34 INTERSTELLAR MATTER

MATIERE INTERSTELLAIRE

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1. INTRODUCTION. (H.J. Habing) This report covers developments in the field of commission 34 between summer 1990 en 1993. Once upon a time, twenty odd years ago, interstellar matter could be studied practically only inside our Galaxy; now emission lines of CO and H_2O have been detected in a galaxy, IRAS10214+4724, at $z= 2.286$. Other detections, of absorption lines seen against quasars, preceded these discoveries, but nevertheless, the still somewhat uncertain emission line measurements are a breakthrough.

Because interstellar matter is now studied deep in the universe, the subject has grown; but it has also grown because more astronomers are involved and many new observational possibilities are continuously realized; the HST is a recent example, millimeter interferometry another. It is the task of commisison 34 to monitor developments in its field of competence and to advise the General Assembly and the Executive Committee of the Union. Traditionally the commission also writes a full report of all the developments in its field of competence. It has become clear that the field is growing so rapidly that the traditional way of reporting is no longer adequate and that we have to rethink the format of this periodic report, why it is needed, and how we find a practicable way to produce a report of a sufficiently wide scope and of acceptable quality.

I thank those members of the Scientific Organizing Committee that contributed to this report at the expense of considerable amount of their time.

2. MOLECULAR CLOUDS. (E. Falgarone)

The evolution of the ideas in this field is largely driven by that of the observing capabilities (larger telescopes, higher frequencies, more sensitive receivers, airborne observations) and that of computers. Sensitive receivers in the millimeter and submillimeter domains allow much faster detections and large dynamical ranges are thus reached in maps of molecular lines. Observations at high altitude (balloons and plane) considerably increase the range of transparent windows through the atmosphere. High angular resolution reached by large telescopes, interferometers and the raise in frequency, provides information on the structure of clouds and star forming regions down to about 100AU. The rapid development of large array cameras in the near infrared provide unprecedented census of the content of young stellar objects (YSOs) over large areas of clouds. The observational improvements are powerfully complemented by the rapid development of parallel computers which allow some of the sophisticated numerical simulations highly desired to approach the complexity of the evolution of interstellar clouds.

2.1 - STRUCTURE

2.1.1 Scale invariant structure of molecular clouds

Large scale maps, mostly in CO and isotopic lines (up to the third rotational transition J=3-2) allow a better approach to the spatial distribution of molecular gas. The considerable increase of the dynamical range between resolution and map sizes and in integrated intensity reveals the self-similarity of the distribution of molecular gas in space and velocity-space. A large degree of connectivity is found at all scales (over four orders of magnitude in size) and the complex structure (filaments, knots....) of the molecular gas is quite reminiscent of what the IRAS sky survey has revealed in the far-infrared. The large scale maps also show the existence of widespread low intensity CO emission and that the decomposition in terms of clumps, a simplifying assumption for modelling, is not alway meaningful. A sensitive survey of a part of the galactic plane (Lee + 1990 ApJ 355 536) reveals the connectivity of the CO emission at very low levels. A new CO

J. Bergeron (ed.), Reports on Astronomy, Vol. XXIIA, 367–397.

survey of the outer arm of the Galaxy reveals giant molecular clouds comparable in size and mass to the inner Galaxy complexes but underluminous in CO (Digel + 1990 ApJL 357 L29). Yet unpublished very sensitive CO observations of the gas layer far out the galactic plane by Dame and Thaddeus also reveal that the CO gas layer extends at higher z than previously thought.

Large data sets now exist at high (or moderate but over larger areas) angular resolution in non-star forming regions. They allow for the first time a broad view of the link between the various components of the cold interstellar medium, and that with young stellar associations.

A survey of a fraction of the high latitude sky has been performed by Heithausen + (1993 AA 268 265). The detected CO clouds are not different than any other molecular clouds. It is the low column density (or low mass) tail of the cloud distribution.

Extensive work has been done on individual high latitude clouds, in MBM 12 (also called L1457 and L1458) in ^{13}CO(J=1–0) by Pound + (1990 ApJ 351 165) with the BTL antenna, in ^{13}CO(J=2–1) by Zimmermann and Ungerechts (1990 AA 238 337) with the KOSMA telescope, and IRAM–30m telescope (Zimmermann, PhD Köln University, 1993), in the Polaris flare by Heithausen + (1990 ApJL 353 L45), Grossman + (1992 AA 264 195), in the HI cloud associated with a molecular cloud in Ursa Majoris by Joncas + (1992 ApJ 397 165).

In the ρ Ophiuchus complex, large scale and very sensitive maps have been done in the ^{13}CO(J=1–0) line by Nozawa + (1991 ApJS 77 647) and in the ^{12}CO(J=1–0) line by de Geus + (1990 AA 231 137). HI, 100μm and molecular emissions are compared at large scale in de Geus and Burton (1991 AA 246 559) for the entire complex associated with ρ Ophiuchus.

In the Taurus–Auriga complex, smaller maps exist in L1495 (Kramer + 1991 AA 251 382) and NGC 1499 (or the California nebula) in Herbertz + (1992 AA 249 483)

In Orion, a ^{13}CO(J=1–0) and CS(J=2–1) survey has been performed with the NRO–45m antenna by Tatematsu + (1993 ApJ 404 643).

For star-forming regions, surveys of gas associated with clusters now exist in CO (Leisawitz 1990 ApJ 359 319) and at HI λ 21cm (de Geus and Leisawitz, 1991 ApJS 75 835). For the first time, the interaction of stars with the interstellar medium has been studied at large scale in the Scorpio–Centaurus complex by de Geus (1992 AA 262 258). It reveals that the influence of a young stellar cluster extends up to about 100 pc, even more.

New statistical approaches to the gas distribution over a wide range of scales have been developed along various lines of thoughts. Analysis in terms of "structure tree" by Houlahan and Scalo (1990 ApJS 72 133; 1992 ApJ 393 172), of fractals by Dickman + (1990 ApJ 365 586), Falgarone + (1991 ApJ 378 186), Zimmermann and Stutzki (1992 Physica A 191 79), Hetem and Lepine (1993 AA 270 451), of wavelet transforms by Henriksen (1990 ApJL 365 L27) and Langer + (1993 ApJL 408 L45) quantify the scale invariance and the correlations in the spatial distribution of molecular gas.

The self–invariant behavior of the cloud structure is possibly related to the turbulent nature of the flows in molecular clouds although other interpretations have been proposed as, for example, the structure generated by collisional fragmentation, Nozakura (1990 MN 243 543). See also section 1.4.

2.1.2 Density structure

Large maps of star–forming regions now exist in several millimetric and submillimetric transitions of many molecules, complemented by maps in the continuum which trace the dust emission up to submillimeter frequencies. Such maps allow in principle the determination of the density and temperature structures although the difficulties met at interpreting the data are often more serious than anticipated, due, for example, to radiative pumping of excited levels by infra–red photons originating in star–forming regions.

Important data sets in nearby molecular clouds are those of Loren + 1990 (ApJ 365 269) for cores in the ρ Ophiuchus complex, Castets + (1990 AA 234 469) and Dutrey + (1993 AA 270 468) in Orion A, Bachiller + (1990 AA 236 461) in Barnard 1, Wilson + (1990 AA 239 305) in DR21/W75, Montalban + (1990 AA 233 527) and Henning + (1992 AA 263 285) in Monoceros R2, and Boden and Heithausen (1993 AA 268 255) in MCLD 126.6+24.5.

The most impressive finding is that large densities and small scale structure down to the resolution of the observations are found everywhere. Clumping on scales smaller than the beam resolution is often inferred from modeling or from a comparison between average column densities and local densities responsible for collisional excitation of molecular transitions. Unexpected dense and small scale structures are found in clouds regions of low average column density by Falgarone + (1992 AA 257 715), in translucent clouds by van Dishoeck and Black (1991 ApJ 366 141), Gredel + (1992 AA 257 245), in cloud edges by Falgarone + (1991 ApJ 378 186). Dense cores are found and studied in many transitions and many molecules in high latitude clouds (Turner, 1992 ApJ 391 158; 1993 ApJ 405 229; in H_2CO 1993 ApJ 410 140, in NH_3 1993 ApJ 411 219; Vallée 1990 AA 233 553), in the reflection nebulae NGC 2023 (White + 1990 AA 227 200), in L1455 (Juan + 1993 AA 270 432) and in NGC2071 (Snell + 1991 ApJ 372 518).

Indirect evidence for very small scale structure in the least opaque interstellar clouds is provided by the sharp changes in the absorption line profiles of atoms and ions, in front of a visual binary for example (Meyer 1990 ApJL 364 L5).

Comparative surveys in various molecules like CCS, HC_3N, HC_5N, NH_3, (Suzuki 1992 ApJ 392 551), HCO^+ and ^{13}CO (Fukui + 1992 ApJ 398 544) reveal not only the complexity of the density structure (via collisional excitation) but also that of the chemistry (see for example Guélin and Cernicharo 1991 AA 244 L21).

Large molecular abundances are found in cirrus clouds while their low average column density (therefore low shielding from the UV field) would lead to opposite predictions (Meyerdierks 1990 AA 230 172; Herbstmeier + 1993 AA 272 514).

The unexpectedly large amounts of dense and warm gas derived from the earliest submillimeter observations of star-forming regions are confirmed by more recent data. Some of these observations have difficulty to be explained by the current models of photon-dominated regions (PDRs), even those which take clumpiness into account. Shock excitation is usually ruled out on kinematic arguments. Clumpiness is characterized by gas at densities larger than $10^5 cm^{-3}$ concentrated in few tenths of the volume with large density contrasts between the clumps and interclump medium. Densities as large as $10^8 cm^{-3}$ are derived in some sources under the assumption of pure collisional excitation of the observed transitions.

In M17, Stutzki and Güsten (1990 ApJ 356 513) find a clump-interclump density contrast of 23 derived from $C^{18}O$ and $C^{34}S$ observations. In W3, NGC 1977 and NGC2023, Howe + (1991 ApJ 373 158) find an even larger value of 10^2 for this contrast derived from 158 μm [CII] observations. Large column densities of ionized carbon in the Orion Nebula are confirmed by the first detection of the isotopic line ^{13}CII which allows a determination of the 158 μm [CII] line optical depth (Stacey + 1991 ApJL 382 L37).

Similar conclusions, namely the existence of large amounts of dense warm gas, are reached by Jaffe + (1990 ApJ 353 193) in NGC2023, on the basis of a comparison of CO emission in rotational lines up to $7 \rightarrow 6$ with the 158 μm [CII] emission, by Graf + (1993 ApJ 405 249) from ^{13}CO(J=6-5) observations of NGC 2024, and in Orion from ^{12}CO(J=4-3) observations by Schulz + (1992 AA 264 629), from ^{12}CO(J=7-6) observations by Howe + (1993 ApJ 410 179) and from CO lines (up to $J=17 \rightarrow 16$) and 158 μm [CII] observations by Stacey + (1993 ApJ 404 219).

Very large densities are also inferred in massive star-forming cores from CS(J=10-9) observations by Hauschildt + (1993 AA 273 L23), from CS(J=7-6) observations by Plume + (1992 ApJS 78 505) and ^{13}CO and ^{12}CO(J=9-8) maps by Boreiko and Betz (1991 ApJ 369 382) who note that the lineshapes are similar for low and high J transitions. In IC1396, (a partially ionized globule) Serabyn + (1993 ApJ 404 247) also derive large densities from a CS multiline analysis.

2.1.3 Mass determinations

Observations of the shadows of high galactic latitude clouds against the soft X-rays background provide estimates of the total column density across these clouds (Snowden + 1991 Science 252 1529; Burrows and Mendenhall 1991 Nature 351 629). Conversion factor between the 100 μm surface brightness and total gas column density are obtained, independently of other tracers like CO.

Mass distribution of clumps are derived from many maps in the hope of finding a relation with the initial mass function for stars. Power laws are systematically found with spectral indexes $\sim$ -1.6 (Williams and Blitz 1993 ApJL 405 L75) and other works quoted above. The power laws for the clump mass spectra do not seem to depend on the linear resolution of the various observations.

2.1.4 Velocity structure: shape of lineprofiles

Gas flows within molecular clouds are highly turbulent. The observed linewidths are orders of magnitude larger than the expected thermal widths and many of the observational works quoted above allowed refinement of the determination of the scaling laws between the internal velocity dispersion of a given scale and its size.

Accordingly, earlier attempts to estimate the role of finite correlation length of the velocity on the radiative transfer have been developed Kegel + (1993 AA 270 407). The impressive result is that, as expected, correlations between the velocities at different positions in clouds, lower the photon escape probability, increase the excitation and mimic the effect of large densities. The impact on the density determination and measurements of isotopic ratios, for instance, may be large and the physical parameters derived from the line analysis should be taken with some caution. New attempts at finding a correlation length in the velocity field have been conducted with the NRO–45m antenna without convincing determinations (Kitamura + 1993 ApJ 413 221). Indeed the situation is yet more complicated since one of the characteristics of turbulence is the existence of velocity correlation at all scales.

Falgarone and Phillips (1990 ApJ 359 344) have proposed that the non–Gaussian wings observed with similar characteristics in non–starforming regions, over several orders of magnitude in size, are a signature of the intermittency of turbulence in molecular clouds. Another interpretation has been proposed for these wings by Elmegreen (1990 ApJL 361 L77), namely the steepening of Alfvén waves in clumpy media. Lambert and Crane (1990 ApJL 359 L19) found that the lineprofiles of various chemical species in absorption along the line of sight to ζ Oph (CN, CH, and CH^+) are quite different in terms of linewidths and linewings which suggests a link between the chemistry and the velocity field, not provided by a shock.

New radiative transfer computations in molecular clouds have been conducted in the frame of clumpy media by Burton and Hollenbach (1990 ApJ 365 620), Wolfire + (1993 ApJ 402 195). The remarkable smoothness of molecular line profiles when observed with an extremely large signal to noise ratio, poses the problem of the actual density structure of the emitting gas. It might consist of thousands of self–gravitating clumps of a few hundreds astronomical units (Tauber 1991 ApJ 375 635)

2.1.5 New gas components in clouds

Fluorescence allows the detection of widespread emission of H_2 in clouds where the ambient UV field is sufficient to excite the 2.2 μm line (Martin + 1990 ApJ 354 220; Burton 1990 ApJ 352 625).

Extended 3.3 μm emission has been detected in M17 Giard + (1992 AA 264 610) which traces the excitation of the C–H bound in molecular clouds.

Molecular clouds with no detected CO emission (therefore composed of H_2 mostly) have been found from comparison between dust 100μm emission and HI line emission (Blitz + 1990 ApJ 352 L13), although the number of such clouds may not be large according to the results of Heithausen's high latitude CO survey (quoted above). An HII region associated with a CO molecular cloud has been found beyond the optical disk of the Galaxy at an estimated distance of 28 kpc (de Geus + 1993 ApJL 413 L97 and Digel + 1994 ApJ).

A 158 μm [CII] ballon–borne line survey of the galactic plane by Shibai + (1991 ApJ 374 522) shows that at large scale the [CII] line distribution follows the CO distribution remarkably well. At small scale, they find diffuse extended emission whose origin is not yet clearly established.

2.1.6 A few persisting and new puzzles

The chemical complexity illustrated by studies quoted above and the line survey conducted between 330 and 355 GHz in Orion by Sutton + (1991 ApJS 77 255) is not yet satisfactorily explained by chemical models. The origin of the large observed CH^+ abundances in molecular clouds is not explained either (Gredel + 1993 AA 269 477).

Observations of ^{12}CO in absorption in front of BL Lac reveal the same velocity profile in absorption as in emission (Marscher + 1991 ApJL 371 L77). This result is confirmed by Lucas and Liszt (1993 AA 276 L3) in other absorption lines. The comparison of emission and absorption lines is a powerful tool (e.g. the work done in the HI λ =21cm line) and to prepare the extension of such a work in the CO line, Liszt and Wilson (1993 ApJ 403 663) have systematically searched for CO(1-0) emission in the direction of all extragalactic sources strong enough to allow aperture synthesis observations of CO.

2.2 - MAGNETIC FIELD

Direct measurements of the magnetic field intensity by Zeeman splitting have been extended to dark clouds. Using the centimeter lines of the OH radical Crutcher + (1993 ApJ 407 175) obtain two positive detections with B$\sim$ 20 and 10μG and a statistical analysis of the non–detections confirms that the average magnetic energy in molecular clouds is comparable to their average (non–thermal) kinetic energy.

The direction of the magnetic field is determined from polarization measurements in the far infrared in emission (Gonatas + 1990 ApJ 357 132) for Orion, in the visible range by absorption of starlight (Goodman + 1990 ApJ 359 363) in Taurus, Perseus and Ophiuchus. Studies of the polarization of the absorption of starlight in the near infrared unexpectedly show no deviation of the polarization direction compared to that derived in the optical (Goodman + 1992 ApJ 399 108). The spatial pattern of the direction of the polarization vector in clouds shows a well–defined mean direction except in clouds with embedded clusters (Myers and Goodman 1991 ApJ 373 509). However, the polarization vector is not always found at the same angle to the main axis of a cloud filament. The dispersion of the polarization direction in several complexes is compared to that of the direction of the gas filaments and is found to be slightly smaller (Goodman + 1990 ApJ 359 363).

