COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS
Number 4660

Konkoly Observatory
Budapest
18 January 1999

HU ISSN 0374 – 0676

DX CETI, A HIGH-AMPLITUDE δ SCUTI STAR

L.L. KISS[1], B. CSÁK[1], J.R. THOMSON[2], K. SZATMÁRY[1]

[1] Department of Experimental Physics & Astronomical Observatory, JATE University, H-6720 Szeged, Dóm tér 9., Hungary, e-mail: l.kiss@physx.u-szeged.hu

[2] David Dunlap Observatory, University of Toronto, Richmond Hill, Canada

The first note on the light variation of DX Ceti (= NSV 00871 = HIP 12113 = HD 16189, $\langle V\rangle = 7.00$, $\Delta V = 0.20$, P = $0\overset{d}{.}1039$, spectral type A5) based on photoelectric observations is that of Stetson (1991) who suspected its variability but did not measure the full light curve. The monoperiodic nature was discovered by the Hipparcos satellite (ESA 1997) and the star was classified as an RRc variable.

We started a long-term observational project of Strömgren photometry and spectroscopy of the newly discovered bright Hipparcos variables (see Kiss et al. 1998 for the first results). DX Cet was chosen because its period is shorter than that of any other RR Lyrae variables and we suspected a probable misclassification. Therefore, accurate determination of the fundamental physical parameters is highly desirable.

The spectroscopic observations were carried out at the David Dunlap Observatory with the Cassegrain spectrograph attached to the 1.88m telescope on November 17/18, 1998. The detector and the spectrograph setup was the same as used by Vinkó et al. (1998). The resolving power was 11,000 and the signal-to-noise ratio reached about 50. The spectra were reduced with standard IRAF tasks, including bias removal, flat-fielding, cosmic ray elimination, order extraction (with the task *doslit*) and wavelength calibration. For the latter, two FeAr spectral lamp exposures were used, which were obtained immediately before and after every six stellar exposures. The observing sequence of FeAr-var-var-var-var-var-var-FeAr was chosen because of the short period of DX Cet. Careful linear interpolation between the two comparison spectra has been applied in order to take into account the sub-pixel shifts of the stellar exposures caused by the movement of the telescope. The exposure time was fixed as 3 minutes, which corresponds to 0.02 in phase, thus avoiding phase smearing of the radial velocity curve.

Radial velocities were determined by cross-correlating the continuum normalized spectra of DX Cet with the spectrum of the IAU standard velocity star HD 187691, using the IRAF task *fxcor*. The spectral type and radial velocity of HD 187691 are F8V and $+0.1 \pm 0.3$ km s^{-1}. The cross-correlated region was between 6550 and 6700 Å. The observed heliocentric radial velocities are presented in Table 1. The velocimetric accuracy is estimated to be about $\pm 1 - 1.5$ km s^{-1}, which is indicated by the residual scatter of the measurements around a fitted low-order Fourier polynomial.

The photometric measurements were obtained using the 0.4 m Cassegrain-type telescope of Szeged Observatory on November 18/19, 1998. The detector was a single-channel

Table 1: The observed heliocentric radial velocities (in km/s)

Hel. J.D.	V_{rad}	Hel. J.D.	V_{rad}	Hel. J.D.	V_{rad}
2451135.7029	18.6	2451135.7511	34.8	2451135.7877	19.7
2451135.7065	18.3	2451135.7535	36.6	2451135.7915	17.5
2451135.7088	19.7	2451135.7558	36.1	2451135.7938	17.3
2451135.7112	18.2	2451135.7606	37.5	2451135.7962	16.1
2451135.7135	21.1	2451135.7629	37.0	2451135.7985	15.1
2451135.7158	22.9	2451135.7653	35.1	2451135.8008	16.1
2451135.7289	28.7	2451135.7676	34.5	2451135.8032	16.2
2451135.7320	28.4	2451135.7699	34.6	2451135.8074	16.0
2451135.7344	29.3	2451135.7723	30.9	2451135.8097	18.1
2451135.7367	31.0	2451135.7760	28.1	2451135.8121	18.8
2451135.7390	31.7	2451135.7783	28.7	2451135.8151	19.9
2451135.7441	35.4	2451135.7807	25.9	2451135.8175	20.2
2451135.7465	33.7	2451135.7830	23.0	2451135.8198	21.4
2451135.7488	33.7	2451135.7853	19.1		

Optec SSP-5A photoelectric photometer equipped with *uvby* filters supplied by the manufacturer. We made differential photometry relative to HD 16647 ($V = 6.25, b-y = 0.26, m_1 = 0.15, c_1 = 0.47$ mag).

