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Francis C. Fekel
Tennessee State University

Gregory W. Henry
Tennessee State University

Melissa L. Hampton
Tennessee State University

Robert E. Fried
Braeside Observatory

Mary D. Morton
Vanderbilt University

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CHROMOSPHERICALLY ACTIVE STARS. XII. ADS 11060 C: A DOUBLE LINED K DWARF BINARY IN A QUINTUPLE SYSTEM

FRANCIS C. FEKEL[1,2]

Center of Excellence in Information Systems, Tennessee State University, 330 Tenth Avenue North, Nashville, Tennessee 37203-3401
Space Science Laboratory, ES-82, NASA Marshall Space Flight Center, Huntsville, Alabama 35812
Electronic mail: fekel@ssl.msfc.nasa.gov

GREGORY W. HENRY[1,3] AND MELISSA L. HAMPTON

Center of Excellence in Information Systems, Tennessee State University, 330 Tenth Avenue North, Nashville, Tennessee 37203-3401
Electronic mail: henry@schwab.tnstate.edu

ROBERT FRIED

Braeside Observatory, P.O. Box 906, Flagstaff, Arizona 86002
Electronic mail: braesida@naucse.cse.nau.edu

MARY D. MORTON

Department of Physics and Astronomy, Vanderbilt University, Nashville, Tennessee 37235

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ABSTRACT

ADS 11060 C is a double lined spectroscopic binary with a period of 25.7631 days and an eccentricity of 0.565. Spectral types of the two stars are estimated as K7 V and M0 V with a magnitude difference of about 0.55 mag in V. The stars appear to be somewhat metal rich with respect to the Sun. Despite the relatively large masses of 0.53 and 0.51 $\mathscr{M}_\odot$, our photometric observations find no evidence for eclipses and we estimate an inclination of $77°\pm11°$. ADS 11060 C is, however, photometrically variable with a period of 9 ± 1 day and an amplitude of 0.05 mag in V. Thus, it is a newly identified BY Draconis variable. The center-of-mass velocity of ADS 11060 C and an estimated parallax of 0.030″ support its physical association with ADS 11060 AB, making this a quintuple system. The projected separation of the AB–C system is nearly 1200 AU. Although the log lithium abundances of the two components of ADS 11060 C are only upper limits, ≤ -0.14, lithium abundances of the AB–C components appear to be consistent with those of similar stars in the α Persei and Pleiades clusters, suggesting an age of about 70 Myr for ADS 11060 AB–C. The system is a possible member of the Pleiades moving group. Listed as an optical counterpart to a source in the *ROSAT* Wide Field Camera extreme-ultraviolet bright source catalog, both ADS 11060 AB and C may contribute to the observed flux.

1. INTRODUCTION

ADS 11060 C [$\alpha=18^h05^m49.9^s$, $\delta=21°26'18''$ (2000), $V=10.62$] is one of several faint visual companions to the close visual binary ADS 11060 AB=HD 165590=V772 Herculis. It lies almost directly south of the brighter components by nearly 30″ (Aitken 1932) and is about 3.6 mag fainter than AB. Eggen (1965) computed the photometric parallaxes of AB and C from his photometry and concluded that these visual components are members of the same system. From an examination of the Strömgren photometry of Perry (1969), Batten *et al.* (1979) concluded that three other components were optical companions to the AB system while the C component, perhaps an M dwarf, appeared to be physically related, in agreement with Eggen's conclusion. Batten *et al.* suggested that the AB–C system was quite young, perhaps as young as the Pleiades cluster.

Abt (1986) included the components of ADS 11060 in his study of a number of possible Trapezium systems. Such multiple systems consist of components whose separations are similar and hence, they are young systems that are dynamically unstable. Although it did not turn out to be a Trapezium system, AD 11060 proved to be one of the most interesting groups in his sample. Abt (1986) concluded that it consisted of the chance projection of two hierarchical systems, one with components A, B, and C at about 32 pc and a second with components D, E, and G at roughly 150 pc. In addition, he classified the C component as K7 V and noted that Ca II double emission lines were present with a velocity separation of 110 km s^{-1}. This latter information led to the extensive spectroscopic and photometric investigations of the system reported here. We identify the more massive star with the stronger absorption lines as the primary or Ca component and the less massive star with the weaker lines as the secondary or Cb component.

