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Dust Structure around AGB Star in 60µm and 100 µm IRAS Survey at Latitude 16.10^0

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Abstract: *A systematic search in the range of J2000 coordinate system provided by K.W. Shu & Y.J. Kwon (2011) of dust structure in the far infrared (100 µm and 60 µm) IRAS (Infrared Astronomical Satellite) survey was performed using Sky View virtual Observatory (1) so that some interesting isolated cavity structures surrounding the cavity structure were expected. The FITS images downloaded from sky view (1) was processed using software Aladin v 2.5. A cavity like structure (major diameter ~ 3.57 pc & minor diameter ~ 1.19 pc) lies in the coordinate of R.A. (J2000) 06h 31m 05s and DEC (J2000) 16d 06m 00s was found at the distance ~ 310 pc (5). We studied the flux density variation and the temperature variation about major diameter, minor diameter and the distance between minimum temperature and minimum flux within the structure. We observed the variation of the temperature is 20.53 K to 21.42 K, with the offset of about 0.89 K, which shows the cavity is independently evolved. The mass profile of each pixel of the structure was also calculated using these temperature.*

Keywords : AGB Star, Interstellar medium, Flux density, Dust color temperature, Mass of dust, Excess mass

1. INTRODUCTION

Low-to-intermediate mass stars end their life on the asymptotic giant branch (AGB) star. AGB stars are the main distributors of dust into the interstellar medium due to their high mass loss rates in combination with an effective dust condensation. It is therefore important to understand the dust formation process and sequence in their extended atmosphere. The interaction between wind and its surroundings in the interstellar medium (ISM) provides a laboratory to study the behavior of dust particles. Actually Asymptotic giant branch (AGB) stars are the final evolution stage of low- and intermediate-mass stars driven by nuclear burning. This phase of evolution is characterized by nuclear burning of hydrogen and helium in thin shells on top of the electron-degenerate core of carbon and oxygen, or for the most massive superAGB stars a core of oxygen, neon, and magnesium. In particular, the recurrent thermonuclear flashes that induce a complex series of convective mixing events provide a rich environment for nuclear production. The nucleosynthesis in AGB stars plays an important role for our understanding of the origin of the elements. AGB stars are the major contributors to the integral luminosity of intermediate-age stellar systems)

1.1 Data Reduction

Each pixels of the FITS image of our region of interest are analyzed using software Aladin v2.5 which is one of the handy and extensively used software in the data reduction processes. This software is designed to reduce and analyze the data collected from the ground based and space telescopes covering all wavelength regions. Information regarding the energy spectrum, relative flux density with coordinate of each pixel, different types of contour maps, longitude and the latitude of the desired structure can be obtained by using this software.

1.2 Contour Map

We intend to study the isolated cavity structure at 60 µm and 100 µm. We adopt the method of drawing contours at different levels so that we can separate the region of maximum and minimum flux density. The best contour level of the selected FITS image is chosen in between 1 to 38.
We are interested in these maxima to study the flux density within the region because our focus is on the temperature prophile and the mass distribution of the dust within the isolated structure. We are interested to study the temperature and mass profile of isolated structure and possibility of star formation in this region. The contour picture is shown in fig.1.

1.3 Flux Density Variation

To calculate temperature and mass of each pixel due to the contribution of dust, we need flux density of all pixel lying inside the outermost contour i.e. isoconter level 38 at 60 μm and 100 μm respectively. It is done by using software Aladin v2.5. Variation of flux density with distance along major diameter (AB), minor diameter CD and the distance between minimum temperature and minimum flux density.

