Dear Colleagues,

It is my pleasure to present you the 153rd issue of the Magellanic Clouds Newsletter. It features a large number of papers related to star clusters, in one way or another. But even if you are not fond of star clusters you are likely to find something of interest among the posts, which include further results from Gaia and work on massive stars but also the interstellar medium.

The next issue is planned to be distributed on the 6th of August.

Editorially Yours,

Jacco van Loon
The VLT-FLAMES Tarantula Survey: XXVIII. Nitrogen abundances for apparently single dwarf and giant B-type stars with small projected rotational velocities

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Previous analyses of the spectra of OB-type stars in the Magellanic Clouds have identified targets with low projected rotational velocities and relatively high nitrogen abundances; the evolutionary status of these objects remains unclear. The VLT-FLAMES Tarantula Survey obtained spectroscopy for over 800 early-type stars in 30 Doradus of which 434 stars were classified as B-type. We have estimated atmospheric parameters and nitrogen abundances using tlyst model atmospheres for 54 B-type targets that appear to be single, have projected rotational velocities, $v \sin i \leq 80$ km s$^{-1}$ and were not classified as supergiants. In addition, nitrogen abundances for 34 similar stars observed in a previous FLAMES survey of the Large Magellanic Cloud have been re-evaluated.

For both samples, approximately 75–80% of the targets have nitrogen enhancements of less than 0.3 dex, consistent with them having experienced only small amounts of mixing. However, stars with low projected rotational velocities, $v \sin i \leq 40$ km s$^{-1}$ and significant nitrogen enrichments are found in both our samples and simulations imply that these cannot all be rapidly rotating objects observed near pole-on. For example, adopting an enhancement threshold of 0.6 dex, we observed five and four stars in our VFTS and previous FLAMES survey samples, yet stellar evolution models with rotation predict only 1.25±0.11 and 0.26±0.51 based on our sample sizes and random stellar viewing inclinations. The excess of such objects is estimated to be 20–30% of all stars with current rotational velocities of less than 40 km s$^{-1}$. This would correspond to ~2–4% of the total non-supergiant single B-type sample. Given the relatively large nitrogen enhancement adopted, these estimates constitute lower limits for stars that appear inconsistent with current grids of stellar evolutionary models. Including targets with smaller nitrogen enhancements of greater than 0.2 dex implies larger percentages of targets that are inconsistent with current evolutionary models, viz. ~70% of the stars with rotational velocities less than 40 km s$^{-1}$ and ~6–8% of the total single stellar population. We consider possible explanations of which the most promising would appear to be breaking due to magnetic fields or stellar mergers with subsequent magnetic braking.

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The search for multiple populations in Magellanic Cloud clusters IV: Coeval multiple stellar populations in the young star cluster NGC 1978

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We have recently shown that the ∼2 Gyr old Large Magellanic Cloud star cluster NGC 1978 hosts multiple populations in terms of star-to-star abundance variations in [N/Fe]. These can be seen as a splitting or spread in the sub-giant and red giant branches (SGB and RGB) when certain photometric filter combinations are used. Due to its relative youth, NGC 1978 can be used to place stringent limits on whether multiple bursts of star-formation have taken place within the cluster, as predicted by some models for the origin of multiple populations. We carry out two distinct analyses to test whether multiple star-formation epochs have occurred within NGC 1978. First, we use UV CMDs to select stars from the first and second population along the SGB, and then compare their positions in optical CMDs, where the morphology is dominantly controlled by age as opposed to multiple population effects. We find that the two populations are indistinguishable, with age differences of 1 ± 20 Myr between them. This is in tension with predictions from the AGB scenario for the origin of multiple populations. Second, we estimate the broadness of the main sequence turnoff (MSTO) of NGC 1978 and we report that it is consistent with the observational errors. We find an upper limit of ∼65 Myr on the age spread in the MSTO of NGC 1978. This finding is in conflict with the age spread scenario as origin of the extended MSTO in intermediate age clusters, while it fully supports predictions from the stellar rotation model.