In reality, the AB visual system is a spectroscopic–visual

[1]Visiting Astronomer, Kitt Peak National Observatory, National Optical Astronomy Observatories, operated by the Association of Universities for Research, Inc., under contract with the National Science Foundation.
[2]NRC Senior Research Associate.
[3]Guest Observer, McDonald Observatory, The University of Texas.

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TABLE 1. Velocity observations of ADS 11060 C.

HJD – 2400000	Phase	V_{Ca} (km s^{-1})	$(O-C)_{Ca}$ (km s^{-1})	V_{Cb} (km s^{-1})	$(O-C)_{Cb}$ (km s^{-1})
46867.999	0.233	–40.6	–0.5	–6.0	–1.6
46869.012	0.273	–41.3	0.3	–2.6	0.2
46970.889	0.227	–39.6	0.1	–4.6	0.1
46971.817	0.263	–40.5	0.8	–2.4	0.7
46972.865	0.304	–42.5	–0.3	–2.1	0.0
46973.839	0.342	–42.4	0.2	–1.8	–0.1
46974.907	0.383	–42.0	0.5	–2.4	–0.7
47244.997	0.867	–5.7	–0.6	–41.8	–0.7
47308.935	0.348	–43.2	–0.6	–2.5	–0.8
47458.654	0.160	–33.4[a]	0.3	–9.8[a]	1.2
47626.975	0.693	–31.3[b]	–0.5	–12.8[b]	1.3
47810.629	0.822	–15.1[b]	0.1	–32.4[b]	–1.9
47811.633	0.861	–5.1	1.6	–38.9	0.6
47812.669	0.901	6.2	0.2	–53.3	–0.5
47813.625	0.938	21.2	–1.7	–70.8	–0.2
47814.633	0.977	42.2	0.3	–90.9	–0.3
47815.627	0.016	32.7	0.3	–80.7	–0.1
48058.948	0.460	–40.4	1.1	–3.3	–0.4
48429.835	0.856	–8.4	–0.6	–37.6	0.7
48508.628	0.915	12.3	0.7	–59.1	–0.4
49078.934	0.051	4.5[c]	0.6	–51.1[c]	–0.5
49102.990	0.985	44.0	0.5	–91.8	0.4
49103.982	0.023	26.1	–0.2	–73.6	0.5

Notes to TABLE 1

[a] Lithium region
[b] Double Gaussian fit
[c] 4550 Å region

triple consisting of two solar-type stars and an unseen third component for which Batten *et al.* (1979) determined periods of 20.25 yr and 0.88 days. Thus, the AB–C system is an hierarchical system of five stars.

2. SPECTROSCOPIC OBSERVATIONS AND VELOCITY REDUCTIONS

ADS 11060 C is one of the faintest stars on our program of spectroscopic observation and could only be observed on nights of very good seeing. Despite this restriction, from 1987 through 1993, 22 observations of ADS 11060 C (Table 1) were obtained at Kitt Peak National Observatory (KPNO) with the coudé feed telescope, coudé spectrograph, and a Texas Instruments charge-coupled device (CCD). One observation was centered at 6695 Å to include the lithium line at 6708 Å, while all the rest have been centered at 6430 Å. The spectrograms cover a wavelength range of about 80 Å and have a resolution of about 0.2 Å. Most of the spectra have signal-to-noise (S/N) ratios of 50:1 or better. One of those with the highest S/N ratio is shown in Fig. 1.

Our observations show that absorption lines from both components of ADS 11060 C are visible, although at red wavelengths the line strengths of Ca and Cb are somewhat unequal with the primary or Ca component having the stronger lines. The late spectral types of the two stars mean that many of the lines in both components are quite strong. Because of the rather eccentric orbit, at most orbital phases the stronger line pairs in the 6430 Å region are partially blended, but several pairs of weak lines are resolvable at our relatively high resolution. It is these weaker lines that have been used for most velocity measurements. Details of the velocity-reduction procedure have been given by Fekel *et al.* (1978).

