ESPM-16, Session 5.4; Wednesday 08/09/2021, 16:09 - 16:22 BST

Seismology of coronal active regions with decayless kink oscillations

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Seismological estimation of the magnetic field:

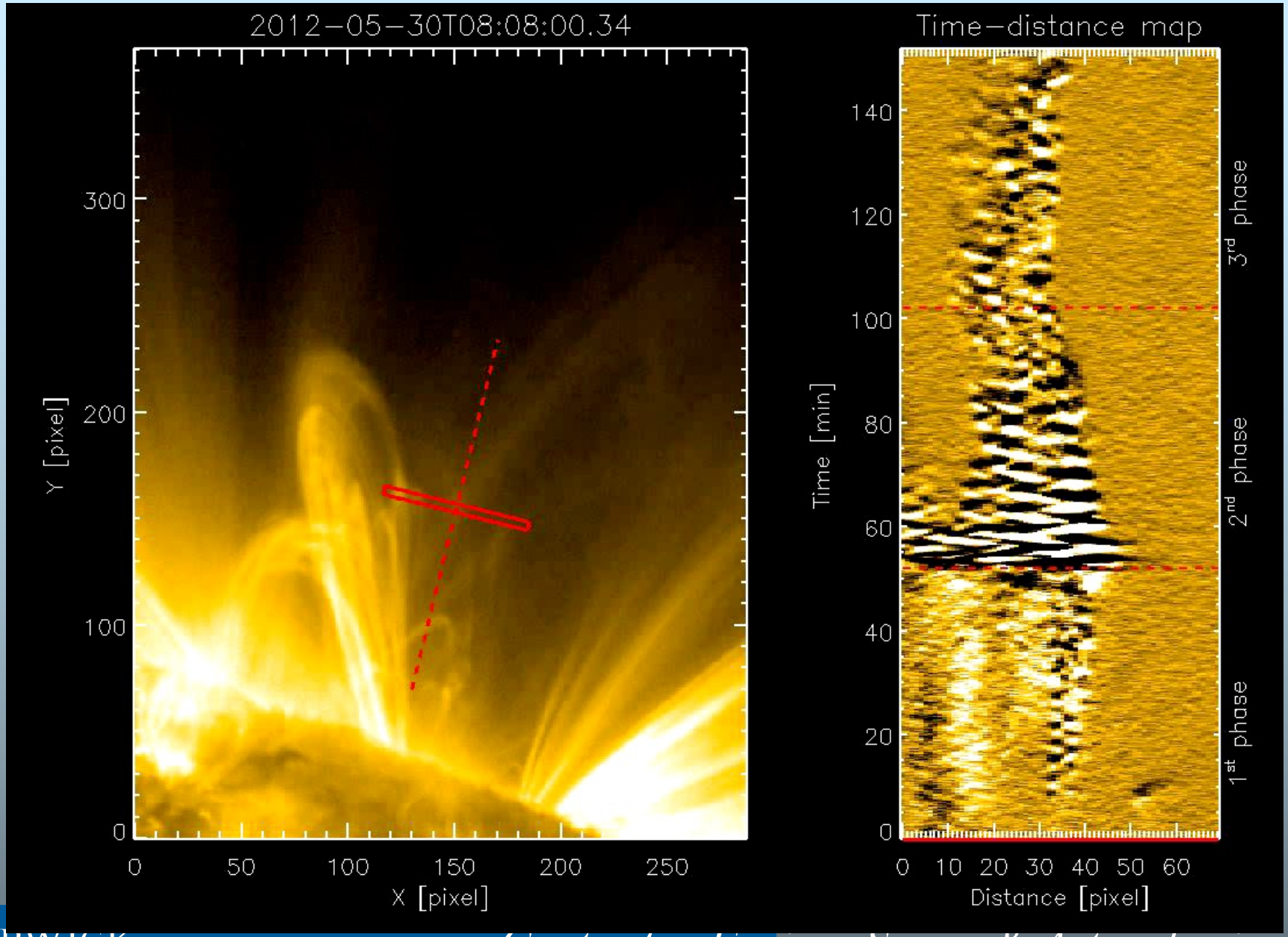
$$B = \sqrt{\mu_0}\,\frac{\sqrt{2}\,L_{\mathrm{loop}}}{P}\sqrt{\rho_i\left(1+\frac{\rho_e}{\rho_i}\right)}$$

Assuming that

- The loop cross-section is constant;
- There is no stratification;
- There is no twist / sigmoidity.

