A WISE view of novae

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Abstract. We present the result of trawling through the WISE archive for data on classical and recurrent novae. The data show a variety of spectral energy distributions, including stellar photospheres, dust and probable line emission. During the mission WISE also detected some novae which erupted subsequent to the survey, providing information about the progenitor systems.

1. Introduction

The Wide-Field Infrared Survey Explorer (WISE) was an all-sky mid-infrared mission (Wright et al. 2010), that operated in wavebands having effective wavelengths \( \lambda = 3.4, 4.6, 12 \text{ and } 22 \mu m \). It commenced its survey on 2010 January 14, completed its all-sky survey on 2010 July 17, and the mission terminated on 2011 February 1. In the course of its survey, WISE detected a number of classical and recurrent novae and we have trawled through the WISE archive for Galactic novae.

Classical novae are well-known to go through a nebular (and in some cases, coronal) phase when emission lines dominate the spectrum. Many of these lines, which are known to be strong in mature novae (see Gehrz et al. 2008; Evans & Gehrz 2012; Helton et al. 2012; Gehrz et al. 2013, and references therein), fall in the WISE bandpasses; for example, neon lines – which are strongest in novae that originate on ONe white dwarfs – affect WISE Bands 1, 3 and 4. As discussed by Martin (1989), infrared fine-structure lines can remain strong for many decades after the nova outburst.

Also, as discussed by Gehrz et al. (2013) and Helton et al. (2013), ~ 20% of novae (and generally those that arise on CO white dwarfs) are dust formers. The mineralogy of the dust is varied, with carbon, silicates and hydrocarbon commonly seen. The dust temperature late in the evolution is typically several hundreds of K, placing its emission in the WISE filters.

We have data-mined the WISE archive for classical and recurrent novae, including mature and recent novae, and novae that have erupted since the WISE mission. We present here the preliminary results of this trawl, and we concentrate on a selection of objects with > 4σ detections in all four WISE bands.
2. Results

2.1. Recurrent novae with giant secondaries

In Fig. 1 we show the WISE spectral energy distributions (SED) of T CrB and RS Oph, two recurrent novae with giant secondaries; we have fitted the data with black body curves having temperatures corresponding to the spectral types of the secondaries. In the case of T CrB, the WISE data are consistent with the Rayleigh-Jeans tail of the secondary, with no evidence for excess emission. However in the case of RS Oph there is clearly an excess in WISE bands 3 and 4, which we attribute to the dust known to be present in the system (Evans et al. 2007; Rushton et al. 2010, 2013). During its recurrent nova eruptions (see Evans et al. 2008, and references therein) there is evidence that the ejected material interacts strongly with the giant secondary wind and the binary environment (Mohamed et al. 2013). There seems to be little evidence for circumstellar material in the environment of T CrB and it will be interesting to see (when its long-awaited eruption occurs!) the extent to which the sequence of events that occurred during the eruption of RS Oph is replicated in T CrB.

![Figure 1](image)

Figure 1. Left: WISE SED of the recurrent nova T CrB; note that there is no evidence for an infrared excess. Right: The recurrent nova RS Oph; note the excess due to dust. In each case the temperature corresponds to the spectral type of the giant component; curves are corresponding black bodies. Error bars are smaller than the plotted points if they are not shown.

2.2. Classical novae with evidence for line emission

In Fig. 2 we show the WISE SEDs of V705 Cas (1993) and V382 Vel (1999). The former was a dust-forming nova, the eruption occurring on the surface of a CO white dwarf. There is clearly a large excess in WISE Band 4 in the SED of V705 Cas, which is very likely due to emission by the [O iv] fine-structure line at 25.89 µm and which is ubiquitous in mature novae. This line was present in V705 Cas in 1996, when it was observed with the Infrared Space Observatory (Salama et al. 1999), although it was weak when it was observed by the Spitzer Space Telescope (Werner et al. 2004; Gehrz et al. 2007); the Spitzer IRS spectrum in the region of the [O iv] line is shown in Fig. 2.

Also shown in Fig. 2 is the decline in the peak flux in the [O iv] line in V705 Cas over the period 1996 (Infrared Space Observatory) – 2007 (WISE). In a comprehensive
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Figure 2. Probable line emission in a CO nova (V705 Cas, top left) and an ONe nova (V382 Vel, top right). Error bars are smaller than the plotted points if they are not shown. Bottom left: Spitzer IRS spectrum of V705 Cas obtained on 2007 August 29, showing the \([\text{O} \ IV]\) 25.89 \(\mu\)m fine-structure line. Bottom right: decline in the peak flux in the \([\text{O} \ IV]\) line between 1996 and 2010 (dashed curve); solid curve is possible variation in the \([\text{O} \ IV]\) flux, based on Martin, (1989) analysis of DQ Her and scaled to the line flux in V705 Cas.

study of the evolution of the line emission of DQ Her (1934), Martin (1989) estimated the evolution of the strengths of a number of recombination and fine-structure lines for ~ 50 years after eruption. With the caveat that this analysis was for the specific case of DQ Her, its stellar remnant and ejecta abundances, the predicted evolution of the \([\text{O} \ IV]\) fine structure line is in surprisingly good (qualitative) agreement with the evolution of the \([\text{O} \ IV]\) line in V705 Cas.

