The Magellanic Clouds Newsletter
An electronic exchange on Magellanic Clouds research

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Happy holidays and best wishes for the New Year!

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Abstracts of Refereed Papers

First Results of a CO Survey of the Small Magellanic Cloud
with NANTEN

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We present the first results from a new 12CO (J = 1–0) survey of the Small Magellanic Cloud (SMC) with the NANTEN millimeter-wave telescope. The survey covered the northeast and southwest regions of the main Bar, and the H II regions N 84, N 88 in the Wing at a linear resolution of ~ 50 pc. Twenty-one giant molecular clouds (GMCs), whose masses are ~ 10^3–10^6 M⊙, were identified. Significant CO emission, T_R ~ 0.36 K, was first detected toward the N 84 region in the Wing, which is comparable to those of the prominent CO clouds associated with infrared sources LIRS 36, LIRS 49 in the Bar. The GMCs exhibit a good spatial correlation with the H II regions and young clusters,
indicating that cluster formation is on-going in these GMCs. On the other hand, they show little
correlation with older clusters or with supernova remnants, suggesting rapid dissipation of CO.

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A CO Survey of the LMC with NANTEN
II. Catalog of Molecular Clouds

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From a $^{12}$CO ($J = 1-0$) survey with the NANTEN telescope, we present a complete catalog of
giant molecular clouds (GMCs) in the Large Magellanic Cloud. In total, 107 CO clouds have been
identified, 55 of which were detected at more than 3 observed positions. For the 55 clouds, the physical
properties, such as size, line width, virial mass, and CO luminosity, are cataloged. From a statistical
analysis of these quantities, we show that GMCs in the LMC are close to gravitational equilibrium.
A comparison with H\textsc{i} data indicates that most of the CO clouds are distributed in dense parts of
H\textsc{i} gas, whose H\textsc{i} column density is greater than $10^{21}$cm$^{-2}$. It is notable that the mass ratio of
the molecular-to-atomic hydrogen of the lower radial velocity component of gas is $\sim 0.2$, which is a factor
of 2 higher than that of the gaseous-disk component, $\sim 0.1$. Molecular clouds are apparently formed
efficiently in the parent atomic clouds in the lower velocity component. The CO Arc, which is a few
kpc scale ordered structure of CO clouds along the southern optical edge of the galaxy, corresponds
well to the the lower velocity component of H\textsc{i} gas.

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A CO Survey of the LMC with NANTEN

III. Formation of Stellar Clusters and Evolution of Molecular Clouds

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In order to elucidate star formation in the LMC, we made a complete study of CO clouds with NANTEN. In the present paper, we compare 55 giant molecular clouds (GMCs), whose physical quantities were well determined, with young objects, such as young stellar clusters and H \textsc{ii} regions. We find that the GMCs are actively forming stars and clusters; 23 and 40 are found to be associated with the clusters and the H \textsc{ii} regions, respectively. The clusters associated with the GMCs are significantly young; \( \sim 85\% \) of them are younger than \( \sim 10 \text{ Myr} \). In addition, compact groups of the young clusters are often found at the peak position of the GMCs, e.g., N 159 and N 44, while much looser groups are away from the GMCs. This suggests that the clusters are formed in groups and disperse as they become old. The distributions of the CO, [C \textsc{ii}], and UV indicate that the GMCs are likely to be rapidly dissipated within several Myr due to UV photons from the clusters. We also estimate the evolutionary time scale of the GMCs; they form stars in a few Myr after their birth, and form clusters during the next few Myr, and are dissipated in the subsequent few Myr.

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Sensitive CO Observations of the LMC Supergiant Shells with NANTEN: Their Effects on the Formation of Molecular Clouds and Stellar Clusters

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A statistical study of the effects of supergiant shells (SGSs) on the formation of stars and molecular clouds was made based on sensitive CO\((J = 1\rightarrow 0)\) observations of the molecular clouds in the LMC with NANTEN. The sensitive observations have detected 168 CO clouds whose mass ranges from \( \sim 4 \times 10^4 \text{M}_\odot \) to \( 3 \times 10^6 \text{M}_\odot \). Out of the 168 clouds, 63 are associated with the SGSs, accounting for \( \sim 35\% \). The surface number and mass densities of the CO clouds are higher by a factor of 1.5–2 at the edge of the SGSs than elsewhere. This suggests the formation of CO clouds under the dynamical effects of the SGSs, such as the accumulation of interstellar medium. Young stellar clusters are more actively formed on the side of the CO clouds facing to the center of the SGSs, particularly where the H\alpha filaments are adjacent to the CO clouds. The number of clusters is increased by a factor of 2 on
the side facing to the center of the SGSs with respect to the CO peaks compared with on the side far from the center. These results strongly suggest that cluster formation is triggered by dynamical effects of the SGSs. We find that $\sim 60\%$ of the young clusters are located within the boundary of the SGSs, and propose that a few $10\%$ of the young clusters of $\tau < 10$ Myr have likely been formed due to dynamical effects of the SGSs.