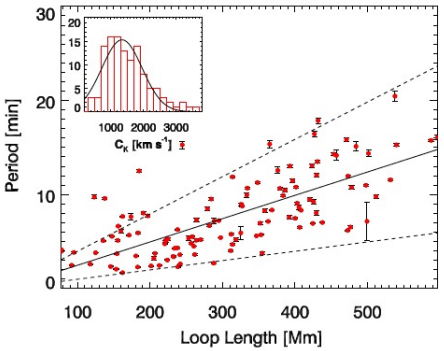
If those conditions are not fulfilled: the field at antinodes.

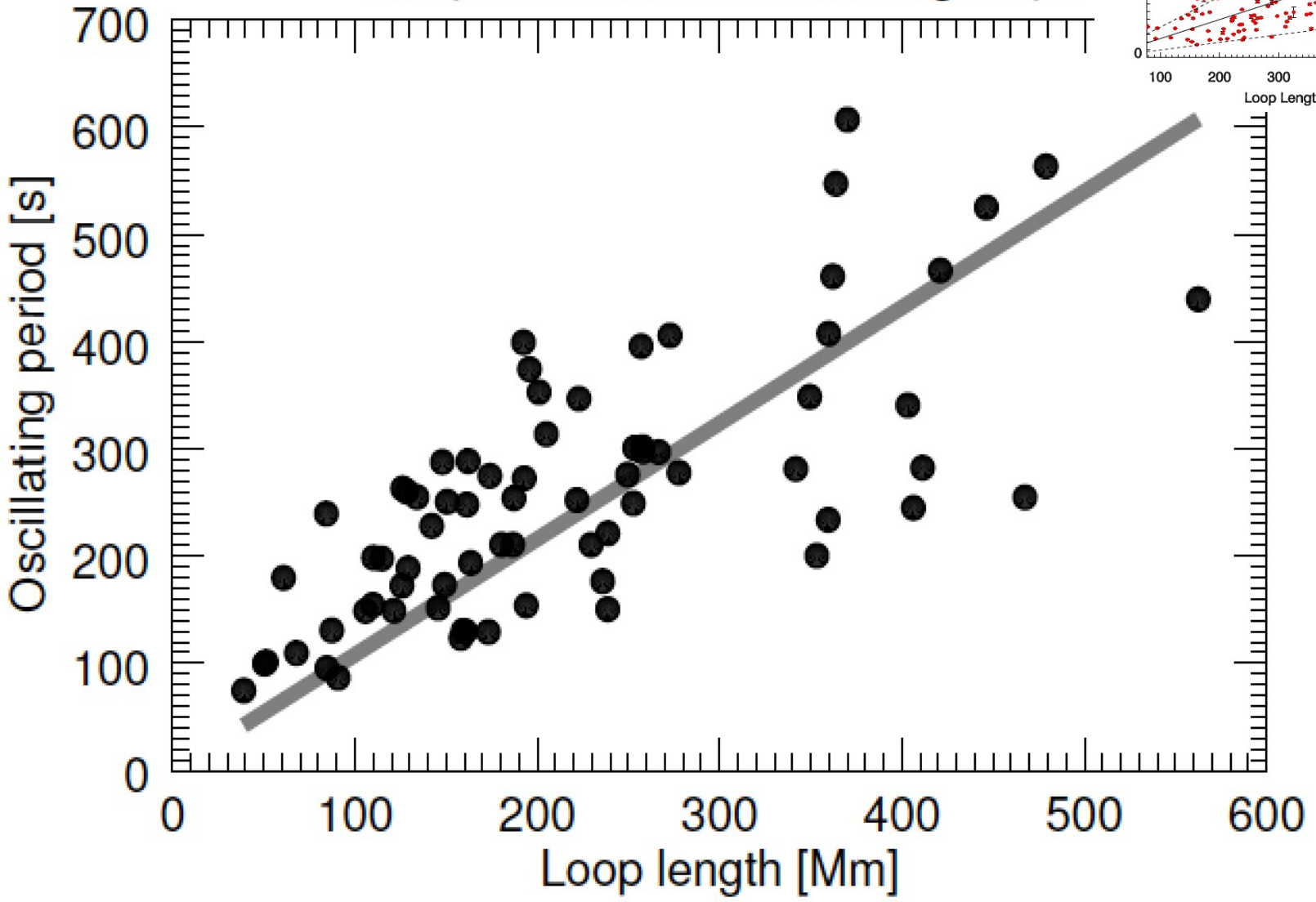
Decayless kink oscillations of coronal loops:



