

DIVISION H **INTERSTELLAR MATTER AND LOCAL UNIVERSE**
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TRIENNIAL REPORT 2016-2018

1. Introduction

Division H covers a wide range of topics relevant to interstellar matter and local galaxies, including the structure, content, chemistry, radiation and dynamics of gas and dust, star-forming regions, stellar clusters, the Milky Way, and other local galaxies. There is considerable overlap with nearly every other Division. The stars in the Milky Way (Division G, including the Sun - Division E) are important for understanding the structure and dynamics of our Galaxy and the history of its star formation and chemical enrichment. The components of the Milky Way are often the best examples of objects in their class, such as massive black holes in the centers of galaxies, cosmic rays or X-ray binaries (Division D), or Exoplanetary systems (Division F). Observational facilities (Division B) usually spend much of their time on Milky Way sources, and other galaxies (Division J) give the best examples of how our Milky Way fits into the Universe at large.

The Working Group on the Galactic Center was formed during this term for the purpose of uniting the many groups and observing programs that study the massive black hole and circumnuclear disk.

This overview lists the most relevant meetings in our field, from <http://www2.cadc-ccda.hia-ihp.nrc-cnrc.gc.ca/meetings/>, along with publications statistics and important surveys, reviews, and databases.

2. IAU Meetings

2.1. 2016

- March: IAU 321 Formation and evolution of galaxy outskirts, Toledo, Spain
- July: IAU 322 The Multi-Messenger Astrophysics of the Galactic Centre, Cairns, Australia
- October: IAU 323 Planetary Nebulae: Multi-Wavelength Probes of Stellar and Galactic Evolution, Beijing China, Nanjing
- November: IAU 329 The Lives and Death-Throes of Massive Stars, Auckland New Zealand

2.2. 2017

- February: IAU 331 SN 1987A, 30 Years Later, La Reunion, France
- March: IAU 332 Astrochemistry VII, Through the Cosmos from Galaxies to Planets, Puerto Varas, Chile
- July: IAU 334 Rediscovering our Galaxy, Potsdam Germany
- September: IAU 330 Astrometry and Astrophysics in the Gaia Sky, Nice France; IAU 336 Astrophysical Masers: Unlocking the Mysteries of the Universe, Cagliari Sardinia Italy; IAU 337 Pulsar Astrophysics - The Next 50 Years, Jodrell Bank Observatory, UK
- November: IAU 339 Southern Horizons in Time-Domain Astronomy, Cape Town South Africa

2.3. 2018

- August: General Assembly in Vienna: IAU 343 Why Galaxies Care About AGB Stars: A Continuing Challenge through Cosmic Time; IAU 344 Dwarf Galaxies: From the Deep Universe to the Present; IAU 345 Origins: From the Protosun to the First Steps of Life; FM6 Galactic Angular Momentum; FM10 Nano Dust in Space and Astrophysics; FM7 Radial metallicity gradients in star forming galaxies

3. Non-IAU Meetings

3.1. 2016

- January: WORKshop for PLANetary Nebulae observationS Lorentz Center, Leiden, Netherlands
- February: Dynamics and accretion at the Galactic Center, Aspen, CO, USA; The Netherlands Globular Clusters and Galaxy Halos, Lorentz Center, Leiden, Netherlands
- March: Protoplanetary Discussions, Edinburgh, UK; SnowPAC 2016: The Galaxy-Halo Connection, Snowbird, Utah USA; 13th Potsdam Thinkshop Near Field Cosmology, Obergurgl University Center, Tyrol, Austria
- April: Molecular Gas in Galactic Environments, Charlottesville, VA USA; Water in the Universe: From Clouds to Oceans, ESA/ESTEC, Noordwijk, The Netherlands; COSMIC-LAB: Star Clusters as Cosmic Laboratories for Astrophysics, Dynamics and Fundamental Physics, Bologna Italy

