DISCUSSION FOLLOWING REVIEW BY C.G. WYNN-WILLIAMS

GILRA: You showed 100μ maps of the Orion Nebula in the neighbourhood of the Trapezium. I want to point out that the dust emission in the immediate vicinity of θ^2A Orionis is probably due to the same dust seen around θ^2A Orionis in scattering in the direct photographs at "continuum" wavelengths discussed by Wurm and Rosino about two decades ago. Now I want to ask a question. You suggested that the 100μ emission around θ^2A Orionis was due to UV photons from the Trapezium. Has θ^2A Orionis been completely ruled out as the source of this radiation?

WERNER: The following points suggest that the infrared radiation from the ionization front in the Orion Nebula is not due to heating by θ^2A Orionis: (1) θ^2A is believed to lie well in front of the ionized region, and (2) the 10μ spectrum of the emission from within a few arcseconds of θ^2A differs from that from the other points along the ridge. This suggests that the heating due to θ^2A is confined to its immediate vicinity (see also Becklin et al. Ap.J. 207, 770, 1976).
Now I have a question for Dr. Spitzer. I believe Copernicus has looked at θ^1C Orionis and θ^2A Orionis. In connection with the discovery of H_2 emission from the Orion Nebula, I want to ask whether the H_2 electronic rotational lines were seen in absorption in the far-UV spectra of these two O stars? What kind of excitation do the observations show?

SPITZER: The Trapezium stars are rather close together for the Copernicus telescope to guide on individually. We have made attempts to observe these stars, but I believe that the results are not yet in a form suitable to be reported.

I.P. WILLIAMS: Interstellar grains can be observed at many wavelengths other than the infrared. There is now general agreement that the optical extinction shows a bimodal size distribution, one corresponding to a silicate core of radius several hundred Ångstroms and the other to an "ice"-coated larger grain of a few thousand Ångstroms. However, these days, there is a feeling that the ice need not be water-ice or ammonia but could be a more complex general "mush" based on C, N and O. It may even be that some of the complex molecules found in space have their origin in this ice.

Hot molecular hydrogen in Orion

FIELD: The Gautier et al. (Ap.J. 207, L129, 1976) observations of vibrationally excited H_2 may be due to a shock-wave propagating from the Orion Nebula into the background molecular cloud. This is interesting in connection with the Elmegreen-Lada prediction that subgroups within associations are formed as the result of such shock-waves. Gautier et al. concluded from line ratios that the H_2 is vibrationally excited by collisions. Field et al. (Ap.J. 151, 953, 1968) showed that HII region-driven shock-waves would excite H_2 rotational lines as well, and this theory was applied by Aannested and Field (Ap.J. 186, L29, 1973) to explain the H_2 rotational excitation observed by Copernicus in λOrionis and other early-type stars. I would like to ask Dr. Copernicus whether it is possible to choose unambiguously between shock excitation and fluorescent excitation of these lines?

SPITZER: Our studies of high-velocity clouds do not seem to be consistent with collisional excitation of the rotational levels at a high kinetic temperature produced by a shock. The radial velocities of H_2 lines absorbed from levels of different J are nearly constant with J, when the contributions from the different components observed in Na I and Ca II by Hobbs are separated out; in contrast one would expect a substantial change of radial velocity with J if high temperatures behind a shock were responsible for rotational excitation, with different levels excited at different locations as the kinetic temperature falls behind the shocks. However, the evidence is less clear for low-velocity clouds, especially for those showing a relatively low rotational excitation temperature for the levels of lowest J.

ZUCKERMAN: The authors of the recent paper reporting H_2 vibration-rotation lines from Orion stated that their observations were incompatible with the ultraviolet excitation model of Black and Dalgarno (Ap.J. 203, 1976). Dr. Dalgarno commented on this in Grenoble that at the high H_2 densities required by Gautier et al. to explain their observations the ultraviolet pumping model is not inconsistent with the observations. Indeed ultraviolet excitation might be required to explain the high population of the $v = 1$ levels. It remains to be seen if the hypothetical source of UV actually exists.

