Gyrochronology: Studying the Stellar Rotation vs. Age Relation using NASA's Kepler and TESS Missions

EMBRY-RIDDLE Aeronautical University. DAYTONA BEACH, FLORIDA

Myles Curtis[1], Dori Stein[1], Heather Hancock[1], Terry D. Oswalt[1], Mariel Lares[1], Derek Buzasi[2]

[1]Dept. Physical Sciences, Embry-Riddle Aeronautical University, Daytona Beach, Florida USA

[2]Dept. Chemistry & Physics, Florida Gulf Coast University, Fort Myers, Florida USA

curtism5@my.erau.edu, steind@my.erau.edu, hancoch2@my.erau.edu, oswaltt1@erau.edu, laresm@erau.edu, dbuzasi@fgcu.edu

Abstract

Gyrochronology is the observed correlation between the age of a cool main-sequence star like the Sun and its rotational period. Various methods can be used to determine stellar rotation periods; however, NASA's Kepler mission and NASA's Transiting Exoplanet Survey Satellite (TESS) mission provide complementary data for this type of project. Kepler focused on a very small observational field for almost four continuous years, whereas TESS continues to survey the entire night sky for intervals of about one month at a time. Due to this difference in cadence, it is important to compare the resulting rotation periods obtained from these surveys. We have constructed TESS light curves to compare to existing Kepler light curves of the same target stars observed at different epochs. Identifying the conditions under which TESS rotation periods may differ from those derived from the Kepler mission can help identify the random and systematic biases of each data set. This poster presents some preliminary results of this comparison.

Keywords: Gyrochronology, stellar rotation periods, NASA, Kepler, light curves, TESS, main-sequence star

Support from NSF grants AST-1910396, AST-2108975 and NASA grants 80NSSC22K0622, 80NSSC21K0245, NNX16AB76G is gratefully acknowledged.

