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COMMISSION H1 — THE LOCAL UNIVERSE

L'UNIVERS LOCAL

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TRIENNIAL REPORT 2006-2009

1. Introduction

The new IAU Commission H1 on "The Local Universe" was founded in 2015. It continues the functions of the former Commission 33 ("Structure and Dynamics of the Galactic System) while adopting a wider definition of its focus and range, including a multi-wavelength approach. This new commission was proposed by Eva Grebel (Germany), Gang Zhao (China – Nanjing), and by the outgoing president and vice-president of Comission 33, Birgitta Nordström (Denmark) and Joss Bland-Hawthorn (Australia). It is one of the commissions of Division H, "Interstellar Matter and Local Universe".

Commission H1 focuses on "near-field cosmology", i.e., studies of the Milky Way and its surrounding galaxies. One of its primary goals is to use this nearby laboratory to study how galaxies in different environments and across a wide range of masses formed and evolved. Recent, ongoing, and forthcoming surveys in all wavelength ranges along with theoretical modeling are flourishing and are providing an unprecedentedly detailed picture of the evolution of our Galaxy and other nearby systems. These efforts exploit the stellar fossil record of ages, detailed chemistry, and kinematics to explore the assembly history and continuing evolution of the Galaxy and its neighbors, complemented by comprehensive studies of the multi-phase interstellar medium and studies of the small-scale distribution of dark matter. The exploration of the nearby universe is a vibrant field that combines and indeed requires efforts in a wide range of astronomical disciplines as epitomized by the diverse expertise of the members of Commission H1.

The exploration of the nearby universe and efforts towards understanding galaxy evolution via near-field cosmology are a vibrant, growing field that combines and requires coordinated efforts in a wide range of astronomical disciplines. We are interested in, for instance, the use of massive stars (C.G2), planetary nebulae (C.H3), pulsating stars (C.G4), or star clusters (C.H4) as tools for understanding galaxy evolution, but their detailed study in their own right is not within the purview of our Commission. Similarly, methods of, e.g., astrochemistry (C.H2), astrometry (C.H1), photometry and polarimetry (C.B6), or computational astrophysics (C.B2) are essential tools towards our goals.

In the nearby universe we can resolve galaxies into individual stars. These Galactic and extragalactic resolved stellar populations are being targeted by ground-based and space-based photometric, spectroscopic, and astrometric surveys (including the time domain). This is complemented by campaigns to map the dust properties and the multi-phase interstellar medium across a wide range of temperatures. Yet other efforts focus on high-energy sources or on searches for dark matter signals from nearby dwarf galaxies.

In the longer term, major new facilities including the Large Synoptic Survey Telescope (LSST), the European Extremely Large Telescope (E-ELT), the Giant Magellan Telescope (GMT), the Thirty Meter Telescope (TMT), the James Webb Space Telescope (JWST), Euclid, the Wide Field Infrared Survey Telescope (WFIRST), the Square Kilometer Array (SKA), the Cherenkov Telescope Array (CTA), the extended ROentgen Survey with an Imaging Telescope Array (eROSITA), and the Advanced Telescope for High-ENergy Astrophysics (ATHENA) will play key roles. Complex cosmological and chemodynamical simulations combining dark matter and baryons are now at or approaching the resolution required to realistically model disk and even dwarf galaxies.

2. Developments within the past triennium

The successful operation of the Gaia spacecraft has been a major milestone, and its observations are continuing. Gaia began its regular science operations in July 2014 and provided its first data release (DR1) in September 2016 (Gaia Collaboration et al. 2016a, 2016b). Gaia DR1 contains positions and magnitudes for 1.1 billion stars as well as positions, parallaxes, and proper motions for more than two million stars based on a combination of Gaia data with the Tycho-2 catalog from the astrometric Hipparcos mission. This combined data set is called the Tycho-Gaia astrometric solution (TGAS; Michalik, Lindegren, & Hobbs 2015), and TGAS in combination with other data (e.g., from the RAdial Velocity Experiment, RAVE; Kunder et al. 2017) forms the basis of a large number of articles during the past triennium. Gaia DR2 is expected in April 2018.

