The Star Clusters Young & Old Newsletter

edited by Giovanni Carraro, Martin Netopil, and Ernst Paunzen
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Dear colleagues,

The final results of the electronic vote for the expression of interest for new IAU commissions have been published last month on the IAU webpage. Our new commission "Stellar clusters throughout cosmic space and time", led by Richard de Grijs, has obtained the second largest number of votes in Division H: Interstellar Matter & Local Universe, and is among the first fifth of all 62 proposed commissions. On April 20, the approval of the commissions will be announced by the Executive Committee.

This time, all scientific topics of the Newsletter are well covered with abstracts. Among them also a new contribution by the Gaia-ESO survey team, the kinematic study on seven globular clusters by Lardo et al. 2015. They also verified that the radial velocities delivered from the survey pipeline are of sufficient quality for a kinematic study. Pipelines are getting more and more important, and this issue contains also two approaches to study cluster parameters in an automatic way, the ASAD and ASteCA packages, by Asa'd and Perren et al., respectively.

We look forward to have everybody's help to disseminate this Newsletter everywhere! Visit our webpage frequently for news and abstracts, which reach us between the SCYON issues!

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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.

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

Star Forming Regions

Discovery of two embedded clusters with WISE in the high Galactic latitude cloud HRK 81.4-77.8

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Molecular clouds at very high latitude ($b > 60°$) away from the Galactic plane are rare and in general are expected to be non-star-forming. However, we report the discovery of two embedded clusters (Camargo 438 and Camargo 439) within the high-latitude molecular cloud HRK 81.4-77.8 using WISE. Camargo 439 with Galactic coordinates $\ell = 81.11°$ and $b = -77.84°$ is an $\sim$ 2 Myr embedded cluster (EC) located at a distance from the Sun of $d_\odot = 5.09 \pm 0.47$ kpc. Adopting the distance of the Sun to the Galactic centre $R_\odot = 7.2$ kpc we derive for Camargo 439 a Galactocentric distance of RGC $= 8.70 \pm 0.26$ kpc and a vertical distance from the plane of -4.97 ± 0.46 kpc. Camargo 438 at $\ell = 79.66°$ and $b = -78.86°$ presents similar values. The derived parameters for these two ECs put HRK 81.4-77.8 in the halo at a distance from the Galactic centre of $\sim$8.7 kpc and $\sim$5.0 kpc from the disc. Star clusters provide the only direct means to determine the high latitude molecular cloud distances. The present study shows that the molecular cloud HRK 81.4-77.8 is currently forming stars, apparently an unprecedented event detected so far among high latitude clouds. We carried out a preliminary orbit analysis. It shows that this ECs are the most distant known embedded clusters from the plane and both cloud and clusters are probably falling ballistically from the halo onto the Galactic disc, or performing a flyby.

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`http://adsabs.harvard.edu/abs/2015arXiv150103707C`

Circumstellar discs in Galactic centre clusters: Disc-bearing B-type stars in the Quintuplet and Arches clusters

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We investigate the circumstellar disc fraction as determined from L-band excess observations of the young, massive Arches and Quintuplet clusters residing in the central molecular zone of the Milky Way. The Quintuplet cluster was searched for L-band excess sources for the first time. We find a total of 26 excess sources in the Quintuplet cluster, and 21 sources with L-band excesses in the Arches cluster, of which 13 are new detections. With the aid of proper motion membership samples, the disc fraction of the Quintuplet cluster could be derived for the first time to be $4.0 \pm 0.7\%$. There is no evidence for a radially varying disc fraction in this cluster. In the case of the Arches cluster, a disc fraction of $9.2 \pm 1.2\%$ approximately out to the cluster's predicted tidal radius, $r < 1.5$ pc, is observed. This excess fraction is consistent with our previously found disc fraction in the cluster in the radial range $0.3 < r < 0.8$ pc. In both clusters, the host star mass range covers late A- to early B-type stars, $2 < M < 15\,M_{\odot}$, as derived from J-band photospheric magnitudes. We discuss the unexpected finding of dusty circumstellar discs in these UV intense environments in the context of primordial disc survival and formation scenarios of secondary discs. We consider the possibility that the L-band excess sources in the Arches and Quintuplet clusters could be the high-mass counterparts to T Tauri pre-transitional discs. As such a scenario requires a long pre-transitional disc lifetime in a UV intense environment, we suggest that mass transfer discs in binary systems are a likely formation mechanism for the B-star discs observed in these starburst clusters.

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Galactic Open Clusters

The OPD Photometric Survey of Open Clusters I. Techniques, program details and first results of robust determination of the fundamental parameters

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Open clusters are considered valuable objects for the investigation of galactic structure and dynamics since their distances, ages and velocities can be determined with good precision. According to the New Catalog of Optically Visible Open Clusters and Candidates (Dias et al. 2002) about 10% of the optically revealed open clusters remain unstudied. However, previous analysis (Moitinho 2010) has indicated that not considering this unstudied population introduces significant biases in the study of the structure and evolution of the Milky Way. In addition, a systematic revision of the data contained in the catalog, collected from the literature, is needed, due to its inhomogeneity.

