A new method for extraction of seismic indices and stellar granulation parameters

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SSI database

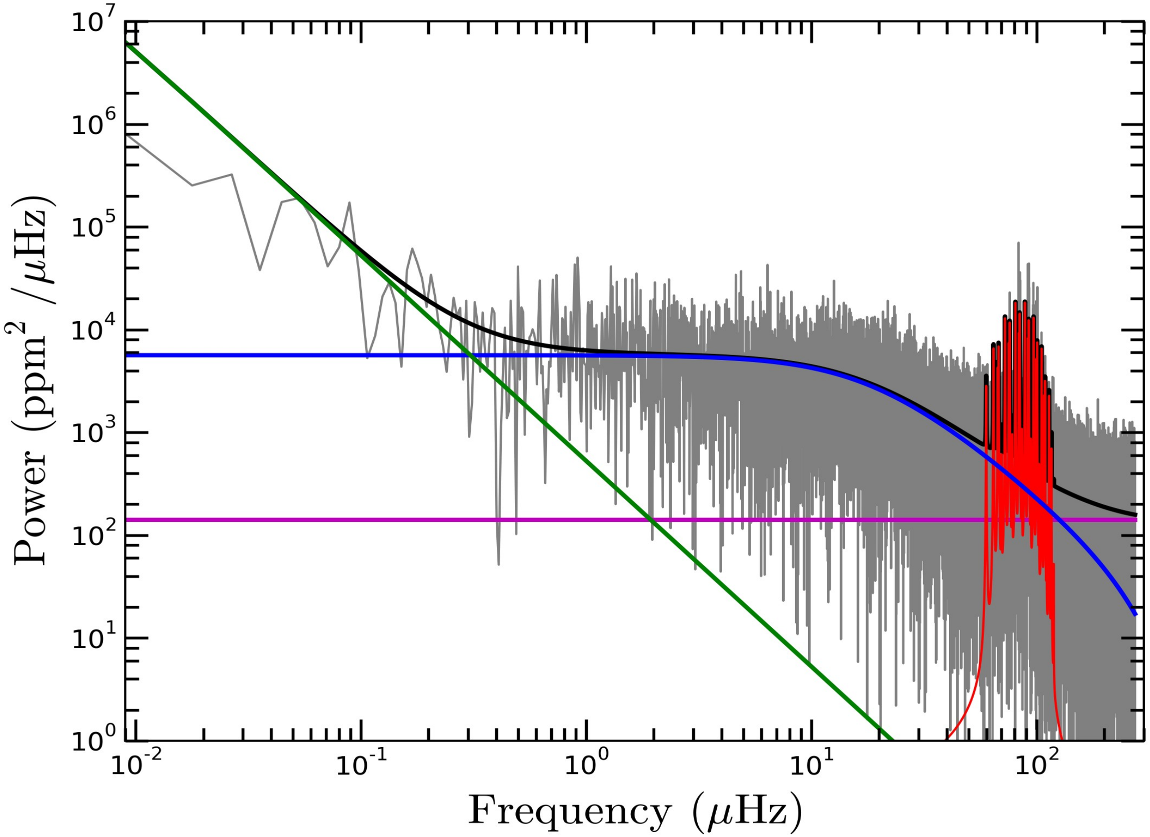
- SSI: Stellar Seismic Indices (see Samadi's poster, PA.S4.20)
  - Website : http://ssi.lesia.obspm.fr/
- Content:
  - Oscillations: $\Delta\nu$ & ν_{max} (Seismic indices)
  - Granulation: τ_{eff} (effective timescale) & σ^2 (Characteristic amplitude)
- Seismic Fondamental parameters (M, R, log g, …) via the tools available at the Seismic Plus Portal

Algorithm

- Our goal : to extract homogeneously as much as possible the seismic indices and parameters of granulation from datasets (CoRoT, Kepler, ...)
- Must be :
  - Automatic
  - Robust & efficient
  - accurate & precise
- Controle on :
  - Bias
  - Dispersions
  - Internal errors

Description of the algorithm MLEUP

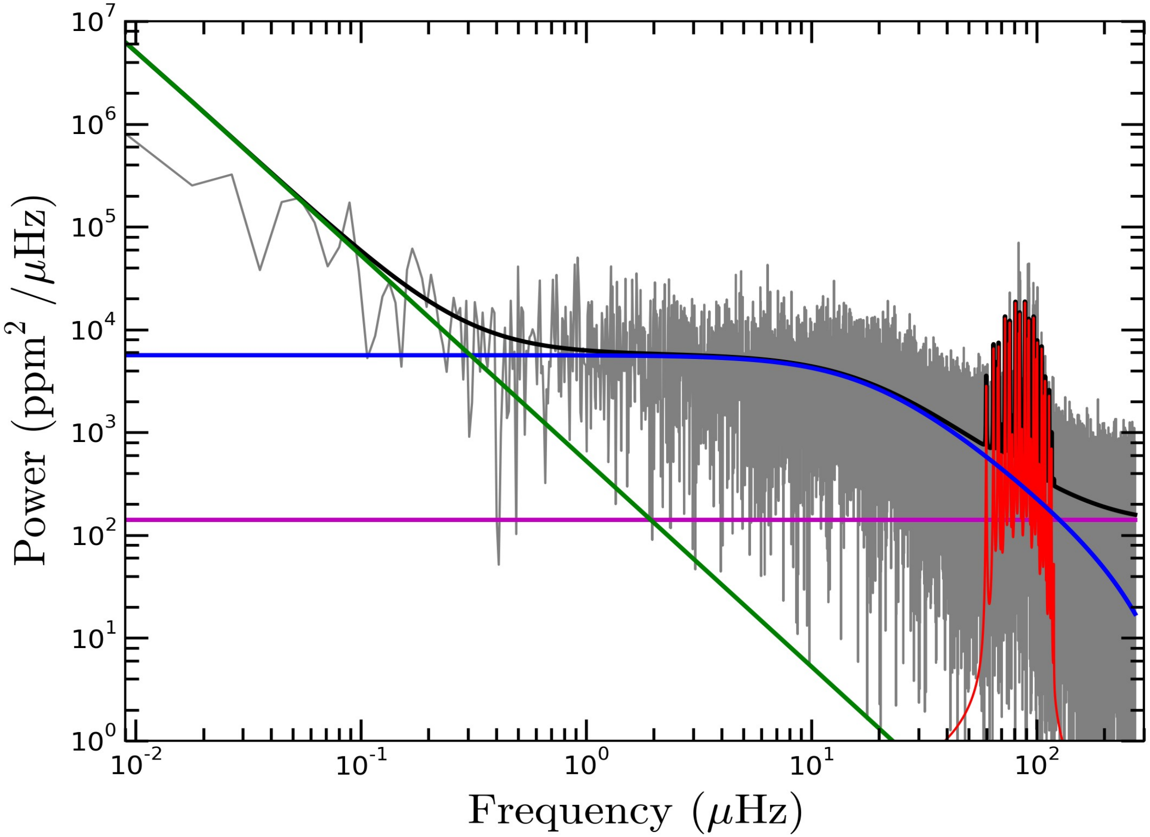
- New method
- Simultaneous measurement of the oscillations and the granulation
- Fit the unsmoothed spectrum using the Maximum Likelihood estimator (MLE, cf. Numerical Recipies)



Description of the algorithm MLEUP

- Model: $$P(\nu) = W + \eta^2(\nu)\left[\left(\frac{P_{act}}{(1+2\pi\tau_{act}\nu)^2}\right) + \frac{P_{gran}}{(1+2\pi\tau_{gran})^{\alpha_{gran}}} + UP(\nu)\right]$$

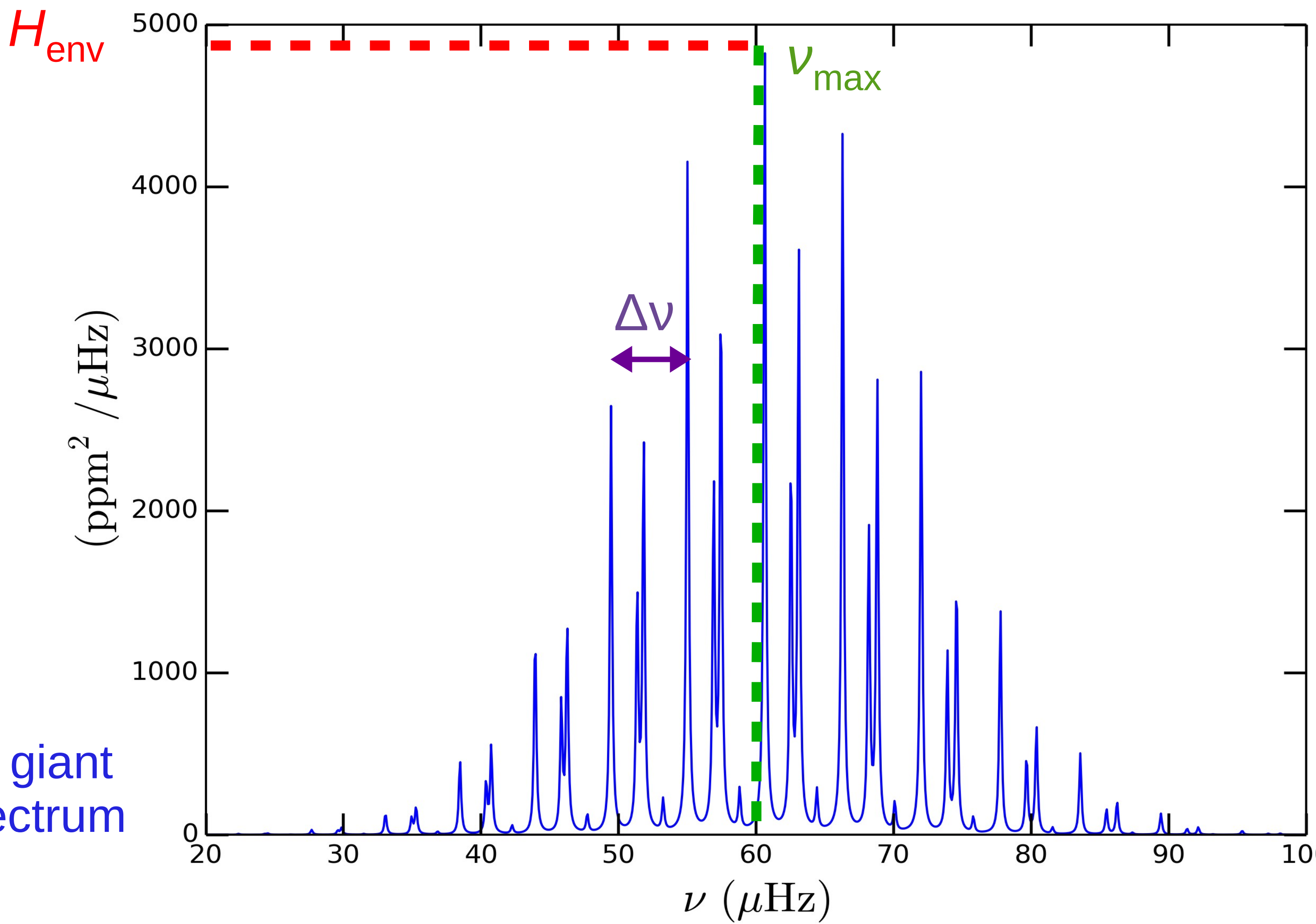
With η(ν) : damping factor (e.g. Kallinger et al. 2014)



