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X-ray Emission from star-forming region NGC 602 in the SMC

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Abstract. We use archival data from *ASCA* X-ray telescope to study supergiant shell SMC 1 in the Wing of the SMC. Diffuse X-ray emission from the area spatially coinciding with the star forming complex NGC 602 is detected. The nature of this emission is presently unclear. We speculate that it could be produced either in the hot bubble around young massive star cluster, or in a recent supernova remnant. New observations are required to reveal the nature of X-ray emission and to better understand the processes that govern star formation in tidal tails of interacting galaxies.

1 The Wing of the SMC and the supergiant shell SGS-SMC 1

The tidal tail of the Small Magellanic Cloud (SMC) or the Wing has low metalicity $Z{\sim}0.004$, (Lee et al. 2005). The content of gas, dust, and stars in the Wing is lower than in the main body of the SMC. These are typical conditions for a dwarf irregular galaxy, which is the most common type among all star forming galaxies (Gallagher & Hunter 1984).

Using deep Hα+[N II] images, Meaburn (1980) found a supergiant shell (SGS) in the SMC − SMC-SGS 1 (Fig. 1). Supergiant shells have diameters $\gtrsim$600 pc and are the largest structures known in the ISM. SGSs that expand perpendicular to the galactic disk form "H I chimneys" (Mac Low & McCray 1988) providing means for hot gas to escape and form hot galactic halos. The rims of SGSs are often beaded with H II regions, indicating connections between the SGS and active star formation.

There are profound questions about mechanisms that drive the expansion of the SGSs. Mechanic energy feedback from an OB association is traditionally invoked, however it is unclear can it alone account for the large kinetic energy required to drive the expansion of a SGS (Rhode et al. 1999; Silich et al. 2008). Alternative mechanisms include the distortion of the ISM by γ-ray bursts (Efremov 1999), instabilities in the turbulent galactic disk (Wada et al. 2000), or collisions of high velocity clouds with a galactic disk (Tenorio-Tagle 1981). The proximity of the Magellanic Clouds is a crucial advantage when we try to understand the physical nature of these superstructures and their rôle in galaxy evolution. The supergiant shell SGS-SMC 1 in the Wing is an ideal nearby lab-

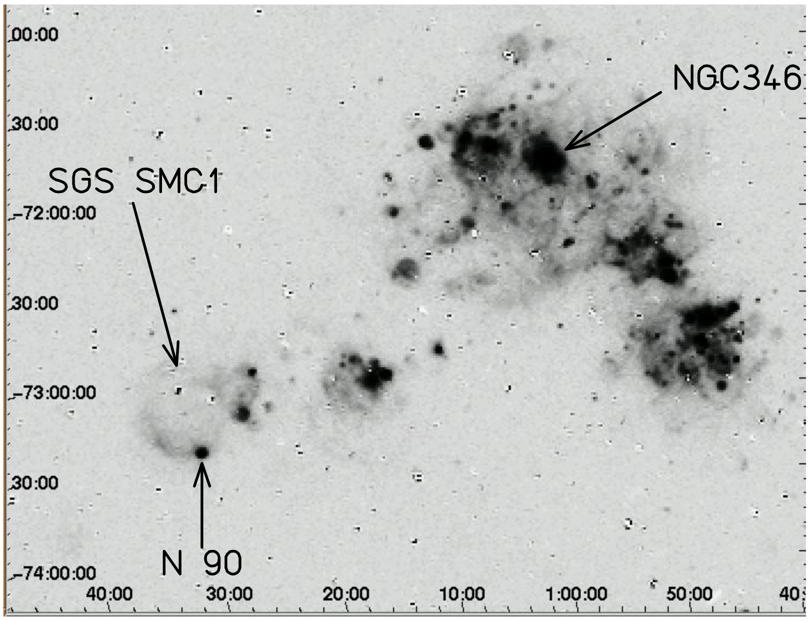

Figure 1. Hα image of the SMC (Gaustad etal. 2001). NGC 602 ionizes HII region N 90 at the rim of SGS-SMC 1 as indicated. NGC 346 is the largest star cluster in the main body of the SMC.

oratory to investigate star formation and feedback in interacting galaxies at low metalicity.

