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A study of RW Ursae Minoris shell

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Abstract. We find an expansion parallax for the slow nova RW UMi (Nova Ursae Minoris 1956). A narrow-band H_α image shows that the diameter of the nova shell in 1995 was $2.94^{-0.49}_{+0.37}$ arcsec. We derive a distance of 5250^{-1050}_{+590} pc, and an absolute magnitude at maximum of $M_v = -7.7^{-0.4}_{+0.3}$ which are consistent with previous estimates for the nova. We also revised known relations between various parameters of nova systems.

Key words: stars: distances – stars: individual: Nova Ursae Minoris 1956 – stars: individual: RW UMi – stars: novae, cataclysmic variables

1. Introduction

1.1. Nova shells

Nova outbursts are believed to occur in all Cataclysmic Variables (CVs). In about 35% of the classified CVs nova outbursts have been observed (Downes et al. 1997). Classical novae at maximum magnitude appear to obey a luminosity-rate of decline relationship (Cohen 1985). The most reliable distance determinations for galactic novae are those obtained from the angular expansion of nova shells, of which 24 are cited in the literature.

Given that every nova should be surrounded by an expanding cloud of ejecta, it is perhaps surprising that the literature contains few images of classical nova remnants; in fact only 30 among the 200 or so known classical novae shells have been detected (Wade 1990; Gill & O'Brien 1998). This is presumably a consequence of the rarity of survey observations (the only previous published studies of this kind is by Cohen 1985; Cohen & Rosenthal 1983; and Duerbeck 1987a). The eruption of a classical nova results in the ejection of $\sim 10^{-4} M_\odot$ of material at velocities of up to several thousands kilometers per second (Warner 1989). The study of this ejected material is important for broad areas of interest such as distance determination, the chemical evolution of the interstellar medium, the physics of dust formation, and gas dynamics. It can also provide additional insight into otherwise unobservable processes that occur during the outburst itself. Our understanding of such mass ejection processes is relevant not only to novae, but also to other objects in which similar mechanisms may be at work, such as planetary nebulae and some supernovae.

1.2. RW UMi

The unusual old slow nova RW UMi (Nova Ursae Minoris 1956) was a high galactic latitude nova of $b = +33^o$ (Downes & Shara 1993). It has received so far little attention from observers and it has been a very poorly studied nova for which little information is available in the literature. Its outburst, which took place in September 1956, was discovered only seven years later on old sky-patrol plates by Kukarkin (1962). Before September 8th, 1956 the star was invisible (plate limit $12^m.5$). On September 24, 1956 the star had a magnitude of about 6.0 and in September 1957 its brightness was about $11^m.5$. The star became later invisible again. The actual maximum brightness of the nova is unknown. There seems also to be some differences in its minimum brightness. According to Kaluzny & Chlebowski (1989) B and V brightness estimates magnitudes of RW UMi from photometric observations were derived as 18.70 and 18.64, respectively (see, Table 2). However, broad-band Johson-Kron V magnitude is defined by Ringwald et al. (1996) as 18.9, and according to Duerbeck (1987b) its photographic magnitude is equal to about 21. Other V magnitudes during 1988, October the 17th and 18th, were estimated by Howell & Kreidl (1988) as about 21–21.5.

Cohen (1985) assumed that the shell emits only in H_α, not in [N II]λ6584 or λ6548, in order to derive the intrinsic shell of RW UMi. The spatially resolved shell of the nova using image observations with a digital detector was marginally first found by Cohen who derived a radius of $1.0^{+0.7}_{-0.3}$ arcsec in 1984. He used the 4-shooter detector mounted at the Cassegrain focus of the 5-m Hale Telescope, giving an image scale of 0.33 arcsec per pixel and used a narrow filter (16 Å FWHM) centred H_α for 1800 s.

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Table 1. Log of observations of RW UMi.

