Division H Days, 2018

Division H Days was a series of review talks on "Interstellar Matter and Local Universe," held at the General Assembly of the International Astronomical Union in Vienna Austria on Friday August 24th and Monday August 27th, 2018. The talks began with reviews of the three symposia that were held in the first week by organizers of those symposia. Four more talks were by PhD Prize winners from the two previous years. The meeting also included short talks from many of the poster presenters and business meetings for the Commissions and the Division. The abstracts of the talks follow.

My thanks to all the speakers and poster presenters for their outstanding contributions,
Bruce Elmegreen, President of Division H, 2015-2018

Viktor Toth: From the Protosun to the First Steps of Life - a review of IAUS 345

The IAU Symposium 345 "Origins: From the Protosun to the First Steps of Life" was an exceptionally multidisciplinary conference. It provided comprehensive reviews and sampled research results on all the essential steps in the formation of the young Earth and Earth-alikes, including star formation, protoplanetary disks, and planet formation. Talks discussed the environment of the early Sun, and the first planetary atmospheres, as well as habitable planets, biological impacts, pre-biotic chemistry, and biology. My short summary of the highlights includes results from theory, observations and experiments.

Sabrina Stierwalt and Kristen McQuinn: Dwarf Galaxies: From the Deep Universe to the Present – a review of IAUS 344

Dwarf galaxies are key tools for understanding structure formation and galaxy evolution across cosmic time. These low-mass systems allow us to not only gain a detailed understanding of stellar, chemical, and dynamical properties in the nearby universe, they also provide a unique window into the complex physics of the early universe. We are in an era where increasingly powerful observing facilities and simulations are inspiring new studies of the building blocks of structure at all epochs of the universe. Our timely symposium brings together the broad dwarf galaxy community, with expertise ranging from local dwarf galaxies to massive star formation in low-metallicity environments, from simulations of feedback in a cosmological context to observations of the faint-end of the luminosity function at high redshift. I will summarize the major outstanding questions in dwarf galaxy evolution addressed in our symposium and the discussions of future challenges and opportunities presented by forthcoming facilities and chemo-dynamical simulations.

Hans Olofsson: Why galaxies care about AGB stars - A continuing challenge through cosmic time – a review of IAUS 343

This symposium aims to build a bridge between research on the AGB stars themselves and its application to the modelling of stellar populations and the chemical evolution of galaxies and the Universe as a whole. It is divided into nine themes:
1 - Stellar structure and evolution to, on, and past the AGB
2 - Nucleosynthesis, mixing, and rotation
3 - Pulsation, dynamical atmospheres, and dust formation
4 - Circumstellar envelopes of AGB stars and their progeny, planetary nebulae

5 - Binarity, planets, and disks
6 - AGB stars in the cosmic matter cycle
7 - Resolved and unresolved AGB populations
8 - Galaxy evolution, including the first AGB stars
9 - New and future observational perspectives
I will summarize the most important advances and challenges in each theme.

Yang Huang (PhD Prize 2017): Galactic kinematics and dynamics from the LAMOST Galactic Spectroscopic Surveys

One of the fundamental tasks of modern astrophysics is the quest of an understanding of how galaxies formed and evolved. Generally, the quest could be pursed in two complementary approaches: statistical analyses of large samples of more distant galaxies (far-field cosmology) and detailed studies of large samples of member stars in our own and other nearby galaxies (near-field cosmology). As a milestone of 'near-field cosmology' to fulfill the quest for understanding galaxy formation and evolution, the LAMOST Galactic Spectroscopic Surveys have hitherto collected quality spectra of over 7.5M Galactic stars, and this number is still increasing at a rate of 1M per annum. Benefitted from this single largest spectroscopic dataset as well as data from other photometric and spectroscopic surveys (e.g. SDSS/SEGUE, SDSS-III/APOGEE, Gaia), significant progresses have been made on the studies of the kinematics and dynamics of the Milky Way, including
1) Accurate estimates the peculiar velocities of the Sun that define the Local Standard of Res;
2) A detailed investigation of the bulk motion of nearby disk stars, in 3-dimension for the first time;
3) Accurate determinations of the Galactic rotation curve out from 8 to 100 kpc and the escape velocity curve from 5 to 14 kpc, as well as of the mass surface density in the solar neighborhood;
4) Finally, by combining the LAMOST measurements and the first Gaia data release, a sample of nearly ten thousand local (within 800 pc) main-sequence turn-off stars has been selected, with very accurate 3-dimensional positions and velocities, as well as chemical composition and age information. The sample allows us to study the local disc(s) in multi-dimensional phase space, yielding pivotal information that help constraint the formation and evolution of the Galactic disc(s).