Nistico et al. 2013A&A...552A..57N

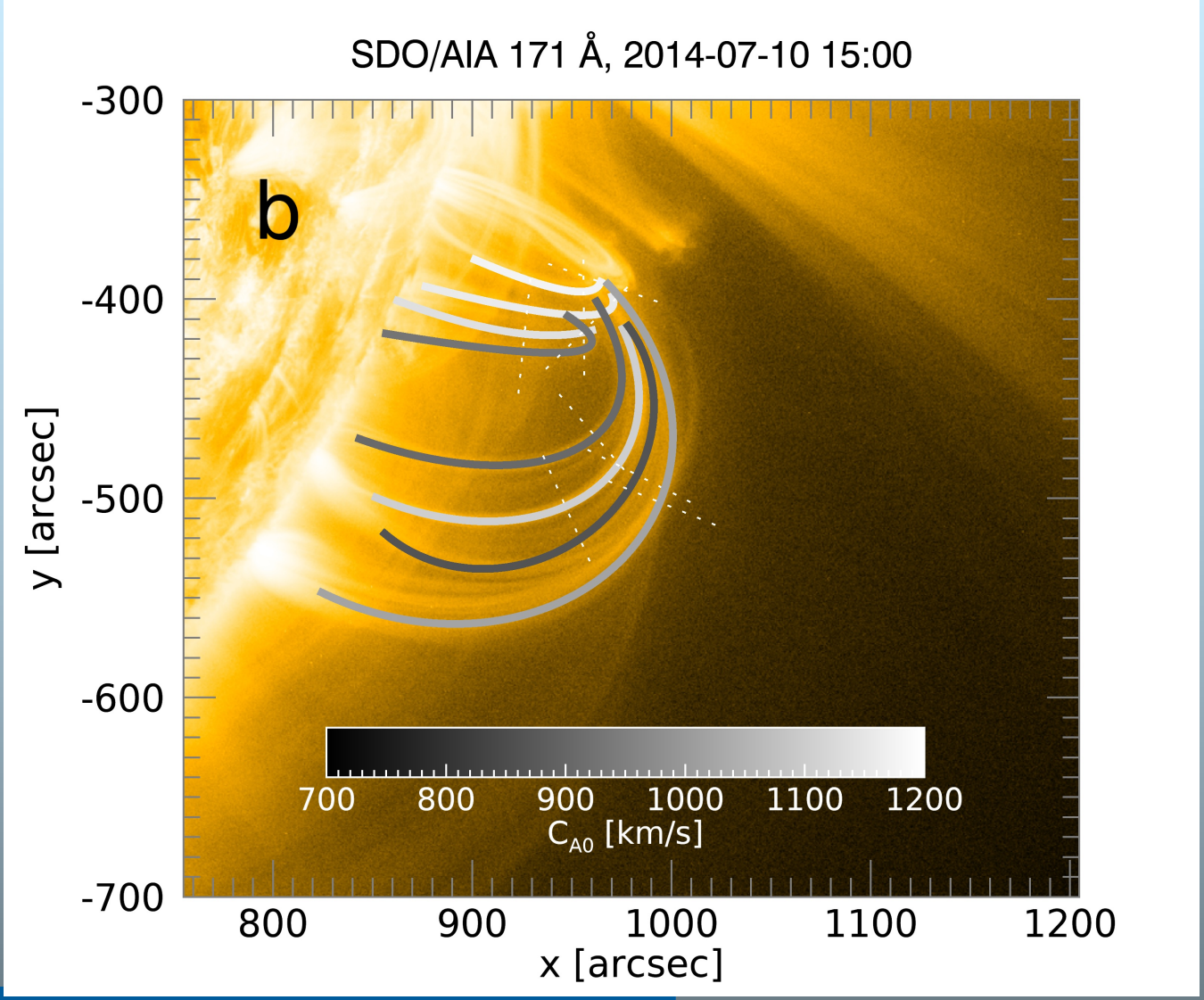
The parameters of oscillating loops





Anfinogentov et al. 2015A&A...583A.136A

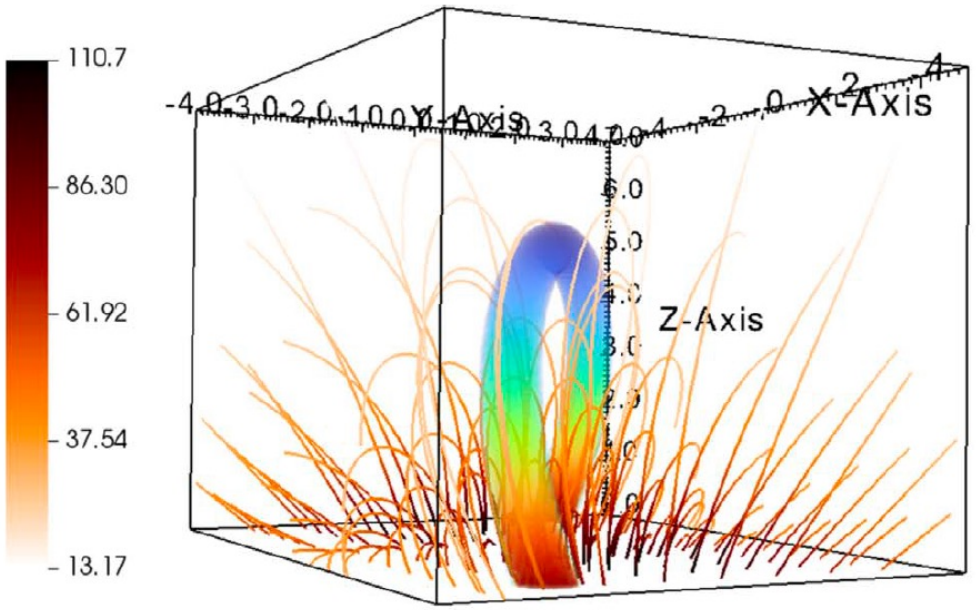
Seismology of a “quiet” active region by decayless oscillations: **Alfvén speed map of AR**

