KP Cyg: An Unusual Metal-Rich RR Lyr Type Star of Long Period

S. M. Andrievsky and V. V. Kovtyukh
Department of Astronomy and Astronomical Observatory, Odessa National University, T.G. Shevchenko Park, 65014, Odessa, Ukraine; scan@deneb1.odessa.ua, val@deneb1.odessa.ua

George Wallerstein
Department of Astronomy, University of Washington, Seattle, WA 98195; wall@astro.washington.edu

S. A. Korotin
Department of Astronomy and Astronomical Observatory, Odessa National University, T.G. Shevchenko Park, 65014, Odessa, Ukraine; serkor@skyline.od.ua

And
Wenjin Huang
Department of Astronomy, University of Washington, Seattle, WA 98195; hwenjin@astro.washington.edu

Received 2010 May 17; accepted 2010 June 2; published 2010 July 22

ABSTRACT. We present the results of a detailed spectroscopic study of the long-period (P = 0.856 days) RR Lyrae star, KP Cyg. We derived abundances of many chemical elements including the light species, iron-group elements and elements of the s-processes. Most RR Lyrae stars with periods longer than 0.7 days are metal-deficient objects. Surprisingly, our results show that KP Cyg is very metal rich ([Fe/H] = +0.18 ± 0.23). By comparison with a number of short-period (P = 1 ∼ 6 days), metal-rich CWB stars, we suggest that KP Cyg may be a very short-period CWB star (BL Her star) rather than an RR Lyrae star. As seen in some CWB stars, KP Cyg shows strong excesses of carbon and nitrogen in its atmosphere. This indicates that the surface of KP Cyg has been polluted by material that has undergone helium burning (to enhance carbon) and proton capture (to transform carbon into nitrogen). We also note that UY CrB, whose period is 0.929 days, also shows an enhancement of C and N, and that two carbon Cepheids of short period, V553 Cen and RT TrA, show similar excesses of carbon and nitrogen.

1. INTRODUCTION

The RR Lyrae stars have been known for a long time to be an old population with diverse metallicity (from near-solar to [Fe/H] ∼ −2.5). They are present in most globular clusters but in widely different numbers ranging from zero to about 200 (Clement et al. 2001). The general properties of RR Lyrae stars can be found in detail in the book by Smith (1995). Most RR Lyrae stars in the field and in clusters are readily divided into two major categories: the RRc-type with periods from approximately 0.20 d to 0.45 days, and the RRab type with periods from about 0.4 to 1.0 days. There is a statistical correlation between metallicities and periods of RR Lyrae stars that the stars with longer periods are generally more metal-poor.

Very few RR Lyrae stars are known with periods longer than 0.75 days. In his classic paper on the metallicity of RR Lyrae stars, Preston (1959) included a few long-period stars that he found to be relatively metal-rich. However, he subsequently noted that the data of some of those stars, mostly their periods, were in error. Among the recently discovered RR Lyrae stars in the Northern Sky Variability Survey (NSVS), Kinemuchi et al. (2009) have found 21 variables with periods between 0.74 and 0.86 days whose metallicities range from [Fe/H] = −1.50 to −2.15 dex, similar to the RR Lyrae stars with periods of 0.60 to 0.75 days.

The general picture of the long-period RR Lyrae stars having low metallicity has not been strongly challenged until the discovery of some long-period RR Lyrae stars in the two globulars, NGC 6388 and 6441 (Pritzl et al. 2000). These two massive clusters have unusual color-magnitude diagrams. Their red giant branches are relatively faint indicating that they are relatively metal-rich for globular clusters. A spectroscopic analysis of red giants in NGC 6388 showed that [Fe/H] = −0.7 (Wallerstein et al. 2007). For NGC 6441, Gratton et al. (2007) found a metallicity of [Fe/H] = −0.34. In addition, for NGC 6441, Clementini et al. (2005) found a metallicity of −0.7 from a sample of its RR Lyrae stars. Both horizontal branches consist of a well-populated red
clump, accompanied by a significant number of blue stars, including a blue tail in NGC 6441. From Preston’s correlation of period and metallicity, such high metallicities indicate that the RR Lyrae stars should have short periods. However, Pritzl et al. (2000) found a wide range of periods in these clusters including numerous variables with periods larger than 0.75 days.

In an attempt to find field RR Lyrae stars that are similar to those with long periods in NGC 6388 and 6441, we have observed a few RR Lyraes with periods greater than 0.75 days. Among them, KP Cyg appears to be the most unusual. First noted by Vogt (1970) and subsequently confirmed by others (Loomis et al. 1988; Schmidt 2002), KP Cyg has a period of about 0.856 days, quite long for an RR Lyrae star. Preston (1959) found its $\Delta S$ value to be around 0, implying that KP Cyg is a metal-rich object. Other than this information, we know little about the star. In this article we present the results of an analysis of the chemical composition in this star’s atmosphere.

