The Star Clusters Young & Old Newsletter

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Dear colleagues,

Mid-September saw the long-awaited Gaia Data Release 1. With it came a preliminary analysis of the Pleiades, which put this standard open cluster close to the distance derived by other methods. Clearly, the Hipparcos parallax measurements of the Pleiades are apparently wrong, for yet unknown reasons. Hopefully, in the next SCYON issue, we can already report the first results for star clusters based on the Gaia DR1. As often mentioned in the past, these astrometric and kinematic data should shed a new light on the nature of Galactic star clusters.
Star clusters in the Magellanic Clouds keep attracting a lot of interest, and no solution has been found so far for the mysterious width of their Main Sequence close to the Turn Off Point. Among the various hypotheses we recall stellar rotation and extended star formation. Recently, a new idea came out, presented in one of this issue abstracts, which invokes stars' variability to explain the broadening of the Main Sequence, and builds on the fact that customarily only a few images are taken to construct Color Magnitude Diagrams, thus loosing control of the variability effect. Basically, stars are caught at whatever phase. Will this be the last explanation? We do not know, but the saga is continuing.
This issue includes 26 abstracts and a number of conference announcements. We note that for some conferences deadlines are just around the corner, so please register and send abstracts in due time!

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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

The Gould's Belt Distances Survey (GOBELINS) I. Trigonometric parallax distances and depth of the Ophiuchus complex

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We present the first results of the Gould's Belt Distances Survey (GOBELINS), a project aimed at measuring the proper motion and trigonometric parallax of a large sample of young stars in nearby regions using multi-epoch Very Long Baseline Array (VLBA) radio observations. Enough VLBA detections have now been obtained for 16 stellar systems in Ophiuchus to derive their parallax and proper motion. This leads to distance determinations for individual stars with an accuracy of 0.3 to a few percent. In addition, the orbits of 6 multiple systems were modelled by combining absolute positions with VLBA (and in some cases, near infrared) angular separations. Twelve stellar systems are located in the dark cloud Lynds 1688; the individual distances for this sample are highly consistent with one another, and yield a mean parallax for Lynds 1688 of $\varpi = 7.28 \pm 0.06$ mas, corresponding to a distance $d = 137.3 \pm 1.2$ pc. This represents an accuracy better than 1%. Three systems for which astrometric elements could be measured are located in the eastern streamer (Lynds 1689) and yield an estimate of $\varpi = 6.79 \pm 0.16$ mas, corresponding to a distance $d = 147.3 \pm 3.4$ pc. This suggests that the eastern streamer is located about 10 pc farther than the core, but this conclusion needs to be confirmed by observations (currently being collected) of additional sources in the eastern streamer. From the measured proper motions, we estimate the one-dimensional velocity dispersion in Lynds 1688 to be 2.8±1.8 and 3.0±2.0 km s^{-1}, in R.A. and DEC., respectively; these are larger than, but still consistent within 1σ, with those found in other studies.

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`https://arxiv.org/abs/1611.06466`

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The Gould's Belt Distances Survey (GOBELINS) II. Distances and structure towards the Orion Molecular Clouds

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We present the results of the Gould's Belt Distances Survey (GOBELINS) of young star forming regions towards the Orion Molecular Cloud Complex. We detected 36 YSOs with the Very Large Baseline Array (VLBA), 27 of which have been observed in at least 3 epochs over the course of 2 years. At least half of these YSOs belong to multiple systems. We obtained parallax and proper motions towards these stars to study the structure and kinematics of the Complex. We measured a distance of 388±5 pc towards the Orion Nebula Cluster, 428±10 pc towards the southern portion L1641, 388±10 pc towards NGC 2068, and roughly ∼420 pc towards NGC 2024. Finally, we observed a strong degree of plasma radio scattering towards λ Ori.

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Young stellar clusters containing massive young stellar objects in the VVV Survey

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The purpose of this research is to study the connections of the global properties of eight young stellar clusters projected in the Vista Variables in the Via Láctea (VVV) ESO Large Public Survey disk area and their young stellar object (YSO) populations. The analysis is based on the combination of spectroscopic parallax-based reddening and distance determinations with main-sequence and pre-main-sequence isochrone fitting to determine the basic parameters (reddening, age, distance) of the sample clusters. The lower mass limit estimations show that all clusters are low or intermediate mass (between 110 and 1800 $M_{\odot}$), the slope Γ of the obtained present-day mass functions of the clusters is close to the Kroupa initial mass function. The YSOs in the cluster's surrounding fields are classified using low resolution spectra, spectral energy distribution fits with theoretical predictions, and variability, taking advantage of multi-epoch VVV observations. All spectroscopically confirmed YSOs (except one) are found to be massive (more than 8 $M_{\odot}$). Using VVV and GLIMPSE color–color cuts we have selected a large number of new YSO candidates, which are checked for variability and 57 per cent are found to show at least low-amplitude variations. In few cases it was possible to distinguish between YSO and AGB classifications on the basis of light curves.

