$\mathcal{SCYON}$

The Star Clusters Young & Old Newsletter

edited by Holger Baumgardt, Ernst Paunzen and Pavel Kroupa

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EDITORIAL

Here is the 32nd issue of the SCYON newsletter. The current issue contains 40 abstracts, one PhD summary, and the second announcement for the IAU Symposium 246 in Capri. It also contains job advertisements for PhD and postdoc positions from Swinburne University and Marseille Observatory.

As usual, we would like to thank all those who sent in their contributions.

Holger Baumgardt, Ernst Paunzen and Pavel Kroupa

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SCYON POLICY

The SCYON Newsletter publishes abstracts from any area in astronomy which are relevant to research on star clusters. We welcome all contributions. Topics to be covered include

1. Abstracts from refereed articles
2. Abstracts from conference proceedings
3. PhD summaries
4. General announcements : Conferences, new databases, and the likes.

Concerning possible infringements to copyright laws, we understand that the authors themselves are taking responsibility for the material they send us. We make no claim whatsoever to owning the material that is posted at our url or circulated by email. The newsletter SCYON is a free service. It does not substitute for our personal opinions, nor does it reflect in any way the views of our respective institutes of affiliations.

SCYON will be published initially once every two months. If the number of contributions justifies monthly installments, we will move toward more frequent issues in order to keep the newsletter relatively short, manageable for us, and up-to-date.

Conference and journal abstracts can be submitted at any time either by web download, or failing this, we also accept abstracts typeset using the latest latex abstract template (available from the SCYON webpage). We much prefer contributors to use the direct download form, since it is mostly automated. Abstracts will normally appear on the website as soon as they are submitted to us. Other contributions, such as PhD summaries, should be sent to us using the LaTeX template. *Please do not submit postscript files, nor encoded abstracts as e-mail attachments.*

All abstracts/contributions will be processed, but we reserve the right to not post abstracts submitted in the wrong format or which do not compile. If you experience any sort of problems accessing the web site, or with the LaTeX template, please write to us at scyon@astro.u-strasbg.fr.

A "Call for abstracts" is sent out approximately one week before the next issue of the newsletter is finalised. This call contains the deadline for abstract submissions for that coming issue and the LaTeX abstract template.

Depending on circumstances, the editors might actively solicit contributions, usually those spotted on a preprint server, but they do not publish abstracts without the author's consent.

We implicitly encourage further dissemination of the letter to institutes and astronomers who may benefit from it.

The editors

SCYON Mirrors

The official Scyon mirror site in Australia is hosted at the Centre for Astrophysics & Supercomputing of the University of Swinburne by Duncan Forbes and his team :

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1. Star Forming Regions

Resolving the Stellar Populations of the Circumnuclear Ring of NGC 7469

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We investigate the stellar populations in the star forming ring of the luminous infrared galaxy NGC 7469. We use *Hubble Space Telescope* multi-wavelength (UV through NIR) imaging complemented with new K-band ground-based long-slit spectroscopy, and mid-IR and radio maps from the literature. Spectral energy distributions (SEDs) and evolutionary synthesis models have been used to characterize the star formation at different scales from those of individual star clusters (tens of pc) to that of the entire star-forming ring (kpc scale). At the smallest scales two different populations of massive ($1 - 10 \times 10^6\,M_\odot$) clusters are identified. About 25% of the clusters are young ($1 - 3\,$Myr) and extincted ($A_V \approx 3$ mag), whereas the vast majority are of intermediate age (~ 9 to $20\,$Myr) and less obscured ($A_V \approx 1$ mag). At larger (hundreds of pc) scale, an analysis of the integrated SED and spectroscopic data of the ring indicates the presence of two stellar populations. The young ($5 - 6\,$Myr) and obscured stellar population accounts for the Brγ, emission and most of the IR luminosity, and about one-third of the stellar mass of the ring. The much less obscured intermediate-age population has properties similar to those of the majority of the (older) $1.1\,\mu$m-selected star clusters. The distribution of these two populations is clearly different and even spatially anti-correlated. The UV-optical-NIR continuum (including the majority of the clusters) of the ring traces mostly the mildly obscured intermediate-age population, while the MIR and radio peaks mark the location of the youngest and obscured star-forming regions. Moreover, the two brightest MIR and radio peaks are spatially coincident with the ends of the nuclear molecular gas bar. This study emphasizes the need for multi-wavelength, high-angular resolution observations to characterize the star formation in the dust-obscured regions commonly present in LIRGs.

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Rotational Velocities For B0-B3 Stars in 7 Young Clusters: Further Study of the Relationship between Rotation Speed and Density in Star-Forming Regions

S. C. Wolff, S. E. Strom, D. Dror
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We present the results of a study aimed at assessing the differences in the distribution of rotation speeds, N (v sin i) among young (1-15 Myr) B stars spanning a range of masses $6 < M/M(sun) < 12$ and located in different environments: 7 low density (rho $<$ 1 M (sun) /pc^3) ensembles that are destined to become unbound stellar associations, and 8 high density (rho $>>$ 1 M (sun) /pc^3) ensembles that will survive as rich, bound stellar clusters for ages well in excess of 10^8 years. Our results demonstrate (1) that independent of environment, the rotation rates for stars in this mass range do not change by more than 0.1 dex over ages t $\sim$ 1 to t $\sim$ 15 Myr; and (2) that stars formed in high density regions lack the cohort of slow rotators that dominate the low density regions and young field stars. We suggest that the differences in N(v sin i) between low and high density regions may reflect a combination of initial conditions and environmental effects: (1) the higher turbulent speeds that characterize molecular gas in high density, cluster- forming regions; and (2) the stronger UV radiation fields and high stellar densities that characterize such regions. Higher turbulent speeds may lead to higher time-averaged accretion rates during the stellar assembly phase. In the context of stellar angular momentum regulation via disk-locking, higher accretion rates lead to both higher initial angular momenta and evolution-driven increases in surface rotation rates as stars contract from the birthline to the Zero Age Main Sequence. Stronger UV radiation fields and higher densities may lead to shorter disk lifetimes in cluster-forming regions. If so, B stars formed in dense clusters are more likely to be released from their disks early during their PMS lifetimes and evolve into rapid rotators as they conserve angular momentum and spin up in response to contraction. By contrast, the majority of their brethren in low density, association forming regions can retain their disks for much or all of their PMS lifetimes, are locked by their disks to rotate at constant angular speed, and lose angular momentum as they contract toward the ZAMS, and thus arrive on the ZAMS as relatively slowly rotating stars

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SPITZER/IRAC-MIPS Survey of NGC2244: Protostellar Disk Survival in the Vicinity of Hot Stars

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We present the results from a survey of NGC 2244 from 3.6 to 24 micron with the Spitzer Space Telescope. The 24micron-8micron-3.6micron color composite image of the region shows that the central cavity surrounding the multiple O and B stars of NGC2244 contains a large amount of cool dust visible only at 24micron. Our survey gives a detailed look at disk survivability within the hot-star-dominated environment in this cavity. Using mid infrared two color diagrams ([3.6]-[4.5] vs [5.8]-[8.0]) we identified 337 class II and 25 class I objects out of 1084 objects detected in all four of these bands with photometric uncertainty better than 10%. Including the 24 micron data, we found 213 class II and 20 class I sources out of 279 stars detected also at this latter band. The center of the class II density contours is in very good agreement with the center of the cluster detected in the 2MASS images. We studied the distribution of the class II sources relative to the O stars and found that the effect of high mass stars on the circumstellar disks is significant only in their immediate vicinity.

