IP PEGASI: CATACLYSMIC STELLAR VARIABILITY WITH ECLIPSING BINARY SUPERIMPOSITION

Mary Dombrowski
36 Heywood Dr.
Glastonbury, CT 06033

Presented at the Annual Meeting of the AAVSO, October 25, 1997

Abstract

Because of its unique light curve which reveals eclipsing secondary superimposition due to the line-of-sight orientation of the system's components, the cataclysmic variable IP Pegasi reveals the presence of an unseen companion through periodic changes in magnitude that can be detected visually during times of outburst. Visual magnitude estimates and CCD photometry reveal eclipses of the primary and accretion disk, verifying the accepted model of a cataclysmic variable star system.

1. Introduction

IP Pegasi (R.A. $23^h20^m39^s$, Decl. +18°08.'7 (1950), 12.0–18.6 B) (Kholopov *et al.* 1985) is a U Geminorum-type star that varies in brightness because it is a compact binary system in which matter is transferred from the secondary star into an accretion disk orbiting the primary white dwarf star (Cannizzo and Kaitchuck 1992). This produces a dynamic condition that causes irregular increases in magnitude followed by long durations of quiescence. The astrophysical understanding of the involved dynamics is complex, and a likely model that explains the rapid changes in magnitude must be derived through analysis of the light curve generated from numerous observations (Worraker *et al.* 1996).

Figures 1–4 are facsimiles of my acrylic paintings showing the four phases of the IP Peg system's eclipse cycle, illustrating the dynamics required to produce the light curve of a single night's visual observations during outburst (Figure 5). The white dwarf primary star has sufficient mass and gravity to maintain a solar-sized-low-mass secondary in a very short-period orbit (Webbink 1989). Because of the small distance between the two components, the secondary star has filled its Roche Lobe and thus is losing matter that is accumulating onto an accretion disk orbiting the white dwarf. The inflow of matter onto the accretion disk is represented by a white spot in the illustrations (Webbink 1989).

2. Observations and analysis

It is the accretion of matter from the accretion disk onto the primary star—the white dwarf—that causes the outbursts, resulting in the IP Peg system increasing in brightness by several magnitudes within a few hours. During outburst, I made visual observations at ten-minute intervals and recorded the apparent magnitude and the Julian Date (to the nearest minute) for analysis. I used the AAVSO preliminary "e" scale chart dated 7/1985 to make the visual observations.

The light curve (Figure 5) shows ~5.2 hours of observations during which the magnitude of IP Peg varied from visual magnitude 12.7 to 13.3. Based on this observing run, my data revealed a 3.8-hour eclipse cycle. P. Szkody provided the ephemeris for IP Peg (Mattei 1993):

$$JD_{min} = 2445616.4156 + 0.15820616\ E. \qquad (1)$$

Figures 1–4. Author's acrylic paintings of the four phases of IP Peg's eclipse cycle during outburst.

Figure 1

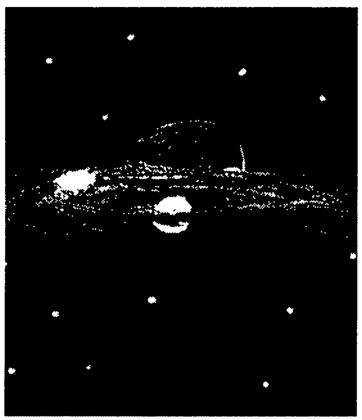


Figure 1. The hot spot (white spot left of center) on the accretion disk is now at maximum visibility, producing the orbital hump in magnitude as it leads the secondary, companion star with its filled Roche lobe.

Figure 2

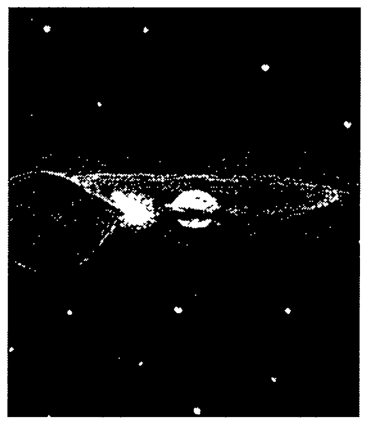


Figure 2. All of the IP Peg system's (visible) components, producing near-maximum total luminosity.

