DIVISION VI / 34 - INTERSTELLAR MATTER

34 INTERSTELLAR MATTER
MATIERE INTERSTELLAIRE

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1. Introduction. (D.R. Flower)

This report covers some of the developments in the field of Commission 34, between the summer of 1993 and 1996. My predecessor, Harm Habing, noted in the last report, published in 1994, "that the traditional way of reporting is no longer adequate and that we have to rethink the format of this periodic report". Some limited progress towards this goal has since been made, and greater discretion is now granted to the organizing committees in the preparation of their reports. The main consequence, as far as Commission 34 is concerned, is that the present report is briefer than in the recent past and makes no pretence at being a comprehensive survey of the literature over the review period. Indeed, "Chemistry" and "Planetary Nebulae" are not covered at all, as they are the topics of recent IAU Symposia (nos. 178 and 180, respectively).

I am very grateful to the members of the organizing committee who have contributed to this report. It is my wish as outgoing president that, if the reports are to continue in the future, they will be made freely available on the WWW in the year of their preparation, rather than a year later, as a volume which has become so expensive that all but the best endowed libraries must hesitate to acquire it.

2. Supernova Remnants. (M. Dopita)

The current reporting period has been characterised by a continuing decline in the more "traditional" optical observations of SNR, but this has been largely offeset by the new results coming in from a wide variety of space missions, BBXRT, HUT, ROSAT, GINGA, and the COMPTON observatory. Much of this work is reported in two conference proceedings published by the Universal Academy Press in Tokyo in 1994; "Frontiers of X-Ray Astronomy", Proceedings of the 28th. Yamada Conference, Nagoya, eds. Y. Tanaka and K. Koyama, ISBN 4-946443-08-8, and "International Conference on X-Ray Astronomy: New Horizon of X-Ray Astronomy-first results from ASCA", Tokyo, eds. F. Makino and T. Ohashi, ISBN 4-946443-22-3.

Another strong growth area has been in the study of extragalactic SNR, where much of the optical work is now concentrated.

The major interest in SNR evolution is now centred about the interaction of the ejecta with the ISM, or the material ejected prior to the supernova explosion. In this context a useful discussion of the background theory can be found in Roger Chevalier's 1994 contribution to the 54th Les Houches Session (p743). Roger is to be congratulated on his elevation to the US Academy of Sciences. A

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general insight into the role of supernova remnants in detemining the overall structure of the ISM can be got from the proceedings of two Manchester Conferences, “The Kinematics and Dynamics of Diffuse Astrophysical Media”, eds. J.E. Dyson and E.B. Carling, 1994, Ap. Space Sci. 216, 1 and 2, and “”Shocks in Astrophysics”, 1995, eds. T.J. Millar and A.C. Raga, Ap. Space Sci. 233, 1 and 2; also published by Kluwer as a separate book ISBN 0-7923-3899-5.

A good website is by Green, D.A. 1995 (”A catalogue of galactic SNR”) at http://www.mrao.cam.ac.uk/surveys/snrs. This contains a very useful summary.

The following report is not intended to be complete, but rather, picks up on the key research highlights of the reporting period.

2.1. YOUNG SNR

2.1.1. *Remnants of Type I SN*

Our understanding of the remnant of SN 1006 has been much improved through space and radio observations. Moffet D.A. + 1993, AJ 106, 1566 measured the expansion of the remnant, and Reynolds, S.P. + 1993 AJ106, 272 has made a polarisation map. GINGA observations are peported by Ozaki, M. + 1994, PASJ, 46, 367, while Fe absorption measurements of the ejecta inside the remnant have been obtained using HST by Wu, C-C. + 1994, ST-ECF/STScI Workshop, ”Science with the HST”, p453.

In Tycho’s SNR, X-ray observations have been used to adduce the knotty structure of the ejecta (Vancura, O. + 1995, ApJ, 441, 680).

2.1.2. *Remnants of Type II SN*

The curious ”jet” in the Crab nebula has been shown to be expanding rapidly by means of optical observations by Fesen, R.A. + 1993, MNRAS, 263, 69. The extraordinary variability of the synchrotron excited wisps near the Crab pulsar has been determined by HST imaging observations. These are not yet formally published, but are available though http://www.stsci.edu/, where other spectacular images of SNR can be found. The secular decline of the radio flux of the Crab nebula is still being monitored at Pushchino. At 927MHz, it is 0.44% per annum , Vinyajkin, E.N. 1993, Pis’ma Ast. Zh., 19, 912. The near IR spectrum of many knots and filaments in the Crab has been studied by Rudy, R.J. + 1994 ApJ, 426,646, while MacAlpine, G.M. 1994 ApJ 432, L131 has made an impressive study of the optical knots. Fabry-perot imaging spectroscopy of both the Crab and of Cas A has been obtained by Lawrence, S.S. + 1995, AJ, 109, 2635.

Amongst the other “plerionic” or filled SNR, Sati-Harb, S. + 1995, ApJ, 439, 722 has made ROSAT observations of CTB80, while in Vela, there is strong evidence for “bullets” of ejecta (Aschenbach, B. + 1995, Nature, 373, 587; Strom, R. + 1995, Nature, 373, 590).

Cas A continues to be studied at radio wavelengths; Anderson, M.C. + 1995, ApJ, 441, 1307 measured the depolarisation of the nebula, and in a companion paper (ApJ, 441, 307) determined the secular change in radio flux, interpreted as decelleration of the remnant. The launch of COMPTEL allows the search for radioactive species ejected by the supernova. In particular, the 1.16 MeV line of 44Ti, which Iyaudin, A.F. 1994, AA 284, L1 seems to have found in Cas A. The observations imply that $10^{-3} \times 10^{-4}$ solar masses were ejected . However, with CGRO/OSSE, the line was not detected (The, L-S. + 1995, ApJ, 444, 244). With ASCA, Holt, S.S. + 1994, PASJ, 46, L151) was able to measure the velocity of expansion of Cas A using the Si K-line at X-ray frequencies.

The young SNR Pup A, G292.0+1.8 and N132D were studied at optical wavelengths by Sutherland, R.S. + 1995, ApJ, 439, 365. These spectra, typical of the O-rich SNR, can be interpreted using a new cloud-shock model in a clumpy ejecta (see theory section, below).

Greiner, J + 1994, AA, 286, L35 has demonstrated that ROSAT can be used to discover young SNR, by finding the remnant G272.2-3.2.

2.2. OLD SNR

2.2.1. *Radio Observations*

The Pushchino catalog of SNR observations at 83, 102 and 111 MHz has now been published (Kovalenko, A.V. 1994, Astron. Rep., 38, 95). High quality radio maps using the VLA have been produced in a series of papers by Dubner, G.M. and collaborators (1993, AJ, 105, 2251; AJ, 108, 207; AJ 111, 1304).

Old SNR have been extensively searched for embedded pulsars, with very little success. Kaspi, V.M + 1996, AJ, 111, 2028 repoert the search of 40 SNR, with only one new potential SNR/pulsar association, that of G335.2+0.1 with PSR J1627-4845. Gorham, P.W. + 1996, ApJ, 458, 257 searched 18 SNR without success.

Amongst studies of individual SNR, one in particular shows evidence for interaction with material ejected earlier in the life of the star, W44 (Koo, B-C. + ApJ, 442, 679).

2.2.2. *Interactions with Molecular Clouds*

The famous case of the interaction of IC 443 with a molecular cloud has been the subject of a number of studies. Inoue, M.Y. + 1993, PASJ, 45, 539 showed that the clumpy stucture of the molecular hydrogen emission made it most likely that both C- and J- shocks are seen together along the line of sight. This is confirmed by the detection of pure rotational excitation of molecular hydrogen by Richter, M.J. + 1995, ApJ, 449, L83. Other molecular and atomic species have been studied, notably CO in the 2-1, 3-2, and 4-3 transitions, and CI (van Dishoeck, E.F. + 1993, AA, 279, 541; White, G.J. 1994 AA, 283, L25).

In RCW 103, Burton, M + 1993 PASA, 10, 327 has mapped both the molecular hydrogen and [Fe II] produced in the shock interaction with a molecular cloud. A radio map of this nebula has been made by Dickel, J.R. + 1996, AJ, 111, 340.

In W 28, Frail, D.A. + 1994, ApJ, 424, L111 has detected shock-excited OH maser emission.

2.2.3. *Optical Observations*

The optical counterpart of G73.9+0.9 has been detected by Lozinskaya, T.A. 1993, Astron. Rep., 37, 240.

