Computation for astronomers

Graded practical IV

Rules: The product of this exam will be a laboratory report — written in English — that you must send to mederic.boquien@uantof.cl by the 14th of April 2020 at 08:30 at the latest. The mark will be based not only on the ***correctness of your results*** but also on the ***clarity of your answers***, on the ***justification of the choices*** you have made, on providing ***adequate illustrations*** (e.g., if your code produces images, it is expected that you show a representative sample), and on the ***quality of the code*** (proper use of classes, functions, etc.) you have written (it must run without errors, be well-structured, adequately commented, etc.). ***Answers provided without justification will be considered incorrect***. You have the right to access documentation and resources over the Internet but this remains an individual work. You must ***not*** work together in any substantial manner among yourselves. If a snippet of code is reused from a website it must be clearly indicated.

Recommendations: Make good use of the 2 hour in-class session at the beginning of this practical exam. Clarify any doubt you may have on the topic. Then do not wait until the last minute to produce a report, it will be too late. Start early and work regularly to avoid any last-minute panic.

Dust emission … in parallel!

After some time working on Gaia, you see Dulcinea again. She is very happy with your help regarding the computation of the dust models last time. She is wondering whether you would be willing to assist her again in her world-class investigations. Now what she would like is to fit the dust emission of galaxies with the models developed by Bruce Draine. She would do it herself but between classes, administration and everything, she has little time left for her own research. She explains to you that this can be done in two main steps. First the computation of a grid of models to determine the monochromatic luminosities and physical properties of each model. Then these models can be fitted to observations to determine the best fit and Bayesian estimates. You tell that you recently learnt how to write a ***parallel*** software in python and that is a great opportunity to apply your new knowledge while reusing the work you have already done with the Draine models.

She rejoices at your offer and she explains to you in more detail what she wants from you.

1. You will compute a grid of models ***in parallel*** by sampling the different input parameters of the model.
    a. You will compute all the combinations of the discrete values of the Draine & Li models. You will sample γ, logarithmically from log γ=-3.0 to log γ=-0.3 (look at the np.logspace() function) with 10 elements. Dulcinea mentions that you can create an iterator to pass the parameters to the sub-processes (e.g, `((p1, p2, p3) for a in list_a for b in list_b for c in list_c)`) with `Pool.starmap()`.
    b. For each model the physical properties and the monochromatic luminosities in W/Hz/(kg of H) in the 24 (`MIPS1`), 70 (`PACS_blue`), 100 (`PACS_green`), 160

(`PACS_red`), 250 (`PSW`), 350 (`PMW`), and 500 (`PLW`) micron bands will be kept in ***RawArray*** objects (one for each ***property*** or ***monochromatic luminosity***). You can compute the luminosities in W/nm/(kg of H) as you did in the past and then convert to W/Hz/(kg of H) remembering that $\lambda L_\lambda = \nu L_\nu$ with λ the pivot wavelength as given in Equation 12 of https://www.aanda.org/articles/aa/pdf/2019/02/aa34156-18.pdf.

2. After the grid of models has been computed, you will fit ***in parallel*** these models to the catalog of objects she has provided to you. That is, each subprocess will fit all the models to one galaxy (you can pass the fluxes and the distance as parameters in `Pool.starmap()`) and several subprocesses will do so in parallel.
    a. First the ***monochromatic luminosities*** need to be converted to mJy[1]. Thankfully you notice that the input catalog already provides the distances in Mpc.
    b. Then you will fit all the models to that galaxy by computing the χ^2. Dulcinea specifies that this corresponds to the first term of Equation 14 in the aforementioned article. The value of α is defined in Equation 13 (again, only the first term). You will store both χ^2 and α in a local array as you will need to use them very soon.
    c. You will determine the best-fit and the associated parameters by finding the models with the smallest χ^2. The ***extensive*** physical properties will need to be multiplied by α to obtain their correct values.
    d. You will determine the Bayesian estimates. To do so you will compute the likelihood[2]-weighted mean of each physical property. You will take the likelihood-weighted standard deviation as the uncertainty. As before, the **extensive** physical properties will need to be multiplied by α.
    e. Finally you will save the best-fit and Bayesian estimates in a FITS table created with `astropy`. Dulcinea specificies she wants estimates of the parameters of the models but also of the dust mass[3], and the total infrared luminosity[4].
3. Finally she wants you to plot your dust masses and total infrared luminosities against the values published in table A1 in https://www.aanda.org/articles/aa/pdf/2019/01/aa34212-18.pdf. Hopefully you should find something very similar.

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[1] 1 Jy = 10^{-26} W/Hz/m².
[2] We will take the likelihood as $\exp(-\chi^2/2)$.
[3] Assume that the mass of H is about a hundred times higher than the dust mass and that the models are initially normalized to 1 kg of H, so α gives the mass of H.
[4] You can approximate this as the bolometric luminosity of the models.