Start of JD	Exp (s)	Filter (Å)	Band pass (Å)
244 9781.51	3600	H_α	45
244 9781.56	1200	6670	50
244 9781.58	2400	6670	50

An optical deep imaging survey of old novae remnants carried out by Slavin et al. (1995) revealed previously unobserved features in the shells of 13 classical novae including RW UMi. They used an auxiliary port of the 4.2-m William Herschel Telescope with a binned EEV3 CCD, giving an image scale of 0.20 arcsec per pixel. They found the remnant of the nova as consisting in a bright central object surrounded by a diffuse region of material. This emission did not arise from the wings of the point spread function (PSF) of the central star. Slices across the frame of the nova suggested that the bulk of the emission was concentrated in a ring at a radius of about 1.5 arcsec. The maximum entropy method deconvolution confirmed it, revealing a ring of inhomogeneous material. They also showed that there were two regions of nebulous emission close to the main object but unconnected to the bulk of the nebula of the nova. The fainter of the two was about 3 arcsec north-west of the nova while the brighter, more extended region was about 8 arcsec directly west. They also noted that it was not clear whether these two regions were real or physically associated with the remnant of the nova.

The most recent CCD photometry of RW UMi in 1997 is reported by Retter (1999), who found a period of 0.0591 ± 0.0003 day in the light curve of the nova.

In this work, we present a nebular expansion parallax and distance estimate for the slow nova RW UMi 38.5 years after outburst, and a brief discussion in the implications of these results.

2. Observations and reductions

We obtained direct images of RW UMi in 1995, March, 5th with the 1.82 m telescope at Asiago – Italy. We used a Tektronix TK512M CCD at the f/9 Cassegrain focus, which yielded a pixel scale of 0.3375 arcsec per pixel. The exposure times were 1200 and 2400 s in 6670 Å band (H_α-off), and 3600 s with the H_α filter (H_α-on). The log of observations is shown in Table 1.

To determine the extent of the H_α nebulosity we used an automatic procedure to measure the full width at half maximum (FWHM) for a number of stars in the field by using $clpackage$ ($images - tv - imexamine$) of IRAF Package (Massey & Davis 1992). The center of each stellar-like object was found by centroiding, and then the shift from the surrounding pixels was calculated with this position. This resulted in an observed intensity versus radius plot, which was fitted with a Gaussian. At certain brightness threshold we found that the scatter of the mean seeing for the widths in the H_α image became significantly larger, and the seeing systematically smaller (see, Table 2).

Table 2. The seeing values for RW UMi (D_o) and five nearby stars (2, 3, 4, 5, 6) in the H_α-on and -off bands. B, V magnitudes of the nova and two comparison stars from Kaluzny & Chlebowski (1989).

No	Seeing H_α-on (arcsec)	Seeing H_α-off (arcsec)	V (mag)	B (mag)
1 (D_o)	4.23	3.11	18.70	18.64
2	2.74	2.76	14.78	15.44
3	3.71	2.76		
4	3.14	2.44	17.16	17.58
5	2.81	3.08		
6	2.79	2.72		
Mean (PSF)	3.04 ± 0.41	2.75 ± 0.23		
Diameter (D)	$2.94^{-0.49}_{+0.37}$	$1.45^{-0.56}_{+0.37}$		

A CCD detector with the highest possible efficiently and lowest possible noise is required to detect the faint shell of RW UMi. Unfortunately, during the observations the seeing and noise values were high, and we could take only a bias frame. Therefore, neither the bias nor flat fields were subtracted from the images in a motivation to better determine the spatially extented structure of RW UMi. The images are shown in Figs. 1 and 2.

3. Results and discussion

3.1. The direct image

We determined the last estimated shell of the nova using the direct imaging observations with the CCD detector made in 1995. A new radius of the shell of $1.47^{-0.24}_{+0.18}$ arcsec was found. We used the following method: The mean seeing (PSF) which was found from the FWHM Gaussian for the nearby field stars around RW UMi in the combined image of the 6670 Å filter was 2.75 ± 0.23 arcsec, compared with 3.11 arcsec for RW UMi. These values yield a nebular diameter of $1.45^{-0.56}_{+0.37}$ arcsec according to equation

