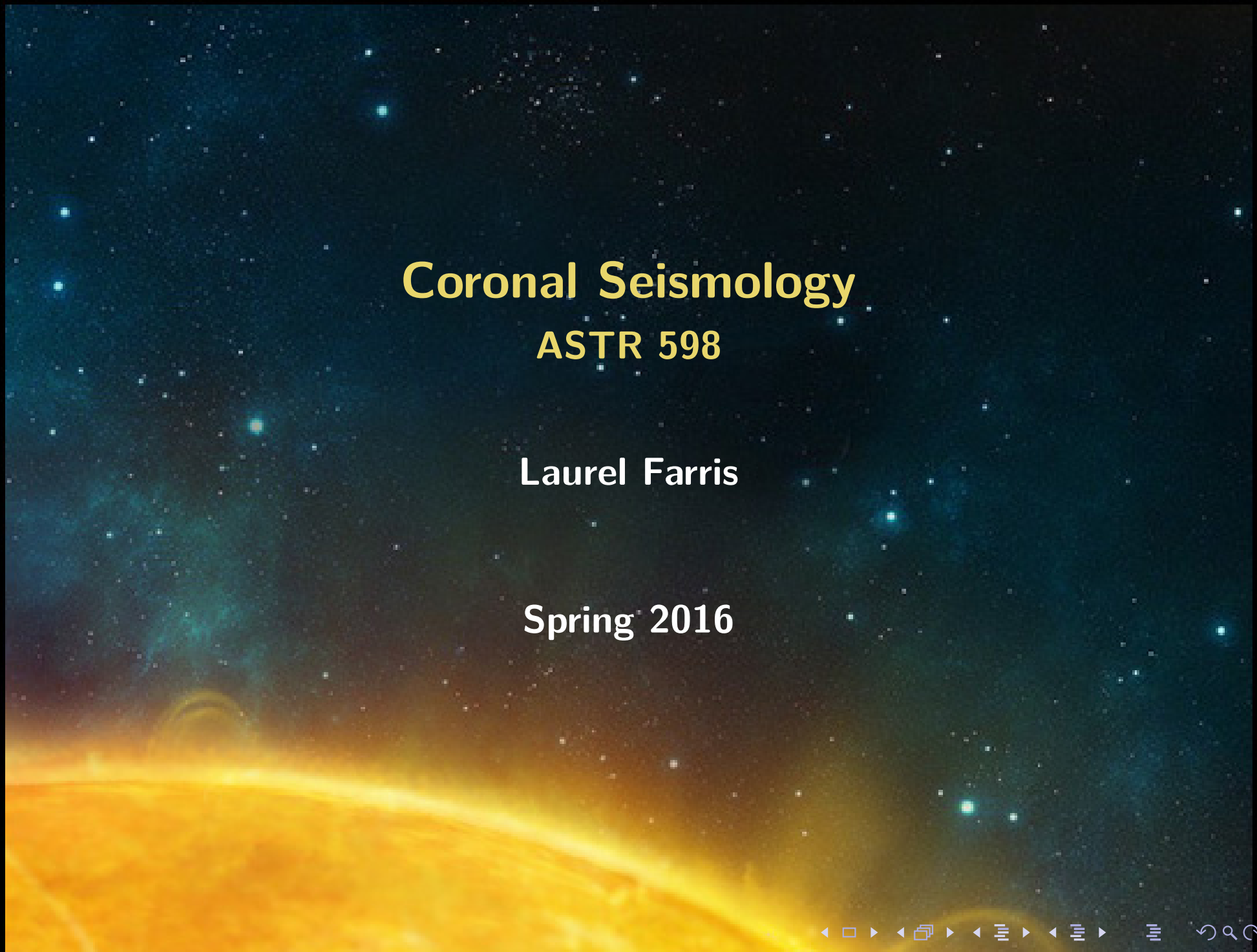


Coronal Seismology

ASTR 598

Laurel Farris

Spring 2016

Coronal seismology

Technique and motivation

Motivation:

- Mystery of coronal heating
- Space weather prediction

Properties of the solar corona that are difficult to measure:

