WISE J180956.27-330500.2: A Candidate AGB star with Ongoing Episodic Mass Loss

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ABSTRACT

Results of infrared photometries and dust shell modeling of a peculiar object WISE J180956.27−330500.2 are presented. The object has shown a significant time variation of its SED in the last 30 years. The variation is understood as a formation and expansion of massive dust shell since late 1990's. The object was suspected to be a red star in the optical wavelengths before the mass ejection, which allows us to hypothesize that the object is possibly the first example of the AGB star just experiencing an episodic mass loss after a thermal pulse. Observation of this object with *SPICA* after some 10 years from now will bring us an important clue to understand the stellar evolution and mass loss, as well as the chemistry in the thick circumstellar envelopes.

1. INTRODUCTION

WISE J180956.27−330500.2 (hereafter WISE J1810) was discovered in the course of studying the *WISE* Preliminary Source Catalog as an object showing a peculiar infrared SED (Figure 1) with a very deep depression at *WISE* 3.4 μm band (Gandhi et al. 2012). The depression cannot be explained by an absorption of any kind of known molecular or dust component. Instead, we found that this peculiar SED of the object can be understood as a transient effect induced by an expanding and cooling dust envelope. No attention had been paid to WISE J1810 previously before our discovery, and therefore the nature of the object is not clear. The digitized photographic survey data show that the star was possibly red. Gandhi et al. (2012) proposed an idea that the object is in the late stage of stellar evolution and the dust shell was formed by a heavy mass loss that took place in late 1990's.

Mass loss from the AGB stars is a major source of heavy elements such as carbon and oxygen into the interstellar space and plays a key role on the chemical evolution of the universe. How the mass loss develops along the evolution of the star has been an important theme in astronomy.

There are a number of AGB stars showing far-IR excess in their SED. Far-IR or radio molecular line mapping around the stars detect extended, physically thin shells, indicating that these stars ejected a significant amount of matters in a short time period thousands years ago (e.g., Olofsson et al. 2000; Izumiura et al. 2011). This phenomenon is considered in relation with thermal pulse, an explosive nuclear burning in the helium shell in the AGB stars (e.g., Iben & Renzini 1983).

WISE J1810 is possibly the first example of an episodic mass-loss for which we can make real-time observations. To clarify the nature of WISE J1810, we are carrying out follow-up observations in various wavelengths. In this article we present the recent photometry data and SED model fitting.

2. PHOTOMETRIC OBSERVATIONS

A set of far-IR–sub-mm photometric observations were carried out using the *Herschel* Space Observatory (Pilbratt et al. 2010) as a Director's Discretionary Time (DDT) observation on October 1, 2012. We carried out imaging photometry using PACS (Poglitsch et al. 2010) and SPIRE (Griffin et al. 2010) at six wavelength, 70, 110, 160, 250, 350, and 500 μm. Data reduction was made using HIPE 11. The result are presented in Figure 2. The *Herschel* data are generally well consistent with the previous observations.

Near-infrared photometry was attempted by the *Infrared Survey Facility* (IRSF; Nagayama et al. 2003) at South Africa on September 29, 2012. SIRIUS camera observed *J*, *H*, and *Ks* band simultaneously. The total exposure time was 140 minutes, resulting the detection limit of 19.3 mag = 20 μJy 18.5 mag = 41 μJy, and 18.5 mag = 27 μJy, for *J*, *H*, and *Ks* band, respectively. WISE J1810 was not detected in any of the bands, despite the fact that the object was Ks = 5.0 mag= 6.9 Jy at the *2MASS* observation epoch. More than 13.5 mag diminishing in *Ks* band supports the presence of extremely thick dust envelope.

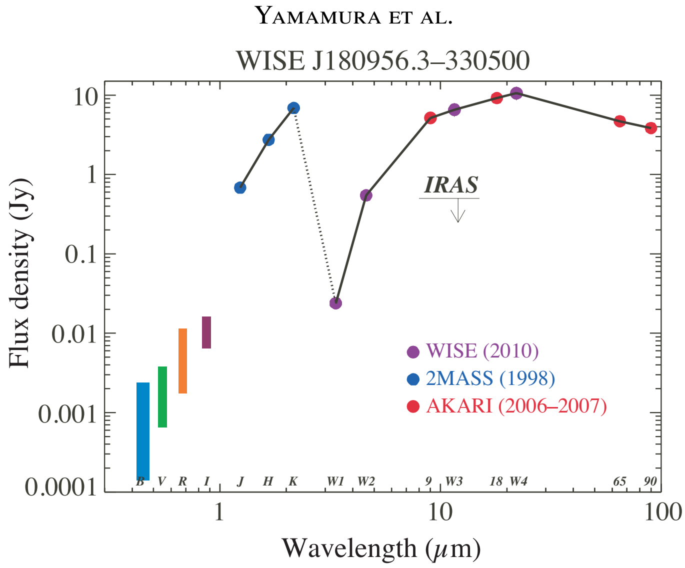

Figure 1. The SED of WISE J1810. The deep depression at 3–4 μm is not explained by any kind of absorption, and should be addressed to the time variation of the object. The optical fluxes shown by bars in the left indicate that the object was a red star.

