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Abstracts of Refereed Papers

Large Scale Diffuse X-ray Emission
from the Large Magellanic Cloud

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X-ray mosaics of the Large Magellanic Cloud (LMC) taken with the ROSAT Position Sensitive Proportional Counter (PSPC) have revealed extensive diffuse X-ray emission, indicative of hot $\geq 10^6$ K gas associated with this irregular galaxy on scales from $\sim 10$ pc to $\geq 1000$ pc. We have selected regions of large-scale ($d \geq 600$ pc) diffuse X-ray emission, such as supergiant shells, the LMC Spur, and the LMC Bar, and examined the physical conditions of the hot gas associated with them. We find that for these objects the plasma temperatures range from $kT \sim 0.15 - 0.60$ keV and the derived electron densities range from $n_e \sim 0.005 - 0.03$ cm$^{-3}$. Furthermore, we have examined the fraction of diffuse X-ray emission from the LMC and compared it to the total X-ray emission. We find that discrete sources such as X-ray binaries and supernova remnants (SNRs) account for $\sim 41\%$ and $\sim 21\%$ of the X-ray emission from the LMC, respectively. In contrast, diffuse X-ray emission from the field and from supergiant shells account for $\sim 30\%$ and $\sim 6\%$ of the total X-ray emission, respectively.

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ROSAT X-ray sources in the field of the LMC;
I. Total LMC gas from the background AGN spectral fits
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We analyzed a sample of 26 background X-ray sources in a \textasciitilde 60 square degree field of the Large Magellanic Cloud observed with the ROSAT PSPC. The sample has been selected from previously classified and optically identified X-ray sources. In addition pointlike and spectrally hard sources with at least 100 to 200 observed counts have been used for the analysis. We performed X-ray spectral fitting and derived total hydrogen absorbing column densities due to LMC gas in the range \((10^{20} - 2 \times 10^{21})\) cm\(^{-2}\). We compared these columns with the H\textsubscript{I} columns derived from a 21-cm Parkes survey of the LMC. For 7 optically identified sources we find, within the uncertainties derived from the X-ray spectral fit, agreement for both columns. For further 19 sources we constrain the LMC columns from the X-ray spectral fit assuming that the powerlaw photon index is that of AGN type spectra. We derive for 20 sources gas columns which are within the uncertainties in agreement with the H\textsubscript{I} columns. We derive for two background sources (RX J0536.9-6913 and RX J0547.0-7040) hydrogen absorbing column densities due to LMC gas, which are in excess to the H\textsubscript{I} columns. These sources - located in regions of large \((\sim 3 \times 10^{21} \text{ cm}^{-2})\) LMC H\textsubscript{I} column densities - could be seen through additional gas which may be warm and diffuse, cold or molecular. For 10 sources we derive upper limits for the gas columns additional to H\textsubscript{I} and constrain the molecular mass fraction to \(< (30-140)\%\).

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X-Rays from Superbubbles in the Large Magellanic Cloud.
VI. A Sample of Thirteen Superbubbles
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We present ROSAT observations and analysis of thirteen superbubbles in the Large Magellanic Cloud. Eleven of these observations have not been previously reported. We have studied the X-ray morphology of the superbubbles, and have extracted and analyzed their X-ray spectra. Diffuse X-ray emission is detected from each of these superbubbles, and X-ray emission is brighter than is theoretically expected for a wind-blown bubble, suggesting that the X-ray emission from the superbubbles has been enhanced by interactions between the superbubble shell and interior SNRs. We have also found significant positive correlations between the X-ray luminosity of a superbubble and its H\textalpha luminosity,
expansion velocity, and OB star count. Further, we have found that a large fraction of the superbubbles in the sample show evidence of “breakout” regions, where hot X-ray emitting gas extends beyond the Hα shell.

