The Stellar Seismic Indices (SSI) data base (WP3-2)

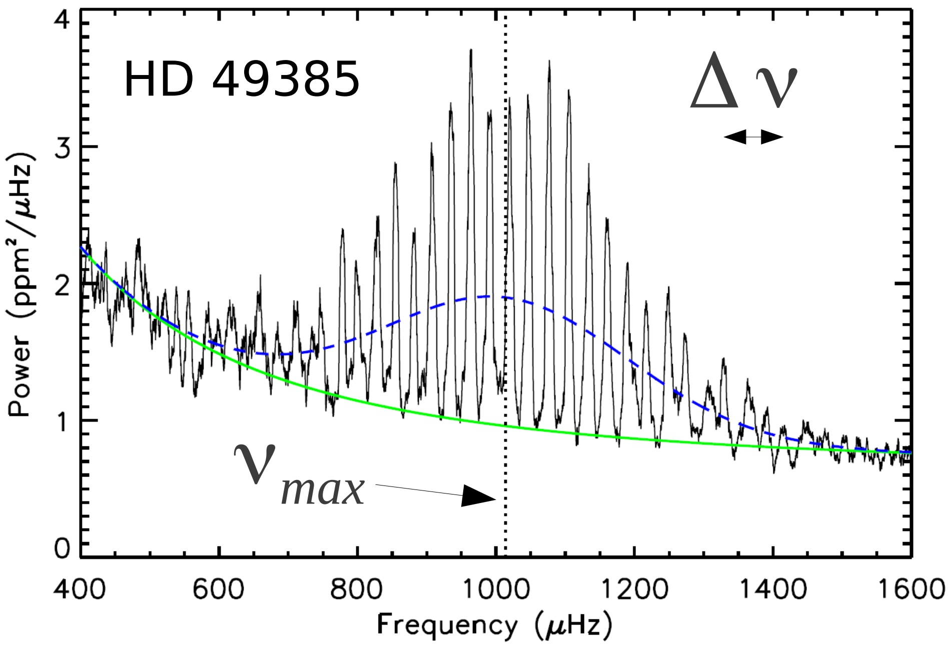
Laboratoire d'Études Spatiales et d'Instrumentation en Astrophysique

- The seismic indices
- Objectives, constraints and requirements
- Algorithms
- Pipeline architecture
- The data base
- Work plan and perspectives

People involved: Christian Renié (Project manager), Mahfoudh Abed (Ing.), Raphaël Peralta (PhD), Réza Samadi (Scientific resp.)

The seismic indices

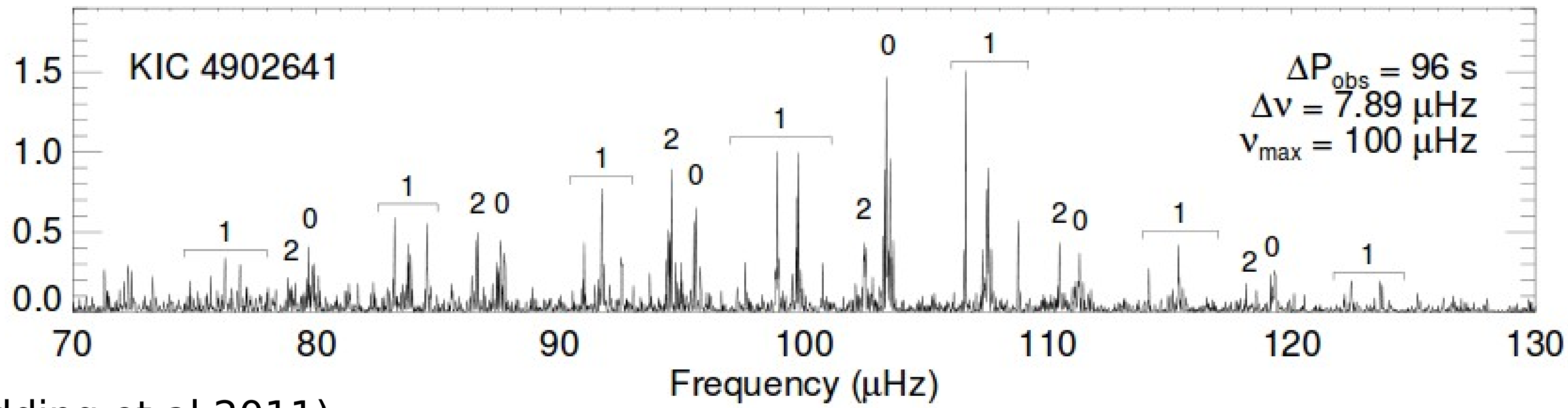
(Deheuvels et al 2009)



ν_{max} Peak frequency

$\Delta\nu$ Mean large separation

$\Delta\Pi$ The mixed modes period spacing



(Bedding et al 2011)

Scaling relations

- Peak frequency (Brown 1991, Kjeldsen & Bedding 1995)

$$\nu_{max} \propto \nu_c \propto \frac{c_s}{2H_p} \propto \frac{g}{\sqrt{T_{eff}}} \propto \frac{M}{R^2\sqrt{T_{eff}}}$$

