A Precursor to Solar Prominence Eruptions

Detection and Analysis of EUV Prominence Oscillations

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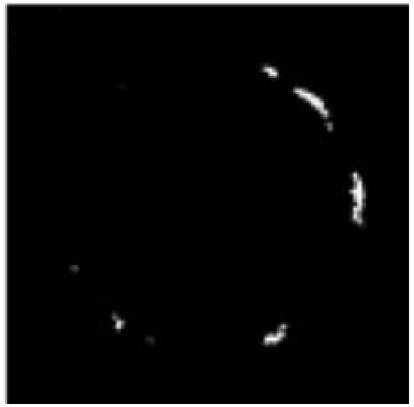
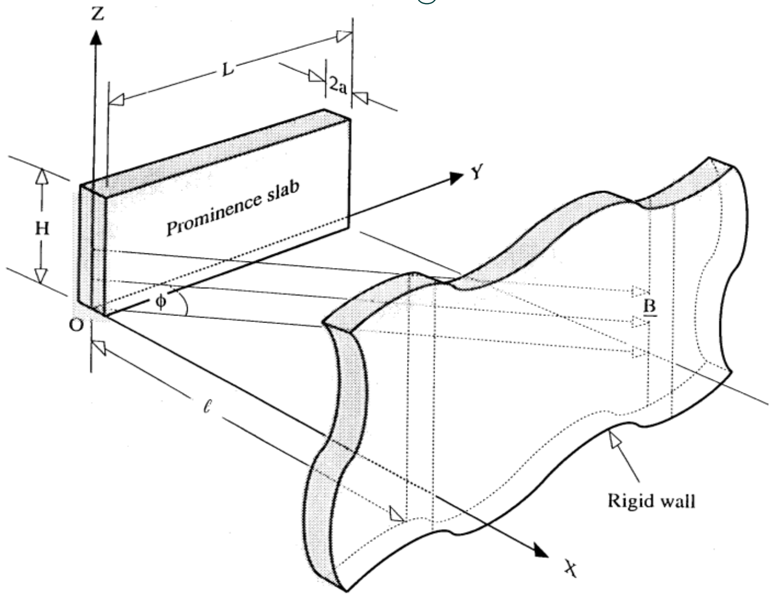
Introduction

- Ultra-long period oscillations detected in EUV filaments with SOHO/EIT data (Foullon et al. 2004)
- Automated detection of EUV prominences with EIT (Foullon & Verwichte 2006)
- Link between period and prominence height investigated (Foullon et al. 2009)
- Filament and prominence observations not simultaneous – EIT only



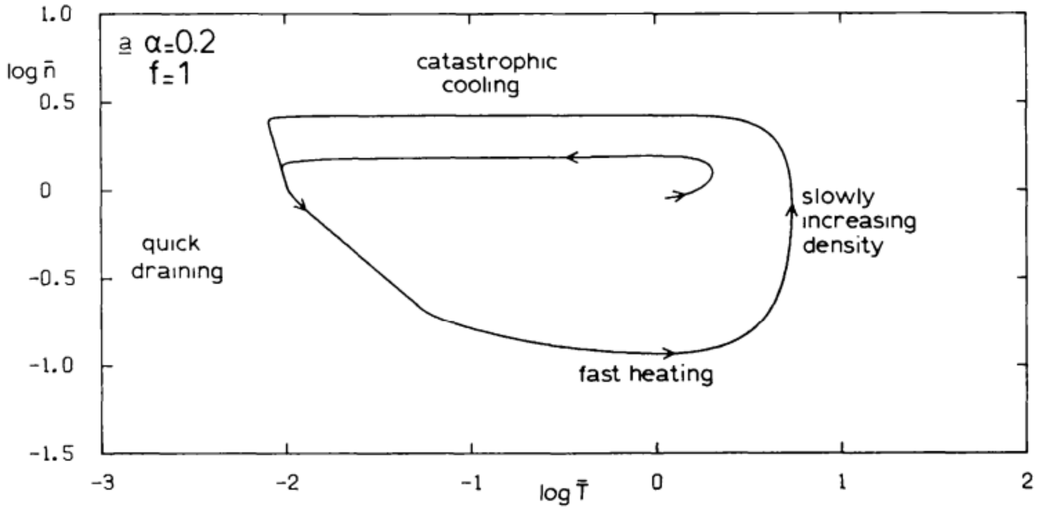
Foullon & Verwichte, 2006

Slow String Modes



Joarder & Roberts, 1993

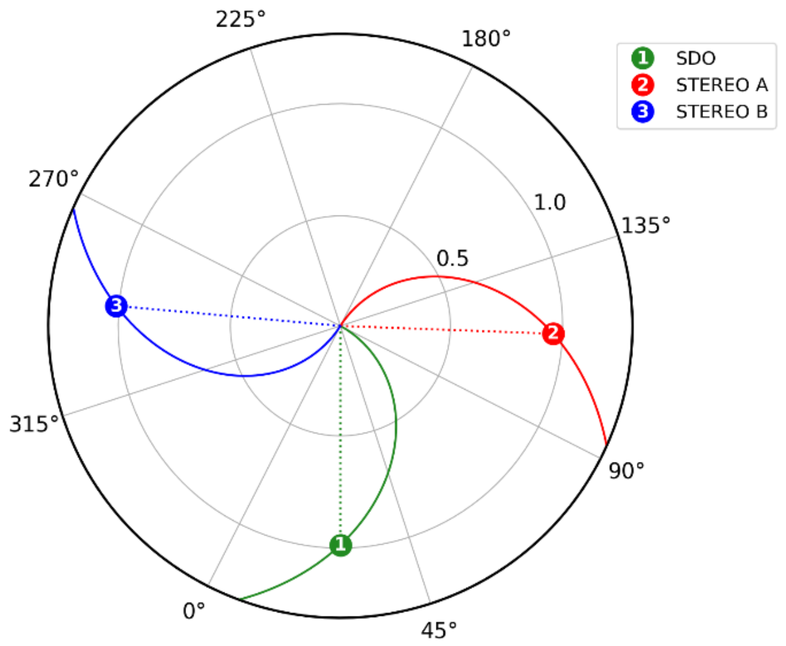
Thermal Cycles

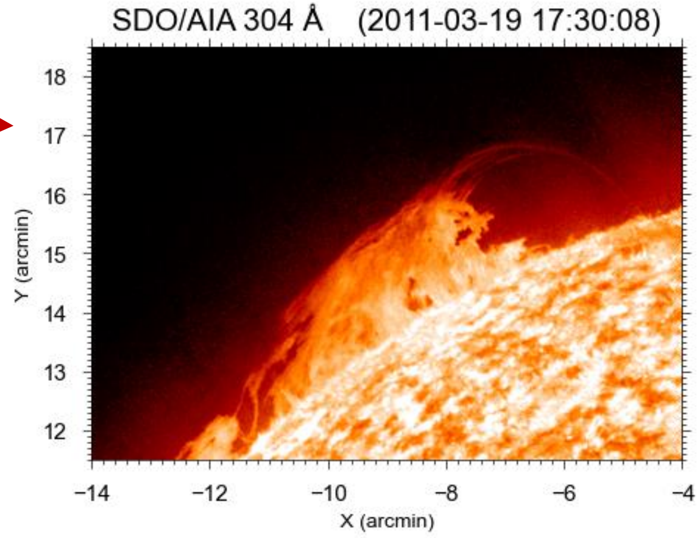


Kuin & Martens, 1982

Prominence in 3D

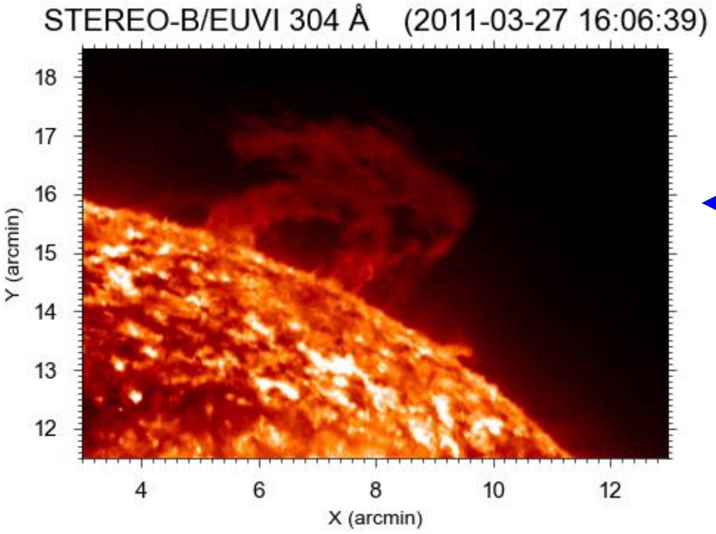
- 2011 – First quadrature between the STEREO spacecraft and SDO
- Facilitates viewing the Sun in three dimensions
- Large prominence first seen in SDO/AIA (Northeastern limb)
- Filament/prominence observed simultaneously from different viewpoints

