

# 2<sup>nd</sup> TLC Group Meeting

Friday 27, 2012

## Investigations on nonstationary signals and systems

*Lorenzo Galleani*

# Rationale

All measured signals are nonstationary

Variety of methods for stationary signals

Few methods for nonstationary signals



The **study of nonstationary signals** is of a fundamental interest

Signals are generated by systems



The **study of systems under nonstationary behavior** is of a fundamental interest

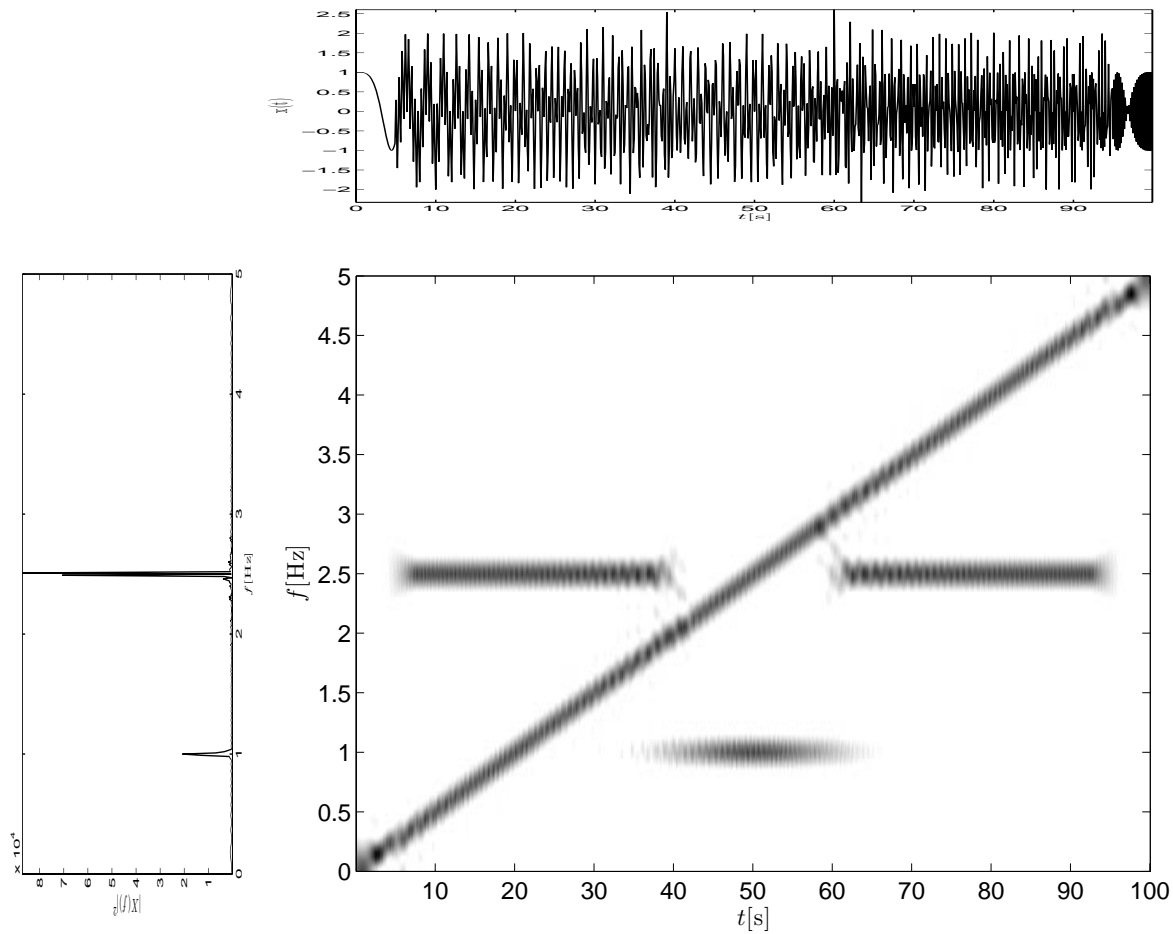
# Time-frequency analysis of systems

Frequency is a fundamental attribute of signals

If the signal is nonstationary, its frequency spectrum changes with time

Time-frequency analysis provides an effective description of signals with time-varying spectra