Description of the algorithm MLEUP

- Universal Pattern: $UP(\nu)=G(\nu)\times\sum_{n=1}^{n_{env}}\sum_{3}^{\ell=0}\mathscr{L}_{n,\ell}(\nu)$

  (cf. Mosser et al. 2011)



Parametric red giant oscillations spectrum

Parameters of granulation

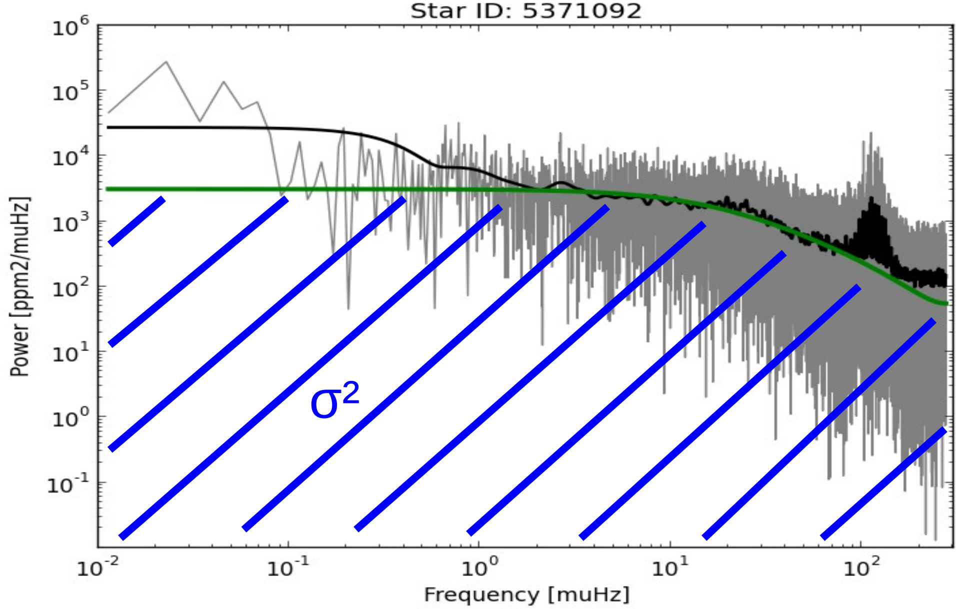
From P_{gran}, τ_{gran} and α_{gran}, we deduce:

- **Characteristic amplitude σ² (ppm)**

  Variance brightness fluctuation (e.g. Ludwig 2006)
  => measures the total integrated energy

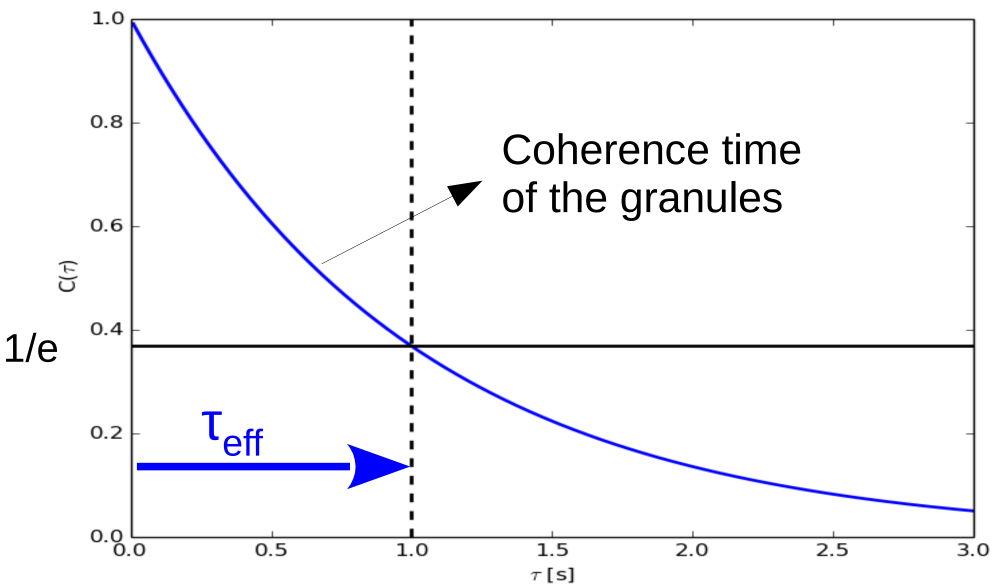
$$\sigma^2_{gran} = \int_0^{+Nyq} P(\nu)\, d\nu = \frac{P_{gran}}{2\tau_{gran}\,\alpha_{gran}\,\sin\left(\frac{\pi}{\alpha_{gran}}\right)}$$

Karoff et al. 2013

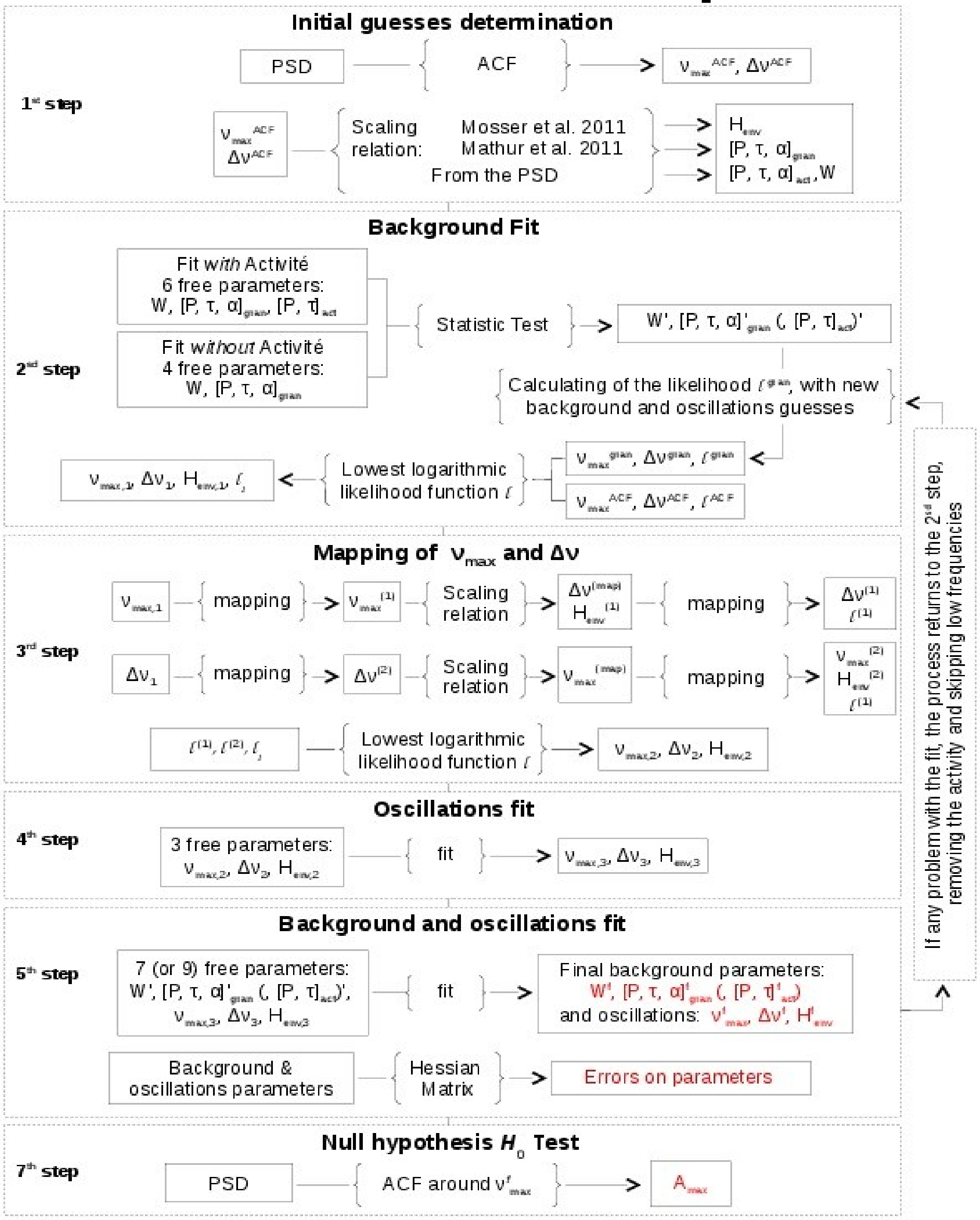


- **Effective timescale τ_{eff} (s)**

  "e-folding time" of the autocorrelation function of the time series (e.g. Mathur et al. 2011; Kallinger et al 2014).
  => measures the temporal coherence in the time domain.

