ANNOTATION

of dissertation for the Philosophy Doctor (PhD) degree on «6D061100 – Physics and Astronomy»

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Study of molecular clouds in star-forming regions

General characteristics of the work

This work presents a multi-wavelength analysis of the Galactic Large Infrared Bubble N24 to investigate the molecular and star formation environment around expanding HII regions. Using data from Herschel and ATLASGAL, the distribution and physical properties of the dust in the bubble were investigated. Using the Clumpfind2d algorithm, 23 dense clumps were identified with sizes and masses in the range of 0.65–1.73 parsec and 600–16300 $M_{\odot}$, respectively. The observations of NH_3 (1,1) and (2,2) were made by the Nanshan 26 meter Radio Telescope to analyze the molecular environment of N24. Analysis of the kinetic temperature and gravitational stability of these clusters suggests gravitational collapse in some of them. The mass-size distribution of nodes and the presence of massive young protostars indicate that the N24 envelope is a region of continuous massive star formation. The consistency of the dynamics and fragmentation timelines, and the abundance of edge-on young stellar objects and clumps, suggest that a "collect and collapse" mechanism is at work at the bubble boundary, but the presence of a dark infrared cloud at the bubble boundary suggests that mechanism of "radiation implosion".

Urgency of the topic

The process of star formation is a complex process that requires taking into account the scattering and accretion of protostellar objects, as well as mass loss due to the star formation system in the form of bipolar outflows.

The infrared (IR) dust bubble, a shell structure formed by the interaction of the expanding HII region with the surrounding interstellar medium (ISM), is a hot topic for studying the effects of massive stellar feedback on the surrounding matter. Over the past decade, significant progress has been made in understanding the nature and star formation of bubbles that form in neighboring shells or bright clusters.

Two mechanisms for triggering star formation around bubbles have been proposed as models: the "collect and collapse" model and the "radiative implosion (RDI)" model. During collect and collapse (C&C), the outwardly expanding HII region compresses and collects the medium in the region between the ionization front (IF) and the shock front (SF). This shell between IF and SF densifies and can collapse to form stars. During the RDI process, IF releases SF into the surrounding molecular cloud, stimulating the collapse of pre-existing subcritical clumps to form stars. Recently, several observational studies and numerical simulations have confirmed that these two mechanisms, especially the C&C mechanism, can successfully explain star formation in several HII regions. In addition, most of the well-studied bubbles are relatively small, and studies of large bubbles with a radius of >5 arc minutes are relatively rare. A large bubble with plenty of time for the surrounding matter to accumulate makes it easier to find evidence for the formation of new generation stars. In order to enlarge our observational sample of giant bubbles to study star formation in their vicinity, we follow Churchwell et al. We chose a large galactic infrared dust bubble N24 from the catalog.

This work used far-infrared observations of N24 from the Herschel Space Observatory and ammonia data from the Nanshan Observatory. These data were used to study the interaction of the bubble with its surroundings, dense clusters around it, as well as to study possible star formation scenarios.

The goal of the work is to study the star formation regions around the dust bubble and to study in more detail the large red outer dust bubble N24 of the Milky Way, as well as to study the dusty gaseous environment of N24. using infrared, submillimeter and radio data along with NH_3 observations.

Objectives of research

1. N24 infrared data review from the Spitzer Space Telescope archive and InfraredArrayCamera (IRAC) band imaging review from the Galactic Legacy Extraordinary Infrared Mid-range Survey (GLIMPSE).

2. Conducting research on molecular radiation at the Nanshan 26-meter radio telescope of the Xinjiang Astronomical Observatory.

3. Determination of dense dust particles located along the layer of dust bubbles, their average size, average temperature, average column density, average mass and average body density.

Research objects: InfraredArrayCamera (IRAC), Galactic Legacy Infrared Midplane Survey Extraordinaire (GLIMPSE) observational data from the Milky Way's large red outer dust bubble N24.

Research subjects: Dense dust particles located along a layer of dust bubbles.

Research methods

The clupfind2d algorithm was used to determine dust particles and their physical characteristics, and the class software environment was used to process radio signals.

The main statements for the thesis defense

1. The distribution of NH_3 molecular emission in radio astronomical observations corresponds to two star formation regions G19.07-0.28 and G18.88-0.49 in the N24.

