IRSTI 41.25.29 https://doi.org/10.26577/RCPh.2024v89i2-03

N.Sh. Alimgazinova[1], N.A. Sharipbay[2], M.T. Kyzgarina[1]*, A.B. Manapbayeva[3,4], K.M. Turekhanova[1], A.Zh. Omar[1], A.M. Demessinova[1], A.A. Alibek[3]

[1]Al-Farabi Kazakh National University, Almaty, Kazakhstan
[2]Galaxy International School, Almaty, Kazakhstan
[3]Academy of Logistics and Transport, Almaty, Kazakhstan
[4]Institute of Experimental and Theoretical Physics, Almaty, Kazakhstan
*e-mail: meir83physics@gmail.com

Study of the N126 dust bubble in the infrared wavelength range

In recent years, the research of bubbles, partially circular structures in the interstellar medium, consisting of dust and gas, has received the considerable attention. The analysis of the structure and evolution of bubbles provides insight into the conditions under which stars and planets form in the interstellar medium. Dust bubbles are inextricably linked with star formation regions and are powerful tools for studying the interaction of young stellar objects with their environment at various stages of evolution.

The main goal of this article is to study the region of the N126 dust bubble, search for and identify young stellar objects. Identification of young stellar objects by their fluxes at infrared wavelengths is relatively recent, and identification criteria are still at the stage of improvement. Therefore, in this article, the criteria for identifying young stellar objects were used according to the works of Koenig X.P. (2012), Koenig X.P. & Leisawitz D.V. (2014) and Fischer W.J. (2016), which are based on analysis of WISE observational data in the near- and mid-infrared bands W1 (3.4 μm), W2 (4.6 μm), W3 (12 μm), and W4 (22 μm). The data from the 2MASS and AllWISE catalogs with reliable non-zero fluxes of infrared radiation sources were used in that work. For the researched dust bubble, young stellar objects of class 0 (protostars) and class I were not detected. 4 objects of class II, 1 object of the class of transition disks and 48 objects of class III were identified. Energy distributions in the spectra for class II objects were constructed, which also confirmed their evolutionary status. For all identified YSOs, color diagrams were constructed showing the locations of the found objects with their corresponding areas of evolution. Maps of the distribution of YSOs in space are analyzed, which indicate possible signs of an initiated star formation process in the N126 dust bubble.

Key words: bubble, infrared radiation, WISE, young stellar objects, evolutionary stage.

Н.Ш. Алимгазинова[1], Н.А. Шарипбай[2], М.Т. Кызгарина*[1], А.Б. Манапбаева[3,4], К.М. Туреханова[1], А.Ж. Омар[1], А.М. Демесинова[1], А.Ә. Әлібек[3]

[1]Әл-Фараби атындағы Қазақ ұлттық университеті, Алматы қ., Қазақстан
[2]Galaxy халықаралық мектебі, Алматы қ., Қазақстан
[3]Логистика және көлік академиясы, Алматы қ., Қазақстан
[4]Эксперименттік және теориялық физика институты, Алматы қ., Қазақстан
*e-mail: meir83physics@gmail.com

N126 тозаң көпіршігін толқын ұзындығының инфрақызыл диапазонында зерттеу

Соңғы жылдары шаң мен газдан тұратын жұлдызаралық кеңістіктегі көпіршіктерді, соның ішінде жартылай сақиналы құрылымдарды зерттеуге көп көңіл бөлінуде. Көпіршіктердің құрылымы мен эволюциясын талдау жұлдызаралық кеңістікте жұлдыздар мен планеталардың пайда болу жағдайларын түсінуге мүмкіндік береді. Шаң көпіршіктері жұлдыз түзілу аймақтарымен тығыз байланысты және эволюциялық дамудың әртүрлі кезеңдерінде жас жұлдызды объектілердің олардың қоршаған ортамен әрекеттесуін зерттеудің басты құралы болып табылады.