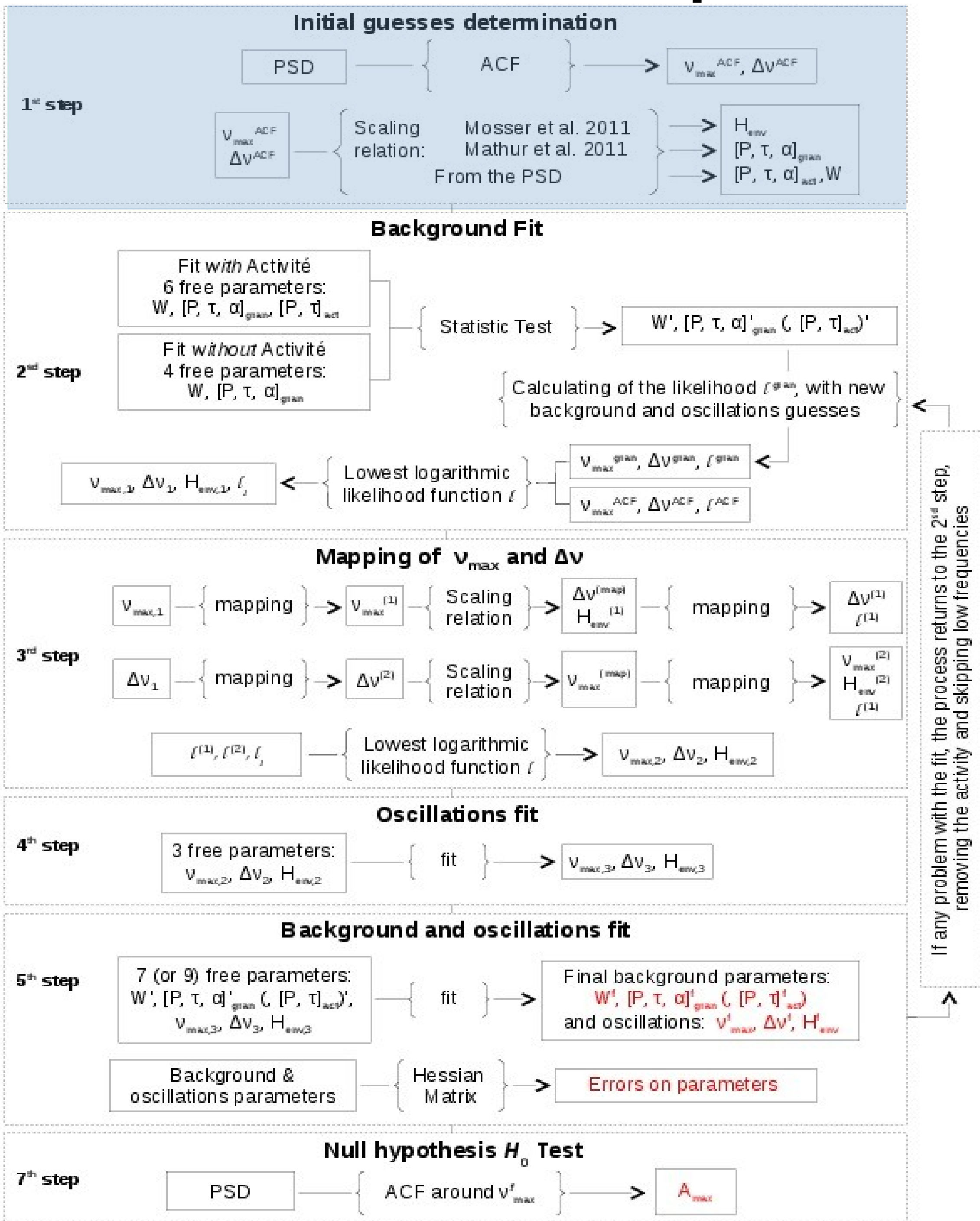


Description of MLEUP



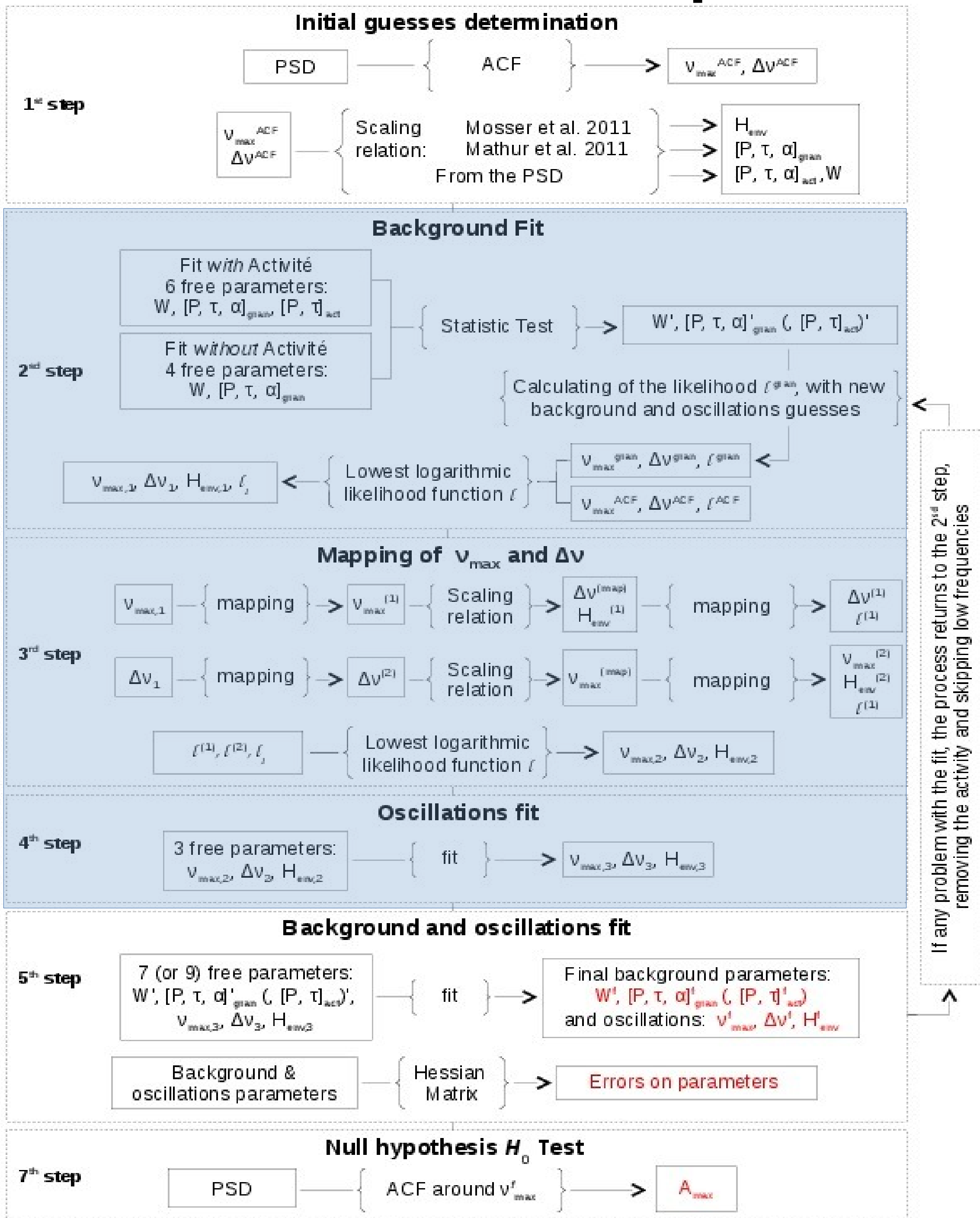
Follows several steps (see R. de Assis Peralta et al. 2016, in prep)

Description du MLEUP



1st guesses estimation
(ACF + scaling relation)

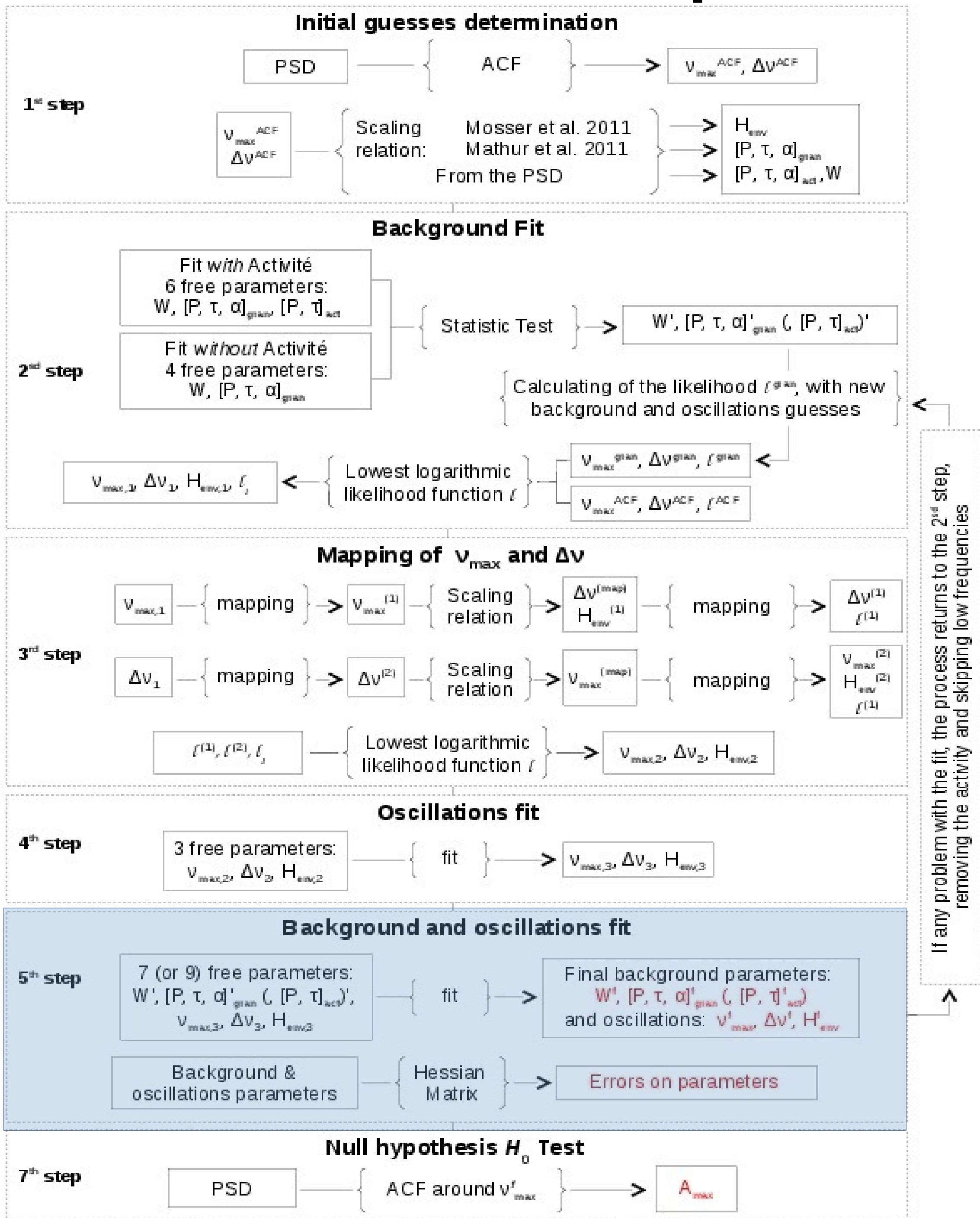
Description du MLEUP



1st guesses estimation (ACF + scaling relation)