2.3 - LINK BETWEEN UV FIELD, CHEMISTRY, DUST AND STRUCTURE.

The existence of large inhomogeneities in the density of molecular clouds is directly inferred from most of the observations quoted above, in all kinds of environments, and is requested to allow the penetration of UV photons deep within molecular clouds. The pervasivity of most of massive regions to UV photons is necessary to explain the observed extended emission of the 158 μm [CII] line (see references quoted above) further confirmed by the extended emission of the 492 GHz [CI] line, in S140 for example (Hernichel + 1992 AA 259 L77). This, and the existence of large amplitude motions induced at all scales in molecular clouds, bear profound impacts on chemical processes and the time evolution of dust grains.

Calculations of the penetration of UV photons in clumpy clouds have been performed by Boissé (1990 AA 228 483) for continuum photons.

To understand the fact that the observed abundances of organic molecules in molecular clouds are closer to computed "early time" abundances than the steady state ones, several groups have tried to couple the chemical evolution with either a time dependent UV irradiation or purely dynamical processes. Rapid turbulent mixing of material between diffuse (UV irradiated) and dense (shielded) regions deeply modifies the chemical abundances (Pineau des Forêts + 1992 MN 256 247; Chièze + 1991 ApJ 373 110). The motions of clouds relative to one another produce intermittent shadowing which also affects the chemical evolution (de Boisanger + 1992 ApJ 401 182; de Boisanger and Chièze 1991 AA 241 581).

Dense cores are made ephemeral structures by frozen-in magnetic field which may revert its evolution toward a protostellar condensation and modify the chemistry (Prasad + 1991 ApJ 373 123).

The chemical fluctuations which are observed at all scales (Goldsmith + 1992 ApJ 385 222 in NGC 2071) are possibly related to some of the above processes, but may be due also to fluctuations in the dust properties (explained as fluctuations in their size spectrum, see Boulanger + 1990 ApJ 364 136). These variations may be connected to the observed diversity of the extinction curves reported in the atlas of extinction curves by Fitzpatrick and Massa (1990 ApJS 72 163) and Papaj + (1991 MN 252 403). Comparisons of the far UV rise of absorption curves with CH and CH$^+$ absorption are made in Jenninskens + (1992 AA 265 L1).

Also possibly connected to the above, Pineau des Forêts + (1992 MN 258 45) and Le Bourlot + (1993 ApJL in press) have shown that there exists a possibility of reaching chaotic behaviour for chemical patterns in the parameter range of molecular clouds.

Many models have been built which try to reproduce the observed inhomogeneities of cloud properties at various scales, taking into account the small scale fluctuations of density and other properties. These fluctuations contrast with the large scale uniformity of some of the cloud properties in our Galaxy, and nearby comparable galaxies. The dust continuum emission of inhomogeneous clouds has been computed by Bernard + (1992 AA 263 258). Attempts to couple the chemistry and radiative transfer of line photons have been published (for homogeneous clouds) in the submillimeter and far infrared ranges by Le Bourlot + (1993 AA 267 233), in the millimeter range by Meixner and Tielens (1993 ApJ 405 216) and by Wolfire + (1990 ApJ 358 116) for clumpy PDRs. Radiative transfer has been computed for CO line photons in such clouds also by Tauber and Goldsmith (1990 ApJL 356 L63), Gierens + (1992 AA 259 271).

2.4 - DENSE CORES AND STAR FORMATION.

As for the less compact parts of molecular clouds, the main result brought in light by recent observations is the existence of substructure in the interiors of dense cores down to the resolution of the observations, with large density contrasts inferred from multitransition analysis at very small scales within the cores.

Observed dense cores in general are far from being thermally supported self– gravitating cores (Fuller and Myers 1992 ApJ 384 523), and models have been built which try to include non–thermal support in the balance equations (Myers + 1992 ApJ 396 631). In one case however, the classical picture of an isothermal self–gravitating core in which inside–out collapse has already started is consistent with observations (Zhou + 1990 ApJ 363 168 and 1993 ApJ 404 232 in the Bok globule B335).

Low–mass star formation has been shown to take place even in small isolated globules. Yun and Clemens (1992 ApJL 385 L21) have detected 14 outflows in a sample of 41 Bok globules, Duvert + (1990 AA 233 190) in IC396, and Reipurth + (1992 AA 256 225) have detected HH objects with extremely recent outbursts in the Bok globule B335.

Early stages of star formation have also been actively looked for in the continuum. Protostellar cold dust condensations are found in molecular clouds survey at $\lambda = 1.3$ mm in ρ Ophiuchus (André + 1990 AA 240 321; Mezger + 1992 AA 265 743) complemented by a VLBI survey of the same cloud (André + 1992 ApJ 401 667), in NGC 2024 (Schulz + 1991 AA 246 570; Mezger + 1992 AA 256 631), in NGC 2264 (Tauber + 1993 ApJ 403 202). Multiwavelength photometry up to $\lambda = 450 \mu$m led to the discovery of a very cold dense fragment, probably gravitationally unstable (Chini + 1993 AA 272 L5). In several cases molecules are found to be depleted in these dust condensations which seems to confirm that some molecules disappear from the gas phase at low enough temperatures and build up molecular ice mantles which are observed in absorption in the near infrared (against intense IR sources, therefore in regions different from cold dense cores). These absorption measurements have allowed the first detections in interstellar space of highly symmetric molecules such as CH_4 (Lacy + 1991 ApJ 376 556), O_2 (Ehrenfreund + 1992 AA 260 431), C_2H_2 and other molecules (Evans + 1991 ApJ 383 674). CO ices have been observed in ρ Oph by Kerr + (1993 MN 262 1047) and Tielens + (1991 ApJ 381 181) in the direction of several protostars.

The issue of molecule depletion onto grains in cold dense cores is still controversial. In NGC 2024, molecular line observations (Mauesberger + 1992 AA 256 640) seem to confirm that the small structures detected in the submillimeter continuum of dust are depleted in molecules while in S106 Richer + (1993 AA 262 839) find that the column densities determined from the dust continuum emission are consistent with those derived from molecular lines.

A remarkable output of the powerful imaging capabilities of near IR cameras is the discovery of very rich young clusters of stars associated with dense cores like in NGC 2264 (Lada + 1993 ApJ 408 471). In L1630, Lada + (1991 ApJ 368 432) have conducted a systematic search for dense cores in the CS(2-1) line complemented by 2μm images of the same area which revealed new small clusters of young stars Lada + (1991 ApJ 371 171).

2.5 - DYNAMICAL EVOLUTION

2.5.1 Formation, lifetime.

Nothing really new is to report in that section. The dilemma is still whether clouds form via gravitational fragmentation (instabilities in large scale supershells of material swept up by supernovae remnants for example or in the galactic gas layer itself at still larger scale) or by collisional agglomeration of much smaller entities.

It is confirmed observationally that molecular clouds are not long-lived and the rate at which self-gravitating molecular material is assembled out of more dispersed gas is thought to be related to the star formation rate of the former generations of stars. The possible link between the observed fractal structure and the star formation rate and initial mass function is discussed in Larson (1992 MN 256 641). Large scale molecular observations of the Orion complex have shown the influence of stellar associations and self-gravity upon the structure of molecular gas. However, in a new paper (Miesch and Bally 1994 ApJ) show that all the statistical properties of the velocity field and brightness distributions are consistent with a turbulent description of the structure.

2.5.2 Virial balance

Many molecular clouds (or parts of molecular clouds) are now known to be far out of virial balance between self-gravity and internal kinetic energy. The internal pressure is found to be up to 100 times the thermal pressure, it is fluctuating between one cloud and another by 3 orders of magnitude and many molecular clouds are considered as transient structures temporarily confined at all scales by some pervading turbulent or magnetic (or both) pressure (most of the corresponding references have been quoted above).

The role of an external magnetic pressure is discussed in Bertoldi and McKee (1992 ApJ 395 140) and McKee and Zweibel (1992 ApJ 399 551). The fraction of molecular H_2 over HI is shown to be extremely sensitive to both the ambient UV radiation field and the external pressure if clouds are in virial balance (Elmegreen 1993 ApJ 411 170)

Thermal conduction and evaporation are discussed in McKee (1990 ApJ 358 375 and 392)

2.5.3 Ambipolar diffusion

Magnetic field is now observed, as said above, with an intensity which makes the magnetic pressure comparable to the kinetic pressure in molecular clouds. Many studies have been conducted to estimate the coupling of the neutrals to the ionized species and the role of charged dust grains is shown to be of fundamental importance (Nakano 1990 MN 242 535 ; Umebayashi and Nakano MN 243 103; Tomisaka 1990 ApJ 362 202).

A minimum wavelength for coupling of neutrals with the magnetic field in clumpy clouds has been found by Elmegreen and Fiebig (1993 AA 270 397) but such a length is highly dependent of the microscopic processes (collisions) at the origin of the coupling, and in particular very sensitive to the (basically unknown) grain size distribution of very small grains.

Mouschovias has addressed the issue of ambipolar diffusion in several contexts (1991 ApJ 371 296 and 373 169; 1992 ApJ 390 144; ApJ 390 166; ApJ 391 199) and Zweibel (1990 ApJ 362 545) the fundamental question of magnetic tangling in molecular clouds.

2.5.4 Turbulence and the growth of gravitational instability

Turbulence may prevent gravitational instabilities to grow. Not only is it an additional support against self-gravity but it is scale dependent and might make the largest scales more stable than the small ones. Bonazzola + (1992 JFM 245 1) have computed the turbulent pressure by using a method inspired by the renormalisation group technics. Léorat + (1990 MN 243 293) have developed numerical simulations of supersonic self-gravitating flows which show the disrupting power of turbulence for a bound structure.

The influence of magnetic field on the velocity fluctuations induced in the gas by its gravitational interaction with stars has been studied by Jacobi + (1990 AA 237 461). They find that the existence of magnetic field increases the energy contained in the velocity fluctuations of the gas to twice the energy of the magnetic field fluctuations.

2.5.5 Thermal effects

3-dimensional hydrodynamical simulations of collapse and fragmentation which take molecular line cooling into account, with therefore a detailed description of the equation of state, have been developed by Monaghan + (1991 ApJ 375 177). They show that, as expected, radiative cooling significantly increases the number of fragments.

Elphick + (1991 MN 250 617) have studied the consequences of the non-linearity of the equation for thermal stability. They derive the motions of the fronts separing the cold and hot stable phases and suggest that thermal instability may be at the origin of some of the complexity of the spatial organisation of the interstellar medium.

Conference proceedings, books

Low mass star formation and pre-main sequence objects 1990 ed. B Reipurth (Munich: ESO)

The evolution of the interstellar medium 1990 ed. L. Blitz (San Francisco: Astronomical Society of the Pacific)

The physics of star formation and early stellar evolution 1991 eds. C.J. Lada and N. Kylafis (Dordrecht: Kluwer)

IAU Symposium 147 *Fragmentation of molecular clouds and star formation* 1991 eds. E. Falgarone, F. Boulanger, G. Duvert, (Dordrecht: Kluwer)

Physical processes in fragmentation and Star formation 1991 eds. R. Capuzzo Dolcetta, C. Chiosi and A. di Fazio (Dordrecht: Kluwer)

Molecular Clouds 1991 eds. R.J. James and T.J. Millar (London: Cambridge University Press)

IAU Symposium 150 *Astrochemistry of Cosmic phenomena* 1992 ed. P.D. Singh (Dordrecht: Kluwer)

Infrared Astronomy with ISO 1992 eds. Th. Encrenaz and M.F. Kessler (New York: Nova Science Publishers)

Star formation in stellar systems 1992 eds. G. Tenorio-Tagle, M. Prieto and F. Sanchez (Cambridge: Cambridge University Press)

Back to the Galaxy 1993 eds. S.S. Holt and F. Verter (American Institute of Physics)

Protostars and Planets III 1993 eds. E.H Levy and J.I. Lunine (Tucson: The University of Arizona Press)

The structure and content of Molecular Clouds 1994 ed. T.L. Wilson (Berlin: Springer -Verlag)

3 CHEMISTRY (D. Flower)

There exists a vast literature on interstellar chemistry, and any attempt to cite individual research papers would be necessarily subjective and incomplete. Accordingly, reference will be made to books and conference proceedings which have appeared during the period under review and which guide the reader to the original papers.

The oft-cited volume honouring Alex Dalgarno, " Molecular Astrophysics" (Hartquist, T.W., ed.: 1990, Cambridge UP) comprises a selection of articles reviewing a variety of aspects of interstellar physics and chemistry. Two other review volumes appeared in the same year: Thronson, H.A. +, ed.: 1990, "The Interstellar Medium in Galaxies", Kluwer, Dordrecht and Watanabe, T. +, ed.: 1990, "Molecular Processes in Space", Plenum, New York. The former may be found particularly helpful to research students.

A welcome addition to the literature was the proceedings of no. 7 in the series of Manchester astronomical conferences (James, R.A. +, ed.: 1991, " Molecular Clouds", Cambridge UP. In the same year appeared the proceedings of a NATO Advanced Study Institute (Greenberg, J.M. +, ed.: 1991, " Chemistry in Space", Kluwer, Dordrecht) and of IAU Symp. No. 147 (Falgarone, E. +, ed.: 1991, " Fragmentation of the Molecular Clouds and Star Formation", Kluwer, Dordrecht). The latter covers topics whose elucidation is the objective of much of the research into the interstellar medium.

IAU Symp. No. 150 (Singh, P.D., ed.: 1992, "Astrochemistry of Cosmic Phenomena", Kluwer, Dordrecht) reviews much of the research in interstellar chemistry, but also has a broader remit. Spectroscopic aspects are additionally covered by Bohme, D.K., ed.: 1992, "Chemistry and Spectroscopy of Interstellar Molecules", University Tokyo Press, and star formation, once again, in Melrose, D., ed.: 1992, "Star Formation in Different Environments", Aust. J. Phys., 45, 387. Researchers into interstellar chemistry may also find useful the proceedings of the second biennial conference on molecular spectroscopic databases (Rothman, L.S. +, ed.: 1992, J. Quant. Spectrosc. Radiat. Transfer, 48, 469). The proceedings of the Faraday Symp. No. 28 on "Chemistry in the Interstellar Medium" (1993, Faraday Trans., 89, 2111) provide a timely and sometimes stimulating review of interstellar chemistry to the end of 1992. Finally, mention should be made of a volume on the closely related topic of "Astronomical Masers" (Elizur, M.: 1992, Kluwer, Dordrecht.)

4.1 INTERSTELLAR DUST (P. G. Martin)

In the time interval considered there have been review papers, compendia from meetings, and monographs which introduce research in this field. Among these are Dwek+ (1992,AnRevAA,30,11), and Mathis (1990,An Rev AA,28,37; 1993, Rpt Prog Phys,56,605); *Physics and Composition of Interstellar Matter* (Krelowski+ 1990, Nicolaus Copernicus University), *Dust and Chemistry in Astronomy* (Millar+ 1993, Institute of Physics), and *Infrared Cirrus and Diffuse Interstellar Clouds* (Cutri+ 1993, ASP); Hoyle+ (1991, *The Theory of Cosmic Grains*, Kluwer), Whittet (1992, *Dust in the Galactic Environment*, Hilger), and Wynn-Williams (1992, *The Fullness of Space: Nebulae, Stardust, and the Interstellar Medium*, Cambridge). The related field of interstellar chemistry was the subject of IAU Symposium 150, *Astrochemistry of Cosmic Phenomena* (Singh 1992, Kluwer); see also Cecchipestellini+ (1992,Nuovo Cimento-C,15,1047).

This report does not aim to be exhaustive of all literature in this field. It does emphasize, with some attempt at comprehensiveness in the current literature, *how* we learn about dust – as much as *what* we are learning – but, on the other hand, it does not pretend to distill all previous knowledge or catalogue all *applications* of dust, i.e., how dust influences or sheds light on various astrophysical phenomena.

4.1. SPECTRAL SIGNATURES. The surest way to verify a component material of interstellar grains is to identify a characteristic spectral feature. This might not tell exactly what form of grain is involved (size; free particle, or core or mantle, or part of composite grain) but it is a beginning. Much recent work is on carbon-bearing grains, which is reflected in the emphasis below.

