34. INTERSTELLAR MATTER

(MATIERE INTERSTELLAIRE)

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1. INTRODUCTION (J. Mathis)

This report covers the period summer 1987 - summer 1990. It is divided into sections written by various experts in each subfield. I would like to thank the many individuals who worked hard in preparing this report. Without their cooperation and hard work this report would not exist.

The following summaries usually begin with a list of general references in the particular subfield (monographs, catalogs, and relevant symposia). Subsequent references to these volumes are sometimes identified by only the editor's name, underlined, plus a page number. All references are given with only one name, followed by a + sign if there are additional authors. The citations in the Soviet and Chinese literature are given in the corresponding journals of English translations, which of course provide the references to the original journal. I have edited several contributions to force them to fit into just slightly more than the space we were allowed, but all papers originally cited are in this version.

Dr. David Flower acknowledges the hospitality of the Director of the Institut d'Astrophysique in Paris, where he prepared his contribution to this Report.

2. THE DIFFUSE INTERSTELLAR MEDIUM (K. S. de Boer)

The continuing trend to study small regions in ever greater spatial and spectroscopic detail resulted in less evidence for the existence of a "diffuse" interstellar medium. The local interstellar medium again received attention, in particular when seen at high galactic latitudes. The SN 1987A allowed to obtain very high S/N data on the ISM of this particular line of sight. An increasing number of programs dealt with reflection nebulae.

Relevant conferences and reviews are: Bloemen 1990,*The Interstellar Disk-Halo Connection in Galaxies*; IAU Symp 144, Kluwer; Cordes+ 1988, *Radio Wave Scattering in the Interstellar Medium*, Am.Inst. Phys. Conf. Proc. 174; Haynes 1990: *The Magellanic Clouds*, IAU Symp 148, Kluwer; Lawrence 1987: *Comets to Cosmology*, IRAS Conference; Lecture Notes in Physics, Springer; Tenorio-Tagle+ 1989: *Structure and Dynamics of the Interstellar Medium*, IAU Coll. 120, in Lecture Notes in Physics, Springer.

A catalogue of all published interstellar absorption line data has been produced at the Centre des Donnees Stellaires by Garcia, B.: 1989, *Interstellar lines catalogue*; Centre des Donnees Stellaires, Obs. de Strasbourg.

2.1. THE DIFFUSE-DISK ISM. Observational techniques improved both in spatial and in wavelength resolution allowed the observation of the finer details of interstellar clouds. In all complexes the filamentary structure became more apparent. Knapp+ (1988,ApJ,331,974) found CO clouds of 0.2 pc size near Alpha

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Ori. Molaro+ (1989, ApJ, 339, L63) found equally fine structure in galactic clouds from a comparison of absorption lines to several stars in the field of SN1987A. Verschuur+ (1989, AJ, 98, 267) report that at higher spatial resolution the 21-cm profiles become narrower, pointing at strong effects of beam-smearing in all existing data. In the spectral domain, Black+ (1988, ApJ, 331, 986) demonstrated that toward Zeta Oph four clouds with substantial column density exist within a width of 3 km s^{-1}, some having turbulent widths of only 0.4 km s^{-1}. A more general result is that interstellar clouds seem to have masses proportional to the square of the radius (Chieze, 1987, AA, 171, 225), while they also exhibit a specific mass- vs space-density distribution (Dickey+, 1989, ApJ, 341, 201). The diffuse ionized gas was further investigated by Reynolds (1988, ApJ, 333, 341; 1989, ApJ, 345, 811) in [S II] and Hα.

The infrared cirrus was subject of many investigations. Since it is best seen at high galactic latitudes, confusion with halo-gas may be present (see below). Furthermore, the cirrus is nearby and may be part of the local interstellar medium (below). Desert+ (1988, ApJ, 334, 815) showed that the cirrus IR-brightness correlates well with hydrogen. A list of 516 IR-excess clouds was presented. Half of the CO-containing clouds found before by Magnani+ (1985, ApJ, 295, 402) coincide with the catalogue. Van Buren (1989, ApJ, 338, 147) argued that the filling factor of the cirrus is 0.2, as derived from the statistics of the association of warm cirrus with OB stars. The brightness seen at the shorter IR wavelengths cannot be explained by classical dust but is rather due to large molecules (see Puget, in Lawrence, p.113).

Element abundances were investigated based on IUE spectra. Murthy+ (1987, ApJ, 315, 675) analysed Lyman-α spectra of very nearby stars and find that D/H = 2×10^{-5}. For Si, Mn, Fe, S, and Zn accurate values were derived for some 220 lines of sight by Van Steenberg+ (1988, ApJSup, 67, 225; 1988, ApJ, 330, 942). The results agree with the much more limited data sets available before. The depletion correlates with the mean line-of-sight density but not with the gas density as can be derived from rotational levels of H_2. Lines of sight into the halo show less depletion, in particular for Fe. For the high-velocity clouds in the direction of SN1987A, Blades+ (1988, ApJ, 332, L75) found metal abundances to be a factor of two below solar, a value depending on the adopted hydrogen column density but in agreement with work done much earlier by others on related lines of sight. From observations of the IR [C I] fine-structure transitions in luminous nebulae Zmuidzinas+ (1988, ApJ, 335, 774) found that there the abundance ratio C I/CO may be 0.1. SH^+ could not be detected in several stars (Magnani+, 1989, AJ, 98, 926). Sommerville+ (1989, MN, 238, 559) demonstrated that there is a good correlation between N(H_2) and N(CH). The abundance values for diffuse disk gas were used to investigate cloud chemistry and dust. Joseph (1988, ApJ, 335, 157) finds no change of depletion during cloud evolution, Joseph+ (1989, ApJ, 340, 314) predict peculiar extinction curves from observed abundance patterns, while Federman+ (1989, ApJ, 338, 140) predicts that C depletes dramatically in clouds with more than 2 mag extinction. The conditions in diffuse clouds in the disk were modelled by van Dishoeck+ (1986, ApJSup, 62, 109) including excitation of some molecules. They could derive the physical conditions in some of the clouds on a few well studied sight-lines. Two new instruments allow now the highest dispersions to be reached in the ultraviolet. First results are available from Snow+

(1987, ApJ, 321, 952) and Jenkins+ (1989, ApJ, 343, 785) on H_2 in π Sco and by Joseph+ (1990, preprint) on the metal lines.

New observation technologies, in particular mapping in the near infrared (1 to 3 μm), led the discovery of numerous reflection nebulae by Lynds+ (1986, PASP, 98, 1294), Scarrot+ (1987, MN,225, 17p), McLean+ (1987, MN, 225, 393), Castelaz+ (1987, ApJ, 314, 317), Lenzen (1987, AA, 173, 124), Yamashita+ (1987, AA, 177, 258; 1988,MN, 233, 899; 1989, ApJ, 336, 832). In some cases bipolar nebulae turned out to be reflection nebulae while in others rapid variations were seen. The well-known nebulae Ced 201 and NGC 2023 were further investigated by Witt+ (1987, ApJ, 321, 912), Gatley+ (1987, ApJ, 318, L73) including CO, and Scarrot+ (1989, MN, 237, 1027). Diffuse scattered UV-light near Zeta Ori was analysed by de Boer+ (1988, AA, 203, 149).

Zeta Oph, the prime star for interstellar lines, again provided new results. A strict upper limit for SH^+ could be derived by Millar+ (1988, MN, 231, 953) while ^{13}CN could be detected (Crane+, 1988, ApJ, 326, L35) and the accuracy of CH could be improved (Palazzi+, 1988, ApJ, 326, 905). The IR fine-structure emission lines of CI could be detected by Keene+ (1987, ApJ, 313, 396) and they were in agreement with earlier Copernicus column densities. CO was investigated in detail by Crutcher+ (1987, ApJ, 316, L71) and Langer+ (1987, ApJ, 322, 450). These and other data were used by van Dishoeck+ (1986, ApJSup, 62, 109; 1988, ApJ, 331, 986) and by Viala+ (1988,AA,190, 215) to model the complexities of that line of sight. Lambert+ (1990, ApJ, 359, L19) showed that at the highest spectral resolution the absorption lines of CN, CH, and CH^+ show fine structure suggesting internal cloud structure.

ρ Oph and its cloud were observed in X-rays with TENNA (Koyama, 1987, PASJapan, 39, 245), in H-α (Wilking+, 1987, AJ, 94, 106), and in IR (Ryter+, 1987, AA, 186, 312). A thermal plasma, pre-MS stars, and the necessity for PAHs were found. Ryter+ claim that the 12 μm IRAS flux is probably entirely due to the molecule-like grains, the PAHs. Minn+ (1987,AA, 184, 315) find a positive correlation between formaldehide and E(B-V) in the Rho Oph cloud. The area of the Sco OB1 association was studied by Crawford+ (1989, ApJ, 336, 212) for the Ca/Na ratio and in the CH absorption lines (Crawford,1989, MN, 241, 595).

The Pleiades reflection nebulosities were further studied. Cernis (1987, ApSpSc, 133, 355) collected Vilnius photometry of 93 stars, Guthrie (1987,QJRAS, 28, 289) found that the ratio R= 3.6, and Castelaz+ (1987, ApJ, 313, 853) analysed the IRAS fluxes, finding the necessity for very small molecular grains. White (1988, AJ, 96, 145) arrived at upper limits of $N(H_2) \leq 2\ 10^{15}$ for the Pleiades nebulae on the basis of the infrared emission.

Radio scintillation provides further information on the structure of the ISM on larger scales. In a summarizing conference, (Cordes+) describes the current view of the ISM as one in which the electron density has a strong and clumpy component with a scale height of < 100 pc (possibly associated with SNRs and HII regions) and a weaker homogeneous component with a scale height of > 500 pc. The stability of the fluxes from a few pulsars suggests that also low frequency variability of extragalactic sources is due to refractive scintillation (Stinebring+, 1990, ApJ, 352, 207).

2.2. LOCAL INTERSTELLAR MEDIUM (LISM) Our knowledge of the LISM has been reviewed by Cox and Reynolds (1987, AnRevAA, 25, 303) and by

Bochkarev (1987, ApSpSc, 138, 229), and it again has been the topic for discussions at various meetings. Absorption line spectroscopy is available from Skuppin+ 1987, AA, 177, 228; Bzowski 1988, ActaAstr, 38,4 43; Mauche+ 1988, ApJ, 335, 829; Crawford 1988, MN, 233, 923; and Murthy 1989, ApJ, 336, 949.

EUV-resonance emission from the LISM in the interplanetary space was investigated by Chassefiere+ (198, AA, 201, 113) and Wu+ (1988, ApJ, 331, 1004) using Prognoz 6, Voyager 1/2, and Pioneer 10 data. The density of the very local ISM is found to be below 0.1 cm^{-3} with a degree of ionization of about 30%. Inside the heliopause, the He behaves with conditions as of the LISM outside the heliopause. Based on stellar data, Bruhweiler+ (1988, ApJ, 335, 188) calculate the EUV radiation field and find that it is dominated by hot white dwarfs and that the LISM is at least 10% ionized.

Hobbs+ (1988, ApJ, 327, 356) investigated the nearest molecular clouds at 60 pc. Little CH was found. On the other hand, Magnani+ (1988, ApJ, 326, 909) find that some high-latitude clouds with E(B-V) = 0.2 have large abundances of molecules (CO, H_2CO). Two classes of diffuse molecular clouds were suggested: the CO-rich and the CO-poor ones (Lada+,1988,ApJ,326,L69). Lilienthal+ (1990,AASup. in pr) determined the thickness of the cloud at 60 pc in Auriga.

2.3. GAS AT HIGH LATITUDES, IN THE HALO, AT HIGH VELOCITIES. The region of gas outside the Milky Way disk connecting the disk and the halo was the topic of an IAU Symposium in 1990 (Bloemen+) and figured prominently in a Colloquium honoring Guido Münch (Tenorio-Tagle+). Here most of the result from the previous years were reviewed. The discovery of molecule-containing clouds at distances of z> 500 pc was intensively discussed and also the relation of N(CO), as was the FIR fluxes from IRAS for the cirrus clouds. There are now 3 clouds above 500pc, the Draco Cloud (Rohlfs+, 1989, AA, 211, 402), the cloud at G 135+54 (Heiles+, 1988, ApJ, 332, 313), and a cloud found by Desert+ (1990, ApJ, 355, L51). Other clouds are interacting with the Milky Way disk (Mebold+,1989,Eur.Reg.IAU,Cambridge UP).

High-ion absorption data details were presented by Savage+ (1987, ApJ, 314, 380), who arrived at scale heights of up to 4 kpc for C IV and N V. The interpretation of the soft X-ray data still did not bring a conclusive model (Snowden+, 1990, ApJ, 354, 211; McCammon+, 1990, AnRevAA, 28, 657). The hot-bubble and stratified halo combination was tested against a model in which the neutral and hot components are well mixed (Hirth+, preprint). Reynolds (1989, ApJ, 339, L29) determined a scale height of up to 2.5 kpc for free electrons. Chimneys of material flowing from the disk into the halo were discussed by Kundt+ (1987, ApSpSc, 136,281) and Ikeuchi (1988, Fund.Cosm.Phys.12, 255).

Two surveys of high velocity clouds (Bajaja+, 1985, ApJSup, 58, 143; and Hulsbosch+,1988, AASS, 75, 191) were combined to cover the entire sky. The data are analyzed by Wakker+ (1990, AA in press). WSRT-data of HVCs reveal spatial fine structure (Wakker, 1990, AA in press) and in HVC 131+1-200 a spin temperature of about 50K is found (Vijfschaft+, 1990, AA in press).

The distance question of the classical HVCs has not led to an answer except that the earlier claim by Songaila+ (1988, ApJ, 329, 580) for the distance to Complex C turned out to be in serious doubt (Lilienthal, 1990, AA,in press). Also it was now shown that the clouds at intermediate and high velocity seen in the direction of the LMC are part of the galactic halo indeed (de Boer+,1990, AA, 233, 523).

2.4. MAGELLANIC CLOUDS. SN1987A triggered much research on the interstellar medium. The brightness allowed to look also for very weak optical lines (Adreani+, 1987, Nature, 326, 770; Baade+, 1988, AA, 194, 237; Magain+, 1987, AA, 184, L5). The IUE absorption line measurements (1987, AA, 177, L17; ApJ, 320, 597) resulted in a catalogue (Blades+, 1988, ApJ, 334, 308). The possible detection of Fe X was discussed by Malaney+ (1988, ApJ, 335, L57) and by Pettini+ (1989, ApJ, 340, 256). All high ions at LMC velocities were analyzed by Savage+ (1989, ApJ, 345, 393). The strengths suggest that the mass accumulated from the pre-SN wind is too small to capture much of the hard-UV SN-blast photons and thus that the SiIV and CIV seen is from regular gas present before the explosion. They also dispute the reality of the Fe X detection. Molaro+ (1989, ApJ, 339, L63) investigated the field around SN1987A and were able to derive depth structure of the LMC in that area. The light echo showed crisp time-spatial images of the dusty patches around SN1987A. This work was summarized by de Boer and by Pettini during IAU Symp 148 (Haynes).

3. MOLECULES, MOLECULAR CLOUDS (Flower, Habing, Genzel).

Books which contain a great deal of experimental, observational and theoretical data relating to interstellar molecules are: Dalgarno, A. +, ed.: 1987, *Spectroscopy of Astrophysical Plasmas*, Cambridge UP, Cambridge; Flower, D.R.: 1990, *Molecular Collisions in the Interstellar Medium*, Cambridge UP, Cambridge; Verschuur, G.L.+, ed.: 1988, *Galactic and Extragalactic Radioastronomy*, Springer-Verlag, New York. Symposium reports and conference proceedings: Carrington, A. +, ed.: 1988, "The Spectroscopy of Molecular Ions", Royal Society, London; Dickman, R.L. +, ed., 1988, "Molecular Clouds in the Milky Way and External Galaxies", Springer, Berlin; Léger, A.+, ed.: 1987, "Polycyclic Aromatic Hydrocarbons and Astrophysics", Reidel, Dordrecht; Millar, T.J.+, ed.: 1988, "Rate Coefficients in Astrochemistry", Kluwer, Dordrecht; Moran, J.M. +, ed. 1988, "Interstellar Matter", ApLet Comm, 26, 153; Pudritz, R.E. +, ed.: 1988, "Galactic and Extragalactic Star Formation", Kluwer, Dordrecht; Reid, M.J. +, ed.: 1988, "The Impact of VLBI on Astrophysics and Geophysics", Kluwer, Dordrecht; Weiler, K.W., ed.: 1987, "Radio Astronomy from Space", Proc. NRAO Workshop, NRAO, West Virginia; Wolstencroft, R.D.+, ed.: 1988 "Millimetre and Submillimetre Astronomy", Kluwer, Dordrecht. Review articles: Flower: 1989, "Molecular Collision Processes in Interstellar Clouds", Phys Rep, 174, 1. Catalogs and surveys related to molecules and molecular clouds: Koo+: 1988, "A Survey of 12.2 GHz Methanol Masers and Their Polarization Properties", ApJ, 326, 931

3.1. CHEMISTRY (D. Flower)

3.1.1 MOLECULAR PROCESSES. The fluorescence of H_2 has been observed in the reflection nebula NGC 2023 by Gatley+ (1987, ApJLet, 318, L73) and Hasegawa+ (1987, ApJLet, 318, L77) and the ratio of para:ortho-H_2 has been derived (Takayanagi+, 1987, ApJLet, 318, L81). These observations of NGC 2023 have been successfully reproduced by the model of Black+ (1987, ApJ, 322, 412). The thermal and fluorescent contributions to the infrared emission of H_2 have been decomposed by Tanaka+ (1989, ApJ, 336, 207). The fluorescence mechanism has been studied theoretically by Sternberg+ (1989, ApJ, 338, 197) and Sternberg (1989, ApJ, 347, 863). The level populations of H_2 under non-equilibrium conditions have been computed by Wagenblast+ (1988, MN, 230, 363; 1989, MN, 237, 1019), and the photodissociation of H_2 in shocks has been modelled by Monteiro+ (1988, MN, 234, 863). Using new molecular data, the photodissociation of CO was studied by Viala+ (1988, AA, 193, 265) and by van Dishoeck+ (1988, ApJ, 334, 771). The rotational equilibrium of C_2 in diffuse interstellar clouds has been evaluated by Le Bourlot+ (1987, AA, 188, 137).

Ultraviolet line emission, following collisional excitation of H_2 by energetic electrons, and the photodestruction of interstellar molecules have been analysed by Sternberg+ (1987,ApJ,320,676) and Gredel+ (1987,ApJLet,323,L137;1989, ApJ, 347,289). The related question of the ratio of C/CO in the interstellar medium has been addressed by these authors and by Stutzki+ (1988,ApJ,332,379), Genzel+ (1988, ApJ,332,1049), Zmuidzinas+ (1988,ApJ,335,774), Frerking+ (1989, ApJ, 344, 311), Flower+ (1989, MN, 239, 741), and Chieze+ (1989, AA, 221, 89).

Reactions leading to the gas-phase synthesis of NH_3 have been studied by Yee+ (1987, MN, 227, 461), Herbst+ (1987, ApJ, 321, 898) and Galloway+ (1989, AA, 211,413). Herbst+ (1989,MN,237,1057) considered the possible formation of H_2S through gas-phase reactions. Neutral reactions that should be fast even in old interstellar clouds have been considered by Graff (1989, ApJ, 339, 239).

Polycyclic aromatic hydrocarbons might carry a large fraction of the negative charge in the interstellar gas and profoundly influence the chemistry, as shown by Lepp+ (1988, ApJ, 324, 553; 1988, ApJ, 329, 418), Pineau des Forets+ (1988, MN, 235, 621), and Bohme+ (1989, ApJ, 342, L91). These molecules might also contribute to the heating of the gas, through the photoelectric effect (d'Hendecourt+ 1987, AA, 180, L9; Lepp+, 1988, ApJ, 335, 769).

The formation of CNO, HCNO and H_2CNO in dense clouds has been considered by Adams+ (1989, AA, 220, 269). The rates of dissociative recombination of H_3^+, HN_2^+ and HCO^+ have been measured by Amano (1990, JCP, 92, 6492). The rate coefficient for H_3^+ is not anomalously small, as previous experimental and theoretical work had indicated. An important contribution to studies of interstellar molecular synthesis has been made by Herd+ (1990, ApJ, 349, 388), who measured OH production in the dissociative recombination of C_3O^+, HCO_2^+ and H_2OH^+.

3.1.2 IDENTIFICATION OF MOLECULES. To assist with astronomical searches, the $2\nu_2$ band of H_3^+ has been observed in the laboratory (Majewski +, 1989, ApJLet, 347, L51). The first phosphorous compound to be identified in the interstellar medium was PN (Turner+, 1987, ApJLet, 321, L75; Ziurys, 1987, ApJLet, 321, L81). The gas-phase synthesis of this species was studied by Millar+ (1987, MN, 229, 41P). Deuterated water has been observed in Orion-KL and NGC 7538 (Henkel+, 1987, AA, 182, 299), and C_3HD in cold interstellar clouds (Bell+, 1988, ApJ, 326, 924). C_3H_2 has been observed in the diffuse medium (Cox+, 1988, AA, 206, 108) and in dark clouds (Cox+, 1989, AA, 209, 382). The implications of the detection of interstellar C_4D were considered by Turner (1989, ApJLet, 347, L39). An astronomical study of the fine and hyperfine structure of C_6H was performed by Cernicharo+ (1987, AA, 181, L1).

Interstellar CH and CH^+ have been detected towards SN 1987A (Magain+, 1987, AA, 184, L5) and in high latitude molecular clouds (de Vries+, 1988, AA, 203, L23), ^{13}CN towards Zeta Oph (Crane+, 1988, ApJLet, 326, L35). More complex species have been definitely or tentatively detected: CH_3NC towards Sgr B2 (Cernicharo+, 1988, AA, 189, L1), CH_3CH_2OH towards W51M (Millar+, 1988, AA, 205, L5), CH_2CN in TMC1 and Sgr B2 (Irvine+, 1988, ApJLet, 334, L107), and HC_3HO in TMC1 (Irvine+, 1988, ApJLet, 335, L89). The protonated form of CO_2, $HOCO^+$, has been found to have an enhanced abundance towards Sgr B2 and Sgr A (Minh+,1988,ApJ, 334, 175). The SiC radical has been detected astronomically and in the laboratory (Cernicharo+,1989, ApJLet, 341, L25)

3.1.3 THEORETICAL MODELS. Several theoretical studies of chemical processes in shocks have been reported. Pineau des Forets+ (1987, MN, 227, 993) have considered the formation of molecules containing two or three carbon atoms, and Leen+ (1988, ApJ, 325, 411) the production of oxygen- and sulphur-bearing species. Neufeld+ (1989, ApJ, 340, 869; 1989, ApJ, 344, 251) have modelled fast dissociative shocks. Fast interstellar shocks have also been studied by Hollenbach+ (1989, ApJ, 342, 306), grain destruction in shocks by McKee+ (1987, ApJ, 318, 674), and PAH erosion by Flower+ (1990, MN, 242, 512). C-shocks in molecular clouds have been analysed by Smith+ (1990, MN, 242, 495; 1990, MN, 243, 498; 1990, MN, 245, 108). A study of the chemistry in the hot molecular cores of star-forming regions was made by Brown+ (1988, MN, 231, 409). A model of the photodissociation region of NGC 7023 was reported by Chokshi+ (1988, ApJ, 334, 803). The important question of the deuterium chemistry in the interstellar medium was addressed by Brown+ (1989, MN, 237, 661; 1989, MN, 240, 25p), Millar+ (1989, ApJ, 340, 906), and Pineau des Forets+ (1989, MN, 240, 167).

Other aspects of interstellar chemistry were covered by Viala+ (1988, AA, 190, 215), who presented a model of the diffuse cloud towards zeta Oph, Roveri+ (1988, AA, 199, 127), who considered the formation of SiN in the gas phase, Wlodek+ (1988, MN, 235, 493), who discussed the synthesis of C_4S, and Langer+ (1989, ApJ Sup, 69, 241; 1990, ApJ, 352, 123), who modelled the formation of C-, N-, O-, and Si-bearing species. Federman+ (1988, ApJ, 328, 777; 1989,ApJ,338, 140) have considered the chemistry of carbon-bearing species.

