Exercises (3)

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5 Magnetic field compression at shocks

Consider a strong shock moving in a medium where an ordered and spatially uniform magnetic field of strength $B_0 = 3\ \mu$G is present. A shock is called *parallel (perpendicular)* when the direction of the magnetic field is parallel (perpendicular) to the shock velocity. Use the MHD theorem of magnetic flux freezing to estimate the strength of the magnetic field downstream of the shock in the case of a parallel and perpendicular shock.

Repeat the exercise considering a shock propagating through a medium where a turbulent magnetic field is present. The turbulent field is characterised by $\langle \vec{B} \rangle = 0$ and $\sqrt{\langle B^2 \rangle} = 3\ \mu$G. The field is isotropic, i.e., $\langle B^2 \rangle = \langle B_x^2 \rangle + \langle B_y^2 \rangle + \langle B_z^2 \rangle$ with $\langle B_x^2 \rangle = \langle B_y^2 \rangle = \langle B_z^2 \rangle$, where B_i is the component of the field along the i axis. The brackets $\langle\rangle$ denote space averaged quantities.

Assume that the magnetic field is weak enough to have no effect onto the shock hydrodynamics.

6 Sensitivity of Cherenkov telescopes for extended sources

Consider an array of Cherenkov telescopes as that in Exercise 2. How would the sensitivity scale for a source of angular extension θ_s larger than the angular resolution of the system $\theta_{res} \sim 0.1°$?

Derive an expression for the minimum detectable gamma-ray luminosity above photon energies of 1 TeV (expressed in erg/s) as a function of the distance to the gamma-ray source and of its physical size. Assume that the source spectrum scales as $E_\gamma^{-2.4}$.

7 Gamma-ray emission from supernova remnants: is it detectable?

Use the results obtained in Exercise 6 to answer this question. Consider a SNR of radius R_s containing 10^{50} ergs in form of cosmic rays characterised by a spectrum $\propto E_p^{-2.4}$. To compute the gamma-ray emission from proton-proton interactions assume that the density of the ambient medium is 1 cm^{-3}. Up to which distance d_{max} a gamma-ray telescope as the one in Exercises 2 and 6 could detect it? Compare d_{max} with the expected distance of the closest supernova remnant and comment the result. [Hint: in the Galaxy 3 supernovae explode per century. Significant gamma ray emission is expected during the non-radiative phases of the supernova remnant evolution, which last $\approx 10^4$ yr. Assume supernova remnants to be distributed uniformly in an infinitesimally thin disk of radius 15 kpc.]