4.1.1. Silicates. Virtually all cosmic Si is in the form of silicates, whose ubiquitous presence is known from the 10 and 20 μm features. The smooth broad profiles of these features indicate an amorphous structure, but the precise mineralogy remains unknown. The 8–23 μm spectrum of circumstellar silicates has been deduced from IRAS LRS spectra (Simpson 1991,ApJ,368,570); there are environmental changes, particularly at 10 μm (also Griffin 1993,MN,260,831). Band strengths and optical constants encompassing near infrared continuum absorption, accounting for inclusions of other materials in silicate grains, have been presented by Ossenkopf+ (1992,AA,261,567). SiH bands near 5 μm, being sensitive to the chemical environment, might indicate the nature of Si bonding (Moore+ 1991,ApJ,373,L31).

4.1.2. 2175 Å. Most explanations of the interstellar 2175 Å extinction "bump" require about 20–30% of the cosmic C. The bump has long been attributed to small particles of graphite, though the identification has never been fully secured with laboratory data. Lorusso+ (1993,SolidStateComm,85,729) have measured ultraviolet spectra of submicron sized graphitic particles; the spectral peak of the surface plasmon resonance shifts with particle size as anticipated. Aannestad vvv(1992,ApJ,386,627) has investigated the potential correlations of feature width, central position, and ultraviolet continuum components in a multicomponent extinction model. Voshchinnikov (1990,SovAL,16,215) examines the dependence of the profile on grain shape.

Hydrogenated amorphous carbon (HAC) is without ultraviolet feature when fully hydrogenated(Blanco+ 1991,ApJ,382,L97), but experiments on processing (dehydrogenation via ultraviolet irradiation or annealing) point to a viable explanation of the "bump" using amor–phous carbon grains (Blanco+ 1993,ApJ,406,739). High-ranking coals (e.g., anthracite) can also be sufficiently graphitized to produce the bump, while material like poorly graphitized coals could carry the underlying continuum (Papoular+ 1993,AA,270,5). The production and isolation of C_{60} (Kratschmer+ 1992,Carbon,30,1143) has opened a new avenue of research. Theoretical explorations have included the electronic transitions of C_{60} and other large molecules (Braga+ 1991,AA,245,232) and of small, hollow, onion-like car–bon particles (Henrard+ 1993,ApJ,406,92).

4.1.3. (Unidentified) Infrared Bands. The "unidentified" infrared emission bands (UIBs) – 3.3, 6.2, 7.7, 8.6, 11.3 μm and other features (e.g., Roche+ 1991,MN,252,282) – are thought to be due to stretch and bending CH modes. The particular bonding of C and H affects the details of the features, which become diagnostic of the carrier [e.g., 3.3 μm is the aromatic C-H stretch, whereas aliphatic groups like methyl (CH3) shift the feature to 3.4 μm]. Tokunaga+ (1991,ApJ,380,452) find two types of profile in high resolution observations of the 3.29 μm emission feature. A working model is a mixture of largely ionized polycyclic aromatic hydrocarbons (PAHs; see Szczepanski+ 1993,Nature,363,699).

In regions where the radiation field varies strongly in hardness and strength the influence of the environment on the size, structure, hydrogenation, and abundance of the various PAHs can be assessed (NGC7027: Sandford 1991,ApJ,376,599; Orion: Siebenmorgen+ 1992,AA,259,614; M17: Giard+ 1992, AA,264,610 and Chrysostomou+ 1992,MN,256,528; HD44179: Sloan+ 1993,ApJ,409,412; and NGC1333: Bregman+ 1993,ApJ,410,668). The 3.3 μm band seems absent inside ionized regions. The strengths of the 7.7 and 11.3 μm features are correlated; from the contributions of the features to the total infrared luminosity it is estimated that 1–5% of C is tied up in aromatic molecules like PAHs; and the precise nature of the carrier of the important underlying continuum is unclear (Zavagno+ 1992,AA,259,241).

Theoretical work suggests that the satellites of the 3.3 μm band are due to the an– harmonicity (Talbi+ 1993,AA,268,805). Laboratory work on infrared absorption spectra of some small isolated neutral and ionized PAHs (Szczepanski+) points to the importance of ionized species. Fluorescent emission spectra of aromatic and aliphatic C-H stretch modes have been recorded, supporting the PAH model (Shan+ 1991,ApJ,383,459). Experiments demonstrate the dependence of the peak C-H absorption wavelength on compactness of the PAH molecules and whether they are free-flying or condensed; astronomical data suggest a compact, condensed form (Flickinger+ 1991,ApJ,380,L43). The 3.40, 3.46, and 3.51 μm emission features in NGC 7027 are not due predominantly to aliphatic side– groups on PAHs (Sandford 1991,ApJ,376,599).

An alternative though related model is based on coal (Papoular+ 1993,FaradayTrans,89,2289; Papoular+ 1991,AA,247,215); the main, insoluble, organic, solid constituent (kerogen) exhibits all of the UIBs as well as an accompanying continuum. A structural distinction compared to PAHs is linking by oxygen bridges. Possible carriers of the 21 μm feature in preplanetary nebulae are discussed by Sourisseau+ (1992,AA,254,L1).

4.1.4. Extended Red Emission. In addition to scattered radiation, the light of reflection nebulae often shows a broad red emission band (extended red emission or ERE; see e.g., Sivan+ 1993 ApJ,404, 258). This has been interpreted as photoluminescence by HAC grains (Duley 1992,MN,258,773) or aromatic components of filmy quenched carbonaceous condensate (QCC; Sakata+ 1992,ApJ,393,L83). Accompanying sharp features in the Red Rectangle nebula (HD 44179) occur in a spatially distinct environment but it is suggested that the molecular carrier is produced from the HAC (Schmidt+ 1991,ApJ, 383,698). Similar ERE has been found in planetary nebulae, but only those that are carbon rich ($C/O > 1$); UIBs are also associated with carbon rich objects, but the carrier is not identical since some nebulae with UIBs do not have the ERE (Furton+ 1992,ApJ,386,587). A red luminescence band found in the Orion Nebula does not correlate with the 3.3 μm UIB feature (Perrin+ 1992,AA,255,271).

4.1.5. Ices. Extensive observations of ices have been made, mostly in molecular clouds. The threshold extinction at which water ice (3.08 and 6.0 μm bands) is deposited on dust shows wide variation from cloud to cloud (Williams+ 1992,MN,258,599). Within Taurus the band and the long-wavelength wing at 3.45 μm show good correlation with A_V and have the same (photodesorption-regulated) threshold (Smith+ 1993,MN,263,749); only about 9% of cosmic O is required in the H_2O ice. Studies have also been made of ices in the laboratory. Changes in the shape of the ice band on transition from crystalline to amorphous water ice (induced by keV ion-irradiation) are relevant to interpreting the thermal history of interstellar ice (Baratta+ 1991,AA,252,421). The 3 μm feature of a SiO condensate (not a silicate) containing trapped and adsorbed H_2O is found to match closely the band toward the Galactic center source IRS 7 (Wada+ 1991,ApJ,375,L17).

An absorption feature at 3.53 μm in W33A has been assigned to methanol; it is the second most abundant molecule (7% relative to H_2O) in the grain mant -les in this line of sight (Grim+ 1991,AA, 243,473). Consistent upper limits on the 9.8 μm feature have been set in other sources (Schutte+ 1991, ApJ, 382,523). Grain surface reactions or condensation directly out of the gas phase must contibute to formation, rather than simply ultraviolet irradiation of the ice mantle (as would be the case for formaldehyde which is not seen strongly). The 6.85 μm feature is not methanol, and so requires another compound.

CO frosts (4.67 μm), ubiquitous in the quiescent molecular cloud environment, have been reviewed by Whittet+ (1991,AARev,2,167); in some lines of sight the gaseous CO is significantly depleted. Details of the band profiles, studied in various mixed ices in the laboratory, clarify the production and nature of the solid CO (Palumbo+ 1993,AA,269,568; Tielens+ 1991,ApJ,381,181). Tielens+ (1991) and Kerr+ (1993,MN,262,1047) identify independent non-polar (e.g., CO) and polar (e.g., H_2O) matrices in the band profiles, which is confirmed with bands at 4.67 and 4.68 μm (Tegler+ 1993,ApJ,411,260). Solid CO_2 is detected at 15.2 μm toward the protostellar object AFGL 961, but not toward other sources with large column densities of water ice [$\tau(3.05\mu m) > 1$; Whittet+ 1991,MN,252,63].

Tegler+ (1993) have identified a broad absorption band at 4.619 μm as a CN-containing compound in a mixed ice. Sandford+ (1993,ApJ,409,65) propose that solid H_2 in H_2O-rich ices can be detected by an infrared absorption band at 2.417 μm. Detection of O_2 in a dirty ice matrix is discussed by Ehrenfreund+ (1992,AA,260,431).

4.1.6. 3.4 μm. The interstellar absorption band at 3.4 μm in diffuse interstellar dust indicates a C-H stretch in the CH_2 and CH_3 groups of a fairly complex carbonaceous material containing aliphatic functional groups (Sandford+ 1991,ApJ,371,607). The subpeak strengths correlate with visual extinction; the material could be an important repository of C in grains (3–40%). The material might be the residue from photoprocessing of more volatile ice mantles or by ion irradiation (§4.3.4; Sandford+; Strazzulla+ 1992,AA,266,434). A broad feature at 3.0 μm is attributed to O-H stretch, but from lack of correlation, apparently not in the same organic material. A 3.4 μm feature is seen in the carbon rich protoplanetary nebula CRL 616 (Lequeux 1990,AA,240,L19).

A distinctive subpeak in dense cloud lines of sight is indicative of diamond-like material, in sharp contrast with diffuse clouds (Allamandola+ 1993,Science,260,64); this dichotomy, two very different and independent solid hydrocarbons, is puzzling from the point of view of grain evolution.

4.1.7. Diffuse Interstellar Bands. A discussion of the diffuse interstellar bands (DIBs) under the rubric of dust might be inappropriate, since despite correlation in strength with E_{B-V}, the carrier does not lie in the solid particles producing the red- dening. Nor is there correlation with the small grains which dominate extinction beyond 1250 Å; in general the carrier behaves like a free neutral species in the gas and responds to the ionization level of the gas as if its ionization/dissociation threshold is somewhat higher than 5 eV (Herbig 1993,ApJ,407,142). Spectropolarimetry of the 5797 Å band shows the carrier is not aligned grains (Adamson+ 1992,ApJ,398,L69). Snow+ (1991,ApJ,382,189) suggest that the relatively narrow profiles of the 5780 and 5797 Å bands in HD 29647 might arise from unusual rotational excitation in molecules. Weakness in these bands in Orion has been attributed to sticking of the carriers to grains (Porceddi+ 1992,AA,260,391). Bands detected in circumstellar matter do not reflect the carbon/oxygen rich dichotomy; nor do they cor- relate with the presence of UIBs (Le Bertre+ 1993,AA,274,909; 1992,AA,255,288). McIntosh+ (1992,MN,255,P37; see also Adamson+1991,MN,252, 234) find that the carriers reside in the surface layers of dark clouds, not deep within them, and a different depth dependence for two different families of bands. Jenniskens+ (1993,AA,274,465) report complex structure in the strong 5780 and 6284 Å bands, possibly indicating a common carrier.

Salama+ (1992,Nature,358,42) use laboratory measurments to suggest that a species like the PAH pyrene cation $C_{16}H_{10}^+$ is responsible for the 4430 Å feature, using 0.2% of cosmic C. Laboratory spectra of the naphthalene cation $C_{10}H_8^+$ indicate discrete absorption bands close to the positions of several DIBs (Salama+ 1992,ApJ,395,301); however, another significant laboratory band is not observed astronomically (Snow+ 1992,ApJ,401,775).

Webster (1993,MN,262,831) develops a theory based on members of an unspecified class of molecular hydrides (perhaps fulleranes $C_{60}H_m$). Carriers with different m in different interstellar habitats might underlie the observational partitioning of the bands into families.

4.1.8. Lack of Signature. Absence of expected spectral features also offers constraints. For example, an 11 μm SiC feature is seen in carbon stars, but there is actually little SiC in the meteorites or the interstellar medium (Whittet+ 1990,MN,244,427) compared to what might have been expected.

Individual PAH molecules have distinctive ultraviolet absorption bands, but it is thought that in a mixture of PAHs no particular band will stand out (e.g., Lee 1993,ApJ,410,127); interstellar PAHs might contribute to the 2175 Å bump and the far ultra- violet rise (Joblin+ 1992,ApJ,393,L79; Verstraete+ 1992,AA,266,513). Ionized PAHs have continuum absorption into the visible which makes them easier to hide for a given energy budget of infrared UIB and continuum emission (Salama+ 1992,Nature,358,42). They contain 10–20% of the cosmic carbon.

The main evidence for amorphous carbon is the featureless infrared continuum emission in circumstellar envelopes of carbon stars; circumstantial evidence is that mentioned above for the relatives: PAH and HAC. Laboratory measurements (Colangeli+ 1992,ApJ,392,284) indicate a feature at 2400 Å that might explain that seen in a class of sources; however, by the same token, the lack of a distinctive feature there in interstellar extinction constrains the amorphous carbon; it is speculated that some modifications might reproduce the 2175 Å feature.

4.2. CONTINUUM. Continuum measurements, the traditional probes of dust, continue to benefit from ever wider spectral coverage.

4.2.1. Extinction. There are variations of the ultraviolet extinction for a given op- tical extinction, again apparent in the atlas of TD-1 extinction curves (Papaj+ 1991,MN,252,403). Simple components of the ultraviolet extinction are the bump, a linear rise, and a far ultraviolet non- linear term. Green+ (1992,ApJ,395,289) have measured the extinction from 1180 to 950 Å in the direction of ρ Oph; the rise below 1000 Å cannot be explained by a standard silicate-graphite model. Voschchinnikov+ (1993,AZ, 70,38) calculated the optical properties and extinction of silicates and graphite particles out to 100 Å.

Webster (1993,MN,262,59; 1992,AA,257,750) suggests that the variable component of extinction associated with the strong rise shortward of 1600 Å is attributable to fulleranes and their ions with various levels of hydrogenation in different environments. The relative strength of very broad structure (VBS) in the 5000–6000 Å region is correlated with that of far ultraviolet continuum extinction (Reimann+ 1991,AA,242,474). Jenniskens+ (1992,AA,265,L1) find the amount of non-linear rise to be proportional to the CH abundance.

4.2.2. Polarization. The wavelength dependence of optical and near-infrared polarization is given by the Serkowski relation with three parameters: strength p_{max}, peak position λ_{max}, and inverse width K. A linear dependence of K on λ_{max} seen overall also holds within individual regions with rather differing environments (Whittet+ 1992,ApJ,386,562). In the infrared there is excess polarization at 3–5 μm relative to the standard Serkowski formula; an infrared power law of index near 1.6 is a better representation; the infrared polarization does not respond to changes in the properties of the grains which give rise to dramatic variations in the wavelength dependence of polarization at shorter wavelengths (Martin+ 1992,ApJ,392,691). Chlewicki+ (1990,ApJ,365,230) calculate the wavelength dependence of interstellar circular polarization for organic refractories.

Ultraviolet spectropolarimetric observations obtained with WUPPE (Clayton+ 1992, ApJ, 385, L53; Wolff+ 1993,ApJ,403,722) along eight lines of sight show three different interstellar polarization wavelength dependences: Serkowski (larger λ_{max}), super-Serkowski, and in one star a bump near 2175 Å. A bare silicate grain model is successful at fitting the continuum wavelength dependence and the bump is attributed to small aligned graphite disks.

4.2.3. Scattering. Two diagnostics are albedo, ω, and asymmetry parameter of the phase function, g. Aspects of diffuse scattered Galactic light are reviewed by Henry+, Leinert, Lequeux, Onaka, and Witt in IAU Symposium 139 (Falgarone+ 1991, Kluwer).

In the ultraviolet there have been numerous measurements of both classical bright reflection nebulae and the diffuse scattered light in the Galaxy, often with discordant interpretations (summary in Hurwitz+ 1991,ApJ,372,167; Murthy+ 1991,ApJ,383,198; Onaka+ 1992,ApJ,379,532; Witt+ 1992,ApJ, 395,L5). One consistent result is a decrease in ω at the 2175 Å extinction bump. Interpretation of recent measurements of NGC 7023 (Witt+ 1993,ApJ,410,714; Murthy+ 1993,ApJ,408,97) seem to be converging on a decreasing ω and fairly constant g into the far ultraviolet, not unexpectedly. In the near infrared, ω might be larger than in some standard models (Sellgren+ 1992,ApJ,400,238).

4.2.4. Near Infrared Emission. The basic process underlying the infrared emission is conversion of ultraviolet photons. In a classical grain, production of near infrared emission requires a small size so that a single photon can "spike" the temperature transiently to a sufficiently high value; a closely related phenomenon occurs for large molecules, like PAHs (Sellgren+ 1992,ApJ,400,238). The quasi-absence of 3.3 μm PAH emission in the H II region M 17 and the strong near infrared emission from 2 to 20 μm indicate the presence of distinct very small grains (Giard+ 1992,AA,264,610). Electron-hole recombination radiation might provide additional emission excesses in all grains (Duley 1992,MN,258,773). Spiking has been modeled in detail by Siebenmorgen+ (1992, AA,266,501); they conclude from the absence of an interstellar 10 μm emission feature that less than 5% of the total silicate abundance is in very small grains ($a < 80$ Å). The 12 and 25 μm IRAS emission in globules can be explained by PAHs and tiny particles of graphite (see also Deluca+ 1993,MN,262,805; Lis+ 1991,ApJ,372,L107). Variations in the abundances of small particles are described by Bernard+ (1992,AA,263,258).

