Interrelated Main-Sequence MLR, MRR, MTR Relations from Planet Hosting Stars

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Abstract

In this study, we investigated the inter-related mass-luminosity, mass-radius and mass-temperature relations of planet-hosting stars. The sample, which is chosen to be main-sequence systems, is divided into two metallicity regimes: one regime is below the average of all samples (z=0.017) and is above it. Suitable figures represent the comparisons of each distinct metallicity regime.

Introduction

Understanding the relationships between stellar mass, luminosity, radius, and temperature is fundamental to the study of stellar astrophysics. These interrelated properties are particularly important for main-sequence stars, which constitute the majority of stars in our galaxy and are key targets in the search for exoplanets. Our previous work (Eker et al., 2018) on this topic has garnered significant attention, as evidenced by the diverse range of papers citing our research.

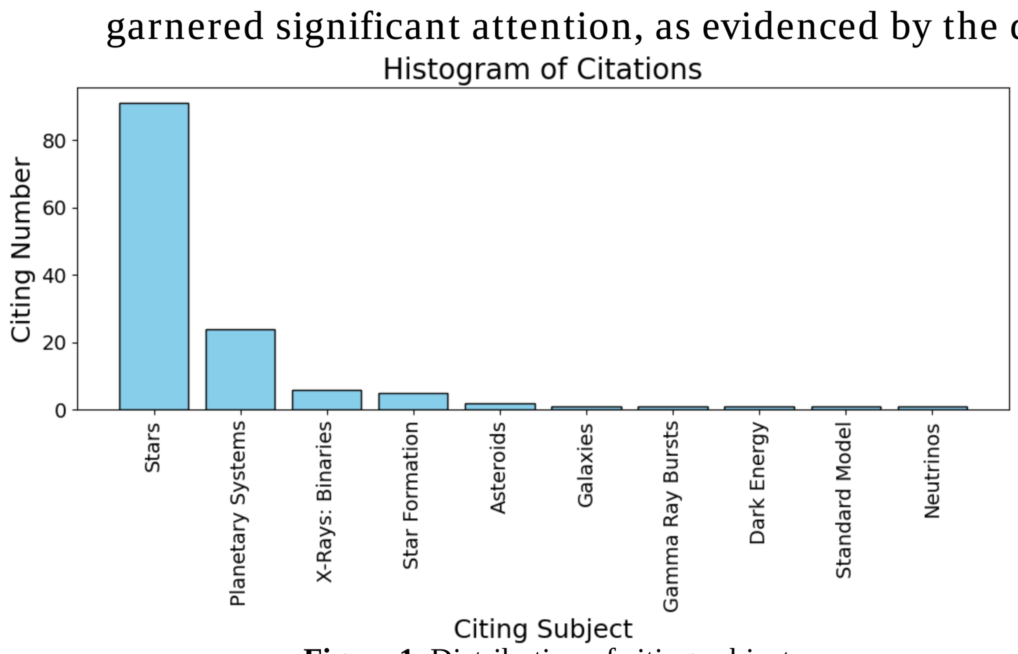
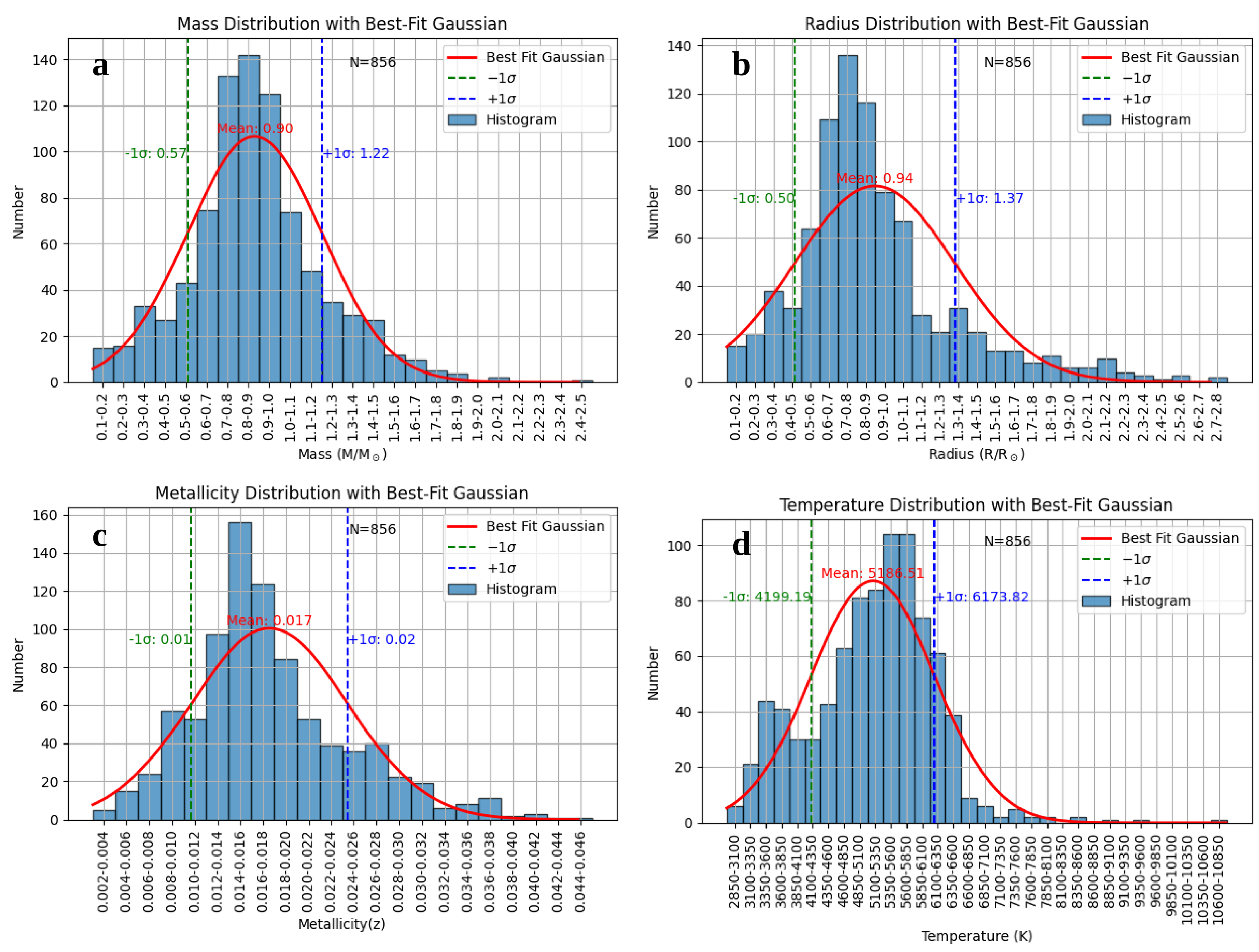


