Astrophysik II: Galaxien und Kosmologie

WS17/18

Übungsblatt 10

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Aufgabe 1. *Dynamical Friction*
Under the assumption of an isotropic velocity distribution one can obtain Chandrasekhars dynamical friction formula:

$$\frac{d\mathbf{v}_M}{dt} = -16\pi^2 G^2 M m_a \ln\Lambda \left[\int_0^{v_M} dv_a v_a^2 f(v_a)\right] \frac{\mathbf{v}_M}{v_M^3} \tag{1}$$

(a) Describe the process of dynamical friction, using your own words (1 point).

(b) Use equation (1) to derive a dynamical friction formula for small v_M (1 point).

(c) Use equation (1) to derive a dynamical friction formula for large v_M (1 point). Hint: For large v_M the integral from (1) gives the number density divided by a constant.

(d) Under the assumption of a maxwellian distribution for the velocity ($f(v_a) = \frac{n}{(2\pi\sigma^2)^{3/2}} \exp(-v_a^2/2\sigma^2)$) derive a friction formula from equation 1 (1 point). Hint: The solution to this task is: $\frac{d\mathbf{v}_M}{dt} = -\frac{4\pi M \rho \ln\Lambda}{v_M^3}\left[erf(X) - \frac{2X}{\sqrt{\pi}\exp -X^2}\right]$ with $X = v_M/(\sqrt{2}\sigma)$

(e) Use the result of (d) to derive the effect of dynamical friction on a black hole in an isothermal sphere with the denisty profile $\rho(r) = v_c^2/4\pi G r^2$. Find the force on the black hole caused by dynmaical friction for X=1 (1 point).

(f) Calculate the angular momentum loss of the black hole (1 point).

(g) Use the time derivative of the angular momentum $L = Mrv_c$ to derive a differntial equation of the form:

$$r\frac{dr}{dt} = -0.428 \ln\Lambda \frac{GM}{v_c} = -0.302 \ln\Lambda \frac{GM}{\sigma}. \tag{2}$$

Solve this equation under the assumption that $ln\Lambda$ is constant. This will lead to a formula for the friction time, which the black hole needs to fall to the center (1 point)

Aufgabe 1. *Quick Questions*

(a) Describe the process of star formation qualitativly (1 point)

(b) Make a sketch of the Hertzsprung-Russel (HR) diagramm and explain the different types of stars using the HR-diagramm (1 point).

(c) Use the sketch of (b) and overplot the Hayashi-line and discribe its meaning (1 point)

(d) What is the cosmic microwave background? (1 point)

(e) Look up and describe the Sunyaev-Zeldovich effect (1 point)

(f) Describe qualitativley how you can use the Sunyaev-Zeldovich effect to calculate the mass of a galaxy cluster (1 point)