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`http://adsabs.harvard.edu/abs/2016AJ....152...74B`

Galactic Open Clusters

The Age and Distance of the Kepler Open Cluster NGC 6811 from an Eclipsing Binary, Turnoff Star Pulsation, and Giant Asteroseismology

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We present the analysis of an eccentric, partially eclipsing long-period (P = 19.23 days) binary system KIC 9777062 that contains main-sequence stars near the turnoff of the intermediate-age open cluster NGC 6811. The primary is a metal-lined Am star with a possible convective blueshift to its radial velocities, and one star (probably the secondary) is likely to be a γ Dor pulsator. The component masses are 1.603 $\pm$ 0.006(stat.) $\pm$ 0.016(sys.) and 1.419 $\pm$ 0.003 $\pm$ 0.008 $M_\odot$, and the radii are 1.744 $\pm$ 0.004 $\pm$ 0.002 and 1.544 $\pm$ 0.002 $\pm$ 0.002 $R_\odot$. The isochrone ages of the stars are mildly inconsistent: the age from the mass-radius combination for the primary (1.05 $\pm$ 0.05 $\pm$ 0.09 Gyr, where the last quote was systematic uncertainty from models and metallicity) is smaller than that from the secondary (1.21 $\pm$ 0.05 $\pm$ 0.15 Gyr) and is consistent with the inference from the color-magnitude diagram (1.00 $\pm$ 0.05 Gyr). We have improved the measurements of the asteroseismic parameters $\Delta\nu$ and ν_{max} for helium-burning stars in the cluster. The masses of the stars appear to be larger (or alternately, the radii appear to be smaller) than predicted from isochrones using the ages derived from the eclipsing stars. The majority of stars near the cluster turnoff are pulsating stars: we identify a sample of 28 δ Sct, 15 γ Dor, and 5 hybrid types. We used the period-luminosity relation for high-amplitude δ Sct stars to fit the ensemble of the strongest frequencies for the cluster members, finding $(m-M)_V$=10.37$\pm$0.03. This is larger than most previous determinations, but smaller than values derived from the eclipsing binary (10.47 $\pm$ 0.05).

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`http://adsabs.harvard.edu/abs/2016ApJ...831...11S`

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Nine new open clusters within 500 pc from the Sun

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Aims: One of the results of the Milky Way Star Clusters (MWSC) survey was the detection of a slight under-density of old (ca. 1 Gyr) clusters within the nearest kilo-parsec from the Sun. This under-density may be due to an ineffectiveness in the detection of larger structures with lower surface brightness. We report on our attempts to reveal such clusters. Methods: We derived proper motions from a combination of Tycho-2 with URAT1, and obtained a mean precision of about 1.4 mas/yr per coordinate for 1.3 million stars north of -20° declination. We cut the sky into narrow proper motion slices and searched for spatial over-densities of stars in each slice. We then examined stars from over-densities in optical and near-infrared colour-magnitude diagrams to determine if they are compatible with isochrones of a cluster. We estimated the field star contamination using our data and the Besançon Galactic model. Results: We detected nine hitherto unknown open clusters in the vicinity of the Sun with ages between 70 Myr and 1 Gyr, and distances between 200 and 500 pc.

