Planets Transiting Non-Eclipsing Binaries

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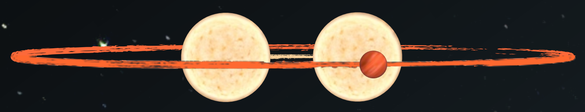
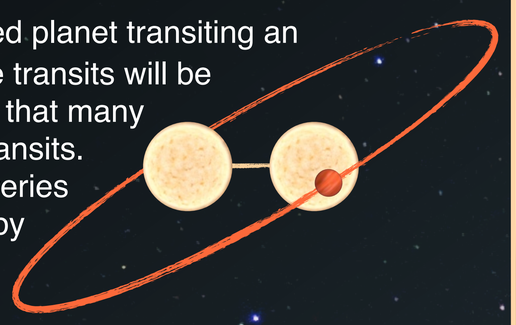
... because most binaries don't actually eclipse

POSSIBLE CIRCUMBINARY TRANSIT GEOMETRIES

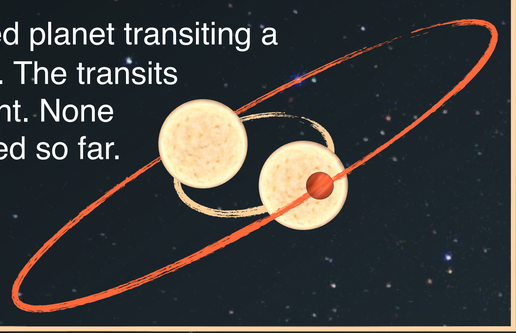
Case 1: Coplanar planet transiting an eclipsing binary. They generally transit every orbit (consecutive transits). Seven Kepler planets discovered so far.



Case 2: Misaligned planet transiting an eclipsing binary. The transits will be infrequent, meaning that many orbits are missing transits. No published discoveries yet but see the talk by Veselin Kostov.

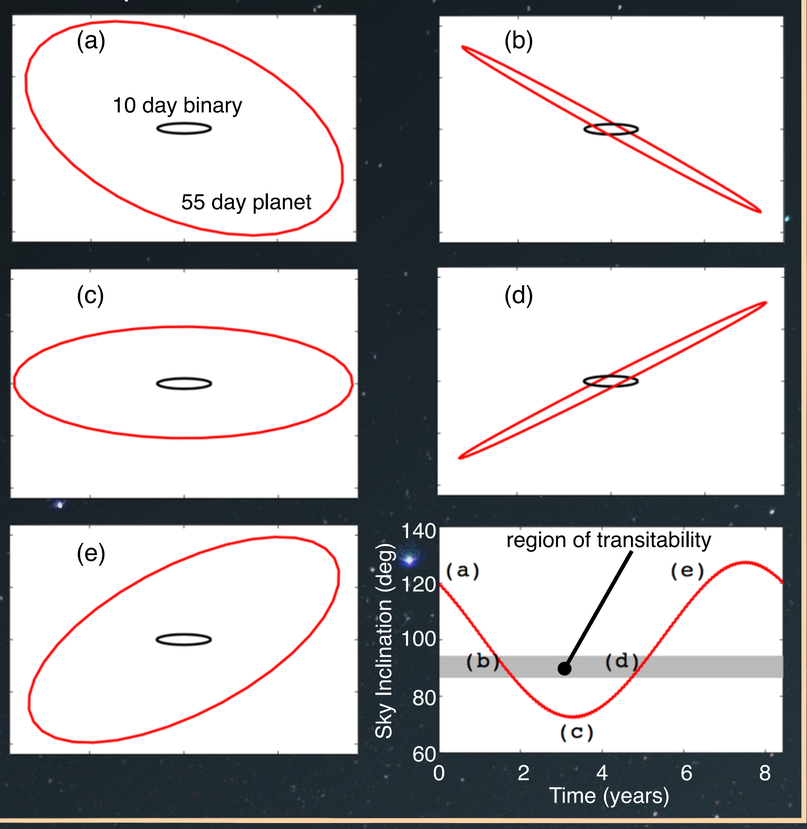


Case 3: Misaligned planet transiting a non-eclipsing binary. The transits will also be infrequent. None have been discovered so far.



RAPID PRECESSION

Interactions from the binary cause the planetary orbit to precess rapidly. Being in a state of transitability is time-dependent.



PREDICTED KEPLER PLANETS

Radial velocity distributions were used to create synthetic sets of circumbinary systems. These only included large planets (> 50 $M_\oplus$) and primary stars between 0.6 and 1.3 $M_\odot$. The distribution of circumbinary mutual inclinations is not known, so we tested a large set of possible distributions. Full details are in Martin & Triaud (in prep).

	Kepler has:	We predict:
Case 1:	2	0.4 → 2.1
Case 2:	?	1.2 → 4.5
Case 3:	?	0.2 → 20

A WIN - WIN SEARCH

There are two possible outcomes of a search around non-eclipsing binaries:

1. Planets found, possibly as many as 70 for all star and planet masses.
2. A null result, helping to constrain formation theories.

