The Star Clusters Young & Old Newsletter

edited by Giovanni Carraro, Martin Netopil, and Ernst Paunzen

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Dear colleagues,

We take advantage of this new issue to give you an update on the rapidly evolving IAU structure and the implications for the star cluster commission. Following the IAU call for Letters of Intent (LoI), 52 new commissions have been proposed. Among them there is our new commission, named “Stellar clusters throughout cosmic space and time”. The IAU has now organised an electronic vote to express interest for up to 3 of the proposed new commissions. This is crucial for us since this vote will determine the importance and relevance of the commission among the astronomical community at large. During the voting everybody can read the LoI and appreciate the efforts made by the proposers to modernise commissions, especially the old commission 37. We expect many of you to be able to vote, and encourage you to express your interest for the new star cluster commission.

This new SCYON issue contains 28 abstracts, announcements of upcoming conferences, and a job announcement. 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!

CONTENTS

About the Newsletter

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

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

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Star Forming Regions

Young open clusters in the galactic star forming region NGC 6357

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NGC6357 is an active star forming region with very young massive open clusters (OC). These clusters contain some of the most massive stars in the Galaxy and strongly interact with nearby giant molecular clouds (GMC). We study the young stellar populations of the region and of the OC Pismis24, focusing on their relationship with the nearby GMCs. We seek evidence of triggered star formation propagating from the clusters. We used new deep JHKs photometry, along with unpublished deep IRAC/Spitzer MIR photometry, complemented with optical HST/WFPC2 high spatial resolution photometry and X-ray Chandra observations, to constrain age, initial mass function, and star formation modes in progress. We carefully examine and discuss all sources of bias (saturation, confusion, different sensitivities, extinction). NGC6357 hosts three large young stellar clusters, of which Pismis24 is the most prominent. We found that Pismis24 is a very young (∼1–3 Myr) OC with a Salpeter-like IMF and a few thousand members. A comparison between optical and IR photometry indicates that the fraction of members with a NIR excess (i. e., with a circumstellar disk) is in the range 0.3–0.6, consistent with its photometrically derived age. We also find that Pismis24 is likely subdivided into a few different sub-clusters, one of which contains almost all the massive members. There are indications of current star formation triggered by these massive stars, but clear age trends could not be derived (although the fraction of stars with a NIR excess does increase towards the HII region associated with the cluster). The gas out of which Pismis24 formed must have been distributed in dense clumps within a cloud of less dense gas ∼1 pc in radius. Our findings provide some new insight into how young stellar populations and massive stars emerge, and evolve in the first few Myr after birth, from a giant molecular cloud complex.

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`http://fr.arxiv.org/abs/1410.4340`

Galactic Open Clusters

Searching for Chemical Signatures of Multiple Stellar Populations in the Old, Massive Open Cluster NGC 6791

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Galactic open and globular clusters (OCs, GCs) appear to inhabit separate regions of the age-mass plane. However, the transition between them is not easily defined because there is some overlap between high-mass, old OCs and low-mass, young GCs. We are exploring the possibility of a clear-cut separation between OCs and GCs using an abundance feature that has been found so far only in GCs: (anti)correlations between light elements. Among the coupled abundance trends, the Na-O anticorrelation is the most widely studied. These anticorrelations are the signature of self-enrichment, i.e., of a formation mechanism that implies multiple generations of stars. Here we concentrate on the old, massive, metal-rich OC NGC 6791. We analyzed archival Keck/HIRES spectra of 15 NGC 6791 main sequence turn-off and evolved stars, concentrating on the derivation of C, N, O, and Na abundances. We also used WIYN/Hydra spectra of 21 evolved stars (one is in common). Given the spectral complexity of the very metal-rich NGC 6791 stars, we employed spectrum synthesis to measure most of the abundances. We confirmed the cluster super-solar metallicity and abundances of Ca and Ni that have been derived in past studies. More importantly, we did not detect any significant star-to-star abundance dispersion in C, N, O and Na. Based on the absence of a clear Na-O anticorrelation, NGC 6791 can still be considered a true OC, hosting a single generation of stars, and not a low-mass GC.