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`http://adsabs.harvard.edu/abs/2016A%26A...595A..22R`

The evolution of the Milky Way: new insights from open clusters

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We have collected high-dispersion echelle spectra of red giant members in the twelve open clusters (OCs) and derived stellar parameters and chemical abundances for 26 species by either line equivalent widths or synthetic spectrum analyses. We confirm the lack of an age-metallicity relation for OCs but argue that such a lack of trend for OCs arise from the limited coverage in metallicity compared to that of field stars which span a wide range in metallicity and age. We confirm that the radial metallicity gradient of OCs is steeper (flatter) for Rgc $<$ 12 kpc ($>$ 12 kpc). We demonstrate that the sample of clusters constituting a steep radial metallicity gradient of slope -0.052 ± 0.011 dex kpc^{-1} at Rgc $<$ 12 kpc are younger than 1.5 Gyr and located close to the Galactic midplane ($|z| < 0.5$ kpc) with kinematics typical of the thin disc. Whereas the clusters describing a shallow slope of -0.015 ± 0.007 dex kpc^{-1} at Rgc $>$ 12 kpc are relatively old, thick disc members with a striking spread in age and height above the midplane ($0.5 < |z| < 2.5$ kpc). Our investigation reveals that the OCs and field stars yield consistent radial metallicity gradients if the comparison is limited to samples drawn from the similar vertical heights. We argue via the computation of Galactic orbits that all the outer disc clusters were actually born inward of 12 kpc but the orbital eccentricity has taken them to present locations very far from their birthplaces.

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Search for variables in six Galactic open clusters

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Variables in open cluster (known distance, age, and metallicity) fields play an important role in stellar astrophysics because they allow to investigate the interior of stars. Therefore, six Galactic open clusters were selected to search for new variables and to complement data for already known variables. As five of these clusters are younger than 40 Myr, we aim at finding variable high-mass stars such as β Cephei and Slowly Pulsating B-type stars as well as classical pulsating stars within the instability strip. About 26 000 images (312 h) photometric images were taken at the 0.8 m (Vienna, Austria) and 1.0 m (Hvar, Croatia) telescope using V and I filters. The differential light curves were analyzed with standard time series analysis methods. In total, 11 variables were found in all investigated clusters. For nine of them, we were able to determine their nature and period. In addition, the membership probabilities from the literature were analyzed.

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`http://adsabs.harvard.edu/abs/2017NewA...52..133P`

A constraint on the formation timescale of the young open cluster NGC 2264: Lithium abundance of pre-main sequence stars

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The timescale of cluster formation is an essential parameter in order to understand the formation process of star clusters. Pre-main sequence (PMS) stars in nearby young open clusters reveal a large spread in brightness. If the spread were considered to be a result of a real spread in age, the corresponding cluster formation timescale would be about 5–20 Myr. Hence it could be interpreted that star formation in an open cluster is prolonged for up to a few tens of Myr. However, difficulties in reddening correction, observational errors, and systematic uncertainties introduced by imperfect evolutionary models for PMS stars can result in an artificial age spread. Alternatively, we can utilize Li abundance as a relative age indicator of PMS star to determine the cluster formation timescale. The optical spectra of 134 PMS stars in NGC 2264 have been obtained with MMT/Hectochelle. The equivalent widths have been measured for 86 PMS stars with a detectable Li line ($3500 < T_{\rm eff}$ [K] ≤ 6500). Li abundance under the condition of local thermodynamic equilibrium (LTE) was derived using the conventional curve of growth method. After correction for non-LTE effects, we find that the initial Li abundance of NGC 2264 is A(Li) = 3.2 $\pm$ 0.2. From the distribution of the Li abundances, the underlying age spread of the visible PMS stars is estimated to be about 3–4 Myr and this, together with the presence of embedded populations in NGC 2264, suggests that the cluster formed on a timescale shorter than 5 Myr.

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`http://adsabs.harvard.edu/abs/2016ApJ...831..116L`

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Prospecting for chemical tags among open clusters

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Determinations of the chemical composition of red giants in a large sample of open clusters show that the abundances of the heavy elements La, Ce, Nd and Sm but not so obviously Y and Eu vary from one cluster to another across a sample all having about the solar metallicity. For La, Ce, Nd and Sm the amplitudes of the variations at solar metallicity scale approximately with the main s-process contribution to solar system material. Consideration of published abundances of field stars suggest that such a spread in heavy element abundances is present for the thin and thick disk stars of different metallicity. This new result provides an opportunity to chemically tag stars by their heavy elements and to reconstruct dissolved open clusters from the field star population.

