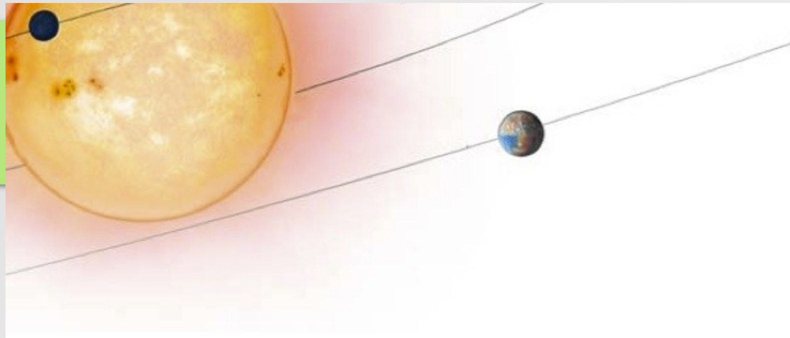


The Solar-like Light-curve Simulator (SLS)

PLATO- PSPSM - WP 126 100

R. Samadi

In short

- Simulate stochastically-excited oscillations
- Include stellar granulation background (and white noise)
- Applications (WP 120):
  - Stellar science performance study
  - Consolidation of the PLATO science case and preparation of the mission
  - Hare and Hounds exercises
- Developed in Python
- Document : PLATO-LESIA-PSPM-TN-014, issue 1.1, sep. 2015

General principle

Model of the expected PSD :

$$\bar{P}(\nu) = W + G(\nu) + O(\nu)$$

W : white noise ; G : granulation ; O : Oscillation spectrum

Stochastic nature of the simulated phenomenon (Anderson et al, 1990's approach):

$$F(\nu) = \sqrt{\bar{P}(\nu)}\ (U + iV)$$

U and V : two Normal distribution ; Hypothesis : uncorrelated phenomenon

Simulated ligth-curve : inverse Fourier transform of F(ν)

Simulated PSD :

$$P(\nu) = |F(\nu)|^2 = \bar{P}(\nu)\ (U^2 + V^2)$$

White noise

The sum of photon noise and other random noises:

$$W = P + N$$

Photon noise scales as the square of star flux: $P = P_0 10^{0.4(V - v_0)}$

V_0 : reference magnitude

Other random noise : scales a the star flux (hypothesis): $N = N_0 10^{0.8(V - v_0)}$

Instrument	Reference magnitude (V_0)	P_0 ppm$^2/\mu$Hz	$\sigma_{P,0}$ ppm per hour
CoRoT - seismology channel	6	0.42	7.7
PLATO - 2 F-cameras	8	26.3	60.5
PLATO - 32 N-cameras	11	5.25	27
Kepler	12	8.3	34

Granulation spectrum

Two components (pseudo-lorentzian):

$$G(\nu) = \sum_{i=1,2} \frac{h_i}{1+(2\pi\tau_i\nu)^{\alpha_i}}$$

(Kallinger et al 2014)

h_i : height(s)

τ_i : characteristic time(s)

α_i : slope(s)

Origin of the two components not well established ….

