HD 101065: Przybylski's Star

Astro 3Y03 Research Proposal
Peter Gysbers
001216629

February 27, 2017

Abstract

HD 101065 is unique in that its surface contains a abnormally high amount of unusual rare-earth elements like lanthanides and short-lived radioactive isotopes as well as unusually low amount of iron-group elements. This star is also rapidly rotating with a period of 12.15 minutes. On a Hertzsprung-Russell diagram it lies in the 'instability strip' along with other pulsating variable stars like the RR Lyrae and Cepheid variables. It is classified as a rotating A-type star (roAp). A theory explaining it's abundance anomalies would have implications for the entire class of roAp stars.

1 Introduction

The abundances of elements in HD 101065's atmosphere were first discovered by Przylbylski in 1961 and later analysed it's abundances [1]. The star now bares his name.

-Przylbylski's star was the first rotating A-type stars to be discovered and remains one of the coolest (in temperature) [2].

-Has the second-most (after the Sun) elements determined but half of spectral lines are still unidentified.

- Strömgren c_1 photometric index abnormally close to zero [3, 4]

- Unusual spectral shape of Balmer lines [5], attempted to fit to a temperature increase in the intermediate atmoshpere

Rapid oscillation produces strong magnetic fields, first measured at $\sim$ 2200G then more recently at $\sim$ 1014 Gauss [6], which encourage vertical diffusion of elements, elements also form patches resulting in oscillation of spectra [7]. Diffusion theory can't fully explain presence of radioactive short-lived elements.

Three hypotheses: [8]

- Th and U over-abundances diffuse to stars surface and decay to various things

- HD 101065 has a binary companion that underwent a supernova, abundance patter explained by the r-process

- Nuclear reactions are occurring at stellar surface including fission.

2 Recent Progress

Recent developments in atmospheric models derived atmospheric parameters and calculate a surface temperature of $T_{eff} = 6400$K [3]. Report needing improved opacity functions. Use a step function with 4 parameters to model stratification of element abundance in atmosphere.

Alternate calculation of $T = 6622$K from an asteroseismological model of the star produced by fitting to oscillation modes extracted from radial velocity data [6]. In order to agree to the parameters a dipolar magnetic field strength of 8.7kG is required but the observed value is 2.3kG.

3 Objectives

To analyse additional lines in the spectrum of HD 101065 to measure rare earth elements and radioactive isotope abundances and their oscillations. Take additional nuclear reactions into account. To use the additional data to improve structural models of the star.

4 Literature Review

5 Methodology

6 Impact

7 Conclusion

References

[1] A. Przybylski. Abundance analysis of the peculiar star hd 101065. *Nature*, 210:20–22, apr 1966.

[2] D. W. Kurtz. HD 101065 - Przybylski's Star: A Most Peculiar Star. In C. A. Tout and W. van Hamme, editors, *Exotic Stars as Challenges to Evolution*, volume 279 of *Astronomical Society of the Pacific Conference Series*, page 351, 2002.

[3] D. Shulyak, T. Ryabchikova, R. Kildiyarova, and O. Kochukhov. Realistic model atmosphere and revised abundances of the coolest ap star hd 101065. *Astronomy and Astrophysics*, 520:A88, sep 2010.

[4] N. Piskunov and F. Kupka. Model Atmospheres with Individualized Abundances. *The Astrophysical Journal*, 547:1040–1056, February 2001.

[5] O. Kochukhov, S. Bagnulo, and P. S. Barklem. Interpretation of the Core-Wing Anomaly of Balmer Line Profiles of Cool Ap Stars. *The Astrophysical Journal*, 578:L75–L78, October 2002.

[6] D. E. Mkrtichian, A. P. Hatzes, H. Saio, and R. R. Shobbrook. The detection of the rich p-mode spectrum and asteroseismology of Przybylski's star. *Astronomy and Astrophysics*, 490:1109–1120, November 2008.

[7] G. Michaud. Diffusion processes in peculiar a stars. *Astrophysical Journal*, 160:641, may 1970.

[8] A. Yushchenko, V. Gopka, S. Goriely, D. Lambert, A. Shavrina, Y. W. Kang, S. Rostopchin, G. Valyavin, B.-C. Lee, and C. Kim. Interplay between Diffusion, Accretion and Nuclear Reactions in the Atmospheres of Sirius and Przybylski's Star. In Y. W. Kang, H.-W. Lee, K.-C. Leung, and K.-S. Cheng, editors, *The Seventh Pacific Rim Conference on Stellar Astrophysics*, volume 362 of *Astronomical Society of the Pacific Conference Series*, page 46, June 2007.