- magnetic field strength, $\vec{B}$
- density
- Alfvén velocity

Solution: coronal seismology

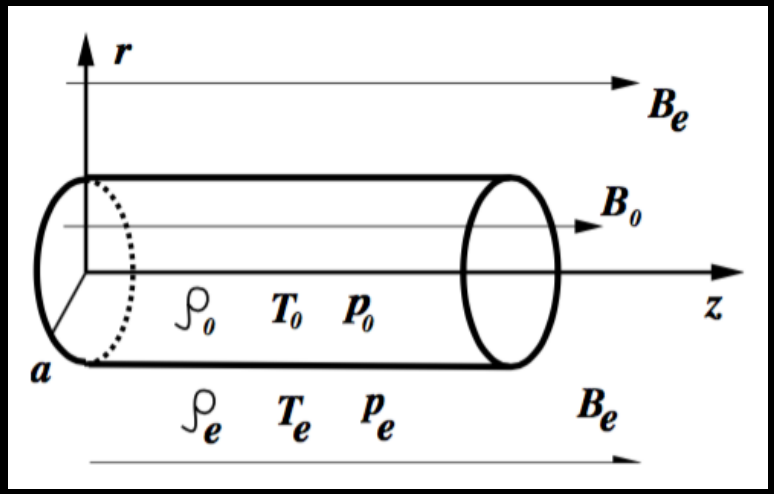
1. Observe disturbances (triggered by flares, footpoint motions)
2. Measure, e.g. period, velocities, timescales
3. Identify the type of wave or mode (MHD theory; stay tuned)
4. Extract coronal parameters from equations

Other questions:

- How are these disturbances initiated?
- How are they damped, and what determines the timescales?

Magnetohydrodynamics (MHD)

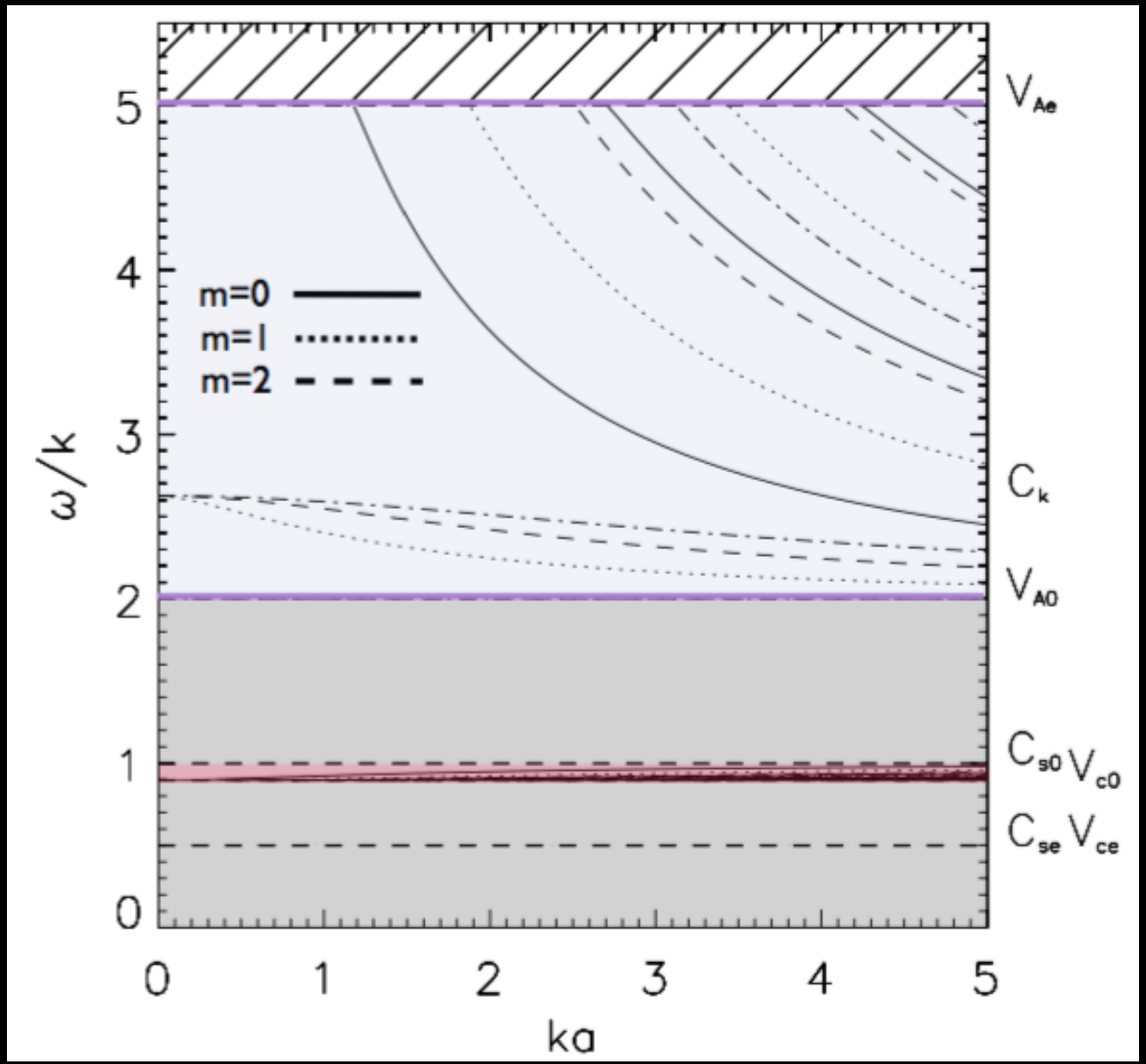
Theory



- Loop modeled by straight flux tube in uniform magnetic field.
- Characteristic speeds are determined by the environment