# Time-frequency tutorial



# Time-frequency analysis of systems

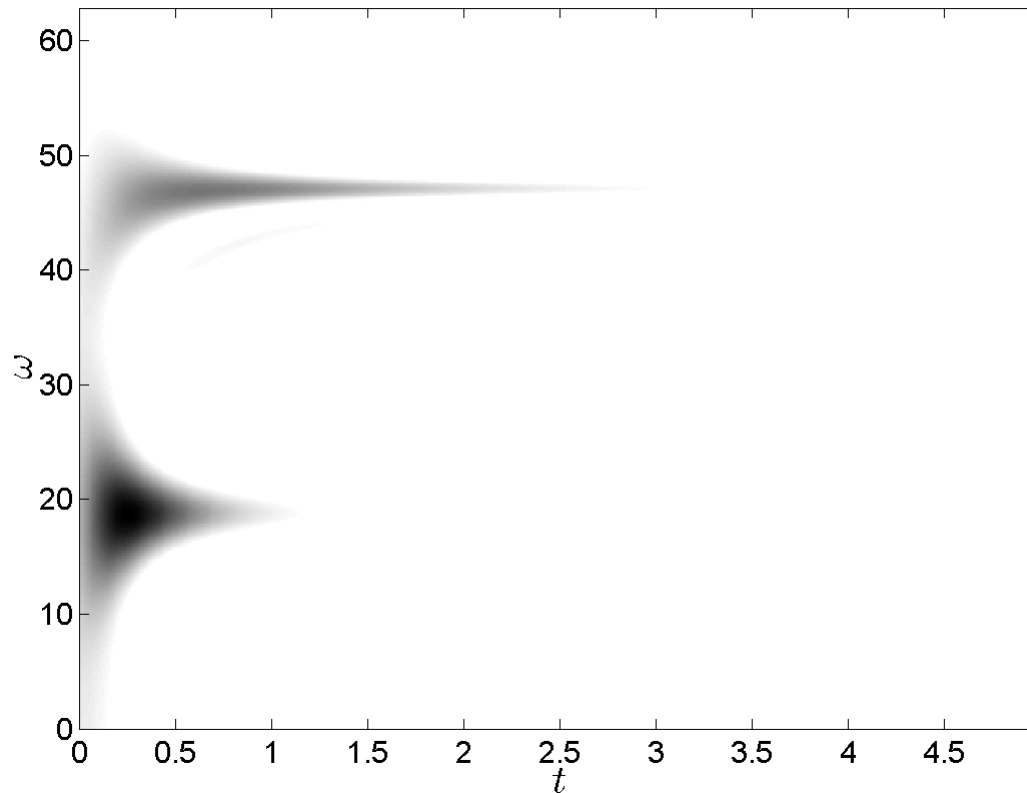
For nonstationary signals, the time-frequency spectrum is more effective than the classical frequency spectrum