The Cygnus SNR has been studied in the coronal lines of [FeX] and [FeXIV] by Sauvageot, J.L. + 1995, AA, 296, 201, who was able to determine the dynamics of the nebula in these species, a remarkable accomplishment. The Balmer-dominated shocked rim of the Cygnus SNR was studied by Hester, J.J. 1994, ApJ, 420, 721.

2.2.4. *Space Based Observations*

Space based observations have been obtained from a wide variety of platforms and in a wide variety of wavebands. Volume 13 of Advances in Space Research (1993) carries a number of reviews of many of these. Specifically, Aschenbach, B , p45 (ROSAT observations), Petre, R + , p57 (BBXRT), Long, K.S., p67 (HUT) and Asaoka, I. + 1193, p277. The most productive X-ray facilities have been ROSAT and ASCA. ROSAT images are available for Kes 79 (Seward, F.D. + 1995, ApJ, 439, 715), CTB80 (Safi-Harb, S. + 1995, ApJ, 439, 722), HB9 (Lehy, D.A. + 1995, AA, 293, 853), 3C400.2 (Saken, J.M. + 1995, ApJ, 443, 231), the Cygnus Loop (Graham, J.R. + 1995, ApJ, 444, 787), W51C (Koo, B-C. + 1995, ApJ, 447, 211) and IC443 (Asoaka, I. + 1994, AA, 284, 573). Indeed, a new SNR has been discovered using ROSAT, G13.3-1.3 (Seward, F.D. + 1995, ApJ, 449, 681).

The COMPTEL and CGRO/OSSE observations of Cas A have already been alluded to in Section 6.1b, above. In addition, Einstein and EXOSAT observations of W44 were given by Jones, L.R. + 1993, MNRAS, 265, 631 while Vancura, O. + 1993, ApJ, 417, 663 gave the EUV spectra observed by Voyager of the Cygnus Loop.

2.3. SNR IN EXTERNAL GALAXIES

The SNR in the Magellanic Clouds have been intensively studied. The Australia Telescope has been used to map most of the bright SNR in the LMC (Dickel, J.R. + 1993, AA, 275, 265 , N63A; Manchester, R.N. + 1993, ApJ, 411, 756, 0540-693; and Dickel, J.R. + 1995, AJ, 109, 200, N132D, N103B, 0519-690). In the SMC Amy, S.W. + 1993, ApJ, 414, 761 have studied 1E0102.2-7219.

The oxygen rich SNR N132D has been subjected to particular scrutiny. High resolution X-ray spectroscopic data from the Einstein Observatory was published by Hwang, U. + 1993, ApJ, 414, 219. Optical and IUE spectrocopy was published by Blair, W.P. + 1994, ApJ, 423, 334. Detailed optical imaging, spectroscopic , and kinematic studies were performed by Sutherland, R.S. + 1995, ApJ, 439, 365 and Morse, J.A. + 1995, AJ, 109, 2104. Space telescope images of this remnant are available from the STScI website.

The Balmer-dominated SNR in the LMC have been observed using high resolution spectroscopy by Smith, R.C. + 1994, ApJ, 420, 286.

Amongst the other O-rich SNR in the Magellanic Clouds, ROSAT HRI X-ray images of 0540-69.3 have been published by Seward, F.D. + 1994, ApJ, 421, 581, and an ASCA spectrum of 1E0102.2-7219 has been obtained by Hayashi, I. + 1994, PASJ, 46, L121.

More generally, Hughes, J.P. + 1995, ApJ, 444, L81 reports on ASCA observations of LMC supernovae, and Rosado, M. + 1993, Rev.Mex.Ast. Ap. 27, 41 and Rosado, M + 1994, AA, 286, 231 give the results on the kinematics of the Magellanic Cloud SNR. Kinematic studies have also, in conjunction with X-ray, radio, and CCD imaging, been used to identify new SNR in the LMC. Smith, R.C. + 1994, AJ, 108, 1266 found two new SNR by this technique, embedded in the Henize nebulae N4D and N9. Similarly, Meaburn, J. + 1995, AA, 293, 532 and Chu, Y-H. + 1995, AJ, 109, 1729 have used these techniques to study the so-called "honeycomb nebula" in the 30 Dor region.

For galaxies further than the LMC, the kinematic technique is also successful, and Yang, H. + 1994, AJ, 107, 651 has discovered SNR in Giant extragalactic HII regions by this method. A number of new SNR candidates have also been identified in M31 (Mangnier, E.A. + 1995, AA, 304, 682).

X-ray observations of external galaxies can also be used to discover new SNR. This was very helpful in confirming the SNR in NGC1313, and Schlegel, E.M. + 1996, ApJ, 456, 187 has even been able to extract the X-ray light curve for this object. During the period of this review an extraordinarily X-ray luminous SNR was discovered in NGC 6946 (Schlegel, E.M + 1994, ApJ, 424, L99), and the optical and radio counterparts have been observed (Blair, W.P. + 1994, ApJ, 424, L103; Van Dyk, S.D. + 1994, ApJ, 425, L77). This remnant has three times the radio luminosity of Cas A and is expanding at 400 km/s.

2.4. THEORY

The fact that SNR evolve into a medium which has been profoundly modified by the prior evolution of the massive star, that the ejecta is certainly clumpy, and shocks themselves may not be stable, has informed a lot of the theoretical work in this field. Numerical simulations of clumpy ejecta have been made for the case of Cas A by Anderson, M.C. + 1994, ApJ, 421, L31. Chevalier, R + 1994, ApJ, 420, 268 has dealt with the problems of circumstellar interaction in Type II SNR. Dynamical studies of the stability of radiative shocks in early SNR have been made by Strickland, R. + 1995, ApJ, 449, 727 and Chevalier, R.A. + 1995, ApJ, 444, 312. Evolution of SNR in the presence of strong magnetic fields has been dealt with by Rozyczka, M. + 1995, MNRAS, 274, 1157. Agaronyan, F.A. + 1994, AA, 285, 645 made predictions that GeV/TeV gamma rays might be produced at observable levels by a SNR/molecular cloud collision. Subsequent observations with EGRET appear to bear this out (Sturner, S.J. + 1995, AA, 293, L17; see also Kirk, J.G. + 1995, AA, 293, L37). The evolution of SNR in pourous media resulting from pre-existing SNR and winds was discussed by Franco, J. + 1994 in the CTS Workshop no. 1 "Evolution of the ISM and the Dynamics of Galaxies", p83. Slavin, J.D. + 1993, ApJ, 417, 187 go so far as to suggest that the

O IV, N V and C IV absorption lines seen in the ISM and gaseous halo of our Galaxy may be produced entirely by a population of old SNR.

Theoretical X-ray spectra for the Kepler SNR were calculated by Decourchelle, A. 1994, AA, 287, 206 and Borkowski, K.J. + 1994, ApJ, 429, 710.

The problem of dust emission and destruction in SNR shocks has been tackled by Dwek, E. + 1996, ApJ, 457, 244. On the other hand, Shmeld, I. 1994, Baltic Ast., 3, 144 has considered the possibility of dust formation.

Finally, the theory of ionising shocks has undergone considerable development. In dense SNR, Franco, J. + 1993, Rev. Mex. Ast. Ap., 27, 133 showed that spectra which look very like those seen in AGN can be seen. A complete shock grid of fast ionising shocks at the low density limit has been given by Dopita, M. A. + 1995, ApJ, 455, 468 and Dopita, M.A. + 1996, ApJS, 102, 161. In the case of the oxygen-rich SNR, the photoionisation effects of the cloud shock were shown by Sutherland, R.S. + 1995, ApJ, 439, 381 to completely dominate over the optical emission of the shock itself, and a very satisfactory agreement with observation was obtained.

3. ISM in Galaxies. (D.M. Elmegreen)

3.1. INTRODUCTION

This report summarizes new research on the interstellar medium in galaxies, based on conferences and books specializing in this subject and published during the period 1993-1995. The review consists of discussions about spiral, dwarf, SO, and elliptical galaxies, as well as interacting systems. Emphasis is placed on radio and optical observations of atomic and molecular gas and star-forming regions, and computer simulations to match and interpret the data. High energy observations, discussions of AGN's, quasars, and LINER's, and clusters of galaxies are included in separate reviews.

