The Star Clusters Young & Old Newsletter

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

Looking in the recent published papers about star clusters, space based data such as from Gaia, Kepler, and TESS bring valuable new insights. But also ground-based spectroscopic and polarimetric data are still most important to get the whole picture. With future releases of the Gaia satellite mission, the question how to interpret color-magnitude diagrams together with astrometric data will become an essential topic. Here, a joint effort is needed in order to estimate reliable cluster parameters including also the metallicity.

We would like to draw attention to the announced conference "Wheel of Star Formation" which will take place in September in Prague, Czech Republic. It will cover many important topics associated to star clusters.

The SCYON editor team:

Giovanni Carraro, Martin Netopil, and Ernst Paunzen

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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.

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Star Forming Regions

The density gradient inside molecular-gas clumps as a booster of their star formation activity

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Star-forming regions presenting a density gradient experience a higher star formation rate than if they were of uniform density. We refer to the ratio between the star formation rate of a spherical centrally-concentrated gas clump and the star formation rate that this clump would experience if it were of uniform density as the magnification factor ζ. We map ζ as a function of clump mass, radius, initial volume density profile and star formation time-span. For clumps with a steep density profile (i.e. power-law slope ranging from -3 to -4, as observed in some high-density regions of Galactic molecular clouds), we find the star formation rate to be at least an order of magnitude higher than its top-hat equivalent. This implies that such clumps experience faster and more efficient star formation than expected based on their mean free-fall time. This also implies that measurements of the star formation efficiency per free-fall time of clumps based on their global properties, namely, mass, mean volume density and star formation rate, present wide fluctuations. These reflect the diversity in the density profile of star-forming clumps, not necessarily variations in the physics of star formation. Steep density profiles inside star-cluster progenitors may be instrumental in the formation of multiple stellar populations, such as those routinely observed in old globular clusters.

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https://ui.adsabs.harvard.edu/abs/2019ApJ...887..179P/abstract

Galactic Open Clusters

On the Metallicity Gradient in the Galactic Disk

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The problem of the chemical composition gradient in the galactic disk is studied based on a sample of metallicity estimates of open star clusters, using Gaia DR2-improved distance estimates. A clearly non-monotonic variation was observed in the average metallicity of clusters with increasing galactocentric distance. One can clearly see the metallicity jump of 0.22 in [Fe/H] at a Galactocentric distance of about 9.5 kpc, which appears to be linked to the outer boundary of the thinnest and youngest component of the galactic disk. The absence of a significant metallicity gradient in the internal ($R < 9$ kpc) and external ($R > 10$ kpc) regions of the disk demonstrates the absence of noticeable metal enrichment at times of the order of the ages corresponding to those of the disk regions under consideration. Observational data show that the disk experiences noticeable metal enrichment only during the starburst epochs. No significant dependence was found between the average metallicity and the age of the clusters.

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Variability in the Massive Open Cluster NGC 1817 from K2: A Rich Population of Asteroseismic Red Clump, Eclipsing Binary, and Main Sequence Pulsating Stars

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We present a survey of variable stars detected in K2 Campaign 13 within the massive intermediate age ($\sim$ 1 Gyr) open cluster NGC 1817. We identify a complete sample of 44 red clump stars in the cluster, and have measured asteroseismic quantities ($\nu_{\rm max}$ and/or $\Delta\nu$) for 29 of them. Five stars showed suppressed dipole modes, and the occurrence rates indicate that mode suppression is unaffected by evolution through core helium burning. A subset of the giants in NGC 1817 (and in the similarly aged cluster NGC 6811) have $\nu_{\rm max}$ and $\Delta\nu$ values at or near the maximum observed for core helium burning stars, indicating they have core masses near the minimum for fully non-degenerate helium ignition. Further asteroseismic study of these stars can constrain the minimum helium core mass in red clump stars and the physics that determines this limit. Two giant stars show photometric variations on timescales similar to previously measured spectroscopic orbits. Thirteen systems in the field show eclipses, but only five are probable cluster members. We identify 32 δ Sct pulsators, 27 γ Dor candidates, and 7 hybrids that are probable cluster members, with most new detections. We used the ensemble properties of the δ Sct stars to identify stars with possible radial pulsation modes. Among the oddities we have uncovered are: an eccentric orbit for a short-period binary containing a δ Sct pulsating star; a rare subgiant within the Hertzsprung gap showing δ Sct pulsations; and two hot γ Dor pulsating star candidates.