4.2.5. Far Infrared Emission. Visual reflection nebulae are analysed by Casey (1991,ApJ,371,183). In the 20-100 μm region the energy distribution of WX Ser suggests that the emissivity of silicates varies as ν^α with $\alpha \sim 1.5$ (Griffin 1993,MN,260,831). Such a flat dependence is seen in carbon stars and planetary nebulae too. In the interstellar medium, far infrared and submillimetre thermal emission is detected in dark clouds and star forming regions, decaying with index $\alpha \sim 1 - 1.5$ (e.g., Hoare+ 1991,MN,251,584). These are all less steep than predicted by the most straightforward models. Solutions being investigated include better treatment of the temperature distribution in quantum heating (Siebenmorgen+ 1992, AA,266,501), and fluffy and inhomogeneous grains (Ossenkopf 1991,AA,251,210; Rouleau+ 1991,ApJ, 377,526; Siebenmorgen 1993, ApJ,408,218). Polarized emission is detected at 1.3 mm (e.g., Leach+ 1991, ApJ,370,257), showing that grains can be aligned in the potentially less favorable conditions in dense molecular clouds.

4.2.6. X-ray Scattering. Forward scattering by dust particles causes a diffuse x-ray halo around background x-ray sources. The extent depends inversely on grain size (Klose 1991,AA,248,624), among other things (Mathis+ 1991,ApJ,376,490), and constrains the fluffiness of grains. Halos around point x-ray sources are discussed by Day+ (1991,MN,251,76), Garcia+ (1992, AJ,103,1325), and Predehl+ (1991, AA,246,L40; 1992,Science,257,935) and are broadly consistent with grain models based on extinction data.

4.3. GRAIN MODELS AND EVOLUTION. All of the building blocks must be assembled into a grain model in varying proportions to explain the observed characteristics of the interaction of radiation with dust and how they change with interstellar environment.

4.3.1. Depletion. That certain elements are in grains can be discerned by measuring depletion in the gas phase. Where dust is des– troyed, as in a shock (Bachiller+ 1991 AA,243,L21; Sophia+ 1993,ApJ, 413,251), depletion is undone; patterns of differential depletion with line width (e.g., two Fe for each Si) are suggestive of mineral composition (Spitzer+ 1993,ApJ,409,299). Depletion differences between line components might be indicative of selective accretion favoring refractory elements (Savage+ 1992, ApJ, 401, 706). The depletions of 26 elements in an average dense interstellar cloud correlate with condensation temperatures more closely than with the first ionization potentials (Hobbs+ 1992,ApJ,411,750).

The precise depletion depends on the cosmic standard adopted. Oxygen abundances from stars in young cluster are slightly lower than solar (Fitzsimmons+ 1992,MN,259,489), lowering the implied depletion. Still, the amount of O in grains is substantial (Cardelli+ 1993,ApJ,402,L17), much more than is bound in silicates. The case for N is less clear (see also Encrenaz+ 1991,SpSciRev,56,83).

4.3.2. Multicomponent Models. Most models have some graphite to explain the bump, silicates, and PAHs. Consider one simple but not unique illustration (Siebenmorgen+ 1992,AA,259,614): (i) large grains ($a > 100$ Å) of silicate and carbon, for the far-infrared emission and the linear rise in the extinction curve; (ii) small graphite particles ($a \sim 4 - 100$ Å), explaining the mid-infrared emission and the 2175 Å extinction bump; (iii) PAHs, producing the near and mid-infrared bands, part of the underlying continuum, and the non-linear rise in the far ultraviolet. Desert+ (1990,AA,237,215) and Rowan-Robinson (1992,MN,258,787) have other recipes. Whether different materials co-exist in composite particles is an open question. Other C can be in HACs or organic refractories (processed ices), probably as mantles. Grain components can be assigned a single size, or more realistically some size distribution. Underlying each of these models is an evolutionary scenario, often not fully elaborated, which gives rise to the grain components and links the chemistry of the interstellar gas and dust.

The mixture might change from place to place in the Galaxy (§4.3.4), including near the Galactic centre; there the ratio $A_V/\tau(9.7\mu m) \simeq 8$, about half the solar neighborhood ratio (Nagata+ 1993, ApJ,406,501); but over the range JHKL the spectral index of the interstellar extinction is ~2.3, only a bit steeper than locally. The mix can change in other galaxies too (e.g., Magellanic Clouds: Pei 1992, ApJ,395,130; Schwering+ 1991,AA,246,231); it is interesting that the increased far ultraviolet extinction in the SMC is accompanied by weaker 12 μm emission (Sauvage+ 1991,AA,237,296).

4.3.3. Circumstellar Origins. Grains are certainly supplied to the interstellar medium by stellar outflows, and some grains survive incorporation in the primitive solar system (§4.3.5). An overview of infrared and millimetre-wave observations in circumstellar envelopes is given by Omont (1993, JPhys-G, 19,39). Both carbon and oxygen-rich (silicate) dust are observed. New investigations have highlighted the possibility of PAHs (Buss+ 1991,ApJ,372,281; Latter 1991,ApJ,377,187; Ryter 1991,AnnPhy,16,507) and iron oxide grains (Rietmeijer 1992,ApJ,400,L39). Whether the rate of supply (e.g., Guglielmo+ 1993,AASupp,99,31) can keep up with destruction or explain the depletion patterns is debateable.

4.3.4. Evolution. The environmental dependence of the interstellar extinction curve offers clues to processes affecting grain evolution. Jenniskens+ (1993,AA,274,439) find that the linear rise is systematically less in dense regions (coagulation of small particles); that the bump is not weakened in dense media, but is sensitive to the presence of strong ultraviolet radiation fields; and that H II regions have abnormal behaviour of the bump width. Implications of deviations from the mean R_V-dependent extinction law are discussed by Cardelli+ (1991,AJ,101,1021), Clayton+ (1993,AJ,105,1880), Mathis+ (1992,ApJ,398,610), and Whittet+ (1993,ApJ,408,573); deviations are largest in the ultraviolet, involving small grains and the effects of grain coatings. Effects of changing the parameterized size distribution are given by Steenman+ (1991,ASpSci,184,9). The line of sight toward cluster NGC 1502 has an unusually small R_V, 2.4 (Tapia+ 1991,MN,253,649).

Vrba+ (1993,AJ,105,1010) study the ρ Oph cloud. The size distribution underlying the polarization changes systematically with R_V, grain size increases with optical depth (coagulation), and the polarization efficiency decreases with increased optical depth or grain size. The youngest dark clouds tend to have the largest grain sizes, suggesting that large grains are produced early on and that after ~ 10^6 yr grain evolution is mainly destruction of larger grains, at least for the outer several magnitudes of A_V. Near compact H II regions, both ionized and neutral regions, Hoare+ (1991,MN,251,584) suggest a decrease in dust to gas ratio compared to the diffuse ISM; see also Pismis+ (1991,MN,249,385). Where grains are shattered or destroyed, as in a supernova shock (Arendt+ 1991,ApJ,368,474), infrared emission is affected.

Grain growth in the dense interstellar medium occurs by coagulation (e.g., Rossi+ 1991,AA,251,587) and mantle deposition. Clearly the long term evolution in a galaxy (e.g., Wang 1991,ApJ,374,456) will be sensitive to what assumptions are made. Chokshi+ (1993,ApJ,407,806) studied the coagulation process in detail, concluding that sticking of small particles to larger ones could be significant on available timescales, but mutual coagulation of the larger particles would not occur. When smaller grains are removed efficiently by coagulation there is a dramatic effect on the visible and, particularly, the ultraviolet portion of the extinction curve, which seems to be in accord with observations of extinction and polarization (Martin+ 1990,ApJ,357,113; 1992,ApJ,392,691).

Icy mantles are seen to have grown in dense clouds, increasing the total mass of grains. Their presence is very important to chemical evolution (Hasegawa+ 1993,MN,263,589). The CO threshold might be controlled by heating by H_2 formation (Duley + 1993,MN,260,37). Subsequent processing of these ices by ultraviolet radiation and cosmic rays could lead, over many cycles in and out of dark clouds, to a buildup of organic refractory material, depending on the yield; explosive desorption is a proposed regulatory mechanism (Schutte+ 1991,AA,244,190). In the extreme, the material could become polymerized and carbonized (Jenniskens+ 1993,AA,273,583; see AA,274,653 for optical constants). Duley+ (1993,MN,260,415) explore direct deposition and subsequent evolution of HAC mantles with application to variations in infrared emission.

4.3.5. Interstellar Grains in Solar Nebulae. Interstellar material including grains is incorporated in stars and, more importantly for sleuthwork, the surrounding nebulae or disks. Some grains might be returned in altered form from these regions. There is ongoing examination of dust in circumstellar disks; for example, a small-particle 10 μm silicate feature much like that in comets or Galactic sources is detected in β Pic (Telesco+ 1991,ApJ,372,L29) and an- other Vega-excess system (Skinner+ 1992, MN,255,P31). Anomalous extinction near Herbig Ae/Be stars is analysed by Gorti+ (1993,AA,270,426).

But most work concerns relics of the early Solar nebula, aspects of which are treated in IAU Colloquium 126, *Origin and Evolution of Interplanetary Dust* (Levasseur-Regourd+ 1991, Kluwer), *Comet Halley: Investigations, Results, Interpretations* (Mason 1990, Horwood), *The Comet Halley Archive Summary Volume* (Sekanina+ 1991, NASA), Wyckoff (1991, Earth-science Reviews,30,125), and Buseck+ (1993 AnnRevEarthPlaSci,21,255).

Greenberg+ (1990,ApJ,361,260) and Tokunaga+ (1990,Icarus,86,208) consider the connection between comets and interstellar dust and ice. Analysis of dust impacts of very fine particles ($< 10^{-17}$ g) near the nucleus of Comet Halley is consistent with an aggregation picture (Sagdeev+ 1990,SovALett, 16,315). It is also interesting that in Comet Halley the "CHON" ma- terial (composed of these light elements, probably a less volatile residue) is intimately mixed with silicates on submicron scales (Lawler+ 1992,Nature,359,810).

A rapidly developing field is study of isotopically anomalous materials in meteorites, providing primary data on stellar and supernova nucleosynthesis (Harper 1993,JPhysG,19,81). This has extended to analysis of extracted fine-grained diamonds (e.g., Russell+ 1991,Science,254,1188; see also Nuth+ 1992,ASpSci,196,117) and microanalytical measurements of individual interstellar grains of graphite and SiC in primitive meteorites and collected interplanetary dust particles (Ott 1993,Nature,364,25). The isotopic compositions of these grains provide a record of stellar nucleosynthesis and of condensation processes near carbon stars (which will not be reviewed); the fact of their survival places constraints on conditions in the solar nebula and early Solar System (see also Bernatowicz+ 1991,ApJ,373,L73; Zinner 1991,SpSciRev,56,147; Zinner+ 1991,Nature,349,51; Amari+ 1992,ApJ,394,L43; Brown+ 1992,Science,258,970; Alexander 1993,GeoCosActa,57,2869; and Prombo+ 1993,ApJ,410,393).

The matrices of ordinary chondrites might contain a common carbon component of interstellar origin (Makjanic+ 1993,Meteoritics,28,63). The 3.4 μm absorption of Galactic center source IRS 7 is remarkably similar to that of the deuterium-rich organic polymer extracted from the Orgueil carbonaceous meteorite (Ehrenfreund+ 1991,AA,252,712). No C_{60} has been found (DeVries+ 1993,GeoCosActa,57,933).

Interstellar grains are even now penetrating into the solar system. The Ulysses spacecraft detected micrometre-size particles identified by their trajectories as being of interstellar origin (Grun+ 1993,Nature,362,428).

4.4. PHYSICAL PROCESSES. Once a grain model is specified, or altered, many observational characteristics can be examined and other potentially useful derivative properties, such as the Rosseland mean opacity (Ali+ 1992,ASpSci,188,109), can be computed.

The simplest grain models are based on electromagnetic scattering by Mie spheres, infinite cylinders, or homogeneous spheroids. Mishchenko (1991,ApJ,367,561; 1990,SovAstLett,16,946) shows how to average the extinction matrix over an ensemble of nonspherical dust grains, oriented axially in the interstellar magnetic field. Wright (1991,ApJ,375,608) has shown that two proposed modifications to the standard theory for the long-wavelength absorption by grains are incorrect (see also Duley+ 1992,MN, 255,243). It is possible to study less symmetric shapes and inhomogenous (e.g., composite or porous) particles using finite element techniques, the most popular of which is the discrete dipole array method. Example investigations are by Kozasa+ (1992,AA,263,423), and Perrin+ (1991,AA,247,497; 1992,CompRendusII,316,47).

The electric potential of grains of differing properties in various interstellar environments has been investigated by Taylor+ (1991,MN,248,148). Reynolds (1992,ApJ,400,L33) discusses photoelectric heating of the warm ionized medium by grains.

Grain surfaces provide sites for the formation of molecules. This process seems well established for H_2 in cold clouds but some aspects are still being studied (Duley+ 1993,MN,260,37). Production of H_2 from modified ice mantles by cosmic rays is explored by Averna+ (1991,AA,245,239).

5. H II REGIONS. (M.R. Rosa)

5.1. INTRODUCTION.

Research on H II regions (HIIRs) benefitted a lot from further gains in observational and computing capabilities. Large amounts of calibrated spectrophotometric data have been obtained, often combined with high spatial resolution and simultaneous coverage of sizeable spatial areas. Similarly, mapping of galactic and extragalactic objects in continuum and spectral lines at X-ray, UV, visible, IR, FIR, mm and radio frequencies no longer suffers from vast differences in spatial resolution and dynamic range. Usually, observational data are now readily transformed into astrophysical quantities and it has become common practice to support the interpretation of such data with dedicated models.

The working concept of classical, homogeneous and isolated H II regions (HIIR) is steadily being replaced by the perception of complex, inhomogeneous volumes of ionized gas mixed with coexisting hot-teneous and neutral-dense volumina and evolving into and interacting heavily with the ambient medium. HIIRs in external galaxies continue to be the focus of a large fraction of research activity in the field, although they have lost their exotic attributes - largely thanks to the very intensive study of the proto-typical 30 Doradus nebula.

In view of the evolution in the field the report has been restructured. Most of the ionized gas studied at the galactic center region proper apparently has little to do with HIIRs around O type stars, and the separate section has been dropped. HIIRs associated with the earliest and the very late phases of O star evolution are considered seperately. Extensive research on proto-typical HIIRs like Orion and 30 Dor has been summarized in a dedicated section. Physical conditions and their interpretation in terms of physical processes supported by models are an additional topic. The section on abundances encompasses work based on both, galactic and extragalactic HIIRs. The section on HIIRs in external galaxies then reflects largely our view of HIIRs and their environment as studied in other galactic systems.

Among relevant general books, proceedings, review articles and catalogues not cited at the beginning of the commissions report are:

Alloin+ 1993,The feedback of chemical evolution on the stellar content of galaxies,Observatoire de Paris; Barbuy+ 1992,The stellar populations of galaxies,IAU Symp 149,Kluwer; Baschek+ 1993,New Aspects of Magellanic Cloud Research, Lect.NotesPhys,416, Springer; Blitz 1991,The evolution of the interstellar medium,ASP Conf.Ser.,12; Bloemen 1991,The interstellar disk-halo connection in galaxies,IAU Symp 144, Kluwer; Burton 1993,Distribution and observed properties of the ISM, in Bartholdi+ 1993, The galactic interstellar medium,Lect.Notes 21st Adv.Course SSAA, Springer; Cassinelli+ 1993,Massive stars: Their lives in the interstellar medium, ASP ConfSer, 35. Edmunds+ 1992,Elements in the cosmos, 31st Herstmonceux Conf, CambridgeUP; Falgarone+ 1991,Fragmentation of molecular clouds and star formation,IAU Symp 147, Kluwer; Franco+ 1993,Star formation, galaxies and the ISM, CambridgeUP; Haynes+ 1991,The Magellanic Clouds,IAU Symp 148,Kluwer; Hollenbach+ 1990,The interstellar medium in galaxies,2nd Wyoming Conf, NASA-CP-30; Klare 1993,Stellar Evolution and interstellar matter,RevModernAstron,6,Springer; Lada+ 1991,The physics of star formation and early stellar evolution,NATO ASI Ser C, MathPhysSci,342,Kluwer; Leitherer+ 1991,Massive stars in star bursts,STScI SympSer, 5, CambridgeUP; Lozinskaya 1992,Supernovae and stellar wind in the interstellar medium, AIP, New York; Palous+ 1992,Evolution of interstellar matter and dynamics of galaxies, CambridgeUP; Thronson+ 1990,The interstellar medium in galaxies,2nd Wyoming Conf,ApSpLib,161, Kluwer; Van der Hucht+ 1991,Wolf-Rayet Stars and interrelations with other massive stars inING NEBULAE galaxies; IAU Symp 143, Kluwer; Proceedings of the 3rd TexMexConfAstrophys, 1992,PASP,103,pp 759-923.

