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YOUNG STELLAR OBJECTS IN THE REGION OF DUST BUBBLE N1

The study of young stellar objects is one of the key studies in astrophysics, as these objects provide a unique window into the processes that occur during the formation of stars and planets. Young stars are often found in clouds of gas and dust, which serve as a kind of "cradle" for their birth. Young stars, especially in massive star clusters, create powerful streams of wind and radiation that knock out dust and gas, creating ring structures, those as bubbles in molecular clouds. Analysis of such structures can provide additional clues about the strength of the interactions between stars and their environment at different stages of their evolution.

The main objective of this study was to study the N1 dust bubble region and search for and identify young stellar objects. Searching for young stellar objects (YSOs) using infrared data from astronomical catalogs is an important and effective method for studying star formation. Young stars and their surroundings are often hidden from visible-light observations by dense clouds of gas and dust, but infrared radiation can penetrate these clouds, allowing astronomers to find objects that would otherwise be invisible.

The identification of young stellar objects in this study was performed according to the algorithm of Koenig & Leisawitz (2014). The observational data of the WISE spacecraft in the near and mid-infrared bands W1 (3.4 μm), W2 (4.6 μm), W3 (12 μm) and W4 (22 μm) were used. Reliable non-zero fluxes of infrared radiation sources from the 2MASS and AllWISE catalogs were selected for the study. For the studied dust bubble, 7 objects of class I and 11 objects of class II were identified, 32 objects were assigned to the transition disk stage. For all identified young stellar objects, color diagrams were constructed showing the locations of the found objects with the corresponding evolutionary regions. Spectral indexes were calculated and energy distributions in the spectra were constructed for young stellar objects, which also confirmed their evolutionary status. The distribution maps of early-stage YSOs within the dust bubble are analyzed, which indicate the patterns of their distribution along filamentary structures in the dust bubble N1.

Key words: bubble, infrared radiation, wise, young stellar objects (YSO), evolutionary stage.

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N1 шаң көпіршігі аймағындағы жас жұлдызды объектілер

Жас жұлдызды объектілерін зерттеу астрофизиканың негізгі зерттеулерінің бірі болып табылады, өйткені бұл объектілер жұлдыздар мен планеталардың пайда болуында болатын процестерге бірегей бағыт береді. Жас жұлдыздар көбінесе газ бен шаңның бұлттарында кездеседі, олар пайда болу үшін "бесік" ретінде қызмет етеді. Жас жұлдыздар, әсіресе үлкен жұлдыздар шоғырында, шаң мен газды қағып, молекулалық бұлттарда сақина тәрізді көпіршік құрылымдарын жасайтын күшті жел мен сәулелену ағындарын жасайды. Мұндай құрылымдарды талдау жұлдыздар мен олардың эволюциясының әртүрлі кезеңдеріндегі қоршаған ортаның өзара әрекеттесу күші туралы қосымша мәліметтер бере алады.

Бұл зерттеудің негізгі мақсаты N1 шаң көпіршігі аймағын зерттеу, жас жұлдыз объектілерін табу және анықтау болды. Астрономиялық каталогтардағы инфрақызыл деректер арқылы жас жұлдыз объектілерін (YSOs) анықтау жұлдыздардың пайда болуын зерттеудің маңызды және тиімді әдісі болып табылады. Жас жұлдыздар мен олардың айналасы көбінесе газ бен шаңның тығыз бұлттарымен көрінетін жарықта бақылаулардан жасырылады, бірақ инфрақызыл сәулелену бұлттар арқылы өтіп, астрономдарға басқаша көрінбейтін заттарды табуға мүмкіндік береді.