Recent review : Belkacem (2012, SF2A, arXiv : arXiv:1210.3505)

- Mean large separation (eg. Ulrich 1986)

$$\Delta\nu \propto \langle\rho\rangle^{1/2} \propto \left(\frac{M}{R^3}\right)^{1/2}$$

Recent review : Belkacem et al (2013, arXiv:arXiv:1307.3132)

Scaling relations

- From **$\Delta\nu$, ν_{max}** and a given effective temperature one can deduce an estimation of **mass and radius**

$$\frac{M}{M_\odot} \simeq \left(\frac{\nu_{max}}{\nu_{max,\odot}}\right)^3 \left(\frac{\Delta\nu}{\Delta\nu_\odot}\right)^{-4} \left(\frac{T_{eff}}{T_{eff,\odot}}\right)^{3/2}$$

$$\frac{R}{R_\odot} \simeq \left(\frac{\nu_{max}}{\nu_{max,\odot}}\right) \left(\frac{\Delta\nu}{\Delta\nu_\odot}\right)^{-2} \left(\frac{T_{eff}}{T_{eff,\odot}}\right)^{1/2}$$

- Mixed mode period spacing ($\Delta\Pi$): $\Delta\Pi \propto \langle\rho\rangle_{core}^{-1/2}$

➔ Opened the way to « Ensemble asteroseismology »
➔ Many applications : stellar structure and evolution, stellar population
➔ See recent reviews : Chaplin & Miglio (2012, ARAA), Mosser (2012, EPJWC), Mosser et al (2013, SF2A), ….

Objectives

➔ **Stellar Seismic Indices (SSI) data base** providing seismic ν_{max}, $\Delta\nu$ and $\Delta\pi$ for scientific community within and beyond stellar physic community

Requirements :

- Define a standard method for each type of seismic parameter
- The « standard » method must be :
  - **Robust** and **efficient**
  - **Accurate**
  - **Precise**

Technical requirements:

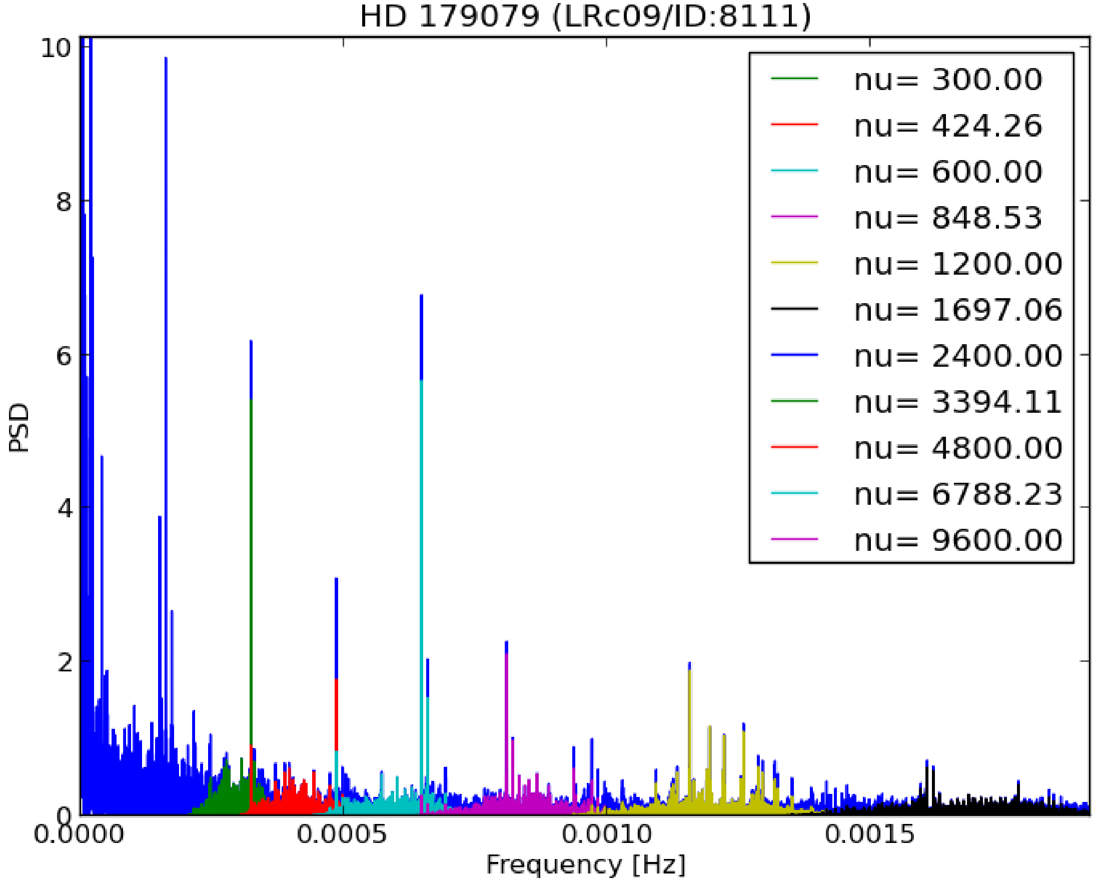
- Compatibility with an heterogeneous source of data (CoRoT, Kepler, OGGLE)
- **Free acess** to the ligh-curves (CoRoT and Kepler)