3.2 MOLECULAR CLOUDS (R. Genzel). The advent of several large mm and submm single dish telescopes (IRAM 30m, SEST 15m, JCMT 15m, Nobeyama 45m and CSO 10m) as well as the continuing operation of a number of dedicated smaller telescopes (CfA/Cerro Tololo, Gornergrat, Nagoya, POM 2, Bordeaux, Bell Labs, Onsala, UMass, NRAO), together with the availability of large mm interferometers (Hat Creek, Nobeyama, OVRO) have led to vigorous research activity in the field of molecular clouds. More recently, interesting results on molecular spectroscopy at near-IR and far-IR wavelengths have become available. The activity in the field is demonstrated by the large number of publications (more than 500 in the period of this report) and international conferences. Recent results, including relevant reviews can be found in conference proceedings, such as Peimbert+ (1987, *Star Forming Regions*, Reidel), Hollenbach+ (1987, *Interstellar Processes*, Reidel), Tenorio-Tagle+ (1989, *Structure and Dynamics of the Interstellar Medium*, Springer), Morfill+ (1987, *Physical Processes in Interstellar Clouds*, NATO ASI 210), Dickman+ (1988, *Molecular Clouds in the Milky Way and External Galaxies*, Springer), Thuan+ (1987, *Starbursts and Galaxy Evolution*, Editions Frontieres), Blitz+ (1988, *Outer*

Galaxy, Springer), Winnewisser+ (1989, *The Physics and Chemistry of Interstellar Molecular Clouds*, Springer), Kaldeich (1989, *Infrared Spectroscopy in Astronomy*, ESA-SP-290), Watt+ (1990, *Submillimetre Astronomy*, Kluwer), Pudritz+ (1988, *Galactic and Extragalactic Star Formation*, Kluwer), Reipurth (1989, *Low Mass Star Formation and Pre-Main Sequence Objects*, ESO publication No. 33). Papers found in these proceedings are usually not listed separately below.

3.2.1 STRUCTURE OF MOLECULAR CLOUDS. It is becoming increasingly evident that molecular clouds have spatial structure on all scales observed so far and that they are highly dynamic systems (Wilson+ 1989, AARev, 1, 141; Bally+ 1987, ApJLet, 312, L45). Detailed, well-sampled maps of individual clouds show spatial structure over 3 or 4 orders of magnitude, from 10 pc to 0.03 pc. A plausible relationship between the mass spectrum of clumps in molecular clouds and resulting stellar masses is emerging (Stutzki+ 1990, ApJ, in press; Zinnecker 1989, in Beckman, *Evolutionary Phenomena in Galaxies*, Cambridge UP).

3.2.2. SURVEYS. Large and small scale surveys are becoming available for an increasing number of regions and the southern hemisphere. Detailed, well sampled maps of CO, ^{13}CO and CS have been made for several individual clouds. Galactic surveys of molecular lines include: Dame (1988, SkyTel, 76, 22); Solomon+ (1989, ApJ, 339, 919); Parkinson+ (1987, QJRAS,28,277), Dame+ (1987,ApJ, 322, 706), Bronfman+ (1988, ApJ, 324, 248), Yurevich+ (1988, Astrof, 28, 230), Knapp(1987, PASP, 99, 1134). Outer Galaxy, Quadrants 2 and 3: Mead (1988, ApJSup, 67, 149), Mead (1988, ApJ, 330, 399), Jacq+ (1988, AA, 195, 93), May+ (1988, AASup,73,51). Individual Regions: Bally+ (1987,ApJLet, 312, L45), Bally+ (1987,ApJSup,65,13), Bally+ (1988,ApJ,324,223), Wouterloot+ (1989, AA, 215, 131), Fukui+ (1988, Vistas, Astr. 31, 217), Jacq+ (1988, AA, 207, 145), Wouterloot+ (1988, AA,203,367), Grabelsky+ (1988, ApJ, 331, 181), Clemens+ (1988, ApJ Sup, 68, 257), Schilke+ (1990, AA, 227, 220), Nyman+ (1989, AA, 216, 185), Little+ (1989, MN, 240, 397), Wouterloot+ (1989, AA Sup, 80, 149), Zhou+ (1989, ApJ, 346, 168), Benson+ (1989, ApJ Sup, 71, 89), Churchwell+ (1990, AA Sup, 83, 119), Lada (1990, PhD Thesis, Texas).

3.2.3. DETERMINATIONS OF MOLECULAR MASS. The important question of how to determine the (normally unobservable) H_2 content of molecular clouds from trace molecules (such as isotopic CO), submm/mm dust emission or gamma-ray emission has continued to be debated (see various contributions in Hollenbach+ 1987, *Interstellar Processes*,Reidel). The conversion of CO flux to H_2 column density as calibrated by the gamma-ray flux has been discussed by McLaren+ (1989, JPhysG, 15,1305), Strong+ (1988, AA, 207, 1), Bloemen (1989, AnRevAA, 27, 469) and Hermsen (1988,SpScRev, 49,17). The CO to H_2 conversion in the context of molecular cloud models has been addressed by Fleck (1988, ApJ, 333, 840) and Elmegreen (1989, ApJ, 338, 178). Mezger+ (1987, AA, 182, 127) and Mezger+ (1988, AA, 191, 44) have argued that H_2 column densities estimated from mm dust emission in dense star forming cores are much larger than those obtained from molecular spectroscopy, indicating freeze-out of molecules in the gas phase.

3.2.4. DYNAMICS AND EVOLUTION. The formation of molecular clouds has been discussed by Franco+ (1988, ApJ, 333, 826), Kolesnik (1987, Kinem Cel Bod (tr. fr. Russian), 3, 50). The stability of clouds is addressed by Myers+ (1988,ApJLet,326,L27),Fleck (1988,ApJ,333, 845), Jog+ (1988, ApJ, 328, 404), Lizano (1989, RevMexAA,18,11). The evolution and destruction of clouds, including the impact of UV radiation and star formation is subject of Shu+ (1987, ApLet Comm,26,217), Nakano(1990,MN,242,535),Chieze+ (1987,AA,183,98), Yorke+ (1989,AA,216,207), Lizano+(1989,ApJ,342,834),McKee (1989, ApJ,345, 782), Charnley (1990,MN,243,405) and Sternberg+ (1989, ApJ,338, 197).

3.2.5. MOLECULAR CLOUDS AND MAGNETIC FIELDS. The importance of magnetic fields for the understanding of molecular clouds has become increasingly evident (Heiles 1987, in *Interstellar Processes*, Hollenbach+,Reidel; Myers+ 1988, ApJLet, 326, L27; Elmegreen 1988, ApJ, 326, 616; Hartquist 1989, MN, 241, 417). Observational investigations of fields in several clouds include Troland+ (1989, ApJLet, 347, L89), Hodapp (1987, ApJ, 319, 842), Aitken+ (1988, MN, 230, 629), Tamura+ (1988, MN, 231, 445), Gomez de Castro (1988, AA, 201, 299), Goodman+ (1989, ApJLet, 338, L61).

3.2.6. MOLECULAR CLOUDS AND STAR FORMATION. The interaction of molecular clouds and star formation has been discussed by McKee (1989, ApJ, 345, 782), Rodríguez+ (1989, ApJ, 347, 461), McCray+ (1987, ApJ, 317, 190), Mazzei (1987, ApSpSci, 139, 37), Leisawitz+ (1988, ApJ, 332, 954), Efremov+ (1988, Pis'maAZh, 14, 817), Mooney+ (1988, ApJLet, 334, L51), Scoville+ (1989, ApJ, 339, 149), Wood+ (1989, ApJ, 340, 265).

Warm molecular and atomic gas at the surfaces of molecular clouds has been found to be widespread and is probably the result of external UV heating (Harris+ 1987, ApJLet, 322, L49; Schmid-Burgk+ 1989, AA, 215, 150), Genzel+ 1988, ApJ, 332,1049; Graf+ 1988, ApJ, 330, 803; Chromey+ 1989, AJ, 98, 2203; Krügel+ 1989, AA, 211, 419; Jaffe+ 1989, ApJ, 344, 265).

3.3. MOLECULAR OUTFLOWS (R. Genzel)

High velocity bipolar molecular outflows, together with H_2O/OH masers, HH-objects, infrared line emission from shocks and stellar jets, are now considered as unambiguous indicators of an intense mass loss phase in the last stages of formation of stars greater than about 1 $M_\odot$ (cf.Snell 1987, in *Star Forming Regions*, Peimbert+, Reidel; Shu+ 1987, AnRevAA, 25, 23). Recent highlights were the discoveries of high velocity neutral atomic outflows that may solve the discrepancy between mass loss rates determined from molecular and ionized gas (Lizano+ 1988, ApJ, 328, 763), the measurement of highly collimated molecular jets (Richer+ 1989, MN, 241, 231; Richer+ 1990, in *Submillimetre Astronomy*, Watt+,Kluwer), Schmid-Burgk+ 1990, AA, in press), and the detection of high velocity molecular "bullets" (Bachiller+ 1990, AA, in press). The role of outflows in protostellar and cloud evolution is discussed in Fukui+ 1989, Nature, 342, 161; Henning (1989, AstrNachr, 310, 363), Welch (1988, ApLCom, 26, 181) and Fukui (1989, in *Low Mass Star Formation and Pre-Main Sequence Objects*, Reipurth, ESO Proc. 33). Physical mechanisms for the mass outflows are addressed in Mao (1989, ChinPhysLett, 1989, 6, 566), Natta (1989, RevMexAA, 18, 29), Franco (1989, RevMexAA, 18, 65), Shu+ (1988, ApJLet, 328, L19) and Uchida (1989,in *Low Mass Star Formation* , Reipurth, ESO Proceed.33). In addition to various observations of individual outflow sources listed below, various surveys of outflows and their interaction with the surrounding cloud can be found in Verdes-Montenegro+ (1989, ApJ, 346, 193), Torrelles+ (1987, ApJ, 321, 884), Parker+ (1988, MN, 234, 67p), Margulis+ (1988, ApJ, 333, 316), Snell+ (1988, ApJ, 325, 853), Heyer+ (1987, ApJ, 321, 370), Mirabel+ (ApJ,318,729). Shocks and chemistry are the subject of Brand+ (1988, ApJLet, 334, 103), Okuda (1988,VistasAstr, 31, 499), Burton+ (1989, MN, 236, 409), Charnley+ (1988, MN, 231, 269), Wilking+ (1990, AJ, 99, 344).

3.3.1. INDIVIDUAL CLOUDS. L1551, molecular lines: Fridlund+ (1989, AA, 223, L13), Fridlund+ (1989, AA, 213, 310), Moriarty+ (1987, ApJLet, 317, L95),Moriarty+ (1988, ApJ, 332, 364), HI: van der Werf+ (1989, AA, 216, 215), visible nebulosities: Rodríguez+ (1989, RevMexAA, 17, 111). **Taurus**; molecular lines: Liseau+ (1988, AA, 192, 153), Cernicharo+ (1987, AA, 176, 299). **Orion A; OMC-1,2;** general review: Genzel+ (1989, AnRevAA, 27, 41); mm-molecular lines: Wilson+ (1989, AA, 214, 321), White+ (1988, AA, 197, 253), Hermsen+ (1988, AA, 201, 276), Jacq+ (1988, AA, 199, L5), Margulis+ (1988, ApJ, 333, 316), Masson+ (1987, ApJLet, 295, L47), Mauersberger+ (1988, AA, 194, L1), Menten+ (1988, AA, 198, 253), Mundy+ (1988, ApJ, 325, 382), Plambeck+ (1987, ApJLet, 317, L101), Plambeck+ (1988, ApJLet, 330, L61), Schloerb+ (1987, ApJ, 319, 426). Submm/FIR lines: Melnick+ (1987, ApJ, 321, 530), White+ (1988, AA, 197, 253), Genzel+ (1988, ApJLet, 333, L59), Stutzki+ (1988, ApJLet, 330, L125), Walker+ (1988, AA, 205, 243), Boreiko+ (1988, ApJLet, 325, L47), Boreiko+ (1989, ApJLet, 346, L97), Stutzki+ (1989, ApJLet, 340, L37), Schmid-Burgk+ (1989, AA, 215, 150). Near-IR lines: Brand+ (1988, ApJLet, 334, L103), Brand+ (1989, MN, 236, 929), Brand+ (1989, MN, 237, 1009), Burton+ (1988, MN, 235, 161), Knacke+ (1988,ApJLet, 335, L27), interpretation of chemistry: Blake+ (1987, ApJ, 315, 621), Ziurys (1988, ApJ, 324, 544), Walmsley+ (1987, AA, 172, 311), magnetic fields: Myers+ (1988, ApJLet, 326, L27); Dust emission: Gear+ (1988, Protostar, 5, 2), Mezger+ (1990, AA, in press), Rayner+ (1989, MN, 241, 469). **NGC 2023,2024,2071**; molecular lines: Jaffe+ (1990, ApJ, 353, 193), Barnes+ (1990, ApJ, 351, 176), Richer+ (1989, MN, 241, 231), Moore+ (1989, MN, 237, 1p), Moriarty-Schieven+ (1989, ApJ, 347, 358), Burton+ (1989, MN, 238, 1513), Iwata+ (1988, ApJ, 325, 372), Yamashita+ (1989, ApJLet, 347, L85); Dust and young stars: Mezger+ (1988, AA, 191, 44), Lada(1990,PhD Thesis,Texas). **Lamda-Ori,Monoceros**; molecular lines: Maddalena+ (1987, ApJ, 323, 179), Heaton+ (1988, AA, 203, 99), infrared sources: Cox+ (1990, AA, 230, 181). **Rho-Oph,G333.6,NGC6334**; molecular lines: Loren(1989, ApJ, 338, 902), Walker+ (1988, ApJ, 332, 335), Menten+ (1989, ApJ, 341, 839), Storey+ (1989, MN, 237,1001), Straw+ (1989, ApJ, 342, 876), Mizuno (1988, AstrHerald, 81, 156); Infrared sources: Ichikawa+ (1989, AJ, 97, 1074), Wootten (1989, ApJ, 337, 858), Straw+ (1989, ApJ Sup, 69, 99), Straw+ (1989, ApJ, 340, 318). **SgrA, SgrB2**; molecular lines: Serabyn+ (1987, AA, 184, 133), Gardner+ (1988, AA, 196, 207), Peng+ (1989, PASAust, 8, 206), Sandqvist (1989, AA, 223,293), Boyce+ (1989, MN, 239, 1013), Sutton+ (1990, ApJ, 348, 503), Geballe+ (1989, AA, 208, 255), Minh+ (1988, ApJ, 334, 175), Genzel+ (1990, ApJ, 356, 160), Guesten+ (1987, ApJ, 318, 124), Bally+ (1987, ApJ Sup, 65, 13), Bally+ (1988, ApJ, 324, 223), Ho+ (1989, BAAS, 20, 1018), radio/IR/submm sources: Mezger+ (1989, AA, 209, 337), Yusef-Zadeh+ (1987, AJ, 94, 1178), Yusef-Zadeh+ (1988, ApJ, 329, 729), Morris+ (1989, ApJ, 343, 703). **W28, W31, W33, W43, W44, M17**; molecular lines: Harvey+ (1988, AA, 197, L19), Keto+ (1987, ApJLet, 323, 117), Matthews+ (1987, AA, 184, 284), Heaton+ (1989, AA, 213, 148), Massi+ (1988, AA, 194, 116), Keto+ (1987, ApJ, 318, 712), Harris+ (1987, ApJLet, 322, L49), Stutzki+ (1988, ApJ, 332, 379), Stutzki+ (1990, ApJ in press). **W49, W51, Cyg**; molecular lines: Welch+ (1987, Sci, 238, 1550), Torrelles+ (1989, ApJ, 343, 222), Dickel+ (1990, ApJ, 351, 189), Little+ (1988, AA, 205, 129), Nadeau+ (1988, AJ, 95, 136), Roelfsema+ (1988, AA, 207, 132), Odenwald+ (1990, AJ, 99, 288), IR/submm: Ward-Thompson+ (1990, MN, 244, 458), Gear+ (1988, MN, 231, 47p), Moore(1987, QJRAS, 28, 264). **Cep, S140, NGC7538**; molecular lines: Grenier+ (1989, ApJ, 347, 231), Sugitani+ (1988, Vistas, 31, 507), Hayashi+ (1988, ApJ, 332, 354), Batrla+ (1988, ApJLet, 330, 67), Doyon+ (1988, ApJ, 334, 883), Kameya+ (1989, ApJ, 339, 222); IR sources: Evans+ (1989, ApJ, 346, 212). **Sharpless regions**; molecular lines: Kogure+ (1988, Vistas, 31, 473), Joncas+ (1988, ApJ, 332, 1030); IR observations: Persi+ (1987, AA Sup, 70, 437), Mampaso+ (1989, AA, 220, 235). **Nearby and high-lat. clouds;** Haikala+ (1989, AA, 223, 287), Armstrong+ (1989, AA, 210, 373), Magnani+ (1988, ApJ, 326, 909), Mebold(1989, in The Physics and Chemistry of Interstellar Molecular Clouds, Winnewisser+, Springer).

3.4 MOLECULES IN EXTERNAL GALAXIES (R. Genzel)

Owing to substantial improvements in infrared and mm/submm instruments during the last few years the molecular interstellar media in external galaxies have become accessible to detailed study (see the various contributions on the subject in Watt+ (1990, *Submillimetre Astronomy*, Reidel) and in Kaldeich (1989, *Infrared Spectroscopy in Astronomy*,ESA-SP-290). Highlights of the past few years include the first detection of CO emission from quasars (Barvainis+ 1989, ApJLet, 337, L69) and Sanders+ (1988, ApJLet, 335, L1), aperture synthesis observations of NGC1068 and M82 (Myers+ 1987, ApJ, 312, L39), Plasenas+ (1990, ApJ, in press), Carlstrom (1988, in *Galactic and Extragalactic Star Formation*, Pudritz+, Kluwer), a survey of near-infrared atomic and molecular lines by Moorwood+ (1988, AA, 203, 278) and the first studies of the molecular gas in the radio galaxy Cen A (Phillips+ (1987, ApJLet, 322, L73), Israel+ (1990, AA, 227, 342), Eckart+ (1989, in *Extranuclear Activity in Galaxies*, Meurs+, ESO Proceedings 32). Of interest was also the study by Sanders+ (1988, ApJ, 325, 74) that points out the possible evolutionary link between star bursts and AGN's.

Millimeter-observations of nearby galaxies were reported by Young+ (1988, ApJ, 324, 115), Stark+ (1987, ApJ, 322, 64), Vogel+ (1987, ApJLet, 321, L145), Lada+ (1988, ApJ, 328, 143), Casoli+ (1988, AA, 198, 43), Wilson+ (1988, ApJ, 333, 611), Kaneko+ (1989, ApJ, 337, 691), Tacconi+ (1989, ApJ Sup, 71, 455), Henkel+ (1990, AA, 230, L5), Becker+ (1989, AA, 211, L19), Brand+ (1989, AA, 211, 315), Ohta+ (1988, PASJ, 40, 653), Plasenas+ (1989, AA, 216, 1), Israel+ (1990, MN, 242, 471), Wiklind+ (1989, AA, 225, 1), Wiklind+ (1990, AA, 227, 394). Molecules other than CO were reported by Carlstrom(1988, in *Galactic and Extragalactic Star Formation*, Pudritz+, Kluwer), Mauersberger+

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(1989, IAU Circ 4889), Henkel+ (1987, AA, 188, L1). Surveys and general discussion of molecular cloud properties were given by Sage+ (1989,ApJLet, 342, L15), Solomon+ (1988, ApJ, 334, 613), Polk+ (1988, ApJ, 332, 432), Verter (1987, ApJ Sup, 65, 555).

Starburst galaxies were investigated by Rieke+ (1988, ApJ, 325, 679), Verter+ (1989, AA, 225, 27), Eckart+ (1990, ApJ, 348, 434), Loiseau+ (1990, AA, 228, 331), Solomon+ (1990, ApJLet, 348, L53), Smith+ (1990, MN, 243, 97).

Distant galaxies and the relationship between star bursts and AGN's were studied by Sanders+ (1988,ApJ, 325, 74), Sanders+ (1988, ApJLet, 335, L1), Barvainis+ (1989, ApJLet,337, L69), Stanford+ (1990, ApJ, 349, 492), Dupraz+ (1990, AA, 228, L5), Zentsova(1988, SovAs, 32, 98), Val'tts+ (1987, Astrophys.26, 302), Sanders+ (1988, Sc, 239, 625), Mirabel+ (1988, ApJLet, 324, L59), Sage+ (1987, ApJLet, 321, L103). Krolik+ (1989,ApJ, 347, 179) pointed out that obscuring tori may be intense far-IR and submm line emitters.

Molecular clouds, spiral arms, bars and interactions were studied from the observational perspective by Rand+ (1990, ApJLet, 349, L43), Gerin+ (1988, AA, 203, 44), Canzian+ (1988, ApJ, 333, 157), Lo+ (1987, ApJLet, 317, L63). Theoretical work on that subject can be found in Song (1989, AcASin, 30, 149), Lesch+ (1990, MN, 242, 194), Olson+ (1990, ApJ, 349, 480), Sil'chenko+ (1987, Astrophys, 26, 363).

Near-IR spectroscopy is reported in several articles in Kaldeich (1989, *Infrared Spectroscopy in Astronomy*, ESA-SP-290) and in Moorwood+ (1988, AA, 203, 278), Israel+ (1990,AA,227,342), Kawara+ (1989,ApJLet, 342, L55), Campbell+ (1989,AJ,97, 995), Israel+ (1988, AA, 190, 21), Fischer+ (1987, ApJ, 320, 667).

Far-IR spectroscopy and the relationship between atomic and molecular gas was discussed by Stacey+ (1989,*The Physics and Chemistry of Interstellar Molecular Clouds*, Winnewisser+, Springer), Stacey(1989, in *Infrared Spectroscopy in Astronomy*, Kaldeich, ESA-SP-290), Wolfire+ (1989, ApJ, 344, 770), Shaya+ (1987, ApJ, 319, 76), Young+ (1989, ApJLet, 347, L55).

3.5. CIRCUMSTELLAR ENVELOPES (H. Habing)

Circumstellar envelopes exhibit very different environments in which rather diverse processes operate. Some environments are fossils of much earlier times; some are continuously produced by stellar winds. As usual, there are usually too few observations to restrain all free parameters. Circumstellar material has now been found around a large number of different types of stars: (a) around main sequence stars such as Vega and β Pictoris; (b) around rapidly rotating early-type stars, such as Be stars; (c) around evolving and evolved hot stars (Of stars and WR stars); (d) around newly-born stars of moderate mass (Herbig Ae and Be stars and T Tau variables); (e) around cool giant stars, notably AGB stars, especially long period variables (OH/IR stars can be considered as extreme LPV's); (f) around supergiants of all kinds; (g) around objects that are in transition from the AGB to become planetary nebulae.

Here a systematic summary of published articles will be given based on their relevance for interstellar matter research. The study of circumstellar envelopes is also of great importance to the study of stellar evolution. Yet, that aspect has been ignored in this report. In the selection the following lead themes have been used: (3.5.1) In the cooler envelopes dust particles are formed. Circumstellar environments may be the birth place for all dust particles. (3.5.2) In the cooler

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envelopes many different molecules are formed. The processes develop under circumstances different from those in the interstellar medium, but yet the circumstellar envelope is an important help in understanding the molecular spectroscopy of the interstellar medium. Normal conditions prevail (sect. 3.5.2.1) but several circumstellar masers are known (sect. 3.5.2.2). (3.5.3) The mass ejected by evolved stars plays a further role in the birth of new stars; evolved stars are an important factor in the ecological cycles of galaxies. Mass loss rates and distribution in the Galaxy are thus important pieces of information.

