The Star Clusters Young & Old Newsletter

edited by Giovanni Carraro, Martin Netopil, and Ernst Paunzen
https://www.univie.ac.at/scyon/
email: scyon@univie.ac.at

The official Newsletter of the IAU Commission H4.

SCYON Issue No. 77 September 30th, 2018

Dear Colleagues,

This editorial is dedicated to an announcement by Amanda Karakas, the new President of the IAU Commission H4, which you can find on the next page.

The current SCYON issue includes numerous paper abstracts, which cover a broad range in star cluster research. We also want to congratulate Maria Tiongco, who recently finished her PhD at the Indiana University. We wish her all the best for the future career! Furthermore, save the date for an upcoming conference in Bologna and register for one which takes place soon in Heidelberg.

The SCYON editor team:

Giovanni Carraro, Martin Netopil, and Ernst Paunzen

CONTENTS

About the Newsletter

SCYON publishes abstracts from any area in astronomy, which are relevant to research on star clusters. We welcome all kinds of submitted contributions (abstracts of refereed papers or conference proceedings, PhD summaries, and general announcements of e.g. conferences, databases, tools, etc.)

The mission of this newsletter is to help all the researchers in the field with a quick and efficient link to the scientific activity in the field. We encourage everybody to contribute to the new releases! New abstracts can be submitted *at any time* using the **webform** on the SCYON homepage.

https://www.univie.ac.at/scyon

Dear Colleagues,

At the IAU General Assembly in Vienna this year, I became President of Commission H4, taking over from Richard de Grijs, who served as President from 2015-2018. Francesca D'Antona is the new Vice President and the Organising Committee now includes the following members: Ernst Paunzen, Andrea Dupree, Eric Peng, Jan Palous, André Moitinho de Almeida and Andrés Piatti. Richard will stay on as an Advisor.

Over the next 3 years I look forward to working with the Organising Committee and all members of our Commission on Star Clusters. I am particularly looking forward to expanding our Commission membership to new IAU Junior Members. I would like to encourage all members of H4 to ask junior members in their departments to join the IAU and our commission. I also encourage all commission members to nominate outstanding students for IAU PhD Prizes.

As President, I am interested in feedback from members about what they would like to see our Commission doing over the next 3 years. Do we want to encourage more IAU Symposium on star clusters research (would our field benefit from a conference series?) – if so now is the time to write a Letter of Intent! We are an active vibrant research field with many members all over the globe – I welcome your ideas and suggestions. Please send them to me or other Organising Commission members.

Finally, I would like to thank past-President Richard de Grijs and the outgoing Organising Committee member Alison Sills for their service over the past 3 years.

Best regards,
Amanda Karakas

For contact details of the Organizing Committee see:

https://www.iau.org/science/scientific_bodies/commissions/H4/

Star Forming Regions

The Planck Cold Clump G108.37-01.06: A Site of Complex Interplay between HII Regions, Young Clusters, and Filaments

S. Dutta [1], S. Mondal [1], M. R. Samal [2], J. Jose [3]

([1]) Satyendra Nath Bose National Centre for Basic Sciences, Kolkata, India; ([2]) Physical Research Laboratory, Ahmedabad, India; ([3]) Indian Institute of Science Education and Research Tirupati, Tirupati, India

The *Planck* Galactic Cold Clumps (PGCCs) are the possible representations of the initial conditions and the very early stages of star formation. With an objective to understand better the star and star cluster formation, we probe the molecular cloud associated with PGCC G108.37-01.06 (hereafter, PG108.3), which can be traced in a velocity range -57 to -51 km s^{-1}. The IPHAS images reveal Hα emission at various locations around PG108.3, and optical spectroscopy of the bright sources in those zones of Hα emission disclose two massive ionizing sources with spectral type O8-O9V and B1V. Using the radio continuum, we estimate ionizing gas parameters and find the dynamical ages of HII regions associated with the massive stars in the range 0.5$-$0.75 Myr. Based on the stellar surface density map constructed from the deep near-infrared CHFT observations, we find two prominent star clusters in PG108.3; of which, the cluster associated with HII region S148 is moderately massive ($\sim$ 240 M$_\odot$). A careful inspection of JCMT ^{13}CO(3$-$2) molecular data exhibits that the massive cluster is associated with a number of filamentary structures. Several embedded young stellar objects (YSOs) are also identified in the PG108.3 along the length and junction of filaments. We find the evidence of velocity gradient along the length of the filaments. Along with kinematics of the filaments and the distribution of ionized, molecular gas and YSOs, we suggest that the cluster formation is most likely due to the longitudinal collapse of the most massive filament in PG108.3.

Accepted by: Astrophysical Journal

http://adsabs.harvard.edu/abs/2018ApJ...864..154D

The double population of Chamaeleon I detected by Gaia DR2

V. Roccatagliata [1], G. G. Sacco [1], E. Franciosini [1], S. Randich [1]

([1]) INAF/Osservatorio Astrofisico di Arcetri, Firenze, Italy

Chamaeleon I represents an ideal laboratory to study the cluster formation in a low-mass environment. Recently, two sub-clusters spatially located in the northern and southern parts of Chamaeleon I were found with different ages and radial velocities. In this Letter we report new insights into the structural properties, age, and distance of Chamaeleon I based on the astrometric parameters from Gaia data release 2 (DR2). We identified 140 sources with a reliable counterpart in the Gaia DR2 archive. We determined the median distance of the cluster using Gaia parallaxes and fitted the distribution of parallaxes and proper motions assuming the presence of two clusters. We derived the probability of each single source of belonging to the northern or southern sub-clusters, and compared the HR diagram of the most probable members to pre-main sequences isochrones. The median distance of Chamaeleon I is ∼190 pc. This is consistent with the revised estimate using the Tycho-Gaia Astrometric Solution, but it is about 20 pc larger than the value commonly adopted in the literature. From a Kolmogorov-Smirnov test of the parallaxes and proper-motion distributions we conclude that the northern and southern clusters do not belong to the same parent population. The northern population has a distance dN = 192.7±0.4 pc, while the southern one dS = 186.5±0.7 pc. The two sub-clusters appear coeval, at variance with literature results, and most of the sources are younger than 3 Myr. The northern cluster is more elongated and extends towards the southern direction partially overlapping with the more compact cluster located in the south. A hint of a relative rotation between the two sub-clusters is also found.

