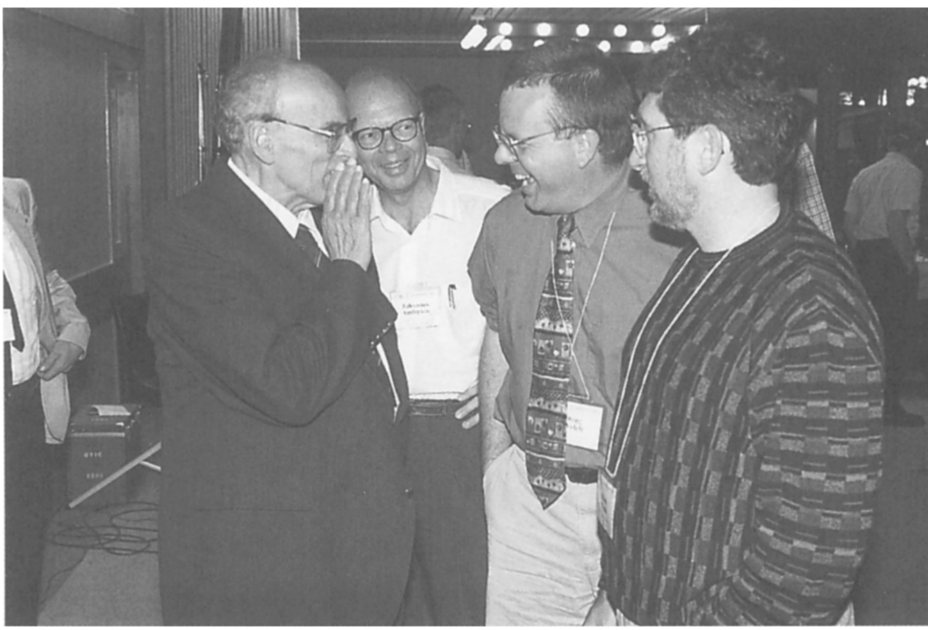
Part 8. Cepheids and Distances

Section A. Invited Reviews

https://doi.org/10.1017/S0074180900118741 Published online by Cambridge University Press



Sidney van den Bergh shares a joke with (left to right) Johannes Andersen, Doug Welch, and Kem Cook.

https://doi.org/10.1017/S0074180900118741 Published online by Cambridge University Press

New Views of the Magellanic Clouds
IAU Symposium, Vol. 190, 1999
Y.-H. Chu, N.B. Suntzeff, J.E. Hesser, and D.A. Bohlender, eds.

Cepheid Variables in the LMC and SMC

D.L. Welch, and the MACHO Collaboration[1]

Dept. of Physics & Astronomy, McMaster University, Hamilton, Ontario, L8S 4M1 Canada

Abstract. In this paper, we will review major new results regarding classical Cepheids, in the Large Magellanic Cloud (LMC) and Small Magellanic Cloud (SMC). Specifically, we discuss recent work regarding multi-mode Cepheids and describe new observations of a W Vir star (HV 5756) and a Cepheid which are each in eclipsing binary systems. An additional interesting pulsating supergiant in an eclipsing system is also identified. Ephemerides for eclipses for the three systems are provided.

1. MACHO Project Status

The MACHO Project is a wide-field photometric survey whose primary goal is to characterize the mass of non-luminous or under-luminous matter along different lines-of-sight in the Milky Way galaxy. As of July 1998, observations span 2100 nights with over 75,000 images archived. Data collection has taken place essentially continuously since 1992, making this one of the most extensive data sets for variable stars obtained in the history of variable star astronomy. It is expected that similar observations will be obtained up until at least 1999 December 31. A relatively recent review of the results of the MACHO Project can be found in Cook *et al.* (1997).

2. Classical Cepheids

At present, the MACHO Project has identified 1767 classical and first-overtone Cepheids in the LMC. EROS has reported a total of 290 Cepheids in the LMC. Both groups agree that the fraction of first-overtone Cepheids is 30%. At shorter periods, the fundamental and first-overtone mode sequences are less distinct, suggesting the possibility of a range in masses and/or ages for these stars. Such a conclusion has been suggested by Bersier *et al.* (1998) and Alcock *et al.* (1999a).

