Assigned: Friday, November 26, 2021 **DMDE Exercise 3**
Due: 13:00, Wednesday, December 15, 2021 25 points

Note that submitted solutions should be in PDF format and include the code that produced your plots! Submissions without code will not be graded! Send any questions to hannah.mccall@uni-bonn.de, or attend office hours on Fridays!

Problem 1: X-ray Mass Profile (10 points)

The gas density profile of a cluster is given by $\rho_{gas}(r) = \rho_{gas}(0)\left(1 + \frac{r^2}{r_c^2}\right)^{-1}$, while the temperature profile is given by $T_{gas}(r) = T_{gas}(0)\left(1 + \frac{r}{7r_c}\right)^{-1.6}$.

a) Determine the X-ray mass profile of the cluster, $M_{tot}(< r)$, using equation 3.1 in the lecture notes and the above profiles. Your final equation should contain known constants, r_c, r, and $T_{gas}(0)$. (4 points)

b) Using $r_c = 0.15$ Mpc and $T_{gas}(0) = 3$ keV, plot $M_{tot}(< r)$. Describe and explain the shape of the plot. (3 points)

c) Determine r_{500} and M_{500} numerically. Remember: r_{500} is the radius within which the mean mass density of the cluster is 500 times greater than the critical density of the Universe, and M_{500} is the mass within this radius. (3 points)

Problem 2: Galaxy Cluster Mass (15 points)

For this problem, use the data found in `Mgas_Mstell.txt` on eCampus.

a) Plot M_{tot} and $M_\star$ vs. M_{gas} and comment on the plots. (5 points)

b) Plot the gas fraction f_{gas} and the baryon fraction f_b vs. M_{gas} and comment on the plots. Note that you will need to calculate the fractions from the provided data. (7 points)

c) Measuring only the gas mass M_{gas} of a cluster, can we estimate its total mass? (1 point)

d) Compare the measurements of f_b from this question with the universal baryonic mass fraction $\frac{\Omega_b}{\Omega_m}$. Does it seem like a reasonable assumption that clusters are representative of the mass distribution of the Universe? (2 points)