

# Graduate mini course: “High Energy Astrophysics – Selected Topics”

## Assignment #3

Due 1pm, Thu Mar 20

This assignment is due before class on Mar 20; that is, at 1:00pm **sharp**. Assignments may be handed in in person at class; may be placed at our offices 1303 (Huirong) or 1304 (Christoph). The instructors will have office hours 2-3pm on Wed.

Show your work, and good luck!

### Question 1 - Damping of streaming instability and X-ray filaments in SNR [10 pts]

It has been observed that X-ray filaments are formed in the supernovae remanants. Generated by synchrothermal emission from Nonthermal electrons, two origins have been proposed for the filaments.

#### 1 (a)

(4 pts) Assuming that the filaments are due to energy loss of electrons, derive the minimum field strength required for the magnetic field if  $l_d = 10^{17}$ cm and  $E_e = 10 - 100$  TeV.

#### 1 (b)

(6 pts) In class, we have shown that streaming instability can be damped by turbulence. Another scenarios is that that the perturbation generated by the instability in the upstream is damped by the downstream turbulence. It is the magnetic field structure that shapes the filaments. Assuming that the growth rate of streaming instability in the upstream is zero, derive the typical length scale of the filament using the wave damping rates  $\Gamma_{fast} = \sqrt{k/L}V^2/v_A$ ,  $\Gamma_{Alf} = \sqrt{k/L}v_A$ .