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The thickening of the thin disk in the third Galactic quadrant

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In the third Galactic quadrant ($180° \leq l \leq 270°$) of the Milky Way, the Galactic thin disk exhibits a significant warp —shown both by gas and young stars— bending down a few kpc below the formal Galactic plane ($b = 0°$). This warp shows its maximum at $l \sim 240°$, in the direction of the Canis Major constellation. In a series of papers we have traced the detailed structure of this region using open star clusters, putting particular emphasis on the spiral structure of the outer disk. We noticed a conspicuous accumulation of young star clusters within 2–3 kpc from the Sun and close to $b = 0^o$, that we interpreted as the continuation of the Local (Orion) arm towards the outer disk. While most clusters (and young stars in their background) follow closely the warp of the disk, our decade-old survey of the spiral structure of this region led us to identify three clusters, Haffner 18(1 and 2) and Haffner 19, which remain very close to $b = 0°$ and lie at distances (4.5, ∼8.0, and 6.4 kpc) where most of the material is already significantly warped. Here we report on a search for clusters that share the same properties as Haffner 18 and 19, and investigate the possible reasons for such an unexpected

occurrence. We present *UBVRI* photometry of 5 young clusters, namely NGC 2345, NGC 2374, Trumpler 9, Haffner 20, and Haffner 21, which also lie close to the formal Galactic plane. With the exception of Haffner 20, in the background of these clusters we detected young stars that appear close to $b = 0°$, and are located at distances up to ~ 8 kpc from the Sun, thus deviating significantly from the warp. These populations define a structure that distributes over almost the entire third Galactic quadrant. We discuss this structure in the context of a possible thin disk flaring, in full similarity with the Galactic thick disk.

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http://arxiv.org/abs/1409.0068

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The old, metal-poor, anticentre open cluster Trumpler 5

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As part of a long term programme, we analyse the evolutionary status and properties of the old and populous open cluster Trumpler 5 (Tr 5), located in the Galactic anticentre direction, almost on the Galactic plane. Tr 5 was observed with WFI@MPG/ESO Telescope using the Bessel U, B, and V filters. The cluster parameters have been obtained using the synthetic colour-magnitude diagram (CMD) method, i.e. the direct comparison of the observational CMD with a library of synthetic CMDs generated with different stellar evolution sets (Padova, FRANEC, and FST). Age, reddening, and distance are derived through the synthetic CMD method using stellar evolutionary models with subsolar metallicity (Z=0.004 or Z=0.006). Additional spectroscopic observations with UVES@VLT of three red clump stars of the cluster were used to determine more robustly the chemical properties of the cluster. Our analysis shows that Tr 5 has subsolar metallicity, with [Fe/H]$=-0.403 \pm 0.006$ dex (derived from spectroscopy), age between 2.9 and 4 Gyr (the lower age is found using stellar models without core overshooting), reddening E(B$-$V) in the range 0.60 to 0.66 mag complicated by a differential pattern (of the order of about $\pm$0.1 mag), and distance modulus $(\mathrm{m-M})_0=12.4 \pm 0.1$ mag.

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New insights on Ba over-abundance in open clusters. Evidence for the intermediate neutron-capture process at play?

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Recently an increasing number of studies were devoted to measure the abundances of neutron-capture elements heavier than iron in stars belonging to Galactic Open Clusters (OCs). OCs span a sizeable range in metallicity ($-0.6 <$ [Fe/H] $< +0.4$), and they show abundances of light elements similar to disk stars of the same age. A different pattern is observed for heavy elements. A large scatter is observed for Ba, with most OCs showing [Ba/Fe] and [Ba/La] overabundant with respect to the Sun. The origin of this overabundance is not clearly understood. With the goal of providing new observational insights we determined radial velocities, atmospheric parameters and chemical composition of 27 giant stars members of five OCs: Cr 110, Cr 261, NGC 2477, NGC 2506 and NGC 5822. We used high-resolution spectra obtained with the UVES spectrograph at ESO Paranal. We perform a detailed spectroscopic analysis of these stars to measure the abundance of up to 22 elements per star. We study the dependence of element abundance on metallicity and age with unprecedented detail, complementing our analysis with data culled from the literature. We confirm the trend of Ba overabundance in OCs, and show its large dispersion for clusters younger than 4 Gyr. Finally, the implications of our results for stellar nucleosynthesis are discussed. We show in this work that the Ba enrichment compared to other neutron-capture elements in OCs cannot be explained by the contributions from the slow neutron-capture process and the rapid neutron-capture process. Instead, we argue that this anomalous signature can be explained by assuming an additional contribution by the intermediate neutron-capture process.

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High-resolution Spectroscopic Observations of Binary Stars and Yellow Stragglers in Three Open Clusters: NGC 2360, NGC 3680, and NGC 5822

