FAR-INFRARED AND RADIO EMISSION FEATURES OF THE GALACTIC NUCLEAR REGION

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Abstract. In this paper the results of the Galactic nuclear region study in far-infrared and radio-wave bands are presented. Image processing methods are used for *SkyView* and *IRSA* archive images. On the basis of image synthesis, image analysis, and isophots the structure of the Galactic nuclear gas-dust disk and its borders are determined. Brightness temperature distributions for gas and dust components of the disk and their average values (T_b^{gas}~1 K, T_b^{dust}~10 K) are obtained. Neutral H I and ionized H II hydrogen maps show non-symmetrical hydrogen distribution. Dust and gas maps indicate the presence of spiral and toroidal disk structure.

1. Introduction

Image processing methods are widely used today to study central regions of active galactic nuclei. Thick layers of dust and gas hide their central massive black holes and accretion disks. Therefore we can understand the phenomena in galactic nuclei only on the basis of their secondary radiation, emitted by environmental interstellar medium. Analysing images of active galactic nuclei it's possible to study not only accretion onto black holes, but also some properties of interstellar gas and dust.

Though the Milky Way Galaxy doesn't show any considerable activity at present, there are strong evidences for its activity in the past [1,2]. The estimations of its central black hole mass gives $2.6\times10^6 M_\odot$ [2]. It is possible to study Galactic Center dust and gas only in infrared ($\lambda\geq10\mu m$) and radio spectral bands, because short-wave near-infrared and optical radiation is absorbed in the interstellar medium substantially.

This paper presents the continuation of Galactic Center structure study at angular size scales of ~3°. In [1] I determined gas-dust-stellar disk size in the Galactic nucleus and found the evidence for spiral branch of the disk (fig.1).

To study gas and dust distribution in the Galactic Center *NASA* archive data from *Infrared Science Archive (IRSA)* and *SkyView* are used.

2. Mid- and far-infrared image analysis

As far as dust particles radiates mainly in far- and mid-infrared, *Infrared Astronomical Satellite (IRAS)* images in four IR bands: 12μm, 25μm, 60μm, and 100μm – from *IRSA* are used to study dust disk shape. Fig. 1 shows contour lines of summarized (12 – 100) μm processed image. As consistent with fig.1 and [1] disk size is 1.63°×0.54° (D=280 pc, h=90 pc).

To obtain more evidences for these results and to study some more features of gas-dust disk structure *SkyView* [3,4] archive images are processed [3,4]. A wide-field extinction E_{B-V} map show the distribution could be the indicator of dust distribution [3]. Fig. 2 presents E_{B-V} distribution in two directions: along galactic longitude and along galactic latitude. Zero point of horizontal axis coincides with Sgr A*. At $E_{B-V}\approx100^m$ disk size is 100′×25′. This result agree with one obtained in [1]. Filament which was defined in [1] as spiral branch is easily seen in E_{B-V} map. It has less condensed structure than in fig.1.

Fig.1. Summarized (12-100) μm image isophots of the Galactic Center show the presence of dust disk and its spiral structure. The spiral branch is shown with a white circle. Image angular resolution is 55".

This can show that stellar-like object in the very center of the white circle couldn't be connected to the spiral branch. Another filament is located at ~1° from the disk center in the direction of galactic longitude increase. It may be the second spiral of the disk. Galactic coordinates of visible centers of both spirals are given in the table. In general extinction map shows inhomogeneous dust distribution in the disk.

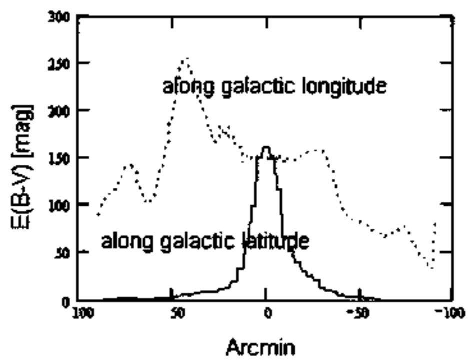

Fig. 2 Extinction E_{B-V} – angular distance from Sgr A dependences for the directions along galactic coordinates (J2000).*

3. Brightness temperature

Temperature is an important parameter of the disk. It is the indicator of dust and gas physical properties, besides temperature distribution could show the origin and distribution of heating sources. On the basis of intensity maps it is possible to determine brightness temperature maps.

To calculate brightness temperature (T_b) of the dust I use a wide field 100μm image. Temperature T_b could be obtained from the expression:

$$T_b^{IR} = \frac{h\nu / k}{\ln\left[1 + \frac{2h\nu^3}{c^2 I_\nu}\right]},$$

where I_ν is intensity of 100μm emission.

Radio emission at ν>10 GHz is thermal. It is radiated mainly from H II regions. To calculate brightness temperature of ionized hydrogen I use 4850 MHz radio emission map [4]. Using Rayleigh-Jeans formula I have:

$$T_b^{Radio} = \frac{c^2}{2\nu^2 k} I_\nu .$$

Fig.3 shows brightness temperature distributions in far-IR (100μm) and in radio band (4850 MHz). It is possible to determine average temperatures T_b for dust and ionized gas: T_b^{gas}~1 K, T_b^{dust}~10 K. Low value of T_b can be explained with small optical thickness of dust and ionized gas. Distribution of T_b^{dust} in rather uniform, T_b^{gas} has well noticeable maximum at ~0.25° around Sgr A*. This may be explained with larger optical thickness of the region.