Бұл зерттеуде жас жұлдызды объектілерді анықтау Koenig & leisawitz (2014) алгоритміне сәйкес жүргізілді. WISE ғарыш аппаратының W1 (3,4 мкм), W2 (4,6 мкм), W3 (12 мкм) және W4 (22 мкм) жақын және орта инфрақызыл жолақтардағы бақылау деректері пайдаланылды. Зерттеу үшін 2MASS және AllWISE каталогтарынан инфрақызыл көздердің нөлдік емес сенімді ағындары таңдалды. Зерттелетін шаң көпіршігі үшін I класстағы 7 объект және II класстағы 11 объект анықталды, 32 объект өтпелі дискілер сатысына жатқызылды. Барлық анықталған жас жұлдыз объектілері үшін сәйкес эволюциялық аймақтары бар табылған объектілердің орналасуын көрсететін түс диаграммалары салынған. Спектрлік индекстер есептеліп, олардың эволюциялық мәртебесін растайтын жас жұлдыздық объектілер үшін спектрлердегі энергияның таралуы құрылды. N1 шаң көпіршігіндегі жіп тәрізді құрылымдар бойымен таралу заңдылықтарын көрсететін шаң көпіршігі шегіндегі эволюцияның ерте кезеңдеріндегі жас жұлдызды объектілерінің таралу карталары талданды.

Түйін сөздер: көпіршік, инфрақызыл сәулелену, wise, жас жұлдызды объектілер, эволюциялық кезең.

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Молодые звездные объекты в регионе пылевого пузыря N1

Исследование молодых звёздных объектов является одной из ключевых исследований астрофизики, так как эти объекты предоставляют уникальное окно в процессы, происходящие при формировании звёзд и планет. Молодые звезды часто находятся в облаках газа и пыли, которые служат как своеобразные "колыбели" для их рождения. Молодые звезды, особенно в массивных звёздных скоплениях, создают мощные потоки ветра и излучение, которые выбивают пыль и газ, создавая кольцевые структуры -пузыри в молекулярных облаках. Анализ таких структур может дать дополнительные подсказки о силе взаимодействия звезд и окружающей среды на разных стадиях их эволюции.

Основной целью данного исследования было изучение области пылевого пузыря N1, поиск и идентификация молодых звездных объектов. Поиск молодых звёздных объектов (YSOs) с помощью инфракрасных данных из астрономических каталогов — это важный и эффективный метод исследования звездообразования. Молодые звезды и их окрестности часто скрыты от наблюдений в видимом свете плотными облаками газа и пыли, но излучение в инфракрасном диапазоне может проникать через эти облака, позволяя астрономам находить объекты, которые иначе были бы незаметны.

Идентификация молодых звездных объектов в данном исследовании проведена согласно алгоритму Koenig & Leisawitz (2014). Были использованы данные наблюдений космического аппарата WISE в полосах ближнего и среднего инфракрасного диапазона W1 (3,4 мкм), W2 (4,6 мкм), W3 (12 мкм) и W4 (22 мкм). Для исследования были отобраны надежные ненулевые потоки источников инфракрасного излучения из каталогов 2MASS и AllWISE. Для исследуемого пылевого пузыря идентифицированы 7 объектов I класса и 11 объектов II класса, 32 объекта отнесены к стадии переходных дисков. Для всех идентифицированных молодых звездных объектов построены цветовые диаграммы, показывающие расположения найденных объектов с соответствующими им областями эволюции. Рассчитаны спектральные индексы и построены распределения энергий в спектрах для молодых звездных объектов, которые также подтвердили их эволюционный статус. Проанализированы карты распределения молодых звёздных объектов ранних стадий эволюции в пределах пылевого пузыря, которые указывают на закономерности их распределения вдоль нитевидных структур в пылевом пузыре N1.

Ключевые слова: пузырь, инфракрасное излучение, wise, молодые звездные объекты (МЗО), эволюционная стадия.

Introduction

In recent years studies of dust bubble regions and associated star-forming regions have attracted considerable attention [1–5], and studying their morphology and evolution may shed light on the conditions that facilitate the formation of stars and planets in interstellar space. Bubbles have a characteristic morphology that indicates the presence of initiated or stimulated star formation processes. Star formation may be triggered by the expansion of a bubble when its shock front compresses and initiates the gravitational collapse of a pre-existing molecular cloud core. This mechanism, based on initiated star formation, is currently in its early stages of study, making it particularly relevant for researchers studying star formation processes.

