34. INTERSTELLAR MATTER

(MATIERE INTERSTELLAIRE)

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I. Introduction
(M. Peimbert)

It has become more evident during the last three years that the study of interstellar matter is paramount to understand the evolution of the universe and its constituents. From observations of the present state of the interstellar medium, in our galaxy, in other galaxies, and between galaxies, it is possible to test theories of: evolution of the universe, formation and evolution of galaxies, formation and evolution of stars and of the evolution of the interstellar medium itself. The amount of information on the interstellar medium that has been gathered during the 1982-1984 period has been very large and the theoretical models that have been ellaborated to explain these observations have been very numerous, these facts show that the subject of our Commission constitutes a very active field of astronomical research.

This report covers the period 1982-1984 and is divided in self-contained sections. References are given by commonly used abbreviations (see the 1979-1981 report of the Commission). It should be noted that due to the space allotted for this report it was not possible to cover all the papers relevant to the work of our Commission produced during this period; moreover for those papers considered, only very brief summaries are presented here. A detailed list of articles on the physics of the interstellar medium and gaseous nebulae carried out in the Soviet Union in the 1981-1984 period was prepared by N.G. Bochkarev and G. Rudnitskij; only a small fraction of these articles are discussed in this report; copies of this list are available from the office of the President of Commission 34.

The presentation of this report was made possible by the generous reviewing efforts of its writers and by the cooperation of the many members of Commission 34 and others who submitted relevant information. We list below a selection of books, conference proceedings, catalogues and review articles published since 1981; many others, particularly the more specialized, are mentioned in other sections of this report.

1. MONOGRAPHS AND OTHER BOOKS

Belov, K.P.: 1983, "Magnetism on the Earth and in Space", Nauka, Moscow. (In Russian)
Duley, W.W., Williams, D.A.: 1984, "Interstellar Chemistry", Academic Press, London.
Goudis, C.: 1982, "The Orion Complex: A Case Study of Interstellar Matter", D. Reidel Publishing Co.
Gurevich, L.E., Chernin, A.D.: 1983, "Origin of Galaxies and Stars", Nauka, Moscow. (In Russian)
Hellwege, K.H., et al. (eds.): 1982, "Landolt-Börnstein, New Series, VI Vol. 2, Subvolume C: Interstellar Matter-Galaxy-Universe", Springer, Heidelberg.
Kostyakova, E.B.: 1982, "Physics of Planetary Nebulae", Nauka, Moscow. (In Russian)
Pottasch, S.R.: 1984, "Planetary Nebulae", D. Reidel Publishing Co.
Rudnitskij, G.M.: 1983, "Molecules in Astrophysics", Institute of Scientific and Technical Information, Moscow. (In Russian)
Sharov, A.S.: 1982, "The Andromeda Nebula", Nauka, Moscow. (In Russian)

Syunyaev, R.A. (ed.): 1982, "Astrophysics and Space Physics", Nauka, Moscow. (In Russian)
Vajnshtejn, S.I.: 1983, "Magnetic Fields in Space", Nauka, Moscow. (In Russian)
Zel'dovich, Ya. B., Ruzmajkin, A.A., Sokoloff, D.D.: 1984, "Magnetic Fields in Astrophysics", Gordon and Breach, London.

2. SYMPOSIUM REPORTS AND CONFERENCE PROCEEDINGS

Audouze, J., et al. (eds.): 1983, "Diffuse Matter in Galaxies", D. Reidel Publishing Co.
Battrick, B., Mort, J. (eds.): 1980, "Second European IUE Conference", ESA Special Pub. 157.
Brahic, A. (ed.): 1982, "The Formation of Planetary Systems", Cepadues Editions.
Bruhweiler, F.C., et al.(eds.): 1984, "The Local Interstellar Medium", IAU Coll. 81, in press.
Cantó, J., Mendoza, E.E. (eds.): 1983, "Symposium on Herbig-Haro Objects, T Tauri Stars and Related Phenomena", RevMexAA, 7.
Danziger, J., Gorenstein, P. (eds.): 1983, "Supernova Remnants and their X-ray Emission", IAU Symp. 101, D. Reidel Publishing Co.
Dickey, J.M., et al. (eds.): 1981, "The Phases of the Interstellar Medium", NRAO, Green Bank, WV (U.S.A.)
Flower, D.R. (ed.): 1983, "Planetary Nebulae", IAU Symp. 103, D. Reidel Publishing Co.
Glassgold, A.E., Huggins, P.J., Schucking, E.L. (eds.): 1982, "Symposium on the Orion Nebula to Honour Henry Draper", AnnNYAcadSci, 395.
Heidmann, J. (ed.): 1983, "Giant H II Complexes Outside our Galaxy", in Highlights of Astronomy, 6, 609.
Kessler, M.F., Phillips, J.P. (eds.): 1984, "Galactic and Extragalactic Infrared Spectroscopy", D. Reidel Publishing Co.
Kondo, Y., Mean, J.M., Chapman, R. (eds.): 1982, "Advances in Ultraviolet Astronomy", NASA, CP-2238.
Radhakrishnan, V. (ed.): 1983, "The Violent Interstellar Medium", in Highlights of Astrononomy, 6, 655.
Rees, M.J., Stoneham, R.J. (eds.).: 1981, "Supernovae: a Survey of Current Research", D. Reidel Publishing Co.
Rolfe, E., et al. (eds.): 1982, "Third European IUE Conference", ESA Special Pub. 176.
Roger, R.S., Dewdney, P.E. (eds.): 1982, "Regions of Recent Star Formation", D. Reidel Publishing Co.
Shaver, P.A., Kunth, D., Kjär, K. (eds.): 1983, "Primordial Helium", European Southern Observatory.
van den Bergh, S., de Boer, K. (eds.): 1984, "Structure and Evolution of the Magellanic Clouds", IAU Symp. 108, D. Reidel Publishing Co.
Wolstencroft, R.D. (ed.): 1984, "Star Formation Workshop", Royal Observatory, Edinburgh.
Wolstencroft, R.D., Greenberg, J.M. (eds.): 1984, "Laboratory and Observational Infrared Spectra of Interstellar Dust", Hilo Workshop, Royal Observatory, Edinburgh.

3. CATALOGUES AND SURVEYS

Alfërova, Z.A., et al.: 1983, "Catalogue of Positions, Angular Sizes, and Flux Densities of Galactic Radio Sources at 21 cm, Astrofiz. Issled. Izv. Spec. Astrophys. Observ., 17, 67.
Blitz, L., Fich, M., Stark, A.A.: 1982, "Catalogue of CO Radial Velocities Toward Galactic H II Regions", ApJSuppl,49, 183.
Gulyaev, S.A., Sorochenko, R.L.: 1983, "Catalogue of Recombination Lines", Prepr. Phys.Inst.Acad.Sci.USSR, Nos: 145,146,168.
Hodge, P.W., Kennicutt, R.C.Jr.: 1983, "An Atlas of H II Regions in 125 Galaxies", AJ, 88, 296.

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Maciel, W.J.: 1984, "A Catalogue of Distances of Planetary Nebulae", AASuppl, 55, 253.
Milne, D.K., Aller, L.H.: 1982, "Radio Observations at 14.7 GHz of Southern Planetary Nebulae", AASuppl, 50, 209.
Schneider, S.E., et al.: 1983, "Radial Velocities of Planetary Nebulae", ApJSupp, 52, 399.

4. REVIEW ARTICLES

*Czyzak, S.J., et al.: 1982, "The Formation and Properties of Grains in the Inter*stellar Medium", Vistas Astron, 25, 337.
Ginzburg, V.L., Ptuskin, V.S.: 1983, "Origin of Cosmic Rays", Sum.Sci.Tech.Ser. Astron.,Inst.Sci.Tech.Inf., Moscow, 24, 94.
Hildebrand, R.: 1983, "Cloud Masses and Dust Properties from Submillimeter Thermal Emission", QJRAS, 24,267.
Ho, P.T.P., Townes, C.H.: 1983, "Interstellar Ammonia", AnnRevAA, 21, 239.
Lequeux, J.: 1982, "The Chemical Composition of Gas and Grains in Dense Interstellar Clouds", Geochim.Cosmochim.Acta, 46, 777.
Lozinskaya, T.A.: 1983, "Supernova Remnants: Observational Data Evolution in the Interstellar Medium", Sum.Sci.Tech.Ser.Astron., Inst.Sci.Tech.Inf., Moscow, 22,33.
Mallik, D.C.V.: 1982, "Planetary Nebulae", BullASIndia, 10, 73.
Morris, M., Rickard, L.J.: 1982, "Molecular Clouds in Galaxies", AnnRevAA, 20, 517.
Nagirner, D.I.: 1983, "Theory of Transfer of Radiation in Spectral Lines", Sum.Sci. Tech.Ser.Astron.,Inst.Sci.Tech.Inf., Moscow, 22, 220.
Pagel, B.E.J., Edmunds, M.G.: 1981, "Abundances in Stellar Populations and the Interstellar Medium in Galaxies", AnnRevAA, 19, 77.
Peimbert, M. et al.: 1984, "Interstellar Matter and Chemical Evolution", Science, 224, 345.
Raymond, J.C.: 1984, "Observations of Supernova Remnants", AnnRevAA, 22, 75.
Schwartz, R.D.: 1983, "Herbig-Haro Objects", AnnRevAA, 21, 209.
Shore, S.N. et al.: 1984, "Stochastic Processes in Astrophysics: Stellar Formation and Galactic Evolution", Adv.Chem.Phys., in press.
Shull, J.M., Beckwith, S.: 1982, "Interstellar Molecular Hydrogen", AnnRevAA, 20,163.
Stein, W.A., Soifer, B.T.: 1983, "Dust in Galaxies", AnnRevAA, 21, 177.
Torres-Peimbert, S.: 1984, "Nucleosynthesis and Planetary Nebulae", in Chiosi and Renzini (eds.), "Stellar Nucleosynthesis", D. Reidel Publishing Co., p. 3.
Trimble, V.: 1983, "Supernovae. Part II. The Aftermath", Review of Modern Physics, 55, 511.
York, D.G.: 1982, "Gas in the Galactic Halo", AnnRevAA, 20, 221.

II. Diffuse Interstellar Medium

(J. Lequeux, U. Mebold)

This review covers the literature from July 1981 to mid -84, but does not pretend to be complete. Emphasis has been put on observations, but some theoretical work is also cited. Overlaps with other sections are unavoidable. Amongst topics not or very incompletely covered one finds: atomic and molecular processes, interstellar chemistry, acceleration and interaction of cosmic rays with interstellar matter, topics related to galactic structure.

The last 3-year period has mainly seen a series of high quality observations or of reanalysis of earlier observations (i.e. Copernicus) aiming at precising physical parameters and at checking and refining ideas which emerged in the previous period: multi-component, non-stationary structure of the interstellar medium (ISM), role of stellar winds, supernova explosions, ionization fronts and shock waves in general, origin and structure of the gaseous halo, etc. A wealth of efforts has also been devoted to the local ISM. The reader should look at the introduction for a list of general references and review papers, some of which cover the present topics.

1. THE DIFFUSE DISK ISM: PHYSICAL PARAMETERS, CHEMICAL COMPOSITION

Survey-like HI observations supplemented the available information about the galactic structure. Blitz (1983, in Surveys of the Southern Galaxy, ed. Burton & Israel, 117) and Blitz et al. (1981, BullAAS, 13, 539) deal with the spiral structure of the outer parts of the galaxy. Kerr, (1983, in Kinematics, Dynamics and Structure of the Milky Way, ed. Shuter, 91) studied the HI distribution in the outer galaxy and the thickness and the total mass of the HI Layer. Westerhout and Wendlandt (1982, AASuppl, 49, 143) finally published their atlas of the HI distribution near the galactic plane (2°>b>-2°). A survey at 31 <ℓ<64°, -3° <b<3° with the Arecibo telescope by Bania and Lockman (1984, ApJSuppl, 54, 513) is used to study HI self-absorption features. The results of the Pulkovo sky HI line survey are presented in various forms (Bystrova, 1981, Nauka; Bystrova, 1983, IzvSAO, 17, 63; Bystrova & Tselovalnicov, 1983, in VINITY, No. 5036-83D; Bystrova, 1984, IzvSAO, 18, 94). Special effort went into completing the coverage of the southern galactic plane (Bajaja, 1983, in Surveys of the Southern Galaxy, ed. Burton & Israel, 49; Kerr, l.c. 113; Riley, l.c.55; Olano et al. 1981, AASuppl, 46, 41). Other publications treated the central part of the galaxy (Rohlfs and Braunsfurth, 1982, AA, 113, 237; Lockmann, 1983, BullAAS, 15, 661). HI absorption line surveys were published and discussed by Mebold et al. (1981, AASuppl, 46, 389; 1982, AA, 115, 223) and Dickey et al. (1983, ApJSuppl, 53, 591). Payne et al. (1982, ApJSuppl, 48, 199) report on emission and absorption observation of extended background sources.

New Zeeman measurements were discussed by Troland and Heiles (1982, ApJ, 252, 179) and Heiles et al. (1981, BullAAS, 13, 828). Liszt et al. (1982, ApJ, 261, 102) carried out HI absorption measurements in the direction of 3C123. Statistical analyses of HI clouds were presented by Anantharamaiah et al. (1984, AA, 138, 131) and by Belfort and Crovisier (1984, AA, 136, 368).

The association of HI to specific galactic objects is frequently discussed. Rodríguez and Moran (1982, Nature, 299, 323) find an association of an HI component at -40 km s^{-1} with the nebula 6302. Braunsfurth (1983, AA, 117, 297) investigated the HI-gas in the Cas OB6 association. Near the molecular cloud in W3 and W4 Hasegawa et al. (1983, AJ, 88, 658) found a fragmentary cold cloud. Bania (1983, AJ, 88, 1222) found HI self-absorption towards an anonymous OB association (ℓ = 55°, 6, b = 0). Pöppel et al. (1982, RevMexAA, 5, 223) observed HI emission related to Gould's belt, and Bystrova (1984, in Structure and Evolution of the Magellanic Clouds, ed. van den Bergh & de Boer, 139) searched for low velocity HI in the Magellanic Stream.

The association of HI, CO and occationally OH was studied in a number of investigations. Wannier et al. (1983, ApJ, 268, 727) compared CO line emission with HI observations and found indications for warm HI halos around molecular clouds. Kazès and Crovisier (1981, AA, 101, 401) investigated the correlation of HI emission and absorption with CO emission and OH absorption lines. The association of CO emission with cold HI is studied by Peters and Bash (1982, in Regions of Recent Star Formation, ed. Roger & Dewdney, 469). King et al. (1982, MN, 198, 255) studied the relation between HI and dust near the south celestial pole.

The general ionization of the disk ISM has been studied using the dispersion of pulsar radio signals (Vivekanand and Narayan, 1983, JAA, 3, 399) combined or not with Hα diffuse emission (Reynolds, 1983, ApJ, 268, 698 and in preparation): it appears that 10 - 30% of the IS volume is filled with ionized gas at $T \cong 10^4$ K with $n_e \cong 0.1 - 0.2$ cm^{-3}. O stars and perhaps planetary nebulae are responsible for this ionization (Reynolds, 1984, ApJ, 282, 191). This gas has a z-extent of at least 500 pc (Reynolds, in preparation). It may be responsible at least in part for the CIV and SiIV absorption lines in the disk (Cowie et al. 1981, ApJ, 248, 528), although CIV sometimes comes from hotter gas. The presence of very hot gaseous components with $8\times10^4 < T < 10^7$ K has been confirmed by many observations at IS lines in

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the UV (cf. H[illegible]quist and Snijders, 1982, Nature, 299, 783), and in the soft X-ray continuum (Garmire, 1983, in IAU Symp. 101, 347; Mc Cammon et al. 1983, ApJ, 269, 107) and lines (Schnopper et al. 1982, ApJ, 253, 131; Rocchia et al. 1982, AA, 130, 53). The contribution of the warm and hot medium to the far UV background through line or 2 photon emission is controversial (Feldman et al. 1981, ApJ, 249, L51; Deharveng et al. 1982, AA, 109, 179; Paresce et al. 1983, ApJ, 266, L107; Zvereva et al. 1982, AA, 116, 312; Paresce et al. 1983, AA, 124, 300; Joubert et al. 1983, AA, 128, 114). A large fraction of the hot medium is contained inside bubbles, shells and supershells (see later).

The abundance of elements in the ISM has been the subject of many papers. Extensive series of data obtained using Copernicus, or optical observations can be found in Rogerson and Upson (1982, ApJSuppl, 49, 353), Chaffee (1982, ApJSuppl, 50, 169), Bohlin et al. (1983, ApJSupp, 51, 277) and Hobbs (1984, ApJSuppl, in press). New discussions of the abundance of deuterium yield a small value $D/H \cong 5\ 10^{-6}$ (Laurent, 1983, in Primordial Helium, Shaver et al. ed., ESO, p. 335; Vidal-Madjar, 1983, in Diffuse Matter in Space, Audouze et al. eds., Reidel, p. 57; Vidal-Madjar et al. 1983, AA, 120, 58). Lithium appears to be not much depleted with respect to solar abundances (Snell and Vanden Bout, 1981, ApJ, 250, 160; Hobbs, 1984, ApJ, in press), but the $^7Li/^6Li$ *ratio is* >25 (Ferlet and Dennefeld, 1983, in Primordial Helium, ed. Shaver et al. ESO, p. 373). Na, K, Rb, Mg, Zn are not much depleted either (Jura and Smith, 1981, ApJ, 251, L43; York and Jura, 1982, ApJ, 254, 88; Chaffee, 1982, op.cit.; Harris et al. 1983, MN, 203, 1225; Murray et al. 1984, ApJ, 282, 481; Phillips et al. 1984, MN, 206, 337). This is also the case for C, N and O (Hobbs et al. 1982, ApJ, 252, L21; Vidal-Madjar et al. 1982, ApJ, 260, 128; York et al. 1983, ApJ, 266, L55). Conversely, many elements are known to be considerably depleted, and there is a general consensus that depletion increases with column density, hence presumably volume density. This is the case for Si (Snow and Joseph, 1981, AJ, 86, 1916), Al (Barker et al. 1984, ApJ, 280, 600), Ca (Snow et al. 1983, ApJ, 265, L67, and others), Cl (Harris and Bromage, 1984, MN, 208, 941) and possibly B (York et al. 1982, ApJ, 255, 524); see also the more general studies by Phillips et al. 1982, MN, 200, 687; Cardelli and Böhm-Vitense, 1982, ApJ, 262, 213; and Tarafdar et al. 1983, ApJ, 267, 156. Fe, also very depleted, poses a special problem since a number of oscillator strengths had to be determined through astrophysical observations (Lugger et al. 1982, ApJ, 257, 135; Shull and van Steenberg, 1983, ApJ, 271, 408). However Nussbaumer et al. (1981, AA, 102, 351) have recalculated f values for FeII, and more recently Nussbaumer and Storey (1984, AA, in press) have done the same for CI. An interesting old observation has been confirmed by many new ones: the depleted elements (Ca, Ti, etc.) are less depleted in high velocity components (Martin and York, 1982, ApJ, 257, 135; Hobbs, 1983, ApJ, 265, 817, etc.). Several authors see in this property the effect of sputtering of grains by relatively high energy particles (Trivedi and Larimer, 1981, ApJ, 248, 563; Duley, 1982, ApSpSc, 85, 221).

A number of studies of the physical conditions in the diffuse clouds have used optical and UV lines of atoms and molecules: Federman and Hobbs, 1982, ApJ, 265, 813; Snow, 1983, ApJ, 266, 576; Welsh, 1983, ApSpSc, 90, 437; Jenkins et al. 1983, ApJ, 270, 88; Younan and Dufton, 1984, MN, 209, 123, and others.

A large number of papers are concerned with molecules in diffuse clouds. Tentative detections of CS^+ (Ferlet et al. 1983, AA, 125, L5), and of H_2O (Snow et al. 1981, ApJ, 250, 163), have been reported. H_2O^+ could not be found (Hayden Smith et al. 1984, ApJ, 277, 196), as well as C_3 (Clegg and Lambert, 1982, MN, 201, 723). Many new observations concern C_2, an interesting tracer of temperature but which may be affected by radiative pumping (Hobbs and Campbell, 1982, ApJ, 254, 108; van Dishoeck and Black, 1982, ApJ, 258, 533; Danks and Lambert, 1983, AA, 124, 188; Hobbs et al. 1983, ApJ, 271, L95; Lutz and Crutcher, 1983, ApJ, 271, L101, Dishoeck and de Zeeuw 1984, MN, 206, 383). CO and ^{13}CO have been observed and discussed by Wannier et al. 1982, ApJ, 254, 100, and Tarafdar and Krishna Swamy, 1982, MN, 200, 431, and CH by Federman (1982, ApJ, 253, 601 and 257, 125), Danks et al. (1984, AA, 130, 62) and Bouloy et al. (AA, 130, 380). The abundances of C_2, CO, CH and CN are reasonably well predicted by standard gas-phase chemistry (Dickman et al. 1983, ApJSupp, 53, 55; Federman et al. 1984, BullAAS, 16, 484), although formation on grains cannot be excluded (Pickles and Williams, 1981, MN, 197, 429; Mann and Williams, 1984, MN, 209, 33). The exception remains CH^+, although its rate of formation by radiative association has been revised upwards by Graff et al. (1983, ApJ, 269, 796): the general consensus is that it is formed in shocks (see e.g. Federman, 1982, op. cit.; Dickman, 1983, op. cit.; Mitchell and Watt, 1984, BullAAS, 16, 464). New analyses of the formation of H_2 have been published by Snow (1983, ApJ, 269, L57) and Jenkins et al. (1983, ApJ, 270, 88).

Diffuse interstellar bands may be due to isolated molecules, but they will be treated in the section on grains.

2. THE LOCAL ISM

A comprehensive review of the local interstellar medium is given in the proceedings of the IAU Coll. 81 (1984). New analyses of the H and He lines scattered by the ISM streaming into the solar cavity show that the hydrogen in this gas is 20-30% ionized, has a density of the order of 0.1 cm^{-3} and a temperature of 10^4 K (Burgin, 1981, Comments Ap, 9, 157; Blum, 1981, AdvSpRes, 1, 197, COSPAR; Ripken and Fahr, 1983, AA, 122, 181; Kunc et al. 1983, Planet SpSc, 31, 1157; Wallis, 1984, AA, 130, 200; Dalaudier et al. 1984, AA, 134, 171). Partial indications suggest that this gas extends to a few parsecs and is photoionized (Crutcher, 1982, ApJ, 254, 82; Oegerle et al. 1982, ApJ, 252, 302; Bobroff et al. 1984, AA, 277, 678). However, the density decreases further away and the temperature rises sharply, suggesting that we are dealing with a bubble or superbubble interior (Frisch, 1981, Nature, 293, 377; Bruhweiler and Kondo, 1981, ApJ, 248, L123; 1982, ApJ, 259, 232 and ApJ, 260, L91; Innes and Hartquist, 1984, MN, 209, 7). However the existence of absorption lines at various radial velocities in the spectra of numerous nearby stars suggest the presence of cold or warm discrete clouds (York, 1983, ApJ, 264, 172; Paresce, 1983, Nature, 302, 806). Frisch and York (1983, ApJ, 271, L59; 1984, BullAAS, 16, 411) have mapped these clouds using Lyman α and NaI, CaII lines.

