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A systematic analysis of the physical parameters of Galactic SNRs

I. Chousein-Basia[1], A. Zezas[1,2], M. Kopsacheili[3], I. Leonidaki[1,2]

[1]Department of Physics, University of Crete, Heraklion, Greece; [2]Institute of Astrophysics, FORTH, Heraklion, Greece; [3]Institute of Space Sciences (ICE, CSIC), Barcelona, Spain

Introduction

Supernova remnants (SNRs) are the testament of the final act in the life of a massive star. They are important for enriching and heating the interstellar medium, and for providing information on the latest stages of stellar evolution. SNRs are characterized by complex physical processes resulting in a multi-phase gas radiating across the electromagnetic spectrum. Over 300 SNRs are known in our Galaxy; however, so far there have not been any systematic studies of their population (mostly in the optical band).

We present an investigation of the physical properties of Galactic SNRs based on an extensive literature survey. We explore the correlations between the physical parameters of SNRs (such as velocity, density and excitation parameters) as a function of their age and type, providing for the first time a picture of the overall trends of the properties of the SNR population within our Galaxy.

Methodology

Our literature survey is based on the Galactic SNR catalogue of Green (2022). We thoroughly examined all available publications of the entire SNR sample focusing on measurements of their shock or expansion velocity, density and temperature, based on a variety of methods and tracers.

We have found data for 63 SNRs with published information. For 34 objects, we also have information on individual regions, providing a picture of the variation of the physical parameters within an object. Age and distance information is obtained from the database of high-energy observations of Galactic SNRs (Ferrand & Safi-Harb, 2012).

In order to account for upper/lower limits, and value ranges reported in these publications, we followed an approach where we draw values from a Heaviside step function or a Gaussian distribution respectively. We then calculate the mean and standard deviation from these draws. For objects with multiple available measurements, we first calculate the mean of these measurements before including them in our statistical analysis.

