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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.

Fig. 1a)

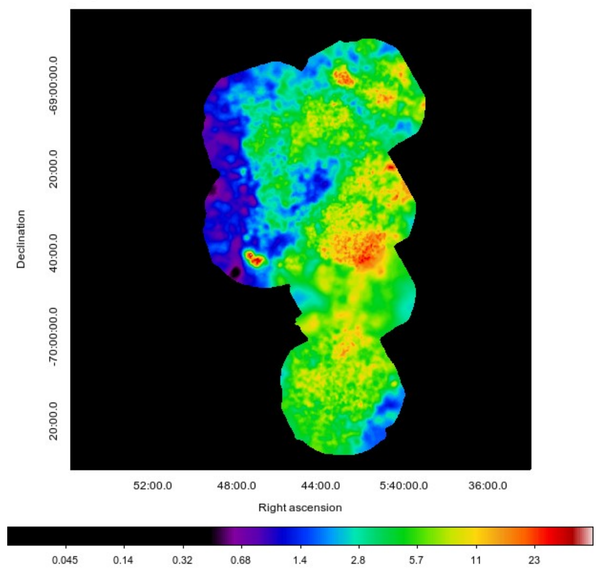


Fig. 1b)

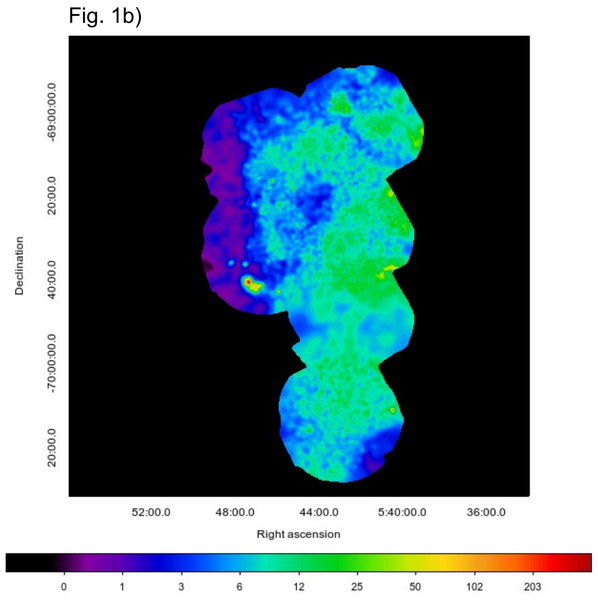


Fig. 1c)

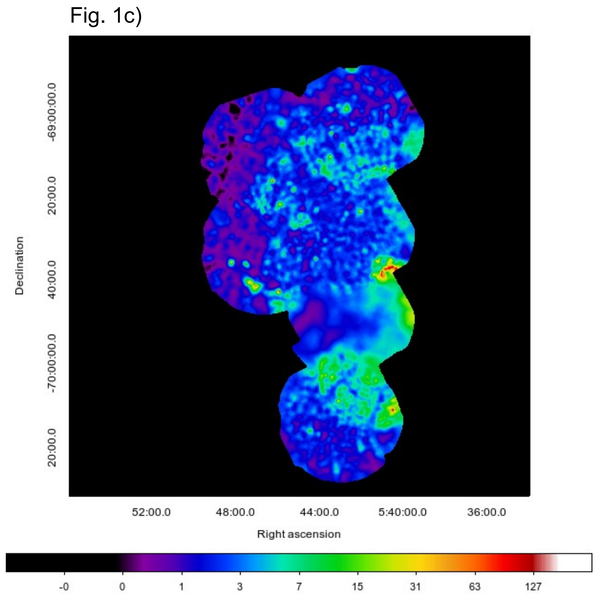
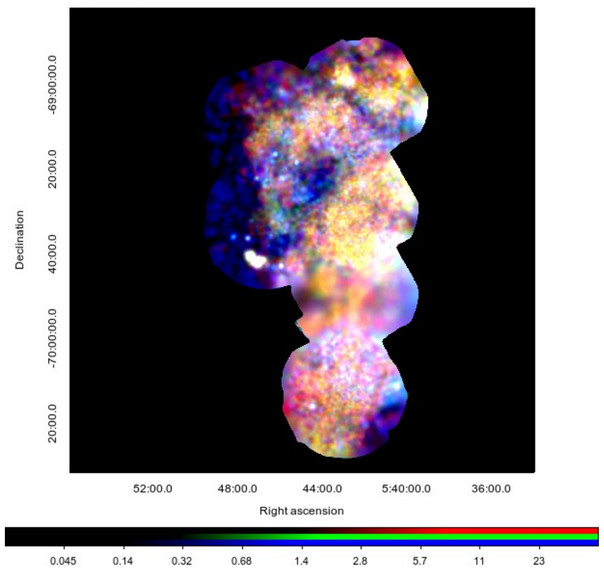