Signals are generated by systems



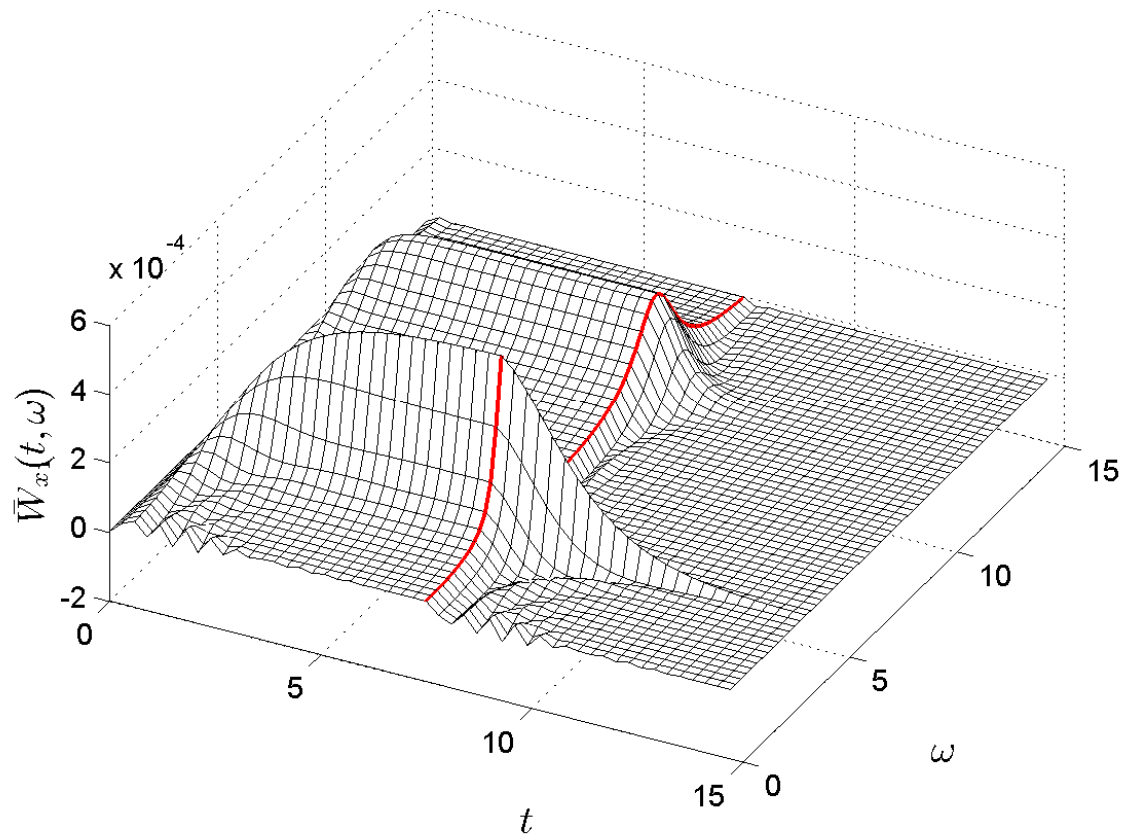
We study systems in the time-frequency domain

# Time-frequency analysis of systems



Impulse response  
[system with two resonances]

# Time-frequency analysis of systems



Response to nonstationary white Gaussian noise  
[system with two modes]

# Statistical Signal Processing for Atomic Timing

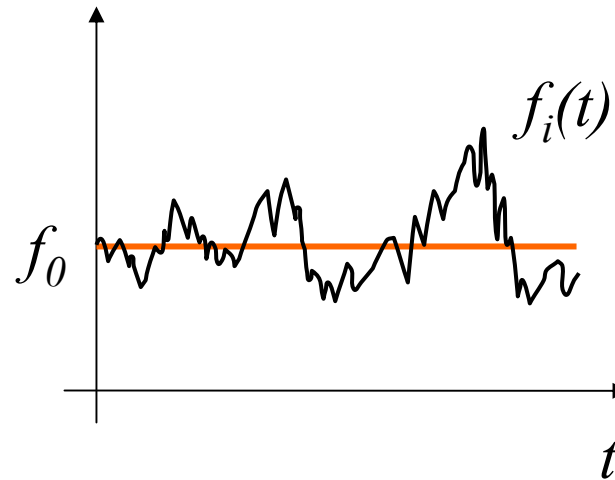
Ultra-stable atomic clocks have a variety of applications

Global Navigation Satellite Systems (GNSSs), such as GPS and the future Galileo system, are based on atomic clocks

