Dear Colleagues,

It is my pleasure to present you the 156th issue of the Magellanic Clouds Newsletter, full of many exciting new results. X-ray binaries and pulsars are setting the tone, followed by hot and massive stars, clusters, results from near-IR surveys and the overall structure of the Magellanic Clouds.

Check out the announcement about SOFIA observations of the Tarantula Nebula!

The next issue is planned to be distributed on the 1st of February 2019. I send you the Season’s Greetings and wish you a peaceful and loving New Year. May collaboration and inclusiveness prevail over competition and exclusion.

Editorially Yours,
Jacco van Loon
The dust-selected molecular clouds in the North–East region of the Small Magellanic Cloud

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We present a high-sensitivity ($1\sigma < 1.6$ mJy beam$^{-1}$) continuum observation in a 343 arcmin$^2$ area of the North–East region in the Small Magellanic Cloud at a wavelength of 1.1 mm, conducted using the AzTEC instrument on the ASTE telescope. In the observed region, we identified 20 objects by contouring $10\sigma$ emission. Through spectral energy distribution (SED) analysis using 1.1 mm, Herschel, and Spitzer data, we estimated the gas masses of $5 \times 10^3$–$7 \times 10^4$ M$_\odot$, assuming a gas-to-dust ratio of 1000. Dust temperature and the index of emissivity were also estimated as 18–33 K and 0.9–1.9, respectively, which are consistent with previous low resolution studies. The relation between dust temperature and the index of emissivity shows a weak negative linear correlation. We also investigated five CO-detected dust-selected clouds in detail. The total gas masses were comparable to those estimated from the Mopra CO data, indicating that the assumed gas-to-dust ratio of 1000 and the $X_{CO}$ factor of $1 \times 10^{21}$ cm$^{-2}$ (K km s$^{-1}$)$^{-1}$, with uncertainties of a factor of 2, are reliable for the estimation of the gas masses of molecular or dust-selected clouds. Dust column density showed good spatial correlation with CO emission, except for an object that associates with bright young stellar objects. The 8-µm filamentary and clumpy structures also showed similar spatial distribution with the CO emission and dust column density, supporting the fact that polycyclic aromatic hydrocarbon emissions arise from the surfaces of dense gas and dust clouds.

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The first ultraviolet detection of the Large Magellanic Cloud pulsar PSR B0540–69

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We observed the young (~1700 yr) pulsar PSR B0540–69 in the near-ultraviolet (UV) for the first time with the Space Telescope Imaging Spectrograph (STIS) aboard the Hubble Space Telescope. Imaging observations with the NUV and FUV-MAMA detectors in TIME-TAG mode allowed us to clearly detect the pulsar in two bands around 2350 Å and 1590 Å, with magnitudes $m_{NUV} = 21.449 \pm 0.019$ and $m_{FUV} = 21.832 \pm 0.103$. We also detected the pulsar-wind nebula (PWN) in the NUV-MAMA image, with a morphology similar to that observed in the optical and near-infrared (IR). The extinction-corrected NUV and FUV pulsar fluxes are compatible with a very steep power law spectrum with spectral index $\alpha_{UV} \sim 3$, non compatible with a Rayleigh–Jeans spectrum, indicating a non-thermal origin of the emission. The comparison with the optical/near-IR power-law spectrum (spectral index $\alpha_{opt/IR} \sim 0.7$), indicates an abrupt turn-off at wavelengths below 2500 Å, not observed in other pulsars. We detected pulsations in both the NUV and FUV data at the 50-ms pulsar period. In both cases, the pulse profile features two peaks closely spaced in phase, as observed in the optical and X-ray light curves. The NUV/FUV peaks are also aligned in phase with those observed in the radio (1.4 GHz), optical, X, and $\gamma$-ray light curves, like in the Crab pulsar, implying a similar beaming geometry across all wavelengths. PSR B0540–69 is now the fifth isolated pulsar, together with Crab, Vela, PSR B0656+14, and the radio-quiet Geminga, detected in the optical, near-UV, near-IR, X-rays and $\gamma$-rays, and seen to pulsate in at least four of these energy bands.

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A multifrequency radio continuum study of the Magellanic Clouds – I. Overall structure and star formation rates

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We present the first low-frequency Murchison Widefield Array (MWA) radio continuum maps of the Magellanic Clouds (MCs), using mosaics from the GaLactic and Extragalactic All-Sky MWA (GLEAM) survey. In this paper, we discuss the overall radio continuum morphology between 76 and 227 MHz and compare them with neutral hydrogen maps, 1.4 GHz continuum maps and optical images. Variation of diffuse emission is noticeable across the Large Magellanic Cloud (LMC) but absent across the bar of the Small Magellanic Cloud (SMC). We also measure the integrated flux densities and derive the spectral indices for the MCs. A double power-law model with fixed $\alpha_1 = -0.1$ fit between 19.7 MHz and 8.55 GHz yields $\alpha_0 = -0.66 \pm 0.08$ for the LMC. A power-law model yields $\alpha_{8.55\, MHz}^{85.5\, MHz} = -0.82 \pm 0.03$
for the SMC. The radio spectral index maps reveal distinctive flat and steep spectral indices for the H\textsc{ii} regions and supernova remnants, respectively. We find strong correlation between H\textsc{ii} regions and H\textalpha\ emission. Using a new 150 MHz–H\textalpha\ relation as a star formation rate indicator, we estimate global star formation rates of 0.068–0.161 M\odot yr\(^{-1}\) and 0.021–0.050 M\odot yr\(^{-1}\) for the LMC and SMC, respectively. Images in 20 frequency bands, and wideband averages are made available via the GLEAM virtual observatory server.

