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LX CYGNI: A MIRA VARIABLE WITH A DRASTIC PERIOD INCREASE

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LX Cygni – α:21$^{\mathrm{h}}$55$^{\mathrm{m}}$57$^{\mathrm{s}}$.03; δ:+48°20′52″.6 (J2000) – is a poorly-studied Mira variable of spectral type S. Although this object has been studied spectroscopically as part of several S-star surveys, little has been published about its pulsation behavior beyond its discovery and subsequent description in the *General Catalog of Variable Stars* (GCVS). Variability was first noted by Hoffmeister (1930). Additional observations were made by Olivier et al. (1940), and the period was determined to be about 461 days, with photographic maxima and minima of 11.9 and 16.5 magnitudes, respectively (Prager & Shapley 1941). Semakin (1955) summarized the work to date on LX Cyg, noting that the period had been variously measured between 454 and 465 days. Finally, the GCVS 4th edition (Kholopov et al. 1985) lists the period as 465.3 days (epoch JD 2438895), noting that between JD 2415000 and 2433300, 460.0 days was a better fit.

This variation in reported period is unremarkable, given the cycle-to-cycle variations in period seen in many Mira variables. However, since 1967, LX Cygni has apparently undergone a significant change in pulsation behavior. The American Association of Variable Star Observers (AAVSO) archive of visual observations – spanning JD 2439818 to 2452605 (November 23, 1967 to November 26, 2002) – show that a dramatic increase in period has occurred since JD 2440000. The period has grown from 460 days to over 580 days, an increase of nearly 25 percent.

For our time-series analysis, we used 961 visual observations by 84 different observers in the AAVSO International Database. Although we have additional CCD data taken in the Johnson V filter, we chose not to include them in the long-term analysis in order to keep the data set as homogeneous as possible. We have instead analyzed the CCD observations separately and discuss them below. We used the *weighted wavelet transform* developed at AAVSO (Foster 1996) to perform the time-series analysis. The wavelet transform allows one to measure the time evolution of the Fourier spectrum of a given dataset, and it is quite sensitive to even small changes in period over both short and long timescales.

We computed the wavelet transform several times with a range of frequencies and wavelet windows. We show the data and a representative wavelet transform in Figure 1, and plot the period and amplitude of the strongest peak as a function of time in Figure 2. Figure 2 clearly shows that the period has increased since the start of the AAVSO data in 1967. The behavior of the period is uncertain at the start and end of the data set due to edge effects of the wavelet transform.

We also note that the amplitude computed from the wavelet transform appears to be variable over the span of observations. It is possible that the real amplitude of the star has changed over time, but this may be an artifact of the wavelet analysis. Wavelet amplitude is sensitive to data gaps, so seasonal windows may be the cause. Analysis of the amplitude variation is continuing, and will be published in a forthcoming paper.

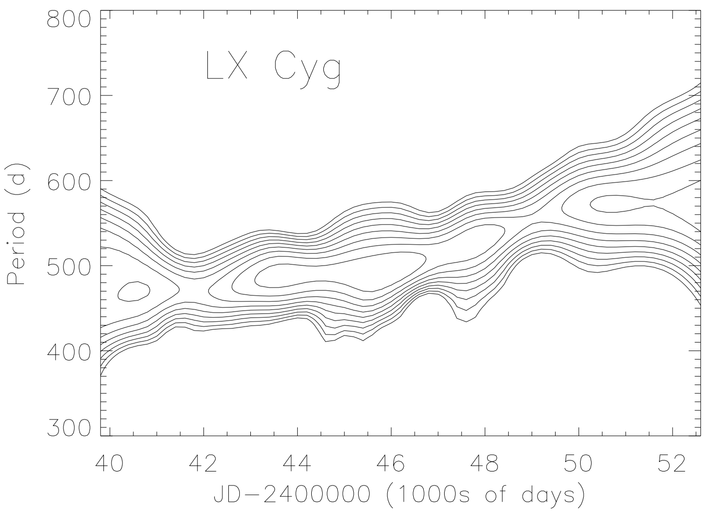

Figure 1. Wavelet transform of LX Cyg. Contours represent the wavelet statistic, w, a measure of the statistical significance of the signal (see Foster 1996). Strongest signal lies at the center of the contours. The wider bands at the beginning and end of the data stream are edge effects, and are artificial.

