DISCUSSION FOLLOWING REVIEW BY P.G. MEZGER AND L.F. SMITH

Do low-mass stars form first?

SILK: I understood you to say that there is evidence that low-mass stars form out of the same cloud in which O stars subsequently form. Could you elaborate on this, and explain how you can distinguish this effect from possible variations in the luminosity function?

MEZGER: I based this statement on work by Iben and Talbot and by Williams and Cremin (for references see review paper), who fitted computed isochrones to the observed HR diagram of young clusters.

I.P. WILLIAMS: The initial work of Cremin and myself was a survey of NGC 2264, NGC 6530 and some other young stellar clusters in which the mass and ages of all the memberstars were determined. This showed that solar mass stars were the oldest stars in all these clusters. A word of caution however is that Strom has shown that circumstellar dust shells are certainly present around many of the stars and this obviously affects their age estimates. The conclusion may however still be true. The whole survey should probably be done again eliminating from it all the stars with a circumstellar dust shell.

STROM: Observations by Warner, Strom and Strom (Ap.J., in press) of 70 stars in NGC 2264 suggest that although infrared excesses are common, it is possible to locate pre-main sequence objects for which no IR excess exists. The location of these objects in the M_V, (B-V) plane suggests a significant (3-6 x 10^6yr) age spread. Unfortunately the number of such "uncontaminated" pre-main sequence objects is not yet sufficient to allow a study of the number of stars formed with a certain mass as a function of time.

SPITZER: It is clearly of great theoretical importance to determine whether or not the stars of lower mass are generally formed together with the high-mass O stars. I would like to raise a question as to how conclusive is your result that in some clusters the low-mass stars were relatively lacking when these systems were first formed. These low-mass stars can be lost by the cluster after formation, either by evaporation or by relative tidal stripping of an extended aura of low-mass stars. Similar processes can be envisaged during the chaotic period when proto-stars have condensed in a cluster but have not yet contracted to stars.

MAEDER: I would like to point out that a change in slope of the mass spectrum (near 1 $M_\odot$) does not in itself necessarily mean that there are two mechanisms of star formation. Changes of slope may merely arise from age effects in the sample of stars or changes in the formation rate.

ZUCKERMAN: I am interested that Dr. Mezger has just used the Orion region to support the notion that O and B stars form after solar mass stars since I was about to use Orion to support just the opposite possibility. In particular, we know that O and B-type stars have formed in Orion within the past few times 10^5 years (e.g. the Trapezium) whereas much lower mass stars seem to be forming now in the infrared cluster called OMC-2. Since the brightest "protostars" in this cluster are apparently of spectral class A, unless the stars in the cluster are very limited in their mass range it seems that G-type stars may also be forming at the present time.

PANAGIA: If I understood correctly, the evidence for low-mass stars forming earlier than massive stars is the fact that in some clusters one observes both early-type and late-type stars on the main sequence. Actually, this fact only implies that the early type stars, which now are on the main sequence, are born later than the late-type stars on the main sequence. However, one cannot exclude that other massive stars have been formed earlier, at the same time as low-mass stars are born, and that they have died already and, of course, cannot be seen any longer. One may even argue that the presence of an O-type star may trigger further stellar formation (of low-mass stars preferentially) through the compression of the surrounding gas by either the shock front at the edge of the resulting HII region or the final blast of a supernova explosion. For all these reasons, I am asking: is there any positive evidence for saying that massive stars are to form later than low-mass stars?

ELSÄSSER: Star formation often takes place in regions of high obscuration where you can only see high-mass bright stars, if any, and no low-mass objects. If the region is clear after some time dynamical effects, like those mentioned by Dr. Spitzer, may have taken place. If one sees young low-mass stars and no bright ones this may be due to a difference in density of the interstellar matter.

SOLOMON: It is of course extremely difficult to rule out low-mass stars observationally. I believe, however, that there are clouds such as in Taurus which are large molecular clouds with extensive low-mass star formation and no massive or luminous stars. In CO emission these clouds have somewhat narrower lines and lower intensities than clouds with more massive stars and probably lower average H_2 densities. These clouds are isolated from any OB association.

