PUBLICATIONS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, **119**: 828–829, 2007 July
© 2007. The Astronomical Society of the Pacific. All rights reserved. Printed in U.S.A.

Dissertation Summary

Knowing Our Neighbors: Fundamental Properties of Nearby Stars

JENNIFER LYNN BARTLETT
Current address: US Naval Observatory, Washington, DC; jbartlett@usno.navy.mil
Thesis work conducted at University of Virginia
Ph.D. thesis directed by Philip A. Ianna; Ph.D. degree awarded 2007 January 4

Received 2007 May 24; accepted 2007 May 31; published 2007 July 17

The stars within 25 pc constitute the sample that we aspire to know thoroughly. A well-understood, volume-limited sample of nearby stars is an essential input for the stellar luminosity function, the mass-luminosity relationship, the stellar velocity distribution, and the stellar multiplicity fraction, including substellar companions. Such samples help define stellar populations and estimate the amount mass contributed by local stars. In addition, the stars in this volume provide insight into stellar evolution and the history of star formation in the disk. These physical relationships and subsamples describe the makeup of our Galaxy and, by extension, more distant galaxies (Kuiper 1942; Reid & Cruz 2002). However, models are being developed from an incomplete catalog with limited parameters. Although trigonometric parallaxes establish both sample membership and the cosmic distance scale, many objects within reach of ground-based telescopes remain unmeasured. To advance the solar neighborhood census, observations of 56 nearby stars are presented, including astrometric companion search results, along with a possible a new infrared parallax program.

Among these nearby stars, Barnard's star is a fascinating M dwarf, not only because of its nearness and high proper motion, but also because of van de Kamp's (1963) announcement that it had a planet. However, PDS scans and analyses of 900+ Leander McCormick Observatory photographic plates failed to detect any planets. This time-series analysis using Lomb-Scargle periodograms (Press et al. 1996) would have detected planets with 2.2 Jupiter masses (M_J) or greater. Prior to the time-series analysis, the relative parallax, proper motion, and secular acceleration of Barnard's star were measured to be 546 ± 1 mas, $10.3612'' \pm 0.0002''$ yr^{-1} in $355.905° \pm 0.001°$, and 1.25 ± 0.04 mas yr^{-2}, respectively. The available photometry and spectroscopy of the 12 reference stars used indicate a correction to absolute of 6 ± 7 mas would be necessary, resulting in an absolute parallax of 552 ± 7 mas, corresponding to a distance of 1.81 ± 0.02 pc and a transverse velocity of 89 km s^{-1}. These results are comparable to those obtained with more modern equipment.

An additional search for potential nearby planets was undertaken through similar time-series analyses of stars in the University of Virginia Southern Parallax Program (SPP; Ianna 1993). For 12 stars (LHS 34, 271, 337, 532, 1134, 1565, 2310, 2739, 2813, 3064, 3242, and 3418), no indication of any unseen companions was detected. However, LHS 288 shows trends suggestive of a $2.4M_J$ planet in a 7 yr orbit. These high proper motion stars all lie within the solar neighborhood. With the exception of the white dwarf LHS 34, these stars are M dwarfs. After a minimum of 50 observations spread over at least 3 years, the relative parallax solutions have errors of less than 3 mas. An upper limit to the mass of companions remaining undetected was established for each star individually; for long-period orbits, these range from $1.7M_J$ to $18M_J$. The lack of any clear signal due to a companion may suggest that gas giants are less common around M dwarfs than solar-type stars.

Before astrometric companions are investigated, trigonometric parallaxes are obtained that can establish membership in the solar neighborhood. A subsample of 43 potential nearby stars was included in the Cerro Tololo Inter-American Observatory Parallax Investigation (CTIOPI), based on less accurate photometric and spectroscopic distance estimates. Astrometric, photometric, and spectroscopic observations began in 2003 December. Although at least another year of observations is anticipated to finalize these measurements, preliminary results based on observations through mid-2006 are available.

According to preliminary parallaxes from this CTIOPI subsample, 28 of the stars are probable members of the solar neighborhood, including three stars (LP 991-84, LHS 6167, and LP 876-10) that apparently lie within 10 pc. Three more stars lie near the 25 pc boundary, and their final parallaxes may still qualify them as members. In addition, LP 869-26 is an apparent binary with newly resolved components separated by approximately $0.7'' \pm 0.3''$. The nearest stars tend to display large proper motions. As expected, high proper motion stars predominate in this subsample. Preliminary proper motions indicate that nine stars have proper motions greater than $0.5''$ yr^{-1}, with 2MASS 02511490−0352459 and 23062928−0502285 moving more than $1.0''$ yr^{-1}. For this subsample, the proper motions convert to tangential velocities that range from about 10 to 129 km s^{-1}.

Previously unidentified members of the solar neighborhood are anticipated to be so cool, red, and dim that they were missed in previous studies. Preliminary photometry (V_C, R_C, and I_C) is available for 16 stars in this CTIOPI subsample. These stars range from approximately 10th to 20th magnitude in V_C. In comparison, the *Hipparcos* catalog is thought to be complete to about 9th magnitude in V (Perryman et al. 1997). The available absolute V magnitudes range from approximately 11th to 19th magnitude. New spectral types are available for 32 M dwarfs of the subsample, which range from M3.0 V for LP 776-025 to M8.5 V for 2MASS 23062928−0502285. At least 70% of the stars in the solar neighborhood are expected to be M dwarfs (Henry et al. 2002).

