

The Variable Star Population in the Center of 47 Tuc as defined by *HST* Observations¹

Ronald L. Gilliland, Peter D. Edmonds, Larry Petro, Abhijit Saha, and Michael Shara

Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218 USA

Abstract. The high stellar densities at the centre of some globular clusters provide prolific breeding grounds for exotic stars, e.g., the 11 msec pulsars in 47 Tuc and numerous blue stragglers. The same high density of stars as viewed on the sky makes ground-based photometry problematic for variable star detection. Even a very few tight binaries can be of fundamental importance for the dynamic evolution of the cluster core. We present results of a continuous 40-hour sequence of U-band CCD exposures acquired with WF/PC on HST. The high spatial resolution coupled with a stable PSF allows nearly Poisson limited time series on some 20,000 stars. The 1000 second sampling and long coverage provide excellent sensitivity to W UMa and δ Scuti variations. Light curves are shown for selected variables and the relative frequencies of binary and variable stars are discussed.

1. Introduction and observations

A matter of considerable importance to the dynamical evolution of globular clusters is whether or not the centrally condensed (and hence presumably more massive than most stars) blue stragglers are primarily single stars, or binaries. Variability monitoring for δ Scuti (usually called SX Phe for Pop. II stars) or W UMa modulation provides important clues to the status (single or binary) of the blue stragglers. We find numerous examples of δ Scuti, W UMa and eclipsing binary variables in 47 Tuc. Variability in the blue stragglers is clearly over-represented relative to the general population.

Our observations were the first to exploit the continuous viewing zone (CVZ) of *HST* for a substantial science program. Over 5-7 September 1993 we obtained a nearly continuous sequence of 99, 1000s exposures with the Planetary Camera (0.043 arcsec pixels) of WF/PC using the F336W (U) filter.

We have discussed the observations and data analysis details in Gilliland et al. (1995). Details concerning variable star detection, and completeness statistics for binary systems will appear in Edmonds et al. (1995).

¹Based on observations with the NASA/ESA *Hubble Space Telescope* obtained at the Space Telescope Science Institute, which is operated by Association of Universities for Research in Astronomy, Incorporated, under NASA contract NAS5-26555.

2. Binary star detections

Our time series with 99 points over 38.5 hours have single measure precisions of about 3-4 mmag for the brightest stars near $m_U \sim 15$ to 0.2 mag near $m_U \sim 20$. The precisions are well modelled by Poisson statistics and readout noise (plus a 'sky' term from the overlapping spherical aberration halos).

The W UMa systems are of particular interest, since our observations are useful for providing a nearly complete census within the 66×66 arcsec region observed. Above $m_U = 19$ our detection sensitivity (Edmonds et al. 1995) averages 77% for a statistically representative distribution of W UMa light curves (Rucinski 1994). We detect 3 W UMa systems among 7700 stars brighter than $m_U = 19$, and thus predict the existence of 4 W UMas in this sample. We have also detected at least 4 other binary systems through eclipses.

3. δ Scuti (SX Phe) detections

We have not yet finalised our U, B, V photometry solutions, and thus will not present colours for the δ Scuti variables. Our search of 7700 stars for δ Scuti-like oscillations turned up 4 stars all of which are contained within the blue straggler domain of $m_V \leq 16.5$, $0.0 \leq B - V \leq 0.6$ (there are 1325 stars in total with $m_V \leq 16.5$, 50 within this preliminary blue straggler domain). Variability at the level of stars A, B & C would have been detected in any of the several thousand stars. The lower amplitude of variable D would only be detectable in favourable cases and our search for variables has not yet been completed at these lower signal levels (nor is its statistical significance established).

Table of δ Scuti Properties

Star	V	Amp. (mag)	Frequency (mHz)
A	15.5	0.075	0.1830
B	15.1	0.06,0.05	0.1133,0.1471
C	15.8	0.038	0.2078
D	14.4	0.003	0.210

Object B clearly displays a double mode; with a period ratio of 0.770 ± 0.002 this falls within the narrow range (0.768 to 0.778) expected for the fundamental and first overtone period ratio for Pop II stars (Peterson & Jørgensen 1972). Consistency checks on membership, cluster distance, and parameters of the variable stars can be obtained by comparison with calibrated period-luminosity relations (Nemec et al. 1994); to be discussed in a journal paper.

References

- Edmonds, P.D., et al. 1995, in preparation
 Gilliland, R.L., et al. 1995, ApJ, in press (July issue)
 Nemec, J.M., Linnell Nemec, A.F., & Lutz, T.E. 1994, AJ, 108, 222
 Peterson, J.D., & Jørgensen, H.E. 1972, A&A, 17, 367
 Rucinski, S.M., 1994, PASP, 106, 462