Searching Beyond the Obscuring Dust Between the Cygnus-Aquila Rifts for Cepheid Tracers of the Galaxy's Spiral Arms

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Abstract A campaign is described, open to participation by interested AAVSO members, of follow-up observations for newly-discovered Cepheid variables in undersampled and obscured regions of the Galaxy, a primary objective being to use these supergiants to clarify the Galaxy's spiral nature. Preliminary multiband photometric observations are presented for three Cepheids discovered beyond the obscuring dust between the Cygnus and Aquila Rifts ($40° \leq \ell \leq 50°$), a region reputedly tied to a segment of the Sagittarius-Carina arm which appears to cease unexpectedly. The data confirm the existence of exceptional extinction along the line of sight at upwards of $A_V \simeq 6$ magnitudes ($d \simeq 2$ kpc, $\ell \simeq 47°$), however, the noted paucity of optical spiral tracers in the region does not arise solely from incompleteness owing to extinction. A hybrid spiral map of the Galaxy comprised of classical Cepheids, young open clusters and H II regions, and molecular clouds presents a consistent picture of the Milky Way and confirms that the three Cepheids do not populate the main portion of the Sagittarius-Carina arm, which does not emanate locally from this region. The Sagittarius-Carina arm, along with other distinct spiral features, is found to deviate from the canonical logarithmic spiral pattern. Revised parameters are also issued for the Cepheid BY Cas, and it is identified on the spiral map as lying in the foreground to most young associations in Cassiopeia. A Fourier analysis of the light curve of BY Cas implies overtone pulsation, and the Cepheid is probably unassociated with the open cluster NGC 663 since the distances, ages, and radial velocities do not match.

1. Introduction

Classical Cepheid variables and young open clusters trace the Galaxy's spiral features in a consistent fashion (Walraven *et al.* 1958; Bok 1959; Kraft and Schmidt 1963; Tammann 1970; Opolski 1988; Efremov 1997; Berdnikov *et al.* 2006; Majaess *et al.* 2009). Establishing distances for newly discovered classical Cepheids is therefore useful for further studies of the Milky Way's structure.

The All Sky Automated Survey (ASAS, Pojmański 2000), the Northern Sky Variability Survey (NSVS, Woźniak *et al.* 2004), and The Amateur Sky Survey (TASS, Droege *et al.* 2006), have possibly made over 200 detections of new Cepheid variables through their photometric signatures (Akerlof *et al.* 2000; Wils and Greaves 2004; Schmidt *et al.* 2007; Berdnikov *et al.* 2009), a sizeable addition to the Galactic sample (Harris 1985; Berdnikov *et al.* 2000; Samus *et al.* 2009). However, some candidates possess only single passband photometry, which is insufficient for establishing either a distance or color excess through existing relations (Tammann *et al.* 2003; Benedict *et al.* 2007; van Leeuwen *et al.* 2007; Fouqué *et al.* 2007; Laney and Caldwell 2007; Majaess *et al.* 2008a; Turner 2009). The present study outlines a campaign of multiband photometry from the Abbey Ridge Observatory (Lane 2007; Majaess *et al.* 2008b) to establish mean *BV* magnitudes for newly detected classical Cepheids in undersampled regions of the Galaxy. The primary focus lies in long period classical Cepheids between the Cygnus-Aquila Rifts ($40° \leq \ell \leq 50°$, Forbes 1983, 1984, 1985; Dame *et al.* 2001; Straižys *et al.* 2003; Prato *et al.* 2008), the intent being to trace the Sagittarius-Carina arm through the first Galactic quadrant, where it appears to cease unexpectedly (e.g., Georgelin and Georgelin 1976). Long period classical Cepheids are young and massive (e.g., Turner 1996), ideal characteristics for objects used to delineate spiral structure, since they have not had time to travel far from their birthplaces in the arms.

This study also highlights ways in which small telescopes, like those used by most AAVSO members, can contribute to our knowledge of Galactic structure via classical Cepheids. The examples may provide inspiration for enthusiasts to add newly-discovered Cepheid variables to their own observing programs. On the order of a thousand variables are flagged as suspected Cepheids in the ASAS alone, of which a small yet relevant fraction are bona fide Cepheids. Multiband Johnson mean magnitudes for such objects would enable the determination of distances and reddenings through existing relationships (e.g., Majaess *et al.* 2008a; Turner 2009). Establishing reliable photometric parameters for new Cepheids increases the size of the Galactic sample, thereby helping to place stronger constraints on a host of Galactic parameters, including its warp and spiral structure (e.g., Majaess *et al.* 2009).