Young stellar objects are stars in the early stages of their evolution. They are also called protostars, as they continue to gain mass from the surrounding giant molecular clouds and have not yet reached the stage of a full-fledged stellar state, since thermonuclear fusion in their cores has not yet been launched. Studying such objects is quite difficult even within our Galaxy. The main problem is that the dense dust clouds surrounding them during the formation stage block visible light, making observations almost impossible. In addition, when these objects heat up, they begin to emit energy mainly in the infrared range. For this reason, infrared observations are considered a key method used by astronomers to identify regions where stars are forming.

Methods

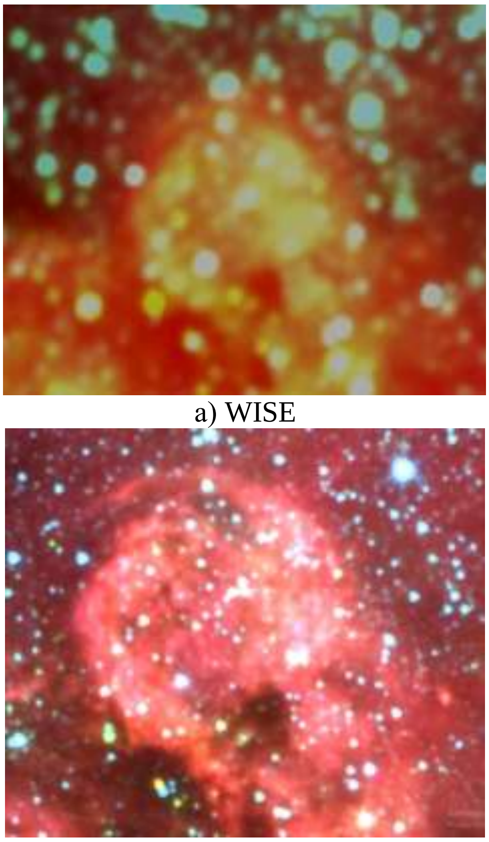
Data

In this study, large-scale surveys in the infrared wavelength range were used: 2MASS and WISE (Wide-Field Infrared Survey Explorer). Observations of the sky in the near-infrared range of J (1.25 μm), H (1.65 μm) and Ks (2.17 μm), obtained by 2MASS, are presented in the catalog of point sources 2MASS All-Sky Catalog of Point Sources (2003) [6]. WISE observations are presented in the AllWISE catalog [7], 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 study, data from the catalogs were selected that have reliable non-zero fluxes: the flux error was taken less than 0.2 mag; the signal-to-noise ratio - w_{SNR} was greater than 3.

Dust bubble N1

N1 is one of the small galactic infrared bubbles catalogued by Churchwell [8]. N1 is a dust bubble centered at $l = 10{,}231^0$, $b = -0{,}305^0$, with a size of 0.98 arcmin and a mean projected thickness of 0.21 arcmin. N1 has a C type of morphology, meaning that the bubble is a complete and closed ring (Figure 1). In [9], the bubble was associated with the HII region G10.16−0.35 and a massive OB2-type capture star. The first measurement of the bubble velocity was in the ionized hydrogen region and not directly to N1. Therefore, the distance of 3.4 kpc corresponds to the distance from the capture cluster G10.16−0.35 [9]. Then in [10] the kinematic distance to the bubble was calculated as a distance (may be up to 14.8 kpc), based on the velocity of ionized gas, measured mainly using radio recombination lines, and assuming circular rotation around the center of the Galaxy. And in [11] the kinematic distance for the bubble was taken to be 2 kpc, its size was also specified as 1 arcmin.



a) WISE

b) Spitzer

Figure 1 - N1 image at near and mid infrared wavelengths

Search and identification of young stellar objects

To identify candidates for young stellar objects, data from the AllWISE catalog, presented in the SIMBAD Astronomical Database (CDS, Strasbourg), were used. Key information about the study region and the sources detected within the specified search radius is presented in Table 1.

