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Status of the Studies of the Hot Interstellar Medium Distribution in the Large Magellanic Cloud

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Abstract

The south-eastern part of the Large Magellanic Cloud (LMC) is a region rich of diffuse X-ray emission. In this area lies the supergiant shell LMC 2 which is a large structure in the cold interstellar medium (ISM) with a size of about 1 kpc. Diffuse X-ray emission that shows correlation with this supergiant shell[1],[2] as well as in a larger area south to the shell has been found with the Einstein Observatory and ROSAT and indicates that this region is filled with hot gas with temperatures of around 1 million Kelvin.[3] We study this hot phase of the interstellar medium in order to better understand its origin, distribution, properties and its meaning for the surrounding region and even for the host galaxy.

For this purpose we have analysed archived XMM-Newton EPIC data of the south-eastern part of the LMC including LMC 2. We have created mosaic images for three different energy bands which clearly show the distribution of the hot ISM as well as a structure near the northern rim of LMC 2 which might be a superbubble. The mosaic images also show spectral variation within this region. The eROSITA all-sky survey will provide a complete and deep coverage of this area which will allow a much better study of the relation between this hot ISM and its surrounding environment. This will lead to a better understanding of the origin and the development of the hot ISM.

Fig. 1a)

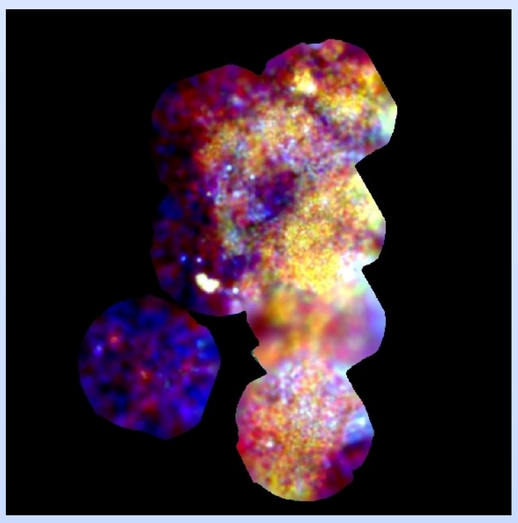

Fig. 1b)

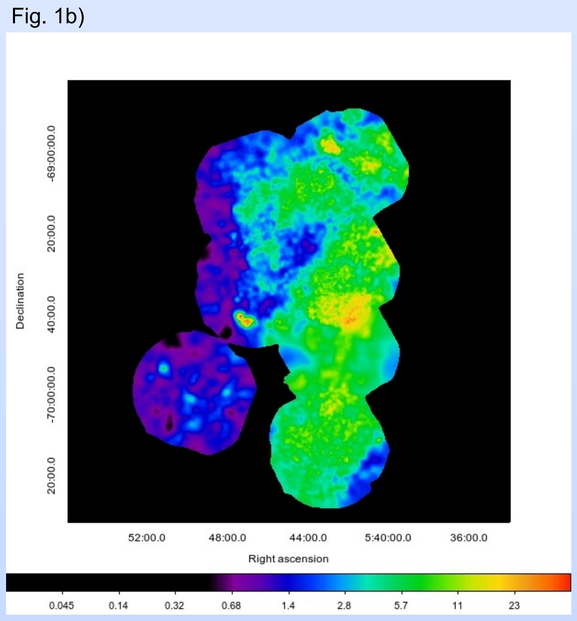

Fig. 1c)

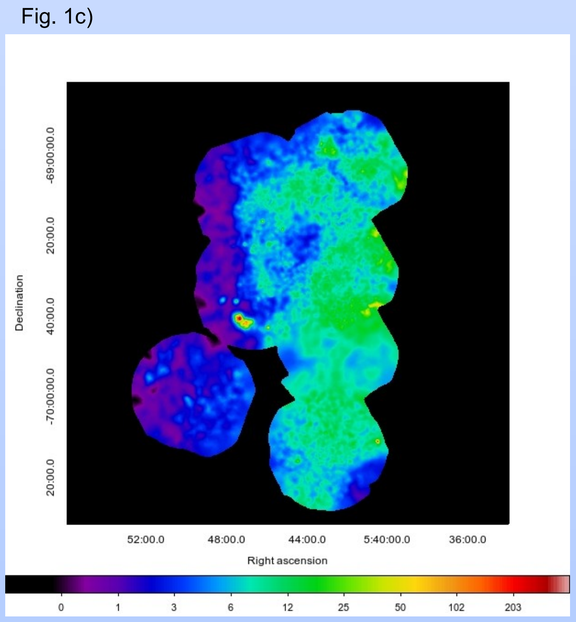

Fig. 1d)