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2. Galactic Center Clusters

The Arches Cluster Mass Function

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We have analyzed H and Ks-band images of the Arches cluster obtained using the NIRC2 instrument on Keck with the laser guide star adaptive optics (LGS AO) system. With the help of the LGS AO system, we were able to obtain the deepest ever photometry for this cluster and its neighborhood, and derive the background-subtracted present-day mass function (PDMF) down to 1.3 Msun for the 5"-9" annulus of the cluster. We find that the previously reported turnover at 6 Msun is simply due to a local bump in the mass function (MF), and that the MF continues to increase down to our 50 % completeness limit (1.3 Msun) with a power-law exponent of Gamma = -0.91 for the mass range of $1.3 < M/Msun < 50$. Our numerical calculations for the evolution of the Arches cluster show that the Gamma values for our annulus increase by 0.1-0.2 during the lifetime of the cluster, and thus suggest that the Arches cluster initially had Gamma of -1.0 $\sim$ -1.1, which is only slightly shallower than the Salpeter value.

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The present day mass function in the central region of the Arches cluster

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University of Amsterdam

We study the evolution of the mass function in young and dense star clusters by means of direct N-body simulations. Our main aim is to explain the recent observations of the relatively flat mass function observed near the centre of the Arches star cluster. In this region, the power law index of the mass function for stars more massive than about 5–6 $M_\odot$ is larger than the Salpeter value by about unity; whereas further out, and for the lower mass stars, the mass function resembles the Salpeter distribution. We show that the peculiarities in the Arches mass function can be explained satisfactorily without primordial mass segregation. We draw two conclusions from our simulations: 1) The Arches initial mass function is consistent with a Salpeter slope down to $\sim 1\,M_\odot$. 2) The cluster is about half way towards core collapse. The cores of other star clusters with characteristics similar to those of the Arches are expected to show similar flattening in the mass functions for the high mass ($>= 5M_\odot$) stars.

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3. Galactic Open Clusters

uvbyCaHbeta CCD Photometry of Clusters. VIII. The Super-Metal Rich, Old Open Cluster NGC 6791

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CCD photometry on the intermediate-band vbyCaHbeta system is presented for the metal-rich, old open cluster, NGC 6791. Preliminary analysis led to [Fe/H] above +0.4 with an anomalously high reddening and an age below 5 Gyr. A revised calibration between $(b\text{-}y)_0$ and [Fe/H] at a given temperature shows that the traditional color-metallicity relations underestimate the color of the turnoff stars at high metallicity. With the revised relation, the metallicity from hk and the reddening for NGC 6791 become [Fe/H] = +0.45 +/- 0.04 and E(b-y) = 0.113 +/- 0.012 or E(B-V) = 0.155 +/- 0.016. Using the same technique, reanalysis of the photometry for NGC 6253 produces [Fe/H] = +0.58 +/- 0.04 and E(b-y) = 0.120 +/- 0.018 or E(B-V) = 0.160 +/- 0.025. The errors quoted include both the internal and external errors. For NGC 6791, the metallicity from m_1 is a factor of two below that from hk, a result that may be coupled to the consistently low metal abundance from DDO photometry of the cluster and the C-deficiency found from high dispersion spectroscopy. E(B-V) is the same value predicted from Galactic reddening maps. With E(B-V) = 0.15 and [Fe/H] = +0.45, the available isochrones predict an age of 7.0 +/- 1.0 Gyr and an apparent modulus of (m-M) = 13.60 +/- 0.15, with the dominant source of the uncertainty arising from inconsistencies among the isochrones. The reanalysis of NGC 6253 with the revised lower reddening confirms that on both the hk and m_1 metallicity scales, NGC 6253, while less than half the age of NGC 6791, remains at least as metal-rich as NGC 6791, if not richer.

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Near-IR imaging of Galactic massive clusters: Westerlund 2

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Abstract

Most stars in the Galaxy were formed in massive clusters. To understand nature's favorite mode of star formation and the initial stages of the life of most stars one needs to characterize the youngest and resolved massive clusters in the Milky Way. Unfortunately young massive clusters are challenging observational targets as they are rare, hence found at large distances, are still embedded in their parental molecular cloud, and are swamped by relatively bright nebulae. In this paper we propose to use deep subarcsec resolution NIR data to derive the basic parameters of the unstudied population of massive cluster Westerlund 2. We present deep JHK_s images ($\sim$ 0.6" seeing) and photometry of Westerlund 2. This is the most complete photometric census of the cluster's population to date. We detect a total of 4701, 5724, and 5397 sources in the J, H, and K_s bands respectively. By comparison with main-sequence and pre-main-sequence model tracks we determine an average visual extinction toward the cluster of 5.8 mag, a likely distance of 2.8 kpc, and an age of 2.0 ± 0.3 Myr for the core of the cluster. Although we have the sensitivity to reach beyond the Hydrogen burning limit in the cluster we are only complete to about 1 $M_\odot$ due to source confusion. We find no evidence for a top-heavy MF, and the slope of the derived mass function is -1.20 ± 0.16. Based on the extrapolation of a field IMF, we roughly estimate the total mass of the cluster to be about 10^4 $M_\odot$. We find compelling evidence for mass segregation in this cluster.

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Medium resolution 2.3micron spectroscopy of the massive Galactic open cluster Westerlund 1

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The Galactic open cluster Westerlund 1 was found only a few years ago to be much more massive than previously thought, with evidence suggesting its mass to be in excess of $10^5 M_\odot$, in the range spanned by young extragalactic star clusters. Unlike those clusters its proximity makes spatially resolved studies of its stellar population feasible. It is therefore an ideal template for a young, massive star cluster, permitting direct comparison of its properties with measurements of velocity dispersion and dynamical mass for spatially unresolved extragalactic clusters.

To this end, we used the long slit near-infrared spectrograph VLT/ISAAC to observe the CO bandhead region near 2.29micron, scanning the slit across the cluster centre during the integration. Spatially collapsing the spectra along the slit results in a single co-added spectrum of the cluster, comparable to what one would obtain in the extragalactic cluster context. This spectrum was analysed the same way as the spectra of almost point-like extragalactic clusters, using red superiant cluster members as velocity templates. We detected four red supergiants which are included in the integrated spectrum, and our measured velocity dispersion is 5.8km/s. Together with the cluster size of 0.86pc, derived from archival near-infrared SOFI-NTT images, this yields a dynamical mass of $6.3*10^4 M_\odot$. While this value is not to be considered the final word, there is at least so far no sign for rapid expansion or collapse.

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Early-type stars in the core of the young open cluster Westerlund 2

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The properties of the early-type stars in the core of the Westerlund 2 cluster are examined in order to establish a link between the cluster and the very massive Wolf-Rayet binary WR20a as well as the H II complex RCW 49. Photometric monitoring as well as spectroscopic observations of Westerlund 2 are used to search for light variability and to establish the spectral types of the early-type stars in the cluster core. The first light curves of the eclipsing binary WR20a in B and V filters are analysed and a distance of 8 kpc is inferred. Three additional eclipsing binaries, which are probable late O or early B-type cluster members, are discovered, but none of the known early O-type stars in the cluster displays significant photometric variability above 1% at the 1-sigma level. The twelve brightest O-type stars are found to have spectral types between O3 and O6.5, significantly earlier than previously thought. The distance of the early-type stars in Westerlund 2 is established to be in excellent agreement with the distance of WR20a, indicating that WR20a actually belongs to the cluster. Our best estimate of the cluster distance thus amounts to 8.0 +/- 1.4 kpc. Despite the earlier spectral types, the currently known population of early-type stars in Westerlund 2 does not provide enough ionizing photons to account for the radio emission of the RCW 49 complex. This suggests that there might still exist a number of embedded early O-stars in RCW 49.

