# The Star Clusters Young & Old Newsletter

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Dear colleagues,

This issue includes 23 abstracts that cover several aspects of star cluster research. For example, the Gaia-ESO public survey is continuing to collect impressive data on star clusters. This allows the team to attack various astrophysical problem with un-precedented details. One example amply covered in this newsletter issue is the abundance of the light Li element in stars in different evolutionary phases, and its connection with mixing, rotation and magnetic fields (Bouvier et al.; Smiljanic et al). In young dwarf stars it is found that the Li content can depend also on the accretion rate and, possibly, can be linked to the planet formation process. In old giants, Li contents can be traced back to the magnetic field of the stars when they were still in the Main Sequence.

We would like to draw your attention also to the paper by Casamiquela et al. They presented first results and an overview of the OCCASO survey. It is not only meant to supplement the currently ongoing or available surveys in this respect, but also to trace several standard clusters in a most homogeneous way. The goal is to provide homogeneous radial velocities, physical parameters and individual chemical abundances (and thus membership probabilities) of six or more Red Clump stars for a sample of 25 old and intermediate-age OCs visible from the Northern hemisphere.

This issue also includes an announcement of Postdoc Research Fellowships at the Pontificia Universidad Catolica de Chile and numerous conferences that demonstrate the strong activity of the star cluster community.

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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

## Cygnus OB2 DANCe: A high precision proper motion study of the Cygnus OB2 association

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We present a high-precision proper motion study of 873 X-ray and spectroscopically selected stars in the massive OB association Cygnus OB2 as part of the DANCe project. These were calculated from images spanning a 15 year baseline and have typical precisions $< 1$ mas/yr. We calculate the velocity dispersion in the two axes to be $\sigma_\alpha(c) = 13.0^{+0.8}_{-0.7}$ and $\sigma_\delta(c) = 9.1 \pm 0.5$ km s$^{-1}$, using a 2-component, 2-dimensional model that takes into account the uncertainties on the measurements. This gives a 3-dimensional velocity dispersion of $\sigma_{3D} = 17.8 \pm 0.6$ km s$^{-1}$ implying a virial mass significantly larger than the observed stellar mass, confirming that the association is gravitationally unbound. The association appears to be dynamically unevolved, as evidenced by considerable kinematic substructure, non-isotropic velocity dispersions and a lack of energy equipartition. The proper motions show no evidence for a global expansion pattern, with approximately the same amount of kinetic energy in expansion as there is in contraction, which argues against the association being an expanded star cluster disrupted by process such as residual gas expulsion or tidal heating. The kinematic substructures, which appear to be close to virial equilibrium and have typical masses of 40–400 M$_\odot$, also do not appear to have been affected by the expulsion of the residual gas. We conclude that Cyg OB2 was most likely born highly substructured and globally unbound, with the individual subgroups born in (or close to) virial equilibrium, and that the OB association has not experienced significant dynamical evolution since then.

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## Analysis of the WN star WR 102c, its WR nebula, and the associated cluster of massive stars in the Sickle Nebula

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The massive Wolf-Rayet type star WR 102c is located near the Quintuplet Cluster, one of the three massive star clusters in the Galactic Center region. Previous studies indicated that WR 102c may have a dusty circumstellar nebula and is among the main ionising sources of the Sickle Nebula associated with the Quintuplet Cluster. The goals of our study are to derive the stellar parameters of WR 102c from the analysis of its spectrum and to investigate its stellar and nebular environment. We obtained observations with the ESO VLT integral field spectrograph SINFONI in the $K$-band, extracted the stellar spectra, and analysed them by means of stellar atmosphere models. Our new analysis supersedes the results previously reported for WR 102c. We significantly decrease its bolometric luminosity and hydrogen content. We detect four early OB type stars close to WR 102c. These stars have radial velocities similar to that of WR 102c. We suggest that together with WR 102c these stars belong to a distinct star cluster with a total mass of about 1000 M$_\odot$. We identify a new WR nebula around WR 102c in the SINFONI map of the diffuse Br$\gamma$ emission and in the HST Pa$\alpha$ images. The Br$\gamma$

line at different locations is not significantly broadened and similar to the width of nebular emission elsewhere in the H II region around WR 102c. The massive star WR 102c located in the Galactic Center region resides in a star cluster containing additional early-type stars. The stellar parameters of WR 102c are typical for hydrogen-free WN6 stars. We identify a nebula surrounding WR 102c that has a morphology similar to other nebulae around hydrogen-free WR stars, and propose that the formation of this nebula is linked to interaction of the fast stellar wind with the matter ejected at a previous evolutionary stage of WR 102c.