A review of the situation including the information from the 21-cm line has been given by York and Frisch (1984, IAU Coll. 81).

3. SHELLS, HOT GAS AND HALO

The phenomenon of the shells and supershells first detected in the 21-cm line and recently reviewed by Heiles (1983, IAU Symp. 101, 367) has been studied with special emphasis on understanding its ubiquity (Stacy, Jackson, 1982, AASuppl, 50, 377) and its astrophysical nature (Gosachinskij, 1982, SovietAstrL, 8; Heiles, 1981, BullAAS, 13, 507).The number of detected objects has been increased (Hu, 1981, ApJ, 248, 119) by employing various criteria including a search list derived from radio continuum data (Sofue and Nakai, 1983, AASuppl, 53, 57; Sufue, 1983, PASJapan, 35, 91) and a search in M31 (Brinks and Bajaja, 1983, IAU Symp. 100, 139). Individual objects studied are those in the Rosette nebula and the Monoceros OB2 association (Gosachinskij and Khersonskij, 1983, Soviet Astr, 26, No. 2; Lockman and Ganzel, 1983, ApJ, 268, 117), the Lupus Loop (Colomb and Dubner, 1982, AA, 112, 141) and a shell close to the pulsar PSR 0809+74 (Velden and Hirth, 1982, AA, 113, 340).

The shells and supershells seen in the 21-cm line and more generally the interaction zones between stellar winds, supernovae and HII regions and the ISM have often been detected in interstellar absorption lines, mainly of CaII,AlIII, CIV, SiIV and NV. See for individual supernova remnants: Jenkins et al. 1981, ApJ, 248, 977; Hobbs et al. 1982, ApJ, 252, L17; Phillips and Gondhalekar, 1983, MN, 202, 483; Jenkins et al. 1984, ApJ, 278, 649; and Blair and Raymond, 1984, BullAAS, 15,

930. For the Carina region, see Walborn and Hesser (1982, ApJ, 152, 156), Walborn (1982, ApJSuppl, 48, 145); Laurent et al. (1982, ApJ, 260, 163), Welsh and Thomas (1983, ApLett, 23, 103) and Walborn et al. (1984, ApJ, 276, 524). Other specific regions have been discussed by Phillips and Gondhalekar (1981, MN, 196, 533) (I Per OB association); Phillips et al. 1984, MN, 206, 55 (I Cyg OB association); de Boer and Nash (1982, ApJ, 255, 477) (HD 46402 in the LMC); Bates et al. (1983, AA, 122, 64) (Loop II); Chanot and Sivan (1983, AA, 121, 19), Bruhweiler et al. (1983, CommentsAp, 10, 1) and Reynolds (1984, in preparation), (Gum Nebula); Königl (1983, MN, 205, 471) (W50); Welsh (1983, MN, 204, 1203) (M8); Cox and Deharveng (1983, AA, 117, 265), Goudis and Meaburn (1984, AA, 137, 152 and 138, 57) (shells in the LMC). Hobbs (1984, ApJ, 280, 132) has even succeeded in discovering [FeX]6375 in absorption in front of λ Cep, but the [FeXIV]5303 line in HD 9352 is variable hence probably circumstellar (Hobbs and Albert, 1984, ApJ, 281, 639).

Many successful attempts have been made to detect interstellar lines in high-latitude distant stars, globular clusters or extragalactic objects. These attempts have confirmed the existence of a galactic halo and have precised its properties. 21-cm line observations show that the Galaxy contains corotating HI that extends to $/z/\sim$ 1500 pc from the plane (Lockman, 1983, BullAAS, 15, 661). The detection of HI counterparts of ionized and neutral heavy elements in the galactic halo is reported by McGee et al. (1983, MN, 205, 1191). This could be produced in the warm interface between hot gas and the far side of molecular clouds in the halo (Hartquist et al. 1982, ApJ, 259, 591). A high-latitude HI-cloud with optical emission (Goerigk et al. 1983, AA, 120, 63) located at $0.5 \lesssim /z/ \lesssim 1.5$ kpc above the plane and observed in CO and H_2CO molecular lines (Mebold et al. 1983, AA, in press) shows clear evidence for an interaction with high velocity clouds (HVCs) at velocities $\leq$-140 km s^{-1} (Kalberla et al. 1984, in IAU Coll. 81, in press). This result, a possible interaction of a high velocity stream at -110 km s^{-1} with local gas (Cohen, 1981, MN, 196, 835) and a study of Mirabel and Morras (1984, ApJ, 279, 86) show that HVCs are halo objects flowing toward the galactic plane. Further studies iterate the discussion whether or not HVCs are intergalactic (Giovanelli, 1981, AJ, 86, 1468), produced by tidal interaction of our Galaxy with the Magellanic Clouds (Cohen, 1982, MN, 199, 281 and 200, 391; Morras, 1982, AA, 115, 249; Morras and Bajaja, 1983, AASuppl, 51, 131) or are galactic objects (Shchekinov, 1980, Astrophys, 16, No. 2). Possibly soft X-ray emission (Bone et al. 1983, ApSpSc, 89, 173; Kalberla et al. 1984, in IAU Coll. 81, in press) and star formation (Dyson and Hartquist, 1983, MN, 203, 1233; Mebold et al. 1984, AA, in press) occurs during interaction of high and low velocity clouds.

The halo gas is visible in low ionization (NaI, CaII, etc.), as well as in high-ionization (CIV, SiIV) lines. One of the difficulties is that it is very inhomogeneous and that the halo lines are not visible in every direction. The statistics of optical absorption lines of Songaila et al. (1981, ApJ, 248, 956) shows that 1/3 to 1 component only can be detected per 100 kpc. The lines of sight to the Magellanic Clouds (Songaila, 1981, ApJ, 248, 945), where the halo has been discovered, might even be atypical (Blades and Morton, 1983, MN, 204, 317). The kinematics of the halo is somewhat controversial: York et al. (1982, ApJ, 255, 467; 1984, ApJ, 276, 92) find a corotation with the disk while de Boer and Savage (1983, ApJ, 265, 210) find a slower rotation at large distances z above the galactic plane. This is embarrassing since many authors use radial velocities of halo lines to locate them in z. de Boer and Savage (1984, AA, 136, L7) find that the halo gas in the direction of the N galactic pole falls on the plane, in agreement with the galactic fountain model.

The halo contains several types of gaseous components with different physical properties, e.g. temperature: Hartquist and Tallant (1981, MN,196, 527). The warm phase (T $<2.4\ 10^4$ K) is seen in the lines of low ionization species. Observations of these lines (Songaila et al. 1981, op.cit.; Keenan et al. 1981, MN, 197, 799; York et al. 1982, 1984, op. cit.; Jenkins et al. 1984, ApJ, 281, 585) show that this

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component is rather concentrated on the galactic plane, although Pettini et al. (1982, MN, 199, 409) suggest a larger extent, based on the hypothesis of corotation. The most thorough study is by Albert (1983, ApJ, 272, 509) who uses IS lines in stars at different distances from the plane; he finds that the warm phase consists in an extension of the disk gas, with low velocities and large amounts of metal depletion, and in a much less depleted, high velocity gas extending at higher z-distances, which makes at least 24% of the mass of the halo gas (see also Albert, 1982, ApJ, 256, L9 and Keenan et al. 1983, MN, 203, 963). The hot halo gas seen in the CIV and SiIV lines extends at even larger distances from the plane with a scale height of at least 3 kpc (Pettini and West, 1982, ApJ, 266, 561; Hartquist et al. 1984, ApJ, 276, 519). Apparently these observations give a better fit with the model of a halo supported by cosmic rays (Hartquist et al. 1983, MN, 203, 1233; Chevalier and Fransson, 1984, ApJ, 279, L43) than with the galactic fountain model. Other theoretical studies bearing on special points are by Hartquist et al. (1982, ApJ, 259, 591), Dyson and Hartquist (1983, MN, 203, 1233). See also the review on the galactic fountain model by Kahn, 1981, in Investigating the Universe, ed. Kahn, Reidel, p. 1. The existence of a halo in the SMC is still controversial (Fitzpatrick and Savage, 1983, ApJ, 267, 93).

4. THEORETICAL STUDIES

Apart from the previous studies concerning the halo, theoretical work has been performed on a number of topics concerning the diffuse medium. A detailed general review is by Lazareff (1983, in Diffuse Matter in Space, ed. Audouze et al. Reidel, p. 141). The determination of the "Spin-Temperature", T_{spin}, from observed quantities was discussed by Payne et al. (1983, ApJ, 272, 540). Kalberla et al. (1983, Mitt. Astron. Ges., 60, 392) related the spin temperature to the clumping in the HI gas. Liszt (1983, ApJ, 275, 163) considered the correlation of T_{spin} with the optical depth and discussed a core-halo model for the HI clouds.

A further topic is the turbulence in the galactic HI-gas. Crovisier and Dickey presented a statistical study of the small-scale structure based on a power-spectral analysis; cf. also Kalberla and mebold (1983, Mitt. Astron. Ges, 58, 101). Alferova and Gosachinskij (1983, Astrofiz. Issl. Izv. Spets. Astrofiz. Obs, 17, 77) made a computer simulation of the HI-emission from spherically symmetric gas clouds.

Some studies are concerned with the evaporation of clouds in a very hot gas: Balbus and McKee, 1982, ApJ, 252, 529; Giuliani, 1984, ApJ, 277, 605; Draine and Giuliani, 1984, ApJ, 281, 690; Balbus, 1984, BullAAS, 16, 444. The fate of clouds in shocks has been treated by Nittmann et al. 1982, MN, 201, 833; Heathcote and Brand, 1983, MN, 203, 67 and Krebs and Hillebrandt, 1983, AA, 128, 411. The dynamics of shells driven by stellar winds, supernovae, or even radiation pressure from field stars (Elmegreen and Chiang, 1982, ApJ, 253, 666) has been discussed by Huang and Weigert (1982, AA, 116, 348), McKee et al. (1984, ApJ, in press) and Wolf and Durisen (1984, BullAAS, 16, 465). Tenorio-Tagle, Rozycska and collaborators have written a large series of papers on stellar wind bubbles and related topics. Theoretical studies on the mass spectrum of clouds are due to Hausman (1982, ApJ, 261, 532) and Pumphrey and Scalo (1983, ApJ, 269, 531). Abbott (1982, ApJ, 263, 723) and Tarrab (1983, AA, 125, 308) have discussed the deposition of energy and momentum in the diffuse ISM of our Galaxy and other galaxies, and Dupree and Raymond (1983, ApJ, 275, L71) have emphasized the interaction of white dwarfs with the ISM. Global models of the ISM have been discussed by Ikeuchi and Tomita (1983, PASJapan, 35, 77), Satoru et al. (1984, MN, 207, 909). Hydrostatic equilibrium with magnetic field has been reviewed by Kuznetsov and Ptuskin (1983, ApSpSc, 94, 5), and Gosh and Ptuskin (1983, Soviet Astr, 9, 49).

III. Molecules and Molecular Clouds
(P.G. Wannier)

1. ISOTOPE ABUNDANCES

Molecular transitions have continued to provide valuable abundance information with only small interpretational errors. A major topic of study has been to determine precisely how large these errors can get.

Carbon isotopic ratios have been made using the 6-cm lines of formaldehyde yielding a value (25) of $H_2{}^{12}CO/H_2{}^{13}CO$ in the galactic center and values near or slightly lower than terrestrial (90) in other galactic sources (Wilson and Jaffe, 1981, ApJ, 245, 866; Gardner and Whiteoak, 1982, MN, 199, 23P; Henkel et al. 1982, AA, 109, 344; 1983, AA, 127, 388). These results are generally consistent with observations of $H_2C^{18}O/H_2{}^{13}CO$ which are somewhat smaller than 90 in the galactic plane and half as large in the galactic center (Gardner and Whiteoak, 1981, MN, 194, 37P; Machnik et al. 1982, ApJ, 254, 538). Observations of $H^{13}CO^+$, $H^{12}CO^+$ and $HC^{18}O^+$ yielded somewhat lower ^{13}C abundances in all sources, in better agreement with previous CO surveys and with a UV determination of $^{12}CO/^{13}CO \sim 55$ in the local interstellar medium (Stark, 1981, ApJ, 245, 99; Wannier et al. 1982, ApJ, 254, 100; Crutcher and Watson, 1981, ApJ, 244, 855).

Four observational projects and one theoretical paper sought to determine the effects of isotopic fractionation and line saturation for CO and concluded that there is fractionation in the outer boundary layers of dense clouds and in the wings of the line profiles (Wilson et al. 1981, ApJ, 243, L47; Bally and Langer, 1982, ApJ, 255, 143; Young et al. 1982, ApJ, 261, 513; Chu and Watson, 1983, ApJ, 267, 151; Penzias, 1983, ApJ, 273, 195). A general search for the unstable ^{14}C variant of CO failed to detect any in seven sources, in keeping with generally accepted age estimates for molecular clouds.

Measurements of the oxygen isotopic ratios used OH, HCO^+ and CO. A survey of galactic sources in CO indicates that $^{18}O/^{17}O$ is very constant (within 5 percent) throughout the galactic disc including the galactic center, but is significantly (40 percent) lower than the terrestrial value of 5.5 (Penzias, 1981, ApJ, 249, 518). Measurements using HCO^+ and OH are in excellent agreement with the CO results (Guelin et al. 1982, ApJ, 263, L89; Bujarrabal et al. 1983, AA, 128, 355). A measure of $^{16}OH/^{18}OH$ is about half the terrestrial one in the galactic center (Whiteoak and Gardner, 1981, MN, 197, 39P).

Measurements of the nitrogen isotopes were made with the J = 1-0 transition of HCN in 16 galactic sources (Wannier et al. 1981, ApJ, 247, 522), yielding $^{14}N/^{15}N$ equal to the terrestrial value with no evidence for a gradient except for a deficiency of ^{15}N in the galactic center, consistent with extensive processing in stars. Measurements of HNN^+ were consistent (Linke et al. 1983, ApJ, 271, L85). A new measurement of the silicon isotopes using SiO has yielded results equal to terrestrial values, contrary to an earlier report (Penzias, 1981, ApJ, 249, 513).

Interstellar D/H has the lure of providing cosmological information, but suffers from fractionation and contamination with newly processed material. UV observations including atomic and molecular hydrogen yielded D/H $\sim$2-5 10^{-5}, but have shown some evidence for contamination by stellar winds (Bruston et al. 1981, ApJ, 243, 161; Vidal-Madjar et al. 1983, AA, 120, 58). The deuterated species of heavy molecules in dense clouds continue to provide information about fractionation rather than about abundances (Beckman et al. 1982, MN, 201, 357; Herbst, 1982, AA, 111, 76).

2. MOLECULAR LINES

2.1 New Lines and Undetected Lines.

New molecular detections have continued to provide valuable information about

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conditions in dense clouds, though the surprises have come from circumstellar envelopes and dense, cold clouds instead of from active star-forming regions as in the past. Eleven new molecular species have been detected and/or confirmed.

Lab spectra and astronomical observations confirmed tentative detections of C_4H and C_3N, species especially prominent in cold clouds (Gottlieb et al. 1983, ApJ, 275, 916; Guelin et al. 1982, AA, 109, 23; Bell et al. 1982, ApJ, 255, L75; Irvine et al. 1981, ApJ, 248, L113). Both C_4H and C_3N give rise to methylated forms which have also been detected in dense clouds. These are CH_3C_4H (Walmsley et al. 1984, AA, 134, L11; Loren et al. 1984, ApJ, 286, L23; MacLeod et al. 1984, ApJ, 282, L89) and CH_3C_3N (Broten et al. 1984, ApJ, 276, L25). Two new ions, HCS^+ and $HOCO^+$, have been detected (Thaddeus et al. 1981, ApJ, 246, L41; Irvine et al. 1983, AA, 127, L10) and C_3H has been detected and confirmed (Johansson et al. 1984, AA, 130,227) as has C_3O. The first molecular ring (albeit a small one), was discovered in IRC+10216: SiCC (Thaddeus et al. 1984, ApJ, 283, L45). A theoretical discussion of $^{16}O^{18}O$ (Black and Smith 1984, ApJ, 277, 562) has led to several unpublished searches and a possible detection. In the near-IR, SiH_4 has been detected in IRC+10216 (Goldhaber and Betz, 1984, ApJ, 279, L55) as has C_2H_4 (Betz, 1981, ApJ, 244, L103). Most recent is a detection of HCl (Blake et al. 1985, ApJ, submitted). Improved spectroscopic information was obtained from observations of CCH (Ziurys et al. 1982, ApJ, 254, 94) and from lab measurements and observations of H_2 (Jennings et al. 1984, ApJ, 282, L85). A tentative detection of HOC^+ has been made on the basis of one weak line toward the SagB2 and upper limits toward 13 other clouds (Woods et al. 1983, ApJ, 270, 583). Frequencies were reported for the diatomic molecules MgO (Steimle et al. 1984, ApJ, 277, L21) FeO (Endo et al. 1984, ApJ, 278, L131) and LiH (Plummer et al. 1984, ApJ, 282, L113).

Several explorations of frequency bands have been made which have uncovered a host of new lines, but almost entirely of species already familiar. One survey of the 3 mm region toward SgrB2 and Orion A yielded 274 new lines (Turner, 1983, ApJ, 23, 217) and another yielded 170 lines in Orion and 45 toward IRC+10216 (Johansson et al. 1984, AA, 130, 227). A survey at 215-247 GHz has detected 544 molecular lines, all but 27 or which are identified as lines of previously detected molecules (Sutton et al. 1985, ApJ, submitted). New physical probes are provided by high frequency lines such as those of CO at 434μ, 153μ and 168μ (Koepf et al. 1982, ApJ, 260, 584; Goldsmith et al. 1981, ApJ, 243, L79; Stacey et al. 1982, ApJ, 257, L37; Stacey et al. 1983, MN, 202, 25P), NH_3 at 524μ (Keene et al. 1983, ApJ, 271, L27) and the 1.2 mm lines of CH_3OH (Boland et al. 1983, ApJ, 271, 183).

Null detections, though less compelling, are nontheless important. A useful set of null detections for practitioners of millimeterwave astronomy is a published set of 100 locations near the galactic plane with no detectable CO emission (<0.5K) (Verter et al. 1983, ApJSuppl, 52, 289). Molecular searches which have not been successful are ones for NaH (Plambeck and Erickson, 1982, ApJ, 262, 606), H_2O^+ (Smith et al. 1984, ApJ, 277, 196), SiN (Ziurys et al. 1984, ApJ, 281, 219). FeO (Merer et al. 1982, ApJ, 256, 151), N_2O (Wilson and Snyder, 1981, ApJ, 246, 86), H_3^+(Oka 1981, Phil.Trans.R.Soc.Ser, A, 303, 543), C_3 (Clegg and Lambert, 1982, MN, 201, 723), $C_3N_2H_4$ and $CH(CN)_3$ (Rydbeck et al. 1981, AA, 97, 192), glycine (Snyder et al. 1983, ApJ, 268, 123), HOCl, CH_3CH_2CCH and $HCOOCH_3$ (Hollis et al. 1983, AA, 126, 393) and HCP and H_2SO_4 (Hollis 1981, ApJ, 251, 541).

2.2 Molecular Excitation

Almost all studies involving molecular spectroscopy require some knowledge of excitation. Calculations have been made where the energy input is from shocks (Draine and Roberge 1984, ApJ, 282, 491), from collisions with hot grains (Krugel and Walmsley 1984, AA, 130, 5), from IR radiation (Carroll and Goldsmith 1981, ApJ, 245, 891) and star formation (Stenholm 1983, AA, 124, 247). The gas temperature is dependent, in turn, on molecular line cooling and studies have been made of ra-

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diation from CO (Gilden 1984, ApJ, 283, 679), H_2O (Takahashi et al. 1983, ApJ, 275, 145) and OH (Flower et al. 1982, MN, 200, 55P). The numerical techniques of radiative transfer in molecular clouds have been scrutinized (Sobolev 1982, Nauchn. Inf., 50, 47; Stenholm 1983, AA, 117, 41; Deguchi and Kwan 1982, ApJ, 260, 579). Analyses have been made of HCO^+ and HCS^+ (Montiero 1984, MN, 210, 1) and of CH (Lien 1984, ApJ, 284, 578). Several observational and theoretical papers have addressed the anomalies of the hyperfine brightnesses of HCN (Sandell et al. 1983, AA, 118, 306; Walmsley et al. 1982, ApJ, 258, L75; Zinchenko and Khersonskij 1982, Astron.Zh., 59, 676). Observations and analysis of ortho-NH_3 indicate an inversion and possible weak maser (Guilloteau et al. 1983, AA, 124, 322). Studies of ortho/para ratios of H_2CO (Kahane et al. 1984, AA, 137, 211) and H_2 (Flower and Watt 1984, MN, 209, 25) determine under what conditions the statistical ratios do not apply. H_2 line excitation has been modelled (Chernoff et al. 1982, ApJ, 259, L97; McKee et al. 1982, ApJ, 259, 647).

2.3 Lines as Probes in Clouds

New probes of physical conditions in clouds have been tried. The existence of weak radiative coupling (metastable states) is desirable for temperature probes and the CH_3C_2H (Askne et al. 1984, AA, 130, 311; Kuiper et al. 1984, ApJ, 276, 211), CH_3CN (Loren and Mundy 1984, ApJ, 286, 232; Andersson et al. 1984, AA, 136, 243) and the metastable states of NH_3 (Walmsley and Ungerechts 1983, AA, 122, 164; Ungerechts et al. 1982, AA, 111, 339) have been so used in molecular clouds (but see Stutzki et al. 1984, AA, 139, 258, for discussion of NH_3). Density probes require molecules with many allowed transitions. HCN (White et al. 1982, MN, 199, 375), HC_3N (Vanden Bout et al. 1983, ApJ, 271, 161), HC_5N (Jennings and Fox 1982, ApJ, 254, 111) and HNCO (Jackson et al. 1984, ApJ, 280, 608) have been used to make such measurements. CO, because of its stability and low dipole moment has been the workhorse to trace the general distribution of molecular material, but its lines are often saturated and ^{13}CO has been used to obtain better statistics of cloud sizes and distribution (Liszt et al. 1981, ApJ, 249, 532).

3. CHEMISTRY

Since the last IAU Report, significant progress has been made in the understanding of the molecular chemistry in interstellar clouds. Reactions critical to the modeling of the chemistry have been measured in the laboratory and studied theoretically. Additional observations of both diffuse clouds and dense clouds have provided additional constraints for the theoretical models. Moreover, the models have become more sophisticated by the inclusion of time dependent phenomena. Many relevant references are given in the section on molecular lines and are not repeated here.