$$D = \sqrt{D_o^2 - PSF^2} \tag{1}$$

where D and D_o are nebular diameter and seeing value of RW UMi respectively while is also the average seeing of the five nearby field stars. From the same analysis of the H_α image we have measured the FWHM of RW UMi to be 4.23 arcsec, whereas the mean FWHM of the five nearby field stars gives 3.04 ± 0.41. Here, we consider the FWHM of RW UMi of a point source plus a shell. Therefore, a nebular diameter of 2.94 arcsec from its H_α image for RW UMi was found. The results are listed in Table 2. All seeing values have a maximum error of -0.49 arcsec, +0.37 arcsec. The intrinsic point source of RW UMi depends somewhat on whether a standard deviation of the mean value of the nearby stars is obtained or some errors of the FWHM Gaussian in IRAF. Obviously the major error of the shell of RW UMi comes from the mean seeing rather than the FWHMs, and in this way it was computed the errors on our derived parameters.

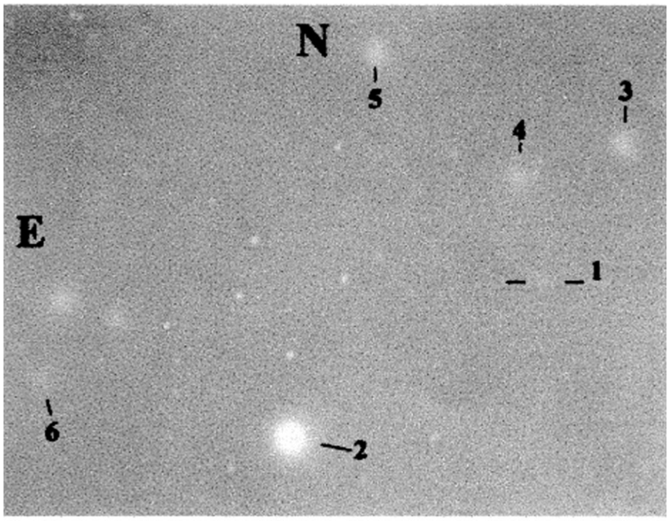

Fig. 1. A direct image of RW UMi obtained in 1995, March, 5th through the H_α filter with an exposure time of 3600 s. Numbers 1 and 2, 3, 4, 5, 6 in the figures show RW UMi and nearby stars, respectively.

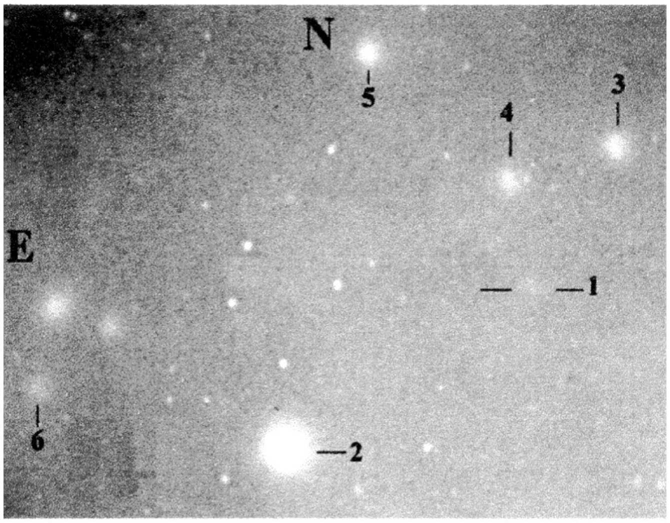

Fig. 2. A direct image through the 6670 Å filter that combines the two exposures of 1200 and 2400 s.

In addition, B and V magnitudes of RW UMi and a few comparison stars were derived by Kaluzny & Chlebowski (1989) from their photometric observations on December 1986, May 23th, 1987 and June 1987. These stars are marked as 1, 2 and 4 in Figs. 1 and 2. The nova erupted in 1956.7. Assuming that the ejected material moves with a constant velocity of 950 kms^{-1} (Cohen 1985) it should had a radius of 1.41 arcsec in 1995.2, at the time of our observations. The value measured from our direct images is $1.47^{-0.24}_{+0.18}$ arcsec, which is in broad agreement with the predicted value.