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Very massive stars: a metallicity-dependent upper-mass limit, slow winds, and the self-enrichment of globular clusters

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One of the key questions in Astrophysics concerns the issue of whether there exists an upper-mass limit to stars, and if so, what physical mechanism sets this limit? The answer to this question might also determine if the upper-mass limit is metallicity (Z) dependent. We argue that mass loss by radiation-driven winds mediated by line opacity is one of the prime candidates setting the upper-mass limit. We present mass-loss predictions (\(dM/dt_{\text{wind}}\)) from Monte Carlo radiative transfer models for relatively cool (\(T_{\text{eff}} = 15\) kK) very inflated massive stars (VMS) with large Eddington \(\Gamma\) factors in the mass range 100–1000 M\odot as a function of metallicity down to 1/100 Z/Z\odot. We employed a hydrodynamic version of our Monte Carlo method, allowing us to predict the rate of mass loss (\(dM/dt_{\text{wind}}\)) and the terminal wind velocity (\(v_\infty\)) simultaneously. Interestingly, we find wind terminal velocities (\(v_\infty\)) that are low (100–500 km s\(^{-1}\)) over a wide Z-range, and we propose that the slow winds from VMS are an important source of self-enrichment in globular clusters. We also find mass-loss rates (\(dM/dt_{\text{wind}}\)), exceeding the typical mass-accretion rate (\(dM/dt_{\text{accret}}\)) of 0.001 M\odot yr\(^{-1}\) during massive-star formation. We have expressed our mass-loss predictions as a function of mass and Z, finding log \(dM/dt = -9.13 + 2.1 \log(M/M_{\odot}) + 0.74 \log(Z/Z_{\odot})\) (M\odot yr\(^{-1}\)). Even if stellar winds do not directly halt & reverse mass accretion during star formation, if the most massive stars form by stellar mergers, stellar wind mass loss may dominate over the rate at which stellar growth takes place. We therefore argue that the upper-mass limit is effectively Z-dependent due to the nature of radiation-driven winds. This has dramatic consequences for the most luminous supernovae, \(\gamma\)-ray bursts, and other black hole formation scenarios at different Cosmic epochs.

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Fast & slow winds from supergiants and Luminous Blue Variables

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We predict quantitative mass-loss rates and terminal wind velocities for early-type supergiants and luminous blue variables (LBVs) using a dynamical version of the Monte Carlo radiative transfer method. First, the observed drop in terminal wind velocity around spectral type B1 is confirmed by the Monte Carlo method – at the correct effective temperature of about 21 000 K. This drop in wind velocity is much steeper than would be expected from the drop in escape speed for cooler stars. The results may be particularly relevant for slow winds inferred for some High-Mass X-ray binaries. Second, the strength of the mass-loss bi-stability jump is found to be significantly larger than previously
assumed. Not only could this make bi-stability braking more efficient in massive star evolution, but a rotationally-induced version of the bi-stability mechanism may now be capable of producing the correct density of outflowing disks around B[e] supergiants, although multi-dimensional modelling including the disk velocity structure is still needed.

For LBVs, we find the bi-stability jump to become larger at higher metallicities, but perhaps surprisingly also larger at lower Eddington parameters. This may have consequences for the role of LBVs in the evolution of massive stars at different metallicities and Cosmic Epochs. Finally, our predicted low wind velocities may be important for explaining the slow outflow speeds of supernova type Ib/IIn progenitors, for which the direct LBV–SN link was first introduced.

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A striking confluence between theory and observations of high-mass X-ray binary pulsars

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We analyze the most powerful X-ray outbursts from neutron stars in eleven Magellanic high-mass X-ray binaries and three pulsating ultraluminous X-ray sources. Most of the outbursts rise to \(L_{\text{max}}\), which is about the level of the Eddington luminosity, while the remaining more powerful outbursts also appear to recognize that limit when their emissions are assumed to be anisotropic and beamed toward our direction. We use the measurements of pulsar spin periods \(P_S\) and their derivatives \(\dot{P}_S\) to calculate the X-ray luminosities \(L_p\) in their faintest accreting ("propeller-line") states. In five cases with unknown \(\dot{P}_S\), we use the lowest observed X-ray luminosities, which only adds to the heterogeneity of the sample. Then we calculate the ratios \(L_p/L_{\text{max}}\) and we obtain an outstanding confluence of theory and observations from which we conclude that work done on both fronts is accurate and the results are trustworthy: sources known to reside on the lowest Magellanic propeller line are all located on/near that line, whereas other sources jump higher and reach higher-lying propeller lines. These jumps can be interpreted in only one way, higher-lying pulsars have stronger surface magnetic fields in agreement with previous empirical results in which \(P_S\) and \(L_p\) values were not used.

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Flaring activity from quiescent states in neutron-star X-ray binaries

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We examine systematically the observed X-ray luminosity jumps (or flares) from quiescent states in millisecond binary pulsars (MSBPs) and high-mass X-ray binary pulsars (HMXBPs). We rely on the published X-ray light curves of
seven pulsars: four HMXBPs, two MSBPs, and the ultraluminous X-ray pulsar M82 X-2. We discuss the physics of their flaring activities or lack thereof, paying special attention to their emission properties when they are found on the propeller line, inside the Corbet gap, or near the light-cylinder barrier. We provide guiding principles for future interpretations of faint X-ray observations, as well as a method of constraining the propeller lines and the dipolar surface magnetic fields of pulsars using a variety of quiescent states. In the process, we clarify some disturbing inaccuracies that have made their way into the published literature.