---

[1]C. Alcock, R.A. Allsman, D. Alves, T.S. Axelrod, A.C. Becker, D.P. Bennett, K.H. Cook, K.C. Freeman, K. Griest, M.J. Lehner, D.W. Kurtz, S.L. Marshall, D. Minniti, B.A. Peterson, M.R. Pratt, P.J. Quinn, A.W. Rodgers (Deceased), A. Rorabeck, W. Sutherland, A. Tomaney, and T. Vandehei

https://doi.org/10.1017/S0074180900118741 Published online by Cambridge University Press

3. Beat Cepheids

Alcock *et al.* (1999b) report some of the results found by Rorabeck (1997). The second-overtone lightcurve derived from 1st/2nd-overtone beat Cepheid lightcurves is found to be very sinusoidal. Beaulieu *et al.* (1997), Welch (1998), and Rorabeck (1997) have reported beat Cepheids in the SMC.

4. Eclipsing Cepheid Variables

We have discovered three Cepheid variables in eclipsing binary systems to date. Times of primary and secondary minima for these systems are given in Tables 1, 2, and 3, respectively.

1. *HV 5756* Our first reported discovery, HV 5756 (MACHO ID 78.6338.24) was reported in Welch *et al.* (1996). A total of six primary minima have been observed at this writing (Dec 1998). Furthermore, images from the Harvard College Observatory plate archives have now been obtained to search for historical minima.

2. *6.6454.5* A finder chart with suitable comparison stars is available at the URL: `http://wwwmacho.mcmaster.ca/EclCep/`. Diluted lightcurve subtracted photometry is shown in Figure 1.

3. *5.4763.71* This system appears to contain a 4.69-day Cepheid with a slowly-varying amplitude and has an orbital period of 123.9 days. It is possibly a low-mass Cepheid (in between the tradition classifications of BL Her and W Vir variables). It is located at equinox J2000.0 coordinates 05:09:59.2 -69:58:28. Both primary and secondary minima are visible in the lightcurve phased with the orbital period. The system is also remarkable in that secondary minimum appears to take place at an orbital phase of 0.55, indicating an eccentric orbit.

These systems are likely just the tip of the iceberg, since the hotter companions are usually more luminous than the pulsator and hence are easily selected.

Table 1. Eclipse Predictions for HV 5756

Primary		Secondary	
JD	UT	JD	UT
2451122.6	1998 Nov 5.1	2451332.6	1999 Jun 3.1
2451542.6	1999 Dec 30.1	2451752.6	2000 Jul 27.1
2451962.6	2001 Feb 22.1	2452172.6	2001 Sep 20.1
2452382.6	2002 Apr 18.1	2452592.6	2002 Nov 14.1
2452802.6	2003 Jun 12.1	2453012.6	2004 Jan 8.1

https://doi.org/10.1017/S0074180900118741 Published online by Cambridge University Press

Table 2. Eclipse Predictions for 6.6454.5

Primary		Secondary	
JD	UT	JD	UT
2450867.06	1998 Feb 22.56	2451065.81	1998 Sep 9.31
2451264.56	1999 Mar 27.06	2451463.31	1999 Oct 11.81
2451662.06	2000 Apr 27.56	2451860.81	2000 Nov 12.31
2452059.56	2001 May 30.06	2452258.31	2001 Dec 14.81
2452457.06	2002 Jul 1.56	2452655.81	2003 Jan 16.31
2452854.56	2003 Aug 3.06	2453053.31	2004 Feb 17.81