In this first paper of a series, we present the observational strategy, data reduction and analysis procedures of a UBRVI photometric survey of southern open star clusters carried out at Pico dos Dias Observatory (Brazil). The aim of the program is to contribute to an unbiased, homogenous collection of cluster fundamental parameters. We show that the implementation of a sequence of systematic procedures considerably improves the quality of the results.

To illustrate the methods we present the first results based on one night of observations. The parameters, reddening, distance, age and metallicity, were obtained by fitting theoretical isochrones to cluster color-color and multidimensional color-magnitude diagrams, applying a cross-entropy optimization algorithm developed by our group, which takes into account UBVRI photometric data weighted using a membership-likelihood estimation.

Accepted by : New Astronomy

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CCD Photometry of NGC 2482 and Five Previously Unobserved Open Star Clusters

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We present Johnson B, V and Sloan ug photometry of six Galactic open clusters that have not been previously studied by means of CCD imagery. These clusters are NGC 2482, AH03 J0748-26.9, and Ruprecht 42, 51, 153, and 154. We used a cross-entropy technique developed by Monteiro and collaborators that eliminates much of the subjectivity previously inherent in main sequence fitting studies, obtaining values and robust errors for the distances, ages, color excesses, and metallicities. If the B-V color excess is larger than 0.1 mag, a value of R_V is also obtained. The clusters studied range in age from 63 Myr to 2.2 Gyr. The central region of NGC 2482 is such that ∼90 percent of the stars in the field down to V = 15.5 are cluster members. The other fields have a much higher percentage of non-cluster stars, but distinct main sequences are seen in AH03 J0748-26.9 and Ruprecht 42. Ruprecht 154 shows marginal evidence for two stellar populations of different ages, which would be a first, but we are not certain if this is even a bona fide cluster.

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http://www.jstor.org/stable/info/10.1086/679743

Sejong Open Cluster Survey (SOS) - IV. The Young Open Clusters NGC 1624 and NGC 1931

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Young open clusters located in the outer Galaxy provide us with an opportunity to study star formation activity in a different environment from the solar neighborhood. We present a UBVI and Hα photometric study of the young open clusters NGC 1624 and NGC 1931 that are situated toward the Galactic anticenter. Various photometric diagrams are used to select the members of the clusters and to determine the fundamental parameters. NGC 1624 and NGC 1931 are, on average, reddened by $< E(B-V) > = 0.92 \pm 0.05$ and 0.74 ± 0.17 mag, respectively. The properties of the reddening toward NGC 1931 indicate an abnormal reddening law ($R_{V,cl} = 5.2 \pm 0.3$). Using the zero-age main sequence fitting method we confirm that NGC 1624 is 6.0 ± 0.6 kpc away from the Sun, whereas NGC 1931 is at a distance of 2.3 ± 0.2 kpc. The results from isochrone fitting in the Hertzsprung-Russell diagram indicate the ages of NGC 1624 and NGC 1931 to be less than 4 Myr and 1.5 – 2.0 Myr, respectively. We derived the initial mass function (IMF) of the clusters. The slope of the IMF ($\Gamma_{\rm NGC1624} = -2.0 \pm 0.2$ and $\Gamma_{\rm NGC1931} = -2.0 \pm 0.1$) appears to be steeper than that of the Salpeter/Kroupa IMF. We discuss the implication of the derived IMF based on simple Monte-Carlo simulations and conclude that the property of star formation in the clusters seems not to be far different from that in the solar neighborhood.

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A revisit to the regions of some van den Bergh open clusters using photometric and astrometric parameters

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We present results of a study that combines photometry and astrometry for the open clusters vdB80, vdB85 and vdB130. We apply a model which analyses the proper motion distribution and the stellar density to find the kinematic parameters and stellar membership in the region of the mentioned open clusters. The astrometric data are obtained from UCAC4 catalogue. For each cluster, we report the centre coordinates, the components of mean proper motion, the angular diameter and the astrometric members. They are: *vdB80:* $\alpha = 97\overset{\circ}{.}73938 \pm 0\overset{\circ}{.}00846$, $\delta = -9\overset{\circ}{.}66953 \pm 0\overset{\circ}{.}01177$, $\mu_\alpha cos\delta = -2.13 \pm 0.47 mas/yr$, $\mu_\delta = -0.95 \pm 0.47 mas/yr$, $12'$, 15 members; *vdB85:* $\alpha = 101\overset{\circ}{.}71670 \pm 0\overset{\circ}{.}00808$, $\delta = 1\overset{\circ}{.}34392 \pm 0\overset{\circ}{.}01253$, $\mu_\alpha cos\delta = 0.89 \pm 0.43 mas/yr$, $\mu_\delta = 3.24 \pm 0.43 mas/yr$, $8'$, 9 members; *vdB130:* $\alpha = 304\overset{\circ}{.}44001 \pm 0\overset{\circ}{.}01407$, $\delta = 39\overset{\circ}{.}32745 \pm 0\overset{\circ}{.}00726$, $\mu_\alpha cos\delta = -4.14 \pm 0.25 mas/yr$, $\mu_\delta = -5.15 \pm 0.25 mas/yr$, $8.6'$, 9 members. We analyse the incidence of the proper motion errors in the determination of the cluster parameters and of the stellar membership and find that they are not significantly changed. We finally compare the astrometric members with the photometric ones given in the literature.

