MAGNETIC CVs AS A BRIGHT REPRESENTATIVE OF CLOSE BINARIES

S. -B. QIAN\(^{1,2,3}\), Z. -T. HAN\(^{1,2,3}\), L. -Y. ZHU\(^{1,2,3}\), W. -P. LIANG\(^{1,2}\), E. FERNÁNDEZ LAJÚS\(^{4,5}\), M. ZEJDA\(^{6}\), L. LIOU\(^{1,2,3}\), B. SOONTHORNTHUM\(^{7}\), and X. ZHOU\(^{1,2,3}\)

\(^{1}\)Yunnan Observatories, Chinese Academy of Sciences (CAS), P. O. Box 110, 650011 Kunming, P. R. China
\(^{2}\)Key laboratory of the structure and evolution celestial bodies, Chinese Academy of Sciences, P. O. Box 110, 650011 Kunming, P. R. China
\(^{3}\)University of the Chinese Academy of Sciences, Yuquan Road 19\#, Sijingshang Blok, 100049 Beijing, P. R. China
\(^{4}\)Facultad de Ciencias Astronómicas Geofísicas, Universidad Nacional de La Plata, 1900 La Plata, Buenos Aires, Argentina
\(^{5}\)Instituto de Astrofísica de La Plata (CCT La plata - CONICET/UNLP), Argentina
\(^{6}\)Department of Theoretical Physics and Astrophysics, Masaryk University, Kotlářská 2, CZ-611 37 Brno, Czech Republic
\(^{7}\)National Astronomical Research Institute of Thailand, 191 Siriphanich Bldg., Huay Kaew Rd., Chiang Mai 50200, Thailand

E-mail: qsb@ynao.ac.cn

(Received November 30, 2014; Revised May 31, 2015; Accepted June 30, 2015)

ABSTRACT

Due to the lack of an accretion disk in a polar (magnetic cataclysmic variable, MCV), the material transferred from the secondary is directly accreted onto the white dwarf, forming an accretion stream and a hot spot on the white-dwarf component. During the eclipses, different light components can be isolated. Therefore, the monitoring of eclipsing polars could provide valuable information on several modern astrophysical problems, e.g., CVs as planetary hosting stars, mass transfer and mass accretion in CVs, and the magnetic activity of the most rapidly rotating cool dwarfs. In the past five years, we have monitored about 10 eclipsing polars (e.g., DP Leo and HU Aqr) using several 2-m class telescopes and about 100 eclipse profiles were obtained. In this paper, we will introduce the progress of our research group at YNOs. The first direct evidence of variable mass transfer in a CV is obtained and we show that it is the dark-spot activity that causes the mass transfer in CVs. Magnetic activity cycles of the cool secondary were detected and we show that the variable mass transfer is not caused by magnetic activity cycles. These results will shed light on the structure and evolution of close binary stars (e.g., CVs and Algols).

Key words: binaries: stars: binaries: close–stars: binaries: eclipsing–stars: evolution

1. INTRODUCTION

Cataclysmic variables (CVs) are semi-detached binaries that contain a white-dwarf primary and a low-mass (spectral types of K and M) secondary. The cool component star fills the critical Roche lobe and transfers mass to the white-dwarf component (e.g., Warner 1995). In a normal CV, the transferred materials form an accretion disk around the white dwarf. However, in a polar (magnetic CV), the magnetic field of the white dwarf is strong enough to prevent the formation of an accretion disk (e.g., Giovannoli & Sabau-Graziati 2012). The transferred materials from the secondary are quickly and directly accreted onto the white dwarf and form an accretion stream and a hot spot on the white dwarf. During the eclipses, light components from the accretion stream and the spot on the white dwarf can be isolated. At the same time, the eclipse times can be determined to a high precision. Therefore, eclipsing polars can provide invaluable information for several problems of modern astrophysics, e.g., CVs as planetary hosting stars, the character and physical mechanisms of mass transfer and mass accretion in CVs, and the magnetic activity of rapidly rotating dwarfs in CVs. In this paper, we will review these aspects in detail.

2. POLARS AS A PLANETARY HOSTING STAR

Ten eclipsing polars (e.g., DP Leo, V2301 Oph, EK UMa, HU Aqr, UZ For, and MN Hya) were selected and monitored photometrically from 2009 using the 1.0-m and 2.4-m telescopes at Yunnan observatories in China, the Danish 1.54-m telescope at La Silla, the 2.15-m "Jorge Sahade" telescope in Argentina, and the 2.4-m telescope in Thailand. The white-light eclipse profile of the eclipsing polar MN Hya observed on April 6, 2013 is shown in Fig. 1. This eclipse profile was obtained using the Danish 1.54-m telescope at La Silla. As shown in the

