Do you mean **The orbital period variations of AH Virginis?** I agree with this change.

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Abstract **Do you mean** We present a study of the orbital period changes of **in AH Virginis?** Note: in an online search, our editorial staff found that the name of this star is "AH Virginis" so we made this change throughout your article. Please confirm that you agree with this change. We perform a careful literature search for all available minima times, from which we derived a new linear ephemeris and constructed an \(O-C\) curve. We found that the orbital period of **AH Virginis** shows a long-term increase, \(dP/\text{d}t = (2.1869 \pm 0.0161) \times 10^{-7} \, \text{d yr}^{-1}\), and a small periodic variation with a period of 37.19 yr. Since **AH Vir** is an overcontact system and the primary component shows strong H\(\alpha\) and Mg II emission lines, we discuss the possible connection between the mass transfer, the magnetic activity and the orbital period changes.

**Key words:** binaries: close — binaries: eclipsing — stars: individual (AH Virginis)

1 INTRODUCTION

**Do you mean** AH Virginis (HD 106400, SAO 100003, ADS 8472A, BD +12°2437; the companion ADS 8472B is at 1.3\(^{\prime}\) separation), abbreviated **AH Vir**, was discovered as to be a W UMa-type eclipsing variable by Guthnick & Prager (1929).\(^7\) It shows strong activity in H\(\alpha\) (Barden 1985) and in Mg II (Rucinski 1974, 1985), and the more massive component is much more active than the smaller secondary (Lu & Rucinski 1993). Since its discovery, photometric and spectroscopic studies have been carried out by many investigators (Prager 1929; Lause 1935a, 1935b, 1937; Zessewitsch 1944; Chang 1948; Huruhata \& Nakamura 1951; Kitamura et al. 1957; Binnendijk 1960, 1984; Jabbar \& Kopal 1983; Kaluzny 1984; Lu \& Rucinski 1993). Prager (1929) published a photographic light curve from which he obtained the orbital period of AH Vir to be about 0.339 d. Lause (1935a, 1935b, 1937) made visual observations and improved the period to be 0.4075191 d. Chang (1948) carried out a spectroscopic study and determined the spectral type of both components to be K0. **Do you mean** Binnendijk (1960, 1984) published the photoelectric observations in the \(B\) and \(V\) bands and found that both the light curves and the orbital period show variability. He attributed such variations to the gaseous material that escaped from a larger greater star into circumstellar space, and stated that AH Vir is an overcontact system.\(^2\) Combining his observations with the data of Chang (1948), Binnendijk determined the parameters of both components to be \(M_1 = 1.38 \, M_\odot\), \(R_1 = 1.47 \, R_\odot\), \(M_2 = 0.58 \, M_\odot\) and \(R_2 = 0.73 \, R_\odot\). Bakos (1977) showed the light curves in the \(B\) and \(V\) bands observed in 1974 and 1975. He reported that only the larger star that is part of AH Vir is close to
the inner Roche lobe (see the fig. 6 of Bakos 1977). Kaluzny (1984) re-analyzed the light curves observed by Binnendijk (1960) and obtained $M_1 = 0.50 M_\odot$, $R_1 = 0.98 R_\odot$, $M_2 = 0.16 M_\odot$, and $R_2 = 0.61 R_\odot$. Lu & Rucinski (1993) performed acquired a new spectroscopic observations. They refined the value of the geometric elements to be $M_1 = 1.36 M_\odot$, $R_1 = 1.40 R_\odot$, $M_2 = 0.41 M_\odot$, $R_2 = 0.83 R_\odot$, $T_1 = 5300$ K, $a = 2.80 R_\odot$, and $i = 85.2^\circ$.

The evidence of the changes in orbital period changes was noted by Kwee (1958), Binnendijk (1960), and Wood & Forbes (1963). It was discussed by Bakos (1977), Demircan et al. (1991), and Hobart et al. (1998). With the minima of the photoelectric observations published from 1960 to 1977, Bakos (1977) revealed that the orbital period is increasing at $\Delta P/\Delta t \approx 1.28 \times 10^{-9}$. He attributed this variation to the mass thrown from the primary component forming a ring along the outer contact surface. Demircan et al. (1991) collected all available minima times published before that time. Do you mean With the quadratic fits to the observed minus calculated ($O - C$) curve, they found that the orbital period of AH Vir shows both a periodic change and a long term increase. The long-term increase was found to be $\Delta P/\Delta E = 2.66 \times 10^{-10}$, and the periodic change had a period of 11.2 yr. In the same time, Demircan et al. (1991) have made the linear fits to the $O - C$ curve and found that the orbital period showed abrupt changes of $\Delta P/\Delta P = 8.7 \times 10^{-6}$ and $\Delta P/\Delta t = 1.4 \times 10^{-5}$ around 1955 and 1971, respectively. They pointed out that the period abrupt increases in period were due to the mass transfer from the less massive to the more massive component. Hobart et al. (1998) reported that the period was increased without a rate of $\frac{dP}{dt} = 2.2687 \times 10^{-7}$ d yr$^{-1}$. But they did not give any explanation about why this occurs.