LADA: Joyce and Grasdalen have recently made a map of the IR emission due to the vibrationally excited H_2 lines. This map shows that the H_2 infrared emission is extended in a ridge which is roughly parallel to the ionization front observed by Gull and Martin. This ridge is also found to be displaced from the Kleinmann-Low and BN objects. In reference to Professor Field's question, both the orientation and position of the observed ridge of IR emission are consistent with, but not required by, the ionization driven shock proposed by Elmegreen and Lada for the formation mechanism of OB stars in associations. In addition, the separation of the ionization front and the H_2 ridge is also consistent with our model. It is interesting that the H_2O and OH masers and the Kleinmann-Low and BN infrared sources are located between the ionization front and the H_2 ridge, just as would be expected from the Elmegreen-Lada model. However, it is possible that the IR emission is not related to the shock of an ionization front but instead associated with some independent phenomena in the star-forming layer. Clearly more work on this interesting result would be highly desirable.

Far-infrared observations of Orion

WERNER: I will report briefly on recent far-infrared observations of the Orion region done from the C-141 airplane with 25" resolution at 30μ, 50μ and 100μ.
The principal features of the spatial distribution of the far-infrared radiation are a sharp peak at the position of the infrared cluster to the northwest of the Trapezium, a smooth extension along the molecular ridge to the north and south of this peak, and an apparent ring of emission around the HII region, which includes the ionization front source described earlier by Wynn-Williams.
Because the objects in the infrared cluster in Orion are the closest and most accessible of the candidate protostars, it is very important to study them and their environment in as much detail as possible.
Two relevant points emerging from the present data are: (1) the peak in the far-infrared emission coincides within a few arc seconds with the position of the cluster, (2) the 50 to 100μ colour temperature of the emission desreases smoothly along the molecular ridge from ∿130 K at the peak to ∿60 K 90" from the peak. The positional coincidence and the temperature gradients show that the infrared cluster is heating the dense central regions of the molecular cloud and therefore strongly support the assertion that the cluster is buried within the cloud, as would be expected if it had formed there in a recent collapse process.
The data show that the far-infrared luminosity from the central 30" around the infrared cluster is ∿4 x 10^4 $L_\odot$, and that the total far-infrared luminosity from the 4' x 4' region mapped is ∿2 x 10^5 $L_\odot$.
About one half of this luminosity comes from the molecular cloud region and is attributable to heating by the infrared cluster, which must therefore have a luminosity of 10^5 $L_\odot$. The remaining far-infrared luminosity comes from the edge of the HII region and, to a lesser extent, from within the HII region, and is attributable to heating by the Trapezium cluster.

SCHATZMAN: How are your results related to the problem of star formation?

WERNER: They provide information about the nature and properties of the objects in the Orion infrared cluster, which are the closest and most accessible candidate protostars.

SOLOMON: The 100μ map you presented has very smooth contours and does not appear to show any fragmentation on the scale of your resolution (about 20" corresponding to 2 x 10^{17} cm). There are clearly several objects which have already formed and these are the 20μ sources, but there does not appear to be any protostellar fragmentation. There is however, obviously fragmentation on a larger scale resolved even by the one arcminute radio beams. This is shown on any large scale map of giant molecular clouds, showing more than one hot spot in CO emission.

ERICKSON: What is the 100μ optical depth at the center of your map of the Kleinmann-Low Nebula? This bears on the question of fragmentation, in that it may be possible that the radiation could be coming from the individual components of the infrared cluster rather than from the central 30 arcsecond region as a whole.

WERNER: The 100μ optical depth is $\sim$0.3.

THADDEUS: A general comment on determining masses from the far-IR measurements: the far-IR emission properties of interstellar grains are of course poorly known, so the mass or density determinations are purely relative ones. An empirical calibration against masses determined by other means would be useful.

GILRA: The observations of the spatial distribution of H_2 2μ emission were mentioned earlier. It was suggested that the maximum emission occurs northwest of the BN object. I do not think that such an inference can be made in a straightforward fashion. We just heard from Dr. Werner that the dust optical depth in emission at 100μ at the center of the K-L nebula is a few tenths. That means that the optical depth in extinction at 2μ (where the H_2 lines are observed) will be substantial. The spatial distribution of extinction at 2μ in the neighbourhood of the K-L nebula has to be disposed of for a proper understanding of the actual spatial distribution (as opposed to the observed distribution) of H_2 emission in and around the K-L nebula.

STROM: Without wishing to begin a semantic discussion concerning the definition of "protostar", I would like to ask whether you feel that you can exclude the possibility that the luminous embedded objects (covered by the rubric "protostars") are actually pre-main sequence objects of high mass approaching the main sequence along equilibrium radiative tracks? Should we not wait for spectroscopic or other more indirect evidence of infall before accepting these fascinating objects as "protostellar"?

