Studies of Dust Properties in Sub−Structures around White Dwarf WD 0307+077 in IRIS Survey

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Abstract

A huge dust structure of size $3^\circ \times 3^\circ$ consisting of many sub−structures of dust nebulae and dust cavities is discovered around the WD 0307+077, located at RA (ICRS): 47.59°, DEC(ICRS):+7.84°, in far−infrared wavelength of IRIS survey. The sub−structure is divided into five isolated dust nebulae (N1, N2, N3, N4 and N5) and two cavities (C1 and C2). The dust color temperature and dust mass are calculated are calculated from the infrared flux density. For the analysis contour plot and Gaussian PDF are used. The estimation of the dust color temperature shows that the all sub−structures are moving towards the thermal stability. The possible results are presented.

Introduction

Study of interstellar dust enables us to explores the distribution of temperature and related phenomenon around the region. There have been many works exploring such events, e.g., properties of dust within the nebulae, FIR loops Pulsar, Supernova remnants, White Dwarf and many more.

In this work, I have chosen a dust structure around White Dwarf WD 0307+077. In 60 μm and 100 μm far infrared image of IRIS this dust structure is observed isolated. Furthermore, it is fragmented into many isolated sub−structures. I have calculated the dust color temperature and dust mass within the all pixels of dust structures using the infrared flux density and presented the analysis of the result.

Sources of Data

I have used data from three separate publicly available sources.

- The IRIS Miville-Deschênes and Lagache 2005 data at 60 μm and 100 μm are downloaded from SkyView Virtual Observatory (`https://skyview.gsfc.nasa.gov`).
- The Gaia Early Data Release 3 (Gaia EDR3) are used from Gaia Archive (`https://gea.esac.esa.int/archive`) for distance.
- The SIMBAD (`http://simbad.u-strasbg.fr/simbad/sim-fcoo`) is used to study the background sources.

Methodology

The estimation of dust color temperature using infrared flux density is done following the method given by Wood et al. 1994 and Schnee et al. 2005, which is given as;

$$T_d = \frac{-96}{ln\{R \times 0.6^{(3+\beta)}\}} \quad (1)$$

Where, R is the ratio of flux density at 60 μm and 100 μm and β is the spectral emissivity index which takes the values from 0 to 2 following Dupac et al. 2003. Using the longer wavelength infrared flux density I have calculated the dust mass following the Schnee et al. 2005, Young et al. 1993 and Hildebrand 1983. The expression for calculation of mass of dust is;

$$M_{dust} = 0.4[\frac{S_\nu D^2}{B(\nu, T_d)}] \quad (2)$$

Where, S_ν= F(100 μm) × MJy/Str × 5.288 × 10^{-9}, 1 MJy/Str = 1 ×10^{-20} kg s^{-2} is the flux density in SI unit, D = 399.28 pc is the distance to the dust structure calculated using Gaia EDR3 and B(ν, T_d) is the Planck's function. To calculate the mass of gas, we assume that the mass of gas is 200 times of the mass of the dust on the basis of Henning and Mutschke 1997.

