Exercises (1)

NPAC Course on High Energy Astrophysics – Stefano Gabici

14 September 2020

1 The normalisation of the cosmic ray spectrum

The *Voyager 1* probe measured the intensity of local cosmic ray protons $j(E)$ which can be (very) roughly represented as:

$$\begin{aligned} j(E) &= A\left(\frac{E}{E_0}\right)^{0.1} \qquad E < E_0 \\ &= A\left(\frac{E}{E_0}\right)^{-2.7} \qquad E > E_0 \end{aligned}$$

where $E_0 \sim 1$ GeV and A a normalisation constant in units of eV^{-1} cm^{-2} s^{-1} sr^{-1}.

Find the value of the normalisation constant A by imposing that the local energy density of cosmic ray protons is $w_{CR} \sim 1$ eV/cm^3. Show that most of the energy is carried by particles with energy $E \gtrsim E_0$.

Finally, estimate the normalisation B (in units of eV^{-1} s^{-1}) and the spectral slope α of the injection spectrum of cosmic rays in the Galactic disk (for $E > E_0$):

$$Q(E) = B\left(\frac{E}{E_0}\right)^{-\alpha} \tag{1}$$

knowing that the residence time of cosmic rays in the Galactic disk scales as $\tau_c \propto E^{-0.3}$ and that the total cosmic ray power of the galaxy is $P_{CR} \sim 10^{41}$ erg/s.