Title: Discovery of Recombining Plasma in G166.0+4.3: A Mixed-Morphology Supernova Remnant with an Unusual Structure

Mixed-morphology supernova remnants (MM-SNRs) have center-filled thermal X-ray emissions in a synchrotron radio shell. From the X-ray spectra of several MM-SNRs (e.g., W49B: Ozawa et al. 2009; IC 443: Yamaguchi et al. 2009), the Suzaku satellite has recently discovered recombining plasmas (RPs) characterized by a higher ionization temperature (kT_z) than an electron temperature (kT_e), while most of shell-like SNRs are explained as collisional ionization equilibrium (CIE: kT_z = kT_e) or ionizing plasma (IP: $kT_z < kT_e$). The formation process of the RPs have not been understood yet.

G166.0+4.3 is a Galactic SNR whose synchrotron radio emission is extremely asymmetric: A large bipolar structure in southwest (Wing region) with a smaller semicircle shell in northeast (Shell region). From a previous X-ray observation with XMM-Newton, Bocchino et al. (2009) classified G166.0+4.3 as a MM-SNR and reported that the plasma is explained by a typical IP model. However, the origin of the unusual structure is still unclear.

We have performed a long-time (totally 230 ks) observation of G166.0+4.3 with the Suzaku satellite in 2014. From the spectral analysis of the Wing region, we confirmed that the plasma is well represented by an IP model with kT_e of 0.85 keV. Applying a similar IP model to the Shell region, however, we found excesses at $\sim$2.0 keV and $\sim$2.6 keV corresponding to $\mathrm{Si_{XIII}}$ Lyα (2.0 keV) and the edge of a radiative recombining continuum of $\mathrm{Si_{XIII}}$ (2.67 keV) + $\mathrm{S_{XIV}}$ Lyα (2.63 keV), respectively. This fact indicates a sign of an RP in the Shell region of G166.0+4.3. We explained the spectrum as an RP model whose electron temperature is 0.46 keV which is smaller than that of the IP model in Wing region. We also found that the Fe-rich ejecta asymmetrically spread over the Wing region. These results suggest an inhomogeneous ambient medium in the vicinity of G166.0+4.3 which provides a clue to the cause of the unusual morphology. A supportive evidence is shown by a recent Fermi observation. Miguel (2013) discovered a GeV gamma-ray emission from the northeast part of this remnant, suggesting an existing of nearby molecular clouds. We also estimated the total ejecta mass to be larger than 8 solar masses. Although no candidate for progenitor has been detected around this remnant, a core-collapse SN is preferable as its origin. In this poster, we will present details of our analysis and discuss a relation between the unusual morphology and the cause of the RPs.