2 Star-forming region NGC 602

As can be seen in Fig. 1, an H II region LHA 115-N 90, or in short N 90, is located at the rim of SMC-SGS 1. N 90 comprises two massive star clusters – NGC 602a and NGC 602b. Some 11′ away is a third star cluster, NGC 602c . Jointly these three clusters are commonly referred to as NGC 602. Each of these clusters contains more than a dozen massive OB stars; a rare WO type massive star is found in NGC 602c (Massey et al. 2000).

Hubble telescope images reveal that the structure NGC 602a is reminiscent of a ring with ridges of dust and gaseous filaments as highlighted by the magnificent "elephant trunks" (Carlson et al. 2007). The massive OB stars shine in the middle of the broken ring. The same morphology is also well defined in the *Spitzer* image. Using color-magnitude diagrams, (Carlson et al. 2007) found that stars in N 90 belong to three distinct age groups: (i) 6 Gyr old extremely metal poor field stars; (ii) 4 Myr old hot massive stars responsible for the ionization of N 90 and pre-main sequence low-mass stars of the same age; (iii) 10 kyr old young stellar objects (YSOs, Class 0.5-1) embedded in the dusty pillars. The quiescence of the Wing, and the low density of gas and dust, are thought as not being favorable to star formation. Yet, the star formation rate in NGC 602 is high and similar to the well-studied Galactic SFRs (Cignoni et al. 2009).

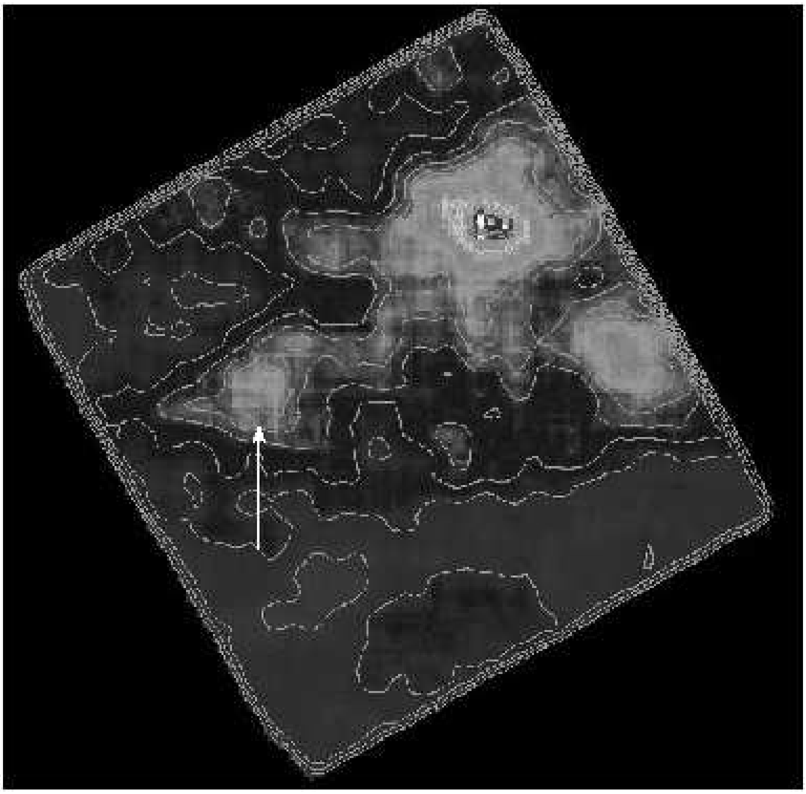

Figure 2. *ASCA* image (0.4-12 keV) of NGC 602 (Oskinova etal. in prep.). An arrow indicates the position of NGC 602a,b. The brightest diffuse source is AXJ0128.4-7329.

