THE MAGELLANIC CLOUDS NEWSLETTER

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Editor: Jacco van Loon

Editorial

Dear Colleagues,

It is with great sadness that the 94th issue of the Magellanic Clouds Newsletter must start with an "In Memoriam", paying respect to the prolific Magellanic Clouds observer, Professor Bengt Westerlund.

This issue further brings to you a rich selection of new results, on the (possibly pan-Magellanic) magnetic field, the structure of the dark side of the Magellanic Clouds, the dust production in evolved stars, supernova remnants, chemical enrichment, the (real) nature of the populous star clusters, and lots more astrophysics.

IAU Symposium 256, "The Magellanic System: Stars, Gas, and Galaxies", dedicated to the memory of Bengt Westerlund, was held last week, on the campus of Keele University. It was great to see many of you there — I wish I would have had more opportunity to talk with you, colleagues and friends. Hopefully many new ideas and collaborations will have emerged, and that the beauty of the Clouds may have inspired us all once again.

The next issue will be distributed on the 1st of October 2008; the deadline for contributions is the 30th of September.

Editorially Yours,
Jacco van Loon

In Memoriam: Bengt E. Westerlund (1921–2008)

Bengt Westerlund, a stellar astronomer and a leading expert in the study of the Magellanic Clouds, has passed away in June 2008 after a short period of illness. He was born in 1921 in Gävle, a city about 110 km north of Stockholm, Sweden. He studied at Uppsala University and got his Ph.D. there in 1953 with a thesis on "Luminosity effects and colour-equivalents as measured in short stellar spectra". He took up an assistant professorship at Uppsala, continued research and teaching, and also worked as a guest at l'Observatoire de Haute Provence together with Daniel Chalonge. After that he became the first astronomer at the new "Uppsala Southern Station" at Mount Stromlo Observatory. Here, the Uppsala astronomers, in collaboration with the Australian colleagues had established a Schmidt telescope with 52 cm aperture, also equipped with an objective prism. This instrument, in spite of its moderate size, played a very significant rôle in the mapping of the Southern Sky, and Bengt Westerlund was leading this work. Here, he started his systematic study of the stellar content of the Southern Milky Way and the Magellanic Clouds which made him internationally well known. He later became a member of the ordinary staff at Mount Stromlo.

In the late 1960s he moved to Steward Observatory in Arizona. Then, in 1970 he became local director of ESO in Chile, where he played an important rôle in a critical phase of the building up of this observatory. In 1975 he was asked to take up the old professorship in astronomy at Uppsala university and the directorship of its Observatory, the position which Anders Celsius carried in the 18^{th} century and which later belonged to Gunnar Malmquist and Erik Holmberg. Westerlund retired in 1987 but continued actively his research, and published no less than 60 papers after 1987. he was member of several academies, including the Royal Swedish Academy of Sciences.

Bengt Westerlund was a generous and enthusiastic teacher. He was the leading and often cited expert on the stellar content in the Magellanic Clouds. He summarized the knowledge about the Clouds in a much appreciated monograph, "The Magellanic Clouds", Cambridge University Press, in 1997. Westerlund also made a number of interesting discoveries. In 1961 he found a star cluster in Ara in the Southern Milky Way behind about 10 magnitudes of extinction which got his name, Westerlund I, and which has turned out to be the richest young cluster known in our Galaxy. Its estimated age is 3 to 5 Myr, and it contains a great number of very bright stars, including about 50 stars with masses above 30 solar masses, among which are numerous Wolf Rayet stars. There is also an active pulsar present in the cluster, suggesting a relatively recent supernova. This cluster is a beautiful symbol of a brilliant research life achievement.

In a poem, "The star day", the Swedish author and Nobel prize winner in literature, Harry Martinson describes how he, when visiting the Mount Stromlo Observatory, is shown the sight of another rich cluster, ω Centauri, through the telescope by a "star man". In the poem Martinson speculates how the sky looks for those who live there.

Difficult to imagine, but still it seems
that such a space so rich in suns
must be suitable as paradise for shining persons

The star man, presenting the cluster to Martinson, was Bengt Westerlund. With his kind and friendly enthusiasm, his encyclopedic knowledge, and his humble wisdom he has spread light for many of us.

Bengt Gustafsson

Fourier Modeling of the Radio Torus Surrounding Supernova 1987A

C.-Y. Ng[1], *B.M. Gaensler*[1], *L. Staveley-Smith*[2], *R.N. Manchester*[3], *M.J. Kesteven*[3], *L. Ball*[3] *and A.K. Tzioumis*[3]

[1]Institute of Astronomy, School of Physics, The University of Sydney, Australia

[2]School of Physics, The University of Western Australia, Australia

[3]Australia Telescope National Facility, CSIRO, Australia

We present detailed Fourier modeling of the radio remnant of Supernova 1987A, using high-resolution 9 GHz and 18 GHz data taken with the Australia Telescope Compact Array over the period 1992 to 2008. We develop a parameterized three-dimensional torus model for the expanding radio shell, in which the emission is confined to an inclined equatorial belt; our model also incorporates both a correction for light travel-time effects and an overall east-west gradient in the radio emissivity. By deriving an analytic expression for the two-dimensional Fourier transform of the projected three-dimensional brightness distribution, we can fit our spatial model directly to the interferometric visibility data. This provides robust estimates to the radio morphology at each epoch. The best-fit results suggest a constant remnant expansion at 4000 ± 400 km s^{-1} over the 16-year period covered by the observations. The model fits also indicate substantial mid-latitude emission, extending to 40° on either side of the equatorial plane. This likely corresponds to the extra-planar structure seen in Hα and Lyα emission from the supernova reverse shock, and broadly supports hydrodynamic models in which the complex circumstellar environment was produced by a progression of interacting winds from the progenitor. Our model quantifies the clear asymmetry seen in the radio images: we find that the eastern half of the radio remnant is consistently $\sim 40\times$ brighter than the western half at all epochs, which may result from an asymmetry in the ejecta distribution between these two hemispheres.

