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Shell Observations of Classical Novae

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Abstract. We present shell observations of some classical novae from the Turkish National Observatory. We reobserved them to image their faint shells a long time after their outbursts. We revise the old findings with the new data and we call attention to narrow band pass observations.

1. Introduction

The most reliable distance determinations for Galactic novae are those obtained from the angular expansion of nova shells, of which much more novae are now known. In this study, shell results of 5 novae are given: QZ Aur, V1974 Cyg, FH Ser, XX Tau, and QU Vul, together with bands of H_α, 6185, 6610, 6670, H_α-continuum and [O III]. The reason for selecting these novae is that we want to reveal the results of two different (epochs of) H_α narrow filter-width observations on the shells, spanning an interval of about 16 years (1995 to 2011). We call attention to the importance of narrow band width on observations of nova shells.

2. Observations

Image observations with filters of H_α and H_α-off were used for identification of the Galactic novae shells in the interval of about 16 years. The image data of 1995 were taken by using the 1.82 m telescope (Asigo Observatory) together with narrow filters: 6563 filter for H_α, 6185, 6610 and 6670 filters for H_α-off. Their band pass widths are 45, 50, 57 and 49 Å respectively. It has a camera scale of 0.3375 arcsec pixel^{-1}. The image data of 2011 were taken by using the 1.5 m telescope (TUBITAK National Observatory) together with narrow filters: 6563 filter for H_α, 4353 [O III] and 6446 (H_α-continuum) filters for H_α-off, with band pass widths of 80, 123 and 94 Å respectively. It has a camera scale of 0.39 arcsec pixel^{-1}. The observing log of the five novae is given in Table 1.

Five samples of QZ Aur among all images of five novae are shown in Figure 1 that includes the images together with two colors and dates of gray for 1995 and orange for 2011.

Table 1. The log of nova image observations. Year in 4th column is the time from nova explosion to observation date. Atmospheric seeing values for quality of the observations are given in the last column.

Nova	Date (dd.mm.yyyy)	Exposure (second)	Year	Filter	Band pass (Å)	Seeing (arcsec)
QU Vul	08.07.1994	2400	9.6	H_α	45	2.4
		600		6610	57	3.0
	11.07.1994	2819	9.6	H_α	45	2.2
		600		6610	57	3.5
	03.11.2010	900	25.9	H_α	80	1.7
		600		$H_\alpha - co$	94	1.8
		600		OIII	123	2.0
FH Ser	10.07.1994	2400	24.4	H_α	45	2.3
		600		6610	57	3.3
	03.11.2010	900	40.7	H_α	80	2.1
		900		$H_\alpha - co$	94	2.0
		900		OIII	123	2.2
XX Tau	30.01.1995	1800	68	H_α	45	2.3
		633		6185	50	2.7
	02.11.2010	900	83.7	H_α	80	1.4
		900		$H_\alpha - co$	94	1.2
		900		OIII	123	1.2
QZ Aur	01.02.1995	3600	31.1	H_α	45	2.6
		3600		6185	50	2.5
	02.11.2010	600	46.8	H_α	80	1.1
		600		$H_\alpha - co$	94	1.1
		600		OIII	123	1.1
V1974 Cyg	05.03.1995	1368	3.1	H_α	45	2.6
	03.11.2010	1200	18.8	H_α	80	1.7
		900		$H_\alpha - co$	94	1.6
		900		OIII	123	2.0

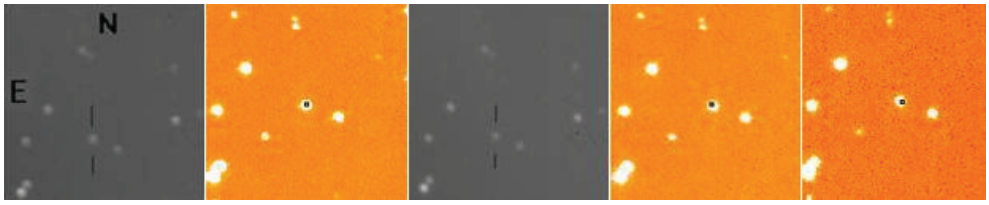

Figure 1. Images of QZ Aur. In 1995 (gray color), the nova shell diameters were measured to be 0.86 arcsec with H_α (1st image) and 0.55 arcsec with 6185 (3th image). In 2011 (orange color), the nova shell diameters were measured to be 0.40 arcsec with H_α (2nd image), 0.17 arcsec with H_α-continuum (4th image), and 0.81 arcsec with [O III] (5th image). The nova and directions were displayed on the images.