As far as we know, the orbital period of AH Vir has not been researched for more than 15 yr, since the work of Hobart et al. (1998). However, up to now, a large number of new minima times have been published by many authors (e.g., Paschke 2012; Hübser et al. 2013; Parimucha et al. 2013; Samolyk 2013). This indicates that the orbital period of AH Vir needs to be further investigated. Do you mean In this paper, we are making an attempt to construct all available minima times from the literature, to construct the $O - C$ diagram, to analyze orbital period variations and try to reveal the mechanism that may cause the orbital changes of AH Vir.

Please provide a plan for the paper in the form Section 2 gives ... Section 3 describes ... etc.

In section 2, we present a detailed analysis of period changes in AH Vir. The mechanisms that may cause the period changes in AH Vir are discussed in Section 3.USD as the conclusion of the paper.

2 DATA COLLECTION AND PERIOD ANALYSIS

In order to construct the $O - C$ diagram and to reveal the overall behavior of the orbital period variation of AH Vir, an extensive search for the light minima timings has been performed. Do you mean We acquired 464 light minima timings are taken from the $O - C$ gateway, and the data were collected from the literature (see Table 1). We note that the linear elements of AH Vir published in the literature are very different (see Lause 1935a; Binnendijk 1960; Bakos 1977; Demircan et al. 1991; Hobart 1998; and Kreiner et al. 2001, 2004). In order to determine the linear element and to calculate the overall $O - C$ values, we apply linear fits to all available minima times and derive a new linear ephemeris as following.

$$\text{Min.} I = \text{HJD}2455673.6892 + 0^d.40752431 \times E.$$  
(1) 
$\pm 0.0010 \quad \pm 0.0000027$

Do you mean The $O - C$ values computed by the new ephemeris (Eq. (1)) are plotted in Figure 1, where open circles denote visual and photographic data, and solid dots are the photoelectric and CCD observations, respectively.?
Table 1 Times of Minima of AH Vir

<table>
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<th>No</th>
<th>JD, Hel.2400000&lt;sup&gt;0&lt;/sup&gt;</th>
<th>Meth.</th>
<th>( \Delta E ) (d)</th>
<th>( (O - C) ) (d)</th>
<th>( (O - C)_1 ) (d)</th>
<th>Residuals (d)</th>
<th>Ref.</th>
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<td>[6]</td>
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Ref.: (1) Prager (1929); (2) Baldwin & Samolyk (1997); (3) Hobart et al. (1998); (4) Baldwin & Samolyk (2002); (5) Samolyk (2010); (6) Samolyk (2012).

**Do you mean** In Figure 1, one can see that the \( O - C \) curve shows smoothly and continuously variable. By setting weights of 1 to visual data, 3 to photographic observations, 8 to photoelectric and 10 to CCD data, a weighted least-squares fit yields the following equation:<sup>1</sup>\[ (O - C) = -0^d.0858(\pm0.0007) + 0^d.9049(\pm0.0053) \times 10^{-5} \times E + 0^d.1268(\pm0.0009) \times 10^{-9} \times E^2. \] From Equation (2), the long-term orbital period increase rate of orbital period \( \sigma \) for AH Vir can be calculated to be \( dP/dt = (2.1869 \pm 0.0161) \times 10^{-7} \text{d yr}^{-1}. \)** Do you mean** The corresponding residuals of \( (O - C)_1 \) from Equation (2), plotted in the second-middle panel of Figure 1, show a small wave-like variation.<sup>†</sup>

Using a least-squares method to fit the \( (O - C)_1 \), we obtain the following solution:<sup>†</sup>\[ (O - C)_1 = +0^d.1268(\pm0.0303) \times 10^{-2} \]
Fig. 1 \((O-C)\) curve of AH Vir based on Equation (1) and its representation by equation Eq. (2) (solid line in the upper panel). The \((O-C)\) residuals and their descriptions in equation Eq. (3) are plotted in the middle panel, showing a small wave-like variation. The final residuals are plotted in the bottom panel. **Please redraw the plot and change the spelling of "Residyals" to "Residuals".**

Do you mean From Equation (3), we can derive the period of the oscillation to be \(P = 37.19\) yr, and the corresponding amplitude is \(A = 0^d.0074(\pm0.0005)\). With the following equation:

\[
\Delta P = 2\pi AP_e / P,
\]

we can obtain the amplitude of the oscillation to be \(\Delta P = 1.3942 \times 10^{-6}\) d.? I agree this change.

