

Search for predicted flows in loops undergoing thermal non-equilibrium

8th Coronal Loops Workshop

G. Pelouze¹ **F. Auchère**¹ **K. Bocchialini**¹ **C. Froment**²
S. Parenti¹ **E. Soubrié**^{1,3}

¹Institut d'Astrophysique Spatiale, Orsay, France

²Institute of Theoretical Astrophysics, University of Oslo, Norway

³Institute of Applied Computing & Community Code, UIB, Spain

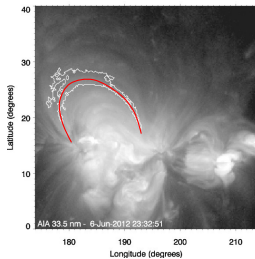
29 June 2017



Pulsations are currently explained with thermal non-equilibrium (TNE)

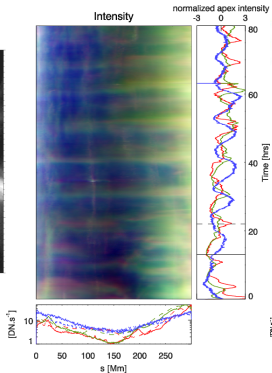
Automatic detection

9 h pulsations in AR 11499



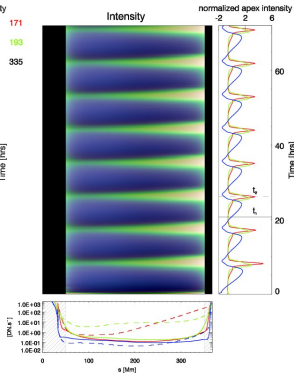
Analysis of observations

Froment et al. (2015)



1D hydro simulations

Froment et al. (2017)

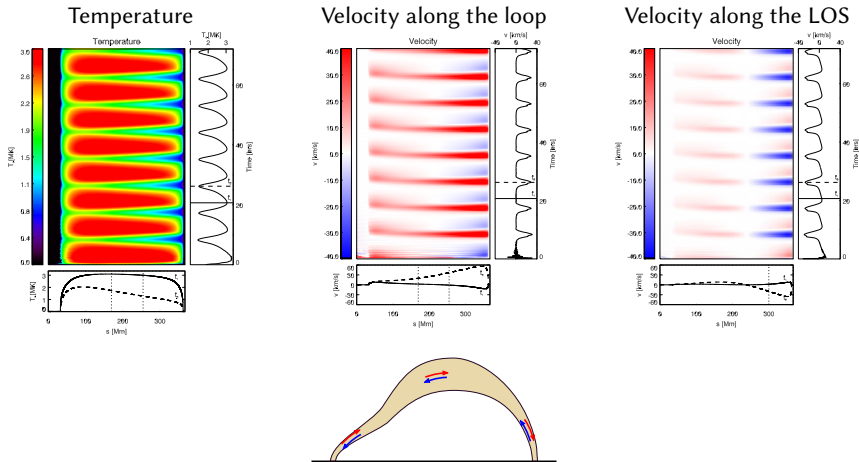


If this interpretation is correct, three predictions should be verified:

1. Coronal rain should be detected in the cold phase of at least some loops pulsations (Clara Froment)
2. At least some events of coronal rain should be periodic (Frédéric Auchère)
3. Periodic flows should be detectable even without visible full condensations

Simulations predict plasma flows in the loops

Simulation results for AR 11499 (Froment et al., 2017):



We should observe periodical flows at coronal temperatures in pulsating loops.

Finding data

What spectrometer should we use?

Based on the simulations, we want to measure:

- velocities of ~ **10 km/s**,
- at **coronal temperatures**,
- over **tens of hours**.

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⇒ **Hinode/EIS**

Finding series of EIS spectra with both **high cadence** and **long duration** is challenging.

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Automatic data mining

- Over 3000 oscillation events found with SDO/AIA between 2010 and 2016
 - Over 200 000 files in the EIS archive from 2010 to 2016
 - For the 30 “best” AIA events, we query the EIS archive for datasets matching these criteria:
 - FOV containing the pulsations
 - observation during at least 5 h
- ⇒ We find EIS data for 4 events.