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Hunting for open clusters in Gaia DR2: 582 new OCs in the Galactic disc

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Open clusters are key targets for studies of Galaxy structure and evolution, and stellar physics. Since the *Gaia* data release 2 (DR2), the discovery of undetected clusters has shown that previous surveys were incomplete. Our aim is to exploit the Big Data capabilities of machine learning to detect new open clusters in *Gaia* DR2, and to complete the open cluster sample to enable further studies of the Galactic disc. We use a machine-learning based methodology to systematically search the Galactic disc for overdensities in the astrometric space and identify the open clusters using photometric information. First, we used an unsupervised clustering algorithm, DBSCAN, to blindly search for these overdensities in *Gaia* DR2 $(l, b, \varpi, \mu_{\alpha^*}, \mu_\delta)$, and then we used a deep learning artificial neural network trained on colour–magnitude diagrams to identify isochrone patterns in these overdensities, and to confirm them as open clusters. We find 582 new open clusters distributed along the Galactic disc in the region $|b| < 20$ deg. We detect substructure in complex regions, and identify the tidal tails of a disrupting cluster UBC 274 of ~ 3 Gyr located at ~ 2 kpc. Adapting the mentioned methodology to a Big Data environment allows us to target the search using the physical properties of open clusters instead of being driven by computational limitations. This blind search for open clusters in the Galactic disc increases the number of known open clusters by 45%.

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A Study of the Blue Straggler Population of the Old Open Cluster Collinder 261

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Blue stragglers (BSs) are stars located in an unexpected region of the color-magnitude diagram (CMD) of a stellar population, as they appear bluer and more luminous than the stars in the turn-off region. They are ubiquitous, since they have been found among Milky Way field stars, in open and globular clusters, and also in other galaxies of the Local Group. Here we present a study on the BS population of the old and metal-rich open cluster Collinder 261, based on Gaia DR2 data and on a multi-epoch radial velocity survey conducted with Fibre Large Array Multi Element Spectrograph (FLAMES) at the Very Large Telescope (VLT). We also analyze the radial distribution of the BS population to probe the dynamical status of the cluster. BS candidates were identified first with Gaia DR2, according to their position on the CMD, proper motions, and parallaxes. Their radial distribution was compared with those of main sequence, red giant, and red clump stars, to evaluate mass segregation. Additionally, their radial velocities (and the associated uncertainties) were compared with the mean radial velocity and velocity dispersion of the cluster. When possible, close binaries and long-period binaries were also identified, based on the radial velocity variations for the different epochs. We also looked for yellow stragglers, i.e., possible evolved BSs. We found 53 BS members of Collinder 261, six of them were already identified in previous catalogs. Among the BS candidates with radial velocity measurements, we found one long-period binary, five close-binary systems, three nonvariable stars; we also identified one yellow straggler.

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The Gaia-ESO Survey: a new approach to chemically characterising young open clusters. I. Stellar parameters, and iron-peak, α-, and proton-capture elements

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Open clusters are recognised as excellent tracers of Galactic thin-disc properties. At variance with intermediate-age and old open clusters, for which a significant number of studies is now available, clusters younger than <150 Myr have been mostly overlooked in terms of their chemical composition until recently (with few exceptions). On the other hand, previous investigations seem to indicate an anomalous behaviour of young clusters, which includes (but is not limited to) slightly sub-solar iron (Fe) abundances and extreme, unexpectedly high barium (Ba) enhancements. In a series of papers, we plan to expand our understanding of this topic and investigate whether these chemical peculiarities are instead related to abundance analysis techniques. We present a new determination of the atmospheric parameters for 23 dwarf stars observed by the Gaia-ESO survey in five young open clusters (ages less than 150 Myr) and one star-forming region (NGC 2264). We exploit a new method based on titanium (Ti) lines to derive the spectroscopic surface gravity, and most importantly, the microturbulence parameter. A combination of Ti and Fe lines is used to obtain effective temperatures. We also infer the abundances of Fe I, Fe II, Ti I, Ti II, Na I, Mg I, Al I, Si I, Ca I, Cr I, and Ni I. Our findings are in fair agreement with Gaia-ESO iDR5 results for effective temperatures and surface gravities, but suggest that for very young stars, the microturbulence parameter is over-estimated when Fe lines are employed. This affects the derived chemical composition and causes the metal content of very young clusters to be under-estimated. Our clusters display a metallicity [Fe/H] between $+0.04 \pm 0.01$ and $+0.12 \pm 0.02$; they are not more metal poor than the Sun. Although based on a relatively small sample size, our explorative study suggests that we may not need to call for ad hoc explanations to reconcile the chemical composition of young open clusters with Galactic chemical evolution models.

