34. INTERSTELLAR MATTER

(MATIERE INTERSTELLAIRE)

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I. Introduction

(J. Lequeux)

The previous report started with optimistic remarks about the increasing importance of the study of interstellar matter in astronomy. This trend has largely been confirmed in the 1985-87 period and it is clear that the subject of our Commission is one of the most active fields of astronomical research. This is also shown by the rapidly growing number of members and by the constitution of new working groups. The major new event in the period has undoubtly been the availability of IRAS data.

The present report covers the period mid-84 to mid-87 and is divided in self-contained sections - A new section concerns the intergalactic medium - References are given by commonly used abbreviations (see the previous reports) and in order to save place only the name of the first author is cited, followed by a + sign if several authors are involved. 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 subject of our Commission during this period, and to do full justice even to the most important papers. A detailed list of articles on the physics of the interstellar medium carried out in the Soviet Union has been prepared by B. Shustov. Only a fraction is discussed in the present report; copies of the list are available from the president of Commission 34.

The presentation of this report was made possible by the reviewing efforts of its writers, mostly members of the Organizing Committee or presidents of Working Groups, and by the cooperation of those of the members of Commission 34 who submitted relevant information. I wish to thank especially Dr. T. Landecker who accepted to write on short notice the chapter on Supernova Remnants. Dr. D. Flower wishes to acknowledge the hospitality of the Bordeaux Observatory where he could write his part. We list below a selection of books, conference proceedings, catalogues and review articles published in the period covered. When cited again in the report, these books, conference proceedings or reviews are only referred to by the year and the underlined name of the first author or editor. Many others, in particular the more specialized conference proceedings and review papers, are cited at the beginning of the various sections of the report. More information can also be found in reports by Commissions whose fields overlap with that of Commission 34, e.g. Comm. 14, 28, 40 and 47.

1. MONOGRAPHS AND OTHER BOOKS

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Gurevich,L.E., Chernin,1.D.: 1987,"Origin of Galaxies and Stars". Nauka, Moscow, 2d edition (in Russian)
Khromov,G.S.: 1985,"Planetary Nebulae: Physics, Evolution, Cosmogony". Nauka, Moscow (in Russian)

Kitchin,C.R.: 1987,"Stars,Nebulae and the Interstellar Medium",Adam Hilger,Bristol
Kondo,Y.+,ed.: 1987,"Exploring the Universe with the IUE Satellite", Reidel, Dordrecht (many review papers)
Lozinskaya,T.A.: 1986,"Supernovae and Stellar Winds: Interaction with the Galactic Gas". Nauka, Moscow.(in Russian)
Marochnik,L.S.+: 1984,"The Galaxy", Nauka, Moscow.(in Russian)
Pottasch,S.R.: 1984,"Planetary Nebulae. A Study of Late Stages of Stellar Evolution", Reidel, Dordrecht

2. SYMPOSIUM REPORTS AND CONFERENCE PROCEEDINGS

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Bochkarev,N.G.+: 1985,"Physics of ISM and Nebulae", Astr.Zh.62,1234
Bochkarev,N.G.: 1986,"Systematization of Atomic Data for Astrophysics", Astr.Zh. 63, 823
Boland,W.+,ed.: 1985,"Birth and Evolution of Massive Stars and Stellar Systems", Reidel, Dordrecht
Bregman,J.N.+,ed.: 1986,"Gaseous Halos of Galaxies", NRAO, Charlottesville
Chiosi,C.+,ed.: 1986,"Spectral Evolution of Galaxies", Reidel, Dordrecht
Danziger,J.,ed.: 1985,"Production and Distribution of CNO Elements",ESO, Garching
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Faber,S.M.,ed.: 1987,"Nearly Normal Galaxies", Springer-Verlag, Berlin
Gahm,G.,ed.: 1986,"Astrophysical Aspects of the Interstellar Medium and Star Formation", Phys.Scripta topical issue
Gondhalekar,P.M.,ed.: 1984,"Gas in the Interstellar Medium", RAL-84-101, Chilton
Henning,T.+,ed.: 1986,"The Role of Dust in Dense Regions of Interstellar Matter", Ap Sp Sci. 128, 1
Hollenbach,D.J.+,ed.: 1987,"Interstellar Processes", Reidel, Dordrecht
Israel,F.P.,ed.: 1986,"Light on Dark Matter", Reidel, Dordrecht
Kahn,F.D.,ed.: 1985,"Cosmical Gas Dynamics", VNU Science Press", Utrecht
Kessler,M.F.+,ed.: 1984,"Galactic and Extragalactic Infrared Spectroscopy", Reidel, Dordrecht
Kondo,Y.+,ed.: 1984,"Local Interstellar Medium", NASA-CP 2345, Washington
Lucas,R.+,ed.: 1985,"Birth and Infancy of Stars", North-Holland, Amsterdam
Longdon,N.,ed.: 1986,"Space-Borne Sub-Millimeter Astronomy Mission",ESA SP-260,Paris
Mead,J.M.+,ed.: 1984,"Future of Ultraviolet Astronomy based on Six Years of IUE Research", NASA CP-2349, Washington
Morfill,G.+,ed.: 1987,"Physical Processes in Interstellar Clouds",Reidel,Dordrecht
Peimbert,M.+,ed.: 1985,"Star Forming Regions", Reidel, Dordrecht
Péquignot,D.,ed.: 1986,"Model Nebulae", Obs. de Paris-Meudon, Meudon
Seggewiss,W.+ : 1985,"Interstellar Materie" Mitt.Astron.Ges. 63, available from H.U. Keller, Planetarium Stuttgart
Serra,G.,ed.: 1985,"Nearby Molecular Clouds", Springer-Verlag, Berlin
Shaver,P.A.+,ed.: 1985,"(Sub)millimeter Astronomy", ESO Conf. Workshops Proc. 22, ESO, Garching
Shields,G.A.,ed.: 1986,"The Texas-Mexico Conference on Nebulae and Abundances", PASP, 98, 956
van Woerden,H.+,ed.: 1985,"The Milky Way Galaxy", Reidel, Dordrecht
Wilson,R.,ed.: 1986,"New Insights in Astrophysics: 8 Years of UV Astronomy with IUE", ESA SP-263, Paris

3. CATALOGUES AND SURVEYS

Avedisova,V.S.: 1985,"Catalogue of Star Formation Regions in our Galaxy", Bull. Inf.Cent. Données Stellaires, 29, 78
Brand,J.+: 1987,"The Velocity Field of the Outer Galaxy in the Southern Hemisphere: II CO Observations of Galactic Nebulae", AA Suppl. 68, 1 and 69, 343

Caux,E.+: 1985,"Far-Infrared Survey of the Southern Galactic Plane", AA,144, 37

Cernicharo,J.+: 1984,"A Catalogue of Visual Extinction in Taurus and Perseus", AA Suppl. 58, 327

Dorschner,J.+: 1984,"A Catalogue of Equivalent Widths of the Interstellar 2200 A Band", Bull.Inf.Cent.Données Stellaires, 27, 141

Feitzinger,J.A.+: 1984,"Catalogue of Dark Nebulae and Globules for Galactic Longitudes 240 to 360 Degrees", AA Suppl. 58, 365

Feitzinger,J.A.+: 1986,"A Large-Scale Atlas of the Milky Way Dark Clouds", Vistas A., 29, 291

Friedemann,C.: 1987,"A Second Catalogue of Equivalent Widths of the Interstellar 2170 A Band", Bull.Inf.Cent.Données Stellaires, 32, 77

Hartley,M.+: 1986,"A Catalogue of Southern Dark Clouds", AA Suppl. 63, 27

Helou,G.+: 1986,"IRAS Small Scale Structure Catalog", US Gov't Printing Office, Washington; also distributed by Centre de Données Stellaires, Strasbourg

IRAS Science Working Team: 1985,"Point Source Catalog", US Gov't Printing Office, Washington; cf. Bull.Inf.Cent.Données Stellaires, 29, 107

Klinglesmith,D.A.+: 1987,"A Palomar Observatory Sky Survey Atlas of Selected Molecular Clouds", ApJ.Suppl. 64, 127

Neckel,Th.+: 1985,"Atlas of Galactic Nebulae", Treugesel-Verlag, Düsseldorf

Rosa,M.+: 1984,"IUE UV Spectra of Extragalactic HII Regions. I.The Catalogue and the Atlas", AA Suppl. 57, 361

Sabbadin,F.: 1984,"A Catalogue of Expansion Velocities in Planetary Nebulae", AA Suppl. 58, 273

Savage,B.D.: 1985,"A Catalog of Ultraviolet Interstellar Extinction Excesses for 1415 Stars", ApJ.Suppl. 59, 397

Scoville,N.Z.+: 1987,"Molecular Clouds and Cloud Cores in the Inner Galaxy", ApJ.Suppl. 63, 821

Ungerechts,H.+: 1987,"A CO Survey of the Dark Nebulae in Perseus, Taurus and Aurifa", ApJ.Suppl. 63, 645

Whiteoak,J.B.: 1985,"3.3 GHz Ground-State Transitions of CH towards Southern HII Regions. I.An Atlas of CH Profiles", Proc.A.Soc.Aust. 6, 6

4. REVIEW ARTICLES

Blinnikov,S.I.+: 1987,"Supernovae and Supernova Remnants: Observations and Theory", AdvSpace Phys. Sov. Sci. Rev. Sect. E, in press

Cowie,L.L.+: 1986,"High-Resolution Optical and Ultraviolet Absorption-line Studies of Interstellar Gas", Ann.Rev.AA., 24, 499

Kaler,J.B.: 1985,"Planetary Nebulae and their Central Stars", Ann.Rev.AA., 23, 89

Lada,C.J.: 1985,"Cold Outflows, Energetic Winds and Enigmatic Jets around Young Stellar Objects", Ann.Rev.AA., 23, 267

Raymond,J.C.: 1984,"Observations of Supernova Remnants", Ann.Rev.AA., 22, 75

Scalo,J.M.: 1986,"The Stellar Initial Mass Function", Fund.Cosm.Phys. 11, 1

Voshchinnikov,N.V.: 1986,"Interstellar Dust", Summaries in Science and Technology, Ser. Space Res. 25, 98

Yorke,H.W.: 1986,"The Dynamical Evolution of HII Regions - Recent Theoretical Developments", Ann.Rev.AA., 24, 49

II. Diffuse Interstellar Medium

(K. S. de Boer)

Emphasis in this report is put on observations since these are vital to further our understanding. The period covered showed a surge in investigations dealing with the local interstellar medium based on a large variety of (mainly) space observations. Also interstellar depletion received a lot of attention due to the large amount of good spectroscopic data available today. At the end of the reporting period SN 1987a came which boosted studies of the ISM in the LMC and of the galactic halo. In the following, mainly papers of the refereed litterature are mentioned; for the relevant conferences and reviews the reader is referred to the listings above. Some reviews pertaining to our topic which appeared in places one would not immediately look for are: Blades (1984,ESA SP-218,11); Savage (1984,NASA CP-2349,3); Salpeter (1985,Seggewiss+,11); de Boer (1985,Seggewiss+,63); Pettini (1985,Danziger,355) and many in (1987,Kondo book).

1. THE DIFFUSE DISK ISM

Neutral hydrogen surveys continued using the 21-cm emission line and the Lyman 121.6nm absorption line. Braunsfurth+(1984,AA.Suppl,57,189) presented 21-cm data for the Milky Way disk at longitudes between -3 and +21 deg from Effelsberg. Crovisier et al.(1985,AA,146,223) investigated small-scale structure of HI using absorption spectra towards background double sources, and showed that column densities may vary by factors larger than 3 over 1/4pc. Greisen+(1986,ApJ,303,702), using the VLA, found that structural changes are smooth on a scale of 1 arcmin. A catalog of HI 21-cm absorption line spectra of galactic radio sources was published in (1987,Izv Spec Ap Obs,24,93). Anomalous velocities for HI gas were analysed by Bash+ (1985,AA,145,127). Shaver (1984,AA,138,131) found that most deviations of observed velocities from galactic rotation are due to random cloud motions. The average density along interstellar lines of sight was investigated by Spitzer (1985,ApJ,290, L21), who found two types of clouds in more uniform warm HI gas. A survey of the southern sky in the H 166α recombination line was published by Hart+(AA Abs,40.131. 195). Carbon recombination lines were seen in absorption towards CasA (Ershov+ 1984, Pis'ma Astron Zh,10,846; 1987,ibid.,13,19) which led Sorochenko+(1987,Pis'ma Astron Zh,13,191) to estimate the CR intensity needed to ionize carbon. Shull+(1985,ApJ, 294,599) published a large survey of HI seen in absorption in IUE spectra of 205 early type stars up to 8.5kpc and with 68 stars in the halo. The gas to dust ratio as derived from Copernicus data is confirmed but now based on a much larger sample (the Rho Oph N(HI) was revised, see below). The distribution of highly ionized gas (SiIV, CIV) was analysed by Kool+(1985,AA,149,151), while Savage+(1985,ApJ,295,L9; 1987,ApJ,314,380) observed these ions and detected NV as well in the general direction of the galactic centre. Hobbs (1984,ApJ,284,L47) presented evidence for very weak absorption by high-velocity FeX from the hot phase of the ISM but showed later (1985,ApJ,298,357) that the absorption feature more likely is due to some agent in cool diffuse clouds. Using CCD echelle data, also Pettini+(1986,ApJ,310,700) failed to detect FeX absorption in the galactic halo on the line of sight to LMC stars.

The pervasiveness of dust in the diffuse medium was highlighted by the discovery of the "infrared cirrus" in the IRAS measurements. Boulanger+ (1985,AA,144,L9) succeeded in demonstrating the connection of individual cirrus features with HI clouds at high latitude north, while McGee+ (1986,MN,221,543) identified similar structures in the south (see further with local ISM). General surveys of extinction, using wide-angle photographs (1984,AA,137,287), photometry (1985,AJ,90,301), and galaxy counts (1986,AA,154,181) were presented, and the spectral structure in the UV was analysed (Savage+,1985,ApJ.Suppl.,59,397; Carnochan, 1986,MN,219,903; 1986, Fitzpatrick+,ApJ,307,286). Diffuse bands were measured (Isobe+,1986,PAS Japan,38, 511; Federman +,1984,ApJ,282,485). Obviously the amount of dust has to match the extinction and the infrared emission; however, there is a large amount of freedom in the models and consistency is often found (de Muizon+,1985,AA,143,160; Dall'Oglio

ApJ,289,609; Cox+,1986,AA,155,380; Rowan-Robinson,1986,MN,219,737). Doubt on the dust nature of the IRAS cirrus came from Harwit et al.(1986,Nature,319,646) who claim that most if not all of the 60 and 100 μm flux may be due to fine-structure emission by OI and OIII.

The ionization structure of the interstellar medium determines which absorption and emission features can be observed. An up to data compilation of the pertinent atomic data with ionization balance calculations for the diffuse medium became available from Pequignot and Aldrovandi(1986,AA,161,169). Mathis(1986,ApJ,301,423) aimed largely at the emissivity of the ionized phase. His calculations were triggered by the continuing observations of diffuse line emission (Hα, and the newly detected OIII and SII) of Reynolds (1984,ApJ,282,191; 1985,ApJ,294,256; 1985,ApJ,298,L27), Ogden+(1985,ApJ,290,238), and of Sivan+(1986,AA,158,279). Combining such measurements with hints at substantial ionization in the very local gas (see next section) Reynolds (1986,AJ,92,653) argues for an excess local EUV flux or a transient recent energetic event. Bixler+(1984,AA,141,422) achieved a new determination of the interstellar radiation field at 100 nm, and Bloemen+(1985,AA,145,391) considered the effect of the diffuse radiation on the production of inverse-compton gamma rays in the galaxy. Fujimoto+(1984,PAS Japan,36,319) presented models for the interaction network of interstellar gas and its diffusive energy. McKee summarized the processes due to injection of radiative, wind, and explosive energy by stars (1986,ApSpSci,118,383), and Kegel+(1986,AA,161,23; 1986,AA,164,337) investigated the effects of friction between the ISM and the system of stars. Hartquist+(1984, ApJ,287,194) adressed Alfven waves and energy dissipation at cloud boundaries, while Shull and Woods (1985,ApJ,288,50) discussed the formation of clouds from thermally instable intercloud gas.

Scintillation of radiation from pulsars was further investigated. At cm wavelengths flicker of 3% was seen over periods of days (Blandford+1986,ApJ,301,L53) but at meter waves with periods of months (Rickett,1986,ApJ,307,564), the latter explaining variations observed in extragalactic radiosources. Shapirovskaya+(1985, Pis'ma Astron.Zh.11,686; Sov Astron,30,no.4) find that low frequency variations do not correlate with galactic direction and they propose that hot ionized plasma is responsible. Also Balasubramanian+(1985,J.AA,6,35) favour a homogeneous medium to explain scintillation seen in pulsars, but Cordes+(1985,ApJ,288,221) required a two phase medium, adding a clumped component with scale height of less than 100pc. Krishnamohan(1986,MN,220,119) then postulated a high density (6 cm^{-3}pc) layer below the galactic plane to explain the anomalous pulsar distribution on the sky. Alurkar+ (1986,Aust J Phys,39,433) added new pulse broadening measurements of 33 pulsars with Parkes and Cordes+(1986,ApJ,307,L27) predicted that multiple pulsar images due to scintillation might be visible with VLBI. Further theoretical analyses by Goodman+(1985,MN,214,519), by Romani+(1986,MN,220,19) and by Cordes+(1986,ApJ,310, 737) showed the effects of diffractive scintillations and of refraction due to a multicomponent interstellar medium on the radiation of pulsars and other radiosources.

More detailed studies of the abundance of elements in the ISM became possible with the increasing size of the IUE data base and a new and independent body of data from BUSS. In addition some newly analysed Copernicus observations were published. In the visual new equipment boosted observational activities. LiI was observed by Ferlet+(1984,AA,138,303), by Hobbs (1984,ApJ,286,252) and in particular by White (1986,ApJ,306,777) who found good correlations with Na, K, C and n(e). Boesgaard (1985,PASP,97,587) further pursued Be with new instrumentation and now finds a factor of 2 depletion. Based on new determinations of f-values Hibbert+ (1985,MN,214,721) and Keenan+(1985,AA,147,89) reanalysed resp. NI and OI data and confirmed the earlier less than 50% depletion, and about 60% depletion of Mg (1984, ApJ,282,481). ClI was investigated by Harris+(1984,ESA SP-218,157) and Federman succeeded in identifying the line found at 108.805nm in Copernicus spectra as also due to ClI. The remaining heavy elements were investigated in several papers, from

Copernicus (Mg P Cl Mn Fe Cu Ni) by Jenkins+(1986,ApJ,301,355), from BUSS (Mg Mn Fe Cr Zn) by de Boer+(1986,AA,157,119), and from IUE (Si S P Fe Zn) by Harris+(1986,MN,220, 271;1986,ApJ,308,240), Gondhalekar (1985,MN,217,585) and Shull+(1987,ApJ Supp, preprint). All authors agree on increased depletion with increased column density, possibly through gas density but definitely correlated with reddening (1984,ApJ,284, 157;1984,ApJ,287,238;1985,ApJ,293,230;1986,MN,222,143;1986,AA,157,119;1986,ApJ,309, 771). An important discovery was that both S (1985,MN,217,585;1986,ApJ,308,240) and Zn (1986,MN,220,271;1986,AA,157,119) are depleted, in contrast to earlier beliefs, by up to a factor of 2 on heavily reddened lines of sight. A summary of current abundance and depletion values is given by de Boer+(1987,Kondo+ book,p.485). Also molecules were seen in absorption such as C_2 (Gredel+,1986,AA,154,336), CN(Federman+ 1984,ApJ,287,219;Snow,1984,ApJ,287,238), CH(Lien,1984,ApJ,284,578; Jura+,1985,ApJ, 294,238) and CH$^+$(Lambert+,1986,ApJ,303,401). CH was detected for the first time in emission from a rotationally excited lever (Ziurys+,1985,ApJ,292,L25). Absorption of CS$^+$ was reported but later turned out to be misidentified (1986,AA,168,259). For data on other molecules see the section on molecular clouds.

Rho Oph gave one of its depletion mysteries away: both new IUE spectra (Shull+, 1985,ApJ,271,408) and a reanalysis of the Copernicus Lyman profile (de Boer+,1986, AA,157,119) showed that log N(HI) is only 20.4, thus reverting this line of sight to the normal category in all respects. The star HD147889 in the Rho Oph cloud shows heavy depletion, with Si possibly behaving like Ca, and many lines of molecules (1985,ApJ,288,277;1985,ApJ,290,251;1985,ApJ,296,213;1986,PASP,98,857;1986,ApJ,302, 492;1986,ApJ,303,433;1986,ApJ,309,771). Meyers+(1985,ApJ,288,148) analysed absorption components and showed that a weak shock processed the gas in the Rho Oph cloud. Klose (1986,Ap Sp Sci,128,135) discussed the Rho Oph cloud with respect to gamma rays and Young+,1986,ApJ,304,L45) presented IRAS far-infrared maps and identified 13 of the 18 sources seen at 12 µm.

Zeta Oph served as prime star in investigations by Federman+(1985,ApJ,290,L55 on Rb), by Hawkins+(1985,ApJ,294,L131 on C isotopes), by van Dishoeck+(1986,ApJ,307, 332 on C_2) and by Pwa+(1986,AA,164,116), while Keene+(1987,ApJ,313,396) found emission in the sub-mm finestructure transitions of CI, which were in agreement with earlier analyses of the CI resonance line strengths. Crutcher+(1987,ApJ,316,L71) resolved CO radio emission towards Zeta Oph into two narrow components. Draine(1986, ApJ,310,408) constructed a shock model for the molecular gas seen towards Zeta Oph and claims that the HII region drives the shock.

The Pleiades were intensively observed both for absorption lines (White,1984, ApJ,284,685 and 695; Younan+,1984,MN,209,123) and radio emission lines (Federman+, 1984,ApJ,283,626). The reflection nebulae were reobserved by Witt+(1985,ApJ,294,216; 1986,ApJ,302,421) and they conclude that the reflection nebulae are within 0.1pc from the stars. IRAS maps of the Pleiades were presented by Castelaz+(1987,ApJ,313, 853) who argue for 50K and very small grains with large UV absorption efficiency to match the Witt+ UV surface brightness.

Shells were seen with various sizes, near OB associations (Nichols-Bohlin+, 1986,AJ,92,642;Silich,1985,Astrofizika,22,563), very thin ones possibly outside the disk (Kulkarni+,1985,ApJ,291,716;Dubner+,1985,Rev Mex AA,10,151) or due to supernovae (Jones+,1985,MN,213,711;Fich,1986,ApJ,303,465). Of particular interest were the analyses of the Cygnus region, where Heske+(1985,AA,148,439) measured radio recombination lines. Bochkarev+(1985,Ap Sp Sci,108,237) summarized all information for the Cygnus superbubble involving OB associations, but they required also 100pc diameter regions of coronal gas at distances of 0.5 to 2.5kpc from the sun in the Carina-Cygnus spiral arm. Broten+(1985,Ap Lett, 24,165) reviewed the evidence for a correlation between the compression and the magnetic field strength in interstellar bubbles. The dynamics and the observability of shells and cavities were investigated by Silich+ (1985,Astrofizika,22,563) and Bocharev+(1985,Ast.Zh,62,103 and 875). Shocks received a lot of attention, in particular in connection with molecular clouds and grain disruption (e.g. 1985,ApJ,288,148; 1985,MN,215,125; 1985,AA,151,121; 1986,MN,218, 729; 1987,Astrofizika,26,113).

2. LOCAL INTERSTELLAR MEDIUM (LISM)

The reporting period started with (1984, Kondo+) "Local Interstellar Medium". The earlier descriptions of Frisch+ (1983,ApJ,271,L59) and Paresce (1984,AJ,89, 1022) were supplemented by contributions dealing with new and old observations of Lyman alpha and of various metals, such as MgII, CII, FeII and SiII, which also result in estimates of local gas columns. Three independent UV data bases are available, each with different instrumental characteristics (Copernicus, BUSS, IUE). Landsman+ (1984,ApJ,285,801; 1986,ApJ,303,791; 1987,ApJ,315,675) used in particular late type stars, but the analysis of the stellar/IS Lyman alpha profile is difficult. Molaro+ worked on MgII stellar emission with superimposed IS absorption (1985 AA,144,81; 1986,AA,161,339), de Boer+ included nearby A-F stars (1986,AA,157,119), and fast rotating stars were used (1984,ESA SP-218,133; 1987,AA,177,228). York+ worked mostly with early type stars and detailed profile fitting (1985,ApJ,296,593; 1986,ApJ,308,232), and Vidal-Madjar and Ferlet et al. concentrated on NaI and CaII with very high dispersion (1986,AA,155,407; 1986,AA,163,204; 1986,AA,168,225). Kondo+ (1984, Kondo+,200) and de Boer et al.(1985,Mitt.AG,63,155; 1986,AA,157,119) analysed the physical conditions of the LISM using NaI, MgI and MgII. The LISM can be described as hot and of low density, in particular in the 3rd galactic quadrant, with large concentrations of gas towards l=130°and l=290°, and with a very close (6pc?) cloud towards l=40°(1986,AA,157,119; 1986,AA,163,204). Discussions on the diffuse soft X-ray emission centered on spatial models for the source function of the hot gas (see also next section).

EUV-resonance emission from the LISM in the interplanetary space was investigated by Clarke+ (1984,AA,139,389), Shemansky+ (1984,IAU Coll.81,24), Suess+ (1985,Nature,317,702), and Baranov (1986,Sov.Astron.Lett,12). The interactions of the LISM with the interplanetary medium and the perturbed plasma interface of the heliosphere were further analysed by Fahr+ (1984,AA,139,551; 1985,AA,142,476; 1986, Adv.Sp.Res,6,13). The systematics of the motions of the local gas and the interplanetary medium were analysed by e.g. Bertaux+ (1984,AA,140,230; 1985,AA,150,1 and 21) and Lallemant+ (1986,AA,168,225) and it appears that there is a systematic flow of interstellar gas from about l=300 deg and at about v=25 km/s through the solar neighbourhood, including the planetary system. However, the exact values differ between the analyses from interstellar lines and the backscattering profiles. The density of the interplanetary medium just inside the Heliopause derived from the Venera 11 and 12 data (Chassefiere+ 1986,AA,160,229) compared favourably with results from other satellites at n(H)= 0.06 cm^{-3}. Further contributions can be found in the proceedings of the COSPAR meeting in Toulouse, 1986.

