

# BINARIES



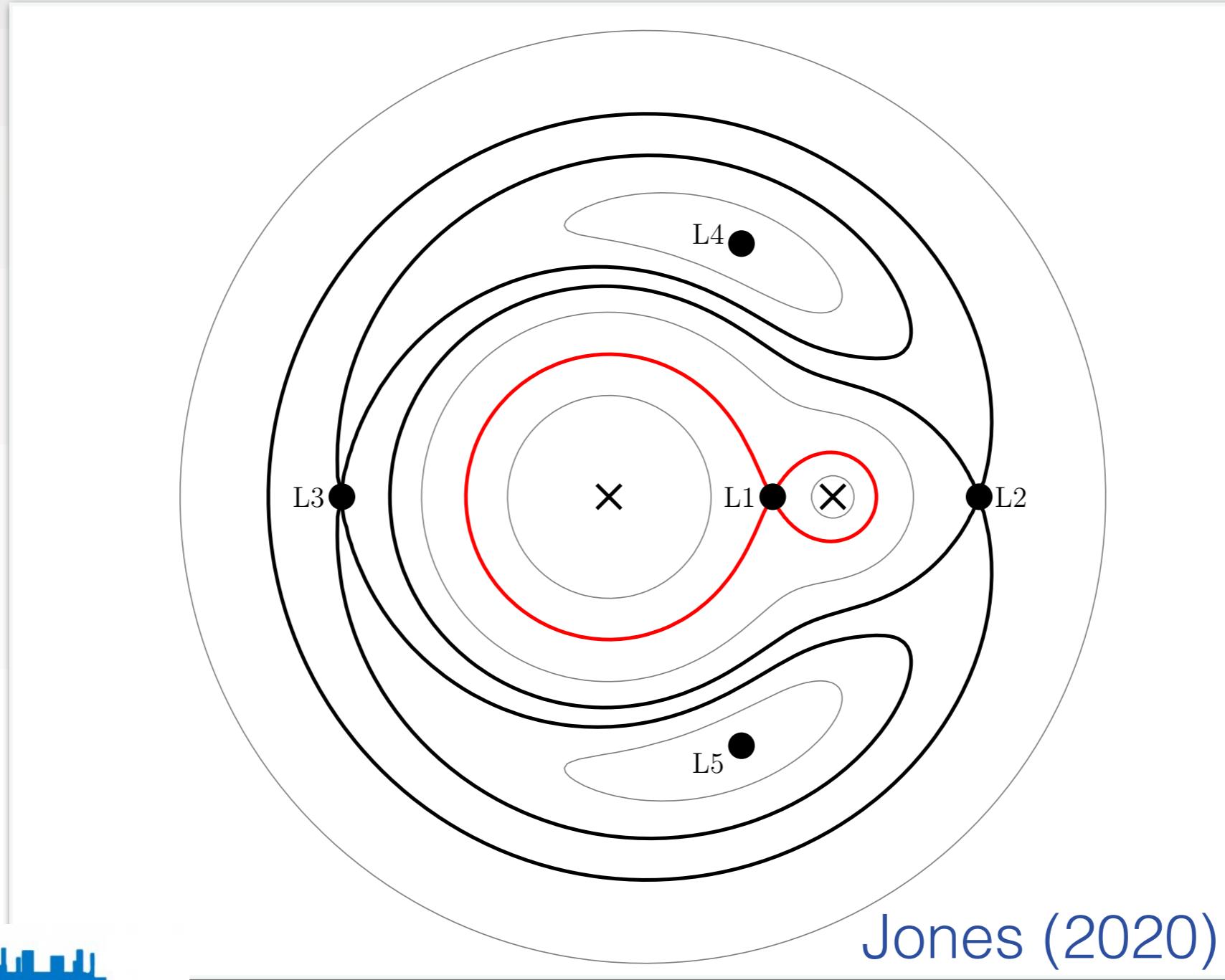
# Binary basics

Different “classes” of binary:

- Visual
- Spectroscopic
- Eclipsing (more generally, photometrically variable)
- Astrometric

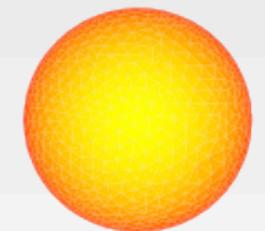
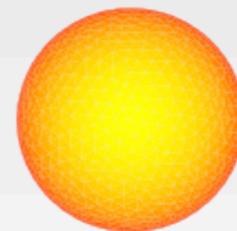


# Roche model

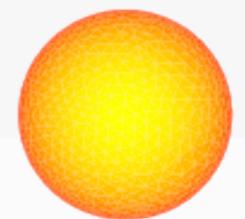
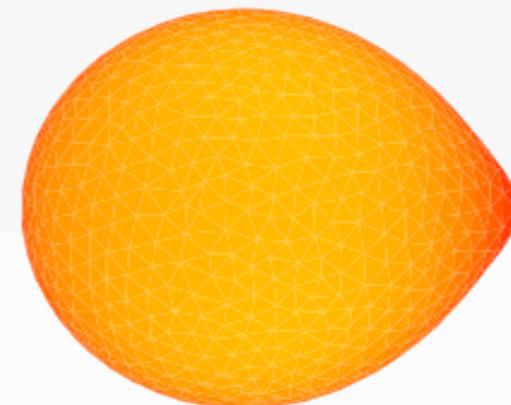


# Photometric variables

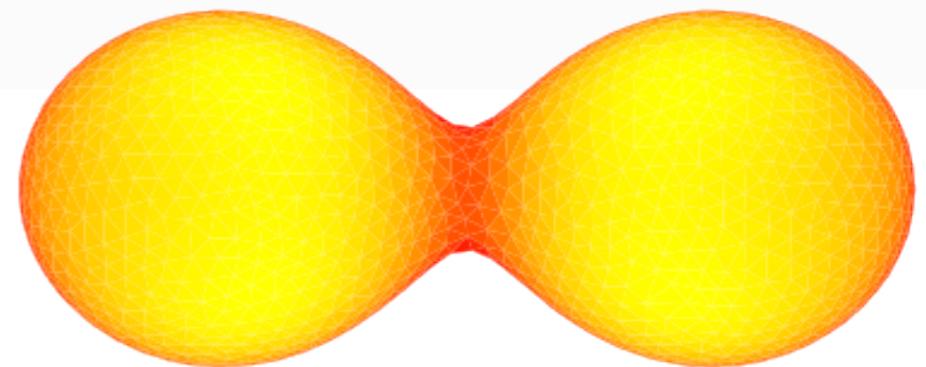
- Detached (Algol-type / EA)



- Semi-detached ( $\beta$  Lyr-type / EB)

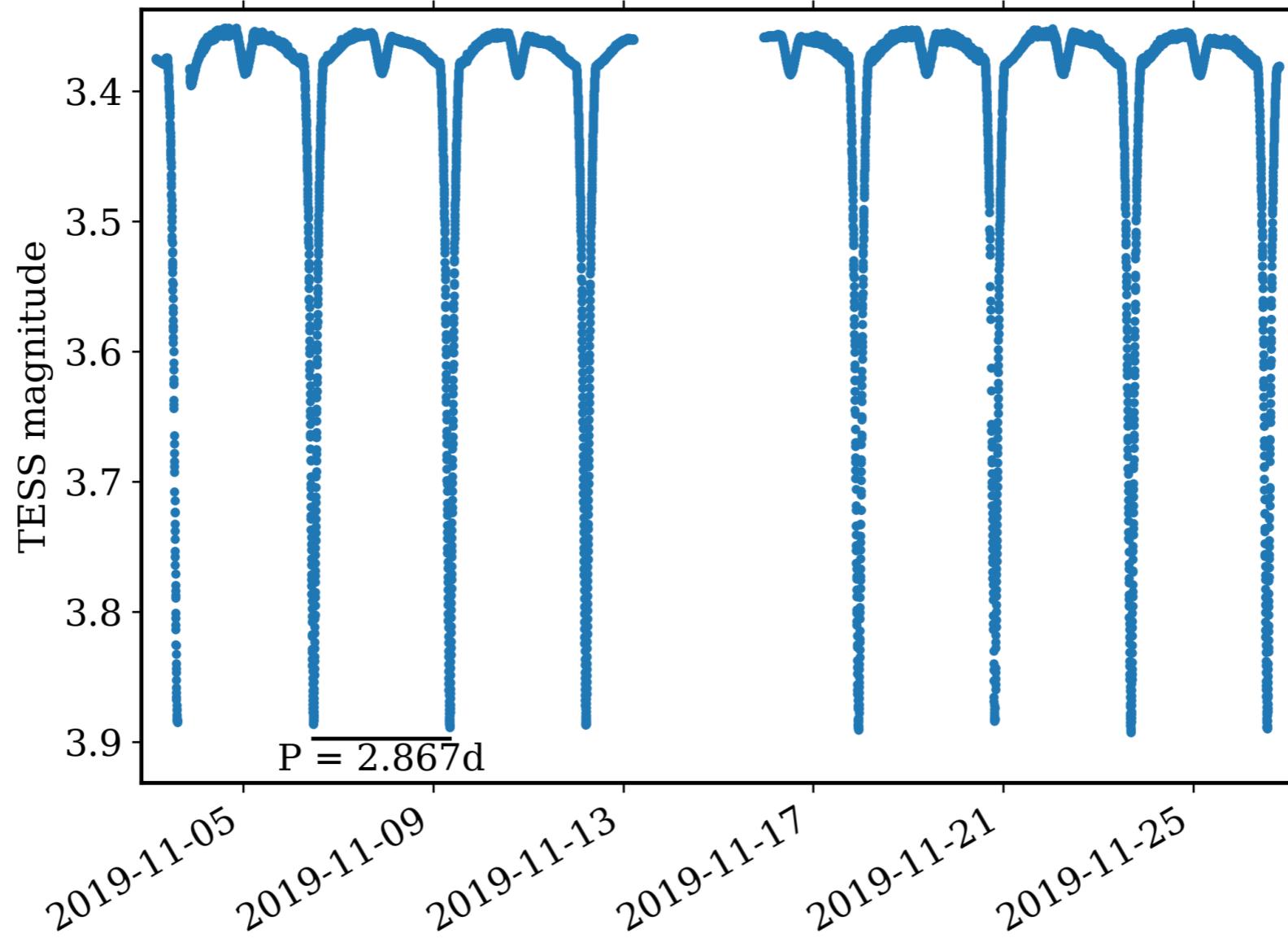


- Contact (W UMa-type / EW)