The radial velocities (Table 1) were determined relative to μ Her A, a G5 IV star. Stockton & Fekel (1992) have determined a velocity of -16.4 km s^{-1} for it relative to β Oph

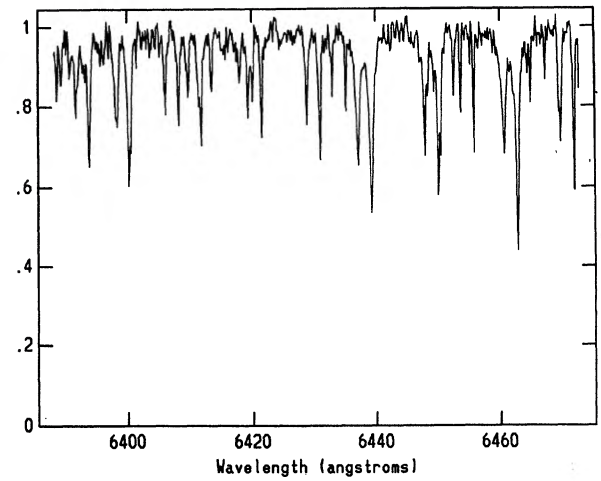

FIG. 1. A portion of a CCD spectrum of ADS 11060 C obtained on 1993 April 26 in which double lines can be clearly seen. The vertical axis is in units of relative intensity.

(Scarfe *et al.* 1990), which is an International Astronomical Union radial-velocity standard star (Pearce 1957).

Two spectra of ADS 11060 C were obtained at phases when all lines were significantly blended. The same velocity-reduction procedure was used for these spectra except that a double Gaussian was fitted to the blended profiles. The two observations are identified in Table 1.

Daryl Willmarth obtained one observation of ADS 11060 C on JD 2449078 with the KPNO coudé feed telescope, coudé spectrograph, and a Tektroniks CCD. This observation was centered in the blue at 4550 Å and had a slightly lower resolution than the red wavelength observations. The velocities were measured relative to μ Her A with the IRAF cross-correlation program, FXCOR.

3. ORBITAL ELEMENTS

After several observing runs it became obvious that the orbit was rather eccentric and that the period, although still unknown, was significantly longer than a few days. It was not until over two years after our observations began that a velocity separation finally was observed that was similar to that seen in Abt's (1986) discovery observation, enabling an approximate period to be determined. The initial value of the period was found with the period-finding program of Deeming (Bopp *et al.* 1970). Preliminary orbital elements for the primary were determined with a slightly modified version of the Wilsing–Russell method (Wolfe *et al.* 1967). These elements were refined with a differential corrections computer program of Barker *et al.* (1967). Finally, a double-lined solution was obtained with all velocities given unit weight. The final orbital elements are listed in Table 2 and the velocities are compared with the computed velocity curves in Fig. 2. Note that the minimum masses computed from the elements are relatively large, suggesting that despite the long period, a search for eclipses should be made. The detection of such eclipses would be extremely important because of the singular dearth of K and M dwarf eclipsing binaries.

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TABLE 2. Orbital elements of ADS 11060 C.

P	25.7631 ± 0.0004 days
T	2447815.223 ± 0.020 JD
γ	−22.66 ± 0.12 km s^{-1}
K_{Ca}	43.14 ± 0.25 km s^{-1}
K_{Cb}	45.37 ± 0.44 km s^{-1}
e	0.565 ± 0.004
ω_{Ca}	18°.17 ± 0°.53
ω_{Cb}	198°.17 ± 0°.53
a_{Ca} sin i	12.61 ± 0.08 x 10^6 km
a_{Cb} sin i	13.26 ± 0.13 x 10^6 km
M_{Ca} sin^3 i	0.534 ± 0.009 $M_\odot$
M_{Cb} sin^3 i	0.507 ± 0.008 $M_\odot$
M_{Ca}/M_{Cb}	1.052 ± 0.008

Standard error of an observation of unit weight = 0.77 km s^{-1}

4. SPECTRAL TYPE AND v sin$i$

The spectral types of the two components were estimated with a procedure similar to that of Strassmeier & Fekel (1990). They identified several luminosity-sensitive and temperature-sensitive line ratios in the 6430 Å region and used them along with the general appearance of the spectrum as spectral-type criteria. In addition, for K and early M dwarfs the strength of the line wings of the saturated lines in this wavelength region is a very useful criterion. A visual inspection of the spectra of the two components indicates that Abt's (1986) combined type of K7 V is approximately correct. Despite the line depth differences between the two stars, both components have similar spectral types and so the stars HD 156026 (K5 V; Houk 1982), 61 Cyg B (K7 V; Keenan & McNeil 1989) and HD 202560 (M1 V: Keenan & McNeil 1989) were used for comparison.

