THE MAGELLANIC CLOUDS NEWSLETTER

An electronic publication dedicated to the Magellanic Clouds, and astrophysical phenomena therein

No. 162 — 3 December 2019

https://www.astro.keele.ac.uk/MCnews

Editor: Jacco van Loon

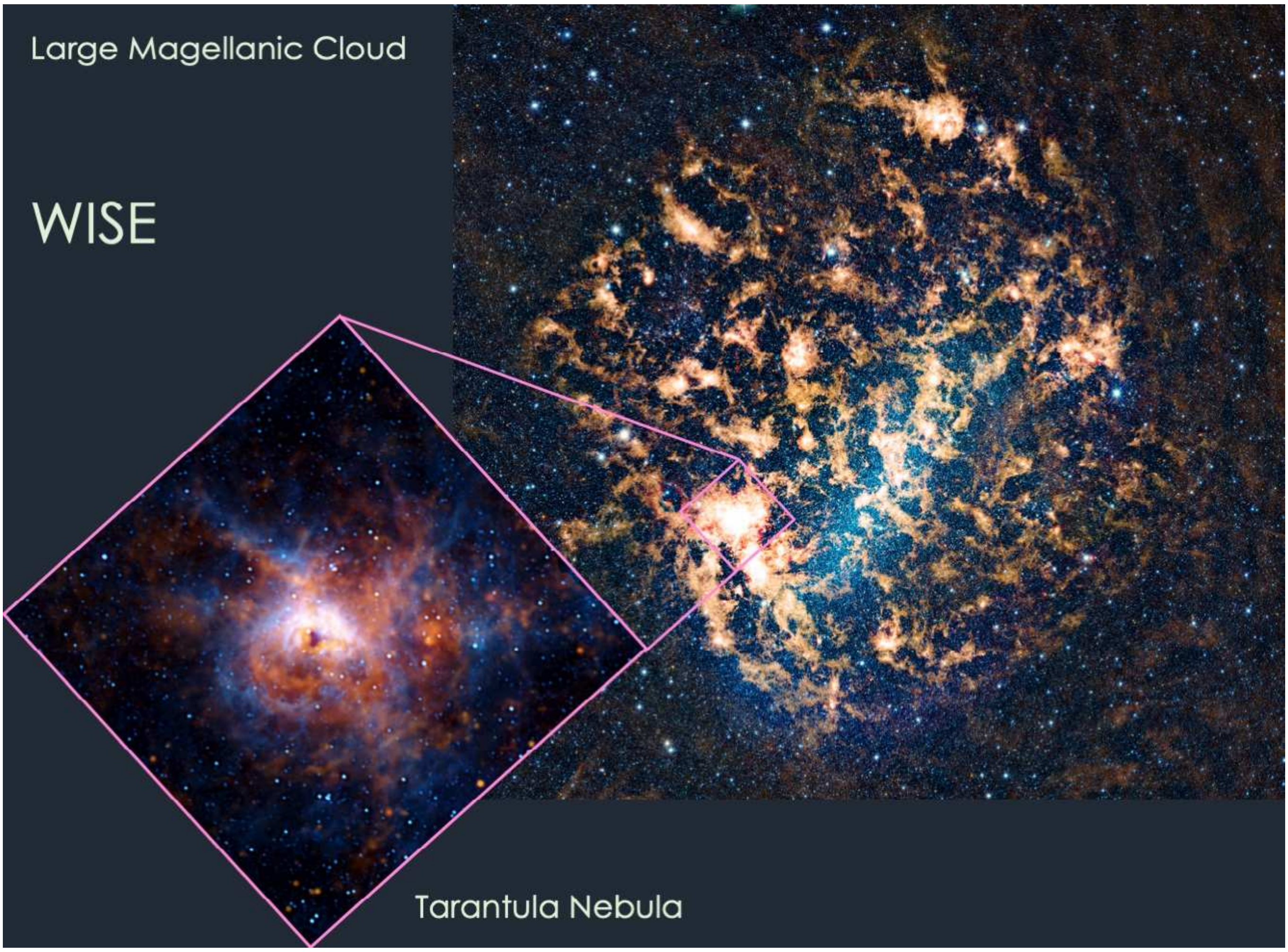

Figure 1: WISE composite image of the LMC and a super-resolved inset of the Tarantula Nebula. See the paper by Jarrett et al. posted in this issue.

Editorial

Dear Colleagues,

It is my pleasure to present you the 162nd issue of the Magellanic Clouds Newsletter, a bumper edition! And again with some fundamental Physics: the cosmic acceleration as (to be) seen towards the LMC!

Have a look at the announcements of meetings on polarimetry (IAU Symposium 360 in Hiroshima, Japan) and the Local Group (Baltimore, USA).

The next issue is planned to be distributed on the 1st of February. I wish you a happy new year full of love and hope.

Editorially Yours,
Jacco van Loon

Refereed Journal Papers

Meta-analysis of electron cyclotron resonance absorption features detected in high-mass X-ray binaries

D.M. Chritodoulou[1,2], *S.G.T. Laycock*[1,3] *and D. Kazanas*[4]

[1]Lowell Center for Space Science and Technology, University of Massachusetts Lowell, Lowell, MA, 01854, USA

[2]Department of Mathematical Sciences, University of Massachusetts Lowell, Lowell, MA, 01854, USA

[3]Department of Physics & Applied Physics, University of Massachusetts Lowell, Lowell, MA, 01854, USA

[4]NASA Goddard Space Flight Center, Laboratory for High-Energy Astrophysics, Code 663, Greenbelt, MD 20771, USA

Using recent compilations of detailed X-ray observations and spectral models of exceptional quality, we record the electron cyclotron resonance absorption (ECRA) features that have been detected in 45 pulsating high-mass X-ray binaries (HMXBs) and ultraluminous X-ray (ULX) sources harboring neutron stars, although seven of these detections are still questionable and another 21 are single and/or not independently confirmed. From the comprehensive catalogs of Jaisawal & Naik and Staubert et al. and from several additional recent observations, we produce two lists of HMXB ECRA sources: a list of 17 sources in which multiple ECRA lines or single very low-energy lines are seen, in which we can reasonably assume that the lowest energy reveals the fundamental cyclotron level for each source; and a "contaminated" list of 38 sources including the 21 detections of single ECRA lines that may (not) be higher-level harmonics. Both lists confirm a previous result that we have obtained independently by modeling the propeller lines of Magellanic HMXB pulsars: the surface dipolar magnetic fields $B_\star$ of HMXB neutron stars are segregated around five distinct values with $B_\star = 0.28 \pm 0.08$, 0.55 ± 0.11, 1.3 ± 0.37, 3.0 ± 0.68 and 7.9 ± 3.1, in units of TG. However, an explanation of this phenomenon is currently lacking. We have found no correlation between these $B_\star$ values and the corresponding observed spin periods, spin period derivatives, orbital periods, maximum X-ray luminosities, neutron star masses or companion star masses.

Published in Research in Astronomy and Astrophysics
Available from https://arxiv.org/abs/1905.05363

Swift observations of SMC X-3 during its 2016–2017 super-Eddington outburst

Shan-Shan Weng[1], *Ming-Yu Ge*[2], *Hai-Hui Zhao*[1], *Wei Wang*[3,4], *Shuang-Nan Zhang*[2,4,5], *Wei-Hao Bian*[1] *and Qi-Rong Yuan*[1]

[1]Department of Physics and Institute of Theoretical Physics, Nanjing Normal University, Nanjing 210023, China

[2]Key Laboratory of Particle Astrophysics, Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, China

[3]School of Physics and Technology, Wuhan University, 430072 Wuhan, Hubei, China

[4]National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012, China

[5]University of the Chinese Academy of Sciences, Beijing, China

The Be X-ray pulsar, SMC X-3 underwent a giant outburst from 2016 August to 2017 March, which was monitored with the Swift satellite. During the outburst, its broadband flux increased dramatically, and the unabsorbed X-ray luminosity reached an extreme value of $\sim 10^{39}$ erg s^{-1} around August 24. Using the Swift/XRT data, we measure the observed pulse frequency of the neutron star to compute the orbital parameters of the binary system. After applying the orbital corrections to Swift observations, we find that the spin frequency increases steadily from 128.02 mHz on August 10 and approach to spin equilibrium ~ 128.74 mHz in 2017 January with an unabsorbed luminosity of $L_{\rm X} \sim 2 \times 10^{37}$ erg s^{-1}, indicating a strong dipolar magnetic field $B \sim 6.8 \times 10^{12}$ G at the neutron star surface. The spin-up rate is tightly correlated with its X-ray luminosity during the super-Eddington outburst. The pulse profile in the Swift/XRT data is variable, showing double peaks at the early stage of outburst and then merging into a single

peak at low luminosity. Additionally, we report that a low temperature ($kT \sim 0.2$ keV) thermal component emerges in the phase-averaged spectra as the flux decays, and it may be produced from the outer truncated disk or the boundary layer between the exterior flow and the magnetosphere.

Published in ApJ, 843, 69 (2017)
Available from https://arxiv.org/abs/1701.02983

Pulse phase-resolved analysis of SMC X-3 during its 2016–2017 super-Eddington outburst

Hai-Hui Zhao[1], *Shan-Shan Weng*[1], *Ming-Yu Ge*[2], *Wei-Hao Bian*[1] *and Qi-Rong Yuan*[1]

[1]Department of Physics and Institute of Theoretical Physics, Nanjing Normal University, Nanjing 210023, China

[2]Key Laboratory of Particle Astrophysics, Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, China

The Be X-ray pulsar SMC X-3 underwent an extra long and ultraluminous giant outburst from 2016 August to 2017 March. The peak X-ray luminosity is up to $\sim 10^{39}$ erg s^{-1}, suggesting a mildly super-Eddington accretion onto the strongly magnetized neutron star. It therefore bridges the gap between the Galactic Be/X-ray binaries ($L_X^{peak} \leq 10^{38}$ erg s^{-1}) and the ultraluminous X-ray pulsars ($L_X^{peak} \geq 10^{40}$ erg s^{-1}) found in nearby galaxies. A number of observations were carried out to observe the outburst. In this paper, we perform a comprehensive phase-resolved analysis on the high quality data obtained with the NuSTAR and XMM–*Newton*, which were observed at a high and intermediate luminosity levels. In order to get a better understanding on the evolution of the whole extreme burst, we take the Swift results at the low luminosity state into account as well. At the early stage of outburst, the source shows a double-peak pulse profile, the second main peak approaches the first one and merges into the single peak at the low luminosity. The second main peak vanishes beyond 20 keV, and its radiation becomes much softer than that of the first main peak. The line widths of fluorescent iron line vary dramatically with phases, indicating a complicated geometry of accretion flows. In contrast to the case at low luminosity, the pulse fraction increases with the photon energy. The significant small pulse fraction detected below 1 keV can be interpreted as the existence of an additional thermal component located at far away from the central neutron star.

Published in Astrophysics and Space Science, 363, 21 (2018)
Available from https://arxiv.org/abs/1801.02482

NuSTAR and XMM–*Newton* observations of SXP 59 during its 2017 giant outburst

Shan-Shan Weng[1], *Ming-Yu Ge*[2] *and Hai-Hui Zhao*[1]

[1]Department of Physics and Institute of Theoretical Physics, Nanjing Normal University, Nanjing 210023, China

[2]Key Laboratory of Particle Astrophysics, Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, China

The Be X-ray pulsar (BeXRP) SXP 59 underwent a giant outburst in 2017 with a peak X-ray luminosity of 1.1×10^{38} erg s^{-1}. We report on the X-ray behaviour of SXP 59 with the XMM–*Newton* and NuSTAR observations collected at the outburst peak, decay, and the low luminosity states. The pulse profiles are energy dependent, the pulse fraction increases with the photon energy and saturates at $\sim 65\%$ above 10 keV. It is difficult to constrain the change in the geometry of emitting region with the limited data. Nevertheless, because the pulse shape generally has a double-peaked profile at high luminosity and a single peak profile at low luminosity, we prefer the scenario that the source transited from the super-critical state to the sub-critical regime. This result would further imply that the neutron star (NS) in SXP 59 has a typical magnetic field. We confirm that the soft excess revealed below 2 keV is dominated by a cool thermal component. On the other hand, the NuSTAR spectra can be described as a combination of the non-thermal

component from the accretion column, a hot blackbody emission, and an iron emission line. The temperature of the hot thermal component decreases with time, while its size remains constant ($R \sim 0.6$ km). The existence of the hot blackbody at high luminosity cannot be explained with the present accretion theories for BeXRPs. It means that either more sophisticated spectral models are required to describe the X-ray spectra of luminous BeXRPs, or there is non-dipole magnetic field close to the NS surface.