Dispersion diagram

Solutions to dispersion relation



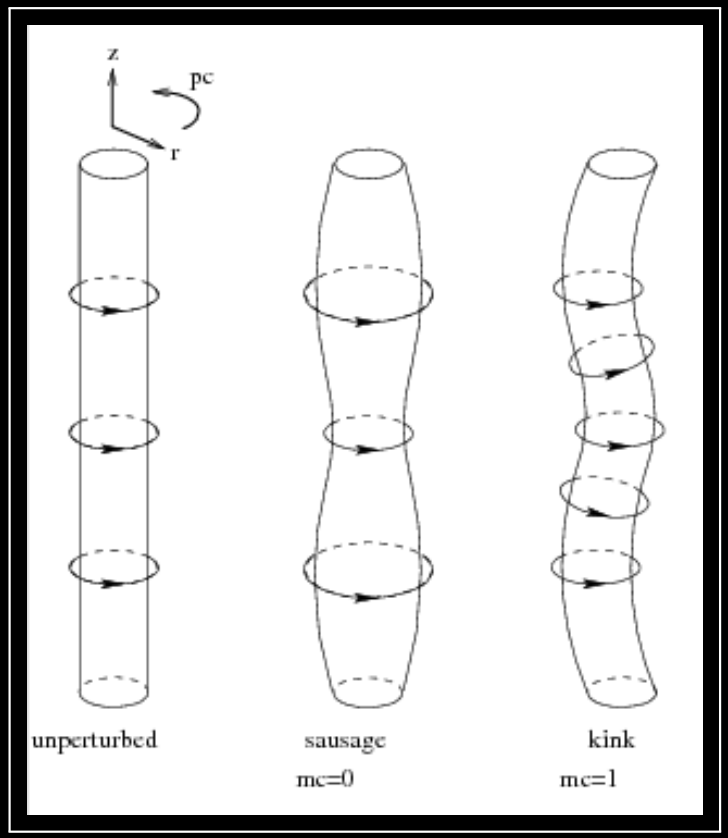
Magnetohydrodynamics (MHD)

Two mode categories

1. Magnetoacoustic $C_s = \sqrt{\frac{\gamma P}{\rho}}$
   - Fast $k_{A_0} < C_{fast} < C_{A_e}$
   - Slow $C_{T_0} < C_{slow} < C_{s_0}$
2. Alfvén $V_A = \frac{B}{\sqrt{\mu_0 \rho}}$

Fast standing oscillations

Kinks vs. Sausages



Kink

- loop spatial displacement
- Asymmetric
- No intensity change
- $k\sigma \ll 1$, or $\sigma \ll \lambda$
- Derive magnetic field!

Sausage

- No loop spatial displacement
- Symmetric
- Intensity change
  $\rightarrow$ density change
- $\lambda \sim \sigma$
- long-wavelength limit

Standing oscillations vs. propagating waves

- In loops, propagating waves damp before reaching opposite footpoint.
- Velocity and intensity are 90° out of phase for standing oscillations, and are in phase for propagating acoustic waves.
- Frequencies less than the cutoff are standing oscillations, waves with frequency greater than the cutoff propagate into the chromosphere.
- no loop shape change or displacement
- near footpoints.

Torsional modes

aka. Alfvén wave

Properties:

- m=0 (Axisymmetric, or azimuthally symmetric)
- transverse (shear) perturbations
- Parallel to $\vec{B}$
- Driving force: magnetic tensioin
- incompressible
- velocity: $v_A = \frac{B}{\mu_o \rho}$; $\sim$ 1000 km s^{-1} in the corona

How to observe:

- Only get Doppler shifts from *long*-period waves ($>$ a few minutes).
- Measure additional (i.e. non-thermal) broadening of coronal emission lines; indirect way to observe short-period waves.
- Spatial variation in Doppler shift for long periods. Gyrosynchrotron emission in radio regime.

Effects of twisting:

- Coupling of various MHD modes

OBSERVATIONS FROM HINODE/EIS OF INTENSITY OSCILLATIONS ABOVE A BRIGHT POINT: SIGNATURE OF THE LEAKAGE OF ACOUSTIC OSCILLATIONS IN THE INNER CORONA

A. K. Srivastava and B. N. Dwivedi

[insert plot/image here]

- HeII 256 Å (TR and low corona)
- FeXV 195 Å (Upper corona)

Another example

What observed and how, values measured, other parameters derived, mode identified, etc.