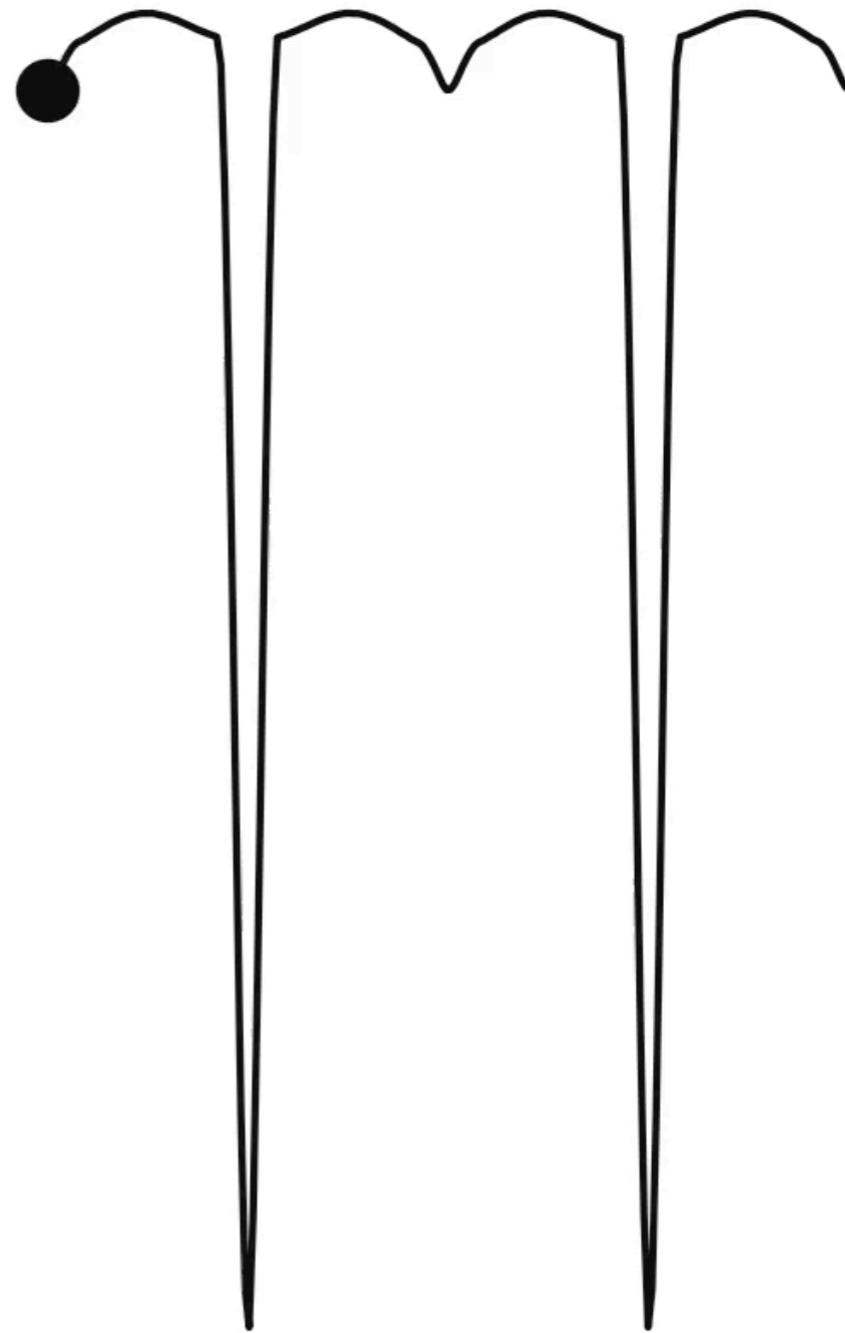
# Detached

Algol ( $\beta$  Persei)



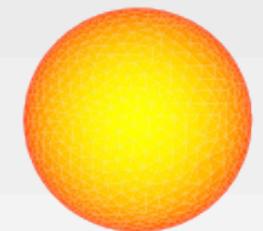
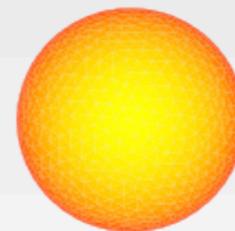
Credit: Warwick Ball

# Detached

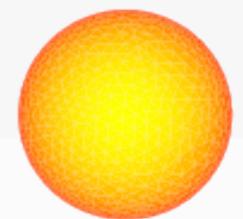
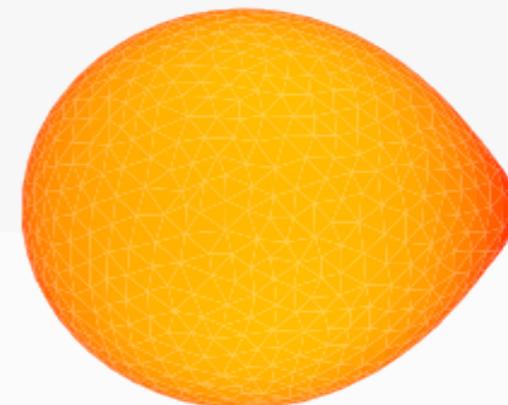


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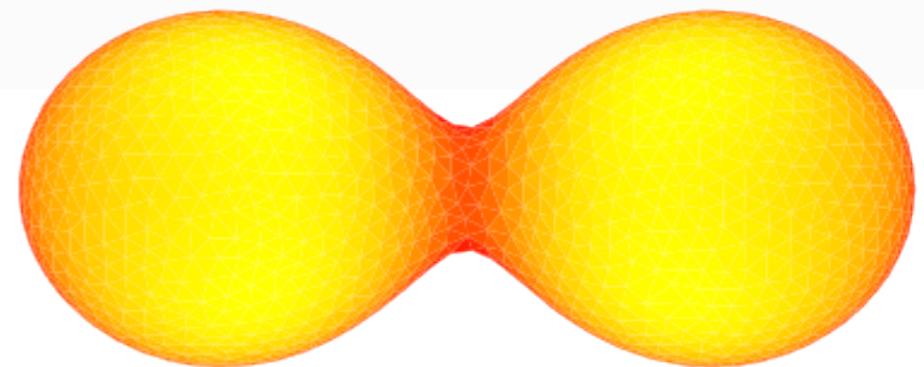
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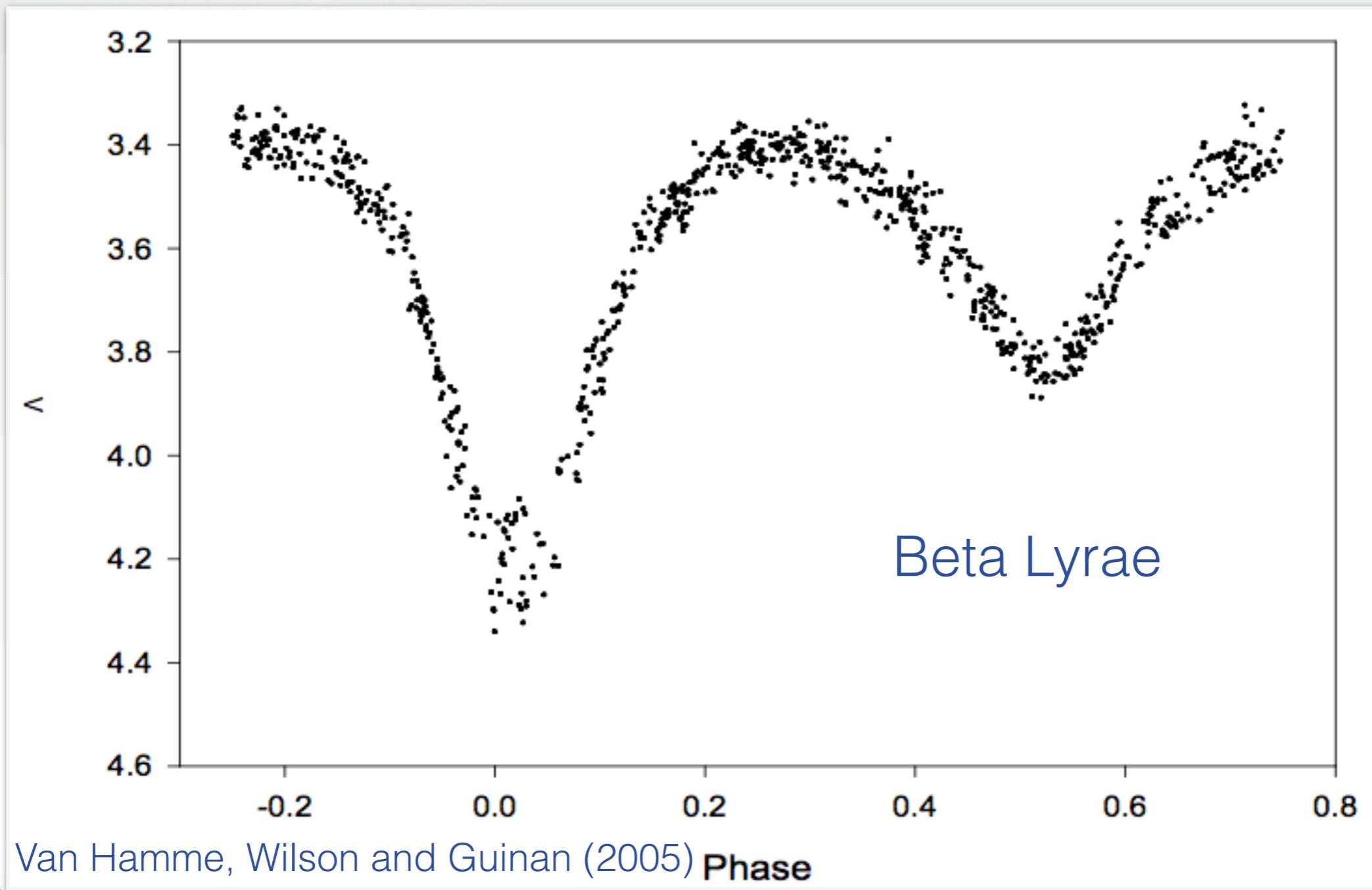
- Semi-detached ( $\beta$  Lyr-type / EB)