Бұл зерттеудің негізгі мақсаты N126 шаң көпіршігі аймағын зерттеу, жас жұлдызды объектілерді іздеу және анықтау болды. Жас жұлдызды объектілерді инфрақызыл толқын ұзындығындағы ағындары бойынша сәйкестендіру жүргізілгеніне салыстырмалы түрде көп уақыт өтпеді, ал сәйкестендіру критерийлері әлі де жетілдіру сатысында. Сондықтан, бұл зерттеудегі жас жұлдызды объектілерді анықтау критерийлері Koenig X.P. (2012), Koenig X. P. & Leisawitz D. V. (2014) және Fischer W.J. (2016), олар W1 (3,4 мкм), W2 (4,6 мкм), W3 (12 мкм) және W4 (22 мкм) жақын және орта инфрақызыл жолақтарындағы WISE бақылау деректерін талдауға негізделген. Зерттеу барысында инфрақызыл сәулелену көздерінің сенімді нөлдік емес ағындары бар 2MASS және AllWISE каталогтарындағы деректер пайдаланылды. Зерттелетін шаң көпіршігі үшін 0 класындағы (алғашқы жұлдыздар) және I класстағы жас жұлдызды объектілер анықталмады. II класты 4 объект, өтпелі дискілер класының 1 объектісі және III класты 48 объект анықталды. II класты объектілерге арналған спектрлердегі энергияның таралулары құрастырылды, бұл олардың эволюциялық статусын растады. Барлық анықталған ЖЖО үшін эволюцияның сәйкес аймақтарымен табылған объектілердің орналасу орындарын көрсететін түсті диаграммалар құрастырылды. N126 шаң көпіршігінде басталған жұлдыз түзілу процесінің мүмкін белгілерін көрсететін ЖЖО-тің ғарышта таралу карталары талданды.

Түйін сөздер: көпіршік, инфрақызыл сәулелер, WISE, жас жұлдызды объектілер, эволюциялық кезең.

Н.Ш. Алимгазинова[1], Н.А. Шарипбай[2], М.Т. Кызгарина*[1], А.Б. Манапбаева[3,4], К.М. Туреханова[1], А.Ж. Омар[1], А.М. Демесинова[1], А.А. Алибек[3]

[1]Казахский национальный университет имени аль-Фараби, г. Алматы, Казахстан
[2]Международная школа Galaxy, г. Алматы, Казахстан
[3]Академия логистики и транспорта, г. Алматы, Казахстан
[4]Институт экспериментальной и теоретической физики, г. Алматы, Казахстан
*e-mail: meir83physics@gmail.com

Исследование пылевого пузыря N126 в инфракрасном диапазоне длин волн

В последние годы большое внимание уделяется исследованиям пузырей - частично кольцевым структурам в межзвездном пространстве, состоящим из пыли и газа. Анализ структуры и эволюции пузырей дает представление об условиях, при которых звезды и планеты образуются в межзвездном пространстве. Пылевые пузыри неразрывно связаны с областями звездообразования и являются мощными инструментами для изучения взаимодействия молодых звездных объектов с окружающей средой на различных стадиях эволюционного развития.

Основной целью данного исследования было изучение области пылевого пузыря N126, поиск и идентификация молодых звездных объектов. Идентификация молодых звездных объектов по их потокам на длинах волн инфракрасного диапазона ведется относительно недавно и критерии идентификации находятся еще на стадии усовершенствования. Поэтому в данном исследовании были использованы критерии идентификации молодых звездных объектов согласно работ Koenig X.P. (2012), Koenig X. P. & Leisawitz D.V. (2014) и Fischer W.J. (2016), которые основаны на анализе данных наблюдений WISE в полосах ближнего и среднего инфракрасного диапазона W1 (3,4 мкм), W2 (4,6 мкм), W3 (12 мкм) и W4 (22 мкм). В исследовании были использованы данные из каталогов 2MASS и AllWISE, имеющие надежные ненулевые потоки источников инфракрасного излучения. Для исследуемого пылевого пузыря молодые звездные объекты 0 (протозвезды) и I класса не были обнаружены. Идентифицированы 4 объекта II класса, 1 объект – класс переходных дисков и 48 объектов – III класса. Построены распределения энергий в спектрах для объектов II класса, которые также подтвердили их эволюционный статус. Для всех идентифицированных МЗО построены цветовые диаграммы, показывающие расположения найденных объектов с соответствующими им областями эволюции. Проанализированы карты распределения МЗО в пространстве, которые указывают на возможные признаки инициированного процесса звездообразования в пылевом пузыре N126.

Ключевые слова: пузырь, инфракрасное излучение, WISE, молодые звездные объекты, эволюционная стадия.

Introduction

Researches of objects in the interstellar medium provide the explanation of star formation processes, galaxy formation and the general structure of the Universe. The improved radiation detection techniques, new technologies and data processing techniques allow to obtain increasingly reliable information and detailed images of the interstellar medium, opening new horizons for scientific research.

In recent years, much attention has been paifocused to the study of bubbles, partially circular structures in interstellar medium, consisting of dust and gas, which are inextricably linked with star formation regions [1-3], so analysis of the structure and evolution of bubbles provide insight into the conditions under which stars and planets form in interstellar space. Bubbles have a morphology that indicates the presence of advanced or stimulated star formation process. The star formation process can occur due to the expansion of the bubble, when the leading shock front overtakes and compresses the pre-existing molecular cloud core. The gravitational collapse of the core occurs at this moment, which is an initiated mechanism of star formation in bubbles. Therefore, the research of it is currently still in its early stages and subject of great interest to researchers in the star formation field.