Table 1– Parameters for object search

Region	R.A. Range (deg)	Decl. Range (deg)	Search radius (arcmin)	Number of objects found
N1	272.255≤α≤272.430	-20.153≤δ≤-20.315	5	444

In this study, an algorithm based on the methodology described in [12, 13] was used to identify young stellar objects. According to the stages of their evolution, young stellar objects are classified into several groups: class 0 (protostars), classes I and II, transition disks, and class III. Identification of young stellar objects was carried out in the specified sequence.

To identify young stellar objects, it is first necessary to eliminate contaminants, i.e. objects that cannot be young stellar objects. These are active galactic nuclei (AGN), stationary stars, as well as sources associated with the emission of polycyclic aromatic hydrocarbons (PAH) and the emission of particles at the leading edge of shock waves [12]. After cleaning the data, in accordance with the criteria outlined in [13], the remaining objects were identified for belonging to a certain class of YSO evolution.

To identify true candidates for YSOs, the identification was carried out in several stages using different approaches.

Initially, the algorithm described in the work of Koenig & Leisawitz (2014) [13] was applied. According to the study, at this stage, no objects of evolution class 0 were detected in the region of the N1 dust bubble of the protostar. A total of 152 objects were identified as candidates for young stellar objects.

At the next stage, a search for information in astronomical databases was performed for all previously identified candidates for young stellar objects. As a result of the search, out of 14 candidates for young stellar objects of class I, it was found that there is information in astronomical catalogs for 8 objects and for some of them, various object types and evolutionary statuses were already indicated. For 5 objects, the status of young stellar objects was confirmed, which was assigned on the basis of the analysis of Spitzer data [14-17], 2 objects are sources of infrared and submillimeter radiation [18, 19] and 1 object is a Wolf-Rayet star, which is a star of a later evolutionary class [20]. Out of 25 candidates for young stellar objects of class II, information was found for 3 objects: 1 object is a candidate for young stellar objects [14], 2 objects are sources of IR and submillimeter radiation [18, 19]. Of the 74 objects that are candidates for class III YSOs, 1 object has been assigned the status of a star [21] and 1 object is a source of IR radiation [22]. A search for information on 39 objects – candidates for class “transition disk” YSOs showed that 1 object is a candidate for YSOs [14] and 1 object is a source of submillimeter radiation [23].

For further study, known objects (except radio and infrared sources) were excluded. Thus, 143 objects remained as candidates for young stellar objects, of which 8 objects are of class I, 24 objects are of class II, 73 objects are of class III and 38 objects that can be classified as transitional disks.

Next, for all found YSOs, color indices were determined and a corresponding color diagram was constructed (Figure 2). Red circles indicate candidates for YSOs of class I, green squares indicate class II, blue triangles indicate "transitional disks" and black stars indicate candidates for YSOs of class III. Since the existing methods for dividing YSOs into evolution classes on color diagrams are still at the stage of improvement, for the analysis of the location of the found YSOs we selected the known and applied for WISE flows criteria for dividing regions [24], which are shown in Figure 2 by dotted lines. The diagram also indicates the regions corresponding to the class of objects.

As can be seen from Figure 2, all candidates for class I YSOs and most candidates for class II YSOs are located in the corresponding area of the diagram. However, 4 objects of the class II YSO candidate are located in other areas of the diagram. The majority of candidates for the "transition disk" class are located to the left of the area indicated for them. They practically fill the area in which, as suggested in [24], AGN sources should be located. The location of the evolutionary stage of transition disks [25] is currently unknown reliably, therefore, assuming that this is an intermediate stage between classes II and III, the location of this object close to the group of class III YSOs is quite explainable. Class III objects are practically formed young stars, therefore their location on the diagram corresponds to their evolution class. The candidates for class III YSOs are located in the immediate vicinity of the candidates for "transitional disks" on the diagram, which may indicate their direct connection in the evolutionary development of objects.