Precise differential CCD photometry for short period Cepheids is needed for Fourier analysis of their light curves in order to help constrain their pulsation mode (Beaulieu 1995; Welch *et al.* 1995; Beaulieu and Sasselov 1998; Zabolotskikh *et al.* 2005), an important characteristic affecting distance estimates ($\simeq$ 30%). The Cepheid BY Cas is provided as a pertinent example of how small telescope photometry can help. Detailed photometry for the star was obtained to assess its pulsation mode and to examine its possible membership in the open cluster NGC 663, an analysis prompted in part by the study of Usenko *et al.* (2001). Cluster membership is important for the calibration of classical Cepheid distances, reddenings, period-mass relations, and period-age relations (Turner 1996; Turner and Burke 2002; Laney and Caldwell 2007; Fouqué *et al.* 2007; Majaess *et al.* 2008a; Turner 2009). Classical Cepheids like BY Cas are also useful to establish the distance of the Sun above the plane, as well as to deduce the classical Cepheid scale height (Fernie 1968; Majaess *et al.* 2009). BY Cas is also identified on a hybrid spiral map of the Milky Way, which was constructed to assess the locations of the Cepheids surveyed within the broader context of the Galaxy.

2. Cepheid research from the ARO

The Abbey Ridge Observatory (Lane 2007; Majaess *et al.* 2008b) is engaged in a campaign aimed at studying Cepheid variables (Turner 2008; Turner *et al.* 2009b). Light curves for several Cepheids being monitored are presented in Figure 1 as an example of what can be achieved by means of small telescopes (e.g., the ARO). Research consists of monitoring northern hemisphere Cepheids to determine rates of period change, a parameter important for constraining rate of stellar evolution and location within the Cepheid instability strip (Turner *et al.* 2006). Suspected connections between classical Cepheids and open clusters are also being investigated (Turner and Burke 2002; Majaess *et al.* 2008a; Turner 2008), the objective being to establish additional calibrators for distance, reddening, period-mass, and period-age relations (Turner 1996; Turner and Burke 2002; Laney and Caldwell 2007; Majaess *et al.* 2008a; Turner 2009). Precise photometry ($\sigma \simeq 0.01$ magnitude) is being obtained for short period classical Cepheids to discriminate between fundamental mode and overtone pulsators, especially in previously ambiguous cases (e.g., BD Cas, Majaess *et al.* 2008a). A future campaign will aim to establish *VI* photometry for Type II Cepheids in globular clusters (Clement *et al.* 2001; Pritzl *et al.* 2003; Horne 2005; Randall *et al.* 2007; Rabidoux *et al.* 2007; Corwin *et al.* 2008), the primary objective being to test the metallicity dependence in Cepheid distance relations (Majaess *et al.* 2009).

The present study highlights our goal to establish mean *BV* observations for long period classical Cepheids discovered in the obscured and undersampled region between the Cygnus and Aquila Rifts (Figure 2).

3. Observations

All-sky *BV* photometry for our program objects were obtained on several nights, with extinction coefficients derived using techniques outlined by Henden and Kaitchuck (1998) and Warner (2006). The data were standardized to the Johnson system using stars in the open cluster NGC 225 for calibration (Hoag *et al.* 1961). Period analysis of the photometry was carried out in the PERANSO software environment (Vanmunster 2006) using the algorithms

ANOVA (Schwarzenberg-Czerny 1996), FALC (Harris *et al.* 1989), and CLEANEST (Foster 1995).

3.1. Cepheids ($40° \leq \ell \leq 50°$)

Observations have been obtained for three newly discovered, suspected long period Cepheids from the NSVS (GSC 01050-00485 and GSC 01049-01505, Woźniak *et al.* 2004; Wils and Greaves 2004) and ASAS (GSC 01050-00361, Pojmański 2000). Phased *V*-band light curves for the Cepheids, and BY Cas, are illustrated in Figure 1, with relevant parameters summarized in Table 1.

Distances to the Cepheids were computed from a mean of *BV* and *VJ* reddening-free classical Cepheid distance relations (Majaess *et al.* 2008a), the latter using mean *J*-band magnitudes derived from single epoch 2MASS observations (Cutri *et al.* 2003) following a prescription outlined in Ma jaess *et al.* (2008a) (an alternative procedure can be found in Soszyński *et al.* 2005). Reddenings for the same stars were estimated from a Cepheid *VJ* color excess relation (Majaess *et al.* 2008a). Single epoch 2MASS infrared *J* magnitudes are available for most Cepheids, newly discovered or otherwise. Caution is urged in their use, however, since bright Cepheids ($J \sim 5$ magnitudes) may have saturated infrared magnitudes given their spectral energy distributions. Also, as noted by Majaess *et al.* (2008a), the derivation of mean magnitudes from single epoch observations has several complications, one being that Cepheids undergo changes in pulsation period (Szabados 1977, 1980, 1981; Berdnikov 1994; Berdnikov *et al.* 1997; Glushkova *et al.* 2006; Turner *et al.* 2006), so a significant time lapse between single epoch observations and those of the reference optical light curves can result in correspondingly large phase offsets. Long period Cepheids, in particular, tend to exhibit both random and rapid period changes (Turner and Berdnikov 2004; Turner *et al.* 2006; Berdnikov *et al.* 2007; Turner *et al.* 2009a). A large uncertainty in the periods determined for recently discovered Cepheids is a primary concern.