Gina Panopoulou (PhD Prize 2018): Interstellar Filaments and Magnetic Field

Filamentary structures host most of the star forming activity in nearby molecular clouds. Thus, a complete understanding of the onset of star formation relies on studying the formation and evolution of such structures. My thesis focused, from an observational perspective, on two particularly interesting properties of filaments: their connection to the magnetic field and their apparent characteristic width.

Filament orientations appear to be closely related to the morphology of the magnetic field within dense star-forming clouds. It is still unclear at what stage(s) of a cloud's life and at what range of length scales the magnetic field plays a critical role in the shaping of cloud material. I will present our investigation of the situation in the poorly studied regime of cloud formation (when the cloud is too diffuse to form stars). We have mapped the (plane-of-sky) magnetic field morphology of a nearby translucent molecular cloud, the Polaris Flare, using starlight polarimetry. We combine this map with Herschel observations of dust filaments to infer the importance of the magnetic field relative to other forces in the cloud.

Dust filaments in the Polaris Flare and other nearby clouds are reported to have a 'characteristic' width of 0.1 pc, irrespective of their column density. However, a complete theoretical explanation for this characteristic scale has proved elusive. By revisiting the analysis of filament widths, we have found that the origin of the typical width can be traced back to biases in the previously adopted analysis.

Tom Millar: Astrochemistry in Molecular Clouds and in the Laboratory

In this talk I will review the development of astrochemistry since the General Assembly in 2015. I will briefly describe recent observations of molecules in interstellar clouds and the successes of models in explaining these. Such observations also present challenges to theory and have led to new computational and laboratory studies on fundamental processes, particularly ice mantle physics and chemistry and state-to-state chemical kinetics.

Ted Bergin: Chemistry of Protoplanetary Disks

With the continuing successful operations of the Atacama Large Millimeter Array (ALMA) we are able to characterize the initial stages of planet formation in great detail. With ALMA we have begun the search for understanding the development of chemical complexity into the age of planet formation and I will present a sample these results. By far the largest effect that has been inferred to be present is the large discrepancies between gas masses measured by CO and those measured by dust. This implies either that there is significant decline in the CO gas phase abundance, even in layers above the sublimation temperature, or that the gaseous disk dissipation is rapid and gas giant formation must occur on short ~Myr timescales. We will discuss the evidence that this major effect is likely due to changes in the CO abundance through a combination of gas-dust interactions and chemical processing in the gas. This has implications on abundances of major carriers of elemental C and O which may leave an imprint in the resulting chemical composition of forming gas giants. Thus, we will also discuss the link between disk chemistry and planet formation.

Susana Lizano: Magnetized Protoplanetary Disks

Protoplanetary disks are expected to form as a result of the gravitational collapse of magnetized rotating dense cores. I will discuss the structure and emission of models of magnetized accretion disks irradiated by the central star expected to form in this process. The mass-to-flux ratio is a critical parameter for their structure. This ratio will be determined observationally in the near future with radio interferometers like ALMA and VLA. I will also discuss the modeling of millimeter observations of the disk around the young star HL Tau.

Yuri Aikawa: Chemistry in Protostellar Cores and Forming Disks

Protostars are formed by the gravitational collapse of dense cloud cores. If the angular momentum of a parental core is conserved, a rotationally supported disk of radius \sim 100 au is expected to form, as well. Angular momentum could be, however, extracted from the system via disk winds/outflows and magnetic fields. ALMA now provides sub-arcsecond (< 100 au in the nearby star forming region) image of the central region of protostellar cores, revealing infalling gas and forming disks around several class 0-I protostars. Various molecular lines, including complex organic molecules (COMs) are also detected in this central region. Since the abundances and chemical timescales of molecules sensitively depend on the temperature and densities, spatial distributions of emission lines vary among species, and could be used to probe the circumstellar structures. I will review recent progresses in the study of protostellar cores and forming disks, with emphasis on chemical signatures.

