Observational Tests for H II Region Models: A "Champagne Party"

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The theoretical model outlined in this article being referred to as the "champagne" model (rather than the "coca-cola", the "ginger-ale", etc.) is not just a question of country of origin or even style: what happens when one or more stars in a molecular cloud start to ionize the gas is not too different from what you would experience if you—with a singular lack of common sense and respect—would place your "Dom Pérignon" in an oven. Drs. Danielle-Marie Alloin and Guillermo Tenorio-Tagle of the ESO Scientific Group in Geneva have just observed an H II region at the edge of a molecular cloud with the 3.6 m telescope. Here are some preliminary results and further details about the sparkling theory.

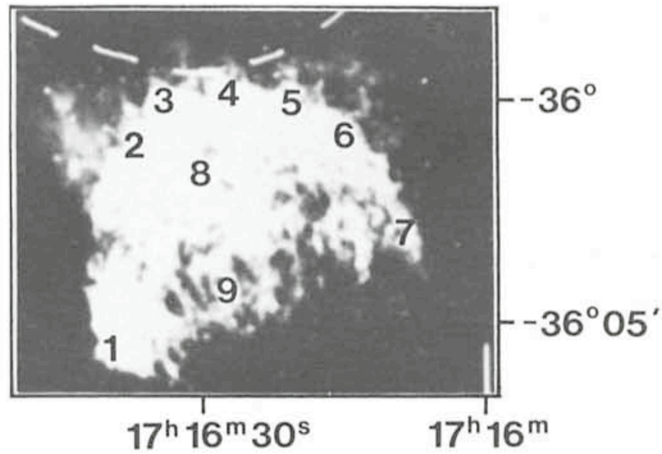

Fig. 1 a: *Hα,* [H II] plate of Gum 61. The selected observed positions are shown through numbers.

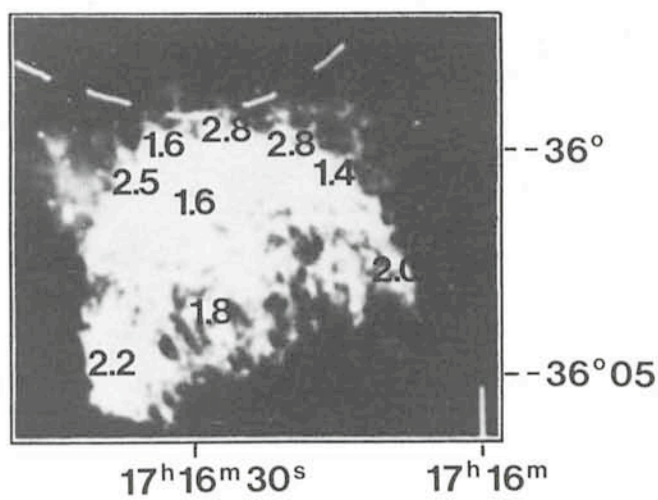

Fig. 1 b: *Gum 61, electron density distribution in units of 10^3 cm^{-3}.*

It is our aim to study *as a single entity* several neighbouring H II regions associated with a molecular cloud. In this way, we believe, one can obtain information about the progressive star formation within the cloud, and about the disruption of the parent cloud through its ionization.

Therefore, we selected as a good candidate NGC 6334 which lies at the edge of the Milky Way at galactic coordinates b = 30′ and l = 351° 30′. One of its components to the south-west, Gum 61, presents a quite unusual aspect: it shows numerous filaments which extend in the south-west direction from the edge of the molecular cloud, as clearly seen on the Hα, [N II] plate displayed in figure 1 a. According to the recent distance estimate of 1.7 kpc (Neckel, 1978) this H II region is about 4 parsec in diameter. An OH maser is also known to be present within the molecular cloud to the north of Gum 61, implying recent star formation all around.

Then, this particular nebula Gum 61 was chosen for our observations on June 30 and July 1st, 1979.

3.6 m Observations of Gum 61

We used the ESO Image Dissector Scanner (Cullum and Fosbury, 1979) attached to the Cassegrain focus of the 3.6 m telescope at La Silla (ESO). A resolution of about .6 nm (= 6 Å) was achieved, using a dispersion of 5.9 nm mm^{-1} over the wavelength range 390–680 nm. Nine different positions were selected: along the boundary of the H II region, in the centre and across a few filaments. These positions are indicated by numbers in figure 1 a.