3.2. Nebular expansion velocity

Faster novae are believed to occur on massive white dwarfs leading to higher, and occasionally Super-Eddington luminosities (Shara 1981). Massive white dwarfs also produce thermonuclear runaways with very low mass envelopes, which can be ejected with high velocities to turn off the visual outburst of the nova. Thus, brighter novae should fade faster than fainter novae. The observed ejection velocity-t_3 correlation can be also explained; it is a direct consequence of the equipartition of the energy flux of the radiation field and the ejected matter (Shara 1981). An emprical correlation between expansion velocity and t_3 was shown by McLaughin (1960) as

$$log(V_{exp})[kms^{-1}] = 3.75 - 0.45 \log(t_3)[days]. \qquad (2)$$

V_{exp} of McLaughin's equation is an average value and was obtained from absorbtion spectra. On the other hand, a theoretical V_{exp}-t_3 correlation was derived by Shara (1981) as

$$log(V_{exp})[kms^{-1}] \simeq 4.28 - 0.5 \log(t_3)[days]. \qquad (3)$$

For testing the expansion velocity values reliability of novae, we adopt Shara's attitude: We expect that fast novae have bigger expansion velocities. If the envelope expands faster then the space volume of the envelope is bigger. Thus, the number of collisions between emissive particles of the envelope decrease faster and consequently, the brightness of the envelope decreases. In Table 3, low and high quality nova samples, their nebular expansion velocities and their rates of decline are collected from the literature. In Fig. 3 we plot the expansion velocity versus the rate of decline for 29 novae with the parameters taken from Table 3. Filled circles show reliable expansion velocity and rate of decline parameters while open circles represent suspicious values. We applied least squares fit for only filled circles (solid line) and derived the following equation

$$\begin{aligned} &log(V_{exp})[kms^{-1}] \\ &\quad = 3.48(\pm0.08) - 0.45(\pm0.05) \log(t_3)[days]. \qquad (4) \end{aligned}$$

The correlation coefficient is r = 0.88. Dotted lines show error estimates as calculated by Bevington (1969). The calibration of McLaughin's correlation was made using Eq. (4). By using this equation, we can estimate the expansion velocity values of novae that have reliable rate of decline values. As we see in Fig. 3, RW UMi doesn't fit correlation. Either its rates of decline or the expansion velocity cause this deviation from the other novae, therefore we suspected that one of this value might be wrong. In fact, two different values of the nova are cited in the literature for the time to decline 2 and 3 magnitudes: t_3 = 140 days (Duerbeck 1987b) and t_2 = 200? days (according to light curve of Kukarkin 1962 and Ahnert 1963 in Cohens's paper 1985). If we accept that Duerbeck's t_3 value is correct then t_2 is calculated to be 94 days. Therefore, the estimate of t_2=200 days is almost certainly incorrect. We consider now the second parameter – the expansion velocity of RW UMi which was given by Cohen as 950 kms^{-1} but he noted that this value is suspicious. He determined this expansion velocity from an H_α profile of RW UMi as was observed with the double spectrograph. Unfortunately, we found no other published information on the expansion velocities of RW UMi. Thus, according to the V_{exp}-t_3 correlation, Cohen's V_{exp} = 950 kms^{-1} value may be smaller and this value in very large limit-interval is probably

Table 3. $V_{exp} - t_3$ data for high and low quality nova samples.