2. OBSERVATION AND DATA REDUCTION

Spectra of KP Cyg were obtained using the echelle spectrograph on the 3.5 m telescope at the Apache Point Observatory (APO). The usable wavelength coverage, limited by the red-sensitive 2048 x 2048 CCD chip, runs from 4000 Å to 9000 Å. The resolving power is about 35,000. The integration time of each exposure was set to 20 ~ 30 minutes to reach good S/N, and to avoid heavy contamination from cosmic-ray events. We then combined the spectra that were taken sequentially within 1 hr, and measured the S/N at the continuum level per pixel in the very clean region between 7550–7600 Å of the combined spectra.

Table 1 lists the dates (JD), phases, heliocentric radial velocities ($V_r$), and derived values of $T_{\text{eff}}$ and $\log g$ for each phase, and the signal-to-noise ratio (S/N) of each spectrum. Our $V_r$ measurements confirm that the period of KP Cyg is around 0.9 days. We also note the presence of anomalous structures in H$\alpha$ such as line doubling and emission. A comparison of the abundances derived from the spectra having anomalous H$\alpha$ profiles with those derived from the spectra showing normal H$\alpha$ profiles demonstrates that there is no very significant difference among the derived [Fe/H] values. We suspect that the anomalous features in the H$\alpha$ line profile originate from the layers far above the line-forming region that is relevant to our abundance analysis.

The spectra were extracted from the raw frames using standard IRAF1 procedures. The continuum level placement, wavelength calibration, and equivalent width measurements were performed with the DECH20 code (Galazutdinov 1992). The final equivalent width measurements are presented in Table 2. The equivalent widths of some very strong or seriously blended lines were not measured. Instead, for these lines, we compared their NLTE synthesized profiles directly with the observed spectra in the abundance analysis (see § 3.2).

### 3. METHOD OF ANALYSIS

3.1. Atmospheric Parameters and LTE Elemental Abundances

The LTE elemental abundances were derived using Kurucz’s WIDTH9 (Kurucz 1996) code with the model atmospheres interpolated from the ATLAS9 model grid. We used log $gf$ values derived from an inverted solar analysis (Kovtyukh & Andrievsky 1999).

The atmospheric parameters of KP Cyg ($T_{\text{eff}}$, log $g$, $V_r$) were determined by meeting a few requirements in our spectroscopic analysis: $T_{\text{eff}}$ and $V_r$ were constrained by minimizing the dependence of the derived iron abundance from each Fe I line on their excitation potentials and equivalent widths; log $g$ was determined by requiring an ionization equilibrium between Fe I and Fe II. While log $g$ may be calculated using the known luminosities and masses of RR Lyrae stars, we preferred to use the method based on the FeI/FeII ionization equilibrium, because the acceleration of the atmosphere during its pulsation cycle is then automatically taken into account. 

---

1 At http://iraf.noao.edu.

### Table 1

| Date      | JD 2450000+ | Phase | S/N | $V_r$ (km s$^{-1}$) | $T_{\text{eff}}$ (K) | $\log g$ | $V_r$ (km s$^{-1}$) | Remarks |
|-----------|-------------|-------|-----|-------------------|----------------------|---------|-------------------|---------|
| 2005 Nov 13 | 3687.606    | .135  | 46  | 8.6               | 7050                 | 2.6     | 2.5               |         |
| 2006 Nov 05 | 4044.672    | .299  | 47  | 13.1              | 6600                 | 3.0     | 3.3               |         |
| 2007 May 01 | 4221.963    | .430  | 73  | 20.3              | 6450                 | 3.4     | 3.5 Ho emission   |         |
| 2005 Sep 24 | 3637.607    | .720  | 88  | 35.6              | 6300                 | 2.4     | 3.2 Ho emission   |         |
| 2006 Oct 03 | 4011.720    | .800  | 47  | 27.5              | 6650                 | 3.0     | 4.2 Ho emission   |         |
| 2005 Sep 13 | 3626.711    | .991  | 91  | −1.8              | 7400                 | 3.0     | 2.5               |         |
### TABLE 2
**Equivalent Widths (EW) in the Program Spectra of KP Cyg**

| \( \lambda \) (Å) | Ion | \( \log gf \) | \( \phi = 0.135 \) | 0.299 | 0.430 | 0.720 | 0.800 | 0.991 |
|-----------------|-----|------------|----------------|------|------|------|------|------|
| 5052.17         | 6   | −1.65      | 0              | 0    | 0    | 131  | 0    | 0    |
| 5380.34         | 6   | −1.84      | 144            | 0    | 0    | 0    | 127  | 0    |
| 6010.68         | 6   | −1.87      | 0              | 0    | 0    | 0    | 62   | 0    |
| 6014.83         | 6   | −1.66      | 0              | 0    | 0    | 0    | 102  | 0    |
| 6587.61         | 6   | −1.13      | 142            | 168  | 145  | 103  | 0    | 153  |