3.2. CONFERENCES

The ESO/OHP Workshop on "Dwarf Galaxies" (eds. G. Meylan, P. Prugniel, ESO Conference Workshop Proceedings No. 49, Garching, Germany 1994), held in France in Sept. 1993, reviewed discoveries of HI holes in dwarf galaxies. HI observations of dwarfs show large, expanding cavities inside dense shells (Puche & Westpfahl, p. 273) which suggest a formation from stellar winds and supernovae. Hα observations of star formation are prominent in overlapping shells. These results are supported by HI observations of broad line profiles, indicating high mass star formation and super bubble blow-outs (Meurer, p. 351). Huge HI disks are seen around many blue compact dwarfs (BCD's; Bosma, p. 187). Dark matter may dominate dwarf kinematics (Brinks & Taylor, p. 263). Many dwarfs classified as HII galaxies have small optically invisible HI companions (Taylor, Brinks, & Skillman, p. 287).

Massive HI clumps in the tidal debris of interacting spirals indicates the formation of dwarf galaxies and star clusters there (Mirabel, Duc, & Dottori, p. 371). Galaxies involved in interactions are more metal-rich than typical field dwarf galaxies, and evidently lack large amounts of dark matter even though they have a high mass fraction of HI.

Models of observed far-IR radiation from BCD's suggests giant star forming complexes near their centers (Izotov & Izotov, p. 459).

The Apr. 1993 Kentucky conference on "Mass-Transfer Induced Activity in Galaxies" (Proceedings: International Astrophysics Conference, ed. I. Shlosman, Cambridge University Press, Cambridge, 1994) discussed observational and theoretical ideas of the ISM in interacting systems. Gas inflow models showed that gas inside corotation is driven to the center to form a nuclear ring at the Inner Lindblad Resonance (Combes, p. 170). If the mass concentration is sufficiently high, viscous forces drive matter inside ILR outward, while bar torques pull matter outside the ILR inward, and 2 ILR's can form. There are periodic orbits near the bar, producing strong torques on the gas. Central fueling may form a gas bar, which leads the bar potential, based on 2-D PM and SPH models with self-gravity (Wada & Habe, p. 284). In a barred galaxy, lack of a secondary bar or ILR leads to nuclear infall (Athanassoula, p. 143). Observed isophotal twists in barred galaxies indicate the presence of secondary bars in many barred galaxies (Shaw, Combes, Axon, & Wright, p. 185).

Counter-rotating disks have been observed in many galaxies, including SO's (Fisher, p. 349). Models of counter-rotating disks show that accretion from a prograde disk onto a retrograde disk can trigger radial inflow and starburst activity (Mihos, p. 372). Galaxy formation and later accretion can lead to deposition of material in disks and rings in spirals, E, and polar ring SO's and E's; associated nuclear activity is related to infall from these events, based on multi-dimensional numerical simulations (Christodoulou, p. 289). Cold gas observed in warped disks or rings in ellipticals indicates accretion (de Zeeuw, p. 420), with metallicities in the accreted gas in excess of 0.5 Z_o (Shields & Hamann, p. 450). In the late phases of mergers, efficient gas infall may lead to quasar-like activity, based on numerical dynamical models (Bekki & Noguchi, p. 406). Infall models support observations of non-circular gas motions in CO in the central kpc regions of spiral galaxies (Kenney, p. 78; Turner, p. 90) and central star formation observations in a variety galaxies, including starburst galaxies and barred galaxies with different Hubble types (Kennicutt, p. 131; Devereux, p. 155; Dressel & Gallagher, p. 165; Beck & Kovo, p. 388).

High-resolution optical imaging indicates ring-like structures and central small bars in some nearby galaxies (Knapen & Beckman, p. 100). Star formation rates inferred from these observations suggest that the gas would be exhausted in the central regions on a short timescale without a refueling mechanism (Beckman, p. 160); gas bars are often associated with nuclear star formation activity.

Numerical 3D hybrid SPH/N-body codes suggest that the global stability of the disk may be influenced by the gas in the halo (Shlosman & Heller, p. 274, 279). In interacting galaxies, the gas is very dissipative and may fuel AGN's in central regions (Scoville, Hibbard, Yun, & van Gorkom, p. 191). VLA HI observations of an interacting system (Kaufman, Elmegreen, Brinks, Elmegreen, & Sundin, p. 358) and subsequent models (Kaufman, Elmegreen, & Thomasson, p. 404) suggest that the velocity dispersion of the ISM is increased by the agitation, leading to self-gravitationally bound cloud complexes with the mass of dwarf galaxies. CO and HI observations of interacting systems indicate that spiral structure and central mass concentrations may result from the perturbations (Zhang, Wright, & Alexander, p. 367). Gas appears to be transferred from spirals to ellipticals in E-S pairs (Mello Rabaca, Sulentic, Rampazzo, & Prugniel, p. 392). Gas bridges have been observed at high resolution in HI and radio continuum (Irwin & Caron, p. 362).

Interstellar gas is mixed by radial flows along bars in spiral galaxies, leading to less steep radial O/H gradients in stronger barred galaxies (Martin, p. 177).

The EIPC Astrophysical Workshop in Elba on "Star Formation, Galaxies, and the Interstellar Medium" (ed. J. Franco, F. Ferrini, & G. Tenorio-Tagle, Cambridge University Press, Cambridge, 1993) in June 1992 considered a wide range of star formation topics. An observational review of CO in nearby spirals shows concentrations in the arms (Adler, p. 7; Wakker & Adler, p. 34); high resolution maps of barred galaxies often show twin peaks of emission (Kenney, p. 14). Perturbed galaxies tend to show stronger and more centrally concentrated molecular gas (Braine, p. 25).

Amorphous galaxies often have extensive HI distributions with central concentrations (van Woerden, Hunter, & Gallagher, p. 22). Lenticular galaxies tend to have more molecular than neutral hydrogen mass (Tacconi-Garman, Tacconi, van Woerden, Bradach, & Thornley, p. 38), probably in a ring or central peak.

K band observations of the hotspot galaxy NGC 1808 are consistent with a strong burst of star formation (Tacconi-Garman, Drapatz, Eckart, Genzel, Hofmann, Krabbe, Rotaciuc, Sams, & Sternberg, p. 42). High resolution HI and Hα measurements indicate the presence of a central bar (Koribalski & Dettmar, p. 45), and a fast-rotating gas ring (Koribalski, Dickey, & Mebold, p. 162).

The spatial distribution of [CII] FIR line emission has been mapped in several spirals and Cen A (Madden, Genzel, Poglitsch, Geis, Townes, Stacey, & Jackson, p. 48). The molecular gas in Cen A is strong throughout the dust lane, with temperatures of 10-20K and densities of 5x10^3 to 10^4 cm^{-3} (Wild, Cameron, Eckart, Rothermel, Rydbeck, & Wiklind, p. 31). Far-IR bulge emission in two early type galaxies implies dust heating by older stars rather than just obscured star formation (Smith, Harvey, Colume, Zhang, DiFrancesco, & Pogge, p. 72). Far-IR and radio emission in spirals is linearly correlated. Some of the far-IR comes from dust in HII regions, and some from diffuse dust (Lisenfeld & Volk, p. 76).

Warm molecular gas (30-50K J=6-5 CO) is observed in the nuclei of the starburst galaxies NGC 253 and M82 (Tacconi, Harris, Hills, & Genzel, p. 171), and a multi-line study has been made of M82 (Wild, Harris, Eckart, Genzel, Graf, Jackson, Russell, & Stutzki, p. 181; Walker, Martin, Phillips, & Bash, p. 199). The first submillimeter detections of HCN and HCO+ lines have been made in these galaxies; the central gas density is ten times higher in NGC 253 than in M82 (Jackson, Paglione, Carlstrom, & Nguyen-Q-Rieu, p. 177).

High velocity gas is observed in NGC 6946 near HI holes, and probably results from stellar winds and supernovae (Kamphuis, p. 105). Supergiant HII shells are seen in irregular galaxies (Bomans & Hopp, p. 159). $H\beta$ luminosities and linewidths are correlated with the size of HII galaxies (Telles & Terlevich, p. 156).

Global star formation rates (Hodge, p. 294; Boselli, p. 308; Dettmar, Becker, & Shaw, p. 315; Young, p. 318), histories (Wilding, Alexander, Crane, & Pooley, p. 301), and mass functions (Puxley, Dayon, Joseph, Brand, & Doherty, p. 192) are considered for normal and starburst galaxies and irregulars based on radio continuum, molecular line, and recombination line ratio observations. The role of magnetic fields in star formation is explored (Field, p. 349). Density wave triggering is suggested for some regions of M51 (Knapen, Beckman, & Cepa, p. 332).