Preliminary results show that we are dealing here with a low excitation, high density nebula. The electron density distribution can be worked out from the [S II] 671.6/673 nm line intensity ratio, and these results are displayed in figure 1 b in units of 10^3 cm^{-3}. As expected, the density appears to be larger all along the boundary of the ionized gas, while, in the centre, we do find a lower value increasing slightly towards the end of the filaments to the south-west.

On the other hand, the excitation parameter, represented as usual by the observed [O III]/Hβ line intensity ratio appears to be twice as large in the northern part of the nebula, next to the molecular cloud, as at the end of the filaments (position 1). This implies the existence of other exciting stars, hidden in the molecular cloud.

The Champagne Model

Recent numerical calculations (Tenorio-Tagle, 1979) have shown us how an H II region enters the "champagne phase" when the discontinuity between cloud (the star formation site = the champagne) and intercloud gas becomes ionized. The ionization front moving into the intercloud gas with supersonic velocities creates and leaves behind a large discontinuity in pressure (between the now ionized cloud and the intercloud gas). This discontinuity sets a "champagne-like effect" by generating a strong isothermal shock and a rarefaction wave. The shock wave

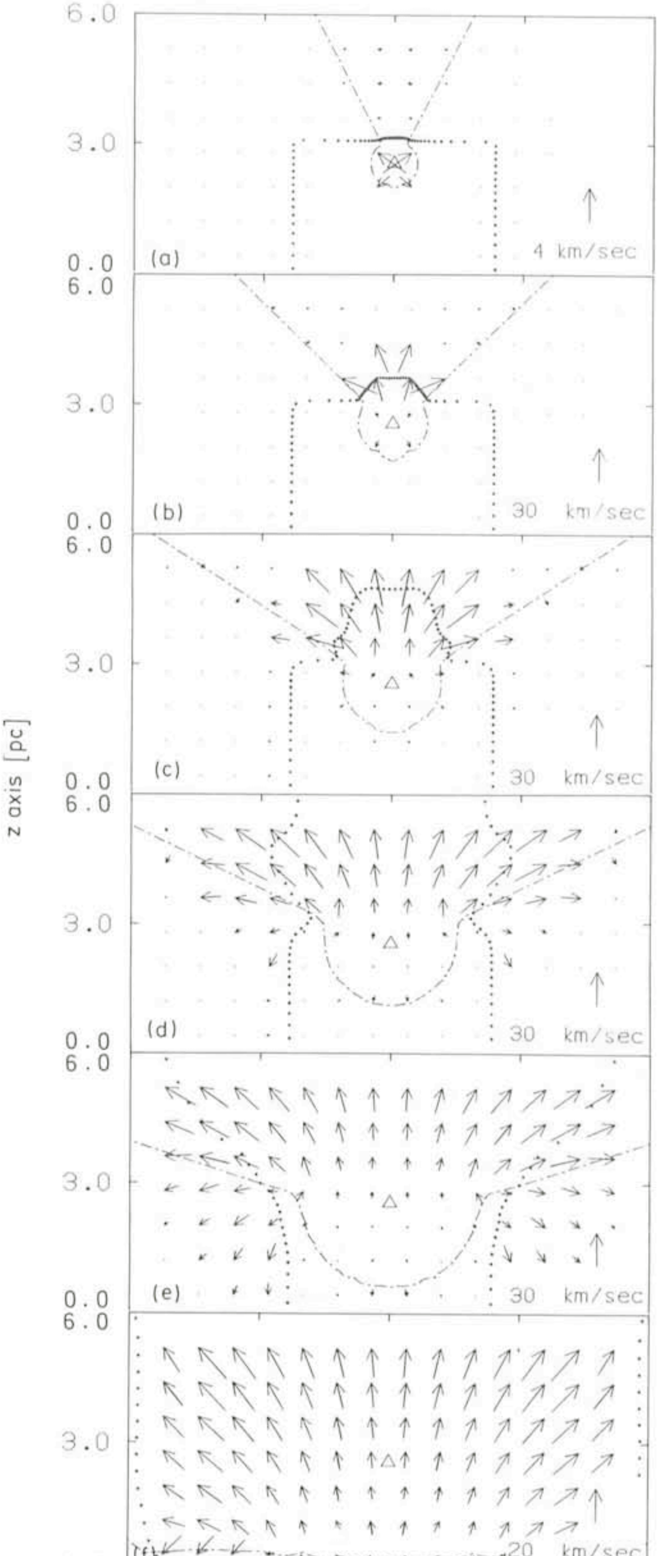

Fig. 2: *The Champagne-flow model at different stages:*
- *crosses delineate the molecular cloud in which the star (a triangle) is born. Dashed-dotted line = ionization front.*
- *arrows indicate the gas velocities in the units given on each figure.*
- *$t = 9.5 \times 10^3$ yrs (a); $= 4.13 \times 10^4$ yrs (b); $= 8.9 \times 10^4$ yrs (c); $= 1.6 \times 10^5$ yrs (d); $= 2.8 \times 10^5$ yrs (e); $= 5.67 \times 10^5$ yrs (f). (Bodenheimer* et al., *1979).*