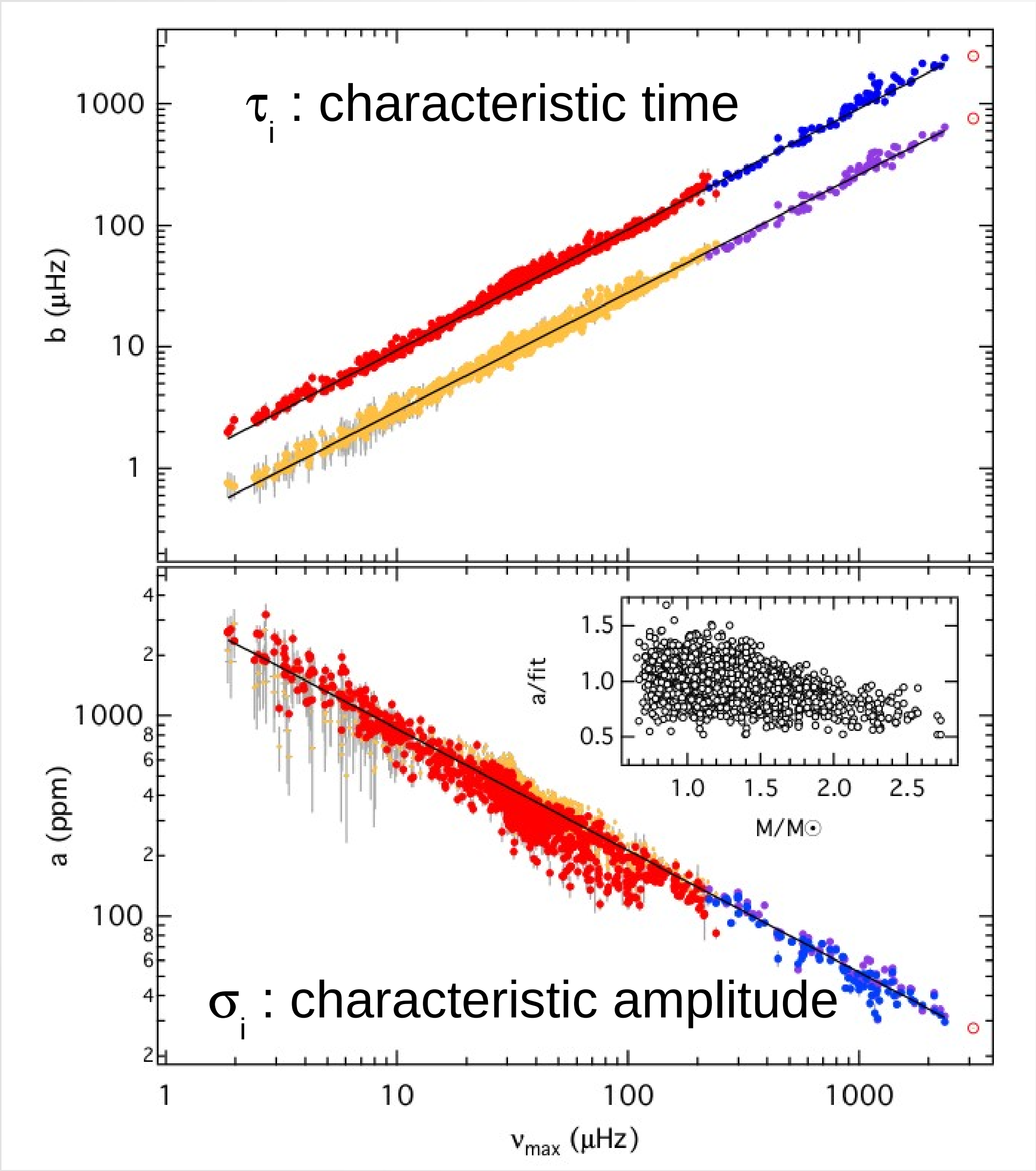
Following Kallinger et al (2014) :

- Slopes fixed (=4)
- h_i and τ_i from scaling relations function of ν_{max}

Square of the total brightness fluctuations (σ^2)

$$\sigma^2 = \sum_i \frac{1}{2} \frac{P_i}{\tau_i \alpha_i \sin(\frac{\pi}{\alpha_i})}$$

Granulation spectrum



Kallinger et al (2014)

See also:
Mathur et al (2011)

Some theoretical supports:
Ludwig (2006)
Mathur et al (2011)
Samad et al (2013 a&b)

More details in Ludwig's talk

Oscillation spectrum

Two types of oscillation spectra:

- Universal Pattern (UP, Mosser et al 2010) with mixed-modes
- Set of theoretical oscillation frequencies derived from a pulsation code (ADIPLS)

$$O(\nu) = \sum_{i=1,N} L_i[\nu]$$

Resolved mode:

$$L_i(\nu) = \frac{H_i}{1 + \left(2(\nu - \nu_i)/\Gamma_i\right)^2}$$

h_i : mode height

ν_i : mode frequency

Γ_i : mode linewidth

Unresolved mode:

$$L_i(\nu) = \frac{\pi \Gamma_i H_i}{2 \delta \nu} sinc^2[\pi(\nu - \nu_i)]$$

Universal pattern

Following Mosser et al (2011)

$$\nu_{n,\ell} = n + \frac{\ell}{2} + \varepsilon(\Delta\nu) - d_{0\ell}(\Delta\nu) + \frac{\alpha_\ell}{2}\left(n - \frac{\nu_{\max}}{\Delta\nu}\right)^2 \Delta\nu + \delta_{n,\ell}$$

Additional term for dipole modes, asymptotic gravity-mode spacing (Mosser et al 2012)

$$\delta_{n,\ell} = \frac{\Delta\nu}{\pi} \arctan\left[q \tan\pi\left(\frac{1}{\Delta\Pi_1 \nu_{n,\ell}} - \epsilon_g\right)\right]$$

Mode amplitudes and line-widths:

Gaussian envelope $$G(\nu) = H_{max} \exp\left[\frac{-(\nu-\nu_{max})^2}{\delta\nu_{env}^2/4\ln 2}\right]$$

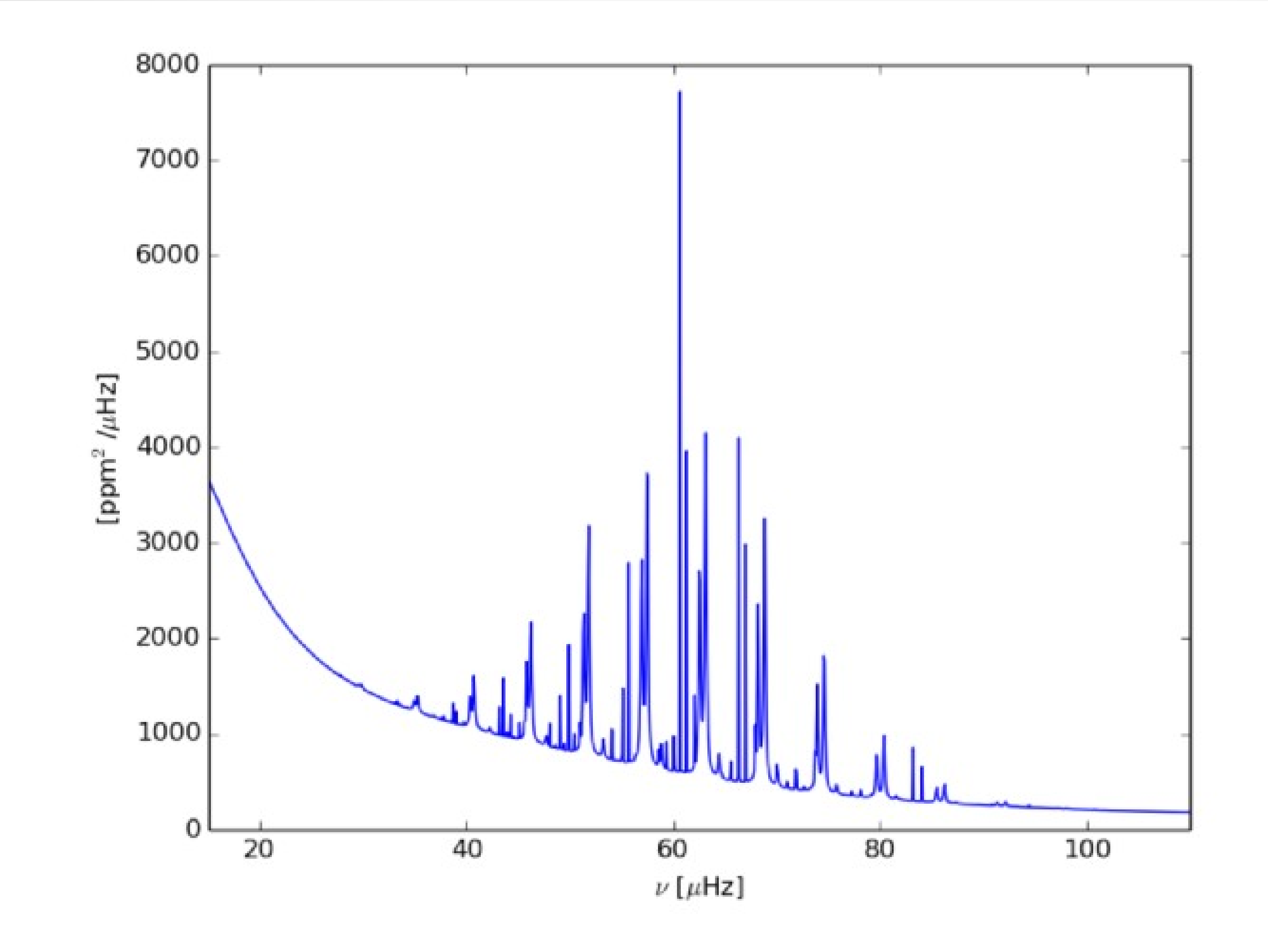
$$H_{max} = \alpha\,\nu_{max}^{-2.38}$$

(Mosser et al 2013, SF2A)

$$\Gamma_{max} = \Gamma_0\left(\frac{T_{eff}}{4800\,K}\right)^{10.8}$$

(Belkacem 2012, SF2A)

