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A *WISE* view of novae – I. The data

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ABSTRACT

We present the results of data-mining the *Wide-field Infrared Survey Explorer* (*WISE*) archive for data on classical and recurrent novae. We find that the detections are consistent with dust emission, line emission, emission by a stellar photosphere, or a combination of these. Of the 36 novae detected in one or more *WISE* bands, 16 are detected in all four; 31 known novae are not detected by *WISE*. We also searched for *WISE* data on post-*WISE* novae, to gain information about nova progenitors. In this first paper, we consider only the *WISE* data. In future papers, we will provide a more detailed modelling of the *WISE* data, and discuss *WISE* data on post-*WISE* novae – including their variability – and will complement the *WISE* data with data from other IR surveys.

Key words: surveys – binaries: symbiotic – circumstellar matter – novae, cataclysmic variables – infrared: stars.

1 INTRODUCTION

Infrared (IR) observations of novae (both classical and recurrent) have been carried out for over 40 yr, starting with the IR photometry of FH Ser by Geisel, Kleinmann & Low (1970, see Gehrz 2008; Evans & Gehrz 2012 for recent reviews). Most IR observations are of individual objects, triggered once a nova is reported. However, all-sky IR surveys provide a different perspective on the nova phenomenon. These include the *IRAS* (Neugebauer et al. 1984) survey (see Harrison & Gehrz 1988, 1990, 1992, 1994, for a discussion of novae and related objects as seen by *IRAS*), *AKARI* (Murakami et al. 2007), and 2MASS (see Hoard et al. 2002, for a discussion of cataclysmic variables, including novae) surveys and, most recently, the *Wide-Field Infrared Survey Explorer* (*WISE*; Wright et al. 2010).

Hoard et al. (2014) have reported the results of searching the *WISE* data base for nova-like variables. A preliminary report of this work is given by Evans et al. (2014).

2 THE *WISE* SURVEY

WISE is an all-sky mid-IR mission (Wright et al. 2010), operating in wavebands centred at 3.4, 4.6, 12, and 22 μm. It commenced its survey on 2010 January 14, and completed its all-sky survey on 2010 July 17; the four-band survey terminated on 2011 February 1 with the exhaustion of hydrogen cryogen and after which *WISE* entered a three-band post-cryo survey phase. Relevant calibration and other information for the *WISE* mission, taken from Wright et al. (2010), are given in Table 1. The *WISE* bandpasses are shown in Fig. 1.

In this paper, we present the data on classical and recurrent novae (RNe) from the *WISE* survey; in future papers, we will discuss our modelling of the data, and *WISE* data on post-*WISE* novae. While the thrust of this work is the exploitation of the *WISE* survey, in later papers we will supplement the *WISE* data with data from other IR surveys as appropriate.

The prime purpose of this paper is to present the *WISE* data, with a brief discussion on a source-by-source basis. For this paper, we discuss the data with no allowance for colour correction (Wright et al. 2010) – although these are generally negligible for 'photospheric' temperatures – or for reddening; we leave this to a more detailed discussion in later papers. Here, we confine our discussion to those novae with detections in at least three *WISE* bands, although in some cases detections in two *WISE* bands are sufficient to draw tentative conclusions.

3 *WISE* OBSERVATIONS OF NOVAE

In the course of its all-sky survey, *WISE* detected a number of classical and RNe. We data-mined the *WISE* catalogue to identify coincident targets using source lists from Bode, Dürbeck & Evans (1989) for pre-1989 novae, and Downes & Shara (1993), Downes, Webbink & Shara (1997), Downes et al. (2001), and Walter et al. (2012) for later novae. We have confined our search to Galactic novae. J2000 positions were taken from SIMBAD,[1] Walter et al. (2012), or Bode et al. (1989).

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[1] http://simbad.u-strasbg.fr/simbad/

Table 1. Characteristics of the *WISE* data (Wright et al. 2010).

WISE band	Effective wavelength (μm)	Zero magnitude flux (Jy)	Positional accuracy (arcsec)
1	3.3	306.681	6.1
2	4.6	170.663	6.4
3	12	29.0448	6.5
4	22	8.2839	12.0

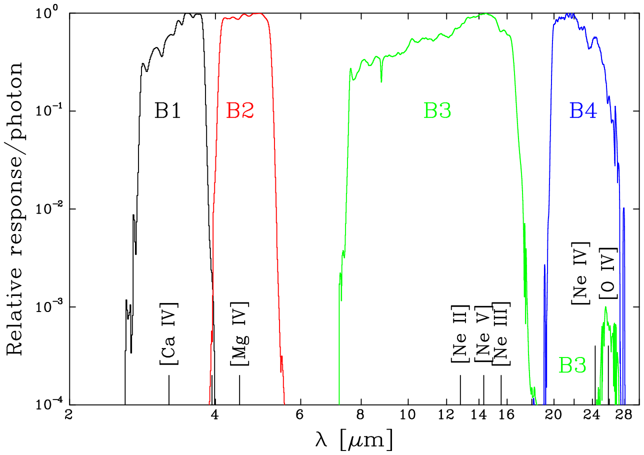

Figure 1. Wavelength responses of *WISE* filters (Wright et al. 2010), together with the locations of a sample of emission lines known to be strong in mature novae.

The criterion for determining that *WISE* had indeed detected a nova was that the *WISE* source position was within the *WISE* positional error of the nova position; a visual check of the *WISE* 3.3 μm field was also performed. Detections are given in Table 2, which includes outburst year. Also given are t_2 and t_3, the times for the light curve (LC) to decline by 2 and 3 mag, respectively, and the LC class; the latter information is of the form $X(t_3)$, where $X =$ S (smooth), P (plateau), D (dust dip), C (cusp), O (oscillations), F (flat-topped), J (jitter). The LC information is taken from Strope, Scheafer & Henden (2010) unless otherwise noted in Table 2.

Table 2 also includes the positions of the nova and associated *WISE* source, the *WISE* fluxes (in mJy and Jy), the difference $\Delta\theta$ (in arcsec) between the *WISE* position and that of the nova, and a crude classification of the *WISE* spectral energy distribution (SED). For the latter, a '$\mathcal{D}$' indicates an SED characteristic of dust emission, an '$\mathcal{S}$' indicates emission from a photosphere, an '$\mathcal{L}$' indicates likely line emission, and an $\mathcal{I}$ signifies inconclusive; in some cases, a hybrid classification (e.g. $\mathcal{SD}$) is possible. In many cases, the possibility of 'photospheric' emission is deduced on the basis of only two *WISE* bands (usually 1 and 2) and the emission may be from the secondary or an accretion disc; we do not discriminate between these two possibilities at this stage. Where we have fitted blackbodies to the *WISE* data, the uncertainty in the temperature is typically ±20 K.

Novae not detected by *WISE* are listed in Table 3. These include objects with *WISE* sources close to the nova position but not within the *WISE* positional uncertainties.

Classical novae (CNe) are well known to go through a nebular (and in some cases, coronal) phase, when emission lines dominate the spectrum. The location of some of these lines in relation to the *WISE* bandpasses are shown in Fig. 1 (see Evans & Gehrz 2012, for a more complete list). The bandpasses encompass a number of IR forbidden lines that are known to be strong in mature (i.e. several hundred days post-maximum) novae. Many of these lines are neon lines that affect mainly *WISE* bands 3 and 4, but there are also coronal lines that affect *WISE* bands 1 and 2. The 'red leak' in band 3 means that (for example) the [O IV] 25.9 μm line, a strong coolant line of the plasma (Woodward & Starrfield 2011), may, when present, contribute to the band 3 flux.

4 RECURRENT AND SUSPECTED RNe OBSERVED BY *WISE*

RNe are a heterogeneous group of objects, in that the donor star may be a main-sequence dwarf or a red giant, that may or may not possess a wind. Relatively few are known (see Anupama 2008) compared with the number of known CNe, but apart from the nature of the donor star the distinction between CNe and RNe is largely the selection effect that an RN has been seen to erupt more than once. The time-scale between RN eruptions is $\lesssim$a human lifetime, while that between CN eruptions is $\gtrsim 10^4$ yr (see Gehrz et al. 1998). Since the sustained study of novae eruptions has a history of ∼100 yr, it seems likely that intereruption time-scales of $\lesssim$100 and ≫100 yr are those that will be most evident at this stage of nova study: it may be that there is a continuum of intereruption time-scales that has yet to become apparent (cf. Darnley et al. 2012). It is therefore clear that, while all novae are recurrent, there are RNe masquerading as CNe (Harrison 1992; Weight et al. 1994; Darnley et al. 2012; Pagnotta & Schaefer 2014).

Also there is evidence that RN eruptions occur on the surfaces of massive white dwarfs (WDs) – close to the Chandrasekhar limit – and there is great interest in determining whether the WD in some RN system is gaining mass, possibly leading to deflagration as a Type Ia supernova (cf. Whelan & Iben 1973).

Reviews of RNe, with emphasis on the RN RS Oph, are given in Bode (1987) and Evans et al. (2008), and a summary of RN properties (as of 2007) is given in Anupama (2008). Strope et al. (2010) provide a discussion of RN LCs.