Figure 3

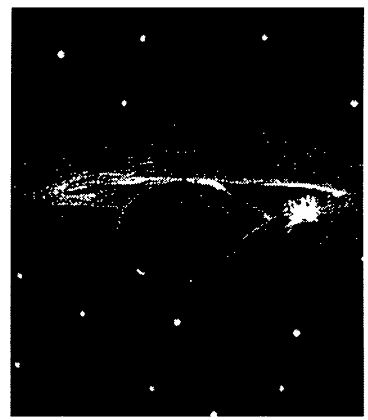


Figure 3. Primary white dwarf star and much of the accretion disk eclipsed by the less massive secondary companion.

Figure 4

Figure 4. The primary white dwarf star is out of eclipse; however, the unseen companion is eclipsing the hot spot.

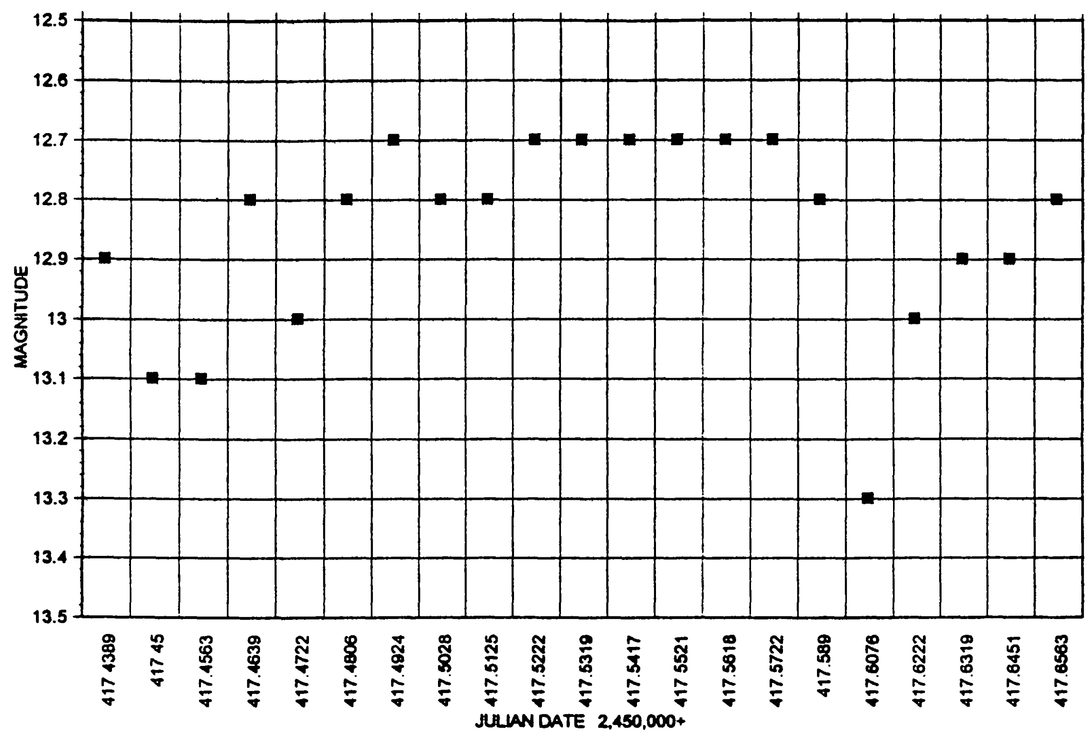


Figure 5. Light curve of visual observations made over ~5.2 hours showing eclipses of IP Peg by an unseen companion. This observation run revealed an eclipse cycle of 3.8 hours.