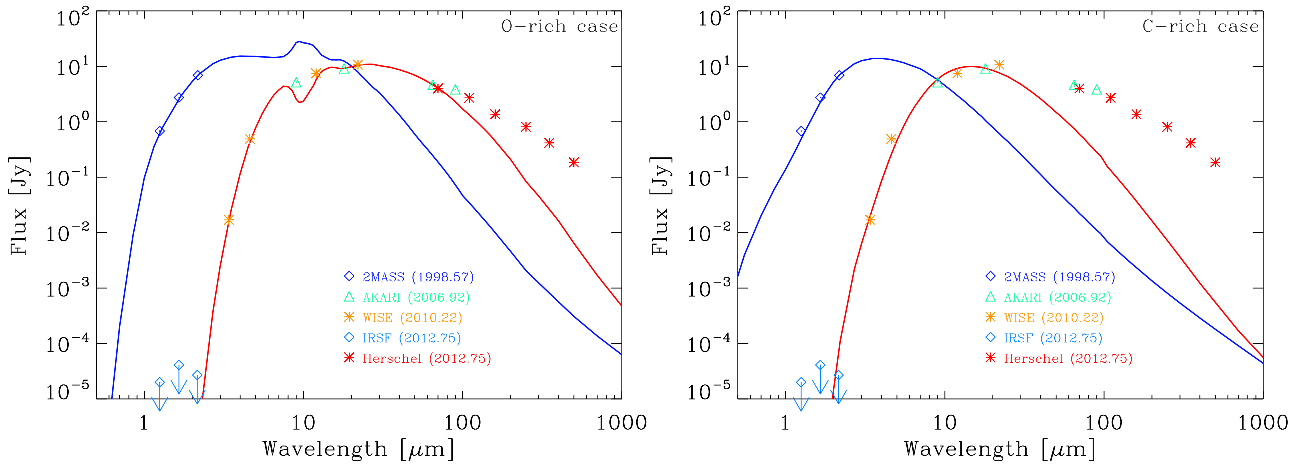

Figure 2. Photometry results of WISE J1810 and dust shell models. Dust shell models are calculated for two separate phases: warm phase (*2MASS* observation epoch) and cool phase (*AKARI–WISE–Herschel* observation ephoch), indicated in blue and red lines, respectively. Two kinds of dust components, oxygen-rich (*left*)and carbon-rich (*right*) cases are examined.

3. DUST SHELL MODELING: PRELIMINARY RESULTS

Dust shell models are constructed to derive physical parameters of the circumstellar shell around WISE J1810. We use DUSTY (Ivezić et al. 1999) for the calculation of dust radiative transfer. A spherical dust shell expanding with a constant velocity is assumed. Since we do not have any clues of dust composition of the shell, we examined two cases; warm silicate dust (Ossenkopf et al. 1992) for oxygen-rich dust shell and amorphous carbon (Hanner 1988) for carbon-rich shell. Nothing is known about the central star except for a speculation that the star is a red-giant (Gandhi et al. 2012). In addition, Gandhi et al. (2012) reported that the bolometric luminosity of the object has decreased by a factor of 4.7 between *2MASS* and *AKARI–WISE*. In the current analysis we express this variation by changing the temperature of the central star. The radius of the central star is assumed to be 1.5×10^{13} cm (1 AU). The observed SED is divided into two datasets; one is the *2MASS* data taken in 1998 and the others are *AKARI*, *WISE*, *Herschel*, and IRSF obtained recently (2006–2012). For the time being time variation in the recent several years is ignored.

The reasonable model SEDs are obtained and shown in Figure 2 and the model parameters are given in Table 1. In the both warm and cool phase the Wien side of the SED constrains the models rather severely and the parameter set for each case is quite unique. Distance is adjusted to scale the model flux to the observed flux.

4. DISCUSSION AND SUMMARY

Although the dust modeling is still preliminary, Figure 2 tells us several important aspects of WISE J1810. The oxygen-rich dust is preferred to account for the far-IR fluxes up to 70 μm. There is still an excess beyond 100 μm, which is likely

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Table 1. The derived model parameters.

Parameter	O-rich case	C-rich case
T_{star}@1998 [K]	3800	3750
T_{star}@2010 [K]	3000	3000
M_{dust}@1998 [$M_{\odot}$]	6.6×10^{-7}	9.5×10^{-8}
R_{shell}@1998 [R_{star}]	15–34	10–23
M_{dust}@2010 [$M_{\odot}$]	3.3×10^{-4}	4.0×10^{-5}
R_{shell}@2010 [R_{star}]	112–131	101–109
V_{exp} [km/s]	40	36
Mass ejection start [yr]	1997.2	1997.2
Distance [kpc]	6.1	6.4

from the dust shells from the previous, moderate mass-loss. Fitting with multiple dust shell model must be an interesting subject.

The total dust mass in the shell for the carbon-rich case is reasonably consistent with those derived from the previous analysis of the extended shells by far-IR observations (e.g., Izumiura et al. 2011). If the shell is oxygen-rich, the total dust mass is significantly larger than that. The dust mass has increased from 1998 to 2010, indicating that the mass loss was still ongoing at the *2MASS* epoch. From the expansion velocity estimated from the change of the shell radius and the thickness of the shell, we suggest that the intensive mass loss lasted only 1–2 years. It is much shorter than the expected high-luminosity period after the thermal pulse (Iben & Renzini 1983) and those expected from the far-IR observations. Further observational and theoretical studies are necessary to reveal the real nature of the phenomenon ongoing in this object.

SPICA observation of WISE J1810 will provide an essential clue to understand the nature of AGB evolution and mass loss. With an interval of some 10 years the object may be enter a new evolutionary phase. Continuous spectroscopic data in the mid- to far-IR range will be an important clue to study the evolutionary status of the object and the physical and chemical processes taking place in the thick dust shell.

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