Published in MNRAS, 489, 1000 (2019)
Available from https://arxiv.org/abs/1908.04908

Herschel spectroscopy of Massive Young Stellar Objects in the Magellanic Clouds

J.M. Oliveira[1], J.Th. van Loon[1], M. Sewiło[2,3], M.-Y. Lee[4,5], V. Lebouteiller[6], C.-H.R. Chen[5], D. Cormier[6], M.D. Filipović[7], L.R. Carlson[8], R. Indebetouw[9,10], S. Madden[6], M. Meixner[11,12], B. Sargent[12] and Y. Fukui[13]

[1]Lennard Jones Laboratories, School of Chemical & Physical Sciences, Keele University, Staffordshire ST5 5BG, UK
[2]CRESST II and Exoplanets and Stellar Astrophysics Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA
[3]Department of Astronomy, University of Maryland, College Park, MD 20742, USA
[4]Korea Astronomy and Space Science Institute, 776 Daedeokdae-ro, 34055 Daejeon, South Korea
[5]Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany
[6]Laboratoire AIM, CEA/Service d'Astrophysique, Bât. 709, CEA-Saclay, 91191 Gif-sur-Yvette Cedex, France
[7]Western Sydney University, Locked Bag 1797, Penrith South DC, NSW 2751, Australia
[8]Independent Scholar, Massachusetts 02125, USA
[9]Department of Astronomy, University of Virginia, P.O. Box 400325, Charlottesville, VA 22904, USA
[10]National Radio Astronomy Observatory, 520 Edgemont Road, Charlottesville, VA 22903, USA
[11]Department of Physics & Astronomy, Johns Hopkins University, 3400 N. Charles Street, Baltimore, MD 21218, USA
[12]Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA
[13]Department of Physics, Nagoya University, Chikusa-ku, Nagoya 464-8602, Japan

We present *Herschel* Space Observatory Photodetector Array Camera and Spectrometer (PACS) and Spectral and Photometric Imaging Receiver Fourier Transform Spectrometer (SPIRE FTS) spectroscopy of a sample of twenty massive Young Stellar Objects (YSOs) in the Large and Small Magellanic Clouds (LMC and SMC). We analyse the brightest far-infrared (far-IR) emission lines, that diagnose the conditions of the heated gas in the YSO envelope and pinpoint their physical origin. We compare the properties of massive Magellanic and Galactic YSOs. We find that [O I] and [C II] emission, that originates from the photodissociation region associated with the YSOs, is enhanced with respect to the dust continuum in the Magellanic sample. Furthermore the photoelectric heating efficiency is systematically higher for Magellanic YSOs, consistent with reduced grain charge in low metallicity environments. The observed CO emission is likely due to multiple shock components. The gas temperatures, derived from the analysis of CO rotational diagrams, are similar to Galactic estimates. This suggests a common origin to the observed CO excitation, from low-luminosity to massive YSOs, both in the Galaxy and the Magellanic Clouds. Bright far-IR line emission provides a mechanism to cool the YSO environment. We find that, even though [O I], CO and [C II] are the main line coolants, there is an indication that CO becomes less important at low metallicity, especially for the SMC sources. This is consistent with a reduction in CO abundance in environments where the dust is warmer due to reduced ultraviolet-shielding. Weak H_2O and OH emission is detected, consistent with a modest role in the energy balance of wider massive YSO environments.

Accepted for publication in MNRAS
Available from https://arxiv.org/abs/1910.01980

Neutron stars and black holes in the Small Magellanic Cloud: The SMC NuSTAR Legacy Survey

M. Lazzarini[1], B.F. Williams[1], A.E. Hornschemeier[2,3], V. Antoniou[4,5], G. Vasilopoulos[6], F. Haberl[7], N. Vulic[2,8], M. Yukita[2], A. Zezas[4,9,10], A. Bodaghee[11], B.D. Lehmer[12], T.J. Maccarone[5], A. Ptak[2,3], D. Wik[2,13], F.M. Fornasini[4], Jaesub Hong[4], J.A. Kennea[14], J.A. Tomsick[15], T. Venters[16], A. Udalski[17] and A. Cassity[6,18]

[1]Department of Astronomy, Box 351580, University of Washington, Seattle, WA 98195, USA
[2]2 Laboratory for X-ray Astrophysics, NASA Goddard Space Flight Center, Code 662, Greenbelt, MD 20771, USA
[3]Department of Physics and Astronomy, Johns Hopkins University, 3400 N. Charles Street, Baltimore, MD 21218, USA
[4]Center for Astrophysics – Harvard & Smithsonian, Cambridge, MA 02138, USA
[5]Department of Physics & Astronomy, Box 41051, Science Building, Texas Tech University, Lubbock, TX 79409, USA
[6]Department of Astronomy, Yale University, P.O. Box 208101, New Haven, CT 06520-8101, USA
[7]Max-Planck-Institut für extraterrestrische Physik, Gießenbachstraße 1, D-85748 Garching bei München, Germany
[8]Department of Astronomy and Center for Space Science and Technology (CRESST), University of Maryland, College Park, MD 20742, USA
[9]Physics Department and Institute of Theoretical and Computational Physics, University of Crete, 71003 Heraklion, Crete, Greece
[10]Foundation for Research and Technology-Hellas, 71110 Heraklion, Crete, Greece
[11]Department of Chemistry, Physics and Astronomy, Georgia College and State University, Milledgeville, GA 31061, USA
[12]Department of Physics, University of Arkansas, 226 Physics Building, 825 West Dickson Street, Fayetteville, AR 72701, USA
[13]Department of Physics and Astronomy, University of Utah, 201 James Fletcher Bldg., Salt Lake City, UT 84112, USA
[14]Department of Astronomy and Astrophysics, The Pennsylvania State University, University Park, PA 16802, USA
[15]Space Sciences Laboratory, 7 Gauss Way, University of California, Berkeley, CA 94720-7450, USA
[16]Laboratory for Astroparticle Physics, NASA Goddard Space Flight Center, Code 661, Greenbelt, MD 20771, USA
[17]Astronomical Observatory, University of Warsaw, Aleje Ujazdowskie 4, 00-478 Warsaw, Poland
[18]Smith College, Northampton, MA 01063, USA

We present a source catalog from the first deep hard X-ray ($E > 10$ keV) survey of the Small Magellanic Cloud (SMC), the NuSTAR Legacy Survey of the SMC. We observed three fields, for a total exposure time of 1 Ms, along the bar of this nearby star-forming galaxy. Fields were chosen for their young stellar and accreting binary populations. We detected 10 sources above a 3σ significance level (4–25 keV) and obtained upper limits on an additional 40 sources. We reached a 3σ limiting luminosity in the 4–25 keV band of $\sim 10^{35}$ erg s^{-1}, allowing us to probe fainter X-ray binary (XRB) populations than has been possible with other extragalactic NuSTAR surveys. We used hard X-ray colors and luminosities to constrain the compact-object type, exploiting the spectral differences between accreting black holes and neutron stars at $E > 10$ keV. Several of our sources demonstrate variability consistent with previously observed behavior. We confirmed pulsations for seven pulsars in our 3σ sample. We present the first detection of pulsations from a Be-XRB, SXP 305 (CXO J005215.4−73191), with an X-ray pulse period of 305.69 ± 0.16 seconds and a likely orbital period of $\sim$ 1160–1180 days. Bright sources ($\gtrsim 5 \times 10^{36}$ erg s^{-1}) in our sample have compact-object classifications consistent with their previously reported types in the literature. Lower luminosity sources ($\lesssim 5 \times 10^{36}$ erg s^{-1}) have X-ray colors and luminosities consistent with multiple classifications. We raise questions about possible spectral differences at low luminosity between SMC pulsars and the Galactic pulsars used to create the diagnostic diagrams.

Published in The Astrophysical Journal
Available from https://arxiv.org/abs/1909.11110
and from https://iopscience.iop.org/article/10.3847/1538-4357/ab3f32#apjab3f32t1

The brightening of the pulsar wind nebula of PSR B0540−69 after its spin-down rate transition

M.Y. Ge[1], F.J. Lu[1], L.L. Yan[2], S.S. Weng[3], S.N. Zhang[1,4], Q.D. Wang[5], L.J. Wang[1], Z.J. Li[6] and W. Zhang[1,4]

[1]Key Laboratory of Particle Astrophysics, Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, China

[2]School of Mathematics and Physics, Anhui Jianzhu University, Hefei 230601, China

[3]Department of Physics and Institute of Theoretical Physics, Nanjing Normal University, Nanjing 210023, China

[4]University of Chinese Academy of Sciences, Chinese Academy of Sciences, Beijing 100049, China

[5]Astronomy Department, University of Massachusetts, Amherst, MA 01003, USA

[6]School of of Architecture and Art, Hebei University of Engineering, Handan 056038, China

It is believed that an isolated pulsar loses its rotational energy mainly through a relativistic wind consisting of electrons, positrons and possibly Poynting flux (Pacini & Salvati 1973; Rees & Gunn 1974; Kennel & Coroniti 1984). As it expands, this wind may eventually be terminated by a shock, where particles can be accelerated to energies of X-ray synchrotron emission, and a pulsar wind nebula (PWN) is usually detectable surrounding a young energetic pulsar (Pacini & Salvati 1973; Rees & Gunn 1974; Kennel & Coroniti 1984). However, the nature and/or energetics of these physical processes remain very uncertain, largely because they typically cannot be studied in a time-resolved fashion. Here we show that the X-ray PWN around the young pulsar PSR B0540−69 brightens gradually up to $32 \pm 8\%$ over the mean previous flux, after a sudden spin-down rate ($\dot{\nu}$) transition (SRT) by $\sim 36\%$ in December 2011, which has very different properties from a traditional pulsar glitch (Marshall et al. 2015). No evidence is seen for any change in the pulsed X-ray emission. We conclude that the SRT results from a sudden change in the pulsar magnetosphere that increases the pulsar wind power and hence the PWN X-ray emission. The X-ray light curve of the PWN suggests a mean life time of the particles of 397 ± 374 days, corresponding to a magnetic field strength of $0.78^{+4.50}_{-0.28}$ mG in the PWN.

Published in Nature Astronomy

Available from https://arxiv.org/abs/1909.04364

and from https://www.nature.com/articles/s41550-019-0853-5

The period–luminosity diagram of long period variables in the Magellanic Clouds. New aspects revealed from Gaia DR2

Thomas Lebzelter[1], Michele Trabucchi[2], Nami Mowlawi[3], Peter R. Wood[4], Paola Marigo[2], Giada Pastorelli[2] and Isabelle Lecoeur-Taibi[3]

[1]University of Vienna, Department of Astrophysics, Austria

[2]Dipartimento di Fisica e Astronomia Galileo Galilei, Università di Padova, Italy

[3]Department of Astronomy, University of Geneva, Switzerland

[4]Research School of Astronomy and Astrophysics, Australian National University, Australia

The period–luminosity (PL) diagram has proven to be a powerful tool for studying populations of pulsating red giants. Gaia DR2 provides a large dataset including many long-period variables (LPVs) on which this tool can be applied. We investigate the location of LPVs from the Large and Small Magellanic Clouds in the PL diagram using various optical and infrared luminosity indicators from Gaia and 2MASS, respectively. Thereby we distinguish between stars of different masses and surface chemistry. The data set taken from the Gaia DR2 catalog of LPVs allows a homogeneous study from low- to high-mass LPVs. They are divided into sub-populations of AGB stars according to their mass and their O- or C-rich nature using the Gaia–2MASS diagram developed by our group. This diagram uses a Wesenheit index $\mathrm{W_{BP,RP}}$ based on Wesenheit functions in the Gaia and 2MASS photometric bands. Four different luminosity indicators are used to study the PL relations. We provide the first observational evidence of a PL relation offset for both fundamental and 1O pulsators between low- and intermediate-mass O-rich stars, in agreement with published pulsation predictions. Among the luminosity indicators explored, sequence C′ is the narrowest in the P–$\mathrm{W_{BP,RP}}$

diagram, and is thus to be preferred over the other PL diagrams for the determination of distances using LPVs. The majority of massive AGB stars and red supergiants form a smooth extension of sequence C of low- and intermediate-mass AGB stars in the P–$W_{BP,RP}$ diagram, suggesting that they pulsate in the fundamental mode. All results are similar in the two Magellanic Clouds.