Wide use of statistical signal processing methods in atomic timing for GNSSs



# Tutorial on Atomic Timing



Frequency deviation

$$y(t) = \frac{f_i(t) - f_0}{f_0}$$

Time deviation

$$x(t) = \int_0^t y(t') dt'$$

Clock noise = Time-varying drift  
+  
 $1/f^\alpha$  processes

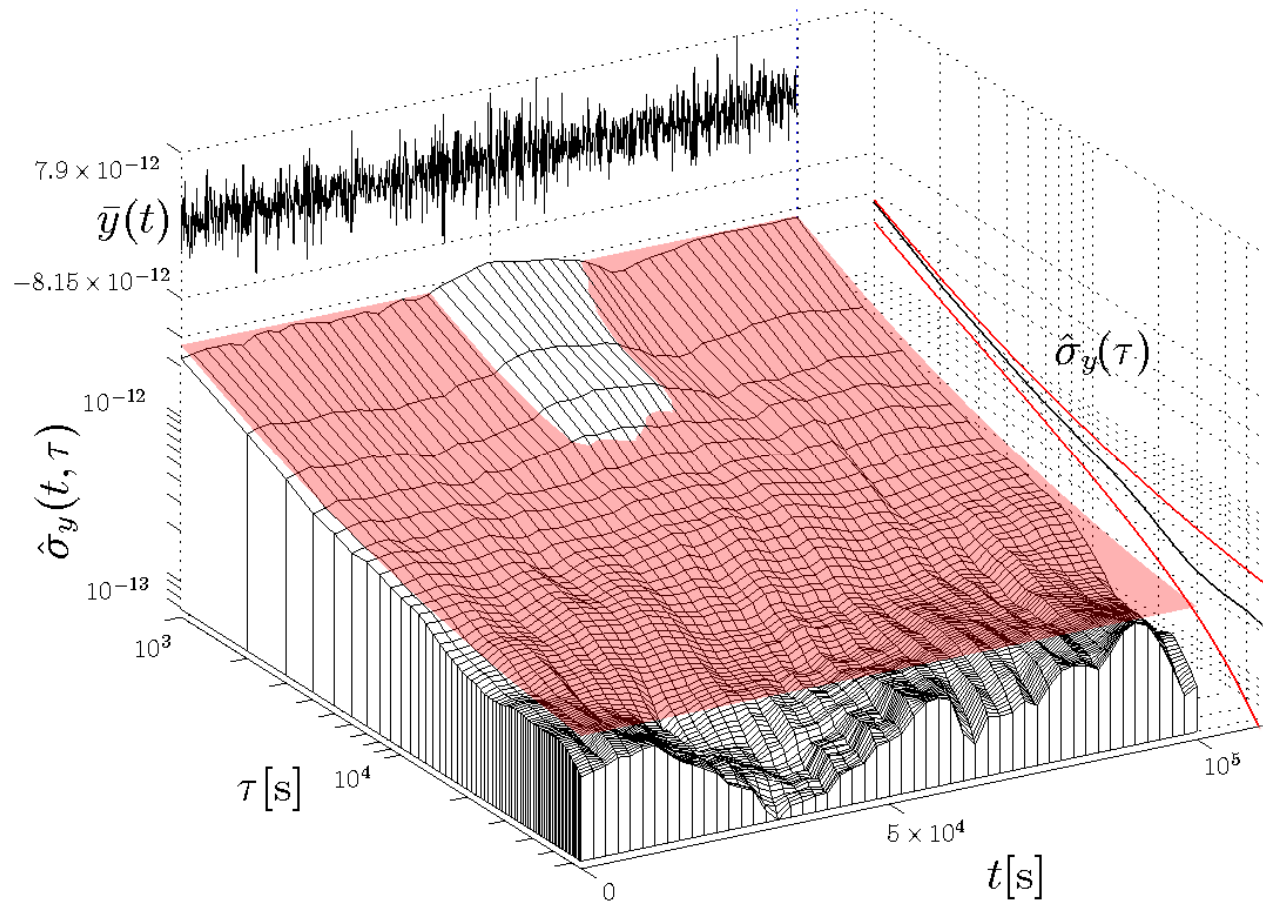
# Problems in Atomic Timing

**Time scale generation** A high-quality virtual clock obtained by averaging an ensemble