Results

Structures and Background Sources

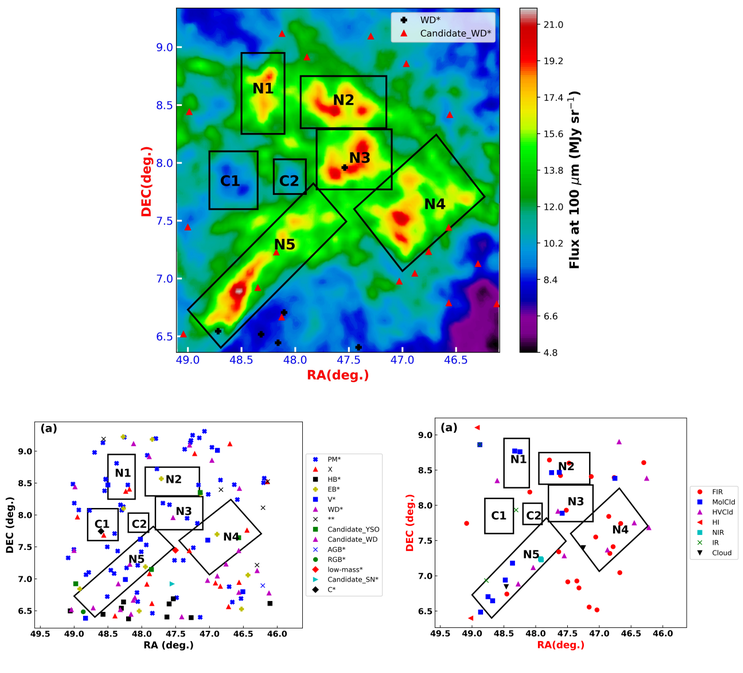

Figure 1. Upper panel shows the 3°×3° IRIS 100 μm FITS image of dust structure located RA (ICRS): 47.59° and DEC (ICRS): +07.84°. The sub−structures are encircled by rectangles. Lower panel shows the important SIMBAD sources within the Dust Structure.

Table 1. Major background sources within dust structure taken from SIMBAD are presented below. OTYPE represents the types of source, name are given according the symbol used in SIMBAD and count represents their number. There are altogether 582 sources within the selected rectangular region.

OTYPE	Count	OTYPE	Count	OTYPE	Count
Star	190	EB*	11	ClG	3
Galaxy	67	LensedImage	11	IR	3
PM*	62	HVCld	10	Cloud	2
Radio	59	HB*	10	brounD*	2
FIR	22	V*	7	GroupG	2
Candidate-WD*	18	WD*	6	PairG	2
X	17	**	6	HI	2
QSO	16	Candidate-YSO	4	NIR	2
MolCld	12	Possible-lensImage	3	Pec*	2
RRLyr	12	AGN-Candidate	3	RGB*	1

Dust Color Temperature

The basic statistics of dust color temperature in each sub−structures is presented in **Table III**.

Table 2. The table shows the statistical information of dust color temperature in total and isolated region of all sub−structures.

Structures	Tmax (K)	Tmin (K)	Tav (K)	Range (K)
Large:All	24.45 ± 1.30	20.18 ± 0.83	21.84 ± 0.01	4.27 ± 1.07
N1: All	22.70 ± 0.40	21.05 ± 0.43	21.91 ± 0.02	1.65 ± 0.43
Isolated	22.70 ± 0.34	21.05 ± 0.49	22.02 ± 0.01	1.65 ± 0.41
N2: All	22.74 ± 0.37	21.03 ± 0.49	22.00 ± 0.01	1.71 ± 0.43
Isolated	22.74 ± 0.22	21.85 ± 0.23	22.28 ± 0.01	0.89 ± 0.22
N3: All	22.73 ± 0.41	21.33 ± 0.29	22.15 ± 0.01	1.40 ± 0.35
Isolated	22.51 ± 0.14	21.87 ± 0.18	22.23 ± 0.01	0.64 ± 0.16
N4: All	23.10 ± 0.54	20.32 ± 0.85	22.03 ± 0.01	2.79 ± 0.70
Isolated	22.94 ± 0.32	21.64 ± 0.33	22.30 ± 0.01	1.30 ± 0.32
N5: All	23.28 ± 0.29	20.78 ± 0.41	22.22 ± 0.01	2.50 ± 0.35
Isolated	23.28 ± 0.35	21.66 ± 0.46	22.59 ± 0.01	1.62 ± 0.41
C1: All	22.60 ± 0.27	21.38 ± 0.33	21.05 ± 0.01	1.22 ± 0.30
Isolated	22.38 ± 0.23	21.38 ± 0.27	21.92 ± 0.01	0.99 ± 0.25
C2: All	22.75 ± 0.32	21.54 ± 0.28	22.11 ± 0.01	1.21 ± 0.30
Isolated	22.55 ± 0.30	21.57 ± 0.19	21.94 ± 0.02	0.98 ± 0.24