3. Shell Size Determination

Seeing values of the five novae from their images with interval of about 16 years were calculated by using IRAF. Nightly seeing values of the atmosphere both Ekar and TUBITAK National Observatories in Table 1 were 1.8-3.5 arcsec and 1.1-2.1 arcsec, respectively. Measured seeing values of QZ Aur and 12 surrounding stars from the images with H_α and 6185 filters in 1995, are given as an example in Table 2. Similar measurements were performed for other novae.

Table 2. The seeing values of QZ Aur and 12 nearby surrounding stars in H_α and H_α-off.

No	Seeing (arcsec)	
	H_α-on (arcsec)	H_α-off (arcsec)
1 (D_o)	2.71	2.54
2	2.56	2.48
3	2.53	2.46
4	2.60	2.50
5	2.50	2.40
6	2.51	2.45
7	2.60	2.49
8	2.65	2.52
9	2.57	2.52
10	2.55	2.47
11	2.57	2.50
12	2.65	2.49
13	2.61	2.51
Mean (PSF)	2.57 ± 0.05	2.48 ± 0.03
Diameter (D)	$0.86^{-0.17}_{+0.14}$	$0.55^{-0.16}_{+0.12}$

In Table 2, the seeing value of D_o star with number (1) belongs to QZ Aur. This is the seeing value that belongs to both the nova and its shell, if there is a shell. The stellar seeing value is taken by the mean seeing value or PSF from the 12 surrounding stars. Because the nova and the surrounding stars were taken the same exposure time and the same conditions, the average of the stellar PSFs would give a measure of a point source. Accordingly to this, shell diameter of the nova, D_o, is equal to the square root of the differences of squares of D_o and PSF; i.e. the nebular diameter,

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

is calculated by the formula. In Table 2, the seeing value of diameter+shell of QZ Aur is 2.71 arcsec and the mean PSF is 2.57 arcsec in H_α; it was measured diameter+shell for 2.54 arcsec and the seeing value of the PSF as 2.48 arcsec in H_α-off. Diameter+shell values of the nova for each the two filters are larger than average seeing values of the stellar profiles. Thus, it is understood there exists a shell of QZ Aur. These shell diameters from the formula were calculated as 0.86 arcsec for H_α and 0.55 arcsec for H_α-off. In the same way, seeing and nebular diameter values of the other novae were given in Table 4. Standard errors in diameters are range of about 11-83 %.

4. Results and Discussion

The shell radii of five Galactic novae obtained from direct image observations over a time interval about 16 years are given in Table 3. This time is extended up to 30 years when using the results of the literature. A comparison of our findings and related parameters in the literature are provided and also drawn in Figure 2.

Table 3. A comparison of the shell radius values of five novae with references. Nightly mean atmospheric seeing values during the observations were given in parentheses in the third column. Mean expansion velocities and absorption values from Esenoglu (1996) were given.

		Shell Radius (arcsec)		V_{exp}	Absorption
Nova	Reference	1995	2011	km s^{-1}	mag
QU Vul	0.53[1] (1998.3)	0.41(2.8)	1.41(1.8)	1285	1.7
FH Ser	2.0[2] (1981.5)	0.98(2.8)	0.41(2.1)	762	2.1
XX Tau	-	0.43(2.6)	0.20(1.1)	890	1.3
QZ Aur	0.13[3] (1993.4)	0.38(2.6)	0.41(1.8)	1250	0.6
V1974 Cyg	2.2[4] (1984)	1.45(2.5)	0.44(1.3)	650	1.3