To confirm our analysis, we also analyzed the available CCD V-band observations from the AAVSO International Database. These observations consist of 106 CCD observations made by six observers, spanning JD 2451236 to 2452601 (February 26, 1999 to November 22, 2002). While the data span is not long enough to reliably determine whether the period is variable, we measured the spacing between the two maxima and three minima present in the data and found a period of 590 ± 10 days. In addition, we visually inspected the older data collected by Olivier et al. (1940), spanning JD 2427334 to 2429595 (1933 to 1939). Although their data are very sparse, the measured separation between the two clearly defined maxima is 465 $\pm$10 days, which is consistent with the published period for that epoch.

The rapid period increase beginning at JD 2445000 appears to be a continuous process, rather than an abrupt, discontinuous change. Therefore, it appears that mode-switching is *not* the reason for the change. If the period continues to increase at the current rate, than this may indicate that LX Cygni is in the middle of a thermal pulse. According to the models of Vassiliadis & Wood (1993), each thermal pulse begins with a sharp period *decrease*, followed by a short, high-amplitude oscillation in period (a decrease by half, and an increase by as much as a factor of three). A period increase of 100 days over a few decades is seen in some of their models, and if LX Cygni is in the midst of a thermal pulse, the period may continue to increase significantly in the coming decades.

LX Cygni appears to be an excellent candidate for a Mira variable undergoing thermal pulses, as the magnitude of the period change is similar (though opposite in sign) to that of T UMi, a star which has undergone a rapid period *decrease* since 1968 (Mattei & Foster 1995; Gál & Szatmáry 1995), as well as that of TY Cas (Hazen & Mattei 2002). Whereas

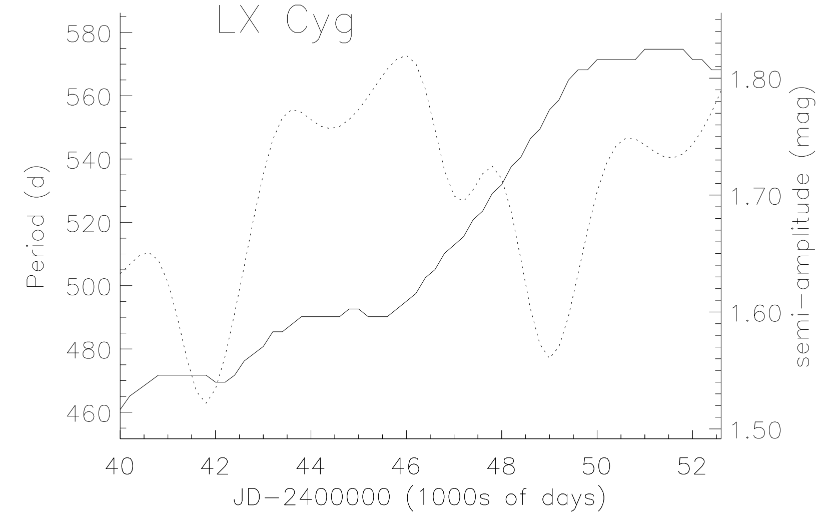

Figure 2. Strongest period (solid line) and its amplitude (dotted line) derived from the wavelet transform of LX Cyg. The period is clearly increasing throughout the span of available data. Because of edge effects in the wavelet transform, it is not clear whether the period has reached a plateau 580 days, or whether it will continue increasing. Continued monitoring over the next several years is strongly encouraged. The amplitude also appears to be variable, and a more sensitive analysis of this variation is underway.

T UMi and TY Cas may have just begun thermal pulses, LX Cygni may be in a later stage since thermal pulses are expected to begin with a period decrease. Further observations of LX Cygni are warranted and strongly encouraged. A more comprehensive analysis of this star is currently in preparation for publication.

We thank the 90 observers worldwide who have contributed over 1000 observations of LX Cygni to the AAVSO International Database. We also thank G. Foster for helpful discussions on this analysis.

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