An Unbiased Far Ultraviolet Survey of Magellanic Cloud Supernova Remnants

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Abstract.

We have undertaken a FUSE survey of Magellanic Cloud supernova remnants, looking primarily for O VI and C III emission lines. Work in earlier cycles with FUSE indicates that optical and/or X-ray characteristics of supernova remnants are not always good predictors of the objects that will be bright and detectable in the UV. The goal of our survey is to test this concept by obtaining spectra of a random sample of Magellanic Cloud remnants with a broad range of radio, optical, and X-ray properties. Previously observed objects and remnants with known high extinction (or known high column densities) are the only objects eliminated from consideration. To date, we have clearly detected O VI emission from 12 of the 33 objects observed, with weak or marginal detections possible in a handful more.

1. Introduction

In the study of emission line objects, the far ultraviolet (FUV) is typically viewed as an extension of the optical. Consequently, FUV observations tend to target objects (or parts of objects) which exhibit strong optical line emission. This criterion has been frequently used in the field of supernova remnant (SNR) research to select suitable targets for ultraviolet observations. There could be many Magellanic Cloud SNRs detectable at a level useful for analysis in the FUV, but which have never been observed because of selection biases. To avoid the selection bias of targeting bright optical/X-ray remnants, we are currently performing a FUSE Guest Investigator survey of all known LMC and SMC SNRs, excluding only those which have been previously observed or are known to exhibit high interstellar extinction. Most of these targets have not previously been observed in the UV.

In our observations a standard exposure of 10 ks with the LWRS aperture is requested, allowing us to detect O VI emission up to 50 times fainter than observed in such bright SNRs as N49 (Blair et al. 2000). The target coordinates are at the radio or X-ray center of each SNR. With this observing setup, even non-detections are of significant interest. Most of the objects are from 1′ to 5′ in extent, which will fill the LWRS aperture (30′′ × 30′′) with emission. This setup
also lessens the impact of relative FUSE channel misalignments and keeps the observations simple. In addition, Doppler shifting from the front and back sides of the SNR shells ($\sim 30-150$ km s$^{-1}$) will move their emission lines out from under the overlying absorption of the host galaxy.

2. FUSE Spectra from the LMC Survey: Two Examples

Our FUSE observations of the MC SNRs were performed between 2003 July 14 and 2004 July 14. During this period, 32 LMC remnants and 1 SMC remnant were observed. O VI emission was detected from 12 of the 33 objects observed. The O VI $\lambda$1032 profiles exhibit a wide range of shapes. Some are broad, some narrow, and some are double peaked. Some SNRs exhibit both O VI and C III emission, while others are only detected in O VI. Thus far the faintest detections in our survey are at flux levels $F(1032) \approx 10^{-14}$ ergs cm$^{-2}$ s$^{-1}$ and $F(977) \approx 1.4 \times 10^{-14}$ ergs cm$^{-2}$ s$^{-1}$. An interesting result already emerging from this survey is that, as suspected, FUV emission is detected even in SNRs where the targeted region exhibits minimal optical and X-ray emission.

In Figs. 1 and 2 we show H$\alpha$ images (from the Magellanic Cloud Emission Line Survey (MCELS), Smith et al. 1999) and FUSE spectra of two "hits" from our sample LMC SNRs. The diameters of these remnants differ significantly: 0454$-$66.5 (N11L; Henize 1956) and 0536$-$70.6 (DEM 249, Davies et al. 1976) are 1$'$ (15 pc) and 2.4$'$ (36 pc) across, likely reflecting different ages. The spectra were produced from the orbital night data, with exposure times of 18.8 ks and 3.2 ks. These two objects exhibit very different spectra: 0454$-$66.5 shows strong and broad O VI and C III emission ($F(1032) \approx 2 \times 10^{-13}$ ergs cm$^{-2}$ s$^{-1}$, $F(977) \approx 1.5 \times 10^{-13}$ ergs cm$^{-2}$ s$^{-1}$, $V_{FWHM} \approx 400$ km s$^{-1}$). On the other hand,
flux levels in 0536−70.6 are nearly ten times fainter, with each of the O VI lines split into two components. Here, the lines are approximately 150 km s$^{-1}$ wide and spaced approximately 230 km s$^{-1}$ apart (see Fig. 2).

3. Summary and Future Directions

Thus far we have detected O VI line emission from over 1/3 of the Magellanic Cloud remnants observed in our survey. This is an ongoing project, and will yield useful constraints on the kinematics of MC SNRs. A broad assortment of data is available to support our FUSE observations: Narrow band MCELS imaging of many LMC/SMC fields of interest are in hand, while longslit echelle observations cutting across many Magellanic Cloud H II regions, bubbles, etc., are available to provide an excellent base of general kinematic information on various regions of potential interest. X-ray observations with Chandra, both in the archive and in ongoing programs, will provide invaluable information on shocked ejecta and blast wave emission in these SNRs. In addition, upcoming Spitzer Cycle 1 observations will provide supplemental information on shocked dust in the LMC SNRs.

References
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