# Constraints on Circumbinary Planet Orbits from Kepler Single Transit Events

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UK Exoplanet Community Meeting
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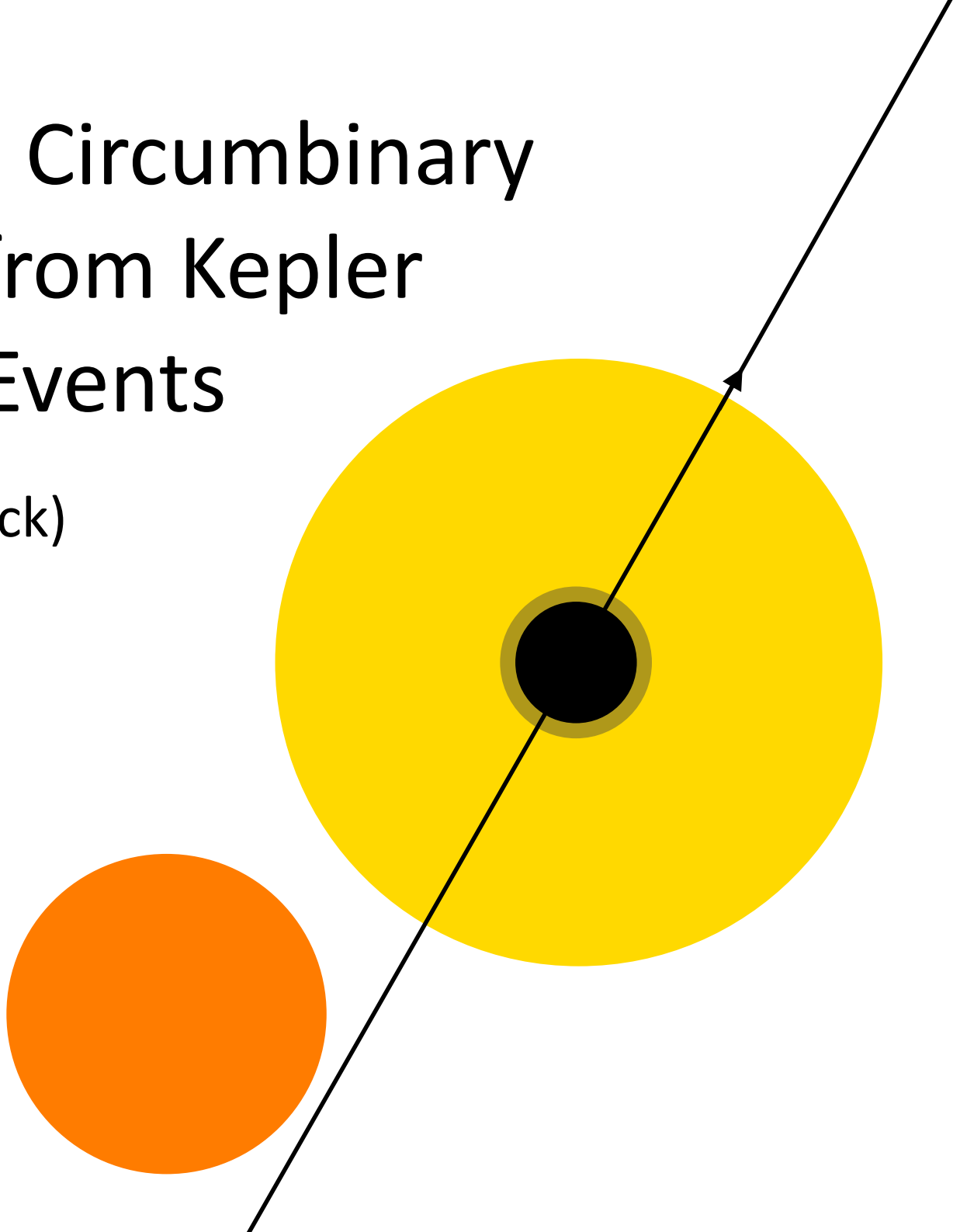
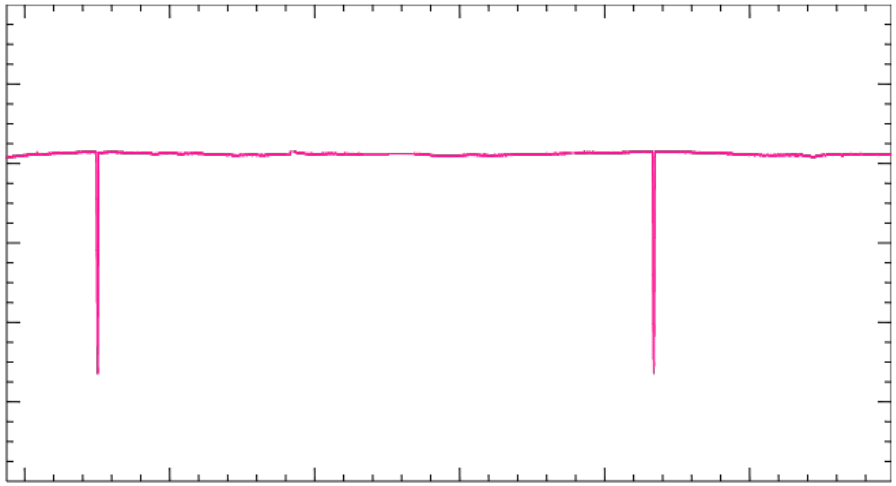


THE UNIVERSITY OF WARWICK

# Single Transit Events



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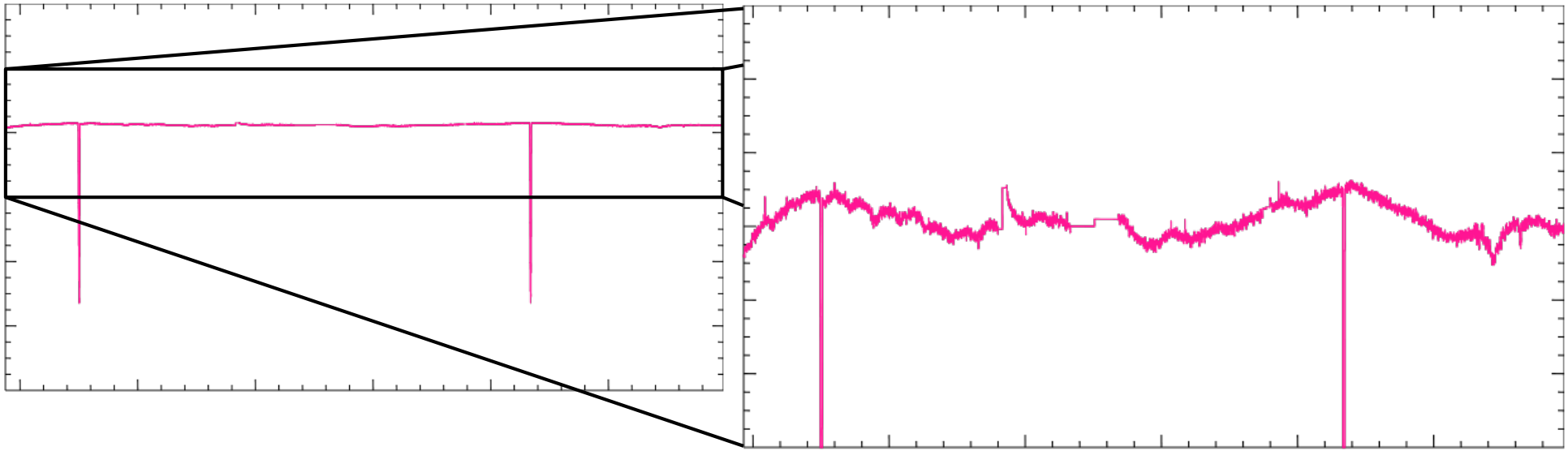