Good reviews are by Olofsson (1988, SpScRev, 47, 145), Bieging (1988, PASP, 100, 97) and Omont (1989, *Highlights of Astronomy*, 8, 367). A useful introduction is by Zuckerman(1987, *Spectroscopy of Astrophysical Plasmas*, eds. Dalgarno+, 185). The topic was the central theme in a workshop in September 1989 in proceedings entitled *From Miras to Planetary Nebulae: Which Path for Stellar Evolution?* (ed. Menessier+ 1990, Editions Frontiere). The topic has been the subject of one or more invited reviews at several meetings: *Circumstellar Matter*, eds. Appenzeller+, 1987, Reidel; *Late Stages of Stellar Evolution*, eds. Kwok+, 1987, Reidel; *Planetary Nebulae*, ed.Torres-Peimbert, 1988, Reidel; *Cool Stars, Stellar Systems and the Sun*, 1987: eds Linsky+, Springer; 1990: Wallerstein, PASP; *The Symbiotic Phenomenon* (=IAUColl #103), eds.Mikolajevska+, 1988, Kluwer; *Atmospheric Diagnostics* ... (=IAUColl #108), ed Nomota+, 1988, Springer, *Mass Outflow From Stars and Galactic Nuclei*, eds Bianchi+, 1988, Kluwer; *Rate Coefficients in Astrochemistry*, eds Millar+, 1988, Kluwer; *The Outer Galaxy*, eds. Blitz+, 1988, Springer; *Evolution of Peculiar Red Giant Stars* (=IAUColl #106), eds. Johnson+, 1989, Cambridge UP, UK.

A useful inventory of stars with circumstellar shells in the solar neighbourhood is by Jura+ (1989, ApJ, 341, 359). A list of carbon stars with bright envelopes is by Claussen+ (1987, ApJSup, 65, 385).

A survey at 2.2 μm in the southern milky way contains many new or only poorly known objects (1987, Epchtein+, AASup, 71, 39 and 79, 411). A study by Beichman+ (1990, AJ, 99, 1569) of IRAS sources at high galactic latitudes identified all sources- all are of previously known types.

Van der Veen+ (1988, AA, 194, 125) discussed the IRAS colours of large numbers of stars with circumstellar shells and proposed a classification. Bedijn (1986, AA, 186, 136) has proposed a chronological sequence of circumstellar envelopes of oxygen rich stars, in which the mass loss rate continuously increases. Support comes from a systematic study of the appearance and disappearance of various maser types by Lewis (1989, ApJ, 338, 234) and of systematic variations in the envelopes of Mira variables (Stencel+, 1990, ApJLet, 350, L45). Willems+ (1988, AA, 196, 173) have added a chronology for the transition from oxygen rich stars to carbon rich and this has lead to a debate (see Zuckerman+ and de Jong, AALet, 223, L20 and L23).

3.5.1 DUST IN CIRCUMSTELLAR ENVELOPES. There are two basic classes of circumstellar envelopes around old stars: those with carbonaceous grains and those with silicate dust. The first group coincides with those of the C-stars; the second group with M-giants. The much less frequent S-stars are clearly intermediate cases. There are a handful of well-established C-stars with silicate grains.

The carbon star IRC+10216 is nearby and strong and can be studied in great detail- a model of the dust shell has been given by le Bertre (AA, 176, 107; 1988,

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AA, 208, 85) and by Ridgway+ (1988, ApJ, 326, 843). Near IR Speckle observations are by Dyck+ (1987, PASP, 99, 99). Martin+ (1987, ApJ, 322, 374) propose that the grains are small and of amorphous carbon; see also Orofino+ (1987, ApSpSc, 138, 127; 1990, AA, 231, 105). An extensive dust shell appears in scattered light at 2.2 μm (Tammann+ 1988, ApJLet, 326, L17).

Exciting news was the new solid state, H_20-ice feature at 46 μm detected by Omont+ (1990, ApJLet, 355, L27) in IRAS0937+1212 ("the Frosty Lion");see also Forveille+ (1987, AALet, 176, L13), Mauron+ (1989, AA, 218, 213) and Rouan+ (1988,AALet, 189, L3).Allamandola+ (1989, ApJLet, 345, L59) report a new PAH band at 5 μm in BD+30° 3139 and Kwok+ (1989, ApJLet, 345, L51) a new band around 21 μm, seen in IRAS spectra.

The SiC feature in carbon stars has been studied by Baron+ (1987, AA, 186, 271); for its strength as a function of the mass loss rate see Skinner+ (1988, MN, 234, 79P). Wdoniak discussed the formation of diamonds in carbon rich stellar outflows (1987, Nature, 328, 325) and a comparison of spectral features with optical constants obtained in the laboratory is made by Pegourie- see also Papoular (199, AA, 204, 138). Little-Marenin+ (1988, ApJ, 333, 305; 1990, AJ, 99, 1173) and Onaka+ (1989, AA,218, 169) studied gradual, systematic changes in the solid state features in the IRAS spectra of stars in the IRAS LRS atlas.

The mystery of the small class of supergiants at high galactic latitudes may have been solved: the best studied of those appear to be post-AGB stars, stars suspected, but never proven as such before. The best example is HR4049.It has a strong IR excess. Waters+ (1989, AA, 211, 208) have extensively studied the star from the ultraviolet to the infrared and draw several conclusions about the extinction law. Observations between 1 and 4 μm of discrete features suggests the presence of very large molecules, perhaps PAH's (Geballe+ 1989, ApJLet, 340, L29).See also Joshii+ (1987, AA, 181, 31) and Hrivnak+ (1989, ApJ, 346, 265).

True supergiants are slowly, but gradually shown to be surrounded by fossil shells of ejected matter: 21cm line observations of Betelgeuze and Mira (Bowers+, 1987, ApJ,315, 305; 1988, ApJ, 332, 299); UV and visual absorption lines in α Sco (Snow+, ApJ, 321, 921); continuum light through a coronograph (AGCar, Paresce+,1989,ApJLet,341,L83) and polarized (scattered) UBV light around mu Cep (Le Borgne,1989, AA, 210, 198). Skinner+ (1988,MN,235, 603) studied the circumstellar envelopes of M-supergiants. The IRAS data base contains extended shells around many supergiants (Stencel+;1988, AJ, 95, 141; 1989, AJ, 97, 1120).

A very large, fossil shell has been detected in IRAS measurements by Hawkins (1990, AALet, 229, L5). Whitelock+ (1989, MN, 241, 393) report the discovery of dust shells around several high latitude A-type stars.

3.5.2 MOLECULAR SPECTROSCOPY OF CIRCUMSTELLAR ENVELOPES

3.5.2.1 Thermally excited emission. Several new lines have been discovered: lines of new species, lines of new isotopes or lines of new excited states. Most prolific continues to be the carbon star IRC+10216: C_6H (Saito+, 1987, PASJ, 39, 193; Guelin+, 1987, AALet, 175, L5); C_2H_4 (1987, Goldhaber+, ApJ, 314, 356), C_2S, C_3S (Cernicharo+, 1987, AALet, 181, L9) C_4H?(Guelin+, 1987, AALet, 183, L1); CS* (Turner, 1987, AALet,182,L9); NaCl, AlCl, KCl (Cernicharo+, 1987, AALet, 183, L1); SiS* (Turner, 1987, AALet, 183, L23), C_2H (Keady+, 1988, ApJ, 331, 539); CO 7-6(Wattenbach+,

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1988, AA, 202, 133), C_3 (Hinkle+, Science, 241, 1319), CO 3-2 (Tauber+, 1989, AJ, 97, 2361), C_5(Bernath+, 1989, Science, 244, 562), C_4Si(Oshisi+, 1989, ApJLet, 345, L83), CP(!) Guelin+ (1990, AALet, 230, L9) and strong HCN maser emission (Lucas+, 1989, AALet, 218, L20). Bieging+ (1989, ApJLet, 343, L25 have mapped the SiS molecular emission. Multi-line studies are by Truong-Bach+ (1987, AA, 176, 285) and by Bujarrabal+ (1989, AA, 219, 256). Isotope ratios of C, N, Si, S have been determined by Kahane+ (1988, AA, 190, 167). Models to explain the spectroscopy of IRC+10216 have been given by Glasgold+ (1987, AA, 180,183), by Nejad+ (1987, AA, 183, 279) and by Schoenberg (1989, AA, 208, 219). The importance of ion-molecule chemistry has been stressed by Bieging+ (1988, ApJLet, 329, L107). The formation of carbon-chain molecules is discussed by Howe+ (1990, MN, 244, 444).

The carbon star CIT6 has also been studied extensively (Zinchenko+, AstrZhur, 64, 870); detection of HCN* with linear but no circular polarization (Goldsmith+, 1988, ApJ, 333, 873; Lis+, 1989, ApJ, 341, 823). In AFGL2688 (the Egg Nebula) several lines of NH_3, HC_5N, HC_7N have been measured and interpreted by Truong-Bach+ (1988, AA, 291); see also Jura+ (1990, ApJ, 351, 222) and Truong-Bach+ (1990, AA, 230, 431). Isotope ratios in carbon stars have been studied by Wannier+ (1987, ApJ, 319, 367) and Jura+ (1988, AA, 201, 80). An outflow with velocity over 200 km/s has been seen in AFGL618 (1989, Ganmie, ApJLet, 345, L87; Cernicharo+, 1989, AALet, 222, L1). Tsuji+ (1988, ApJLet, 327, L23) and Kahane+ (1988, ApJLet, 328, L25) find asymmetric outflow from VHya. TXPsc has an irregular structured CO shell (Heske+,1989,AALet,218, L5). A successful survey for circumstellar CO around optically bright carbon stars has been conducted by Olofsson+ (1987,AALet,183,L13). Around some carbon rich stars discrete enhancements have been seen in the outflow, attributed by the authors (Olofsson+, AALet, 230, L13) to hiccups in the flow caused by thermal pulses.

Oxygen stars are no less interesting. The molecular envelope of Mira has been discussed by Planesas+ (1990, ApJ, 351, 263). A well studied case is the supergiant IRC+10420; a detailed model based on infrared absorption lines was presented by Fix+ (1987, ApJ, 312, 290). The bipolar star OH231.8+4.2, known as "the Rotten Egg" or as the "Calebash", has a rich molecular spectrum (Morris+, 1987, ApJ, 321, 888); the SO_2 spectrum is effected by the biconical flow (Jackson+, 1988, ApJLet, 335, L83)- see further under 3.5.2.2. Spectroscopy of various nitrogen bearing molecules in oxygen rich environments has been reported by Necessian+ (1989,AA, 210,225); spectroscopy of carbon molecules by Lindqvist+ (1988,AA,205,L15). Excited H_20 has been found around VYCMa and WHya (Menten+,1989,ApJLet,341,L91). A chemistry model for oxygen rich stars has been discussed by Mammon+ (1987,ApJ,323,306).

A somewhat separate group are IRAS sources with very "cold" colours; many are likely to be objects in transition to the planetary nebula stage. CO observations have been reported by Likkel+ (1987,AALet,173,L11). More general surveys have been conducted by Rieu+ (1987,AA, 180,117; 1988,ApJ,330,374), by Olofsson+ (1988,AALet,196,L1) and by Knapp+ (1989,ApJ,336,822).

3.5.2.2 Stellar Maser Sources. A few catalogues of stellar maser sources have appeared: OH (1989, te Lintel Hekkert+, AASup, 78, 399), SiO (Engels+, 1989, AASup, 81, 323), H_2O (Comoretto+, AASup, 84, 179). Non-thermal amplification effects (maser effects) have been discovered in HCN* (Guilloteau+, 1987, AALet, 176, L24; Izumira+, 1987, ApJLet, 323, L81); (Lucas+ (1988, AA, 94, 230), Zinchenko+ (1988, Astron.Tsirk, 1525, 13), (Goldsmith+, 1988, ApJ, 333, 873). Two spectacular new masers have been discovered: maser emission in hydrogen recombination lines at about 1mm in MWC 349 by Martin-Pentado+ (1989, AALet, 215, L13; 1989, AALet, 229, L9), and a submillimeter H_2O-maser (1990, Cernicharo+, AA, 231, L15; 1990, Menten+, ApJLet, 350, L17).

SiO-masers. Masers have now been detected in stars at the centre of the Galaxy (Lindqvist+, 1987, AALet, 172, L3). A systematic survey of the strength of SiO-maser emission in different stellar types has been made by Bujarrabal+ (1987, AA, 175, 164). Semi-regular variables and supergiants may also contain SiO-masers (Alcolea+, 1990, AA, 231, 431). Martinez+ (1988, AASup, 74, 273) have monitored SiO-masers over three years and conclude that the maser originates very close to the stellar photosphere.

Masers in highly excited rotational states have been discovered by Jewell+ (1987, ApJ, 323, 749), in the v=3 level (Alcolea+, 1989, AA, 211, 187), from rare SiO isotopes (Zhou+, 1988, AcAstrSin, 29, 252=ChinAstrAstr, 13, 46; Barcia+ (1989, AALet, 215, L9), and from many southern sources (Allen+, 1989, MN, 236, 363). Muchmore+ (1987, ApJLet, 315, L141) argue that cooling via SiO lines cause a thermal instability in the stellar atmosphere. Dyson+ (1990, MN, 241, 625) suggest that certain concentrations of matter observed in the planetary nebula NGC7293 may be the remnants of a now defunct SiO-maser.

H_2O-masers. Lindqvist (1990, AA, 229, 165) report H_2O maser emission in stars at the galactic centre. Zuckerman+ (1987, AA, 173, 263), Engels+ (1988, AA, 191, 283) and Engels+ (Nature, 332, 49), Deguchi+ (1989, MN, 239, 825) search for H2O-masers in IRAS sources. Berulis+ (1987, PismaAstrZh, 13, 305=SovAstronLet, 13) report monitoring flares of emission in RTVir. Lane+ (1987, ApJ, 323, 756) have observed twelve stars with VLBI techniques and determined angular distributions of the maser spots. Mira variables have smaller distributions than supergiants. One Mira (IKTau) has two shells of maser spots. Some surprise has risen from the detection of H2O-masers around (only a few) carbon stars- the outflowing material should not contain water molecules (Benson+, 1987, ApJLet, 316, L37; Nakada+, 1987, ApJLet, 323, L77; Little-Marenin+, 1988, ApJ, 330, 828; Deguchi+, 1988, ApJLet, 316, L37; Lloyd Evans, 1990, MN, 243, 336; Lambert+, 1990, AJ, 99, 1612).

OH-masers. Sivagnanam, in collaboration with others, has made a large and systematic study of OH-masers around optically detectable Miras (1988, AA, 206, 285;1989, AA, 211, 341;1990, AA, 233, 112;1990, AA, 229, 171). A major conclusion is that OH-masers are always present if the mass loss rate is high enough. Bowers+ (1988, ApJ, 330, 339) have mapped OH maser spots around U Orionis and concluded that the OH is distributed biconically. A more pronounced case of biconical flow is OH231.8+4.2, the "Rotten Egg" or the "Calebash" (Reipurth, 1987, Nature, 325, 787). For some time it was a unique object; now it appears to be a member of a small class of similar objects (Likkel+, 1988, ApJ, 329, 914; te Lintel Hekkert+, 1988, AALet, 202, L19). Chapman (1988, MN, 230, 415) reports a bipolar structure also for the object OH19.2-1.0.

Fix(1987, AJ, 93, 433) reports accurate observation with very high spectral resolution of OH/IR stars and finds confirmation that the maser is produced in discrete "flakes"; somewhat similar conclusions are reached by Cohen+ (1987, MN, 225, 491), Bowers+ (1990, ApJ, 354, 676) and by Zell+ (1990, AJ, 99, 314). Welty+ (1987, ApJ, 318, 852) mapped five OH/IR stars and concluded that the maser emission is produced in only a few (~10) major clumps. Szymcak (1987,ApSpSci,139,63;1989,MN, 237, 561) has considered basic requirements of the OH maser to operate: enough UV flux and the existence of density fluctuations.

Large numbers of new OH/IR stars have been detected starting from IRAS source lists (Eder+, 1988, ApJSup,66,183). Gaylard+ (1988,MN,235,123;1989, MN, 236, 247) find always an OH maser provided the IRAS sources is strong enough and has the infrared spectrum of an AGB star with a thick circumstellar shell. Why Lewis+ (1987, AJ, 94, 1025) failed to detect OH in many IRAS sources is unexplained.

3.5.3. THE RETURN OF STELLAR MATTER INTO INTER-STELLAR SPACE. The rate at which stellar matter is returned into interstellar space is determined by individual mass loss rates and by the distribution of the stars in space. Some progress is being made in the determination of each factor. Bedijn (1987, AA, 186, 136;1988, AA, 205, 105) has studied the development and the statistics of stars with circumstellar shells. He concludes that AGB stars will increase slowly their mass loss rate and continue to do so until their core is bare-see also Chan+ (1988,ApJ, 334, 362) for a similar point of view. A systematic study of the mass loss rate of OH/IR stars is by Netzer+ (1987, ApJ, 323, 734); even more general is the study by Sopka+ (1989, AA, 210, 78). Very general equations for mass loss rates are given by Nugis (1989, SovAstrLet, 15, 19) and by Nieuwenhuijzen+, 1990, AA, 231, 134). From a study of nearby IR absorption lines, Jones+ (1988, AJ, 95, 158) confirm that both AGB stars and true supergiants develop into OH/IR stars; but the supergiants have systematically higher outflow velocities. The distribution of OH/IR stars in the Galaxy has been studied by Chapman (1987, PASP, 99, 1190), of carbon stars by Thronson+ (1987, ApJ, 322, 770). The distribution of carbon stars appears to be different from expected and from that of the oxygen-rich stars. Zuckerman+ (1989, ApJ, 209, 119) conclude that carbon stars originate from a wide variety of initial masses.

3.6. INTERSTELLAR MASERS (D. Flower)

Whilst work continues on the acquisition and interpretation of the more established interstellar masers, OH and H_2O, a great deal of attention has been focussed on the more recently discovered methanol (CH_3OH) maser during the period under review. Methanol masers in star- formation regions have been reported by Wellington (1987,ApJLet, 321, L159) and Haschick+ (1989, ApJ, 346, 330), in the Orion region by Menten+ (1988, AA, 198, 267) and Pambeck+ (1988, ApJLet, 330,L61), and towards the NGC 6334 region by Menten+(1989,ApJ,341, 839). A strong new maser line of methanol was reported towards DR21(OH) (Batrla+1988, ApJLet, 329, L117), and CH_3OH masers were discovered in association with IRAS sources (Kemball+,1988,ApJLet,331,L37). High resolution observations of methanol masers were reported by Menten+(1988, ApJ,331, L41; 1988, ApJ, 333, L83) and McCutcheon+ (1988, ApJLet, 333, L79). Ammonia masers were studied by Wilson+ (1988, AA, 206, L26; 1990, AA, 229, L1) and by Johnston+ (1989, ApJLet, 343, L41), who made VLA observations of the $^{15}NH_3$ maser associated with NGC 7538. These latter measurements were interpreted by Flower+ (1990, MN, 244, 4P) in terms of the evolution of the cloud. NGC7538 (IRS1) is also a formaldehyde (H_2CO) maser source (Pratap+,1989, ApJ, 341, 832).

Water vapour masers have been observed in association with young visible stars by Rodríguez+ (1987, AA, 186, 319). Long-term monitoring of the H_2O maser in Cepheus A has been performed by Mattila+ (1988, AA Sup, 73, 209), and the time variation of type I H_2O masers studied by Peng (1989, AA, 216, 165; 1989, AA, 216, 173). Water-maser polarization in star- forming regions has been scrutinized by Barvainis+ (1989, AJ, 97, 1089); magnetic field strengths have been deduced by Fiebig+ (1989, AA, 214, 333). The Orion-KL super water maser was studied by Garay+ (1989, ApJ, 338, 244). Submillimetre masers were reported by Menten+ (1990, ApJLet, 350, L41) and interpreted by Neufeld+ (1990, ApJ, 352, L9). The collisional pumping of H_2O masers by species of particles at different temperatures was considered by Anderson+ (1990, ApJLet, 348, L69).

Using VLA observations, Forster+ (1989, AA, 213, 339) studied the spatial relationship of H(2)O and OH masers. Other work on OH masers included: the association of the ground-state maser with regions of star formation (Gaume+, 1987, ApJ Sup, 65, 193); the correlation of main-line masers with IRAS FIR flux densities (Moore+,1988, MN, 231, 887); a VLBI search for very compact structure in 16 OH masers (Kemball+, 1988, MN, 234, 713); the spatial distribution of OH masers in Orion-KL (Johnston+, 1989, ApJ, 341, 847). VLBI synthesis observations of the excited-state OH emission sources in W3(OH) have been reported by Baudry+ (1988, AA, 201, 105), and the collisional pumping of excited state masers discussed by Kylafis+ (1990, ApJ, 350, 209). Mechanisms for producing circular polarization in star-forming regions and the deduction of magnetic field strengths were studied by Deguchi+ (1987, NASA CP-2466, 87). Submillimetre observations revealed that DR21(OH) is a double source (Gear+, 1988,MN,231, 7P). There are molecular outflows in OH megamasers (Baan+,1989,ApJ,346, 680).

4. INTERSTELLAR DUST- THE GRIME AND GRIT OF INTERSTELLAR SPACE (P.G. Martin)

In the time interval under consideration there have been several compendia from important meetings and key review papers which are to be considered primary references for an introduction to research in the field of interstellar dust. Among these are IAU Symposium 135, *Interstellar Dust* (Allamandola+ 1989, Kluwer); *Dust in the Universe* (Bailey+ 1988, Cambridge UP), *Interstellar Dust and the IUE* (Longdon 1988 ESA SP-281, 2), the third IRAS conference (*Comets to Cosmology*, Lawrence 1987, Springer-Verlag), Mathis (1990, AnRevAA; 1990, Ast LettComm, 26, 239) and Cox+ (1989, AARev, 1, 49), and Malina+, 1990, *Extreme Ultraviolet Astronomy* (Pergammon). Consider also monographs by Verschuur (1989, *Interstellar Matters*, Springer) and Whittet (1990, *Dust in the Galactic Environment*, Hilger). The present report is fairly selective, concentrating on interstellar rather than circumstellar phenomena. Attention is given to the properties of dust and immediate consequences, rather than to items such as the distribution of dust in the Galaxy (Dubjago 1988, AstNach, 309, 65) or its presence in globular clusters (Forte+1989, ApJ, 345, 222; Mendez+1989, ApJ, 338, 136). Not treated either are uses of dust such as in probing the geometry of the magnetic field (Vrba+1988, AJ, 96, 680; Sato+1988, MN, 230, 321; Jones 1989, ApJ, 346, 728) or of the dense regions near compact reflection nebulae like GL 490 and R Mon (Hodapp 1990, ApJ, 352, 184; Yamashita+1989, ApJ, 336, 832; Scarrot+1989, MN, 237, 621; Persson+1988, ApJ, 326, 339). Dust in the

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solar system is treated in Atreya+, 1989, *Origin and Evolution of Planetary and Satellite Atmospheres* (U. Arizona) and Kerridge+, 1989, *Meteorites and the Early Solar System* (Univ. Arizona).

4.1. TYPES OF DUST. Interstellar dust is basically grime and grit, according to its primary composition, carbon and silicates, respectively. In dense clouds ices form, probably on the surfaces of these grains. Subsequent photoprocessing of the ices might produce a refractory substance called "yellow stuff" (Greenberg 1989, AdvSpRes, 9, 13); the distinctive importance of this material depends on the amount of photoprocessing, and in the most jaundiced view "yellow stuff" degenerates to just another form of grime.