**Note.**—Table 2 is published in its entirety in the electronic edition of the *PASP*. A portion is shown here for guidance regarding its form and content.

* Code for ions, e.g., 2601 = Fe II.

* EW of 0 means that the EW measurement of the line is not available.

### TABLE 3
**List of the Lines Used for NLTE Calculations**

| Ion  | \( \lambda \) (Å) | \( \chi \) (eV) | \( \log gf \) | \( \log \epsilon(El) \) (5) | Ion  | \( \lambda \) (Å) | \( \chi \) (eV) | \( \log gf \) | \( \log \epsilon(El) \) (10) |
|------|-------------------|----------------|-------------|-----------------------------|------|-------------------|----------------|-------------|-----------------------------|
| C I  | 5052.17           | 7.685          | −1.30       | 8.43                        | Na I | 4982.81           | 2.104          | −0.96       | 6.25                        |
|      | 5380.34           | 7.685          | −1.62       | 8.43                        |      | 5380.34           | 7.685          | −1.62       | 8.43                        |
|      | 6014.83           | 8.643          | −1.58       | 5682.63                     |      | 6014.83           | 8.643          | −1.58       | 5682.63                     |
|      | 6413.55           | 8.771          | −2.00       | 5688.19                     |      | 6413.55           | 8.771          | −2.00       | 5688.19                     |
|      | 6587.61           | 8.537          | −1.13       | 5688.20                     |      | 6587.61           | 8.537          | −1.13       | 5688.20                     |
|      | 6655.51           | 8.337          | −1.79       | 6154.22                     |      | 6655.51           | 8.337          | −1.79       | 6154.22                     |
|      | 7087.83           | 8.647          | −1.44       | 6160.74                     |      | 7087.83           | 8.647          | −1.44       | 6160.74                     |
|      | 7100.12           | 8.643          | −1.47       | 8183.25                     |      | 7100.12           | 8.643          | −1.47       | 8183.25                     |
|      | 7108.93           | 8.640          | −1.59       | 8194.79                     |      | 7108.93           | 8.640          | −1.59       | 8194.79                     |
|      | 7111.47           | 8.640          | −1.09       | 8194.82                     |      | 7111.47           | 8.640          | −1.09       | 8194.82                     |
|      | 7113.17           | 8.647          | −0.77       | 4167.27                     | Mg I | 4167.27           | 4.346          | −0.77       | 7.58                        |
|      | 7115.17           | 8.643          | −0.93       | 4702.99                     |      | 7115.17           | 8.643          | −0.93       | 4702.99                     |
|      | 7115.18           | 8.640          | −1.47       | 5172.68                     |      | 7115.18           | 8.640          | −1.47       | 5172.68                     |
|      | 7116.99           | 8.647          | −0.91       | 5183.60                     |      | 7116.99           | 8.647          | −0.91       | 5183.60                     |
|      | 7119.65           | 8.643          | −1.15       | 5528.40                     |      | 7119.65           | 8.643          | −1.15       | 5528.40                     |
|      | 7473.30           | 8.771          | −2.04       | 5711.09                     |      | 7473.30           | 8.771          | −2.04       | 5711.09                     |
|      | 7476.17           | 8.771          | −1.57       | 6696.02                     | Al I | 6696.02           | 3.143          | −1.48       | 6.43                        |
|      | 7483.44           | 8.771          | −1.37       | 6698.66                     |      | 7483.44           | 8.771          | −1.37       | 6698.66                     |
|      | 7848.24           | 8.848          | −1.73       | 7835.30                     |      | 7848.24           | 8.848          | −1.73       | 7835.30                     |
|      | 7852.86           | 8.851          | −1.68       | 7836.13                     |      | 7852.86           | 8.851          | −1.68       | 7836.13                     |
|      | 7860.88           | 8.851          | −1.15       | 7836.13                     |      | 7860.88           | 8.851          | −1.15       | 7836.13                     |
|      | 8335.14           | 7.685          | −0.44       | 8772.87                     |      | 8335.14           | 7.685          | −0.44       | 8772.87                     |
| N I  | 7442.29           | 10.330         | −0.39       | 7.89                        |      | 7442.29           | 10.330         | −0.39       | 7.89                        |
|      | 7468.31           | 10.336         | −0.19       | 8773.90                     |      | 7468.31           | 10.336         | −0.19       | 8773.90                     |
|      | 8184.86           | 10.330         | −0.28       | 8773.90                     |      | 8184.86           | 10.330         | −0.28       | 8773.90                     |
|      | 8188.01           | 10.326         | −0.29       | 6743.44                     |      | 8188.01           | 10.326         | −0.29       | 6743.44                     |
|      | 8210.71           | 10.330         | −0.73       | 6743.53                     |      | 8210.71           | 10.330         | −0.73       | 6743.53                     |
|      | 8216.33           | 10.336         | 0.09        | 6743.64                     |      | 8216.33           | 10.336         | 0.09        | 6743.64                     |
|      | 8223.12           | 10.330         | −0.32       | 6748.57                     |      | 8223.12           | 10.330         | −0.32       | 6748.57                     |
|      | 8242.38           | 10.336         | −0.32       | 6748.68                     |      | 8242.38           | 10.336         | −0.32       | 6748.68                     |
|      | 8680.28           | 10.336         | 0.35        | 6748.84                     |      | 8680.28           | 10.336         | 0.35        | 6748.84                     |
TABLE 3 (Continued)

