Statistical study of the decay-less kink oscillations

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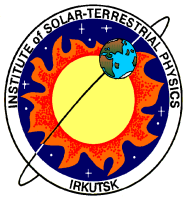
MHD Seismology of the Solar Corona in the Era of SDO/AIA
ISSI-Beijing 2015



Based on the paper in A&A

A&A 583, A136 (2015)
DOI: 10.1051/0004-6361/201526195

Astronomy & Astrophysics

Decayless low-amplitude kink oscillations: a common phenomenon in the solar corona?⋆

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Received 27 March 2015 / Accepted 18 August 2015

Outline

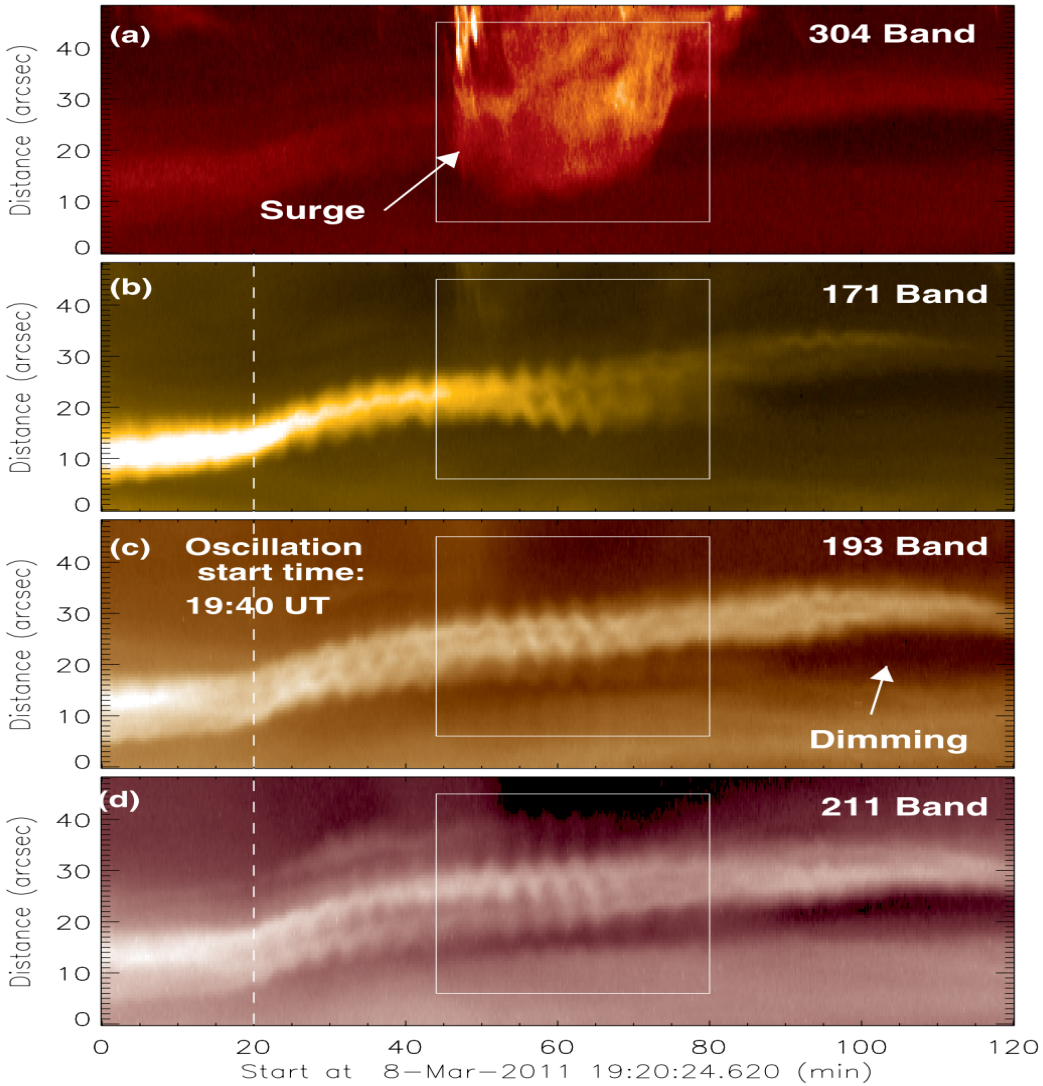
Decaying oscillations

Ashwanden et.al.(1999); Nakariakov et.al.(1999);Schrijver et. al. (1999)

- Large amplitude > 1 Mm
- Induced by eruptive events (CME, flare etc)
- Fast decaying (3-4 periods)
- Relative rare detected ($\sim$100 events in a year)
- Intensively studied since 1999

First observations of the decay-less oscillations

Wang, T. et al , ApJL, (2012)

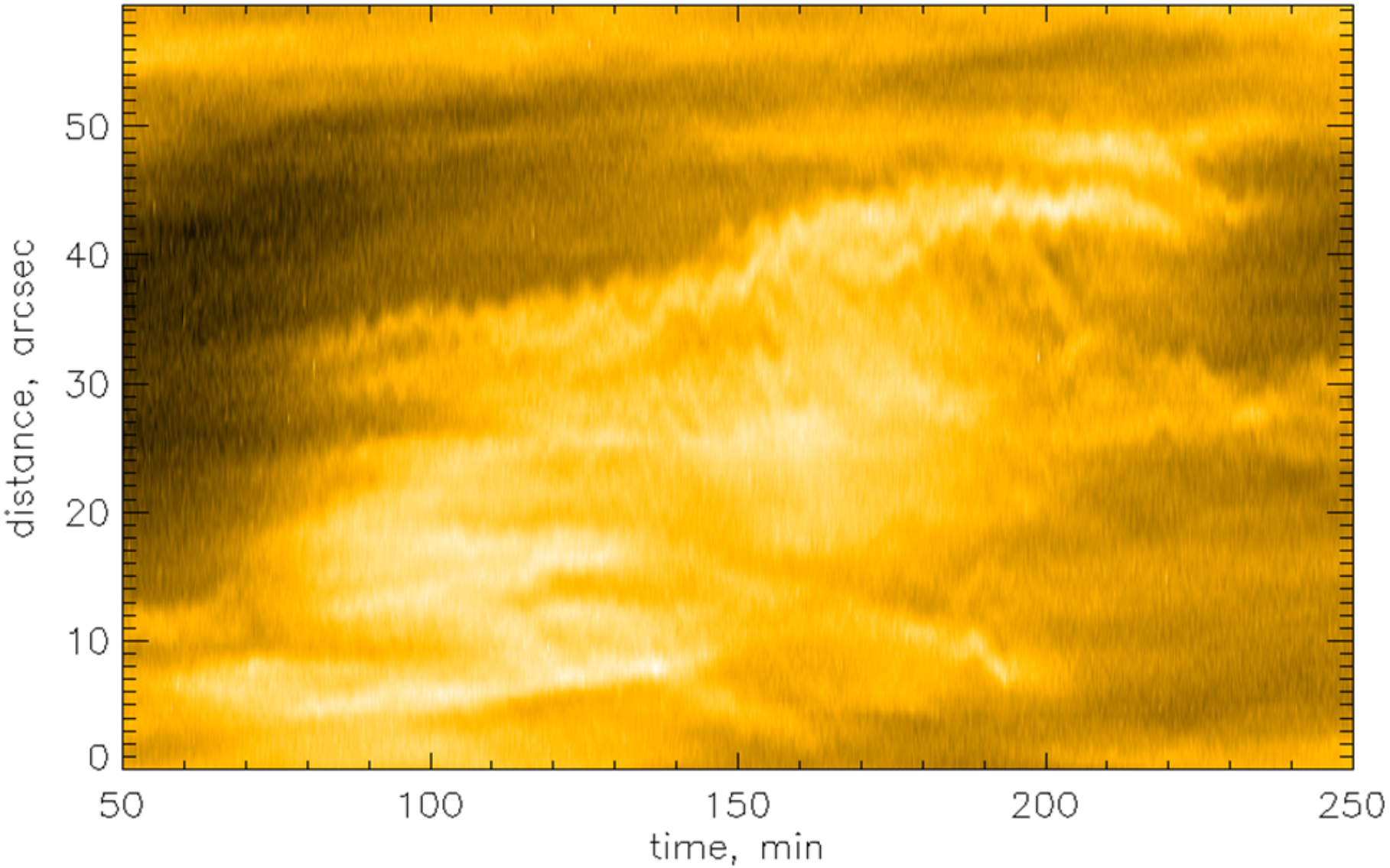


Decay-less oscillations

Video

Decay-less oscillations

Typical time-distance plot



Known properties of the decay-less oscillations

G. Nisticò et. al (2013), S. Anfinogentov et. al (2013), G. Nisticò et. al. (2014)

- Displacement amplitude $\sim 0.2\ \mathrm{Mm}$
- Velocity amplitude $\sim 2\ \mathrm{km} \cdot \mathrm{s}^{-1}$
- No connection with eruptive events
- No significant decay
- Can be observed during several hours in a certain active region
- Most probable are the fundamental kink mode
  - Oscillation period depends on the loop length
  - All segments of an oscillating loop are found to oscillate in phase
  - Amplitude maximum is located at the top of the loop