Improvement of those estimates by fits and mapping

Description du MLEUP



1st guesses estimation (ACF + scaling relation)

Improvement of those estimates by fits and mapping

Simulateous estimation of :

- Seismic indices : $\Delta\nu$, ν_{max}, H_{env}
- Parameters of granulation : σ^2 & τ_{eff}

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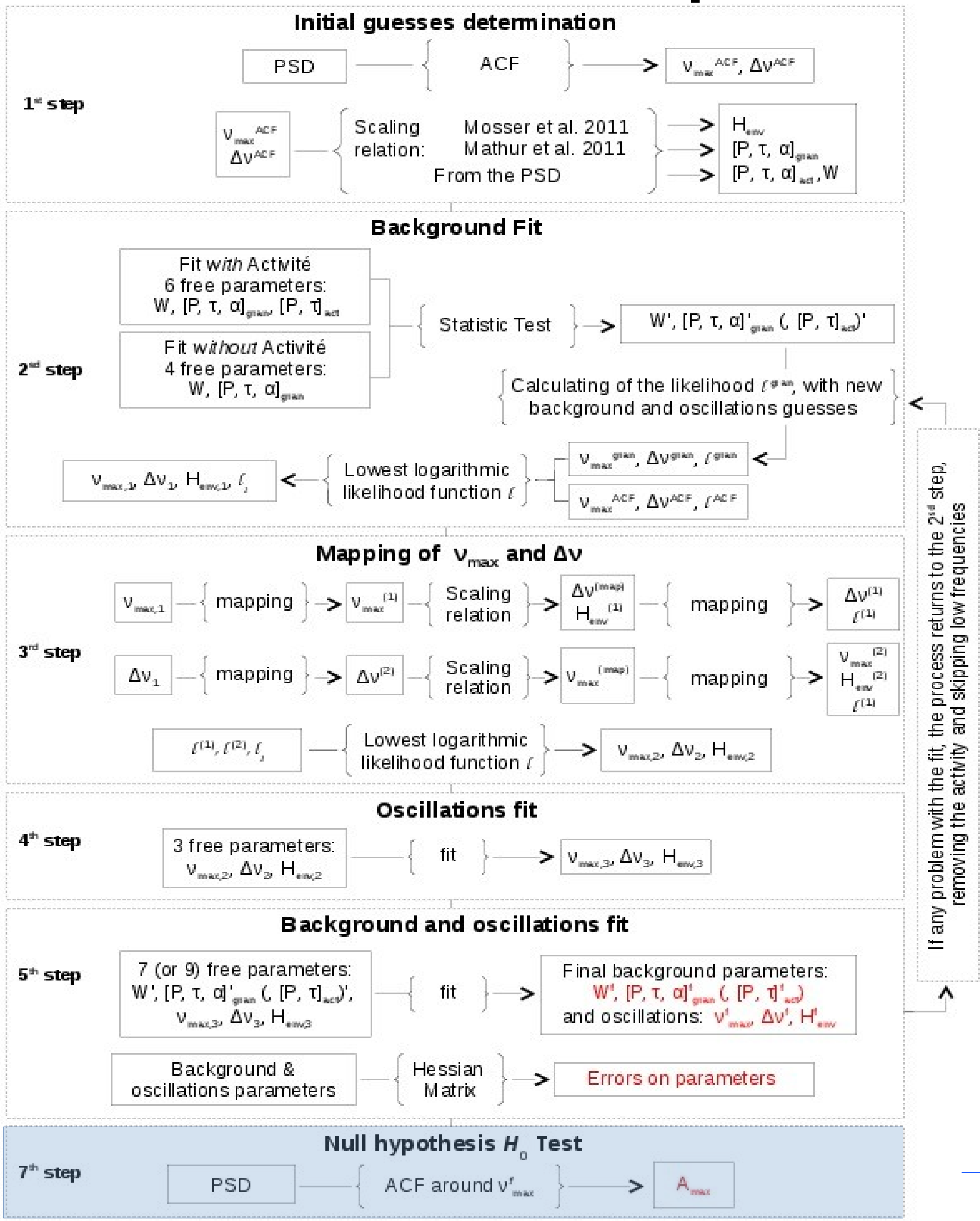

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Simulateous estimation of :
- Seismic indices : $\Delta\nu$, ν_{max}, H_{env}
- Parameters of granulation : σ^2 & τ_{eff}

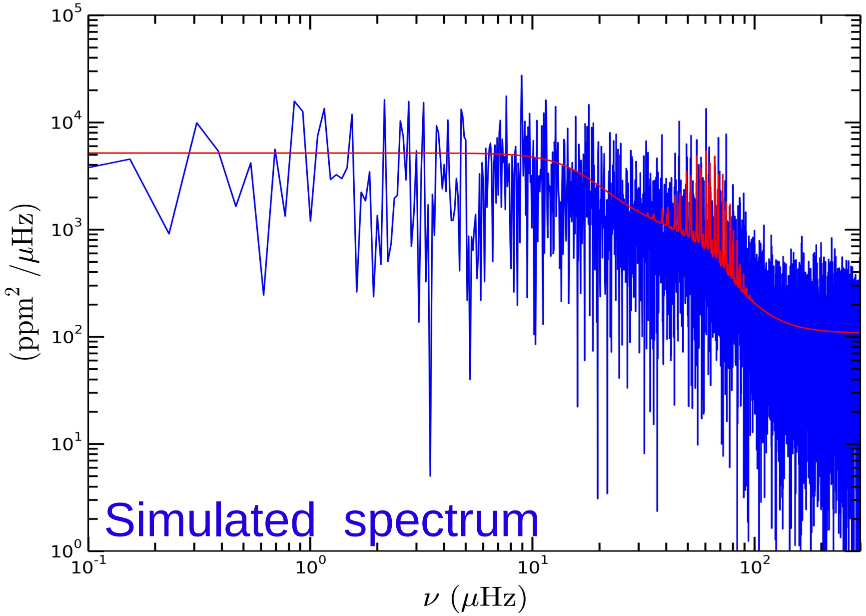
H_0 statistic test (via the ACF, cf. Mosser et al. 2009)

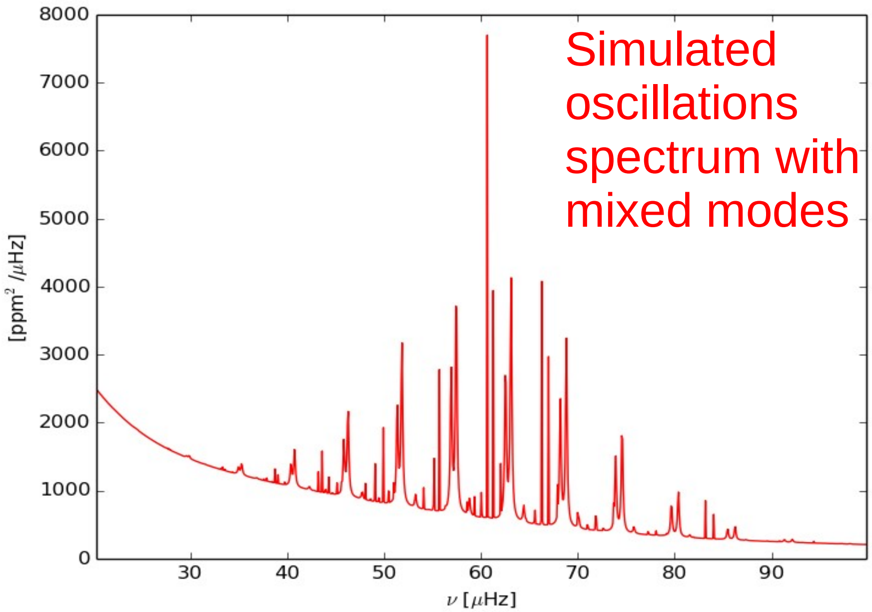
Simulations

- Why:
  - To caracterize the bias, dispersions and internal errors of MLEUP
  - To correct the bias in application to real data

Model used in the simulations

- Model used in simulations:
  - Granulation with 2 components (scaling relations taken from Kallinger et al. 2014)
  - Oscillations using the UP (cf. Mosser et al. 2011) including mixed modes of RGB and clump stars (scaling relations from Vrard et al. 2016)
  - White noise representative of observation conditions for CoRoT and Kepler.
  - No activity



