The Magellanic Clouds Newsletter
An electronic exchange of Magellanic Clouds information
Edited by: You-Hua Chu and Dominik J. Bomans
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From the Editors
Here is the first issue of the Magellanic Clouds Newsletter, published at a time when the Magellanic Clouds are shining bright overhead at midnight in the south. We thank people who have given us comments, suggestions, and encouragements. Special thanks go to those who have sent abstracts and news items. The next issue will be published in mid-January, a reminder for abstracts will be sent in early January.

We have set up a WWW page for the MC Newsletter. The http address is
Back issues of the MC Newsletters can be downloaded from this page in either Latex or Postscript format. We intend to link this page to other MCs-related sites. If we have missed your MCs-related page, please let us know. In the future, we will add more service features to this web page.

A proposal has been submitted to the American Astronomical Society (AAS) to request a topical session for the Magellanic Clouds at the 188th AAS meeting in Madison, Wisconsin to be held on June 9-13, 1996. Thanks to all who replied to the query. As soon as we hear from the AAS, we will announce further information in the future newsletters as well as the WWW page.

Announcement: Magellanic Clouds Catalogue of Stars now available in Bonn
The first preliminary version of the Magellanic Catalogue of Stars (MACS) - see The Messenger 81 (1995) 20 - is now available from our anonymous ftp account in Bonn. The catalog contains about 244,000 positions generally better than 0.5” for uncrowded stars in the LMC and the SMC down to B = 16.
You can access the data by  ftp ftp.astro.uni-bonn.de
login as anonymous
and go to the directory  pub/macs
There you can find the following files:
README:  General information
lmc.asc:  ASCII file, 175,779 records
smc.asc:  ASCII file, 67,782 records

The total amount of disk space needed is about 13.1 MB. The data come without compression, since
some colleagues had difficulties with uncompressing such large amounts of data.

There is no dedicated software for catalog search. Also, the cross-identification with the Bochum
catalog of astrophysical information on bright stars in the direction of the LMC is still missing. But
we are working on it, as well as writing the article about the MACS in a refereed journal (probably
A&A Sup.). A version of the MACS will be available from the CDS under catalogue number 1/221.
Critics, comments and bug reports are welcome!

The announcement of MACS was submitted by Dr. Hans-Joachim Tucholke. Please contact him for
further informations:

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Paper Abstracts

Formation of the nebular complex N11 in the Large Magellanic Cloud

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N11, the second largest nebula of the LMC, is formed of a large bubble surrounded by 9 bright nebulae
and filaments. We have observed this nebular complex with a scanning Fabry-Perot interferometer
at H\alpha and [OIII] 5007 wavelengths. The kinematics of this field agrees with the results of the stellar
content and of the molecular studies, and shows that such a structure can be the consequence of a
sequential star formation. The elements of this result are deduced from the energetic input inside the
ionized gas by the stellar winds of the associations LH9 and LH10. The evaluated dynamical lifespan
of small nebular entities associated with the more massive stars of LH10, are found significantly shorter
than for the gas ionized by the association LH9.

Therefore sequential star formation can be triggered at the shock boundaries of the nebula excited
by an OB association in a time scale shorter than previously found, and of at most a few 106 yrs. It
thus leads to the evidence for a new class of giant bubble, designated as “ring of H11 regions” bubble
with several distinctive characteristics. It is discussed that the bubbles of this type are formed by
sequential star formation over time scales shorter than previously found for some superbubbles.
Accepted by Astronomy and Astrophysics, for preprints, contact margarit@astrosecu.unam.mx

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N157B: A Crab-Like Supernova Remnant with an X-ray-Emitting Shell

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We present ROSAT HRI and ASCA SIS X-ray observations of the supernova remnant N157B, which is embedded within the OB association LH99 in the Large Magellanic Cloud. The X-ray emission from the remnant can be decomposed into a point-like source, probably representing a pulsar, a resolved nebula, likely powered by the pulsar, and a patchy shell of dimension ~ 17 pc. The flat and featureless ASCA spectra at ~ 1.5 keV confirm the Crab-like nature of the remnant. However, at lower energies there is strong evidence for a weak thermal spectral component, which accounts for about 20% of the soft X-rays. In particular, the spectra show abundance-enhanced neon and magnesium lines at ~ 0.9 keV and ~ 1.3 keV, indicating that the remnant originates in a massive progenitor. By interpreting both the thermal spectral component and the shell as representing the remnant’s outer shock, we infer the age of the remnant to be about 4 \times 10^3 yr and the energy release in the supernova about 2 \times 10^{50} erg. We also present evidence for the hot superbubble and natal molecular cloud of LH99. The interactions of N157B with these stellar and interstellar components explain much of the complexity observed in the remnant.