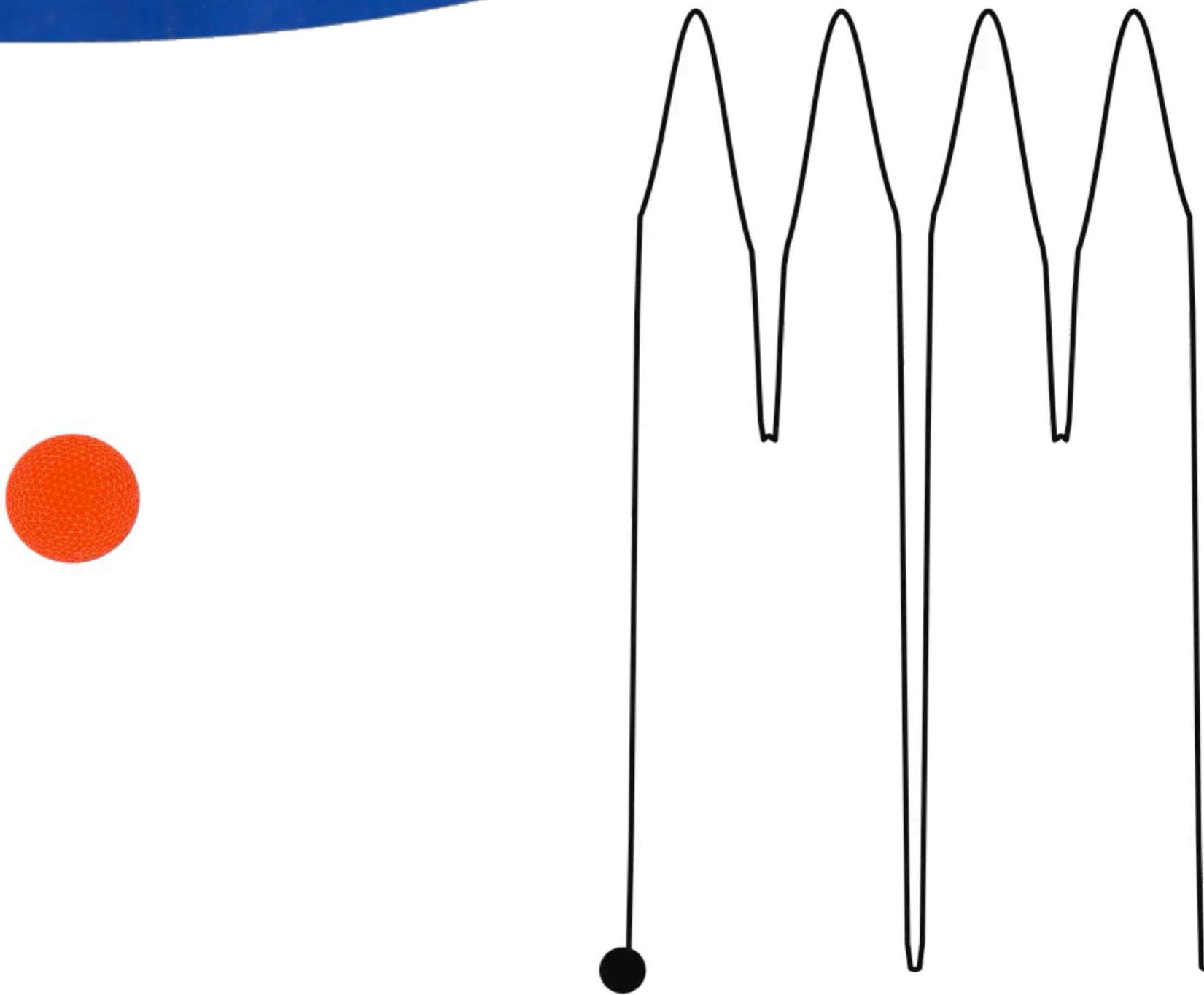
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# Semi-detached

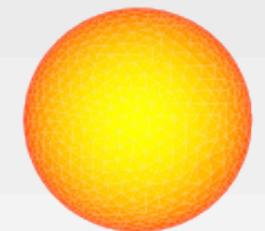
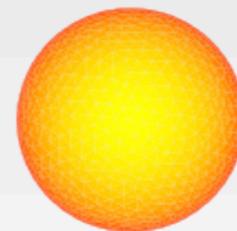


# Semi-detached

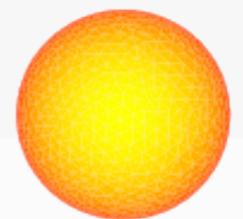
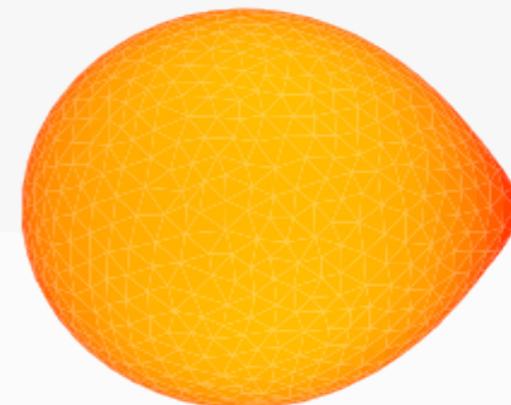


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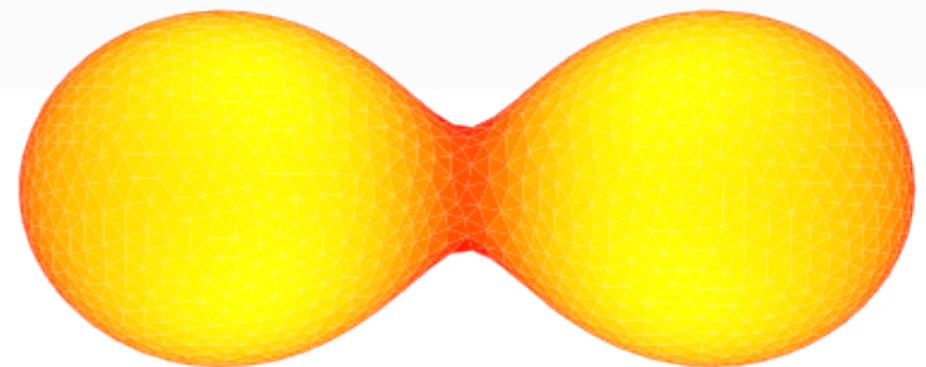
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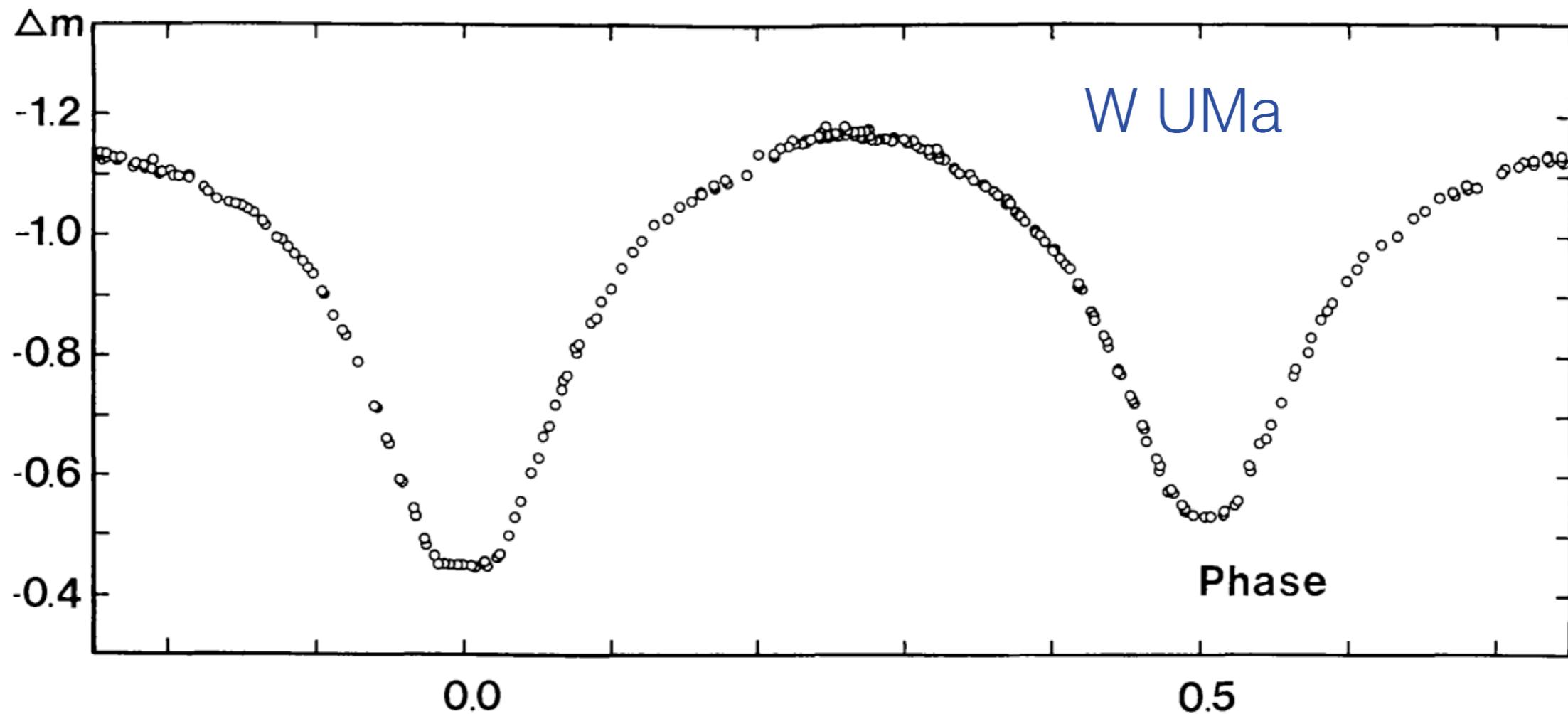


