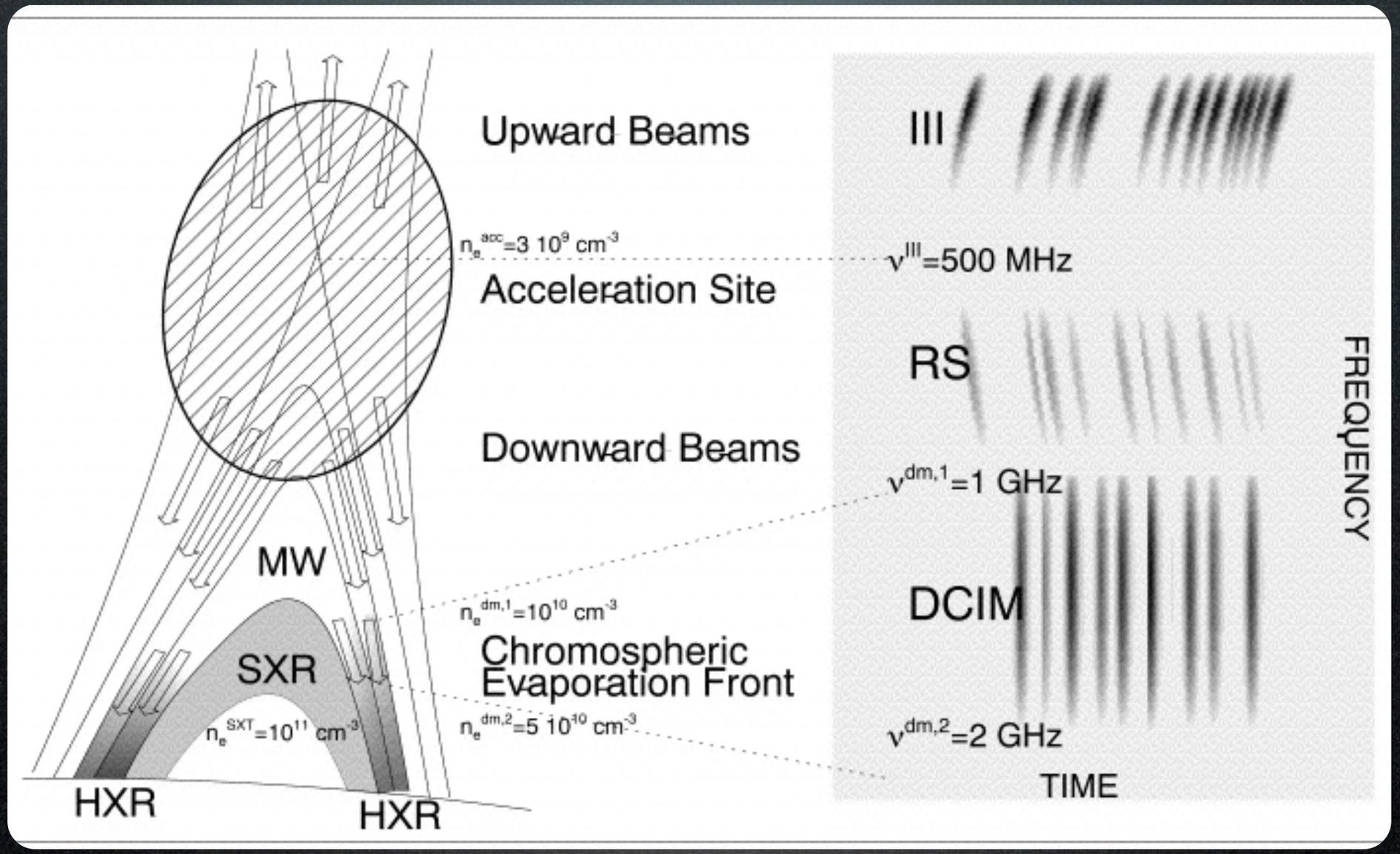
Connectivity in the solar EUV irradiance.

Anatoliy Vuets[1], Thierry Dudok de Wit [1].

1) LPC2E, CNRS and University of Orléans

Energy propagation in flare events



Aschwanden et al, 2001

Tools that’ve been used so far

- Fourier analysis
- Wavelet analysis
- Correlation analysis

All these methods provide
UNDIRECTED connectivity
estimations.

Introducing the Granger causality

How can we estimate the directed empirical relationships between a system outputs?

A variable X_2 'Granger causes' variable X_1 if information about the past of X_2 helps predict the future of X_1:

CG = $\ln(\xi_R/\xi_U)$

$$X_1(t) = \sum_{j=1}^{p} A_{11,j} X_1(t-j) + \xi_R(t)$$

$$X_1(t) = \sum_{j=1}^{p} A_{21,j} X_1(t-j) + \sum_{j=1}^{p} A_{22,j} X_2(t-j) + \xi_U(t)$$