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Galactic Globular Clusters

On the black hole content and initial mass function of 47 Tuc

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The globular cluster (GC) 47 Tuc has recently been proposed to host an intermediate-mass black hole (IMBH) or a population of stellar-mass black holes (BHs). To shed light on its dark content, we present an application of self-consistent multimass models with a varying mass function and content of stellar remnants, which we fit to various observational constraints. Our best-fitting model successfully matches the observables and correctly predicts the radial distribution of millisecond pulsars and their gravitational accelerations inferred from long-term timing observations. The data favours a population of BHs with a total mass of $430^{+386}_{-301}\,M_{\odot}$, but the most likely model has very few BHs. Since our models do not include a central IMBH and accurately reproduce the observations, we conclude that there is currently no need to invoke the presence of an IMBH in 47 Tuc. The global present-day mass function inferred is significantly depleted in low-mass stars (power-law slope $\alpha = -0.52^{+0.17}_{-0.16}$). Given the orbit and predicted mass-loss history of this massive GC, the dearth of low-mass stars is difficult to explain with a standard initial mass function (IMF) followed by long-term preferential escape of low-mass stars driven by two-body relaxation, and instead suggests that 47 Tuc may have formed with a bottom-light IMF. We discuss alternative evolutionary origins for the flat mass function and ways to reconcile this with the low BH retention fraction. Finally, by capturing the effect of dark remnants, our method offers a new way to probe the IMF in a GC above the current main-sequence turn-off mass, for which we find a slope of -2.49 ± 0.08.

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New Candidate Planetary Nebulae in Galactic Globular Clusters from the VVV Survey

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Only four globular cluster planetary nebulae (GCPN) are known so far in the Milky Way. About 50 new globular clusters have been recently discovered toward the Galactic bulge. We present a search for planetary nebulae within $3'$ of the new globular clusters, revealing the identification of new candidate GCPN. These possible associations are PN SB 2 with the GC Minni 06, PN G354.9-02.8 with the GC Minni 11, PN G356.8-03.6 with the GC Minni 28, and PN Pe 2-11 with the GC Minni 31. We discard PN H 2-14 located well within the projected tidal radius of the new globular cluster FSR1758 because they have different measured radial velocities. These are interesting objects that need follow-up observations (especially radial velocities) in order to confirm membership and to measure their physical properties in detail. If confirmed, this would double the total number of Galactic GCPN. Based on observations taken within the ESO programmes 179.B-2002 and 298.D-5048.

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A MUSE study of the inner bulge globular cluster Terzan 9: a fossil record in the Galaxy

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Moderately metal-poor inner bulge globular clusters are relics of a generation of long-lived stars that formed in the early Galaxy. Terzan 9, projected at 4.12° from the Galactic center, is among the most central globular clusters in the Milky Way, showing an orbit which remains confined to the inner 1 kpc. Our aim is the derivation of the cluster's metallicity, together with an accurate measurement of the mean radial velocity. In the literature, metallicities in the range between $-2.0<$[Fe/H]<-1.0 have been estimated for Terzan 9 based on color-magnitude diagrams and CaII triplet (CaT) lines. Given its compactness, Terzan 9 was observed using the Multi Unit Spectroscopic Explorer (MUSE) at the Very Large Telescope. The extraction of spectra from several hundreds of individual stars allowed us to derive their radial velocities, metallicities, and [Mg/Fe]. The spectra obtained with MUSE were analysed through full spectrum fitting using the ETOILE code. We obtained a mean metallicity of [Fe/H]≈-1.10 ± 0.15, a heliocentric radial velocity of $v_r^h = 58.1 \pm 1.1$ km s^{-1}, and a magnesium-to-iron [Mg/Fe] = 0.27 ± 0.03. The metallicity-derived character of Terzan 9 sets it among the family of the moderately metal-poor Blue Horizontal Branch clusters HP 1, NGC 6558, and NGC 6522. Based on observations collected at the European Organisation for Astronomical Research in the Southern Hemisphere, Paranal, Chile, under ESO programme 097.D-0093.

