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Evolution of pulsar wind nebula - supernova remnant systems

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Neutron stars are typically born in core-collapse supernova explosions, and are often rapidly spinning with a large initial rotational energy E0 that can approach or even exceed the SN explosion's kinetic energy, ESN. Their considerable surface dipole magnetic field causes them to spin down, channeling their rotational energy into an extremely relativistic MHD wind. This inflates a pulsar wind nebula (PWN) that is confined within and drives a shock into the part of the stellar envelope that was ejected in the SN explosion, known, at later times, as a SN remnant (SNR). Such wind nebulae emit synchrotron radiation from radio to X-ray and are observed around many young Galactic pulsars, as well as around one magnetar. Here we study the long term dynamics of a PWN-SNR system, including the many different dynamical phases of the interactions between the wind and SNR as well as the SNR and the surrounding circum-stellar medium, which forms shocks on both sides of the SNR. For example, when the reverse shock created at the interaction with the circumstellar medium reaches the outer edge of the PWN, it compresses it and the system enters the "reverberation"phase, which is hard to study analytically. In particular, we focus on the differences between fast (E0 > ESN) and slow (E0 < ESN) initial rotation, and the inner structure of the flow within the wind nebula. Following several 3D MHD simulations studies that found a low magnetization within the PWN in agreement with PWN observations, we use relativistic hydrodynamic simulations and neglect the effect of magnetic fields on the PWN' s dynamics. We exploit self-similar properties of the shock structures to initialize our simulations as close to the reverberation phase as we need it to be, bypassing the free-expansion phase to save on computation time and thus allowing the study of a greater range of timescales.

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