Universal pattern



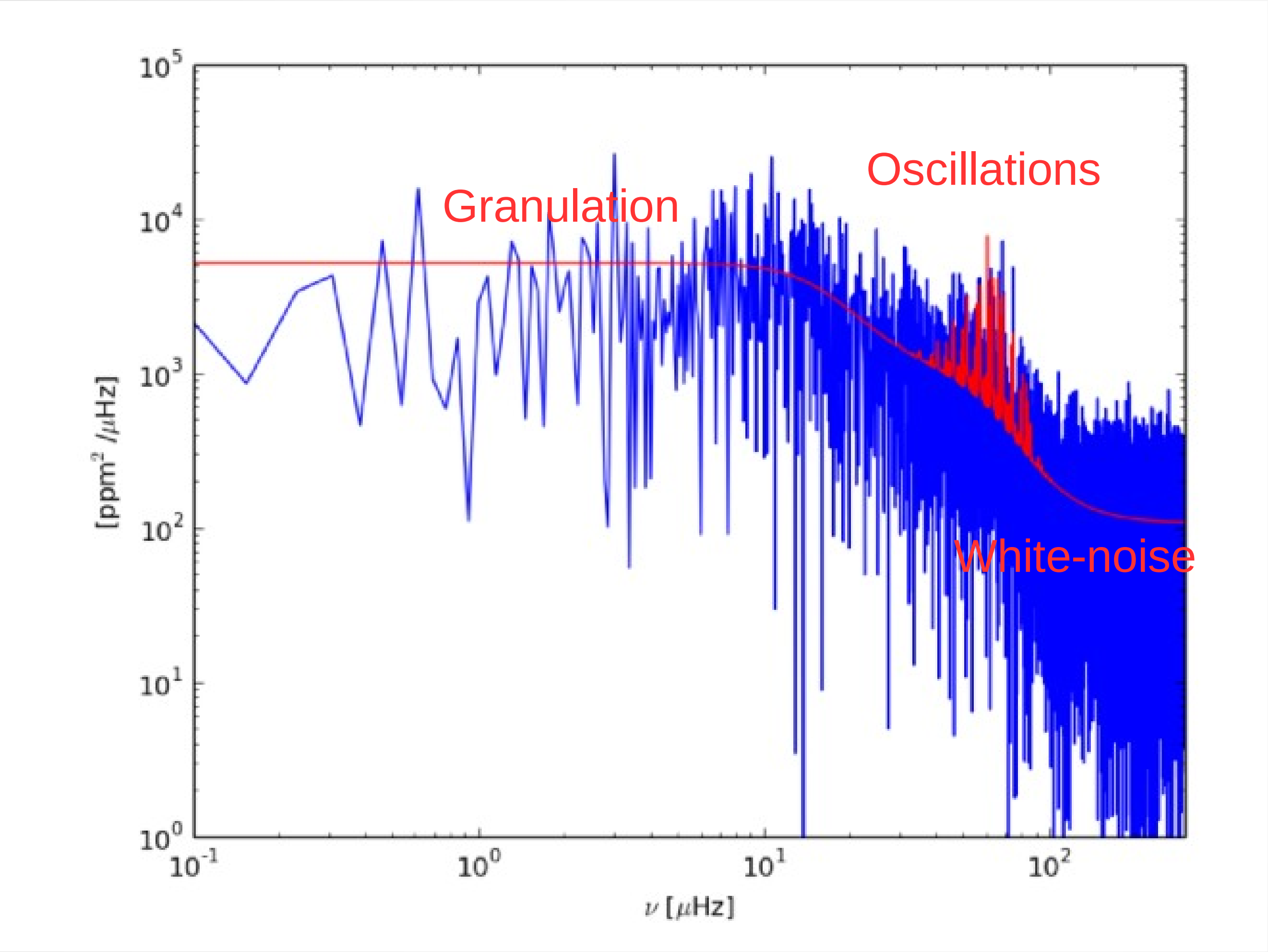
Theoretical spectrum ("expectation")

Input parameters:
- νmax

- Δν
- Teff

- q (coupling)

Universal pattern



R. Samadi, The Solar-Like Light Curve Simulator, PSPM WP 120 Meeting, 23-24 May 2016

Simulated spectrum (for a given realization)

