

# **Temporal and Frequency Variations of Flares observed by LYRA onboard of PROBA2**

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Discussion of Solar activities on 13 June 2010 based on temporal and frequency analysis of Zirconium (1-20nm) and Aluminum (17-80nm) channels of the LYRA instrument flown on board of PROBA

- INTRODUCTION TO PROBA2
- INTRODUCTION TO LYRA
- TEMPORAL ANALYSIS OF CX FLARE ON 2010-06-13
- FREQUENCY ANALYSIS OF SAME FLARE
  - INTRODUCTION TO WAVELET
  - WAVELET ANALYSIS OF LYRA DATA
  - FLARE RESULTS
- CONCLUSION AND DISCUSSION

LYRA EUV channels are suitable for flare analysis in time domain. Some flares show oscillations during impulsive phase, e.g. 0.1Hz and 0.014Hz for the 2010-06-13 flare

# PROBA2 – in a nutshell



Built as part of ESA's PRoject for OnBoard Autonomy  
Launched on 2<sup>nd</sup> November 2010 into Earth – sun  
synchronous - orbit

## Spacecraft

- Dimension: 80x70x60cm
- Mass: 120kg, of which 35 for payload
- Highly autonomous
- ~720km altitude
- sun-pointing

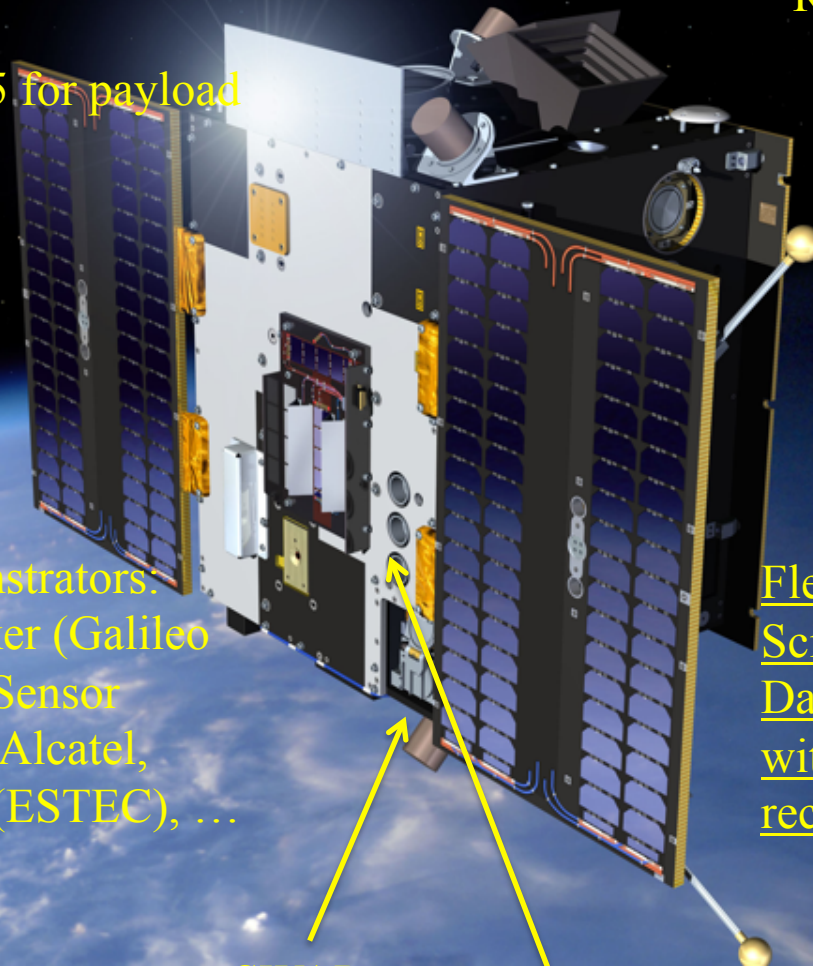
## Technology Demonstrators

17 technological demonstrators:  
BepiColombo star tracker (Galileo  
Avionica), Digital Sun Sensor  
(TNO), GPS Receiver (Alcatel,  
DLR), Laser Reflector (ESTEC), ...

## Ground Segment

- Mission Operations  
Centre located at Redu
- ~10 daily passes from  
Redu or Svalbard (S-band)

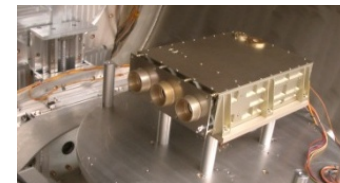
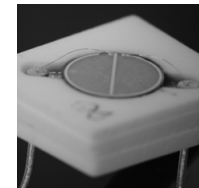
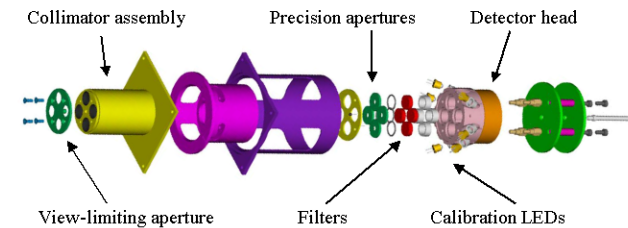
Flexible commanding at  
Science Centre (P2SC)  
Data processing at P2SC  
within 30-45min after data  
reception.



# Large Yield Radiometer (LYRA)



- 3 Units, each with 4 channels:  
Lyman-Alpha 121.6nm, Herzberg  
200-220nm, Aluminum 17-80nm,  
Zirconium 1-20nm
- Unit 2 is operated continuously at 20  
Hz (100Hz demonstrated), Unit1 and  
Unit3 for calibration purpose and  
dedicated campaigns

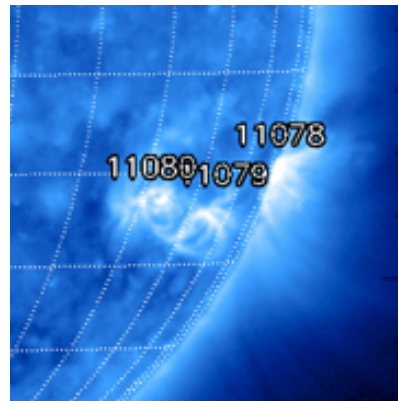
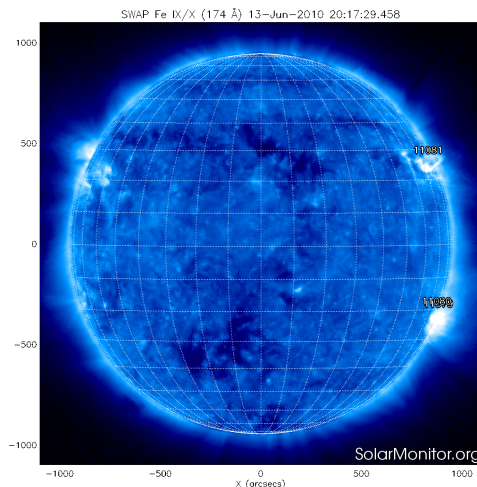
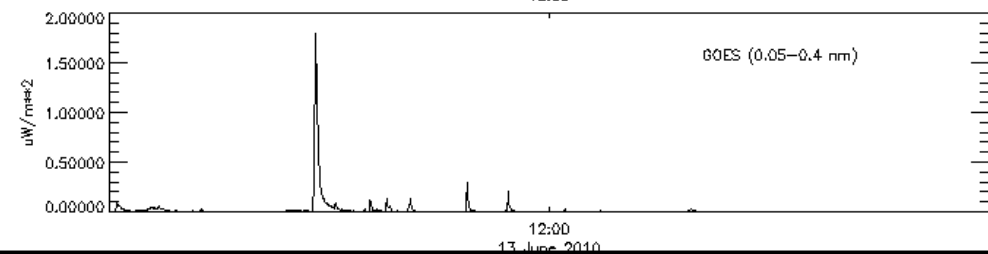
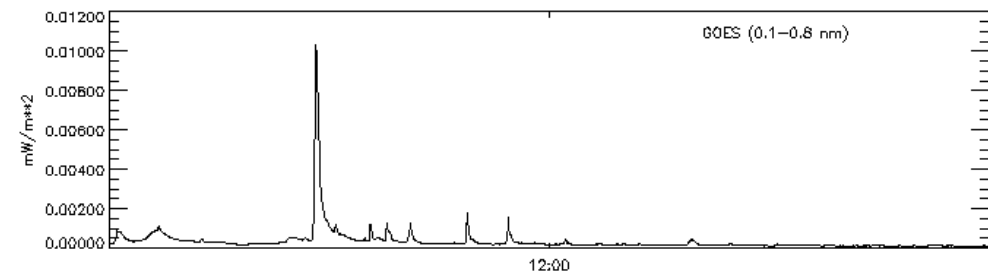
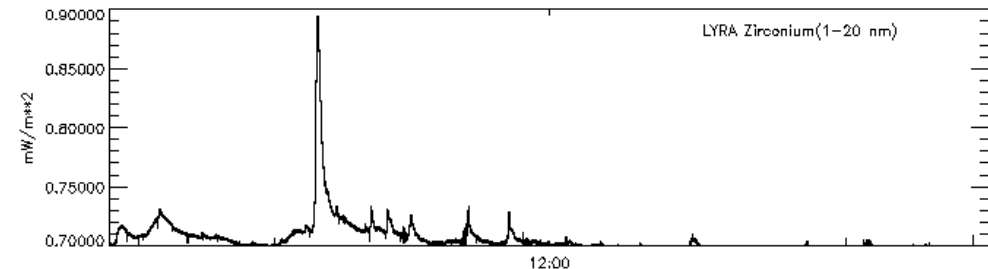
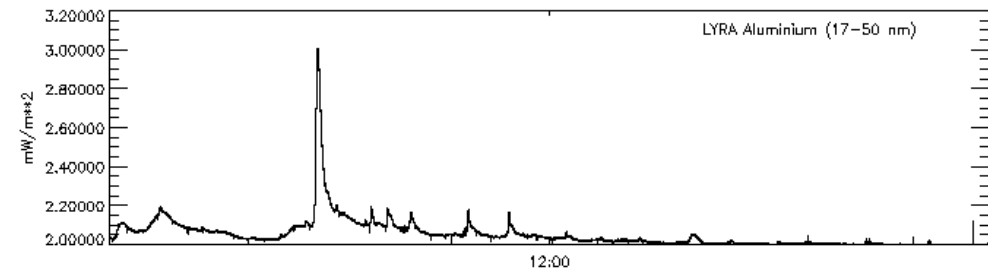