Starbursts in tidal debris of interacting galaxies are dwarf galaxy size (Mirabel & Duc, p. 130).

Spatial distributions of molecular gas in galaxies are reviewed in the 1993 Germany conference "The Structure and Content of Molecular Clouds: 25 Years of Molecular Radioastronomy" (eds. T. Wilson & K. Johnston, Springer-Verlag, Germany 1994; Mauersberger & Henkel, p. 293).

The CTS Workshop on the "Evolution of Interstellar Matter and Dynamics of Galaxies" was held in Prague in 1991 (Proceedings, eds. J. Palous, W. Burton, & P. Lindblad, Cambridge University Press, Cambridge, 1992). Supergiant HI shells were reported in the irregular galaxy NGC 2366 (Bomans & Hopp, p. 63). Inner Lindblad Resonance rings may be sites of star formation as a result of tightly wound nonlinear gas density waves excited by disk spiral structure (Yuan, p. 286). Three-arm spirals embedded in multiple-arm disks may be waves generated by two-arm wave modes (Elmegreen & Elmegreen, p. 276). Gas streaming was simulated in M51 and NGC 4736 based on gravitational potential inferred from red images (Combes, Garcia-Burillo, & Gerin, p. 291). Observations of polar rings around elliptical galaxies were reported (Berczik & Kolesnik, p. 383; p. 385). Neutral hydrogen gas dynamics in NGC 1808 were observed (Koribalski & Dahlem, p. 372), and star formation in NGC 2976 was discussed (Brouillet, Notni, Bronkalla, Baudry, & Henkel, p. 406). A multi-phase statistical approach for the star formation history in galaxies, which involves the star formation rates, initial mass function, self-regulation and propagation, and interactions has been developed (Ferrini, p. 304).

IAU Colloquium 140 on "Astronomy with Millimeter and Submillimeter Wave Interferometry" held in Japan in Oct. 1992 (Astronomical Society of the Pacific Conf. Ser., 59, eds. M. Ishiguro & J. Welch, San Francisco, 1994) included many papers on molecular gas in external galaxies. Massive molecular clouds in M51 were observed in arm (Tosaki, Kawabe, & Taniguchi, p. 353) and interarm (Tosaki, Taniguchi, & Kawabe, p. 355) regions. Nuclear outflow producing molecular gas spurs in a tilted distribution outside of a rigidly rotating ring are observed in NGC 3079 (Irwin & Sofue, p. 357), and jets are seen in CO in NGC 4258 (Plante, Handa, & Lo, p., 359). The vertical structure of the gas in NGC 891 has been examined (Handa, Sofue, Ikeuchi, & Ishizuki, p. 361). Molecular clouds in M31 were observed in order to determine the H_2/CO conversion factor (Sofue, Takabayashi, & Murata, p. 366). Correlations between molecular gas and near-IR luminosity in spirals were considered (Hurt, Turner, Levine, Merrill, & Gatley, p. 370).

The ESO/EIPC Workshop on "Structure, Dynamics, and Chemical Evolution of Elliptical Galaxies" (eds. J. Danziger, W. Zeilinger, & K. Kjar, ESO Conf. Workshop Proc., 45, ESO, 1993) was held in Elba in May 1992. Long slit spectra of a sample of 45 early type galaxies were used to determine abundance indices as a function of radius (Danziger, Carollo, Buson, Matteucci, & Brocato, p. 399). Ultraviolet evidence for star formation in a sample of 34 early-type galaxies is not related in a simple way with mergers (Buson, Bertola, Burstein, & Renzini, p. 493). An Hα disk is observed in NGC 5077 (ibid.). Multiphase models for star formation histories in ellipticals (Ferrini & Paggianti, p. 507) and chemical evolution models for ellipticals, including supernova remnants and star formation rates depending on total gas mass and metallicity (Fritze-von Alvensleben, p. 501) are discussed.

Optical and IRAS observations of nearby giant ellipticals shows that dust generally is present due to mergers and interactions (Goodfrooij, de Jong, Norgaard-Nielsen, Hansen, & Jorgensen, p. 579). Counter-rotating gas disks are observed in some S0's (Fisher, Illingworth, Franx, & Rix, p. 585), and gas rotation is observed in several inner bulges (Zasov & Sil'chenko, p. 607). Merger histories are studied via line strengths for 74 E+S0 galaxies (Schweizer, p. 651) and in NGC 4365 (Surma, p. 669). A sample of 185 S0 galaxies was surveyed for ionized gas (Zeilinger, Bertola, & Buson, p. 593). Molecular gas is mapped in several early-type galaxies (Wiklind & Henkel, p. 599; Rangarajan & Fabian, p. 643).

The "Morphological and Physical Classification of Galaxies" International Workshop of the Osservatorio Astronomico de Capodimonte was held in Sept. 1990 in Italy (eds. G. Longo, M. Capaccioli, & G. Busarello, Kluwer, Netherlands, 1992). Gas disks and dust lanes in ellipticals are considered as different views of the same feature (de Zeeuw, p. 139). Low mass HI and CO disks are found in 10% of ellipticals; the HI is extended, while the CO is centrally peaked (van Gorkom, p. 233). Optical emission lines in ellipticals are reviewed and compared with cooling-flow and infall events (Macchetto & Sparks, p. 191). Ionized gas in SO's is considered (Bertola, Buson, & Zeilinger, p. 397; Paquet, Bender, & Seifert, p. 399).

Bar influences on the kinematics of gas disks in spirals, as traced by HI, Hα, and CO, may lead to secular evolution (Bosma, p. 207). A summary of cold gas in late-type spirals is presented (Sancisi, p. 239).

The International Spring Meeting of the Astronomische Gesellschaft in Mar. 1993 in Germany was a "Panchromatic View of Galaxies - Their Evolutionary Puzzle" (ed. G. Klare, Astron. Ges. Abst. Ser., 8, 1993). Many HI and optical studies of gas and star formation in dwarf, irregular, and BCD galaxies are presented (Hunter, van Woerden, & Gallagher, p. 31; Meurer, Carignan, Staveley-Smith, & Killeen, p. 32; Mateo, p. 34; Westpfahl & Puche, p. 35; Bomans & Hopp, p. 36; Gibson & Gallagher, p. 37; Izotov, Guseva, Lipovetsky, & Kniazev, p. 41; James, p. 42; Lo, Sargent, & Young, p. 43; Marlowe, Heckman, Wyse, & Schommer, p. 44; Papaderos, Loose, Fricke, & Thuan, p. 45; Pustil'nik, Thuan, & Lipovetsky, p. 46; Richter, Schmidt, Thanert, & Braun, p. 47; Schmidt & Boller, p. 48; Vilchez, p. 49). Observations of star-forming activity in spirals are discussed (Notni, p. 66; van der Werf, Madden, Poglitsch, Genzel, Krabbe, Geis, & Stacey, p. 68).

Oscillations and bursts of star formation are considered (Firmani & Tutukov, p. 133; Korchagin, Ryabtsev, & Vorob'ev, p. 136). CO observations of barred spirals (Nakai, p. 139) and CO (4-3) in nearby spiral nuclei (Gusten, Serabyn, Kasemann, Schinckel, Schneider, Schultz, & Young, p. 537) are given. Neutral hydrogen high velocity clouds (Schulman, Bregman, Roberts, & Brinks, p. 141) and ionized extraplanar gas (Dettmar, p. 122) are observed in nearby disk galaxies.

Hα, optical, VLA, and CO intensities are compared in IRAS galaxies (van Driel, p. 251).

The Moriond Astrophysics Meeting "Physics of Nearby Galaxies: Nature or Nurture?" was held in France in Mar. 1992 (eds. T. Thuan, C. Balkowski, & J. Tran Thanh Van, Editions Frontieres, France, 1992). HI (Sancisi, p. 31) and CO (Combes, p. 35) gas distributions in normal and interacting disks are discussed. Interacting galaxies have more molecular gas than normal galaxies but comparable atomic gas, suggesting a tidal infall of diffuse ionized gas which cools. Line ratios have been used to determine that O/H abundance gradients exist in barred galaxies but that they are less steep in the bar regions (Martin, Roy, & Belley, p. 101). 3-D N-body simulations show that radial gas transport and secondary bar structure is caused by bars (Friedli & Martinet, p. 527).

