IRSTI 41.25.29 https://doi.org/10.26577/RCPh.2023.v86.i3.02

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SEARCH AND IDENTIFICATION OF YOUNG STELLAR OBJECTS IN INFRARED DUST BUBBLES N19

In last times the dynamic development of astrophysics studied the interaction of matter and radiation on cosmos space, as well as the appearance of new possibilities of observation of celestial bodies allow to investigate the physical processes in the interstellar medium in detail. The density and quantity of interstellar gas and dust determine the possibility of new star formation, meanwhile star changes the properties of the surrounding interstellar medium, they heat it, support the continues movement of gas and supplement the medium with their own matter and change their chemical composition. In the present work, the first searches of young stellar objects were carried out in the region of the infrared duct bubble N19 and also there were created the program for searching of new stellar objects in computer simulation by MatLab. 11 objects were attributed to the young stars of I class by the found sources of infrared radiation, 26 objects to the II class and 20 objects are regarded to the young stars at the stage of transition disks. As a result, “a color-color” diagram for young stellar objects candidates detected near the infrared dust bubble N19 was constructed. In addition, there were analyzed the ranges of variation of the color indices and that diagram allows to determine the new criteria for determination of the new star objects in accordance with the stage of their evolution.

Key words: young stellar objects, infrared dust bubble N19, interstellar medium, star

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N19 инфрақызыл тозаңды көпіршік аймағында жас жұлдыз объектілерді іздеу және анықтау

Соңғы жылдары ғарыш кеңістігіндегі денелер мен сәулеленудің өзара әрекеттесуін зерттейтін астрофизика ғылымының қарқынды дамуы, сондай-ақ аспан денелерін бақылаудың жаңа әдістерінің пайда болуы жұлдыз аралық ортада физикалық процестерді мұқият зерттеуге мүмкіндік беріп келеді. Жұлдыздардың пайда болу мүмкіндігі жұлдызаралық газ бен тозаңның тығыздығы мен мөлшеріне байланысты, ал жұлдыздар қоршаған жұлдызаралық ортаның қасиеттерін өзгертеді, оны қыздырады, газдың үздіксіз қозғалысын қолдайды және қоршаған ортаны өз заттарымен толықтырып, оның химиялық құрамын өзгертеді. Ұсынылған жұмыста бірінші рет N19 инфрақызыл тозаңды көпіршік аймағында жас жұлдыз объектілеріне іздеу жүргізілді. Таңдалған қажеттеі критерийлер бойынша жас жұлдыз объектілерін іздеуге арналған компьютерлік ортады MatLab математикалық модельдеу бағдарламасы жасақталды. Табылған инфраақызыл сәулелену көздерінен I класс жас жұлдыздарына жататын 11 объект, ал II классқа 26-сы және 20-сы өтпелі диск сатысындағы жас жұлдыз объектісі болатыны анықталды. Нәтижесінде инфрақызыл N19 тозаңды көпіршік маңында жас жұлдыз нысандарына үміткерлер үшін “түс-түс” диаграммасы тұрғызылған. Сонымен қатар, түс көрсеткіштерінің өзгеру диапазондары талданған және осы диаграмма жас жұлдыз объектілерін олардың эволюциялық сатысына сәйкес анықтаудың жаңа критерийлерді айқындауға мүмкіндік беретіндігін көрсетілген.

Түйін сөздер: жас жұлдыз объектісі, N19 инфрақызыл тозаң көпіршігі, жұлдызаралық орта, жұлдыз

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Поиск и идентификация молодых звездных объектов в инфракрасном пылевом пузыре N19

