Chapter 6 The Solar Neighborhood: Future Development

6.1 INTRODUCTION

The census of the solar neighborhood will command the efforts of astronomers for some time to come. Progress on the 5- and 10-parsec (pc) samples only exposes the incompleteness of the 20- and 25-pc samples. Finishing the innermost volume will allow additional effort to be put into the next shell. Technological improvements increase our access to the dimmest stars and substellar objects and enable us to expand the solar neighborhood. Each advance in our census flows outward and enhances many branches of astronomy. Despite great progress in determining the fundamental properties of nearby stars and measuring their distances through trigonometric parallaxes, this work has demonstrated that the census remains incomplete. Work on the defining solar neighborhood will continue well into this century.

6.2 BARNARD'S STAR

Although only a slight chance remains that the planets described by van de Kamp (1963b, 1982) orbit Barnard's Star (McCarthy *et al.*2007, in preparation), this work has contributed to our knowledge of the position and motion of the second closest stellar system to our own. However, the absolute parallax resulting from this study suffers from a large and highly uncertain correction to absolute (5.6 mas ± 6.7 mas), which is significantly larger than the corrections used by the United States Naval Observatory (Harrington *et al*. 1993) and Benedict *et al*. (1999). Therefore, the value of this final measurement from the Leander McCormick Observatory would benefit from additional data. Spectra were recently obtained for the reference stars using the 40-inch

reflector at Fan Mountain Observatory. Spectroscopic distances based on these spectra may improve the distances obtained using broad-band photometry and reduce the size and uncertainty in the correction to absolute.

Of historical interest, a time-series analysis, similar to that discussed in Chapter 2, could be applied to the measurements of Barnard's Star obtained by van de Kamp at Sproul Observatory (1982). For his final analysis, van de Kamp measured nearly 20,000 exposures on 4,580 plates taken on 1,200 nights between 1938 and 1981. This collection of Barnard's Star images is unique and is unlikely to be matched. If Sproul Observatory still has the measurements made with the Grant two-coordinate measuring machine (van de Kamp 1977a) and is willing to make those available, a time-series analysis would be relatively straight-forward. Such an effort could provide further insight into van de Kamp's work and the continuing debate on whether he could have detected the planets he described (1982).

6.3 SOUTHERN PARALLAX PROGRAM

The Southern Parallax Program (SPP) observed about ninety stars between 1987 and 2002, including those described in Chapter 3. Begam, Ianna, and Patterson are preparing the final parallaxes and proper motions for publication. Additional photometry is planned to improve the differential color refraction (DCR) corrections and to reduce the relative measurements to absolute ones.

Of the thirteen SPP stars tested for low mass companions, LHS 288 remains an intriguing possibility. Further monitoring of LHS 288, such as currently undertaken by the Research Consortium on Nearby Stars (RECONS) or possibly using the Hubble

Space Telescope (HST), could clarify whether the apparent signal is spurious or the product of a planet. The Cerro Tololo Inter-American Observatory (CTIO) Parallax Investigation (CTIOPI) recently published a parallax for LHS 288 (Henry *et al*. 2006); the residuals from that measurement could also be subjected to a time-series analysis to see whether similar periods emerge from that data set.

When selecting stars from the SPP for time-series analysis, we selected those with small errors in their relative parallaxes, which should be accompanied by small residuals. A perturbation due to a companion should stand out from the noise in those residuals. However, the small errors may be an indication that no orbital component is present. An alternative approach would have used larger errors to identify host candidates. The corresponding large residuals may be evidence of presence of an orbital component. On the other hand, the large error may merely reflect noisy or sparse data. Another selection from the ninety SPP stars using the second approach could be more fruitful and might also produce candidates for further monitoring. In addition, a comparison of the results of the two searches could provide guidance for future selections from other programs.

6.4 CTIOPI

The preliminary results from the CTIOPI subsample described in Chapter 4 are encouraging. When complete, this work will probably contribute twenty-nine stars to the solar neighborhood including three new members of the 10-pc sample. When the final parallaxes and proper motions are calculated, distances should also be obtained for the members of identified common proper motion pairs that were not determined during

this preliminary analysis. The dropped stars should be reconsidered for inclusion. In addition, when resources permit the expansion of CTIOPI again, the lists of possible nearby stars from which this subsample was drawn still contain more than two hundred candidates. Many of these CTIOPI stars will be potential targets for the Space Interferometry Mission (SIM).

As demonstrated in Chapters 2 and 3, once final parallaxes and proper motions are established, the resulting residuals can be tested for any periodic motion indicative of the presence of a low-mass companion. Therefore, a time-series analysis using the Lomb-Scargle method (Press *et al*. 1992) is a reasonable extension of a modern parallax program. Eventually, such an analysis should be carried out for selected stars in this CTIOPI subsample to determine whether any of these host planets. The detection or non-detection of such planets would provide additional insight into the frequency of planets around low mass stars.

6.5 FAN MOUNTAIN OBSERVATORY

The initial astrometric evaluation of the new infrared camera on the refurbished 31-inch reflector at Fan Mountain Observatory (Kanneganti *et al*. 2007, in preparation) indicates that the currently attainable precision is adequate to measure parallaxes. Chapter 5 suggests some improvements to the current hardware, software, and procedures that might improve the results achieved.

The determination of parallaxes and proper motions requires a multi-year commitment of observing time; CTIOPI measurements typically require four seasons of observations spread over 2.5 years (Jao *et al*. 2005). Before the University of Virginia

(UVa) commits to an infrared parallax program, some additional astrometric testing might be appropriate, including evaluation of possible higher-order plate constants, the analysis of stacked images, the assessment of the other proposed filters, and the measurement of an actual parallax. Other factors, such as weather patterns and light pollution at the site, will also play a role in the final decision. Anther consideration is whether a sufficient number of the brown dwarf candidates visible from Charlottesville are bright enough to be observed using FanCam. Should such a program go forward, it could make a significant contribution both to the nearby star census and to our knowledge of brown dwarfs generally.

6.6 DISCUSSION

Additional projects grow naturally from the work described herein, each of which would contribute to our knowledge of the nearest stars. Similarly, detecting and characterizing new members of the solar neighborhood will continue to put forward fresh questions about the solar neighborhood and the Milky Way Galaxy of which it is part. While each of these undertakings brings us closer to completing the 25-pc census, identifying the nearly 4,100 missing stellar systems within the current limits of the solar neighborhood is an ambitious mission. However, large-scale surveys, such as the recently dedicated Panoramic Survey Telescope and Rapid Response System (Pan-STARRS)[21] and planned Large Synoptic Survey Telescope (LSST)[22], should produce

[21]The University of Hawai'i maintains a website describing their new telescope at http://pan-starrs.ifa.hawaii.edu/public/

[22]The LSST Corporation maintains a website detailing their proposed telescope at http://www.lsst.org/lsst_home.shtml

immense quantities of astrometric data. Extracting information pertinent to the solar neighborhood will employ new techniques along with the traditional tools.

As we continue to develop our knowledge of the stars within the solar neighborhood, we will derive an appropriate sense of place within both our Milky Way Galaxy and the larger Universe. Someday, we hope to know thoroughly these stars that lie so close to our own Sun. For a limited volume, we may be able to claim that we can tell the number of the stars and call them by their names.