Unfortunately, spectrum-addition combinations of these reference spectra resulted in a spectrum whose lines were not strong enough to reproduce the ADS 11060 C spectrum. Results listed in the catalog of Cayrel de Strobel *et al.* (1992) indicate that HD 156026 and 61 Cyg B are slightly metal poor relative to the Sun, making the components of ADS 11060 C somewhat metal rich. Such a result supports the conclusion of Batten *et al.* (1979) that the ADS 11060 AB–C system is relatively young. Other chromospherically active K dwarf binaries such as HD 8357 and HD 163621 are also somewhat metal rich.

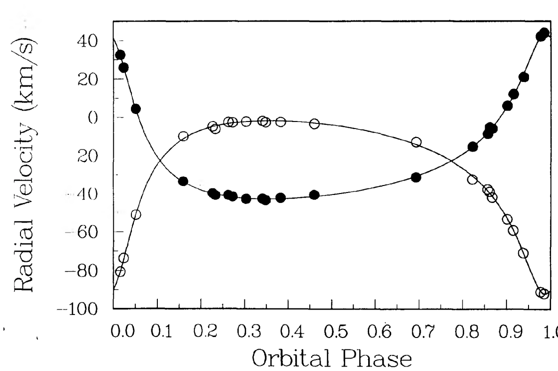

FIG. 2. A plot of the computed radial velocity curves of ADS 11060 C compared with the observations. Filled circles are velocities of the primary, component Ca, while open circles are of the secondary, Cb.

Because of the line-depth problem, a scaled spectrum of one of the reference stars was fitted to the primary star's spectrum to estimate its spectral type. The residual spectrum then was likewise fitted. The wings of the strong lines of both components are quite significant and a spectral type as early as K5 for either component is eliminated. The best fit to both the primary and secondary appears to be K7 V with the secondary being slightly later than this type, so types of K7 V and M0 V are estimated.

For ADS 11060 C, Perry (1969) obtained a $b-y=0.856$. Olsen's (1984) preliminary *uvby* calibration for G and K dwarf stars shows that such a value is intermediate between that of K7 V ($b-y=0.804$) and M0 V ($b-y=0.910$). Eggen' (1965) $B-V$ and $U-B$ colors of this visual component are consistent with a K7 V type from the spectral type–color relation of Johnson (1966). Thus, both Johnson and Strömgren photometry support our spectral-type determination.

The line depth ratio at 6430 Å was determined from several pairs of lines in three different spectra. The resulting magnitude difference is 0.45±0.1 mag for a wavelength that is about 0.6 of the way between the Johnson V and R bandpasses.

The projected rotational velocities of the two components were determined in the same manner as the v sin i values previously determined by Fekel *et al.* (1986). Most of the lines in the 6430 Å region are saturated or partially blended and, therefore, inappropriate to measure. The narrowest lines in this region give v sin $i \leqslant 5$ km s^{-1}.

5. PHOTOMETRIC OBSERVATIONS

Photometric observations of ADS 11060 C were acquired for two purposes: (1) to search for possible mutual eclipses of the two dwarf components and (2) to search for the presence of starspot-induced rotational brightness modulation that would allow the rotation period of ADS 11060 C to be compared to the pseudosynchronous rotation period predicted for its rather eccentric orbit. Johnson B and V photometric observations were acquired around the time of the star's opposition at both McDonald and Braeside Observatories in the summer of 1990 and at Braeside in 1991.

The 1990 McDonald observations were made on six nights from JD 2448063 to JD 2448069 with the 0.8 m Cassegrain telescope on Mt. Locke. A McDonald two-star photometer in single-channel mode was used in conjunction with an Amperex 56DVP photomultiplier tube operated at ambient temperature. All observations of ADS 11060 C were made differentially with respect to the comparison star HD 165569 (V=7.62; Reglero *et al.* 1991), the brightest optical companion of the system, and then reduced to differential magnitudes in the Johnson system with mean extinction and transformation coefficients determined on three nights from observations of Landolt standard stars. A diaphragm 10″ in diameter, the smallest available with the photometer, was used to minimize scattered light from ADS 11060 AB, which is about four magnitudes brighter and less than 30″ away. Except for the last night, all observations were made in the standard sequence C, S, K, C, V, C, V, C, V, C, K, S, C;

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where C is the comparison star, S is the sky, K is the check star (HD 165524), and V is ADS 11060 C. Each of the 13 sequences completed during the observing run was averaged into a single observation. The standard deviation of the 13 check minus comparison differential magnitudes from their mean was 0.007 mag in B and 0.005 mag in V, which suggests good constancy of both comparison and check stars. On JD 2448069, the last night of the run and a time of conjunction according to our orbital solution, ADS 11060 C was monitored continuously throughout the night with the sequence CSVCSV... to search for a possible secondary eclipse.