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On the Mass Spectrum of Giant Molecular Clouds in the Large Magellanic Cloud

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Based on a new sensitive survey of the giant molecular clouds (GMCs) in the Large Magellanic Cloud, we derived the mass spectrum for them. In the mass range from $\sim 8 \times 10^4 M_\odot$ to $3 \times 10^6 M_\odot$, a power law with an index value of $-1.9 \pm 0.1$ shows the best fit to the data. This is consistent with numerical simulations that explain both the $\text{H}_2$ and CO clumpy distributions by Wada et al. (2000; ApJ, 540, 797), but is significantly steeper than that of the GMCs in the Galaxy. This may be consistent with the drastic dissipation of the GMCs in the LMC due to higher UV radiation fields than in the Galaxy.

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Infrared Emission from Interstellar Dust.
III. The Small Magellanic Cloud

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The infrared (IR) emission from interstellar dust in the Small Magellanic Cloud (SMC) is modelled using a mixture of amorphous silicate and carbonaceous grains, including a population of PAH molecules. (1) The IR spectrum of the quiescent molecular cloud SMC B1#1 can be reproduced by our dust model provided the PAH mixture has intrinsic IR band strengths which differ from the band strengths which best fit Milky Way PAH mixtures. The variation in the PAH IR band strengths may be a consequence of the differing metallicity or environmental conditions. (2) The dust model is also
able to reproduce the spectral energy distribution from near-IR to far-IR for the SMC B1#1 cloud, as well as for the entire SMC Bar region. The general SMC Bar region must have a much lower PAH abundance than in the SMC B1#1 cloud.

Submitted to: The Astrophysical Journal

The Global Content, Distribution, and Kinematics of Interstellar O VI in the Large Magellanic Cloud

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We present Far Ultraviolet Spectroscopic Explorer (FUSE) observations of interstellar O VI absorption towards 12 early-type stars in the Large Magellanic Cloud (LMC). The observations have a velocity resolution of ≤ 20 km s⁻¹ (FWHM) and clearly show O VI 1031.926 Å absorption at LMC velocities towards all 12 stars. From these observations we derive column densities of interstellar O VI in this nearby galaxy; the observed columns are in the range log N(O VI) = 13.9 to 14.6, with a mean of 14.37 and a standard deviation of ±38% (±0.14 dex). The observations probe several sight lines projected onto known superbubbles in the LMC, but these show relatively little (if any) enhancement in O VI column density compared to sight lines towards relatively quiescent regions of the LMC. The observed LMC O VI absorption is broad, with Gaussian dispersions σ ≈ 30 to 50 km s⁻¹. This implies temperatures T ≤ (2 − 5) × 10⁶ K, indicating that much of the broadening is non-thermal because O VI has a very low abundance at such high temperatures. The O VI absorption is typically displaced ~ −30 km s⁻¹ from the corresponding low-ionization absorption associated with the bulk of the LMC gas.

The general properties of the LMC O VI absorption are very similar to those of the Milky Way halo. The average column density of O VI and the dispersion of the individual measurements about the mean are identical to those measured for the halo of the Milky Way, even though the metallicity of the LMC is a factor of ~ 2.5 lower than the Milky Way. The velocity dispersion measured for the LMC material is also consistent with recent measurements of the Galactic halo. The striking similarities in these quantities suggest that much of the LMC O VI may arise in a vertically-extended distribution similar to the Galactic halo. We discuss the measurements in the context of a halo composed of radiatively cooling hot gas and/or turbulent mixing layers. If the observed O VI absorption is tracing a radiatively cooling galactic fountain flow, the mass flow rate from one side of the LMC disk is of the order \( \dot{M} \sim 1 \, M_\odot \, \text{yr}^{-1} \), with a mass flux per unit area of the disk \( \dot{M}/\Omega \sim 2 \times 10^{-2} \, M_\odot \, \text{yr}^{-1} \, \text{kpc}^{-2} \).