3.1 Molecular Processes

Isotope exchange reactions have been measured in the laboratory (Adams and Smith 1981, ApJ, 248, 373; Smith et al. 1982, ApJ, 263, 123). The reactions involving O^+ and H, as well as the reactions between CH^+ and H or H_2, have been investigated experimentally (Federer et al. 1984, Phys.Rev.Lett., 52, 2084). Laboratory measurements relate to the synthesis of complex molecules (Adams and Smith, 1981, ApJ, 247, L123; Herbst, Adams and Smith 1983, ApJ, 269, 329; Smith et al. 1983, ApJ, 272, 365). Lab measurements have been undertaken at the characteristic temperatures of interstellar clouds (Barlow et al. 1984, Phy.Rev.Lett., 52, 902; Smith and Adams 1984, ApJ, 284, L13), including the recombination of H_3^+, which affects the determination of the electron abundance. The measurements confirm theoretical predictions (Michels and Hobbs 1984, ApJ, 286, L27).

The radiative association of C^+ and H has been studied (Graff et al. 1983, ApJ,

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269, 796), as has the association of C^+ and H_2 (Herbst 1982, ApJ, 252, 810). More general discussions have been reported (Bates 1983, ApJ, 267, L121; 1983, ApJ, 270, 564). The endothermic reactions $C^+ + H_2$ and $O + H_2$ have also been treated (Herbst and Knudson 1981, ApJ, 245, 529). The photodissociation rates in the presence of the interstellar ultraviolet radiation field for C_2 (Pouilly et al. 1983, J.Phys.B., 16, 437), OH (van Dischoeck and Dalgarno 1983, ApJ, 277, 576), and CN (Lavendy et al. 1984, J.Molec.Spectros., 106, 395) have been estimated theoretically. Recent laboratory data on photoabsorption cross sections have been obtained, indicating that in some cases the quantal estimates may be uncertain by a factor of five or so (Lee 1984, ApJ, 282, 172; Nee and Lee 1984, ApJ, in press). Other related theoretical investigations include the selective photodissociation of CO isotopes (Bally and Langer 1982, ApJ, 255, 143; Chu and Watson 1983, ApJ, 267, 151) and the transport of UV radiation (Roberge et al. 1981, ApJ, 243, 817).

3.2 Diffuse Clouds

Several important observations of the diffuse gase are given in section 4b and are not repeated here. Measurements of CO absorption with IUE (Tarafdar and Krishna Swamy 1981, MN, 196, 67; 1982, MN, 200, 431; Tarafdar 1983, MN, 204, 1081; McLachlan and Nandy 1984, MN, 207, 355) have substantiated an earlier finding that CO correlates with H_2. New measurements of CH and CH^+ (Federman 1982, ApJ, 257, 125) constrain chemical models. CN observations indicate that the reaction $C_2 + N$ is crucial to the formation of CH (Federman 1984, ApJ, in press).

Time independent calculations (Pickles and Williams 1981, ApSpSc, 80, 337) and time dependent calculations (Mann and Williams 1984, MN, 209, 33), as well as those including the effects of shocks (Mitchell and Deveau 1983, ApJ, 266, 646) have been performed.

3.3 Dense Clouds

New observations of the cyanopolyynes (Bujarrabal et al. 1981, AA, 99, 239; Snell et al. 1981, ApJ, 244, 45; Benson and Myers 1983, ApJ, 270, 589; Cernicharo et al. 1984, AA, 138, 371), the detection of other acetylene-based carbon chained molecules (see section 2a on molecular lines) the detection of CH_3CN (Matthews and Sears 1983, ApJ, 267, L53), and the detection of C_3O (Matthews et al. 1984, Nature, 310, 125) have been obtained. The distribution of C_2H has been measured also (Huggins et al. 1984, AA, 133, 347). These and earlier observations have been modeled with gas phase reactions playing the dominant role (Freeman and Millar 1983, Nature, 301, 402; Herbst 1983, ApJSupp, 53, 41; Suzuki 1983, ApJ, 272, 579; Millar and Freeman 1984, MN, 207, 405; 1984, MN, 207, 425; Herbst et al. 1984, AA, 138, L13; Stahler 1984, ApJ, 281, 209), with grain surface reactions (Millar 1982, ApSpSc, 87, 435), and with shocks included (Mitchell 1983, MN, 205, 765; 1984, ApJSuppl, 54, 1; Duley and Williams 1984, MN, 211, 97). A time dependent model with gas phase chemistry (Leung et al. 1984, ApJSuppl, 56, 231) has illustrated that the large observed abundance of neutral carbon (Phillips and Huggins 1981, ApJ, 251, 533; Wootten et al. 1982, ApJ, 256, L5) may be the key to hydrocarbon production. The role shocks play in the neutral carbon abundance has also been analyzed (Williams and Hartquist 1984, MN, 210, 141).

The chemistry of sulfur-bearing compunds has been studied both observationally and theoretically. Emission from CS (Goldsmith and Linke 1981, ApJ, 325, 482), SiS (Dickinson and Rodríguez Kuiper 1981, ApJ, 247, 112), and SO_2, as well as HCS^+ has been analyzed. These measurements have been compared to the results of theoretical models based on gas phase reactions (Prasad and Huntress 1982, ApJ, 260, 590) and grain chemistry (Millar 1982, MN, 199, 309). The gas phase models predict that O and O_2 are not present in large quantities because of their rapid reactions with sulfur.

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The ionization fraction in dense clouds has been analyzed in terms of DCO^+/ HCO^+ (Guelin et al. 1982, AA, 107, 107; Wootten et al. 1982, ApJ, 255, 160), although the new recombination measurements for H_3^+ (Smith and Adams 1984, ApJ, 284, L13) may alter the interpretations. The ionization fraction may also be determined by HCS^+/CS (Millar 1983, MN, 202, 683). The chemistry involving CO^+ has been studied in the laboratory (Huntress et al. 1982, AA, 114, 275), theoretically (Defrees et al. 1984, ApJ, 279, 322), and through observations of the isomers HOC^+ and HCO^+. Observational studies of CN (Churchwell and Bieging 1983, ApJ, 265, 216; Crutcher et al. 1984, ApJ, 283, 668) and the isomers HCN and HNC (Goldsmith et al. 1981, ApJ, 249, 524) have been made. Deuterated cyanopolyynes have been detected and have been analyzed in terms of gas phase versus grain formation (MacLeod et al. 1981, ApJ, 251, L33; Schloerb et al. 1981, ApJ, 251, L37); a recent theoretical study of surface reactions has been presented (Tielens 1983, AA, 119, 177). Deuterated water has been observed as well (Olofsson 1984, AA, 134, 36). Comprehensive theoretical models for the simpler species have been carried out (Graedel et al. 1982, ApJSuppl, 48, 321; Watt 1983, MN, 205, 321; Boland and de Jong 1984, AA, 134, 87; Langer et al. 1984, ApJ, 277, 581). The chemistry of phosphorus has been analyzed (Thorne et al. 1984, ApJ, 280, 139). The formation rate of H_2 on grain surfaces has been studied (Snow 1983, ApJ, 269, L57), and the effects of the formation on cloud evolution have been investigated (Suchkov et al. 1982, Astrofizika, 4, 629; El Shalaby et al. 1983, JASEgypt, 5, 1). Shock formation in the cloud near IC443 has been studied observationally (DeNoyer and Frerking 1981, ApJ, 246, L37) and theoretically, where it was found that HCO^+ is not formed in the shock but through enhanced ionizing radiation, (Elitzur 1983, ApJ, 267, 174). The collision-induced dissociation of molecules behind shocks has been analyzed theoretically (Roberge and Dalgarno 1982, ApJ, 255, 176; Lepp and Shull 1983, ApJ, 270, 578).

3.4 Circumstellar Shells

Long-chain carbon chemistry was studied by means of a survey of HC_3N (Jewell and Snyder 1982, ApJ, 255, L69; 1984, ApJ, 278, 176) and by observations of HC(nC_2)N out to n = 5 ($HC_{11}N$)(Feldman et al. 1982, Nature, 295, 389). Observations of CN (Wootten et al. 1982, ApJ, 257, 151), of HCN (Bieging et al. 1984, ApJ, 285, 656) and of SiS (Nguyen-Q-Rieu et al. 1984, ApJ, 286, 276) in IRC+10216 indicate the importance of photodissociation in the outer shells (Huggins et al. 1984, ApJ, 279, 284) and have led to the realization that self-shielding from ambient UV photons is important for the abundant species, CO and H_2 (Wootten et al. 1982, ApJ, 256, L5; Morris and Jura 1983, ApJ, 264, 546; Huggins and Glassgold 1982, AA, 87, 1828). The chemistry of C_3H has been modelled (Nejad et al. 1984, AA, 134, 129).

4. CLOUD MORPHOLOGY, DYNAMICS AND EVOLUTION

4.1 Magnetic Fields

The role of magnetic fields in the evolution of interstellar clouds remains an important, but largely unsolved problem. This is not for lack of effort, but is due to the difficulty of measuring the weak fields which may nontheless dominate. Zeeman splitting in the 21-cm line has indicated magnetic energy densities unexpectedly insensitive to density, and smaller than energies of macroscopic motions (Troland and Heiles 1982, ApJ, 252, 179; Brown and Chang 1983, ApJ, 264, 134; Fleck 1983, ApJ, 264, 139). Zeeman splitting of the OH maser line has led to mixed results in dense regions (Crutcher and Kazes 1983, AA, 125, L23; Hansen 1982, ApJ, 260, 599; Crutcher et al. 1981, ApJ, 249, 134). A prediction of several percent polarization of millimeterwave lines toward dense clouds (Goldreich and Kylafis 1981, ApJ, 243, L75; Kylafis 1983, ApJ, 267, 137) led to a search using CO, ^{13}CO, HCN and CS toward 14 dense clouds which yielded no detections to levels as small as 0.5 per cent (Wannier et al. 1983, ApJ, 267, 126). Nontheless, magnetic fields have been invoked to explain the curious kinematics of the dark cloud B5 (Dudorov and Sazonov 1982, Nauchn.Inf , 50, 98; Young et al. 1981, ApJ, 251, L81). The role of fields in collapsing clouds has been studied theoretically by several groups with a view, especially, to determining whether or not the fields can escape (Paleologou and Mouschovias 1983, ApJ, 275, 838; Mouschovias and Paleologou 1981, ApJ, 246, 48; Black and Scott 1982, ApJ, 263, 696; Nakano, 1982, PASJapan, 34, 337; Scott 1983, ApJ, 275, 836; Nakano 1983, PASJapan, 35, 209; Dorfi 1982, AA, 114, 151).

4.2 Diffuse Molecular Gas and Dense Cloud Boundaries

Several studies have focused attention on how dense clouds interact with other components of the interstellar medium. It is by such interactions that dense clouds are formed and, presumably, often destroyed.

HI and CO emission lines correlate in velocity, but not in line intensity (Kazes and Crovisier 1981, AA, 101, 401), consistent with a conclusion from observations of CH that most diffuse clouds may actually be the outer portions of dense clouds (Federman and Willson 1982, ApJ, 260, 124). The first direct observations of diffuse gas at the boundary layers of dense clouds were made with high-resolution strip maps across projected edges of CO clouds, indicating the presence of warm (> 100 K) HI halos 0.5 to several pc thick (Wannier et al. 1983, ApJ, 268, 727). The detection of absorption by HCO^+, CS, C_2 and HCN millimeter lines toward HII regions indicates the presence of molecules in low density material, probably surrounding dense clouds (Nyman 1983, AA, 120, 307; 1984, AA, 141, 323). Absorption line studies of H_2CO (Goss et al. 1984, AA, 139, 317) and NH_3 (Batrla et al. 1984, AA, 136, 127) toward CasA find similar cloudlets, some also present in HI observations.

Studies concentrating on diffuse molecular gas include optical absorption line studies of C_2 (Danks and Lambert 1983, AA, 124, 188; Hobbs and Campbell 1982, ApJ, 254, 108; Cosmovici and Strafella 1981, AA, 98, 408; van Dishoeck and DeZeeuw 1984, MN, 206, 383; Hobbs et al. 1983, ApJ, 271, L95; Crutcher and Lutz 1983, ApJ, 271, L101), CH (Danks et al. 1984, AA, 130, 62). Studies toward the region of the Pleiades have been made using millimeter emission lines (Federman and Wilson 1984, ApJ, 283, 626) and optical absorption-lines (White 1984, ApJ, 284, 685; 1984, ApJ, 284, 695). Observations of interactions of dense clouds with energetic, ionized gas have been made toward bright optical rims (Wootten et al. 1983, ApJ, 269, 147), the Orion Bright Bar (Omodaka et al. 1984, ApJ, 282, L77), compact HII regions (Ho et al. 1981, ApJ, 246, 761; Forster and Boland 1982, AA, 114, 109) Planetary Nebulae (Storey 1984, MN, 206, 521), and supernova remnants (DeNoyer 1983, ApJ, 264, 141); Huang et al. 1983, ApJ, 272, 609; Wootten 1981, ApJ, 245, 105).
Recent calculations of dense cloud evaporation in the presence of hot gas (Giuliani 1984, ApJ, 277, 605; Bedijn and Tenorio-Tagle 1984, AA, 135, 81) have characterized the resulting winds and shocks and bright rim formation. Generally, molecular observations have not proved to be sensitive probes of such interactions.

Three surveys have studied small clouds in the solar neighborhood (Stark 1984, ApJ, 281, 624; Lebrun and Huang 1984, ApJ, 281, 634; Blitz, Magnani and Mundy, 1984, ApJ, 282, L9) and conclude that these high-latitude objects are young , low-mass ($\sim 100\ M_{\odot}$) objects, associated with HI clouds but not gravitationally bound. However, another search for high latitude CO indicates a lack of molecular material outside of dense clouds (Wilkinson and Stark 1983, AJ, 88, 1832). A compilation of diffuse cloud data has been made (Dickman et al. 1983, ApJSuppl, 53, 55). A careful study of CO and its rare isotopic variants have yielded a new relation between visual extinction and CO column density, (Frerking et al. 1982, ApJ, 262, 590).

4.3 Dense Clouds

A survey of $\sim$ 100 dense cloud cores has been carried out using lines of CO and NH_3 (Myers et al. 1983, ApJ, 264, 517; Myers and Benson 1983, ApJ, 266, 309; Myers 1983, ApJ, 270, 105) and concludes that cores are smaller, denser and have narrower lines in regions with active star formation. Two surveys, using lines of H_2CO and NH_3, indicate that cloud motions do not increase markedly toward dense cores (Bieging et al. 1982, AASuppl, 49, 607; Macdonald et al. 1981, MN, 195, 387). Two surveys have been made using CO J = 2-1 and J = 1-0 especially toward giant dense clouds with self-absorbed line profiles and have found the physical properties of the absorbing envelopes and have corrected previous values for the core gas temperatures (Huggins et al. 1981, ApJ, 245, 512; Loren et al. 1981, ApJ, 245, 495). Surveys were made of 80 southern hemisphere dark clouds in CO J = 2-1 (de Vries et al. 1984, AASuppl, 56, 333) and toward 100 clouds in H_2CO absorption (Gardner and Whiteoak 1984, MN, 210, 23). Autocorrelation analyses of CO emission can determine the structure of clouds (Scalo 1984, ApJ, 277, 556; Stenholm 1984, AA, 137, 133). Surveys have also been made using the millimeter lines of CN (Crutcher et al. 1984, ApJ, 283, 668) and CS (Snell et al. 1984, ApJ, 276, 625).

Studies of individual star forming regions include the Orion complex (White and Phillips 1981, MN, 194, 947; Johnston et al. 1983, ApJ, 271, L89; Harris et al. 1983, ApJ, 265, L63). CepA (Hughes and Wouterloot 1984, ApJ, 276, 204; Gusten et al. 1984, AA, 138, 205), the Serpens object (GGD29) (Ungerechts and Gusten 1984, AA, 131, 177), the Taurus complex (Henkel et al. 1981, AA, 99, 270; Baudry et al. 1981, AA, 104,101; Walmsley et al. 1981, AA, 95, 143), W33 (Stier et al. 1984, ApJ, 283, 573) W3 (Wright et al. 1984, ApJ, 281, L71; Thronson et al. 1984, ApJ, 284, 597; Zeng et al. 1984, AA, 140, 169; Dickel et al. 1984, AA, 135, 107), NGC 2024 (Thronson et al. 1984, ApJ, 280, 154; Black and Willner 1984, ApJ, 279, 673), MonOB1 and MonOB2 (Wouterloot 1984, AA, 134, 244), M17 (Jaffe and Fazio 1982, ApJ, 257, L77; Martin et al. 1984, MN, 208, 35), NGC 7538 (Dickel et al. 1981, ApJ, 250, L43; Henkel et al. 1984, ApJ, 282, L93; Campbell and Thompson 1984, ApJ, 279, 650), eight IR-selected star-formation regions (Jaffe et al. 1984, ApJ, 281, 237), southern HII regions (Brand et al. 1984, AA, 139, 181), Heiles Cloud 2 (Schloerb and Snell 1984, ApJ, 283, 129), Rho Oph (Zeng et al. 1984, AA, 141, 127) TMC (Goldsmith and Sernyak Jr., 1984, ApJ, 283, 140; Irvine and Schloerb 1984, ApJ, 282, 516; Gaida et al. 1984, AA, 137, 17), the Ophiuchus complex near the upper Scorpius association (Wouterloot 1984, AA, 135, 32), B335 (Menten et al. 1984, AA, 137, 108), S88 (Harvey et al. 1981, ApJ, 250, 200), S235 (Nordh et al. 1984, AA, 131, 221; Evans and Blair 1981, ApJ, 246, 394), S128 (Ho et al. 1981, ApJ, 243, 526) and various dark clouds (Phillips and White 1981, MN, 194, 1981).

The galactic center region has continued to fascinate molecular astronomers. Lines of NH_3 and CH_3CN probed gas temperatures with varying results (Cummins et al. 1983, ApJ, 266, 331; Wilson et al. 1982, AA, 115, 185; Morris et al. 1983, AJ, 88, 1228). H_2CO absorption line studies have focused on both low velocity and high velocity features, the latter indicating the ejection of gas from the galactic nucleus (Whiteoak et al. 1983, MN, 202, 11P; Gusten and Downes 1981, AA, 99, 27). Additional studies have been made with the CO J = 1-0 line and the main lines of OH (Inatani 1982, PASJapan, 34, 515; Venger et al. 1981, Pis'maAZh, 7, 295) and with the 2μ lines of shocked H_2 (Gatley et al. 1984, MN, 210, 565).

5. CIRCUMSTELLAR MOLECULAR ENVELOPES

A key event in post-main-sequence evolution is the rapid loss of material from red giants in dense winds. As with the advanced stages of star formation, the dense envelopes are best studied by means of molecular lines, and recent advances have been made from thermal microwave, infrared and maser observations. Chemistry in circumstellar shells is particularly interesting and is covered in the section on chemistry.

5.1 Millimeterwave Observations

Surveys of millimeterwave CO (and ^{13}CO) emission have been carried out by several groups using infrared sky surveys as guides to the source selection process

(Zuckerman 1981, AJ, 86, 84; Knapp et al. 1982, ApJ, 252, 616; Knapp and Morris 1985, ApJ, in press; Wannier and Sahai 1985, ApJ, in press). These surveys indicate that there are about equal proportions of carbon-rich and oxygen-rich object among stars with massive winds (10^{-7} to 10^{-4} $M_{\odot}$/yr) and that the mass loss rates of carbon-rich stars are larger than for oxygen-rich stars. The $^{13}C/^{12}C$ ratio is larger in the oxygen-rich stars, consistent with the formation of carbon-rich envelopes by injection of fairly pure ^{12}C into envelopes rich in ^{13}C from CNO processing. $^{17}CO/^{18}CO$ in IRC+10216 is far larger (∿5 as opposed to 1/5) than terrestrial or interstellar values (Penzias 1981, ApJ, 249, 518).

Detailed observations of the carbon-rich object IRC+10216 have led to models with larger mass-loss rates than previously calculated (Kwan and Linke 1982, ApJ, 254, 587) though interferometric observations of HCN indicate that the rate may be decreasing with time (Bieging et al. 1984, ApJ, 285, 656). Extensive observations of the millimeter-wave spectrum of IRC+10216 (e.g. Johansson et al. 1982, AA, 107, 128) have refined our understanding of chemistry and radiative transfer.

5.2 Infrared Spectroscopy

Infrared molecular lines have yielded important information about the inner envelopes, where mass-loss is initiated, and about the outer photospheres, where there is interaction with the Mira shocks. Most observations have used CO, either the $\Delta J = 1$ fundamental vibration-rotation band or the overtone bands. A survey of nine giants indicated episodic mass-loss (Bernat 1981, ApJ, 246, 184). Time sequence observations of variable stars in the CO overtone bands traced the dynamics of the shocks and have detected warm (∿ 1000 K), quiescent layers of gas which may represent where outward acceleration is initiated (Hinkle et al. 1982, ApJ, 252, 697; 1985, ApJSuppl, in press). Techniques of spatial mapping have been combined with high-resolution CO spectroscopy. Combined speckle/spectral observations of IRC+10216 and Mira have shown CO emission (Dyck et al. 1983, ApJ, 271, L79; Beckwith et al. 1985, ApJ, submitted). Larger scale mapping has used annular observing apertures to isolate weak CO emission features out to 6 arcsec (Sahai and Wannier 1985, ApJ, in press). A survey of oxygen isotope ratios in nine stars has yielded mixed results, but indicates that the standard assumptions about late stellar evolution are in need of some revision (Harris and Lambert 1984, ApJ, 285, 674). Observations of 2.1μ H_2 in the bipolar nebulae CRL 2688 and 618 (Beckwith et al. 1984, ApJ, 280, 648) and in NGC 7027 (Isaacman 1984, AA, 130, 151) indicate that shocks may result from interaction of a fast wind with an older, slower dense wind remnant.

5.3 OH Maser Observations

The most fruitful maser lines for observations of red giants are those of OH. Most, but not all 1612 MHz sources are associated with late-type variable stars (Engels 1982, Veroff.Astron.Inst.Bonn. Nr. 95, 91; Jones et al. 1983, ApJ, 273, 669) and a survey of 114 OH masers has been made (Baud et al. 1981, AA, 95, 156,171). The most dramatic results have come by use of radio interferometers, including the VLA, MERLIN and VLBI. Two surveys using the VLA indicate that the OH masers are in shells distributed spherically around the central stars (Reid et al. 1981, AJ, 86, 897; Bowers et al. 1983, ApJ, 274, 733; Chapman et al. 1984, MN, 207, 149). These results agree with MERLIN observations in two sources, but are at odds with results from IRC+10420, an F8 supergiant, which seems to contain a bipolar flow (Norris et al. 1982, Nature, 299, 131; Diamond et al. 1983, AA, 124, L4; Booth et al. 1981, Nature, 290, 384) and from NML Cyg which has a complex structure (Diamond et al. 1984, MN, 207, 611). VLA and time sequence observations of another 1667 MHz source, OH 231.8+4.2, indicate bipolar flow (Morris et al. 1982, ApJ, 259, 625; Bowers and Morris 1984, ApJ, 276, 646). VLBI observations of the VYCma 1665 and 1667 MHz masers indicate a rotating disc, and Zeeman splitting indicates a ∿1 milligauss field (Benson and Mutel 1982, ApJ, 253, 199). A survey of stokes polarimetry was carried out in IRC+10420 and in seven late-type variables yielding information about their magnetic fields (Claussen and Fix 1982, ApJ, 263, 153). Models of OH masers involve photodissociation of water by ambient UV photons (Huggins and Glassgold 1982, AJ, 87, 1828).

