ANSWERS

Part 1. ● With the parallax we get the distance: $D = \frac{1}{parallax} = 48.38\ pc$, **[1 pt]**

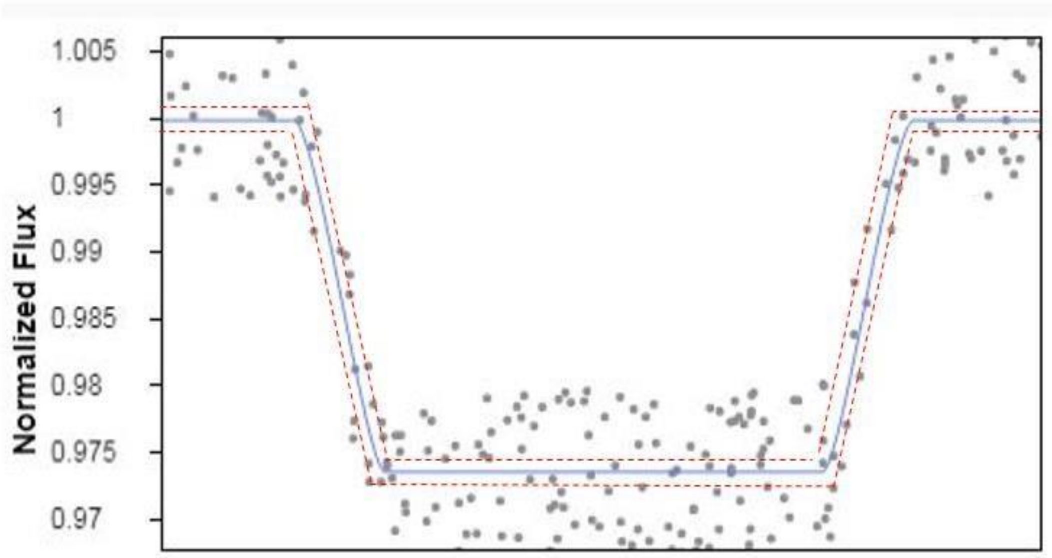
then we get the absolute magnitude using the distance modulus $M_V = m_v - 5\ log_{10}(D) + 5 = 4.2067$, **[1 pt]** and finally we go for the luminosity

As BC is assumed to be the same for all F/G stars, $(M_V - M_{V_\odot}) = (M_{bol} - M_{bol\odot})$ **[2 pt]** by comparing with the magnitude of the Sun: $\frac{L}{L_\odot} = 10^{-0.4(M_V - M_{V_\odot})} = 1.759$. **[1 pt]**

- We find the stellar radius from the Stephan-Boltzmann law, which in solar units leads to $\frac{Teff_\star^4}{Teff_\odot^4} = \frac{R_\star^2}{R_\odot^2}\frac{L_\star}{L_\odot}$ **[2 pt]**, i.e., $R_\star[R_\odot] = \sqrt{\frac{L_\star[L_\odot]\,Teff_\odot^2}{L\,Teff_\star^2}} = 0.808$. **[2 pt]**
- Now to find the stellar mass consider the surface gravitational acceleration, which for Gauss' law and spherical symmetry considerations is: $g = G\frac{M_\star}{R_\star^2}$, **[1 pt]** then one solves $M_\star$ for and puts it in the right units, $M_\star = 0.825\ [M_\odot]$ **[3 pt]**
- Planet's orbital radius comes from $a = \sqrt[3]{\frac{GMT^2}{4\pi^2}} = 0.0425\ A.U$ **[3 pt]**
- Finally, checking the dimming due to the transit this is of approximately 2.6%, which is give by the ratio between the areas of the planet disk and the stellar disk, i.e., $\left(\frac{R_p}{R_\star}\right)^2 = 0.026$, **[2 pt]** leading to $R_p = 1.296\ [R_J]$ **[2 pt]**

Luminosity of the star	Radius of the star	Mass of the star	Mean planet's orbital radius	Radius of the planet in Jupiter's radius
$L_\star[L_\odot]$	$R_\star[R_\odot]$	$M_\star[M_\odot]$	$a\,[au]$	$R_p\,[R_J]$
1.759	0.808	0.825	0.0425	1.296

Tolerance: one digit in the second decimal position



Part 2.

