

PROBLEMS INVISIBLES course J. Silk

WIMP freeze-out

1. What are limits on velocity-weighted annihilation cross-section to give the range dark matter fraction, ie $\Omega_{DM} = 0.01$ to 1.0
2. What fraction of DM has annihilated? What is diffuse annihilation flux (gamma rays, neutrinos) towards the galactic poles?
Compare with Fermi limits.

Cosmology issues

3. Calculate dark matter density at present epoch assuming a specified ratio of dark mass/light per galaxy. Compare with Planck value.
Deduce the mean mass-to-light ratio of the universe.
4. When did universe become dark matter dominated? Assume WIMP DM (Cold dark matter.
5. What is ratio of photons to baryons? Today and at epoch of 1 second.
6. Estimate the relic neutrino flux.
7. What is the required neutrino mass for the neutrinos to account for the DM.
Demonstrate that this possibility is in conflict with neutrino mass determinations

Compact bodies

8. Estimate capture rate by Sun of DM particles. What is mass fraction of Sun in DM, if particles do not annihilate, or if they do. Adopt the freeze-out cross-section.
Repeat for a neutron star.

Primordial black holes

9. Suppose DM consists of PBHs. Calculate PBH accretion rate in IGM today.
10. The Hawking temperature of a black hole is $1/8\pi M$ in units with $c=G=k=\hbar=1$. What is this in SI units.
Calculate the luminosity of a black hole?
Calculate black hole evaporation rate.
What mass black hole is evaporating today?
11. Suppose PBH are the DM. Suppose PBH form on the scale of the horizon volume. What is PBH mass if it formed at BBN epoch? QCD epoch ?
12. Suppose one PBH forms per horizon volume. What is PBH abundance per horizon volume at BBN?
What fraction of horizon volumes formed PBHS at the BBN epoch? At the quark-hadron phase transition?