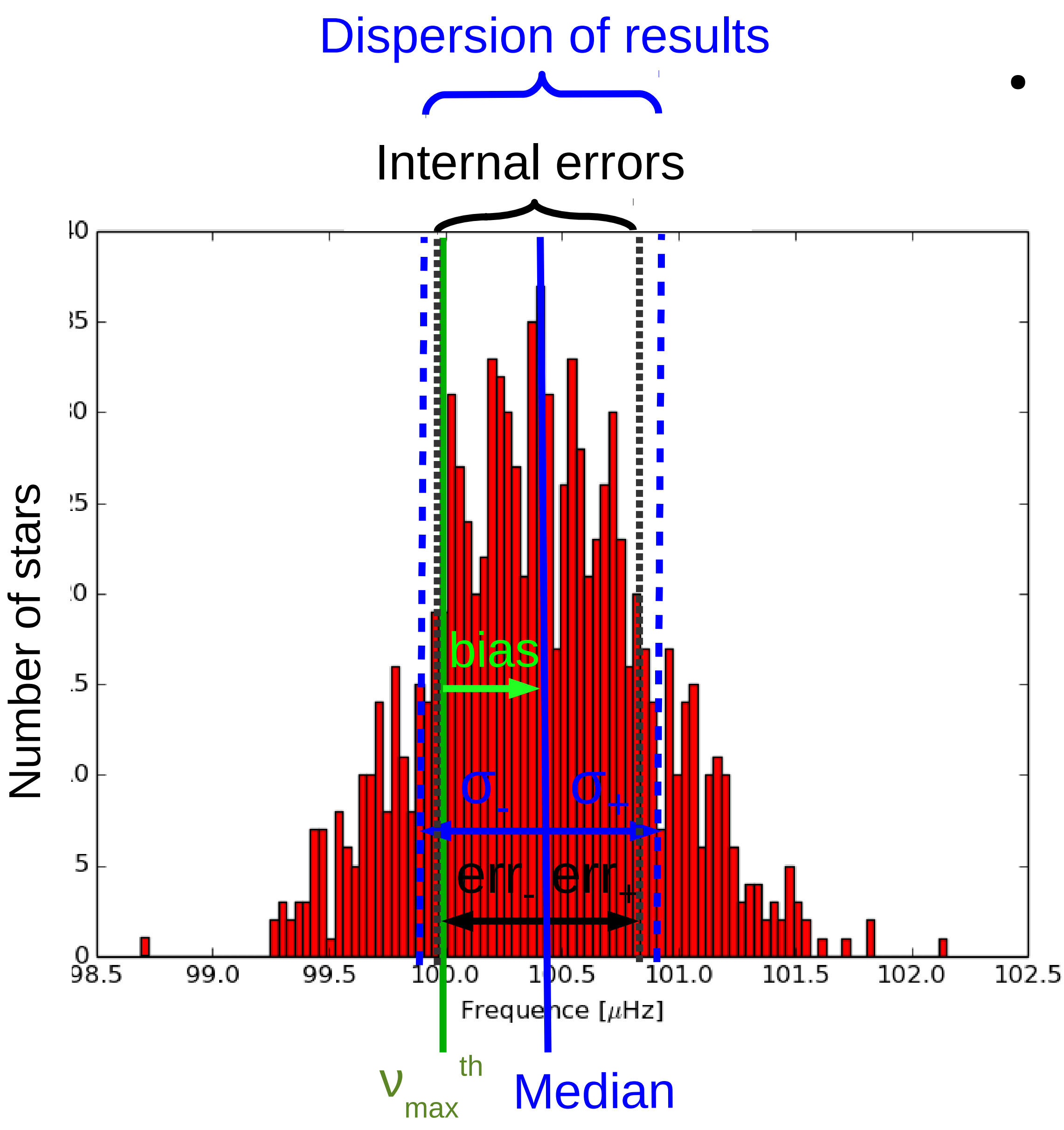


Description of the simulations

- Simulations of 2 datasets for observation conditions representative of Kepler and CoRoT data:

Satellite	Kepler	CoRoT
Duration; sample; magnitude	T=1000 d; dt=1740 s; V=12	T=150 d; dt=512 s; V=13
ν_{max} range	From 10 to 310 µHz by step 30 µHz	From 10 to 110 µHz by step 20 µHz
Evolutionary stage (ES)	RGB & Clump	RGB & Clump
# of simulation/ν_{max}/ES	1000 realizations	1000 realizations

Simulations analysis



- Characterization of performances:
  - **Bias** :

$$bias = \frac{median(X) - X^{th}}{X^{th}}$$

  - **Dispersions σ±** :

$$\sigma_{\pm} = \frac{|q_{\pm 34\%} - median(X)|}{X^{th}}$$

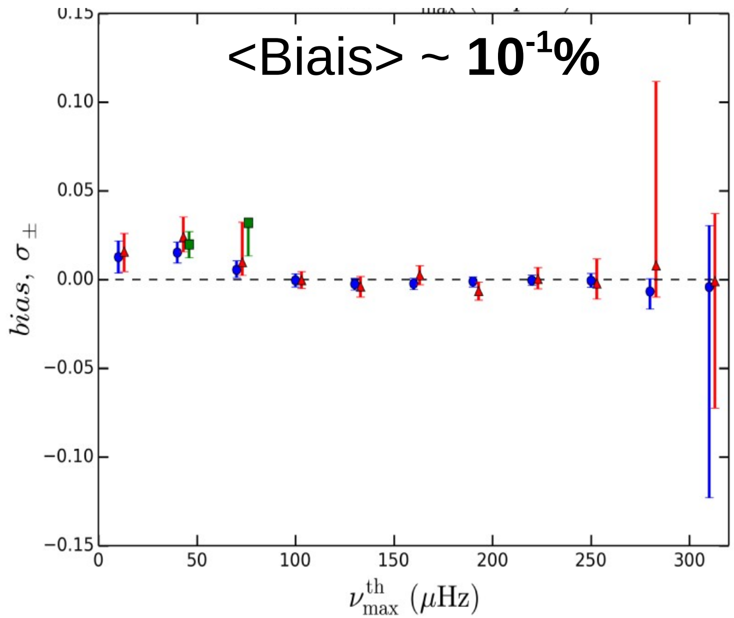
  - **Internal errors err± :**

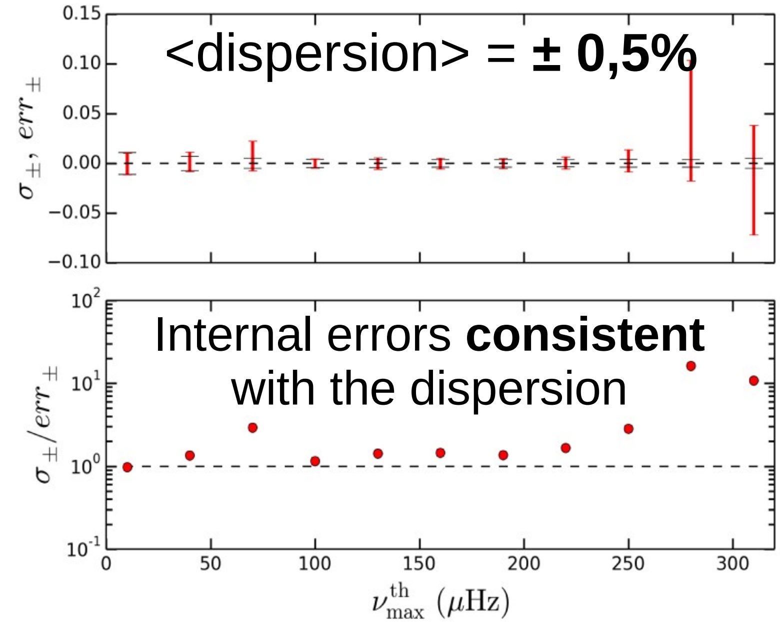
$$err_{\pm} = \frac{mediane(\delta X)}{X^{th}}$$

Some simulation results (Kepler)

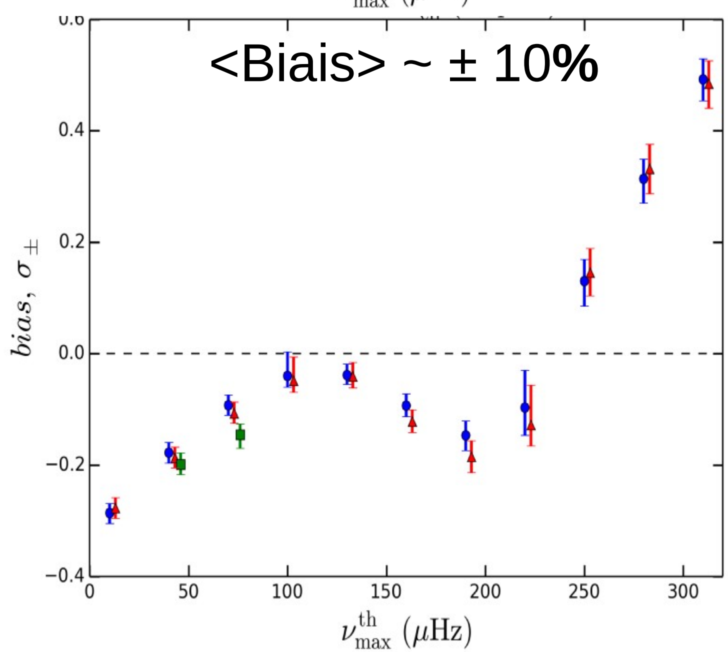
Without mixed mode
RGB
Clump

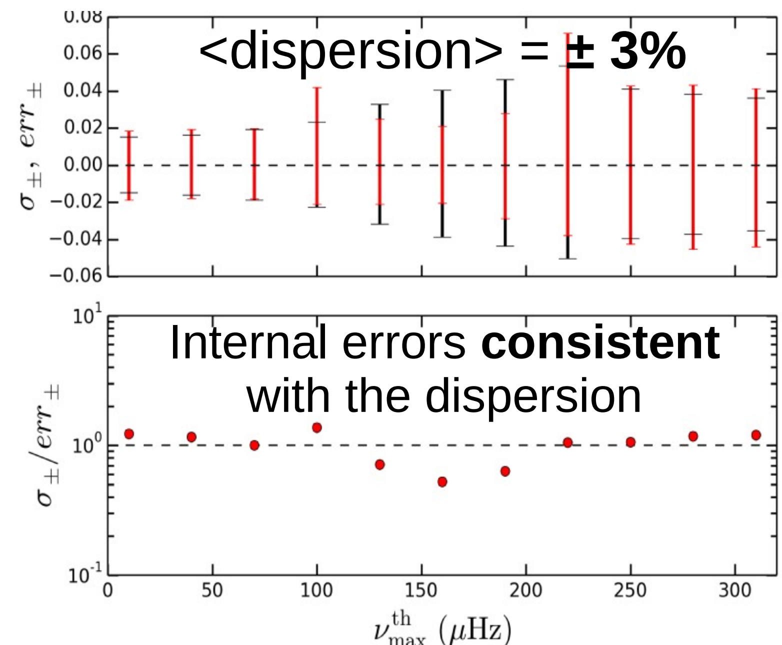
ν_{max}





τ_{eff}





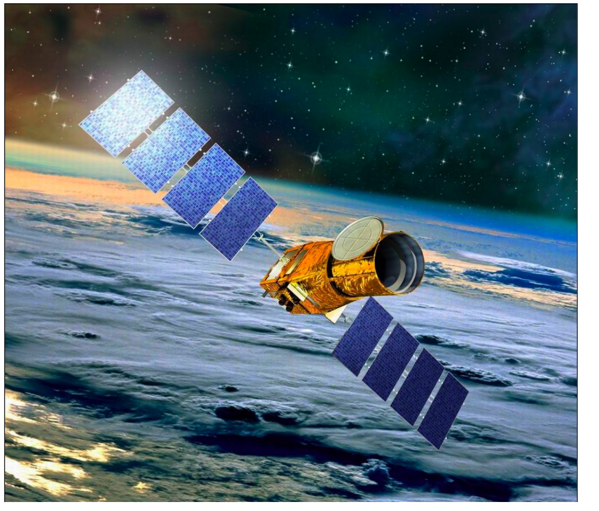
Simulations

	Significance of the bias ($< bias >$) range: [min; max]		Mean value of the dispersion $< \sigma_\pm >$		Internal errors with regards to the dispersion	
	Kepler	CoRoT	*Kepler*	CoRoT	*Kepler*	CoRoT
H_{env}	yes (+1%) [−30; +40%]	no (+15%) [−5; +25%]	±10%	±25%	consistent	consistent
ν_{max}	no (10^{-1}%) [−0,5; +2%]	no (10^{-2}%) [−2; +2%]	±0,5%	±4%	consistent	consistent
$\Delta\nu$	no (10^{-3}%) [-10^{-4}; $+10^{-1}$%]	no (10^{-2}%) [-10^{-2}; $+10^{-1}$%]	$\pm10^{-3}$%	$\pm10^{-1}$%	overestimation (×4)	consistent
τ_{eff}	yes (−2%) [−30; +50%]	no (−5%) [−15; −0,5%]	±3%	±8%	consistent	consistent
σ^2	yes (+3%) [−30; +30%]	no (+1%) [−4; +8%]	±3%	±6%	underestimation (×3)	consistent

Table A1. Table summarizing general trends in terms of bias, dispersion and internal errors of the MLEUP method obtained with the RGB simulations for observations representative of *Kepler* and CoRoT data.