Nova	V_{exp} (kms^{-1})	Ref.	t_3 (day)	Ref.
high quality				
V603 Aql	1500	1	**8**	2
	1700	2		
	<1600>			
V1229 Aql	575	3	32	2
	750	4	37	2
	<662.5>		38?	1
			<34.5>	
T Aur	400	1	**100**	2
	655	5		
	<527.5>			
V1500 Cyg	1180	3	**3.6**	2
	1500	6		
	1600	7		
	2000	8		
	<1550>			
V1668 Cyg	735	5	23	2
	< 760 >	9	24.3	12
	<747.5>		30	13
			<25.8>	
HR Del	460	6	220	14
	520	5	230	2
	550	8	**<225>**	
	<510>			
DQ Her	< 289.4 >	10	**94**	2
	315	5		
	320 ± 20	11		
	325	2		
	<312.4>			
V446 Her	**1235**	3	**16**	2
CP Lac	1300	1	**10**	2
	1600	5		
	<1450>			
DK Lac	**1075**	3	**32**	2
BT Mon	**800**	5	**42**	1
GK Per	**1200**	2	**13**	2
V400 Per	**630**	5	**43**	2
RR Pic	400	1	**150**	2
	475	5		
	<437.5>			
V373 Sct	**840**	5	**85**	2
high quality				
LW Ser	**600**	5	**50**	2
LV Vul	**860**	3	**37**	2
NQ Vul	**705**	5	**65**	2
PW Vul	**470**±60	15	97	2
			147 ± 6	23
			<122>	
low quality				
V500 Aql	**1380**	3	**42**	2
N Aql 1995	**<675>**	16	**12.8**c	16
			48c	24
V476 Cyg	725	2	16	1
	790:	5	16.5	2
	1070^{a}c		**<16.25>**	
	1510^{b}c			
	<757.5>			
V1974 Cyg	**1250**	2	25.5c	25
	1500 ± 250	2	**42**	26
	1600 ± 100	17		
	~ 2080 ± 120	18		
V533 Her	580	5	**44**	2
	1050	3		
	<815>			
CP Pup	700	1	**8**	15
	710	5		
	1600	19		
FH Ser	425 ± 25	20	**62**	2
	560	21		
	700	8		
	1100	6		
	<762.5>			
XX Tau	**650**?	3	**42**	2
RW UMi	**950**?	3	**140**	2
QU Vul	1000	22	28 ± 4	23
	1375	13	31	13
	1380	22	40	2;27
	1440 ± 100	13	**<34.8>**	
	1570	13		
	~ 1700	13		
	<1285>			

[a] Calculated from Eq. (4)
[b] Calculated from Eq. (5)

Notes:
(*i*) Main sources: Duerbeck (1987b), Cohen & Rosenthal (1983) and Cohen (1985).
(*ii*) Values marked by "c" were calculated in this work. Symbol "< >" shows mean values. Symbols ":" and "?" show uncertain values. The bold values are used in Fig. 3.

1. Duerbeck (1981), 2. Duerbeck (1987b), 3. Cohen (1985), 4. Della Valle & Duerbeck (1993), 5. Cohen & Rosenthal (1983), 6. Seaquist (1989), 7. Becker & Duerbeck (1980), 8. Hjellming et al. (1979), 9. Stickland et al. (1981), 10. Baade (1940), 11. Ferland (1980), 12. Mallama & Skillman (1979), 13. Rosino et al. (1992), 14. Drechsel et al. (1977), 15. Ringwald & Naylor (1996), 16. Iijima et al. (1995), 17. Rosino et al. (1994), 18. Rafanelli et al. (1995), 19. Bowen (1956), 20. Esenoglu (1996), 21. Duerbeck (1992), 22. Taylor et al. (1987), 23. Andreä et al. (1994), 24. Greeley et al. (1995), 25. Harward et al. (1992), 26. Chocholl et al. (1993), 27. Saizar & Ferland (1994).

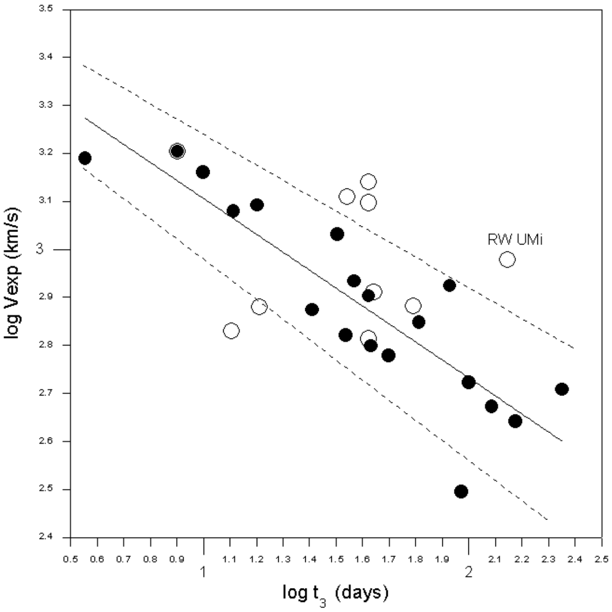

Fig. 3. V_{exp}-t_3 correlation. Filled circles represent novae with reliable V_{exp} and t_3 parameters while open circles correspond to systems with suspicious parameters. The solid line is the least squares fit for the high quality sample (filled circles). Dotted lines show error estimates as calculated from (Bevington 1969).