4.1 T CrB

T CrB is an RN that has undergone two known eruptions, in 1866 and 1946 (Anupama 2008); its next eruption is overdue. The donor star has spectral classification M3III (Anupama 2008).

The *WISE* SED for T CrB is shown in Fig. 2. The *WISE* data are consistent with photospheric blackbody at 4300 K (cf. ∼3500 K for an M3III star; Cox 2000). Within the *WISE* photometric uncertainties – and in contrast to RS Oph (see below and Evans et al. 2007) – there is no evidence for dust in the T CrB system.

4.2 KT Eri

KT Eri erupted in 2009 and is a suspected RN (Darnley et al. 2012; Pagnotta & Schaefer 2014). It is exceptional for having a reasonably well-covered and extensive pre-eruption LC (Hounsell et al. 2010; McQuillin et al. 2012). The rapid LC decline and the small amplitude suggest that it might be an RN (Hounsell et al. 2010). Darnley et al. (2012) suspected that the donor star is evolved; they give the near-IR colours as $R - I \simeq 0.6$, $J - H = 0.42$, $H - K_s = 0.05$; Darnley et al. suggest a classification of ∼G2III and effective temperature ∼5500 K; the reddening ($E(B - V) = 0.08$) is too low to impact significantly on the IR colours.

The *WISE* SED is shown in Fig. 2. All we can say is that the band 1–3 data are just consistent with the Rayleigh–Jeans

Table 2. *WISE* fluxes.

Nova	Outburst year	t_2, t_3 (d)	LC class	RA, Dec. (J2000) Upper value: *WISE* Lower value: GCVS	Date of first *WISE* observation YYYY-MM-DD	$B1$ (3.3 µm) (mJy) (Jy)	$B2$ (4.6 µm) (mJy) (Jy)	$B3$ (12 µm) (mJy) (Jy)	$B4$ (22 µm) (mJy) (Jy)	$\Delta\theta$ (arcsec)	Classification/ comment
V603 Aql	1918	5, 12	O(12)	18 48 54.64 +00 35 03.43 18 48 54.636 +00 35 03.37	2010-04-01	14.63 ± 0.40	8.22 ± 0.25	<3.17	<6.43	0.51	$\mathcal{I}$ –
V1229 Aql	1970	18, 32	P(32)	19 24 44.56 +04 14 48.06 19 24 44.52 +04 14 48.7	2010-04-13	0.22 ± 0.01	0.12 ± 0.02	<0.36	<2.48	0.70	$\mathcal{I}$ –
V1370 Aql	1982	15, 28	D(28)	19 23 21.32 +02 29 25.43 19 23 21.10 +02 29 26.1	2010-04-12	0.33 ± 0.02	0.11 ± 0.02	<0.27	<2.30	2.69	$\mathcal{I}$ –
V1494 Aql	1999	8, 16	O(16)	19 23 05.29 +04 57 18.83 19 23 05.30 +04 57 19.1	2010-04-11	0.81 ± 0.03	0.45 ± 0.02	<0.31	9.51 ± 1.41	0.27	$\mathcal{L}$ –
T Aur	1891	80, 84	D(84)	05 31 59.13 +30 26 44.87 05 31 59.12 +30 26 45.0	2010-03-08	1.16 ± 0.03	0.72 ± 0.02	0.40 ± 0.15	<3.36	0.17	$\mathcal{I}$ –
QZ Aur	1964	–, 23–30	–	05 28 34.08 +33 18 21.65 05 28 34.08 +33 18 21.8	2010-03-08	0.33 ± 0.01	0.17 ± 0.02	<0.28	<2.24	0.15	$\mathcal{I}$ t_3 from [1]
T Boo	1860	–, –	–	14 14 1.97 +19 04 3.79 14 14 06 .0 +19 03 54	2010-01-14	0.50 ± 0.01	0.30 ± 0.01	<0.23	2.05 ± 0.81	1.74	$\mathcal{I}$ –
V705 Cas	1993	33, 67	D(67)	23 41 47.18 +57 30 59.65 23 41 47.19 +57 30 59.5	2010-01-12	0.80 ± 0.02	0.49 ± 0.02	1.15 ± 0.17	13.08 ± 1.06	0.18	$\mathcal{L}$ –
V723 Cas	1995	263, 299	J(299)	01 05 05.34 +54 00 40.35 01 05 05.36 +54 00 40.3	2010-01-22	1.34 ± 0.03	0.81 ± 0.02	0.55 ± 0.090	<1.37	0.19	$\mathcal{SL}$ –
V1065 Cen	2007	11, 26	–	11 43 10.30 –58 04 04.85 11 43 10.33 –58 04 04.3	2010-01-18	0.58 ± 0.05	0.44 ± 0.03	12.75 ± 0.28	29.53 ± 1.36	0.56	$\mathcal{DL}$ t_2, t_3 from [3]
T CrB	R1946	4, 6	S(6)	15 59 30.14 +25 55 12.68 15 59 30.16 +25 55 12.59	2010-02-05	4.70±0.78	2.70±0.19	0.50± 0.01	0.17± 0.01	0.20	$\mathcal{S}$; [2] –
AR Cir	1906	–, –	–	14 48 09.51 –60 00 27.48 14 48 09.53 –60 00 27.5	2010-02-17	15.17 ± 0.38	7.92 ± 0.18	<2.68	8.13 ± 1.92	0.27	$\mathcal{SI}$ Symbiotic?
DZ Cru	2003	–, –	–	12 23 16.08 –60 22 34.34 12 23 16.2 –60 22 34	2010-01-26	53.3 ± 0.01	156 ± 1	1075 ± 12.9	963 ± 11.5	1.38	$\mathcal{D}$ –
V476 Cyg	1920	–, 16.5	–	19 58 24.46 +53 37 07.56 19 58 24.46 +53 37 07.5	2010-05-20	0.26 ± 0.01	0.15 ± 0.01	<0.14	<1.23	0.06	$\mathcal{I}$ t_3 from [1]
V1974 Cyg	1992	19, 43	P(43)	20 30 31.60 +52 37 51.85 20 30 31.61 +52 37 51.3	2010-05-29	0.25 ± 0.01	0.15 ± 0.01	0.40 ± 0.07	2.59 ± 0.65	0.57	$\mathcal{L}$ –
V2361 Cyg	2005	–, –		20 09 18.78 +39 48 51.74 20 09 19.05 +39 48 52.9	2010-05-31	0.54 ± 0.02	0.11 ± 0.01	<0.63	6.37 ± 1.14	2.42	$\mathcal{I}$ –
V2362 Cyg	2006	9, 246	C(246)	21 11 31.88 +44 48 03.16 21 11 32.346 +44 48 03.66	2010-05-31	1.51 ± 0.05	0.78 ± 0.02	1.18 ± 0.11	13.60 ± 0.90	4.76	$\mathcal{I}$ –
V2467 Cyg	2007	8, 20	O(20)	20 28 12.48 +41 48 36.52 20 28 12.52 +41 48 36.5	2010-05-17	2.28 ± 0.11	3.58 ± 0.15	22.22 ± 1.37	226.1 ± 9.4	0.38	$\mathcal{LD}$? –