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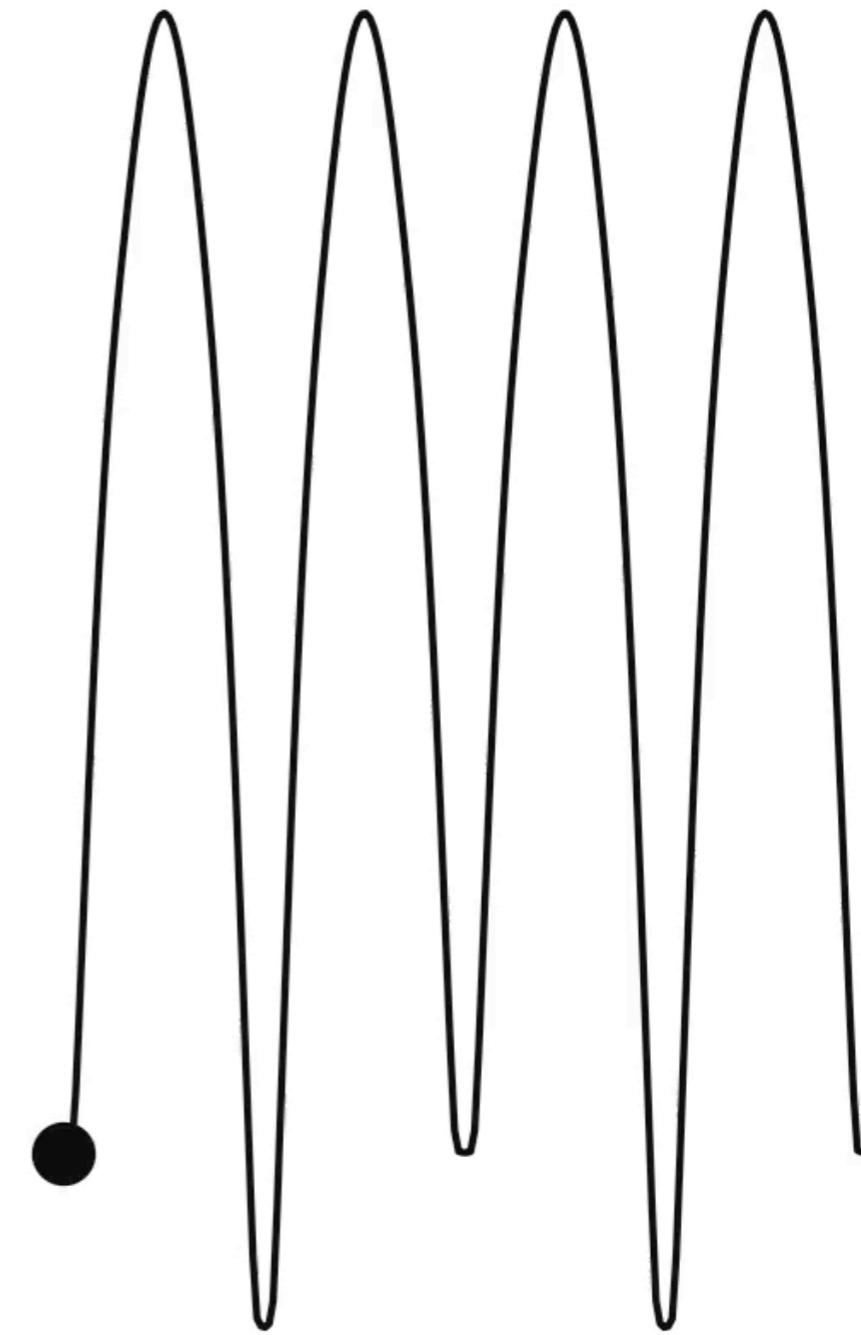


# Contact

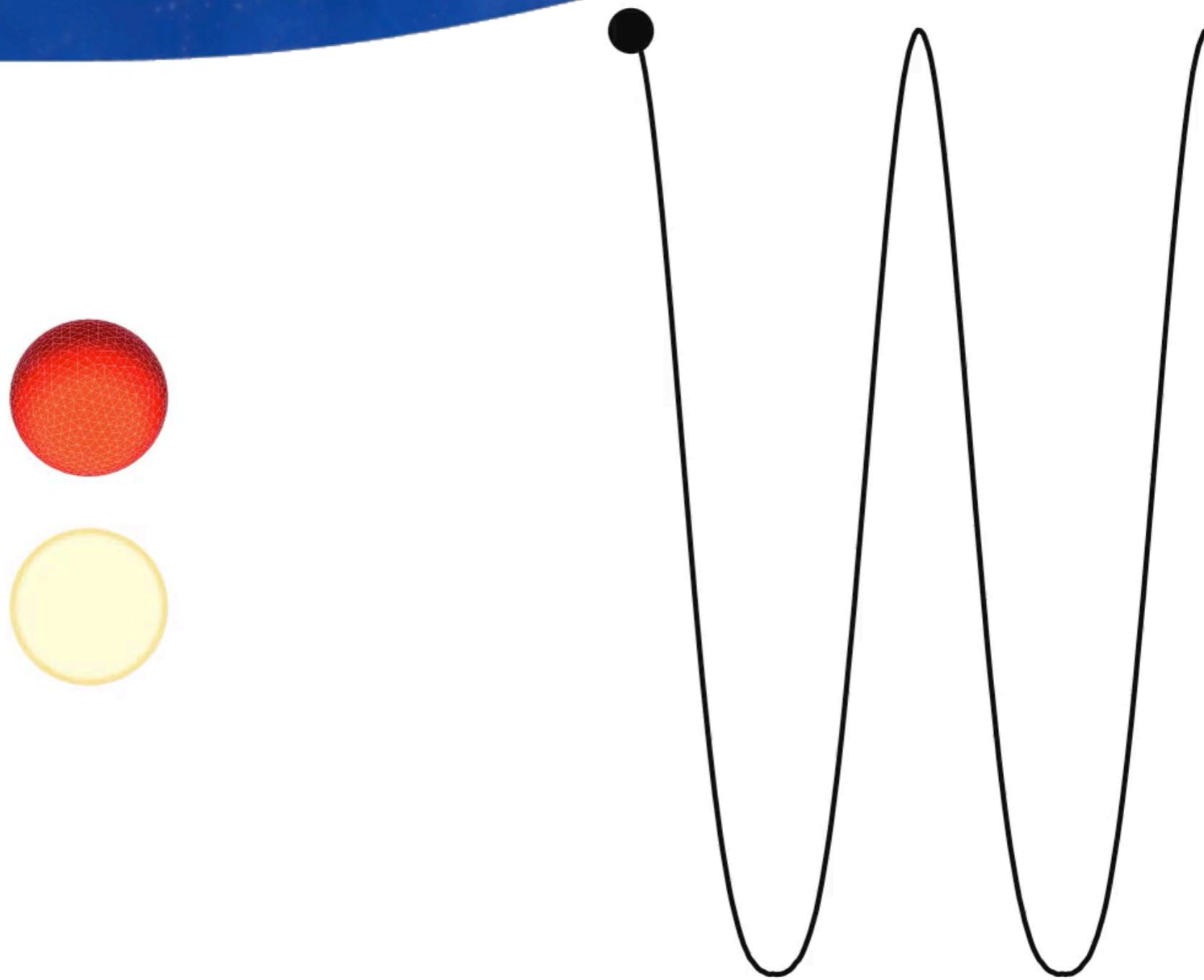
ROBERT A. BREINHORST (1970)



