# DART

Energy Dissipation in Didymos Prior to Hera's Arrival

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Introduction
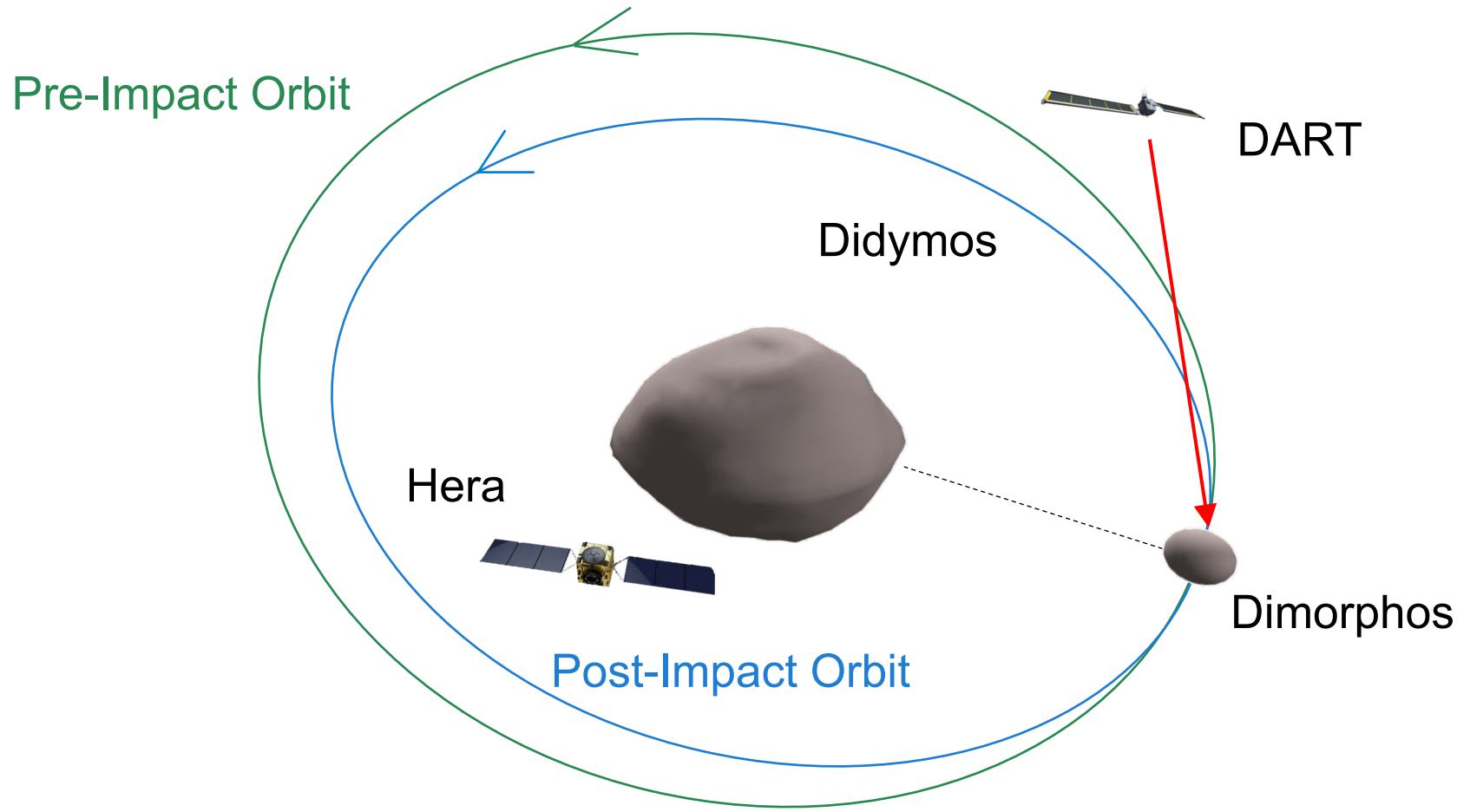
Full 2-Body Problem
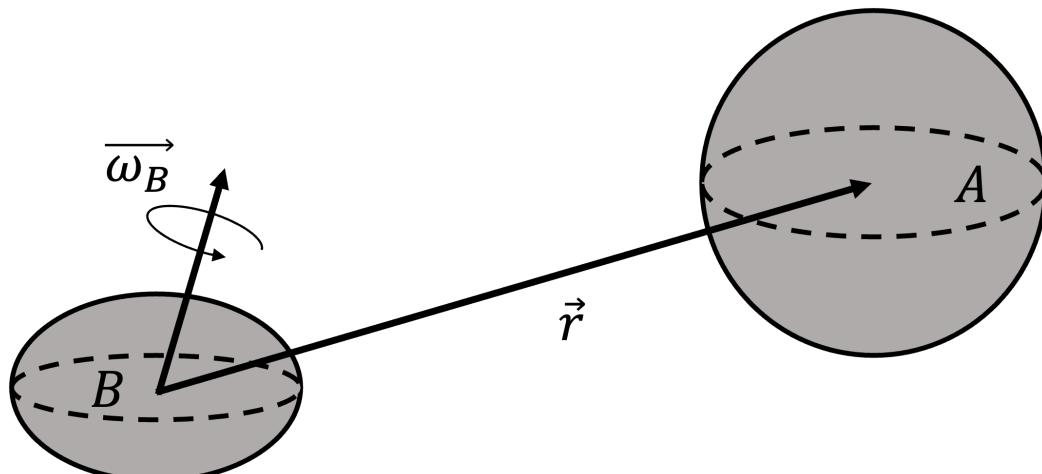
$$\ddot{\vec{r}} + 2\vec{\omega}_B \times \dot{\vec{r}} + \dot{\vec{\omega}}_B \times \vec{r} + \vec{\omega}_B \times (\vec{\omega}_B \times \vec{r}) = \mathcal{G}(M_A + M_B)\frac{\partial U}{\partial \vec{r}}$$

$$\mathbf{I}_B \cdot \dot{\vec{\omega}}_B + \vec{\omega}_B \times \mathbf{I}_B \cdot \vec{\omega}_B = -\mathcal{G}M_A M_B \vec{r} \times \frac{\partial U}{\partial \vec{r}}$$

$$U = -\frac{\mathcal{G}M_A M_B}{r} - \frac{\mathcal{G}M_A(A + B + C - 3\Phi)}{2r^3}$$

$$\Phi = \frac{Ax^2 + By^2 + Cz^2}{r^2}$$

Tidal Torque

$$\Gamma_i = -\text{sign}(\omega_i - \omega_{orb})\frac{3}{2}\left(\frac{3}{4\kappa\rho_i}\right)^2 \frac{GM_A^2 M_B^2}{r^6 R_i}\frac{k_i}{Q_i}$$
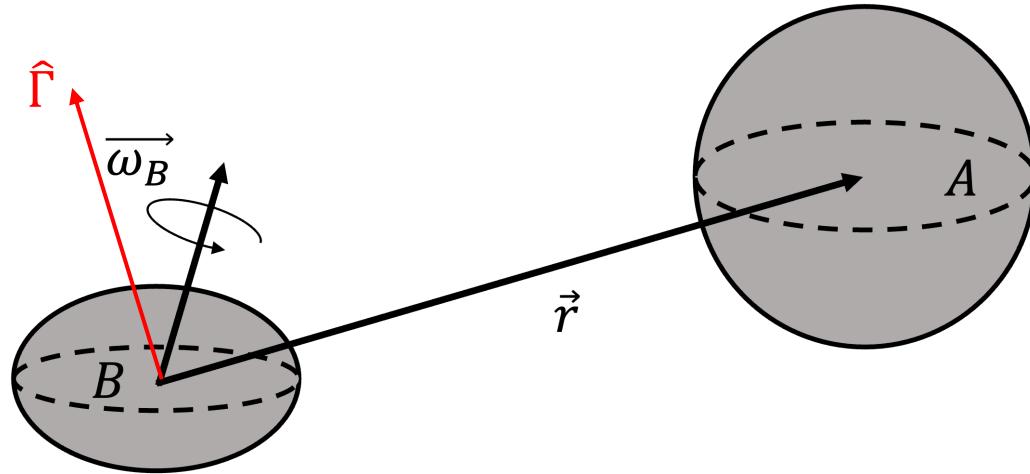

$$\dot{\phi} = \omega_i - \omega_{orb}.$$

$$\hat{\Gamma}_i = -\frac{\dot{\phi} - (\dot{\phi}\cdot\hat{r})\hat{r}}{|\dot{\phi} - (\dot{\phi}\cdot\hat{r})\hat{r}|}$$