Far-IR emission is largely controlled by star formation, but increasing contributions from diffuse cirrus occurs in later type spirals; in early galaxies, heating of dust leads to FIR emission (Thuan

& Sauvage, p. 111). Hα and uv observations of spiral arms provide insight into star formation in NGC 4258, M51, and M31 (Courtes, p. 139).

HI-rich SO galaxies show blue light or Hα structure, which is not present in gas-poor SO's; this result is consistent with a gas density threshold requirement for star formation (Eder, p. 171).

3.3. REVIEWS

The *Annual Review of Astronomy and Astrophysics*, vol. 30, 1992, includes "Warps" by J. Binney, p. 51, which describes 21 cm observations of deviations from planar disks in galaxies and discusses the theory of warping based on a consideration of the halo, infall of gas, and the role of mergers. This volume also includes "Radio Emission from Normal Galaxies" by J. Condon, p. 575, which discusses free-free emission and absorption, synchrotron radiation, cosmic rays, and correlations between FIR and radio emission and star formation rates. J. Barnes and L. Hernquist present "Dynamics of Interacting Galaxies", p. 705, including discussions of tidal bridges and tails, accretions, and mergers in the context of numerical simulations.

The *Annual Review of Astronomy and Astrophysics*, vol. 32, 1994, includes "Physical Parameters along the Hubble Sequence" by M. Roberts and M. Haynes, p. 115. Optical galaxy luminosities are compared with neutral hydrogen and carbon monoxide observations as well as ionized regions and chemical abundances for a wide range of galaxy types.

4. Diffuse interstellar clouds (E.F. van Dishoeck)

The study of diffuse interstellar clouds has greatly benefitted from observational developments in the last 3 years. In the ultraviolet, the Goddard High Resolution Spectrograph (GHRS) on the refurbished *Hubble Space Telescope* has provided important new data on elemental abundances and molecular excitation. Efficient high-resolution spectrographs coupled with CCD detectors on large ground-based optical telescopes have been used to trace the velocity structure of the diffuse gas and survey the diffuse interstellar bands. Submillimeter telescopes and the COBE satellite have been employed to probe the [C I] and high-J CO emission from translucent and high-latitude clouds. Finally, millimeter absorption line studies using interferometers have opened up a whole new line of research on the physical structure and chemistry of diffuse clouds. The proceedings of the "First Symposium on the Infrared Cirrus and Diffuse Interstellar Clouds" (Cutri & Latter 1994) describes the state of our knowledge up to mid-1993. In the following, only a few selected highlights of subsequent years are given. For recent work on dust, and PAH's in diffuse interstellar clouds, see the section on interstellar dust by Martin in this volume. Reviews on diffuse interstellar bands have been given by Herbig (1995) and Tielens & Snow (1995).

4.1. ULTRAVIOLET OBSERVATIONS

An excellent review on recent UV observations is given by Meyer (1997). The high S/N capability of the GHRS has made it possible to accurately measure the gas-phase abundances of several important elements by using very weak (equivalent width $\sim$1 mÅ) unsaturated lines. Specifically, Meyer et al. (1996) have determined the mean interstellar gas-phase oxygen abundance to be only $(3.16 \pm 0.09) \times 10^{-4}$. Since the amount of oxygen tied up in dust grains is unlikely to be larger than 1.8×10^{-4}, this implies that at most 2/3 of the solar oxygen abundance is accounted for in the local interstellar medium.

Cardelli et al. (1996) have found a mean gas-phase carbon abundance of $(1.4 \pm 0.2) \times 10^{-4}$ from the very weak C II] λ2325 intersystem transition toward 6 stars. If the total interstellar carbon abundance is also only 2/3 of the solar value, as in the case of oxygen, this would tightly constrain extinction models which use a lot of carbon in the dust.

Snow et al. (1996) have investigated the elemental abundances in the more highly-reddened, translucent cloud toward HD 154368 using HST. For most species, the depletions are less than found toward ζ Oph.

Searches for new interstellar molecules with strong electronic transitions in the ultraviolet continue. Federman et al. (1995) have reported a 2.4σ feature toward ζ Oph coincident with HCl C–X (0,0) R(0) $\lambda1290$. The same spectrum also shows the first detection of UV absorption from vibrationally excited H_2. The weakness of the H_2 lines suggests that the UV radiation incident on the ζ Oph cloud is less than thought previously, resulting in less UV pumping.

4.2. OPTICAL OBSERVATIONS

Haffner & Meyer (1995) have pushed the faintness limits of the Kitt Peak 4m echelle spectrograph and reported a tentative detection of interstellar C_3. Felenbok & Roueff (1996) have invigorated ground–based searches for the OH A-X $\lambda3078$ band through observations toward 2 stars.

The origin of CH^+ in diffuse clouds continues to be a mystery. Very high resolution ($R = 5 \times 10^5 - 10^6$) observations by Crane et al. (1995) and Crawford (1995) find no velocity differences between CH and CH^+ absorption for a given line of sight. The CH^+ lines are, however, significantly broader than the CH lines, which, in turn, are broader than the CN lines. Gredel et al. (1993) and Gredel (1996) have used lower resolution data to observe these molecules in a larger sample of translucent clouds, and find that the CH^+ column density continues to increase with extinction. These findings are inconsistent with an interpretation in terms of a single shock model. Current favorite scenarios involve CH^+ formation at turbulent interfaces.

Meyer & Blades (1996) have observed high–resolution Ca II and Na I line profiles toward a number of binary systems, many of which show some variation in the line strengths between the two lines of sight. These indicate the presence of (dense) structures on scales ranging from 500 to 20,000 AU. Similar small–scale structure has been inferred by Frail et al. (1994) from multi–epoch H I 21 cm absorption observations toward high–velocity pulsars.

4.3. MILLIMETER ABSORPTION LINES

In the last few years, enormous progress has been made in studying absorption lines of molecules in local diffuse clouds toward extragalactic background sources (quasars, AGN's) (see Lucas & Liszt 1997 for an overview). Lucas & Liszt (1994) and Hogerheijde et al. (1995) showed that the tri–atomic molecules HCO^+ and HCN are remarkably abundant in diffuse clouds, at least two orders of magnitude more than predicted by theory. Lucas & Liszt (1996) have surveyed 30 lines of sight and detected HCO^+ 3 mm absorption approximately 30% as often as 21cm H I absorption.

4.4. (SUB–)MILLIMETER EMISSION LINES

With the improved sensitivity of (sub–)millimeter receivers, the detection of very weak emission lines from diffuse, translucent and high–latitude clouds has become possible. Turner (1995a,b, 1996) has presented a series of papers on the physical and chemical structure of translucent clouds. Gredel et al. (1994) have surveyed the CO emission in a sample of southern translucent clouds previously studied by optical absorption lines toward background stars. Stark & van Dishoeck (1994) and Ingalls et al. (1994) detected [C I] 492 GHz emission from a few high–latitude clouds in which not all carbon has yet been transformed in CO. A global, large scale overview of the atomic fine–structure cooling emission ([C II], [N II], [O I], ...) from diffuse gas in our Galaxy is given by COBE (Bennett et al. 1994).

4.5. THEORY

Theoretical models of diffuse clouds have evolved beyond the steady–state homogeneous, plane–parallel slabs in several ways. Models of the radiative transfer, thermal balance and chemistry in inhomogeneous interstellar clouds of arbitrary geometry have been developed by Spaans (1996) using a Monte–Carlo method. Goldshmidt & Sternberg (1995) have presented time–dependent calculations of the H_2 infrared emission resulting from ultraviolet pumping in low–density PDRs, whereas Lee et al. (1996) have performed time–dependent chemistry calculations. The CO photodissociation and rotational excitation have been re–investigated by Warin et al. (1996), incorporating the most recent experimental data on the CO spectroscopy. Chemical models involving intermittent dissipation of turbulence have been developed by several groups to explain the large abundance of CH^+ (Falgarone et al. 1995, Spaans 1995, Federman et al. 1996). The same models are invoked to produce the observed amounts of HCO^+ in diffuse clouds. Hartquist & Dalgarno (1996) have presented a review of molecular diagnostics in the interstellar medium.

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5. Molecular Clouds. (E. Falgarone)

During the period 1993–1996, a few international conferences have each time gathered a large fraction of the community working in the field of interstellar molecular clouds.

