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A study of far infrared loop at -5° Galactic latitude around pulsar J1627-5547

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Abstract

We present physical properties of the core region of infrared loop G329-05 which is found to be located within 1° from the pulsar PSR J1627-5547. The loop has 3-fold reduced flux density than its surroundings. In the 100 micron infrared map, a new cavity-like isolated far infrared dust structure of core region (size ~0.75^0 x 0.23^0 **)** is found at R.A. (J2000)= $16^h\ 27^m\ 19.9^s$ & Dec. (J2000) = $-56^0 35'14''$. This loop is believed to be formed because of high pressure events occurred in the past. The dust color temperature of the core region is found to lie in the range 25.26 ± 0.09 K to 27.91 ± 0.09 K, whereas the value of dust color temperature increased to 36.72 ± 0.18 K for the outer region. The dust color temperature and dust mass distribution maps showed that the low temperature region has greater density as expected. The dust mass of the core region of the loop is found to be 1.67 x 10^{27} kg i.e. about 0.00835 $M_\odot$. The core region of the loop is found to be edge-on ($i > 78^0$) whereas the larger structure is faced-on ($i = 0^0$). Possible explanation of results will be presented.

Keywords: ISM; Far infrared loops; Dust color temperature and Dust mass; inclination angle.

1. Introduction

The large scale structure of the interstellar medium (ISM) in the galaxy is diverse, with a complex distribution of cavities, filaments, arcs, loops, lobes and shells [1]. The most studied Galactic shells were formed by supernova explosions and winds of massive stars [2]. However, high velocity clouds may also form large cavities when in falling from the Galactic halo and colliding with the ISM of the disc. A remarkable example of high velocity cloud – Galactic disc interaction is the north celestial pole loop [3]. The evolution of bubbles and super bubbles produced by supernovae explosions and stellar winds of association are the primary processes that determine the structure and energetic of all components of the diffused interstellar medium. Kiss et al. (2004) & Koenyves et al. (2007) [4, 5] identified 462 Far infrared loops using 100 and 60 µm IRAS maps. They studied their size, luminosity, distributions and concluded that these structures are formed and governed by supernovae and stellar winds at the low galactic latitude. At high galactic latitude fractal structures of loops suggest the probability of super-sonic turbulence. On 100 and 60 µm IRAS maps [6] found two giant (2.1 pc, 0.9pc) bipolar dust emission structures centered on PN NGC 1514 representing one of the very few none cases where the preserved history of all main mass-loss phases of a star of intermediate initial mass. We intend to find the physical properties of infrared loop (Kiss et al., 2004 & Koenyves et al., 2007; KK loop here after) near to ATNF pulsar.

In the present work, we intend to find an isolated far infrared cavity nearby pulsar and KK-loop and study its physical properties (dust color temperatures, dust mass, inclination angle, etc). Finally we are interested to understand its formation and evolution. The role of the pulsar in the structure formation will be discussed.

2. Region of Interest

By performing systematic search using the catalogue reported by Kiss et al. [4] and Koenyves et al.[5], we have selected a new cavity-like region close to far infrared cavity GIRL G329-05 for the study. Following are the selection criteria of the loop:

a) The core region of the loop should have flux minima at 100μm IRAS maps,
b) the major diameter should be greater than 0.5^0,
c) should be located within 1^0 of ATNF pulsar,
d) should lie in the Galactic plane ($-20^0 < b < 20^0$), and
e) no diffuse optical emission

The loop is centered at R.A. (J2000) = $16^h\ 27^m\ 19.9^s$ & Dec. (J2000) = $-56^0 35' 14''$ prominent cavity is seen in both bands 60μm and 100μm. The pixel size of the image is $0.8^0 \times 0.8^0$ as shown in fig 1.

