The Light Curve of Periodic Comet Wirtanen

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Abstract

The light curve of Periodic Comet Wirtanen has been analyzed for the 1986 and 1991 apparitions, the only two monitored by visual observers, The comet's light curve displays a rapid rise of the order of five magnitudes between -73 days and -45 days (prior to perihelion). From -45 to (about) +16 days the comet brightens at a rate of approximately 0.022 magnitudes per day. After reaching peak brightness, the comet fades by about 0.031 magnitudes per day. The comet's intrinsic brightness was 0,5 -0.7 magnitudes fainter during the 1991 apparition than in 1986. There are indications that this comet may have experienced brightness flares of about one magnitude in 1986.

Periodic Comet Wirtanen (P/Wirtanen) was discovered photographically as a 17th magnitude object on January 15, 1948 by Carl A. Wirtanen (Lick Observatory, California). As summarized by Kronk (1984), the comet remained faint, never becoming brighter than 15th magnitude, during

the apparitions prior 1986. P/Wirtanen has had two recent C1OSC approaches with Jupiter, one in 1972 and another in 1984. This reduced the comet's perihelion distance from 1.61 AU to 1.26 AU and then to 1,08 AU. The final reduction in perihelion distance brought the comet within reach of the visual observer. As a result, the comet was observed visually by a number of observers both in 1986 and 1991. The physical properties of P/Wirtanen are of considerable interest because it is a potential target of the European Space Agency's Rosetta mission. This paper summarizes the light curves of P/Wirtanen from the 1986 and 1991 apparitions.

The Magnitude Data

All the magnitude data used in this study, with the exception of four estimates, were obtained from *The international Comet Quarterly (ICQ*; Numbers 58-60, 62-63 for the 1986 apparition and 80-82, 84 for the 1991 apparition). In addition to the *ICQ* data, a single visual estimate for the 1986 apparition, not reported in the *ICQ*, was obtained from J. Bortle (private communication and also published onIAUC4193). In addition, the photographic recovery magnitudes from 1985 and 1991 were obtained from *IAUC*s 4139 and 5303, respectively.

The two apparitions required different approaches for the selection of observations, For the 1991 apparition (199 1 XVI = 1991 s), a standard approach was used of selecting those observers having made a specified minimum number of magnitude estimates, For P/Wirtanen 1991 XVI, a minimum of five magnitude estimates (made on different nights) were required. The advantage of this approach is that the observations of different observers can be compared over time.

Observer biases can be estimated and corrected. A total of 60 observations made by seven observers met the selection criterion. Two photographic recovery magnitudes, made by Seki, were also included, Thus a total of 62 observations were selected for the study. The observers arc summarized in Table 1.

The 1986 apparition (1986 VI = 1985q) posed a more difficult data selection problem. Fewer observations were made during this earlier apparition. In large measure, this was because I'/Halley was at its peak brightness during P/Wirtanen's period of visibility. Many observers, who would have followed P/Wirtanen, were traveling to observe P/Halley. In fact, only 11 observations, made by two observers, would have qualified using the criterion applied in the 1991 apparition data selection. This is insufficient to fully document the apparition, It was decided to accept all reasonably consistent observations. In all, 29 observations by 10 observers were selected, In addition, the photographic recovery (nuclear, m_2) magnitude estimate by Gilmore and Kilmartin was also used, bringing the total number of observations to 30. Table 1 lists the observers,

It is interesting to note that five observers provided data for both apparitions. [A sixth observer (Keen; KEE) also observed the comet during both apparitions, but made only one observation in 1991.] In every case, the same instrumentation was used for both apparitions,

Data Analysis

The 1991 apparition of P/Wirtanen was evaluated first because of the greater number of observations, Two approaches were tried initially. These included applying no aperture correction to the magnitude estimates and using the standard aperture corrections suggested by Morris (1973). Both approaches resulted in about a one magnitude scatter and neither were considered completely satisfactory.

To improve the light curve, individual observer corrections were derived by intercomparing the observations of different observers. 'I'he derived corrections are listed in Table 1 and the resulting light curve is shown in Figure 1a. The scatter in the light curve has been reduced to about half a magnitude. An exception is the four preperihelion points that are about one magnitude brighter than the other observations. These observations are all by a single observer (Nakamura, NAK01), his only preperihelion data, Although Nakamura's preperihelion observations are not consistent with other observers, his postperihelion data are in good agreement with the other magnitude estimates, Using information supplied by Nakamura (private communication), possible systematic differences (e.g., comparison stars, observing location, etc.) in his pre- and postperihelion estimates were investigated, However, the reason for the discrepancy in Nakamura's preperihelion data remains a mystery. It is possible, but seems unlikely, that all these observations represent brightness flares. Nakamura (private communication) reports that his field notes do not indicate anything in the comet's morphology to suggest brightness flares at the time of his observations.

