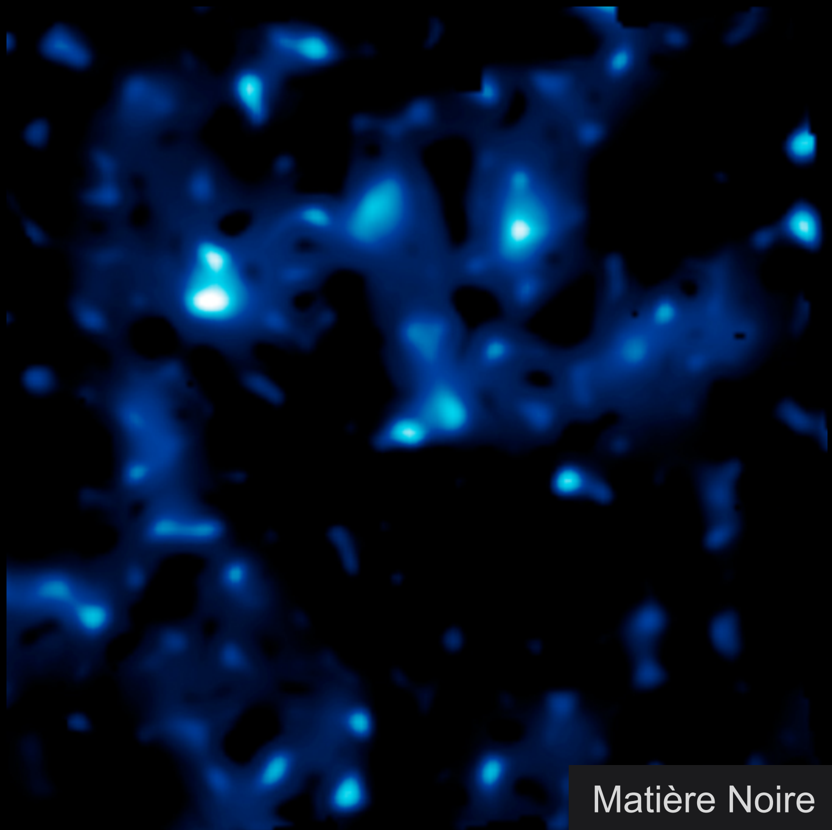
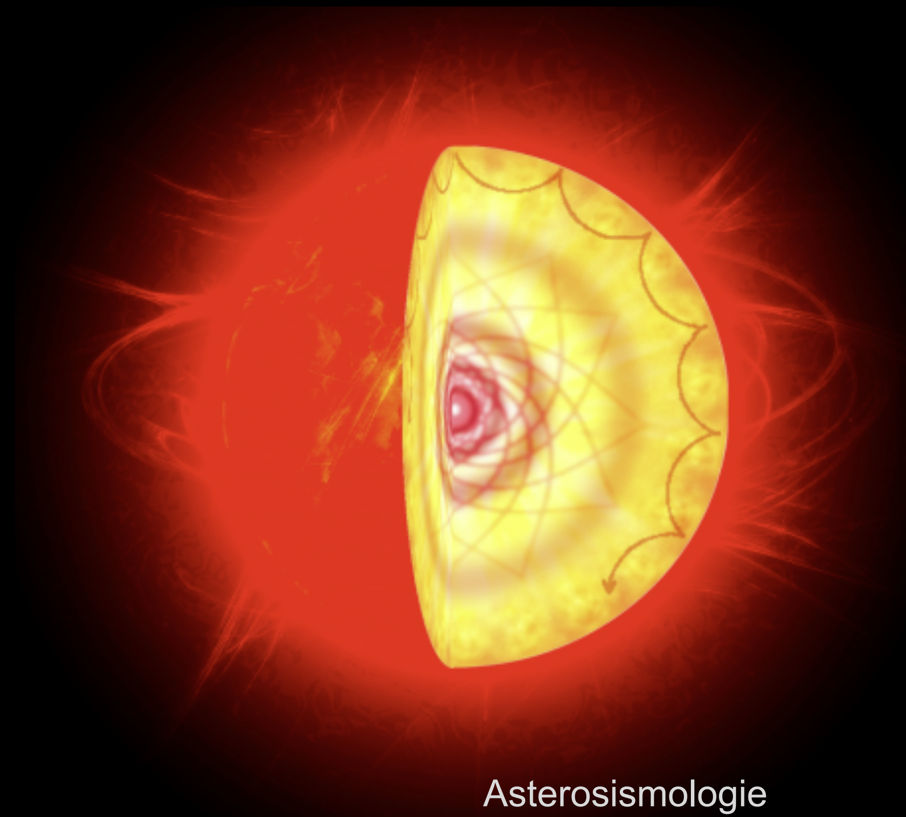
Les données manquantes en astrophysique





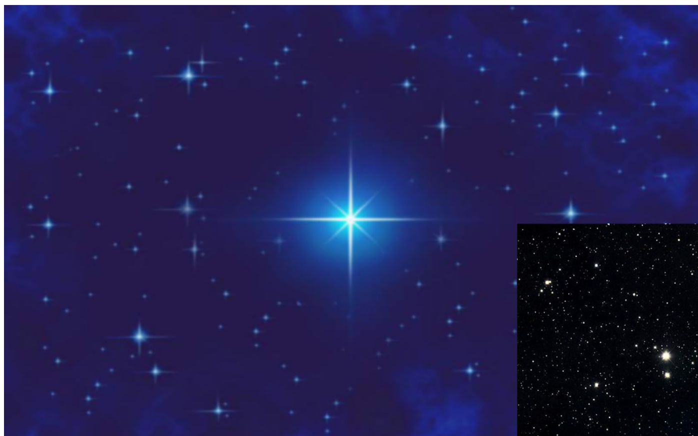
Sandrine Pires
sandrine.pires@cea.fr
Collaborateurs: J.L Starck, R. Garcia, S. