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A study of the Cometary Globules in the Gum Nebula

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Among the smaller interstellar molecular clouds the Cometary Globules (CGs) stand out due to their peculiar morphology. They are characterised by compact, dusty heads with long faintly luminous tails extending on one side and narrow bright rims on the other side. There exists a significant population of CGs in the Gum Nebula. The Gum Nebula is a large structure ~ 125 parsec in radius delineated by $H\alpha$ emitting filaments. The true nature of the Gum Nebula is ill understood. The CGs in the Gum Nebula are distributed over a region ~ 80 parsec in radius with their tails pointing away from an apparent common centre. In the visible region these globules have bright rims on the side facing the common central region. Some of the heads have embedded young stars. In the region bounded by the CGs there are a few massive hot stars including ζ Puppis believed to be the most luminous star in the southern sky. It has been suspected that the morphological appearance of the CGs may be due to the influence of these stars.

A detailed study of the system aimed at understanding its origin and kinematics was undertaken using the 10.4m millimeter-wave radio telescope at the Raman Research Institute (Sridharan 1992a,b). The study consisted of ^{12}CO observations of the heads and the tails of the CGs using the $J = 1 \rightarrow 0$ millimeter-wave rotational transition of the carbon monoxide molecule. In addition, the Globule No. 22 was mapped in both ^{12}CO and ^{13}CO. An analysis of the radial velocities obtained from the survey has led to the following findings:

1. The system of CGs is expanding with respect to a morphological centre at ~ 12 km s^{-1}. The expansion age is ~ 6 Myr.
2. Some of the tails observed show systematic velocity gradients. If the tails were formed due to the elongation resulting from these velocity gradients then the estimated stretching age is ~ 3 Myr.
3. The mass of CG 22 is ~ 27 $M_\odot$. Interestingly, if the cloud was in virial equilibrium then its mass must be ~ 250 $M_\odot$.

There have been previous conjectures that the young stars embedded in the heads of some of the globules may have been formed as a result of external triggering. To clarify this question an analysis of the locations of the embedded young stellar objects (YSOs, identified from the IRAS survey) in the dark clouds in the Gum-Vela region was undertaken. The conclusion is that the YSOs have a statistically significant tendency to fall on the sides of the dark clouds facing the morphological centre rather than the far sides.

From the above analysis we come to the following conclusions:

1. The rough agreement between the expansion age and the tail-stretching age suggests a common origin of the expansion and the formation of the tails. The presence of young stars of comparable ages in the heads of some of the globules and the locations of IRAS sources suggest that the processes responsible for the expansion may have also triggered star formation in them.
2. The radiation pressure from the hot stars in the central region or the stellar winds from them cannot account for the momentum of the expanding globules. It is more likely that the rocket effect arising out of the heating and the consequent anisotropic ablation of the globules can supply the necessary momentum.

All the above conclusions can be reconciled easily if one could argue that they are causally connected and have a common origin. The main apparent obstacle to such a unified picture for the system of CGs in the Gum Nebula is that although there appears to be a morphological centre there are no identifiable objects, say, massive stars, presently located at or near the morphological centre. However, the observed large proper motion of the massive star ζ Puppis holds an important clue, leading to the following scenario : It is an extraordinary fact that ζ Puppis has a large proper motion ~ 75 km s^{-1}, and its trajectory when extrapolated backwards passes close to the morphological centre of the system of CGs. It has been known for a long time that large space velocities of massive stars can only be understood in terms of the effects of the explosion as a supernova, of one of the stars in a binary system. If one accepts this picture then it follows that ζ Puppis had a companion more massive than itself and till roughly half a million years ago there must have been a massive binary system near the centre of the system of CGs. The combined effect of the ultra-violet radiation and the stellar wind from this binary as well as from other stars in the neighbourhood, must have resulted in much of the molecular material in the vicinity being blown away except the numerous regions of enhanced density (condensations) in the original molecular cloud. Continued effect of the radiation and stellar winds resulted in these condensations being set in motion, as well as developing cometary tails. Roughly half a million years ago the companion of ζ Puppis exploded as a supernova propelling the latter towards its present location.

The thesis work also involved the development of a wide-band mechanically tuned local oscillator using the Gunn diode. The oscillator tunes over the frequency range 75-115 GHz covering most of the 3-mm atmospheric transmission window and can pump two Schottky mixers. Rotational transitions of many astrophysically important molecules including CO fall in this range.

References

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