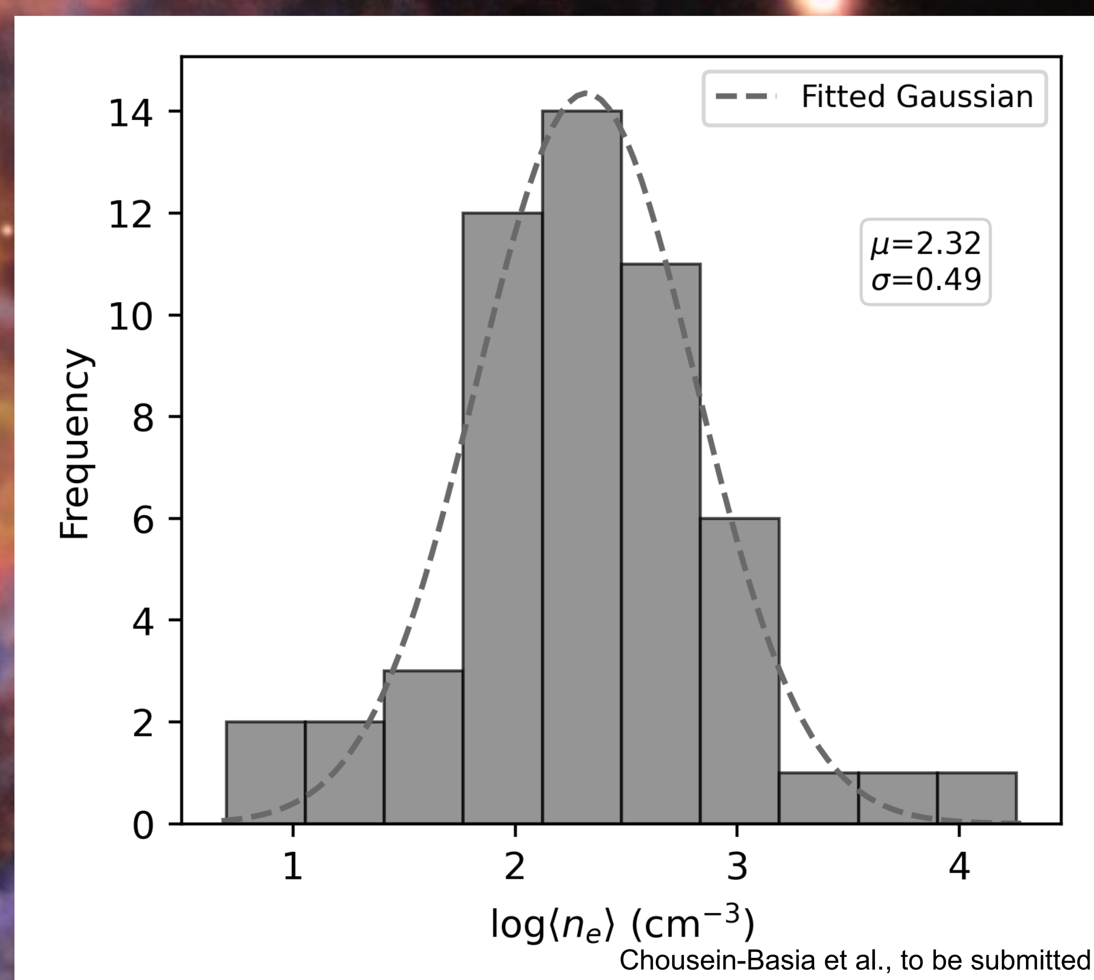

Figure 1: Histogram of the distribution of electron density across the population of 63 Galactic SNRs with available measurements.

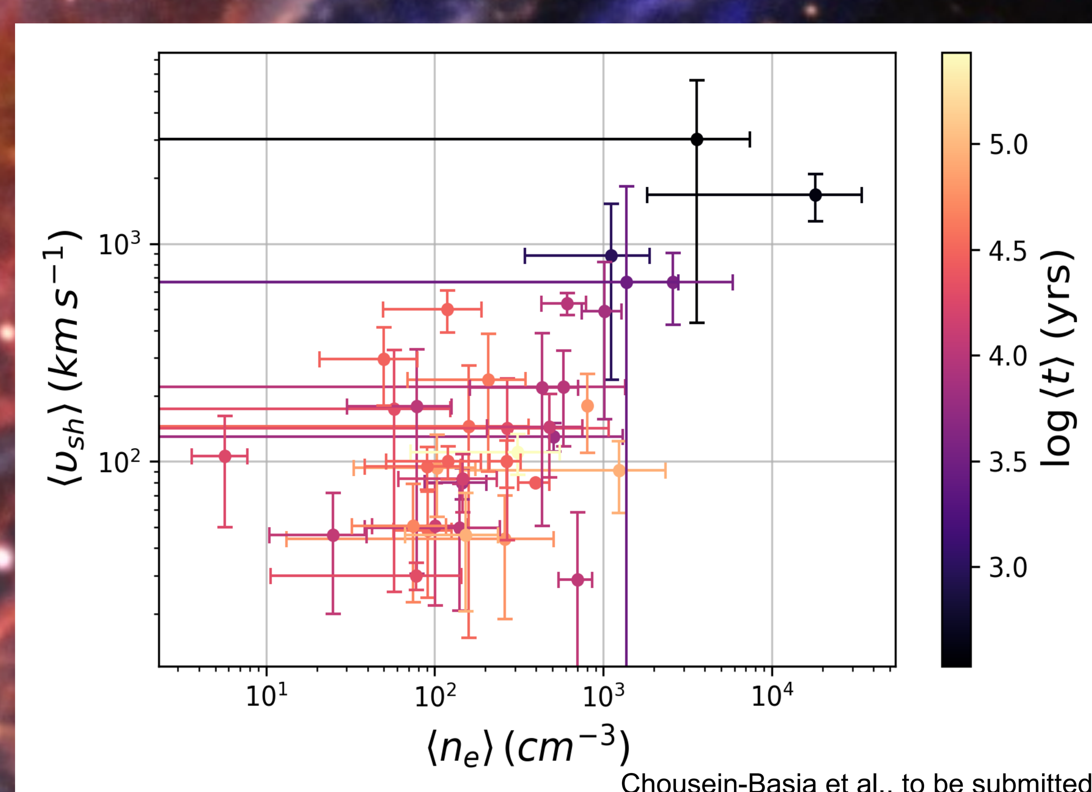

Figure 3: Mean shock velocity as a function of mean electron density. A weak upward trend is observed.

Results

Fig. 1 shows a histogram of the density of the SNRs. We find that it follows a log-normal distribution with mean $\log(n_e)$=2.32 cm^{-3} and a standard deviation of 0.49.