Murray & Dermott, 1999
Vokrouhlický et al, 2007

NPA Rotation

$$\dot{E}_{NPA} = \frac{a^4 \rho M_B \widetilde{\omega}_B^5}{\mu Q} \Psi$$
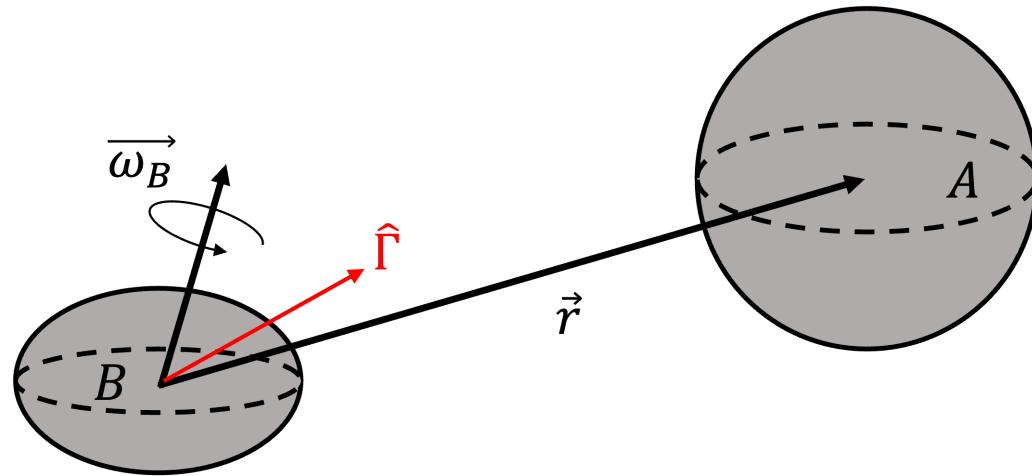
$$\kappa = \mathbf{H}_B \times \hat{z}$$

$$\widehat{\Gamma} = \frac{\mathbf{H}_B \times \kappa}{|\mathbf{H}_B \times \kappa|}$$

Breiter et al, 2012

Tidal Parameters

Tidal quality number Q

Tidal Love number k

Lamé constant μ

$\left.\right\}$ Related in basic tidal theory