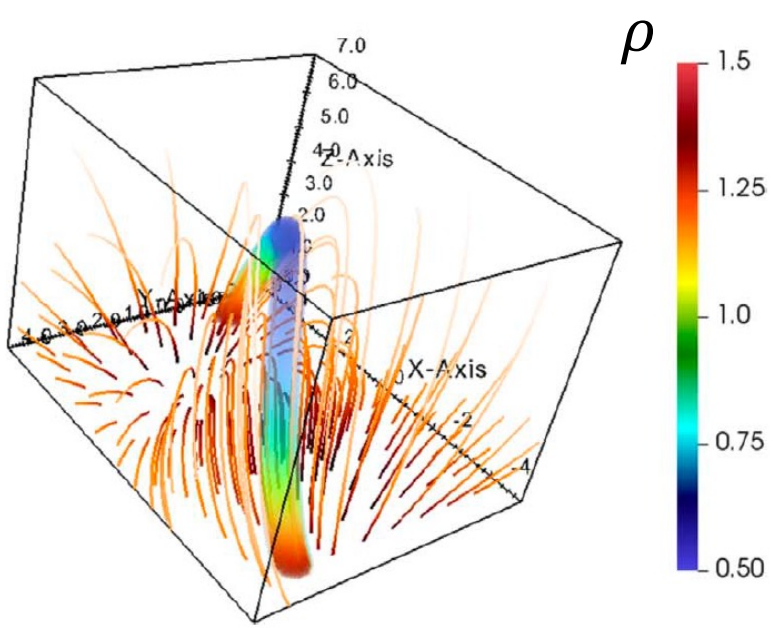


Anfinogentov & Nakariakov *ApJL* **884**, L40, 2019

Standing kink waves in sigmoid solar coronal loops: Implications for coronal seismology

Accounting for both the twist (sigmoidity) and stratification:



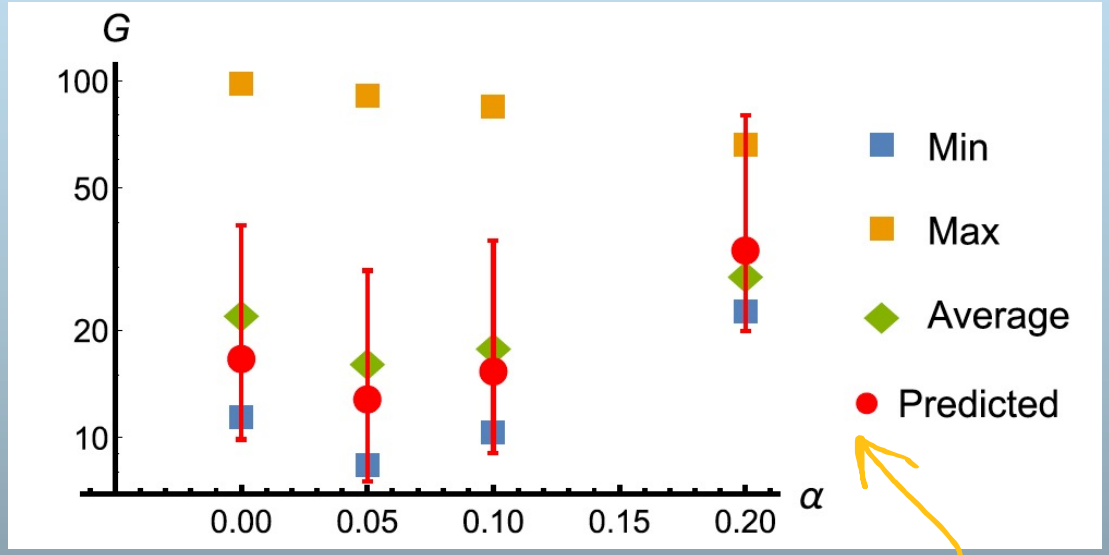


Magyar & Nakariakov, ApJ 894:L23, 2020

The Measured Period, the Length of the Centrally Traced Loop Magnetic Field Line, and the Theoretical Oscillation Period Calculated from Equation (11)

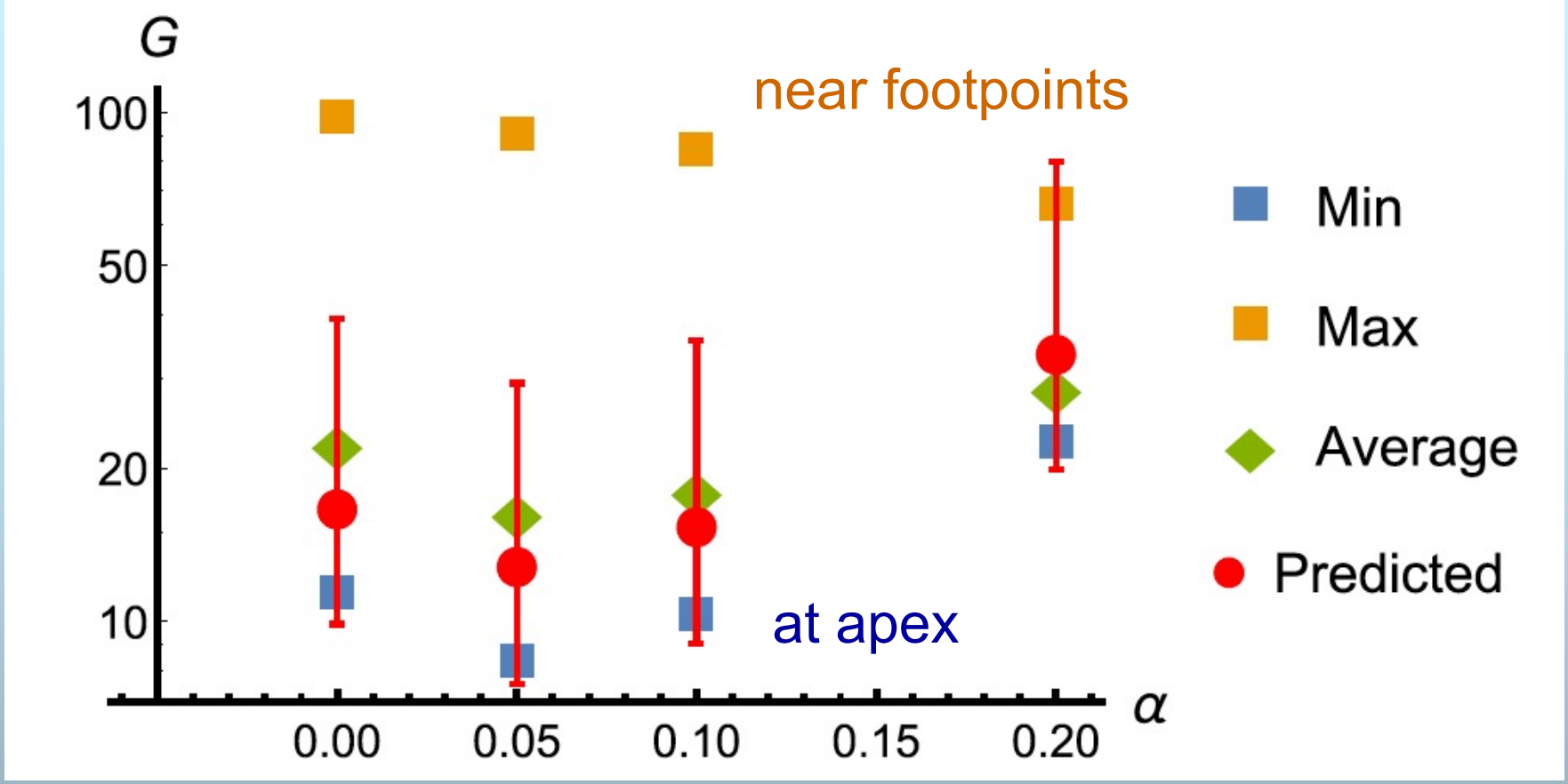
α	Loop Length (Mm)	Period (s)	Theor. Period (s)
0	126.7	202.5	202.5
0.05	148.3	289.3	305.4
0.1	150.8	251	264.7
0.2	148.9	120.3	145.4