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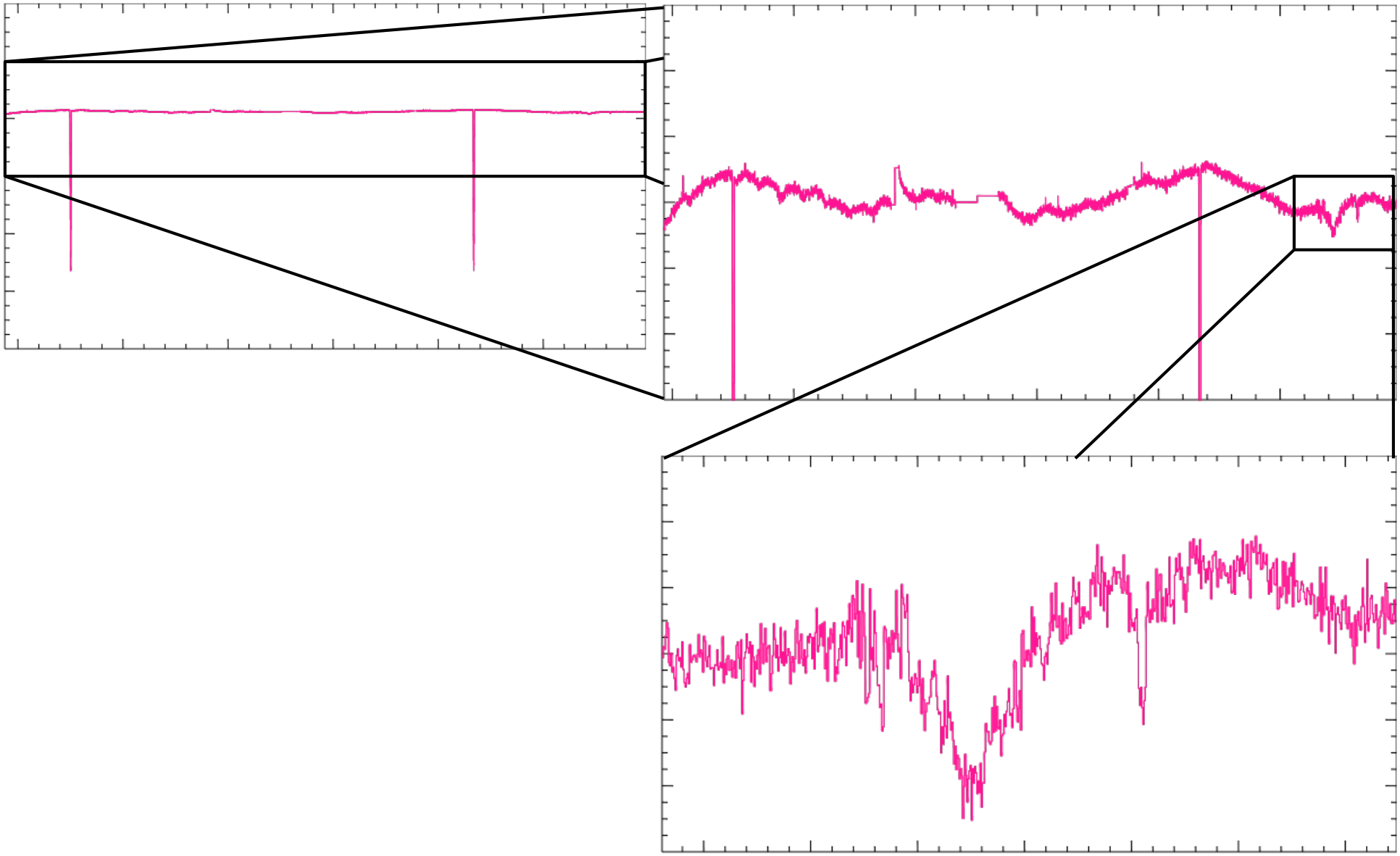

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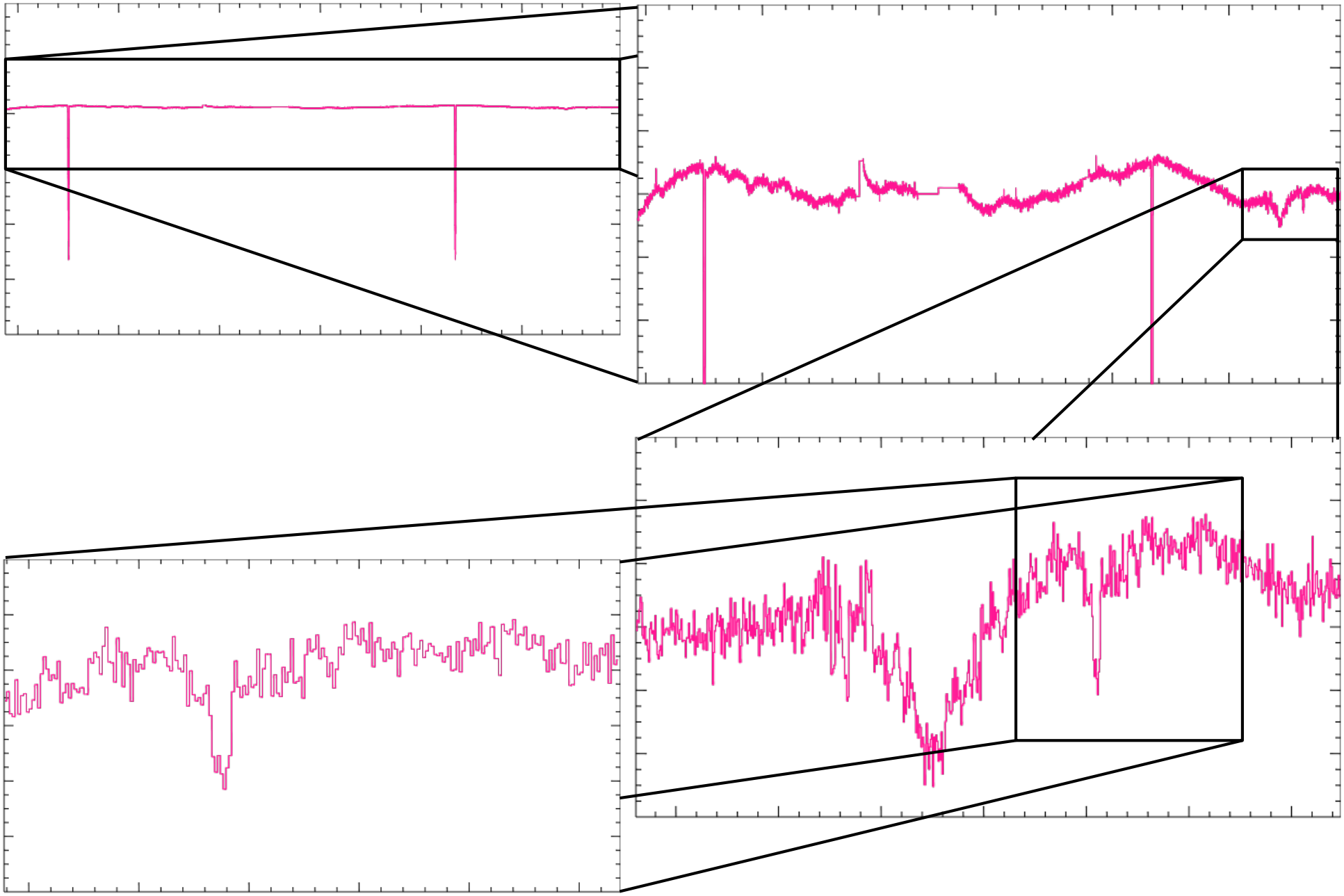

