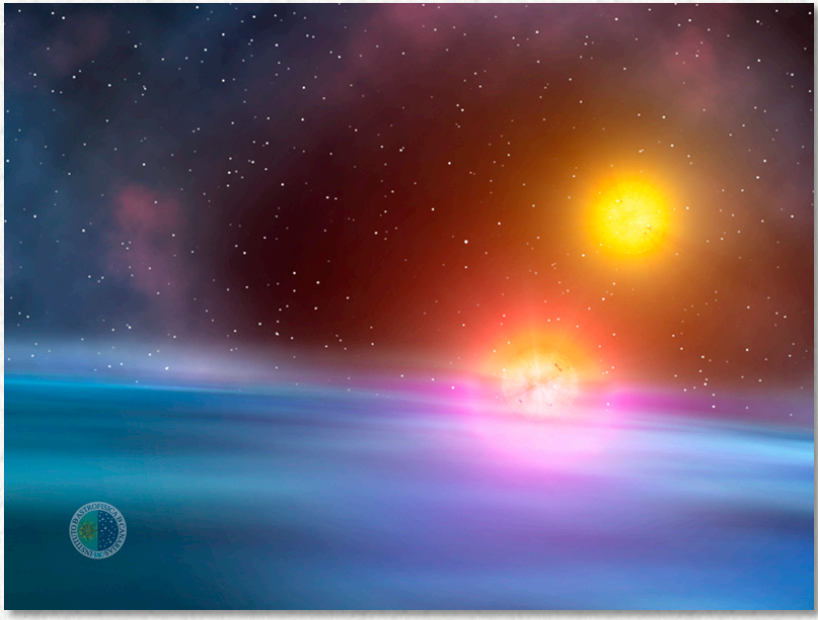
Circumbinary planet (CBP) detection: implications for the PIC



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PLATO WP 112510
Photometric detection of circumbinary planets

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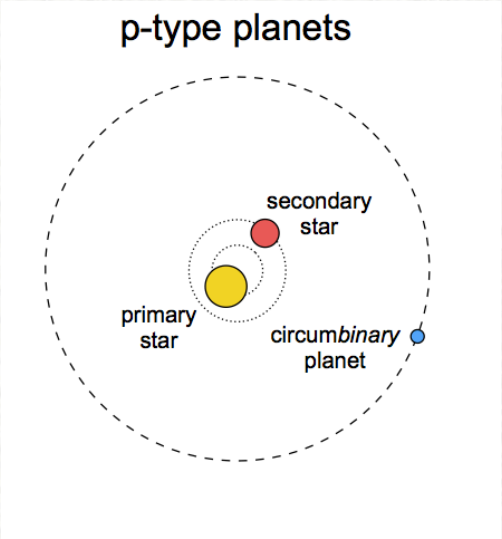


CBPs -> PLATO Core sample?

CBPs fitting into principal PLATO *Scientific Questions* (see Don's talk yesterday):

Certainly fit into:
Obj.1 'How do planets and planetary systems form and evolve?'
Potentially also:
Obj 3 'Are there potentially habitable planets?'

and they fit with these derived 'Science Objectives':

S3: Study the typical architectures of planetary system
... provide constraints on planetary system formation and evolution processes

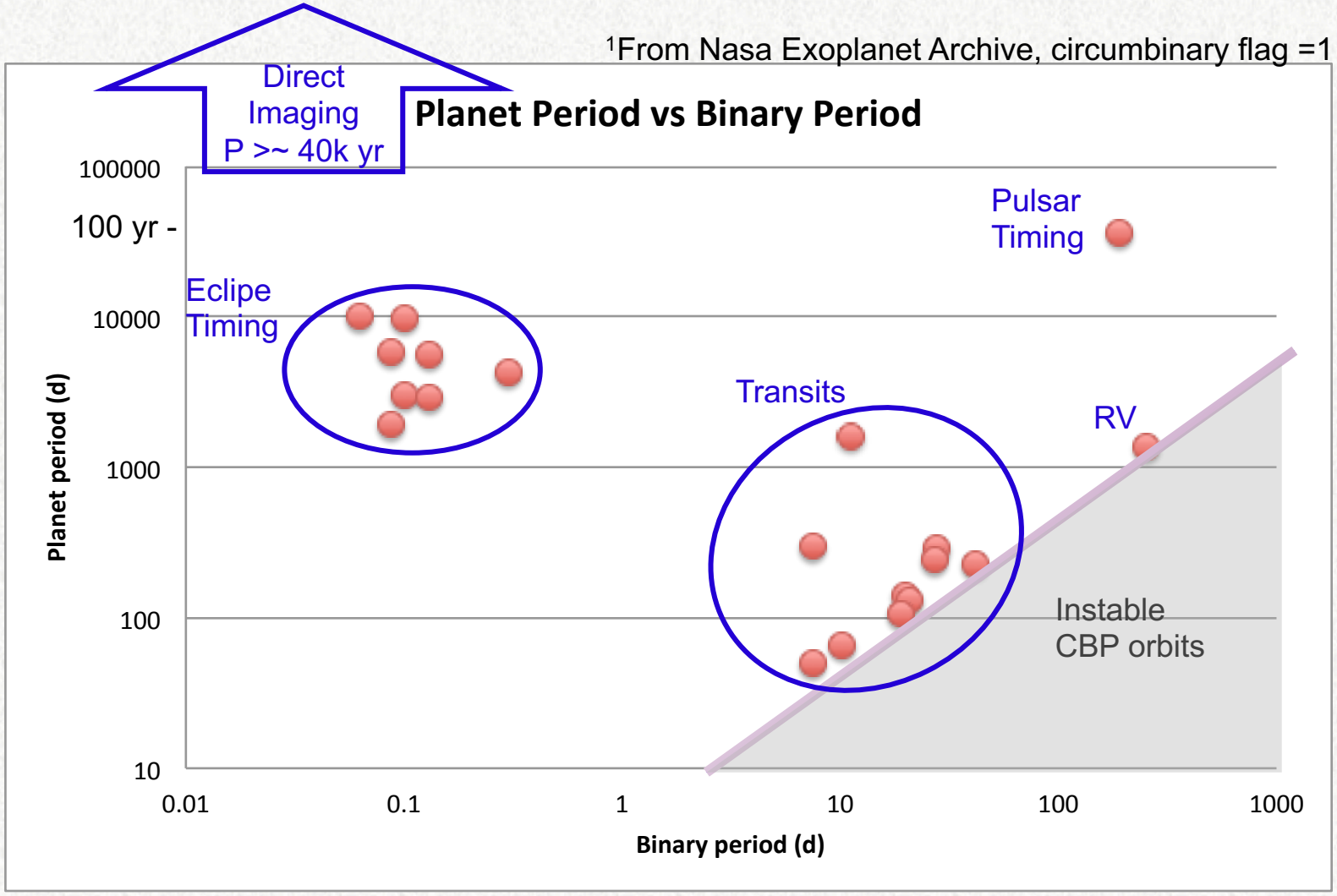
S4: Analyze the correlation of planet properties and their frequencies with stellar parameters

Planet formation around binaries does have common factors
(e.g. formation from protoplanetary disc)
and differences
(e.g. resonances in these discs; stability issues):

Global planet formation theories need to account for CBPs as well!

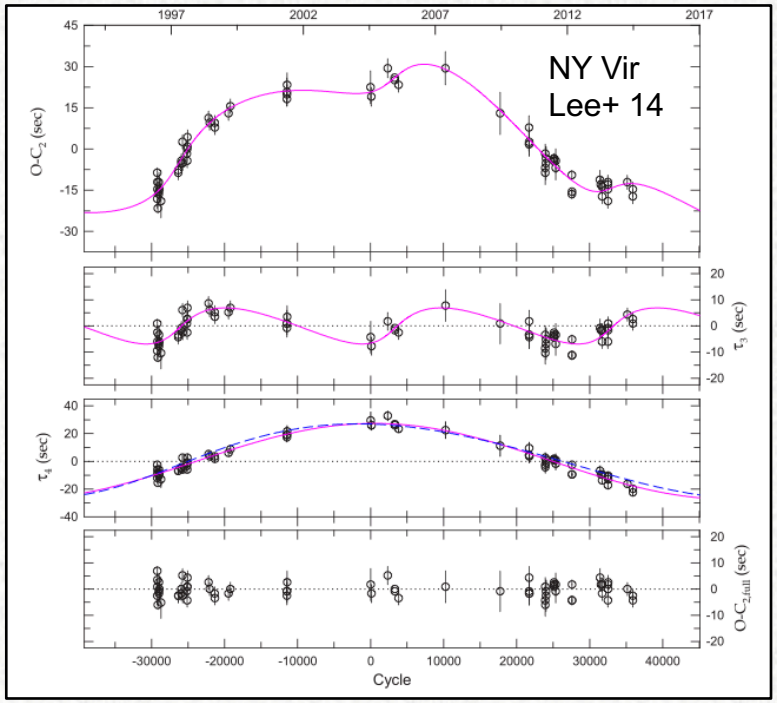
26 known CBPs[1]: Distinct populations pending on discovery method