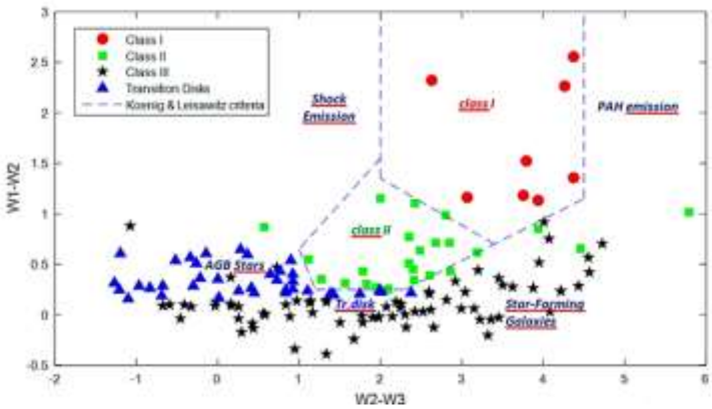


Figure 2 – Color-color diagram for the YSO in the region of dust bubble N1

As we can see, for most candidates for YSOs, their location on the diagram indicates the correct identification of their evolutionary stages. However, this is not enough to identify true YSOs, so additional studies have been conducted.

The next step in the study was to apply a typical classification of the YSO, which is calculated based on the slope of the DES, i.e. the spectral index is determined

$$\alpha = \frac{d\log(\lambda F_\lambda)}{d\log(\lambda)}.$$

Typically, the incline of the DES is measured between ~2 and 20 μm, the use of mid-IR DES fluxes allows measuring the IR emission of the disk and the inner shell of the YSO, so this IR range is used in this study. For different classes of YSOs, the spectral index has different ranges. This is due to the fact that as YSOs age, their circumstellar environment changes, and this change is reflected in the shape of their DES in the form of the presence of infrared excesses caused by their optically thick disks. In the standard system originally developed in [26], young stellar objects: of class I have DES inclinations $\alpha \geq 0,3$; of class II have $-1,6 \leq \alpha < -0.3$; of class III have $\alpha < -1.6$; sources with a "flat spectrum" have $-0.3 \leq \alpha < 0.3$. Class I YSOs have ascending or flat spectra in the range from 3 to 22 μm and are considered to be an early stage associated with the presence of a significant, infalling circumstellar envelope. Class II YSOs have decreasing DES in this wavelength range, with the emission coming only from the optically thick circumstellar disk [26–28]. Class III YSOs are characterized by very small infrared excesses and are often indistinguishable from young main-sequence stars based on infrared observations alone. In addition to Class I–III YSOs, there are also YSOs with little or no near-IR excess in the 1–10 μm range and large excesses above 10–20 μm [29]. These objects, known as "transition disk" sources, are thought to be YSOs with a cleared inner disk and a truncated, optically thick outer disk. The age of transition disks is unknown, as various possible origin scenarios are considered. One of the most likely scenarios is that transition disks are an intermediate stage between class 2 and class 3.

We used a technique to determine the spectral index that includes data from all four WISE bands. Measuring the inclination using only four WISE bands can mitigate absorption effects due to the nearly identical absorption coefficients across the entire WISE wavelength range, i.e. $A_{W[1,4]} \approx 0.5 A_K$ [30]. For all previously identified YSOs for which values are available in all four WISE bands, we used the equation to find the spectral index according to [31]:

$$\alpha_M = 0.36(W1 - W2) + 0.58(W2 - W3) + \\ +0.41(W3 - W4) - 2.90.$$

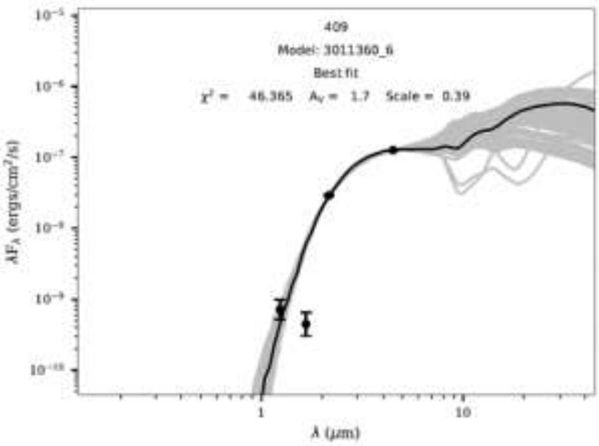
This is a weighted average of the slopes obtained between successive pairs of WISE bands, presented in magnitudes. The numerical coefficients are a combination of the magnitude-flux density conversion coefficients at the corresponding wavelengths and weighting coefficients.