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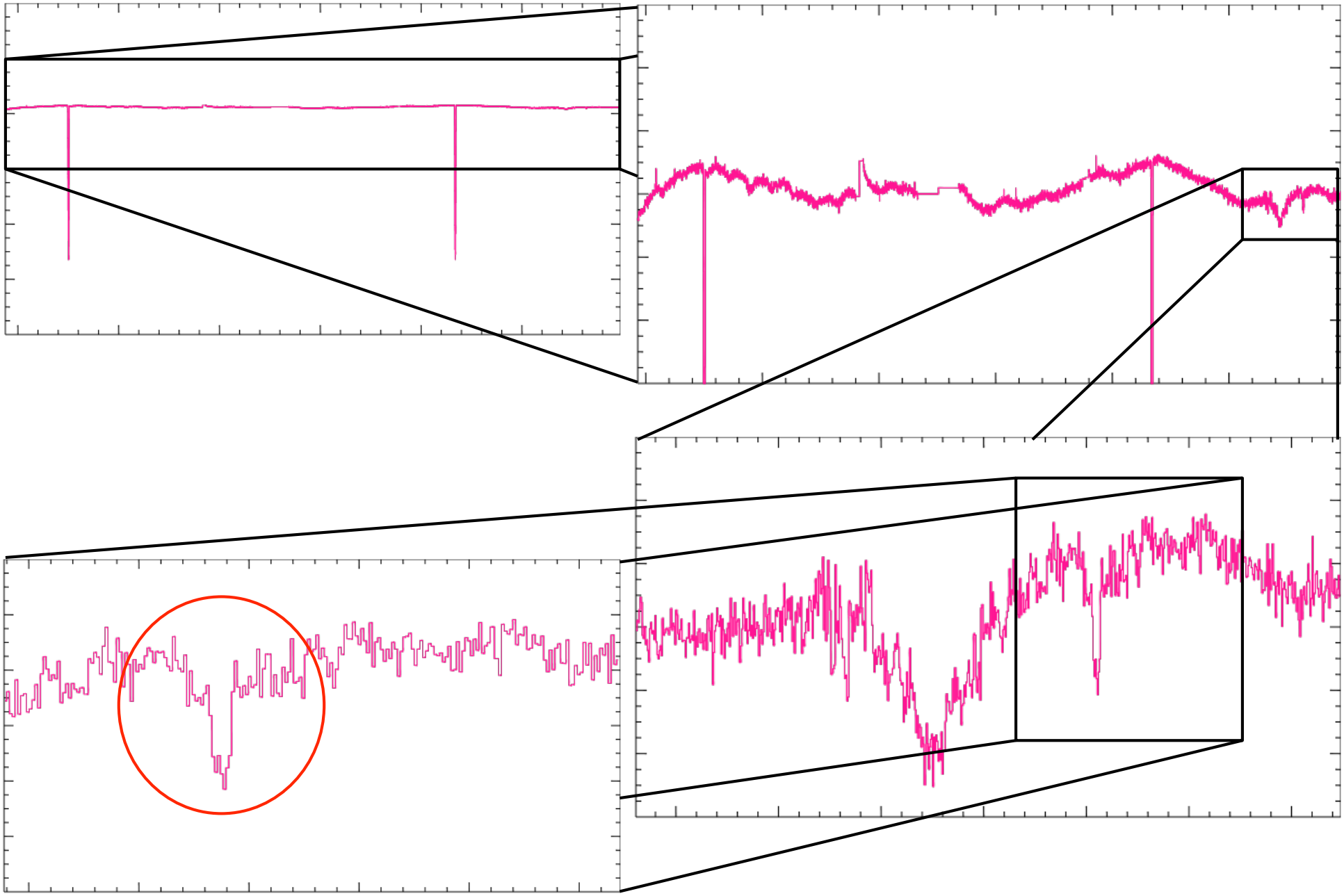

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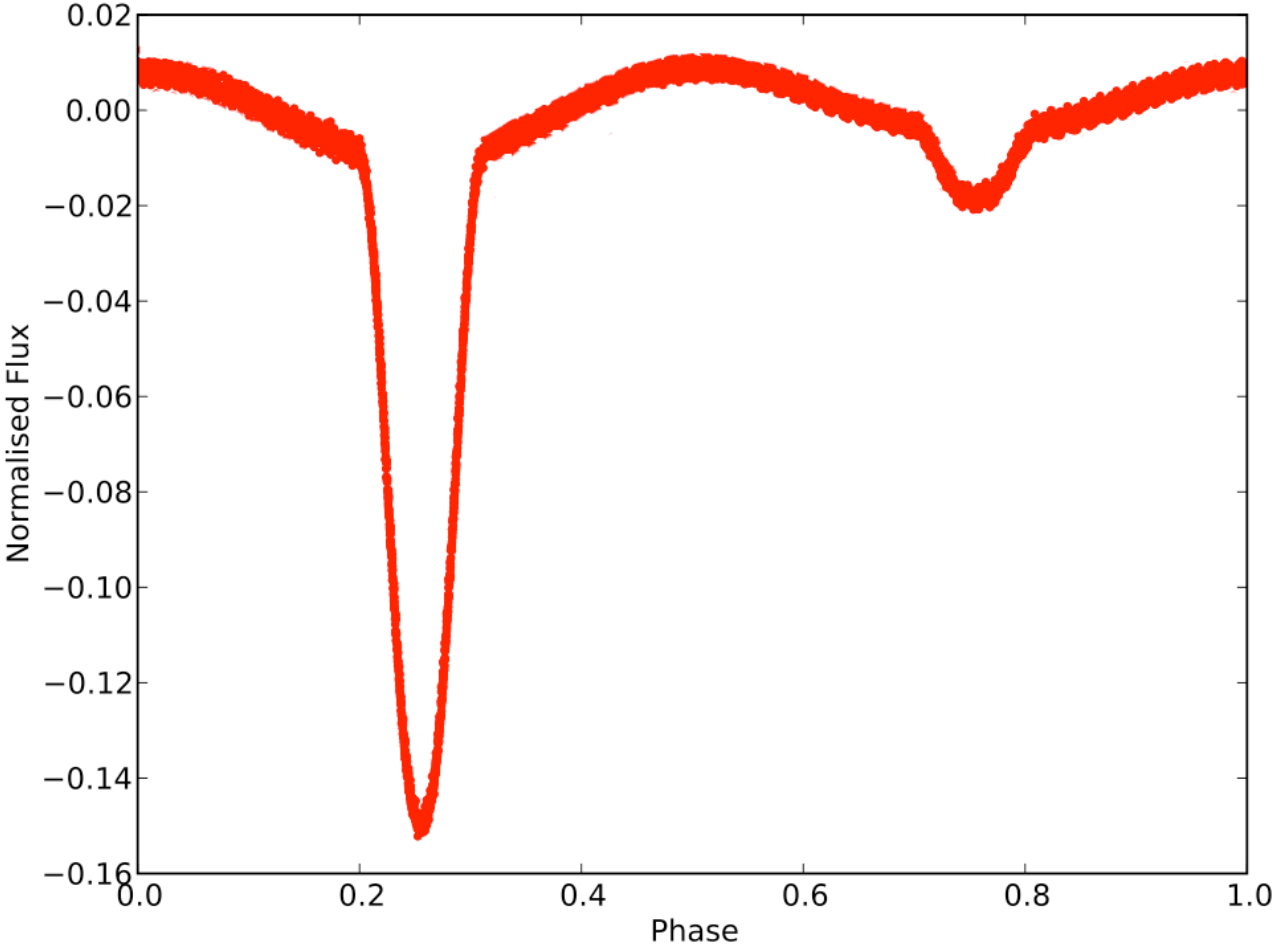