В последнее время стремительное развитие астрофизики, которая изучает взаимодействие вещества и излучения в космическом пространстве, как и появление новых возможностей наблюдений небесных тел, позволило детально исследовать физические процессы в межзвездной среде. От плотности и количества межзвездного газа и пыли зависит возможность зарождения звезд, а звезды меняют свойства окружающей межзвездной среды – нагревают ее, поддерживают непрестанное движение газа, пополняют среду своим веществом, меняют ее химический состав. В данной работе первые произведен поиск молодых звездных объектов в регионе инфракрасного пылевого пузыря N19; по выбранным критериям идентификации разработаны программы поиска молодых звездных объектов в компьютерной среде математического моделирования MatLab. Из найденных источников инфракрасного излучения 11 объектов отнесены к молодым звездам I класса, 26 источников – к молодым звездным объектам II класса и 20 объектов – к молодым звездным объектам, находящимися на стадии переходных дисков. В результате построена диаграмма «цвет-цвет» для кандидатов в молодые звездные объекты, которые обнаружены вблизи инфракрасного пылевого пузыря N19. Также проанализированы диапазоны изменения показателей цвета и показано, что данная диаграмма позволяет определить новые критерии для определения молодых звездных объектов в соотвествии со стадией их эволюции.

Ключевые слова: молодые звездные объекты, инфракрасный пылевой пузырь N19, межзвездная среда, звезда

Introduction

The dust bubbles are the most significant morphological features of the interstellar medium. The research and analysis of the dust bubbles' composition provide additional information about the stellar winds that create them as well as about the structure and the physical properties of surrounding of stellar medium. In addition, the study of dust bubbles gives supplementary information about the physical parameters of gas and dust in expanding bubbles, supports to understand their influence to the magnetic field in stellar medium and also the processes of star formation and the rate of mass loss during stellar evolution [1-5].

The star formation in dust bubbles can be triggered by their expansion, when the leading shock front overtakes and compresses the pre-existing care of the molecular cloud. This leads to the gravitational collapse of the core, as a result of them there are created all conditions for initiated star formation in the region of the interstellar medium. The bubbled are observed in the infrared wavelength range, so the research of star formation processes is possible by studying of the fluxes at these wavelengths.

Recently, the search of young stellar objects in the interstellar medium based by their fluxes in infrared wavelength range are provided due to the fact that observational techniques and methods of conducting observations are developing, more reliable observational data on stellar objects have become available and catalogs including a large data stream on space objects have been formed. At the present time, there are already reliable techniques for the identification of young stellar objects, which are based on the analysis of their energy distributions in spectra, on the analysis of color diagrams, and on different criteria on fluxes and color indices [6-10].

In this present work the region of the interstellar medium near the N19 dust bubble is investigated for the detection of young stellar objects using the criteria described in Koenig et.al [11, 12].

Materials and Methods

In this research the large-scale surveys and catalogs of infrared data were used: 2 MASS (Two Micron All-Sky Survey) and WISE (Wide-field Infrared Survey Explorer) [13-20].

2MASS presents observations of the near-infrared sky at a wavelength of 2 microns. 2MASS uses two new highly automated 1.3-meter telescope, one of them at the mountain Hopkins, Arizona and other at CTION, Chile. Each telescope is equipped with three-channel camera, and each channel consisting of a 256x256 array of HgCdTe detectors capable of simultaneously observing the sky at J (1.25 μm), H (1.65 μm), and Ks (2.17 μm). In addition, there are used 2MASS All-Sky Catalog of Point Sources (2003), a catalog of point sources across the sky at a wavelength of two microns.

WISE (Wide-Field Infrared Survey Explorer) is the infrared space telescope of NASA launched into Earth orbit on December 14, 2009. The main instrument of WISE observatory is the cryogenic five-mirror a focal telescope with diameter 40 cm, with a focal length of 1.35 m and a field of view of 47 angular minutes. The telescope is equipped with four cameras, each operating in a different range: 3.4, 4.6, 12, and 22 microns. The AllWISE catalog of pion siurces in the mid-infrared at wavelengths of 3.4, 4.6, 12 and 22 μm (W1, W2, W3 and W4, respectively) was used in this work.

