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Division VI: Interstellar Matter

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Commission 34: Interstellar Matter

1. Introduction

Commission 34 covers diffuse matter in space on scales ranging from the circumstellar to the galactic and intergalactic. As such it has enormous scope and because of this, it alone forms Division VI. Key aspects include star formation, matter around evolved stars, astrochemistry, nebulae, galactic and intergalactic clouds and the multitude of effects of the interaction of stars with their surroundings. Associated with these areas are a huge range of physical and chemical processes including hydrodynamics and magneto-hydrodynamics, radiative processes, molecular physics and chemistry, plasma processes and others too numerous to name. These are complemented by an equally huge range of observational studies using practically all space and ground-based instrumentation at nearly all observable wavelengths. A glance at any data-base of publications over the past few years attests to the vigorous state of these studies. The current membership of the Division is around 800. It also has three separate working groups.

2. Selected Scientific Highlights

2.1. *Star Formation*

Given their importance in the astrophysical scheme of things, it is hardly surprising that star formation studies, both theoretical and observation, still burgeon. Low-mass star formation continues its substantial progress. Particularly interesting developments have been in the formation of low-mass star formation in the early universe. It is well known that H_2 cooling leads only to the formation of fragments much more massive than a solar mass. Recent work has shown that even very small abundances of C or O (as small as a fraction of 1% of solar) can lead to fragmentation into much lower mass clouds. This enrichment may be due to supernovae and involve dust. These ideas are supported by the discovery of stars with very low ($\sim 10^{-5}\times$ solar iron and of order a few per cent solar C) metal abundances. Star formation at high z is throwing up much to exercise the mind. The observation of HCN line emission from an infra-red luminous quasar at $z = 2.56$ indicates star formation is taking place. Perhaps even more exciting is the indication of star formation by the strong infra-red emission from the galaxy J1148+5251 at $z = 6.4$. This also has implications for dust formation since large amounts of dust (perhaps greater than $10^8\,M_\odot$ in some high z QSOs and galaxies) must be formed over a time scale of less than about 1 Gyr. This is probably too short for the formation in AGB stars and a supernova origin is supported by the recent discovery of perhaps several $M_\odot$ of dust in the young supernova remnant Cas A. Spitzer results have also shown that stars have been formed in the very short time scale of about 7×10^8 yr after the Big Bang.

Although star formation by the triggering effects of such pressure-inducing agencies as supernova remnants and HII regions are quite properly embedded in the collective subconscious of star formation experts, an interesting variation has been the discovery of the formation of a young stellar cluster (NGC 6231) triggered only relatively recently (a few million years ago) by a globular cluster (NGC 6397) passing through the plane of the Milky Way. Star formation also seems to take place in perhaps slightly unexpected regions, for example outside obviously gas-rich regions in some galaxies. CO data also indicates star formation in gas between the LMC, SMC and the Milky Way, but this is perhaps not unexpected given the debris that must be there as a results of their mutual interaction.

The problem of massive star formation continues to cast its shadow (the time when it will throw illumination seems still distant). Much theoretical effort has gone into studies of the accretion and the merger scenarios. There are still serious questions regarding the numerical resolution in some of these studies and it is arguable whether any computations that (for wholly understandable reasons) neglect magnetic fields can really be taken very seriously. Of course observational studies may eventually provide a dispassionate resolution to these questions. Very recently, two observational studies have tended to favor the accretion model. The Sub Millimeter Array operating at 917μm has shown the existence of a rotating disc of radius about 300 AU associated with the 15 $M_{\odot}$ young star Ceph A. This is supported by 3.6 cm VLA data indicating a collimated outflow perpendicular to the disc. Additional support for massive discs around a fairly massive star has come from 2μm observations of the Becklin-Neugebauer object.

2.2. *Astrochemistry*

The central role of astrochemistry in star formation studies is now well established. Molecular line emissions are the best probes of the dynamics resulting in star formation. Chemistry leads to variations of abundances and the lines of molecules with reasonably constant fractional abundances are, in principle, the most appropriate to observe. In regions where low-mass stars form N_2H^+ is a good tracer of the mass, whereas CS is not. Recently, CS has been found to be a good tracer of mass in some regions of high-mass star formation, whereas N_2H^+ is not. The explanation for this difference in utility of these two molecules as mass tracers in the different types of star forming regions is interestingly related to the dynamics occurring in the star formation process. Chemical arguments coupled with numerical collapse calculations show that the more rapid the collapse the better CS will trace the mass whereas the slower the collapse the better N_2H^+ will trace the mass. This clearly shows that detailed chemical modeling is necessary for the extraction of dynamical information from molecular observations of many regions.