KUHI: Dr. Solomon just mentioned my point: namely that the Taurus cloud is full of low-mass stars and contains no high-mass stars earlier than B8. Therefore it is a good example of a cloud in which low-mass stars form first and could support your hypothesis that high-mass stars form later.

MOUSCHOVIAS: After the courageous, but aborted, effort by Dr. Mezger to pronounce my name, I can now understand why Greeks who immigrate change their names from Agamemnon to Charlie ..... In a more serious vein, if we were to observe a cluster consisting of only low-mass stars, it does not by any means follow that low-mass stars form first. I submit that the hierarchical fragmentation in the presence of a magnetic field (as described by Mestel a decade ago) has simply been too efficient. The more massive stars, that may require more special conditions to form because of the tendency of a collapsing blob of matter to break up, may have simply missed their chance. The order in which stars form may still be from the more massive members of this cluster to the less massive ones.

MAEDER: Pictures of radio intensities, like that shown by Prof. Mezger for NGC 1805, where many subcondensations may be seen in the cloud could provide a basic check of theories of star formation, because models of collapse predict a specific dependence of the Jeans mass on the distance to the centre of the cloud. In this connection I would like to note that work by Burki in galactic associations and by Lucke in associations of the Magellanic Clouds clearly suggests that the most massive stars are preferentially located at the edge of the associations.

MOUSCHOVIAS: Dr. Mezger has mentioned that, once an HII region is formed in a dense cloud, this child may turn around and eat up its mother (i.e. it can disperse the cloud). This is not correct. The calculations on which this statement is based have used a cloud density of 10 cm^{-3} (see review by Field in the proceedings of the Liège Symposium on Star Formation). That is an unrealistically low value for a region that has just given birth to stars. A more reasonable value, say $10^5\mathrm{cm}^{-3}$, leads to the conclusion that an 05 star does not have enough momentum over its lifetime to disperse a dense, massive cloud - kinetic energy is not conserved (see 1976, Ap.J., 207, 141).

KERR: I believe that it is not easy to distinguish clearly between interarm regions and spiral arm regions. In particular, there is not complete agreement on the location of the spiral arms. Some people would put the Orion nebula inside an arm. Probably the pattern of arms and shock fronts is rather irregular.

COX: How does the binary nature of 0 star families affect the evolutionary picture which you have described?

MEZGER: Calculations by Yorke and Krügel, to which I referred in our review paper, have been made for spherical collapse onto a central star. However, W3A has obviously two exciting stars, labelled IRS 2 and IRS 2a. The presence of IRS 2a slightly distorts the shell-like structure.

McCREA: Another way in which 0 stars may arise where clouds and stellar clusters are present is accretion. Many years ago (Vistas in Astronomy 2, 1694, 1956) I calculated that there is a good chance of a small number of stars growing to large mass in this way. Accretion is itself in the

nature of a runaway process. If a star is in favorable conditions its mass increases very rapidly, whereas under slightly different conditions accretion is unimportant. If some O stars are produced in this way, it could explain why they are formed after stars of smaller mass.
R.A. Lyttleton reviewed the theory a few years ago; he confirmed the results and remarked that the inference is strengthened by the higher cloud-densities that have come to be accepted since the work was first done.

BOK: Barnard objects approximately double their mass by accretion from the interstellar medium in one galactic revolution, 200 million years.

STROM: In giant HII complexes in M33 (e.g. NGC 604) which appear to be density-bounded, there appear to be no molecular clouds detected. If this is so, these complexes of $M \simeq 10^4 - 10^6 M_\odot$ must form stars very efficiently and ionize the entire molecular cloud. Does this suggest that we must have efficient "triggering" mechanisms such as the Lada-Elmegreen hypothesis?

PALMER: We (Rickard et al., Ap.J., in press) have searched for CO emission in the direction of several HII regions - as well as several dark patches between HII regions - in M33, and have not detected any yet. However, we did not have time to make a definitive search in that galaxy, and our sensitivity would have permitted us to detect only CO clouds as strong as the strongest galactic CO clouds. Of perhaps greater interest - because most of the face of the galaxy was searched - is the search for H_2O maser emission by Andrew et al. in M33 (Astr. Astroph. 39, 421, 1975). They found no sources at all, to a limit well below the intensity of the strongest galactic H_2O masers. The reasons why this galaxy seems to differ from ours in molecular content are not understood. I suspect that this difference is not as great as it appears; rather, it probably requires more sensitive and more extensive searches to find the molecular component of M33.