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Flaring Activity from Quiescent States in Neutron-Star X-ray Binaries

Not an Oxymoron: Some X-ray Binary Pulsars with Enormous Spinup Rates Reveal Weak Magnetic Fields

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Three high-mass X-ray binaries have been discovered recently exhibiting enormous spinup rates. Conventional accretion theory predicts extremely high surface dipolar magnetic fields that we believe are unphysical. Instead, we propose quite the opposite scenario: some of these pulsars exhibit weak magnetic fields, so much so that their magnetospheres are crushed by the weight of inflowing matter. The enormous spinup rate is achieved before inflowing matter reaches the pulsar’s surface as the penetrating inner disk transfers its excess angular momentum to the receding magnetosphere which, in turn, applies a powerful spinup torque to the pulsar. This mechanism also works in reverse: it spins a pulsar down when the magnetosphere expands beyond corotation and finds itself rotating faster than the accretion disk which then exerts a powerful retarding torque to the magnetic field and to the pulsar itself. The above scenarios cannot be accommodated within the context of neutron-star accretion processes occurring near spin equilibrium, thus they constitute a step toward a new theory of extreme (far from equilibrium) accretion phenomena.

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Not an Oxymoron: Some X-ray Binary Pulsars with Enormous Spinup Rates Reveal Weak Magnetic Fields

Long-term properties of accretion discs in X-ray Binaries – III. A search for spin–super-orbital correlation in SMC X-1

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Thanks to long-term X-ray monitoring, a number of interacting binaries are now known to show X-ray periodicities
on timescales of tens to hundreds of binary orbits. In some systems, precession of a warped accretion disc is the leading model to explain the super-orbital modulation. The High Mass X-ray Binary SMC X-1 showed two excursions in super-orbital period (from \( \sim 60 \) d to \( \sim 45 \) d) during the 1996–2011 interval, suggesting that some characteristic of the accretion disc is varying on a timescale of years. Because its behaviour as an X-ray pulsar has also been intensively monitored, SMCX-1 offers the rare chance to track changes in both the accretion disk and pulsar behaviours over the same interval. We have used archival X-ray observations of SMCX-1 to investigate whether the evolution of its super-orbital variation and pulse period are correlated. We use the 16-year dataset afforded by the RXTE All-Sky Monitor to trace the behaviour of the warped accretion disc in this system, and use published pulse-period histories to trace the behaviour of the pulsar. While we cannot claim a strong detection of correlation, the first super-orbital period excursion near MJD 50,800 does coincide with structure in SMCX-1’s pulse period history. Our preferred interpretation is that the super-orbital period excursion coincides with a change in the long-term spin-up rate of the SMCX-1 pulsar. In this scenario, the pulsar and the accretion disc are both responding to a change in the accretion flow, which the disc itself may regulate.

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Spectral analysis of SXP 59.0 during its 2017 outburst and properties of the soft excess in X-ray binary pulsars

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We report the results provided by the XMM–Newton observation of the X-ray binary pulsar SXP 59.0 during its most recent outburst in April 2017. The source was detected at \( f_X(0.2–12 \text{ keV}) = 8 \times 10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1} \), one of its highest flux levels reported to date. The measured pulse period was \( P_{\text{spin}} = 58.949(1) \text{ s} \), very similar to the periods measured in most of the previous observations. The pulsed emission was clearly detected over the whole energy range between 0.2 and 12 keV, but the pulse profile is energy dependent and the pulsed fraction increases as the energy increases. Although the time-averaged EPIC spectrum is dominated by a power-law component (with photon index \( \Gamma = 0.76 \pm 0.01 \)), the data show an evident soft excess, which can be described with the sum of a black-body and a hot thermal plasma component (with temperatures \( kT_{\text{BB}} = 171^{+11}_{-14} \text{ eV} \) and \( kT_{\text{APEC}} = 1.09^{+0.16}_{-0.09} \text{ keV} \), respectively). Moreover, the EPIC and RGS spectra show narrow emission lines due to N, O, Ne, Mg, and Fe. The phase-resolved spectral analysis of the EPIC data shows that the flux of the black-body component varies with the pulse phase, while the plasma component is almost constant. We show that the black-body component can be attributed to the reprocessing of the primary emission by the optically thick material at the inner edge of the accretion disc, while the hot plasma component is due to a diffuse gas far from the accretion region and the narrow emission lines of the RGS spectrum are most probably due to photo-ionized matter around the accreting source.

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A likely runaway star cluster in the outer disc of the Large Magellanic Cloud

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We present results from photometric and spectroscopic data obtained with SOAR and Gemini observatory facilities in the field of a recently discovered star cluster. The cluster, projected towards the Eastern side of the outer disc of the Large Magellanic Cloud (LMC), was originally placed nearly 10 kpc behind the LMC with an age and metallicity typical of the innermost LMC star cluster population. We assigned radial velocity (RV) memberships to stars observed spectroscopically, and derived the cluster age and distance from theoretical isochrone fitting to the cluster colour–magnitude diagram. The new object turned out to be a 0.9 Gyr old outer LMC disc cluster, which possibly reached the present position after being scattered from the innermost LMC regions where it might have been born. We arrived at this conclusion by examining the spatial distribution of LMC star clusters of similar age, by comparing the derived spectroscopic metallicity with that expected for an outside–in galaxy formation scenario, by considering the cluster internal dynamical stage as inferred from its derived structural parameters and by estimating the circular velocity of a disc that rotates with the corresponding star cluster radial velocity at the cluster’s deprojected distance, which resulted to be nearly 60 per cent higher than that of most of the outer LMC disc clusters.