An individual cloud was recognized by Hobbs+ (1986,ApJ,306,L109) at b=-34° and l=159° with d=65pc. This and other clouds, such as those found in CO by Magnani + (1985,ApJ,295,402) may be related to the so called "cirrus" as seen in IRAS far-infrared emission. These structures apparently have small radial velocities and, although at high latitude, do not belong to the halo (see next section).

3. GAS AT HIGH LATITUDES, IN THE HALO, AT HIGH VELOCITIES

The vaguely defined "halo" of the Milky Way is best seen at high latitudes and may contain high-velocity gas. However, low-velocity gas may exist well outside the Milky Way disk, and gas at high latitudes may be very local. This ambiguity played its part in the research carried out over the past few years.
Studies of gas outside the heavily populated galactic disk region continued with searches for CO emission. Both in the northern hemisphere (Blitz and Magnani et al. 1984,ApJ,282,L9; 1985,ApJ,295,402; 1986,ApJ,301,395; Mattila+, in 1985, Serra,15) and in the southern hemisphere (Keto+,1986,ApJ,304,466) CO clouds were found. The

discovery from the IRAS data of the existence of veils of dusty gas at high galactic latitudes continued to arouse great interest. Comparisons with HI, CO and extinction data were made, of which the latter were least successful due to overall small reddening values. However, the cirrus could be recognized on PSS plates as faint blue whisps, due to the reflection of diffuse galactic light by cirrus dust (de Vries+,1985,AA,145,L7). The comparisons with CO showed very productive and Weiland+ (1986,ApJ,306,L101) established that all previously discovered high latitude CO clouds coincided with the peaks of IRAS 100 micron cirrus emission. Wakker + (1986,AA,170,84) then looked for coincidences of the IRAS cirrus with halo high velocity clouds, but found none. For a few cirrus-CO clouds distance estimates could be mase based on star counts or absorption lines: Magnani+ (1986,AA,168,271) found 75 pc in one case, Weiland+ (1986,ApJ,306,L101) arrive at about 100pc, and Hobbs+ (1986, ApJ,306,L109) find 65 pc for a cloud at l=159°, b=-34°.

The high latitude Draco cloud was intensely investigated by Mebold+. High velocity gas is seen stretching along the sky and ending near "the" Draco cloud, which in itself shows substantial velocity structure. The vicinity shows enhanced soft X-ray emission (Hirth+ 1985,AA,153,249), which might be due to a collision of high velocity gas with more local gas at rest. Further observations then revealed emission from molecules such as CO, H_2CO, and NH_3 (1985,AA,151,427; 1987,AA,180, 213). Using various methods, Goerigk+ (1986,AA,162,279) estimate the distance of the cloud at between 0.8 and 2.5 kpc. Johnson (1986, ApJ,309,321) catalogued all 100 micron sources in the Draco field.

The soft X-ray intensities (McCammon+,1983,ApJ,269,107) show an anticorrelation with HI which was intensively investigated. Marshall+ (1984,ApJ,287,633) presented similar results and discussed a two component model for the radiation source. Knude (1985,AA,147,155) looked for cloud shadows and Jahoda+ (1985,ApJ,290, 229; 1986,ApJ,311,L57) made a statistical analysis; both required complex X-ray source models, and it appears likely that little of the detected soft X-ray flux stems from the galactic corona. Rather a hot stratum interspersed with neutral clouds is producing the observed anticorrelation (Mebold+, preprint).

All the work on classical high velocity clouds (HVCs) was reviewed by van Woerden+ (1985,van Woerden+,387). Further reports may be found in that symposium. McGee+ (PAS Austr. 1986,6,358, and 471) discussed new 21-cm data of halo gas in the direction of the Magellanic Clouds and of the bridge between LMC and SMC. Observational results from absorption line studies (mostly in the UV) have been presented by Savage (NASA CP-2349, 3) and by de Boer (1985,Mitt.A.G,63,21). York+ (1986, AJ,91,354) presented a list of RR Lyr stars near HVCs to plan absorption observations. New absorption data in the direction of M3 (galactic north pole) show inflow of gas (de Boer+ 1984,AA,136,L7) while Songaila+ (1985,ApJ,293,L15) report on possible absorption towards an RR Lyr star at 2 kpc. Observations of extragalactic objects added little hard data on clouds in the Milky Way halo, except maybe for the direction to NGC 3783 (West+, 1985,MN,215,481), where an absorbing cloud was seen at +241 km/s, the same speed as a HVC; the distance to this cloud remains elusive. QSO observations showed many absorption line systems as usual (see further Comm. 28 and 47), but Meyer+ (1987,ApJ,315,L5) argued that at least 15% of the lines classified as Lyman alpha forest are rather misidentified metal lines. Analysing the little data available in the literature, Morton+ (1986, MN,220,927) suggest that the CaII absorption arises in a thick disk. The metallicity of the HVCs seen earlier towards the LMC are near solar (see 1985, Danziger, p.355; Proc.Astron.Soc.Aust.6,358 and 42.131.311). Fine structure in HVCs was investigated by Arzamasova (1985, Soobshch.Spets.Astrofiz.Obs.46,69). Saar+ (1984, Tartu Obs.Pub.50,280) analysed the possible distances of three clouds, finding less than 1 kpc or more than 30 kpc; on the other hand, Kaelble+ (1985,AA,143,408), who analysed the older Giovanelli HVC sample and included IUE observations, found consistency for distances between 2 and 5 kpc, with typical motions of 100 km/s towards the disk, parallel to galactic rotation and towards the rotation axis of the

Milky Way. Infalling clouds may plunge into the disk and Tenorio-Tagle (1986,AA,170,107; 1987,AA,179,219) mode models for the shape of the shocks in such collisions. Most papers considered the ionizations structure of the gas in the halo, in particular SiIV vs CIV. Savage+ presented absorption data for long sight lines reaching outside the disk in the direction of the galactic centre and they found pronounced NV in addition to the obvious SiIV and CIV (1985,ApJ,295,L9). If the halo is hot it might contain FeX, but Pettini+ (1986,ApJ,310,700) failed to detect it on the line of sight to the LMC. Chevalier+ (1984,ApJ,279,L43; 1985,ApJ,296,35) tested models with cosmic ray ionization. Bregman+ (1986, ApJ,309,833) showed that plain photoionization plays a very important role with for each wavelength domain a prolific contributor, such as disk OB stars, halo PN and pAGB stars (also 1986, AA,142,321), energetic galaxies, and so on.

4. MAGELLANIC CLOUDS

The diffuse interstellar medium in the Magellanic Clouds has been probed by means of interstellar absorption lines in the visual and the UV and through surveys of HI. However, a pronounced imbalance persists between the set of stars studied in the visual and in the ultraviolet (de Boer, 1984,ESA SP-218, p.179). Cohen (1984 AJ,89,1779) published CaII data for 31 SMC stars and Ferlet + observed NaI lines in the LMC (1985,AA,152,151). From UV absorption of weak lines (O Mg S Cr Mn Ni Zn) de Boer+ (1985,MN,207,115) found a metal abundance in the LMC in front of R136 of a factor 2-3 below galactic. A new radio 21-cm survey was produced by Rohlfs+(1984, AA,137,343), which is the follow up of the early 21-cm work of the 1960s. McGee+ (1986,PAS.Austr.6,358 and 471) presented new 21-cm measurements towards the Magellanic Clouds and the Bridge region. The SN1987a allowed very accurate measurements of interstellar lines in all wavelength domains (1987,AA,177,L17 and L37), which showed to be similar to those towards R136. An analysis of all information of gas in Shapley III indicated that its edges expand with 35 km/s and that the origins of the structure lie 15Myr ago (Dopita+, 1985,ApJ,297,599).

III. Molecules and Molecular Clouds

(D. Flower, H. Habing, P.G. Wannier)

1. CHEMISTRY

There has been considerable activity in the field of interstellar chemistry during the period under review, including several more or less directly relevant conferences and workshops. Those not cited at the beginning of this report are : Doschek G.A.,ed.: 1984,"UV and X-ray Spectroscopy of Astrophysical and Laboratory Plasmas", NRL, Washington;Haschick,A.D.,ed.: 1986,"Masers, molecules and mass outflows in star-forming regions", Haystack Obs., Westford, Mass.; Vardya,M.S.+,ed.: 1987, "Astrochemistry", Reidel, Dordrecht. The fundamental question "Is interstellar chemistry useful?" was addressed by Dalgarno (1986: QJRAS,27,83). Much work has been done on the assumption that the answer to this question is positive, including a survey of the important category of bimolecular ion-molecule reactions (Anicich+: 1986, ApJ.Suppl,62,553). References to more specialized work are given below.

1.1. Molecular Processes

Photo-dissociation is an important process, at least in diffuse molecular clouds. Photodissociation rates for OH, OD, and CN have been reported by Nee+(1985, ApJ,291,202), who measure the OH photodissociation cross-section to be 2 to 3 times higher than calculated by van Dishoek+ (1983,JCP,79,873). The VUV predissociating states of CO have been studied spectroscopically in the laboratory by Eidelsberg+ (1987,J.Mol.Spectrosc,121,309),and CO self-shielding in the interstellar medium by Glassgold+ (1985,ApJ,290,615). Cross-sections for the photoionization of C_2 in its ground state have been computed by Padial+(1985,ApJ,298,369). At high kinetic temperatures, the collisional dissociation of H_2 by H may become important (Dove+,1986, ApJ,311,L93).

Much work has been devoted to ion-neutral reactions, particularly with hydrogen molecules. Adams+(1984,MN,211,857) measured the dependence on the centre-of-mass kinetic energy of the rates of the reactions with H_2 of C^+, N^+, $C_2H_2^+$,$C_2H_3^+$, C_3H^+ and $C_3H_2^+$. The experimental data relating to the $C^+(H_2,H)CH^+$ reaction were reevaluated by Chesnavich+(1984,ApJ,287,676). Such studies are relevant to, for example, CH^+ formation in MHD shocks. The rate of the $N^+(H_2,H)NH^+$ reaction was measured at low temperature ($8 \leq T \leq 70$ K) by Marquette+(1985,AA,147,115) and Luine+, 1985,ApJ,299,L67. Reactions leading to the chemical fractionation of deuterium have been studied in the laboratory by Adams+(1985,ApJ,294,L63).

Clary (1985,Mol Phys, 54,605) suggested that reactions of ions with polar molecules would proceed very much faster than the Langevin rate at interstellar temperatures, and this has been confirmed experimentally (Adams+,1985,ApJ,296,L31). Rate constants for reactions of ions with the cyanopoly-ynes have been measured (Bohme+,1985,MN,213,717;Daniel+,1986,ApJ,303,439;Knight+,1986,MN,219,89). Rates of reactions relevant to the formation and destruction of HCl have also been measured (Smith+,1985,ApJ,298,827), and this chlorine-bearing molecule has been detected (see below).

Rate coefficients for radiative association reactions have been revised by Herbst (1985,ApJ,291,226). The radiative association of H_2 and CH_3^+ has been studied by Herbst(1985,AA,153,151) and Bates(1985,ApJ,298,382;1987,ApJ,312,363), and of H_2 and C_3H^+ by Herbst+(1984,ApJ,285,618). The rates of dissociative recombination and of electron collisional dissociation have been compared by Zhdanov (1986,Sov Astron, 30,278), and the vexed question of the products of the dissociative recombination of polyatomic molecular ions addressed by Bates(1986,ApJ,306,L45). Protonation reactions have been discussed by Pauzat+(1986,AA,159,246), and the specific case of the protonation of CO by Dixon+(1984,JCP,81,3603).

1.2. Identification of Molecules

The molecular ion H_3^+ is believed to play a key role in interstellar chemistry but is difficult to detect because it has no permanent dipole moment. Its (forbidden) rotational spectrum has been computed by Pan+(1986,ApJ,305,518). The $1_{10}-1_{11}$ sub-mm line of the isotope H_2D^+, which does possess a dipole moment, has been measured in the laboratory by Bogey+(1984,AA,137,L15) and possibly detected by Phillips+ (1985,ApJ,294,L45). Another molecular ion, H_3O^+, has been sought (Wootten+,1986,AA, 166,L15) and perhaps detected (Hollis+,1986,Nature, 322,524). The deuterated molecule CCD has been detected at a level which is believed to be consistent with ion-molecule formation schemes (Combes+,1985,AA,147,L25). Other heavy hydrocarbon molecules have also been observed and identified: C_3H (Thaddeus+,1985,ApJ,294,L49; Gottlieb+,1985,ApJ,294,L55;Gottlieb+,1986,ApJ,303,446), cyclic-C_3H_2 (Thaddeus+,1985, ApJ,299,L63;Matthews+,1985,ApJ,298,L61;Matthews+,1986,ApJ,307,L69), C_5H (Cernicharo+, 1986,AA,164,L1;Gottlieb+,1986,AA,164,L5) and C_6H (Suzuki+,1986,PAS Japan,38,911; Guélin+,1987,AA,175,L5). The deuterated form of C_3H_2 has also been detected (Gerin+, 1987,AA,173,L1), as well as the ^{13}C-substituted form (Gomez-Gonzalez+,1986,AA,168, L11;Madden+,1986,ApJ,311,L27) following a laboratory study (Bogey+,1986,AA,159,L8). A chlorine-bearing molecule,HCl, has been observed in OMC-1 (Blake+,1985,ApJ,295, 501). The structure and spectrum of the cyclic molecule SiC_2 have been studied (Oddershede+,1985,JCP,83,1702). Protonated HCN has been detected (Ziurys+,1986,ApJ, 302,L31).

1.3. Theoretical Models

Much work continues to be devoted to developing and refining chemical models of both cold and hot (shocked) molecular gas in the interstellar medium. The chemistry in dynamically evolving clouds has been studied by Tarafdar+(1985,ApJ,289, 220). The time-dependence of the chemistry in dense clouds has been investigated by Mitchell (1984,ApJ,287,665), Watt (1985,MN,212,93), Watt+(1985,MN,213,157), Millar+(1985,MN,217,507), Williams (1986,QJRAS,27,64), Duley (1986,QJRAS,27,403) and Brown+(1986,MN,223,405). Models have been constructed by Mann+(1984,MN,209,33), d'Hendecourt+(1985,AA,152,130) which take into account grain-surface reactions. Diffuse cloud models are discussed by Mann+(1985,MN,214,279) and van Dishoeck+(1986, ApJ Suppl,62,109). Steady-state chemical models of both diffuse and dense clouds have been reported by Viala(1986,AA Suppl,64,391) and Viala+(1986,AA,160,301). Models of photodissociation regions have been evolved by Tielens+(1985,ApJ,291,722 and 747). Theoretical studies of specific aspects of the interstellar chemistry have been undertaken: the chemistry of OD (Croswell+: 1985,ApJ.289,618) and of chlorine-bearing molecules (Blake+: 1986,ApJ.300,145), the CH_3NC/CH_3CN isomer ratio (DeFrees+: 1985,ApJ.293,236), and the high HCS^+/CS ratio in TMC-1 (Millar+: 1985, MN,216,1025). The effects on models of dense clouds of the very large low-temperature rate coefficients for reactions between ions and polar molecules have been investigated by Herbst+(1986,ApJ,310,378). The physics and chemistry of polycyclic aromatic hydrocarbon (PAH) molecules are discussed by Omont (1986,AA,164,159) and the destruction of these molecules in reactions with atoms and ions by Duley+(1986, MN,219,859). No chemical model has yet given a satisfactory explanation of the high C/CO ratio observed by Keene+(1985,ApJ,299,967). Elaborate models of chemical processes in interstellar shocks have been developed. These models have been used to study molecule formation, in particular CH^+ formation, in diffuse interstellar clouds (Mitchell+: 1985,AA,151,121;Pineau des Forêts+: 1986,MN,220,801;Draine+: 1986,ApJ,310,392;Draine: 1986,ApJ,310,408). A correlation between the column densities of CH^+ and rotationally excited H_2 has been observed (Lambert+: 1986,ApJ, 303,401), suggestive of a common shock origin. The formation of SH^+ in shocks has also been studied (Millar+: 1986,MN,221,673;Pineau des Forêts+: 1986,MN,223,743).

2. ISOTOPE ABUNDANCES

Molecular transitions have continued to provide valuable information about the interstellar C, N and O isotopes. In this regard, a reference of special usefulness is Danziger,ed.: 1985. A more general set of results is presented in the proceedings from the Texas-Mexico Conference on Nebulae and Abundances (1986,PASP, 98,956). A very active area is that of abundances in the winds from red giant stars. Also, a major effort has been to understand interstellar deuterium.

2.1. Interstellar C, N and O Isotopes

A survey of the inner galaxy in the lines of ^{13}CO and $C^{18}O$ has extended work previously confined to the region from 4-12 kpc (Taylor+: 1986,BAAS,18,1026). The results are generally consistent with earlier conclusions: there is a modest enhancement of ^{13}C in the galactic disc with a large enhancement in the Galactic Center. A galactic survey of the $^{14}N/^{15}N$ ratio in NH^3 shows a similar result: a slight, constant, enrichment in the disc and a large enhancement in the Galactic Center (Güsten+: 1985,AA,145,241). The generally large ^{13}C abundance inferred from CO observations in GMC's has found support from observations of CH^+ in the local gas (Hawkins+: 1985,ApJ.294,131;Hawkins+: 1987,ApJ.317,926) which yield $^{12}C/^{13}C = 43\pm4$ and from observations of isotopic forms of C_3H_2 and CH_3OH in GMC's (Gomez-Gonzalez+: 1986,AA,168,L11;Blake+: 1984,ApJ.286,586).

2.2. Interstellar Deuterium

Interstellar D/H has the lure of providing cosmological information, but many molecules suffer severe fractionation and contamination from processed stellar material. That also makes the subject interesting to interstellar chemists. HI observations are used in connection with H_2 and HD observations and a recent measurement is consistent with previous estimates of $D/H > 10^{-5}$ in the local gas (Landsman+,1984, ApJ,285,801). In dense clouds, several new deuterated species have been detected: C_3HD (Bell+,1986,ApJ,311,L89), CCD (Vrtilek+,1985,ApJ,296,L35), and C_3DH (Gérin+, 1987,AA,173,L1) and one species predicted (Croswell+,1985,ApJ,289,618). Such results have been interpreted in finely tuned chemical models generally consistent with a D/H ratio of 10^{-5} (Dalgarno+,1984,ApJ,287,L47; Herbst+,1987,ApJ,312,351; Brown+, 1986,MN,223,429). Such results have been input to models of galactic nucleosynthesis which indicate a need for an early generation of stars (Vangioni-Flam+,1987,AA, submitted).

2.3. Circumstellar C, N, O and Si Isotopes

The understanding of interstellar isotopic ratios is intimately connected with red giant stars, which are responsible for the production and injection of several of the CNO isotopes. In carbon stars with the largest mass-loss rates, millimeter emission lines were used to measure $^{17}O/^{18}O$, $^{18}O/^{16}O$ and $^{12}C/^{13}C$ (Wannier+,1987,ApJ, 319) and to survey $^{12}C/^{13}C$ (Knapp+,1985,ApJ,293,281). In stars with less opaque envelopes, IR absorption provided C and O isotopes in 21 C-stars (Harris,1987,ApJ, 316,294); four SC stars (Dominy+,1986,ApJ,300,325); nine MS, S and SC stars (Dominy+,1987,ApJ,317,810) and $^{12}C/^{13}C$ in 15 others (Sneden+,1986,ApJ,311,826). ^{17}O is always enriched though highly variable, leading to a considerable puzzle when compared to the very constant and modest enrichment in the Galactic disc (Wannier, Danziger,ed.,1985). ^{13}C is always enriched, with values from 4 to 100 and with some indication that C-rich objects have less ^{13}C enrichment, consistent with a ^{12}C dredge-up from the stellar core. Observations of $^{29}Si/^{30}Si$ are, as expected, consistent with the terrestrial abundance ratios (Cernicharo+,1986,AA,167,L9;Fox+,1984, BAAS,16,491).

3. CLOUD MORPHOLOGY, DYNAMICS AND EVOLUTION

3.1. Mainly theoretical considerations on individual clouds

Mass distribution in clouds, fragmentation, clumpiness have been dealt with in general terms by Bhatt+(1984,MN,209,69), Arquila +(1985, ApJ,297,436), Mundy+ (1986,ApJ,306,670), Kwan+(1986,ApJ,309,783), Pérault+(1985,AA,152,371; 1986,AA,157, 139), Falgarone+(1985,AA,142,157; 1986,AA,162,235), Blitz+(1986,ApJ.Lett,300,L89), Evans+(1987,ApJ,312,344), Chièze (1987,AA,171,225). Thermal instabilities have been discussed by Gilden (1984,ApJ,283,679), and (equilibrium) structures of rotating clouds by Hachisu+(1985,AA,143,435), Arquila+(1986,ApJ,303,356), Kiguchi+(1987, preprint). Boss (1985,ApJ.Lett,292,L71) argues that velocity information may be misinterpreted in case of binary formation. Turbulence in clouds was discussed by Stenholm (1984,AA,137,133), by Silk (1985,ApJ.Lett,292,L71) and by Canuto+(1985, ApJ.Lett,294,L125); on the line formation in turbulent fields see Albrecht+(1987, AA,176,317). Van de Hulst (1987,AA,173,115) started a series of papers on multiple scattering in spherical dust clouds. Tielens+(1985,ApJ,291,722,747) discuss photo dissociation regions; for evaporation of clouds see Balbus (1985,ApJ,291,518); for collisions: Lattanzio+(1985,MN,215,125). A simulation of life cycles of molecular clouds going through periods of star formation has been made by Bodifée+(1985,AA, 142,297).

3.2. Systems of molecular clouds

Clouds in the Inner Galaxy: see Myers+(1986,ApJ,301,398), Dame+(1986,ApJ,305, 892); in the Carina Arm: Cohen+(1985,ApJ.Lett,290,L15); Grabelsky+(1987,ApJ,315, 122). There is also some interest in the Outer Galaxy: Terebey+(1986,ApJ,308,357), Huang+(1986,ApJ,309,804), Mead+(1986,ApJ,311,321). For clouds in Gould's belt see Taylor+(1987,ApJ,315,104). Results of large surveys from the northern hemisphere have been reported by the Columbia group (1985,ApJ,297,751) and the Massachusetts-Stony Brook group (1985,ApJ.Lett,292,L19; 1986,ApJ.Lett,301,L19; 1985,ApJ,289,373).

See further Feitzinger+(1986,ApJ,305,534) and Schlosser+(1984,AA,137,287), Drapatz +(1984,MN,210,11^{P}), Kwan+(1987,ApJ,315,92) and Peters+(1987,ApJ,317,646).

3.3. Shocks, magnetic fields, collapse

Chernoff (1987,ApJ,312,143) and Draine+(1984,ApJ,282,491) discuss shocks. Collapse and fragmentation is discussed by Hachisu+(1984,AA,140,259), Larson (1985, MN,214,379), Rengarajan (1984,ApJ,287,671). Bonazzola+(1987,AA,172,293) find a smaller tendency toward collapse in a turbulent medium. The collapse of rotating clouds has been calculated by Boss (1987,ApJ,316,721). For effects on dense clouds by supernova remnants see Oettl+(1985,AA,151,33), Tenorio-Tagle+(1986,AA,155,120; 1987,AA,176,329), Tenorio-Tagle+(1985,AA,148,52), Odenwald+(1985,ApJ,292,460), White+(1987,AA,173,337), and Pollock (1985,AA,150,339). Magnetic fields in dense clouds are discussed by Heiles+(1986,ApJ,301,339); the dissipation of magnetic structure is discussed by Nakano+(1986,MN,218,663; 1986,MN,221,319), Elitzur+(1985, ApJ,298,170), Elmegreen (1985,ApJ,299,196). The structure of magnetic gas clouds has been calculated by Benz (1984,AA,139,378); the polarization of molecular lines by Deguchi+(1984,ApJ,285,126); OH Zeeman Splitting is reported by Kazès+(1986,AA, 164,328).

3.4. Globules

The formation of globules is calculated by Sandford+(1984,ApJ,282,178); their thermal emission by Lee+(1987,ApJ,317,197). Casali (1986,MN,223,341) reports near-IR observations, Jones+(1984,ApJ,282,675), Bachiller+(1984,AA,140,414) and Stenholm (1985,AA,144,179) discuss the inner structure, and Williams+(1985,MN,212, 181) and Joshi+(1985,MN,215,275) report polarization measurements of background (!) stars. Reipurth+(1984,AA,137,L1) report about the formation of stars of low mass. See also Menten+(1984,AA,137,108) and Turner+(1986,AA,167,157).

3.5. High-latitude clouds

Two independent detections of molecular clouds at high galactic latitudes have been reported: a cloud in Draco (Mebold+: 1985,AA,151,427; 1986,AA,180,213; 1986,AA,162,279). Several high-latitude clouds have been detected and studied by Blitz and others (1984,ApJ.Lett,282,L9; 1985,ApJ,295,402; 1986,ApJ,301,395; 1986, AA,168,271; 1986,ApJ.Lett,306,L109); Halpern+(1987,ApJ,12,L31) find an X-ray source in one such cloud and suggest it to be a very young star. Further papers of interest are Keto+(1986,ApJ,304,466), Heithausen+(1987,AA,179,263), Sandell+(1987, AA,179,255), de Vries+(1985,AA.Lett,145,L7), Weiland+(1986,ApJ.Lett,306,L101). Wakker+(1986,AA,170,84) searched the IRAS data for far infrared emission from dust in high-velocity clouds and found none; this probably indicates a significant difference between these clouds and the high latitude molecular "cirrus" clouds.