(1) Krautter et al. 2002, (2) Lang 1992, (3) Paresce 1994, (4) Cohen 1985

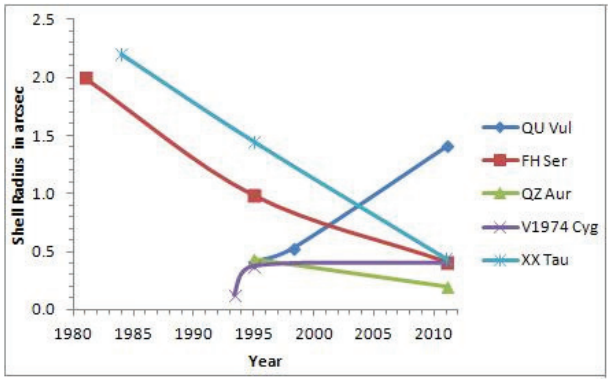

Figure 2. Evolution of the five nova radii in the years. It was indicated by different colors and symbols for each nova.

Table 4. The calculated seeing and shell diameter values of the five novae. The novae together with the numbers of stars in the same CCD image were indicated in parentheses.

	Seeing (arcsec)										Nebular Diameter (arcsec)				
	H_α							H_α-off			Nova				
Nova	Nova Do		Field Stars		Nova Do			Field Stars			H_α		H_α-off		
	1995	2011	1995	2011	1995	2011		1995	2011		1995	2011	1995	2011	
						H_α-c	O III		H_α-c	O III				H_α-c	O III
QZ Aur	2.71	1.21	2.57(12)	1.15(28)	2.54	1.15	1.55	2.48(12)	1.13(28)	1.32(28)	0.86	0.40	0.55	0.17	0.81
V1974 Cyg	2.69	1.85	2.58(7)	1.66(29)		1.85	2.15		1.65 (29)	1.98 (29)	0.76	0.82		0.83	0.83
FH Ser	3	2.27	2.26(7)	2.12(27)	3.31	2.22	2.32	3.28(7)	2.04(27)	2.22(27)	1.97	0.82	0.44	0.89	0.67
XX Tau	3.73	1.44	2.34(11)	1.37(25)	-	1.08	1.24	2.70(11)	1.23(25)	1.24(24)	2.90	0.44	-	-	-
QU Vul	2.57	3.30	2.44(10)	1.69(34)	3.25	3.58	2.03	3.05(10)	1.82(34)	2.03(34)	0.82	2.83	1.12	3.08	-
	2.39		2.24(10)								0.81				

As shown in Table 3, the nebular expansion parallax of QZ Aur has not been studied enough in the literature except for our paper of Esenoglu (2002). In addition, it appears to be a small shell of the considered new nova V1974 Cyg and to comply with the literature. In this study we took positive result for only QU Vul. The shell of QU Vul has expanded in the time with its high expansion velocity. However, the shells of the other three novae seem almost to collapse. A short discussion on this issue is given below.

In Figure 2, shell radii of the FH Ser, XX Tau and also a little bit QZ Aur seem to be reduced in the time that is for long about 30 years in spite of the best observation conditions. The expansion velocities of these three novae are about 1.6 times slower than those of QU Vul and V1974 Cyg. Is the emergence of small shells associated with being small expansion velocities or an observation error? On the other hand, the filter widths used in the observations of 2011 are about two times larger than those used in 1995. I wonder if a small occurrence of the shell radii has, is it an effect of the filter widths? Or does the density or brightness of some nova shells decrease in time? We put the interstellar medium values between the novae and us in the Table 3, too. These mean absorption values of the three novae with the small radii and the other two novae are 1.6 and 1.2 mag, respectively.

Our nova shell conclusion is summarized as follows.

1) We found the recent shell diameters of QU Vul and V1974 Cyg of 2.83 and 0.82 arcsec in 2011, respectively. The shells of QU Vul, FH Ser and XX Tau were found to be smaller and these results are not reliable.

2) Our nova shell observations have been sensitive to the width of filter that we used 7 different widths with the range of about 80 Å. We recommend that our interpretation could be verified by using some narrower filters.

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