1.4 Dust Color Temperature Estimation

Adopting the similar method as that of Schnee et al. (2005) the dust temperature was calculated from the IRAS 60 μm and 100 μm flux densities[3]. By knowing the ratio of flux densities at 60 μm and 100 μm, the temperature contribution due to dust color can be calculated. The dust temperature T_d in each pixel of a FIR image can be obtained by assuming that the dust in a single beam is isothermal and that the observed ratio of 60 μm to 100 μm emission is due to black body radiation from dust grains at T_d, modified by a power law of spectral emissivity index. The flux density of emission at a wavelength λ_i is given by

$$F_i = \left[\frac{2hc}{\lambda_i^3\left(e^{\frac{hc}{\lambda_i kT_d}}\right)-1}\right] N_d \, \alpha\lambda \, \frac{-\beta}{i} \, \Omega i \quad \text{... (1)}$$

where β is the spectral emissivity index, N_d is the column density of dust grains, α is a constant which relates the flux with the optical depth of the dust, and Ω_i is the solid angle subtended at λ_i by the detector. We use the equation following Dupac et al. (2003)[4].

$$\beta = \frac{1}{\delta + \omega Td} \quad \text{... (2)}$$

to describe the observed inverse relationship between temperature and emissivity spectral index.

With the assumptions that the dust emission is optically thin at 60 μm and 100 μm and that $\Omega_\omega \sim\sim \Omega_{100}$ (true for IRAS image), we can write the ratio, R, of the flux densities at 60 μm and 100 μm as

$$R = 0.6^{-(3+\beta)} \frac{e^{144/T_d} - 1}{e^{240/T_d} - 1} \quad \text{... (3)}$$

The value of β depends on dust grain properties like composition, size, and compactness. For reference, a pure blackbody would have β = 0, the amorphous layer-lattice matter has β ~ 1, and the metals and crystalline dielectrics have β ~ 2.

For a smaller value of T_d, 1 can be dropped from both numerator and denominator of Eq. (3) and it takes the form

$$R = 0.6^{-(3+\beta)} \frac{e^{144/T_d}}{e^{240/T_d}} \quad \text{... (4)}$$

Taking natural logarithm on both sides of Eq. (4) , we find the expression for the temperature as

$$T_d = \frac{-96}{In\{R \times 0.6^{(3+\beta)}\}} \quad \text{... (5)}$$

where R is given by

$$R = \frac{F(60\mu m)}{F(100\mu m)} \quad \text{... (6)}$$

F(60 μm) and F(100 μm) are the flux densities in 60 μm and 100 μm respectively. One can use Eq. (5) for the determination of the dust grain temperature.

1.5 Dust Mass Estimation

Further analysis of the structure need the mass of the structure. Dust masses are estimated from the infrared background corrected flux densities at 100 μm image. The distance of the structure was provided by Weinberger (2014) [5]. We are calculating dust mass following the analysis of Meaburn et al. (2000)[6]. The infrared flux can be measured from IRAS Sky View images and images from the Groningen using ALADIN2.5. The resulting dust mass depends on the physical and chemical properties of the dust grains, the adopted dust temperature and the distance to the object. The final expression for the dust mass can be written as:

$$M_{dust} = \frac{4a\rho}{3Q_\nu} \left|\frac{S_\nu D^2}{B(\nu,T)}\right| \quad \text{... (7)}$$

where, a = weighted grain size , ρ = grain density, Q_ν = grain emissivity

S_ν = f × MJy/Str × 5.288 × 10^{-9} where, 1 MJy/Str = 1 ×10^{-20} Kg s^{-2} and f = relative flux density measured from the image (IRAS 100 μm image).

D = distance of the structure

B(ν, T) = Planck's function, which is the function of the temperature and the frequency and given by the expression:

$$B(\nu, T) = \frac{2h\nu}{C^2} \left[\frac{2hc}{e^{\frac{h\nu}{kT}} - 1}\right] \quad \text{... (8)}$$

where, h = Planck's constant, c = velocity of light ν = frequency at which the emission is observed, T = the average temperature of the region

Value of various parameters we use in the calculation of the dust mass in our region of interest are as follows:

a = 0.1 μm [Young et al. (1993)]

ρ = 1000 Kg m^{-3} [Young et al.(1993)]

Qν = 0.0010 for 100 μm and 0.0046 for 60 μm respectively [Young et al. (1993)].