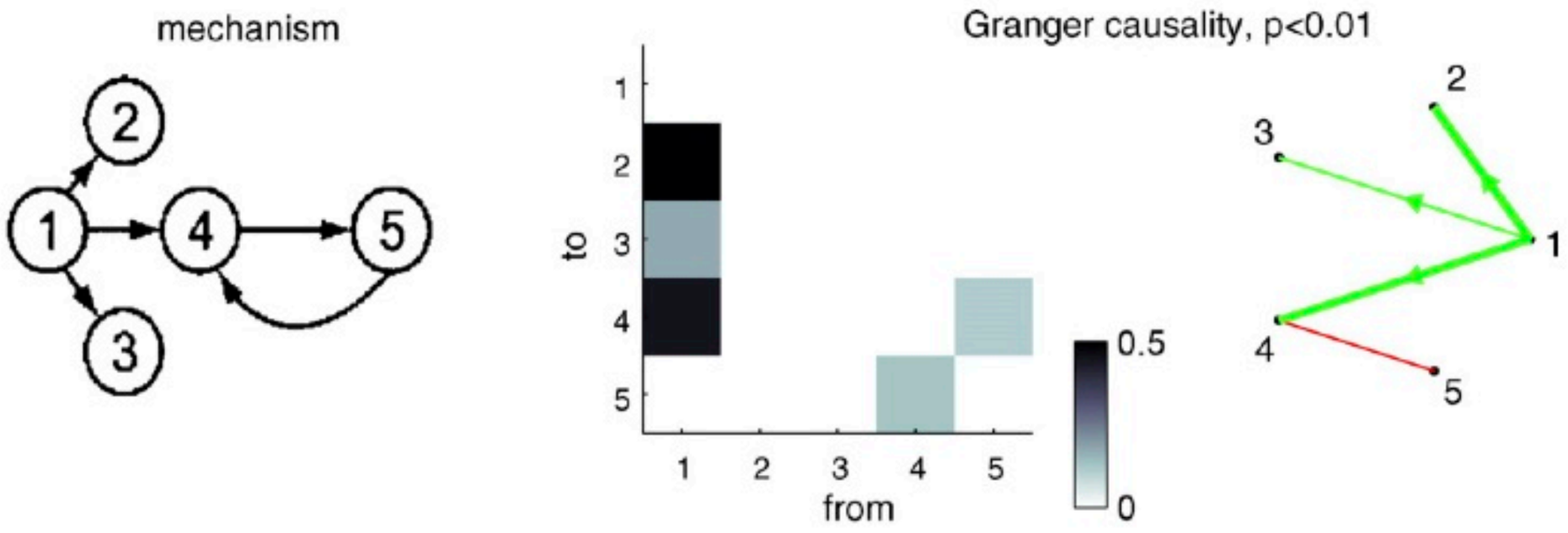
$$\mathcal{F}_{2\to 1} = \ln \frac{\mathrm{var}(\xi_R)}{\mathrm{var}(\xi_U)}$$

A brief example

Model

$$
\begin{aligned}
x_1(t) &= 0.95\sqrt{2}x_1(t-1) - 0.9025x_1(t-2) + w_1(t) \\
x_2(t) &= 0.5x_1(t-2) + w_2(t) \\
x_3(t) &= -0.4x_1(t-3) + w_3(t) \\
x_4(t) &= -0.5x_1(t-2) + 0.25\sqrt{2}x_4(t-1) + 0.25\sqrt{2}x_5(t-1) + w_4(t) \\
x_5(t) &= -0.25\sqrt{2}x_4(t-1) + 0.25\sqrt{2}x_5(t-1) + w_5(t)
\end{aligned}
$$