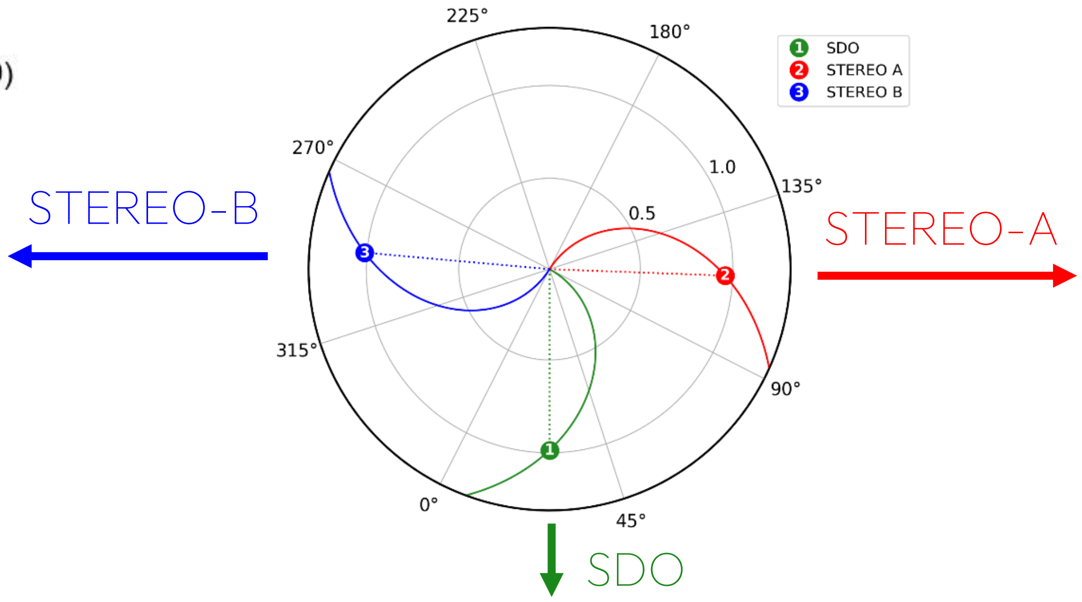


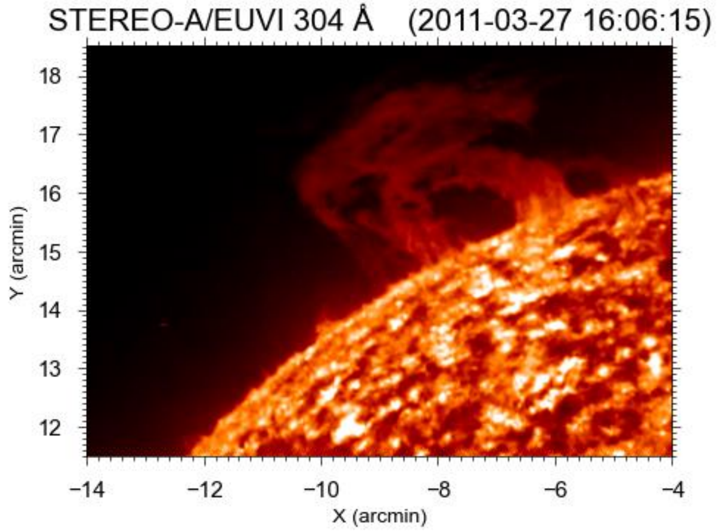


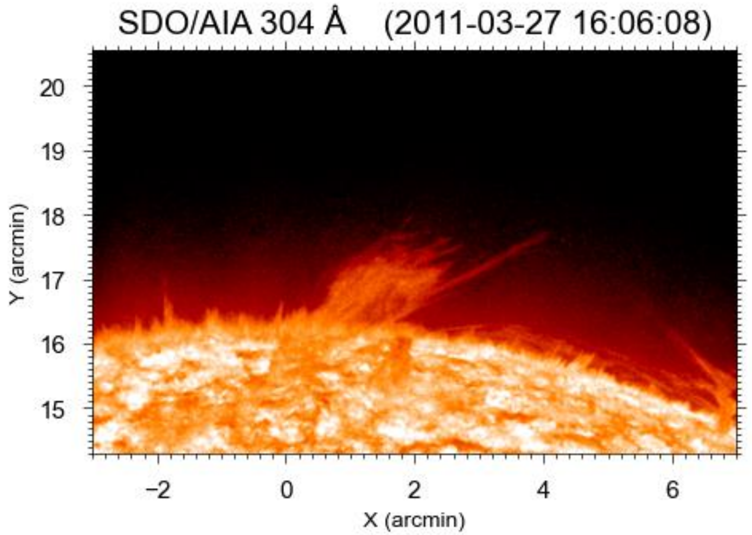
Prominence Eruption

27th March 2011









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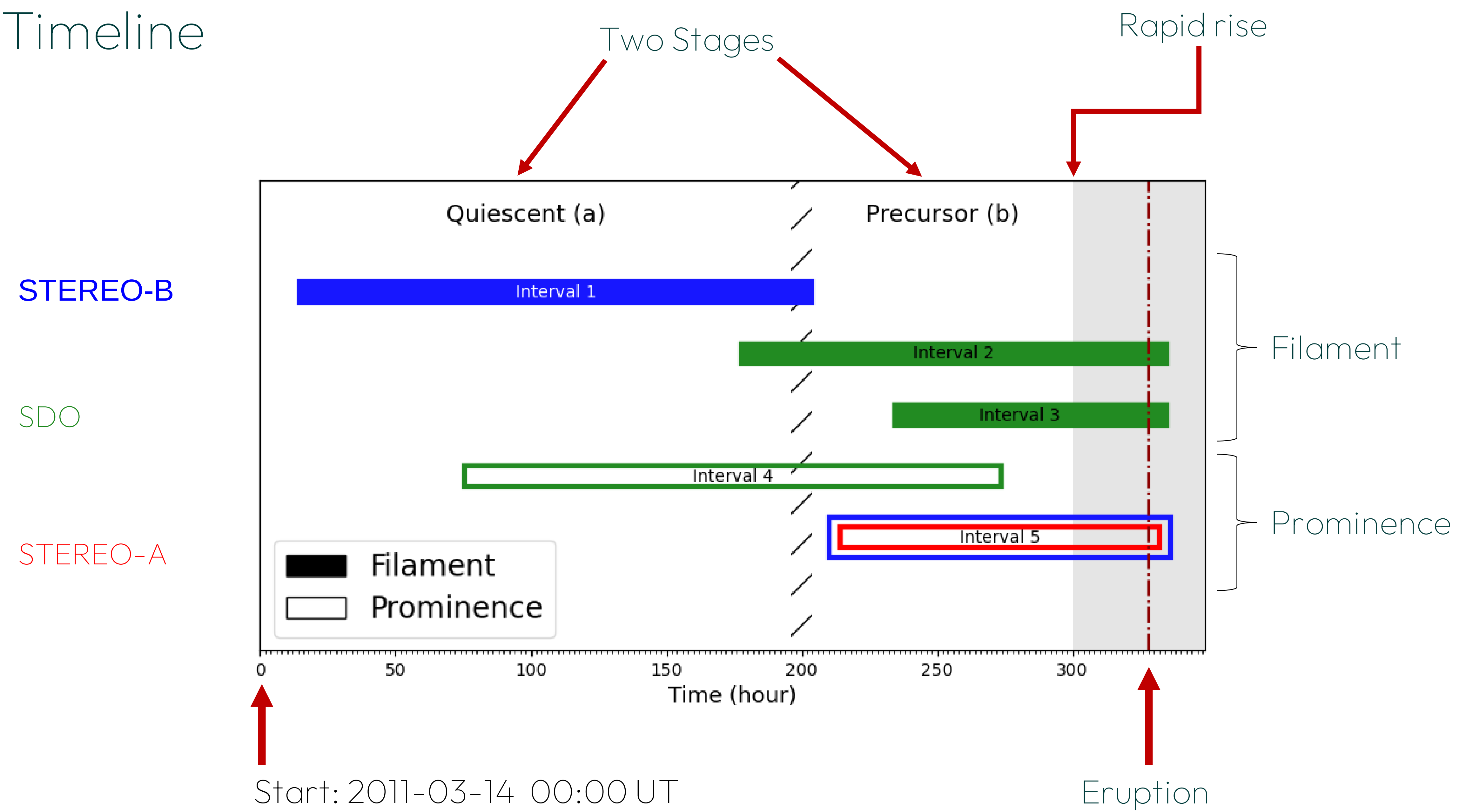
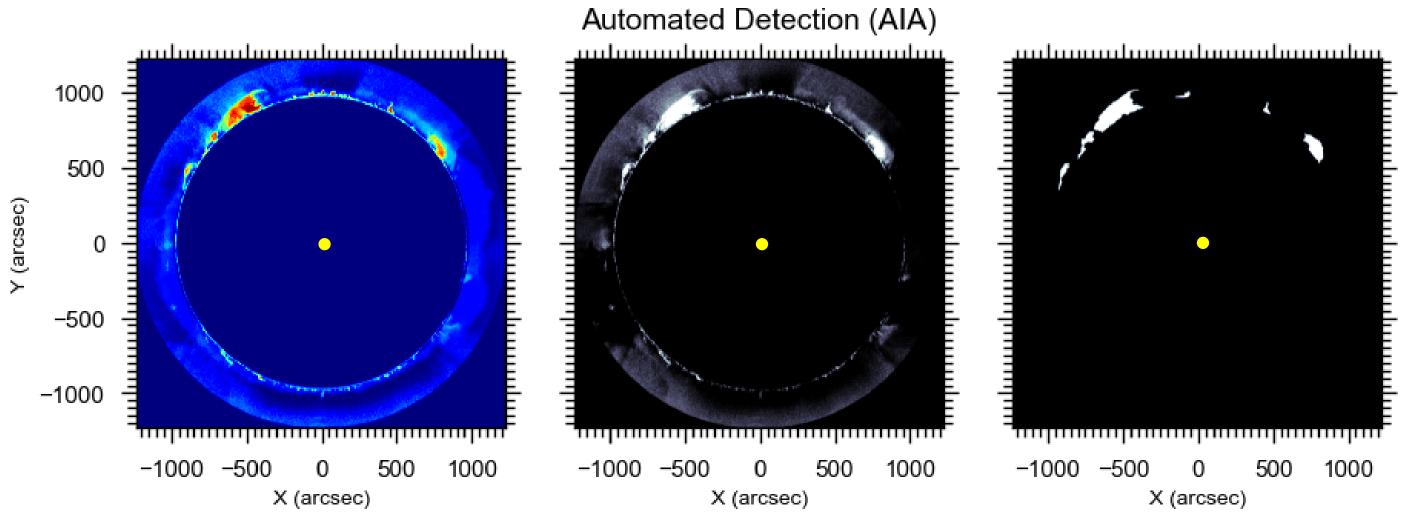