STROM: If one estimates for giant HII complexes in external galaxies (e.g. M101, M33), the number of O stars required to ionize the gas (Searle, Ap.J. 168, 327, 1971). If one then normalizes a Salpeter initial luminosity function to fit the number of O stars required, then the number of stars predicted on the lower main sequence is so large that we must assume either an extraordinarily high star formation efficiency or an initial mass for the giant complexes of perhaps as large as $10^7 M_\odot$.

SILK: Use of the Salpeter function in inferring the mass of OB associations in other galaxies is extremely sensitive to the power of the mass function. A small degree of flattening can avoid any mass divergence in the low mass end.

BOK: I am second to no one present here in my admiration for the density wave theory of Lin and Shu and the associated shock wave approach of William Roberts. I am, however, detecting in this Symposium a tendency to accept the density wave theory as gospel. This is a dangerous trend. The present density wave theory is still a hypothesis and we must not call on it for all cases where we need compression. Other avenues must be explored. I note, for example, that there has hardly been any mention of possible effects of supernova explosions. Also - may I point out that there are many places in our galaxy and especially in the Magellanic clouds, where star formation takes place and where no obvious large-scale shock waves are present.

COX: It seems to me that if we have an age sequence of puffs of stars in a strung-out association, then the massive stars which have died on the oldest end should have produced supernovae. Is there any evidence for supernova activity along this sequence, and is it possible that these explosions help with the compression of the cloud to drive the next round of star formation?

MEZGER: I don't know about supernova explosions in the Orion OB association.

HERBIG: There are three "runaway" O, early B stars whose velocity vectors (according to Blaauw and Morgan, Ap.J. 119, 625, 1954) point back to the Orion region and seem to have left (or crossed) that area 3 to 5 x 10^6 years ago. It has been hypothesized that these massive stars were released from a binary system when one component exploded as a Type II supernova.

BLAAUW: Indeed, if one looks for evidence for past supernovae explosions in Orion, then the runaway stars that escaped from the Orion association may be the best way for pointing to the epoch when these events happened. But one should not forget that we do not yet have direct proof that the rapid mass loss in a double star that was proposed to explain the runaway stars is identical to the supernova explosion.

HERBST: Referring to the question by Dr. Cox on whether there is observational evidence for supernova-induced star formation in OB associations: CMa R I is a star formation region containing the Herbig-emission star Z CMa. It is associated with CMa OB I (distance 1150 pc) and it is located on the edge of a large-scale ring feature of nebulosity which may plausibly be interpreted as a dense shell swept up by a supernova explosion. The dimension of the ring (diameter 60 pc) is such that a reasonable SN outburst energy (3 x 10^{50} ergs) in a uniform medium of reasonable initial density (1 cm^{-3}) would have produced such a feature in $\sim$3 x 10^5yrs - consistent with the probable ages of the R-association members. Confirmation of the supernova hypothesis, possibly through a proper motion study of the R-association stars, would be very important.

ELMEGREEN: I originally considered the possibility that supernovae provide the pressure which may trigger the gravitational collapse of an OB subgroup. Although this may be an important source of compression in isolated regions, a supernova shock will lose its pressure much more quickly than will an ionization front for the high densities observed in molecular clouds. Thus, the pressure from ionization fronts will probably dominate supernova pressures at the time of formation of an OB subgroup in the model of Elmegreen and Lada.

ISOBE: I would like to comment on the distribution of stars in the molecular cloud in the Orion association. I counted the number of stars on the Palomar Sky Atlas red and blue prints. The number density of stars is less than 100 per square degree in the region extending from the Orion nebula to the south-east where the molecular cloud is located. There is a clear ridge structure of stellar density (4000 stars per square degree) along the Barnard Loop except in the direction of the molecular cloud. Therefore in this direction the gas emitting the Hα radiation, the molecular cloud and the stars are situated in this order with increasing distance from the sun (Isobe, IAU Symp. 52, p.433, 1973). Polarization observations by Appenzeller (Astr. Astroph. 36, 99, 1974) show that the magnetic field in the region surrounding the Orion nebula may be arranged as in a "magnetic pocket". This irregular structure of the magnetic field suggests that star formation is active in this region.