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Red supergiants in the JWST era. I: Near-IR photometric diagnostics

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The Near Infrared Camera (NIRCam) on the James Webb Space Telescope (JWST) will be an incredibly powerful instrument for studying red supergiants (RSGs). The high luminosities and red peak wavelengths of these stars make them ideal targets for JWST/NIRCam. With effective photometric diagnostics in place, imaging RSG populations in multiple filters will make it possible to determine these stars’ physical properties and, in cases where JWST pre-explosion imaging is available, to identify RSG supernova progenitors. This paper uses observed and model spectra of Galactic RSGs to simulate JWST/NIRCam near-IR photometry and colors, quantify and test potential diagnostics of effective temperature and bolometric magnitude, and present photometric techniques for separating background RSG and foreground dwarf populations. While results are presented for the full suite of near-IR filters, this work shows that (F070W–F200W) is the JWST/NIRCam color index most sensitive to effective temperature, F090W is the best band for determining bolometric magnitude, and the (F070W–F090W) vs. (F090W–F200W) color–color diagram can be used to separate foreground dwarf and background RSG samples. The combination of these three filters is recommended as the best suite of photometric observations to use when studying RSGs with JWST.

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We present a comprehensive stellar atmosphere analysis of 329 O- and B-type stars in the Small Magellanic Cloud (SMC) from the RIOTS4 survey. Using spectroscopically derived effective temperature ($T_{\text{eff}}$) and surface gravities, we find that classical Be stars appear misplaced to low $T_{\text{eff}}$ and high luminosity in the spectroscopic Hertzsprung–Russell diagram (sHRD). Together with the most luminous stars in our sample, the stellar masses derived from the sHRD for these objects are systematically larger than those obtained from the conventional HRD. This suggests that the well-known, spectroscopic mass-discrepancy problem may be linked to the fact that both groups of stars have outer envelopes that are nearly gravitationally unbound. The non-emission-line stars in our sample mainly appear on the main-sequence, allowing a first estimate of the terminal-age main-sequence (TAMS) in the SMC, which matches the predicted TAMS between 12 and 40 $M_\odot$ at SMC metallicity. We further find a large under-abundance of stars above $\sim 25 M_\odot$ near the ZAMS, reminiscent of such earlier findings in the Milky Way and LMC.

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### Resolved kinematics of runaway and field OB stars in the Small Magellanic Cloud

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We use Gaia DR2 proper motions of the RIOTS4 field OB stars in the Small Magellanic Cloud (SMC) to study the kinematics of runaway stars. The data reveal that the SMC Wing has a systemic peculiar motion relative to the SMC Bar of $(v_\alpha, v_\delta) = (62 \pm 7, -18 \pm 5)$ km s$^{-1}$ and relative radial velocity $+4.5 \pm 5.0$ km s$^{-1}$. This unambiguously demonstrates that these two regions are kinematically distinct: the Wing is moving away from the Bar, and towards the Large Magellanic Cloud with a 3-D velocity of $64 \pm 10$ km s$^{-1}$. This is consistent with models for a recent, direct collision between the Clouds. We present transverse velocity distributions for our field OB stars, confirming that unbound runaways comprise on the order of half our sample, possibly more. Using eclipsing binaries and double-lined spectroscopic binaries as tracers of dynamically ejected runaways, and high-mass X-ray binaries (HMXBs) as tracers of runaways accelerated by supernova kicks, we find significant contributions from both populations. The data suggest that HMXBs have lower velocity dispersion relative to dynamically ejected binaries, consistent with the former corresponding to less energetic supernova kicks that failed to unbind the components. Evidence suggests that our fast runaways are dominated by dynamical, rather than supernova, ejections.

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SMASHing the LMC: A tidally induced warp in the outer LMC and a large-scale reddening map

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We present a study of the three-dimensional (3D) structure of the Large Magellanic Cloud (LMC) using \( \sim 2.2 \) million red clump (RC) stars selected from the Survey of the MAgellanic Stellar History. To correct for line-of-sight dust extinction, the intrinsic RC color and magnitude and their radial dependence are carefully measured by using internal nearly dust-free regions. These are then used to construct an accurate 2D reddening map (165 deg\(^2\) area with \( \sim 10' \) resolution) of the LMC disk and the 3D spatial distribution of RC stars. An inclined disk model is fit to the 2D distance map, yielding a best-fit inclination angle of \( i = 25.86^{+0.73}_{-1.39} \) degrees with random errors of \( \pm 0.19 \) and line-of-nodes position angle of \( \theta = 149.23^{+6.41}_{-8.35} \) degrees with random errors of \( \pm 0.49 \). These angles vary with galactic radius, indicating that the LMC disk is warped and twisted likely due to the repeated tidal interactions with the Small Magellanic Cloud (SMC). For the first time, our data reveal a significant warp in the South-Western part of the outer disk starting at \( \rho \sim 7' \) that departs from the defined LMC plane up to \( \sim 4 \) kpc toward the SMC, suggesting that it originated from a strong interaction with the SMC. In addition, the inner disk encompassing the off-centered bar appears to be tilted up to \( 5'–15' \) relative to the rest of the LMC disk. These findings on the outer warp and the tilted bar are consistent with the predictions from the Besla et al. simulation of a recent direct collision with the SMC.