4.1.1. Grime. Not so long ago carbon in interstellar grains was supposed to be in the form of graphite. This form seems to have been displaced in prominence by "amorphous carbon". Amorphous is intended to describe the disordered non-crystalline nature, but is also a good description of the level of our knowledge about this interstellar substance. However, there has been lots of activity and progress in this area. The main evidence bearing on the presence of amorphous carbon and its relatives, polycyclic aromatic carbon molecules (PAHs), are the infrared spectral features (UIBs), the "cirrus" component of the infrared background, extended red fluorescent emission from hydrogenated amorphous carbon (HAC) in reflection nebulae and the featureless infrared dust continuum in carbon stars. Copious research on PAHs in the interstellar environment is reviewed by Allamandolla+ (1989, ApJSup, 71, 733) and Léger+ (1989, AnRevAA, 14, 181) and so will not be dealt with so extensively here. PAH formation in circumstellar envelopes has been modeled by Frenklach+ (1989, ApJ, 341, 372). Kroto (1989, AnnPhys,14,169;1988,PhilTransRoySocLon, SerA, 325, 405) has emphasized the relevance of C_{60} and other "fullerenes" to understanding the structure of soot. Amorphous carbon, with a strong continuum in the infrared, is a favored candidate for IR continuum emission in Orion KL (Nakada 1988,PASJ,40, 331). Amorphous carbon may be present in Comet Halley (Colangeli+1990,ApJ,348, 718).

A generic UIB spectrum is given by Cohen+ (1989, ApJ, 341, 246), and a large sample of spectra by de Muizon+ (1989, AA, 227, 526). New features at 11 and 5 μm are reported by Witteborn+ (1989, ApJ, 341, 270) and Allamandola+ (1989, ApJ, 345, L59). The importance of N doping in activating the 6.2 and 7.7 μm features is proposed by Saperstein+ (1989, ApJ, 342, L47). Spectral examination has been made of amorphous-C samples prepared in the laboratory (Blanco+ 1988, ApJ, 875) and on naturally occurring substances like coal (Papoular+1988, AA, 217, 204) to clarify the nature of the individual bands. Sakata+ (1990, ApJ, 353, 543) argue that filmy quenched carbonaceous condensate provides a better match to the 3.3 μm feature than do PAHs. Balm+ (1990, MN, 245, 193) suggest carbonaceous microparticles containing internal H for the 11.3 μm feature.

The basic process underlying the near infrared emission, is conversion of individual ultraviolet photons. In a classical grain this requires a small size, so that a single photon can "spike" the temperature to a high value (Guhathakurta+1989, ApJ, 345, 230). This thermal approximation might be valid for the internal conversion in PAH molecules (Leger+1989, AA, 216, 148), though ultimately a full quantum treatment is probably desirable to assess the relative line strengths. A case intermediate between small grains and free molecules is that proposed by

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Duley+ (1988, MN, 231, 969; MN, 234, 61P), in which thermally isolated islands in porous HAC coatings on large grains can be raised to a sufficiently high temperature to explain at least the mid-infrared emission. The origin of the emission and photochemical evolution of the carriers can be studied with spatial mapping of regions such as the Orion Bar (Geballe+1989, ApJ, 341, 278; Roche+1989, MN, 236, 485; Sellgren+1990, ApJ, 349, 120; Duley+1990, ApJLet, 351, L52).

The 3.3 μm feature is now seen in the infrared cirrus (Giard+1989, AA, 215, 92) as predicted, connecting the cirrus phenomenon to PAHs and HAC. The infrared cirrus is reviewed by Hauser(1989, AstLetComm, 26, 249). The dust to gas ratio in the cirrus clouds is measured by Heithausen+ (1989, AA, 214, 347). Electron heating of small dust grains is discussed by Hayakawa (1988, AstSpSci, 144, 629). Chlewicki+ (1989, AA, 207, L11) argue for a multi-component model to match all three short wavelength IRAS wavebands.

The extended red emission in reflection nebulae has been interpreted as photoluminescence by HAC grains which have been rehydrogenated in narrow H_2 photodissociation zones (Witt+ApJ, 1990, 355, 182). The spatial variations in intensity, shape, and peak wavelength of the emission are attributed to varying H concentrations (Witt+1988, ApJ, 325, 837). Sharper spectral features are indicative of diamond bonding in the amorphous carbon (Duley+1988, AstSpSci, 150, 387; MN, 230, 1P).

Small particles of graphite are still a prime explanation for the interstellar 2200Å extinction "bump" (Draine in Allamandola+89, p313). Graphite di-layers have been studied by Trickey+ (1988, ApJLet, 336, L37). HACs and PAHs do not produce the bump. Also it has been shown that the UIBs, the bump, and the diffuse interstellar bands at 5780, 6284 and 6614 Å do not share a common carrier (Waters+ 1989,AA,211,208; Buss+1989,ApJ,347,977). The properties of the bump appear to vary throughout the young HII region NGC6530 (Boggs+ 1989, ApJ, 209) and M8 (Boggs+ 1990, ApJ, 358, 441), suggesting graphitization of small grains of amorphous carbon by the ultraviolet radiation (Sorrell 1990, MN, 243, 570).

Pre-solar grains can be studied in meteorites (Nuth in Kerridge+90, p984). In C2 meteoritic material are found crystals of diamond and SiC, but no graphite (Nuth; Tang+1989, GeoCosm Acta, 52, 1235; see also Nature, 339, 117 and 351). The diamonds might form in grain-grain collisions of amorphous carbon particles (Blake+1988, Nature, 332, 611)) while the SiC particles are of circumstellar origin. There is actually little SiC in the meteorites or the interstellar medium (Whittet+1990, MN, 244, 427) compared to what might have been expected.

4.1.2. Grit. The ubiquitous presence of silicates is known from the 10 and 20 μm features. There appears to be a consensus that the smooth broad profiles of these features indicates an amorphous structure; however, the precise mineralogy remains unknown. Nuth+ (1990, AstSpSci, 163, 79) have discussed the nature and evolution silicate dust. A mean spectrum of circumstellar silicates has been deduced from IRAS LRS spectra (Volk+1988, ApJ, 331, 435). Polarimetry at 20 μm in BN in Orion reveals a feature strength unexpectedly strong relative to that at 10 μm (Aitken+1989, MN, 236, 919). Sharper structure at 10 μm is evidence for some high temperature annealing near GL 2591 (Aitken+1988, MN, 230, 629). Crystalline olivine is detected in comets (Campins+1989, ApJ, 341, 1059). Further laboratory experiments on optical constants have been carried out (Dorschner+

1988, AA, 198, 223; Koike+1989, MN, 239, 127). A grain size > 800Å in the red giant outflow of α Sco has been deduced (Seab+1989, ApJ, 347, 479).

4.1.3. Ice. Extensive studies of ices have been made, mostly in molecular clouds though there is crystalline ice in some cool star envelopes (Omont+1990, ApJLet, 355, L27) and protoplanetary nebulae (Eiroa+1989, AA, 223, 271). In Taurus, the threshold for ice formation is 3 magnitudes of visual extinction (Whittet+1988, MN, 233, 321), while in ρ Oph it is much higher, about 10 magnitudes, perhaps because of a stronger UV radiation environment (Tanaka+1990, ApJ, 352, 724). Ice band profiles have been measured in protostars (Smith+1989, ApJ, 344, 413) and further interstellar polarization has been carried out (Hough+1988, MN, 230, 107; Hough+1989, MN, 241, 71; Scarrot+1989, MN, 237, 995). Modelling of infrared reflection nebulae including the ice band indicates an increased grain size, 0.5 μm (Pendleton+1990, ApJ, 349, 107; McCorkle 1989, PASP, 101, 133).

Extensive studies have also been made of ices in the laboratory (Grim+1989, AASup, 78, 161; Khare+1989, Icarus, 79, 350; Allamandola+1989, Icarus, 76, 255; Sanford+1990, ApJ, 355, 357), with emphasis on UV photoprocessing, and the properties of ions and of molecular species like methanol and carbon dioxide. Both solid CO (Whittet+1989, MN, 241, 707) and carbon dioxide (d'Hendecourt+1989, AA, 223, L5) have now been detected.

4.2. GRAIN MODELS AND EVOLUTION. Grain models take into account the above components, but in different ways and to different degrees. For example, in the model of Duley+ (1989, MN, 236, 709) HACs feature prominently, not as separate grains, but as coatings on silicates; the authors use optical properties from thin films (Ogmen+1988, ApJLet, 334, L117). Small bare silicates produce the ultraviolet bump. Most other models have some graphite to explain the bump. Organic refractory coatings are important repositories of carbon in the model by Greenberg+ (1989, AnnPhys, 14, 103). Mathis+ (1989, ApJ, 341, 808) propose composite fluffy particles, formed by aggregation of the basic subcomponents. Underlying each of these models is an evolutionary scenario, often not fully elaborated, which gives rise to the grain components and links the chemistry of the interstellar gas and dust (Irvine+ in Atreya+89, p3). One of the more ambitious studies is of the stochastic evolution of dust through the various phases of the interstellar medium (Liffman+1989, ApJ, 340, 853; Clayton+1989, ApJ, 346, 531; Liffman 1990, ApJ, 355, 518).

Grains, or at least grain cores, must arise in dense environments. The chronology of grain formation in circumstellar shells is considered by Stencel+ (1990, ApJ, 350, L45) and Jura+ (1990, ApJ, 351, 583). Optical evidence for dust formation in the Crab supernova remnant is presented by Fesen+ (1990, ApJ, 351, L45) and Hester+ (1990, ApJ, 357, 539). Porous organic grains from comets are proposed by Hoyle+ (1988, AstSpSci, 140, 191; 151, 285). Other processes affect the further development of grain properties. Depletion of gas phase species will occur in the interstellar medium, but the basic depletion pattern appears to be set early in the grain lifetime (Joseph+1988, ApJ, 335, 157; 1989, ApJ, 340, 314 and 347, 561) and is suggestive of a Si and Fe rich core, and a Mg and S rich mantle. Grains can also grow by coagulation (Hayakawa+ (1988, PASJ, 40, 341). Grain destruction in shocks is important, but perhaps not complete for the protected grain cores. The relevance of shocks to the very small grains invoked for the IR cirrus has been explored by comparison with CO and HI distributions (Heiles+ 1988, ApJ, 332, 313). Very small grains might also be destroyed by strong ultraviolet radiation fields (Boulanger+1988, ApJ, 332, 328; see also UIBs above). Some grains might be ejected from the Galaxy (Barsella+1989,AA,209, 349).

The evolution of dust can be examined by study of changes in the extinction curve in different environments. Orion was considered by Cardelli+ (AJ, 95, 1988) and Shulov (1988, Astrofiz, 30, 259), Carina by Tapia+ (1988, MN, 232, 661) and Roth (1988, MN, 233, 773), and the line of sight to HD38087 by Snow+ (1989,ApJ, 342, 295). Grain models are constrained as well by polarization and by scattering measurements of the albedo and phase function (Witt+1990,AJ,99, 888).

4.3. EXTINCTION AND POLARIZATION. It has been known for some time that there are variations on the ultraviolet extinction for a given optical extinction. This has been quantified. Aiello+ (1988, AASup, 73, 195) have compiled extinction curves from the IUE archives and deduced by variance analysis that three independent components contributing to the curve are present. Fitzpatrick+ (1988, ApJ, 328, 734) made a similar study, fitting a Lorentzian component for the bump, a common FUV curvature component, and an underlying linear component to the data. Cardelli+ (1989, ApJ, 345, 245) found the remarkable result that changes in the visual and ultraviolet extinction curve could by predicted by a single parameter function of R, the ratio of total to selective extinction at V. On the other hand, the infrared portion of the extinction curve appears not to change. Joseph+ (1989, ApJ, 340, 314) has shown that peculiarities in the extinction can be predicted from gas phase abundances: CN rich/iron poor lines of sight have a shallower bump.

The wavelength of maximum polarization is well correlated with colour excess ratios which measure R (Clayton+1988, ApJ, 327, 911). The ratio of polarization to extinction is smaller for large R, indicating lower polarization efficiency for larger grains (Clayton+1988, AJ, 96, 695). Martin+ (1990, ApJ, 357, 113) investigated a common power law behaviour in the infrared extinction (slope 1.8), and found that the polarization had an intriguingly similar common power law behaviour, despite large changes in the optical. Nagata (1990, ApJLet, 348, L13) and Jones (1990, AJ, 99, 1894) have extend polarization observations to 3.8 μm, with measurements consistent with this power law. Thus different grain populations appear to respond similarly to changes in the environment, and the changes are in the sense of larger modifications at the smaller particle end of the size distribution.

To investigate the opacity of grains at ionizing wavelengths, Martin+ (in Malina+90) have extended the Mathis, Rumpl, and Nordsieck model to X-ray wavelengths. The continued rise in extinction in the FUV is seen by Voyager experiments (Snow+1990, ApJLet, 359, L23), but there is a decrease predicted after a broad maximum near 16 eV.

4.4. FIR and X-RAY. The FIR and X-ray wavebands are two in which fresh contributions are being made. Hildebrand (1988, QJRAS, 29, 327) and Cox+ (1989, AARev, 1, 49) have reviewed the use of sub-millimetre and FIR techniques to study dust. Observations of HII regions show that the spectral index of the dust absorption cross section is about 1.75 from 1.1 to 0.8 mm, flattening to about 1 in 0.8 to 0.35 mm (Gear+1989, MN231, 55P). Dust emission in the sub-millimetre (Schwartz+1989, ApJ, 336, 519) and at 100 μm (Langer+1989, ApJ, 335, 355)

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has been used to investigate the (variable) dust to CO ratio. Polarized emission has been detected at 1.3 mm (Novak+1990, ApJ, 355, 166) and 100 μm (Gonatas+1990, ApJ, 357, 132), showing that grains can be aligned in the potentially unfavorable conditions in dense molecular clouds. Sodrowski+ (1989, ApJ, 336, 762) have decomposed the cold dust emission seen by IRAS into components associated with HI and molecular hydrogen.

Forward scattering by dust particles causes a diffuse X-ray halo around background X-ray sources. Detections have been extended to supernova remnants (Mauche+1989, ApJ, 336, 843) with the size and strength consistent with expectations from interstellar grain models. However, this process is not relevant to Cyg X-1 (Kitamoto+1989, PASJ, 41, 81). Lunar occultation measurements of the Galactic center sources indicate a grain size near 0.06 μm; the energy dependence of the scattered intensity points to the presence of iron in the grains (Mitsuda+1990, ApJ, 353, 480). Iron in grains is explored by Jones (1990, MN, 245, 331).

4.5. DIFFUSE INTERSTELLAR BANDS. DIB research is reviewed by Krelowski (1988, PASP, 100, 896). Families of bands are investigated by Westerlund+ (1989, AA, 218, 216). New red lines have been discovered by Herbig (1988, ApJ, 331, 991), with evidence for regular spacing in energy. Intrinsic profiles of yellow and red bands have been extracted by Westerlund+ (1988, AA, 203, 134), revealing multiple components and line asymmetry. Somerville (1988, MN, 234, 655) shows that the strengths of the 4430 and 5780Å features are not related to interstellar cloud density, placing new constraints on molecules or surfaces processes as carriers. The UV bump and the DIBs do not share the same carrier (Benvenuti+1989, AA, 223, 329; see also UIBs above). Ballester+ (1990, ApJ, 356, 507) have begun to assess the relevance of trapped atoms in carbon C_{60} cages.

4.6. PHYSICAL PROCESSES. Electromagnetic scattering calculations by the discrete dipole array method are described by Draine (1988, ApJ, 333, 848) and Wright (1988, Nature, 336, 227) with applications to carbon particles. This method has been extended to porous or composite particles (Perrin+1990,AA, 228, 238), and irregular (fractal) particles (Hawkins+ in Malina+90). Composite or heterogeneous particles have been considered by Mathis+(1989,ApJ,341,808) and Lien (1990,ApJ,355,680), and porous particles by Jones (1988,MN,243, 209).

The electric potential of grains of differing properties in various interstellar environments has been investigated (Millet 1989, AA, 214, 327; Bel 1989, AA, 208, 331; Il'in 1988,Astrofiz, 28, 386). Lepp+ (1988, ApJ, 335, 769) have studied the photoelectric heating by small grains/large molecules.

Grain surfaces provide sites for the formation of molecules. This process is well established for molecular hydrogen in cold clouds and has further application in more hostile environments such as behind dissociating shocks (Hollenbach+ 1989, ApJ, 342, 306; Neufeld+1989, ApJ, 340, 869) and in the Crab nebula filaments (Fesen+1990, ApJ, 351, L45). Complex molecular species can form in the ice mantles, and might be released into the dense molecular clouds (Brown+ 1989, MN, 237, 661; Brown 1990, MN, 243, 65; Brown+1990, MN, 244, 432).

5. STAR FORMATION (L. Rodríguez, P. Myers)

Conference proceedings are *Galactic and Extragalactic Star Formation* (1988) ed. Pudritz+ (Kluwer), *Formation and Evolution of Low Mass Stars* (1988)ed. Dupree+ (Dordrecht), *Low Mass Star Formation and Pre-Main Sequence Objects* (1989),ed. Reipurth(ESO), *Star-Forming Regions and Ionized Gas* (1989)ed. Torres-Peimbert+ (RevMexAA,18), and *Structure and Dynamics of the Interstellar Medium* (1989)ed. Tenorio-Tagle+ (Springer-Verlag). **Reviews** of star formation in molecular clouds (Shu+: 1987, AnRevAA,25,23), enhanced star formation in the centers of galaxies (Telesco: 1988, AnRevAA,26,343), the Orion star-forming region (Genzel: 1989,AnRevAA, 27,41), and T Tauri stars (Bertout: 1989,AnRevAA,27,351; Appenzeller: 1989, AARev, 1,291) were published in the period considered.

5.1. MOLECULAR CLOUDS (P. Myers). Observations of the infrared cirrus, and/or diffuse molecular gas, with visual extinction about 1 mag or less, were made using IRAS, optical techniques, or molecular lines. They were reported in groups of regions by de Vries+,1987,ApJ, 319, 723, Schwartz, 1987, ApJ, 320, 258, Federman+, 1987, ApJ, 322, 960, Hobbs+, 1988, ApJ, 327, 356, and 1989, ApJ, 346, 232, Falgarone+, 1988, AA, 205, L1, Januzzi+, 1988, ApJ, 332, 995, Magnani+, 1989, ApJ, 339, 244, Turner+, 1989, ApJ, 344, 292. They were reported in L1642 by Sandell+, 1987, AA, 181, 283, Laureijs+, 1987, AA, 184, 269, Liljestrom+, 1988, AA, 196, 243, and Liljestrom+, 1989, AA, 210, 337. Populations of diffuse clouds were discussed by Lada+,1988,ApJ,326,L69. Small clouds were reported toward α Ori by Knapp+, 1988, ApJ, 331, 974.

Dark clouds and their dense cores, with extinction about 1 - 10 mag, were observed mostly with molecular lines in groups of regions by Benson and Myers, 1989, ApJSup, 71, 89, Clemens+, 1988, ApJSup, 68, 257, Harju, 1989, AA, 219, 293, Klinglesmith+, 1987, ApJSup, 64, 127, Sandqvist+, 1988, AA, 205, 225, Colgan+, 1989, ApJ, 336, 231, Zhou+, 1989, ApJ, 346, 168. They were observed in the following individual regions: **B5**: Langer+,1989,ApJ,337,355; **B18:** Snell+,1989,ApJ,337,739; **the Coalsack**: Nyman+,1989,AA,216,185; Seidensticker+,1989,AA,225,192; **GGD 12-15**: Heaton+,1988,AA,203,99; the **Gum nebula**: Sahu+,1988,AA,195,269; **L134:** van der Werf+, 1988, AA, 201, 311, 189, 207: **L134N:** Swade, ApJ, 1989, 345, 881; **L1551**: Sargent+, 1988, ApJ, 333, 936, Menten+, 1989, AA, 223, 258, and van der Werf+, 1989, AA, 216, 215; **L1582**: Zhou+, 1988, ApJ, 333, 809; **L1709**: Minn+, 1987, AA, 184, 315; the **Ophiuchus clouds**: Loren, 1989, ApJ, 338, 902, and 925; **Perseus, Taurus, and Auriga**: Ungerechts+, 1987, ApJSup, 63, 645.

Giant clouds with mass 10^5 Suns or more, and their dense cores, with density 10^5 cm-3 or greater, were observed in molecular lines and /or in the radio continuum in the inner Galaxy by Scoville+, 1987, ApJSup, 63, 821, in the outer Galaxy by Mead, 1988, ApJSup, 67, 149, in Orion and Perseus by Wouterloot+, 1988, AA, 203, 367 , and in groups of regions by Schloerb+, 1987, ApJ, 319, 426, Gordon+, 1987, ApJ, 323, 766, Zmuidzinas+, 1988, ApJ, 335, 774, Wadiak+, 1988, ApJ, 324, 931, Schenewerk+, 1988, ApJ, 328, 785, Braz+, 1987, AA, 181, 19, Richardson+, 1988, AA, 198, 237, Walker+, 1988, AA, 205, 243, Cox+, 1989, AA, 209, 382, Krugel+, 1989, AA, 211, 419, Schwartz+, 1989, ApJ, 336, 519, Wilking+, 1989, ApJ, 345, 257, Wood+, 1989, ApJSup, 69, 831, Woody+, 1989, ApJ, 337, L45. Regions associated with open clusters were observed by Leisawitz+, 1989, ApJSup, 70, 731.

Observations of individual giant clouds and cores were made in AFGL 2591 by Torrelles+, 1989, ApJ, 343, 222, Cep A by Doyon+, 1988, ApJ, 334, 883, Hayashi+, 1988, ApJ, 332, 354, Hughes1988, ApJ, 333, 788, Cep OB3 by Carr, 1987, ApJ, 323, 170, Cyg X by Odenwald+, 1989, ApJ, 345, L47, DR21 by Roelfsema+, 1989, AA, 222, 247 and Richardson+, 1989, AA, 224, 199, DR21(OH) by Padin+, 1989, ApJ, 337, L45, G10.6-0.4 by Keto+, 1987, ApJ, 318, 712, G34.3+0.2 by Henkel+, 1987, AA, 182, 137, Matthews+, 1988, AA, 184, 284, and Heaton+, 1989, AA, 213, 148, GL2591 by Mitchell+, 1989, ApJ, 341, 1020, HH7-11 by Grossman+, 1987, ApJ, 320, 356, LkHa 101 by Becker+, 1988, ApJ, 324, 893, M17 by Harris+, 1987, ApJ, 322, L49, Stutzki+, 1988, ApJ, 332, 379, Genzel+, 1988, ApJ, 332, 1049, Massi+, 1988, AA, 194, 116, Gusten+, 1988, AA, 204, 253, Matsuhara+, 1989, ApJ, 339, L67, MWC349 by Martin-Pintado+, 1989, AA, 215, L13, and 222, L9, N2024 by Barnes+, 1989, ApJ, 342, 883, and Moore+, 1989, MN, 237, 1P, N2071 by Tauber+, 1988, ApJ, 325, 846, N2264 by Krugel+, 1987, AA, 185, 283, N6334 by Rodriguez+, 1988, ApJ, 333, 801, N7538 by Pratap+, 1989, ApJ, 341, 832, Orion by Churchwell+, 1987, ApJ, 321, 516, Masson+, 1988, ApJ, 324, 538, Mundy+, 1988, ApJ, 325, 382, Petuchowski+, 1988, ApJ, 326, 376, White+, 1988, AA, 197, 253, Hermsen+, 1988, AA, 201, 276 and 285, Mauersberger+, 1988, AA, 205, 235, Zeng+, 1988, AA, 206, 117, Wilson+1989, AA, 214, 321, Schmid-Burgk+, 1989, AA, 215, 150, Hippelein+, 1989, AA, 213, 323, Wilson+, 1989, ApJ, 340, 894, Johnston+, ApJ, 1989, 341, 847, Migenes+, 1989, ApJ, 347, 294, S106 by Barsony+, 1989, ApJ, 343, 212, S140 by Evans+, 1987, ApJ, 323, 145 and 1989, ApJ, 346, 212, S201 by Felli+, 1987, AA, 182, 313 and Mampaso+, 1989, AA, 220, 235 , S247/252 by Kompe+, 1989, AA, 221, 295, and Chavarria-K+, 1989, AA, 215, 51, S254-258 by Heyer+, 1989, ApJ, 346, 220, SgrB2 by Carlstrom+, 1989, ApJ, 337, 408, W3(OH) by Reid+, 1987, ApJ, 312, 830, Menten+, 1988, ApJ, 331, L41, Dickel+, 1987, AA, 185, 271, Mauersberger+, 1988, AA, 201, 276, Baudry+, 1988, AA, 201, 105, W31 byGhosh+, 1989, ApJ, 347, 338, W33 by Keto+, 1989, ApJ, 347, 349, W51 by Jaffe+, 1989, ApJ, 344, 265, and Kogut+, 1989, ApJ, 346, 763.