Accepted by: Astronomy & Astrophysics

http://adsabs.harvard.edu/abs/2018arXiv180806931R

Galactic Open Clusters

Radial velocity and chemical composition of evolved stars in the open clusters NGC 6940 and Tombaugh 5

M. Baratella [1], G. Carraro [1], V. D'Orazi [2], E. Semenko [3]

([1]) Dipartimento di Fisica e Astronomia Galileo Galilei, Padova, Italy; ([2]) INAF, Padova Astronomical Observatory, Padova, Italy; ([3]) Special Astrophysical Observatory, Russian Academy of Sciences, Nizhny Arkhyz, Russia

We present and discuss medium resolution (R$\sim$13000), high signal-to-noise (SN$\sim$100), spectroscopic observations in the field of the open clusters NGC 6940 and Tombaugh 5. Spectra were recorded for seven candidate red giant stars in both clusters. For the latter we present the very first chemical abundance analysis. We derive radial velocities for all the stars in NGC 6940, confirming membership to the cluster for all of them, while on the same ground we exclude two stars in To 5. We perform a chemical abundance analysis of different atomic species, in particular FeI, SiI, CaI, TiI and NiI. The mean metallicity of NGC 6940 is [Fe/H]=+0.09±0.06 dex, in good agreement with previous works, while for To 5 is [Fe/H]=+0.06±0.11 dex. Therefore, both clusters exhibit a chemical composition close to the solar value, and do not deviate from the [Fe/H] Galactic radial abundance gradient. With these new values we estimate the fundamental cluster parameters, after having derived clusters' distances from the *Gaia* DR2 database. By adopting these distances, we derive updated estimated for the clusters ages: 1.0±0.1 Gyr of NGC 6940 and 0.25±0.05 Gyr for Tombaugh 5.

Accepted by: Astronomical Journal

http://adsabs.harvard.edu/abs/2018arXiv180908831B

. . . .

A Gaia DR2 view of the Open Cluster population in the Milky Way

T. Cantat-Gaudin [1], C. Jordi [1], A. Vallenari [2], and 10 co-authors

([1]) Institut de Ciencies del Cosmos, Universitat de Barcelona (IEEC-UB), Barcelona, Spain; ([2]) INAF-Osservatorio Astronomico di Padova, Padova, Italy

Open clusters are convenient probes of the structure and history of the Galactic disk. They are also fundamental to stellar evolution studies. The second Gaia data release contains precise astrometry at the sub-milliarcsecond level and homogeneous photometry at the mmag level, that can be used to characterise a large number of clusters over the entire sky. In this study we aim to a establish list of members and derive mean parameters, in particular distances, for as many clusters as possible, making use of Gaia data alone. We compile a list of thousands of known or putative clusters from the literature. We then apply an unsupervised membership assignment code, UPMASK, to the Gaia DR2 data contained within the fields of those clusters. We obtained a list of members and cluster parameters for 1229 clusters. As expected, the youngest clusters are seen to be tightly distributed near the Galactic plane and to trace the spiral arms of the Milky Way, while older objects are more uniformly distributed, deviate further from the plane, and tend to be located at larger Galactocentric distances. Thanks to the quality of GaiaDR2 astrometry, the fully homogeneous parameters derived in this study are the most precise to date. Furthermore, we report on the serendipitous discovery of 60 new open clusters in the fields analysed during this study.

Accepted by: Astronomy & Astrophysics

http://adsabs.harvard.edu/abs/2018arXiv180508726C

The chemical composition of the oldest nearby open cluster Ruprecht 147

A. Bragaglia [1], X. Fu [1,2], A. Mucciarelli [2], G. Andreuzzi [3,4], P. Donati [1]

([1]) INAF-Osservatorio di Astrofisica e Scienza dello Spazio, Bologna, Italy; ([2]) Department of Physics and Astronomy, Bologna University, Bologna, Italy; ([3]) Fundación Galileo Galilei - INAF, Breña Baja, La Palma, Spain; ([4]) INAF-Osservatorio Astronomico di Roma - Sede di Monteporzio Catone, Monte Porzio Catone, Italy

Rup147 is the closest old open cluster, with a distance of less than 300 pc and an age of about 2.5Gyr. It is therefore well suited for testing stellar evolution models and for obtaining precise and detailed chemical abundance information. We combined photometric and astrometric information coming from literature and the Gaia mission with very high-resolution optical spectra of stars in different evolutionary stages to derive the cluster distance, age, and detailed chemical composition. We obtained spectra of six red giants using HARPS-N at the TNG. We also used ESO archive spectra of 22 main sequence stars, observed with HARPS at the 3.6m telescope. The very high resolution (115000) and the large wavelength coverage (about 380-680nm) of the twin instruments permitted us to derive atmospheric parameters, metallicity, and detailed chemical abundances of 23 species from all nucleosynthetic channels. We employed both equivalent widths and spectrum synthesis. We also re-derived the cluster distance and age using Gaia parallaxes, proper motions, and photometry in conjunction with the PARSEC stellar evolutionary models. We fully analysed those stars with radial velocity and proper motion/parallax in agreement with the cluster mean values. We also discarded one binary not previously recognised, and six stars near the MS turn-off because of their high rotation velocity. Our final sample consists of 21 stars (six giants and 15 MS stars). We measured metallicity (the cluster average [Fe/H] is +0.08, rms=0.07) and abundances of light, α, Fe-peak, and neutron-capture elements. The Li abundance follows the expectations, showing a tight relation between temperature and abundance on the MS, at variance with M67, and we did not detect any Li-rich giant. We confirm that Rup147 is the oldest nearby open cluster. This makes it very valuable to test detailed features of stellar evolutionary models.

Accepted by: Astronomy & Astrophysics

http://adsabs.harvard.edu/abs/2018arXiv180906868B

. . . .