No strong constraints: treat as unknowns

Likely range for $\frac{Q}{k}$: $10^3 - 10^6$

Nimmo & Matsuyama, 2019
Goldreich & Sari, 2009

Primary Rotation
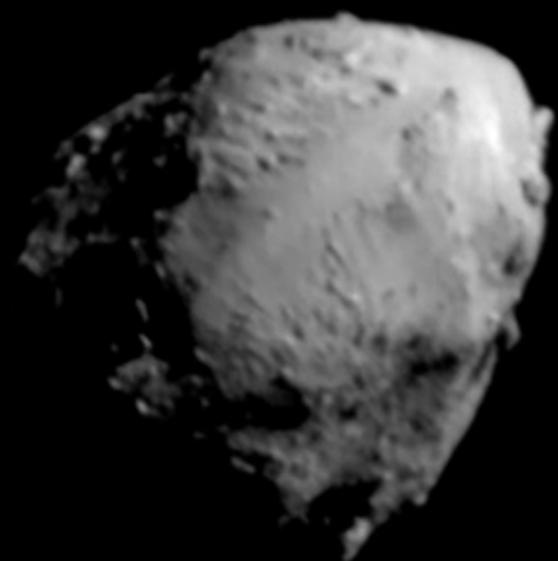
Spin Period
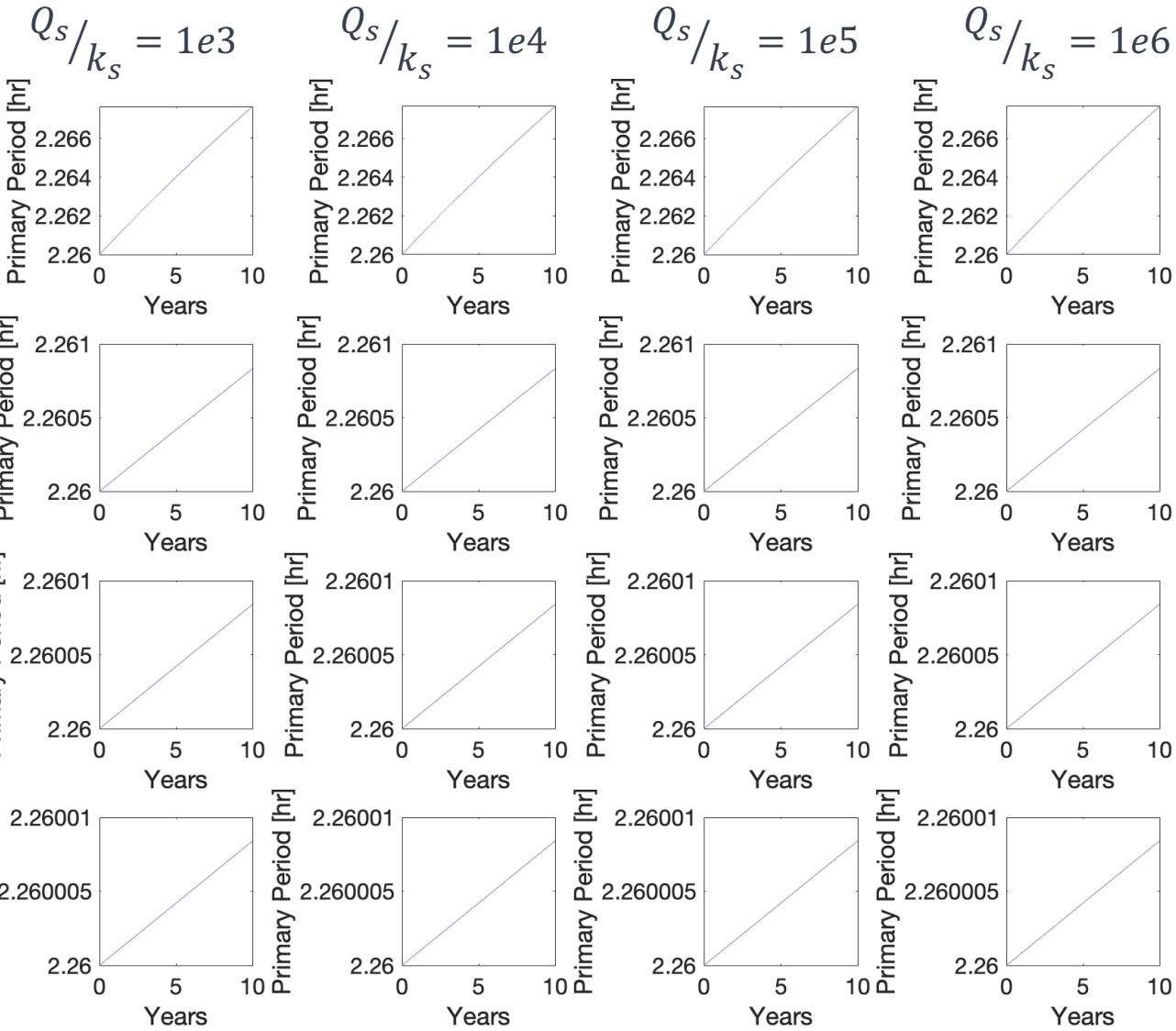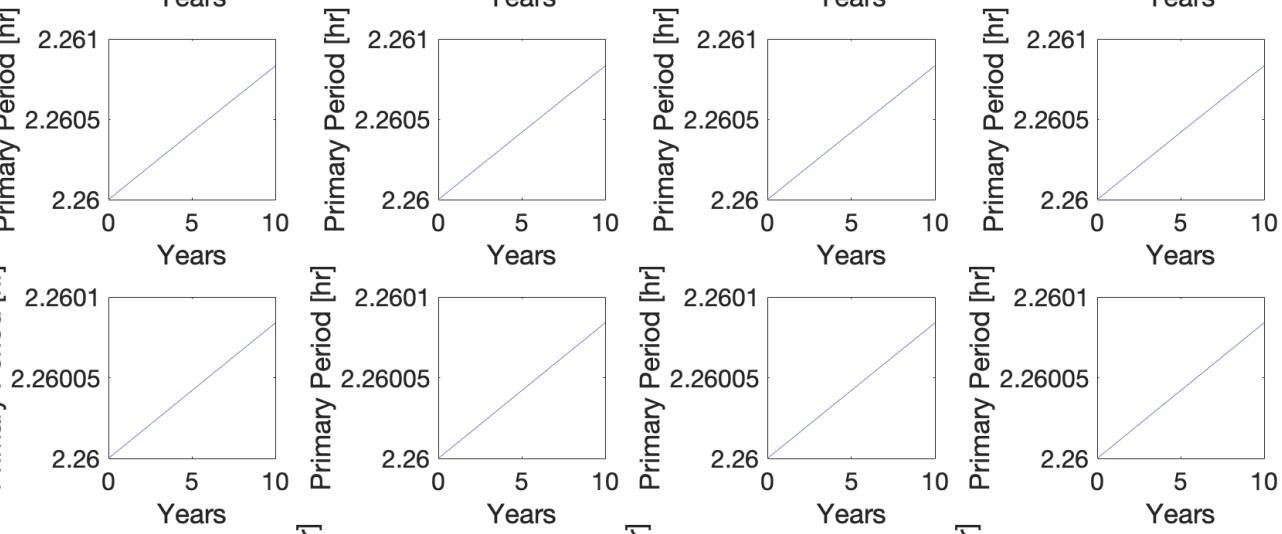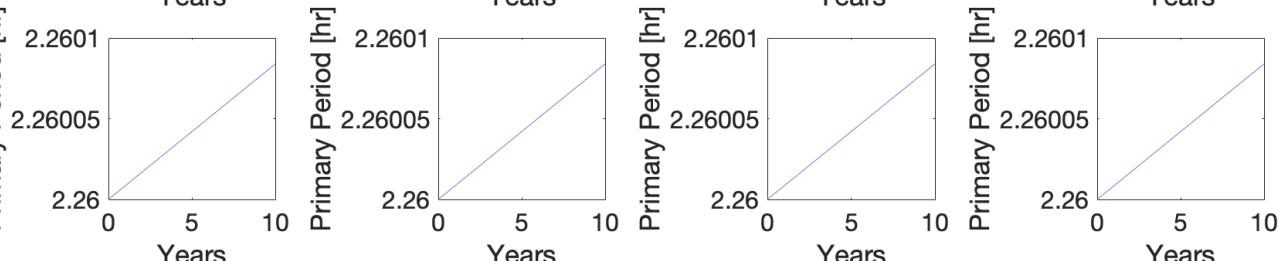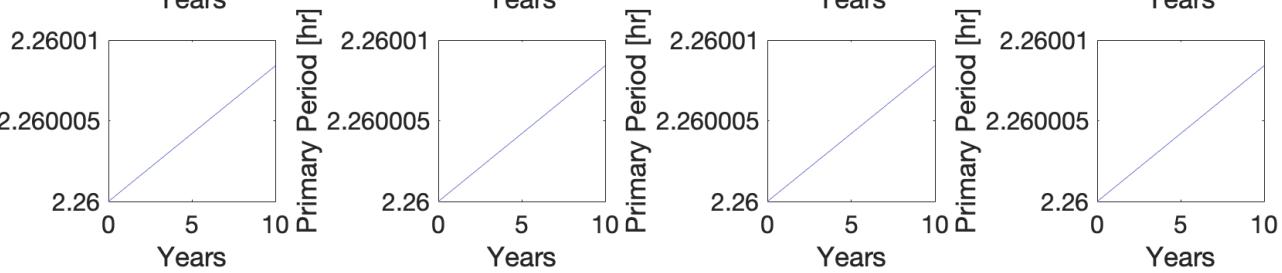
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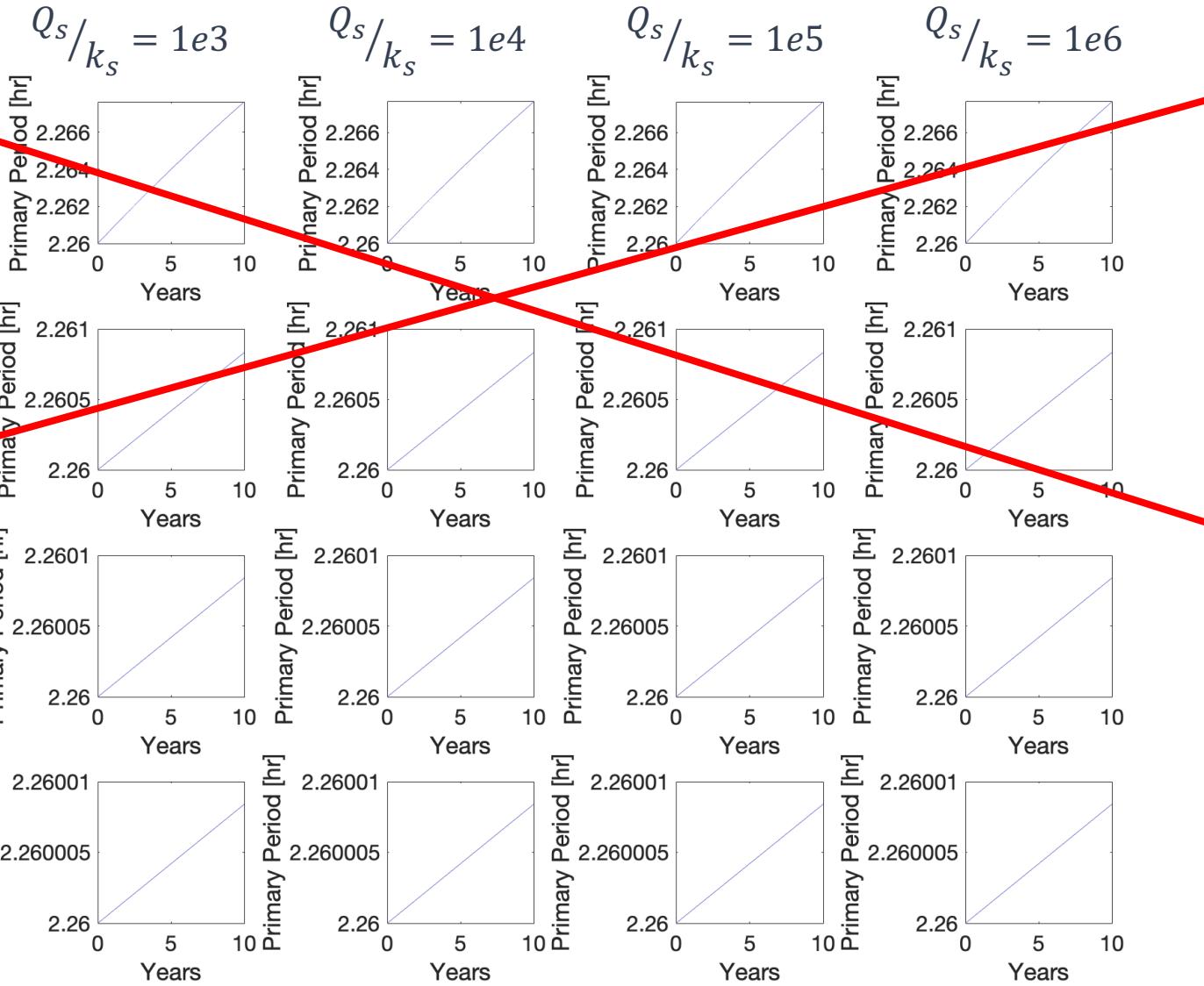
Stable Libration