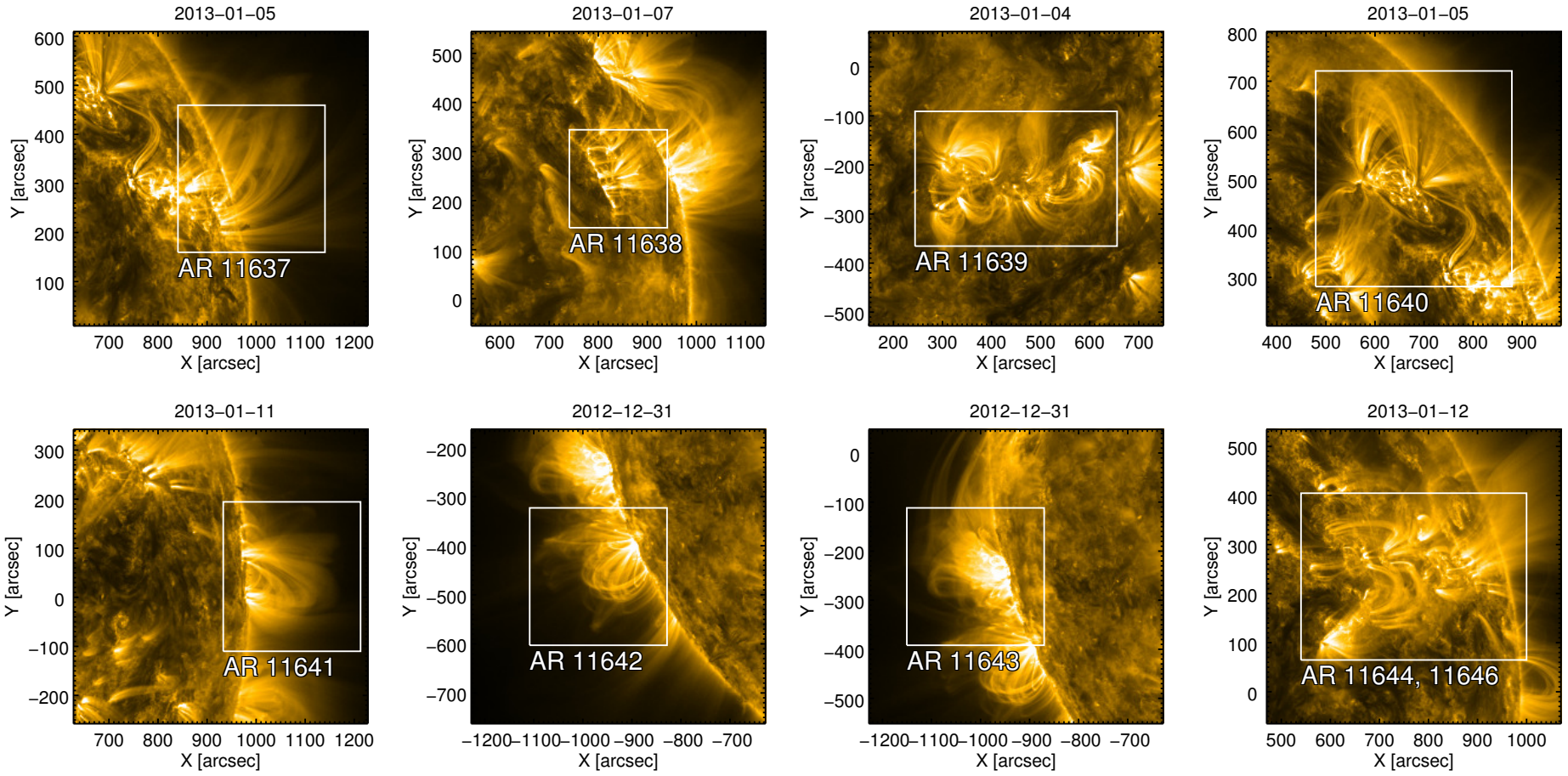
Problem statement

Step by step description

- Representative sampling
  - 21 active regions one by one (NOAA 11637-11657)
- Constructing a set of time-distance plots from 171Å images for each AR
- Visual inspection of the plots to identify oscillation patterns
- Measuring loop length, oscillation period, and amplitude