It was not possible, due to the small number of observations, to derive observer-specific corrections for the 1986 analysis. Instead, the corrections obtained for the 1991 apparition were used for those observers who observed the comet at both apparitions. This approach gave acceptable results. A correction for Keen was estimated using his single 1991 observation. All other observers were assumed to require no correction. The light curve for the 1986 apparition is depicted in Figure lb. As will bc discussed below, there is a suggestion that P/Wirtanen experienced flares in brightness in 1986. However, the brightest observation (at t=+24 days) was the only magnitude estimate made by Linder (LIN02). Thus, there is no way to calibrate this observation to know whether the comet was real] y this bright, (A comparison of Linder's observations of other comets made during the same period indicates that his magnitude estimates are reasonably consistent with other observers,) This illustrates the difficulty when only one or two observations are available from a given observer.

Interpretation of the Light Curves

The light curve constructed from the 1991 observations (Figure 1a) clearly shows that the comet reaches peak brightness about 16 days after perihelion. Prior to reaching its maximum brightness, the comet is brightening at a rate of about 0.022 ($\pm$ 0.003 standard error) magnitudes per day (based on a linear regression). The decline in brightness (0.031 $\pm$ 0,003 magnitudes per day) is steeper, The 1991 heliocentric magnitude data (excluding Mr. Nakamura's preperihelion observations) can be represented by the following formulae:

Time from Perihelion (days)	
-43 to -I-16	9.13 -0.022 (t - 16)
+16 to +87	9.34 -t- 0.031(t - 16)

where t is the time (in days) from perihelion. This fit is shown in Figure 1a. These equations do not have the same value at t=+16 days because there is approximately a 0.5 magnitude drop in brightness between t=+ 16 and t=+20 days.

The linear regression results for the 1986 apparition show a rise in brightness of 0.019 (±0.005) magnitudes per day and a decline of 0.037 (±0.01 O) magnitudes per day, excluding the apparent flare at t=+24 days. These values are within errors of 1991 parameters. Because the 1991 parameters are better determined, these have been adopted to represent the 1986 data in the formulae below and in Figure 1b.

Time from Perihelion (days)	
-45 to +16	8.65 -0.022 (t - 16)
+16 to +52	8,65 + 0.031 (t - 16)

Clearly, the comet was 0,5 -0.7 magnitudes brighter than in 1991. A decrease in intrinsic brightness during the first few apparitions at a closer perihelion distance is not unexpected.

The question as to whether or not this comet experiences significant brightness flares (> 0.5

magnitudes in amplitude) is unresolved. There is no conclusive evidence in the 1991 apparition to support this possibility. However, in the 1986 apparition there arc indications that flares or longer period brightening may have occurred. The most obvious example is the Linder observation at t=+24 days. Just prior to that, there arc two observations at about t=+ 18 days by Bouma (BOU) and Hasubick (HAS03) that are significantly brighter than their other observations. in Hasubick's case, the comet brightened by more than a magnitude in eight days. There is one complication. This is the only observation for which each observer used binoculars. The other possible flare occurred at t=-15 days, Using the same instrument, Keen found the comet's heliocentric magnitude to be 0.8 magnitude brighter than when observed 24 days later. (The comet should have brightened during this period instead of fading.)

The Composite Light Curve

Figure 2 shows a composite light curve with data from both apparitions included. In addition to the visual estimates, the photographic recovery observations are displayed, The' dashed line in Figure 2 depicts the estimated light curve prior to the visual observations, Rather than a smooth increase in brightness, P/Wirtanen apparently undergoes a very rapid brightening between t=-73 days and t=45 days. The comet's intrinsic brightness increases by a factor of about 100 during this four-week period. This is preceded by a more gradual brightening,

Summary

It has been demonstrated that the light curve of P/Wirtanen is quite complex. This comet displays a rapid surge in brightness preperihelion, followed by a more gradual brightening until about t=+ 16 days. A somewhat sleeper falloff then follows. Although not conclusive, there is evidence to support the possibility of brightness variations in 1986 of more than 0,5 magnitude, In 1991, there was a 0.5 magnitude fading between t=+16 and +20 days, which was possibly associated with the shutdown of a vent on the nucleus. In general, the slopes of the two light curves agree. However, the comet's intrinsic brightness faded 0.5 -0,7 magnitudes from 1986 to 1991,