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Binary stars in open clusters are very useful targets in constraining the nucleosynthesis process. The luminosities of the stars are known because the distances of the clusters are also known, so chemical peculiarities can be linked directly to the evolutionary status of a star. In addition, binary stars offer the opportunity to verify a relationship between them and the straggler population in both globular and open clusters. We carried out a detailed spectroscopic analysis to derive the atmospheric parameters for 16 red giants in binary systems and the chemical composition of 11 of them in the open clusters NGC 2360, NGC 3680, and NGC 5822. We obtained abundances of C, N, O, Na, Mg, Al, Ca, Si, Ti, Ni, Cr, Y, Zr, La, Ce, and Nd. The atmospheric parameters of the studied stars and their chemical abundances were determined using high-resolution optical spectroscopy. We employ the local thermodynamic equilibrium model atmospheres of Kurucz and the spectral analysis code MOOG. The abundances of the light elements were derived using the spectral synthesis technique. We found that the stars NGC 2360-92 and 96, NGC 3680-34, and NGC 5822-4 and 312 are yellow straggler stars. We show that the spectra of NGC 5822-4 and 312 present evidence of contamination by an A-type star as a secondary star. For the other yellow stragglers, evidence of contamination is given by the broad wings of the Hα. Detection of yellow straggler stars is important because the observed number can be compared with the number predicted by simulations of binary stellar evolution in open clusters. We also found that the other binary stars are not s-process enriched, which may suggest that in these binaries the secondary star is probably a faint main-sequence object. The lack of any s-process enrichment is very useful in setting constraints for the number of white dwarfs in the open cluster, a subject that is related to the birthrate of these kinds of stars in open clusters and also to the age of a cluster. Finally, rotational velocities were also determined and their values were compared with those already determined for field giant stars.

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Galactic Globular Clusters

Three discrete groups with homogeneous chemistry along the red giant branch in the globular cluster NGC 2808

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We present the homogeneous reanalysis of Mg and Al abundances from high resolution UVES / FLAMES spectra for 31 red giants in the globular cluster NGC2808. We found a well defined Mg-Al anticorrelation reaching a regime of subsolar Mg abundance ratios, with a spread of about 1.4 dex in [Al/Fe]. The main result from the improved statistics of our sample is that the distribution of stars is not continuous along the anticorrelation as they are neatly clustered into three distinct clumps each with different chemical composition. One group (P) shows the primordial composition of field stars of similar metallicity, and the other two (I and E) have increasing abundances of Al and decreasing abundances of Mg. The fraction of stars we found in the three components (P: 68%, I: 19%, E: 13%) is in excellent agreement with the number ratios computed for the three distinct main sequences in NGC 2808: for the first time there is a clear correspondence between discrete photometric sequences of dwarfs and distinct groups of giants with homogeneous chemistry. The composition of the I group cannot be reproduced by mixing of matter with extreme processing in hot H-burning and gas with pristine, unprocessed composition, as also found in the recent analysis of three discrete groups in NGC 6752. This finding suggests that different classes of polluters were probably at work also in NGC 2808.

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Are there any first-generation stars in globular clusters today?

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Several models compete to explain the abundance properties of stellar populations in globular clusters. One of the main constraints is the present-day ratio of first- and second-generation stars that are currently identified based on their sodium content. We propose an alternative interpretation of the observed sodium distribution, and suggest that stars with low sodium abundance that are counted as members of the first stellar generation could actually be second-generation stars. We compute the number ratio of second-generation stars along the Na distribution following the fast rotating massive star model using the same constraints from the well-documented case of NGC 6752 as in our previous developments. We reproduce the typical percentage of low-sodium stars usually classified as first-generation stars by invoking only secondary star formation from material ejected by massive stars and mixed with original globular cluster material in proportions that account for the Li-Na anti-correlation in this cluster. Globular clusters could be totally devoid of first-generation low-mass stars today. This can be tested with the determination of the carbon isotopic ratio and nitrogen abundance in turn-off globular cluster stars. Consequences and related issues are briefly discussed.

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Mass segregation in the outer halo globular cluster Palomar 14

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We present evidence for mass segregation in the outer-halo globular cluster Palomar 14, which is intuitively unexpected since its present-day two-body relaxation time significantly exceeds the Hubble time. Based on archival Hubble Space Telescope imaging, we analyze the radial dependence of the stellar mass function in the cluster's inner 39.2 pc in the mass range of 0.53–0.80 $M_{\odot}$, ranging from the main-sequence turn-off down to a V-band magnitude of 27.1 mag. The mass function at different radii is well approximated by a power law and rises from a shallow slope of 0.6 ± 0.2 in the cluster's core to a slope of 1.6 ± 0.3 beyond 18.6 pc. This is seemingly in conflict with the finding by Beccari et al., who interpret the cluster's non-segregated population of (more massive) blue straggler stars, compared to (less massive) red giants and horizontal branch stars, as evidence that the cluster has not experienced dynamical segregation yet. We discuss how both results can be reconciled. Our findings indicate that the cluster was either primordially mass-segregated and/or used to be significantly more compact in the past. For the latter case, we propose tidal shocks as the mechanism driving the cluster's expansion, which would imply that Palomar 14 is on a highly eccentric orbit. Conversely, if the cluster formed already extended and with primordial mass segregation, this could support an accretion origin of the cluster.