5.4 Other Masers

SiO has maser and thermal emission lines. Maser emission has been studied using the v = 1, J = 1-0, J = 2-1, J = 3-2 and J = 5-4 (Clemens and Lane 1983, ApJ, 266, L117; Clark et al. 1984, ApJ, 276, 572) lines of SiO as well as the v = 2, J = 2-1 transition (Olofsson et al. 1981, ApJ, 247, L81). There is strong evidence from a survey of six objects, of variable intensity correlating with the IR fluxes of periodically variable stars (Wolff and Carlson 1982, ApJ, 257, 161) and a survey of 54 v = 1, J = 1-0 masers has yielded a statistically complete survey to approximately 300 pc. Maser emission was found toward four objects near dense clouds, objects which seem to be red super-giants (Ukita and Goldsmith 1984, AA, 138, 194). Modelling of SiO maser emission has also been improved (Elitzur et al. 1983, ApJ, 274, 210; Langer and Watson 1984, ApJ, 284, 751).

A systematic survey of short-period semi-regular stars has yielded six new water masers, indicating the presence of a different class of maser star (Dickenson and St. Clair Dinger 1982, ApJ, 254, 136). An SiS maser (v = 0, J = 1-0) was detected in IRC+10216 (Grashoff et al. 1981, AA, 101, 238; Henkel et al. 1983, ApJ, 267, 184), *understood by observations of many rotational transitions of SiS (Sahai* et al. 1984, ApJ, 284, 144).

6. HIGH-VELOCITY OUTFLOWS

One of the most striking results of recent years is the discovery of numerous high velocity, generally bipolar flows near dense cores and embedded IR sources in molecular clouds, apparently arising from outflow along the poles of stellar accretion discs (Bally and Lada 1983, ApJ, 265, 824). The best studied object is the high-velocity source in Orion, though the general importance of such outflows can only be appreciated from the studies of many other occurrences.

6.1 The Orion High-Velocity Source

The first direct indication of the importance of the IR source, IRc2, came from VLBI observations of the water masers, yielding proper motions of several arcsec/yr, centered on the deeply embedded source. (Genzel et al. 1981, ApJ, 244, 884). Observations of the J = 3-2 transition of CO and of SiO v = 0, J = 2-1 with the Hat Creek interferometer further indicated the importance of IRc2 by detecting red-shifted and blue-shifted jets to the east and west of IRc2 respectively (Erickson et al. 1982, ApJ, 261, L103; Wright et al 1983, ApJ, 267, L41). Interferometry of J = 1-0 CO (Masson et al. 1984, ApJ, 283, L37) and of HCO^+ (Vogel et al. 1984, ApJ, 283, 655) have further refined our understanding of the interaction between the high velocity material and the quiescent gas. Interferometry located the centers of OH (VLA) and SiO (Hat Creek) maser emission around IRc2 (Hansen and Johnston 1983, ApJ, 267, 625; Wright and Plambeck 1983, ApJ, 267, L115) and MERLIN observations of OH indicate a rotating torus (Norris 1984, MN, 207, 127. IR polarization convincingly showed that IRc2 and the Becklin-Neugebauer sources are the illuminating sources in the entire region, with other IR sources merely being reflection nebulae (Werner et al. 1983, ApJ, 265, L13). Polarimetry of the SiO maser indicates its origin in a rotating, expanding disc (Barvainis 1984, ApJ, 279, 358). High spectral resolution IR spectroscopy at 2-5μ indicated the existence of several components associated with the outflow region and provided a detailed look at the central, ultra-dense wind and surrounding dense molecular disc (Scoville et al. 1983, ApJ, 275, 201).

The region of molecular gas shocked by the outflow has been extensively studied by means of vibration/rotation lines of molecular hydrogen, leading to estimates of the mass (.02-.05 $M_{\odot}$), temperature (2000-3000 K) and line-of-sight extinction (1-4 mag at 2μ) (Scoville et al. 1982, ApJ, 253, 136; Beckwith et al. 1983, ApJ, 264, 152; Knacke and Young 1981, ApJ, 249, L65; Beck et al. 1982, ApJ, 253, L83; Nadeau et al. 1982,ApJ, 253, 154; Beck and Beckwith 1983, ApJ, 271, 175; Beck 1984, ApJ, 281, 205). Other molecular observations which have focused on the highly excited gas near the origin of the outflow have used high excitation lines of HCCCN (Loren et al. 1981, ApJ, 244, L107; Goldsmith et al. 1982, ApJ, 260, 147), the 153μ and 168μ rotational lines of CO (Stacey et al. 1982, ApJ, 257, L37; 1983, MN, 202, 25P), CH_3CN (Goldsmith et al. 1983, ApJ, 274, 184) and CH_3OH (Lovas et al. 1982, ApJ, 253, 149). New Herbig-Haro objects have been discovered (Axon and Taylor 1984, MN, 207, 241).

Several other molecular transitions have been used to further define the nature of the outflow and shocked gas including CO, H_2CO, H_2O, HCO^+, SO, SiO, NH_3 and HCN (van Vliet et al. 1981, AA, 101, L1; Solomon et al. 1981, ApJ, 245, L19; Olofsson et al. 1982, AA, 113, L18; Phillips and White 1983, MN, 202, 1093; Plambeck et al. 1982, ApJ, 259, 617; Kuiper et al. 1984, ApJ, 283, 106; Hasegawa et al. 1984, ApJ, 283, 106; Friberg 1984, AA, 132, 265; Kuiper et al. 1981, ApJ, 251, 88; Harris et al. 1983, ApJ, 265, L63; Rydbeck et al. 1981, ApJ, 243, L41; Wright et al. 1981, ApJ, 245, L87; Wootten et al. 1984, ApJ, 277, 189).

6.2 Other High-Velocity Sources

Observations of NGC 2071 show its bipolar flow to be orthogonal to a dense, rotating disc, presumably associated with a forming star (Lichten 1982, ApJ, 253, 593; Bally 1982, ApJ, 261, 558; Schwartz et al. 1983, ApJ, 267, L109; Persson et al. 1981, ApJ, 251, L85; Bally and Stark 1983, ApJ, 266, L61; Takano et al. 1984, ApJ, 282, L69; Wootten et al. 1984, ApJ, 279, 633). CO observations in several objects indicate that molecular emission arises in the outer boundaries of a cavity swept out by the outflow (Snell et al. 1984, ApJ, 284, 176). A survey of high-velocity sources reviews the properties of known outflows (Bally and Lada 1983, ApJ, 265, 824). Individual sources observed are W3 (Claussen et al. 1984, ApJ, 285, L79). AFGL2591 (Lada et al. 1984, ApJ, 286, 302), HH 7-11 (Snell and Edwards 1981, ApJ, 251, 103), L1529 (Lichten 1982, ApJ, 255, L119), L1551 (Kaifu et al. 1984, AA, 134, 7), HH 24-27 and HH 1-2 (Snell and Edwards 1982, ApJ, 259, 668), NGC 7538 (IRS 1-3) (Campbell and Thompson 1984, ApJ, 279, 650; Campbell 1984, ApJ, 282, L27), GL437 (Arquilla and Goldsmith 1984, ApJ, 279, 664), CepA (Cohen et al. 1984, MN, 210, 425), GL490 (Lada and Harvey 1981, ApJ, 245, 58; Kawabe et al. 1984, ApJ, 282, L73), G35.2-0.74 (Matthews et al. 1984, AA, 136, 282), W49 and W51 (Ho, Genzel and Das, 1983, ApJ, 266, 596; Downes et al. 1982, ApJ, 252, L29; Beckwith and Zuckerman 1982, ApJ, 255, 536; Genzel et al. 1981, ApJ, 247, 1039), S156 (Joy et al. 1984, ApJ, 284, 161), RCW97 Brand et al. 1984, AA, 139, 181; R Mon (HH 39) (Canto et al. 1981, ApJ, 244, 102), GGD 12-15 (Rodríguez et al. 1982, ApJ, 260, 635), GGD 27/28 (de Vries et al. 1984, AASuppl, 56, 333), PV Cephei (Levreault 1984, ApJ, 277, 634), Elias 1-12 (Levreault 1983, ApJ, 265, 855), HH objects 19-27, 1-3, 35,36 and 63 (Edwards and Snell, 1984, ApJ, 281, 237) and in four dark clouds (Frerking and Langer 1982, ApJ, 256, 523). Observations were made using millimeterwave CS (Thronson and Lada 1984, ApJ, 284, 135).

Interpretations of the widespread occurrence of high-velocity outflows generally involve massive discs (Torrelles et al. 1983, ApJ, 274, 214) but sometimes also involve magnetic fields (Draine 1983, ApJ, 270, 519; Pudritz and Norman 1983, ApJ, 274, 677). It has also been suggested that most outflowing regions will result in stars of less than 4 $M_{\odot}$ (Beckwith et al. 1983, ApJ, 267, 596).

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7. MASERS

During the past four years maser research has benefitted from widespread application of new radio interferometers and from the completion of a number of complete surveys. Much important maser work has focused on observations of material around late-type stars and bipolar flows, and the references given in those sections are not repeated here.

OH masers have been studied in a set of three surveys of mainline emission covering the galactic longitude range 326°-60° including the galactic center region (Caswell et al.1980, AustJPhys,33, 639;Caswell and Haynes 1983, AustJPhys,36,361; 1983,AustJPhys,36,417) yielding 144 maser sources, almost entirely associated with HII regions. Interferometry of OH was done with the VLA (Ho et al.1983,ApJ,265,295; Dickel et al.1982, MN, 198,265), MERLIN (Norris et al.1982,MN,201,209) and using VLBI techniques (Haschick et al. 1981,ApJ,244,76;Fouquet and Reid 1982,AJ,87,691; Forster et al. 1982,MN,201,7P). Generally the OH masers are located in shells at the edges of HII regions, indicating shock excitation of the masers.

Water masers have been used in surveys made according to various selection criteria: toward known OH masers (Caswell et al. 1983, AustJPhys, 36, 401; 1983, AustJPhys, 36, 443), radio continuum peaks (Braz and Scalise, 1982, AA, 107, 272), infrared sources (Jaffe et al. 1981, ApJ, 250, 621; Crocker and Hagen 1983, AASuppl, 54, 405), bright nebulosities (Sandell and Olofsson 1981, AA, 99, 80) and Herbig-Haro objects (Haschick et al. 1983, ApJ, 265, 281). Of these, IR sources and OH masers proved to be the most reliable signpost of H_2O maser emission.

Several studies have focused on the 1979 maser outburst in Orion, associated with action of an emerging proto-star (Abraham et al. 1981, AA, 100, L10; Matveenko et al. 1982, Pis'ma AZh, 8, 711;Matveenko et al. 1983, Pis'ma AZh, 9, 456; Strel'nitskij 1982, Pis'ma AZh, 8, 165). Another time-variable maser has been studied in the direction of the supernova remnant Kes 45 (Sandell et al. 1983,AA, 124, 139) and three interferometric studies have been made toward W51 (Downes et al. 1981, ApJ, 249, 124), W49 (Walker et al. 1982, ApJ, 255, 128) and toward 7 other HII regions (Lada et al. 1981, ApJ, 243, 769).

VLA maps have been made of the only two known H_2CO masers, toward SgrB2 (Whiteoak and Garner 1983, MN, 205, 27P) and NGC 7538 (Rots et al. 1981, ApJ, 245, L15) and further studies have been made of the equally unusual SiO maser in Orion (Ukita et al. 1981, PASJapan, 33, 341; Olofsson et al. 1981,AA, 100, L30). Calculations have modelled SiO, H_2O and methanol masers in star-forming regions (Varshalovich et al. 1983, Pis'ma AZh, 9, 395; Grinen and Grigor'ev 1983, Pis'ma AZh, 9, 463; Sobolev and Strel'nitskij 1983, Pis'ma AZh, 9, 26; Strel'nitskij 1984, MN, 207, 340) and have modelled maser pumping in the presence of cold grains (Deguchi 1981, ApJ, 249, 145).

IV. Interstellar Grains
(J.S. Mathis)

For reasons of space, this overview cannot cover some very intersting work on circumstellar and interplanetary grains, both of which have bearing on interstellar dust.

Continuum extinction has been determined much more accurately than before in the near-infrared (1 - 10μm) spectral region (Koornneef 1983, AA, 128, 84; Castor and Simon 1983, ApJ, 265, 304; Willner and Pipher 1983, ApJ, 265, 760; Leitherer and Wolf 1984, AA, 132, 151; Landindi et al. 1984, AA, in press; Rieke and Lebofsky 1984, ApJ, in press). The derived values of A(λ)/A(V) differ by up to 50% in the 2 - 4 μm range. The extinction law has been investigated in several dark clouds (Herbst et al. 1982, AJ, 87, 98; Vrba and Rydgren 1984, ApJ, 283, 123; Chini and

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Krügel 1983, AA, 117, 289). As is well known, R, defined as A(V)/E(B-V), is larger in dark clouds than for diffuse dust. A large R and a large wavelength of maximum polarization, λ(max), are usually taken to imply a larger-than-average grain size. However, Chini and Krügel (op.cit.) show from models that this is not necessarily the case; they can produce many counterexamples, except that large λ(max) is always correlated with the size of silicate cylinders. Extinction in dark clouds is apparently rather similar to that in diffuse regions for λ < 0.5 μm, and the large value of R in dark clouds arises from the extinction between V and B increasing more slowly than normal (Hyland et al. 1982, MN, 201, 1095). The Taurus dark cloud has a normal value of R (Straizys et al. 1982, ApSpSci, 85, 271). The IR/visual extinction is also the same in the LMC and SMC as in the Galaxy (Koornneef 1982, AA, 107, 249; Morgan and Nandy 1982, MN, 199, 979; Nandy et al. 1984, MN, in press).

Maps of the visual extinction in various directions have been determined from galaxy counts (Burstein and Heiles 1982, AJ, 87, 1189; Strong 1983, MN, 202, 1015) and Strömgren photometry (Perry and Johnston 1982, ApJ, 50, 451). Knudel (1983, AA, 126, 89) suggest that about 5% of the sky at high latitudes is covered by clouds. The results of the IRAS satellite on IR "cirrus" (Low et al. 1984, ApJ, 278, L19) should clarify the picture.

Ultraviolet extinction has been studied by means of the IUE satellite. Variations in extinctions from star to star put powerful constraints on the nature of grains. A large catalog of measurements of the strength of the λ2175 feature ("the bump") is compiled in Guertler et al. (1982, AstrNach, 303, 105) and in Friedemann et al. (1983, AstrNach, 304, 237).

Krelowski and Strobel (1982, ActaAstr, 32, 331) and Greenberg and Chlewicki (1983, ApJ, 272, 563) find that the bump and visual extinction are correlated, but the extinction in the 0.17-0.13 μm region (hereafter called the "FUV rise") varies independently of the other two. However, de Boer (1983, AA, 125, 258) finds a star with a normal FUV extinction and an extinction excess from 0.5 μm through the bump. Variations of UV extinction from star to star have been discussed in 1367 stars of type B3 or earlier by Meyer and Savage (1981, Apj, 248, 545) using ANS data. They find that there are wide variations in the strength of the bump and in the FUV rise. They show examples of stars which are not embedded in dark clouds in which the visual extinction, FUV rise, and bump very independenly. In detailed IUE studies, Massa et al. (1983, ApJ, 266, 662) and Witt et al. (1984, ApJ, 248, 545) confirmed the result that deviations for stars in the general diffuse ISM are not uncommon. The implications of this fact is that the estimation of the reddening of an object by removal of the λ2175 bump is rather dangerous. A most interesting finding is that the maximum of the bump is at almost exactly the same wavelength in all stars, independent of its strength.

Ultraviolet extinction within the Cep OB3 Association has been studied by Barsella et al. (1982, AA, 111, 130), who concluded that the dust is graphite-rich from the strength of the bump, and by Massa and Savage (1984, ApJ, 279, 310), who found a regular decrease of the FUV rise as the line of sight progresses into successively denser parts of the associated molecular cloud. The "graphite richness" may be a "small-silicate poverty" within the cloud, assuming that indeed the bump is related to graphite (see the following discussion on theories). The dust in front of Herschel 36 in M20 (Hecht et al. 1982, ApJ, 263, L391) is similar to that in the Orion Nebula (Bohlin and Savage 1981, ApJ, 249, 109). The star HD 29647 in the Taurus cloud has a very peculiar extinction, with a weak bump (Seab et al. 1981, ApJ, 246, 788) possibly caused by icy coatings as implied by the observed (but weak) 3.01 μm absorption band (Goebel 1983, ApJ, 268, L41). Peculiar extinction for the Wolf-Rayet stars has been suggested by Garmany et al. (1984, ApJ, 278, 233).

Extinction in the LMC is like that in the Milky Way for the IR and visual regions (Nandy and Morgan 1982, MN, 200, 979; Koornneef 1982, AA, 107, 247), but with an N(H)/E(B-V) four times larger than the Galactic average. This ratio presumably reflects the gas/dust ratio, by mass, in the two objects. The UV extinction in the LMC is well known to differ from Galactic, with a weak bump and a steep FUV rise (Nandy et al. 1981, MN, 192, 955; Koornneef and Code, 1981, ApJ, 247, 860). The extinction has been fitted by a simple analytical expression (Howarth 1983, MN, 203, 301). The bump is stronger than the LMC average towards the core of the giant HII region 30 Doradus (Fitzpatrick and Savage, ApJ, 279, 301). The difference in extinction between two stars of the same spectral type but different reddenings suggests a Galactic extinction law, rather than LMC, for the dust between them.

Ultraviolet extinction deviates even more from Galactic in the SMC than in the LMC. There is almost no bump (Nandy et al. 1982, MN, 201, 1p; Prevot et al. 1984, AA, 132, 389). The dust/gas ratio is even higher than in the LMC, but must be regarded as highly uncertain because of the very low extinctions involved (see also Fitzpatrick 1984, ApJ, 282, 436). At least one star in the SMC, Sk 143, has a "normal" Galactic UV extinction law (Lequeux et al. AA, 113, L15).

Infrared absorption and emission features have been recently reviewed by Willner (1983, 16th ESLAB Symp.). The 3.07 μm "ice" absorption feature has been studied extensively observationally (Knacke et al. 1982, ApJ, 260, 141; Joyce and Simon 1982, ApJ, 260, 604). The feature is fitted well by amorphous water and ammonia ices. Léger et al. (1983, AA, 117, 164) suggest that the long-wavelength wing is caused by large ice particles; Hagen et al. (1983, AA, 117, 132) feel that it is due to complex molecular ices, perhaps by formaldehyde ice as well (Hagen et al. 1980, AA, 86, L3). Extensive laboratory studies of ices of water and other substances (Hagen et al. 1983, AASuppl, 51, 389; Moore et al. 1983, Icarus, 54, 388) show that the C-O stretch absorption at about 5 μm is strong. It is not seen in many sources with strong 3.07 μm bands, which suggests that ammonia is the more likely cause of the longward wing of that band. Whittet et al. (1983, Nature, 303, 218) have detected the 3.07 μm band in several stars in the Taurus cloud which have only modest amounts of extinction (3-6 mag at V), whereas it was formerly believed that about 20 mag were required for the ice band to be detectable.

Roche and Aitken (1984, MN, 208, 481) find that the shape of the 9.7 μm band in six Wolf-Rayet stars is better fitted by the band profile in μ Cephei than by the usually assumed profile, taken from the Orion Nebula. The ratio of visual extinction to optical depth at 9.7 μm is 18.5, larger than usually quoted. A very peculiar 9.7 μm profile has been observed in Mark 231 by Breger and Witteborn (1984, ApJ, 281, L17).

Kitta and Krätchmer (1983, AA, 122, 105) have considered the 12 μm feature of water ice in various mixtures of water and other materials. They conclude that the 12 μm ice band must be present in objects which show the 3.07 μm band. However, Hagen et al. (1983, AASuppl, 51, 389) suggest that the feature may be shifted to longer wavelengths where there is a strong telluric band. Of course, the 12 μm feature coincides with the "silicate" feature and may be hidden if the continuum is improperly drawn.

The 3.4 μm absorption feature of the C-H stretch, observed in IRS 7 near the Galactic center (Allen and Wickramasinghe 1984, Nature, 294, 239) is especially interesting. There are many other complex absorption features in the 2.9-3.3 μm region of this object, but no convincing sign of the 3.07 μm ice band. This fact is important because it shows that C-H bonds exist on grains which are not deeply embedded in dark clouds. Which molecules give rise to the 3.4 μm absorption band is not clear. There is a rather weak absorption at 6.0 μm (Willner et al. 1982, ApJ, 253, 174), well correlated with the 3.07 μm strength, which is presumably the bending mode of water ice. There is also an unidentified band at 6.8 μm which is correlated with the short-wavelength side of the ice band, but not with the long. Strazzulla et al. (1984, AA, 133, 77; 1983, MN, 204, 59p) have studied synthesized polymetric residues produced from proton bombardment of hydrocarbons. The 3.4 μm absorption band is produced independently of the hydrocarbon used in the bombardment.

The 4.67 μm absorption band has been detected in several molecular cloud sources by Lacy et al. (1984, ApJ, 276, 533). It has a structure which can be well explained by solid CO and some molecule containing the C-N triple bond. In one source, gaseous CO bands were observed instead of the solid-CO feature.

The 3.2-3.6 μm emission bands are very complex, with different profiles from source to source (Allen et al. 1982, MN, 199, 1017). The presence of many telluric bands makes the 3-4 μm region a difficult one for the determination of accurate profiles. The unidentified emission features at 3.3,6.2,7.6,8.8 and 11.4 μm are observed in many objects (Aitken and Roche 1984, MN, 208, 751). Emission features near 3.5 μm have been identified with formaldehyde (Bass et al. 1983, ApJ, 265, 290). Most of the emission features have been suggested by Leger and Puget (1984, AA, 137, L5) to be produced by warm coronene, a polycyclic aromatic with a structure of linked benzene rings, and H on the edges. They suggest that a molecule of about 50 carbon atoms arranged in a matrix of linked benzene rings might agree rather well with observations. Dwek et al. (1981, ApJ, 243, 677) show that a very high efficiency of fluorescence is required if the emission bands are to be produced by that process.

Scattering by grains has been investigated in the visual reflection nebulae in the Pleiades (Cottrell and Witt, 1983, AJ, 88, 418) and NGC 1999 (Smith 1983, MN, 205, 349). In the UV, Morgan et al. (1982, MN, 199, 399) and Tanaka et al. (1984, ApJ, 280, 213) have observed the Orion Loop Nebulosity. Witt et al. (1982, ApJ, 261, 192) have studied NGC 7023 extensively. Unfortunately, the determination of albedo and phase parameter from the measurements depends critically upon the assumptions regarding the geometry of the reflecting grains and illuminating star.

The most interesting finding of the studies of reflection nebulae is that there is an excess emission in the 2-5 μm range in NGC 2023, 7023 and 2068 (Sellgren et al. 1983, ApJ, 271, L13; Sellgren 1984, ApJ, 277, 623). This excess emission extends into the red spectral region (Witt et al. 1984, ApJ, 281, 708). At present, it is not clear whether the excess represents the thermal radiation from a single tiny grain following its absorption of a single photon, or alternatively some fluorescence process. If the emission extends to wavelengths as short as 0.65 μm, the required grain temperatures are improbably high. All of these nebulae show a strong 3.4 μm emission band.