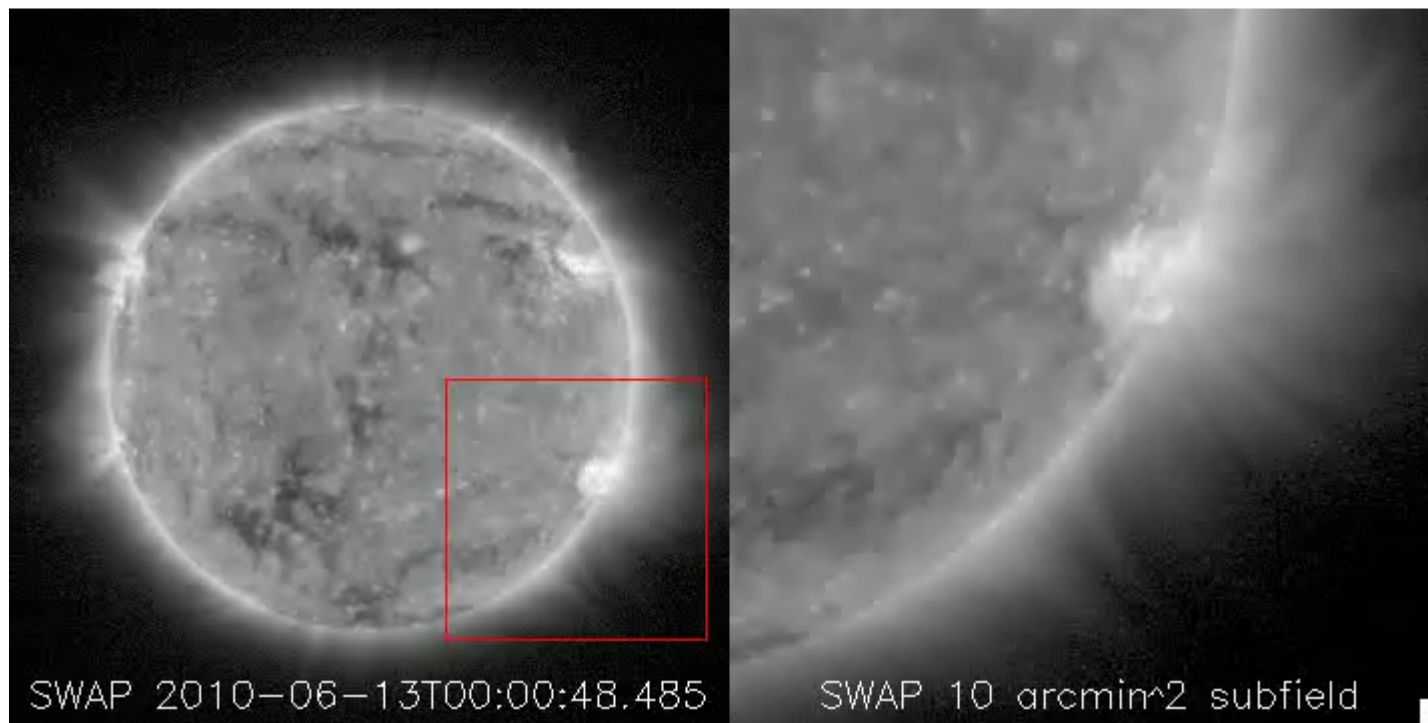
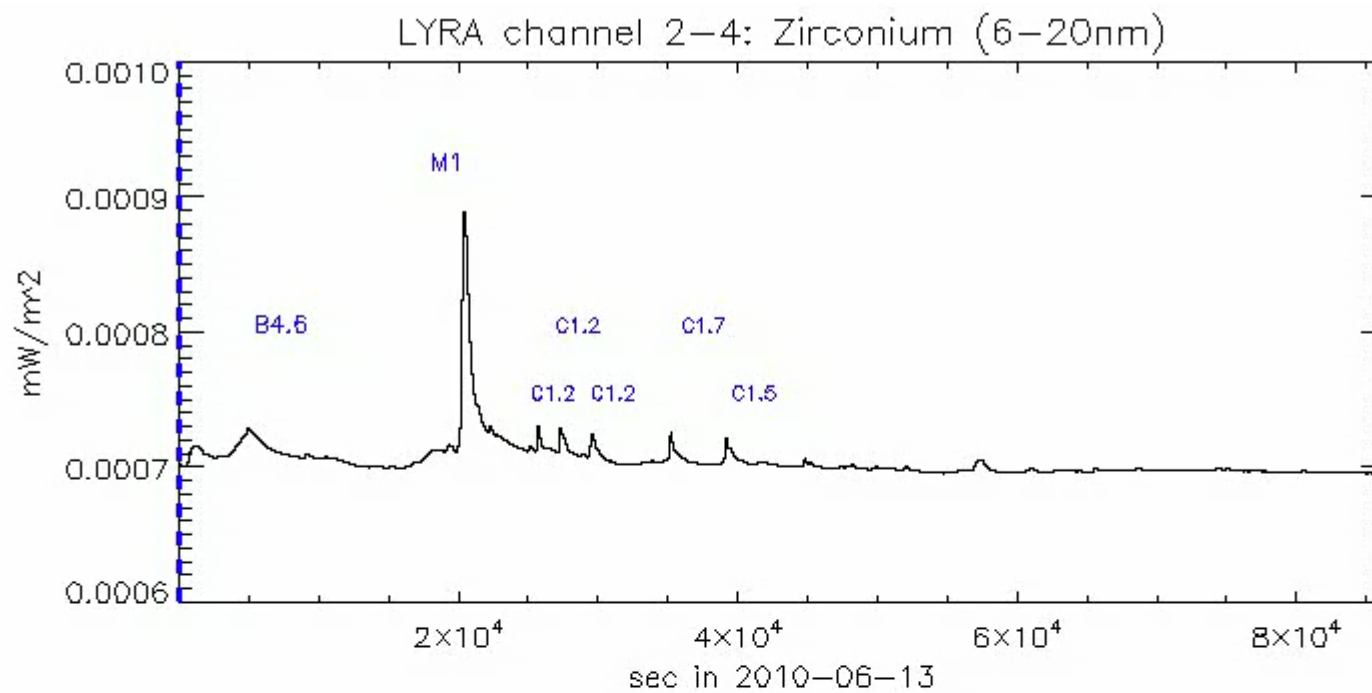
# Events on 13 June 2010



Several flares were observed by LYRA

2010/06/13 00:06:00-00:26:00	B8.8	1079
2010/06/13 02:28:00-02:35:00	B4.6	1079
2010/06/13 05:30:00-05:44:00	M1.0	1079
2010/06/13 06:08:00-06:13:00	C1.2	1081
2010/06/13 06:55:00-07:00:00	B5.3	1081
2010/06/13 07:05:00-07:10:00	C1.2	1080
2010/06/13 07:31:00-07:38:00	C1.2	1079
2010/06/13 08:06:00-08:16:00	C1.2	1081
2010/06/13 09:41:00-09:48:00	C1.7	1081
2010/06/13 10:47:00-10:55:00	C1.5	1081
2010/06/13 12:24:00-12:29:00	B4.3	1081
2010/06/13 13:20:00-13:26:00	B2.5	1081
2010/06/13 14:24:00-14:30:00	B2.4	1081
2010/06/13 15:45:00-15:59:00	B4.2	1081
2010/06/13 18:10:00-18:17:00	B1.8	1081