| Ion       | λ (eV) | log $g_f$ | log $\epsilon(E)_\odot$ (5) | Ion       | λ (eV) | log $g_f$ | log $\epsilon(E)_\odot$ (10) |
|-----------|--------|-----------|-------------------------------|-----------|--------|-----------|-------------------------------|
| O I       | 5577.34| 1.967     | -8.24                         | K I       | 7664.91| 0.000     | 0.13                          |
|           | 6155.97| 10.740    | -0.67                         |           | 7698.97| 0.000     | -0.17                         |
|           | 6156.76| 10.741    | -0.45                         | Sr II     | 4077.71| 0.000     | 0.15                          |
|           | 6158.17| 10.741    | -0.31                         |           | 4161.79| 2.940     | -0.41                         |
|           | 6300.30| 0.000     | -9.75                         |           | 4215.52| 0.000     | -0.18                         |
|           | 6363.77| 0.020     | -10.30                        | Ba II     | 4554.03| 0.000     | 0.08                          |
|           | 7771.94| 9.146     | 0.33                          |           | 4554.05| 0.000     | -0.79                         |
|           | 7774.16| 9.146     | 0.19                          |           | 4554.00| 0.000     | -1.01                         |
|           | 7775.38| 9.146     | -0.03                         |           | 5853.68| 0.604     | -1.00                         |
|           | 8446.24| 9.521     | -0.52                         |           | 6141.71| 0.704     | -0.08                         |
|           | 8446.35| 9.521     | 0.18                          |           | 6496.89| 0.604     | -0.46                         |
|           | 8446.75| 9.521     | -0.05                         |           | 6496.89| 0.604     | -1.32                         |

Fig. 1.—Examples of the best-fit synthesized NLTE profiles (solid lines) are overplotted on the observed spectra (filled circles).
3.2. NLTE Elemental Abundances

The NLTE effects were considered in deriving the abundances of such elements as carbon, nitrogen, oxygen, sodium, magnesium, aluminum, sulfur, potassium, strontium, and barium. The details of the atomic models used for calculating the NLTE line profiles are described in a series of papers by: Andrievsky et al. (2001, 2007, 2008, 2009, 2010a, 2010b) for carbon, sodium, aluminum, barium, magnesium, potassium, and strontium, respectively; Korotin (2009) for sulfur; Mishenina et al. (2000) for oxygen; and Lyubimkov et al. (2010) for nitrogen. The NLTE abundances of these elements were derived using a NLTE spectrum synthesis code adapted from MULTI (see Carlsson 1986 and Korotin et al. 1999a, 1999b). The list of the lines used in the NLTE calculations and their parameters are given in Table 3.

Because some of the NLTE-treated lines are blended with other lines, we used the combined NLTE and LTE synthetic spectra when we compared the NLTE line profiles with the observed spectra. This was done using the code SYNTHV (Tsymbal 1996), which was developed for LTE spectrum synthesis. We calculated the synthetic spectra for the selected regions comprising the lines of interest and all nearby lines that are found in VALData-base (Kupka et al. 2000). Meanwhile, for each line treated in NLTE, the corresponding b-factors (the ratios of the NLTE to LTE populations in the involved energy levels) were calculated by MULTI and then fed into SYNTHV for calculating the NLTE line source functions. Some examples of the NLTE profile fitting in KP Cyg spectra are shown in Figure 1.