Fig. 2 (bottom of the page) shows the shock velocity for all objects with available measurements. We see that the vast majority has velocities of ~50–250 km/s. However, there are a few objects with velocities higher than 1000 km/s. These are mostly Type Ia or oxygen-rich SNRs, (including some well known X-ray emitting objects).

In **Figs. 3 and 4** we explore the relation between shock velocity and density or age. We see that there is no strong correlation between velocity and density. However, there is a clear anticorrelation between velocity and age (as expected from SNR evolution models; grey points in Fig 4). This indicates that age is the driving factor of the SNR shock velocity for optically emitting SNRs.

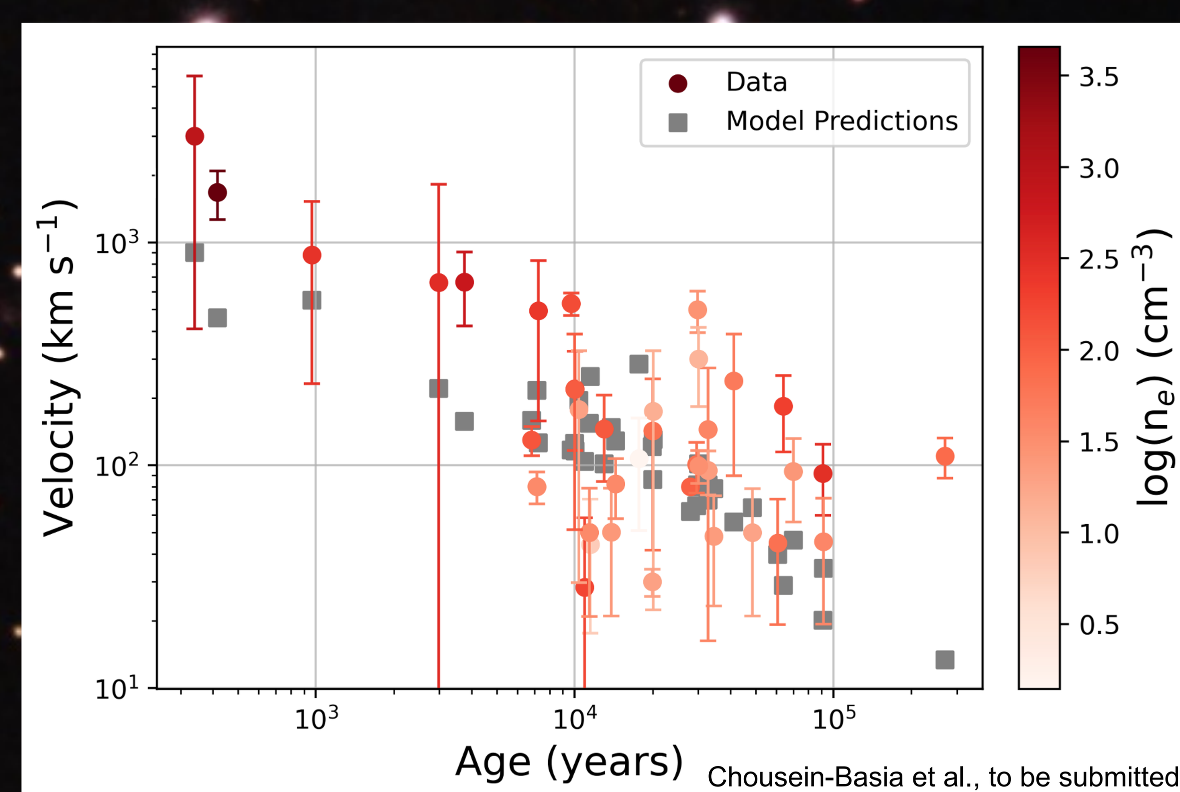

Figure 4: A plot of the shock velocity against the SNR age. The points are color-coded according to the measured electron density. Grey squares show the expected expansion velocities based on basic evolution models (Cioffi et al. 1988) and the measured electron density and age of each SNR. The agreement between the observations and the expected velocities from the models is remarkable.