An additional ten stars from the ASAS are to be monitored as well, with relevant details to appear in a separate study.

3.2. BY Cas

The discovery of variability in BY Cas is attributed to Beljawsky (1931) (Gorynya *et al.* 1994). A Fourier analysis of the new ARO photometry yields an amplitude ratio $R_{21} = 0.069 \pm 0.011$, a value implying overtone pulsation (Welch *et al.* 1995; Beaulieu and Sasselov 1998; Zabolotskikh *et al.* 2005). The distance to BY Cas was computed from a mean of *BV* and *VI* reddening-free classical Cepheid distance relations (Majaess *et al.* 2008a), and the reddening was determined using a Cepheid *VI* color excess relation formulated from the same study. Infrared photometry (I_C) catalogued by Berdnikov *et al.* (2000) was used.

The membership of BY Cas in NGC 663, and thus its inferred distance and pulsation mode, have been questioned previously by Usenko *et al.* (2001). The implied age (t ~ 10^8 yrs, Turner 1996) and resulting distance for the Cepheid (Table 1) are inconsistent with parameters for the cluster NGC 663 (d $\simeq$ 2.8 kpc, t $\simeq 2 \times 10^7$ yrs, Phelps and Janes 1994), a discrepancy also confirmed by recent radial velocity measures of the cluster and Cepheid (Liu *et al.* 1991; Gorynya *et al.* 1994; Mermilliod *et al.* 2008). BY Cas is therefore unlikely to be a member of NGC 663, and its parameters obtained through use of the Cepheid relations are preferred (Table 1).

Lastly, Gorynya *et al.* (1994) argue on the basis of radial velocities that BY Cas is a binary Cepheid (Szabados 2003a).

4. The spiral nature of the Milky Way

Maps of the Milky Way's spiral structure exhibit striking differences (Russeil 2003; Nakanishi and Sofue 2003; Vallée 2005; Benjamin *et al.* 2006; Churchwell *et al.* 2009; Hou *et al.* 2009; Majaess *et al.* 2009). Some 150 years after Alexander (1852) first suggested that the Milky Way was a spiral, there is currently no consensus on the number of arms in our Galaxy. Moreover, the Sagittarius-Carina and Local arm are not well matched by superposed logarithmic spirals (Forbes 1983; Russeil 2003; Majaess *et al.* 2009). That may not be surprising given that an organized and idealistic grand design structure is not a characteristic shared by a sizeable fraction of the universe's spirals, including perhaps the Milky Way. Readers are encouraged to examine images of spiral galaxies observed by HST or catalogued in photographic atlases (Sandage and Bedke 1988) and note that galaxies commonly exhibit arms that branch, merge, twist unexpectedly, and feature a degree of irregularity or flocculence. Furthermore, the possible scenario of the Sun within a spur/Local arm (e.g., Russeil 2003) indicates that such features are likely not unique, and probably exist elsewhere in the Galaxy.

Majaess *et al.* (2009) noted that classical Cepheids (e.g., Berdnikov *et al.* 2000) and young open clusters (Dias *et al.* 2002; Mermilliod and Paunzen 2003) (YOCs) trace spiral features consistently (Figure 3, top and middle). The location of the classical Cepheids studied here have been tagged on the classical Cepheid-YOC map (triangles, Figure 3, middle). BY Cas appears to lie foreground to young associations in Cassiopeia (F, Figure 3, top). The new long period Cepheids occupy an obvious gap in the classical Cepheid-YOC data for Galactic longitudes spanning $\ell \simeq 35° - 50°$ (Forbes 1983, 1984, 1985; Majaess *et al.* 2009). The gap has complicated efforts to track the Sagittarius-Carina arm (A, Figure 3, top) through this region of the first quadrant, which straddles the Cygnus and Aquila Rifts (Figure 2).

The Cepheids studied here indicate that the extinction is exceptional along this line of sight, partly because of a nearby molecular cloud (Forbes 1983, 1984, 1985). The derived reddenings for the Cepheids at $\ell \simeq 47°$ (Table 1), in tandem with a standard ratio of total to selective extinction ($R = A_V / E_{B-V} = 3.06$, Turner 1976), imply extinction amounting to upwards of $A_V \simeq 3$ magnitudes per kiloparsec, in general agreement with previous results (Forbes 1983, 1984, 1985; Straižys *et al.* 2003). A hybrid spiral structure map consisting of classical Cepheids, YOCs and H II regions (Hou *et al.* 2009), and molecular clouds (Hou *et al.* 2009) indicates that the absence of optical spiral tracers in this region is not tied to incompleteness resulting from large extinction (Figure 3, bottom). An alternative delineation of the Sagittarius-Carina arm which deviates from the canonical superposed patterns is again advocated (Forbes 1983; Russeil 2003; Majaess *et al.* 2009). The arm appears to trace along features *A* and *B* (Figure 3, top) and may continue thereafter along $\ell \simeq 35°$ (Figure 3, bottom). The distinct signature of an additional arm possibly connecting to the Sagittarius-Carina arm can be traced through feature *C* (Figure 3, top). An abundance of optical tracers near $\ell \simeq 0°$ may be a junction that branches into the Carina (*A*) and Centaurus (*E*) features (Figure 3, top). More work is needed to thoroughly examine the connections. Classical Cepheids, YOCs and H II regions, and molecular clouds otherwise delineate the Milky Way's spiral features consistently at other Galactic longitudes.