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`http://adsabs.harvard.edu/abs/2016ApJ...831..202L`

Investigation of open clusters based on IPHAS and APASS survey data

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We adapt the classical Q-method based on a reddening-free parameter constructed from three pass-band magnitudes to the filter set of IPHAS survey and combine it with the maximum-likelihood-based cluster parameter estimator by Naylor and Jeffries (2006) to determine the extinction, heliocentric distances, and ages of young open clusters using Hα and ri data. The method is also adapted for the case of significant variations of extinction across the cluster field. Our technique is validated by comparing the colour excesses, distances, and ages determined in this study with the most bona fide values reported for the 18 well-studied young open clusters in the past, and a fairly good agreement is found between our extinction and distance estimates and earlier published results. although our age estimates are not very consistent with those published by other authors. We also show that individual extinction values can be determined rather accurately for stars with $(r-i)_0 > 0.1$. Our results open up a prospect for determining a uniform set of parameters for northern clusters based on homogeneous photometric data, and for searching for new, hitherto undiscovered open clusters.

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`https://arxiv.org/abs/1611.04110`

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Radial velocities and metallicities of red giant stars in the old open cluster NGC 7762

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We present and discuss radial velocity and the very first metallicity measurements for nine evolved stars in the poorly known old open cluster NGC 7762. We isolated eight radial velocity cluster members and one interloper. Radial velocities are in good agreement with previous studies. NGC 7762 turns out to be of solar metallicity within the uncertainties ([Fe/H]=0.04±0.12). For this metallicity, the cluster age is 2.5±0.2 Gyr, and falls in a age range where only a few old open clusters are known. With respect to previous studies, we find a larger distance, implying the cluster to be located at 900^{+70}_{-50} pc from the Sun. For most of the elements we measure solar-scaled abundance ratios. We searched the literature for open clusters of similar age in the solar vicinity and found that NGC 7762 can be considered a twin of Ruprecht 147, a similar age cluster located at only 300 pc from the Sun. In fact, beside age, also metallicity and abundance ratios are very close to Ruprecht 147 values within the observational uncertainties.

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`https://arxiv.org/abs/1611.02509`

Galactic Kinematics from Data on Open Star Clusters from the MWSC Catalogue

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Open star clusters from the MWSC (Milky Way Star Clusters) catalogue have been used to determine the Galactic rotation parameters. The circular rotation velocity of the solar neighborhood around the Galactic center has been found from data on more than 2000 clusters of various ages to be $V_0 = 236 \pm 6$ km s^{-1} for the adopted Galactocentric distance of the Sun $R_0 = 8.3 \pm 0.2$ kpc. The derived angular velocity parameters are $\Omega_0 = 28.48 \pm 0.36$ km s^{-1} kpc^{-1}, $\Omega_0' = -3.50 \pm 0.08$ km s^{-1} kpc^{-2}, and $\Omega_0'' = 0.331 \pm 0.037$ km s^{-1} kpc^{-3}. The influence of the spiral density wave has been detected only in the sample of clusters younger than 50 Myr. For these clusters the amplitudes of the tangential and radial velocity perturbations are $f_\theta = 5.6 \pm 1.6$ km s^{-1} and $f_R = 7.7 \pm 1.4$ km s^{-1}, respectively; the perturbation wavelengths are $\lambda_\theta = 2.6 \pm 0.5$ kpc ($i_\theta = -11^\circ \pm 2^\circ$) and $\lambda_R = 2.1 \pm 0.5$ kpc ($i_R = -9^\circ \pm 2^\circ$) for the adopted four-armed model ($m = 4$). The Sun's phase in the spiral density wave is $(\chi_\odot)_\theta = -62^\circ \pm 9^\circ$ and $(\chi_\odot)_R = -85^\circ \pm 10^\circ$ from the residual tangential and radial velocities, respectively.

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http://adsabs.harvard.edu/abs/2016arXiv160908341B

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The Detached Eclipsing Binary KV29 and the Age of the Open Cluster M11

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We present an extensive set of photometry and radial velocities for the detached eclipsing binary KV 29 in the intermediate-aged open cluster M11 (NGC 6705). Spectroscopy shows that the system is double-lined and all available evidence (proper motion, photometry, and position on the CMD) indicates it is a member of the cluster. We find the period of the binary to be 4.64276±0.00001 days. We find masses $3.604^{+0.002}_{-0.011}$M$_\odot$ and $1.837^{+0.001}_{-0.006}$M$_\odot$ and radii $5.392^{+0.018}_{-0.035}$R$_\odot$ and $1.656^{+0.007}_{-0.044}$R$_\odot$ for the primary and secondary stars, respectively. Because the primary star in the binary is rapidly evolving and is brighter than the cluster turnoff in a color-magnitude diagram, the measurement of its radius leads to a strong constraint on the cluster age. We find the age of M11 to be 222^{+2}_{-3}±15 Myr, where the quoted uncertainties come from statistical errors in the calculated masses and radii, and systematic uncertainties due to the ambiguity of the metallicity of the open cluster and variations within the isochrone models concerning heavy elements and convective overshooting.