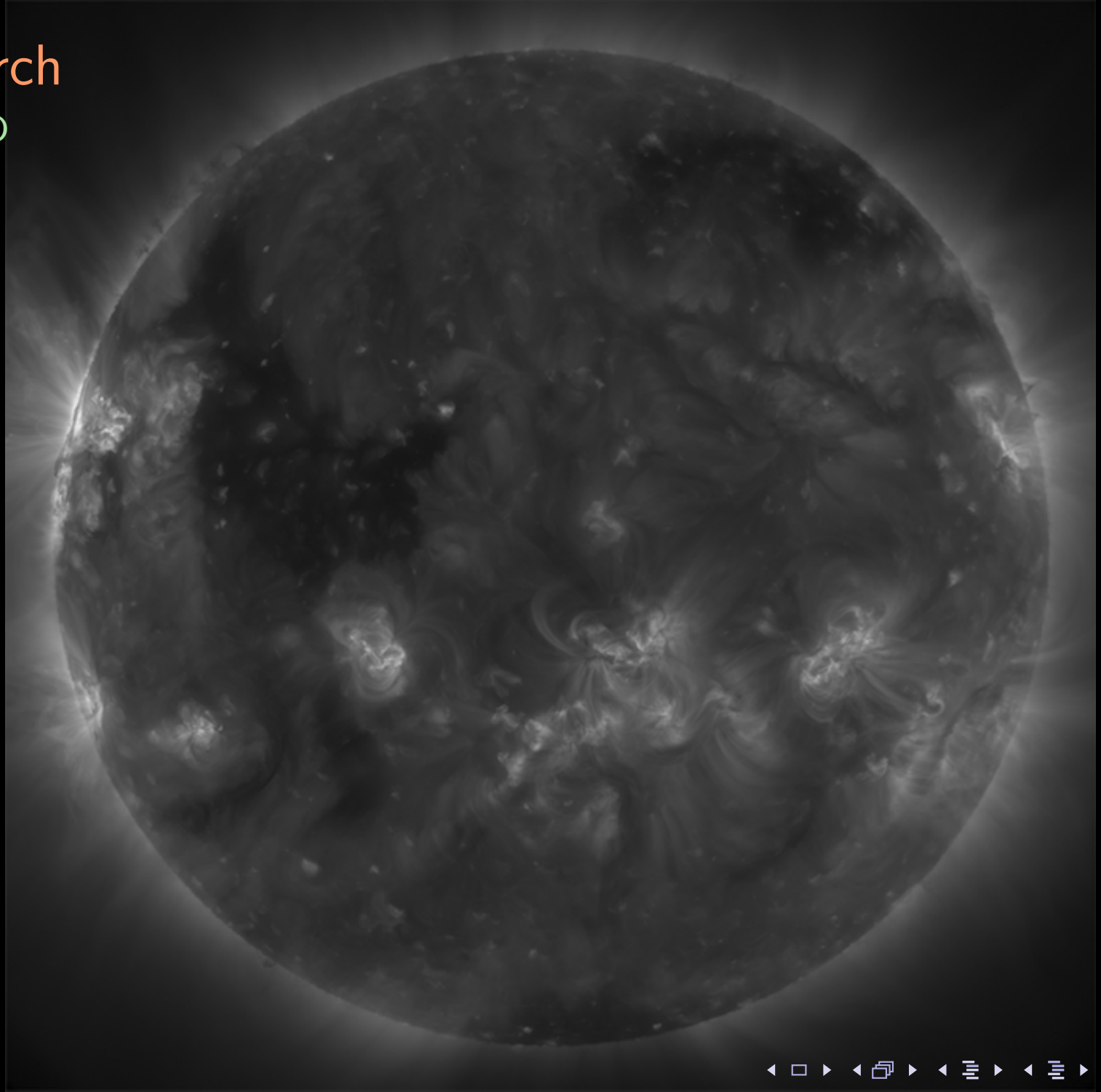
A third example

Important Properties

	period	**decay time**	**velocity**
kink osc	value	value	value
sausage osc	value	value	value
acoustic osc	20 m	5–30 m	200 km s^{-1}
acoustic waves	value	value	value
fast waves	value	value	value
torsional modes	10 m	value	1000 km s^{-1}

