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The first multi-color light curve analysis of FI Lyn and new V and Rc light curve analysis for GN Boo, two W-subtype W Ursae Majoris systems

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HIGHLIGHTS

- This is the first multi-color light curve analysis of the eclipsing binary star FI Lyn.
- We present new light curve analysis of the known contact binary GN Boo.
- FI Lyn shows an increasing period while GN Boo shows cyclic oscillations of its period.
- Both the systems are W-subtype W Ursae Majoris systems.
- The absolute dimensions of the systems are estimated.

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ABSTRACT

Here we present the first analysis of the B, V and I_c CCD light curves of the W UMa type eclipsing binary star FI Lyn obtained in the year 2009 (8 nights) and in the year 2010 (2 nights), and new CCD V and R_c light curves of the known contact eclipsing binary GN Boo obtained in 4 nights in May 2012. Our data permits us the determination of ten and six new times of minimum light respectively for FI Lyn and GN Boo and refine both the orbital periods of the systems to $P = 0.3732612$ days and $P = 0.3016022$ days. The periods of both the systems are variable. FI Lyn shows an increasing period at the rate of dP/dt 1.05×10^{-6} days yr^{-1} while GN Boo shows cyclic oscillations. The observed light curves are analyzed simultaneously with the Wilson–Devinney program analysis; the geometrical and photometric elements are derived. Our solutions show that FI Lyn and GN Boo belong to the W-subtype W Ursae Majoris contact binary class, consisting of a hotter, less massive primary star eclipsed at primary minimum with a primary spectral type of G1 and G8 and a companion of spectral type G3 and G4 respectively. We found, for FI Lyn a mass ratio of $q = 2.58$, the degree of contact of $f = 38.9\%$, an orbital inclination of $i = 71^{\circ}.5$ and a small temperature difference between the components of about $\Delta T = 150$ K indicating a good thermal contact, while for GN Boo we found a mass ratio of $q = 3.33$, the degree of contact of $f = 24.3\%$, an orbital inclination of $i = 83^{\circ}.6$ and a difference between the components temperature of about $\Delta T = 620$ K. The elements obtained from the W–D analysis are used to compute the physical parameters of the systems in order to study their evolutionary status.

1. Introduction

FI Lyn (GSC 03421-01871, TYC 3421-1871-1; ($\alpha_{2000} = 08^h17^m27^s$, $\delta_{2000} = +51^{\circ}51'46''$) was reported as eclipsing binary star by Otero (2008) analyzing the public data release from the Northern Sky Variability Survey (Woźniak et al., 2004). In his paper Otero (2008) gives the first period of the system $P = 0.373260$, the type of variability EW, and the first light curve obtained between March 1999 and March 2000.

That light curve shows, well visible, the typical O'Connell effect (OConnell, 1951) with the secondary maximum brighter by about 0.05 mag. than the primary one.

In 2011, the 80 Name-List of variable stars Kazarovets et al. (2011) assigned to TYC 3421-1871-1 the actual denomination.

Only two authors observed this star from 2011 to 2013 and published times of minimum (ToM): Diethelm (2011b, 2012,

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2013) and Hübscher (2013) two ToM, while with our observations we obtained 10 ToM in the years 2009–2010.

GN Boo (GSC 02022-00079, TYC 2022-79-1; (α_{2000} =$14^h50^m07^s$, $\delta_{2000} = +29^{\circ}38'58''$) was discovered by the Robotic Optical Transient Search Experiment I (ROTSE-I) from the all-sky surveys for variable stars (Akerlof et al., 2000).

Subsequently Blättler and Diethelm (2001) obtained an unfiltered light curve that did not show any difference in height of the maxima and they suggested a period of $P = 0.301601$.

In 2003, based on the observations of the SuperWASP Cameras of the WASP Project (Wide Angle Search for Planets) (Pollacco et al., 2006) another unfiltered light curve was published for GN Boo, also this did not show different heights of maxima.

Sanders et al. (2005) published CCD V and R_c light curves that show the primary maximum slightly higher that the secondary one. A new period $P = 0.3016027$ days was found and the study of the O–C diagram allowed the authors the conclusion that the period of GN Boo is decreasing. Their analysis of the light curves lead to an W-subtype W UMa system with a mass ratio of $q = 3.050$ and fill-out factor $f = 27\%$. A small (12°) cool starspot was placed on the larger star in order to model the asymmetries of the maxima.

Recently Yang et al. (2013) published new Johnson–Cousins–Bessel UBVRI observations carried out between the years 2008 and 2012. Those observations do not show the O'Connell effect. They found a mass ratio $q = 0.32$ ($1/q = 3.12$) a fill-out factor of 5.8% and a W-subtype WUMa contact binary. An analysis of the O–C diagram lead the authors to the conclusion that the observed cyclic changes may result from magnetic activity cycles or light-time effect due to a third body.