3 DISCUSSION

Do you mean Our results suggest that the orbital period of AH Vir exhibits a secular increase, \(dP/dt = (2.1869 \pm 0.0161) \times 10^{-7}\) d yr\(^{-1}\), and a small periodic variation with periods of 37.19 yr. If AH Vir is an overcontact system (Binnendijk 1960, 1984), the period secular increase in period may be due to the mass transfer from the less massive to the more massive component (but this is not quite the case for an overcontact binary). However, Bakos (1977) showed the configuration of AH Vir being a semi-contact case (see the fig. 6 of Bakos 1977). He stated that the larger star of AH Vir is close to the inner Roche lobe and attributed the increase in orbital period increase to the mass transfer from the larger to the smaller component in the form of gas streams. **The question of whether AH Vir is an overcontact or semi-contact system?** This leads us to consider the configuration of AH Vir in this system. From the Lu & Rucinski (1993) results, the absolute parameters of AH Vir are \(M_1 = 1.36 M_\odot, M_2 = 0.41 M_\odot, R_1 = 1.40 R_\odot, R_2 = 0.83 R_\odot, \) and \(a = 2.80 R_\odot\). Using the
Period Variations of AH Vir:ins, 5

equation (Eggleton 1983)
\[
\frac{r_L}{a} = \frac{0.49q^2}{0.6q^2 + \ln(1 + q^2)},
\]
and with \( q_1 = M_1/M_2 \) and \( q_2 = M_2/M_1 \), we can compute the radii of Roche lobes of AH Vir to be
\[
r_L1 = 1.35 R_\odot < R_1 = 1.40 R_\odot \quad \text{and} \quad r_L2 = 0.79 R_\odot < R_2 = 0.83 R_\odot.
\]
This indicates that AH Vir is a true overcontact system. Do you mean In this case, the secular increase of the orbital period of AH Vir cannot only be explained by other mechanisms besides the mass transfer from the larger to the smaller component gas streams, as Bakos (1977) pointed out. It may result from the mass transfer from the smaller to the larger component. With the equation (5) of Kwee (1958), and taking \( M_1 = 1.36 M_\odot \) and \( M_2 = 0.41 M_\odot \), we can calculate the mass exchange rate to be
\[
dM_1/dt = -dM_2/dt = 1.05 \times 10^{-7} M_\odot \text{ yr}^{-1}.
\]

\textbf{Do you mean} Since AH Vir shows strong activity in Mg II (Rucinski 1985) and H\alpha (Barden 1985) and the more massive component is much more active than the smaller secondary (Lu & Rucinski 1993), we assume that the period oscillation in period is caused by the magnetic activity cycle of the primary component. The theory that the magnetic activity causes the change in orbital period change in the binary was firstly proposed by Applegate (1992). It was later developed by Lanza et al. (1998, 2002).? By using the formula of from Applegate (1992)
\[
B^2 \sim 10 \frac{GM^2}{R^4} \left( \frac{a}{R} \right)^2 \frac{\Delta P}{P},
\]
Do you mean and adopting the parameters \( M = M_1 = 1.36 M_\odot, R = R_1 = 1.40 R_\odot, a = 2.80 R_\odot, P = 37.19 \text{ yr}, \) and \( \Delta P = 1.3942 \times 10^{-6} \text{ d} \), the mean surface magnetic field of the component due to activity component can be calculated to be \( B = 1.487 \text{ kG} \).

\section{4 CONCLUSIONS}

We have made a satisfactory fit to the \( O-C \) diagram by using a weighted least-squares method. Do you mean We conclude that the orbital period of AH Vir is undergoing both a secular period increase in period and cyclic variations. The cyclic variations may be originated in the cycle of magnetic activity cycle of the primary component. The period-long-term increase in period can be interpreted as the mass transfer from the smaller to the larger component. I agree this change.

\textbf{Acknowledgements} This work was partly supported by the Chinese National Natural Science Foundations of China (Grant Nos. 11273022, 11173019, and 11133007), and the Key Laboratory for the Structure and Evolution of Celestial Objects, Chinese Academy of Sciences. It is also supported by a grant of from the John Templeton Foundation and NAOC. The authors thank the referee for their valuable comments and suggestions in revising the manuscript.

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