Submitted to Astrophysical Journal, for preprints contact wqd@nwu.edu
Preprints also available at "http://www.astro.nwu.edu/astro/wqd/paper/n157b"

30 Dor Nebula as Hot and H II Gas Outflows from a GMC

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As the most luminous H II region in the Local Group, the 30 Dor nebula in the Large Magellanic Cloud plays a vital role in our understanding of interactions between massive stars and the interstellar medium (ISM) and of starburst regions discovered in more distant galaxies. I discuss a scenario for the formation of the 30 Dor nebula. The nebula is understood as outflows of hot and radiatively ionized (H II) gases from a Giant Molecular Cloud (GMC), which was likely formed in a collision between two supershells. The primary driving force of the outflows is R136, which was born and is still embedded in the GMC. I discuss implications of such intermixed hot and H II gas outflows on the global structure and evolution of the ISM.

In “The Interplay between Massive Star Formation, the ISM and Galaxy Evolution”, eds: D. Kunth et al., in press, for preprints, contact wqd@nwu.edu
Preprints also available at "http://www.astro.nwu.edu/astro/wqd/paper/30d_dif".

Extinction and reddening of H II regions in the Small Magellanic Cloud

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We present absolute H\(\alpha\) and H\(\beta\) fluxes, obtained with a Fabry-Perot spectrophotometer, of 24 bright
H II regions in the Small Magellanic Cloud. The photographic Hα maps of Kennicutt & Hodge (1986) are re-calibrated using these new Hα fluxes; the new calibration gives fluxes 25% smaller than those previously published. These photographic and photoelectric Hα data are used in conjunction with radio continuum observations at 843 MHz from the Molonglo Observatory Synthesis Telescope to study the dust associated with SMC H II regions. For most regions the derived reddenings and extinctions are compatible with the standard Galactic extinction law and uniform interstellar extinction. A few regions display relatively high reddening and extinction; these are bright compact sources, such as N13AB, N27 and the cores of N81 and N88, all of which probably have closely associated dust. Low resolution H I observations do not detect these high concentrations of dust.

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### 10⁴ - 10⁶ K Ionized Gas in the Large Magellanic Cloud

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The Large Magellanic Cloud is one of the only two galaxies in which the 10⁴ – 10⁶ K ionized interstellar gas and its underlying massive stellar population can be studied with a sub-parsec resolution over the entire galaxy. Our ability to study the hot ionized gas in the Large Magellanic Cloud has been enhanced by the availability of the space-based ROSAT, ASCA, HST, and IUE observatories. Existing UV interstellar absorption line studies of the LMC confirm the existence of 10⁵ K gas in large superbubbles and supergiant shells, but cannot conclude on the existence of a continuous hot gaseous halo of the LMC. Recent ROSAT X-ray observations of the LMC show 10⁶ K gas in large shell structures as well as in regions not associated with any interstellar structures. The relationship among the 10⁴, 10⁵, and 10⁶ K components is discussed for interstellar structures at various scale sizes.

**Rev. Mex. Astron. Astrofis., in press, for preprints, contact chu@astro.uiuc.edu**

### CIV absorption from hot gas inside supergiant shell LMC 4 observed with HST and IUE

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High resolution ultraviolet spectra with HST-GHRS of two stars in the direction of the supergiant shell LMC 4 unambiguously show absorption by substantial quantities of CIV gas at velocities near the the systemic velocity of the LMC. In combination with the detection of diffuse X-rays from the LMC by ROSAT and other supporting data, this demonstrates that the interior of LMC 4 is filled with tenuous hot gas.

CIV interstellar absorption is seen over a large velocity range, having at least 2 components at about 280 and 320 km s⁻¹. The strong component at 280 km s⁻¹ has a width of 40 km s⁻¹ and a column density in the order of 3 x 10¹³ cm⁻². The width of the absorption is best explained by bulk motions of CIV-containing gas clouds inside LMC 4. These hot clouds or layers around cold clouds have to have a relatively high filling factor inside LMC 4 to fit the observations. The characteristics of the CIV gas component at 320 km s⁻¹ are such that they trace a blast wave from a recent supernova within the LMC 4 cavity. Galactic CIV absorption is also present, as expected for these lines of sight.