Massive ground-based spectroscopic surveys such as the optical Gaia-ESO Survey (GES) have advanced our understanding of the chemical evolution of the Galactic bulge, disk, and open clusters (e.g., Magrini et al. 2017). The near-infrared APO Galactic Evolution Experiment (APOGEE) has provided an unprecedentedly detailed picture of the metallicity trends in the thin and thick disks across a Galactocentric radius of 3 − 15 kpc. The α-poor thin disk shows a radial metallicity gradient, being metal-rich in the inner and metal-poor in the outer disk (Hayden et al. 2015). The Milky Way experienced considerable quenching after the thick disk formed $\geqslant 9$ billion years ago (Haywood et al. 2016). Further advances in chemically and kinematically mapping the Milky Way come from, e.g., the Large Sky Area Multi-Object Fibre Spectroscopic Telescope (LAMOST, e.g., Liu et al. 2017) and the Galactic Archaeology with HERMES survey (GALAH, e.g., Martell et al. 2017). Asteroseismology data from the Kepler satellite reveal that there are still discrepancies between Galactic models and observations (Sharma et al. 2017).

New multi-object, wide-field spectroscopic facilities are currently under development and will become available in the near future. These include, e.g., the Prime Focus Spectrograph (PFS) for the Subaru Telescope, the Dark Energy Spectroscopic Instrument (DESI) for the Mayall Telescope, the 4-metre Multi-Object Spectroscopic Telescope (4MOST) for VISTA, the Multi-Object Optical and Near-infrared Spectrograph (MOONS) for the VLT, the multi-object spectrograph WEAVE for the William Herschel Telescope, and the Maunakea Spectroscopic Explorer (MSE) for CFHT.

On small scales, three-dimensional optical spectroscopy with integral field units such as the Multi-Unit Spectroscopic Explorer (MUSE) or the K-band Multi Object Spectrograph (KMOS) can provide thousands of stellar spectra in crowded regions such as globular clusters or the Galactic center suitable for spectral typing, metallicity and kinematic studies (e.g., Kamann et al. 2018; Feldmeier-Krause et al. 2017), or nebular velocity and abundance maps of star-forming regions (e.g., McLeod et al. 2015).

Regarding major imaging surveys, the first data releases of the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS, *grizy* imaging; Chambers et al. 2016), the Dark Energy Survey (DES, *grizY* imaging; The Dark Energy Survey Collaboration et al. 2016), and Skymapper (*uvgriz* imaging; Wolf et al. 2018) are now publicly available. Among other things, these surveys led to the discovery of new stellar overdensities in the Milky Way (e.g., Grillmair et al. 2017; Shipp et al. 2018) and of ultra-faint dwarf spheroidal (dSph) satellite galaxies, some of which may be satellites of the Magellanic Clouds (e.g., Drlica-Wagner et al. 2015; Laevens et al. 2015).

Intermediate or narrow-band filters such as Skymapper's v-band or the Ca H&K filters of CFHT's Pristine survey are used to identify metal-deficient stars (e.g., Howes et al. 2016; Starkenburg et al. 2017). The Canada-France Imaging Survey (CFIS) complements the SDSS and Pan-STARRS via deep u-band imaging, enabling accurate and efficient stellar metallicity and distance determinations (Ibata et al. 2017).

New ultra-faint dSph candidates have also been discovered in other surveys during the past triennium, for instance via the Hyper Suprime Cam (HSC) Subaru Strategic Program (SSP; see, e.g., Homma et al. 2018), or the VLT Survey Telescope ATLAS survey (e.g., Torrealba et al. 2016). Many of the known and new satellites appear to follow a planar distribution called the Vast Polar Structure (e.g., Pawlowski, McGaugh, & Jerjen 2015), although the physical nature of this structure is under debate. Progress was also made in the characterization of the M31 satellites (e.g., Martin et al. 2017), many of which were discovered in the Pan-Andromeda Archaeological Survey (PAndAS).