WYNN-WILLIAMS: Theoretical models of the evolution of massive protostars by Larson, Appenzeller and Kahn indicate that the Kelvin-Helmholtz timescales are shorter than the accretion timescales. The core of one of these objects therefore approximates to a ZAMS star of continually increasing mass. In other words, massive stars do not have a recognisable equilibrium radiative track as far as we know.

Ionization fronts in Orion

ZUCKERMAN: Dr. Wynn-Williams has emphasized the ionization front in the Orion Nebula that lies between θ^1 and θ^2. I would like to call attention to another probable ionization front in Orion that has recently been investigated by Kutner, Evans and Tucker (Ap.J.209, 952, 1976).

Since Orion is now moving into the night sky, I hope that those astronomers to whom such considerations matter will investigate this ionization front this winter. The front in question lies just to the south of NGC 1977 where Kutner et al. show that the extended Orion CO cloud ends abruptly. It is probable that NGC 1977 is ionization-bounded by the molecular cloud; therefore a variety of observations are suggested. Optical astronomers might measure the ionization state and radial velocity of various elements as a function of distance from the presumed ionization front. Infrared astronomers might detect a "bar" of radiation parallel to the front as they have done in the Orion Nebula. Radio astronomers could attempt to detect C^+ and H^+ recombination radiation from in front of and behind the front respectively and, in addition, make a continuum aperture synthesis map of the HII region. Because of its relative proximity to the Earth, this HII region is worthy of special study.

FIELD: While Dr. Zuckerman is on the stage, would he be willing to describe the morphology of the Orion Nebula and NGC 1977 with respect to the CO cloud? In particular, how would he describe the arrangement of material in depth?

ZUCKERMAN: It was pointed out by Kleinmann and Low and by Kutner and Thaddeus that the K-L nebula and the molecular cloud, respectively, must be located behind the main emitting mass of the Orion HII region (or else they would absorb its light). I have suggested that the HII region is ionization-bounded on its rear side by the molecular cloud (Ap.J. 183, 863, 1973; Ann. Rev. Astr. Ap. 12, 279, 1974) and that the K-L nebula is located in the front portion of the molecular cloud right behind this ionization front (HII Regions and Related Topics, Wilson and Downes ed., Springer-Verlag, 1975, p.360). The infrared cluster OMC-2 is apparently also near the front edge of the molecular cloud or else the CalTech astronomers could not have detected it. It therefore probably lies at about the same distance from the Earth as either the K-L nebula or the Trapezium but ∿1 pc to the north. (The K-L nebula and the Trapezium are probably separated by no more than ∿0.5 pc along the line of sight). Finally according to the recent observations of Kutner, Evans, and Tucker the molecular cloud appears to end abruptly at NGC 1977. This suggests that NGC 1977 is ionization-bounded to the south by the molecular cloud, similar to the Orion Nebula case, but rotated by ∿90° with respect to our line of sight. Again, since we see NGC 1977 it must be towards the front and/or to the north of the molecular cloud.