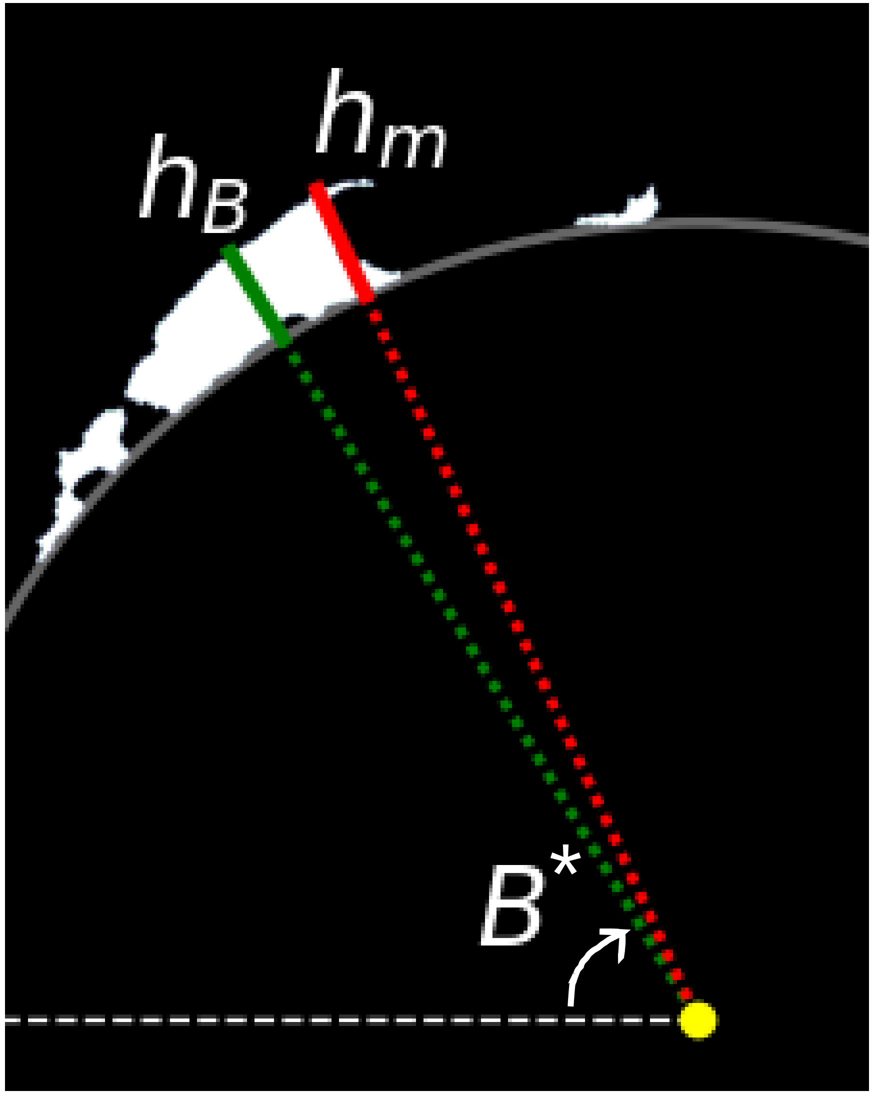
Timeline



Two Stages
Rapid rise
Quiescent (a)
Precursor (b)
STEREO-B
SDO
STEREO-A
Interval 1
Interval 2
Interval 3
Interval 4
Interval 5
Filament
Prominence
Filament
Prominence
0
50
100
150
200
250
300
Time (hour)
Start: 2011-03-14 00:00 UT
Eruption