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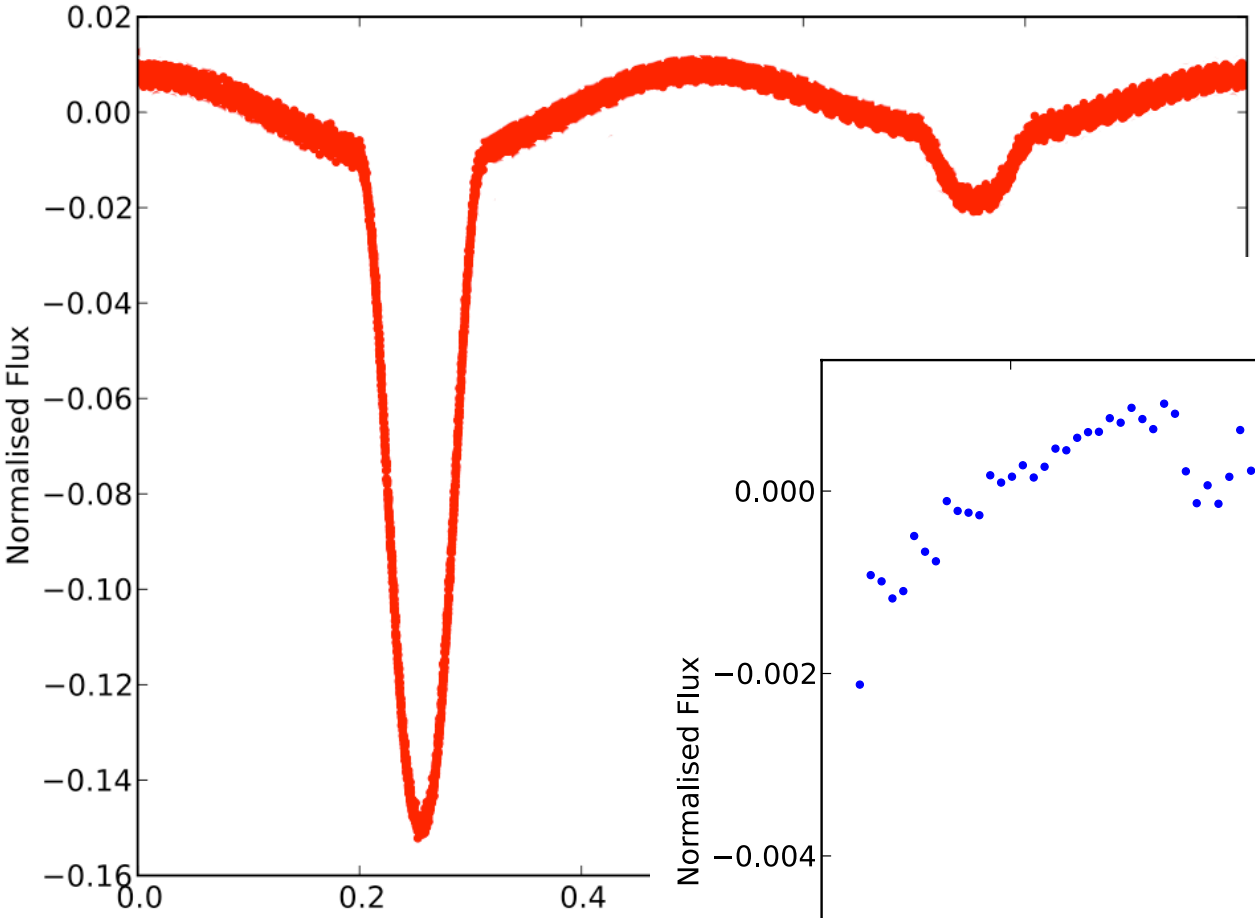
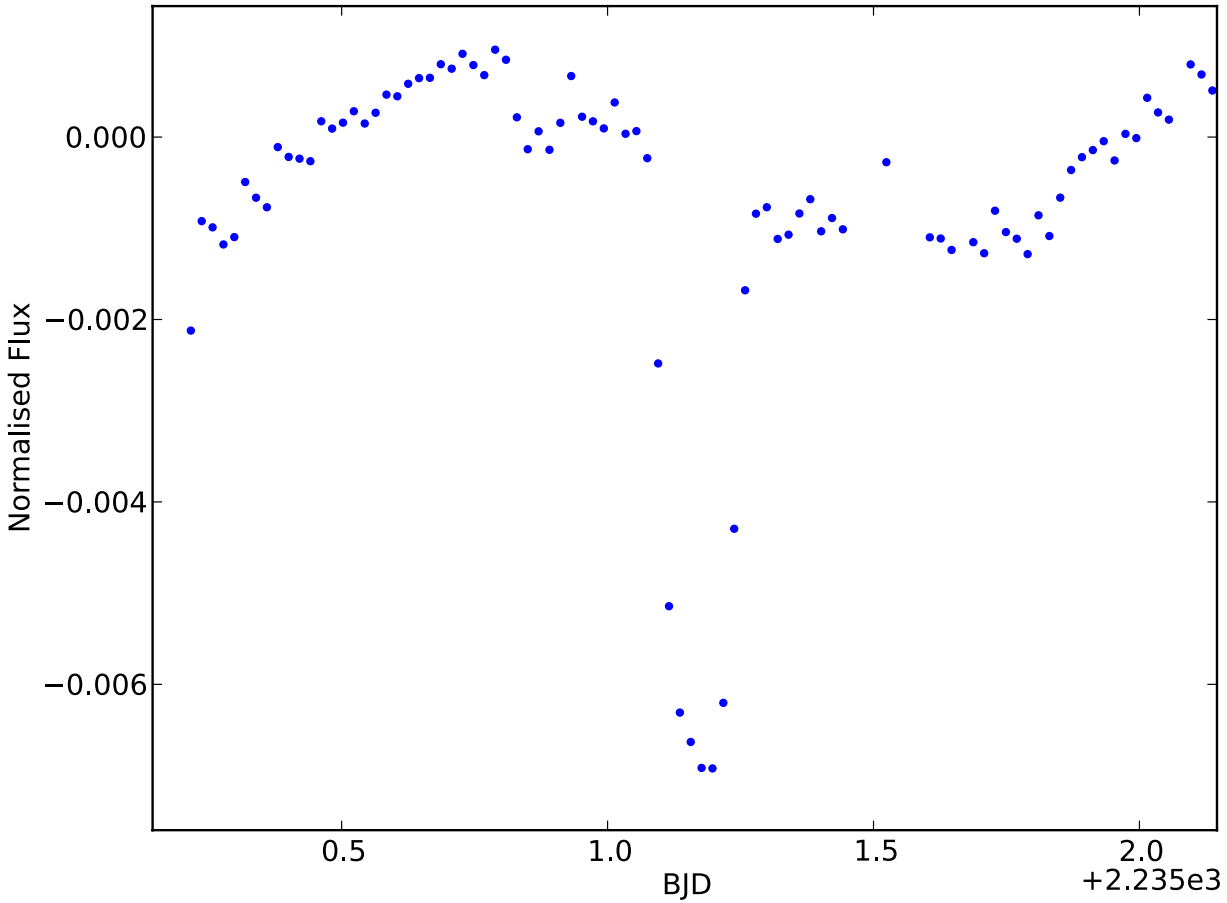


# Aims

- Search for plausible transit paths for circumbinary planets.
- Constrain range of orbital parameters as strongly as possible.

