Figure 1: Type Ia supernova remnant N 103B with coronal [Fe xiv] emission showing up as a fluorescent green triangle. This image was generated using a new tomographical technique, based on a spectrum extracted from the position of the yellow dot. See Seitenzahl et al., 2019, Phys. Rev. Lett. 123, 041101.
Dear Colleagues,

It is my pleasure to present you the 161st issue of the Magellanic Clouds Newsletter. Star clusters, supernova remnants, and more.

For the second time in a row the newsletter presents fundamental Physics: dark matter particles shot at us by the LMC!

See also the announcement of the IAU ombud at the end of the newsletter.

The next issue is planned to be distributed on the 1st of December.

Editorially Yours,
Jacco van Loon
The search for multiple populations in Magellanic Clouds clusters – V. 
Correlation between cluster age and abundance spreads

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In our HST photometric survey, we have been searching for multiple stellar populations (MPs) in Magellanic Clouds (MCs) massive star clusters which span a significant range of ages ($\sim 1.5$–11 Gyr). In the previous papers of the series, we have shown that the age of the cluster represents one of the key factors in shaping the origin of the chemical anomalies. Here we present the analysis of four additional clusters in the MCs, namely Lindsay 38, Lindsay 113, NGC 2121 and NGC 2155, for which we recently obtained new UV HST observations. These clusters are more massive than $\sim 10^4 M_\odot$, and have ages between $\sim 2.5$–6 Gyr, i.e. located in a previously unexplored region of the cluster age/mass diagram. We found chemical anomalies, in the form of N spreads, in three out of four clusters in the sample, namely in NGC 2121, NGC 2155 and Lindsay 113. By combining data from our survey and HST photometry for 3 additional clusters in the Milky Way (namely 47 Tuc, M 15 and NGC 2419), we show that the extent of the MPs in the form of N spread is a strong function of age, with older clusters having larger N spreads with respect to the younger ones. Hence, we confirm that cluster age plays a significant role in the onset of MPs.

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Optical tomography of chemical elements synthesized in type Ia supernovae

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We report the discovery of optical emission from the nonradiative shocked ejecta of three young type Ia supernova remnants (SNRs): SNR 0519$-69.0$, SNR 0509$-67.5$, and N 103B. Deep integral field spectroscopic observations reveal broad and spatially resolved [Fe XIV] 5303 Å emission. The width of the broad line reveals, for the first time, the reverse shock speeds. For two of the remnants we can constrain the underlying supernova explosions with evolutionary models. SNR 0519$-69.0$ is well explained by a standard near-Chandrasekhar mass explosion, whereas for SNR 0509$-67.5$ our
analysis suggests an energetic sub-Chandrasekhar mass explosion. With [S xii], [Fe ix], and [Fe xv] also detected, we can uniquely visualize different layers of the explosion. We refer to this new analysis technique as “supernova remnant tomography”.

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The Wolf–Rayet content of the Local Group and beyond

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Wolf–Rayet stars (WRs) represent the end of a massive star’s life as it is about to turn into a supernova. Obtaining complete samples of such stars across a large range of metallicities poses observational challenges, but presents us with an exciting way to test current stellar evolutionary theories. A technique we have developed and refined involves interference filter imaging combined with image subtraction and crowded-field photometry. This helps us address one of the most controversial topics in current massive star research: the relative importance of binarity in the evolution of massive stars and formation of WRs. Here we discuss the current state of the field, including how the observed WR populations match with the predictions of both single and binary star evolutionary models. We end with what we believe are the most important next steps in WR research.