Contour Plot

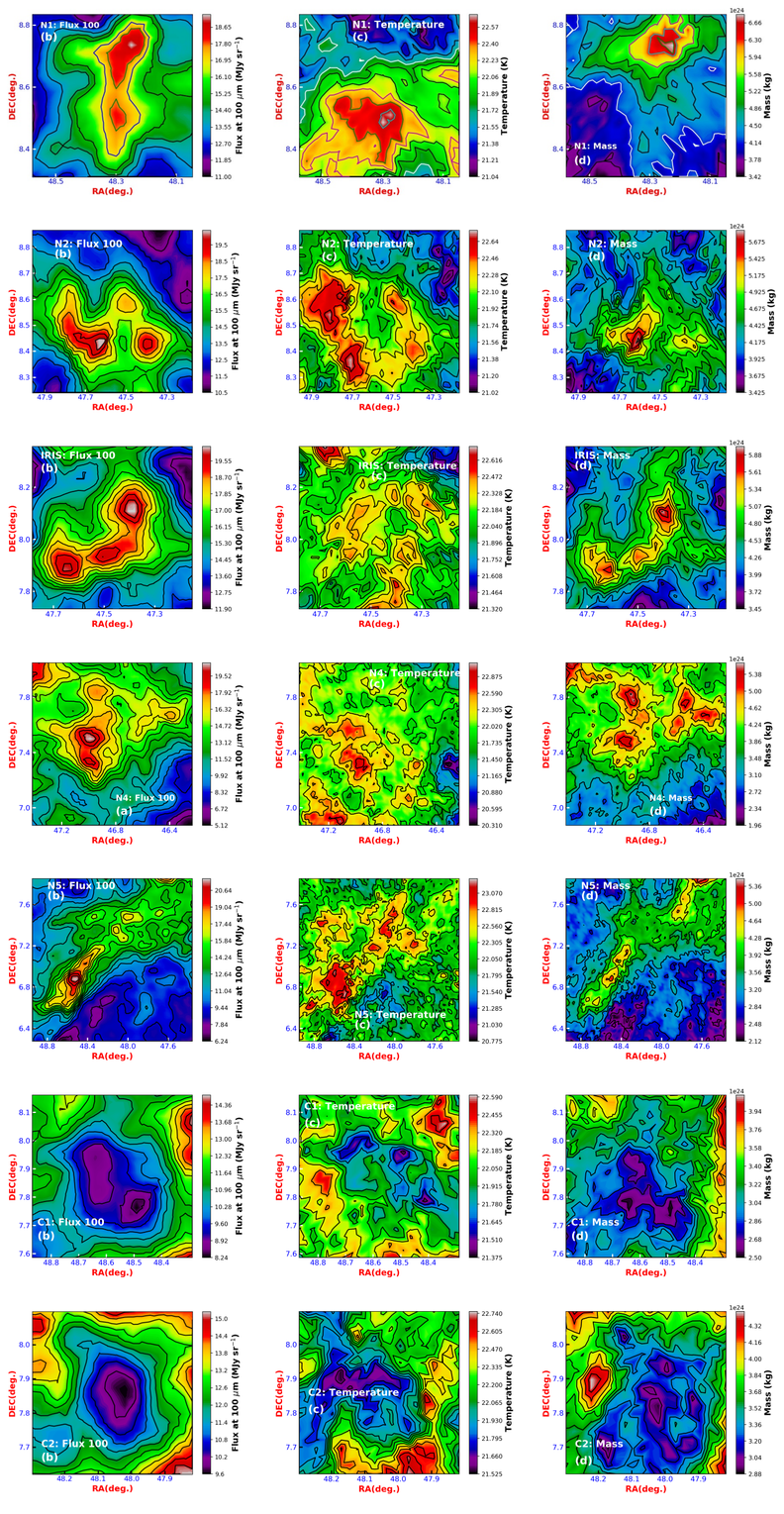

Figure 2. The figures shows the contour maps for infrared flux (b), dust color temperature (c) and dust mass (d) for all sub−structures.