- May: Diffuse Matter in the Galaxy, Magnetic Fields, and Star Formation - A Conference Honoring the Contributions of Richard Crutcher & Carl Heiles, University of Wisconsin, Madison, USA
- June: Supernova Remnants: An Odyssey in Space after Stellar Death, Chania, Crete, Greece; EPoS 2016 The Early Phase of Star Formation - Progress after 10 years of EPoS A Meeting in Memory of Francesco Palla, Castle Ringberg, Tegernsee, Germany
- July: International Symposium and Workshop on Astrochemistry - ISWA: Understanding the extraterrestrial molecular complexity through experiments, observations and models: Campinas, SP, Brazil; The role of feedback in the formation and evolution of star clusters, Sexten Centre for Astrophysics, Sexten, Italy; The Multi-Messenger Astrophysics of the Galactic Centre, Far North Queensland, Australia; Multiple Populations in Stellar Clusters: Where do we stand? Sexten, Italy; Star Formation in Different Environments, Quy nhon, Vietnam
- August: Heidelberg Gaia Sprint, Heidelberg, Germany; Star Clusters: from Infancy to Teenagehood, Max-Planck Haus, Heidelberg, Germany; Comparing Apples with Apples: Concordance Between Simulations and Observations of Star Formation, Lorentz Center, Leiden, Netherlands; Cosmic Dust, Sendai, Japan; Star Formation, Exeter, United Kingdom; How galaxies form stars, Stockholm, Sweden
- September: ISM2016 - Theoretical aspects of the (non-)thermal interstellar medium, Max Planck Institute for Astrophysics, Garching, Germany; MODEST-16 NYC: The Interplay Between Gas and Gravitational Dynamics American Museum of Natural History, NY, USA; Heating and cooling processes in the interstellar medium, Cologne, Germany; Workshop Multiple Faces of interstellar dust MPE/MPA, Garching, Germany; Interstellar shocks: models, observations & experiments, Torun, Poland; The Milky Way and its environment: gaining insights into the drivers of galaxy formation and evolution, Paris, France; VIALACTEA2016: The Milky Way as a Star Formation Engine, Rome, Italy
- October: The Local Truth: Galactic Star-formation and Feed-back in the SOFIA Era - Celebrating 50 years of airborne astronomy, Pacific Grove, CA; New York City Gaia Sprint, Simons Center for Computational Astrophysics, NYC
- November: Chemical Abundances in Gaseous Nebulae, Campos do Jordão, São Paulo, Brazil; Gaia 2016 Data Release #1 Workshop, ESAC, Madrid, Spain; E&F White Research conference on Galactic Archaeology and Stellar Physic, Canberra, Australia
- December: Cologne-Prague-Kiel meeting 2016: Star formation, accretion, and feedback in galactic nuclei, Castle Wahn, Cologne, Germany; The hydride toolbox, Paris, France

3.2. 2017

- January: Star Formation and Nearby Galaxies with JWST: Science and Observation Planning, Keck Institute for Space Studies, Caltech
- February: Molecules in Astrophysics and Astrobiology, Interdisciplinary Winter School, Zurich, Switzerland; The Physics of the ISM - 6 years of ISM-SPP 1573: what have we learned?, Cologne, Germany
- March: Star Formation from Cores to Clusters, Santiago, Chile
- April: Multi-Scale Star Formation, Morelia, Mexico; April: Big Questions in Astrophysics - the next decades, Lund, Sweden
- May: Phase Transitions in Astrophysics, NORDITA - Stockholm; Quantifying and Understanding the Galaxy-Halo Connection, Kavli Institute for Theoretical Physics; Third Winter School of the Valongo Observatory: Astrochemistry of the ISM, Stellar Populations in Globular Clusters, Evolution of Stellar Populations in Galaxies, Observa-

tional Cosmology: Observations Meet Theory, Rio de Janeiro, Brazil; Midwest Magnetic Fields workshop, Madison, Wisconsin, USA

- June: Francesco's Legacy: Star Formation in Space and Time, Firenze, Italy; Star Cluster Formation: Mapping the first few Myr's, El Escorial, Spain; What matter(s) around galaxies: resolving the physics of the circumgalactic medium, Durham University; Comparing simulations and observations of the varying scales of star formation, Prague, Czech Republic; EWASS 17 Special Session 9: Understanding the environmental dependence of star formation - the importance of Big Data, Prague, Czech Republic

- July: The Interstellar Medium Beyond 3D, Orsay, France; Galactic Star Formation with Surveys, Haus der Astronomie, Heidelberg, Germany; Linking Observations and Theory Across the Scales of Star Formation in Galaxies, Sexten Center for Astrophysics, Italy; Large Surveys of the Great Andromeda Galaxy, Lorentz Center, Leiden, NL; Current and future perspectives of chemical modelling in astrophysics, Hamburg; Summer school, Formation of complex molecules in space and on planets - From interstellar clouds to life, Tartu, Estonia; Measuring Star Formation in the Radio, Millimetre, and Submillimetre, The University of Manchester, Manchester, United Kingdom