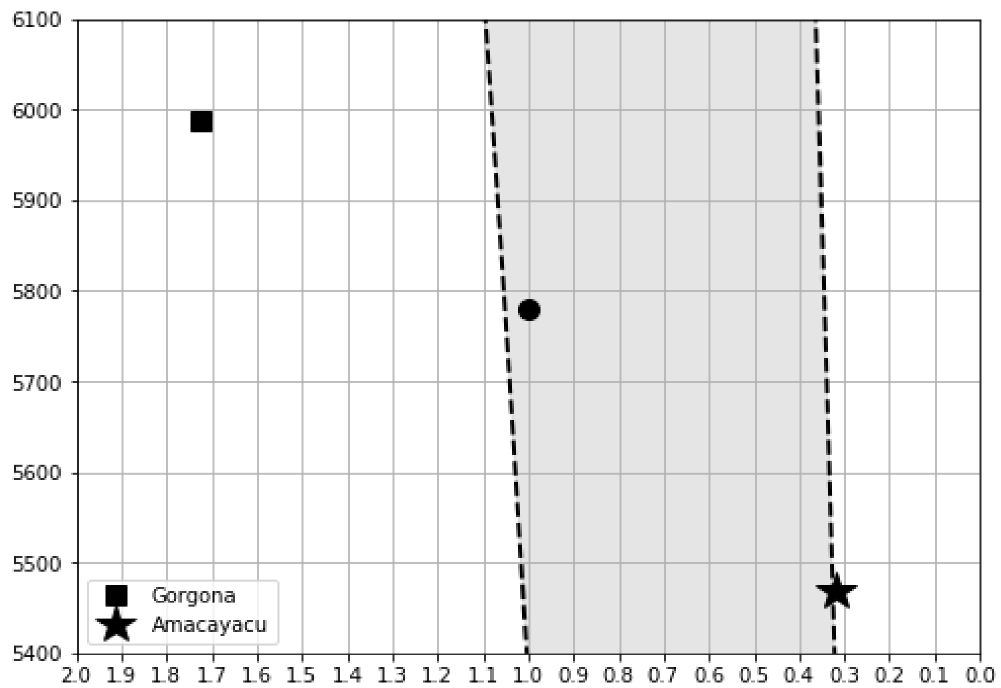
2.1) One first needs to calibrate the axes. The shown circle representing the Earth gives as a vertical mark in 5778 °K, and a horizontal one at $S_{eff} = 1$. Then one need to retrieve additional data from one or more of the additional observations:

- Having the temperature mark for the Sun, one can estimate S_{min}, adding a second mark on the horizontal axis, so the scale of this one can be calibrated. Then one can proceed backwards, starting from a given value of S_{min} or S_{max}, find the corresponding temperature, so the vertical axis can be calibrated as well.
- Alternatively, one can notice that the limiting S_{max} curve crosses the X axis in $S_{eff} = 1$, and look numerically for the corresponding temperature of the bottom line, thus calibrating the vertical axis. Then starting from a given temperature, one calibrates de horizontal one pivoting on S_{min} / S_{max} calculations as explained before.

  There are several ways, some more precise than others. The student should be as careful as possible (we give small tolerance to the error in the calibrations of the axes). A tricky part is that the X-axis increases towards the left, but this is something rigorous students will discover, as there is no self-consistency otherwise. Intuition may also help if one knows that Earth is closer to the high-flux end of the Sun's habitable zone.