Results

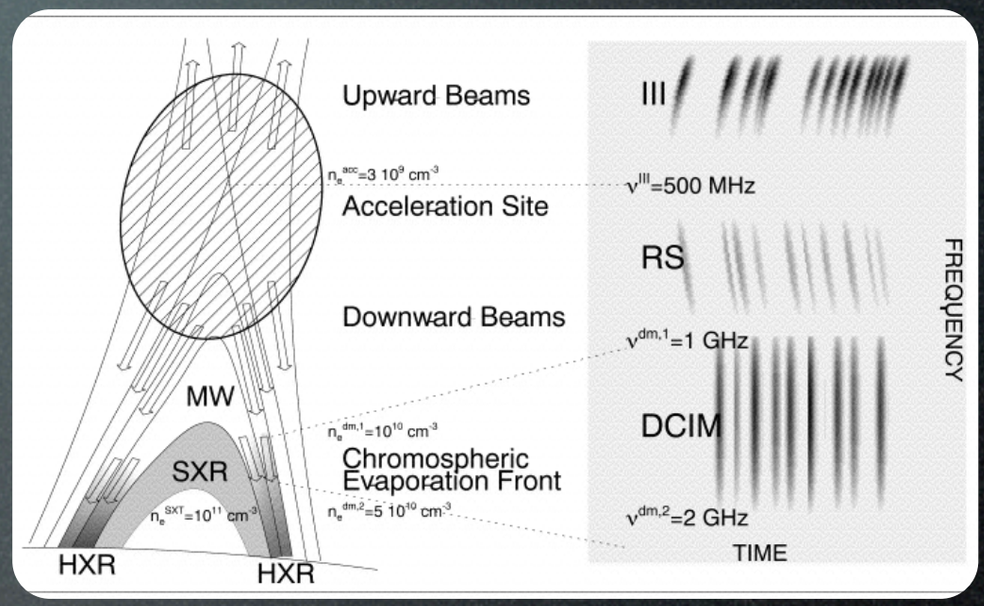


Seth, 2010

Description of our investigation

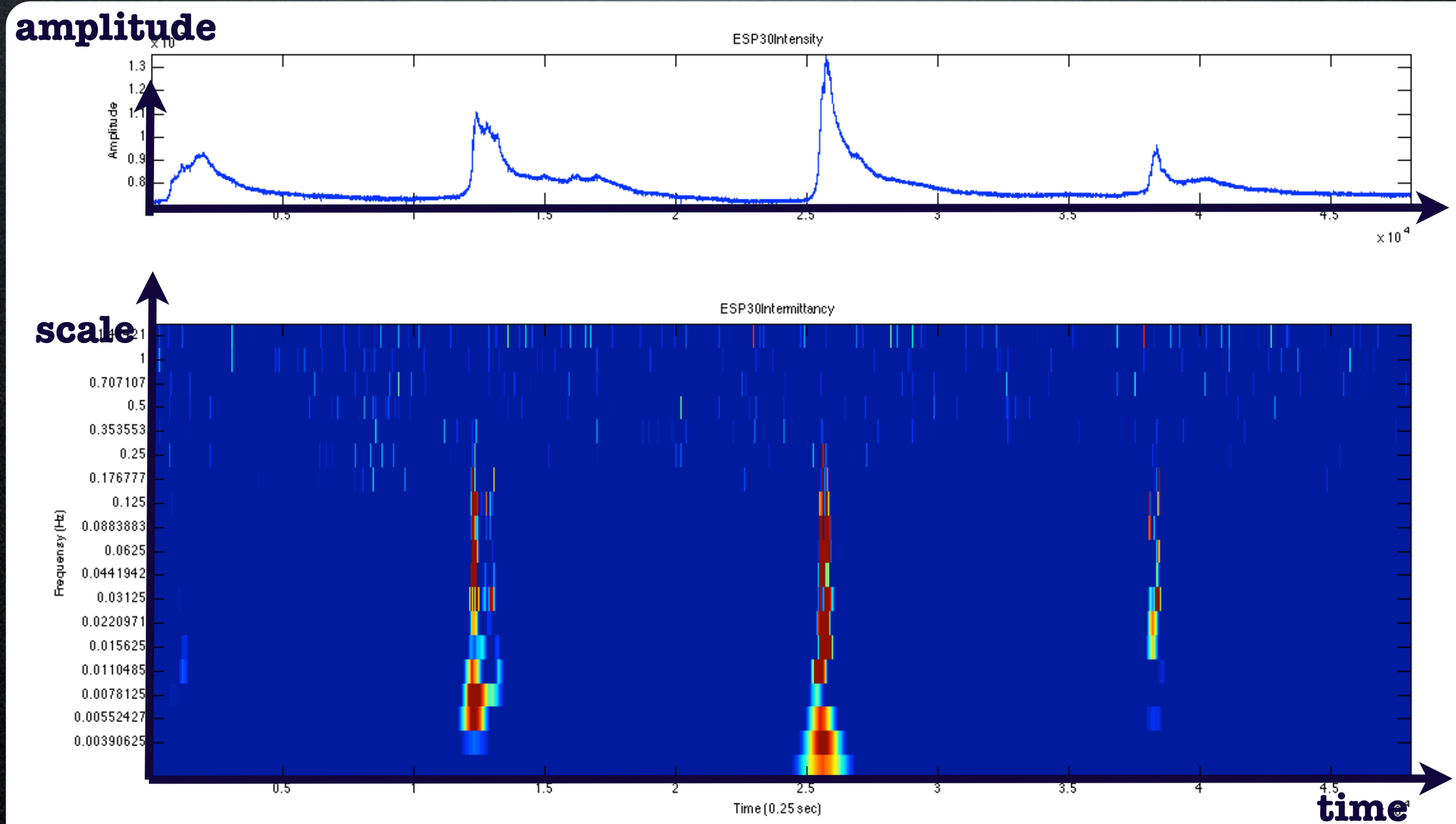
Here we consider four X-class flares observed by X-ray and EUV channels. Each flare is decomposed into a set of different timescales. We focus on 10-25 sec scale features.

LYRA and PREMOS channels are in progress.