# Temporal Analysis of M1.0 Flare



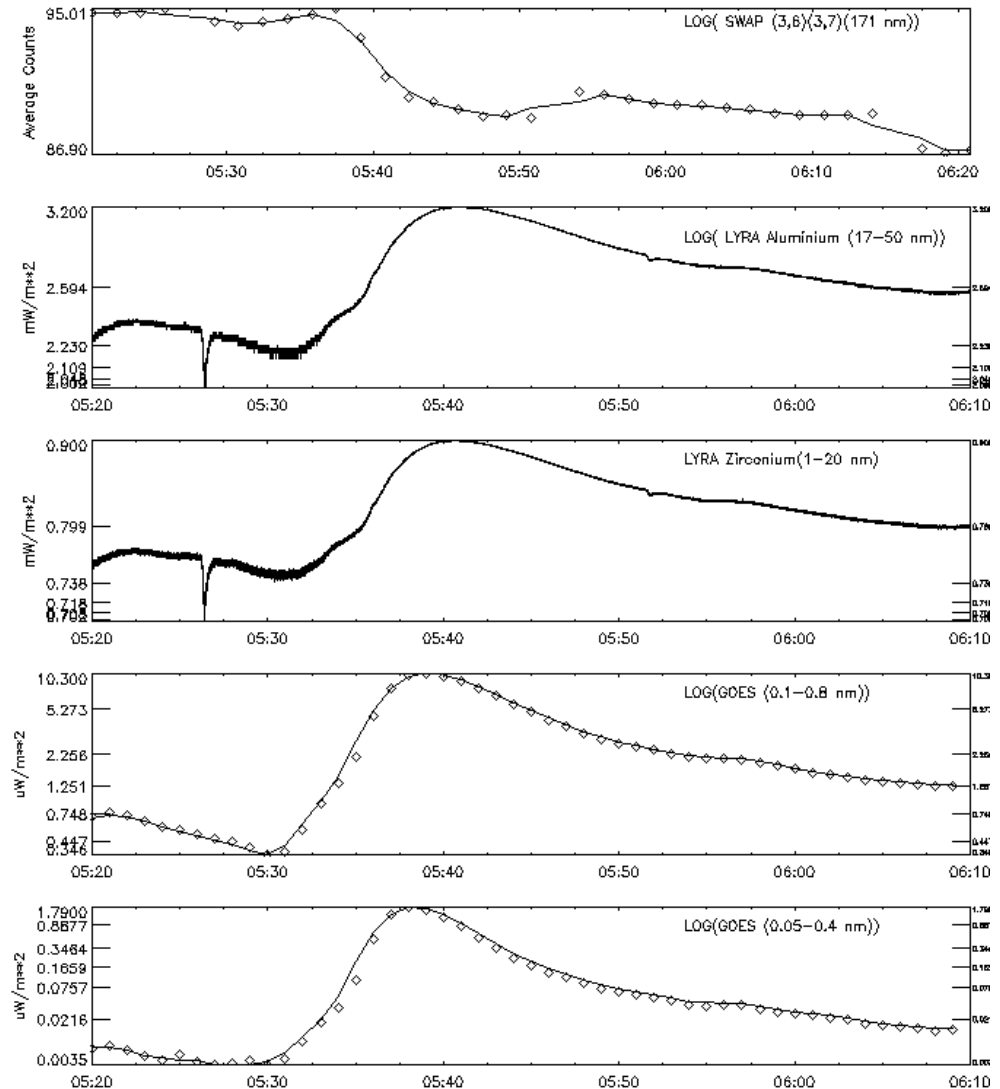
R1: summed average of SWAP 17.4 nm over AR1079 (also including AR1078 and AR1080)

R2: LYRA Aluminum: 17-80nm

R3: LYRA Zirconium: 1-20nm

R4: GOES long wavelength 0.1-0.8nm

R5: GOES short wavelength 0.05-0.4nm



# Frequency Analysis of Flares using Wavelet

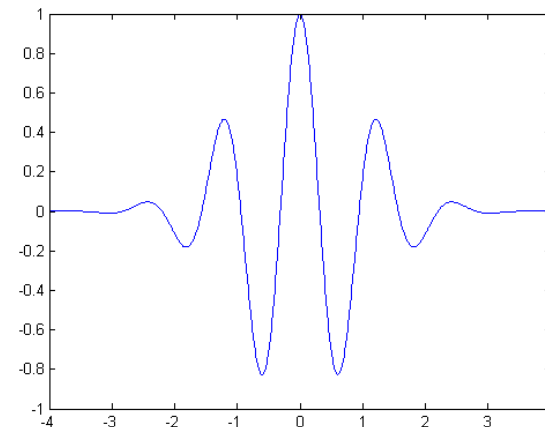


The continuous wavelet transform of a discrete sequence  $x_n$  is defined as the convolution of  $x_n$  with a scaled and translated version of  $\psi_0(\eta)$ :

$$W_n(s) = \sum_{n'=0}^{N-1} x_{n'} \Psi^* \left[ \frac{(n' - n)\delta t}{s} \right]$$

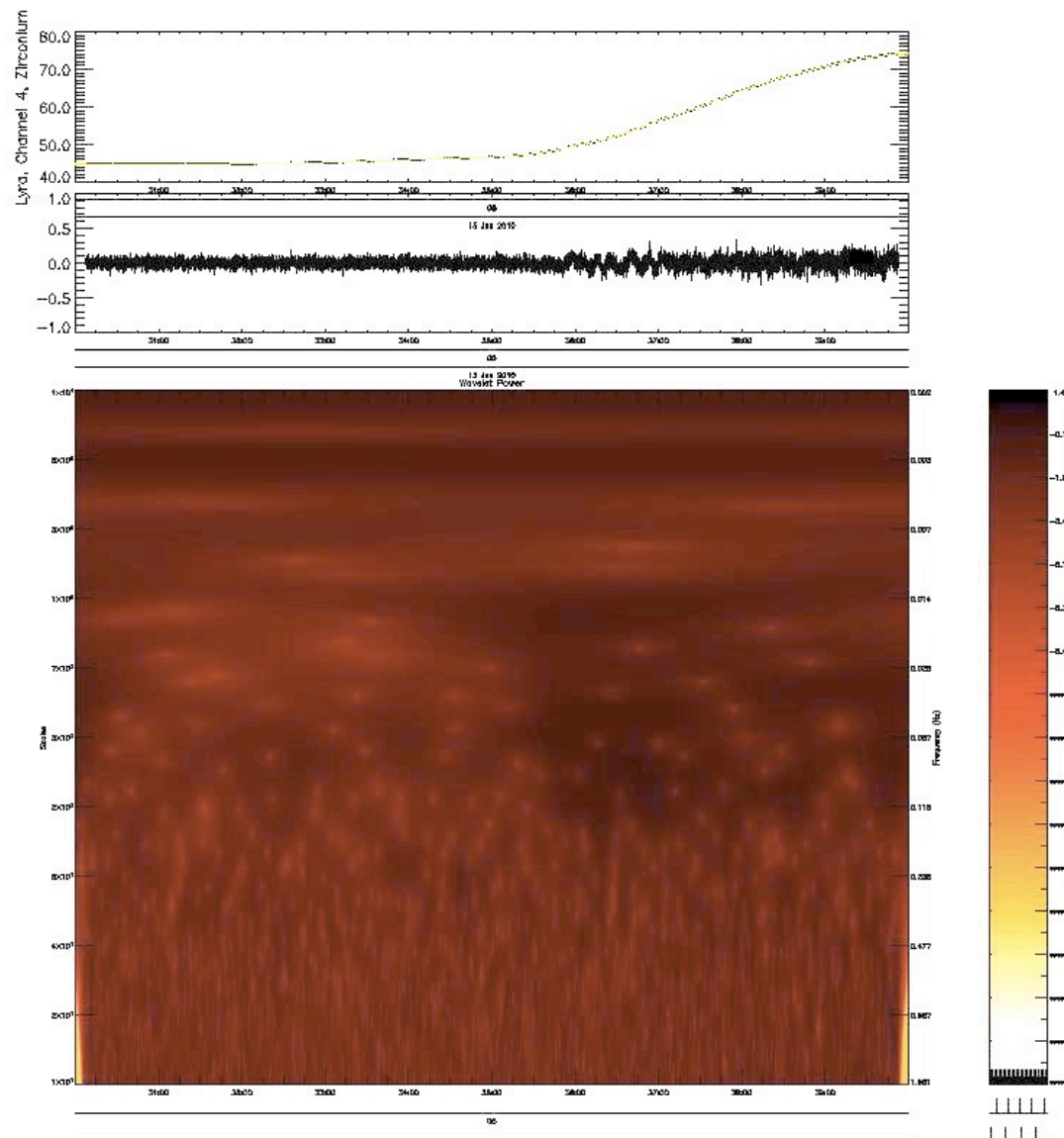
By varying the wavelet scale  $s$  and translating along the localized time index  $n$ , one can construct a picture showing both the amplitude of any features versus the scale and how this amplitude varies in time.

Several motherwavelets were analyzed and for no specific reasons, we selected the Morlet wavelet for our analysis.