Joao Alves: Age gradients in the nearby star formation regions: the Blue Streams

In this talk, I will summarize recent results in the literature on age gradients in nearby star-forming regions and report on the discovery of a 300 pc long, dynamically cold stellar structure comprising hundreds of massive OB stars towards Orion. We measure a clear age gradient along this long structure, from young-to-old as one moves away from the Orion clouds, suggesting a common origin. Rather than expanding, the Orion OB I association seems to be streaming as part of a much larger stream. Our results confirm the existence of Blue Streams (Bouy & Alves 2015), large co-moving groups of young stars, and suggest that star formation and dispersal processes are more coherent than previously thought. I will briefly describe possible scenarios for the origin of the Blue Streams and their impact the local neighborhood.

Richard de Grijs: Not-so-simple stellar populations in nearby massive star clusters

Around the turn of the last century, star clusters of all kinds were considered "simple" stellar populations. Over the past decade, this situation has changed dramatically. At the same time, star clusters are among the brightest stellar population components and, as such, they are visible out to much greater distances than individual stars, even the brightest, so that understanding the intricacies of star cluster composition and their evolution is imperative for understanding stellar populations and the evolution of galaxies as a whole. In this review of where the field has moved to in recent years, we place particular emphasis on the properties and importance of binary systems, the effects of rapid stellar rotation, and the presence of multiple populations in Magellanic Cloud star clusters across the full age range. Our most recent results imply a reverse paradigm shift, back to the old simple stellar population picture for at least some intermediate-age (~1--3 Gyr-old) star clusters, opening up exciting avenues for future research efforts.

Long Wang (PhD Prize 2017): The DRAGON simulations: globular cluster evolution with a million stars

Introducing the DRAGON simulation project, we present the first direct N-body simulations of four massive globular clusters (GCs) with 10^6 stars and 5% primordial binaries at a high level of accuracy and realism. The GC evolution is computed with NBODY6++GPU and follows the dynamical and stellar evolution of individual stars and binaries, kicks of neutron stars and black holes (BHs), and the effect of a tidal field. We investigate the evolution of the luminous (stellar) and dark (faint stars and stellar remnants) GC components and create mock observations of the simulations (i.e. photometry, colour–magnitude diagrams). By connecting internal processes to observable features, we highlight the formation of a long-lived 'dark' nuclear subsystem made of BHs, which results in a two-component structure. The inner core is dominated by the BH subsystem and experiences a core-collapse phase within the first Gyr. It can be detected in the stellar (luminous) line-of-sight velocity dispersion profiles. The outer extended core – commonly observed in the (luminous) surface brightness profiles – shows no collapse features and is continuously expanding. Variations in the initial mass function can result in significantly different GC properties (e.g. density distributions) driven by varying amounts of early mass-loss and the number of forming BHs. For global observables like core and half-mass radii, the direct simulations agree well with Monte Carlo models, while the details indicate the difference of BH dynamics in the cluster core. We are continuing to improve the simulation tools to achieve faster computational performance for even larger N and more realistic models.

Siyao Xu (PhD Prize 2018): Theory of Interstellar Turbulence

Turbulence and magnetic fields are ubiquitous in the Universe. Their importance to astronomy cannot be overestimated. The theoretical advancements in MHD turbulence achieved during the past two decades have significantly influenced many fields of astronomy. Constructing predictive theories of the magnetic field generation by turbulence and the dissipation of MHD turbulence is the core of the thesis. These fundamental non-linear problems were believed to be tractable only numerically. This thesis provided complete analytical descriptions in quantitative agreement with existing numerics, as well as theoretical predictions in physical regimes still unreachable by simulations, and explanations of various related observations. The thesis further promoted the astrophysical applications of MHD turbulence theories, including (i) the particle acceleration and radiation in high-energy phenomena, e.g., Gamma-Ray Bursts, supernova remnants, cosmic rays; (ii) interstellar density fluctuations and the effect on observations, e.g., Faraday rotation, scattering measurements of Galactic and extragalactic radio sources; (iii) density and magnetic field structure in molecular clouds toward star formation. It demonstrates the key role of MHD turbulence in connecting diverse astrophysical processes and unraveling long-standing astrophysical problems, as foreseen by Chandrasekhar, a founder of modern astrophysics.