Infrared imaging surveys such as the Wide-field Infrared Survey Explorer (WISE) aid in tracing recent and ongoing Galactic star formation and led to the discovery of numerous obscured star clusters in the Galactic disk (Camargo et al. 2016). The optical Panchromatic Hubble Andromeda Treasury (PHAT), an imaging survey with the Hubble Space Telescope (HST), permitted the characterization of the star formation history of the disk of M31 (Williams et al. 2017). The star cluster formation efficiency across M31's disk was found to vary in PHAT depending on mid-plane pressure and H_2- or H I-dominated environments (Johnson et al. 2016).

Stellar time-domain surveys such as the Optical Gravitational Lensing Experiment (OGLE), which focuses on the Magellanic Clouds and the Galactic bulge, and the near-infrared VISTA Variables in the Vía Láctea (VVV) survey, which observes the bulge and the surrounding disk, are key to Galactic archaeology with variable stars. These surveys revealed the three-dimensional structure of the old component of the Galactic bulge as traced via RR Lyrae stars (Pietrukowicz et al. 2015) and uncovered a young and thin stellar disk across the Galactic bulge traced by classical Cepheids (Dékány et al. 2015). They also revealed the three-dimensional structure of the Magellanic Clouds and of the Bridge (e.g., Jacyszyn-Dobrzeniecka et al. 2017), and led to the detection of new open and globular cluster candidates (e.g., Minniti et al. 2017).

Near-infrared spectra from, e.g., APOGEE, GES, the Bulge RR Lyrae Radial Velocity Assay (BRAVA-RR), and the GIRAFFE Inner Bulge Survey (GIBS) improve our knowledge of the chemistry and kinematics of the bulge components (e.g., Schultheis et al. 2015; Rojas-Arriagada et al. 2017; Kunder et al. 2016; Zoccali et al. 2017). The observational data (also from earlier imaging and spectroscopic surveys) suggest that the Milky Way's bulge with its bar and boxy/peanut structure and various kinematic and chemical subcomponents is primarily a pseudo-bulge formed from an early disk via a buckling instability (e.g., Shen & Li 2016). Combining data from imaging, time domain, and spectroscopic surveys led to improved dynamical modeling of the Galactic bulge and bar and an inferred low dark matter fraction. Chemo-dynamical modeling with N-body or made-to-measure models is making advances in reproducing the disk origin of the bulge, its bar/peanut and orbital structure, and chemical gradients (e.g., Athanassoula, Rodionov, & Prantzos 2017; Fragkoudi et al. 2017; Portail et al. 2017).

Galactic halo RR Lyrae stars from the time-domain Catalina Surveys were used to identify streams or to constrain the mass of the Milky Way in combination with LAMOST and Sloan Digital Sky Survey (SDSS) data (Mateu et al. 2018; Ablimit & Zhao 2017). The shape of the Galactic halo has been traced combining RR Lyrae stars identified in Gaia DR1 and 2MASS (Iorio et al. 2018). Most of the intermediate-age stars in the halo (as traced by carbon stars with Catalina light curves) come from the Sagittarius dSph, but some are also associated with other substructure (Huxor & Grebel 2015). Even in sparsely time-sampled data from Pan-STARRS, RR Lyrae stars have been identified with high confidence (Sesar et al. 2017). The most distant Galactic RR Lyrae stars with distances > 200 kpc were found in the DES High cadence Transient Survey (HiTS) and resemble the properties of RR Lyrae in ultrafaint dSphs (Medina et al. 2018).

Regarding the interstellar medium, the first data release of the new Effelsberg-Bonn H I Survey (EBHIS) was published (Winkel et al. 2016). The molecular gas content of the Galactic halo, which is likely connected to the Galactic fountain, was quantified using EBHIS, Parkes Galactic All-Sky Survey, and Planck FIR survey data (Röhser et al. 2016). HST Cosmic Origins Spectrograph (COS) observations were used to constrain the size and kinematics of the northern Fermi Bubble (Bordoloi et al. 2017). Data of the diffuse γ-ray emission from the Fermi Large Area Telescope (Fermi-LAT) suggest that also M31 may show nuclear outflows resulting in two Fermi bubbles perpendicular to its disk (Pshirkov, Vasiliev, & Postnov 2016). In the Milky Way, HST's COS is being used to characterize the circum-Galactic medium and the abundances in high-velocity clouds, confirming the importance of gas accretion to sustain the Galactic disk's star formation (Richter et al. 2017). Abundance measurements in the Leading Arm of the (gaseous) Magellanic Stream suggest an origin from the Small Magellanic Cloud, which also seems to hold for the majority of the trailing Stream (Fox et al. 2018).