Table 2 – *continued.*

Nova	Outburst year	t_2, t_3 (d)	LC class	RA, Dec. (J2000) Upper value: *WISE* Lower value: GCVS		Date of first *WISE* observation YYYY-MM-DD	*B*1 (3.3 µm) (mJy) (Jy)	*B*2 (4.6 µm) (mJy) (Jy)	*B*3 (12 µm) (mJy) (Jy)	*B*4 (22 µm) (Jy)	$\Delta\theta$ (arcsec)	Classification/ comment
				06 44 12.05	+29 56 41.9							t_3 from [7]
DN Gem	1912	16, 35	P(35)	06 54 54.35	+32 08 27.52	2010-03-22	0.22 ± 0.03	0.13 ± 0.02	<0.93	<2.03	0.48	$\mathcal{I}$
				06 54 54.35	+32 08 28.00							t_3 from [1]
DQ Her	1934	76, 100	D(100)	18 07 30.26	+45 51 32.55	2010-03-22	1.94 ± 0.03	1.24 ± 0.03	0.34 ± 0.10	<2.69	0.07	$\mathcal{S}$
				18 07 30.25	+45 51 32.6							–
V533 Her	1963	30, 43	S(43)	18 14 20.49	+41 51 22.39	2010-03-23	0.55 ± 0.01	0.34 ± 0.01	<0.27	<1.47	0.30	$\mathcal{I}$
				18 14 20.48	+41 51 22.1							–
RS Oph	R2006	7, 14	P(14)	17 50 13.16	–06 42 28.52	2010-03-17	1.04±0.12	0.72±0.03	252 ± 3	153 ± 4	0.5	$\mathcal{SD}$; [3]
				17 50 13.20	–06 42 28.48							–
GK Per	1901	6, 13	O(13)	03 31 12.00	+43 54 15.24	2010-02-12	36.40 ± 0.77	22.46 ± 0.46	4.72 ± 0.17	2.51 ± 0.86	3.12	$\mathcal{S}$
				03 31 11.82	+43 54 16.8							–
RR Pic	1925	73, 122	J(122)	06 35 36.08	–62 38 24.31	2010-04-10	4.47 ± 0.10	3.09 ± 0.06	0.94 ± 0.061	<1.33	0.16	$\mathcal{SI}$
				06 35 36.06	–62 38 24.37							–
T Pyx	R2011	32, 62	P(62)	09 04 41.51	–32 22 47.61	2010–05–14	0.91 ± 0.02	0.67 ± 0.02	<0.28	<4.52	0.15	$\mathcal{I}$; [3]
				09 04 41.50	–32 22 47.5							–
V3890 Sgr	R1990	6, 14	–	18 30 43.28	–24 01 08.97	2010-03-26	216 ± 5	119 ± 2	33.2 ± 0.6	12.93 ± 1.42	0.08	$\mathcal{S}$; [3]
				18 30 43.28	–24 01 08.9							–
U Sco	R2010	1, 3	P(3)	16 22 30.80	–17 52 43.28	2010-02-24	1.58 ± 0.04	0.77 ± 0.02	0.78 ± 0.15	<2.89	0.08	$\mathcal{L}$?; [3]
				16 22 30.80	–17 52 43.2							–
V745 Sco	R1989	–, –	–	17 55 22.23	–33 14 58.62	2010-03-18	330 ± 011	248 ± 5	131 ± 2	64.36 ± 2.08	0.21	$\mathcal{SD}$; [3]
				17 55 22.27	–33 14 58.5							–
V1186 Sco	2004	12, 62	J(62)	17 12 51.26	–30 56 37.33	2010-03-09	1.91 ± 0.10	2.10 ± 0.08	7.16 ± 0.26	4.07 ± 1.19	0.79	$\mathcal{L}$
				17 12 51.21	–30 56 37.2							–
V1280 Sco	2007	–, 34	–	16 57 41.20	–32 20 36.40	2010-03-04	2.53±0.21	7.58±0.37	24.29±2.48	13.95±0.15	2.74	$\mathcal{D}$
				16 57 40.91	–32 20 36.4							t_3 from [2]
EU Sct	R?1949	–, –	–	18 56 13.23	–4 12 32.26	2010-04-02	22.78 ± 0.44	11.62 ± 0.23	2.68 ± 0.23	<2.33	0.76	$\mathcal{S}$; [4]
				18 56 13.12	–4 12 32.3							–
CT Ser	1948	–, >100?	–	15 45 39.10	+14 22 31.77	2010-02-05	0.18 ± 0.01	0.11 ± 0.01	<0.29	<2.64	0.07	$\mathcal{I}$
				15 45 39.08	+14 22 31.8							t_3 from [1]
V382 Vel	1999	6, 13	S(13)	10 44 48.45	–52 25 30.79	2010-01-07	0.42 ± 0.02	0.29 ± 0.01	4.33 ± 0.13	6.41 ± 0.72	0.49	$\mathcal{L}$
				10 44 48.39	–52 25 30.7							–

Notes. [1] O'Brien & Bode (2008); [2] Helton et al. (2010); [3] RN; [4] Potential recurrent; [5] Hounsell et al. (2010); [6] McQuillin et al. (2012); [7] Harrison & Gehrz (1990).

Table 3. Pre-2010 novae not detected by *WISE*.

Nova	Outburst year	Nova	Outburst year
LS And	1971	V838 Her	1991
OS And	1986	CP Lac	1935
CI Aql	1917	BT Mon	1939
V1301 Aql	1975	CP Pup	1942
V1419 Aql	1993	V597 Pup	2007
V842 Cen	1986	V4077 Sgr	1982
IV Cep	1971	V4021 Sgr	1977
BY Cir	1995	V723 Sco	1952
Q Cyg	1876	V1187 Sco	2004
V1668 Cyg	1978	FH Ser	1970
V2274 Cyg	2001	LW Ser	1978
V2361 Cyg	2005	NQ Vul	1976
V2491 Cyg	2008	PW Vul	1984
DN Gem	1912	QU Vul	1984
V446 Her	1960	QV Vul	1987
V827 Her	1987		

tail of a blackbody, but the temperature is poorly constrained by the *WISE* data alone; however, there remains a large excess in band 4. The *WISE* data do not discriminate between line and dust emission.

4.3 RS Oph

The best studied of the RNe, RS Oph has undergone five known and two suspected eruptions (Anupama 2008). The donor star is an early (M0/M2) giant with a ^{12}C/^{13}C ratio of 16 ± 3, an underabundance of C and an overabundance of N relative to solar values (Pavlenko et al. 2008, 2010). Pavlenko et al. determined an effective temperature of 4100 ± 100 K for the donor star. Silicate dust – seemingly oblivious to the 2006 eruption – was prominent in a spectrum obtained with the Infrared Spectrograph (IRS; Houck et al. 2004) on the *Spitzer Space Telescope* (Werner et al. 2003; Gehrz et al. 2007) in 2007 (Evans et al. 2007; Woodward et al. 2008).

The *WISE* SED is shown in Fig. 2. The band 1–2 data seem consistent with a 2560 K blackbody, leaving an excess in bands 3–4; we identify this with the dust in the RS Oph system, although the [O IV] fine-structure line – commonly seen in CNe (Helton et al. 2012) and indeed present in the IR spectrum of RS Oph (Evans et al. 2007a) – may contribute in band 4. We defer a discussion of this point to detailed modelling.

4.4 T Pyx

T Pyx is a well-known RN which underwent its sixth known eruption in 2011. The nature of the donor star is uncertain. Observations with the *Herschel Space Observatory* during the 2011 eruption revealed a weak far-IR excess (Evans et al. 2012), attributed to an IR echo from pre-existing dust.

T Pyx is detected in *WISE* bands 1 and 2 only (see Fig. 2). The bands 1 and 2 data are consistent with a 2190 K black body (BB) but in view of the limited nature of the data this is not conclusive.

4.5 V3890 Sgr

V3890 Sgr is an RN that underwent eruptions in 1962 and 1990. The secondary star is classed as M5III (Anupama 2008). The *WISE* SED is consistent with a blackbody photosphere at 2310 K (Fig. 2). This is somewhat cooler than the effective temperature of an M5III (3170 K; Cox 2000). There is no evidence for either line emission or a dust excess.

4.6 V745 Sco

V745 Sco underwent RN eruptions in 1937 and 1989; the secondary star is classed as M6III (Anupama 2008), corresponding to an effective temperature of 3250 K. The *WISE* SED seems (like that of RS Oph) to be consistent with a blackbody at 2090 K, together with a dust excess (see Fig. 2).

4.7 U Sco

U Sco is a well-known eclipsing RNe with eruptions in 1863, 1906, 1936, 1979, 1987, 1999 and 2010; a possible eruption in 1917 has been identified (Anupama 2008). The secondary is constrained to be between an F3 and a G subgiant (Mason et al. 2012); Anupama (2008) gives K2IV (effective temperature 4620 K).

The *WISE* SED is shown in Fig. 2. The interpretation of the *WISE* SED is constrained by the fact that the *J*-band flux is ∼0.3 mJy (Darnley et al. 2012): there is no blackbody at the temperature of a K2IV subgiant that is consistent with the *WISE* and *J*-band fluxes. It is likely therefore that the IR SED is due to the presence of emission lines.

4.8 EU Sct

EU Sct had an eruption in 1949 and was identified as a potential RN by Weight et al. (1994) on the basis of its *JHK* colours (see however Pagnotta & Schaefer 2014); the near-IR colours are $J - H = 1.08$, $H - K_s = 0.38$ by Darnley et al. (2012); Darnley et al. and Weight et al. (1994) give the reddening as $E(B - V) = 0.84$, so that the dereddened colours correspond to an early M giant classification.

The *WISE* data are shown in Fig. 2. The band 1–2 data are consistent only with the Rayleigh–Jeans tail of a blackbody so the temperature is not constrained by the *WISE* data alone; this leaves a slight excess in band 3 whose origin is unclear.

5 CNe OBSERVED BY *WISE*

Like RNe, CN eruptions occur following thermonuclear runaway on the surface of a WD in a semidetached binary system. The nature of the WD can determine the course of the eruption. CN eruptions on CO WD (‘CO novae’) tend to result in the ejection of lower mass than those on ONe WDs, and often result in dust formation. CN eruptions on ONe WDs (‘neon novae’) eject higher mass, and often result in coronal emission; CNe displaying coronal emission are rarely strong dust producers. The energetics of the eruption are characterized by t_2 (or t_3). Strope et al. (2010) provide a description of CN LCs, and t_2 and t_3 for a large number of objects.

Overviews of CNe are given in Bode (2010), Gehrz et al. (1998), Bode & Evans (2008), Woodward & Starrfield (2011), Saikia & Anupama (2012), and Woudt & Ribeiro (2014).

5.1 V603 Aql

This is a well-studied nova with a well-observed stellar and nebular remnant. It was not detected by *IRAS* (Harrison & Gehrz 1988).