Figure 1. Distribution of citing subjects.

To illustrate the broad scientific interest in our study, we present a histogram of a total of 140 citing papers. This histogram demonstrates the wide array of science topics that intersect with our research on main-sequence stars and their properties. The citations span areas such as stellar evolution, exoplanet discovery, star formation, and more.

The Sample

Our study focuses on a carefully selected sample of main-sequence stars known to host planets. This sample provides a robust basis for examining the Mass-Luminosity, Mass-Radius, and Mass-Temperature relations for several metallicity regimes.



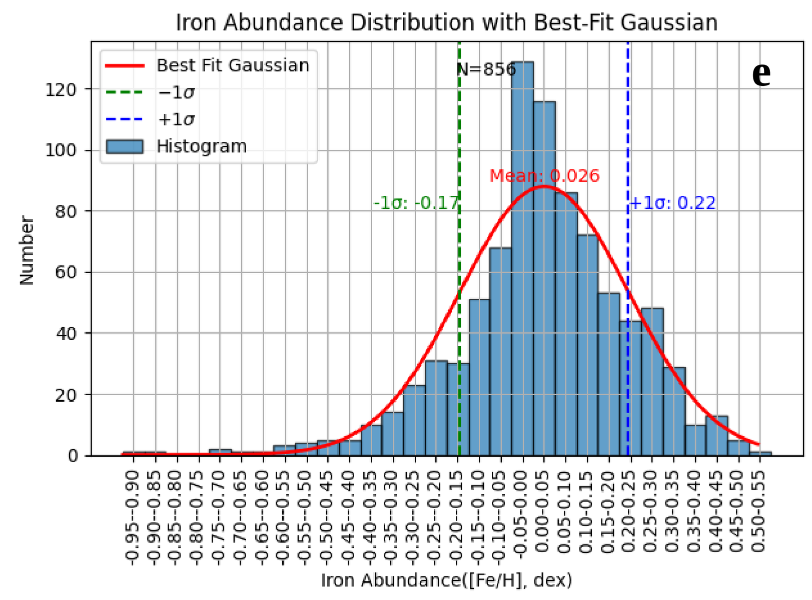


Figure 2. Distribution of mass (a), radius (b), metallicity (c), temperature (d) and iron abundance (e) parameters used in our study. For each distribution, a best-representing Gaussian is given together with mean value of the distribution and 1-σ value.

Methodology

In this study, we employ Spectral Energy Distribution (SED) fitting to estimate the interstellar extinction affecting the observed stellar parameters. The simplified SED fitting with Planck function as described in Bakış and Eker (2022) yielded E(B-V) for each target with an uncertainty of 0.01 mag. The SED fitting also allowed us to investigate the luminosity class of the targets.