The 1990 and 1991 Braeside observations were made with the 0.4 m telescope and photoelectric photometer described by Fried (1986, 1991). The comparison star and observing sequences were the same as used at McDonald. Observations were reduced to Johnson B and V differential magnitudes with seasonal mean extinction and transformation coefficients. The 1990 Braeside observations were made on six nights between JD 2448057 and JD 2448070, including JD 2448069 when the star was monitored simultaneously with McDonald during the possible secondary eclipse. The 1991 Braeside data consist only of monitoring observations on JD 2448434, the computed time of the opposite conjunction and a possible primary eclipse. A 25″ diaphragm was used from JD 2448057 to JD 2448061 (the first three nights only). A 15″ diaphragm was used thereafter.

6. PHOTOMETRIC RESULTS

6.1 Eclipse Search

The 1990 monitoring observations during times of the possible secondary eclipse did not reveal any sign of eclipse. The McDonald observations covered the seven-hour interval from JD 2448069.6296 to JD 2448069.9189 and were brought to a conclusion by the low altitude of the star and oncoming twilight. The predicted time of mid-secondary eclipse (JD 2448069.9007) occurred approximately 30 min before the end of this interval. The standard deviation of the individual observations during this interval from the mean of all the observations on this night was 0.009 mag in V, slightly larger than the standard deviation of the check star observations noted above, but no trend in the data with time was present. The somewhat larger scatter in the monitoring observations is expected since each datum represents only one observation of ADS 11060 C instead of the average of multiple measures as in the standard nightly observing sequence. Also, the observations of ADS 11060 C were more sensitive to centering and tracking errors than were observations of the comparison and check stars because of scattered light from the bright, nearby AB component.

The JD 2448069 Braeside observations covered the seven-hour interval from JD 2448069.6708 to JD 2448069.9590 and, therefore, extended 1.5 h past the predicted time of mid-secondary eclipse or 1 h later than the McDonald observations because of the longitude difference between the two observatories. Again, no trend in the data was seen and the standard deviation of the observations from their mean was 0.019 mag in V. Possible reasons for these

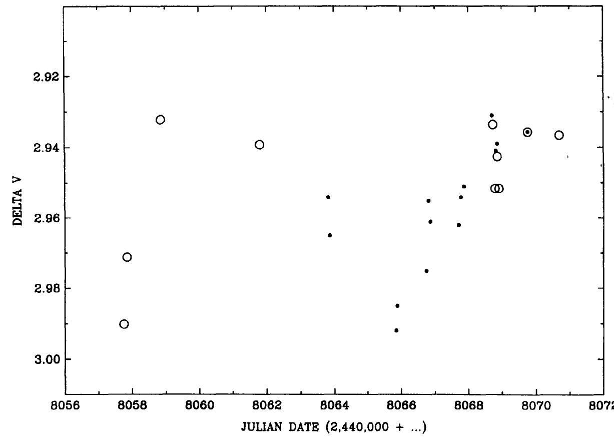

FIG. 3. A plot of the V band photometry of ADS 11060 C, taken in 1990 from McDonald (filled circles) and Braeside (open circles) Observatories, that reveals the system to be a new BY Draconis variable.

somewhat higher errors compared to McDonald include increased scattered light into the larger 15″ diaphragm used at Braeside coupled with larger centering and tracking errors and the smaller aperture of the Braedside telescope. Errors in our calculated times of conjunction probably do not exceed 0.6 h so we conclude that no secondary eclipse is observable in ADS 11060 C.