3.6. Individual clouds

Many papers have appeared dealing with individual clouds or regions;although most of these have relevance for some of the topics discussed above, they are summarized here per region. The most studied region remains the Orion molecular cloud; two other regions of prominent interest remain the Taurus dark cloud complex and the cloud complex containing ρ Oph. Orion: Bloemen (1984,AA,139,37), Omodaka+ (1984,ApJ.Lett,282,L77), Werner+(1984,ApJ.Lett,282,L81), Hasegawa+(1984,ApJ,283, 117), Vogel+(1984,ApJ,283,655), Jaffe+(1984,ApJ,284,637), Loren+(1984,ApJ,286,232), Hasegawa+(1984,ApJ.Lett,287,L91), Lester+(1985,AJ,90,2331), Padman+(1985,MN,214, 251), Bastien+(1985,AA,146,86), Hermsen+(1985,AA,146,134), Heske+(1985,AA,149,199), Mason+(1985,ApJ Lett,295,L47), Vogel+(1985,ApJ,296,600), Wright+(1985,ApJ Lett,297, L11), Watson+(1985,ApJ,298,316), Goldsmith+(1985,ApJ,299,405), Zivrys+(1986,ApJ. Lett,300,L19), Maddalena+(1986,ApJ,303,375), Sugitani+(1986,ApJ,303,667), Crawford +(1986,ApJ Lett,303,L57), Davis+(1986,ApJ,304,481), Mundy+(1986,ApJ Lett,304,L51), Crutcher+(1986,ApJ,307,302), Dragoran+(1986,ApJ,308,270), Goldsmith+(1986,ApJ,310,383), Pendleton+(1986,ApJ,311,360), Wilson+(1986,AA,158,L1), White+(1986,AA,162,253), Takaba+(1986,AA,166,276), Nakajima+(1986,MN,221,483), Zeng+(1987,AA,172,299), Walmsley+(1987,AA,172,311), Bally+(1987,ApJ Lett, 312,L45), Blake+(1987,ApJ,315,621), Plambeck+(1987,ApJ Lett,317,L101), Geballe+(1987,ApJ Lett,317,L107).

Taurus: Kleiner+(1984,ApJ,286,255; 1985,ApJ,295,466), Gaida+(1984,AA,137,17), Cernicharo+(1984,AA,138,371), Moneti+(1984,ApJ,282,508), Irvine+(1984,ApJ,282,516), Schloerb+(1984,ApJ,283,129), Goldsmith+(1984,ApJ,283,140), Mollar+(1985,MN,216,1025), Colgan+(1986,AJ,91,107), Takano+(1985,AA,144,363), Ungerer+(1985,AA,146,123), Cernicharo+(1985,AA,149,273), Crutcher(1985,ApJ,288,604), Blake+(1985,ApJ,295,501), Brown+(1985,ApJ,297,302), Murphy+(1985,ApJ,298,818), Lebrun+(1986,AA,154,181), Cernicharo+(1986,AA,160,181), Duvert+(1986,AA,164,349), Matthews+(1986,ApJ,300,766), Tamura+(1986,MN,224,413), Cernicharo+(1987,AA,176,299), Olano+(1987,AA,179,202), Kleiner+(1987,ApJ,312,837).

ρ Ophiuchi: Zeng+(1984,AA,141,127), Lada+(1984,ApJ,287,610), Meyers+(1985,ApJ,288,148), Snow+(1985,ApJ,288,277), Feigelson+(1985,ApJ Lett,289,L19), Crutcher+(1985,ApJ,290,251), Castilaz+(1985,ApJ,290,261), Wilking+(1985,ApJ,293,165), Wadiak+(1985,ApJ Lett,295,L43), Cardelli+(1986,ApJ,302,492), Snow+(1986,ApJ,303,433), Young+(1986,ApJ Lett, 304,L45), Loren+(1986,ApJ,306,142).

Two isolated clouds that merit further studies are a very cold and quiet cloud in Monoceros (Maddalena+,1985,ApJ,294,231) and one in Norma, that produces new stars (Alvarez+,1986,ApJ,300,756).

Other papers concerning individual clouds are the following:
M17: Schultz+(1985,AA,142,363), Keene+(1985,ApJ,299,867), Rainey+(1986,AA,171,252), Snell+(1986,ApJ,304,780), Schultz+(1987,AA,171,297). W3: Zeng+(1984,AA,140,169), Kolesnik (1986,AA,169,268), Thronson+(1984,ApJ,284,597), Claussen+(1984,ApJ Lett,285,L79), Turner+(1984,ApJ Lett,287,L81), Thronson+(1985,ApJ,297,662), Mauersberger+(1986,AA,166,L26), Melnick+(1986,ApJ,303,638), Thronson (1986,ApJ,306,160), Reid+(1987,ApJ,312,830), Gordon (1987,ApJ,316,258). CasA: Barcla+(1984,AA,136,127), Goss+(1984,AA,139,317), Troland+(1985,ApJ,298,808). DR21: Johnston+(1984,ApJ Lett,285,L85), Dickel+(1985,ApJ,290,256), Dickel+(1986,AA,162,221). W49: Dreher+(1984,ApJ,283,632), Goss+(1985,MN,215,197), Miyawaki+(1986,ApJ,305,353). Chameleopardalis: Torisera+(1985,AA,153,207), Jones+(1985,AJ,90,1191), Whittet+(1987,MN,224,497).

Other clouds have been described in the papers by Gardner+(1984,MN,210,23), Federman+(1984,ApJ,283,626), Joy+(1984,ApJ,284,161), Chini+(1984,AA,137,117), Eiroa (1984,AA,141,263), Richardson+(1985,MN,216,713), Rossano+(1985,AJ,90,308), Martin-Pintado+(1985,AA,142,131), Arnal+(1985,AA,145,369), Olofsson+(1985,AA,146,337), Mauersberger+(1985,AA,146,168), Kahane+(1985,AA,146,325), Despois+(1985,AA,148,83), Crovisier+(1985,AA,149,209), Fulkerson+(1985,ApJ,287,723), Hayashi+(1985,ApJ,288,170), Smith+(1985,ApJ,291,571), Haschick+(1985,ApJ,292,200), Zheng+(1985,ApJ,293,522), Makinen+(1985,ApJ,299,341), Kutner+(1985,ApJ,299,351), Martin-Pintado+(1985,ApJ,299,386), Churchwell+(1986,ApJ,300,729), Graham (1986,ApJ,302,352), Redeman+(1986,ApJ,303,300), Loughran+(1986,ApJ,303,629), Lebrun (1986,ApJ,306,16), Mundy+(1986,ApJ Lett,311,L75), Chini+(1986,AA,154,L8), Matthews+(1986,AA,155,99), Sorochenko (1986,AA,155,237), Ungerechts+(1986,AA,157,207), Chini+(1986,AA,157,L1), White+(1986,AA,159,309), Mattila (1986,AA,160,157), Celnik (1986,AA,160,287), Stenholm+(1986,AA,161,150), Murphy+(1986,AA,167,234), Andersson+(1986,AA,167,L1), Menten+(1986,AA,169,271), Casoli+(1986,AA,169,281), Wilking+(1986,AJ,92,103), Kuiper+(1987,MN,227,1013), Richard+(1987,MN,228,43), Menten+(1987,AA,177,L57), Walmsley+(1987,AA,179,231), Clark (1987,AA,180,L1), Avery+(1987,ApJ,312,848), Straw+(1987,ApJ,314,283), Jaffe+(1987,ApJ,316,231); Vallée (1987,ApJ,317,693), Henkel+(1984,ApJ,282,L93), Moreno+(1986,AA,161,130), Cunninghamm+(1984,MN,210,891), Liszt+(1985,AA,142,237).

The galactic center remains of interest: Hiromoto+(1984,AA,139,309), Liszt+(1985,AA,142,245), Güsten+(1985,AA,142,381), Sandqvist+(1985,AA,152,L25), Armstrong+(1985,ApJ,288,159), Ho+(1985,ApJ,288,575), Harris+(1985,ApJ Lett,294,L93), Gezari+(1985,ApJ,299,1007), Gatley+(1986,MN,222,299), Walmsley+(1986,AA,155,129), Mezger+(1986,AA,160,324), Serabyn+(1986,AA,161,334), Serabyn+(1986,AA,169,85), Thronson+(1986,ApJ,300,396), Churchwell+(1986,ApJ,305,405), Bania (1986,ApJ,308,868), Goldsmith+(1987,ApJ Lett,313,L5), Goldsmith+(1987,ApJ,314,525), Heiligman (1987, ApJ,314,747), Vogl+(1987,ApJ,316,243).

On the Magellanic clouds only 3 papers appear in this list: Morgan (1984,MN, 209,241), Epchtein+(1984,AA,140,67), Israel+(1986,ApJ,303,186). On M31/M33 : Boulanger+(1984,AA,140,L5), Blitz (1985,ApJ,296,481), Ryden+(1986,ApJ,305,823), Casoli+(1987,AA,173,43), Vogel+(1987,ApJ,321,L145).

On other galaxies: Sadler+(1985,MN,214,177), Bhatt+(1986,MN,219,217), Rydbeck+(1985,AA,144,282), Stark+(1986,ApJ,310,660), Blitz+(1986,ApJ,311,142), Young+(1986,ApJ Lett,311,L17), Wyse (1986,ApJ Lett,311,L41), Sanders+(1987,ApJ Lett,312, L5), Sargent+(1987,ApJ Lett,312,L35), Myers+(1987,ApJ Lett,312,L39), Lo+(1987,ApJ, 312,574), Lo+(1987,ApJ Lett,317,L63).

4. HIGH VELOCITY OUTFLOWS

Flows of matter at high speed from young stellar objects have been reviewed by Lada (1985,ARAA,23,267); the review contains a catalogue of 68 high-velocity molecular flows. The flows are noticed by a variety of indicators: high velocity H_2O masers; broad emission lines of thermally excited molecules (e.g. CO); emission lines of vibrationally excited H_2 ; Herbig-Haro objects; "FU Orionis" type objects (very rare). A new detection method is probably through the absorption lines of CO at 4.8 micron: in M8E the lines show the presence of warm CO near the star (Larson+:1986,ApJ,307,295). An IR polarization study by Lenzen (1987,AA,173, 124) uncovered several reflection nebulae very close to the central objects. Near-infrared cameras have shown the existence of loops or arcs (Forrest+:1986,ApJ Lett, 311,L81). Observations of emission lines of CS by Heyer+(1986,ApJ,308,134) show no symmetries associated with the bipolar axis and they conclude that the wind is not focussed by large interstellar objects. Mundt+(1984,AA,140,17) discovered three more optical jets, and Krauter (1986,AA,161,195) discovered a jet in Th28. A systematic mapping program in a CO line led Fukui+(1986,ApJ Lett,311,L81) to the discovery of 7 new outflow sources. Masses and energetics in six well-studied flows have been estimated by Margulis+(1985,ApJ,299,925).

From IRAS data luminosities have been derived of 45 sources associated with molecular outflows by Morzukewich+(1986,ApJ,311,371); the range is from a few solar luminosities for e.g. TTau to several times 10^6 solar luminosities for NGC 6334. Low-luminosity sources have been studied in infrared lines by Smith+(1987, ApJ,316,265), who conclude that low-luminosity sources are likely to be qualitatively different from high-luminosity sources.

The mechanisms that produces these huge flows are not yet known; explanations have been proposed by Cameron (1985,ApJ Lett,299,L83), by Kwok+(1985,ApJ,299,191), and by Choe+(1986,ApJ,305,131). More earthly approaches to theoretical support have been taken by Reynolds (radio continuum spectra; 1986,ApJ,304,713), by Liseau +(geometrical information from the shapes of CO line profiles; 1986,ApJ,304,459, see also Cabrit+:1986,ApJ,307,313); and in papers on the bow shocks associated with HH regions (Choe+:1985,ApJ,288,388; Raga, 1986,AJ,92,637; Hartigan+:1987,ApJ, 316,323; Raga+:1986,AJ,92,119).

The most surprising area (Orion/Monoceros) contains at least three different active regions: Orion A (M42), Orion B (NGC2024), and the Monoceros Area (Mon R2).

In the cloud L1641, that contains M42, there are now 7 high outflow sources providing enough momentum to stabilize the cloud; 4 of these 7 have been discovered via a systematic CO survey for high velocity wings (Fukui+,1986,ApJ Lett,311,L85).

Other papers concerning the flows in this general area are: Orion A: Kuiper+,1984,ApJ,283,106; Jones+,1985,AJ,90,1320; Schwarz+,AJ,90,1820; Thronson+, 1986,AJ,91,1350; Meaburn, 1986,AA,164,358; Wilson+,1986,AA,167,L17; Taylor+,1986, MN,221,155; Geballe+,1986,ApJ,302,693; White+,1986,ApJ,302,701; Ziurys+,1987,ApJ Lett,314,L49. Several papers deal with Herbig Haro objects in the Orion nebula (HH1 and HH2): UV and optical spectrum: (Meaburn+,1984,AA,138,36; Brugel+,1985, ApJ Lett,292,L75; Boehm+,1985,ApJ,294,533; Boehm+,1987,ApJ,316,349); infrared: (Strom+,1985,AJ,90,2281; Pravdo+,1987,ApJ,314,308; Harvey+,1986,ApJ,301,346); radio continuum emission: (Pravdo+,1985,ApJ Lett,294,L117); Martin-Pintado+,1987, AA,176,L27).

Orion B: Sanders+(1985,ApJ Lett,293,L39); Chalabaev+(1986,AA,168,L7); Russel+ (1987,MN,226,287).

Mon R: Brugel+(1984,ApJ Lett,298,L73); Aspin+(1985,AA,149,158); Hughes+(1985, ApJ,289,238).

Papers concerned mainly with specific regions are:

L1551 IRS5: radio sources: (Bieging+,1985,ApJ Lett,289,L5; Snell+,1985,ApJ,290,587; Rodriguez+,1986,ApJ Lett,301,L25); optical obs.: (Mundt+,1985,ApJ Lett,297,L41; Sarcander+,1985,ApJ Lett,288,L51); infrared: (Edwards+,1986,ApJ Lett,306,L65; Clark +,1986,AA,154,L25; Clark+,1986,AA,158,L1); velocity gradients in CO flow (Fridlund +,1984,AA,137,L17); no rotating disk (NH_3: Menten+,1985,AA,146,369; CS: Moriarty-Schievan+,1987,ApJ Lett,317,L95); high velocity OH: (Mirabel+,1985,ApJ Lett,294, L39); rotation measures in background galaxies: (Simonetti+,1986,ApJ,303,659); a thick disk: (Strom+,1985,AJ,90,2575).

AFGL2591: 12CO observations indicating the flow and IR observations by Lada+ (1984,ApJ,286,302); a compact rotating disk from NH_3 (Takano+,1986,AA,158,14) and some faint radio sources (Cambell, 1984,ApJ,287,334).

Cepheus A: source of flow (Cohen+,1984,MN,210,425; Guesten+,1984,AA,138,205; Torelles+,1986,ApJ,305,721); optical and IR observations (Linzen+,1984,AA,137,202; Hartigan+,1986,AJ,92,1155); CO(3-2) line: (Richardson+,1987,AA,174,197); HCO+: (Loren+,1984,ApJ,287,707); rotation measures of background galaxies: (Simonetti+, 1986,ApJ,303,659).

AFGL 490: (Kawabe+,1984,ApJ Lett,282,L73); Gear+(1986,MN,219,835). R Cor Aus: Ward-Thompson+(1985,MN,215,537); Castelaz+(1987,ApJ,314,317); Hartigan+(1987,AJ,93, 913). G35.2-0.74: Matthews+(1984,AA,136,282); Dent+(1985,AA,136,282). NGC 2071 : Takano+(1984,ApJ Lett,282,L69); Takano+(1986,AA,167,333); Takano (1986,ApJ Lett, 300,L85); Scoville+(1986,ApJ,303,416) (high resolution mapping of radio line).

Various other papers: Zealey+(1984,AA,140,L31); Campbell (1984,ApJ Lett,282, L27); Torrelles+(1985,ApJ,288,595); Harvey+(1985,ApJ,288,725); Richardson+(1985, ApJ,290,637); Sato+(1985,ApJ,291,708); Schwarz+(1985,ApJ,295,89); Cohen+(1985,ApJ, 296,620); Cohen+(1985,ApJ,296,633); Little+(1985,AA,142,378); Aspin+(1985,AA,144, 220); Lightfood+(1986,MN,221,993); Castelaz+(1986,ApJ,300,406); Zealey+(1986,AA, 158,L9); Buehrke+(1986,AA,163,83); Guesten+(1986,AA,164,342).

5. CIRCUMSTELLAR MOLECULAR ENVELOPES (CSE's)

The study of dense winds from red giants has evolved dramatically due to progress in the techniques for observing millimeter-wave, infrared and maser transitions of circumstellar molecules. A reference of special use is from a conference on Mass Loss from Red Giants (1985, Morris and Zuckerman, eds., Reidel, Dordrecht) which includes reviews of nearly all aspects of CSE's up to 1984. Isotopic abundances in CSE's are reported above, in the section on Isotope Abundances.

5.1. Millimeter-wave Observations

Surveys of millimeter-wave CO emission have been carried out by several groups using infrared luminosities as guides to the source selection process (Knapp+: 1985,ApJ.292,640; Zuckerman+: 1986,ApJ,304,394; Zuckerman+: 1986,ApJ,304,401; Wannier+: 1986,ApJ,311,335; Likkel+: 1987,AA,173,L11; Wannier+,ApJ, in press). The total number of known CSE's is now about 100, of which half are C-rich and half O-rich. With the improved statistics, there has been progress in understanding the interrelations of mass-loss rate, gas-to-dust ratios, IR luminosities and abundances, but not without considerable scatter and notable exceptions to each rule (Zuckerman+: 1986,ApJ.311,345; Knapp: 1985,ApJ.293,273; Knapp: 1986,ApJ.311,731). In this regard, two objects of special note are 1) a particularly hot and photo-dissociated outflow of very modest proportions and displaying HI emission (Huggins: 1987,ApJ,313,400; Bowers+: 1987,ApJ,315,305), and 2) IRAS 09371+1212, a particularly cold and dense outflow of large proportions and displaying strong circumstellar ice bands (Forveille+: 1987,AA,176,L13). Also, with additional observations, the division of stars into clear C/O abundance classes has been muddied by the detection of HCN in O-rich sources (Deguchi+: 1985, Nature,317,336; Jewell+: 1986,Nature,323,311).

Great progress has been made on determining the structure and chemistry of CSE's, subjects which are intimately intertwined. Many relevant articles appear in the proceedings of an IAU symposium on Astrochemistry (Vardya+,1985).
Direct observations of CSE structure have been made by new arrays, and by decreasing antenna beamsizes. CRL 2688, in particular, has been mapped at cm wavelengths in NH_3 and HC_7N with the VLA (Nguyen-Q-Rieu+: 1986,AA,165,204), at mm wavelengths in CO with the OVRO interferometer and the Nobeyama 45m telescope (Heiligman+: 1986,ApJ,308,306; Kawabe+: 1987,ApJ,314,322) and in the near IR in H_2(Beckwith+: 1984,ApJ,280,648). These complementary techniques lead to a detailed picture of a rapid bipolar outflow and a dense molecular toroid surrounded by a cool, extended envelope. The greatest attention has been focused on IRC+10216 where interferometry of HCN (Bieging+: 1984,ApJ,285,656) and maps of C_2H and CN (Truong-Bach+: 1987, AA,176,285) confirm predictions based on models which include photodissociation chemistry. Several new CSE chemical models have appeared focusing on molecule formation, especially near the stellar surface (Tsuji: 1986,Ann.rev.AA,24,89; Shmeld+: 1985,Sov.Astron.Lett,11; Slavsky: 1984,Proc.Southwest Reg.Conf. for Astron.Astrophys.,9,43). One model, including photo-dissociation effects, predicts the spatial extent of circumstellar molecular ions (Glassgold+: 1986,AA,157,35) and models of ion-molecule chemistry have been made for both C-rich and O-rich stars (Nejad+: 1987,AA,in press; Nejad+: 1987,MN, submitted).

The steady march of new molecular lines in CSE's is also led by IRC+10216. Of particular interest is a series of transitions of vibrationally excited states of well-known molecules, namely: 1) HCN (v=1) (Ziurys+: 1986,ApJ,300,L19), 2) CS (V=1) (Turner: 1987,ApJ, submitted, and 3) SiS (v=1) (Turner: 1987,ApJ, submitted). These transitions probe small radii and reflect intersting envelope kinematics. Other new lines are of SiCC (Thaddeus+: 1984,ApJ,283,L45; Snyder+: 1985,ApJ, 290,L29), SO_2 (Lucas+: 1986,AA,154,L12), C_5H (Cernicharo+: 1986,AA,167,L5), CO (6-5) (Sahai: 1987,ApJ,318,in press), C_6H (Guelin+: 1987,AA,175,L5; Saito+: 1987, PASJ,39,193), C_2H_4 (Goldhaber+: 1987,ApJ,314,356), HSiCC or HSCC (Guelin+: 1986, AA,157,L17), a new line of NH_3 (Nguyen-Q-Rieu+: 1984,AA,138,L5), and a line survey of IRC+10216 and CIT6 (Henkel+: 1985,AA,147,143). Each of these lines, along with high signal-to-noise spectra of CO in IRC+10216 (Huggins+: 1986,ApJ.304,418) provides grist for models which use radiative transfer and self-consistent molecular excitation to yield a detailed radial molecular structure in IRC+10216 (Sahai:1987, ApJ.318 in press; Morris+: 1985,AA,142,107). Models of O-rich and non-spherically symmetric objects are less advanced, but will be called for with such new observations as those of SO and SO2 in O-rich stars (Guilloteau+: 1986,AA,165,L1) and HCN in C-rich bipolar reflection nebulae (Deguchi+: 1986,ApJ,303,810). Sought, but not found, were CCℓ, CℓO, MgO and TiO (Millar, 1987,AA,in press), while Cernicharo+ (1987,AA,183,L10) have found NaCℓ, AℓCℓ, KCℓ and perhaps AℓF.

5.2. Infrared Observations

Infrared spectroscopy has 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 of the work has been from CO bands, though a 2400-2778 cm^{-1} atlas has revealed lines of OH, CH, SiO, CS and HCl in observations of K,M,C and S stars (Ridgway+: 1984,ApJ,54,177). The CO bands themselves provide a lot of flexibility, and the hotter, denser, regions are probed by successively larger vibrational overtone numbers and by higher rotational levels. The fundamental 4.6 micron band has been used, with annular observing apertures, to isolate weak CO emission features separated by up to 6arcsec in IRC+10216, revealing an unexpectedly hot rotation temperature (Sahai+: 1985,ApJ,299,424). The firstovertone band at 2.3 microns has been observed in 18 M-type stars to measure circumstellar C/H (Tsuji: 1986,AA,156,8). Second overtone bands, formed near the stellar photosphere, have yielded time-sequence observations which follow the passage of regular shocks in eight Mira variables and one SRa variable star (Hinkle+: 1984,ApJ.Suppl,56,1). Finally, several authors have used the CO bands to derive C and O isotope abundances in CSE's and these results are discussed above in the section on "Isotope Abundances" (above). In addition to the CO vibration/rotation bands, significant attention has been focused on the formation of very large molecules (PAH's) and the initiation of dust formation. That subject is treated more extensively under the section on "Interstellar Dust" (below). In circumstellar environments, laboratory experiments have demonstrated a possible path to form long-chain hydrocarbons and small PAH's (Heath+: 1987,ApJ,314,352) and several authors have focused on the problem of initiating grain growth formation (Kozasa+: 1984, Ap.Space Sci,98,61; Dojkov: 1985,Ref.Zh,51, Astron.5.51.431; Jura+: 1985,ApJ.292, 487; Shmeld: 1985,Astron.Zh.62,1229). The problem of distinguishing C-rich from O-rich chemistries has been further muddied by observations of silicate features around C-rich stars, (Little-Marenin: 1986,ApJ,307,L15; Willems+: 1986,ApJ,309, L39).

5.3. OH Maser Observations

A general survey of galactic OH masers confirms a population peak at R$\approx$7.5kpc (Tong+: 1984, Chinese AA,8,343). A survey near the galactic center with the VLA has revealed 33 stars, strongly concentrated at the Sgr A West source and with unusually large expansion velocities (Winnberg+: 1985,ApJ,291,L45). A survey at the galactic tangent point has been used to derive intrinsic physical parameters of OH/IR stars (Baud+: 1985,ApJ,292,628). In addition, an IRAS source selection criterion has been proven effective (Lewis+: 1985,Nature,313,200) and a general survey has turned up seven new CSE sources (Slootmaker+: 1985, AA Suppl,59,465). A search for OH emission from symbiotic stars was unsuccessful (Norris+: 1984,Proc. Astron.Soc.Aust.,5,562) and a search for emission from short-period Mira's partially successful (Dickenson+: 1987,AJ,92,416).

With the regular spectral line operations of the VLA and MERLIN have come many continuing studies of the spatial structure of OH emission. VLA observations of 11 objects near the tangent point reveals general circular symmetry, in agreement with an earlier survey and places the Sun at 9.2 ± 1.2 kpc from the galactic center (Herman+ 1985,AA,143,122). Detailed VLA studies have been made of notable objects IRC+10420 (Bowers: 1984,ApJ,279,350) and OH231.8+4.2 (Bowers: 1984,ApJ,276, 646). MERLIN observations have also continued apace, with maps of OH127.8-00 (Diamond+: 1985,MN,216,1), U Ori (Chapman+: 1985,MN,212,375) and five other objects, including a review of prior maps (Diamond+: 1985, MN,212,1).

Other techniques include studies of the regular (Herman+: 1985,AA Suppl,59, 523; Bowers+: 1984,ApJ,276,646) and sudden (Lewis+: 1986,ApJ,302,L23; Yudaeva:1986, Pis'ma Astron.Zh.12,No5,361; Le Squeren+: 1985,AA,152,85) time variabilities of the maser features, allowing details of structure to be inferred and sometimes simply leading to puzzlement. Studies using high-resolution spectrometers reveal the presence of many (thousands) of small masing elements (Fix: 1986,AJ,93,433; Fix: 1987,AJ,92,433) and of unexpected magnetic fields (Cohen+: 1987,MN,225,491). Maser polarization has been used to infer time variation in the velocity field (Ukita+: 1984,AA,138,343). General models of OH masers have been made (Alcock+: 1986,ApJ, 305,837; Dickinson: 1987,ApJ,313,408) as well as ones applicable to specific cases (Grinin: 1985,Izv.Krymskoj Astrofiz.70,139).