5.2. STRUCTURE AND INTERRELATION WITH ENVIRONMENT

5.2.1 Surveys

Surveys conducted with improved sensitivity and spatial resolution continue to reveal new objects. Equally important, however, is the gain in insight into the structure of the ionized medium in the galactic disk and its interrelation with molecular, neutral, and stellar components.Searches of elusive HIIRs around early B stars have been conducted by Shestakova+ 1990,Sov.Astron.Lett.,16,462. Progress is reported on the deep MWG Ha survey with detection of an optical HIIR at 11.7 kpc distance in the Coalsack region (LeCoarer+ 1992,AA,257,389).

Optical HIIRs have been surveyed with the VLA (Fich 1993,ApJS,85,475). Other reports on radio surveys include: Gaylard 1991, 3rd Haystack Obs Conf on ISM; Azcarte 1991,ApSpSci,180,105; Whiteoak 1990,ProcAstrSocAust,8,274. Most of the 1800 sources listed in the latter survey are ultracompact (uc)HIIRs and OH stars (Whiteoak 1992,AA,262,251). Similarly the VLA 20cm continuum survey of northern galactic plane (1992 discrete sources) is dominated by ucHIIRs (Becker+ 1990,ApJ,358,485), as is the case in the galactic center region survey (Helfand+ 1992,ApJS,80,211). Galactic worms (118), probably the walls of superbubbles around evolved HII regions, have been catalogued by Koo+ 1992,ApJ,390,108. Radio surveys and pointed observations also include: Reich+ 1990,AAS,85,633; Fuerst+ 1990,AAS,85,691; Fuerst+ 1990,AAS,85,805; Azcarte 1992,ASpSc,194,225; Wu Yuefang+ 1992,ActaAstrSin,12,365; Abramenkov+ 1992,SovAstr,36,374.

5.2.2 Global structures. Global structures with high complexity are now regularly seen in radio and optical maps of HIIRs. Commonly this is interpreted as star formation activity at various stages between the early obscured IR luminous sources, the cloud evaporation and blister phase, and the late phases characterized by the formation of superbubbles by OB star winds and SNe (Pismis 1990,AA,234,443; Ward-Thompson+ 1991,MNRAS,248,670; Tateyama+ 1991,MNRAS,249,716; Pineault+ 1990,MN,246,169). The apparent absence of SNRs in the radio morphology of the Cygnus OB2 region might be a sign for the relative youth of this SF event (Wendker+ 1991,AA,241,551).

Pattern recognition techniques to distinguish optical images of HIIRs from SNRs have been employed by Inglis+ 1990,MN,246,358. A statistical study of HIIR/SNR correlations in the galaxy has been performed by LiZongwei+ 1991,ApJ,378,93. The disentangling of obscured complexes using radio and IR maps has been discussed by Van der Werf+ 1990,AA,235,407; the role of low frequency mapping in Kassim+ 1990, Low Freq.Astrophys from Space,Lect.Notes Phys, Springer.

Blister HIIRs at various aspect angles and obscuration have been observed eg. by Vallée+ 1991, AA, 250, 143 and Tapia+ 1991,AA,242,388. A 10 arcmin radio jet is seen in Orion B NGC 2024 (Subrahmanyan 1992,MNRAS,254,719), a region studied also at 1.3cm by Gaume+ 1992,ApJ,388,489. Multifrequency mapping of the S187 complex composed of HIIRs, HI clouds and molecular material has been reported by Joncas+ 1992,ApJ,387,591, and the Champaign phase of GM 24 was studied by Gomez+ 1993,ApJ,409,269.

5.2.3 Internal Structure of HIIRs.

Internal structure is best studied in Orion (see Section 4), but seems to be complex also in other HIIRs. Inhomogeneities and clumping are deduced from FIR, NIR and visual line density estimators as well as the radio continuum (Colgan+ 1991,ApJ,366,172). Related to density inhomogeneities is the continuing quest for direct proves of significant temperature inhomogeneities, which might be traced eg. by differing Te estimates from radio continuum and radio recombination lines in the case of W51 (Copetti+ 1991,MNRAS,250, 127). Bok globules and HH-like objects embedded in H II regions have been studied eg. by Duvert+ 1990,AA,233,190; Gyulbudagyan+ 1991,Astroph,33,528; Bohigas 1992,RevMexAA,24,765. Additional work on the problem of density and temperature inhomogeneities is reported in Section 5.

X-rays observed from the Carina and the Orion nebulae can be associated with the winds of Eta Car, resp. Thet1 Ori, and with a diffuse component, probably due to the multitude of unresolved T-Tauri stars (Koyama+ 1990,ApJ,362,215; Yamauchi+ 1993,ApJ,403,268). Kinematics of HIIRs have been studied by Clayton 1990,MNRAS,246,712; Pismis+ 1991,PASP,103,843. HIIRs with unusually narrow radio recombination lines were observed by Planesas+ 1991,RevMexAA,22,19. The propagation of waves in H II regions and the turbulence spectrum are considered theoretically by Krasnobaev+ 1991,SovAstrLett,17,396;

5.2.4 Dust associated with HIIRs. Dust is seen as continuum and band emission in the IR and FIR as well as through its extinction properties. Central issues remain the question of how much of the dust observed is actually located inside the ionized volumina, and whether or not the grain properties are different from the diffuse ISM and the dense cloud environments (O'Dell+ 1992,ApJ,399,L67).

Observations of scattered stellar light in M8 showing He+ lines in absorption have been used to derive Dust/Gas mass ratios (Sanchez+ 1991,RevMexAA,22,285). Peculiarities in UV extinction correlated with column densities of C IV and Si IV have been observed towards stars embedded in or seen through the M8 HIIR (Boggs+ 1990, ApJ,358,441). Deviations of dust extinction from mean R-dependance have been discussed by Mathis+ 1992,ApJ,398,610. De-alignment of grains in H II regions is substantial unless strong magnetic fields are invoked (Anderson+ 1993,AA,270,479)

Emission at mm and IR wavelengths of dust associated with HIIRs has been observed (Sievers+ 1991,AA,251,231; LuoShaoguang 1991,Chi AA,16,33), an account of the 3.29 mu dust emission feature in HIIRs has been given by Tokunaga+ 1991,ApJ, 380,452. In M17 dust seems to be depleted in the ionized gas phase (Giard+ 1992,AA,264,610). Dust grain processing inside the HIIRs has been investigated by Sorrell 1992,MN,255,594 and Siebenmorgen+ 1992,AA,259,614. Different grain size populations are also invoked by Pismis+ 1991,MNRAS,249,385. The iron oxide band ad 21 mu may contribute a good fraction of the total IRAS flux observed in HIIRs (Cox 1990,AA,236,L29). Fluorescence and scattering by PAH dust particles might account for far red emission bands observed across the Orion nebula (Perrin+ 1992,AA,255,271).

5.2.5 The Galactic Center.

Close to the galactic center HIIRs apparently are different from classical HIIRs. In the Arc region they might be ionized by impact with a strong magnetic field (Serabyn+ 1991,AA,242,376), a view not shared by (Maloney+ 1992,401,559). Radio recombination lines of Sgr A West indicate Te of 20 - 40 000 K (Roberts+ 1991, ApJ,366,L15). FIR lines and continuum of the arc filaments are consistent with stars of Teff 35 000 K - but the structure and the absence of such stars are difficult to explain (Erickson+ 1991, ApJ,370,L69). An extended region of ionized gas around the galactic center sources is seen in NIR He and H lines (Geballe+ 1991,ApJ,370,L73), a bow shock wind-wind collision indicated around IRS 7 (Yusef-Zadeh+ 1992,ApJ,385,L41).

5.3.0 EARLY AND LATE STAGES OF O STAR EVOLUTION

5.3.1 Compact (cHIIRs) and ultracompact HIIRs (ucHIIRs). The traditional phases, cHII and ucHII, from deeply embedded objects to fully developped classical HIIRs have received continuing interest. A broad description of the state of research on the population of about 2500 estimated ucHIIRs in the Galaxy has been given by Churchwell 1990,AARev,2,79. Bow shock models for ucHIIRs around O stars moving through the cloud medium can yield a unifying picture for their radio morphologies (Mac Low+ 1991,ApJ,369,395; Van Buren+ 1992,ApJ,394,534). Dust emission from ucHIIRs has been modelled by Hoare+ 1991,MNRAS,251,584 Observational work on the ionized component of individual cHIIRs has been reported by Zhou Zhen-pu+ 1990,Chin.AA,15,232; Estalella+ 1991,ApJ,371,626; Wood+ 1991,ApJ,372,199; Gaume+ 1991,ApJ,376,608;Fey+ 1992, AJ,103,234. Statistics of cHIIR in IRAS PSC data base have been evaluated by Zhou Zhen-pu+ 1990,Chin.AA,15,207. One of the only 4 high excitation optical cHIIR in the LMC has been described by Heydari-Malayeri+ 1990,AA,240,481, IR images of embedded young stars in M8 (Woodward+ 1990,ApJ,365,252), M17 (Lada+ 1991,ApJ,374,533), NGC 3603 and 30 Dor (Lapierre+ 1991 ASP (012.050) 155) indicate normal solar neighborhood IMFs.

5.3.2 Nebulae around stars. Ring nebuale around Wolf-Rayet stars and nebulosities ionized by other highly evolved massive stars have been the subject of studies aiming at the evolution of the nebulae and of the chemical abundances in the evolved stellar surfaces (Arnal+ 1991,AA,250,171; DeFreitasPacheco 1992,AA,266,36; Dopita+ 1990,ApJ,359,419; Esteban+ 1991,AA,244,205; Esteban+ 1992, ApJ, 390, 536; Heydari-Malayeri+ 1992,AA,236,L21; in Garmany 1990,ASP ConfSer 132: Smith+ p132; Rosa+ p135; see also in Van der Hucht+ 1991,IAU Symp 143: Dopita+ p371, Vilchez+ p379, Smith p385, Pakull P391, Montmerle p397, Cassinelli+ p421, Esteban+ p422; Niemela+ p425). The northern sky has been searched again for very low surface brightness ring nebulae by Miller+ 1993,ApJS,85,137. Objects with morphologies of wind–swept bubbles generally show ISM abundance ratios. Nebulae clearly composed of ejecta show O/H deficiencies and N/H, He/H overabundances with respect to the ISM. These abundance anomalies are typical for CNO cycled zones at the surfaces of evolved massive stars (Esteban+ 1992,AA,259,629). The dust content of WR ring nebulae is consistent with stellar material in ejection type nebulae and with ISM swept up material in wind blown bubbles (Marston 1991,ApJ, 366,181; Mathis+ 1992,ApJ,384,197).

5.4. PROTO-TYPICAL H II REGIONS

5.4.1 Orion Nebula.

The Orion nebula proper has received large attention again, stimulated by unprecedented capabilities in high sensitivity, high resolution imaging and spectroscopy at all wavelengths. On the smallest scales networks of ionized filaments, possibly shocked ionized gas, have been revealed in radio continuum maps (Yusef-Zadeh 1990,ApJ,361,L1). This is complemented by the extraordinarily high degree of structure at subarsecond resolution seen in particular in [SII] line HST WFPC images (Hester+ 1991,ApJ,369,L75). Further detail includes edges of ionization fronts (O'Dell+ 1991,PASP,103,824), shocks and proto-stellar disks (O'Dell+ 1993,ApJ,410,696). The radio morphology from scales of 10' to 0.1" is presented by Felli+ 1993,AAS,98,137).

Across the main body of the nebula ionization fronts at the near side are visible in stellar He I, Ca II absorption lines (O'Dell+ 1993,ApJ,403,687). Kinematical data from [OI] emission (O'Dell+ 1992,ApJ,387,229) and of radio recombination lines (Gosachinskij+ 1992,Sov.Atron.Lett,18,No 2) are used to study the ionization fronts at the rear side towards the molecular cloud. Motions have been mapped in [SIII] (Wen+ 1993,ApJ,409,262).

Physical conditions and extinction across the main body have been studied at 2" resolution by means of imaging spectrophotometry (Pogge+ 1992,ApJ,399,147). An area study of extinction and scattering in Orion based on 21cm and Hbeta maps indicates that most of the extinction occures in front of the nebula (O'Dell+ 1992,ApJ,399,L67), with possible ramifications on models assuming particle processing to explain extinction anomalies. Studies of neutral inclusions contain: high velocity resolution spectra of ionized knots and jets (Meaburn+ 1993,260,625); sub-parsec sized neutral cloudlets (Van der Werf+ 1990,ApJ,364,157); large scale interaction of the HIIR with the molecular cloud (Rodriguez-Franco+ 1992,AA,264,592)

A detailed "blister" model for Orion has been discussed by Rubin+ 1991,ApJ,374,564, Rubin+ 1991, PASP,103,834; new spectrophotometric observations and a corresponding model also by Baldwin+ 1991, ApJ, 374, 580. Extensive spectrophotometric data of faint emission lines (Osterbrock+ 1992,ApJ,389,305) indicate apparent depletion of Fe and Ni by a factor 5. HI and HeI lines agree rather well with recombination line theory.

At larger scales the assymetric blister type nature of the ionized region at the edge of a molecular cloud is revealed by mapping at low frequencies, where the large optical depths towards the core region allow for a direct determination of an electron temperature of 7865 K (Subrahmanyan 1992,MNRAS,254,291). On the other hand, intermediate band photometry of the visible part of the blister reveals symmetry about the Trapezium cluster (Greve+ 1993,AAS,99,577). Techniques to isolate line emission, nebular continuum and scattered stellar light in narrow and broad band imaging of H II regions are demonstrated on the example of the Orion nebula (Waller+ 1990,PASP,102,1217). At the largest scales Barnards Loop has been mapped between 12 and 25 MHz (Abramenkov+ 1992,Sov.Astron.J,36,246).

5.4.2 The 30 Doradus Nebula.

30 Dor, the proto-type of an evolved giant HIIR, has been mapped from radio to X-ray wavelengths. [OIII] and continuum images show that this 1 kpc diamtere HIIR is enclosed by a dust ring (Bruhweiler+ 1991,ApJ,370,551). Radio maps reveal embedded SNRs (eg. Sabalisck+ 1990,Rev.Mex.AA,21,507). X-ray images demonstrate that hot gas must be well mixed with the HIIR (Wang+ 1991,ApJ,370,541; Truemper+ 1991,Nat,349,579), likely due to both, stellar winds and SNe. Evidence of shocked gas is seen in the HIIR emission line spectum (Rosa 1993, in Klare 1993, cit, p 145). The related gas kinematics and stellar content have been revisited by Lortet+ 1991,AAS,89,185. Information on the stellar and dust contents can also be deduced from Astro-1 UV (Cheng+ 1992,ApJ,395,L29) and NIR images (Rubio+ 1992,AA,261,L29). The extinction towards 30 Dor has been studied using Paschen/Balmer line ratios by Greve+ 1991,AA,251,575.

A break-through in the quest for the nature of the 30 Dor cluster core R 136 was acieved by resolving it into a tight group of luminous early type stars of various evolutionary stages in HST FOC images (Weigelt+ 1991,ApJ,378,L1). The interaction of the evolving O star burst with the ISM has been set into context by (Walborn+ 1992,ApJ,399,L87). Work in progress on the stellar content of the entire 30 Dor OB cluster indicates that the IMF is not very different from the solar neighborhood. A CMD of 2400 stars, 150 of which have now spectroscopic classifications, has been presented by Parker 1992,PASP, 104,1107.

5.5. PHYSICAL PROCESSES AND MODELS

As quantitatively more high quality observational material became available, the past 3 years have seen a fresh impetus on activities to understand and model details of the physical processes in H II regions. Very detailed models of the Orion nebula are reported in Section 4.1.

Testing of the HI level populations on radio recombination line spectra showed that standard departure coefficients provide a sufficient description, while Lyα pumping seems to be of no importance (Wilson+ 1990,AA,238,331). At mm wavelengths (H36-H60) the same conclusion was reached by Gordon+ 1990,ApJ,365,606. Non-LTE effects were also studied by Cersosimo+ 1992,AA,239,287. Recombination line theory combined with radiative transfer in dusty nebulae and their impact on uncertainties in the observational determination of the primordial H/He abundance was investigated by Hummer+ 1992,MN,254,277. The recombination line spectrum of neutral Helium has been reassesed by Smits 1991,MN,251,316.