The Gaia DR2 view of the Gamma Velorum cluster: resolving the 6D structure

E. Franciosini [1], G. G. Sacco [1], R. D. Jeffries [2], and 4 co-authors

([1]) INAF - Osservatorio Astrofisico di Arcetri, Florence, Italy; ([2]) Astrophysics Group, Keele University, Keele, UK

Gaia-ESO Survey observations of the young Gamma Velorum cluster led to the discovery of two kinematically distinct populations, Gamma Vel A and B, respectively, with population B extended over several square degrees in the Vela OB2 association. Using the Gaia DR2 data for a sample of high-probability cluster members, we find that the two populations differ not only kinematically, but are also located at different distances along the line of sight, with the main cluster Gamma Vel A being closer. A combined fit of the two populations yields $\varpi_A = 2.895 \pm 0.008$ mas and $\varpi_B = 2.608 \pm 0.017$ mas, with intrinsic dispersions of 0.038 ± 0.011 mas and 0.091 ± 0.016 mas, respectively. This translates into distances of $345.4^{+1.0+12.4}_{-1.0-11.5}$ pc and $383.4^{+2.5+15.3}_{-2.5-14.2}$ pc, respectively, showing that Gamma Vel A is closer than Gamma Vel B by $\sim$38 pc. We find that the two clusters are nearly coeval, and that Gamma Vel B is expanding. We suggest that Gamma Vel A and B are two independent clusters located along the same line of sight.

Accepted by: Astronomy & Astrophysics

http://adsabs.harvard.edu/abs/2018A%26A...616L..12F

Open cluster kinematics with Gaia DR2

C. Soubiran [1], T. Cantat-Gaudin [2], M. Romero-Gomez [2], and 16 co-authors

([1]) Laboratoire d'Astrophysique de Bordeaux, Univ. Bordeaux, Pessac, France; ([2]) Institut de Ciències del Cosmos, Universitat de Barcelona (IEEC-UB), Barcelona, Spain

Open clusters are very good tracers of the evolution of the Galactic disc. Thanks to Gaia, their kinematics can be investigated with an unprecedented precision and accuracy. The distribution of open clusters in the 6D phase space is revisited with Gaia DR2. The weighted mean radial velocity of open clusters was determined, using the most probable members available from a previous astrometric investigation that also provided mean parallaxes and proper motions. Those parameters, all derived from Gaia DR2 only, were combined to provide the 6D phase space information of 861 clusters. The velocity distribution of nearby clusters was investigated, as well as the spatial and velocity distributions of the whole sample as a function of age. A high quality subsample was used to investigate some possible pairs and groups of clusters sharing the same Galactic position and velocity. For the high quality sample that has 406 clusters, the median uncertainty of the weighted mean radial velocity is 0.5 $\mathrm{km\,s^{-1}}$. The accuracy, assessed by comparison to ground-based high resolution spectroscopy, is better than 1 $\mathrm{km\,s^{-1}}$. Open clusters nicely follow the velocity distribution of field stars in the close Solar neighbourhood previously revealed by Gaia DR2. As expected, the vertical distribution of young clusters is very flat but the novelty is the high precision to which this can be seen. The dispersion of vertical velocities of young clusters is at the level of 5 $\mathrm{km\,s^{-1}}$. Clusters older than 1 Gyr span distances to the Galactic plane up to 1 kpc with a vertical velocity dispersion of 14 $\mathrm{km\,s^{-1}}$, typical of the thin disc. Five pairs of clusters and one group with five members are possibly physically related. Other binary candidates previously identified turn out to be chance alignment.

Accepted by: Astronomy & Astrophysics
http://adsabs.harvard.edu/abs/2018arXiv180801613S

Galactic Globular Clusters

On the relationship between metallicity distributions of globular clusters and of circumgalactic gas

I. A. Acharova [1], M. E. Sharina [2]

([1]) Faculty of Physics, Southern Federal University, Rostov-on-Don, Russia; ([2]) Special Astrophysical Observatory, Russian Academy of Sciences, N. Arkhyz, Russia

The abundance of alpha elements and iron in stars of globular clusters shows the composition of the gaseous medium, in which they have been formed. In the present paper, we discuss a possibility to consider dense clouds of circumgalactic gas (partial Lyman limit systems and Lyman limit systems) observed in the 100 – 130 kpc neighbourhood of galaxies at redshifts of 0.1<z<1.1 as being the residual parts of clouds, in which globular clusters have been formed. Conclusions have been drawn based on statistical analysis of the abundance of magnesium and iron in globular clusters and in circumgalactic clouds and on the spatial location of objects of both types.

Accepted by: Monthly Notices of the Royal Astronomical Society

http://adsabs.harvard.edu/abs/2018MNRAS.481.2074A

. . . .

The GeMS/GSAOI Galactic Globular Cluster Survey (G4CS) I: A Pilot Study of the stellar populations in NGC 2298 and NGC 3201

S. Monty [1,2], T. H. Puzia [3], B. W. Miller [4], and 12 co-authors

([1]) Department of Physics and Astronomy, University of Victoria, Victoria, Canada; ([2]) Research School of Astronomy and Astrophysics, Australian National University, Canberra, Australia; ([3]) Institute of Astrophysics, Pontificia Universidad Catolica de Chile, Macul, Santiago, Chile; ([4]) Gemini Observatory/AURA, Southern Operations Center, La Serena, Chile

We present the first results from the GeMS/GSAOI Galactic Globular Cluster Survey (G4CS) of the Milky-Way globular clusters (GCs) NGC 3201 and NGC 2298. Using the Gemini South Adaptive Optics Imager (GSAOI), in tandem with the Gemini Multi-conjugate adaptive optics System (GeMS) on the 8.1-meter Gemini-South telescope, we collected deep near-IR observations of both clusters, resolving their constituent stellar populations down to $K_s \simeq 21$ Vega mag. Point spread function (PSF) photometry was performed on the data using spatially-variable PSFs to generate JHK_s photometric catalogues for both clusters. These catalogues were combined with Hubble Space Telescope (HST) data to augment the photometric wavelength coverage, yielding catalogues that span the near-ultraviolet (UV) to near-infrared (near-IR). We then applied 0.14 mas/year accurate proper-motion cleaning, differential-reddening corrections and chose to anchor our isochrones using the lower main-sequence knee (MSK) and the main-sequence turn-off (MSTO) prior to age determination. As a result of the data quality, we found that the K_s vs. F606W$-K_s$ and F336W vs. F336W$-K_s$ color-magnitude diagrams (CMDs) were the most diagnostically powerful. We used these two color combinations to derive the stellar-population ages, distances and reddening values for both clusters. Following isochrone-fitting using three different isochrone sets, we derived best-fit absolute ages of 12.2±0.5 Gyr and 13.2±0.4 Gyr for NGC 3201 and NGC 2298, respectively. This was done using a weighted average over the two aforementioned color combinations, following a pseudo-χ^2 determination of the best-fit isochrone set. Our derived parameters are in good agreement with recent age determinations of the two clusters, with our constraints on the ages being or ranking among the most statistically robust.