Published in A&A
Available from https://arxiv.org/abs/1909.07924

The *Hubble* Catalog of Variables (HCV)

A.Z. Bonanos[1], M. Yang[1], K.V. Sokolovsky[1,2,3], P. Gavras[4,1], D. Hatzidimitriou[1,5], I. Bellas-Velidis[1], G. Kakaletris[6], D.J. Lennon[7,8], A. Nota[9], R.L. White[9], B.C. Whitmore[9] et al.

[1]IAASARS, National Observatory of Athens, Penteli 15236, Greece
[2]Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824, USA
[3]Sternberg Astronomical Institute, Moscow State University, Universitetskii pr. 13, 119992 Moscow, Russia
[4]RHEA Group for ESA–ESAC, Villanueva de la Cañada, 28692 Madrid, Spain
[5]Department of Physics, National and Kapodistrian University of Athens, Panepistimiopolis, Zografos 15784, Greece
[6]Athena Research and Innovation Center, Marousi 15125, Greece
[7]Instituto de Astrofísica de Canarias, E-38205 La Laguna, Tenerife, Spain
[8]ESA, European Space Astronomy Centre, Villanueva de la Cañada, 28692 Madrid, Spain
[9]Space Telescope Science Institute, Baltimore, MD 21218, USA

Aims: Over its lifetime and despite not being a survey telescope, the *Hubble* Space Telescope (HST) has obtained multi-epoch observations by multiple, diverse observing programs, providing the opportunity for a comprehensive variability search aiming to uncover new variables. We have therefore undertaken the task of creating a catalog of variable sources based on archival HST photometry. In particular, we have used version 3 of the *Hubble* Source Catalog (HSC), which relies on publicly available images obtained with the WFPC2, ACS, and WFC3 instruments onboard the HST.
Methods: We adopted magnitude-dependent thresholding in median absolute deviation (a robust measure of light curve scatter) combined with sophisticated preprocessing techniques and visual quality control to identify and validate variable sources observed by *Hubble* with the same instrument and filter combination five or more times.
Results: The *Hubble* Catalog of Variables (HCV) includes 84 428 candidate variable sources (out of 3.7 million HSC sources that were searched for variability) with $V \leq 27$ mag; for 11 115 of them the variability is detected in more than one filter. The data points in the light curves of the variables in the HCV catalog range from five to 120 points (typically having less than ten points); the time baseline ranges from under a day to over 15 years; while $\sim 8\%$ of all variables have amplitudes in excess of 1 mag. Visual inspection performed on a subset of the candidate variables suggests that at least 80% of the candidate variables that passed our automated quality control are true variable sources rather than spurious detections resulting from blending, residual cosmic rays, and calibration errors.
Conclusions: The HCV is the first, homogeneous catalog of variable sources created from the highly diverse, archival HST data and currently is the deepest catalog of variables available. The catalog includes variable stars in our Galaxy and nearby galaxies, as well as transients and variable active galactic nuclei. We expect that the catalog will be a valuable resource for the community. Possible uses include searches for new variable objects of a particular type for population analysis, detection of unique objects worthy of follow-up studies, identification of sources observed at other wavelengths, and photometric characterization of candidate progenitors of supernovæ and other transients in nearby galaxies. The catalog is available to the community from the ESA *Hubble* Science Archive (eHST) at the European Space Astronomy Centre (ESAC) and the Mikulski Archive for Space Telescopes (MAST) at Space Telescope Science Institute (STScI).

Published in A&A, 630, 92 (2019)
Available from https://arxiv.org/abs/1909.10757
and from https://www.aanda.org/component/article?access=doi&doi=10.1051/0004-6361/201936026

A census of B[e] supergiants

Michaela Kraus[1]

[1]Astronomical Institute, Czech Academy of Sciences, Fričova 298, 251 65 Ondřejov, Czech Republic

Stellar evolution theory is most uncertain for massive stars. For reliable predictions of the evolution of massive stars and their final fate, solid constraints on the physical parameters, and their changes along the evolution and in different environments, are required. Massive stars evolve through a variety of short transition phases, in which they can experience large mass-loss either in the form of dense winds or via sudden eruptions. The B[e] supergiants comprise one such group of massive transition objects. They are characterized by dense, dusty disks of yet unknown origin. In the Milky Way, identification and classification of B[e] supergiants is usually hampered by their uncertain distances hence luminosities, and by the confusion of low-luminosity candidates with massive pre-main sequence objects. The extragalactic objects are often mistaken as quiescent or candidate luminous blue variables, with whom B[e] supergiants share a number of spectroscopic characteristics. In this review, proper criteria are provided, based on which B[e] supergiants can be unambiguously classified and separated from other high luminosity post-main sequence stars and pre-main sequence stars. Using these criteria, the B[e] supergiant samples in diverse galaxies are critically inspected, to achieve a reliable census of the current population.

Published in Galaxies, 7, 83 (2019)
Available from https://arxiv.org/abs/1909.12199
and from https://www.mdpi.com/2075-4434/7/4/83

Stellar pulsation and the production of dust and molecules in Galactic carbon stars

Kathleen E. Kraemer[1], *G.C. Sloan*[2,3,4], *Luke D. Keller*[5], *Iain McDonald*[6], *Albert A. Zijlstra*[6,7] *and Martin A.T. Groenewegen*[8]

[1]Institute for Scientific Research, Boston College, 140 Commonwealth Avenue, Chestnut Hill, MA 02467, USA
[2]Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA
[3]Department of Physics and Astronomy, University of North Carolina, Chapel Hill, NC 27599-3255, USA
[4]Center for Astrophysics and Planetary Science, Cornell University, Ithaca, NY 14853-6801, USA
[5]Department of Physics and Astronomy, Ithaca College, Ithaca, NY, USA
[6]Jodrell Bank Centre for Astrophysics, Alan Turing Building, University of Manchester, Manchester, M13 9PL, UK
[7]Laboratory for Space Research, The University of Hong Kong, Pokfulam Road, Hong Kong, China
[8]Koninklijke Sterrenwacht van België, Ringlaan 3, B-1180 Brussels, Belgium

New infrared spectra of 33 Galactic carbon stars from FORCAST on SOFIA reveal strong connections between stellar pulsations and the dust and molecular chemistry in their circumstellar shells. A sharp boundary in overall dust content, which predominantly measures the amount of amorphous carbon, separates the semi-regular and Mira variables, with the semi-regulars showing little dust in their spectra and the Miras showing more. In semi-regulars, the contribution from SiC dust increases rapidly as the overall dust content grows, but in Miras, the SiC dust feature grows weaker as more dust is added. A similar dichotomy is found with the absorption band from CS at $\sim 7.3\ \mu$m, which is generally limited to semi-regular variables. Observationally, these differences make it straightforward to distinguish semiregular and Mira variables spectroscopically without the need for long-term photometric observations or knowledge of their distances. The rapid onset of strong SiC emission in Galactic carbon stars in semi-regulars variables points to a different dust-condensation process before strong pulsations take over. The break in the production of amorphous carbon between semi-regulars and Miras seen in the Galactic sample is also evident in Magellanic carbon stars, linking strong pulsations in carbon stars to the strong mass-loss rates which will end their lives as stars across a wide range of metallicities.

Accepted for publication in The Astrophysical Journal
Available from https://arxiv.org/abs/1910.11401

The role of cluster mass in the multiple populations of Galactic and extragalactic globular clusters

Edoardo P. Lagioia[1], *Antonino P. Milone*[1], *Anna F. Marino*[1,2], *Giacomo Cordoni*[1] *and Marco Tailo*[1]

[1]Dipartimento di Fisica e Astronomia "Galileo Galilei", Università di Padova, Vicolo dell'Osservatorio 3, I-35122, Padua, Italy
[2]Centro di Ateneo di Studi e Attività Spaziali "Giuseppe Colombo" – CISAS, via Venezia 15, I-35131, Padua, Italy

Studies based on *Hubble* Space Telescope (HST) photometry in F275W, F336W, and F438W have shown that the incidence and complexity of multiple populations (MPs) in globular clusters (GCs) depend on cluster mass. This result, however, is based on nearby, low-reddening Galactic GCs, for which we can obtain accurate F275W photometry. In this work, we exploit HST photometry in F336W, F438W, and F814W to characterize MPs in 68 Galactic and extragalactic GCs by using the pseudocolor $C_{F336W,F438W,F814W}$, which is more efficient in terms of observation time than the pseudocolor $C_{F275W,F336W,F438W}$ adopted in previous works. We first analyze the Galactic GCs alone and find that the red giant branch (RGB) color width strongly correlates with [Fe/H]. After removing the dependence from metallicity, we obtain a strong correlation with cluster mass, thus confirming previous findings. We then exploit the RGB width to compare MPs in Galactic and extragalactic GCs. Similarly to Galactic GCs, the RGB width of Magellanic Cloud (MC) GCs correlates with cluster mass after removing the dependence from metallicity. This fact demonstrates that cluster mass is the main factor affecting the properties of MPs. The MC clusters exhibit, on average, narrower RGBs than Galactic GCs with similar mass and metallicity. We suggest that this difference is a signature of stellar mass loss in Galactic GCs. As an alternative, the mass–RGB-width relation would depend on the host galaxy. Finally, we use ground-based photometry to investigate Terzan 7 through the $C_{U,B,I}$ pseudocolor, ground-based analogs of $C_{F336W,F438W,F814W}$ and find that this cluster is consistent with a simple population.

Published in The Astronomical Journal
Available from https://arxiv.org/abs/1909.08439
and from https://doi.org/10.3847/1538-3881/ab45f2

The WISE Extended Source Catalogue (WXSC) I: The 100 largest galaxies

T.H. Jarrett[1], *M.E. Cluver*[2,3], *M.J.I. Brown*[4], *D.A. Dale*[5], *C.W. Tsai*[6] *and F. Masci*[7]

[1]Department of Astronomy, University of Cape Town, Rondebosch, South Africa
[2]Centre for Astrophysics and Supercomputing, Swinburne University of Technology, John Street, Hawthorn 3122, Victoria, Australia
[3]Department of Physics and Astronomy, University of the Western Cape, Robert Sobukwe Road, Bellville 7535, South Africa
[4]School of Physics and Astronomy, Monash University, Clayton 3800, Victoria, Australia
[5]Department of Physics and Astronomy, University of Wyoming, Laramie, WY 82071, USA
[6]Department of Physics and Astronomy, University of California, Los Angeles, Los Angeles, CA, 90095, USA
[7]Infrared Processing and Analysis Center, California Institute of Technology, Pasadena, CA 91125, USA

We present mid-infrared photometry and measured global properties of the 100 largest galaxies in the sky, including the well-studied Magellanic Clouds, Local Group galaxies M 31 and M 33, the Fornax and Virgo Galaxy Cluster giants, and many of the most spectacular Messier objects (e.g., M 51 and M 83). This is the first release of a larger catalog of extended sources as imaged in the mid-infrared, called the WISE Extended Source Catalogue (WXSC). In this study we measure their global attributes, including integrated flux, surface brightness and radial distribution. The largest of the large are the LMC, SMC and the Andromeda Galaxy, which are also the brightest mid-infrared galaxies in the sky. We interrogate the large galaxies using WISE colors, which serve as proxies for four general types of galaxies: bulge-dominated spheroidals, intermediate semi-quiescent disks, star-forming spirals, and AGN-dominated. The colors reveal a tight "sequence" that spans 5 magnitudes in W2−W3 color, ranging from early to late-types, and low to high star-forming activity; we fit the functional form given by: $(W1 - W2) = [0.015 \times e^{\frac{(W2-W3)}{1.38}}] - 0.08$. Departures from this sequence may reveal nuclear, starburst, and merging events. Physical properties and luminosity attributes are computed, notably the diameter, aggregate stellar mass and the dust-obscured star formation activity. To effectively study and compare these galaxy characteristics, we introduce the 'pinwheel' diagram which depicts physical properties

with respect to the median value observed for WISE galaxies in the local universe. Utilized with the WXSC, this diagram will delineate between different kinds of galaxies, identifying those with similar star formation and structural properties. Finally, we present the mid-infrared photometry of the 25 brightest globular clusters in the sky, for which many are also the largest and brightest objects orbiting the Milky Way, including ω Centauri, 47 Tucanæ and a number of famed night-sky targets (e.g., M 13).