Unfortunately, due to the unfavorable weather conditions the accuracy was acceptable only for the V (±0.02) and c_1 (±0.035) data. The light and radial velocity curves are presented in Fig. 1.

Our photometric observations allowed estimation of the mean Strömgren colours which can be compared to previous observations of Stetson (1991 – S91): $\langle b-y\rangle = 0.19$ mag (0.180 by S91), $\langle m_1\rangle = 0.16$ mag (0.163 by S91), $\langle c_1\rangle = 0.85$ mag (0.808 by S91). The uncertainty of the mean values is about $\pm(0.01-0.02)$ mag. These values were used in the following analysis.

We have obtained one new time of maximum (HJD(max)=2451136.4227). Using the Hipparcos ephemeris (HJD(max) = 2448500.0730, P = $0\overset{d}{.}1039530$) we calculated an O−C value of -0.002 days, which suggests a very stable period. If we assume that this small negative value is due to a slightly shorter period, then the resulting corrected period is P = $0\overset{d}{.}1039529$, very close to the Hipparcos value. We conclude that the difference does not exceed the accuracy of the period determination and suggests a stable monoperiodic pulsation in DX Cet. This result is in very good agreement with the theoretical predictions of Breger & Pamyatnykh (1998) concerning the period changes of δ Scuti stars (see below).

The geometric distance of DX Cet, as measured by the Hipparcos satellite, is only 110 ± 12 pc. Since the star is far from the Galactic plane and lies within close proximity to the Sun, the interstellar reddening can be neglected. Thus, the apparent magnitude can be easily converted to absolute magnitude. The calculated visual absolute magnitude is 1.78 ± 0.24 mag, while the bolometric absolute magnitude (BC(A5) = -0.15, Carroll & Ostlie 1996) is 1.63 ± 0.24. The corresponding luminosity is $17.8 \pm 4 L_{\odot}$.

The metallicity, expressed with the [Fe/H] value, was determined by Eq. (2) of Malyuto (1994). The result is [Fe/H] = -0.05 ± 0.2, suggesting a nearly solar composition. The atmospheric parameters $T_{\rm eff}$ and $\log g$ were obtained using the recent synthetic colour grids of Kurucz (1993). An average $T_{\rm eff} - \log g$ pair was calculated with a two-dimensional linear

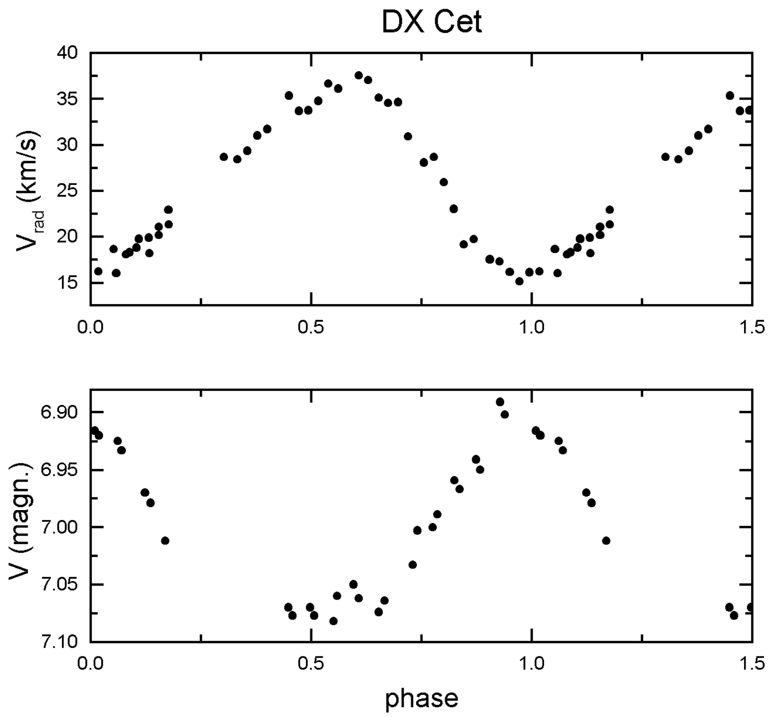

Figure 1. The radial velocity and light variations of DX Cet.

interpolation in the $(b-y)_0-(c_1)_0$ colour-colour diagram. The resulting parameters are: $\langle T_{\rm eff}\rangle = 7250 \pm 200$ K, $\langle \log \ g\rangle = 3.6 \pm 0.2$ dex.