Accepted by: Astrophysical Journal

http://adsabs.harvard.edu/abs/2018arXiv180805271M

Clusters in the Magellanic clouds

Cluster kinematics and stellar rotation in NGC 419 with MUSE and adaptive optics

S. Kamann [1], N. J. Bastian [1], T.-O. Husser [2], and 9 co-authors

([1]) Astrophysics Research Institute, Liverpool John Moores University, Liverpool, UK; ([2]) Institut für Astrophysik, Georg-August Universität, Göttingen, Germany

We present adaptive optics (AO) assisted integral-field spectroscopy of the intermediate-age star cluster NGC 419 in the Small Magellanic Cloud. By investigating the cluster dynamics and the rotation properties of main sequence turn-off stars (MSTO), we demonstrate the power of AO-fed MUSE observations for this class of objects. Based on 1 049 radial velocity measurements, we determine a dynamical cluster mass of $1.4 \pm 0.2 \times 10^5\,\mathrm{M}_\odot$ and a dynamical mass-to-light ratio of 0.67 ± 0.08, marginally higher than simple stellar population predictions for a Kroupa initial mass function. A stacking analysis of spectra at both sides of the extended MSTO reveals significant rotational broadening. Our analysis further provides tentative evidence that red MSTO stars rotate faster than their blue counterparts. We find average $V \sin i$ values of $87 \pm 16\,\mathrm{km\,s^{-1}}$ and $130 \pm 22\,\mathrm{km\,s^{-1}}$ for blue and red MSTO stars, respectively. Potential systematic effects due to the low spectral resolution of MUSE can reach $30\,\mathrm{km\,s^{-1}}$ but the difference in $V \sin i$ between the populations is unlikely to be affected.

Accepted by: Monthly Notices of the Royal Astronomical Society

http://adsabs.harvard.edu/abs/2018MNRAS.480.1689K

. . . .

Accurate radial velocity and metallicity of the Large Magellanic Cloud old globular clusters NGC 1928 and NGC 1939

A. E. Piatti [1,2], N. Hwang [3], A.A. Cole [4], M.S. Angelo [5], B. Emptage [4]

([1]) Consejo Nacional de Investigaciones Científicas y Técnicas, Buenos Aires, Argentina; ([2]) Observatorio Astronómico de Córdoba, Córdoba, Argentina; ([3]) Korea Astronomy and Space Science Institute, Daejeon, Korea; ([4]) School of Natural Sciences, University of Tasmania, Hobart, Australia; ([5]) Laboratório Nacional de Astrofísica, Itajubá, MG, Brazil

We present results obtained from spectroscopic observations of red giants located in the fields of the Large Magellanic Cloud (LMC) globular clusters (GCs) NGC 1928 and NGC 1939. We used the GMOS and AAOmega+2dF spectrographs to obtain spectra centred on the Ca II triplet, from which we derived individual radial velocities (RVs) and metallicities. From cluster members we derived mean RVs of RV NGC 1928 = 249.58 ± 4.65 $\mathrm{km\,s^{-1}}$ and RV NGC 1939 = 258.85 ± 2.08 $\mathrm{km\,s^{-1}}$, and mean metallicities of [Fe/H] NGC 1928 = -1.30 ± 0.15 dex and [Fe/H] NGC 1939 = -2.00 ± 0.15 dex. We found that both GCs have RVs and positions consistent with being part of the LMC disc, so that we rule out any possible origin but that in the same galaxy. By computing the best solution of a disc that fully contains each GC, we obtained circular velocities for the 15 known LMC GCs. We found that 11/15 of the GCs share the LMC rotation derived from HST and Gaia DR2 proper motions. This outcome reveals that the LMC disc existed since the very early epoch of the galaxy formation and experienced the steep relatively fast chemical enrichment shown by its GC metallicities. The four remaining GCs turned out to have circular velocities not compatible with an in situ cluster formation, but rather with being stripped from the SMC.

Accepted by: Monthly Notices of the Royal Astronomical Society

http://adsabs.harvard.edu/abs/2018MNRAS.481...49P

Search for an intrinsic metallicity spread in old globular clusters of the Large Magellanic Cloud

A. E. Piatti [1,2], **A. Koch** [3]

([1]) Consejo Nacional de Investigaciones Científicas y Técnicas, Buenos Aires, Argentina; ([2]) Astronomical Observatory of Córdoba, Córdoba, Argentina; ([3]) Zentrum für Astronomie der Universität Heidelberg, Astronomisches Rechen-Institut, Heidelberg, Germany

We report for the first time on the magnitude of the intrinsic [Fe/H] spread among ten old globular clusters (GCs) of the Large Magellanic Cloud (LMC). Such spreads are merely observed in approximately five per cent of the Milky Way GCs and recently gained more attention in theoretical models of GC evolution. We derived metallicities with a typical precision of 0.05 dex $\leq \sigma$[Fe/H] $\leq$ 0.20 dex for an average of 14 red giant branch stars per GC from Strömgren photometry. The respective, metallicity-sensitive indices have been calibrated to precise and accurate high-dispersion spectroscopy. For all clusters we found null [Fe/H] spreads with a typical uncertainty of 0.04 dex, with the possible exception of NGC 1786 that shows an intrinsic dispersion of 0.07±0.04 dex. The mean, observed standard deviation of the derived metallicities for nearly 40 per cent of our GC sample amounted to smaller than 0.05 dex. At present, we cannot exclude that the remaining GCs also have intrinsic Fe-abundance variations in excess of 0.05 dex, but in order to significantly detect those, the measurement errors on individual [Fe/H]-values would need to be lowered to the 0.03–0.07 dex level. These findings suggest, along with those from ages and light-element abundances, that the LMC GCs studied here are alike to the majority of Galactic GCs.

