THE INTERACTION OF NOVA SHELLS WITH THE INTERSTELLAR MEDIUM*

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Abstract. Decelerations of the shells around the novae V603 Aql, V476 Cyg, DQ Her and GK Per were determined from photographs and recent CCD observations. The deceleration is larger for higher expansion velocities, the mean half-lifetime, after which the expansion velocity has dropped to half its initial value, is 75 years.

1. Introduction

The interaction of expanding nova shells with the interstellar medium was discussed theoretically by Oort (1946, 1951) and by Kluyver (1951). The "snowplough" model of Oort, based only on the conservation of momentum and energy and simple assumptions concerning momentum exchange between the shell and the ISM, yields half-lifetimes (times after which the expansion velocity has dropped to half its initial value) of 48 and 102 years, respectively, for shells with masses of 10^{-5} and 10^{-4} $M_\odot$ and expansion velocities of 1000 km s^{-1}.

Until now, only the shell of GK Per was considered a good candidate for measuring deceleration, although no quantitative data were published. In the case of V603 Aql, recent papers stated that the shell has disappeared. Here, we report the determination of deceleration of four nova shells, based on measurements of old photographs and recent CCD frames, obtained through a wide Hα filter at the 2.2m telescope of Calar Alto.

*Based on observations obtained at the European Southern Observatory, La Silla, Chile, and at the Centro Astronomico Hispano-Aleman Calar Alto, operated by the Max-Planck-Institut für Astronomie, Heidelberg

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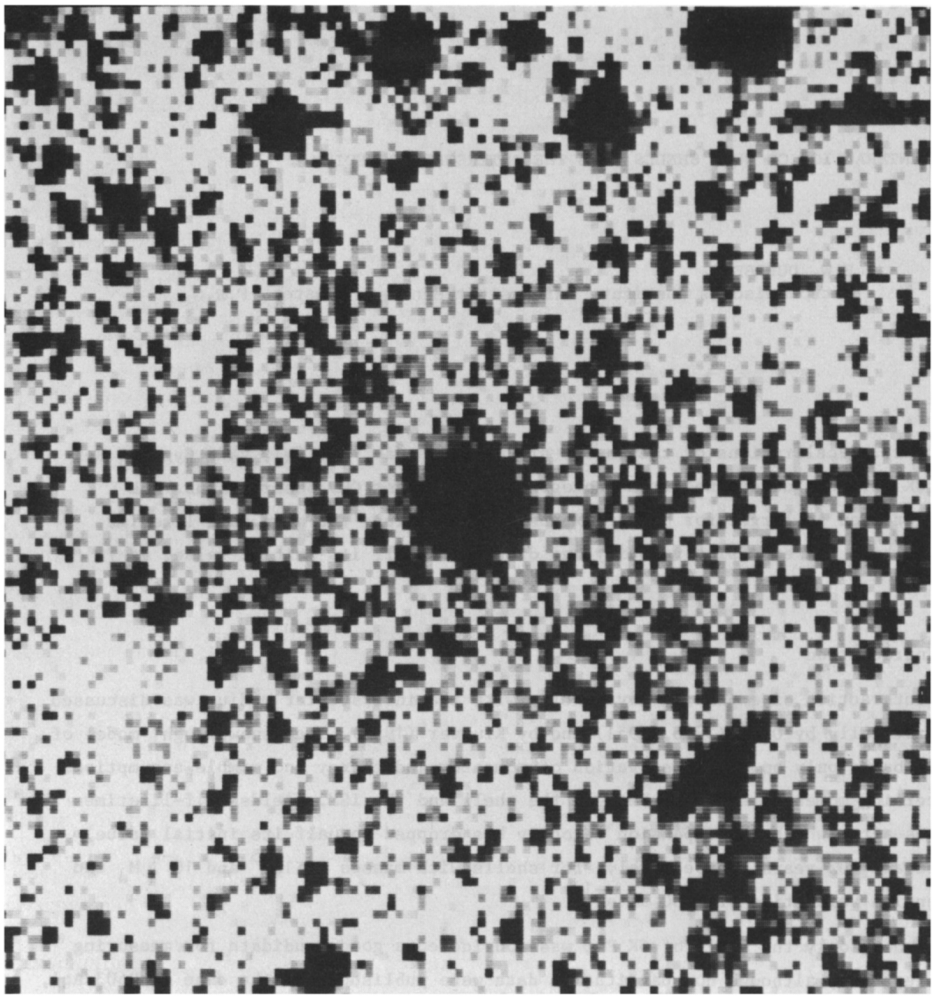

Fig. 1. The shell around V603 Aql, exposed on a IIIa-F plate for 100 minutes through a RG 630 filter at the prime focus of the ESO 3.6 m telescope. The shell becomes visible after application of several image processing procedures.