TESS

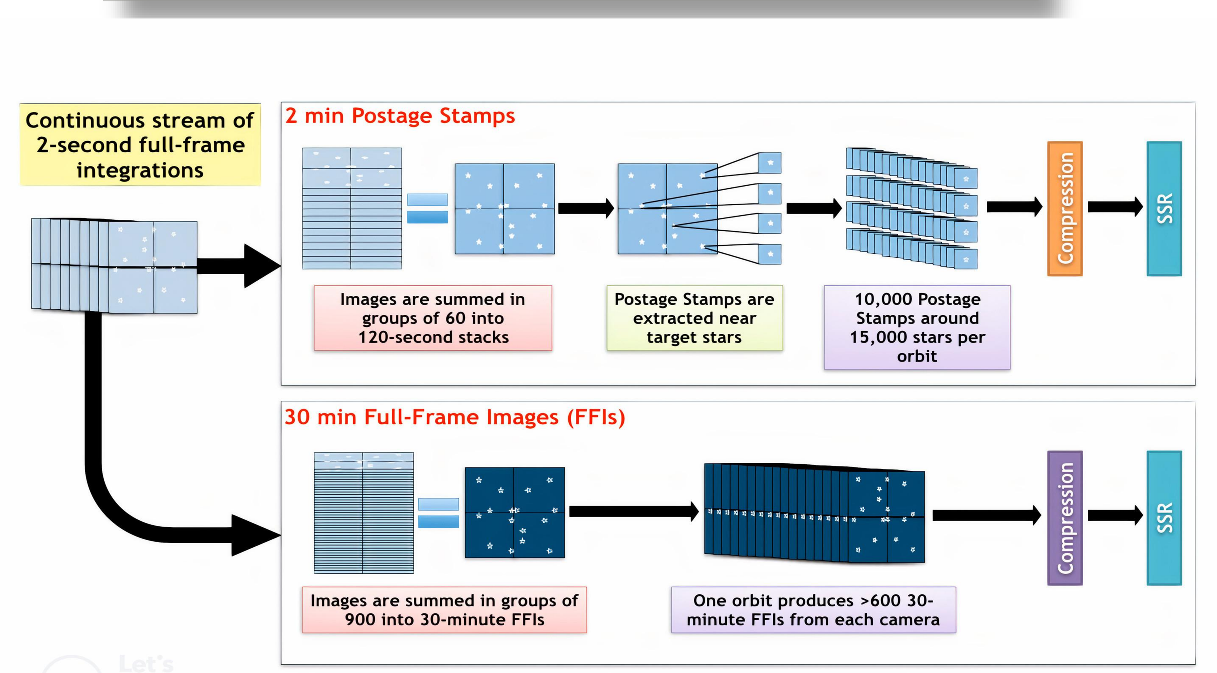

Figure 1: The process of TESS images being compressed

- **Purpose and Background**
  - TESS, while originally a planet-finding mission, is used in gyrochronology due to its ability to collect stellar data which can be implemented into light curves.
  - Target Pixel Files (TPF) are extracted from TESS Full Frame Images (FFIs). FFIs were recently released, allowing to create TPFs for targets that where not planned or asked to observed
  - This implementation allow to add to our TESS sample new targets that previously observed by the Kepler and K2 missions.
  - TESS is a wide-field satellite that monitors a 24 by 90 degree area of the sky for 27 days moving from northern to southern hemisphere (MIT, CfA, NASA).
  - For TESS one detector pixel is equal to about 21 arcseconds (TESS SSC, NASA, Greenbelt, MD).

NASA

NSF

Kepler

- **Purpose and Background**
  - The Kepler Exoplanet Mission, launched in 2009, detects Earth-size planets that can potentially support human life.
  - Since the Kepler Space telescope surveys a portion of the Milky Way, it can also be beneficial to measure the rotation of stars.
  - As Kepler continuously monitors the brightness of stars over a long time period, it can detect periodic variations in brightness caused by sunspots. By studying these brightness variations, scientists are able to infer the rotation periods of stars.
- **Size of Observational Field**
  - Kepler's field of view can cover about a hand at arm's length, or 2 dips from the Big Dipper. In simplicity, it can look at over 100,000 stars in one region of the sky (exoplanets.nasa.gov).
- **How many targets per pixel**
  - The pixels can have more than one target star.

