A NOTE ABOUT MULTIPLE SYSTEMS OF DENSE MOLECULAR CLOUDS

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ABSTRACT

The space distribution of some small dense clouds with point-like IR sources, resembles the clustering of young OB stars. It can be assumed that such objects contain heavy obscured high-luminosity stars on the ZAMS. From the comparison of infrared and radio data it follows that in typical cases, only one B star is the source of the radiation of the cloud. The total mass of the cloud is of the order of one solar mass. If the individual fragments of the cloud are gravitationally unstable, then in the later stage of the evolution only low-mass stars are formed. One can therefore expect that young OB stars are most frequently accompanied by low-mass pre-Main Sequence stars.

Observations of molecular clouds in the radio and infrared spectral region have lead to discoveries of multiple systems of IR sources associated with the dense cores of molecular complexes and accompanied by H II regions, OH and H_2O masers. A few examples can be mentioned: OMC-1, OMC-2, CRL 437, CRL 2591, W3, IRS 5,6,7, Barnard 42 (ρ Oph molecular cloud), Mon R2, NGC 7538, S 106, S 140, S 255 and Cep A OB association.

Most of such infrared sources tend to form multiple systems with the average distance of the order 0.1 pc between the individual components and resemble the Trapezium-like clustering of OB stars. The co-existence of OB associations and dense molecular clouds with IR sources can be demonstrated by OMC-1 which is evidently associated with Trapezium stars in the Orion region (Wynn-Williams and Becklin 1974).

The typical bolometric luminosities of such infrared sources are 10^4 to 10^5 L_o supporting the idea that these objects are O and B stars in an early evolutionary stage on/or just reaching the ZAMS, obscured in heavy absorbing clouds. The occurrence of recombination lines in the infrared spectra and continuum radiation at GHz frequencies clearly indicates the presence of ionized gas which would be located in

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a fairly dusty H II region inside the cloud core.

The assumption that the underlying energy source within the cloud can be a hot Main-Sequence star is also supported by the silicate absorption feature at 10 μm which was detected in several infrared sources (IRS). The compact IRS possess some variety of observable properties; however, the pre-Main-Sequence evolution of wide binaries or common-proper-motion pairs (CPM) should preferably be related to the evolutionary processes in multiple systems of small dense clouds with point-like IRS.

It is reasonable to guess that almost the entire radiation of the star is absorbed by the dust and reradiated in the infrared with a maximum near $\lambda \geq 6$ μm, i.e. corresponding to a black-body temperature $\lessdot$ 450 K. Since the continuum radiation at 5 GHz is due to photoionization inside the dense core, a comparison of the infrared luminosity and radio data can help to determine the spectral type of the obscured star and the optical depth for the Lyman-continuum of a dusty H II region. Due to the small angular dimension of compact molecular clouds, the useful observational data in the GHz spectral range can only be provided by VLA observations.

Multiple systems of IRS suitable for such a study are for instance, Cepheus A, Sharpless 140 and 255, which were observed by Beichman et al. (1979) with a high VLA angular resolution at 5 GHz, and in the infrared up to $\lambda = 25\mu$m. The observed properties of the above mentioned IRS are used for an estimate of the spectral type of the embedded star. Table 1 gives the distance and apparent size of the studied objects, the total luminosity $\int L_\lambda \cdot d\lambda$ derived from the 25 μm flux and the Lyman-continuum photon flux N_{Lyc}. All these data are adopted and revised from the paper by Beichman et al. Since Beichman's measurements provide an integral flux for all three IRS in Cep A only, it was assumed that the total luminosity of the individual source is approximately proportional to its size at $\lambda = 6$ cm. The Lyman photon flux N_{Lyc} is derived by Rubin's method (Rubin 1968). For the τ_{Lyc} estimate and the determination of the star type the methods of Panagia (1973) and Natta and Panagia (1976), respectively, were applied. τ_{Lyc} is the optical depth for the Lyman-continuum of the dusty H II region inside the dust core.

The mass of gas and dust M_{gd} in the cloud are estimated under the following assumptions: a) The upper limit of the average column densities of ^{13}CO is 10^{17} cm^2. b) The abundance of isotopic species is terrestrial. c) The abundance ratio of CO/H_2 is typical for a compact cloud: 6×10^{-5} (Thaddeus 1977). d) The contribution of dust to the total mass is considerably less than 0.1 of the gas mass. Although the results depend on the models of high-luminosity ZAMS stars, the obscured stars always tend to be single B0 stars, with the exception of S 255 where there are two possibilities: either a single O 9.5 star or a binary of types B 0.5 + B 0. The narrowness of the star type range is due to the narrow range of allowed combinations

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of total luminosity, N_{Lyc} and reasonable upper limits for τ_{Lyc}.

Table 1

IRS	R	Size at 6 cm	$\int L_\lambda \cdot d\lambda$	N_{Lyc}	Star type	τ_{Lyc}	M_{gd}
	kpc	arcsec	10^4L	$10^{44}s^{-1}$			M_o
Cep A	0.73						
1		4x1	2.5	7	BO	7.6	0.45
2		2x1	1.5	3	BO	8.0	0.30
3		2x1	(1.0)	(2)	(BO)	(9.2)	(0.3)
S 140	0.9						
1		2x1	1.4	4	B 0.5	4.8	0.35
S 255	2.5	3	2.3	33	O 9.5 or	7.0	3
					B 0.5 + B O	5.5	

The results, of course, must be regarded as approximate and preliminary. The aim of this paper is to show the possible perspective of such studies. Nevertheless, it seems to be evident that the presence of only late single O or early B stars in IRS associated with compact molecular clouds, is more likely than the occurrence of a hot binary with equal mass of the components.

The mass of the clouds surrounding the IRS may be somewhat underestimated but the correct value should be about $1 \leq M_o < 3$. Therefore, a further collapse in the cloud would result in a low-mass star. The minimal critical mass M_c of a collapsing fragment is according to Silk (1978), $M_c \sim (T^6 M_o)/(10^8 K \tau)$ where T is the temperature of the dust grains (identical with the gas temperature, i.e. $T \leq 100$ K) and τ the visual optical depth of the fragment. Assuming that $\tau \sim 5 \tau_{Lyc} \sim 50$, the minimal value of M_c is about 0.02 M_o. The mass distribution of secondaries can therefore be expected to be in the range $0.02 < M_o < 3$. This conclusion is in agreement with the fact that long-period binaries possess a van Rhijn distribution of masses (Abt and Levy, 1976).

Since the free-fall time and pre-Main-Sequence phase of a star with 1 M_o is about 5×10^2 longer than that of a typical BO star, one can expect that a relatively large number of OB stars on the main-sequence are accompanied (in wide binaries or CPM systems) by low-luminosity stars. They are still in the pre-main sequence stage as, e.g., the T Tau or YY Ori stars.

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