ANNOTATION

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

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Radioastronomical characteristics of molecular clouds and star formation

General description of work

This work is devoted to the study of molecular outflows associated with the formation of massive stars. The clumps were selected from the CO High Resolution Survey (COHRS) with relatively strong CO emissions (3–2) from the large area galaxy survey using the APEX telescope. The identification of the outflow among the original sample was mainly carried out by checking the linear wings of the CO (3–2) spectra and PV diagrams with a section along the latitude and longitude of the galaxy.

Relevance of the topic

Star formation is a complex process involving the collapse and accretion of matter onto protostellar objects, as well as the loss of mass by the star formation system in the form of bipolar streams. The mechanism behind the triggering of molecular efflux is important for understanding massive star formation. The outflow of new stars transfers momentum and energy to the surrounding molecular cloud at distances of several AU. up to tens of pc from the star. In 1976, the first molecular outflow was discovered in the star-forming region of Orion KL. Over the past ~ 40 years, the amount of low mass outflow has increased significantly, leading to the emergence of several different models. However, the number of molecular outflows associated with the formation of massive stars is relatively small. Given that massive star formation processes are still under active discussion, more massive outflows need to be found for detailed study to understand these processes.

Molecular efflux is a useful tool for improving our understanding of the formation of stars of all masses, especially stars with high mass. For low-mass stars, bipolar outflows caused by accretion disks are the main building blocks of the formation process, supported by theoretical models and observations. However, the process of massive star formation is still controversial.

Systematic studies of outflows associated with massive star formation began much later than studies of low-mass processes. A search for CO (1–0) wings in the direction of 122 massive star-forming regions (MSFs) showed that 90% of them are located on wings of medium and high velocity. CO (1–0) mapping of 10 MSF regions identified five massive outflows. A later study of the CO (2–1) line of 69 massive protostellar candidates also showed that high-velocity gas is a common feature of massive young stellar objects. Bipolar outflow was identified in 21 of 26 sources. These studies show that high mass outflow is much more massive and energetic than low mass outflow. The collimation factors of massive and low-mass

outflows do not differ significantly, which differs from other results. In studies of large outflows associated with 6.7 GHz methanol masers, it was found that outflows with large mass obey the same scaling law between outflow activity and clump masses as for objects with low mass, which indicates the generality of the formation processes. low-mass and massive stars. These outflows are powerful enough to induce turbulence in the environment, but do not significantly contribute to cloud turbulence.

From the above, we can conclude that a careful study of molecular outflows associated with massive star formation is necessary.

Traditional outflow search methods are usually based on reference sources of known star formation activity from other observations. Infrared sources have been used as indicators of molecular efflux. An unbiased large-scale search for molecular efflux has been made possible in the last decade by massive data from a series of molecular line studies with an angular resolution of arcmin.

However, manual identification studies are time consuming, non-repetitive, and involve subjective factors such as how people perceive an image. There are a limited number of attempts to implement computer-based churn search methods. In recent years, machine learning algorithms have become widespread in the field of pattern recognition due to their simplicity and accuracy. Relying on a set of predefined patterns rather than fixed criteria, they would be ideal tools for identifying patterns, such as churn, that are difficult to define explicitly.

The use of machine learning methods in analyzing astrophysical datasets is growing. These techniques, which can process large amounts of data in a short period of time, make machine learning even more attractive. With a constant stream of machine learning innovations, its astronomy applications show tremendous potential. This new method of data analysis requires a different perspective on astronomical problems, the development of new ideas about the data, and active collaboration with researchers in computer science, engineering and other fields.

Machine learning techniques provide a promising way to abstract the identification and classification process as needed. The algorithms defining these methods are data-driven and designed to study the relationship between controlled and desired parameters without using parametric physical models. As more information becomes available and the quality and size of the exercise set improves, machine learning can improve its knowledge and model the dataset to make more accurate predictions. Plus, unlike humans, machine learning models can quickly and automatically predict new data through a new scaling process.

The aim of the work is to identify large outflows and study in detail to understand the formation of massive stars.

Research objectives

1. Determine the outflows between the original samples by checking the linear wings of the spectra of CO (3-2) and PV diagrams with a section along the latitude and longitude of the galaxy.

2. Calculate the physical parameters of the outflow.

3. Comparing the parameters of the outflow with the properties of the clump, discuss the physical values of these parameters.

Research objects: Clumps with relatively strong CO (3–2) emissions from the ATLASGAL source.

Research subject: is a patterns of phenomena occurring in molecular outflows.

Method of investigation

For the analysis of radio astronomical signals in this dissertation, the methods of complex analysis are used. Computer analysis was carried out using Gildas and Python programs.

Main provisions to be protected

1. Analysis of PV diagrams (position-velocity) constructed from the COHRS data show the presence of 157 new clumps of star formation with massive outflows ($M_{clump} > 13M_{\odot}$) in the region of the Galaxy $10° < l < 55°$ and $|b| \le 0.5°$.

2. At advanced stages of star formation (MSF with the H II region), clumps have high values of physical parameters ($M_{clump} > 2.5\times10^{3}M_{\odot}$, $L_{bol} > 3.0\times10^{5}L_{\odot}$, $T_{dust} > 20K$, $N_{H_2} > 10^{22.4}cm^{-2}$), as well as a high rate of matter outflow ($\dot{M}_{out} > 3.2\times10^{-3}M_{\odot}yr^{-1}$).