2.3. *Circumstellar Matter in the late stages of Stellar Evolution*

The presence of crowns, haloes, jet-like features, cometary tails, clumps, FLIERS, arcs, rings and multi-polar structures are stunningly apparent in the Hubble Space Telescope photographs of planetary nebulae. There is still no consensus of opinion for the origin of many of these features. The observation of a high speed (~ 100 km s^{-1}) collimated flow (or jet-like feature) in the vicinity of the red giant V Hydrae, thought to be in transition to the PNe stage, suggests that directed flows may be responsible for the shaping of bipolar planetary nebulae and could even play a role in FLIER formation. The high speed of such a flow argues for a companion star more condensed than the red giant and there are analogies with symbiotic systems (e.g. R Aquarii) where jets have been known to exist for some time. In the case of V Hydrae, the jet is extremely young—less than 3 yr old- and this could indicate episodic behavior. Many PNe may owe their complex

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morphologies and dynamical structures to the evolution of circumstellar matter in binary (or even higher order) systems. The tremendously influential interacting wind model may be an approximate description for part of a more complex evolutionary framework. Recent work on NGC 7293 (the Helix Nebula) suggests also that at least for old PNe, the cessation of the fast wind-envelope interaction plays a role in determining the present observed nebular dynamics. The famous cometary knots in the Helix also continue to attract attention. The discovery of warm H_2 in their dense molecular cometary heads poses a major puzzle. The importance of magnetic fields in planetary nebula formation and structure is the subject of lively debate and some controversy. Finally, the shaping of PNe (e.g. Sh2-188) by their interaction with the ambient interstellar matter is receiving more observational and theoretical attention.

Our picture of the explosive ejection of material from stars gets more complex. Chandra data on Cas A seem to show the existence of two iron-rich, silicon-poor, jets of material over scales extending a parsec or so from the explosion site. This suggests that the jets were formed immediately after the stellar explosion. Spitzer data on the type Ia supernova SN 2002 may also indicate asymmetric ejection of material. The remarkable outburst of V838 Monocerus that had associated a luminosity increase of 10^4 may also be an important recurrent phenomenon as far as surrounding gas is concerned.

2.4. *The Interstellar Medium in Galaxies*

HII regions still command much attention. Ionization fronts (IFs) have been studied in the context of structures such as the famous pillars in M16, the Eagle Nebula. Important studies have been made of the stability of IFs including both the effects of finite acceleration and recombination. These studies show that this latter process can stabilize the Rayleigh-Taylor instability associated with the acceleration, at least in the linear regime. Studies have been made in detail of the morphology and dynamics of the multitude of ionization fronts on the surface of the dense molecular cloud associated with the Orion nebula. The development of 3-D models for HII regions (and planetary nebulae) has continued. An important code used is MOCASSIN, which is a fully self-consistent 3-D photoionization and dust radiative transfer code.

Considerable progress has been made in the study of winds driven by energy deposition from the stars in super star clusters. Particularly important is the role of cooling resulting from the metal content. Recent Hubble Space Telescope data suggests that starbursts may be a collection of these super star clusters. The effects the super-winds generated by such starbursts have on their surroundings is dramatically illustrated by observations of a velocity-coherent shell of neutral H that screens the whole of a young massive galaxy at $z = 3$. This shell has a lateral extent of about 100 kpc and seems to have been swept up by the superwind generated in an extensive starburst that occurred several 10^8 yr ago.

A high resolution CO-line survey of galaxies in the Virgo cluster has been obtained using the Nobeyama mm-wave Array. High-density centrally peaked molecular cores are found to be a general feature of the central hundred pc or so of normal spiral galaxies. Very high velocities within the cores are indicative of massive cores and deep gravitational potential wells. Our Milky Way galaxy still provides intriguing data. Using a new rotation curve, three-dimensional distributions of the HI and CO gas have been obtained. HI gas is distributed over a 20 kpc radius in the form of a huge fat warped disk. The CO gas though is concentrated in a thin sheet in the central several kpc sandwiched by HI gas. A number of multiple spiral arms have been identified. Developments with ALMA continue. From 2004, Japan has started to act as the third team after Europe and the USA. A submillimetre observatory at the worlds highest site has been opened (ASTE;

Atacama Submillimetre Telescope Experiments). This is a collaborative venture between the National Observatory of Japan, the Institute of Astronomy of the University of Tokyo and other universities. Various galactic objects and nearby galaxies have been imaged in the CO 3-2 line. Other receiver systems and spectrometers are being developed.