Since studies of infrared dust bubbles are a powerful tool for studying of star-forming regions, the identification of young stellar objects plays an important role in to understand their interaction with the environment at different stages of evolutionary development.

The main goal of this study is to investigate the region near the dust bubble N126, to search and to identify young stellar objects (YSO).

Methods

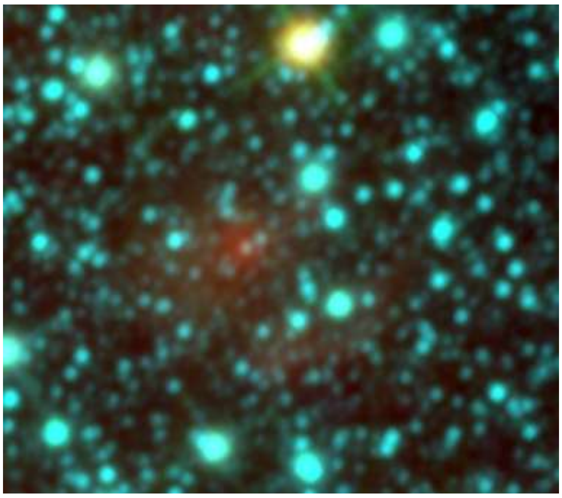
Data

The given research used the large-scale surveys in the infrared wavelength range: 2MASS and WISE (Wide-Field Infrared Survey Explorer). Near-infrared sky observations of *J* (1.25 μm), *H* (1.65 μm) and *Ks* (2.17 μm) obtained by 2MASS were presented in the 2MASS All-Sky Catalog of Point Sources (2003) [4]. WISE observations were presented in the AllWISE catalog [5], which contains radiation fluxes in the near and mid-infrared range at wavelengths *W1* (3.4 μm), *W2* (4.6 μm), *W3* (12 μm) and *W4* (22 μm).

For this investigarion, the following data from catalogs with reliable non-zero fluxes was selected: the flux error should be less than 0.2 mag; signal-to-noise ratio - w_{SNR} greater than 3.

Infrared dust bubble N126

N126 is one of the small galactic infrared bubbles cataloged by Churchwell [6]. N126 is a dust bubble centered at в $l = 59{,}606^0$, $b = 0{,}330^0$ with an average radius of about $0{,}03^0$ (1.87 arcmin) and an average shell thickness of $0{,}008^0$ (0,5 arcmin). In terms of its morphology, N126 is type *B* and *Fl*, which means that the bubble is a broken or incomplete ring, the structure of it is flocculent or lumpy (Figure 1). The scientific work [7] mentions the diffuse morphology of N126.



a) WISE

b) Spitzer

Figure 1 - Image of N126 at near and mid-infrared wavelengths

According to [8], the distance to N126 is 6.3 kpc. The coordinates of the central position and radius of the galactic IR bubble N126 estimating on a circular scale were refined in [9]. According to that work, the galactic coordinates are $l = 59{,}601^0$, $b = 0{,}319^0$, and the radius of the bubble is 1.98 arcmin.In addition, the component brightness distributions were also obtained:

$\log(L_{PAH}/L_{Sun}) = 3.83 \pm 0.12$,

$\log(L_{warm}/L_{Sun}) = 4.04 \pm 0.20$ and

$\log(L_{cold}/L_{Sun}) = 3.42 \pm 0.15$.

Based on the brightness of the PES, warm and cold dust, the authors calculated the total IR brightness of the dust bubble $\log(L_{TIR}/L_{Sun}) = 4.31 \pm 0.11$. According to the information on the flux densities obtained using (< 2*R*) circular aperture photometry, Figure 2 shows the energy distribution in the spectrum of the N126 dust bubble.

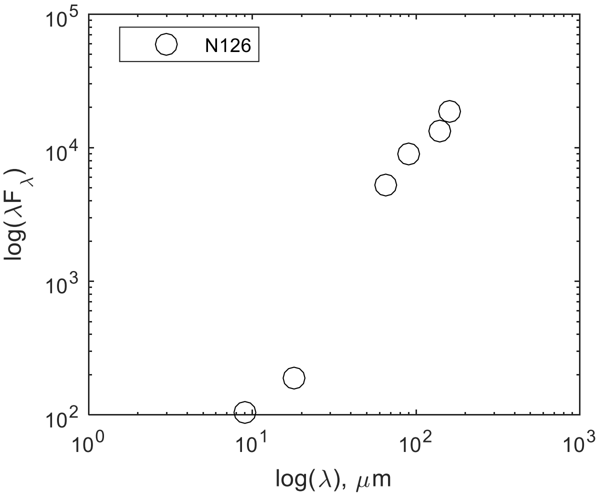


Figure 2 – Energy distribution in the spectrum of the N126 dust bubble

Results and Discussion

The search for young stellar objects was carried out in the astronomical database SIMBAD Astronomical Database - CDS (Strasbourg) using the catalogs describing above on this paper. Basic information on the region and the sources finding within the search radius are shown in Table 1.

