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UNSTABLE OBJECTS IN MOLÈCULAR CLOUD LDN 133

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The results of investigation of molecular cloud LDN133 and connected with it unstable objects HHL59, HHL59A, HHL59B and HHL59C are given. IR nebula and IR stars cluster are also connected with LDN133. It is shown that two different molecular outflows are present: 1. A red shifted molecular outflow from IR nebula, connected with HHL59, and 2. A bipolar molecular outflow from the object HHL59A. An IRAS point source IRAS 17554-2606 is connected with IR nebula. Observations with narrow band filters revealed existence of HH objects and jets from several unstable stars of this region. There are three filaments, ejected from IR nebula with condensation at their ends. Two 8-type cometary nebulae, connected with unstable stars were also discovered.

Key words: molecular cloud: HH objects: ejections: IR nebula

1. Introduction. This paper is one in the series of papers devoted to the observations of Southern molecular clouds and also of YSOs and star forming regions, connected with them [1-3]. V.A.Ambartsumian was the first, who discovered, that OB-stars are originated in OB-associations [4] and often as Trapezium-type systems [5]. The same is so on T Tauri type and Herbig Ae/Be stars, which are originated in T-associations [6]. In several clouds we observed molecular outflows (red shifted or blue shifted or both blue shifted and red shifted).

The molecular outflows can be divided in two types. 1. Outflows connected with massive stars (or protostars) in large star forming regions (e.g. core of the Orion molecular cloud). 2. Outflows associated with stars of low and intermediate masses (e.g. T Tauri or Herbig A_e/B_e - type stars). In this paper we present results of observations of molecular cloud LDN 133 and several YSOs and HH objects, connected with that cloud. The star forming region in that cloud is of type 2, that is the stars are mainly of middle masses (Herbig A_e/B_e , T Tauri type et al.).

2. CO(1-0) observations of LDN133. The ¹²CO(1-0) observations of the region in the direction of LDN 133 were carried out with the 15-m SEST (Swedish-ESO Submillimetre Telescope) telescope at Cerro la Silla, Chile. The telescope beam size at 115 GHz is 45" and the beam efficiency is 0.70. The positions toward the source were observed with a spacing of 40" in frequencyswitched mode, with a frequency throw of 10 MHz. The telescope was equipped with a SIS detector and a high-resolution acousto-optical spectrometer with 1000 channels and a velocity resolution of 0.112 km/s. These observations were done with late Prof. Jorge May. Observations were done at 30 of August, 2003.

Fig.1 shows the ${}^{12}CO(1-0)$ spectra observed toward LDN 133 arranged in a map-like distribution. As we can see from Fig.1 the mean velocity of LDN 133 is about 10 km/s. From Fig.1 we can also conclude that there are two molecular outflows. 1. Red shifted molecular outflow. The velocity of that outflow is in the range (19.17 - 20.83) km/s or in respect of the velocity of molecular cloud LDN 133 is in the range (9.17 - 10.83) km/s (this outflow is from IR nebula, see below). 2. Bipolar outflow from the object HHL 59A (see below). Red shifted outflow is in the range (12.077 - 14.996) km/s or in respect of the velocity of



Fig.1. ¹²CO(1-0) spectra toward LDN 133 cloud, arranged in a map-like distribution.

molecular cloud LDN 133 is in the range (2.077 - 4.996) km/s, and blue shifted outflow in the range (2.916 - 7.915) km/s or in respect of the velocity of LDN 133 is in the range $(-7.084 \div -2.085)$ km/s. As is well known the bipolar outflow is due to the existence of thick dust ring around the source of outflow.

We can calculate the time, necessary for red outflow from IR nebula to reach the present dimensions of that outflow. From Table 1 these dimensions are 340" or 6×10^{13} km. The velocity of outflow is 10 km/s (see above) and for the time we will receive 2×10^5 year.