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The vertical Na-O relation in the bulge globular cluster NGC 6553

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In this article, we present a detailed chemical analysis of seven red giant members of NGC 6553 using high-resolution spectroscopy from VLT FLAMES. We obtained the stellar parameters (T_{eff}, Log(g), v_t, [Fe/H]) of these stars from the spectra, and we measured the chemical abundance for 20 elements, including light elements, iron-peak elements, α-elements, and neutron-capture elements. The metallicities in our sample stars are consistent with a homogeneous distribution. We found a mean of [Fe/H] $= -0.14 \pm 0.07$ dex, in agreement with other studies. Using the α-elements Mg, Si, Ca, and Ti, we obtain the mean of [α/Fe] $= 0.11 \pm 0.05$. We found a vertical relation between Na and O, characterized by a significant spread in Na and an almost non-existent spread in O. In fact, Na and Al are the only two light elements with a large intrinsic spread, which demonstrates the presence of multiple populations (MPs). An intrinsic spread in Mg is not detected in this study. The α, iron-peak, and neutron-capture elements show good agreement with the trend of the bulge field stars, indicating similar origin and evolution, in concordance with our previous studies for two other bulge globular clusters (NGC 6440 and NGC 6528).

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The origin of the globular cluster FSR 1758

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Globular clusters in the Milky Way are thought to have either an *in situ* origin, or to have been deposited in the Galaxy by past accretion events, like the spectacular Sagittarius dwarf galaxy merger. We probe the origin of the recently discovered globular cluster FSR 1758, often associated with some past merger event and which happens to be projected toward the Galactic bulge. We performed a detailed study of its Galactic orbit, and assign it to the most suitable Galactic component. We employed three different analytical time-independent potential models to calculate the orbit of the cluster by using the Gauss Radau spacings integration method. In addition, a time-dependent bar potential model is added to account for the influence of the Galactic bar. We ran a large suite of simulations via a Montecarlo method to account for the uncertainties in the initial conditions. We confirm previous indications that the globular cluster FSR 1758 possesses a retrograde orbit with high eccentricity. The comparative analysis of the orbital parameters of star clusters in the Milky Way, in tandem with recent metallicity estimates, allows us to conclude that FSR1758 is indeed a Galactic bulge intruder. The cluster can therefore be considered an old metal-poor halo globular cluster formed *in situ* that is passing right now in the bulge region. Its properties, however, can be roughly accounted for by also assuming that the cluster is part of some stream of extra-Galactic origin. We conclude that assessing the origin, either Galactic or extra-galactic, of globular clusters is surely a tantalising task. In any case, by using an *Occam's razor* argument, we tend to prefer an *in situ* origin for FSR 1758.

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Reverse engineering the Milky Way

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The ages, metallicities, alpha-elements and integrals of motion of globular clusters (GCs) accreted by the Milky Way from disrupted satellites remain largely unchanged over time. Here we have used these conserved properties in combination to assign 76 GCs to 5 progenitor satellite galaxies – one of which we dub the Koala dwarf galaxy. We fit a leaky-box chemical enrichment model to the age-metallicity distribution of GCs, deriving the effective yield and the formation epoch of each satellite. Based on scaling relations of GC counts we estimate the original halo mass, stellar mass and mean metallicity of each satellite. The total stellar mass of the 5 accreted satellites contributed around 10^9 $M_\odot$ in stars to the growth of the Milky Way but over 50% of the Milky Way's GC system. The 5 satellites formed at very early times and were likely accreted 8–11 Gyr ago, indicating rapid growth for the Milky Way in its early evolution. We suggest that at least 3 satellites were originally nucleated, with the remnant nucleus now a GC of the Milky Way. Eleven GCs are also identified as having formed ex-situ but could not be assigned to a single progenitor satellite.

