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Damping of self-generated Alfvén waves in a partially ionized medium and the grammage of cosmic rays in the proximity of supernova remnants

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CR propagation nearby SNRs

Runaway **CRs escaping from SNRs**, propagate in the source region and excite **Alfvén waves** through **resonant streaming instability**. This produces a **suppression of the CR diffusion coefficient,** with respect to the typical interstellar value, within few tens pc from the source. The level of self-generated waves is limited by several damping processes:

- **ion-neutral damping** in a partially ionized medium (IN)
- **turbulent damping** (Farmer-Goldreich), due to the interaction with pre-existing Alfvénic turbulence (FG)
- **non-linear Landau damping** (NLL)

In a partially ionized medium, as the warm ionized (WIM) and warm neutral (WNM), IN is dominant effect.

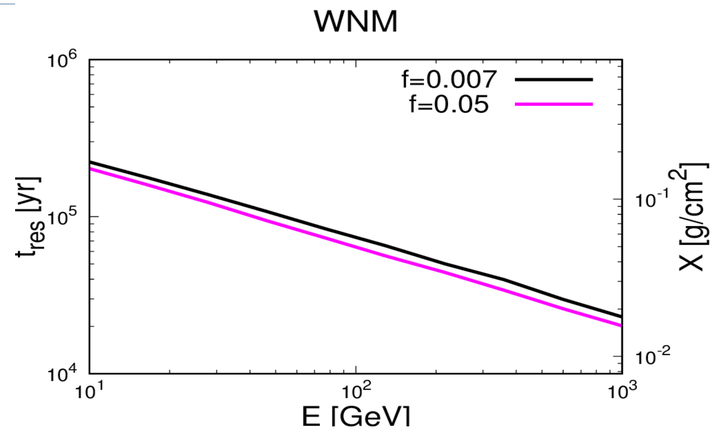
IN damping is due to the momentum transfer and the charge exchange between ions and neutrals, and depends on the level of ionization and on the species of the colliding particles.

In a WIM and WNM there are H ions and neutral H and He.

Residence time and grammage

If the CR self-confinement around sources is effective, an appreciable amount of **grammage** may be accumulated in the source region, namely, a significant fraction of **CR secondaries** would be produced in the vicinity of CR sources, and not during the time spent by CRs in the Galactic disk, as usually assumed. **This would constitute a profound modification of the standard view of CR transport in the Galaxy.**

- We solved the transport equation for CRs escaping from a SNR embedded in a WNM and a WIM, and for self-generated waves
- We estimated the residence time, Tres, of CRs in a region of ~100 pc around the source and the corresponding grammage, X (see figures below)



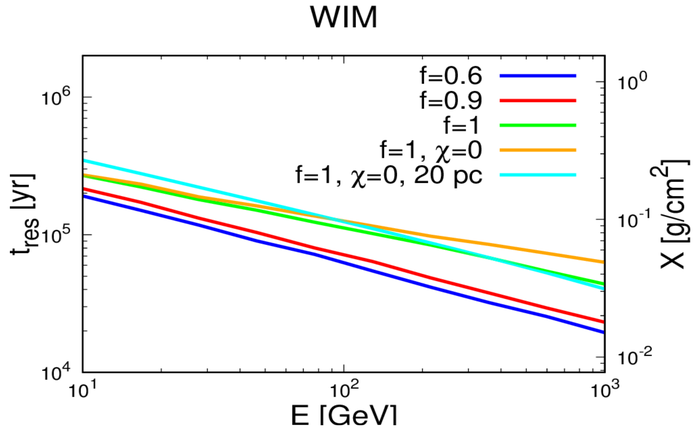


Figure: Different colors mark different values of the hydrogen ionization fraction *f*, while the helium-to-hydrogen ratio X =0.1

Conclusions

- while the effect of self-confinement increases the residence time compared to what expected from propagation in a typical interstellar diffusion coefficient
- the damping mechanisms, especially IN, strongly limit such residence time
- **the source grammage is found to be negligible compared to that inferred form observation in the energy range 10 GeV - 1 TeV, contrary to what was previously suggested in the literature.**

https://arxiv.org/pdf/2106.04948.pdf