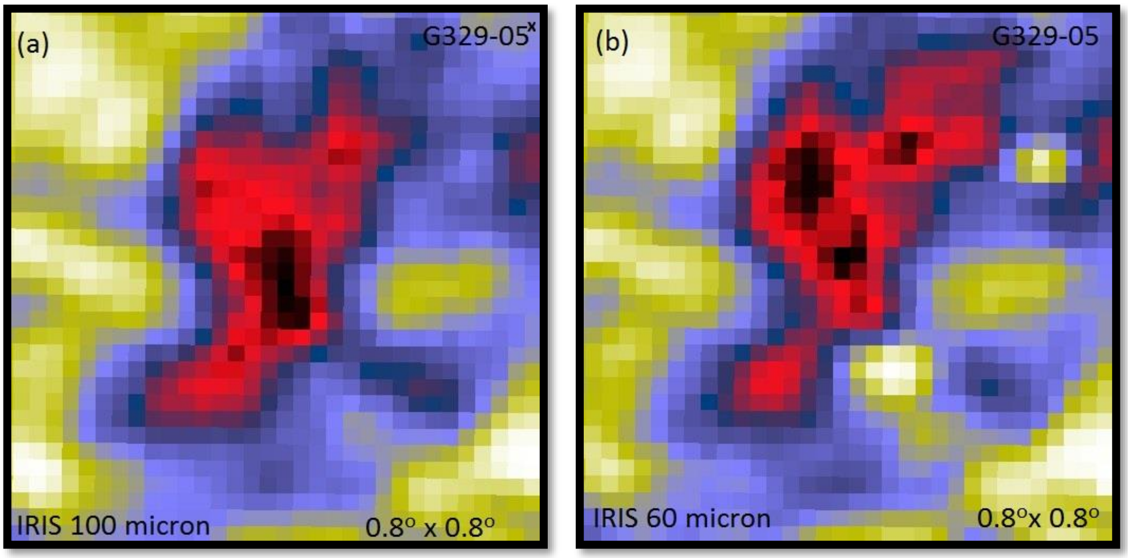

Fig. 1: $0.8^0 \times 0.8^0$ IRAS image of our region of interest at 100 micron (a) and 60 micron (b) JPEG images of G329-05 KK-loop having cavity. The 'x' sign in the North-East corner represents the position of pulsar J1627-5547. (Source: Sky view virtual observatory, 2017)

3. Methods

3.1 Dust Color temperature Estimation:

We adopt the method developed by Schnee [7] to calculate the dust color temperature from the IRAS 60μm and 100μm flux densities. For dust color temperature estimation we use the expression as

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

The value of the spectral emissivity index (β) depends on dust grain properties as composition, size, and compactness. For reference, a pure blackbody would have $\beta = 0$, the amorphous layer-lattice matter has $\beta \sim 1$, and the metals and crystalline dielectrics have $\beta \sim 2$ [8].

where R is given

$$R = \frac{F(60\ \mu m)}{F(100\ \mu m)} \tag{2}$$

F (60 micron) and F (100 micron) are the flux densities at 60 μm and 100 μm, respectively. In this way we can use equation (1) for the determination of the dust grain temperature (Dupac et al. 2003).

3.1 Dust Mass Estimation

The dust masses are estimated from the IR flux densities. The resulting dust mass depends on the physical and chemical properties of the dust grains, the adopted dust temperature T_d and the distance D to the object [9].

$$M_{dust} = \frac{4}{3}\frac{a\rho}{Q_\nu}\left[\frac{S_\nu D^2}{B(\nu,T)}\right] \tag{3}$$

Where, a = Weighted grain size = 0.1 μm

ρ = Grain density = 3000 Kg m^{-3}

Q_ν= grain emissivity = 0 .0010 for 100μm and 0.0046 for 60μm respectively [10].