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Explaining the mass-to-light ratios of globular clusters

J.M. Diederik Kruijssen[1,2]

[1]Astronomical Institute, Utrecht University, Princetonplein 5, NL-3854 CC Utrecht, The Netherlands. E-mail: kruijssen@astro.uu.nl

[2]Leiden Observatory, Leiden University, PO Box 9513, NL-2300RA Leiden, The Netherlands

The majority of observed mass-to-light ratios of globular clusters is too low to be explained by 'canonical' cluster models, in which dynamical effects are not accounted for. Moreover, these models do not reproduce a recently reported trend of increasing M/L with cluster mass, but instead predict mass-to-light ratios that are independent of cluster mass for a fixed age and metallicity. This study aims to explain the M/L of globular clusters in four galaxies by including stellar evolution, stellar remnants, and the preferential loss of low-mass stars due to mass segregation. In this Letter, analytical cluster models are applied that account for stellar evolution and dynamical cluster dissolution to samples of globular clusters in Cen A, the Milky Way, M 31 and the LMC. The models include stellar remnants and cover metallicities in the range $Z = 0.0004 - 0.05$. Both the low observed mass-to-light ratios and the trend of increasing M/L with cluster mass can be reproduced by including the preferential loss of low-mass stars, assuming reasonable values for the dissolution timescale. This leads to a mass-dependent M/L evolution and increases the explained percentage of the observations from 39% to 92%. This study shows that the hitherto unexplained discrepancy between observations and models of the mass-to-light ratios of globular clusters can be explained by dynamical effects, provided that the globular clusters exhibiting low M/L have dissolution timescales within the ranges assumed in this Letter. Furthermore, it substantiates that M/L cannot be assumed to be constant with mass at fixed age and metallicity.

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Multiple stellar populations in three rich Large Magellanic Cloud star clusters

A.D. Mackey[1], *P. Broby Nielsen*[1], *A.M.N. Ferguson*[1] *and J.C. Richardson*[1]

[1]Institute for Astronomy, University of Edinburgh, Scotland

We present deep color-magnitude diagrams for three rich intermediate-age star clusters in the LMC, constructed from archival ACS F435W and F814W imaging. All three clusters exhibit clear evidence for peculiar main-sequence turn-offs. NGC 1846 and 1806 each possess two distinct turn-off branches, while the turn-off for NGC 1783 shows a much larger spread in color than can be explained by the photometric uncertainties. We demonstrate that although all three clusters contain significant populations of unresolved binary stars, these cannot be the underlying cause of the observed turn-off morphologies. The simplest explanation is that each cluster is composed of at least two different stellar populations with very similar metal abundances but ages separated by up to ~ 300 Myr. The origin of these unusual properties remains unidentified; however, the fact that at least three massive clusters containing multiple stellar populations are now known in the LMC suggests a potentially significant formation channel.

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Molecules and dust production in the Magellanic Clouds

Jacco Th. van Loon[1], *Martin Cohen*[2], *Joana M. Oliveira*[1], *Mikako Matsuura*[3,4], *Iain McDonald*[1], *Gregory C. Sloan*[5], *Peter R. Wood*[6] *and Albert A. Zijlstra*[7]

[1]Astrophysics Group, Lennard-Jones Laboratories, Keele University, Staffordshire ST5 5BG, UK

[2]Radio Astronomy Lab, 601 Campbell Hall, University of California at Berkeley, Berkeley CA 94720-3411, USA

[3]National Astronomical Observatory of Japan, Osawa 2-21-1, Mitaka, Tokyo 181-8588, Japan

[4]Department of Physics and Astronomy, University College London Gower Street, London WC1E 6BT, UK

[5]Cornell University, Astronomy Department, Ithaca, NY 14853-6801, USA

[6]Research School of Astronomy and Astrophysics, Australian National University, Cotter Road, Weston Creek, ACT 2611, Australia

[7]Jodrell Bank Centre for Astrophysics, The University of Manchester, Alan Turing Building, Manchester M13 9PL, UK

We present ESO/VLT spectra in the 2.9–4.1 μm range for a large sample of infrared stars in the Small Magellanic Cloud (SMC), mainly carbon stars, massive oxygen-rich Asymptotic Giant Branch (AGB) stars, and red supergiants. Strong emission from Polycyclic Aromatic Hyrdrocarbons (PAHs) is detected in the spectrum of the post-AGB object MSX SMC 29. Water ice is detected in at least one Young Stellar Object, IRAS 01042−7215, for the first time in the SMC. The strength and shapes of the molecular bands detected in the evolved stars are compared with similar data for stars in the Large Magellanic Cloud (LMC). Absorption from acetylene in carbon stars is found to be equally strong in the SMC as in the LMC, but the LMC stars show stronger dust emission in their infrared colours and veiling of the molecular bands. This suggests that a critical link exists in the formation of dust from the molecular atmosphere in carbon stars which scales with the initial metallicity. Nucleation seeds based on a secondary element such as titanium or silicon provide a plausible explanation. In oxygen-rich stars, both the nucleation seeds and molecular condensates depend on secondary elements (in particular titanium, silicon, and/or aluminium), which explains the observed lower molecular abundances and lower dust content in the SMC stars. Emission from silicon monoxide seen in some oxygen-rich AGB stars and red supergiants in the SMC suggests that these metal-poor stars are able to drive strong pulsation shocks through their molecular layers. Data for pulsating dusty AGB stars and supergiants in the LMC are used to show that pulsation is likely the critical factor in driving mass loss, as long as dust forms, rather than the stellar luminosity. Finally, we suggest that the reduced dust production and consequently slower winds of metal-poor AGB stars and red supergiants are more likely to result in chemical inhomogeneities and small-scale structure in the interstellar medium.