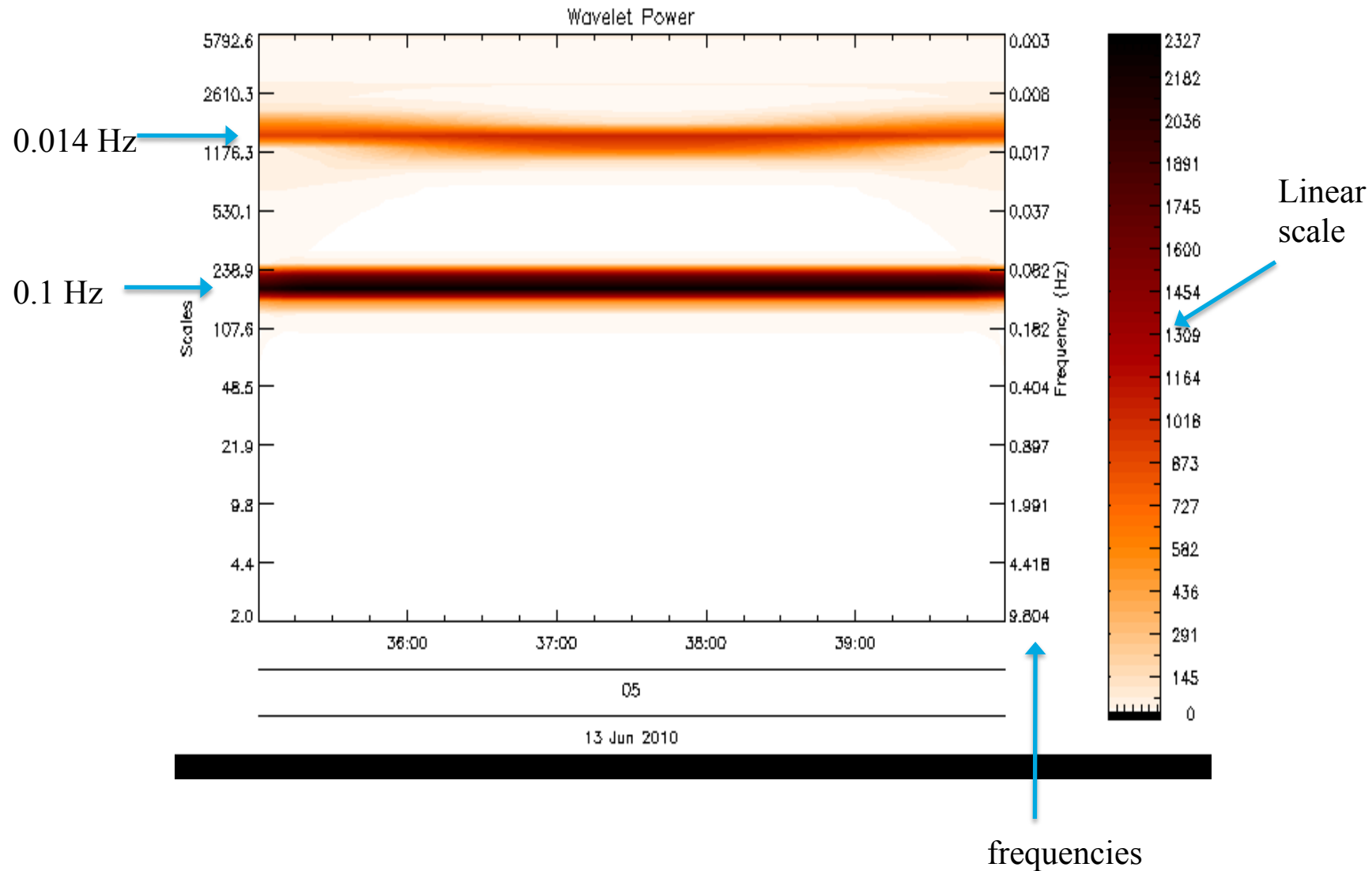




# Wavelet of M1.0 flare



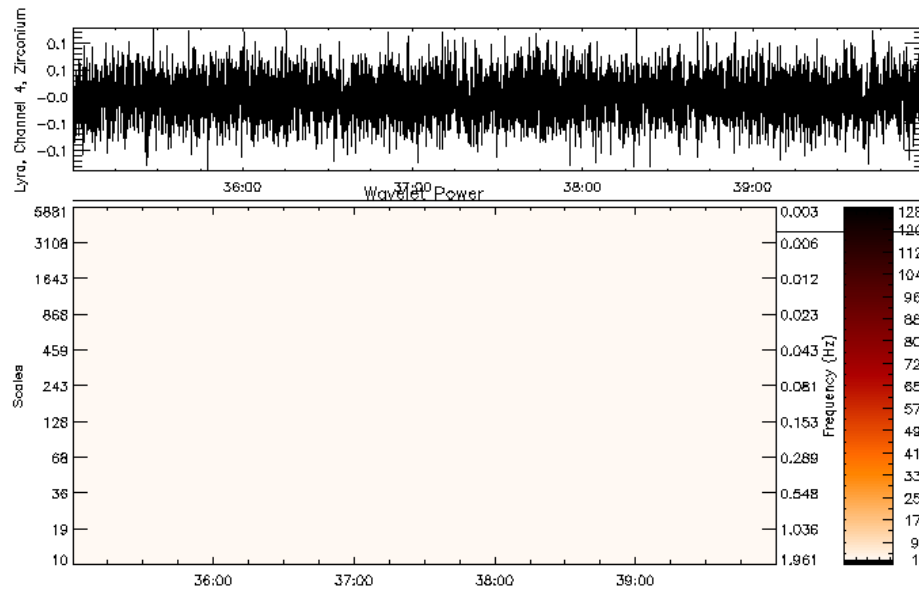
# Wavelet Training I: Two Frequencies



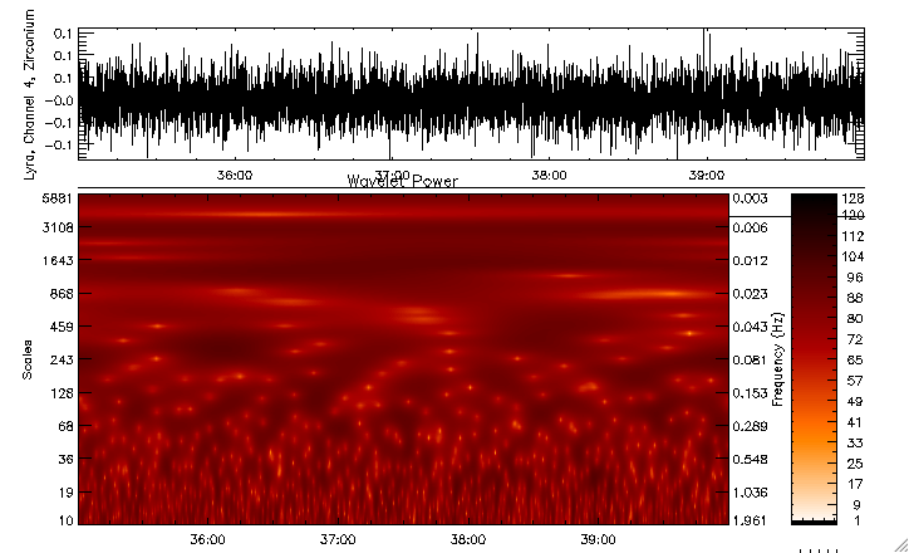
# Wavelet Training II: noise



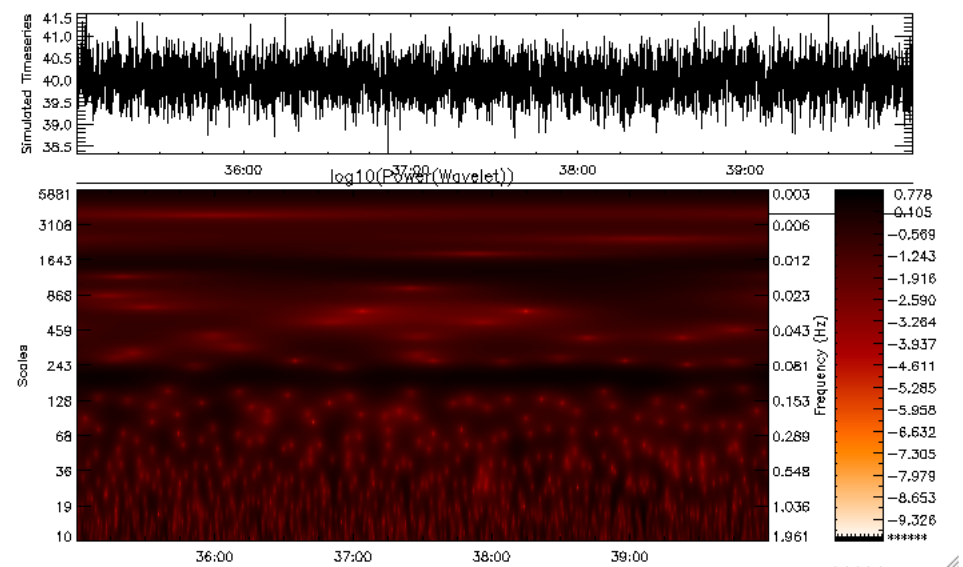
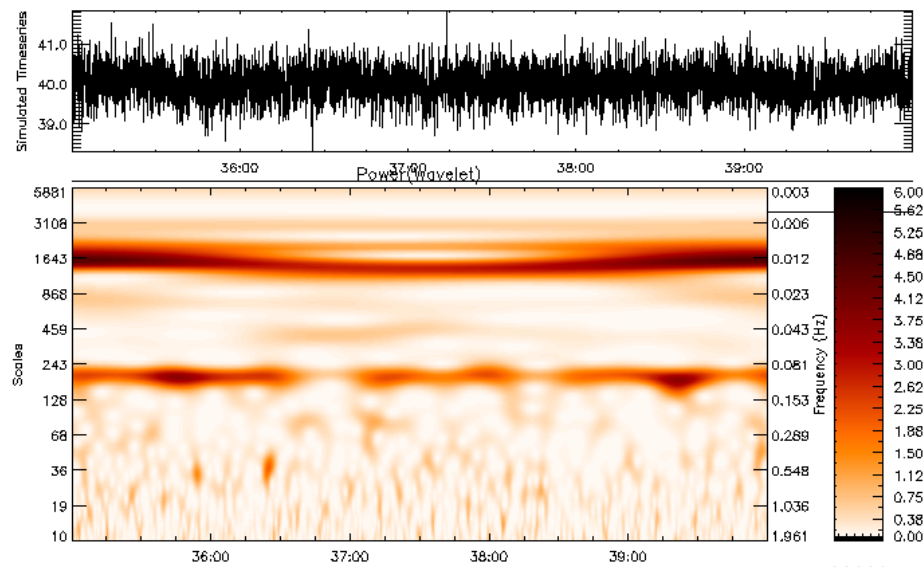
Z-axis plotted in linear scale