Mass and Gaussian Distribution of Temperature

Table 3. The table presents the Dust and Gas mass in kg and in terms of solar mass in dust structure and sub −structures.

Structures	Dust Mass (kg)	Dust Mass ($M_\odot$)	Gas Mass (kg)	Gas Mass ($M_\odot$)
Large: All	5.25×10^{28}	2.64×10^{-2}	1.05×10^{31}	5.28
N1: All	3.63×10^{27}	1.82×10^{-3}	7.26×10^{29}	0.36
Isolated	7.95×10^{26}	4.00×10^{-4}	1.59×10^{29}	0.08
N2: All	3.63×10^{27}	1.82×10^{-3}	7.26×10^{29}	0.36
Isolated	1.20×10^{27}	6.03×10^{-4}	2.40×10^{29}	0.12
N3: All	3.03×10^{27}	1.50×10^{-3}	6.06×10^{29}	0.30
Isolated	1.31×10^{27}	6.59×10^{-4}	2.62×10^{29}	0.13
N4: All	8.31×10^{27}	4.50×10^{-3}	1.78×10^{30}	0.90
Isolated	1.76×10^{27}	8.86×10^{-4}	3.51×10^{29}	0.18
N5: All	1.34×10^{28}	6.75×10^{-3}	2.69×10^{30}	1.351
Isolated	2.91×10^{27}	1.47×10^{-3}	5.85×10^{29}	0.29
C1: All	1.82×10^{27}	9.13×10^{-4}	3.63×10^{29}	0.18
Isolated	6.15×10^{26}	3.09×10^{-4}	1.20×10^{29}	0.06
C2: All	1.42×10^{27}	7.13×10^{-4}	2.84×10^{29}	0.14
Isolated	3.38×10^{26}	1.79×10^{-4}	6.76×10^{28}	0.03

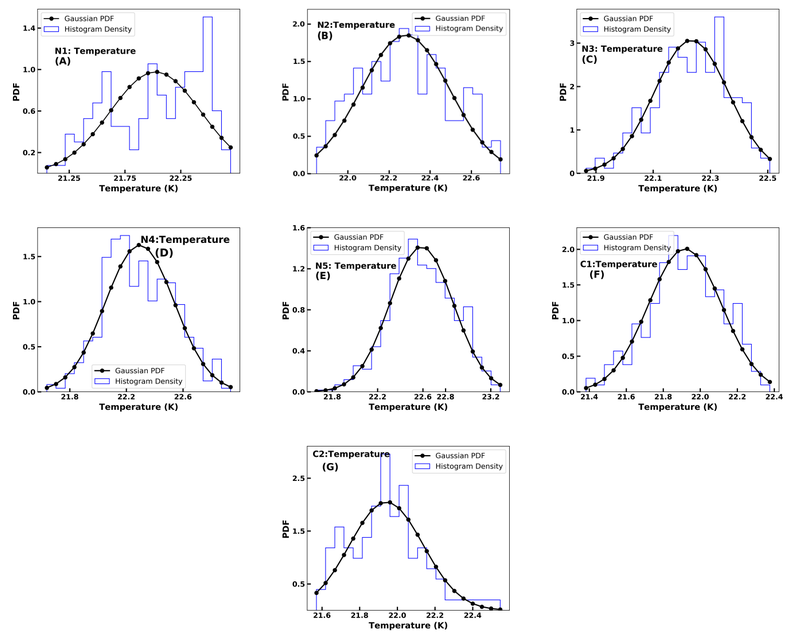

Figure 3. Figure shows the Gaussian distribution for dust color temperature for sub−structures.

Conclusions

- The dust color temperature of all the nebulae and cavities lie between the 20 K to 24 K, with range not more than 3 K. This much range of temperature suggests that the sub−structures are moving towards the thermal stability.
- The dust mass also reports the similar mass composition within all sub−structures.
- Study of Gaussian distribution of dust color temperature shows the sub−structures are more or less disturbed by the background sources observed in the SIMBAD database, which includes the various type of stars and ISM components.

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