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Background galaxies as reddening probes throughout the Magellanic Clouds

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We study the spectral properties in the range 3600Å – 6800Å of the nuclear region of galaxies behind the Magellanic Clouds. The radial velocities clarified the nature of the objects as background galaxies or extended objects belonging to the Clouds. For most galaxies behind the main bodies of the LMC and SMC, radial velocities were measured for the first time. In the present sample typical LMC background galaxies are nearby (4000 < V(km/s) < 6000), while SMC’s are considerably more distant (10000 < V(km/s) < 20000). We determine the reddening in each line of sight by matching a reddening-free galaxy template with comparable stellar population. For the LMC main body we derive a combined Milky Way and internal reddening value E(B-V)_{MW+i} = 0.12±0.10, while for the SMC E(B-V)_{MW+i} = 0.05±0.05. By subtracting Milky Way reddening values for galaxies projected onto the surroundings of each Cloud, we estimate average internal reddening values ΔE(B-V) = 0.06 and 0.04, respectively for the main bodies of the LMC and SMC. The Clouds are optically thin, at least in the directions of the studied background galaxies which are often difficult to be identified as such on ESO/SERC sky survey images. Nevertheless, more reddened zones may occur where it is difficult to identify galaxies.

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Detection and study of the compact HII region N26A-B in the SMC

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This paper presents new imagery and spectrophotometric results for the N26 H II region in the Small Magellanic Cloud. The observations using monochromatic images and low-resolution spectra (3700—10000 Å) reveal a compact and complex nebula composed of two cores A and B where A in the region of Hβ is brighter than B by a factor ~ 5 and distance of 2″. The core A of FWHM ~ 2.1″ or 0.6 pc presents a high excitation [O III] λλ5007 + 4959/Hβ up to ~ 8 and a high reddening E(B-V) ≤ 0.6, while the core B is less excited but has a higher reddening ≥ 0.8. Each core contains one
exciting source; the brighter one should be responsible for the high excitation of A. The apparent spectral type of the two cores ranges from O7 to O9 V and the gas electron density and temperature were derived from the absorption and emission-line intensities. The total mass of the ionized gas is evaluated at 13 Mʘ. The chemical abundances of He, O, N, Ne, S, and Ar were computed. These abundances seem consistent with average abundances for SMC H II regions, except N that appears slightly overabundant. N26A-B is comparable to the objects previously observed in the LMC and SMC that we have called “blobs”.

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HST study of the LMC compact star forming region N83B

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High resolution imaging with the Hubble Space Telescope uncovers the so far hidden stellar content and the nebular features of the high excitation compact H II region N83B in the Large Magellanic Cloud (LMC). We discover that the H II region is powered by the most recent massive starburst in the OB association LH 5 and the burst has created about 20 blue stars spread over ~ 30" on the sky (7.5 pc). Globally N83B displays a turbulent environment typical of newborn massive star formation sites. It contains an impressively ridge, likely created by a shock and a cavity with an estimated age of only ~ 30,000 yr, sculpted in the ionized gas by the powerful winds of massive stars. The observations bring to light two compact H II blobs, N83B-1 and N83B-2, and a small arc-nebula, N83B-3, lying inside the larger H II region. N83B-1, only ~ 2".8 (0.7 pc) across, is the brightest and most excited part of N83B. It harbors the presumably hottest star of the burst and is also strongly affected by dust with an extinction of A_V = 2.5 mag. The second blob, N83B-2, is even more compact, with a size of only ~ 1" (0.3 pc). All three features are formed in the border zone between the molecular cloud and the ionized gas possibly in a sequential process triggered by the ionization front of an older H II region. Our HST imaging presents an interesting and rare opportunity to observe details in the morphology of the star formation in very small spatial scales in the LMC which are in agreement with the concept of the fractal structure of molecular star forming clouds. A scenario which supports hierarchical massive star formation in the LMC OB association LH 5 is presented.

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**HST observations of the LMC compact H II region N 11A**

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We present a study of the LMC compact H II region N 11A using *Hubble Space Telescope* imaging observations which resolve N 11A and reveal its unknown nebular and stellar features. The presence of a sharp ionization front extending over more than 4'' (1 pc) and fine structure filaments as well as larger loops indicate an environment typical of massive star formation regions, in agreement with high [O III]/Hβ line ratios. N 11A is a young region, as deduced from its morphology, reddening, and especially high local concentration of dust, as indicated by the Balmer decrement map. Our observations also reveal a cluster of stars lying towards the central part of N 11A. Five of the stars are packed in an area less than 2'' (0.5 pc), with the most luminous one being a mid O type star. N 11A appears to be the most evolved compact H II region in the Magellanic Clouds so far studied.