Observations were reported concerning hydrodynamic processes and internal motions in relatively diffuse clouds by Odenwald+, 1987, ApJ, 318, 702, and 1988, ApJ, 325, 320, and by Blitz+, 1988, ApJ, 331, L127. Internal motions in more massive clouds were discussed for various HII regions by O'Dell+, 1988, AA, 198, 283, for Orion by Castaneda, 1988, ApJSup, 67, 93, van Altena+, 1988, AJ, 95, 1744, and Jones+, 1988, AJ, 95, 1755, for S142 by Joncas+, 1988, ApJ, 332, 1030, for W3 by Hayashi+, 1989, ApJ, 340, 298, and for W3(OH) by Wilson+, 1987, AA, 186, L5.

Physical relationships among observables, including the molecular line width, column density, and cloud size, were presented by Solomon+, 1987, ApJ, 319, 730, Myers+1988, ApJ, 329, 392, and ApJ, 326, L27, Fleck, 1988, ApJ, 328, 299, and discussed by Milgrom, 1989, AA, 211, 37, Kegel, 1989, AA, 225, 517, Elmegreen, 1989, ApJ, 338, 178, McKee, 1989, ApJ, 345, 782.

Models of cloud formation were presented by Franco+, 1988, ApJ, 333, 826, Elmegreen, 1989, ApJ, 344, 306, and Smith, 1989, MN, 238, 835, and of cloud structure by Mundy+,1987, ApJ, 318, 392 and Wilson+, 1987, AA, 184, 291. Formation of low-mass dense cores was modeled by Lizano+, 1989, ApJ, 342, 834, and formation of condensations in shocks by Tomisaka, 1987, PASJ, 39, 109, and Kimura+, 1988, MN, 234, 51. Theoretical discussions of cloud mass, energy, stability, and fragmentation were given by Di Fazio+, 1987, AA, 184, 263, Hasegawa,1988, PASJ, 40, 219, MacLaren+,1988, ApJ, 333, 821, Fleck, 1988, ApJ, 333, 840, and ApJ, 333, 845, Black+, 1988, ApJ, 331, 986, Maloney, 1988, ApJ, 334, 761, Evans+, 1989, ApJ, 340, 307, Fleck, 1989, AJ, 97, 783, and Herrera+, 1989, MN, 237, 257. Turbulence and internal motions were discussed by Jog+, 1988, ApJ, 328, 404, Henriksen, 1988, ApJ, 331, 359, Stenholm, 1988, AA, 190, 259, Spicker+, 1988, AA, 191, 186, Chieze+, 1989, AA, 221, 89. Rotation and its effect on line profiles were discussed by Adelson+, 1988, MN, 235, 349. Self-gravitating flows were discussed by Alecian, 1988, AA, 196, 1, and the stability of spherical flows was considered by Ori+, 1988, MN, 234, 821. Self-similar collapse was discussed by Lynden-Bell+,1988, MN, 233, 197.

The diffuse cloud filling factor was discussed by VanBuren, 1989, ApJ, 338, 147, and collisions were discussed by Keto+, 1989, ApJ, 346, 122 and Lattanzio+, 1988, MN, 232, 565. Dynamics of cloud complexes were discussed by Monaghan+, 1988, MN, 231, 515. Mechanisms of cloud destruction and cluster gas removal were discussed by Yorke+, 1989, AA, 216, 207, Verschueren+, 1989, AA, 219, 105, Bertoldi, 1989, ApJ, 346, 735, and Long, 1989, ApJ, 341, 796. The distribution of molecular cloud masses was discussed by Dickey+, 1989, ApJ, 341, 201, and Elmegreen, 1989, ApJ, 347, 859.

5.2. INFRARED SOURCES (P. Myers) Observations of relatively low-luminosity sources in diffuse and dark clouds were presented for groups of sources by Myers+, 1987, ApJ, 319, 340, Simon+, 1987, ApJ, 320, 344, Clark, 1987, AA, 180, L1, Laureijs+, 1988, AA, 192, L13, Chelli+, 1988, AA, 207, 46, Hetem+, 1988, AA(Suppl), 76, 347, Parker, 1988, MN, 235, 139, Wilking+, 1989, ApJ, 345, 257, Rodriguez+, 1989, ApJ, 347, 461, Little+, 1989, MN, 240, 397. Individual low-luminosity regions were observed in B5 by Beichman+, 1988, ApJ, 332, L81, in the ESO 210-6 A cloud by Sahu+, 1989, AA, 218, 221, near Haro 6-10 by Leinert+, 1989, ApJ, 342, L39, in HH 1,2,3 by Schmid-Burgk+, 1989, AA, 215, 150, in L1551 by Carr+, 1987, ApJ, 321, L71, Moneti+, 1988, ApJ, 327, 870, Hodapp+, 1988, ApJ, 335, 814, Stocke+, 1988, ApJSup, 68, 229, and Campbell+, 1988, AJ, 95, 1173, in L1688 by Barsony+, 1989, ApJ, 346, L93, Thompson+, 1989, ApJ, 344, 799, and Ward-Thompson+, 1989, MN, 341, 119, in L1689 by Wootten, 1989, ApJ, 337, 858, in Ophiuchus by Ichikawa+, 1989, AJ, 97, 1074, in Serpens by Eiroa+, 1987, AA, 188, 46, Zhang+, 1988, AA, 196, 236 and 199,170, Eiroa+, 1989, AA, 223, L5, and Eiroa+, 1989, AA, 210, 345. Correlations between IRAS emission, line emission, and visual extinction were presented for the Ophiuchus region by Jarrett+, 1989, ApJ, 345, 881. Far-infrared limb brightening was discussed by Leung+, 1989, ApJ, 337, 293. Models of the infrared spectral energy distribution of low-luminosity IRAS sources, based on the gas density and temperature distribution in a rotating, collapsing dense core, were presented by Adams+,1987, ApJ, 312, 788.

Observations of luminous sources in more massive clouds were presented for groups of sources by Chini+, 1987, AA, 181, 378, Kuiper+, 1987, MN, 227, 1013, Persi+, 1987, AA(Suppl), 70, 437, Richards+, 1987, MN, 228, 43, Carballo+, 1988, MN, 232, 497, Gear+, 1988, MN, 231, 55P, Ghosh+, 1989, ApJSup, 69, 233, Campbell+, 1989, AJ, 98, 643. Individual luminous regions were observed in the Carina nebula by Ghosh+, 1988, ApJ, 330, 928, in

DR21(OH) by Gear+, 1988, MN, 231, 47P, in GL490 by Persson+, 1988, ApJ, 326, 339, Mundy+, 1988, ApJ, 329, 907, Yamashita+, 1990, ApJ, 336, 832, in M17SW by Elmegreen+, 1988, ApJ, 335, 803, in Mon OB1 by Margulis+, 1989, ApJ, 345, 906, in N2024 by Mezger+, 1988, AA, 191, 44, and Moore+, 1989, MN, 241, 19P, in N2264 by Castelaz+, 1988, ApJ, 335, 150, in N6334 by Straw+, 1989, ApJ, 340, 318, in N7538 by Campbell+, 1988, AJ, 95, 1185, N7538 IRS9 by Eiroa+, 1988, AA, 190, 283, in OH0739-14 by Woodward+, 1989, ApJ, 337, 754, in OMC-2 by Rayner+, 1989, MN, 241, 469, in R Mon by Aspin+, 1988, AA, 197, 242, in S106 by Mezger+, 1987, AA, 182, 127, Riera+, 1989, AA, 210, 351, in W3A by Hayward+, 1989, ApJ, 345, 894,in W3(OH) by Campbell+, 1989, ApJ, 345, 298, in W51 by Bally+, 1987, ApJ, 323, L73, and Little+, 1989, AJ, 97, 1716.

5.3. MAGNETIC FIELDS. (P. Myers) Observations of the Zeeman effect, indicating magnetic field strength in star-forming regions, were reported for various clouds by Crutcher+, 1987, AA, 181, 119, and by Fiebig+, 1989, AA, 214, 133. Observations were reported for B1 by Goodman+,1989,ApJ,338,L61, for L204 by Heiles,1988,ApJ,324,321, for Orion by Heiles,1987,*Interstellar Processes*, eds. Hollenbach+(Reidel),171, and Troland+1989,ApJ,337,342, for S106 by Kazes+ 1988,ApJ,335,263, for W3 by Troland+,1989,ApJ, 347,L89, and for W3(OH) by Garcia-Barreto+,1988, ApJ, 326, 954. Observations of Faraday rotation, indicating the local magnetic field, were discussed by Rand+, 1989, ApJ, 343, 760.

Observations of interstellar optical polarization, indicating the direction of the magnetic field strength, projected on the plane of the sky, were reported for large dark globules by Hoddap, 1987, ApJ, 319, 842, for B18 and B216 in Taurus by Heyer+, 1987, ApJ, 321, 855, for Cep A by Hoddap+, 1989, AJ, 97, 166, for L1641 by Vrba+, 1988, AJ, 96, 680, for a southern HI cloud by Luna+, 1988, AA, 198, 249. Infrared polarimetry was reported in Serpens by Warren-Smith+, 1987, MN, 227, 749, in Ophiuchus by Sato+, 1988, MN, 230, 321, in N1333 by Tamura+, 1988, MN, 231, 445. Depolarization due to multiple clouds along the line of sight was discussed by Jones, 1989, ApJ, 346, 728. Far-infrared polarization was reported by Novak+, 1989, ApJ, 345, 802. Polarimetry of the millimeter-wavelength continuum in Orion was presented by Clemens+, 1988, AJ, 95, 510. Upper limits on polarization of mm-wavelength spectral lines were discussed by Lis+, 1988, ApJ, 328, 304. Magnetic implications of the "super" H2O maser in Orion were discussed by Garay+, 1989, ApJ, 338, 244.

Equilibrium models of molecular clouds in which magnetic fields are prominent were presented by Campbell+, 1987, MN, 229, 549, Tomisaka+, 1988, ApJ, 326, 208, ApJ, 335, 239, and1989, ApJ, 341, 220, Myers+, 1988, ApJ, 329, 392 and ApJ, 326, L27, Fleck, 1988, ApJ, 328, 299, Nakano, 1988, PasJ, 40, 593, Baureis+, 1989, AA, 225, 405, Amari+, 1989, AA, 208, 361, and Lizano+, 1989, ApJ, 342, 834. Theoretical discussions of physical processes in magnetized clouds were given for MHD shocks by Wardle+,1987, ApJ, 321, 321, for ambipolar diffusion by Zweibel, 1988, ApJ, 329, 384, for Alfven wave scattering by Li+, 1987, ApJ, 322, 248, for Alfven- driven winds by Jatenco-Pereira+, 1989, MN, 236, 1, for collision fronts by Elmegreen, 1988, ApJ, 326, 616, for mean field damping by turbulence, by van Geffen+, 1989, AA, 213, 429, for flux dissipation during protostellar collapse by El-Nawaway+, 1988, MN, 232, 809, for magnetic braking of rotation by Dorfi, 1989, AA, 225, 507, and Nakano, 1989, MN, 241,495, for magnetization of cloud edges by Vallee,1989, AA, 224,191, and for magnetic reconnection by Zweibel, 1989, ApJ, 340, 550. Candidate molecular lines for observation of the Zeeman effect were given by Bel+,1989,AA, 224, 206.

5.4. HERBIG-HARO OBJECTS (L. Rodríguez). The study of Herbig-Haro objects and their environments is currently being pursued with a variety of techniques. A catalog has been compiled by von Hippel+ (1988, AASup, 74, 431). In the optical and UV new observational results were presented by Solf+ (1988, ApJ, 334, 229), Raga+ (1988, RevMexAA, 16, 13; 1988, AJ, 95, 543; 1988, AJ, 95, 1783; 1990, AJ, 99, 1912), Burkhe+ (1988, AA, 200, 99), Reipurth+ (1988, AA, 202, 219; 1989, AA, 220, 249; 1990, AA, 229, 527), Lenzen(1988, AA, 190, 269), Graham+ (1988, AJ, 95, 1197; 1988, PASP, 100, 1529; 1990, PASP, 102, 117), Lee+ (1988, AJ, 96, 1690), Scarrott+ (1988, MN, 231, 1055; 1988, MN, 232, 725; 1990, MN, 242, 419), Clayton(1988, MN, 231, 33p), Rodríguez+ (1989, RevMexAA, 17, 111), Noriega-Crespo+ (1989, AJ, 98, 1388; 1990, AJ, 99, 1918), and Rolf+ (1990, MN, 242, 109).

In the infrared results were published by Schwartz+ (1987, ApJ, 322, 403; 1988, ApJLet, 334, L99), Tapia+ (1988, MN, 224, 587), Zinnecker+ (1989, ApJ, 342, 337), Roth+ (1989, AA, 222, 211), and Wilking+ (1990, AJ, 99, 344).

In the radio regime there were papers by Grossman+ (1987, 320, 356), Rodríguez+ (1989, RevMexAA, 17, 59), Curiel+ (1989, RevMexAA, 17, 137), Hughes(1989, AJ, 97, 1114), and Davis+ (1990, MN, 244, 173) Rodríguez+ (1990, ApJ, 352, 645) reports a detailed radio continuum study of the HH1-2 system made with the VLA. Yusef-Zadeh+ (1990, ApJLet, 348, 61) reports synchrotron emission from an HH-like object in Orion. The interferometric observations of HCO^+ made by Rudolph+ (1988, ApJLet, 326, 31) suggest that several of the components of HH7-11 may be shocked ambient cloudlets. In this source Hartigan+ (1989, ApJLet, 347, 31) present a detailed comparison of molecular hydrogen and optical images.

5.5. JETS (L. Rodríguez) Optical jets emanating from young stars have been studied by Mundt+ (1987, ApJ, 319, 275; 1988, ApJLet, 333, 69), Poetzel+ (1989, AA, 224, 13), Magakyan+ (1989, SovAstrLet, 15, 53), Movsesyan(1989, SovAstrLet, 15, 57), and Ray+ (1990, ApJLet, 357, 45). Theoretical modeling of the optical jets is reported by Sakurai(1987, PASJapan, 39, 821), Raga(1988, ApJ, 335, 820; 1989, AJ, 98, 976), Tenorio-Tagle+ (1988, AA, 202, 256), Blondin+ (1989, ApJLet, 337, 37), Hartigan(1989, ApJ, 339, 987), and Canto+ (1988, AA, 192, 287; 1989, RevMexAA, 17, 65). The jet phenomenon in young stars has also been studied in the radio wavelengths by Schwartz(1989, ApJLet, 338, 25) and Rodríguez+ (1990, ApJ, 352, 645)

5.6. PRE-MAIN SEQUENCE STELLAR WINDS AND BIPOLAR FLOWS (L. Rodríguez). The detection and detailed study of outflows continues to be a very active area. The detection of extremely high velocity H I and CO in HH7-11 (Lizano+ 1988, ApJ, 328, 763) was interpreted as evidence for neutral winds that accelerate surrounding gas, producing the molecular outflow phenomenon. Several papers discussed results that appear to imply that shock-enhanced chemistry takes place in the outflowing gas (Ziurys 1988, ApJ, 324, 544; Sandell+ 1988, ApJ, 329, 920; Rodríguez+ 1989, ApJ, 337, 712). A review of the observations related to the chemistry of shocks and outflows was given by Welch(1988, ApLetComm, 26, 181). The problem of molecule formation in fast neutral winds from protostars was discussed by Rawlings+ (1988,MN,230,695) and Glassgold+ (1989,ApJLet,336,29). Models for Alfvén-driven protostellar winds are given by Jatenco-Pereira+ (1989, MN, 236, 1).

New molecular outflows were reported by Heyer+ (1987, ApJ, 321, 370; 1989, ApJ, 346, 220), Iwata+ (1988, ApJ, 325, 372), Snell(1988, ApJ, 325, 853), Schwartz+ (1988, ApJ, 327, 350), Levreault(1988, ApJ, 330, 897), Harvey+ (1988, AA, 197, 19), Parker+ (1988, MN, 234, 67p), Kameya+ (1989, ApJ, 339, 222), Sato+ (1989, ApJ, 343, 773), Yamashita+ (1989, ApJ, 347, 894), Haikala+ (1989, AA, 223, 287), Liljestrom+ (1989, AA, 210, 337), Armstrong+ (1989, AA, 210, 373), Tamura+ (1990, ApJ, 350, 728), Snell+ (1990, ApJ, 352, 139), Ziurys+ (1990, ApJLet, 356, 25), Bachiller+ (1990, AA, 231, 174), and Richer(1990, MN, 245, 24p).

Improved maps of known molecular outflows were obtained and analyzed by Masson+ (1987, ApJ, 319, 446; 1990, ApJLet, 357, 25), Moriarty-Schieven+ (1987, ApJ, 319, 742; 1988, ApJ, 332, 364; 1989, ApJ, 338, 952), Hirano+ (1988, ApJLet, 327, 27), Hayashi+ (1988, ApJ, 332, 354), Margulis+ (1988, ApJ, 333, 316; 1989, ApJ, 343, 779; 1990, ApJ, 352, 615), Cabrit+ (1988, ApJ, 334, 196), Walker+ (1988, ApJ, 332, 335), Phillips+ (1988, AA, 190, 289), Liseau+ (1988, AA, 192, 153), Koo(1989, ApJ, 337, 318), Schulz(1989, ApJ, 341, 288), Barsony(1989, ApJ, 345, 268), Schulz+ (1989, ApJ, 341, 288), Fridlund+ (1989, AA, 213, 310; 1989, AA, 223, 13), Richer+ (1989, MN, 241, 231), Mizuno+ (1990,ApJ,256,184), and Martin-Pintado+ (1990,ApJLet,357, 49). In some of the best studied molecular bipolar outflows there is now evidence that the high-velocity gas is in shell-like structures (Moriarty-Schieven+ 1989, ApJ, 347, 358 ; Little+ 1990, AA, 232, 173).

Theoretical work on the molecular outflows and their observational parameters is reported by Canto+ (1987, ApJ, 321, 877) and McKee+ (1987, ApJ, 322, 275). The paper by Cabrit+ (1990, ApJ, 348, 530) extends previous work on modeling accelerated and constant velocity outflows to the decelerated outflow case.

Several papers studied the interaction of the winds and flows with the surrounding dense gas (Torrelles+ 1987, ApJ, 321, 884; 1989, ApJ, 343, 222; 1989, ApJ, 346, 756; 1990, ApJ, 349, 529; Myers+ 1988, ApJ, 324, 907; Mathieu+ 1988, ApJ, 330, 385; Marcaide+ 1988, AA, 197, 235; Heaton+ 1988, AA, 203, 99; Anglada+ 1989, ApJ, 341, 208; Verdes-Montenegro+ 1989, ApJ, 346, 193; Yamashita+ 1989, ApJLet, 347, 85; Menten+ 1989, AA, 223, 258; Plambeck+ 1990, ApJLet, 348, 65; Haschick+ 1990, ApJ, 352, 630).

A remarkable non-thermal triple radio source in Serpens (Rodríguez+ 1989, ApJLet, 346, 85) seems to be experiencing a bipolar expansion similar to that of bipolar outflows. The exciting sources of many bipolar outflows can be obscured so severely that its detection and proper identification is only possible at radio and mm wavelengths (Rodríguez+ 1989, RevMexAA, 17, 115). In some cases, like NGC2264G and L1448, the outflow is rather powerful but the exciting star appears to be of modest luminosity. Wolk+ (1990, PASP, 102, 745) speculated that some outflows could be driven by very low-mass stars.

Infrared images of bipolar outflow regions were discussed by Aspin+ (1988, AA, 197, 242), Heckert(1988, AJ, 95, 821), Campbell+ (1988, AJ, 95, 1173), Burns+ (1989, AJ, 98, 643), Burton+ (1989, MN, 238, 1513), Hodapp(1990, ApJ,352,184),Garden+(1990,ApJ,354,232), and Hayashi+(1990,ApJ, 354, 242).

5.7. PRE-MAIN-SEQUENCE DISKS (L. Rodríguez). A large body of indirect evidence seems to point to the existence of circumstellar disks around young stars. Part of this literature is the analysis and modeling of UV, optical and infrared observations from T Tauri and FU Orionis stars with the help of disk models (Edwards+ 1987, ApJ, 321, 473; Kenyon+ 1988, ApJ, 325, 231; 1989, ApJ, 342, 1134; 1989, ApJ, 344, 925; Adams+ 1988, ApJ, 326, 865; Bertout+ 1988, ApJ, 330, 350; Hartmann+ 1989, ApJ, 338, 1001; Basri+ 1989, ApJ, 341, 340; Clarke+ 1989, MN, 236, 495; Gledhill+ 1989, MN, 236, 139; Hartigan+ 1990, ApJLet, 354, 25; Cabrit+ 1990, ApJ, 354, 687; Clarke+ MN, 242, 439).

Also the observations of mm and sub-mm emission from young stars have been interpreted in terms of circumstellar disks and have been used to derive disk masses in the 0.01 to 1 solar mass range (Weintraub+ 1989, ApJLet, 340, 69; Keene+ 1990,ApJ,355,635; Adams+ 1990,ApJ,357,606; Sandell+1990,AA,232,347). The most complete study of this kind was made by Beckwith+ (1990, AJ, 99, 924).

Perhaps the most convincing evidence available at present for the existence of circumstellar disks around young stars is the interferometric mapping of carbon monoxide, that in sources like HL Tau (Sargent+ 1987, ApJ, 323, 294) and T Tau (Weintraub+ 1989, ApJ, 344, 915) suggest that the gas may be in Keplerian rotation around a solar mass central star. An ammonia ring in NGC2071 has also been interpreted to be in Keplerian rotation around an object with 5 solar masses (Zhou+ 1990, ApJ, 355, 159).

5.8. STAR FORMATION (P. Myers). Observations indicating the process of star formation were presented by Welch+, 1987, Science, 238, 1550, Keto+, 1987, ApJ, 323, L117 and 1988, ApJ,324,920, and Neckel+,1989, AA, 210, 378.

Statistical studies concerning the incidence of star formation from cloud to cloud, and within clouds, and the distribution of stellar masses, were presented by Mooney+, 1988, ApJ, 334, L51, Wouterlout+, 1988 , AA, 191, 323, Rana, 1987, AA, 184, 104, Heydari-Malayeri+, 1988, AA, 201, L41, Richter+, 1988, AA, 206, 219, Strom+, 1988, AJ, 95, 534, Walter+, 1988, AJ, 96, 297, Wilking+, 1989, ApJ, 340, 823, Strom+, 1989, ApJ, 345, L79, and 346, 133, Rieke+, 1989, ApJ, 339, L71, Wood+, 1989, ApJ, 340, 265, Straw+, 1989, ApJSup, 69, 99.

Theoretical models of gas cloud stability, fragmentation, and collapsing motion in the context of star formation were presented by Tohline+, 1987, ApJ, 322, 787 and1988, ApJ, 325, 699, Hachisu+, 1987, ApJ, 323, 592 and 1988, ApJSup, 66, 315, Suto+, 1988, ApJ, 326, 527, Voit, 1988, ApJ, 331, 343, Silk+, 1988, ApJ, 335, 295, Chieze+, 1987, AA, 183, 98, Sugitani+, 1989, ApJ, 342, L87. Solar nebula evolution was discussed by Boss, 1989, ApJ, 345, 554. The roles of ambipolar diffusion and molecule depletion in low-mass star formation were discussed by Hartquist+, 1989, MN, 241, 417. Models featuring rotating clouds were presented by Boss, 1987, ApJ, 319, 149, 1988, ApJ, 331, 370, and 1989, ApJ, 346, 184 and 336. Williams+, 1988, ApJ, 334, 449, and Hachisu+, 1988, ApJSup, 66, 315, Durisen+, 1989, ApJ, 345, 959. Disk formation in a cluster was discussed by Illarionov+,1988, SovA, 32, 148. Disk stability was discussed by Abramowicz+, 1987, ApJ, 323, 629, Blaes+, 1988, ApJ, 326, 777, Adams+, 1989, ApJ, 347, 1012, Papaloizou+, 1989, ApJ, 344, 645. Formation of binary stars was discussed by Pringle, 1989, MN, 239, 361.