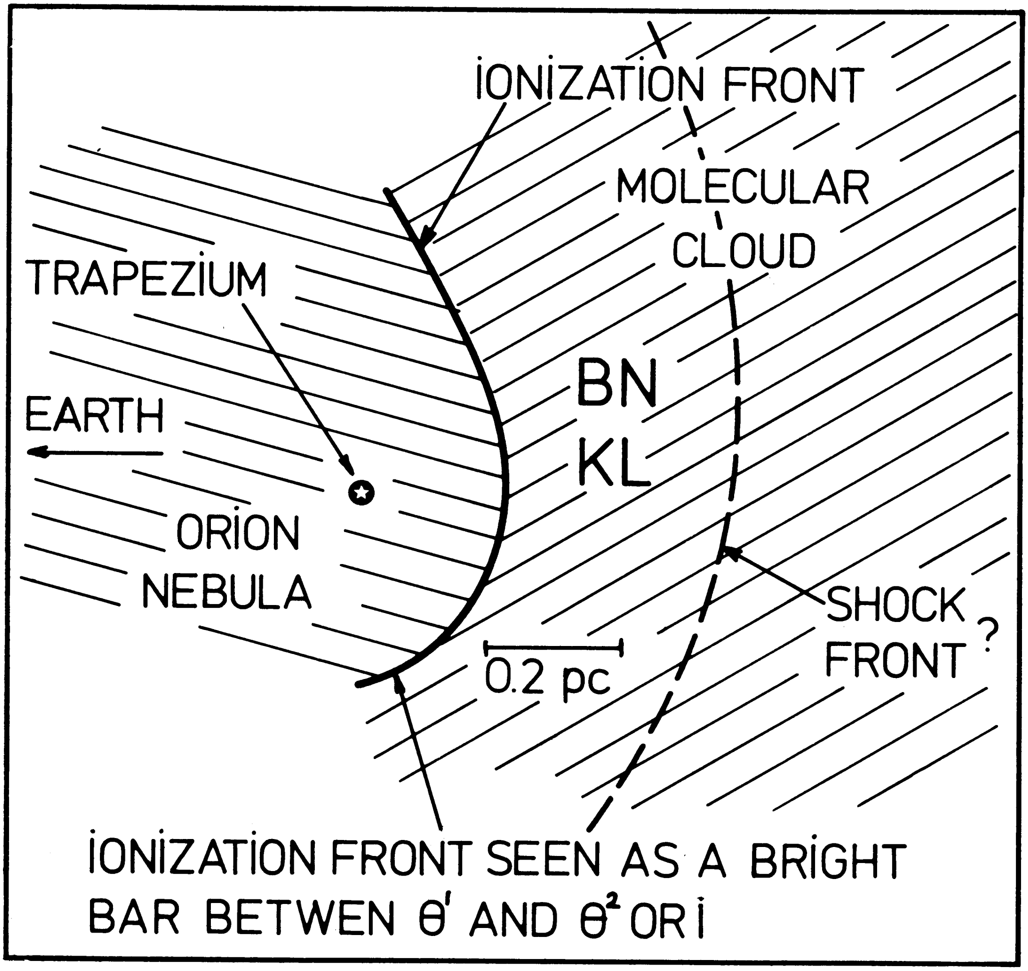
PEIMBERT: We have made optical observations at many points of the Orion Nebula located to the east and west of the optical ionization front between θ^1 and θ^2 Ori. We find that the ionization and energy input in the western regions are dominated by θ^1 Ori C while the eastern regions are dominated by θ^2 Ori. About 80% of the ionizing flux corresponds to θ^1 Ori C and about 20% to θ^2 Ori. The heating of the dust in the eastern part of the ionization front and in particular the 10 μ emission might very well be due to θ^2 Ori. A determination of the dust temperature might help to decide which is the energy source.

STEIN: I am still confused by the location of the I-front interaction between the Orion HII region and the molecular cloud. From Zuckerman's description it seems the I-front lies behind the visible HII region perpendicular to the line of sight. Is that correct?

ZUCKERMAN: Yes, that is correct for one of the two fronts we have been speaking about. The other front is optically visible and lies between θ^1 and θ^2.

McCREA: Would you please draw a section in a plane at right angles to the plane of the sky as inferred from the observations?

ZUCKERMAN:



ISOBE: I would like to report on evidence for globules in the Orion Nebula from optical observations. The continuum light scattered by dust grains is strong evidence for dust inside the nebula.
From a statistical treatment of intensity fluctuations of several lines, Tamura (Contribution from Tohoku University 1977) obtained that the number and the size of globules in the central region ($<3'$) are $\sim$400 and 0.001 pc, respectively. These results are consistent with the globules proposed by Dyson (Ap. Space Sci. 1, 388, 1968) in order to explain the line splitting of [O III] lines. Therefore, we conclude that there are many globules even in the region within 0.3 pc from the Trapezium.

KUIPER: Several years ago, Dr. Neal Evans and I, in collaboration with Dr. Zuckerman, started a project to map the C75α line at 15 GHz with the NASA 64 m antenna at Goldstone, California, which has a resolution of $1\overset{'}{.}3$ at that frequency. The data are very incomplete but indicate a few interesting things pertinent to the present discussion. The carbon line vanishes abruptly across the ionization front to the northwest, and was not seen at all at the Kleinmann-Low position where we had expected it to be strong. Towards the southeast, at the position of that ionization front, the line becomes quite narrow, about half of its width at the Trapezium position, and at one point just across the front, it was not seen. The line was also quite strong to the north, at a position in the dark lane. Unfortunately, because of the heavy spacecraft-tracking commitments of the Goldstone facility, we were unable to complete this project.