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The Distances to Open Clusters from Main-Sequence Fitting. III. Improved Accuracy with Empirically Calibrated Isochrones

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We continue our series of papers on open cluster distances with a critical assessment of the accuracy of main-sequence fitting using isochrones which employ empirical corrections to the color-temperature relations. We use four nearby open clusters with multicolor photometry and accurate metallicities, and present a new metallicity for Praesepe ([Fe/H] = +0.11 +/- 0.03) from high-resolution spectra. The internal precision of distance estimates is about a factor of five better than the case without the color calibrations. After taking into account all major systematic errors, we obtain distances accurate to about 2–3% when there exists a good metallicity estimate. Metallicities accurate to better than 0.1 dex may be obtained from BVI_CK_s photometry alone. We also derive a helium abundance for the Pleiades of Y = 0.279 +/- 0.015, which is equal within the errors to the Sun's initial helium abundance and that of the Hyades. Our best estimates of distances are $(m - M)_0$ = 6.33 +/- 0.04, 8.03 +/- 0.04, and 9.61 +/- 0.03 to Praesepe, NGC 2516, and M67, respectively. Our Pleiades distance at the spectroscopic metallicity, $(m - M)_0$ = 5.66 +/- 0.01 (internal) +/- 0.05 (systematic), is in excellent agreement with several geometric distance measurements. We have made calibrated isochrones for $-0.3 <= [Fe/H] <= +0.2$ available online.

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Rotation and Abundances in Ap Members of NGC 6475

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The connection between age, rotation and chemical abundance of magnetic Ap stars is poorly understood. Using open clusters, we are able to study samples of stars that are both co-eval and co-environmental. By determining rotation and chemical abundance for Ap star members of clusters with various ages, the variations of these properties as a function of age and environment can be derived. All four probable Ap star members of the open cluster NGC 6475, as well as one normal late B star, were studied using detailed spectrum synthesis of high resolution UVES-POP spectra. Probable cluster membership was confirmed for all five stars, however chemical abundance anomalies only appear to be present in spectra of three. Projected rotational velocity and chemical abundances for 21 elements ranging from C to Eu are presented for the 5 stars. In the three peculiar stars we find overabundances of Si, Cr, Mn, Fe and rare earths such as Nd, characteristic of Ap stars. The set of chemically peculiar stars show fairly homogeneous abundance tables, however notable differences exist for a few elements. There also exist appreciable differences in the $v \sin i$, and main sequence evolutionary stage of the chemically peculiar stars. This may hint at the underlying processes giving rise to the observed abundance anomalies. With this first detailed study of chemical abundances of a complete sample of magnetic Ap/Bp stars in an open cluster, we have initiated an exploration of the environmental and evolutionary influence on chemical peculiarity.

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The Monitor project: Rotation of low-mass stars in the open cluster NGC 2516

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We report on the results of an i-band time-series photometric survey of NGC 2516 using the CTIO 4m Blanco telescope and 8k Mosaic-II detector, achieving better than 1% photometric precision per data point over $15< \ i < \ 19$. Candidate cluster members were selected from a V vs V-I colour magnitude diagram over $16 < V < 26$ (covering masses from 0.7 $M_\odot$ down to below the brown dwarf limit), finding 1685 candidates, of which we expect ∼1000 to be real cluster members, taking into account contamination from the field (which is most severe at the extremes of our mass range). Searching for periodic variations in these gave 362 detections over the mass range $0.15< \ M/M_\odot < \ 0.7$. The rotation period distributions were found to show a remarkable morphology as a function of mass, with the fastest rotators bounded by P> 0.25 days, and the slowest rotators for M< 0.5 $M_\odot$ bounded by a line of $P \sim M^3$, with those for M> $0.5 M_\odot$ following a flatter relation closer to P ∼ constant. Models of the rotational evolution were investigated, finding that the evolution of the fastest rotators was well-reproduced by a conventional solid body model with a mass-dependent saturation velocity, whereas core-envelope decoupling was needed to reproduce the evolution of the slowest rotators. None of our models were able to simultaneously reproduce the behaviour of both populations.

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Towards absolute scales of radii and masses of open clusters

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In this paper we derive tidal radii and masses of open clusters in the nearest kiloparsecs around the Sun. For each cluster, the mass is estimated from tidal radii determined from a fitting of three-parametric King's profiles to the observed integrated density distribution. Different samples of members are investigated. For 236 open clusters, all contained in the catalogue ASCC-2.5, we obtain core and tidal radii, as well as tidal masses. The distributions of the core and tidal radii peak at about 1.5 pc and 7 - 10 pc, respectively. A typical relative error of the core radius lies between 15% and 50%, whereas, for the majority of clusters, the tidal radius was determined with a relative accuracy better than 20%. Most of the clusters have tidal masses between 50 and 1000 $m_{\odot}$, and for about half of the clusters, the masses were obtained with a relative error better than 50%.

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Element abundances in the metal rich open cluster NGC6253

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We have carried out a big FLAMES survey of 10 Galactic open clusters aiming at different goals. One of them is the determination of chemical abundances, in order to put constraints on the radial metallicity gradient in the disk and its evolution. One of the sample clusters is the very metal rich NGC 6253. We have obtained UVES high resolution spectra of seven candidate cluster members (from the turn off up to the red clump) with the goal of determining the chemical composition of NGC 6253 and to investigate its origin and role in the interpretation of the radial metallicity gradient in the disk. Equivalent width analysis and spectral synthesis were performed using MOOG and Kurucz model atmospheres. We derived abundances of Fe, alpha- and Fe-peak elements, the light element Na and the s-process element Ba. Excluding two likely non-members and the clump giant, whose metallicity from equivalent widths is overestimated, we find an average [Fe/H]=+0.36+/-0.07 (rms) for the cluster. For most of the other elements we derive solar abundance ratios.

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Multisite campaign on the open cluster M67. II. Evidence for solar-like oscillations in red giant stars

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Measuring solar-like oscillations in an ensemble of stars in a cluster, holds promise for testing stellar structure and evolution more stringently than just fitting parameters to single field stars. The most ambitious attempt to pursue these prospects was by (Gilliland 1993) who targeted 11 turn-off stars in the open cluster M67 (NGC 2682), but the oscillation amplitudes were too small (¡20micromag) to obtain unambiguous detections. Like Gilliland (1993) we also aim at detecting solar-like oscillations in M67, but we target red giant stars with expected amplitudes in the range 50-500micromag and periods of 1 to 8 hours. We analyse our recently published photometry measurements, obtained during a six-week multisite campaign using nine telescopes around the world. The observations are compared with simulations and with estimated properties of the stellar oscillations. Noise levels in the Fourier spectra as low as 27micromag are obtained for single sites, while the combined data reach 19micromag, making this the best photometric time series of an ensemble of red giant stars. These data enable us to make the first test of the scaling relations (used to estimate frequency and amplitude) with an homogeneous ensemble of stars. The detected excess power is consistent with the expected signal from stellar oscillations, both in terms of its frequency range and amplitude. However, our results are limited by apparent high levels of non-white noise, which cannot be clearly separated from the stellar signal.

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4. Galactic Globular Clusters

Gamma-rays from Globular Clusters

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It is expected that specific globular clusters can contain up to a hundred of millisecond pulsars. These pulsars can accelerate leptons at the shock waves originated in collisions of the pulsar winds and/or inside the pulsar magnetospheres. Energetic leptons diffuse gradually through the globular cluster comptonizing stellar and microwave background radiation. We calculate the GeV-TeV γ-ray spectra for different models of injection of leptons and parameters of the globular clusters assuming reasonable, of the order of 1%, efficiency of energy conversion from the pulsar winds into the relativistic leptons. It is concluded that leptons accelerated in the globular cluster cores should produce well localized γ-ray sources which are concentric with these globular clusters. The results are shown for four specific globular clusters (47 Tuc, Ter 5, M13, and M15), in which significant population of millisecond pulsars have been already discovered. We argue that the best candidates, which might be potentially detected by the present Cherenkov telescopes and the planned satellite telescopes (AGILE, GLAST), are 47 Tuc on the southern hemisphere, and M13 on the northern hemisphere. We conclude that detection (or non-detection) of GeV-TeV γ-ray emission from GCs by these instruments put important constraints on the models of acceleration of leptons by millisecond pulsars.

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Why haven't loose globular clusters collapsed yet?