Results and Discussion

N19 is an infrared dust bubble with galactic coordinates l=17.0770, b= 0.9460, which is represented in the catalog of E. Churchwell et.al. (2006)

Firstly there is determined the center point of the object relative to which the emission sources in the near and mid-infrared range are selected within a radius of 5 angular minutes for searching of young star objects in the region of infrared dust bubbles N19 (Figure 1).

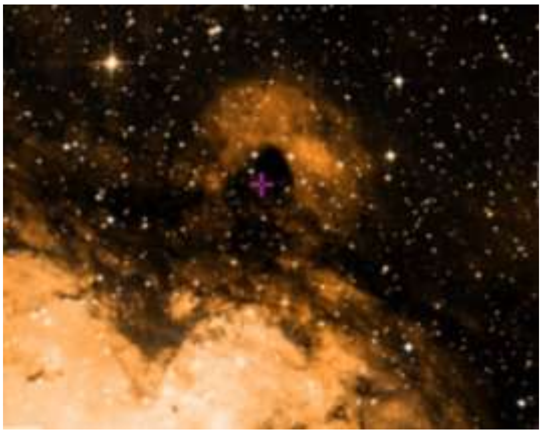

Figure 1 – The Aladdin database: the image of N19 in DSS, a digitized version of several photographic astronomical surveys of the night sky taken by the Space Telescope of Science Institution between 1983 and 2006 indicating the selected center point.

In the AllWISE Data Release (Cutri+ 2013) source catalog we specified the value of the central search point and the search radius for infrared sources. Here there is also selected the values that are necessary for working with the data. There are the distances from the central point, the equatorial coordinates, the catalog name WISE (at the wavelengths of 3.4 μm, 4.6 μm, 12 μm, and 22 μm) and 2MASS (at the wavelengths of 1.25 μm, 1.65 μm, and 2.17 μm) intensity values, and the corresponding errors for each flux. These radiation intensities or fluxes are dimensionless physical values characterized the illumination created by a celestial object in the vicinity of the observer. Subjectively its value is perceived as brilliance (for point sources) or brightness (for extended sources). In this case, the luminosity of one source is indicated by comparing it with the luminosity of another, taken as a standard. Such standards are usually specially selected non-variable stars.

The search found 547 sources of the infrared radiation in the region of N19. In that way, there are constructed the table containing the information on the found sources of infrared radiation.

The first step in the research was to work in Excel: we removed the objects, which did not have the flux number in the considering wavelengths: 1.25 μm, 1.65 μm, 2.17 μm, 3.4 μm, 4.6 μm, 12 μm, and 22 μm. Then we deleted the objects which had the values of radiation intensity with large errors more than 0.2 mag (the unit of flux, a dimensionless measure of objects' brightness). In that way, we had only 406 objects, which had the reliable data of radiation fluxes.

The second step was to delete the contaminating factors in the search of young stellar bodies from the table of objects. With the help of the developed programs in MatLab we **removed** the objects which represent the radiation of active galactic nuclei (AGN), sources of normal star formation regions of galaxies, shock waves, and radiation of polycyclic aromatic hydrocarbon (PAH) molecules formed as a result of chemical reactions in the cold regions of the molecular cloud. These objects are the polluting factors.

Therefore, we have 400 sources of the infrared radiation, which are considered as the candidates of the young stellar objects. The third step was to check the remaining objects for fulfillment of the criteria described in Koenig, 2014. Initially we search the young stellar objects of I class.

The young star objects of I class (protostars) are the reddest objects and they are selected according to the following criteria:

$$[4.6]-[12]>2.0\,;$$
$$[3.4]-[4.6]>-0.42\cdot([4.6]-[12])+2.2\,;$$
$$[3.4]-[4.6]>0.46\cdot([4.6]-[12])-0.9\,;$$
$$[4.6]-[12]<4.5\,,$$

here $[3.4]$ is the radiation flux at wavelength of 3.4 μm, $[4.6]$ is the radiation flux at wavelength of 4.6 μm, $[12]$ is the radiation flux at wavelength of 12 μm. The difference between $[3.4]$ and $[4.6]$ is called the color index, which is the spectral characteristics of the observed radiation of star determined by the measurement of energy in the given range of electromagnetic spectrum.