5.4. Other Masers

A new strong maser, of HCN, has revealed itself in CIT6 (Guilloteau+: 1987,AA, 176,L24), being the first strong maser ever seen in a C-rich envelope. Otherwise, H_2O and SiO masers, in O-rich envelopes have provided most information. SiO maser emission has been studied using the v=1, J=1-0, J=2-1, J=3-2 and J=5-4 lines as well as v=2, J=2-1. The most extensive SiO survey used the NRO antenna, simultaneously observing six SiO transitions. SiO masers were detected in 83 stars, with a v=3 maser in eight stars and a suggestion of ^{29}SiO (v=0) masing in six stars (Cho+: 1986,Astr.Space Sci,118,237). Using OH masers to guide source selection an NRO survey also detected SiO masers (v=1 and 2) near the galactic center (Lindqvist +: 1987,AA,172,L3). Other surveys have also revealed a significant number of new SiO maser sources (Jewell+: 1985,ApJ,298,L55; Barcia+: 1985,AA,142,L9; Nyman+:1986, AA,160,352; Bujarrabal+: 1987,AA,175,164). Time variability and polarization of SiO v=1 maser sources has been undertaken by several groups (Nyman+: 1985,AA,147, 309; Nyman+: 1986,AA,158,67; Miller+: 1984,ApJ,287,892; Clark+: 1985,ApJ,289,756; Snyder: 1987,AJ,92,416), suggesting a correlation with the Mira pulsation and a pump located close to the star. The pedestal features, not the intense spikes, are revealed to be the most useful in deriving general properties of the envelopes. One star, χ Cyg, has also been monitored in the v=2, J=2-1 line (Olofsson+: 1985, AA,150,169). A multi-transitional polarization study of SiO masers reveals that features arising from the same rotational state, but different vibrational states originate in the same volumes of gas, but different rotational states are from different volumes (Barvainis+: 1985,ApJ,288,694). A collisional model of SiO masers now includes all observed transitions and predicts relative maser strengths including non-observed transitions (Bolgova: 1984, Nauchn.Inf.57,39). The polarization of SiO masers has been modeled with the use of radiative transfer in the presence of magnetic fields (Deguchi+: 1986,ApJ,302,108) and a detailed model of the SiO maser in VY CMa includes a rotating disc and two independent gas streams(Zhou+ : 1984,AA,138,359).

A number of surveys of the 22 GHz H_2O maser have been made (Engels+: 1986,AA, 167,129; Zuckerman+: 1987,AA,173,263; Engels+: 1984,AA,140,L9; Bowers+: 1984,ApJ, 285,637). These surveys indicate emission generally from about 10^{15} cm, with amplitudes correlated with mass-loss rate and OH and IR variability. A suggested phase lag with respect to OH implies a collisional pump for the H_2O maser. One oddball maser source, associated with the carbon star EU and is shown to originate in a binary pair including an M giant (Benson+: 1987, ApJ,316,L37). The spatial structures of H_2O masers have been studied in VX Sgr with MERLIN (Chapman+: 1986,MN,220,

513) and in RX Boo, R Aql, RR Aql and NML Cyg with the VLA (Johnston+: 1985,ApJ, 290,660) revealing details of the spatial, velocity and magnetic field structure. Time variability of H_2O emission reveals aperiodic behaviour, suggesting the passage of individual Mira shocks far out into the CSE (Gomez Balboa+: 1986,AA,159, 166). A new model of H_2O maser emission, using current collision cross-sections, satisfactorily reproduces the 22 GHz maser and predicts other strong maser lines in the 227-789 micron region (Cooke+: 1985,ApJ,295,175).

6. INTERSTELLAR MASERS

The observational and theoretical study of masers in both the interstellar gas and stellar envelopes continues to provide valuable information on the physical state of the emitting regions. Of the various masers which have been detected, OH and H_2O continue to be the most extensively observed, followed by NH_3, SiO, H_2CO and CH_3OH (methanol). General references not cited at the beginning which are relevant to the period under review are: Burke,ed.:1984,"Quasat - a VLBI Observatory",ESA-SP213; Haschick, ed.1986:"Masers, Molecules and mass outflows in star-forming regions", Haystack, Westford.

6.1. OH masers

Observations of W51 (main) using the VLBI technique (Benson+: 1984,AJ,89,1391) display Zeeman splitting indicative of mG magnetic fields. There have been VLA observations of NGC 7538(IRS1) by Palmer+,(1984,MN,211,41P) and of Sgr B2 (Gardner+: 1987,MN,225,469). MERLIN observations of 1665 MHz emission from W75N were reported by Baart+ (1986,MN,219,145). Other observations relate to OH megamasers (Baan+: 1985,ApJ,298,L51; Bottinelli+: 1985,AA,151,L7), a maser outburst in Ceph A (Cohen +: 1985,MN,216,51P), late-type stars (see Section 6.3 above), and to Mira variables, infrared stars, and molecular clouds (Slootmaker+: 1985,AA Suppl,59,465).The peculiar OH maser G24.3+0.1 has been observed by Paschenko (1984,Sov.Astron.Lett., 10,303). The collisional pumping of the main lines has been discussed by Andresen+ (1984,AA,138,L17), on the basis of laboratory data. The problem of radiation transport has been considered by Field+(1984,MN,211,799, erratum in 1985, MN,213,495) and Field (1985,MN,217,1), and also by Deguchi+: (1986,ApJ,300,L15).

6.2. H_2O masers

The H_2O masers in star-forming regions have been discussed by Downes (Lucas+, 1985,557). A young stellar object has been discovered near the water masers in W3 (OH) (Turner+: 1984,ApJ,287,L81). Flares have been observed in the 8 km/s H_2O maser source in Orion (Abraham+: 1986,AA,167,311), in W75N (Lekht+: 1984,Sov.Astron.Lett. 10,307) and H_2O maser outbursts which may be connected with protoplanetary rings by Matveenko (1986,Sov.Astron,30). Maser emission from stars in the IRAS point source catalogue is reported by Zuckerman+: (1987,AA,173,263), and in nearby galaxies by Whiteoak+ (1986,MN,222,513). The related questions of radiative transfer are discussed by Chandra+ (1984,AA,140,295), of maser pumping by Kylafis+ (1986,ApJ, 300,L73), and of the influence of magnetic fields by Deguchi+ (1986,ApJ,302,750). A cloud-cloud collision model for H_2O maser excitation has been presented by Tarter + (1986,ApJ,305,467).

6.3. Other masers

New interstellar masers in non-metastable ammonia have been reported by Madden +(1986,ApJ.300,L79), and an interstellar $^{15}NH_3$ maser by Mauersberger+ (1986,AA,160, L13). Both maser and thermal emission from ammonia have been observed towards the star-forming region W51 (IRS2) by Mauersberger+ (1987,AA,173,352). Observations have been made with the VLA of both methanol (Menten+:1985,ApJ,293,L83) and formaldehyde (Gardner+: 1986,MN,218,385). New maser lines of methanol are reported by Morimoto+(1985,ApJ,288,L11). The masers of silicon oxide have been observed in red-supergiants and in the vicinity of molecular clouds by Ukita+(1984,AA,138,194), and in Mira variables, short-period variables, and OH/IR stars by Jewell+(1985,ApJ, 298,L55).

IV. Interstellar Dust

(J.S. Mathis)

In addition to the references listed at the beginning, several specialized symposia are: Wolstencroft R.D.+,ed.,1984, "Laboratory and Observational Infrared Spectra of Interstellar Dust", Occas.Rep.Roy.Obs.Edinburgh No 12;Nuth,J.A.+,ed., 1985,"Interrelationships among Circumstellar, Interstellar and Interplanetary Dust", NASA CP-2403;Léger,A.+,ed.,1987, "Polycyclic Aromatic Hydrocarbons and Astrophysics" Reidel,Dordrecht;Geogenthal workshop: 1986, "The Role of Dust in Dense Regions of Interstellar Matter", ApSpSci,128.

Emission from dust: Many objects, all of which contain dust, (Willner,1984, Kessler+,84) show "Unidentified Infrared Bands" (hereafter "UIBs", but also called "UIR bands" by many authors). They range from 3.28 to 11.4 µm, with a plateau of emission extending out to 13 µm and probably extending to wavelengths beyond this value (Cohen+,1986,ApJ,302,737). They are strong in the reflection nebulae NGC 2023 and NGC 7023 (Sellgren+,1985,ApJ,299,416). Witt+(1984,ApJ,281,708;1986,ApJ,294,216 and 225) found that the emission extends to wavelengths of about 0.6 µm and has a component of broad bands and a continuum. Castelaz+(1986,ApJ,313,853) determined the IRAS surface brightness maps of the reflection nebulae in the Pleiades and found a high 12/25 µm color temperature at both large and small distances from the various stars. As regards interstellar dust, probably the most important findings of the IRAS satellite were the existence of streaks of diffuse material called "cirrus" (Low+,1984,ApJ Lett,278,L19). This material is primarily visible in the 60 and 100 µm IRAS filters, is quite faint at 25 µm, but is surprisingly strong at 12 µm, with a high color temperature (typically 250 K) between the 12 and 25 µm band ratios (Hauser+,1984,ApJ Lett,278,L15). The high 12/25 µm color temperature showed that the emission is a non-equilibrium process. High-latitude molecular clouds and cirrus are closely related in space (Weiland+,1986,ApJ Lett, 306,L101), suggesting that the cirrus is only about 100pc from the plane of the Galaxy. However, cirrus is not always bright where the CO emission is strong, and conversely. There are streams of cirrus seen near the LMC but of Galactic origin (McGee+,1986, MN,221,571) which have narrow-line 21-cm emission.

Interpretation of the excess emission: The excess emission at wavelengths of a few micrometers can arise from one or both of two related processes: (a) It might be radiative cascading from high vibrational levels of a molecule excited after absorption of a photon. This process tends to concentrate the emitted energy into bands, but there might be a real continuum if the molecule is excited enough. (b) The emission may arise from the thermal emission of a tiny grain, heated to hundreds of K by the absorption of a single photon and cooling. This grains might be thought of as a disordered molecule, so large that its bands are replaced by a continuum. Temperature fluctuations in small grains have been modelled by Draine+ (1985,ApJ.292,494) and by Désert+(1986,AA,160,295), treating the grain classically. Fluctuations caused by a grain being struck by a single energetic electron in hot gas have been modelled by Dwek (1986,ApJ,302,363).

There is at present little doubt that some form of hydrogenated carbon is responsible for the UIBs and associated continuum, but precisely what form is controversial. Léger (1984,AA,137,L5) and Puget+(1985,AA,142,L19) suggested that the UIBs can be accounted for by about 6% of the cosmic carbon being in the form of polycyclic aromatic hydrocarbons (benzene-ring structures), hereafter "PAHs", of up to about 60 carbons, and that the spectrum of an excited PAH should correspond to the UIBs. Independently, Allamandola+(1985,ApJ.Lett.290,L25) pointed out that the

Raman spectra of auto soot, containing PAHs and amorphous hydrogenated carbon particles, strongly resembles the 5 - 10 μm emission spectrum of the Orion Nebula. Barker+(1987,ApJ Lett,315,L61) use the width of the observed UIBs to suggest that no more than 20 or 30 C atoms are in the PAHs. Reasons for associating PAHs with the UIBs and possibly the NIR emission continuum are discussed extensively in Léger and d'Hendecourt's article in (1987,Léger+,223), where there are many other important papers about these molecules. The properties of PAHs, such as their ionization and recombination cross-sections, response to photons, and the like have been also discussed by Omont (1986,AA,164,159). PAHs in space are likely to be ionized, either negatively in low radiation fields or positively near stars (as in reflection nebulae). There are problems with understanding the UIBs completely on the basis of PAHs. Duley+(1986,MN,219,859) have shown that chemical reactions in the interstellar medium might destroy PAHs rapidly. Donn+(1987,BAAS,18,1030) have objected to the idea on the basis of a lack of agreement between the emission of the UIBs and PAHs obtained in the laboratory, and the likely production of fluorescence from a molecule in a high energy state. Such fluorescence is not seen in the spectrum of many reflection nebulae, nor in the diffuse galactic light of the night sky.

A highly ordered form of carbon which is produced when solid carbon is irradiated with a laser is a hollow molecule of sixty regularly spaced carbon atoms called "buckminsterfullerene" after the architect who designed houses with a similar structure (Kroto+, 1986,Nature,318,162). Zhang+(1986,J Phys Chem,90,525) discuss spherical forms of carbon. These forms are very stable against photodissociation. They may be the cause of the λ 2175 bump (Hoyle+,1986,Ap Sp Sci,122,181). There is another form of carbon which might well be responsible for some or most of the IR emission: hydrogenated "amorphous" carbon (HAC). Such material should be called "disordered", because there are domains of graphite-like structure within it, as well as tetrahedral bonds (diamond) and randomly placed carbons. There can well be H atoms both on the surface and within the interior since H is readily intercalated in such material. Laboratory studies of HACs (Borghesi+,1987,ApJ,314,422) show many, but not all, of the UIBs. Duley (1984,ApJ,287,694) measured the indices of refraction of amorphous carbon in the optical through the UV. His material contains tetrahedral (diamond) bonding which may affect the far-UV absorption properties. The optical properties of HACs and many other material are discussed in an excellent article by Tielens and Allamandola in (1987,Hollenbach+,p.397). Tiny (50 Å) diamonds are actually found in some meteorites (Lewis+,1987,Nature,326,160). Materials which produce the UIBs in the laboratory have been produced by discharges through methane gas (Sakata+,1984,ApJ Lett,287,L51). This material is probably some sort of disordered aromatic hydrocarbon.

The "Red Rectangle" (HD 44179) shows that the red/IR emission can be quite strong in some cases. It is a dense nebula surrounding HD 44179 (AO III). d'Hendecourt+(1986,AA,170,91) showed that its broad emission bands can be accounted for by PAHs even if they are isolated molecules. They require about 10% of cosmic C in PAHs. The PAHs in the Red Rectangle might be smaller and simpler than in the general ISM because the radiation field there is more benign (Cohen+,1986,ApJ,302, 737). Duley(1985,MN,215,259) showed that the emission from the Red Rectangle could also be caused by HACs. Wdowiak(1985,Nuth+,A41) suggested that PAHs condensed onto solid grains would produce broadband emission.

The properties of Ultraviolet (UV) Extinction have been reviewed by Friedemann+ (1986,Ap.Sp.Sci.128,71) and by Mathis (1987,Kondo+ book,517). It has become increasingly clear that the UV extinction (from $\lambda = 0.3$ μm to 0.12 μm) can be separated into three components:(a) a smooth (assumed linear) background increasing with λ^{-1}, (b) the λ2175 "bump", and (c) the "far-UV rise", which is a rapidly increasing extinction for $\lambda < 0.16$ μm. Witt+(1984,ApJ.279,698), Carnochan (1986,MN,219,903) and Nicolet (1987,AA,177,233) have determined the variations of UV extinction in many objects. Massa+(1986,ApJ.Suppl,60,305) and Fitzpatrick+(1986,ApJ,307,286) have done careful analyses of the extinction laws of five clusters and of the best-determined early-type stars. They find that the width of the bump varies significantly (up to a factor of two) from region to region, with dust in dense clouds having a wider bump than in the diffuse interstellar medium. A very interesting result is that the central wavelength of the bump, λ_0, is very constant within the sample of stars they studied: a maximum variation from the mean of only 17 Å, and a mean variation of 9 Å. However, the variations among lines of sight from one cluster to another show that the variation in λ_0 are real.

By comparison of the spectrum of the central star in a reflection nebula with that of the nebula, Witt+(1986,ApJ.Lett,305,L23) conclude that there is a scattering feature on the long-wavelength side of the bump. Most theories regarding the origin of the bump attribute it to very small particles which do not scatter efficiently. There is an anticorrelation between the 60/100 μm ratio in diffuse clouds and the strength of the bump (Leene+: 1987,AA,174,L1). The origin of the bump is still controversial. Small graphite particles are probably the most favored explanation for it (Hecht: 1986,ApJ,305,817; 1987,ApJ,314,429, and other authors). It can possibly be fitted by oxides and glassy carbon (Duley+: 1983,Ap.Sp.Sci,95,187). It might also be absorption of OH^- ions in tiny silicates (Steel+: 1987,ApJ,315,337) or be of biological origin (Hoover+: 1986,Earth, Moon and Planets,35,19).

The "Far-UV Rise": There is a steep rise in extinction with λ^{-1} below $\lambda = 0.16$ μm which seems uncorrelated with optical properties of the extinction (Greenberg+: 1983,ApJ.272,563;Franco+: 1985,AA,147,191). The shape of the extinction is similar from one line of sight to another, so there is probably a single grain component responsible for this extinction. The spectra of reflection nebulae (Sellgren+: 1985, ApJ,299,416) strongly suggest that this material is not small silicate particles (Désert+: 1986,AA,159,328) because there is a deficiency of emission at the 9.7 μm band of silicates, while the emission is caused by the absorption of energetic photons by small grains or large molecules. Clayton+(1986,AJ,93,157) find that there is a very strong far-UV rise in stars in the cluster Trumpler 37.

Distribution of dust: The locations of clouds and local regions of excess extinction have been studied by several workers. Knude published uvbyβ photometry of stars in Selected Area 132 (1986,AA Suppl,63,313). Urasin+(1987,Astr.Nach,308,5) determined the distribution of dust in the interval 7°-222° and obtained a model of a two-arm spiral structure. Uranova determined the distribution of dust in the local spiral arm in Cygnus (1985,Pis'ma AZh,11,251). Star counts from various regions are used to determine the distribution of dust (Feitzinger+: 1984,AA Suppl,58,365; 1986,ApJ,305,534).Bochkarev (1984,Pis'ma AZh,10,184;Sov.Astr.Lett,10) discusses the formation of arclike dust structures from the action of stellar winds and supernovae on the ISM. The distribution of absorption in the Rosette Nebula and others was determined by Guseva+(1984,Pis'ma AZh,10,741; 1985,Astrofiz,22,505), in the W3 complex by Kolesnik (1986,AA,169,268), and in NGC 2516 by Clocchiatti+(1986,AJ,92,1130).

The dust along the line of sight to the galactic center is similar to that in the usual diffuse interstellar medium rather than that in molecular clouds (Roche+: 1985,MN,215,425). Butchart+(1986,AA,154,L5) have determined an excellent profile of the 3.4 μm absorption band of IRS 7 near the Galactic Center. The band is important because it is caused by the C-H stretch of materials and coatings on grains. The 1.3 mm emission of dust near the galactic center has been determined by Mezger+ (1986,AA,160,324).

Extinction at optical wavelengths is modulated by a Very Broad Band structure (Krelowski+: 1986,AA,166,271) which has been reported in the past. For wavelengths of a few micrometers, extinction is closely proportional to λ^{-1} (Rieke+: 1985,ApJ. 288,618). Extinction has been studied from the spectroscopy of molecular H by Davis+ (1986,ApJ.304,481) with similar results.

Theories of dust: Many current ideas have some form of amorphous carbon (e.g., Rowanta-Robinson,1986,MN,219,737) in a bare silicate-carbon mixture, or hydrogenated amorphous carbon (Hecht,1986,ApJ,305,817;1987,ApJ,314,429). The λ 2175 bump is contributed by graphite on these theories. There is also the strong possibility that PAHs are present. The biological origin of grains has been advocated (Jabir+, 1986,ApSpSci,123,351) but criticized by Duley (1984,QJRAS,25,109,1984).

Extensive calculations concerning the extinction and polarization properties of dust were reported by the Leningrad group (Voshchinnikov+,1986,Astrofizika,24, 307 and 523; 25,197). The spectral properties of silicates in the infrared were modelled by Pavlova (1984,Trudy Ap Inst Alma-Ata,44,20,1984).

Far-infrared (FIR) radiation is primarily a diagnostic of the energy sources of the dust, but it can be interpreted by various grain models because the optical properties of the grains do play a role in the spectrum of the emerging radiation. Unfortunately, the size distribution of the particles also enters. The "standard" means of interpreting FIR observations, and the quantities which can be derived from them, has been explained very clearly by Hildebrand(1983,QJRAS,24,267). The determination of the temperature distribution of a mixture of particles has been given by Pajot+(1986,AA,157,393).

Observations of the far-infrared/sub-mm radiation from the Galaxy have been reported by Hauser+(1984,ApJ Lett,278,L15; 150,250,and 300 μm), Pajot+(1986,AA,154, 55), and de Bernardis+(1984,ApJ,278,150; 150-400 and 350-3000 μm). The FIR observations were combined with previous measurements of the radiation field from 2 μm through 3 mm to construct models of the heating and cooling of the dust in the Galaxy (Cox+,1986,AA,155,380). The FIR continuum in several other galaxies has been measured (Thronson+,1987,ApJ,318,645). Helou (1986,ApJ,311,L33) has discussed the IRAS colors for normal galaxies. The IRAS measurements have been discussed, in connection with other FIR data, by Persson+(1987,ApJ,314,513). Unfortunately, 100 μm is somewhat too short a wavelength to detect most of the luminosity from most galaxies.

The time-dependent chemistry of dense clouds as regards expulsion of icy mantles from dust grains has been discussed by d'Hendecourt+(1986,AA,158,119), Grim+ (1986,AA,167,161), and Greenberg (1984,Origins of Life,14,25; 1983,Wolstencroft+, 1). This process might be in competition with the "standard" gas-phase chemistry picture of interstellar chemistry. The sticking probability of gas atoms sticking to grains was calculated by Leitch-Devlin+(1985,MN,213,295), and the changes of the grain surface caused by accretion and the growth of mantles by grains in dark clouds, have been discussed by Jones+(1985,MN,217,413,1985).

The formation of grains in circumstellar shells has been reviewed by Jura(1985, Nuth+,3) and Draine (ibid.,19). It is safe to say that condensation theory is one of the poorest-understood aspects of the interstellar medium. The condensation and grain growth in circumstellar shells was discussed by Pearce (1986,AA,157,335);Gail+ (1986,AA,166,225; 1987,AA,171,197;177,186), and Muchmore+(1987,ApJ Lett,315,L141). The radiation pressure on the grains can be the dominant force in the stellar wind, and the available material puts a limit for the rate of mass loss from the late-type stars. Nucleation has been studied in the laboratory by Nuth+(1986,J Chem Phys, 85,1116), and theories do not fit the results well. The far-infrared energy distribution of both C-rich and O-rich stars (Sopka+,1985,ApJ,294,242) indicates a rather slow decrease in the absorption at very long wavelengths, which is characteristic of an amorphous rather than a crystalline material. The destruction of dust, mainly by shocks arising from supernovae arising within the galaxy, has been modelled by McKee+(1987,ApJ,318,674). The theoretical lifetime for grains is disturbingly low (< 1 Gyr).

The Diffuse Interstellar bands (DIBs) are very likely caused by some material coated onto dust grains. They seem to fall in three groups, within which the correlation of strengths is quite good (Chlewicki+: 1986,ApJ,305,455; 1987,AA,173, 131; Krelowki+: 1987,ApJ,312,860). The groups are distinguished by the breadth of the feature. Nos diffuse interstellar bands have been discovered in the ultraviolet portion of the spectrum, although careful searches have been made. The correlation of the DIB at 4430 Å with polarization and UV extinction was studied by Krelowski+ (1987,ApJ,316,449). Shapiro+ (1986,ApJ,310,872) consider theoretical profiles of DIBs associated with resonant impurities in grains. Measurements of three of the DIBs for stars with low reddening (Federman+: 1984,ApJ,282,485) show a correlation with the column density of molecular hydrogen. PAHs may account for the DIBs (Léger +: 1985,AA,146,81; van der Zwet+: 1985,AA,146,76; Crawford+: 1985,ApJ.Lett.293,L45).

Depletions of gas-phase elements have been discussed in Part II of this commission 34 report. For our purpose, one should note that carbon has poorly-determined depletions (Welty+: 1986,PASP,98,857) and that depletions increase in general with the mean gas density along the line of sight.

The UV extinction in the LMC (see Nandy,IAU Symp.108,341) was studied by Clayton+(1985,ApJ,288,558) and Fitzpatrick (1986,AJ,92,1068). The extinction is especially different from Galactic in the 30 Doradus region, where the 2175 Å "bump" is weak and the FUV rise is very strong. In other parts of the LMC, though, the extinction is fairly similar to Galactic. The gas-to-dust ratio is about four times larger than in the Galaxy (Koornneef, IAU Symp.108,333), which is consistent with the O/H ratio in the LMC relative to the Galaxy. In the SMC, Bouchet+(1985,AA,149, 330) find a normal visible-IR extinction curve although the far-UV is very different from galactic, and a gas-to-dust ratio about 8 times larger than in the Galaxy.

Polarization of the light from the Pleiades was studied by Breger (1986,ApJ, 309,311) and in three stars by Clarke (1986,AA,156,213). A very interesting observation is the polarization of emitted thermal radiation from two positions deep within the Orion molecular cloud (Hildebrand+: 1984,ApJ.Lett.284,L51; Dragovan: 1986,ApJ.308,270). This observation shows that grains are aligned even in very dense regions of space, where there should be thermal equilibrium between the grains and gas. Mathis (1986,ApJ.308,281) explained the wavelength dependence of polarization by assuming that there are superparamagnetic inclusions within grains, and only those grains which have one or more inclusions are aligned. Polarization by scattering has been modelled by Matsumura+(1986,Ap.Sc.Sci.126,155). Lee+(1985,ApJ. 290,211) used the polarization of the 0.7 µm feature in the BN object can lead to estimates of the band strength of the feature and the shape of the grains. They suggest that the grains are oblate.

Polarization in the dark lane in Cen A shows a perfectly normal wavelength dependence (Hough+: 1987,MN,227,1P) but peaks at 0.43 µm, which is considerably smaller than the average (0.55 µm) for our Galaxy. This may mean the grains are smaller; it could also be affected by alignment mechanisms.

V. Star Formation

(Bruce G. Elmegreen)

Research on star formation published between July 1984 and June 1987 is summarized here. The topics considered are: the clumpy structure of molecular clouds, magnetic fields, the collapse and stability of clouds, Herbig-Haro objects and jets, pre-main-sequence stellar winds, pre-main-sequence circumstellar disks, the initial mass function and efficiency of star formation, scenarios for star formation, and general properties of particular regions of star formation. Because of a lack of space, there are no references to extragalactic star formation, starburst galaxies, and models of the early solar system. There is also no discussion of the general literature on T Tauri stars and molecular clouds, unless a direct reference to implications for star formation is made by the authors. Presumably these neglected topics will be covered elsewhere in these IAU Reports (see Reports of Commissions 28,29,33,36,37,40 and the subsections on interstellar molecules in Commission 34).