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We report on the discovery of a surprising observed correlation between the slope of the low-mass stellar global mass function (GMF) of globular clusters (GCs) and their central concentration parameter c=log(r_t/r_c), i.e. the logarithmic ratio of tidal and core radii. This result is based on the analysis of a sample of twenty Galactic GCs with solid GMF measurements from deep HST or VLT data. All the high-concentration clusters in the sample have a steep GMF, most likely reflecting their initial mass function. Conversely, low-concentration clusters tend to have a flatter GMF implying that they have lost many stars via evaporation or tidal stripping. No GCs are found with a flat GMF and high central concentration. This finding appears counter-intuitive, since the same two-body relaxation mechanism that causes stars to evaporate and the cluster to eventually dissolve should also lead to higher central density and possibly core-collapse. Therefore, more concentrated clusters should have lost proportionately more stars and have a shallower GMF than low concentration clusters, contrary to what is observed. It is possible that severely depleted GCs have also undergone core collapse and have already recovered a normal radial density profile. It is, however, more likely that GCs with a flat GMF have a much denser and smaller core than suggested by their surface brightness profile and may well be undergoing collapse at present. In either case, we may have so far seriously underestimated the number of post core-collapse clusters and many may be lurking in the Milky Way.

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Na-O Anticorrelation and HB. II. The Na-O anticorrelation in the globular cluster NGC 6752

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We are studying the Na-O anticorrelation in several globular clusters of different Horizontal Branch (HB) morphology in order to derive a possible relation between (primordial) chemical inhomogeneities and morphological parameters of the cluster population. We used the multifiber spectrograph FLAMES on the ESO Very Large Telescope UT2 and derived atmospheric parameters and elemental abundances of Fe, O and Na for about 150 red giant stars in the Galactic globular cluster NGC 6752. The average metallicity we derive is [Fe/H]=-1.56, in agreement with other results from red giants, but lower than obtained for dwarfs or early subgiants. In NGC 6752 there is not much space for an intrinsic spread in metallicity: on average, the rms scatter in [Fe/H] is 0.037+/-0.003 dex, while the scatter expected on the basis of the major error sources is 0.039+/-0.003 dex. The distribution of stars along the Na-O anticorrelation is different to what was found in the first paper of this series for the globular cluster NGC 2808: in NGC 6752 it is skewed toward more Na-poor stars, and it resembles more the one in M 13. Detailed modeling is required to clarify whether this difference may explain the very different distributions of stars along the HB.

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Na-O Anticorrelation and HB. IV. Detection of He-rich and He-poor stellar populations in the globular cluster NGC 6218

E. Carretta, A. Bragaglia, R.G. Gratton, G. Catanzaro, F. Leone, E. Sabbi, S. Cassisi, R. Claudi, F. D'Antona, P. Francois, G. James, G. Piotto

We used the multifiber spectrograph FLAMES on the ESO Very Large Telescope UT2 to derive atmospheric parameters, metallicities and abundances of O and Na for 79 red giant stars in the Galactic globular cluster NGC 6218 (M 12). We analyzed stars in the magnitude range from about 1 mag below the bump to the tip of the Red Giant Branch. The average metallicity we derive is [Fe/H]=-1.31+/-0.004+/-0.028 dex (random and systematic errors, respectively), with a very small star-to-star scatter (rms=0.033 dex), from moderately high-resolution Giraffe spectra. This is the first extensive spectroscopic abundance analysis in this cluster. Our results indicate that NGC 6218 is very homogeneous as far as heavy elements are concerned. On the other hand, light elements involved in the well known proton-capture reactions of H-burning at high temperature, such as O and Na, show large variations, anticorrelated with each other, at all luminosities along the red giant branch. The conclusion is that the Na-O anticorrelation must be established in early times at the cluster formation. We interpret the variation of Na found near the RGB-bump as the effect of two distinct populations having different bump luminosities, as predicted for different He content. To our knowledge, NGC 6218 is the first GC where such a signature has been spectroscopically detected, when combined with consistent and homogeneous data obtained for NGC 6752 to gain in statistical significance.

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Na-O Anticorrelation and HB. VI. The chemical composition of the peculiar bulge globular cluster NGC 6388

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We present the LTE abundance analysis of high resolution spectra for red giant stars in the peculiar bulge globular cluster NGC 6388. Spectra of seven members were taken using the UVES spectrograph at the ESO VLT2 and the multiobject FLAMES facility. We exclude any intrinsic metallicity spread in this cluster: on average, [Fe/H]=-0.44+/-0.01+/-0.03 dex on the scale of the present series of papers, where the first error bar refers to individual star-to-star errors and the second is systematic, relative to the cluster. Elements involved in H-burning at high temperatures show large spreads, exceeding the estimated errors in the analysis. In particular, the pairs Na and O, Al and Mg are anticorrelated and Na and Al are correlated among the giants in NGC 6388, the typical pattern observed in all galactic globular clusters studied so far. Stars in NGC 6388 shows an excess of alpha-process elements, similar to the one found in the twin bulge cluster NGC 6441. Mn is found underabundant in NGC 6388, in agreement with the average abundance ratio shown by clusters of any metallicity. Abundances of neutron-capture elements are homogeneously distributed within NGC 6388; the [Eu/Fe] ratio stands above the value found in field stars of similar metallicity.

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5. Extragalactic Clusters

The Young Star Cluster System in the Antennae: Evidence for a Turnover in the luminosity function

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The luminosity functions (LFs) of star cluster systems (i.e. the number of clusters per luminosity interval) are vital diagnostics to probe the conditions of star cluster formation. Early studies have revealed a clear dichotomy between old globular clusters and young clusters, with the former characterised by Gaussian-shaped LFs, and the latter following a power law. Recently, this view was challenged by studies of galaxy merger remnants and post-starburst galaxies. In this paper we re-evaluate the young ($\lesssim$ few hundreds of Myrs, with the majority $\lesssim$ few tens of Myrs) star cluster system in the ongoing spiral-spiral major merger system NGC 4038/39, the "Antennae" galaxies. The Antennae galaxies represent a very active and complex star-forming environment, which hampers cluster selection and photometry as well as the determination of observational completeness fractions. A main issue of concern is the large number of bright young stars contained in most earlier studies, which we carefully exclude from our cluster sample by accurately determining the source sizes. The resulting LFs are fitted both with Gaussian and with power-law distributions, taking into account both the observational completeness fractions and photometric errors, and compared using a likelihood ratio test. The likelihood ratio results are rigidly evaluated using Monte Carlo simulations. We perform a number of additional tests, e.g. with subsets of the total sample, all confirming our main result: that a Gaussian distribution fits the observed LFs of clusters in this preferentially very young cluster system significantly better than a power-law distribution, at a (statistical) error probability of less than 0.5 per cent.

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Globular clusters and dwarf galaxies in Fornax - I. Kinematics in the cluster core from multi-object spectroscopy

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We acquired radial velocities of a significant number of globular clusters (GCs) on wide fields between galaxies in the nearby Fornax cluster of galaxies, in order to derive their velocity dispersion radial profile and to probe the dynamics of the cluster. We used FLAMES on the VLT to obtain accurate velocities for 149 GCs, within a 500x150 kpc strip centered on NGC 1399, the Fornax central galaxy. These objects are at the very bright tail (M_V < -9.5) of the GC luminosity function, overlapping the so-called "ultra-compact dwarfs" magnitude range. Eight of the brightest FLAMES-confirmed members indeed show hints of resolution in the subarcsecond pre-imaging data we used for selecting the 500 targets for FLAMES spectroscopy. Ignoring the GCs around galaxies by applying $3d_{25}$ diameter masks, we find 61 GCs of $20.0 < V < 22.2$ lying in the intra-cluster (IC) medium. The velocity dispersion of the population of ICGCs is 200 km/s at 150 kpc from the central NGC 1399 and rises to nearly 400 km/s at 200 kpc, a value which compares with the velocity dispersion of the population of dwarf galaxies, thought to be infalling from the surroundings of the cluster.