Part 1: Prominence Detection



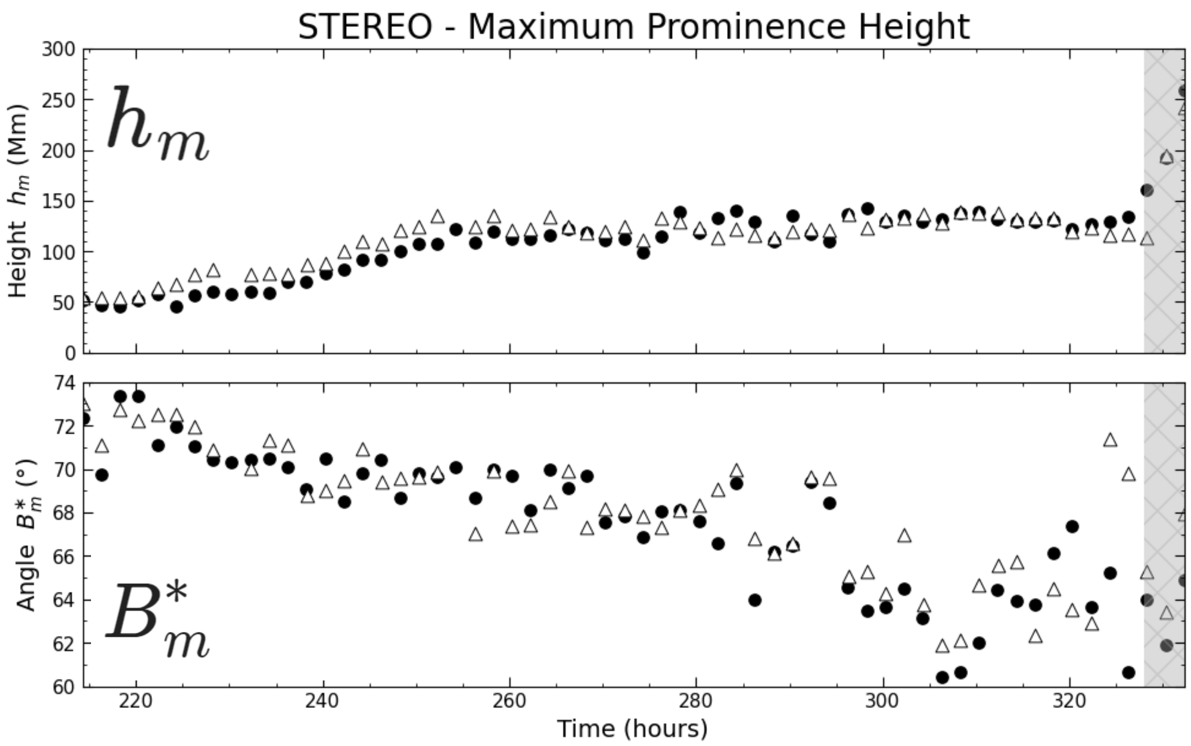


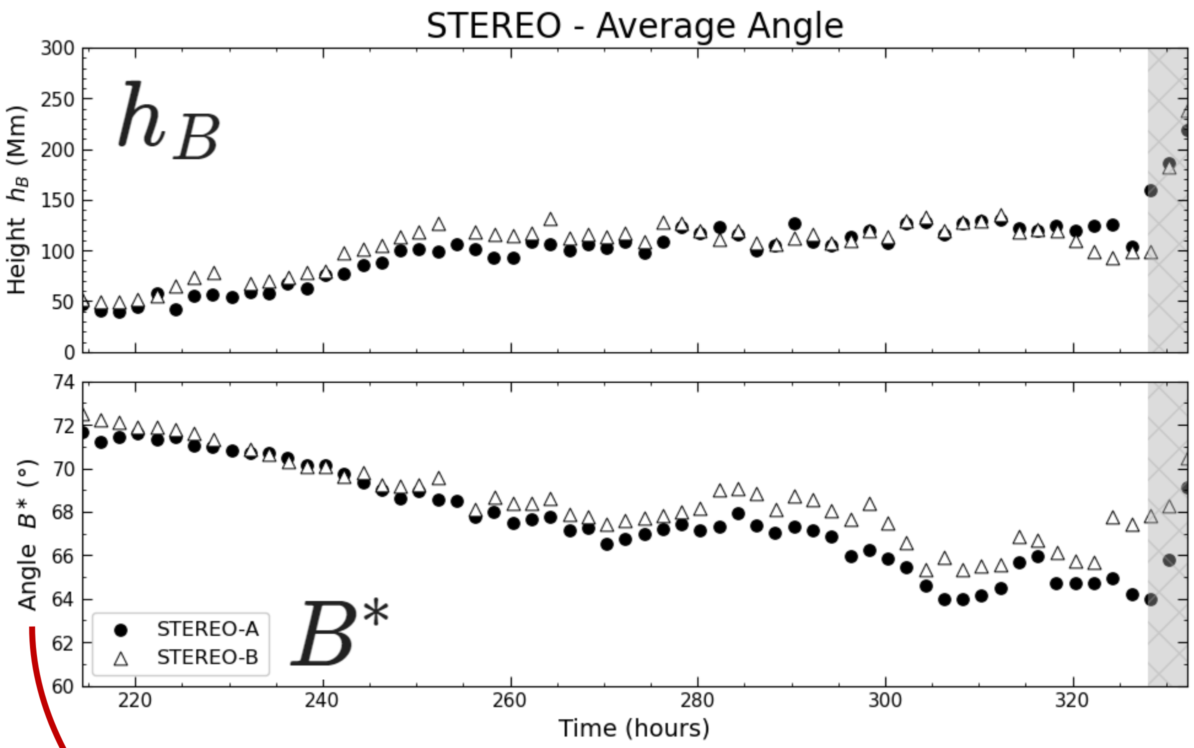
- Automated detection developed for STEREO/EUVI and SDO/AIA
- Obtain apparent height and limb angle (B^*) of each prominence.

Part 1: Prominence Height Profiles

Precursor Stage (b)

Interval 5





- ➢ Same methods done for Quiescent Stage (a) – SDO, Interval 4
- ➢ To estimate physical height, the limb angle must now be fixed.

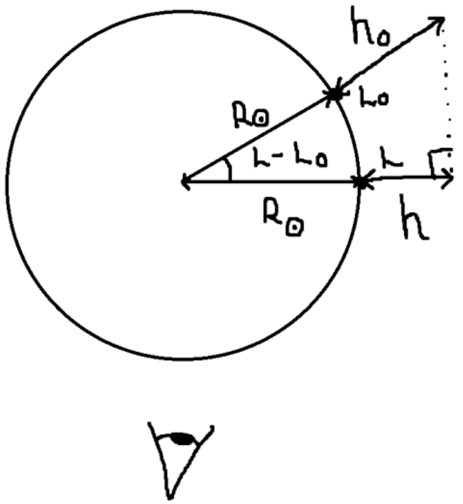
$$B^* = \frac{\sum_k B_k^* h_k}{\sum_k h_k}$$

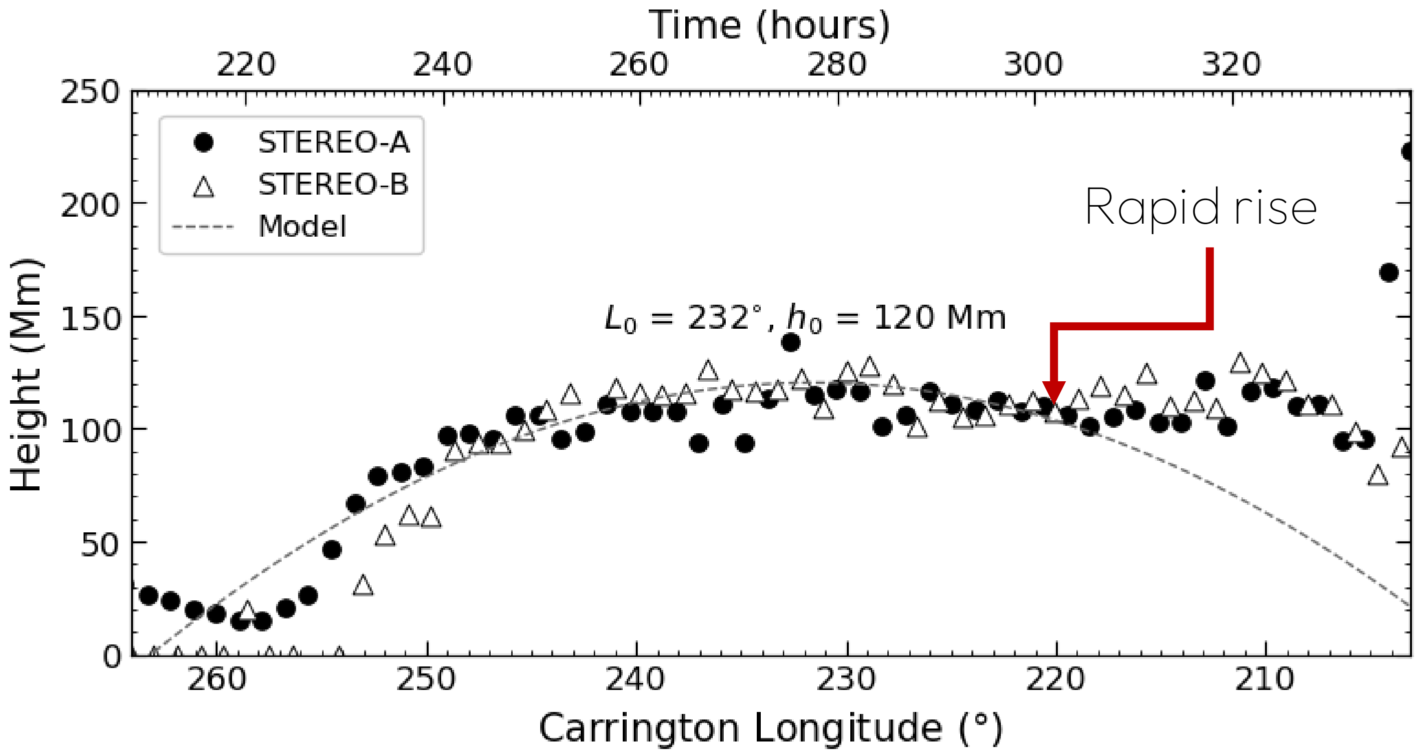
Part 1: Prominence Height Model

Precursor Stage (b)

Interval 5

- Function fitted to apparent height measurements
- Model works best for quiescent prominences with thin longitudinal extent
- Significant deviation in buildup to eruption (~ 300 h).