Fig. 1d)



Methods

For our studies of this region, we used archival XMM-Newton EPIC data (PI: Y.-H. Chu). 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.

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 a-c) and a smoothed RGB-image (see Fig. 1 d) 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 1kpc. 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.

Fig. 1: Intensity maps (a - c) and RGB-image (d) 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 2.1 ks. This makes the images less resolved at this position after smoothing.
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): soft energy band: 0.3 – 0.8 keV; b): medium energy band: 0.8 – 1.5 keV; c): hard energy band: 1.5 – 4.5 keV;
d): true-colour-image with red: 0.3 – 0.8 keV, green: 0.8 – 1.5 keV, blue: 1.5 – 4.5 keV

Comparison to the distribution of the warm ISM

In order to compare the distribution of the hot ISM with the distribution of the warm ISM, the X-ray intensity maps can be compared to an Hα-image of the same LMC 2 region. The used Hα-image which has been provided by MCELS[6] is shown in Fig. 2. The shell-like structure in the warm ISM is clearly visible in this Hα-image of the supergiant shell as well as in Fig. 2b, which is a composite of Hα, [SII] and [OIII] emission lines obtained by MCELS. Figure 3 is a composite of the contours of the Hα-image of Fig. 2a) and the broadband XMM-Newton X-ray data with energies from 0.3 – 8.0 keV. A projected correlation of the hot ISM and the Hα-contours can be noticed, which indicates that the hot ISM might be located within this supergiant shell.

Fig. 2a)

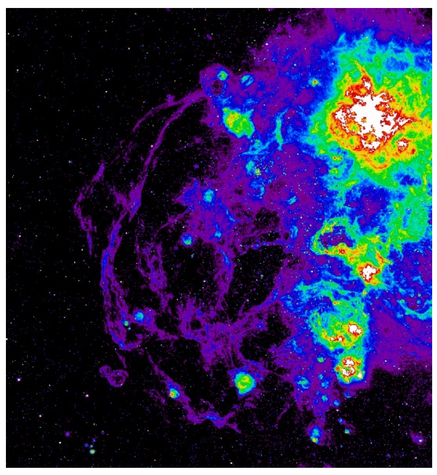


Image: MCELS

Fig. 2b)

Image: MCELS

Fig. 3

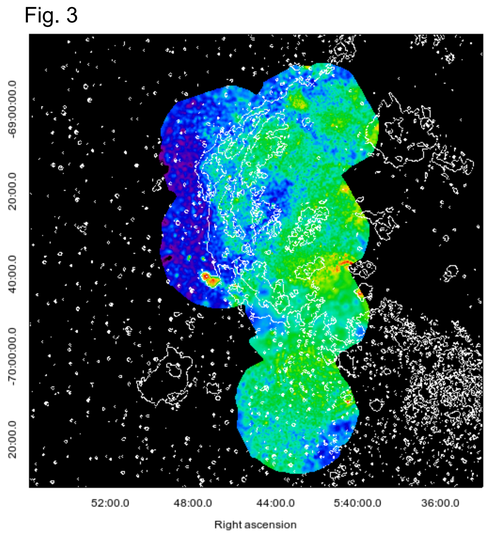


Fig. 2: Distribution of the warm ISM in the LMC 2 region. In the south-eastern part of the images, the double-structure of DEM L 316 is visible. North of DEM L 299, a small shell-like structure can be seen.
a) Hα-image of the LMC 2 region from MCELS[6] ;
b) Composite of Hα, [SII] and [OIII] data created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

Fig. 3: Composite of the Hα-contours of Fig. 2a (MCELS) with the broadband (0.3 – 8.0 keV) X-ray image showing the correlation between the warm and the hot ISM in the south-eastern LMC region.

Summary & Outlook

The created 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.

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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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