Data analysis

- Analysis of:
  - All **CoRoT** data observed during more than 50 days (~110,000 stars)



  - All long cadence **Kepler** data (~200,000 stars)

Data analysis

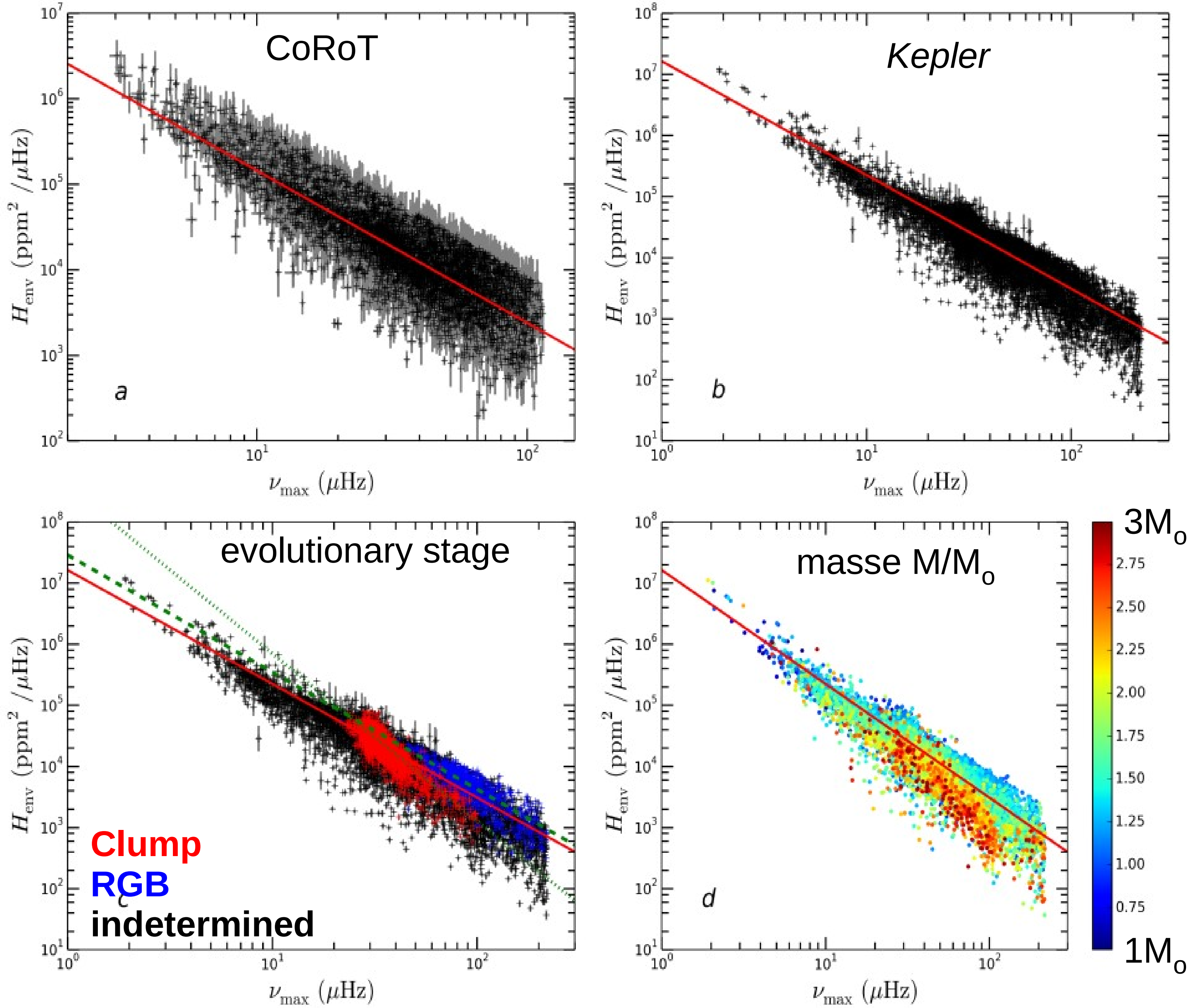
- For some Kepler stars, we have additional informations:
  - **T_{eff}** for almost all the Kepler data (cf. Mathur et al. 2016 in prep)

    → T_{eff} + $\Delta\nu$ & ν_{max} => **seismic Mass & Radius**

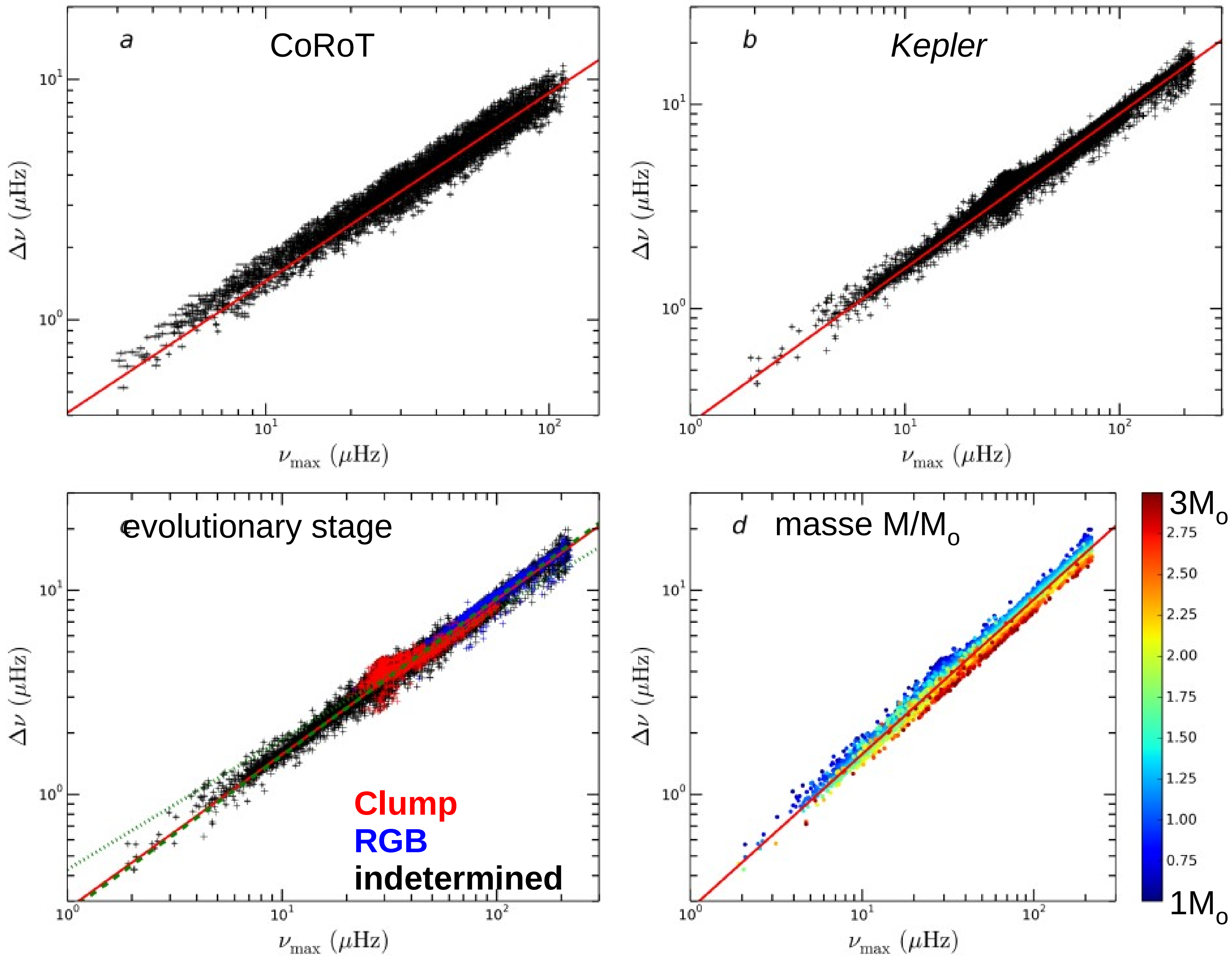
  - Evolutionary stages for ~5000 Kepler stars (cf. Vrard et al. 2016)