Libration
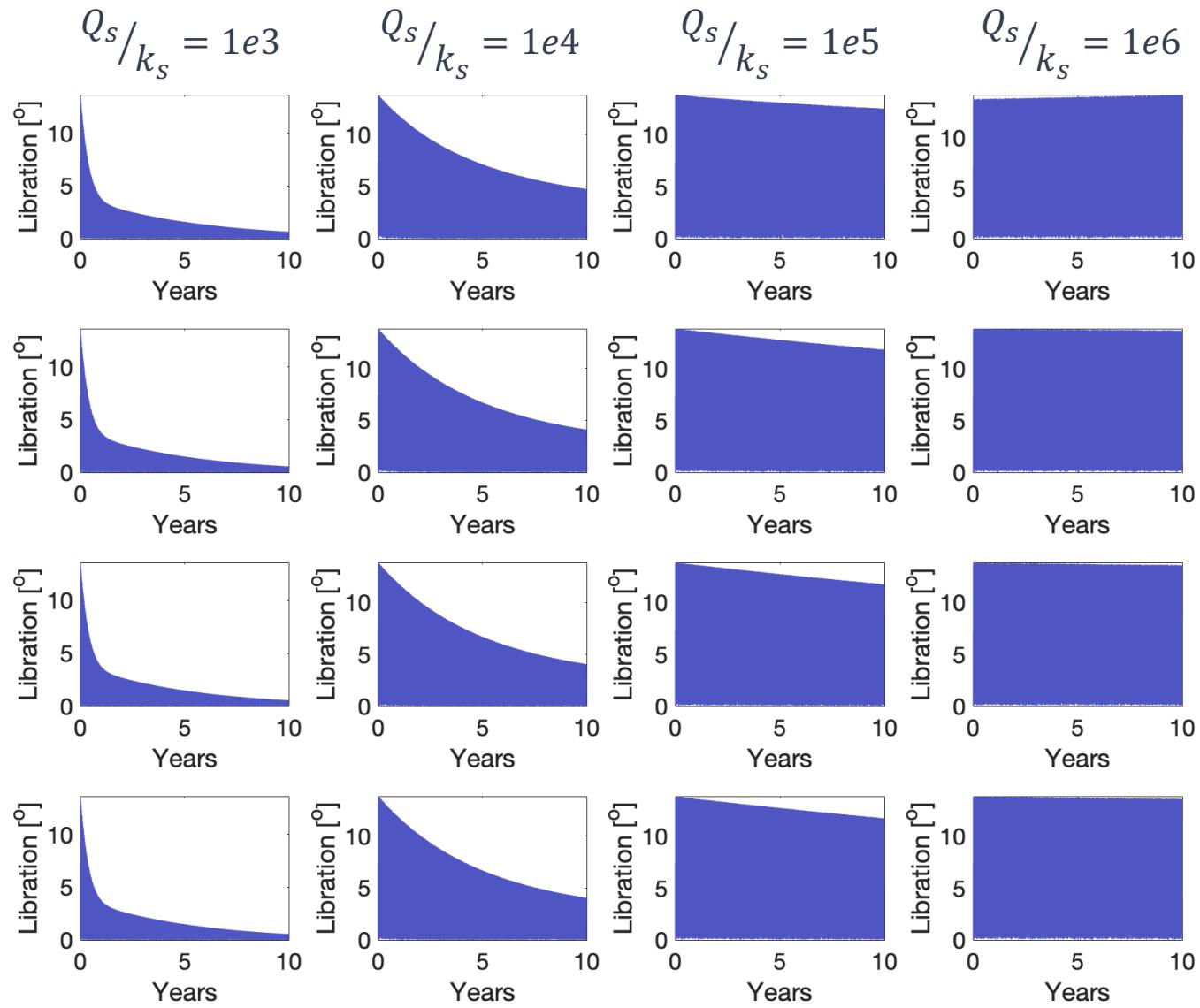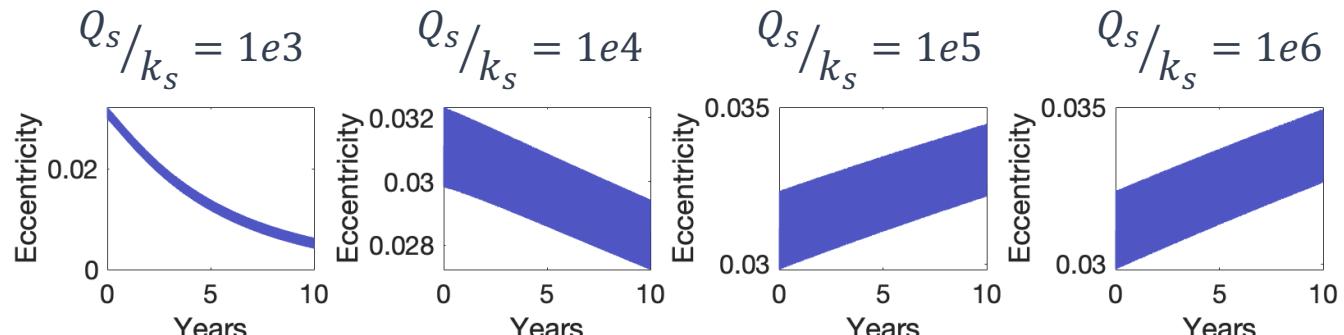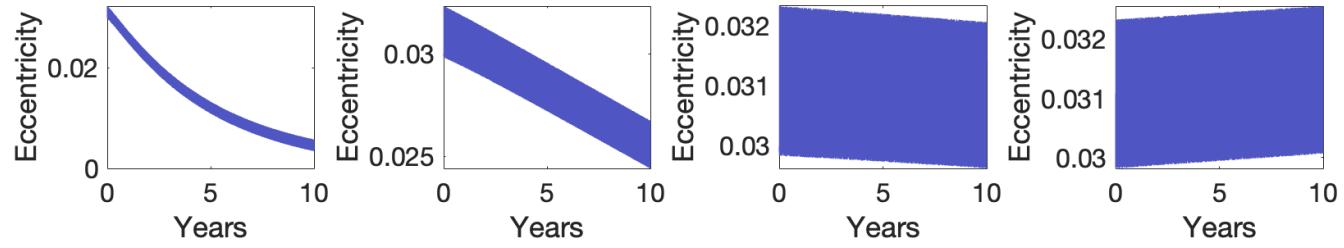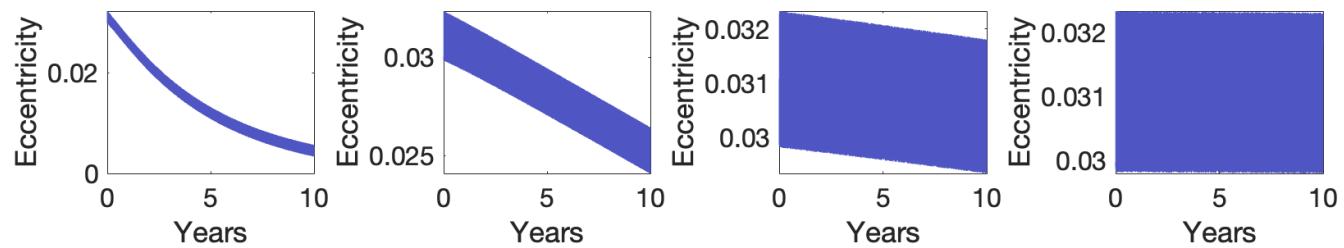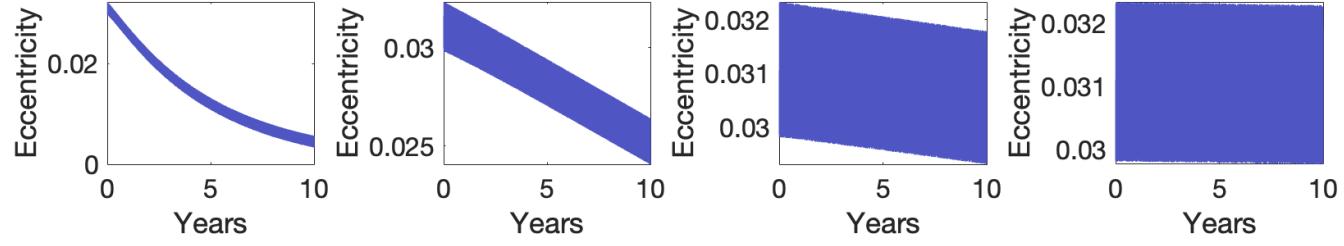
Eccentricity