of clocks

**Clock steering** Synchronization of a clock with respect to a more stable time reference

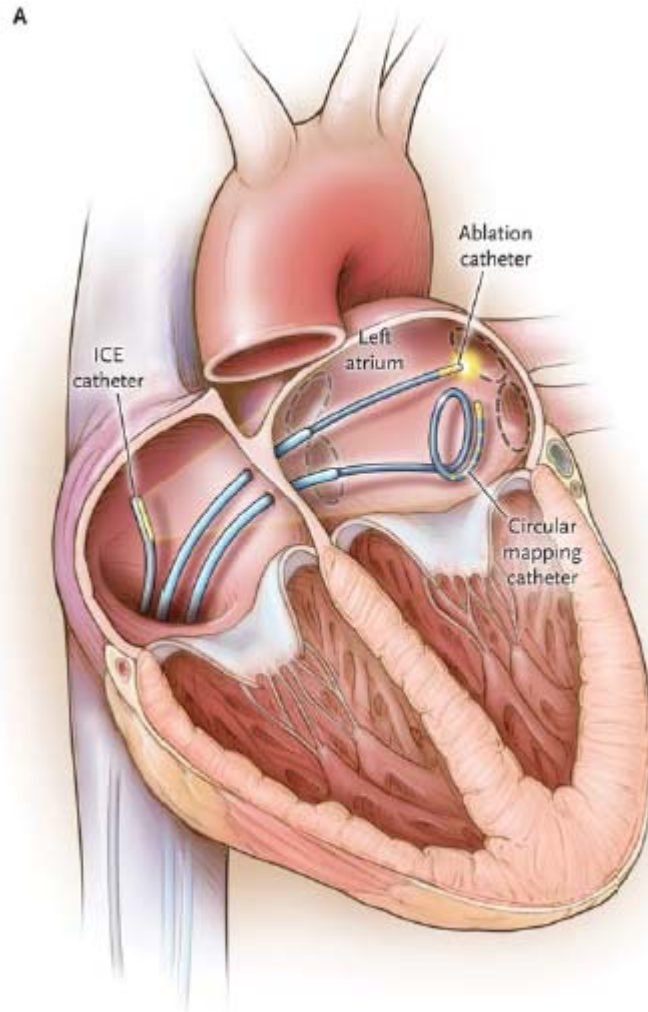
**Detection of anomalies** Fast and reliable detection of anomalies occurring in atomic clocks

# Detection of Anomalies



Dynamic Allan variance

# Signal Processing for Atrial Fibrillation



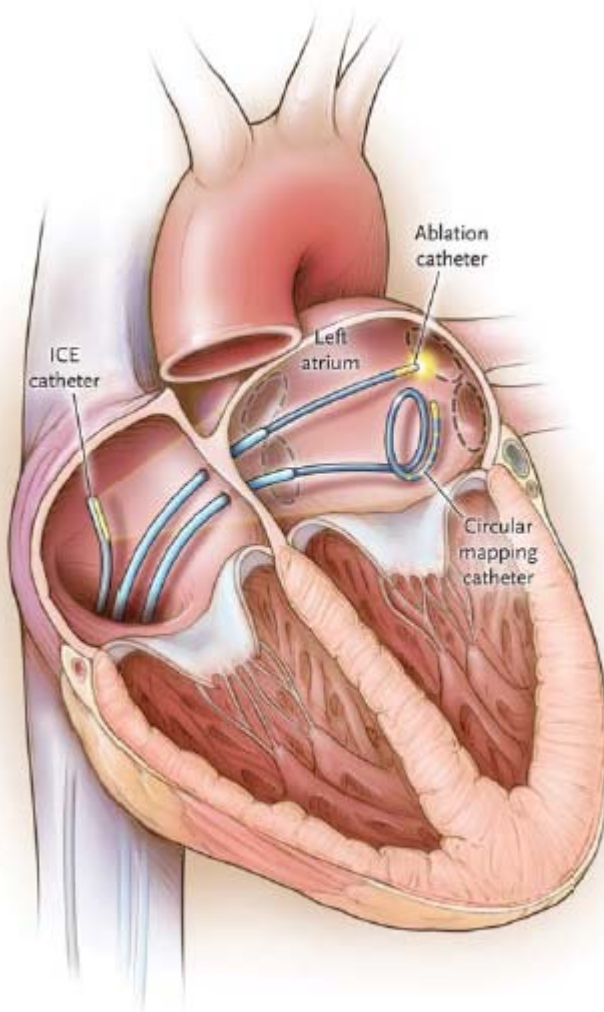
Atrial fibrillation affects millions of people in Europe