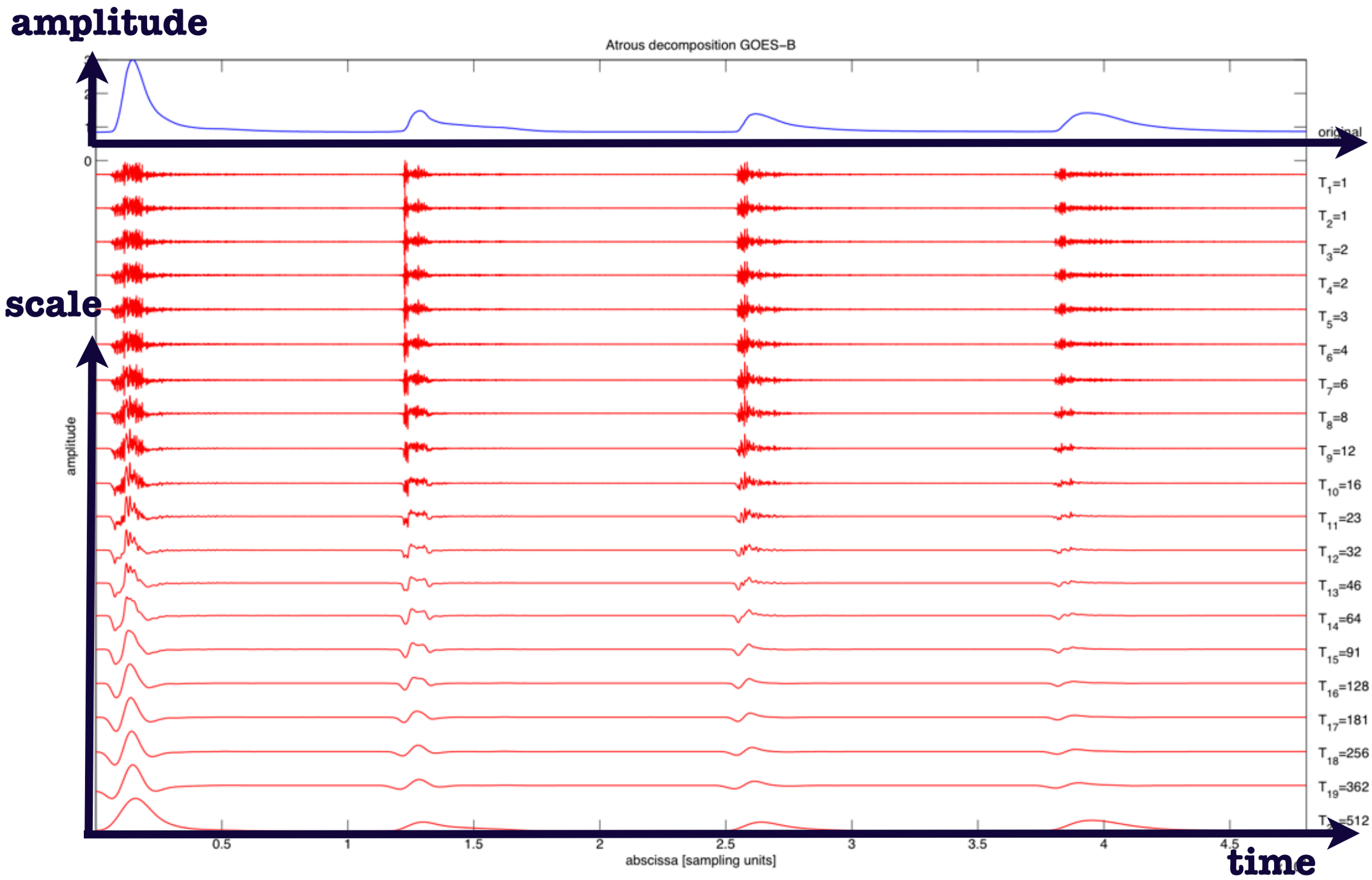


Instrument	Bandpass, nm	Description	Max cadence, sec
GOES A	0.05 - 0.3	continuum	1
GOES B	0.1 - 0.8	continuum	1
EVE/ESP 1	0.1-5.9	continuum, Fe XVIII	0.25
EVE/ESP 18	17.2-20.6	Fe IX, Fe X, Fe XI, & Fe XII emission	0.25
EVE/ESP 26	23.1-27.6	He II 25.6 nm emission + blend with weaker lines	0.25
EVE/ESP 30	28.0-31.6	He II 30.4 nm emission + blend with weaker lines	0.25