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Gaia and HST astrometry of the very massive $\sim 150 \, M_\odot$ candidate runaway star VFTS 682

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How very massive stars form is still an open question in astrophysics. VFTS 682 is among the most massive stars known, with an inferred initial mass of $\sim 150 \, M_\odot$. It is located in 30 Doradus at a projected distance of 29 pc from the central cluster R 136. Its apparent isolation led to two hypotheses: either it formed in relative isolation or it was ejected dynamically from the cluster. We investigate the kinematics of VFTS 682 as obtained by Gaia and Hubble Space Telescope astrometry. We derive a projected velocity relative to the cluster of $38 \pm 17$ km s$^{-1}$ (1-$\sigma$ confidence interval). Although the error bars are substantial, two independent measures suggest that VFTS 682 is a runaway ejected from the central cluster. This hypothesis is further supported by a variety of circumstantial clues. The central cluster is known to harbor other stars more massive than $150 \, M_\odot$ of similar spectral type and recent astrometric studies on VFTS 16 and VFTS 72 provide direct evidence that the cluster can eject some of its most massive members, in agreement with theoretical predictions. If future data confirm the runaway nature, this would make VFTS 682 the most massive runaway star known to date.

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The VMC Survey – XXXII. Pre-main-sequence populations in the Large Magellanic Cloud

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Detailed studies of intermediate- and low-mass pre-main-sequence (PMS) stars outside the Galaxy have so far been conducted only for small targeted regions harbouring known star formation complexes. The VISTA Survey of the Magellanic Clouds (VMC) provides an opportunity to study PMS populations down to solar masses on a galaxy-wide scale. Our goal is to use near-infrared data from the VMC survey to identify and characterise PMS populations down to \( \sim 1 \) \( M_\odot \) across the Magellanic Clouds. We present our colour–magnitude diagram method, and apply it to a \( \sim 1.5 \) deg\(^2\) pilot field located in the Large Magellanic Cloud. The pilot field is divided into equal-size grid elements. We compare the stellar population in every element with the population in nearby control fields by creating a \( \sim \) scale. Our goal is to use near-infrared data from the VMC survey to identify and characterise PMS populations down to solar masses on a galaxy-wide scale. The pilot field is divided into equal-size grid elements. We compare the stellar population in every element with the population in nearby control fields by creating \( K_s/(Y−K_s) \) Hess diagrams; the observed density excesses over the local field population are used to classify the stellar populations. Our analysis recovers all known star formation complexes in this pilot field (N 44, N 51, N 148, and N 138) and for the first time reveals their true spatial extent. In total, around 2260 PMS candidates with ages \( \lesssim 10 \) Myr are found in the pilot field. PMS structures, identified as areas with a significant density excess of PMS candidates, display a power-law distribution of the number of members with a slope of \( \sim 0.86 \pm 0.12 \). We find a clustering of the young stellar populations along ridges and filaments where dust emission in the far-infrared (FIR) (70 \( \mu m \) – 500 \( \mu m \)) is bright. Regions with young populations lacking massive stars show a lower degree of clustering and are usually located in the outskirts of the star formation complexes. At short FIR wavelengths (70 \( \mu m \), 100 \( \mu m \)) we report a strong dust emission increase in regions hosting young massive stars, which is less pronounced in regions populated only by less massive (\( \lesssim 4 M_\odot \)) PMS stars.

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Stellar population diagnostics of the massive star binary fraction

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Populations of massive stars are directly reflective of the physics of stellar evolution. Counting subtypes of massive stars and ratios of massive stars in different evolutionary states have been used ubiquitously as diagnostics of age and metallicity effects. While the binary fraction of massive stars is significant, inferences are often based upon models incorporating only single-star evolution. In this work, we utilize custom synthetic stellar populations from the Binary Population and Stellar Synthesis (bpass) code to determine the effect of stellar binaries on number count ratios of different evolutionary stages in both young massive clusters and galaxies with massive stellar populations. We find that many ratios are degenerate in metallicity, age, and/or binary fraction. We develop diagnostic plots using these stellar
count ratios to help break this degeneracy, and use these plots to compare our predictions to observed data in the Milky Way and the Local Group. These data suggest a possible correlation between the massive star binary fraction and metallicity. We also examine the robustness of our predictions in samples with varying levels of completeness. We find including binaries and imposing a completeness limit can both introduce $\gtrsim 0.1$ dex changes in inferred ages. Our results highlight the impact that binary evolution channels can have on the massive star population.

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Systematic comparison of initial velocities for neutron stars in different models

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I have studied the initial velocity (Maxwellian and exponential distributions) and the scale height of isolated old (aged $\sim 10^9$ yr) neutron stars (NSs) at different Galactocentric distances $R$ in three population models. The smooth time-independent 3-D axisymmetric gravitational potentials (Miyamoto–Nagai and Paczyński models) were also used. The correlation between these quantities significantly affects the shapes of the profiles and distributions of the simulated sample, because the differences in the initial kick can arise from differences in the formation and evolution of NSs with other physical parameters. The scale height of the density distribution increases systematically with $R$. I have also shown that the distribution of old NSs in these population models agrees with the observed structure of the Galaxy in terms of initial velocities (1-D and 3-D), as well as the scale height distributions. These distributions tend to have an asymptotic behavior at the point $R = 2.75$ kpc. This means that the quality of the models can be described in terms of a mean of the fitted Gaussian, and this could also give an overall perspective of the phase space properties of nearby old NSs on a given gravitational potential.