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## Photoevaporation and close encounters: how the environment around Cygnus OB2 affects the evolution of protoplanetary disks

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In our Galaxy, star formation occurs in a variety of environments, with a large fraction of stars formed in clusters hosting massive stars. OB stars have an important feedback on the evolution of protoplanetary disks around nearby young stars and likely on the process of planet formation occurring in them. The nearby massive association Cygnus OB2 is an outstanding laboratory to study this feedback. It is the closest massive association to our Sun, and hosts hundreds of massive stars and thousands of low mass members. In this paper, we analyze the spatial variation of the disk fraction in Cygnus OB2 and we study its correlation with the local values of Far and Extreme ultraviolet radiation fields and the local stellar surface density. We present definitive evidence that disks are more rapidly dissipated in the regions of the association characterized by intense local UV field and large stellar density. In particular, the FUV radiation dominates disks dissipation timescales in the proximity (i.e. within 0.5 pc) of the O stars. In the rest of the association, EUV photons potentially induce a significant mass loss from the irradiated disks across the entire association, but the efficiency of this process is reduced at increasing distances from the massive stars due to absorption by the intervening intracluster material. We find that disk dissipation due to close stellar encounters is negligible in Cygnus OB2, and likely to have affected 1% or fewer of the stellar population. Disk dissipation is instead dominated by photoevaporation. We also compare our results to what has been found in other young clusters with different massive populations, concluding that massive associations like Cygnus OB2 are potentially hostile to protoplanetary disks, but that the environments where disks can safely evolve in planetary systems are likely quite common in our Galaxy.

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# The Gaia-ESO Survey: A lithium-rotation connection at 5 Myr?

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The evolution of lithium abundance in cool dwarfs provides a unique probe of non-standard processes in stellar evolution. Aims. We investigate here the lithium content of young low-mass stars in the 5 Myr-old star forming region NGC 2264 and its relationship with rotation. We combine lithium equivalent width measurements (EW(Li)) from the Gaia-ESO Survey with the determination of rotational periods from the CSI 2264 survey. We consider only bona fide non accreting cluster members in order to minimize uncertainties on EW(Li). We report the existence of a relationship between lithium content and rotation in NGC 2264 at an age of 5 Myr. The Li- rotation connection is seen over a restricted temperature range ($T_{\rm eff}$=3800–4400 K) where fast rotators are Li-rich compared to slow ones. This correlation is similar to, albeit of lower amplitude than, the Li-rotation connection previously reported for K dwarfs in the 125 Myr-old Pleiades cluster. We investigate whether the non-standard pre-main sequence models developed so far to explain the Pleiades results, which are based on episodic accretion, pre-main sequence core-envelope decoupling, and/or radius inflation due to enhanced magnetic activity, can account for an early development of the Li-rotation connection. While radius inflation appears to be the most promising possibility, each of these models has issues. We therefore also discuss external causes that might operate during the first few Myr of pre-main sequence evolution, such as planet engulfment and/or steady disk accretion, as possible candidates for the common origin for Li-excess and fast rotation in young low-mass pre-main sequence stars. The emergence of a connection between lithium content and rotation rate at such an early age as 5 Myr suggests a complex link between accretion processes, early angular momentum evolution, and possibly planet formation, which likely impacts early stellar evolution and still is to be fully deciphered.

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# Galactic Open Clusters

## The Gaia-ESO Survey: Inhibited extra mixing in two giants of the open cluster Trumpler 20?

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We report the discovery of two Li-rich giants, with A(Li) $\sim$ 1.50, in an analysis of a sample of 40 giants of the open cluster Trumpler 20 (with turnoff mass $\sim$ 1.8 $M_{\odot}$). The cluster was observed in the context of the Gaia-ESO Survey. The atmospheric parameters and Li abundances were derived using high-resolution UVES spectra. The Li abundances were corrected for nonlocal thermodynamical equilibrium (non-LTE) effects. Only upper limits of the Li abundance could be determined for the majority of the sample. Two giants with detected Li turned out to be Li rich: star MG 340 has A(Li) non-LTE = 1.54 $\pm$ 0.21 dex and star MG 591 has A(Li) non-LTE = 1.60 $\pm$ 0.21 dex. Star MG 340 is on average $\sim$ 0.30 dex more rich in Li than stars of similar temperature, while for star MG 591 this difference is on average $\sim$ 0.80 dex. Carbon and nitrogen abundances indicate that all stars in the sample have completed the first dredge-up. The Li abundances in this unique sample of 40 giants in one open cluster clearly show that extra mixing is the norm in this mass range. Giants with Li abundances in agreement with the predictions of standard models are the exception. To explain the two Li-rich giants, we suggest that all events of extra mixing have been inhibited. This includes rotation-induced mixing during the main sequence and the extra mixing at the red giant branch luminosity bump. Such inhibition has been suggested in the literature to occur because of fossil magnetic fields in red giants that are descendants of main-sequence Ap-type stars.