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New insights into the formation of the blue main sequence in NGC 1850

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Recent discoveries of bimodal main sequence (MSs) associated with young clusters (with ages ≤1 Gyr) in the Mag-
ellanic Clouds have drawn a lot of attention. One of the prevailing formation scenarios attributes these split MSs to a bimodal distribution in stellar rotation rates, with most stars belonging to a rapidly rotating population. In this scenario, only a small fraction of stars populating a secondary blue sequence are slowly or non-rotating stars. Here, we focus on the blue MS in the young cluster NGC 1850. We compare the cumulative number fraction of the observed blue-MS stars to that of the high-mass-ratio binary systems at different radii. The cumulative distributions of both populations exhibit a clear anti-correlation, characterized by a highly significant Pearson coefficient of $-0.97$. Our observations are consistent with the possibility that blue-MS stars are low-mass-ratio binaries, and therefore their dynamical disruption is still ongoing. High-mass-ratio binaries, on the other hand, are more centrally concentrated.

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Seeing red in NGC 1978, NGC 55, and NGC 3109

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Spectra of the intermediate age star cluster NGC 1978 and the dwarf irregular galaxies NGC 55 and NGC 3109 that span the 0.7 to 1.1 $\mu$m wavelength interval are discussed. The NGC 1978 spectra are used to examine stochastic effects on the integrated red light from an intermediate age cluster. The removal of either the brightest M giant or the brightest C star from the co-added NGC 1978 spectrum has minor affects on the equivalent widths of the Ca triplet. The most robust signature of C stars in the integrated cluster spectrum at these wavelengths is the CN band head near 0.79 $\mu$m. The equivalent widths of Ca triplet lines in the NGC 1978 spectrum and in the spectra of individual cluster stars are larger than expected for a scaled-solar abundance system, and it is suggested that these stars have been subject to extra mixing processes. Ca lines weaken with increasing distance from the disk plane in the NGC 55 spectra. Comparisons with models suggest that the red light from NGC 55 is dominated by stars with ages 1–2 Gyr, in agreement with star-forming histories (SFHs) obtained from the analysis of CMDs. The NGC 3109 observations sample three different parts of that galaxy but have a low signal-to-noise ratio. Comparisons with models suggest that the light from the NGC 3109 disk at red wavelengths is dominated by RSGs with ages of at most a few tens of Myr, in qualitative agreement with SFHs that are based on photometric measurements.


Using star clusters as tracers of star formation and chemical evolution: the chemical enrichment history of the Large Magellanic Cloud

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The star formation (SFH) and chemical enrichment (CEH) histories of Local Group galaxies are traditionally studied by analyzing their resolved stellar populations in a form of color–magnitude diagrams obtained with the *Hubble* Space Telescope. Star clusters can be studied in integrated light using ground-based telescopes to much larger distances. They represent snapshots of chemical evolution of their host galaxy at different ages. Here we present a simple theoretical framework for the chemical evolution based on the instantaneous recycling approximation (IRA) model. We infer a CEH from a SFH and vice versa using observational data. We also present a more advanced model for the evolution of individual chemical elements which takes into account the contribution of supernovae type Ia. We demonstrate that ages, iron and $\alpha$-element abundances of 15 star clusters derived from fitting of their integrated optical
spectra reliably trace the CEH of the Large Magellanic Cloud obtained from resolved stellar populations in the age range $40 \text{ Myr} < t < 3.5 \text{ Gyr}$. The CEH predicted by our model from the global SFH of the LMC agrees remarkably well with the observed cluster age–metallicity relation. Moreover, the present day total gas mass of the LMC estimated by the IRA model ($6.2 \times 10^8 \text{ M}_\odot$) matches within uncertainties the observed H\textsc{i} mass corrected for the presence of molecular gas ($5.8 \pm 0.5 \times 10^8 \text{ M}_\odot$). We briefly discuss how our approach can be used to study SFHs of galaxies as distant as 10 Mpc at the level of detail that is currently available only in a handful of nearby Milky Way satellites.

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Evidence of differential tidal effects in the old globular cluster population of the Large Magellanic Cloud

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We present for the first time extended stellar density and/or surface brightness radial profiles for almost all the known Large Magellanic Cloud (LMC) old globular clusters (GCs). These were built from DECam images and reach out to $\sim 4$ times the GCs’ tidal radii. The background subtracted radial profiles reveal that the GCs located closer than $\sim 5$ kpc from the LMC centre contain an excess of stars in their outermost regions with respect to the stellar density expected from a King profile. Such a residual amount of stars – not seen in GCs located farther than $\sim 5$ kpc from the LMC centre – as well as the GCs’ dimensions, show a clear dependence with the GCs’ positions in the galaxy, in the sense that, the farther the GC from the centre of the LMC, the larger both the excess of stars in its outskirts and size. Although the masses of GCs located inside and outside $\sim 5$ kpc are commensurate, the outermost regions of GCs located closer than $\sim 5$ kpc from the LMC centre appear to have dynamically evolved more quickly. These outcomes can be fully interpreted in the light of the known GC radial velocity disc-like kinematics, from which GCs have been somehow mostly experiencing the influence of the LMC gravitational field at their respective mean distances from the LMC centre.