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Probing the accretion induced collapse of white dwarfs in millisecond pulsars

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This paper investigates the progenitors of Millisecond Pulsars (MSPs) with a distribution of long orbital periods ($P_{\text{orb}} > 2$ d), to show the link between white dwarf (WD) binaries and long orbits for some binary MSPs through the Accretion Induced Collapse (AIC) of a WD. For this purpose, a model is presented to turn binary MSPs into wide binaries and highly circular orbits ($e < 0.1$) through the asymmetric kick imparted to the pulsar during the AIC process, which may indicate a sizeable kick velocity along the rotation of the proto-neutron star. The results show the effects of shock wave, binding energy, and mass loss (0.2 $M_\odot$). The model shows the pulsar systems are relevant to AIC-candidates.

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The dynamical mass and evolutionary status of the type-II Cepheid in the eclipsing binary system OGLE-LMC-T2CEP-211 with a double-ring disk

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We present the analysis of a peculiar W Virginis (pWVir) type-II Cepheid, OGLE-LMC-T2CEP-211 (\(P_{\text{puls}} = 9.393\) d), in a double-lined binary system (\(P_{\text{orb}} = 242\) d), which shed light on virtually unknown evolutionary status and structure of pWVir stars. The dynamical mass of the Cepheid (first ever for a type-II Cepheid) is \(0.64 \pm 0.02\) M☉ and the radius \(R = 25.1 \pm 0.3\) R☉. The companion is a massive (5.67 M☉) main-sequence star obscured by a disk. Such configuration suggests a mass transfer in the system history. We found that originally the system (\(P_{\text{init}} = 12\) d) was composed of 3.5 and 2.8 M☉ stars, with the current Cepheid being more massive. The system age is now \(\sim 200\) My and the Cepheid is almost completely stripped of hydrogen, with helium mass of \(\sim 92\%\) of the total mass. It finished transferring the mass 2.5 My ago and is evolving towards lower temperatures passing through the instability strip. Comparison with observations indicate a reasonable \(2.7 \times 10^{-8}\) M☉ y⁻¹ mass loss from the Cepheid. The companion is most probably a Be main-sequence star with \(T = 22000\) K and \(R = 2.5\) R☉. Our results yield a good agreement with a pulsation theory model for a hydrogen-deficient pulsator, confirming the described evolutionary scenario. We detected a two-ring disk (\(R_{\text{disk}} \sim 116\) R☉) and a shell (\(R_{\text{shell}} \sim 9\) R☉) around the companion, that is probably a combination of the matter from the past mass transfer, the mass being lost by the Cepheid due to wind and pulsations, and a decretion disk around a rapidly rotating secondary. Our study together with observational properties of pWVir stars suggests that their majority are products of a similar binary evolution interaction.

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A near-infrared variable star survey in the Magellanic Clouds: The Small Magellanic Cloud data

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A very long term near-infrared variable star survey towards the Large and Small Magellanic Clouds was carried out.
Shedding light on the isolation of Luminous Blue Variables

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In the standard view of massive star evolution, luminous blue variables (LBVs) are transitional objects between the most massive O-type stars and Wolf–Rayet (WR) stars. With short lifetimes, these stars should all be found near one another. A recent study of LBVs in the Large Magellanic Cloud (LMC) found instead that LBVs are considerably more isolated than either O-type stars or WRs, with a distribution intermediate between that of the WRs and red supergiants (RSGs). A similar study, using a more restricted sample of LBVs, reached the opposite conclusion. Both studies relied upon the distance to the nearest spectroscopically identified O-type star to define the degree of isolation. However, our knowledge of the spectroscopic content of the LMC is quite spotty. Here we re-examine the issue using carefully defined photometric criteria to select the highest mass unevolved stars (“bright blue stars,” or BBSs), using spatially complete photometric catalogs of the LMC, M31, and M33. Our study finds that the LBVs are no more isolated than BBSs or WRs. This result holds no matter which sample of LBVs we employ. A statistical test shows that we can rule out the LBVs having the same distribution as the RSGs, which are about 2\times more isolated. We demonstrate the robustness of our results using the second-closest neighbor. Furthermore, the majority of LBVs in the LMC are found in or near OB associations as are the BBS and WRs; the RSGs are not. We conclude that the spatial distribution of LBVs therefore is consistent with the standard picture of massive star evolution.

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Feedback from massive stars at low metallicities: MUSE observations of N 44 and N 180 in the Large Magellanic Cloud

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We present MUSE integral field data of two H\textsc{ii} region complexes in the Large Magellanic Cloud (LMC), N44 and N180.
N180. Both regions consist of a main superbubble and a number of smaller, more compact H II regions that formed on the edge of the superbubble. For a total of 11 H II regions, we systematically analyse the radiative and mechanical feedback from the massive O-type stars on the surrounding gas. We exploit the integral field property of the data and the coverage of the He II λ5412 line to identify and classify the feedback-driving massive stars, and from the estimated spectral types and luminosity classes we determine the stellar radiative output in terms of the ionising photon flux Q0. We characterise the H II regions in terms of their sizes, morphologies, ionisation structure, luminosity and kinematics, and derive oxygen abundances via emission line ratios. We analyse the role of different stellar feedback mechanisms for each region by measuring the direct radiation pressure, the pressure of the ionised gas, and the pressure of the shock-heated winds. We find that stellar winds and ionised gas are the main drivers of H II region expansion in our sample, while the direct radiation pressure is up to three orders of magnitude lower than the other terms. We relate the total pressure to the star formation rate per unit area, ΣSFR, for each region and find that stellar feedback has a negative effect on star formation, and sets an upper limit to ΣSFR as a function of increasing pressure.