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Damp Mergers: Recent Gaseous Mergers without Significant Globular Cluster Formation?

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Here we test the idea that new globular clusters (GCs) are formed in the same gaseous ("wet") mergers or interactions that give rise to the young stellar populations seen in the central regions of many early-type galaxies. We compare mean GC colors with the age of the central galaxy starburst. The red GC subpopulation reveals remarkably constant mean colors independent of galaxy age. A scenario in which the red GC subpopulation is a combination of old and new GCs (formed in the same event as the central galaxy starburst) can not be ruled out; although this would require an age-metallicity relation for the newly formed GCs that is steeper than the Galactic relation. However, the data are also well described by a scenario in which most red GCs are old, and few, if any, are formed in recent gaseous mergers. This is consistent with the old ages inferred from some spectroscopic studies of GCs in external systems. The event that induced the central galaxy starburst may have therefore involved insufficient gas mass for significant GC formation. We term such gas-poor events "damp" mergers.

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Remnant of a "Wet" Merger: NGC 34 and its Young Massive Clusters, Young Stellar Disk, and Strong Gaseous Outflow

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This paper presents new images and spectroscopic observations of NGC 34 (Mrk 938) obtained with the du Pont 2.5-m and Baade 6.5-m telescopes at Las Campanas, plus photometry of an archival V image obtained with Hubble Space Telescope. This $M_V = -21.6$ galaxy has often been classified as a Seyfert 2, yet recently published infrared spectra suggest a dominant central starburst. We find that the galaxy features a single nucleus, a main spheroid containing a blue central disk and much outer fine structure, and tidal tails indicative of two former disk galaxies. At present these galaxies appear to have completed merging. The remnant shows three clear optical signs that the merger was gas-rich ("wet") and accompanied by a starburst: (1) It sports a rich system of young star clusters, of which 87 have absolute magnitudes $-10.0 \geq M_V \geq -15.4$. Five clusters with available spectra have ages in the range 0.1–1.0 Gyr and photometric masses of $2 \times 10^6 \leq M \leq 2 \times 10^7\ M_\odot$; they are gravitationally bound young globulars. (2) The blue central disk appears to be young. It is exponential, can be traced to >10 kpc radius, and has a smooth structure and colors suggesting that its optical light is dominated by a ∼400 Myr old poststarburst population. And (3), the center of NGC 34 drives a strong outflow of cool, neutral gas, as revealed by broad blueshifted Na I D-lines. The center-of-line velocity of this gas is -620 km s^{-1}, while the maximum detected outflow velocity reaches -1050 km s^{-1}. Assessing all available evidence, we suggest that NGC 34 stems from two recently merged gas-rich disk galaxies with an estimated mass ratio of $1/3 \leq m/M \leq 2/3$. The remnant seems to have first experienced a galaxy-wide starburst that then shrank to its current central and obscured state. The strong gaseous outflow came last.

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A Survey of Compact Star Clusters in the South-West Field of the M31 Disk. Structural Parameters

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We present structural parameters for 51 compact star clusters from the survey of star clusters conducted in the South-West field of the M 31 disk by Kodaira et al. (2004). Structural parameters of the clusters were derived by fitting the 2-D King and EFF (Elson, Fall and Freeman 1987) models to the V-band cluster images. Structural parameters derived for two M 31 clusters, which are in common with the study based on the HST data (Barmby et al. 2002), are consistent with earlier determination. The M 31 star cluster structural parameters in general are compatible with the corresponding Milky Way galaxy and Magellanic Clouds cluster parameters.

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Age constraints for an M31 globular cluster from SEDs-fit

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We have constrained the age of the globular cluster S312 in the Andromeda galaxy (M31) by comparing its multicolor photometry with theoretical stellar population synthesis models. This is both a check on the age of this globular cluster, as well a check on our methodology. Main-sequence photometry has been the most direct method for determining the age of a star cluster. S312 was observed as part of the Beijing-Arizona-Taiwan-Connecticut (BATC) Multicolor Sky Survey from 1995 February to 2003 December. The photometry of BATC images for S312 was taken with 9 intermediate-band filters covering $5000-10000$Å. Combined with photometry in the near-ultraviolet (NUV) of *GALEX*, broad-band $UBVR$ and infrared JHK_s of 2MASS, we obtained the accurate spectral energy distributions (SEDs) of S312 from $2267-20000$Å. A quantitative comparison to simple stellar population models yields an age of $9.5^{+1.15}_{-0.99}$ Gyr, which is in very good agreement with the previous determination by main-sequence photometry. S312 has a mass of $9.8 \pm 1.85 \times 10^5 M_\odot$, and is a medium-mass globular cluster in M31. By analysis of errors of ages determined based on the SED fitting method of this paper, secure age constraints are derived with errors of < 3 Gyr for ages younger than 9 Gyr. In fact, the theoretical SEDs are not sensitive to the variation of age for ages greater than ~ 10 Gyr. Therefore, for globular clusters as old as the majority of the Galactic GCs, our method do not distinguish them accurately. We emphasize that our results show that even with multiband photometry spanning NUV to K_s, our age constraints from SED fitting are distressingly uncertain, which has implications for age derivations in extragalactic globular cluster systems.

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A black hole in a globular cluster

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Globular star clusters contain thousands to millions of old stars packed within a region only tens of light years across. Their high stellar densities make it very probable that their member stars will interact or collide. There has been considerable debate about whether black holes should exist in these star clusters. Some theoretical work suggests that dynamical processes in the densest inner regions of globular clusters may lead to the formation of black holes of ∼1,000 solar masses. Other numerical simulations instead predict that stellar interactions will eject most or all black holes that form in globular clusters. Here we report the X-ray signature of an accreting black hole in a spectroscopically-confirmed globular cluster in the Virgo Cluster giant elliptical galaxy NGC 4472. This object has an X-ray luminosity of about $4*10^{39}$ ergs/sec, making it brighter than any non-black hole object can be in an old stellar population. The X-ray luminosity varies by a factor of 7 in a few hours, ruling out the possibility that the object is several neutron stars superposed.

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6. Dynamical simulations - Theory

The Dynamical Implications of Multiple Stellar Formation Events in Galactic Globular Clusters

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Various galactic globular clusters display abundance anomalies that affect the morphology of their colour-magnitude diagrams. In this paper we consider the possibility of helium enhancement in the anomalous horizontal branch of NGC 2808. We examine the dynamics of a self-enrichment scenario in which an initial generation of stars with a top-heavy initial mass function enriches the interstellar medium with helium via the low-velocity ejecta of its asymptotic giant branch stars. This enriched medium then produces a second generation of stars which are themselves helium-enriched. We use a direct N-body approach to perform five simulations and conclude that such two-generation clusters are both possible and would not differ significantly from their single-generation counterparts on the basis of dynamics. We find, however, that the stellar populations of such clusters would differ from single-generation clusters with a standard initial mass function and in particular would be enhanced in white dwarf stars. We conclude, at least from the standpoint of dynamics, that two-generation globular clusters are feasible.

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N-body Models of Rotating Globular Clusters

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We have studied the dynamical evolution of rotating globular clusters with direct N-body models. Our initial models are rotating King models; we obtained results for both equal-mass systems and systems composed out of two mass components. Previous investigations using a Fokker-Planck solver have revealed that rotation has a noticeable influence on stellar systems like globular clusters, which evolve by two-body relaxation. In particular, it accelerates their dynamical evolution through the gravogyro instability. We have validated the occurence of the gravogyro instability with direct N-body models. In the case of systems composed out of two mass components, mass segregation takes place, which competes with the rotation in the acceleration of the core collapse. The "accelerating" effect of rotation has not been detected in our isolated two-mass N-body models. Last, but not least, we have looked at rotating N-body models in a tidal field within the tidal approximation. It turns out that rotation increases the escape rate significantly. A difference between retrograde and prograde rotating star clusters occurs with respect to the orbit of the star cluster around the Galaxy, which is due to the presence of a "third integral" and chaotic scattering, respectively.

