzer & Neuhäuser 2000; Zuckerman, Song, & Webb 2001), TW Hydrae at 60 pc (Kastner et al. 1997; Webb et al. 1999), and η Chamaeleontis at 97 pc (Mamajek, Lawson, & Feigelson 1999). These associations, which also are located in the southern hemisphere, are distinguishable by their differing age, space motions, and locations in space. Indeed, based on the V and W components of space motion and age diagnostics, we include in Table 1

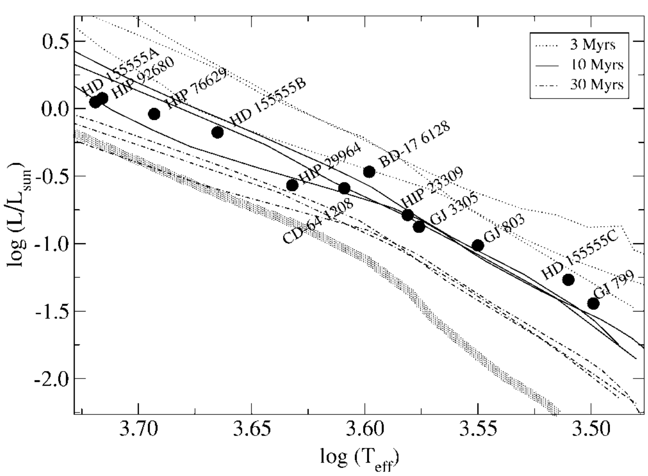

FIG. 1.—H-R diagram showing 3, 10, and 30 million yr solar metallicity isochrones from Siess, Dufour, & Forestini (2000), Palla & Stahler (1993), and D'Antona & Mazzitelli (1997). Measured quantities listed in Table 1 (V, $V-I_C$, and distance from Earth) were translated to luminosity (L) and effective temperature (T_{eff}) with relationships corresponding to the 12 Myr isochrone in Siess et al. (2000) with color-to-temperature conversions of Siess, Forestini, & Dougados (1997). For BD −17°6128, $L = 0.34 \pm 0.06\ L_\odot$ and $T_{\mathrm{eff}} =$ 3960 K were used (van den Ancker et al. 2001). The thick shaded line represents the zero-age main sequence from Siess et al. (2000).

three systems that were originally suggested to be members of the Tucana stream (HIP 92680, 95261, and 95270; Zuckerman & Webb 2000). HIP 95261 (HR 7329) has a brown dwarf companion of probable age ∼10 Myr and mass ∼35 times that of Jupiter (Lowrance et al. 2000; Guenther et al. 2001).

The associations listed above are of interest for various reasons. But when one's focus is the study of planets and circumstellar disks, the stars in the β Pic moving group have important advantages over all others because Table 1 stars are substantially closer than stars in TW Hydrae and η Chamaeleontis, and substantially younger than stars in Tucana/Horologium (see discussion below).

Not included in the above list of nearby very young associations is the unusual Capricornus group at 48 pc (van den Ancker et al. 2000) because we have subsumed it into the β Pic moving group. This resulted from our accurate measurement of the radial velocity of BD −17°6128 ($V_{\mathrm{rad}} = -6.3 \pm 0.9$ km s^{-1}; D. Kaisler et al. 2001, in preparation), which enabled us to calculate *UVW* for it and for HD 199143. In addition, with adaptive optics at the Lick Observatory 3 m telescope, we resolved both BD −17°6128 and HD 199143 as 1″–2″ separation binaries (D. Kaisler et al. 2001, in preparation).

