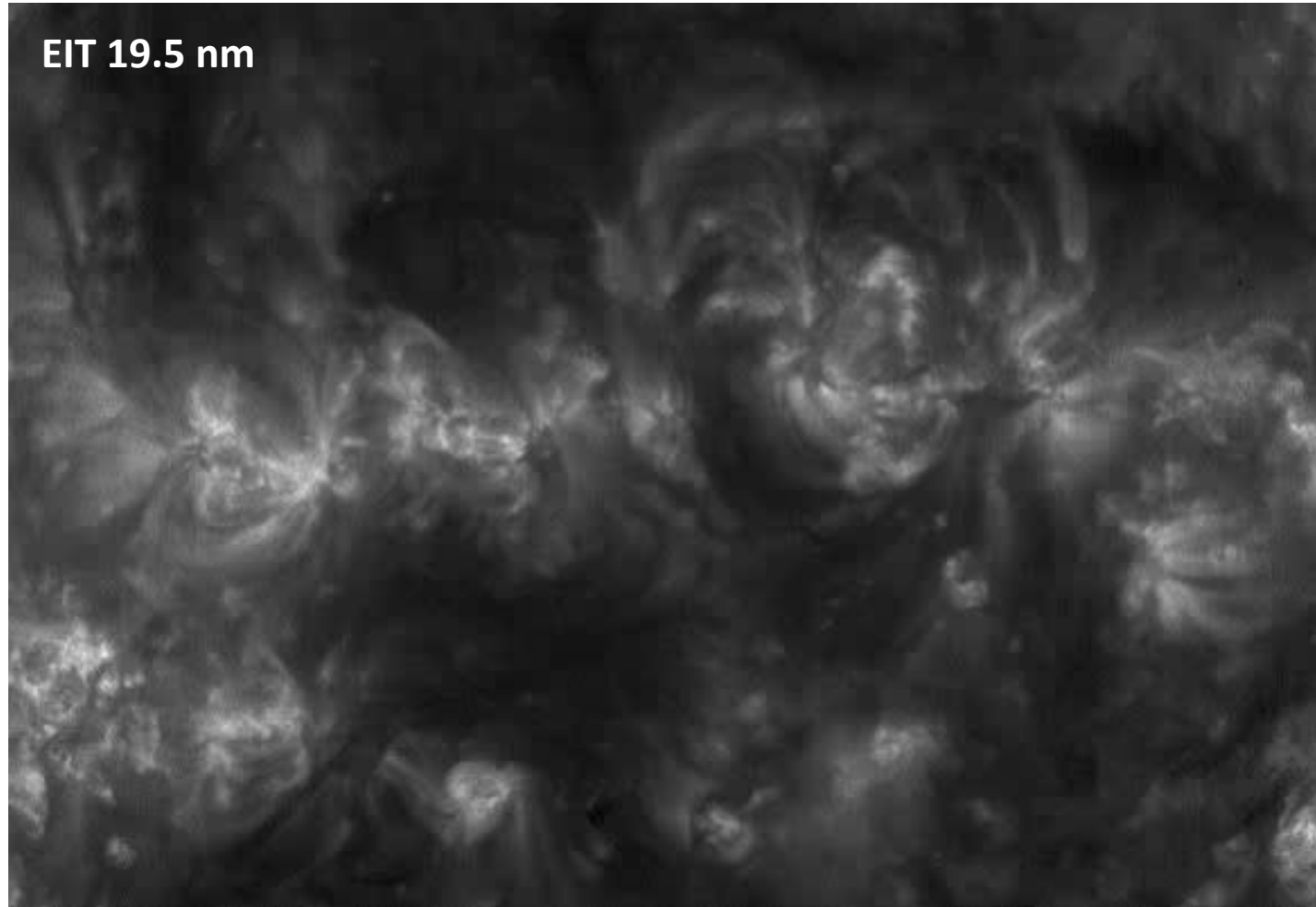


Pulsating Active Region Loops



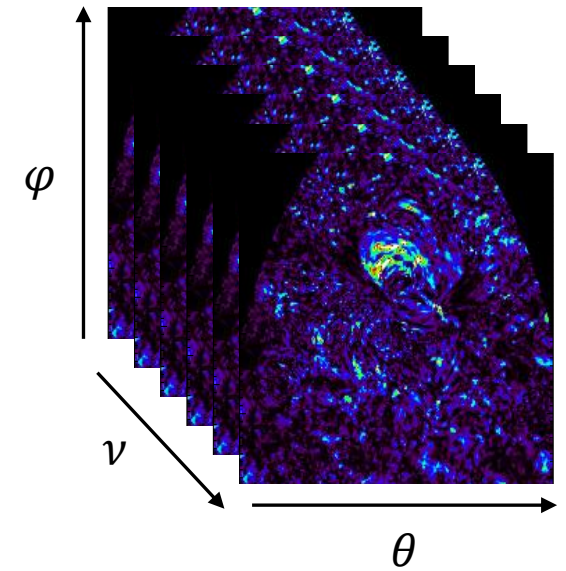
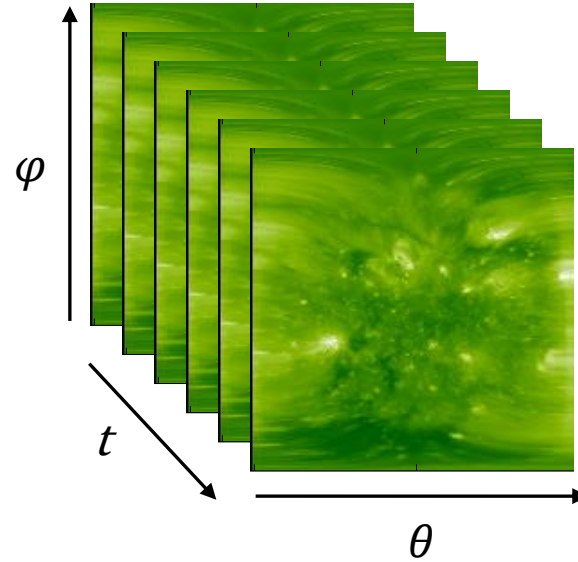
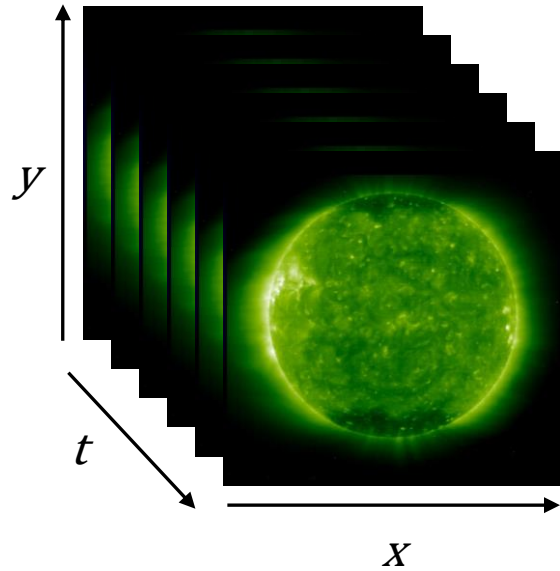
F. Auchère, K. Bocchialini, J. Solomon, E. Tison