2. Observations and data reduction

2.1. Instrumentation

The measurements were collected by one of us (MM) using the instruments of the Stazione Astronomica Betelgeuse (MPC code B75) located in Magnago, Italy, consisting in a 0.25 m f/10 SchmidtCassegrain telescope equipped, in the years 2009–2010 (at the time of the measurements on FI Lyn), with a Kodak KAF-0402E CCD Camera (768 × 510 pixels of 9 × 9 micron), 16 bit A/D converter without antiblooming gate; and in the year 2012 (at the time of the measurements on GN Boo) with a Kodak KAF-0261E CCD Camera (512 × 512 pixels of 20 × 20 micron), 16 bit A/D converter, without antiblooming gate. The raw images were reduced using Astronomical Image Processing for Windows (AIP4Win) software by Richard Berry and James Burnell; data reduction (dark subtraction, flat field division) and automatic aperture photometry of the target objects (variable, comparison and check stars) were performed excluding images with poor SNR, generally less than 100, or with tracking errors. Measurements were made in the B, V, R_c and I_c bands using Johnson–Cousins filters and transformed into standard differential magnitudes as described by Cohen (2002).

2.2. FI Lyn

A total of 524 filtered B, 531 V and 602 I_c CCD measurements were collected in ten nights between J.D. 2454881 and J.D. 2455230. The comparison star used was UCAC4-710-048649 (12.05 B, 11.44 V, 10.78 I_c), while UCAC4-710-048630 (11.11 B, 9.96 V, 8.81 I_c) served as check star. B and V magnitudes of both comparison and check stars come from APASS – the AAVSO Photometric All-Sky Survey (Henden et al., 2009), while I_c magnitude was derived from JK magnitudes of 2MASS – Two Micron All Sky Survey (Skrutskie et al., 2006) – using the formula published by Warner (2006).

2.3. GN Boo

A total of 314 filtered V and 307 R_c CCD measurements were collected on four nights between J.D. 2456057 and J.D. 2456066. The comparison star used was UCAC4-598-052482 (11.52 V, 11.38 R_c), while UCSC4-599-052188 (12.65 V, 12.34 R_c) served as check star. V magnitude of both comparison and check stars come from APASS – the AAVSO Photometric All-Sky Survey Henden et al., 2009, while R_c magnitude was derived from JK magnitudes of 2MASS – Two Micron All Sky Survey (Skrutskie et al., 2006) – using the formula published by Warner (2006).

3. Eclipsing times and orbital period changes for FI Lyn and GN Boo

3.1. FI Lyn

The new ToM, presented in Table 1,[1] are all heliocentric and determined by the Kwee and van Woerden (1956) method. These new data, combined with other 6 ToM found in literature, and using the linear ephemeris (1) published in the GCVS (Samus et al., 2012)

$$Min.I = HJD2451578.8120 + 0^d.373260XE. \quad (1)$$

shows more clearly the period variation of the system in the O–C diagram of Fig.1 (left panel) and permit us to refine the orbital period as follows:

$$Min.I = HJD2451578.8133(15) + 0^d.3732611(2)XE. \quad (2)$$

In the right panel of the same figure the line shows the second order polynomial fit to the data phased with the ephemeris (2).

A quadratic ephemeris determined by a least squares fitting to all the minima gives:

$$Min.I = HJD2451578.8775(9) + 0^d.3732609(5) + 5.35(3)X10^{-10}XE. \quad (3)$$

The general trend of the (O–C) curve in Fig. 1 (right panel, solid line) shows an upward parabolic variation indicating a long-term period increase at rate of dP/dt 1.05×10^{-6} days yr^{-1}. It could be explained by the mass transfer from the less massive component to the more massive one. Considering a conservative mass transfer this yields a mass transfer rate of $\dot{M} = 1.6 \times 10^{-6}$ $M_{\odot}$ yr. However the period increase rate of dP/dt 1.05×10^{-6} days yr^{-1} is rather large for a contact binary and is only supported by a few eclipse times. The upward parabolic change shown in Fig. 1 (right panel) may be only a part of a long-period cyclic oscillation that may be caused be the presence of a third body. To confirm this conclusion, more times of light minimum are required in the future.

3.2. GN Boo

In the years 2005 and 2013, the period of GN Boo was analysed by two different authors. Sanders et al. (2005) concluded a decreasing orbital period; Yang et al. (2013) proposed a cyclical period change with a period of about 9.9 years as result from magnetic activity cycles or light-time effect due to a third body.

From our observations 6 new light minimum timings were determined, included those published in IBVS 6091 (Martignoni, 2014) that are part of these observational set, are all heliocentric and determined by the Kwee and van Woerden (1956) method.

[1] Table 1 is available at online journal of New Astronomy.