Table 1 – Parameters for searching of objects

Region	R.A. range (deg)	Decl. range (deg)	Search radius (arcmin)	Number of found objects
N126	295,364 ≤α ≤ 295,447	23,712 ≤δ ≤ 23,741	5	463

The algorithm for identifying young stellar objects is used according to the scheme [10, 11]. The young stellar objects are grouped on dependence of evolution's stage: *class 0* (protostars), *class I* and *II*, *transition disks* and *class III* [12-15]. Therefore, identification is carried out in the same manner in that study. First of all, it is necessary to remove polluting factors (*AGN; stationary stars; sources corresponding to PAH emission and particle emission at the leading edge of shock waves*).

The young stellar objects of class 0 (protostars) and class I were not detected. 4 objects of class II, 1 object of the class of transition disks and 48 objects of class III were identified for the investigating dust bubles. Information on flows for 20 YSOs was presented in Table 2.

Table 2 – YSOs

Class YSO	RA(J2000) h:m:s	DE(J2000) d:m:s	AllWISE	W1, mag	W2, mag	W3, mag	W4, mag
II	19 41 49	+23 42 07	J194149.48+234207.9	13.602	13.467	10.873	7.068
II	19 41 44	+23 41 19	J194144.43+234119.9	10.388	10.009	7.592	5.257
II	19 41 47	+23 45 21	J194147.40+234521.4	11.188	10.933	8.949	8.667
II	19 41 46	+23 38 34	J194146.58+233834.1	6.902	6.126	5.161	5.642
Tr.disc	19 41 45	+23 46 11	J194145.53+234611.1	9.805	9.561	8.708	4.029
III	19 41 47	+23 43 26	J194147.00+234326.5	11.204	10.826	8.052	5.394
III	19 41 45	+23 42 20	J194145.11+234220.8	13.042	13.483	10.864	7.823
III	19 41 47	+23 41 55	J194147.14+234155.5	10.796	10.680	10.284	7.241
III	19 41 52	+23 42 55	J194152.21+234255.6	12.060	11.980	8.783	5.281
III	19 41 51	+23 42 00	J194151.00+234200.3	13.729	14.296	10.871	5.602
III	19 41 46	+23 41 42	J194146.88+234142.2	9.516	9.531	10.623	7.040
III	19 41 49	+23 41 40	J194149.45+234140.9	13.736	14.695	10.656	8.409
III	19 41 44	+23 41 54	J194144.32+234154.4	13.219	13.642	10.505	8.089
III	19 41 52	+23 43 02	J194152.91+234302.0	10.537	10.517	8.471	5.566
III	19 41 48	+23 41 30	J194148.88+234130.7	13.844	14.968	10.626	8.408
III	19 41 50	+23 41 39	J194150.78+234139.2	13.264	13.804	10.859	8.818
III	19 41 54	+23 42 54	J194154.34+234254.6	13.113	13.195	10.316	6.062
III	19 41 54	+23 43 17	J194154.26+234317.1	13.003	13.085	9.906	6.619
III	19 41 55	+23 42 32	J194155.08+234232.5	13.074	12.949	8.813	5.463
III	19 41 42	+23 41 31	J194142.39+234131.2	10.393	10.357	7.970	5.970

For all finding YSOs, the color indicators were determined and their diagram was constructed in Figure 3. The green squares indicated class II YSOs, the blue triangles indicate class "transition disk" YSOs, and class III objects were marked with black stars. Since existing methods for separating YSOs into evolution classes on color diagrams are still at the stage of improvement. There were selected the criteria for dividing areas to famous and used for WISE flows for analyzation of finding YSOs' location. In Figure 3, the dotted lines showed the criteria for YSO having the various classes of evolution [11]. The boundaries of the areas in the diagram were indicated in accordance with the classification presented in [16].