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On the spread of ages among the young stars in the LMC association NGC 1948

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The ages of the young associations located at the border of the supergiant shell LMC4 are essential parameters to understand the formation and the evolution of that supergiant shell. We present spectra in the UV and the optical wavelength range of eleven stars in NGC 1948 in order to establish the location of the top of the main sequence more accurately than possible from photometry alone. From the present data we derive an age for NGC 1948 of 5 – 10 Myr, a much tighter range than derived earlier by Vallenari et al. (1993), but located at the lower border of the age range given by those authors. Two stars seem to be as old as 40 Myr, but from their location at the border of the association they may be non-members. The given range of ages corresponds to a real spread in the ages of the sample stars and not to an error estimate of a precisely fixed age.

Submitted to Astronomy & Astrophysics, for preprints, contact jmwill@astro.uni-bonn.de
Preprints also available at http://aibn55.astro.uni-bonn.de:8000/~jmwill/publications.html

UBV Photometry of OB Associations within Superbubbles of the Large Magellanic Cloud

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This work presents UBV photometry of the stellar populations associated with 7 superbubble nebulae and 5 classical HII regions in the Large Magellanic Cloud. Although the nebular morphology of the superbubbles appears to be substantially evolved compared to the classical nebulae, the color-magnitude diagrams do not reveal any noticeable correlation between the resident stellar population and nebular morphology. The photometry presented here will be used in a forthcoming paper to examine further the stellar content and dynamics of these superbubbles.

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The Stellar Content of Superbubble HII Regions in the Large Magellanic Cloud

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I examine the stellar population enclosed within a sample of 6 LMC superbubbles and compare these clusters with previously studied OB associations in classical HII regions. The H-R diagrams, constructed with spectral classifications of the most massive stars, do not reveal any systematic differences between OB associations resident within superbubbles and classical nebulae; the main-sequence turnoffs show stars as massive and luminous as those in classical HII regions. Assuming the superbubble structures result from the stellar winds and/or supernovae of the associations, the similarity
of the stellar populations to those of classical HII regions implies that the shell formation timescale is somewhat shorter than the cluster evolutionary timescale for these objects. The stellar winds and/or supernovae of the one or two most massive stars must therefore dominate the formation of the superbubbles. The star-forming events for the superbubble associations are also no more extended in duration than that of other OB associations. Finally, the IMF slopes are not systematically different from those previously found. Since the OB associations within superbubbles appear normal, the shell structures must be the result of normal OB stellar influences. I also present a few spectrograms of interesting massive stars, including S149, a probable new B[e] supergiant.

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On the nature of the blue giants in NGC 330

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The young SMC cluster NGC 330 contains a number of blue stars that lie above the main-sequence turnoff found from our isochrone fitting and below the position of the blue supergiants. We used our own, new spectroscopy and published data on these stars to investigate their possible nature. Problems in interpreting the evolutionary status of the blue giants have been found in several preceding studies. In theoretical HRDs, these stars lie in the rapidly traversed post main-sequence gap, similar to the unexpected concentration found by Fitzpatrick & Garmany (1990) in the HRD of the LMC.

We argue that these stars probably are core H burning main-sequence stars that appear as blue stragglers resulting from binary evolution as described in the simulations of Pols & Marinus (1994) and effects of rapid rotation. Many of the blue stragglers are Be stars and likely rapid rotators. We suggest that there is evidence for the presence of blue stragglers also in NGC 1818, NGC 2004, and NGC 2100. We point out that blue stragglers may be a general phenomenon in the CMDs of young clusters in the Magellanic Clouds and discuss the implications for IMF and age determinations.

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UBV CCD Photometry of the LMC Double Cluster NGC 1850

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We present UBV CCD photometry of the double cluster NGC 1850 located at the NW edge of the bar of the Large Magellanic Cloud. The color-magnitude diagram shows that NGC 1850 has a prominent population of massive core-He burning stars which is incomparably richer than any other known star clusters. The reddening is estimated from the \((U-B) - (B-V)\) diagram to be \(E(U-V) = 0.15 \pm 0.05\). We have estimated the ages of NGC 1850 and a very compact blue star cluster (NGC 1850A) located at \(\sim30^\circ\) west of NGC 1850 using isochrones based on the convective overshooting models: \(80 \pm 10\) Myrs and \(5 \pm 2\) Myrs, respectively. Several evidence suggest that it is probably the compact cluster NGC 1850A that is responsible for the arc-shaped nebulosity (Henize N 103B) surrounding the east side of NGC 1850.