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## The Galactic star cluster NGC 4337: estimates of its photometric and dynamical mass

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In this contribution we discuss various estimates of the mass of NGC 4337, an old open cluster located in the inner Galactic disk. We derive its mass in different ways. First, we obtain a lower estimate of the cluster mass using the surface density profile of the cluster and its luminosity and mass function by means of star counts out of a photometric data set in the UBVI passbands. This data set is also used to derive fundamental cluster parameters. Second, we obtain dynamical estimates of the cluster mass as based on a large survey of cluster star radial velocities. The dynamical estimates correspond to significantly larger values than those from star count estimates. We can roughly match these two estimate sets taking into account the contribution of invisible mass in the form of both low mass stars and remnants of high mass stars in the cluster.

**Submitted to : Mem. Soc. Astron. Ital.**

## Stellar open clusters membership probabilities: an N-dimensional geometrical approach

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We present a new geometrical method aimed at determining the members of open clusters. The methodology estimates, in an N-dimensional space, the membership probabilities by means of the distances between every star and the cluster central overdensity. It can handle different sets of variables, which have to satisfy the simple condition of being more densely distributed for the cluster members than for the field stars (as positions, proper motions, radial velocities and/or parallaxes are). Unlike other existing techniques, this fact makes the method more flexible and so can be easily applied to different datasets. To quantify how the method identifies the cluster members, we design series of realistic simulations recreating sky regions in both position and proper motion subspaces populated by clusters and field stars. The results, using different simulated datasets (N = 1, 2 and 4 variables), show that the method properly recovers a very high fraction of simulated cluster members, with a low number of misclassified stars. To compare the goodness of our methodology, we also run other existing algorithms on the same simulated data. The results show that our method has a similar or even better performance than the other techniques. We study the robustness of the new methodology from different subsamplings of the initial sample, showing a progressive deterioration of the capability of our method as the fraction of missing objects increases. Finally, we apply all the methodologies to the real cluster NGC 2682, indicating that our methodology is again in good agreement with preceding studies.

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## Open clusters in Auriga OB2

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We study the area around the H II region Sh 2-234, including the young open cluster Stock 8, to investigate the extent and definition of the association Aur OB2 and the possible role of triggering in massive cluster formation. We obtained Strömgren and J, H, $K_S$ photometry for Stock 8 and Strömgren photometry for two other cluster candidates in the area, which we confirm as young open clusters and name Alicante 11 and Alicante 12. We took spectroscopy of 33 early-type stars in the area, including the brightest cluster members. We calculate a common distance of $2.80^{+0.27}_{-0.24}$ kpc for the three open clusters and surrounding association. We derive an age 4–6 Ma for Stock 8, and do not find a significantly different age for the other clusters or the association. The star LS V +34 23, with spectral type O8 II(f), is likely the main source of ionization of Sh 2-234. We observe an important population of pre-main- sequence stars, some of them with discs, associated with the B-type members lying on the main sequence. We interpret the region as an area of recent star formation with some residual and very localized ongoing star formation. We do not find evidence for sequential star formation on a large scale. The classical definition of Aur OB2 has to be reconsidered, because its two main open clusters, Stock 8 and NGC 1893, are not at the same distance. Stock 8 is probably located in the Perseus arm, but other nearby H II regions whose distances also place them in this arm show quite different distances and radial velocities and, therefore, are not connected.

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## GU Monocerotis: A high-mass eclipsing overcontact binary in the young open cluster Dolidze 25

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The eclipsing binary GU Mon is located in the star-forming cluster Dolidze 25, which has the lowest metallicity measured in a Milky Way young cluster. GU Mon has been identified as a short-period eclipsing binary with two early B-type components. We set out to derive its orbital and stellar parameters. Methods. We present a comprehensive analysis, including B and V light curves and 11 high-resolution spectra, to verify the orbital period and determine parameters. We use the stellar atmosphere code FASTWIND to obtain stellar parameters and create templates for cross-correlation. We obtain a model to fit the light and radial-velocity curves using the Wilson-Devinney code iteratively and simultaneously. The two components of GU Mon are identical stars of spectral type B1 V, with the same mass and temperature. The lightcurves are typical of an EW-type binary. The spectroscopic and photometric analyses agree on a period of 0.896640 ± 0.000007 d. We determine a mass of 9.0 ± 0.6 $M_\odot$ for each component and temperatures of 28 000 ± 2 000 K. Both values are consistent with the spectral type. The two stars are overfilling their respective Roche lobes, sharing a common envelope, and therefore the orbit is synchronised and circularised. The GU Mon system has a fill-out factor above 0.8, containing two dwarf B-type stars on the main sequence. The two stars are in a very advanced stage of interaction, with their extreme physical similarity likely due to the common envelope. The expected evolution of such a system will very probably lead to a merger while still on the main sequence.