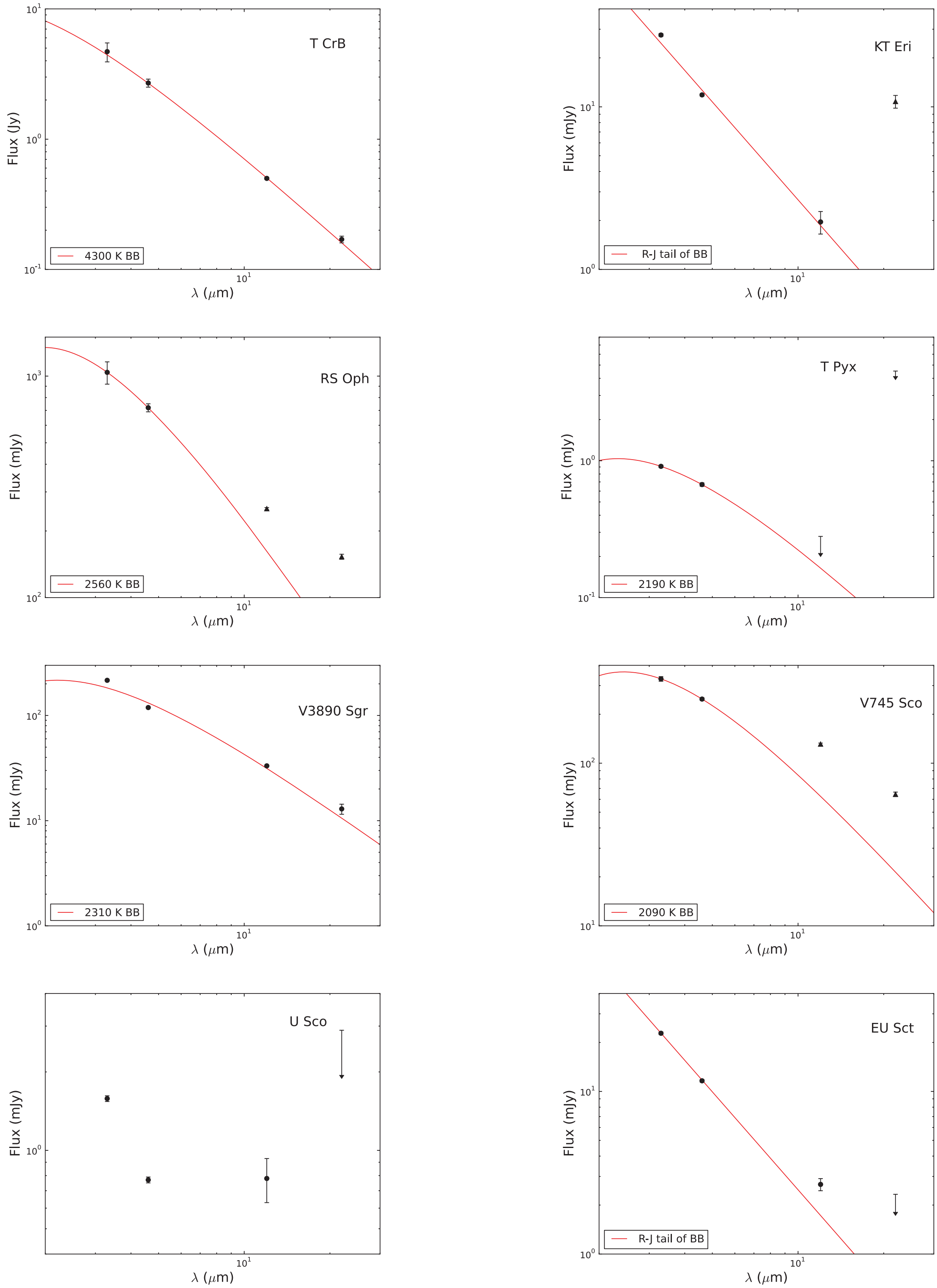

Figure 2. RNe and suspected RNe in the *WISE* data base. Top left: TCrB. Top right: KT Eri. Upper left middle: RS Oph. Upper right middle: T Pyx. Lower left middle: V3890 Sgr. Lower right middle: V745 Sco. Bottom left: U Sco. Bottom right: EU Sct. Errors are smaller than plotted points if not shown.

There are strong detections in *WISE* bands 1 and 2, and good positional coincidence (0.5 arcsec) between the *WISE* source and the nova; we are confident that the *WISE* source is associated with the nova remnant. However, the *WISE* data do not enable us to draw any conclusions about the nature of the IR emission.

5.2 V1229 Aql

A poorly observed nova, with a resolved optical shell (Cohen 1985); it was not detected by *IRAS* (Harrison & Gehrz 1988). The *WISE* source is <1.7 arcsec from the nova. There is a strong detection in *WISE* band 1 and a moderate detection in band 2; the nova is not detected in bands 3 and 4. Again no conclusions can be drawn about the nature of the IR emission.

5.3 V1370 Aql

V1370 Aql was a well-observed dusty nova and was one of the first to show the now familiar ‘chemical dichotomy’, in which both C-rich and O-rich dusts condense (Snijders et al. 1987). In their survey of novae with *IRAS*, Harrison & Gehrz (1988) reported a detection in *IRAS* band 1, although Callus et al. (1987) give only upper limits.

The *WISE* source is some 2.7 arcsec from the nova, but within the uncertainties of the *WISE* positions. As with V1229 Aql, no conclusions can be drawn about the nature of the IR emission.

5.4 V1494 Aql

This was a very well-observed nova in which the binary displays eclipses. Optical and radio observations (Eyres et al. 2005) showed the material ejected in the 1999 eruption was highly clumpy and non-spherical, while X-ray observations (Drake et al. 2003) revealed oscillations and a transient ‘burst’.

V1494 Aql was observed using the *Spitzer* IRS by Helton et al. (2012), who complemented the IR data with optical spectroscopy. The flux in the [O IV] 25.9 µm fine-structure line was 18.7×10^{-16} W m^{-2} in 2007, with a peak flux density of $\sim$6 Jy over the period 2004 April–2007 October (Helton et al. 2012). Oxygen was overabundant relative to solar by a factor of $\gtrsim$15, depending on the assumed electron density.

The *WISE* SED is included in Fig. 3, in which the largest flux is in band 4. Given the strength of [O IV] 25.9 µm in 2007 it seems probable that the flux in the *WISE* filters likely has an emission-line origin.

5.5 T Aur

T Aur is another nova system in which the central binary is eclipsing; there was no *IRAS* source at the position of the nova (Harrison & Gehrz 1988). The *WISE* source is within $\sim$0.2 arcsec of the nova; the *WISE* data are shown in Fig. 3. The data in bands 1 and 2 are consistent with a photospheric blackbody at 3740 K, suggesting that the *WISE* band 1, 2 data are seeing the main-sequence secondary. However, this leaves an excess at 12 µm whose origin is not clear.

5.6 QZ Aur

Another poorly observed nova with a resolved optical shell; the *WISE* source is within 0.2 arcsec of the nova position. We have detections in *WISE* bands 1 and 2 only, and no conclusions can be drawn about the nature of the IR emission.

5.7 T Boo

T Boo is the oldest ‘old nova’ for which we have searched the *WISE* data base. The *WISE* source is some 1.7 arcsec from the position of the nova, well within the *WISE* positional uncertainty. There are strong detections in bands 1 and 2, with a marginal detection in band 3. Without complementary data, it is not possibly to determine the origin of the IR emission.

5.8 V705 Cas

This dusty nova was discovered on 1993 December 14 and was well observed in the IR. It exhibited a deep minimum in its visual LC, the characteristic signature of prolific dust formation (Evans et al. 1996, 1997, 2005; Mason et al. 1998; Salama et al. 1999, Helton et al., in preparation); maximum dust emission occurred around day 105 (Mason et al. 1998). Observations using the Short Wavelength Spectrometer on the *Infrared Space Observatory* (*ISO*) detected no dust, although *Spitzer* IRS observations (Helton et al., in preparation) show a weak dust continuum longwards of $\sim$15 µm. We note however that the *ISO* observations were executed some time (days 950, 1265, and 1455) after maximum dust emission.

The [O IV] 25.9 µm fine-structure line was clearly detected with *ISO* in observations made 950 and 1265 d after eruption, with peak flux 8.94 and 13.4 Jy, respectively, and integrated flux 5.2×10^{-15} and 5.8×10^{-15} W m^{-2}, respectively (Salama et al. 1999). Salama et al. concluded that O was overabundant in V705 Cas by at least 25 relative to solar, while the neon abundance was 0.5 times solar at most. The [O IV] line was also strongly detected by the *Spitzer* IRS (Helton et al., in preparation).

The *WISE* source is within 0.2 arcsec of the nova and the SED is included in Fig. 4. In *WISE* bands 1–3, the flux is consistent with a weak continuum but there is a clear excess in band 4, with a peak flux density of 13.08 mJy. This is very likely due to emission in the fine-structure [O IV] 25.9 µm line, which was prominent in the first $\sim$3 yr after outburst.