The ρ Ophiuchi cloud

ELSÄSSER: Presently at our new observatory in Southern Spain, observations of dark clouds are carried out with a cooled S1 image-tube camera and other IR equipment for longer wavelengths. I would like to present a few preliminary results of the ρ Oph dark cloud which were obtained by Mr. Chini, Dr. Weinberger and myself. These results are based on photographs in R (0.7μ) and I (0.9 - 1.0μ).
Strom, Grasdalen and Vrba (SGV) in two papers (Ap.J.184, L53, 1973; Ap.J. 197, 77, 1975) published 67 sources which were mainly discovered by 2μ observations. On our I photographs of the same field we could identify 27 of those sources, that means about 40%. 15 of those are also recorded on our R plates. The identified sources are not the brighter ones of the SGV-sample. Their H magnitudes are between 7 and 11.8, whereas the unidentified ones have H between 7.8 and 12.3 (according to Table 1 of Vrba et al., Ap.J. 197, 77, 1975).
For several of the sources we have in common with SGV, we determined spectral types and extinction taking into account our R and I brightnesses in addition to the IR magnitudes of SGV. This determination is not a unique one since different combinations of spectral type and extinction can reproduce the observed energy distribution. If we assume main

sequence stars we find spectral types between B and F, but G and K giants with less extinction also reproduce the observations. The latter most probably would be background objects. The A_V values we find are ≤ 15 with very few exceptions and tend to be lower than those of SGV.
On the other hand we find on the R and I photographs numerous, very red stars which were not recorded by SGV, within their field and in neighbouring areas. We cannot exclude at this moment that these are mainly stars in the background of the cloud.
We do not find any object at the position of Oph 6, the most intense compact HII region within the cloud according to Brown and Zuckerman (Ap.J. 202, L 125, 1975). It lies in a surprisingly empty area where the visual extinction could well be above 20 magnitudes.

WERNER: What were your sensitivity limits at R and I?

ELSÄSSER: The limiting magnitudes are 16th magnitude in the I filter and 18th magnitude in the R filter.

BAART: We have mapped the ρ Ophiuchi region at 2.3 GHz and we find an extensive HII region which is ionisation-bounded, to the south of the dark cloud. Do infrared objects show any clustering towards the south side of the dark cloud where the ionisation front is?

ELSÄSSER: Not according to the now available observational material which does not yet cover the whole cloud.

ENCRENAZ: We have made a synthesis map of the ρ Ophiuchi dark cloud with the Westerbork array. We have detected more than 10 sources, only 3 of them coincide with the sources published by Brown and Zuckerman. Within our noise limit, there is no source at the position of the B3 star HD 147 889.

GILRA: I want to make a comment about an infrared source in the ρ Oph dark cloud discussed briefly by Dr. Thaddeus yesterday. The source was found by Fazio et al. (Ap.J. 206, L 165, 1976) and is somewhat to the east of the B2 V star HD 147889. I want to point out that there is a CRL source at about this position at 10μ and 20μ. In the CRL Catalogue this source has been identified with a variable star which is the star SR 22 in the Struve and Rudkjøbing paper on T Tauri and related stars in the ρ Oph dark cloud (Ap.J. 109, 92, 1949). Struve and Rudkjøbing classified it as A?. However, L. Kuhi and M. Cohen (private communication) have classified it as M3e. I do not think that SR 22 is the identification for this CRL object. I think that the CRL source and the Fazio et al. source are the same. The question whether HD 147889 is responsible for the infrared radiation can be resolved by mapping this source at 10μ and 20μ. This mapping has not been done presumably because the object is listed as identified in the CRL Catalogue!

ENCRENAZ: We have carried out observations of the Carbon recombination lines C 166α and C 210β of the ρ Ophiuchi cloud with the Nançay radiotelescope (Astr. Astroph. 48, 167, 1976; Astr. Astroph. 52, 299, 1976). A broadening of the lines is explained by collisions of Carbon atoms with ions rather than with electrons which are much more efficient at the prevailing conditions in dark clouds ($n(e) \simeq 1.5\ cm^{-3}$, $T \simeq 10\text{-}20$ K).

SCHATZMAN: Would you think that the CII lines are formed in a different region than the molecular lines?

ENCRENAZ: The peak of the carbon-emitting region does not coincide with the peak of the molecular emission (^{13}CO, H_2CO, CS, C_2H). There is 5 or 6 arc minutes difference in right ascension clearly resolved with the Nançay telescope (Carbon line) and with the Millimeter Wave Observatory (molecules). However, the situation is not as clear for the molecular ions (HCO^+, N_2H^+,...).