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A general catalogue of extended objects in the Magellanic System

Eduardo Bica[1], *Charles Bonatto*[1], *Carlos M. Dutra*[2] *and João F.C. dos Santos Jr*[3]

[1]Departamento de Astronomia, Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves 9500, Porto Alegre 91501-970, RS, Brazil

[2]Universidade Federal do Pampa — UNIPAMPA, Centro de Ciéncias da Saũde, Rua Domingos de Almeida, 3525, Bairro São Miguel, Uruguaiana 97500-009, RS, Brazil

[3]Departamento de Física, ICEx, Universidade Federal de Minas Gerais, Av. António Carlos 6627, Belo Horizonte 30123-970, MG, Brazil

We update the SMC, Bridge, and LMC catalogues of extended objects that were constructed by members of our group from 1995 to 2000. In addition to the rich subsequent literature for the previous classes, we now also include H I shells and supershells. A total of 9305 objects were cross-identified, while our previous catalogues amounted to 7900 entries, an increase of $\approx 12\%$. We present the results in subcatalogues containing 1445 emission nebulae, 3740 star clusters, 3326 associations, and 794 H I shells and supershells. Angular and apparent size distributions of the extended objects are analysed. We conclude that the objects, in general, appear to respond to tidal effects arising from the LMC, SMC, and Bridge. Number-density profiles extracted along directions parallel and perpendicular to the LMC bar, can be described by two exponential-disks. A single exponential-disk fits the equivalent SMC profiles. Interestingly, when angular-averaged number-densities of most of the extended objects are considered, the profiles of both Clouds do not follow an exponential-disk. Rather, they are best described by a tidally-truncated, core/halo profile, despite the fact that the Clouds are clearly disturbed disks. On the other hand, the older star clusters taken isolately, distribute as an exponential disk. The present catalogue is an important tool for the unambiguous identification of previous objects in current CCD surveys and to establish new findings.

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Outside-in disk evolution in the LMC.

Carme Gallart[1], *Peter B. Stetson*[2], *Ingrid P. Meschin*[1], *Frederic Pont*[3] *and Eduardo Hardy*[4,5]

[1]Instituto de Astrofísica de Canarias. E-38200 La Laguna, Spain; carme;imeschin@iac.es

[2]Herzberg Institute of Astrophysics, National Research Council, Victoria, BC, Canada V9E 2E7; Peter.Stetson@nrc.gc.ca

[3]Geneva University Observatory, 1290 Sauverny, Switzerland; frederic.pont@obs.unige.ch

[4]NRAO, Chile; ehardy@nrao.cl

[5]Departamento de Astronomía, Universidad de Chile, Chile

From the analysis of the color-magnitude diagrams and color functions of four wide LMC fields located from $\sim$2 to 6 kpc from the kinematic center of the LMC we present evidence that, while the oldest population is coeval in all fields, the age of the youngest component of the dominant stellar population gradually increases with galactocentric distance, from currently active star formation in a field at 2.3°, to 100 Myr, 0.8 Gyr, and 1.5 Gyr in fields at 4.0°, 5.5°, and 7.1°, respectively. This outside-in quenching of the star formation in the LMC disk is correlated with the decreasing H I column density (which is $< 2 \times 10^{20}$ cm^{-2} in the two outermost fields with little or no current star formation).

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From B[e] to A[e]. On the peculiar variations of the SMC supergiant LHA 115-S 23 (AzV 172)

Michaela Kraus[1], *Marcelo Borges Fernandes*[2,3], *Jiří Kubát*[1] *and Francisco X. de Araújo*[4]

[1]Astronomical Institute, Ondřejov Observatory, Ondřejov, Czech Republic

[2]Royal Observatory of Belgium, Brussels, Belgium

[3]Observatoire de la Côte d'Azur, Grasse, France

[4]Observatório Nacional, Rio de Janeiro, Brazil

Optical observations from 1989 of the Small Magellanic Cloud (SMC) B[e] supergiant star LHA 115-S 23 (in short: S 23) revealed the presence of photospheric He I absorption lines, classifying S 23 as a B8 supergiant. In our high-resolution optical spectra from 2000, however, we could not identify any He I line. Instead, the spectral appearance of S 23 is more consistent with the classification as an A1 supergiant, maintaining the so-called B[e] phenomenon. The observed changes in spectral behaviour of S 23 lead to different spectral classifications at different observing epochs. The aim of this research is, therefore, to find and discuss possible scenarios that might cause a disappearance of the photospheric He I absorption lines within a period of only 11 years. From our high-resolution optical spectra, we perform a detailed investigation of the different spectral appearances of S 23 based on modern and revised classification schemes. In particular, we derive the contributions caused by the interstellar as well as the circumstellar extinction self-consistently. The latter is due to a partly optically thick wind. We further determine the projected rotational velocities of S 23 in the two epochs of spectroscopic observations. Based on its spectral appearance in 2000, we classify S 23 as A1 Ib star with an effective temperature of about 9000 K. This classification is supported by the additional analysis of the photometric UBV data. An interstellar extinction value of $E(B-V) \simeq 0.03$ is derived. This is considerably lower than the previously published value, which means that, if the circumstellar extinction due to the stellar wind is neglected, the interstellar extinction, and hence the luminosity of the star, are overestimated. We further derive a rotation velocity of $v \sin i \simeq 150$ km s^{-1}, which means that S 23 is rotating with about 75% of its critical speed. The object S 23 is thus the fourth B[e] supergiant with confirmed high projected rotational velocity. The most striking result is the apparent cooling of S 23 by more than 1500 K with a simultaneous increase of its rotation speed by about 35% within only 11 years. Since such a behaviour is excluded by stellar evolution theories, we discuss possible scenarios for the observed peculiar variations in S 23.

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X-Ray observations of the Large Magellanic Cloud pulsar PSR B0540−69 and its PWN

Riccardo Campana[1], *Teresa Mineo*[2], *Alessandra De Rosa*[3], *Enrico Massaro*[1], *Anthony J. Dean*[4] *and Loredana Bassani*[5]

[1]Department of Physics, University of Rome "La Sapienza", Rome, Italy

[2]INAF-IASF, Palermo, Italy

[3]INAF-IASF, Rome, Italy

[4]School of Physics and Astronomy, University of Southampton, UK

[5]INAF-IASF, Bologna, Italy

PSR B0540−69 is a young pulsar in the Large Magellanic Cloud that has similar properties with respect to the Crab Pulsar, and is embedded in a Pulsar Wind Nebula. We have analyzed the complete archival RXTE dataset of observations of this source, together with new Swift-XRT and INTEGRAL-IBIS data. Accurate lightcurves are produced in various energy bands between 2 and 60 keV, showing no significant energy variations of the pulse shape. The spectral analysis shows that the pulsed spectrum is curved, and is best fitted up to 100 keV by a log-parabolic model: this strengthens the similarities with the Crab pulsar, and is discussed in the light of a phenomenologic multicomponent model. The total emission from this source is studied, the relative contributions of the pulsar and the PWN emission are derived, and discussed in the context of other INTEGRAL detected pulsar/PWN systems.

