A tool to simulate a light-curve including solar-like oscillations with granulation and photon noises

Purpose : to provide a tool to simulate CoRoT light-curves of the seismology channel.

Interests :

- To **test** some **analysis techniques** (e.g. Hare and Hound exercices) with a **validated tool** available for all the CoRoT SWG.
- To help the **selection** of the best star candidates , thus to optimize the scientific return of the mission.

☞ **public tool**, package can be downloaded at : http://www.lesia.obspm.fr/~corotswg/

Simulated signal = modes + noise

Modes :

- **Theoretical mode excitation rates** are calculated according to Samadi et al (2003, A&A, 404, 1129)
- **Theoretical mode damping rates** are obtained from the tables calculated by Houdek et al (1999, A&A 351, 582)
- The **mode light-curves** are simulated according to Anderson et al (1990, Apj, 364, 699)

Noise :

Noise = photon noise + stellar (granulation) « noise »

✗ No other instrumental noise than photon noise
✗ No activity noise

- **Stellar granulation** simulation is based on : Harvey (1985, ESA-SP235, p.199)
- **Instrumental photon noise** is computed in the case of COROT but can been changed.

Simulation inputs:

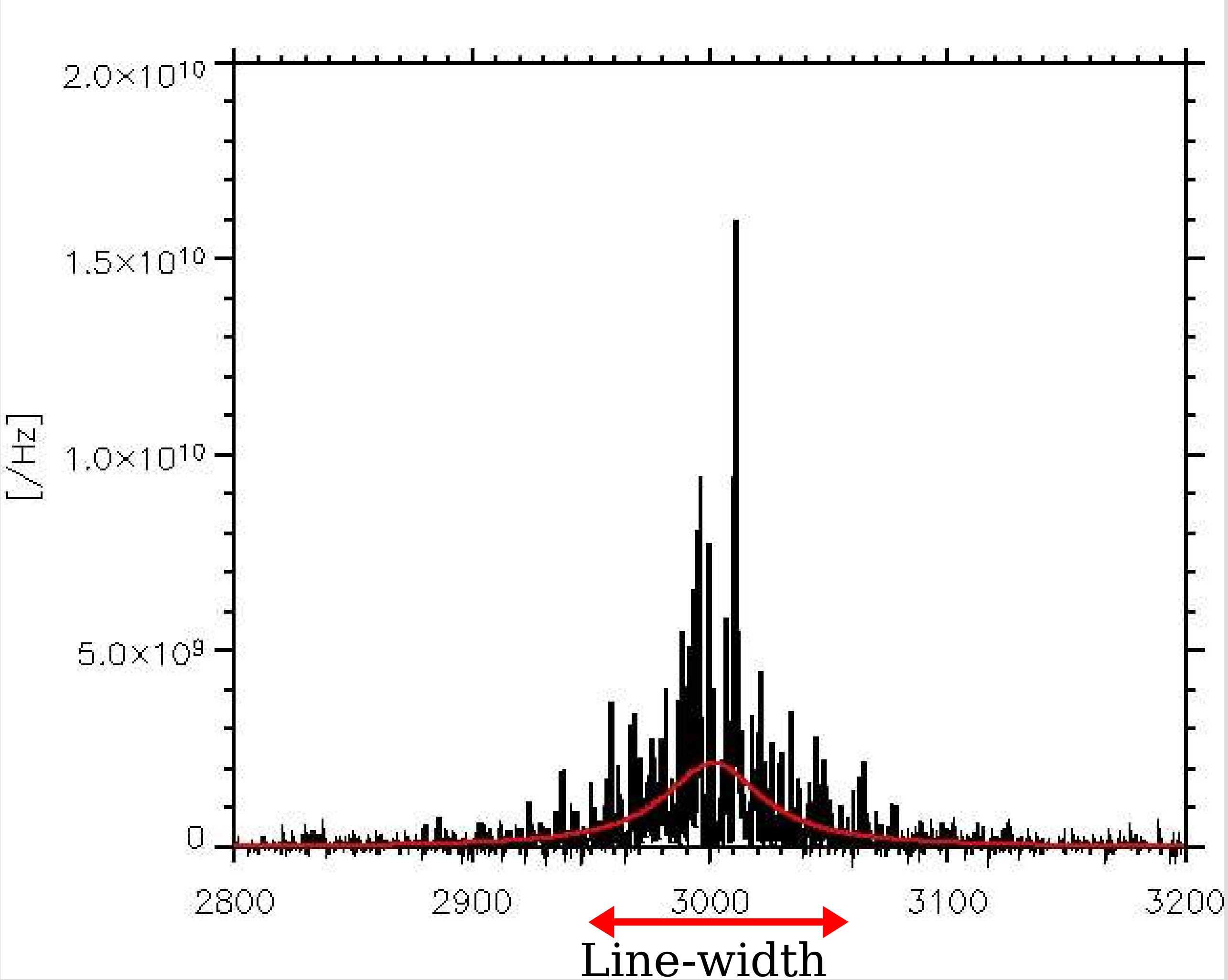
- Duration of the time series and sampling
- Characteristics (magnitude, age, etc...) of the star
- Option : characteristics of the instrument performances (photon noise level for the given star magnitude)