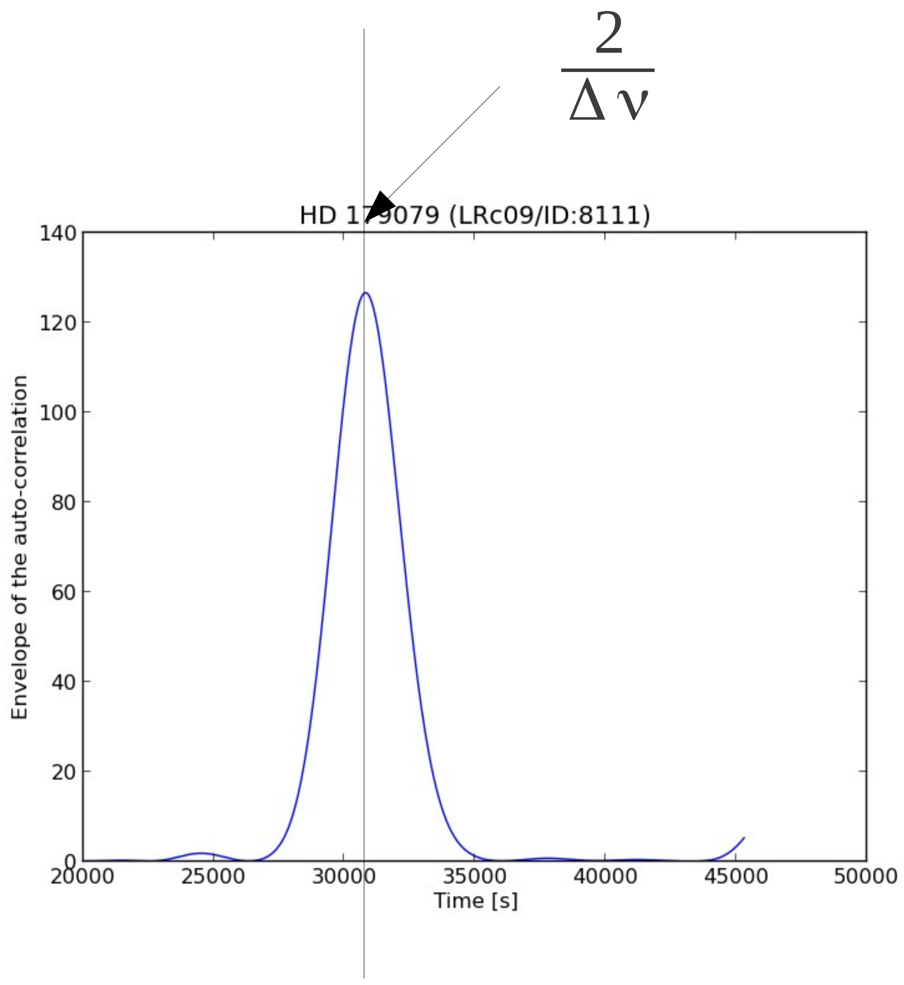
Algorithms

- PDS : Fast Lomb-Scargle periodogram using Non-equispaced Fast Fourier Transform (NFFT) by B. Leroy (2012, A&A). Python package : pynfftls : (https://pypi.python.org/pypi/pynfftls/)
- $\Delta\nu$: autocorrelation method (Roxburgh & Vorontsov 2006 ; Mosser & Appourchaux 2009) → **ACF** method
- ν_{max} :
  - Envelop modelling: fit a Gaussian envelop to the smoothed PDS (eg. Huber et al 2009, Mosser & Mathur et al 2010, Hekker et al 2010 …)
  - Background: granulation component + white noise component
- Iterative procedure :
  - ACF method provides guesses for the Envelop modelling
  - Recompute $\Delta\nu$ using the ν_{max} obtained from the modelled envelop
- By-product
  - Background modelling : provides the granulation parameters → possible applications (see Samadi et al 2013)