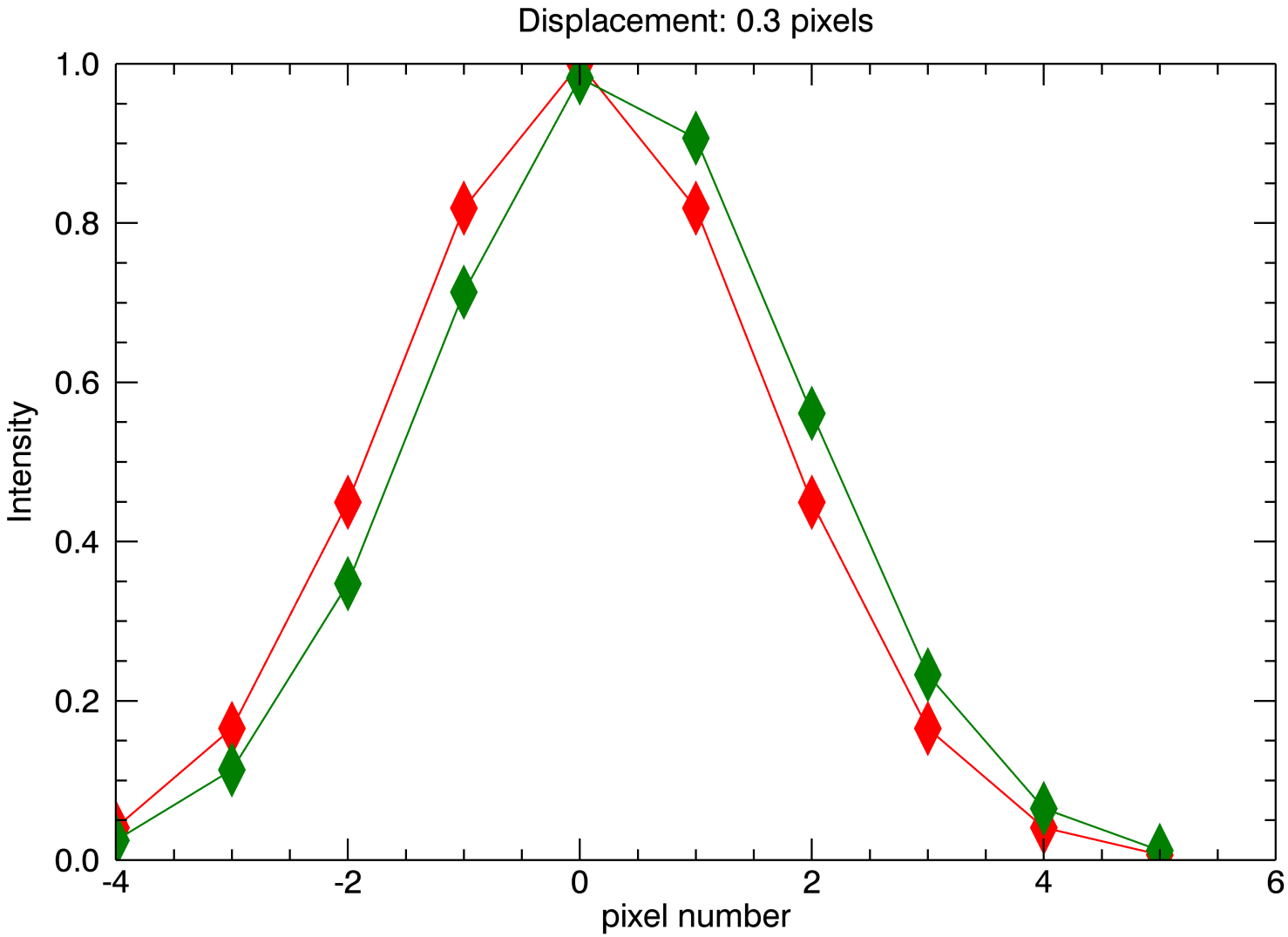
Problem statement

Examples of inspected active regions



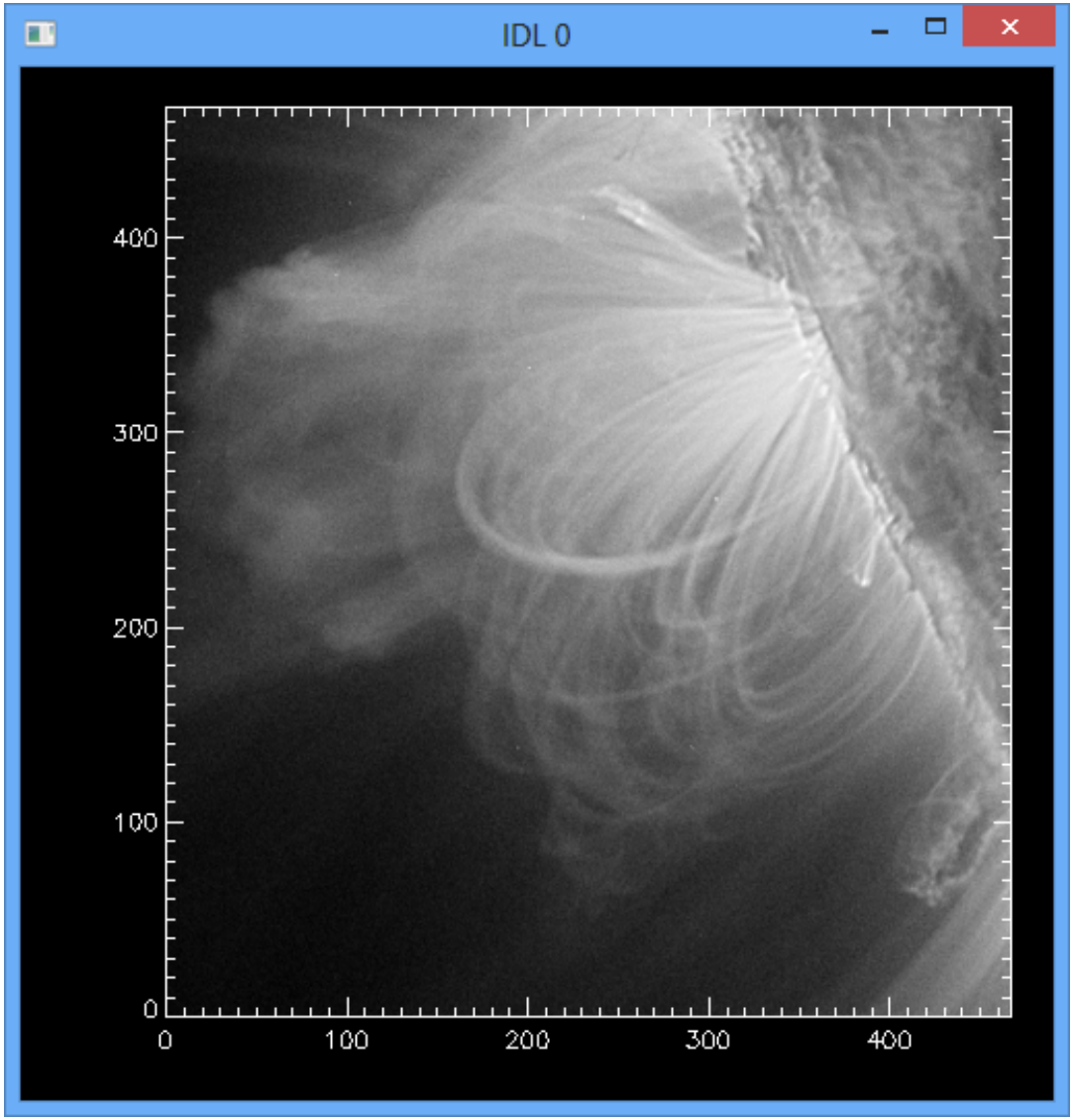
Methods

Is it really possible to identify sub-pixel displacements?



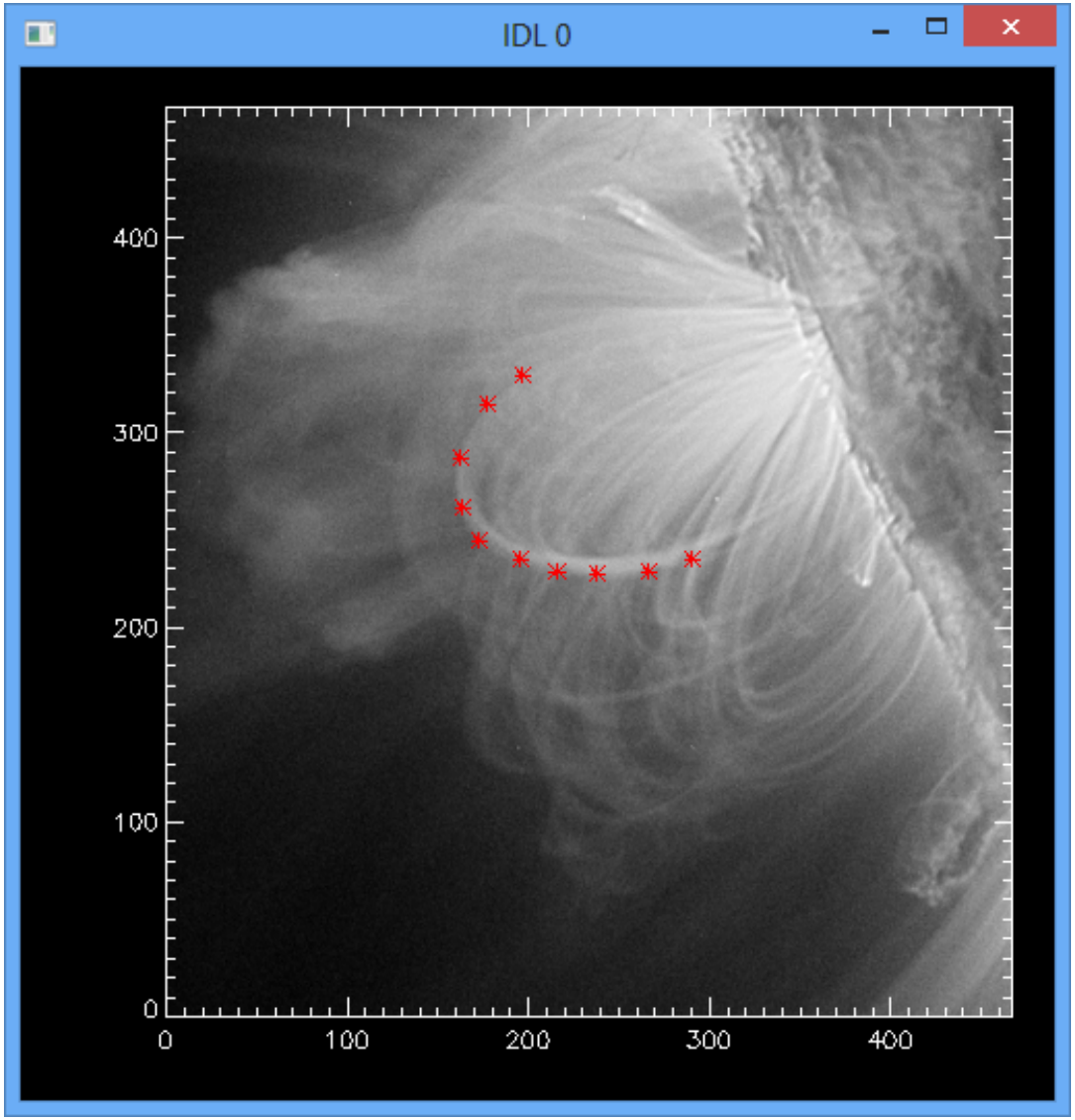
Multiple slits perpindicular to the loop

171 Å image



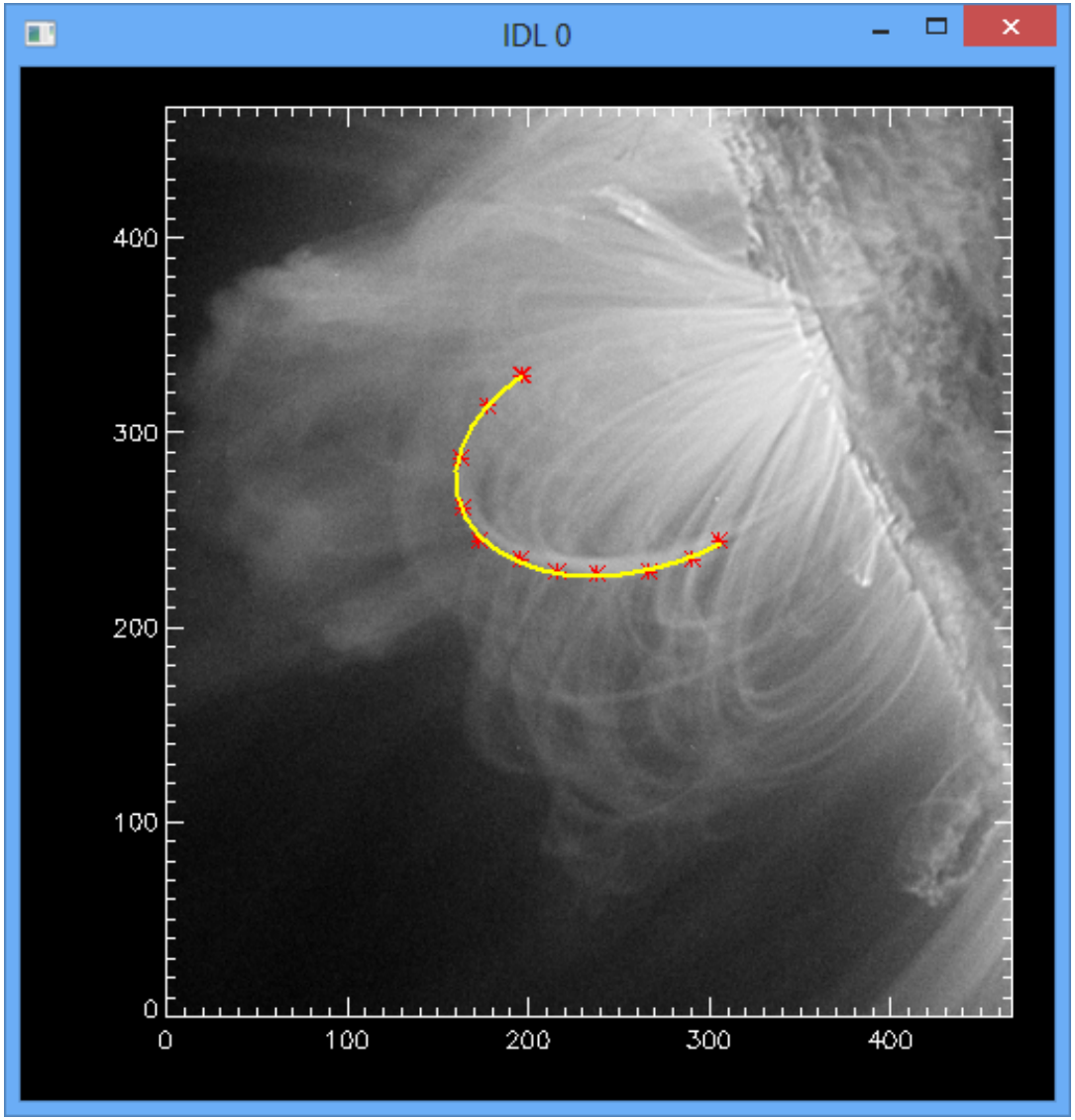
Multiple slits perpindicular to the loop