S_ν= total flux density of the region whose mass is to be determined

$S_\nu = f \times 5.288 \times 10^{-9}$ MJy/Sr

D = distance of the structure

$B(\nu,T)$ = Planck's function given by,

$$B(\nu,T) = \frac{2h\nu^3}{c^2}\left[\frac{1}{e^{\frac{h\nu}{kT}}-1}\right] \tag{4}$$

where,

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

Using these values the equation (3) takes the form:

$$M_{dust} = 0.4\left[\frac{S_\nu D^2}{B(\nu,T)}\right] \tag{5}$$

We use the equation (5) for the calculation of the dust mass. It is clear from the expression (4) that the value of Planck function $B(\nu,T)$ for longer wavelength is higher than that of the shorter wavelength. Consequently, the range of $B(\nu,T)$ for fixed temperature (says ΔT) goes narrower if wavelength of the images increases [11].

Inclination angle is the angle between the line of sight and normal to the plane of the structure. The inclination angle *i* of the structure can be determined by the method [12] given by equation (6) below

$$cos^2 i = \frac{\left[\left(b/a\right)^2-(q^*)^2\right]}{1-(q^*)^2} \tag{6}$$

where b/a is the axial ratio and q* is the intrinsic flatness. Holmberg used the value of q* to be 0.23 for oblate spheroid.

4. Results and Discussion

Here we present physical properties of a look-like structure that we found at -5^0 galactic latitude in the far infrared IRAS maps. Figure (2) shows image of the cavity. In the image, the dark and bright color represents the minimum and maximum values of flux densities, respectively.

IRAS 100μm fits image for RA/Dec(J2000) = 16^{h}27^{m}19.9^s /-56^{0}35'14" is shown in figure (2), here fig (a) represents core region of the cavity surrounded by contour & fig (b) represents lines AB represent major diameter and CD minor diameter passing through minimum flux pixel respectively. The value of minimum flux at the center of the cavity is found to be 23.36 MJy/sr. The maximum flux of the contour levels of the core region of the loop is found to be 27.92 MJy/sr.

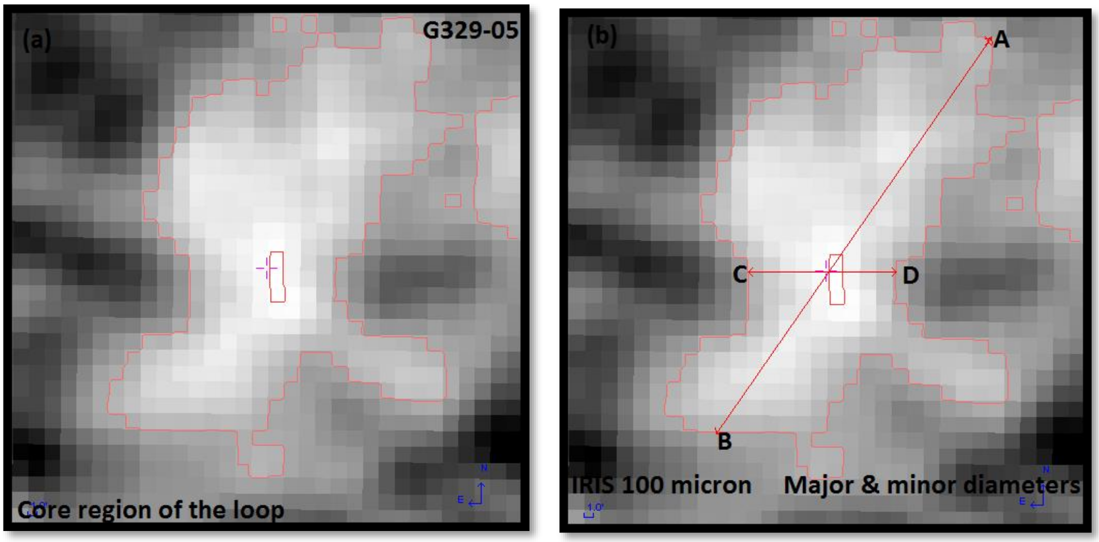

Fig. 2: Dust structures of the at 100 micron. (a) The contour levels are drawn. The appropriate isocontour is found at 27.92 MJy/sr corresponding to level 82. (b) The lines AB & CD represent the major and minor diameters passing through minimum flux density (flux-minima).