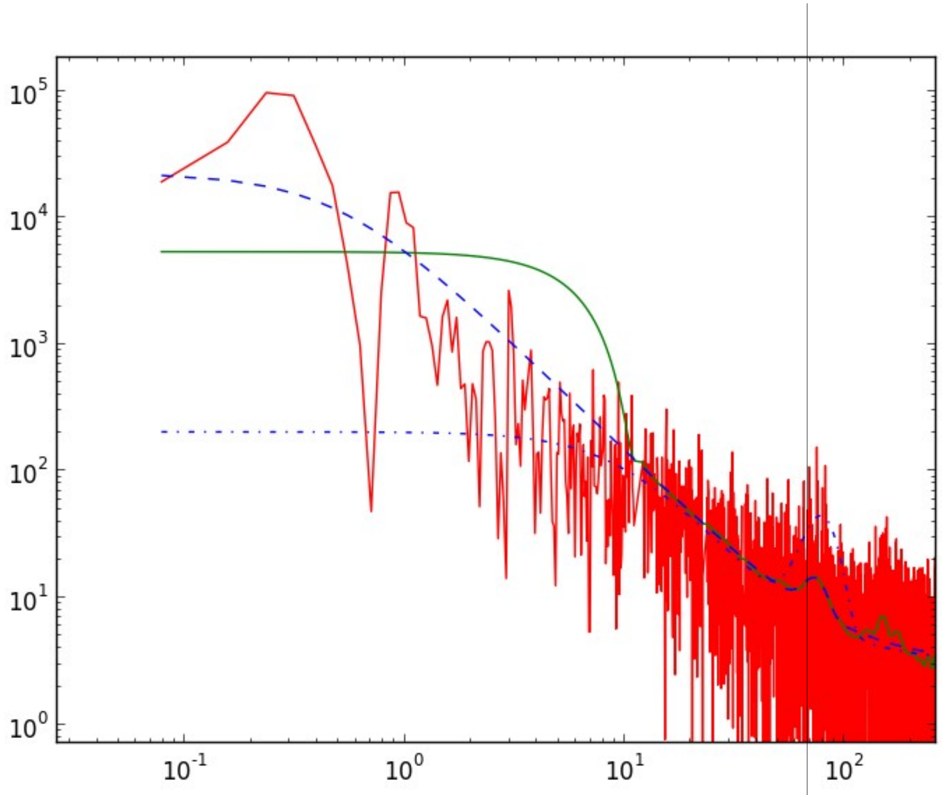
The autocorrelation method

Roxburgh & Vorontsov (2006) ; Mosser & Appourchaux 2009





Envelop («bump»)+ background



Smoothed PDS

Raw PDS

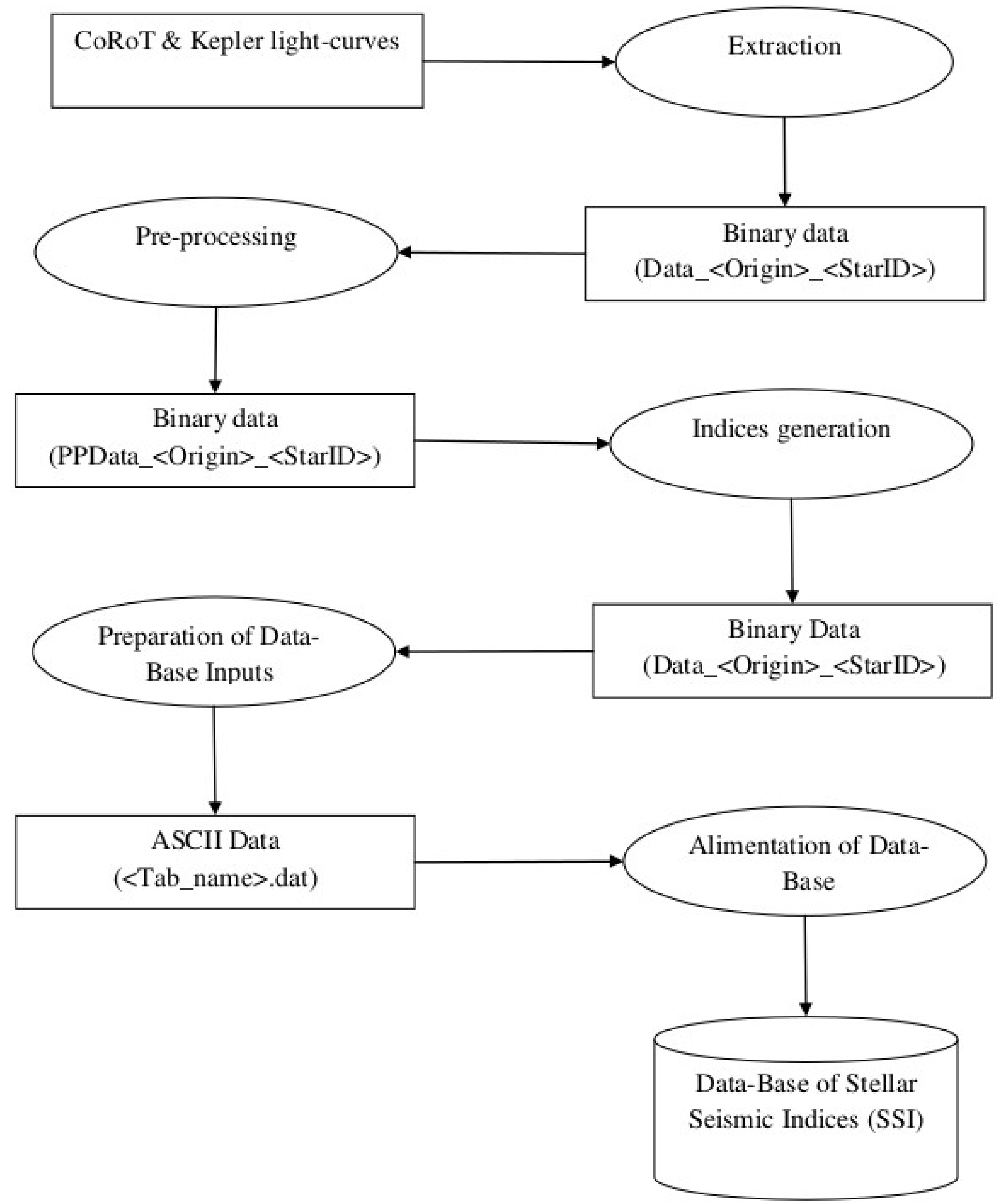
Fit

ν_{max}

Pipeline architecture

- Data extraction
- Pre-processing : jump correction, trend correction, calculation of the PDS
- Processing : the generation of the seismic indices
- Insertion into the SSI DB

