3D HD MODELLING OF SNR IC 443: effects of the inhomogeneous medium in shaping the remnant morphology

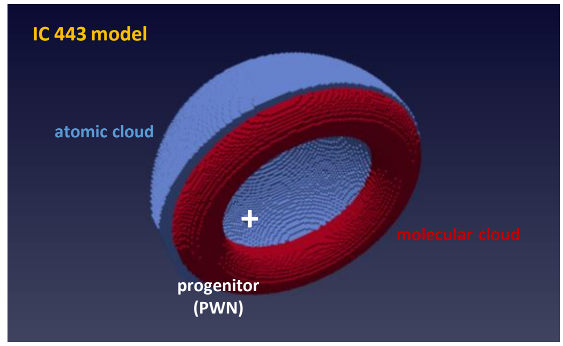
S. Ustamujic[1], S. Orlando[1], E. Greco[2,1], M. Miceli[2,1], F. Bocchino[1], and G. Peres[2,1]

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

Email: sabina.ustamujic@inaf.it

CONTEXT

The distribution of the interstellar medium in the vicinity of supernova remnants (SNRs) plays a fundamental role for our understanding of their morphology and evolution. IC443 is a SNR at a distance of 1.5 kpc located in a quite complex environment since it interacts with nearby clouds (Troja et al. 2006, Su et al. 2014). Troja et al. (2008) suggested that SNR IC 443 has evolved inside the pre-existing wind-blown bubble, which likely originated from the massive progenitor star of the remnant (probably related to PWN CXOU J061705.3+222127). The association between the PWN and IC443 is still debated considering its off-center position. Proposed age for SNR IC443 varies from ~3–4 kyr (Troja et al. 2008) to ~20–30 kyr (Chevalier 1999, Bykov et al. 2008). Indications for the presence of overionized plasma have been found (Yamaguchi et al. 2009, Matsumura et al. 2017) and recently a collimated jet of ejecta has been discovered (Greco et al. 2018).
Thus, SNR IC 443 has become a good laboratory to study several astrophysical phenomena. In this poster we present our preliminary results for the SNR interaction with molecular clouds (MCs).



SNR IC 443 interacts with a molecular cloud in the northwestern and southeastern areas and with an atomic cloud in the northeast.

AIMS

In this study we aim at investigating the effects of the inhomogeneous medium in shaping the morphology of SNR IC 443, constrain the energy of the supernova (SN) explosion and determine the age of the remnant.

METHODS

We have developed a 3D hydrodynamic (HD) model for SNR IC 443 describing the post-explosion evolution of a SN, the subsequent transition from the phase of SN to that of SNR, and finally the interaction of the SNR with the surrounding environment, parametrized in agreement with the results of the multiwavelength data analysis. The calculations were carried out with the PLUTO code (Mignone et al. 2007).

We performed a wide exploration of the parameter space and synthesized the X-ray emission, including the deviations of equilibrium of ionization and the deviations of ion-electron temperature equilibration.

PRELIMINARY RESULTS

Our model reproduces the morphology of IC443 SNR, considering the origin of the explosion at the position of the PWN at that instant (inferred from the PWN proper motion).

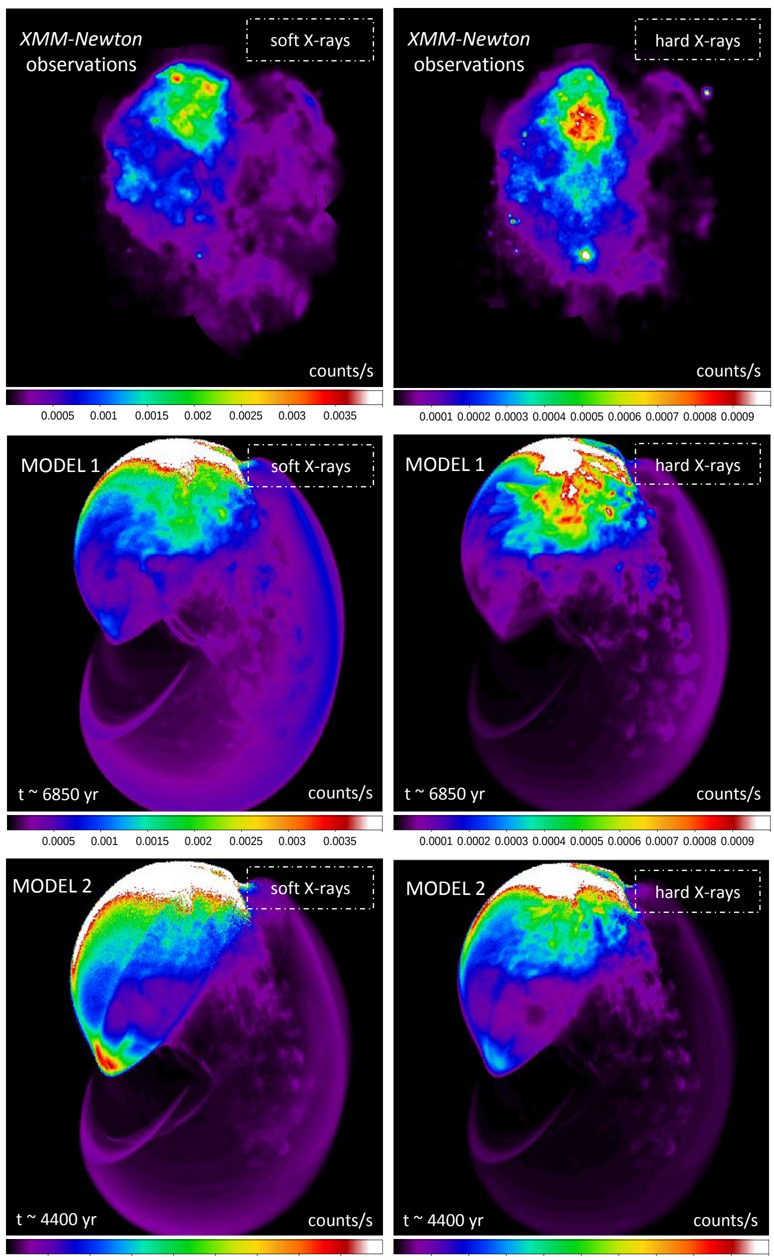
We compare X-ray emission maps from XMM-Newton observations in the soft (0.3 – 1.4 keV) and hard (1.4 – 5.0 keV) bands with those synthesized from the models (see the panels on the right). The maps correspond to the two extreme cases studied:

MODEL 1 (M1): explosion energy 10^{51} erg

MODEL 2 (M2): explosion energy 2.5×10^{51} erg

We find that the count rate values in M2 are much higher than those observed (note the different scales), thus we conclude that the energy of the SN explosion was closer to that of model M1.

We constrained the age of SNR IC 443: 4000 – 7000 yr.



FUTURE WORK

The results presented here are preliminary and intended to find the parameters of the ambient medium. In the future, we will investigate the following issues:

- Overionization of plasma in SNRs.
- Jets and asymmetries in SNRs.
- Origin of non-thermal (hadronic) emission → gamma-ray emission and cosmic-rays.

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