Z-axis plotted in log10 scale



# Wavelet Training III: frequencies + noise



## Frequency Analysis of M1.0 Flare using Wavelet Analysis

Plots in 10 minutes interval

05:10 – 05:20

05:20 – 05:30

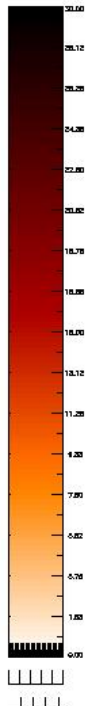
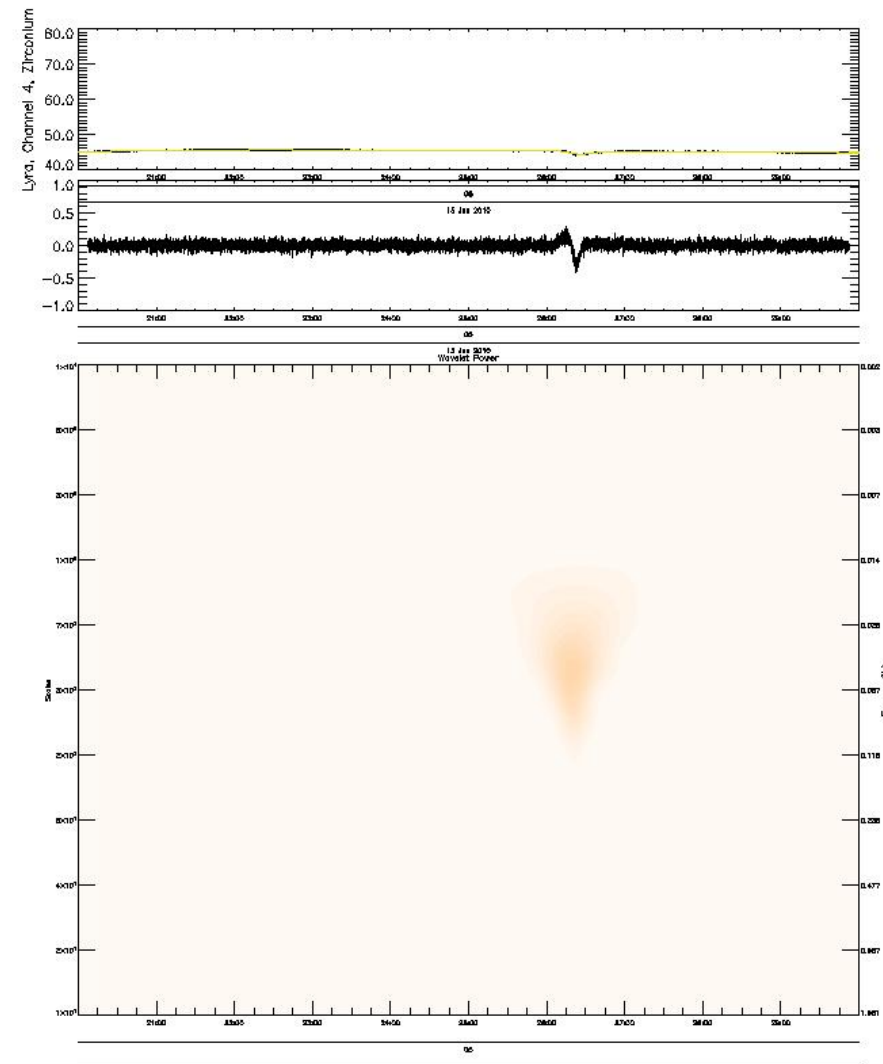
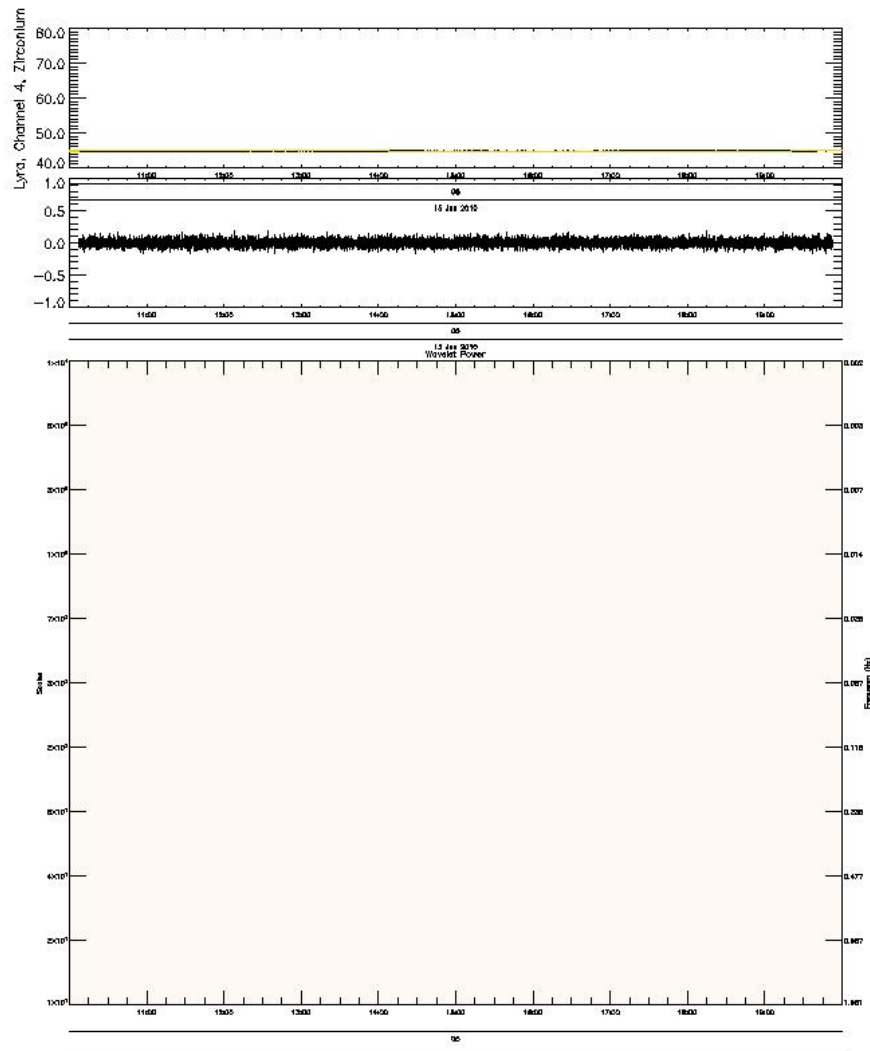
05:30 – 05:40

05:40 – 05:50

All x-scales and y-scales and z-scales are identical over the plots.