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**A Comprehensive Look at LH72 in the Context of Supergiant Shell LMC-4**

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Stellar spectroscopy, *UBV* photometry, Hα imaging, and analysis of data from the ATCA H I survey of the LMC are combined in a study of the LMC OB association LH 72 and its surroundings. LH 72 lies on the rim of a previously identified H I shell, SGS-14, and in the interior of LMC-4, one of the LMC’s largest known supergiant shells. Our analysis of the H I data finds that SGS-14 is expanding with velocity *v* _exp_ ~ 15 km s⁻¹, giving it an expansion age of ~15 Myr. Through the stellar spectroscopy and photometry, we find similar ages for the oldest stars of LH 72, ~15–30 Myr. We confirm that LH 72 contains an age spread of ~15–30 Myr, similar to the range in ages of stars derived for the entire surrounding supergiant shell. Combining analysis of the O and B stars with Hα imaging of the HII region DEM 228, we find that DEM 228 accounts for only 60% of the available ionizing Lyman continuum photons. Comparing the distribution of ionized gas with that of the HI, we find
that DEM 228 and LH 72 are offset by $\sim 1 - 2'$ from the peak 21-cm emission, towards the interior of SGS-14. Taken together, these results imply that SGS-14 has cleared its interior of gas and triggered the formation of LH 72. On the basis of our results, we suggest that LMC-4 was not formed as unit but by overlapping shells such as SGS-14, and that LH 72 will evolve to produce a stellar arc similar to others seen within LMC-4.

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Ages and metallicities of five intermediate-age star clusters projected towards the Small Magellanic Cloud

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Colour-magnitude diagrams are presented for the first time for L32, L38, K 28 (L 43), K 44 (L 68) and L 116, which are clusters projected onto the outer parts of the Small Magellanic Cloud (SMC). The photometry was carried out in the Washington system $C$ and $T_1$ filters allowing the determination of ages by means of the magnitude difference between the red giant clump and the main sequence turnoff, and metallicities from the red giant branch locus. The clusters have ages in the range 2-6 Gyr, and metallicities between $-1.65 < [\text{Fe/H}] < -1.10$, increasing the sample of intermediate-age clusters in the SMC. L 116, the outermost cluster projected onto the SMC, is a foreground cluster, and somewhat closer to us than the Large Magellanic Cloud. Our results, combined with those for other clusters in the literature, show epochs of sudden chemical enrichment in the age-metallicity plane, which favour a bursting star formation history as opposed to a continuous one for the SMC.

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Hα emission line spectroscopy in NGC 330
On the hybrid model for global oscillations in Be star circumstellar disks

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We perform an observational test on global oscillations in Be star circumstellar disks in the metal deficient environment of the SMC. According to the hybrid model of disk oscillations early-type Be stars require an optically thin line force to establish a density wave. The low metallicity in the SMC should therefore diminish or prevent the formation of disk oscillations in early-type Be stars. We present short wavelength range spectra around Hα of 48 Be stars in the young open cluster NGC 330 in the SMC. We find that the fraction of early-type Be stars in NGC 330 which host a global disk oscillation does not differ from the known fraction of Galactic field Be stars. This observational result is in contradiction to the theoretical prediction. We discuss several interpretations and propose a further observational test.

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Variability and spectra of LMC giants: results from DENIS and EROS

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We present the first combined photometric results from the near–infrared DENIS survey and the micro–lensing EROS survey in a region of about 0.5 square degrees, in the Bar of the Large Magellanic
Cloud and including the optical center (OC) field. A sample of $\approx 800$ cross-identified stars has been analyzed, many of them have been classified according to the shape of their light curve. We also present spectroscopic data on 126 objects in the OC, 30 previously known and 96 newly discovered by the DENIS survey. The carbon or oxygen rich nature of the observed sources has been determined on the basis of the molecular absorption bands of TiO, VO, CN, C$_2$ and on the basis of the $J - K_S$ color for the remaining sources. Three period–luminosity relations are clearly identified by three different type of sources: Semi–Regular of type a ($SR_a$), b ($SR_b$) and Mira variables. Carbon–rich stars occupy mostly the upper part of these relations. 65% of the thermal pulsing asymptotic giant branch population is formed by long period variables.

