Open Problems in Modern Astrophysics – Problem set 1. Autumn 2021
The answers should be returned by ***Friday (17.9) 4pm (16.00) in Moodle****, link through the official course homepage. The answers to the problem set will be discussed on Tuesday (21.9) at 12.15-14.00 in Room D123, Exactum.*

This problem set will contain **General** questions and questions based on the two papers:
Anglada-Escude, G.; Amado, P.J.; Barnes, J. et al., 2016, Nature, 536, 437: "A terrestrial planet candidate in a temperate orbit around Proxima Centauri (**Paper 1**)
Carson, J.; Thalmann, C.; Janson, M, et al., 2013, ApJL, 763, 32: "Direct Imaging Discovery of a "Super-Jupiter"around the Late B-type Star κ And" (**Paper 2**)

1. **General question 1**
   (a) Describe briefly the main methods for detecting extrasolar planets and give rough estimates for how many exoplanets have been found to date in total using each different method.
   (b) Describe briefly what are the main two formation mechanisms for planets. Explain which method is favoured at the moment and why. Finally explain why the metallicity of the host star should correlate positively with the probability of harbouring a giant planet in only one of the two formation mechanisms and state if such a correlation has been observed.
   (c) What requirements are needed to make a planet Earth-like? What are biosignatures and how could they be detected on an extrasolar planet? Have any truly Earth-like planets been detected so far? If not, what is the most Earth-like planet known? In your personal opinion, what are the prospects of finding a Earth-twin within the next 5-10 years?

2. **General question 2**
   (a) So called 'hot Jupiters' have been detected in very tight orbits around their host stars. Why were it a surprise to find such massive planets orbiting their host stars so nearby? Where were these planets most probably formed and what is their future if gravitational tidal evolution is considered?
   (b) How can the cloud structure and even 'weather' be observed on massive exoplanets? Why would you expect extremely strong winds on hot Jupiters that orbit very close to their host star? Many hot Jupiters seem to be very 'bloated', i.e. their radii are larger than expected for their masses. What could potentially explain such observations?
   (c) Using the internet give an update on the status of recently finished exoplanet missions such as *COROT* and *KEPLER* and missions currently ongoing such as *TESS* and *CHEOPS* and finally other future missions that are in planning, such as *PLATO*. What methods of exoplanet detections have these missions used or are planning to use? How many planets and of what masses did these missions find or expect to find?

3. Based on **Paper 1** answer the following questions:
   (a) How was the planet around Proxima Centauri detected? Studying Figure 1. why was the new data from the Pale Red Dot observing campaign crucial for detecting the planet? The authors of the paper use two statistical methods for describing the reliability of their detection. Briefly what are these two methods and how reliable is the detection of this planet, i.e. how improbable is a false detection?

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(b) What is the period of the detected planet and are there any other potential planets in this system? How large is the radial velocity amplitude of the detection and how does it compare to other similar planet candidates? Why was the planet not detected before 2016? Are there any other stellar phenomena that can cause a periodic light signal, if so, how do the authors test for this?

(c) What is the likelihood of habitability of this planet? What factors argue for habitability and what factors make the planet less likely to be habitable? In particular how does the irradiance compare with the Earth and why is the X-ray flux at this planet so much higher than at Earth?

4. Based on **Paper 2** answer the following questions:

   (a) The planet was first imaged in the J-, H- and K-bands with a coronagraphic mask. What wavelengths do the J-, H- and K-bands correspond to and why were these bands used and finally, what is a coronagraphic mask? In later observations in the L'-band the coronagraphic mask is not needed, why?

   (b) Analyse Figure 2. in the paper and explain how these measurements can be used to confirm that the object orbits its host star. How can the age of the object be estimated based on its kinematic motion?

   (c) How are the mass and temperature of the object derived and describe briefly what modelling assumptions go into the model (i.e. what are the DUSTY and COND evolutionary tracks?). What factors strengthen the notion that the object is an actual planet and not a brown dwarf? Finally, why do the authors of the paper prefer to use the term "super-Jupiter" for the object and how is this connected to the deuterium burning limit?