Accepted for publication in The Astrophysical Journal Supplement Series
Available from https://arxiv.org/abs/1910.11793
and from https://vislab.idia.ac.za/research

Size diversity of old Large Magellanic Cloud clusters as determined by internal dynamical evolution

F.R. Ferraro[1,2], B. Lanzoni[1,2], E. Dalessandro[2], M. Cadelano[1,2], S. Raso [1,2], A. Mucciarelli[1,2], G. Beccari[3] and C. Pallanca[1,2]

[1]Bologna University, Italy
[2]INAF–OAS, Bologna, Italy
[3]ESO, Germany

The distribution of size as a function of age observed for star clusters in the Large Magellanic Cloud (LMC) is very puzzling: young clusters are all compact, while the oldest systems show both small and large sizes. It is commonly interpreted as due to a population of binary black holes driving a progressive expansion of cluster cores. Here we propose, instead, that it is the natural consequence of the fact that only relatively low-mass clusters have formed in the last $\sim$ 3 Gyr in the LMC and only the most compact systems survived and are observable. The spread in size displayed by the oldest (and most massive) clusters, instead, can be explained in terms of initial conditions and internal dynamical evolution. To quantitatively explore the role of the latter, we selected a sample of five coeval and old LMC clusters with different sizes, and we estimated their dynamical age from the level of central segregation of blue straggler stars (the so-called dynamical clock). Similarly to what found in the Milky Way, we indeed measure different levels of dynamical evolution among the selected coeval clusters, with large-core systems being dynamically younger than those with small size. This behaviour is fully consistent with what expected from internal dynamical evolution processes over timescales mainly set by the structure of each system at formation.

Accepted for publication in Nature Astronomy
Available from https://arxiv.org/abs/1909.02049

Star density profiles of six old star clusters in the Large Magellanic Cloud

B. Lanzoni[1,2], F.R. Ferraro[1,2], E. Dalessandro[2], M. Cadelano[1,2], C. Pallanca[1,2], S. Raso[1,2], A. Mucciarelli[1,2], G. Beccari[3] and P. Focardi[1]

[1]Bologna University, Italy
[2]INAF–OAS, Bologna, Italy
[3]ESO, Germany

We used resolved star counts from *Hubble* Space Telescope images to determine the center of gravity and the projected density profiles of 6 old globular clusters in the Large Magellanic Cloud (LMC), namely NGC 1466, NGC 1841, NGC 1898, NGC 2210, NGC 2257 and Hodge 11. For each system the LMC field contribution was properly taken into account by making use, when needed, of parallel HST observations. The derived values of the center of gravity may differ by several arcseconds (corresponding to more than 1 pc at the distance of the LMC) from previous determinations. The cluster density profiles are all well fit by King models, with structural parameters that may differ from the

literature ones by even factors of two. Similarly to what observed for Galactic globular clusters, the ratio between the effective and the core radius has been found to anti-correlate with the cluster dynamical age.

Accepted for publication in ApJ
Available from https://arxiv.org/abs/1911.01928

Kinematics: a clean diagnostic for separating supernova remnants from H II regions in nearby galaxies

Sean D. Points[1], *Knox S. Long*[2,3,6], *P. Frank Winkler*[4,6] *and William P. Blair*[5,6]

[1]National Optical Astronomy Observatory/Cerro Tololo Inter-American Observatory, Chile
[2]Space Telescope Science Institute, USA
[3]Eureka Scientific, Inc., USA
[4]Middlebury College, USA
[5]Johns Hopkins University, USA
[6]Visiting Astronomer, Cerro Tololo Inter-American Observatory, Chile

Many more supernova remnants (SNRs) are now known in external galaxies than in the Milky Way. Most of these SNRs have been identified using narrowband imaging, separating SNRs from H II regions on the basis of [S II]:Hα ratios that are elevated compared to H II regions. However, the boundary between SNRs and H II regions is not always distinct, especially at low surface brightness. Here we explore velocity structure as a possible criterion for separating SNRs from H II regions, using a sample of well-studied SNRs in the Large Magellanic Cloud as well as a small number of SNRs in the galaxy M 83. We find, perhaps not surprisingly, that even at large diameters, SNRs exhibit velocity broadening sufficient to readily distinguish them from H II regions. We thus suggest that the purity of most extragalactic samples would be greatly improved through spectroscopic observations with a velocity resolution of order 50 km s^{-1}.

Accepted for publication in ApJ
Available from https://arxiv.org/abs/1910.07007

Physical conditions in the gas phases of the giant H II region LMC N11: II. Origin of [C II] and fraction of CO-dark gas

V. Lebouteiller[1,2], *D. Cormier*[1], *S.C. Madden*[1], *M. Galametz*[1], *S. Hony*[3], *F. Galliano*[1], *M. Chevance*[4], *M.-Y. Lee*[5,6], *J. Braine*[7], *F.L. Polles*[8], *M. Angel Requeña-Torres*[9], *R. Indebetouw*[10,11], *A. Hughes*[12] *and N. Abel*[13]

[1]AIM, CEA, CNRS, Université Paris–Saclay, Université Paris Diderot, Sorbonne Paris Cité, F-91191 Gif-sur-Yvette, France
[2]Department of Physics and Astronomy, University of North Carolina, 290 Phillips Hall CB 3255, Chapel Hill, NC 27599, USA
[3]Institut für theoretische Astrophysik, Zentrum für Astronomie der Universität Heidelberg, Albert-Überle Str.2, 69120 Heidelberg, Germany
[4]Astronomisches Rechen-Institut, Zentrum für Astronomie der Universität Heidelberg, Mönchhofstraße 12-14, 69120 Heidelberg, Germany
[5]Korea Astronomy and Space Science Institute, 776 Daedeokdae-ro, 34055 Daejeon, South Korea
[6]Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany
[7]Laboratoire d'Astrophysique de Bordeaux, Univ. Bordeaux, CNRS, B18N, allée Geoffroy Saint-Hilaire, F-33615 Pessac, France
[8]LERMA, Observatoire de Paris, PSL Research Univ., CNRS, Sorbonne Univ., 75014 Paris, France
[9]Department of Astronomy, University of Maryland, College Park, ND, 20742-2421, USA
[10]Department of Astronomy, University of Virginia, Charlottesville, VA 22904, USA
[11]National Radio Astronomy Observatory, 520 Edgemont Road, Charlottesville, VA 22903, USA
[12]IRAP, Université de Toulouse, CNRS, UPS, CNES, 31400, Toulouse, France
[13]University of Cincinnati, Clermont College, 4200 Clermont College Drive, Batavia, OH 45103, USA

Context: The ambiguous origin of the [C II] 158μm line in the interstellar medium complicates its use for diagnostics

concerning the star-formation rate and physical conditions in photodissociation regions.
Aims: We investigate the origin of [C II] in order to measure the total molecular gas content, the fraction of CO-dark H_2 gas, and how these parameters are impacted by environmental effects such as stellar feedback.
Methods: We observed the giant H II region N11 in the Large Magellanic Cloud with SOFIA/GREAT. The [C II] line is resolved in velocity and compared to H I and CO, using a Bayesian approach to decompose the line profiles. A simple model accounting for collisions in the neutral atomic and molecular gas was used in order to derive the H_2 column density traced by C^+.
Results: The profile of [C II] most closely resembles that of CO, but the integrated [C II] line width lies between that of CO and that of H I. Using various methods, we find that [C II] mostly originates from the neutral gas. We show that [C II] mostly traces the CO-dark H_2 gas but there is evidence of a weak contribution from neutral atomic gas preferentially in the faintest components (as opposed to components with low [C II]/CO or low CO column density). Most of the molecular gas is CO-dark. The CO-dark H_2 gas, whose density is typically a few 100s cm^{-3} and thermal pressure in the range $10^{3.5-5}$ K cm^{-3}, is not always in pressure equilibrium with the neutral atomic gas. The fraction of CO-dark H_2 gas decreases with increasing CO column density, with a slope that seems to depend on the impinging radiation field from nearby massive stars. Finally we extend previous measurements of the photoelectric-effect heating efficiency, which we find is constant across regions probed with *Herschel*, with [C II] and [O I] being the main coolants in faint and diffuse, and bright and compact regions, respectively, and with polycyclic aromatic hydrocarbon emission tracing the CO-dark H_2 gas heating where [C II] and [O I] emit.
Conclusions: We present an innovative spectral decomposition method that allows statistical trends to be derived for the molecular gas content using CO, [C II], and H I profiles. Our study highlights the importance of velocity-resolved photodissociation region (PDR) diagnostics and higher spatial resolution for H I observations as future steps.

Accepted for publication in A&A
Available from https://arxiv.org/abs/1911.03280

First detection of [^{13}C II] in the Large Magellanic Cloud

Yoko Okada[1], Ronan Higgins[1], Volker Ossenkopf-Okada[1], Cristian Guevara[1], Jürgen Stutzki[1] and Marc Mertens[1]

[1]I. Physikalisches Institut der Universität zu Köln, Germany

Context: [^{13}C II] observations in several Galactic sources show that the fine-structure [^{12}C II] emission is often optically thick (the optical depths around 1 to a few).
Aims: Our goal was to test whether this also affects the [^{12}C II] emission from nearby galaxies like the Large Magellanic Cloud (LMC).
Methods: We observed three star-forming regions in the LMC with upGREAT on board SOFIA at the frequency of the [C II] line. The 4-GHz bandwidth covers all three hyperfine lines of [^{13}C II] simultaneously. For the analysis, we combined the [^{13}C II] $F = 1$–0 and $F = 1$–1 hyperfine components as they do not overlap with the [^{12}C II] line in velocity.
Results: Three positions in N159 and N160 show an enhancement of [^{13}C II] compared to the abundance-ratio-scaled [^{12}C II] profile. This is likely due to the [^{12}C II] line being optically thick, supported by the fact that the [^{13}C II] line profile is narrower than [^{12}C II], the enhancement varies with velocity, and the peak velocity of [^{13}C II] matches the [O I] 63-μm self-absorption. The [^{12}C II] line profile is broader than expected from a simple optical depth broadening of the [^{13}C II] line, supporting the scenario of several PDR components in one beam having varying [^{12}C II] optical depths. The derived [^{12}C II] optical depth at three positions (beam size of 14″, corresponding to 3.4 pc) is 1–3, which is similar to values observed in several Galactic sources shown in previous studies. If this also applies to distant galaxies, the [C II] intensity will be underestimated by a factor of approximately 2.

Published in A&A Letters
Available from https://arxiv.org/abs/1910.12693

Search for surviving companions of progenitors of young LMC Type Ia supernova remnants

Chuan-Jui Li[1,2], *Wolfgang E. Kerzendorf*[3], *You-Hua Chu*[2,4], *Ting-Wan Chen*[5], *Tuan Do*[6], *Robert A. Gruendl*[4], *Abigail Holmes*[4], *Ryoko Ishioka*[2], *Bruno Leibundgut*[3], *Kuo-Chuan Pan*[7], *Paul M. Ricker*[4] *and Daniel Weisz*[8]

[1]Graduate Institute of Astrophysics, National Taiwan University, Taipei 10617, Taiwan

[2]Institute of Astronomy and Astrophysics, Academia Sinica, P.O. Box 23-141, Taipei 10617, Taiwan

[3]European Southern Observatory, Karl-Schwarzschild-Straße 2, 85748 Garching bei München, Germany

[4]Department of Astronomy, University of Illinois at Urbana–Champaign, 1002 West Green Street, Urbana,IL 61801, U.S.A.

[5]Max-Planck-Institut für Extraterrestrische Physik, Gießenbachstraße 1, 85748, Garching bei München, Germany

[6]Physics and Astronomy Department, University of California, Los Angeles, CA 90095-1547, USA

[7]Department of Physics and Institute of Astronomy, National Tsing Hua University, Hsinchu 30013, Taiwan

[8]Department of Astronomy, University of California, 501 Campbell Hall #3411, Berkeley, CA 94720-3411, U.S.A.

We have used two methods to search for surviving companions of Type Ia supernova progenitors in three Balmer-dominated supernova remnants (SNRs) in the Large Magellanic Cloud: 0519−69.0, 0505−67.9 (DEM L71), and 0548−70.4. In the first method, we use the *Hubble* Space Telescope photometric measurements of stars to construct color–magnitude diagrams (CMDs), and compare positions of stars in the CMDs with those expected from theoretical post-impact evolution of surviving main sequence or helium star companions. No obvious candidates of surviving companion are identified in this photometric search. Future models for surviving red giant companions or with different explosion mechanisms are needed for thorough comparisons with these observations in order to make more definitive conclusions. In the second method, we use Multi-Unit Spectroscopic Explorer (MUSE) observations of 0519−69.0 and DEM L71 to carry out spectroscopic analyses of stars in order to use large peculiar radial velocities as diagnostics of surviving companions. We find a star in 0519−69.0 and a star in DEM L71 moving at radial velocities of 182 ± 0 km s^{-1} and 213 ± 0 km s^{-1}, more than 2.5σ from the mean radial velocity of the underlying stellar population, 264 km s^{-1} and 270 km s^{-1}, respectively. These stars need higher-quality spectra to investigate their abundances and rotation velocities to determine whether they are indeed surviving companions of the SN progenitors.