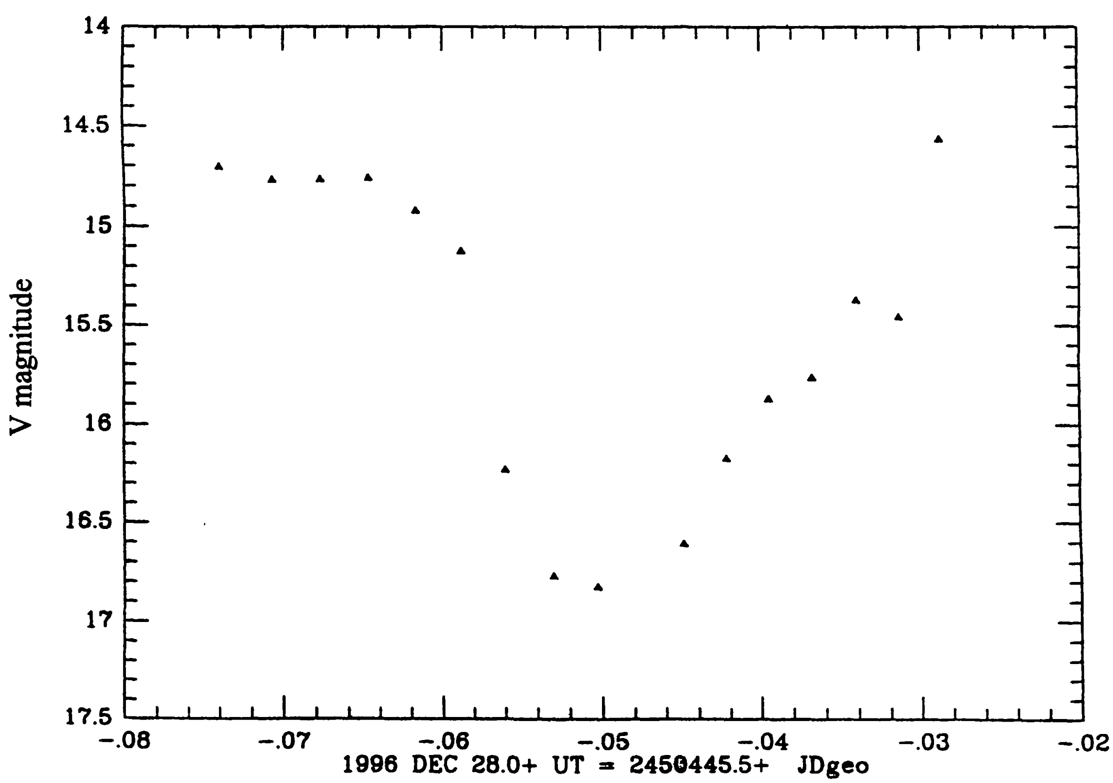


Figure 6. CCD(V) light curve showing a full eclipse of IP Peg.

Figure 7

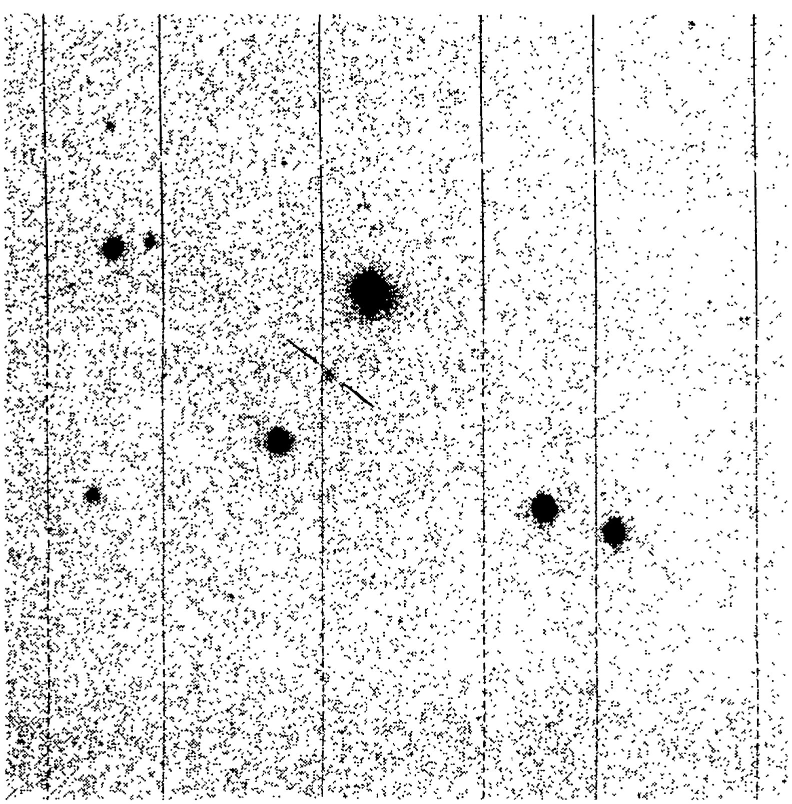
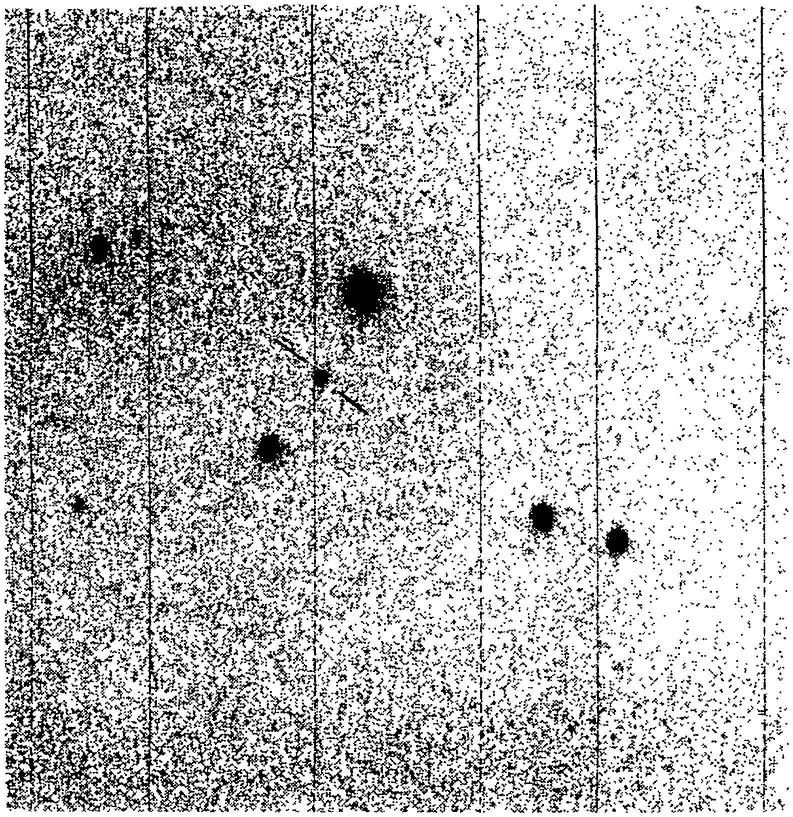