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A Spectroscopic Survey of WNL Stars in the LMC: General Properties and Binary Status

O. Schnurr[1,2], *A.F.J. Moffat*[2], *N. St-Louis*[2], *N.I. Morrell*[3] *and M.A. Guerrero*[4]

[1]University of Sheffield, UK

[2]Université de Montréal, Canada

[3]Las Campanas Observatory, Chile

[4]Instituto de Astrofísica de Andalucía, Spain

We report the results of an intense, spectroscopic survey of all 41 late-type, nitrogen-rich Wolf-Rayet (WR) stars in the Large Magellanic Cloud (LMC) observable with ground-based telescopes. This survey concludes the decade-long effort of the Montr'eal Massive Star Group to monitor every known WR star in the Magellanic Clouds except for the 6 crowded WNL stars in R 136, which will be discussed elsewhere. The focus of our survey was to monitor the so-called WNL stars for radial-velocity (RV) variability in order to identify the short- to intermediate-period ($Pla200$ days) binaries among them. Our results are in line with results of previous studies of other WR subtypes, and show that the binary frequency among LMC WNL stars is statistically consistent with that of WNL stars in the Milky Way. We have identified four previously unknown binaries, bringing the total number of known WNL binaries in the LMC to nine. Since it is very likely that none but one of the binaries are classical, helium-burning WNL stars, but rather superluminous, hence extremely massive, hydrogen-burning objects, our study has dramatically increased the number of known binaries harbouring such objects, and thus paved the way to determine their masses through model-independent, Keplerian orbits. It is expected that some of the stars in our binaries will be among the most massive known. With the binary status of each WR star now known, we also studied the photometric and X-ray properties of our program stars using archival MACHO photometry as well as Chandra and ROSAT data. We find that one of our presumably single WNL stars is among the X-ray brightest WR sources known. We also identify a binary candidate from its RV variability and X-ray luminosity which harbours the most luminous WR star known in the Local Group.

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XMM-Newton observations of the Small Magellanic Cloud: Be/X-ray binary pulsars active between October 2006 and June 2007

F. Haberl[1], *P. Eger*[1] *and W. Pietsch*[1]

[1]MPE, Germany

We analysed eight XMM-Newton observations toward the Small Magellanic Cloud (SMC), performed between October 2006 and June 2007, to investigate high mass X-ray binary systems. We produced images from the European Photon Imaging Cameras (EPIC) and extracted X-ray spectra and light curves in different energy bands from sources which yielded a sufficiently high number of counts for a detailed temporal and spectral analysis. To search for periodicity we applied Fourier transformations and folding techniques and determined pulse periods using a Bayesian approach. To identify optical counterparts we produced X-ray source lists for each observation using maximum likelihood source detection techniques and correlated them with optical catalogues. The correlations were also used for astrometric boresight corrections of the X-ray source positions. We found new X-ray binary pulsars with periods of 202 s (XMMU J005929.0−723703), 342 s (XMMU J005403.8−722632), 645 s (XMMU J005535.2−722906) and 325 s (XMMU J005252.1−721715), in the latter case confirming the independent discovery in Chandra data. In addition we detected sixteen known Be/X-ray binary pulsars and six ROSAT-classified candidate high mass X-ray binaries. From one of the candidates, RX J0058.2−7231, we discovered X-ray pulsations with a period of 291 s which makes it the likely counterpart of XTE J0051−727. From the known pulsars, we revise the pulse period of CXOU J010206.6−714115 to 967 s, and we detected the 18.37 s pulsar XTE J0055−727 (= XMM J004911.4−724939) in outburst, which allowed us to localise the source. The pulse profiles of the X-ray pulsars show a large variety of shapes from smooth to highly structured patterns and differing energy dependence. For all the candidate high mass X-ray binaries optical counterparts can be identified with magnitudes and colours consistent with Be stars. Twenty of the Be/X-ray binaries were

detected with X-ray luminosities in the range 1.5×10^{35} erg s $^{-1}$ – 5.5×10^{36} erg s^{-1}. The majority of the spectra is well represented by an absorbed power-law with an average power-law index of 0.93. The absorption (in addition to the Galactic foreground value) varies over a wide range between a few 10^{20} H cm^{-2} and several 10^{22} H cm^{-2}. An overall correlation of the absorption with the total SMC HI I column density suggests that the absorption seen in the X-ray spectra is often largely caused by interstellar gas.

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The Chemical Enrichment History of the Small Magellanic Cloud and Its Gradients

Ricardo Carrera[1], *Carme Gallart*[1], *Antonio Aparicio*[1], *Edgardo Costa*[2], *Rene A. Méndez*[2] *and Noelia E. D. Noël*[1]

[1]Instituto de Astrofísica de Canarias, Spain
[2]Departamento de Astronomía, Universidad de Chile, Casilla 36–D, Santiago, Chile

We present stellar metallicities derived from Ca II triplet spectroscopy in over 350 red giant branch stars in 13 fields distributed in different positions in the SMC, ranging from $\sim 1^\circ$ to $\sim 4^\circ$ from its center. In the innermost fields the average metallicity is [Fe/H] ~ -1. This value decreases when we move away towards outermost regions. This is the first detection of a metallicity gradient in this galaxy. We show that the metallicity gradient is related to an age gradient, in the sense that more metal-rich stars, which are also younger, are concentrated in the central regions of the galaxy.

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Spectral distribution of Be/X-ray binaries in the Small Magellanic Cloud

V.A. McBride[1], *M.J. Coe*[1], *I. Negueruela*[2], *M.P.E. Schurch*[1] *and K.E. McGowan*[1]

[1]University of Southampton, UK
[2]University of Alicante, Spain

The spectral distributions of Be/X-ray binaries in the Large Magellanic Cloud and Galaxy have been shown to differ significantly from the distribution of isolated Be stars in the Galaxy. Population synthesis models can explain this difference in spectral distributions through substantial angular momentum loss from the binary system. In this work we explore the spectral distribution of Be/X-ray binaries in the Small Magellanic Cloud (SMC) using high signal-to-noise spectroscopy of a sample of 37 optical counterparts to known X-ray pulsars. Our results show that the spectral distribution of Be/X-ray binaries in the SMC is consistent with that of the Galaxy, despite the lower metallicity environment of the SMC. This may indicate that, although the metallicity of the SMC is conducive to the formation of a large number of HMXBs, the spectral distribution of these systems is likely to be most strongly influenced by angular momentum losses during binary evolution, which are not particularly dependent on the local metallicity.