Dependence of the rate of star formation on gas density

MOUSCHOVIAS: I have a comment bearing on the theoretical understanding of the dependence of the rate of star formation on the gas density. The fact that the density is higher closer to the Galactic plane gives us only one power of the density. The statistical model of cloud-cloud collisions of Field and Saslaw (Ap.J. 142, 568, 1965) gives naturally a ρ^2 dependence because of the binary nature of the star formation process. Another suggestion was made by Mouschovias, Shu and Woodward (1974, Astr. Astroph. 33, 73). Close to the galactic plane, one power of the density comes indeed from the fact that the gas density is higher there. A second, positive-power contribution comes from the assumption that a larger fraction of clouds will collapse close to the galactic plane because of the higher ambient (intercloud) pressure (and density) there. Altogether, we expect the rate of star formation to be proportional to ρ^n, where $1 < n < 2$. The precise value of n can be determined theoretically only if we know the detailed distribution of cloud masses. This dependence of the rate of star formation on the gas density can account for the fact that HII regions are more closely confined to the Galactic plane than HI.

COX: It seems to me that the small-scale height of molecular hydrogen, together with the present picture of H_2 being a major part of the mass, essentially invalidates the idea that the O-star scale height is less than the gas scale height (which suggested a greater than linear dependence of star formation on gas density).

FIELD: Penston calculated the dynamical evolution of colliding clouds with a Monte-Carlo program and found that the agglomeration of small clouds into massive ones (molecular clouds) should be accompanied by a decreasing root-mean-square random velocity. He adduced evidence based on the statistics of interstellar calcium-line velocities that this is the case. Because low turbulent velocities imply small-scale heights in the galaxy, this seems to fit into the fact that the CO clouds appear to form a thinner layer than the HI, and that the OB stars which form from them are also found in a thin layer.

I.P. WILLIAMS: Simons, Handbury and I have just completed a rerun of Penston's work, eliminating his assumption that all collisions occur at the same mean angle and have equal probability of collision. We get the same basic results but do not get the high mass, high velocity runaway clouds which Penston found, the reason being fairly obvious, Penston overestimates "nose-to-tail" collisions.

LEQUEUX: There seems to be a misunderstanding concerning observational checks of Schmidt's law of star formation. In its original (and physically meaningful) form it reads $\rho_* \alpha \rho_{gas}{}^n$, the ρ's being volume densities and n $\simeq$2 [the suffix $_*$ means young stars]. However most people who try checking it use the directly observed surface densities and try correlations of the form $\sigma_* \alpha \sigma_{gas}{}^k$, which do not yield convincing results. However, if we know the thickness z_{gas} of the gaseous disk we can estimate ρ_{gas} from σ_{gas} and z_{gas}. This can be done for our galaxy from direct observations. In the external galaxies M31 and M33 Guibert and Viallefond from our department have estimated z_{gas} as a function of radius from the density-wave theory combined with available observations. z_* is not determined directly, but if we have $\rho_* \alpha \rho_{gas}{}^n$ then $z_* \simeq z_{gas}/\ n^{\frac{1}{2}}$. In all three cases (our galaxy, M31 and M33) Guibert and Viallefond find that $(\sigma_*/z_{gas})\ \alpha\ (\sigma_{gas}/z_{gas})^n$ for various galactocentric distances, with $1.4<n<2.3$, thus implying $\rho_* \alpha \rho_{gas}{}^n$ in agreement with Schmidt's law. Surprisingly they obtain approximately the same results for (1) the galaxy where H_2 has been taken into account, (2) M31 where H_2 has not been taken into account and (3) M33 where H_2 has not been taken into account and where the density wave theory predicts no spiral shock. Note that if one plots instead of σ_{Lyc} vs σ_{gas} for our galaxy (see review by Mezger and Smith, fig.10), log (σ_{Lyc}/z_{gas}) vs log (σ_{gas}/z_{gas}) for various galactocentric distances one obtains a good correlation, with n $\simeq$2. The data corresponding to the regions within R = 4 kpc are extremely uncertain, but I think that the rate of star formation in the inner 130 pc is also consistent with Schmidt's law, with $1 < n < 3$.