EIS datasets

Main characteristics of the 4 datasets

	Date	NOAA AR	Duration [h]	# of periods	Rasters	Exp. time [s]	Eclipses / gaps
1	2010-11-02	11120	5.7	1.5	60	20	No
2	2011-09-02	11283	40	6.9	236	9	Yes
3	2012-06-03	11494	28.7	5.9	178	3	Yes
4	2012-11-02	11602	13.6	2.3	88	20	Yes

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Lines used

Ion	Wavelength [Å]	Blends
Fe XII	195.119	Fe XII
Fe XII	186.887	Fe XII, Fe VIII, Ni XI (?)

- Velocity: Fe XII 195.119 Å
- Density: Fe XII 186.887 / 195.119 Å (most sensitive around 1.5 MK)

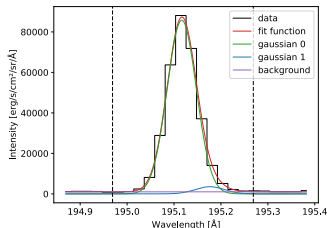
From CHIANTI and Young et al. (2009)

Data preparation and line fitting

- Data preparation using Solar Soft routine `eis_prep.pro`
- Per-pixel line fitting with `eis_auto_fit.pro` to reduce spectral cubes to intensity and velocity maps

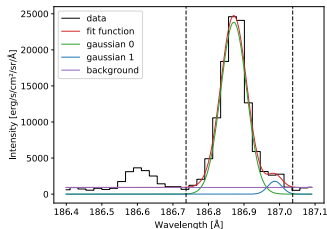
Window 1 – 2 gaussians:

- Fe XII 195.119 and 195.179 Å
- same width
- fixed wavelength separation



Window 2 – 2 gaussians:

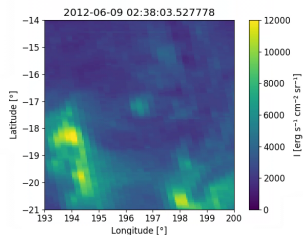
- Fe XII 186.887 Å and Ni XI (?) 187.179 Å



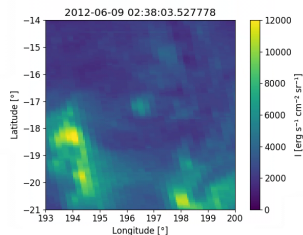
Coalignment and Carrington transformation

Spatial coalignment of EIS time series with AIA

Original pointing



Aligned with AIA

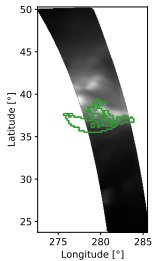


Compensation of the solar rotation

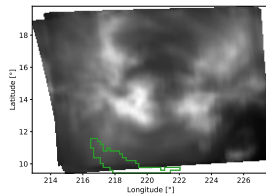
All maps are converted into Carrington coordinates.