Using these values the expression (7) takes the form:

$$M_{dust} = 0.4 \left[\frac{S_v D^2}{B(v,t)} \right] \quad \ldots (9)$$

We use the above equation for the calculation of the dust mass.

2. RESULT AND DISCUSSION

2.1 Structure: Contour Maps

While going through the systematic search we discovered an isolated cavity in the spectrum of the 100 μm and 60 μm at the R.A. 06h 31m 16s and DEC 16◦ 06 m 00 s. With the help of the software ALADIN2.5, we have drawn the contour maps to distinguish the minimum flux region in the field of the interest. We select the contour level at 38 and major axis, minor axis and line passing through minimum temperature and minimum flux was drawn which was shown in the Fig 1. While drawing the major axis and the minor axis we should pass it through the minimum flux pixel.

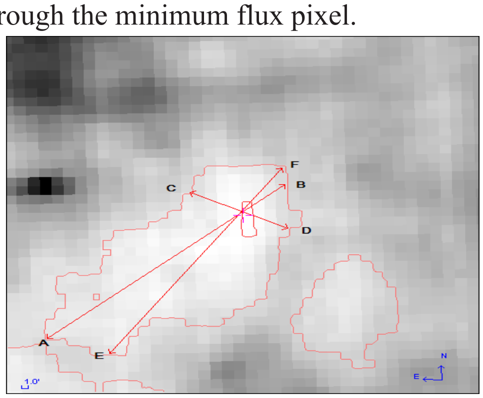

Fig. 1

Figure 1. The image of IRAS survey of the R.A. 06h 31m 05s and DEC 16◦ 06 m 00 s at the contour level 38 with major axis AB, minor axis CD, line joining minimum temperature and minimum flux EF.

This gives the distance of major diameter of the structure is 3.57 pc and minor diameter of the structure is 1.19 pc, whose calculation is shown latter.

2.2 Flux Density Variation

By using the ALADIN2.5 software, flux density variation of the region of interest is studied. We obtained the graph of flux density variation along the major axis, minor axis and line joining the minimum temperature region and minimum flux region considering R.A. 06h 31m 05 s and DEC 16◦ 06m 00 s as center. We plotted it with the help of the ORIGIN5.0 for the polynomial fit of the data.

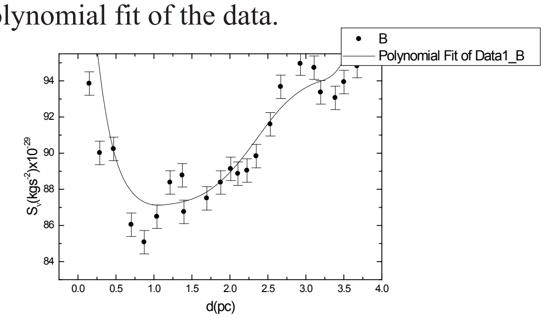

Fig. 2

Figure 2: Showing the variation of flux density along major diameter of isocontour level 38 . The distribution of flux density along major diameter with distance of AGB star AGB 06315, +1606.The solid circle with ±σ/√n error bar represents the standard error of the distribution. The solid curve represents the best fit polynomial(6th order polynomial).

The polynomial equation of the fitted line is,

$S_v = 101.27 - 61.08\, d + 102.53\, d^2 - 86.20\, d^3 + 38.08\, d^4 - 8.27\, d^5 + 0.69\, d^6$

Similarly the variation of flux density along minor diameter is plotted.

