SCIENTIFIC PROPOSAL FOR INDIVIDUAL EXTERNAL COLLABORATION

Spatially resolved study of the X-ray emission from galactic Supernova Remnants

Marco Miceli[1,2]

[1]Dipartimento di Fisica & Chimica, Università di Palermo, Piazza del Parlamento 1, 90134 Palermo, Italy
[2]INAF-Osservatorio Astronomico di Palermo, Piazza del Parlamento 1, 90134 Palermo, Italy

The leftovers of supernova explosions (SuperNova Remnants, SNRs) govern the physical and chemical evolution of our Galaxy. An exploding star releases $\sim 10^{51}$ erg of kinetic energy through some solar masses of metal-rich ejecta that expand supersonically and drive powerful shocks back and forth in the ambient medium (forward shock) and ejecta themselves (reverse shock). The forward shock expands in a "cloudy" environment and interacts with the interstellar inhomogeneities, thus driving different thermal conditions in the shocked plasma and producing a very broad-band elettromagnetic emission which extends from the radio band up to the X-rays. On the other hand, the revers shock interacts with the fragments of the progenitor star expelled at supersonic speed (several 10^4 km/s) in the explosion. The ejecta are chemically enriched of heavy elements synthesized during the life of the progenitor star and during its death, through the explosive nucleosynthesis processes. Therefore, the complex structures of SNRs contain the imprint of the SN explosion physics, as well as the results of the interaction of the blast wave with the circumstellar material.

While in young SNRs the reverse shock is still close to the forward shock and the inner layers of ejecta are generally cold and unshocked, in evolved SNRs the reverse shock has had the time to reach the SNR center and therefore all the ejecta material has been shocked and heated to X-ray emitting plasma temperatures. For this reason, SNRs like the Vela SNR, with an age of $\sim 10^4$ yr, may provide a complete picture of the distribution of the ejecta inside the remnant, with the great advantage of a large spatial resolution due its proximity (the distance to the Vela SNR is about 250 pc). On the other hand, in middle aged SNRs the mass of the shocked interstellar medium (ISM) is typically larger than that of the ejecta and the bright, soft X-ray emission produced by the interaction of the forward shock with the inhomogeneous ISM dominates the global X-ray spectrum, thus making it difficult to reveal the ejecta emission and to study its properties.

A first leap forward in the study of ejecta in middle-aged SNRs has been obtained with the analysis of the ROSAT observations of Vela SNR. Aschenbach et al. 1995 (Nat, 373, 587) identified 6 X-ray emitting features (with a characteristic boomerang shape) protruding beyond the primary blast wave and labeled shrapnel A-F. The symmetry axis pointing back to SNR center and the opening angle of the bow shocks both suggest an origin in terms of ejecta bullets moving supersonically in the ambient medium. The ejecta origin for Shrapnel A-F has been later confirmed by dedicated *XMM-Newton*, *Chandra* and *Suzaku* observations.

Moreover, Miceli et al. 2008 (ApJ, 676, 1064) have discovered for the first time a few metal-rich knots *inside* the Vela SNR shell. The chemical composition of these knots reveal that they are ejecta bullets, similar to those observed by LaMassa et al. 2008 (ApJ, 689, 121), who found enhanced O, Ne and Mg abundances in a region in the Vela Cocoon nebula. The evolution of ejecta shrapnels in the Vela SNR has been modelled with detailed hydrodynamic simulations by Miceli et al. 2013 (MNRAS, 430, 2864). However, because of its high angular extension (diameter $D \sim 8°$), the Vela SNR has only been sparsely covered in high spectral resolution X-ray observations. Therefore, it is has not been possible to study the distribution of the physical and chemical properties of the ejecta across the remnant.

The $eROSITA$ data will allow us to cover the whole shell of the Vela SNR and to obtain a detailed description of both the ISM and the ejecta. The high sensitivity and effective area of the new data will allow us to identify the ejecta knots over the whole remnant, through the combination of image analysis (narrow-band maps, equivalent width maps on specific emission lines, etc.) and spatially resolved spectral analysis. The complete mapping of the chemical abundances in the ejecta will provide a thorough insight on the explosive nucleosynthesis processes in core-collapse SNe, on the mechanisms of overturning and mixing of ejecta layers, and on the ejecta-ISM mixing processes. Also, it will be possible to map the physical properties of the shocked ISM, by putting forward the preliminary results obtained within the ROSAT all-sky survey (see Lu & Aschenbach 2000, A&A, 362, 1083).

Similar analysis can be carried out for other galactic SNRs, whose high angular extension has hampered so far a complete coverage with the current generation of X-ray telescopes. Possible candidates include the large Lupus Loop; G332.5-5.6, characterized by a puzzling X-ray morphology which has not been studied in detail yet (see Suárez et al. 2015, A&A, in press, for an X-ray study limited to its central region); and the powerful cosmic ray accelerator RX J0852.0-4622 (also known as Vela Jr.), whose X-ray emission lies within the Vela SNR shell.

We also plan to perform dedicated multi-D MHD simulations to obtain a deeper level of diagnostics for our X-ray targets. The synergy of these two complementary aspects will strengthen the scientific outcome.

The expected duration of the projects is two years. The results will be published in high-impact peer-reviewed journals and presented in international meetings. We will also spread our findings with press-releases and we plan to organize public-outreach seminars and lectures for the students of the Dipartimento di Fisica e Chimica at the University of Palermo.

Potential collaborators in the eROSITA consortium include Dr. M. Sasaki and Dr. P. J. Kavanagh (University of Tübingen).