On the assumption that the band 4 flux is indeed due to [O IV], the decline in the peak flux in the [O IV] line in V705 Cas over the period 1996 (*ISO*)–2007 (*WISE*) is shown in Fig. 4. In this figure, we take the peak flux in the line as a proxy for the integrated flux, and we make the implicit assumption that there is no change in line width with time. In a comprehensive study of the evolution of the line emission of nova DQ Her (1934), Martin (1989) undertook a detailed study of the long-term ($\sim$50 yr) evolution of nebular, coronal, and fine-structure lines; the study included a number of the mid- and far-IR lines now routinely seen in the spectra of mature novae. The predicted evolution of the [O IV] flux is also shown in Fig. 4. With the caveat that Martin’s analysis was for the specific case of DQ Her, its stellar remnant and ejecta abundances, the predicted evolution of the [O IV] fine-structure line is in surprisingly good (qualitative) agreement with the evolution of the [O IV] line in V705 Cas.

While the [Ne II] 12.8 µm fine-structure line was detected in ground-based observations (Evans et al. 1997) and by the *Spitzer* IRS (Helton et al., in preparation), it was not detected by *ISO*. We also show in Fig. 4 the observed evolution of the [Ne II] 12.8 µm fine-structure line in V705 Cas over an $\sim$15 yr period. It is evident that the [Ne II] line in V705 Cas peaked much earlier, and decayed more quickly, than the [O IV] line.

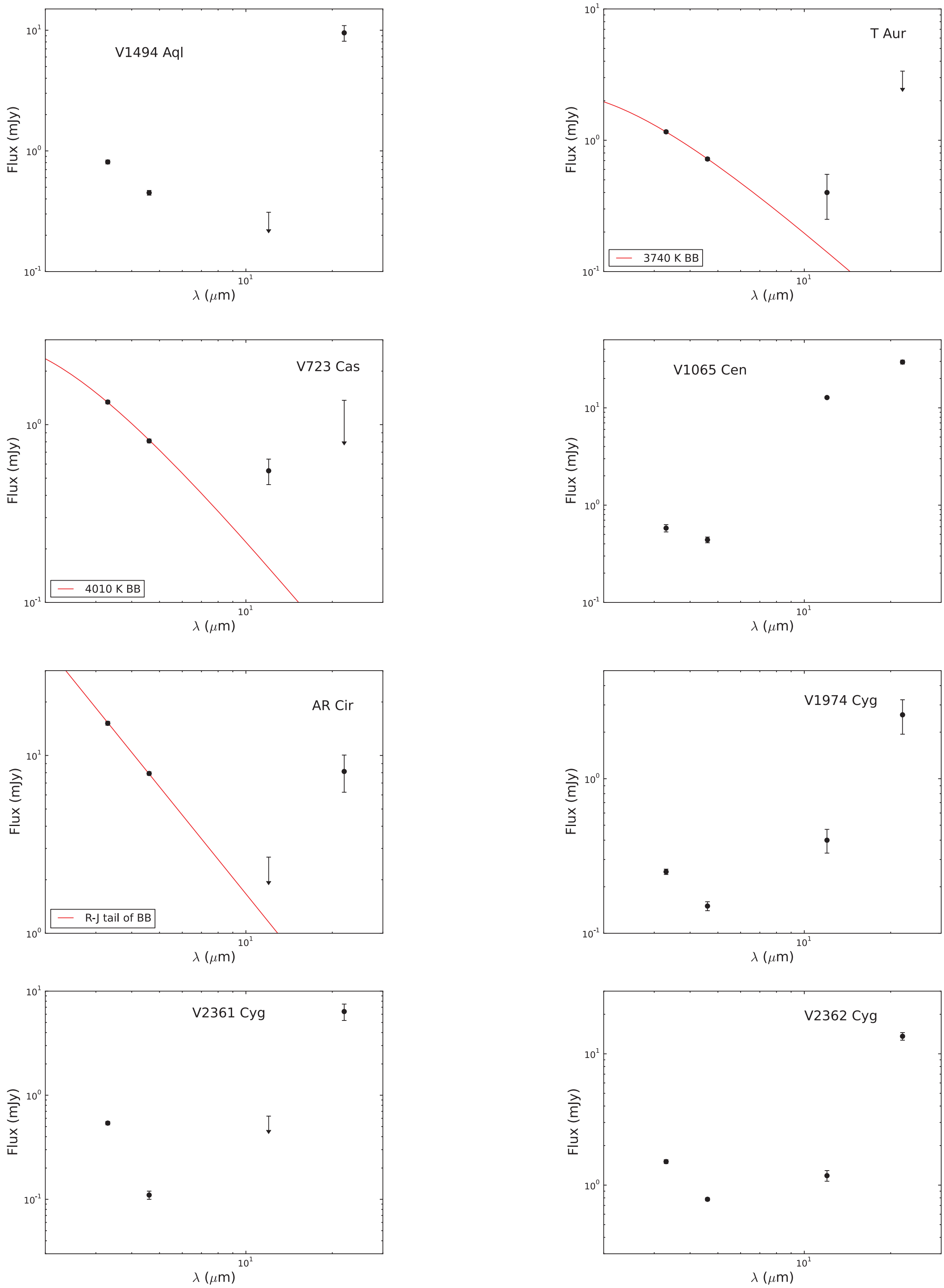

Figure 3. Classical novae in the *WISE* data base; see text for details. Top left: V1494 Aql. Top right: T Aur. Upper middle left: V723 Cas. Upper middle right: V1065 Cen. Lower middle left: AR Cir. Lower middle right: V1974 Cyg. Bottom left: V2361 Cyg. Bottom right: V2362 Cyg. Errors are smaller than plotted points if not shown. CNe in the *WISE* data base; see text for details. Top left: V2467 Cyg. Top right: HR Del. Upper middle left: DQ Her. Upper middle right: GK Per. Lower middle left: RR Pic. Lower middle right: V1186 Sco. Lower left: V1280 Sco. Lower right: V382 Vel. Errors are smaller than plotted points if not shown.

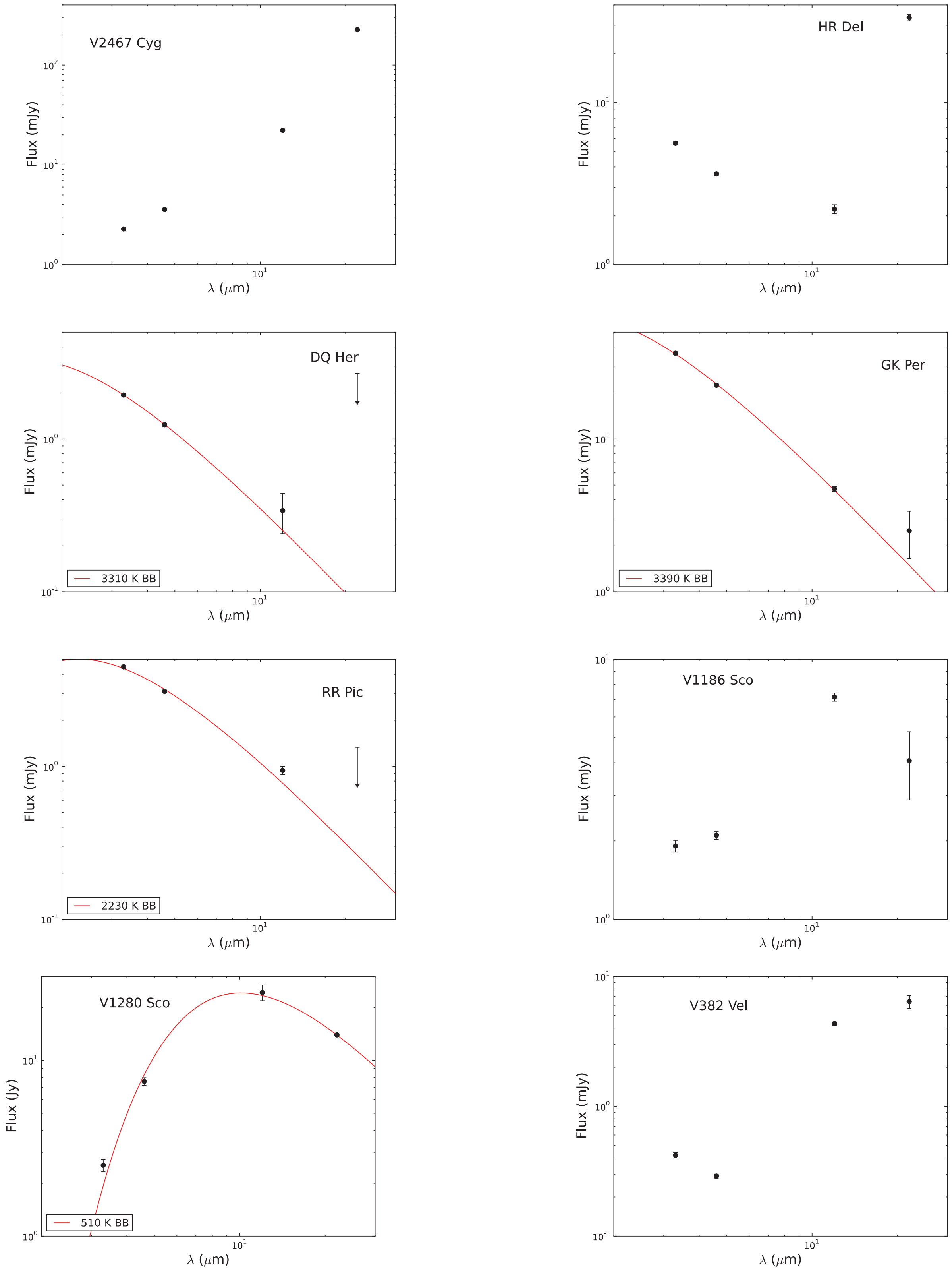

Figure 3 – *continued.*

5.9 V723 Cas

This nova had an erratic LC, and displayed strong coronal-line emission in the IR (Evans et al. 1997); the distance is 4 kpc (Evans et al. 1997; Lyke & Campbell 2009). Evans et al. also concluded that the secondary must be evolved for mass transfer to occur. Lyke & Campbell (2009) found that high-spatial-resolution images showed that the [Si VI] and [Ca VIII] coronal lines form an equatorial