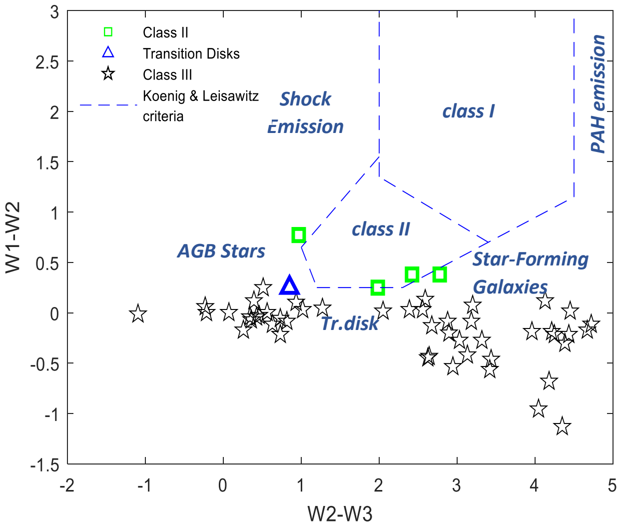


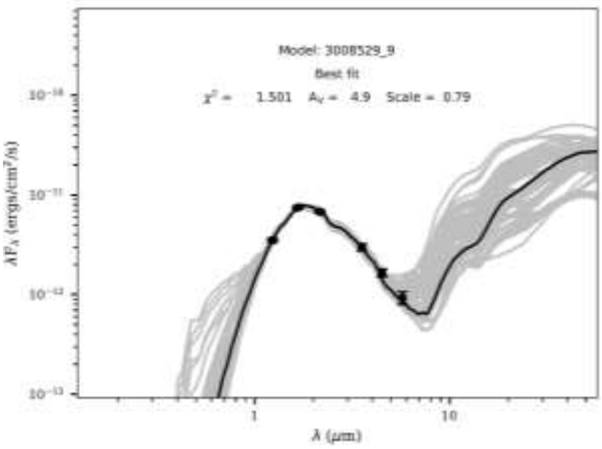
Figure 3 – Color-color diagram for the YSOs in the region of the N126 dust bubble

Figure 3 illustrateS that objects of class II are located at the edges of the corresponding evolution region, which indicates the correct identification of the evolution class of these objects. An object of the “Transition disks” class is lied near its corresponding evolution region. The location of the evolutionary stage of transition disks is currently unknown with certainty. Therefore, taking into account the assumptions of recent relevant research it is an intermediate stage between classes II and III and the location of this object near the group of class III YSOs is quite understandable. The objects on class III are practically formed young stars, so their location on the diagram corresponds to their evolution class. It is interesting that YSOs with class III are located in small groups on both sides of the “transition disks” region, which indicates a direct connection between the evolutionary development of objects with “transition disks” and class III.

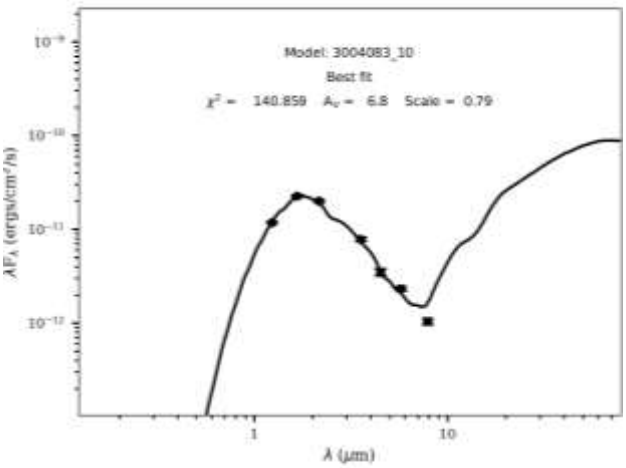
Moreover, for all of finding objects there were searched for information in astronomical databases in order to identify previously unidentified objects. As a result of the search, no information on the evolutionary status and spectral type of the object was found in the catalogs for the receiving young stellar objects.

For three class II YSOs, the astronomical catalogs GLIMPSE Source Catalog (I + II + 3D) (IPAC 2008) [17] and MIPSGAL 24μm point source catalog (Gutermuth+, 2015) [18] contain information on fluxes, on the basis of it the distributions were constructed energy in the spectra with suitable models according to [19]. Figure 4 shows that YSOs have an IR excess in the spectrum, which corresponds to our previously determined evolutionary status of these objects.

The map of the integrated intensity of infrared radiation at near and mid-range wavelengths is shown in Figure 5, where the locations of found and identificated candidates for young stellar objects are plotted. The white triangle corresponds to the YSO of the “transition disks” class, the red circles to the YSO of class II and the yellow stars to the YSO of class III. The white cross is the coordinates of the center of the dust bubble in accordance of the Churchwell catalog [6].



a) J194149.48+234207.9



b) J194146.58+233834.1

Figure 4 – DES for YSOs on class II: points – observational data, lines – theoretical models (black line – the most suitable model)

Figure 5 illustrates that the YZO distribution has a thread-like structure. Class II YSOs are located near large sources of infrared radiation, and the bulk of the found class III YSOs lies in the southern region of bubble's circular structure. Most objects are placed at the edges of flocculent structures and are observed in small groups.