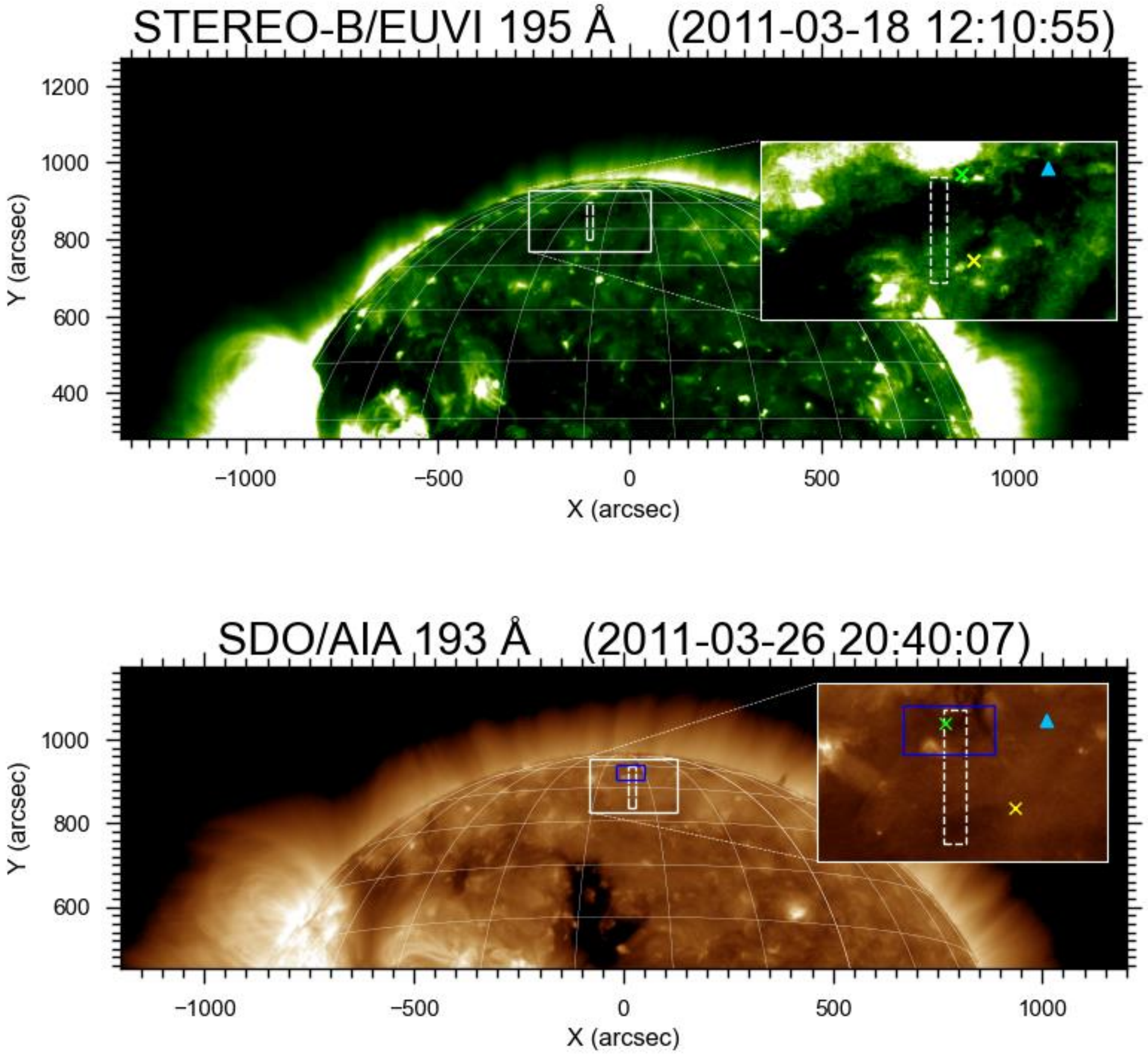




$$\frac{h(L)}{R_\odot} = \left(\frac{h_0}{R_\odot} + 1\right)\cos(L - L_0) - 1$$

Part 2: Filament Regions

- Analysis of filament oscillations in a similar region to the height observations
- Spacecraft configuration allows us to track the filament for longer
- Investigate whether oscillations could be interpreted as slow string modes
- Second overlapping region chosen to explore further dynamics.



