Astrophysik II: Galaxien und Kosmologie

WS17/18

Übungsblatt 5

22.11.2017

Aufgabe 1. *Calculating the mass of the Coma-galaxy-cluster*
In 1933 Fritz Zwicky made some assumptions to calculate the masses of different galaxy clusters. We try to follow his way of thinking and calculate the mass of the Coma-cluster.

(a) First of all we need to derive a general form of the virial theorem. You can do that by using classical mechanics. Proof that the following equation is valid.

$$\langle T \rangle = \frac{\alpha}{2} \langle V \rangle, \tag{1}$$

with $\langle T \rangle$ as the time average of the kinetic energy and $\langle V \rangle$ as the time average of the total potential energy of the system. Hint: Use the simplification of a power law potential using the Ansatz $V(r) \propto r^{\alpha}$

(b) Now look at the special case of gravity. Show that you obtain the following result if gravity is acting:

$$\langle T \rangle = -\frac{1}{2} \langle V \rangle. \tag{2}$$

(c) Back in 1933 Zwicky made the assumption, that a galaxy cluster is an object which contains a large number of objects. Further he stated the galaxies in the cluster are homogneous distributed, within the cluster. Assume that the cluster is a perfect sphere with finite radius R and mass M. Using this assumptions, calculate the clusters gravitational potential.

(d) Use (b) and (c) to write down a formula for the mass of the galaxy cluster.

(e) Can you imagine any difficulties concerning the Ansatz of Zwicky?
Hint: You have to cancel out the factor of 3 in the denominator. Think about why.

(f) By now, you should have found a formula where the mass of the cluster only depends on its Radius, and the double averaged velocities of the galaxies in the cluster (and some constants). Observers do not know the double averaged total velocities. They know the line of sight velocities. They are conected via:

$$\bar{\bar{v}}^2 = 3\bar{\bar{v}}^2_{L.O.S.} \tag{3}$$

Write down the final formula, Zwicky found back in 1933. Hint: Zwicky's result is: $M = 3R\bar{\bar{v}}^2_{L.O.S.}/5G$

(g) The radius of the Coma cluster is $2 \cdot 10^6$ light-years and its $\bar{\bar{v}}^2_{L.O.S.} = 5 \cdot 10^{15} cm^2 s^{-2}$. Calculate the mass of the cluster in solar masses.

(h) Zwicky counted arround 1000 galaxies in the cluster. Calculate the average mass of each galaxy. Further he determined the avergae luminosity to $8.5 \cdot 10^7$ solar luminosities. Calculate the mass to light ratio for the system and compare to the Kapteyn stellar system with a mass to light ratio of 3. What is the conclusion that you can draw from this.

(a) 1 point; (b)+(c) 1 point; (d)+(e)+(f) 1 point; (g)+(h) 1 point