Accepted by: Astrophysical Journal
http://adsabs.harvard.edu/abs/2018arXiv180901709P

. . . .

Hints for multiple populations in intermediate-age clusters of the Small Magellanic Cloud

A. E. Piatti [1,2]

([1]) Consejo Nacional de Investigaciones Científicas y Técnicas, Buenos Aires, Argentina; ([2]) Astronomical Observatory of Córdoba, Córdoba, Argentina

We report on the magnitude of the intrinsic [Fe/H] spread in the Small Magellanic Cloud (SMC) intermediate-age massive clusters NGC 339, 361, Lindsay 1 and 113, respectively. In order to measure the cluster metallicity dispersions, we used accurate Strömgren photometry of carefully selected cluster red giant branch (RGB) stars. We determined the Fe-abundance spreads by employing a maximum likelihood approach. The spreads obtained using the more accurate photometry of the brighter RGB stars resulted to be marginal ($\sim$ 0.05±0.03 dex) for NGC 339 and NGC 361, while for Lindsay 1 and Lindsay 113 we obtained metallicity spreads of 0.00±0.04 dex. From these results, we speculated with the possibility that NGC 361 is added to the group of four SMC clusters with observational evidence of multiple populations (MPs). Furthermore, in the context of the present debate about the existence of Fe-abundance inhomogeneities among old clusters with MPs, these outcomes put new constrains to recent theoretical speculations for making this phenomenon visible.

Accepted by: Astronomical Journal
http://adsabs.harvard.edu/abs/2018arXiv180908123P

The most distant clusters

The Globular Cluster Systems of Ultra-diffuse Galaxies in the Coma Cluster

S. Lim [1,2], E. W. Peng [1,2], P. Ct [3], and 4 co-authors

([1]) Department of Astronomy, Peking University, Beijing, China; ([2]) Kavli Institute for Astronomy and Astrophysics, Peking University, Beijing, China; ([3]) Herzberg Astronomy and Astrophysics Research Centre, National Research Council of Canada, Victoria, Canada

Ultra-diffuse galaxies (UDGs) are unusual galaxies with low luminosities, similar to classical dwarf galaxies, but with sizes up to ∼5 larger than expected for their mass. Some UDGs have large populations of globular clusters (GCs), something unexpected in galaxies with such low stellar density and mass. We have carried out a comprehensive study of GCs in both UDGs and classical dwarf galaxies at comparable stellar masses using Hubble Space Telescope (HST) observations of the Coma cluster. We present new imaging for 33 Dragonfly UDGs with the largest effective radii (>2 kpc), and additionally include 15 UDGs and 54 classical dwarf galaxies from the HST/ACS Coma Treasury Survey and the literature. Out of a total of 48 UDGs, 27 have statistically significant GC systems, and 11 have candidate nuclear star clusters. The GC specific frequency (S_N) varies dramatically, with the mean S_N being higher for UDGs than for classical dwarfs. At constant stellar mass, galaxies with larger sizes (or lower surface brightnesses) have higher S_N , with the trend being stronger at higher stellar mass. At lower stellar masses, UDGs tend to have higher S N when closer to the center of the cluster, i.e., in denser environments. The fraction of UDGs with a nuclear star cluster also depends on environment, varying from ∼40% in the cluster core, where it is slightly lower than the nucleation fraction of classical dwarfs, to $\lesssim$20% in the outskirts. Collectively, we observe an unmistakable diversity in the abundance of GCs, and this may point to multiple formation routes.

Accepted by: Astrophysical Journal

http://adsabs.harvard.edu/abs/2018ApJ...862...82L

The Next Generation Virgo Cluster Survey (NGVS). XXXI. The Kinematics of Intracluster Globular Clusters in the Core of the Virgo Cluster

A. Longobardi [1], E. W. Peng [2,1], P. Côté [3], and 21 co-authors

([1]) Kavli Institute for Astronomy and Astrophysics, Peking University, Beijing, China; ([2]) Department of Astronomy, Peking University, Beijing, China; ([3]) Herzberg Astronomy and Astrophysics Research Centre, National Research Council of Canada, Victoria, Canada

Intracluster (IC) populations are expected to be a natural result of the hierarchical assembly of clusters, yet their low space densities make them difficult to detect and study. We present the first definitive kinematic detection of an IC population of globular clusters (GCs) in the Virgo cluster, around the central galaxy M87. This study focuses on the Virgo core, for which the combination of Next Generation Virgo Cluster Survey photometry and follow-up spectroscopy allows us to reject foreground star contamination and explore GC kinematics over the full Virgo dynamical range. The GC kinematics changes gradually with galactocentric distance, decreasing in mean velocity and increasing in velocity dispersion, eventually becoming indistinguishable from the kinematics of Virgo dwarf galaxies at R > 320 kpc. By kinematically tagging M87 halo and intracluster GCs, we find that (1) the M87 halo has a smaller fraction (52 ± 3%) of blue clusters with respect to the IC counterpart (77 ± 10%), (2) the $(g' - r')_0$ versus $(i' - z')_0$ color-color diagrams reveal a galaxy population that is redder than the IC population, which may be due to a different composition in chemical abundance and progenitor mass, and (3) the ICGC distribution is shallower and more extended than the M87 GCs, yet still centrally concentrated. The ICGC specific frequency, $S_{N,ICL} = 10.2 \pm 4.8$, is consistent with what is observed for the population of quenched, low-mass galaxies within 1 Mpc from the cluster's center. The IC population at Virgo's center is thus consistent with being an accreted component from low-mass galaxies tidally stripped or disrupted through interactions, with a total mass of $M_{ICL,tot} = 10.8 \pm 0.1 \times 10^{11}M_\odot$.