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References

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Morris, C. S. (1973). On Aperture Corrections for Comet Magnitude Estimates. *Publications of the Astronomical Society of the Pacific, 85, 470-473.*

Table 1

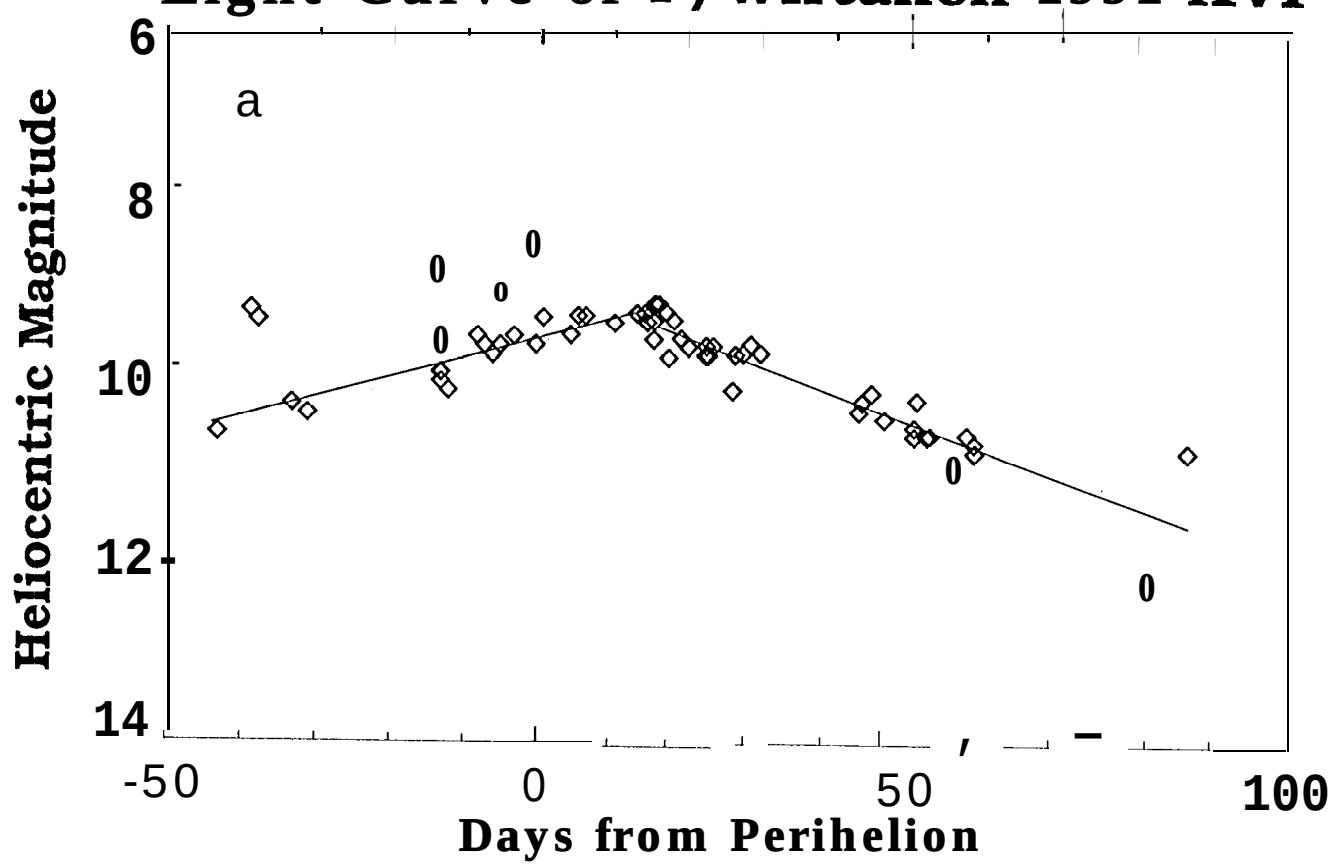
Summary of P/Wirtanen Observers

Observer	Number of Observations 1986 VI	1991 XVI	Personal Correction (Δ magnitude)
J. E. Bortle (BOR)	1	5	+0.3
R. J. Bouma (BOU)	6		0.0 [a]
A. C. Gilmore/P. M Kilmartin	1		0.0 [a,p]
A. Hale (HAL)	3	9	-0.1 [a]
W. Hasubick (HAS02)	2		0.0
R. A. Keen (KEE)	2	(1)	0.0
V. L. Korneyev (KOR01)		14	+0.2
J. Linder (LIN02)	1		0.0 [a]
J. C. Merlin (MER)	1		0.0 [a]
R. J. Medic (MOD)		6	0.0 [s]
C. S. Morris (MOR)	5	9	0.0
W. C. Morrison (MOR03)	4	8	-0.4
A. Nakamura (NAK01)	4	9	0.0
T. Seki		2	0.0 [a,p]
Total	30	62	

[a] A correction of 0.0 is assumed.