Matching the distribution of classical Cepheids, YOCs and H II regions, and molecular clouds to a standard spiral pattern is rather challenging, especially in consideration of feature *F* (Figure 3), often treated as a major spiral feature (the reputed Perseus arm). No superposition of such a pattern has been made in Figure 3. Lastly, caution is urged because the spiral map displays features which are somewhat reminiscent of the "fingers of God effect" (see chapter 12 of Shu 1982).

5. Summary

Described here is a photometric campaign initiated at the Abbey Ridge Observatory aimed at establishing multiband photometry for new Cepheids. The objective is to determine reddenings and distances for key Cepheid variables in undersampled and heavily obscured regions of the Milky Way so to further elucidate any potential spiral structure. A general framework is outlined for AAVSO members interested in conducting similar research. Preliminary observations and photometric parameters are presented for three classical Cepheids discovered by the NSVS (Woźniak *et al.* 2004; Wils and Greaves 2004) and ASAS (Pojmański 2000) between the Cygnus-Aquila Rifts ($40° \leq \ell \leq 50°$), a region purportedly tied to a segment of the Sagittarius-Carina arm which appears to cease unexpectedly (e.g., Georgelin and Georgelin 1976). Reddenings inferred from the Cepheids confirm exceptional extinction along the line of sight at upwards of $A_V \simeq 6$ magnitudes ($d \simeq 2$ kpc, $\ell \simeq 47°$), however, it is shown by constructing a hybrid spiral map of the Milky Way from classical Cepheids, YOCs and H II regions, and molecular clouds, that the scarcity of optical spiral tracers in the region is not a consequence of incompleteness

owing to extinction. Rather, the hybrid map advocates an alternative delineation for the Sagittarius-Carina arm, and many other distinct features, which are not matched by conventional logarithmic spiral patterns. The three Cepheids surveyed between the Cygnus and Aquila Rifts ($40° \leq \ell \leq 50°$) do not populate the main portion of the Sagittarius-Carina arm.

The spiral tracers produce a consistent illustration of the Milky Way, reaffirming the importance of adopting a multifaceted approach to facilitate an interpretation of the Galaxy's complex structure. Supplementing optical spiral tracers like classical Cepheids with indicators that are less sensitive to extinction (e.g., molecular clouds) provides larger statistics and more confident conclusions.

Revised parameters issued for the Cepheid BY Cas place it mainly foreground to the young associations in Cassiopeia. The Cepheid is argued to be an overtone pulsator based on a Fourier analysis of its light curve. BY Cas is probably unassociated with the open cluster NGC 663, which exhibits a different distance, age, and radial velocitiy.

The future release of the ASAS-3N survey shall provide a statistically valid sample of new Cepheids with multiband *VI* photometry, thereby enabling the distances and reddenings for the variables to be readily determined. Observatories like the ARO and those run by fellow AAVSO members will continue to serve a role, especially in supplementing the faint end of the survey where the photometric zero-point becomes too uncertain. The present study supports a tradition of utilizing small telescopes to conduct pertinent Cepheid research (Percy 1980, 1986; Turner 1998; Turner *et al.* 1999, 2005, 2009b; Szabados 2003b).

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References

Akerlof, C., *et al.* 2000, *Astron. J.*, **119**, 1901.

Alexander, S. 1852, *Astron. J.*, **2**, 97.

Beaulieu, J. P. 1995, in *Astrophysical Applications of Stellar Pulsation*, eds. R. S. Stobie, and P. A. Whitelock, ASP Conf. Series Vol. 83, 260.

Beaulieu, J. P., and Sasselov, D. D. 1998, in *A Half Century of Stellar Pulsation Interpretation: A Tribute to Arthur N. Cox*, eds. P. A. Bradley and J. A. Guzik, ASP Conf. Series 135, p. 368.

Beljawsky, S. 1931, *Astron. Nachr.*, **243**, 115.

Benedict, G. F. *et al.* 2007, *Astron. J.*, **133**, 1810.

Benjamin, R. A., Churchwell, E., Haffner, M., and GLIMPSE team 2006, *Bull. Amer. Astron. Soc.*, **38**, 1229.