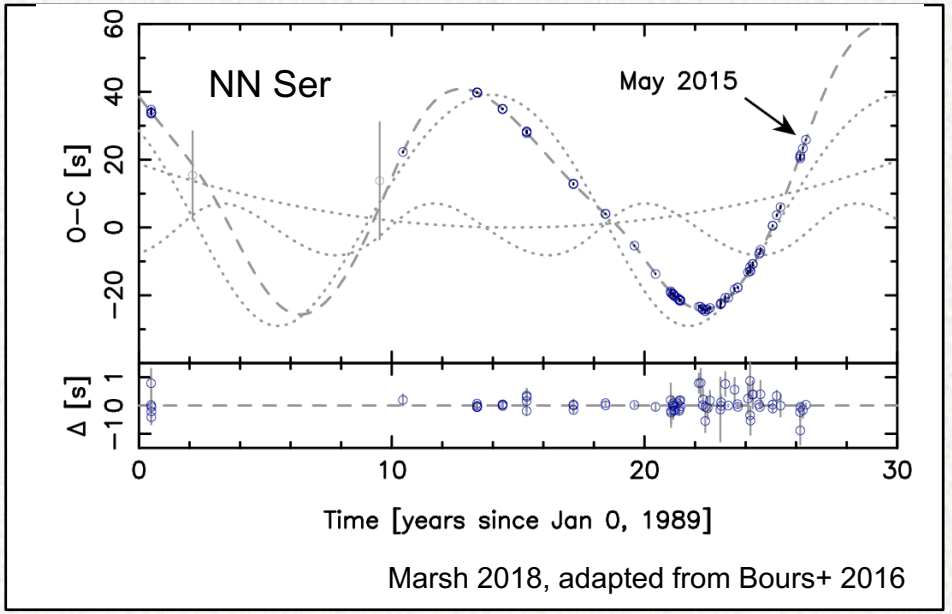
[1]From Nasa Exoplanet Archive, circumbinary flag =1



In PLATO 2.0 paper (Rauer+ 2014):
PLATO will increase number of transiting CBPs several times over Kepler (realistic: 3-4 times)

CBPs discovered by eclipse timing variations (ETV)





All 10 EBP discovered on evolved stars with a compact component, from light-time effect:
Pulsars, ecl. binaries dM /WD; dM/sdB. (Pbin ~0.1d)

Required for discovery are:
- Identification of suitable target
- Long observing coverage (P_{planet} >~ 5yr)
- Precise eclipse timing measures (5secs or better)

From eq. for eclipse timing precison (Deeg&Tingley (2017):
For EBs with deep (50%) eclipses, PLATO could reach 5sec timing precision up to 18th mag (on single eclipses!) IF cadence is sufficiently fast (ideal: 25sec).