Eva Schinnerer: Molecular Interstellar Medium in Nearby Galaxies as seen by ALMA

ALMA has opened up a new window on the study of the interstellar medium (ISM) in nearby galaxies and in particular its molecular gas phase. Thanks to the order of magnitude improvement in sensitivity and angular resolution compared to previously existing facilities, it is now possible to obtain new insights on molecular outflows, the rich chemistry of the molecular gas reservoir, the molecular ISM structure (including that of Giant Molecular Clouds) and thus the impact of star formation processes onto molecular gas disk. I will highlight selected results from ALMA and provide a short outlook onto future ALMA capabilities relevant for molecular ISM studies of nearby galaxies.

Juntai Shen: The Milky Way Bar and Bulge

Our Milky Way is a barred spiral galaxy. I review the recent progresses on the properties of the Galactic bar and bulge, and the major theoretical models and techniques to understand the Milky Way bulge. Despite these recent advances, a complete bulge formation model that explains the full kinematics and metallicity distribution is still not fully understood. Upcoming large surveys are expected to shed new light on the formation history of the Galactic bar and bulge.

Edith Falgarone: Interstellar Turbulence

Fifteen years after the one-hundred-page review of Elmegreen and Scalo on interstellar turbulence, do we understand better what it is? Their review was ending by: “Our current embrace of turbulence as an explanation for interstellar matter structures and motions may be partly based on an over-simplification of available models and a limitation of observational techniques. This state of the field guarantees more surprises in the coming decades.” Surprises have been delivered indeed, thanks to the prodigious improvement of observational capabilities and the 100-fold increase of computer power. I will focus on a few of them, in the perspective of an upcoming decade of further discoveries.

Misha Haywood: The Thick Disk of the Milky Way

There is mounting evidence that the formation of the thick disk of the Milky Way was a major phase in the evolution of our Galaxy, increasing its metallicity from below -2 dex to solar, forming half its stellar mass, and setting the initial conditions for the formation of the inner thin disk. I will discuss these results and their implication for the evolution of our Galaxy.

Cornelia Lang: The Milky Way Galactic Center: Highlights from the Core of our Galaxy

In addition to harboring a supermassive black hole at its very core, the Galactic Center is one of the most physically extreme environments in the Galaxy. Dense and massive molecular clouds are abundant in this region, yet star formation is not as active as one might expect. In addition, radio observations have revealed a population of synchrotron-emitting filaments that provide insight on the magnetic field strength and configuration in this unique region of the Galaxy. Physical interactions may be occurring at the interfaces of dense molecular clouds and the interstellar magnetic filaments. I will review recent observational results over the full electromagnetic spectrum -- from radio wavelength measurements through high energy observations -- that reveal the detailed and complex astrophysics in the nearest galactic nuclei.

Cristina Chiappini: Age Dating the Stars in the Milky Way using Astrometry and Asteroseismology: Messages from the Oldest Stars

Because most stars carry in their outer envelopes the chemical composition inhered at birth, it should be possible to map the star formation history in different parts of the Milky Way by measuring, for stars of different ages, a large array of chemical elements covering different nucleosynthetic sites. This goal seems to be still reachable even in the presence of radial stellar mixing, i.e., the fact that stars can move away from their birth places, loosing most of their kinematical memory. We will illustrate how the combination of detailed multi-dimensional chemical analysis and precise ages can have an great impact on our current understanding of the formation of the MW, and especially of its oldest populations, such as halo, thick disk and bulge.

Eva Grebel: Dwarf Galaxies in the Local Group

The study of Local Group dwarf galaxies is a vibrant, rapidly advancing field. Recent discoveries have vastly increased the number of known Local Group dwarfs. We now know more than one hundred of these objects. Low-surface-brightness dwarf spheroidal (dSph) satellites dominate by far. Some very faint dSphs even appear to be satellites of other dwarfs. The ultra-faint dSph galaxies may be close to the lower mass limit of dark matter halos with star formation. Intriguingly, the new discoveries also include the lowest-mass star-forming dwarf irregulars known so far, probing the conditions for gas retention vs. quenching. Most of the dwarfs seem to have a preferred spatial distribution along a great plane, but recent measurements of proper motions suggest that not all of them are kinematically associated with that plane. Cosmological simulations indicate that while satellite infall along filaments is expected, the apparent association of galaxies with a plane may be in part fortuitous with planes being transitory structures. Regarding simulations, substantial progress has been made in resolving the small-scale challenges of the Lambda CDM model by accounting for baryonic effects, particularly feedback and local and cosmological reionization. Major advances have also been made in characterizing the chemistry of Local Group dwarfs based on spectroscopic studies of individual stars. These reveal enrichment by individual supernova events and help to uncover the early star formation history of low-mass halos. Even very low-mass dwarfs often show sizeable abundance spreads and extended star formation activity prior to quenching. Through comparison with the elemental abundances in Galactic halo stars, these studies impose constraints on the accretion history of our Milky Way. The least luminous, least massive dSphs tend to be also the most dark-matter-dominated objects, making them important test cases for putative carriers of dark matter.