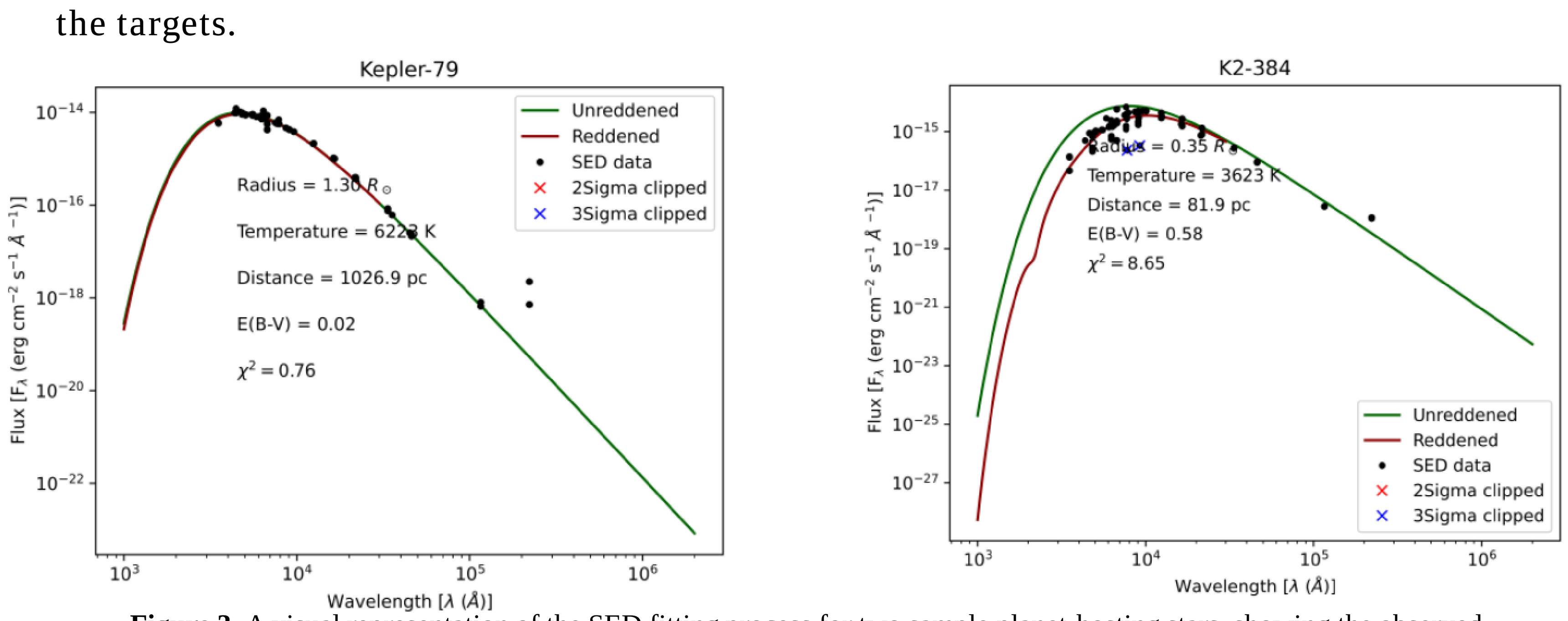


Figure 3. A visual representation of the SED fitting process for two sample planet-hosting stars, showing the observed photometric data points, the best-fit Planck function with interstellar reddening, and the derived extinction value.

MLR

The Mass-Luminosity Relation (MLR) is a fundamental tool in astrophysics, providing insights into the correlation between a star's mass and its luminosity. In our study, we derive the MLR for planet-hosting stars with different metallicities.
Using our sample, we generate mass-luminosity diagrams and fit functions for several distinct metallicity values. The