TESS VS Kepler

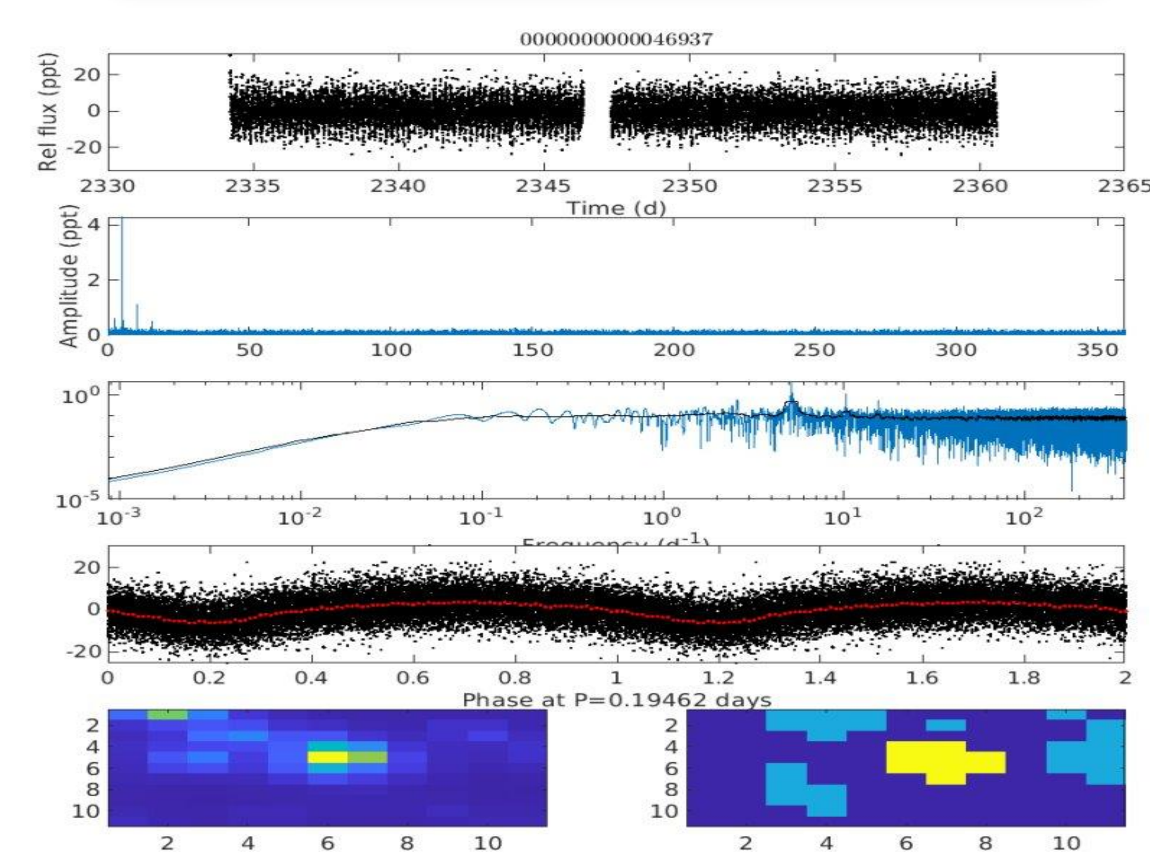

Figure 2: An example of TESS light curve data taken by Dr. Derek Buzasi

Although both the Kepler and TESS missions are designed to hunt for exoplanets, they have many differences that impact the resulting data. These differences include:

- **Type of target**
  - Kepler surveyed Sun-like stars for transiting Earth-sized planets
  - TESS surveys the closest, brightest stars for small, transiting planets
- **Size of observational field**
  - Kepler surveyed a fixed field
  - TESS surveys the full sky by sectors
- **Number of target stars**
  - Kepler targeted 136,000 stars
  - TESS targets 200,000 stars

These are just some, but not all, of the differences between these two missions. Kepler is known to be more precise than TESS, which is why they are useful to compare TESS to Kepler(exoplanets.nasa.gov, 2022).

TESS Observational Errors

- **Errors**
  - Throughout the data calibration, some errors occurred; specifically, since TESS was designed to look at half of the night sky at a time, the images were ultimately less precise
  - The pixels are so large that they can contain more than one target star, so the resolution is not ideal
  - Both TESS and Kepler have data gaps due to interruptions in observations

TESS Instrumental Errors

- **Errors**
  - The main instrumental errors that occurred in data was light curve inaccuracy, likely caused by observational issues with narrowing range to fit only one target
  - There is commonly an issue with excessive noise within data
  - When light curve data was randomized to ensure no repetitive data occurred, this was not the case and repeating periods occurred even when the data was randomized

Conclusion

It is clear that for a variety of reasons, TESS data requires further analysis to determine the nature of its errors and identify possible solutions. This project aims to compare existing light curves from targets of the Kepler mission to those this team generates using data from the TESS mission. Software such as TESScut is one way these light curves can be generated. It is possible to obtain two different light curves for the same target star observed by each mission separately. These light curves could suggest what the root cause of the instrumental errors are, which can then lead to improvements in the observational errors. Kepler is known for its accuracy. That along with the overlap of targets between these missions makes Kepler a good standard to determine where TESS data falls short. As this project continues, a high volume of TESS light curves that can be generated may suggest trends in the data. These could be used to investigate possible improvements to TESS.

Support from NSF grants AST-1910396, AST-2108975 and NASA grants 80NSSC22K0622, 80NSSC21K0245, NNX16AB76G is gratefully acknowledged.