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and from https://www.mdpi.com/2075-4434/7/3/74/xml

The intrinsic reddening of the Magellanic Clouds as traced by background galaxies – I. The bar and outskirts of the Small Magellanic Cloud

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We present a method to map the total intrinsic reddening of a foreground extinguishing medium via the analysis of
spectral energy distributions (SEDs) of background galaxies. In this pilot study, we implement this technique in two distinct regions of the Small Magellanic Cloud (SMC) – the bar and the southern outskirts – using a combination of optical and near-infrared $ugrizYJK_s$ broadband imaging. We adopt the LePhare $\chi^2$-minimisation SED-fitting routine and various samples of galaxies and/or quasi-stellar objects to investigate the intrinsic reddening. We find that only when we construct reddening maps using objects classified as galaxies with low levels of intrinsic reddening (i.e. ellipticals/lenticulars and early-type spirals), the resultant maps are consistent with previous literature determinations i.e. the intrinsic reddening of the SMC bar is higher than that in the outer environs. We employ two sets of galaxy templates – one theoretical and one empirical – to test for template dependencies in the resulting reddening maps and find that the theoretical templates imply systematically higher reddening values by up to 0.20 mag in $E(B - V)$. A comparison with previous reddening maps, based on the stellar components of the SMC, typically shows reasonable agreement. There is, however, significant variation amongst the literature reddening maps as to the level of intrinsic reddening associated with the bar. Thus, it is difficult to unambiguously state that instances of significant discrepancies are the result of appreciable levels of dust not accounted for in some literature reddening maps or whether they reflect issues with our adopted methodology.

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An X-ray and optical study of the outbursting behaviour of the SMC Be X-ray binary SXP 91.1

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In this paper we report on the optical and X-ray behaviour of the Be X-ray binary, SXP 91.1, during a recent type I outburst. We monitored the outburst using the Neil Gehrels Swift Observatory. These data were supported by optical data from the Southern African Large Telescope (SALT) and the Optical Gravitational Lensing Experiment (OGLE) to show the circumstellar disc activity. Matter from this disc accretes onto the neutron star, giving rise to the X-ray outburst as seen in the synchronous evolution of the optical and X-ray lightcurves. Using data taken with OGLE we show that the circumstellar disc has exhibited stable behaviour over two decades. A positive correlation is seen between the colour and magnitude from the OGLE and MACHO observations, which indicates that the disc is orientated at relatively low inclination angles. From the OGLE and Swift data, we demonstrate that the system has shown relative phase offsets that have persisted for many years. The spin period derivative is seen to be at maximum spin-up at phases when the mass accretion rate is at maximum. We show that the neutron star in SXP 91.1 is an unusual member of its class in that it has had a consistent spin period derivative over many years, with the average spin-up rate being one of the highest for known SMC pulsars. The most recent measurements of the spin-up rate reveal higher values than the global trend, which is attributed to the recent mass accretion event leading to the current outburst.

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Consistent calibration of the tip of the red giant branch in the Large Magellanic Cloud on the Hubble Space Telescope photometric system and implications for the determination of the Hubble constant

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The tip of the red giant branch (TRGB) is a promising standard candle for measuring extragalactic distances, but inaccuracies between ground and Hubble Space Telescope (HST) system photometry used in its absolute calibration currently limit its potential. We present the calibration of the TRGB in the Large Magellanic Cloud (LMC) on the HST/ACS F814W system. We used archival HST observations of 12 fields in the LMC to derive blending corrections and photometric transformations for two comparatively low-resolution, ground-based wide-area imaging surveys of the LMC that are frequently used to measure the TRGB. We show that measurements of the TRGB in the LMC and in the Small Magellanic Cloud (SMC) based on these surveys are biased (too bright) by up to ~0.1 mag in the optical due to blending, and that the bias is a function of local stellar density. The ground-to-HST correction enables us to place the LMC TRGB zeropoint on the ACS F814W system, which is commonly used for extragalactic calibrations, while benefiting from the large sample of TRGB stars from ground-based observations. We applied the ground-to-HST corrections to the LMC TRGB magnitudes from Jang & Lee (2017) and obtained an extinction-corrected TRGB magnitude of $I_0 = 14.507 \pm 0.012$ (stat) $\pm 0.028$ (sys) mag on the ACS F814W system. Using the geometric distance from Pietrzyński et al. (2019), this corresponds to an absolute TRGB magnitude of $M_{F814W} = -3.97 \pm 0.04$ mag.