- August: The Circle of Life: Connecting the Intergalactic, Circumgalactic, and Interstellar Media, Kruger Park, South Africa; Star formation in different environments (SFDE17): From local Clouds to Galaxies ,ICISE, Quy Nhon, Vietnam; Cosmic Dust, National Astronomical Observatory of Japan, Mitaka, Japan; Molecules in space: Linking the interstellar medium to (exo)planets, Washington DC, USA

- September: The science of Gaia and future challenges, Lund Observatory, Sweden; MODEST 17 - Modelling and observing dense stellar systems, Prague, Czech Republic; 70 years of stellar associations, Byurakan observatory, Armenia; Stellar Populations and the Distance Scale, Kavli Institute for Astronomy and Astrophysics, Beijing, China;

- October: The Role of Gas in Galaxy Dynamics, Valletta, Malta; Piercing the Galactic Darkness: Stellar populations in the highly extincted regions of the Milky Way, Haus der Astronomie, Heidelberg, Germany

- November: The Initial Mass Function: From Top to Bottom, Royal Astronomical Society, Burlington House, London, UK

- December: Asymmetric Planetary Nebulae VII, Hong Kong

3.3. 2018

- February: Magnetic Fields or Turbulence: Which is the critical factor for the formation of stars and planetary disks? Hsinchu, Taiwan; Water during planet formation and evolution, Zurich

- March: Star and Planet Formation in the Southwest 2, Oracle, AZ; Interstellar Medium in the Nearby Universe, Bamberg, Germany

- May: Cosmic rays: the salt of the star formation recipe, Osservatorio Astrofisico di Arcetri, Florence, Italy; From Prestellar cores to solar nebulae, Paris-Saclay University; Interstellar: the matter, Cozumel, Mexico; Formation of substellar objects: theory and observations, Madrid, Spain; Shocking Supernovae: surrounding interactions and unusual events, Stockholm University, Stockholm, Sweden; The Olympian Symposium 2018: Gas and stars from milli- to mega- parsecs, Paralia Katerini's, Mt. Olympus, Greece

- June: Bubbles Big and Small: From supernovae, Fermi Bubbles to the Circumgalactic Medium, Indian Institute of Science, Bangalore, India; KIAA Forum on Gas in Galaxies–Star Formation and Quenching, The Kavli Institute for Astronomy and Astrophysics, Beijing, China; Cosmic RayS and the Interstellar Medium, Université Grenoble Alpes, France; MODEST-18: Dense stellar systems in the era of GAIA, LIGO and LISA, Santorini, Greece; Cosmic Dust: origin, applications & implications, Copenhagen, Denmark

- July: The Laws of Star Formation: from the Cosmic Dawn to the Present Universe, Cambridge, UK; Multiple Populations in Stellar Clusters, Sexten, Italy; Cosmic Cycle of Dust and Gas in our Galaxy: from old to young Stars, Quy Nhon, Vietnam; Astrochemistry: Past, Present and Future, Caltech, Pasadena, CA USA; Unveiling the Physics of Protoplanet Formation: Connecting Theory to Observations, Aspen Center for Physics, Aspen, CO USA; The formation of globular clusters at high and low redshift; tracing star and cluster formation across cosmic times, Sexten, Italy
- August: Cosmic Dust, Institute of Space and Astronautical Science, Sagami-hara, Japan
- September: Our Astro-Chemical History: Past, Present, and Future, Hof van Saksen, Assen, The Netherlands; Extrasolar Cloud Academy: Cloud Formation and Properties in Extrasolar Planets, Les Houches Advanced School for Physics, France
- October: Cosmic Dust and Magnetism, Daejeon, Korea
- November: Hendrik van de Hulst Centennial Symposium: The Interstellar Medium of Galaxies: Status and Future Perspectives, Leiden, The Netherlands; Interstellar filament paradigm: On their formation, evolution, and role in star formation, Nagoya Japan; The Survival of Dense Star Clusters in the Milky Way System, Heidelberg, Germany

4. Publications

Division H has publications in a wide range of topics. The numbers of publications in refereed journals give some indication of the proportion of work in various sub-fields. For the period from 2015 to 2018 (prior to this writing date of February 2018), the SAO/NASA Astrophysical Data Service tallies these counts according to the appearance of key words in the abstracts:

- Local dwarfs and local group galaxies: 200
- Interstellar chemistry: 400
- Planetary Nebulae: 300
- Star clusters or Globular Clusters: 18000
- Star Formation: 7000
- Interstellar Matter: 7000
- Milky Way Galactic Center: 400

5. Surveys and Databases

- The ATLASGAL survey completed a map of the Southern Galactic plane using the APEX telescope at 870 μm (T. Csengeri et al. 2014, *A&A*, 565, A75).