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Super-soft X-ray sources in the fields of the Magellanic Clouds

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Five super-soft X-ray sources (SSS) have been observed in the field of the Small Magellanic Cloud with ROSAT during the all-sky Survey and during deep pointed observations. They show absorbed blackbody spectra with temperatures of 10 to 60 eV and luminosities of at least $3 \times 10^{36}$ erg s$^{-1}$ to well above the Eddington limit for accretion onto a $1 M_\odot$ compact object. One of the new super-soft X-ray sources detected by ROSAT, RX J0048.4-7332, is identified with the symbiotic nova SMC 3 in the SMC, two further SSS discovered by ROSAT, RX J0058.6-7146 and RX J0112.9-7521, are not yet confirmed as SMC members. The two SSS in the SMC detected by the Einstein satellite, 1E0056.8-7154, correlating with the planetary nebula N67, and 1E0035.4-7230 were observed by ROSAT as well. Several models are considered to explain the nature of these sources: Near-Eddington accretion onto neutron stars (NSs), hydrogen (or helium) burning on the central stars of planetary nebulae (PNe), or on accreting white dwarfs (WDs), hot and luminous extended accretion disks surrounding compact WDs, accretion on subdwarfs. The high luminosities deduced from the X-ray observations by ROSAT favor WDs accreting at high rates ($> 10^{-7} M_\odot yr^{-1}$) and stable burning hydrogen or helium. If accretion occurs over system evolutionary timescales then NSs may be formed by accretion induced collapse. The detection of an X-ray eclipse by ROSAT in Cal 87, a SSS in the LMC, supports the model of a hot region occulted by the optical companion star. The observation of an X-ray turn-on from RX J0058.6-7146 with a duration of about one day is an important signature for short-time variability of SSS. The different behavior of the SSS argues against the description of a unique new class of objects.

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X-ray binary systems in the Small Magellanic Cloud

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We present the result of a systematic search for spectrally hard and soft X-ray binary systems in the Small Magellanic Cloud (SMC). This search has been applied to ROSAT PSPC data (0.1-2.4 keV) collected during nine pointed observations towards this galaxy covering a time span of ~2 years from October 91 till October 93. Strict selection criteria have been defined in order to confine the sample of candidates. Finally seven spectrally hard and four spectrally soft sources were selected from the list as candidates for binaries in the SMC. The sample is luminosity limited (above ~ $3 \times 10^{35}$ erg s$^{-1}$).

SMC X-1 was observed during a full binary orbit starting with a low-state covering an X-ray eclipse and emerging into a bright long-duration flare with two short-duration flares separated by ~ 10 hours. The Be type transient SMC X-2 was redetected by ROSAT (second reported outburst). Variability was found in the X-ray source RX J0051.8-7231, already discovered by Einstein and in RX J0052.1-7319, which is also known from Einstein observations. RX J0101.0-7206 was discovered at the north-eastern boundary of the giant SMC HII region N66 during an X-ray outburst and half a year later during a quiescent phase. A variable source, RX J0049.1-7250, located north-east of the SMC supernova remnant N 19 and which may either be an X-ray binary or an AGN turns out to be strongly absorbed which puts it behind the SMC. If interpreted as an X-ray binary, it radiates at the Eddington limit
in the X-ray bright state. Another variable and hard X-ray source RX J0032.9-7348 was discovered at the south-eastern border of the body of the SMC. A HMXB nature is favored for this source.

A high mass X-ray binary nature is favored for the persistent sources where an optical counterpart of spectral type O or B has been identified. A possible Be type nature is favored for the few transient X-ray sources for which an optical identification with a B star has been achieved. We find about equal numbers of persistent (and highly variable) and transient X-ray binaries and binary candidates. Sources for which no optical candidate has been found in catalogs are candidate low-mass X-ray binaries (LMXBs) or black hole binaries. We searched for Cal 87 like systems in the SMC pointed catalog and found none. This implies, that these systems are very rare and currently not existent in the SMC. A new candidate supersoft source (SSS) RX J0103.8-7254 has been detected, but we cannot exclude that it is a foreground object.

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Dissertation Abstracts

Stellar Population Studies in Nearby Galaxies

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My Thesis covers the (1) development of new tools for stellar population studies, (2) study of old and intermediate-age populations in the dwarf spheroidal galaxies Sculptor and Fornax, and (3) analysis of young Magellanic Cloud clusters and their surroundings, and detailed studies of their stellar content. Here I will summarize my results for the Magellanic Clouds.