Interstellar Polarization has been studied in molecular clouds (Werner et al. 1983, ApJ, 265, L13; Cudlip et al. 1982, MN, 200, 1169; Moneti et al. 1984, ApJ, 282, 508; Joyce and Smith 1982, ApJ, 260, 604), in the Pleiades (Breger 1984, AA, 137, 145), and in field stars (Tinbergen 1982, AA, 121, 158; Wolstencroft and Smith 1984, MN, 208, 461). The last paper shows an interesting ripple structure in the wavelength dependence of the polarization. An improved empirical fit to the wavelength dependence of polarization has been given by Wilking et al. (1982, AJ, 87, 695). The width of the $p(\lambda)$ curve increases with $\lambda(max)$. Clarke and Al-Roubaie (1983, MN, 202, 137) have discussed the effects of noise on the $p(\lambda)$ law. Polarization in the LMC is very similar to that in the Galaxy, both in the form for $p(\lambda)$ and in the values for $\lambda(max)$ (Clayton et al. 1983, ApJ, 265, 194).

The size distribution of the grains affects the x-ray scattering from the heavy elements in the grains. Observations of halos around x-ray sources are consistent with a power-law distribution of particles sizes (Catura 1983, ApJ, 275, 645). The chemical composition is also uncertain. Sakata et al. (1984, Nature, 301, 493) show that a λ2175 feature is produced by the residue from discharges in gaseous hydrocarbons. It has been suggested (Duley et al. 1979, ApSpSc, 65, 69) that the bump is caused by surface defects on MgO grains. MacLean et al. (1982, ApJ,

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256, L61) show that MgO produces more blue light by fluorescence when irradiated by UV at λ2200 than at other wavelengths, and interpret this observation to mean that MgO absorbs more at λ2200 than elsewhere. However, Hoyle et al. (1983, ApSpSc, 92, 433) show that the observed extinction is about an order of magnitude too much to be produced by these grains, and Duley (1983, ApSpSc , 92,45) states that CO absorption onto small MgO grains shifts the wavelength of the bump to shorter wavelengths, which is not observed in several stars with CO absorption lines in their IUE spectra. Murray et al. (1984, ApJ, 282, 481) show that almost half of Mg is in the gas phase, which makes the abundance constraints on the MgO-bump connection even more severe. Millar (1982, ApSpSc, 86, 497) has claimed that SiO has enough stability to exist in the interstellar chemically reducing environment, so that the 9.7 μm bump could be caused by SiO, but Nuth and Donn (1983, ApSpSc, 95, 175) point out major additional problems with the SiO interpretation of the 9.7 μm feature. Duley and Najdowsky (1983, ApSpSc, 95, 187) have given an extensive explanation of interstellar extinction using oxide grains.

Grains form in the upper photospheres of O-rich M giants and supergiants because of the rapid drop in temperature caused by the spherical extension of the atmosphere (Schmid-Burgh and Scholz 1981, MN, 194, 805). The formation of graphite, as opposed to amorphous carbon, in C-rich atmospheres has been discussed (Woodrow and Auman 1982, ApJ, 257, 247; Gail and Sadlmayr 1984, AA, 132, 163; Gail et al. 1984, AA, 133, 320). The carbon star R Cor Bor does not have the bump in its UV spectrum (Hecht et al. 1984, ApJ, 280, 228), so presumably makes amorphous C grains. Novae are C-rich, but it is not clear whether the grains which emit the observed IR are formed within the expanding shell or were in the ejecta from the red giant progenitor (Bode and Evans 1981, MN, 197, 1055; 1982, ApJ, 254,263). A similar situation applies to supernovae (Dwek et al. 1983, ApJ, 274, 168 and 175).

The chemical composition of mantles of ices on grains have been predicted theoretically by Thielens and Hagen (1982, AA, 114, 245). The trapping of molecules on grains was discussed by Burke and Hollenbach (1983, ApJ, 265, 223). Leger (1983, AA, 123, 271) finds that CO should condense onto cold grains in only modestly dark clouds, while observations show that it does not. Johnston et al. (1983, AA, 123, 343) show that mantles can be eroded surprisingly efficiently by low-energy cosmic rays. Processed icy mantles, when warmed, produce a refractory "yellow stuff" residue (Greenberg 1982, in Comets, ed. L. Wilkening, U.Ariz.Press, p. 131; Moore et al. 1983, Icarus, 54, 388). The destruction of more refractory mantles on grains in molecular clouds by shocks (Draine et al. 1983, ApJ, 264, 485) is reasonably efficient and is heavily influenced by the presence of a magnetic field, which softens the shock and increases the importance of collisions of gas and dust.

Dust and gas can possibly be gravitationally separated within a molecular cloud (Williams and Bhatt 1982, MNRAS, 199, 465; Bhatt and Desai 1982, ApSpSc, 84, 163). The IRAS satellite also detected dust emission from regions of the sky in which there seems to be little HI (Low et al. 1984, ApJ, 278, L19), and there is a separation of gas and dust as seen in a particular high-latitude position (King et al. 1982, MN, 198, 255).

Possibly grains have a biological origin (Jabir et al. 1982, ApSpSc, 86, 321; Hoyle and Wickramasinghe 1982, ApSpSc, 86, 341). However, Duley (1984, QJRAS, 25, 109) and Whittet (1984, MN, 210, 479) have shown that the biological model of interstellar grains requires too much phosporous by more than an order of magnitude.

Depletion studies of ions in the gas phase are surveyed by Bohlin et al. (1983, ApJSuppl, 51, 277). Depletions increase with increasing gas density, even in the diffuse ISM (Harris et al. 1984, ApJ, 284, 157). There are only modest depletions of O and N, about the same factor for each (York et al. 1983, ApJ, 266, L83), and in C (Hobbs et al. 1982, ApJ, 252; Jenkins et al. 1983, ApJ, 270, 88). Zinc is mostly gaseous and is a good tracer of the gas column density (York and Jura

1982, ApJ, 254, 88), while Si, Mn and Fe are severly depleted (Lugger et al. 1982, ApJ, 259, 67; Phillips et al. 1982, MN, 200, 687), and Ca within a dark cloud has the greatest depletion yet measured (Snow et al. 1983, 265, 267). There is strong evidence that the depletion is less at large distances from the galactic plane (Albert 1982, ApJ, 256, L9); Hobbs 1983, ApJ, 265, 817), and is greater within dark clouds (Tarafdar et al. 1983, ApJ, 267, 156).

It is still an open question whether or not most interstellar chemistry takes place on grain surfaces or in the gas phase. The arguments are summarized in papers in the 16th ESLAB Symposium, Galactic and Extragalactic Infrared Spectroscopy, 1983. It is clear that molecular hydrogen is produced on grain surfaces, apparently very efficiently (Jenkins et al. 1983, ApJ. 270, 88). Grain-surface chemistry has been studied (Millar 1982, MN, 199, 309; 1982, ApSpSc, 87, 435; Jones et al. 1983, ApSpSc, 96, 141). The results look promising. However, so do the predictions from gas-phase chemistry (Graedel et al. 1982, ApJSuppl, 48, 321; Freeman and Millar 1983, Nature, 301, 402; Herbst 1983, ApJSupp, 53, 41;Dickman et al. 1983, ApJSupp, 53, 55), both in equilibrium and following shocks (Draine et al. 1983, ApJ, 264, 485; Mitchell,MN, 1983, 205, 765). Interstellar molecules within dark clouds may be the products of reactions within grain mantles after being warmed (Allamandola et al. 1982, AA, 109, L12). The amount of gaseous C in clouds suggests rapid circulation within these clouds (Boland and de Jong 1982, ApJ, 261, 110).

The far-infrared emission ("FIR"; $\lambda > 80\mu m$) observed from the Galaxy is emitted following absorption of starlight. The FIR has been discussed, with references to observations, by Mezger et al. (1982, AA, 105, 372) and Mathis et al. (1983, AA, 128, 212) in terms of the bare-grain silicate and graphite ("MRN") model. Other observations are in Jaffe et al. (1982, Apj, 252, 601) and Campbell et al. (1984, ApJ, 284, 566). The results are, of course, dependent upon the FIR emissivities of the assumed constituents.

The optical constants of graphite and silicates have recently been discussed by Draine and Lee (1984, ApJ, 285, 89). Tanabe et al. (1983, PASJapan, 35, 397) have given constants for graphite, amorphous C, and SiC; Millar (1981, ApSpSc, 78, 505) for oxide grains; Kitta and Krätschmer (1983, AA, 122, 105) and Léger et al. (1983, AA, 117, 164) for amorphous ice.

V. STAR FORMATION
(B.G. Elmegreen)

1. INTRODUCTION

The rate of progress in understanding star formation and pre-main sequence (PMS) objects has been higher in the last three years than it has at any previous time. Radio and speckle interferometric observations reveal the clumply structure of clouds and the disks around embedded stars. The structure of the Kleinmann-Low nebula in Orion is nearly understood. The gravitational collapse phase of star formation has been observed in a few sources, and embedded stars have been found to possess strong winds, or, in some cases, jets. Numerical computations of cloud collapse can now simulate fragmentation in some detail, although a shift in emphasis toward analytic methods for simple geometries has occurred.

Star formation has also been observed to influence the surrounding medium over distances as large as a kiloparsec, leading to the speculation that star formation can propagate over these scales, and to the concept of feedback control between star formation and interstellar matter. Cloud formation mechanisms are also beginning to be recognized on kiloparsec scales, and several observations of star and cloud complexes of this size have been made. Models of propagating star formation in galaxies are beginning to recognize the predictions of these models.

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Reviews of star formation may be found in the proceedings of "Regions of Recent Star Formation" (1982, ed. Roger and Dewdney, Reidel), "The Formation of Planetary Systems" (1982, ed. A. Brahic, Cepadues Editions), "Symposium on the Orion Nebula to Honor Henry Draper" (ed. Glassgold, Huggins and Schucking, 1983, AnnNYAcadSci, Vol. 395), and "Proceedings of a Symposium on Herbig-Haro Objects, T Tauri Stars and Related Phenomena" (1983, ed. Cantó and Mendoza, RevMexAA, Vol.7).

2. OBSERVATION OF STAR FORMATION ON SMALL SCALES

The contraction of gas onto a protostar has been observed in W3(OH) by Rickard et al. 1982, AJ, 87, 1806) and Wouterloot (1984, AA, 135, 32), and in a few other sources by Forster and Boland (1982, AA, 114, 109). OH associated with possible young protostars has been found by Caswell and Haynes (1983, AustJPhys, 36, 361). The contraction of small molecular clouds was observed by Myers, Linke and Benson (1983, ApJ, 264, 517), and of larger clouds by Riley et al. (1982, MN, 199, 197). Star formation in the smallest clouds may proceed by the quasistatic contraction of a dissipating turbulent envelope onto a thermal-pressure-supported core (Myers, 1983, ApJ, 270, 105). Some globules may contract from filaments (Leung et al. 1982, ApJ, 262, 582). These contractions are so slow that many globules appear to be nearly in equilibrium (Myers and Benson 1983, ApJ, 266, 309; Dickman and Clemens 1983, ApJ, 271, 143).

Small-scale clumpy structure in clouds was observed using a variety of techniques. NH_3 shows clumps in the following sources: Orion (Ziurys et al. 1981, AA, 104, 288; Zuckerman et al. 1981, ApJ, 250, L39; Harris et al. 1983, ApJ, 265, L63; Pauls et al. 1983, AA, 124, 23; Batrla et al. 1983, AA, 128, 279), W51 (Ho et al. 1983, ApJ, 266, 596); Taurus (Ungerechts et al. 1982, AA, 111, 339), G35.2-0.74 (Brown et al. 1982, MN, 201, 121) and DR21 (Matsikis et al. 1981, ApJ, 250, L85). Clumps are inferred from H_2CO in W3 (Arnal et al. 1982, MN, 201, 317), from HC_3N in TMC1 (Schloerb et al. 1983, Ap, 267, 163), from HNCO in several clouds (Jackson et al. 1984, ApJ, 280, 608), from CS in W51 and DR21(OH) (White et al. 1983, MN, 204, 1117), in M17, S140 and NGC 2024 (Snell et al. 1984, ApJ, 255, 149) and in other clouds (Snell et al. 1982, ApJ, 255, 149), from several molecules in Taurus (Baudry et al. 1981, AA, 104, 101), and from near-infrared observations in Orion (Smith et al.1983, AJ, 88, 469) and far-infrared observations in Orion (Drapatz et al. 1983 AA, 128, 207), W3 (Jaffe et al. 1983, ApJ, 273, L89), Cha I (Wesselius et al. 1984, ApJ, 278, L37) and S235 (Nordt et al. 1984, AA, 131, 221). Line profiles of clumpy clouds were discussed by Martin et al. 1984, MN, 208, 35).

PMS circumstellar disks or rings have been found in the following sources: IRc2 in Orion (see Orion discussion below), HL Tau (Cohen and Schmidt 1981, AJ, 86,1228; Cohen 1983, ApJ, 270, L69, FU Ori (Smith et al. 1982, ApJ, 258, 170, near the Herbig-Haro objects HH 24-27 (Matthews and Little, 1983, MN, 205, 123), S106 (Gehrz et al. 1982, ApJ, 254, 550); Staude et al. 1982, ApJ, 255, 95; Bally and Scoville 1982, ApJ, 255, 497; Harvey et al. 1982, ApJ, 258, 568; Churchwell and Bieging 1982, ApJ, 258, 515; Stutzki et al. 1982, AA, 111, 201; Solf and Carsenty 1982, AA, 113, 142; Bally et al. 1983, ApJ, 272, 154, N2071 (Bally 1982, ApJ, 261, 558; Schwartz et al. 1983, ApJ, 267, L109), N2261 (Gething et al. 1982, MN, 198, 881), NGC 1333 (Schwartz et al. 1983, ApJ, 267, L109), N6334V (Harvey and Wilking 1984, ApJ, 280, L19), L1455 and L1551 (Davidson and Jaffe 1984, ApJ, 277, L13), Cha I (Cohen and Schwartz 1984, AJ, 89, 277), M8 (Lightfoot et al. 1984, MN, 208, 197), LkHα208 (Shirt et al. 1983, MN, 204, 1257), and in a few other sources (Torrelles et al. 1983, ApJ, 274, 214; Turner and Matthews 1984, ApJ, 277, 164). These disks are usually perpendicular to bipolar flows from centrally located stars. Dense, unresolved material has also been found associated with embedded A and B stars by Harvey et al. 1984, ApJ, 278, 156.

Bipolar outflows are commonly observed in the vicinity of embedded PMS stars. Survey for broad pedestals in the line profiles from molecular clouds were made by

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Loren 1981,(ApJ, 249, 550), Frerking and Langer (1982, ApJ, 256, 523), Bally and Lada (1983, ApJ, 265, 824), Plambeck et al. (1983, ApJ, 266, 321), and de Vries et al. (1984, AASuppl, 56, 333). Surveys for such high velocity molecular emission near T Tauri stars were made by Kutner et al. (1982, ApJ, 259, L35), Edwards and Snell (1982, ApJ, 261, 151), Levreault (1983, ApJ, 265, 855), and Calvet et al. (1983, ApJ, 268, 739). Surveys near Herbig-Haro objects were made by Snell and Edwards (1981,ApJ, 251, 103; 1982, ApJ, 259, 668), Rodríguez et al. (1982, ApJ, 260, 635), Edwards and Snell (1983, ApJ, 270, 605; 1984, ApJ, 281, 237); and Haschik et al. (1983, ApJ, 265, 281). Surveys for high velocity H_2O masers were made by García-Barreto et al. (1981, RevMexAA, 5, 87) and Jaffe et al. (1981, ApJ, 250, 621). An optical search for bipolar nebulae was made by Neckel and Staude (1984, AA, 131, 200). Other evidence for PMS winds is the excited H_2 emission from shocked gas. Studies of this emission were made by Persson et al. (1981, ApJ, 251, L85); Beckwith and Zuckerman (1982, ApJ, 255, 536; Bally and Lane (1982, ApJ, 257, 612); Simon and Joyce (1983, ApJ, 265, 864); Brown et al.(1983, MN, 203, 785), and for Orion (see below). Surveys for radio continuum or line emission from embedded stellar winds were made by Simon et al. (1981, ApJ, 251, 552; 1983, ApJ, 266, 623); Thompson (1982, ApJ, 257, 171); Bally and Predmore (1983, ApJ, 265, 778); Thompson et al.(1983, ApJ, 266, 614), and McGregor et al. (1984, PASP, 96, 315). HI emission was found in a region of mass outflow by Bally and Stark (1983, ApJ, 266, L61). Anisotropic outflow from T Tauri stars was discussed by Cohen (1982, PASP, 94, 266).

Other studies of molecular outflow refer to the following sources: the Carina nebula (White and Phillips 1983, MN, 202, 255), G35.2-0.74 (Little et al. 1983, MN, 203, 409), N2071 (Lichten 1982, ApJ, 253, 593; Wootten et al. 1984, ApJ, 279, 633), S206 (Pişmiş and Hasse 1982, RevMexAA, 5, 209), the Cha T association (Schwartz and Henize 1983, AJ, 88, 1665), W49N (Downes et al. 1982, ApJ, 252, L29; Walker et al. 1982, ApJ, 255, 128), W51 (Downes et al. 1982, ApJ, 252, L29; Ho et al. 1983, ApJ, 266, 596). L1529 (Lichten 1982, ApJ, 255, L119), L1551 (Phillips 1982, AA, 116, 130; Nagata et al. 1983, AA, 119, L1; Emerson et al. 1984, ApJ, 278, L49), S106 (Pişmiş and Hasse 1981, RevMexAA, 5, 79; Felli et al. 1984, AA, 135, 261), the Serpens cloud near S68 (Nordh et al. 1982, AA, 115, 308; Ungerechts and Gusten (1984 AA, 131, 177, M8E (Simon et al. 1984, ApJ, 278, 170), Cep A (Ho et al. 1982, ApJ, 262, 619), Sh2-269 (Heydari-Malayeri et al. 1982, AA, 113, 118), AFGL 961 (Lada and Gautier 1982, ApJ, 261, 161), NGC 7538 (Campbell and Thompson 1984, ApJ, 279, 650), GL 437 (Arguilla and Goldsmith 1984, ApJ, 279, 664), and in a distant dark cloud (Bruck and Godwin 1984, MN, 206, 37). Some of these PMS flows may have been eruptive (Mundt and Hartmann 1983, ApJ, 268, 766), and some may be clumpy (Phillips 1982, AA, 116, 130; and see Orion paragraph, below).

PMS jets were found in regions of mass outflow by Mundt et al. 1983, ApJ, 265, L71), Strom et al. 1983, ApJ, 271, L23) and Mundt and Fried (1983, ApJ, 274, L83). Other Herbig-Haro (HH) objects were discovered in M16 (Meaburn and White 1982, MN, 199, 121), on the periphery of the Gum Nebula (Dopita et al. 1982, ApJ, 263, L73), in NGC 7129 (Magakyan 1983, Pis'ma AZh, 9, 155), in Orion (see below), and in a number of regions by Gyul'budagyan (1982, Pis'ma AZh, 8, 232). Studies of exciting stars near HH objects were made by Axon et al.(1982, MN, 200, 239), Dyck et al. 1982, ApJ, 255, L103), Graham (Surveys of Southern Gal 229 1983); Cohen and Schwartz (1983, ApJ, 265, 877); Reipurth and Wamsteker (1983, AA, 119, 14); Cohen et al. (1984, ApJ,278, 671; 1984, ApJ, 281, 250) and Schwartz et al. (1984, ApJ, 280, L23). Searches for exciting stars near H_2O masers were made by Moorwood and Salinari (1981, AA, 102, 197; 1983, AA, 125, 342) and Braz and Epchtain (1982, AA, 111, 91); stars near S106 were found by Lacasse et al. (1981, AA, 104, 57 and Hofmann and Larson (1982, AA, 116, 179). Spectra of HH objects were analyzed by Cohen and Schmidt (1981, AJ, 86, 1228), Brugel et al. (1981, ApJSuppl, 47, 117), Bohm-Vitense et al. (1982, ApJ, 262, 224; Brugel et al. (1982, ApJ, 262, L35), Schwartz (1983, ApJ, 268, L37);Graham and Elias (1983, ApJ, 272, 615); Bohm et al. (1983, AA, 125, 23), Krautter et al. (1984, AA, 132, 169); Hartmann and Raymond (1984, ApJ, 276, 560), and Bohm and Bohm-Vitense (1984, ApJ, 277, 216). Proper motions of HH objects were

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detected by Herbig and Jones (1981, AJ, 86, 1232); 1982, AJ, 87, 1223; 1983, AJ, 88, 1040).

The Kleinmann-Low Region of the Orion cloud complex is the most thoroughly studied site of massive star formation. It appears to be comprised of a large cavity (Wynn-Williams et al. 1984, ApJ, 281, 172) swept out by a bipolar wind from IRc2 (Knapp et al. 1981, ApJ, 250, 175; Phillips et al. 1982, MN, 199, 1033; Genzel et al. 1982, ApJ, 259, L103; Erickson et al.1982, ApJ, 261, L103; Wright et al. 1983, ApJ, 267, L41; Wright and Plambeck 1983, ApJ, 267, L115). Two other nearby PMS stars, BN and IRc9, also have winds, although weaker than that from IRc2 (Moran et al. 1983 ApJ, 271, L31; Scoville et al. 1983, ApJ, 275, 201; Beck 1984, ApJ, 281, 205). IRc2 is surrounded by a disk or torus of dense neutral matter (Werner et al. 1983, ApJ, 265, L13; Chelli et al. 1984, ApJ, 280, 163) that may be rotating and expanding (Plambeck et al. 1982, ApJ, 259, 617; Barvainis 1984 ApJ, 279, 358) and, possibly, unbound (Norris 1984, MN, 207, 127). The wind from IRc2 is clumpy (Kuiper et al. 1981, ApJ, 251, 88; Wootten et al. 1984, ApJ, 277, 189) and it interacts with the cavity wall by driving a hydromagnetic shock wave into the surrounding cloud (Draine and Roberge 1982, ApJ, 259, L91; Chernoff et al. 1982, ApJ, 259, L97). The shock produces vibrationally and rotationally excited H_2 emission (Knacke and Young 1981, ApJ, 249, L65; Joyce and Simon 1982, MN, 200, 39p; Scoville et al. 1982, ApJ, 253, 136; Nadeau et al. 1982, ApJ, 253, 154; Beck et al. 1982, ApJ, 253, L83; Davis et al. 1982, ApJ, 259, 166). The wind itself may produce HH objects (Harvey et al. 1983, AnnNYAcadSci, 395, 199; Axon and Taylor, 1984, MN, 207, 241) and high velocity H_2O maser emission (Abraham et al. 1981, AA, 100, L10). Low mass embedded stars are in the region (Lonsdale et al. 1982, AJ, 87, 1819; Hyland et al. 1984, MN, 206, 465), and low mass visible stars are in the Orion Nebula (Walker 1983 ApJ, 271, 642; McNamara and Huels 1983, AASuppl, 54, 221; Herbig 1983, AnnNYAcadSci, 395, 64).

