

## **Internship Progress: Final Report**

**ICTP PWF: Bangladesh**, represented by Prof. Nabil Iqbal and Ahmed Rakin Kamal (Program Organizers),

- **Mentor**, Asif ud-Doula
- **Collaborator Mentor**, Gillian Pearce
- **Intern**, Haniah Mokhtar

## **Introduction**

After the introductory part and further discussions, of my research topic, had been completed, I decided to work on the question of planetary habitability. Under the guidance of mentors, I explored various habitability criteria on exoplanets and reviewed research papers in this field. Following this, we decided that I would be working on the habitability of planets around K-stars. K-stars have long main-sequence lifetimes, and it is thought that the continuous habitable zones of such stellar systems could hopefully have favorable conditions for life to emerge and evolve, and have bio signatures detectable over long distances. Although much research has been conducted on M-stars (where it is thought that habitable exoplanets are most likely to be capable of sustaining life), less is known about exoplanets around K-stars. Therein lies the novelty of my research. I have used exoplanetary catalogues to source data on K-stars and their exoplanets.

## Work Description

My initial approach involved looking in research papers in the scientific literature to find background information on stars and why exoplanets around some stars are more likely to be potential candidates on which life might emerge and evolve. A sample of research papers I read is listed at the end of this report. Reading these papers introduced me to terminology concerning the topic of life on exoplanets and the Physics of stars. I learned about Wien's Law, Stefan's Law and how these enable us to relate the properties of a given star (eg radiation emitted) to such factors as temperature on exoplanets orbiting the parent (host) star. Temperature is one factor that could determine if life might evolve on a given exoplanet, but other factors like the amount and type of radiation (eg ultra-violet, x-Ray etc) emitted by the parent (host) star are also factors. I learned a lot about the Physics of stars through reading the research papers. I could then apply this to determining the likelihood of life emerging and evolving on exoplanets around K-stars.

We held weekly sessions over Zoom to discuss my progress and problems. I also learned a lot about the application of computer code to undertake the calculations for K-stars and exoplanets, mentioned above. I learned Python to facilitate these calculations.

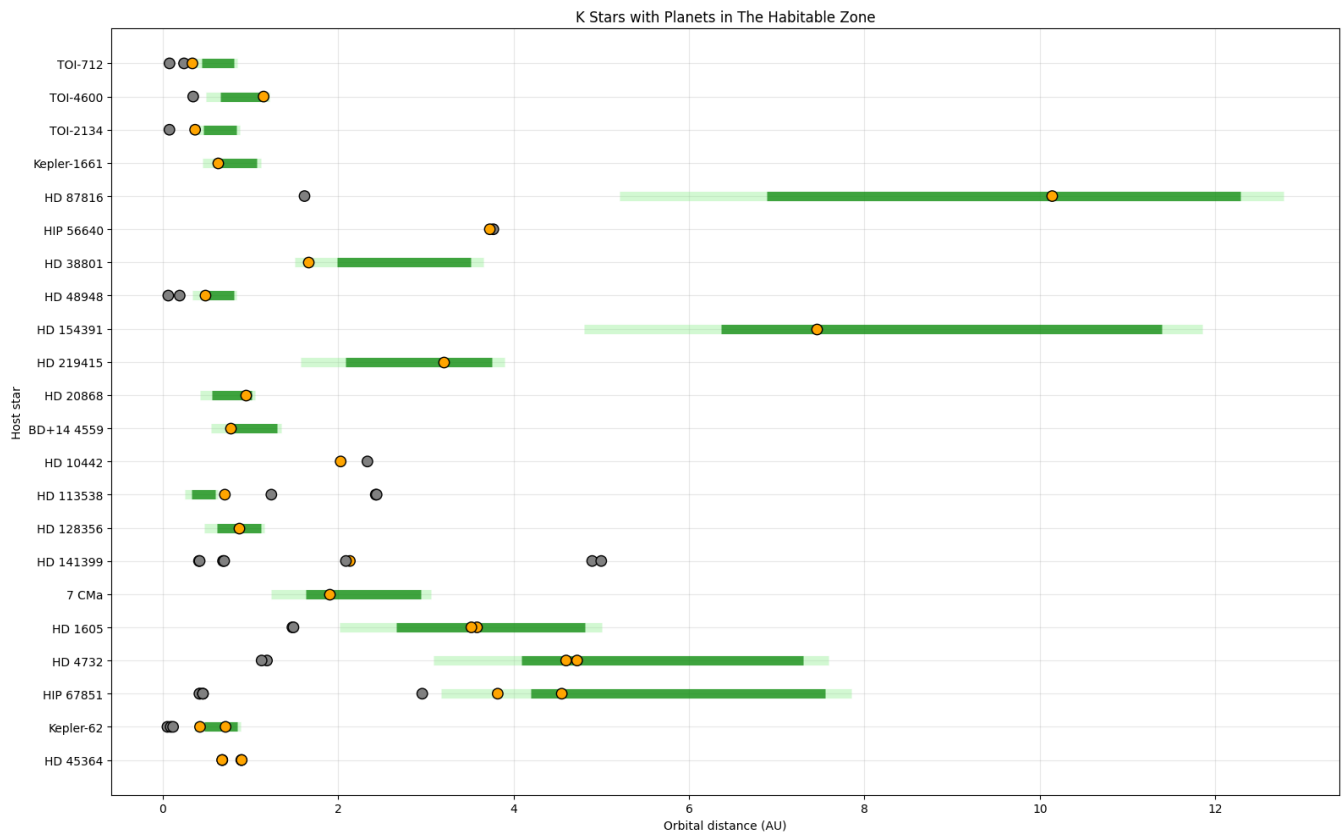
Having become familiar with these concepts, I explored planetary characteristics in more detail. I sourced and research papers on rocky planet formation, water transport, life vs stellar evolution, cloud effects, the effect of UV radiation vs life, and so on. The mentors also guided me, suggesting articles, papers, and sites. I am currently producing results and plotting graphs resulting from my research concerning the habitability of exoplanets around K-stars. An example of one such plot is shown in figure 1 below in the section on "current progress".