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Galactic globular cluster 47 Tucanae: new ties between the chemical and dynamical evolution of globular clusters?

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It is generally accepted today that Galactic globular clusters (GGCs) consist of at least two generations of stars that are different in their chemical composition and perhaps age. However, knowledge about the kinematical properties of these stellar generations, which may provide important information for constraining evolutionary scenarios of the GGCs, is still limited. In this work we therefore study the connections between chemical and kinematical properties of different stellar generations in the Galactic globular cluster 47 Tuc. To achieve this goal, we used abundances of Li, O, and Na determined in 101 main sequence turn-off (TO) stars with the aid of 3D hydrodynamical model atmospheres and NLTE abundance analysis methodology. We divided our sample TO stars into three groups according to their position in the [Li/Na] – [Na/O] plane to study their spatial distribution and kinematical properties. We find that there are statistically significant radial dependencies of lithium and oxygen abundances, A(Li) and A(O), as well as that of [Li/Na]abundance ratio. Our results show that first-generation stars are less centrally concentrated and dynamically hotter than stars belonging to subsequent generations. We also find a significant correlation between the velocity dispersion and O and Na abundance, and between the velocity dispersion and the [Na/O] abundance ratio.

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Palomar 5 and its Tidal Tails: A Search for New Members in the Tidal Stream

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In this paper we present the results of a search for members of the globular cluster Palomar 5 and its associated tidal tails. The analysis has been performed using intermediate and low resolution spectroscopy with the AAOmega spectrograph on the Anglo-Australian Telescope. Based on kinematics, line strength and photometric information, we identify 39 new red giant branch stars along 20 deg of the tails, a larger angular extent than has been previously studied. We also recover eight previously known tidal tail members. Within the cluster, we find seven new red giant and one blue horizontal branch members and confirm a further twelve known red giant members. In total, we provide velocity data for 67 stars in the cluster and the tidal tails. Using a maximum likelihood technique, we derive a radial velocity for Pal 5 of -57.4 ± 0.3 km s^{-1} and a velocity dispersion of 1.2 ± 0.3 km s^{-1}. We confirm and extend the linear velocity gradient along the tails of 1.0 ± 0.1 km s^{-1}/deg, with an associated intrinsic velocity dispersion of 2.1 ± 0.4 km/s. Neither the velocity gradient nor the dispersion change in any significant way with angular distance from the cluster, although there is some indication that the gradient may be smaller at greater angular distances in the trailing tail. Our results verify the tails as kinematically cold structures and will allow further constraints to be placed on the orbit of Pal 5, ultimately permitting a greater understanding of the shape and extent of the Galaxy's dark matter halo.

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Ejection of globular cluster interstellar media through ionization by white dwarfs

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UV radiation from white dwarfs can efficiently clear Galactic globular clusters (GCs) of their intracluster medium (ICM). This solves the problem of the missing ICM in clusters, which is otherwise expected to build up to easily observable quantities. To show this, we recreate the ionizing flux in 47 Tuc, following randomly generated stars through their AGB, post-AGB and white dwarf evolution. Each white dwarf can ionize all the material injected into the cluster by stellar winds for $\sim$3 Myr of its evolution: $\sim$40 such white dwarfs exist at any point. Every GC's ICM should be ionized. The neutral cloud in M15 should be caused by a temporary overdensity. A pressure-supported ICM will expand over the cluster's tidal radius, where it will be truncated, allowing Jeans escape. The modelled Jeans mass-loss rate approximates the total stellar mass-loss rate, allowing efficient clearing of ICM. Any cluster's ICM mass should equal the mass injected by its stars over the sound-travel time between the cluster core and tidal radius. We predict $\sim$ 11.3 solar masses of ICM within 47 Tuc, cleared over $\sim$4 Myr, compared to a dynamical timescale of 4.3 Myr. We present a new mass hierarchy, discussing the transition between globular clusters dwarf galaxies.

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Tidal Stream Morphology as an Indicator of Dark Matter Halo Geometry: the Case of Palomar 5

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This paper presents an example where the morphology of a single stellar stream can be used to rule out a specific galactic potential form without the need for velocity information. We investigate the globular cluster Palomar5 (Pal 5), which is tidally disrupting into a cold, thin stream mapped over 22 degrees on the sky with a typical width of 0.7 degrees. We generate models of this stream by fixing Pal 5's present-day position, distance and radial velocity via observations, while allowing its proper motion to vary. In a spherical dark matter halo we easily find models that fit the observed morphology. However, no plausible Pal 5 model could be found in the triaxial potential of Law & Majewski 2010, which has been proposed to explain the properties of the Sagittarius stream. In this case, the long, thin and curved morphology of the Pal 5 stream alone can be used to rule out such a potential configuration. Pal 5 like streams in this potential are either too straight, missing the curvature of the observations, or show an unusual morphology which we dub stream-fanning: a signature sensitive to the triaxiality of a potential. We conclude that the mere existence of other thin tidal streams must provide broad constraints on the orientation and shape of the dark matter halo they inhabit.