Accepted by: Astrophysical Journal

http://adsabs.harvard.edu/abs/2018ApJ...864...36L

Dynamical evolution - Simulations

Very massive stars in not so massive clusters

S. Oh [1,2], **P. Kroupa** [1,3]

([1]) University of Bonn, Bonn, Germany; ([2]) University of Sheffield, Sheffield, UK; ([3]) Charles University in Prague, Prague, Czech Republic

Very young star clusters in the Milky Way exhibit a well-defined relation between their maximum stellar mass, $m_{\rm max}$, and their mass in stars, $M_{\rm ecl}$. A recent study shows that the young intermediate-mass star cluster VVV CL041 possibly hosts a $\gtrsim$80 $M_\odot$ star, WR62-2, which appears to violate the existence of the $m_{\rm max}$–$M_{\rm ecl}$ relation since the mass of the star is almost two times higher than that expected from the relation. By performing direct N-body calculations with the same mass as the cluster VVV CL041 ($\approx$3000 $M_\odot$), we study whether such a very massive star can be formed via dynamically induced stellar collisions in a binary-rich star cluster that initially follows the $m_{\rm max}$–$M_{\rm ecl}$ relation. Eight out of 100 clusters form a star more massive than 80 $M_\odot$ through multiple stellar collisions. This suggests that the VVV CL041 cluster may have become an outlier of the relation because of its early-dynamical evolution, even if the cluster followed the relation at birth. We find that more than half of our model clusters host a merger product as its most massive member within the first 5 Myr of cluster evolution. Thus, the existence of stars more massive than the $m_{\rm max}$–$M_{\rm ecl}$ relation in some young clusters is expected due to dynamical processes despite the validity of the $m_{\rm max}$–$M_{\rm ecl}$ relation. We briefly discuss evolution of binary populations in our model.

Accepted by: Monthly Notices of the Royal Astronomical Society
http://adsabs.harvard.edu/abs/2018MNRAS.481..153O

....

The Structural and Kinematic Evolution of Central Star Clusters in Dwarf Galaxies and Their Dependence on Dark Matter Halo Profiles

J. J. Webb [1,2], **E. Vesperini** [2]

([1]) Department of Astronomy and Astrophysics, University of Toronto, Toronto, Canada; ([2]) Department of Astronomy, Indiana University, Swain West, Bloomington, USA

Through a suite of direct N-body simulations, we explore how the structural and kinematic evolution of a star cluster located at the center of a dwarf galaxy is affected by the shape of its host's dark matter density profile. The stronger central tidal fields of cuspier halos minimize the cluster's ability to expand in response to mass loss due to stellar evolution during its early evolutionary stages and during its subsequent long-term evolution driven by two-body relaxation. Hence clusters evolving in cuspier dark matter halos are characterized by more compact sizes, higher velocity dispersions and remain approximately isotropic at all clustercentric distances. Conversely, clusters in cored halos can expand more and develop a velocity distribution profile that becomes increasingly radially anisotropic at larger clustercentric distances. Finally, the larger velocity dispersion of clusters evolving in cuspier dark matter profiles results in them having longer relaxation times. Hence clusters in cuspy galaxies relax at a slower rate and, consequently, they are both less mass segregated and farther from complete energy equipartition than cluster's in cored galaxies. Application of this work to observations allows for star clusters to be used as tools to measure the distribution of dark matter in dwarf galaxies and to distinguish isolated star clusters from ultra-faint dwarf galaxies.

Accepted by: Monthly Notices of the Royal Astronomical Society
http://adsabs.harvard.edu/abs/2018MNRAS.479.3708W

Stellar-mass black holes in young massive and open stellar clusters and their role in gravitational-wave generation III: dissecting black hole dynamics

S. Banerjee [1,2]
([1]) Helmholtz-Institut für Strahlen- und Kernphysik (HISKP), University of Bonn, Bonn, Germany; ([2]) Argelander-Institut für Astronomie (AIfA), University of Bonn, Bonn, Germany

Stellar-remnant black holes (BH) in dense stellar clusters comprise a natural setup to trigger general-relativistic (GR) inspiral and merger of binary black holes (BBH), detectable by the LISA and the LIGO-Virgo, through dynamical encounters inside such environments. In this work, the intricacies of such dynamical interactions are probed utilizing realistic, self-consistent, post-Newtonian, direct N-body evolutionary models of young massive and open stellar clusters. Particularly, the configurations of the compact subsystems, that drive the in-cluster GR BBH coalescences, are tracked on the fly. Such an approach reveals that the GR coalescences within the open clusters take place primarily via chaotic interactions involving triple BH systems. Although less frequently, such mergers are found to happen also in higher-order subsystems such as quadruples and in subsystems involving non-BH members; the mergers can themselves be BH—non-BH, which events would leave electromagnetic signatures. Close, fly-by encounters inside the clusters can also make BBHs and other types of double-compact binaries temporarily post-Newtonian; such binaries would potentially contribute to the GW background for the LISA and the PTA. These calculations, furthermore, suggest that open clusters are potential hosts for not only detached BH—main-sequence binaries, as recently identified in the globular cluster NGC 3201, but also a wide variety of other types of remnant—non-remnant binaries, which are assembled via dynamical interactions inside the clusters and which have the prospects of being discovered in radial-velocity surveys.

Accepted by: Monthly Notices of the Royal Astronomical Society
http://adsabs.harvard.edu/abs/2018arXiv180506466B

. . . .

The origin of the ‘blue tilt’ of globular cluster populations in the E-MOSAICS simulations

C. Usher [1], **J. Pfeffer** [1], **N. Bastian** [1], **and 3 co-authors**
([1]) Astrophysics Research Institute, Liverpool John Moores University, Liverpool, UK

The metal-poor sub-population of globular cluster (GC) systems exhibits a correlation between the GC average colour and luminosity, especially in those systems associated with massive elliptical galaxies. More luminous (more massive) GCs are typically redder and hence more metal-rich. This 'blue tilt' is often interpreted as a mass-metallicity relation stemming from GC self-enrichment, whereby more massive GCs retain a greater fraction of the enriched gas ejected by their evolving stars, fostering the formation of more metal-rich secondary generations. We examine the E-MOSAICS simulations of the formation and evolution of galaxies and their GC populations, and find that their GCs exhibit a colour-luminosity relation similar to that observed in local galaxies, without the need to invoke mass-dependent self-enrichment. We find that the blue tilt is most appropriately interpreted as a dearth of massive, metal-poor GCs: the formation of massive GCs requires high interstellar gas surface densities, conditions that are most commonly fostered by the most massive, and hence most metal rich, galaxies, at the peak epoch of GC formation. The blue tilt is therefore a consequence of the intimate coupling between the small-scale physics of GC formation and the evolving properties of interstellar gas hosted by hierarchically-assembling galaxies.