Accepted for publication in The Astrophysical Journal

Available from https://arxiv.org/abs/1910.01093

The 3D kinematics of gas in the Small Magellanic Cloud

Claire E. Murray[1], *J.E.G. Peek* [2,1], *Enrico M. Di Teodoro*[3], *N.M. McClure-Griffiths*[3], *John M. Dickey*[4] *and Helga Denes*[5]

[1]Johns Hopkins University, USA

[2]Space Telescope Science Institute, USA

[3]Australian National University, Australia

[4]University of Tasmania, Australia

[5]ASTRON, Netherlands Institute for Radio Astronomy, The Netherlands

We investigate the kinematics of neutral gas in the Small Magellanic Cloud (SMC) and test the hypothesis that it is rotating in a disk. To trace the 3D motions of the neutral gas distribution, we identify a sample of young, massive stars embedded within it. These are stars with radial velocity measurements from spectroscopic surveys and proper motion measurements from Gaia, whose radial velocities match with dominant H I components. We compare the observed radial and tangential velocities of these stars with predictions from the state-of-the-art rotating disk model based on high-resolution 21 cm observations of the SMC from the Australian Square Kilometer Array Pathfinder telescope. We find that the observed kinematics of gas-tracing stars are inconsistent with disk rotation. We conclude that the kinematics of gas in the SMC are more complex than can be inferred from the integrated radial velocity field. As a result of violent tidal interactions with the LMC, non-rotational motions are prevalent throughout the SMC, and it is likely composed of distinct sub-structures overlapping along the line of sight.

Accepted for publication in ApJ

Available from https://arxiv.org/abs/1910.11283

The VMC Survey – XXXV. Model fitting of LMC Cepheid light curves

Fabio Ragosta[1,2,3], *Marcella Marconi*[3], *Roberto Molinaro*[3], *Vincenzo Ripepi*[3], *Maria Rosa L. Cioni*[4], *Maria Ida Moretti*[3], *Martin A.T. Groenewegen*[5], *Samyaday ChoudHury*[6,7], *Richard de Grijs*[6,7,8], *Jacco Th. van Loon*[9], *Joana M. Oliveira* [9], *Valentin D. Ivanov* [10] *and Carlos Gonzalez-Fernandez*[11]

[1]Dipartimento di Fisica, Via Cinthia, I-80126 Fuorigrotta, Naples, Italy

[2]INFN sez. di Napoli Compl. Univ. di Monte S. Angelo, Edificio G, Via Cinthia, I-80126, Napoli, Italy

[3]INAF–Osservatorio Astronomico di Capodimonte, via Moiariello 16, I-80131, Naples, Italy

[4]Leibniz-Institut für Astrophysik Potsdam, An der Sternwarte 16, D-14482 Potsdam, Germany

[5]Koninklijke Sterrenwacht van België, Ringlaan 3, B1180 Brussels, Belgium

[6]Department of Physics and Astronomy, Macquarie University, Balaclava Road, Sydney, NSW 2109, Australia

[7]Research Centre for Astronomy, Astrophysics and Astrophotonics, Macquarie University, Balaclava Road, Sydney, NSW 2109, Australia

[8]International Space Science Institute–Beijing, 1 Nanertiao, Zhongguancun, Hai Dian District, Beijing 100190, China

[9]Lennard-Jones Laboratories, School of Chemical and Physical Sciences, Keele University, ST5 5BG, UK

[10]European Southern Observatory, Karl-Schwarzschild-Str. 2, D-85748 Garching bei München, Germany

[11]Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK

We present the results of the light curve model fitting technique applied to optical and near-infrared photometric data for a sample of 18 Classical Cepheids (11 fundamentals and 7 first overtones) in the Large Magellanic Cloud (LMC). We use optical photometry from the OGLE III database and near-infrared photometry obtained by the European Southern Observatory public survey "VISTA near-infrared survey of the Magellanic Clouds system". Iso-periodic nonlinear convective model sequences have been computed for each selected Cepheid in order to reproduce the multi-filter light curve amplitudes and shape details. The inferred individual distances provide an intrinsic weighted mean value for the LMC distance modulus of $\mu_0 = 18.56$ mag with a standard deviation of 0.13 mag. We derive also the Period–Radius, the Period–Luminosity and the Period–Wesenheit relations that are consistent with similar relations in the literature. The intrinsic masses and luminosities of the best-fitting models show that all the investigated pulsators are brighter than the predictions of the canonical evolutionary mass–luminosity relation, suggesting a significant efficiency of non-canonical phenomena, such as overshooting, mass loss and/or rotation.

Published in MNRAS
Available from https://arxiv.org/abs/1910.05052
and from https://ui.adsabs.harvard.edu/abs/2019MNRAS.490.4975R/abstract

Multiple populations in globular clusters and their parent galaxies

A.P. Milone[1], *A.F. Marino*[1,2], *G.S. Da Costa*[3], *E.P. Lagioia*[1], *F. D'Antona*[4], *P. Goudfrooij*[5], *H. Jerjen*[3], *D. Massari*[6,8], *A. Renzini*[7], *D. Yong*[3], *H. Boumgardt*[9], *E. Dondoglio*[1], *C. Li*[10], *M. Tailo*[1], *R. Asa'd*[11] *and E.M. Ventura*[1]

[1]Dipartimento di Fisica e Astronomia "Galileo Galilei", Univ. di Padova, Vicolo dellOsservatorio 3, Padova, I-35122, Italy

[2]Centro di Ateneo di Studi e Attività Spaziali, "Giuseppe Colombo" – CISAS, Via Venezia 15, Padova, I-35131, Italy

[3]Research School of Astronomy & Astrophysics, Australian National University, Mt. Stromlo Observatory, via Cotter Rd., Weston, ACT 2611, Australia

[4]Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Roma, Via Frascati 33, I-00040, Monteporzio Catone, Roma, Italy

[5]Space Telescope Science Institute, 3800 San Martin Drive, Baltimore, MD 21218, USA

[6]Kapteyn Astronomical Institute, University of Groningen, NL-9747 AD Groningen, The Netherlands

[7]Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Padova, Vicolo dell'Osservatorio 5, Padova, I-35122, Italy

[8]Dipartimento di Fisica e Astronomia, Università degli Studi di Bologna, Via Gobetti 93/2, I-40129 Bologna, Italy

[9]School of Mathematics and Physics, The University of Queensland, St. Lucia, QLD 4072, Australia

[10]School of Physics and Astronomy, Sun Yat-sen University, Zhuhai 519082, China

[11]American University of Sharjah, Physics Department, P.O. Box 26666, Sharjah, UAE

The 'chromosome map' diagram (ChM) proved a successful tool to identify and characterize multiple populations (MPs) in 59 Galactic Globular Clusters (GCs). Here, we construct ChMs for 11 GCs of both Magellanic Clouds

(MCs) and with different ages to compare MPs in Galactic and extra-Galactic environments, and explore whether this phenomenon is universal through 'place' and 'time'. MPs are detected in five clusters. The fractions of 1G stars, ranging from $\sim 50\%$ to $> 80\%$, are significantly higher than those observed in Galactic GCs with similar present-day masses. By considering both Galactic and MC clusters, the fraction of 1G stars exhibits: (i) a strong anti-correlation with the present-day mass, and (ii) with the present-day mass of 2G stars; (iii) a mild anti-correlation with 1G present-day mass. All Galactic clusters without MPs have initial masses smaller than $\sim 1.5 \times 10^5$ M$_\odot$ but a mass threshold governing the occurrence of MPs seems challenged by massive simple-population MC GCs; (iv) Milky Way clusters with large perigalactic distances typically host larger fractions of 1G stars, but the difference disappears when we use initial cluster masses. These facts are consistent with a scenario where the stars lost by GCs mostly belong to the 1G. By exploiting recent work based on Gaia, half of the known Type II GCs appear clustered in a distinct region of the integral of motions space, thus suggesting a common progenitor galaxy. Except for these Type II GCs, we do not find any significant difference in the MPs between clusters associated with different progenitors.

Accepted for publication in MNRAS
Available from https://arxiv.org/abs/1910.09683

The young massive SMC cluster NGC 330 seen by MUSE. I. Observations and stellar content

J. Bodensteiner[1], H. Sana[1], L. Mahy[1], L.R. Patrick[2,3], A. de Koter[1,4], S.E. de Mink[5,4], C.J. Evans[6], Y. Götberg[7], N. Langer[8], D.J. Lennon[2], F.R.N. Schneider[9] and F. Tramper[10]

[1]Instituut voor Sterrenkunde, K.U. Leuven, Celestijnenlaan 200D, 3001 Leuven, Belgium
[2]Instituto de Astrofísica de Canarias, E-38205 La Laguna, Tenerife, Spain
[3]Universidad de La Laguna, Dpto. Astrofísica, E-38206 La Laguna, Tenerife, Spain
[4]Astronomical Institute Anton Pannekoek, Amsterdam University, Science Park 904, 1098 XH, Amsterdam, The Netherlands
[5]Center for Astrophysics, Harvard & Smithsonian, 60 Garden Street, Cambridge, MA 02138, USA
[6]UK Astronomy Technology Centre, Royal Observatory, Blackford Hill, Edinburgh, EH9 3HJ, UK
[7]The observatories of the Carnegie institution for science, 813 Santa Barbara St., Pasadena, CA 91101, USA
[8]Argelander-Institut für Astronomie, Universität Bonn, Auf dem Hügel 71, 53121 Bonn, Germany
[9]Heidelberger Institut für Theoretische Studien, Schloß-Wolfsbrunnenweg 35, 69118 Heidelberg, Germany
[10]Institute for Astronomy, Astrophysics, Space Applications & Remote Sensing, National Observatory of Athens, P. Penteli, 15236 Athens, Greece

A majority of massive stars are part of binary systems, a large fraction of which will inevitably interact during their lives. Binary-interaction products (BiPs), i.e. stars affected by such interaction, are expected to be commonly present in stellar populations. BiPs are thus a crucial ingredient in the understanding of stellar evolution. We aim to identify and characterize a statistically significant sample of BiPs by studying clusters of 10–40 Myr, an age at which binary population models predict the abundance of BiPs to be highest. One example of such a cluster is NGC 330 in the Small Magellanic Cloud. Using MUSE WFM-AO observations of NGC 330, we resolve the dense cluster core for the first time and are able to extract spectra of its entire massive star population. We develop an automated spectral classification scheme based on the equivalent widths of spectral lines in the red part of the spectrum. We characterize the massive star content of the core of NGC 330 which contains more than 200 B stars, 2 O stars, 6 A-type supergiants and 11 red supergiants. We find a lower limit on the Be star fraction of $32 \pm 3\%$ in the whole sample. It increases to at least $46 \pm 10\%$ when only considering stars brighter than $V = 17$ mag. We estimate an age of the cluster core between 35 and 40 Myr and a total cluster mass of $88^{+17}_{-18} \times 10^3$ M$_\odot$. We find that the population in the cluster core is different than the population in the outskirts: while the stellar content in the core appears to be older than the stars in the outskirts, the Be star fraction and the observed binary fraction are significantly higher. Furthermore, we detect several BiP candidates that will be subject of future studies.