The APEX Telescope Large Area Survey of the Galaxy (ATLASGAL), the most sensitive ground-based submilliter survey of the Galactic midplane to date, reveals massive cold clumps and the earliest stages of embedded massive star formation (e.g., Urquhart et al. 2018). High-resolution observations with the Atacama Large Millimeter Array (ALMA) are being used to probe, for example, the Galactic Center and the origin of its nuclear star cluster (e.g., Tsuboi et al. 2016) and high-mass star formation in low-metallicity environments such as in the Magellanic Clouds (e.g., Saigo et al. 2017). The combination of Spitzer and Herschel data of the Magellanic Clouds shows that asymptotic giant branch stars are the most significant contributors to the global dust budget (Srinivasan et al. 2016).

3. Meetings (September 2015 – July 2018)

2015 (starting in September)

- "Life-cyle of Gas in Galaxies: A Local Perspective" (Dwingeloo, The Netherlands, August 31 – September 04, 2015)
- "Science with MOS: Toward the E-ELT Era" (Cefalú, Italy, Sept. 07 – 11, 2015)
- "Feedback in the Magellanic Clouds" (Baltimore, USA, October 05 – 07, 2015)
- "Observational Evidence of Gas Accretion onto Galaxies" (Charlottesville, USA, October 09 – 11, 2015)
- "High-precision Studies of RR Lyrae Stars from Dynamical Phenomena to Mapping the Galactic Structure" (Visegrád, Hungary, October 19 – 22, 2015)

- "Gaia-ESO Third Science Meeting" (Vilnius, Lithuania, December 01 – 04, 2015)
- "M-th Aarseth N-body Meeting" (Prague, Czech Republic, December 15 – 18, 2015)

2016

- "Dynamics and accretion at the Galactic Center" (Aspen, USA, Feb. 07 – 12, 2016)
- "Globular Clusters and Galaxy Halos" (Leiden, The Netherlands, Feb. 22 – 26, 2016)
- "Science with the Atacama Pathfinder Experiment (APEX)" (Tegernsee, Germany, March 06 – 09, 2016)
- "SnowPAC 2016: The Galaxy-Halo Connection" (Snowbird, USA, Mar 13–18, 2016)
- "**IAU Symposium 321**: Formation and Evolution of Galaxy Outskirts" (Toledo, Spain, March 14 – 18, 2016)
- "ASTROPLATE2016 - International workshop on scientific use, digitization and preserving astronomical photographic records" (Prague, Czech Rep., March 14–18, 2016)
- "13th Potsdam Thinkshop Near Field Cosmology" (Obergurgl, Austria, March 29 – April 03, 2016)
- "Molecular Gas in Galactic Environments" (Charlottesville, USA, April 03–06, 2016)
- "From Stars to Massive Stars" (Gainesville, USA, April 06 – 09, 2016)
- "COSMIC-LAB: Star Clusters as Cosmic Laboratories for Astrophysics, Dynamics and Fundamental Physics (MODEST 16)" (Bologna, Italy, April 18 – 22, 2016)
- "The Cold Universe" (Santa Barbara, USA, April 25 – July 15, 2016)
- "The Cosmic FIR Landscape" (Lisbon, Portugal, May 04 – 06, 2016)
- "Diffuse Matter in the Galaxy, Magnetic Fields, and Star Formation – Honoring the Contributions of R. Crutcher & C. Heiles" (Madison, USA, May 22 – 25, 2016)
- "LSST @ Europe2" (Belgrade, Serbia, June 20 – 24, 2016)
- "Dark Matter 2016 (DM2016). From the smallest to the largest scale" (Santander, Spain, June 27 – July 01, 2016)
- "MUSE first year science and beyond" (Athens, Greece, July 04 – 08, 2016)
- "Discs in Galaxies - 2016 Munich Joint Conference" (Garching, Germany, July 10 – 14, 2016)
- "The role of feedback in the formation and evolution of star clusters" (Sesto, Italy, July 18 – 22, 2016)
- "Star Formation in Different Environments" (Quy nhon, Vietnam, July 25–29, 2016)
- "First Stars V" (Heidelberg, Germany, August 01 – 05, 2016)
- "Heidelberg Gaia Sprint" (Heidelberg, Germany, August 08 – 12, 2016)
- "Star Clusters: from Infancy to Teenagehood" (Heidelberg, Germany, August 08 – 12, 2016)
- "Stars on the run: Run-away and hyper-velocity stars" (Bamberg, Germany, August 16 – 19, 2016)
- "Star Formation 2016" (Exeter, UK, August 21 – 26, 2016)
- "Crossing the Rubicon: the fate of gas flows in galaxies" (Santarcangelo di Romagna, Italy, September 05 – 09, 2016)
- "MODEST-16 NYC: The Interplay Between Gas and Gravitational Dynamics" (New York, USA, September 06 – 09, 2016)
- "The Milky Way and its environment: gaining insights into the drivers of galaxy formation and evolution" (Paris, France, September 19 – 23, 2016)
- "Precision Spectroscopy 2016: Stellar structure, Nucleosynthesis and Chemical Evolution" (Porto Alegre, Brazil, September 19 – 21, 2016)
- "VIALACTEA2016: The Milky Way as a Star Formation Engine" (Rome, Italy, September 26 – 30, 2016)