Separation

Separation

$$\dot{a} > \dot{e}$$

$$\dot{e} > \dot{a}$$
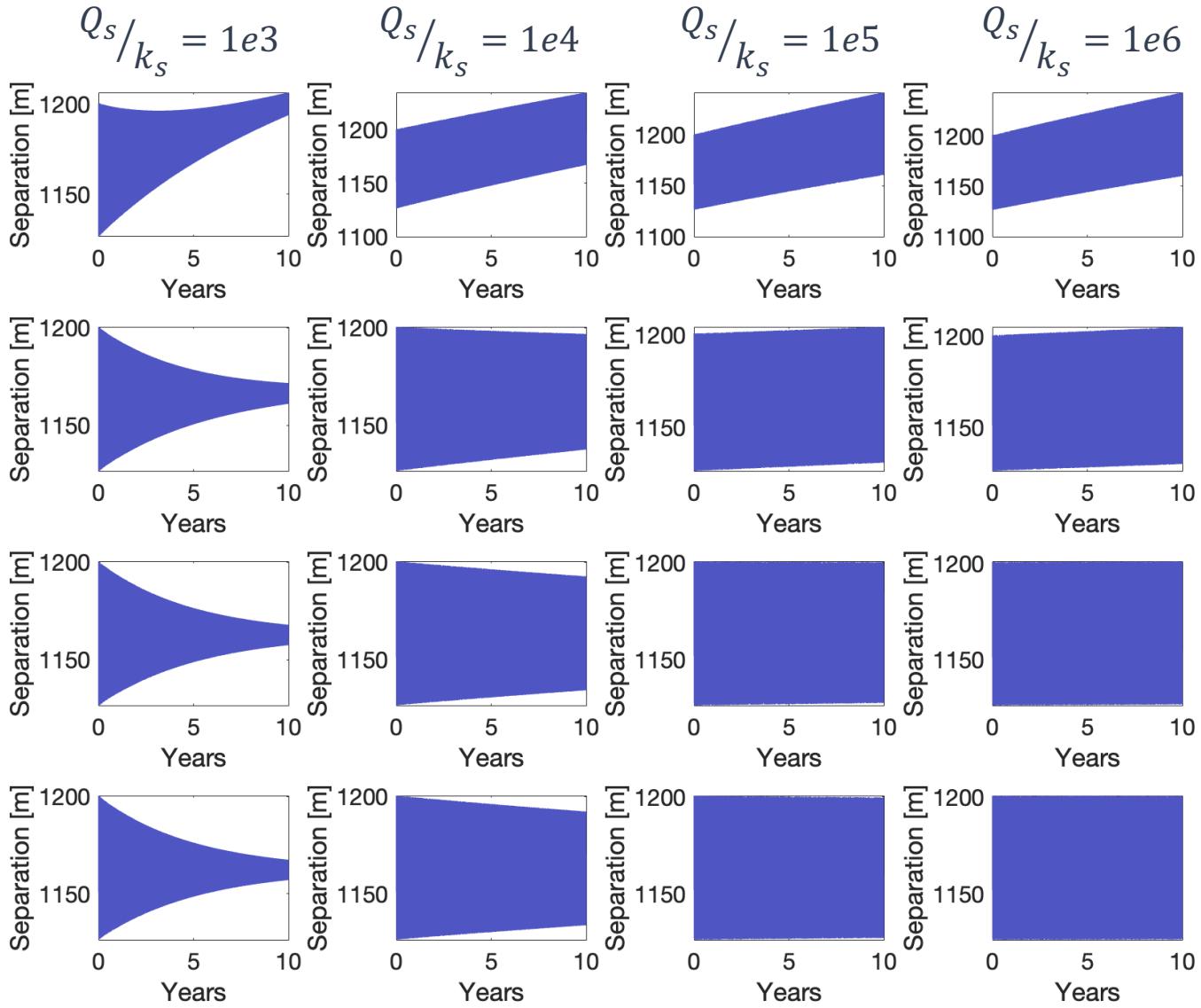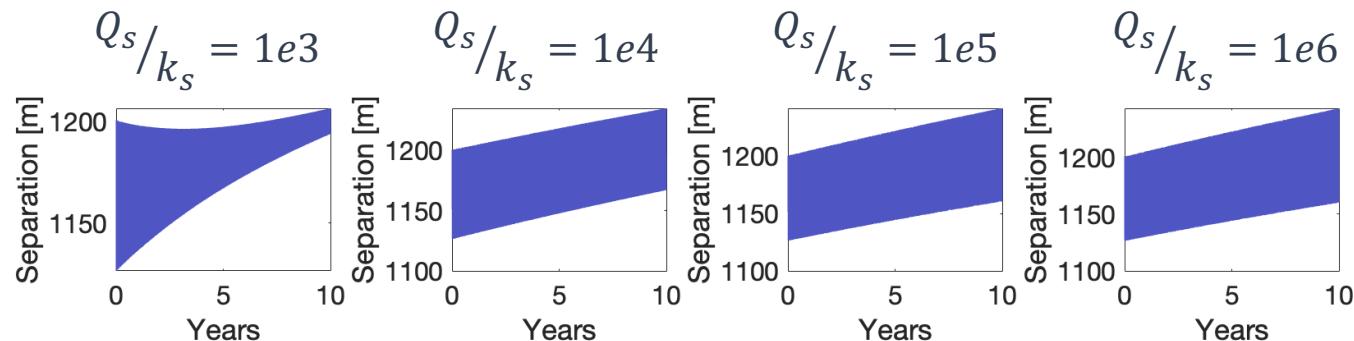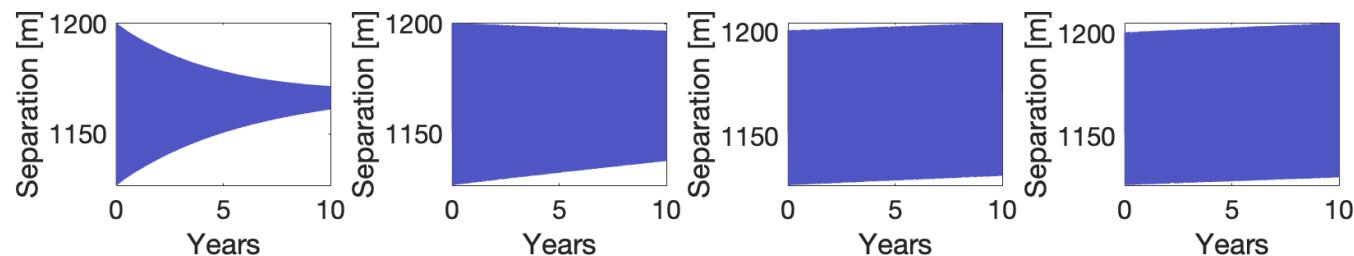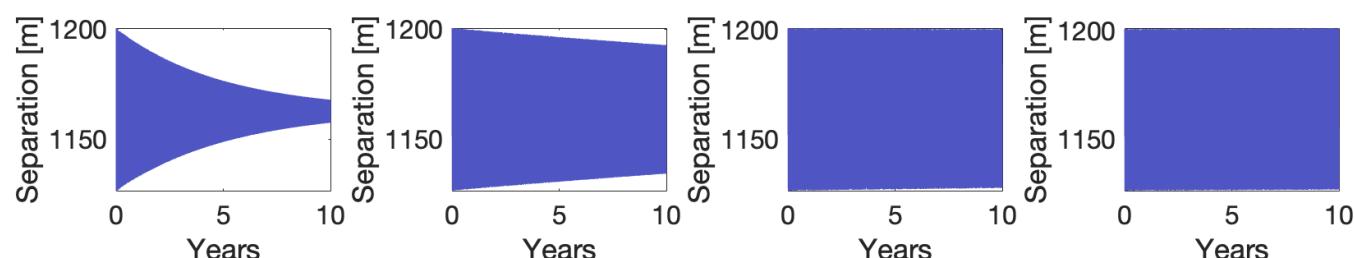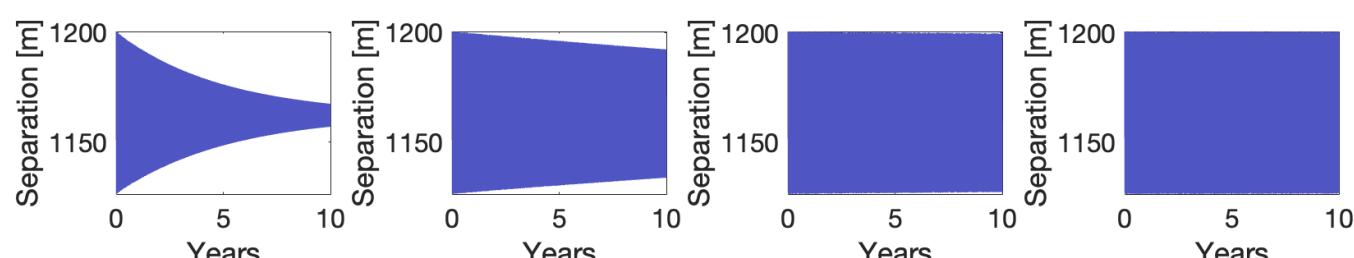
Tumbling
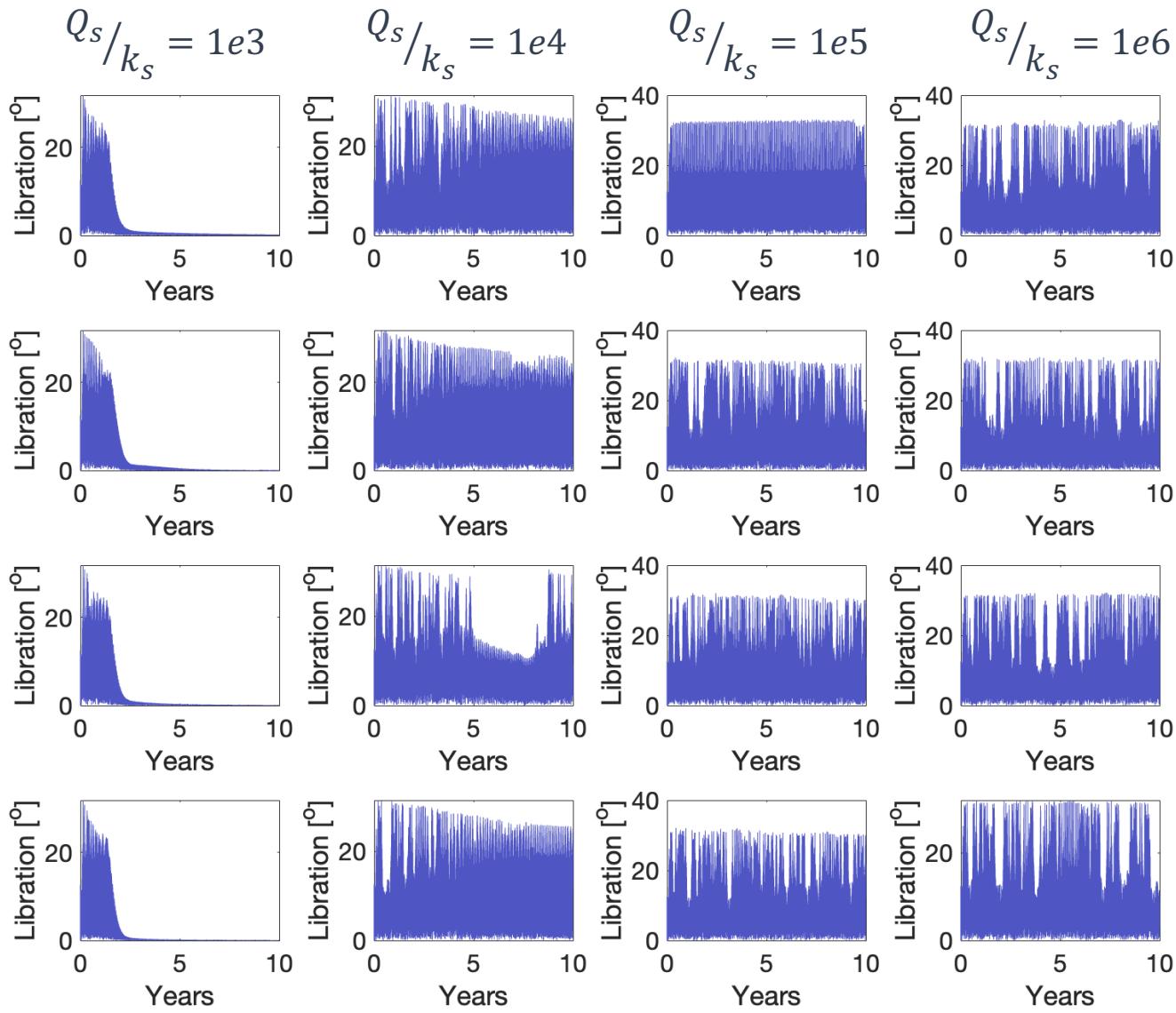
Libration