- **"The Cold Universe"**, eds. T. Montmerle, C.J. Lada, I.F. Mirabel & J. Trân Thanh Vân, (Editions Frontières) held in Les Arcs (France) in March 1993
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– **"CO: twenty five years of millimeter wave spectroscopy"**, IAU Symposium 170, eds. W.B. Latter, S.J.E Radford, P.R. Jewell, J.G. Mangum and J. Bally, held in Tucson (USA) in May 1995. The entire text of the proceedings and most of the figures can be collected at the following address: http://www.tuc.nrao.edu/meeting/proceedings/

– **"The Interplay between Massive Star Formation, the Insterstellar Medium and Galaxy Evolution"**, eds D. Kunth, B. Guiderdoni, M. Heydari–Malayeri, Tranh Xuan Thuan, (Editions Frontières), held in Paris in July 1995.

The book **Protostars and Planets III**, eds. E. Levy and J. Lunine (Tucson: University of Arizona Press) is now published and contains a number a review papers on molecular clouds.

It is significant, I think, that most of the titles of these conferences emphasize both the role of the environment upon the evolution of molecular clouds and the strong coupling of the physics and chemistry. The framework in which for instance star formation is now studied extends from the AU scale to galactic scales, and even to that of interacting galaxies in the case of star bursts. This evolution has proven very fruitful, although it has made the problem more complex. There have been many important advances during these last three years but, to my opinion, the most promising is the apprehension that many processes are at work in interstellar dense clouds, that none of them is clearly dominant and and that the size of the systems which have to be considered to describe their physics often exceeds the size of the galaxies themselves. I select a few papers below.

5.1. CO EMISSION AS A TRACER OF MOLECULAR CLOUDS

Surveys of the sky in the rotational lines of CO have been extended to regions out of the galactic plane (Dame & Thaddeus 1994 ApJL 436 L173) and outside the Solar circle (Digel + 1994 ApJ 422 92). The improved sensitivity of these surveys progressively reveals that CO is ubiquitous, raising the issue of its formation and destruction processes (May + 1993 AAS 99 103). In particular, if the high z CO is ejected from the plane, it has to be by a mechanism which does not destroy the molecule, or CO has to be reformed efficiently in the unshielded regions. These surveys also revealed regions of active star formation outside the edge of the "optical disk" up to 28 kpc from the Galactic Center (de Geus + 1993 ApJL 413 L97).

A CO(J=2–1) survey of the first quadrant (Sakamoto + 1995 ApJS 100 125) compared to a previous CO(J=1–0) survey at the same angular resolution provides an average value R=0.66 for the J=2–1/J=1–0 line intensity ratio. This ratio decreases with increasing galactocentric radius.

The validity of the CO(J=1-0) emission as a tracer of the molecular mass is still questioned. Results provided by EGRET, the high energy γ–ray telescope aboard the Gamma–Ray Observatory, confirm that at large scale in nearby star forming complexes, the integrated emission of ^{12}CO(J=1-0), W(CO), is a good tracer of the mass of H_2 and that the ratio $X=N(H_2)/W(CO)$ does not differ much from the values deduced from other mass calibrators. The best average for local clouds, at the scale of $\sim$ 3pc, is $X=(1.1\pm 0.2)\times 10^{20}\mathrm{cm}^{-2}$ $(\mathrm{K\ km\ s}^{-1})^{-1}$ (Hunter + 1994 ApJ 436 216; Digel + 1995 ApJ 441, 270).

Another independent estimate of the total mass of nearby complexes is provided by the COBE/DIRB results of Wall + (1996 ApJ 456 566). The gas mass, at the scale of one hundred parsecs, is derived from the submillimeter dust emission. The mass determinations in the Orion complex are in remarkable agreement with those deduced from the CO(J=1-0) emission. Values of the X factor deduced from a CO survey at high latitude (Heithausen + 1993 AA 268 265) combined with the associated IRAS far–infrared emission are also comparable.

5.2. THE SCALING LAWS

Further works have confirmed and extended to either smaller scales or different environments the existence of scaling laws between the mass, size and internal velocity dispersion of molecular clouds, and in particular the analysis of the ^{13}CO(J=1–0) survey at high angular resolution of the Orion A and B molecular complexes (Miesch & Bally 1994 ApJ 429 645).

Searches for a correlation length in the velocity field are still negative (Kitamura + 1993 ApJ 413 221) which suggests that the accessible scales of molecular clouds are still smaller than energy injection scale and larger than the dissipation scale. The range over which self–smilarity holds is therefore now larger than four orders of magnitude. Pfenniger & Combes (1994 AA 285 94) have built a fractal model of the entire hierarchy of molecular clouds in which the structure only results from gravitational fragmentation, down to scales of ~ 10AU.

5.3. THE DENSITY STRUCTURE

At large scales, several giant molecular complexes have been mapped in the CO isotopic lines (Dobashi + 1994 ApJS 95 419; Williams + 1995 ApJ 451 252; Mizuno + 1995 ApJL 445 L161; Heyer + 1996 ApJ 463 630; Onishi + 1996 ApJ 465 815). The large dynamical range of the recent maps provides an unprecedented census of the statistical properties of the molecular gas distribution (clump mass spectra, average properties of dense cores, ...). A detailed comparison of the ^{13}CO(J=1–0) emission in the Taurus–Auriga complex with the continuum emission of cold dust (i.e. with a brightness ratio I(60μm)/I(100μm) smaller than the average value of 0.2 for the Galactic plane) shows that they both trace the same cold and dense component inside molecular clouds and that this component is structured into very elongated filaments with aspect ratios larger than 10 (Abergel + 1994 ApJL 423 L59). A general finding is the existence of small structures of gas denser than 10^4cm^{-3} even in low average column density environments like high latitude clouds (Reach + 1995 ApJ 441 244).

New results seem to further support these findings. Observations of H_2CO in absorption against extragalactic sources have confirmed a short term variability in the shape of the absorption profiles (Marsher + 1993 ApJL 419 L101; Moore & Marscher 1995 ApJ 452 671). This time variability is interpreted as the probe of the existence of small scale structure down to ~ 50AU in quiescent molecular clouds (Marsher & Stone 1994 ApJ 433 705). It cannot be due only to small scale variations of chemical abundances because the derived densities (~ 10^5cm^{-3}) are much larger than the average density of clouds but these observations leave open the question of the amount of mass contained in these small scale structure.

In photon dominated regions, small scale structure has also been detected in the v=1–0 S(1) line of H_2 (in NGC 2023, Field + 1994 AA 286 909; in NGC 7023, Lemaire + 1996 AA 308 895; in the Orion bar, van der Werf + 1996 AA 313 633). This structure in the H_2 line is likely tracing that of the densest regions of the dark material where H_2 molecules are being photodissociated.

In low mass dense cores, small scale structure has been found also down to the smallest accessible scales in nearby molecular clouds. The high density tracers used by Langer + (1995 ApJ 453 293) in TMC1 confirm that these structures are dense, although it is not yet possible to determine which fraction of the cores mass lies in these structures. The above observations have been performed with an unprecedented velocity resolution of 0.008 km s^{-1} which shows that the velocity dispersion at these scales is not yet thermal but is due to subsonic turbulence. A similar conclusion is reached by Fuller & Myers (1993 ApJ 418 273) with HC_3N lines. In the pre–protostellar core L1498 (Lemme + 1995 AA 302 509; Kuiper + 1996 ApJ 468 761) significant differences are found in the maps of various molecules (CCS, CS, C_3H_2, NH_3). These are interpreted as due to time–dependent effects in the chemistry.

In high mass dense cores, Bergin + (1996 ApJ 460 343) and Zhou + (1994 ApJ 428 219) derive from CS multi–line observations that the gas is clumped into very high density unresolved structures. Systematic searches for dense cores of large column densities using the submillimeter emission of cold dust at 800μm or 1.3 mm have provided independent measurements of the density distribution within these dense cores (André + 1993 ApJ 406 122; André & Montmerle 1994 ApJ 420 837; Ward–Thomson + 1994 MNRAS 268 276; Bontemps + 1995 AA 297 98) which can now be confronted with core models.

The detection of large amounts of atomic carbon in molecular clouds is also confirmed (Plume + 1994 ApJL 425 L49, Minchin 1995 AA 301 894 in S140; Schilke + 1995 AA 294 L17 in TMC1; White + 1995 AA 299 179 in Orion; Tauber + 1995 AA 297 567 in the Orion bar). It could result from the deep UV penetration inside clouds due to their high degree of fragmentation but also be a consequence of turbulent diffusion (Xie + 1995 ApJ 440 674) or chemical bistability in dark clouds (Le Bourlot + 1993 ApJL 416 L87; 1995 AA 297 251).