We revisited the method used by Freedman et al. (2019) to determine the extinction of the TRGB in the LMC after accounting for the blending measured in the LMC and SMC ground photometry. We found that blending in their adopted SMC TRGB photometry (from Zaritsky et al. 2002) caused a ~0.06 mag overestimate of the LMC extinction in the $I$ band. We determine a value for the Hubble constant of $H_0 = 72.4 \pm 1.9 \text{ km s}^{-1} \text{ Mpc}^{-1}$ for the TRGB+SNe Ia distance ladder.

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How much graphene in space?

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The possible presence of graphene in the interstellar medium (ISM) is examined by comparing the interstellar extinction curve with the ultraviolet absorption of graphene calculated from its dielectric functions experimentally obtained with the electron energy loss spectroscopy (EELS) method. Based on the absence in the interstellar extinction curve of the ~2755 Å $\pi-\pi^*$ electronic interband transition of graphene, we place an upper limit of ~20 ppm of C/H on the interstellar graphene abundance, exceeding the previous estimate by a factor of ~3 which made use of the dielectric functions measured with the spectroscopic ellipsometry (SE) method. Compared with the SE method which measures graphene in air (and hence its surface is contaminated) in a limited energy range of ~0.7–5 eV, the EELS probes a much wider energy range of ~0–50 eV and is free of contamination. The fact that the EELS dielectric functions are substantially smaller than that of SE naturally explains why a higher upper limit on the graphene abundance is derived with EELS. Inspired by the possible detection of C$_{24}$, a planar graphene sheet, in several Galactic and extragalactic planetary nebulae, we also examine the possible presence of C$_{24}$ in the diffuse ISM by comparing the model IR emission of C$_{24}$ with the observed IR emission of the Galactic cirrus and the diffuse ISM toward $l = 44^{\circ}irc20'$ and $b = -0^{\circ}20'$. An upper limit of ~20 ppm on C$_{24}$ is also derived from the absence of the characteristic vibrational bands of C$_{24}$ at ~6.6, 9.8 and 20 µm in the observed IR emission.

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Probing the missing link between the Diffuse Interstellar Bands and the total-to-selective extinction ratio $R_V - I$. Extinction versus reddening

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The carriers of the still (mostly) unidentified diffuse interstellar bands (DIBs) have been a long-standing mystery ever since their first discovery exactly 100 years ago. In recent years, the ubiquitous detection of a large number of DIBs in a wide range of Galactic and extragalactic environments has led to renewed interest in connecting the occurrence and properties of DIBs to the physical and chemical conditions of the interstellar clouds, with particular attention paid to whether the DIB strength is related to the shape of the interstellar extinction curve. To shed light on the nature and origin of the DIB carriers, we investigate the relation between the DIB strength and $R_V$, the total-to-selective extinction ratio, which characterizes how the extinction varies with wavelength (i.e. the shape of the extinction curve). We find that the DIB strength and $R_V$ are not related if we represent the strength of a DIB by its reddening-normalized equivalent width (EW), in contrast to the earlier finding of an anti-correlation in which the DIB strength is measured by the extinction-normalized EW. This raises a fundamental question about the appropriate normalization for the DIB EW.

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An ALMA view of molecular filaments in the Large Magellanic Cloud I: The formation of high-mass stars and pillars in the N 159E–Papillon Nebula triggered by a cloud–cloud collision

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We present the ALMA observations of CO isotopes and 1.3-mm continuum emission toward the N 159E–Papillon Nebula in the Large Magellanic Cloud (LMC). The spatial resolution is 0″25–0″28 (0.06–0.07 pc), which is a factor of 3 higher than the previous ALMA observations in this region. The high resolution allowed us to resolve highly filamentary CO distributions with typical width of ~ 0.1 pc (full width half maximum) and line mass of a few × 100 M⊙ pc$^{-1}$. The filaments (more than ten in number) show outstanding hub–filament structure emanating from the Nebular center toward the North. We identified for the first time two massive protostellar outflows of ~ 10$^{4}$ yr dynamical age along one of the most massive filaments. The observations also revealed several pillar-like CO features around the
Nebula. The H ii region and the pillars show complementary spatial distribution and the column density of the pillars is an order of magnitude higher than that of the pillars in the Eagle Nebula (M 16) in the Galaxy, suggesting an early stage of pillar formation with an age younger than \( \sim 10^5 \) yr. We suggest that a cloud–cloud collision triggered the formation of the filaments and protostar within the last \( \sim 2 \) Myr. It is possible that the collision is more recent since part of the kpc-scale H i flows come from the tidal interaction resulting from the close encounter between the LMC and SMC \( \sim 200 \) Myr ago as suggested for R 136 by Fukui et al. (2017).

