Astronomy News

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The Paper

Kepler-16:
A Transiting Circumbinary Planet

Laurance R. Doyle et al.

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Kepler-16

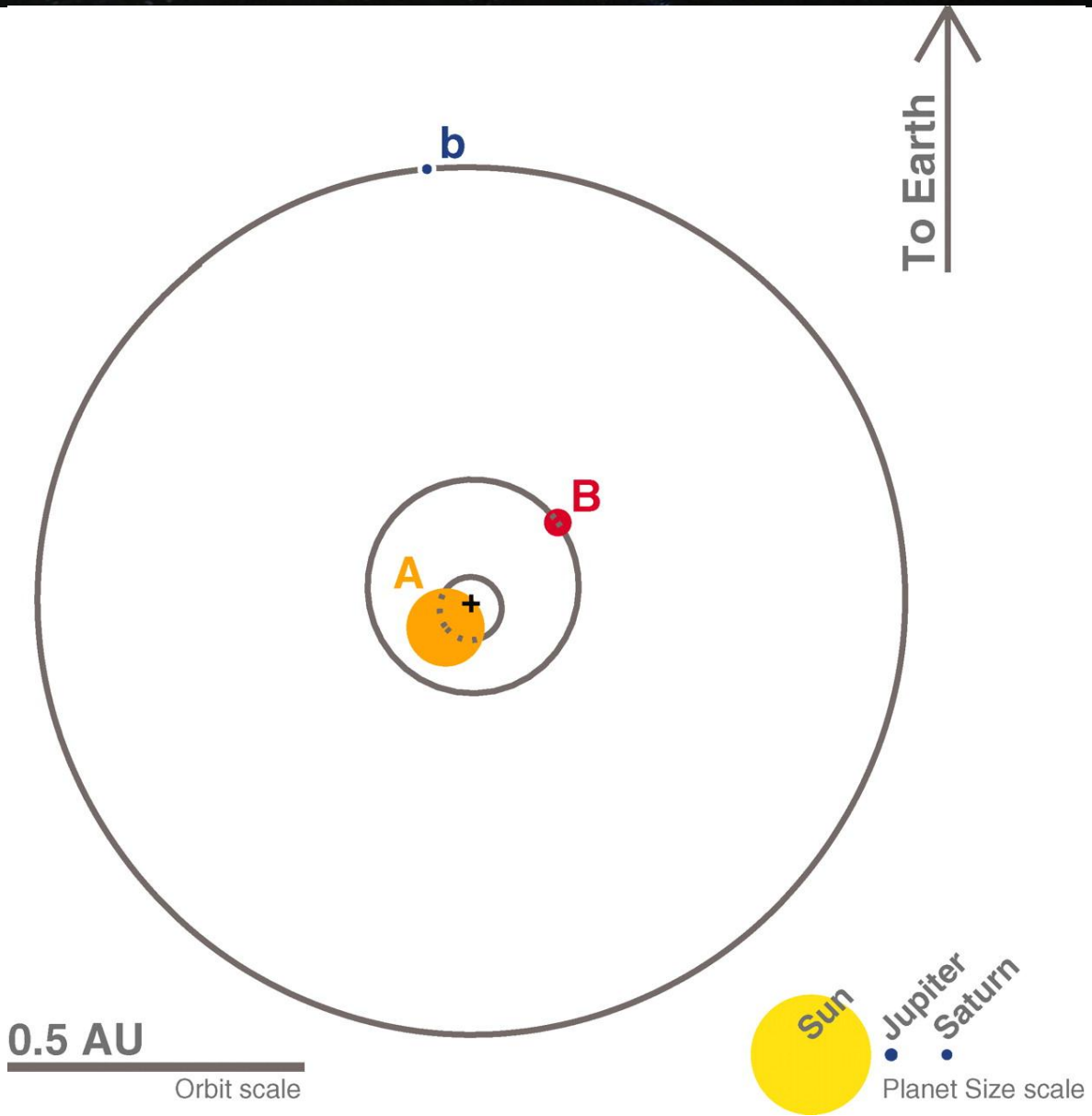
- Detection of a transiting circumbinary planet (Kepler-16b) around a binary star system based on photometric data from Kepler

- Kepler-16 was identified as an eclipsing binary with 41-day period

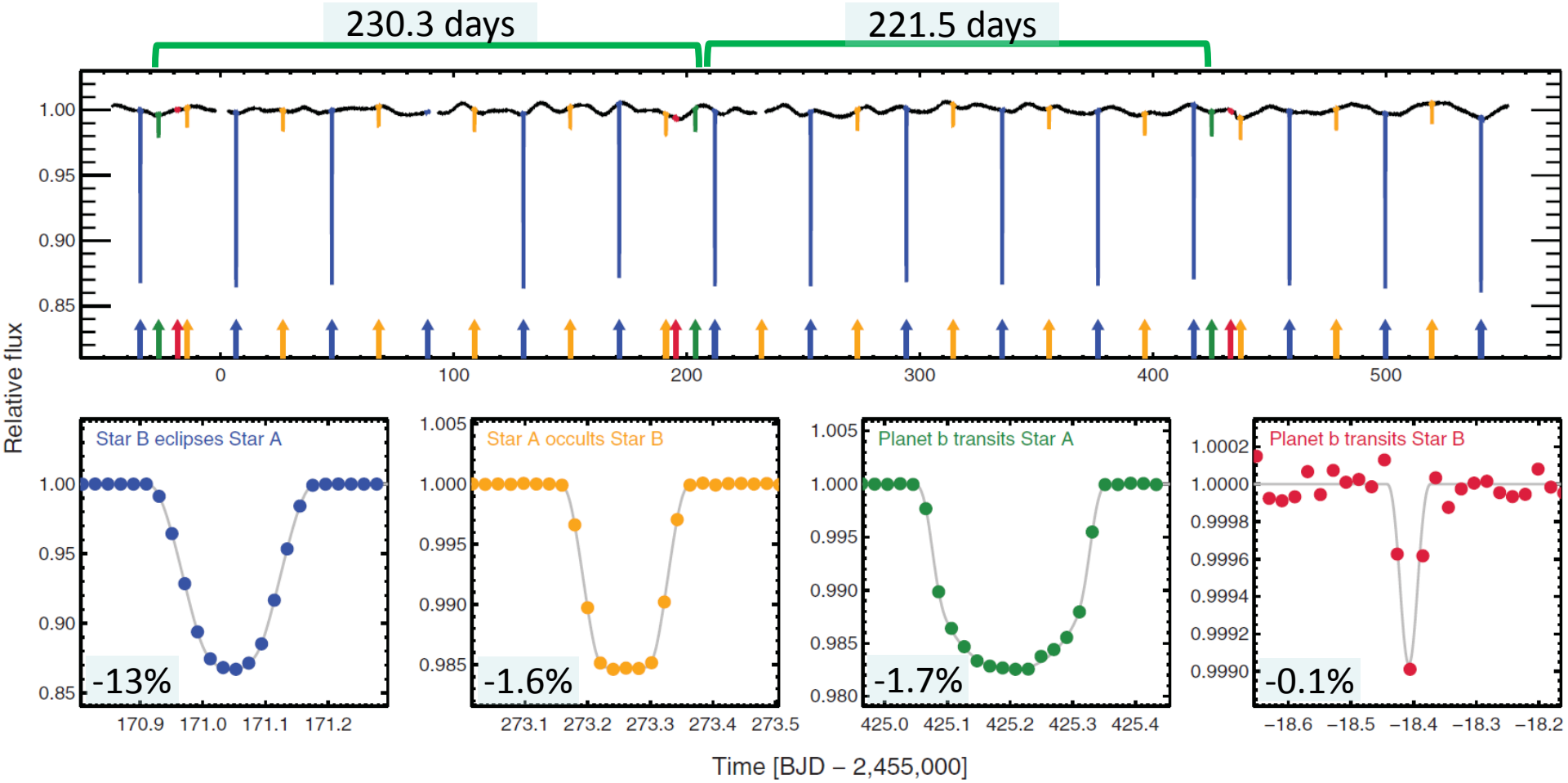
- No previous case have direct evidence of a circumbinary planet by observing a planetary transit

  (Kepler is a 0.95m space telescope)