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Identification of AGN in the XMM–Newton X-ray survey of the SMC
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Context: Finding Active Galactic Nuclei (AGN) behind the Magellanic Clouds (MCs) is difficult because of the high stellar density in these fields. Although the first AGN behind the Small Magellanic Cloud (SMC) were reported in the 1980s, it is only recently that the number of AGN known behind the SMC has increased by several orders of magnitude.

Aims: The mid-infrared colour selection technique has been proven to be an efficient means of identifying AGN, especially obscured sources. The X-ray regime is complementary in this regard and we use XMM–Newton observations to support the identification of AGN behind the SMC.

Methods: We present a catalogue of AGN behind the SMC by correlating an updated X-ray point source catalogue from our XMM–Newton survey of the SMC with already known AGN from the literature as well as a list of candidates obtained from the ALLWISE mid-infrared colour selection criterion. We studied the properties of the sample with respect to their redshifts, luminosities and X-ray spectral characteristics. We also identified the near-infrared counterpart of the sources from the VISTA observations.

Results: The redshift and luminosity distributions of the sample (where known) indicate that we detect sources from nearby Seyfert galaxies to distant and obscured quasars. The X-ray hardness ratios are compatible with those typically expected for AGN. The VISTA colours and variability are also consistent in this regard. A positive correlation was observed between the integrated X-ray flux (0.2–12 keV) and the ALLWISE and VISTA magnitudes. We further present a sample of new candidate AGN and candidates for obscured AGN. All of these make an interesting subset for further follow-up studies. An initial spectroscopic follow-up of 6 out of the 81 new candidates showed all six sources are active galaxies, albeit two with narrow emission lines.

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Calibrating interstellar abundances using SNR radiative shocks

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Using integral field data we extract the optical spectra of shocked interstellar clouds in Kepler’s supernova remnant located in the inner regions of our Galaxy, as well as in the Large Magellanic Cloud (LMC), the Small Magellanic Cloud (SMC), NGC 6822 and IC 1613. Using self-consistent shock modelling, we make a new determination of the chemical composition of the interstellar medium (ISM) in N, O, Ne, S, Cl and Ar in these galaxies and obtain accurate estimates of the fraction of refractory grains destroyed in the shock. By comparing our derived abundances with those obtained in recent works using observations of B stars, F supergiant stars and H II regions, we provide a new calibration for abundance scaling in the range $7.9 \lesssim \log O/H \lesssim 9.1$.

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On collision course: the nature of the binary star cluster NGC 2006 / SL 538

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The LMC hosts a rich variety of star clusters seen in close projected proximity. Ages have been derived for few of them showing differences up to few million years, hinting at being binary star clusters. However, final confirmation needs to be done through spectroscopic analysis. Here we focus on the LMC cluster pair NGC 2006–SL 538 and aim to determine whether the star cluster pair is a bound entity (binary star cluster) or a chance alignment. Using the MIKE échelle spectrograph at LCO we have acquired integrated-light spectra for each cluster. We have measured radial velocities by two methods: a) direct line profile measurement yields $v_r = 300.3 \pm 6.6$ km s$^{-1}$ for NGC 2006 and $v_r = 310.2 \pm 4.6$ km s$^{-1}$ for SL 538. b) By comparing observed spectra with synthetic bootstrapped spectra yielding $v_r = 311.0 \pm 0.6$ km s$^{-1}$ for NGC 2006 and $v_r = 309.4 \pm 0.5$ km s$^{-1}$ for SL 538. Finally when spectra are directly compared, we find a $\Delta v = 1.08 \pm 0.47$ km s$^{-1}$. Full-spectrum SED fits reveal that the stellar population ages lie in the range 13–21 Myr with a metallicity of $Z = 0.008$. We find indications for differences in the chemical abundance patterns as revealed by the helium absorption lines between the two clusters. The dynamical analysis shows that the two clusters are likely to merge within the next ~150 Myr. The NGC 2006–SL 538 cluster pair shows radial velocities, stellar population and dynamical parameters consistent with a gravitational bound entity. We conclude that this is a genuine binary cluster pair, and we propose that their differences in ages and stellar population chemistry is most likely due to variances in their chemical enrichment history within their environment. We suggest that their formation may have taken place in a loosely bound star-formation complex which saw initial fragmentation but then had its clusters become a gravitationally bound pair by tidal capture.

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Discovery of redshifted He-like Iron absorption line from luminous accreting neutron star SMC X-1

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We have analyzed X-ray data of SMC X-1 obtained with \textit{Suzaku}, and discovered a combination of an absorption line and an underlying broadened emission line centered at 6.4 keV in an observation performed on May 19, 2012. This absorption line is centered at 6.61\textsuperscript{+0.02}_{-0.03} keV with an absorption strength of 5.9\textsuperscript{+1.7}_{-1.4}, naturally interpreted as an He\textsubscript{α} resonance line of Fe at 6.7 keV that has a redshift of 4000\textsuperscript{+1400}_{-1300} km s\textsuperscript{-1}. Although \textit{Suzaku} observed this system ten times during 11 months in 2011–2012, the absorption feature has been seen only in a single observation when the NS was in a rising phase of the super-orbital modulation, which can be regarded as an egress from occultation by an extended accretion disk. We therefore attribute the line to a low density, highly ionized absorber in an accretion disk corona arising from the disk illuminated by the NS’s intense X-rays. This interpretation also agrees with a discussion on the photoionization degree and the line depth.