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`http://adsabs.harvard.edu/abs/2015NewA...36...70O`

Galactic Globular Clusters

On the serendipitous discovery of a Li-rich giant in the globular cluster NGC 362

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We have serendipitously identified the first lithium-rich giant star located close to the red giant branch bump in a globular cluster. Through intermediate-resolution FLAMES spectra we derived a lithium abundance of A(Li)=2.55 (assuming local thermodynamical equilibrium), which is extremely high considering the star's evolutionary stage. Kinematic and photometric analysis confirm the object as a member of the globular cluster NGC 362. This is the fourth Li-rich giant discovered in a globular cluster but the only one known to exist at a luminosity close to the bump magnitude. The three previous detections are clearly more evolved, located close to, or beyond the tip of their red giant branch. Our observations are able to discard the accretion of planets/brown dwarfs, as well as an enhanced mass-loss mechanism as a formation channel for this rare object. Whilst the star sits just above the cluster bump luminosity, its temperature places it towards the blue side of the giant branch in the colour-magnitude diagram. We require further dedicated observations to unambiguously identify the star as a red giant: we are currently unable to confirm whether Li production has occurred at the bump of the luminosity function or if the star is on the pre zero-age horizontal branch. The latter scenario provides the opportunity for the star to have synthesised Li rapidly during the core helium flash or gradually during its red giant branch ascent via some extra mixing process.

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A Measurement of Diffusion in 47 Tucanae

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Using images from the Hubble Space Telescope Wide-Field Camera 3, we measure the rate of diffusion of stars through the core of the globular cluster 47 Tucanae using a sample of young white dwarfs identified in these observations. This is the first direct measurement of diffusion due to gravitational relaxation. We find that the diffusion rate $\kappa \approx 10$–13 arcsecond^2 Myr^{-1} is consistent with theoretical estimates of the relaxation time in the core of 47 Tucanae of about 70 Myr.

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Globular Cluster Streams as Galactic High-Precision Scales – The Poster Child Palomar 5

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Using the example of the tidal stream of the Milky Way globular cluster Palomar 5 (Pal 5), we demonstrate how observational data on tidal streams can be efficiently reduced in dimensionality and modeled in a Bayesian framework. Our approach combines detection of stream overdensities by a Difference-of-Gaussians process with fast streakline models of globular cluster streams and a continuous likelihood function built from these models. Inference is performed with Markov chain Monte Carlo. By generating $\approx 10^7$ model streams, we show that the unique geometry of the Pal 5 debris yields powerful constraints on the solar position and motion, the Milky Way and Pal 5 itself. All 10 model parameters were allowed to vary over large ranges without additional prior information. Using only readily-available SDSS data and a few radial velocities from the literature, we find that the distance of the Sun from the Galactic Center is 8.30±0.25 kpc, and the transverse velocity is 253±16 km/s. Both estimates are in excellent agreement with independent measurements of these two quantities. Assuming a standard disk and bulge model, we determine the Galactic mass within Pal 5's apogalactic radius of 19 kpc to be $(2.1\pm0.4) \times 10^{11}$ $M_\odot$. Moreover, we find the potential of the dark halo with a flattening of $q_z = 0.95^{+0.16}_{-0.12}$ to be essentially spherical – at least within the radial range that is effectively probed by Pal 5. We also determine Pal 5's mass, distance and proper motion independently from other methods, which enables us to perform vital cross-checks. Our inferred heliocentric distance of Pal 5 is $23.6^{+0.8}_{-0.7}$ kpc, in perfect agreement with, and more precise than estimates from isochrone fitting of deep HST imaging data. We conclude that finding and modeling more globular cluster streams is an efficient way for mapping out the structure of our Galaxy to high precision. With more observational data and by using additional prior information, the precision of this mapping can be significantly increased.

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The Gaia-ESO Survey: Kinematics of seven Galactic globular clusters

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The Gaia-ESO survey is a large public spectroscopic survey aimed at investigating the origin and formation history of our Galaxy by collecting spectroscopy of representative samples (about 105 Milky Way stars) of all Galactic stellar populations, in the field and in clusters. The survey uses globular clusters as intra- and inter-survey calibrators, deriving stellar atmospheric parameters and abundances of a significant number of stars in clusters, along with radial velocity determinations. We used precise radial velocities of a large number of stars in seven globular clusters (NGC 1851, NGC 2808, NGC 4372, NGC 4833, NGC 5927, NGC 6752, and NGC 7078) to validate pipeline results and to preliminarily investigate the cluster internal kinematics. Radial velocity measurements were extracted from FLAMES/GIRAFFE spectra processed by the survey pipeline as part of the second internal data release of data products to ESO. We complemented our sample with ESO archival data obtained with different instrument configurations. Reliable radial velocity measurements for 1513 bona fide cluster star members were obtained in total. We measured systemic rotation, estimated central velocity

dispersions, and present velocity dispersion profiles of all the selected clusters, providing the first velocity dispersion curve and the first estimate of the central velocitydispersion for the cluster NGC 5927. Finally, we explore the possible link between cluster kinematics and other physical parameters. The analysis we present here demonstrates that Gaia-ESO survey data are sufficiently accurate to be used in studies of kinematics of stellar systems and stellar populations in the Milky Way.