Accepted for publication in A&A
Available from https://arxiv.org/abs/1911.03477

High angular resolution ALMA images of dust and molecules in the SN 1987A ejecta

Phil Cigan[1], *Mikako Matsuura*[1], *Haley L. Gomez*[1], *Remy Indebetouw*[2], *Fran Abellán*[3], *Michael Gabler*[4], *Anita Richards*[5], *Dennis Alp*[6], *Timothy A. Davis*[1], *Hans-Thomas Janka*[4], *Jason Spyromilio*[7], *M.J. Barlow*[8], *David Burrows*[9], *Eli Dwek*[10], *Claes Fransson*[11], *Bryan Gaensler*[12], *Josefin Larsson*[6], *P. Bouchet*[13,14], *Peter Lundqvist*[11], *J.M. Marcaide*[3], *C.-Y. Ng*[15], *Sangwook Park*[16], *Pat Roche*[17], *Jacco Th. van Loon*[18], *J.C. Wheeler*[19] and *Giovanna Zanardo*[20]

[1]School of Physics and Astronomy, Cardiff University, Cardiff CF24 3AA, UK
[2]Department of Astronomy, University of Virginia, P.O. Box 400325, Charlottesville, VA 22904, USA
[3]Departamento de Astronomía y Astrofísica, Universidad de Valencia, C/Dr. Moliner 50, E-46100 Burjassot, Spain
[4]Max-Planck-Institut für Astrophysik, Karl-Schwarzchild-Straße 1, D-85748 Garching bei München, Germany
[5]JBCA, School of Physics and Astronomy, University of Manchester, Manchester M13 9PL, UK
[6]Department of Physics, KTH Royal Institute of Technology, The Oskar Klein Centre, AlbaNova, SE-106 91 Stockholm, Sweden
[7]European Southern Observatory, Karl-Schwarzschild-Straße 2, 85748 Garching bei München, Germany
[8]Department of Physics and Astronomy, University College London, Gower Street, London, WC1E 6BT, UK
[9]Department of Astronomy and Astrophysics, Pennsylvania State University, University Park, PA 16802, USA
[10]Observational Cosmology Lab., Code 665, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA
[11]Department of Astronomy, Stockholm University, The Oskar Klein Centre, AlbaNova, SE-106 91 Stockholm, Sweden
[12]Dunlap Institute for Astronomy and Astrophysics, 50 St. George Street, Toronto, ON M5S 3H4, Canada
[13]DRF/IRFU/DAp, CEA-Saclay, F-91191 Gif-sur-Yvette, France
[14]NRS/AIM, Université Paris Diderot, F-9119, Gif-sur-Yvette, France
[15]Department of Physics, The University of Hong Kong, Pokfulam Road, Hong Kong, China
[16]Department of Physics, University of Texas at Arlington, Arlington, TX 76019, USA
[17]Astrophysics, Department of Physics, University of Oxford, DWB, Keble Road, Oxford OX1 3RH, UK
[18]Lennard-Jones Laboratories, Keele University, ST5 5BG, UK
[19]Department of Astronomy, The University of Texas at Austin, 1 University Station C1400, Austin, TX 78712-0259, USA
[20]International Centre for Radio Astronomy Research, M468, University of Western Australia, Crawley, WA 6009, Australia

We present high angular resolution (~ 80 mas) ALMA continuum images of the SN 1987A system, together with CO $J = 2 \to 1$, $J = 6 \to 5$, and SiO $J = 5 \to 4$ to $J = 7 \to 6$ images, which clearly resolve the ejecta (dust continuum and molecules) and ring (synchrotron continuum) components. Dust in the ejecta is asymmetric and clumpy, and overall the dust fills the spatial void seen in Hα images, filling that region with material from heavier elements. The dust clumps generally fill the space where CO $J = 6 \to 5$ is fainter, tentatively indicating that these dust clumps and CO are locationally and chemically linked. In these regions, carbonaceous dust grains might have formed after dissociation of CO. The dust grains would have cooled by radiation, and subsequent collisions of grains with gas would also cool the gas, suppressing the CO $J = 6 \to 5$ intensity. The data show a dust peak spatially coincident with the molecular hole seen in previous ALMA CO $J = 2 \to 1$ and SiO $J = 5 \to 4$ images. That dust peak, combined with CO and SiO line spectra, suggests that the dust and gas could be at higher temperatures than the surrounding material, though higher density cannot be totally excluded. One of the possibilities is that a compact source provides additional heat at that location. Fits to the far-infrared–millimeter spectral energy distribution give ejecta dust temperatures of 18–23 K. We revise the ejecta dust mass to $M_{\rm dust} = 0.2$–0.4 M$_\odot$ for carbon or silicate grains, or a maximum of < 0.7 M$_\odot$ for a mixture of grain species, using the predicted nucleosynthesis yields as an upper limit.

Accepted for publication in ApJ
Available from https://arxiv.org/abs/1910.02960
and from https://iopscience.iop.org/article/10.3847/1538-4357/ab4b46

The effect of our local motion on the Sandage–Loeb test of the cosmic expansion

Takuya Inoue[1,2,3], *Eiichiro Komatsu*[3,4], *Wako Aoki*[5,6], *Takeshi Chiba*[7], *Toru Misawa*[8] *and Tomonori Usuda*[5,6]

[1]Department of Mechanical Engineering, Graduate School of Science and Engineering, Doshisha University, 1-3 Tatara Miyakodani, Kyotanabe-shi, Kyoto 610-0394, Japan

[2]Ecole Centrale de Lille, ECLille, Cité Scientifique, F-59650 Villeneuve d'Ascq, France

[3]Max-Planck-Institut für Astrophysik, Karl-Schwarzschild Str. 1, D-85741 Garching bei München, Germany

[4]Kavli Institute for the Physics and Mathematics of the Universe, Todai Institutes for Advanced Study, the University of Tokyo, Kashiwa, 277-8583 Japan

[5]National Astronomical Observatory of Japan (NAOJ), 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan

[6]Department of Astronomical Science, School of Physical Sciences, The Graduate University for Advanced Studies, SOKENDAI, 2 -21-1 Osawa, Mitaka, Tokyo 181-8588, Japan

[7]Department of Physics, College of Humanities and Sciences, Nihon University, Tokyo 156-8550, Japan

[8]School of General Education, Shinshu University, 3-1-1 Asahi, Matsumoto, Nagano 390-8621, Japan

Redshifts of an astronomical body measured at multiple epochs (e.g., separated by 10 years) are different due to the cosmic expansion. This so-called Sandage–Loeb test offers a direct measurement of the expansion rate of the Universe. However, acceleration in the motion of Solar System with respect to the cosmic microwave background also changes redshifts measured at multiple epochs. If not accounted for, it yields a biased cosmological inference. To address this, we calculate the acceleration of Solar System with respect to the Local Group of galaxies to quantify the change in the measured redshift due to local motion. Our study is motivated by the recent determination of the mass of Large Magellanic Cloud (LMC), which indicates a significant fraction of the Milky Way mass. We find that the acceleration towards the Galactic Center dominates, which gives a redshift change of 7 cm s^{-1} in 10 years, while the accelerations due to LMC and M 31 cannot be ignored depending on lines of sight. We create all-sky maps of the expected change in redshift and the corresponding uncertainty, which can be used to correct for this effect.

Accepted for publication in Publications of the Astronomical Society of Japan
Available from https://arxiv.org/abs/1911.01467

Monitoring the superorbital period variation and spin period evolution of SMC X-1

Chin-Ping Hu[1,5], *Tatehiro Mihara*[2], *Mutsumi Sugizaki*[3], *Yoshihiro Ueda*[1] *and Teruaki Enoto*[1,4]

[1]Department of Astronomy, Kyoto University, Kitashirakawa-Oiwake-cho, Sakyo-ku, Kyoto 606-8502, Japan

[2]MAXI team, Institute of Physical and Chemical Research (RIKEN), 2-1, Hirosawa, Wako, Saitama 351-0198, Japan

[3]Department of Physics, Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro-ku, Tokyo 152-8551, Japan

[4]The Hakubi Center for Advanced Research, Kyoto University, Kitashirakawa-Oiwake-cho, Sakyo-ku, Kyoto 606-8502, Japan

[5]JSPS International Research Fellow

The X-ray pulsar SMC X-1 shows a superorbital modulation with an unstable cycle length in the X-ray band. We present its timing behaviors, including the spin, orbital, and superorbital modulations, beyond the end of the *Rossi* X-ray Timing Explorer mission. The time-frequency maps derived by the wavelet Z-transform and the Hilbert–Huang transform suggest that a new superorbital period excursion event occurred in ∼MJD 57100 (2015 March). This indicates the excursion is recurrent and probably (quasi)periodic. The hardness ratio obtained with the Monitor of All-sky X-ray Image (MAXI) suggests increased absorption during the transition from the high to the low state in the superorbital cycle. Compared to the regular epochs, the superorbital profile during the excursion epochs has a shallower and narrower valley, likely caused by a flatter warp. By tracking the spin period evolution with the MAXI Gas Slit Camera in 2–20 keV, we derive an averaged spin-up rate of $\dot{\nu} = 2.515(3) \times 10^{-11}$ s^{-2} during the period between MJD 55141 (2009 November) and 58526 (2019 February). We obtain no positive correlation between the spin frequency residual and the superorbital frequency, but a torque change accompanying the superorbital period excursion is possible. We suggest that the accretion torque on the neutron star could be changed by various mechanisms, including the change of mass accretion rate and the warp angle. We update the value of the orbital

decay as $\dot{P}_{\rm orb}/P_{\rm orb} = -3.380(6) \times 10^{-6}$ yr^{-1}. Finally, we reconfirm the detection of the superorbital modulation in the optical band and its coherence in phase with the X-ray modulation.

Published in The Astrophysical Journal
Available from https://arxiv.org/abs/1910.00200
and from https://iopscience.iop.org/article/10.3847/1538-4357/ab48e4

Isochrone-cloud fitting of the extended main-sequence turn-off of young clusters

Cole Johnston[1], Conny Aerts[1,2,3], May Gade Pedersen[1] and Nathaniel Bastian[4]

[1]Instituut voor Sterrenkunde, K.U. Leuven, Celestijnenlaan 200D, 3001 Leuven, Belgium
[2]Department of Astrophysics, IMAPP, Radboud University Nijmegen, P.O. Box 9010, 6500 GL Nijmegen, The Netherlands
[3]Max Planck Institute for Astronomy, Königstuhl 17, 69117 Heidelberg, Germany
[4]Astrophysics Research Institute, Liverpool John Moores University, 146 Brownlow Hill, Liverpool L3 5RF, UK

Context: Extended main-sequence turn-offs (eMSTOs) are a commonly observed property of young clusters. A global theoretical interpretation for eMSTOs is still lacking, but stellar rotation is considered a necessary ingredient to explain eMSTOs.
Aims: We aim to assess the importance of core-boundary and envelope mixing in stellar interiors for the interpretation of eMSTOs in terms of one coeval population.
Methods: We constructed isochrone-clouds based on interior mixing profiles of stars with a convective core calibrated from asteroseismology of isolated galactic field stars. We fitted these isochrone-clouds to the measured eMSTO to estimate the age and core mass of the stars in the two young clusters NGC 1850 and NGC 884, assuming one coeval population and by fixing the metallicity to the one measured from spectroscopy. We assessed the correlations between the interior mixing properties of the cluster members and their rotational and pulsational properties.
Results: We find that stellar models based on asteroseismically-calibrated interior mixing profiles lead to enhanced core masses of eMSTO stars. Additionally, these models can explain a significant fraction of the observed eMSTOs of the two considered clusters in terms of one coeval population of stars, which have similar ages to those in the literature, given the large uncertainties. The rotational and pulsational properties of the stars in NGC 884 are not sufficiently well known to perform asteroseismic modelling as it is achieved for field stars from space photometry. The stars in NGC 884 for which we have $v \sin i$ and a few pulsation frequencies show no correlation between these properties and the core masses of the stars that set the cluster age.
Conclusions: Future cluster space asteroseismology may allow for the interpretation of the core masses in terms of the physical processes that cause them, based on the modelling of the interior mixing profiles for the individual member stars with suitable identified modes.

Accepted for publication in Astronomy & Astrophysics
Available from https://arxiv.org/abs/1910.00591

Young stars raining through the Galactic Halo: the nature and orbit of Price-Whelan 1

Michele Bellazzini[1], Rodrigo A. Ibata[2], Nicolas Martin[2,3], Khyati Malhan[4], Antonino Marasco[5,6] and Benoit Famaey[2]

[1]INAF – Osservatorio di Astrofisica e Scienza dello Spazio, via Gobetti 93/3, 40129 Bologna, Italy
[2]Observatoire Astronomique de Strasbourg, Université de Strasbourg, CNRS UMR7550, Strasbourg, France
[3]Max-Planck-Institut für Astronomie, Heidelberg, Germany
[4]The Oskar Klein Centre for Cosmoparticle Physics, Department of Physics, Stockholm University, AlbaNova, Stockholm, Sweden
[5]Kapteyn Astronomical Institute, University of Groningen, P.O. Box 800, 9700 AV Groningen, The Netherlands
[6]INAF – Osservatorio Astrofisco di Arcetri, largo E. Fermi 5, 50127 Firenze, Italy

We present radial velocities for five member stars of the recently discovered young (age = 100–150 Myr) stellar system

Price-Whelan 1 (PW 1), that is located far away in the Galactic Halo ($D \sim 29$ kpc, $Z \sim 15$ kpc), and that is probably associated to the Leading Arm (LA) of the Magellanic Stream. We measure the systemic radial velocity of PW 1, $v_{\rm r} = 275 \pm 10$ km s^{-1}, significantly larger than the velocity of the LA gas in the same direction. We re-discuss the main properties and the origin of this system in the light of these new observations, computing the orbit of the system and comparing its velocity with that of the H I in its surroundings. We show that the bulk of the gas at the velocity of the stars is more than 10° (5 kpc) away from PW 1 and the velocity difference between the gas and the stars become larger as gas closer to the stars is considered. We discuss the possibilities that (a) the parent gas cloud was dissolved by the interaction with the Galactic gas, and (b) that the parent cloud is the high velocity cloud HVC 287.5+22.5+240, lagging behind the stellar system by ~ 25 km s^{-1} and $\sim 10°$. This HVC, that is part of the LA, has metallicity similar to PW 1, displays a strong magnetic field that should help to stabilise the cloud agains ram pressure, and shows traces of molecular hydrogen. We also show that the system is constituted of three distinct pieces that do not differ only by position in the sky but also by stellar content.