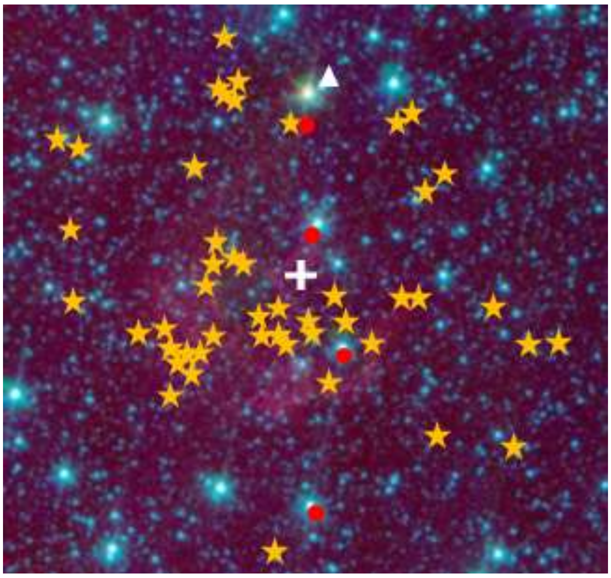


Figure 5 – Distribution of YSOs in space in the Spitzer image. Denoted: «+» – coordinates of the center of the bubble, «Δ» – "transition disks", «o» – II class, «☆» – III class

Figure 6 shows the number of YSOs on the dependence of distance from the center of the dust bubble. The crumpled structure is observed near the center of the dust bubble, and there are shown that any YSOs are not detected in this area. in addition, there are noticed the maximum number of YSOs at a distance of approximately 145 to 155 arcseconds, i.e. in the inner region of the dust bubble between the flocculent structures. however, there are not observed any YSOs at a distance of approximately 180 arcseconds, which is a region of flocculent structures. Furthermore, the number of YSOs decreases with increasing of distance.

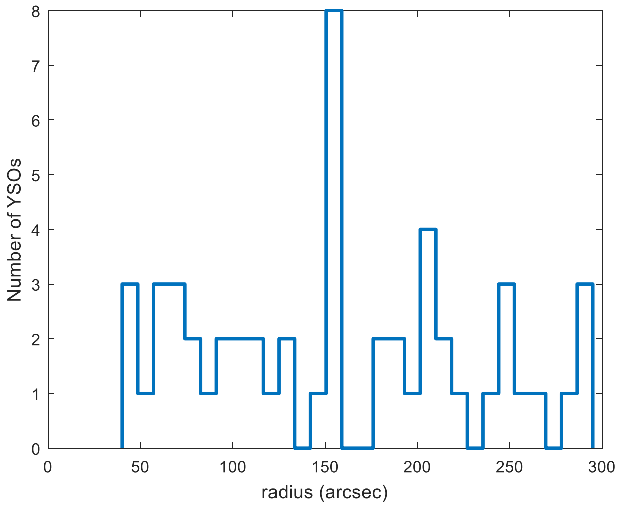


Figure 6 – Distribution of the number of YSOs on the dependence of distance to the bubble's center coordinate

Conclusion

In the present research the region near the N126 dust bubble was investigated. The search and identification of YSOs at various stages of evolution were carried out on the basis of applied infrared radiation fluxes near and mid-wavelength ranges. As a result of the study, 4 objects of class II, 1 object of the class of transition disks and 48 objects of class III were found. The color-color diagrams were constructed showing the correspondence of the location of the finding objects with the areas of evolution. A search for information was carried out in astronomical catalogs, and on the basis of it the energy distributions in spectra with the most suitable theoretical models were constructed for class II YSOs. The DES diagrams show that YSOs have an IR excess in the spectrum corresponding to the evolutionary status of these objects which were previously determined. Maps of the distribution of small objects in space were also analyzed, which indicated the presence of initiated star formation process in the N126 dust bubble.

Acknowledgment

The author associate professor, Dr. Turekhanova K.M. is grateful to the "500 Scientists" project by the Bolashak Scholarship Programme for supporting the research internship at the Cambridge University.

References

1 Manapbaeva A.B., Esimbek J., Alimgazinova N.Sh., Kyzgarina M.T., Atamurat A.B. N22 shan kopirshikteri zhanyndagy zhas zhuldyz obektilerin anyqtau // Izvestija Nacional'noj Akademii nauk Respubliki Kazahstan. Ser. Fiz-mat. – 2021. -T. 3. - № 337. - C. 96-105. (in Kaz.)