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The Magellanic Cloud Calibration of the Galactic Planetary Nebula Distance Scale

Letizia Stanghellini[1], *Richard A. Shaw*[1] *and Eva Villaver*[2]

[1]National Optical Astronomy Observatory, Tucson, USA

[2]Space Telescope Science Institute, European Space Agency, Baltimore, USA

Galactic planetary nebula (PN) distances are derived, except in a small number of cases, through the calibration of statistical properties of PNe. Such calibrations are limited by the accuracy of individual PN distances which are obtained with several non-homogeneous methods, each carrying its own set of liabilities. In this paper we use the physical properties of the PNe in the Magellanic Clouds, and their accurately known distances, to recalibrate the Shklovsky/Daub distance technique. Our new calibration is very similar (within 1%) of the commonly used distance scale by Cahn et al. (1992), although there are important differences. We find that neither distance scale works well for PNe with classic ("butterfly") bipolar morphology, and while the radiation bounded PN sequences in both the Galactic and the Magellanic Cloud calibration have similar slopes, the transition from optically thick to optically thin appears to occur at higher surface brightness and smaller size than that adopted by Cahn et al. The dispersion in the determination of the scale factor suggests that PN distances derived by this method are uncertain by at least 30%, and that this dispersion cannot be reduced significantly by using better calibrators. We present a catalog of Galactic PN distances using our re-calibration which can be used for future applications, and compare the best individual Galactic PN distances to our new and several other distance scales, both in the literature and newly recalibrated by us, finding that our scale is the most reliable to date.

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Formation and evolution of the Magellanic Clouds. II. Structure and kinematics of the Small Magellanic Cloud

Kenji Bekki[1]

[1]University of New South Wales, Australia

We investigate structural, kinematical, and chemical properties of stars and gas in the Small Magellanic Cloud (SMC) interacting with the Large Magellanic Cloud (LMC) and the Galaxy based on a series of self-consistent chemodynamical simulations. We adopt a new "dwarf spheroidal model" in which the SMC initially has both old stars with a spherical spatial distribution and an extended H I gas disk. We mainly investigate SMC's evolution for the last 3 Gyr within which the Magellanic stream (MS) and the Magellanic bridge (MB) can be formed as a result of the LMC-SMC-Galaxy interaction. Our principal results, which can be tested against observations, are as follows. The final spatial distribution of the old stars projected onto the sky is spherical even after the strong LMC-SMC-Galaxy interaction, whereas that of the new ones is significantly flattened and appears to form a bar structure. Old stars have the line-of-sight velocity dispersion (σ) of ~ 30 km s^{-1} and slow rotation with the maximum rotational velocity (V) of less than 20 km s^{-1} and show asymmetry in the radial profiles. New stars have a smaller sigma than old ones and a significant amount of rotation ($V/\sigma > 1$). H I gas shows velocity dispersions of $\sigma = 10 - 40$ km s^{-1} a high maximum rotational velocity ($V \sim 50$ km s^{-1}), and the spatial distribution similar to that of new stars. The new stars with ages younger than 3 Gyr show a negative metallicity gradient in the sense that more metal-rich stars are located in the inner regions of the SMC. The MB inevitably contains old stars with the surface mass densities of $6 - 300 \times 10^4$ M$_\odot$ deg^{-2} depending on initial stellar distributions of the modeled SMC. We find that the dwarf spheroidal model can explain more self-consistently the observed kinematical properties of stars and gas, compared with another type of the model ("the disk model") in which the SMC initially consists of stellar and gas disks. We suggest that the SMC needs to be modeled as having a spheroidal component rather than being a purely disk for better understanding the SMC evolution.

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A Radio and Optical Polarization Study of the Magnetic Field in the Small Magellanic Cloud

S. A. Mao[1], *B. M. Gaensler*[2], *S. Stanimirović*[3], *M. Haverkorn*[4], *N. M. McClure-Griffiths*[5], *L. Staveley-Smith*[6] *and J. M. Dickey*[7]

[1]CfA, USA
[2]University of Sydney, Australia
[3]UW Madison, USA
[4]UC Berkeley, USA
[5]ATNF, Australia
[6]UWA, Australia
[7]University of Tasmania, Australia

We present a study of the magnetic field of the Small Magellanic Cloud (SMC), carried out using radio Faraday rotation and optical starlight polarization data. Consistent negative rotation measures (RMs) across the SMC indicate that the line-of-sight magnetic field is directed uniformly away from us with a strength 0.19 ± 0.06 μG. Applying the Chandrasekhar-Fermi method to starlight polarization data yields an ordered magnetic field in the plane of the sky of strength 1.6 ± 0.4 μG oriented at a position angle $4^\circ \pm 12^\circ$, measured counter-clockwise from the great circle on the sky joining the SMC to the Large Magellanic Cloud (LMC). We construct a three-dimensional magnetic field model of the SMC, under the assumption that the RMs and starlight polarization probe the same underlying large-scale field. The vector defining the overall orientation of the SMC magnetic field shows a potential alignment with the vector joining the center of the SMC to the center of the LMC, suggesting the possibility of a "pan-Magellanic" magnetic field. A cosmic-ray driven dynamo is the most viable explanation of the observed field geometry, but has difficulties accounting for the observed uni-directional field lines. A study of Faraday rotation through the Magellanic Bridge is needed to further test the pan-Magellanic field hypothesis.

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A possible common halo in the Magellanic Clouds

Kenji Bekki[1]

[1]UNSW, Australia

Recent observational and theoretical studies on the three-dimensional (3D) space motions of the Large and the Small Magellanic Clouds (LMC and SMC, respectively) have strongly suggested that the latest proper motion measurements of the Magellanic Clouds (MCs) are consistent with their orbital evolution models in which the MCs have arrived in the Galaxy quite recently for the first time. The suggested orbital models appear to be seriously inconsistent with the tidal interaction models in which the Magellanic Stream (MS) can be formed as a result of the mutual tidal interaction between the MCs and the Galaxy for the last ∼2 Gyr. Based on orbital models of the MCs, we propose that if the MCs have a common diffuse dark halo with the mass larger than $\sim 2 \times 10^{10}$ $M_\odot$, the MCs can not only have the present 3D velocities consistent with the latest proper motion measurements but also interact strongly with each other and with the Galaxy for the last 2 Gyr.These results imply that if the observed proper motions of the MCs are true ones of the centers of mass for the MCs, the common halo of the MCs would need to be considered in constructing self-consistent MS formation models. We discuss whether the origin of the possible common halo can be closely associated either with the past binary formation or with the MCs having been in a small group.