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The Hubble Space Telescope UV Legacy Survey of galactic globular clusters - II. The seven stellar populations of NGC 7089 (M2)

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We present high-precision multiband photometry for the globular cluster (GC) M2. We combine the analysis of the photometric data obtained from the Hubble Space Telescope UV Legacy Survey of Galactic GCs GO-13297, with chemical abundances by Yong et al., and compare the photometry with models in order to analyse the multiple stellar sequences we identified in the colour-magnitude diagram. We find three main stellar components, composed of metal-poor, metal-intermediate, and metal-rich stars (hereafter referred to as population A, B, and C, respectively). The components A and B include stars with different s-process element abundances. They host six sub-populations with different light-element abundances, and exhibit an internal variation in helium up to $\Delta Y \sim 0.07$ dex. In contrast with M22, another cluster characterized by the presence of populations with different metallicities, M2 contains a third stellar component, C, which shows neither evidence for sub-populations nor an internal spread in light-elements. Population C does not exhibit the typical photometric signatures that are associated with abundance variations of light elements produced by hydrogen burning at hot temperatures. We compare M2 with other GCs with intrinsic heavy-element variations and conclude that M2 resembles M22, but it includes an additional stellar component that makes it more similar to the central region of the Sagittarius galaxy, which hosts a GC (M54) and the nucleus of the Sagittarius galaxy itself.

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Clusters in the Magellanic clouds

The Morphology of the Sub-Giant Branch and Red Clump Reveal No Sign of Age Spreads in Intermediate Age Clusters

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A recent surprise in stellar cluster research, made possible through the precision of Hubble Space Telescope photometry, was that some intermediate age (1–2 Gyr) clusters in the Large and Small Magellanic Clouds have main sequence turn-off (MSTO) widths that are significantly broader than would be expected for a simple stellar population (SSP). One interpretation of these extended MSTOs (eMSTOs) is that age spreads of the order of ∼500 Myr exist within the clusters, radically redefining our view of stellar clusters, which are traditionally thought of as single age, single metallicity stellar populations. Here we test this interpretation by studying other regions of the CMD that should also be affected by such large age spreads, namely the width of the sub-giant branch (SGB) and the red clump (RC). We study two massive clusters in the LMC that display the eMSTO phenomenon (NGC 1806 & NGC 1846) and show that both have SGB and RC morphologies that are in conflict with expectations if large age spreads exist within the clusters. We conclude that the SGB and RC widths are inconsistent with extended star-formation histories within these clusters, hence age spreads are not likely to be the cause of the eMSTO phenomenon. Our results are in agreement with recent studies that also have cast doubt on whether large age spreads can exist in massive clusters; namely the failure to find age spreads in young massive clusters, a lack of gas/dust detected within massive clusters, and homogeneous abundances within clusters that exhibit the eMSTO phenomenon.

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Star-formation rates from young-star counts and the structure of the ISM across the NGC346/N66 complex in the SMC

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The rate at which interstellar gas is converted into stars, and its dependence on environment, is one of the pillars on which our understanding of the visible Universe is build. We present a comparison of the surface density of young stars (Σ_*) and dust surface density (Σ_d) across NGC346 (N66) in 115 independent pixels of 6×6 pc^2. We find a correlation between Σ_* and Σ_d with a considerable scatter. A power law fit to the data yields a steep relation with an exponent of 2.6±0.2. We convert Σ_d to gas surface density (Σ_g) and Σ_* to star formation rate (SFR) surface densities (Σ_{SFR}), using simple assumptions for the gas-to-dust mass ratio and the duration of star formation. The derived total SFR ($4\pm1\cdot10^{-3}$ M$_\odot$ yr^{-1}) is consistent with SFR estimated from the Hα emission integrated over the Hα nebula. On small scales the Σ_{SFR} derived using Hα systematically underestimates the count-based Σ_{SFR}, by up to a factor of 10. This is due to ionizing photons escaping the area, where the stars are counted. We find that individual 36 pc^2 pixels fall systematically above integrated disc-galaxies in the Schmidt-Kennicutt diagram by on average a factor of ∼7. The NGC346 average SFR over a larger area (90 pc radius) lies closer to the relation but remains high by a factor of ∼3. The fraction of the

total mass (gas plus young stars) locked in young stars is systematically high (∼10 per cent) within the central 15 pc and systematically lower outside (2 per cent), which we interpret as variations in star formation efficiency. The inner 15 pc is dominated by young stars belonging to a centrally condensed cluster, while the outer parts are dominated by a dispersed population. Therefore, the observed trend could reflect a change of star formation efficiency between clustered and non-clustered star-formation.