Fields of view

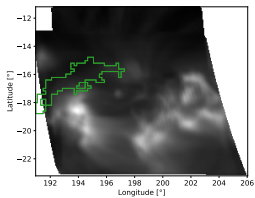
Case 1



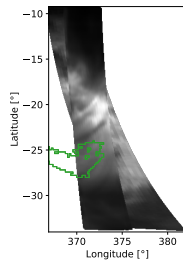
Case 2



Case 3



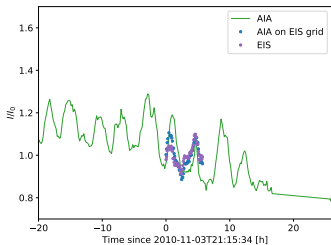
Case 4



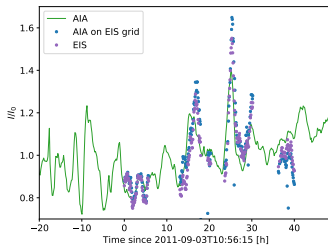
Intensity pulsations

EIS Fe XII 195.119 Å / AIA 193 Å

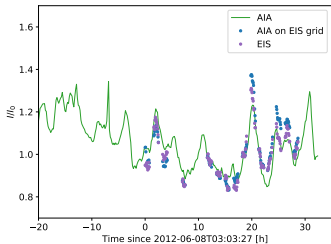
Case 1



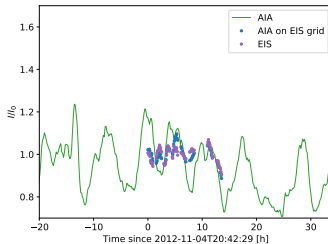
Case 2



Case 3



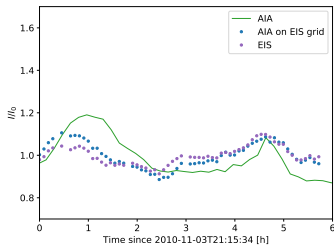
Case 4



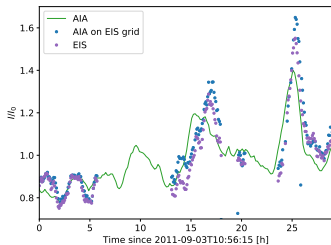
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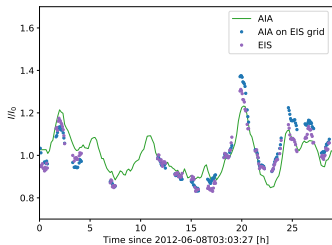
Case 1



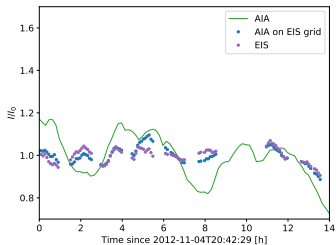
Case 2



Case 3



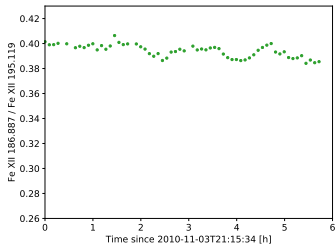
Case 4



Pulsations in density ?

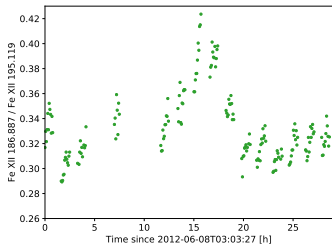
Fe XII 186.887 / Fe XII 195.119 Å

Case 1

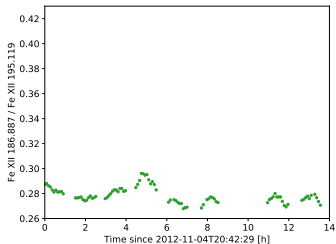


Case 2
(no densities)

Case 3



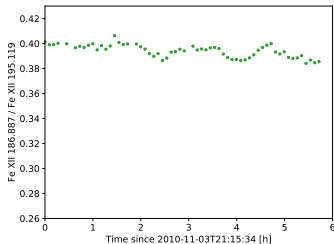
Case 4



Pulsations in density ?

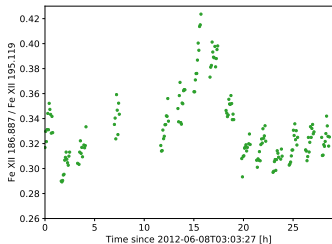
Fe XII 186.887 / Fe XII 195.119 Å

Case 1

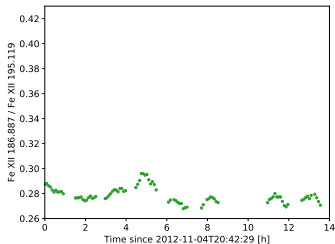


Case 2
(no densities)

Case 3



Case 4

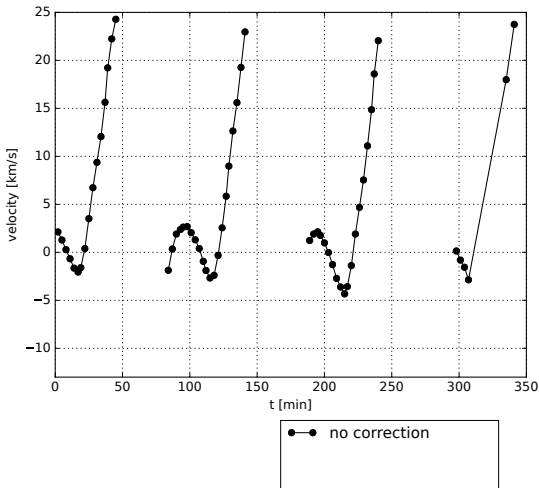


⇒ ~ 7% variation for case 3.