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## The OCCASO survey: Presentation and radial velocities of 12 Milky Way open clusters

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Open clusters (OCs) are crucial for studying the formation and evolution of the Galactic disc. However, the lack of a large number of OCs analyzed homogeneously hampers the investigations about chemical patterns and the existence of Galactocentric radial and vertical gradients, or an age-metallicity relation. To overcome this, we have designed the Open Cluster Chemical Abundances from Spanish Observatories survey (OCCASO). We aim to provide homogeneous radial velocities, physical parameters and individual chemical abundances of six or more Red Clump stars for a sample of 25 old and intermediate-age OCs visible from the Northern hemisphere. To do so, we use high resolution spectroscopic facilities (R∼62,000) available at Spanish observatories. We present the motivation, design and current status of the survey, together with the first data release of radial velocities for 77 stars in 12 OCs, which represents about 50% of the survey. We include clusters never studied with high-resolution spectroscopy before (NGC 1907, NGC 6991, NGC 7762), and clusters in common with other large spectroscopic surveys like the Gaia-ESO Survey (NGC 6705) and APOGEE(NGC 2682 and NGC 6819). We perform internal comparisons between instruments to evaluate and correct internal systematics of the results, and compare our radial velocities with previous determinations in the literature, when available. Finally, radial velocities for each cluster are used to perform a preliminar kinematic study in relation with the Galactic disc.

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# Rotation periods for cool stars in the 4Gyr-old open cluster M67, the solar-stellar connection, and the applicability of gyrochronology to at least solar age

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We report rotation periods for 20 cool (FGK) main sequence member stars of the 4 Gyr-old open cluster M67 (= NGC2682), obtained by analysing data from Campaign 5 of the K2 mission with the Kepler Space Telescope. The rotation periods delineate a sequence in the color-period diagram (CPD) of increasing period with redder color. This sequence represents a cross-section at the cluster age of the surface $P = P(t, M)$, suggested in prior work to extend to at least solar age. The current Sun is located marginally (approx. one sigma) above M67 in the CPD, as its relative age leads us to expect, and lies on the $P = P(t, M)$ surface to within measurement precision. We therefore conclude that the solar rotation rate is normal, as compared with cluster stars, a fact which strengthens the solar-stellar connection. The agreement between the M67 rotation period measurements and prior predictions further implies that rotation periods, especially when coupled with appropriate supporting work such as spectroscopy, can provide reliable ages via gyrochronology for other similar FGK dwarfs from the early main sequence to solar age and likely till the main sequence turnoff. The M 67 rotators have a rotational age of 4.2 Gyr, with a standard deviation of 0.7 Gyr, implying that similar field stars can be age-dated to precisions of ∼17%. The rotational age of the M67 cluster as a whole is therefore 4.2 Gyr, but with a lower (averaged) uncertainty of 0.2 Gyr.

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# Galactic Globular Clusters

## High resolution spectroscopic analysis of seven giants in the bulge globular cluster NGC 6723

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Globular clusters associated with the Galactic bulge are important tracers of stellar populations in the inner Galaxy. High resolution analysis of stars in these clusters allows us to characterize them in terms of kinematics, metallicity, and individual abundances, and to compare these fingerprints with those characterizing field populations. We present iron and element ratios for seven red giant stars in the globular cluster NGC 6723, based on high resolution spectroscopy. High resolution spectra (R $\sim$ 48 000) of seven K giants belonging to NGC 6723 were obtained with the FEROS spectrograph at the MPG/ESO 2.2 m telescope. Photospheric parameters were derived from $\sim$130 Fe i and Fe ii transitions. Abundance ratios were obtained from line-to-line spectrum synthesis calculations on clean selected features. An intermediate metallicity of [Fe/H] = $-0.98 \pm 0.08$ dex and a heliocentric radial velocity of $v_{hel} = -96.6 \pm 1.3$ km s$^{-1}$ were found for NGC 6723. Alpha-element abundances present enhancements of [O/Fe] = $0.29 \pm 0.18$ dex, [Mg/Fe] = $0.23 \pm 0.10$ dex, [Si/Fe] = $0.36 \pm 0.05$ dex, and [Ca/Fe] = $0.30 \pm 0.07$ dex. Similar overabundance is found for the iron-peak Ti with [Ti/Fe] = $0.24 \pm 0.09$ dex. Odd-Z elements Na and Al present abundances of [Na/Fe] = $0.00 \pm 0.21$ dex and [Al/Fe] = $0.31 \pm 0.21$ dex, respectively. Finally, the s-element Ba is also enhanced by [Ba/Fe] = $0.22 \pm 0.21$ dex. The enhancement levels of NGC 6723 are comparable to those of other metal-intermediate bulge globular clusters. In turn, these enhancement levels are compatible with the abundance profiles displayed by bulge field stars at that metallicity. This hints at a possible similar chemical evolution with globular clusters and the metal-poor of the bulge going through an early prompt chemical enrichment.