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No Evidence for Significant Age Spreads in Young Massive LMC Clusters

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Recent discoveries have put the picture of stellar clusters being simple stellar populations into question. In particular, the color-magnitude diagrams of intermediate age (1–2 Gyr) massive clusters in the Large Magellanic Cloud (LMC) show features that could be interpreted as age spreads of 100–500 Myr. If multiple generations of stars are present in these clusters then, as a consequence, young (<1 Gyr) clusters with similar properties should have age spreads of the same order. In this paper we use archival Hubble Space Telescope (HST) data of eight young massive LMC clusters (NGC 1831, NGC 1847, NGC 1850, NGC 2004, NGC 2100, NGC 2136, NGC 2157 and NGC 2249) to test this hypothesis. We analyzed the color-magnitude diagrams of these clusters and fitted their star formation history to derive upper limits of potential age spreads. We find that none of the clusters analyzed in this work shows evidence for an extended star formation history that would be consistent with the age spreads proposed for intermediate age LMC clusters. Tests with artificial single age clusters show that the fitted age dispersion of the youngest clusters is consistent with spreads that are purely induced by photometric errors. As an additional result we determined a new age of NGC 1850 of ∼100 Myr, significantly higher than the commonly used value of about 30 Myr, although consistent with early HST estimates.

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The most distant clusters

Constraining globular cluster formation through studies of young massive clusters - V. ALMA observations of clusters in the Antennae

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Some formation scenarios that have been put forward to explain multiple populations within Globular Clusters (GCs) require that the young massive cluster have large reservoirs of cold gas within them, which is necessary to form future generations of stars. In this paper we use deep observations taken with Atacama Large Millimeter/sub-millimeter Array (ALMA) to assess the amount of molecular gas within 3 young (50–200 Myr) massive ($\sim10^6$ $M_\odot$) clusters in the Antennae galaxies. No significant CO(3–2) emission was found associated with any of the three clusters. We place upper limits for the molecular gas within these clusters of $\sim1\times10^5$ $M_\odot$ (or <9 % of the current stellar mass). We briefly review different scenarios that propose multiple episodes of star formation and discuss some of their assumptions and implications. Our results are in tension with the predictions of GC formation scenarios that expect large reservoirs of cool gas within young massive clusters at these ages.

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PHAT Stellar Cluster Survey II. Andromeda Project Cluster Catalog

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We construct a stellar cluster catalog for the Panchromatic Hubble Andromeda Treasury (PHAT) survey using image classifications collected from the Andromeda Project citizen science website. We identify 2,753 clusters and 2,270 background galaxies within $\sim$0.5 deg^2 of PHAT imaging searched, or $\sim$400 kpc^2 in deprojected area at the distance of the Andromeda galaxy (M31). These identifications result from 1.82 million classifications of $\sim$20,000 individual images (totaling $\sim$7 gigapixels) by tens of thousands of volunteers. We show that our crowd-sourced approach, which collects >80 classifications per image, provides a robust, repeatable method of cluster identification. The high spatial resolution Hubble Space Telescope images resolve individual stars in each cluster and are instrumental in the factor of $\sim$6 increase in the number of clusters known within the survey footprint. We measure integrated photometry in six filter passbands, ranging from the near-UV to the near-IR. PHAT clusters span a range of $\sim$8 magnitudes in F475W (g-band) luminosity, equivalent to $\sim$4 decades in cluster mass. We perform catalog completeness analysis using >3000 synthetic cluster simulations to determine robust detection limits and demonstrate that the catalog is 50% complete down to $\sim$500 $M_\odot$ for ages <100 Myr. We include catalogs of clusters, background galaxies, remaining unselected candidates, and synthetic cluster simulations, making all information publicly available to the community. The catalog published here serves as the definitive base data product for PHAT cluster science, providing a census of star clusters in an L* spiral galaxy with unmatched sensitivity and quality.

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Accretion in action: phase space coherence of stellar debris and globular clusters in Andromeda's South-West Cloud

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A central tenet of the current cosmological paradigm is that galaxies grow over time through the accretion of smaller systems. Here, we present new kinematic measurements near the centre of one of the densest pronounced substructures, the South-West Cloud, in the outer halo of our nearest giant neighbour, the Andromeda galaxy. These observations reveal that the kinematic properties of this region of the South-West Cloud are consistent with those of PA-8, a globular cluster previously shown to be co-spatial with the stellar substructure. In this sense, the situation is reminiscent of the handful of globular clusters that sit near the heart of the Sagittarius dwarf galaxy, a system that is currently being accreted into the Milky Way, confirming that accretion deposits not only stars but also globular clusters into the haloes of large galaxies.