EIS spectral drift and velocity measurements

- Thermo-elastic effects (up to 70 km/s)

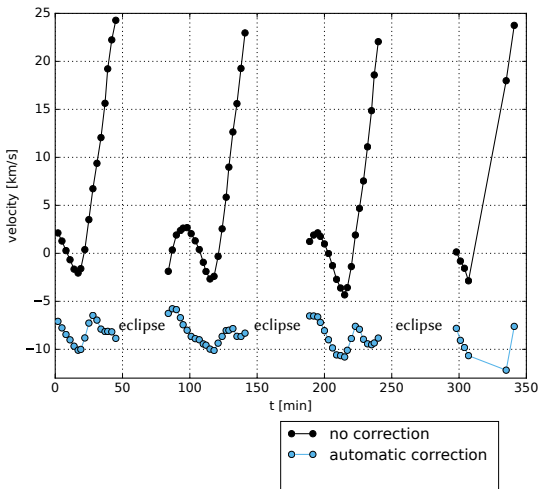
Average velocity in the full field of view



EIS spectral drift and velocity measurements

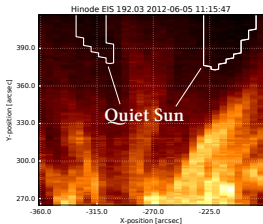
- Thermo-elastic effects (up to 70 km/s)
- Kamio et al. (2010) correction (residuals ~ 5 km/s)

Average velocity in the full field of view

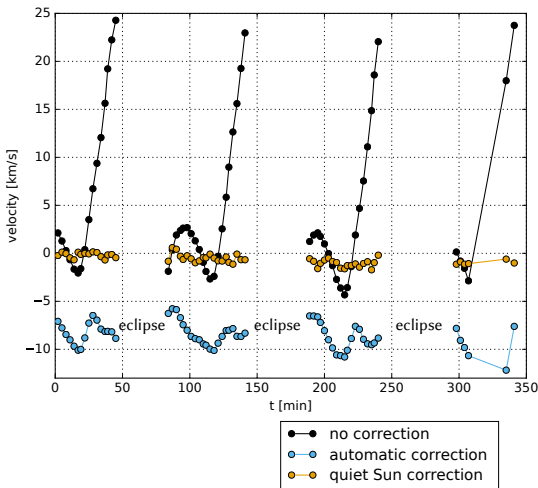


EIS spectral drift and velocity measurements

- Thermo-elastic effects (up to 70 km/s)
- Kamio et al. (2010) correction (residuals ~ 5 km/s)
- Correction using the “quiet Sun”