- In September 2016, The GAIA satellite Data Release #1 provided positional data and magnitudes for one billion Milky Way sources, parallax and proper motions for 2 million sources, and 3000 light curves for Cepheids and RR Lyrae stars. A map of one billion stars is expected to be released in April 2018.

- Data on Open Clusters in the Milky Way and the Magellanic Clouds:

<http://www.univie.ac.at/webda/>

- Data on Galactic Globular Clusters: <http://physwww.mcmaster.ca/~harris/Databases.html>
- Catalog of Open Clusters and Galactic Structure: <https://wilton.unifei.edu.br/ocdb/>
- The Open Supernova Catalog: <https://sne.space/>
- Release of the publicly available, time-dependent, gas-grain chemical code, UCLCHEM

(J. Holdship et al. 2017, *Astron. J.*, 154, 38)

- Newsletter on star clusters, SCYON (<http://www.univie.ac.at/scyon/>) edited by G. Carraro, M. Netopil, and E. Paunzen.

• Star Formation Newsletter (<http://www.ifa.hawaii.edu/users/reipurth/newsletter.htm>), edited by Bo Reipurth

6. Reviews

6.1. 2014

• “The Present and Future of Planetary Nebula Research,” K. Kwitter et al. 2014, *Revista Mexicana de Astronomía y Astrofísica*, 50, 203.

6.2. 2015

• “Radio emission from supernova remnants,” G. Dubner and E. Giacani, 2015, *A&ARev*, 23, 3

• “Hypervelocity Stars,” W.R. Brown 2015, *ARA&A*, 53, 15

• “Interstellar Dust Grain Alignment,” B.G. Andersson, et al. 2015, *ARA&A*, 53, 501

• “Observations of the Icy Universe,” A.C. Adwin Boogert et al. 2015, *ARA&A*, 53, 541

• “Molecular Clouds in the Milky Way,” M. Heyer and T.M. Dame, 2015, *ARA&A*, 53, 583

• “Near-Field Cosmology with Extremely Metal-Poor Stars,” A. Frebel and J. E. Norris, 2015, *ARA&A*, 53, 631

6.3. 2016

• “Complex organics in space from Solar System to distant galaxies,” S. Kwok, 2016, *A&ARev*, 24, 8

• “The Remnant of Supernova 1987A,” R. McCray and C. Fransson 2016, *ARA&A*, 54, 19

• “Accretion onto Pre-Main-Sequence Stars,” L. Hartmann et al. 2016, *ARA&A*, 54, 135

• “Interstellar Hydrides,” M. Gerin et al. 2016, *ARA&A*, 54, 181

• “The Magellanic Stream: Circumnavigating the Galaxy,” E. D’Onghia and A.J. Fox, 2016, *ARA&A*, 54, 363

• “Protostellar Outflows,” J. Bally 2016, *ARA&A*, 54, 491

• “The Galaxy in Context: Structural, Kinematic, and Integrated Properties,” J. Bland-Hawthorn and O. Gerhard, 2016, *ARA&A*, 54, 529

• “Six Decades of Spiral Density Wave Theory,” F.H. Shu, 2016, *ARA&A*, 54, 667

6.4. 2017

• “Toward a self-consistent astronomical distance scale,” R. de Grijs et al. 2017, *Sp.Sci.Rev.*, 212, 1743

• “Observing Interstellar and Intergalactic Magnetic Fields,” J.L. Han 2017, *ARA&A*, 55, 2017, 111

• “The Circumgalactic Medium,” J. Tumlinson et al. 2017, *ARA&A*, 55, 389

• “Negative Ions in Space,” T. J. Millar et al. 2017, *Chem. Rev.*, 117, 1765

6.5. 2018

• “Cosmic Ray Production in Supernovae,” A.M. Bykov et al. 2018, *Sp.Sci. Rev.*, 214, 41

