Problem Set #6

Due Friday, December 8 at 5pm

Please indicate the time spent on the assignment and list any collaborators. You can submit the assignment by emailing a single PDF to dressing@berkeley.edu or by placing a hard copy in my mailbox or under my door (Campbell 605E).

1. Science Journalism: New planet discovered!

The discovery of the planet Ross 128 b made headlines this week. Answer the following questions after reading the press release issued by the European Southern Observatory (https://www.eso.org/public/news/eso1736/), the referred journal article by Bonfils et al (2017, accepted to A&A, doi:10.1051/0004-6361/201731973, http://adsabs.harvard.edu/cgi-bin/bib_query?arXiv:1711.06177), and two Ross 128 b news articles of your choice. Include references to your news articles along with your assignment and pick articles from publications with different styles. If you selected an article in a major newspaper for the first article, you might pick an article from a blog or astronomy magazine for the second article. At least one of your two articles should be from a reputable source.

a. In your own words, how did Bonfils et al. (2017) detect the planet and what do they know about the system?

b. The titles of the article and press release both refer to Ross 128 as a "quiet star." What does that phrase mean and what are the implications for planet detection and habitability?

c. Do you find this discovery exciting? Write a few sentences about why or why not.

d. Referring back to Problem Set #3 and assuming that Ross 128 b has an Earth-like composition, estimate the radius of the planet (in Earth radii) and the transit depth.

e. How does the transit depth compare to the precision of the K2 photometry?

f. Unfortunately, the K2 photometry did not display any transits. Is that surprising? (i.e., what is the geometric likelihood of transit for a planet with the orbital period of Ross 128 b?)

g. How do Bonfils et al. (2017) propose to learn more about Ross 128 b in the future?

h. In your opinion, how well does the ESO press release summarize the paper? Using citations from the press release, identify a few passages that accurately or inaccurately capture the underlying science. If you find any misleading or false statements in the press release, indicate how you would correct those aspects of the press release. Consider the images, videos, and associated captions in addition to the main text of the press release.

i. Repeat question (h) using a news article of your choice.

j. Repeat question (h) using a second news article of your choice. Remember that this article should be from a different style of publication.

2. Biosignatures

a. What are biosignatures?

b. Referring to Schwieterman et al. (2017; arXiv:1705.05791), describe six potential biosignatures from Earth-like planets. Include examples of gaseous, surface, and temporal biosignatures.

c. Consulting Meadows et al. (2017, arXiv:1705.07560), describe three false positive scenarios in which the detection of O_2 does not mean that a planet is inhabited.

d. How would you look for these potential biosignatures? At which wavelengths would you like to observe and how would you acquire the observations?

3. Guest Lectures

a. Write two things you learned from Monday's class with Howard Isaacson.

b. Write two things you learned from Wednesday's class with Lea Hirsch.

4.* For Experienced Programmers: *Probing the atmosphere of the mystery planet!

In this problem, you will investigate the atmospheric composition of our (in)famous mystery planet.

a. Eliza Kempton's `Exo-Transmit` code is a publicly available package for modeling exoplanet transmission spectra. Download the code from her GitHub page (https://github.com/elizakempton/Exo_Transmit) and complete the installation by following the instructions in the provided `README` and `USR_MANUAL.txt` files. **Do this step early so that you don't run into installation problems right before the deadline.**

b. Following the instructions in the "sample run of program" section of the `USR_MANUAL.txt`, modify the input files to generate a model atmosphere. Include the modified input files and a plot of the resulting spectrum in your submitted problem set.

c. Now change the input parameters to match those of the mystery planet and repeat part (b). Recall that the host star is a mid-M dwarf with $M_\star = 0.157\,\mathrm{M}_\odot$, $R_\star = 0.211\,\mathrm{R}_\odot$, and $T_{\rm eff} = 3026$ K. Assume that the planet has a radius of $2.7\,\mathrm{R}_\oplus$ and a mass of $6.6\,\mathrm{M}_\oplus$. Show your work when calculating derived quantities (e.g., surface gravity and equilibrium temperature) and justify your choices for the unknown parameters. Include the modified input files and a plot of the resulting spectrum in your submitted problem set.