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Investigation of Galactic open cluster remnants: the case of NGC 7193

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Galactic open clusters (OCs) that survive the early gas-expulsion phase are gradually destroyed over time by the action of disruptive dynamical processes. Their final evolutionary stages are characterized by a poorly populated concentration of stars called open cluster remnant (OCR). This study is devoted to assess the real physical nature of the OCR candidate NGC 7193. GMOS/Gemini spectroscopy of 53 stars in the inner target region were obtained to derive radial velocities and atmospheric parameters. We also employed photometric and proper motion data. The analysis method consists of the following steps: (i) analysis of the statistical resemblance between the cluster and a set of field samples with respect to the sequences defined in colour-magnitude diagrams (CMDs); (ii) a 5-dimensional iteractive exclusion routine was employed to identify outliers from kinematical and positional data; (iii) isochrone fitting to the $K_s \times (J - K_s)$ CMD of the remaining stars and the dispersion of spectral types along empirical sequences in the $(J - H) \times (H - K_s)$ diagram was checked. A group of stars was identified for which the mean heliocentric distance is compatible with that obtained via isochrone fitting and whose metallicities are compatible with each other. Fifteen member stars observed spectroscopically were identified together with other 19 probable members. Our results indicate that NGC 7193 is a genuine OCR, of an once very populous OC, for which the following parameters were derived: $d = 501 \pm 46$ pc, $t = 2.5 \pm 1.2$ Gyr, $\langle [Fe/H] \rangle = -0.17 \pm 0.23$ and $E(B-V) = 0.05 \pm 0.05$. Its luminosity and mass functions show depletion of low mass stars, confirming the OCR dynamically evolved state.

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`https://arxiv.org/abs/1610.00972`

Galactic Globular Clusters

Blue straggler star populations in globular clusters - II. Proper-motion cleaned HST catalogues of BSSs in 38 Galactic GCs

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We present new blue straggler star (BSS) catalogues in 38 Milky Way globular clusters (GCs) based on multipassband and multi-epoch treasury survey data from the Hubble Space Telescope. We measure precise astrometry and relative proper motions of stars in all target clusters and performed a subsequent cluster membership selection. We study the accuracy of our proper-motion measurements using estimates of central velocity dispersions and find very good agreement with previous studies in the literature. Finally, we present a homogeneous BSS selection method, that expands the classic BSS selection parameter space to more evolved BSS evolutionary stages. We apply this method to the proper-motion cleaned GC star catalogues in order to define proper-motion cleaned BSS catalogues in all 38 GCs, which we make publicly available to enable further study and follow-up observations.

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`http://adsabs.harvard.edu/abs/2016MNRAS.462.3401S`

Clusters in the Magellanic clouds

The overlooked role of stellar variability in the extended main sequence of LMC intermediate-age clusters

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Intermediate-age star clusters in the Large Magellanic Cloud show extended main sequence turn offs (MSTOs), which are not consistent with a canonical single stellar population. These broad turn offs have been interpreted as evidence for extended star formation and/or stellar rotation. Since most of these studies use single frames per filter to do the photometry, the presence of variable stars near the MSTO in these clusters has remained unnoticed and their impact totally ignored. We model the influence of Delta Scuti using synthetic CMDs, adding variable stars following different levels of incidence and amplitude distributions. We show that Delta Scuti observed at a single phase will produce a broadening of the MSTO without affecting other areas of a CMD like the upper MS or the red clump; furthermore, the amount of spread introduced correlates with cluster age as observed. This broadening is constrained to ages $\sim$ 1–3 Gyr when the MSTO area crosses the instability strip, which is also consistent with observations. Variable stars cannot explain bifurcated MSTOs or the extended MSTOs seen in some young clusters, but they can make an important contribution to the extended MSTOs in intermediate-age clusters.