Our results of the NLTE abundance analysis of KP Cyg need to be compared to the Sun. Hence we chose to use the same source for the model atmospheres for both the Sun and KP Cyg. We used Kurucz’s solar model to derive our NLTE abundances in the Sun in the same way as we did for KP Cyg. Solar equivalent widths were obtained from observations of the asteroid, Vesta, obtained by Don York, using the same instrument (the APO echelle spectograph) as was used for the KP Cyg spectra. The derived NLTE abundances of the Sun (based on the line list of Table 3) are given in columns (5) and (10) of Table 3.

In Table 4, we show the sensitivity of the NLTE oxygen abundance to the variation in the adopted atmospheric parameters. As one can see, the changes of the parameters within our observational uncertainty (\(\Delta T_{\text{eff}} \approx \pm 150 \text{ K}\), \(\Delta \log g \approx \pm 0.2\), and \(\Delta V_t \approx \pm 0.3 \text{ km s}^{-1}\)) cause only small fluctuations in the derived oxygen abundance (\(<0.2\) dex).

4. DISCUSSION

The final derived elemental abundances are given in Table 5. The abundances of the iron-group elements in KP Cyg are consistent with the results by Preston (1959) (\(\Delta S = 0\)). According to the combined data presented by Smith (1995, Fig. 3.9), there are no RR Lyr stars in globular clusters both with metallicity higher than \(-1.0\) and periods larger than 0.8 days except for a few stars in the two puzzling clusters, NGC 6388 and 6441, and a single star in 47 Tuc. The supersolar metallicity and unusually long period makes KP Cyg even more peculiar than the stars in NGC 6388 and 6441. It casts a doubt on the RR Lyrae classification of KP Cyg.

RR Lyrae stars and short-period type II Cepheids (CWB for short, also called BL Her stars) are known to have a helium-burning core and a hydrogen-burning shell surrounding the core. In the CN cycle, \(^{12}\text{C}\) is converted to \(^{14}\text{N}\) through the reaction \(^{12}\text{C}(p, \gamma)^{13}\text{N}(\beta^+, \nu)^{13}\text{C}(p, \gamma)^{14}\text{N}\). In addition, \(^{13}\text{C}\) may capture an \(\alpha\)-particle to produce \(^{16}\text{O}\). \(^{12}\text{C}\) may become a source of neutrons through the \(^{13}\text{C}(\alpha, n)^{16}\text{O}\) reaction. The neutrons may then be captured by nuclei of the iron peak elements to create Co and Cu, as well as many other heavier elements. Analysis of the abundances of CNO as well as the light and heavy s-process elements in these stars is the key to understanding how these processes function inside a star.

Our NLTE results for CNO clearly show that carbon and nitrogen are significantly in excess in KP Cyg, while oxygen demonstrates only a moderate overabundance. An overabundance can be also noted for sodium and aluminum. Altogether these facts testify that this star has experienced dredge-up of the materials processed in CNO and NeNa (and perhaps MgAl) cycles. Similar enhancements of C and N in some of the CWB type stars were recently noted by Maas et al. (2007). In Table 6 we show the values of \(\log e (C + N + O)\) and \(\log e (C + N)\) for our program star and several short-period (\(P < 7\) days) CWB stars from Maas et al. (2007). All 7 stars are more metal-rich than the RR Lyr stars in globular clusters. The Sun is listed for comparison (the necessary input CNO abundances are from Table 3).