LYNDEN-BELL: Are the coefficients A in the relationship star formation $= A\ \rho^2$ the same in all three galaxies, or does the work have 3 free parameters A_1, A_2, A_3?

LEQUEUX: Unfortunately the indicators of stellar formation rate used by Guibert and Viallefond are not the same for the three galaxies; they used the number of giant HII regions for our galaxy, the number of OB associations for M31, and the number of bright stars for M33, thus the A's cannot be compared. It should not be impossible in the future to have relative values for the A's in several galaxies and to see whether they depend on the spiral shock wave strength or other parameters.

SOLOMON: You used a value of 10^6 $M_\odot$ for the interstellar mass within 130 pc of the galactic center. Most of the interstellar matter there is molecular and the mass is about 5 x 10^7 $M_\odot$ (Scoville et al. Ap.J.187, L 63, 1974). How does this affect your results?

LEQUEUX: This would fit with a Schmidt index n not much greater than one.

R.C. SMITH: I want to describe briefly a paper by B.F. Madore (MNRAS 178, 1, 1977) related to the question of how the rate of star formation depends on gas density. He points out that in the usual observational determination of Schmidt's law (as has just been described by Dr. Lequeux) one compares the star density now with the gas density now. Theoretically, the rate of star formation depends on the gas density at the time of formation, which must have been higher. To estimate the effect of this, Madore has taken a distribution of gas, assumed a rate of star formation $R\alpha\rho^n$ (for various n) and followed the evolution of the number density of stars N_* and of the gas density ρ. After the stars are formed he uses the normal observational procedure to compare N_* with ρ for his models and for $n = \frac{1}{2}$ finds $N_*\alpha\rho^2$, in agreement with what is actually measured in the usual derivations of Schmidt's law (normally quoted as $dN/dt_*\alpha\rho^2$) Thus (a) the observed $N_* - \rho$ relation does not tell us directly about the rate of star formation and (b) the observations imply that $R\alpha\rho^{\frac{1}{2}}$ which is what would be expected theoretically if the dominant mechanism of star formation is gravitational, since the free-fall time is proportional to $\rho^{-\frac{1}{2}}$ giving a rate proportional to $\rho^{\frac{1}{2}}$.

C.J. CESARSKY: I have a question to all workers on stellar birth rates. The densities ρ needed in these studies are always averaged over some portion of the galactic plane. Given the lack of homogeneity of the interstellar medium, it is clear that the value of ρ supposed to characterize a certain region can vary by a large factor. Drs. L.F. Smith and Lequeux specified that ρ is averaged over annuli around the galactic centre. What is ρ in the work described by R.C. Smith? What was it in Schmidt's work?

LEQUEUX: In our galaxy, the distribution of HII regions and of H_2 are quite similar, and very different from that of the HI gas. In M31, on the contrary, it appears that the associations are distributed like the HI gas, hinting that the H_2 and HI distributions may be similar.

This would explain the similarity of the results found by Guibert and Viallefond for our galaxy (with H_2) and M31 (without H_2).

MEZGER: I would like to comment on the reinstatement of Schmidt's law $dM_*/dt \alpha \rho^2$ by Lequeux. Both we (see review by Mezger and Smith) and Lequeux used the same observations. But we refer dM_*/dt to the total column density of gas N_H in an annulus, while Lequeux refers dM_*/dt to an average density defined as $<N_H> = N_H$/(scale height of atomic H). We have the following objections against Lequeux's procedure: (1) in the relevant range of galactic radii $4<R(\mathrm{kpc})<13$ more than 60 percent of the Hydrogen is molecular. However, out to 8 kpc the scale height of CO which should be used by Lequeux, is constant. Therefore, his analysis should give the same result as ours, (2) if dM_*/dt would depend on $<N_H>$ one would expect that the characteristics of clouds out of which stars are formed change with R. However an analysis of CO observations by Burton and Gordon (see review by Kerr) shows, that the characteristics of molecular clouds are rather constant but that the number of clouds increases towards the galactic centre.
Therefore we believe that it is physically more meaningful to investigate dM_*/dt as a function of N_H than of $<N_H>$.