To be listed in Table 1, in addition to having the same space motion as β Pic, a star must display at least one clear sign of extreme youth because some older and unrelated stars may accidentally have this same space motion. We estimated the expected number of such (old) stars as follows. From the set of ∼22,000 *Hipparcos* stars with radial velocities known from the literature, we found 497 stars within 50 pc of Earth with $-30 < U < 0$, $-30 < V < 0$, and $-20 < W < 0$. This volume [in (km s^{-1})^3] of *UVW* space is densely and fairly uniformly filled with the 497 stars and well encompasses the *UVW* range of the stars in Table 1. The *UVW* volume of Table 1 stars is 81 (km s^{-1})^3. Thus, we anticipate that two old stars would lie in the *UVW* volume of Table 1 stars, but none appear among the sample of 497. In addition, those few stars within 50 pc of Earth with *UVW* slightly outside of the volume of velocity space defined by Table 1 stars show no obvious signs of extreme youth.

The velocity range, $\leq \pm 2$ km s^{-1}, displayed by Table 1 stars is characteristic of velocity dispersions measured in star-forming interstellar molecular clouds. Thus, plausibly, the β Pic group formed in such a cloud or cloud complex. Some of the velocity dispersion apparent in *UVW* may be due to measurement error, especially in radial velocity. For most of the Table 1 stars, radial velocity errors are $\leq$2 km s^{-1}. For the A and early F-type stars and for rapidly rotating lower mass stars, radial velocity errors can be twice as large.

The large spatial extent of the β Pic moving group (at its young age) implies that it never formed a tightly bound cluster like the Pleiades. This is also apparent from the existence of many wide binaries (∼3000 AU) and the large velocity dispersion of Table 1 stars compared to Pleiades stars (velocity dispersion of 0.42 km s^{-1} per axis; Jones 1970).

The age of the β Pic moving group may be derived from the properties of its lower mass members, those of spectral type late K and M. Ages of young, low-mass stars may be estimated in two ways from theoretical models. One technique involves placement of a star on pre–main-sequence evolutionary tracks in a Hertzsprung-Russell (H-R) diagram; the other technique is based on the time required to deplete lithium in a stellar atmosphere. Based on the theoretical models, ages of ∼30 Myr have been estimated for stars in the Tucana and Horologium associations and ∼10 Myr for members of the TW Hydrae association. From the location on the H-R diagram (Fig. 1), other age indicators as listed above, and lithium equivalent widths intermediate in strength between Tucana-Horologium and TW Hydrae stars, we estimate that the β Pic moving group is 12^{+8}_{-4} Myr old. Thus, we define the group as nearby stars that have *UVW* velocity each within ∼2 km s^{-1} of those of β Pic and age consistent with 12 Myr.

Some stars in Table 1 have been extensively studied appearing in hundreds of papers listed in SIMBAD. At the opposite extreme, HIP 23309 is so obscure that, as of this writing, there are zero references to it in SIMBAD, despite its station as the star in Table 1 closest to β Pic (separation 8 pc). In any event, the existing literature portrays the stars in Table 1 as a hodgepodge of uncertain age and overall status; recognition as members of a common group of known age brings welcome order to this wonderfully diverse stellar collection.

4. CONCLUSION

The β Pic moving group contains many of the youngest, closest stars to Earth. All systems listed in Table 1 include a *Hipparcos* star so that parallaxes are known and, thus, *UVW* space motions can be calculated. In our program in progress at Siding Spring and Lick observatories, we have spectroscopically identified young, nearby Tycho Catalog stars that—pending measurements of accurate parallaxes so that *UVW* can be determined—may also be β Pic group members (I. Song, M. S. Bessell, & B. Zuckerman 2001, in preparation). As new ground- and space-based techniques and instruments are developed during the coming decades, surely members of the β Pic moving group will be prime targets in the investigation of forming planetary systems.