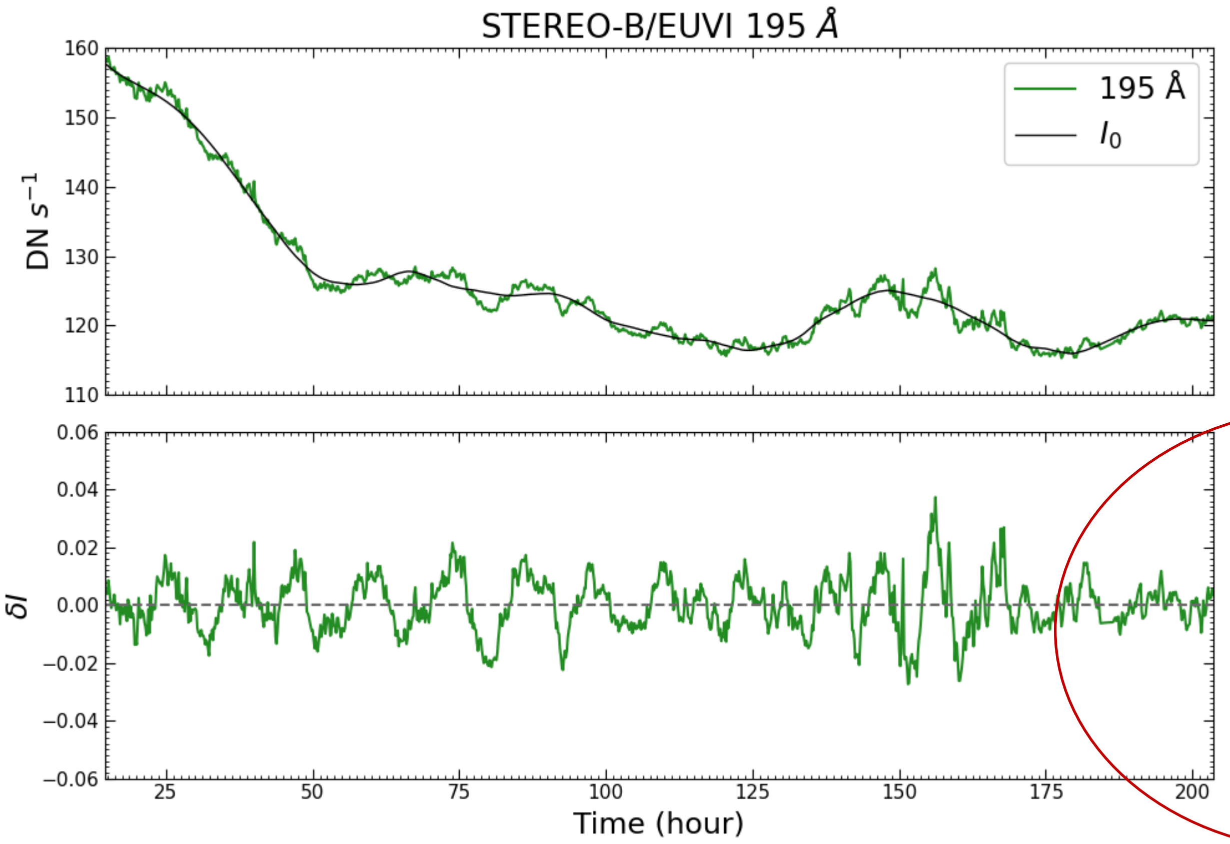
Part 2: Filament Timeseries

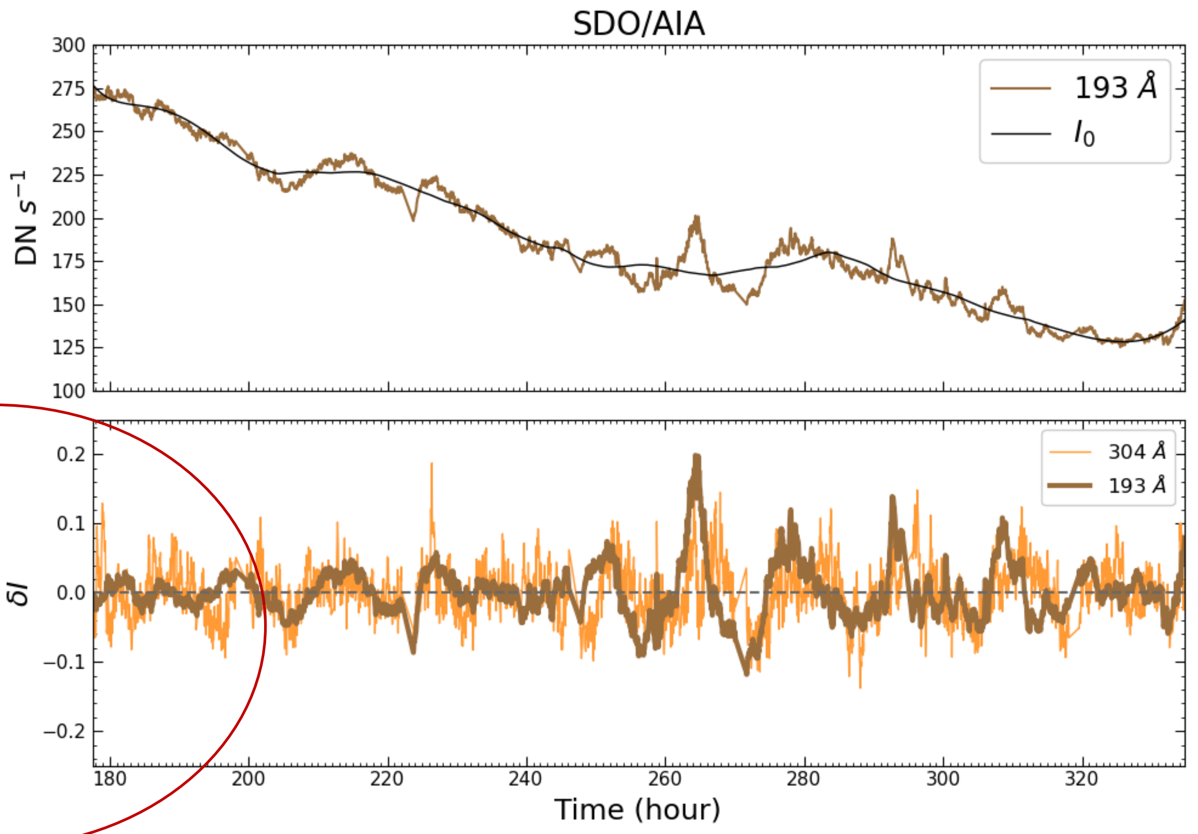
Quiescent Stage (a)

Interval 1

Precursor Stage (b)

Interval 2

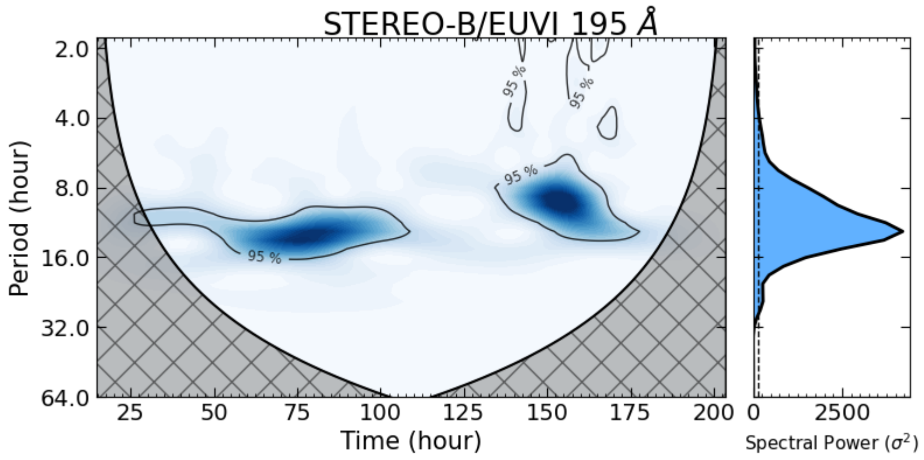


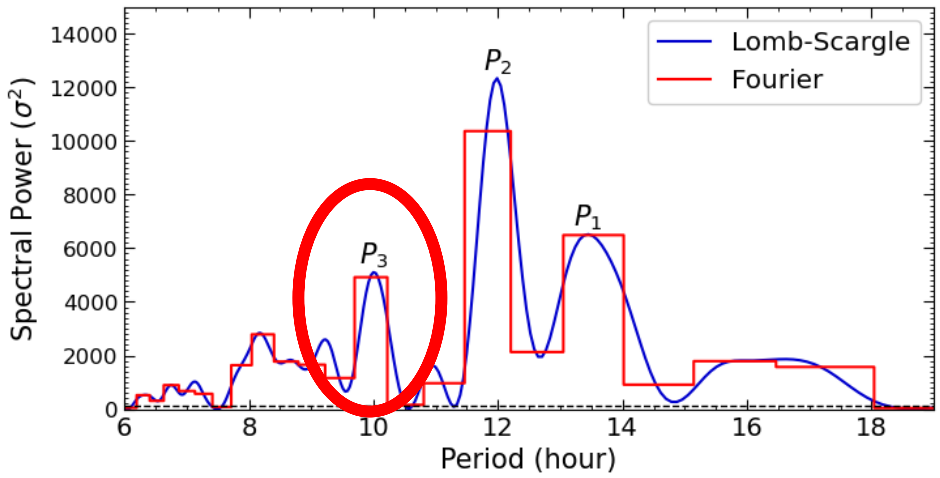


Part 2: Filament Oscillation Period

Quiescent Stage (a)

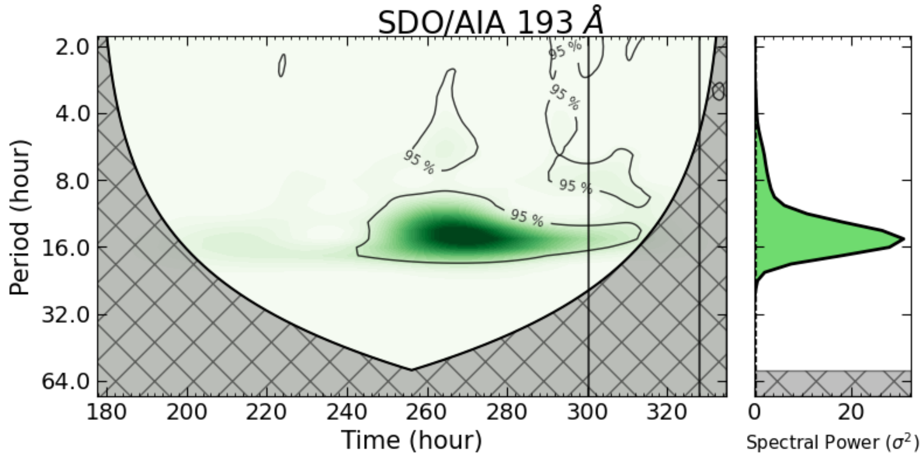
Interval 1

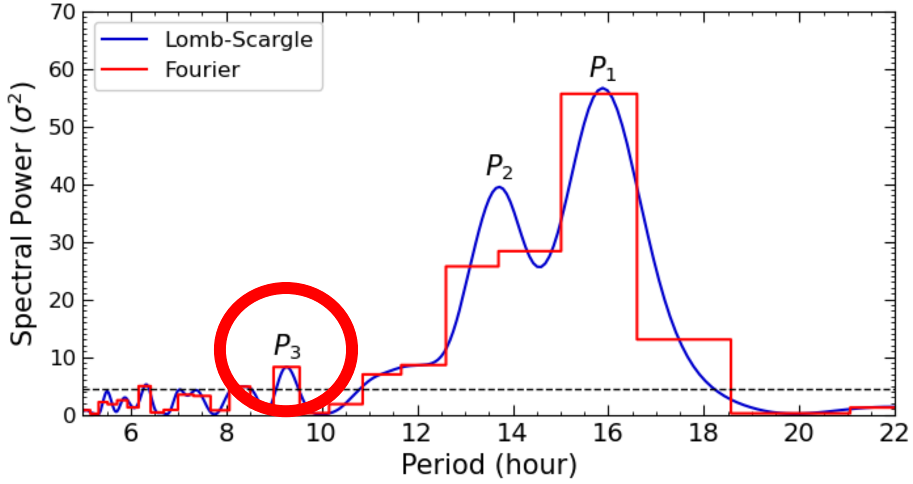




Precursor Stage (b)