Berdnikov, L. N. 1994, *Astronomy Lett.*, **20**, 232.

Berdnikov, L. N., Dambis, A. K., and Vozyakova, O. V. 2000, *Astron. Astrophys., Suppl. Ser.*, **143**, 211.

Berdnikov, L. N., Efremov, Y. N., Glushkova, E. V., and Turner, D. G. 2006, *Odessa Astron. Publ.*, **18**, 26.

Berdnikov, L. N., Ignatova, V. V., Pastukhova, E. N., and Turner, D. G. 1997, *Astronomy Lett.*, **23**, 177.

Berdnikov, L. N., Kniazev, A. Y., Kravtsov, V. V., Pastukhova, E. N., and Turner, D. G. 2009, *Astronomy Lett.*, **35**, 39.

Berdnikov, L. N., Pastukhova, E. N., Gorynya, N. A., Zharova, A. V., and Turner, D. G. 2007, *Publ. Astron. Soc. Pacific*, **119**, 82.

Bok, B. J. 1959, *Observatory*, **79**, 58.

Churchwell, E., *et al.* 2009, *Publ. Astron. Soc. Pacific*, **121**, 213.

Clement, C. M., *et al.* 2001, *Astron. J.*, **122**, 2587.

Corwin, T. M., Borissova, J., Stetson, P. B., Catelan, M., Smith, H. A., Kurtev, R., and Stephens, A. W. 2008, *Astron. J.*, **135**, 1459.

Cutri, R. M. *et al.* 2003, *The IRSA 2MASS All-Sky Point Source Catalog*, NASA/IPAC Infrared Science Archive, http://irsa.caltech.edu/applications/Gator/

Dame, T. M., Hartmann, D., and Thaddeus, P. 2001, *Astrophys. J.*, **547**, 792.

Dame, T. M., and Thaddeus, P. 1985, *Astrophys. J.*, 297, 751.

Dias, W. S., Alessi, B. S., Moitinho, A., Lépine, J. R. D. 2002, *Astron. Astrophys.*, **389**, 871.

Droege, T. F., Richmond, M. W., Sallman, M. P., Creager, R. P. 2006, *Publ. Astron. Soc. Pacific*, **118**, 1666.

Efremov, Y. N. 1997, *Astronomy Lett.*, **23**, 579.

Elmegreen, D. M. 1985, in *The Milky Way Galaxy*, Proc. 106 Symp. Groningen, Netherlands, May 30–June 3, 1983, Reidel, Dordrecht, 255.

Feast, M. 1999, *Publ. Astron. Soc. Pacific*, **111**, 775.

Feast, M. 2001, arXiv:astro-ph/0110360.

Fernie, J. D.1968, *Astron. J.*, **73**, 995.

Fernie, J. D. 1976, *The Whisper and the Vision—The Voyages of the Astronomers*, Clarke, Irwin, Toronto.

Fernie, J. D. 2002, *Setting sail for the universe: astronomers and their discoveries*, Rutgers University Press, New Brunswick, NJ.

Forbes, D. 1983, *The Distribution of Spiral Structure Tracers in the Region of the Galaxy Between 30 Degrees and 70 Degrees*, Ph.D. Thesis, Univ. Victoria, Canada.

Forbes, D. 1984, *Astron. J.*, **89**, 475.

Forbes, D. 1985, *Astron. J.*, **90**, 301.

Foster, G. 1995, *Astron. J.*, **109**, 1889.

Fouqué, P. *et al.* 2007, *Astron. Astrophys.*, **476**, 73.

Freedman, W. L., and Madore, B. F. 1996, in *Clusters, Lensing, and the Future of the Universe*, eds. V. Trimble and A. Reisenegger, ASP Conf. Proc. 88, 9.

Georgelin, Y. M., and Georgelin, Y. P. 1976, *Astron. Astrophys.*, **49**, 57.

Glushkova, E. V., Berdnikov, L. N., and Turner, D. G. 2006, *Mem. Soc. Astron. Italiana*, **77**, 127 7.

Gorynya, N. A., Samus, N. N., Rastorgouev, A. S. 1994, *Inf. Bull. Var. Stars*, No. 4130, 1.

Harris, A. W. *et al.* 1989, *Icarus*, **77**, 171.

Harris, H. C. 1985, *Astron. J.*, **90**, 756.

Henden, A. A., and Kaitchuck, R. H. 1998, *Astronomical Photometry: A Text and Handbook for the Advanced Amateur and Professional Astronomer*, Willmann-Bell, Richmond.

Hoag, A. A., Johnson, H. L., Iriarte, B., Mitchell, R. I., Hallam, K. L., and Sharpless, S. 1961, *Publ. United States Naval Obs.*, **17**, 343.

Hoffleit, D. 2002, *Misfortunes As Blessings in Disguise: The Story of My Life*, AAVSO, Cambridge, MA.