Monica Rubio: The Large and Small Magellanic Clouds

The Large and Small Magellanic clouds (LMC, SMC) are the best local templates for studying the life cycle of the ISM and star formation in low metallicity environments (LMC; Z=0.5 Zo and SMC, Z=0.2 Zo). Their proximity (LMC: D = 50 kpc; SMC: D = 60 kpc), provide a unique opportunity to resolve individual clouds, allowing us to conduct detailed studies of the different phases of the ISM in low-metallicity environments using various gas and dust tracers. We will present the latest results obtained in the study of the physical properties of the star formation regions, the molecular gas, the new generation of stars and its effect of environment in these regions. These studies provide key insights into the star formation process at low metallicities, which is crucial to interpret observations of high-z galaxies.

Naomi McClure-Griffiths: The Magellanic Stream

Galaxies do not evolve in isolation. Most evidence suggests that galaxies' evolutionary paths are influenced by their merger histories. Interactions between galaxies, and the gas they provide, can determine whether a galaxy will become a starburst or fade away. Fortunately, the Universe has provided us a front-row seat for observing the interaction of two dwarf galaxies, the Magellanic Clouds, with our own Milky Way. Much of this interaction history is traced through the Magellanic Stream, which is one of the most impressive features in the atomic hydrogen (H I) sky, extending over 200 degrees from the Magellanic Clouds. This tail of neutral and ionized gas extends from the Magellanic Clouds in at least two dominant twisted strands. Based on gas metallicity measurements, it seems that one strand may originate in the Large Magellanic Cloud (LMC) and the other in the Small Magellanic Cloud (SMC). In this talk I will review current knowledge of the Magellanic Stream and lay out some questions that we hope will be addressed with future studies.

Avery Meiksin: Circumgalactic Medium of the Milky Way and M31

A summary will be provided of recent results on the gas content and flows around the Milky Way and M31 based on UV, optical and radio measurements. Possible consequences of these flows on star formation in the Milky Way and M31 will be discussed.

Edvige Corbelli: The Interstellar Medium of M33

Recent high-resolution surveys of the gas content of M33 and of its star forming regions, allow a detailed view and analysis of the interstellar gas distribution across the whole disk of the nearest blue spiral galaxy. I will show some results of analysis of the interplay between gravity and turbulence on the processes that locally lead to or are triggered by the formation of stars, starting from the atomic phase down to the molecular gas prior to cloud dispersal. The disk of M33 is not uniform, as will be briefly outlined, and its interstellar medium reflects the variety of dynamical, chemical and thermal processes that may contribute to its evolution. The timescales of local star formation episodes and the duration of the giant molecular cloud lifecycle, however, do not vary much and they are well established thanks to infrared selected Young Stellar Cluster surveys in this galaxy. On larger scales, gas and stellar gravity affect the formation of gaseous arms and filaments in flocculent galaxies. Recent numerical simulations of the M33 disk underline this and the role of gas dissipation and turbulence on the growth of low density interarm holes and on the fragmentation of dense filaments. Hence, the ISM has a fundamental role in linking the disk dynamics of isolated young galaxies to individual star forming sites. If gas replenishment from the intergalactic medium is taking place, as is likely for M33, then this might affect the efficiency of the gas to star conversion down to very small scales, although the details of how this happens are not clear yet.

Maud Galametz: The Properties of Interstellar Dust in the Local Universe

The interstellar dust is a key galaxy component and a strong diagnostic tool to trace the lifecycle of matter in the ISM. Herschel and Planck have revolutionised our understanding of dust properties in our own Galaxy and nearby galaxies. Recent observations and comparisons of AV estimates from the dust with optical estimates in the Galaxy have highlighted the need of a new recalibration of our dust reservoirs. In this seminar, I will discuss how our knowledge of the dust composition has improved with the latest IR and submm observations, how grain growth is one of the key parameters of the evolution of a galaxy ISM and the importance of taking dust evolution in the ISM into account in our future SED models. I will also discuss dust polarization and how it can be used to probe the nature of the dust grains themselves.