Cosmology Course
problems for the oral exam
February 5th and 6th 2019

1. (a) Advantages of different parts of the electromagnetic spectrum for cosmological observations. Applications of other emissions for cosmology.
   (b) Astronomical units.
   (c) Observed structures.
   (d) The Cosmological Principle.
   (e) Olber's paradox and its solutions.
   (f) Hubble Law and the evidence for the expansion of the Universe.
   (g) Evidence for the dark matter.

2. (a) The energy-momentum tensor for the perfect fluid.
   (b) "Construction" of the FRLW metric and its application for cosmology.
   (c) The derivation of the Friedmann equations.
   (d) The covariant conservation of the energy-momentum tensor and its consequences.
   (e) Conformal time η, radial coordinate χ and the length element $d\tau^2$.
   (f) The particle horizon.
   (g) The Hubble sphere.
   (h) The velocity-distance relation in GR, the recession velocity as a function of the redshift.
   (i) Past null cone.
   (j) Derivation of
   $$\text{emission} \quad \rightarrow \quad \frac{\lambda(t_1)}{R(t_1)} = \frac{\lambda(t_0)}{R(t_0)} \quad \leftarrow \quad \text{detection}$$
   (k) Derivation of
   $$1 + z = \frac{R_0}{R}$$

3. (a) The de Sitter model.
   (b) The evolution of energy density for $p = w\rho$.
   (c) Solutions of the Friedmann equation for $k = 0$ in the presence of matter which satisfy $p = w\rho$.
   (d) The deceleration parameter and its determination.
   (e) The age of the Universe for RD with $k \neq 0$.
   (f) The age of the Universe for MD with $k \neq 0$.
   (g) The age of the Universe in the presence of matter and cosmological constant for $k = 0$.
   (h) The age of the Universe: the general case.
   (i) Future of the Universe as a function of Ω_i for $k = 0, \pm 1$.
   (j) Cosmological luminosity distance and determination of cosmological parameters Ω_i.

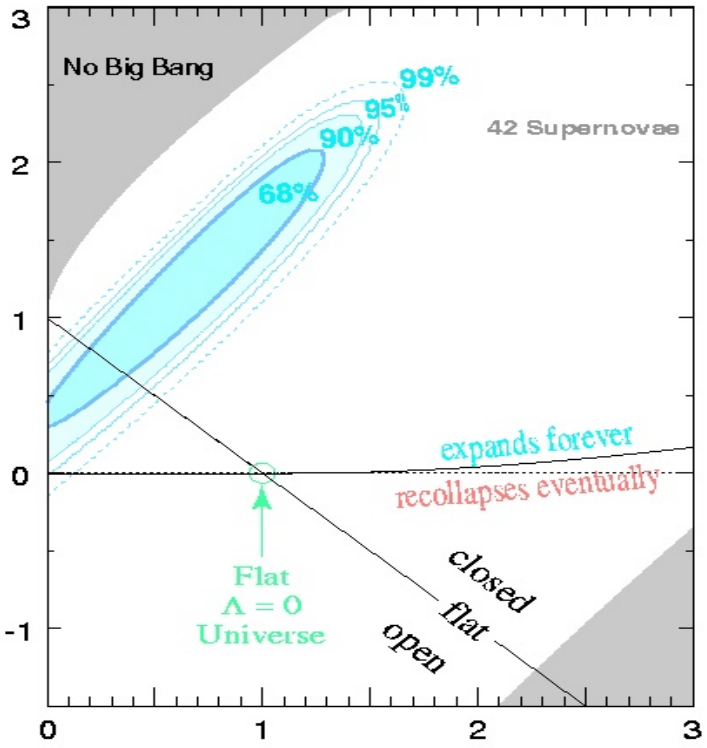

Figure 1: Confidence region for Ω_m vs. Ω_Λ plane, from SCP.

(k) Determination of distances adopting Cepheids and the period-luminosity relationship.

(l) Discuss the content of the figure 1.

(m) Distance to the particle horizon as a function of the redshift.

(n) The standard candles and the determination of cosmological parameters.

4. (a) Relations between fundamental interactions and cosmology.

(b) Number density, energy density and pressure for a gas in equilibrium. Non-relativistic and ultra-relativistic limits.

(c) Distribution functions after decoupling, massless and non-relativistic case.

(d) Relation between time and temperature.

(e) Entropy and its role in cosmology.

(f) Decoupling of neutrinos.

5. (a) The Boltzmann equation.

(b) Hot relics.

(c) Cold relics e.g. heavy stable neutrino.

(d) BBN.

(e) BBN constraints on fundamental interactions.

(f) Recombination.

6. (a) The horizon problem.

(b) The flatness problem.

(c) The basic mechanism of inflation.

(d) The horizon problem versus inflation.

(e) The inflation from a single real inflaton.

(f) Reheating