4.1 Dust Color Temperature, Dust Mass and Inclination angle

We calculated dust color temperature of all pixels of the loop. For the calculation of dust color temperature, we adopt the method developed [7] and [8]. The region with minimum and maximum temperature is found to lie in the range of 25.26 ± 0.09 K at R.A. (J2000) = $16^h30^m17.77^s$ & Dec (J2000) = -56^o 03'51.10" to 27.91 ± 0.09 K at R.A. (J2000) = 16^h 31^m 12.48^s & Dec (J2000) = -56^o 29' 19". An offset of about 2 K suggest that the core of the loop is stable. The average dust temperature calculated using the slope of F(100) and F(60) plot (Figure 3b), is found to be 25.85 K. The minimum temperature region is found to be elongated along East-West direction (Figure 3c). The distribution of dust color temperature fits well with Gaussian (Fig.3e) with Gaussian centre 25.70 K. The value of T_d of the larger structure is found to be 36.72 K. Therefore the cavity is cold (low density) enough at the core region than that of the outer region. An offset of 16 K temperature suggest that the cavity is dynamically active. The dust mass contours (Figure 3d) seems to follow the expected trend: higher density at low temperature region (Fig.3 c, d)

The distribution of T_d (Dust color temperature) is well fitted by a Gaussian plot (Figure 3e). The value of ΔT_d of the core region is small which indicates that the dust is mostly in thermal equilibrium whereas, in outer region the temperature offset is 16K which suggests that the cavity is not in thermal equilibrium.

We used [12] method, equation (6), to calculate the inclination angle of the core and whole loop. The inclination angle of the core and whole loop are found to be 78^0 and 0^0 respectively. It means the core region is edge-on where as outer region of this loop is completely faced-on. The size of the large structure of the KK- loop is 1.4^0x1.4^0 [5] where as of the core region is found to be 0.75^0 x 0.23^0. Therefore, the size of the core region of this loop is only about 9 % of the whole loop.

Using the distance of the loop to be 200 pc [13], the dust mass of the cavity is found to be 1.67 x 10^{27}Kg i.e. about 0.00835 $M_\odot$ by using equation (5). The outflow nature in the core region along major diameter (north-south direction) has been observed. This is probably due to wind of pulsar J1627-5547 which is situated at a distance of 0.79^0 from the KK-loop G329-05. Besides this, we found 3, 22 and 76 number of pulsars within 3^o, 6^o and 9^o radii respectively from the KK-loop. The

Age and Dispersion measure of the nearby pulsar J1627-5547 is found to be 7.57 x 10^6 years and 1666.2 cm^{-3} pc respectively (ATNF pulsar catalogue).