propagates into the ionized intercloud gas and becomes the edge of the density-bounded side of the nebula, while the rarefaction wave enters the ionization-bounded side and moves towards the bottom of the bottle. In this way, "champagne" begins to stream away from the cloud, reaching supersonic velocities (u > 3 sound speed), while it spreads over a large volume, as shown in figure 2. Many observers will recognize this event as a blister at the edge of a cloud, how rude!

In order to explain our observations, we should bear in mind that, during the champagne phase, the other ionization front which moves in the cloud, i.e. to the bottom of the bottle, doesn't know anything about the champagne shower occurring on the other end. This holds until the rarefaction wave crosses the position of the star and a larger amount of photons speed its propagation. However, before this occurs, the ionization-bounded side of the nebula expands as postulated by the classical formulation (Spitzer, 1968). Consequently another weaker rarefaction wave is also present in the flow, moving from the bottom of the bottle towards the exciting star. Thus, between the two rarefaction waves, one should expect an enhancement both in pressure and density, as shown in figure 3.

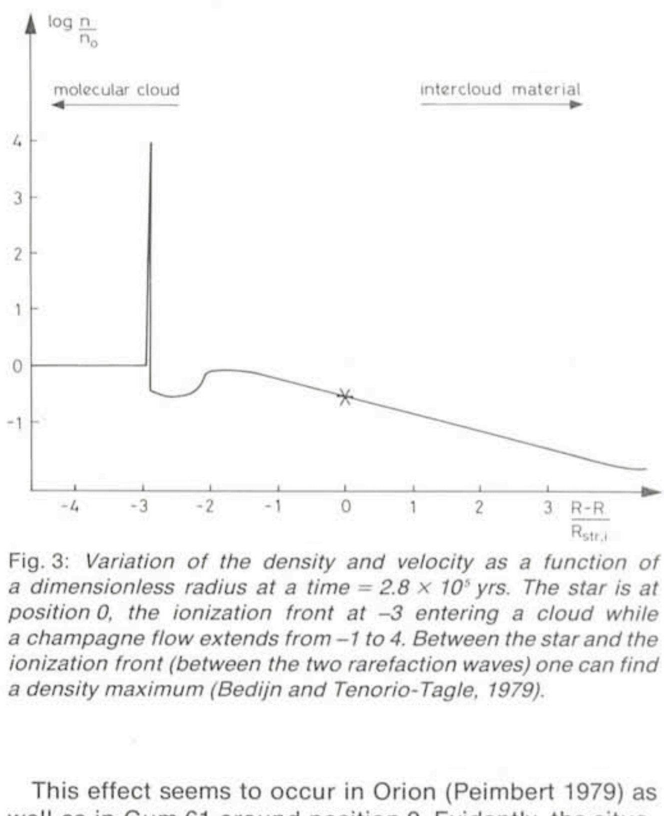

Fig. 3: *Variation of the density and velocity as a function of a dimensionless radius at a time $= 2.8 \times 10^5$ yrs. The star is at position 0, the ionization front at –3 entering a cloud while a champagne flow extends from –1 to 4. Between the star and the ionization front (between the two rarefaction waves) one can find a density maximum (Bedijn and Tenorio-Tagle, 1979).*

This effect seems to occur in Orion (Peimbert 1979) as well as in Gum 61 around position 9. Evidently, the situation might be more complicated than the simple one described in those models which assume a single ionizing star. We have already seen from the [O III]/Hβ line intensity ratio that other exciting stars partly contribute to the ionization.