Observations (not mentioned elsewhere) of other regions of massive star formation concern W51 (Genzel et al. 1981 ApJ, 247, 1039; and 1982, ApJ, 255, 527; Jaffe et al. 1984, ApJ, 279, L51), W51N (Schneps et al. 1981, ApJ, 249, 124), W58 (Vogel and Welch 1983, ApJ, 269, 568), W33 (Haschick and Ho 1983, ApJ, 267, 638), W3 (Neugebauer et al. 1982, AJ, 87, 395; Dyck and Staude 1982, AA, 109, 320; Dickel et al. 1983, AA, 125, 320; Wright et al. 1984, ApJ, 281, L71), W3(OH) (Norris et al. 1982, MN, 201, 209), W3/4/5 (Thronson and Price 1982, AJ, 87, 1288), IC 1805 (Joshi and Sagar 1983, JRAS Can, 77, 40), M16 (Mufson et al. 1981, ApJ, 248, 992; McBreen et al. 1982, ApJ, 254, 126; Walsh and White 1982, MN, 199, 9p, M17 (Jaffe and Fazio 1982, ApJ, 257, L77), S128 (Mampaso et al. 1984, MN, 207, 465), NGC 6334 (Rodríguez et al. 1982, ApJ, 255, 103; Gezari 1982, ApJ, 259, L29; Harvey and Gatley 1983, ApJ, 269, 613), NGC 2024 (Thompson et al. 1981, ApJ, 249, 622; Jiang et al. 1984, AA, 135, 249; Thronson et al. 1984, ApJ, 280, 154), NGC 2071 (Calamai et al. 1982, AA, 109, 123), IC 5146 (McCutcheon et al. 1982, ApJ, 256, 139; Wilking et al. 1984, AJ, 89, 496), OH 351.78-0.54 (Fix et al. 1982, ApJ, 259, 657), ON-1 (Israel and Wootten 1983, ApJ, 266, 580), Cep OB III (Sargent et al. 1983, AJ, 88, 1236), Cep OB IV (Rossano et al. 1983, AJ, 88, 1835), Vul OB I (Turner 1981, JRAS Can 75, 252), Mon OB I and NGC 2264 (Ogura 1984, PASJapan, 36, 139; Sargent et al. 1984, AA, 135, 377), Sgr B2 and G34.3+0.2 (Benson and Johnston 1984, ApJ, 276, 181), CrA (Cruz-González et al. 1984, ApJ, 279, 679) and Mon R2 (Willson and Folch-Pi 1981, AJ, 86, 1084; McCarthy 1983, ApJ, 257, L93). Additional observations of embedded young clusters were made by Ho and Haschick (1981, ApJ, 248, 622), Sargent et al. (1981, ApJ, 249, 607), Hackwell et al. (1982, ApJ, 252, 250), Ho et al. (1983, ApJ, 265, 295), Krassner et al. (1983,AJ, 88, 972) and Jaffe et al. (1984, ApJ, 281, 225). Infrared spectra of young stars were studied by Willner et al.(1982, ApJ, 253, 174) and Harvey (1984, PASP, 96, 297), and infrared speckel interferometry of protostars was studied by Dyck and Howell (1982, AJ, 87, 400).

Low mass stars have been found in globules with dense NH_3 cores (Benson et al. 1984, ApJ, 279, L27), in B5 (Beichman et al. 1984, ApJ, 278, L45), B18 (Myers 1982, ApJ, 257, 620), B335 (Keene et al. 1983, ApJ, 274, L43), the Cha I cloud (Hyland et

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al. 1982, MN, 201, 1095; Baud et al. 1984, ApJ, 278, L53), and the Ophiuchus cloud (Wilking and Lada 1983, ApJ, 274, 698; Sargent et al. 1983, AJ, 88, 88). Star formation in Bok globules was discussed by Reipurth (1981, Messenger, 26, 2; 1983, AA, 117, 183). A search for Hα emission line stars in Bok globules was made by Ogura and Hasagawa (1983, PASJapan, 35, 299).

Observations of magnetic fields in regions of stars formation include polarization studies of the ρOph cloud (Hong, 1981, JKoreanASoc, 14, 37), M17 (Chesterman et al. 1982, MN, 200, 965), the Serpens nebula (King et al. 1983, MN, 202, 1087) and Per OB 2 (1981, Markkanen Proc. 3rd Finnish-Soviet Astron.Symp. 17). Zeeman measurements of molecular cloud field strengths were made for the HI line in the Orion molecular cloud (Heiles and Troland 1982,ApJ, 260, L23), and for the OH line throughout the Orion region by Hansen (1982, ApJ, 260, 599), Crutcher and Kazes (1983, AA, 125, L23), Hansen and Johnston (1983, ApJ, 267, 625), and in several other sources by Norris et al. (1982, MN, 201, 191). Magnetic field strengths were inferred from Faraday rotation in HII regions by Heiles et al. (1981, ApJ, 247, L77) Field strength upper limits were reported for several sources by Crutcher et al. (1981, ApJ, 249, 134) and Silverglate (1984, ApJ, 279, 694).

Regions where star formation appears to have been stimulated include: W4 (Braunsfurth 1983, AA, 117, 297), W5 (Wilking et al. 1984, ApJ, 279, 291), W28 (Odenwald et al. 1984, ApJ, 279, 162), W51 (Lightfoot et al. 1983, MN, 205, 653), M8 (Lightfoot et al. 1984, MN, 208, 197), G134.2+0.8 (Hughes and Viner 1982, AJ,87, 685), the Carina Nebula (de Graauw et al. 1981, AA, 102, 257), NGC 7538 (Campbell and Thompson 1984, ApJ, 279, 650), S128 (Heske and Wendker 1982, AA, 113, 170), Stock 16 (Turner 1983, JRAS Can, 77, 261), a cometary globule (Brand et al. 1983, MN, 203, 215), OH maser clusters near cloud edges (Ho et al. 1983, ApJ, 265, 295), OH 342.01+0.25 (Sandell et al. 1983, AA, 124, 139) and Orion (Isobe 1983, AnnNYAcad Sci, 395, 165).

Star formation persists in a region longer than the collapse time of the molecular cloud. Extended formation times for star clusters have been suggested by Jakobsen (1981, PASP, 93, 547), Guetter (1982, AJ, 86, 1057), Herbst and Miller (1982, AJ, 87, 1478), Duncan and Jones (1983, ApJ, 271, 663), Adams et al. 1983, ApJSuppl, 53, 893), and Stauffer et al. (1984, ApJ, 280, 202). There may be a problem with the determination of ages from Li abundances, however (Giampapa 1984, ApJ, 277, 235), and from theoretical pre-main sequence tracks on an HR diagram (Mercer-Smith et al. 1984, ApJ, 279, 363), although Stahler (1983, ApJ, 274, 822) identifies a "birthline" on this diagram.

3. THEORY OF STAR FORMATION ON SMALL SCALES

For non-magnetic clouds, I-D numerical collapse calculations were performed by Wang and Qian (1981, Ann Shanghai ObsAcadSci, 3, 166), and 1-D semi-analytical calculations were made by Stahler et al. (1981, ApJ,248, 727) and Ballone and Fofi (1982, ApSpSci, 85, 293). Collapse models for Bok globules were studied by Villere and Black (1982, ApJ, 252, 524). Two-dimensional cloud collapse was followed by Narita et al. (1983, MN, 203, 491), Virgopia and Ferraioli (1981, ApSpSci, 78,211, and 1981, ApSpSci, 79, 129) Boss and Haber (1982, ApJ, 255, 240), Boss and Black (1982, ApJ, 258, 270); Cassen and Moosman (1982, Icarus, 48, 353), and Boss (1984, ApJ, 277, 768). Fragmentation during 3-D collapse was studied numerically by Boss (1981, ApJ, 250, 636; 1983, Icarus, 55, 181), Gingold and Monaghan (1981, MN, 197, 461; 1983, MN, 204, 715), Bodenheimer and Boss (1981, MN, 197, 477), Wood (1982, MN, 199, 331), Rozyczka (1983, AA, 125, 45), Miyama et al. 1984, ApJ, 279, 621), and analytically by Tohline (1981, ApJ, 248, 717), Bernstein and Book (1981, ApJ, 251, 271), Silk (1982, ApJ, 256, 514), and Boss (1982, ApJ, 259, 159).

The equilibrium of clouds was studied by Hayashi et al. (1982, Prog.TheorPhys, 68, 1949), Izotov and Kolesnik (1982, AstrometrAstrofizVyp, 46, 3), Kolesnik and

Kravchuk (1982, Pis'ma AZh, 8, 234), Stahler (1983, ApJ, 268, 155 and 165) and Schmitz (1984, AA, 131, 309). The effect of the stellar velocity dispersion on cloud collapse was discussed by Kegel and Volk (1983, AA, 119, 101). The stability of cylinders was studied by Karnik (1982, ApSpSc, 83, 209) and Bastien (1983, AA, 119, 109); the stability of rings by Qian and Wang (1981, Ann ShangaiObsAcadSci, 3, 161), and the stability of layers by Welter (1982, AA, 105, 237), Tomisaka and Ikeuchi (1983, PASJapan, 35, 187), and Vishniac (1983, ApJ, 274, 152). Stability of the Taurus clouds was discussed by Nurmanova (1982, AstronZh, 59, 61). Gravitational torques in protostellar disks were discussed by Larson (1984, MN, 206, 197), magnetic fields in disks were discussed by Ray (1983, IrishAJ, 16, 39), and accretion on binary stars in disks was studied by Artymowicz (1983, ActaAstr, 33, 223).

The self-gravitational collapse of magnetic clouds was followed numerically by Phillips (1982, ProcAstrSocAustr, 4, 371) and Dorfi (1982, AA, 114, 151). An analytical study of field topology was made by Dudorov and Sazonov (1982, NauchnIfnVyp, 50, 98). Stability criteria for 3-D media with rotation,magnetic fields, finite conductivity and various other properties were studied by Sharma and Thakur (1982, ApSpSc, 81, 95), Sharma (1982, ApSpSc, 85, 263; 1983, ApSpSc, 94, 419), and Chajlani and Purohit (1983, ApSpSc, 94, 425). The collapse of magnetic cylinders was investigated by Karnik and Talwar (1981, ApSpSc, 79, 379), Karnik (1982, ApSpSc, 82, 283) and Nuzhnova (TrAstrofizInstAlma-Ata, 39, 114). Time dependent 1-D and 2-D collapse calculations with magnetic diffusion were performed by Nakano (1983, PAS Japan,34, 337; 1983, PASJapan, 35, 87; 1983, PASJapan, 35, 209), Black and Scott (1982, ApJ, 263, 696), Scott (1983, ApJ, 275, 836; 1984, ApJ, 278, 396), Shu (1983, ApJ, 273, 202), and Paleologou and Mouschovias (1983, ApJ, 275, 838). Magnetic rotational braking was studied by Dudorov and Sazonov (1983, NauchnInfVyp, 52, 29).

The triggering of star formation in a pressurized cloud or cloud clump was studied theoretically by several groups. The ionization and compression of inhomogeneities in a cloud was discussed by Klein et al. (1983, ApJ, 271, L69), and the compression of isolated globules was calculated by Nittmann (1981, MN, 197, 699), Sandford et al. (1982, ApJ, 260, 183), LaRosa (1983, ApJ, 274, 815), and Krebs and Hillebrandt (1983, AA, 128, 411). Rayleigh-Taylor instabilities in supernova-compressed regions were discussed by Baierlein et al. (1981, Icarus, 48, 49) and Baierlein (1983, MN, 205, 669). Triggering by cloud-cloud collisions was discussed by McCrea (1982, Prog. in Cosmol. 239), Struck-Marcell (1982, ApJ, 259, 127), Suchkov et al. (1982, Astrofizica, 18, 629), Yoshii and Sabano (1983, Theor Aspects on Struct Activity and Evol of Gal, 76), Dyson and Hartquist (1983, MN, 203, 1233), and Gilden (1984, ApJ, 279, 335). Such triggering mechanisms may produce self-regulated star formation inside a cloud core (1983, ApJ, 264, 508). Self-regulation by X-ray ionization was considered by Silk and Norman (1983, ApJ, 272, L49). The role of the magnetic field in propagating star formation was discussed by Welter and Nepveu (1982, AA, 113, 277).

Models for the formation of bound galactic clusters were considered by Elmegreen (1983, MN, 203, 1011) and of globular clusters by Suchkov et al. (1981, Pis' ma AZh, 7, 617), and Smith (1982, ApJ, 259, 607). Theoretical models for the origin of the initial stellar mass function were made by Hong (1981, J Korean ASoc, 14, 89), Zinnecker (1982, MittAstronGes, 55, 160), Hunter and Fleck (1982, ApJ, 256, 505) Ferrini et al. (1983, MN, 202, 1071), and Elmegreen and Mathiew (1983, MN, 203, 305). Differences in the stellar mass fucntion for large and small clouds were noted by Larson (1982, MN, 200, 159). A discussion of star formation efficiencies for galactic clusters is in Mathieu (1983, ApJ, 267, L97) and for OB associations, in Duerr et al. (1982, ApJ, 261, 135).

Models for winds around PMS stars were discussed by Barral and Cantó (1981, RevMexAA, 5, 101), Hartmann and MacGregor (1982, ApJ, 259, 180), Konigl (1982, ApJ, 261, 115), Beckwith et al. (1983, ApJ, 267, 596), Draine (1983, ApJ, 270, 519), Pudritz and Norman (1983, ApJ, 274, 677), Dyson (1983, AA, 124, 77), Torbett (1984, ApJ, 278, 318) and Kundt (1984, ApSpSc, 98, 275). A model for the H_2O maser environment was studied by Strelnitskij (1984, MN, 207, 339), and a numerical hydrodynamical model of HH objects was made by Sandford and Whitaker (1983, MN, 205,105).

4. STAR FORMATION ON LARGE SCALES

Evidence for coherent cloud structure or star formation on scales larger than several hundred parsecs comes from the observation of giant star complexes (Efremov 1982, Pis'ma AZh, 8, 585 and 663; Smith 1982, ApJ, 261, 463), spiral arm and interarm superassociations (Dolidze 1981, Pis,ma AZh, 7, 666; Condon 1983, ApJSuppl, 53 , 459), stellar streams and moving groups (Latyshev 1980, AstronTsirk, 1141, 7; Eggen 1983, MN, 204, 377,391 and 405), the simultaneous formation of multiple galactic clusters (Barkhatova and Pavlovskaya 1981, AstronTsirk, 1155,4; Lynga and Wramdemark 1984, AA, 132, 58), and the giant HI clouds and star formation patches in the Large Magellanic Clouds (Page and Carruthers 1981, ApJ, 248, 906), M101 (Blitz et al. 1981, ApJ, 249, 76; Viallefond et al. 1981, AA, 104, 127; 1982, AA, 115, 373) and M31 (Nakai and Sofue 1982, PASJapan, 34, 199). The molecular cloud mass distribution is dominated by the largest masses (Casoli et al. 1984, AA, 132, 99).

Theoretical studies of cloud and star formation on a kiloparsec scale were concerned with self-gravitational instabilities in the interstellar gas (Elmegreen 1982, ApJ, 253, 634 and 655; Viallefond et al. 1982, AA, 115, 373; Elmegreen and Elmegreen, 1983, MN, 203, 31; Jog and Solomon 1984,ApJ, 276, 114 and 127), and the growth of large clouds from colliding small clouds (Casoli and Combes 1982, AA, 110, 287; Kwan and Valdés 1983, ApJ, 271, 604; Roberts and Hausman 1984, ApJ, 277, 744). Such cloud formation operates faster in a density wave spiral arm, so these mechanisms may explain how density waves trigger star formation. Large-scale triggering appears necessary because density wave arms may contain the largest cloud complexes and HII regions in a galaxy (Rumstay and Kaufman 1983, ApJ, 274, 611).

Supernovae and other pressures from young stars may disturb the environment of a star-forming region over a distance of several hundred parsecs or more. In some cases such disturbances have led to the formation of new stars (Dixon et al. 1981, ApSpSc, 78, 189; Pişmiş and Hasse 1982, RevMexAA, 5, 161; Gosachinskij and Khersonskij 1982, AZh, 59, 237; Elmegreen 1982, in Submm-Wave Astr, 1; de Boer and Nash 1982, ApJ, 255, 447; Braunsfurth and Feitzinger, 1983, AA, 127, 113). Two-way interactions between star formation and interstellar matter may produce self-regulated star formation, as discussed by Shore (1981, ApJ, 249, 93; 1983, ApJ, 265, 202), Tomisaka et al. (1981, ApSpSc, 78, 273), Loose and Fricke (1982, MittAstron Ges, 55, 100), Loose et al. (1982, AA, 105, 342), Cox (1983, ApJ, 265, L61), Franco and Cox (1983, ApJ, 273, 243), Comins (1983, ApJ, 274, 595), and Ikeuchi et al. (1984, MN, 207, 909). Cloud-fluid/star formation models were simulated numerically by Prendergast (1982 in Extragalactic Molecules), and Struck-Marcell and Scalo (1984, ApJ, 277, 132).

Models of stochastic self-propagating star formation (SSPSF) in galactic disks included a two-component interstellar medium to study grand design spirals (Seiden et al. 1982, ApJ, 253, 91) and gas distributions (Seiden 1983, ApJ, 266, 555). SSPSF simulations also modeled spiral arm spurs (Feitzinger and Schwerdtfeger 1982, AA, 116, 117), thick disks (Statler et al. 1983, ApJ, 270, 79) and long-time galaxy evolution (Freedman and Madore 1983, ApJ, 265, 140). Spiral arm generation by stochastic inhibition of star formation was discussed by Freedman and Madore (1984, ApJ, 280, 592), and spiral arm shapes were derived analytically by Cowie and Rybicki (1982, ApJ, 260, 504) and Balbus (1984, ApJ, 277, 550). Observations related to SSPSF predictions were made by Kaufman (1981, ApJ, 250, 534), Janes and Adler (1982, ApJSuppl, 49, 425), Isserstedt (1984, AA, 131, 347) and Schlosser and Musculus (1984, AA, 131, 367).

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Enhanced star formation in interacting galaxies has been suggested for Arp 299 (Bushouse and Gallagher 1984, PASP, 96, 273), NGC 5253 (Moorwood and Glass 1982, AA, 115, 84), N5430 (Keel 1982, PASP, 94, 765), Arp 91 (Jenkins 1984, ApJ, 277, 501), and several galactic nuclei by Kennicutt and Keel (1984, ApJ, 279, L5). Star formation in cluster galaxies that accrete gas has been studied by Fabian et al. (1982, MN, 201, 933) and Sarazin and O'Connell (1983, ApJ, 268, 552). Variations of the initial stellar mass function within a galaxy or from galaxy to galaxy were discussed by van den Bergh (1982, The Most Massive Stars, 253), Lequeux (ibid.,261), Puget et al. (1982, Regions of Recent Star Form. 249), Berkhuijsen (1982, AA, 112, 369), Garmany et al. (1982, ApJ, 263, 777), and Sil'chenko (1984, SovietAstrL, 10, No. 7).

VI. HII Regions
(P.A. Shaver)

1. INTRODUCTION

HII regions are now being studied at wavelengths spanning almost the entire electromagnetic spectrum. Progress is particularly notable in high-resolution radio mapping, in millimeter wave spectroscopy, and infrared spectroscopy and imaging. Some of these areas are reviewed in preceding sections (e.g. molecular clouds,star formation), and the following discussion is largely restricted to representative papers on the properties of well-evolved, conventional H II regions.

Recent reviews have been written on the Orion Nebula (Peimbert 1982, AnnNYAcad Sci, 395m 24; Goudis, The Orion Complex: A Case Study of Interstellar Matter), on far-IR line observations (Harwit 1982, AnnNYAcadSci, 395, 56), on ultraviolet observations (Peimbert 1981, The Universe at UV Wavelengths, p. 557; Patriarchi and Perinotto 1983, MemSAItal, 54, 529), on abundances (Pagel and Edmunds 1981, AnnNY AcadSci, 19, 77; 1984, Stellar Nucleosynthesis, Reidel 341), and on extragalactic HII regions (1983, Highlights of Astronomy, 6, pp. 609-635). Two recent books contain several relevant papers, and will be referred to frequently: Regions of Recent Star Formation, 1982, eds. Roger & Dewdney, Reidel (hereafter RRSF), and Primordial Helium, 1983, eds. Shaver, Kunth & Kjär, ESO (hereafter PH). Two surveys of galactic HII regions were made recently by Wink et al. (1982, AA, 108, 227) in the radio continuum and recombination line, and Blitz et al. (1982, ApJSuppl, 49, 183) in the CO line. Fich and Blitz (1984, ApJ, 279, 125) have studied the distribution and properties of HII regions in the outer galaxy.

2. STRUCTURE

A great deal of effort has gone into mapping the structure of HII regions over a wide range in wavelength. At the lowest radio frequencies they are observed in absorption against the galactic background (Abramenkov and Krymkin 1982, SovietAstr, 26, 160; 1983, SovietAstr, 27, 32). At higher radio frequencies the emphasis has been on high-resolution mapping, particularly with interferometers like the VLA (e.g. 1981, AA, 100, 28 and 42; 1981, AA, 101, 39; 1981, ApJ, 248, 622; 1981, ApJ, 250, 227; 1981, AA, 103, 50; 1982, ApJ, 255, 103 and 527; 1982, ApJ, 256, 127; 1982, RRSF, 39 and 181; 1982, AA, 108, 412; 1982, ApSpSc, 84, 143; 1982, AASuppl, 48,345; 1982, AJ, 87, 685; 1982, AA, 115, 164; 1983, AJ, 88, 972; 1983, AA, 120, 322; 1983, AA, 124, 116; 1983, AA, 125, 320; 1983, AA, 126, 433; 1983, AJ, 88, 1470; 1983, ApJ, 267, 638; 1983, ApJ, 272, 154; 1983, SovietAstr, 27, 628; 1984, ApJ, 278, 170). At the highest resolution and sensitivity, compact HII regions are often resolved into shell-like structures (Turner and Matthews 1984, ApJ, 277, 164), and ultracompact HII regions, presumably the youngest, are found embedded in more diffuse nebulae (e.g. 1982, AnnNYAcadSci, 395, 204; 1983, ApJ, 271, L31; 1984, ApJ, 277, 181), and in dense molecular clouds (e.g. 1983, ApJ, 265, 778; 1983, ApJ, 266, 623; 1984, ApJ, 276, 204; 1984, ApJ, 281, 225). Main-line OH masers are invariably found to be

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associated with such ultracompact HII regions (Garay et al. 1984, ApJ, in press). Radio recombination line maps have also been made, using both single dish and interferometer radio-telescopes (1982, RRSF, 39; 1982, AASuppl, 48, 345; 1982, AA, 115, 164; 1983, AJ, 88, 1470; 1984, AJ, 89, 95; 1984, ApLett, 24, 1).

