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Modeling the supernova remnant RX J1713.7 – 3946: particle acceleration, gamma-ray emission, and neutrino flux

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KM3NET neutrino telescope

KM3NeT (https://www.km3net.org/) is a research infrastructure housing the next generation neutrino telescopes. The infrastructure consists of a cabled network of deep-sea neutrino detectors located in the Mediterranean Sea. In particular, the ARCA neutrino telescope of KM3NeT, installed about 100 kilometers off-shore the small town of Portopalo di Capo Passero on Sicily (Italy), will be dedicated to the search for very high-energy cosmic neutrinos from distant astrophysical sources such as supernovae.

SNR RX J1713.7 – 3946

RX J1713.7 – 3946 (hereafter RXJ1713) is the brightest TeV gamma-ray and nonthermal X-ray SNR observed. Its X-ray emission is dominated by synchrotron emission that arises from very energetic electrons accelerated at the shock front. The origin of the TeV gamma-ray emission has been a matter of active debate since both hadronic and leptonic scenarios can reproduce the data under certain assumptions.

The remnant, situated at a distance of 1 kpc, is thought to be associated with the SN explosion observed by Chinese astronomers in the year 393. The very bright compact source 1WGA J1713.4-3949, found close to the geometrical center of the SNR, is likely to be the neutron star remaining from the SN explosion. The SNR seems to be evolving in a clumpy medium with molecular clouds observed in the vicinity of the remnant.

AIMS

In this study we aim at reconstructing the density distribution and geometry of the ambient environment where RXJ1713 evolved, investigate the way it influences the morphological properties of the SNR, and assess the role of the hadronic emission, which is crucial to derive constraints on the neutrino emission.

METHODS

We developed a 3D hydrodynamic (HD) model for RXJ1713, which describes the interaction of the SNR with the cavity wall of the progenitor in an ambient medium characterized by dense interstellar clouds. The calculations were carried out with the PLUTO code (Mignone et al. 2007, ApJS, 170, 228).

We performed a preliminary exploration of the parameter space describing the initial blast wave and the environment, including the mass of the ejecta, the energy and position of the explosion, as well as the density, structure, and geometry of the surrounding ambient medium.

PRELIMINARY RESULTS

Our model reproduces the morphology of RXJ1713 considering the line of sight outlined in **Fig. 3**. After the initial expansion of the ejecta through the wind of the progenitor star, the forward shock interacts with a molecular cloud with density ~100 cm^{-3} forming the bright cap observed in the NW in **Fig. 4** (right panel), while continues to expand freely in the rest.

The maps presented here correspond to the reference case (M_{ej} = 12.6 $M_{\odot}$, E = 2x10^{51} erg) at t ~ 1800 years.

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 role of clumps and turbulence in the ambient medium
- Magnetic field → MHD model
- Non-thermal emission
- Gamma-ray and neutrino emission

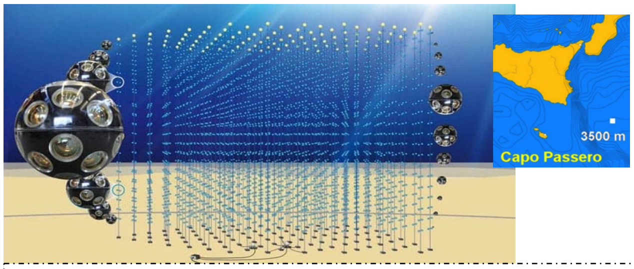

Figure 1: Artist's impression of the KM3NeT detector with the location of the Italian infrastructure indicated on the right. **Credit:** H.E.S.S. Collaboration.

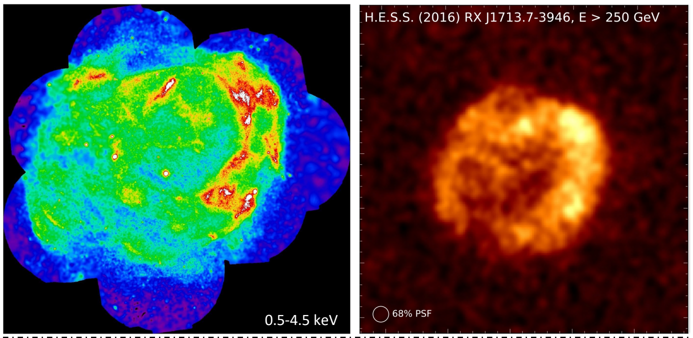

Figure 2: SNR RXJ1713. **Left:** A high resolution mosaic of XMM-Newton EPIC observations. **Credit:** Image courtesy of F. Acero and ESA/XMM-Newton. **Right:** H.E.S.S. gamma-ray excess count images. **Credit:** H.E.S.S. Collaboration.

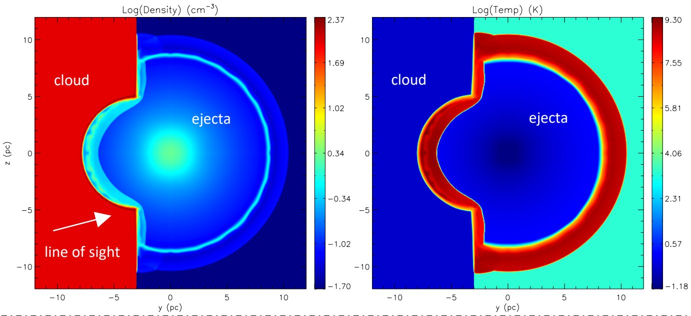

Figure 3: Density (left) and temperature (right) distributions in logarithmic scale in the (0; y; z) plane at t ~ 1800 years for the reference model.

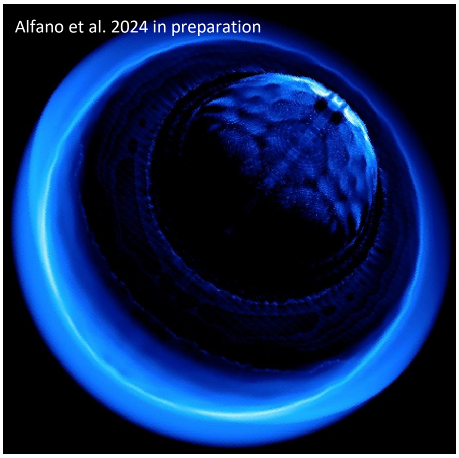

Figure 4: Density of the shocked plasma (T > 1 MK and v > 1000 km/s), integrated along the line of sight, for the reference model, at t ~ 1800 years. The image is represented in square root color-scale and adaptively smoothed to a signal-to-noise ratio of 25. We expect most of the non-thermal emission coming from the bright north-western region where the forward shock interacts with the spherical cap.