Points along the loop path



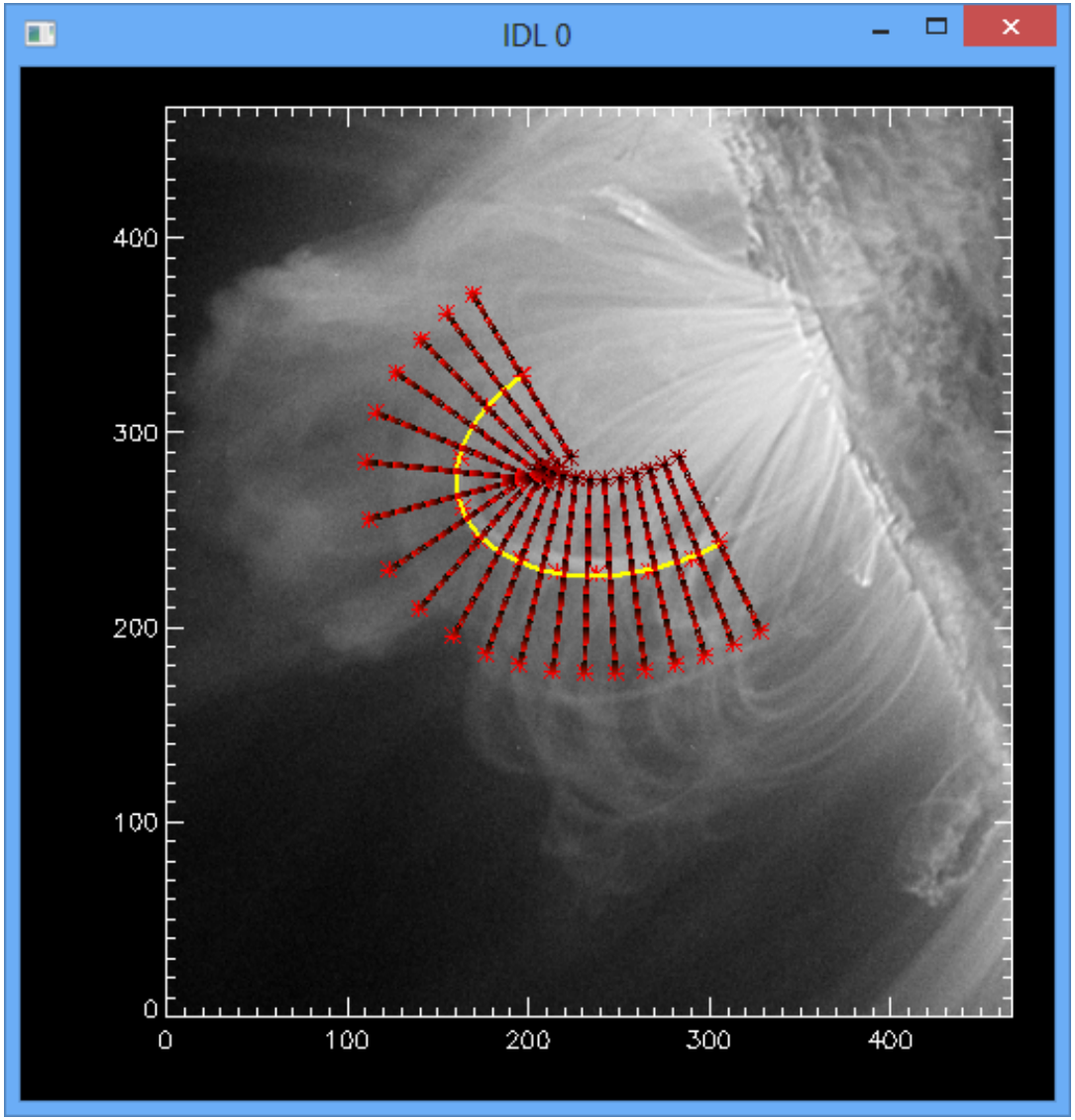
Multiple slits perpindicular to the loop

Fitting the loop path as an ellipse in the picture plain



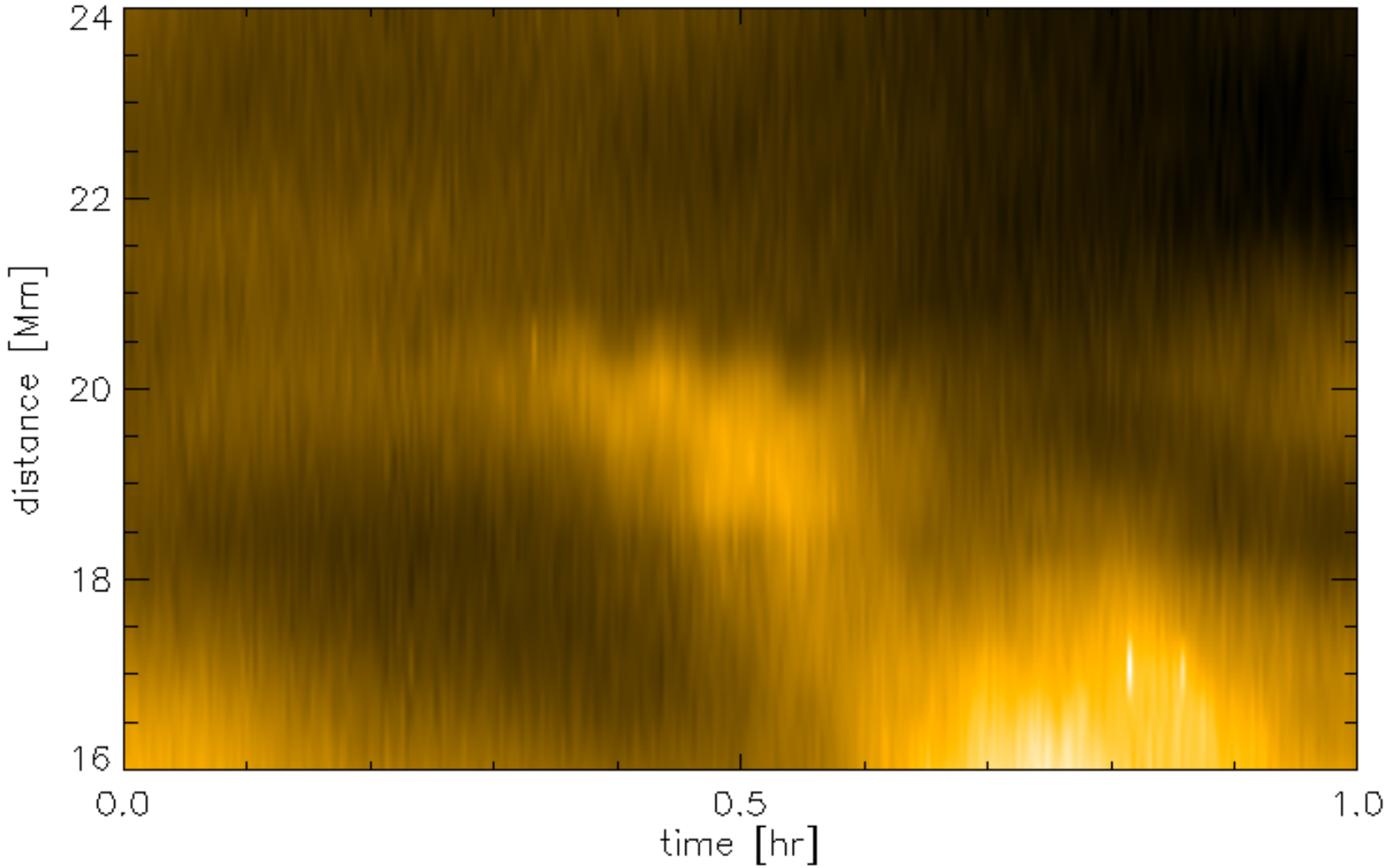
Multiple slits perpindicular to the loop