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The shortest-period Wolf–Rayet binary in the Small Magellanic Cloud: part of a high-order multiple system


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Context: SMC AB 6 is the shortest-period (6.5 d) Wolf–Rayet (WR) binary in the Small Magellanic Cloud, and is therefore crucial for the study of binary interaction and formation of WR stars at low metallicity. The WR component in AB 6 was previously found to be very luminous ($\log L/L_\odot = 6.3$) compared to its reported orbital mass ($8 \text{ M}_\odot$), placing it significantly above the Eddington limit. Through spectroscopy and orbital analysis of newly acquired optical data taken with UVES, we aim to understand the peculiar results reported for this system and explore its evolutionary history.
Results: We find that AB 6 contains at least four stars. The 6.5-d period WR binary comprises the WR primary (WN3:h, star A) and a rather rapidly rotating early O-type companion (O5.5 V, star B). Static N and He lines suggest the presence of an emission line star (O5.5 I(f), star C). Finally, narrow absorption lines portraying a long-term radial velocity variation show the existence of a fourth star (O7.5 V, star D). Star D appears to form a second 140-d period binary together with a fifth stellar member, which is a B-type dwarf or a black hole. It is not clear that these additional components are bound to the WR binary. The WR star is found to be less luminous than previously thought \( \log L / L_\odot = 5.9 \) and, adopting 41 M\(_\odot\) for star B, more massive (18 M\(_\odot\)). Correspondingly, the WR star does not exceed the Eddington limit. We derive the initial masses of 60 and 40 M\(_\odot\) for stars A and B and an age of 3.9 Myr for the system. The WR binary likely experienced non-conservative mass transfer in the past supported by the relatively rapid rotation of star B.

Conclusions: Our study shows that AB 6 is a multiple – probably quintuple – system. This finding resolves the previously reported puzzle of the WR primary exceeding the Eddington limit and suggests that the WR star exchanged mass with its companion in the past.

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Red supergiant stars in the Large Magellanic Cloud. II. Infrared properties and mid-infrared variability

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The characteristics of infrared properties and mid-infrared (MIR) variability of red supergiant (RSG) stars in the Large Magellanic Cloud (LMC) are analyzed based on 12 bands of near-infrared (NIR) to MIR co-added data from 2MASS, Spitzer and WISE, and \(~6.6\) years of MIR time-series data collected by the ALLWISE and NEOWISE-R projects. 773 RSGs candidates were compiled from the literature and verified by using the color-magnitude diagram (CMD), spectral energy distribution (SED) and MIR variability. About 15% of valid targets in the IRAC1-IRAC2/IRAC3 diagram may show polycyclic aromatic hydrocarbon (PAH) emission. We show that arbitrary dereddening Q parameters related to the IRAC4, S9W, WISE3, WISE4, and MIPS24 bands could be constructed based on a precise measurement of MIR interstellar extinction law. Several peculiar outliers in our sample are discussed, in which one outlier might be a RSG right before the explosion or an extreme asymptotic giant branch (AGB) star in the very late evolutionary stage based on the MIR spectrum and photometry. There are 744 identified RSGs in the final sample having both the WISE1- and WISE2-band time-series data. The results show that the MIR variability is increasing along with the increasing of brightness. There is a relatively tight correlation between the MIR variability, mass loss rate (MLR; in terms of \( K_s - WISE3 \) color), and the warm dust or continuum (in terms of WISE4 magnitude/flux), where the MIR variability is evident for the targets with \( K_s - WISE3 > 1.0 \) mag and \( WISE4 < 6.5 \) mag, while the rest of the targets show much smaller MIR variability. The MIR variability is also correlated with the MLR for which targets with larger variability also show larger MLR with an approximate upper limit of \( \log \dot{M}(M_\odot \, \text{yr}^{-1}) = -6.1 \). Both the variability and the luminosity may be important for the MLR since the WISE4-band flux is increasing exponentially along with the degeneracy of luminosity and variability. The identified RSG sample has been compared with the theoretical evolutionary models and shown that the discrepancy between observation and evolutionary models can be mitigated by considering both variability and extinction.