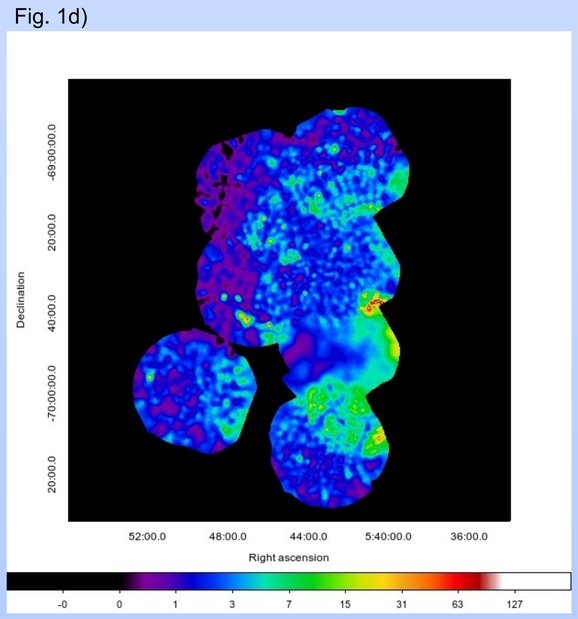

Fig. 1: RGB-image (a) intensity maps (b - d) and of the south-eastern part of the Large Magellanic Cloud in different energy bands showing the distribution of the hot ISM in this region. The pointing at RA 05:43:0.00, Dec -69:49:60.00 has very low statistics with an effective exposure of 3 ks. This makes the images less resolved at this position after smoothing. The same is true for the pointing at RA 05:49:0.00, Dec -70:00:00.00, which has an effective exposure time of about 2.4 ks.
In the eastern part, the supernova remnants DEM L 316 are visible, in the northern part another bright structure is recognizable which is located next to DEM L 299.
a): true-colour-image with red: 0.3 – 0.8 keV, green: 0.8 – 1.5 keV, blue: 1.5 – 4.5 keV;
b): soft energy band: 0.3 – 0.8 keV; c): medium energy band: 0.8 – 1.5 keV; d): hard energy band: 1.5 – 4.5 keV

Methods

For our studies of this region, we used seven archival XMM-Newton EPIC data (PI: Y.-H. Chu and F. Haberl respectively). For the data reduction, the XMM-Newton Extended Source Analysis Software (ESAS) package[4] has been used. This package allows the creation of background-subtracted, exposure corrected images as well as the production of source spectra and model particle background spectra for EPIC MOS and pn data. ESAS is part of the XMM-Newton Science Analysis System[5] (SAS), of which version 11.0.0 has been used for these studies.
For background estimation, three further XMM-Newton observations of the South Ecliptic Pole (PI: B. Altieri) have been processed (total exposure time: about 30 ks) and will later be considered for the spectral analysis.

Resulting X-ray images

Figure 1 shows the resulting, smoothed intensity maps of the hot ISM in the south-eastern region of the LMC in the energy bands from 0.3 – 0.8 keV, 0.8 – 1.5 keV and 1.5 – 4.5 keV (see Fig. 1 b-d) and a smoothed RGB-image (see Fig. 1 a) created out of these energy bands. The images are mosaic images of six different observations and are exposure-corrected. For these mosaics, point sources and soft proton flares have been removed and the quiescent particle background has been subtracted. Further, MOS CCDs in anomalous states have been excluded from the data due to their enhanced background in the lower energy bands.

The distribution of the hot ISM is clearly visible in the soft and medium energy band intensity maps. It shows an arc-like structure that is correlated to LMC 2 and is extended over an area of about 1 kpc. In the south of LMC 2, a bright structure is visible which corresponds to the supernova remnants DEM L 316 (see also Fig. 2b). Another structure is located in the northern part of the image which is projected next to DEM L 299.
In the intensity map of the hard energy band, a lot of stray light is present which most likely originates from LMC X-1 which lies just outside the field of view on the western side of these observations.