Far-infrared broadband maps (1982, ApJ, 254, 126; 1982, ApJ, 258, 568; 1983, MN, 205, 653; 1984, ApJ, 279, 679; 1984, MN, 207, 659; 1984, AA, 135, L14; 1984,MN, 208, 197) have been used to study the distribution and temperature of dust in and around the HII regions and the overall energy balance, and near-infrared maps (1982, ApJ, 252, 250; 1982, ApJ, 254, 550; 1982, AJ, 87, 1288; 1983, AA, 120, 1; 1984,MN, 206, 465; 1984, MN, 207, 465) have been used to study the hot dust component and the exciting stars. Several HII regions have been mapped in infrared emission lines (1981, ApJ, 250, L35; 1982, RRSF, 73; 1982, ApJ, 255, 510; 1983, ApJ, 264, 538;1983, MN, 202, 859; 1983, ApJ, 265, L7; 1983, ApJ, 268, 721; 1983, ApJ, 275, 130) to determine density and ionization distributions, and in some cases abundances.

Narrow-band optical images have been obtained for several HII regions (1981, ApSpSc, 78, 235; 1981, AA, 101, 397; 1981, AA, 102, 316; 1982, AA, 105, 329; 1982, PASP, 94, 453; 1982, ApSpSc, 85, 405; 1982, ApSpSc, 88, 477; 1983, AA, 124, 1; 1983, ApSpSc, 89, 407; 1983, AASuppl, 53, 403; 1983, AA, 125, 320; 1983, MN, 203, 977; 1983, Astron Tsirk, 1252, 3). Münch and Hippelein (1982, AnnNYAcadSci, 395, 170) found that the [CI]9850A distribution is flatter than that of Hα in the Orion Nebula, and that the [CI] emission is particularly strong in the dust lane of NGC 2024. Cesarsky (1982, AA, 113, L7) suggests that this line originates in regions where radio Cnα emission is found, and that the excitation is recombination, not collisions. Walsh (1982, MN, 201, 561) found a complex structure south of θ^2 Orionis in [SII] maps of N_e and velocity.

3. PHYSICAL CONDITIONS

New techniques are being used to study the properties of HII regions.Distances to some HII regions have been obtained using H_2O maser proper motions (Genzel et al. 1981, ApJ, 244, 884; 1981, ApJ, 247, 1039; Schneps et al. 1981, ApJ, 249, 124). Magnetic field strengths in HII regions are being explored using Faraday rotation of polarized background sources (Heiles et al. 1981, ApJ, 247, L77) and Zeeman splitting of recombination lines (Silvergate 1984, ApJ, 279, 694). Far-UV (1981, ApLett, 22, 135), X-ray (1982, Science 215, 61) and γ-ray (1981, PhilTransRSocLondon, 301, 569) observations have been made of the Orion Nebula.

The measured electron densities in HII regions now span almost eight decades. At one extreme, very low-density HII regions ($N_e \sim 0.1 - 10$ cm^{-3}) have been found around high-latitude O stars (Reynolds and Ogden 1982, AJ, 87, 306) and star clusters (Cersósimo 1982, ApLett, 22, 157). At the other extreme, densities as high as 10^7 cm^{-3} have been found in ultracompact HII regions using high-resolution interferometer observations (e.g. Moran et al. 1983, ApJ, 271, L31); some of these objects have EM $\sim 10^9$ pc cm^{-6}, M $\sim 10^{-6}$ $M_\odot$, R $\sim 10^{-4}$ pc, and turnover frequencies above 20-30 GHz. Smirnov et al. (1984, AA, 135, 116) studied Stark broadening in RRLs from Orion, and found it to be consistent with current models of that HII region. Infrared lines are increasingly being using to determine electron densities (e.g. 1981, ApJ, 250, 605; 1982, ApJ, 259, L109; 1983, MN, 202, 859; 1983, ApJ,268, 721), and optical lines continue to be used for this purpose (e.g. 1982, Astron Tsirk 1228, 3 and 6; 1983, Astron Tsirk 1301, 1 and 3). A comparison of radio (rms) and optical densities yields the filling factor (e.g. 1983, MN, 204, 53).

Electron temperatures have been measured in more HII regions using optical lines (1983, MN, 204, 53; 1984, ApSpSc, 100, 451) and radio recombination lines (e.g. 1981, MN, 196, 889; 1983, MN, 204, 53; 1983, MN, 205, 719; 1983, SovietAstrL, 9, 341; 1983, ApJ, 266, 263; 1983, AA, 127, 211). Radio and optical temperatures agree well, indicating that temperature fluctuations are small. The relative effects

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of T_{eff}, Z and Ne on electron temperature have been studied observationally (1983, MN, 204, 53) and theoretically (Rubin 1984, ApJ, in press). Maciel and Pottasch (1982, AA, 106, 1) studied the contribution to heating by electrons ejected from dust grains after absorption of UV photons.

Dust within HII regions has been studied in a number of ways: infrared maps and spectroscopy (above), extinction (1981, AASuppl, 45, 451; 1984, AA, 133, 313), polarization (1982, PASJapan, 33, 313; 1982, ApJ, 255, 95; 1982, MN, 200, 965;1983, MN, 202, 11; 1983, Astrophys 19, No. 1), and UV scattering (1981, ApJ, 249, 99; 1981 ApLett, 22, 5; 1982, ApJ, 255, 87). Williams and Zealey (1983, MN, 203, 433) showed that the 3.28 μm feature is associated with dust. Nakano et al. (1983, ApSp Sc, 89, 407) concluded from Hα and V-band maps that there is a dust depletion zone in the centre of some HII regions. Mathis (1983, ApJ, 267, 119) showed that a wavelength-dependent dust albedo affects the extinction determined from the Hβ/Hα ratio, and suggested methods for dereddening emission-line objects.

The excitation and energy balance have been examined by identifying and studying the exciting stars and their relationship with the HII regions (e.g. 1981, Ap Lett, 22, 5; 1982, AnnNYAcadSci, 395, 64; 1982, Science, 215, 61; 1982, ApJ, 263, 130; 1983, ApJ, 270, 169; 1983, AA, 124, 273). Chanot and Sivan (1983, AA, 121,19) have measured the total Hα flux of the Gum Nebula, and find it to be in ionization balance with the known exciting stars; they conclude that it is a normal HII region, except for an unusual [SII]/Hα ratio indicative of shocks. Franco and Savage (1982, ApJ, 255, 541) studied CIV and SiIV absorption lines in IUE spectra of stars in the Orion Nebula, and considered the possible cause of the high excitation: X-rays, collisions, or UV photons. Herter et al. (1983, AASuppl, 51, 195) outlined a method of determining excitation conditions in HII regions independent of chemical abundance, using IR fine structure lines.

Increasingly sophisticated model HII regions have been produced. Extensive grids of model HII regions, covering a wide range in stellar effective temperatures, stellar and nebular abundances, and nebular densities have been published by Stasinska (1982 AASuppl, 48, 299), Köppen et al. (1983, AA, 118, 203), and Rubin (1984, ApJ, in press). Various authors have studied the effects of stellar abundances in NLTE atmospheres (Borsenberger and Stasinska 1982, AA, 106, 158), HII regions ionized by associations (Copetti and Bica 1983, ApSpSc, 91, 381), HII regions with arbitrary density distributions (Oliva and Panagia 1983, ApSpSc, 94, 437), far-IR lines from dusty HII regions (Aannestad et al.(1984 AA, in press), the effects of opacity due to heavy elements in the HII region (Rubin 1983, ApJ, 274, 671), and radiative transfer processes (Elitzer 1984, ApJ, 280, 653). McCall (1984, MN, 208, 253) has given revised emission coefficients for several prominent lines as a function of temperature and density. Detailed models of some individual HII regions have also been produced (e.g. 1982, RRSF, 53,; 1982, ApJ, 255, 497; 1983, ApJ, 265, 239; 1983, AA, 124, 77; 1983, ApJ, 274, 650; 1984, ApJ, 279, 650).

The internal kinematics of several HII regions have been studied using radio and optical emission lines (e.g. 1981, MN, 196, 995; 1981, ApJ, 248, 992; 1981, ApJ, 250, 615; 1981, ApSpSc, 78, 189; 1982, MN, 200, 771; 1982, AA, 113, 118; 1982, RevMexAA,5, 161 and 209; 1982, RevMexAA, 6, 269; 1982, ApSpSc, 86, 331; 1982, ApSp Sc, 87, 13; 1982, AA, 115, 164; 1982, ApJ, 252, 156; 1983, ApJ, 269, 164; 1983, RevMexAA, 8, 51 and 83; 1983, ApJ, 273, 639; 1983, ApJ, 274, 650; 1984, ApLett, 24, 1). Optical and UV absorption-line spectroscopy of stars in HII regions provide an independent view of these kinematics from a variety of ions (1982, ApJ, 252, 156; 1982, ApJ, 260, 163; 1983, ApSpSc, 90, 437; 1983, MN, 204, 1203; 1984, ApJ, 276, 524; 1984, MN, 207, 167); Walborn (1982, ApJSuppl, 48, 145) has found a systematic expansion of 15-20 km/s and smaller scale features with velocities of hundreds of km/s in the Carina Nebula, and Franco and Savage (1982, ApJ, 255, 541) found velocities of ~25 km/s in the Orion Nebula. Fich et al. (1982, RRSF, 201) conclude from a study of 151 HII regions that typically the bulk of ionized gas flows away from the parent molecular cloud at 5-10 km/s.

4. EVOLUTION

Radio and infrared observations can now discern the earliest stages in the evolution of an HII region as it evolves from the protostellar cocoon (e.g. 1982, ApJ, 257, 171; 1982, RRSF, 83; 1983, AA, 125, 342; 1983, ApJ, 265, 778; 1983, ApJ, 266, 614 and 623; 1983, ApJ, 271, L31; 1984, ApJ, 276, 204; 1984, ApJ, 277, 164 and 181; 1984, ApJ, 281, 225).

Theoretical calculations of the subsequent evolution of model HII regions allow for an increasing complexity of conditions, as computer codes evolve. Tenorio-Tagle and co-workers have modelled the evolution of HII regions in collapsing molecular clouds, around evolving OB associations, and into a hot phase III (e.g. 1982, RRSF, 1 and 15; 1982, AA, 108, 25; 1982, AA, 112, 1 and 104; 1982, AA, 115, 207). Ionization front interactions and the formation of bright rims and globules have been studied by Brand (1981, MN, 197, 217), Sandford et al. (1982, RRSF,129), and Bedijn and Tenorio-Tagle (1984, AA, 135, 81). Icke (1981, ApJSuppl, 45, 585) and Yorke et al. (1983, AA, 127, 313) have produced theoretical radio continuum and far-IR maps of a variety of model HII regions. Smith (1982, ApJ, 259, 607) has modelled HII regions formed in globular and open cluster protoclouds, and McKee et al. (1984, ApJ, 278, L115) have studied the evolution of photoionized stellar wind bubbles. The observations indicate that no single model is universally applicable (e.g. 1982, RRSF, 25; 1984, ApJ, 277, 164), presumably a reflection of the wide variety of initial conditions and evolutionary stages that actually exist.

5. ABUNDANCES AND GALACTIC GRADIENTS

Further work has been done to derive chemical abundances in HII regions from radio, infrared, and optical spectroscopic data, and their distribution across the galactic plane. Some papers critically examined methods of abundance determination for helium(Lockman 1982, ApJ, 256, 543; Stasińska 1983, PH, 255) and sulfur (Dennefeld and Stasińska 1983, AA, 118, 234), and others suggested new approaches to abundance determination (Mathis 1982, ApJ, 261, 195; Simpson and Rubin 1984, ApJ, 281, 184). Rood et al. (1984, ApJ, 280, 629) have detected the cosmologically important 8.7 GHz hyperfine line of $^3He^+$ in a few HII regions. Silvergate (1984,ApJ, 278, 604) found gas phase Si, Mg, and Fe to be depleted near HII regions, using radio recombination line observations.

Shaver et al. (1983, MN, 204, 53) combined radio and optical data on HII regions distributed over the galactic disk to determine the gradients in electron temperature and abundances (O,N,S,Ne,Ar). The temperature gradient, which is thought to be caused by the abundance gradient, has also been measured in other recent radio studies (1981, MN, 196, 889; 1983, ApJ, 266, 263; 1983, AA, 127, 211). Radio observations have also been used to search for a helium abundance gradient, but it is not yet clear if such a gradient exists (1981, MN, 196, 889; 1982, ApJ, 259, 595; 1983, MN, 204, 53; 1983, PH, 281 and 299).

Several papers have been written on abundances and gradients from IR spectroscopy (e.g. 1981, ApJ, 250, 186; 1982, ApJ, 262, 153 and 164; 1983, AA, 127, 383); Lester et al. (1983 ApJ, 271,618) used the ratio of the [NIII] 57 μm and [OIII] 52 μm lines to determine a model-independent estimate of the N/O ratio in several HII regions.

6. GALACTIC CENTRE

A new VLA map reveals Sgr A to have a spiral structure, with the non-thermal point source close to the peak in the thermal emission (Ekers et al. 1983, AA, 122, 143). The cause of this morphology is unclear, but tidal distortion of infalling material is a strong possibility. Interferometric radio recombination line observations with the WSRT (Bregman and Schwarz 1982, AA, 112, L6) and the VLA (van Gorkom et al. in preparation) should assist in the interpretation. A 76α survey of the galactic centre region has been made (1982, Proc ASAust, 4, 453), and several infrared lines have been detected in Sgr A (1981, ApJ, 248, L109 and 524; 1983, ApJ, 267, L37; 1984, ApJ, 276, 551). Lacy et al. (1982, ApJ, 262, 120) modelled the central parsec in terms of clouds generated by stellar collisions.

7. EXTRAGALACTIC HII REGIONS

HII regions in other galaxies have been reviewed and catalogued by Hodge (1982 AJ, 87, 1341) and Hodge and Kennicutt (1983, AJ, 88, 296). New catalogues have been given of HII regions in NGC 1313 (1983, AASuppl, 51, 353) and M83 (1983, ApJ, 274, 611). Radio, infrared, and optical maps have been made of several extragalactic HII regions (e.g. 1982, AA, 105, 229; 1982, AA, 111, L11; 1983, AA, 118, 116; 1983, AA, 119, 185; 1984, AA, 133, 93); Georgelin et al. (1983, AASuppl, 54, 459) and Lawrie and Kwitter (1982, ApJ, 255, L29) find filamentary and ringlike nebulae in the LMC and M101, and show that their [SII]/Hα ratio is intermediate between normal HII regions and SNRs. Van den Bergh (1981, AJ, 86, 1464) derived an analytical expression for the frequency distribution of HII region diameters, and this has been confirmed for irregular galaxies by Hodge (1983, AJ, 88, 1323).

The excitation and internal kinematics of extragalactic HII regions have received much attention. Several observations were made of R136a, the "supermassive star" in the 30 Doradus Nebula (e.g. 1981, Science, 212, 1497; 1983, ApJ, 273, 597); Worley (1984, ApJ, 278, L109) and others conclude that it is not a single object. Massey and Hutchings (1983, ApJ, 275, 578) find spectroscopically similar objects in M33 HII regions. Internal motions of extragalactic HII regions have been studied in more detail (1981, ApSpSc, 78, 443; 1983, AA, 117, 265); they appear to be chaotic, and no single model accounts for them all (1984, ApJ, 280, 580). Gallagher and Hunter (1983, ApJ, 274, 141) and Rosa and Solf (1984, AA, 130, 29) disagree with the suggestion of Terlevich and Melnick (1981, MN, 195, 839) that the internal motions are largely gravitational. Several papers have been written on W-R stars in extragalactic HII regions (1981, ApJ, 248, 1015; 1981, ApJ, 249, 471; 1982, AA, 105, 410; 1982, AA, 108, 339; 1983, AASuppl, 53, 97).

Abundances have been measured in several more extragalactic HII regions (1981, AJ, 86, 989; 1982, ApJ, 252, 461 and 594; 1982, ApJ, 255, 1; 1983, J KoreanAS 16, 1). Blair et al. (1982, ApJ, 254, 50) find the M31 abundance gradient to be similar to that of other spirals. Rosa (1983, PH, 317) has pointed out possible systematic observational effects in such abundance determinations. Kunth (1983, PH, 305) reviewed the determination of Y_p from extragalactic HII regions.

Other studies of extragalactic HII regions include the following: 1981, AA, 102, 245; 1981, ApSpSc, 80, 267; 1981, ApJ, 249, 76; 1981, ApJ, 250, 103; 1983,ApJ, 266, 568; 1983, AA, 127, 395; 1984, ApJ, 279, L1 and 578; 1984, MN, 207, 25 and 801. Lequeux et al. (1981, AA, 103, 305) considered the properties of several extragalactic HII regions, and concluded that they mainly result from massive bursts of star formation of very short duration.

VII. Supernova Remnants
(S. D'Odorico)

The status of supernova remnant research as in late 1982 is comprehensively reviewed in the proceedings of the IAU Symposium No. 101, "Supernova Remnants and their X-ray Emission" (1983, J. Danziger and P. Gorenstein, eds., R. Reidel Publ. Co., herewith referred to as IAU 101). In this report, the papers published in the Proceedings are quoted unless published elsewhere in a more extended version. A review of the subject is also given by Raymond (1984, AnnRevAA, 22, 75).

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1. X-RAY OBSERVATIONS

As it is indicated by the title of Symposium 101, the more interesting body of new information on SNR came in the X-ray band, mostly through the observation of the Einstein satellite and its predecessor, HEAO-1. There are now 135 galactic radio SNR, out of which 40 are seen optically and 33 have been detected in X-rays (van den Bergh 1983, IAU 101, 597). X-ray maps with inferences on the physical conditions and/or the nature of the progenitor have been published for the remnants G296.1-0.7 (Markert et al. 1981, ApJ, 248, L17), Puppis A (Petre et al. 1981, ApJ, 258, 22), G292.0+1.8, the second galactic remnant with oxygen rich filaments (Tuohy et al. 1982, ApJ, 260, L65; Braun et al. 1983, IAU 101, 159), W28 (Andrews et al. 1983, ApJ, 266, 684), G29.7-0.3 (Becker et al. 1983, ApJ, 268, 93), G78.2+2.1 (Higgs et al. 1983, IAU 101, 281), the Cygnus Loop (Ku et al. 1983, ApJ, 278, 615), IC 443, W44 and W49B (Watson et al. 1983, IAU 101, 273), IC 443 and Puppis A (Petre et al. 1983, IAU 101, 289), HB3 (Venkatesan et al. 1984, MN, 208, 251), and W49B (Pye et al. 1984, MN, 207, 649). In some cases (W49B, W28 and G29.7+0.3) the X-ray data were coupled with radio observations of comparable resolution. Detection of X-ray emission from 3C 400 and MSH 15-56 has been reported by Agrawar et al. (1983, ApSp Sc, 89, 279). Ballet et al. (1984, AA, 133, 357) interpret the X-rays and the coronal lines observations in the Cygnus loop.

Young remnants, being powerful X-ray sources, have been the subject of detailed investigation. The X-ray data do provide information on the distribution and total mass of the hot gas and some indication on the composition of the ejecta. Fabian et al. (1981, Nature, 295, 508) have discussed the remnant of SN 1006AD. Tycho has been studied by Reid et al. (1982, ApJ, 261, 485), Seward et al. (1983, ApJ, 266, 287) and Gorenstein et al. (1983, IAU 101, 1). Evidence on a halo around Cas A is reported by Stewart et al. (1983, IAU 101, 59). Pisarski et al. (1983, ApJ, 277, 710) infer from the X-ray map of RCW 86, the remnant of SN 185AD, that it was most likely a type I event. White and Long (1983, ApJ, 264, 196) present the HRI map of Kepler. Remnants with center filled morphologies (plerions) are established as a separate category in the X-ray domain as well. Becker (1983, IAU 101, 321) presents a review of X-ray observations while Weiler summarizes our present understanding of these objects (1983, IAU 101, 299). MSH 15-52 is discussed by Seward et al. (1984, ApJ, 281, 650), 3C 58 and CTB 80 by Becker et al. (1981, ApJ, 255, 557) and G21.5-09 by Becker and Szymkowiak (1981, ApJ, 248, L23).

X-ray maps of remnants have been carefully scanned for the detection of compact sources, possible remnants of the SN progenitor or ejecta of the explosion. Seward et al. (1983, ApJ, 267, 698) discuss two compact sources in MSH 15-17 (RCW 89), Gregory and Fahlman (1983, IAU 101, 429) and Gregory et al. (1983, IAU 101, 437) the X-ray pulsar in the remnant G109.1-1.0.

Spectroscopic studies of the hot gas at X-ray frequencies give information on the physical conditions and the high ionization stages of iron and other elements. Manzo et al. (1983, AA, 122, 124) report on the spectrum of Cas A between 2 and 10 KeV, Kahn et al. (1983, ApJ, 269, 212) on the HEAO-1 soft X-ray observations of Vela. A review of the Einstein results with the low resolution Solid State Spectrometer on young remnants is given by Holt (1983, IAU 101, 17), while Canizares et al. (1983, IAU 101, 205) discuss the high resolution observations of bright remnants with the Focal Plane Crystal Spectrometer. The velocity structure of Cas A from the X-ray emission lines is discussed by Markert et al. (1983, ApJ, 268, 134). Winkler et al. (1983, IAU 101, 245) derive the properties of a bright X-ray knot in Puppis A from FPCS data. Galas et al. (1981, ApJ, 250, 216) discuss the low energy X-ray spectrum of IC 443. While these spectroscopic data do provide information on the relative abundances, it appears still rather difficult to derive accurate values both for lack of spectral resolution and of accurate models.

2. THEORY

Theory of the SNR emission and evolution has however made considerable progress in this period with focus on the production of X-rays. Non-ionization equilibrium modelling of X-ray emission has been done by Shull (1982, ApJ, 262, 308 and 1983, IAU 101, 99) for young remnants and by Hamilton et al. (1983, ApJSuppl, 51, 115) for adiabatic SNR. Non-equilibrium effects have been discussed also by Groneschild and Mewe (1981, AASuppl, 84, 305) and Teske (1983, ApJ, 277, 832). Jones et al. (1981, ApJ, 249, 185) discuss X-ray production in the pre-blast wave phase. The effect of the reverse shock has been studied by Hamilton and Sarazin (1984, ApJ, 281, 682), in particular for the case of pure heavy elements SN ejecta (1984, Princeton preprint). Reynolds and Chanan (1984, ApJ, 281, 673) studied the processes to produce X-ray emission from Crab like SNR. Still centered on the theoretical interpretation of X-ray emission are the works by McKee (1983, IAU 101, 87), Pravdo and Nugent (1983, IAU 101, 29), Fabian et al. (1983, IAU 101, 119), Yorke et al. (1983, IAU 101, 393), Long et al. (1982, ApJ, 260, 202) for the long term effects of ejecta, Falle and Garlick (1982, MN, 201, 635) for the case of the Cygnus Loop, and by Berman and Kahn (1983, MN, 205, 303) for the X-ray emission shortly after the SN event.