Accepted by : The Astrophysical Journal Letters
`http://adsabs.harvard.edu/abs/2016ApJ...832L..14S`

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A high fraction of Be stars in young massive clusters: evidence for a large population of near-critically rotating stars

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Recent photometric analysis of the colour-magnitude diagrams (CMDs) of young massive clusters (YMCs) have found evidence for splitting in the main sequence and extended main sequence turn-offs, both of which have been suggested to be caused by stellar rotation. Comparison of the observed main sequence splitting with models has led various authors to suggest a rather extreme stellar rotation distribution, with a minority (10–30%) of stars with low rotational velocities and the remainder (70–90%) of stars rotating near the critical rotation (i.e., near break-up). We test this hypothesis by searching for Be stars within two YMCs in the LMC (NGC 1850 and NGC 1856), which are thought to be critically rotating stars with decretion disks that are (partially) ionised by their host stars. In both clusters we detect large populations of Be stars at the main sequence turn-off ($\sim$30–60% of stars), which supports previous suggestions of large populations of rapidly rotating stars within massive clusters.

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`https://arxiv.org/abs/1611.06705v1`

The most distant clusters

Young star clusters in circumnuclear starburst rings

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We analyse the cluster luminosity functions (CLFs) of the youngest star clusters in three galaxies exhibiting prominent circumnuclear starburst rings. We focus specifically on NGC 1512 and NGC 6951, for which we have access to Hα data that allow us to unambiguously identify the youngest sample clusters. To place our results on a firm statistical footing, we first explore in detail a number of important technical issues affecting the process from converting the observational data into the spectral-energy distributions of the objects in our final catalogues. The CLFs of the young clusters in both galaxies exhibit approximate power-law behaviour down to the 90 per cent observational completeness limits, thus showing that star cluster formation in the violent environments of starburst rings appears to proceed similarly as that elsewhere in the local Universe. We discuss this result in the context of the density of the interstellar medium in our starburst-ring galaxies.

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`http://arxiv.org/abs/1610.09125`

Dynamical evolution - Simulations

Radial variation in the stellar mass functions of star clusters

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A number of recent observational studies of Galactic globular clusters have measured the variation in the slope of a cluster's stellar mass function α with clustercentric distance r. In order to gather a deeper understanding of the information contained in such observations, we have explored the evolution of $\alpha(r)$ for star clusters with a variety of initial conditions using a large suite of N-body simulations. We have specifically studied how the time evolution of $\alpha(r)$ is affected by initial size, mass, binary fraction, primordial mass segregation, black hole retention, an external tidal field, and the initial mass function itself. Previous studies have shown that the evolution of α_G is closely related to the amount of mass loss suffered by a cluster. Hence for each simulation we have also followed the evolution of the slope of the cluster's global stellar mass function, α_G, and have shown that clusters follow a well-defined track in the α_G-$d\alpha(r)/d(ln(r/r_m))$ plane. The location of a cluster on the $\alpha_G - d\alpha(r)/d(ln(r/r_m))$ plane can therefore constrain its dynamical history and, in particular, constrain possible variations in the stellar initial mass function. The α_G-$d\alpha(r)/d(ln(r/r_m))$ plane thus serves as a key tool for fully exploiting the information contained in wide field studies of cluster stellar mass functions.

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On the link between energy equipartition and radial variation in the stellar mass function of star clusters

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We make use of N-body simulations to determine the relationship between two observable parameters that are used to quantify mass segregation and energy equipartition in star clusters. Mass segregation can be quantified by measuring how the slope of a cluster's stellar mass function α changes with clustercentric distance r, and then calculating $\delta_\alpha = \frac{d\alpha(r)}{dln(r/r_m)}$ where r_m is the cluster's half-mass radius. The degree of energy equipartition in a cluster is quantified by η, which is a measure of how stellar velocity dispersion σ depends on stellar mass m via $\sigma(m) \propto m^{-\eta}$. Through a suite of N-body star cluster simulations with a range of initial sizes, binary fractions, orbits, black hole retention fractions, and initial mass functions, we present the co-evolution of δ_α and η. We find that measurements of the global η are strongly affected by the radial dependence of σ and mean stellar mass and the relationship between η and δ_α depends mainly on the cluster's initial conditions and the tidal field. Within r_m, where these effects are minimized, we find that η and δ_α initially share a linear relationship. However, once the degree of mass segregation increases such that the radial dependence of σ and mean stellar mass become a factor within r_m, or the cluster undergoes core collapse, the relationship breaks down. We propose a method for determining η within r_m from an observational measurement of δ_α. In cases where η and δ_α can be measured independently, this new method offers a way of measuring the cluster's dynamical state.