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The lost dark matter in the SMC

Kenji Bekki[1] *and Snežana Stanimirović*[2]

[1]UNSW, Australia

[2]University of Wisconsin, USA

We show that the mass ($M_{\rm dm}$) and the mean density ($\rho_{\rm dm}$) of the dark matter halo within the optical radius (~ 3 kpc) of the Small Magellanic Cloud (SMC) are unusually low, based on the high-resolution neutral hydrogen (H I) observations of the SMC. The estimated $M_{\rm dm}$ and $\rho_{\rm dm}$ are 7.5×10^7 $M_{\odot}$ and 6.7×10^{-4} $M_{\odot}$ pc^{-3}, respectively, for the V-band stellar-to-mass-to-light ratio ($M_{\rm s}/L_{\rm V}$) of 1. The maximum possible $M_{\rm dm}$ and $\rho_{\rm dm}$ are, however, 7.8×10^8 $M_{\odot}$ and 6.9×10^{-3} $M_{\odot}$ pc^{-3}, respectively, if we consider the possible uncertainties in $M_{\rm s}/L_{\rm V}$. These values are rather low, given that the total baryonic mass (i.e., gas and stars) of the SMC is $(1.6 - 2.4) \times 10^9$ $M_{\odot}$. We thus present two possible scenarios for the origin of the derived unusually low-mass and low-density halo of the SMC. One is that the dark matter halo of the SMC has the Burkert profile with a large core radius (> 1 kpc) (thus a low density) and a large mass ($M_{\rm dm} > 3 \times 10^9$ $M_{\odot}$) so that most of the dark halo mass can be located outside the optical radius. In this scenario, the dark halo would have already lost a significant fraction of its original mass due to the strong tidal interactions with the Galaxy and possibly with the Large Magellanic Cloud (LMC). The other scenario is that the SMC is a "tidal dwarf" formed from tidal tails of merging or interacting luminous galaxies and thus has almost no dark matter halo. We show that the former scenario is more plausible and realistic, and thus suggest that the dark mater halo of the SMC is likely to have the initial total mass and core radius as large as, or larger than, 6.5×10^9 $M_{\odot}$ and 3.2 kpc, respectively. The observed high baryonic density of the SMC, relative to other dwarf irregular galaxies, implies its unique formation history.

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A Three-Decade Outburst of the LMC Luminous Blue Variable R 127 Draws to a Close

Nolan R. Walborn[1]*, Otmar Stahl*[2]*, Roberto C. Gamen*[3]*, Thomas Szeifert*[4]*, Nidia I. Morrell*[5]*, Nathan Smith*[6]*, Ian D. Howarth*[7]*, Roberta M. Humphreys*[8]*, Howard E. Bond*[1] *and Daniel J. Lennon*[1]

[1]Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA

[2]ZAH, Landessternwarte Königstuhl, 69117 Heidelberg, Germany

[3]Complejo Astronómico El Leoncito, Avda. España 1412 Sur, J5402DSP, San Juan, Argentina

[4]European Southern Observatory, Alonso de Córdova 3107, Santiago, Chile

[5]Las Campanas Observatory, The Carnegie Observatories, Casilla 601, La Serena, Chile

[6]Astronomy Department, University of California, 601 Campbell Hall, Berkeley, CA 94720, USA

[7]Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, UK

[8]Astronomy Department, 116 Church Street, S.E., University of Minnesota, Minneapolis, MN 55455, USA

The paradigmatic Luminous Blue Variable R 127 in the Large Magellanic Cloud has been found in the intermediate, peculiar early-B state, and substantially fainter in visual light, signaling the final decline from its major outburst that began between 1978 and 1980. This transformation was detected in 2008 January, but archival data show that it began between early 2005 and early 2007. In fact, significant changes from the maximum, peculiar A-type spectrum, which was maintained from 1986 through 1998, had already begun the following year, coinciding with a steep drop in visual light. We show detailed correspondences between the spectrum and light, in which the decline mimics the rise. Moreover, these trends are not monotonic but are characterized by multiple spikes and dips, which may provide constraints on the unknown outburst mechanism. Intensive photometric and spectroscopic monitoring of R 127 should now resume, to follow the decline presumably back to the quiescent Ofpe/WN9 state, in order to fully document the remainder of this unique observational opportunity.

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The influence of chemical composition on the properties of Cepheid stars. II — The iron content

Romaniello, M.[1], *Primas, F.*[1], *Mottini, M.*[1], *Pedicelli, S.*[1,2], *Lemasle, B.*[3], *Bono, G.*[1,2,4], *François, P.*[5], *Groenewegen, M. A. T.*[6] *and Laney, C. D.*[7]

[1]European Southern Observatory, Karl-Schwarzschild-Straße 2, D-85748 Garching bei München, Germany

[2]Università of Roma Tor Vergata, Department of Physics, via della Ricerca Scientifica 1, I-00133 Rome, Italy

[3]Université de Picardie Jules Verne, Faculté des Sciences, 33 rue Saint-Leu, 80039 Amiens Cedex 1, France

[4]INAF-Osservatorio Astronomico di Roma, via Frascati 33, I-00040 Monte Porzio Catone, Italy

[5]Observatoire de Paris-Meudon, GEPI, 61 avenue de l'Observatoire, F-75014 Paris, France

[6]Royal Observatory of Belgium, Ringlaan 3 B-1180 Brussels, Belgium

[7]South African Astronomical Observatory, PO Box 9, 7935 Observatory, South Africa