- The luminosity of Gorgona's host star was found in Part A. After finding the luminosity of Amacayacu's one the final plot looks like this:

For placing Gorgona in the right position [2 pt]



For calculating flux and placing Amacayacu in the right position [4 pt]

Grading Scheme:

TOTAL: 15 pts

Points should be given to partial achievements like:

- Horizontal axis - **[4 pt]** – sun position - **[1 pt]**
- Vertical axis - **[5 pt]** – sun position - **[1 pt]**

2.2) NONE of the exoplanets lie in habitable zones. They orbit their stars too close, so the effective flux is many times larger than S_{max}. The long-but-straightforward answer is to perform all the calculations. The elegant, clever one, is to note that Amacayacu orbits the faintest/coolest star, and it is the one farthest away, so its effective flux is the absolute minimum of the whole set. This effective flux was calculated as ~0.3 in A), assuming a distance of 1 A.U. With the real distance, 0.08 A.U, it grows by a factor $\frac{1}{0.08^2} \sim 156$., i.e., it has $S_{eff} \sim 46$,, but the habitable zone

for this range of temperatures can not exceed $S_{eff} \sim 1.1$, which completely closes the case.

Grading Scheme [10 pts]:

- **9 pts** If the student argues about the case of Amacayacu as limiting case, concluding that none of the exoplanets lie in the HZ, even if the flux is wrongly calculated. **1 pt** additional for getting Amacayacu's Seff with 10% error or less.

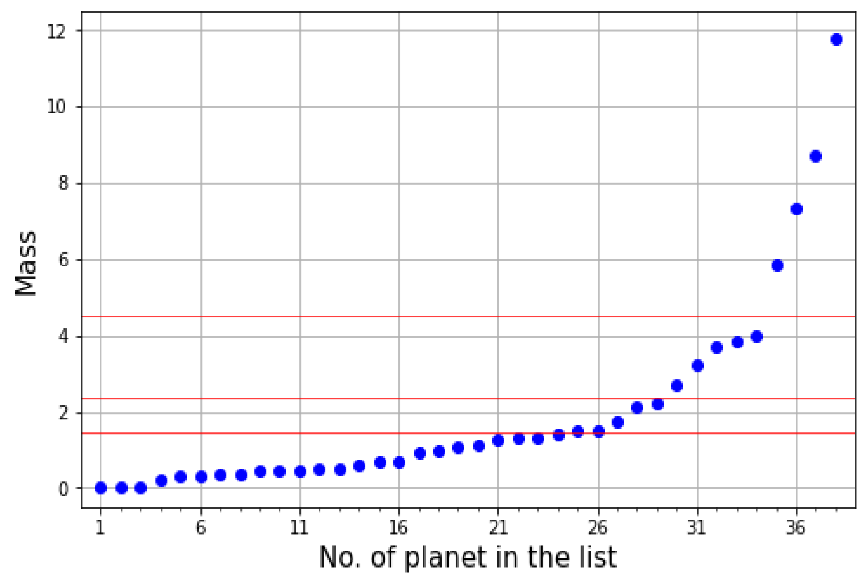
If the student applies an exhaustive solution:

- Each effective flux must be calculated correctly up to a 10% , giving **1 point** per each Seff. **3 additional pts** for explaining that all these fluxes are way too much for the HZ, which can only be awarded if all the 7 fluxes are correct. This is because it is pointless to argue about calculating numbers and comparing, if you do not calculate well. **Part 3.**

3.1) 3 pts per each row. 1 pts extra for the only number in the last row.