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For preprints, contact howk@pha.jhu.edu
Also available from the URL http://fuse.pha.jhu.edu/~howk/Papers/
Accurate Stellar Population Studies
from Multiband Photometric Observations

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We present a new technique based on multi-band near ultraviolet and optical photometry to measure both the stellar intrinsic properties, i.e. luminosity and effective temperature, and the interstellar dust extinction along the line of sight to hundreds of stars per square arcminute. The yield is twofold. On the one hand, the resulting reddening map has a very high spatial resolution, of the order of a few arcseconds, and can be quite effectively used in regions where the interstellar material is patchy, thus producing considerable differential extinction on small angular scales. On the other hand, combining the photometric information over a wide baseline in wavelength provides an accurate determination of temperature and luminosity for thousands of stars. As a test case, we present the results for the region around Supernova 1987A in the Large Magellanic Cloud imaged with the \textit{WFPC2} on board the Hubble Space Telescope.

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For preprints, contact mromanie@eso.org
http://www.eso.org/~mromanie/accurate.ps.gz
Thesis Abstract

Large-scale star formation in the Magellanic Clouds derived from analysis of stellar populations

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Supershells with diameters larger than 300 pc need gigantic energy amounts of $\geq 10^{53}$ erg for their formation. Since they are visible in all irregular galaxies as contiguous shells in H$\alpha$ and H$\beta$, the question about their creation mechanism arises.

Photometric studies in $UBV$ passbands in both Magellanic Clouds are presented. They comprise an investigation on five regions (N70, a strip inside and an outer field of LMC2, N171, and N214) at the east side, i.e. at the leading front of the LMC moving through the galactic halo, and data inside the supergiant shells LMC4, LMC1, LMC7, and SMC1.

One main result of these studies is the absence of an age gradient on large scales. In LMC4 and LMC1, the young central associations (LH77 and LH15, respectively) consist of coeval stars, thus requiring a large-scale star formation trigger.

The photometric results (except of the LMC1 data) derived in 44 CCD fields, which are available electronically (see below), sum up to 314505 $BV$ data points. Of these, 136155 have $U$ information (derived in 14 CCD fields) in addition to $BV$.

Ph.D. Thesis completed at Rheinische Friedrich-Wilhelms-Universität Bonn on Nov 13, 2001 under the direction of Prof. Dr. Klaas S. de Boer.


For preprints of the summary (on 9 pages), see
http://www.astro.uni-bonn.de/~jbraun/download/ps/phdsummary.ps.gz
or contact jbraun@astro.uni-bonn.de

Photometric data are also available at
http://vizier.u-strasbg.fr/cgi-bin/VizieR?-source=II/232

For additional information see the URL
http://www.astro.uni-bonn.de/~jbraun/phdt.html
Abstracts of Non-Refereed Papers

The Magellanic Stream event as a gaseous disk
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Around the calculated position of the Magellanic Stream’s great circle two very extended Zones (I and II) were chosen situated azimuthally opposed each other. These Zones were observed with the RATAN-600 telescope in the HI radioline at the relative low LSR velocities. Six hours were necessary to cross the Zones at every declination from $-40$ to $+62.5$ degrees. The comparison was made of the warp-like signals in the Magellanic Stream and those in the galactic gaseous disk (the North and the South warps). Their sizes, the amount and the direction of the displacements relative to the RA direction in the Magellanic Stream were evaluated. The position of the plane through maximum deformations was determined. The behaviour of the HI in the Stream shows that there is possibly a gaseous disk like that of the polar ring in one external galaxy.

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Hiccups in the night:
X-ray monitoring of the two Crab-like LMC pulsars
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We are undertaking an extensive X-ray monitoring campaign of the two Crab-like pulsars in the Large Magellanic Clouds, PSR B0540-69 and PSR J0537-6910. We present our current phase-connected timing analysis derived from a set of 50 pointed X-ray observations spanning several years. From our initial 1.2 yr monitoring program of the young 50 ms pulsar PSR B0540-69, we find the first compelling evidence for a glitch in its rotation. This glitch is characterized by $\Delta \nu / \nu = (1.90 \pm 0.05) \times 10^{-9}$ and $\Delta \dot{\nu} / \dot{\nu} = (8.5 \pm 0.5) \times 10^{-5}$. Taking into account the glitch event, we derive a braking index of $n = 1.81 \pm 0.07$, significantly lower than previous reported. For the 16 ms pulsar, PSR J0537-6910, we recorded 6 large glitch events during a period of nearly 3 years, the highest rate of all known Crab-like systems. Despite the extreme timing activity, the long term spin-down of this pulsar continues to average $-1.9743 \times 10^{-10}$ Hz/s.

For preprints, contact eric@astro.columbia.edu
Also available from the URL http://www.astro.columbia.edu/~evg/two_lmc_pulsars.ps