The System


b
To Earth
B
A
0.5 AU
Orbit scale
Sun
Jupiter
Saturn
Planet Size scale

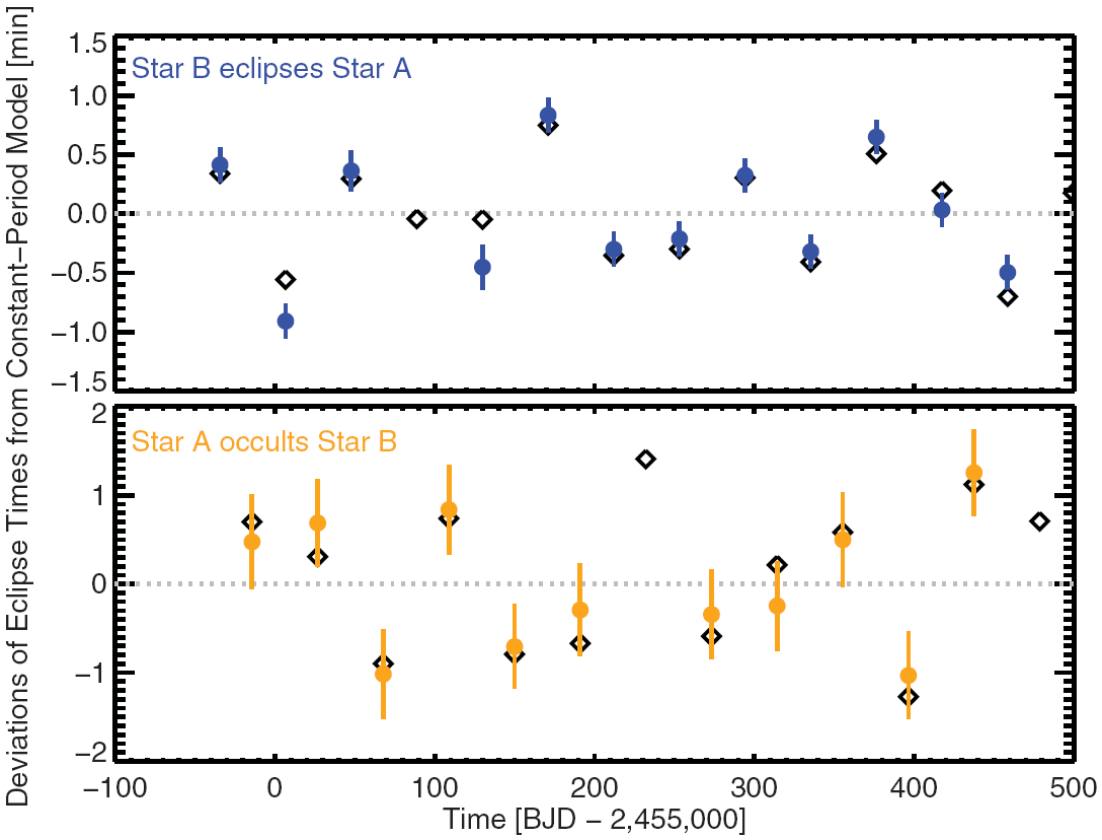
Photometry



- 3 additional drops in the light curve indicate the presence of a 3rd body

Period variation

- Primary and secondary eclipse were found to depart from strict periodicity by deviations on the order of 1 min