d. Repeat (c) using two additional sets of assumptions for the unknown parameters. At least one of these new models should include clouds.

e. Surprise! Your friends somehow managed to give you *HST* observations of the mystery planet for your birthday. Your friends signed your birthday card using the codename "WFC3." What is the meaning behind that nickname?

f. Download your new data from the website and plot the transmission spectrum of the mystery planet.

g. Produce a second figure showing both the HST data and your simulated spectra. How do they compare?

h. Experiment with the `Exo-Transmit` input parameters to try to reproduce the observed data. Describe your findings and include a plot of your best-fit spectrum.

i. Were you able to determine the composition of the mystery planet's atmosphere? If so, verify that the planet would be able to retain the atmosphere and comment on whether the result is consistent with current theories of planet formation and evolution. If not, which additional observations would be most helpful for breaking lingering degeneracies? Which facilities might be able to obtain those data?

5. For Experienced Programmers: *Is anyone home?*

The following data sets may or may not contain planetary signals. Analyze the data sets using the skills you've acquired in C249 and report any signs of planets. You will likely need to use *periodograms* to determine the periods of any potential planets. The Lomb-Scargle periodogram is often used for radial velocity data while transit hunters typically employ box-fitting least squares periodograms. (There's a Lomb Scargle package in Astropy.) Remember that planets are not the only explanation for changes in radial velocity or decreases in brightness. Have fun!

a. Photometric observations of a star with $M_\star = 0.912\,\mathrm{M}_\odot$, $R_\star = 0.944\,\mathrm{R}_\odot$, and $T_{\rm eff} = 5460$K.

b. Photometric observations of a star with $M_\star = 0.13\,\mathrm{M}_\odot$, $R_\star = 0.17\,\mathrm{R}_\odot$, and $T_{\rm eff} = 3068$K.

c. Photometric observations of a star with $M_\star = 1.17\,\mathrm{M}_\odot$, $R_\star = 1.56\,\mathrm{R}_\odot$, and $T_{\rm eff} = 5670$K.

d. Photometric observations of a star with $M_\star = 0.54\,\mathrm{M}_\odot$, $R_\star = 0.52\,\mathrm{R}_\odot$, and $T_{\rm eff} = 3755$K.

e. Photometric observations of a star with $M_\star = 1.03\,\mathrm{M}_\odot$, $R_\star = 1.07\,\mathrm{R}_\odot$, and $T_{\rm eff} = 5690$K.

f. Spectroscopic observations of star E.

g. Another set of spectroscopic observations of star E. These data are relative radial velocities. You will need to fit for the offset between data sets F and G.epler-454

6. Programming-Free Alternative to Problem 4: *Highlights from the Literature*

Select one paper from each category and summarize the motivation, methodology, results, and conclusions. Include a representative figure from each paper and write a few sentences explaining how the figure connects to the rest of the paper. Your full answer for each paper should be 1–2 paragraphs. You may summarize up to three additional papers (6 papers total) for extra credit.

a. Pick 1: Rugheimer et al. 2015; Wolf 2015

b. Pick 1: Foreman-Mackey et al. 2013; Kreidberg 2015; Kempton et al. 2017

c. Pick 1: Rodler & Lopez-Morales 2014; Wright et al. 2016

7. Programming-Free Alternative to Problem 5: *Extraordinary Claims*

You are the science editor for a major (reputable) newspaper. Write a 1-page document explaining the observational evidence that you would require before running stories with the following headlines:

a. "Habitable planet detected around Wolf 359!"

b. "Galaxy teeming with germs!"

c. "Intelligent life is everywhere (else) in the galaxy!"