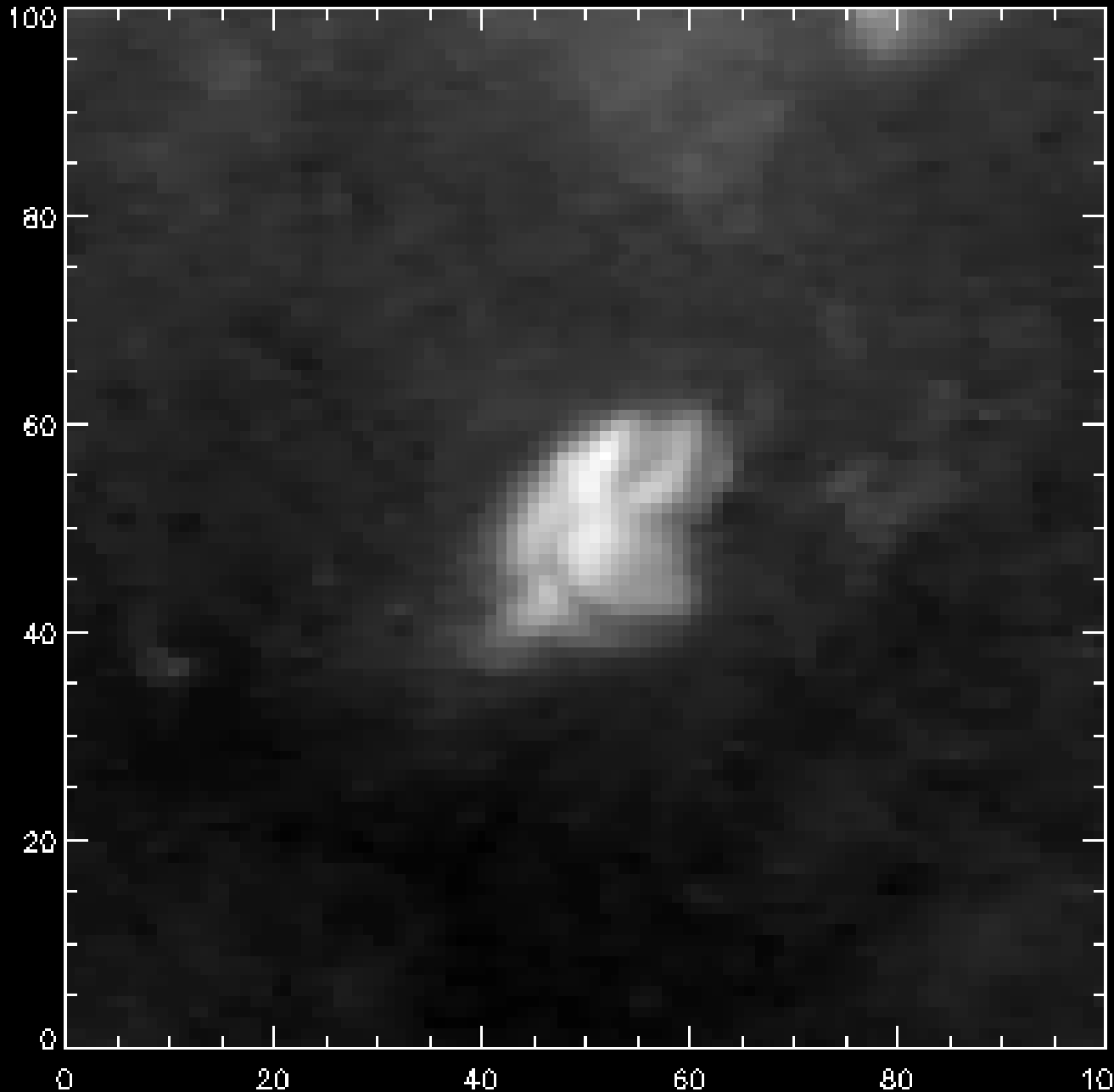
Research

AIA/SDO