Interval 2

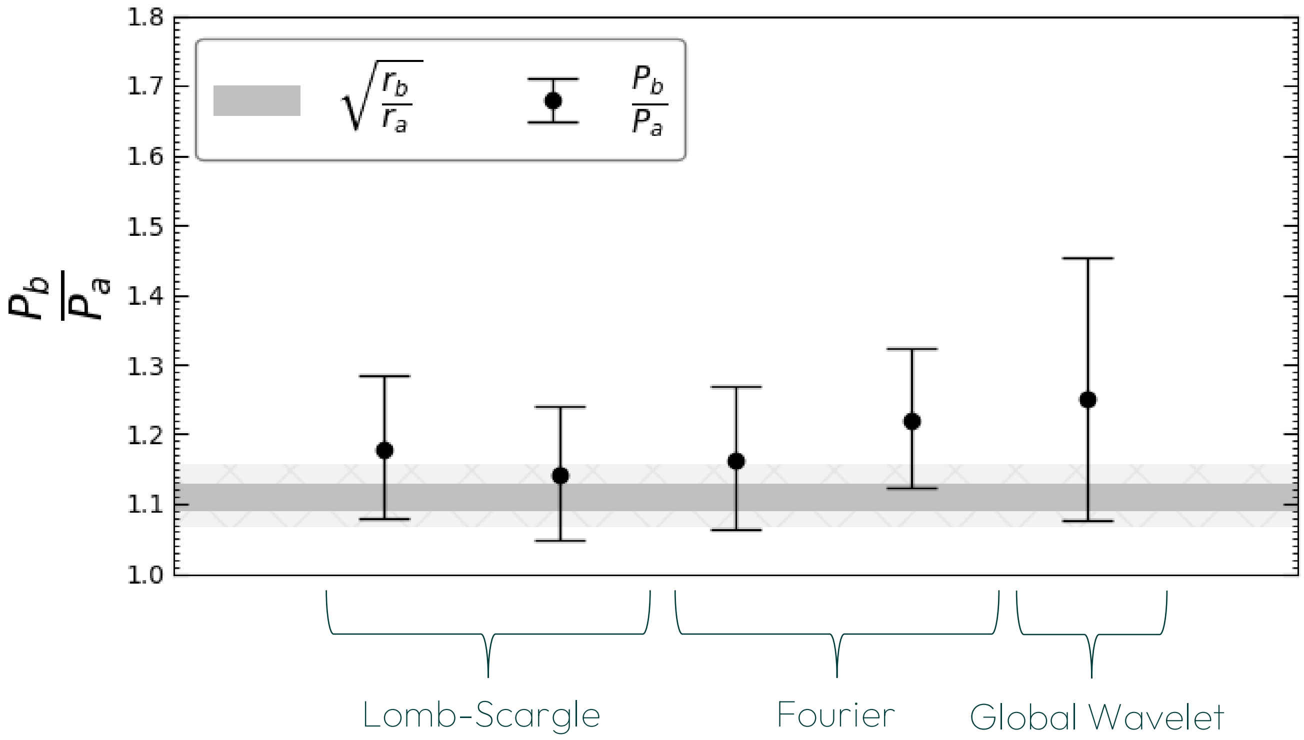




Part 3: Slow String Mode Interpretation

$$\frac{P_b}{P_a} = \sqrt{\frac{r_b}{r_a}}$$

- Simultaneous height measurement and period detection
- Compare periods and heights in Quiescent (a) and Precursor(b) stages
- Results suggest slow string modes explanation is plausible.



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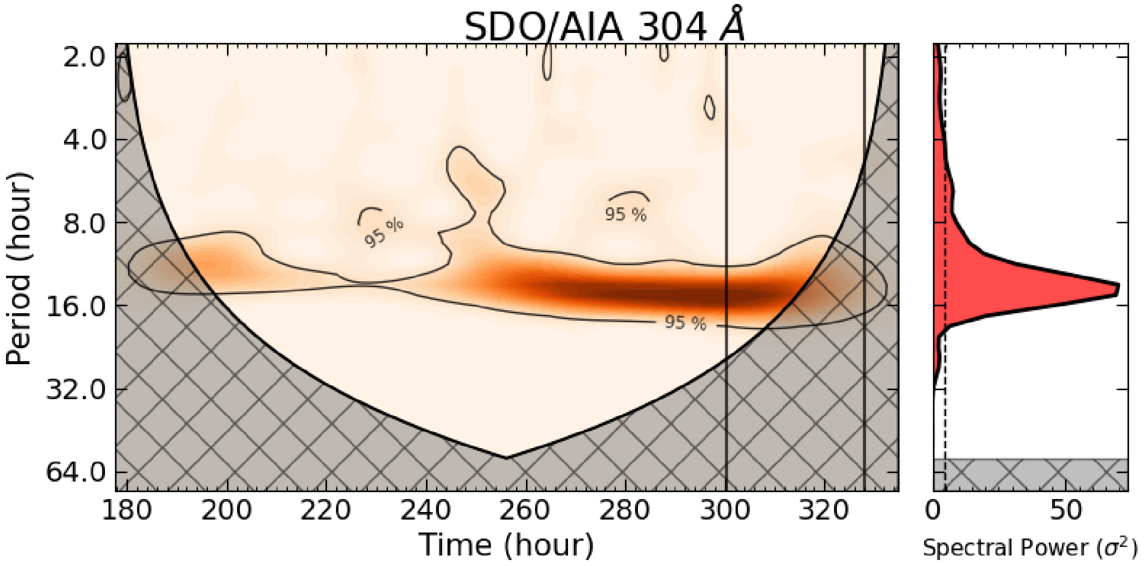
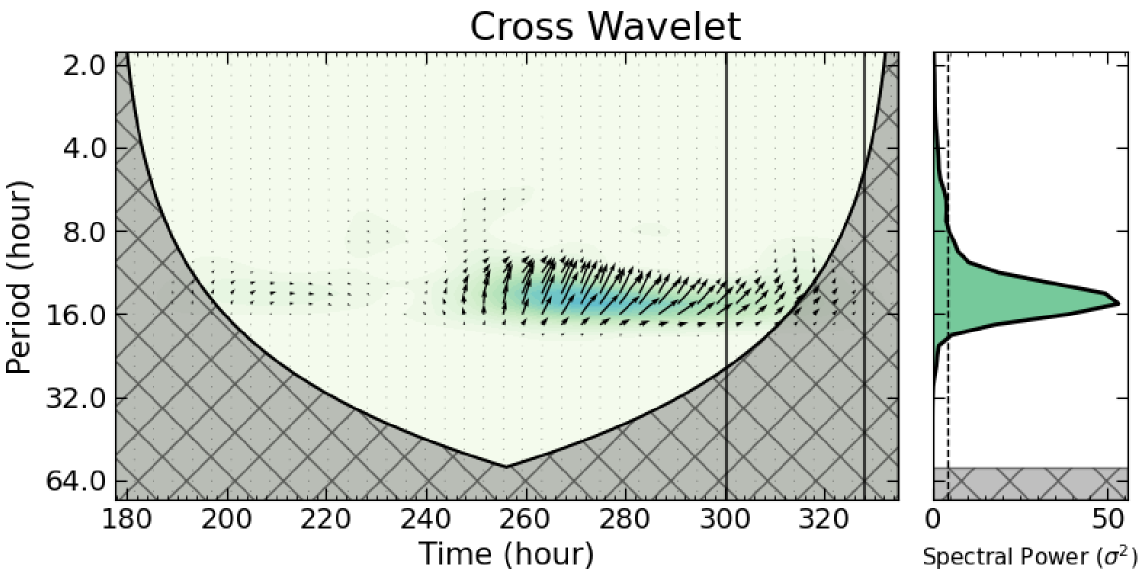
Part 3: Thermal Cycle Signature

- ➢ Higher-cadence data in 304 Å allows two-wavelength comparison
- ➢ Period increase also seen in AIA 304 Å
- ➢ Phase shifts in the precursor stage.