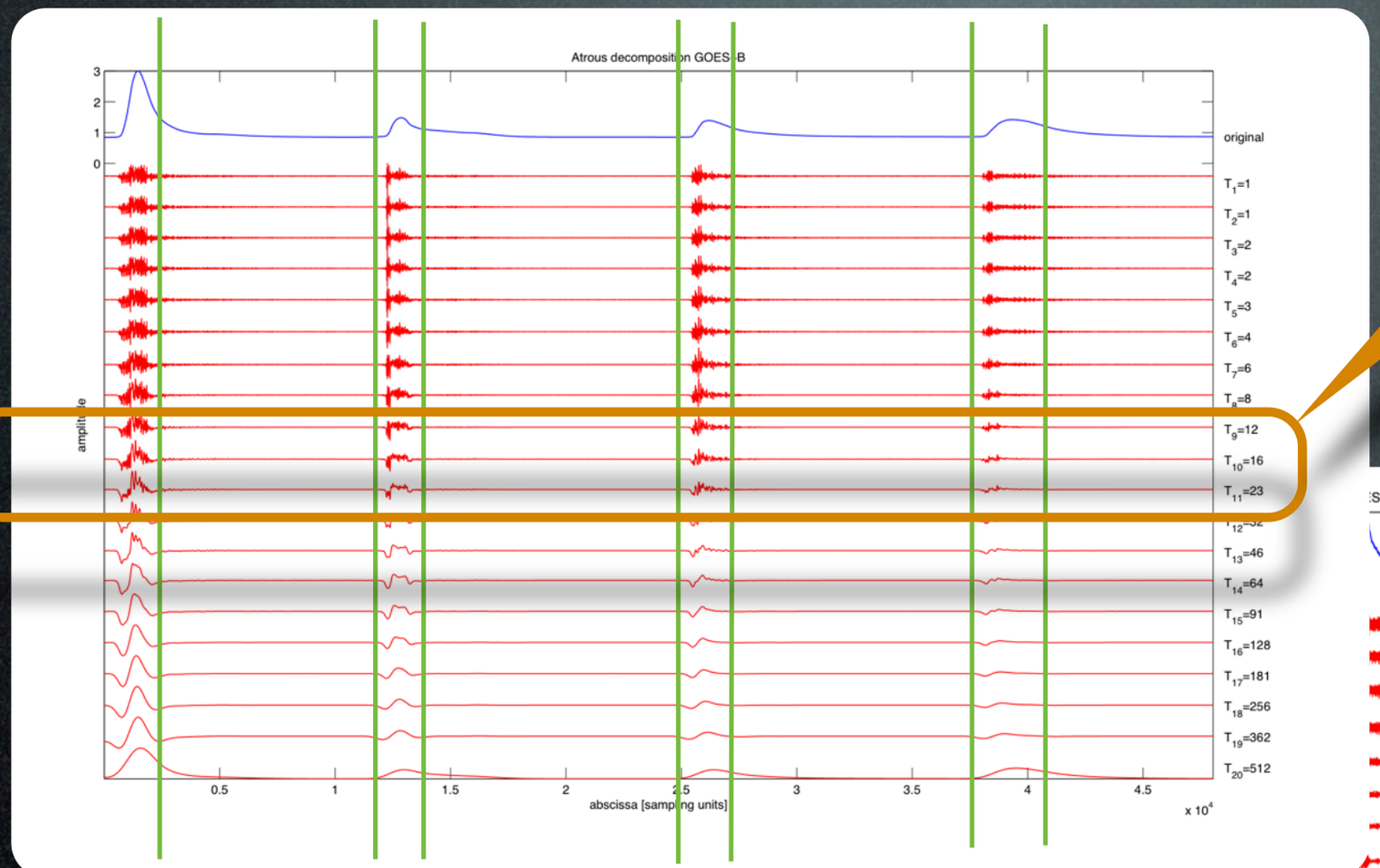
Oscillations during the impulsive phase



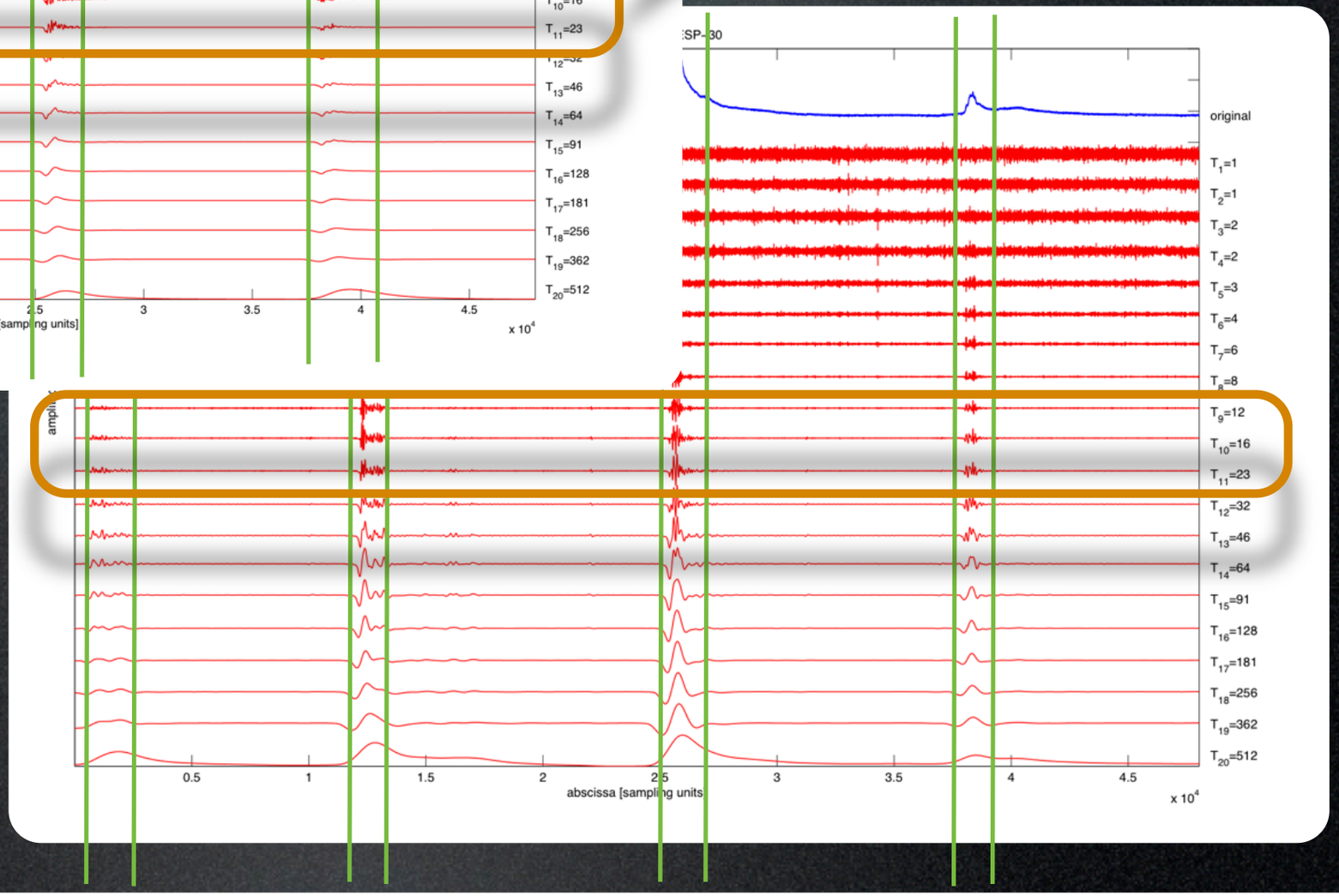
Multiscale decomposition



Multiscale decomposition

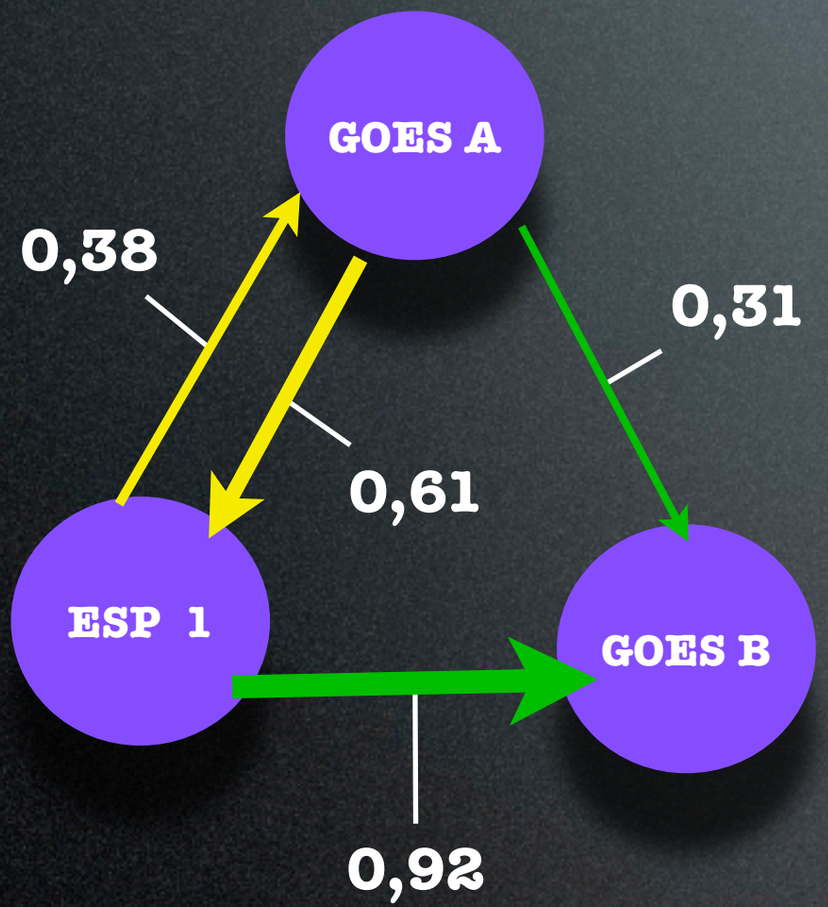


Target timescale of 16 sec. Fast oscillation mode.