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The origin of the Milky Way globular clusters

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We present a cosmological zoom-in simulation of a Milky Way-like galaxy used to explore the formation and evolution of star clusters. We investigate in particular the origin of the bimodality observed in the colour and metallicity of globular clusters, and the environmental evolution through cosmic times in the form of tidal tensors. Our results self-consistently confirm previous findings that the blue, metal-poor clusters form in satellite galaxies which are accreted onto the Milky Way, while the red, metal-rich clusters form mostly in situ or, to a lower extent in massive, self-enriched galaxies merging with the Milky Way. By monitoring the tidal fields these populations experience, we find that clusters formed in situ (generally centrally concentrated) feel significantly stronger tides than the accreted ones, both in the present-day, and when averaged over their entire life. Furthermore, we note that the tidal field experienced by Milky Way clusters is significantly weaker in the past than at present-day, confirming that it is unlikely that a power-law cluster initial mass function like that of young massive clusters, is transformed into the observed peaked distribution in the Milky Way with relaxation-driven evaporation in a tidal field.

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A stellar-mass black hole population in the globular cluster NGC 6101?

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Dalessandro et al. observed a similar distribution for blue straggler stars and main-sequence turn-off stars in the Galactic globular cluster NGC 6101, and interpreted this feature as an indication that this cluster is not mass-segregated. Using direct N-body simulations, we find that a significant amount of mass segregation is expected for a cluster with the mass, radius and age of NGC 6101. Therefore, the absence of mass segregation cannot be explained by the argument that the cluster is not yet dynamically evolved. By varying the retention fraction of stellar-mass black holes, we show that segregation is not observable in clusters with a high black hole retention fraction (>50% after supernova kicks and >50% after dynamical evolution). Yet all model clusters have the same amount of mass segregation in terms of the decline of the mean mass of stars and remnants with distance to the centre. We also discuss how kinematics can be used to further constrain the presence of a stellar-mass black hole population and distinguish it from the effect of an intermediate-mass black hole. Our results imply that the kick velocities of black holes are lower than those of neutron stars. The large retention fraction during its dynamical evolution can be explained if NGC 6101 formed with a large initial radius in a Milky Way satellite.

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N-body modeling of globular clusters: Masses, mass-to-light ratios and intermediate-mass black holes

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We have determined the masses and mass-to-light ratios of 50 Galactic globular clusters by comparing their velocity dispersion and surface brightness profiles against a large grid of 900 N-body simulations of star clusters of varying initial concentration, size and central black hole mass fraction. Our models follow the evolution of the clusters under the combined effects of stellar evolution and two-body relaxation allowing us to take the effects of mass segregation and energy equipartition between stars self-consistently into account. For a subset of 16 well observed clusters we also derive their kinematic distances. We find an average mass-to-light ratio of Galactic globular clusters of $< M/L_V >= 1.98 \pm 0.03$, which agrees very well with the expected M/L ratio if the initial mass function of the clusters was a standard Kroupa or Chabrier mass function. We do not find evidence for a decrease of the average mass-to-light ratio with metallicity. The surface brightness and velocity dispersion profiles of most globular clusters are incompatible with the presence of intermediate-mass black holes (IMBHs) with more than a few thousand $M_\odot$ in them. The only clear exception is ω Cen, where the velocity dispersion profile provides strong evidence for the presence of a $\sim$40,000 $M_\odot$ IMBH in the centre of the cluster.

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MOCCA-SURVEY database I. Accreting white dwarf binary systems in globular clusters – II. Cataclysmic variables – progenitors and population at birth

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This is the second in a series of papers associated with cataclysmic variables (CVs) and related objects, formed in a suite of simulations for globular cluster evolution performed with the MOCCA Monte Carlo code. We study the properties of our simulated CV populations throughout the entire cluster evolution. We find that dynamics extends the range of binary CV progenitor properties, causing CV formation from binary progenitors that would otherwise not become CVs. The CV formation rate in our simulations can be separated into two regimes: an initial burst (< 1 Gyr) connected with the formation of the most massive WDs, followed by a nearly constant formation rate. This result holds for all models regardless of the adopted initial conditions, even when most CVs form dynamically. Given the cluster age-dependence of CV properties, we argue that direct comparisons to observed Galactic field CVs could be misleading, since cluster CVs can be up to 4 times older than their field counterparts. Our results also illustrate that, due mainly to unstable mass transfer, some CVs that form in our simulations are destroyed before the present-day. Finally, some field CVs might have originated from GCs, as found in our simulations, although the fraction of such escapers should be small relative to the entire Galactic field CV population.