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The Puzzling Negative Orbit-Period Derivative of the Low-Mass X-Ray Binary 4U 1820-30 in NGC 6624

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4U 1820-30 is a low-mass X-ray binary near the center of the globular cluster NGC 6624 consisting of, at least, one neutron star and one helium white dwarf. Analyzing 16 years of data from the Rossi X-ray Timing Explorer (RXTE) allows us to measure its orbital period and its time derivative with unprecedented accuracy to be $P = 685.01197 \pm 0.00003$ s and $\dot{P}/P = -5.3 \pm 0.3 \times 10^{-8}$ yr^{-1}. Hence, we confirm that the period derivative is significantly negative at the $> 17\sigma$ level, contrary to theoretical expectations for an isolated X-ray binary. We discuss possible scenarios that could explain this discrepancy, and conclude that the center of NGC 6624 most likely contains large amounts of non-luminous matter such as dark remnants. We also discuss the possibility of an IMBH inside NGC 6624, or that a dark remnant close to 4U 1820-30 causes the observed shift.

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The most distant clusters

The effect of spatial resolution on optical and near-IR studies of stellar clusters: Implications for the origin of the red excess

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Recent ground based near-IR studies of stellar clusters in nearby galaxies have suggested that young clusters remain embedded for 7–10Myr in their progenitor molecular cloud, in conflict with optical based studies which find that clusters are exposed after 1–3Myr. Here, we investigate the role that spatial resolution plays in this apparent conflict. We use a recent catalogue of young (<10 Myr) massive (>5000 $M_{\odot}$) clusters in the nearby spiral galaxy, M83, along with Hubble Space Telescope (HST) imaging in the optical and near-IR, and ground based near-IR imaging, to see how the colours (and hence estimated properties such as age and extinction) are affected by the aperture size employed, in order to simulate studies of differing resolution. We find that the near-IR is heavily affected by the resolution, and when aperture sizes >40 pc are used, all young/blue clusters move red-ward in colour space, which results in their appearance as heavily extincted clusters. However, this is due to contamination from nearby sources and nebular emission, and is not an extinction effect. Optical colours are much less affected by resolution. Due to the larger affect of contamination in the near-IR, we find that, in some cases, clusters will appear to show near-IR excess when large (>20 pc) apertures are used. Our results explain why few young (>6 Myr), low extinction ($A_V < 1$ mag) clusters have been found in recent ground based near-IR studies of cluster populations, while many such clusters have been found in higher resolution HST based studies. Additionally, resolution effects appear to (at least partially) explain the origin of the near-IR excess that has been found in a number of extragalactic YMCs.

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Constraining globular cluster formation through studies of young massive clusters - IV. Testing the fast rotating massive star scenario

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One of the leading models for the formation of multiple stellar populations within globular clusters is the 'fast rotating massive star' (FRMS) scenario, where the ejecta of rapidly rotating massive stars is mixed with primordial material left over from the star formation process, to form a second generation of stars within the decretion discs of the high-mass stars. A requirement of this model, at least in its current form, is that young massive (i.e. proto-globular) clusters are not able to eject the unused gas and dust from the star formation process from the cluster for 20–30 Myr after the formation of the first generation of stars, i.e. the cluster remains embedded within the gas cloud in which it forms. Here, we test this prediction by performing a literature search for young massive clusters in nearby galaxies, which have ages less than 20 Myr that are not embedded. We report that a number of such clusters exist, with masses near or significantly above 10^6 $M_\odot$, with ages between a few Myr and $\sim$15 Myr, suggesting that even high-mass clusters are able to clear any natal gas within them within a few Myr after formation. Additionally, one cluster, Cluster 23 in ESO 338-IG04, has a metallicity below that of some Galactic globular clusters that have been found to host multiple stellar populations, mitigating any potential effect of differences in metallicity in the comparison. The clusters reported here are in contradiction to the expectations of the FRMS scenario, at least in its current form.

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Dynamical evolution - Simulations

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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The effect of primordial mass segregation on the size scale of globular clusters

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We use direct N-body calculations to investigate the impact of primordial mass segregation on the size scale and mass-loss rate of star clusters in a galactic tidal field. We run a set of simulations of clusters with varying degrees of primordial mass segregation at various galactocentric radii and show that, in primordially segregated clusters, the early, impulsive mass-loss from stellar evolution of the most massive stars in the innermost regions of the cluster leads to a stronger expansion than for initially non-segregated clusters. Therefore, models in stronger tidal fields dissolve faster due to an enhanced flux of stars over the tidal boundary. Throughout their lifetimes, the segregated clusters are more extended by a factor of about 2, suggesting that (at least) some of the very extended globular clusters in the outer halo of the Milky Way may have been born with primordial mass segregation. We finally derive a relation between star-cluster dissolution time, T_{diss}, and galactocentric radius, R_G, and show how it depends on the degree of primordial mass segregation.