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## Multiple stellar populations in the globular cluster M3 (NGC 5272): a Strömgren perspective

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We present Strömgren photometry of the Galactic Globular Cluster M3 to study its multiple generations phenomenon. The use of different colour-magnitude diagrams and especially of the notoriously efficient $c_y$ index allowed us to detect a double Red Giant Branch in the cluster CMD. After decontamination from fore- and background sources, the two sequences turned out to be equally populated. The two components also show a bimodal radial distribution well corresponding to that predicted by numerical simulations for clusters living in an intermediate dynamical evolutive state and with a population with modified chemical composition that was born more centrally concentrated than the primordial. The analysis of high-resolution spectra quantitatively demonstrates that the two detected sequences correspond to the first (Na-poor) generation and the second (Na-rich) generation, thus confirming the importance of synergy between photometry and spectroscopy.

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# Clusters in the Magellanic clouds

## Extended Main Sequence Turn-Offs in Low Mass Intermediate Age Clusters

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We present an imaging analysis of four low mass stellar clusters ($< 5000$ $M_{\odot}$) in the outer regions of the LMC in order to shed light on the extended main sequence turn-off (eMSTO) phenomenon observed in high mass clusters. The four clusters have ages between 1–2 Gyr and two of them appear to host eMTSOs. The discovery of eMSTOs in such low mass clusters – $> 5$ times less massive than the eMSTO clusters previously studied – suggests that mass is not the controlling factor in whether clusters host eMSTOs. Additionally, the narrow extent of the eMSTO in the two older ($\sim$ 2 Gyr) clusters is in agreement with predictions of the stellar rotation scenario, as lower mass stars are expected to be magnetically braked, meaning that their CMDs should be better reproduced by canonical simple stellar populations. We also performed a structural analysis on all the clusters and found that a large core radius is not a requisite for a cluster to exhibit an eMSTO.

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## No evidence for younger stellar generations within the intermediate-age massive clusters NGC 1783, NGC 1806 and NGC 411

**I. Cabrera-Ziri [1,2], F. Niederhofer [3,4,5], N. Bastian [2], and 11 co-authors**

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Recently, Li et al. claimed to have found evidence for multiple generations of stars in the intermediate-age clusters NGC 1783, NGC 1806 and NGC 411 in the Large and Small Magellanic Clouds. Here we show that these young stellar populations are present in the field regions around these clusters and are not likely associated with the clusters themselves. Using the same data sets, we find that the background subtraction method adopted by the authors does not adequately remove contaminating stars in the small number Poisson limit. Hence, we conclude that their results do not provide evidence of young generations of stars within these clusters.

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http://arxiv.org/abs/1604.06106

## Searching for GC-like abundance patterns in young massive clusters

**I. Cabrera-Ziri [1,2], C. Lardo [2], B. Davies [2], and 4 co-authors**

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Studies during the last decade have revealed that nearly all Globular Clusters (GCs) host multiple populations (MPs) of stars with a distinctive chemical patterns in light elements. No evidence of such MPs has been found so far in lower-mass ($\lesssim 10^4$ $M_\odot$) open clusters nor in intermediate age (1-2 Gyr) massive ($> 10^5$ $M_\odot$) clusters in the Local Group. Young massive clusters (YMCs) have masses and densities similar to those expected of young GCs in the early universe, and their near-infrared (NIR) spectra are dominated by the light of red super giants (RSGs). The spectra of these stars may be used to determine the cluster's abundances, even though the individual stars cannot be spatially resolved from one another. We carry out a differential analysis between the Al lines of YMC NGC 1705: 1 and field Small Magellanic Cloud RSGs with similar metallicities. We exclude at high confidence extreme [Al/Fe] enhancements similar to those observed in GCs like NGC 2808 or NGC 6752. However, smaller variations cannot be excluded.

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## A Young Cluster With an Extended Main Sequence Turnoff: Confirmation of a Prediction of the Stellar Rotation Scenario

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We present Hubble Space Telescope photometry of NGC1850, a ∼100 Myr, $\sim 10^5$ $M_\odot$ cluster in the Large Magellanic Cloud. The colour magnitude diagram clearly shows the presence of an extended main sequence turnoff (eMSTO). The use of non-rotating stellar isochrones leads to an age spread of ∼40 Myr. This is in good agreement with the age range expected when the effects of rotation in MSTO stars are wrongly interpreted in terms of age spread. We also do not find evidence for multiple, isolated episodes of star-formation bursts within the cluster, in contradiction to scenarios that invoke actual age spreads to explain the eMSTO phenomenon. NGC 1850 therefore continues the trend of eMSTO clusters where the inferred age spread is proportional to the age of the cluster. While our results confirm a key prediction of the scenario where stellar rotation causes the eMSTO feature, direct measurements of the rotational rate of MSTO stars is required to definitively confirm or refute whether stellar rotation is the origin of the eMSTO phenomenon or if it is due to an as yet undiscovered effect.