We calculated the mean stellar radius combining the mean temperature, luminosity and solar values $T_{\rm eff} = 5770$ K and $M_{\rm bol} = 4.75$ (Allen 1976). It is $R_* = 2.7 \pm 0.5 R_\odot$. A stellar mass of $M_* = 1.5 \pm 0.6 M_\odot$ was obtained from the $\log g$ and R_* values by means of the effective gravity

$$g_{\rm eff} = G\frac{M_*}{R_*^2} + p\frac{dV_{\rm r}}{dt},$$

where $p = 1.36$ is the projection factor (Burki & Meylan 1986). In summary, therefore, we adopt

$$M_V = 1.78 \pm 0.24 \text{ mag}$$
$$M_{\rm bol} = 1.63 \pm 0.24 \text{ mag}$$
$$L = 17.8 \pm 4 L_\odot$$
$$[\text{Fe/H}] = -0.05 \pm 0.2$$
$$\langle T_{eff}\rangle = 7250 \pm 200 \text{ K}$$
$$\langle \log \ g\rangle = 3.6 \pm 0.2 \text{ dex}$$
$$\langle R_*\rangle = 2.7 \pm 0.5 R_\odot$$
$$M_* = 1.5 \pm 0.6 M_\odot$$

All of the parameters discussed above suggest the probable misclassification of DX Cet. All of them lie far beyond the typical range of RR Lyrae variables, however, they are very consistent with the typical δ Scuti properties. Our conclusion based on the physical parameters is that DX Cet is a monoperiodic, high-amplitude δ Scuti star. The stability of its period is in perfect agreement with the theoretical calculations of Breger & Pamyatnykh

(1998), who predict a small rate of the period change (smaller than 10^{-7} year^{-1}, see Fig. 6 in their paper) for δ Scuti variables with similar physical parameters.

The mode of pulsation is another relevant question. The relatively large amplitudes of the light and radial velocity variations suggest radial pulsation. The "classical" pulsation constant ($Q = P(M/R^3)^{1/2}$) was calculated to be 0.029 ± 0.012. According to the theoretical pulsational models (e.g. Petersen & Jørgensen 1972, Milligan & Carson 1992), both fundamental and first overtone pulsation modes are consistent with the observed physical parameters. The position of DX Cet on the (log $T_{\rm eff}$ − log g) and (log $T_{\rm eff}$ − log $L/L_\odot$) diagrams is very close to the evolutionary tracks of $M = 1.8 - 2.0 M_\odot$ (Breger & Pamyatnykh 1998).

This work has been supported by Hungarian OTKA Grants #F022249, #T022259, Grant PFP 5191/1997, Szeged Observatory Foundation and Foundation for Hungarian Education and Science (AMFK).

References:

Allen, C.W., 1976, *Astrophysical quantities*, The Athlone Press, London
Breger, M., Pamyatnykh, A.A., 1998, A&A, 332, 958
Burki, G., Meylan, G., 1986, A&A, 159, 261
Carroll, B.W., Ostlie, D.A., 1996, An introduction to modern stellar astrophysics, Addison-Wesley Pub., New York
ESA, 1997, The Hipparcos and Tycho Catalogues, ESA SP-1200
Kiss, L.L., Csák, B., Thomson, J.R., Vinkó, J., 1998, A&A, submitted
Kurucz, R.L., 1993, ATLAS9 Stellar Atmosphere Programs and 2 km/s Model Grids, CD-ROM No. 13
Malyuto, V., 1994, A&AS, 108, 441
Milligan, H., Carson, T.R., 1992, Ap&SS, 189, 181
Petersen, J.O., Jørgensen, H.E., 1972, A&A, 17, 367
Stetson, P., 1991, AJ, 102, 589
Vinkó, J., Evans, N.R., Kiss, L.L., Szabados, L., 1998, MNRAS, 296, 824