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An ALMA view of molecular filaments in the Large Magellanic Cloud II: An early stage of high-mass star formation embedded at colliding clouds in N 159W–South

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We have conducted ALMA CO isotopes and 1.3 mm continuum observations toward filamentary molecular clouds of the N 159W–South region in the Large Magellanic Cloud with an angular resolution of \( \sim 0^\prime 25 \) \( (\sim 0.07 \) pc). Although the previous lower resolution \( (\sim 1^\prime) \) ALMA observations revealed that there is a high-mass protostellar object at an intersection of two linear-shaped filaments in \(^{13}\text{CO}\) with the length scale of \( \sim 10 \) pc (Fukui et al. 2015), the spatially resolved observations, in particular, toward the highest column density part traced by the 1.3-mm continuum emission, the N 159W–South clump, show complicated hub–filamentary structures. We also discovered that there are multiple protostellar sources with bipolar outflows along the massive filament. The redshifted/blueshifted components of the \(^{13}\text{CO}\) emission around the massive filaments/protostars show complementary distribution to each other, which is considered to be a possible piece of evidence for a cloud–cloud collision. We propose a new scenario that the supersonically colliding gas flow triggered the formation of both the massive filament and protostars. This is a modification of the earlier scenario of cloud–cloud collision which postulated the two filamentary clouds prior to the high-mass star formation by Fukui et al. (2015). A recent theoretical study of the shock compression in colliding molecular flows by Inoue et al. (2018) demonstrates that the formation of filaments with hub-structure is a usual outcome of the collision, lending support for the present scenario. In the theory the filaments are formed as dense parts in a shock compressed sheet-like layer, which resembles "an umbrella with spokes".

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The supernova remnant population of the Small Magellanic Cloud

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Aims: We present a comprehensive study on the supernova remnant (SNR) population of the Small Magellanic Cloud (SMC). We measured multi-wavelength properties of the SMC SNRs and compare them to those of the Large Magellanic Cloud (LMC) population.

Methods: This study combines the large dataset of XMM–Newton observations of the SMC, archival and recent radio continuum observations, an optical line emission survey, and new optical spectroscopic observations. We were therefore able to build a complete and clean sample of 19 confirmed and four candidate SNRs. The homogeneous X-ray spectral analysis allowed us to search for SN ejecta and Fe K line emission, and to measure interstellar medium (ISM) abundances. We estimated the ratio of core-collapse to type Ia supernova rates of the SMC based on the X-ray properties and the local stellar environment of each SNR.

Results: After the removal of unconfirmed or misclassified objects, and the addition of two newly confirmed SNRs based on multi-wavelength features, we present a final list of 21 confirmed SNRs and two candidates. While no Fe K line is detected even for the brightest and youngest SNR, we find X-ray evidence of SN ejecta in 11 SNRs. We estimate a fraction of 0.62 to 0.92 core-collapse supernova for every supernova (90% confidence interval), higher than in the LMC. The difference can be ascribed to the absence of the enhanced star-formation episode in the SMC, which occurred in the LMC 0.5–1.5 Gyr ago. The hot-gas abundances of O, Ne, Mg, and Fe are 0.1–0.2 times solar. Their ratios, with respect to SMC stellar abundances, reflect the effects of dust depletion and partial dust destruction in SNR shocks. We find evidence that the ambient medium probed by SMC SNRs is less disturbed and less dense on average than in the LMC, consistent with the different morphologies of the two galaxies.