results illustrate how metallicity influences the MLR, with higher metallicity stars generally showing different luminosity levels at the same mass compared to their lower metallicity counterparts. In Fig. 4a, mass-luminosty data in our sample is shown with two metallicity values, which are shown in grey and black for z<0.017 and z>0.017, respectively. In Fig. 4b, MLR from our previous study (Eket et al. 2018) is shown. In each panel the mass regimes are shown with vertical lines.

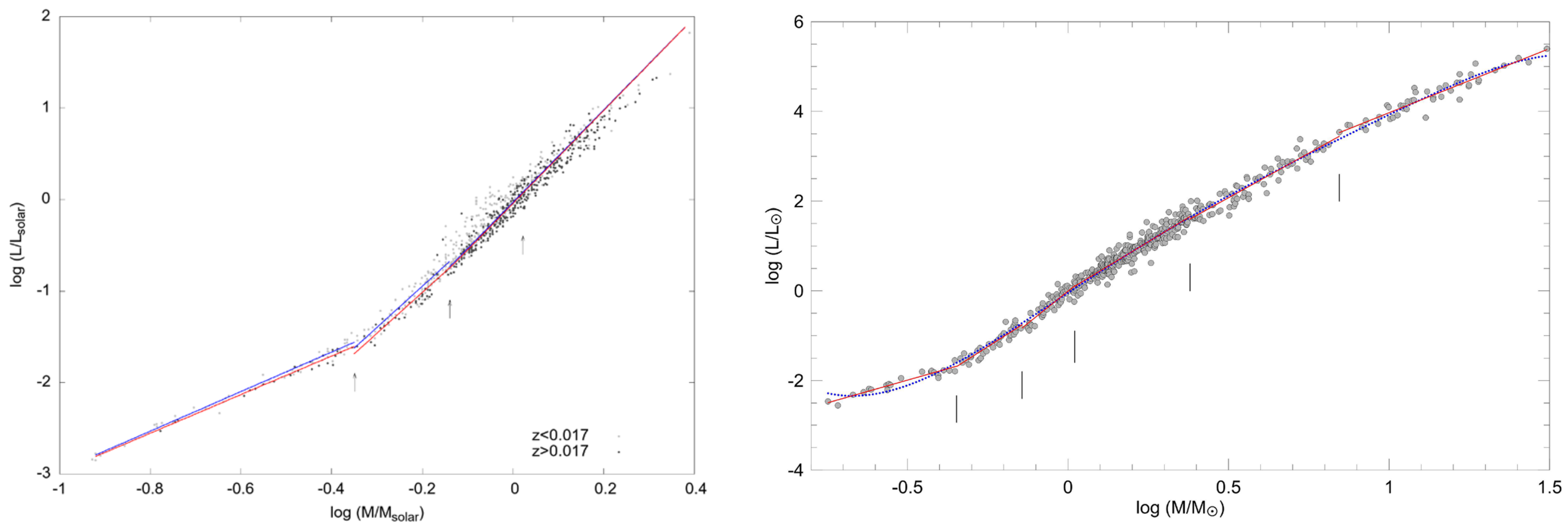


Figure 4. MLR from planet-hosting stars with different metallicities (left) and from eclipsing binary components (right).