In our research 9 infrared sources out of 400 objects meet these conditions (the flux data are presented in Table 1 (Appendix 1)).

The fourth stage: the remaining 391 objects were checked to see if they correspond the criteria for young stellar objects of II class. The young stellar objects of III class are slightly less reddened objects and are distinguished by colors:

$$[3.4]-[4.6]>0.25;$$
$$[3.4]-[4.6]<0.9\cdot([4.6]-[12])-0.25;$$
$$[3.4]-[4.6]>-1.5\cdot([4.6]-[12])+2.1;$$
$$[3.4]-[4.6]>0.46\cdot([4.6]-[12])-0.9;$$
$$[4.6]-[12]<4.5.$$

There are also found 19 objects corresponding all criteria simultaneously, which are presented above (the flux data in Table 2 (Appendix 2)).

The fifth step. For identification of candidates in young stellar objects there are used the next criteria among previously unclassified objects with non-zero photometric error: the fluxes of H (1.65 μm) and Ks (2.17 μm) in the catalog 2MASS and the fluxes in the wavelengths 3.4 μm and 4.6 μm in the catalog of ALLWISE. 15 objects with such fluxes were selected here. The criteria of young stellar objects of I and II classes according to 2MASS and AllWISE catalogs are:

$$H-Ks>0.0,$$
$$H-Ks>-1.76\cdot([3.4]-[4.6])+0.9,$$
$$H-Ks<\frac{0.55}{0.16}\cdot([3.4]-[4.6])-0.850.9,$$
$$[3.4]\leq 13.0.$$

The objects satisfying these conditions are further checked according to the following criteria which separate from I class.

$$H-Ks>-1.76\cdot([3.4]-[4.6])+2,25.$$

That way, there are found 2 young stellar objects of I class and 13 stellar objects of II class.

The objects which did not satisfy these conditions are checked for affiliation to young stellar objects and the transitional disks. The candidates to transitional disks are identified by the deficit of infrared flux in the mid infrared range with spectral energy distribution. These objects were the transitional from young stellar with the optic thick disks that extend to the inner of surface of the star (i.e. objects of II class) to the objects where the disk has dissipated (i.e. young stellar III objects). Moreover, there were found 22 transitional disks (the flux data are presented in Table 3 (Appendix 3))

In each step, the selected candidates of young stellar objects are checked to the conditions consistent with the sources of active galactic nuclei. The polluting factors were also detected here, so there are fewer candidates for young stellar bodies.

As a result of this research there were selected a total 57 candidates of young stellar objects: 11 of them are of I class, 26 of them are of II class and 20 objects are the transitional disks. Furthermore, there were constructed the color-color diagram for our selected candidates (Fig.2).

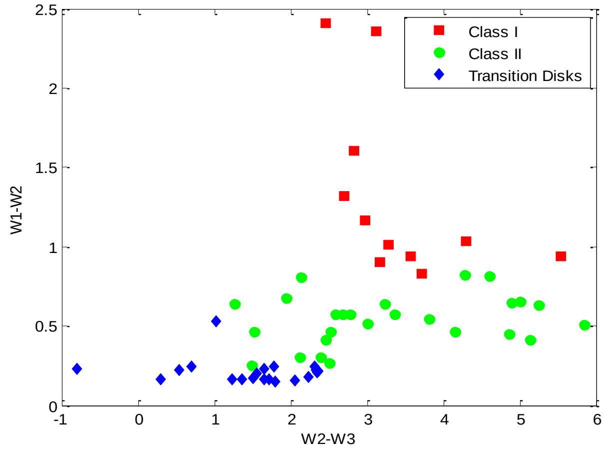

Figure 2 – A color-color diagram of candidates to young stellar objects near infrared dust bubbles N19

The dependences of color indices by the data of catalog AllWISE were demonstrated in Figure 3, where there was shown that the transitional disks occupy the area of smaller color indices than objects of I and II classes. The color index determining near infrared range for I class objects has the largest range of values, while it is the smallest for the transitional disks. For the transitional disks W1-W2 it has values mostly near 0.2, for II class it varies from 0.3 to 1.8 and for I class it is above 0.8 and reached a value of 2.5. The candidates of II class objects have the largest flux difference in the mid-infrared range W2-W3 than for I class and transitional disks.