Simulation outputs: time series and spectra for :

- mode signal (solar-like oscillations)
- photon noise
- granulation noise

Observed power spectrum of a solar-like oscillation :

☞ Lorentzian profile in 1st approximation



Modeling the solar-like oscillations spectrum

Each solar-like oscillation is a superposition of a large number of excited and damped proper modes:

$$\sum_j A_j \; \exp[-i2\;\pi\nu_0\;\; t]\;\exp[-\eta(t-t_j)]\;H(t-t_j)\;+\;c.c$$

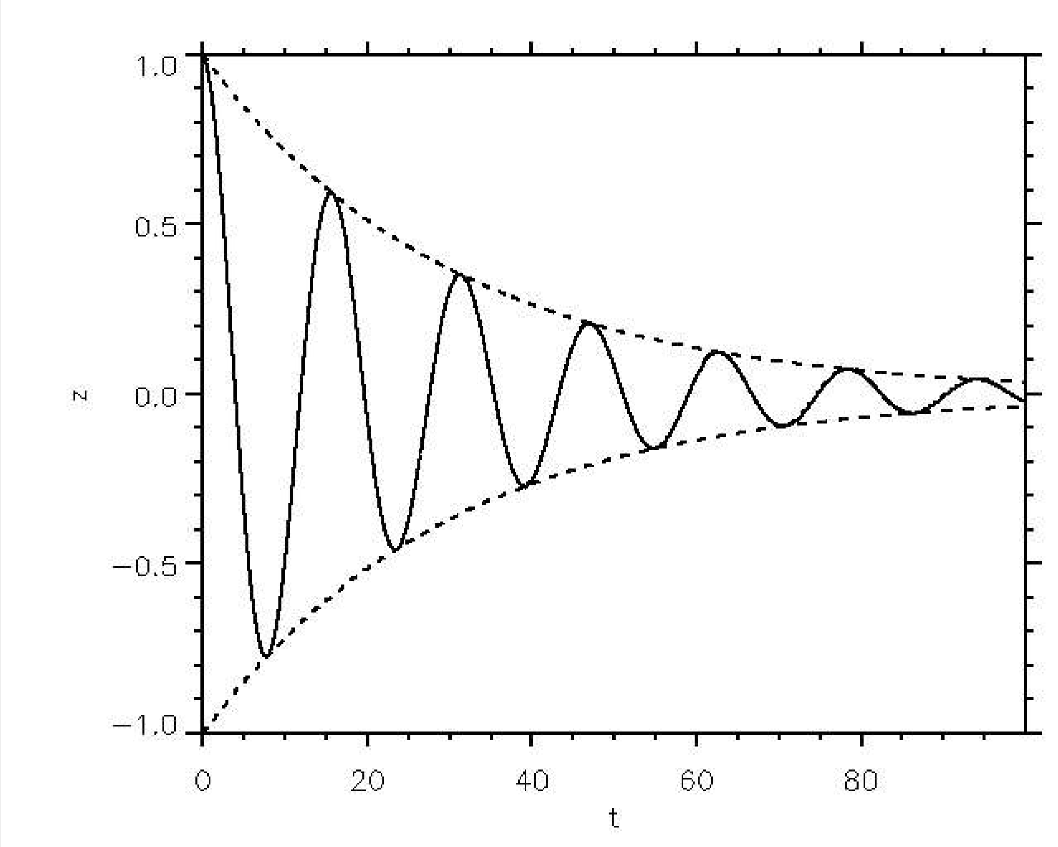
Aj : amplitude at which the mode « j » is excited by turbulent convection