Nigra et al. (2008) do not detect systematic expansion of the N90 H II region (that is ionized by massive stars in NGC 602). They suggest that star formation in NGC 602 is induced by compression and turbulence associated with the interaction of neighboring giant H I shells. On the other hand, Schmalzl et al. (2008) suggest that star formation is induced by tidal interactions between the LMC and the SMC. Both these suggestions are made prior to the detection of X-ray emission.

3 X-ray emission from NGC 602 and open questions

A part of SGS-SMC 1 was covered by *ASCA*'s survey of the SMC. Yokogawa et al. (2003) report a source of unidentified nature, AXJ0128.4-7329, close to the center of the SGS. AXJ0128.4-7329 is located $\approx 5.5'$ away from of NGC 602. This source appears extended and has luminosity $L_{\rm X} = 3 \times 10^{35}$ erg/s. The analysis of its *ASCA* spectrum shows that it can be best fitted by soft thermal emission ($kT \approx 0.3$) plus a power-law component with $\gamma \approx 1.2$. Interestingly, AX J0128.4-7329 appears to be connected with N 90 by a bridge of diffuse X-rays. The age of blue stars in NGC 602 is $\sim$4 Myr. If one of the *ASCA* sources is a SNR, it is the remains of a very massive star ($M_{\rm i} \gtrsim 100\,M_\odot$).

Our careful analysis of *ASCA*'s SIS images also reveal that area coinciding with NGC 602 is an extended X-ray source of rather low surface brightness (see Fig. 2). The *ASCA* data are not sufficient to clarify the nature of this emission. However, our discovery opens a few outstanding questions. Among them is how to reconcile the results of optical spectroscopy that indicates that N 90 H II region is quiescent with presence of hot plasma ($T \sim$few MK) in this region. Another urgent question concerns the nature of hot gas filling N 90. Is it a bubble blown by winds of massive stars, or is a supernova remnant? Is there a casual connection between hot gas and current star formation? Of special interest is to understand the relationship between SGS-SMC 1 and the young massive cluster NGC 602. Is there is a hot superbubble within SGS-SMC 1? The upcoming observations with *Chandra* X-ray telescope will answer these questions.

References

Carlson, L.R. 2007, ApJ, 665, 109
Cignoni, M., et al. 2009, AJ, 137, 3668
Efremov, Yu. N.,Ehlerova, S., & Palous, J. 1999, A&A, 350, 457
Gallagher & Hunter, 1984, ARA&A, 22, 37
Gouliermis, D.A., Quanz, S.P., & Henning, Th. 2007, ApJ, 665, 306
Lee, J.-K., Rolleston, W.R.J., Dufton, P.L., & Ryans, R.S.I. 2005, A&A, 429, 1025
Mac Low, M.-M. & McCray, R. 1988, ApJ, 324, 776
Massey, Ph., Waterhouse, E., & DeGioia-Eastwood, K. 2000, AJ, 119, 2214
Meaburn 1980, MNRAS, 192, 365
Nigra, L., Gallagher, J.S., III, Smith, L.J., Stanimirovic, S., Nota, A., & Sabbi, E. 2008, PASP, 120, 972
Rhode, K.L., Salzer, J.J., Westfahl, D.J., & Radice, L. 1999, AJ, 118, 323
Silich, S., Elias, F., & Franco, J. 2008, ApJ, 681, 1327
Schmalzl, M., Gouliermis, D.A., Dolphin, A. E., Henning, Th. 2008, ApJ, 681, 290
Tenorio-Tagle, G. 1981, A&A, 94, 338
Wada, K., Spaans, M., & Kim, S. 2000, ApJ, 540, 797
Yokogawa et al. 2003, PASP, 55, 161