[p] Photographic magnitude estimate. The Seki estimates are total magnitudes (ml). The Gilmore and Kilmartin estimate is a nuclear magnitude (m_2). Photographic magnitudes are typically fainter than corresponding visual estimates.

[s] Medic's last observation, at t=+82 days, was made with a larger instrument. This observation was corrected -0.6 magnitudes based on Medic's own intercomparisons with his smaller telescope,


Light Curve of P/Wirtanen 1991 XVI
a
Heliocentric Magnitude
6
8
10
12
14
-50
0
50
100
Days from Perihelion

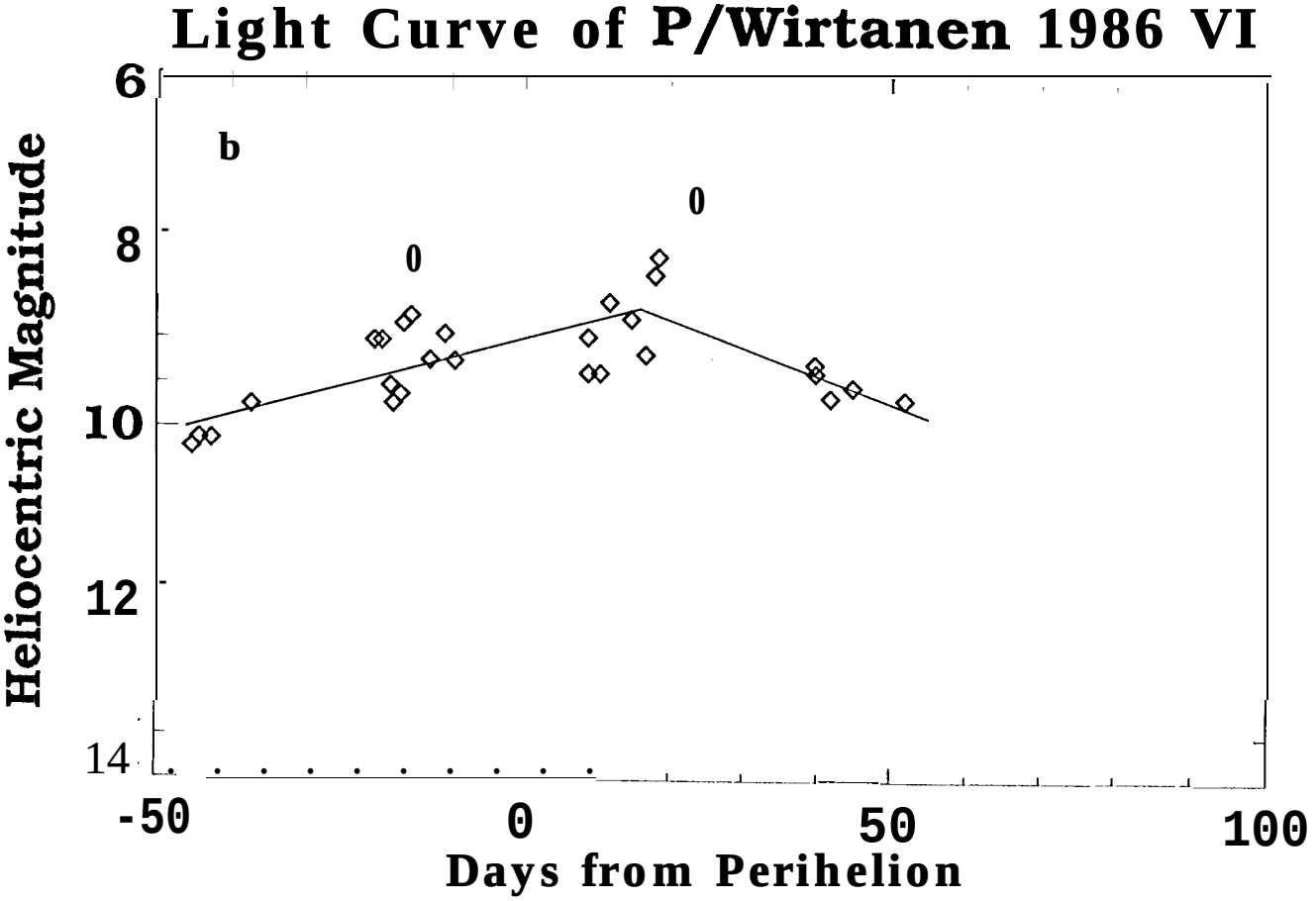

Light Curve of P/Wirtanen 1986 VI
b
Heliocentric Magnitude
6
8
10
12
14
-50
0
50
100
Days from Perihelion