✗ Coded in python (≥ 2.7)
✗ Multiprocessing capability

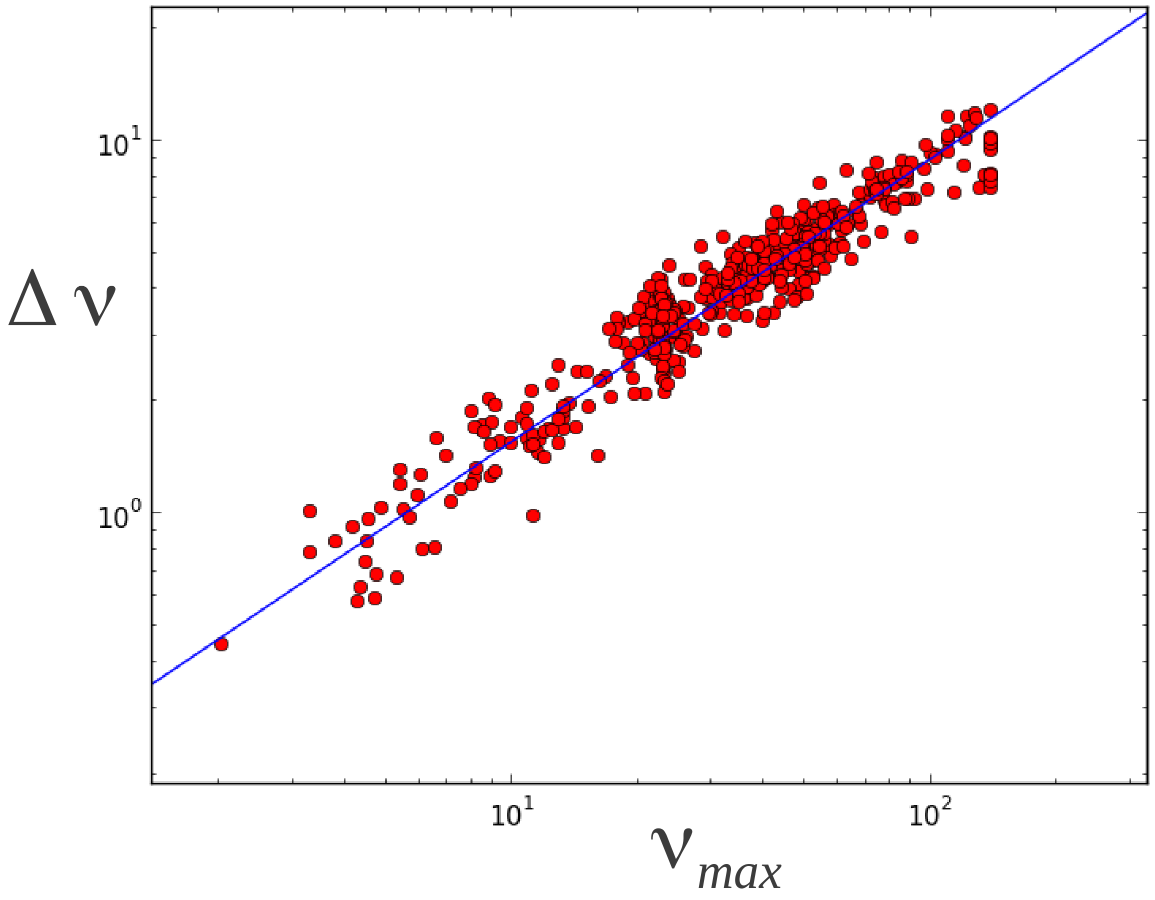


Some results

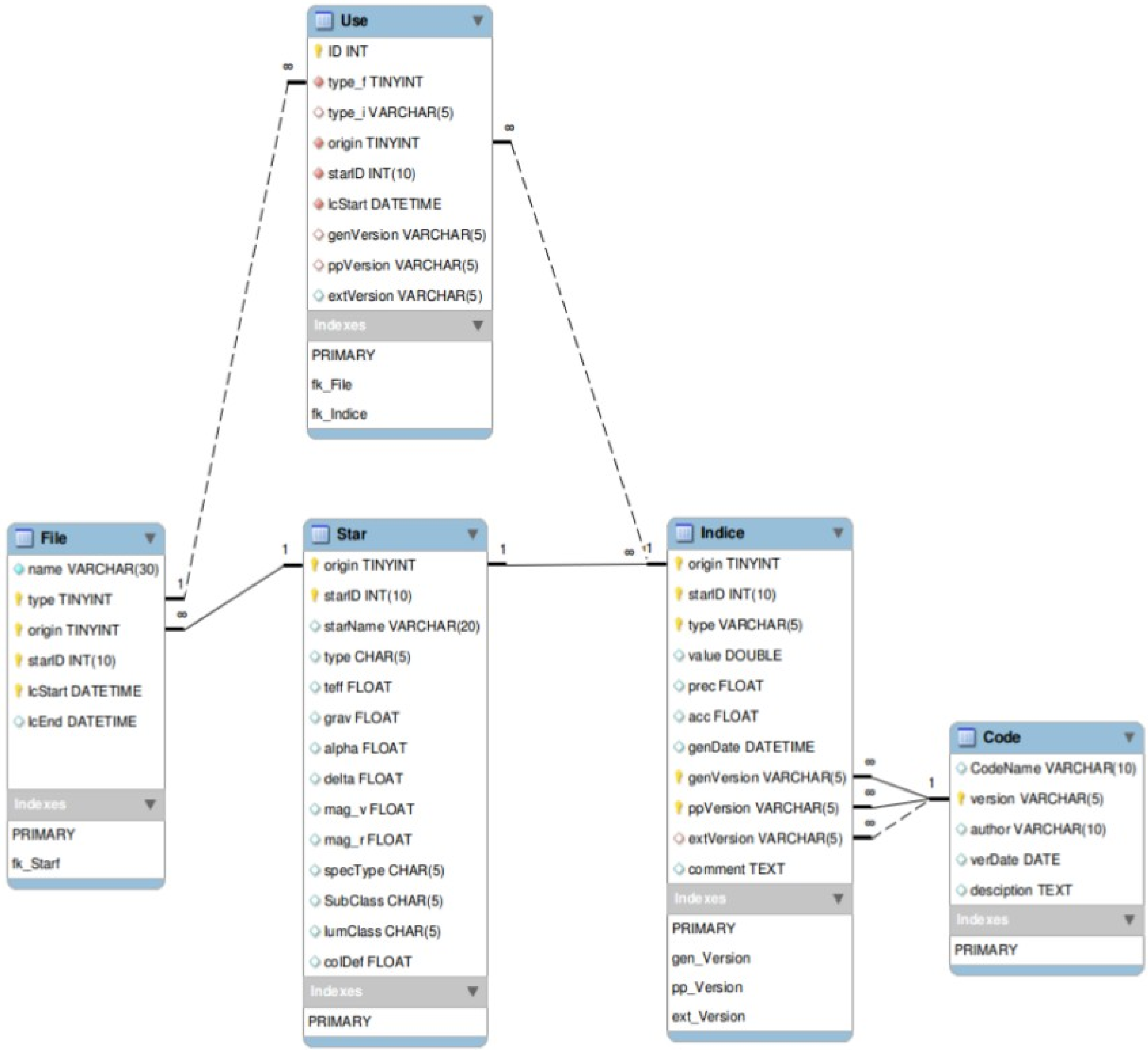
- ~ 1500 CoRoT targets brighter than mag. 13.
- Luminosity class III
- Spectral type : G-M
- « N2 » data from the Exo-Channel (with some remaining jumps and holds ...)

- Seismic indices obtained for ~ 500 targets (~ half)