Formation of massive stars was discussed by Wolfire+, 1987, ApJ, 319, 842, Elmegreen, 1989, ApJ, 340, 786, and Nakano, 1989, ApJ, 345, 464, and formation of young clusters by Danilov, 1987, SovA, 31, 343, Kenicutt+, 1988, AJ, 95, 720, and Schroeder+, 1988, ApJ, 326, 756. An analytic theory of self-propagating star formation was presented by Neukirch+, 1988, MN, 235, 1343. D burning and the "birthline" in the HR diagram were discussed by Stahler, 1988, ApJ, 332, 804. Star formation from superstrings was discussed by Brosche+, 1989, AA, 219, 13. An observable signature of a collapsing cloud was presented by Anglada+, 1987, AA, 186, 280, and Zinchenko+, 1987, SovA, 31, 254.

Several lists of molecular clouds, some of which may be sites of star formation, were compiled by Clemens+ (1988, ApJSup, 68, 257) and surveyed for ammonia by Benson+ (1989, ApJSup, 71, 89). Cesaroni+ (1988, AASup, 76, 445) compiled a catalog of water vapor masers north of a declination of -35^{o}. Strom+ (1989, ApJSup, 71, 183) present a study of the stellar population in L1641.

6. H II REGIONS (M. Rosa)

Improved understanding of atomic and hydrodynamic processes have enabled an improved understanding of such astrophysical questions as the chemical evolution of galaxies, the boundary conditions for star formation, and the evolution of massive stars. Much effort has been concentrated on phases of the ISM intimately linked with HII regions, namely extended HII region envelopes (EHE), the warm interstellar medium (WIM), neutral interfaces and photodissociation regions (PDR).

6.1. GENERAL REFERENCES are Debarbat,S.,1988, *Mapping the Sky*, IAU Sym 133, Kluwer, Dordrecht; Verschuur,G.L.+,1988, *Galactic and Extragalactic Radio Astronomy*, Springer, Berlin; Verschuur,G.L,1989, *Interstellar Matters*,Springer,New York. Osterbrock has updated and enlarged the well-known text book (1989, *Astrophysics of Gaseous Nebulae and Active Galactic Nuclei*, now including novae and AGNs. Reviews of H II regions are: Genzel+ (1989, AnRevAA, 27,41); Dufour (1989,ESA-SP-263,577). General literature in the field includes: Beckman, J.E.+,1989, *Evolutionary Phenomena in Galaxies*, Cambridge UP (with communicated papers in 1989,ApSpSci 156/157); Condon 1990, *Large Scale Surveys of the Sky*, NRAO Workshop 20,Green Bank,WV,USA; Dalgarno+ 1987, *Spectroscopy of Astrophysical Plasmas*, Cambridge UP, with articles by Lynds (p1), Brown (p35), Aller (p89); Gordon+, 1990, *Radio Recombination Lines: 25 Years of Investigation*, IAU Coll 125, Kluwer, Dordrecht; Tenorio-Tagle+, 1989, *Structure and Dynamics of the Interstellar Medium*, IAU Coll 120, Springer,Berlin; Thuan, 1987, *Starbursts and Galaxy Evolution*, Ed.Frontiere, Paris ; Waddington,1989,*Cosmic Abundances of Matter*, AIPConf.Proc. 183, NY.

A general atlas of nebulae is Neckel,Th.+,1988, *Atlas of galactic Nebulae*,Treugesell-Verlag, Düsseldorf, FRG. Several catalogues, some with increasingly detailed spectral properties obtained from scanning devices, have been produced: (Hodge 1987, PASP, 99, 915; 1988, Deharveng+ AA Sup, 73, 407; Petit+ 1988, AASup, 74, 475; Bieging 1988, PASP, 100, 97; Copetti+ 1989, AA Sup, 77, 327; Hodge+ 1989, PASP, 101, 32; Zaritsky+1989, AJ, 97, 97; Dottori+

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1989, ApSpSci, 156, 283; Cepa+ 1989, AASup, 79, 41; Hodge+ 1989, PASP, 101, 640; Cepa+ 1990, AASup, 83, 211; McCall+ 1990, AJ, 100, 193; Arsenault+ 1990, AA, 234, 23; Price+ 1990, AJ, 100, 420; Hodge+ 1990, PASP, 102, 26)

6.2. STRUCTURE. The morphology and interrelation of individual large and compact H II regions, and of entire star formation complexes and spiral arm segments, have been investigated at scales between several arcminutes and subarc-seconds, and at wavelengths between the decametric radio and the optical regime.

The recombination line survey of Lockman (1989, ApJSup, 71, 469) increased the number of known large radio HII regions by a factor of two, confirming the N-S asymmetry in the galactic distribution and delineating two spiral arms. An H I emission/absorption experiment towards radio HII regions has been made (Kukar, 1990, ApJ, 352, 192). Reports on surveys include: (Fürst+, 1987, AASup, 69, 403; 1989, Whiteoak+ ProcASAustralia,8, 176; Joncas+, 1990, AASup, 82, 113; Becker+ 1990, ApJ, 358, 485). Recombination line and continuum show a statistical mass-luminosity relation (Oskanyan 1988, Astrof, 29, 107). The radio H II region luminosity function is compatible with an intermediate Sb-c type for the Milky Way galaxy (Smith+, 1990, PASP, 101, 649).

IRAS 60 μm and cm radio continuum fluxes correlate in detail (Broadbent+, 1989,MN,237,381). Criteria to find H II regions in IRAS data have been developed (Hughes+, 1989,AJ,97, 786). Spectra of misclassified PNe have revealed 27 new optical HII regions (Acker+, 1987, AASup, 71, 163). Strong hidden radio regions have been traced optically (Georgelin+, 1988, AA, 205, 95) and a very distant HII region was found (Georgelin+, 1988, AA, 190, 61). Hα luminosities and linewidths have been determined for almost 300 optical HII regions (Fich+ 1990, AJ, 99, 622).

Radio, mm, submm, FIR, IR and optical maps in recombination, collisional and molecular lines as well as the continuum have been used to study structural details of individual HII regions: (eg. Mizutani+ 1987,MN, 228, 721; Vittoni+ 1987,AA,179,157; Reynolds1988,AJ,96,670; Shestakova+1988,SovA Let,14, 24; Celnik+1988,AA,192,316; Heydari-Malayeri 1988,AA,202,240; Rodríguez 1988, ApJ, 333, 801; Lozinskaya+ 1987, Astrof, 31,493; Kogut+ 1989, ApJ, 346, 763; Akabane+ 1989, PASJ, 41, 809; Just+ 1990, AA, 232, 477; Duvert+ 1990, AA, 233, 190; Gordon 1990, ApJ, 352, 636; 1990, Pismis AA, 234, 443).

Among the many studies on deeply embedded compact and ultracompact H II regions are: subarcsecond maps of Sgr B2 (Gaume+ 1990, ApJ, 351, 538); a model for S 106 (Ershev+ 1988, SovA Let, 14, 87); and on dust (Gear+ 1988, MN, 231, 55p). Ultracompact HII regions are very likely the manifestation of the early 15% of the ZAMS lifetime of O stars (Churchwell+ 1990, AA Sup, 83, 119). Cometary HII regions and possibly most of the UC HII regions may be, however, bow-shocks from windy stars moving in molecular clouds (Van Buren+ 1990, ApJ, 353, 570). The vast literature on C and UC HII regions and this most recent development are reviewed by Churchwell (1990, AARev, in press).

Blister-like H II regions at the edges of molecular clouds have been mapped and geometrical models proposed (Felli+ 1987, AA, 182, 313; Valée 1987, AJ, 94, 679; Azcárate+ ,1988, RevMAA, 16,3; Evans+ 1989, ApJ, 346, 212; Kömpe+ 1989, AA, 221, 295; Barnes+ 1989, ApJ, 342, 883; Gómez+ 1990, AA, 234, 447). Large shell-like structures are seen in radio maps (Evans+ 1989, ApJ, 346, 763; van der Werf+ 1990, AA, 235, 407). The structure in neutral interfaces and photodissociation regions has been investigated (Matsuhara+ 1989,ApJ Let,339, L67; Hayashi+ 1990, ApJ, 354, 242; Roelfsema+ 1987, AA, 174, 232; Van der Werf+ 1989, AA, 224, 209; Torrelles+ 1990, ApJ, 349, 529). Low density envelopes, halos and EHEs are observed and inferred (Azcárate+ 1987, RevMAA, 15, 125; Müller+ 1987, AA, 183, 327; 1989, AIP Conf 174,185,New York; Spangler+ 1990, ApJ Let, 353, L29).

The findings on the structure of ionized regions in the Galaxy are mirrored in images of external galaxies: H II filaments punching out to 4 kpc height above a 1 kpc thick H II disk in an edge-on galaxy (Rand+ 1990, ApJ Let, 352, L1); and the deep face-on view onto M 33 (Courtes+1987, AA, 174, 28), revealing ~ 750 "classical" HII regions of grossly diverse morphology in a chaotic background.

6.3. PHYSICAL CONDITIONS. The diagnostic capabilities of radio recombination lines from HII regions have been reviewed by Sorochenko 1989,AN,310,389 (see also IAU Coll 125). Plasma diagnostics from O^{+2} triplet state lines have been investigated (Bhatia+1988, ApJ 331,826) and their excitation mechanism reviewed (Sternberg+ 1988, CommAp, 13, 29). Non-LTE effects in radio line transitions are observed on a 10% level only in high density regimes (Sorochenko+ 1988, AA, 198, 233; 1989,RevMAA, 17, 91; Martín-Pinado+ 1989, AA, 215, L13),and may provide plasma diagnostic tools (Gordon, 1989, ApJ, 337, 782; Walmsley 1990, AA Sup, 82, 201).

Electron densities determined from forbidden line ratios in planetary nebulae have been compared by Stanghelleni+ (1989, ApJ, 343, 811). [Cl III] and [Ar III] estimates are in good agreement, [S II] and [O II] estimates systematically lower by about 30%. Filling factors have been discussed (Almleaky+ 1989, AA, 224, 328) and Kassim+ (1989, ApJ, 338, 152). Constraints on Te,ne, filling factors and ionizing sources are derived for EHEs (Kassim 1990, ApJ, 347, 915) The same medium is seen in 68 spirals (Israel+ 1990, ApJ, 352, 30)], and WIM (Reynolds 1989, ApJ, 345, 811; Songaila+ 1989, ApJ Let, 345, 71; Guhathakurta+ 1989, ApJ, 346, 773; Reynolds 1990, ApJ, 348, 153).

An electron temperature gradient is observed for 316 radio H II regions, however with a variance at any given radius comparable to the whole range of Te (Caswell+ 1987, AA, 171, 261). A shallower Te gradient is reported from EHEs (Azcárate+ 1990, RevMAA, 20, 23). A very hot, distant HII region (Puche+ 1989, AA, 206, 89; de Muizon+ 1990, AASup, 83, 337) and several very cool objects (Lockman 1989, ApJSup, 71, 469) have been found. A model of the radio Orion nebula with T(core) = 8500 K, T(halo) = 6700 K has been presented (Wilson+ 1987, AA, 184, 291). Tabulations of emission line intensities in the spectrum of Orion accessible from ground are given for ~60 lines (700-1100 nm) by Osterbrock+ (1990, ApJ, 352, 561), and for ~220 lines at submm/mm waves by Jewell+ (1989, ApJSup, 70, 833).

Dust absorption of Ly-α and UV continuum has been studied using μm to cm wave maps and spectra (Antonopoulou+ 1987, AA, 173, 108; Ghosh+ 1989, ApJSup, 69, 233; Salter+ 1989, AA, 225, 167). IRAS LR spectra of HII regions are dominated by line emission (de Muizon 1990, AA Sup, 83, 337). Dust temperatures and grain sizes seem to differ considerably inside and outside ionized regions (Cox+ 1990, AA, 230, 181; Maihara+ 1990, ApJ, 354, 549; Ward-Thompson+ 1990, MN, 244, 458). Internal dust optical depths of have been determined (Rozhkovskii 1989, SovA, 33, 328). Most of the dust seen towards H

II/dust/mol complexes is, however, not mixed with the ionized gas (eg.: 1987, Kinem.Phys.Cel.Bodies,3,62; Gordon+ 1987, ApJ, 323, 766; Scoville+ 1989, ApJ, 339, 149; Heyer+ 1989, ApJ, 346, 220; McCall+ 1990, ApJ, 357, 502).

The extinction in Orion has been studied using nebular and stellar light (Greve+ 1989, AA, 215, 113; Shulor+ 1989, Astrof, 30, 154). Stars with dusty envelopes are seen in Orion photographs (1990,PASP,100,547; Castalez, 1990, ApJ Let, 348, L29). Optical polarization maps of Orion (Leroy, 1987, AA, 186, 322) indicate a 15% level contamination of emission line emissivities by scattering. Ionizing stars have been classified in order to study the IMF (Hunter+ 1990, AJ, 99, 846), to determine distances (Forbes 1989, AASup, 77, 439; Lahaulla 1989, AJ, 97, 1727; Guetter+ 1989, AJ, 98, 611) or ages (Melnick+ 1989,AA, 213, 89).

Model nebulae have been produced to study: the effects of density variations on line emissivities (Rubin 1989, ApJSup, 69, 897); the differences between homogeneous models to those with semi-realistic structure, velocity fields and internal dust (Cota+ 1988, ApJ, 326, 889); the IR spectra expected from dusty H II regions (Aannestad 1989, ApJ, 338, 162); spectra of X-ray photoionized nebulae (Liedahl+ 1990, ApJ Let, 350, L37).

Observations and theory of photodissociation regions have been reviewed by Genzel+ (1989, ESA-SP-290, 115). Observational work includes: Stutzki+ 1988, ApJ, 332, 379; Richardson+ 1989, AA, 224, 199; Vallée 1989, ApJ, 341, 238; Bregman+1989,ApJ,344,791; Vallée 1989,AA,213,295; Wolfire+1990,ApJ, 358, 116. Pressure equilibrium is found between H II and molecular regimes from an analysis of CII stimulated emission (Vallée 1987, AA, 178, 237). H_2 lines from PDRs are due to a mixture of shock excitation, UV fluorescence or thermal radiation (Sternberg 1989, ApJ, 338, 197) depending on environment, as shown by observations (Oliva+1988,AA,197,261; Tanaka+ 1989, ApJ, 336, 207; Hippelein+ 1989, AA, 213, 323). IR spectral maps across ionization fronts have been made (Roche+ 1989, MN, 236, 485; Witteborn 1989, ApJ, 341, 270; Sellgren+ 1990, ApJ, 349, 120).

6.4. EVOLUTION. The detailed velocity field in Orion was studied (Castañeda, 1989, ApJSup, 67, 93). Walker+ (1988, PASP, 100, 1505) confirms the existence of proper motions in nebular features with tangential velocities of up to 80 km/sec. Dense ionized gas is seen flowing away from neutral condensations (Garay, ApJ 314, 535) with speeds of up to 150 km/sec (Meaburn, MN 233, 791). The kinematics in several nebulae are interpreted as blister type and champagne flows (Hänel, 1987, AA 176, 347; Georgelin+, 1990, AA, 230, 440), or stellar winds (Meaburn+ 1987, MN 229, 253), or expanding Strömgren sphere (Wisotzki+ 1989, AA, 221, 311).

Inhomogeneous turbulence (Henriksen 1988, ApJ 331, 359) and turbulent mixing between HII layers and bubble interiors (Kahn+1990, MN, 242, 209) have been studied. Hydrodynamical evolutionary models have been constructed with realistic environments (density gradients, molecular clouds) (Franco+ 1990, ApJ, 349, 126; Yorke+ 1989, AA, 216, 207). Theoretical studies on wind-blown bubbles include Dorland+ (1987,AA,177,243), Hanami+ (1987, AA, 181, 343) and Gratton (1988, AA, 202, 177). Supernova remnants in HII regions are treated in IAU Coll. 101: theoretically by McGee (p.205), observationally by Chu and Kennicutt (p.201), and with a complete evolutionary model from ZAMS to SNR stage by Shull+ (p231).

Different evolutionary phases of H II regions are seen in large scale studies of star formation areas (eg.: Piepenbrink+ 1988, AA, 191, 313; Lozinskaya+ 1988, SovA Let, 14, 100; Avedisova 1989, Astrof, 30, 140; Sitnik 1989, SovA Let, 15, 388; Cersosimo 1990, ApJ, 356, 156; Henning+ 1990, AA, 227, 542). An account of nebulae around evolved (Of,WR) stars has been given by Dufour (1989, RevMAA, 18,87). Physical conditions and kinematics have been determined (Lozinskaya+ 1988, SovA Let, 14, 385; de Muizon+ 1988, AA, 193, 248; Marston+ 1988, MN, 235, 391; Whitehead+ 1988, AA, 196, 261; Dyson+ 1990, AA, 226, 270). Abundance determinations show varying degrees of N and He enrichments (Leitherer+ 1987, AA, 175, 208; Dufour+ 1988, ApJ, 327, 859; Esteban+ 1990, AA, 227, 515). Stellar FUV continua are constraint by ionization requirements (Rosa+ 1990, ASP Conf.Ser.,7,135; Dopita+ 1990, ApJ, 351, 563). The X-ray flux observed in NGC 6888 falls short by a factor 10 from classical wind-bubble predictions (Kaehler+ 1987, ApSpSc, 135, 105; Bochkarev 1989, Nature, 332, 518).

6.5. ABUNDANCES AND GALACTIC GRADIENTS. Abundance determinations in HII regions have been reviewed thoroughly by Meyer (1989, AIP Conf.Proc., 183, 245) and put into the galactic and cosmological context. The He/H ratio in Orion and M17 as determined from mm recombination lines is in excellent agreement with previous (optical) values (Peimbert+1988,PASJ,40, 581). N/O ratios from FIR lines (N^{++}/O^{++}) are typically a factor 2 higher than optical (N^+/O^+) determinations, and leave little room for a galactic gradient (Rubin+ 1988, ApJ 327,377). A solar O/H for Orion is derived by Rubin (1989,ApJSup, 69, 897) on the basis of model HII regions with large ne inhomogeneities. Abundance determinations of ^{3}He/H have been made using the 8.7 GHz line (Bania+ 1987, ApJ, 323, 30). Too strong a [Ni II] NIR emission in Orion seems to trace problems with atomic data rather then a real Ni excess (Henry+ 1988, ApJ, 329, 693).

The determination of galactic abundance gradients (mostly O/H) in HII regions are challenged also by very recent reports on the absence of any such gradients in early B stars and young cluster F stars (see Fitzsimmons+ 1990, AA, 232, 437; Boesgaard+ 1990, ApJ 351, 467; Friel+ 1990, ApJ, 351, 480). Collisional depopulation of the 2^3S level in He^0 is significant, but less then claimed previously (Peimbert+, 1987, RevMAA, 15, 117); Clegg+ 1989, MN, 239,869; see also Péquignot+ 1988, AA, 206, 298; Almog+ 1989, MN, 238, 57).

6.6. GALACTIC CENTER. In addition to the progress covered by the Symposium on the galactic center (July 1988), reviews have been presented by Güsten (1987,AIP Conf. Proc., 155, 19), and by Genzel & Townes (1987, AnRevAA, 25, 377). More recent studies of the thermal gas (Sgr A West) include (Anantharamaiah+ 1988, MN, 235, 151; Mezger+ 1989, AA, 209, 337; Okumura+ 1989, ApJ 347, 240; Seiradakis+ 1989, AASup, 81, 291).The velocities observed are in accord with orbital motions (Serabyn+ 1988, ApJ, 326, 171). The arc and its filaments are likely nonthermal (Lasenby+ 1989, ApJ, 343, 177; Morris+ 1989, ApJ, 343, 703), a linear polarization of 9% has been measured at 7.6 cm Vinjajkin+ (1989, Pishma(SovA Let) 15, 971). The conditions in the radio arc and in the molecular gas are also compatible with OB star ionization (Cersosimo 1990, ApJ, 356, 156). Further progress on the identification of the ionizing source(s) may be expected to come through spectroscopy of the NIR infrared sources around IR16C (Tollestrinp+ 1989, AJ, 98, 204; Rieke+ 1989, ApJ Let, 344, L5).

6.7. EXTRAGALACTIC H II REGIONS. H II regions in external galaxies (EHR) have been a continued focus of interest, in particular in studies aimed at aspects of star formation, chemical evolution of galaxies and the primordial abundance of He. A very comprehensive review has been prepared by Shields (1990, Ann. Rev. AA, 28). The properties of EHRs have also been reviewed by Kennicutt (1990, in *Star Formation*, STScI Workshop, Baltimore, MD).

The extensive set of catalogued integral properties over a wide range of galaxy types and luminosities has been analyzed (Kennicutt+ 1989, ApJ, 337, 761; Zaritsky+ 1989, AJ, 97, 1022). Many more catalogues, some with increasingly detailed spectral properties obtained from scanning devices, have been produced: (Hodge, 1987, PASP, 99, 915; Deharveng+ 1988, AASup, 73, 407; Petit+ 1988, AASup, 74, 475; Bieging 1988,PASP,100,97; Copetti+ 1989, AASup, 77, 327; Hodge+ 1989, PASP, 101, 32; Zaritsky+ 1989, AJ, 97, 97; Dittori+ 1989,ApSpSci, 156, 283; Cepa+ 1989, AASup, 79, 41; Hodge+ 1989, PASP, 101, 640; Cepa+ 1990, AASup, 83, 211; McCall+ 1990, AJ, 100, 193; Arsenault+ 1990, AA, 234, 23; Price+ 1990, AJ, 100,420; Hodge+ 1990, PASP, 102, 26).

The structure of EHRs has been investigated (Testor+ 1987, AA, 178, 25; Heydari-Malayeri+ 1987, AA, 184, 300; Roy+ 1989, AJ, 97, 1010; McCall+ 1990, AJ, 100,193). Velocity fields have been mapped and discussed in terms of turbulence or expansion, driven by champagne flows, stellar winds or SN events (Clayton 1987, AA, 173, 137; Laval+ 1987, AA, 175, 199; Clayton 1988, MN, 231, 191; Meaburn+ 1988, MN, 235, 375; Vilchez+ 1989, ApSpSci, 156, 237).

Infrared properties of EHRs in M33 are similar to those in the Galaxy (Deul 1989, AA, 218, 78; Rice+ 1990, ApJ, 358, 418). Extinction towards EHRs has been determined through radio continuum, Bracket and Balmer lines (van der Hulst+ 1988, AA, 195, 38; Skillman+ 1988, AA, 203, 226; Kaufman+ 1989, ApJ, 345, 674), with the extinction as derived from the ratios of recombination lines to continuum always larger than that derived from ratios among recombination lines. Correlations are found between the effective temperatures of the ionizing stars, O/H, Av, and L(FIR) (Roy+ 1987, MN, 228, 883; Greve+ 1987, AASup, 74, 167; Campbell 1988, ApJ, 335, 644). Marked differences are seen in the IR, FIR properties of LMC and SMC HII regions (Roche+ 1987, MN, 228, 269; Loisseau+ 1987, AA, 178, 62; Klien+ 1988, AA, 211, 280). H_2 emission has been detected towards a few HII regions in the Magellanic Clouds and in M 33 (Kawara+ 1988, PASP, 100, 458; Israel+ 1988, AA, 190, 21; Israel+ 1990, MN, 242, 471).

A very extensive grid of photoionization models aimed at EHR analysis has been made available by Stasinska (1990, AASup, 83, 501). Similar models have been investigated and used to constrain ionization correction factors and effective ionizing temperatures (Vilchez+ 1988, MN, 231, 257; Campbell 1988, ApJ, 335, 644; Garnett 1989, ApJ, 345, 282; Mathis+ 1990, AA, in press). Modelling and observations of spectral evolution are discussed (Olofssen 1989, AASup, 80, 317; Terlevich+ 1990, MN, 242, 48p; Copetti 1990, AA, 229, 533).