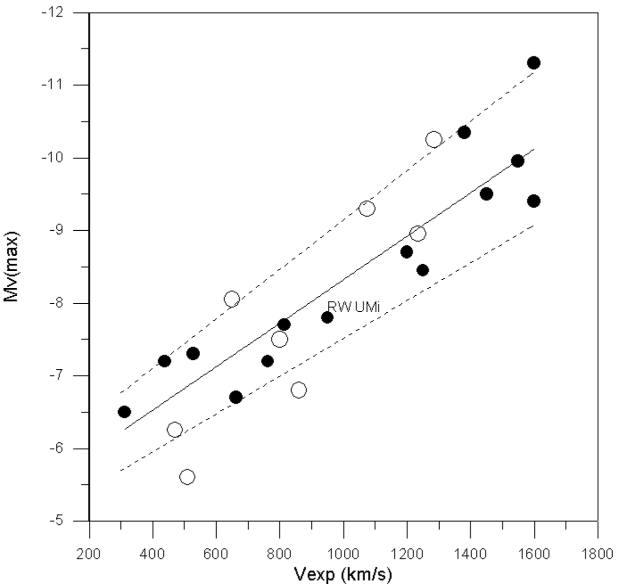

Fig. 4. $M_v(max)$-V_{exp} correlation. Filled circles represent reliable novae which were observed for more than two times. Open circles show suspicious novae which were observed during only one or two occasions. The solid line is the least squares fit for the high quality sample (filled circles). Dotted l ines show error estimates as calculated from (Bevington 1969).

most suspicious. However, these comments have to be checked using more observations. On the other hand, the shell radius indicates that the FWHM of the emission lines is a suitable measure of twice the expansion velocity of the shell (Cohen & Rosenthal 1983). Ringwald et al. (1996) found that FWHM = 2200 ± 700 kms^{-1} using by H$_\alpha$ emission line for RW UMi. This result yields an expansion velocity of 1100 kms^{-1}. The expansion velocities of RW UMi might have therefore, overestimated according to Fig. 3.

3.3. Distance and absolute magnitude at maximum

We assume a constant expansion speed of 950 kms^{-1} since the nova outburst. This expansion velocity yields nova shell radii for RW UMi for 27.3 yr and 38.5 yr after its outburst of 8.18×10^{16} and 1.15×10^{17} cm, respectively. Taking also into account the expansion velocity, we find an average expansion rate of $0.038^{-0.006}_{+0.005}$ arcsec per year and a distance of 5250^{-1050}_{+590} pc from the observed diameter. These results are very consistent with the values of 0.037 arcsec yr^{-1} and 5470 pc obtained by Cohen (1985) and with Slavin et al. (1995) distance estimation of 5000 ± 2000 pc by nebular expansion parallax from its nebular remnant.

These distances also in turn imply a distance from the galactic plane of z = 2850 pc. In general, the characteristic of a nova outburst are determined by the mass and temperature of the white dwarf and the accretion rate (see, e.g., Prialnik & Kovetz 1995). Of these, in particular, the white dwarf mass is the most relevant parameter for this work since more massive-white dwarfs produce the more violent outburst thus smaller t_3 and higher expansion velocities. In contrast, less massive white dwarfs have weaker outburst therefore longer t_3 and lower expansion velocities. Thus, RW UMi should probably contain a less massive white dwarf according to the results mentioned in Sect. 3. This suggestion is consistent with the short photometric period found by (Retter 1999) (Sect. 1.2) assuming that it is the binary period of the nova. Short orbital period CVs tend to have less massive primaries (Warner 1995). This implication for slow novae is supported by Della Valle et al. (1992), who found that slow novae containing low mass white dwarfs are located close to the galactic bulge, whereas RW UMi is located far away from the galactic plane at z = 2850 pc.