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https://arxiv.org/abs/2002.01512

The WAGGS project-III. Discrepant mass-to-light ratios of Galactic globular clusters at high metallicity

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Observed mass-to-light ratios (M/L) of metal-rich globular clusters (GCs) disagree with theoretical predictions. This discrepancy is of fundamental importance since stellar population models provide the stellar masses that underpin most of extragalactic astronomy, near and far. We have derived radial velocities for 1622 stars located in the centres of 59 Milky Way GCs – 12 of which have no previous kinematic information – using integral-field unit data from the WAGGS project. Using N-body models, we determine dynamical masses and M/LV for the studied clusters. Our sample includes NGC 6528 and NGC 6553, which extend the metallicity range of GCs with measured M/L up to [Fe/H] ~ -0.1 dex. We find that metal-rich clusters have M/L_V more than two times lower than what is predicted by simple stellar population models. This confirms that the discrepant M/L–[Fe/H] relation remains a serious concern. We explore how our findings relate to previous observations, and the potential causes for the divergence, which we conclude is most likely due to dynamical effects.

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Clusters in the Magellanic clouds

An Updated Small Magellanic Cloud and Magellanic Bridge Catalog of Star Clusters, Associations, and Related Objects

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We present a catalog of star clusters, associations, and related extended objects in the Small Magellanic Cloud (SMC) and the Magellanic Bridge with 2741 entries, a factor 2 more than a previous version from a decade ago. Literature data up until 2018 December are included. The identification of star clusters was carried out with digital atlases in various bands currently available in the Digitized Sky Survey and the Machine Automatique à Mésurer pour l'Astronomie. imaging surveys. In particular, we cross-identified recent cluster samples from the Visible and Infrared Survey Telescope for Astronomy near-infrared YJK s survey of the Magellanic System, Optical Gravitational Lensing Experiment IV, and Survey of the MAgellanic Stellar History surveys, confirming new clusters and pointing out equivalencies. A major contribution of the present catalog consists of the accurate central positions for clusters and small associations, including a new sample of 45 clusters or candidates in the SMC and 19 in the Magellanic Bridge, as well as a compilation of the most reliable age and metallicity values from the literature. A general catalog must also deal with the recent discoveries of 27 faint and ultra-faint star clusters and galaxies projected on the far surroundings of the Clouds, most of them from the Dark Energy Survey. The information on these objects has been complemented with photometric, spectroscopic, and kinematical follow-up data from the literature. The underluminous galaxies around the Magellanic System, still very few as compared to the predictions from Λ Cold Dark Matter simulations, can bring constraints to galaxy formation and hierarchical evolution. Furthermore, we provide diagnostics, when possible, of the nature of the ultra-faint clusters, searching for borders of the Magellanic System extensions into the Milky Way gravitational potential.

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Dynamical evolution - Simulations

The possible role of stellar mergers for the formation of multiple stellar populations in globular clusters

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Many possible scenarios for the formation of multiple stellar populations (MSP) in globular clusters (GCs) have been discussed so far, including the involvement of asymptotic giant branch stars, fast rotating main sequence stars, very massive main sequence stars and mass-transferring massive binaries based on stellar evolution modelling. But self-consistent, dynamical simulations of very young GCs are usually not considered. In this work, we perform direct N-body modelling of such systems with total masses up to $3.2 \times 10^5 M_\odot$, taking into account the observationally constrained primordial binary properties, and discuss the stellar-mergers driven both by binary stellar evolution and dynamical evolution of GCs. The occurrence of stellar mergers is enhanced significantly in binary-rich clusters such that stars forming from the gas polluted by merger-driven ejection/winds would appears as MSPs. We thus emphasize that stellar mergers can be an important process that connects MSP formation with star cluster dynamics, and that multiple MSP formation channels can naturally work together. The scenario studied here, also in view of a possible top-heavy initial mass function (IMF), may be particularly relevant for explaining the high mass fraction of MSPs (the mass budget problem) and the absence of MSPs in young and low-mass star clusters.