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`http://arxiv.org/abs/1604.01046`

# The most distant clusters

## A Possible Solution for the M/L-[Fe/H] Relation of Globular Clusters in M31: A metallicity and density dependent top-heavy IMF

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The observed mass-to-light ($M/L$) ratios of a large sample of GCs in M31 show an inverse trend with metallicity compared to what is expected from Simple Stellar Population (SSP) models with an invariant canonical stellar IMF, in the sense that the observed $M/L$ ratios decrease with increasing metallicity. We show that incorporating the effect of dynamical evolution the SSP models with a canonical IMF can not explain the decreasing $M/L$ ratios with increasing metallicity for the M31 GCs. The recently derived top-heavy IMF as a function of metallicity and embedded cluster density is proposed to explain the lower than expected $M/L$ ratios of metal-rich GCs. We find that the SSP models with a top-heavy IMF, retaining a metallicity- and cluster mass-dependent fraction of the remnants within the clusters, and taking standard dynamical evolution into account can successfully explain the observed $M/L-[Fe/H]$ relation of M31 GCs. Thus we propose that the kinematical data of GCs can be used to constrain the top-heaviness of the IMF in GCs.

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`http://adsabs.harvard.edu/abs/2016arXiv160504913H`

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## The Very Massive Star Content of the Nuclear Star Clusters in NGC 5253

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The blue compact dwarf galaxy NGC 5253 hosts a very young starburst containing twin nuclear star clusters, separated by a projected distance of 5 pc. One cluster (#5) coincides with the peak of the H-alpha emission and the other (#11) with a massive ultracompact H II region. A recent analysis of these clusters shows that they have a photometric age of 1±1 Myr, in apparent contradiction with the age of 3–5 Myr inferred from the presence of Wolf-Rayet features in the cluster #5 spectrum. We examine Hubble Space Telescope ultraviolet and Very Large Telescope optical spectroscopy of #5 and show that the stellar features arise from very massive stars (VMS), with masses greater than 100 $M_{\odot}$, at an age of 1–2 Myr. We further show that the very high ionizing flux from the nuclear clusters can only be explained if VMS are present. We investigate the origin of the observed nitrogen enrichment in the circum-cluster ionized gas and find that the excess N can be produced by massive rotating stars within the first 1 Myr. We find similarities between the NGC 5253 cluster spectrum and those of metal poor, high redshift galaxies. We discuss the presence of VMS in young, star-forming galaxies at high redshift; these should be detected in rest frame UV spectra to be obtained with the James Webb Space Telescope. We emphasize that population synthesis models with upper mass cut-offs greater than 100 Msun are crucial for future studies of young massive star clusters at all redshifts.

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## No sign (yet) of intergalactic globular clusters in the Local Group

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We present Gemini/GMOS imaging of twelve candidate intergalactic globular clusters (IGCs) in the Local Group, identified in a recent survey of the SDSS footprint by di Tullio Zinn & Zinn (2015). Our image quality is sufficiently high, at $\sim 0.4$–$0.7''$, that we are able to unambiguously classify all twelve targets as distant galaxies. To reinforce this conclusion we use GMOS images of globular clusters in the M31 halo, taken under very similar conditions, to show that any genuine clusters in the putative IGC sample would be straightforward to distinguish. Based on the stated sensitivity of the di Tullio Zinn & Zinn (2015) search algorithm, we conclude that there cannot be a significant number of IGCs with $M_V \leq -6$ lying unseen in the SDSS area if their properties mirror those of globular clusters in the outskirts of M31 – even a population of 4 would have only a $\sim 1\%$ chance of non-detection.

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## Star Clusters in M31: VII. Global Kinematics and Metallicity Subpopulations of the Globular Clusters

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We carry out a joint spatial–kinematical–metallicity analysis of globular clusters (GCs) around the Andromeda Galaxy (M31), using a homogeneous, high-quality spectroscopic dataset. In particular, we remove the contaminating young clusters that have plagued many previous analyses. We find that the clusters can be divided into three major metallicity groups based on their radial distributions: (1) an inner metal-rich group ([Fe/H] $> -0.4$), (2) a group with intermediate metallicity (with median [Fe/H]$=-1$), (3) and a metal-poor group, with [Fe/H] $< -1.5$. The metal-rich group has kinematics and spatial properties like the disk of M31, while the two more metal-poor groups show mild prograde rotation overall, with larger dispersions – in contrast to previous claims of stronger rotation. The metal-poor GCs are the least concentrated group; such clusters occur five times less frequently in the central bulge than do clusters of higher metallicity. Despite some well-known differences between the M31 and Milky Way GC systems, our revised analysis points to remarkable similarities in their chemodynamical properties, which could help elucidate the different formation stages of galaxies and their GCs. In particular, the M31 results motivate further exploration of a metal-rich GC formation mode in situ, within high-redshift, clumpy galactic disks.