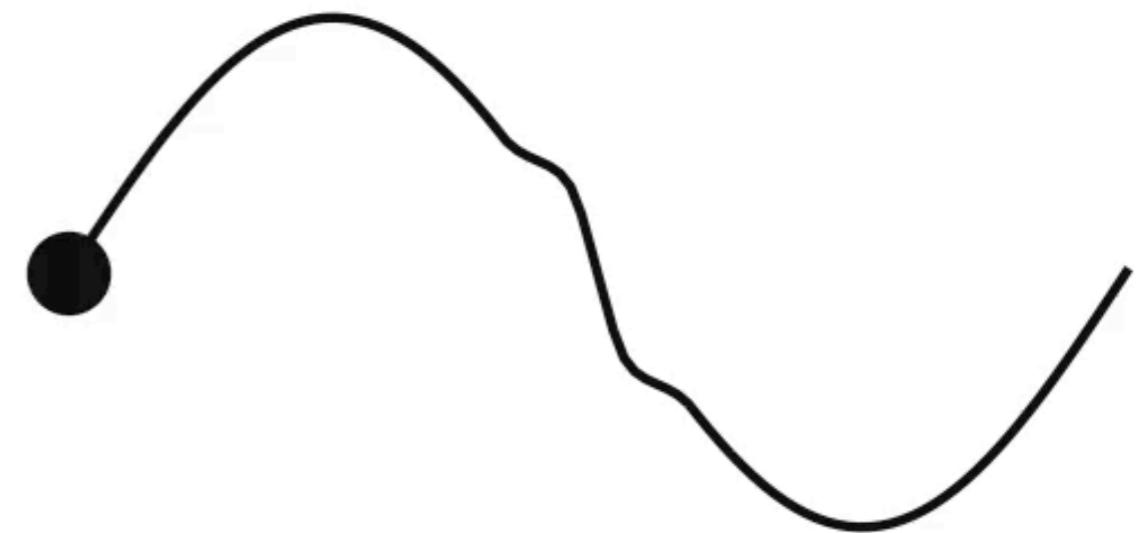
# Contact



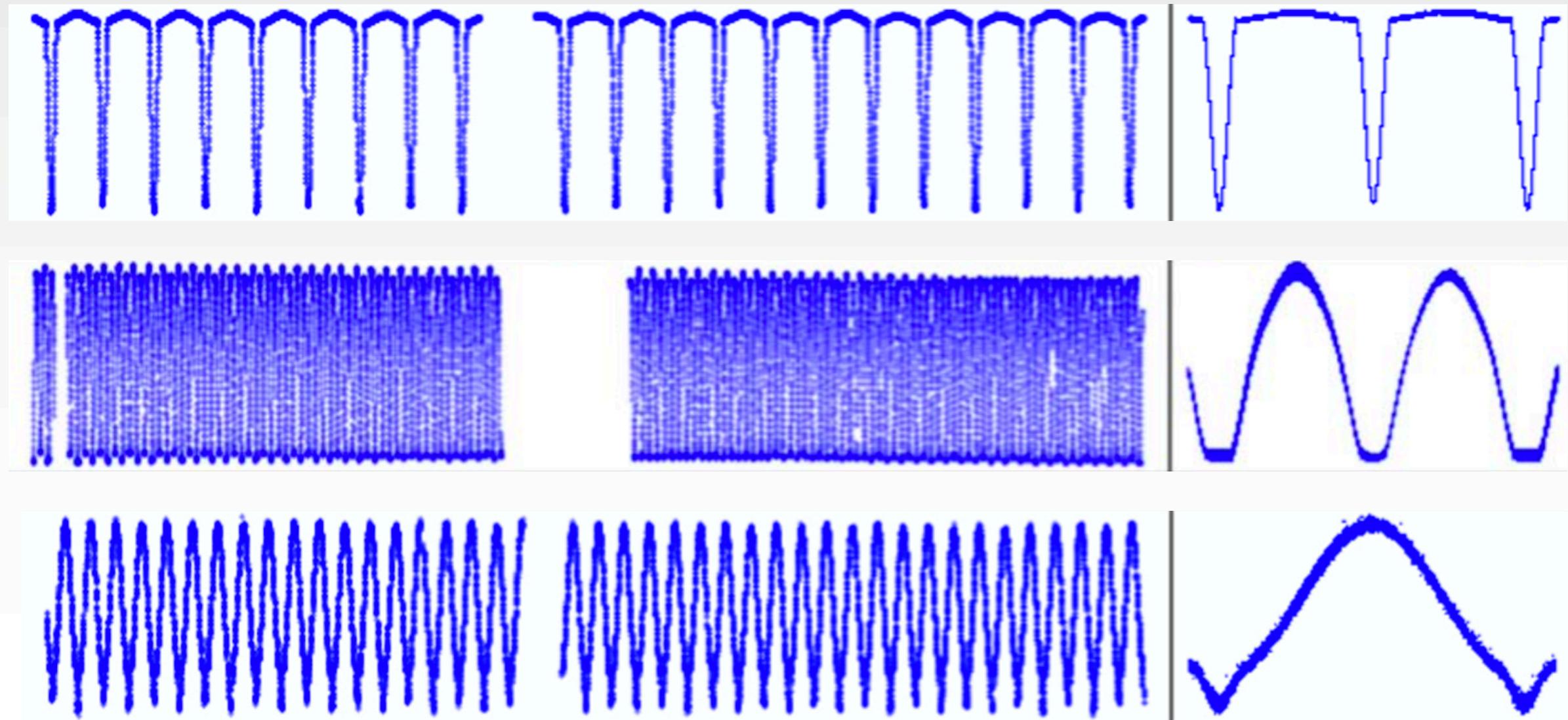
# Irradiated



# Rossiter-McLaughlin effect

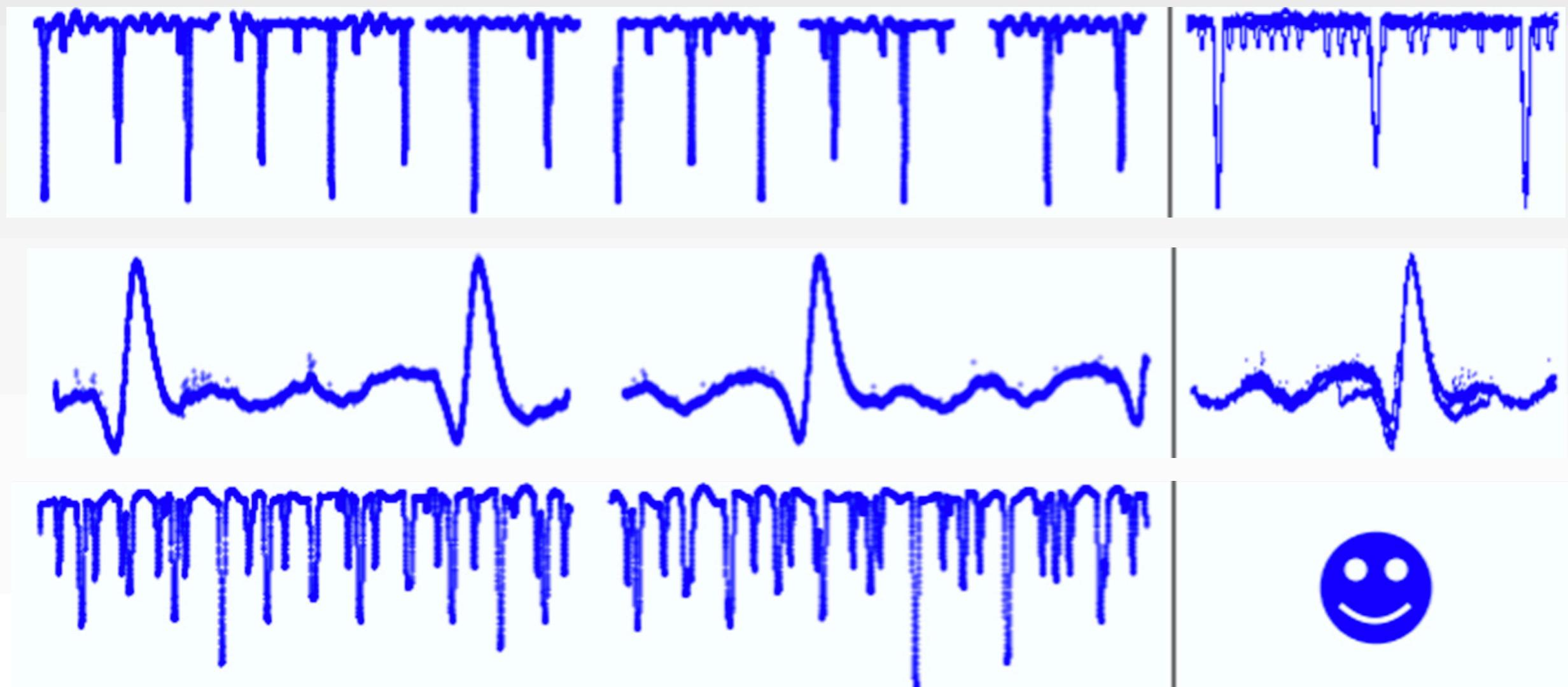


# Binary game!



Prsa et al. (2022)

# Binary game!



Prsa et al. (2022)