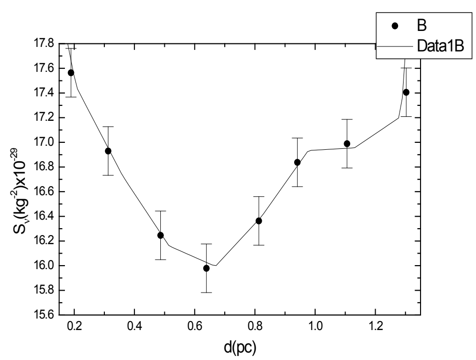

Fig. 3

Figure 3: Showing the variation of flux density along minor diameter of isocontour level 38 . The distribution of flux density along minor diameter with distance of AGB star AGB 06315, +1606. The solid circle with ±σ/√n error bar represents the standard error of the distribution. The solid curve represents the best fit polynomial(7th order polynomial).

The polynomial equation of the fitted line is,

$$S_v = 110.45 - 193.46d + 838.65\,d^2 - 2060.62\,d^3 + 2572.93\,d^4 - 1399.05d^5 + 136.13d^6 + 84.74d^7$$

Then we studied the variation of flux density with the distance along the line joining the minimum flux and minimum temperature.

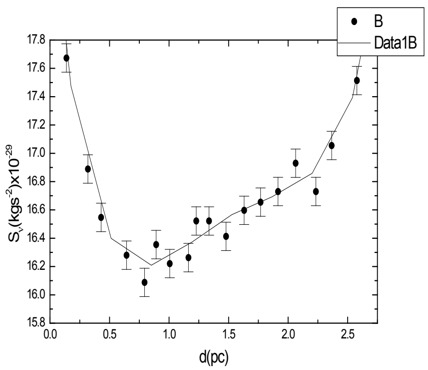

Fig. 4

Figure 4: Showing the variation of flux density along distance between minimum temperature and minimum flux of isocontour level 38 of the same AGB star. The solid circle with $\pm\sigma/\sqrt{n}$ error bar represents the standard error of the distribution. The solid curve represents the best fit polynomial(4rth order polynomial).

The polynomial equation of the fitted line is,

$$S_v = 98.48 - 42.41d + 48.40\,d^2 - 22.11\,d^3 + 3.63\,d^4$$

2.3 Dust Color Temperature Variation

Using the method of Schnee et al. (2005)[3] ,we calculated dust color temperature of each pixel inside the outer isocontour 38 in the region of interest. We use the IRAS 100 μm and 60 μm FITS images downloaded from the IRAS server[1]. For the calculation of temperature we choose the value of β = 2 following the explanation given by Dupac et al. (2003)[4]. The region with minimum and maximum temperature is found to lie in the range of 20.53 K to 21.42 . So offset temperature is 0.89 K. It means for low temperature variation , there is symmetric outflow or symmetric distribution of density and temperature. Variation of temperature along major diameter AB with distance is shown in figure 5.

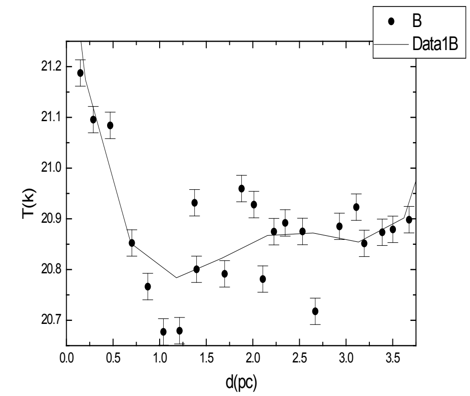

Fig. 5

Figure 5: Showing the variation of dust temperature with distance along major diameter AB of isocontour level 38 of the same AGB star. The solid circle with $\pm\sigma/\sqrt{n}$ error bar represents the standard error of the distribution. The solid curve represents the best fit polynomial(5^{th} order polynomial).

The polynomial equation of the fitted line is,

$$T = 21.43 - 1.46d + 1.11d^2 - 0.31d^3 + 0.02d^4 + 0.002d^5$$

Variation of dust temperature along minor diameter CD with distance is shown in figure 6.