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Integrated Light Chemical Tagging Analyses of Seven M31 Outer Halo Globular Clusters from the Pan-Andromeda Archaeological Survey

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Detailed chemical abundances are presented for seven M31 outer halo globular clusters (with projected distances from M31 greater than 30 kpc), as derived from high resolution integrated light spectra taken with the Hobby Eberly Telescope. Five of these clusters were recently discovered in the Pan-Andromeda Archaeological Survey (PAndAS)—this paper presents the first determinations of integrated Fe, Na, Mg, Ca, Ti, Ni, Ba, and Eu abundances for these clusters. Four of the target clusters (PA06, PA53, PA54, and PA56) are metal-poor ([Fe/H] < -1.5), alpha-enhanced (though they are possibly less alpha-enhanced than Milky Way stars at the 1 sigma level), and show signs of star-to-star Na and Mg variations. The other three globular clusters (H10, H23, and PA17) are more metal rich, with metallicities ranging from [Fe/H] $= -1.4$ to -0.9. While H23 is chemically similar to Milky Way field stars, Milky Way globular clusters, and other M31 clusters, H10 and PA17 have moderately low [Ca/Fe], compared to Milky Way field stars and clusters. Additionally, PA17's high [Mg/Ca] and [Ba/Eu] ratios are distinct from Milky Way stars, and are in better agreement with the stars and clusters in the Large Magellanic Cloud (LMC). None of the clusters studied here can be conclusively linked to any of the identified streams from PAndAS; however, based on their locations, kinematics, metallicities, and detailed abundances, the most metal-rich PAndAS clusters H23 and PA17 may be associated with the progenitor of the Giant Stellar Stream, H10 may be associated with the SW Cloud, and PA53 and PA56 may be associated with the Eastern Cloud.

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Dynamical evolution - Simulations

The formation of NGC 3603 young starburst cluster: "prompt" hierarchical assembly or monolithic starburst?

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The formation of very young massive clusters or 'starburst' clusters is currently one of the most widely debated topic in astronomy. The classical notion dictates that a star cluster is formed in situ in a dense molecular gas clump. The stellar radiative and mechanical feedback to the residual gas energizes the latter until it escapes the system. The newly born gas-free young cluster eventually readjusts with the corresponding mass-loss. Based on the observed substructured morphologies of many young stellar associations, it is alternatively suggested that even the smooth-profiled massive clusters are also assembled from migrating less massive subclusters. A very young (age approx. 1 Myr), massive (> 10000 solar mass) star cluster like the Galactic NGC 3603 young cluster (HD 97950) is an appropriate testbed for distinguishing between the above 'monolithic' and 'hierarchical' formation scenarios. A recent study by Banerjee & Kroupa demonstrates that the monolithic scenario remarkably reproduces the HD 97950 cluster. In particular, its shape, internal motion and the mass distribution of stars are found to follow naturally and consistently from a single model calculation undergoing approx. 70 per cent by mass gas dispersal. In this work, we explore the possibility of the formation of the above cluster via hierarchical assembly of subclusters. These subclusters are initially distributed over a wide range of spatial volumes and have various modes of subclustering in both absence and presence of a background gas potential. Unlike the above monolithic initial system that reproduces HD 97950 very well, the same is found to be prohibitive with hierarchical assembly alone (with/without a gas potential). Only those systems which assemble promptly into a single cluster (in approx. 1 Myr) from a close separation (all within approx. 2 pc) could match the observed density profile of HD 97950 after a similar gas removal. These results therefore suggest that the NGC 3603 young cluster has formed essentially monolithically, i.e., either in situ or via a prompt assembly, followed by a substantial residual gas expulsion. Both scenarios are consistent with the inferred young age and the small age spread of this cluster. Future observations of molecular cloud filaments with ALMA and proper motion measurements of young clusters with Gaia will provide more direct tests of such birth environments.

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Neutron star natal kicks and the long-term survival of star clusters

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We investigate the dynamical evolution of a star cluster in an external tidal field by using `N-body` simulations, with focus on the effects of the presence or absence of neutron star natal velocity kicks.We show that, even if neutron stars typically represent less than 2% of the total bound mass of a star cluster, their primordial kinematic properties may affect the lifetime of the system by up to almost a factor of four. We interpret this result in the light of two known modes of star cluster dissolution, dominated by either early stellar evolution mass loss or two-body relaxation. The competition between these effects shapes the mass loss profile of star clusters, which may either dissolve abruptly ("jumping"), in the pre-core-collapse phase, or gradually ("skiing"), after having reached core collapse.

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The Dynamical Evolution of Stellar Black Holes in Globular Clusters

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Our current understanding of the stellar initial mass function and massive star evolution suggests that young globular clusters may have formed hundreds to thousands of stellar-mass black holes, the remnants of stars with initial masses from $\sim 20 - 100\,M_{\odot}$. Birth kicks from supernova explosions may eject some black holes from their birth clusters, but most should be retained. Using a Monte Carlo method we investigate the long-term dynamical evolution of globular clusters containing large numbers of stellar black holes. We describe numerical results for 42 models, covering a range of realistic initial conditions, including up to 1.6×10^6 stars. In almost all models we find that significant numbers of black holes (up to $\sim 10^3$) are retained all the way to the present. This is in contrast to previous theoretical expectations that most black holes should be ejected dynamically within a few Gyr. The main reason for this difference is that core collapse driven by black holes (through the Spitzer "mass segregation instability") is easily reverted through three-body processes, and involves only a small number of the most massive black holes, while lower-mass black holes remain well-mixed with ordinary stars far from the central cusp. Thus the rapid segregation of stellar black holes does not lead to a long-term physical separation of most black holes into a dynamically decoupled inner core, as often assumed previously. Combined with the recent detections of several black hole X-ray binary candidates in Galactic globular clusters, our results suggest that stellar black holes could still be present in large numbers in many globular clusters today, and that they may play a significant role in shaping the long-term dynamical evolution and the present-day dynamical structure of many clusters.

