Open Problems in Modern Astrophysics – Problem set 2. Autumn 2021

The answers should be returned by ***Friday (1.10) 4pm (16.00) in Moodle****, link through the official course homepage. The answers to the problem set will be discussed on Tuesday (5.10) at 12.15-14.00 in Room D123, Exactum.*

This problem set will contain **General** questions and questions based on the two papers:
Luhman, K.L., 2013, ApJL, 767, 1: "Discovery of a Binary Brown Dwarf at 2 pc from the Sun" (**Paper 1**)
Carter, J.A., Fabrycky, D.C., Ragozzine, D. et al., 2011, Science, 331, 562: "KOI-126: A Triply Eclipsing Hierarchical Triple with Two Low-Mass Stars" (**Paper 2**)

1. **General question 1**

   (a) Describe briefly how you would go about in detecting brown dwarfs using a large-scale survey. What wavebands would you use, what are the typical colours and temperatures of brown dwarfs? How would kinematic data be useful to you?

   (b) Describe briefly how the spectral sequence has been extended beyond spectral class M. What spectral features are used to classify brown dwarfs? What indicators of youth can be used to estimate the ages of brown dwarfs? Using spectral line information how can you classify the physical size of a brown dwarf?

   (c) Explain briefly what type of formation mechanisms for low-mass stars have been proposed and given the current observational evidence for brown dwarfs which scenario seems to be the favourite model at the moment?

2. **General question 2**

   (a) At what mass and spectral class does the hydrogen fusion limit set in? Why cannot objects below this limit produce energy through hydrogen fusion? What objects can fuse deuterium in their cores? Is deuterium fusion important for the global energy budget of these objects, motivate your answer.

   (b) What does the initial mass function (IMF) describe? How would you go about determining the shape of the initial mass function? At what mass approximately does the IMF typically peak? Find out what the terms bottom-heavy and top-heavy IMF mean and give examples of environments where the IMF is bottom-heavy and top-heavy, respectively.

   (c) How well do theoretical spectral evolution models work for brown dwarfs and low-mass stars when compared with the observations? Why is the agreement between theory and observations worse for brown dwarfs when compared to normal main sequence stars? What would be the best approach to improve on this situation?

3. Based on **Paper 1** answer the following questions:

   (a) Describe briefly how the object in the paper was found? What was the role of WISE in detecting the source? How do the observed colours of the object compare with other M, L and T dwarfs? What is the spectral class of this object?

   (b) How was the parallax and proper motion of the object measured? The object is a binary system, how could this potentially affect the measurement of the proper motion?

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(c) What was the derived distance for the object and how many known stellar systems are found at a closer distance to the Sun than this object? Given its proximity how come this object was only discovered now? The atmosphere of this object has also been studied in a Nature paper published in 2014 by Crossfield et al. Summarise in 2-3 sentences the main idea and results of this paper.

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

   (a) The authors in this paper report a discovery of a interesting stellar system. Describe briefly what is particularly interesting about this system and how it was discovered.

   (b) Why could this system not be modelled using simple Newtonian mechanics and Keplerian orbits? Studying Figure 1. in the paper explain why there are occasional absences of the eclipses between the stars in the system, i.e. why are the eclipses not repeated on a regular basis? Compare this to the case of a binary system and explain the difference.

   (c) Studying Figure 2. and Table 1. why are the results of this paper especially important for models of low-mass stellar evolution? How can the observations be used to study the internal structure of low-mass stars? Finally, why are low-mass stars fully convective?