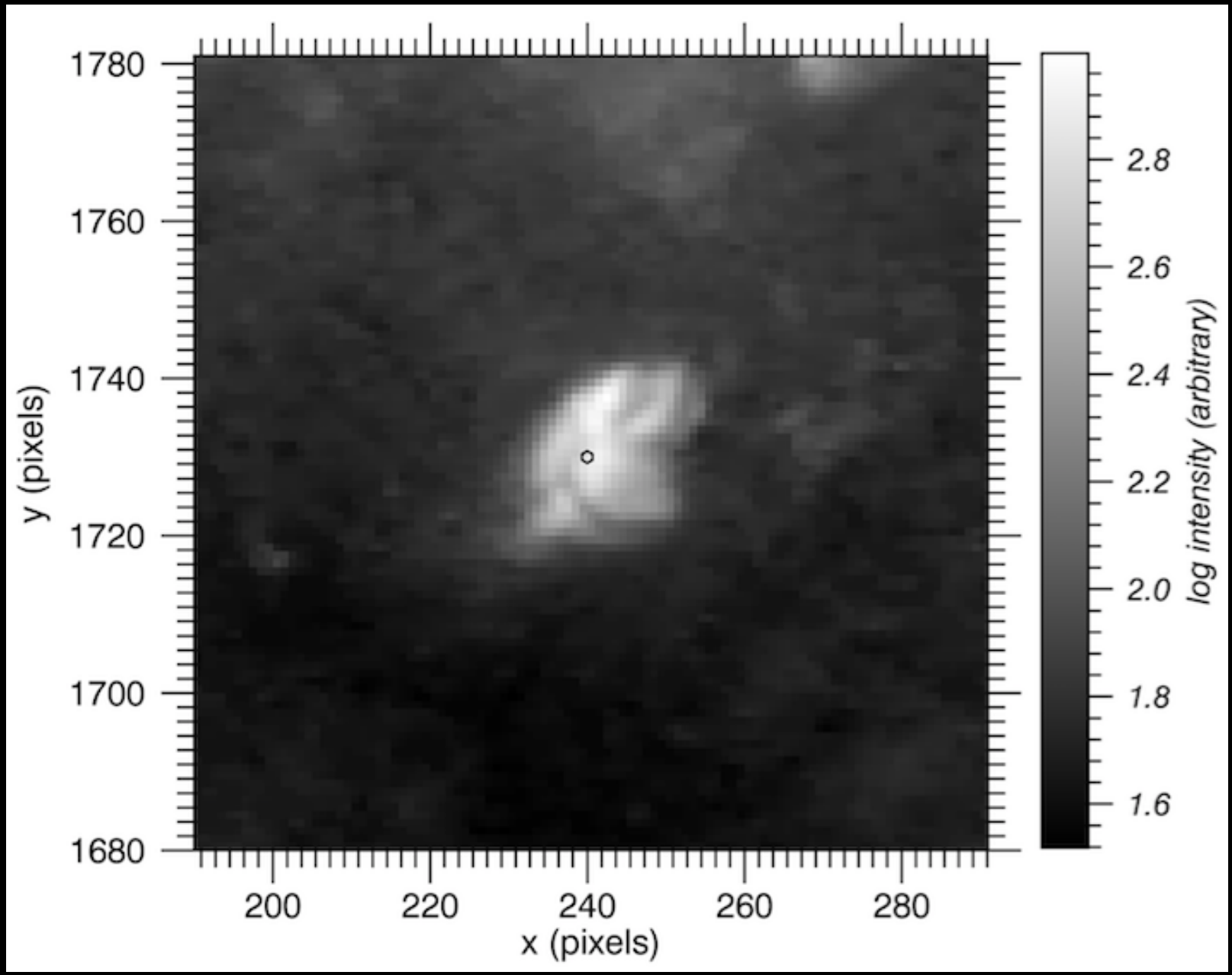


Research

[Looks nicer than white background]