$$P = 2\int_{s_a}^{s_b} \frac{ds}{c_k(s)}$$



$$B = \sqrt{\mu_0}\frac{\sqrt{2}\,L_{\text{loop}}}{P}\sqrt{\rho_i\left(1+\frac{\rho_e}{\rho_i}\right)}$$

Magyar & Nakariakov, ApJ 894:L23, 2020



The possibility of seismologically determining the sigmoidity of the loop, and hence free magnetic energy, if some other method to determine the average magnetic field is available, e.g., force-free extrapolation.

How can we have a decayless monochromatic oscillation of a damped oscillator?

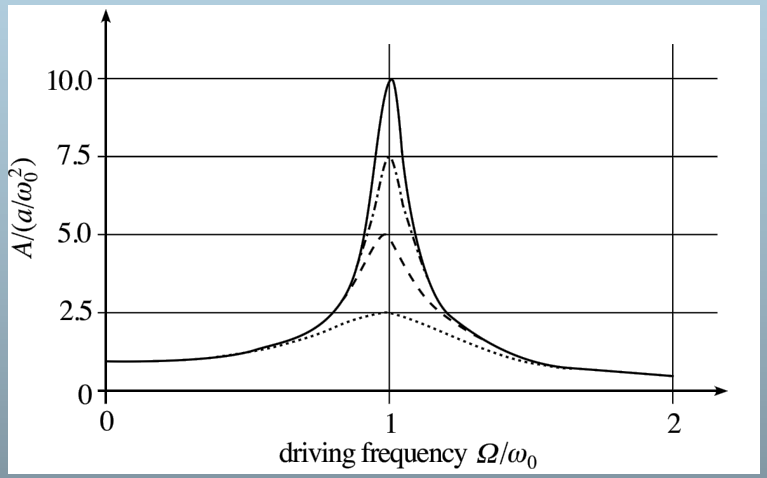
$$\frac{d^2a(t)}{dt^2} + \delta\frac{da(t)}{dt} + \Omega_K^2 a(t) = f(t).$$