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The survival of star clusters with black hole subsystems

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Recent observations have detected top-heavy initial mass functions (IMFs) in dense star forming regions like the Arches cluster. Whether such IMFs also exist in old dense stellar systems like globular clusters is difficult to constrain, because massive stars already became black holes (BHs) and neutron stars (NSs). However, studies of stellar dynamics find that BHs/NSs influence the long-term evolution of star clusters. Following Breen & Heggie (2013) and by carrying out two-component N-body simulations, we demonstrate how this dynamical impact connects with the shape of IMFs. By investigating the energy balance between the BH subsystem and the global, we find that to properly describe the evolution of clusters, a corrected two-body relaxation time, $T_{rh,p} = T_{rh}/\psi$, is necessary. Because depends on the total mass fraction of BHs, M_2/M_1, and the mass ratio, m_2/m_1, the cluster dissolution time is sensitive to the property of BHs or IMFs. Especially, the escape rate of BHs via ejections from few-body encounters is linked to mass segregation. In strong tidal fields, top-heavy IMFs easily lead to the fast dissolution of star clusters and the formation of BH-dominant dark clusters, which suggests that the observed massive GCs with dense cores are unlikely to have extreme top-heavy IMFs. With the future observations of gravitational waves providing unique information of BHs/NSs, it is possible to combine the multi-message observations to have better constrains on the IMFs of old star clusters.

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Miscellaneous

Nuclear Star Clusters

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We review the current knowledge about nuclear star clusters (NSCs), the spectacularly dense and massive assemblies of stars found at the centers of most galaxies. Recent observational and theoretical work suggest that many NSC properties, including their masses, densities, and stellar populations vary with the properties of their host galaxies. Understanding the formation, growth, and ultimate fate of NSCs therefore is crucial for a complete picture of galaxy evolution. Throughout the review, we attempt to combine and distill the available evidence into a coherent picture of NSC evolution. Combined, this evidence points to a clear transition mass in galaxies of $\sim 10^9$ solar masses where the characteristics of nuclear star clusters change. We argue that at lower masses, NSCs are formed primarily from globular clusters that inspiral into the center of the galaxy, while at higher masses, star formation within the nucleus forms the bulk of the NSC. We also discuss the coexistence of NSCs and central black holes, and how their growth may be linked. The extreme densities of NSCs and their interaction with massive black holes lead to a wide range of unique phenomena including tidal disruption and gravitational wave events. Lastly, we review the evidence that many NSCs end up in the halos of massive galaxies stripped of the stars that surrounded them, thus providing valuable tracers of the galaxies' accretion histories.

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Proceedings abstracts

Structure and kinematics of the wide vicinity of the Alpha Persei open cluster

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We present the results of an investigation of the wide (approximately 100x100°) vicinities of the open cluster Alpha Persei (Melotte 20) by the data of the Gaia DR2 catalog. We select two structures in this region. The first one is the cluster proper with the mass of 900 solar masses approximately and the tidal radius of 12.8 parsecs (4.2°) with an extended corona with a radius of about 20 degrees. The second one is a "stream"or the "filament", extending over 70° approximately. This "stream" is slightly farther than the cluster and overlaps with it partially. Both the cluster and the "stream" have the structural features arguing for their mutual tidal interaction. We determined the cluster rotation parameters. The different hypotheses of the "stream" origin are discussed.

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https://astro.insma.urfu.ru/sites/default/files/school/y2020/WS49_2020_bib.pdf

Conferences

MODEST 20: Dense Star Clusters in the Era of Large Surveys

02–07 February, 2020
Mumbai, India
http://www.tifr.res.in/~modest20/

Star Clusters 2020

09–11 March, 2020
La Serena, Chile
https://www.gemini.edu/clusters2020/

Uncovering the Physics of Formation of Globular Clusters and their Host Galaxies

11–14 May, 2020
Santa Barbara, CA, USA
https://www.kitp.ucsb.edu/activities/clusters-c20

registration deadline: April 5, 2020

Cool Stars, Stellar Systems, and the Sun (CS21)

22–26 June, 2020
Toulouse, France
https://coolstars21.github.io/

abstract submission deadline: early March 2020

Wheel of Star Formation

14–18 September, 2020
Prague, Czech Republic
https://janfest2020.asu.cas.cz/

pre-registration open