Institut d'Astrophysique Spatiale
frederic.auchere@ias.u-psud.fr



- There are slowly pulsating active region loops in there
- Very slow (hours) ... but evident once you know where they are!
- Can they tell us anything about the heating of coronal loops ?

Systematic search of long period pulsations



1. EIT 195 data

01/1996 to 07/2010
~6 days long sequences
~12 minutes cadence

2. Tracking

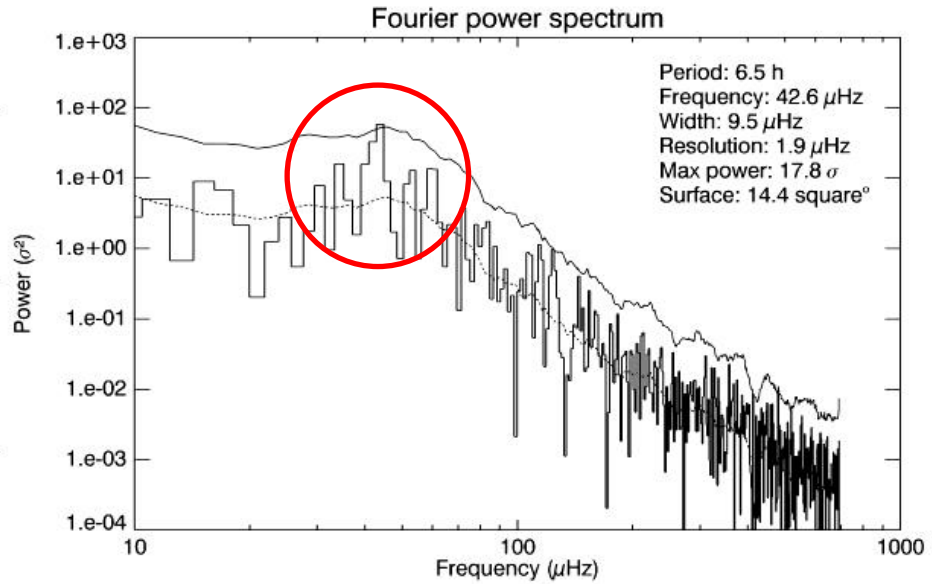
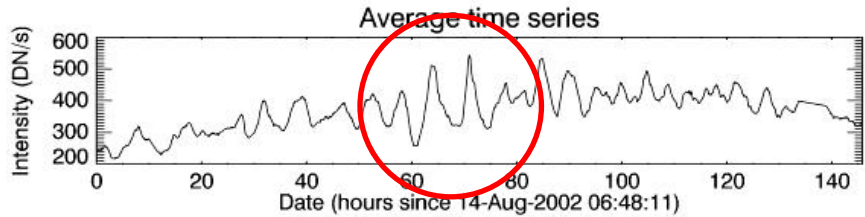
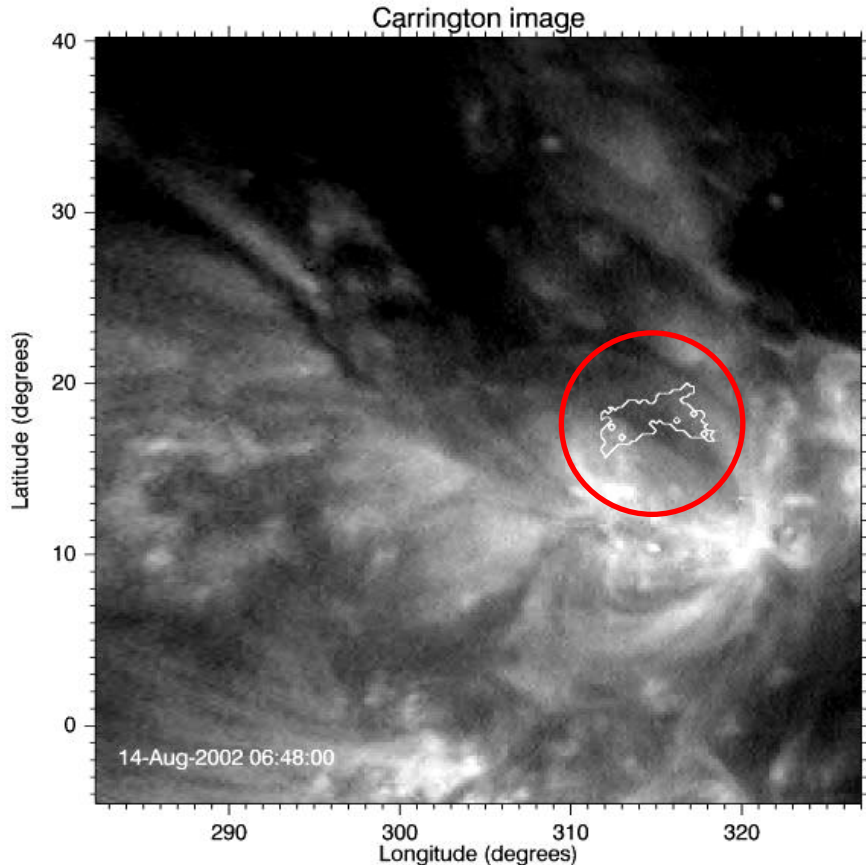
Heliographic coordinates
 $45^\circ \times 100^\circ$ ROI
Differential rotation