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# Dynamical evolution - Simulations

## Testing lowered isothermal models with direct N-body simulations of globular clusters

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Several self-consistent models have been proposed, aiming at describing the phase space distribution of stars in globular clusters. This study explores the ability of the recently proposed LIMEPY models (Gieles & Zocchi) to reproduce the dynamical properties of direct N-body models of a cluster in a tidal field, during its entire evolution. These dynamical models include prescriptions for the truncation and the degree of radially-biased anisotropy contained in the system, allowing us to explore the interplay between the role of anisotropy and tides in various stages of the life of star clusters. We show that the amount of anisotropy in an initially tidally underfilling cluster increases in the pre-collapse phase, and then decreases with time, due to the effect of the external tidal field on its spatial truncation. This is reflected in the correspondent model parameters, and the best-fit models reproduce the main properties of the cluster at all stages of its evolution, except for the phases immediately preceding and following core collapse. We also notice that the best-fit LIMEPY models are significantly different from isotropic King models, especially in the first part of the evolution of the cluster. Our results put limits on the amount of radial anisotropy that can be expected for clusters evolving in a tidal field, which is important to understand other factors that could give rise to similar observational signatures, such as the presence of an intermediate-mass black hole.

**Accepted by : Monthly Notices of the Royal Astronomical Society**
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## Dynamical ejections of massive stars from young star clusters under diverse initial conditions

**S. Oh and P. Kroupa**

University of Bonn, Bonn, Germany

We study the effects that initial conditions of star clusters and their massive star population have on dynamical ejections of massive stars from star clusters up to an age of 3 Myr. We use a large set of direct N-body calculations for moderately massive star clusters ($M_{\rm ecl} \sim 3000$ M$_\odot$). We vary the initial conditions of the calculations, such as the initial half-mass radius of the clusters, initial binary populations for massive stars and initial mass segregation. We find that the initial density is the most influential parameter for the ejection fraction of the massive systems. The clusters with an initial half-mass radius $r_h(0)$ of 0.1 (0.3) pc can eject up to 50% (30%) of their O-star systems on average, while initially larger ($r_h(0)$=0.8 pc) clusters, that is, lower density clusters, eject hardly any OB stars (at most ∼4.5%). When the binaries are composed of two stars of similar mass, the ejections are most effective. Most of the models show that the average ejection fraction decreases with decreasing stellar mass. For clusters that are efficient at ejecting O stars, the mass function of the ejected stars is top-heavy compared to the given initial mass function (IMF), while the mass function of stars that remain in the cluster becomes slightly steeper (top-light) than the IMF. The top-light mass functions of stars in 3 Myr old clusters in our N-body models agree well with the mean mass function of young intermediate-mass clusters in M 31, as reported previously. This implies that the IMF of the observed

young clusters is the canonical IMF. We show that the multiplicity fraction of the ejected massive stars can be as high as 60%, that massive high-order multiple systems can be dynamically ejected, and that high-order multiples become common especially in the cluster. We also discuss binary populations of the ejected massive systems. Clusters that are initially not mass-segregated begin ejecting massive stars after a time delay that is caused by mass segregation. When a large kinematic survey of massive field stars becomes available, for instance through Gaia, our results may be used to constrain the birth configuration of massive stars in star clusters. The results presented here, however, already show that the birth mass-ratio distribution for O-star primaries must be near uniform for mass ratios q > 0.1.

**Accepted by : Astronomy & Astrophysics**
http://arxiv.org/abs/1604.00006

# Conferences

## Third Conference on Stellar Astrophysics in honor of Prof. Dr. J. J. Clariá

21–24 June, 2016
Córdoba, Argentina
http://jae2016.oac.uncor.edu/

registration closed, contact organizers

## The Role of Feedback in the Formation and Evolution of Star Clusters

18–22 July, 2016
Sexten, Italy
http://www.sexten-cfa.eu/en/conferences/2016/details/72-the-role-of-feedback-in-the-formation-and-evolution-of-star-clusters.html

Participation and poster abstract submission still possible

## Multiple Populations in Stellar Clusters: Where do we stand?

25–29 July, 2016
Sexten, Italy
http://www.sexten-cfa.eu/en/conferences/2016/details/74-6-multiple-populations-in-stellar-clusters-where-do-we-stand.html