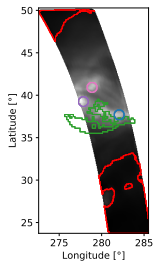


Average velocity in the full field of view

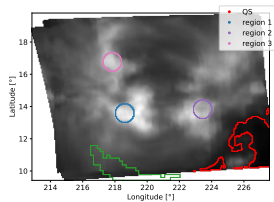


Selecting loops footpoints

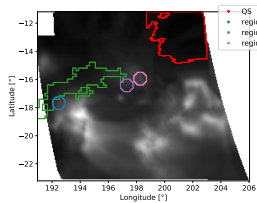
Case 1



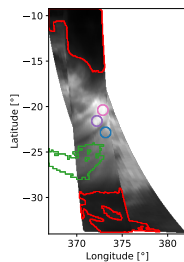
Case 2



Case 3



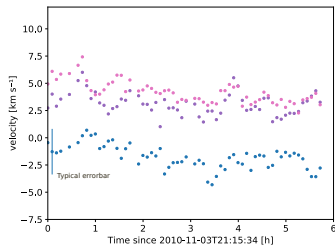
Case 4



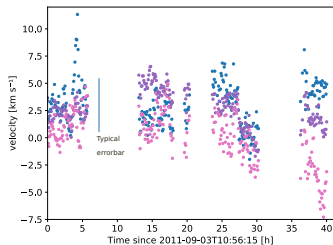
Searching for the predicted velocities

Fe XII 195.119 Å

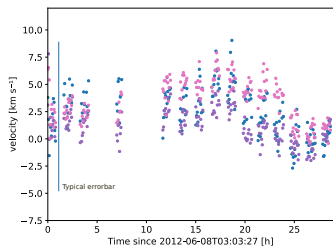
Case 1



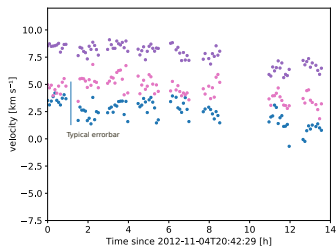
Case 2



Case 3



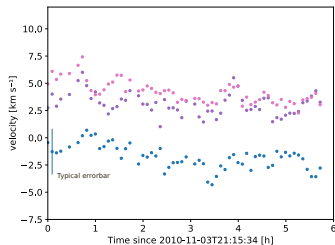
Case 4



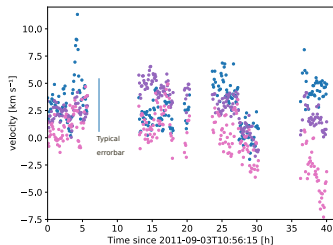
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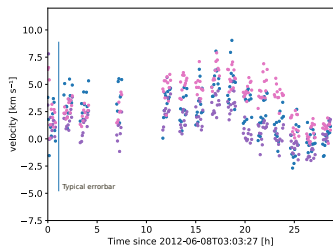
Case 1



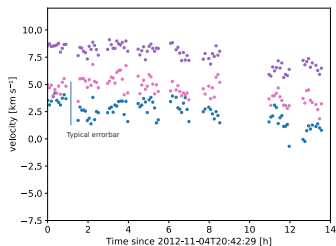
Case 2



Case 3



Case 4



⇒ No pulsations in velocity.

Discussion

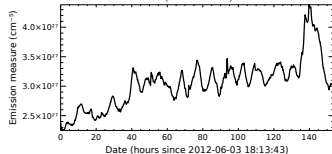
Simulations:

- Density variations of ~ 4
- Fe XII 186.887 / 195.119 variation of ~ 2

Observations:

- AIA: EM variation of $\sim 15\%$
- EIS: Fe XII 186.887 / 195.119 variation of 7%

Emission Measure from AIA (C. Froment)



Discussion

Simulations:

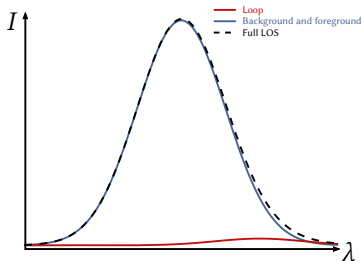
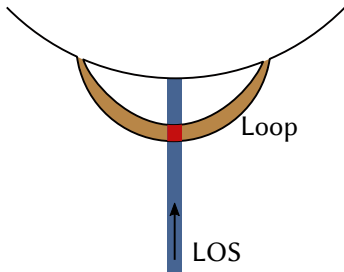
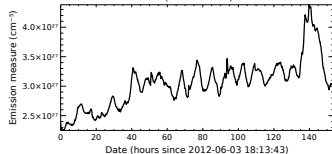
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- Fe XII 186.887 / 195.119 variation of ~ 2

Observations:

- AIA: EM variation of $\sim 15\%$
- EIS: Fe XII 186.887 / 195.119 variation of 7%

⇒ We measure variations 30× lower than in the simulations.

Emission Measure from AIA (C. Froment)



Conclusion

Summary

- All of the 4 datasets have limitations
- **Density** variations of about 7%
- Pulsations in **velocity** cannot be identified

Prospects

- More data mining
- HOP in preparation: long period variations of plasma parameters in loops

Bibliography

Froment, C., et al. 2017, ApJ, 835, 272

Froment, C., et al. 2015, ApJ, 807, 158

Kamio, S., et al. 2010, Solar Physics, 266, 209

Young, P. R., et al. 2009, Astronomy and Astrophysics, 495, 587