ZAH - Astronomisches Rechen-Institut
Galactic and Extragalactic Astronomy (MVAstro3) - Winter semester 2021
Hitesh Lala `Hitesh.Lala@uni-heidelberg.de`

Exercise Sheet #5

Submit by Friday 26-03-2021

Exercise 1. - Metallicity of the Galactic bulge, Large and Small Magellanic clouds
RR Lyrae stars are invaluable tracers in the study of Galactic structure and history. They can be used to study the chemical composition of old stellar populations through simple empirical relations and photometric data.

The Optical Gravitational Lensing Experiment (OGLE survey) observes the densest stellar regions of the Milky Way and of two nearby satellite galaxies (the Large and Small Magellanic Clouds) with a prime focus on searching for gravitational microlensing events. It also produces a large catalog of variable objects, especially pulsating variables like RR Lyrae stars.

(a) Go to the OGLE website (links in the footnote [1]) and download the files containing a list of RR Lyrae stars that lie in the direction of the Galactic bulge, and the Large and Small Magellanic Cloud (LMC and SMC). The description for all three files can be found here: `ftp://ftp.astrouw.edu.pl/ogle/ogle4/OCVS/blg/rrlyr/README`

The relation from Smolec (2005) connects light curve parameters with metallicity:

$$[\mathrm{Fe/H}] = -3.142 - 4.902 \cdot \mathrm{Period} + 0.824(\varphi_{31} + \pi), \tag{1}$$

where φ_{31} is a Fourier coefficient. Calculate the metallicity for RR Lyraes in all three systems, plot its distribution and determine its median values. In addition, calculate also a mean period for all three systems.

(b) The actual values for the median metallicities for the Galactic bulge, LMC and SMC, calculated using RR Lyraes, are $[\mathrm{Fe/H}]_{\mathrm{bulge}}$ = -1.02 dex, $[\mathrm{Fe/H}]_{\mathrm{LMC}}$ = -1.39 dex and $[\mathrm{Fe/H}]_{\mathrm{SMC}}$ = -1.77 dex. The Galactic bulge has a distance of $\sim$ 8 kpc from us, the LMC is $\sim$ 50 kpc away, and the SMC $\sim$ 60 kpc. Discuss what could have caused the difference between your and the actual values.

(c) From table 2 in article *Catelan, M. 2009, Ap&SS, 320, 261*[2], extract values of mean periods and metallicities for globular clusters and plot them together with values obtained from part a) in a period vs. [Fe/H] plot and and briefly comment.

(40 points)

Exercise 2. - G-dwarf problem

1. What are the possible explanations for G-dwarf problem? (10 points)

   (a) It just wasn't in the cards...

   (b) Illuminati with their acolytes are responsible...

---

[1] `ftp://ftp.astrouw.edu.pl/ogle/ogle4/OCVS/smc/rrlyr/RRab.dat`
`ftp://ftp.astrouw.edu.pl/ogle/ogle4/OCVS/lmc/rrlyr/RRab.dat`
`ftp://ftp.astrouw.edu.pl/ogle/ogle4/OCVS/blg/rrlyr/RRab.dat`

[2] `https://arxiv.org/pdf/astro-ph/0507464.pdf` Contact me if you cannot extract the table.

(c) Something else, and please elaborate.

A simple way of describing the chemical enrichment of a galaxy is the so-called "closed-box-model". Assuming no in- and out-flow of gas in the Galactic disk, this model describes how the gas is enriched with time, starting from an initial metallicity Z_0, with metals formed in stars and released (for e.g.,) through supernova explosions. Once all the gas has been used up, the mass of stars dM with metallicity between Z and $Z + dZ$ can be described as follows:

$$\frac{dM}{dZ} \propto \exp\left(-\frac{Z - Z_0}{y}\right), \tag{2}$$

where y is the yield, which is assumed to be constant. Derive an expression for the total mass of stars with metallicity below a given value Z'. (10 points)