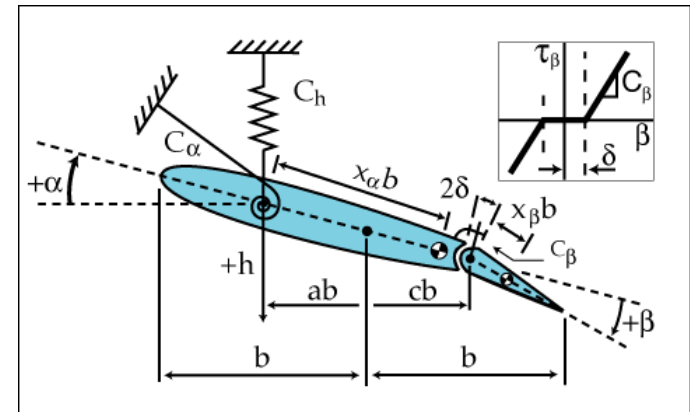
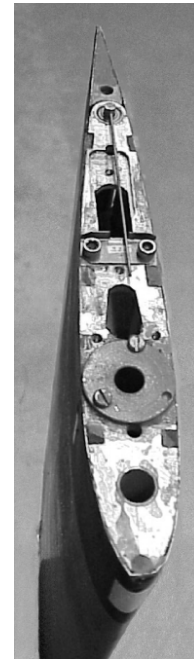
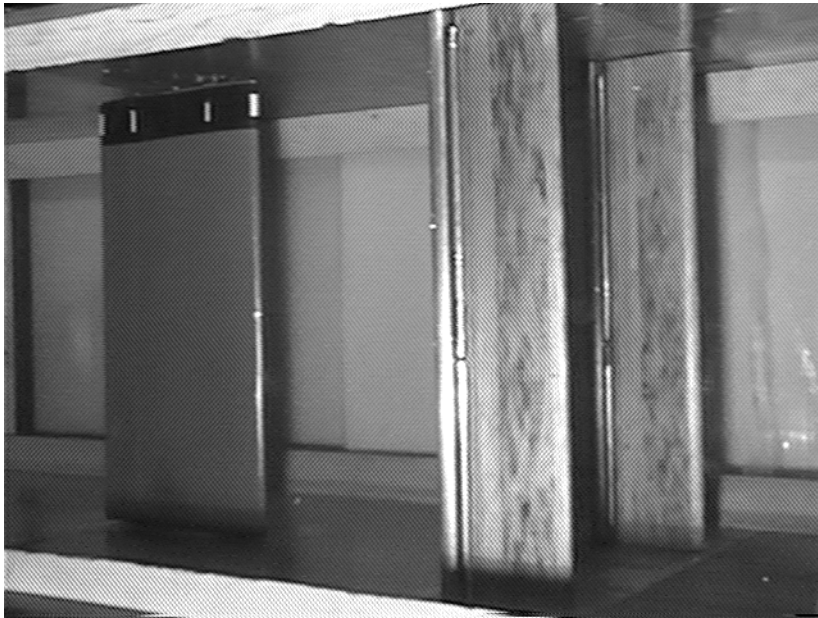
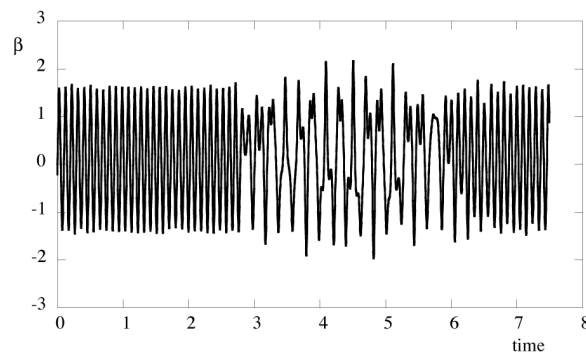


6. Co-existing LCO's in an airfoil with a loose flap



The (upstream) slotted cylinders alter the flow and hence the airfoil is disturbed.