tj : instant at which its is excited

ν_0 : mode frequency

η : mode (linear) damping rate

H : Heaviside function



Modeling the solar-like oscillations spectrum (continue)

$$\sum_j A_j \exp[-i 2\pi\nu_0 t] \exp[-\eta(t-t_j)] H(t-t_j) + c.c.$$

Line-width :

$$\Gamma_\nu = \eta/\pi$$

Fourier spectrum

$$P(\nu) \simeq \frac{\sum_j \tilde{A}_j}{1 + 2i(\nu-\nu_0)/\Gamma_\nu} = \frac{U}{1 + 2i(\nu-\nu_0)/\Gamma_\nu}$$

$$U = \sum_j \tilde{A}_j$$

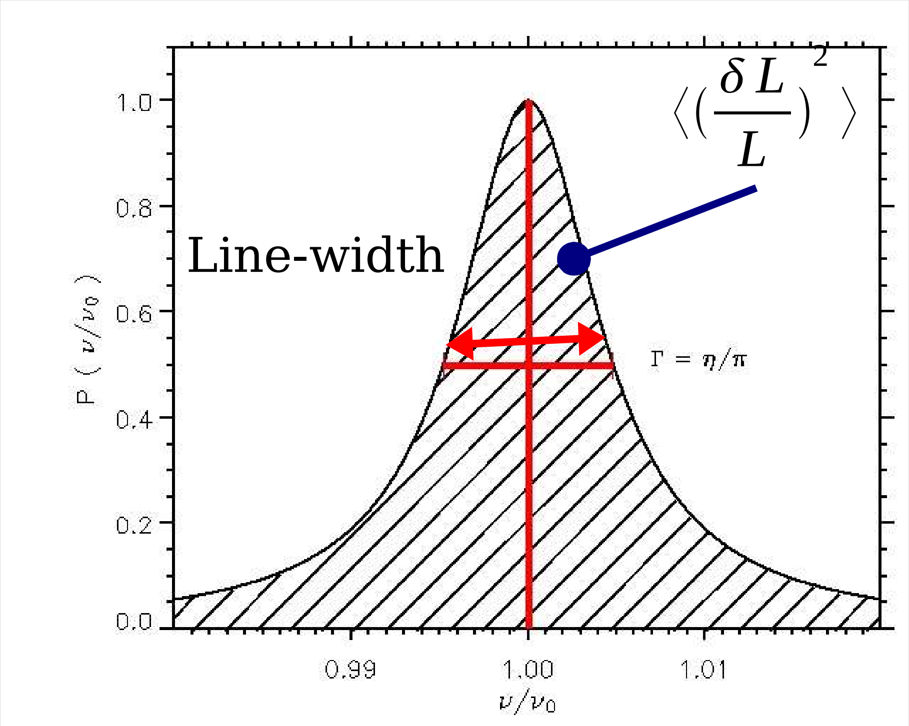
Power spectrum

$$\|P(\nu)\|^2 \simeq \frac{\|U\|^2}{1 + [2(\nu-\nu_0)/\Gamma_\nu]^2}$$

☞ The **stochastic fluctuations** from the mean Lorentzian profil are simulated by **generating** the imaginary and real parts of **U** according to a **normal distribution** (Anderson et al , 1990).

