Testing asteroseismology with red giants in eclipsing binary stars

M. Benbakoura, P. Gaulme, J. McKeever, P. G. Beck, J. Jackiewicz, R. A. García

Introduction

Asteroseismology is a powerful tool to measure the main properties of stars and probe their internal structure. The Kepler mission provided exquisite 4-year oscillation data for about 200 000 targets (Borucki et al., 2010). Red giants are of particular interest because their low-frequency high-amplitude oscillations can be analysed to probe their interior and constrain stellar models. However, the seismic scaling relations have been calibrated on the Sun. Therefore, they are expected to be valid for solar-like star but it is necessary to investigate if they still work for red giants.

Aims

Gaulme et al. (2016) selected a sample of 18 eclipsing binary systems containing a red giant observed by Kepler. Among these stars, they calculated the masses and radii of 10 giants using eclipses and radial velocities and compared these results with the seismically inferred values. They found a systematic error for both quantities. Radii were overestimated by asteroseismic relations by 5% and mass by 15%. In this work, we aim at extending the sample. We selected 16 eclipsing binary systems observed by Kepler, among which 6 are double-line spectroscopic and show oscillations. In this work, we detail the methods used to infer dynamical and seismic masses and radii and present the preliminary results of our study.

Methods

For each star, we prepared two light curves from the Kepler raw data (Target Pixel Files): one for modelling the eclipses, the second for studying oscillations and surface rotation. For the latter, we removed the eclipses and followed the method of García et al. (2011). We filtered out the variability to get the eclipses light curves. We used the high resolution spectrometer ARCES of the 3.5m Telescope at Apache Point Observatory (APO) to measure the radial velocities. Eclipses and radial velocities were modelled with JKTEBOP (Southworth, 2013). Figure 1 shows the eclipses and radial velocities of KIC 4054905. From these data, we could infer dynamically the mass and radius of each component of the system.