    → Distinction between **RGB & Clump stars**

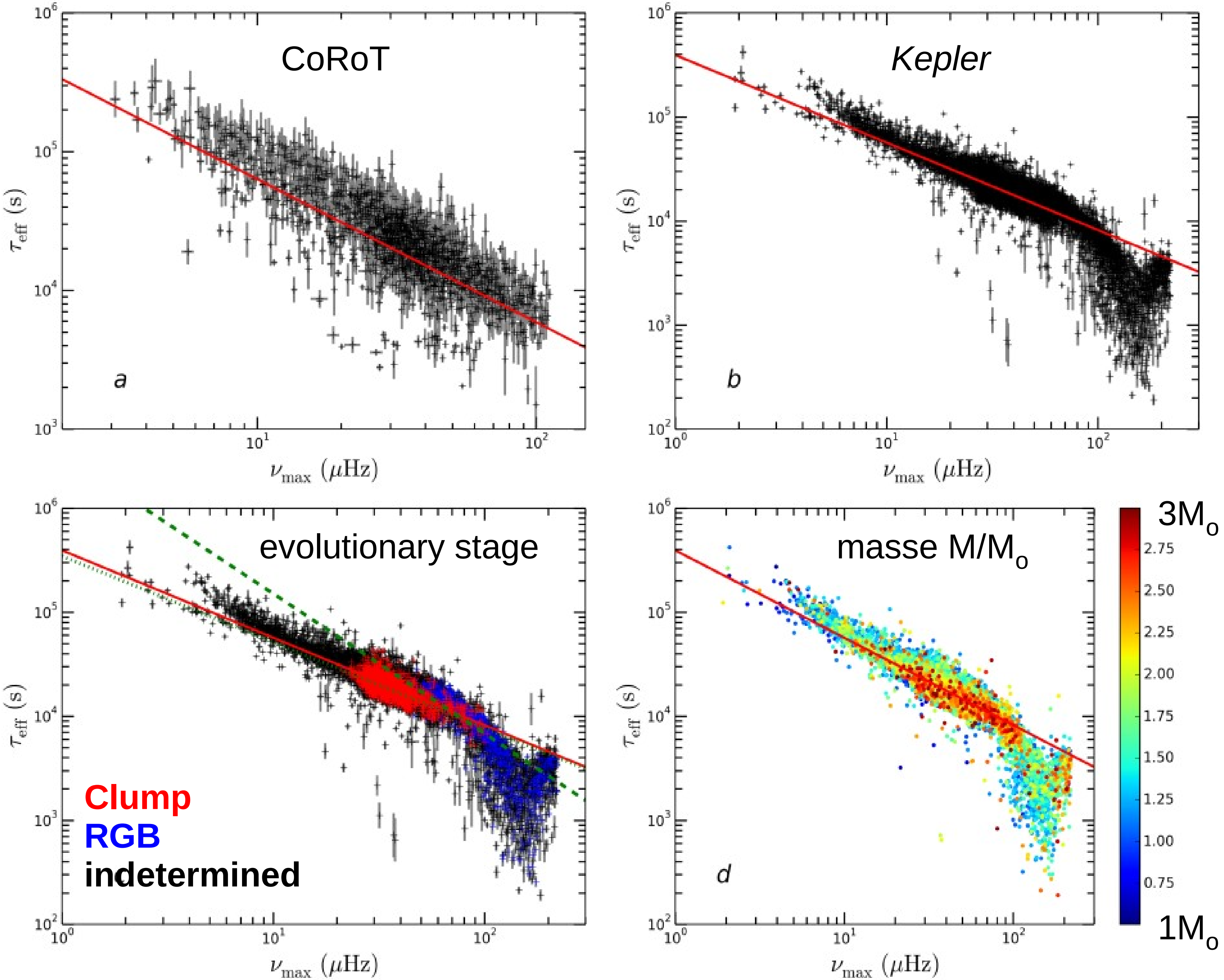
Results analysis: $H_{env} = f(\nu_{max})$



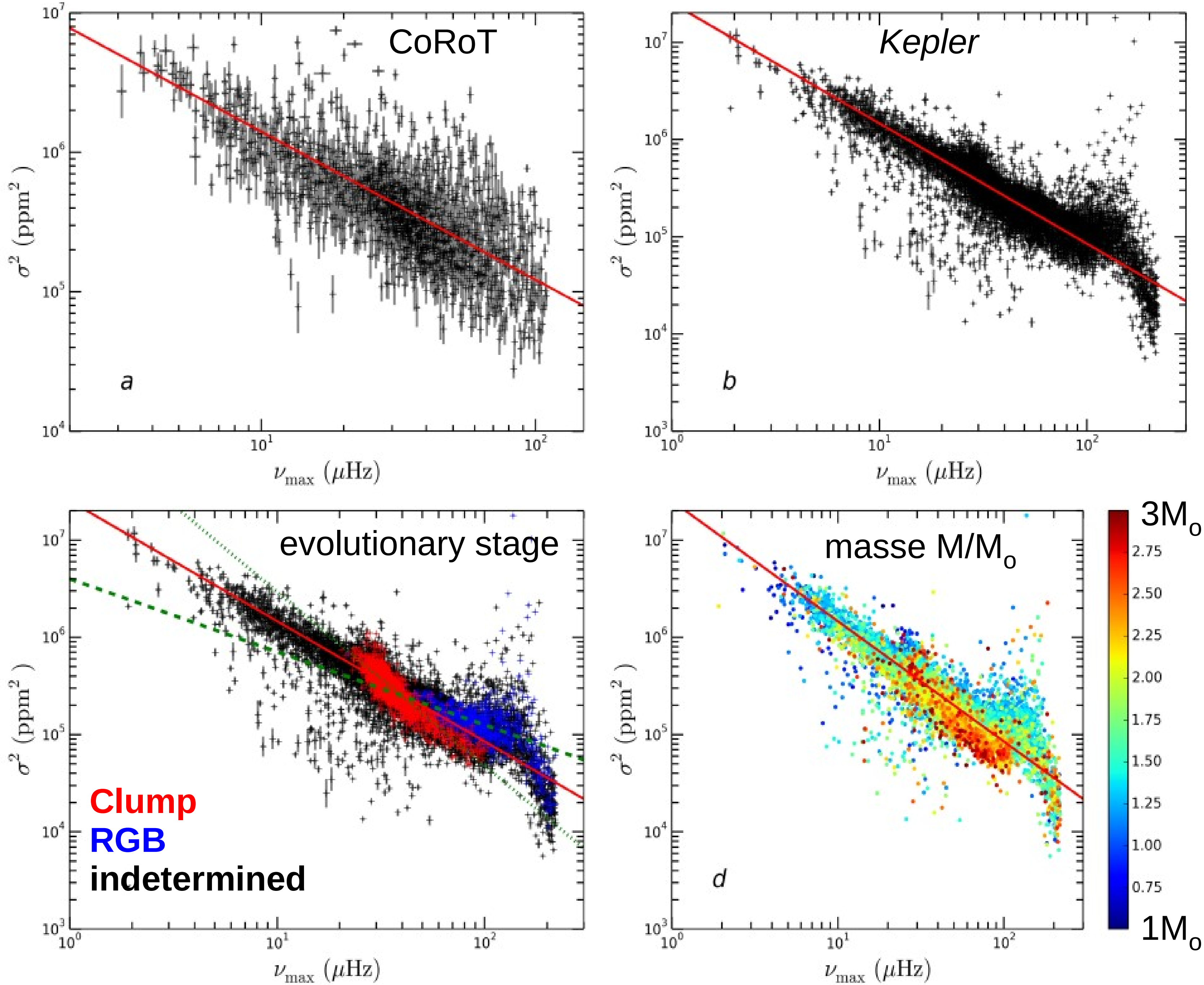
Results analysis: $\Delta\nu = f(\nu_{max})$



Results analysis: $\tau_{eff} = f(\nu_{max})$



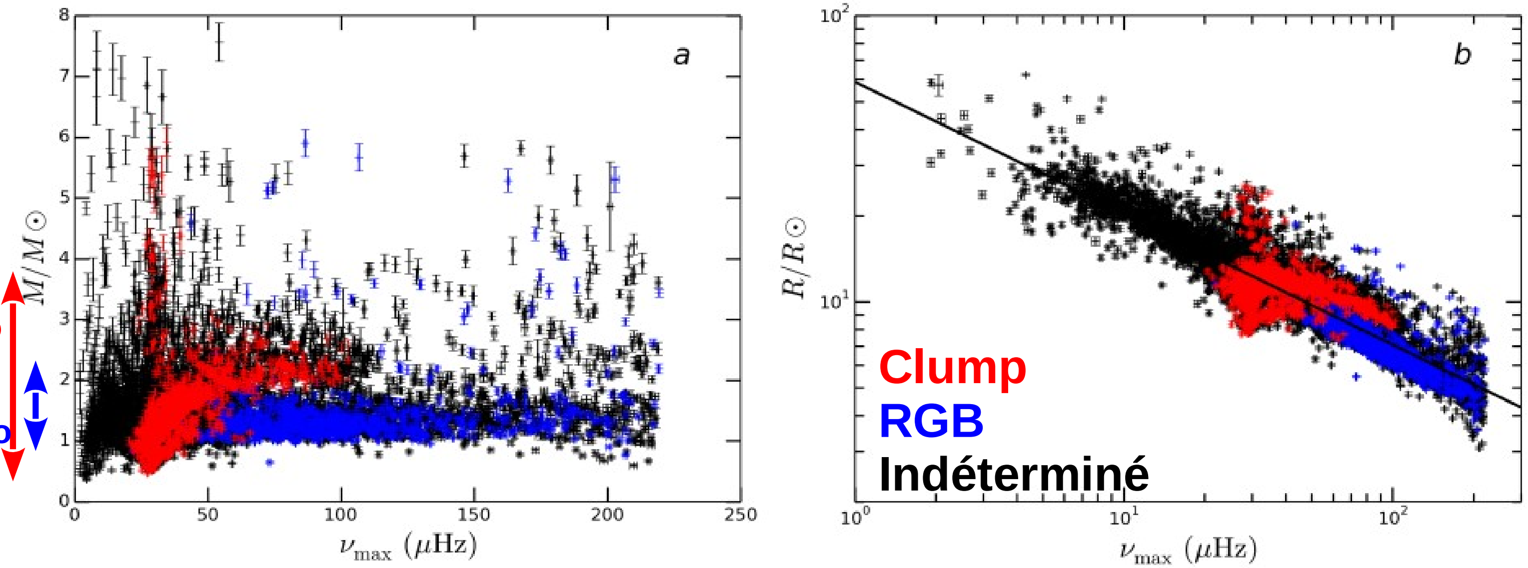
Results analysis: $\sigma^2 = f(\nu_{max})$



