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INFRARED OBSERVATIONS OF DUST AROUND HELIUM NOVA V445 PUPPIS

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ABSTRACT

We detected bright mid- to far-infrared emission from the helium nova V445 Puppis in the AKARI all-sky survey data taken in 2006. Assuming an optically thin condition, we decomposed the spectral energy distribution (SED) of V445 Puppis in October 2006 by model fitting and found that the SED can be explained by a combination of cold amorphous carbon (125 K and the mass of $4.5^{+6.6}_{-2.7} \times 10^{-4}$ M$_\odot$) and warm amorphous carbon (250 K and the mass of $1.8^{+1.0}_{-0.5} \times 10^{-5}$ M$_\odot$). Assuming that the former is pre-existing dust formed in the past nova outbursts and the latter is newly formed dust in December 2000's nova wind, this result suggests that the amount of dust formed around V445 Puppis in a single outburst is larger than 10^{-5} M$_\odot$, which is larger than those in any other classical novae ever reported.

Key words: dust, extinction – infrared: ISM – novae, cataclysmic variables – stars: mass loss

1. INTRODUCTION

Outburst of V445 Puppis was discovered at the end of 2000. While the distance to V445 Puppis is still unclear, 4.9 kpc (Iijima & Nakanishi, 2008; Kato et al., 2008) is adopted in this paper. Its companion is a helium star (Ashok & Banerjee, 2003). V445 Puppis is regarded as the only helium nova that has ever been observed. No hydrogen line was detected and the presence of strong C I emission was confirmed (Ashok, 2005). A significant decrease in the V-band light curve in July 2001 seems to correspond to the onset of dust formation in the nova ejecta of December 2000's outburst (Ashok & Banerjee, 2003). Theoretical studies suggest that the white dwarf mass is very massive ($M_{\rm WD} \geq 1.35$ M$_\odot$) and half of the accreted matter remains on the white dwarf. Consequently the white dwarf mass is expected to be increasing. Therefore, this nova is regarded as a candidate of Type Ia supernova progenitor (Kato et al., 2008).

2. OBSERVATIONS

In this research, we analyzed observational data of the AKARI all-sky survey (Kawada et al., 2007; Ishihara et al., 2010). During the survey, V445 Puppis was observed once in October 2006, day ∼2100 from the outburst. This nova was detected in 5 bands, S9W (9.0 μm), L18W (18.0 μm), N60 (65.0 μm), WideS (90.0 μm), and WideL (140.0 μm). In order to construct the whole near- to far-infrared spectral energy distribution (SED), the near-infrared observation data collected almost at the same epoch are employed from Woudt et al. (2009).

3. RESULTS OF PHOTOMETRY

The result of photometry is summarised in Table 1. The near- to far-infrared SED constructed from our observations is shown in Figure 1 with the black squares. The horizontal bars correspond to the range of wavelength in each band, and the vertical error bars indicate uncertainties in the flux. For most data points the uncertainties are smaller than the size of the squares.

4. DUST MODEL FITTING

We carried out model fitting of the SED obtained from our dataset. Assuming an optically thin case, emission of dust grains of a radius a, a total mass $M_{\rm di}$, and a temperature $T_{\rm di}$ at a distance of R can be written by

$$F_\nu(\lambda) = \left[\sum_{i=1} \frac{M_{\rm di}}{4\pi a^3 \sigma_i/3} Q_i^{\rm abs}(\lambda, a)\pi B_\nu(\lambda, T_{\rm di}) \left(\frac{a}{R}\right)^2\right] \cdot \exp\left(-\tau_\lambda\right), \quad (1)$$

where $Q_i^{\rm abs}(\lambda, a)$ is the absorption efficiency of dust with a radius of a, σ_i is the mass density of the dust particle, and τ_λ is the optical depth for foreground extinction at λ. Free parameters in this equation are $M_{\rm di}$, $T_{\rm di}$, and the foreground extinction of silicate τ_λ. We note that $Q_i^{\rm abs}(\lambda, a)$ is proportional to a^{-1} in the infrared wavelength range. Therefore, the observed flux is independent of the grain size a on conditions that $M_{\rm di}$ is treated as a free parameter. We used the value of $\tau_{(\lambda=9.7\mu{\rm m})}$ to normalise τ_λ and eventually obtained the magnitude of the foreground extinction A_V by assuming $A_V/\tau_{9.7\mu{\rm m}} = 18.5$ mag (Mathis, 1990).

As a result of the model fitting considering two components ($i = 1, 2$), we found that the observed SED can be well explained by two components of amorphous carbon with different temperatures: $4.5^{+6.6}_{-2.7} \times 10^{-4}$ $M_\odot$ at 125 K (cold component) and $1.8^{+1.0}_{-0.5} \times 10^{-5}$ $M_\odot$ at 250 K (warm component). The value of A_V is $\sim$12.5 mag. The SED of the best fit model is shown in Figure 1, where the solid line in black represents the total flux of the two components, the broken line in light gray indicates the cold component, and the dashed-dotted line in dark gray shows the warm component. Assuming that the cold component is the pre-existing dust, the warm component corresponds to the newly-formed dust in the outburst in 2000. This suggests that the amount of dust is larger than 10^{-5} $M_\odot$ per nova outburst event in the case of V445 Puppis. Such massive dust formation has never been reported in other classical novae (cf., Gerhz et al., 1992). Further observations at later epochs in the mid- to far-infrared would be important to demonstrate the dust formation history of this peculiar nova outburst.

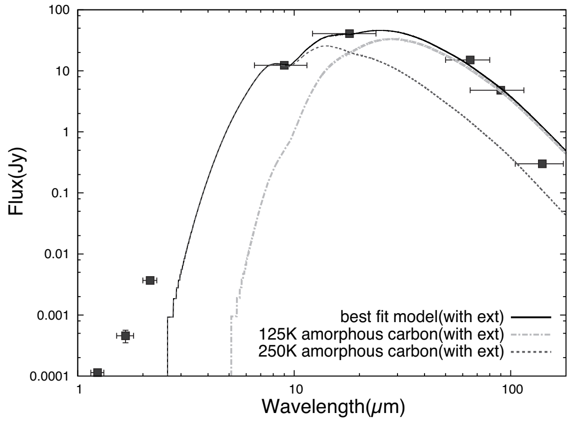

Figure 1. Observed SED of V445 Puppis at day$\sim$2100 together with the result of model fitting. The horizontal bars indicate the width of the band and the vertical bars show the uncertainty in the flux. The solid line in black shows the total emission of the two dust components. The broken line in light gray indicates the cold component, while the dashed-dotted line in dark gray shows the warm component. Each line includes the foreground extinction of $A_V = 12.5$ mag.

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Table 1
Summary of photometry of V445 Puppis at October 2006

Band	Effective wavelength (μm)	Band width (μm)	Flux (Jy)	Uncertainty (Jy)
S9W	9.0	5	12.34	0.04
L18W	18.0	12	40.7	0.05
N60	65.0	31	15.06	0.23
WideS	90.0	51	4.80	0.06
WideL	140.0	71	$< 0.09^a$	—

a: 3σ upper limit.

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