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2. Observations and Results

2.1. V603 Aql

The size of the nebular disc was measured by Barnard (1918, 1920), Aitken (1919, 1920, 1921), Hubble and Duncan (1927), and Baade (Adams 1941). The shell is also visible on the Palomar Observatory Sky Survey plate E-193, taken 1950 July 18/19, and, after some image processing, on a direct IIIa-F plate taken at the prime focus of the ESO 3.6m telescope in 1982 June (Fig. 1). It is also visible on a CCD frame taken in 1984 August. Mean values of the early observations and results of more recent observations are given in Table 1.

2.2. GK Per

Due to the somewhat irregular appearance of the shell of GK Per - for the detection of an underlying symmetry, see Seitter and Duerbeck (1986) - only the distance between the stellar remnant and the south-western "bar" was measured on photographs and on a CCD frame. Results are given in Table 1.

2.3. V476 Cyg

A photograph taken by Baade (Adams 1944) and published by Boyarchuk (1970), and a CCD frame (Fig. 2) are available. Results are given in Table 1.

2.4. DQ Her

The shell is elliptical; only the major axis was considered. Results from published measurements (Baade 1940, 1942), photographs (Mustel and Boyarchuk 1970) and a CCD frame are given in Table 1.

3. Discussion

The temporal variation of the radius of a shell can be approximated by

$$r(t) = c_0 + c_1\, t + \frac{1}{2}\, c_2\, t^2$$

where c_0, the size of the shell at the time of outburst, is assumed to be zero. c_1 is the initial radial expansion rate, measured in " yr^{-1}. In combination with the spectroscopically determined expansion velocity of the shell, v_{exp} in km s^{-1}, it is used for the nebular expansion distance d in pc

$$d = \frac{0.211\, v_{exp}}{c_1} \quad .$$

c_2 is the deceleration parameter (in " yr^{-2}), which can be converted into the more conceptual braking b (in km s^{-1} yr^{-1}):

$$b = \frac{c_2}{c_1}\, v_{exp} \quad .$$

The half-lifetime is determined by

$$t_{1/2} = \frac{v_{exp}}{2\, b} = \frac{1}{2}\, \frac{c_1}{c_2} \quad .$$

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Table 1. Sizes of nova shells at different epochs

nova	date	$t - t_o$ (yr)	diameter (")	reference
V603 Aql	1918.43	0	0	(outburst)
	1918 Oct-Dec	0.42	1.09	Barnard (1918)
	1919 Jun-Sep	1.18	2.86	Aitken (1919), Barnard (1920)
	1920 Jun-Jul	2.04	3.51	Aitken (1920), Barnard (1920)
	1921 Jun-Jul	3.04	5.03	Aitken (1921)
	1922.55	4.12	8.2	Hubble and Duncan (1927)
	1926 May-Sep	8.10	16.0	"
	1927.32	8.89	17.6	"
	1940.5	22.07	45	Adams (1941)
	1950.55	32.11	62*	POSS red plate
	1982.47	64.04	104*	ESO 3.6m red plate
	1984.57	66.14	108*	CA 2.2m CCD
GK Per**	1901.14	0	0	(outburst)
	1917.86	16.72	11.8	Lick plate***
	1934.75	33.61	19.5	Oort (1946)
	1943.73	42.59	22.5	Oort (1946)
	1949.70	48.56	23.4	Lick plate***
	1959.96	58.82	27.8	Sky & Telescope 20,7(1960)
	1977.7	76.72	32.8	Lick plate***
	1984.60	83.46	36.0	CA 2.2m CCD
V476 Cyg	1920.64	0	0	(outburst)
	1944.0	23.36	2.25	Adams (1944), Boyarchuk (1970)
	1984.64	64.00	5.6	CA 2.2m CCD
DQ Her	1934.94	0	0	(outburst)
	1940.62	5.68	3.5 x 2.7	Baade (1940)
	1942.6	7.66	4.0 x 3.0	Baade (1942)
	1951.67	16.73	7.6 x 6.25	Mustel and Boyarchuk (1970)
	1956.66	21.72	10.3 x 8.4	"
	1967.43	32.49	15.5 x 12.25	"
	1977.37	42.43	18.35x14.0	Williams et al. (1978)
	1984.60	49.66	21.2 x 15.1	CA 2.2m CCD