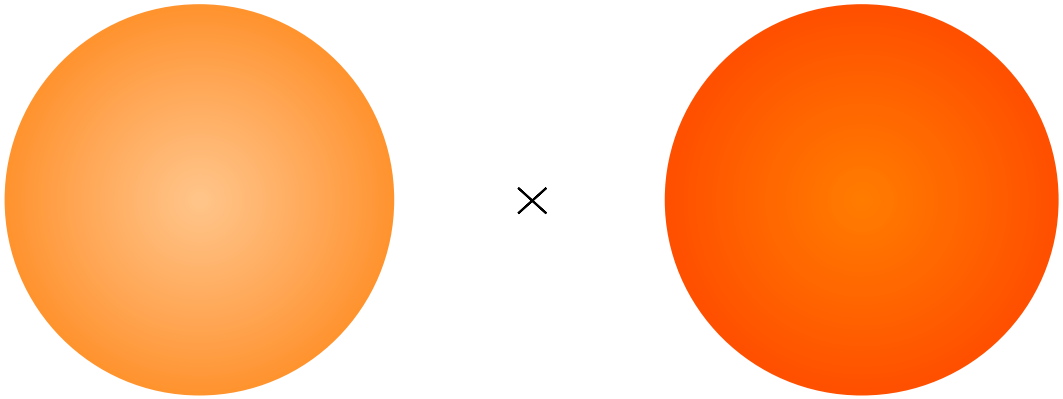
- Model viable transit paths given input parameters for:
  - Binary stars
  - Transit

# Input Parameters

- Period and separation of the binary
- Stellar radii
- Phase of the primary star at $t_0$
- Transit duration
- Transit depth
- Minimum orbital period
- Maximum orbital period
- Number of acceptable paths to find

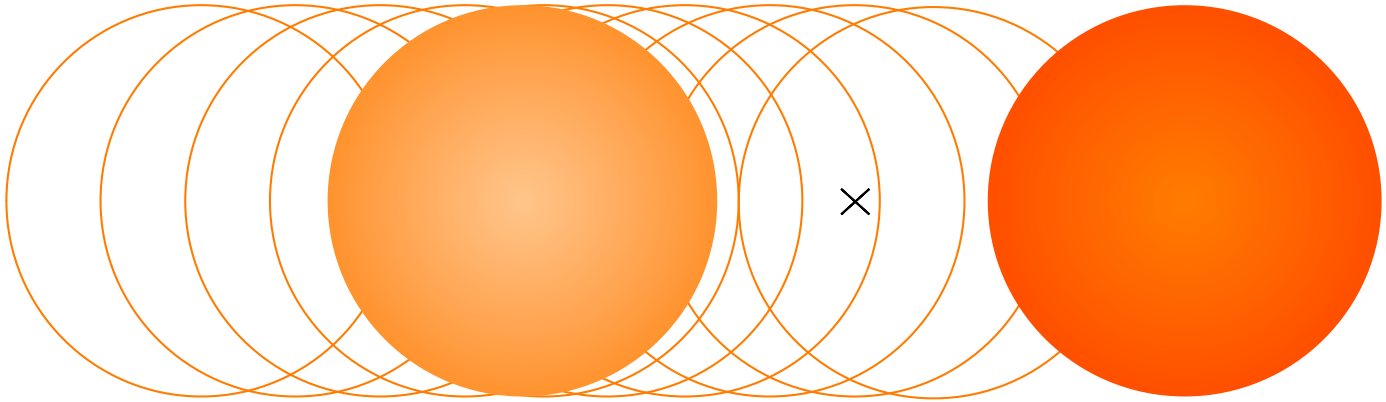
# Modelling the Binary

- Start with definition of binary star parameters.



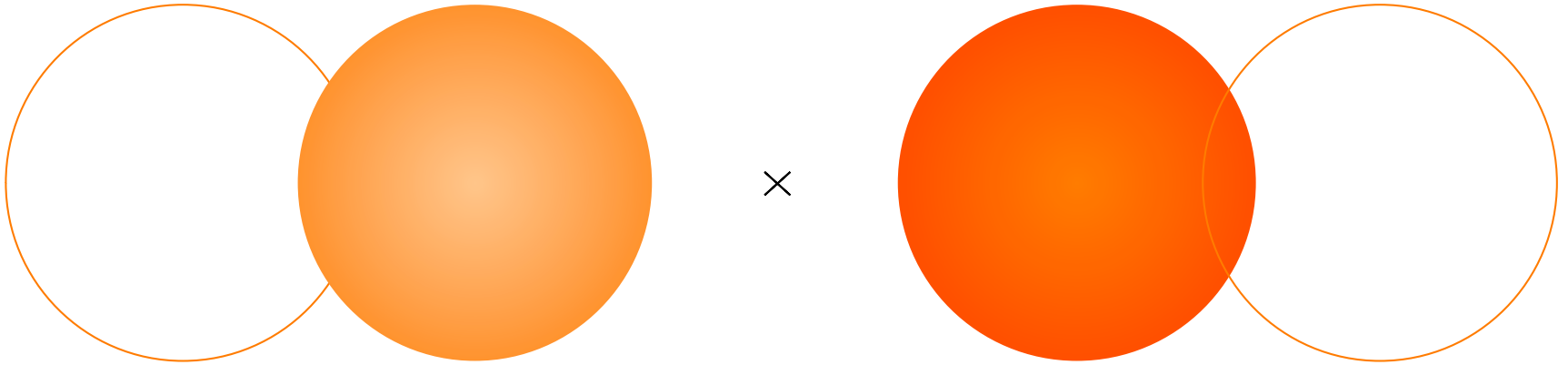
# Modelling the Binary

- Calculate stellar positions around orbit.