Conference proceedings that include discussions of star formation are apart from those cited at the beginning of the report: "Workshop on Star Formation"(1984) ed. Wolstencroft (Occas.Rep.Royal Obs. Edinb.);"Frontiers of Astronomy and Astrophysics" (1984) ed. Pallavicini (Soc.Astron.Ital.); "Second Asian-Pacific Regional Meeting on Astronomy" (1984)ed. Hidayat+ (Pustaka); "Theoretical Aspects on Structure,Activity and Evolution of Galaxies III" (1985)ed. Aoki+ (Tokyo Astron.Obs.); "Tercera Reunion Regional Latinoamericana de Astronomia" (1985)ed. Sahade+ (Rev. Mex.Astron.Ap.10); "Third Asian-Pacific Regional Meeting of the IAU" ed. Kitamura+ (Ap.Sp.Sci.118,119); "Luminous Stars and Associations in Galaxies" (1986)ed. de Loore+ (Reidel). Individual contributions to conferences are not referenced here.

Reviews of T Tauri stars were written by Imhoff (1984,NASA Publ CP-2349,81) and Herbst (1986:PASP,98,1088). L1551 was reviewed by Emerson (1985:Nature,318, 604). Welch+ (1985:Science,228,1389) reviewed pre-main-sequence jets and Pudritz (1986:PASP,98,709) reviewed pre-main-sequence disks. Stahler (1986:PASP,98,1081) reviewed primordial star formation. Other reviews of star formation, aside from those in conference proceedings, were published by Turner (1984:Vistas Astron.27, 303) and York (1985:Mitt,Astron,Ges,63,89).

1. CLUMPY STRUCTURE IN MOLECULAR CLOUDS

Clumps with masses between 1 and 1000 solar masses and sizes on the order of 0.01 to 0.1 pc have been observed with NH_3, H_2CO or CS in molecular clouds associated with Cas A (Batrla+: 1984,AA,136,127), NGC 7538 (Henkel+: 1984,ApJ,282,L93), ρOph (Zeng+: 1984,AA,141,127; Wadiak+: 1985,ApJ,295,L43), W3(OH) (Turner+:1984,ApJ, 287,L81), W51A (Arnal+: 1985,AA,145,369), ON1 (Zheng+: 1985,ApJ,293,522),the Orion ridge (Mundy+: 1986,ApJ,304,L51), W49A (Goss+: 1985,MN,215,197), CepA (Torrelles+: 1986,ApJ,305,721), M17 (Snell+: 1986,ApJ,304,780), M17, S140 and NGC 2024 (Mundy+: 1986,ApJ,306,670), G34.3+0.2 (Andersson+: 1986,AA,167,L1), DR21 (Dickel+: 1986,AA, 162,221; Richardson+: 1986,MNRAS,219,167), NGC 7129 and GGD12-15 (Güsten+:1986,AA, 164,342), in Perseus globules (Bachiller+: 1986,AA,168,262), IC 348 (Bachiller+: 1987,AA,173,324) and in several other clouds (Mauersberger+: 1986,AA,162,199). Ammonia clumps have also been seen in the envelope of W3(OH)(Reid,Myers and Bieging 1987,ApJ,312,830). Hot OH clumps were observed by Walmsley+ (1986,AA,167,151).

Clumps have been observed with CO in several clouds by Pérault+ (1985,AA,152, 371; 1986,AA,157,139),in Orion by Bally+ (1987,ApJ,312,L45),and in IRAS star forming regions by Casoli+ (1986,AA,169,281). Jaffe+ (1987,ApJ,316,231) found dense cores with the 7-6 transition of CO. A CO interclump medium in the Rosette cloud was discussed by Blitz and Stark (1986,ApJ,300,L89).

Clumps have also been observed at FIR or sub-mm wavelengths in S255, W3 and OMC1 (Jaffe+: 1984,ApJ,284,637), W51 and DR21 (Harvey+: 1986,ApJ,300,737), and W3, M42, W49A and W51A (Gordon: 1987,ApJ,316,258).

Absorption of background starlight reveals small cloud clumps too, as shown by Rossano (1985,AJ.90,308), Cernicharo+ (1985,AA,149,273) and Casali (1986,MNRAS, 223,341).

Research on the physical structure and dynamics of clumps and cloud turbulence was done by Falgarone and Puget (1985,AA,142,157; 1986,AA,162,235), Stenholm (1985,AA,144,179), Kessel'man+ (1985,SovAstron,29,417), Yoo+ (1986,J.Korean Astr. Soc,19,33), Kleiner+ (1984,ApJ,286,255; 1985,ApJ,295,466; 1987,ApJ,312,837) and Dickman+ (1985,ApJ,295,479). Spectra of clumpy clouds were calculated by Kwan+: (1986,ApJ,309,783)and the energy dissipation rate in clumpy clouds was evaluated by Elmegreen (1985,ApJ,299,196).

Several formation mechanisms for clumps were considered: self-gravitational cloud fragmentation (Larson,1985,MNRAS,214,379;Tohline,1985,ApJ,292,181;Schloerb and Snell,1984,ApJ,283,129), stellar winds (Silk,1985,ApJ,292,L71), fragmentation in an ionization-front shock (Rainey+,1987,AA,171,252) or supernova shock (White+,1987, AA,173,337), and thermal instabilities (Gilden,1984,ApJ,283,679;Grazini+,1987,Ap Lett,25,235).

Clump or globule compression by surrounding ionization was discussed by Ho+ (1986,ApJ,305,714) and King (1987,MNRAS,226,473).

2. MAGNETIC FIELD OBSERVATIONS

Magnetic field strengths in cloud clumps were measured from HI (Schwarz+,1986, ApJ,301,320) and OH lines (Heiles+,1986,ApJ,301,331) on the line of sight to CasA. The magnetic field was found to be perpendicular to the Taurus filaments, suggesting a compression of gas along the mean field direction (Moneti+,1984,ApJ,282,508; Tamura+,1987,MNRAS,224,413). The same orientation occurs in L204 (McCutcheon+,1986, ApJ,309,619). The field is parallel to filaments in Cygnus (McDavid,1984,ApJ,284, 141) and in Can Maj OB1 (Vrba+,1987,ApJ,317,207). In the Horsehead nebula, the field is parallel to the surrounding fields, suggesting that the grains may not be aligned in dense regions (Zaritsky+,1987,AJ,93,1514). The field orientation in B5 was studied by Joshi+,(1985,MNRAS,215,275). A summary of observed field strengths is in Troland+(1986,ApJ,301,339).

3. COLLAPSE AND STABILITY

Infall or collapse onto a protostar was observed by Gee+(1985,MNRAS,215,15p), Garay+(1985,ApJ,289,681), Zinchenko+(1985,AZ,62,860), Walker+(1986,ApJ,309,L47), and Menten+(1987,AA,177,L57). This interpretation of the observations for W3 (OH) was questioned by Welch+(1987,ApJ,317,L21). Collapse was inferred for the globule B5 by Boss(1985,ApJ,288,L25).

The globule B335 was said to be in rotational equilibrium by Frerking+(1985, Icarus,61,22), but most globules are not rotating fast enough for such support (Casali+,1987,MNRAS,225,481). The density gradient in molecular clouds was determined to be inverse square by Fulkerson+(1984,ApJ,287,723).

Theoretical work on cloud stability criteria was done by Kiguchi+(1987,ApJ,317, 830), and Schmitz(1986,AA,169,171). Stability in the presence of turbulence was discussed by Bonazzola+(1987,AA,172,293). The stability of magnetic disks was discussed by Mestel+(1985,MNRAS,212,275). The equilibrium structure of a magnetic cloud around a new star, and the tendency for this structure to help collimate a bipolar flow, was discussed by Nagasawa+(1985,PASJ,37,369).

Hachisu+(1984,AA,140,259) determined a criterion for fragmentation of a rotating collapsing cloud. Monaghan+(1984,PAS Australia,5,493) and Boss (1986,ApJ Suppl, 62,519) studied fragmentation in collapse models and Phillips (1986,PAS Australia, 6,205) discussed fragmentation in colliding magnetic clouds. Vanajakshi+(1985,ApJ, 294,502) considered collapse with turbulent viscosity. Liu (1984,Chin AA,8,310) simulated ring formation and fragmentation. Boss (1987,ApJ,316,721) calculated the collapse of a rotating cloud further than had been done before and got a disk and an evacuated polar cavity into which a wind might be channeled.

Analytical calculations of cloud collapse were made by Terebey+(1984,ApJ,286, 529), Whitworth+(1985,MNRAS,214,1) and Hunter (1986,MNRAS,223,391).

Analytical studies of the emergent radiation from collapsing clouds or protostars were made by Adams+(1985,ApJ,296,655;1986,ApJ,308,836), Kolesnik (1985,AZ,62, 518), Wolfire (1987,ApJ,315,315), Adams+(1987,ApJ,312,788) and Crawford+ (1986,MNRAS, 221,923). Beall (1987,ApJ,316,227) calculated the appearance of a protostellar disk.

Mestel+ (1984,AA,136,98) calculated some general properties of magnetic cloud collapse. Three-dimensional magnetic collapse models were made by Benz (1984,AA,139, 378) and Phillips (1986,MNRAS,221,571; 1986,MNRAS,222,111). Collapse with ambipolar diffusion was studied by Mouschovias+(1985,ApJ,291,772) and Nakano (1986,MNRAS,218, 663; 1986,MNRAS,221,319), and the effect of diffusion on angular momentum transport was discussed by Mouschovias+(1986,ApJ,308,781). Angular momentum transport between clumps in a cloud was studied by Mouschovias+(1985,ApJ,298,190-205). Angular momentum transport by gravitational torques in a disk was calculated by Boss (1984,MNRAS, 209,543).

4. HERBIG-HARO OBJECTS

Several new HH objects were found by Magakyan (1984, Pis'ma AZ,10,661), Reipurth (1985,AA,Suppl,61,319) and Krautter (1986,AA,161,195).

Proper motions of HH objects show expansion away from a central source (Gyul'budagyan,1984,Astrof,20,115;Jones+,1984,AJ,89,1404;Schwartz+,1984,AJ,89,1735, and Jones+,1985,AJ,90,1320). Time variability was noted by Walsh (1986,Ap Sp Sci, 118,439) and Reipurth+(1986,Nature,320,336).

The exciting sources for some HH objects were determined to be T Tauri stars, some of which show radio emission and extended infrared emission (Bieging,Cohen+, 1984,ApJ,282,699;Reipurth+,1985,AA,150,307;Rodriguez+,MNRAS,214,9P;Pravdo+,1985, ApJ,293,L35;Vrba+,1985,AJ,90,2074;Cohen+,1986,ApJ,302,L55,1986,ApJ,307,L21; Cohen+, 1987,ApJ,316,311; Bührke+,1986,AA,163,83;Goodrich,1986,AJ,92,885; Tapia+,1987,MNRAS, 224,587; Böhm+,1987,PASP,99,265). A study of bare T Tauri stars and a discussion of the implications for star formation were made by Walter (1987,PASP,99,31).

The possibility that FU ORI type stars could power the associated outflow was discussed by Reipurth (1985,AA,143,435), Graham+(1985,ApJ,289,331), Silvestro+(1984, ESA.Pub.SP-207 p.235), Mundt+(1985,ApJ,297,L41), Hartmann+(1985,ApJ,299,462) and Goodrich(1987,PASP,99,116). Periodic ejections were discussed by Meaburn+(1985, MNRAS,215,761).

Excited emission from molecular hydrogen was found or mapped around HH objects by Zealey+(1984,AA,140,L31), Zealey+(1986,AA,158,L9), Harvey+(1986,ApJ,301,346) and Lightfoot+(1986,MNRAS,221,993).

Other properties of HH objects determined from emission lines, such as velocities, densities, time-variability and shock structure, were discussed by Lenzen, Hodapp and Solf (1984,AA,137,202), Meaburn+(1984,AA,138,36), Pettersson (1984,AA, 139,135), Brugel+(1985,ApJ,292,L75), Brugel+(1984,NASA.Publ.CO-2349,p.171),Cohen+ (1985,ApJ,296,620), Schwartz+(1985,AJ,90,1820),Hartigan+(1986,AJ,91,1357), Meaburn (1986,AA,164,358),Böhm+(1985,ApJ,294,533), Solf+(1986,ApJ,305,795), Taylor+(1986, MNRAS,221,155), Lighfoot+(1986,MNRAS,221,47p), Raga+(1986,AJ,92,119), Böhm+(1987, ApJ,316,349), Hartigan+(1986,AJ,92,1155), Meaburn+(1987,MNRAS,225,863) and Solf+ (1987,AJ,93,1172). Low excitation emission around embedded stars was mapped by Morgan+(1984,ApJ,285,L71) and Brα emission was surveyed by Persson+(1984,ApJ,286, 289).

These observations imply that many HH objects are bow shocks. Some form around bullets or jets emitted by the exciting stars, others form around stationary or slowly moving clumps that are exposed to winds from the exciting stars.

Deep photographic surveys of the regions around HH objects show jets, knots and loops (Walsh+,1985,MNRAS,217,31; Hartigan+,1985,ApJ Supp,59,383; Bohigas+,1985 Rev Mex AA,11,149; Strom+,1986,ApJ Suppl,62; see also section below on jets). An

IRAS survey of the region around HH 1 and 2 found several faint embedded stars (Pravdo+: 1987,ApJ,314,308). Cardelli+ (1984,NASA.Publ.CO-2349,p.175) studied the dust near HH objects. NH_3 observations of HH 46 and 47 show a disk at the IR source which is too low in mass to confine the outflow (Kuiper+: 1987,PASP,99,107). NH_3 observations of HH 1 and 2 show dense clumps close to the exciting star, and they show the compressed wall of the cavity associated with the high velocity flow (Martin+: 1987,AA,176,L27). High resolution CO observations of Orion, NGC 2071, GL490 and S140 also show a shell at the edge of the wind cavity (Snell+: 1984,ApJ, 284,176).

Theoretical aspects of shock models for HH objects were discussed by several of the above authors, in addition to Hartigan+:(1987,ApJ,316,323), Tenorio-Tagle+ (1984,AA,137,276; 1984,AA,141,351), Choe+ (1985,ApJ,288,338), Liseau+ (1986,ApJ, 304,459) and Raga (1986,AJ,92,637). The possibility that some HH objects are shocks around old jets was discussed by Lightfoot+ (1986,MNRAS,221,993; 1986,MNRAS,221, 47p).

5. JETS

Optical jets are occasionally observed near embedded windy pre-main-sequence stars. In addition to the jets associated with HH objects discussed above, new jets were discovered in HH 6-5B, HH 33/40 and HH 19 (Mundt+: 1984,AA,140,17),R Mon (Brugel+:1984,ApJ,287,L73), Orion B (Sanders+:1985,ApJ,293,L39), DG Tau (Jones+: 1986,ApJ,311,L23), HH34 (Reipurth+:1986,AA,164,51) and GGD34, RN043, HH3,5 (Ray: 1987,AA,171,145). The jet in RN043 extends for 1.4pc, which the longest found so far. The jet in DG Tau was observed to turn on (Cohen+:1986,AJ,92,1396). A jet near Orion IRC9 was suggested by the observation of fingers of excited H_2 emission (Taylor+:1984,Nature,311,236). The jet in L1551 IRS5 is occulted on one side by a circumstellar disk (Snell+:1985,ApJ,290,587). Another jet in V645 Cyg was studied by Goodrich (1986,ApJ,311,882), and a spectrum of the jet in L1551 was studied by Sarcander+:(1985,ApJ,288,L51).

The theory of pre-main-sequence jets was discussed by Fukue+(1986,Nature,321, 841), who considered precession, Shibata+(1986,ApSpSci,118,443; 1986,PASJ 38,631), who modeled the acceleration of disk gas by a twisting polar magnetic field, Kaburaki+ (1987,AA,172,191), who consider jet alignment by a toroidal magnetic field in an accretion disk, and Sakashita+ (1986,PASJ,38,879), who model jet formation by the interaction between a spherical wind and a plane parallel gas layer. Fujue+ (1986,PASJ,38,895) studied the effect of gravity from a stellar torus on the jet flow, and the shock structure inside a jet was studied by Falle+ (1987,MNRAS, 225,741), A model of wind acceleration from a massive disk was made by Pudritz (1985,ApJ.293,216).

6. PRE-MAIN-SEQUENCE STELLAR WINDS AND BIPOLAR FLOWS

One of the most active fields in star formation research today is pre-main-sequence winds and bipolar flows near embedded stars. Molecular outflows were studied for the following sources: AFGL 2591 (Lada+:1984,ApJ.286,302), G327.3-0.6 (Brand+:1984,AA,139,181), B335, L723 and L1455 (Goldsmith+:1984,ApJ.286,599), NGC 6334 IRS V-1 (Simon+:1985,MNRAS 212,21), L379 (Hilton+:1986,AA,154,274), an IRAS source in Orion (Wolstencroft+:1986,MNRAS 218,1), and a high resolution study of Orion (Wilson+:1986,AA,167,L17), DR21 (Richardson+:1876,MNRAS 219,167), 3 IRAS sources in B5 (Goldsmith+:1986,ApJ,303,L11), IRAS 1827-145 (La Bertre,Epchtein+: 1984,AA,138,353), B335 (Langer+:1986,ApJ,306,L29), Ori A, L1641, NGC 2071 and the Oph dark cloud (Fukui+:1986,ApJ,311,L85), and another study of NGC 2071 (Takano+: 1986,AA,167,333), Mon OB1 (Margulis+:1986,ApJ,309,L87), 9 globules (Avery+:1987, ApJ,312,848), NGC 7023 (Watt+:1986,AA,163,194), the Boomerang nebula and PV Ceph (Neckel+:1987,AA,175,231), V645 Cyg (Torrelles+:1987,AA,177,171), R Cr Aus(Hartigan +:1987,AJ,93,913), and S235B (Nakano+:1986,PASJ,38,531). High velocity OH absorption was found in L1551 (Mirabel+:1985,ApJ,294,L39). The energies and masses of outflow sources were discussed by Margulis+:(1985,ApJ,299,925).

High density gas or clumps were observed in the outflows associated with Ori A (Masson+:1984,ApJ,283,L37), Ori B (Russell+:1987,MNRAS,226,237), Cep A (Loren+: 1984,ApJ,287,707; Richardson+:1987,AA,174,197), L1551 (Walmsley+:1987,AA,179,231), NGC 2071 (Takano:1986,ApJ,300,L85), NGC 2071, NGC 7538 and W49 (Scoville+: 1986, ApJ,303,416), M16 and the Rosette nebula (Meaburn+:1986,MNRAS,220,745), NGC 7538 (Kameya+:1986,PASJ,38,793), and in several other sources (Thronson+:1984,ApJ,284, 135; Richardson+:1985,ApJ,290,637). The possibility of a wind near the Horsehead nebula in Orion was discussed by Reipurth+ (1984,AA,137,L1), Warren-Smith+ (1985, MNRAS,215,75), and Neckel+ (1985,AA,147,L1).

Shells surrounding outflows were observed in L1551 (Snell+:1985,ApJ,295,490; Rainey+:1987,AA,179,237), and Taurus (Murphy+:1985,ApJ,298,818), and the shocked cloud/wind interface was seen in M8E (Larson+: 1986,ApJ,307,295). Images of cones or bubbles around wind sources were obtained by Campbell+ (1986,ApJ,305,336) and Forrest+ (1986,ApJ,311,L81). The M8 hourglass region was imaged in the infrared by Allen(1986,MNRAS,219,35).

Winds were observed very close to the stars in W3 IRS5 (Claussen+:1984,ApJ. 285,L79), GL2591 (Geballe+:1985,ApJ.291,L55) and NGC 2071, W49 and NGC 7538 (Scoville+:1986,ApJ.303,416).

Radio continuum radiation from the central stars was observed by Schwartz+: (1985,ApJ,295,89) and Snell+:(1986,ApJ,303,683). The mass loss rates found in this latter study are too low to explain the observed molecular flows. Other observations of ionized winds from embedded stars were by Tanaka+(1985,PASP,97,1112), Schwartz+ (1986,ApJ,303,233), Chalabaev+ (1986,AA,168,L7), and Smith+ (1987,ApJ, 316,265). Other observations of ionized structures in wind regions were made by White+ (1986,AA,156,301). Winds near Herbig Ae-Be stars were discussed by Canto+ (1984,ApJ,282,631) and Scarrott+ (1986,MNRAS,223,505).

Excited molecular hydrogen emission was observed in the vicinity of outflow sources by Phillips+ (1985,AA,145,118), Matsumoto+ (1985,PASJapan,37,129), Garden+ (1986,MNRAS,220,203), Lane+ (1986,ApJ,310,820), Oliva+ (1986,AA,164,104), Geballe+ (1986,ApJ,302,693), and Longmore+ (1986,MNRAS,221,589).

Confinement of deflection of the flow by cloud clumps was discussed by Fridlund+ (1984,AA,137,L17), Weliachew+ (1985,AA,153,139), Wootten+ (1987,ApJ,317, 220), and Torelles+ (1985,ApJ,288,595).

Flow orientations are often found to be close to that of the surrounding magnetic field, or to that of another flow source (Cohen+:1984,MNRAS,210,425; Vrba+: 1986,AJ,92,633; Langer+:1986,ApJ,306,L29). Magnetic field strengths in flow regions were estimated by Simonetti+ (1986,ApJ,303,659).

Optical and infrared polarization studies of winds often show the locations of the exciting stars, and sometimes suggest that the line of sight from the star to the wind is obscured less than the line of sight from the star to the observer, as if an obscuring disk surrounds the star (Beckwith+:1984,ApJ,287,793; Draper+: 1985,MNRAS,216,7; Hodapp:1984,AA,141,255; Cohen+:1985,ApJ,296,620; King+:1985,MN RAS,213,11; Castelaz+:1986,ApJ.300,406; McLean+:1987,MNRAS,225,393; Harvey+:1987, ApJ,317,173, and Lenzen:1987,AA,173,124). A polarization map of excited H_2 emission in Orion was made by Hough+ (1986,MNRAS,222,629).

The dust around wind sources may be heated by uv radiation from the shock (Clark+:1986,AA,168,L1), and it may be located at the wind-cloud interface (Clark+: 1986,AA,154,L26). The dust and gas is also heated by the embedded stars (Takano:

1986,ApJ,303,349). The energy of the flow in L1551 was determined by Edwards+(1986, ApJ,307,L65). Without a large amount of light scattering, radiation pressure is too small to drive the winds (Mozurkewich+,1986,ApJ,311,371).

Theoretical discussions on the observable properties of winds were made by Dyson (1984,ApSpSci, 106,181), Bastien (1987,ApJ,317,231), Okuda+(1986,PASJ,38,199), and Cabrit+(1986,ApJ,307,313). Polarization models for scattered light were made by Heckert+(1985,AJ,90,2291). An energy conserving wind model was made by Kwok+(1985, ApJ,299,191).

7. PRE-MAIN-SEQUENCE DISKS

Disks or elongated structures have been observed in the vicinity of embedded pre-main-sequence stars using emission from scattered light in HL Tau (Grasdalen+, 1984,ApJ,283,L57), from NH$_3$ in Cep A (Güsten+,1984,AA,138,205; Torrelles+,1986,ApJ, 305,721), although Menten+(1985,AA,146,375) found no NH$_3$ disk in L1551,from CS in NGC 2071 (Takano+,1984,ApJ,282,L69), GL 490(Kawabe+,1984,ApJ,282,L73), the Orion KL region (Hasegawa+,1984,ApJ,283,117), and in several other sources (Heyer+,1986, ApJ,308,134), although Moriarty-Schieven+(1987,ApJ,317,L95) found no CS disk in L1551, from HCN in S106 (Bieging,1984,ApJ,286,591), from H$_2$CO in L1551 (Duncan+,1987, MNRAS,224,721), from CO in IRAS 16293-2422 (Mundy Wilking+,1986,ApJ,311,L75), from IR polarization in several sources (Sato+,1985,ApJ,291,708), and from the near and far-infrared and sub-mm wavelength range in L1551 (Strom+,1985,AJ,90,2575), GL 490 (Gear+,1986,MNRAS,219,835), M8E (Simon+,1985,ApJ,298,328), S106 (Harvey+,1987,ApJ, 316,L75), and a number of other sources (Cohen+,1985,ApJ,296,633). Orientations of the disks perpendicular to the magnetic field were noted in the above papers by Sato+ and Mundy+.

The orientations of disks or elongated structures perpendicular to bipolar outflows or jets have been discussed for the sources L1551 (Bieging+,1985,ApJ,289, L5; Rodriguez+,1986,ApJ,301,L25), although no velocity gradient similar to that expected from a disk was found in L1551 (Batrla+,ApJ,298,L19), for G34.3+0.1 (Heaton+ 1985,MNRAS,217,485),G35.2-0.74 (Matthews+,1984,AA,136,282; Dent+,1984,MNRAS,210, 173),G35.2N (Dent+,1985,AA,146,375), Orion (Vogel+,1984,ApJ,283,655), HH24-26 (Little+,1985,AA,142,378), GGD12-15 (Harvey+,1985,ApJ,288,725), R Mon(Aspin+,1985, AA,149,158), HH1,2 (Torrelles+,1985,ApJ,294,L117; Strom+,1985,AJ,90,2281), CRL 2591 (Takano+,1986,AA,158,14), NGC 7538 (Scoville+,1986,ApJ,303,416;Campbell,1984,ApJ, 282,L27), L723 (Torrelles+,1986,ApJ,307,787), MWC 349 (Hamann+,1986,ApJ,311,909; White+,1985,ApJ,297,677), R Cor Aust (Castelaz+,1987,ApJ,314,317), and HH46-47 (Kuiper+,1987,PASP,99,107).