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The effect of spiral arm passages on the evolution of stellar clusters

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We study the effect of spiral arm passages on the evolution of star clusters on planar and circular orbits around the centres of galaxies. Individual passages with different relative velocity (V_{drift}) and arm width are studied using N-body simulations. When the ratio of the time it takes the cluster to cross the density wave to the crossing time of stars in the cluster is much smaller than one, the energy gain of stars can be predicted accurately in the impulsive approximation. When this ratio is much larger than one, the cluster is heated adiabatically and the net effect of heating is largely damped. For a given duration of the perturbation, this ratio is smaller for stars in the outer parts of the cluster compared to stars in the inner part. The cluster energy gain due to perturbations of various duration as obtained from our N-body simulations is in good agreement with theoretical predictions taking into account the effect of adiabatic damping. Perturbations by the broad stellar component of the spiral arms on a cluster are in the adiabatic regime and, therefore, hardly contribute to the energy gain and mass loss of the cluster. We consider the effect of crossings through the high density shocked gas in the spiral arms, which result in a more impulsive compression of the cluster. The time scale of disruption is shortest at 0.8-0.9 R_{CR} since there V_{drift} is low. This location can be applicable to the solar neighbourhood. In addition, the four-armed spiral pattern of the Milky Way makes spiral arms contribute more to the disruption of clusters than in a similar but two-armed galaxy. Still, the disruption time due to spiral arm perturbations there is about an order of magnitude higher than what is observed for the solar neighbourhood.[ABRIDGED]

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On the Origin of Mass-Metallicity Relations, Blue Tilts, and Scaling Relations for Metal-poor Globular Cluster Systems

Kenji Bekki, Hideki Yahagi, and Duncan Forbes
University of New South Wales (Australia)

We investigate formation processes and physical properties of globular cluster systems (GCSs) in galaxies based on high-resolution cosmological simulations with globular clusters. We focus on metal-poor clusters (MPCs) and correlations with their host galaxies by assuming that MPC formation is truncated at a high redshift ($z_{trun} > 6$). We find that the correlation between mean metallicities (Z_{gc}) of MPCs and their host galaxy luminosities (L) flattens from z=z_{trun} to z=0. We also find that the observed relation ($Z_{gc} \sim L^{0.15}$) in MPCs can be reproduced well in the models with $Z_{gc} \sim L^{0.5}$ at $z = z_{trun}$ when $z_{trun} \sim 10$, if mass-to-light-ratios are assumed to be constant at $z = z_{trun}$. However, better agreement with the observed relation is found for models with different mass-to-light-ratios between $z = z_{trun}$ and z=0. It is also found that the observed color-magnitude relation of luminous MPCs (i.e., "blue tilts") may only have a small contribution from the stripped stellar nuclei of dwarf galaxies, which have nuclei masses that correlate with their total mass at $z = z_{trun}$. The simulated blue tilts are found to be seen more clearly in more massive galaxies, which reflects the fact that more massive galaxies at z=0 are formed from a larger number of dwarfs with stellar nuclei formed at $z > z_{trun}$. The half-number radii (R_e) of GCSs, velocity dispersions of GCSs (sigma), and their host galaxy masses (M_h) are found to be correlated with one another such that $R_e \sim M_h^{0.57}$ and sigma $\sim M_h^{0.32}$.

Accepted by : Monthly Notices of the Royal Astronomical Society
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Origin of Abundance Inhomogeneity in Globular Clusters

K. Bekki, S. W. Campbell, J. C. Lattanzio, J. E. Norris
University of New South Wales, Australia

We numerically investigate abundance properties of the Galactic globular clusters (GCs) by adopting a new "external pollution" scenario. In this framework, GCs are assumed to originate in forming low-mass dwarfs embedded in dark matter subhalos at very high redshifts (z) and thus be chemically influenced by field AGB stars of the dwarfs during early GC formation processes. In this external pollution scenario, the ratio of the total mass of infalling gas to that of AGB ejecta during GC formation in a dwarf (s) and the time scale of gas infall ($sigma_I$) are the most important key parameters that can determine abundance properties of GCs. We mainly investigate the abundance inhomogeneity among light elements (e.g., C, N, O, Na, and Al) of stars in GCs by using the latest stellar yield models of metal-poor AGB stars with and without third dredge-up. Our principal results for the models with no third dredge-up, which are more consistent with observations, are as follows. Both [N/Fe] and [C/Fe] can be diverse among stars within a GC owing to chemical pollution from field AGB stars. [N/Fe] distributions in some GCs can clearly show bimodality whereas [C/Fe] is monomodal in most models. [N/Fe] distributions depend on s such that models with smaller s (i.e., larger mass fraction of AGB ejecta used for GC formation) show the [N/Fe] bimodality more clearly. N-rich, C-poor stars in GCs also have higher He abundances owing to pollution from massive AGB stars with He-rich ejecta. The number fraction of He-rich stars (Y$>$ 0.30) is higher for the models with smaller s and shorter $sigma_I$ for $3 < s < 24$ and $10^5 < sigma_I < 10^7$ yr. He abundances of stars correlate with [N/Fe] and [Al/Fe] and anticorrelate with [C/Fe], [O/Fe], and [Na/Fe] within GCs in our models. Although our model can much better explain the observed C-N and Mg-Al anticorrelations than previous theoretical models, it is in strong disagreement with the observed O-Na anticorrelation.

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Post-Newtonian N-body simulations

Sverre J. Aarseth
Institute of Astronomy University of Cambridge

We report on the first fully consistent conventional cluster simulation which includes terms up to post$^{5/2}$ Newtonian in the potential of the massive body. Numerical problems for treating extremely energetic binaries orbiting a single massive object are circumvented by employing the special "wheel-spoke" regularization method of Zare (1974) which has not been used in large-N simulations before. Idealized models containing N = 10^5 particles of mass 1 $M_\odot$ with a central black hole of 300 $M_\odot$ have been studied on GRAPE-type computers. An initial half-mass radius of $r_h = 0.1$ pc is sufficiently small to yield examples of relativistic coalescence. This is achieved by significant binary shrinkage within a density cusp environment, followed by the generation of extremely high eccentricities which are induced by Kozai (1962) cycles and/or resonant relaxation. More realistic models with white dwarfs and ten times larger half-mass radii also show evidence of GR effects before disruption. Experimentation with the post-Newtonian terms suggests that reducing the time-scales for activating the different orders progressively may be justified for obtaining qualitatively correct solutions without aiming for precise predictions of the final gravitational radiation wave form. The results obtained suggest that the standard loss-cone arguments underestimate the swallowing rate in globular clusters containing a central black hole.

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The presence of intermediate-mass black holes in globular clusters and its connection with extreme horizontal branch stars

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INAF - Osservatorio Astronomico di Teramo, via M. Maggini, I- 64100 Teramo (Italy)

By means of a multimass isotropic and spherical model including self-consistently a central intermediate-mass black hole (IMBH), the influence of this object on the morphological and physical properties of globular clusters is investigated in this paper. Confirming recent numerical studies, it is found that a cluster (with mass M) hosting an IMBH (with mass M_{BH}) shows, outside the black hole gravitational influence region, a core-like profile resembling a King profile with concentration $c < 2$, though with a slightly steeper behaviour in the core region. In particular, the core logarithmic slope is s< 0.25 for reasonably low IMBH masses ($M_{BH} < 10^{-2}$M), while c decreases monotonically with M_{BH}. Completely power-law density profiles (similar to, e.g., that of collapsed clusters) are admitted only in the presence of a black hole with an unrealistic M_{BH}¿M. The mass range estimate 12s - 4.8 < log(M_{BH}/M) < -1.1c - 0.69, depending on morphological parameters, is deduced considering a wide grid of models. Applying this estimate to a set of 39 globular clusters (including G1, in M31), it is found that NGC 2808, NGC 6388, M80, M13, M62 and M54 probably host an IMBH. For them, the scaling laws $M_{BH} \sim 0.02$(M/Msol)$^{0.8}$ Msol and $M_{BH} \sim 100$(sigma$_{obs}$/km s^{-1})$^{0.9}$ Msol, are identified from weighted least-squares fit. An important result of this "collective" study is that a strong correlation exists between the presence of an extreme blue horizontal branch (HB) and the presence of an IMBH, at a statistically significant level of confidence (>90 percent). In particular, the presence of a central IMBH could explain why extreme HB stars are observed in M13 and NGC 6388, but not in M3 and 47 Tuc where this object is likely absent according to our analysis.