Set of theoretical mode frequencies

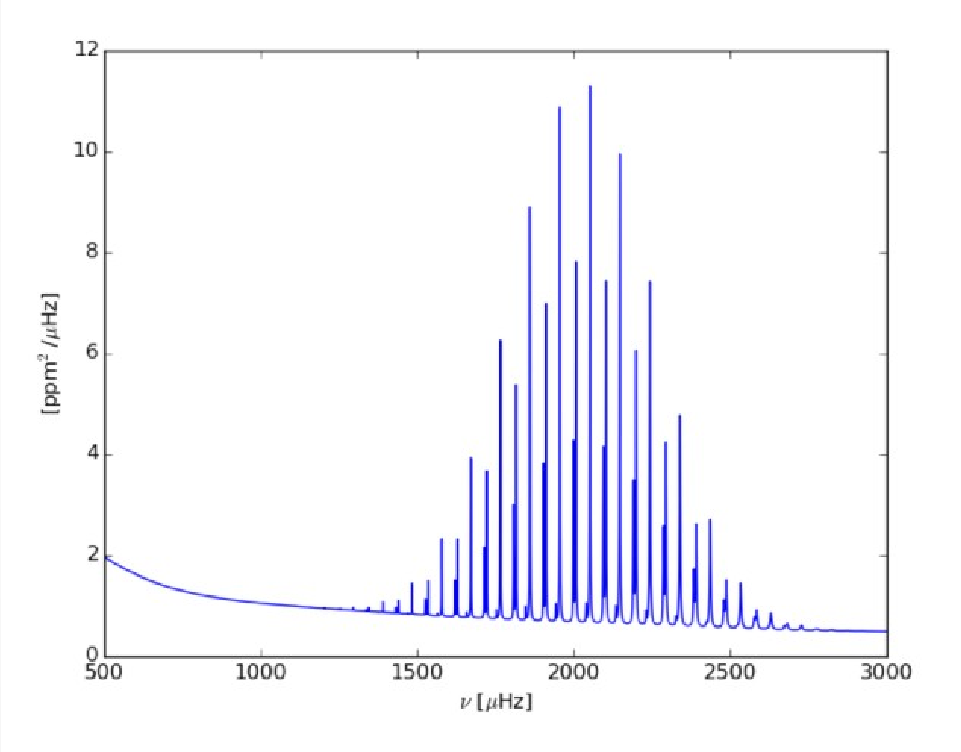
Theoretical adiabatic frequencies : as given by ADIPLS

Spilling : constant (Ledoux's constant from ADIPLS)

Surface effects :
Lorentzian component (Sonoi et al 2015)
2 free input parameters (a,b)

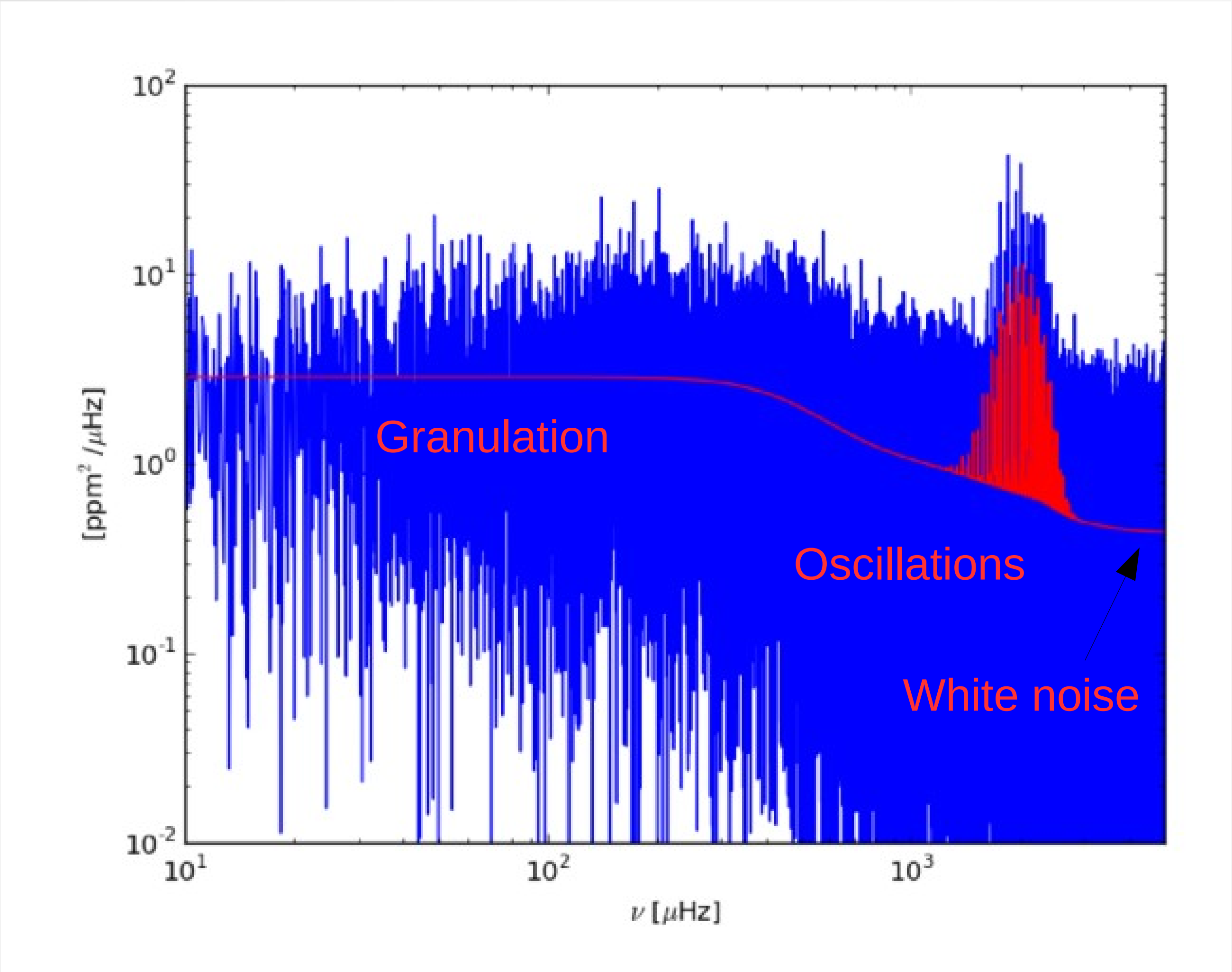
Amplitudes : observationnal scaling relation from Corsaro et al (2013)