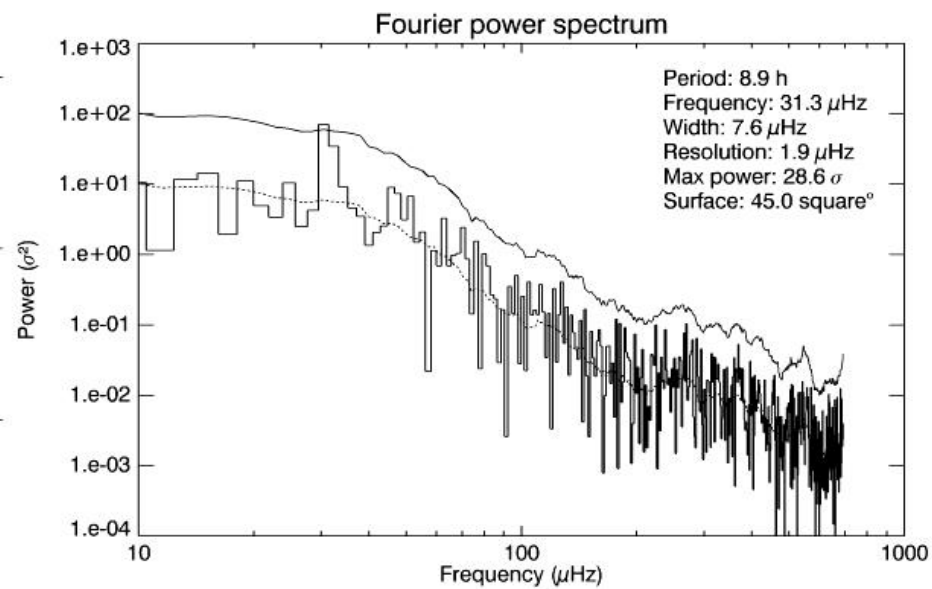
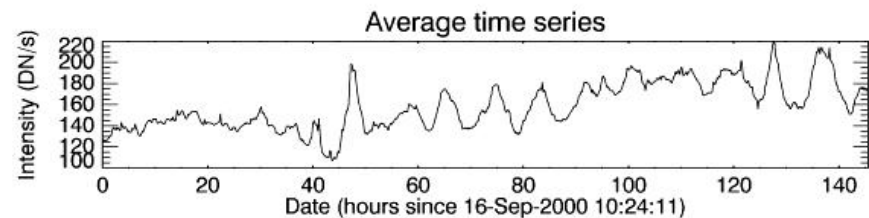
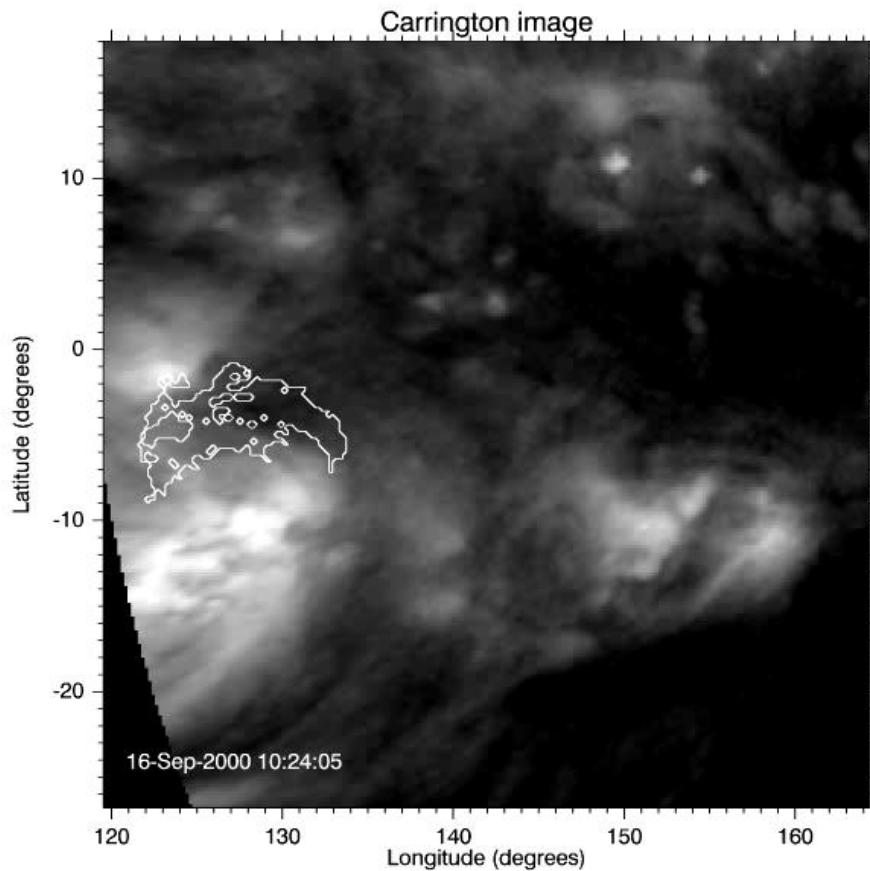
3. PSD