Figure 2 shows that the C and N excesses in the short-period CWB stars are very similar to that of KP Cyg. As Maas et al. (2007) have suggested, the excess of C must be due to helium burning during or after the core flash. The excess of N must be due to proton capture by C. The oxygen abundances do not show the great excesses of N. This means that O was
| Ion     | $\phi = 0.135$ | $\phi = 0.299$ | $\phi = 0.315$ | $\phi = 0.720$ | $\phi = 0.800$ | $\phi = 0.991$ | Mean |
|---------|----------------|----------------|----------------|----------------|----------------|----------------|------|
|        | [E/H]          | $\sigma$    | N       | [E/H]          | $\sigma$    | N       | [E/H]          | $\sigma$    | N       | [E/H]          | $\sigma$    | N       | [E/H]          | $\sigma$    | N       |
| C I     | +0.26          | 0.13         | 23      | +0.92          | 0.13         | 18      | +0.95          | 0.11         | 19      | +0.77          | 0.15         | 17      | +0.79          | 0.15         | 14      | +0.67          | 0.12         | 16      |
| N I     | +0.41          | 0.12         | 4       | +0.29          | 0.12         | 6       | +0.34          | 0.12         | 6       | +0.24          | 0.12         | 3       | +0.29          | 0.12         | 4       | +0.34          | 0.14         | 4       | +0.32          |
| Na I    | +0.54          | 0.12         | 6       | +0.45          | 0.12         | 5       | +0.48          | 0.10         | 6       | +0.54          | 0.10         | 6       | +0.51          | 0.12         | 5       | +0.38          | 0.14         | 4       | +0.48          |
| Mg I    | +0.04          | 0.12         | 6       | -0.05          | 0.12         | 3       | +0.07          | 0.14         | 5       | -0.05          | 0.12         | 5       | -0.13          | 0.12         | 6       | -0.13          | 0.15         | 4       | -0.02          |
| Al I    | +0.16          | 0.12         | 10      | +0.32          | 0.06         | 14      | +0.29          | 0.10         | 17      | +0.14          | 0.18         | 7       | +0.34          | 0.11         | 20      | +0.16          | 0.18         | 8       | +0.25          |
| Si I    | +0.11          | 0.12         | 10      | +0.32          | 0.13         | 4       | +0.34          | 0.11         | 6       | +0.21          | 0.12         | 2       | +0.27          | 0.13         | 2       | +0.14          | 0.14         | 3       | +0.26          |
| Si II   | +0.26          | 0.13         | 5       | +0.32          | 0.13         | 4       | +0.34          | 0.11         | 6       | +0.21          | 0.12         | 2       | +0.27          | 0.13         | 2       | +0.14          | 0.14         | 3       | +0.26          |
| S I     | +0.27          | 0.12         | 1       | -0.20          | 0.12         | 1       | -             | -             | -       | -0.10          | 0.12         | 1       | -0.10          | 0.12         | 1       | +0.10          | 0.12         | 1       | -0.01          |
| Ca I    | +0.04          | 0.12         | 9       | +0.03          | 0.12         | 9       | +0.03          | 0.15         | 8       | +0.19          | 0.23         | 8       | +0.05          | 0.14         | 10      | -0.15          | 0.12         | 7       | +0.03          |
| Sc II   | -0.11          | 0.07         | 4       | +0.32          | 0.17         | 6       | +0.37          | 0.16         | 5       | -0.07          | 0.18         | 5       | +0.15          | 0.18         | 7       | 0.01           | 0.13         | 3       | +0.14          |
| Ti I    | -0.20          | 0.04         | 3       | +0.13          | 0.12         | 5       | +0.14          | 0.14         | 5       | -0.08          | 0.16         | 3       | +0.04          | 0.06         | 7       | +0.03          | -1           | 0       | +0.02          |
| V I     | +0.04          | 0.12         | 2       | +0.31          | 0.12         | 4       | +0.11          | 0.13         | 6       | +0.08          | 0.20         | 3       | +0.03          | 0.13         | 7       | -             | -             | 0       | +0.05          |
| Cr I    | -0.07          | 0.07         | 3       | +0.09          | 0.14         | 4       | +0.02          | 0.12         | 6       | -0.15          | 0.19         | 3       | +0.00          | 0.18         | 9       | -             | -             | 0       | -0.01          |
| Cr II   | -0.05          | 0.08         | 5       | +0.17          | 0.08         | 5       | +0.14          | 0.11         | 3       | -0.04          | 0.18         | 4       | +0.05          | 0.10         | 8       | +0.14          | 0.14         | 3       | +0.06          |
| Mn I    | +0.11          | 0.12         | 2       | +0.15          | 0.05         | 2       | +0.16          | 0.19         | 3       | +0.34          | -2           | 2       | +0.15          | 0.17         | 6       | -0.14          | -1           | 0       | +0.14          |
| Fe I    | +0.09          | 0.12         | 68      | +0.29          | 0.10         | 72      | +0.30          | 0.15         | 88      | +0.05          | 0.19         | 59      | +0.18          | 0.12         | 137      | +0.12          | 0.18         | 55      | +0.18          |
| Fe II   | +0.09          | 0.13         | 17      | +0.29          | 0.08         | 15      | 0.131          | 0.12         | 18      | +0.08          | 0.19         | 10      | +0.16          | 0.13         | 30      | +0.13          | 0.11         | 12      | +0.18          |
| Ni I    | +0.06          | 0.13         | 15      | +0.36          | 0.13         | 23      | +0.16          | 0.08         | 25      | +0.16          | 0.15         | 12      | +0.11          | 0.11         | 24      | +0.20          | 0.19         | 8       | +0.18          |
| Sr II   | -             | -             | -       | -             | -             | -       | +0.12          | 0.17         | 2       | -             | -             | -       | +0.05          | 0.15         | 1       | +0.050         | 0.15         | 2       | +0.07          |
| Y II    | +0.08          | 0.21         | 3       | +0.35          | 0.16         | 4       | 0.151          | 0.15         | 5       | +0.08          | 2             | -       | -0.01          | 0.13         | 1       | 0.13           | -1           | 0       | +0.13          |
| Ba II   | +0.20          | 0.14         | 4       | -0.15          | 0.10         | 4       | -0.20          | 0.10         | 4       | -0.35          | 0.10         | 3       | -0.15          | 0.150        | 4       | -0.34          | 0.13         | 4       | -0.16          |
| Nd II   | -             | -             | -       | +0.12          | 0.02         | 2       | +0.24          | 0.20         | 3       | +0.25          | -2           | 0       | -0.20          | -2           | 0       | -               | -             | 0       | +0.13          |