VANDEN BOUT: In response both to Dr. Strom's plea for infrared mapping of "less prominent" regions and Dr. Solomon's question as to whether the 2μ sources detected in dark clouds are actually associated with the clouds, let me say that we have searched numerous CO clouds for 2μ sources and almost always find one or more at the position of peak CO emission intensity. Additional infrared sources are also found, but the high rate of coincidence with CO "hotspots" certainly means that some are embedded in the clouds. We believe this technique of CO mapping followed by 2μ mapping and longer wavelength infrared photometry is a very efficient method for locating BN-like objects. The infrared source we found in the S140 cloud is a prime example.

ELSÄSSER: If you find an IR source coincident with an HII region, the energy distribution of which can be represented by a highly obscured early-type star, one can be rather sure that the object belongs to the cloud. If there is no coincidence of this type, one cannot exclude that it is a background object. Another kind of evidence would be an increase of the number of highly obscured objects with increasing extinction in the cloud. This we do not observe in the Oph cloud.

BOK: Is there any hope that fairly soon infrared observers will be able to detect objects like Barnard's with temperatures of the order of 10 K?

WERNER: Dust clouds of this temperature can be detected at 1 mm if their 1 mm opacity is $\gtrsim 0.01$; this 1 mm opacity corresponds roughly to $\gtrsim 100$ magnitudes of visual extinction.

Miscellaneous contributions

THOMPSON: I would like to present some results based on 1-2.5μ spectra of MWC 297 and MWC 349 at a resolution of $\Delta\lambda/\lambda \simeq 3\times10^{-4}$. These sources are newly formed stars still embedded in their natal material. Emission lines of the Brackett and Paschen series of Hydrogen and O I λ11287 are seen in both objects. MWC 349 displays He I recombination lines, one of which λ20581 is very density-sensitive. A high excitation line of the O I quintet series is seen at 5925 cm^{-1} in MWC 349. The continuum flux is due to dust emission.

HABING: In his review paper, Dr. Wynn-Williams mentioned a characteristic group of infrared point sources that he described as "similar to the BN object in Orion". He mentioned two possible interpretations for these objects given in the literature: that they could be late-type supergiants, reddened by large amounts of foreground extinction or that they could be protostars. Although the latter interpretation has attracted the largest interest, it lacks theoretical support. As far as I am aware, the only attempt to give a self-consistent model for the BN object has been made by Larson (1969, M.N.R.A.S. 145, 297). Although this model fitted reasonably well the observations available at that time, it no longer fits the new observations, notably those at 10 and 20 μm. I would like to report on calculations of an improved model, that does fit all observations. The calculations have been made by P.J. Bedijn at Leiden Observatory.

The model is as follows. A star of mass M and luminosity L is at the centre of a spherical cloud (cocoon) that collapses in free-fall onto the star. Since the mass inflow rate $\dot{M}$ is assumed to be constant throughout the cloud, the density distribution is proportional to $r^{-3/2}$. Through absorption of the stellar flux, the dust in the infalling gas is heated and re-radiates its energy in the infrared. The radiative flux is conserved, but its spectrum becomes cooler, the farther out one goes.

Bedijn calculates in a self-consistent way the emerging spectrum and the temperature distributions of dust particles in the cocoon. It turns out that beyond about 10^{16} cm the infalling matter is so cool that it no longer emits radiation in the wavelength range of interest (1μm to 30μm). However, it does absorb heavily in this wavelength range. Hence, the density structure outside 10^{16}cm is irrelevant and the only thing that counts is the total optical depth outside 10^{16}cm, which one can express in terms of A_V. For this absorption Bedijn uses Van de Hulst's curve No.15 (called by some people the "dutch opacity"), to which a silicate absorption band is added, of the form given by Gillet and Forrest (1973, Ap.J.179, 483) and with $A_V/\tau_{10\mu} = 24$.

The model calculations show that the most critical assumptions concern the dust opacity. To explain the observations the following two assumptions proved to be necessary:

(1) Taking dust particles with realistic absorption characteristics, at least two kinds of particles are required: silicate and graphite. Without the first, there is never enough radiation at 20μm compared to that at 10μm; without the second, the peak is never at wavelengths as short as is observed, nor is there sufficient optical depth at $\lambda < 5\mu m$.