# Parameterisation

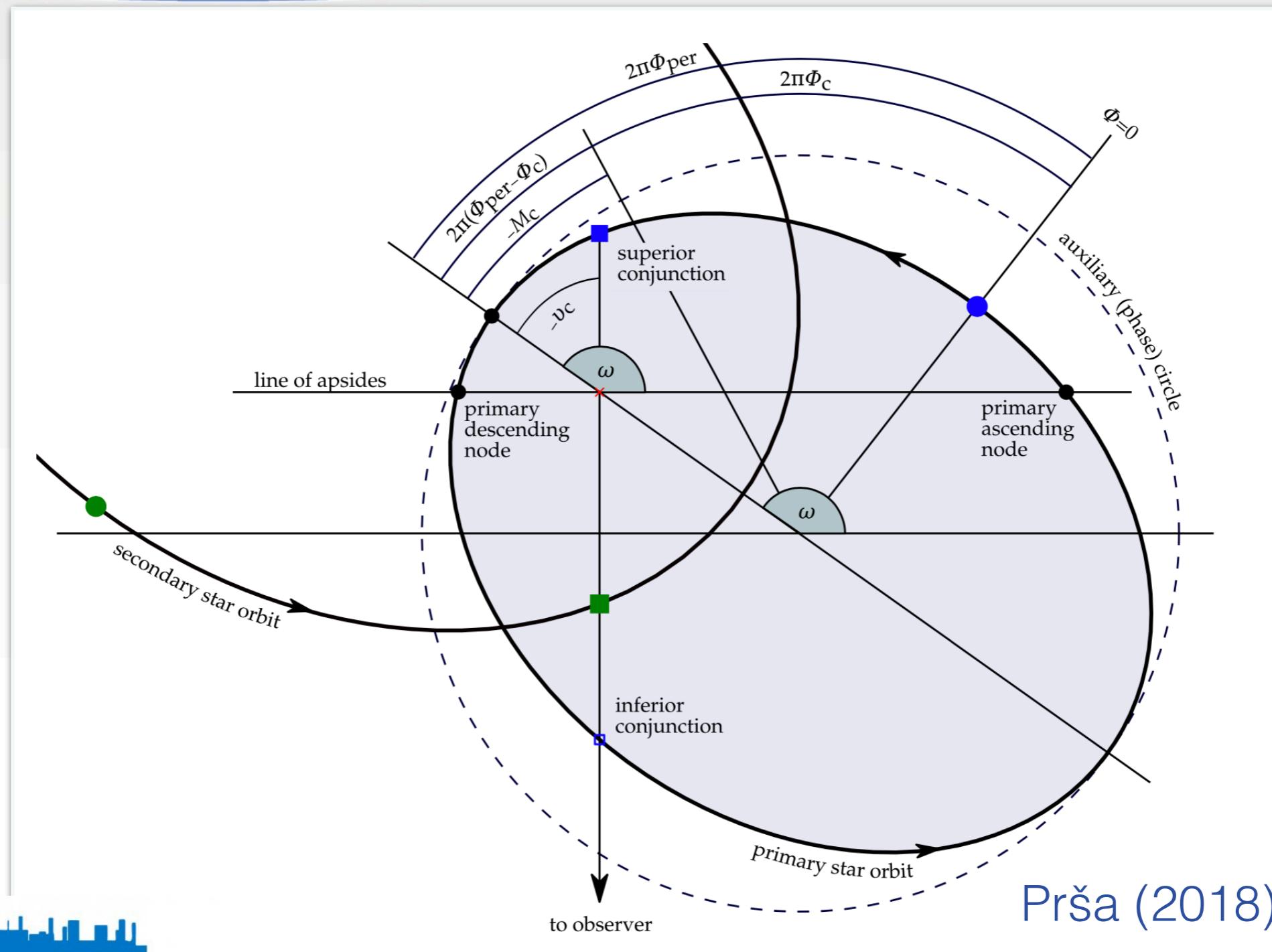
## Stellar parameters

- Masses, temperatures, radii

## Orbital parameters

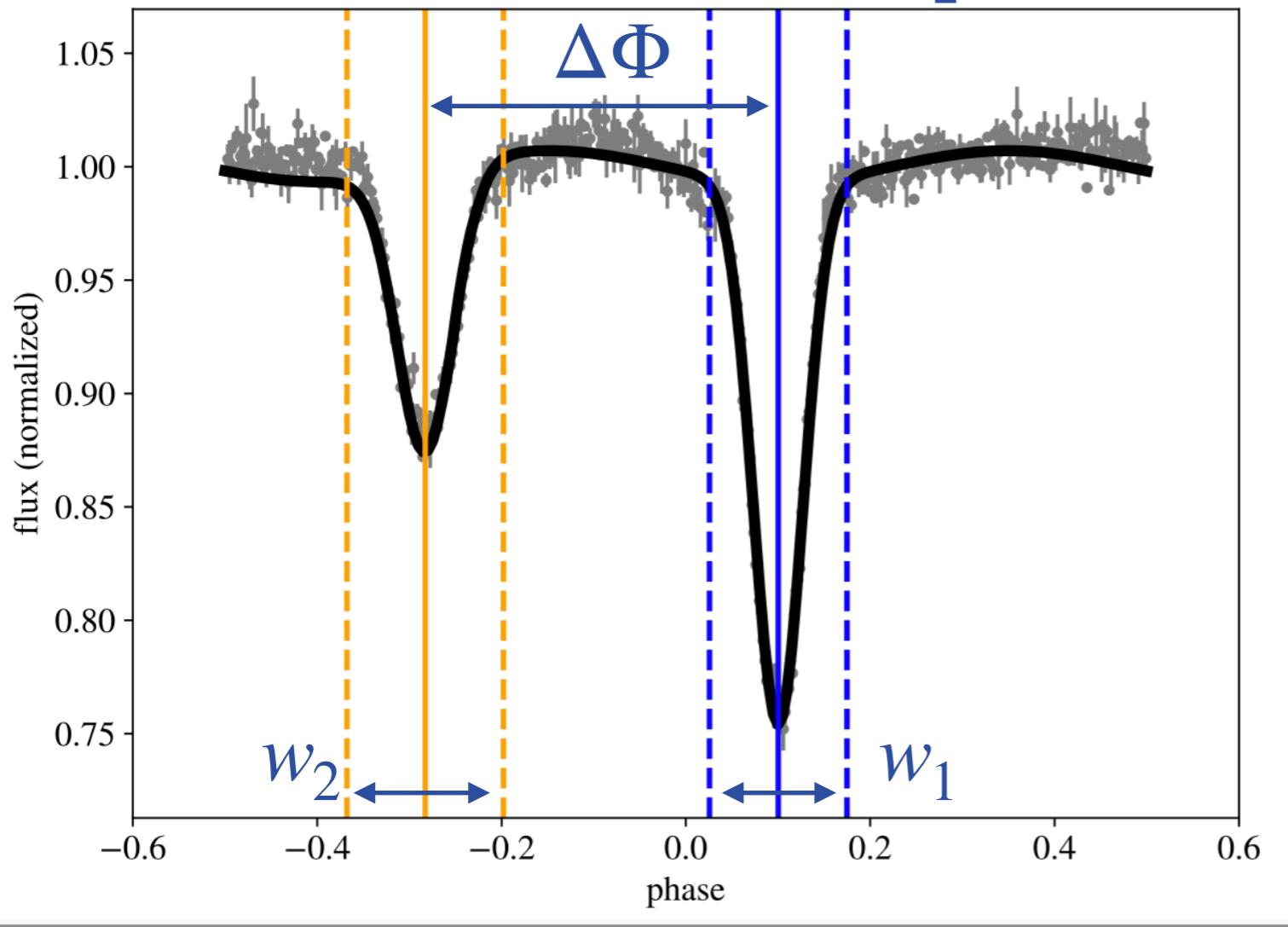
- Period (plus time of superior conjunction and  $dp/dt$ )
- Eccentricity (and argument of periastron)
- Inclination

# Parameterisation



# Direct from observations

$$e = \left[ \sin^2\left(\frac{\psi - \pi}{2}\right) + \left(\frac{w_2 - w_1}{w_2 + w_1}\right)^2 \cos^2\left(\frac{\psi - \pi}{2}\right) \right]^{1/2}$$

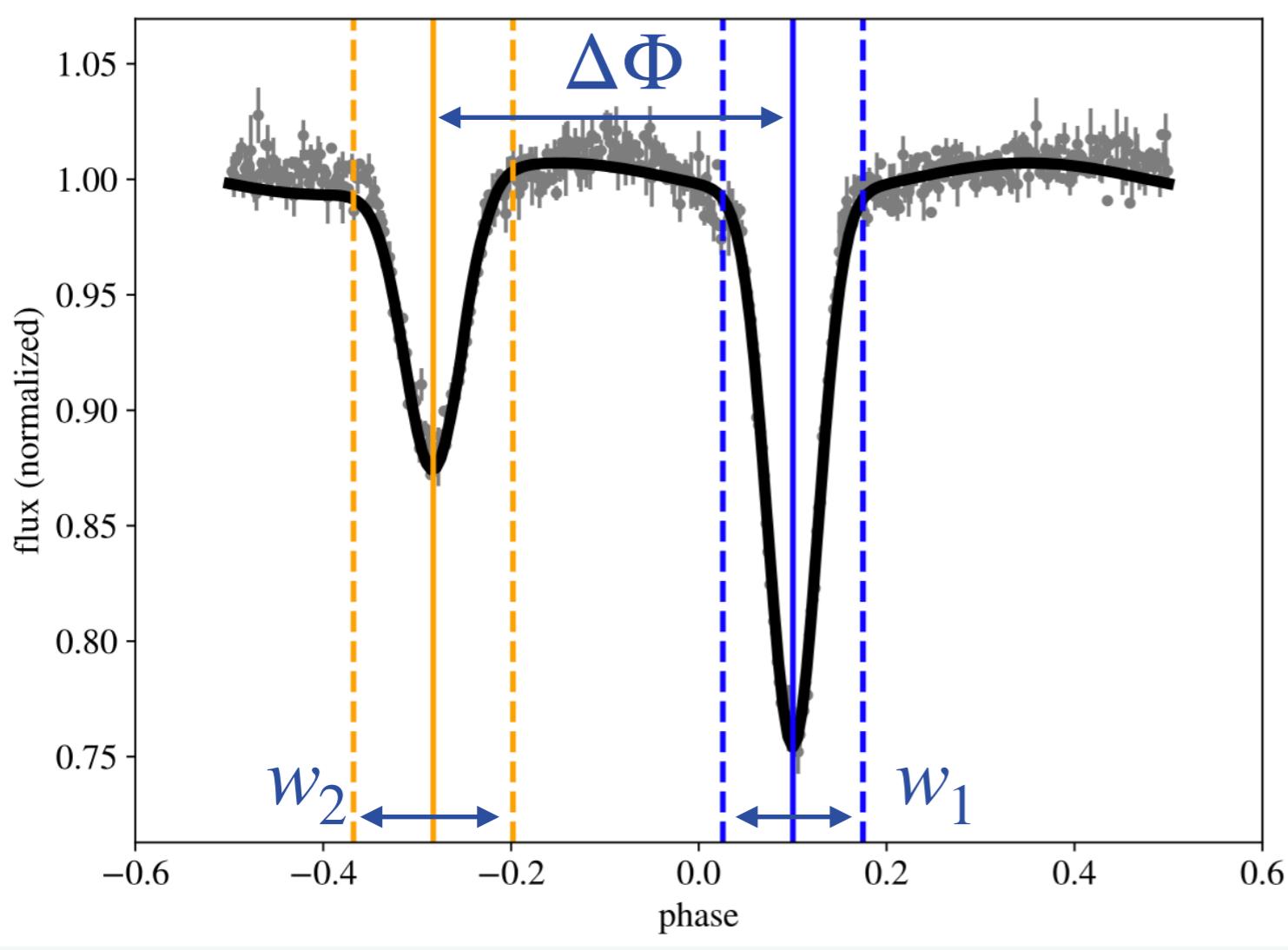


$$2\pi\Delta\Phi = \psi - \sin\psi$$

Conroy et al. (2020)

# Direct from observations

$$\omega_1 = \arcsin \left( \frac{1}{e} \frac{w_2 - w_1}{w_2 + w_1} \right)$$



$$\omega_2 = \arccos \left( \frac{\sqrt{1 - e^2}}{2e \tan(\psi - \pi)} \right)$$

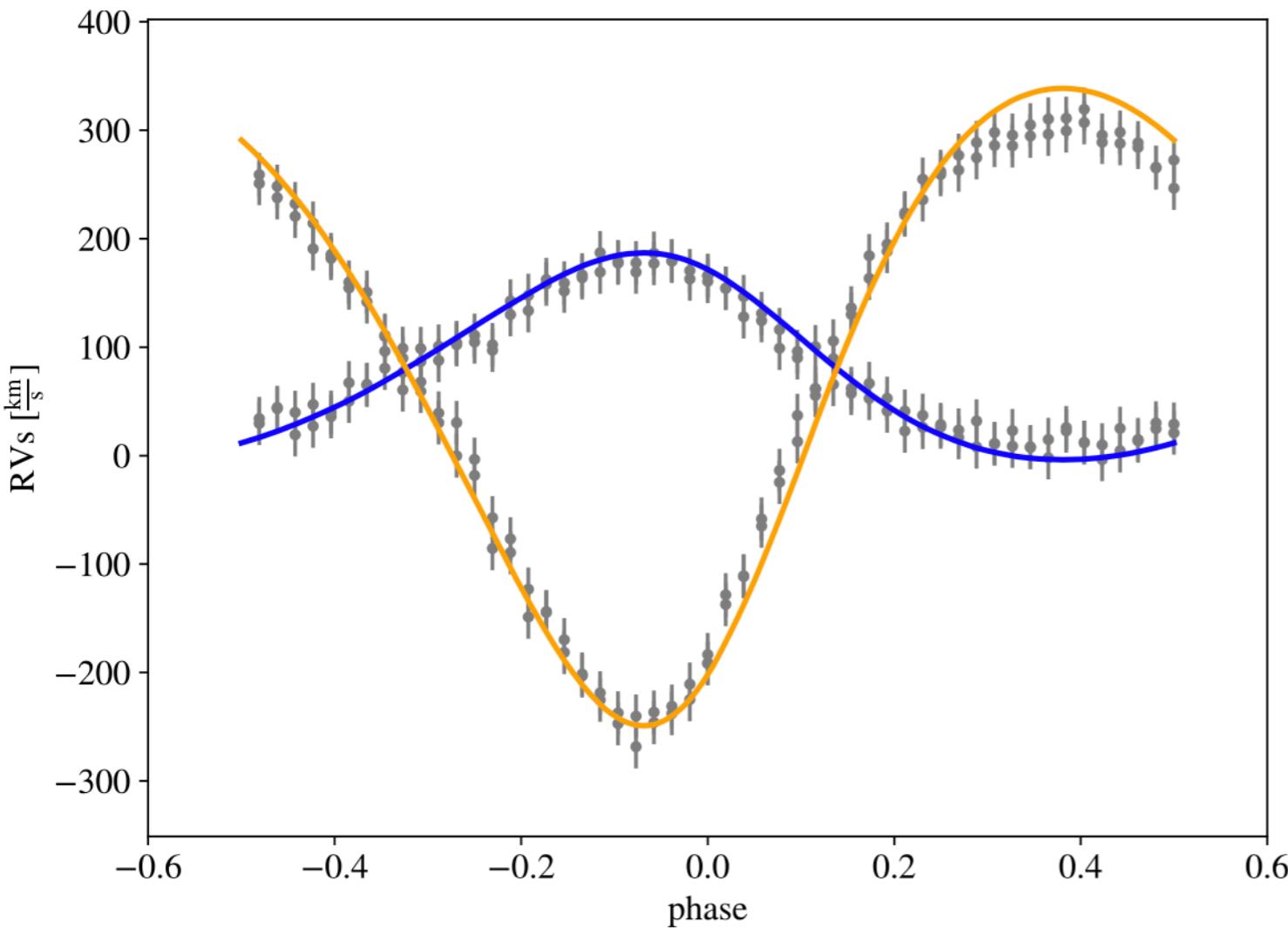
If  $\omega_1 \geq 0$ ,  $\omega = \omega_2$

else if  
 $\omega_1 < 0$ ,  $\omega = 2\pi - \omega_2$

$$\psi = \pi + 2 \arctan \frac{e \cos \omega}{\sqrt{1 - e^2}}$$

Conroy et al. (2020)