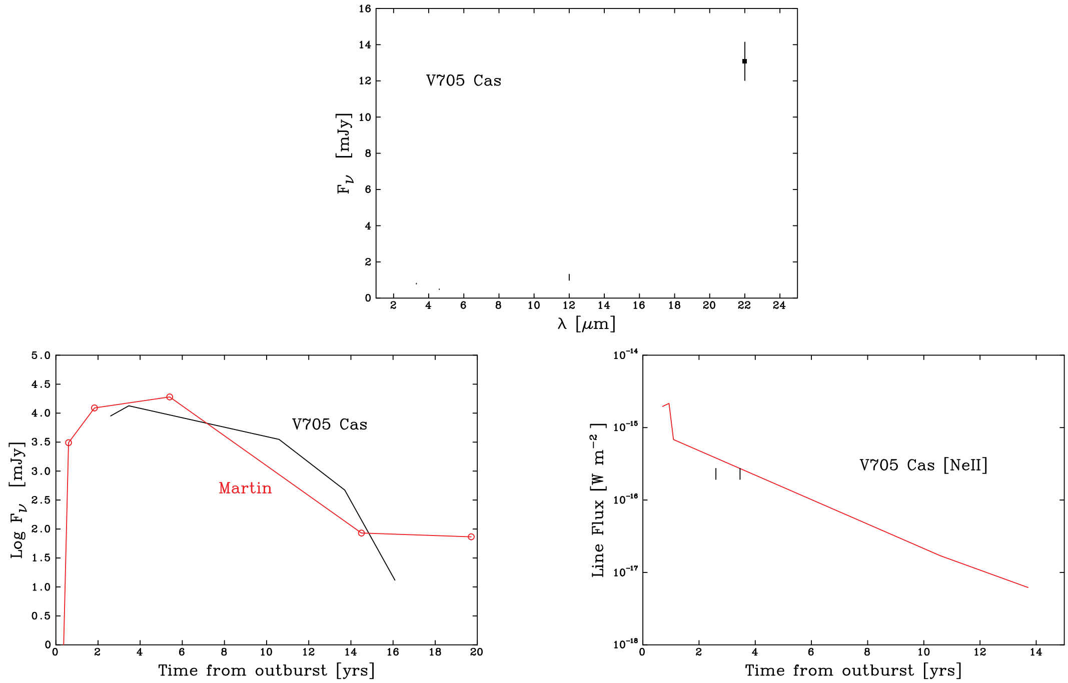

Figure 4. Top: *WISE* SED of V705Cas. Bottom left: black points and line: peak flux (in Jy) of the [O IV] 25.9 μm fine-structure line in V705Cas, based on *ISO*, *Spitzer*, and *WISE* data; red points and line: predicted variation of the [O IV] flux, calculated for DQ Her by Martin (1989). Bottom right: observed variation of the [Ne II] 12.8 μm fine-structure line, based on ground-based (Evans et al. 1997), *ISO* (Salama et al. 1999), and *Spitzer* IRS (Helton et al., in preparation) data. See text for details.

ring, while [Al IX] was in a prolate spheroid; all of these lines were detected from ground-based IR observations by Evans et al. (1997).

The *WISE* source is within 0.2 arcsec of the position of the nova; the *WISE* SED is included in Fig. 3. The fluxes in bands 1 and 2 fit well to a blackbody with temperature 4010 K and radius 5.5 $R_\odot$, reasonably consistent with a K2IV (effective temperature 4 600 K) star at 4 kpc. We therefore tentatively conclude that the *WISE* data are consistent with photospheric emission and, given the absence of dust immediately after outburst (Evans et al. 1997), the band 3 flux is almost certainly due to line emission.

5.10 V1065 Cen

V1065 Cen was another dust former and was observed with the *Spitzer* IRS by Helton et al. (2010). Analysis of the emission-line spectrum leads to abundances relative to solar of He/H = 1.6 ± 0.3, N/H = 144 ± 34, O/H = 58 ± 18, and Ne/H = 316 ± 58; the extent of its neon overabundance places V1065 Cen in the category of 'neon novae'. The condensed dust consisted primarily of silicates, and the dust mass is estimated by Helton et al. to be in the range $(0.2-3.7) \times 10^{-7}$ $M_\odot$. A sequence of *Spitzer* observations showed that the peak in the dust emission shifted from ∼10 to ∼20 μm, with nebular and fine-structure lines superimposed, over an ∼700 d period (Helton et al. 2010); in particular, the [Ne II] 12.8 μm, and the [Ne V] 24.3 μm and [O IV] 25.9 μm lines were prominent, superimposed on the broad 9.7 and 18 μm silicate features, respectively.

The *WISE* SED is included in Fig. 3. In view of the known mid- and far-IR properties of this nova, it is likely that the *WISE* emission consists of emission lines superimposed on the still-cooling dust continuum.

5.11 AR Cir

Harrison (1992) has suggested on the basis of its 1906 LC that the nova status of the object is doubtful. Its near-IR colours are more akin to a giant (M0III) donor star and coupled with its LC and low outburst amplitude, Harrison concluded that AR Cir is more likely a symbiotic star (see also Pagnotta & Schaefer 2014).

The *WISE* source is within 0.3 arcsec of the target and the *WISE* SED is shown in Fig. 3. All we can say is that the *WISE* band 1 and 2 data are consistent with the Rayleigh–Jeans tail of a blackbody. The *WISE* data are insufficient to allow us to draw any conclusion about the nature of the *WISE* band 4 emission.

5.12 DZ Cru

DZ Cru was a dusty nova with prominent 'aromatic infrared' (AIR) features typical of novae. Ground-based IR observations of DZ Cru were carried out by Rushton et al. (2008), and *Spitzer* observations by Evans et al. (2010).

The *WISE* SED is shown in Fig. 5; data from the *Spitzer* campaign (Evans et al. 2010) are shown in a separate frame. The *WISE* data clearly show the continued cooling of the dust shell. The *Spitzer* data approximately correspond to a 470 K blackbody, while a reasonable representation of the *WISE* data is obtained for a blackbody at $T_d = 420$ K (see Fig. 5). For simple outflow, the dust temperature should decline with time t as $T_d \propto t^{-2/(\beta+4)}$, where the emissivity of the dust is $\propto\lambda^{-\beta}$. With $T_d \simeq 470$ K, when DZ Cru was observed by *Spitzer* in 2007 September (day 874), uniform outflow would lead us to expect $T_d \simeq 300$ K ($\beta = 1$), or 320 K ($\beta = 2$) at the time of the *WISE* observations (day 2350); a blackbody would have cooled to 285 K. A more detailed discussion of this will be given in a later paper.

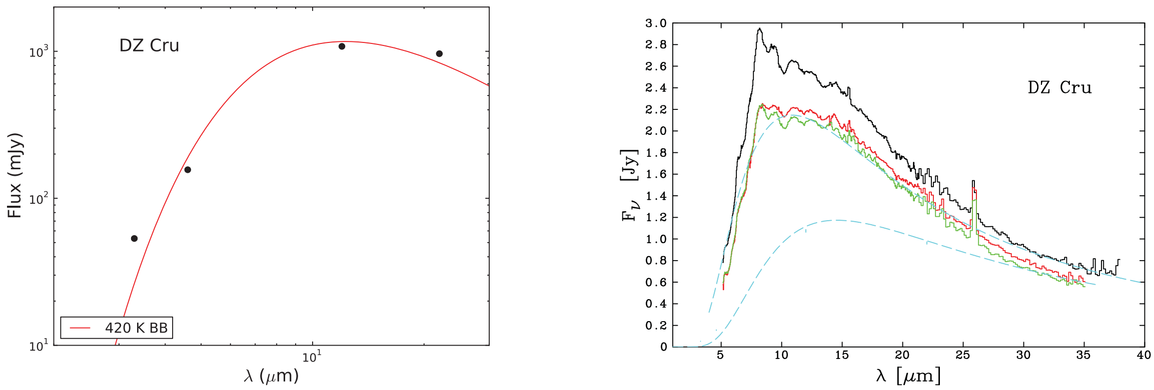

Figure 5. Left: SED of DZ Cru from *WISE*. Solid curve is a 420 K blackbody. Right: evolution of the dust shell of DZ Cru, comparing *Spitzer* data from Evans et al. (2010, solid spectra) with the *WISE* data (points). The broken curves are 470 and 420 K blackbodies through the *Spitzer* and *WISE* data. Errors are smaller than plotted points. See text for discussion.

5.13 V476 Cyg

This is a poorly observed nova with a resolved nebular remnant (Gill & O'Brien 2000). The *WISE* source is within 0.1 arcsec of the nova position. We have detection in *WISE* bands 1 and 2 only, but no conclusions can be drawn about the nature of the IR emission.

5.14 V1974 Cyg

V1974 Cyg, discovered just before maximum light by Collins et al. (1992). It was shown by Gehrz et al. (1992) to have strong [Ne II] 12.8 μm emission, classifying it as a neon nova. Subsequently, V1974 Cyg developed numerous coronal lines in the IR, including [Al VI] 3.6 μm, [Al VIII] 3.7 μm, [S IX] 1.25 μm, [Mg VIII] 3.0 μm, and [Ca IX] 3.18 μm (Woodward et al. 1995). Salama et al. (1996) observed this CN with *ISO*, and reported strong [Ne VI] 7.6 μm, [Ne V] 14.3 μm, [Ne V] 24.3 μm emission, consistent with its status as a neon nova; [Ne II] 12.8 μm was not detected.

The *WISE* SED is included in Fig. 3. Extensive ground-based, *ISO* and *Spitzer* observations suggest that dust did not form in the ejecta; we are therefore confident in assigning the *WISE* fluxes to emission lines. Fig. 3 indicates that the [Ne III] 15.5 μm, and [O IV] 25.9 μm lines measured in 1996 with *ISO* (Salama et al. 1996) and with *Spitzer* during 2003–2007 (Helton et al. 2012) are likely still strong in 2010–2011.

In Fig. 6, we again compare the variation of the flux in the [O IV] 25.9 μm line in V1974 Cyg with that predicted by Martin (1989), recalling the caveat that Martin's calculations were for the specific case of DQ Her; we again make the assumption (see discussion of V705 Cas above) that there is no change in the line width over the period 1992–2010 so that the peak flux is a measure of the integrated line flux. However, we again see that the variation of the [O IV] flux is broadly consistent with Martin's prediction.

Although we have LC for the various Ne lines from *ISO* and *Spitzer* data, comparing these with Martin's predictions is not appropriate as V1974 Cyg was a neon nova, while DQ Her was not; we would not expect agreement between theory and observation for the neon lines.

5.15 V2361 Cyg

Russell et al. (2005) reported IR spectroscopy of this nova, showing a continuum indicating dust emission at 970 K, on which were superimposed a number of broad (∼2600 km s^{-1}) emission lines.

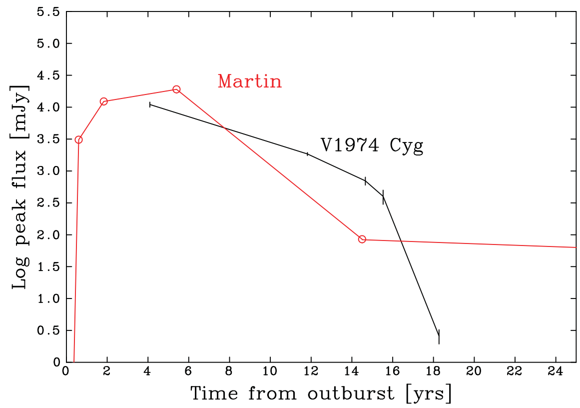

Figure 6. Black points and line: flux of the [O IV] 25.9 μm fine-structure line in V1974 Cyg, based on *ISO*, *Spitzer*, and *WISE* data; red points and line: predicted variation of the [O IV] flux, calculated for DQ Her by Martin (1989). See text for details.

Later IR observations by Venturini et al. (2005) showed that the dust emission had diminished, as had the extinction reported by Russell et al., presumably due to the dispersal of the dust reported by Russell et al.. Venturini et al. also reported the presence of the coronal lines [Si VI] and [Ca VIII].

The *WISE* source is some 2.5 arcsec from the position of the nova, and the *WISE* SED is included in Fig. 3. In view of the cooling dust shell and the emission lines seen in the near-IR by Russell et al. (2005), the nature of the emission in the *WISE* data is unclear.

5.16 V2362 Cyg

This well-observed nova had an extraordinary LC, displaying a large amplitude 'cusp' that peaked some 200 d after maximum light; the cusp was superimposed on the general decline of the LC (see Kimeswenger et al. 2008, and references therein). The cusp was accompanied by a rise in the X-ray flux and a shift in excitation to lower energies (Lynch et al. 2008). *Spitzer* observations (Lynch et al. 2008) showed that dust formed in the ejecta at ∼1400 K some 240 d after the eruption; the dust showed emission features at 6.37, 8.05, and 11.32 μm that were distinct from the usual AIR features seen in nova dust; there was also a broad 'plateau' from 15–21 μm. The ubiquitous [O IV] 25.9 μm fine-structure line was superimposed on the dust continuum.

The *WISE* source is within 5 arcsec of the nova, just within the *WISE* positional uncertainty. The SED is shown in Fig. 3; in view of the presence of dust and strong [O IV] emission, we again have insufficient information to determine the nature of the *WISE* emission.

5.17 V2467 Cyg

This nova was extensively observed in the IR. Ground-based IR observations showed strong coronal-line emission, including [Si VI], [Si VII], [Ca VIII], [S VIII], and [S IX]. Later, the excitation had clearly increased, with [Si X], [S XI] present (Perry et al. 2007). In addition to these lines, Russell et al. (2007) reported the rarely seen [P VII] feature at 1.37 μm; the coronal lines displayed complex profiles. There was no evidence of dust (Mazuk et al. 2007), although as noted above, dust formation is rarely seen in 'coronal' novae. A possible progenitor was identified by Steeghs et al. (2007). *Spitzer* IRS observations (Woodward et al., in preparation) also showed a strong emission-line spectrum, and possibly a weak dust continuum longwards of ∼15 μm.

The *WISE* source is within 1.4 arcsec of the nova and the SED is shown in Fig. 3. It is likely that the *WISE* emission is due to emission lines although further analysis (to be presented elsewhere) is needed to rule out dust emission.

5.18 HR Del

This nova and its stellar and nebular remnant have been very well observed and studied. It was noted as an *IRAS* source by Callus et al. (1987), who reported a detection in *IRAS* band 1, while Harrison & Gehrz (1988) reported detections in *IRAS* bands 1, 2, and 3. It was also observed with *ISO* (Salama et al. 1998), who found that the peak flux in the [O IV] 25.9 μm fine-structure line was ∼4 Jy in 1996 April.

The *WISE* SED is included in Fig. 3 and there is excellent positional coincidence between the *WISE* source and the nova. Although it was a very slow nova (t_3 = 231 d), HR Del seems not to have been a dust former. It seems certain therefore that the *WISE* fluxes are due to line emission, and we note that [O IV] seems still to have been strong in 2010.

5.19 DM Gem

This is a poorly studied nova. The *WISE* source is within 2 arcsec of the nova, and there are secure detections in bands 1 and 2. However, there is insufficient information to draw any conclusions as to the origin of the *WISE* emission.

5.20 DN Gem

This is another poorly studied nova, albeit with a known orbital period (3.068 h) and a resolved nebular remnant (see Bode & Evans 2008). The *WISE* source is within 0.5 arcsec of the nova; there are detections in bands 1 and 2, although neither is strong. Again, we have insufficient information to draw any conclusions as to the origin of the *WISE* emission.

5.21 DQ Her

This is a very well observed and studied nova, which is an eclipsing binary. The deep minimum in the 1934 LC was interpreted by McLaughlin (1935) as being due to dust formation: DQ Her is the prototype of dust-forming novae. It has a resolved and well-studied nebular remnant (see O'Brien & Bode 2008, and references therein), the optical spectrum of which has been studied for well over 50 yr. Martin (1989) has used CLOUDY (Ferland et al. 2013) to model the nebula over the period 1934–1982, and has predicted the evolution of the line emission, from the ultraviolet to the far-IR.

The *WISE* source is within 0.1 arcsec of the nova and the SED is shown in Fig. 3. The *WISE* band 1–3 data are reasonably well fitted by a 3310K blackbody, corresponding to an early M dwarf star at 485 pc (Martin 1989). It is therefore likely that the *WISE* data are detecting emission from the stellar photosphere.

5.22 V533 Her

This nova has a resolved remnant (see O'Brien & Bode 2008, and references therein). It is also unusual in that its LC is known prior to its 1963 outburst (see Warner 2008).

The *WISE* source is close (0.2 arcsec) to the nova but there is insufficient information to draw any conclusion about the nature of the emission.

5.23 GK Per

The first bright nova of the 20th century, this is a very well studied object. It has an evolved (K2IV) secondary (Darnley et al. 2012), a resolved nebular remnant (O'Brien & Bode 2008; Liimets et al. 2012), and seems to lie within a planetary nebula (Seaquist et al. 1989). It was not detected in the *IRAS* survey (Harrison & Gehrz 1988).