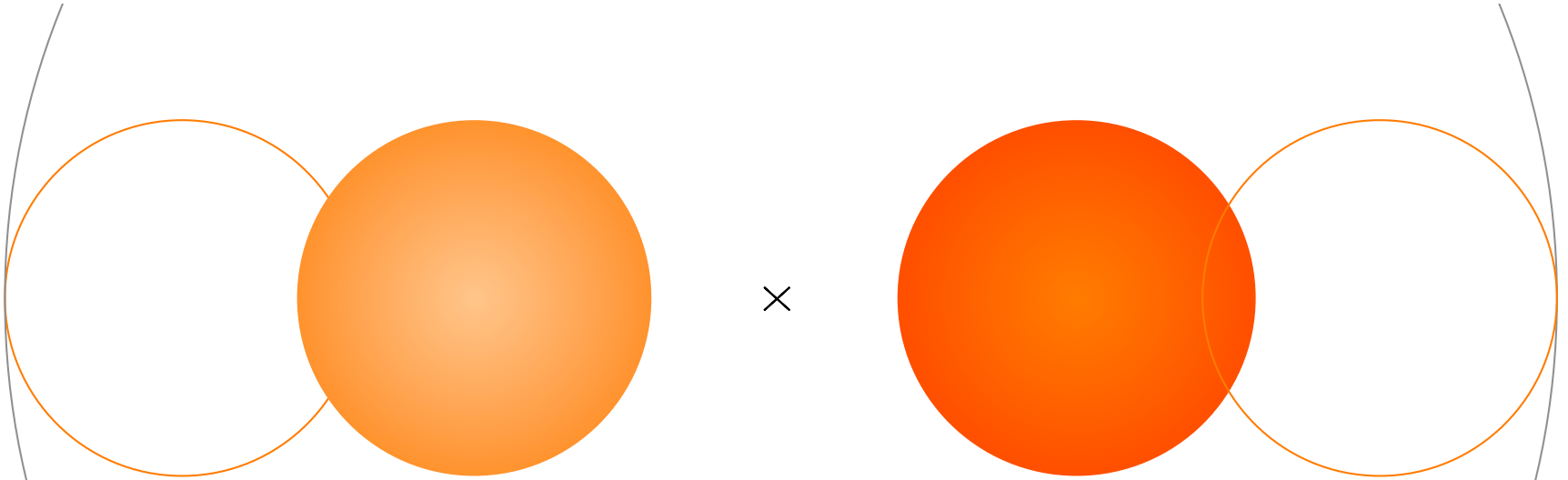
# Modelling the Binary

- Find maximum distance from centre-of-mass.

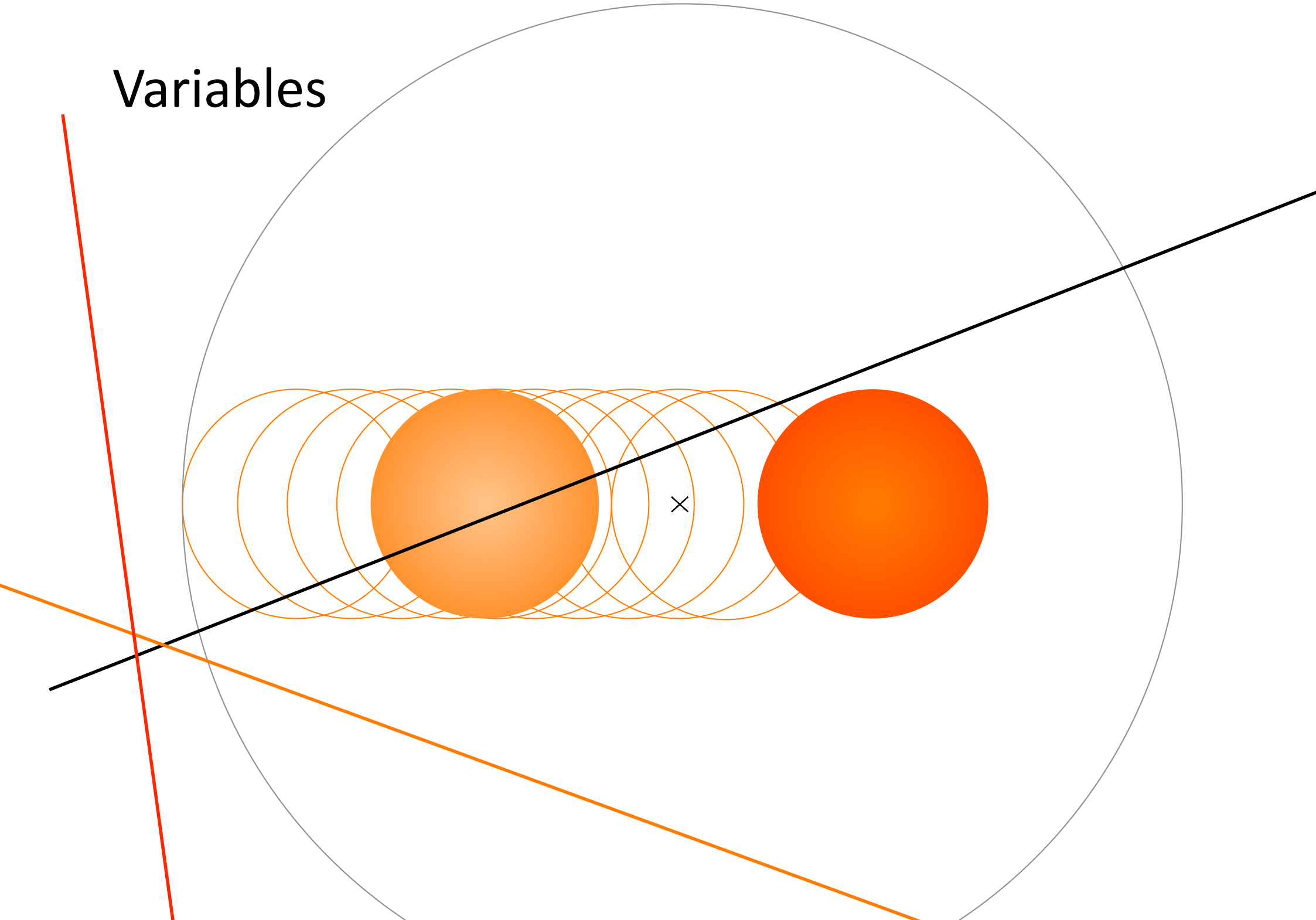


# Modelling the Binary

- Find maximum distance from centre-of-mass.
  - This defines the viable ‘binary circle’.