Notes: * major axis

** for GK Per, the distance between central star and SW bar is given

*** photographic prints kindly communicated by M.F. Bode, Lancashire Polytechnic

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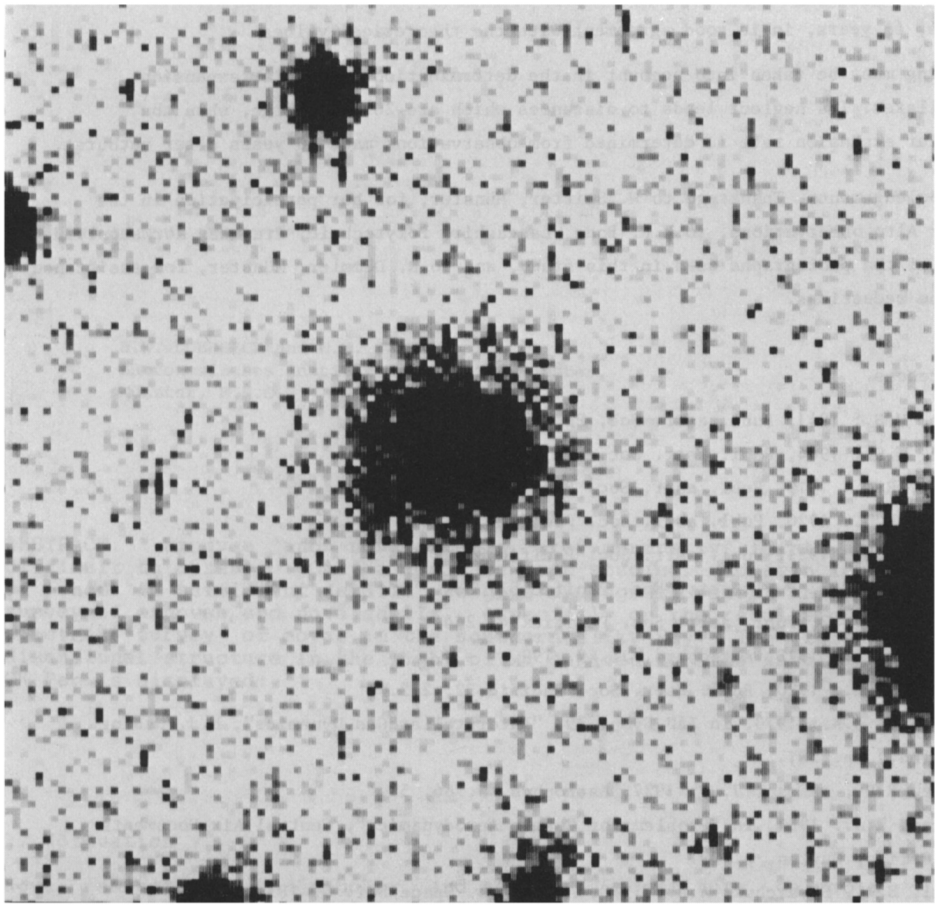

Fig. 2. A CCD frame of the shell around V476 Cyg, taken through a wide band Hα filter at the Cassegrain focus of the CA 2.2 m telescope, exposure time 30 minutes. In both figures, north is up and west to the right. The plate scale can be determined from the data of Table 1.

Table 2. Expansion and deceleration of nova shells

nova	v_{exp}(km s^{-1})	c_1(" yr^{-1})	b(km s^{-1} yr^{-1})	$t_{1/2}$(yr)	d(pc)
V603 Aql	1700	1.09	13.2	65	330
GK Per	1200	0.65	10.3	58	390
V476 Cyg	725	0.10	3.1	117	1500
DQ Her	325	0.26	2.4	67	265

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In all cases, the c_2 term proved to be significant. All observed and derived quantities are listed in Table 2. It is seen that the deceleration is larger for shells with higher expansion velocities. The mean value of the determined half-life-times, 65 years, is in good agreement with the theoretical values.

Braking must be taken into account in the determination of nebular expansion parallaxes. Its neglect leads to distances which are 20% too large, when the nebular expansion rate is determined from observations made 50 years after outburst.

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