Despite the orbits' large eccentricity, primary eclipse is only somewhat more likely to occur than secondary eclipse because of their orientation to the Earth. Monitoring observations were conducted during a 1991 conjunction at opposition from Braeside and covered the 6 h interval from JD 2448434.6805 to JD 2448434.9254. No sign of an eclipse was seen. The standard deviation of the observations from their mean was 0.022 in the V and no slope was evident with time. However, the calculated moment of conjunction, JD 2448434.9837, occurred approximately 1.4 h after the completion of the observations so we cannot completely rule out a short-duration partial eclipse. The ephemeris for a possible primary eclipse is JD 2447816.669+25.7631 E.

6.2 Starspot Period

While we find no evidence of eclipses, the V data, taken in 1990 at both McDonald and Braeside between JD 2448056 and JD 2448072 and plotted in Fig. 3, do reveal ADS 11060 C to be a new BY Draconis variable star with an amplitude of about 0.05 mag. Each filled circle represents the mean differential magnitude derived from one standard sequence taken at McDonald. The open circles represent the same from Braeside. Multiple sequences were taken on some nights and are represented as separate points. The scatter of the observations within a single night is largely because of scattered light combined with centering errors. As noted above, the check minus comparison star observations on these nights agree more closely. The circled point represents the average of the monitoring observations taken at McDonald on JD 2448069 and the average of the corresponding observations taken at Braeside but made coincident with Mc-

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Donald by adding 0.025 mag to the Braeside observations. This was necessary to correct for the effect of the larger diaphragm used at Braeside, which resulted in more scattered light in the diaphragm of the ADS 11060 C observations. The Braeside observations thus appear too bright compared to the McDonald observations and have all been corrected for this effect. All observations from JD 2448068 onward have been made fainter by the same 0.025 mag difference observed between the two simultaneous sets of monitoring observations. The four Braeside observations prior to JD 2448068 were shifted downward by 0.048 mag. This larger correction was necessary because of the larger diaphragm used for these earliest observations. Unfortunately, no coincident observations exist from McDonald to explicitly determine the shift required. Therefore, the average of the two brightest observations was compared with the McDonald monitoring observations on JD 2448069 to determine the shift to be applied. This seems reasonable since the conjunction appears to have occurred roughly at light maximum and is the best we could do to make use of the early Braeside observations.

Periodogram analysis of the V data in Fig. 3 gives a period of 9.0 ± 1.0 day. A similar analysis of the B data gives the same result. The period determination should be considered a preliminary result because of the difficulty of measuring ADS 11060 C so close to a bright companion and the resulting scatter, the necessity of shifting the Braeside data, and the short time base of the observations in Fig. 3, which cover only 1.5 cycles.

7. DISCUSSION

7.1 The ADS 11060 C System

One spectrum of the lithium region at 6708 Å was obtained. Although there are two features at the nominal wavelength of the lithium line the S/N ratio of about 40:1 for this spectrum makes it difficult to determine if the features are indeed real. Nevertheless, it is obvious that neither star has even a moderate strength lithium line and an upper limit of 25 mÅ is determined for the true (corrected for dilution) equivalent width of both lines. From Table 2 of Soderblom *et al.* (1993) and an assumed T_e=4000 K, this corresponds to log ϵ(Li)≤ -0.14 for each component.

As noted above, there are few accurate masses for K and M dwarfs. If we assume that the mass of ADS 11060 Cb is 0.59 $\mathscr{M}_\odot$, the same as that of the M1 V stars of the eclipsing binary YY Geminorium (Bopp 1974), then the inclination is 72°. An inclination of $77°\pm11°$ covers a reasonable range of masses for Cb from 0.51 to 0.68 $\mathscr{M}_\odot$.

Following the theoretical work of Hut (1981) on pseudo-synchronous rotation, Hall (1986) examined an extensive number of late-type chromospherically active binaries and identified four systems, AR Psc, 54 Cam, BY Dra, and HR 7578, that appeared to be pseudosynchronously rotating. Despite a 25% increase in the number of chromospherically active binary stars listed from the first (Strassmeier *et al.* 1988) to the second edition (Strassmeier *et al.* 1993) of the catalog, we have not found any new pseudosynchronous systems. Of the four systems identified by Hall (1986), 54 Cam contains a pair of subgiants while AR Psc and BY Dra, consists of dwarfs. The photometric period of 16.5 days for HR 7578 (Hooten & Hall 1990) is about a factor of two greater than the pseudosynchronous period and so this star should be eliminated from the sample. We have recently identified one more binary, the G giant HR 2054, that is probably pseudo-synchronously rotating.