Strictly related to the previous papers are those which deal in general terms with the interaction of the SN explosion with the interstellar or circumstellar medium. Several scenarios and problems have been considered: The evolution of a remnant in an inhomogeneous, three-phase medium (Cowie et al. 1981, ApJ, 247,908; McKee 1982, in "Supernovae, a Survey of Current Research", 433), the interaction of SN of type II and I with the surrounding medium (Chevalier 1981, ApJ, 251, 254; 1982, ApJ, 259, L85 and IAU 101, 71; Itoh and Fabian 1984, MN, 208, 925), the spherization of the remnant of a non-symmetrical explosion (Bisnovaty-Kogan and Blinnikov 1982, AstZh, 59, 876), the evaporation of clouds in a hot gas (Balbus and McKee 1982, ApJ, 252, 529), the production of acoustic waves (Spitzer 1982, ApJ, 262, 315), the heating of the IM by SNR (Cox,IAU 101, 385), the effect of the explosion in a plane-stratified medium (Falle et al. 1984, MN, 208, 925). The interaction of two remnants (Bodenheimer et al. 1984, AA, in press), the interaction with a molecular cloud (Tenorio-Tagle et al. 1984, Max Planck, MPA preprint 117) and the evolution in a six-phase IM (Ikeuchi et al. 1984, MN, 207, 909).

The mechanisms for acceleration of relativistic electrons have been discussed by Fedorenko (1981, AstZh, 58, 790; 1983, ApSpSc, 96, 25), Cavallo (1982, AA, 111, 368), Blandford and Cowie (1982, ApJ, 260, 625), Hartquist and Morfill (1983, ApJ, 266, 271), Boydan and Völk (1983, AA, 122, 129). The properties of the cooling filaments in old SNR W50, the SNR which contains SS 433, have been discussed by Panagia and Weiler (1981, Vistas in Astr, 25, 87) and van den Bergh (1981, Vistas in Astr, 25, 104). A possible mechanism to produce radio emission from very young remnants is discussed by Bandiera et al. (1983, AA, 126, 7). A number of papers are related to the Crab: The probable mass of the progenitor (Nomoto 1982, IAU 101, 139), the origin of the spur (Kundt 1983, AA, 121, L15), the evolution as driven by the pulsar (Reynolds and Chevalier 1984, ApJ, 278, 630; Chevalier 1984, ApJ, 280, 797). The transition between radio SN and plerions is discussed by Bandiera et al. (1984, ESO preprint 325). Modelling of oxygen rich ejecta was computed by Itoh (1981, PASJapan, 33, 521) and by Dopita et al. (1984, ApJ, 282, 142). A word of caution to the theoreticians comes from a laboratory simulation of a SN explosion (Borowksy et al. 1984, ApJ, 280, 802): no sweep-up of the ambient plasma was detected.

3. STUDIES IN OPTICAL, ULTRAVIOLET AND INFRARED FREQUENCIES

There has been no breakthrough or new major discoveries in this spectral range, but a large body of new information has been collected. Radial velocity and/or spectrophotometric studies of the emission lines have been carried out for W63

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(Rosado and González,1981, RevMexAA, 5, 93), G65.2+5.7 (Rosado 1981, ApJ, 250,222), the Cygnus Loop, Cas A and Kepler in the near infrared (Dennefeld and Andrillat 1981, AA, 103, 44 and Dennefeld 1982, AA, 112, 215), the Cygnus Loop (Doroshenko et al. 1982, AstrZh, 59, 699; Fesen et al. 1982, ApJ, 262, 171), and Hα filament in the Cygnus Loop (Treffers ApJ, 250, 213), 3C 400.2 (Rosado 1983, RevMexAA, 8,59), RCW 103 and Milne 23 (Ruiz 1983, AJ, 88, 1210), RCW 86, 103 and Kepler (Leibowitz and Danziger 1983, MN, 204, 273), 3C 58 (Fesen 1983, ApJ, 270, L53), IC 443 (Fesen 1983, ApJ, 281, 658), and G292.0+1.8 (Dopita and Tuohy 1984, ApJ, 282, 135). Pskovsky (1981, AstrZh, 58, 1022) has rediscussed the data on Cas A. Danziger (1983, IAU 101, 193) has presented a summary of results and open problems on the interpretation of spectroscopic data. Studies based on imagery in the light of emission lines have been carried out for HB3 (Fesen and Gull 1983, PASP, 95, 196), G126.2+1.6, G206.9+ 2.3, CTB 13 (Rosado 1982, RevMexAA, 5, 127), G65.3+5.7, G126.2+1.6 (Sitnik et al. 1983, AstrZh, 50, 503), W28 (Zealey et al. 1983, IAU 101, 267) and the Cygnus Loop (Hester et al. 1983, ApJ, 273, 219).

The Crab is still the subject of many investigations. Murdin and Clark (1981 Nature, 294, 543) discuss the optical halo, McLean et al. (1983 Nature,304, 243) the optical polarization, Fesen and Gull (1983, IAU 101, 145) the jet, Dennefeld and Pequignot (1983, AA, 127, 42), Henry et al. (1984, ApJ, 278, 619) and Henry (1984, ApJ, 281, 644) the optical near infrared spectrum.

Proper motions have been studied in the remnant of SN 1006 (Hesser and van den Bergh 1981, ApJ, 251, 549) and in Cas A and RCW 89 (van den Bergh and Kamper 1983, ApJ, 268, 129; 1984, ApJ, 200, L51). The velocity dispersion in single filaments of the Cygnus Loop, IC 443, Vela and Puppis A has been studied by Shull (1981 ApJ, 253, 682; 1983, ApJ, 269, 218).

Studies of the interstellar absorption have been carried out with IUE in stars in the direction of the Monoceros Loop (Vidal-Majar et al. 1981, 3rd Eur. IUE Conf., 412), of S 147 (Phillips and Gondhalekar 1983, MN, 202, 483), SN 1006 (Wu et al. 1983, ApJ, 269, L5) and Vela (Jenkins et al.1984, ApJ, 278, 649). A review of UV observations of SNR is given by Raymond (1983, AdvSpRes, 2, 145). New data are presented for Cygnus and Vela (1981, "The Universe at UV Wavelengths", ed. Chapman, NASA, 595), the Crab Nebula (Davidson et al. 1981, ApJ, 253, 696) and again the Cygnus Loop (Raymond et al. 1983, ApJ, 275, 636).

There is a lack of good infrared data on SNR, despite theoretical predictions on possible emission (Dwek 1981, ApJ, 247, 614, and Dwek and Werner 1981, ApJ, 248, 138). Dinerstein et al. (1982, ApJ, 255, 552) report an unsuccessful search in Cas A, D'Odorico and Moorwood (1982, ESO Messenger 28,24) a possible detection in N49 in the LMC and Marsden et al. (1984, ApJ, 278, L29) a detection of an infrared excess due to dust in the Crab with IRAS. There are also unpublished reports of detection in other remnants with the same satellite.

4. STUDIES AT RADIO WAVELENGHTS

Since most of the remnants are detected at radio frequencies only, the number of new investigations in this domain is still quite large.

Studies of a general character have been carried out on the following topics: on the radio morphology of SNR (1981, Shaver AA, 105, 306), on SNR classification (Sakhibov and Smirnov 1981, Pis'ma AZh, 8, 281), on the status of radio studies (Dickel 1983, IAU 101, 213), on the association with pulsars (Radhakrishnan and Srinavasan 1983, IAU 101, 487), on the statistical determination of the SN birth rate (Srinivasan and Dwarakanath 1983, JAA, 3, 351), on SNR evolution from an updated catalogue (Green 1984, MN, 209, 449), on their collective properties (Cowsik and Sarkar 1984, MN, 207, 745) and on the Σ/D relationship (Allakhverdiyev et al. 1983, ApSpSc, 97, 287). Studies of, or related to, individual remnants are generally

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based on improved angular resolution or on the extension of the known spectrum to other frequencies. They are listed below in order of increasing galactic longitude: Map of Sgr A East (Goss et al. 1983, IAU 101, 65), HI near W28 (Venger et al. 1982, AstrZh, 59, 20), G9.8+0.6, a newly identified SNR (Caswell 1983, MN, 204, 833), the plerionic SNR G24.7+0.6 and G27.8+0.6 (Reich et al. 1984, AA, 133, L4), 1.4 GHz maps of G15.9+0.2, G27.4+0.0, G41.1-0.3 (Caswell et al. 1982,MN, 200, 1143), 2.7 and 4.7 GHz observations of G33.2+0.6 (Reich 1981, AA, 106, 314), HI near W44 (Venger et al. 1981, AstrZh, 58, 1187), 1.7 and 2.7 GHz fluxes and polarization of W50 (Downes et al. AA, 103, 277), maps at two frequencies of G57.1+1.7, a newly identified SNR (Gómez-González and del Romero 1983, AA, 123, L5), the possible plerionic remnant G65.7+12 (Landecker and Caswell 1983, AJ, 88, 1810), 10 GHz observations of G68.8+2.6 (Sofue et al. 1983, PASJapan, 35, 437), map of the Cygnus Loop at 34.5 MHz (Sastry et al. 1981, AA, 103, 393) and at high resolution (Green and Gull 1983, IAU 101, 329), maps of G93.3+6.9 at 4.75 GHz (Lalitha et al. 1984, AA, 131, 196), multi-frequency observations of G109.2-1.0 (Hughes et al. 1983, IAU 101, 455; Downes 1983, MN, 203, 695; Sofue et al. 1983, PASJapan, 35, 447), Cas A at 20 and 25 MHz (Bovkoon et al. 1981, ApSpSc, 81, 221), HI and continuum from CTB 1 (Landecker et al. 1982, AJ, 87, 1374), multi-frequency study and polarization of G119.5+9.8 (Sieber et al. 1981, AA, 103, 393), 11 and 6-cm observations of G126.2+1.6 (Fürst et al. 1984, AA, 133, 11), morphology and spectrum of G127.1+0.5 (Pauls et al. 1982, AA, 112, 120; Geldzahler and Shaffer 1982, ApJ,260, L69; Fürst et al. 1984, AA, 133, 11), on the distance of 3C 58 (Green and Gull 1982, Nature, 299, 606), observations of HB9 at 25 and 34.5 MHz (Abranin and Bazelyan, 1982, ApSpSc, 88, 199; Dwaratakanath et al. 1982, JAA, 3, 207), on the structure of VRO 42.05.01 (Landecker et al. 1982, ApJ, 261, L41), 69.8-cm observations of S 147 (Angehofer and Kundu 1981, AJ, 86, 1003), 21-cm map of Puppis A at improved resolution (Milne et al. 1983, MN, 204, 237), on the single nature of G296.05-0.50 (Caswell and Barnes 1983, ApJ, 271, L55), G320.4-1.2 at 843 MHz (Manchester and Durdin 1983, IAU 101, 421), radio maps at 1' resol. of G327.6+14.6 (Caswell et al. 1983, MN, 204, 915), of G330.2+1.0 (Caswell et al. 1983, MN, 204, 915) of G340.4+0.4, G340.6+0.3, G341.9-0.3, G342.0-0.2, G352.7-0.1 (Caswell et al. 1983, MN, 203, 595), 21-cm continuum and line maps of G347.+22, a possible new SNR (Colomb et al. 1984, AA, 130, 294) and high resolution maps of G349.7+0.2 and G357.7-0.1 (Shaver et al. 1984, Nature, in press).

Changes of the radio structure with time have been studied in young SNR and a review is given by Strom (1983, IAU 101, 37). Cas A has been studied by Tuffs (1983, IAU 101, 49) and Tycho by Strom et al. (1982, MN, 200, 473). The decline of radio fluxes from Cas A, Crab and SN 1572 is discussed by Ivanov et al. (1981, Pis'ma AZh, 8, 83).

5. EXTRAGALACTIC SNR

I consider the progress made in the study of SNR in the Magellanic Clouds through the Einstein results and the new radio and optical observations as the most significant achievement in this period. There are now 32 SNR in the LMC and 11 in the SMC and the sample is judged to be complete to 40 pc diameter. Papers of general character on the MC SNR concern spectroscopy and imaging (Lasker 1981, PASP, 93, 422), radio obs. of SNR candidates in the SMC (Mills 1982, MN, 200, 1007), optical studies (Mathewson et al. 1983, ApJSuppl, 51, 344), X-ray properties from the LMC SNR (Long 1983, IAU 101, 525) and the SMC SNR (Inoue et al. 1983, IAU 101, 535), radio maps and general properties (Mills et al. 1984, AustJPhys, 37, 321), a complete catalogue with a general discussion and its updating (Mathewson et al. 1984, ApJSuppl, 55, 189 and 1984, ApJSuppl, in press), the interpretation of the Σ/D relationship (Fusco-Femiano and Preste Martinez 1984, IAU Symp. 108, 315), an optical, spectroscopy study of 9 remnants with discussion of the abundances (Danziger and Leibowitz 1984, MN, submitted).

Detailed investigations have been carried out on 1E 0102.2-7219 in the SMC

(Dopita et al. 1981, ApJ, 248, L105; Tuohy and Dopita 1983, ApJ, 268, L11), on the X-ray spectra of 6 SNR in the LMC (Clark et al. 1981, ApJ, 255, 440), on the Balmer lines SNR (Tuohy et al. 1982, ApJ, 261, 473), on multicolor photometry of remnants (Greve et al. 1982, AA, 111, 171), on N175B in 30 Dor B (Gilmozzi et al. 1983, MN, 202, 927), on the optical spectra of N132D and 0540-69.3 in the LMC (Dopita and Tuohy 1984, ApJ, 282, 135), on N49 as the possible site of γ-ray and optical bursts (Pizzichini et al. 1983, IAU 101, 573; Pedersen et al. 1984, Nature, 312, 46), and on high resolution spectra of N63A and N49 (Shull 1983, ApJ, 275, 592 and 611).

There are only a few new results on other extragalactic SNR. D'Odorico and Dopita (1983, IAU 101, 517) and Dopita et al. (1984, ApJ, 276, 653) present the optical spectra of SNR in IC 1613 and NGC 6822 and discuss the dependence of line intensities of old SNR on the abundances in the ISM. New data on the powerful SNR in NGC 4449 are given by de Bruyn (1983, AA, 119, 301), Blair et al (1983, ApJ, 271, 84 and 1984, ApJ, 279, 708), Bignell and Seaquist (1983, ApJ, 270, 140). A possible SNR in NGC 185 is identified by Gallagher et al. (1984, ApJ, 281, 263) but not confirmed at radio frequencies (Dickel et al. 1984, AJ, submitted).

SNR in M31 have been further studied optically (Blair et al. 1981, ApJ, 247, 879; Dennefeld and Kunth 1981, AJ, 86, 989), at 21 and 6-cm (Dickel et al. 1981, ApJ, 252; Dickel and D'Odorico 1984, MN, 206, 351). Berkhuijsen (1983, AA, 120, 147) discuss the Σ/D correlation for SNR in M31 and M33.

The detection at radio frequencies of powerful SNR near the nucleus of M82 is reported by Kronberg and Biermann (1983, IAU 101, 583).

VIII. Planetary Nebulae
(Y. Terzian)

1. GENERAL STUDIES

The IAU held Symposium No. 103 on Planetary Nebulae in 1982 in London, U.K. The proceedings were edited by D. Flower and appeared in a volume Planetary Nebulae (1983, D. Reidel Publ. Co.). The proceedings report on: observations of planetary nebulae; physical processes; chemical abundances;origin; and central stars.

A book, Planetary Nebulae, by S.R. Pottasch was published in 1984 (D. Reidel Publ. Co.). This book surveys the history; morphology and evolution, distribution, spectra and abundances, line and continuum emission, distances, mass loss, central stars, and the influence of planetary nebulae on the interstellar medium. Kaler (1984, preprint) has completed a general review on "Planetary Nebulae and their Central Stars", where he presents up-to-date information on the nebulae, their central stars, and their place in stellar evolution.

Several comprehensive studies of planetary nebulae were undertaken. Maciel (1984, AASuppl, 55, 253) compiled a catalogue of distances of 486 galactic planetary nebulae. Milne and Aller (1982, AASuppl, 50, 209) presented radio data for 397 southern nebulae at 14.7 GHz. Schneider et al. (1983, ApJ Suppl, 52, 399) published a comprehensive catalogue of planetary nebulae radial velocities, and Schneider and Terzian (1983, ApJ, 274, L61) used this catalogue to derive the galactic rotation curve of our galaxy beyond the solar system. Gathier (1984, Ph.D. Thesis, Groningen) studied the distances and physical properties of planetary nebulae. Ultraviolet studies of planetary nebulae and their central stars were reported by Adams (1983, Ph.D. Thesis, London).

A number of unusual planetary nebulae have been investigated. F.G. Sagittae was found to have unusual brightness variations (Arkhipova et al.1983, Astron.Circ. USSR 1250, 1). Arkhipova (1983, Variable Stars USSR, 22, 25), and Kostjakova and

Arkhipova (1983, Astron. Circ. USSR 1270, 3) have also reported photometric variations in V1016 and IC 4997. Dufour (1984 ApJ, in press) determined that if NGC 2818 is associated with a Population I star cluster, then it is of exceptional size, mass, expansion velocity and age. Feibelman (1984, ApJ, in press) studied the Butterfly nebula, M2-9; and the bipolar nebula NGC 2346 was studied by Feibelman and Aller (1983, ApJ, 270, 150). Recillas-Cruz and Pişmiş (1984, MN, 210, 57) have studied the kinematics and morphology of NGC 650-651. Luminosities and masses of three planetary nebulae nuclei in the Magellanic Clouds were determined from IUE observations by Stecher et al. (1982, ApJ, 262, L41). These authors suggest that the progenitors of these three nebulae had a mas of $\sim 4\ M_\odot$.

Adams et al. (1984, MN, 207, 471) have presented a detailed study of the planetary nebula K648, which is a member of the globular cluster M15.

2. YOUNG PLANETARY NEBULAE

A number of extensive studies of young planetary nebulae have been undertaken. Issacman (1984, MN, 208, 399) observed 62 compact nebulae at λ20 and λ6-cm and determined that compact nebulae are both younger and more distant than those which are more resolved. Turner and Terzian (1984, AJ, 89, 501) also observed compact nebulae at λ12 cm including CRL 618, HMSge, and He2-459; and Kwok (1984, preprint) observed small nebulae at λ6 cm. Sabbadin et al. (1984, AA, 136, 200) studied the internal motions of fourteen compact nebulae. Rodríguez and García-Barreto (1984, RevMexAA, 9, 153) concluded that the HI absorption lines in five of seven nebulae are due to line of sight clouds unrelated to the planetary nebulae, the exceptions are NGC 6302 and NGC 2440.

Goodrich and Dahari (1984, ApJ, in press) studied M4-18 and reported the coolest central star temperature of $22 \pm 2 \times 10^3$K. They suggest that M4-18 is a young nebula about 4000 years old. Feibelman (1983, ApJ, 275, 628) has reported IUE observations of the compact nebula M1-2, and Sabbadin (1984, MN, 209, 889) obtained high dispersion spectra of fourteen compact nebulae.

3. MASS LOSS AND NEBULAR EXPANSION

Harrington and Feibelman (1983, ApJ, 277, 716) reported on the remarkable nebula A30 and its central star. They find that the central star is losing mass via a 4000 km s^{-1} stellar wind, which must produce a shock upon encountering the nebulosity.

O'Dell and Ball (1984, ApJ, in press) have measured the velocities of material in NGC 2392 and found very high velocities of about 93 km s^{-1} for the inner shell. High velocity material is streaming outwards at places with a velocity of ±190 km s^{-1}. This material is probably accelerated by a strong stellar wind. Kaler et al. (1984, preprint) have discussed a new method for determining planetary nebulae distances by using the P Cygni profiles which are produced by strong stellar winds.

4. CENTRAL STARS

Reay et al. (1984, AA, 137, 113) determined Zanstra temperatures for nine central stars using a method which involves imaging the nebulae. They find stellar temperatures between 10^5 and 2×10^5 K. Méndez et al. (1984 AA, in press) report on the spectra of central stars of planetary nebulae and derive physical parameters. Kaler and Feibelman (1984 ApJ, in press) discuss the central star of the nebula Abell 78, and Feibelman and Kaler (1983 ApJ, 269, 592) report on the binary central star of the nebula LT5(339+88°1). Kondratjeva (1984 Trudy AstrophysInstUSSR, 44,30) obtained the continuous spectral distribution of eleven central stars of planetary nebulae and derived Zanstra temperatures and luminosities.

5. GENERAL OBSERVATIONS AND COMPOSITION

Carrasco, Serrano and Costero (1983, RevMexAA, 8, 187) have reported the Hβ absolute fluxes of fifty-five planetary nebulae. Pritchet and Grillmair (1984 PASP, 96, 349) presented high-sensitivity spectrophotometry of several planetary nebulae. Whitelock (1984, preprint) has made infrared JHK photometric measurements of eighty-two planetary nebulae. Pottasch et al. (1984 AA, 278, L33) report infrared results from IRAS and discuss the N III and S IV spectral lines. Shure et al. (1984 ApJ, 281, L29) present the [Ne III] 36.02 μm line in NGC 6543.

Feibelman (1983 AA, 122, 335) has studied the profiles and intensity ratios of the C IV λ1548, 1550 emission lines in eleven planetary nebulae.

The chemical abundances of twenty-eight planetary nebulae have been computed by Kondratjeva (1983 Trudy AstrophInstUSSR, 42). Barker and Cudworth (1984 ApJ, 278, 610) derive the chemical abundances of a new halo planetary nebula 61+41°1.

Aller and Czyzak (1983 ApJSuppl, 51, 211) used theoretical models to interpret observations of forty-one planetary nebulae and to derive chemical abundances.

6. DUST

Pottasch et al. (1984 AA, 138, 10) have reported IRAS measurements of 46 bright planetary nebulae. Dust temperatures were computed and the dust in the younger nebulae was found to be hotter. Pnillips et al. (1984 AA, 133, 395) made near infrared measurements of planetary nebulae and concluded that small grain of radius $\sim 10^{-3}$ μm, with low thermal capacity, may explain their observations.

Gee et al. (1984 MN, 208, 517) have performed submillimeter observations of the cold dust associated with NGC 7027 and derive a dust temperature of ∿ 20 K. Arens (1984 ApJ, 279, 685) explain the λ10μm emission from NGC 7027 by assuming two distinct grain populations. They also suggest that the warm dust component is well mixed with the nebular ionized gas.

Bentley et al. (1983, ApJ, 278, 665) found that the infrared dust emission in BD+30°3639 spacially co-exists with the emission of the ionized gas.

7. MODELS OF PLANETARY NEBULAE

Yorke et al. (1983, SovietAstrL, 9, 156) have computed evolutionary sequences of spherically symmetric numerical models simulating planetary nebulae, covering the period from envelope detachment to dispersal. Phillips (1984 AA, 137, 92) has discussed the dynamics, evolution and formation rate of planetary nebulae and finds that the formation rate is similar to that for white dwarfs, $\sim 2\times10^{-3}$ kpc^{-3} yr^{-1}.

Sabbadin et al. (1984 AA, 136, 181) try to interpret the internal motions of planetary nebulae with two possible models, a fast stellar wind, and a sudden ejection by the central star. Also, Sabbadin et al. (1984 AA, 136, 193) interpret their observations of NGC 1535 and NGC 2022 by the model of the sudden mass ejection from a central star.

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