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Towards a comprehensive knowledge of the star cluster population in the Small Magellanic Cloud

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The Small Magellanic Cloud (SMC) has recently been found to harbour more than two hundred per cent increase of its known cluster population. We provide here with solid evidence that such an unprecedented number of clusters could be largely overestimated. On the one hand, the fully-automatic procedure used to identify such an enormous cluster candidate sample did not recover \( \sim 50 \) per cent, in average, of the known relatively bright clusters located in the SMC main body. On the other hand, the number of new cluster candidates per time unit as a function of time results noticeably different to the intrinsic SMC cluster frequency (CF), which should not be the case if these new detections were genuine physical systems. We additionally found that the SMC CF varies spatially, in such a way that it resembles an outside–in process coupled with the effects of a relatively recent interaction with the Large Magellanic Cloud. By assuming that clusters and field stars share the same formation history, we showed for the first time that the cluster dissolution rate also depends on the position in the galaxy. The cluster dissolution results higher as the concentration of galaxy mass increases or external tidal forces are present.

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The effects of binary stars on the color–magnitude diagrams of young-age massive star clusters

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Extended main-sequence turnoffs (eMSTO) have been observed in the color–magnitude diagram (CMD) of intermediate-age and young star clusters. The origin of the eMSTO phenomenon is still highly debated. Calculations show that the blue and faint (BF) stars in the CMD of NGC 1866 are hydrogen main sequence (MS) + naked He star systems. The He star derives from the massive star of a binary system. The BF stars and the red and faint MSTO stars belong to the same stellar population. The values of \( m_{F336W} \) and \( m_{F336W} - m_{F814W} \) of the BF stars are mainly determined by the masses of He stars and H-MS stars, respectively. The behaviors of the BF stars in the CMD are well explained by the H-MS + He-star systems. The BF stars provide a strict restriction on the age of the stellar population. Moreover, the bimodal MS of NGC 1866 can also be reproduced by a younger binary population. The calculations show that part of the blue and bright (BB) MS stars of NGC 1866 are H-MS + He-star systems, H-MS + white dwarf systems, and merged stars in a binary scenario. The H-MS stars of the H-MS + He-star systems for the BB stars are significantly more massive than those of the BF stars. Once the H-MS + He-star systems and their membership in NGC 1866 are confirmed, the extended star-formation histories and the effects of binaries can be confirmed in the young star cluster.

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Gaia proper motions and orbits of the ultra-faint Milky Way satellites

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The second data release from the Gaia mission (DR2) provides a comprehensive and unprecedented picture of the motions of astronomical sources in the plane of the sky, extending from the solar neighborhood to the outer reaches of the Milky Way. I present proper motion measurements based on Gaia DR2 for 17 ultra-faint dwarf galaxies within
100 kpc of the Milky Way. I compile the spectroscopically-confirmed member stars in each dwarf bright enough for Gaia astrometry from the literature, producing member samples ranging from 2 stars in Triangulum II to 68 stars in Bootes I. From the spectroscopic member catalogs I estimate the proper motion of each system. I find good agreement with the proper motions derived by the Gaia collaboration for Bootes I and Leo I. The tangential velocities for 14 of the 17 dwarfs are determined to better than 50 km s$^{-1}$, more than doubling the sample of such measurements for Milky Way satellite galaxies. The orbital pericenters are well-constrained, with a median value of 38 kpc. Only one satellite, Tucana III, is on an orbit passing within 15 kpc of the Galactic center, suggesting that the remaining ultra-faint dwarfs are unlikely to have experienced severe tidal stripping. As a group, the ultra-faint dwarfs are on high-velocity, eccentric, retrograde trajectories, with nearly all of them having space motions exceeding 370 km s$^{-1}$. A large majority of the objects are currently close to the pericenters of their orbits. In a low-mass ($M_{\text{vir}} = 0.8 \times 10^{12} M_{\odot}$) Milky Way potential, 8 out of the 17 galaxies lack well-defined apocenters and appear likely to be on their first infall, indicating that the Milky Way mass may be larger than previously estimated or that many of the ultra-faint dwarfs are associated with the Magellanic Clouds. The median eccentricity of the ultra-faint dwarf orbits is 0.79, similar to the values seen in numerical simulations, but distinct from the rounder orbits of the more luminous dwarf spheroidals.