It will increase with population aging

Treating atrial fibrillation costs billions of euros

# The Basis of Atrial Fibrillation

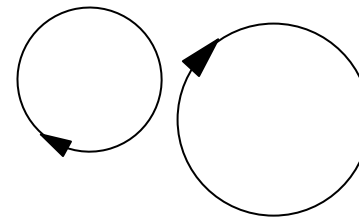
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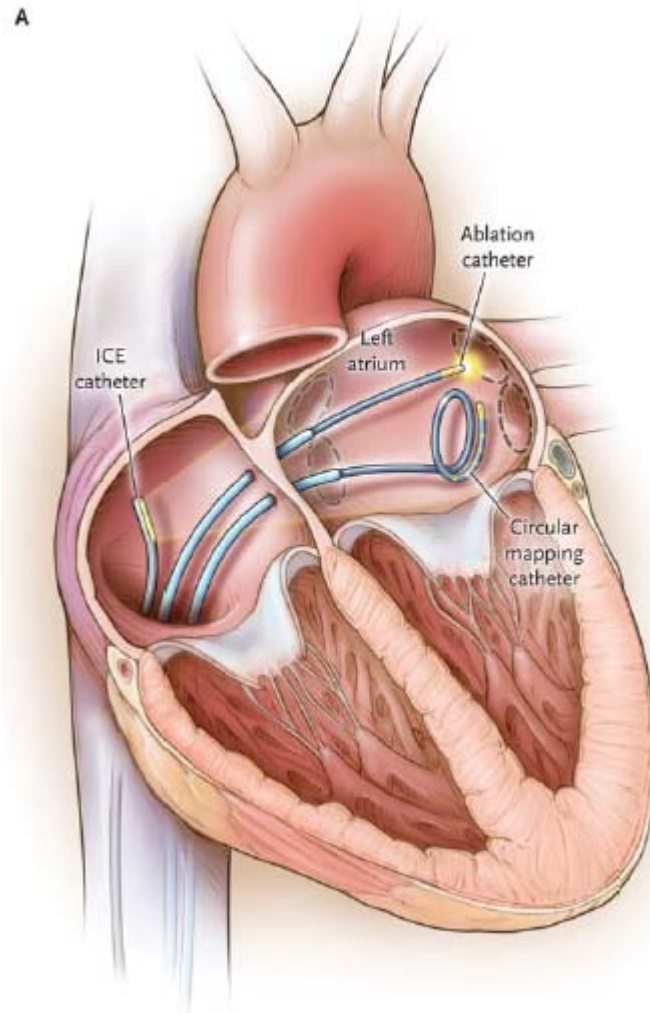
Two facts are required

1. Trigger that initiates the dysrhythmia
2. Substrate that sustains the dysrhythmia

[Re-entry circuits]