5.4. TURBULENCE

Further works have been dedicated to the statistical characterization of the non–thermal part of the velocity field of molecular clouds, i.e. randomness as opposed to turbulence or waves (Dubinski + 1995 ApJ 448 226; Falgarone + 1994 ApJ 436 728). The impact of the intermittency of the energy dissipation in turbulence upon the thermal balance of interstellar clouds (Falgarone & Puget 1995 AA 293 840) and the induced chemistry (Falgarone + 1995 AA 300 870) has been estimated.

A very unique set of observations with the Plateau de Bures interferometer has cast additional doubt on our understanding of molecules in interstellar clouds. Molecules like C_2H, HCO^+, HCN, HNC, CN, N_2H^+ ... extremely difficult to detect in low density environments because of the high dipole moment of the rotational transitions, have been detected in absorption against extragalactic continuum sources (Lucas & Liszt 1993 AA 276 L33; 1994 AA 282 L5; 1996 AA 307 237). The HCO^+ absorption line survey of Lucas & Liszt (1996 AA 307 237) discloses an extremely good correlation between the OH and HCO^+ column densities along these lines of sight. Similar detections have been obtained with the Owens valley interferometer (Hogerheijde + 1995 ApJ 441 L93). The lines of sight sample ordinary interstellar gas and areas where even CO is not detected. An efficient formation process has to be invoked to explain the large column densities observed in regions of low average obscuration. One possibility is that they form in the regions of intermittency of turbulence.

5.5. MAGNETIC FIELD AND MHD WAVES

New measurements of Zeeman splitting have provided determinations of the average line of sight component of the magnetic field (Crutcher + 1993 ApJ 407 175 from OH lines; Goodman & Heiles 1993 ApJ 424 208; Myers + 1995 ApJ 442 177 from the HI line). OH and HI lines provide magnetic field intensities of the order of 10 to 20μG. In general, the average magnetic energy is found to be comparable to the average non–thermal kinetic energy. Upper limits of 100 μG have been obtained with CN lines in star forming regions (Lazareff + 1996 ApJ 456 217). Polarization measurements at 2μm do not provide any significant difference between the polarization direction in the visible range and in the near IR although the cloud depth sampled by 2μm measurements is larger. This may suggest that the measurements are dominated by the polarization of the signal along the line of sight (Goodman + 1995 ApJ 448 748).

Several papers analyze the role of MHD waves in supporting the clouds against self-gravity. Zweibel & McKee (1995 ApJ 439 779) establish a link between the non–thermal kinetic energy, the only directly observable quantity, and the unseen sources of energy (magnetic and gravitational). Gammie & Ostriker (1996 ApJ 466 814) and Fatuzzo & Adams (1993 ApJ 412 146) analyze the effects of non–linear Alfvèn waves and their dissipation rate on the dynamical evolution of clouds and their support against self–gravity. McKee & Zweibel (1995 ApJ 440 686) compute the pressure due to MHD waves inside clouds, its dependence with density and the implication of this dependence upon the gravitational stability criterion. Tagger + (1995 AA 299 940) compute the long term decoupling between neutrals and magnetic field (and ions) in Alfvèn waves and show that neutrals and magnetic field expel each other.

Global descriptions of the dynamical evolution of the interstellar medium at the kiloparsec scale in a spiral galaxy, have been proposed, on the basis of 2–dimensional simulations of compressible turbulence with self–gravity and magnetic field (Vasquez-Semadeni + 1995 ApJ 441 702; Passot + 1995 ApJ 455 536).

5.6. RADIATIVE TRANSFER CALCULATIONS

Significant improvements in the understanding of the millimeter line emission from molecular clouds, have been produced. Monte Carlo simulations of the emission of an assembly of randomly moving clumps show that a fundamental feature of millimeter lines, namely their Gaussian shapes despite their high optical depth, is reproduced for clumps occupying a small volume filling factor in a cloud with a velocity dispersion much larger than their internal velocity dispersion (Park & Hong 1995 300 890).

Kegel + (1993 AA 270 407) on the other hand have pursued their approach of radiative transfer calculations in a turbulent medium of uniform density with a random velocity field, the correlation length of which is varied compared to the photon mean free path. Their results in some sense are the same as those obtained with the clump models i.e. the features of the CO lines are best reproduced in a velocity field with large velocity correlation length.

5.7. GRAVITATIONAL STABILITY OF DENSE CORES

A few candidates of collapsing structures may have been found according to their spectral signatures (Wang + 1995 ApJ 454 217; Choi + 1995 ApJ 448 742; Myers + 1995 ApJL 449 L65). The spectral signatures are extremely difficult to analyze, though. In particular infall and outflows seem to be both present in L1527 (Zhou + 1996 ApJ 466 296).

The radiative cooling rates of dense molecular cores have been computed by Neufeld + (1995 ApJS 100 132) for cold cores and by Neufeld & Kaufman (1993 ApJ 418 263) for warm cores.

Computations of the evolution of self–gravitating dense cores with ambipolar diffusion confirm that the time scale for dense core formation is sigificantly longer than the free–fall time in dense gas (Mouschovias & Psaltis 1995 ApJ 444 L105; Basu & Mouschovias 1994 432 720; 1995 452 386; 1995 453 271).

Galli & Shu (1993 ApJ 417 220) analytically follow the evolution of singular isothermal spheres in a uniform magnetic field and find that the presence of magnetic field does not significantly modify the solutions with no field.

6. Interstellar Dust. (Peter G. Martin)

In June 1996 a scientific symposium was hosted by NASA Ames Research Center. Two publications based on this meeting will provide a welcome introduction to many current research topics involving interstellar dust, its properties, and its importance in many astrophysical processes. The first, containing the invited review talks, is "From Stardust to Planetesimals" (Pendleton, Y.J. and Tielens A.G.G.M., eds., 1997, Astronomical Society of the Pacific Conference Series, San Francisco: BookCrafters). Poster papers are summarized in "From Stardust to Planetesimals: Contributed Papers" (Kress, M., Tielens, A.G.G.M., and Pendleton, Y.J. eds., 1997, NASA CP-xxxx).

A year earlier a conference was held on "Polarimetry of the Interstellar Medium" at Rensselaer Polytechnic Institute (Roberge, W. G. and Whittet, D.C.B., eds., 1996, Astronomical Society of the Pacific Conference Series, 97, San Francisco: BookCrafters). Beginning with general properties of dust, this comprehensive collection focusses on polarization caused by dust, whether by extinction, emission, or scattering, and covering ultraviolet to submillimetre wavelengths.

Complementary material on dust and molecules can be found in the proceedings of the first conference ever held on "The Diffuse Interstellar Bands" (Tielens, A.G.G.M., and Snow, T.P., eds., 1995, Kluwer: Dordrecht).

ISO is bringing spectacular new information on dust, particularly spectroscopic clues to the identity of icy mantles in cold dense regions of the interstellar medium. Many of the new ISO results are summarized in a special volume of Astronomy and Astrophysics (October, 1996).

7. Star Formation. (Bo Reipurth)

The number of studies in the field of star formation has continued the rapid increase of recent years, as testified by the large number of meetings and proceedings. Perhaps the most important finding of the past three years has been the identification of what appears to be the long sought protostars, thanks to advances in sub-millimeter detectors. Also, in the same period observations with a variety of techniques have firmly established that binarity among young stars is at least as common as on the main sequence. Finally, observations of star forming regions with the *Hubble Space Telescope* appeared during the past three years, in particular showing details of exposed circumstellar disks around young stars in Orion, and revealing astonishing details in the structure of Herbig-Haro jets. These and many other results are discussed in the numerous proceedings and review articles listed below.

The *Star Formation Newsletter*, a monthly electronic publication dedicated to early stellar evolution and molecular clouds, provides easy and rapid access to the latest results in these fields. At the time of writing, fifty issues have appeared. Researchers and students who wish to be on the mailing list can contact the editor, Bo Reipurth, at reipurth@eso.org.

In the following, major publications in the period under review, are listed.