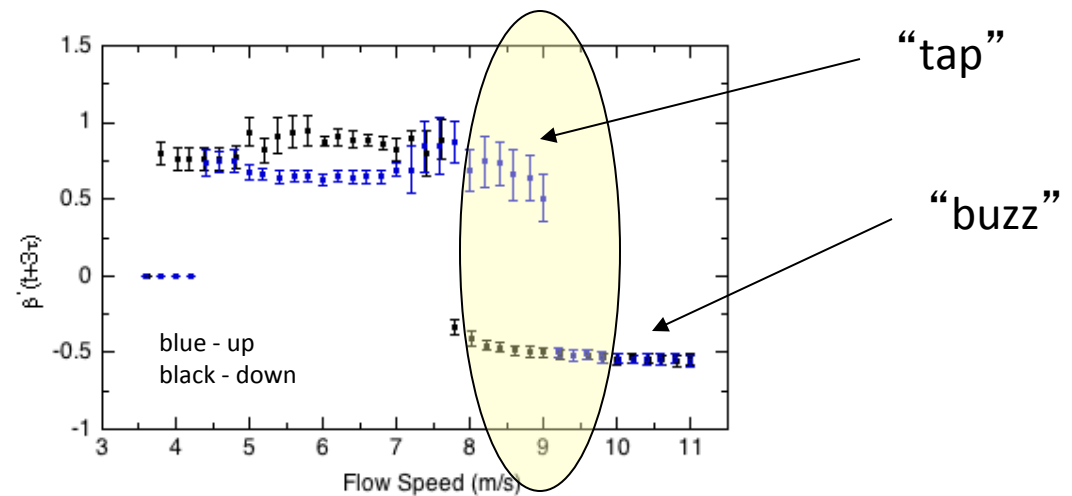
The **freeplay** in the flap stiffness is also a non-smooth characteristic.

- 3 Structural States $\vec{X} = [\alpha, \beta, h]^T$
- Control Surface Freeplay
- Aerodynamic Forces -
Theodorsen theory (2D incompressible flow)

- EOM

$$\begin{aligned} \left(M_s - \frac{\kappa}{\pi} M_{NC} \right) \ddot{\vec{X}} + \left(B_s - \frac{\kappa}{\pi} \left(\frac{U}{b} \right) \left[B_{NC} + \frac{1}{2} R S_2 \right] \right) \dot{\vec{X}} \\ + \left(K_s - \frac{\kappa}{\pi} \left(\frac{U}{b} \right)^2 \left[K_{NC} + \frac{1}{2} R S_1 \right] \right) \vec{X} \\ = \frac{\kappa}{\pi} \left(\frac{U}{b} \right) \left(R \left[C_1 \left(\frac{U}{b} \right)^2 C_2 \left(\frac{U}{b} \right) \right] \right) \vec{X}_{aug} \end{aligned}$$

Co-existing oscillations in the region of **hysteresis** (actually there are (at least) three such regions in this range)



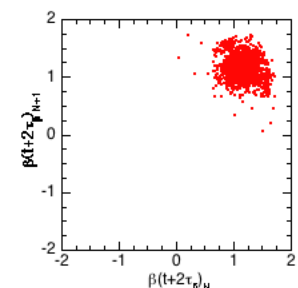
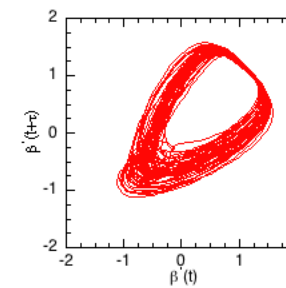
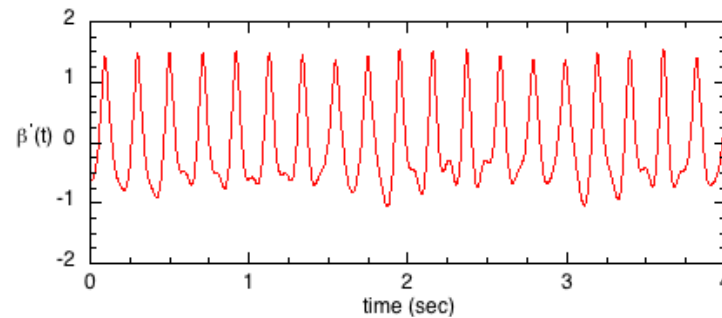
contact occurs at $b = |1.0|$