Participation and poster abstract submission still possible

## Star Clusters: from Infancy to Teenagehood

8–12 August, 2016
Heidelberg, Germany
http://wwwstaff.ari.uni-heidelberg.de/infant_clusters_2016/

Participation and poster abstract submission still possible

## Stars on the run - A meeting on run-away and hyper-velocity stars

16–19 August, 2016
Bamberg, Germany
http://www.black-hole.eu/index.php/hvs2016

Abstract submission deadline (talk/poster): July $4^{th}$

## MODEST-16 NYC: A Conference on Gas and Gravitational Dynamics

6–9 September, 2016
New York City, USA
www.amnh.org/our-research/physical-sciences/astrophysics/events/modest-16-nyc

Abstract submission deadline: May $31^{st}$

## 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

## Frontiers in Theoretical and Applied Physics (with sessions on Stellar Clusters)

22–25 February, 2017
Sharjah/Dubai, United Arab Emirates
http://www.aus.edu/info/200227/conferences/586/ftaps_2017/1

# Jobs

## Postdoctoral Research Fellowships

**Institute of Astrophysics, Pontificia Universidad Catolica de Chile, Santiago**

The Institute of Astrophysics of Pontificia Universidad Catolica (IA-PUC) and the Center of Astro-Engineering of the Universidad Catolica (AIUC) invite applications for postdoctoral research fellowships in the areas of observational, theoretical, computational astrophysics and/or instrumentation to work either on existing projects or in close collaboration with one or more faculty members at IA-PUC (www.astro.puc.cl) and/or AIUC (www.aiuc.puc.cl). Selected candidates will be sponsored by IA-PUC/AIUC professors to apply for 3-year FONDECYT postdoctoral grants from the Chilean national funding agency, CONICYT. Eligibility for the FONDECYT grants is limited to recent PhDs (received roughly between July, 2013 and Nov, 2016). In exceptional instances (e.g., instrumentation), applicants may be directly hired by IA-PUC/AIUC beforehand.

The IA-PUC/AIUC provides a vibrant, dynamic, and productive international environment with 20 professors, 45+ postdoctoral researchers (22 FONDECYT fellows), and 40+ graduate students. Members of IA-PUC/AIUC are leading or are active participants in several ongoing international collaborations: The HST Coma Cluster Core Project (C3PO), the Next Generation Fornax/Virgo Surveys (NGFS/NGVS), Survey of Centaurus A's Baryonic Structures (SCABS), VST-ATLAS u-band extension, Frontier Fields Survey, PESSTO, NuSTAR Legacy Surveys, SDSS-IV (w/ eBOSS, MANGA and APOGEE data access), Vista Variables Via Lactea (VVV), Max Planck Partner Group on the Galactic Centre, Millennium Nucleus on Protoplanetary Discs (MAD), the Atacama Cosmology Telescope (ACT), VLT Multi Object Optical and Near-infrared Spectrograph (VLT-MOONS), Fibre Dual Echelle Optical Spectrograph (FIDEOS), TAO-AIUC high Resolution Y band Spectrograph (TARdYS), and the Cherenkov Telescope Array (CTA).

While resident at IA-PUC/AIUC, the candidate will qualify as a member of the Chilean community with 10% privileged access on all telescopes in Chile, including ESO/Paranal's 4x8m VLT and 4m VISTA, La Silla's 3.5m NTT and 3.6m and 2.2m telescopes, Gemini-South 8m, Carnegie's 2.5m and Magellan 2x6.5m, CTIO's 4m (Blanco), SOAR 4m, as well as ASTE, APEX, and ALMA. There is also strong interest in our Institute to work towards the next-generation telescopes to be placed in Chile, such as LSST, GMT, E-ELT, and CTA. Additionally, IA-PUC/AIUC hosts two supercomputers (512-cores, 520-cores) and a GPU cluster (1792 Tesla cores), which are available for numerical simulations, large databases, and data analyses.

Applicants should submit by email and in PDF format to Prof. Franz Bauer (**fbauer@astro.puc.cl**) by Friday, July 1st, 2016 the following documents: a brief cover letter; CV including exact or expected PhD date; publication list; research summary (max. three pages) describing past projects and possible plans while resident at IA-PUC/AIUC; the names of three people willing to write letters of recommendation upon request.

We strongly encourage applicants to make early contact with IA-PUC/AUIC professors working on their subjects of interest, to seed collaborations on joint projects leading to the submission of successful FONDECYT applications. IA-PUC and AIUC are committed to equal opportunity and diversity in its workforce. Women and minorities are strongly encouraged to apply.

*For further information, contact:* Prof. Franz Bauer, `fbauer@astro.puc.cl`