Horne, J. D. 2005, *J. Amer. Assoc. Var. Star Obs.*, **34**, 61.

Hou, L. G., Han, J. L., and Shi, W. B. 2009, *Astron. Astrophys.*, **499**, 473.

Kraft, R. P., and Schmidt, M. 1963, *Astrophys. J.*, **137**, 249.

Lane, D. J. 2007, "96th Spring Meeting of the AAVSO," http://www.aavso.org/aavso/meetings/spring07present/Lane.ppt.

Laney, C. D., and Caldwell, J. A. R. 2007, *Mon. Not. Roy. Astron. Soc.*, **377**, 147.

Liu, T., Janes, K. A., and Bania, T. M. 1991, *Astron. J.*, **102**, 1103.

Majaess, D. J., Turner, D. G., and Lane, D. J. 2008 (a), *Mon. Not. Roy. Astron. Soc.*, **390**, 1539.

Majaess, D. J., Turner, D. G., and Lane, D. J. 2009, arXiv:0903.4206.

Majaess, D. J., Turner, D. G., Lane, D. J., and Moncrieff, K. E. 2008 (b), *J. Amer. Assoc. Var. Star Obs.*, **36**, 90.

Mermilliod, J.-C., Mayor, M., and Udry, S. 2008, *Astron. Astrophys.*, **485**, 303.

Mermilliod, J.-C., and Paunzen, E. 2003, *Astron. Astrophys.*, **410**, 511.

Nakanishi, H., and Sofue, Y. 2003, *Publ. Astron. Soc. Japan*, **55**, 191.

Opolski, A. 1988, *Acta Astron.*, **38**, 375.

Percy, J. R. 1980, *J. Roy. Astron. Soc. Canada*, **74**, 334.

Percy, J. R. 1986, *The Study of Variable Stars Using Small Telescopes*, Cambridge Univ. P., Cambridge.

Phelps, R. L., and Janes, K. A. 1994, *Astrophys. J., Suppl. Ser.*, **90**, 31.

Pojmański, G. 2000, *Acta Astron.*, **50**, 177.

Prato, L., Rice, E. L., and Dame, T. M. 2008, *Handbook of Star Forming Regions, Volume I: The Northern Sky,* ASP Monograph Publications, Vol. 4., ed. B. Reipurth, 18.

Pritzl, B. J., Smith, H. A., Stetson, P. B., Catelan, M., Sweigart, A. V., Layden, A. C., and Rich, R. M. 2003, *Astron. J.*, **126**, 1381.

Rabidoux, K., *et al.* 2007, *Bull. Amer. Astron. Soc.*, **39**, 845.

Randall, J. M., Rabidoux, K., Smith, H. A., De Lee, N., Pritzl, B., and Osborn, W. 2007, *Bull. Amer. Astron. Soc.*, **38**, 276.

Russeil, D., 2003, *Astron. Astrophys.*, **397**, 133.

Samus, N. N., *et al.* 2009, VizieR Online Data Catalog, 1, 2025.

Sandage, A., and Bedke J. 1988, *Atlas of Galaxies Useful for Measuring the Cosmological Distance Scale*, NASA Special Publ., Vol. 496, Space Telescope Science Institute, Baltimore.

Schmidt, E. G., Langan, S., Rogalla, D., and Thacker-Lynn, L. 2007, *Astron. J.*, **133**, 665.

Schwarzenberg-Czerny, A. 1996, *Astrophys. J.*, **460**, L107.

Shu, F. H. 1982, *A Series of Books in Astronomy*, University Science Books, Mill Valley, CA.

Soszyński, I., Gieren, W., and Pietrzyński, G. 2005, *Publ. Astron. Soc. Pacific*, **117**, 823.

Straižys, V., Černis, K., and Bartašiūtė, S. 2003, *Astron. Astrophys.*, **405**, 585.

Szabados L., 1977, *Commun. Konkoly Obs.*, **70**, 1.

Szabados L., 1980, *Commun. Konkoly Obs.*, **76**, 18.

Szabados L., 1981, *Commun. Konkoly Obs.*, **77**, 1.

Szabados, L. 2003a, *Inf. Bull. Var. Stars*, No. 5394, 1.

Szabados, L. 2003b, in *The Future of Small Telescopes In The New Millennium. Volume III—Science in the Shadows of Giants*, ed. T. D. Oswalt, Astrophys. Space Sci. Library, 289, Kluwer Academic Publishers, Dordrecht, p.207.

Szabados, L. 2006, *Commun. Konkoly Obs.*, **104**, 105.

Tammann, G. A. 1970, in *The Spiral Structure of our Galaxy*, ed. W. Becker and G. T. Kontopoulos, IAU Symp. 38, 236.

Tammann, G. A., Sandage, A., and Reindl, B. 2003, *Astron. Astrophys.*, **404**, 423.

Turner, D. G. 1976, *Astron. J.*, **81**, 97.