The obtaining diagram allowed to highlight the regions occupied by candidates of young stellar objects. Moreover, in this scientific work there were used the other criteria of color indices, as a result on the basis of this diagram we could classify young stellar objects since they were grouped in the diagram according to their evolution stage.

Conclusion

In that present article there were given the results of search of young stellar in the infrared dust bubbles N19, the primary analysis of obtained data and the selection of objects by the criteria of identification of young stellar objects. The distribution diagram was constructed in space of stellar objects. From found sources of infrared radiation 11 objects were attributed to young star of I class, 26 bodies to young star of II class and 20 objects of young stellar objects at the stage of transitional disks. A color-color diagram was plotted for candidates of young stellar objects which were detected near the infrared dust bubbles N19. The ranges of color indices' variation were analyzed and there were shown that that diagram allows to define the new criteria for identification of young stellar objects corresponding with their evolution.

Acknowledgment

The authors are grateful to N.Sh. Alimgazinova for numerous discussions of the problem.

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Appendix 1

Table 1. Candidates to the young atellar objects of I class

Full	RAJ2000 "h:m:s"	DEJ2000 "d:m:s"	AllWISE	W1 mag	W2 mag	W3 mag	W4 mag	J mag	H mag	K mag
N19_YSO_1	18 18 31.607376	-13 37 14.91636	J181831.60-133714.9	11.584	10.642	7.066	5.017	16.604	14.513	13.241
N19_YSO_2	18 18 43.839288	-13 38 07.86228	J181843.83-133807.8	12.293	10.69	7.861	3.398	18.445	16.5	13.881
N19_YSO_3	18 18 45.062400	-13 39 12.67992	J181845.06-133912.6	11.219	8.859	5.734	1.791	0	0	0
N19_YSO_4	18 18 31.269360	-13 32 49.81956	J181831.26-133249.8	12.421	11.479	5.944	7.478	17.146	14.823	13.526
N19_YSO_5	18 18 39.489144	-13 41 40.29324	J181839.48-134140.2	10.852	10.021	6.302	0.866	16.797	14.848	12.425
N19_YSO_6	18 18 20.661768	-13 41 56.48892	J181820.66-134156.4	11.713	10.811	7.64	1.75	18.156	16.818	14.137
N19_YSO_7	18 18 09.773472	-13 36 10.92852	J181809.77-133610.9	7.997	6.679	3.976	1.642	15.018	12.473	10.473
N19_YSO_8	18 18 38.639928	-13 41 57.35364	J181838.63-134157.3	9.839	8.804	4.501	0.35	14.239	12.596	11.597
N19_YSO_9	18 18 32.846184	-13 32 39.37848	J181832.84-133239.3	11.015	8.609	6.144	5.867	18.159	15.892	12.83
N19_YSO_10	18 18 34.549752	-13 42 31.24476	J181834.54-134231.2	12.309	11.296	8.016	1.424	17.7	16.747	14.361
N19_YSO_11	18 18 47.127840	-13 34 42.41784	J181847.12-133442.4	11.243	10.076	7.102	3.564	16.312	14.06	12.709