Submitted to AAS Journals

HST astrometry in the 30 Doradus region: II. Runaway stars from new proper motions in the Large Magellanic Cloud


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We present a catalog of relative proper motions for 368,787 stars in the 30 Doradus region of the Large Magellanic Cloud (LMC), based on a dedicated two-epoch survey with the Hubble Space Telescope (HST) and supplemented with proper motions from our pilot archival study. We demonstrate that a relatively short epoch difference of 3 years is sufficient to reach a $\sim 0.1$ mas yr$^{-1}$ level of precision or better. A number of stars have relative proper motions exceeding a 3-$\sigma$ error threshold, representing a mixture of Milky Way denizens and 17 potential LMC runaway stars. Based upon 183 VFTS OB-stars with the best proper motions, we conclude that none of them move faster than $\sim 0.3$ mas yr$^{-1}$ in each coordinate – equivalent to $\sim 70$ km s$^{-1}$. Among the remaining 351 VFTS stars with less accurate proper motions, only one candidate OB runaway can be identified. We rule out any OB star in our sample moving at a tangential velocity exceeding $\sim 120$ km s$^{-1}$. The most significant result of this study is finding 10 stars over wide range of masses, which appear to be ejected from the massive star cluster R 136 in the tangential plane to angular distances from 35$''$ to 407$''$, equivalent to 8–98 pc. The tangential velocities of these runaways appear to be correlated with apparent magnitude, indicating a possible dependence on the stellar mass.

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Anti-correlation between X-ray luminosity and pulsed fraction in the Small Magellanic Cloud pulsar SXP 1323

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We report the evidence for the anti-correlation between pulsed fraction (PF) and luminosity of the X-ray pulsar SXP 1323, found for the first time in a luminosity range $10^{35}$–$10^{37}$ erg s$^{-1}$ from observations spanning 15 years. The phenomenon of a decrease in X-ray PF when the source flux increases has been observed in our pipeline analysis of other X-ray pulsars in the Small Magellanic Cloud (SMC). It is expected that the luminosity under a certain value decreases as the PF decreases due to the propeller effect. Above the propeller region, an anti-correlation between the PF and flux might occur either as a result of an increase in the un-pulsed component of the total emission or a decrease of the pulsed component. Additional modes of accretion may also be possible, such as spherical accretion and a change in emission geometry. At higher mass accretion rates, the accretion disk could also extend closer to the neutron star (NS) surface, where a reduced inner radius leads to hotter inner disk emission. These modes of plasma accretion may affect the change in the beam configuration to fan-beam dominant emission.

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Gaia DR2 confirms that candidate Thorne-Żytkow object HV 2112 is in the SMC

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The Gaia DR2 proper motion places HV 2112 in the Small Magellanic Cloud (SMC), consistent with it being a Thorne-Żytkow object

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Gaia Data Release 2: Kinematics of globular clusters and dwarf galaxies around the Milky Way

Gaia Collaboration et al.1

1European Space Agency & Gaia Data Processing and Analysis Consortium, various countries

The goal of this paper is to demonstrate the outstanding quality of the second data release of the Gaia mission and its power for constraining many different aspects of the dynamics of the satellites of the Milky Way. We focus here on determining the proper motions of 75 Galactic globular clusters, nine dwarf spheroidal galaxies, one ultra-faint system, and the Large and Small Magellanic Clouds. Using data extracted from the Gaia archive, we derived the proper motions and parallaxes for these systems, as well as their uncertainties. We demonstrate that the errors,
statistical and systematic, are relatively well understood. We integrated the orbits of these objects in three different Galactic potentials, and characterised their properties. We present the derived proper motions, space velocities, and characteristic orbital parameters in various tables to facilitate their use by the astronomical community. Our limited and straightforward analyses have allowed us for example to (i) determine absolute and very precise proper motions for globular clusters; (ii) detect clear rotation signatures in the proper motions of at least five globular clusters; (iii) show that the satellites of the Milky Way are all on high-inclination orbits, but that they do not share a single plane of motion; (iv) derive a lower limit for the mass of the Milky Way of \( 9.8^{+6.7}_{-2.7} \times 10^{11} \, M_\odot \) based on the assumption that the Leo I dwarf spheroidal is bound; (v) derive a rotation curve for the Large Magellanic Cloud based solely on proper motions that is competitive with line-of-sight velocity curves, now using many orders of magnitude more sources; and (vi) unveil the dynamical effect of the bar on the motions of stars in the Large Magellanic Cloud. All these results highlight the incredible power of the Gaia astrometric mission, and in particular of its second data release.