- "**IAU Symposium 323**: Planetary Nebulae: Multi-wavelength Probes of Stellar and Galactic Evolution" (Beijing, China, October 09 – 14, 2016)
- "New York City Gaia Sprint" (New York, USA, October 17 – 21, 2016)
- "Chemical Abundances in Gaseous Nebulae" (São Paulo, Brazil, Nov. 02 – 05, 2016)
- "Gaia 2016 Data Release #1 Workshop" (Madrid, Spain, November 02 – 04, 2016)
- "Gaia Data Workshop" (Heidelberg, Germany, November 21 – 24, 2016)
- "Galactic Archaeology and Stellar Physics" (Canberra, Australia, Nov 21–25, 2016)
- "Wide-Field Variability Surveys: A 21st-Century Perspective" (San Pedro de Atacama, Chile, November 27 – December 02, 2016)
- "Stellar aggregates over mass and spatial scales" (Bad Honnef, Germany, December 05 – 09, 2016)

2017

- "Star Formation and Nearby Galaxies with JWST: Science and Observation Planning" (Pasadena, USA, January 18 – 20, 2017)
- "Star Formation from Cores to Clusters" (Santiago, Chile, March 06 – 09, 2017)
- "Multi-Scale Star Formation" (Morelia, Mexico, April 02 – 06, 2017)
- "**IAU Symposium 330**: Astrometry and Astrophysics in the Gaia Sky" (Nice, France, April 24 – 28, 2017)
- "Quantifying and Understanding the Galaxy-Halo Connection" (Santa Barbara, USA, May 15 – 19, 2017)
- "Surveying the Cosmos: The Science From Massively Multiplexed Surveys" (Sydney, Australia, June 05 – 09, 2017)
- "Francesco's Legacy: Star Formation in Space and Time" (Firenze, Italy, June 05 – 09, 2017)
- "The Third PANDA Symposium on Time-Domain Astronomy" (Nanjing, China, June 12 – 16, 2017)
- "Star Cluster Formation: Mapping the first few Myrs" (El Escorial, Spain, June 14 – 15, 2017)
- "The Interstellar Medium Beyond 3D" (Orsay, France, July 03 – 28, 2017)
- "Galactic Star Formation with Surveys" (Heidelberg, Germany, July 03 – 07, 2017)
- "**IAU Symposium 334**: Rediscovering our Galaxy" (Potsdam, Germany, July 10 – 14, 2017)
- "Large Surveys of the Great Andromeda Galaxy" (Leiden, The Netherlands, July 12 – 20, 2017)
- "2017 Heidelberg Gaia Sprint" (Heidelberg, Germany, July 17 – 21, 2017)
- "Measuring Star Formation in the Radio, Millimetre, and Submillimetre" (Manchester, UK, July 24 – 26)
- "Celebrating 25 years of the OGLE project" (Warsaw, Poland, July 24 – 28, 2017)
- "Star Formation in Different Environments (SFDE17): From Local Clouds to Galaxies" (Quy Nhon, Vietnam, August 06 – 11, 2017)
- "The science of Gaia and future challenges" (Lund, Sweden, Aug. 30–Sept. 01, 2017)
- "Stellar Populations and the Distance Scale (a conference in honour of Jeremy Mould)" (Beijing, China, September 11 – 15, 2017)
- "The RR Lyrae 2017 Conference. Revival of the classical pulsators: from galactic structure to stellar interior diagnostics" (Niepolomice, Poland, September 17 – 21, 2017)
- "ages^2: Taking stellar ages to the next power" (Elba, Italy, September 18 – 22, 2017)
- "MODEST 17 – Modelling and observing dense stellar systems" (Prague, Czech Republic, September 18 – 22, 2017)
- "70 Years of Stellar Associations" (Byurakan, Armenia, September 25 – 27, 2017)