TALBOT: When I began chemical evolution computations some years ago, I ran into the same sort of problems with ρ_g^n. I discussed (Talbot, 1971, Ap. Letters 8, 111) the necessity of incorporating the width of the gas W_g along with other problems which affect this type of observational analysis (e.g., a variable IMF or a variable number of countable HII regions for a unit of star formation). Talbot and Arnett (1975, Ap.J. 205, 535) present models of disks in which the effect of a variable W_g is clearly very important. Their quantity $\eta(6)$ is proportional to the surface density of 0 stars. A plot of it versus the surface density of gas behaves nothing like a power law even for models where ρ_g^n was used. The proper interpretation of the variations of quantities across disk galaxies requires much more refined models than the simple power law prescription.
The power law prescription has very little physical justification, it is simply an ad hoc parametrization which was adequate as long as there were only limited observations to compare with. The proper way to do such computations for disk galaxies is to use a star formation rate per unit mass of gas which is of the form $\nu = E/\tau$ where τ is based upon physical processes which provoke clouds to form stars at the interval τ and E is the efficiency of star formation in those clouds once provoked. A formalism for doing this and some tentative models for τ and E are described in a paper in preparation for publication.

PEIMBERT: I think that the determination of the electron temperature of HII regions is a very powerful tool to determine the heavy element abundance and the diagram presented by Dr. L.F. Smith for our Galaxy presents an important step in the study of heavy element abundances as a function of distance to the galactic centre. The electron temperature for HII regions in our Galaxy seems to indicate that the heavy element abundances stay level or slightly decrease from 5 kpc to the centre. This result apparently is in contradiction with results for other spiral galaxies, which indicate that the relative abundances with respect to Hydrogen of Nitrogen and maybe other heavy elements increase towards the galactic centre. It is possible that the heating mechanisms in the galactic centre HII regions might be somewhat different to those of spiral arm HII regions rendering the relative abundance determinations uncertain. This might be the case if a significant amount of the heating in the galactic centre is due to cloud collisions or X-ray ionization. Therefore I would like to see an independent confirmation of the heavy element content of the galactic centre by observations of Neon, Oxygen, Argon and Sulphur lines in the far-infrared. Preliminary results from observations of the NeII 12.8μ line emission by the group at University College, London seem to indicate an overabundance of Neon for the galactic centre.

LEQUEUX: Our numerical computations of chemical galactic evolution (Vigroux et al., Astr.Astroph. 52, 1, 1976) show that ^{12}C and ^{16}O do not show strong abundance gradients in the central parts of spiral galaxies, while ^{14}N does. This fits with the lack of dependence with radius of the electronic temperature of galactic HII regions observed in the central part of our galaxy, this temperature being governed mainly by the abundance of O, not N.

Small-scale structure inside HII regions

LORTET: The relevance of optical data of HII regions to the problem of star formation has already been demonstrated in a number of previous contributions to this Symposium. I would like to make two general points and then mention a few recent and significant optical observations.

There seems to be general agreement that star formation does not take place simultaneously in the different parts of the same physical complex. Therefore it is important to study different kinds of objects, even if not the youngest ones, in order to know which group formed first, where in the complex, what is the gas density, which fraction of the mass is involved, etc.

It is obvious that optical observations have the advantage of both spectral and spatial resolution. This allows determination of local properties such as: density (in low-excitation ionized regions by [O II] or [S II] doublet lines), temperature and, even more important, their variations through the nebula, the velocity field, the stellar radiation field and, finally, some idea of the structures involved (departure from simple symmetries) and some hints on the amount of absorbing and/or scattering dust. An additional advantage of the optical data is their completeness: the whole surface of the sky has been mapped (Palomar Sky Survey and its Southern Extension) and star catalogues are complete to a certain limiting magnitude. On the other hand, the survey is not complete in depth along the line of sight, but this very limitation has a positive aspect, namely to help to disentangle the different regions along a line of sight. I want to emphasize that the most severe limitation of our knowledge is now set by the fact that we receive information integrated along the line of sight. This is a problem encountered at all wavelengths. Only velocity information from line observations offers some kind of way out.