Slits perpendicular to the loop path



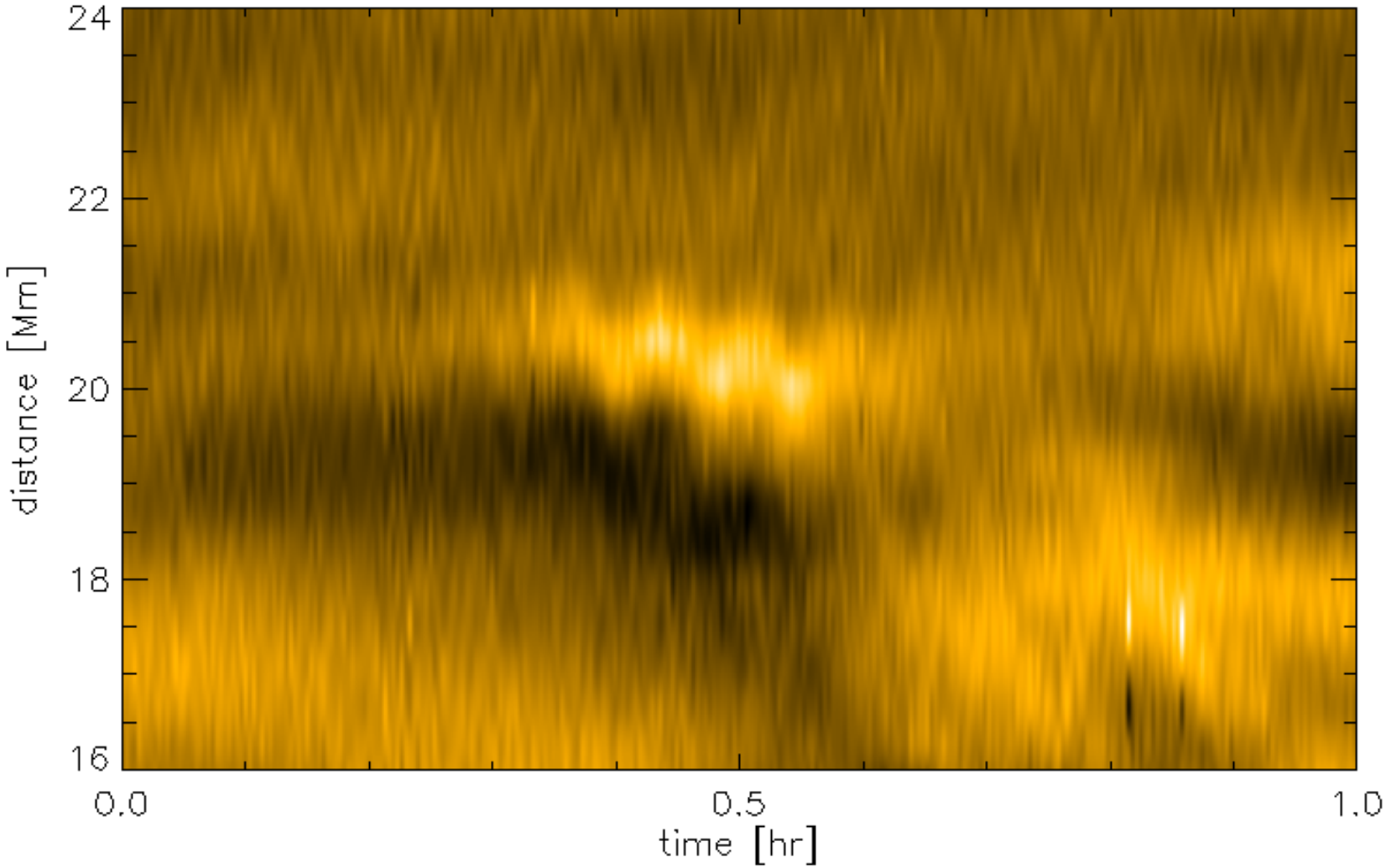
Fitting the parameterss

Time-distamce plot of an oscillating event



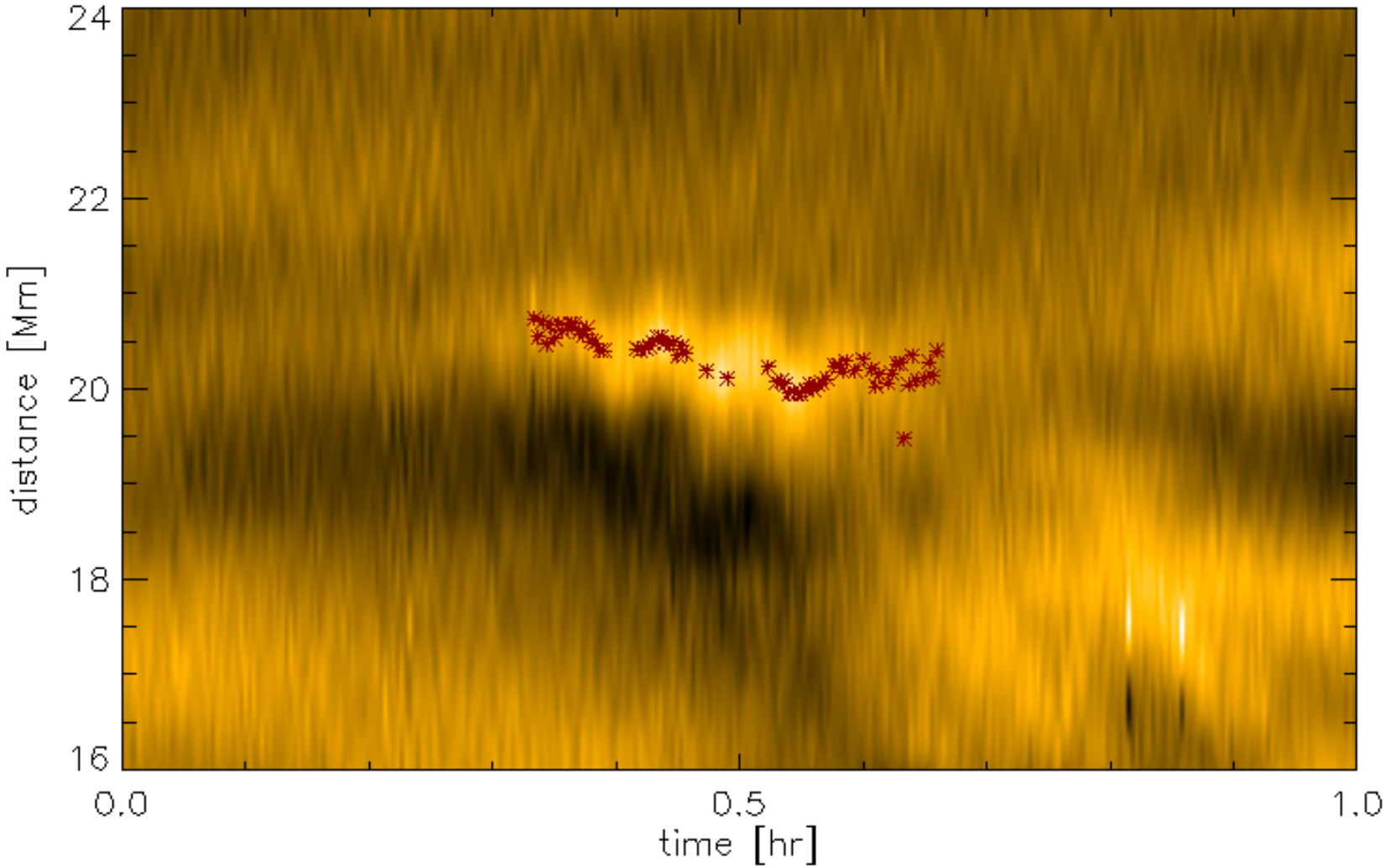
Fitting the parameterss

Intensity derivative along the spatial axis



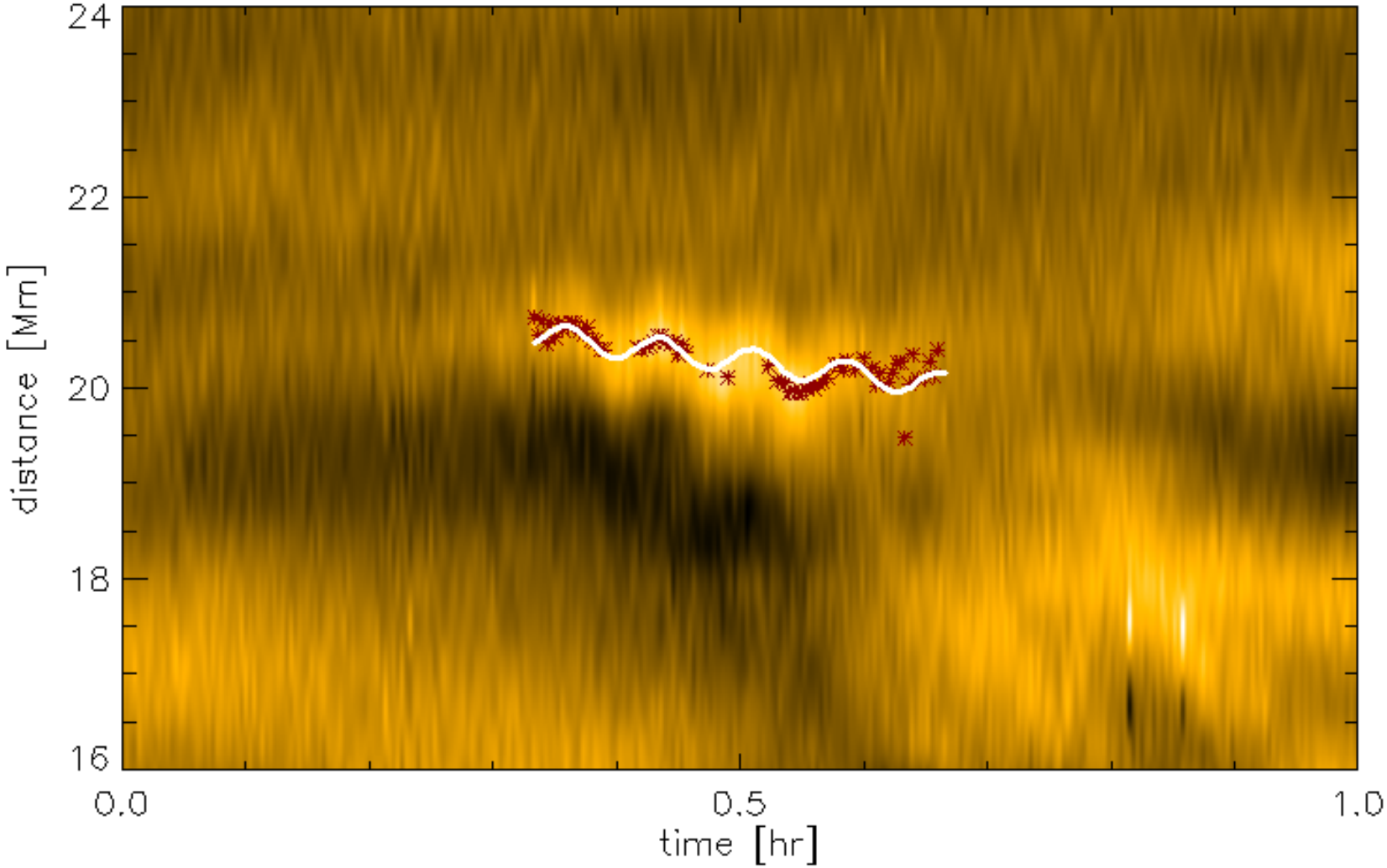
Fitting the parameterss

Gaussian profile fitting



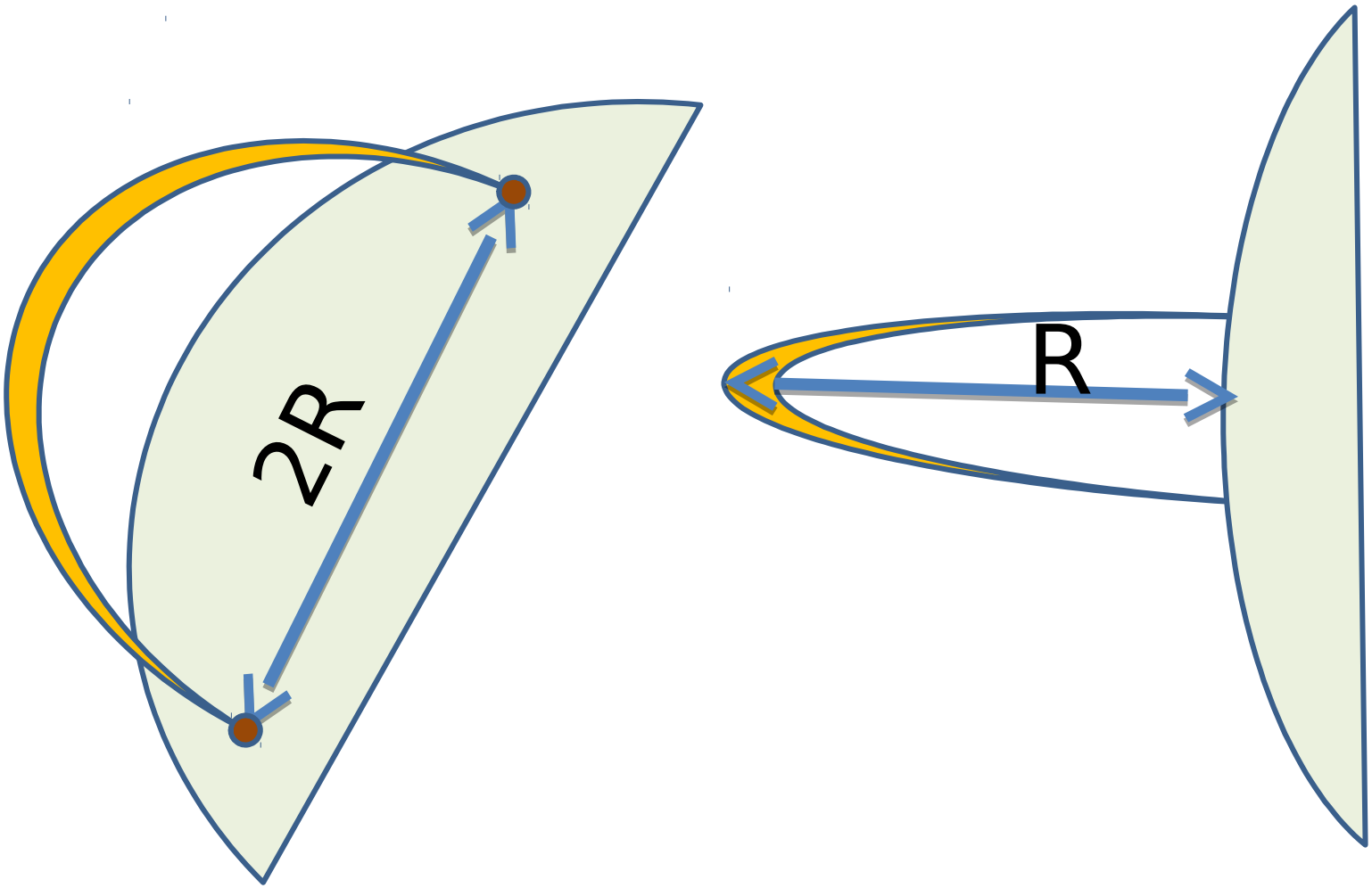
Fitting the parameterss

Fitting a sine: $x(t) = \xi \sin\left(\frac{2\pi t}{P} + \phi_0\right) + a_1 x + a_0$



Measuring oscillation parameters

Estimating the length of the loop



Results

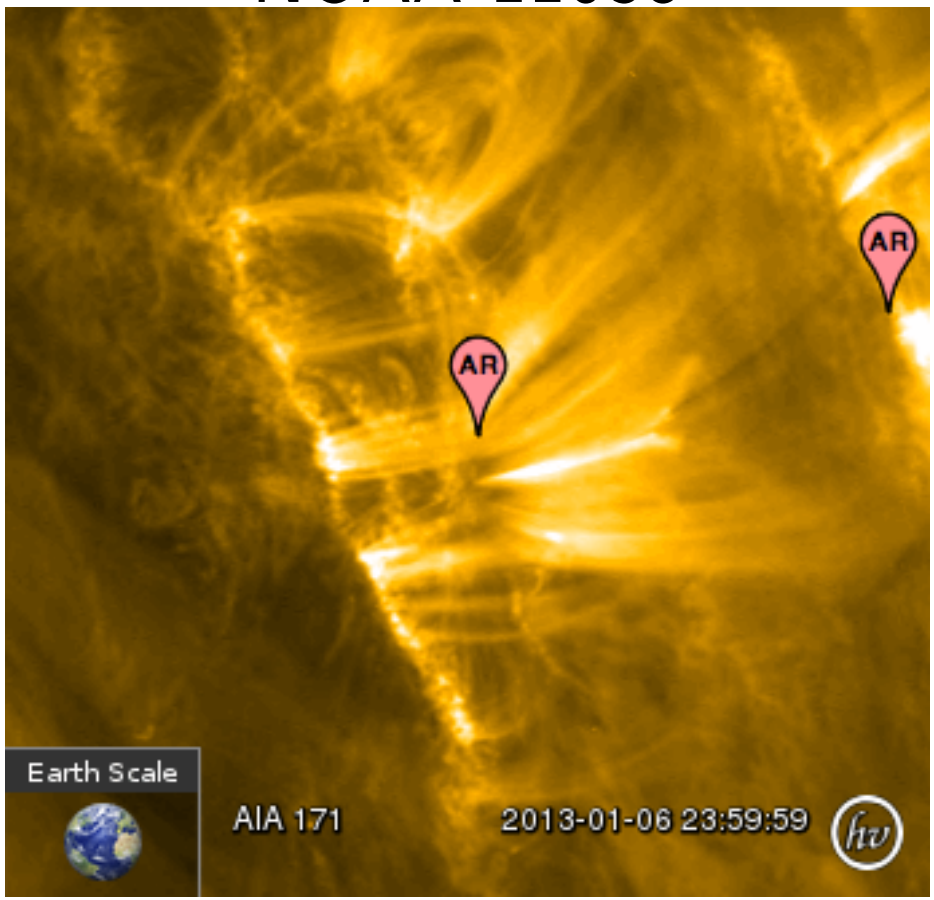
Decay-less low-amplitude oscillations — a common phenomenon

AR	Date	Oscillations [yes/no]	Sunspots [yes/no]
11637	2013-01-05	yes	no
11638	2013-01-07	**no**	yes
11639	2013-01-04	yes	no
11640	2013-01-05	yes	yes
11641	2013-01-11	yes	no
11642	2012-12-31	yes	yes
11643	2012-12-31	yes	no
11644, 11646	2013-01-12	yes	yes
11645	2013-01-10	yes	yes
11647	2013-01-04	**no**	no
11648	2013-01-15	yes	no
11649	2013-01-13	yes	yes
11650	2013-01-05	yes	yes
11651	2013-01-07	yes	no
11652	2013-01-07	yes	yes
11653	2013-01-06	yes	yes
11654	2013-01-08	yes	yes
11655	2013-01-14	yes	yes
11656	2013-01-20	yes	no
11657	2013-01-20	yes	no