One of the three young Magellanic Cloud clusters that I analyzed in my Thesis, NGC 330, is considered a cornerstone for the understanding of stellar evolution in metal-poor environments. I investigated why previous metallicity determinations for this cluster with various methods differ by more than one dex in [Fe/H] and show that the discrepancies can be largely reconciled when using the same reddening. By simultaneous multi-colour isochrone fitting I determined ages, metallicities, reddenings, and distances in a consistent manner with no prior assumptions other than the evolutionary models used. Comparisons of the cluster population with the surrounding young field suggest that different star formation mechanisms were at work for clusters of similar age. In the cases of NGC 330 and NGC 2004, large-scale star formation processes in the field appear to have triggered the collapse of these clusters’ birth clouds, while in the case of NGC 1818 the surrounding field is clearly older.

Previous studies found a number of bright blue stars in young Magellanic clusters to be giants spectroscopically and to lie in the blue Hertzsprung gap. It was suggested that stellar evolutionary theories may need to be revised and that large age spreads are present in these clusters. In my Thesis, I show that position and properties of these stars can be reconciled with their being in part blue stragglers that underwent binary mass transfer and/or being rapid rotators, while I identify others as Be stars. All these stars are probably still in the hydrogen core burning phase. This implies that (1) previously inferred large age spreads and spreads in star formation times are much smaller, (2) ages of young Magellanic Cloud clusters may have been systematically underestimated by mistaking blue stragglers for the main-sequence turnoff, and (3) the upper slopes of the IMFs may need to be re-evaluated.
I developed a new efficient survey method for emission-line stars that uses a narrow-band filter centered on the emission line, a broadband filter to measure the continuum, and a second filter to obtain temperature information. Investigating the Be star content of young Magellanic Cloud clusters I find it generally higher than in young Galactic open clusters. Of all clusters studied to date, I found NGC 330 outstanding even with respect to the other young Magellanic clusters. I find the Be phenomenon strongly peaked toward early B types while covering the entire B star spectral range. I conclude that Be stars are in the evolutionary phase of main-sequence stars. I show that Hα luminosity and infrared excess are well correlated but do not depend on spectral class. I find a much less pronounced correlation between Hα luminosity and ultraviolet excess as expected from theory. I identify a number of variable Be stars, binaries, and one possible shell star.

My Ph.D. work was carried out at the European Southern Observatory as an ESO Student Fellow, as long-term visitor at the Space Telescope Science Institute, and as Graduate Fellow of the German Research Foundation at Bonn University, all under the direction of Prof. Klaas S. de Boer. My Thesis was completed in 1995 September, and the degree was awarded in November.

The Stellar Content and Dynamics of Superbubbles in the Large Magellanic Cloud

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The interaction between massive stars and the interstellar medium (ISM) is a fundamental process determining the structure and composition of the ISM. This work examines the stellar content and resulting dynamics of superbubbles in the Large Magellanic Cloud (LMC).

In work with P. Massey, I first show analytically that for 2 single-O star bubbles in M33, the evolution of wind power as the stars evolve is important in the bubble evolution. In a second prototype study, we find that the LMC superbubble DEM 152 shows evidence for sequential star formation, based on differing ages between the stars interior and exterior to the shell. We construct a numerical form of the standard Weaver et al. (1977) evolutionary model for wind-driven bubbles, and use the stellar census to compare the predicted shell evolution with the observed kinematics. There is a substantial discrepancy: the shell's observed expansion velocity is too large relative to its radius.

I then find that the color-magnitude diagrams of the associations within 7 LMC superbubbles and 5 classical HII regions are indistinguishable. The H-R diagrams, constructed with spectral types for 6 superbubble clusters, also appear similar to those in classical HII regions, implying that the shell formation timescale is shorter than the cluster evolutionary timescale. The stellar winds of the 1–2 most massive stars must therefore dominate the shell formation. The star-forming events for the superbubble associations are also no more extended in duration than that of other OB associations. The slopes of the initial mass functions appear normal.

Numerical modeling of the 6 superbubbles shows results falling into two distinct categories: “high-velocity” objects showing anomalous kinematics like DEM 152 and “low-velocity” objects which appear fairly consistent with the model. X-ray evidence suggests that the high-velocity objects have been accelerated by supernova remnant (SNR) impacts. Results for both categories imply an overestimate in the growth rate equivalent to an effective input power of up to an order of magnitude too large. I suggest that the superbubbles are likely to be struck and “burst” by such SNR impacts if the prior stellar wind power is \( \log L_w \lesssim 37.8 \text{ erg s}^{-1} \). The interior coronal gas is then expelled by the pressure differential with the environment, which could greatly enhance the dispersal and distribution of the
hot ionized medium. A minority of superbubbles with stellar wind power above the threshold are more likely to grow to the sizes of supergiant shells.

Ph.D. Thesis completed at the University of Arizona, 1995 October (awarded in December), under the direction of Prof. Robert C. Kennicutt, Jr.