http://pkas.kas.org
3. CHARACTER OF MASS TRANSFER AND MASS ACCESSION

Mass transfer is very important for understanding the evolution and observational properties of close binary stars. Most CVs (e.g., polars and some dwarf novae and nova-like CVs) show brightness changes in different states (e.g., high, intermediate, and low brightness states). The most plausible reason for these state changes is variation of mass transfer and mass accretion. However, direct evidence is lacking because of the influence of an accretion disk in a normal (non-magnetic) CV. Because they lack an accretion disk, the transferred material from the secondary in polars is quickly and directly accreted onto the white dwarf. Monitoring of eclipsing polars provides a good chance to study the properties of mass transfer in close binary stars. However, no eclipsing polars have been monitored for a long time, and only a few non-eclipsing polars have been monitored photometrically, including the brightest polar AM Her (e.g., Hessman et al. 2000; Kafka & Honeycutt 2003, 2005; Wu & Kiss 2008).

Three of the white-light eclipse profiles of HU Aqr obtained in 2011 using the 2.4 m telescope in Yunnan observatories are shown in Fig. 3. As shown in the figure, HU Aqr varied from a high state to a low state. On September 9, 2011 HU Aqr was at a high brightness state, and the distortion in the ingress profile is visible, suggesting that there is an accretion stream from the secondary to the white-dwarf component. At the same time, we could see a hot spot on the white dwarf. Therefore, the system is at the high brightness state. Both the existence of the accretion stream and of the hot spot reveal a high rate of mass accretion at high brightness state. From December 6 to 16, 2011, the system declined to a low brightness state, the distortion in the ingress profile disappeared and the eclipse profiles became symmetric. These suggest that there are no hot spots on the white dwarf and no accretion streams are seen between the components. These observational
properties indicate that no mass transfer and accretion between both components occurred during low brightness states. The out-of-eclipse brightness variation is correlated with the change of the eclipse profile suggesting that both the hot spot and the accretion stream are produced instantaneously. This is direct evidence of variable mass transfer and accretion in the CV.

4. MAGNETIC ACTIVITY OF THE RAPIDLY Rotating Dwarfs

Two eclipse profiles of the polar V2301 Oph observed on May 29, 2011 and on June 18, 2014 are shown in Fig. 1. The two profiles were observed using the 2.15-m Jorge Sahade telescope at Complejo Astronomico El Leoncito (CASLEO), San Juan, Argentina. During the observation, a Versarray 1300B camera with a thinned EEV CCD36-40 de 1340×1300 pix CCD chip was used, and no filters were used. At the bottoms of the eclipses, the white dwarf together with its hot spot and the accretion stream all are eclipsed by the cool secondary. Only the red-dwarf component is visible and provides a constant contribution. Therefore, it is the only chance to measure the brightness change of a mass donor in a CV caused by the activity of a dark spot. The secondary in a CV is usually a cool K- or M-type star that rotates about 300 times as the Sun does. By monitoring an eclipsing polar, we can understand the properties of dark-spot activity and magnetic activity cycles.

5. DISCUSSIONS AND CONCLUSIONS

Based on previous discussions we concluded that eclipsing polars are very useful for investigating several interesting questions in modern astrophysics. We have monitored this type of binary star for several years and some preliminary results have been obtained. We show that planets and brown dwarfs can exist in a completely different kind of host stars, i.e., polars. The observations in the previous section give direct evidence for variable mass transfer and accretion in CVs. A cyclic brightness variation of the secondary in HU Aqr was discovered that can be explained by the dark-spot activity cycle. It is the first time an activity cycle for a fast-rotating mass donor in a CV has been detected. Our results reveal that the variable mass accretion is not caused by magnetic activity cycles of the fast-rotating red dwarf. We will continue to monitor this group of stars and details will be studied in the future.

ACKNOWLEDGMENTS

This work is supported by Chinese Natural Science Foundation (No.11133007 and No. 11325315). New CCD photometric observations of eclipsing polars were obtained with the 1.0-m and the 2.4-m telescope of Yunnan Observatories, the Danish 1.54-m telescope at La Silla, the 2.15-m “Jorge Sahade” telescope in Argentina, and the 2.4-m telescope in Thailand.

REFERENCES

Kafka, S. & Honeycutt, R. K., 2005, AJ. High/Low States in Magnetic Cataclysmic Variables, 130, 742
Qian S. -B., Zhu L. -Y., Dai Z. -B., Fernandez Lajus, E., Xiang F. -Y., & He, J. -J., 2012b, Circumbinary Planets

Figure 3. Comparison of eclipsing profiles in high and low brightness states.

Figure 4. Eclipsing profiles of V2301 Oph obtained with the 2.15-m “Jorge Sahade” telescope in Argentina.

This is a representation of the document as if you were reading it naturally.