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Are all RR Lyrae stars modulated?  

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We analyzed 151 variables previously classified as fundamental mode RR Lyrae stars from Campaigns 01–04 of the *Kepler* two wheel (K2) archive. By employing a method based on the application of systematics filtering with the aid of co-trending light curves in the presence of a large amplitude signal component, we searched for additional Fourier signals in the close neighborhood of the fundamental period. We found only 13 stars without such components, yielding the highest rate of 91% of modulated (Blazhko) stars detected so far. A detection efficiency test suggests that this occurrence rate likely implies a 100% underlying rate. Furthermore, the same test performed on a subset of the Large Magellanic Cloud RR Lyrae stars from the MACHO archive shows that the conjecture of high true occurrence rate fits well to the low observed rate derived from this database.

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Metals and dust in the neutral ISM: the Galaxy, Magellanic Clouds, and damped Lyman-α absorbers

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*Context:* The presence of dust in the neutral interstellar medium (ISM) dramatically changes the metal abundances that we measure. Understanding the metal content in the neutral ISM, and a direct comparison between different environments, has been hampered to date because of the degeneracy to the observed ISM abundances caused by the effects of metallicity, the presence of dust, and nucleosynthesis. *Aims.* We study the metal and dust content in the neutral ISM consistently in different environments, and assess the universality of recently discovered sequences of relative abundances. We also intend to assess the validity of [Zn/Fe] as a tracer of dust in the ISM. This has recently been cast into doubt based on observations of stellar abundances, and needs to be addressed before we can safely use it to study the ISM.

*Methods:* In this letter we present a simple comparison of relative abundances observed in the neutral ISM in the Galaxy, the Magellanic Clouds, and damped Lyman-α absorbers (DLAs). The main novelty in this comparison is the inclusion of the Magellanic Clouds.
**Results:** The same sequences of relative abundances are valid for the Galaxy, Magellanic Clouds, and DLAs. These sequences are driven by the presence of dust in the ISM and seem "universal".

**Conclusions:** The metal and dust properties in the neutral ISM appear to follow a similar behaviour in different environments. This suggests that a dominant fraction of the dust budget is built up from grain growth in the ISM depending of the physical conditions and regardless of the star formation history of the system. In addition, the DLA gas behaves like the neutral ISM, at least from a chemical point of view. Finally, despite the deviations in [Zn/Fe] observed in stellar abundances, [Zn/Fe] is a robust dust tracer in the ISM of different environments, from the Galaxy to DLAs.

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**Gaia DR2 reveals a very massive runaway star ejected from R 136**

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A previous spectroscopic study identified the very massive O2 III star VFTS 16 in the Tarantula Nebula as a runaway star based on its peculiar line-of-sight velocity. We use the Gaia DR2 catalog to measure the relative proper motion of VFTS 16 and nearby bright stars to test if this star might have been ejected from the central cluster, R 136, via dynamical ejection. We find that the position angle and magnitude of the relative proper motion (0.338 ± 0.046 mas yr⁻¹, or approximately 80 ± 11 km s⁻¹) of VFTS 16 are consistent with ejection from R 136 approximately 1.5 ± 0.2 Myr ago, very soon after the cluster was formed. There is some tension with the presumed age of VFTS 16 that, from published stellar parameters, cannot be greater than 0.9±0.3 Myr. Older ages for this star would appear to be prohibited due to the absence of He I lines in its optical spectrum, since this sets a firm lower limit on its effective temperature. The dynamical constraints may imply an unusual evolutionary history for this object, perhaps indicating it is a merger product. Gaia DR2 also confirms that another very massive star in the Tarantula Nebula, VFTS 72 (alias BI 253; O2III–V(n)((f*))), is also a runaway on the basis of its proper motion as measured by Gaia. While its tangential proper motion (0.392±0.062 mas yr⁻¹ or 93±15 km s⁻¹) would be consistent with dynamical ejection from R 136 approximately 1 Myr ago, its position angle is discrepant with this direction at the 2σ level. From their Gaia DR2 proper motions we conclude that the two ~ 100 M⊙ O2 stars, VFTS 16 and VFTS 72, are fast runaway stars, with space velocities of around 100 km s⁻¹ relative to R 136 and the local massive star population. The dynamics of VFTS 16 are consistent with it having been ejected from R 136, and this star therefore sets a robust lower limit on the age of the central cluster of ~ 1.3 Myr.