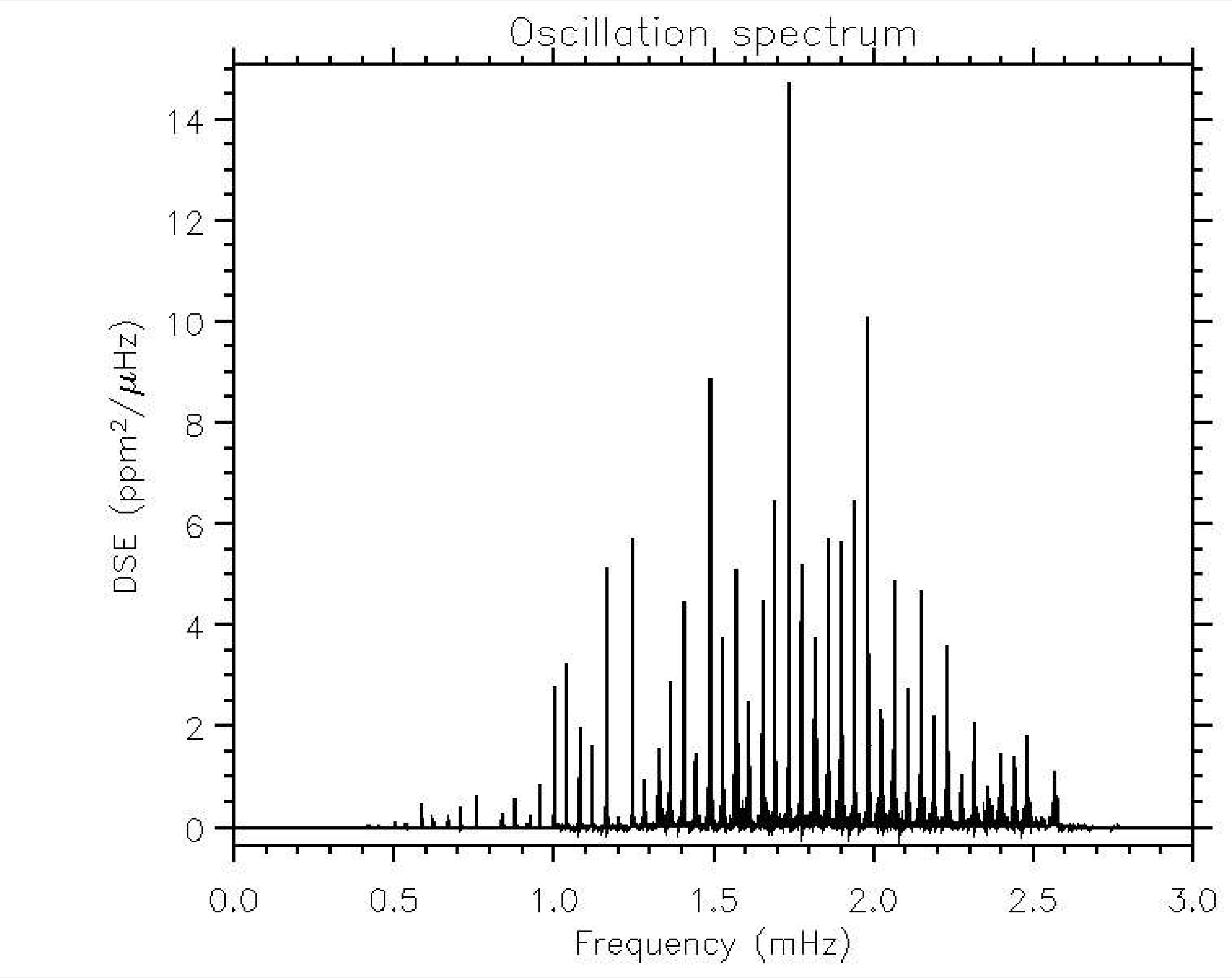
We have necesseraly: $\langle (\frac{\delta L}{L})^2 \rangle = \sum_k \|P_k(\nu)\|^2$

☞ constraints on: $\langle \|U\|^2 \rangle$



☞ Γ and δL/L predicted on the base of theoretical models.