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Which young clusters/associations are we missing today?

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Currently clusters/associations of stars are mainly detected as surface density enhancements relative to the background field. While clusters form, their surface density increases. It likely decreases again at the end of the star formation process when the system expands as a consequence of gas expulsion. Therefore the surface density of a single cluster can change considerably in young clusters/associations during the first 20 Myr of their development. We investigate the effect of the gas expulsion on the detectability of clusters/associations typical for the solar neighborhood, where the star formation efficiency is <35%. The main focus will be laid on the dependence on the initial cluster mass. *Nbody* methods are used to determine the cluster/association dynamics after gas expulsion. We find that, even for low background densities, only clusters/associations with initial central surface densities exceeding a few 5000 $M_\odot\,pc^{-2}$ will be detected as clusters at ages ∼5 Myr. Even the Orion Nebula cluster, one of the most massive nearby clusters, would only be categorized as a small comoving group with current methods after 5 Myr of development. This means that cluster expansion leads to a selection effect - at ages of <1–2 Myr the full range of clusters/associations is observed whereas at ages > 4 Myr only the most massive clusters are identified, while systems with initially $M_c < 3\,000\ M_\odot$ are missing. The temporal development of stellar properties is usually determined by observing clusters of different ages. The potentially strong inhomogeneity of the cluster sample makes this methods highly questionable. However, Gaia could provide the means to rectify this situation as it will be able to detect lower mass clusters.

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A flexible method to evolve collisional systems and their tidal debris in external potentials

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We introduce a numerical method to integrate tidal effects on collisional systems, using any definition of the external potential as a function of space and time. Rather than using a linearisation of the tidal field, this new method follows a differential technique to numerically evaluate the tidal acceleration and its time derivative. Theses are then used to integrate the motions of the components of the collisional systems, like stars in star clusters, using a predictor-corrector scheme. The versatility of this approach allows the study of star clusters, including their tidal tails, in complex, multi-components, time-evolving external potentials. The method is implemented in the code `NBODY6` (Aarseth 2003).
Code available at: `http://personal.ph.surrey.ac.uk/~fr0005/nbody6tt.php`

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Biases in the inferred mass-to-light ratio of globular clusters: no need for variations in the stellar mass function

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From a study of the integrated light properties of 200 globular clusters (GCs) in M31, Strader et al. found that the mass-to-light ratios are lower than what is expected from simple stellar population (SSP) models with a 'canonical' stellar initial mass function (IMF), with the discrepancy being larger at high metallicities. We use dynamical multi-mass models, that include a prescription for equipartition, to quantify the bias in the inferred dynamical mass as the result of the assumption that light follows mass. For a universal IMF and a metallicity dependent present day mass function we find that the inferred mass from integrated light properties systematically under estimates the true mass, and that the bias is more important at high metallicities, as was found for the M31 GCs. We show that mass segregation and a flattening of the mass function have opposing effects of similar magnitude on the mass inferred from integrated properties. This makes the mass-to-light ratio as derived from integrated properties an inadequate probe of the low-mass end of the stellar mass function. There is, therefore, no need for variations in the IMF, nor the need to invoke depletion of low-mass stars, to explain the observations. Finally, we find that the retention fraction of stellar-mass black holes (BHs) is an equally important parameter in understanding the mass segregation bias. We speculatively put forward to idea that kinematical data of GCs can in fact be used to constrain the total mass in stellar-mass BHs in GCs.

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Miscellaneous

Analyzer of spectra for Age Determination (ASAD) - algorithm and applications

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Analyzer of Spectra for Age Determination (`ASAD`) is a new package that can easily predict the age and reddening of stellar clusters from their observed optical integrated spectra by comparing them to synthesis model spectra. The ages obtained with `ASAD` are consistent with ages obtained from previous cluster age methods requiring a more rigorous and time-consuming analysis. This package not only provides fast results, but also allows the user to comprehend the accuracy of these results by providing surface plots and spectral plots for all combinations of observations and models. `ASAD` is available for download on the Web and can be immediately used on both Mac and Windows.

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The inefficiency of satellite accretion in forming extended star clusters

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The distinction between globular clusters and dwarf galaxies has been progressively blurred by the recent discoveries of several extended star clusters, with size (20–30 pc) and luminosity ($-6 < M_V < -2$) comparable to the one of faint dwarf spheroidals. In order to explain their sparse structure, it has been suggested that they formed as star clusters in dwarf galaxy satellites that later accreted onto the Milky Way. If these clusters form in the centre of dwarf galaxies, they evolve in a tidally-compressive environment where the contribution of the tides to the virial balance can become significant, and lead to a super-virial state and subsequent expansion of the cluster, once removed. Using N-body simulations, we show that a cluster formed in such an extreme environment undergoes a sizable expansion, during the drastic variation of the external tidal field due to the accretion process. However, we show that the expansion due to the removal of the compressive tides is not enough to explain the observed extended structure, since the stellar systems resulting from this process are always more compact than the corresponding clusters that expand in isolation due to two-body relaxation. We conclude that an accreted origin of extended globular clusters is unlikely to explain their large spatial extent, and rather favor the hypothesis that such clusters are already extended at the stage of their formation.