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The long-term dynamical evolution of disc-fragmented multiple systems in the Solar Neighborhood

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The origin of very low-mass hydrogen-burning stars, brown dwarfs, and planetary-mass objects at the low-mass end of the initial mass function is not yet fully understood. Gravitational fragmentation of circumstellar discs provides a possible mechanism for the formation of such low-mass objects. The kinematic and binary properties of very low-mass objects formed through disc fragmentation at early times (¡ 10 Myr) were discussed in Li et al. (2015). In this paper we extend the analysis by following the long-term evolution of disc-fragmented systems, up to an age of 10 Gyr, covering the ages of the stellar and substellar population in the Galactic field. We find that the systems continue to decay, although the rates at which companions escape or collide with each other are substantially lower than during the first 10 Myr, and that dynamical evolution is limited beyond 1 Gyr. By t = 10 Gyr, about one third of the host stars is single, and more than half have only one companion left. Most of the other systems have two companions left that orbit their host star in widely separated orbits. A small fraction of companions have formed binaries that orbit the host star in a hierarchical triple configuration. The majority of such double companion systems have internal orbits that are retrograde with respect to their orbits around their host stars. Our simulations allow a comparison between the predicted outcomes of disc-fragmentation with the observed low-mass hydrogen-burning stars, brown dwarfs, and planetary-mass objects in the Solar neighborhood. Imaging and radial velocity surveys for faint binary companions among nearby stars are necessary for verification or rejection for the formation mechanism proposed in this paper.

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Miscellaneous

Massive stars reveal variations of the stellar initial mass function in the Milky Way stellar clusters

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We investigate whether the stellar initial mass function (IMF) is universal, or whether it varies significantly among young stellar clusters in the Milky Way. We propose a method to uncover the range of variation of the parameters that describe the shape of the IMF for the population of young Galactic clusters. These parameters are the slopes in the low and high stellar mass regimes, γ and Γ, respectively, and the characteristic mass, M_{ch}. The method relies exclusively on the high mass content of the clusters, but is able to yield information on the distributions of parameters that describe the IMF over the entire stellar mass range. This is achieved by comparing the fractions of single and lonely massive O stars in a recent catalog of the Milky Way clusters with a library of simulated clusters built with various distribution functions of the IMF parameters. The synthetic clusters are corrected for the effects of the binary population, stellar evolution, sample incompleteness, and ejected O stars. Our findings indicate that broad distributions of the IMF parameters are required in order to reproduce the fractions of single and lonely O stars in Galactic clusters. They also do not lend support to the existence of a cluster mass-maximum stellar mass relation. We propose a probabilistic formulation of the IMF whereby the parameters of the IMF are described by Gaussian distribution functions centered around $\gamma = 0.91$, $\Gamma = 1.37$, and $M_{ch} = 0.41$ $M_\odot$, and with dispersions of $\sigma_\gamma = 0.25$, $\sigma_\Gamma = 0.60$, and $\sigma_{M_{ch}} = 0.27$ $M_\odot$ around these values.

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Conferences

Stellar aggregates over mass and spatial scales 631. Wilhelm und Else Heraeus-Seminar

5–9 December, 2016
Bad Honnef, Germany
https://astro.uni-bonn.de/conferences/aggregates2016/index.html

maximum number of participants is reached, contact the organizers

FTAPS_Astrophysics (with focus on Stellar Clusters)

22–25 February, 2017
Sharjah/Dubai, United Arab Emirates
http://ar-as.org/ftaps2017/

abstract submission closes at 30th Nov. 2016

Star Formation from Cores to Clusters

6–9 March, 2017
Santiago, Chile
http://www.eso.org/sci/meetings/2017/star-formation2017.html

abstract submission closes at 1st Dec. 2016

IAU Symp. 330: Astrometry and Astrophysics in the Gaia sky

24–28 April, 2017
Nice, France
https://iaus330.sciencesconf.org/resource/page/id/25

abstract submission closes at 4th Dec. 2016

IAU Symp. 334: Rediscovering our Galaxy

10–14 July, 2017
Potsdam, Germany
https://iaus334.aip.de/

registration closes at 31st Dec. 2016

MODEST 17 - Modelling and observing dense stellar systems

18–22 September, 2017
Prague, Czech Republic
http://astro.mff.cuni.cz/events/modest17/