Turner, D. G. 1996, *J. Roy. Astron. Soc. Canada*, **90**, 82.

Turner, D. G. 1998, *J. Amer. Assoc. Var. Star Obs.*, **26**, 101.

Turner, D. G. 2008, *J. Amer. Assoc. Var. Star Obs.*, **36**, 140.

Turner D. G. 2009, *Astrophys. Space Sci.,* submitted.

Turner, D. G., Abdel-Sabour Abdel-Latif, M., and Berdnikov, L. N. 2006, *Publ. Astron. Soc. Pacific*, **118**, 410.

Turner, D. G., and Berdnikov, L. N. 2004, *Astron. Astrophys.*, **423**, 335.

Turner, D. G., and Burke, J. F. 2002, *Astron. J.*, **124**, 2931.

Turner, D. G., Forbes, D., Leonard, P. J. T., Abdel-Sabour Abdel-Latif, M., Majaess, D. J., and Berdnikov, L. N. 2009a, arXiv:0905.0834.

Turner, D. G., Horsford, A. J., and MacMillan, J. D. 1999, *J. Amer. Assoc. Var. Star Obs.*, **27**, 5.

Turner, D. G., Majaess, D. J., Lane, D. J., Szabados, L., Kovtyukh, V. V., Usenko, I. A., and Berdnikov, L. N. 2009b, arXiv:0907.2969.

Turner, D. G., Savoy, J., Derrah, J., Abdel-Sabour Abdel-Latif, M., and Berdnikov, L. N. 2005, *Publ. Astron. Soc. Pacific*, **117**, 207.

Usenko, I. A., Kovtyukh, V. V., Klochkova, V. G., Panchuk, V. E., and Yermakov, S. V. 2001, *Astron. Astrophys.*, **367**, 831.

van Leeuwen, F., Feast, M. W., Whitelock, P. A., and Laney, C. D. 2007, *Mon. Not. Roy. Astron. Soc.*, **379**, 723.

Vallée, J. P. 2005, *Astron. J.*, **130**, 569.

Vanmunster, T. 2006, PERANSO period analysis software, CBABelgium.com.

Walraven, T., Muller, A. B., and Oosterhoff, P. T. 1958, *Bull. Astron. Inst. Netherlands*, **14**, 81.

Warner, B. D. 2006, *A Practical Guide to Lightcurve Photometry and Analysis*, Springer, Berlin.

Welch, D. L., *et al.* 1995, in *Astrophysical Applications of Stellar Pulsation: the Interaction between Observation and Theory*, eds. R. S. Stobie and P. A. Whitelock, IAU Coll. 155, ASP Conf. Series Vol. 83, 232.

Wils, P., and Greaves, J. 2004, *Inf. Bull. Var. Stars*, No. 5512, 1.

Woźniak, P. R., *et al.* 2004, *Astron. J.*, **127**, 2436.

Zabolotskikh, M. V., Sachkov, M. E., Berdnikov, L. N., Rastorguev, A. S., and Egorov, I. E., 2005, in *The Three-Dimensional Universe with Gaia*, eds. C. Turun, K. S. O'Flaherty, and M. A. C. Perryman, (ESA SP-576), 723 (http://www.rssd.esa.int/index.php?project=Gaia&page=Gaia_2004_Proceedings).

Table 1. Cepheids observed from the Abbey Ridge Observatory.

Star ID	ℓ (°)	P (days)	V	B–V	V_a	B_a	d (kpc)	E_{B-V}
GSC 01050-00485	47.61	18.25 ± 0.03	14.02	3.02	0.9	1.5	2.0	1.9
GSC 01050-00361	47.56	8.63 ± 0.01	10.44	1.96	0.42	0.62	1.1	1.1
GSC 01049-01505	45.49	20.84 ± 0.03	13.92	2.53:	0.7	1.0:	5.2:	1.4:
BY Cas	129.55	3.2215 ± 0.0006	10.38	—	1.29	—	1.7	0.6

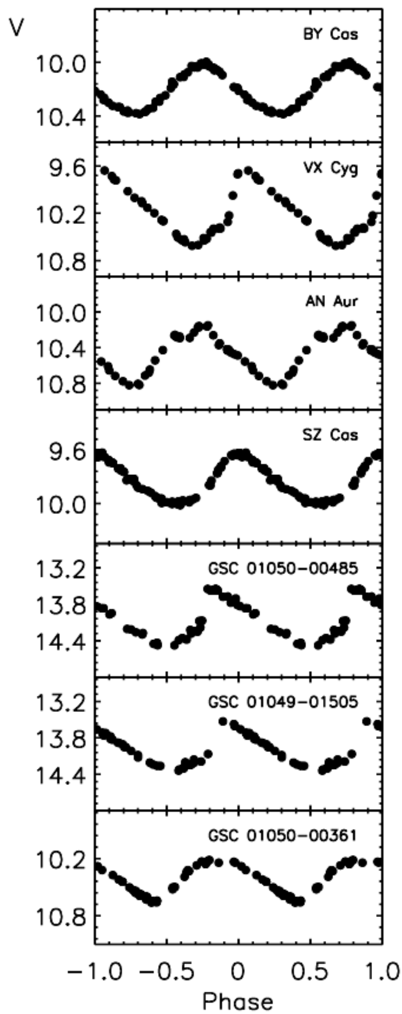

Figure 1. Light curves for several Cepheids being monitored from the Abbey Ridge Observatory.