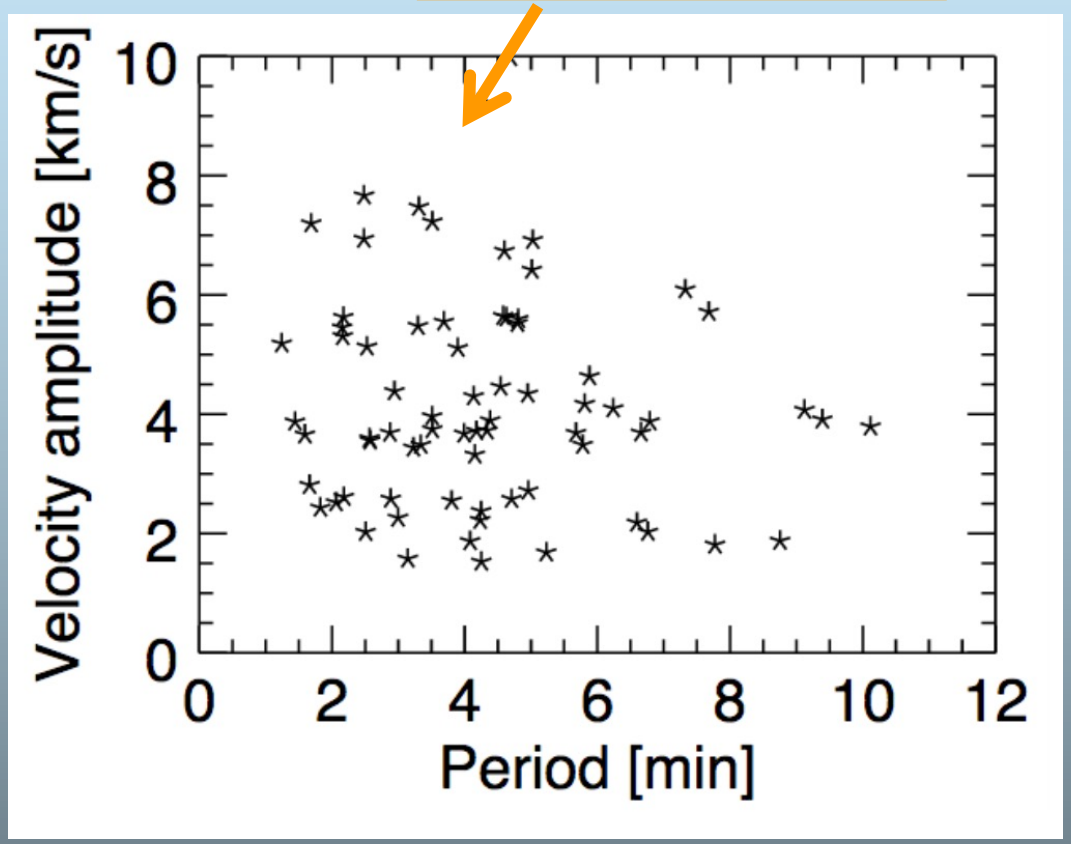
Can *f(t)* be periodic? (E.g., leakage of p-modes, chromospheric 3-min oscillations)

Demonstration that the decayless kink oscillations are not excited by the leakage of p-modes or 3-min oscillations:

No signatures of resonance

Amplitudes of ensemble of harmonically driven uncoupled oscillators:





Nakariakov et al. 2016A&A...591L...5N

Thus, *f(t)* cannot be periodic:

no signature of resonance.

→ We **exclude** the leakage of p-modes or 3-min oscillations as a driver of decayless kink oscillations

Remaining options:

- Self-oscillations (Nakariakov et al. 2016A&A...591L...5N; Karampelas & Van Doorsselaere 2021ApJ...908L...7K)
- Random driver (Afanasyev et al. 2020A&A...633L...8A; Ruderman & Petrukhin 2021MNRAS.501.3017R)

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Conclusions

- Decayless kink oscillations are natural modes of coronal loops, as their oscillation period scales linearly with the loop length.
- Seismology during quiet periods.
- Possibility to probe free magnetic energy?

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Kink Oscillations of Coronal Loops

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Abstract

Kink oscillations of coronal loops, i.e., standing kink waves, is one of the most studied dynamic phenomena in the solar corona. The oscillations are excited by impulsive energy releases, such as low coronal eruptions. Typical periods of the oscillations are from a few to several minutes, and are found to increase linearly with the increase in the major radius of