MRR

The Mass-Radius Relation (MRR) is a fundamental tool in stellar astrophysics, particularly useful in the study of exoplanets and stellar clusters. By understanding how a star's mass correlates with its radius, we can infer key properties of stars and their planetary systems. The MRR aids in determining the physical characteristics of exoplanets when the host star's parameters are known, allowing for more accurate modeling of planetary sizes and compositions.
In our analysis, we derive the MRR for our sample of planet-hosting stars. The mass-radius diagrams presented show the fitted functions for stars with two different metallicity values. These functions illustrate how metallicity impacts the radius for a given stellar mass, providing insights into the structural differences and evolution of stars with varying compositions.
Our results highlight the importance of metallicity in defining the MRR, which is critical for interpreting the observed properties of exoplanets and for studying the stellar populations in clusters. The detailed mass-radius diagrams emphasize the need to account for metallicity when applying the MRR in exoplanet research and cluster studies.

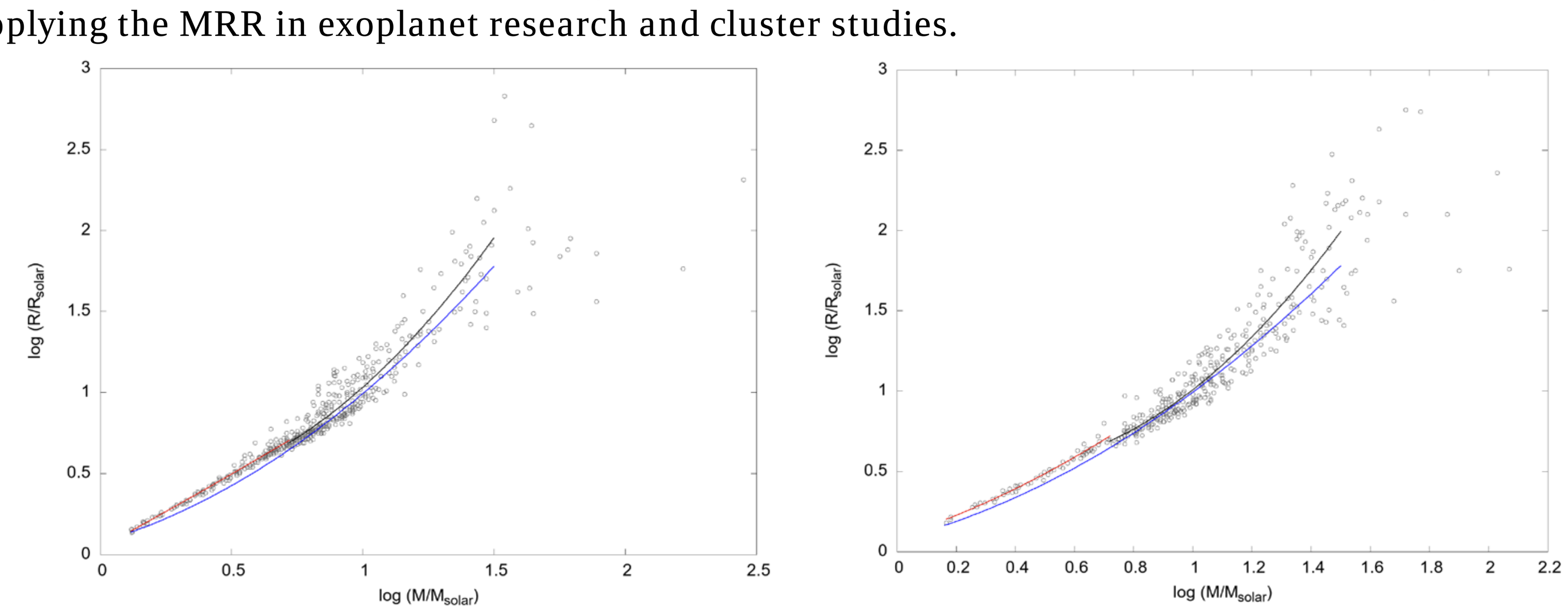
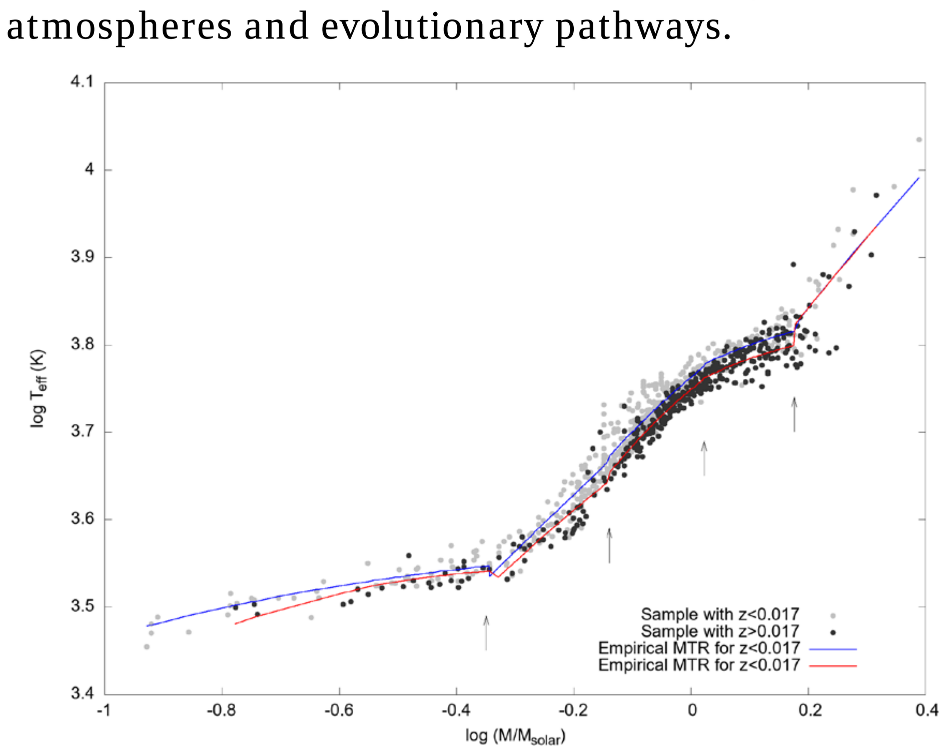


Figure 5. MRR from planet-hosting stars with lower (z<0.017) metallicity (left) and higher (z>0.017) metallicity (right).

MTR

The Mass-Temperature Relation (MTR) is a crucial aspect of stellar astrophysics, offering insights into the physical properties and evolutionary stages of stars. By examining how stellar mass correlates with effective temperature, we can infer key characteristics of stars and their potential to host planets.
In this study, we derive the MTR for our sample of planet-hosting stars. The mass-temperature diagrams presented illustrate the relationships between stellar mass and effective temperature, with fitted functions accounting for two distinct metallicity values. These functions reveal how metallicity influences the effective temperature for a given stellar mass, shedding light on the variations in stellar atmospheres and evolutionary pathways.



The detailed mass-temperature diagrams emphasize the need to consider metallicity when applying the MTR, as it affects the star's temperature and, consequently, the interpretation of observational data. This comprehensive understanding of the MTR is essential for advancing our knowledge of stellar physics and exoplanetary systems.

Figure 5. MTR from planet-hosting stars with lower (z<0.017) metallicity (grey data, blue model) and higher (z>0.017) metallicity (black data, red model).

Acknowledgements

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References

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