Line-widths : observationnal scaling relation from Appourchaux et al (2012)



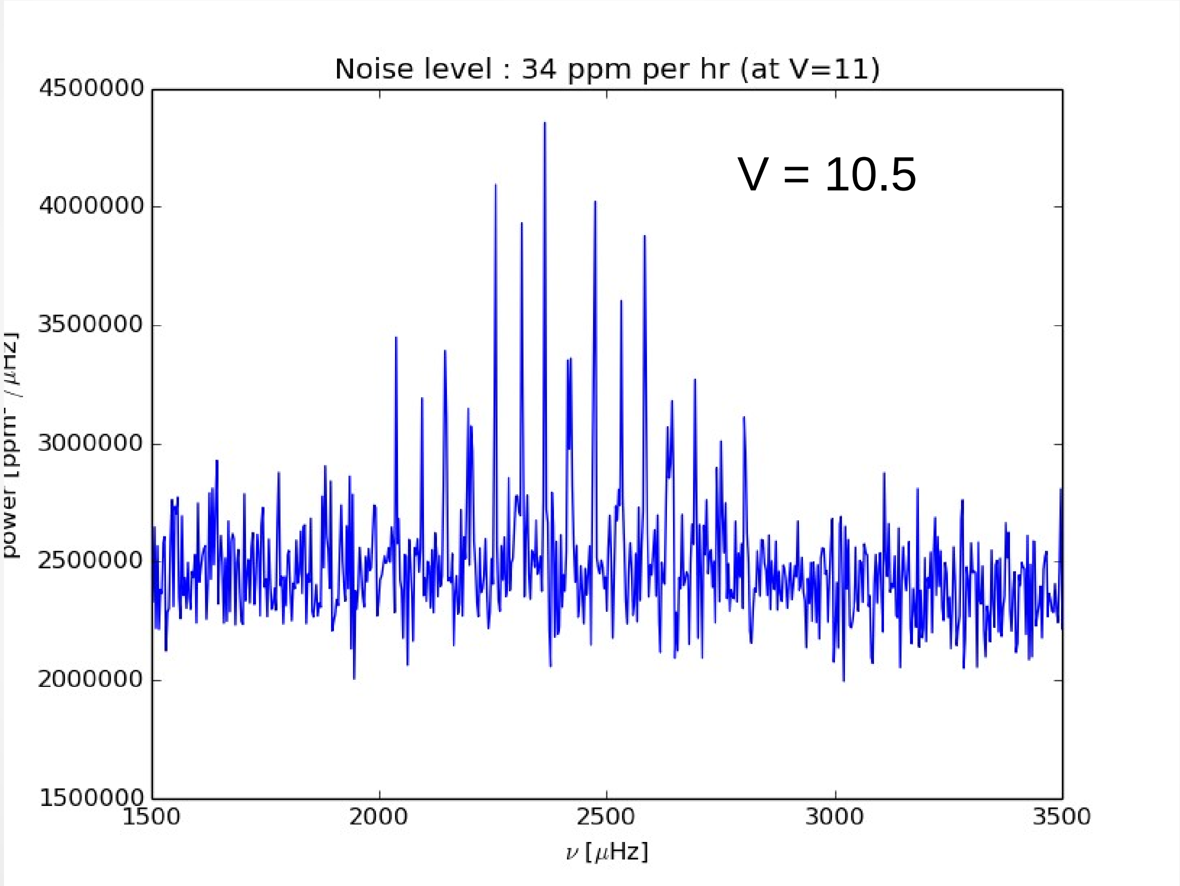
A typical PLATO target

Set of theoretical mode frequencies



Set of theoretical mode frequencies

PLATO application

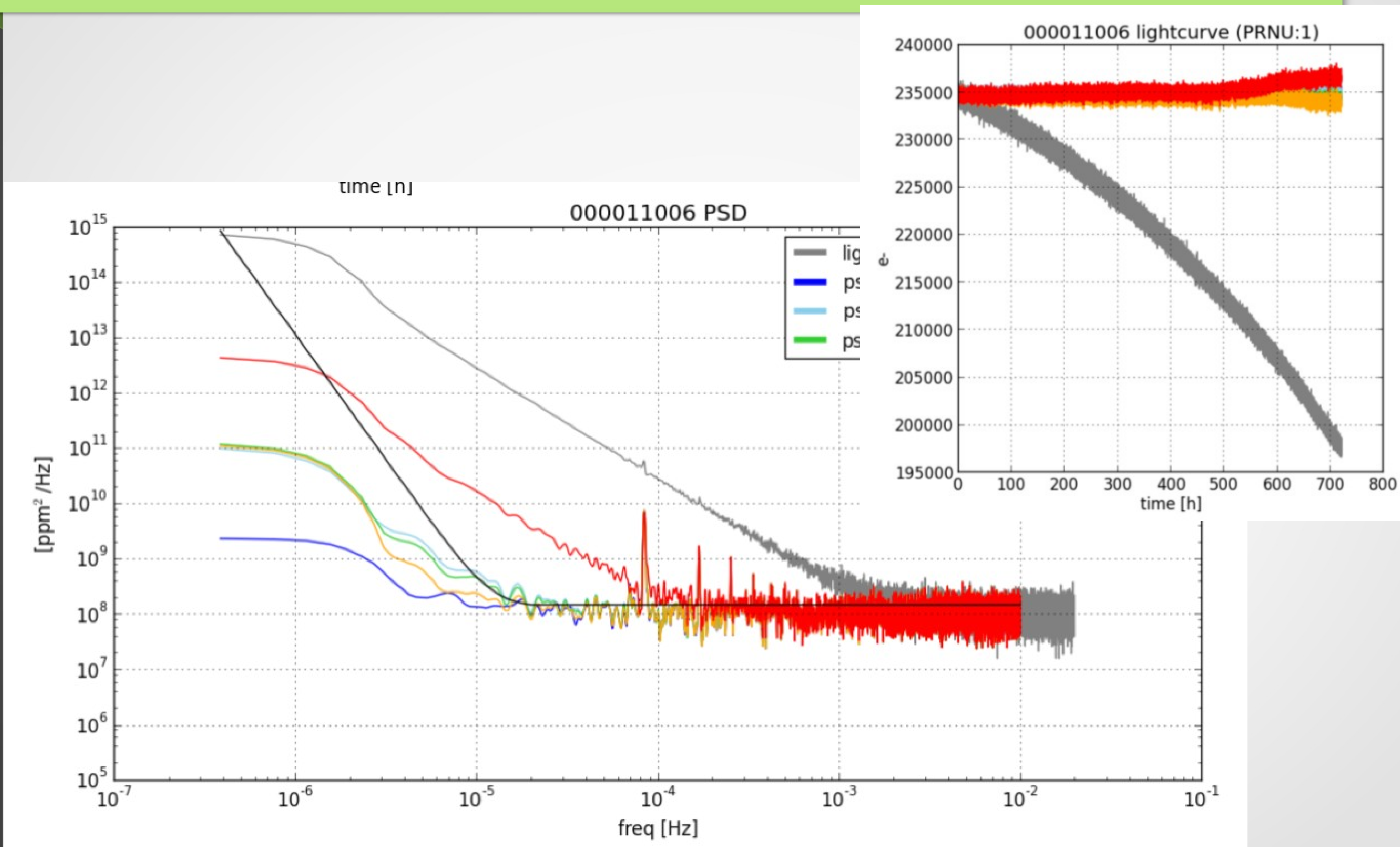


Conclusion and perspectives

- Easy to install and use , fast