Research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240
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x (pixels)
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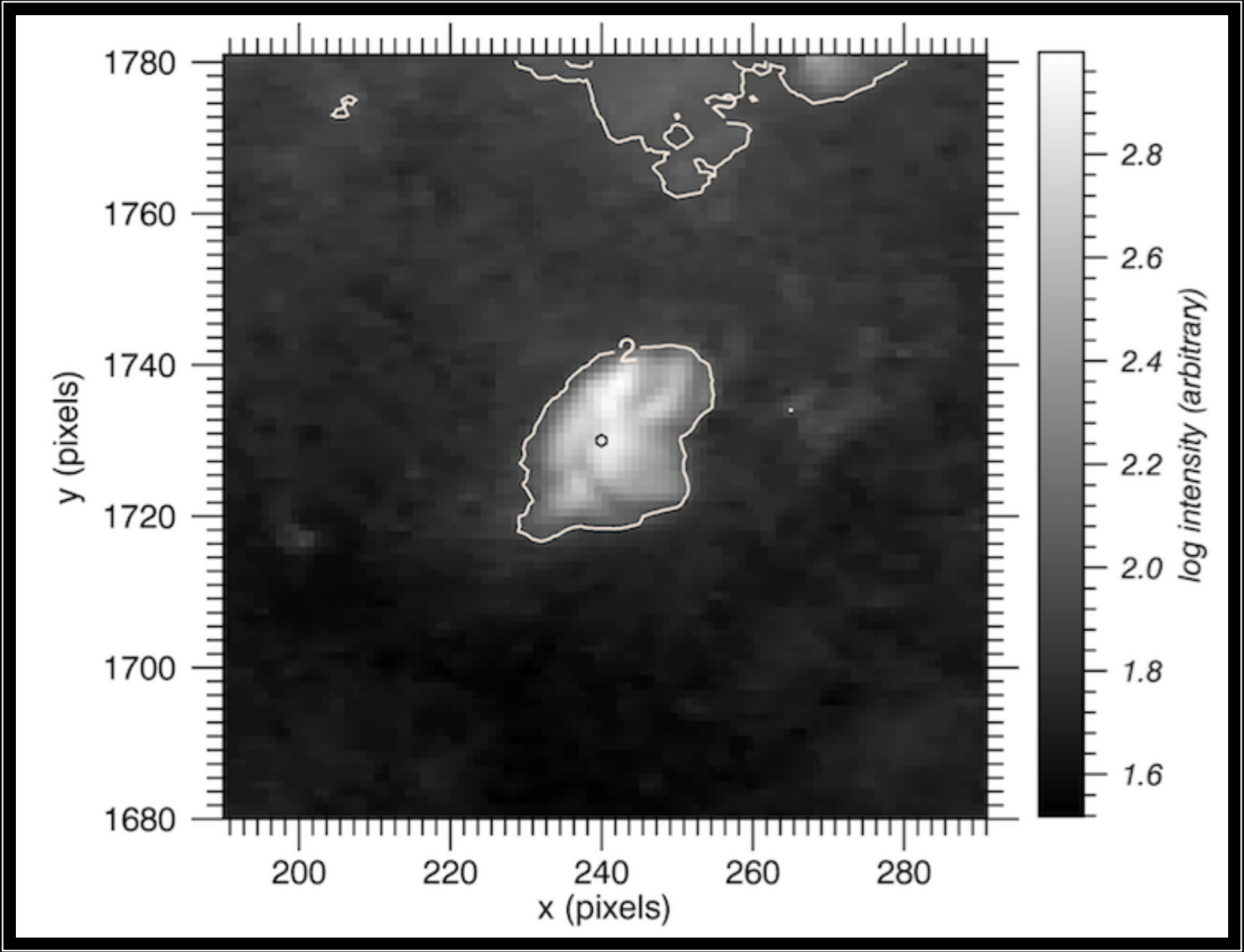
2.0
1.8
1.6
log intensity (arbitrary)

Research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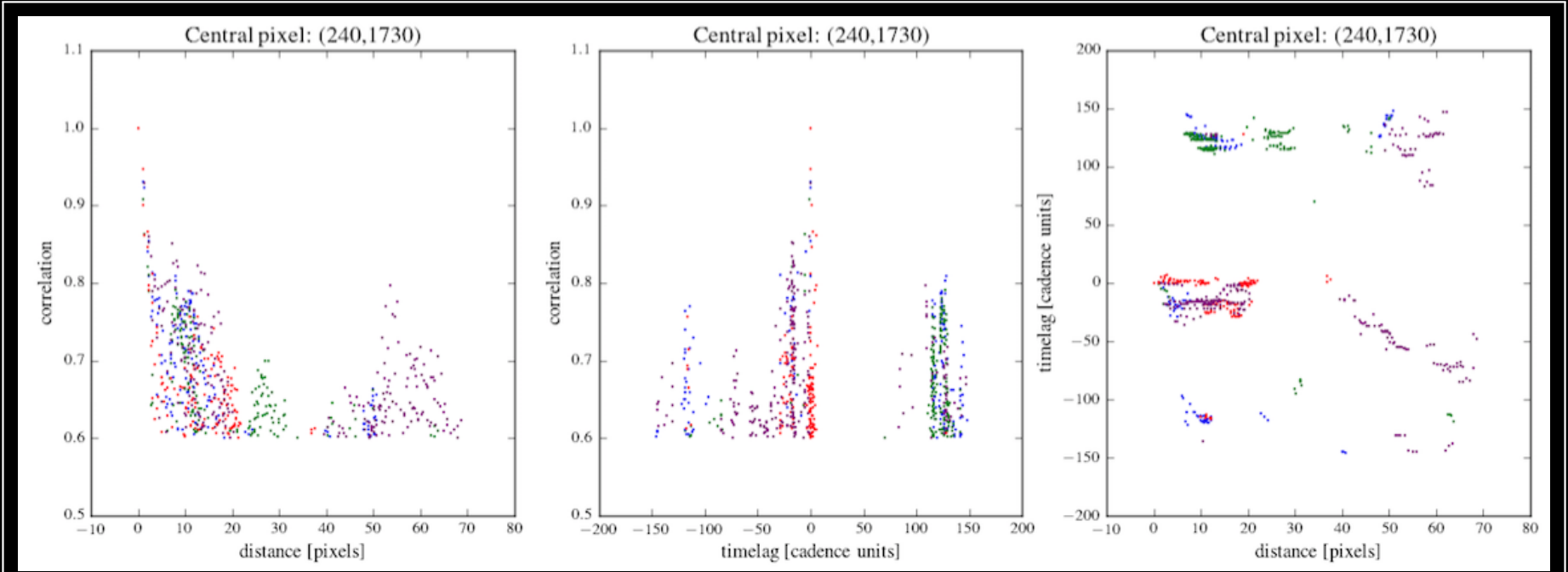
log intensity (arbitrary)