(2) The silicate grains must have a considerable opacity at $\lambda \leq 5\mu m$, in spite of what is found for terrestrial silicates. Although this

assumption may appear rather ad hoc, it is supported by the fact that an analysis of the infrared spectra of late type oxygen-rich giants requires the same kind of silicate absorption properties. This latter conclusion has also been independently reached by Jones and Merrill, 1976, Ap.J.209, 509.

Model parameters for a best fit to the spectrum of the BN object are: $L=11000\ L_\odot$, $M=11\ M_\odot$ (corresponding to a BOV star) and $\dot{M}= 3.7\times10^{-6} M_\odot yr^{-1}$. Silicate particles constitute 0.6 percent of the gas mass density, graphite particles 0.2 percent. The spectrum of the collapsing cloud is modified by $A_V=50^m$ foreground extinction. The agreement between model and observations is quite good. The 3.1 µm absorption band of ice could have been included in the model calculations, without changing any fundamental results. There is a slight systematic deviation between the predicted and the observed shape of the 9.7 µm silicate band that occurs also in the control calculations of late-type giants. This is probably due to the simplifications that Gillett and Forrest made in deriving the intrinsic shape of the silicate band.

The model fit is not unique; other combinations of L, M and A_V can reproduce the observed spectrum. However, the conclusion that at least two dust particles are required to explain the observations, appears quite firm. Finally, models like this are probably good starting points for further calculations, e.g. for the study of maser theories.

FIELD: Your model is very nice, and I can understand why you see silicate in absorption; it is simply that the outer layers are cooler. I don't understand, however, Dr. Wynn-Williams' statement that Scoville's model explains the apparent absorption simply as a "radiative transfer effect".

WYNN-WILLIAMS: The paper by Kwan and Scoville showed that the material responsible for the 10µ feature can be associated with the emitting object and need not necessarily be truly interstellar. Of course it is cooler than the dust toward the centre of the source or else no line would be formed.

FIELD: You mentioned calculating the evaporative surface for silicates and graphite. Presumably you could do the same for ice. If you were to do that, do you think that there would be enough ice outside the evaporative surface to explain the observed ice band?

HABING: Yes. Assuming that ice evaporates around $T \simeq 100$ K, we find that the whole cloud outside 10^{16} cm will be cool enough to contain ice. Assuming $A_V/\tau_{ice} \simeq 30$ (Gillett et al., Ap.J. 207, 763 (1976) find this for NGC 2024 # 2) one obtains $\tau_{ice} \simeq 1.7$, comparable to the observed value 1.46.

LENA: The Meudon Observatory and the Space Science Group in Groningen have jointly observed from aircraft the source L1204 near the S140 region. Scans made across the ionization front show strong emission in two spectral bands (70-95μ and 115-195μ), of a source smaller than 5 arc min located on the dark cloud side. Fluxes are respectively 6.4 and 3.2 x 10^{-14}W cm^{-2} in these bands. Assuming a λ^{-2} emissivity of the dust, one gets T_{dust} = 35 ± 2.5K comparable to $T(^{12}CO)$ = 27K. These values are close to Goldreich and Kwan's values of 35K and 26K respectively, for a rather high density of 2 X $10^4 cm^{-3}$. We derive the opacity in three different ways: using the ratio $^{12}CO/^{13}CO$ = 89 and the observed lines, one gets A_V=22; using a standard dust model (Ryter and Puget, Ap.J. in press) and the derived total IR luminosity, one gets $N_H = 4.2 \times 10^{22} cm^{-2}$ and A_V=18; finally, using the near-IR observations of a bright source located at the same position, we get a value of M_V= -6.5 which fits the total IR luminosity and needs A_V=30 to explain the near-IR observations. This region seems to be a typical dense molecular cloud, probably at a distance of 900 pc, where the geometry is rather simple and deserves further study.