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High Performance Direct Gravitational N-body Simulations on Graphics Processing Unit

Simon Portegies Zwart Robert Belleman Peter Geldof
University of Amsterdam

We present the results of gravitational direct N-body simulations using the commercial graphics processing units (GPU) NVIDIA Quadro FX1400 and GeForce 8800GTX, and compare the results with GRAPE-6Af special purpose hardware. The force evaluation of the N-body problem was implemented in Cg using the GPU directly to speed-up the calculations. The integration of the equations of motions were, running on the host computer, implemented in C using the 4th order predictor-corrector Hermite integrator with block time steps. We find that for a large number of particles ($N > 10^4$) modern graphics processing units offer an attractive low cost alternative to GRAPE special purpose hardware. A modern GPU continues to give a relatively flat scaling with the number of particles, comparable to that of the GRAPE. Using the same time step criterion the total energy of the N-body system was conserved better than to one in 10^6 on the GPU, which is only about an order of magnitude worse than obtained with GRAPE. For $N > 10^6$ the GeForce 8800GTX was about 20 times faster than the host computer. Though still about an order of magnitude slower than GRAPE, modern GPU's outperform GRAPE in their low cost, long mean time between failure and the much larger onboard memory; the GRAPE-6Af holds at most 256k particles whereas the GeForce 8800GTF can hold 9 million particles in memory.

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Were most Low Mass X ray Binaries born in Globular Clusters?

Francesca D'Antona, Anamaria Teodorescu, Paolo Ventura
INAF-Ossevatorio di Roma (Italy)

We summarize the status of art of the secular evolution of low mass X–ray binaries (LMXBs)and take a close look at the orbital period distribution of LMXBs and of binary millisecond pulsars (MSP), in the hypothesis that this latter results from the LMXB evolution. The deficiency of systems below the period gap, which in cataclysmic binaries occurs between 2 and 3hr, points to a very different secular evolution of LMXBs with respect to their counterparts containing a white dwarf compact object. The presence of several ultrashort period LMXBs (some of which are also X–ray millisecond pulsars), the important fraction of binary MSPs at periods between 0.1 and 1 day, the periods (26 and 32hr) of two "interacting" MSPs in Globular Clusters are other pieces of the puzzle in the period distribution. We consider the possible explanations for these peculiarities, and point out that Grindlay's old proposal that all (most of) LMXBs in the field were originally born in globular clusters must be carefully reconsidered.

To appear in : astro-ph/0612645 invited talk at the meeting: The Multicoloured Landscape of Compact Objects and their Explosive Origins: Theory vs. Observations, Cefalu', 11-24 June 2006, to be published in AIP Conf.Proc.
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The first stages of the evolution of Globular Clusters

Francesca D'Antona, Paolo Ventura, Vittoria Caloi
INAF-Ossevatorio di Roma & INAF-IASF, Roma (Italy)

The majority of the inhomogeneities in the chemical composition of Globular Cluster (GC) stars appear due to primordial enrichment. The most studied model today claims that the ejecta of Asymptotic Giant Branch (AGB) stars of high mass -those evolving during the first 100Myr of the Clusters life- directly form a second generation of stars with abundance anomalies. In this talk, we review the status of the art with regard to this model, whose major problems are i) the modelling of the chemical anomalies is still not fully complete, and ii) it requires an IMF peculiarly enhanced in the intermediate mass stars. The model predicts enhanced helium abundance in the stars showing chemical anomalies, and the helium abundance distribution can be roughly derived from the morphology of the horizontal branch. Such distribution may possibly help to falsify the model for the first phases of evolution of GCs. As an illustration, we compare the results of the analysis of the HB morphology of some clusters.

To appear in : astro-ph/0612654 Conference: From Stars to Galaxies: Building the Pieces to Build up the Universe, Venice, October 16-20, 2006 -to appear in the Astronomical Society of the Pacific Conference Series, Eds. A. Vallenari, R. Tantalo,.L. Portinari and A. Moretti
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Conference summary: Mass loss from stellar clusters

M. Gieles
([1]) Utrecht University ([2]) ESO Santiago

This conference dealt with the mass loss from stars and from stellar clusters. In this summary of the cluster section of the conference, I highlight some of the results on the formation and the fundamental properties of star clusters (Sect. 2), the early stages of their evolution (Sect. 3) and go into more detail on the subsequent mass evolution of clusters (Sect. 4). A discussion on how this may, or may not, depend on mass is given in Sect. 5. Obviously, there will be a bias towards the topics where Henny Lamers has contributed. Some of the contributions to these proceedings have already reviewed extensively the topics of clusters mass loss and disruption, so I will try to fit these in a general framework as much as possible.

To appear in : 6 pages, To appear in "Mass loss from stars and the evolution of stellar clusters". Proc. of a workshop held in honour of H.J.G.L.M. Lamers, Lunteren, The Netherlands. Eds. A. de Koter, L. Smith and R. Waters (San Francisco: ASP) (astro-ph/0702267)
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Star clusters in the solar neighborhood: a solution to Oort's problem

H.J.G.L.M. Lamers & M. Gieles
Utrecht University

In 1958 Jan Oort remarked that the lack of old clusters in the solar neighborhood (SN) implies that clusters are destroyed on a timescale of less than a Gyr. This is much shorter than the predicted dissolution time of clusters due to stellar evolution and two-body relaxation in the tidal field of the Galaxy. So, other (external) effects must play a dominant role in the destruction of star clusters in the solar neighborhood. We recalculated the survival time of initially bound star clusters in the solar neighborhood taking into account: (1) stellar evolution, (2) tidal stripping, (3) perturbations by spiral arms and (4) encounters with giant molecular clouds (GMCs). We find that encounters with GMCs are the most damaging to clusters. The resulting predicted dissolution time of these combined effects, t_{dis} = 1.7 (Mi/$10^4 M_\odot$)$^{0.67}$ Gyr for clusters in the mass range of $10^2 < M < 10^5 M_\odot$, is very similar to the disruption time of t_{dis} =1.3+/-0.5 (M/$10^4 M_\odot$)$^{0.62}$ Gyr that was derived empirically from a mass limited sample of clusters in the solar neighborhood within 600 pc. The predicted shape of the age distribution of clusters agrees very well with the observed one. The comparison between observations and theory implies a surface star formation rate (SFR) near the sun of 3.5x$10^{-10} M_\odot$ yr^{-1} pc^{-2} for stars in bound clusters with an initial mass in the range of 10^2 to 3x$10^4 M_\odot$. This can be compared to a total SFR of 7-10x$10^{-10} M_\odot$ yr^{-1} pc^{-2} derived from embedded clusters or 3-7x$10^{-9} M_\odot$ yr^{-1} pc^{-2} derived from field stars. This implies an infant mortality rate of clusters in the solar neighborhood between 50% and 95%, in agreement with the results of a study of embedded clusters.