Modeling the solar-like oscillations spectrum (continue)



Simulated spectrum of solar-like oscillations for a stellar model with M=1.20 located at the end of MS.

Photon noise

COROT specification:
For a star of magnitude m_0=5.7, the photon noise in an amplitude spectrum of a time series of 5 days is $B_0 = 0.6$ ppm

For a given magnitude m, $B = B_0 10^{(m - m0)/5}$

Stellar noise

In Doppler:

noise = granulation + mesogranulation + supergranulation

each modelled as $P(\nu)=4\sigma^2\tau / (1+(2\pi\nu\tau)^2)$

(τ and σ : characteristic time and velocity)

[Harvey 1984, 1985]

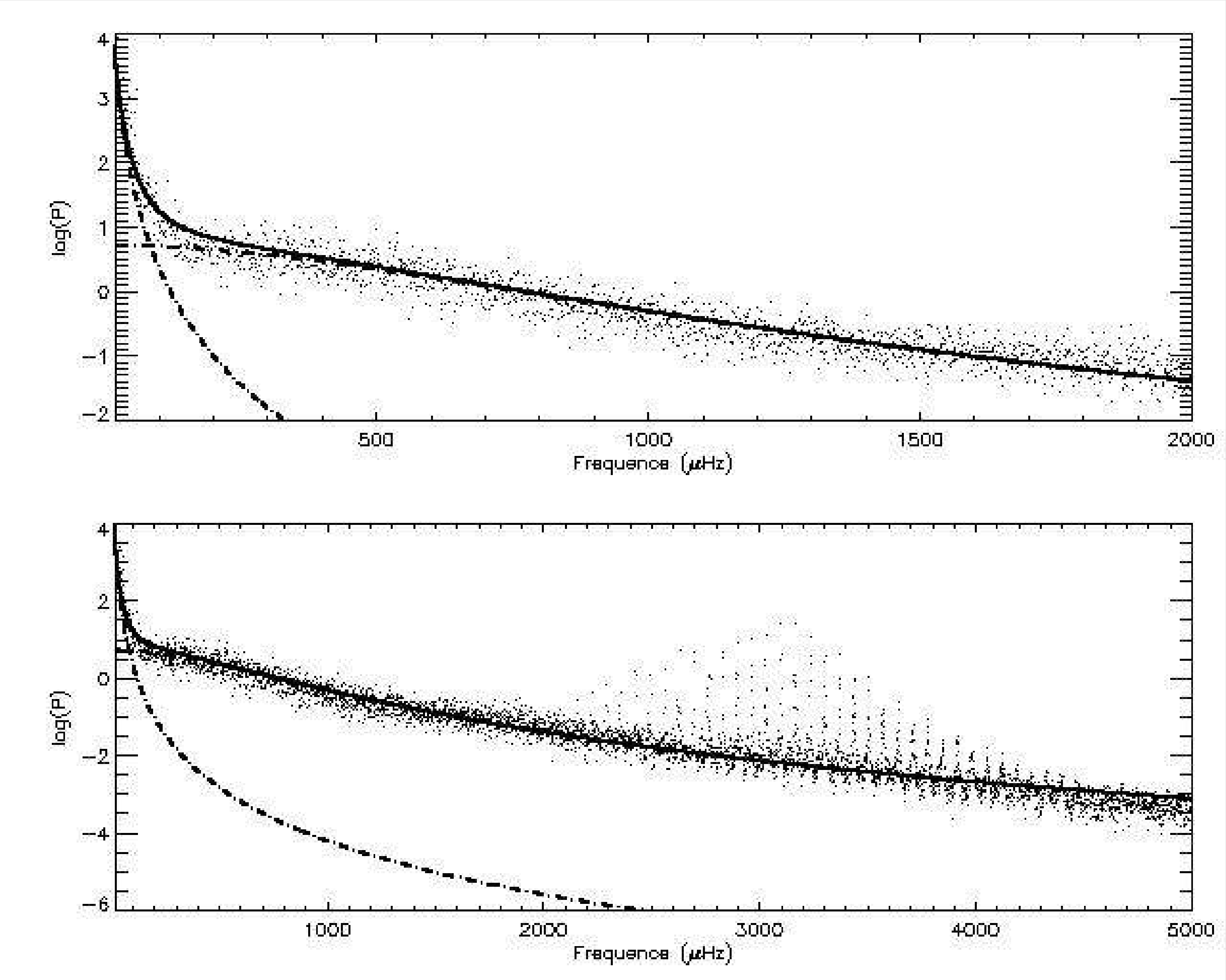
In intensity:

noise = granulation + activity

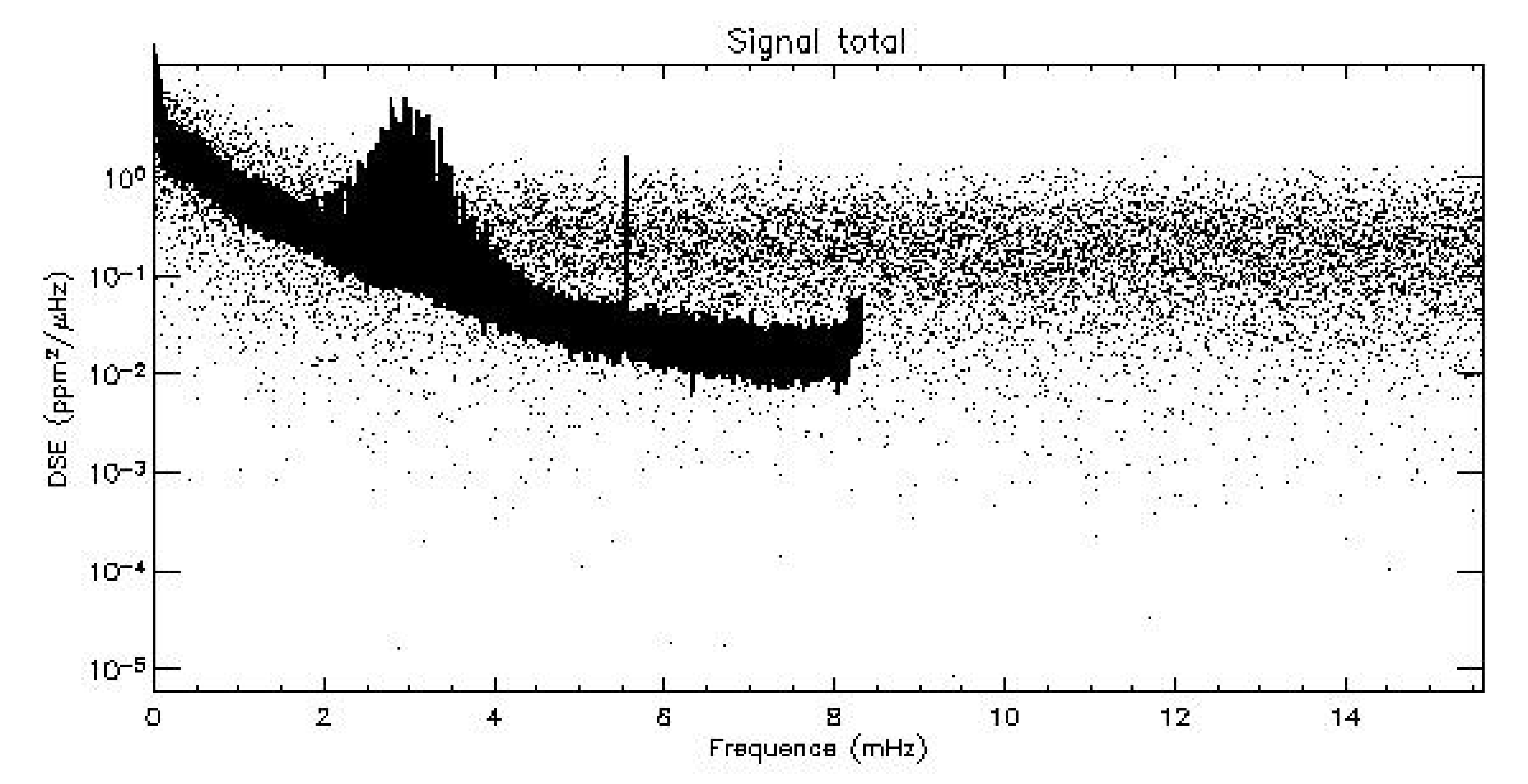
($\sigma = dL/L$)