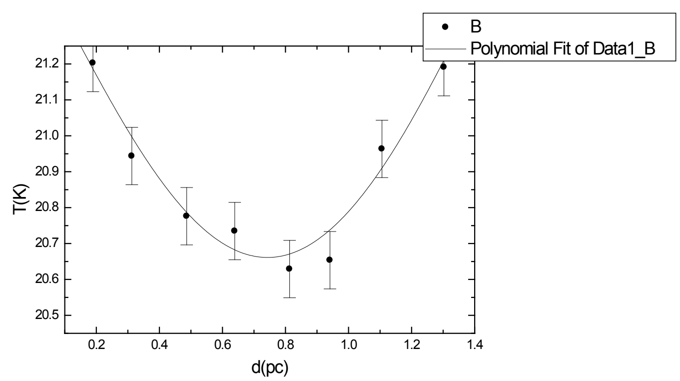

Fig. 6

Figure 6: Showing the variation of dust temperature with distance along minor diameter CD of isocontour level 38 of the same AGB star. The solid circle with $\pm\sigma/\sqrt{n}$ error bar represents the standard error of the distribution. The solid curve represents the best fit polynomial(4^{rth} order polynomial).

The polynomial equation of the fitted line is,

$$T = 21.50 - 1.64\,d - 0.67d^2 + 2.37d^3 - 0.78\,d^4$$

Similarly the variation of dust temperature along line joining between minimum temperature and minimum flux EF with distance is shown in figure 7.

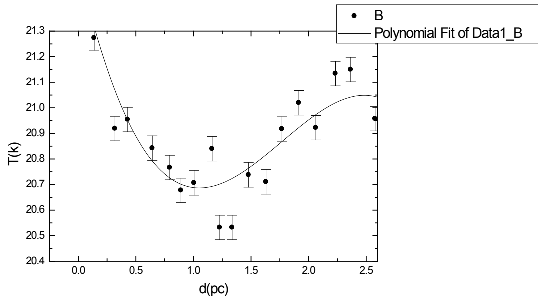

Fig. 7

Figure 7: Showing the variation of dust temperature along line joining between minimum temperature and minimum flux EF of isocontour level 38 of the same AGB star. The solid circle with $\pm\sigma/\sqrt{n}$ error bar represents the standard error of the distribution. The solid curve represents the best fit polynomial(3rd order polynomial).

The polynomial equation of the fitted line is,

$$T = 21.51 - 1.90d + 1.31d^2 - 0.25d^3$$

The region in which minimum and maximum temperature is found in the range of 20.53K to 21.42 K with an offset temperature of dust 0.89 K . Such low offset temperature variation shows that there is symmetric outflow or symmetric distribution of density and temperature. It further suggests that our structure is not independently evolved or the role of discrete point sources in the field of cavity is important for the structure destruction mechanism. The cavity may be in thermally pulsating phase. The dust color temperature less than 20 K represents the interstellar cirrus cloud. Thus our far infrared dust structure (i.e. Cavity) is not a cirrus cloud. Another region of cloud fulfill the criteria of Cirrus clod.

2.4 Size of the Structure

To measure the major and minor diameter for each FITS image, we used a simple expression for the calculation, L = R × θ, where R = 310pc is the distance of the structure from us provided by Weinberger (5) and θ = pixel size (in radian). After calculation the major and minor diameter of the cavity region are 3.57 pc and 1.19 pc respectively at contour level 38 in the 100 μm image. Thus, the size of the structure is 3.57 pc × 1.19 pc .

2.5 Dust Mass Estimation

For the calculation of dust mass, we need the distance to the region of interest. The distance of the structure provided by Weinberger (2014)[5] is 310 pc. By using the temperature of each pixel and corresponding distance of the structure, we calculated mass of each pixel. Average mass of each pixel is 8.22×10^{25} kg and total mass of the structure is 2.06×10^{28} kg.

2.6 Calculation of Excess Mass

For calculation of excess mass, we have drawn two circles i.e. inner and outer circle with the help of software Aladin v8.0 . Circle through major diameter is supposed as outer circle and the circle through minor diameter is supposed as inner diameter of the interested region . With the help of those circle we have calculated excess mass

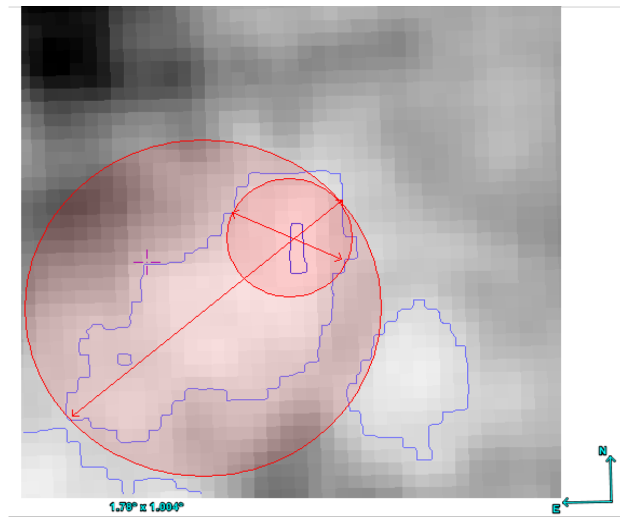

Fig. 8

Figure 8: Showing the inner circle and outer circle drawn in the structure for calculation of excess mass.

From the calculation total mass of the inner circle was found to be 5.54×10^{27} kg and average mass of inner circle was 8.148×10^{25} kg. Similarly the total mass of outer circle including inner circle was 4.709×10^{28} kg and the average mass was 8.440×10^{25} kg. So the average mass deficit in the inner pixel which was blown away by the AGB star is 4.7×10^{28} kg i.e.o.o236 M_{sun} per pixel.

3. CONCLUSIONS

A systematic search of dust structure in the far infrared (100 μm and 60 μm) IRAS (Infrared Astronomical Satellite) survey was performed using Sky View Virtual Observatory to find an isolated new cavity. We searched for the all C-rich AGB star surrounding in our galaxy, we found an isolated cavity like structure having cavity at both 60 μm and 100 μm wavelength at the center R.A. 06d 31m 0 s and DEC

16◦ 06m 00s . The distance of the structure was found to be 310 pc[5]. The software ALADIN2.5 is used for the data reduction and ORIGIN5.0 for the plotting graphs. The physical properties of the structure, a study of flux density and temperature variation, dust color temperature, mass of dust, mass deficit per pixel of the cavity was calculated. Our conclusion are as follows:

- The major and minor diameter of the cavity like structure is found to be 3.57 pc and 1.19 pc respectively.
- The maximum and minimum flux was found to be at R.A. 06h 33m 49.4s DEC +15◦ 34m 37.6s & R.A. 06h 32m 36,6s DEC +15◦ 49m 47s . maximum and minimum temperature is at R.A. 06h 32m 22.1s DEC 15◦ 50m 51s & at R.A. 06h 32m 49.1s DEC 15◦ 55m 17s respectively.
- The region in which minimum and maximum temperature is found in the range of 20.53K to 21.42 K with an offset temperature of dust 0.89 K . Such low offset temperature variation shows that there is symmetric outflow or symmetric distribution of density and temperature.
- The flux and the temperature variation does not fit the Gaussian variation it mean the cavity prefer polytropic behavior.
- The total mass of the inner circled cavity was 5.54×10^{27} Kg, the average mass of the inner circle was 8.148×10^{25} Kg and that of the outer circle including inner was 4.709×10^{28} Kg and 8.44×10^{25} Kg respectively. The mass deficit per pixel of the structure was 4.7×10^{28} Kg i.e. 0.0236 M_{sun}.

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