In Table 1 the data on radiation from molecular cloud LDN 133 and on molecular outflows are presented, where the antenna temperature is expressed in the units of 0.28 K. The cells in Table 1 are the same as in Fig.1. In each cell the antenna temperatures from Fig.1 are given. In the upper row to the left is antenna temperature of ${}^{12}CO(1-0)$ radiation from main cloud, to the right is antenna temperature of ${}^{12}CO(1-0)$ radiation of red shifted outflow

Table 1

DISTRIBUTION OF ANTENNA TEMPERATURE OF CO EMISSION FROM THE CLOUD LDN 133 AND OF MOLECULAR OUTFLOWS INSIDE THE CLOUD

25	8	27	12	26	13	26.	11	28	12	25	16	25	13
5	3	5	4	6	5	4	2	2	4	4	2	6	5
24	8	28	8	26	9	27	9	25	11	25	12	24	10
5	4	3	3	6	5	4	2	5	4	5	5	10	4
26	9	30	62	28	7	27	11	29	13	26	7	25	7
3	2	3		6	5	7	6	3	5	5	6	10	6
25	10	29	8	27	9	30	13	30	8	27	6	27	6
3	4	6	2	7		8	5	6	8	7	6	7	9
25	12	27	10	27	14	31	12	28	8	28	6	27	7
6	2	10	3	7	7	9	5	6	8	7	5	8	6
25	14	25	11	25	11	26	12	28	7	26	5	27	7
9	2	10	6	9	10	10	9	11	8	10	5	14	8
22	11	25	12	25	12	27	11	28	7	26	7	29	9
7	2	9	6	12	10	15	9	17		20	12	19	14

from IR nebula (see above). In the low row to the left is antenna temperature of ${}^{12}CO(1-0)$ radiation of blue shifted outflow from HHL 59A (see above), to the right is antenna temperature of ${}^{12}CO(1-0)$ radiation of red shifted outflow from HHL 59A (see above).

As we can see from Table 1, the densest part of the molecular cloud is in the central part of the Table, which corresponds to the place of IR nebula and an object HHL 59, it means that IR nebula and cluster of IR stars are situated in the densest part of the cloud. It is obvious that the first red outflow comes from the IR nebula and has NW - SE elongation, the second outflow (both red shifted and blue shifted) comes from SW part of the Table, which corresponds to the place of HHL 59A.

3. Optical observations of LDN 133 region. These observations were done on 5th of June, 2002 on Danish 1.54-m telescope. That telescope is situated at La Silla, Chile, altitude is 2340 m, the optics is of a Ritchey-Chritien design. The observations were done with several narrow-band filters. With R filter (ESO 452, $\lambda(nm) = 648.87$, $\Delta\lambda(nm) = 164.7$), exposure 200' (see Fig.2, 3a, 4b). 2. With SII filter (ESO 701, $\lambda(nm) = 672.72$, $\Delta\lambda(nm) = 6.31$), exposure 500' (see Fig.3b). With OIII filter (ESO 690, $\lambda(nm) = 500.99$, $\Delta\lambda = 5.66$), exposure 600'. We also give here DSS1 B, DSS2 R and 2MASS K images of the region.

There are several nebular objects connected with dark nebula LDN 133 (see Fig.2). The most interesting is the object HHL 59 [7] (G1-19 [8], see Fig.3

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a and b). In [9] is given that HHL 59 is connected with OB-association Sco OB 4, which is situated at the distance 1180 pc [10]. HHL 59 in optical region consists of two stars (stars 1 and 2 from Table 2) and several bright patches,



Fig.2. Dark nebula LDN 133. Image, obtained with R filter. N is to the top, E to the left. The sizes of image are 13'x 13'. a - object HHL 59A, b - object HHL 59, c - object HHL 59B.





Fig.3. a. Image of HHL 59 obtained with R filter. N is to the top, E to the left. The sizes of image are 1'.2 x 1'.2. a - star 1 from Table 2, b - star 2 from Table 2, c - cometary nebula, d - HH objects. b. Image of HHL 59 obtained with *SII* filter. N is to the top, E to the left. The sizes of image are 1'.2 x1'.2. a - star 1 from Table 2, b - star 2 from Table 2, c - cometary nebula, d - HH objects. c. 2MASS K image of HHL 59. N is to the top, E to the left. The sizes of image are are are 6' x 6'. a - IR nebula, b, c, d, e - correspondingly condensations 5, 6, 7 and 8 from Table 2.