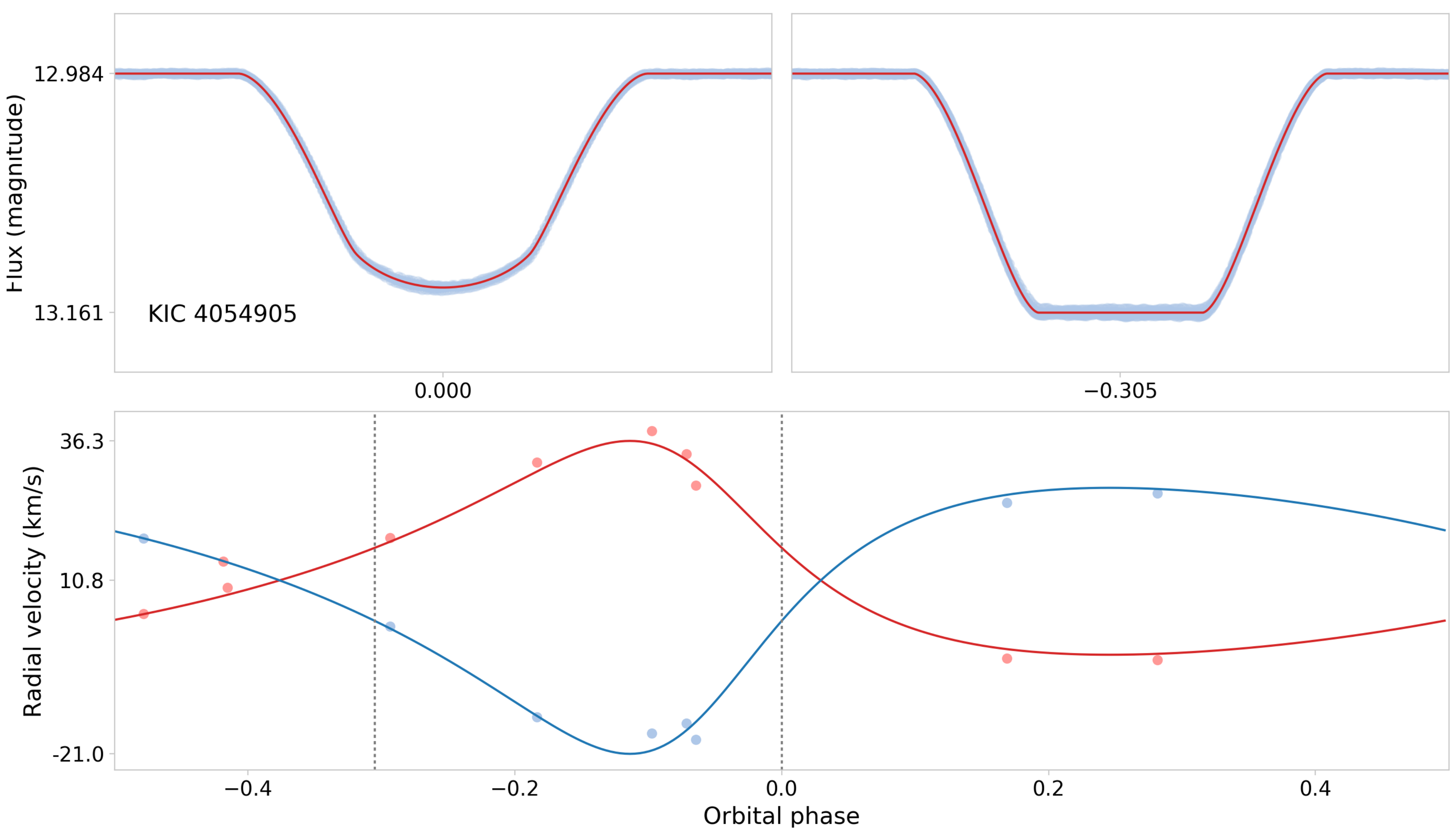

Figure 1. Eclipses and radial velocities of KIC 4054905.
Top left panel : primary eclipse. Blue dots correspond to the processed Kepler data and the solid red line represents the fit of JKTEBOP.
Top right panel : secondary eclipse.
Bottom panel : radial velocities. The red (resp. blue) dots correspond to the observations performed at APO and the solid line represents the fit of JKTEBOP for the red giant (resp. the companion). Vertical dotted lines illustrate the orbital phases of primary and secondary eclipses.

References

- W. J. Borucki, D. Koch, G. Basri et al., 2010, Science, 327, 977
- R. A. García, S. Hekker, D. Stello et al., 2011, MNRAS, 414, L6
- P. Gaulme, J. Jackiewicz, T. Appourchaux & B. Mosser, 2014, ApJ, 785, 5
- P. Gaulme, J. McKeever, J. Jackiewicz et al., 2016, ApJ, 832, 121
- J. Southworth, 2013, A&A, 557, A119

Results

Figure 2 shows a comparison between seismic and dynamical masses and radii. Among our sample, only one star has been observed enough to investigate further the result of Gaulme et al. (2016). This work is in progress and upcoming observations should allow us to investigate further this comparison.