RW UMi was poorly observed around its outburst event. Since the maximum observed magnitude of RW UMi was m_v = 6.0 (Kukarkin 1962), our distance estimate suggests an absolute magnitude at maximum of $M_v = -7.7^{-0.4}_{+0.3}$ with an interstellar extinction A_v = 0.1 (Cohen 1985).

To test our result of the absolute magnitude at maximum, we used a similar way for nebular expansion velocity calculation. We expect that, fast novae have stronger outbursts and bigger expansion velocities than slow novae (previous section). Low and high quality nova samples, their absolute magnitudes at maximum and their expansion velocities were collected from the literature and given in Table 4. The relation between the absolute magnitudes at maximum and the expansion velocities is shown in Fig. 4 which is based on the data shown in Table 4. Using the linear relation (5), for the best values were selected from the literature. We were obliged to follow this way for some values because of their citing more than one time for a same parameter in the literature. In Fig. 4, filled circles represent reliable novae

Table 4. $M_v(max)$-V_{exp} data for high and low quality nova samples.

Nova	$M_v(max)$	Ref.	V_{exp} (kms^{-1})	Ref.
high quality				
V500 Aql	− − **10.35**	1;2	**1380**	1
V603 Aql	−9.3c		1500	2
	−9.3	3	1700	13
	−9.6	4	**<1600>**	
	<–9.4>			
V1229 Aql	−6.6	1	575	1
	−6.7	5	750	5
	−6.7c		**<662.5>**	
	<–6.7>			
T Aur	−6.5	4;6	400	5
	−7.2c		655	7
	−7.7	6;7	**<527.5>**	
	−7.9	6;7		
	<–7.3>			
V1500 Cyg	−9.5	1	1180	1
	−9.94c		1500	14
	−9.95	2	1600	8
	−10	8	2000	15
	−10.1	4	**<1550>**	
	−10.2	6		
	<–9.95>			
V1974 Cyg	−7.0c		**1250**	13
	−8.1c		1500 ± 250	13
	−8.47	9	1600 ± 100	16
	−8.5c		∼ 2080 ± 120	17
	−8.8	10		
	<–8.45>			
DQ Her	−5.2 to −5.8	3	< 289.4 >	3
	−6.1c		315	7
	−6.2	6;7	320 ± 20	11
	−6.4c		325	13
	−7.3	11;12	**<312.4>**	
	≅ −7.3	12		
	<–6.5>			
V533 Her	−7.14	1	580	7
	−7.45	6;7	1050	1
	−7.7	1	**<815>**	
	−7.8c			
	−8.5	7		
	<–7.7>			
CP Lac	−9.15	4	1300	4
	−9.5c		1600	7
	−9.6c		**<1450>**	
	−9.6	4		
	−9.8	6		
	<–9.5>			
GK Per	−8.55	6;7	**1200**	13
	−8.6c			
	−8.9	3		
	<–8.7>			
high quality				
RR Pic	−6.9	4	400	4
	−7.3	6;7	475	7
	−7.4c		**<437.5>**	
	<–7.2>			
CP Pup	−9.55	6;7	700	4
	−11.05	4	710	7
	−11.2	18	**1600**	24
	−11.3c			
	−11.5	4		
	<–11.3>			
FH Ser	−6.8	6;7	425 ± 25	22
	−7.0c		560	19
	−7.2	19	700	15
	−7.3	19	1100	14
	−7.55	6;7	**<762.5>**	
	−7.2	20		
	<–7.2>			
RW UMi	$-7.7^{-0.4}_{+0.3}$	21	**950**?	1
	−7.75c			
	−7.8	1		
	≤ −7.85	1		
	<–7.8>			
low quality				
HR Del	−5.05	6;7	460	14
	−6.1c		520	7
	<5.6>		550	15
			<510>	
V446 Her	−8.7	1	**1235**	1
	−9.2c			
	<–8.95>			
DK Lac	−9.2c		**1075**	1
	−9.35	1		
	<–9.3>			
BT Mon	− − **7.5**	7	**800**	7
XX Tau	−8.05	1	**650**?	1
	−9.36	22		
	<–8.05>			
LV Vul	− − **6.8**	1	**860**	1
PW Vul	−6.2	23	**470**±60	23
	−6.3 ± 0.3	23		
	<–6.25>			
QU Vul	− − **10.25**	22	1000	25
			1375	26
			1380	25
			1440 ± 100	26
			1570	26
			∼ 1700	26
			<1285>	