Appendix 2

Table 2. Candidates to the young atellar objects of II class

Full	_RAJ2000 "h:m:s"	_DEJ2000 "d:m:s"	AllWISE	W1 mag	W2 mag	W3 mag	W4 mag	J mag	H mag	K mag
N19_YSO_12	18 18 34.817640	-13 39 24.40080	J181834.81-133924.4	9.696	9.445	7.954	2.627	15.834	12.48	10.812
N19_YSO_13	18 18 24.497712	-13 39 34.68708	J181824.49-133934.6	11.611	11.161	6.297	2.227	15.041	14.003	13.333
N19_YSO_14	18 18 27.976896	-13 35 04.21044	J181827.97-133504.2	10.315	9.678	8.407	5.753	18.11	13.295	11.172
N19_YSO_15	18 18 39.219000	-13 39 22.78512	J181839.21-133922.7	11.535	11.072	9.551	7.103	17.107	14.338	12.7
N19_YSO_16	18 18 39.300672	-13 39 39.74148	J181839.30-133939.7	11.677	11.103	8.328	4.852	17.198	14.594	12.602
N19_YSO_17	18 18 37.806384	-13 40 18.24636	J181837.80-134018.2	9.688	9.273	6.808	2.165	17.985	13.106	11.022
N19_YSO_18	18 18 34.256256	-13 40 48.60264	J181834.25-134048.6	10.414	9.735	7.787	4.524	16.32	14.633	11.823
N19_YSO_19	18 18 28.384056	-13 41 16.09404	J181828.38-134116.0	10.292	9.642	4.753	3.914	16.337	14.45	13.349
N19_YSO_20	18 18 44.012712	-13 36 06.04080	J181844.01-133606.0	10.309	9.738	7.143	4.125	16.205	12.91	11.326
N19_YSO_21	18 18 44.604960	-13 36 27.75492	J181844.60-133627.7	10.182	9.879	7.486	3.579	16.889	13.054	11.241
N19_YSO_22	18 18 28.096560	-13 41 34.43172	J181828.09-134134.4	9.916	9.505	4.368	0.715	12.447	11.858	11.47
N19_YSO_23	18 18 27.297672	-13 41 44.49876	J181827.29-134144.4	10.13	9.313	4.701	3.591	15.589	14.015	13.792
N19_YSO_24	18 18 40.283424	-13 34 17.50296	J181840.28-133417.5	11.634	10.811	6.525	3.219	14.918	13.513	12.69
N19_YSO_25	18 18 35.962440	-13 33 33.45120	J181835.96-133333.4	11.739	11.085	6.077	5.089	17.728	14.941	13.713
N19_YSO_26	18 18 45.373560	-13 35 45.29472	J181845.37-133545.2	11.067	10.798	8.286	3.67	16.233	14.133	12.71
N19_YSO_27	18 18 38.978784	-13 33 47.34216	J181838.97-133347.3	9.291	8.989	6.866	6.669	14.968	11.77	10.246
N19_YSO_28	18 18 45.457296	-13 39 41.82660	J181845.45-133941.8	9.64	9.173	6.643	1.789	15.706	12.308	10.561
N19_YSO_29	18 18 19.990464	-13 41 51.11808	J181819.99-134151.1	11.623	10.812	8.672	2.348	14.981	14.303	13.119
N19_YSO_30	18 18 37.773288	-13 33 11.42676	J181837.77-133311.4	10.473	9.899	6.542	3.558	14.332	12.907	11.912
N19_YSO_31	18 18 31.785528	-13 32 43.20420	J181831.78-133243.2	11.743	11.112	5.862	5.051	17.271	15.345	14.377
N19_YSO_32	18 18 48.368856	-13 39 02.67408	J181848.36-133902.6	11.323	10.752	8.061	3.068	17.914	15.134	12.734
N19_YSO_33	18 18 37.566336	-13 33 01.77192	J181837.56-133301.7	11.33	10.868	6.708	3.42	14.74	13.352	12.634
N19_YSO_34	18 18 49.753608	-13 36 33.58152	J181849.75-133633.5	11.921	11.407	8.397	3.469	18.321	15.309	13.051
N19_YSO_35	18 18 37.905768	-13 42 14.14152	J181837.90-134214.1	11.669	11.163	5.312	0.964	15.249	13.617	12.87
N19_YSO_36	18 18 38.306568	-13 32 49.43184	J181838.30-133249.4	11.394	10.846	7.024	4.724	14.656	13.931	13.422
N19_YSO_37	18 18 49.478520	-13 35 45.85164	J181849.47-133545.8	11.819	11.181	7.948	4.482	18.152	14.816	12.828