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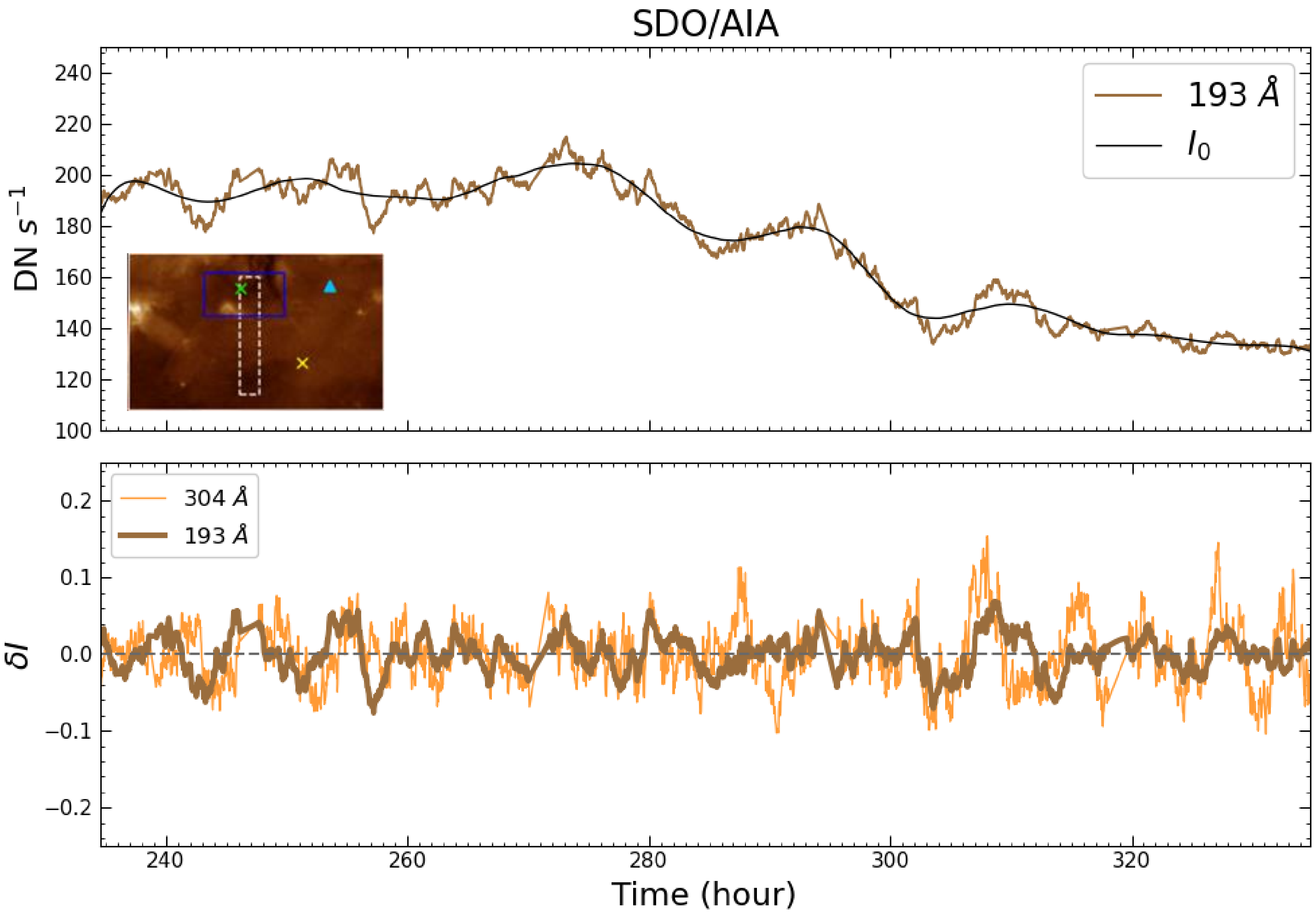
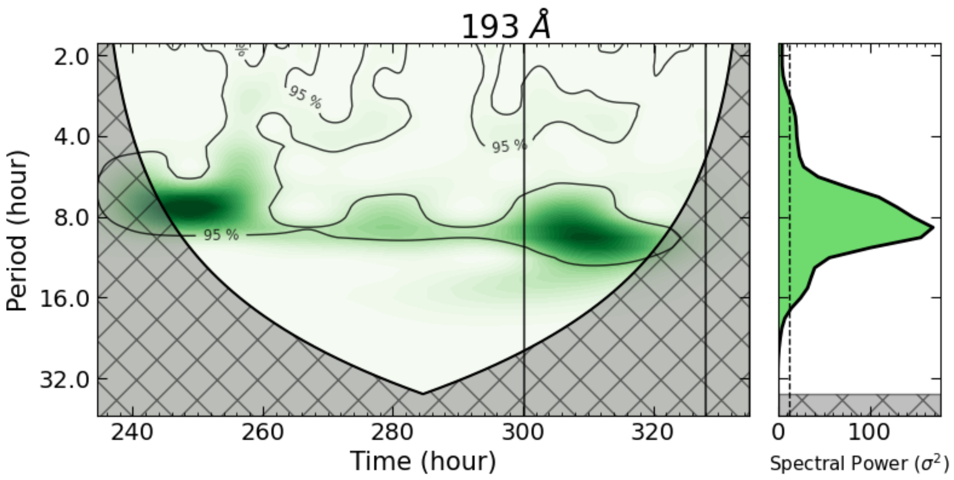
Part 3: Shorter-Period Behaviour

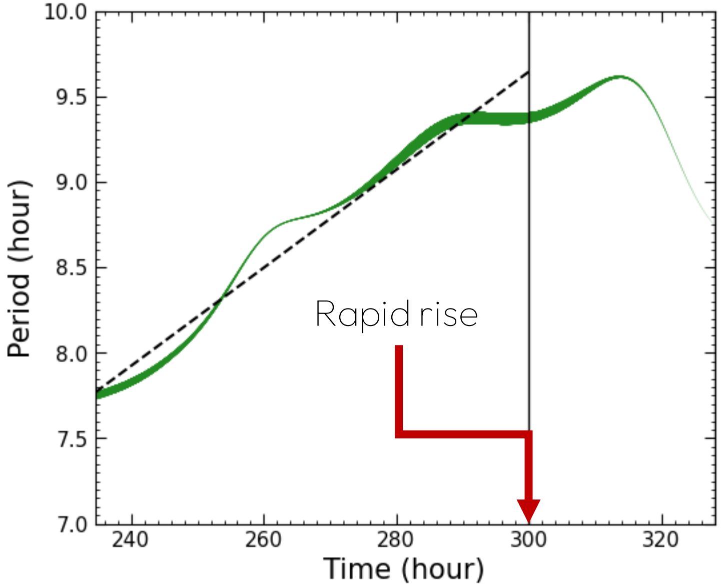
Precursor Stage (b)

Interval 3





P_3



$\Delta P_3 \approx 2$ hr

$\Delta T \approx 65$ hr

$$\frac{\Delta P_3}{\Delta T} \approx 0.03$$

Conclusions

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- Multi-spacecraft configuration facilitates simultaneous observations of prominence material and corresponding filament
- Periods increase (P_1 and P_2) in filament plasma between two stages correlates with prominence height increase – supports slow string mode interpretation
- Phase shifts between bandpasses may indicate presence of a thermal limit cycle
- Period increase (P_3) during precursor stage (b).

Beckwith-Chandler, Foullon & Verwichte, 2024, ApJ, to be submitted.

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