# Direct from observations

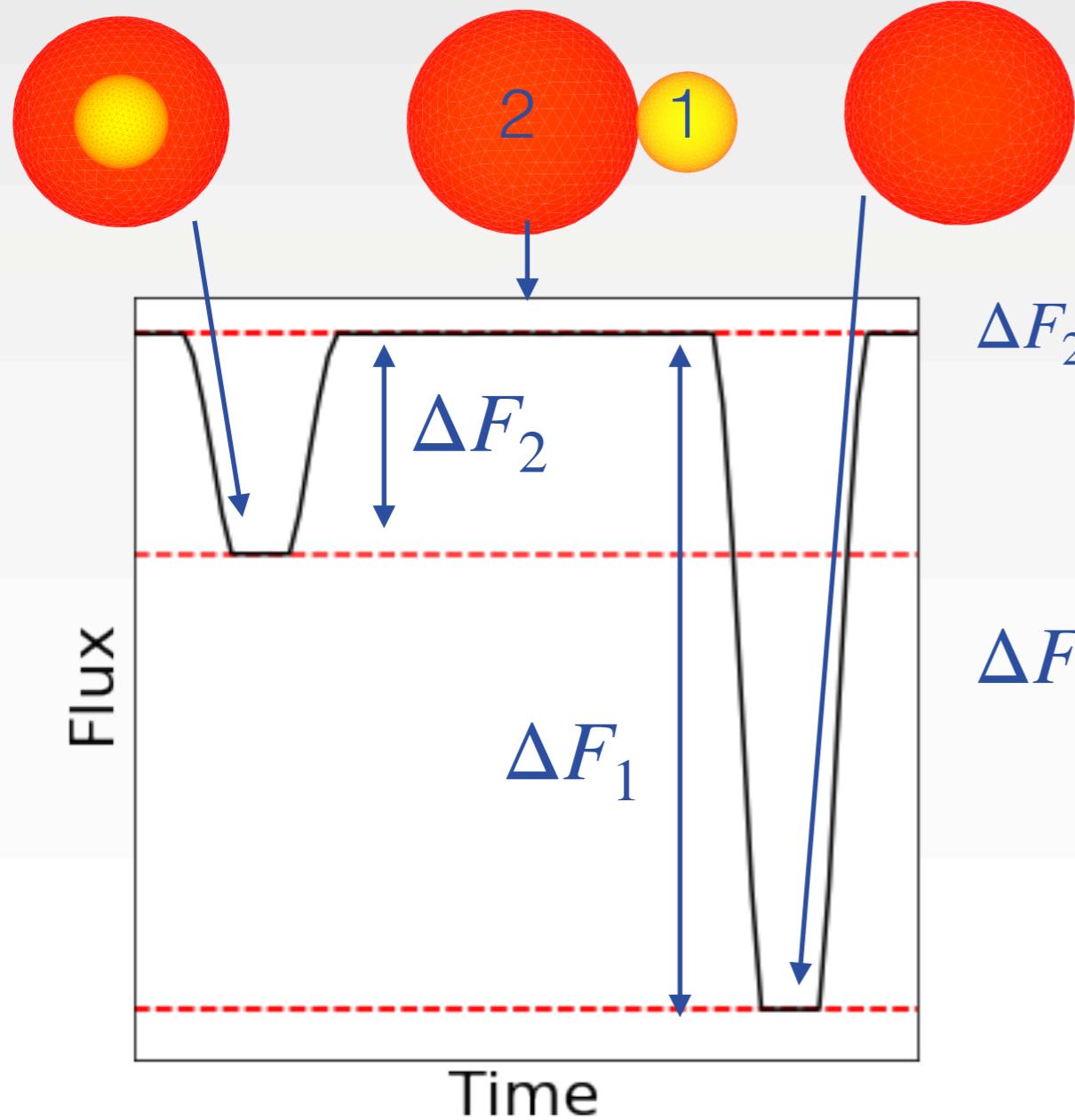


Conroy et al. (2020)

$$v_\gamma = \frac{RV_1(\theta) + q RV_2(\theta)}{1 + q}$$

$$q = \frac{RV_1(\theta) - v_\gamma}{-RV_2(\theta) + v_\gamma}$$

# Rough temperatures



For blackbodies:

$$F \propto R^2 T^4$$

$$\Delta F_2 = R_1^2 T_1^4 + R_2^2 T_2^4 - [(R_2^2 - R_1^2) T_2^4 + R_1^2 T_1^4]$$

$$\Delta F_2 = R_1^2 T_2^4$$

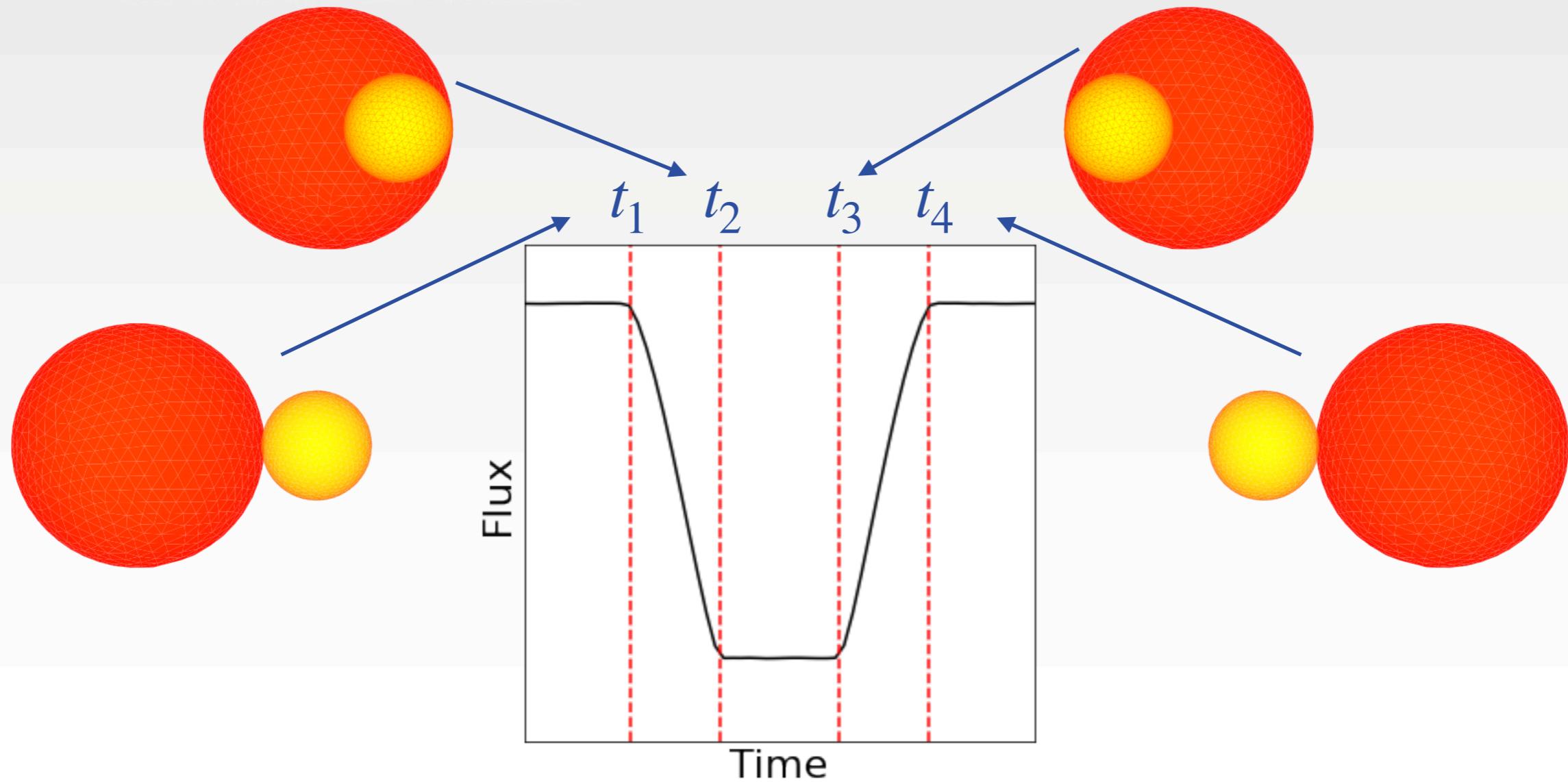
$$\Delta F_1 = R_1^2 T_1^4 + R_2^2 T_2^4 - R_2^2 T_2^4$$

$$\Delta F_1 = R_1^2 T_1^4$$

$$\frac{\Delta F_1}{\Delta F_2} = \left( \frac{T_1}{T_2} \right)^4$$

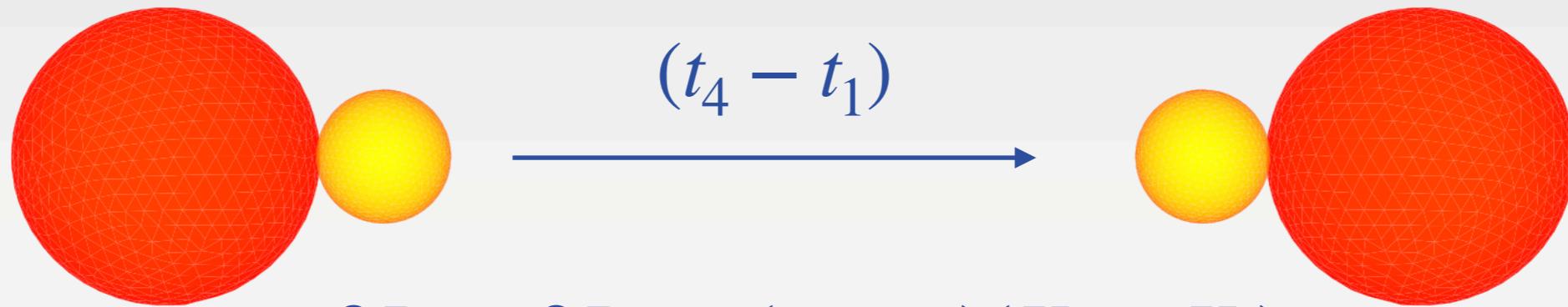
Assumes blackbodies, bolometric  
observations and total eclipses

# Rough radii

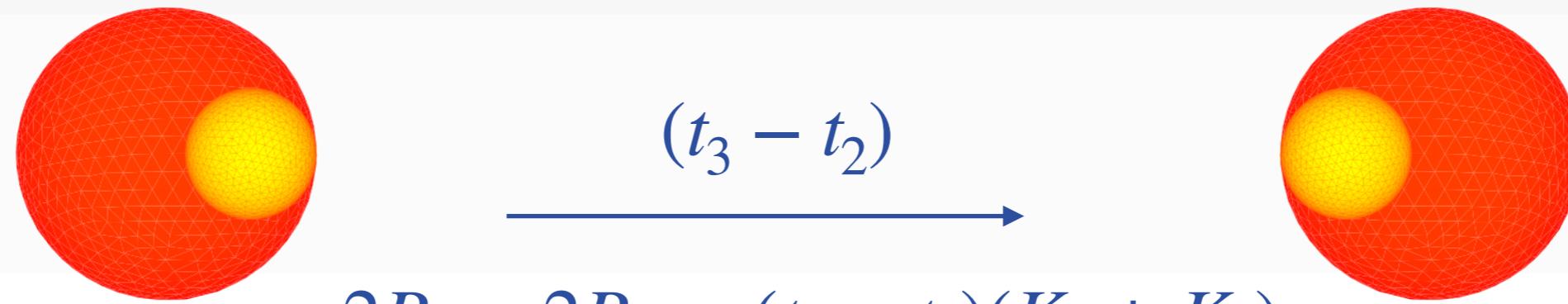


# Rough radii

Assumes  $e=0$  and  $i=90^\circ$



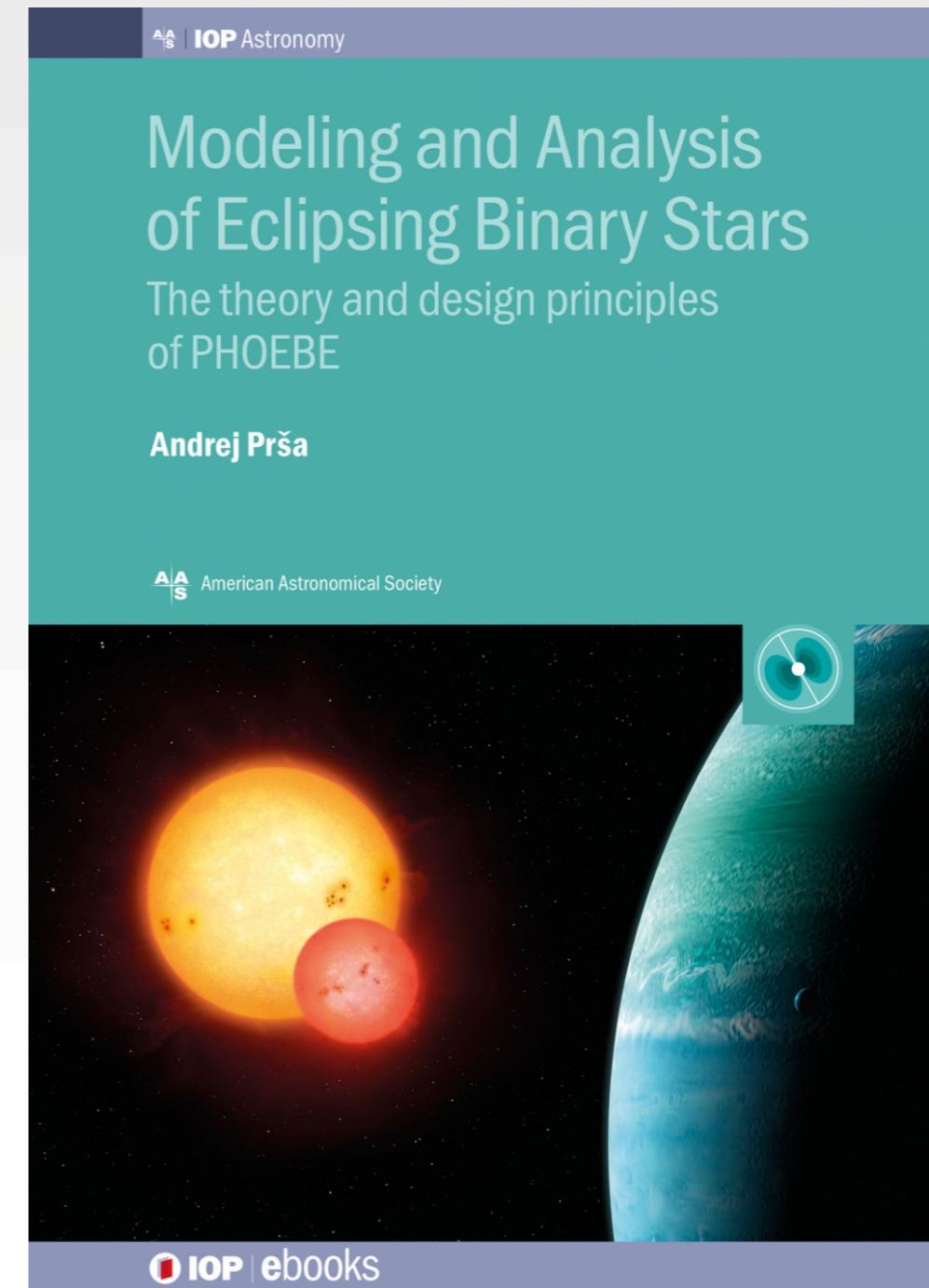
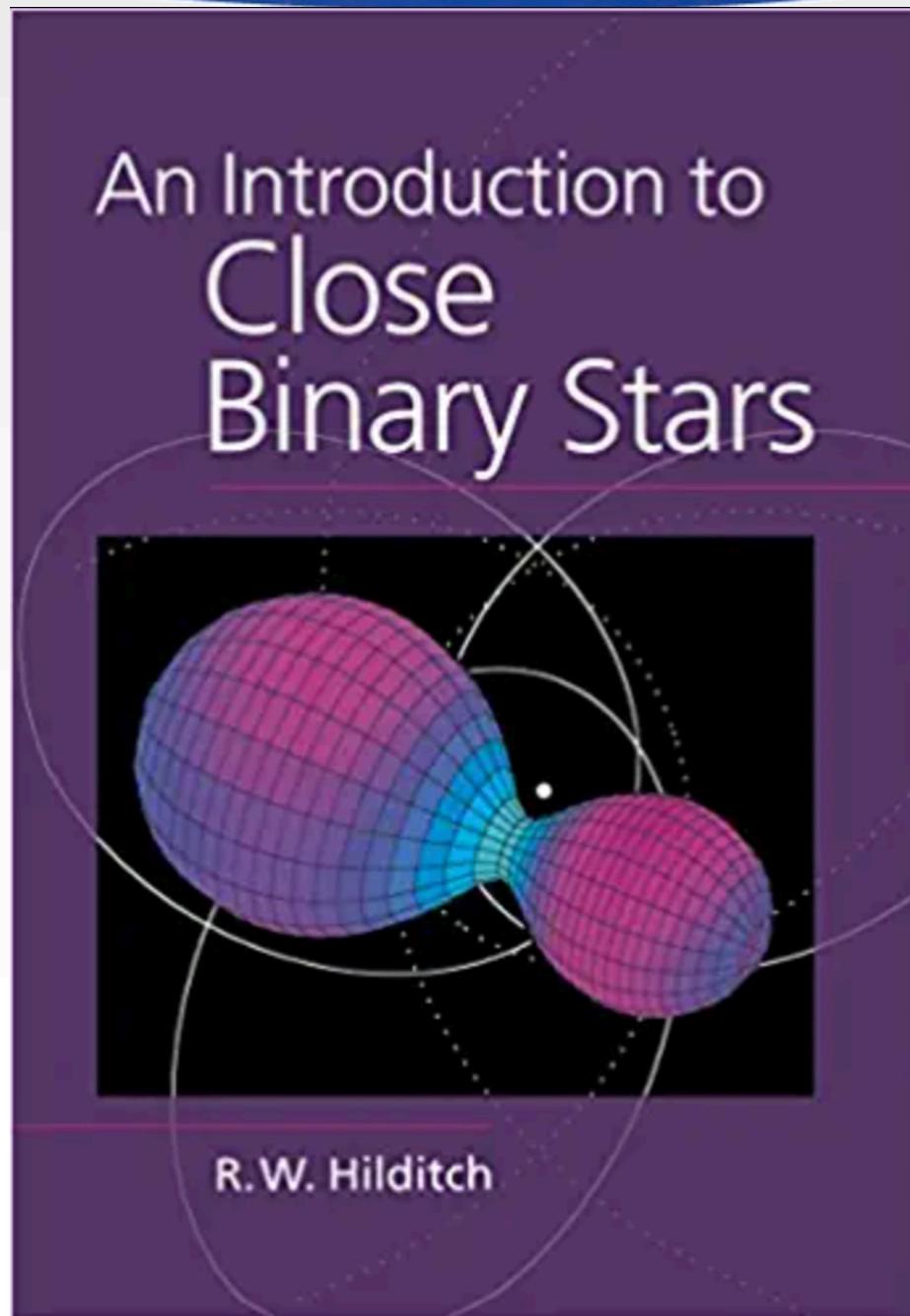
$$2R_1 + 2R_2 = (t_4 - t_1)(K_1 + K_2)$$



$$2R_2 - 2R_1 = (t_3 - t_2)(K_1 + K_2)$$

Add or subtract and solve for the radius!

# Further reading...



# Simulating a binary

- Geometric model and choice of meshing
  - Informed by orbital and stellar parameters
- Emergent flux
  - Model atmosphere
  - Limb-darkening
  - Gravity brightening
- Integrate exposed mesh elements at chosen times/phases