Research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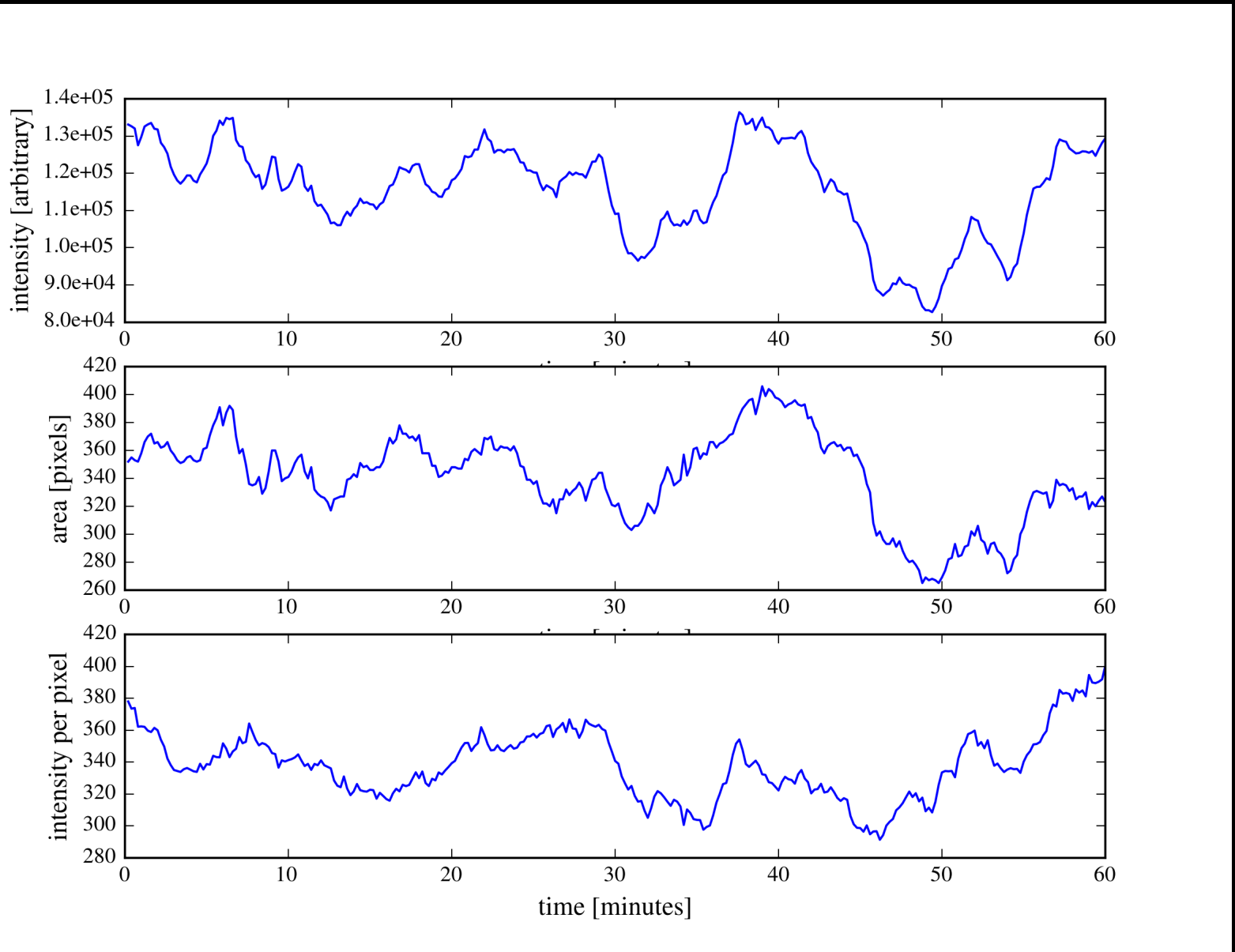
correlation
distance [pixels]
Central pixel: (240,1730)
correlation
timelag [cadence units]
Central pixel: (240,1730)
timelag [cadence units]
distance [pixels]

Research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area [pixels]
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380
360
340
320
300
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intensity per pixel
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360
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320
300
280
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10
20
30
40
50
60
time [minutes]

Acknowledgements