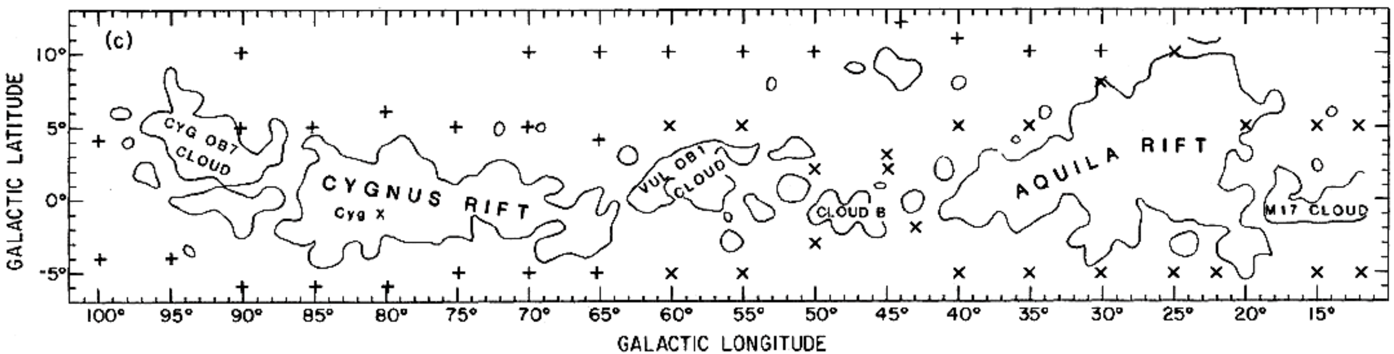

Figure 2. Velocity-integrated CO emission map from the seminal work of Dame and Thaddeus (1985). Much of the region is obscured by molecular clouds, hampering efforts to infer the Galaxy's spiral structure using optical tracers.

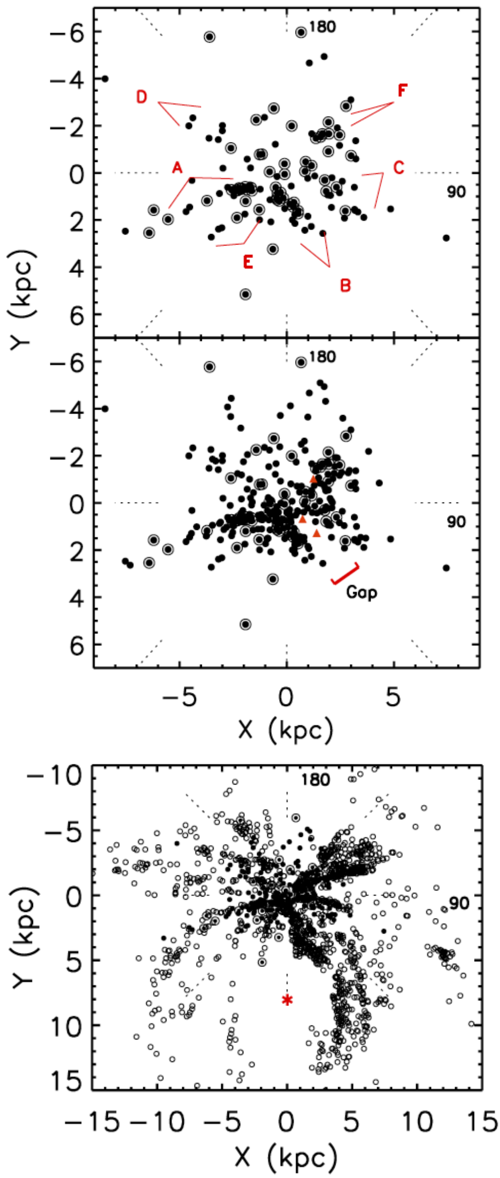

Figure 3. Top and middle: local spiral structure as delineated by classical Cepheid variables (solid points) and young open clusters (YOCs, circled points). See Majaess *et al.* (2009) for details and the corresponding identifiers. Middle: the gap of optical tracers and locations of the Cepheids (triangles) studied here are highlighted. Bottom, the structure of the Milky Way as illustrated by classical Cepheids, YOCs and H II regions, and molecular clouds (see text for details). Galactic center is denoted by an asterisk (Majaess *et al.* 2009).