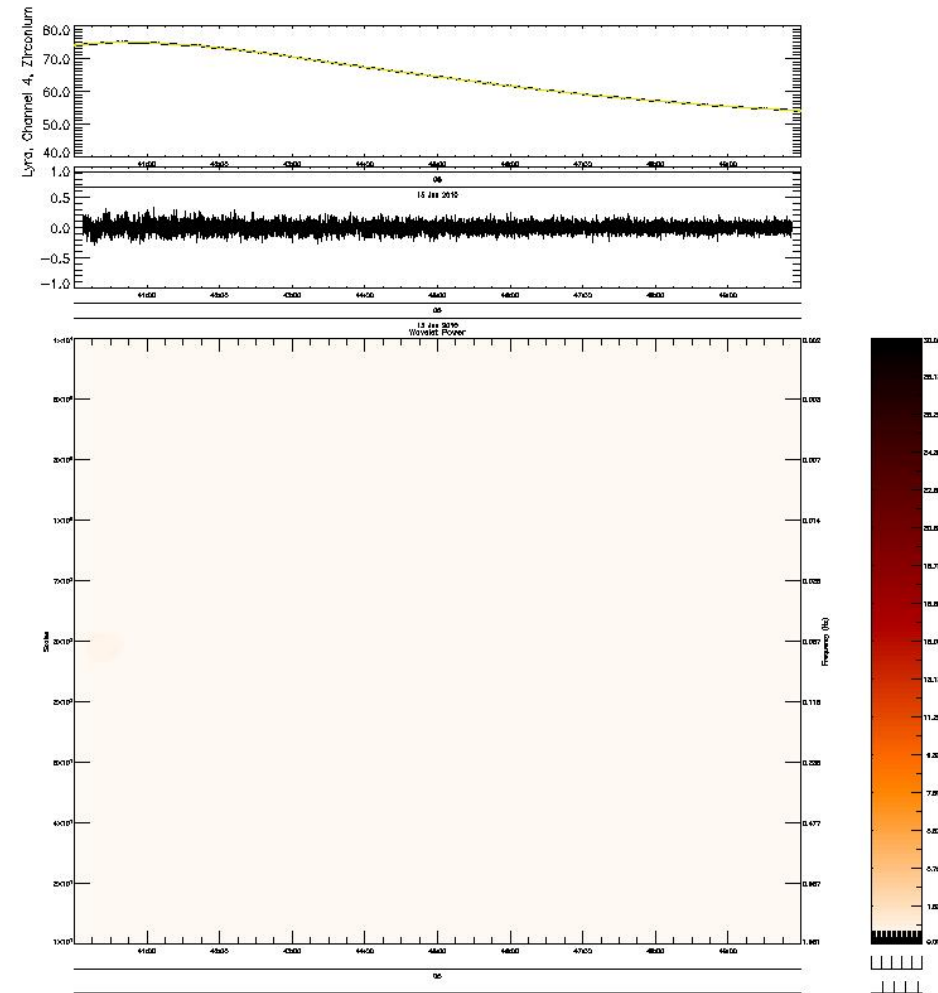
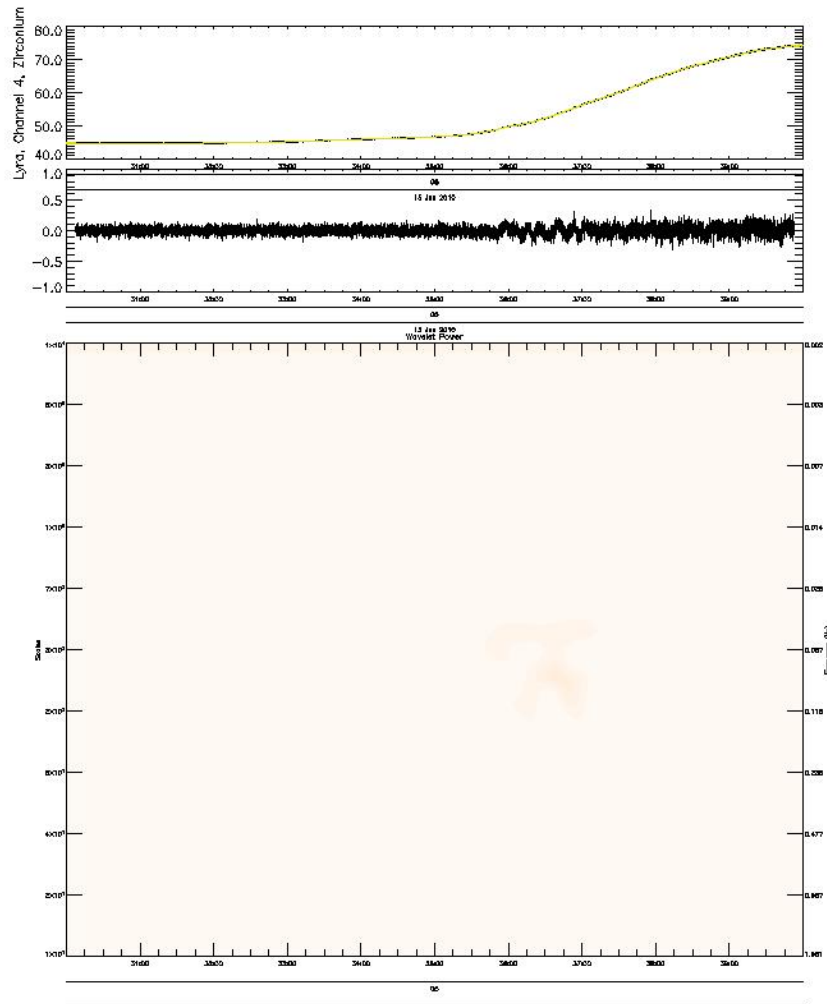
05:10 – 05:20

05:20 – 05:30



05:30 – 05:40

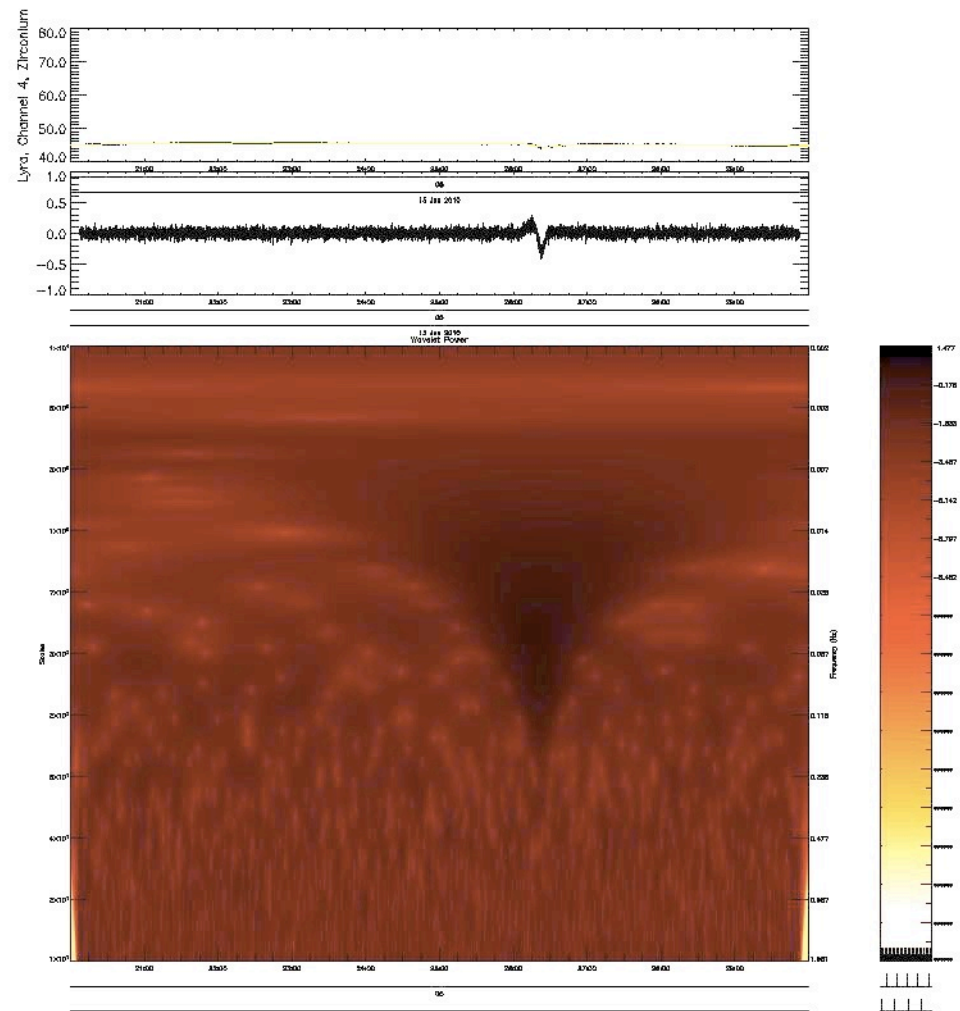
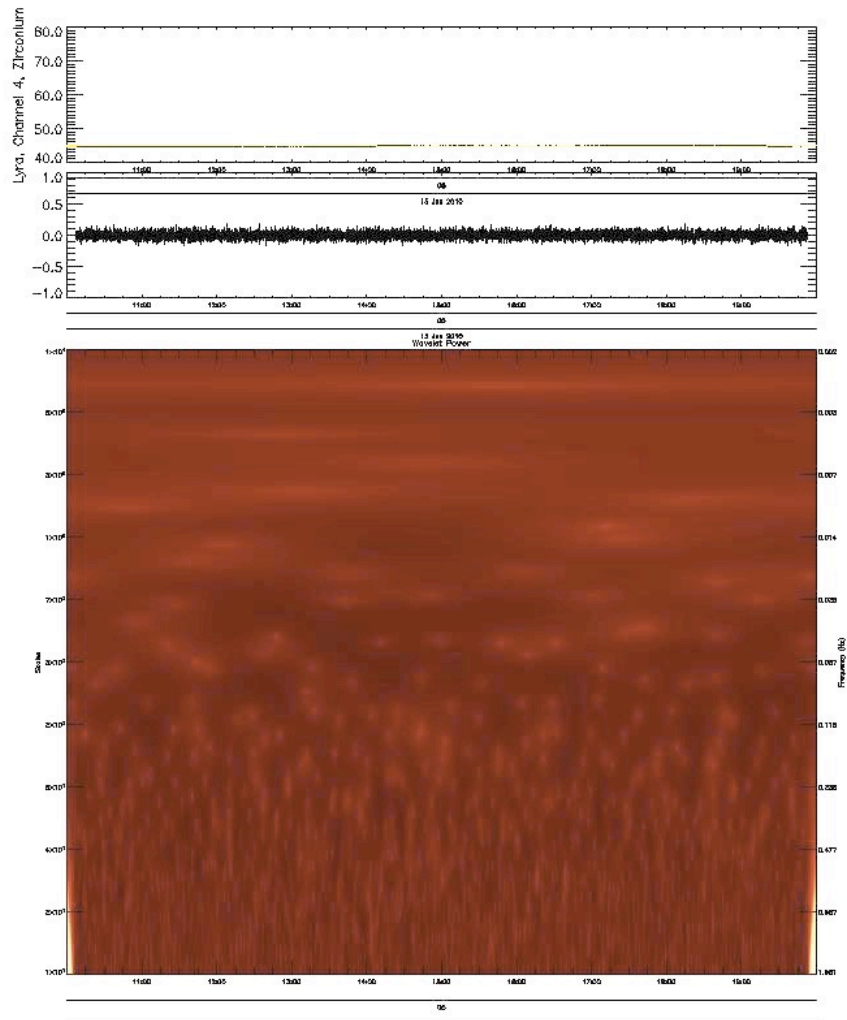
05:40 – 05:50