A number of recent papers have presented monochromatic photographs, brightness distributions and radial velocity distributions across an ionization front. I want to emphasize two points: (1) The electron density is found to increase when entering the neutral cloud. However, this is observed only when the spatial resolution is sufficient (less than about 0.1 pc). It is encouraging to note that ionization fronts viewed edge-on are now rediscovered at infrared wavelengths and even in the radio molecular lines; moreover an increase in the dust density has been observed for Orion (see the review by Wynn-Williams). (2) A large spread in velocity (typically about 20 to 30 km s^{-1} in Hα) and/or line splitting is often present. Most of this may be the result of the acceleration of the ionized gas entering the HII region. The boundary of an HII region should be visualized as a complicated "sculpture habitable" rather than part of a smooth sphere. As a result, the velocity histogram may be distorted (for instance two-peaked for Sharpless 158 in Hα). Also the HII region may react on the kinematics of the bordering cloud (or rather part of it). It seems promising to study in detail the interface between the ionized gas and the neutral cloud (structure, density, turbulent velocity in both the ionized and the neutral gas).

Most of the brightest parts of visible HII regions are now thought to be ionization fronts. I would like to emphasize that at radio-wavelengths also, some so-called compact HII regions are of a similar nature. For instance in Sharpless 206 (Deharveng et al., Astr. Astroph. 48, 63, 1976) knots A,B,C,D and in Sharpless 158 (Deharveng et al. 1976, in preparation) where the condensations A1, A2 and A3 in the 6 cm radio map of Israel (Thesis, Leiden University, 1976) are seen in Hβ as well and are closely correlated with peaks in density (from [S II] lines and [O III] /Hβ). Thus, in both nebulae, we find gas concentrations of density 1-3 x 10^3 cm^{-3}, linear dimensions of a few tenths of parsecs and an excitation parameter of 10 to 20 pc cm^{-2} so that these concentrations are probably excited by one external O star.

Thus in summary, optical observations of HII regions can be quite useful in the following ways:

(1) They can be used as a guide and as a check on other observations.

(2) For a detailed study, choose a region from its optical appearance and whenever possible close to the sun. HII regions and also reflection nebulae as a rule are excellent indicators of dense and active clouds.

(3) Survey an area as large as possible for emission at other wavelengths. Negative results are of importance also. Map where there is a positive

detection as large an area as possible.
(4) Before attempting to construct an often too simplified model for a newly discovered object check, whether it does not bear some resemblance to a better-known object with an optical counterpart.
Finally, I would like to express the wish that in a near future we define criteria for "young associations", some kind of generalization of the OB, R and T associations.

FIELD: In Grenoble there was a discussion of the bubbles in HII regions predicted by theorists to be caused by stellar winds. Have you found examples of such a phenomenon, perhaps manifested by a shell structure in the optical images of HII regions? If so, how common is such behaviour?

LORTET: We possibly have found evidence for stellar wind in a nebula excited by an O5 star (Sharpless 206). The appearance is quite similar to the well-known Bubble Nebula (NGC 7635 near Sharpless 162) excited by an O6.5 III f star: a regular ring, visible in Balmer and high-excitation lines ([O III]) and absent in lower-excitation lines ([N II]). The star is excentric in the sense that the ring is nearer to the star (and brighter) where the brightness of the rest of the nebula is higher (see photographs in Deharveng et al., 1976, reference cited above).
The stellar spectrum has not been observed with sufficient spectral resolution to detect the presence or absence of the f character. There may be a number of nebulae where such structures have been missed so far, because monochromatic photographs are necessary to disentangle these high-excitation features from other kinds of narrow structures. Similar structures are also found as a rule in nebulae excited by Wolf-Rayet stars, for which the stellar wind may be an order of magnitude stronger (in energy) than for Of stars. NGC 6888 is a well-known example, other outstanding ones are NGC 2359 (Sharpless 298), NGC 6357 (Sharpless 11). However, the spectra of the rings have not been investigated in all cases.