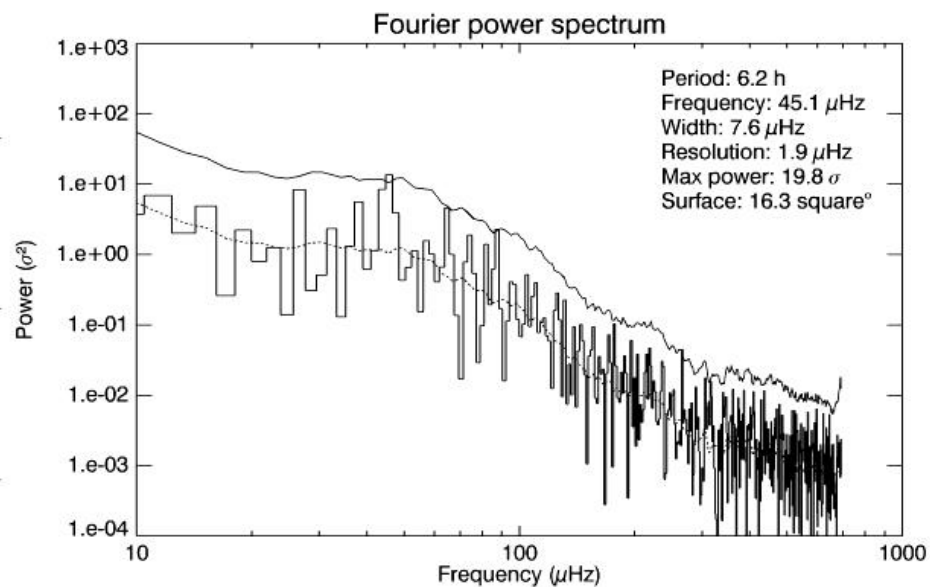
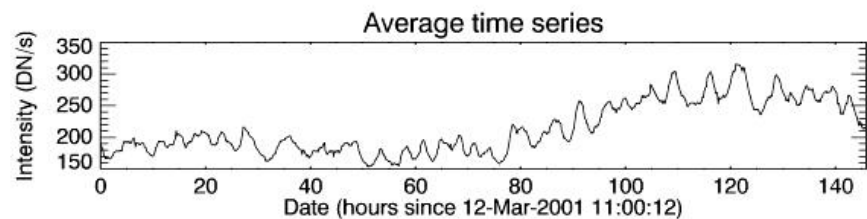
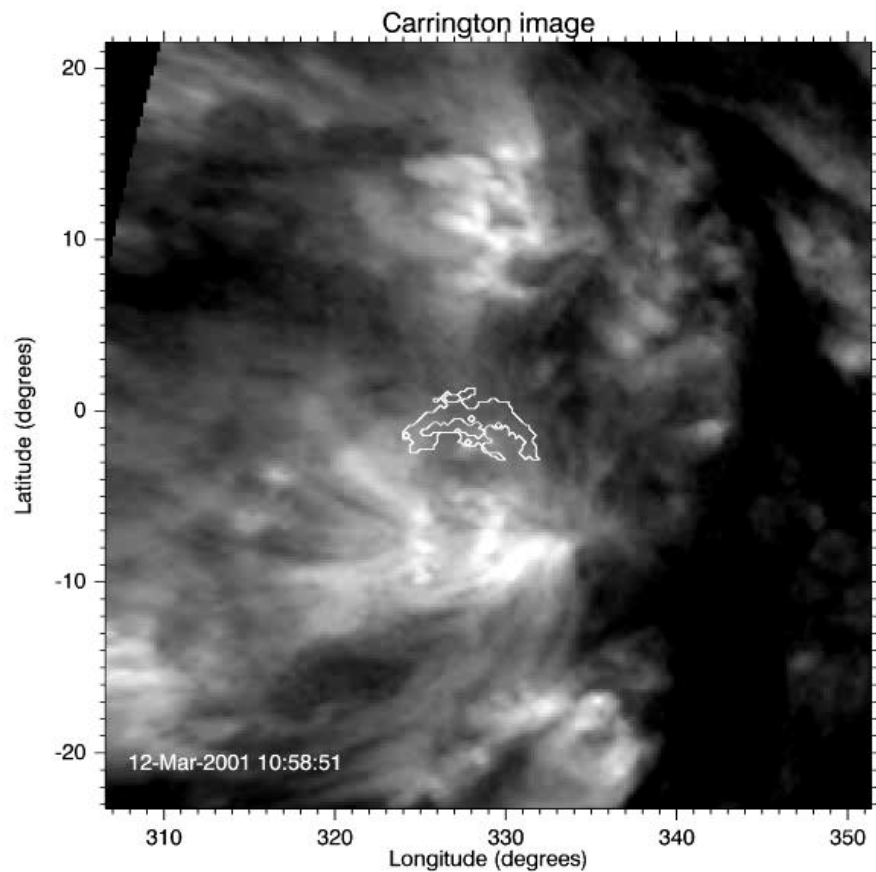
FFT
Thresholding (10σ)
Growth & clustering

A nice one ...

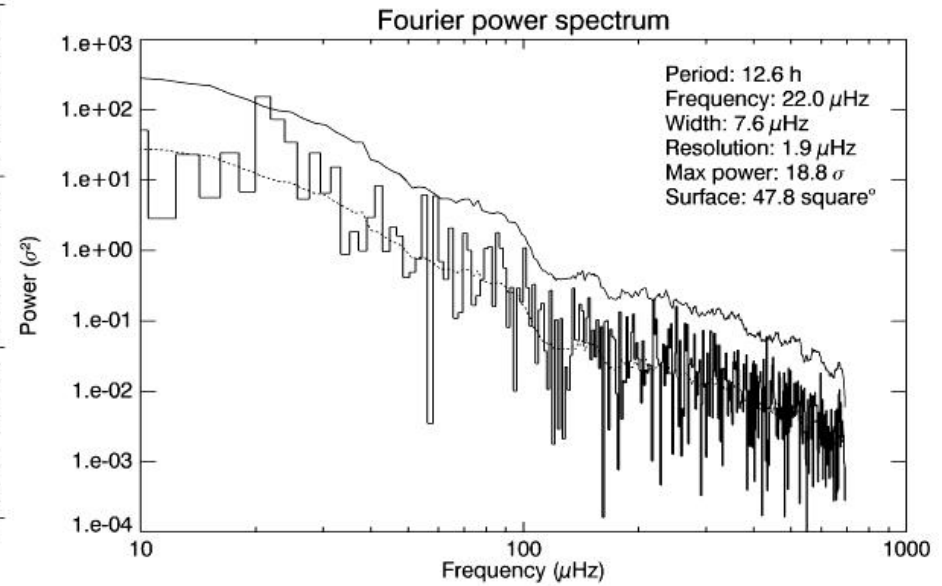
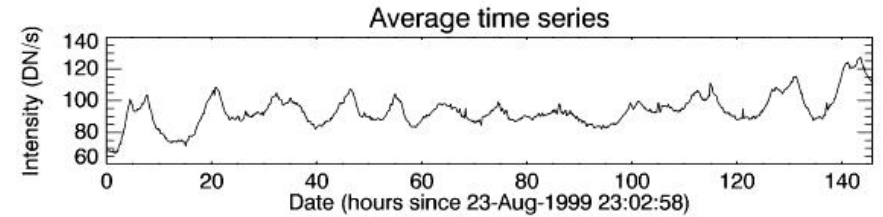
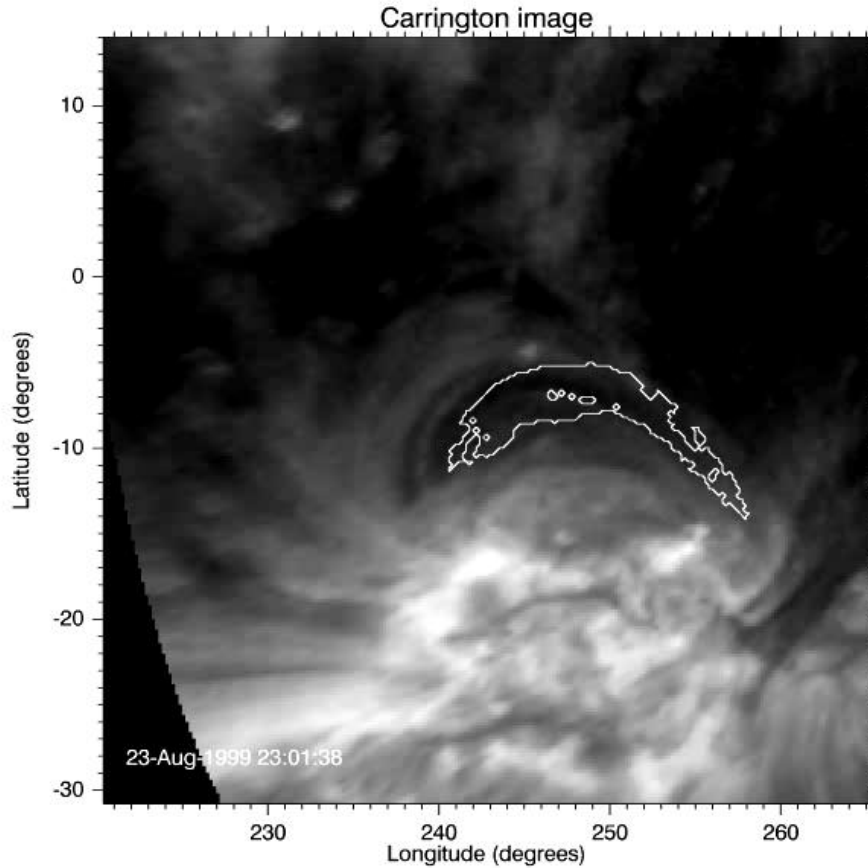
~25% intensity variations