Flare 09/08/2011

causality during impulsive phase



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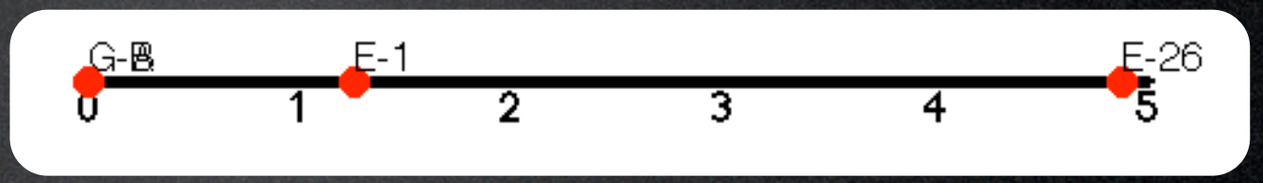
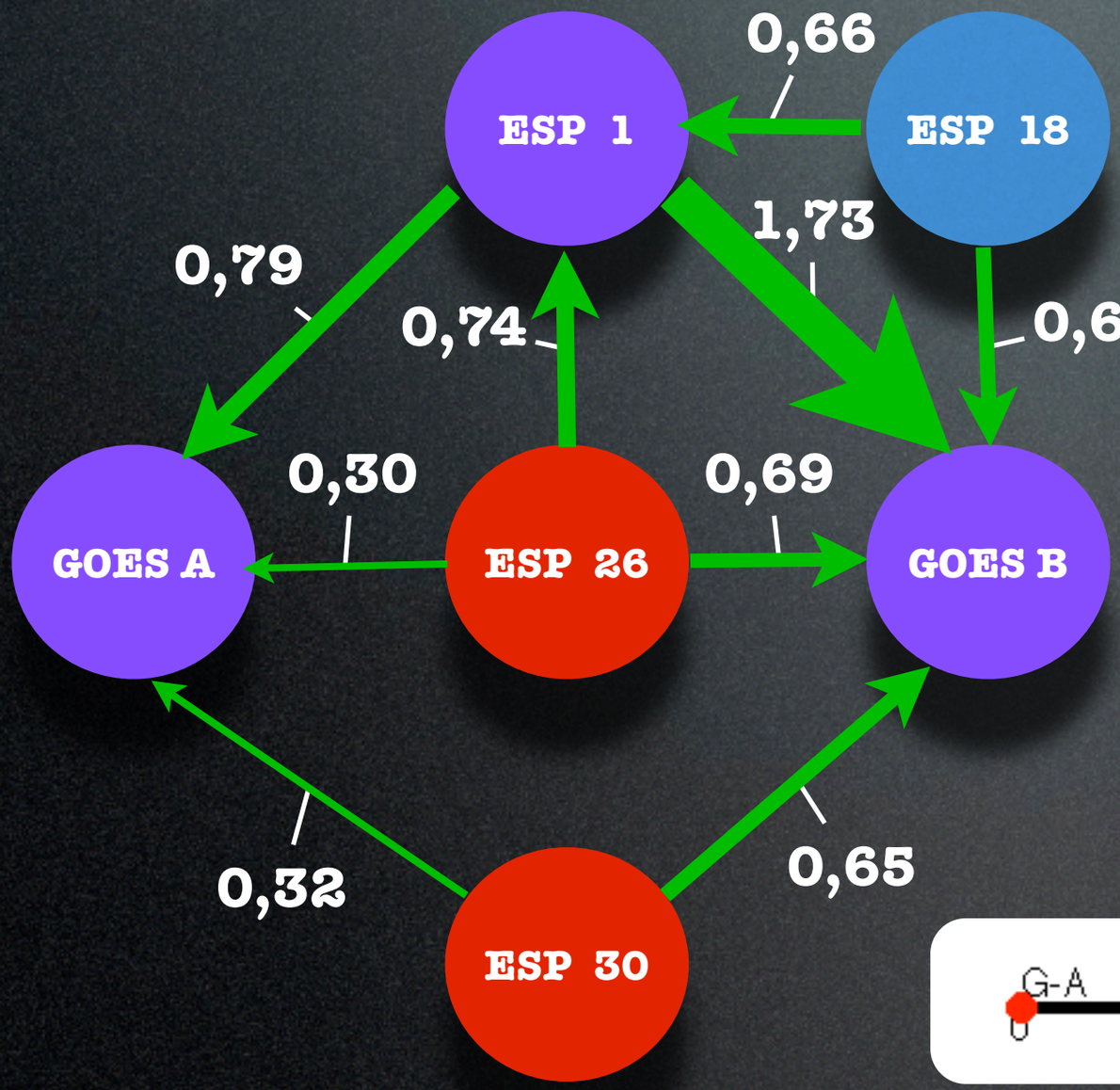
EVE/ESP 1	0.1-5.9
EVE/ESP 18	17.2-20.6
EVE/ESP 26	23.1-27.6
EVE/ESP 30	28.0-31.6