Fig 1

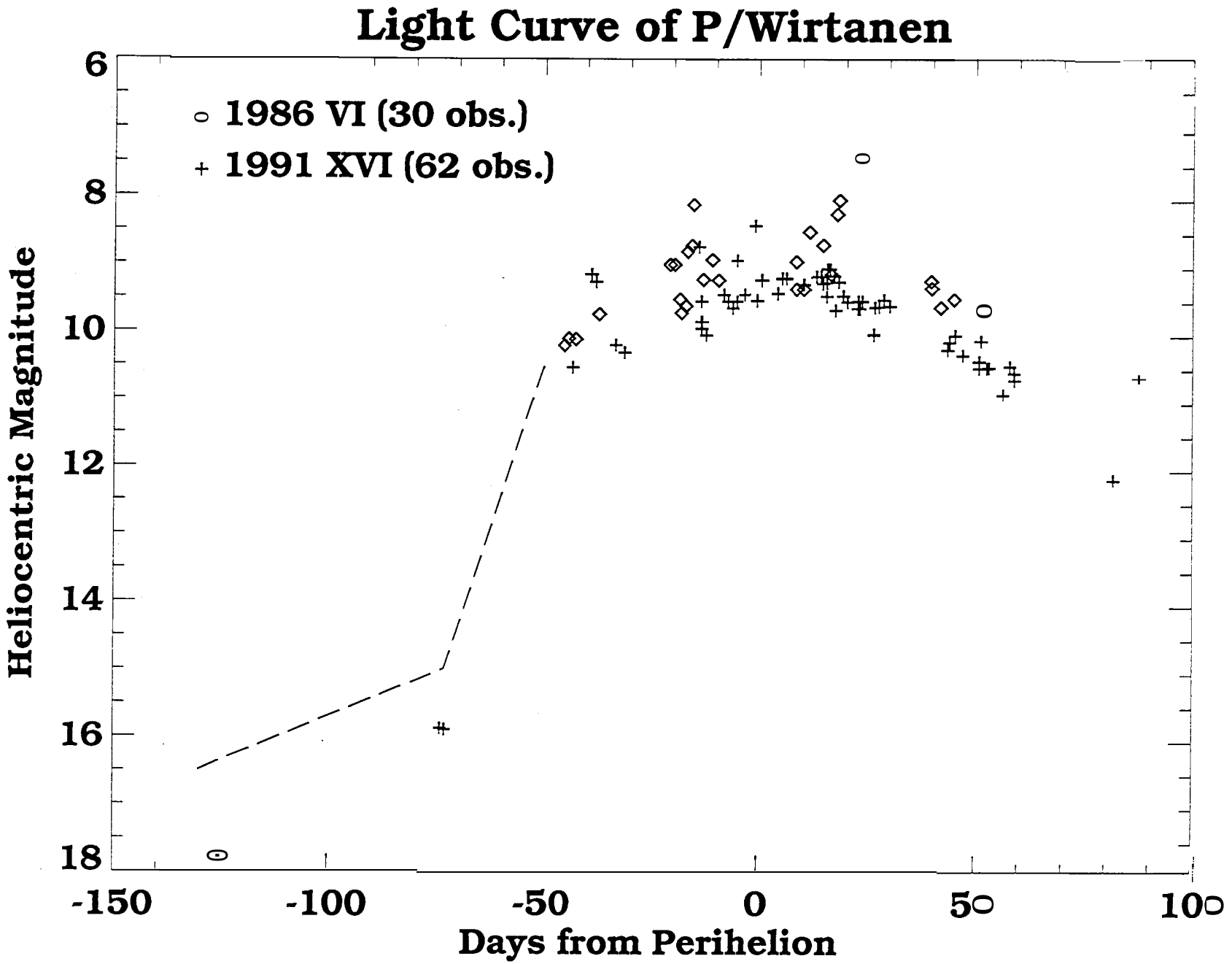

Light Curve of P/Wirtanen
1986 VI (30 obs.)
1991 XVI (62 obs.)
Heliocentric Magnitude
6
8
10
12
14
16
18
-150
-100
-50
0
50
100
Days from Perihelion

Fig 2