Photoionization models have been used extensively in order to provide ionization correction factors (Mathis+ 1991,AA,245,625), to determine the behaviour of ionic electron temperatures (Garnett 1992, AJ, 103, 1330), and to study effects of stellar atmosphere models on predicted emission line spectra (Evans 1991, ApJS, 76, 985). Peimbert+ 1991,PASP,103,815 investigated the effect of shock waves on the integrated spectra of HIIRs, and the use of NeIII/OII line ratios for He ICFs was looked at by Blum+ 1991,PASP,103,1182)

A model for PIG radio continuum spectra was produced by Pastor+ 1991,AA,246,551. Models for the IR emission from OB star environments have been presented by Leisawitz+ 1991,ApJS,77,451; escape of Ly a radiation from a multiphase ISM by Neufeld 1991,ApJ,370,L85. The radiative cooling of optically thin plasmas, eg. HIM surrounding HIIRs or located in wind/SN bubbles inside HIIRs, has been investigated by Schmutzler+ 1993,AA,273,318. Scattering of light in nebulae has been studied analytically by Kolesov+ 1991, Astroph.,33,No 2.

Density inhomogeneities have been included analytically into photoionization codes by Williams 1992, ApJ, 392, 99 and applied to Nova envelopes. Density sensitive line ratios in models of inhomogeneous nebulae have been studied by Safier 1992,ApJ,392,492 and a density gradient model was produced for IZw18 (Campbell+ 1990,ApJ,362,100).

The Bowen fluorescence mechanism has been studied further by Kastner+ 1990, ApJ,362,745; observationally by Lin+ 1993,MN,261,465. Excess [NIII] line emission in planetary nebulae seemingly does not arrise from Bowen type resonance fluorescence (Kastner+ 1991,ApJ, 381,L59) but rather from continuum fluorescence (Ferland 1992,ApJ,389,L63). Charge transfer reactions are reviewed by Shields 1990,in Molecular Astrophysics (Hartquist ed.),CUP,p461. The unidentified emission lines at 2.2 mu were studied further in PNs and cHIIR, and should correspond to ionization potentials of order 50 eV (Geballe+ 1991,MN,253,75).

5.6. ABUNDANCES AND GALACTIC GRADIENTS

Reviews on chemical composition include Aller 1990,PASP,102,1097; Dinerstein 1990, 2nd Wyoming Conf. on ISM,p 257; and Shields 1990,AnnRevAA,28,525.

A constant, but rather low, C/H was found across the Orion nebula by Walter 1991,PASP,103,830; invoking rather large Te fluctuations Walter+ 1992,ApJ,397,196 arrive at solar like CNO abundances on their set of new data from 22 positions in the nebula. A multi-position (17) analysis of the chemical composition of M17 was presented by Peimbert+ 1992,RevMexAA,24,155, and the ionization structure of a real nebula compared with photoionization models.

Anomalously high He+/H+ abundances have been reported from radio recombination line observations of DR-21 (Tsivilev 1990,Sov.Astron.Lett.,17,1) and W3 (Roelfsema+ 1992,ApJ,394,188). He+/H+ abundances from radio recombination lines have also been analyzed by Peimbert+ 1992,ApJ,395,484. The issue of primordial He/H abundance determinations using galactic and extragalactic HII regions has been looked at again (Pagel+ 1990,Proc.Astron.Soc.Aust.,8,243; Maciel+ 1991,RevMexAA,21,197; Olive+ 1991, ApJ,380,L1), and the role of local He enrichment from evolving massive stars was investigated (Pagel+ 1992,MN,255,325; Campbell 1992,ApJ,401,157).

In irregular galaxies N/O does not show systematical variations with O/H, the scatter in N/O is possibly due to the burst-like nature of the SF events (Garnett 1990,ApJ,363,142) and the self-enrichment of HIIRs (Pilyugin 1992,AA,260,58). N/H abundances in HIIRs in the outer galaxy are also relatively high (Fich+ 1991,ApJ,366,107). Ar/S in IZw18 is cosmic within 0.2 dex (McCall+ 1990,2nd Wyoming, 151).

The galactic abundance gradient has further been studied on a sample of small H II regions (Hunter 1992,ApJS,79,469). The chemical composition and abundance gradients in external galaxies were also the subject of many papers reported in Section 6. The abundance gradients now known for some 30 galaxies were discussed by Vila-Costa+ 1992,MN,259,121. Grids of photoionization models were again computed in order to study the role of possible IMF variations and stellar metallicity on the OII/OIII excitation sequence in extragalactic HIIRs (McGaugh 1991,ApJ,380,140).

Depletion of refractory elements affects the cooling and, at the high Z end, may lead to factor 2 overestimates of O/H (Henry 1993,MN,261,306). New transition probabilities for CI and Ar (Raassen+ 1992,AAS,95,223) and new photoionization and recombination cross sections from the Opacity Project (Nahar+ ApJ,397,792) can be expected to have impacts on nebular models and chemical abundance determinations.

The comparison of LMC/SMC and galactic abundance ratios as derived from H II regions and F stars shows S/O, C/O to be in agreement for stars in SMC and Galaxy, C/O deficient in the SMC on the basis of HII data (Spite+ 1990, AA,234,67; Russel+ 1992,ApJ,384,508). O/H abundances in Virgo cluster spirals are substantially higher than those in comparable field galaxies, and the O/H gradients appear to be flatter (Shields 1991,PASP,103,916; Henry+ 1992,MN,258,321; Martin+ 1992,ApJ,397,463). The same trends are found in early type spirals in the field (Oey+ 1993,ApJ,411,137). S/O gradients in debate in previous years could not be found in M101 and M51 (Diaz+ 1990,Rev.Mex.AA.,21,223; Diaz+ 1991,MN,253,245), but might be related to ICF uncertainties.

5.7. H II REGIONS IN EXTERNAL GALAXIES.

Shields 1990,AnnRevAA,28,525 reviewed physical properties of HIIR in external galaxies and methods of abundance determinations, Kennicutt 1991, in Leitherer+ 1991,cit,p 157 the stellar contents.

The atlas of HIIRs in M101 by Hodge+ 1990,ApJS,73,661 triples the catalogued objects to 1264. For the same galaxy Scowen 1991,PASP,103,902 and Scowen+ 1992,AJ,104,92 have mapped and analyzed physical conditions of 600 HIIRs. Further catalogues yielding eg. HIIR luminosity functions, velocity dispersions, estimates of SF activity, of IMF parameters, of extinction properties and of chemical abundances in spiral have been produced by: Aparicio+ 1992,AA,260,77; Arsenault+ 1990,AA,234,23; Belley+ 1992,ApJS,78,61; Coradi+ 1991,AA,244,27; Courtes+ 1993,AA,268,419; Duval+ 1991,AA,241,375; Gonzalez-Serrano+ 1991,AA,242,334; Hodge+ 1990,PASP,102,657; Krienke+ 1991,PASP,103,661; Pastoriza+ 1993,MN,260,177; Rand 1992,AJ,103,815; Richer+ 1992,AJ,103,54; Roy+ 1993,ApJ,406,60; Rubin+ 1991,MN,252,550; Sakhibov+ 1990,Sov.Astron.,34,236; Sivan+ 1990,AA,237,23; Skillman 1991,PASP,103, 919; Strobel+ 1990,PASP,102,657; Strobel+ 1991,ApJ,383,148; Von Hippel+ 1990,AJ,100,403.

Spectrophotometric data for chemical abundance analysis were also obtained by Walsh+ 1993,MN,262, 27; Garnett+ 1992,AJ,104,1714; Burenkov+ 1990,Astroph.,32,135; Heydari-Malayeri+ 1990, AA, 234, 99; Price+ 1990,AJ,100,420; Roy+ 1991,AJ,101,825. On the basis of such data statistics of the HIIR population in spirals were the topics of contributions by Caldwell+ 1991,ApJ,370,526; Cepa+ 1990 ApSpSci 170,297; Garcia-Gomez+ 1991,AAS,89,159 and Ye 1992,MNRAS,255,32. Correlations of HIIRs with historical SN events have been looked at by Van Dyk 1992,AJ,103,1788.

As spatial resolution and sensitivity increase, studies on HIIRs in nearby galaxies begin to offer us views on the complex ISM analogous to what is seen locally. The complex N120 in the LMC for example turns out to be a sample of *classical HIIRs, SNRs and wind blown bubbles (eg. Laval+ 1992,AA,253,213;* McCall+ 1990,AJ,100,193). Molecular gas is found in Magelanic Cloud HIIRs (Israel+ 1991,AA,250,475) and in those in M33 (Scoville+ 1992,ApJ,385,512; Viallefond+ 1992,AA,265,437). Density inhomogeneities are revealed (Castaneda+ 1990,ApSpSci 171,203; Masegosa+ 1991,AA,249,505; Castaneda+ 1992,AA,260,370), diffuse X-ray emission not associated with distinct SNRs is observed (Chu+ 1990,ApJ,365,510), and large scale filaments and superbubbles are found outside the classical HII regions (Hunter+ 1990,ApJ,362,480; 1992,ApJ,391,L9).

The dust content of LMC HII regions was studied using photometry of embedded stars (Greve+ 1990,AAS,85,895). IRAS maps have been produced for HIIRs in M33 (Rice+ 1990,ApJ,358,418). Multi-frequency radio/IR/optical data were analyzed in order to evaluate the amount of dust heating by non-ionizing UV photons in HII galaxies (Dultzin-Hacyan+ 1990,AA,238,28), and to disentangle the thermal HIIRs from the non-thermal smooth disk in M101 (Graeve+ 1990,AA,238,39). High resolution mm continuum maps of the M 82 HIIRs were produced by Carlstrom+ 1991,ApJ,366,422)

Spectra often show high velocity features, sometimes summing up to 3000 km/s broad components of the nebular emission lines, likely due to the combined effect of stellar winds and SNe (Castaneda+ 1990,ApJ,365,164; Roy+ 1991,ApJ,367,141; Roy+ 1992,ApJ,386,498; YeTaisheng+ 1991,MNRAS,249,722. Velocity dispersions in HIIRs of NGC 1275 have been studied by Shields+ 1990,AJ,100,1805.

The stellar content of extragalactic HIIRs, most of which are 30 Doradus type evolved, giant objects around populous clusters of O stars and their late evolutionary WR phases, has been studied using properties of the integrated spectra or the UV flux (Bohlin+ 1990,ApJ,363,154; Ivanov 1991,MN,251,281; Terlevich+ 1991,Rev.Mex.AA,21,192; Hill+ 1992, ApJ,395,L37). Classification and number counting of individual stars or groups thereof have been reported by Debray 1990,IAU Symp 143,427; Drissen+ 1990,ApJ,364,496; Drissen+ 1993,AJ,105,1400 (based on HST FOC images); Rubio+ 1990,Rev.Mex.AA,21,249; and Deharveng+ 1992,AA,259,480; Dynamical constraints on star formation using HIIR data were deduced by Waller+ 1991, in IAU Symp 146, 187)

HeII emission, apparently of nebular origin, is found in serveral LMC/SMC and other extragalactic HIIRs (Garnett+ 1991,ApJ,373,458). Garnett+ 1991,PASP,103,850 discuss possible sources which include extremely hot massive stars, supported by new non-LTE stellar atmosphere models (Gabler+ 1992, AA, 265, 656), shocked gas, or strong X-ray radiators such as LMC X-1. Drissen+ 1991,AJ,101,1659 found 19 candidates for ring nebulae in M33, but no none of those HeIII regions.

Finally, arguments were brought forward that HIIRs in star forming galaxies at semi-cosmological redshifts might be the metal line absorbers in QSO spectra (Gruenwald+ 1992,ApJS,78,153; Yanni+ 1992, ApJ, 391, 569).

6. SUPERNOVA REMNANTS (T.Lozinskaya and M.Dopita)

6.1. INTRODUCTION

Recent general reviews on Supernova and their remnants are to be found in IAU Coll. No 115; "High Resolution X-Ray Spectroscopy of Cosmic Plasmas", ed. Burton 1990, the 10th Santa Cruz Summer Workshop in Astronomy and Astrophysics: "Supernovae"; Ed. Woosley, S.R., the NATO Advanced Research Workshop on "Physical processes in Hot Cosmic Plasmas", 1990, the AIP Conf. Proc. No 211, 1990, and the ESO/EIPC Workshop on "SN1987A and other SNe", 1991. A major review of the interaction of supernovae and mass-loss stars with their environments is given in Lozinskaya T.A., 1992 "Supernovae and Stellar wind in the Interstellar Medium", AIP:New York. A review of the interaction of supernovae with circumstellar matter is presented by Chevalier R.A., 1990 in "Supernovae", p. 91-110. A review of supernova remnants in general is given in Strom R.G. 11th. European Regional Astronomy Meeting of IAU: "New windows to the universe", v.2, p.463-477.

The study of SNRs has been much enhanced in the period of review by the the combination of observations made in different on wavebands, such as the comparative morphological analysis of Pup A at radio IR, optical and X-ray frequencies by Arendt R.G. + 1990 (ApJ 310,266), the optical/X-ray/radio images of SNR 3C 400.2 by Winkler P.F + 1993 (ApJ 405, 608) or the comparison of the VLA radio and EINSTEIN

X-ray morphology of G33.6+0.1 by Velusamy T.+ 1991 (AJ 102, 676). These show clearly that the way to the future understanding of SNR evolution is through a mutli-disciplinary approach.

6.2 YOUNG SUPERNOVAE

6.2.1. Plerionic or Pulsar-Containing SNR

The Crab Nebula has been a continued focus of interest. CCD observations of the optical polarisation of the Crab Nebula have been used to study magnetic field structure in the synchrotron nebula (Hickson P., and van den Bergh S. 1990 ApJ 365, 224). Multifrequency high-resolution observations by Bietenholz M.F.+ (1990 Ap. J. 357, L13 ; 1991 ApJ 368, 231), show the magnetic field of the Crab Nebula is generally well ordered on a scale size of about 10", aligned radially along most of the periphery. Depolarization is caused by a network of filaments containing thermal gas, which are too small to be seen individually. The field in the Crab Nebula 'jet' is aligned along its length. The authors conclude that the jet is most likely the result of a high-velocity beam formed inside the nebula. On the other hand numerical simulation by Cox C.I.+ 1991 (MNRAS 250, 750) support the model in which jet is formed by the interaction of the SNR material with a cooled trail left by the progenitor star. Based on their model the authors conclude that Crab is situated within the warm component of the ISM and its the outer halo which has been proposed does not exist. Marcelon, M. +1990 (AA 228, 471) have shown from optical spectroscopy that the jet is expanding as a cylinder at 260km/s. CCD images have been obtained in the continuum at different polarization angles by Michel F.C.+ 1991 (ApJ 368, 463). These show that the dominant synchrotron emission comes from an hour-glass shaped structure symmetrically centered on the pulsar. This pattern can be provided by the pulsar magnetized wind organized azimuthally about the pulsar spin axis provided that the torus is slightly inclined to our line of sight. The overall polarization picture shows "scalloping" of the external regions of the synchrotron nebula and depolarization across its face. This can be understood if the bright filaments ejected by SN form a conductive Faraday "cage" which encloses the synchrotron nebula.

Bietenholz M.F + 1991(ApJ 373, L59) have measured the expansion of the synchrotron nebula. This rate of expansion is similar to that of line-emitting filaments. It is shown that the synchrotron component expands homologously but with acceleration so that it now seems to be larger than that of optical filaments. If confirmed, this implies that the relativistic gas is currently "bursting through" the net of filaments of thermal plasma.

Multifrequency VLA observations at different epochs allow one to obtain both the rate of expansion and changes in the radio spectra of the filaments (Velusamy T. + 1992 MNRAS 255, 210). The radio spectrum was shown to become steeper at the outer region of the shell suggesting shock acceleration of relativistic electrons. Images of the Crab nebula at 178 and 750 MHz have been reconstructed from lunar occultation data (Agafonov M.I.+ 1990, Astron Zh. tom 67, 549; Sov. Astron. 34, 275).

The thermal filaments have been studied by Hester J.J. + 1990 (ApJ 357, 539). They present 1.644 micron [FeII] and 1.57 micron continuum images. The ratio of IR to optical synchrotron emission show variations which appear to be related to position of the pulsar. MacAlpine G.M. and Uomoto A. 1991 (Ast. J. 102, 218) have measured the luminosity in the H- beta and HeI lines and in the synchrotron continuum. The mass of the line-emitting gas is estimated to be 1-2 M(sun) in agreement with previous measurements. Hennessy, G.S. + 1990 (ApJ 395, L13) have presented UV images made with UIT. Observations of the both the filaments and the continuum in the far UV have been made by Blair W + 1992 (ApJ 399, 611) using the Hopkins UV telescope (HUT). These suggest that the optical filaments are subject to a large variation in the ionisation parameter, although it is also possible that the C abundance is a factor of 10 above solar. An expansion velocity of 1100 km/s, was also found. Fesen, R.A. 1990 (ApJ 351, L45) has established the presence of dusty inclusions in filaments bright in [O I], [C I] and [S II]. Strom, R.G. + 1992 (Nature 358, 654) established from IRAS data that the dust temperature is 48K and the dust mass is $0.02M_\odot$.