7.1. BOOKS, PROCEEDINGS, REVIEW ARTICLES 1 JULY 1993 - 30 JUNE 1996

7.1.1. *Books and Proceedings*

1. Protostars and Planets III, Eds. E.H. Levy & J.I. Lunine, University of Arizona Press 1993, ISBN 0-8165-1334-1.
2. Astrophysical Jets, Eds. D. Burgarella, M. Livio & C.P. O'Dea, Space Telescope Science Institute Symposium Series vol. 6, Cambridge University Press 1993, ISBN 0-521-44221-4.
3. Stellar Jets and Bipolar Outflows, Eds. L. Errico & A.A. Vittone, Astrophysics and Space Science Library vol. 186, Kluwer Academic Publishers 1993, ISBN 0-7923-2521-4.
4. Star Formation and Techniques in Infrared and mm-Wave Astronomy, Eds. T.P. Ray & S.V.W. Beckwith, Lecture Notes in Physics vol. 431, Springer Verlag 1994, ISBN 0-387-58196-0.
5. Stellar and Circumstellar Astrophysics, Eds. G. Wallerstein & A. Noriega-Crespo, Astronomical Society of the Pacific Conference Series vol. 57, 1994, ISBN 0-937707-76-7.
6. The Nature and Evolutionary Status of Herbig Ae/Be Stars, Eds. P.S. The, M.R. Perez & E.P.J. van den Heuvel, Astronomical Society of the Pacific Conference Series vol. 62, 1994, ISBN 0-937707-81-3.
7. Clouds, Cores and Low Mass Stars, Eds. D.P. Clemens & R. Barvainis, Astronomical Society of the Pacific Conference Series vol. 65, 1994, ISBN 0-937707-84-8.
8. Planetary Systems: Formation, Evolution and Detection, Eds. B.F. Burke, J.H. Rahe, E.E. Roettger, Kluwer Academic Publishers 1994, ISBN 0-7923-2895-7.
9. The Structure and Content of Molecular Clouds, Eds. T.L. Wilson & K.J. Johnston, Lecture Notes in Physics vol. 439, Springer Verlag 1994, ISBN 3-540-58621-0.
10. Circumstellar Dust Disks and Planet Formation, Eds. R. Ferlet & A. Vidal-Madjar, Editions Frontieres 1994, ISBN 2-86332-173-0.
11. The Cold Universe, Eds. T. Montmerle et al., Editions Frontieres 1994, ISBN 2-86332-150-1.
12. Violent Star Formation from 30 Dor to QSOs, Ed. G. Tenorio-Tagle, Cambridge University Press 1994, ISBN 0521472776.
13. Molecular Clouds and Star Formation, Eds. C. Yuan & J. You, World Scientific 1995, ISBN 9810218710.
14. The Physics and Chemistry of Interstellar Molecular Clouds, Eds. G. Winnewisser & G.C. Pelz, Lecture Notes in Physics vol. 459, Springer Verlag 1995, ISBN 3-540-60482-0.
15. Circumstellar Matter 1994, Eds. G.D. Watt & P.M. Williams, Astrophys. & Space Sci. vol. 224, 1995.
16. Circumstellar Disks, Outflows and Star Formation, Eds. S. Lizano & J.M. Torrelles, Rev. Mexicana Astron. Astrofis. Serie de Conferencias vol. 1, 1995.

17. Gaseous Nebulae and Star Formation, Eds. M. Pena & S. Kurtz, Rev. Mexicana Astron. Astrofis. Serie de Conferencias vol. 3, 1995.
18. Disks and Outflows around Young Stars, Eds. S.V.W. Beckwith et al., Lecture Notes in Physics vol. 465, Springer Verlag 1996, ISBN 3540613897.
19. Chondrules and the Protoplanetary Disk, Ed. R.H. Hewins, R.H. Jones & E.R.D. Scott, Cambridge University Press 1996, ISBN 0521552885.
20. The Interplay between Massive Star Formation, the ISM, and Galaxy Evolution, Eds. D. Kunth et al., Editions Frontieres, ISBN 2-86332-194-3.
21. The Role of Dust in the Formation of Stars, Eds. H.U. Kaufl & R. Siebenmorgen, Springer Verlag 1996, ISBN 3540614621.

7.1.2. *Review Articles (not included in the above proceedings)*

1. Herbig-Haro Jets from Time-Dependent Sources, A.C. Raga, Astrophys. & Space Sci. 208, 163, 1993.
2. Young Bipolar Nebulae, H.J. Staude & H. Elsaesser, The Astron. Astrophys. Rev. 5, 165, 1993.
3. Millimeter and Submillimeter Interferometry of Astronomical Sources, A.I. Sargent & W.J. Welch, Annual Review Astron. Astrophys. 31, 297, 1993.
4. Theoretical, Observational, and Isotopic Estimates of the Lifetime of the Solar Nebula, F.A. Podosek & P. Cassen, Meteoritics 29, 6, 1994.
5. Abundances in the Interstellar Medium, T.L., R.T. , Annual Review Astron. Astrophys. vol. 32, 191, 1994.
6. Pre-Main Sequence Binaries, R.D. Mathieu, Annual Review Astron. Astrophys. 32, 465, 1994.
7. The Rotational Evolution of Low-Mass Pre-Main Sequence Stars, J. Bouvier, in Cool Stars, Stellar Systems, and the Sun, ed. J.P. Caillault, ASP Conf. Ser. vol. 64, 1994.
8. Early Stellar Evolution, S.W. Stahler, Pub. Astron. Soc. Pacific 106, 337, 1994.
9. Radio Continuum Observations of Disks and Young Stars, L.F. Rodriguez, Rev. Mexicana Astron. Astrofis. 29, 69, 1994.
10. The Observational Study of Herbig-Haro Shock Waves, K.H. Bohm, in Shocks in Astrophysics, eds. T. Millar & A.C. Raga, p. 11, Kluwer 1995.
11. Coupled Stellar jet/Molecular Outflow Models, A.C. Raga, in Kinematics and Dynamics of Diffuse Astrophysical Media, eds. J. Dyson & E. Carling, p. 105, Kluwer 1995.
12. The Inventory of Interstellar Materials available for the Formation of the Solar System, S.A. Sandford, Meteoritics 31, 449, 1996.
13. The Birth of Stars: Herbig-Haro Jets, Accretion and Protoplanetary Disks, J. Bally, J. Morse, B. Reipurth, in STScI/ST-ECF Workshop Science with the Space Telescope-II, eds. P. Benvenuti, F.D. Macchetto, E.J. Schreier, 1996.
14. Radio Jets in Young Stellar Objects, G. Anglada, in Radio Emission from Stars and the Sun, Eds. A.R. Taylor & J.M. Paredes, p. 3, ASP Conf. Ser. vol. 93, 1996.
15. Radio Emission as a Probe of Large-Scale Magnetic Structures around Young Stellar Objects, P. Andre, in Radio Emission from Stars and the Sun, Eds. A.R. Taylor & J.M. Paredes, p.3, ASP Conf. Ser. vol. 93, 1996.
16. The FU Orionis Phenomenon, L. Hartmann & S.J. Kenyon, Annual Review Astron. Astrophys. vol. 34, 207, 1996.
17. Bipolar Molecular Outflows from Young Stars and Protostars, R. Bachiller, Annual Review Astron. Astrophys. vol. 34, 111, 1996.

8. H II regions. (Michael Rosa)

8.1. GENERAL

About a century after the first successful recording of an H II region spectrum by Henry Draper in 1882, and almost 70 years after the identification of the "Nebulium" lines with forbidden transitions of [O III] by Bowen in 1928, the analysis of H II region spectra is a widely utilized tool to obtain ionization conditions and chemical abundances for research in topical fields such as stellar evolution and nucleosynthesis, galactic evolution and cosmology. Thus the routine work related to H II regions is to a very large extent published in regular journals and may be conveniently found either through these journals indices, the Astronomy and Astrophysics Abstract Series or via the search engines on the World Wide Web.

8.1.1. *Open issues*

Clearly the superior resolving power of the HST has provided us in the visual wavelength range with an unprecedented insight into the complexity of real H II regions (eg. O'Dell & Wong, AJ 111, 846, 1996 and references therein). Such images remind us about the still unresolved question about the intrinsic accuracy of the various methods available for chemical abundance analysis. What is the impact of density inhomogeneities on ionization and temperature structure; are these the long discussed temperature fluctuations? Will the spatial integration of the spectrum of a remote H II region smear out any such detail, and will it therefore come closer to the idealized case of homogeneous photoionization models? Which is the "true" local ISM reference abundance: the solar system [O/H], or that of H II regions, at about 0.2 dex lower?

8.2. PROGRESS REVIEW

The progress in the field, which is largely due to improved instrumentation, updated atomic data and more complex photoionization codes, as well as the open issues, have been very comprehensively reviewed by Harriet L. Dinerstein (in "Cosmic Abundances", ASP Conf. Ser. 99, 1996, p 337), including a very contemporary list of primary references.