Time lags, sec



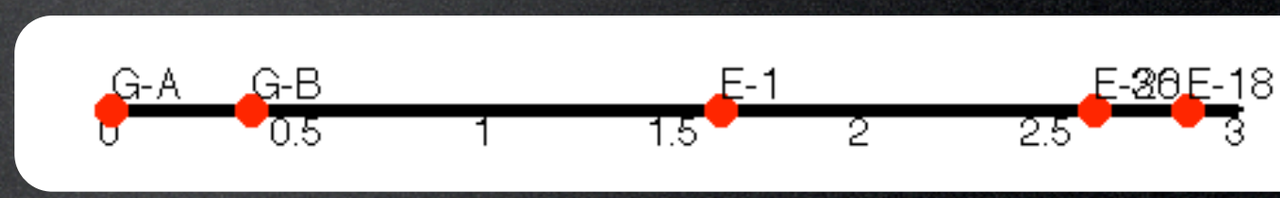
Flare 06/09/2011

causality during impulsive phase



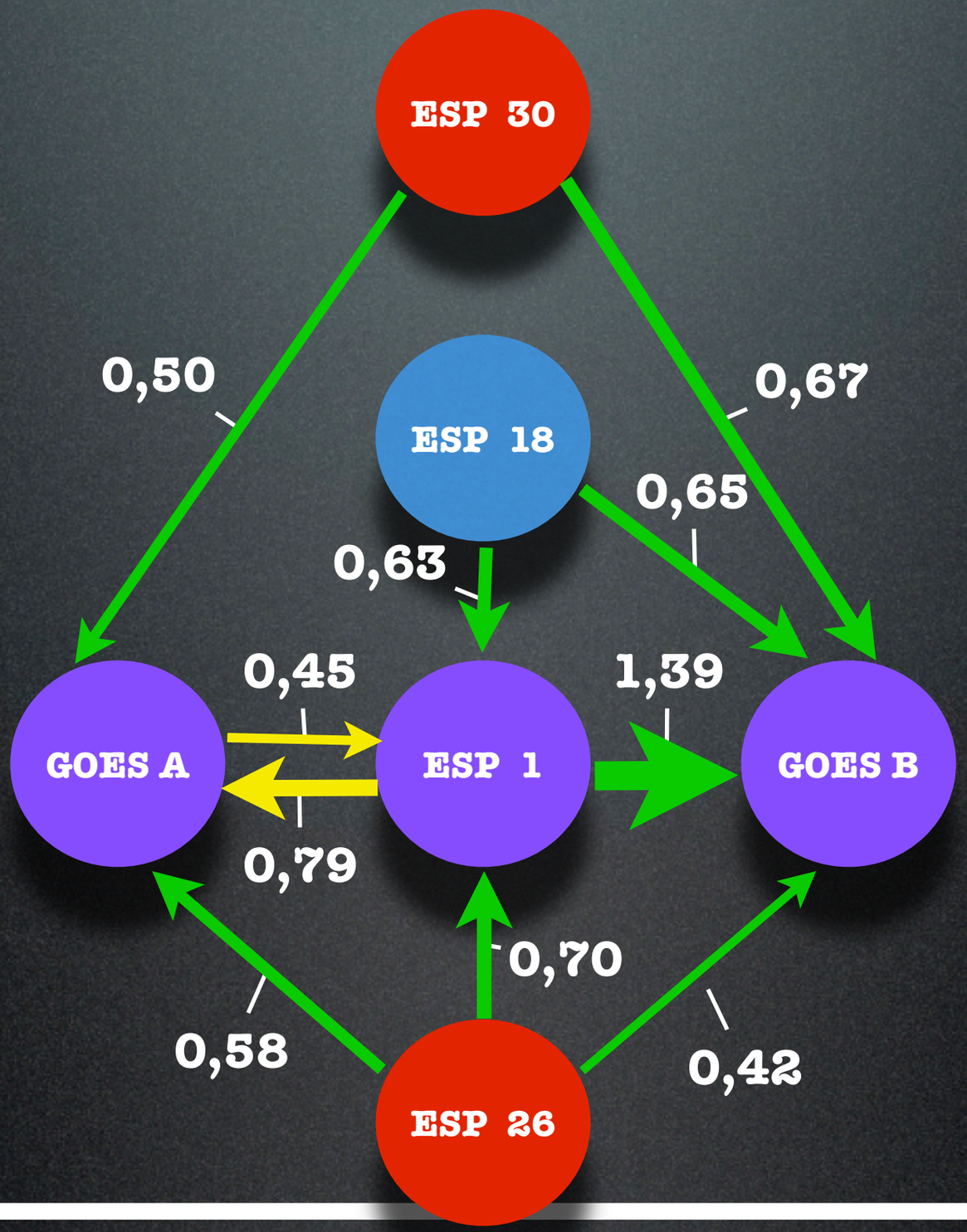
Instrument	Bandpass, nm
GOES A	0.05 - 0.3
GOES B	0.1 - 0.8
EVE/ESP 1	0.1-5.9
EVE/ESP 18	17.2-20.6
EVE/ESP 26	23.1-27.6
EVE/ESP 30	28.0-31.6