2. The main parameters of the 23 dense clumps correspond to the following values: average width - 0.92 ± 0.06 parsec, average temperature 20.8 ± 0.5 K, average column density 0.86 (± 0.19) x 10^{22} cm^{-2}, mean mass 2.66(±0.81) x 10^3 $M_\odot$ mean body density 7.75 (± 0.46) x 10^3 cm^{-3}.

3. Based on the mass distribution of dense clumps, 11 young stellar objects (YSOs) have been identified, 9 of which have masses greater than $8M_\odot$.

Scientific novelty is due to the fact that the following works were carried out for the first time:

1. The infrared structure and distributions of molecular radiation were examined, and two key regions G19.07-0.28 and G18.88-0.49 in the N24 shell were found to correspond to star formation caused by an expanding bubble.

2. 23 clumps are classified according to the stages of their evolution. Almost all of them are distributed along the bubble membrane and have the following parameters: average width - 0.92 ± 0.06 parsec, average temperature 20.8 ± 0.5 K, average column density 0.86 (± 0.19) x 10^{22} cm^{-2}, mean mass 2.66(±0.81) x 10^3 $M_\odot$ mean body density 7.75 (± 0.46) x 10^3 cm^{-3}.

3. When comparing spectral energy distributions, 11 YSOs were identified and 9 of them were shown to have a mass greater than $8M_\odot$. This distribution of dense clusters indicates that they can all form massive stars.

Theoretical and practical significance of the work

The scientific results obtained in the dissertation work can be used to study the processes and understand the mechanism of star formation.

Personal contribution of the author

The author of the dissertation was directly involved in observations, processing and analysis of spectral data at an observatory in China (Xinjiang Astronomical Observatory of the Chinese Academy of Sciences, Urumqi).

The results of the analysis were obtained personally in a computer software environment. Research tasks and discussion of scientific results were carried out jointly with scientific supervisors.

Reliability of results

The reliability of the scientific results of the work is confirmed by comparison with the results of studies of similar objects obtained by other authors and published in an international scientific journal.

Publications

Based on the materials of the dissertation, 6 publications were published.
Among them, 1 article in a highly rated journal (Q1) included in the Thomson Reuters database and the international scientific database Scopus.

1. Алимбетова Д.А., Агишев А.Т., Көмеш Т., Тілеуқұлова А.Қ. Распределение NH_3 в области звездообразования. // al-Farabi Kazakh National University Recent Contributions to Physics. — 2021, 76, №1, — С. 12-15.

2. Alimbetova D.A., Xu Li, Jarken Esimbek, Jianjun Zhou, W. A. Baan, Weiguang Ji, Xindi Tang, Gang Wu, Xiaoke Tang, Qiang Li, Yingxiu Ma, Serikbek Sailanbek, Dalei Li, Molecular environs and triggered star formation around the large Galactic infrared bubble N 24. // Monthly Notices of the Royal Astronomical Society, Volume 487, Issue 2, August 2019. P. 1517–1528.

3. Алимбетова Д.А., Агишев А.Т., Хохлов С.А. Инфрақызыл N24 көпіршіктің айналасындағы жұлдыздың қалыптасуы. // Журнал проблем эволюции открытых систем. — 2020, 1, №1, — С.65-70.

4. Агишев А.Т. , Алимбетова Д.А., Хохлов С.А. Орион тұмандығындағы интеграл формалы жіпшесінің негізгі жотасы бойындағы турбуленттілік пен өзқауымдылық. // Журнал проблем эволюции открытых систем. — 2019, 1, №21, — С. 61-66.

5. Агишев А.Т. , Алимбетова Д. А. Информационная энтропия основного хребта нити интегральной формы скорость-температура в облаке Ориона. // Фараби Әлемі 2019. – Казахстан, С.243.

6. Алимбетова Д.А. Молекулярное окружение большого галактического инфракрасного пузыря N 24 // Фараби Әлемі 2021. – Казахстан, С.175.

Volume and structure of the work

The thesis consists of an introduction, three parts, a conclusion, a list of references and an appendix. The work is presented in the form of an 85-page typewritten text with 29 figures, 19 formulas, 5 tables and a bibliography containing 109 titles.