M dwarf primaries may be less common than primaries of earlier spectral types (Fischer & Marcy 1992). Three close binaries and four common proper motion pairs were previously identified in this CTIOPI subsample. However, preliminary parallaxes for LP 731-76 and BD −10 3166 indicate that they are probably not physically related. In addition to resolving LP 869-26AB, the preliminary parallaxes for 11 stars indicate that they are at least 1.5 times more distant than photometric or spectroscopic estimates; unresolved components might explain these discrepancies. Consequently, this subsample of M dwarfs may contain as many as 18 multiples, which is similar to the 42% found by Fischer & Marcy (1992).

Despite the continuing importance of ground-based parallax measurements, few active programs remain. In addition, because of the likelihood that new members of the solar neighborhood belong to the late M, L, and T classes, the ability to measure parallaxes in the infrared would be helpful. To these ends, the astrometric quality of the new infrared camera on the 31 inch (0.8 m) Tinsley reflector at Fan Mountain Observatory in Covesville, Virginia, was assessed. The Virginia Astronomical Instrumentation Laboratory (VAIL) developed and installed this instrument, FanCam (S. Kanneganti et al. 2007, in preparation), which saw first light in 2004 December. When mounted, FanCam has a 27.56″ mm^{-1} scale and an 8.7″ field of view. The detector is a Rockwell Hawaii I HgCdTe, 1k × 1k focal plane array with 18.5 μm pixels (0.5″ pixel^{-1}). Its rms read noise is 17 e^{-}. FanCam is equipped with multiple filters, including 2MASS J, H, and K_s (S. Kanneganti et al. 2007, in preparation).

To evaluate the potential for an infrared parallax program using FanCam, 68 exposures of an open cluster (NGC 2420) taken with the J filter in a range of hour angles during 2005 January, February, and November were selected. Exposures lasted from 2 to 30 s. Flat-fielding of images followed procedures and used IRAF routines being developed for FanCam (C. Park 2006, private communication). Positions of 16 astrometric evaluation stars were then measured using the SPP image reduction pipeline. The repeatability of measured positions was assessed using the mean error in a single observation of unit weight.

The precision for all frames considered is 1.31 $\pm$ 0.67 μm and 1.34 $\pm$ 0.77 μm in x (R.A.) and y (decl.), respectively. Although CCDs in the visual and near-infrared routinely achieve greater precision, these values are within the range reported for the infrared parallax program at the US Naval Observatory. Vrba et al. (2004) report preliminary parallaxes with average mean errors of unit weight of 1.15 $\pm$ 0.36 μm and 1.32 $\pm$ 0.36 μm in x and y, respectively. Therefore, an infrared parallax program with FanCam would be feasible. Such a program could provide much needed distances for brown dwarfs and very low mass stars and contribute significantly to the solar neighborhood census.

The fundamental volume-limited solar neighborhood sample is the foundation for understanding our Milky Way, including its component stars and populations. The observations reported here have identified new members of that sample and characterized them in terms of position, distance, transverse velocity, luminosity, spectral type, and multiplicity. Through this and similar efforts, the census is becoming more complete and increasingly detailed.

M. Begam, R. Patterson, T. Henry, W.-C. Jao, J. Subasavage, T. Beaulieu, the RECONS team, M. Skrutskie, C. Park, S. Kanneganti, and VAIL assisted with various stages of this research. NSF grants AST 98-20711 (PI: P. Ianna) and 05-07711, Georgia State University (subcontract of NASA-SIM project), Litton Marine Systems, the University of Virginia, Hampden-Sydney College, and the Levinson Fund of the Peninsula Community Foundation supported this research. The ANU Research School of Astronomy and Astrophysics provided generous observing time allocations. CTIOPI was an NOAO Survey Program and continues as part of the SMARTS Consortium.

REFERENCES

Fischer, D. A., & Marcy, G. W. 1992, ApJ, 396, 178
Henry, T., Walkowicz, L. M., Barto, T. C., & Golimowski, D. 2002, AJ, 123, 2002
Ianna, P. A. 1993, in IAU Symp. 156, Developments in Astrometry and Their Impact on Astrophysics and Geodynamics, ed. I. Mueller & B. Kolaczek (Dordrecht: Kluwer), 75
Kuiper, G. P. 1942, ApJ, 95, 201
Perryman, M. A. C., et al. 1997, A&A, 323, L49
Press, W., Teukolsky, S., Vetterling, W., & Flannery, B. 1996, Numerical Recipes in FORTRAN 77, Vol. 1 (2nd ed.; New York: Cambridge Univ. Press)
Reid, I. N., & Cruz, K. L. 2002, AJ, 123, 2806
van de Kamp, P. 1963, AJ, 68, 515
Vrba, F. J., et al. 2004, AJ, 127, 2948