Eccentricity
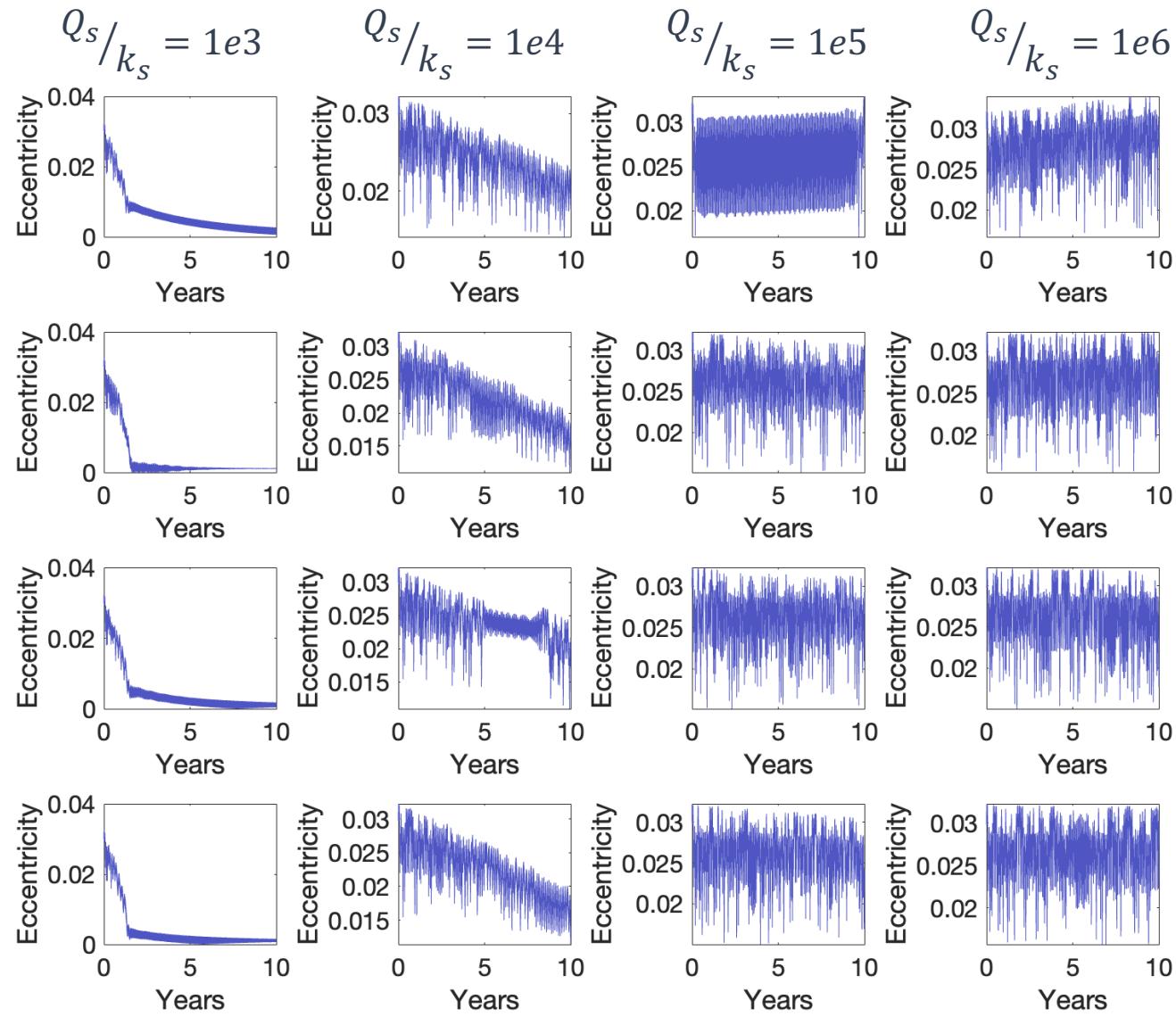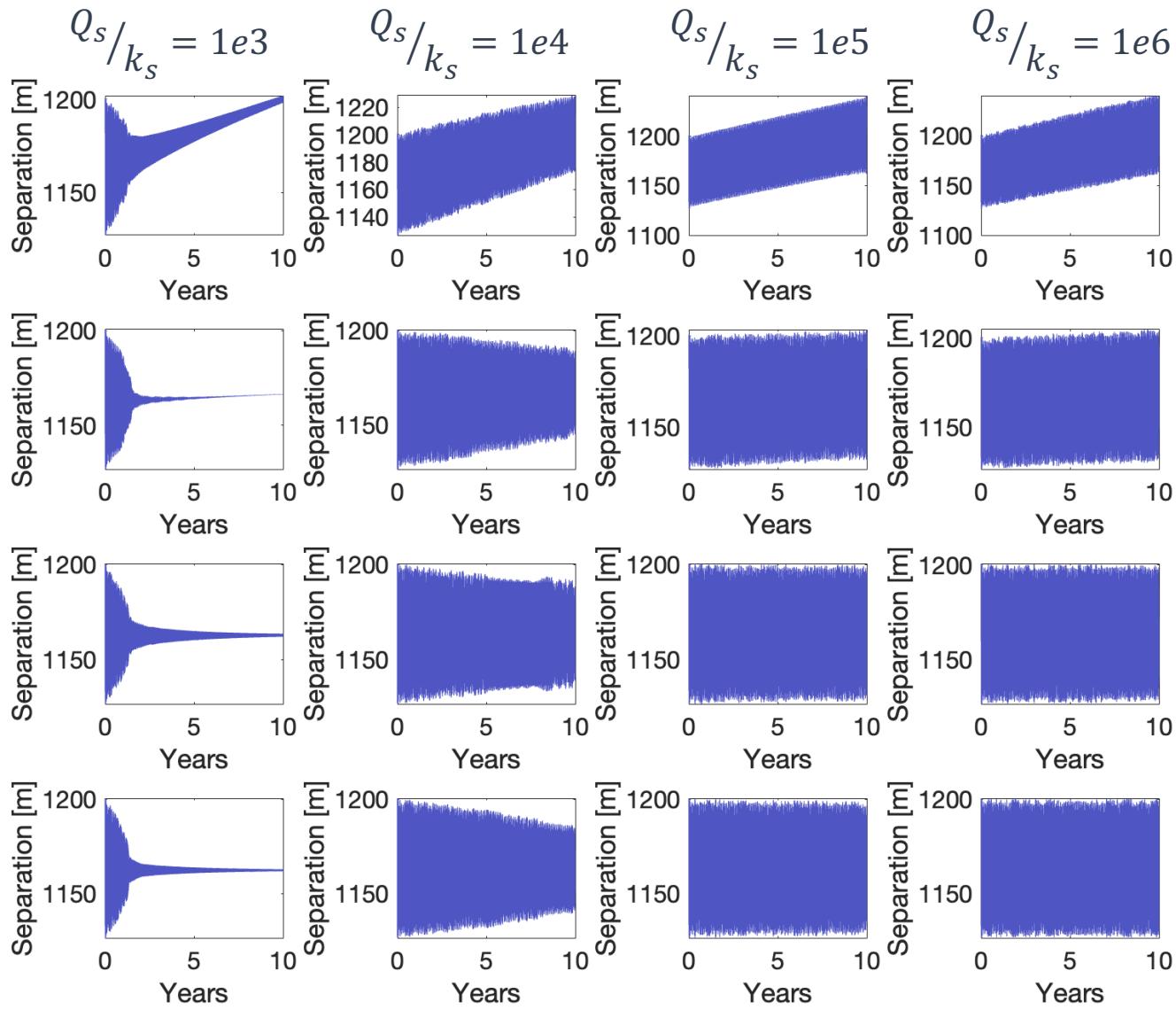
# Separation

What Will Hera See?
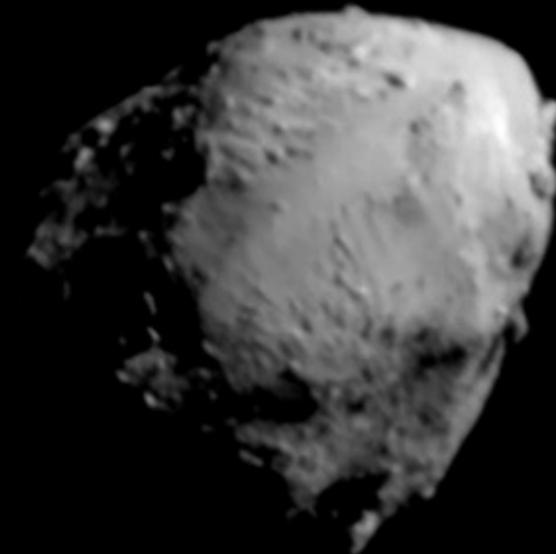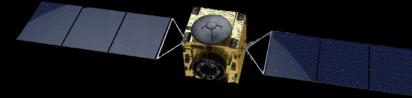
Hera Mission

Key measurements:

   Libration amplitude
   Separation distance

Is dissipation observable?