Notes:
(*i*) Main sources: Cohen & Rosenthal (1983), Cohen (1985), Lang (1992) and Duerbeck (1981).
(*ii*) Values marked by "c" were calculated in this work. Symbol "< >" shows mean values. Symbol "?" shows uncertain values. The bold values are used in Fig. 4.

1. Cohen (1985), 2. Della Valle (1991), 3. Baade (1940), 4. Duerbeck (1981), 5. Della Valle & Duerbeck (1993), 6. Lang (1992), 7. Cohen & Rosenthal (1983), 8. Becker & Duerbeck (1980), 9. Esenoglu (2000), 10. Paresce (1994), 11. Ferland (1980), 12. Martin (1989), 13. Duerbeck (1987b), 14. Seaquist (1989), 15. Hjellming et al. (1979), 16. Rosino et al. (1992), 17. Rafanelli et al. (1995), 18. Williams (1982), 19. Duerbeck (1992), 20. Della Valle et al. (1997), 21. This work, 22. Esenoglu (1996), 23. Ringwald & Naylor (1996), 24. Bowen (1956), 25. Taylor et al. (1987), 26. Rosino et al. (1992).

which were observed during more than two occasions and open circles correspond to less reliable objects which were observed during only one or two occasions. Error boundaries are shown by the two dashed lines. The absolute magnitude at maximum of RW UMi which is found in this work is consistent with the relation represented by Fig. 4 and Eq. (5), and with the data on other novae. We derive the following relation with a correlation coefficient of r = 0.92

$$M_v(max) = -5.332(\pm 0.415) - 0.003(\pm 0.0004) V_{exp}[kms^{-1}]. \quad (5)$$

M_v(max) of RW UMi of $M_v = -7.7^{-0.4}_{+0.3}$ found in this work is in good agrement with M_v(max)≤ -7.8 given by Cohen (1985). An absolute bolometric magnitude at maximum is derived after applying a bolometric correction of -0.1 (Livio 1994), yielding M_{bol}(max) = $-7.8^{-0.4}_{+0.3}$. It is concluded that RW UMi slightly exceeded the Eddington luminosity according to the absolute magnitude as a slow nova since the Eddington limit of M_{bol}(max) is -7 for slow novae at maximum (Starrfield 1988).

4. Summary

The main results of this work are as follows:

1. We observed the shell of RW UMi nearly 40 years after its outburst and found that the diameter of the nova shell in 1995 was $2.94^{-0.49}_{+0.37}$ arcsec.
2. A distance of 5250^{-1050}_{+590} pc and $M_v = -7.7^{-0.4}_{+0.3}$ were obtained excluding the possibility of large systematic error in the expansion velocity. They are consistent with previous estimates for the nova. Notably, this work also indicates that accurate determination of the expansion velocity of RW UMi is required.
3. A few parameters for well-observed novae were collected from the literature to refine known relations between parameters of classical novae. These data were used to derive a new calibration for both the expansion velocity – the rate of decline relation ship and the absolute magnitude at maximum – the expansion velocity relationship for galactic novae.
4. RW UMi seems to slightly exceed the Eddington luminosity.

Finally, the expansion phase in novae is still relatively poorly understood. Further studies of their expansion parallaxes with better conditions and perhaps a statistical approach will allow a better understanding of this phase. Because of the implications that the distribution has for the physics of the nova-phenomenon, it is important to improve the observational and correlational significance of the findings of the present work.

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