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The size of star clusters accreted by the Milky Way

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We perform N-body simulations of a cluster that forms in a dwarf galaxy and is then accreted by the Milky Way to investigate how a cluster's structure is affected by a galaxy merger. We find that the cluster's half mass radius will respond quickly to this change in potential. When the cluster is placed on an orbit in the Milky Way with a stronger tidal field the cluster experiences a sharp decrease in size in response to increased tidal forces. Conversely, when placed on an orbit with a weaker tidal field the cluster expands since tidal forces decrease and stars moving outwards due to internal effects remain bound at further distances than before. In all cases, we find that the cluster's half mass radius will eventually be indistinguishable from a cluster that has always lived in the Milky Way on that orbit. These adjustments occur within 1–2 half mass relaxation times of the cluster in the dwarf galaxy. We also find this effect to be qualitatively independent of the time that the cluster is taken from the dwarf galaxy. In contrast to the half mass radius, we show the core radius of the cluster is not affected by the potential the cluster lives in. Our work suggests that structural properties of accreted clusters are not distinct from clusters born in the Milky Way. Other cluster properties, such as metallicity and horizontal branch morphology, may be the only way to identify accreted star clusters in the Milky Way.

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The evolutionary tracks of young massive star clusters

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Stars mostly form in groups consisting of a few dozen to several ten thousand members. For 30 years, theoretical models provide a basic concept of how such star clusters form and develop: they originate from the gas and dust of collapsing molecular clouds. The conversion from gas to stars being incomplete, the left over gas is expelled, leading to cluster expansion and stars becoming unbound. Observationally, a direct confirmation of this process has proved elusive, which is attributed to the diversity of the properties of forming clusters. Here we take into account that the true cluster masses and sizes are masked, initially by the surface density of the background and later by the still present unbound stars. Based on the recent observational finding that in a given star-forming region the star formation efficiency depends on the local density of the gas, we use an analytical approach combined with N-body simulations, to reveal evolutionary tracks for young massive clusters covering the first 10 Myr. Just like the Hertzsprung-Russell diagram is a measure for the evolution of stars, these tracks provide equivalent information for clusters. Like stars, massive clusters form and develop faster than their lower-mass counterparts, explaining why so few massive cluster progenitors are found.

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Contribution of stripped nuclear clusters to globular cluster and ultracompact dwarf galaxy populations

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We use the Millennium II cosmological simulation combined with the semi-analytic galaxy formation model of Guo et al. to predict the contribution of galactic nuclei formed by the tidal stripping of nucleated dwarf galaxies to globular cluster (GC) and ultra-compact dwarf galaxy (UCD) populations of galaxies. We follow the merger trees of galaxies in clusters back in time and determine the absolute number and stellar masses of disrupted galaxies. We assume that at all times nuclei have a distribution in nucleus-to-galaxy mass and nucleation fraction of galaxies similar to that observed in the present day universe. Our results show stripped nuclei follow a mass function $N(M) \sim M^{-1.5}$ in the mass range $10^6 < M/\mathrm{M}_\odot < 10^8$, significantly flatter than found for globular clusters. The contribution of stripped nuclei will therefore be most important among high-mass GCs and UCDs. For the Milky Way we predict between 1 and 3 star clusters more massive than $10^5\mathrm{M}_\odot$ come from tidally disrupted dwarf galaxies, with the most massive cluster formed having a typical mass of a few times $10^6\mathrm{M}_\odot$, like omega Centauri. For a galaxy cluster with a mass $7 \times 10^{13}\mathrm{M}_\odot$, similar to Fornax, we predict $\sim$19 UCDs more massive than $2 \times 10^6\mathrm{M}_\odot$ and $\sim$9 UCDs more massive than $10^7\mathrm{M}_\odot$ within a projected distance of 300 kpc come from tidally stripped dwarf galaxies. The observed number of UCDs are $\sim$200 and 23, respectively. We conclude that most UCDs in galaxy clusters are probably simply the high mass end of the GC mass function.