• “Pulsar Timing and Its Application for Navigation and Gravitational Wave Detection,” W. Becker et al. 2018, *Sp.Sci.Rev.*, 214, 30

- “The Morphologies and Kinematics of Supernova Remnants,” L.A. Lopez and R.A. Fesen, 2018, *Sp.Sci.Rev.*, 214, 44
- “High-Mass Star and Massive Cluster Formation in the Milky Way,” F. Motte et al. 2018, *ARA&A*, 56, in press (arXiv:1706.00118)
- “Multiple Stellar Populations in Globular Clusters,” N. Bastian N. and C. Lardo 2018, *ARA&A*, 56, in press (arXiv:1712.01286)
- “The Birth of Star Clusters,” 2018, S. Stahler (Ed.), *Astrophys.Sp.Sci.Lib.*, Springer, Vol. 424

7. Developments within the past triennium

- A method to obtain stellar ages for red giants throughout the Milky Way, and a map of these ages showing an older Milky Way center (M. Ness et al. 2016, *ApJ*, 823, 114)
- Realization that the extended main-sequence turn-off regions routinely observed in the color–magnitude diagrams of intermediate-age (1–3 Gyr-old) stars clusters, mostly in the Magellanic Clouds, do not necessarily imply the presence of a stellar age range in a given cluster, but that a ‘simple’ stellar population exhibiting a range in stellar rotation rates may be a more realistic explanation (e.g., Li et al. 2016, *RAA*, 16, 179; Bastian & Lardo 2018, *ARA&A*, in press)
- First million-body simulation of a star cluster over a significant fraction of the cosmic age, including the most complete input physics to date (Wang et al. 2016, *MNRAS*, 458, 1450)
- First detections of complex molecules in protoplanetary disks, methyl cyanide CH₃CN (K. Oberg et al. 2015, *Nature*, 520, 198) and methanol, CH₃OH (C. Walsh et al. 2016, *ApJ*, 823, L10)
- Detection of the aromatic molecule benzonitrile, C₆H₅CN (B. McGuire et al. 2018, *Science*, 359, 202)
- Development of the largest chemical kinetic model, containing around 120,000 reactions, describing the full spin chemistry of deuteration in the dark cloud TMC-1 (L. Majumdar et al. 2017, *MNRAS*, 466, 4470)
- New prospects for observing general relativity effects near the Galactic Center supermassive black hole using orbits of pulsars such as the Galactic Center magnetar in the vicinity of SgrA* (G.C. Bower et al. 2015, *ApJ*, 798, 120)
- Discovery of a wall of neutral hydrogen around the gamma-ray Fermi Bubble in the galactic center (Lockman & McClure Griffiths 2016, *ApJ*, 826, 215)
- New models of gas flow, star formation and feedback that suggest the Central Molecular Ring oscillates between bursting and quiescent states (M.R. Krumholz, et al. 2016, *MNRAS*, 466, 1213)
- Characterization of the Galactic thin and thick disk in [alpha/Fe] vs. [Fe/H] with APOGEE across a radial range of 15 kpc, finding that the metal-poor, alpha-enhanced thick disk is prominent only in the inner regions, and that the alpha-poor thin disk has a metallicity gradient with radius (Hayden et al. 2015, *ApJ*, 808, 132)
- Discovery of numerous metal-poor, ultra-faint dwarf spheroidal galaxies in the Dark Energy Survey, several of which may be associated with the Magellanic Clouds (e.g., Bechtol et al. 2015, *ApJ*, 807, 50; Drlica-Wagner et al. 2015, *ApJ*, 813, 109; Torrealba et al. 2018, *MNRAS*)
- Heightened activity for molecular research in Planetary Nebulae following the previous discovery of fullerene (e.g., Diaz-Luis et al. 2015, *A&A* 573, 97)
- Advances in chemical analysis of Galactic Planetary Nebulae, especially regarding oxygen enrichment (Delgado-Inglada et al. 2015, *MNRAS* 449, 1797), the discrepant

common envelope and binary abundances (Corradi et al. 2015, ApJ, 803, 99), and the comparison between data and yields from AGB stellar models (e.g., Ventura et al. 2015, MNRAS 452, 3679)

- New post-AGB evolutionary models (M.M. Miller Bertolami 2016, A&A 588, 25)

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