Accepted by: Monthly Notices of the Royal Astronomical Society
http://adsabs.harvard.edu/abs/2018MNRAS.480.3279U

The long-term evolution of star clusters formed with a centrally-peaked star-formation-efficiency profile

B. Shukirgaliyev [1,2], G. Parmentier [1], A. Just [1], P. Berczik [3,4]

([1]) Astronomisches Rechen-Institut, Zentrum für Astronomie der Universität Heidelberg, Germany; ([2]) Fesenkov Astrophysical Institute, Almaty, Kazakhstan; ([3]) NAO of China and Key Laboratory for Computational Astrophysics, Chinese Academy of Sciences, Beijing, China; ([4]) Main Astronomical Observatory, NAS of Ukraine, Kyiv, Ukraine

We have studied the long-term evolution of star clusters of the solar neighborhood, starting from their birth in gaseous clumps until their complete dissolution in the Galactic tidal field. We have combined the "local-density-driven cluster formation model" of Parmentier & Pfalzner (2013) with direct N-body simulations of clusters following instantaneous gas expulsion. We have studied the relation between cluster dissolution time, t_{dis}, and cluster "initial" mass, M_{init}, defined as the cluster mass at the end of the dynamical response to gas expulsion (i.e. violent relaxation), when the cluster age is 20-30 Myr. We consider the "initial" mass to be consistent with other works which neglect violent relaxation. The model clusters formed with a high star formation efficiency (SFE – i.e. gas mass fraction converted into stars) follow a tight mass-dependent relation, in agreement with previous theoretical studies. However, the low-SFE models present a large scatter in both the "initial" mass and the dissolution time, and a shallower mass-dependent relation than high-SFE clusters. Both groups differ in their structural properties on the average. Combining two populations of clusters, high- and low-SFE ones, with domination of the latter, yields a cluster dissolution time for the solar neighborhood in agreement with that inferred from observations, without any additional destructive processes such as giant molecular cloud encounters. An apparent mass-independent relation may emerge for our low-SFE clusters when we neglect low-mass clusters (as expected for extra-galactic observations), although more simulations are needed to investigate this aspect.

Accepted by: Astrophysical Journal

http://adsabs.harvard.edu/abs/2018ApJ...863..171S

. . . .

Binary black hole mergers from globular clusters: the impact of globular cluster properties

J. Hong [1,2], E. Vesperini [2], A. Askar [3,4], and 3 co-authors

([1]) Kavli Institute for Astronomy and Astrophysics, Peking University, Beijing, China; ([2]) Department of Astronomy, Indiana University, Bloomington, USA; ([3]) Nicolaus Copernicus Astronomical Centre, Polish Academy of Sciences, Warsaw, Poland; ([4]) Lund Observatory, Department of Astronomy and Theoretical Physics, Lund University, Sweden

The dense environment of globular clusters (GCs) can facilitate the formation of binary black holes (BBHs), some of which can merge with gravitational waves within the age of the Universe. We have performed a survey of Monte Carlo simulations following the dynamical evolution of GCs with different masses, sizes, and binary fractions and explored the impact of the host GC properties on the formation of BBH mergers. We find that the number of BBH mergers from GCs is determined by the GC's initial mass, size, and primordial binary fraction. We identify two groups of BBH mergers: a primordial group whose formation does not depend on cluster's dynamics, and a dynamical group whose formation is driven by the cluster's dynamical evolution. We show how the BBH origin affects the BBH mergers' main properties such as the chirp mass and merging time distributions. We provide analytic expressions for the dependence of the number of BBH mergers from individual GCs on the main cluster's structural properties and the time evolution of the merger rates of these BBHs. These expressions provide an essential ingredient for a general framework allowing to estimate the merger rate density. Using the relations found in our study, we find a local merger rate density of 0.18-1.8 $Gpc^{-3}yr^{-1}$ for primordial BBH mergers and 0.6-18 $Gpc^{-3}yr^{-1}$ for dynamical BBH mergers, depending

on the GC mass and size distributions, initial binary fraction, and the number density of GCs in the Universe.

Accepted by: Monthly Notices of the Royal Astronomical Society
http://adsabs.harvard.edu/abs/2018MNRAS.480.5645H

Miscellaneous

Isochrony in 3D radial potentials.
From Michel Hénon ideas to isochrone relativity: classification, interpretation and applications

A. Simon-Petit [1], J. Perez [1], G. Duval [2]
([1]) Ensta ParisTech, Paris Saclay University, Applied Mathematics Laboratory, France; ([2]) INSA Rouen, Mathematics & Informatics Laboratory, France

Revisiting and extending an old idea of Michel Hénon, we geometrically and algebraically characterize the whole set of isochrone potentials. Such potentials are fundamental in potential theory. They appear in spherically symmetrical systems formed by a large amount of charges (electrical or gravitational) of the same type considered in mean-field theory. Such potentials are defined by the fact that the radial period of a test charge in such potentials, provided that it exists, depends only on its energy and not on its angular momentum. Our characterization of the isochrone set is based on the action of a real affine subgroup on isochrone potentials related to parabolas in the R2 plane. Furthermore, any isochrone orbits are mapped onto associated Keplerian elliptic ones by a generalization of the Bohlin transformation. This mapping allows us to understand the isochrony property of a given potential as relative to the reference frame in which its parabola is represented. We detail this isochrone relativity in the special relativity formalism. We eventually exploit the completeness of our characterization and the relativity of isochrony to propose a deeper understanding of general symmetries such as Kepler's Third Law and Bertrand's theorem.