- "Modes of Star Formation: A Symposium in Honor of Jay Gallagher" (Aspen, USA, September 25 – 29, 2017)
- "The Role of Gas in Galaxy Dynamics" (Valletta, Malta, October 02 – 06, 2017)
- "Piercing the Galactic Darkness: Stellar populations in the highly extincted regions of the Milky Way (GALDARK2017)" (Heidelberg, Germany, October 16 – 19, 2017)
- "With One Hand Waving Free. Celebrating the 60th birthday of John Lattanzio" (Port Douglas, Australia, October 29 – November 04, 2017)
- "A Celebration of CEMP and Gala of GALAH" (Melbourne, Australia, November 13 – 17, 2017)
- "**IAU Symposium 339**: Southern Horizons in Time-Domain Astronomy" (Stellenbosch, South Africa, November 13 – 17, 2017)

2018 (ending in August)

- "Dwarfs Stars and Clusters with K2: a Workshop" (Boston, USA, Jan. 16 – 18, 2018
- "Science with Precision Astrometry" (Baltimore, USA, March 13 – 15, 2018)
- "ISM in the Nearby Universe" (Bamberg, Germany, March 26 – 28, 2018)
- "The Small-Scale Structure of Cold(?) Dark Matter" (Santa Barbara, USA, April 09 – June 22, 2018)
- "2018 New York City Gaia Sprint" (New York, USA, June 04 – 08, 2018)
- "Bubbles Big and Small: From supernovae and the Fermi Bubbles to the Circumgalactic Medium" (Bangalore, India, June 11 – 14, 2018)
- "LSST@Europe3: Building Science Collaborations" (Lyon, France, June 11–15, 2018)
- "MODEST-18: Dense Stellar Systems in the Era of Gaia, LIGO, & LISA" (Santorini, Greece, June 25 – 29, 2018)
- "Near-Field Cosmology with the Dark Energy Survey's DR1 and Beyond" (Chicago, USA, June 27 – 29, 2018)
- "Stellar Halos Across the Cosmos" (Heidelberg, Germany, July 02 – 06, 2018)
- "Multiple Populations in Stellar Clusters" (Sesto, Italy, July 09 – 13, 2018)
- "The formation of globular clusters at high and low redshift; tracing star and cluster formation across cosmic times" (Sesto, Italy, July 16 – 20, 2018)
- "LSST 2018 Project and Community Workshop" (Tucson, USA, Aug. 13 – 17, 2018)
- "**IAU Symposium 343**: Why Galaxies Care About AGB Stars: A Continuing Challenge through Cosmic Time" (Vienna, Austria, August 20 – 23, 2018)
- "**IAU Symposium 344**: Dwarf Galaxies: From the Deep Universe to the Present" (Vienna, Austria, August 20 – 24, 2018)
- "**IAU Symposium 347**: Early Science with ELTs (EASE)" (Vienna, Austria, August 28 – 31, 2018)

4. Useful Databases

Milky Way models:

- **Besançon** model: model2016.obs-besancon.fr/ (new version)
- **TRILEGAL**: stev.oapd.inaf.it/cgi-bin/trilegal
- **Galaxia**: galaxia.sourceforge.net./
- **GalMod**: www.galmod.org/gal/