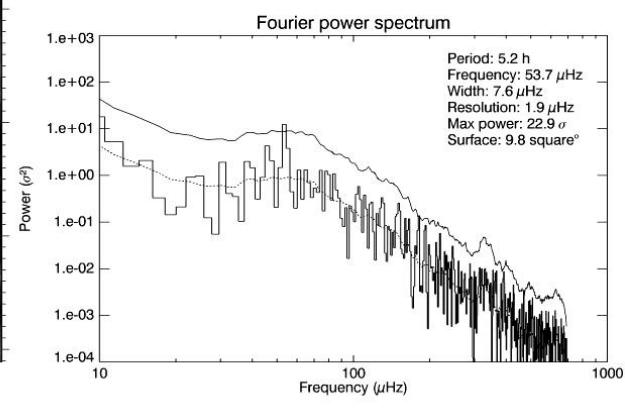
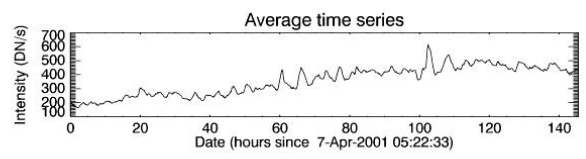
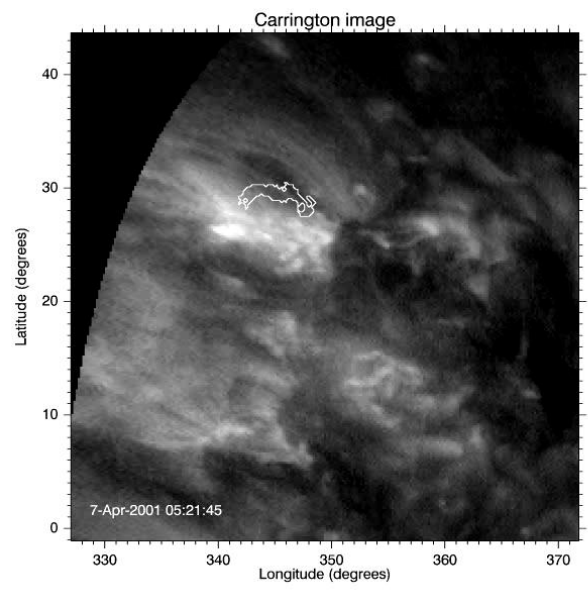
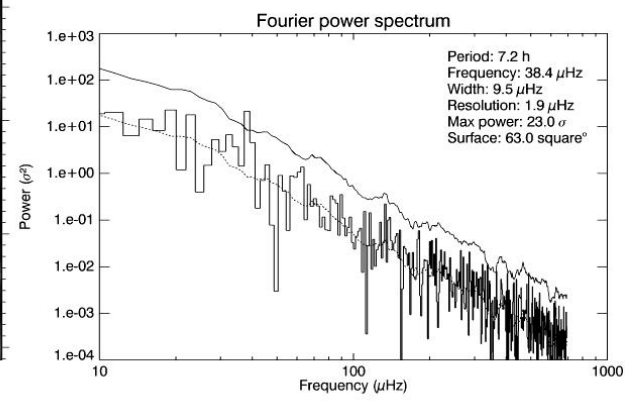
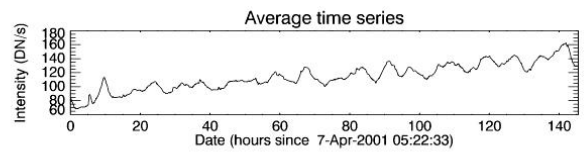
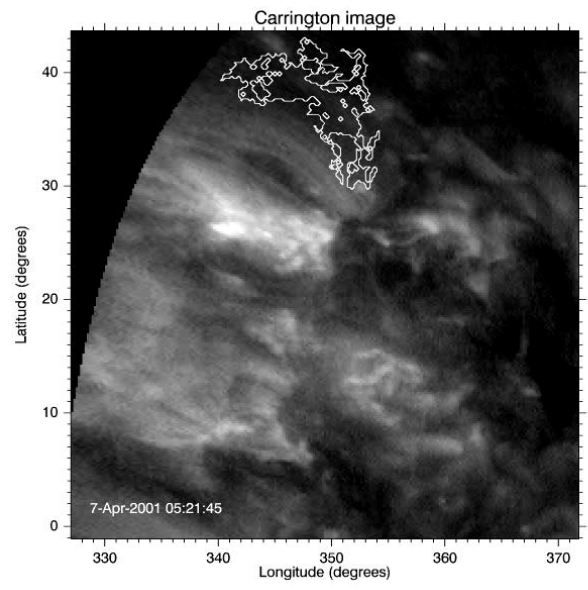




... that was a big one !