Accepted by: Communications in Mathematical Physics
https://arxiv.org/abs/1804.11282

. . . .

Kinematic Groups in the Corona of the Ursa Majoris Flow Indicated by Gaia Data

S. V. Vereshchagin [1], N. V. Chupina [1], E. S. Postnikova [1]
([1]) Institute of Astronomy, Russian Academy of Sciences, Moscow, Russia

The internal kinematics of the Ursa Majoris stellar flow is considered. The details of the flow structure are considered, and new candidate members are searched for using high-precision Gaia DR1 TGAS data. The flow structure is studied using apex diagrams, which have been shown to be effective in studies of open clusters. To select member-stars of the flow, a chain of filters was applied to the spatial coordinates and velocities, photometric data, and elemental abundances of potential members. The nonuniform kinematic structure of the flow, manifest through its separation into different velocity directions for the core and three groups in the corona, is confirmed. Several filters were used to identify three candidate members. These included apex diagrams, $M_V - (B-V)_0$ diagrams, and the abundances of Fe, Mg, Al, Si, Ti, and Ni.

Accepted by: Astronomy Reports
http://adsabs.harvard.edu/abs/2018ARep...62..502V

Proceedings abstracts

Astrophysical Parameters of Open Cluster NGC 6793

Z. F. Bostanci [1], T. Yontan [1], S. Bilir [1], and 4 co-authors
([1]) Department of Astronomy and Space Sciences, Science Faculty, Istanbul University, Istanbul, Turkey

We present the results of CCD UBV photometric observations of the open cluster NGC 6793. We use Gaia second data release (DR2) astrometric data to determine cluster member stars located within the cluster field. Taking into account these members, we determine the fundamental astrophysical parameters of the cluster such as reddening, distance, metallicity, and age using independent methods. We infer the reddening and metallicity of the cluster as E(B−V)=0.34±0.03 mag and [Fe/H]=−0.104±0.118 dex, respectively, using the U−B × B−V two-color diagram and UV excesses of the F-G type main-sequence stars. We fit the color-magnitude diagrams of NGC 6793 with the PARSEC isochrones and derive the distance modulus, distance and age of the cluster as μ=9.95±0.11 mag, d=601±31 pc and t=500±50 Myr, respectively.

To appear in: Turkish Physical Society 34th International Physics Congress (also it was submitted to Canadian Journal of Physics)

. . . .

Astrophysical Parameters of NGC 7086

T. Yontan [1], S. Bilir [1], Z. F. Bostanc [1], and 4 co-authors
([1]) Department of Astronomy and Space Sciences, Science Faculty, Istanbul University, Istanbul, Turkey

In this study, we present the results of CCD UBV photometric observations of the open cluster NGC 7086. We use Gaia second data release (DR2) astrometric data to determine cluster member stars in the field of the cluster. Using these members, we determine basic astrophysical parameters of the cluster such as reddening, distance, metallicity and age via independent methods. Using the U−B × B−V two-color diagram and UV-excesses of the F and G type main-sequence stars, the reddening and metallicity of NGC 7086 were inferred as E(B−V)=0.75±0.07 mag and [Fe/H]=−0.095±0.134 dex, respectively. We fit the V × U−B and V × B−V color-magnitude diagrams of NGC 7086 with the PARSEC isochrones and derive the distance modulus, distance and age of the cluster as μ=13.37±0.23 mag, d=1618±182 pc and t=150±25 Myr, respectively. Moreover, we take into account most likely member stars and calculate the distance of NGC 7086 from Gaia DR2 trigonometric parallaxes as d = 1682±139 pc. Distance values derived in this study and from Gaia DR2 data are compatible with each other. Therefore, we can say that the astrophysical parameters of the cluster are the least affected by the degeneration.

To appear in: Turkish Physical Society 34th International Physics Congress (also it was submitted to Canadian Journal of Physics)

Ph.D. (dissertation) summaries

Kinematical Evolution of Tidally Limited Star Clusters

Maria Tiongco
Department of Astronomy, Indiana University, Bloomington, IN, USA

Globular star clusters are traditionally pictured as dynamically simple and single stellar population systems; however, many recent results from photometric, spectroscopic, and astrometric studies are revealing that globular clusters are more complex than previously thought. In particular, kinematical features such as the presence of anisotropy in the velocity distribution and differential rotation, and the existence of multiple stellar populations characterized by variations in light element abundances among their stars, are some of the key observational findings. These new results and the forthcoming large amount of data from surveys such as the Gaia astrometric survey call for a renewed effort on the theoretical front to characterize the evolution of the internal kinematics of star clusters. My thesis work has aimed to build a theoretical framework to interpret these new observational results and to understand their link with a globular cluster's dynamical history. I have focused on the study of the evolution of the internal kinematics of star clusters as driven by the effects of two-body relaxation and the external Galactic tidal field. By means of a large suite of N-body simulations, I have explored the three-dimensional structure of the velocity space of tidally-perturbed clusters, by characterizing their degree of anisotropy and their rotational properties. These studies showed that a cluster's kinematical properties contain distinct imprints of the cluster's initial structural properties, dynamical history, and tidal environment. Finally, by relaxing some simplifying assumptions about the alignment of the rotation axis of the cluster relative to the tidal field, I have also shown how the interplay between a cluster's internal evolution and the interaction with the host galaxy can produce complex morphological and kinematical properties. Building on this fundamental understanding, I will study the dynamics of multiple stellar populations in globular clusters, with attention to the largely unexplored role of rotation. This body of results will provide essential guidance for a meaningful interpretation of the emerging dynamical complexity of globular clusters in the era of Gaia and other upcoming large spectroscopic surveys.

PhD thesis completed at the Indiana University under the supervision of Enrico Vesperini.

Conferences

Survival of Dense Star Clusters in the Milky Way System

19–23 November, 2018
Heidelberg, Germany
http://www.mpia.de/~mwstreams/

Registration and payment deadline: 26th October

. . . .

IAUS 351: Star Clusters: from the Milky Way to the Early Universe (MODEST 19)

27–31 May, 2019
Bologna, Italy

Save the date, details will follow