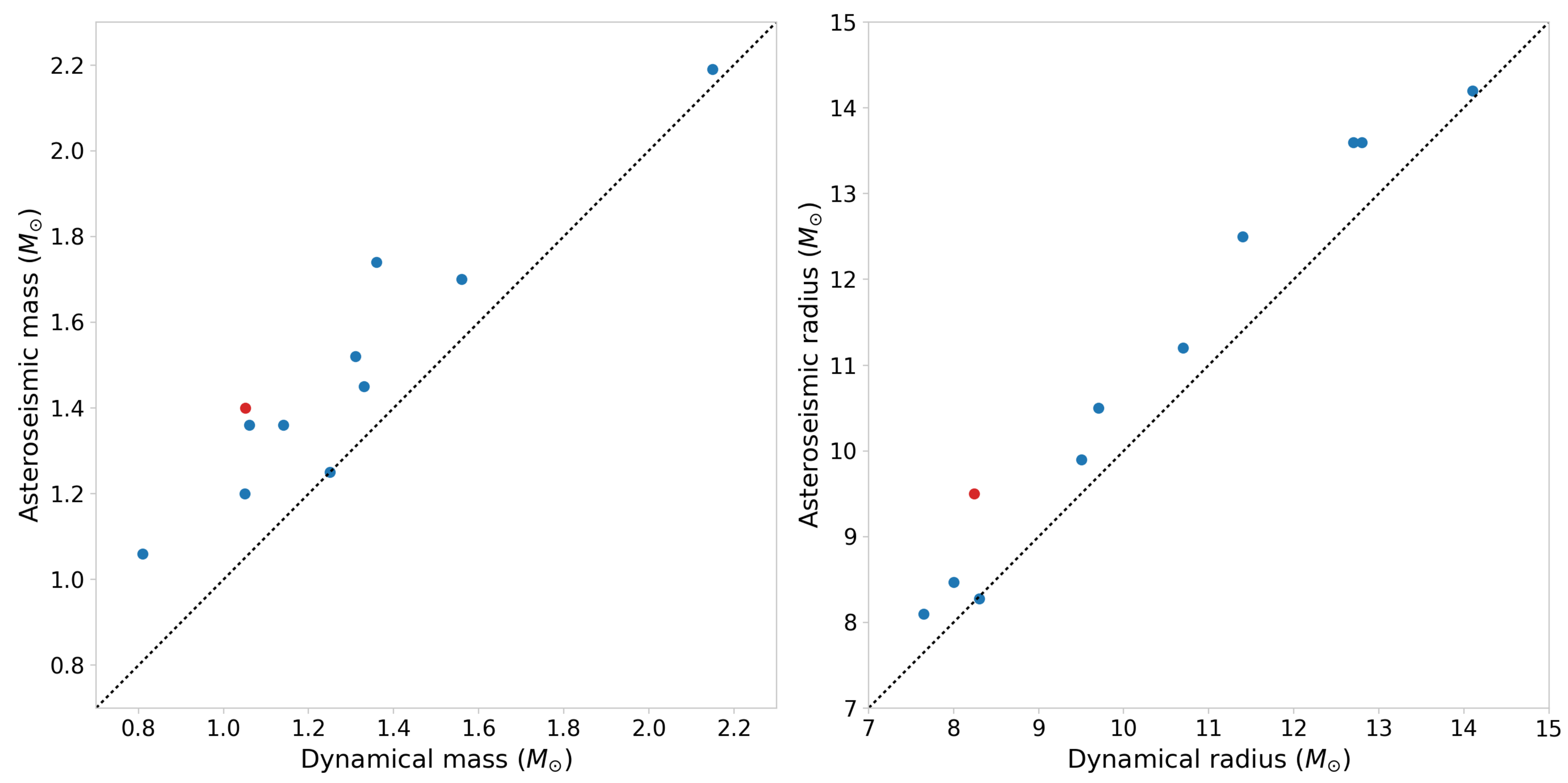

Figure 2. Comparaison between dynamical and asteroseismic masses and radii. Blue dots illustrate the results of Gaulme et al. (2016) and red dots correspond to our measurements.

Conclusion

This work is consistent with the result of Gaulme et al. (2016). Observations have started in the beginning of 2016 and will be over in fall 2017. Investigating a larger sample of stars could give a better idea of the correction to apply. A theoretical calculation could explain why these values are overestimated.

We also noticed, as Gaulme et al. (2014), that we could split our sample in two groups according to their orbital period. The shortest period systems do not show oscillations while the longest period systems do. This suggests that tidal interaction spins up the red giant within the stars and that the dynamo-generated surface magnetic field inhibits the pressure modes.

KIC	Period	M	R
4360072	1087	2.3	14.9
7293054	672	2.1	12.6
6757558	421	1.3	5.1
10074700	366	1.4	4.2
5866138	342	2.9	10.0
9153621	306	2.0	12.6
4054905	275	1.4	9.5
7768447	122	1.4	9.1
9904059	103	1.4	5.7
10015516	68	3.0	11.6

Table. Orbital period (days), seismic masses and radii (in solar units) for stars that show oscillations in our sample.

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Contact

M. Benbakoura, UMR AIM, CEA Saclay, mansour.benbakoura@cea.fr