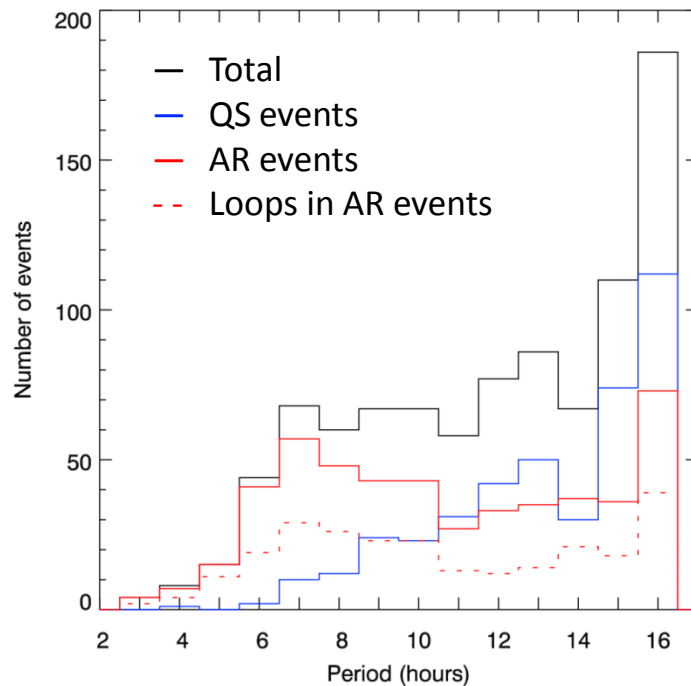
Two in one AR



Some statistics

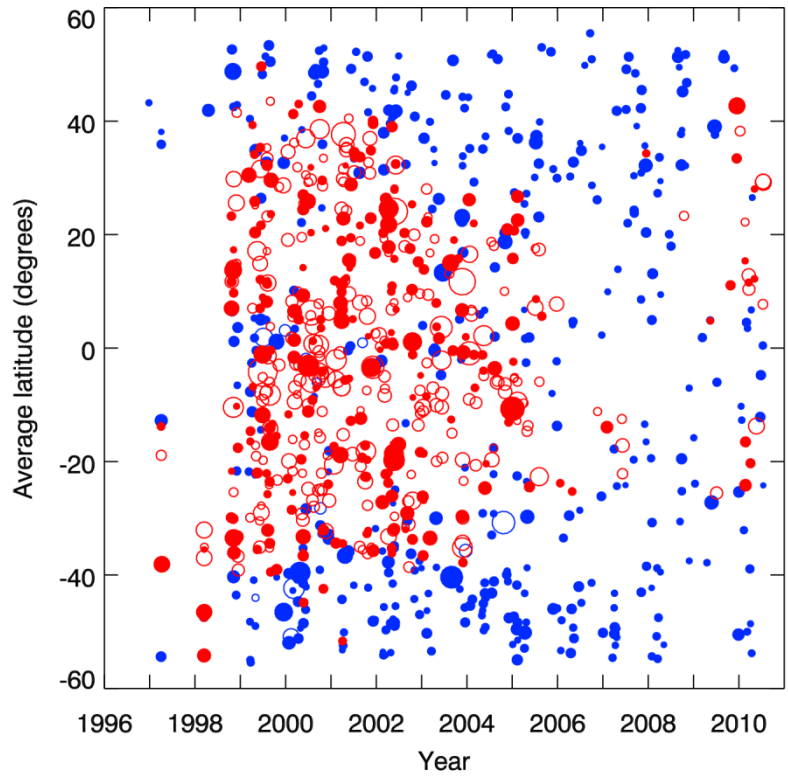
- 917 detections !
- Every event visually examined ...
 - “Active Region”, “Quiet Sun”, “Other”
 - Tagged for association with loops

| | All events | Loop events |
|---------------|------------|-------------|
| Quiet Sun | 411 (45%) | 13 (5%) |
| Active Region | 499 (54%) | 254 (95%) |
| Other | 7 (1%) | 1 (0%) |
| Total | 917 | 268 |

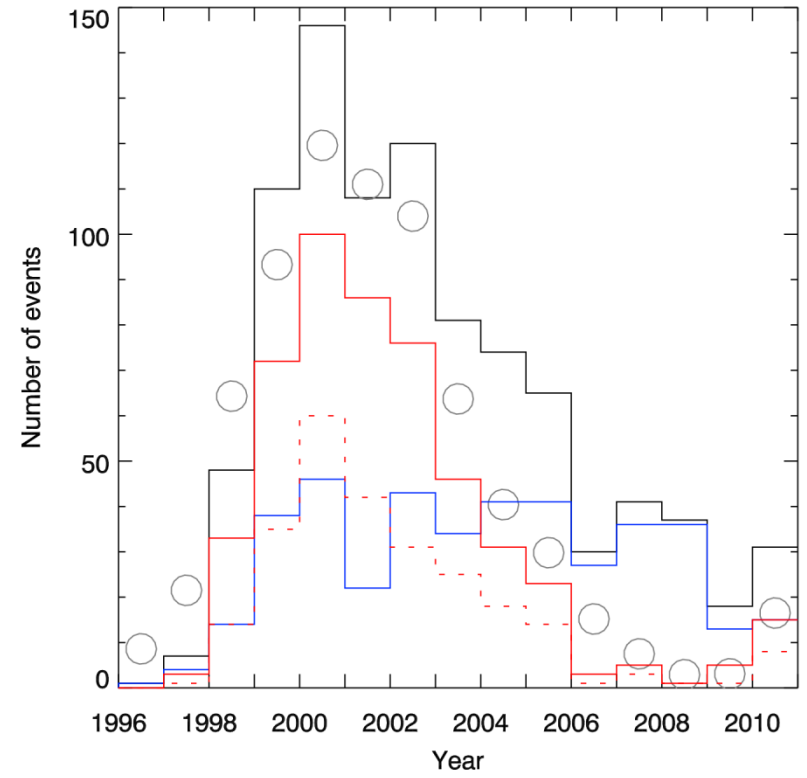


| | Period (h) | |
|---------------|------------|--------|
| | Average | Median |
| Quiet Sun | 13.3 | 14.2 |
| Active Region | 10.7 | 10.4 |
| Loops in AR | 10.6 | 10.3 |

Evolution with solar cycle



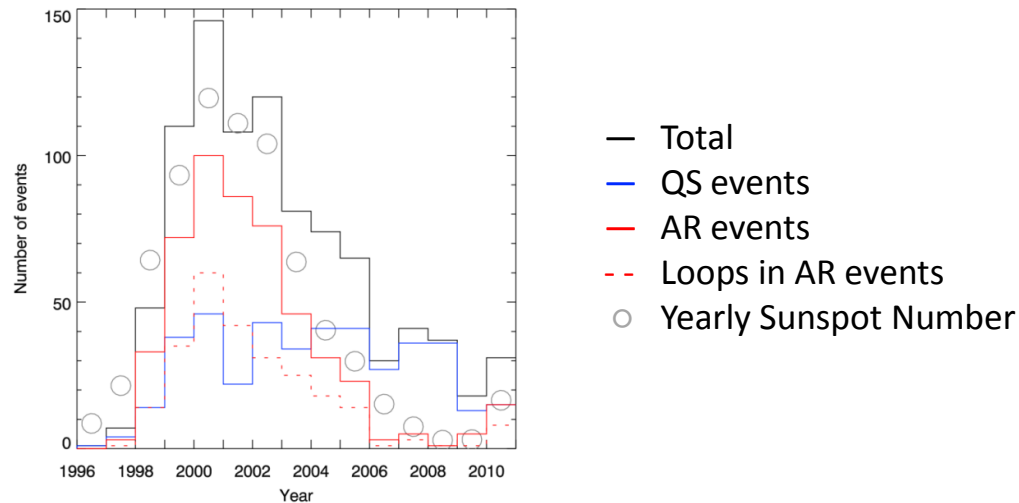
- QS events
- AR events
- Loops in AR events



- Total
- QS events
- AR events
- - - Loops in AR events
- Yearly Sunspot Number

A common phenomenon ?