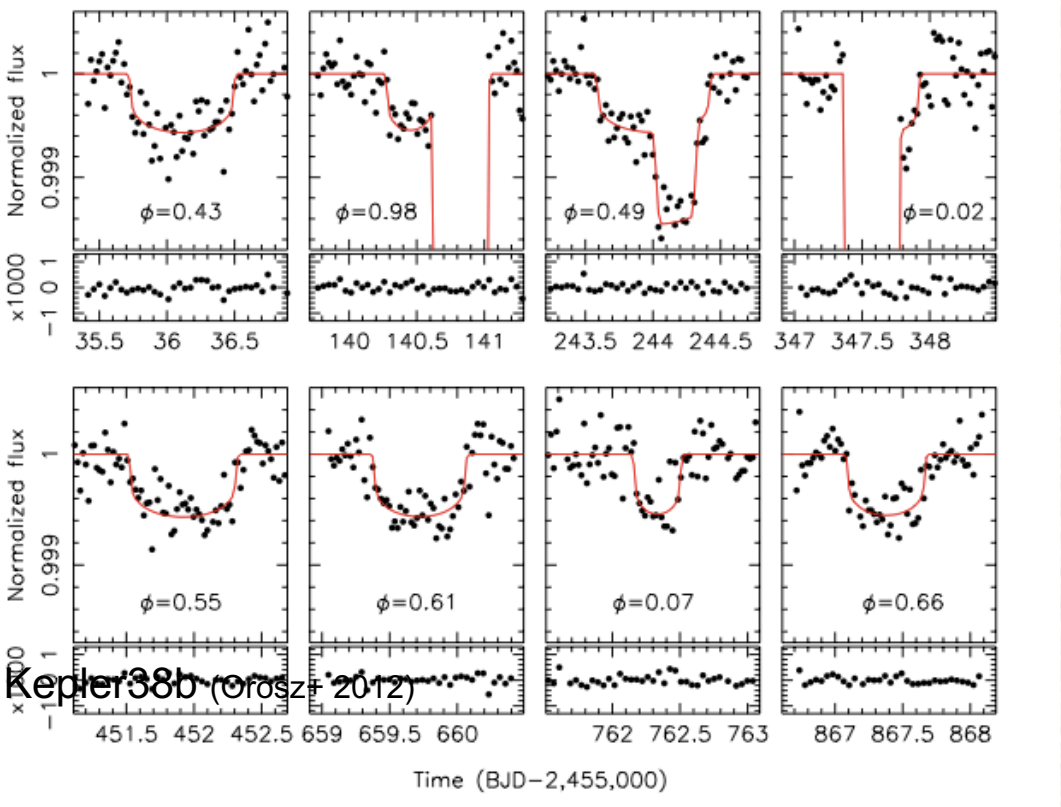
ETV timing on non-compact systems: transiting CBP systems Kepler-16,34,35 show ETV of 10s -1min from orbital dynamics (not light-time effect). Some further candidates exist.

CBP detection by transit

Method features:

- Unique transit signal, but low amplitudes
- Details of transit depend on EB phase.
- low probability of false positive

Currently known planets:
Around binaries with > 7d period.
Inner planets are close to inner stability limit.
Planets are Uranus – Saturn sized



Kepler38b (Orosz+ 2012)

Selection of targets:

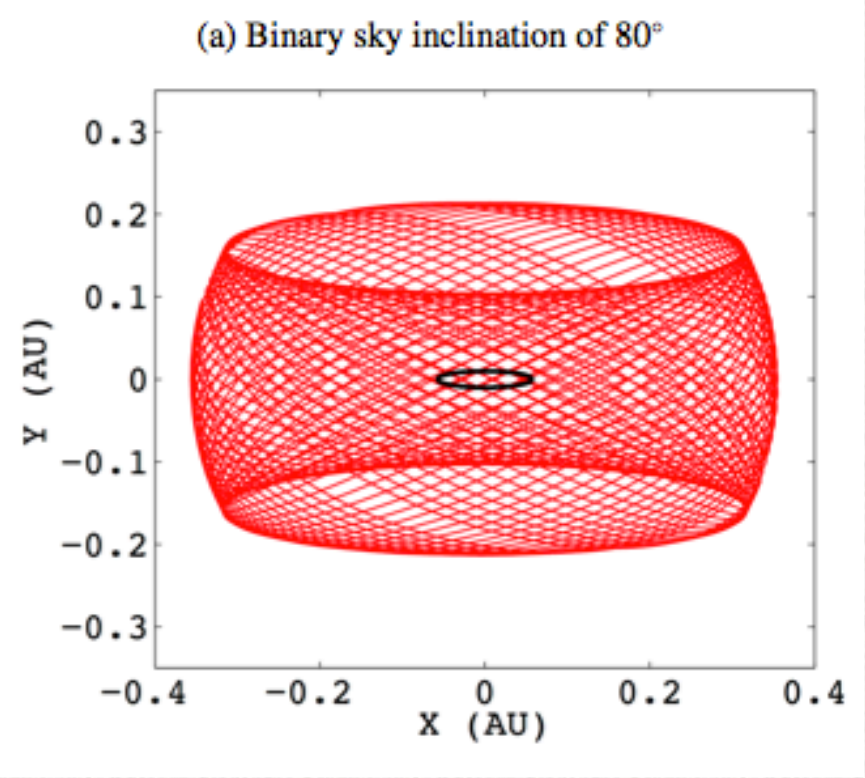
- EBs with P ≳ 5d

- mag. ≲ 15 (From requirement: ≲0.1% rms over 6mins)