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The Hubble Tarantula Treasury Project (HTTP) has provided an unprecedented photometric coverage of the entire star-burst region of 30 Doradus down to the half Solar mass limit. We use the deep stellar catalogue of HTTP to identify all the pre-main-sequence (PMS) stars of the region, i.e. stars that have not started their lives on the main-sequence yet. The photometric distinction of these stars from the more evolved populations is not a trivial task due to several factors that alter their colour–magnitude diagram positions. The identification of PMS stars requires, thus, sophisticated statistical methods. We employ machine learning classification techniques on the HTTP survey of more than 800,000 sources to identify the PMS stellar content of the observed field. Our methodology consists of 1) carefully selecting the most probable low-mass PMS stellar population of the star-forming cluster NGC 2070, 2) using this sample to train classification algorithms to build a predictive model for PMS stars, and 3) applying this model in order to identify the most probable PMS content across the entire Tarantula Nebula. We employ Decision Tree, Random Forest and Support Vector Machine classifiers to categorise the stars as PMS and Non-PMS. The Random Forest and Support Vector Machine provided the most accurate models, predicting about 20,000 sources with a candidateship probability higher than 50 percent, and almost 10,000 PMS candidates with a probability higher than 95 percent. This is the richest and most accurate photometric catalogue of extragalactic PMS candidates across the extent of a whole star-forming complex.
The first release of the AST3-1 point source catalogue from Dome A, Antarctica

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The three Antarctic Survey Telescopes (AST3) aim to carry out time domain imaging survey at Dome A, Antarctica. The first of the three telescopes (AST3-1) was successfully deployed on January 2012. AST3-1 is a 500 mm aperture modified Schmidt telescope with a 680 mm diameter primary mirror. AST3-1 is equipped with a SDSS $i$ filter and a 10k $\times$ 10k frame transfer CCD camera, reduced to 5k $\times$ 10k by electronic shuttering, resulting in a 4.3 deg$^2$ field-of-view. To verify the capability of AST3-1 for a variety of science goals, extensive commissioning was carried out between March and May 2012. The commissioning included a survey covering 2000 deg$^2$ as well as the entire Large and Small Magellanic Clouds. Frequent repeated images were made of the center of the Large Magellanic Cloud, a selected exoplanet transit field, and fields including some Wolf–Rayet stars. Here we present the data reduction and photometric measurements of the point sources observed by AST3-1. We have achieved a survey depth of 19.3 mag in 60 s exposures with 5 mmag precision in the light curves of bright stars. The facility achieves sub-mmag photometric precision under stable survey conditions, approaching its photon noise limit. These results demonstrate that AST3-1 at Dome A is extraordinarily competitive in time-domain astronomy, including both quick searches for faint transients and the detection of tiny transit signals.

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Three-dimensional structure of the Magellanic System

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We have determined the three-dimensional structure of the Magellanic Clouds and Magellanic Bridge using over 9000 Classical Cepheids (CCs) and almost 23000 RR Lyrae (RRL) stars from the fourth phase of the OGLE project.

For the CCs we calculated distances based on period-luminosity relations. CCs in the LMC are situated mainly in the bar that shows no offset from the plane of the LMC. The northern arm is also very prominent with an additional smaller arm. Both are located closer to us than the entire sample. The SMC has a non-planar structure that can be described as an ellipsoid extended almost along the line of sight. We also classified nine of our CCs as Magellanic Bridge objects. These Cepheids show a large spread in three-dimensions.

For the RRL stars, we calculated distances based on photometric metallicities and theoretical relations. Both Magellanic Clouds revealed a very regular structure. We fitted triaxial ellipsoids to our LMC and SMC samples. In the LMC we noticed a very prominent, non-physical blend-artifact that prevented us from analyzing the central parts of this galaxy. We do not see any evidence of a bridge-like connection between the Magellanic Clouds.