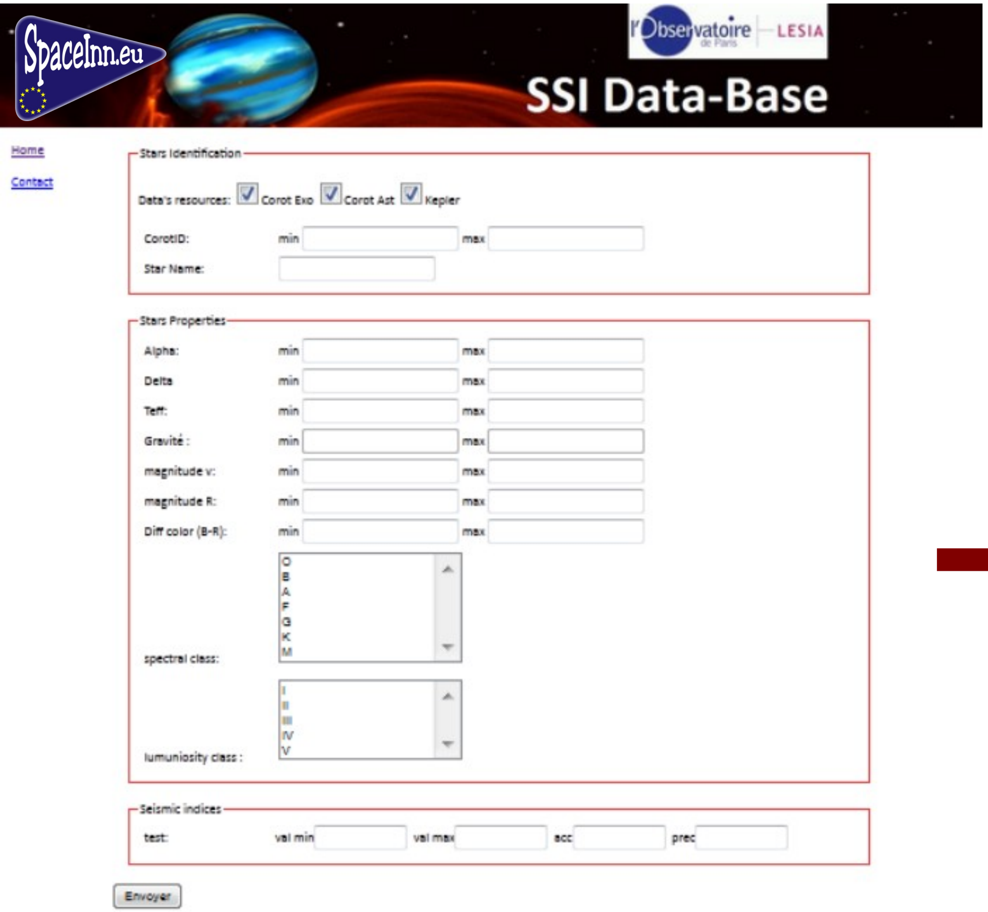
- Performance (24 CPU-cores):
  - Pre-processing time: 10'
  - Processing time : 15'