time series

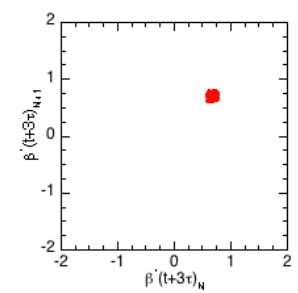
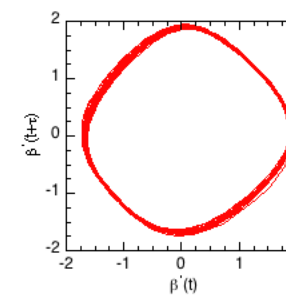
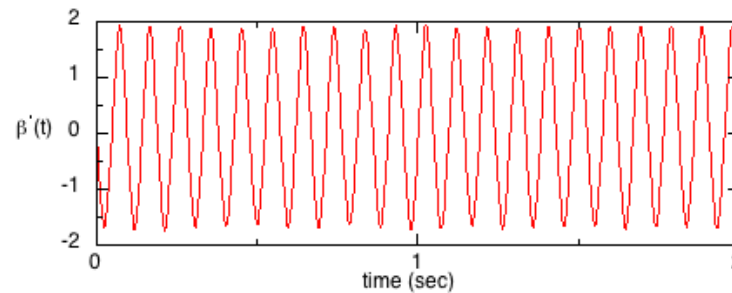
phase
projections

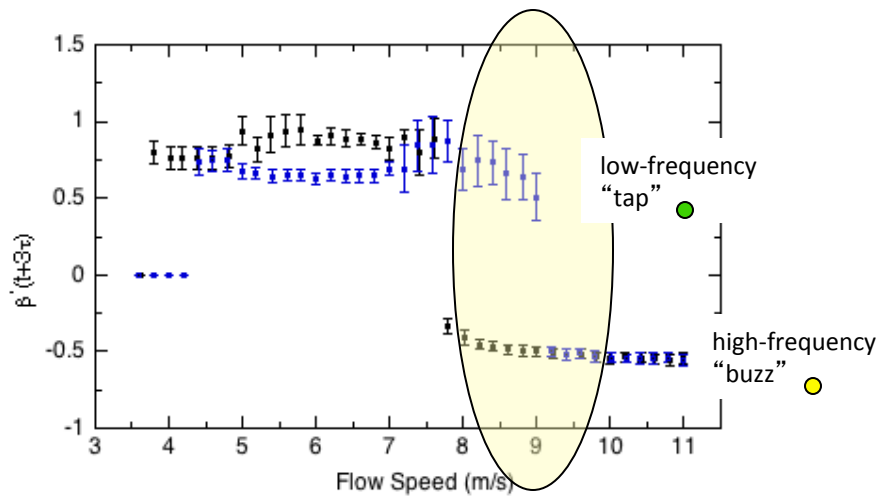
Poincaré
sections

low-frequency
“tap” ~ 5 Hz



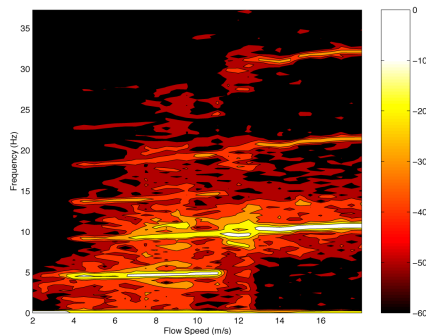
high-frequency
“buzz” ~ 10.5 Hz





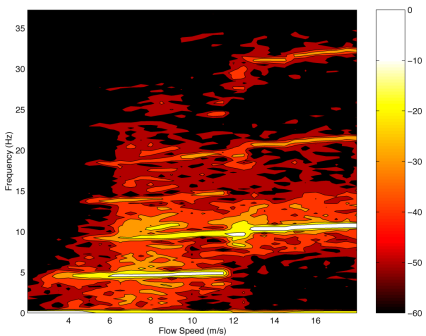
An alternative (frequency-based) view is provided by the **spectrogram**, or waterfall plots (lower left).

Run
down



The big problem here is the 6D phase space. Hence these Poincaré sections are projections but they do show the relative dominance of each type of motion.

Sweep
up



Airfoil flaps wear loose, and hence this is a preventative maintenance issue.