3. The mechanical force, determined by the analysis of the intensity spectra of CO (3-2) molecules, in massive clumps grows with increasing luminosity, similarly to clumps with a low mass, which corresponds to a linear approximation on a logarithmic scale ($\lg(F_{out}) = -4.90 + 0.70\lg(L_{bol})$).

The scientific novelties of work are:

1. A total of 157 high mass outflows were identified in the full sample with a detection rate of 20%, and properties of 84 streams with well-defined bipolar fluxes and reliable distances were calculated.

2. Outflows were identified in 5 stationary clumps (5/19 or 26%), in 7 protostellar clumps (7/93 or 8%), in 67 YSO clumps (67/386 or 17%) and in 78 MSF clumps (78 / 269 or 29%), respectively. The probability of detecting immobile clumps of 26% is preliminary due to the small sample size.

3. The statistical relationship between the mass of the outflow and the mass of clumps for our sample is. $\lg(M_{out}/\mathrm{M}_{\odot}) = (-1.1\pm0.21) + (0.9\pm0.07)\lg(M_{clump}/\mathrm{M}_{\odot})$.

Theoretical and practical significance of the work

The results obtained in the dissertation can be used to study the processes of formation of massive stars and understand the mechanism of their formation.

Personal contribution of the author

The author of the thesis participated in the processing and analysis of spectral data at the Xinjiang Astronomical Observatory (XAO), Chinese Academy of Sciences - Urumqi, China).

The results of the analysis were obtained by the candidate himself. The tasks were set and the results were discussed with the supervisors.

The reliability of the results

The reliability of the scientific conclusions of the work is confirmed by the coincidence of theoretical models, conclusions about the study of similar objects, obtained by other authors.

Approbation of work

The main results contained in the dissertation were published in 7 scientific papers, of which:

Articles with a high impact-factor according to the database of Thomson Reuters or in the publications included in the international scientific database Scopus:

1. Li Q., Zhou J., Esimbek J., He Y., Baan W.A., Li D., Wu G., Tang X., Ji W., Zhexeray D. High-mass Outflows Identified from COHRS CO (3–2) Survey // The Astrophysical Journal. – 2018. – Vol. 867, № 2. – P. 167.

Articles in publications recommended by CQAES of Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan:

1. Жексебай Д.М., Хохлов С.А., Әсілхан Ә.Д., Хохлов А.А. Машиналық оқытудың (machine learning) көмегімен молекулалық бұлттарды және жұлдыздардың қалыптасуын жіктеу // Вестник КазНИТУ. – 2020. – Т. 139, № 3. – С. 142-149.

2. Жексебай Д.М., Хохлов С.А., Кожагулов Е.Т. Прогнозирования параметров и классификация молекулярного оттока с помощью сверточных нейронных сетей //Recent Contributions to Physics. – 2020. – Т. 75, № 4. – С. 88-95.

3. Kozhagulov Y.T., Zhexebay D.M., Sarmanbetov S.A., Sagatbayeva A.A., Zholdas D. Comparative analysis of object detection processing speed on the basis of neuroprocessors and neuroaccelerators //Известия Национальной академии наук Республики Казахстан. – 2020. – Vol. 332, № 4. – P. 61-67.

Publications in collections of theses of reports:

1. Zhanabaev Z.Zh., Kozhalgulov Y.T., Khokhlov S.A., Ibraimov M.K., Zhexebay D.M., Agishev A.T. Commercialization of Studies of Neural Network Integrated Circuits //«Қоғамдық сананы жаңғыртудағы жоғары оқу орнының рөлі:«Университет 4.0 моделіне көшу» атты 48-ші ғылыми-әдістемелік конференциясының материалдары, 2018. – Т. 18. – С. 216.

2. Жексебай Д.М., Сарманбетов С.А., Агишев А.Т. Биометрическая система на основе нейронных сетей для учета рабочего времени //Международная научная конференция студентов и молодых ученых, «ФАРАБИ ӘЛЕМІ», 2019. – С. 254.

3. Sagatbayeva A.A., Aitu B., Kanishuly I., Zhexebay D. Deep neural networks for object detection //Международная научная конференция студентов и молодых ученых, «ФАРАБИ ӘЛЕМІ», 2019. – С. 283.

Copyright certificates:

1. Кожагулов Е.Т., Ибраимов М.К., Хохлов С.А., Жексебай Д.М., Сарманбетов С.А. FarabiVision 1 – Биометрическая система для учета

рабочего времени по идентификаций лица //Авторское свидетельство, 2019. № 1464.

2. Агишев А.Т., Хохлов С.А., Кожагулов Е.Т., Сарманбетов С.А., Жексебай Д.М., Ибраимов М.К. KITC STAT – Система для подсчета посетителей и видеоаналитики //Авторское свидетельство, 2019. № 5461.

Relationship of the thesis topic with the plans of scientific works

The methods developed in the dissertation work are applied under the Fostering Productive Innovation Project the Science Committee of the Ministry of Education of the Republic of Kazakhstan on the topic: "Machine vision based on an adaptable self-organizing neural network", in accordance with the plans of research work.

Structure and volume of the thesis

The dissertation consists of an introduction, three sections, a conclusion, a list of references and one appendix. The work is presented on 124 typewritten pages, illustrated with 41 figures, 2 formulas and 5 tables are given. The list of used sources contains 211 items.