The *WISE* source is some 3 arcsec from the nova, within the *WISE* positional uncertainties; the *WISE* SED is shown in Fig. 3. The data in all four *WISE* bands seem consistent with a 3390 K blackbody, corresponding to an early K2 subgiant.

5.24 RR Pic

RR Pic has a resolved nebular remnant that has been studied over a range of wavelengths (see O'Brien & Bode 2008, and references therein). RR Pic was not detected by *IRAS* (Harrison & Gehrz 1988).

The *WISE* source is less than 0.2 arcsec from the position of the nova; the *WISE* SED is shown in Fig. 3. The band 1 and 2 data can be fitted with an ∼2230 K blackbody, although the temperature is very poorly constrained.

5.25 V1186 Sco

V1186 Sco was a well-studied nova. Its LC displayed a slow rise to maximum, and there was a prominent secondary maximum (see Schwarz et al. 2007). It was observed by *Spitzer* (Schwarz et al. 2007) and, despite the fact that it was a CO nova, there was no evidence of dust emission.

The *WISE* source is <1 arcsec from the position of the nova. The *WISE* SED is shown in Fig. 3. It is superficially similar to an ∼500 K blackbody but as V1186 Sco is known not to have been a dust producer, we can rule out dust emission. The emission detected by *WISE* is very likely due to line emission.

5.26 V1280 Sco

V1280 Sco was a dusty nova with a complex visual LC and seemingly invariant dust temperature (see Chesneau et al. 2008); high-spatial-resolution observations by Chesneau et al. (2012) showed that the dust resided in polar caps. The *WISE* source is ∼2.8 arcsec from the nova, well within the *WISE* positional uncertainties, and the SED is shown in Fig. 3. The nova is strongly detected in all four *WISE* bands and the data are consistent with a 510 K blackbody.

5.27 CT Ser

This is a poorly studied nova. The *WISE* source is within 0.1 arcsec of the position of the nova. The nova is detected in bands 1 and 2 only and the data are insufficient to draw any conclusions about the nature of the emission.

5.28 V382 Vel

V382 Vel was a fast nova; it is in the class of ONe novae, based on the detection of prominent [Ne II] 12.8 μm emission at 43.6 d after maximum (Woodward et al. 1999). *Spitzer* spectra of V382 Vel (Helton et al. 2012) showed strong emission by [Ne II] 12.8 μm, [Ne III] 15.5 μm, and [O IV] 25.9 μm. Emission lines of [Ne V] were present at 14.3 and 24.30 μm, but at a much lower level than the other neon species; no [Ne VI] 7.6 μm emission was detected. There was also weak emission from [S IV] 10.5 μm and [Ar III] 8.9 μm. In keeping with its neon nova status, V382 Vel did not produce any dust.

The *WISE* source is ∼0.5 arcsec from the nova and is strongly detected in all four *WISE* bands. The SED is shown in Fig. 3; in view of the fact that V382 Vel was not a dust-former, the *WISE* data indicate that the lines seen by *Spitzer* were still strong in 2010.

6 POST-*WISE* NOVAE OBSERVED BY *WISE*

A number of novae erupted after *WISE* completed its mission. This gives us an opportunity of obtaining a glimpse of the mid-IR properties of the nova progenitors. At the time of writing, *WISE* detected four of these; the data are listed in Table 4. However, care should be exercised in using and interpreting these data as they stand as the *WISE* catalogue indicates that there may have been significant flux variations during the course of the *WISE* mission. We therefore defer a detailed discussion of these objects to a later paper and give only a brief description here.

6.1 V959 Mon

V959 Mon (Nova Mon 2012) is exceptional in that it was a γ-ray source (Cheung et al. 2012). It is a weak source in *WISE* bands 1 and 2, and there is some evidence for variability.

6.2 V5590 Sgr

This slow nova (still referred to in the literature as Nova Sagittarii 2012b), was discovered on 2012 April 23, although it seems to have been bright at least a year earlier (Walter et al. 2012); it has been a Small and Moderate Aperture Research Telescope System (SMARTS) target for optical and IR photometry, and spectroscopy (Walter et al. 2012).

The *WISE* SED is shown in Fig. 7. The data are consistent with a cool continuum, at ∼1115 K. While it is tempting to associate this emission with hot dust (possibly dust from a giant companion wind), it is not possible to rule out a V838 Mon-type event (see e.g. Evans et al. 2003).

Table 4. *WISE* detections of post-2011 novae.

Nova	Outburst date (UT) yyyy-mm-dd.dd	RA, Dec. (J2000) Upper value: *WISE* Lower value: GCVS	Date of first *WISE* observation YYYY-MM-DD	*B1* (3.3 μm) (mJy) (Jy)	*B2* (4.6 μm) (mJy) (Jy)	*B3* (12 μm) (mJy) (Jy)	*B4* (22 μm) (mJy) (Jy)	$\Delta\theta$ (arcsec)	Comment
PNV J14250600−5845360 Nova Cen 2012b	2012-04-5.47	14 25 06 −58 45 36 14 25 06.10 −58 45 34.07	2010-02-13	2.22 ± 0.07	1.03 ± 0.04	<0.37	<2.26	2.12	
V959 Mon	2012-08-9.8	06 39 38.57 +05 53 51.59 06 39 38.74 +05 53 52.0	2010-03-23	0.41 ± 0.01	0.19 ± 0.02	<0.610	<2.668	2.39	
V2677 Oph Nova Oph 2012b	2012-05-19.48	17 39 56 −24 47 42 17 39 55.84 −24 47 37.21	2010-03-14	31.12 ± 0.75	13.75 ± 0.35	4.04 ± 0.26	3.95 ± 1.02	5.31	
V5590 Sgr Nova Sgr 2012b	2012-04-23.7	18 11 03.71 −27 17 29.37 18 11 03.75 −27 17 28.4	2010-03-21	1.17±0.11	1.30±0.05	0.54±0.01	0.29±0.01	1.58	*IRAS*, 2MASS, *AKARI* source

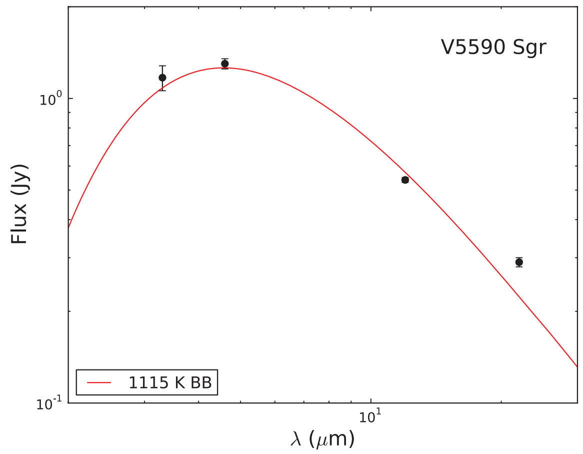

Figure 7. *WISE* SED of V5590 Sgr. Errors are smaller than plotted points if not shown.

Table 5. Post-2011 novae not detected by *WISE*.

GCVS name	Other name	Outburst/discovery date (UT)
	Nova Aql 2012	2012 Oct 20.4
V834 Car	Nova Car 2012	2012 Feb 26.5
V1368 Cen	Nova Cen 2012	2012 Mar 23.4
V1369 Cen	Nova Cen 2013	2013 Dec 2.7
V339 Del	Nova Del 2013	2013 Aug 14.6
PR Lup	Nova Lup 2011	2011 Aug 4.7
V2676 Oph	Nova Oph 2012a	2012-03-25.79
V2677 Oph	Nova Oph 2012b	2012 May 19.5
V1311 Sco	Nova Sco 2010 No. 2	2010 Apr 25.8
V1312 Sco	Nova Sco 2011	2011 Jun 1.6
V1313 Sco	Nova Sco 2011 No. 2	2011 Sep 06.4
V1324 Sco	Nova Sco 2012	2012 May 22.8
V5588 Sgr	Nova Sgr 2011b	2011 Mar 27.8
V5589 Sgr	Nova Sgr 2012	2012 Apr 21.0
V5591 Sgr	Nova Sgr 2012c	2012 Jun 26.6
V5592 Sgr	Nova Sgr 2012d	2012 July 7.5
V5593 Sgr	Nova Sgr 2012e	2012 Jul 16.5

6.3 Non-detections

We list in Table 5 post-2011 novae that were not detected in the *WISE* survey. In some cases, the novae listed have *WISE* sources close to the position of the nova but not within the positional uncertainties of the *WISE* survey.

7 CONCLUSIONS

We have searched the *WISE* data base for IR sources that might be associated with mature novae (including classicals and recurrents). We have found 36 possible associations with old novae; these show a mix of photospheric, line and dust emission, or a combination of two of these; 48 novae (including those which erupted during or after the *WISE* mission) seem to have no counterparts in the *WISE* survey.

We have also searched the *WISE* data base for sources associated with novae that erupted after the *WISE* mission had terminated, giving some information about nova progenitors.

In future papers, we will be reporting on detailed modelling of the *WISE* data.

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