Didymos

ϕ

R

Dimorphos

Measurement accuracy (optimistic):
   ~1 deg libration angle*
   ~0.1 m separation*
      *Hera requirements document
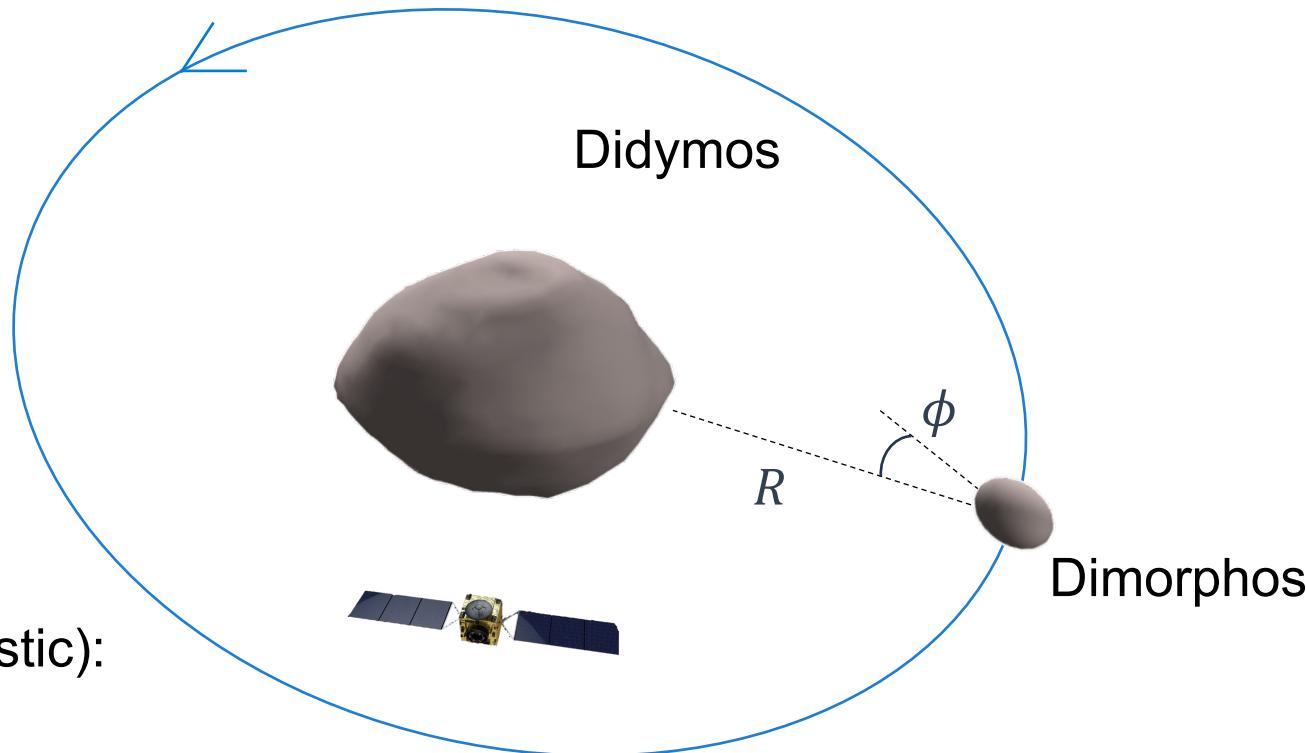
Libration Damping
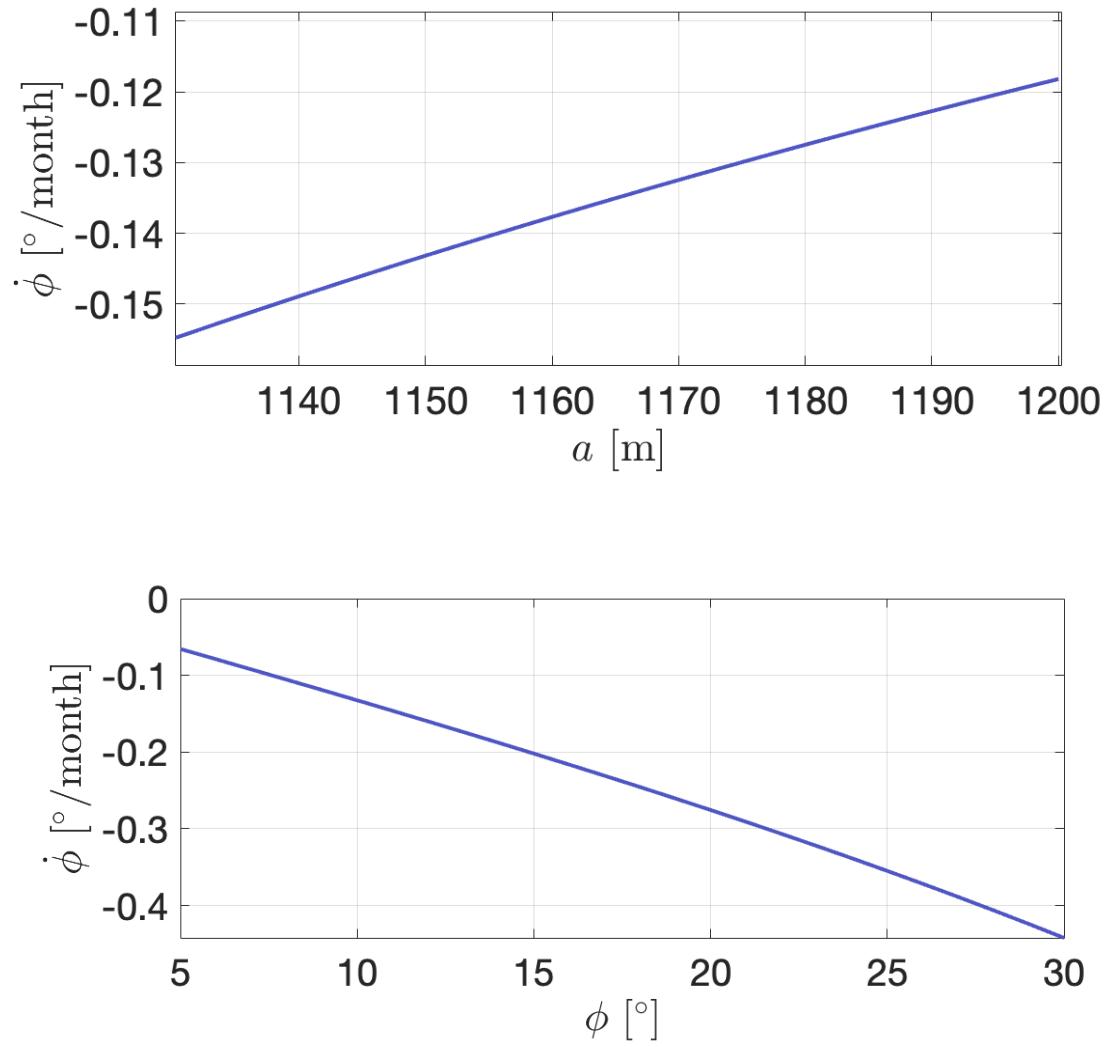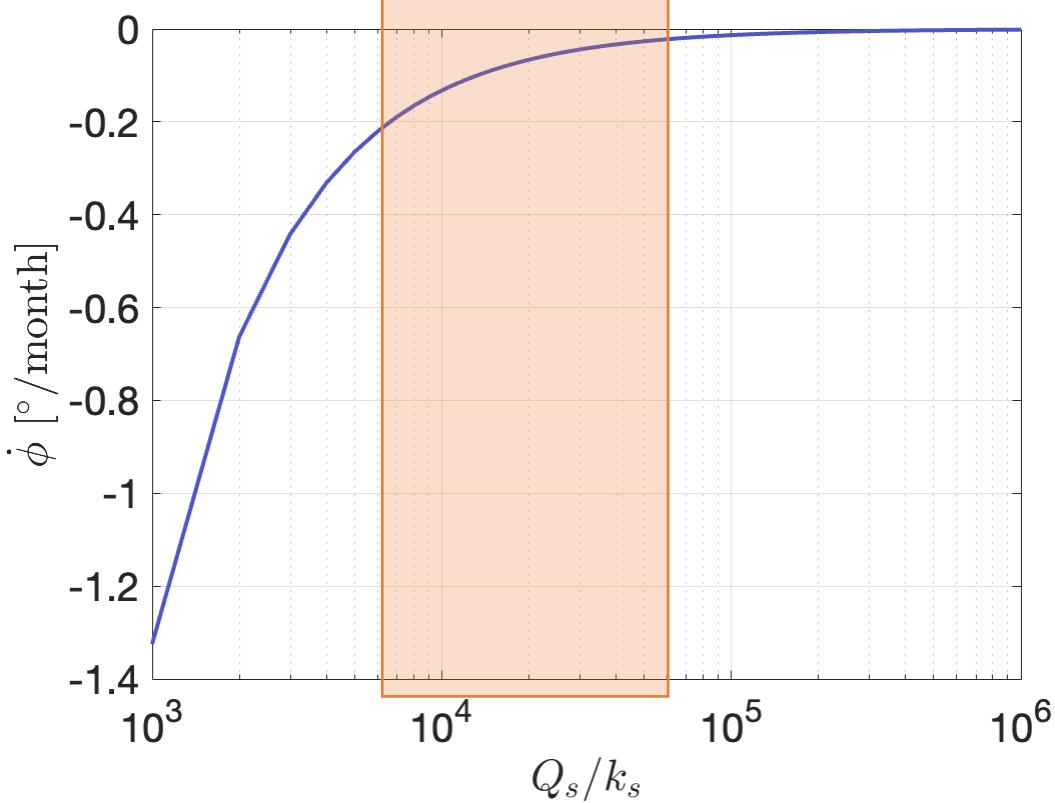
Jacobson et al, 2014
Jacobson & Scheeres, 2011