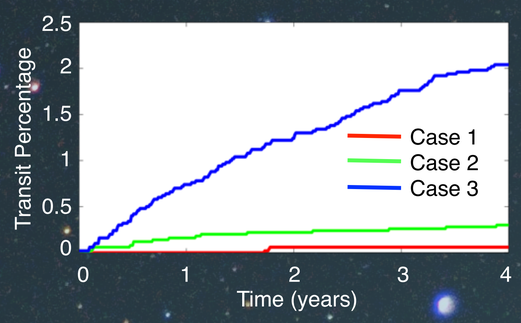
TRANSITABILITY

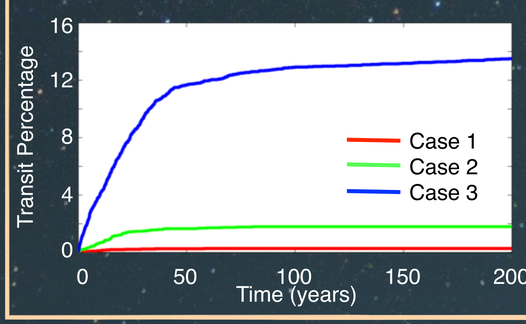
An orbital configuration where the planet and binary orbits intersect on the sky, such that transits are possible but not guaranteed every orbit.

DYNAMIC TRANSIT PROBABILITIES

The concept of transitability and the effect of precession lead to transit probabilities that increase with time. Below are simulations for Kepler-16-like systems, but with random mutual inclinations between 0 and 15°.

Over a Kepler timespan: longer observations → more orbits → more chances to transit.

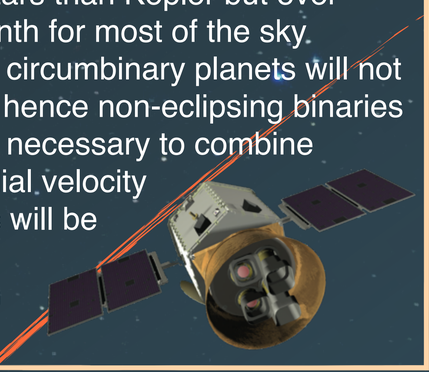




Over a very long time: every planet that can transit will transit. Sometimes there is never transitability, despite precession.

TESS APPLICATIONS

TESS will observe more stars than Kepler but over much less time: only a month for most of the sky (longer at the poles). Most circumbinary planets will not have consecutive transits, hence non-eclipsing binaries are very relevant. It will be necessary to combine infrequent transits with radial velocity follow-up. Luckily the stars will be bright! Dynamic transit probabilities help justify an extended mission.



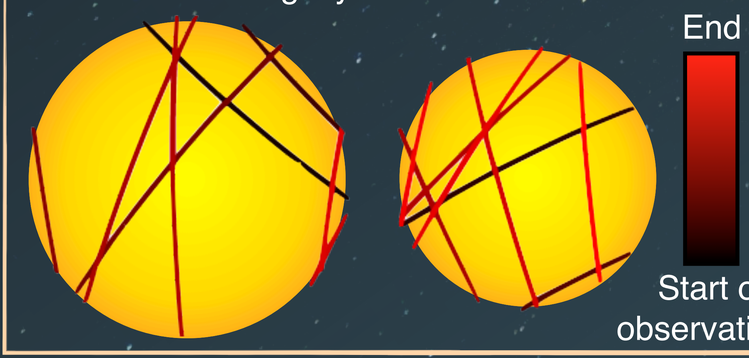
THINKING OUT OF THE PLANE

Circumbinary searches so far have been biased towards coplanarity. We have observed misalignment in hot Jupiters and protoplanetary discs, so why not circumbinary planets too?

This YouTube animation explains why winking binaries like KH 15D, WL4 and YLW 16A could be the key:

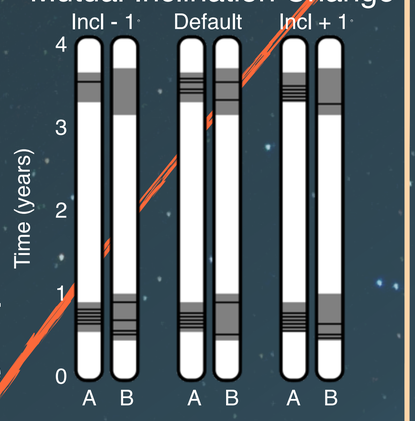
STELLAR TOMOGRAPHY

The transits you do get will be highly varied. This is a simulation over 4 years for a near-polar orbit. The relative motion slightly curves some transit chords.



TRANSIT TIMING GENOMES

Each system possesses a unique *genome* that is *sequenced* through observations. These are transits (black lines) of the primary (A) and secondary (B) stars within regions of transitability (grey) for three almost identical simulations. The observed transit sequence is highly sensitive to the orbital parameters.



IMAGES
star: http://mipa.de
planet: http://csirouniverseblog.files.wordpress.com
background: http://blog.adambavier.com