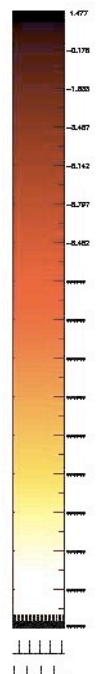
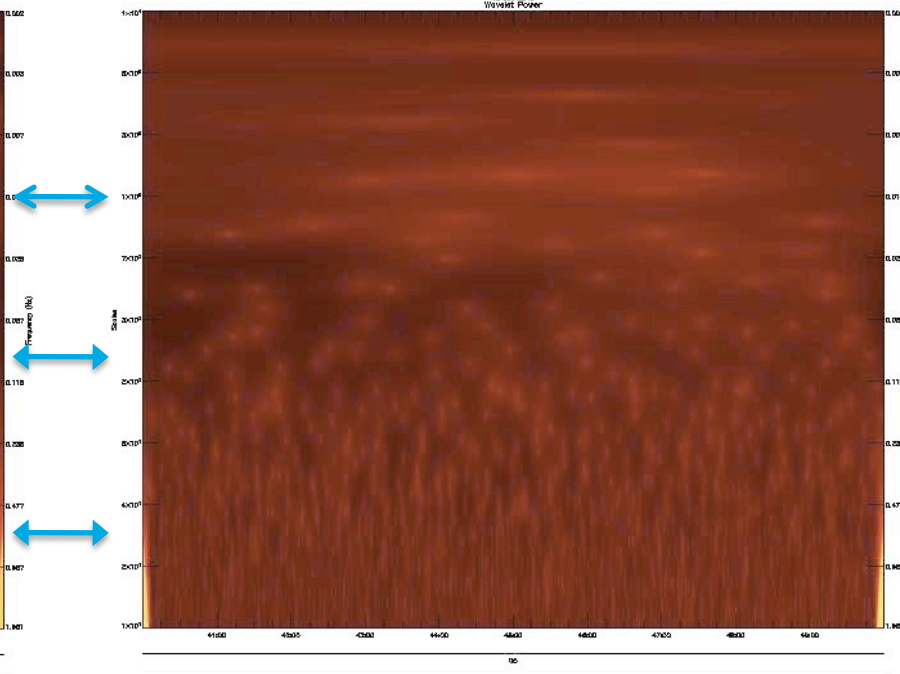
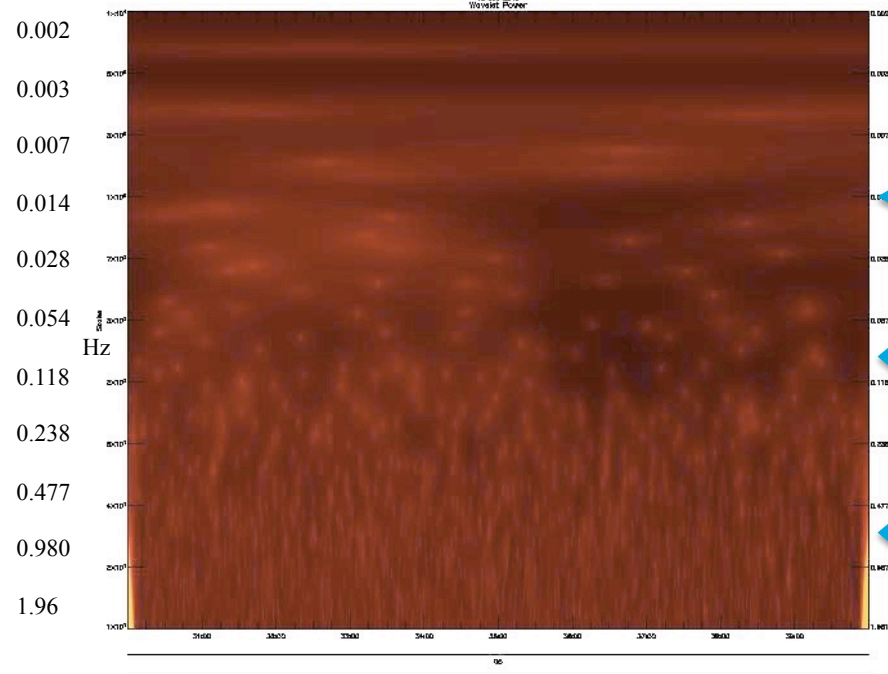
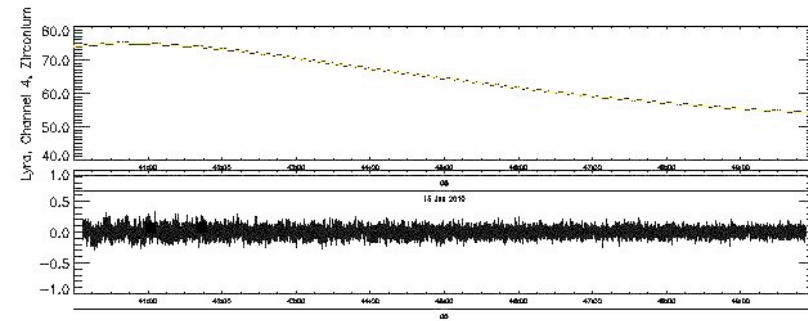
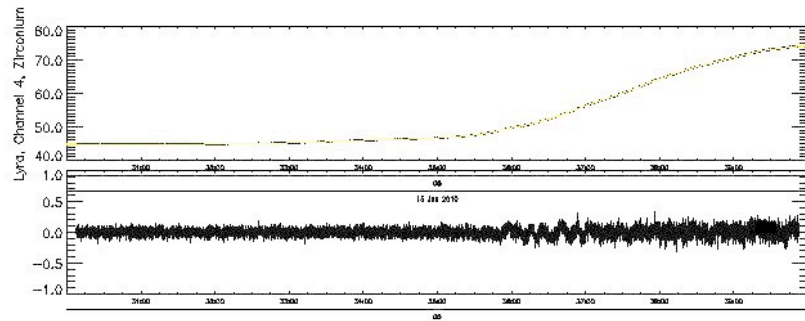
05:10 – 05:20

05:20 – 05:30



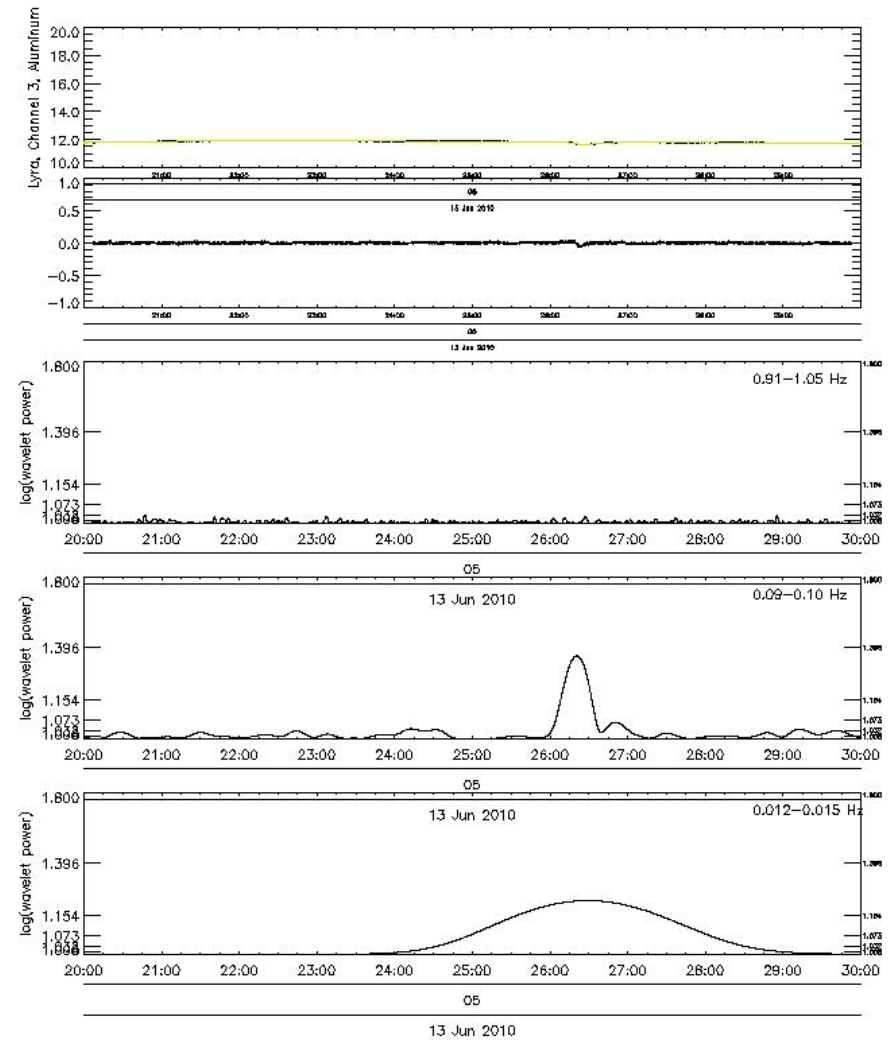
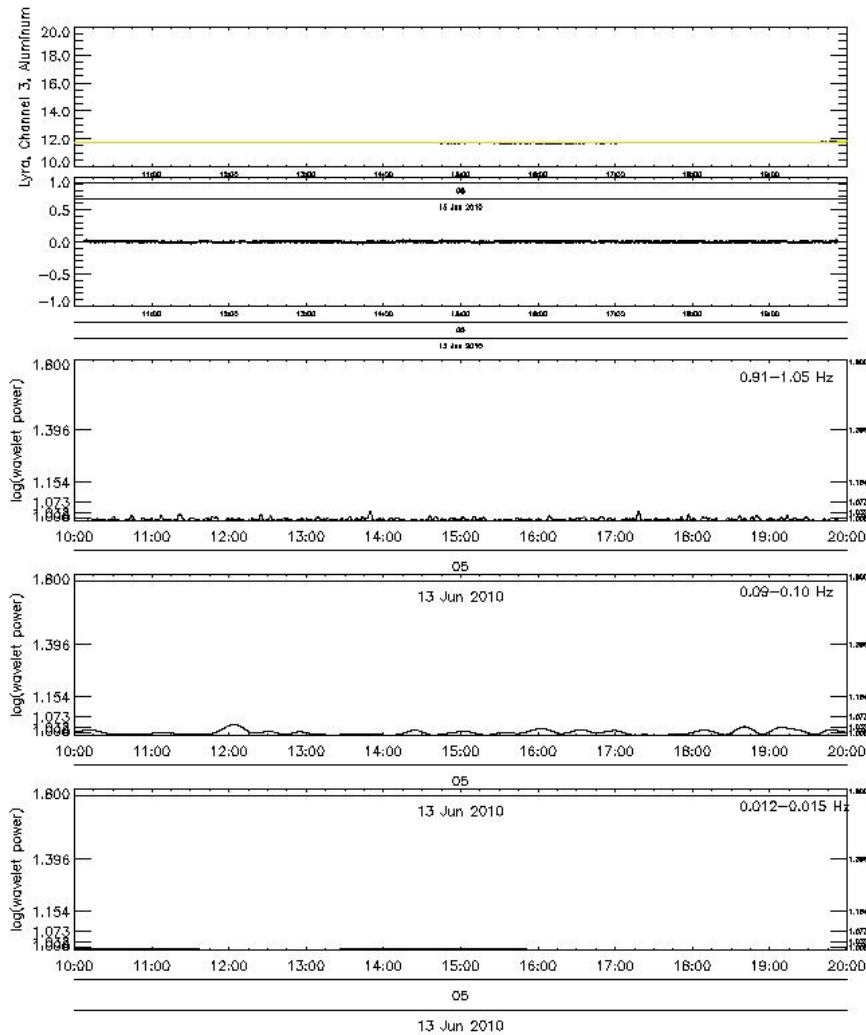
05:30 – 05:40