Observations with IRAS have been combined with 21 cm data on the ISM around the Crab nebula (Romani, R.W. + 1990 Ap. J. 349, L51). These show an extensive bubble ($\approx$ 180 pc in diameter for an assumed distance of 2 kpc). This bubble is surrounded by a dense shell and is thought to have been blown by the progenitor stellar wind.

Finally, Lang, M.J. + 1990 (Nucl. Phys. B, Proc. Suppl. 14A, 165) and Vacanti G. + 1991 (ApJ 377, 467) have confirmed detection of the Crab nebula at TeV energies.

Despite the continuing interest in the Crab nebula, studies of other Crab-like SNR have continued to yield insights into the physics of this class of object. In particular, the X-ray spectra obtained with LAC of Ginga show that all, or most, Crab-like SNR have an X-ray spectral index near a value of 2. (Asaoka I. and Koyama K., 1990 P. A. S. Japan. 42, 625). The morphology of SNRs with pulsars has been considered by Bhattacharua D., 1990 (J. Ap. Ast. 11, 125)

The SNR 0540-69 in the LMC is one of the better examples of the complex phenomena presently thought to accompany a crab-like SN II expolosion. Caraveo P.A.+ 1992 (Ap. J. 396, L103) provided high-resolution optical imaging of this SNR. They discovered previously unseen structure smaller than the synchrotron nebula having a totally different shape, which could be interpreted as either a ring seen edge-on or else a jet. Chanan, G.A. + 1990 (ApJ 352, 167) measured the synchrotron nebula to be polarised by 5.6% at V.

Koo B.-C.+ 1990 (ApJ 364, 178) have detected an HI shell in the old, pulsar-powered SNR CTB 80. Its size and expansion velocity imply a dynamical age of about 8 10^4 yrs, close to the pulsar age 10^5 yrs. The shape of HI shell fits well that of previously known IR shell. Fesen, R.A.+ 1990 (AA 240, 376) presented a fully sampled data cube describing the kinematics of the core of CTB 80. The model suggested is that of an ellipsoidal shell expanding at a velocity of about 90 km/s , with a high systemic radial velocity 36+-10 km/s, excited by the central pulsar, PSR 1951+32. The timing properties of this pulsar were reported by Foster R.S.+ 1990 (ApJ 356, 243).

A search for fast-moving features in the optical remnant of 3C 58 by Van den Bergh S. 1990 Ap. J 357, p. 138) have not revealed any high velocities (v ¡ 500 km/s for bright crisp knots ¡1000 km/s for faint fuzzy features). The nebulosity may represent quasi-stationary circumstellar material acted on by passage of the fast-moving SN-shell.

The SNR G5.4-1.2 is a shell-type SNR having a pulsar and plerion just outside. It is assumed to be a more evolved version of CTB 80; the pulsar assumed to have already penetrated the shell. New polarisation observations of this SNR by Milne D.K. + 1992 (MNRAS 255, 707) reveal an extremely high high rotation measure. Kundt W., 1992 (Ast. Space Sci. 190, 159) considered the illumination of a similar object, the SNR G5.3-1 (=bird) by its pulsar PSR 1757-24.

Low-frequency 34.5 MHz observations of the Vela SNR by Dwarakanath K.S., 1991 J. Astrophys. Astron., 12, 199 gave a spectral index of -0.16+-0.02 for Vela X and -0.53+-0.03 for Vela YZ confirming that Vela X is a plerion, while Vela YZ is a shell-type SNR.

A number of recently discovered pulsar-SNR associations have been studied. PSR 1758-24 and G5.4-1.2, a remarkable pulsar-SNR association,has been investigated in detail (Manchester R.N. +1991 MNRAS 253, 7P; Kundt W., 1992, Ap. Space Sci. 190, 159; Milne D.K.+ 1992 MNRAS 255, 707). New observations of both the SNR G308.8-0.1 (previously known as an unusual SNR) and the pulsar PSR J1341-6220 (previously considered not to be related because of its location outside the SNR shell) show that the SNR to be shell-like and containing a short- period pulsar of age about 12 000 yrs (Caswell J.L. + 1992, ApJ 399, L151;Kaspi V.M. + 1992 ApJ, 399, L155). Kassim N.E.+ 1990 (Nature, 343, 146) have proposed a possible new association of the pulsar PSR 1800-21 with the SNR G 8.7-0.1 (W30). Finally, Wolszczan A.+ 1991(ApJ 372, L99) have discovered a young 267 ms pulsar within the radio shell SNR W44. Bignami G.F., Caraveo P.A., Mereghetti S., 1992 (ApJ 389, L67) report that the optical counterpart of 1E 1207.4-5209, the central X-ray source of a ring-shaped SNR PKS 1209-52 remains unseen down to V=24. Sanbonmatsu K.Y.+ 1992 (AJ 104, 2189) have given a distance determination for the SNR G27.4+0.0 and its central X-ray source.

6.2.2. Remnants of Type Ia Supernovae

Optical CCD interference filter imagery and long-slit spectroscopy of Kepler's SNR (Blair W.P+ 1991 ApJ 366, 484) revealed nonradiative (Balmer dominated) shock emission from knots. The shock velocity is estimated to lie in the range 1530-2000 km/s. An expansion time scale of 3200+-1200 yrs was found by Bandiera R. + 1991 (ApJ 374, 186) from the proper motion of 50 optical knots measured over a baseline of half century. The space velocity of 248+-12 km/s (for an assumed distance 4.5 kpc) confirms that the progenitor was a high-velocity object. The dynamics of the interaction of Kepler's SNR with the dense circumstellar medium, taken into account stellar wind of a moving progenitor and multiple shocks formation have been considered by Borkowski K.J. + 1992 (ApJ 400, 223).

Hatsukade I. + 1990 (PASJ 42, 279) discussed the X-ray spectrum of Kepler's SNR, and derived parameters of the hot non-equilibrium plasma. From this they were able to determine the abundance of iron, and to compared the results with those found for the Tycho SNR. Soft X-ray spectra of the SN 1006 (Leahy D.A. +1991 ApJ 374, 218) confirmed the theoretical "reverse-shocked ejecta" model of this SNR.

Smith R.C. + 1991 (ApJ 375, 652) analysed the optical spectra of six Balmer-dominated SNRs: Tycho, SN 1006 and four SNR of this class in the LMC. All but one in the LMC objects exhibit the broad (580 to 2300 km/s FWHM) Hα lines characteristic of collisionless shocks. The Hα line widths compared with theoretical models gave the shock velocity. These authors demonstrate that the intensity ratio of broad to narrow components is not a reliable diagnostic of shock velocity. Long K.S. and Blair W.P., 1990 (Ap. J. 358, L13) have identified Balmer- dominated filaments in RCW 86. The shock velocity derived from the wide Hα component (500-930 km/s) indicates that this SNR is rather young.

High-resolution radio observations of the Tycho's SNR at several frequencies (Dickel J.R + 1991AJ 101, 2151; Wood G. + 1992 AJ 103, 1338) have been used to determine the intrinsic direction of the magnetic field. In this remnant, the field shows cellular pattern with a net radial orientation and fairly low degree of polarization. A CCD image of Tycho SNR obtained in [Fe XIV] line failed to detect any emission (Teske, R.G. 1990 ApJ 362, 563).

6.2.2. Oxygen–Rich Type II Supernova Remnants

The general morphological structure of Cas A at 81 MHz is found to be similar to that at 1380 MHz; however the spectral index varies over the image (Woan G. and Duffett-Smith P.J., 1990 MNRAS 243, 87). These measurements show that Cas A does not contain a steep-spectrum compact component with a flux density higher than a few Jy, contrary to what had been suggested by earlier observations at metre wavelengths. The spectral index variations over a range of -0.64 to -0.92 have been used to study the relativistic electron population in Cassiopeia A (Anderson M.C. and Rudnick L. 1990, BAAS 22, 751; Anderson M. + 1991 ApJ 373, 146). Regions of steeper spectral index can be associated with compact features such as the "bow shocks"; whereas flatter spectra are associated with the bright radio ring. According to the model bow shocks are caused by dense clumps of ejecta newly encountering the shocked ISM, whereas the ring maps out the blast wave. Cas A shows a secular flux-density decrease. At the wavelength 7.9 m this has been measured to be (0.70+- 0.19)% /year over the period 1956-1991; half of the value derived by extrapolation of the frequency dependence of the rate of decline in flux (Vinyajkin, E.N. + 1992, Pisma Astron. Zh 18, 755). On the other hand, Hook I.M. +,1992 (AA. 255, 285) measured the rate of decrease at 81.5 MHz and now find no evidence for a dependence of the rate of flux decrease with frequency.

An upper limit of optical depth in the H165α and H166α radio recombination lines was obtained by R. L. Sorochenko and G. T. Smirnov 1993 (Pisma Astron. Zh. 19, 359). This result can be understood if the fossil HII region around Cas A has a higher temperature than that of a "normal" HII region or if the low-frequency cut-off in the Cas A spectrum is not entirely due to the interstellar medium.

A small region of the bright rim of Cas A was mapped in its 20 μmemission (Greidanus H. and Strom R.G., 1991 AA 249,521). This revealed no correlation between IR structures and fast moving optical knots, X-ray structures or radio condensations. In particuler, the detailed correlation between hot X-ray plasma and heated dust predicted by the theory is totally absent.

Fesen R.A., 1990 (AJ 99, 1904) discovered that Ne-rich filaments exist in Cas A. New clues to the nature of the Cas A progenitor were provided by the discovery that one knot in the NE ejecta 'jet' exhibits Hα and [NII] emission like those seen in quasi-stationary flocculi, as well as [OI], [OIII] and [SII] such as seen in fast-moving knots (Fesen R.A. and Becker R.H., 1991 ApJ 371, 621). These observations suggest that, at the time of the explosion the progenitor posessed a thin Hydrogen-rich outer layer. This places constraints on the evolutionary phase of the probable WR progenitor.

VLA observations of the SNR Puppis A at 327 and 1515 MHz by Dubner G.M., + 1991 (AJ 101, 1466) show signs of interaction of the shell with the inhomogeneous surrounding gas. They also found an excellent correlation between radio and x-ray morphologies and variations of spectral index over the image.

Hwang U. + 1992 (BAAS 24, 790) have presented high-resolution X- ray spectroscopy of the oxygen-rich SNR in the LMC, N132D, while Canizares, C.R. 1990 (IAU Coll. # 115, p136) has analysed EINSTEIN focal plane crystal spectrometer data of Pupp A, Cas A, and N132D in the LMC.

The SNR MSH 15-52 is an example of an oxygen-rich SNR containing a pulsar bright at X-Ray wavelengths. Trussoni E. + 1990 (AA 234, 403) provided X-ray EXOSAT observations of this system. Thorsett S.E. 1992 (Nature, 356, 690) has speculated on the possible identification of the PSR 1509-58 in the SNR MSH 15-52 with the "guest star" of A.D.185.

6.3 OLD SUPERNOVA REMNANTS.

6.3.1. Radio Observations.

The number of known SNRs known is growing rapidly, mainly thanks to radio observations. For the first time we have been able to observe in detail the birth of a radio SNR in SN 1987A (Staveley-Smith L.+ 1992 Nature 355,147).

The catalog of galactic SNR (Green D.A., 1991, PASP 103, 209) in its updated version (Green D.A., 1993, A Catalog of galactic SNR, MRAO, University of Cambridge, Department of Physics) now contains 182 objects. A WSRT radio survey at 327 MHz of the galactic plane region $44° < l < 90°$ has been provided by Taylor A.R.+ 1992 (AJ 103, 942) using WSRT at 327 MHz. A total 24 SNRs were identified, 11 of which are newly discovered objects. The excess of filled-center objects remarked upon, if confirmed, would be important for understanding of evolution of synchrotron emission of relativistic electrons either shock accelerated or ejected by a central pulsar. The southern galactic plane is being currently surveyed by the MOST operating at 843 MHz (Whiteoak J.B.Z., 1990, PAS. Australia. 8, 274), and Gorham P.W. 1990 (ApJ 364, 187) has provided a radio/infrared/optical study of candidate SNRs from the Clark Lake 30.9 MHz galactic plane survey. Of the 80 sources detected, more than half show one or more of the characteristics typical for SNRs. High-resolution 330 MHz VLA observations of 20 galactic SNRs have been reported by Kassim N.E., 1992 (AJ 103, 943). Trushkin S.A. + 1990 (Astrofiz. Issled. Izv. Spets. Astrofiz. Obs., 25, 84); Bull. Spec. Astrophys. Obs.-North Caucasus 25, 83) presented multifrequency radio observations with RATAN of 14 SNRs in the region $85° < l < 135°$.

A survey of HI 21 cm emission lines toward all northern SNRs by Koo B.-C+ 1991 (Ap. J.382 204) shows that among 103 objects observed four (G27.7-0.6, W51, CTB80, HB21)have definitely and a further 12 have probably related HI shells. Furthermore, 15 SNRs are associated with high-velocity (70 to 160 km/s) clouds, which are probably shock accelerated.

Several newly discovered objects and many well known galactic SNRs have been mapped at radio frequencies. These include the new composite SNR of low surface brightness G322.5-0.1. (Whiteoak J.B.Z. 1992 MNRAS 256, 121); high-resolution observations at 408 and 1420 MHz of G160.9+2.6 (HB9) by Leahy D.A.+ 1991 (AJ 101, 1033); new intensity maps at 4.75 GHz, linear polarisation and spectral index distribution on the CTA104A (Mantovani F. + 1991 AA, 247, 545); and observations of the SNR G73.9+0.9 embedded in a very complicated region inside the Cygnus supershell (Pineault S. + 1990 MNRAS, 246,169).

Radio observations of the "X-ray detected" SNR G156.2+5.7 (Reich W. + 1992, AA 256, 214) revealed a highly polarized non-thermal shell, having the lowest surface brightness at 1 GHz of all known SNRs. A weak HI shell detected may be associated with the SNR if this was created by a progenitor stellar wind.

New high-resolution VLA polarimetric observations of the filaments in the SNR IC 443 show the size scale of the largest region of locally organized magnetic field is about 85 arcsec = 0.6 pc (Wood G.A., + 1991 AJ 102, 224). NRAO observations of Cygnus loop at 408 MHz (Green D.A. 1990 AJ 100, 1927) reveal spectral index variations.

VLA observations of of the unusual SNR CTB 37A/B show that this does not have a jet but is instead superposed on a second, previously unidentified SNR G348.5-0.0 (Kassim N.E. +1991 ApJ 374, 212). These observations also reveal a remarkable "blow-out" region from the nearby SNR G348.5+0.1.

6.3.2. Molecular Observations.

Many objects display a SNR shock interactions with dense interstellar clouds, dense molecular material in interstellar clouds. A particularly fine example is provided by IC 443 which has been studied in HI by Moorhause A. + 1991 (MNRAS 253, 662). Dickman, R.L. + 1992 (ApJ 400, 203) present high resolution maps in CO and HCO+. An analysis of these gives a total molecular mass of 2000 $M_\odot$) and an expansion velocity of 25 km/s in the molecular gas. Bedogni R. + 1990 (AA, 231, 481); and Green D.A.+ 1992 (MNRAS 254, 686) find evidence of shocked molecular material associated with the SNR G33.6+0.1 in their CO and HCO observations.

Several SNRs have been found to possess molecular envelopes: for example, Uchida K.I.+ 1992 (ApJ 398, 128) identified a dense molecular ring surrounding the nonthermal radio shell G359.1-0.5 and Gomes Y. + 1991 (ApJ 377, 519) found a dense molecular envelope around the compact HII region G5.89-0.39 (W28 A2). Further studies of the molecular cloud associated with the SNR G109.1-1.0 have been provided by Tatematsu K. +1990 (ApJ 351, 157); Wang Z.+ 1992 (ApJ 388, 127); and Ni Chen-ping + 1990 (Acta Astron. Sin. 31, 121-127; English. Transl. Cin. Astron. Astrophys. 14, 422). The radio and X-ray semi-circular morphology of the shell of CTB 109 is shown to be a result of explosion at the edge of a dense interstellar cloud.