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Miscellaneous

Gamma-rays and neutrinos from dense environment of massive binary systems in open clusters

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TeV gamma-ray emission has been recently observed from direction of a few open clusters containing massive stars. We consider the high energy processes occurring within massive binary systems and in their dense environment by assuming that nuclei, from the stellar winds of massive stars, are accelerated at the collision region of the stellar winds. We calculate the rates of injection of protons and neutrons from fragmentation of these nuclei in collisions with stellar radiation and matter of the winds from the massive companions in binary system. Protons and neutrons can interact with the matter, within the stellar wind cavity and within the open cluster, producing pions which decay into γ-rays and neutrinos. We discuss the detectability of such γ-ray emission by the present and future Cherenkov telescopes for the case of two binary systems Eta Carinae, within the Carina Nebula, and WR 20a, within the Westerlund 2 open cluster. We also calculate the neutrino fluxes produced by protons around the binary systems and within the open clusters. This neutrino emission is confronted with ANTARES upper limits on the neutrino fluxes from discrete sources and with the sensitivity of IceCube.

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http://arxiv.org/abs/1410.7553

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Pre-main-sequence isochrones - III. The Cluster Collaboration isochrone server

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We present an isochrone server for semi-empirical pre-main-sequence model isochrones in the following systems: Johnson-Cousins, Sloan Digital Sky Survey, Two-Micron All-Sky Survey, Isaac Newton Telescope (INT) Wide-Field Camera, and INT Photo- metric Hα Survey (IPHAS)/UV-Excess Survey (UVEX). The server can be accessed via the Cluster Collaboration webpage
http://www.astro.ex.ac.uk/people/timn/isochrones/. To achieve this we have used the observed colours of member stars in young clusters with known age, distance and reddening to create fiducial loci in the colour-magnitude diagram. These empirical sequences have been used to quantify the discrepancy between the models and data arising from uncertainties in both the interior and atmospheric models, resulting in tables of semi-empirical bolometric corrections in the various photometric systems. The model isochrones made available through the server are based on existing stellar interior models coupled with our newly derived semi-empirical bolometric corrections. As part of this analysis, we also present new cluster parameters for both the Pleiades and Praesepe, yielding ages of 135^{+20}_{-11} and 665^{+14}_{-7} Myr as well as distances of 132 ± 2 and 184 ± 2 pc, respectively (statistical uncertainty only).

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How does a low-mass cut-off in the stellar IMF affect the evolution of young star clusters?

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We investigate how different stellar initial mass functions (IMFs) can affect the mass loss and survival of star clusters. We find that IMFs with radically different low-mass cut-offs (between 0.1 and 2 $M_\odot$) do not change cluster destruction time-scales as much as might be expected. Unsurprisingly, we find that clusters with more high-mass stars lose relatively more mass through stellar evolution, but the response to this mass loss is to expand and hence significantly slow their dynamical evolution. We also argue that it is very difficult, if not impossible, to have clusters with different IMFs that are initially "the same", since the mass, radius and relaxation times depend on each other and on the IMF in a complex way. We conclude that changing the IMF to be biased towards more massive stars does speed up mass loss and dissolution, but that it is not as dramatic as might be thought.

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Stellar age spreads in clusters as imprints of cluster-parent clump densities

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It has recently been suggested that high-density star clusters have stellar age distributions much narrower than that of the Orion Nebula Cluster, indicating a possible trend of narrower age distributions for denser clusters. We show this effect to likely arise from star formation being faster in gas with a higher density. We model the star formation history of molecular clumps in equilibrium by associating a star-formation efficiency per free-fall time to their volume density profile. We focus on the case of isothermal spheres and we obtain the evolution with time of their star formation rate. Our model predicts a steady decline of the star formation rate, which we quantify with its half-life time, namely, the time needed for the star formation rate to drop to half its initial value. Given the uncertainties affecting the star formation efficiency per free-fall time, we consider two distinct values: 0.1 and 0.01. In both cases, we conclude that denser molecular clumps yield narrower star age distributions in clusters. Published densities and stellar age spreads of young clusters and star-forming regions actually suggest that the time-scale for star formation is of order a few free-fall times. We also discuss how the age-bin size and uncertainties in stellar ages affect our results. We conclude that there is no need to invoke the existence of multiple cluster formation mechanisms to explain the observed range of stellar age spreads in clusters.

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Short dissipation times of proto-planetary discs - an artifact of selection effects?

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The frequency of discs around young stars, a key parameter for understanding planet formation, is most readily determined in young stellar clusters where many relatively coeval stars are located in close proximity. Observational studies seem to show that the disc frequency decreases rapidly with cluster age with <10% of cluster stars retaining their discs for longer than 2–6 Myr. Given that at least half of all stars in the field seem to harbor one or more planets, this would imply extremely fast disc dispersal and rapid planet growth. Here we question the validity of this constraint by demonstrating that the short disc dissipation times inferred to date might have been heavily underestimated by selection effects. Critically, for ages >3Myr only stars that originally populated the densest areas of very populous clusters, which are prone to disc erosion, are actually considered. This tiny sample may not be representative of the majority of stars. In fact, the higher disc fractions in co-moving groups indicate that it is likely that over 30% of all field stars retain their discs well beyond 10 Myr, leaving ample time for planet growth. Equally our solar system, with a likely formation time > 10 Myr, need no longer be an exception but in fact typical of planetary systems.