Prospects for the studies with eROSITA data

The eROSITA all-sky survey will provide a deep exposure of this region, which is located close to the South Ecliptic Pole, and will enable the study of this complete area of hot ISM, including the connections of LMC 2 to its surrounding region.
Due to the size of this region, XMM-Newton could cover this area only partially. With eROSITA, a whole image of this area will be available, which will provide us with information about the interactions of the hot ISM with neighbouring objects and medium, which is crucial in order to describe the origin and development of the hot ISM in this region.
Comparison of the X-ray emission with for example the Hα emission of the same region will allow conclusions about the interactions between the different phases of the ISM (see Figure 2, provided by MCELS, and Figure 3).

Fig. 2a)

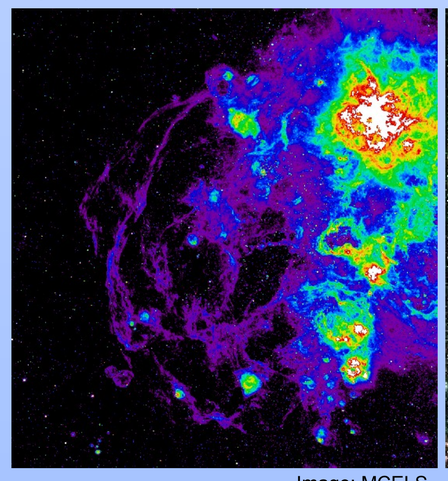

Image: MCELS

Fig. 2b)

Image: MCELS

Fig. 3

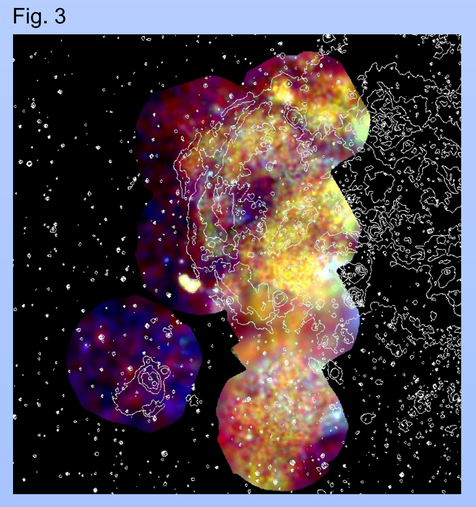

Fig. 2: Distribution of the warm ISM in the LMC 2 region. In the south-eastern part of the images, the double-structure of DEM L 316 is visible. North of DEM L 299, a small shell-like structure can be seen.
a) Hα-image of the LMC 2 region from MCELS[6] ;
b) Composite of Hα, [SII] and [OIII] data created by Points et al.[7] from MCELS

Fig. 3: Composite of the Hα-contours of Fig. 2a (MCELS) with the true-colour X-ray image showing the correlation between the warm and the hot ISM in the south-eastern LMC region.

Summary & Outlook

The processed images show the distribution of the hot ISM in the south-eastern LMC region. The supernova remnants DEM L 316 and a bright structure close to DEM L 299 are visible in the images. In further studies, we will examine the properties of the hot ISM in this region like the temperature, density and extension of the plasma. We will study the local and global distribution of the hot ISM in this area and will compare the ISM within the supergiant shell with the ISM in the smaller structure in the north of this region. For this purpose, the data will be further reduced by subtracting residual soft proton flares and spatially resolved spectra will be created. With the data of the eROSITA all-sky survey, a complete picture of this region will be available which will allow the study of the connections between the hot ISM and its surrounding environment.

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References: [1] Wang & Helfand: LMC-2 as a blowout of a hot superbubble, Astrophysical Journal 1991, [2] Snowden & Petre: An X-ray image of the large magellanic cloud, Astrophysical Journal 1994, [3] Points et al.: The supgergiant shell LMC 2. II. Physical properties of the 10^6 K gas, Astrophysical Journal 2000, [4] ESAS: http://xmm2.esac.esa.int/external/xmm_sw_cal/background/epic_esas.shtml; S. L. Snowden, K. D. Kuntz: Cookbook for analysis procedures for XMM-Newton EPIC MOS observations of extended objects and the diffuse background, 2011, ftp://xmm.esac.esa.int/pub/xmm-esas/xmm-esas_4.3.pdf, [5] SAS: http://xmm.esa.int/sas/, [6] MCELS: http://www.ctio.noao.edu/mcels/, [7] Points et al.: The supgergiant shell LMC 2. I. The kinematics and physical structure, Astrophysical Journal 1999

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