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An extragalactic chromosome map: The intermediate age SMC cluster

Lindsay 1

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The discovery of star-to-star abundance variations (a.k.a. multiple populations – MPs) within globular clusters (GCs), which are generally not found in the field or in lower mass open clusters, has led to a search for the unique property of GCs that allow them to host this phenomenon. Recent studies have shown that MPs are not limited to the ancient GCs but are also found in massive clusters with ages down to (at least) 2 Gyr. This finding is important for understanding the physics of the MP phenomenon, as these young clusters can provide much stronger constraints (e.g., on potential age spreads within the clusters) than older ones. However, a direct comparison between ancient GCs and intermediate
clusters has not yet been possible due to the different filters adopted in their studies. Here we present new HST UV photometry of the 7.5 Gyr, massive SMC cluster, Lindsay 1, in order to compare its pseudo colour–colour diagram to that of Galactic GCs. We find that they are almost identical and conclude that the MPs phenomenon is the same, regardless of cluster age and host galaxy.

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Multiple populations in integrated light spectroscopy of intermediate age clusters

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The presence of star-to-star light-element abundance variations (a.k.a. multiple populations – MPs) appears to be ubiquitous within old and massive clusters in the Milky Way and all studied nearby galaxies. Most previous studies have focussed on resolved images or spectroscopy of individual stars, although there has been significant effort in the past few years to look for multiple population signatures in integrated light spectroscopy. If proven feasible, integrated light studies offer a potential way to vastly open parameter space, as clusters out to tens of Mpc can be studied. We use the NaD lines in the integrated spectra of two clusters with similar ages (2–3 Gyr) but very different masses, NGC 1978 (3 × 10^5 M⊙) in the LMC and G 114 (1.7 × 10^7 M⊙) in NGC 1316. For NGC 1978, our findings agree with resolved studies of individual stars which did not find evidence for Na spreads. However, for G 114, we find clear evidence for the presence of multiple populations. The fact that the same anomalous abundance patterns are found in both the intermediate age and ancient GCs lends further support to the notion that young massive clusters are effectively the same as the ancient globular clusters, only separated in age.

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Multiple stellar populations in NGC 1866. New clues from Cepheids and colour–magnitude diagram

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We perform a comprehensive study of the stellar populations in the young Large Magellanic Cloud cluster NGC 1866, combining the analysis of its best-studied Cepheids with that of a very accurate colour–magnitude diagram (CMD) obtained from the most recent Hubble Space Telescope photometry. We use a Bayesian method based on new PARSEC stellar evolutionary tracks with overshooting and rotation to obtain ages and initial rotation velocities of five well-studied Cepheids of the cluster. We find that four of the five Cepheids belong to an initially slowly rotating young population (of 176 ± 5 Myr), while the fifth one is significantly older, either 288 ± 20 Myr for models with high initial rotational velocity (ω_i ∼ 0.9), or 202 ± 5 Myr for slowly rotating models. The complementary analysis of the CMD rules out the latter solution while strongly supporting the presence of two distinct populations of ∼ 176 Myr and ∼ 288 Myr, respectively. Moreover, the observed multiple main sequences and the turn-offs indicate that the
younger population is mainly made of slowly rotating stars, as is the case of the four younger Cepheids, while the older population is made mainly of initially fast rotating stars, as is the case of the fifth Cepheid. Our study not only reinforces the notion that some young clusters like NGC1866 harbor multiple populations, but gives also hints that the first population, the older, may inherit the angular momentum from the parent cloud while stars of the second one, the younger, do not.

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The highest-speed local dark matter particles come from the Large Magellanic Cloud

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Using N-body simulations of the Large Magellanic Cloud (LMC’s) passage through the Milky Way (MW), tailored to reproduce observed kinematic properties of both galaxies, we show that the high-speed tail of the Solar Neighborhood dark matter distribution is overwhelmingly of LMC origin. Two populations contribute at high speeds: 1) Particles that were once bound to the LMC, and 2) MW halo particles that have been accelerated owing to the response of the halo to the recent passage of the LMC. These particles reach speeds of 700–900 km s$^{-1}$ with respect to the Earth, above the local escape speed of the MW. The high-speed particles follow trajectories similar to the Solar reflex motion, with peak velocities reached in June. For low-mass dark matter, these high-speed particles can dominate the signal in direct-detection experiments, extending the reach of the experiments to lower mass and elastic scattering cross sections even with existing data sets. Our study shows that even non-disrupted MW satellite galaxies can leave a significant dark-matter footprint in the Solar Neighborhood.