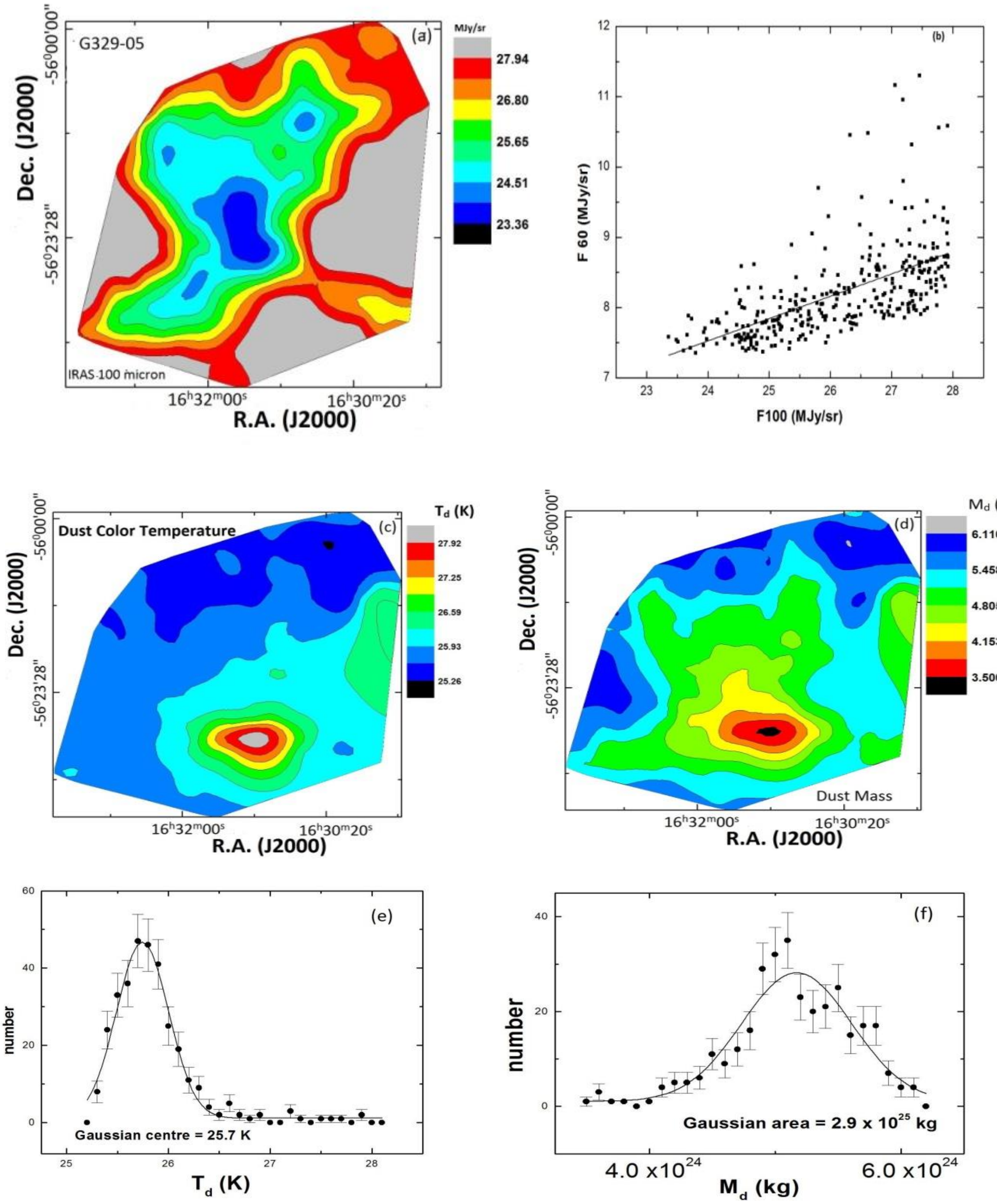

Fig.3 (a): IRAS 100µm far infrared images of the core region of KK-loop G329-05 centered at R.A. (J2000) = $16^h27^m19.9^s$, Dec. (J2000) = -56^0 35'14".The flux contours are shown which represents 23.36, 24.51, 25.65, 26.80 and 27.94 MJy/sr. (b) Flux at 100 µm versus 60 µm plot. The dust color temperature (c) and dust mass (d) contour maps. The contour levels are shown. The distribution of dust color temperature (e) and dust mass (f). The solid curve represents Gaussian fits. The Gaussian parameters are given.

5. Conclusions

We present physical properties of G329-05 dusty loops at far infrared (60 µm and 100 µm) IRAS maps located around ATNF pulsar within 1^0 radius. The dust color temperature, dust mass, inclination angle and the size of the core region of the KK- loop are studied and are compared with its larger structures [4, 5] in IRAS maps. We conclude our results as follow:

a) Dust color temperature and dust mass distributions show a very good agreement with Gaussian. However the outer region show relatively higher temperature with an offset of about 16 K than that of its core region, suggesting the loop is dynamically unstable.

b) The inclination angle of the core region is found to be 78^0, suggesting edge-on appearance. At the outer region, the inclination angle is found to be 0^0, i.e. faced-on.

c) The dust mass of the core region is estimated to be 1.67 x 10^{27} kg, i.e. about $0.00835M_\odot$ at a distance 200 pc.

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