Dust maps:

- Schlegel, Finkbeiner, & Davis (1998) dust maps: w.astro.berkeley.edu/∼marc/dust/
- Schlafly & Finkbeiner (2011) & others: dustmaps.readthedocs.io/en/latest/maps.html
- 3-D dust mapping with Pan-STARRS 1: argonaut.skymaps.info./

Imaging surveys of the Milky Way and nearby galaxies:

- AAVSO Photometric All-Sky Survey (**APASS**): www.aavso.org/apass
- Beijing-Arizona Sky Survey (**BASS**): legacysurvey.org/bass/
- Dark Energy Camera Legacy Survey (**DECaLS**): legacysurvey.org/decamls/
- Gaia Data Release 1 (**Gaia DR1**): www.cosmos.esa.int/web/gaia/dr1
- Galaxy Evolution Explorer data (**GALEX**): galex.stsci.edu/GR6/
- Galactic Legacy Infrared Mid-Plane Survey Extraordinaire (**GLIMPSE**): www.astro.wisc.edu/sirtf/
- Magellanic Clouds Emission-line Survey (**MCELS**): astro.wsu.edu/worthey/html/mcsurvey.html
- Magellanic Clouds Photometric Survey (**MCPS**): djuma.as.arizona.edu/~dennis/mcsurvey
- Panchromatic Hubble Andromeda Treasury (**PHAT**): archive.stsci.edu/prepds/phat/
- Panoramic Survey Telescope and Rapid Response System 1 (**Pan-STARRS1**): panstarrs.stsci.edu/
- Sloan Digital Sky Survey (**SDSS**): www.sdss.org/
- Survey of the Magellanic Stellar History (**SMASH**): datalab.noao.edu/smash/smash.php
- Two-Micron All-Sky Survey (**2MASS**): www.ipac.caltech.edu/2mass/
- VISTA NIR YJK$_s$ survey of the Magellanic System (**VMC**): star.herts.ac.uk/~mcioni/vmc/
- WISE co-adds and forced SDSS photometry (**unWISE**): unwise.me/

Time-domain surveys:

- General Catalog of Variable Stars (**GCVS**): sai.msu.su/gcvs/gcvs/
- **ASAS-SN** Variable Stars Database: asas-sn.osu.edu/variables
- **Catalina** Surveys Data Release 2 (CSDR2): nesssi.cacr.caltech.edu/DataRelease/
- **Kepler** Data Archive: archive.stsci.edu/kepler/
- Optical Gravitational Lensing Experiment (**OGLE**): ogle.astrouw.edu.pl/
- Palomar-Quest Survey: www.astro.caltech.edu/~george/pq/
- Palomar Transient Factory (**PTF**) & Zwicky Transient Facility (**ZTF**): www.ptf.caltech.edu/
- VISTA Variables in the Vía Láctea (**VVV**): vvvsurvey.org/

Stellar spectroscopic databases:

- Bulge Radial Velocity Assay (**BRAVA**): brava.astro.ucla.edu/
- Empirical stellar templates from BOSS: zenodo.org/record/321394
- Gaia Data Release 1 (**Gaia DR1**): www.cosmos.esa.int/web/gaia/dr1
- **Gaia FGK Benchmark Stars**: www.blancocuaresma.com/s/benchmarkstars
- GALactic Archaeology with HERMES (**GALAH**): galah-survey.org/
- Gaia-ESO Survey (**GES**): www.gaia-eso.eu/
- **Hypathia Catalog Database** (abundances): www.hypatiacatalog.com/
- **JINAbase** for metal-poor stars: jinabase.pythonanywhere.com/
- Large Sky Area Multi-Object Fibre Spectroscopic Telescope (**LAMOST**): dr1.lamost.org/
- RAdial Velocity Experiment (**RAVE**): www.rave-survey.org/
- Stellar Abundances for Galactic Archaeology (**SAGA**): sagadatabase.jp/
- Sloan Digital Sky Survey (**SDSS**, includes **APOGEE**, **SEGUE**): www.sdss.org/surveys/

Eva K. Grebel
President of the Commission

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