The conducted study of the spectral index showed that for most candidates in the YSO, the spectral index values correspond to the previously determined evolution class. Thus, for candidates in the YSO of class I, only 1 object is assigned to class II, out of 24 objects of class II, 13 IR radiation sources have flat and characteristic class I spectra. Since the evolutionary stage of "transitional disks" is considered an intermediate stage between classes 2 and 3, then for most candidates in the YSO this is confirmed by the values of the spectral indices, only 6 objects have flat and characteristic class I spectra. The results of the study on candidates for YSO s of classes I and II, as well as the transition disk class, are presented in Table 2. The results for class III are not presented, since these are already practically formed young stars, while the main emphasis in the study is on identifying YSO s of earlier evolutionary classes.

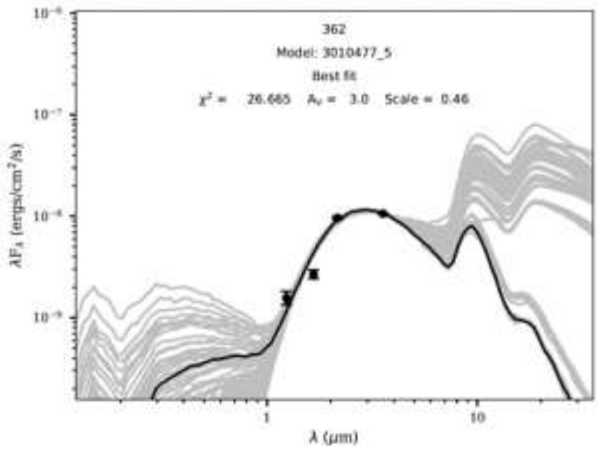
Table 2 – YSO candidates

N	RA(J2000) h:m:s	DE(J2000) d:m:s	AllWISE ID	W1, mag	W2, mag	W3, mag	W4, mag	α_M
I Class								
1.	18 09 25.1	-20 14 14.7	J180925.06-201414.7	10.851	9.495	5.120	0.316	2.10
2.	18 09 15.6	-20 16 03.7	J180915.59-201603.6	10.547	9.364	5.614	1.201	1.51
3.	18 09 28.4	-20 16 43.4	J180928.39-201643.3	12.335	9.779	5.411	-1.016	3.19
4.	18 09 31.3	-20 16 24.0	J180931.27-201624.0	9.889	8.365	4.575	1.433	1.14
5.	18 09 21.9	-20 10 05.5	J180921.90-201005.4	12.915	10.651	6.382	0.875	2.65
6.	18 09 39.4	-20 12 39.2	J180939.43-201239.1	12.416	11.257	8.195	5.795	0.28
7.	18 09 33.6	-20 18 07.9	J180933.55-201807.8	9.488	7.163	4.539	-2.406	2.31
II Class								
8.	18 09 20.7	-20 15 47.0	J180920.70-201546.9	11.166	10.532	8.048	7.453	-0.99
9.	18 09 30.1	-20 14 00.7	J180930.12-201400.6	11.504	10.786	8.105	7.723	-0.93
10.	18 09 31.5	-20 13 56.2	J180931.51-201356.2	10.587	9.722	9.153	6.478	-1.16
11.	18 09 16.8	-20 15 59.3	J180916.81-201559.3	8.406	7.249	5.244	2.893	-0.36
12.	18 09 16.0	-20 11 43.5	J180916.02-201143.5	10.448	9.902	8.787	6.697	-1.20
13.	18 09 34.4	-20 12 40.9	J180934.42-201240.9	11.052	10.795	8.698	5.587	-0.32
14.	18 09 09.1	-20 14 40.8	J180909.13-201440.8	11.273	10.767	8.418	6.476	-0.56
15.	18 09 16.2	-20 10 36.0	J180916.18-201035.9	10.174	9.868	8.041	5.143	-0.54
16.	18 09 25.7	-20 09 26.8	J180925.69-200926.7	9.949	9.609	7.201	7.123	-1.35
17.	18 09 24.3	-20 09 12.8	J180924.30-200912.8	10.309	9.994	8.427	5.875	-0.83
18.	18 09 43.1	-20 15 29.5	J180943.07-201529.4	10.627	10.271	9.003	6.197	-0.89