# Current Progress

I have successfully collected planetary data on K-star systems from

<https://exoplanetarchive.ipac.caltech.edu/index.html> and I am analyzing these data using Python. To-date,

I have found data for about 740 candidate exoplanets for K-star system, out of which only 27 lie within the habitable zones (optimistic limit in which life is most likely to exist on a given exoplanet) around a parent host star according to my calculations. This will be used with any other information concerning these exoplanets eg atmospheric spectroscopic data to comment on the likelihood that those exoplanets might be suitable for life to emerge and evolve on. I then intend to write up my results and conclusions in a research paper (a review) which will be submitted to a journal for publication. An example of a graphical representation of a sample of my results is shown in figure 1 below.



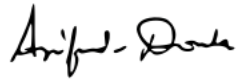
**Figure 1:** Light green band (optimistic habitable zone), Green band (conservative habitable zone), orange dots (probable habitable planets), grey dots (other exoplanets in that stellar system)

## **List of papers I explored:**

- Habitable Zones around Main Sequence Stars - James F. Kasting, Daniel P. Whitmire, Ray T. Reynolds
- Forming rocky exoplanets around K-dwarf stars - P. Hatalova, R. Brasser, E. Mamonova and S. C. Werner
- Remote life-detection criteria, habitable zone boundaries, and the frequency of Earth-like planets around M and late K stars - James F. Kasting, Ravikumar Kopparapu, Ramses M. Ramirez, and Chester E. Harman
- The compositional diversity of rocky exoplanets around K-dwarf stars - P. Hatalova, J. P. Brodholt, R. Brasser, Y. Shan, and S. C. Werner
- HAZMAT. V. The Ultraviolet and X-ray Evolution of K Stars – Tyler Richey-Yowell, Evgenya L. Shkolnik, Adam C. Schneider, Ella Osby, Travis Barman, and Victoria S. Meadows
- Astrophysical Conditions for Planetary Habitability - Güdel, M., Dvorak, R., Erkaev, N., Kasting, J., Khodachenko, M., Lammer, H., Pilat-Lohinger, E., Rauer, H., Ribas, I., & Wood, B. E.
- Origin of Water in the Terrestrial Planets: Insights from Meteorite Data and Planet Formation Models - Andre Izidoro and Laurette Piani

**Asif ud-Doula**

Mentor, Penn State Scranton



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**Haniah Mokhtar**

Intern, BRAC University



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