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A Supermassive Black Hole in an Ultracompact Dwarf Galaxy

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Ultracompact dwarf galaxies (UCDs) are among the densest stellar systems in the universe. These systems have masses up to 200 million solar masses, but half light radii of just 3-50 parsecs. Dynamical mass estimates show that many UCDs are more massive than expected from their luminosity. It remains unclear whether these high dynamical mass estimates are due to the presence of supermassive black holes or result from a non-standard stellar initial mass function that causes the average stellar mass to be higher than expected. Here we present the detection of a supermassive black hole in a massive UCD. Adaptive optics kinematic data of M60-UCD1 show a central velocity dispersion peak above 100 km/s and modest rotation. Dynamical modeling of these data reveals the presence of a supermassive black hole with mass of 21 million solar masses. This is 15% of the object's total mass. The high black hole mass and mass fraction suggest that M60-UCD1 is the stripped nucleus of a galaxy. Our analysis also shows that M60-UCD1's stellar mass is consistent with its luminosity, implying many other UCDs may also host supermassive black holes. This suggests a substantial population of previously unnoticed supermassive black holes.

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`http://arxiv.org/abs/1409.4769`

The Panchromatic High-Resolution Spectroscopic Survey of Local Group Star Clusters - I. General Data Reduction Procedures for the VLT/X-shooter UVB and VIS arm

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Our dataset contains spectroscopic observations of 29 globular clusters in the Magellanic Clouds and the Milky Way performed with VLT/X-shooter. Here we present detailed data reduction procedures for the VLT/X-shooter UVB and VIS arm. These are not restricted to our particular dataset, but are generally applicable to different kinds of X-shooter data without major limitation on the astronomical object of interest. ESO's X-shooter pipeline (v1.5.0) performs well and reliably for the wavelength calibration and the associated rectification procedure, yet we find several weaknesses in the reduction cascade that are addressed with additional calibration steps, such as bad pixel interpolation, flat fielding, and slit illumination corrections. Furthermore, the instrumental PSF is analytically modeled and used to reconstruct flux losses at slit transit and for optimally extracting point sources. Regular observations of spectrophotometric standard stars allow us to detect instrumental variability, which needs to be understood if a reliable absolute flux calibration is desired. A cascade of additional custom calibration steps is presented that allows for an absolute flux calibration uncertainty of less than ten percent under virtually every observational setup provided that the signal-to-noise ratio is sufficiently high. The optimal extraction increases the signal-to-noise ratio typically by a factor of 1.5, while simultaneously correcting for resulting flux losses. The wavelength calibration is found to be accurate to an uncertainty level of approximately 0.02 Å. We find that most of the X-shooter systematics can be reliably modeled and corrected for. This offers the possibility of comparing observations on different nights and with different telescope pointings and instrumental setups, thereby facilitating a robust statistical analysis of large datasets.

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http://arxiv.org/abs/1409.4663

Conferences

The Milky Way Unravelled by Gaia GREAT Science from the Gaia Data Releases

1-5 December, 2014
Barcelona (Spain)
https://gaia.ub.edu/Twiki/bin/view/GREATITNFC/WebHome

Late registration deadline 24th November 2014!

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MODEST 15 Modelling and Observing Dense Stellar Systems in Chile

2-6 March, 2015
Concepción (Chile)
http://www.astro-udec.cl/modest15/

Early registration deadline 30th November 2014!

Jobs

Postdoctoral position
in Theoretical and Computational Astrophysics

Department of Astronomy, Indiana University, Bloomington, USA

Applications are invited for a postdoctoral position in Theoretical and Computational Astrophysics to work with Professor Enrico Vesperini in the Department of Astronomy at Indiana University, Bloomington. Areas of research interest include formation and dynamical evolution of star clusters, multiple stellar populations in globular clusters, hydrodynamical, N-body and Fokker-Planck numerical simulations of globular cluster formation and evolution. Applications from candidates with experience in the observational study of star clusters and the comparison between theoretical models and observations are also encouraged.

The initial appointment will be for two years with extension to the third year depending on satisfactory progress. Start date is expected to be August 2015 but is negotiable. Applicants must hold a Ph.D. in Physics or Astronomy by the start date of appointment.

Deadline: January 10, 2015

Details on the position, the application procedure, and general information can be found at:

`https://indiana.peopleadmin.com/postings/1242`

Questions regarding the position or application process can be addressed by email to
Professor Enrico Vesperini (evesperi@indiana.edu).