Deviations of the stellar eclipse times from constant period model

Dots: observed
Diamonds: model

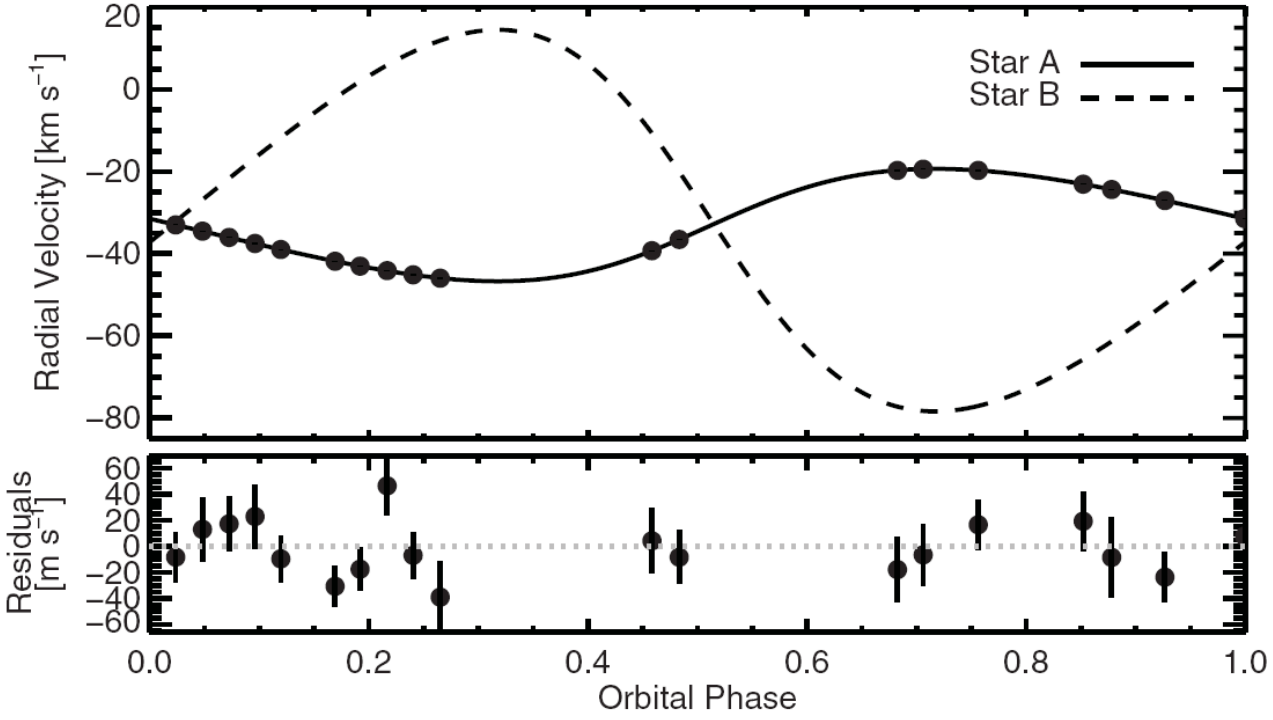
Identification of Kepler-16b

- The 3rd body causes timing variation in two ways:
  - [Light travel-time effect] Periodic motion of the center of mass of the stellar binary, which causing periodic variations in the time required for the eclipse signals to reach Earth (P. Sybilski et al. 2011)
  - [Dynamics effect] Gravitational attraction of each star to the 3rd body varies with time because of the relative positions of all 3 bodies, which causing perturbations in the stars orbital parameters (R. Schwarz et al. 2011)

- Both effect depend on the mass of the 3rd body
  - The mass of the 3rd body was determine by fitting the eclipse data with a numerical model of 3-body gravitational interaction

Radial Velocity

- To determine the stellar masses and an absolute distance, spectroscopic observations was took to track the radial velocity variations of star A



Observed radial velocity variations of star A as a function of orbital phase

Dots: data
Curve: best-fitting model

(based on observations with the spectrograph of the Tillinghast 1.5m telescope)

Data fitting

- The model was base on the assumption that
  - 3 bodies under the influence of mutual Newtonian gravitational forces
  - the disks of stars A and B to be circular
  - a quadratic law decline in intensity toward the limb (K. Mandel et al. 2002)

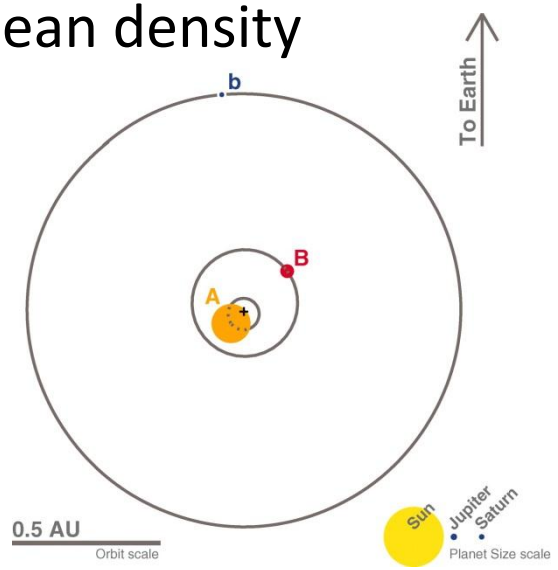
- Modify the code that was used for triple star system (J. A. Carter et al. 2011)

- Fit all of the photometric data within 6 hours of any eclipse or transit

- The model parameters were adjusted to fit the photometric and radial velocity data

Kepler-16b

- Kepler-16b is similar to Saturn with higher mean density
  - Mass $0.333 \pm 0.016\ M_J$
  - Radius $0.7538 \pm 0.0025\ R_J$
  - Mean density $0.964 \pm 0.046\ g/cm^3$



- Long-term changes
  - The planetary transits across star A should cease in early 2018, and return sometime around 2042
  - The planetary transits across star B are already grazing and are predicted to disappear for 35 years beginning in May 2014

Animation

- http://kepler.nasa.gov/multimedia/animations/artistsconcepts/