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REFERENCES

Barrado y Navascués, D., Stauffer, J. R., Song, I., & Caillault, J.-P. 1999, ApJ, 520, L123
Beckers, J. M. 1993, ARA&A, 31, 13
Coté, J. 1987, A&A, 181, 77
Cutispoto, G., Pastori, L., Tagliaferri, G., Messina, S., & Pallavicini, R. 1999, A&AS, 138, 87
D'Antona, R. A., & Mazzitelli, I. 1997, Mem. Soc. Astron. Italiana, 68, 807
Gagné, M., Valenti, J. A., Linsky, J. L., Tagliaferri, G., Covino, S., & Güdel, M. 1999, ApJ, 515, 423
Guenther, E. W., Neuhäuser, R., Huélamo, N., Brandner, W., & Alves, J. 2001, A&A, 365, 514
Hatzes, A. P., & Kürster, M. 1999, A&A, 346, 432
Jayawardhana, R., & Greene, T., eds. 2001, ASP Conf. Ser. 244, Young Stars near Earth: Progress and Prospects (San Francisco: ASP)
Jones, B. 1970, AJ, 75, 563
Jura, M., Malkan, M., White, R., Telesco, C., Pina, R., & Fisher, R. S. 1998, ApJ, 505, 897
Jura, M., Zuckerman, B., Becklin, E. E., & Smith, R. C. 1993, ApJ, 418, L37
Kastner, J. H., Zuckerman, B., Weintraub, D. A., & Forveille, T. 1997, Science, 277, 67
Lowrance, P. J., et al. 2000, ApJ, 541, 390
Macintosh, B., et al. 2001, in ASP Conf. Ser. 244, Young Stars near Earth: Progress and Prospects, ed. R. Jayawardhana & T. Greene (San Francisco: ASP), 309
Mamajek, E. E., Lawson, W. A., & Feigelson, E. D. 1999, ApJ, 516, L77
Mannings, V., & Barlow, M. J. 1998, ApJ, 497, 330
Marcy, G. W., Cochran, W. D., & Mayor, M. 2000, in Protostars and Planets IV, ed. V. Mannings, A. P. Boss, & S. S. Russell (Tucson: Univ. Arizona Press), 1285
Martin, E. L., & Brandner, W. 1995, A&A, 294, 744
Mathioudakis, M., & Mullan, D. J. 1999, A&A, 342, 524
Palla, F., & Stahler, S. W. 1993, ApJ, 418, 414
Pasquini, L., Cutispoto, G., Gratton, R., & Mayor, M. 1991, A&A, 248, 72
Siess, L., Dufour, E., & Forestini, M. 2000, A&A, 358, 593
Siess, L., Forestini, M., & Dougados, C. 1997, A&A, 324, 556
Silverstone, M. D. 2000, Ph.D. thesis, Univ. California, Los Angeles
Soderblom, D. R., Jones, B. F., Balachandran, S., Stauffer, J. R., Duncan, D. K., Fedele, S. B., & Hudon, J. D. 1993, AJ, 106, 1059
Song, I., Weinberger, A., Becklin, E. E., Zuckerman, B., & Chen, C. 2001, AJ, in press
Stelzer, B., & Neuhäuser, R. 2000, A&A, 361, 581
Strassmeier, K. G., Fekel, F. C., Bopp, B. W., Dempsey, R. C., & Henry, G. W. 1990, ApJS, 72, 191
Strassmeier, K. G., & Rice, J. B. 2000, A&A, 360, 1019
Tagliaferri, G., Covino, S., Fleming, T. A., Gagne, M., Pallavicini, R., Haardt, F., & Uchida, Y. 1997, A&A, 321, 850
Torres, C. A. O., da Silva, L., Quast, G. R., de la Reza, R., & Jilinski, E. 2000, AJ, 120, 1410
van den Ancker, M. E., Pérez, M. R., de Winter, D., & McCollum, B. 2000, A&A, 363, L25
van den Ancker, M. E., et al. 2001, in ASP Conf. Ser. 244, Young Stars near Earth: Progress and Prospects, ed. R. Jayawardhana & T. Greene (San Francisco: ASP), 69
Webb, R. A., Zuckerman, B., Platais, I., Patience, J., White, R. J., Schwartz, M. J., & McCarthy, C. 1999, ApJ, 512, L63
Zuckerman, B., Song, I., & Webb, R. A. 2001, ApJ, 559, 388
Zuckerman, B., & Webb, R. A. 2000, ApJ, 535, 959