8. THE INITIAL MASS FUNCTION AND STAR FORMATION EFFICIENCY

The initial mass function (IMF) was modelled by cloud fragmentation and coalescence by Yoshii+(1985,ApJ,295,521), who considered that the stars that already formed heat the remaining gas. A time dependence of the IMF was also discussed by Di Fazio (1986,AA,159,49) and Brown (1986,ApSpSci,122,287). The influence of hierarchical fragmentation was studied by Zinnecker (1984,MNRAS,210,43). Smith (1985,ApJ, 293,251) studied gas accretion and a possible turnover in the IMF at low mass.

De Gioia-Eastwood (1984,PASP,96,582) devised a method to determine the IMF in an embedded cluster. Cudlip+(1984,MNRAS,211,563) suggested that low mass stars in Ophiuchus formed quiescently and that a high mass star formed in an interacting region. Van Buren (1985,ApJ,294,567) suggested that the IMF is shallower than the Salpeter function after correcting for local dust on the line-of-sight to stars of various masses. Low-mass stars near the Trapezium cluster were observed by Herbig+ (1986,ApJ,307,609). A model of bimodal star formation was compared to observations of the solar neighborhood by Wyse+(1987,ApJ,313,L11). Wouterloot+(1986,AA,168,237) found that the luminosity function of IRAS sources agrees with the standard IMF.

Reid (1987,MNRAS,225,873) studied the IMF in low mass stars.

Rengarajan(1984,ApJ,287,671) determined that the star formation efficiency is constant in molecular clouds because the CO flux is proportional to the FIR flux. Myers+(1986,ApJ,301,398) also determined the efficiency of star formation by comparison of IR, radio continuum and CO fluxes. The efficiency in regions of cluster formation was discussed by Elmegreen+(1985,ApJ,294,523).

9. SCENARIOS FOR STAR FORMATION

Self-regulating models for star formation on various scales have been discussed by Franco(1984,AA,137, 85), Fujimoto+(1984,PASJ,36,319), Bodifée+(1985,AA,142, 297), Chiang+(1985,ApJ,297,507), Brosche+(1985,AA,153,157), Bodifée(1086,ApSpSci, 122,41), Korcgagin+(1986,Kinematika Fiz.Nebesn.Tel2,22), Pudritz+(1987,ApJ,316,213), and Nepveu(1987,AA,175,91).

Various theories of propagating star formation were discussed by Sandford+ (1984,ApJ,282,178), McCray+(1987,ApJ,317,190) and Kimura+(1987,ApSpSci,129,261). Applications to specific sources were made by Dopita+(1985,ApJ,297,599), Thronson+ (1985,ApJ,297,662), Ho+(1986,ApJ,305,714), Handa+(1986,PASJ,38,361), Arnal+(1987, AA,174,78), Felli+(1987,AA,175,193), Olano+(1987,AA,179,202), and Kun+(1987,ApSpSci, 134,211). A model of chemical evolution including propagation was made by Shore+ (1987,ApJ,316,663). Cameron (1984,Icarus,60,416) discussed extinct radioactivity and propagating star formation.

Star formation in globular clusters was modelled by Tenorio-Tagle+(1984,MNRAS, 221,635) and Smith+(1987,ApJ,316,206). Pre-main-sequence evolution of primordial stars was modelled by Stahler+(1986,ApJ,308,697).

Star formation by cloud-cloud collisions was discussed by Scoville+(1986,ApJ, 310,L77). Lattanzio+(1985,PAS Australia,5,495;1985,MNRAS,215,125) suggest that such collisions will only destroy the clouds. Star formation triggered by colliding gas flows or crashing turbulent eddies was discussed by Sabano+(1985,ApSpSci,115,85) and Hunter+(1986,ApJ,305,309). Observations of collisionally-triggered star formation were suggested by Haschick+(1985,ApJ,292,200).

10. OTHER STUDIES OF REGIONS OF STAR FORMATION

Large-scale maps and analyses of the distribution of molecules, dust, embedded stellar sources, etc., were made for the following sources: G35.2-0.74 (Tapia+,1985, MNRAS,213,833), G30.8-0.0 and G25.4-0.2 (Lester+,1985,ApJ,296,565), GL961 (Lenzen+, 1984,AA,137,365; Castelaz+,1985,AJ,90,1113), GL4176 and GL4182 (Persi+,1986,AA,157, 29),L1641 (Nakajima+,1986,MNRAS,221,483; Takaba+,1986,AA,166,276),L810(Neckel+,1985, AA,153,253; Turner,1986,AA,167,157), M8 (Woodward+,1986,AJ,91,870), M17 (Schulz+, 1987,AA,171,297), NGC 1333 (Jennings+,1987,MNRAS,226,461), NGC 2244(Guseva+,1984, Pis'ma AZ,10,741), NGC 2264 (Kalandadze+,1986,Kinematika Fiz Nebesn Tel,2,27),NGC 3603(Baier+,1985,AA,151,61), NGC 6334(Laughran+,1986,ApJ,303,629), NGC 6334, NGC 6193 and IC 4628(Phillips+,1986,AA Suppl,65,465), NGC 6357(Persi+,1986,AA,170,97), NGC 7129 (Draper+,1985,MNRAS,212,5p),NGC 7538(Lynds+,1986,ApJ,306,532), IC 443 (Odenwald+,1985,ApJ,292,460), Serpens MC 2(Churchwell+,1986,ApJ,300,729),Chamaeleon (Thé+,1986,AA,155,347; Jones+,1985,AJ,90,1191;Toriseva+,1985,AA,153,207; Whittet+, 1987,MNRAS,224,497), the Gum nebula (Graham,1986,ApJ,302,352; Pettersson,1987,AA, 171,101), Carina (Whiteoak+,1985,PAS Australia,5,552), a cloud in Monocerous (Maddalena+,1985,ApJ,294,231), the Cas OB2 region (Lozinskaya+,1986,ApSpSci,121, 357), Taurus (Duvert+,1986,AA,164,349), Lupus (Murphy+,1986,AA,167,234), Ophiuchus (Young+:1986,ApJ,304,L45; Loren+,1986,ApJ,306,142; André+,1987,AJ,93,1182), Draco (Johnson+;1986,ApJ,309,321), Orion (Thronson+,1986,AJ,91,1350; Lester+,1985,AJ,90, 2331; Garay Moran+,1987,ApJ,314,535; Plambeck+,1987,ApJ,317,L101; Geballe+,1987, ApJ,317,L107), OMC-1 (Masson+,1985,ApJ,295,L47), OMC-2 (Pendleton+,1986,ApJ,311,360) the KL nebula in Orion (Viscuso+:1985,ApJ,296,142), Ori B (Crutcher+:1986,ApJ,307, 302), ON1 (Matthews+:1986,AA,155,99), Orion and Cepheus (Wouterloot+:1986,AA,168, 237), the magellanic bridge (Meaburn:1986,MNRAS,223,317), the LMC (Epchtein+:1984, AA,140,67), R136a in 30 Dor (Weigelt+:1985,AA,150,L18), N160 in the LMC (Heydari-Malayeri+:1986,AA,162,180), W3 (Thronson+:1984,ApJ,284,597; Thronson:1986,ApJ,306, 160), W3(OH) (Mauersberger+:1986,AA,166,L26), W33 (Stier+:1984,ApJ,283,573), W40 (Smith+:1985,ApJ,291,571), W49A (Miyawaki+:1986,ApJ,305,353), W49N (Dreher+:1984, ApJ,283,632), W51 (Cunningham+:1984,MNRAS,210,891; Ohishi+:1984,PASJ,36,505; Rengarajan+:1984,ApJ,286,573; Cox+:1987,MNRAS,226,703; Mauersberger+:1987,AA,173, 352), W51 and DR21 (Harvey+:1986,ApJ,300,737), W3, M42, W49A and W51A (Gordon:1987, ApJ,316,258), DR6, 7, and 22 (Odenwald+:1986,ApJ,306,122), Mon R2 (Hugues+:1985, ApJ,289,238; Hodapp:1987,AA,172,304), S140 (Lester+:1986,ApJ,309,80), S156 (Joy+: 1984,ApJ,284,161), S128 (Haschick+:1985,ApJ,292,200), S255 (Richardson+:1985,MNRAS 216,713), S254-S257 (Henkel+:1986,AA,165,197), Sandqvist 187 (Alvarez+:1986,ApJ. 300,756), LkHα101 (Redman+:1986,ApJ,303,300; Dewdney+:1986,ApJ,307,275), IRAS 04238+5336 (Wynn-Williams+:1986,ApJ,304,409), IRAS 19520+2759 and IRAS 01133+6434 (Arquilla+:1987,AA,173,271), Cep A (Hugues:1985,ApJ,298,830), K3-50, W51-IRS 2E and G333.6-0.2 (Hofmann+:1986,AA,160,18), B62 (Reipurth+:1986,AA,166,148), B335 (Frerking+:1987,ApJ,313,320), SgrB2 (Goldsmith+:1987,ApJ,313,L5; 1987,ApJ,314,525; Vogel+:1987,ApJ,316,243), RCW 108 (Straw+:1987,ApJ,314,283), Sco OB2 (Cappa de Nicolau+:1986,AA,164,274), and Serpens SVS20 (Eiroa+:1987,AA,179,171).

Surveys of dust, IR, HII and CO emission, embedded stars, etc. in regions of star formation were made by Waller+:(1987,ApJ,314,397), Chini+:1986,AA,167,315), Braz+:1987,AA,176,245), Heckert+:(1984,AJ,89,1379), McGregor+:(1984,ApJ,286,609), Chini+(1986,AA,157,L1), Arquilla+:(1986,MNRAS,220,125), Beichman+:(1986,ApJ,307, 337) and Clark:(1987,AA,180,L1).

VI. HII Regions

(M. Peimbert)

1. INTRODUCTION

H II regions are paramount for the study of: the formation and evolution of massive stars, the energy input to the interstellar medium and the evolution of the chemical abundances in our galaxy and other galaxies. Hundreds of papers based on observations in almost all domains of the electromagnetic spectrum were published in the 1984-1987 period covered by this review. The following discussion will be restricted to representative papers in this area.

Apart from the books, proceedings, atlas and catalogues cited at the beginning of the report, the general relevant literature contains: Kunth, ed.: 1986, "Star Forming Dwarf Galaxies", ed. Frontières, Paris, hereafter SFDG; Backer, ed.: 1987, "The Galactic Center" AIP, Chicago, hereafter GC. The conference proceeding edited by Pequignot, 1986, is designated hereafter as MNP.

2. STRUCTURE

A large number of papers based on radiobservations has been devoted to determine the structure of galactic H II regions. High resolution studies have been carried out with the VLA, the RATAN-600, and other radiotelescopes (e.g.: 1984, SoobSpecApObs, 43, 56; 1984, MN, 209, 209; 1984, AA, 136, 53; 1984, ApJ, 282, L27; 1984, MN, 210, 173; 1985, AJ, 90, 59; 1985, AJ, 90, 310; 1985, ApJ, 288, L17; 1985, PASJapan, 37, 123; 1985, AA, 147, 84; 1985, AZh, 62, 229; 1985, AZh, 62, 482; 1985, AJ, 90, 2061; 1985, AA, 152, 387; 1986, MN, 219, 39P; 1986, ApJ, 307, 275; 1986, ApJ, 308, 288; 1986, AJ, 92, 75). From radio observations: the stellar types of the ionizing stars have been estimated (e.g.: 1984, MN, 209, 209; 1985, AJ, 90, 2061), compact or supercompact H II regions have been studied (e.g.: 1984, SoobSpecApObs, 43, 56; 1985, AZh, 62, 218; 1985, AJ, 90, 310; 1985, ApJ, 288, L17; 1985, AZh, 62, 482; 1985, Pis'maAZh, 11, 27; 1986, Pis'maAZh, 12, 353; 1986, IzvSpecApObs, 23, 3; 1987, IzvSpecObs, 24), and blister type H II regions have been analyzed (e.g.: 1985, AA, 152, 387; 1986, ApJ, 309, 553; 1986, AJ, 92, 75). Radio and optical data have been combined to stablish the structure of many H II regions (e.g.: 1984, Astrofisika, 20, 199; 1984, MN, 211, 149; 1984, MN, 211, 155). Radio images of ionized bright rim structures show discrete condensations that may be the result of Rayleigh-Taylor instabilities at the interface between the ionized and neutral phases of the interstellar medium (1985, ApJ, 298, 292). Ershov considered the possibility of detection of hydrogen fine-structure radio lines in H II regions (1987, Pis'maAZh, 13, 285).

Many papers on infrared mapping of H II regions are presented in the literature, the main results derived from these observations are: the dust temperature, density and optical depth distributions, the stellar infrared luminosities and the presence of stellar winds (e.g.: 1984, MN, 211, 15; 1984, ApJ, 283, 573;1985,AJ,90, 88; 1985, AA, 144, 275; 1985, ApJ, 291, 571; 1985; AA, 146, 337; 1985, ApJ, 296, 565; 1985, NASA CP-2353, 164; 1986, AA, 154, L8; 1986, ApJ, 300, 737; 1986, AA, 157, L1; 1986, AA, 158, 143; 1986, ApJ, 303, 629; 1986, ApJ, 303, L57; 1986, ApJ, 306, 122; 1986, AA, 170, 97).

Optical studies of emission line intensities have been used to determine the density structure and, in some cases, the ionization and velocity structures (e.g.: 1984, AstronTsirk, 1309, 1338, 1339; 1984, AA, 140, 24; 1984, Astrofizika, 20,199; 1985, AstronTsirk, 1369; 1985, AJ, 90, 92; 1985, ApJ, 294, 578; 1985, MN, 216, 761; 1985, AA, 152, 254; 1986, AstronTsirk, 1444, 1449,1457; 1986, ApSpSc, 119, 131; 1986, AZh, 63, 246; 1986, AA, 162, 265). By means of the ASTRON satellite UV energy distributions (λλ1500-3500) for Orion, M8 and M17 were obtained by Pronik and Petrov (1986, AZh, 63, 1016).

The interface between the H II and H I regions has been studied by observations of neutral hydrogen associated with H II regions (1984, ApSpSc, 107, 271; 1985, JKoreanAS, 18, 100; 1986, PASJapan, 38, 347); models have been presented to explain the dynamical interaction between the H II and H I regions (1984, ApSpSc, 107, 289; 1986, PASJapan, 38, 347).

OH and H_2O masers associated with compact or ultracompact H II regions have been detected in many sources, in some cases the H_2O masers are closer to the central star than the OH masers, moreover while some authors argue that the OH masers form in expanding shells others srgue that they are part of a remnant envelope which is still collapsing toward the newly formed star (e.g.: 1984, ApJ, 283, 632; 1984, MN, 211, 41P; 1985, AA, 153, 179; 1985, ApJ, 289, 681; 1985, MN, 213, 641; 1985, ApJ, 298, 830).

The relationship between H II regions and molecular clouds has been studied by several groups. The genetic connection between H II regions and molecular clouds has been stressed, many molecular and atomic transitions have been mapped across the interface regions, models of the H II-molecular cloud structure, including the velocity field, have also been presented (e.g.: 1984, ApJ, 282, L81; 1985, ApJ,290, L59; 1985, ApJ, 292, 200; 1985, ApJ, 293, 522; 1985, ApJ, 299, 341; 1985, ApJ, 299, 351; 1986, AA, 160, 287; 1986, Astrofisika, 24, 257; 1986, ApJ, 303, 638; 1986, ApJ, 303, 683; 1986, PASJapan, 38, 361; 1986, ApJ, 307, 302).

3. PHYSICAL CONDITIONS

X-ray observations and predictions have been made for H II regions. The extended X-ray emission from the Rosette nebula is coincident with the central radio minimum suggesting that hot gas originating from the central O stars is responsible for the diffuse X-rays and the thick hollow shell appearance (1985, MN, 217, 69). High temperature plasma with $T \simeq 4\times10^7$K has been detected in the Orion nebula as well as an X-ray emission feature at 6.69±0.06 keV (1986, PASJapan, 38, 723). The X-ray emission from ring nebulae around WR and Of stars, due to stellar winds, has been predicted (1985, AZh, 62, 103; 1986, MNP, 246).

The local electron densities were determined from: optical observations of the [S II] and [Cℓ III] lines, far-infrared observations of the [O III] and [N III] lines, Stark broadening of radio recombination lines, and from radio observations of two $Hn\alpha$ lines and continuum (e.g.: 1983, AstronTsirk, 1301; 1984, AstronTsirk, 1320; 1985, AA, 145, 347; 1985, Pis'maAZh, 11, 17; 1985, ApJSS, 57, 571; 1986, ApJ, 306, 532).

The mean electron temperature has been determined for a large number of galactic H II regions based on radio observations, in many cases the accuracy of the determination depends on the evaluation of deviations from LTE (e.g.: 1984, AA, 138, 225; 1984, MN, 211, 149; 1984, MN, 211, 155; 1984, MN, 211, 339; 1985, AA,146, L19; 1985, AZh, 62, 1057; 1985, ApJSS, 57, 571; 1986, ApJ, 301, 813; 1986, AA, 160, 129; 1986, RMexAA, 13, 15).

Two reviews of the effects of dust in H II regions were presented by Mathis and Münch (1986, PubASP, 98, 995; 1985, MittAGes, 63, 65). One millimeter continuum observations of galactic H II regions imply that most of the dust emission appears to come from dust within the H II region (1984, AA, 137, 117). The effect of dust scattering internal to H II regions has been studied based on simple analytical models (1984, AA, 139, 30). Measurements of dust scattered light from M20 indicate that grains have high albedo and a strongly forward-throwing phase function (1985, ApJ, 288, 164). Observations of M8 favor models with small refractory grains (1986, AJ, 91, 870). The heating of H II regions by electrons ejected from grains has been considered (1986, RMexAA, 12, 257; 1986, ApSpSc, 126, 211). The broad Balmer profiles present over the face of Car II are shown to be due to dust scattered Balmer emission from η Car (1986, RMexAA, 13, 27). A 4 mm excess over the free-free emission from W3 has been found and has been ascribed to large-size grains (1986, PASJapan, 38, 775). The stellar polarization in the direction of S252 is similar to the values observed for the nearby field stars (1986, ApSpSc, 128, 125).

Important improvements in computer capabilities have made possible more sophisticated treatments of photoionized models of H II regions (e.g.: 1986, MNP, 235). Different problems have been studied in the literature: ionization correction factors for nebulae of low degree of ionization (1985, ApJ, 291, 247), the helium ionization correction factor for H II region complexes (1986, PubASP, 98, 1061), the importance of the ionization parameter (1986, MNP, 225; 1986, PubASP, 98, 1072), different geometries like blister nebulae (1984, ApJ, 287, 653), O and N infrared emission from blister nebulae (1986, AA, 161, 347), homogeneous grids of models for different heavy element abundances (1984, ApJSS, 57, 349; 1985, ApJSS, 58,125), the effect of dust on radiative transfer (1986, MN, 221, 923), the effect of Lyman line pumping on model H II regions (1986, AA, 156, 393), star in motion relative to the surrounding medium (1986, ApJ, 300, 745), the importance of ionization from the $n = 2$ level of hydrogen for regions with densities higher than 10^8 cm^{-3} (1984, ApJ, 283, 165).

Optical and near-infrared emission lines have been observed by means of high, intermediate and low dispersion spectra as well as Fabry-Pérot interferometry, from these observations the structure and dynamics of many H II regions have been studied (e.g.: 1984, AA, 137, 245; 1984, AA, 138, 451; 1984, ApJ, 283, 640; 1984, RMexAA, 9, 119; 1984, MN, 211, 267; 1984, MittAGes, 62, 302; 1985, ApJ, 288, 142; 1986, AA, 155, 6; 1986, MN, 219, 895; 1986, ApJ, 304, 767; 1986, MN, 220, 745; 1986, ApJ, 307, 649). Observational constraints on dynamical models have been discussed by Meaburn (1986, MNP, 167). The mean velocity dispersion as a function of size has been studied for a few H II regions in terms of turbulent motions (e.g.: 1984, ApJ, 285, 109; 1985, ApJ, 288, 142; 1986, ApJ, 304, 767; 1986, ApJ, 307, 649; 1986, PubASP, 98, 1002). Kelvin-Helmholtz instabilities have been suggested for the generation and maintenance of nebular turbulence for Sharpless 142 (1985, ApJ, 288, 142). An explanation of the observed turbulent motions based on Kolmogorov's theory seems indicated to a first approximation, but there is poor agreement in many major details (1986, ApJ, 304, 767; 1986, PubASP, 98, 1002). A method for determining large scale expansion (or contraction) velocities based on observations of radio recombination lines was developed by Gulyaev and Sorochenko (1985, Bull AbastumaniApObs, 59, 135).

4. EVOLUTION

High dynamic range radio continuum maps show that ionized gas appears to flow around dense neutral condensations, this observation supports a model where radiation-driven ionization shock fronts lead to: the efficient implosion of nearby neutral condensations and the formation of second generation stars (1986, ApJ, 305, 714).

Models to study the evolution of H II regions emphasizing different aspects have been computed. The evolution of a neutral envelope surrounding an H II region ionized by an O5 star was calculated (1985, AstrofizIIzvS, 20, 95). The effect of a strong stellar wind on the structure of an H II region was considered (1983, Astrofizika, 19, 559). The kinetic efficiencies of stellar wind bubbles were estimated (1986, ApJ, 306, 538). Comparison of models with observations suggests that, for hollow H II regions, the shock at the edge of the wind cavity is not adiabatic but strongly dissipative (1986, AA, 160, 1). A model is presented for the dynamical evolution of an H II region in a cloudy medium (1986, MNP, 211). Models of line formation have been computed for the champagne phase (1984, AA, 138, 325). A self-consistent model of the evolution of a spherical nebula including the ionization structure, the energy balance and a hydrodynamics code has been computed (1986,MNP, 215). The time evolution of the Hβ equivalent width and the [O III]/Hβ line ratio for models with a single burst of star formation has been computed, it is found that these two ratios decrease monotonically and that they can be used as age indicators (1986, AA, 156, 111).

5. ABUNDANCES AND GALACTIC GRADIENTS

Aller gave a review paper on fifty years of nebular chemical compositions (1986, PubASP, 98, 957). The potential of infrared and far-infrared emission lines for studying nebular abundances has been reviewed by Dinerstein (1986, PubASP, 98, 979). The abundances of Ne^+, Ar^+, Ar^{++}, S^{++} and S^{+3} have been determined for five compact H II regions based on infrared line emissions (1984, ApJ, 285, 174). The He^+/H^+ abundance ratio for three positions of the Rosette nebula has been determined (1985, AA, 144, 171). The nitrogen and helium enrichment for four ring nebulae has been obtained (1984, ApJ, 287, 840). Variations of the relative abundances of N, O and S in NGC 6164-4 have been determined and are discussed (1986, ApSpSc, 120, 17). The Si^+/H^+ abundance ratio has been detected near θ^1 Ori C (1986, ApJ, 301, L57). The N/H, O/H and Ne/H values have been determined for the Orion nebula based on far-infrared observations, the N/O ratio is about a factor of two higher than that derived from optical lines (1986, ApJ, 311, 895).

A galactic electron temperature gradient of 310 K kpc^{-1} has been derived from H I 166α observations (1985, RMexAA, 10, 179).

6. GALACTIC CENTER

In addition to the Symposium on the galactic center, a review on Saggitarius A and its environment was presented by Brown and Liszt (1984, AnnRevAA, 22, 223). The ionized gas in the galactic center forms a unique H II region in the Galaxy; the inner 1.0 pc, centered at SgrA west or at IRS 16, is dust defficient and it is not yet clear if a central source (central engine) or if star formation is responsible for the observed structure (1987, GC, 1,8,30,39,79). There are several observations that indicate that almost certainly star formation in the inner 10 pc of the galaxy is going on at present and that O and B stars are being formed (e.g.: 1985, MN, 215, 69P; 1987, GC, 79).

7. EXTRAGALACTIC H II REGIONS

The study of extragalactic H II regions has increased at a faster rate than that of galactic H II regions. Supergiant H II regions, that are almost absent in the Galaxy, have been used for the study of: star formation, the chemical evolution of galaxies, preliminary estimates of the value of H_0 and the determination of the pregalactic or primordial helium abundance.

The structure, luminosity and distribution of giant and supergiant H II regions has been studied by several groups (e.g.: 1984, ApJ, 287, 116; 1984, PubASP, 96, 944; 1985, ApJ, 293, 400; 1985, AASS, 62, 63; 1985, AA, 145, 170; 1986, AA,154, 357; 1987, ApJ, 319, 61). The electron density has been determined for a few objects based on the [O II] 3726/3729 ratio (1984, ApJ, 283, 158). Extragalactic H II regions have been used as tracers of the stellar content and of starburst galaxies (e.g.: 1985, ApJSS, 58, 533; 1985, AA, 143, 347; 1985, ApJ, 288, 175; 1985, AJ, 90, 80; 1985, AA, 148, 443; 1985, AA, 152, 427; 1986, IAUSymp,116, 355; 1986, SFDG, 395; 1986, MN, 223, 811; 1986, PASJapan, 38, 571; 1986, PubASP, 98, 1032; 1987, RMexAA, 14, 144; 1987, Exploring the Universe with the IUE Satellite, ed. Y. Kondo, Reidel, hereafter EUIUE, p. 605; 1987, EUIUE, 623; 1987, AA, 180, 12). Molecular hydrogen emission has been detected in the direction of giant H II regions in the SMC, the LMC and M33 (1985, ApJ, 291, 156; Israel, F.P. preprint). The velocity field at various scales has been determined for 30 Doradus and NGC 604 (1984, MN, 211, 521; 1984, AA, 141, 49). The relationship between the linear diameter and the velocity width for 47 H II regions and between the Hα luminosity and the velocity dispersion for 43 objects has been analyzed (1986, ApJ, 300, 624; 1986, AA, 160, 374), furthermore the integrated Hα velocity profiles of 47 extragalactic H II regions have been discussed (1986, AJ, 92, 567).