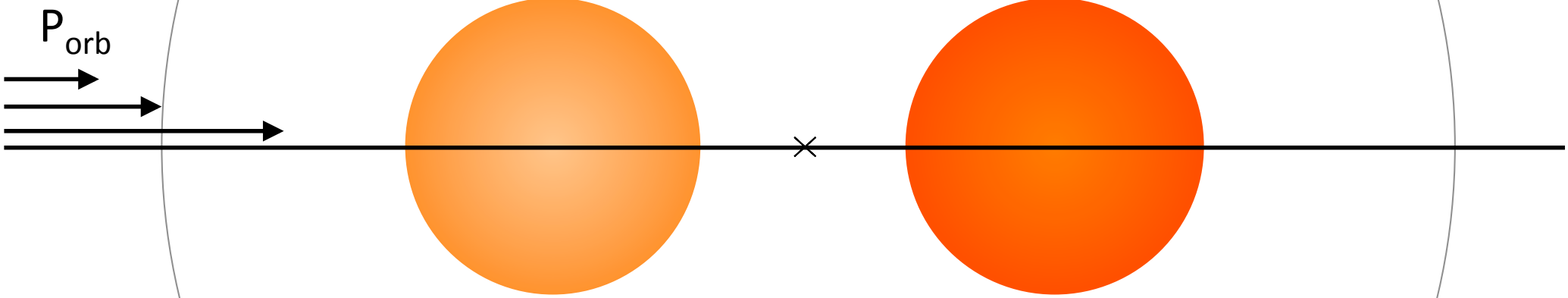


# Variables



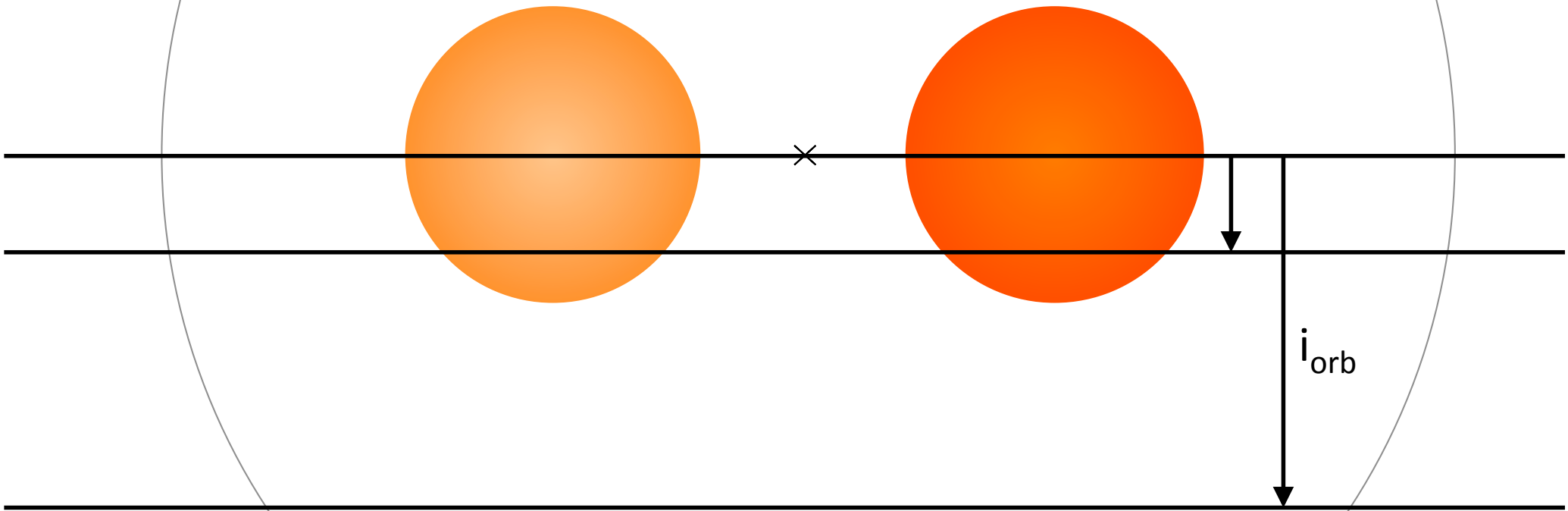
# Variables: Orbital Period

- Period defines orbital velocity, and thus transit duration.



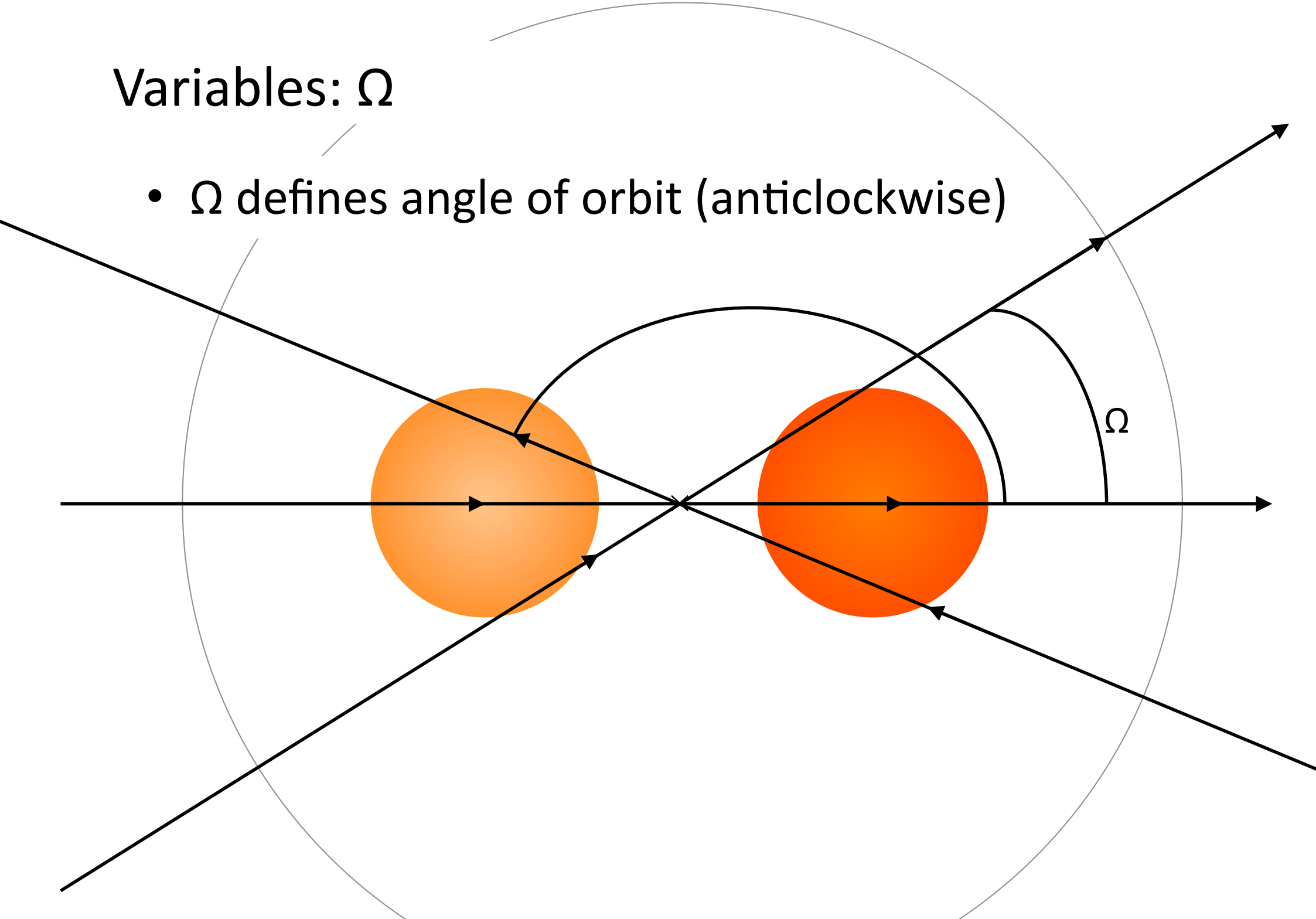
# Variable: Orbital Inclination

- Inclination defines ‘impact parameter’.



# Variables: Ω

- Ω defines angle of orbit (anticlockwise)