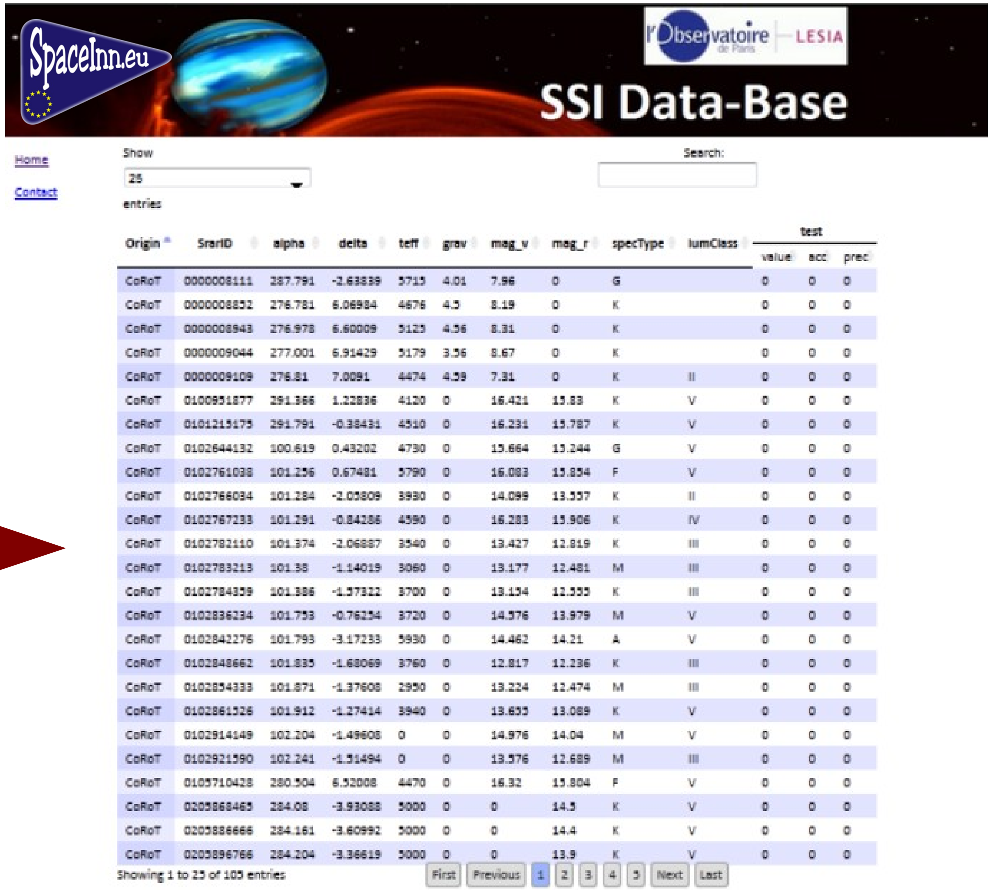


The date base : architecture



The date base : interface





Origin	SrarID	alpha	delta	teff	grav	mag_v	mag_r	specType	lumClass	test		
										value	acc	prec
CoRoT	0000008111	287.791	-2.63839	5715	4.01	7.96	0	G		0	0	0
CoRoT	0000008852	276.781	6.06984	4676	4.5	8.19	0	K		0	0	0
CoRoT	0000008943	276.978	6.60009	5125	4.56	8.31	0	K		0	0	0
CoRoT	0000009044	277.001	6.91429	5179	3.56	8.67	0	K		0	0	0
CoRoT	0000009109	276.81	7.0091	4474	4.59	7.31	0	K	II	0	0	0
CoRoT	0100951877	291.366	1.22836	4120	0	16.421	15.83	K	V	0	0	0
CoRoT	0101215175	291.791	-0.38431	4510	0	16.231	15.787	K	V	0	0	0
CoRoT	0102644132	100.619	0.43202	4730	0	15.664	15.244	G	V	0	0	0
CoRoT	0102761038	101.236	0.67481	5790	0	16.083	15.854	F	V	0	0	0
CoRoT	0102766034	101.284	-2.05809	3930	0	14.099	13.557	K	II	0	0	0
CoRoT	0102767233	101.291	-0.84286	4590	0	16.283	15.906	K	IV	0	0	0
CoRoT	0102782110	101.374	-2.06887	3540	0	13.427	12.819	K	III	0	0	0
CoRoT	0102783213	101.38	-1.14019	3060	0	13.177	12.481	M	III	0	0	0
CoRoT	0102784359	101.386	-1.57322	3700	0	13.134	12.555	K	III	0	0	0
CoRoT	0102836234	101.753	-0.76254	3720	0	14.576	13.979	M	V	0	0	0
CoRoT	0102842276	101.793	-3.17233	5930	0	14.462	14.21	A	V	0	0	0
CoRoT	0102848662	101.835	-1.68069	3760	0	12.817	12.236	K	III	0	0	0
CoRoT	0102854333	101.871	-1.37608	2950	0	13.224	12.474	M	III	0	0	0
CoRoT	0102861526	101.912	-1.27414	3940	0	13.655	13.089	K	V	0	0	0
CoRoT	0102914149	102.204	-1.49608	0	0	14.976	14.04	M	V	0	0	0
CoRoT	0102921590	102.241	-1.51494	0	0	13.576	12.689	M	III	0	0	0
CoRoT	0105710428	280.504	6.52008	4470	0	16.32	15.804	F	V	0	0	0
CoRoT	0205868465	284.08	-3.93088	5000	0	0	14.5	K	V	0	0	0
CoRoT	0205886666	284.161	-3.60992	5000	0	0	14.4	K	V	0	0	0
CoRoT	0205896766	284.204	-3.36619	5000	0	0	13.9	K	V	0	0	0

Data sets

- ✔ **CoRoT** :
  - Red Giants ~ 10,000
  - Main Sequence + Sub-Giants ~ 100
- ✔ **Kepler** :
  - Red Giants ~ 10,000
  - Main Sequence + Sub-Giants ~ 1,000
- ✔ **OGLE** (Optical Gravitationnal Lensing Experiment) :