FELLI: I am going to report briefly some preliminary results of a search survey of small-scale structure inside galactic HII regions. The justification for doing so is that at several stages in this Symposium it has been suggested that compact HII regions are related to the first phases in the process of star formation.
The survey that I am carrying out includes more than 100 HII regions and the observations are nearing completion. The observations are carried out with the Westerbork Synthesis Radio Telescope at a frequency of 5 GHz. To give an idea of the sensitivity in terms of possibility of detecting the Strömgren sphere of an OB star, the ionization-bounded HII region of an O9.5 star can be observed down to a distance of 10 kpc.
The basic output of the observations is the radio flux emitted by HII complexes which is contained in small angular diameter components with respect to that contained in low-surface brightness extended halos.
The sample of HII regions that I have selected, together with synthesis radio observations of other observers, provides a fairly complete set of

sources, to allow some statistical studies of the general properties, which is the final goal of this project. The obvious bias is that I am searching only known radio HII regions. Out of the observed sample, about 15 small angular components were detected, while for the remaining, an upper limit can be put to the presence of structure.
Comparison of this data with Palomar Sky Survey prints indicates the following results: (1) the detected compact components are associated in most of the cases with small optical nebulosities, characterized by the presence of strong obscuration, (2) in no case was compact structure detected at the edges of very extended HII regions, which were included in the sample.

LORTET: I would put emphasis on the fact that ionization fronts as a rule are not at all smooth surfaces. An illustration was provided just before by Felli for Sharpless 201; Sharpless 156 and 158 are other examples. As a result, the velocity field of the ionized gas is often found to spread over more than 10 km s^{-1} (L. Deharveng, in preparation). The turbulence of the HII region might in turn react on the kinematics of part of the bordering clouds. Thus, it is not safe to interpret the velocity field in a neutral cloud in terms of large organized motions such as collapse or rotation before the detailed geometry (structure and density distribution) of the cloud is known and the absence of major interaction with HII regions is established.

FIELD: In discussions with Dr. Michel of München, I learned of the existence of a hole around θ^1Ori. Perhaps this can be explained by a stellar wind. If so, we must consider the effects of winds in creating velocity fields in and around HII regions, including the associated molecular clouds. Perhaps the velocities you denumber can be explained by such a mechanism.

LORTET: The existence of brightness holes near the exciting star is very common. However, the explanation is not always straightforward as the radio continuum brightness distribution sometimes does not show the hole. As for the velocity field, so far we found no clear indication of any velocity jump for any nebula. When splitting occurs in a line, it develops rather smoothly along the ring of the interferogram, and may be interpreted as some kind of expanding shell. However, the coverage of the nebula is very incomplete by the method used so far by L. Deharveng. For instance, no measurement has been made in the high-excitation ring of Sharpless 206 near the star. Pressure Fabry-Perot interferometers would be more suitable to discover small-scale anomalies in the velocity field, and so would be the use of high-excitation lines.

ELMEGREEN: If stellar winds are long-lasting, then they will simply be a source of additional pressure at the ionization - shock front which enters the molecular cloud. This will not alter the basic point of the model of shock-induced star formation proposed by Elmegreen and Lada.

PEIMBERT: Pikelner suggested several years ago that the density fluctuations of ionized material present in HII regions might be partly due to stellar winds compressing the ionized gas.

LEQUEUX: Dr. Tenorio-Tagle has made a detailed study of neutral globules embedded in HII regions and shown that their lifetime is quite a bit longer than one would think at first glance. This is due to the presence of shock waves moving ahead of the ionization front. Therefore if a globule does not collapse under the action of the external pressure, it will persist for some 10^5 years.

ISOBE: The lifetime of globules in HII regions is of the order of 10^5yr even in the central region. The time scale is longer than that of the exciting star of the Trapezium stars in the Orion Nebula. (Dopita, Isobe and Meaburn 1975, Ap.Sp.Sc. 34, 91).

ELMEGREEN: It is not necessary that neutral inhomogeneities in HII regions be initially present as inhomogeneities in the adjacent molecular clouds. Instabilities in the shocked layer ahead of an ionization front may cause similar features, especially if stars form in the layer and cause it to break up.

SILK: Recent observations using the Copernicus ultraviolet spectrometer by York and colleagues at Princeton of a number of early-type stars have revealed the presence of anomalous Si III absorption features in the form of an asymmetry in the wings of the principal component. Corresponding features are not found for lower excitation ions, nor in higher excitation ions (e.g. S IV), and it is believed that gas is being observed at a temperature of about 50.000 K. I would like to suggest that one may be observing regions of shocked gas within an HII region that may be associated with high velocity motions of clumps of gas.