Time lags, sec



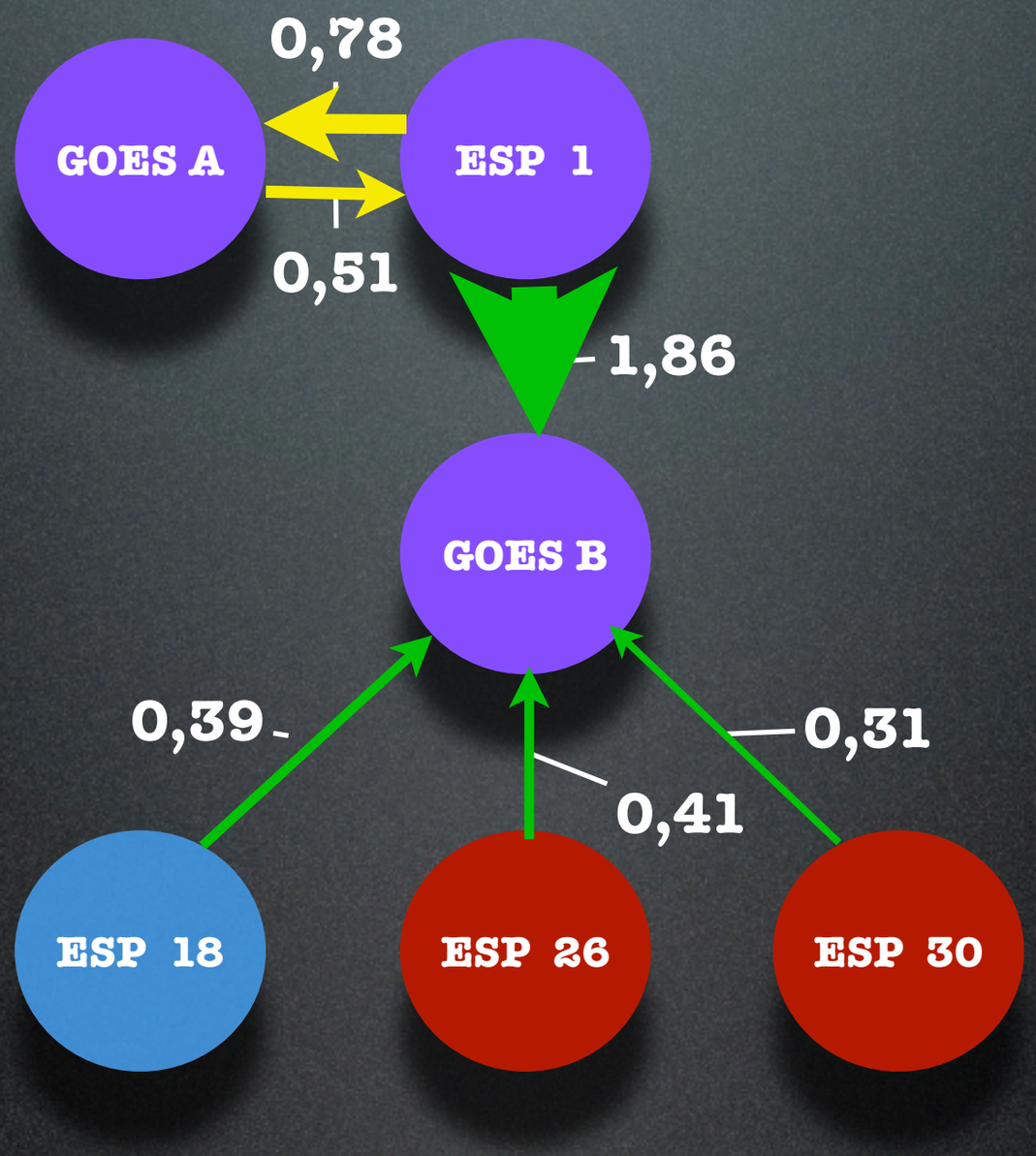
Flare 07/09/2011

causality during impulsive phase

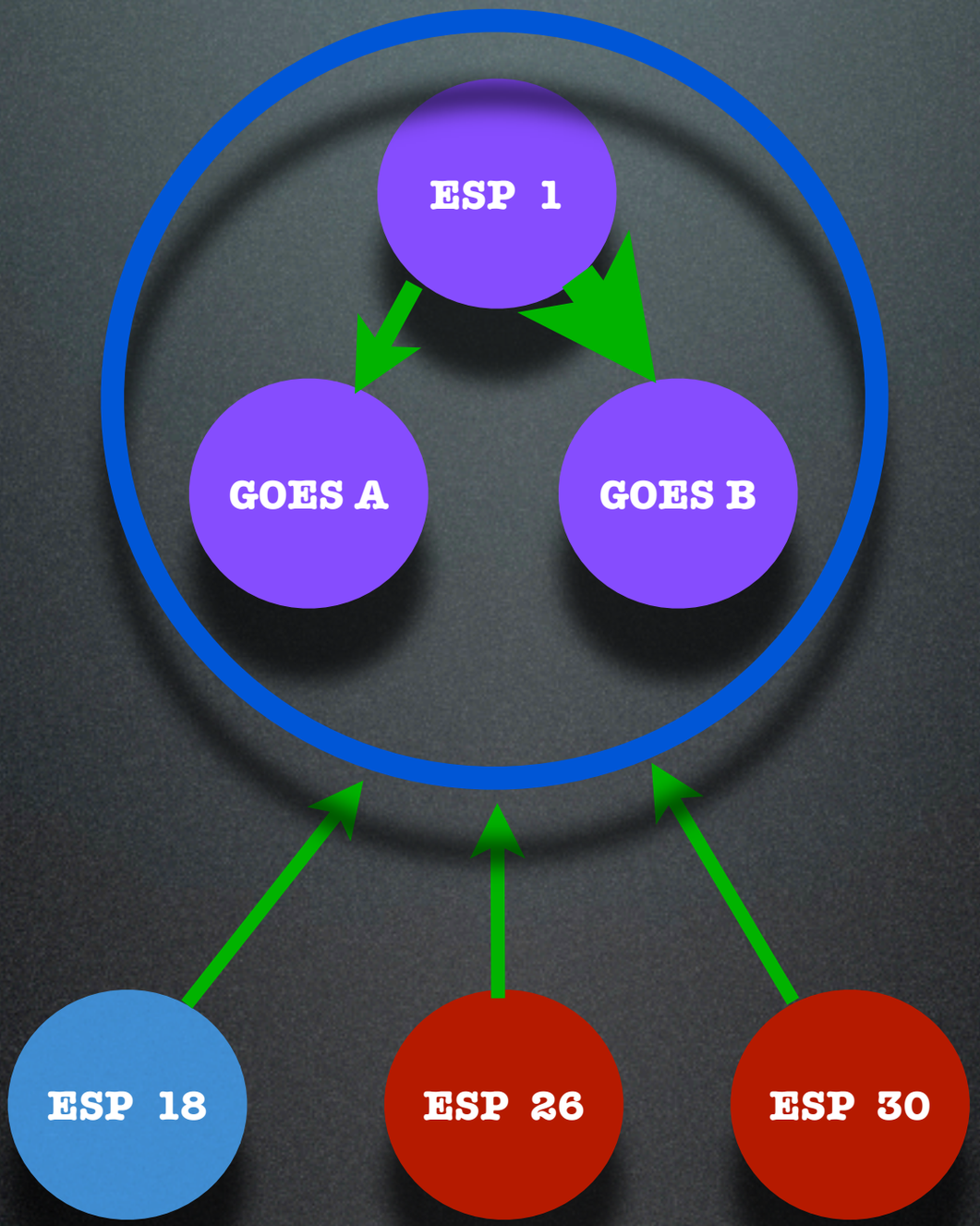


Flare 24/09/2011

causality during impulsive phase



General picture for impulsive phase



Conclusions

- The Granger causality provides bidirectional representation of statistical relationships between outputs of a physical system.
- Additional insights on the underlaying physical processes which manifest itself in the variability of solar EUV and X-rays irradiance.
- Strong causal flow from ESP-1 to GOES-B and GOES-A channels during the impulsive phases.
- Strong causality from EUV channels to X-Rays channels during the impulsive phases.
- Each flare has it’s own features.