Published in MNRAS
Available from https://arxiv.org/abs/1910.04899
and from https://academic.oup.com/mnras/article/490/2/2588/5581515

Towards early-type eclipsing binaries as extragalactic milestones: I. Physical parameters of OGLE-LMC-ECL-22270 and OGLE-LMC-ECL-06782

Mónica Taormina[1], *G. Pietrzyński*[1], *B. Pilecki*[1], *R.-P. Kudritzki*[2,3], *I.B. Thompson*[4], *D. Graczyk*[5], *W. Gieren*[6], *N. Nardetto*[7], *M. Górski*[6], *K. Suchomska*[1], *B. Zgirski*[1], *P. Wielgórski*[1], *P. Karczmarek*[6] *and W. Narloch*[6]

[1]Centrum Astronomiczne im. Mikołaja Kopernika PAN, Bartycka 18, 00-716 Warsaw, Poland
[2]Institute for Astronomy, University of Hawai'i at Manoa, 2680 Woodlawn Drive, Honolulu, HI 96822, USA
[3]LMU München, Universitätssternwarte, Scheinerstr. 1, 81679 München, Germany
[4]Carnegie Observatories, 813 Santa Barbara Street, Pasadena, CA 91101-1292, USA
[5]Centrum Astronomiczne im. Mikołaja Kopernika PAN, Rabiańska 8, 87-100 Toruń, Poland
[6]Universidad de Concepción, Departamento de Astronomía, Casilla 160-C, Concepción, Chile
[7]Laboratoire Lagrange, UMR7293, Université de Nice Sophia–Antipolis, CNRS, Observatoire de la Côte d'Azur, Nice, France

In this first paper of the series we describe our project to calibrate the distance determination method based on early-type binary systems. The final objective is to measure accurate, geometrical distances to galaxies beyond the Magellanic Clouds with a precision of 2%. We start with the analysis of two early-type systems for which we have collected all the required spectroscopic and photometric data. Apart from catalog publications, these systems have not been studied yet, and this is the first time the modeling of light and radial velocity curves is performed for them. From the analysis we obtained precise physical parameters of the components, including the masses measured with a precision of 0.6–1% and radii measured with a precision of 0.4–3%. For one system we determined the (V–K) color and estimated the distance using the bolometric flux scaling method ($DM = 18.47 \pm 0.15$ mag), which agrees well with our accurate determination of the distance to the Large Magellanic Cloud from late-type giants. For the same system we determined the surface brightness of individual stars using our model, and checked that it is consistent with a recent surface brightness–color relation. We compared our results with evolution theory models of massive stars and found they agree in general; however, models with higher overshooting values give more consistent results. The age of the system was estimated to range from 11.7 to 13.8 Myr, depending on the model.

Accepted for publication in The Astrophysical Journal
Available from https://arxiv.org/abs/1910.08111

Radio emission from interstellar shocks: Young type Ia supernova remnants and the case of N103B in the Large Magellanic Cloud

R.Z.E. Alsaberi[1], *L.A. Barnes*[1], *M.D. Filipović*[1], *N.I. Maxted*[1,2], *H. Sano*[3], *G. Rowell*[4], *L.M. Bozzetto*[1], *S. Gurovich*[5], *D. Urošević*[6], *D. Onić*[6], *B.-Q. For*[7,8], *P. Manojlović*[1,9], *G. Wong*[1,9], *T.J. Galvin*[1,9,10], *P. Kavanagh*[11], *N.O. Ralph*[1], *E.J. Crawford*[1], *M. Sasaki*[12], *F. Haberl*[13], *P. Maggi*[14], *N.F.H. Tothil*[1] *and Y. Fukui*[3]

[1]Western Sydney University, Locked Bag 1797, Penrith South DC, NSW 1797, Australia
[2]School of Science, University of New South Wales, Australian Defence Force Academy, Canberra, ACT 2600, Australia
[3]Institute for Advanced Research, Nagoya University, Chikusa-ku, Nagoya 464-8601, Japan
[4]School of Physical Sciences, University of Adelaide, North Terrace, Adelaide, SA 5005, Australia
[5]Instituto de Astronomía Teórica y Experimental - Observatorio Astronómico Córdoba (IATE–OAC–UNC–CONICET), Argentina
[6]Department of Astronomy, Faculty of Mathematics, University of Belgrade, Studentski trg 16, 11000 Belgrade, Serbia
[7]International Centre for Radio Astronomy Research, University of Western Australia, 35 Stirling Hwy, Crawley, WA 6009, Australia
[8]ARC Centre of Excellence for All Sky Astrophysics in 3 Dimensions (ASTRO 3D), Australia
[9]CSIRO Astronomy and Space Sciences, Australia Telescope National Facility, P.O. Box 76, Epping, NSW 1710, Australia
[10]International Centre for Radio Astronomy Research, CurtinUniversity, Bentley, WA 6102, Australia
[11]School of Cosmic Physics, Dublin Institute for Advanced Studies, 31 Fitzwillam Place, Dublin 2, Ireland
[12]Remeis Observatory and ECAP, Universität Erlangen-Nurnberg, Sternwartstr. 7, 96049 Bamberg, Germany
[13]Max-Planck-Institut für extraterrestrische Physik, Gießenbachstraße, 85748 Garching bei München, Germany
[14]Université de Strasbourg, CNRS, Observatoire astronomique de Strasbourg, UMR 7550, F-67000 Strasbourg, France

We investigate young type Ia supernova remnants(SNRs) in our Galaxy and neighbouring galaxies in order to understand their properties and early stage of their evolution. Here we present a radio continuum study based on new and archival data from the Australia Telescope Compact Array (ATCA) towards N103B, a young ($\leq$ 1000 yr) spectroscopically confirmed type Ia SNR in the Large Magellanic Cloud (LMC) and proposed to have originated from a single degenerate (SD) progenitor. The radio morphology of this SNR is asymmetrical with two bright regions towards the north–west and south–west of the central location as defined by radio emission.
N103B identified features include: a radio spectral index of -0.75 ± 0.01 (consistent with other young type Ia SNRs in the Galaxy); a bulk SNR expansion rate as in X-rays; morphology and polarised electical field vector measurements where we note radial polarisation peak towards the north–west of the remnant at both 5500 and 9000 MHz.The spectrum is concave-up and the most likely reason is the non-linear diffusive shock acceleration (NLDSA) effects or presence of two different populations of ultra-relativistic electrons.
We also note unpolarised clumps near the south–west region which is in agreement with this above scenario. We derive a typical magnetic field strength for N103B of 16.4 μG for an average rotation measurement of 200 rad m^{-2}.However, we estimate the equipartition field to be of the order of $\sim$ 235 μG with an estimated minimum energy of $E_{\rm min} = 6.3 \times 10^{48}$ erg. The close ($\sim 0.^{\circ}5$) proximity of N103B to the LMC mid-plane indicates that an early encounter with dense interstellar medium may have set an important constraint on SNR evolution.
Finally, we compare features of N103B to six other young type Ia SNRs in the LMC and Galaxy, with a range of proposed degeneracy scenarios to highlight potential differences due to a different models. We suggest that the single degenerate scenario might point to morphologically asymmetric type Ia supernova explosions.

Published in Astrophysics & Space Science
Available from https://arxiv.org/abs/1911.04051

The VISCACHA survey – deep and resolved photometry of star clusters in the Magellanic Clouds

Bruno Dias[1,2], *Francisco Maia*[3], *Leandro Kerber*[4], *João F.C. Santos Jr.*[5], *Eduardo Bica*[6], *Tina Armond*[7], *Beatriz Barbuy*[8], *Luciano Fraga*[9], *Jose A. Hernandez-Jimenez*[2], *Orlando J. Katime Santrich*[4], *Raphael A.P. Oliveira*[8], *Angeles Pérez-Villegas*[8], *Andrés Piatti*[10,11], *Bruno Quint*[12], *David Sanmartin*[12], *Mateus S. Angelo*[13], *Stefano O. Souza*[8], *Rodrigo G. Vieira*[8], *Pieter Westera*[14], *Celeste Parisi*[10,15], *Doug Geisler*[16,17,18], *Dante Minniti*[2,19,20], *Roberto Saito*[21], *Lilia Bassino*[22,10], *Bruno De Bortoli*[22,10], *André Figueiredo*[8] and *Leandro Rímulo*[23]

[1]European Southern Observatory, Alonso de Córdova 3107, Vitacura 19001, Chile

[2]Departamento de Física, Facultad de Ciencias Exactas, Universidad Andrés Bello, Av. Fernandez Concha 700, Las Condes, Santiago, Chile

[3]Instituto de Física – UFRJ, Bloco A Centro de Tecnologia, Av. Athos da Silveira Ramos, 149 – Cidade Universitária, Rio de Janeiro, 21941-909, Brazil

[4]Universidade Estadual de Santa Cruz, Depto. de Ciências Exatas e Tecnológicas, Rodovia Jorge Amado km 16, 45662-900, Brazil

[5]Universidade Federal de Minas Gerais, ICEx, Av. Antônio Carlos 6627, 31270-901, Brazil

[6]Universidade Federal do Rio Grande do Sul, Instituto de Física, Av. Bento Gonçalves 9500, 91501-970, Brazil

[7]Universidade Federal de São João del-Rei, Departamento de Estatística, Física e Matemática, Campus Alto Paraopeba, Rod.: MG 443, KM 7, Ouro Branco – MG, 36420-000, Brazil

[8]Universidade de São Paulo, IAG, Rua do Matão 1226, 05508-090, Brazil

[9]Laboratório Nacional de Astrofísica, Rua Estados Unidos 154, 37504-364, Brazil

[10]Consejo Nacional de Investigaciones Científicas y Técnicas, Av. Rivadavia 1917, C1033AAJ, Buenos Aires, Argentina

[11]Observatorio Astronómico de Córdoba, Laprida 854, 5000, Córdoba, Argentina

[12]Gemini Observatory, c/o AURA – Casilla 603, La Serena, Chile

[13]Centro Federal de Educação Tecnológica de Minas Gerais, Av. Monsenhor Luiz de Gonzaga, 103, Nepomuceno 37250-000, Brazil

[14]Universidade Federal do ABC, Centro de Ciências Naturais e Humanas, Avenida dos Estados, 5001, 09210-580, Brazil

[15]Instituto de Astronomía Teórica y Experimental, Laprida 854, Córdoba, Argentina

[16]Departamento de Física y Astronomía, Universidad de La Serena, Avenida Juan Cisternas 1200, La Serena, Chile

[17]Instituto de Investigación Multidisciplinario en Ciencia y Tecnología, Universidad de La Serena. Benavente 980, La Serena, Chile

[18]Departmento de Astronomía, Universidad de Concepción, Casilla 160-C, Concepción, Chile

[19]Millennium Institute of Astrophysics, Av. Vicuña Mackenna 4860, 782-0436 Macul, Santiago, Chile

[20]Vatican Observatory, Vatican City State V-00120, Italy

[21]Departamento de Física, Universidade Federal de Santa Catarina, Trindade 88040-900, Florianópolis, SC, Brazil

[22]Facultad de Ciencias Astronómicas y Geofísicas de la Universidad Nacional de La Plata, and Instituto de Astrofísica de La Plata (CCT La Plata – CONICET, UNLP), Paseo del Bosque S/N, B1900FWA La Plata, Argentina

[23]Universidad de los Andes, Departamento de Física, Carrera 1 18A-10, Bloque Ip, Bogotá, Colombia

The VISCACHA (VIsible Soar photometry of star Clusters in tApii and Coxi HuguA[1]) Survey is an ongoing project based on deep and spatially resolved photometric observations of Magellanic Cloud star clusters, collected using the SOuthern Astrophysical Research (SOAR) telescope together with the SOAR Adaptive Module Imager. So far we have used $>$ 300 h of telescope time to observe $\sim$ 150 star clusters, mostly with low mass ($M < 10^4$ M$_\odot$) on the outskirts of the LMC and SMC. With this high-quality data set, we homogeneously determine physical properties using deep colour–magnitude diagrams (ages, metallicities, reddening, distances, mass, luminosity and mass functions) and structural parameters (radial density profiles, sizes) for these clusters which are used as a proxy to investigate the interplay between the Magellanic Clouds and their evolution. We present the VISCACHA survey and its initial results, based on our first two papers. The project's long term goals and expected legacy to the community are also addressed.