We wonder if the other H II regions which constitute the NGC 6334 complex might represent different stages of the champagne phase: some of them are more extended while others are smaller in size but not in brightness. The study of the whole complex would certainly give us a better idea about the progress and site of star formation.

Finally, we would like to stress the fact that the velocity field determination in the whole area would provide the key to understand the formation and evolution of such a complex.

References

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NEWS AND NOTES

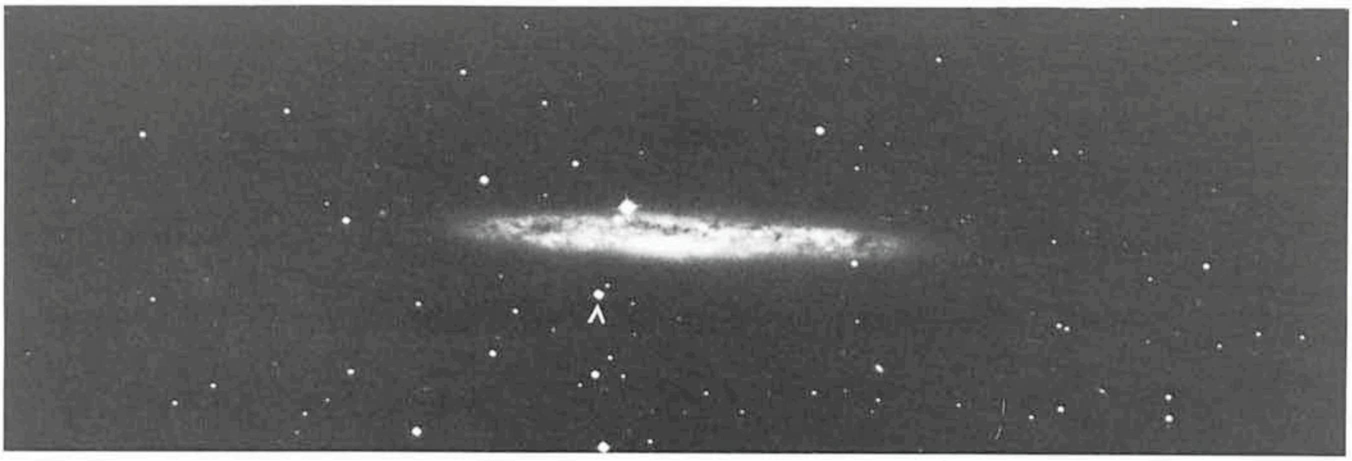
The Supernova That Was Not . . .

The ESO 1 m Schmidt telescope is a major supplier of observational material to many European astronomers. The plates are taken by the ESO observers on La Silla, sent by diplomatic bag to the Sky Atlas Laboratory in Geneva, registered and checked and then forwarded to the astronomer who asked for the plates to be taken.

Two plates were taken during the month of May 1979 for one of these programmes, showing the galaxy NGC 4517. It so happened that the ESO astronomer who checked the plates in Geneva (R. West) noticed that there was an additional, apparently stellar image (see arrow) on one of the plates, near the galaxy.

A supernova was strongly indicated, although the position in the galaxy, far from the main plane, was somewhat peculiar. And suddenly it became clear that the image was on the plate that was taken *first,* but not on the *second*! Who has ever heard about a supernova that disappears in the course of ten days?

The mystery was quickly solved. A print-out of the minor planets in the field showed that at the position of the supposed supernova, the 13^{m}5 minor planet (268) ADOREA would have been virtually stationary (i.e. not moving as seen from the Earth) at the exact time of the first plate, but well away from the galaxy on the second plate. A careful inspection of the image also shows that it is slightly elongated, confirming the explanation.



Two photos of galaxy NGC 4517, both 2-hour exposures on IIIa-J emulsion behind a GG385 filter, obtained with the ESO Schmidt telescope on May 18 (upper) and May 28 (lower), 1979.