Dufour (1987, EUIUE, 577) presented a review of IUE observations of galactic and extragalactic H II regions with an emphasis on the CNO abundances. Pagel (1986, PubASP, 98, 1009) presented a review of current problems related to abundances in extragalactic H II regions. Several reviews on the chemical evolution of galaxies based on H II observations are present in the literature (e.g.: 1985, MN, 217,391; 1986, Highlights of Astronomy, ed. J.P. Swings, Reidel, p. 377; 1986, SFDG, 403; 1986, PubASP, 98, 973; 1986, PubASP, 98, 1057; 1987, AA, 172, 15; 1987, Interstellar Processes, ed. D.J. Hollenbach and H.A. Thronson, Reidel, p. 667). Abundances of many extragalactic H II regions have been reported in the literature (e.g.: 1985, ApJ, 290, 449; 1985, ApJ, 292, 155; 1986, AA, 154, 352; 1986, AA, 158, 266; 1986, PubASP, 98, 1025; 1986, AA, 162, 180; 1987, ApJ, 317, 163; 1987, MN, 226, 19; 1987, RMexAA, 14, 178). An extensive study of abundance gradients of extragalactic H II regions reveals a good fit between models and observations if nitrogen is a product of secondary nucleosynthesis (1985, ApJSS, 57, 1), a similar result is obtained by an independent study (1986, ApJ, 307, 431). Many papers on abundance gradients of spiral galaxies are present in the literature (e.g.: 1984, MN, 211, 507; 1984, AJ, 89, 1702; 1986, PubASP, 98, 1032; 1986, ApJ,309, 544; 1987, ApJ, 317, 82).

A review on the pregalactic helium abundance and its relationship with cosmology was presented by Boesgaard and Steigman (1985, AnnRevAA, 23, 319). Many observations of the He/H ratio and many determinations of the pregalactic helium abundance, Y_p, from extragalactic H II regions are present in the literature (e.g.: 1985, AA, 146, 269; 1985, ApJSS, 58, 321; 1986, SFDG, 183; 1986, SFDG, 197; 1986, PubASP, 98, 984; 1986, PubASP, 98, 1005; 1986, ApJ, 311, 45; 1986, AA, 158, 266; 1986, AA, 154, 352). The best observations indicate that $Y_p = 0.232 \pm 0.005$ (1σ) and that $\Delta Y/\Delta Z = 3.5 \pm 0.7$ (1σ). Ferland (1986, ApJ, 310, L67) has suggested that the effect of collisional excitation from the He I 2^3S state reduces Y_p to about 0.207, on the other hand Peimbert and Torres-Peimbert (1987, RMexAA, 14, 540) argue that the collisional excitation effect has been overestimated and that Y_p should be reduced only from about 0.232 to about 0.228.

Giant and supergiant H II regions have also been used as distance indicators and in principle they provide an independent value of H_0 (1985, AA, 143, 469; 1987, MN, 226, 849; 1987, RMexAA, 14, 158). Finally a 100 kpc cloud of ionized gas at a redshift of 1.825 has been detected through observations of Lyman α emission (1987, ApJ.319,L39), *these type of objects might be indicative of young or recently forming galaxies.*

VII. Supernova Remnants

(T. Landecker)

Supernova remnant (SNR) research at the beginning of the review period is well summarized by Lozinskaya (1985,ApSpPhysRev,3,35) and IAU Colloquium 101, held at the end of the period, provides an overview of recent developments. Progress in instrumentation has in the usual way led to new understanding. The IRAS data have become available, revealing shock-heated dust in SNRs. IR and X-ray spectroscopy have advanced allowing study of the composition of ejecta. Better detectors have led to improved optical images and have permitted spectroscopy of faint features. Oxygen-rich ejecta in SNRs have been studied. Many more extragalactic SNRs have been studied at all wavelengths. Improved radio telescope sensitivity has revealed low-brightness features of known SNRs and allowed the detection of many new ones. Good data have been obtained on temporal changes in young SNRs at radio wavelengths. SNRs resembling the Crab are being found in increasing number; in particular, a very close facsimile to the Crab Nebula has been discovered in the LMC. Composite SNRs with Crab-like and shell SNR features, have been recognized. Advances have been made in associating various types of SNRs with the various types of supernovae and statistical studies of SNR radio properties continue, but not without controversy over their interpretation. Theoretical work has continued on SNR evolution in an inhomogeneous ISM; the modification of its environment by the progenitor star has been recognized as a very important influence on SNR evolution. Relevant conference publications include: Bartel,ed.: 1985,"Supernovae as Distance Indicators",Springer-Verlag,Berlin; Durgaprasad+,ed.: 1985,"18th International Conference on Cosmic Rays",Tata Inst.,Bombay; Kafatos+,ed.: 1985,"The Crab Nebula and Related Supernova Remnants",Cambridge U.Press,London; Jones+,ed.: 1985,"19th International Cosmic Ray Conference",NASA CP-2376,Washington; Peacock,ed.: 1985, "X-ray Astronomy in the EXOSAT Era",SpSciRev,40,1; Srinivasan+,ed.: 1986,"Supernovae, their Progenitors and Remnants",Suppl. to JAA; Proc. IAU Colloquium 101, to be published.

The theory of SNR evolution in homogeneous and cloudy media remains the subject of much work. Cox (1986,ApJ,304,771) considers SNR evolution in isotropic media, and shows that SNR properties depend on present density and post-shock temperature only. Kundt (1985,Kafatos+,151) argues that SNR shells consist of rampresure confined filaments, not Sedov-Taylor blast waves. Raymond (1986,Pequignot+, 145) models radiative and non-radiative shocks and predicts optical and UV properties. Hester (1987,ApJ,314,187) has developed a sheet description of shocks in middle-aged SNRs like the Cygnus Loop. Shull+(1985,MN,212,799 and IAU Coll.101) present analytical models of SNR evolution in the environment created by its progenitor. Cioffi+(IAU Coll.101) develop an analytical model of adiabatic and radiative SNRs. Chieze (1986,AdvSpRes,6,129) discusses evaporative SNRs. Innes+(1986, Pequignot,153; 1987,MNRAS,224,179), Bertschinger (1986,ApJ,304,154) and Gaetz (IAU Coll.101) consider instabilities of radiative shocks and Bychkov (1985,Pis'ma AZh, 11,911; 1986,AstroSpetsAstroObs,21,58; 1986,AZh,63,939) discuss their optical and radio emission. Hamilton (1985,ApJ,291,523) develops similarity solutions for ejecta driven blast waves. Hugues+(1985,ApJ,291,544) have modelled X-ray emission from Kepler's SNR including non-equilibrium ionization (NEI) in a hydrodynamic (HD) calculation. Jerius+(IAU Coll.101) discuss effects of NEI on X-ray emission from adiabatic SNRs. Pimenov (1985,Pis'ma AZh,11,265) interprets radio features of SNRs as magnetic field perturbations.

Preite-martinez (1986,Pequignot,204) uses a HD code to study interaction of a young SNR with an interstellar (IS) cloud. Tenorio-Tagle+ use a 2-dimensionel HD code to study:-SNR-SNR (1984,AA,138,215) and SNR-Molecular cloud interaction (1985, AA,145,70), applying the latter model to the Cygnus Loop (1986,AA,148,52); cloud crushing (1986,AA,155,120) and condensation and ejection of clouds (1987,AA,176,329) by a SNR; shock reflection (1986,AA,167,120); and sequential SN explosions in an OB association (1987,AA,182,120). Rumyantsev (1985,Astrofiz,22,157) considers filament formation by shock collisions.

Dopita+(1984,ApJ,282,142) discuss models for optical emission from oxygen-rich ejecta in young SNRs. Kafatos (1985,Kafatos+,13) models forbidden line emission in the Crab Nebula. Sunyaev+(1984,Pis'ma AZh,10,483) predict radio lines from heavy elements in SNRs. Gondhalekar (1985,MN,216,57P)has studied depletion of elements in SNR filaments. Shull (IAU Coll.101) reviews line emission processes in atomic and molecular shocks.

Injection of energy into the ISM by stars before and after they become SNe is reviewed by McKee (1986,ApSpSci,118,383). SNRs expand in an ISM modified by the progenitor; Lozinskaya (IAU Coll.101) discusses the influence of WR and O-f stars, including those in associations, on their surroundings. Clark (1984,Gondhalekar,169) critically reviews the use of SNRs as probes of the ISM. Braun (IAU Coll.101) discusses ISM interactions which most influence SNR dynamics and brightness. McKee (IAU Coll.101) reviews SNR shocks in an inhomogeneous ISM. Clifford (1984,MN,211, 125) models SNR interaction with a two-phase ISM. Cowie (1984,Kondo+,287) shows that the local ISM may be described as the interior of an SNR.

Stellar winds and SNe in OB associations act together to generate supershells in the ISM. Examples are found in Cygnus (Bochkarev+: 1985,ApSpSci,108,237) and in the Perseus Arm (Fich: 1986,ApJ,303,465) and perhaps in the local ISM (Innes+: 1984, MN,209,7; Arnaud+: 1984,Kondo+,301 and 1986,AdvSpRes,6,119). Supershell structure is reviewed by McCray (IAU Coll.101) and modelled by Wolff (1987,MN,224,701), Tomisaka+(1986,PASJ,38,697), Silich (1985,Astro.22,563), and MacLow+(IAU Coll.101). Collective effects of SNRs and supershells on galaxies have been considered by Kafatos and McCray (1986,de Loore+,ed.:IAU Symp.116,Reidel), MacLow+(1986,PASP,98, 1104), Dopita (IAU Coll.101), and by Tomisaka and Ikeuchi (IAU Coll.101).

Chevalier (1985,Kafatos+,63) reviews evolution of the Crab Nebula. Davidson+ (1985,AnnRevAA,23,119) review knowledge of the ejecta and the progenitor. Kennel+ (1984,ApJ,283,694) study energization by the central pulsar and Craig+(1985,AA,149, 171) the resultant synchrotron source. The shock wave expected around the Crab, has been searched for (1985,Kafatos+,81,89,115;1986,AA,157,335). Lundquist+(1986,AA,162, L6) predict a fast shell should be detectable in the UV. X-ray observations give information on injection of energy in the nebula (1985,Nature,313,662;1985,Kafatos+, 197;Ogowara+,1986,in "X-Ray Astronomy 1984",ed.Oda+,ISAS,Tokyo). Abundances have been studied by X-ray (Schattenburg+:1986,ApJ,301,759) andoptical spectroscopy (1986, Pis'ma AZh,12,440;1986,PASP,98,1044). Van den Bergh+(1986,Nature,321,46) have resolved filaments into small knots. Henry+(IAU Coll.101) have studied Ni emission. Radio emission from the Crab has been mapped (1984,Pis'ma AZh,10,730;1985,MN,212, 359;Kafatos+,115,133;1986,Pis'ma AZh,12,275). The jet seen in the Crab has been well studied (1984,ApJLett,285,L75;1985,Nature,313,661;Kafatos+,115,127;ApJ Lett,294, L121;AA,151,101;1986,ApJ,306,259). A significant discovery is the close resemblance of the SNR LMC 0540-693 to the Crab Nebula. It contains an X-ray and optical pulsar (1984,ApJ Lett,287,L19;1985,Nature,313,659) and is a synchrotron nebula (1984,ApJ Lett,287,L23;1986,Srinivasan,119). Reynolds (1985,ApJ,291,152) considers its evolution and age. A synchrotron shell has been sought around 3C58 with no success (1985,AJ,90,2312;1986,MN,218,533;Landecker+: 1987,AJ,94,111). Fesen+(IAU Coll.101) have measured expansion velocities in 3C58 and proper motion of filamants. CTB80, an unusual SNR with a Crab-like core, has been studied optically (1985,Kafatos+, 257; Observatory,105,7), in X-ray (1984,ApJ,285,607) and in the radio (1984,AA,139, 43). Strom (preprint) finds pulsar-like properties in its central source. The Vela-X region has been observed in X-rays (1985,AdvSpRes,5,53;Kafatos+,203;SpSciRev,40,487;

ApJ.299,821). Milne+(1987,AA,167,117) have shown that Vela-X does not differ in radio spectral index from the rest of the Vela SNR.

Srinivasan+(1984,JAA,5,403) and Lozinskaya (1986,AZh,63,914) consider the evolution of pulsar-driven SNRs. Radio observations have been made of Crab-like SNRs G20.0-0.2 (1985,ApJ Lett,297,L25), and G291.0-0.1 (1986,MN,219,815). X-ray observations have been made of G21.5-0.9, 3C58 and Vela-X (1985,Kafatos+,219;SpSciRev, 40,513; 1986,ApJ Lett,300,L59), G291.1-0.1, G308.7+0.0 and G328.4+0.2 (1986,ApJ, 302,718). Composite remnants with a Crab-like component and an outer shell are receiving increasing attention. Radio and X-ray observaitons have been made of G0.9+ 0.1 (Helfand+: 1987,ApJ,314,203), G18.94-1.06 (Barnes+: IAU Coll.101), G24.7+0.6 (Becker+: IAU Coll.101), G27.4+0.0 (1985,ApJ,288,703), G29.7-0.3 (1984,ApJ,283,154; 1985,ApJ,295,456).

Considerable effort continues to be expended on observations and theoretical investigations of Cas A. Van den Bergh+(1986,ApJ,307,723) put new limits on any stellar remnant of the SN. Fesen+(1986,ApJ,306,248) have observed nitrogen-rich ejecta. Koyama+(1986,Oda+,ed."X-Ray Astronomy 84",ISAS,Tokyo,289), Tsunemi+(1986, ApJ,306,248) and Markert+(IAU Coll.101) have used X-ray spectroscopy to study abundances. Jansen+(1985,AdvSpRes,5,49) have mapped X-ray temperature structure. Morfill+(1984,Nature,311,358) have observed an X-ray halo beyond the shock front. Dwek+(1987,ApJ,315,571) present IRAS observations; the emission is largely from shock-heated dust. Dinerstein+(1987,ApJ,312,314) find IR evidence for dust within the ejecta. Kenneys+(1985,ApJ,298,644) have mapped the 86 GHz brightness and polarization.

Recent work on Tycho's SNR has concentrated on X-ray data. Davelaar+(1985,SpSci Rev,40,467) have measured abundances spectroscopically. Hamilton+(1986,ApJ,300,713) model the X-ray spectrum. NEI models are reported by Brinkmann+(IAU Coll.101). Itoh+ (IAU Coll.101) model the X-ray spectrum with a carbon deflagration Type Ia SN. Smith+(IAU Coll.101) predict radio and X-ray emission from a simple HD model. X-ray spectra of Kepler's SNR have been modelled by Ballet+(IAU Coll.101) using NEI HD models. Matsui+(1984,ApJ,287,295) have compared radio and X-ray images. Optical structure has been mapped by Bandeira+(1986,MemASocItal,56,773); a catalog of features is presented by D'Odorico+(1986,AJ,91,1382). Bandiera (preprint) considers the origin of Kepler's SNR. The memnant of SN1006 has been mapped in the radio by Reynolds+(1986,AJ,92,1138) and by Roger+(preprint) and in the X-ray by Jones+(1986, Oda+,ed. "X-Ray Astronomy 84",ISAS,Tokyo,305). Vartanian+(1985,ApJ Lett,288,L5) have detected strong X-ray emission lines. Hamilton+(1986,ApJ,300,698) analyze the X-ray spectrum using NEI models.

The dividing line between SNe and SNRs is indistinct. Weiler+(1986,ApJ,301, 790; Science,231,1251) review observations of radio SNe. Graham+(1986,MN,218,93) have made a significant detection of iron in a SN using IR spectroscopy. Bandiera+ (1984,ApJ,285,134) suggest that radio SNe evolve into Crab-like SNRs. Chevalier (1984,ApJ Lett,285,L65; 1985,Gondhalekar+,128,IAU Coll.101) Fransson (1986,in Mihalas+, ed. "Radiation hydrodynamics of Stars and Compact Objects", Springer-Verlag,Berlin, 141) and Dickel+(1986,NASA TM-88342,67 and IAU Coll.101) discuss interaction of young SNRs with the circumstellar medium (CSM). Liang+(1984,AnnNYAcadSci,422,233) study interaction of ejecta with the CSM and ISM. Band+(IAU Coll.101) extend this work to adiabatic SNRs. Bedogni+(IAU Coll.101) discuss instabilities due to electron heat conduction. Itoh (1984,ApJ,285,601) discusses effects of temperature relaxation on X-ray properties. Canizares (1986,Oda+,ed."X-Ray Astronomy 84",ISAS, Tokyo,275) reviews X-ray results on ejecta dominated SNRs. Glushak (1986,Sov.A.Lett 11,350) discusses evolution of the radio spectrum of young shell SNRs. Reynolds (IAU Coll.101) has studied radio structure in 3C58 and SN1006 and discusses particle acceleration and transport. Bohigas (1984,RevMexAA,9,13) deduces the mass ejected in SN events from studies of young SNRs. Mezger+(1986,AA,167,145) have observed Cas A and the Crab Nebula at 1.2mm; the IR luminosity of the Crab is dominated by synchrotron emission but dust emission prevails in Cas A.

Changes with time of the radio appearance of a number of young SNRs have been detected. Tuffs (1986,MN,219,13)has compared 5 GHz images of Cas A over a 4-year period and Green (IAU Coll.101) has used 151 MHz data with a 2.3-year baseline. Braun+(1987,Nature,327,395) have used 3 images spread over 4-years to show clumps of ejecta overtaking the radio shell; resultant bow shocks cause the observed structure. Temporal changes in total radio flux density of Cas A are recorded by Barabanov+(1986,AZh,63,926) and Walczowski+(1985,MN,212,27P). Van den Bergh+(1985, ApJ,293,537) review optical studies of Cas A from 1951 to 1983. Aller+(1985,ApJ, Lett,293,L73) have measured a decrease in the 8 GHz flux density of the Crab Nebula from 1968 to 1984. However, Green (1987,MN,225,11P) shows that the flux density of 3C58 has increased over a comparable period.

Theory indicates that some SNe form a condensed object and an expanding SNR. Seinivasan (1986,Srinivasan+,105), Qadir+(1986,ChinPhysLett,3,189) and Akujor (1987, ApSpSci,135,187) discuss pulsar-SNR correlations. Nomoto+(1986,ApJ Lett,305,L19; 1986,Comments Ap, 11,151)discuss neutron star cooling and its effect on X-ray emission from young SNRs. Seward (1986, Comments Ap, 11,15) summarizes X-ray observations of five SNRs containing neutron stars. Manchester (1987,AA,171,205) models radio emission from most SNRs as the result of biconical outflow from a central object. Feigelson (1986,CanJPhys,64,474) and Becker (1986,CanJPhys,64,482) discuss production of outflows from degenerate stars in SNRs. Haynes+(1986,Nature,324,233) have observed a nebula associated with Cir X-1 which may have been ejected from an SNR. Van Gorkom+(1986,Srinivasan+,93) have made a radio search for compact sources in SNRs. Compact sources have been shown to be NOT associated with the SNRs G74.9+ 1.2 (1984,ApJ,286,284), G127.1+0.5 (1984,JAA,5,425), G109.1-1.0 (1986,CanJPhys,64, 479) and Tycho (Green+: 1987,MN,224,1055).

The Cygnus Loop and IC443 are the canonical old SNRs and attract observers at all wavelengths. Hester+ have studied filaments of the Cygnus Loop (1986,ApJ,300, 675,698; IAU Coll.101; Raymond+, preprint) using optical, UV and X-ray data. Based on this data Hester (1987,ApJ,314,187) has proposed a model of SNR filaments as sheets. Fesen+(1985,ApJ,295,43) have investigated a non-radiative filament in the Cygnus Loop. Teske+(1985,ApJ,292,22) present images in a coronal line of iron. Greidanus+(IAU Coll.101) have mapped filaments using an imaging Fabry Perot interferometer. Kritsuk (1986,Astrofiz,26,45) suggests that thermal instabilities play a part in filament formation. Ballet+ and Charles+(1985,SpSciRev,40,481;ApJ,295,456) have mapped the Cygnus Loop in X-rays, and Vedder+(1986,ApJ,307,269) have found evidence of NEI from X-ray lines. Straka+(1986,ApJ,306,266) have compared high-resolution radio and optical images. Green presents a detailed image at 408 MHz. Braun+ (1986,AA,164,208) analyze IRAS observations of the Cygnus Loop and conclude that the expanding SNR has encountered a pre-existing high density shell.

Braun+(1986,AA,164,193) have also analyzed IRAS data for IC443 and conclude that this SNR too has expanded into a pre-existing shell, part of a network of stellar wind bubbles. Mufson+(1986,AJ,92,1349; IAU Coll.101) have investigated IC443 at radio, IR,optical, UV and X-ray wavelengths. Gensheimer+ (1986,PASP,98, 1147) and Ballet (IAU Coll.101) have mapped IC443 in a coronal line of iron. Graham+ (1987,ApJ,313,847) and Wright+ (IAU Coll.101) present IR spectroscopy of a number of iron lines. Molecular gas and IRAS sources associated with IC443 have been studied by Huang+ (1986,NASATM-88342,69). White+ (1987,AA,173,337) and Burton (IAU Coll.101) have observed a number of molecules in these clouds, and Mitchell (IAU Coll.101) models their chemistry. Green (1986,MN,221,473) has mapped IC443 at 151 and 1419 MHz and has detected spectral index variation across the source, but Erickson+(1985,ApJ,290,596) show that the overall spectrum follows a power law from 20 MHz to 11 GHz.

In the review period, the increasing sensitivity of radio telescopes has led to discovery of new SNRs and to improved maps of others. G357.7-0.1 and G5.3-1.0 have been mapped by Becker+(1985,Nature,313,115,118) who consider them a new type of non-thermal radio source, powered by outflow from a binary system. G357.7 -0.1 was also observed by Shaver+(1985,Nature,313,113). On the other hand Caswell+(1987, MN,252,329) conclude that G5.3-1.0 is part of a larger shell SNR. Papers which present data on many SNRs include Milne+(1985, ProcASocAust,6,78) -50 southern SNRs; Fürst+(1985,MittAGes,63,149) -14 new SNRs;Reich+(IAU Coll.101) -32 new SNRs; Tateyama+(IAU Coll.101) -flux densities of 15 SNRs at 22 GHz; Reich+(1986,AA,155, 185) -2 new SNRs; Milne (IAU Coll.101 and preprint) radio polarization catalogue for 70 SNRs; Trushkin+(1986,preprint) SNRs between longitudes 85 and 135 degrees. Green (1985,MN,216,69) has searched for very young SNRs and lists 42 sources thought NOT to be SNRs.

New radio data on the following SNRs or possible SNRs has been published: - G2.4+1.4 (Green+,1987,MN,225,221), G7.7-3.7 (1986,MN,223,487), G8.7-0.1 (1986,AJ, 92,1372,G11.2-0.3 (1984,MN,210,845;1985,ApJ,296,461), G18.9-1.1 (1985,Nature,314, 720;1986;AA,92,1372;Fürst+,IAU Coll.101), G19.96-0.18(1986,AA,92,1372), G24.7+0.6 (Becker+,1987,ApJ,316,660),G41.1-0.3(1985,ApJ,296,461),W50(1986,MN,218,393), G50.29-0.4 and G54.09+0.26 (1985,AA,151,L10), G54.5-0.3 (1985,AJ,90,1224: 1986,JAA,7,105), G70.68+1.2 (1985,AA,151,L10; 1986,MN,219,39P), G71.23+1.47 (1985,AA,151,L10), G73.9+0.9(Chastenay+,IAU Coll.101), G93.7-0.3 and G94.0+1.0 (1984,AA,138,469;1985,AJ,90, 1082), G109.1+1.0 (1984,ApJ,283,147), G132.6+1.5 (Landecker+,1987,AJ,94,111),G160.9+2.6 (Leahy+,IAU Coll.101), G166.2+2.5 (1986,MN,221,809; Kim+,IAU Coll.101), G166.0+4.3 (Pineault+,1987,ApJ,315,580), G179.0+2.7 (1986,AA,154,303), S147 (1986,AA,163, 185), G192.8-1.1 (1985,AJ,90,1076), G206.9+2.3 (1986,ApJ,301,813), G292.0+1.8 (1986, AA,162,269), G312.4-0.4 (1985,MN,216,753), G348.5+0.1 and G348.7+0.3(1984,MN,210, 845), G349.7+0.2(1985,Nature,313,113), G350.1-0.3(1986,AA,162,217). Radio studies of SNRs at the end of the review period were summarized by Caswell(IAU Coll.101).

Evidence continues to accumulate suggesting that the galactic loops are old SNRs. Parkinson+(1985,SpSciRev,40,503) have studied soft X-ray emission from Loops I and III. Bhat+(1985,Jones+,342) have detected a gamma-ray excess from Loop I. Arnal+ (1986,RevMexAA,12,298) discuss possible star formation induced by the Lupus Loop. Radio spectroscopy of HI and CO lines has provides powerful probes of SNR/ISM interaction. *Gosachinskij+(1985,ApSpSci, 108,303) present observations of HI shells near* 12 SNRs. Braun and Strom(1986,AA Suppl, 63,345) have found post-shock HI in four SNRs (G78.2+1.8, G109.1-0.1, G166.0+4.3, and IC443). HI has been observed near: - G296.5+10.0(1986,AJ,91,343), G166.2+2.5(1986,MN,221,209), W50(1986,Astrofiz,25,287), G166.0+4.3 (Landecker+,IAU Coll.101); G18.95-1.1(Fürst+, IAU Coll.101). CO has been observed near W28 and W44 (Velusamy,IAU Coll.101); G109.1-1.0 (Tatematsu+,IAU,Coll. 101). Fukui+(IAU Coll.101) present observations of CO in the vicinity of five SNRs. Dubner+(IAU Coll.101) have detected HI and CO near Puppis A. Huang+(1986,ApJ,309, 804) list molecular clouds which they associate with SNRs between longitudes 70 and 210°. They use these associations to derive a new surface brightness-diameter (sigma-D) relationship (1985,ApJ Lett,295,L13).

Studies of the sigma-D relationship, based on the radio properties of SNRs, have continued. Green (1984,MN,209,449) has critically reviewed the available distance estimates. He concludes that sigma-D is of little value. Allakhverdiyev+(1986, ApSpSci,121,21; Astrofiz,24,97,397) conclude that sigma-D is relevant for shell SNRs in dense environments but not for low-brightness SNRs. Berkhuijsen(1986,AA,166,257; preprint;IAU Coll.101) concludes that the sigma-D relationship results from dependence of SNR properties on ISM density, not from an evolutionary sequence. Duric+ (1986,ApJ,301,308)have theoretically reproduced the observed sigma-D relationship.