*NLTE abundances.
not significantly enhanced by the capture of $\alpha$-particles by C. Figure 3 shows that the high values of $\log \epsilon (C+N+O)$ are mainly due to the excess of C and N, while the influence of O is very limited. It is clear that the enhancement of N in these stars is due to the combination of the triple-alpha reaction and proton capture rather than just the rearrangement of the original CNO isotopes.

The evidence suggests that KP Cyg probably belongs to the CWB variables rather than to the RR Lyrae stars. Another RR Lyrae star (Wallerstein et al. 2009), UY CrB, seems to be very similar to KP Cyg because it follows the same CNO trends shown in Figures 2 and 3, and has a long period (0.929 days, Schmidt 2002). The two carbon cepheids V553 Cen and RT TrA, first recognized by Lloyd Evans (1983) and analyzed by Wallerstein & Gonzalez (1996) and by Wallerstein et al. (2000), have been included in Table 6 and in Figures 2 and 3. Their C and N excesses are similar to those of KP Cyg. In fact, there is no reason why variables should be classified according to whether their periods are greater or less than the rotation period of the Earth. When the importance of the so-called break at 1 day is disregarded, KP Cyg could also be a short-period classical cepheid. Its low Galactic latitude of $5^\circ$ certainly permits that.

### 5. CONCLUSION

KP Cyg has an unusually long pulsational period ($P = 0.856$ days) for an RR Lyrae star. If it is an RR Lyrae star, KP Cyg is expected to be a metal-poor star. However, the derived iron abundance completely rules out the possibility that KP Cyg is a metal-poor star. Our analysis suggests that KP Cyg is more likely a short-period CWB type star. Its low Galactic latitude of only $5^\circ$ is notable. The origin of the relatively metal-rich RR Lyrae and CWB stars remains uncertain since they have not been related to another population such as a globular cluster of solar metallicity. It may be necessary to reach out to dE galaxies such as the companions to M31 to find RR Lyrae or CWB type stars of solar metallicity in a system that we understand better than our own complicated Galaxy. Perhaps the 30 m telescopes now being designed will be able to accomplish that.

S. M. A. and V. V. K. would like to express their gratitude to the Kenilworth Fund of the New York Community Trust for the financial support of this study. The individual financial support from Kenilworth Fund was made possible through CRDF. S. M. A. also thanks the Paris Observatory, Meudon, for its hospitality while this article was in the final stages of preparation. We thank Don York for the spectrum of Vesta, and Marta Mottini for reading the manuscript and making some good suggestions. We also thank the referee, George Preston, for his helpful comments. Much of the information about KP Cyg was gathered with the help of SIMBAD.

**TABLE 6**

| Star     | $P$ (days) | [Fe/H] | $\log \epsilon (C+N+O)$ | $\log \epsilon (C+N)$ |
|----------|------------|--------|--------------------------|------------------------|
| KP Cyg   | 0.9        | +0.18  | 9.59                     | 9.45                   |
| UY CrB   | 0.9        | −0.40  | 9.20                     | 8.94                   |
| BX Del   | 1.1        | −0.24  | 9.43                     | 9.29                   |
| VY Pyx   | 1.2        | −0.46  | 9.18                     | 8.97                   |
| BL Her   | 1.3        | −0.18  | 9.22                     | 9.04                   |
| SW Tau   | 1.6        | +0.18  | 9.73                     | 9.66                   |
| AU Peg   | 2.4        | −0.24  | 9.11                     | 8.80                   |
| DQ And   | 3.2        | −0.50  | 8.71                     | 8.42                   |
| TX Del   | 6.2        | +0.06  | 9.50                     | 9.25                   |
| Sun      |            |        |                          |                        |

**FIG. 2.** $\log \epsilon (C+N)$ vs. [Fe/H] for KP Cyg, UY CrB, the short-period CWB stars (plus symbols) from Maas et al. (2007), two carbon cepheids, and the Sun.