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`http://arxiv.org/abs/1411.1069`

A Hero's little horse: Discovery of a dissolving star cluster in Pegasus

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We report the discovery of an ultra-faint stellar system in the constellation of Pegasus. This concentration of stars was detected by applying our overdensity detection algorithm to the Sloan Digital Sky Survey Data Release 10 and confirmed with deeper photometry from the Dark Energy Camera (DECam) at the 4 m Blanco telescope. The best-fitting model isochrone indicates that this stellar system, Kim 1, features an old (12 Gyr) and metal-poor ([Fe/H] ~ -1.7) stellar population at a heliocentric distance of 19.8 $\pm$ 0.9 kpc. We measure a half-light radius of 6.9 $\pm$ 0.6 pc using a Plummer profile. The small physical size and the extremely low luminosity are comparable to the faintest known star clusters Segue 3, Koposov 1 and 2, and Muñoz 1. However, Kim 1 exhibits a lower star concentration and is lacking a well-defined center. It also has an unusually high ellipticity and irregular outer isophotes, which suggests that we are seeing an intermediate mass star cluster being stripped by the Galactic tidal field. An extended search for evidence of an associated stellar stream within the 3 deg^2 DECam field remains inconclusive. The finding of Kim 1 is consistent with current overdensity detection limits and supports the hypothesis that there are still a substantial number of extreme low-luminosity star clusters undetected in the wider Milky Way halo.

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`http://iopscience.iop.org/0004-637X/799/1/73/`

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Discovery of a faint outer halo Milky Way star cluster in the southern sky

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We report the discovery of a new, low luminosity star cluster in the outer halo of the Milky Way. High quality *gr* photometry is presented, from which a color-magnitude diagram is constructed, and estimates of age, [Fe/H], [α/Fe], and distance are derived. The star cluster, which we designate as Kim 2, lies at a heliocentric distance of $\sim$105 kpc. With a half-light radius of $\sim$12.8 pc and ellipticity of $\epsilon \sim 0.12$, it shares the properties of outer halo GCs, except for the higher metallicity ([Fe/H] ~ -1.0) and lower luminosity ($M_V \sim -1.5$). These parameters are similar to those for the globular cluster AM 4, that is considered to be associated with the Sagittarius dwarf spheroidal galaxy. We find evidence of dynamical mass segregation and the presence of extra-tidal stars that suggests Kim 2 is most likely a star cluster. Spectroscopic observations for radial-velocity membership and chemical abundance measurements are needed to further understand the nature of the object.

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ASteCA - Automated Stellar Cluster Analysis

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We present the **A**utomated **Ste**llar **C**luster **A**nalysis package (`ASteCA`), a suit of tools designed to fully automate the standard tests applied on stellar clusters to determine their basic parameters. The set of functions included in the code make use of positional and photometric data to obtain precise and objective values for a given cluster's center coordinates, radius, luminosity function and integrated color magnitude, as well as characterizing through a statistical estimator its probability of being a true physical cluster rather than a random overdensity of field stars. `ASteCA` incorporates a Bayesian field star decontamination algorithm capable of assigning membership probabilities using photometric data alone. An isochrone fitting process based on the generation of synthetic clusters from theoretical isochrones and selection of the best fit through a genetic algorithm is also present, which allows `ASteCA` to provide accurate estimates for a cluster's metallicity, age, extinction and distance values along with its uncertainties. To validate the code we applied it on a large set of over 400 synthetic `MASSCLEAN` clusters with varying degrees of field star contamination as well as a smaller set of 20 observed Milky Way open clusters (Berkeley 7, Bochum 11, Czernik 26, Czernik 30, Haffner 11, Haffner 19, NGC 133, NGC 2236, NGC 2264, NGC 2324, NGC 2421, NGC 2627, NGC 6231, NGC 6383, NGC 6705, Ruprecht 1, Tombaugh 1, Trumpler 1, Trumpler 5 and Trumpler 14) studied in the literature. The results show that `ASteCA` is able to recover cluster parameters with an acceptable precision even for those clusters affected by substantial field star contamination.
`ASteCA` is written in Python and is made available as an open source code which can be downloaded ready to be used from it's official site.

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`http://arxiv.org/abs/1412.2366`

Conferences

Orion (un)plugged

1-8 July, 2015
Vienna, Austria
https://www.univie.ac.at/alveslab/orion_unplugged/

The meeting will have two main parts: an online conference, followed by a physical meeting.
Registration deadline: April 30, 2015

Feedback in the Magellanic Clouds

5-7 October, 2015
Baltimore, USA
http://www.stsci.edu/institute/conference/fimc/

Abstract submission deadline: April 30, 2015.