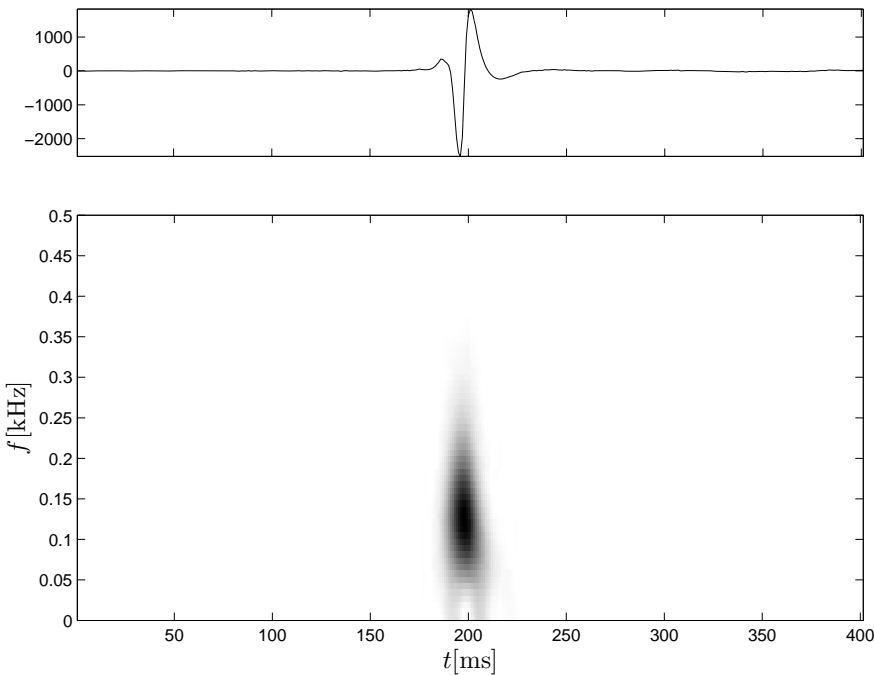
# Catheter Ablation for Atrial Fibrillation



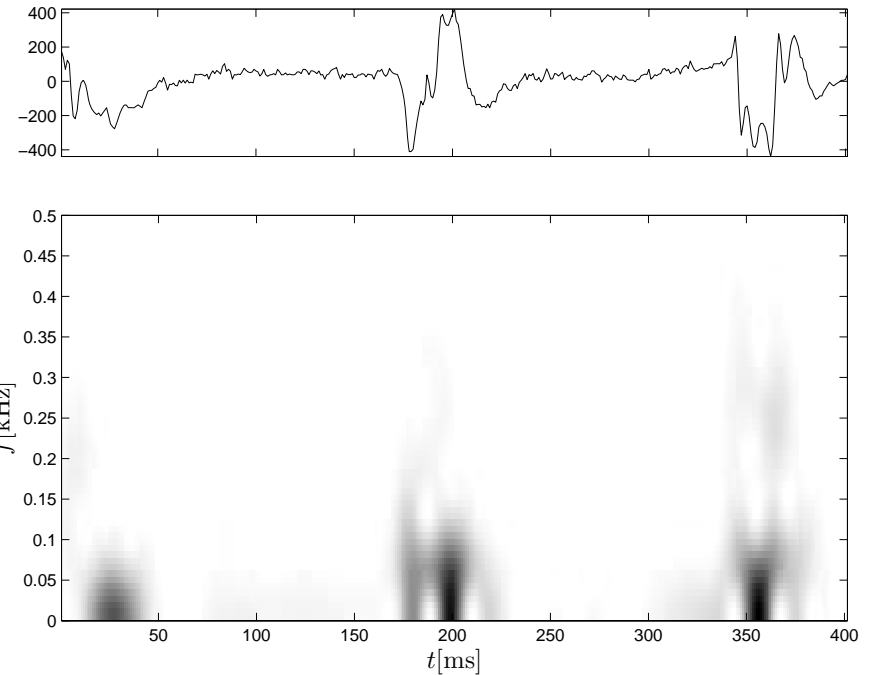
The RF catheter burns the substrate to

1. Isolate the trigger
2. Interrupt the re-entry circuits

# Improving Catheter Ablation



In rhythm



In atrial fibrillation

# Credits

## Time-Frequency

Cohen

Lo Presti

## Atomic Timing

Tavella

Sesia

Cernigliaro

## Atrial Fibrillation

Pagana

Grossi

Bianchi

Ruo Roch