I would also like to report on some other work by D. Rouan, J.L.Puget, K.de Boer and myself. We have observed the diffuse emission from the galactic plane in a wavelength band 70-95μ from the Caravelle aircraft. We scanned at $\ell \simeq 28°$ over a latitude interval $-1° < \ell < 0°$, in an area selected to avoid known HII regions or dark clouds. The scans consistently show diffuse emission with an intensity of 1.4 x 10^{-4} W $m^{-2} ster^{-1}$ in the band. A wide component is detected within $|b| < 0.5°$, and a narrow component within $|b| < 0.1°$. The correspondence between the infrared brightness distribution of the narrow component and the ^{12}CO brightness distribution perpendicular to the plane at the same longitude is striking. A not previously observed source has also been detected at a distance of about 40' below the plane. Although we cannot rule out a chance coincidence of this diffuse emission with a nearby source in the 6.3' beam, we believe to have detected the integrated dust emission from the plane. Computing the total hydrogen column density to be $N_H(\ell_{II} = 30°) = 1.5 \times 10^{23} cm^{-2}$, one gets τ(100μ) = 0.2 with a reasonable dust model (1% ratio to gas in mass, amorphous silicates, λ^{-2} wavelength emissivity dependence). The dust should be a good tracer of the total amount of material along the line-of-sight. Since only one wavelength band could be observed in this run, it is impossible to derive a unique value for the mean dust temperature. According to a recent model by Ryter and Puget (Ap.J. in press) the dust temperature and the total IR luminosity are related as follows: $L_{IR} = 3.2 \times 10^{-38} T^{5.8}$ watt(H atom)$^{-1}$. An average temperature of 22K for the dust along the line-of-sight fits the measured IR luminosity in the band. It is true that a smaller amount of dust at a higher temperature would also agree with the measured value, but then the total IR luminosity would be much higher, in contradiction with earlier measurements made by J. Pipher (IAU 53, p.559, 1973). Although multi-band measurements are required to confirm this result, we point out several implications: (a) the fact that $T_{dust} > T_{CO}$, the latter having been quoted to be 10K, indicates that the dust is located on the average in clouds where the density does not allow complete thermalization of gas and dust; (b) the total IR luminosity is a measure of the total stellar radiation field which is ultimately transferred to long wavelengths; (c) the scale height of the dust temperature distribution with respect to CO deserves further investigation, because it is a tracer of the stellar UV radiation, which has a very short mean free path in the dust.

FIELD: Can you rule out the possibility that your far-infrared emission originates in point sources, such as compact HII regions?

LENA: Not at all. In fact the diffuse emission is the sum of contributions due to HII regions with hot dust $T_d \sim 60K$, due to colder dense clouds with $T_d \sim 20K$, and due to the intercloud medium with even cooler dust. We nevertheless deduce that the second contribution is probably the main one: if the first one were dominant, the total infrared luminosity per Hydrogen atom, averaged along the line-of-sight, would be too high by a factor close to 10. We cannot completely rule out a chance coincidence with a nearby object, but the agreement with the CO distribution makes the dense clouds the most probable source of the infrared emission.

PEIMBERT: The radio observations in the direction of the galactic centre presented yesterday indicate that most of the CO is located below the galactic plane. Is it possible from your observations to say if the dust shows a similar distribution to that of CO?

LENA: We have searched for this effect, but one clearly needs a complete scan across the galactic plane. Unfortunately the guide star we used did not allow to cross the plane. Yet the actual data do not show such a trend.

RYTER: I would like to briefly discuss some implications of the observations presented by Lena [....]. The diffuse far-IR emission is most likely due to the presence of new-born, still undetectable, stars embedded in the clouds. If a Star Formation Rate (SFR) per unit mass of interstellar gas is deduced, and compared to the SFR derived from star counts in the solar neighbourhood, [....] we find $SFR/SFR_\odot \simeq 10\text{-}20$. Either of two conclusions can be drawn from these high values of $SFR/SFR_\odot$: (1) in the very early phase of their life, stars are more massive (much more luminous) than when they become visible, (2) star counts in the solar neighbourhood are not representative of the SFR per unit mass of interstellar gas in denser regions of the Galaxy.

FIELD: While you were talking, I computed from the observational data $L_{IR} = 3 \times 10^{43}$ erg sec^{-1} for the entire galaxy, a value comparable with L_{OPT}. Indeed, a substantial fraction of the optical light of the galaxy should be absorbed by grains and re-emitted in the IR, simply because the mean free path of a photon is usually less than the relevant galactic dimension. These considerations suggest that L_{IR} would be of the order you state even if there were no star formation.

RYTER: It is true that the IR and optical luminosities are very similar, but the spatial distribution is quite different. Most of the IR radiation comes from the 5 kpc ring of clouds, whereas a large fraction of visible light comes from the galactic bulge. The radiation field exciting the IR emission has a density $\gtrsim 10$ times the average starlight density.