**FIG. 3.** $\log \epsilon (C+N)$ vs. $\log \epsilon (C+N+O)$ for KP Cyg, UY CrB, the short-period CWB stars (plus symbols) from Maas et al. (2007), two carbon cepheids, and the Sun.
REFERENCES

Andrievsky, S. M., Kovtyukh, V. V., Korotin, S. A., Spite, M., & Spite, F. 2001, A&A, 367, 605
Andrievsky, S. M., Spite, M., Korotin, S. A., Spite, F., Bonifacio, P., Cayrel, R., Hill, V., & P., François 2007, A&A, 464, 1081
———. 2008, A&A, 481, 481
Andrievsky, S. M., Spite, M., Korotin, S. A., Spite, F., François, P., Bonifacio, P., Cayrel, R., & Hill, V. 2009, A&A, 494, 1083
Andrievsky, S. M., Spite, M., Korotin, S. A., Spite, F., Bonifacio, P., Cayrel, R., François, P., & Hill, V. 2010a, A&A, 509, 88
Andrievsky, S. M., Spite, M., Korotin, S. A., Spite, F., Bonifacio, P., François, P., Cayrel, R., & Hill, V. 2010b, A&A, submitted
Carlsson, M. 1986, Uppsala Obs. Rep., 33
Clement, C. M., et al. 2001, AJ, 122, 2587
Clementini, G., et al. 2005, ApJ, 630, L145
Galazutdinov, G. A. 1992, Preprint Special Astrophysical Observatory RAS, 92
Gratton, R. G., Lucatello, S., Bragaglia, A., Carretta, E., Cassisi, S., Momany, Y., Pancino, E., Valenti, E., et al. 2007, A&A, 464, 953
Kinemuchi, K., Smith, H. A., Wozniak, P. R., & McKay, T. A. 2009, AJ, 132, 1202
Korotin, S. A. 2009, Astron. Rep., 53, 651
Korotin, S. A., Andrievsky, S. M., & Luck, R. E. 1999a, A&A, 351, 168
Korotin, S. A., Andrievsky, S. M., & Kostynchuk, L Yu. 1999b, Ap&SS, 260, 531
Kovtyukh, V. V., & Andrievsky, S. M. 1999, A&A, 351, 597
Kupka, F., Ryabchikova, T. A., & Piskunov, N. E., et al. 2000, Baltic Astron., 9
Kurucz, R. 1996, in ASP Conf. Ser. 108, Model Atmospheres and Spectrum Synthesis, ed. S. J. Adelman, F. Kupka, & W. W. Weiss (San Francisco: ASP) 270
Lloyd Evans, T. 1983, Observatory, 103, 276
Lyubimkov, L. S., Lambert, D. L., Korotin, S. A., Poklad, D. B., Rachkovskaya, T. M., & Rostopchin, S. I. 2010, MNRAS, in press
Loomis, Ch., Schmidt, E. G., & Simon, N. R. 1988, MNRAS, 235, 1059
Maas, T., Giridhar, S., & Lambert, D. L. 2007, ApJ, 666, 378
Mishenina, T. V., Korotin, S. A., Kholokova, V. G., & Panchuk, V. E. 2000, A&A, 353, 978
Preston, G. W. 1959, ApJ, 130, 507
Pritzl, B., Smith, H. A., Catelan, M., & Sweigart, A. V. 2000, ApJ, 530, L41
Schmidt, E. G. 2002, ApJ, 123, 965
Smith, H. A. 1995, RR Lyrae Stars, Cambridge Univ. Press
Tsymbal, V. V. 1996, ASP Conf. Ser. 108, Model Atmospheres and Spectrum Synthesis, ed. S. J. Adelman, F. Kupka, & W. W. Weiss (San Francisco: ASP)
Vogt, M. 1970, Inf. Bull. Variable Stars, 468, 1
Wallerstein, G., & Gonzalez, G. 1996, MNRAS, 282, 1236
Wallerstein, G., Kovtyukh, V. V., & Andrievsky, S. M. 2007, AJ, 133, 1373
———. 2009, ApJ, 692, L127
Wallerstein, G., Matt, S., & Gonzalez, G. 2000, MNRAS, 311, 414