The Cepheid period-luminosity (PL) relation is unquestionably one of the most powerful tools at our disposal for determining the extragalactic distance scale. While significant progress has been made in the past few years towards its understanding and characterization both on the observational and theoretical sides, the debate on the influence that chemical composition may have on the PL relation is still unsettled. With the aim to assess the influence of the stellar iron content on the PL relation in the V and K bands, we have related the V-band and the K-band residuals from the standard PL relations of Freedman et al. (2001) and Persson et al. (2004), respectively, to [Fe/H]. We used direct measurements of the iron abundances of 68 Galactic and Magellanic Cepheids from FEROS and UVES high-resolution and high signal-to-noise spectra. We find a mean iron abundance ([Fe/H]) about solar ($\sigma = 0.10$) for our Galactic sample (32 stars), -0.33 dex ($\sigma = 0.13$) for the Large Magellanic Cloud (LMC) sample (22 stars) and -0.75 dex ($\sigma = 0.08$) for the Small Magellanic Cloud (SMC) sample (14 stars). Our abundance measurements of the Magellanic Cepheids double the number of stars studied up to now at high resolution. The metallicity affects the V-band Cepheid PL relation and metal-rich Cepheids appear to be systematically fainter than metal-poor ones. These findings depend neither on the adopted distance scale for Galactic Cepheids nor on the adopted LMC distance modulus. Current data do not allow us to reach a firm conclusion concerning the metallicity dependence of the K-band PL relation. The new Galactic distances indicate a small effect, whereas the old ones support a marginal effect.

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Age Determination of Six Intermediate-age SMC Star Clusters with HST/ACS

Katharina Glatt[1,2,3], *Eva K. Grebel*[3], *Elena Sabbe*[3,4], *John S. Gallagher III*[2], *Antonella Nota*[4], *Marco Sirianni*[4], *Gisella Clementini*[5], *Monica Tosi*[5], *Daniel Harbeck*[2], *Andreas Koch*[6], *Andrea Kayser*[1] *and Gary Da Costa*[7]

[1]Astronomical Institute, Department of Physics and Astronomy, University of Basel, Venusstraße 7, CH-4102 Binningen, Switzerland

[2]Department of Astronomy, University of Wisconsin, 475 North Charter Street, Madison, WI 53706-1582, USA

[3]Astronomisches Rechen-Institut, Zentrum für Astronomie der Universität Heidelberg, Mönchhofstr. 12-14, D-69120 Heidelberg, Germany

[4]Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA

[5]INAF - Osservatorio Astronomica di Bologna, Via Ranzani 1, 40127 Bologna, Italy

[6]Department of Physics and Astronomy, University of California at Los Angeles, 430 Portola Plaza, Los Angeles, CA 90095-1547, USA

[7]Research School of Astronomy & Astrophysics, The Australian National University, Mt. Stromlo Observatory, via Cotter Rd., Weston, ACT 2611, Australia

We present a photometric analysis of the star clusters Lindsay 1, Kron 3, NGC 339, NGC 416, Lindsay 38, and NGC 419 in the Small Magellanic Cloud (SMC), observed with the Hubble Space Telescope Advanced Camera for Surveys (ACS) in the F555W and F814W filters. Our color magnitude diagrams (CMDs) extend ∼3.5 mag deeper than the main-sequence turnoff points, deeper than any previous data. Cluster ages were derived using three different isochrone models: Padova, Teramo, and Dartmouth, which are all available in the ACS photometric system. Fitting observed ridgelines for each cluster, we provide a homogeneous and unique set of low-metallicity, single-age fiducial isochrones. The cluster CMDs are best approximated by the Dartmouth isochrones for all clusters, except for NGC 419 where the Padova isochrones provided the best fit. Using Dartmouth isochrones we derive ages of 7.5 ± 0.5 Gyr (Lindsay 1), 6.5 ± 0.5 Gyr (Kron 3), 6 ± 0.5 Gyr (NGC 339), 6 ± 0.5 Gyr (NGC 416), and 6.5 ± 0.5 Gyr (Lindsay 38). The CMD of NGC 419 shows several main-sequence turn-offs, which belong to the cluster and to the SMC field. We thus derive an age range of $1.2 - 1.6$ Gyr for NGC 419. We confirm that the SMC contains several intermediate-age populous star clusters with ages unlike those of the Large Magellanic Cloud (LMC) and the Milky Way (MW). Interestingly, our intermediate-age star clusters have a metallicity spread of ∼0.6 dex, which demonstrates that the SMC does not have a smooth, monotonic age-metallicity relation. We find an indication for centrally concentrated blue straggler star candidates in NGC 416, while for the other clusters these are not present. Using the red clump magnitudes, we find that the closest cluster, NGC 419 (∼50 kpc), and the farthest cluster, Lindsay 38 (∼67 kpc), have a relative distance of ∼17 kpc, which confirms the large depth of the SMC. The three oldest SMC clusters (NGC 121, Lindsay 1, Kron 3) lie in the north-western part of the SMC, while the youngest (NGC 419) is located near the SMC main body.

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Ejecta, Dust, and Synchrotron Radiation in B0540−69.3: A More Crab-Like Remnant than the Crab

Brian J. Williams[1], *Kazimierz J. Borkowski*[1], *Stephen P. Reynolds*[1], *John C. Raymond*[2], *Knox S. Long*[3], *Jon A. Morse*[4], *William P. Blair*[5], *Parviz Ghavamian*[5], *Ravi Sankrit*[6], *Sean P. Hendrick*[7], *R. Chris Smith*[8], *Sean Points*[8] *and P. Frank Winkler*[9]

[1]Physics Dept., North Carolina State University, USA
[2]Harvard-Smithsonian Center for Astrophysics, USA
[3]Space Telescope Science Institute, USA
[4]NASA Goddard Space Flight Center, USA
[5]Dept. of Physics and Astronomy, Johns Hopkins University, USA
[6]Space Sciences Laboratory, U.C. Berkeley, USA
[7]Physics Dept., Millersville University, USA
[8]CTIO, Chile
[9]Dept. of Physics, Middlebury College, USA