Transitional disks								
19.	18 09 15.0	-20 14 02.6	J180915.02-201402.5	10.162	9.994	9.980	6.484	-1.40
20.	18 09 24.8	-20 11 44.9	J180924.81-201144.8	9.092	8.774	10.044	7.108	-2.32
21.	18 09 19.5	-20 11 47.0	J180919.50-201146.9	10.262	10.053	8.634	6.220	-1.01
22.	18 09 31.9	-20 12 55.1	J180931.88-201255.0	9.801	9.549	8.631	4.928	-0.76
23.	18 09 17.5	-20 11 57.6	J180917.46-201157.5	10.417	9.986	9.223	6.175	-1.05
24.	18 09 13.7	-20 12 36.6	J180913.66-201236.6	10.078	9.840	7.855	4.575	-0.32
25.	18 09 32.4	-20 12 12.9	J180932.43-201212.8	10.015	9.615	8.967	5.342	-0.90
26.	18 09 21.6	-20 10 56.3	J180921.64-201056.3	9.917	9.349	9.684	4.520	-0.77
27.	18 09 33.3	-20 12 03.6	J180933.33-201203.6	9.856	9.258	8.892	5.456	-1.06
28.	18 09 29.9	-20 11 06.0	J180929.88-201106.0	8.497	7.892	8.034	3.378	-0.86
29.	18 09 08.1	-20 13 08.7	J180908.12-201308.6	9.210	8.928	9.230	5.270	-1.35
30.	18 09 08.8	-20 15 53.9	J180908.78-201553.8	10.013	9.750	10.582	3.791	-0.50
31.	18 09 10.7	-20 11 29.9	J180910.72-201129.9	10.073	9.804	9.388	5.926	-1.14
32.	18 09 32.6	-20 11 04.8	J180932.57-201104.7	7.920	7.377	7.890	4.142	-1.47
33.	18 09 39.5	-20 14 35.8	J180939.49-201435.8	10.647	10.247	9.323	6.043	-0.88
34.	18 09 08.9	-20 11 43.0	J180908.91-201143.0	7.260	6.717	5.819	3.442	-1.21
35.	18 09 10.0	-20 11 21.7	J180910.08-201121.7	10.984	10.734	9.900	6.142	-0.79
36.	18 09 06.3	-20 12 43.4	J180906.34-201243.4	9.003	8.645	8.858	5.577	-1.55
37.	18 09 40.0	-20 13 54.9	J180940.08-201354.8	10.567	10.221	9.490	5.702	-0.80
38.	18 09 39.3	-20 15 29.0	J180939.30-201529.0	9.167	8.557	9.748	6.917	-2.21
39.	18 09 06.2	-20 15 55.6	J180906.23-201555.5	9.980	9.696	10.375	5.271	-1.10
40.	18 09 36.3	-20 11 05.2	J180936.32-201105.2	8.657	8.320	7.394	5.098	-1.30
41.	18 09 07.0	-20 11 27.2	J180907.04-201127.2	8.992	8.770	6.757	3.935	-0.50
42.	18 09 33.1	-20 10 20.3	J180933.11-201020.3	10.265	9.977	10.941	8.304	-2.27
43.	18 09 39.2	-20 11 48.2	J180939.23-201148.2	9.748	9.241	9.510	6.425	-1.61
44.	18 09 38.4	-20 11 24.7	J180938.37-201124.6	10.439	10.231	8.490	6.454	-0.98
45.	18 09 27.9	-20 09 42.7	J180927.85-200942.6	11.175	10.943	9.840	7.780	-1.33
46.	18 09 42.4	-20 14 42.7	J180942.43-201442.6	8.888	8.536	8.530	5.157	-1.39
47.	18 09 02.5	-20 15 04.2	J180902.53-201504.2	10.134	9.922	9.085	4.128	-0.31
48.	18 09 40.5	-20 11 48.3	J180940.48-201148.3	10.749	10.105	9.824	6.668	-1.21
49.	18 09 10.7	-20 10 13.0	J180910.66-201012.9	8.774	8.616	9.718	6.936	-2.34
50.	18 09 43.0	-20 13 10.4	J180943.01-201310.4	9.343	9.103	8.842	5.660	-1.36