Table 2

N	α(2000)	δ(2000)	V	B - V	J	J - H	H - K
1	17 ^h 58 ^m 34 ^s .055	-26°06'57".53	17.170	2.47	10.048	2.264	1.817
2	17 58 34.151	-26 06 51.11	16.910	-0.54	11.476	1.942	1.439
3	17 58 34.778	-26 07 00.24			15.321	1.801	1.062
4	17 58 34.973	-26 07 06.91			15.627	1.557	1.677
5	17 58 35.078	-26 06 56.55	1. 1.		14.170	1.495	0.761
6	17 58 33.858	-26 07 14.48	1.000		17.399	3.206	2.086
7	17 58 32.96	-26 06 54.80					
8	17 58 33.41	-26 07 08.00		1	and the	1.000	
9	17 58 30.647	-26 09 49.09	13.050	0.02	10.688	2.264	1.817
10	17 58 48.238	-26 01 22.58	12.570	-0.3	10.726	0.198	0.081
11	17 58 31.165	-26 08 58.81		1.00	13.528	2.445	1.150
12	17 58 31.514	-26 08 56.11	1000		13.640	2.459	1.038
13	17 58 31.388	-26 09 03.35			15.067	2.885	1.132

DATA ON OBJECTS CONNECTED WITH LDN 133

scarcely visible on DSS1B image and rather bright on DSS2 R image and on the images obtained with SII and OIII narrow band filters. Such characteristics have HH objects. Besides HH objects there are also narrow arcs, which are seen most sharply with SII filter. These arcs are connected with stars 1 and 2, there is also a patch directing in opposite side (see Fig.3). It is not excluded, that this nebula is a cometary 8-like nebula, but very red. 2MASS K image of HHL 59 shows that there is a bright IR nebula, connected with IR stars, embedded in very dense part of nebula, as was concluded above from Table 1 (see Fig.3c). From Table 1 we can see that there is a red shifted molecular outflow with the center on IR nebula and elongated in NW-SE direction. We can suppose that from IR nebula there is no blue shifted outflow, and hence HH objects are due to outflow from stars 1 and/or 2 from Table 2, but not from IR nebula itself. There are several condensations connected with IR nebula by filaments. Perhaps these filaments are jets, which have condensations on their ends. The data on these condensations are given in Table 2. In Table 2 the data on IR stars, connected with IR nebula (objects 1 - 4), on condensations at the ends of filaments (objects 5 - 8) and on nebular stars in LDN 133 (objects 9, 10) are given. In first column of Table 2 the number of objects is given, in columns 2 and 3 - the coordinates of objects, in columns 4 - 8 correspondingly the V, B - V values and IR colours of objects are given (data are taken from Vizier).

In the literature there are also other objects, which have filaments with condensations on their ends. In Table 3 data on several such objects are given. In column 1 are the numbers of objects, in column 2 the names of condensations, in columns 3 and 4 IR colours of condensations are given and

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in column 5 are the references of papers in which these objects are included (the data are taken from Vizier).

For the condensations from Table 3 we will have the following mean values: J-H=1.586, H-K=0.89. Condensation 5 from Table 2 has IR colours, rather close to these mean values. Condensation 6 has IR colours much higher, which means that condensation 6 has a thick dust envelope.

Table 3

Number	Name	J - H	H - K	Ref.
1 2 3	"a" "d" "a"	1.762 1.68 1.37 1.29	1.181 1.00 0.75 0.74	[2] [3] [11]
5	12	1.83	0.78	[12]

DATA ON CONDENSATIONS AT THE ENDS OF FILAMENTS

There are several other nebular objects connected with LDN 133.

1. HHL 59A. This object is a star with a semi ring nebula (or perhaps an 8-like nebula, because there is a part of second ring), better seen on DSS1 B image (see Fig.4). As we can see from Table 1, there are both red shifted and blue shifted outflows in SW part of that Table (see above). This bipolar outflow can be due to the ejections from the object HHL 59A. Red shifted and blue shifted outflows almost coincide with each other, it means that the outflows are oriented in opposite directions parallel to the line of sight. The object HHL 59A is connected with the star 9 from Table 2. As we can see from Table 2, this star is not of late type, because its IR colours are close to 0. If we assume that distance is 1180 pc, we will receive $M_{\nu} = 2^{\infty}.70$. With B - V = 0.02we will receive for that star spectral type ~A0V (see [13]). As this star is connected with a cometary nebula, it can be a Herbig A/B, star. Not far from HHL 59A is situated a group of three IR stars, which has a Trapezium type configuration (objects 11-13 from Table 2). As we can see from Table 2, these stars have very close values of IR magnitudes and colours, which are in favor of their similar spectral types and close physical relations. The IR colours are typical for late type stars with dense circumstellar disks. The distance between the stars in this configuration is ~0.02 pc. In [14] the tight Trapezium type configurations are considered, their dimensions are in the range 0.01 - 0.1 pc, so that this system is a tight Trapezium type system, which is in early stage of evolution of such systems.