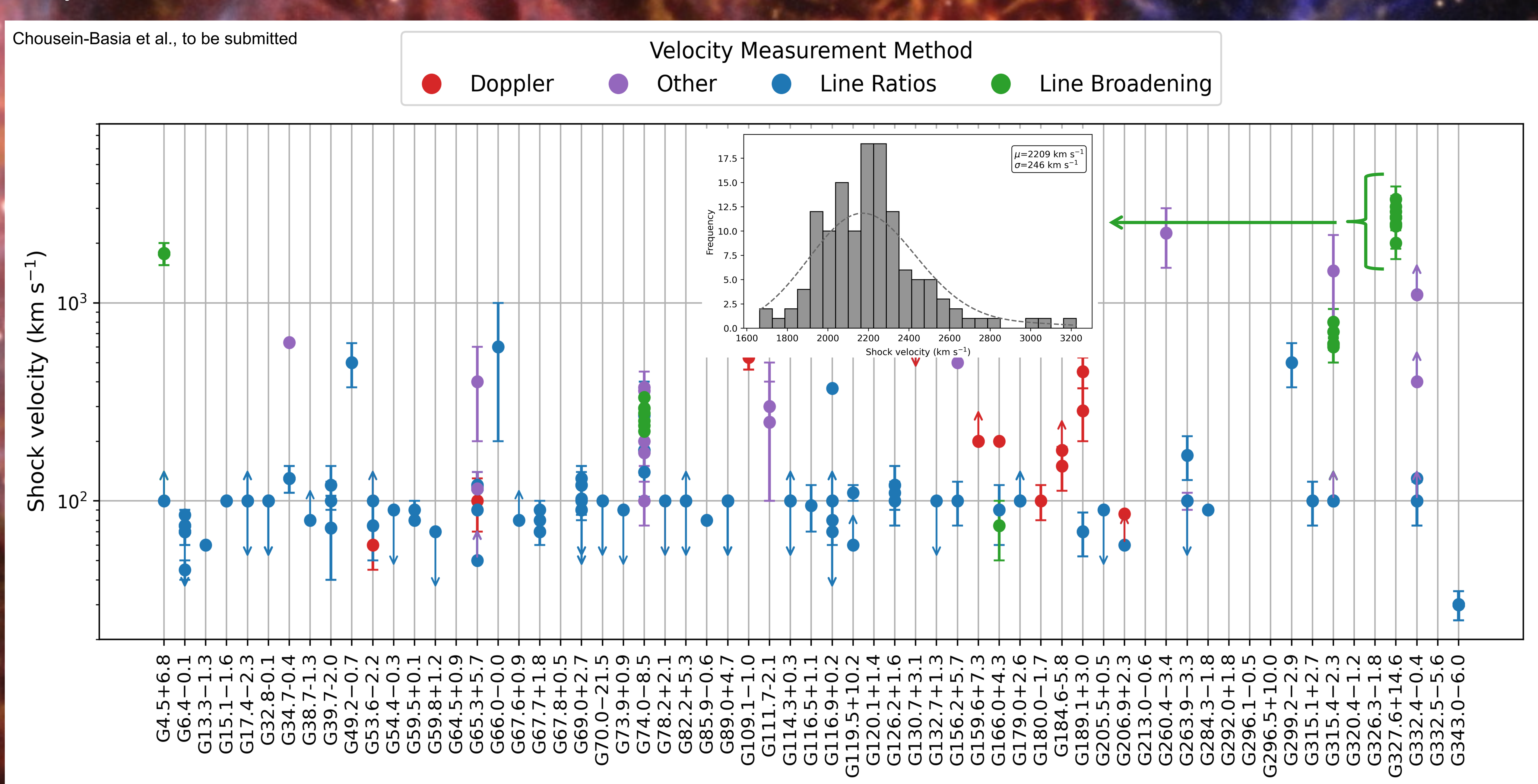

Figure 2: Shock velocities and respective errors for the SNRs with available measurements in the literature. The data points are color-coded according to the method used for the velocity determination. For objects with multiple measurements we calculate the mean velocity and standard deviation using the sampling approach described above. The velocities are well below 500 km s^{-1} for most objects, with a few objects reaching values up to 1500-3000 km s^{-1} in extreme cases (e.g. relatively young objects).

The insert shows a histogram of all available velocity measurements for the SN1006 (133 individual regions). The standard deviation of the measurements (246 km/s) is indicative of the robustness of these measurements.

References

1. Green D. A., 2022, `A Catalogue of Galactic Supernova Remnants (2022 December version)', Cavendish Laboratory, Cambridge, United Kingdom (available at http://www.mrao.cam.ac.uk/surveys/snrs/).
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Background Image: The Veil Nebula; Skinakas Observatory