Table 3. Eclipse Predictions for 5.4763.71

Primary		Secondary	
JD	UT	JD	UT
2451270.40	1999 Apr 1.90	2451338.54	1999 Jun 9.04
2451394.30	1999 Aug 3.80	2451462.44	1999 Oct 10.94
2451518.20	1999 Dec 5.70	2451586.34	2000 Feb 11.85
2451642.10	2000 Apr 7.60	2451710.24	2000 Jun 14.75
2451766.00	2000 Aug 9.50	2451834.14	2000 Oct 16.65
2451889.90	2000 Dec 11.40	2451958.04	2001 Feb 17.54
2452013.80	2001 Apr 14.30	2452081.94	2001 Jun 21.44
2452137.70	2001 Aug 16.20	2452205.84	2001 Oct 23.35
2452261.60	2001 Dec 18.10	2452329.74	2002 Feb 24.25
2452385.50	2002 Apr 21.00	2452453.64	2002 Jun 28.15

Acknowledgments. Work performed at Lawrence Livermore National Laboratory (LLNL) is supported by the Department of Energy (DOE) under contract W7405-ENG-48. Work performed by the Center for Particle Astrophysics (CfPA) on the University of California campuses is supported in part by the Office of Science and Technology Centers of the National Science Foundation (NSF) under cooperative agreement AST-8809616. Work performed at MSO is supported by the Bilateral Science and Technology Program of the Australian Department of Industry, Technology and Regional Development. DLW and AJR were supported, in part, by a Research Grant from the Natural Sciences and Engineering Research Council of Canada (NSERC) during this work.

References

Alcock, C. *et al.* 1999a, AJ, in press

Alcock, C. *et al.* 1999b, ApJ, in press

Beaulieu, J.-P. *et al.* 1997, A&A, 321, L5

https://doi.org/10.1017/S0074180900118741 Published online by Cambridge University Press

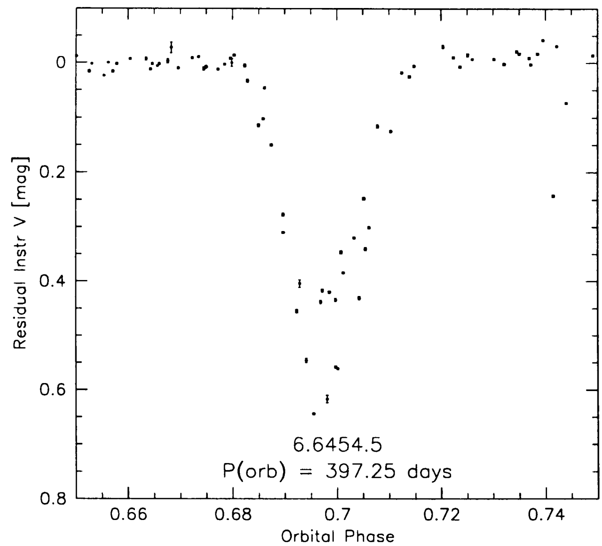


Figure 1. Five consecutive primary minima of the system containing the 4.97-day classical Cepheid 6.6454.5 phased with an orbital period of 397.25 days. The scatter in the minima is not observational in origin but is due to the removal of the contaminated Cepheid lightcurve from the data. A full solution of the system is required to remove the variation during eclipse properly. An epoch of mid-eclipse is HJD 2449277.1. Primary eclipses typically last about 12 days.

Bersier, D. 1998, A.S.P. Conf. Series, 135, 24

Cook, K.H. *et al.* 1997, Proc. 12th I.A.P., 17

Rorabeck, A. 1997, M.Sc. thesis, McMaster University

Welch D.L., 1998, A.S.P. Conf. Series, 135, 355

Welch D.L., *et al.* 1998, I.A.U. Circular 6802

Welch D.L., *et al.* 1996, I.A.U. Circular 6434

Discussion

Sidney van den Bergh: Do amplitude-modulated Cepheids fall on the normal period-luminosity relation?

Welch: The amplitude-changing Cepheids are all around a period of $1\overset{d}{.}25$. As I recall, their colours are not distinct from the population of "normal" Cepheids.

Carme Gallart: Any news about anomalous Cepheids?

Welch: An excellent question. It is likely that the shortest-periods objects in our selections are "anomalous" Cepheids, since, at some point, intermediate-mass Cepheid progenitors no longer can enter the Cepheid instability strip. However, the stars, at that point, can be fed from older and lower mass stars.

https://doi.org/10.1017/S0074180900118741 Published online by Cambridge University Press