2 Nazar A.B., Manapbayeva A.B., Alimgazinova N.SH., Kyzgarina M.T., Demessinova A.M. Identification of young star objects near dust bubble N10 // Recent contributions to physics. – 2022. - №4 (83). - P.13-20.

3 Alisher A.M., Aslan D., Turekhanova K.M. Search and identification of young stellar objects in infrared dust bubbles N19// Recent Contributions to Physics. – 2023. – No3 (86). – P.12-20.

4 https://vizier.cds.unistra.fr/viz-bin/VizieR-3?-source=II/246/out&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa

5 https://vizier.cds.unistra.fr/viz-bin/VizieR-3?-source=II/328/allwise&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa

6 Churchwell E., Povich, M.S., Allen, D. et al. The Bubbling Galactic Disk // The Astrophysical Journal. – 2006. – Vol.649, Iss.2. – P.759-778.

7 Russeil D., Pestalozzi M. et al. Giving physical significance to the Hi-GAL data: determining the distance of cold dusty cores in the Milky Way // A&A. – 2011. –– Vol.526. – P. A151.

8 Watson C., Hanspal U., Mengistu A. Triggered Star Formation and Dust Around Mid-infrared-identified Bubbles // The Astrophysical Journal. – 2010. – Vol.716, Iss.2. – P.1478-1492.

9 Yasuki Hattori, Hidehiro Kaneda, et al. Mid- and far-infrared properties of Spitzer Galactic bubbles revealed by the AKARI all-sky surveys //Publications of the Astronomical Society of Japan. – 2016. – Vol.68, Iss.3. – P.37.

10 Koenig X.P. et al. Wide-field infrared survey explorer observations of the evolution of massive star-forming regions // The Astrophysical Journal. – 2011. – Vol. 744. – №. 2. – P. 130.

11 Koenig X. P., Leisawitz D. V. A classification scheme for young stellar objects using the wide-field infrared survey explorer AllWISE catalog: revealing low-density star formation in the outer galaxy // The Astrophysical Journal. – 2014. – Vol. 791. – №. 2. – P. 131.

12 Lada C. J. Star formation: from OB associations to protostars // Symposium-International astronomical union. – Cambridge University Press, 1987. – Vol. 115. – P.1-18.

13 Robitaille V.P. A modular set of synthetic spectral energy distributions for young stellar objects // Astronomy & Astrophysics. – 2017. – Vol. 600. – P. A11.

14 Allen et al. Initial Results from the Spitzer Young Stellar Cluster Survey // The Astrophysical Journal Supplement Series. – 2004. – Vol. 154. – №. 1. – P. 367.

15 Gutermuth R. A. et al. The Spitzer Gould belt survey of large nearby interstellar clouds: discovery of a dense embedded cluster in the Serpens-Aquila Rift //The Astrophysical Journal. – 2008. – Vol. 673. – №. 2. – P. L151.

16 Fischer W. J. et al. A WISE Census of Young Stellar Objects in Canis Major // The Astrophysical Journal. – 2016. – Vol. 827. – №. 2. – P. 96.

17 https://vizier.cds.unistra.fr/viz-bin/VizieR-2

18 https://vizier.cds.unistra.fr/viz-bin/VizieR-3?-source=J/AJ/149/64/catalog&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa

19 Robitaille V.P. et al. Interpreting spectral energy distributions from young stellar objects. II. Fitting observed SEDs using a large grid of precomputed models // The Astrophysical Journal Supplement Series. – 2007. – Vol. 169. – №. 2. – P. 328.

References

1 A.B. Manapbaeva, J. Esimbek, N.Sh. Alimgazinova, M.T. Kyzgarina, A.B. Atamurat, Izvestija Nacional'noj Akademii nauk Respubliki Kazahstan. Ser. Fiz-mat, 3 (337), 96-105 (2021). (in Kaz.)

2 A.B. Nazar, A.B. Manapbayeva, N.SH. Alimgazinova, M.T. Kyzgarina, A.M. Demessinova, Recent Contributions to Physics, 4 (83), 13-20 (2022).