If our preliminary 9.0 day period represents the rotation period of one of the components of ADS 11060 C, then that star also rotates very nearly at the pseudosynchronous rotation rate and the system may be added to the very small list of such binaries. The orbital period of 25.76 days and an eccentricity of 0.565 result in a predicted pseudosynchronous rotation period (Hut 1981) of 7.3 days. Although this value is not within the formal error bars of our period determination, we expect that our actual uncertainty in the period could be somewhat larger because of the reasons cited above. In any case, at least one component of ADS 11060 C seems to rotate much closer to the pseudosynchronous period than the orbital period.

There are 19 other systems listed in Strassmeier *et al.* (1993) that have eccentric orbits but are not pseudosynchronously rotating. The vast majority of these are subgiants or giants that may currently be going or just recently have gone through a stage of evolution in which the radius was rapidly changing and so have not yet had time for the rotation rate to become pseudosynchronous.

Our 9 day period and an assumed radius of 0.6 $R_\odot$ result in a rotational velocity of 3.4 km s^{-1}, in agreement with our upper limit of 5 km s^{-1} for v sin i but below the cutoff of 5 km s^{-1} proposed by Bopp & Fekel (1977) for the onset of enhanced activity. More recent work has shown that the convective turnover time is an equally important parameter. Thus, it is not surprising that such a slowly rotating star should display enhanced starspot activity, which results in the rotational modulation of its brightness. A K7 V star, with an unreddened $B-V$ of 1.30 (Johnson 1966) would have a convective turnover time of approximately 71 days (Gilliland 1985). Therefore, the Rossby number (the ratio of rotation period to convective turnover time) is approximately 0.11. As shown clearly by Hall (1991), enhanced dynamo activity occurs in stars with Rossby number less than 0.67.

7.2 The Nature of the AB–C System

To get an overall view of ADS 11060 C and to place it in the appropriate context, we briefly summarize information about the brighter AB system. As noted in the introduction, the visual components A and B form a spectroscopic–visual triple system, whose spectroscopic properties have been extensively discussed by Morbey *et al.* (1977) and Batten *et al.* (1979). Only two of the three stars are visible spectroscopically. The stars in the short-period orbit, a G0 V star and a spectroscopically invisible late K or early M dwarf companion, undergo shallow eclipses (Scarfe 1977) every 0.88 days. These two stars orbit a G5 V star in an extremely eccentric ($e=0.96$) orbit with a period of 20.25 yr. Boyd *et al.* (1985) ascribed additional light variations found outside of eclipse to a starspot wave. An extensive analysis of the different light variations was made by Bruton *et al.* (1989) and addi-

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tional observations were obtained and analyzed by Reglero *et al.* (1991). Batten *et al.* (1979) followed later by Reglero *et al.* (1991) noted that both G stars had Ca II H and K emission reversals, making both components chromospherically active. Finally, Batten *et al.* (1979) noted that the AB system is quite young, perhaps having an age similar to that of the Pleiades cluster. From Strömgren photometry Reglero *et al.* (1991) concluded that the components of the ADS 11060 AB system are close to the ZAMS line.

Are our new results consistent with the conclusion reached by previous investigators that ADS 11060 C is a physical companion of ADS 11060 AB? For ADS 11060 AB, Batten *et al.* (1979) found a center-of-mass velocity of -22.8 km s^{-1}. This value differs by only 0.1 km s^{-1} from the value we have found for ADS 11060 C. Although slightly contaminated by the scattered light of the AB components, our maximum V magnitude of 10.55 is in good agreement with V=10.62 of Eggen (1965). The parallax of the C component can be estimated from V=10.6 mag, a magnitude difference of about 0.55 mag, and an assumed M_v=8.5 (Corbally & Garrison 1984). These quantities result in a distance of 33 pc or a parallax of 0.030″ compared with an orbital parallax of 0.024″″±0.01″ for the AB components (Batten *et al.* 1979). Given the uncertainties in the estimated parallax of the C component, the two parallaxes are in reasonable agreement. Thus, our results for the C component support the previous conclusion that it is a physical member of the AB system.