[Harvey 1993, Appourchaux 2002]

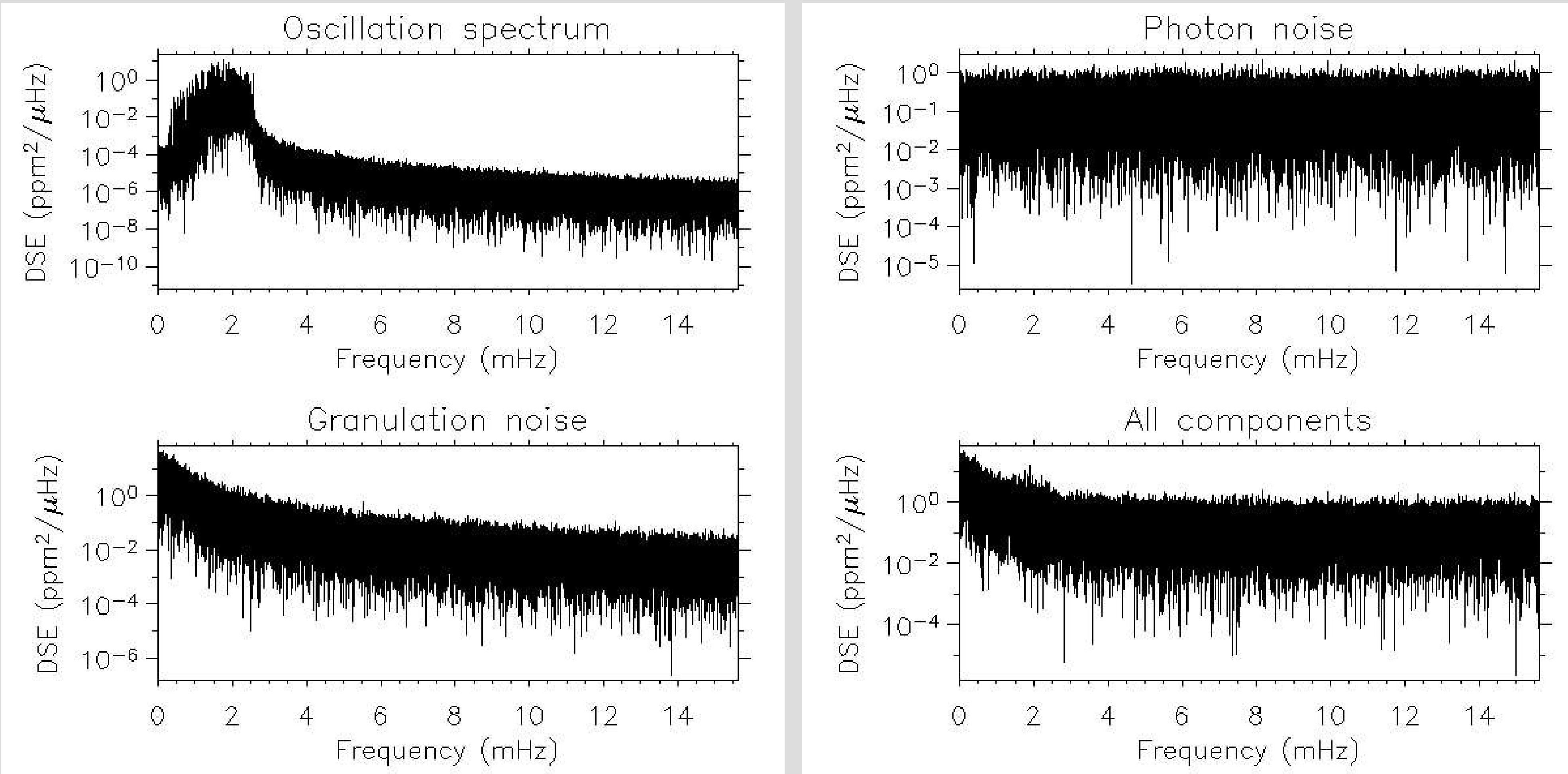
Stellar (Sun) noise: LOI/SoHO



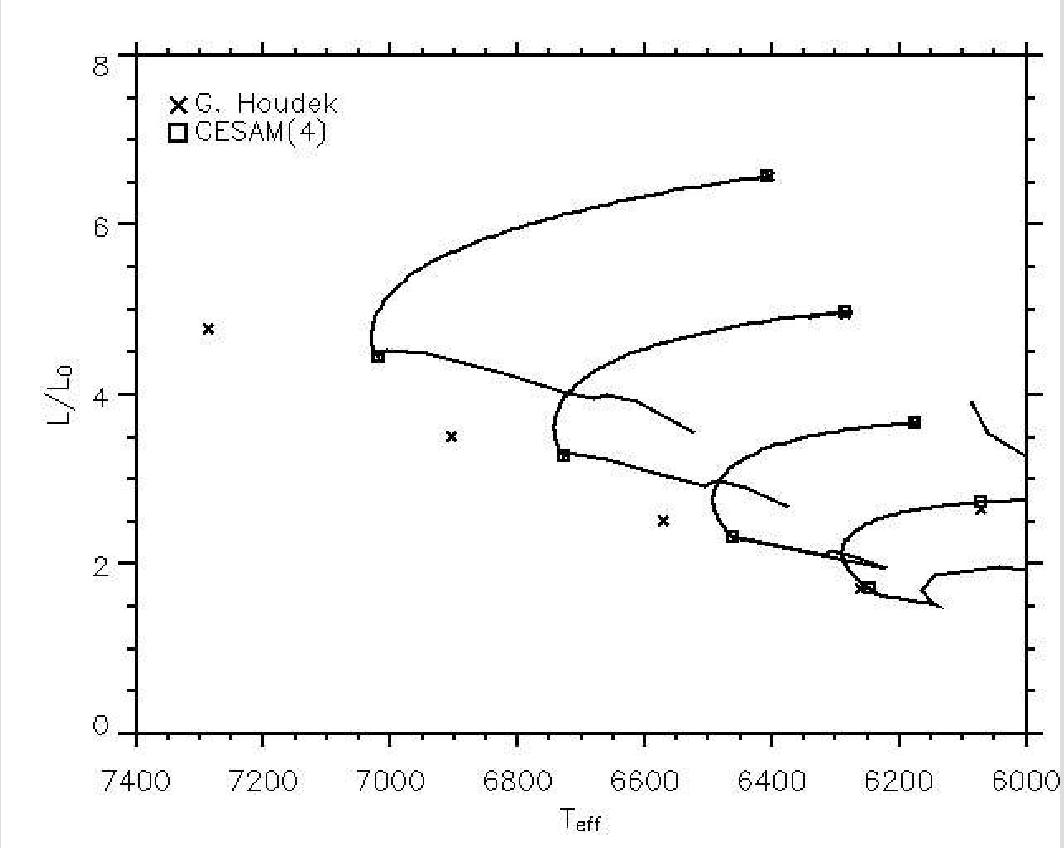
Stellar (Sun) noise: Simu vs LOI/SoHO



Some results



Available models



- Masses : 1.2 ; 1.3 ; 1.4 ; 1.5 ; 1.6
- Ages : ZAMS et TAMS

☞ the simulator as well as some representatives time series can be downloaded at :

http://www.lesia.obspm.fr/~corotswg/