Eccentricity Damping
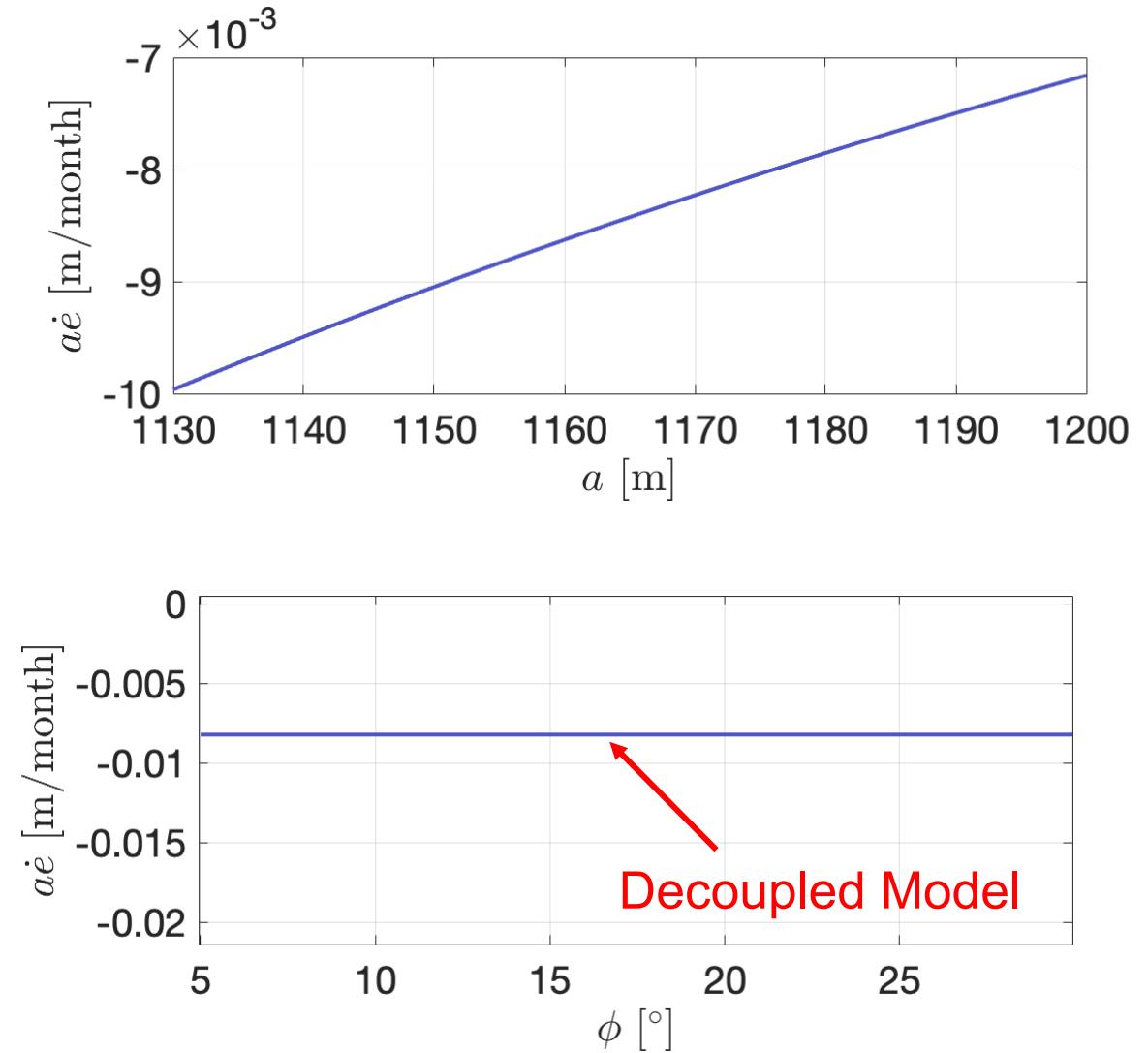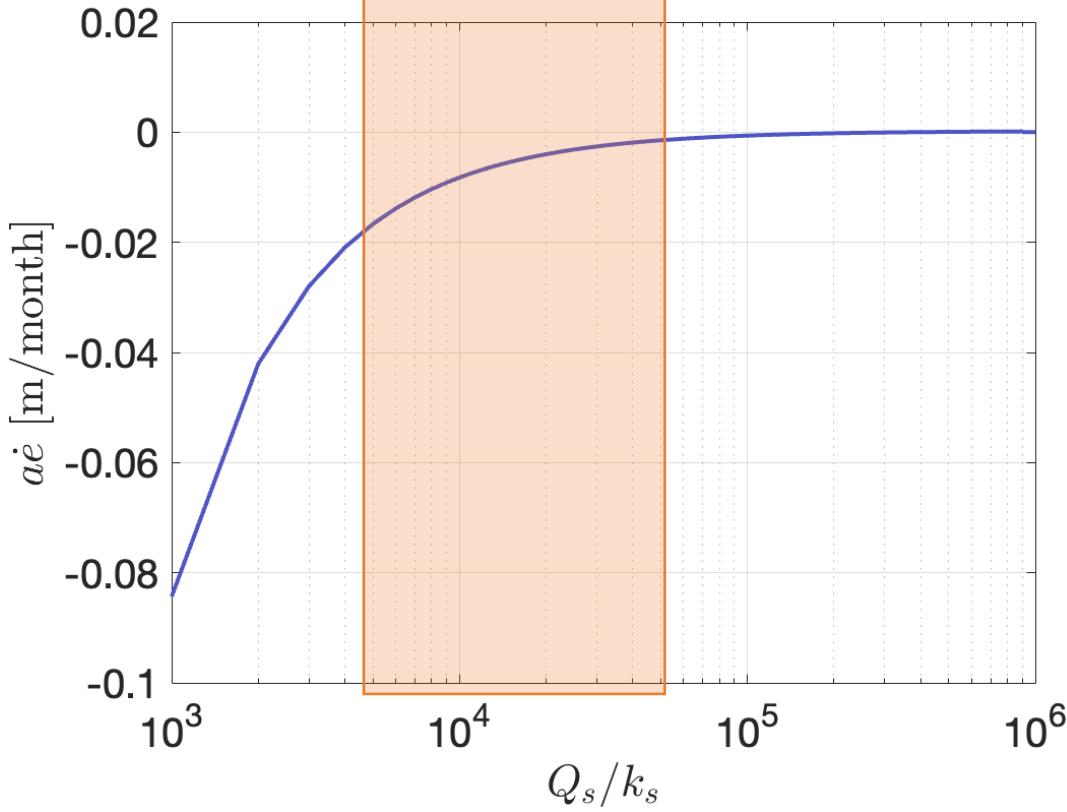
Jacobson et al, 2014
Jacobson & Scheeres, 2011

Hera Mission

Planned 6 month mission

Measurement accuracy (optimistic):
- ~1 deg libration angle*
- ~0.1 m separation*

    *Hera requirements document

Potential first measurement of small body dissipation

Primary parameters are likely unobservable

More difficult if tumbling