- Deep eclipsing EBs (i ≈ 90˚) :
  -> detection of CBPs of known types

CBP in ‘misaligned’ systems ?

misaligned: orbital planes of stellar binary and of planets have strong mutually inclination
(all known CBPs: $i_{mutua}l \lesssim 3.5^{\circ}$)



Martin & Triaud 2014

Detection of misaligned CBPs (unknown but well possible) :

- On stellar binaries of any inclination
  (deep/ shallow/no eclipses
- transit observability only within time-windows

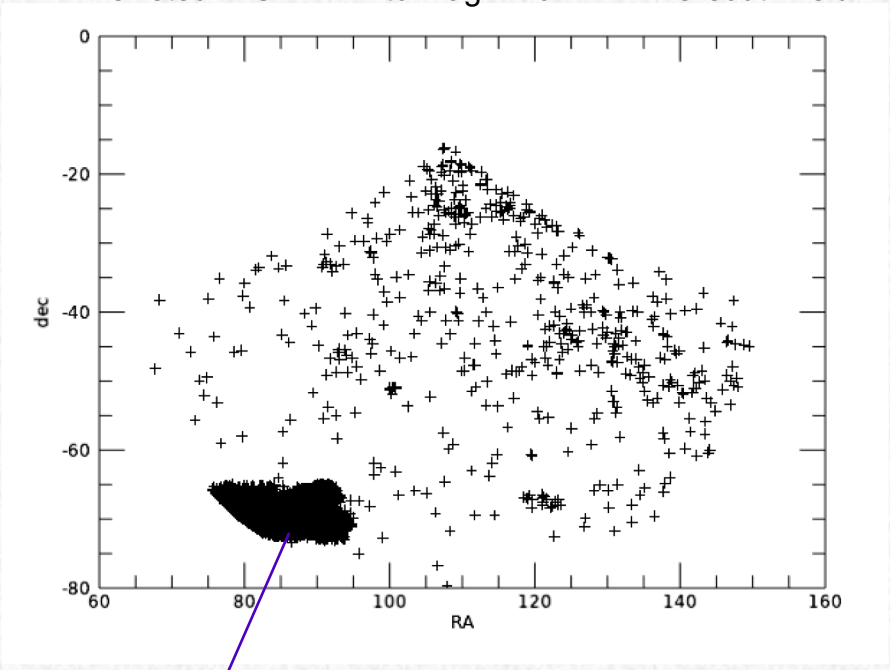
(sparse; single transits or few ones over years to centuries)

TBDecided:
Inclusion of specific sample of shallow/non-eclipsing binaries for *potential* detection of misaligned CBP

Then, TBDone:
Evaluate if non-eclipsing binaries can be found from off-eclipse brightness variations in TESS data
(if $P_{bin} > 7$ days, not likely)

Potential targets for CBP search by PLATO

EBs listed in SIMBAD to mag ≤ 16 in PLATO south field



OGLE deep coverage (to 20mag)

Extrapolating the EB count in OGLE field (48deg^2) to a PLATO field (2232deg^2):

Mag ≤10: 200 EB
Mag ≤13: 2 000 EB -> targets for transit search (potentially to 15mag)
Mag ≤16: 50 000 EB -> targets for ecl-timing survey (potentially to 18mag)

mag: is brightest value among BVRI (simbad)

Issues for CBP detection with PLATO PIC

All CBP detection efforts: Require long observing duration; step&stare fields of lesser relevance

From TESS: EBs with P$\lesssim$ 28d and brighter $\lesssim$ 12mag will become known very soon

For CBP transit search: EBs with $\lesssim$ 13-14 mag will be prime sample

For CBP eclipse timing survey : rather faint EBs with compact component
(18mag? Need revision of contamination. Ideal: high-cadences of 25/50sec)
->pre-launch photometric monitoring: longer baselines for EB-timing

The case of CBP on non-eclipsing (shallow) binaries: -> potential unkown
with TESS, from spectral surveys -> potential to define pre-launch sample?
and/*or* analyze mono-transits for binarity once they are found.

Need provision to add EBs to PIC: into main-catalogue; into Sample 5?
also: Facilities to include type-specific information (binary period, amplitude)
(the same goes for guest proposals)

Thank you

¡Gracias!