Proper motions may also be used to examine the physical relationship of the AB and C components. Unfortunately, we have been unable to find in the literature any proper motion measurements for ADS 11060 C. The list of observations in The Washington Visual Double Star Catalog maintained at the U.S. Naval Observatory (Worley 1992) contains seven measurements of the AB–C system; the first in 1905 and the last in 1971. The observations suggest that the position angle and separation of AB–C have been constant over this span of 66 yr. Such a result is consistent with the components having common proper motions.

Herbig (1965) found from a sample of solar-type stars that the lithium abundances of such stars decrease with age. From observations of solar and late-type dwarfs in young clusters such as the Pleiades and Hyades, it was found that the rate of depletion depends on mass (e.g., Zappala 1972; Cayrel *et al.* 1984); the later the spectral type, the more quickly lithium is depleted. Unfortunately, additional observations have shown that the depletion mechanism depends on additional parameters (e.g., Duncan & Jones 1983; Boesgaard & Tripicco 1986; Soderblom *et al.* 1993), which have not been completely identified. The current situation has been extensively discussed by Soderblom *et al.* (1993). Despite the complications, if other properties such as rotation and chromospheric activity are indicative of youth, the lithium abundances of the components may be used to provide an estimate of the age of ADS 11060.

For such an age estimate the key star of the system is component B, the G5 V visual companion, which is nominally single but is chromospherically active, is rapidly rotating with a $v \sin i$ of 11 km s^{-1} (Strassmeier & Fekel 1990), and has a lithium line with a large equivalent width. Batten *et al.* (1979) listed the observed lithium equivalent widths of the Aa (G0 V) and B (G5 V) components. We determined true equivalent widths of 171 mÅ for Aa and 203 mÅ for B from the estimated luminosity ratio of those components. From Table 2 of Soderblom *et al.* (1993) both components have log ϵ(Li)=3.2±0.3. As shown in the previous subsection, the C (K7 V+M0 V) components have log abundances less than -0.14. The abundances of the four components were compared with the lithium abundance vs temperature relations of several young clusters (Fig. 9 of Soderblom *et al.* 1993). The low abundances of the C components are consistent with each of the cluster relations. The lithium abundances of components Aa and B, however, are significantly greater than those of similar stars in the Hyades where, for example, a G5 V star has a log ϵ(Li)=2.2. The abundances of Aa and B are consistent with the upper envelope of stars of similar temperatures in both α Persei and the Pleiades, suggesting an age similar to the Pleiades of about 70 Myr for ADS 11060 AB–C.

Following Strassmeier *et al.* (1993), the orbital parallax of AB and proper motions from the PPM catalog (Röser & Bastian 1991) result in space motions (in a right handed coordinate system) of -7.4, -23.5, -4.5 km s^{-1} for the U, V, W components, respectively. The errors of the proper motions are the primary contributors to the uncertainties of these values with the total errors estimated to be about 2 km s^{-1} for the U and V components and about 1 km s^{-1} for W. The space motions for the Pleiades moving group are -9, -27, -12 km s^{-1} (Soderblom & Mayor 1993; Eggen 1975) indicating that ADS 11060 AB–C is a possible member of this young stellar kinematic group.

Wide visual binary systems have been studied both theoretically and observationally in an attempt to examine the formation and destruction processes that have occurred throughout galactic history. Observational results (e.g., Latham *et al.* 1984; Abt 1988) indicate that bound systems exist for solar-type wide binaries with separations of at least 2000 AU. Indeed, the ADS 11060 system was one of the systems included in Abt's (1988) study.

The measured separation of 28″ (Aitken 1932) for the AB–C system and the orbital parallax of Batten *et al.* (1979) result in a projected separation of almost 1200 AU. From Kepler's Third Law such a semimajor axis results in a period of nearly 21 000 yr. The Sun's nearest neighbor is a somewhat similar system containing two G dwarfs and a distant M dwarf companion that may be in a bound orbit (Matthews & Gilmore 1993). Proxima Centauri, however, has a projected separation of 10 500 AU from Alpha Centauri AB (Kamper & Wesselink 1978), nearly 10 times greater than that of the ADS 11060 AB–C system.

Pounds *et al.* (1993) identified the ADS 11060 system with the position of a bright extreme-ultraviolet source observed with the ROSAT UK Wide Field Camera. Both ADS 11060 AB and C fall within the 90% confidence error circle radius of 57″ for this source. Since the C component has been shown to have enhanced activity, it, as well as the AB system, may be a contributor to the extreme-ultraviolet flux.

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