Submitted to JCAP

**Conference Papers**

Search for point-like TeV sources in the Large Magellanic Cloud

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The Large Magellanic Cloud (LMC) is an irregular satellite galaxy of the Milky Way, which has been observed extensively in Very-High-Energy (VHE) $\gamma$ rays with the H.E.S.S. telescopes since 2004 and reaches now a total observation time of 280 h. The exposure of the LMC is rather inhomogeneous, the region around the Tarantula Nebula having an exposure of up to 220 h while the exposure in the outer parts of the LMC is as low as 5h. A search for point-like sources was performed on this data set. This search resulted in the detection of the four already known sources (N157B, N132D, 30 Dor C and LMC P3) but no further significant emission was revealed. Based on catalogues of pulsars, supernova remnants and high-mass X-ray binaries upper limits on the $\gamma$-ray flux of these objects were derived. In this talk updated results on the known $\gamma$-ray sources as well as upper limits on the non-detected objects will be presented. It will be shown that for a large part of the LMC the existence of VHE $\gamma$-ray sources with a similar luminosity as the already known sources can be excluded.

Poster contribution, published in 36th International Cosmic Ray Conference 2019
and from [https://pos.sissa.it/358/716/](https://pos.sissa.it/358/716/)
Multiple stellar populations: from old Milky Way globulars to young star clusters

Anna F. Marino

I present the latest results from our group about the multiple stellar populations in the old Milky Way globular clusters (GCs) and in the young systems both in the Magellanic Clouds and in the Milky Way. For the ancient GCs in our Galaxy I summarize the chemical properties of the stellar populations as observed on the chromosome map. Both Type I and Type II GCs are discussed. For the youngest clusters I will briefly report our latest spectroscopic analysis on the Large Magellanic Cloud cluster NGC 1818 and the Galactic open cluster NGC 6705 (M 11), which supports the co-existence of stellar populations with different rotation rates.


Available from https://arxiv.org/abs/1908.11704

Candidates for non-pulsating stars located in the Cepheid instability strip in the Large Magellanic Cloud based on Strömgren photometry

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We present candidates for non-pulsating stars lying in the classical Cepheid instability strip based on the Optical Gravitational Lensing Experiment (OGLE) photometric maps combined with Strömgren photometry obtained with the 4.1-m Southern Astrophysical Research (SOAR) telescope, and Gaia Data Release 2 data in four fields in the Large Magellanic Cloud. We selected 19 candidates in total. After analysis of their light curves from OGLE surveys we found that all these stars appear to be photometrically stable at the level of a few mmag. Our results show that non-pulsating stars might constitute to about 21–30 per cent of the whole sample of giant stars located in the classical instability strip. Furthermore, we identified potential candidates for classical Cepheids with hot companions based on their Strömgren colours.

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Announcement

The IAU ombud

Dear Colleagues,

this is to alert you to a new facility set up at the IAU under its Division G (Stars): the IAU ombud. It provides a mechanism to report issues you have encountered or witnessed within the astronomical community. Examples of issues you might wish to bring to the attention of the union include malpractice such as bullying, harassment, sabotage or discrimination, but positive stories are also welcome. You do not need to be a member of the IAU.

The facility is totally anonymous and strictly confidential – we will not know who you are unless you tell us. The comments received will not be passed on to third parties and only be made available in summarised and analysed form to the executive committee of the IAU and in particular its Working Group on Equity and Inclusion. Thereafter, all data will be destroyed.

While the union will not be able to act upon individual cases, it may help define the actions it takes to promote a fair and diverse research culture.

The IAU ombud can be accessed from the link below.

Jacco van Loon, Vice-President of IAU Commission G3 (Stellar Evolution)

See also http://freesuggestionbox.com/pub/qxrqnsf