- 499 AR events detected in active regions in 14 years
- Example: number of active regions in 2000 ?
 - ~480 NOAA sunspot groups
 - *50% recurring?*
 - → *240 distinct ARs*
 - Yearly SSN
 - → *150 distinct ARs*



- From 50 to 75% of ARs undergoes a pulsating event in its lifetime
- Is this the normal mode for Active Regions ?

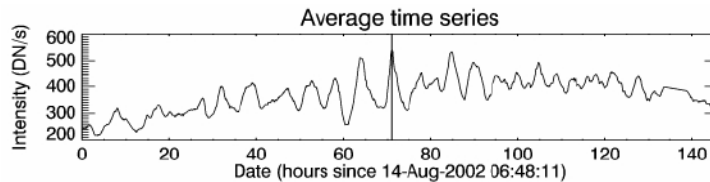
Interpretation

○ Waves?

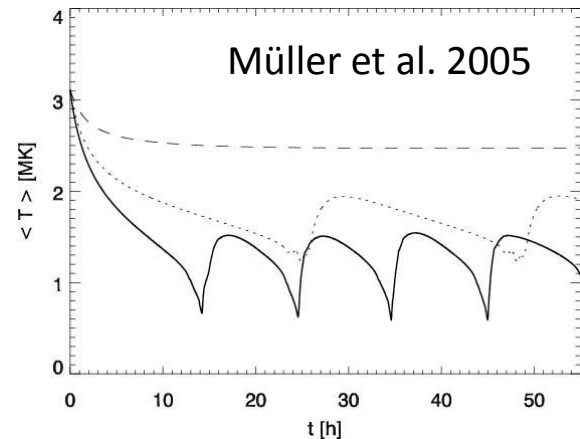
- Would have to be standing waves
- Loops lengths of 2400 Mm needed for periods of several hours ...
- Filaments MHD modes (e.g. Foullon et al. 2004) ? No association with filaments ...

○ Thermal non-equilibrium?

- Condensation-evaporation cycles (e.g. Karpen et al. 2001, Mok et al. 2008)



?=



○ Issues with thermal non equilibrium (Klimchuk et al. 2010)

- Models produce very localized brightenings in monolithic loops
- Observations show uniform loops
- Multithreaded loops improve the agreement with observations
- But how to create periods with multithreaded loops ?

Other ways ?

- Energy equation (constant pressure)

$$\rho C_p \frac{\partial T}{\partial t} = E_h - P_0^2 \chi_0 T^{-5/2} - \frac{\partial}{\partial s} \left(\kappa_0 T^{5/2} \frac{\partial T}{\partial s} \right)$$

Heating
Radiative losses
Conduction

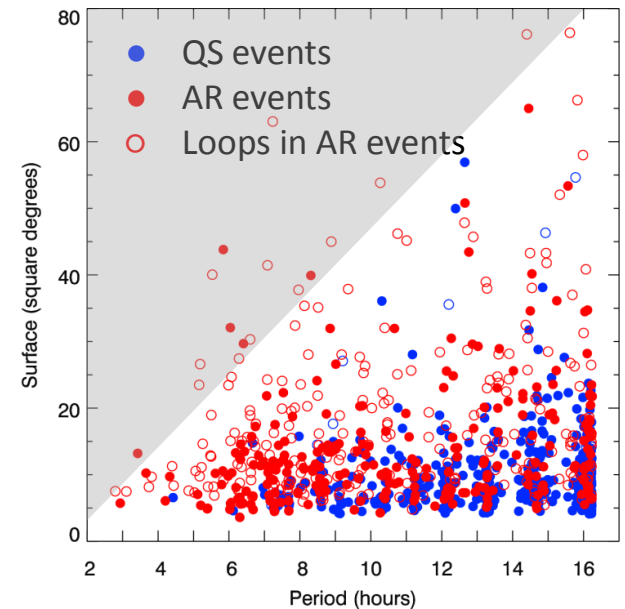
- Stationary case → à la Rosner - Tucker - Vaiana

$$E^0 \sim 10^{-6} T^{7/2} L^{-1} \text{ erg.cm}^{-2}.\text{s}^{-1}$$

- Perturbation around E^0 during $\Delta t < \tau_{cool}$ (pulse)

$$\tau_{cool} \sim 10^{-1} \frac{L}{\sqrt{T}} \sim \text{few hours}$$

- What forcing can produce cycles & with what periods ?
- Can the observed periods constrain the properties of the heating?



○ Summary

- 917 events found, **499 events in AR**, ≥ 254 associated with loops
- Periods between 2 and 16 hours
- Intensity variations $\sim 25\%$ and up
- Many of the events last for up to 6 days
- Unnoticed up to now because very slow
- NOT artifacts

○ Interpretation of the active region events ?

- Not waves
- Thermal non-equilibrium?
- Small perturbations around equilibrium?
 - Right characteristic times
 - Can we produce cycles?
 - Threads (if any) still need to be in phase

○

○ To be continued...

- What are the **411 QS events** ?
- Analyze in detail a few nice **AR events**
 - Tracking of individual loops (AIA)
 - Spectral diagnostics desirable (EIS?)
 - Help from modelers wanted!

