Eclipsing binary stars with Kepler K2

A foretaste of PLATO complementary science

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Detached eclipsing binaries

• Best source of *precise, model-independent* mass and radius measurements for normal stars

• Ideal for testing/calibrating stellar models

• With parallaxes, can also add *precise, model-independent* $T_{\text{eff}}$ measurements.

• Spectroscopic analysis $\Rightarrow T_{\text{eff}}, [\text{Fe/H}], [\alpha/\text{Fe}], A_{\text{Li}}$
Total eclipses

- Light curve gives $r_1 = R_1/a$, $r_2 = R_2/a$, $i$, $e \cos \omega$, $e \sin \omega$, $f_2/f_1$
- Narrow total eclipses $\Rightarrow$ inclination $i \approx 90^\circ$
- Deep partial eclipses give similar accuracy in parameters
- Shallow partial eclipses more ambiguous $-$ spectroscopy helps.
Precision mass measurements

TZ For, HARPS

- $M_1 = 2.057 \pm 0.001 \, M_{\text{Sun}}$
- $M_2 = 1.958 \pm 0.001 \, M_{\text{Sun}}$

Gallene et al., 2016
Current EB sample

- Mass/radius error ± 1 - 2%
- Short orbital period
  - (tidally locked)
- Mostly “twin” stars
- Few low mass stars
- Few evolved stars
- Inhomogeneous Teff scale
- [Fe/H] often missing and not homogeneous

Bayesian mass and age estimates for transiting exoplanet host stars
Maxted et al., 2015

www.astro.keele.ac.uk/jkt/debcat
K2 light curves - ideal case

K2 data, $K_p=10.1$, $P=35.02d$

- $R_1/a = 0.02082 \pm 0.00002$
- $R_2/a = 0.01431 \pm 0.00002$
- $i = 89.734 \pm 0.004$
- $e = 0.0458 \pm 0.0008$

$\pm$ systematic error (tbc)

Maxted & Hutcheon, in prep.
K2 campaigns 1, 2 and 3

Maxted & Hutcheon, in prep.
TZ For

Gallene et al., 2016
TZ For - mass error effect

0.1% mass error

1% mass error

Valle et al. 2017
Helium abundance

![Graph showing Helium abundance versus age in Gyr.](image-url)
HAT-P-11

\[ Y = Y_{\text{BBN}} + 0.984 \, Z + \Delta Y \]

\[ \rho_* = \frac{3M_*}{4\pi R_*^3} = \frac{3\pi}{GP^2(1+q)} \left( \frac{a}{R_*} \right)^3 \]
Tidally induced pulsations

BW Aqr, $P = 6.72\text{d}$, $e = 0.18$
Star spot modulation
K2 + WASP

$P = 62.59 \text{d}$, $e = 0.64$, $K_p = 12.4$
ellc

- Doppler boosting
- Light travel time effect
- Gravity darkening
- Reflection
- Spots
- Fast!

```bash
$ pip install ellc
```
Conclusions

• Becoming possible to select a sample of DEBS to suite a given scientific question (DEBS on demand)
  • Certainly true once TESS data are available
• Precision in mass and radius measurements has improved by an order of magnitude in recent years
  • Challenge will be to make sure accuracy is maintained
  • This precision is needed to calibrate models
• PLATO will provide asteroseismology for stars in DEBS
  • Can validate mass/radius estimates from asteroseismology
  • Exquisite tests of stellar physics