# Procedure

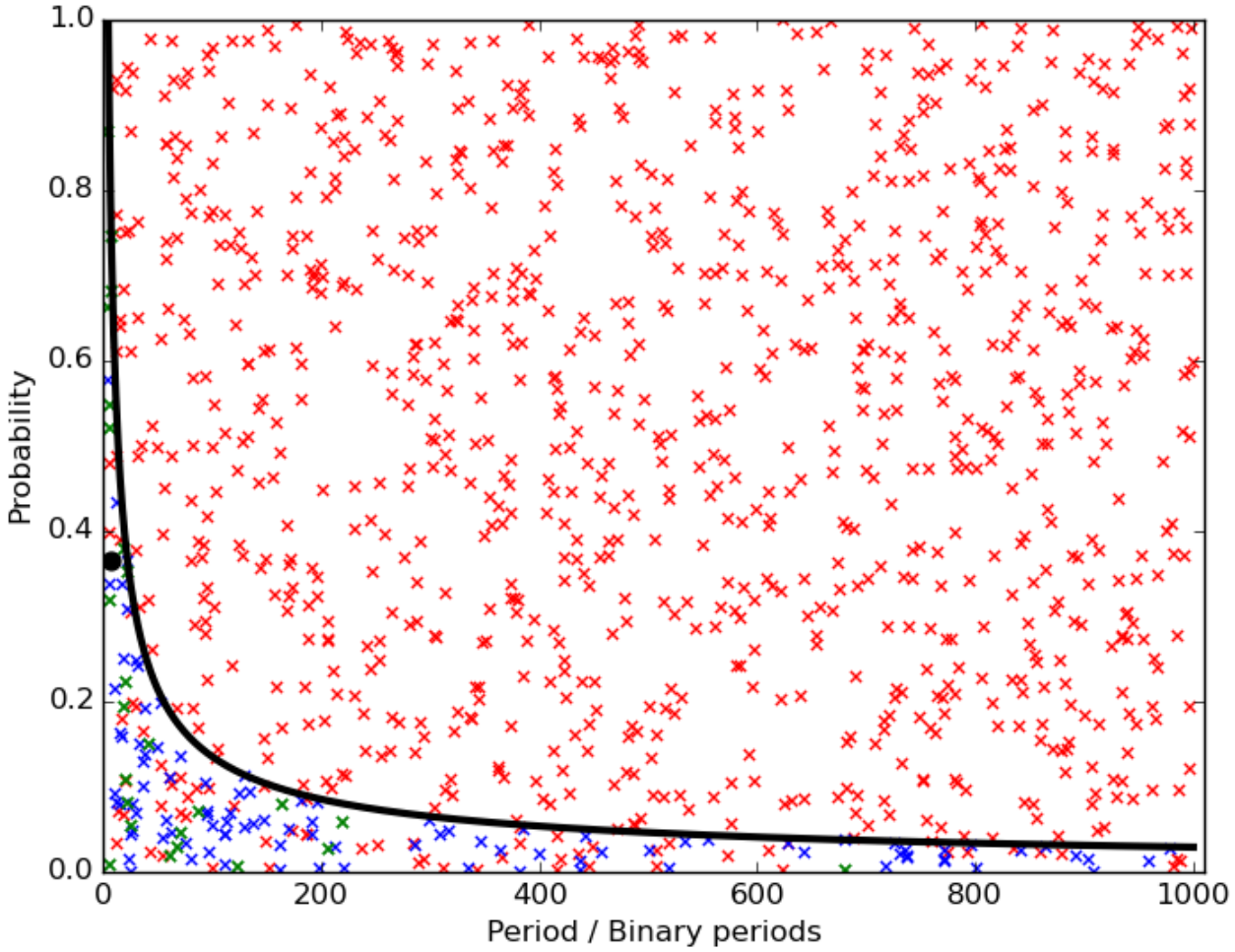
- Sample distributions of:
  - inclination [uniform in $\cos(i_{orb})$]
  - Ω [uniform]
  - period [uniform]

  - transit probability [uniform in range 0-1]

# Procedure

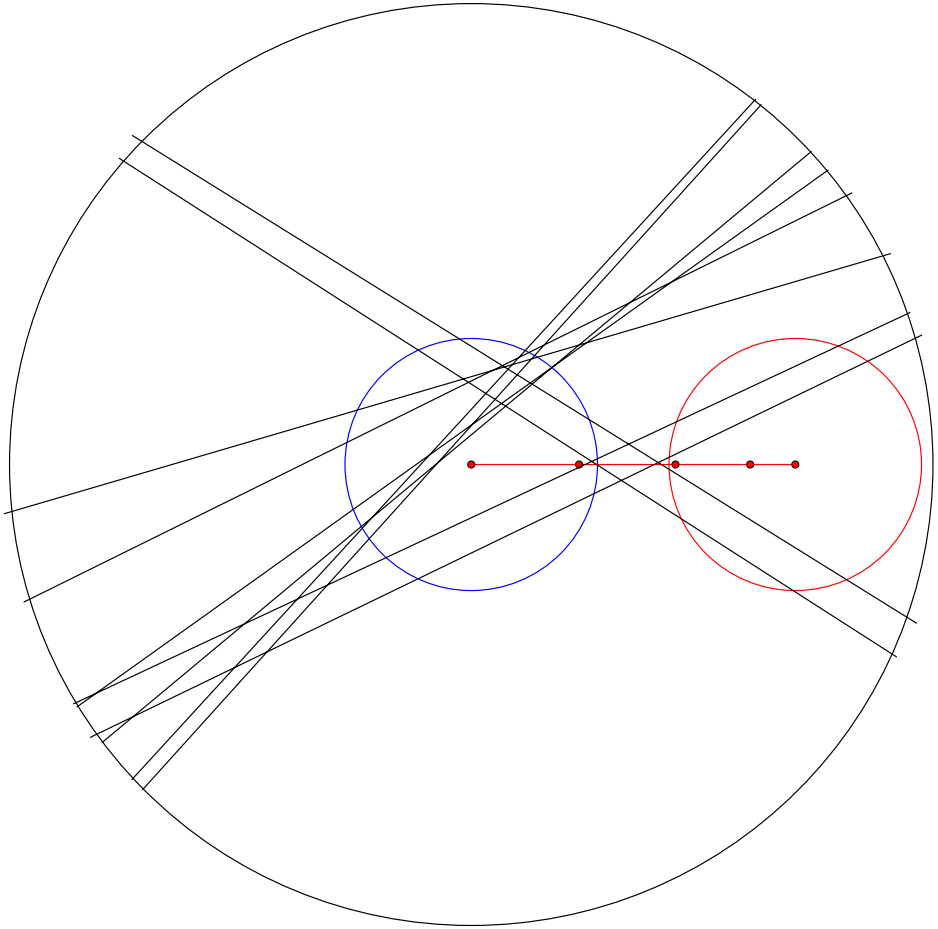
- Initial cut based on transit probability curve, normalised to 1 at minimum search period.
  - If $P > P_{tr}(P_{orb})$, reject sample.
- Does path cross the 'binary circle'?
  - If **yes**, does path intersect *primary*?
    - If **yes**, does duration match requirement?
      - If **yes**, are there other transits within five transit widths either side?
        - If **no**, path is **GOOD**!

# Procedure


1.0
0.8
0.6
0.4
0.2
0.0
Probability
0
200
400
600
800
1000
Period / Binary periods

# Testing: Sun-Sun binary

- Input parameters:
  - $P_{binary}$ = 1.0 d
  - $phase_0$ = 0
  - $T_{dur}$ = 5.0 hr
  - depth = 1.0%
  - $P_{orb,\ min}$ = 5 x $P_{binary}$
  - $P_{orb,\ max}$ = 1000 x $P_{binary}$



- With a sample of 100 accepted paths:
  - $P_{orb}$ = 22.7 ± 28.3 d
  - $i_{orb}$ = 0.35° ± 0.87 (89.65° ± 0.87)
  - Ω = 40.3° ± 130.1

# Testing: future work

- Account for planetary radius – small effect, but could be important for duration matching.
- Transits of secondary star?
  - As alternative source of event.
  - Include in check for additional transit events.
- Test with real systems

- Improve speed and efficiency.
  - Currently 1:30,000-4,000,000 for accepted:rejected steps!

# Conclusions

- We are developing tools to constrain orbital parameters for circumbinary planets based on single transit events.
  - Model the transit paths as $f(P_{orb}, i_{orb}, \Omega)$

- Preliminary results show that constraints are loose, and will vary strongly with the binary parameters.

- Provides useful information for studies of orbital precession.