V382 Vel, on the other hand, was an ONe nova (Woodward et al. 1999) which displayed strong neon lines (Woodward et al. 1999; Shore et al. 2003; Helton et al. 2012). The WISE SED for this object shows a strong excess in Bands 3 and 4. The WISE data are superficially consistent with the presence of strong fine-structure and coronal lines, specifically \([\text{Ne} \ II]\) 12.8 \(\mu\)m, \([\text{Ne} \ V]\) 14.3 \(\mu\)m and \([\text{Ne} \ III]\) 15.55 \(\mu\)m in Band 3, and \([\text{Ne} \ V]\) 24.32 \(\mu\)m, \([\text{O} \ IV]\) 25.89 \(\mu\)m in Band 4; all these lines were present in Spitzer spectra of V382 Vel (Helton et al. 2012). Further modelling is necessary to verify this and this is in progress.
2.3. Classical novae with evidence for dust emission

In Fig. 3 we show the WISE SEDs of DZ Cru (2003) and V1280 Sco (2007), both of which were prolific dust-producers, and both of which were observed by Spitzer. Fig. 3 includes the Spitzer data for DZ Cru from Evans et al. (2010); these data were fitted with DUSTY (Ivezić & Elitzur 1997) using amorphous carbon at $\sim 470$ K. The WISE data show that the dust emission is shifting to longer wavelengths and declining in flux as the dust disperses.

![Figure 3](image)

Figure 3. Left: Evolution of the dust shell of DZ Cru. Upper three spectra are from the Spitzer Space Telescope; the curve is a DUSTY fit. WISE data are at the bottom of the diagram, with DUSTY fit. Right: Dust shell of V1280Sco, with DUSTY fit. Error bars are smaller than the plotted points if they are not shown. See text for details.

We have attempted to fit the WISE data for DZ Cru with DUSTY. A constraint is that the inner radius of the dust shell when DZ Cru was observed by WISE (day 2351) might be expected to be related to that in 2007 (day 874) when DZ Cru was observed by Spitzer, for example by the assumption of uniform outflow; the resulting dust temperature is $\sim 320$ K, although the fit is not entirely satisfactory (see Fig. 3).

The dust shell around V1280 Sco was observed at high spatial resolution by Chesneau et al. (2012), who found that the dust resides in a bipolar configuration. The WISE data suggest that the dust temperature at the inner edge of the shell was $\sim 500$ K in 2010 (see Fig. 3).

2.4. Post-WISE novae

In Fig. 4 we show the WISE SEDs of the recurrent T Pyx and Nova Sgr 2012b.

The SED of T Pyx during the 2011 eruption is shown in Fig. 4 (top right). Data from the Herschel Space Observatory (Pilbratt et al. 2010) show excess emission longward of 50 $\mu$m, which Evans et al. (2012) attributed to interstellar dust that had been swept up by a wind (either permanent, from the binary, or from nova eruptions) from the T Pyx binary. The WISE data for T Pyx suggest an excess at 22 $\mu$m. Further work is needed to establish whether the same material is responsible for the excess pre- and post-WISE.

The WISE SED of Nova Sgr 2012b is also shown in Fig. 4 in which the WISE data have been supplemented by data from 2MASS, MSX and IRAS; we see strong emission...
Figure 4. Top left: The WISE SED of T Pyx prior to its 2011 eruption; note the excess in Band 4. Top right: The SED of T Pyx during its 2011 eruption, including data from Mt. Abu, SMARTS, Spitzer IRAC and Herschel (see Evans et al. 2012, for details); note the excess longward of $\sim 50 \mu m$, and the difference in the flux levels before and during the eruption. Bottom: WISE SED of the progenitor of Nova Sgr 2012b; WISE data have been supplemented by data from the 2MASS (open squares), MSX (small filled circles) and IRAS (triangle) catalogue. Error bars are smaller than the plotted points if they are not shown. See text for details.

which peaks at $\sim 4 \mu m$. This is consistent with optical spectroscopy of this nova, which reveals a symbiotic-like system (F. M. Walter, private communication).

3. Conclusions

While the WISE survey does not have the broad wavelength coverage of the IRAS survey it has vastly superior sensitivity and spatial resolution. It will surely be as valuable a resource for investigating the circumstellar environment of novae as was IRAS some 30 years ago (e.g. Harrison & Gehrz 1990). Moreover it has the potential to provide unprecedented information about nova progenitors.

Full details of this work will be published elsewhere.

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