  - Red Giants ~ 20,000

In the future :

- **PLATO** (ESA M3 project): to characterize exoplanets and their host stars in the solar neighbourhood. 1.2 million stars observed during at least ~ 3 months and up to 2 years
- **SINDICS** (Seismic INDICes Survey) : propose the 1st seismic all sky survey of our galactic environnement.

Work plan and perspectives

- Algorithms :
  - Implementation of the « **Universal pattern** » (Mosser et al 2011, A&A Letter)
  - Implementation of the calculation of the **asymptotic** mixed mode period spacing (e.g. Mosser et al, 2012, A&A, 5140, A143)
  - Validation and calibration : in progress … (R. Peralta)
- Pipeline :
  - Optimisation
  - Increase robustness
  - Interface with OGGLE data
- Date base :
  - VO capability :
    - Implementation of the **Table Access Protocol** (TAP → VO standard) using **DaCHS framework** (TAP implementation developed by the German VO).
    - In collaboration with **VO-Pari**s (http://voparis-srv.obspm.fr/portal)
  - Interface improvement (administrative side)

➔Objective : open the data base at J + 48 months

Thank you !

ΔΠ : The mixed modes period spacing

Contrary to p modes, g modes follow an asymptotic relation in period:

$$\Pi_{n,\ell} = \Delta\Pi \left(n + \epsilon_g\right)$$

Asymptotic value :

$$\Delta\Pi \propto \left(\int_{\text{core}} N \frac{\mathrm{dr}}{r}\right)^{-1}$$

Dimension analysis :

$$N^2 \propto \frac{g^2 \rho}{P} = \frac{g}{H_p}$$

$$\Delta\Pi \propto \langle\rho\rangle_{\text{core}}^{-1/2}$$

➔The period spacing provides information on the core properties

Extensive comparisons :

- Verner et al 2011 (MNRAS, 415, 3539)
- Hekker et al (2011, A&A, 525, A131)

(from Verner et al 2011)

$$\left.\begin{array}{rcl} \nu_{max} & \sim & 5\% \\ \Delta\nu & \sim & 1\% \\ \Delta T_{eff} & \sim & 100\mathrm{K} \end{array}\right\} \Rightarrow \begin{array}{l} \frac{\Delta M}{M} \sim 20\% \\ \frac{\Delta R}{R} \sim 10\% \end{array}$$