Since the majority of SN explosions occur in dense molecular complexes and/or OB associations the only way to properly understand their nature is to consider the evolutionary history of a whole area. A number of investigations have demonstrated the productivity of such approach:

From CO, HI and radio continuum observations, Tatematsu K.+ 1990, (AA. 237, 189) have reconstructed the kinematics of the SNR HB21 and its interaction with a "wall"of atomic and molecular gas and individual dense clouds in the complex region Cyg OB7. Nichols-Bohlin J. + 1993 (AJ 105, 672) considered the interstellar environment around the WR star HD 192163 which is supposed to have been influenced by a previous SN explosion in the Cyg OB1 supershell. HI and CO observations of the field containing the SNR HB3 (Routledge D. + 1991, AA, 247, 529) permits reconstruction of a complete model for the evolution of the complex region W3+W4+HB3, the associated atomic and molecular gas, and the Cas OB6 stellar population and star formation history. A CO emission shell has been found around SNR G54.4-0.3 (Junkes N., 1991 Proc. AS. Australia., 9, 315).The SNR appears to expand into the wind- blown bubble interior to this shell. Pineault S., + 1993 (AJ 105, 1060) have found an expanding HI shell around the SNR CTA1 and two cavities in the far IR as measured by IRAS. The SNR appears to have broken out into low-density regions.

Multiple SNe regulate the phase structure of the ISM both around OB associations and generally, in the gaseous disk of the Galaxy. This problem has been considered by Heiles C., 1990 (Ap. J., 354, 483); and Cioffi D.F. + 1991 (ApJ 367, 96). Zongwey Li, + 1991 (ApJ 378, 93) have discussed the statistical correlation of galactic SNRs and spiral arms.

6.3.3. Infrared Observations of Old SNRs

The IRAS mission opened a new tool for the study of both SNRs and their interstellar environments. Saken J.M., +1992 (ApJS 81, 715) have presented an IRAS survey of galactic SNRs. Arendt R.G., + 1992, ApJ 400, 562) have developed a new technique for analyzing for the IR emission of a SNR and applied it to the Cygnus Loop. They distinguish two components. The first is spatially correlated with the X-ray and arises from collisionally heated dust in the shocked gas. The second is spatially correlated with the optical filaments and arises both from dust which is radatively or collisionally heated within filaments and from IR lines emitted by the shocked gas. Graham J.R. + 1991 (ApJ 372, L21) and Graham J.R.+ 1991 (AJ 101, 175) discovered vibrationally excited molecular hydrogen coincident with and ahead of the optical filaments in the Cygnus Loop. Arendt R.G. 1991 (AJ 101, 2160) has discussed IRAS observations of a large area around the composite SNR G320.4-1.2. A pointlike source is prominent at 25 μmmap near the pulsar. Arendt R.G., + 1991 (ApJ 368, 474) have performed a quantitative analysis of the IRAS observations of Pup A. These enabled them to derive both the global properties of the SNR and details of dust heating, the grain size distribution, the dust mass etc.

Oliva E.+ 1990 (AA 240, 453) presented a detailed study of IR spectra of RCW 103 in the range 1.0-2.5 μm. IR maps and fluxes for the young SNR RCW 86 (Greidanus + 1990 AA 240, 385) were compared with other historical SNRs.The IR temperature is shown to decrease with age; densities derived from the IR and from X-ray data are comparable. However, X-ray masses are found to be an order of magnitude larger than the IR masses.

Using IRAS data, Gahm G.F.+ 1990 (AA 228, 477) have distinguished a void of $4.5^\circ x 3^\circ$ in Lupus surrounded by a ring of enhanced emission which is coincident both in position and in shape with an extended X-ray source suggested by Riegler et al. to be a SNR 7to10 10^4 yr old. The SNR appears to be expanding within a larger bubble with a radius $\approx 7^\circ$.

6.3.4. X-Ray Observations of Old SNRs.

Reviews of X-ray observations, high resolution spectroscopy and plasma diagnostics of SNRs have been presented by Bleeker J.A.M., 1990 (Adv. Space Res. 10, 143), and Canizares C.R., 1990 (IAU Coll. No 115: High Resolution X-ray Spectroscopy of Cosmic Plasmas. p.136).

Seward, F.D. 1990 (ApJS., 73, 781) has gathered X-ray images of the 47 galactic SNRs observed by the EINSTEIN satellite into a definitive catalog. However, X-ray observations using ROSAT have now opened a new page in the study of SNRs (Smith A., 1990, ESA Bull., No.62, 59). For the first time a galactic SNR has been discovered at X-ray frequencies using ROSAT (Pfeffermann E.+1991AA 246, L28).

ROSAT PSPC and optical images of the SNR W44 by Rho J.-H. + 1992 (BAAS 24, 791) show the same centrally peaked X-ray morphology observed by Einstein, in contrast to the shell-like radio morphology. Similar results have been found for both W28 and 3C 400.2 (Long K.S.+ 1991 ApJ 373, 567). This is possibly the result of thermal evaporation of dense clouds, increasing the density of the hot gas (White R.L.+ 1991 ApJ 373, 543). The X-ray image of W44 also shows locally brighter emission and clumps along the optical filaments, suggesting both are produced by the interaction between the supernova shock and regions of enhanced ambient density. Observation of soft X-ray emission from the SNR G18.95- 1.1 (Ashenbach B.+ 1991 AA, 246, L32) revealed a shell-like morphology. This SNR was previously thought to be a composite one. It is located in a low density region created by the pre- supernova wind.

HEAO-1 A2 X-ray observations of the Cygnus Loop by Leahy D.A.+ 1990 (BAAS 22, 752 and ApJ 363, 547) gave the best spectra to date. A two component model gave an excellent fit to the data. Images of the Cygnus Loop at the X-ray energies above 1.5 keV (Hatsukade I., + 1990 ApJ 362, 566) show a center-filled morphology proving that a high-temperature low- density plasma fills the interior of the old remnant.

An image in the hard (2.5-25 kev) X-ray emission from the Vela SNR (Willmore A.P. + 1992 MNRAS 254, 139) displays a synchrotron nebula around the Vela pulsar, about 1 deg across, roughly aligned along the direction of the PSR's spin axis. This accounts for about 48total emission in 4-25 keV band. The power required to produce the relativistic electrons in the nebula is estimated to be 75rotational energy loss of the PSR.

Kaastra, J.S. + 1992 (AA 264, 654) have analysed the GINGA X-ray spewctrum of RCW 86. If this SNR can be identified with the supernova of AD 185, then its distance is about 1.0kpc, and the explosion energy was $2x10^{51}$ ergs.

Leahy D.A.+ 1992 (ApJ 374, 218) have finally discovered X-ray emission associated with the Gum nebula. Both the X-ray and optical properties of the Gum nebula are consistent with a SNR of an age of about $2x10^6$ yrs.

6.3.5. Optical/UV Observations of Old Supernova Remnants.

A number of detailed studies of the best investigated SNR Cygnus Loop have allowed us to better understand the shock-wave dynamics in an old SNR and its interaction with the ambient ISM. TAURUS observations in the Hα and [OIII] lines by Greidanus H.+ 1991 (AASupp 89, 15) allow study of the small-scale radial velocity structure of optical filaments. Detailed interpretation the data in terms of both "curved sheets" and "shocked clouds" was given by Greidanus H.+ 1992 (AA 257, 265). Shull P.+ 1991 (ApJ 383,

714) used Fabry-Perot scans of 61 fields and proper motions at 39 locations to show that the Cygnus Loop is expanding asymmetrically into the ambient gas, with rest-frame velocity as high as 380 km/s the near half and 150 km/s in the far half of the shell. This is explained as a result of the progenitor's location near a density discontinuity in the ISM and of the action of its wind on the ambient gas.

The Hα images of three regions in the Cygnus Loop obtained by Fesen R.A. + (AJ 104, 719) provide a nice insight into the outer filaments and the shock-cloud interactions. A faint Balmer-dominated filament is identified 30 arc min beyond the line of radiative filaments, resolving the nature of the weak X-ray, optical and nonthermal radio emission observed to the west of NGC 6960. Strongly curved Balmer- dominated filaments along W and SW edge apparently indicate shock diffraction caused by shock passage in between clouds. Shull P.+ 1991 (PASP 103, 811) obtained optical spectra of the near side of Cygnus Loop in the central part. One filament displays Balmer-dominated spectra.

Cornett, R.H. + 1992 (ApJ 355, L9) has presented UIT images of the Cygnus Loop. Blair W.P. + 1991 ApJ 379, L33) report the discovery of a fast radiative shock wave in the Cygnus Loop using the Hopkins UV telescope. Strong emission lines of CIII 977 Å, NIII 912 Å, and OVI 1038 Åwere seen. The gas appears to be excited by a 170 km/s shock wave with some contribution from lower shock velocities. Ultraviolet imaging observations of the Cygnus Loop have been reported by Blair W.P + 1991(ApJ 374, 202) and Cornett R.H. + 1992 (ApJ 395, L9). Blair W.P. +1992 (BAAS 24, 791) have obtained narrow band images of a number of SNRs with the Wide Field Planetary Camera on HST. Images of NGC 6995 obtained in the coronal lines [Fe X] and [Fe XIV] cannot be interpreted in terms of cloud evaporation and these tend to support the "curved sheets" model of Hester and Cox according to Teske R.G. 1990 (ApJ 365, 256).

Wang Z.R.+ 1992 (PASJ, 44, 303) detected hard X-rays from the SNR IC443 implying an electron temperature higher than 10 kev and a density smaller than 0.1 cm^{-3}. Teske R.G., 1991 (Ap J, 383, 233) detected both [FeXIV] and [Fe X] line emission on the northern rim of this SNR, implying a shock velocity =¡ 400 km/s.

The large angular size of the Vela SNR allows one to use interstellar lines in spectra of field stars to study the hot gas and the dynamics of the shell (Wallerstein G. + 1990, MNRAS 245,701; Wallerstein G. +1992, AJ 103, 1346). Using IUE spectra of the SNR and new spectra of HD 72088 Raymond J.C.+ 1991 (ApJ 383, 226) have found evidence for a thermally unstable 150 km/s shock wave and for a nonthermal contribution to the pressure in the Vela SNR.

6.4. EXTRAGALACTIC SUPERNOVA REMNANTS.

A multiwavelength study of the SNR N49 have been made by Vancura O. +1992 (ApJ 394, 158). This has been used to derive shock conditions and their variation within the SNR. Vancura O.+ 1992 (ApJ 401, 220) obtained far-UV observations (912-1860 A) of this remnant using the Hopkins UV telescope, detecting lines of OVI, OIV, CIV and HeII. The bulk of both CIV and optical emission originates in shocks with v¡=140 km/s but most of the OVI originates in optically faint, 190-270 km/s shocks traversing dense clouds. Chemical abundances for this and other Magellanic Cloud SNR were given by Russell, S.C. +1990 (ApJS 64, 93).

Chu Y.-H.+ 1992 (AJ 103, 1545) have performed echelle and imaging Fabry-Perot observations of the 30 Dor B SNR embedded in an HII region. The relation of progenitor star to HII and OB association sheds light on the evolution of a SNR in a star formation region. Scanning interferometer observations of the shell N186E in the LMC (Rosado M.+ 1990 AA 238, 315) were used to analyze the kinematics of the complex and a possible interaction between the old SNR with a younger one, N186D.

A new complete catalog of SNR candidates in M33 was given by Long, K.S. + 1990 (ApJS 72, 61). Smith R.C.+1993 (ApJ 407, 564) have been reported on optical emission-line properties and chemical abundances derived for the best candidates of this list.

6.5. DEVELOPMENTS IN THE THEORY OF SNR

A number of studies continue to provide insight into the evolution of SNR in a uniform or cloudy medium. White R.L.+ 1991(ApJ 373, 543) have found a new similarity solution that describes SNR evolution in an

ISM with evaporating clouds. Different model parameters produce remnants that are strikingly different from "ordinary" shells. In particular, the effects of clouds evaporation may explain SNRs which display shell-like radio emission and centrally peaked X-ray morphologies. Draine B.T. + 1991 (ApJ 383,621) demonstrated that SN events in dense clouds result in efficient conversion of the explosion energy to X-rays, which irradiate and extensively ionise the surrounding medium. Asvarov A.I.+ (1991 Pis'ma Astron. Zh. 17, 702; English transl. Sov. Astron. Lett. 17, 297) have considered the energy distribution of shock-accelerated electrons in a SNR. A model for the evolution of radioemission of the shell-type SNR in their adiabatic Sedov phase was given by Asvarov A.I. 1992 (Astron Zh 69, 753). It is assumed that the electrons are diffusively accelerated at the shock front but that the magnetic field is interstellar; adiabatic losses of the accelerated electrons are taken into account. Reynolds S.P+ 1992 (ApJ 399, L75) predict radio spectra resulting from the Fermi mechanism in the SNR of Tycho and Kepler and in SN1006. They find that the spectrum is slighly concave to high frequency, with a mean slope significantly steeper than the classical value of -0.5 , in excellent agreement with observation.

The evolution of a SNR in a strongly magnetized medium and with cosmic rays has been considered by Insertis F.M.+ 1991 (MNRAS 252, 82). Ferriere K.M.+ 1990 (BAAS 22, 750) and Ferriere K.M.+ 1991 (ApJ 383, 602) find that when the shock velocity falls below 110 km/s, ion-neutral collisions in the vicinity of the shock dissipate the waves which couple the cosmic rays to the thermal gas, impeding cosmic-ray acceleration. Kang H.+ (1992 ApJ 399,182) performed a simplified treatment of the effects of cosmic ray acceleration on the evolution of a SNR. Dorfi E.A., 1991, (AA 251, 597) made a numerical study of the evolution of SNRs including the non-linear effects of particle acceleration in shock waves to consider the production of Gamma rays and cosmic rays in SNRs with radiative cooling. Jones T.W.+ 1992 (ApJ 396,575) have also considered cosmic-ray- modified SNR shocks. In an attempt to explain asymmetrical SNR Fulbright M.S.+ 1990 (ApJ 357, 591) have discussed the efficiency of relativistic particle acceleration depending upon the obliquity between the shock and magnetic field; see also Mineshige S.+ 1990 (ApJ 355, L47).

Aslanov A.I. + (1990 AA 229, 196) computed the hard X-ray emission to be expected from young SNRs. Wei Cui+ 1992 (ApJ 401, 206) generated two-temperature models of old SNR with both ion and electron thermal conduction. Brinkmann W. 1992 (AA 254, 460) considered non- equilibrium, non-LTE ionisation in SNRs and estimated the relevant time scales in young SNRs.

The interaction between a pulsar and an associated SNR has been discussed from a theoretical viewpoint by Chevalier R.A+ (1992 ApJ, 396, 540) this has provided a complete picture of pulsar nebulae in supernovae and the effects of the pulsar's wind shocks in SNR; particularly relevant to observations of plerions.

The late evolution of SNRs and their fossil hot bubbles, taking into account magnetic field has been discussed by Slavin J.D. + 1992 (ApJ 392, 131)with a view to reexamining the filling fraction of the hot gas that can be sustained in an ISM regulated by SNe. Byckov K.V., 1991 (Astron.Zh. 68, 1181;English transl. in Sov.Astron. 35, No 6) has considered SNRs at the stage when the preshock pressure regulates the evolution. At this stage the intense radiative cooling stops, a new adiabatic phase begins, and the relative thickness of the swept up shell grows.

Igumenshchev I.V. + (1992 Astron, Zh. 69, 479; English translation in Sov.Astron. 36, No.3.) have made numerical studies of both a SN explosion in a disk-like envelope, assumed to be produced by nonspherical mass loss from the presupernova and of a SN remnant moving in homogeneous gas.

Investigation of the evolution of SNRs inside pre-existing wind- driven bubbles or cavities provide an appropriate starting point in the analysis of the observed properties of real SNRs. Tenorio-Tagle G.+ (1991 MNRAS 251,318) and Franco J.+ (1991 PASP, 103, 803) have performed 2D hydrodynamical calculations of a SN explosion within wind-driven bubbles assuming different density distribution in the ejecta.

The effect of axisymmetric or asymetric matter distributions on SNR evolution has been considered by a number of authors. Korycansky D.G. 1992 (ApJ 398, 184) has considered an off-center point explosion in a radially stratified medium in terms of the Kompaneets approximation. Bisnovatyj-Kogan G.S + 1991 (Astron.Zh. 68, 749; English transl. in Sov.Astron. 35, 370) made a numerical hydrodynamic investigation of adiabatic SNR evolution in three dimensions in media with asymmetric density distribution. The evolution of density and vorticity generated in the interaction of a SNR with an interstellar cloud has been discussed by Stone J.M.+ 1992 (ApJ 390, L17). They suggest vortex filaments may be the location of radio emission knots in young SNR. According to Franco J.+ 1993 (ApJ 407, 100) in OB associations, where sequential SN explosions take place the impact of supernova fragments may influence the evolution of collective supernova remnants.

Chevalier R.A.+ 1992 (ApJ 392, 118) have investigated the convective instabilities resulting from the interaction of ejecta with steep power-law density profile expanding into a relatively flat stationary power-law density profile. In the linear regime the solutions are all nonstable above a critical wavenumber and the growth rate is greatest at the position of the contact discontinuity. Two-dimensional numerical hydrodynamic computations make it possible to follow the instability into the nonlinear regime. Results obtained agree well with X-ray observations of the Tycho SNR, its radio morphology, and expansion.