Seminar II
Strange Universe

1. General instructions

This document provides preparation instructions for the second of the two seminars forming part of the examination for the 2011 version of the undergraduate course *Cosmology*. This seminar deals with the analysis of a mock data set from which various kinds of cosmological information can be extracted.

The point of this exercise is to:

- Practice analyzing astronomical data
- Practice scientific creativity
- Practice critical thinking
- Practice presenting scientific results in front of an audience (and questioning the results of others)

In preparing for the seminar, you should try to:

- Analyze the mock data set available from the course homepage and try to extract as much cosmological information from it as possible. The questions listed in section 4 of this document may serve as guidance as to what it may be fruitful to focus on.
- Prepare to present your conclusions in front of the class. The use of Powerpoint (or similar software), transparancies or the blackboard is highly encouraged. Plots should be used to substantiate your claims.

You are perfectly welcome to collaborate with your classmates when preparing for the seminar, but once there – everyone is on their own. This means that you are not supposed to rely on the calculations, notes, viewgraphs etc. of others.

2. The background

You are a crew member on a spaceship send out to explore a recently discovered wormhole[1] in the outskirts of the solar system. As soon as you arrive at your destination, things start to go wrong. The entire spacecraft is swallowed by the wormhole and transported to some unfamiliar location in space. Many of the systems onboard are damaged in the process, and the first few months at the other end of the wormhole are spent repairing the ship. While the human crew is busy with manual labour, the automatic telescopes onboard start gathering astronomical data that will hopefully allow your new spacetime coordinates to be determined.

The ship has now been adequately fixed, and the time is ripe to start analyzing the data. The artificial intelligence onboard has already searched the sky for familiar constellations of stars and concluded that you are indeed a long way from home. The ship is apparently adrift in intergalactic space, and the Milky Way is nowhere to be seen. The captain selects some of the top cosmologists onboard and asks them to analyze the data on more distant objects to figure out where you have ended up. You are (along with your classmates) hand-picked for this prestigious task, and given access to the relevant data. After a few days of data analysis, the captain summons you to a meeting (the seminar) where you are expected to present your results.

[1] A topological defect that, in principle, may serve as a bridge from one region of spacetime to another. In the science fiction literature, is is often assumed that such objects may allow passage to far reaches of our own Universe, or even to some parallel Universe with properties radically different from of our own.

3. The data set

The data set, which is downloadable as an ascii[2] file from the course homepage, contains the sky coordinates, redshifts, luminosity distances and sky coordinates of 250 galaxies at redshifts $z < 0.2$. The format of this file is:

- **Column 1:** Sequential galaxy number
- **Column 2:** The inclination Θ (where $0° \leq \Theta \leq 180°$) of each object on the celestial sphere (unit: degrees)
- **Column 3:** The azimuth φ (where $0° \leq \varphi \leq 360°$) of each object on the celestial sphere (unit: degrees)
- **Column 4:** The redshift z of each galaxy, as derived from emission or absorption lines (unit: unitless)
- **Column 5:** The luminosity distance D_L of each galaxy (unit: Mpc).

These objects represent a random, volume-limited sample of some of the most massive galaxies at $z < 0.15$. The errorbars on Θ, φ and z can be assumed to be negligibly small, whereas the D_L measurements can be assumed to have a relative error of 20%. Please note that the direction corresponding to the origin of the astronomical coordinate system (Θ,φ) has been arbitarily chosen and is of no relevance for this exercise. The luminosity distances are based on measurements of cepheid variables in the target galaxies. The artificial intelligence onboard has carefully scrutinized the light curves and spectra of the cepheids, but found nothing that would suggest that these objects are any different from the cepheids found in your familiar Universe.

4. Topics to explore

Here is a list of some of the issues that in principle can be addressed with the available data set. You are of course welcome (and highly encouraged) to explore other properties of the data as well. If you discover interesting anomalies in the data, then please try come up with possible explanations for them. If there are more than one explanation for any given phenomenon, then please also try to think about what further observations could help discriminate between the different alternatives.

- What is the expansion rate (Hubble parameter) of this Universe?
- Is this Universe homogeneous?
- Is this Universe isotropic?
- Has the wormhole transported you to a different Universe, or are you still in the Universe where you left off?
- Is there anything to suggest that you have traveled in time?

Erik Zackrisson, October 2011

[2]i.e. a regular text file, which you should be able to open in any text editor or load directly in *Matlab* or *Octave* using the *load* command.