Appendix 3

Table 3. Candidates to the young stellar objects as the transitional disks

Full	_RAJ2000 "h:m:s"	_DEJ2000 "d:m:s"	AllWISE	W1 mag	W2 mag	W3 mag	W4 mag	J mag	H mag	K mag
N19_YSO_38	18 18 28.059504	-13 37 28.44768	J181828.05-133728.4	8.82	8.592	9.394	7.23	15.11	11.534	9.829
N19_YSO_39	18 18 37.744656	-13 38 23.19468	J181837.74-133823.1	10.074	9.908	8.681	4.725	15.615	12.457	10.902
N19_YSO_40	18 18 29.806968	-13 40 04.49544	J181829.80-134004.4	8.825	8.626	7.062	3.568	14.206	11.143	9.694
N19_YSO_41	18 18 25.333080	-13 39 56.58192	J181825.33-133956.5	10.687	10.479	8.139	3.188	16.783	13.725	11.888
N19_YSO_42	18 18 21.746520	-13 39 28.30068	J181821.74-133928.3	10.808	10.657	8.864	5.903	15.471	12.977	11.82
N19_YSO_43	18 18 35.625792	-13 35 23.86104	J181835.62-133523.8	9.772	9.548	9.005	3.305	14.513	11.944	10.576
N19_YSO_44	18 18 40.489824	-13 37 03.83052	J181840.48-133703.8	10.102	9.869	8.223	2.06	13.931	12.02	10.857
N19_YSO_45	18 18 40.972920	-13 37 40.91448	J181840.97-133740.9	9.535	9.363	7.856	4.06	12.171	12.001	10.505
N19_YSO_46	18 18 19.424208	-13 35 42.41976	J181819.42-133542.4	9.138	8.977	8.679	3.375	14.119	11.335	9.915
N19_YSO_47	18 18 18.881424	-13 39 21.37896	J181818.88-133921.3	10.102	9.857	9.158	1.762	15.558	12.671	11.353
N19_YSO_48	18 18 41.926752	-13 36 39.71376	J181841.92-133639.7	10.626	10.448	8.213	3.856	16.864	13.59	11.782
N19_YSO_49	18 18 36.705648	-13 40 44.66172	J181836.70-134044.6	8.87	8.624	6.845	3.836	16.348	12.428	10.449
N19_YSO_50	18 18 13.835976	-13 38 13.52076	J181813.83-133813.5	8.8	8.272	7.24	4.367	13.615	11.041	9.645
N19_YSO_51	18 18 36.226080	-13 34 03.45108	J181836.22-133403.4	9.503	9.26	6.948	3.223	15.788	12.251	10.497
N19_YSO_52	18 18 41.216808	-13 40 53.91228	J181841.21-134053.9	8.737	8.513	6.187	1.377	14.921	11.79	10.228
N19_YSO_53	18 18 23.347080	-13 41 48.88536	J181823.34-134148.8	8.829	8.668	6.95	3.305	13.892	10.999	9.619
N19_YSO_54	18 18 11.621160	-13 39 46.61460	J181811.62-133946.6	8.456	8.289	6.928	4.896	13.92	10.79	9.305
N19_YSO_55	18 18 44.902728	-13 34 38.47332	J181844.90-133438.4	10.079	9.922	7.868	3.632	15.364	12.452	10.988
N19_YSO_56	18 18 46.737432	-13 35 14.08740	J181846.73-133514.0	10.307	10.088	7.722	3.493	14.889	12.41	11.233
N19_YSO_57	18 18 43.497360	-13 41 10.22460	J181843.49-134110.2	10.1	9.937	8.279	1.42	15.834	12.613	11.111