Abundance and gradient determinations include: Peña+ 1987, RevMAA, 14, 178; Vilchez+ 1988, MN, 235, 633; Walsh+ 1989, ApJ, 341, 722; Vilchez+ 1988, PASP, 100, 1428). Constant [S/O] over a wide range of [O/H] is established using [SII] and NIR [SIII] observations (Garnett 1989, ApJ, 345, 282). [N/O] shows

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significant scatter at low [O/H], sometimes correlated with [He/H], within individual objects, possibly due to self-enrichment by WR stars, SNe or excessive loss of O in galactic winds (Vigroux+ 1987, AA, 172, 15; González-Riestra+ 1987, AA, 186, 64; Walsh+ 1989, MN, 239, 297; Skillman+ 1988, AA, 199, 61; 1987,Thuan,p145; Pagel 1987,Thuan, p227). More EHRs with very low [O/H] have been found in unevolved dwarf irregular galaxies and analyzed to constrain primordial He and ideas about the chemical evolution of galaxies (Skillman+ 1988, AA, 196, 31; Skillman+ 1989, MN, 240, 563; Izotov+ 1990, Nature, 343, 238; Moles+ 1990, AA, 228, 310). [N/O] and [C/O] apparently are solar-like in I Zw 18 (Dufour 1990, ApJ, 350, 149). Good agreement exists for [S/H] as determined from H II regions and stars, but not for [C/O] (Spite+ 1990, AA, 234, 67).

New data on HII regions in M101 reconfirm gradients in [O/H], [N/O] and [He/H], show solar values and no gradient in [S/O], [Ne/O] and [Ar/O], and yield a primordial He abundance $Yp = 0.230 \pm 0.006$ (Torres-Peimbert+ 1990, ApJ, 345, 186). Pagel+ (1989, RevMAA 18, 156) arrive at a similar Yp using 3 very metal deficient blue compact galaxies. Steigman+ (1989, Comm.Ap,14, 97) discuss the proper correction of Yp for stellar helium contamination.

The latest evolutionary stages (WR,SN) of very massive stars are observed directly or inferred otherwise in EHRs (Rosa+ 1988, AA, 192, 57; Chu+ 1988, AJ, 96, 1874; Goodrich+ 1989, ApJ, 342, 908; Condon+ 1990, ApJ, 357, 97). Strong HeII λ4686 emission in LMC,SMC HII regions (Kennicutt 1990, IAU Symp Magellanic Clouds, Sidney, in press) implies high Teff or X-ray ionization (Pakull+ 1989, Nature, 337, 337). One EHR in M 101 is probably associated with an Einstein X-Ray source (Trinchieri+ 1990, ApJ, 356, 110).

Related studies of HII galaxies, clumpy irregulars, near nuclear rings of SF, etc. include: Moorwood+ 1987, AA, 184, 63; Burenkov+ 1987, Astrof, 27, 396; Burenkov+ 1987, Astrof, 27, 576; 1987, Maehara+ PASJ,39,393; Arsenault+ 1988, AA, 200, 29; González-Riestra+ 1988, AA, 202, 27; 1988,AA,203,44; Augarde+ 1990, AA, 233, 348). Abundances and SF rates in disk-EHRs of Seyfert galaxies are reported (Evans+ 1987,ApJ,319,662; Shields+1990,ApJ,353, L7).

A value of $H_0 = 89 \pm 10$ km s^{-1} Mpc^{-1} has been derived using velocity dispersions in EHRs (Melnick+ 1988, MN, 235, 297). The calibration of the empirical luminosity - velocity dispersion relations and the governing physics (turbulence, stellar winds, or gravity) are still a matter of debate (O'Dell+ 1988, AA, 198, 283; Arsenault+ 1988, AA, 201, 199; Israel+ 1989, MN, 242, 471).

7. SUPERNOVA REMNANTS (M. Dopita)

7.1. INTRODUCTION. Recent **reviews** on Supernovae and their remnants have been given by Chevalier and Seward 1988 in *Multiwavelength Astrophysics*, ed. F.A. Cordova, Cambridge UP:Cambridge, P295, and Weiler, K.W., and Sramek, R.A. (1988 AnRevAA, 26, 295). A useful catalog of Galactic SNR is given by Green (1988 Ap Space Sci 148,3), and an IRAS catalog by Arendt, R.G. (1989 Ap J Sup., 70, 181). **Conference proceedings** are IAU Colloq. 101, "Supernova Remnants and the Interstellar Medium", ed. Roger+, (Cambridge UP) 1987 and "Supernova Shells and their Birth Events" , ed. Kundt, (Springer:Berlin) 1988; hereafter IAU#101 and "Supernova Shells" respectively.

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7.2. YOUNG SNR. The full variety of properties exhibited by young SNR has only recently been fully appreciated. For general purposes we can classify them into three main groups, the plerionic or Crab-like objects, the oxygen-rich SNR, and the remnants of Type I supernovae. However, some objects share physical properties generally associated with those of SNR in other groups. Observations made with the Einstein satellite had suggested that one property, that of extended X-ray halos, is apparently common to all classes, being found in the prototypes of the three classes, the Crab nebula, Cas A, and the remnants of Tycho's and Kepler's SNR. Mauche+ (1989 Ap J, 336, 843) have shown that this is simply the result of scattering of X-rays by grains in the intervening ISM.

7.2.1. Plerionic SNR. The plerionic class of SNR are the Crab-like SNR with a filled center radio morphology, and evidence for a central neutron star/pulsar. New discoveries in the review period have enlarged the known number of this class of object (Becker+ (1988 A J, 95, 883) and Velusamy+ (1988 A J, 95, 1162)).

The chemical composition of the filaments in the Crab nebula itself has been estimated by Golovatyj+ (1987 Astrophysics,25,542) MacAlpine+ (1989, ApJ,342,364). find strong evidence for chemical fractionation in the remnant, helium-rich material being found in a torus and in bipolar lobes, while the region at the base of the optical jet is rich in nickel. They conclude that the precursor star had a mass of 20-30 $M_{\odot}$, with 6 -9 $M_{\odot}$ in the hydrogen-burnt core. The kinematics of the jet has been investigated using an imaging Fabry-Perot by Marcelin + (1990 AA 228,471). This work confirms that the jet is an cylinder expanding at 260 km s^{-1}, apparently homologously with the rest of the nebula. Davidson (1987, AJ, 94, 964) has presented global spectra of the Crab, and suggests that the visual continuum may be rapidly changing. However, Veron-Cetty+ (1988, AA, 201, L27) find little evidence of continuum variability in the optical, and stringent limits have been placed on any radio variability (Vinyajkin+, 1988, A Zh., 65, 883). An exciting new result has been the detection of TeV gamma rays from the Crab (Weekes+,1988, BAAS 20,1055).

de Gouveia Dal Pino+ (1989, MN, 240, 573) have argued that the filaments in the Crab are generated by the action of a thermal synchrotron instability. Recently Fesen+ (1990 ApJ Let. 351,L45) have established the presence of dust globules associated with filaments emitting in the [OI], [CI] and [S II] lines. These cores are also found to contain excited molecular hydrogen (Graham+, 1990 ApJ 352, 172). Thus it seems certain that both dust and molecules were formed in the early evolution of the SNR.

The similarity of CTB 80 with the Crab has been strengthened by the discovery by Strom (1987 ApJ Let., 319, L103) of a compact radio source apparently associated with an unresolved X-ray source, probably a pulsar/neutron star,embedded in the region of the flat-spectrum, polarised radio emission in the nebular core. Optical continuum emission, possibly of synchrotron origin is also seen; Graser+ (1987 Mitt. A. Ges., #70, 393). The core contains a pulsar with a 39.5ms period (Kulkarni+ (1988 Nature, 331, 50); Fruchter+ (1988 Nature, 331, 53); Foster+ (1990 ApJ 356,243)), but has no X-ray counterpart, as shown by Angelini+ (1988 ApJ Let. , 330, L43). This pulsar may have a high proper motion; Fesen+ (1988 Nature, 334, 229).The extended core shares many of the optical features of the Crab, including a filled center with filaments and knots; Becker (1987 IAU Symp#125, "Origin and Evolution of Neutron Stars" eds. D. Helfand and J-H Huang, Reidel:Dordrecht, P91). Blair+ (1988 A J., 96, 1011) find that these filaments consist of both radiative and Balmer-dominated shocked material, and Hester and Kulkarni suggest that these are excited by a pulsar wind and have presented both narrow band images and spectrophotometry to support this (Hester+ (1988 ApJ Let., 331, L121); Hester+ (1989 ApJ, 340, 362)). Whitehead+ (1989 MN, 237, 1109) have investigated the kinematics of the filaments, and also present narrow band images. The kinematics suggest that either the filaments have high velocities in the plane of the sky, or else that the remnant is nearer than hitherto supposed, possibly less than 1 kpc.

The remnant 3C58 was shown to have an expansion velocity of 1100 km s^{-1} by Fesen+ (1988 IAU Colloq#101, P55). The filaments fill the entire volume, much like in the Crab, and are very strong in nitrogen emission. The remnant 0540-69.3 in the LMC shares both plerionic and oxygen-rich characteristics, and is discussed in the following section. Another example of the plerionic class may be G18.95-1.1 (Furst+,1989, AA, 209, 361).

7.2.2 Oxygen-Rich SNR. The discovery of oxygen-rich emission knots in Puppis A has placed it in the select class of Cas A- like SNR. Winkler,+ (1988 IAU Colloq. #101, p65) have shown that the system of oxygen-rich filaments is quite extensive, and from proper motions, find an expansion age of 3700+/-300 yr. Winkler+ (1989 Nature 337,48) suggest that a complex, chemically inhomogeneous swirl of filaments near the centre of Pupp A may be the result of a second SN, but the absence of X-ray or radio emission associated with it seems to make this unlikely. Teske+ (1987, ApJ , 318, 370) have investigated the bright north-eastern rim of Puppis A in the coronal lines [Fe X] 6374 and [FeXIV] 5303. By comparing these with the Einstein X-ray images, they find a flat gradient of ionisation temperature behind the shock which they ascribe to density inhomogeneities. Such clouds have been detected in CO and HI; Dubner+(1988, AASup, 75, 363).

Self consistent parameters for the Cas A SNR have been estimated by Contini (1987 A A, 183, 53). The preshock density of the hard X-Ray region, fast-moving knots, and quasi-stationary flocculi are estimated at 5, 10-50 and 100-300 cm-3 respectively, and corresponding shock velocities are 5000, 1000-4000, and < 300km s^{-1}, respectively. The necessity for such multi-component modelling has been confirmed by the EXOSAT observations; Jansen+ (1988 ApJ, 331, 949). Fesen+ (1988 ApJ Let., 329, L89) have discovered faint, outlying knots of nitrogen-rich material with very high ejection velocities indicating an explosion about AD 1680. These properties also suggest that the progenitor star was of WN class, a conclusion which is supported by a review of the properties of Cas A; Lozinskaya (1988 Tartu Astros. Obs. Teated, #89, 164). Green+ (1988 MN, 231, 735) suggest on the basis of its radio morphology that G11.2-0.3 may be a Cas A-like SNR left over from the historical supernova of AD 386.

The remnant E0102.2-72.2 in the SMC has been imaged by the HRI on the Einstein satellite; Hughes (1988 IAU Colloq. #101, P125). The X-Ray emission forms a thick ring some 6 pc in diameter. More remarkably, the X-ray spectrum appears to be fit by a single line at 0.9 keV, indicating an almost pure neon composition in the shock-heated X-ray gas. The optical and UV spectra of this remnant, and of N132D in the LMC reveals lines of C,O,Ne and Mg; Blair+ (1988 IAU Colloq. #101, P187), and Blair+ (1989 ApJ, 338, 812) suggest that models involving both shocks and X-ray photoionisation may be required to adequately describe the spectra. The remaining oxygen-rich remnant in the Magellanic Clouds; 0540-69.3 shows several plerionic features as well. Its spectrum shows a polarised optical synchrotron continuum; Chanan+ (1990 ApJ, 352, 167). This is excited by the 50mS pulsar which it contains. This pulsar appears to suffer period glitches, as determined using EXOSAT; Ogelman+ (1990 ApJ.Let., 353, L21). The surrounding nebula shows emission lines of O,S, Ar, Ni and Fe, as well as highly red-shifted Ha. Its expansion age is only 760 plus or minus 50 years; Kirshner+ (1989 ApJ, 342, 260).

7.2.3 Type I and Collisionless Shock SNR. The historical Type I SNRs are frequently found to be associated with Balmer-dominated (collisionless) shock emission. This property is thought to result from the absence of strong winds from the precursor and the absence or weakness of a UV pulse at the time of the explosion leaves the surrounding ISM undisturbed and predominantly neutral.

The proper motion of the Balmer-dominated filaments in the remnant of SN 1006 by Long+ (1988 ApJ, 333, 749) has constrained the distance to lie between 1.7 and 3.1kpc. Koyama+ (1987 PASJ., 39, 437), using Tenma, find the X-ray spectrum of SN 1006 to be softer than previously thought when the diffuse emission is corrected for.

A beautiful set of high resolution radio maps of Kepler's SNR has been obtained by Dickel+ (1988ApJ , 330, 254) showing the evolution as it expands into a variable ISM. Collisionless shocks have been found by Fesen+ (1989,ApJ, 338, L13). Smith+ (1989,ApJ, 347, 925) conclude, on the basis of EXOSAT spectra that iron is overabundant in the ejecta by at least a factor of six, and that the material behind the shock is in thermal balance, but not in ionisation equilibrium.

The X-ray emission from Tycho has been modelled on the basis of a detailed model of the ISM and a deflagration model for the supernova by both Itoh+ (1989 ApJ, 334, 279) and Brinkman+ (1989 AA, 221, 385). These models show the importance of the ionisation structure in the hydrodynamic evolution, and a distance of 2.4-3 kpc and a pre-shock density of 0.5 - 1.0 cm^{-3} is derived.

The overproduction of iron in Type I supernova events has now been directly confirmed by two very elegant observations. First, the iron produced has been seen directly in absorption in the spectrum of an OB subdwarf which lies by chance behind the remnant of SN1006 (Hamilton+ (1988 IAU Colloq. 101, p55); Fesen+ (1988 ApJ, 327, 164) ; Hamilton+ (1988 ApJ, 327, 178)), and second, it has been observed in absorption against the optical spectrum of M31 in the case of the remnant of S And; (Fesen+ 1989 ApJ Let., 341, L55).

7.3. EVOLVED SNR

7.3.1 Radio Observations. Radio evidence of distortions produced by the ISM is given in a large number of papers (Landecker+, 1987A J., 94, 111) ; Kesteven+ ,1987 A A, 183, 118; Landecker+ ,1988 IAU Colloq. #101, p245; Velusamy, 1988, IAU Colloq. 101, p261). Many new galactic SNR have been discovered in radio continuum surveys of the Galactic plane (Reich+, 1988 IAU Colloq. #101, p253), and detailed mapping of Galactic sources has continued using the many telescopes now available: Morsi+ ,1987 AASuppl Ser., 71, 189; Becker+, 1987 A J., 94, 1629; Chastenay+,1988 IAU Colloq.101, p297; Leahy+, 1988 IAU Colloq. 101, P301; Tateyama+, 1988 IAU Colloq. 101, p305; Milne+, 1988Aust. J. Phys., 40, 709; Woermann+, 1988 MN, 234, 971; Roger+, 1988 ApJ, 332, 940; Joncas+, 1989 AA, 219, 303; Junkes+, 1988 "Supernova Shells", p134; Shen+, 1990 ApJ. 356,241. Helfand+ (1989 ApJ, 341, 151) argue that most of the unidentified radio sources in the Galaxy are, in fact, SNR.

7.3.2 IR Observations. The IRAS satellite has provided a new tool for the study of SNR. Mapping of several remnants has been carried through, and provides a basis for comparison with radio data, Leahy+ (1988 MN, 235, 805). Data from this satellite has produced extensive evidence for the existence of collisionally heated dust in SNR. The question of whether this will dominate the cooling in evolved SNR has been the subject of debate. Dwek+ (1987ApJ Let., 320, L27) claim that it will, whereas Graham+ (1987 Ap J., 319, 126) argue on the basis of observations of LMC SNR that, in a two-phase medium, it will not.

The interaction of the SNR with local molecular clouds can produce shock waves which strongly excite the v = 1-0 S(1) line of H_2, giving information on both the SNR and the surrounding ISM. A particularly fine example is IC 443, in which the blast wave appears to be interacting with the remains of a molecular disk produced during the formation of the star which exploded (Burton+ (1988MN, 231, 617). This region also produces a shock-excited [O I] 63 μm line; Burton+ (1990 ApJ, 355, 197). There is clear evidence, Ziurys+ (1989, ApJ, 341, 857), of shock-induced molecular chemistry in these clouds. Shock excited molecular hydrogen has also been detected in RCW 103; Oliva+ (1989 AA, 214, 307).

7.3.3 Optical and UV Observations. There has been remarkably little optical work on evolved SNR in the period of review. Optical chelle observations of old SNR by Greidanus,+ (1988 IAU Colloq. 101, p443) have been used to demonstrate that multiple shock structures contribute to the signal at any one point. This has been confirmed by Meaburn+ (1990 AA, 227, 191) in the case of IC 443. Here the observations suggest that several wavey sheets of shocked material contribute to the final profiles. Yu-Hua Chu+ (1988 AJ., 95, 1111) has shown that associated HII region emission may also contaminate the data. Profiles of the coronal [FeX] and [FeXIV] emissions have been obtained using a Fabry-Perot for the Cygnus Loop and in IC 443 (Ballet+, 1989 AA, 211, 217, Sauvegeot+ 1990 AA, 232, 203), and images have been obtained by Brown+ (1988 ApJ, 334, 852) in IC 443. The velocity dispersions are quite small, of order 100 km s^{-1}.

7.3.4 X-Ray Observations. The recent X-ray observations by the Einstein, Tenma, and EXOSAT satellites are reviewed by Aschenbach (1988 IAU Colloq. #101, P99), and a catalog of Einstein images is given by Seward (1988 IAU Colloq. #101, P115). The X-ray data for the Cygnus Loop shows clearly that multi-component modelling is required; Tsunemi+ (1988 PASJ, 40, 449). Claas+ (1989 ApJ, 337, 399) find that RCW 86 also shows strong evidence for non-equilibrium ionisation effects in its X-ray spectrum. In the light of these and of theoretical results, the derivation of temperatures, luminosities and Sedov parameters from simple fits to X-Ray observations (Singh+(1987ApJ,322,80); Leahy (1987ApJ,322,917)) must now be considered to be an outmoded technique.

7.4. SNR IN EXTERNAL GALAXIES. The number of known SNR candidates in external Galaxies other than the Magellanic Clouds continues to mount, thank principally to optical surveys such as those in M33 by Long+ (1988, IAU Colloq. #101, P197; Long+ (1990 ApJSuppl.,72, 61). A few of these have been confirmed in M33 by VLA observations of the radio continuum; Duric (1988 IAU Colloq. #101, P289). In the radio, SN and young SNR are recognised by VLBI, and a number of these have been well studied (Bartel (1900 "Supernova Shells",P206). The extraordinary number of SNR in the starburst galaxy M82 has been emphasised by Biermann (1988, "Supernova Shells", P219). Wilkinson+

(1990 MN, 242, 529) have established, from very high resolution radio observations, that the source 41.9+58 in M83 is a shell-like remnant, decreasing in its radio luminosity. It appears to have an age of only about 50 yr, and is 50-100 times as luminous as a normal radio SNR.

Historical supernovae in other galaxies are now being detected. Long+ (1989 ApJ Let., 340, L25) have found the remnant of SN 1957D in M83 and Fesen+ (1990 ApJ, 351, 437) have found the remnant of SN 1980K in NGC 6946. A highlight of observational technique was the detection of the remnant of SN 1885,S And, in its iron-line absorption against M31 by Fesen+ (1989 ApJ Let., 341, L55).

From the radio observations of Antonucci+ (1988 ApJ Let. , 330, L97), a large population of compact sources has been found in the nuclear regions of the starburst galaxy NGC 253. A similar group has been found by Duric+ (1988 ApJ Let. , 332, L67) in NGC 4736. These bear a close resemblance to those in M82, and are a strong observation evidence for the importance of collective effects of supernova explosions in such environments.

7.5. SHOCK-WAVE THEORY. The particle acceleration processes responsible for the radio emission of SNRs is discussed by Green (1988"Genesis and Propagation of Cosmic Rays", eds. M.M. Shapiro and J.P. Wefel, NATO ASI 220 Reidel:Dordrecht, p205). Young bright SNR generally have spectral indices steeper than the 0.5 predicted by the basic shock acceleration theory.

Berkhuijsen (1987 AA, 181, 398) argues that the observed exponents of about unity in the cumulative N-D relationships for SNR are in effect, an artefact of the variations of local density in the ISM. When corrections for this are made then the data are much closer to the Sedov prediction. The developments that have occurred in the theory of shock propagation in a clumpy medium has been reviewed by McKee (1988 IAU Colloq. 101, P201), and the details of the magnetic field amplification, and synchrotron emission has been treated by Dickel+ (1988 IAU Colloq. 101, P235), Dickel+ (1989 ApJSup., 345, L21) and Schickeiser+ (1989 AA, 219, 192). Particle acceleration at modified shock fronts is discussed by Schneider + (1989 AA, 217, 344) and Kirk+ (1989 AA, 225, 559).

Progress in the prediction of the X-ray emission characteristics of young SNR continues to be made as models of increasing sophistication are constructed. The need for non-equilibrium ionisation solutions for the ionisation balance of the light elements is now generally recognised (Markert+ (1988, IAU Colloq. 101, P129); Smith+ (1988, IAU Colloq. 101, P133); Brinkmann+ (1988 IAU Colloq. 101, P137); Fischbach+ (1988 IAU Colloq. 101, P153)). Some authors are also taking the possibility of non equilibration of the electronic and ionic temperature into account (Jerius+ (1988 IAU Colloq. 101, P145), Jerius+ (1988 ApJSuppl Ser., 66, 99)). Two temperature radiative shockwave models with thermal conduction have been developed by Kazimierz+ (1989 ApJ, 336, 875). The effects of charge-transfer effects behind the shock on the theoretical X-ray spectra of SNR has been investigated by Wise+ (1989 ApJ, 345, 384). The importance of the growth of density perturbations in radiative shocks has been discussed by Blondin+ (1989, ApJ Let., 345, L21). However, Smith (1989 MN, 238, 235) has demonstrated that magnetic field serve to stabilise instabilities and prevent the formation of secondary shocks for velocities of less than 200 km s^{-1}. Cargill+ (1988 ApJ Let., 329, L29) have suggested that plasma instabilities between the reflected and/or transmitted ions and the background electrons at the foot of collisionless shock fronts in SNR can give rise to rapid anomalous electron heating. This could explain 10keV X-ray emission of SNR. The hard (>10keV) emission in SNR has been explained by Asvarov+ (1990 AA, 229, 196) as due to electron bremsstrahlung from Fermi-accelerated electrons at the shock front. Acceleration efficiencies of 10^{-3} to 10^{-4} are required.

The theoretical description of the optical and UV emission line spectrum of oxygen-rich SNR remains problematic. for example, see Itoh (1988 PASJ, 40, 673). Simple low-velocity radiative shocks are inadequate. Electron conduction must certainly be taken into account; Borkowski+ (1990 ApJ., 348, 169). This produces a warm extended photoinised region which can emit the [OI] line observed. Possibly a new mechanism is needed. Dopita (1988 Aust. J. Phys., 40, 789) suggests that the emission may arise from an R-Type photoionisation front driven into a cloud by the X-ray emitting fast shock.

The theory of molecular shocks has seen rapid progress as the chemistry of meolecular dissociation and reformation has been properly accounted for by Hollenbach+ (1989, ApJ, 342, 306), Neufeld+ (1989 ApJ, 340, 869) and Neufeld+ (1989 ApJ, 344, 251). The role of ionisation and SNR in the destruction of molecular clouds is discussed by Yorke+ (1989, AA, 216, 207).