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Conference Papers

A near-infrared VISTA of the Small Magellanic Cloud

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VISTA observed the Small Magellanic Cloud (SMC), as part of the VISTA survey of the Magellanic Clouds system (VMC), for six years (2010–2016). The acquired multi-epoch YJK\textsubscript{s} images have allowed us to probe the stellar populations to an exceptional level of detail across an unprecedented wide area in the near-infrared. This contribution highlights the most recent VMC results obtained on the SMC focusing, in particular, on the clustering of young stellar populations, on the proper motion of stars in the main body of the galaxy and on the spatial distribution of the star formation history.


Constraining the progenitor evolution of GW 150914

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One of the largest surprises from the LIGO results regarding the first gravitational wave detection (GW150914) was
the fact the black holes (BHs) were "heavy", of order 30–40 M☉. The most promising explanation for this obesity is that the BH–BH merger occurred at low metallicity (Z): when the iron (Fe) contents is lower this is expected to result in weaker mass loss during the Wolf-Rayet (WR) phase. We therefore critically evaluate the claims for the reasons of heavy BHs as a function of Z in the literature. Furthermore, weaker stellar winds might lead to more rapid stellar rotation, allowing WR and BH progenitor evolution in a chemically homogeneous manner. However, there is as yet no empirical evidence for more rapid rotation amongst WR stars in the low Z environment of the Magellanic Clouds. Due to the intrinsic challenge of determining WR rotation rates from emission lines, the most promising avenue to constrain rotation-rate distributions amongst various WR subgroups is through the utilisation of their emission lines in polarised light. We thus provide an overview of linear spectro-polarimetry observations of both single and binary WRs in the Galaxy, as well as the Large and Small Magellanic Clouds, at 50% and 20% of solar Z, respectively. Initial results suggest that the route of chemically homogeneous evolution (CHE) through stellar rotation is challenging, whilst the alternative of a post-LBV or common envelope evolution is more likely.

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Morphology of stellar populations in the Magellanic Clouds using the VMC survey

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The Magellanic Clouds are nearby dwarf irregular galaxies that represent a unique laboratory for studying galaxy interactions. Their morphology and dynamics have been heavily influenced by their mutual interactions as well as with their interaction(s) with the Milky Way. We use the VISTA near-infrared YJHKσ survey of the Magellanic Clouds system (VMC) in combination with stellar partial models of the Large Magellanic Cloud (LMC), the Small Magellanic Cloud (SMC) and the Milky Way to investigate the spatial distribution of stellar populations of different ages across the Magellanic Clouds. In this contribution, we present the results of these studies that allow us to trace substructures possibly related to the interaction history of the Magellanic Clouds.


Blue straggler populations beyond the Milky Way

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Although the formation of blue straggler stars (BSSs) is routinely attributed to stellar interactions in binary systems, the relative importance of the direct collision and slow(er) stellar coalescence formation channels is still poorly understood. We selected a sample of 24 Magellanic Cloud star clusters for which multi-passband Hubble Space Telescope
images are available to address this outstanding question. We compiled a BSS database, containing both traditional and evolved BSSs. We found a robust correlation between the number of BSSs in a cluster’s core and its core mass, \( N_{\text{BSS,core}} \propto M_{\text{core}}^{0.51 \pm 0.07} \), which supports the notion that BSS formation is linked to a population’s binary fraction. At low stellar collision rates, the mass-normalised number of BSSs does not appear to depend on the collision rate, which implies that the coalescence-driven BSS formation channel dominates. Comparison with simulations suggests that stellar collisions contribute less than 20% to the total number of BSSs formed.


Review Paper

Asymptotic giant branch variables in nearby galaxies

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Certain types of large amplitude AGB variable are proving to be powerful distance indicators that will rival Cepheids in the JWST era of high precision infrared photometry. These are predominantly found in old populations and have low mass progenitors. At the other end of the AGB mass-scale, large amplitude variables, particularly those undergoing hot bottom burning, are the most luminous representatives of their population. These stars are < 1 Gyr old, are often losing mass copiously and are vital to our understanding of the integrated light of distant galaxies as well as to chemical enrichment. However, the evolution of such very luminous AGB variables is rapid and remains poorly understood. Here I discuss recent infrared observations of both low- and intermediate-mass Mira variables in the Local Group and beyond.

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Announcement

SOFIA Community Science I
HAWC+ Polarimetry of 30 Doradus

The Stratospheric Observatory for Infrared Astronomy (SOFIA) is a Boeing 747SP aircraft modified to accommodate a 2.7-meter gyro-stabilized telescope, which is mainly focused to studying the Universe at infrared wavelengths. As part of the Strategic Director’s Discretionary Time (S-DDT) program, SOFIA performs observations of relevant science cases and immediately offers science-ready data products to the astronomical community. We present the first data release of the S-DDT program on far-infrared imaging polarimetric observations of 30 Doradus using the High-resolution Airborne Wideband Camera-Plus (HAWC+) at 53, 89, 154, and 214 μm. We present the status and quality of the observations, an overview of the SOFIA data products, and examples of working with HAWC+ polarimetric data that will enhance the scientific analysis of this, and future, data sets. These observations illustrate the potential influence of magnetic fields and turbulence in a star-forming region within the Tarantula Nebula.