Figure 8



Figures 7–8. CCD(V) images made 34 minutes apart on December 28.0, 1996 UT, showing IP Peg eclipsing during quiescence.

The brevity of the eclipses supports the value of approximately $1.0M_{\odot}$ for the white dwarf component. Analysis of the light curve shows the presence of the hot spot and a deep eclipse of the accretion disk and primary by the large, less dense secondary. From this graph I conclude that the three-dimensional orientation of this system presents itself in a similar manner to an eclipsing binary star system.

My visual observations of IP Peg were limited to times of outburst, when the star could be seen in my Celestron-1 1 telescope. Because of the limitations of my visual investigation of IP Peg's eclipses, I was given the opportunity to use the CCD instrumentation at Mt. Holyoke College under the direction of Dr. Ronald Zissell. Using a Photometrics CH250 CCD with a magnitude limit of magnitude ~19.0, we collected 17 data points, taken at four-minute intervals over a 68-minute period on December 28.0 UT, 1996. My observations were based on photoelectric standards published in Goranskij (1985). At the time of my observations, IP Peg was in quiescence, and its eclipses produced a visual magnitude change from 14.7 to 16.9. The CCD(V) light curve (Figure 6) shows a full eclipse of the IP Peg system. Figures 7 and 8 are CCD(V) images, taken 34 minutes apart, showing IP Peg's eclipse cycle during quiescence.

3. Acknowledgements

I would like to thank the AAVSO, especially Dr. Janet Mattei, and Dr. Ronald Zissell of Mt. Holyoke College, for their support and encouragement throughout my project. This science project represents my efforts in understanding the astrophysical nature of the IP Peg system. In recognition of these efforts, I was awarded a national first place by the NASA/NSTA Student Space Involvement Program in the space astronomy category.

References

Cannizzo, J. K., and Kaitchuck, R. H. 1992, *Sci. Amer.*, **266**, 42.

Frank, J., King, A., and Raine, D. 1992, *Accretion Power in Astrophysics*, 2nd ed., Cambridge University Press, England.

Goranskij, V. P., Shugarov, S. Yu., Orlowsky, E. I., and Rahimov, V. Yu. 1985, *Inf. Bull. Var. Stars*, No. 2653.

Kholopov, P. N., Samus, N. N., Kazarovets, E. V., and Perova, N. B. 1985, *Inf. Bull. Var. Stars*, No. 2681.

Mattei, J. A. 1993, *AAVSO Alert Notice,* No. 179, AAVSO, Cambridge, MA.

Webbink, R. F. 1989, *Amer. Sci.*, 77, 248.

Worraker, W. J., Naylor, T., Poyner, G., and Robinson, S. J. 1996, in *Cataclysmic Variables and Related Objects*, eds. A. Evans and J. H. Wood, Kluwer Acad. Publ., Dordrecht, The Netherlands.