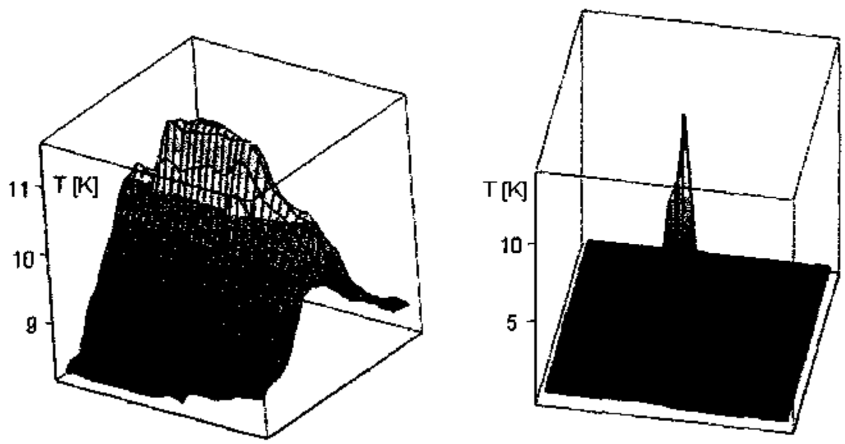

Fig.3. Far-IR 100μm (left) and radio 4850 MHz (right) brightness temperature distributions. Angular size of each image is 3°. Sgr A is in the center of both images. Positive directions of horizontal axes conforms to the decrease of galactic coordinates.*

4. H I and H II components

Dust and gas interstellar medium components inseparably evolutionary linked with each other. For all regions of the Galaxy there is correlation between extinction and hydrogen column density [5]:

$$N_H = 5.9 \times 10^{21} E_{B-V}\ cm^{-2} .$$

Using this relation and E_{B-V} map it's possible to arrange hydrogen column density map. It is presented in fig.4. To compare H I distribution with H II one, 4850 MHz image is combined with N_H contour lines. It's seen that gas is distributed asymmetrically in the disk. A point of gas (and dust) concentration has galactic coordinates (J2000): l_C=0°.688, b_C=–0°.1. Hydrogen column density of the disk varies appropriately in three times (fig.4).

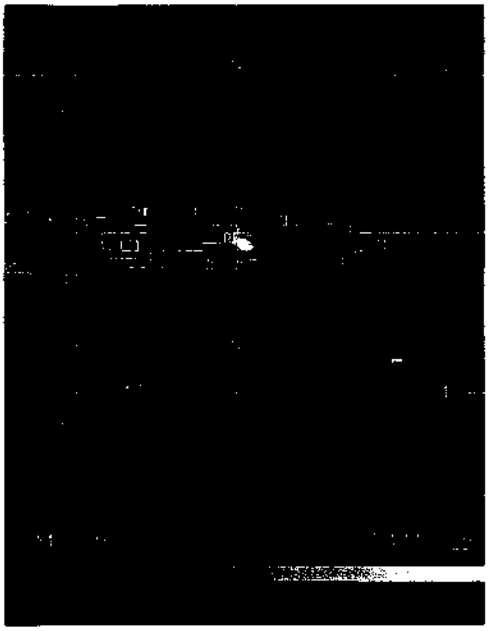

Fig.4. Ionized H II (image) and neutral H I (isophots) hydrogen map of the Galactic Center region. Isophots correspond to hydrogen column density: 1^{st} line – 3.4×10^{23} cm^{-2}, 2^{nd} – 6.1×10^{23} cm^{-2}, 3^{rd} – 8.6×10^{23} cm^{-2}. Galactic coordinate grid (J2000) is shown.

5. Discussion and conclusion

In this paper I improved Galactic nuclear disk size estimation. Assuming Sun – Galactic Center distance is 10 kpc, diameter of the disk is 280 pc, its height is 90 pc on the basis of *IRAS* images. On the basis of *SkyView* dust map [3]: D=290 pc, h=70 pc. Therefore the average values are: D_{disk}=285 pc, h_{disk}=80 pc. Gas-dust disk is optically thin in far-IR and 4850 MHz radio band. The results of sections 2 and 4 show that both dust and gas components of the disk are distributed asymmetrically. The point of gas and dust concentration is presented in the table. But in general mass distribution may be symmetrical, because stars and compact relativistic objects can give comparatively large contribution to it. Section 3 shows that almost uniform T_b^{dust} distribution results in uniform heating source distribution. Therefore the most probable candidates for heating sources are stars of the Galactic nucleus.

This paper presents new evidences for spiral structure of the Galactic nucleus. The second possible spiral branch is found. It is located in ~1° in the direction of galactic longitude increase. The exact values of spiral branch galactic coordinates are given in the table. But a question about curling directions of spirals are still without answer. Increased values of extinction E_{B-V} on both disk edges (fig.2) are explained with dust column densities larger than in central disk parts. Therefore central disk (without spirals) could have a shape which is similar to torus. Such structures are observed in many galaxies with active nuclei [6].

Thus the presence of gas-dust disk and its structure in the Milky Way Galaxy nucleus relates our Galaxy with active galaxies. It could be the additional evidence for Galactic past activity.

Spiral 1	l_{S1}=359°.016 b_{S1}=–0°.645
Spiral 2	l_{S2}=1°.15 b_{S2}=–0°.125
Column density center	l_C=0°.688 b_C=–0°.1

Galactic coordinates (J2000) of gas-dust nuclear disk filaments.

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