3 A.M. Alisher, D. Aslan, K.M. Turekhanova, Recent Contributions to Physics, 3 (86), 12-20 (2023).

4 https://vizier.cds.unistra.fr/viz-bin/VizieR-3?-source=II/246/out&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa

5 https://vizier.cds.unistra.fr/viz-bin/VizieR-3?-source=II/328/allwise&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa

6 E. Churchwell, M.S. Povich, D. Allen, et al. The Astrophysical Journal, 649 (2), 759-778 (2006).

7 D. Russeil, M. Pestalozzi et al., A&A, 526, A151 (2011).

8 C. Watson, U. Hanspal, A. Mengistu, The Astrophysical Journal, 716(2), 1478-1492 (2010).

9 Yasuki Hattori, Hidehiro Kaneda, et al., Publications of the Astronomical Society of Japan, 68 (3), 37 (2016).

10 X.P. Koenig et al., The Astrophysical Journal, 744 (2), 130 (2011).

11 X.P. Koenig, D.V. Leisawitz, The Astrophysical Journal, 791 (2), 131 (2014).

12 C.J. Lada, Star formation: from OB associations to protostars // Symposium-International astronomical union, Cambridge University Press, 115, 1-18 (1987).

13 V.P. Robitaille, Astronomy & Astrophysics, 600, A11 (2017).
14 Allen et al., The Astrophysical Journal Supplement Series, 154(1), 367 (2004).
15 R.A. Gutermuth et al., The Astrophysical Journal, 673 (2), L151 (2008).
16 W.J. Fischer et al. The Astrophysical Journal, 827(2), 96 (2016).
17 https://vizier.cds.unistra.fr/viz-bin/VizieR-2
18 https://vizier.cds.unistra.fr/viz-bin/VizieR-3?-source=J/AJ/149/64/catalog&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa
19 V.P. Robitaille et al., The Astrophysical Journal Supplement Series, 169(2), 328 (2007).

Article history:
Received 26 March 2024
Accepted 25 April 2024

Мақала тарихы:
Түсті – 26.03.2024
Қабылданды – 25.04.2024

Information about authors:

1. **Nazgul Alimgazinova** – Cand. of Phys. and Math. Sc., Al Farabi Kazakh National University (Almaty, Kazakhstan, email: nazgul.alimgazinova@kaznu.kz).

2. **Nursultan Sharipbay** – schoolboy, Galaxy International School (Almaty, Kazakhstan, email: sharipbaynurs@gmail.com).

3. **Meiramgul Kyzgarina** (corresponding author) – PhD, Al Farabi Kazakh National University (Almaty, Kazakhstan, email: meir83physics@gmail.com).

4. **Arailym Manapbayeva** – PhD, Institute of Experimental and Theoretical Physics, Academy of Logistics and Transport, (Almaty, Kazakhstan, email: manapbayava.arailym@gmail.com).

5. **Kundyz Turekhanova** – Cand. of Phys. and Math. Sc., Ass.Prof., Al Farabi Kazakh National University (Almaty Kazakhstan, email: kundyz@physics.kz).

6. **Aruzhan Omar** – PhD student, Al Farabi Kazakh National University (Almaty Kazakhstan, email: omaruzhan@gmail.com).

7. **Aizat Demessinova** – PhD, Al Farabi Kazakh National University (Almaty Kazakhstan, email: aizat.dem@gmail.com).

8. **Akmaral Alibek** – PhD, Ass.Prof., Academy of Logistics and Transport, (Almaty Kazakhstan, email: Alibek_akmaral@list.ru).

Авторлар туралы мәлімет:

1. **Назгуль Алимгазинова** – физ.-мат.ғыл. канд., әл-Фараби атындағы Қазақ Ұлттық университеті (Алматы қ., Қазақстан, email: nazgul.alimgazinova@kaznu.kz).

2. **Нұрсұлтан Шарипбай** – оқушы, Galaxy халықаралық мектебі, (Алматы қ., Қазақстан, email: sharipbaynurs@gmail.com).

3. **Мейрамгуль Кызгарина** (автор корреспондент) – PhD, әл-Фараби атындағы Қазақ Ұлттық университеті (Алматы қ., Қазақстан, email: meir83physics@gmail.com).

4. **Арайлым Манапбаева** – PhD, Эксперименттік және теориялық физика институты, Логистика және көлік академиясы (Алматы қ., Қазақстан, email: manapbayava.arailym@gmail.com).

5. **Құндыз Туреханова** – физ.-мат.ғыл. канд., қауымд.проф., әл-Фараби атындағы Қазақ Ұлттық университеті (Алматы қ., Қазақстан, email: kundyz@physics.kz).

6. **Аружан Омар** – PhD студенті, әл-Фараби атындағы Қазақ Ұлттық университеті(Алматы қ., Қазақстан, email: omaruzhan@gmail.com).

7. **Айзат Демесинова** – PhD, әл-Фараби атындағы Қазақ Ұлттық университеті (Алматы қ., Қазақстан, email: aizat.dem@gmail.com).

8. **Ақмарал Әлібек** – PhD, қауымд.проф., Логистика және көлік академиясы, (Алматы қ., Қазақстан, email: Alibek_akmaral@list.ru).