Preite-Martinez+(1986,AA,157,6) have studied energy and diameter for LMC SNRs. Berkhuijsen(1984,AA,140,431) has studied SN rates in M31, M33 and the Galaxy and *concludes that only a small fraction of SNRs have been detected.* Clark (1984,Gondhalekar,ed."Mass Loss from Astronomical Objects",RL-82-075) reviews work on SN rates, explosion energy, and on progenitors. Weiler(1985,Kafatos+,227) reviews evolution of Crab-like SNRs. Sakhibov+(1985,ByulInstAstrofiz,75,3) have used SNR statistics to deduce explosion energy. Xinji+(IAU Coll.101) have studied the distribution and birthrate of galactic SNRs. Li+(IAU Coll.101) have examined the correlation of galactic SNRs and spiral arms. Van den Bergh+(preprint) have studied the SN rate in Shapley-Ames galaxies. Van den Bergh (preprint) relates the various types of SNRs to the various types of SNe.

Improved instrumentation has permitted observation of faint optical features in SNRs. Fesen+(1985,ApJ,292,29) have studied abundance gradients in the Galaxy from spectrophotometry of 7 SNRs. Pineault+(1985,AA,151,52) have mapped G166.0+4.3. Winkler+(1985,ApJ,299,981) have detected oxygen in Puppis A. Van den Bergh and Pritchet(1986,PASP,98,448) have used CCDs to map faint features in Cas A, the Crab Nebula and CTB80. Meaburn+(1986,MN,222,593) have used echelle spectrograms to detect blast wave-cloud interactions in RCW103. Itoh(1986,PASJ,38,717) has studied OI emission from Puppis A and Cas A. Kirshner+(1987,ApJ,315,L135) have studied high velocity emission in SN1006 and Tycho. Teske+(1987,ApJ,318,370) have observed coronal iron lines in Puppis A.

The data from IRAS has had a substantial impact on SNR studies. This field is reviewed by Dwek+(1986,NASA-TM-88342) and by Dwek(IAU Coll.101). Most IR emission from SNRs arises from shock heated dust, and IR emission appears to be an important cooling mechanism for SNRs. Braun (1987,AA,171,233) has prepared IR images of Cas A, Tycho and Kepler from IRAS data. The emission arises from IS or CS material, not from ejecta. Graham+(1986,Israël,397;1987,ApJ,319,126)have examined IRAS data for LMC SNRs. Arendt(IAU Coll.101) shows that one third of known galactic SNRs are detectable in the IRAS data. Moorwood+(IAU Coll.101) have studied the IR spectra of galactic and LMC SNRs. Dennefeld (1986,AA,157,267) has studied abundances using IR spectroscopy. Rengarajan+(IAU Symp.120) show that IRAS point sources are found preferentially on SNR shells, and interpret these as dust knots heated by X-ray emission.

X-ray studies have been reviewed by Aschenbach (1985,SpSciRev,40,447; 1986, Highlights A,7,649) and by Strom (1986,ESA,SP-239,43). Hamilton+(1984,ApJ,284,601) interpret X-ray spectra including NEI, and Bleeker (1985,MN,220,501) and Markert+ (1986,IAU Coll.86,NRL,Washington,76) discuss observational evidence of NEI. Seward (IAU Coll.101) has reprocessed X-ray images of 44 SNRs from Einstein data. Smith (IAU Coll.101) presents Exosat spectral data for 8 SNRs. X-ray data have been published for the following SNRs -G29.7-0.3 (1985,Jones+,394), W28 and 3C400.02 (1985, Kafatos+,211), W44 (1985,MN,217,99), W49B (1985,ApJ,296,469), HB3 (1985,ApJ,294,183), Monoceros (1985,MN,213,15P; 1986,MN,220,501), Puppis A (1986,ESA SP-239,137;Fischbach+,IAU Coll.101), RCW86 (1986,ESA SP-239,107), RCW103 and MSH 14-63 (1984,ApJ, 284,612), PKS 1209-52 (1985,SpSciRev,40,475;Kellett+: 1987,MN,225,199;Matsui+,IAU Coll.101), 1E1149.4-6209 in Crux (1986,ApJ,302,606).

Extensive bodies of new data on Magellanic Cloud SNRs have been published by Mills+(1984),AustJPhys,37,321-radio data), Mathewson+(1985,ApJ.Suppl,58,197-optical data), Danziger+(1985,MN,216,365-spectrophotometry), Graham+(IAU Coll. 101-infrared data), Dopita+(1984,ApJ,282,135-spectrophotometry of young oxygen-rich SNRs). Contini (1987,AA,174,5) has fitted models to optical line ratios for LMC SNRs. Other studies of Magellanic Cloud SNRs are:-N157B (1984,AA,140,390), N63A (1986,AA,164, 26), N132D (Hughes: 1987,ApJ,314,103; Lasker,IAU Coll.101) and 1E0102-7219 (Hughes, Blair+, Lasker, IAU Coll.101).

Long (1985,SpSciRev,40,531) has reviewed observations of extragalactic SNRs and Dickel+(1985,Bartel,100) have reviewed techniques for detecting them. SNRs have been observed in:-M33 (1985,ApJ,289,582; 1985,JAA,6,145; Blair+,Duric,Long+,IAU Coll. 101), M82 (1985,Bartel,88), NGC 185, IC 1613 and NGC 6822 (1985,AJ,90,414), M101(1986, ApJ,311,85). Cox+(1986,ApJ,304,657) estimate the SNR rate in M101 from X-ray data. Artyukh+(1986,Pis'ma AZh,12,739)deduce the SNR density in M33 from radio data.

Cowan+(1985,Bartel,75) discuss radio observations of historical SNe.

The subject of cosmic ray (CR) acceleration in SNRs is an active field; only a few papers can be referred to here. Conferences Durgaprasad+, Jones+ and 1986, Shapiro,ed. "Cosmic Radiation in Contemporary Astrophysics", Reidel, include many relevant references. Wolfendale (1986,Shapiro (ibid),135) reviews CR origin and propagation. CR acceleration by SNR shocks is treated by Bulanov+(1984,Pis'ma AZh, 10,594), Jokipii+(1985,ApJLett,290,L1), Dorfi+(1985,Jones+,136), Allakhverdiyev+ (1986,ApSpSci,123,237), and Axford (1986,Kahn,119). Cowsik+(1985,Durgaprasad+,306) consider electron acceleration in SNRs and effects on SNR spectra and evolution. Volk (1985,Audouze+,ed. "High Energy Astrophysics",Ed. Frontières,Paris) treats the non-linear theory of CR acceleration. The effects of particle acceleration on SNR evolution are discussed by Heavens (1984,MN,211,195), Glushak (1986,Pis'ma AZh, 11,825), Volk+(1985,Jones+,148; 1986,Kahn,101) and Droge+(1987,AA,178,252). Jokipii (1987,ApJ,313,842) examines diffusive shock acceleration, and shows that orientation of the magnetic field affects acceleration efficiency. Blandford (IAU Coll.101) reviews particle acceleration in SNR shocks and the confrontation of theory with observations.

VIII. Planetary Nebulae

(Y. Terzian)

1. GENERAL STUDIES

A number of relevant books, conference reports, catalogues or surveys and review papers are cited at the beginning of this report. Moreover, IAU is scheduled to conduct Symposium 131 on Planetary Nebulae (PN) in Mexico City during the first week of October 1987. Acker edited "Les Nébuleuses Planétaires: Comptes Rendus Sur Les Journées De Strasbourg" in 1986. Statistical surveys of PN and their central stars were discussed by Amnuel+(1984,ApSpSci,107,19;1985,ApSpSci,113,59).

Acker+ worked on producing a new general catalog of PN, which should be available by the IAU General Assembly in 1988. Acker+(1987,AASuppl,in press), and Sabbadin+(1987,AASuppl,in press) examined in detail a group of misclassified nebulae. Saurer+(1987,AASuppl,in press), and Hartl+(1987,AASuppl,in press) reported on the identification of new PN, many of them of very low brightness. Maehara+(1987,AA, 178,221) reported on the identification of NGC 2242 as a PN rather than as a galaxy. Shaw+(1985,PASP,97,1071) have identified seven new PN in Baade's Window.

Méndez+(1987,AA,in press) presented high resolution spectroscopic observations of many central stars of PN. Ishida+(1987,AA,178,227) have identified two extremely faint and old PN, and present a list of 31 nebulae within a distance of 500 pc from the Sun. They estimate a large birthrate of 8×10^{-3} kpc^{-3} yr^{-1}, and conclude that the total number of PN in our galaxy is larger than 10^5. Gathier (1987,AA,in press) derived a very different birthrate of 2.4×10^3 kpc^{-3} yr^{-1} from a group of 30 PN with individually determined distances. Stenholm (1986,Acker,25) described a spectroscopic program to observe 1500 PN of which 476 objects have already been observed. Pottasch+(1986,AA,161,363) described measurements of IRAS spectra of PN.

2. DISTANCES

The problem of distance determinations of PN has remained very difficult, inspite of several studies that have examined this issue carefully (Gathier,1987, AA,in press; Kwok,1985,ApJ,290,568). Kaler+(1985,PASP,97,594) measured accurate extinctions towards 8 nebulae and derived dust-distances, however they conclude that typical distance uncertainties are ±55%. Gathier+(1986,AA,157,171) derived distances to 12 nebulae using the reddening-distance method and conclude distance accuracies from 10 to 40%. Gathier+(1986,AA,157,191) use HI absorption observations in the direction of PN to derive kinematical distances. For 12 nebulae the derived distances have an uncertainty of less than ∿ 50%. Kaler+(1985,ApJ,288,305) have suggested deriving wind distances from the P Cygni profiles, where one can infer the gas escape velocity. Masson (1985,ApJ,302,L27) reported the measurement of the angular expansion of NGC 7027 with VLA observations and derived a distance to this object of 940 ± 200 pc. Terzian (1987, Sky and Telescope, p.128) described the nebular angular expansion method of determining distances with VLA observations for the nearby nebulae.

3. MORPHOLOGY

Substantial progress has been made in observations of the morphology of PN. Balick (1987,Sky and Telescope, p.125) presented a comprehensive study of the shaping of PN. Chu+(1987,preprint) have studied the multiple shell nebulae and conclude that the frequency of multiple shell events is as high as ≥ 0.5. Kwok (1985,AJ,90,49) reported on VLA maps of 10 compact nebulae, and Basart+(1987,ApJ, 317,412) reported on additional VLA maps of BD 30°3639,NGC 6572, NGC 6590 and NGC 7027. In addition Balick+(1987,preprint) reported on optical and radio (VLA) images of NGC 6543, IC 3568 and NGC 40. Sabbadin+(1985,MN,217,538) discussed in detail the structure of NGC 3587 from optical spectroscopic observations. Hua+(1986,AJ,92,853) reported high resolution optical observations of IC 351. Moreno+(1987,AA,178,319) presented very deep photographic, narrow band images of NGC 6720 and have revealed the presence of extended filanetary structure in its halo. Jewitt+(1986,ApJ,302, 727) showed results of a CCD survey to detect outer halos around 44 PN,and have reported that 2/3 possess extensive outer halos. Zuckerman+(1986,ApJ,301,772) have examined a large sample of PN and concluded that among 108 nonstellar objects ∿ 50% show bipolar morphological symmetry, and ∿ 30% display elliptical symmetry. Pascoli (1987,AA,180,191) discussed in detail the origin of bipolar structures and has computed models assuming intra-nebular magnetic fields.

4. MOLECULAR AND NEUTRAL HYDROGEN OBSERVATIONS

Exciting new developments have taken place during the last few years in our understanding of the transition from red giant stars to PN. A recent review on this topic has been given by Kwok(1987,"Late Stages of Stellar Evolution", Reidel 321). Knapp (1987, MittAstronGes, in press) has discussed the molecular line observations and the mass loss from red giants, and has concluded that the mass returned to the Galaxy from red giants is about $1M_{\odot}$/yr. Ground based and IRAS observations of pre-planetary nebulae have revealed dust grains in the circumstellar envelopes of luminous red giant stars (Zuckerman+,1986,ApJ,311,345; Kwok+,1986,ApJ,303,451; Likkel+, 1987,AA,173,L11).

Thronson+(1986,ApJ,300,749) have searched for molecular emission from NGC 7027, and other than CO, they detected CN. Phillips+(1985,AA,151,421) have presented CO maps of NGC 7027. Huggins+(1986,ApJ,305,L29; 1986,MN,220,33P) have detected significant CO emission associated with NGC 7293, NGC 2346 and NGC 6720, implying that a significant fraction of these nebulae have not yet been ionized. Pottasch+(1987,AA, 177,L49) reported the detection of radio continuum radiation from two OH/IR stars, and Payne+(1987,ApJ, in press) reported the detection of OH from NGC 6302 and Vy 2-2; they also present a detailed VLA map of the 1612 MHz OH maser emission of NGC 6302. Rodriguez+(1985,MN,215,353) reported the detection of λ 21 cm neutral hydrogen in the PN NGC 6302, and Taylor+(1987,AA,176,L5) also reported HI from IC 418. HI has also been observed by Altschuler+(1986,ApJ,305,L85) from IC 4997.

5. SPECIAL OBJECTS AND STUDIES

Atherton+(1986:Nature,230,423) detected the central star of NGC 2440 and derived a Zanstra temperature of 350,000K. Heap(1987:Nature,326,571) reported IUE observations of the same star derived a stellar temperature of 200,000K.

Feibelman (1987,PASP,99,270) reported a stellar temperature of 94,000K for the high galactic latitude star of the nebula 75 + 35°1, and Bianchi+(1987,AA,181,85) using IUE observations derived a temperature of 90,000K, log $L/L_\odot$ = 4.4, R = 0.66 $R_\odot$, and M = 1.1 $M_\odot$ for the central star of NGC 40. Kaler+(1985,ApJ,297,724) studied the IUE spectra of 32 central stars and derived Zanstra temperatures ≥ 70,000K. Aller+ (1985,ApJ,296,492) derived a temperature of 160,000K for the central star of NGC 6741. de Korte+(1985,AdvSpaceRes,5,57) reported the detection of X-ray emission from the PN NGC 1360. Pronik+(1986,Astron Zh, 63,1016) made UV observations of NGC 2352 and NGC 6853 with the ASTRON satellite. Kostyakova +(1985-6,Astron Tsirk, 1380-1460) studied the variability of PN including HM and FG Sge. YM29 was studied by Lozinskaya+(1986,Astron Zh, 63,255). NGC 7293 was studied by Leene+(1987,AA,173,145), and by Walch+(1987,MN,224,885). [OII] studies of PN were made by O'Dell+(1984,ApJ, 283,158). Studies of galactic abundance and electron temperature gradients were made using PN by Faundez-Abans+(1986,AA,158,228), and by Maciel+(1985,AA,149,365) respectively. Sabbadin+(1986,AASuppl,65,259) studied the internal motions 32 PN, and Sabbadin+(1985,MN,213,563) reported on the expansion velocities of 22 nebulae.

6. PN IN THE MAGELLANIC CLOUDS, M31 AND M33

Barlow (1987,MN,227,161) studied 32 nebulae in the Magellanic Clouds and deduced a mean ionized mass of 0.27 $M_\odot$. Small nebulae were observed using speckle interferometry by Wood+(1985,ProcAstronSocAust,6,54); these results show a mean ionized mass of 0.08 $M_\odot$. Barlow+(1986,MN,223,151) have also made speckle interferometric observations of the SMC N2 nebula. Morgan+(1985,MN,213,491) have detected 10 additional PN in the SMC, raising the number to 44. Gull+(1986,Wilson,295) presented IUE results on 15 nebulae in the LMC and the SMC. Dopita+(1985,ApJ,297,593) discussed the identification of highly energetic nebulae in the LMC. A series of preprints by Dopita+, to be published in ApJ, discuss various aspects of the LMC PN. Nolthenius+(1987,ApJ,317,62) have surveyed PN in the outer parts of M31, and Lequeux+(1987,AASuppl, 67,169) have made a new survey of PN in M33.

7. NEBULAR EVOLUTION

The dynamical evolution of PN was considered under the Interacting-Stellar-Winds model by Volk+(1985,AA,153,79). Schmidt-Voight+(1987,AA,174,211 and 223) have studied the influence of stellar evolution on the evolution of the nebulae. Balick (1987,AJ,in press) discussed the evolution of PN with respect to structure, ionization and morphological sequences. O'Dell+(1985,ApJ,289,526) formulated a detailed model for NGC 2392.

Theoretical models of PN nuclei were considered by Tylenda (1986,AA,156,217), in an attempt to explain the appearance of double-envelopes in the nebulae.

IX. Intergalactic Medium

(P. Shaver)

This new section in the Commission 34 Report is devoted to the diffuse intergalactic medium (IGM). Thus, halos of galaxies, for example, are not included, and even quasar absorption lines, which may have more to do with galaxies, are referred to here only insofar as they have a bearing on the more diffuse IGM. Symposium or conference proceedings where relevant information can be found are: Mardirossian+, ed.: 1984,"Clusters and Groups of Galaxies",Reidel; Richter+,ed.: 1985,"The Virgo Cluster of Galaxies",ESO,Garching, plus a few cited later.

For the most part the IGM has proved difficult to detect, let alone study in detail, so it is understandable that most of the work has concentrated on hot gas in clusters of galaxies, for which there is a relative abundance of observations. Indirect information about this intracluster medium has been obtained by studying its apparent effect on ejecta from active galaxies, e.g. radio jets and lobes (Spangler+: 1984,AJ,89,1478; Smith: 1984,MN,211,767; Arnaud+: 1984,MN,211,981; Jaffe+: 1984, Mardirossian+,293; O'Dea+: 1985,AJ,90,929; Hanisch+: 1985,AJ,90,1407; Stocke+: 1985,ApJ,299,799; Miller+: 1985,MN,215,799; Jaffe+: 1986,AJ,91,199; Fedorenko+: 1986,Sov.Astron.30,No.1; Feigelson+: 1987,ApJ,312,101). The effects of a dense, hot intracluster medium on gas in galaxies (Giovanelli+: 1985,ApJ,292,404; Balkowski+: 1985, Richter+,37; Haynes: 1985,ibid.45; Warmels: 1985,ibid.51; van Gorkom+: 1985,ibid.61; Giovanelli: 1985,ibid.67; Kennedy+: 1985,ibid.165) and intergalactic clouds (Rephaeli+: 1985,MN,215,453; Sotnikova: 1986,Astrofiz,25,139) have been considered, also the influence of galaxy winds and ejecta on the IGM (Silk: 1984, in Mass Loss from Astronomical Objects,ed. Gondhalekar,128; Kundt+: 1985,AA,142,150).

X-ray emission from intracluster gas has made possible relatively detailed studies - morphology, spectroscopy, inferences regarding density, temperature, and abundances, theoretical models, etc. (Feretti+: 1984,AA,139,50; Gorbatskij: 1984, Astrofiz,20,42; Sotnikova: 1984,Astrofiz,21,415; Bahcall+: 1984,ApJ,284,L29; Stewart+: 1984,ApJ,285,1; Fabricant+: 1984,ApJ,286,186; Chanan & Abramopoulos:1984, ApJ,287,89; Gil'fanov & Sunyaev: 1984,Sov.Astr.Lett.10,137; Ulmer+: 1984, Mardirossian+,307; Kriss+: 1984,ibid.313; Jones+: 1984,ibid.319; Porter: 1984,ibid. 351; Branduardi-Raymont+: 1985,AdvSpRes,5,133; Rothenflug+: 1985,AA,144,431; Gerbal+: 1985,AA,146,119; Konyukov: 1985,Astrofiz,22,163; Matilsky+: 1985,ApJ,291,621; Henrikson+: 1985,ApJ,292,441; Hu+: 1985,ApJSuppl,59,447; Caganoff+: 1985,ProcASA, 6,151; Fabian: 1985,SpSciRev,40,653; Smith+: 1985,ibid.661; Norgaard-Nielsen+: 1985,ibid.669; Henrikson+: 1985,ibid.681; Jones+: 1985,"X-ray Astronomy '84",ed. Oda ISAS,355; Fabricant+: 1985,ibid.381; Rothenflug+: 1985,ibid.391; Gerbal+: 1985, ibid.395; Gerbal+: 1986,AA,158,177; Friaca: 1986,AA,164,6; Henry+: 1986,ApJ,301, 689; Henrikson+: 1986,ApJ,302,287; Ulmer+: 1986,ApJ,303,162; Canizares+: 1986,ApJ, 304,312; Bertschinger+: 1986,ApJ,306,L1; Miller: 1986,MN,220,713; Sarazin: 1986, RevModPhys,58,1). Kowalski+(1984,ApJSuppl,56,403) have analyzed X-ray data on 3600 clusters.

Much theoretical work has concentrated on the possibility of cooling flows (e.g. Pallister: 1985,MN,215,335; Fabian+: 1985,MN,216,923; Fabian+: 1986,ApJ,305, 9). Radio emission (Kotanyi: 1985,Richter+,13; Dennison: 1986,AA,159,251), UV emission (Holberg+: 1985,ApJ,292,16) and γ-rays (Houston+: 1984,J Phys,G10,L147) from intracluster gas have been considered. Vallée+(1987,Ap Lett,25,181) discuss the determination of the intracluster magnetic field by combining rotation measures and X-ray emission. Work has continued on searches for and possible detections of the Sunyaev-Zeldovich effect (Davies+: 1984,Mardirossian+,267; Aliakberov+: 1985, S.S.Astrofiz.Obs.Vyp,48,81; Andernach+: 1986,AA,169,78; Radford+: 1986,ApJ,300,159; Birkinshaw+: 1986,Highlights Astron,7,321; Partridge+: 1987,ApJ,317,112; Chase+: 1987,MN,225,171).

Searches for intergalactic HI clouds have generally been negative (e.g. Altschuler+: 1987,AA,178,16). The discovery of one such cloud in Leo was therefore of great interest, stimulating VLA observations (Schneider+: 1986,AJ,91,13), detection of smaller nearby HI clouds (Schneider: 1985,ApJ,288,L33), infrared and optical searches (Skrutskie+: 1984,ApJ,282,L65; Pierce+: 1985,AJ,90,450; Kibblewhite+: 1985,MN,213,111) with a possible detection in Hα (Reynolds+: 1986,ApJ,309,L9), and interpretations in terms of galaxy interactions (Rood+: 1984,ApJ,285,L5; 1985,ApJ,288,535).

The possibility of intergalactic dust has received further attention (Voshchinnikov+: 1984,Adv Sp Sci,3,443; 1984,Astrofiz,21,401; 1984,Ap Sp Sci,103,301; Shaver: 1985,AA,143,451; de Bernardis+: 1985,ApJ,288,29; Khersonskij+: 1985,Ap Lett,24,217; 1985,Ap Sp Sci,117,179; Evans+: 1985,MN,213,1p; Rudnicki+: 1985,Nuovo Cimento C,8C,368; Tanaka: 1985,PASJ,37,481; Evans+: 1985,Sp Sc Rev,40,701; Reaves: 1985,Richter+,433; Horstmann: 1986,Mitt Astron Ges,65,237; Greenberg+: 1987,Nature,327,214). There is some evidence for extinction of quasars by foreground clusters (Shanks+: 1986,in Quasars,ed. Swarup+,Reidel,37; Phillipps: 1986,Ap Lett,25,19), but no evidence of reddening in the spectra of distant quasars (Steidel+: 1987,ApJ,313,171; Wright+: 1987,preprint).

A new, more stringent limit on HI in the IGM has been set using the Gunn-Peterson test (Sargent: 1987,"Observational Cosmology",ed. Hewitt+,Reidel,777). The photoionization of the high-redshift IGM has been studied (e.g. Shapiro: 1986,PASP,98,1014; Bechtold+: 1987,ApJ,315,180; Bajtlik+: 1987,preprint; Donahue+: 1987,preprint; Barcons+: 1987,preprint), and the possibilities of detecting it through dispersion (Wiita+: 1984,Observatory,104,270; Barcons+: 1985,ApJ,289,33) or refraction (Burke: 1984,ESA-SP,213,153) effects were considered. A 0.6 keV OVIII Lyα absorption feature has been observed in the spectrum of a $z = 0.1$ BL Lac object (Canizares+: 1984,ApJ,278,99), which could be intrinsic (Krolik+: 1985,ApJ,295,104), or possibly from the distributed IGM (Shapiro: 1986,"Galaxy Distances and Deviations from Universal Expansion",ed. Madore+,Reidel,203). Other papers dealt with heating and evolution (e.g. Couchman: 1985,MN,214,137; Barausov+: 1985,Sov Astron Lett,11,372; Ikeuchi+: 1986,ApJ,301,522), molecules (Shchekinov+: 1984,Astr Zh,61,460; MacLow+: 1984,BAAS,16,962; Shchekinov+: 1985,Astr Zh,62,841; Couchman: 1985,MN,214,137; Nakai+: 1986,PASJ,38,603; Shchekinov+: 1986,Pis'ma Astr Zh,12,499), and magnetic fields (Beech: 1985,Ap Sp Sci,116,207; Andreasyan: 1986,Astrofiz,24,363).

It is still unclear whether the IGM contributes significantly to the X-ray background, but many recent papers have dealt with this important question (Marshall+: 1984,ApJ,283,50; Elvis+: 1984,ApJ,283,479; Maccacaro+: 1984,ApJ,283,486; Kowalski+: 1984,ApJ Suppl,56,403; Setti: 1985,"Non-Thermal and Very High Temperature Phenomena in X-Ray Astronomy",ed. Perola+,U. Roma,159; Fabian: 1985,"Observational and Theoretical Aspects of Relativistic Astrophysics and Cosmology",103; Zamorani: 1985,"X-Ray Astronomy '84",ed. Oda+,ISAS,419; Schmidt+: 1986,ApJ,305,68; Tucker+: 1986,ApJ,308,53; Guilbert+: 1986,MN,220,439; Setti: 1986,Mitt Astron Ges Nr,67,133; Anderson+: 1986,"Quasars",ed. Swarup+,Reidel,247; Schmidt: 1986,"Structure and Evolution of AGN",ed. Giuricin+,Reidel,3; Giacconi+: 1987,ApJ,313,20; Segal: 1987,ApJ,313,543; Barcons: 1987,ApJ,313,547).