3. Working Groups

Planetary Nebula Working Group: Chair: Sun Kwok (Canada);
Agnes Acker (France), Michael Barlow (UK), George Jacoby (USA), Jim Kaler (USA), Walter Maciel (Brazil), Dipankar Mallik (India), Mario Perinotto (Italy), Stuart Pottasch (Netherlands), Luis Rodrguez (Mexico), Detlef Schnberner (Germany), Yervant Terzian (USA), Romuald Tylenda (Poland), Peter Wood (Australia).

Astrochemistry Working Group: Chair: Ewine van Dishoeck (The Netherlands);
L. Allamandolla (USA), J.H. Black (Sweden), G.A. Blake (USA), P. Caselli (Italy), P. Ehrenfreund (The Netherlands), G. Garay (Chile), M. Guelin (France), C. Henkel (Germany), U.G. Jorgensen (Denmark), J.P. Maier (Switzerland), K.M. Menten (Germany), T.J. Millar (UK), Y.C. Minh (S. Korea), M. Ohisi (Japan), A. Raga (Mexico), J. Rawlings (UK), B. Rowe (France), J. Yang (China).

IAU Symposium 231 “Astrochemistry Throughout the Universe: Recent Sucesses and Current Challenges” was held August 29–September 2 2005 at the Asilomar Conference Grounds, Pacific Grove, California, USA. The meeting attracted about three hundred participants from nearly thirty different countries. The scientific programme consisted of 58 oral presentations and 217 posters were displayed. The meeting was the sixth in a series that dates back to 1979.

Star Formation Working Group: Chair: Francesco Palla (Italy);
B. Reipurth (USA-Secretary), R. Bachiller (Spain), M. Burton (Australia), L. Cram (Australia), Y. Fukui (Japan), G. Garay (Chile), T. Henning (Germany), C.J. Lada (USA), M.T. Lago (Portugal), S. Lizano (Mexico), J. Palous (Czechia), A. Sargent (USA), S. Strom (USA).

4. Major Conferences

A Massive Star Odyssey from Main Sequence to Supernova (IAU Symposium 212); Lanzarote, Spain June 24–28, 2002

Recycling Intergalactic and Interstellar Matter (IAU Symposium 217); Sydney Australia, July 14–17, 2003

Star Formation at High Angular Resolution (IAU Symposium 221); Sydney Australia, July 22–25, 2003

Asymmetrical Planetary Nebulae III: Winds, Structure and the Thunderbird; Mt. Rainer, Washington, USA July 28–August 1 2003

The Interplay among Black Holes, Stars and the ISM in Galactic Nuclei (IAU Symposium 222); Gramado, Rio Grande do Sul, Brazil, March 1–5, 2004

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Planetary Nebulae Beyond the Milky Way; ESO Headquarters, Garching, Germany May 19–21 2004

Massive Star Births: A Crossroads for Astrophysics (IAU Symposium 227); Catania, Italy May 16–20 2005.

Planetary Nebulae as Astronomical Tools; Gdansk, Poland June 28–July 2 2005

Astrochemistry throughout the Universe: Recent Successes and Current Challenges IAU Symposium 231); Monterey, USA August 29–September 2 2005

5. Major New Publications

An extensive Atlas and Catalogue of dark clouds based on the Digital Sky Survey has been made where star counting techniques have been applied to 1043 plates. The Catalogue gives AV maps covering the entire region in $|b| < 40$ deg. in figures as well as in a FITS formatted database.

"Atlas and Catalog of Dark Clouds". Dobashi, K., Uehara, H., Kandori R., Sakurai, T., Kaiden, M., Umemoto, T., Sato, F., 2005. Publications of the Astronomical Soiciety of Japan 57, S1. Data available in FITS format at:
http://astro.u-gakugei.ac.jp/∼tenmon/Atlas/index.html

6. Further Sources

The "Star Formation Newsletter" is a monthly electronic publication which provides abstracts of recently accepted papers and dissertations in the fields of star formation, molecular clouds and the interstellar medium. All issues can be found at:
http://www.eso.org/gen-fac/pubs/starform/

"A General Catalogue of Herbig-Haro Objects" is a complete list of all known Herbig-Haro objects with coordinates, extensive notes and a full list of references to the literature for each object. The catalogue which is now in its 2nd edition is updated every few years and can be down loaded from: http://casa.colorado.edu/hhcat

Other useful links to star formation can be found at the web site of the Center for Star and Planet Formation at the Institute for Astronomy at the University of Hawaii. It can be found at: http://www2.ifa.hawaii.edu/CSPF/
Amongst other things this web site gives links to numerous catalogues, books, dissertations and major review articles. It also lists all upcoming meetings relevant to star and planet formation.

John Dyson
President of Division VI

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