05:40 – 05:50



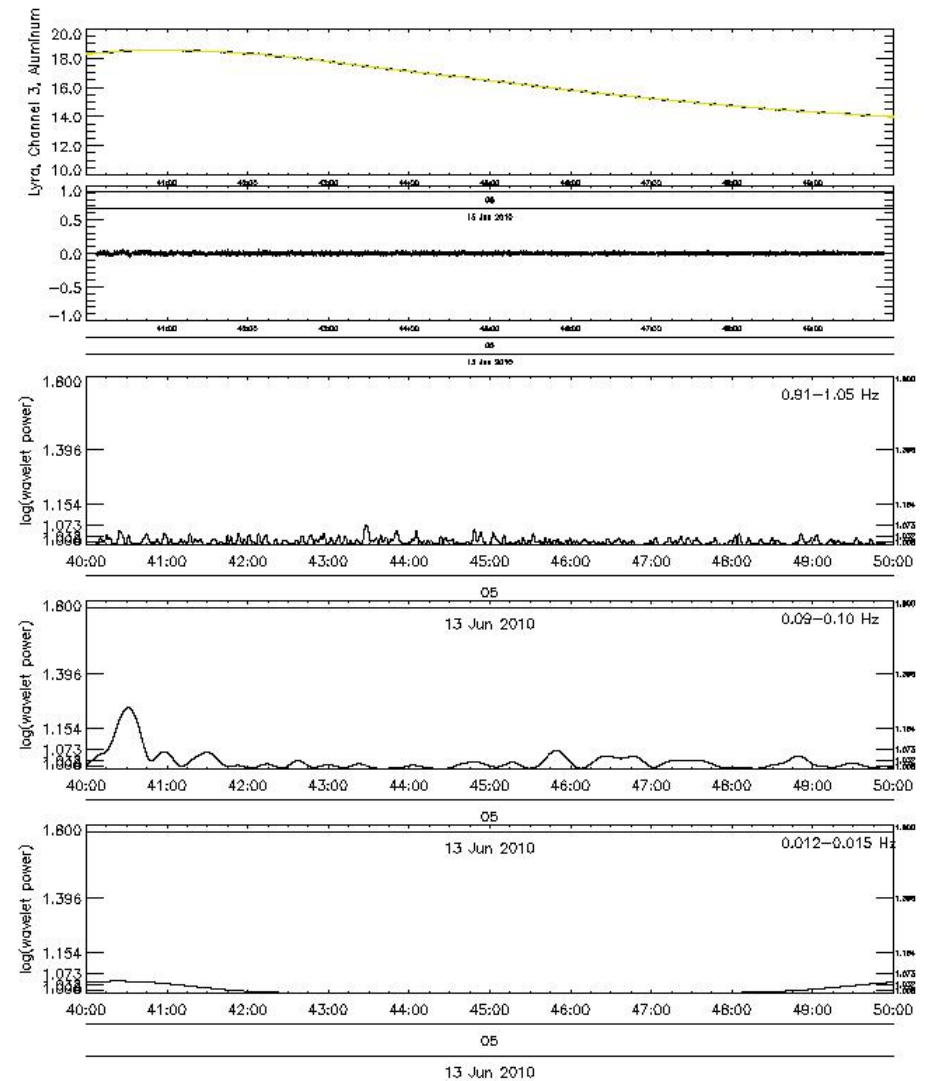
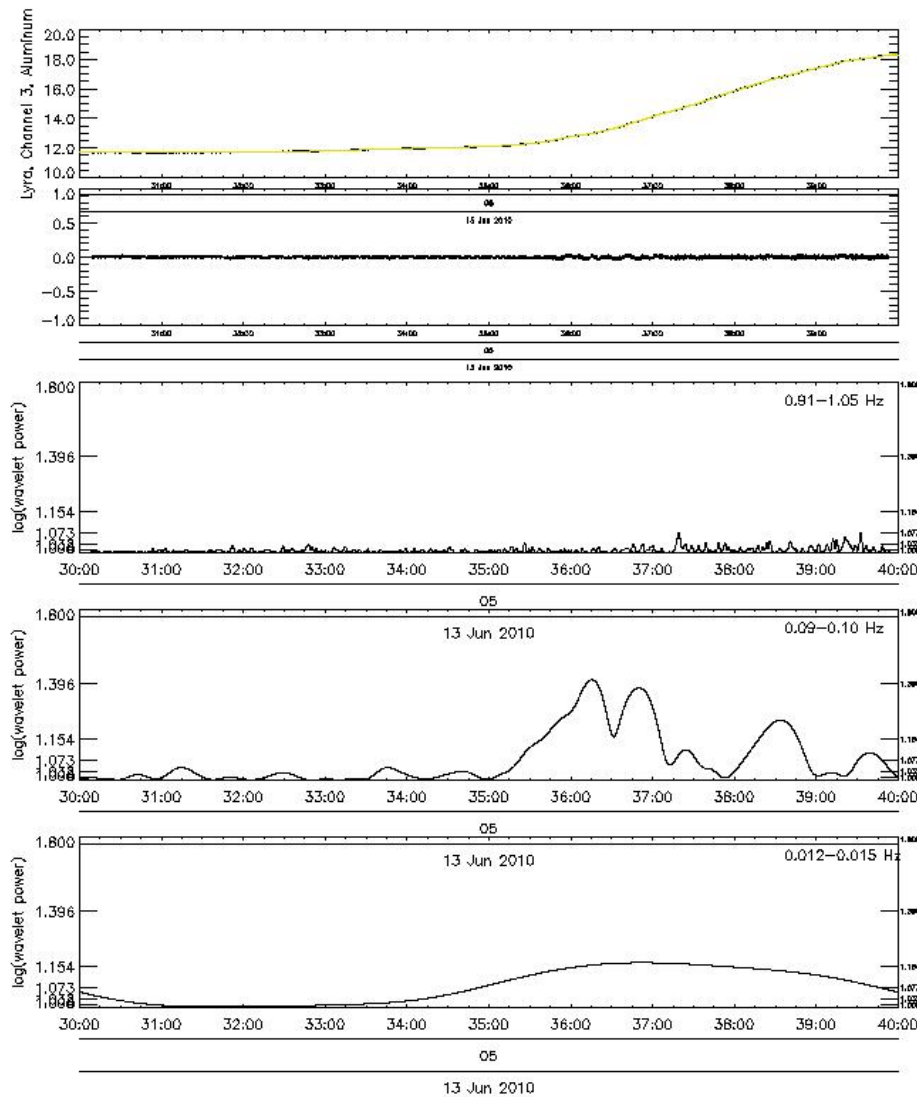
05:10 – 05:20

05:20 – 05:30



05:30 – 05:40

05:40 – 05:50



- LYRA EUV channel time series (Zirconium, Aluminum) suitable for analysis of solar events
- Frequency analysis
  - No frequencies components/oscillations higher than 0.1/0.2 Hz found so far, but can not be excluded -> more analysis needed
  - Oscillations found at 0.1 Hz and 0.014 Hz
    - No indication that these components could be caused by instrumental or spacecraft effects
    - Components detected for other flares, but are very seldom
    - For the observed flare, there were 3 active regions near the limb, so it can not be excluded that the oscillations are caused by superposition of several events
    - It's likely however that the observed oscillations are caused by
      - Geometry: e.g. energy released in different directions and these are seen as oscillations
      - Energy: e.g. physical processes at chromosphere
      - Energy: e.g. energy loss during electron and ion evolution through corona