Low-mass sample	Sample size	μ	σ	$\mu + \sigma$	No. of planets to exclude
Full / Original	38	1.99	2.55	4.54	4
1st subsample	34	1.23	1.11	2.34	5
2nd subsample	29	0.84	0.61	1.45	5
Final subsample	24	-	-	-	-

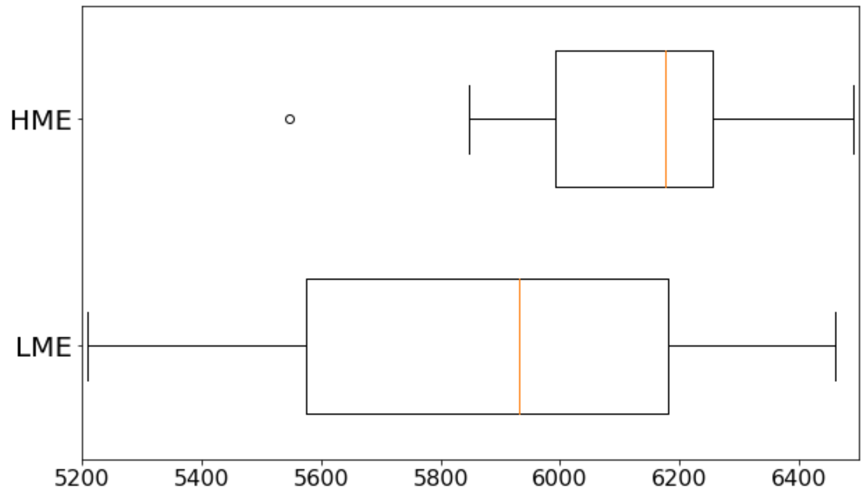
3.2) **Graph plotting technique: Coverage [1 pt], labelling [1 pt], correct plotting [1.5 pt], horizontal lines [0.5 pt x 3]**



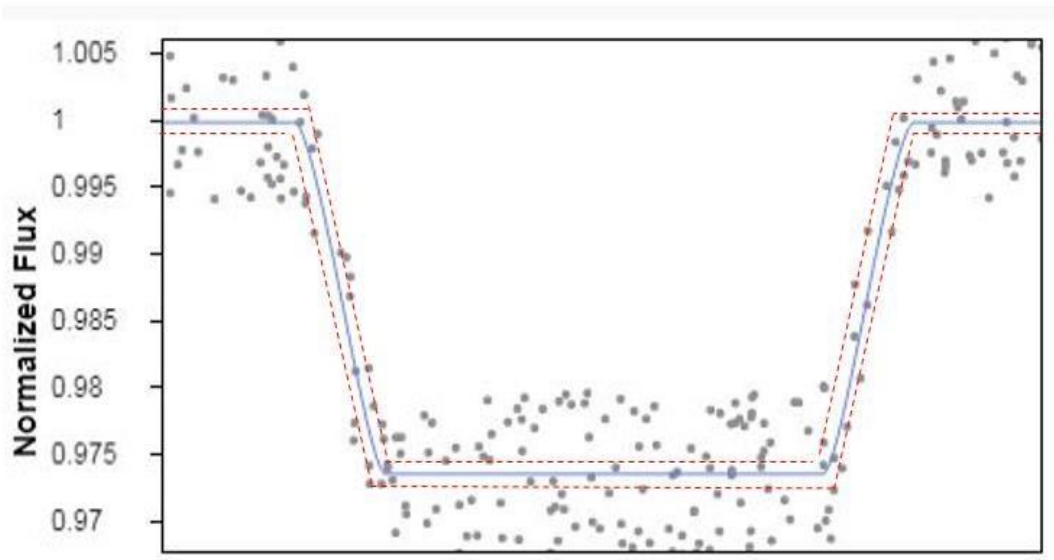
3.3) **1.5 pts** for each quartile, **1 pt** for each median. Tolerance 5%. 0.5 for each min and max

T_{eff}	Min.	1st Quartile	Median	3rd Quartile	Max
LME	5209	5574.5	5932.5	6181.75	6460
HME	5548	5992.5	6177.0	6255.0	6490

3.4) **Boxplot [1.5 pt] x 2, outlier [1 pt]**



Yes, the boxplots indicate that HMEs tend to get formed around hotter stars. **[1 pt]**


Normalized Flux
1.005
1
0.995
0.99
0.985
0.98
0.975
0.97