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Period – magnitude relationships in BVIJHK-Bands for fundamental mode and first overtone Cepheids

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We present theoretical period - magnitude relationships for Cepheids in different filters for fundamental and first overtone pulsators, completing the work by Alibert et al. (1999). The results are provided for different metallicities characteristic of the Magellanic Clouds and the Milky Way. In contrast to the fundamental mode, we find a small metallicity effect on the period - luminosity relationship for the first overtone, due to the sensitivity of the period ratio $P_1/P_0$ with metallicity. Comparison is made with observations from OGLE and EROS in the Small and Large Magellanic Clouds. We emphasize the constraint on theoretical predictions provided by the combination of both fundamental and first overtone observed sequences. We obtain excellent agreement between models and data in a log $P$ - $W_1$ (Wesenheit index) diagram for a distance modulus for the LMC $\mu_0 = 18.60$ - 18.70. We analyse the uncertainties of the fundamental period - magnitude relationships and the consequences on distance determination. We show that an arbitrary shift of the instability strip by 350 K in $T_{\text{eff}}$ yields up to 0.45 mag effect on $M_V$ at a given period, whereas the effect is less than 0.1 mag in the $K$-band. Using recent near-IR observations in the Large Magellanic Cloud and our $P - M_K$ relationship, we derive a distance modulus for the LMC in agreement with the value based on $W_1$ data.

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X-ray and UV Orbital Phase Dependence in LMC X–3

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The black-hole binary LMC X-3 is known to be variable on time scales of days to years. We investigate X-ray and ultraviolet variability in the system as a function of the 1.7 day binary phase using a 6.4 day observation with the Rossi X-ray Timing Explorer (RXTE) from December 1998. An abrupt 14% flux decrease, lasting nearly an entire orbit, is followed by a return to previous flux levels. This behavior occurs twice, at nearly the same binary phase, but it is not present in consecutive orbits. When the X-ray flux is at lower intensity, a periodic amplitude modulation of 7% is evident in data folded modulo the orbital period. The higher intensity data show weaker correlation with phase. This is the first report of X-ray variability at the orbital period of LMC X-3. Archival RXTE observations of LMC X-3 during a high flux state in December 1996 show similar phase dependence. An ultraviolet light curve obtained with the High Speed Photometer aboard the Hubble Space Telescope shows orbital modulation consistent with that in the optical, caused by the ellipsoidal variation of the spatially deformed companion.

The X-ray spectrum of LMC X-3 can be acceptably represented by a phenomenological disk-blackbody plus a power law. Changes in the spectrum of LMC X-3 during our observations are compatible with earlier observations during which variations in the 2-10 keV flux are tracked closely by the disk geometry spectral model parameter.

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Metallicities for Double Mode RR Lyrae in the Large Magellanic Cloud

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Metallicities for six double mode RR Lyrae’s (RRd’s) in the Large Magellanic Cloud have been estimated using the ΔS method. The derived [Fe/H] values are in the range [Fe/H] = −1.09 to −1.78 (or −0.95 to 1.58, adopting a different calibration of [Fe/H] vs ΔS).

Two stars in our sample are at the very metal rich limit of all RRd’s for which metal abundance has been estimated, either by direct measure (for field objects) or on the basis of the hosting system (for objects in globular clusters or external galaxies).

These metal abundances, coupled with mass determinations from pulsational models and the Petersen diagram, are used to compare the mass-metallicity distribution of field and cluster RR Lyrae variables.
We find that field and cluster RRd's seem to follow the same mass-metallicity distribution, within the observational errors, strengthening the case for uniformity of properties between field and cluster variables.

At odds to what is usually assumed, we find no significative difference in mass for RR Lyrae’s in globular clusters of different metallicity and Oosterhoff types, or there may even be a difference contrary to the commonly accepted one, depending on the metallicity scale adopted to derive masses. This “unusual” result for the mass-metallicity relation is probably due, at least in part, to the inclusion of updated opacity tables in the computation of metal-dependent pulsation models.

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