Results analysis: Mass & radius

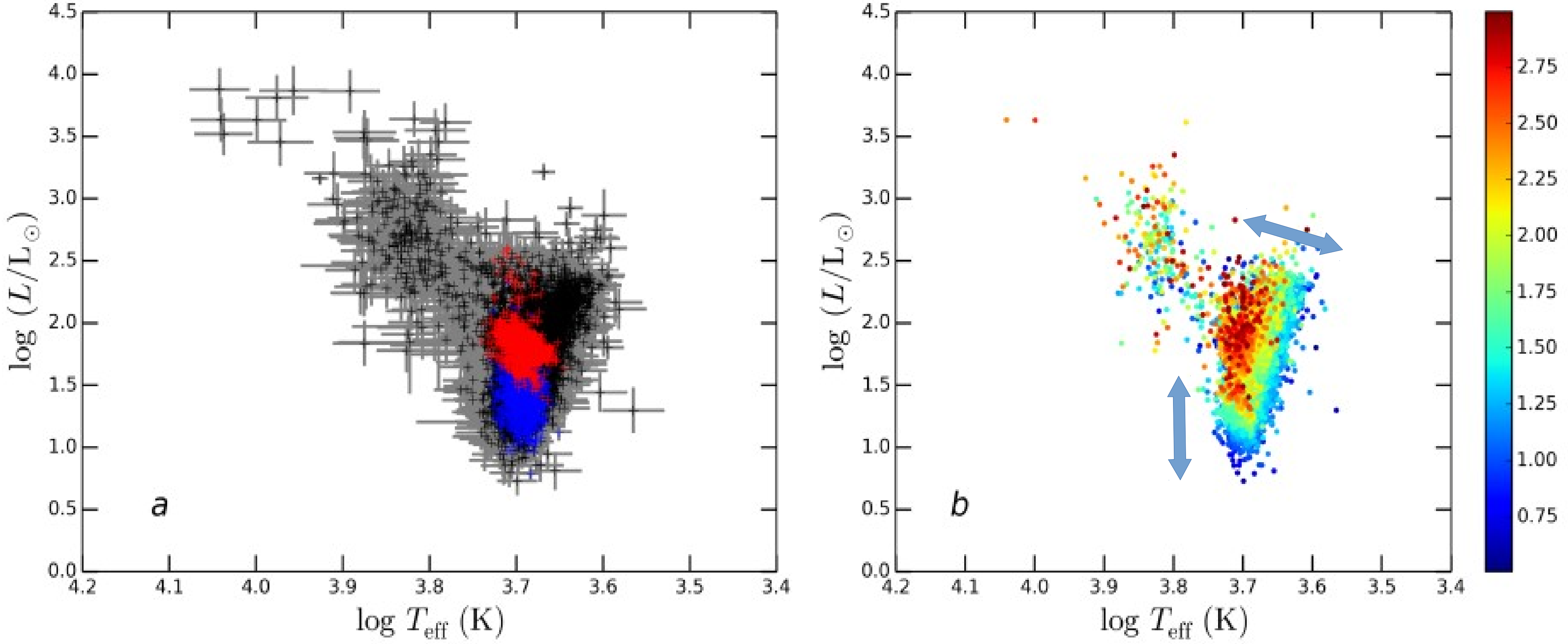
$0{,}5\ M_o < \Delta M_{clump} < 3{,}5\ M_o$

$1\ M_o < \Delta M_{RGB} < 2\ M_o$



Clump
RGB
indetermined

Results analysis: HR diagram



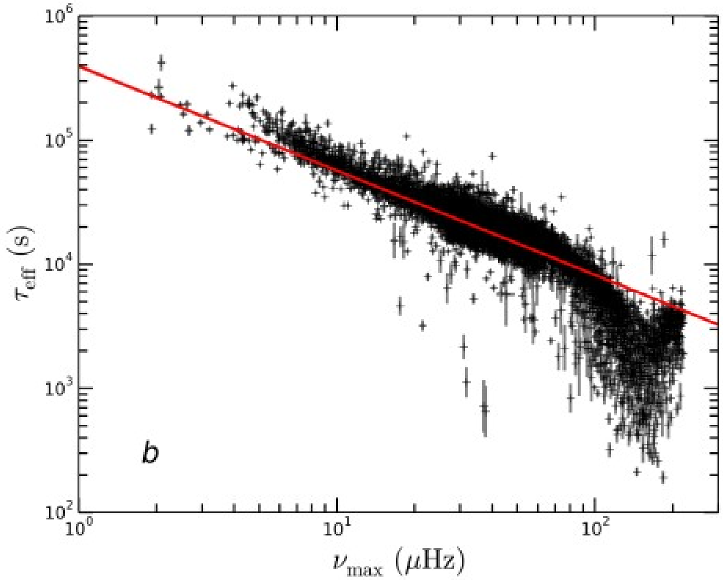
Results analysis: Number of stars

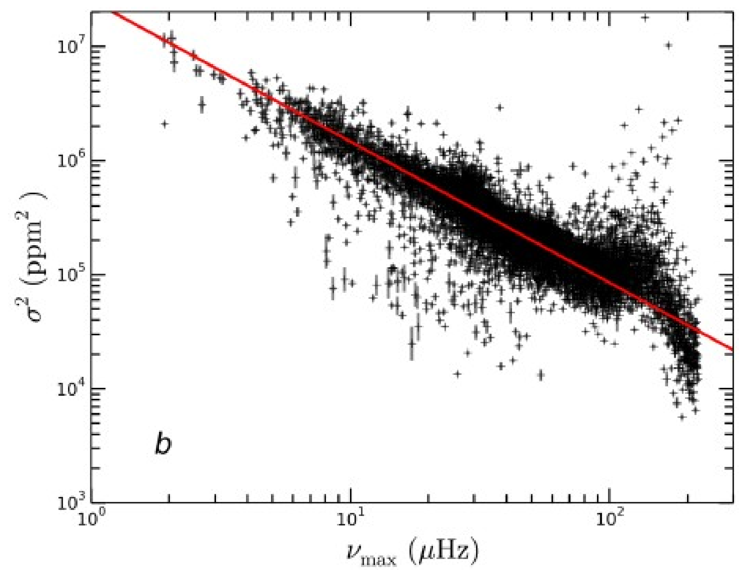
- Number of Kepler stars for which we obtained:
  - The seismic indices: ~14,000
  - The seismic indices and the granulation parameters: ~13,000

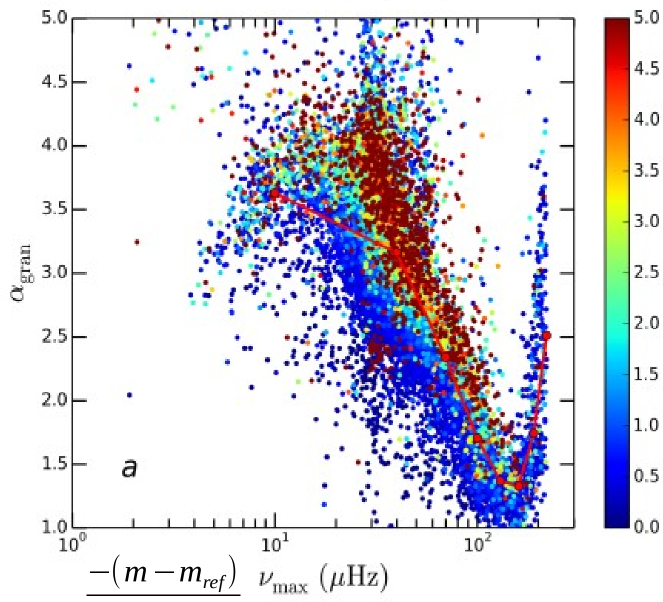
- Number of CoRoT stars for which we obtained:
  - The seismic indices: ~6000
  - The seismic indices and the granulation parameters: ~2000

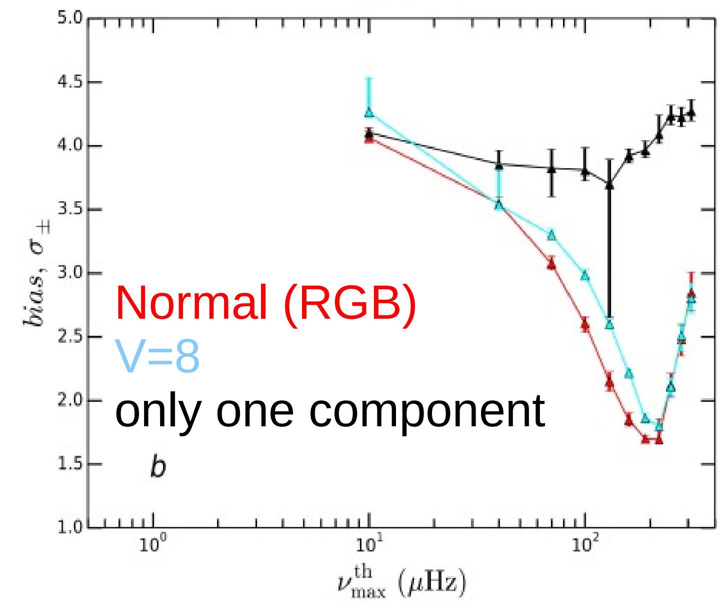
Thank you

Granulation slope









$$L(\nu)=\frac{P_{gran}}{1+(2\pi\nu\tau_{gran})^{\alpha_{gran}\neq 2}}$$

$$\frac{F}{F_{ref}}=10^{\frac{-(m-m_{ref})}{2,5}}$$

with F_{ref} = 12,5

Parameter	$\delta(err)$ CoRoT (%)		$\delta(err)$ *Kepler* (%)	
	negative	positive	negative	positive
$H_{\rm env}$	-27%	$+37\%$	-6.0%	$+6.4\%$
$\nu_{\rm max}$	-1.7%	1.7%	$-0,57\%$	$+0,57\%$
$\Delta\nu$	$-0,16\%$	$0,16\%$	$-0,041\%$	$+0,041\%$
$\tau_{\rm eff}$	-17%	$+20\%$	-3.8%	$+3.9\%$
σ^2	-17%	$+21\%$	-4.0%	$+4.1\%$
$P_{\rm gran}$	-22%	$+29\%$	-4.4%	$+4.6\%$
$\tau_{\rm gran}$	-16%	$+20\%$	-3.7%	$+3.9\%$
$\alpha_{\rm gran}$	-8%	$+8\%$	-2.1%	$+2.1\%$
$M/{\rm M}_\odot$	—	—	-4.2%	$+4.2\%$
$R/{\rm R}_\odot$	—	—	-1.4%	$+1.4\%$

Table B1. Median of the relative internal errors $err_\pm$ given in percentage, for the results obtained with the CoRoT and *Kepler* selected datasets (see Tab. B3 for more informations about the datasets used for each indices and parameters).

Perspectives

- Détermination de la T_{eff} « sismique »
  - $\Delta\nu$, ν_{max} (sismique) + A_m, m, p (Gaia) → $T_{eff} = 10^{\frac{M_{\odot} - 5 + A_m - m}{12{,}5}} p^{-2/5} \left(\frac{\Delta\nu}{\Delta\nu_{\odot}}\right)^{4{,}5} \left(\frac{\nu_{max}}{\nu_{max,\odot}}\right)^{-2/5} T_{eff,\odot}$