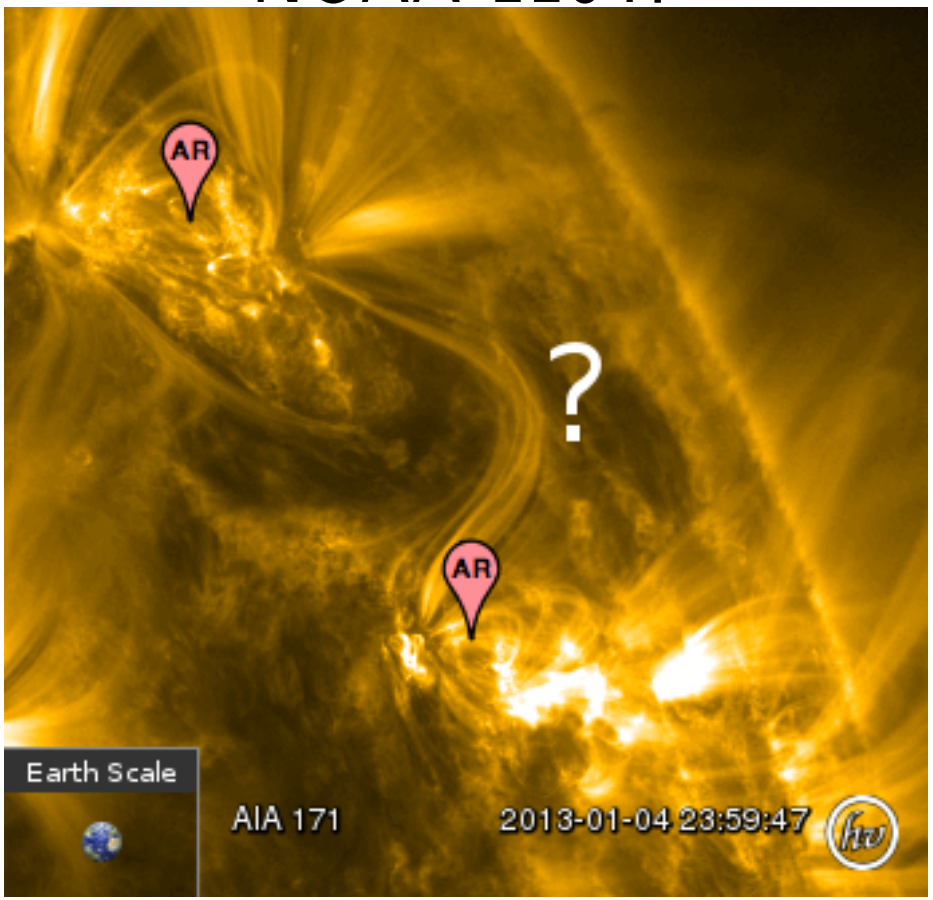
Results

Active regions where no oscillations were found

NOAA 11638

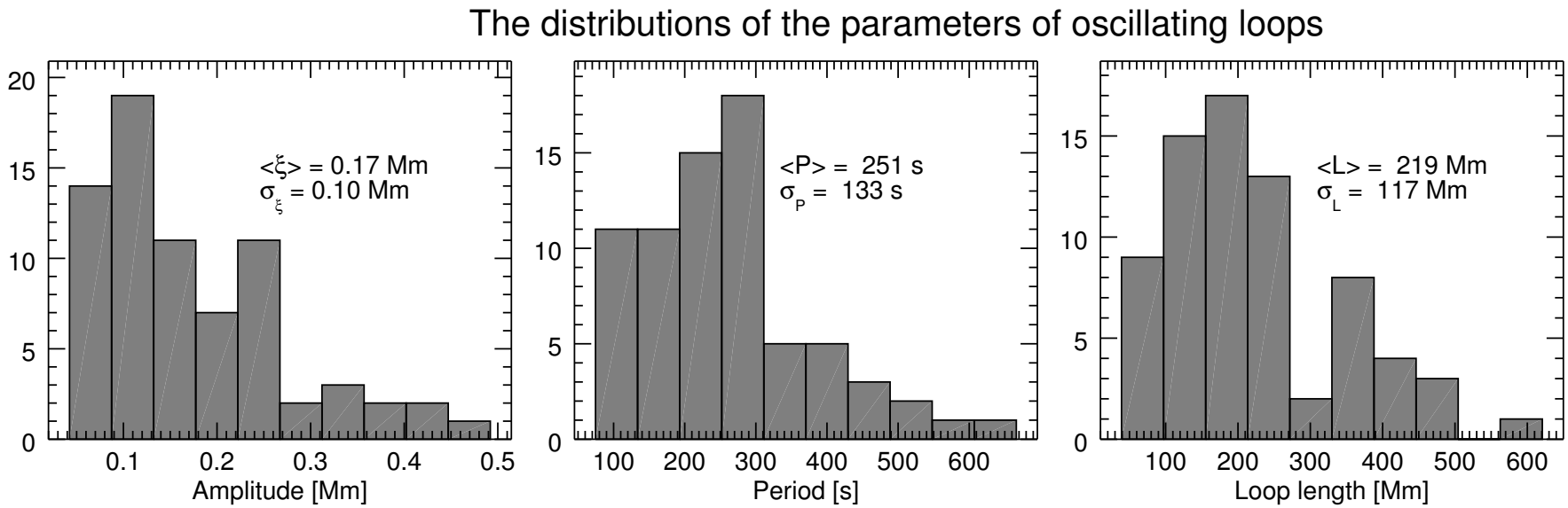


NOAA 11647



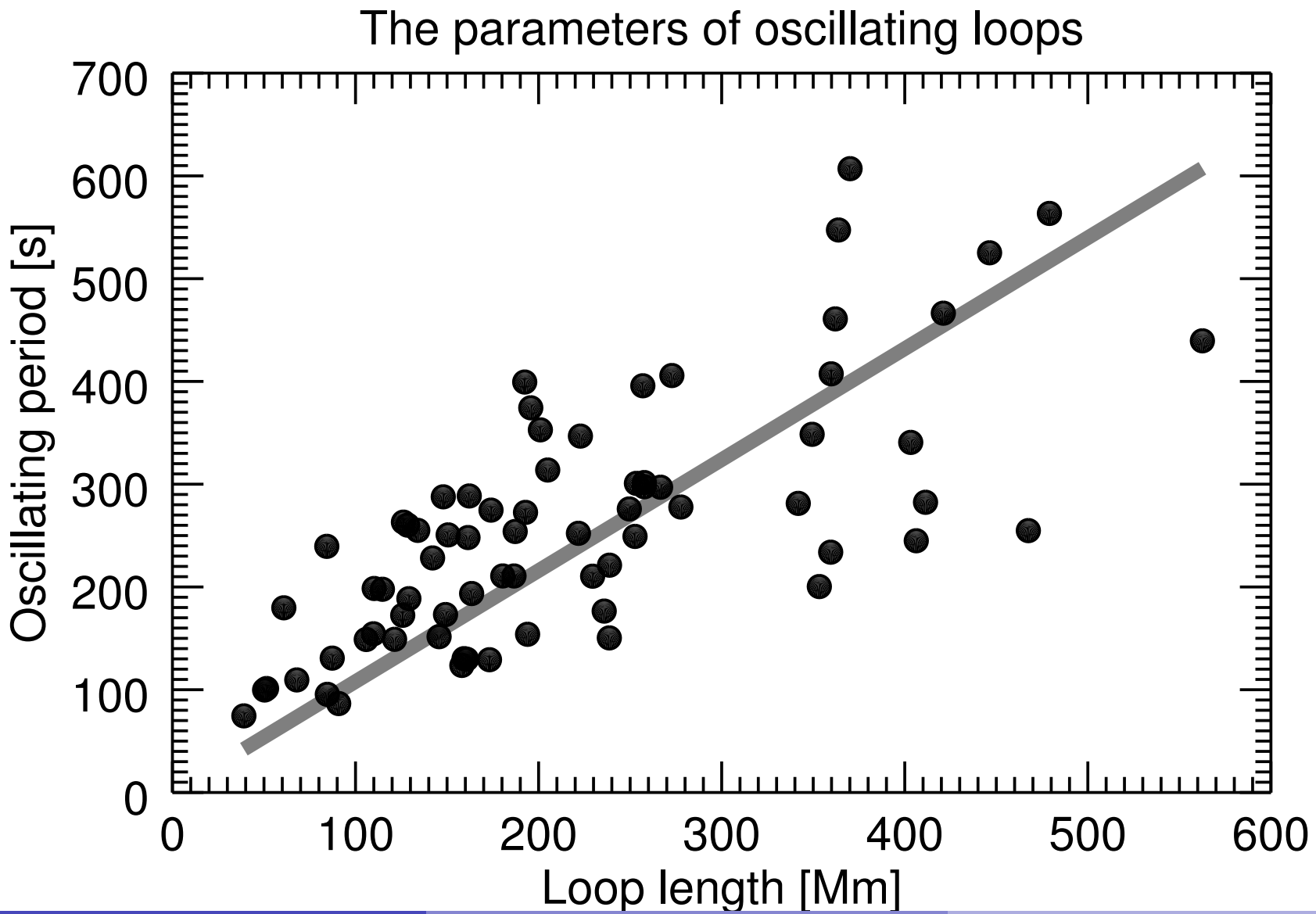
Results

Parameters distribution *(70 oscillating loops, NOAA 11637-11657)*



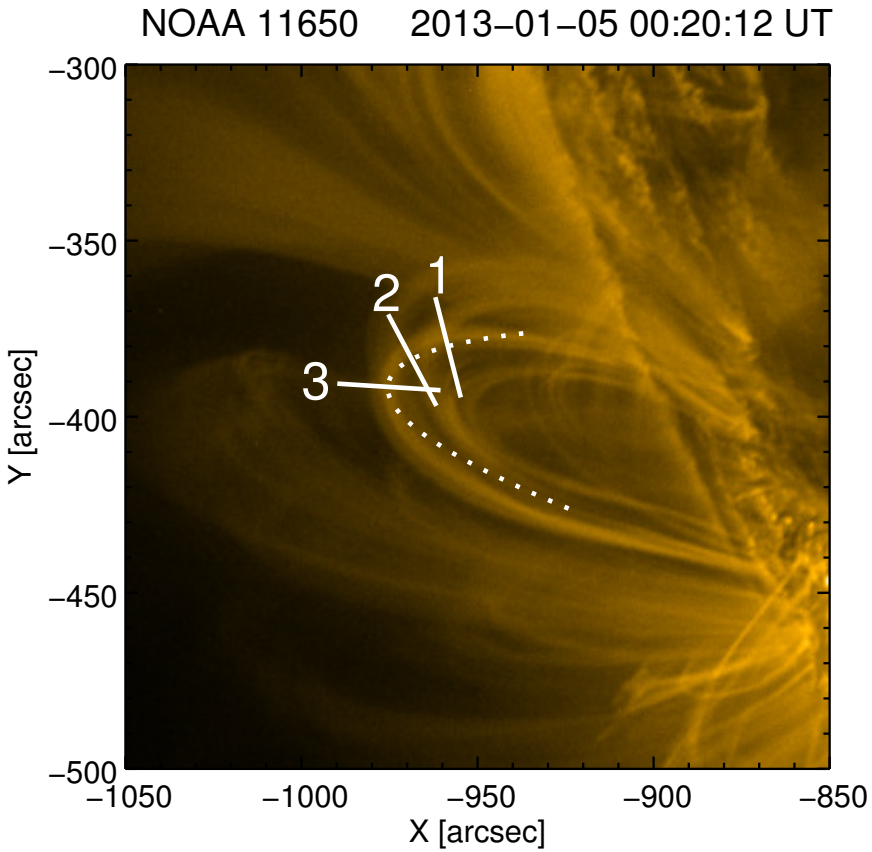
Seismological sensitivity

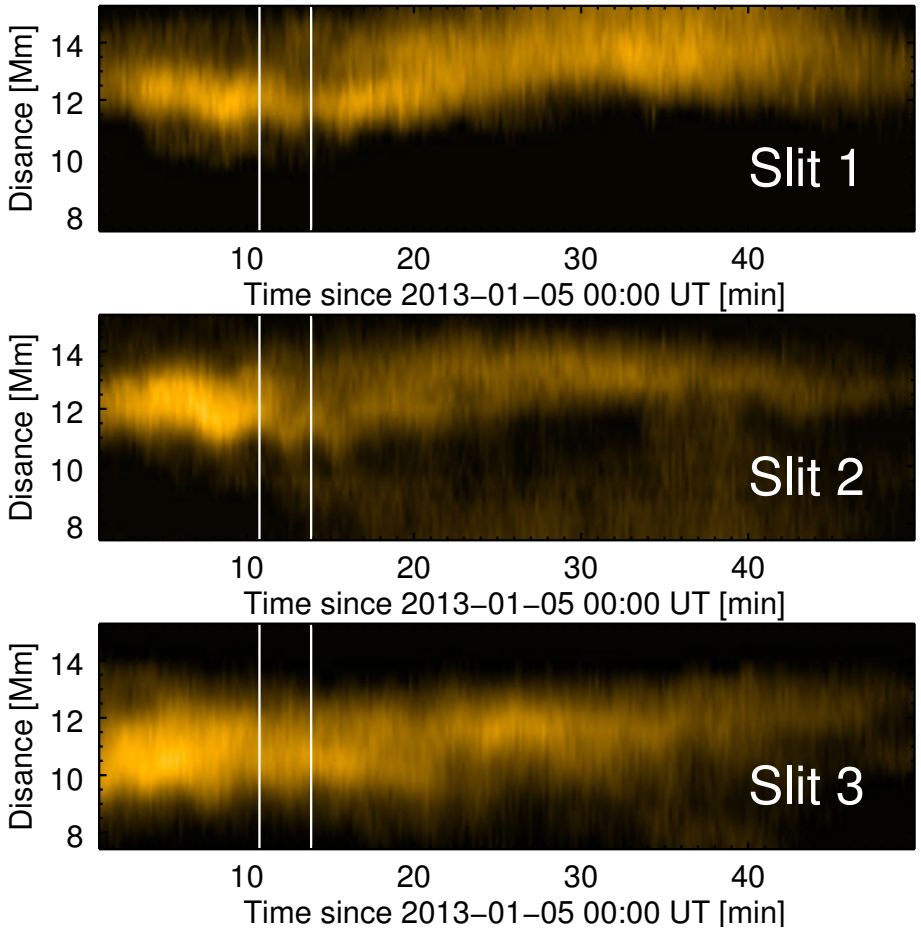
Loop length vs oscillation period *(70 oscillating loops, NOAA 11637-11657)*



In phase oscillations

Different slits





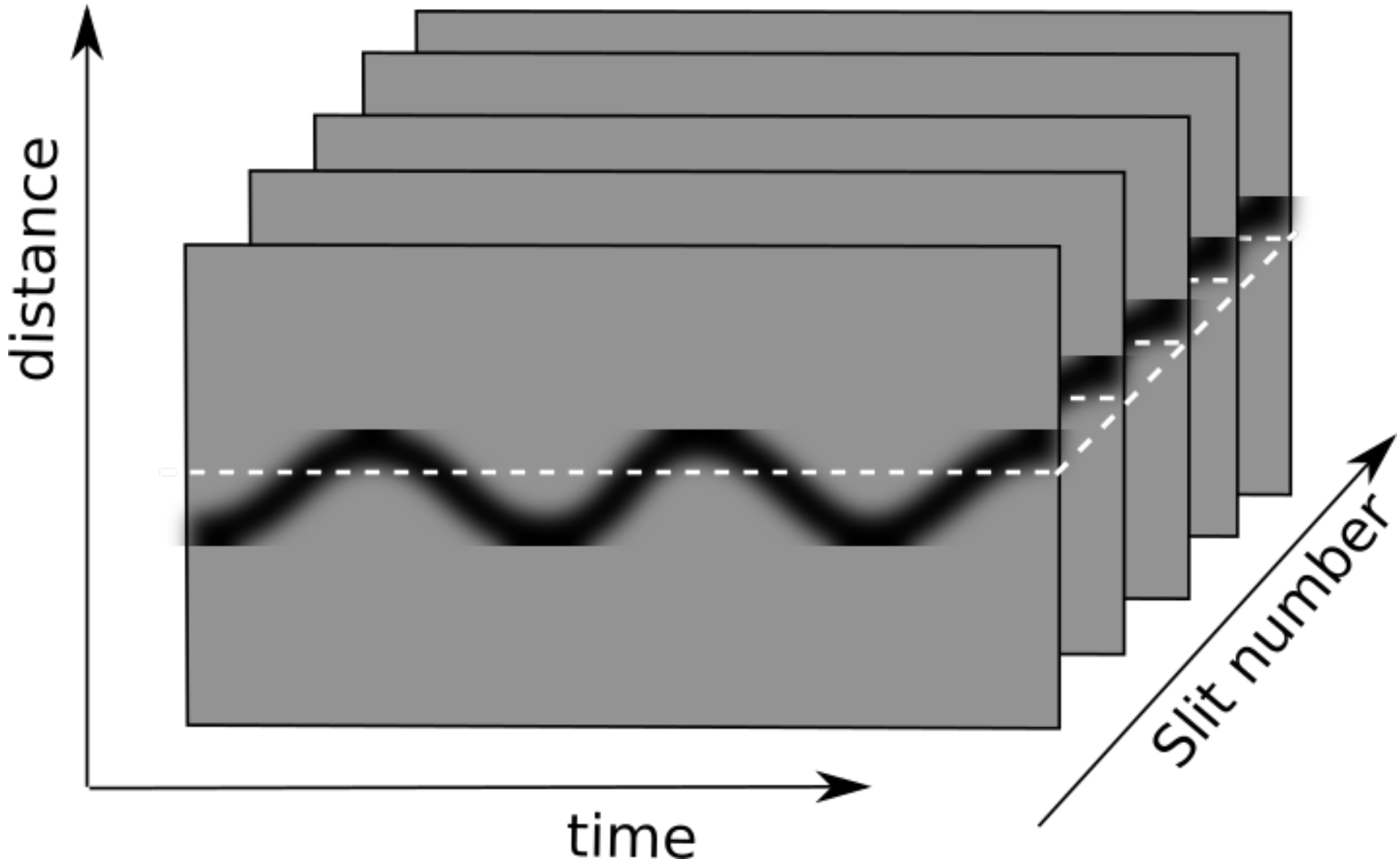
Conclusions

- Permanently occur in almost any AR at any time
  - They were found in 19 of 21 inspected ARs
- Periodic driver is less probable
- Standing kink oscillations
  - Oscillation period increases with the length of the loop
  - All segments of the loop oscillate in phase
  - Amplitude maximum is located close to the apex of the loop
- The promising tool for the MHD seismology of the solar corona
  - Observed in any active region
  - Seismologically sensitive

Thank you for your attention!

Cross correlation analysis (NOAA 11654)

Idea



Cross correlation analysis (NOAA 11654)

Results