We present near and mid-infrared observations of the pulsar-wind nebula (PWN) B0540−69.3 and its associated supernova remnant made with the *Spitzer Space Telescope*. We report detections of the PWN with all four IRAC bands, the 24 μm band of MIPS, and the Infrared Spectrograph (IRS). We find no evidence of IR emission from the X-ray/radio shell surrounding the PWN resulting from the forward shock of the supernova blast wave. The flux of the PWN itself is dominated by synchrotron emission at shorter (IRAC) wavelengths, with a warm dust component longward of 20 μm. We show that this dust continuum can be explained by a small amount ($\sim 1-3\times10^{-3}$ $M_\odot$) of dust at a temperature of $\sim 50 - 65$ K, heated by the shock wave generated by the PWN being driven into the inner edge of the ejecta. This is evidently dust synthesized in the supernova. We also report the detection of several lines in the spectrum of the PWN, and present kinematic information about the PWN as determined from these lines. Kinematics are consistent with previous optical studies of this object. Line strengths are also broadly consistent with what one expects from optical line strengths. We find that lines arise from slow (~ 20 km s^{-1}) shocks driven into oxygen-rich clumps in the shell swept-up by an iron-nickel bubble, which have a density contrast of $\sim 100 - 200$ relative to the bulk of the ejecta, and that faster shocks (~ 250 km s^{-1}) in the hydrogen envelope are required to heat dust grains to observed temperatures. We infer from estimates of heavy-element ejecta abundances that the progenitor star was likely in the range of 20–25 $M_\odot$.

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The Magellanic zoo: Mid-infrared Spitzer spectroscopy of evolved stars and circumstellar dust in the Magellanic Clouds

Sloan, G.C.[1], *Kraemer, K.E.*[2], *Wood, P.R.*[3], *Zijlstra, A.A.*[4], *Bernard-Salas, J.*[1], *Devost, D.*[5] *and Houck, J.R.*[1]

[1]Cornell University, USA
[2]Air Force Research Laboratory, USA
[3]Australian National University, USA
[4]University of Manchester, UK
[5]Canada France Hawaii Telescope, USA

We observed a sample of evolved stars in the Large and Small Magellanic Clouds (LMC and SMC) with the Infrared Spectrograph on the Spitzer Space Telescope. Comparing samples from the SMC, LMC, and the Galaxy reveals that the dust-production rate depends on metallicity for oxygen-rich stars, but carbon stars with similar pulsation properties produce similar quantities of dust, regardless of their initial metallicity. Other properties of the oxygen-rich stars also depend on metallicity. As the metallicity decreases, the fraction of naked (i.e. dust-free) stars increases, and among the naked stars, the strength of the 8 um absorption band from SiO decreases. Our sample includes several massive stars in the LMC with long pulsation periods which produce significant amounts of dust, probably because they are young and relatively metal rich. Little alumina dust is seen in circumstellar shells in the SMC and LMC, unlike in Galactic samples. Three oxygen-rich sources also show emission from magnesium-rich crystalline silicates. Many also show an emission feature at 14 μm. The one S star in our sample shows a newly detected emission feature centered at 13.5 μm. At lower metallicity, carbon stars with similar amounts of amorphous carbon in their shells have stronger absorption from molecular acetylene (C_2H_2) and weaker emission from SiC and MgS dust, as discovered in previous studies.

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Conference Papers

Non-Linear Cepheid Period-Luminosity Relation and the Interaction of Stellar Photosphere with Hydrogen Ionization Front

C. Ngeow[1] *and S.M. Kanbur*[2]

[1]University of Illinois (Urbana-Champaign), USA
[2]SUNY-Oswego, USA

The Cepheid period-luminosity (P-L) relation is regarded as a linear relation (in $\log P$) for a wide period range from ~ 2 to ~ 100 days. However, several recent controversial works have suggested that the P-L relation derived from the Large Magellanic Cloud (LMC) Cepheids exhibits a non-linear feature with a break period around 10 days. Here we review the evidence for linear/non-linear P-L relations from optical to near infrared bands. We offer a possible theoretical explanation to account for the nonlinear P-L relation from the idea of stellar photosphere — hydrogen ionization front interaction.

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Galactic and Extragalactic Distance Scales: The Variable Star Project

Michael W. Feast[1]

[1]University of Cape Town, South Africa

This paper summarizes the status of a large project to improve distance scales of various classes of variable stars. This is being carried out by a large group in Cape Town, Japan, England and the USA. The results are illustrated by giving the distances to the Large Magellanic Cloud and the Galactic Centre (R_0) as well as the value of the Hubble constant (H_0) based on our current results. The classes of variables considered are; Classical Cepheids, Type-II Cepheids, RR Lyrae stars, O- and C-type Miras.

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Nonradial Modes in Classical Cepheids

P. Moskalik[1] *and Z. Kołaczkowski*[2,3]

[1]Copernicus Astronomical Center, Warsaw, Poland
[2]Universidad de Concepcíon, Concepcíon, Chile
[3]Wrocław University Observatory, Wrocław, Poland

Systematic search for multiperiodicity in the LMC Cepheids (Moskalik, Kołaczkowski & Mizerski 2004) has led to discovery of low amplitude nonradial modes in a substantial fraction of overtone pulsators. We present detailed discussion of this new type of multimode Cepheid pulsators and compare them to similar nonradial pulsators discovered among RR Lyrae stars. Finally, we show first detections of secondary nonradial modes in FU/FO double-mode Cepheids.

Poster contribution, published in Wrocław HELAS Workshop "Interpretation of Asteroseismic Data", 23–27 June 2008. Comm.Ast., Eds. W. Dziembowski, M. Breger & M. Thompson (the link below has an elaborated version of the proceedings paper)
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Blazhko Effect in Double Mode Cepheids

P. Moskalik[1] *and Z. Kołaczkowski*[2,3]

[1]Copernicus Astronomical Centre, Warsaw, Poland
[2]Universidad de Concepcíon, Concepcíon, Chile
[3]Wrocław University Observatory, Wrocław, Poland

Systematic survey for multiperiodicity in the LMC Cepheids (Moskalik, Kołaczkowski & Mizerski 2004, 2006) has led to discovery of several new forms of pulsational behaviour. One of them is periodic amplitude and phase modulation observed in many first/second overtone (FO/SO) double mode Cepheids. In the current paper we present detailed discussion of this newly discovered phenomenon, based on a combined OGLE+MACHO sample of double mode pulsators.

Oral contribution, published in "Nonlinear Stellar Hydrodynamics", 9–11 July 2007, Paris, France. EAS Pub. Ser. (EDP Sciences), Eds. M.-J. Goupil, Z. Kollath, P. Kervella & N. Nardetto (invited paper)
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