Ph 444   Problem Set 2

Due: Friday, September 19, 2014

1. A simple model for the lumpiness of the universe is that all of the matter is collected into clumps, each of mass m_c, with a number density n_c. These clumps could represent galaxies, clusters of galaxies, or even superclusters (clusters of galaxy clusters). In this problem we will focus on the simple situation where just one kind of clump is present and see what this implies for the typical departure from homogeneity in spherical volumes of increasing size.

   a. Assume that the clumps are placed at random such that each small volume of space, dV, has a uniform probability, $n_c dV$, of containing the center of a clump. Then the number of clumps seen in a volume V has a Poisson distribution. What is the average number of clumps, N, expected in volume V? In a sample of many different spheres, what will be the standard deviation of N, σ_N, about its mean?

   b. If the clusters are the only mass in the universe, how does the average fractional deviation of the mass in a sphere, σ_M/M, vary with M? You should get a power-law dependence on M. How does your result compare to the observed dependence, which is approximately $\sigma_M/M \propto M^{-2/3}$ for large spheres?

   c. Let the clumps represent clusters of galaxies. Then $m_c = 10^{12}$ $M_\odot$ and $n_c = 4 \times 10^{-5}$ clusters/Mpc^3. (This cluster mass and number density yield the observed density of matter in the universe. Clusters are actually less common than this since not all galaxies are in clusters.) What is σ_M/M for a sphere with a radius of 100 Mpc? For a sphere with the Hubble radius of 4300 Mpc?

2. This problem will give you some experience with the Aladin Sky Atlas server by examining a notable location on the sky. Start the server using the link on the class home page (http://vizier.hia.nrc.ca/viz-bin/nph-aladin.pl; the US mirror is not working currently).

   a. Under the "File" menu, select "Load astronomical image" and then the "Aladin image server". In the window that appears, make sure that the "Aladin images" tab is selected under Image servers (it starts with this being the case) and type the following Right Ascension and Declination coordinates into the target box: 12 59 48.7 +27 58 50. Type a radius of 5 arcmin into the Radius box and push the Submit button. This will return a list of images. Select the topmost POSSII F image and the topmost 2MASS K image and push the Submit button. This will load images from these two surveys into the image stack. Note how you can switch which image is displayed by clicking on an image in the stack. With the POSS image displayed, push the assoc button to the right of the image

and create a blink plane with your two images. View this plane. Which image appears to show the fainter objects, POSS or 2MASS?

b. Select the VLA tab under Image Server in the server selector (NOT "image" from the menu at the top of the window), select the VLA FIRST survey from the pull-down menu, request a 7' radius, and push the submit button. This loads an image of the intensity of radio emission at 1.4 GHz as a function of position on the sky. Create a blink plane of all three images. What does the radio image show?

c. Select the "All Vizier" tab on the right-hand side of the Server Selector window. Select "Clusters of galaxies" from the Astronomy list and push submit. Select the "Abell and Zwicky Clusters of Galaxies" catalog from the resulting list and push submit on that window. Click on the symbol in the image that represents a catalog entry. Report the number of this cluster in the Abell catalog and the richness group (n) of the cluster as determined by Abell.

d. Next select "Galaxies" from the Vizier window, push submit, select the HY-PERLEDA entry from the list of catalogs, and push select there to display the entries. What is the PGC catalog number for the two brightest galaxies in the image (to the left and right of the center of the POSS image)? Click on the "alternate names" box of the catalog line that displays after clicking on the catalog symbol in the image to bring up the full catalog entry in a separate window. Use this to determine the NGC number of the two brightest galaxies.

e. Select the "Surveys" tab on the Server Selector window and select the 2MASS Point Source Catalog. Push submit to display the sources detected by 2MASS in this field. What is the K magnitude measured by 2MASS for the left-hand of the two bright galaxies? What is the K magnitude of the bright star in the upper-right corner of the POSS image?

3. Ryden problem 3.2

4. Ryden problem 3.3