To appear in : 6 pages, To appear in "Mass loss from stars and the evolution of stellar clusters". Proc. of a workshop held in honour of H.J.G.L.M. Lamers, Lunteren, The Netherlands. Eds. A. de Koter, L. Smith and R. Waters (San Francisco: ASP) (astro-ph/0702267)
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Title: Star clusters
by Mark Gieles

Astronomical Institute, Utrecht University, Princetonplein 5, 3584 CC Utrecht, The Netherlands

Promotor: Prof. Henny Lamers
Co-promoter: dr. Simon Portegies Zwart

Thesis committee: Prof. Tim de Zeeuw, Prof. Pavel Kroupa, Prof. Frank Verbunt, dr. Soeren Larsen, dr. Lia Athanassoula

defended on October 20, 2006

Abstract:

Star clusters are observed in almost every galaxy. In this thesis we address several fundamental problems concerning the formation, evolution and disruption of star clusters. From observations of (young) star clusters in the interacting galaxy M51, we found that clusters are formed in complexes of stars and star clusters. These complexes share similar properties with giant molecular clouds, from which they are formed. Many (70%) of the young clusters will not survive the fist 10 Myr, due to the removal of left over gas. We study the evolution of clusters that have survived this first 10 Myr, to become bound star clusters that have cleared their primordial gas content. We determined the life time of such star clusters in M51 and the solar neighbourhood and compare these values, including existing values from literature, to the results of N-body simulations. These simulations consider realistic star clusters, with a stellar initial mass function, stellar evolution, accurate treatments of binaries and the tidal field of the host galaxy. We found that the observed disruption times of clusters in the solar neighbourhood and M51 are shorter than predicted by the simulations by a factor of 5 and 10, respectively. We studied the effect of additional perturbations by spiral arm crossings and encounters with giant molecular clouds with N-body simulations. We found that the mass loss due to these external perturbations, combined with the mass loss due to stellar evolution and the galactic tidal field can explain the observed disruption times. The star clusters in the solar neighbourhood have much lower masses than the young clusters observed in merging and interacting galaxies. We show that this can be largely explained by size-of- sample effects, that is, when more star clusters are observed, the chance of finding a more massive one is higher. However, we showed that there can exist a physical maximum to the cluster mass, which should be observable in the cluster luminosity function. We found this observational signature in the luminosity function of clusters in M51. A comparison to a cluster population model, that was developed for this thesis research, suggests that the maximum cluster mass in M51 is $5x10^5$ solar masses. In the merging Antennae galaxies a similar luminosity function was observed. However, the maximum mass is four times higher there, suggesting that the maximum mass depends on galactic environment.

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SECOND ANNOUNCEMENT

Dynamical Evolution of Dense Stellar Systems
IAU Symposium 246
5-9 September 2007, Capri, Italy

DEADLINES REMINDER AND HOTELS RESERVATIONS

March 1 - IAU Travel Grant application deadline
March 15 - Early registration deadline
April 1 - LOC Hotel reservation deadline
April 20 - Deadline for abstract submission for oral presentations

1) HOTEL RESERVATIONS ARE NOW OPEN.

The LOC has reserved a block of rooms in a number of hotels in Capri and Anacapri. The block of rooms reserved by the LOC will be available only until April 1.

***** We strongly encourage participants to make their hotel reservations as soon as possible.*****

Capri is a beautiful and very popular place, early September is still a very busy time and it can be difficult to find a convenient/not too expensive lodging if you wait too long to make your reservation.

For additional information about hotels and the hotel reservation form please visit the conference website at http://www.physics.drexel.edu/∼iaus246 Information on hotel reservations is in the section "Venue/Travel Info"

2) Financial support:

DEADLINE TO APPLY FOR IAU FINANCIAL SUPPORT: March 1, 2007

Limited funds are available to support part of the travel, lodging and registration costs of some participants. Please see the symposium website for additional information on how to apply for IAU financial support (please notice that the application form has to be sent to the SOC Chair).

3) Conference registration:

Registration is open.

(DEADLINE FOR EARLY REGISTRATION FEE: MARCH 15)

Please visit the conference website at http://www.physics.drexel.edu/∼iaus246 for information about registration and to download the registration fee payment form.

4) Abstract submission:

ABSTRACT SUBMISSION DEADLINE TO BE CONSIDERED FOR AN ORAL PRESENTATION: APRIL 20, 2007

Additional Information:

See the symposium website http://www.physics.drexel.edu/∼iaus246 or send an e-mail to: iaus246@physics.drexel.edu

Postdoctoral Position in Globular Cluster Systems and Galaxy Formation

Matching funds for 1 year are available to support a Postdoctoral position to work with Prof. Duncan Forbes in the Centre for Astrophysics & Supercomputing at Swinburne University in Australia. The successful candidate is expected to find at least 1 year of salary from an International Fellowship scheme. This will then be matched by Prof. Forbes with local funds to extend the stay to at least 2 years.

The Postdoc will have substantial freedom to explore their own research but is expected to work on a topic relevant to either Globular Cluster Systems or Galaxy Formation/Evolution. The Postdoc would join an active group in the area of extragalactic astronomy and cosmology. Swinburne University hosts a supercomputer and has good access to the AAT, Gemini and Magellan telescopes.

The starting date in 2007 or early 2008 is negotiable. Research will be carried out at the Centre for Astrophysics & Supercomputing - one of Australia's top astronomy institutes. Further details can be found on our web pages: http://astronomy.swin.edu.au/ Interested candidates should contact Prof. Forbes directly to confirm common research interests (dforbes@swin.edu.au).

Possible International Fellowship schemes include: The Royal Society for UK nationals
`http://www.royalsoc.ac.uk/funding.asp?id=2118`

The NSF Distinguished International Postdoctoral Research Fellowship for US nationals
`http://www.nsf.gov/div/index.jsp?div=DMS#mpsdrf`

The Japan Society for the Promotion of Science for Japanese nationals
http://www.jsps.go.jp/english/index.html

Endeavour Research Fellowship for most nationalities
`http://www.endeavour.dest.gov.au/individual_awards/endeavour_research_fellowships.htm`

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PhD Scholarship in Globular Cluster Systems and Galaxy Formation

A PhD scholarship is available to work with Prof. Duncan Forbes in the Centre for Astrophysics & Supercomputing at Swinburne University in Australia. The successful candidate will work on either Globular Cluster Systems as part of the SAGES project or Galaxy Groups as part of the GEMS survey. Optical data will come from the Keck, Gemini or Magellan telescopes. Candidates should have a relevant 1st class honours degree, or equivalent, and a genuine enthusiasm for PhD research in observational astronomy. Research publications and experience with the reduction of long-slit or multi-slit spectra would be a major advantage.

The scholarship pays ∼$22,000/yr and includes a tuition waiver. It is open to both foreign and Australian nationals. Non-english speakers will need to pass an IELTS exam with no less than a 6.0 in each band. The starting date in 2007 is negotiable. Research will be carried out at the Centre for Astrophysics & Supercomputing - one of Australia's top astronomy institutes. Further details can be found on our web pages: http://astronomy.swin.edu.au/ Interested candidates should contact Prof. Forbes directly for details of application materials required (dforbes@swin.edu.au).

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Postdoc position at the Observatoire Astronomique de Marseille

The 'Laboratoire d'Astrophysique de Marseille' (LAM), part of the 'Observatoire Astronomique de Marseille Provence' (OAMP), offers a post-doc position in the area of Dynamics of Galaxies.

The successful candidate will work with Dr. Lia Athanassoula on a project to model the formation and secular evolution of disk galaxies. More details on the project can be found at http://www.oamp.fr/dynamique/halobar.html

Candidates should have a PhD in Physics or Astronomy by the time of the appointment. Experience with N-body and hydro codes is desirable.

The position is for two years, with a possibility of extension of one more year. Starting date is in the fall of 2007. Funds for travel are available in addition to the salary. Computing means available include access time on supercomputers, and a dedicated cluster, partially equipped with GRAPE boards.

Applicants should send a CV, a list of publications, and a research statement, and arrange for three letters of recommendation, all to be sent to `lia_AT_oamp.fr` Applications should be received by March 31, 2007.