Also, to confirm the evolutionary status for objects observed by Spitzer and having reliable information on fluxes in the astronomical catalogs GLIMPSE Source Catalog (I + II + 3D) (IPAC 2008) [32] and MIPSGAL 24μm point source catalog (Gutermuth+, 2015) [33], energy distributions in the spectra were constructed with suitable models according to the work [34] (Figure 3). As can be seen from the figure, the YSOs have an IR excess in the spectrum, which corresponds to the evolutionary status of these objects that we previously determined.



a) J180933.55-201807.8



б) J180937.60-201126.6

Figure 3 – SED for candidates for YSO I (a) and II (b) classes: dots – observational data, lines – theoretical models (black line – the most suitable model)

Thus, excluding all objects whose evolution classes do not match according to two features, we assume that the remaining ones are the most likely candidates for YSOs.

Figure 4 shows a map of the distribution of the found and identified candidates for young stellar objects of classes I and II. The black cross is the coordinates of the center of the dust bubble, according to the Churchwell catalog [8]. Here we observe that the distribution of candidates for YSOs of early spectral classes is subject to a certain pattern, which allows us to identify the filamentary structures along which they are located, which indicates one of the possible signs of initiated star formation.

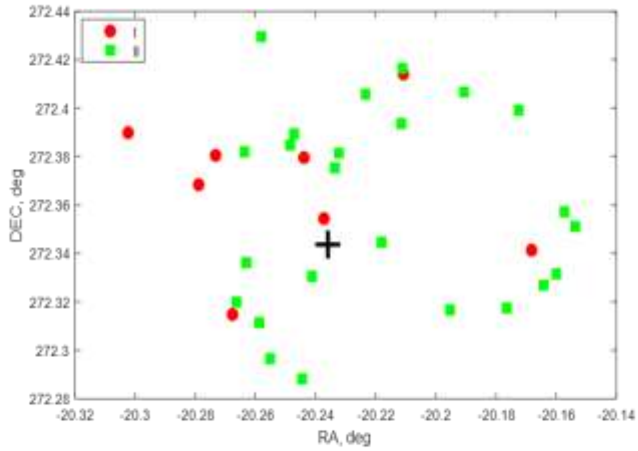


Figure 4 – Distribution of the YSO in space on the Spitzer image. Designations: "+" – coordinates of the bubble center, " red circles" – class I, " green squares" – class II

Conclusion

In this study the region near the N1 dust bubble was studied. Based on the use of infrared radiation fluxes in the near and middle wavelength ranges, the search and identification of YSOs depending on the stages of evolution was performed. The study was carried out in several stages, which included testing the data by criteria and by the spectral index, constructing a color-color diagram and a map of the distribution of identified objects in space, searching for information in astronomical catalogs and constructing a DES. As a result of the study, 50 objects are presented as candidates for YSOs: 7 objects of class I, 11 objects of class II and 32 objects of the "transition disk" class. We assume that these objects are young stellar objects.

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