The dynamics of the SNR shells has been investigated by Cioffi+ (1988 ApJ, 334, 252) and by Band+ (1988 ApJ, 334, 266). These studies demonstrate the importance of the time of onset of cooling, and on configuration of the initial ejecta and the density distribution around the supernova. Ciotti+ (1989 A Ap, 215, 347) and Tenorio-Tagle+ (1990 MN, 244, 563) have looked at the expansion of SNR within a pre-existent cavity, whilst Itoh+ (1989 MN, 236, 885) have investigated the effect of the circumstellar medium on the X-ray emission from young SNR. Koo+ (1990 ApJ, 354, 513) have developed an elegant analytic treatment for the propagation of nonrelativistic blast waves in media of finite mass such as in exponential, gaussian and power-law atmospheres. This represents a considerable advance on the Kompaneets approximation.

The relation between super-bubbles and the triggering of star formation has been the subject of several theoretical studies. Tenorio-Tagle+ (1987 A Ap, 186, 287) show that differential rotation cannot prevent the formation of molecular clouds in the swept-up material around an evolved OB association. Two dimensional hydrocode modelling of multi-SNR by Tenorio-Tagle+ (1987A A, 182, 120) shows R-T unstable breakup of supershells, a result confirmed by Igumenshchev+ (1988, A Tsirk., #1532, 21). The large scale dynamics of superbubble blowout has been treated hydrodynamically by MacLow+ (1989 ApJ, 337, 141) and the effects of this process on hot halo of galaxies, and the structure of the ISM has been considered by Norman+ (1989, ApJ, 345, 372).

8. PLANETARY NEBULAE (S. Pottasch)

8.1. GENERAL STUDIES. There are several **symposium proceedings** dedicated completely or in part to PN research: Torres-Peimbert (1988), Kwok+ (1987), Bianchi+ (1988), Kondo (1987), Azzopardi+ (1987), Mennessier+ (1990), Priete-Martinez (1988), and Acker (1990). The individual contributions of these symposia constitute a general review of many of the individual fields, and will generally not be cited here. A new general **catalog** of PN should be available at the end of 1990 (Acker+ 1990 ESO). A large listing of radio measurements has

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become available by Zijlstra+ (1990, AASup, 79, 329) and by Aaguist+ (1990, AASup, 84, 229). Misclassified nebulae have been discussed by Acker+ (1987, AASup, 71, 163), by Zijlstra+ (1990, AASup, 82, 253), by Acker+ (1990, AASup, in pr). A spectral atlas of PN in the ultraviolet has been made by Feiblemann+ (1988, NASA RP-1203). A catalog of expansion velocities has been made by Weinberger (1989, AASup, 78, 301). **Reviews** of PN are: Planetary Nebulae, 1988, IAU Symp 131, ed. S. Torres-Peimbert (Kluwer, Dordrecht); Late Stages of stellar evolution, 1987, ed. S. Kwok and S.R. Pottasch (Reidel, Dordrecht); Mass Outflows from Stars and Galactic Nuclei, 1988, ed. L. Bianchi and R. Gilmozzi (Kluwer, Dordrecht); Exploring the Universe with the IUE Satellite, 1987, ed. Y. Kondo, (Reidel, Dordrecht); Stellar Evolution and Dynamics in the Outer Halo of the Galaxy, 1987, ed. N. Azzopardi and F. Matteucci (ESO Workshop Proceedings No.27); Planetary Nebulae, 1990, ed. A. Acker, (Strasbourg Proceedings CNRS-URA 1280); From Mira to Planetary Nebulae, 1990, ed M.O. Mennessier and A. Omont; Proceedings Montpellier Workshop (Editions Frontieres, Paris). The **classification** of PN has been amended by Faundez-Abans+ (1987, AA, 183, 324), Kondrat'eva (1987, Alma Ata, 48, 22), Amnuel+ (1989, ApSpSci, 154, 21). **New PN** have been reported by Kinman+ (1988, AJ, 95, 804), by Lundstrom+ (1988, AA, 196, 233), Gasparyan+ (1988, Af, 82), Manchado+ (1989, AA, 218, 267), Cappellaro+ (1989, AA, 218, 241), Kwitter+ (1989, AJ, 97,1423), Menzies+ (1990, MN, in pr.), Hu+ (1990, AA, 234, 435), Melmer+ (1990, MN, 243, 236), Garcia-Lario+ (1990, AASup, 82, 527). A large listing of new PN has been given by Pottasch+ (1988, AA, 205, 248) and Ratag+ (1990, AA, 233, 181). **Photography** of PN in the direction of the galactic center have been made by Moreno+ (1988, PASP, 100, 620). Hβ photometry of 460 PN is reported by Acker+ (1989, AASup, 77, 487).

8.2. DISTANCES. The problem of distance determination is a critical one. Individual distances have been studied by Gathier (1987, AASup, 71, 245), Huemer+ (1988, AASup, 72, 383), Weinberger+ (1988, AA, 191, 297), Gurzadyan+ (1988, Akad.Nauk SSSR, 300, 316), Masson (1989, ApJ, 336, 294), Gomez+ (1989, ApJ, 345, 862), and Masson(1989, ApJ, 346, 243). A discussion of PN scale heights has been made by Zijlstra+ (1990, AA, subm).

Related to distance determinations are the work of Faundez-Abans+ (1988, Rev.Mex.AA, 16, 105) on abundance gradients, and the properties of galactic center PN by Pottasch (1990, AA, 236, 231). A statistical discussion is given by Weidemann (1989, AA, 213, 155).

8.3.MORPHOLOGY. Multiple shell nebulae have been studied by Chu+ (1987, ApJSup, 64, 529) and Middlemass+ (1989, MN, 239, 1 and 5p), extended emission by Monk+ (1990, MN, 242, 457) and Phillips+ (1990, AA, in pr.), Manchado+ (1989, AA, 222, 219), Bassgn+ (1989, AA, 218, 273)

Morphological studies (including kinematic interpretation) have been made by Balick (1987, AJ, 94, 671), Balick+ (1987, AJ, 94, 948, 958 and 1641), Lopez (1987, AA, 186, 303), Lutz (1987, PASP, 99, 1148), Bennett (1987, ApJLet, 323, L123), Hua (1988, AA, 193, 273), Clayton (1988, AA, 195, 263), Aspin+ (1988, AA, 196, 227), Hoey (1988, Ir.AJ, 18, 227), Juguet+ (1988, AA, 205, 267), Icke+ (1989, AJ, 97, 462), Balick (1989, AJ, 97, 476), Pismis (1989, MN, 237, 611), Soker (1989, ApJ, 340, 927), Aaquist+ (1989, AA, 222, 227),

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Igumenschchev+ (1989, Af, 30, 282), Garay+ (1989, AA, 215, 101), Morris+ (1990, PASP, in pr), O'Dell+ (1990, ApJ, in pr), Kalm+ (1990, MN, 242, 505), Breitschwerdt+ (1990, MN, 244, 521), Walton+ (1990, AA, 230, 445), Pascoli (1990,AA, 232,184), (1990,AASup,83,604), and Hippelein+ (1990,AA,in pr). An interesting morphological model has been proposed by Masson (1990, ApJ, 348, 580); one for NGC 7027 has been given by Middlemass (1990, MN,244,294)

8.4. MOLECULES, H_2, and H I OBSERVATIONS. Molecular hydrogen is an important indicator that a PN is ionization bounded. It has been studied by Zuckerman+ (1988, ApJ, 324, 501),Gussie+ (1988, JRASC, 82, 69), Reay+ (1988, MN, 232, 615), Greenhouse+ (1988, ApJ, 325, 604), Dinerstein+ (1988, ApJLet, 327, L27), Webster+ (1988, MN, 235, 533)

Many more OH sources have been found. Studies are by Payne+ (1988,ApJ, 326, 368), Zijlstra+ (1989, AA, 217, 157), Bowers+ (1989, ApJ, 347, 325), Lewis (1990, AJ, 99, 710), Lewis+ (1990, ApJ, in pr), Tamura+ (1990, AA, 232, 195), and Shibata+ (1989, ApJ, 345, L55). CO has been studied by Healy+ (1988, AJ, 95, 866), Likkel+ (1988, AA, 198, L1), Bachiller+ (1989, AA, 210, 366), Bujarrabal+ (1988, AA, 204, 242), Gammie+ (1989, ApJ, 345, L87), Huggins+ (1989, ApJ, 346, 201),Sahai+ (1990, AA, in pr), Woodsworth+ (1990, AA, 228, 503). Other molecules studied include C_3H_2 by Cox+ (1987, AA, 181, L19), HeH+ by Moorhead+ (1988, ApJ, 326, 899), HCO^+ and HCN by Deguchi+ (1990, ApJ, 351, 522). Neutral hydrogen in IC 418 has been studied by Taylor+ (1988, JRASC, 82, 276), (1989, ApJ, 340, 932), (1990, ApJ, 351, 515). Proto-plantetary nebulae are discussed in some of the above and Kwok+ (1988, JRASC, 82, 288),Volk+ (1989, ApJ, 342, 345), Hrivnak+ (1989, ApJ,346, 265).

8.5. BINARY STARS. Binary PN can yield important information about distance and the only independent information concerning the central star mass. A35 has been studied by Jasniewicz+ (1988, AA, 189, L7), (1990, AA, in pr). LT5 by Noskova(1989, AZh, 15, 346), HFG 1 by Acker+ (1990, AA, 233, L21). The effect of close binaries on the morphology has been discussed by Bond+ (1990, ApJ, 355, 568).

8.6. CENTRAL STARS. Photometry and/or spectra photometry have been obtained by Louise+ (1987, AASup, 70, 201), Golovatyj (1987, AZH, 13, 589), Bianchi+ (1987, AA, 181, 85), Heber+ (1988, AA, 194, 223), Gathier+ (1988, AA, 197, 266), Tylenda+ (1989, AASup, 77, 39), Shaw+ (1989, ApJSup, 69, 495), Kaler+ (1989, ApJSup, 70, 213), Mendez+ (1990, AA, 229, 152), Schonberner+ (1990, AA, 231, L33), Mendoza (1990, AA, 233, 137), and Jacoby+ (1989, AJ, 98, 1662).

Central star temperatures have been obtained by Golovatyj (1987, AZh, 64, 724; Sov.A, 31, 379, Sov.ALet, 13, 246), Mendez+ (1988, AA, 190, 113), Mendez+ (1988, AA, 198, 287), Walton+ (1988, AA, 200, L21), Jacoby (1988, ApJ, 333, 193), Gurzadyan (1988, ApSpSci, 149, 343), Gleizes+ (1989, AA, 222, 237), Egikyan (1989, Af, 30, 270), Patriarchi+ (1989, ApJ, 345, 327), Kaler+ (1989, ApJ, 345, 871), Preite-Martinez+ (1989, AASup, 81, 309), Heap+ (1990, ApJ, 353, 200), and Grewing+ (1990, AA, in pr). Stellar winds have been discussed by Lucy+ (1987, AA, 188, 125), Kaler+ (1988, ApJ, 324, 528), Perinotto+ (1989, ApJ, 337, 382), Nikitin+ (1989, Af, 30, 151), Cerruti-Sola+

(1989, ApJ, 345, 339), Hutsemekers+ (1989, AA, 219, 237). Identifications have been made by Kwitter+ (1988, AJ, 96, 997).

8.7. ABUNDANCES AND OTHER SPECTROSCOPIC STUDIES. Abundance studies almost invariably deal with the physical conditions in the nebulae as well, and some have sufficiently detailed spectroscopic observations to enable nebulae to be modeled. Studies have been made of Hu 1-2 (Sabbadin+, 1987, AA, 182, 305), SwSt1 (de Freitas Pacheco+, 1987, MN, 227, 773), CPD-56\circ 8032 and He2-113 (Kameswara Rao, QJRAS, 1987, 28, 261), NGC 6879 and 6881 (Kaler+, 1987, PASP, 99, 952), NGC 6720 (Barker, 1987, ApJ, 322, 922), NGC 2242(Garnett+, 1988, AJ, 95, 119; 1989, PASP, 101, 541), A78 (Manchado+, 1988, AA, 191, 128), He2-277 and He 1312 (de Freitas Pacheco+, 1987, RevMexAA, 15, 89), K3-66, 67 and 71 (Tamura+, 1987, PASP, 99, 1264), NGC 6565 and 6644. (Aller+, 1988, PASP, 100, 192), NGC 6826 (Barker, 1988, ApJ, 326, 164), Keyes+ (1990, PASP, 102, 59), (Pegiugnot+, 1988, AA, 206, 298). NGC 7027 (Aller+, 1988, Proc.NAcSci, 85, 2417), NGC 6153 and IC 4593) (Anandarao+, 1988, AA, 202, 215), He2-104 (Lutz, 1988, IAU Coll 103, 305; Schwarz+, 1989, ApJ, 344, L29), DDDM1 (Shchelkanova, 1988, AZh, 65, 943; SovA, 32, 493), H 12 (Miranda+, 1989, AA, 214, 353), NGC 1535 (Barker, 1989, ApJ, 340, 921), PN in M22, (Cohen+, 1989, ApJ, 346, 803), He2-99 (Kaler+, 1989, ApJSup, 70, 213), M2-9 and M1-91 (Goodrich, 1990, ApJ, in pr), NGC 2242 and NGC 4361(Torres-Peimbert+, 1990, AA, 233, 540).

A large study of 51 PN has been made by Aller+ (1987, ApJSup, 65, 405; 1988, Sym.Cos. Abun.) Galactic bulge nebulae have been studied by Webster (1988, MN, 230, 337). The Ne/O ratio has been studied by Henry (1989, MN, 241, 453). Several nebulae have further been studied by Gutierrez-Moreno+ (1988, PASP, 100, 1497), Rowlands+ (1989, ApJ, 341, 901), Acker+ (1989, AASup, 80, 201). The effect of density variations has been studied by Rubin (1989, ApJSup, 69, 897).

Studies of helium have been made by Peimbert+,(1987, RevMexAA, 14, 540; 15, 117), Pequignot+ (1988, AA, 191, 278), Maciel (1988, AA, 200, 178). Electron densities are given by Stanghellini+ (1989, ApJ, 343, 811). Magnesium has been studied by Middlemass(1988, MN, 231, 1025); Silicon by Ashley+ (1988, ApJ, 331, 532), Argon by Keenan+ (1988, AA, 202, 253), Ratag+ (1990, AA, 227, 207), Oxygen by Barnett+ (1988, MN, 234, 241), Meatheringham+ (1988, ApJ, 334, 862), O'Dell+ (1989, ApJ, 341, L79), Rudy+ (1989, ApJ, 346, 799), Keenan+ (1990, ApJ, 350, 262). Atomic parameters have been studied by Nikitin+ (1987, Tartu AO, 52, 262, 270), Viegas-Aldrovandi (1988, ApJ, 331, 523), and Keenan+ (1988, JAA, 9, 237), (1989, JAA, 10, 147).

Filling factors have been discussed by Mallik+ (1988, RevMexAA, 16, 111).

8.8. DUST AND INFRARED RADIATION. The 3.3 μm feature has been studied by Martin (1987, AA, 182, 290), Nagata+ (1988, ApJ, 326, 157). A 21 μm feature has been discussed by Kwok+ (1989, ApJ, 345, L51) and 25 μm feature by Cox (1990, AA, in pr). Spectroscopic images of NGC 7027 are given by Woodward+ (1989, ApJ, 342, 860) and for NGC 6572 and BD+30° 3639 by Hora+ (1990, ApJ, 353, 549). Near infrared photometry has been made by Pena+ (1987, RevMexAA, 14, 534) and Preite-Martinez+ (1989, AA, 218, 264). Dust grains are discussed by Lenzuni+ (1989, ApJ, 345, 306); the dust content of two

PN by Hoare (1990, MN, 244, 193). Scattering of soduim D has been studied by Dinerstein+ (1988, ApJ, 335, L23).

Studies based on IRAS measurements include Hu (1987, AASin, 7, 317), Leene+ (1988, AA, 202, 203), Hoare+ (1988, MN, 235, 1049), Cohen+ (1989, ApJ, 341, 246),Jourdain de Muizan + (1990, AASup, 83, 337) Cn1-1 has been studied by Bhatt (1989, AA, 214, 331)

8.9. SPECIAL STUDIES. The CIII/Si III ratio has been studied by Feibelman+ (1987, ApJ, 319, 407).A discussion of nebular models has been given by Aller (1987, PASP, 99, 1145).Dynamics are discussed by Icke+ (1989, AA, 211, 409) and Bobrowsky+ (1989, ApJ, 347, 307); recombination lines and microturbulence by Vallee+ (1990, 230, 457). Pulsations have been discussed by Liebert+ (1988, PASP, 100, 187), Bond+ (1990, AJ, in pr) Condensations in NGC 7293 have been studied by Dyson+ (1989, MN, 241, 625). A possible stellar wind in CRL 618 has been discussed by Martin-Pintado (1988, AA, 197, L15). X-ray observations have been discussed by Tarafdar+ (1988, ApJ, 327, 342; 343, 1007), Apparao+ (1989, ApJ, 344, 826).A catalogue of expansion velocities has been prepared by Weinberger(1989, AASup, 78, 301). Interaction of PN with the ISM has been discussed by Borkowski+ (1990, ApJ, in pr).

8.10. EVOLUTION. Studies into one of the several aspects of PN evolution have been made by Mendez+ (1988, AA, 197, L25), Kaler (1988, PASP, 100, 627), Kaler+ (1988, AJ, 96, 1407), Kondrateva (1989, SovAl, 15, 13), Gathier+ (1989, AA, 209, 369), Stasinska (1989, AA, 213, 274), Zijlstra+ (1989, AA, 216, 245), Tylenda+ (1989, AA, 217, 209), Kostyakova+ (1989, A Tsirk.1537, 9), Pottasch+ (1989, AA, 221, 123), Weinberger (1989, Rev.Mod.A, 2, 167), McCarthy+ (1990, ApJ, 351, 230), Dopita+ (1990, ApJ, 357, 140), Szczerba (1990, AA, in pr), Blocker+ (1990, AA, in pr), Chan+ (1990, AA, in pr), Kaler+ (1990, ApJ, in pr), Sweigart+ (1990, ApJ, in pr), Stasinska+ (1990, AA, in pr), Harpaz+ (1990, AA, in pr)

8.11. EXTRAGALACTIC STUDIES. Important work is being done on PN in extragalactic systems, which have the advantage of being at a known distance. The use of PN as standard candles has been discussed by Ciardullo+ (1988, PASP, 100, 1218; 1989, ApJ, 339, 53; 1989, ApJ, 344, 715), Jacoby+ (1989, ApJ, 339, 39; 1989, ApJ, 344, 704; 1990, ApJ, 356, 332). Masses in the Magellanic Clouds have been discussed by Barlow(1987, MN, 227, 161). Spectroscopic studies in the Magellanic Clouds include Pena+ (1988,RevMexAA, 16, 55), Boroson+ (1989, ApJ, 339, 844), Henry+ (1989, ApJ, 339, 872). Kinematics in the MC has been discussed by Hardy+ (1989, ApJ, 344, 210).

9. INTERGALACTIC INTERSTELLAR MEDIUM (A. C. Fabian)

Relevant conference volumes are Pallavicini: 1988, *Hot Thin Plasmas in Astrophysics*, Kluwer; Fabian: 1988, *Cooling Flows in Clusters and Galaxies*, Kluwer; Oegerle+: 1990, *Clusters of Galaxies*, Cambridge UP.

Arguments based on the likely inefficiency of galaxy formation (particularly if `biasing' operates) and on winds from young galaxies predict the existence of a widespread, diffuse intergalactic medium (IGM). It is still undetected, although the

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allowed parameter range has recently been constrained to exclude a hot,uniform, X-ray background-emitting, phase (Mather+ 1990, ApJ, 354, L37). This result has been obtained from the lack of any observable Compton distortion in the spectrum of the microwave background as measured by the Cosmic Background Explorer satellite. It is therefore likely that the present temperature of the IGM lies between about 10^4 K (from the Gunn-Peterson limit on HI of Steidel+:1990, ApJ, 318, L11) and about 10^7 K. This last value depends on when the gas was heated. The necessary re-ionization of the Universe has been discussed (Shapiro+:1987, ApJ, 321, L107; Giroux+: 1990, in *Physical Processes in Fragmentation and Star Formation*, ed Capuzzo Dolcetta+, in press; Shapiro 1990, Ann NY Acad Sci, 571, 128; Donahue+ 1987, ApJ, 323, L13; Ostriker 1988, IAU Symp 130, Audouze+) and some constraints are obtained from the Lyman forest in quasar spectra (Blades+, ed.1987, *QSO Absorption Systems Probing the Universe*, Cambridge UP) if it is assumed that they are embedded in the IGM. Some indirect evidence for an IGM has also been obtained from correlating the size of radio sources with their redshift (Rosen+1988, ApJ, 330, 16).

The gross properties of intergalactic gas in clusters and groups of galaxies - the intracluster medium (ICM) - have been further studied in general (Sarazin 1988, *X-ray emission from clusters of galaxies*, Cambridge UP; Edge 1989, PhD thesis, Univ Leicester; Hatsukade 1990, ISAS preprint; Fabian 1988, in Pallavacini; Mushotzky 1988, in Pallavacini; Forman+1990, in Oegerle+, 257; Evrard 1990, in Oegerle+, 287; Cavaliere+ 1988, in Pallavacini, 315; Cavaliere+ 1988, ApJ, 331, 660; Rephaeli+ 1988, ApJ, 333, 133) and in particular clusters (Hughes+ 1988, ApJ, 327, 615; Hughes1989, ApJ, 337, 21; Crawford 1989, MN, 236, 277; David+ 1990, ApJ, 356, 32; Singh+ 1988, ApJ, 330, 620; Singh+ 1988, ApJ, 331, 672; Lea+ 1988, ApJ, 332, 81; Okumura+ 1988, ApJ, PASJ, 40, 639; Fabricant+ 1988, ApJ, 336, 77; Edge+ 1988, in Pallavacini, 335). The combination of measurements on the Sunyaev-Zeldovich decrement and the X-ray flux still gives a puzzling result (McHardy+ 1990, MN, 242, 148). More distant clusters have been found from their X-ray emission (Gioia+ 1990, ApJSupp, 72, 567). Strong evolution of the X-ray luminosity function, in the sense that the most luminous clusters are more numerous at the current epoch, has been discovered (Edge+ 1990, MN, 245, 559; Gioia+ 1990, ApJ, 356, L35). No emission has yet been detected from an intrasupercluster medium (Persic+ 1988, ApJ, 327, 1).

Cooling flows appear to be common in the cores of clusters (Arnaud 1988, Fabian, 63; Pesce+ 1990, MN, 244, 58). Strong supporting evidence for cooling has been provided by X-ray spectroscopy (Mushotzky+ 1988, Fabian, 47; Canizares+ 1988, Fabian, 63). Much observational (X-ray, optical and radio) and theoretical (for and against) has been carried out on cooling flows (Balbus+ 1989, ApJ, 341, 611; Bregman+ 1988, ApJ, 326, 639; Bregman+ 1988, ApJ, 341, 49; Begelman+ 1990, MN, 244, 26P; Hattori+ 1990, MN, 242 399; Heckman+ 1989, ApJ, 338, Johnstone+ 1988, MN, 233, 581; Jaffe+ 1988, Fabian, 145; Loewenstein 1989, MN, 238, 15; Loewenstein+ 1990, MN, 242, 120; O'Connell+1989, AJ, 98, 180; Pringle 1989, MN, 239, 479; Romanishin+ 1989, ApJ, 341, 41; Rosner+ 1989, ApJ, 338, 761; Soker+ 1990, ApJ, 348, 73; Tribble 1989, MN, 238, 1247; Tribble 1989, MN, 238, 1; Bertschinger 1989, ApJ, 340, 666). Several of these studies suggest that the ICM, deep in the cluster core, is turbulent, multiphase and at least as complex as the interstellar medium in galaxies.