2. HHL 59B. A group of HH objects, which are well seen with R and SII filters (see Fig.4b).

3. HHL59C. A star with a nebula and jet, which is seen on both DSS1 B

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image (see Fig.4c) and DSS1 R image (see Fig.4d), but the direction of outflow is different on this images and the blue jet is much brighter. It is interesting, that this jet is not seen on DSS2 R image, maybe it is because of bad quality of that image. Blue jets are very scarce in our Galaxy. The place of HHL 59C is out of the region of our $^{12}CO(1-0)$ observations, so we cannot say anything definite about the existence of molecular outflow from this object. The star with jet is the star 10 from Table 2. It has B - V = -0.3 and IR colours very close to 0. If the distance is 1180 pc, we will have $M_{\nu} = 2.22$. From [10] these values are typical for late B stars. As this star has a jet, it can be Herbig A/B, star.

IR nebula is associated with an IRAS point source IRAS 17554-2606. In [15] a rather successful attempt was done for classification of IR sources on the basis of their IR colours. Three quantities are involved: $R(1, 2) = \log((F(25) \times C))$



Fig.4. a. DSS2 B image of HHL 59A. N is to the top, E is to the left. The sizes of image are $6' \times 6'$. a - star 9 from Table 2, b -cometary nebula. b. Image of HHL 59B obtained with R filter. N to the top, E to the left. The sizes of image are $1'.2 \times 1'.2$. a - HH object. c. DSS1 B image of HHL 59C. N to the top, E to the left. The sizes of image are $6' \times 6'$. a - star 10 from Table 2, b - blue jet. d. DSS1 R image of HHL 59C. N to the top, E to the left. The sizes of object are $6' \times 6'$. a - star 10 from Table 2, b - blue jet. a - star 10 from Table 2, b - red jet.

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12)/ $F(12) \ge 25$); $R(2, 3) = \log((F(60) \ge 25)/(F(25) \ge 60))$; $R(3, 4) = \log((F(100) \ge 60)/(F(60) \ge 100))$. For different kinds of IR sources these parameters have been computed and for three types of young objects these parameters are within definite ranges. 1. Objects associated with water masers. 2. T Tauri type stars. 3. Cold non evolved sources embedded in dark clouds. For the source IRAS 17554-2606 we obtain from [16]: R(1, 2) = -0.062; R(2, 3) = -0.097; R(3, 4) = 0.20; we can conclude that this source is a type 2 source, that is its IR colours are typical for a T Tauri type star. For such objects IR colours are in the following ranges [15]: R(1, 2) = (-0.25 + -0.2), R(2, 3) = (-0.5 + -0.1), R(3, 4) = (-0.25 + -0.2).

4. Conclusions. Molecular cloud LDN 133 is situated in OB-association Sco OB4 at the distance 1180 pc. The cloud is connected with star formation region embedded in it - an IR nebula and cluster of IR stars, connected with that nebula. The cloud is connected also with several unstable nebular stars. ¹²CO(1-0) observations show existence of red shifted molecular outflow from IR nebula and of bipolar (both red shifted and blue shifted) outflow from HHL 59A. Observations with narrow band filters revealed existence of HH objects, connected with unstable stars and also of two 8-type cometary nebulae. With IR nebula is connected also an IRAS point source. Near to HHL 59A there is a group of three stars, having Trapezium type configuration. The distances between the stars are ~0.02 pc, which is common for tight Trapezium type systems. The stars in the group have IR colours, typical for stars with dust envelopes.

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НЕСТАЦИОНАРНЫЕ ОБЪЕКТЫ В ОБЛАКЕ LDN 133

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Приводятся результаты изучения молекулярного облака LDN 133 и связанных с ним нестационарных объектов HHL 59, HHL 59A, HHL 59B и HHL 59C. Показано, что имеет место красное молекулярное истечение из связанной с HHL 59 ИК туманности, погруженной в LDN 133, а также биполярное молекулярное истечение из объекта HHL 59A. Точечный источник IRAS. IRAS 17554-2606, связан с ИК туманностью. Наблюдения с узкополосными фильтрами выявили наличие объектов X-A и струй из нескольких нестационарных звезд в этой области. Из ИК туманности выходят четыре волокна, заканчивающихся сгущениями. Обнаружены также две 8-образные кометарные туманности, связанные с нестационарными звездами.

Ключевые слова: молекулярное облако: объекты Х-А: выбросы: ИК туманность

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