Poster contribution, published in IAUS 351 "Star Clusters: From the Milky Way to the Early Universe", eds. A. Bragaglia, M.B. Davies, A. Sills & E. Vesperini
Available from https://arxiv.org/abs/1909.02566

[1]LMC and SMC names in the Tupi–Guarani language spoken by native people in Brazil

Spectroscopy of LMC cluster stars

Andrea K. Dupree[1], *Christian I. Johnson*[1], *Mario Mateo*[2] *and Antonino P. Milone*[3]

[1]Center for Astrophysics – Harvard & Smithsonian, Cambridge, MA, USA

[2]Dept. of Astronomy, University of Michigan, Ann Arbor, MI, USA

[3]Univ. di Padova, Padova, I-35122, Italy

High resolution spectra of stars in the ≈ 200 Myr LMC globular cluster, NGC 1866, reveal rapidly rotating stars with variable Hα emission and absorption, and signatures of outflowing material. The variable Hα line can substantially affect photometric measurements obtained with HST/WFC3 narrow-band filters.

Oral contribution, published in IAUS 351 "Star Clusters: From the MIlky Way to the Early Universe" (2019), eds. A. Bragaglia, M.B. Davies, A. Sills & E. Vesperini
Available from https://arxiv.org/abs/1910.12922

Confirming Bologna A: an old star cluster in the SMC

Michele Bellazzini[1], *Elena Pancino*[2], *Francesco R. Ferraro*[3] *and Peter B. Stetson*[4]

[1]INAF–Osservatorio di Astrofisica e Scienza dello Spazio di Bologna, Via Gobetti 93/3, I-40129 Bologna, Italy

[2]INAF–Osservatorio Astrofisico di Arcetri, Largo Enrico Fermi 5, I-50125 Firenze, Italy

[3]DIFA–Università degli Studi di Bologna, Via Gobetti 93/3, I-40129 Bologna, Italy

[4]Herzberg Astronomy and Astrophysics, National Research Council, 5071 West Saanich Road, Victoria, British Columbia V9E 2E7, Canada

Bologna A (Bo A) was discovered by Bellazzini et al. (2005, hereafter B05) as a small (angular radius $\sim 40''$) stellar system in the background of the massive Galactic globular cluster (GC) 47 Tuc, just $\simeq 15'$ apart from its center. Thanks to the newly available data from Stetson et al. (1902) and Gaia DR2, we have firmly established that Bologna A is a star cluster of old/intermediate age belonging to the SMC.

Oral contribution, published in Research Notes of the AAS
Available from https://iopscience.iop.org/article/10.3847/2515-5172/ab0c0d

Review Papers

Complex organic molecules in star-forming regions of the Magellanic Clouds

Marta Sewiło[1,2], Steven B. Charnley[3], Peter Schilke[4], Vianney Taquet[5], Joana M. Oliveira[6], Takashi Shimonishi[7,8], Eva Wirström[9], Remy Indebetouw[10,11], Jacob L. Ward[12], Jacco Th. van Loon[6], Jennifer Wiseman[13], Sarolta Zahorecz[14,15], Toshikazu Onishi[14], Akiko Kawamura[15], C.-H. Rosie Chen[16], Yasuo Fukui[17] and Roya Hamedani Golshan[4]

[1]CRESST II and Exoplanets and Stellar Astrophysics Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

[2]Department of Astronomy, University of Maryland, College Park, MD 20742, USA

[3]Astrochemistry Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

[4]I. Physikalisches Institut der Universität zu Köln, Zulpicher Str. 77, 50937, Köln, Germany

[5]INAF, Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, 50125 Firenze, Italy

[6]Lennard-Jones Laboratories, Keele University, ST5 5BG, UK

[7]Frontier Research Institute for Interdisciplinary Sciences, Tohoku University, Aramakiazaaoba 6-3, Aoba-ku, Sendai, Miyagi, 980-8578, Japan

[8]Astronomical Institute, Tohoku University, Aramakiazaaoba 6-3, Aoba-ku, Sendai, Miyagi, 980-8578, Japan

[9]Department of Space, Earth and Environment, Chalmers University of Technology, Onsala Space Observatory, 43992, Onsala, Sweden

[10]Department of Astronomy, University of Virginia, P.O. Box 400325, Charlottesville, VA 22904, USA

[11]National Radio Astronomy Observatory, 520 Edgemont Rd., Charlottesville, VA 22903, USA

[12]Astronomisches Rechen-Institut, Zentrum für Astronomie der Universität Heidelberg, Mönchhofstr. 12-14, 69120 Heidelberg Germany

[13]NASA Goddard Space Flight Center, 8800 Greenbelt Rd., Greenbelt, MD 20771, USA

[14]Department of Physical Science, Graduate School of Science, Osaka Prefecture University, 1-1 Gakuen-cho, Naka-ku, Sakai, Osaka 599-8531, Japan

[15]Chile Observatory, National Astronomical Observatory of Japan, National Institutes of Natural Science, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan

[16]Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69 D-53121 Bonn, Germany

[17]Nagoya University, School of Science, Furo-cho, Chikusa-ku, Nagoya, JP 464-8602, Japan

The Large and Small Magellanic Clouds (LMC and SMC), gas-rich dwarf companions of the Milky Way, are the nearest laboratories for detailed studies on the formation and survival of complex organic molecules (COMs) under metal poor conditions. To date, only methanol, methyl formate, and dimethyl ether have been detected in these galaxies – all three toward two hot cores in the N113 star-forming region in the LMC, the only extragalactic sources exhibiting complex hot core chemistry. We describe a small and diverse sample of the LMC and SMC sources associated with COMs or hot core chemistry, and compare the observations to theoretical model predictions. Theoretical models accounting for the physical conditions and metallicity of hot molecular cores in the Magellanic Clouds have been able to broadly account for the existing observations, but fail to reproduce the dimethyl ether abundance by more than an order of magnitude. We discuss future prospects for research in the field of complex chemistry in the low-metallicity environment. The detection of COMs in the Magellanic Clouds has important implications for astrobiology. The metallicity of the Magellanic Clouds is similar to galaxies in the earlier epochs of the Universe, thus the presence of COMs in the LMC and SMC indicates that a similar prebiotic chemistry leading to the emergence of life, as it happened on Earth, is possible in low-metallicity systems in the earlier Universe.

Published in ACS Earth and Space Chemistry
Available from https://arxiv.org/abs/1909.06843
and from
https://pubs.acs.org/articlesonrequest/AOR-mPUVfkWhtGmqXI5KbiR7; doi:10.1021/acsearthspacechem.9b00065

Massive stars in the Tarantula Nebula: A Rosetta Stone for extragalactic supergiant H II regions

Paul Crowther[1]

[1]University of Sheffield, UK

A review of the properties of the Tarantula Nebula (30 Doradus) in the Large Magellanic Cloud is presented, primarily from the perspective of its massive star content. The proximity of the Tarantula and its accessibility to X-ray through radio observations permit it to serve as a Rosetta Stone amongst extragalactic supergiant H II regions since one can consider both its integrated characteristics and the individual properties of individual massive stars. Recent surveys of its high mass stellar content, notably the VLT FLAMES Tarantula Survey (VFTS), are reviewed, together with VLT/MUSE observations of the central ionizing region NGC 2070 and HST/STIS spectroscopy of the young dense cluster R 136, provide a near complete Hertzsprung–Russell diagram of the region, and cumulative ionizing output. Several high mass binaries are highlighted, some of which have been identified from a recent X-ray survey. Brief comparisons with the stellar content of giant H II regions in the Milky Way (NGC 3372) and Small Magellanic Cloud (NGC 346) are also made, together with Green Pea galaxies and star forming knots in high-z galaxies. Finally, the prospect of studying massive stars in metal poor galaxies is evaluated.

Published in "Luminous Stars in Nearby Galaxies" special issue of Galaxies (guest editor Roberta Humphreys)
Available from https://arxiv.org/abs/1911.02047
and from https://www.mdpi.com/journal/galaxies/special_issues/Luminous

Predicting the next local supernova

John Middleditch[1]

[1]University of California, USA (retired)

Core collapse within blue supergiant stars, as occurred within Sk −69°202/Supernova 1987A, is generally attributed to a merger of two electron-degenerate cores within a common envelope, with a merged mass in excess of 1.4 solar. Supernova 1987A also had *two* associated bright sources, one with about 8% of the Hα flux, and 74 milli-arcseconds distant by day 50, and another, four times fainter and 160 milli-arcseconds away in the opposite direction on day 30. Using recent advances in our understanding of pulsars, we can show that the second source was the result of the core-merger process, which can drive a relativistic jet of particles *prior* to the completion of the merger process, *whether this proceeds to core collapse, or not.* As with those resulting from core-collapse, such beams and jets are likely to produce an obvious spectral signature (e.g., in red/blue-shifted Hα), which can be detected in nearby galaxies. There is very likely a time interval of a few months, during which such supergiant stars, a high fraction of which will eventually undergo core collapse, can be identified. These can be carefully followed observationally to maximize the chance of observing core collapses as they happen. Such studies may eventually help in using such objects as standard candles.

Published in arXiv
Available from https://arxiv.org/abs/1910.03797

IAU Symposium 360, Astronomical Polarimetry 2020 New Era of Multi-Wavelength Multi-Wavelength Polarimetry

We are pleased to announce IAU Symposium 360, "Astronomical Polarimetry 2020 – New Era of Multi-Wavelength Multi-Wavelength Polarimetry", which will be held at Hiroshima, Japan, 23–27 March, 2020.

Please feel free to circulate this along within your department or institution. Please find more information at https://astropol2020-iau.jp, which is still being updated.

Important Dates

- Abstract submission deadline: November 25$^{\rm th}$ 2019
- Early registration deadline: November 25$^{\rm th}$ 2019
- Travel grant application deadline: November 20$^{\rm th}$ 2019
- Late registration deadline: January 25$^{\rm th}$ 2020
- On-site registration: TBD

Scientific Rationale
Astronomical Polarimetry 2020 (Astropol 2020) is the next in a series of international conferences. The aim of this series of conferences is to bring researchers interested in astronomical polarimetry together to share and discuss recent results and advances in technical and scientific aspects in all relevant astronomical fields.

Since 2014, when the latest ASTROPOL took place in Grenoble, a number of sophisticated instruments and datasets have become available to the community. ALMA was inaugurated in and started polarization observations in 2014. Adaptive optics aided 8-m class telescopes, such as Subaru, VLT and Gemini have been providing high-contrast spectropolarimetry. There is also the *Robert Stobie* Spectrograph (RSS) spectropolarimeter on the 11-m SALT telescope and the mid-infrared CanariCam polarimeter on the Gran Telescopio Canarias (GTC), that may become available to the public in the future. Data release of the all-sky radio and submillimeter polarization mapping by the *Planck* satellite has had a strong impact in many astronomical fields. The SOFIA/HAWC+ FIR polarimeter is available to the community. In addition, Astrosat and Hitomi and balloon experiments have offered us new insights into the polarized sky in X-rays and γ-rays.

ASTROPOL 2020 will demonstrate that a new era of polarimetry has come to the astronomical community.

The Symposium poster can be seen/downloaded from:
https://astropol2020-iau.jp/wordpress/wp-content/uploads/2019/09/astropol2020-iau360_wo_logos.pages-7.pdf

See also https://astropol2020-iau.jp

The Local Group. Assembly and Evolution

We are excited to announce the 2020 STScI Spring Symposium, "The Local Group: Assembly and Evolution", to be held at the Space Telescope Science Institute in Baltimore, USA, from April 20 to 23, 2020.

In this symposium, we will bring together researchers studying the assembly and evolution of the Local Group and its components, so that we may review and discuss the current status of the field and future opportunities. Some of the key questions we will address throughout this meeting are:

- How did the Milky Way system assemble and form?
- How similar/different are the Milky Way and M 31 systems?
- What mechanisms drive the formation and evolution of the Local Group and its constituent galaxies?
- What can we learn about the Local Group by studying other groups and clusters in the local Universe?

The symposium will include invited reviews, regular/short contributed talks, and posters. For additional information or questions visit the symposium website below or email the co-chairs at ss2020@stsci.edu

See also http://www.stsci.edu/contents/events/stsci/2020/april/the-local-group-assembly-and-evolution