- Free access for PLATO consortium members

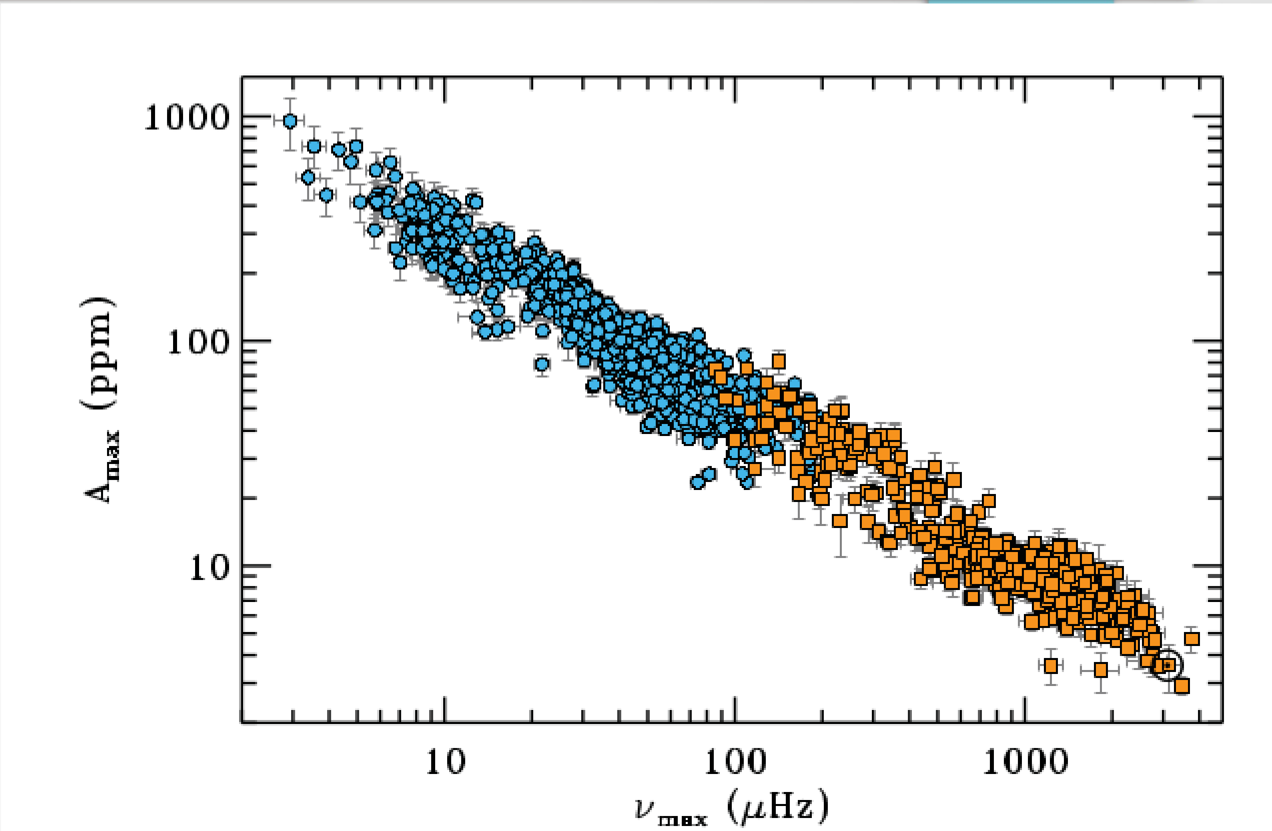
- Treatment of the mode line-widths (e.g. results from non-adiabatic pulsations)
- Activity component
- Realistic instrumental effects (“red noise”, periodic perturbations, ….)

Predicted instrumental “red” noise



Observational scaling relation of mode amplitudes

Corsaro et al (2013)



$$\ln\left(\frac{A_{\rm bol}^{(3)}}{\mathrm{A}_{\rm bol,\odot}}\right) = (2s-3t)\ln\left(\frac{\nu_{\max}}{\nu_{\max,\odot}}\right) + (4t-4s)\ln\left(\frac{\Delta\nu}{\Delta\nu_\odot}\right) + (5s-1.5t-r+0.2)\ln\left(\frac{T_{\rm eff}}{\mathrm{T}_{\rm eff,\odot}}\right)\,, \qquad (43)$$

-24 May 2016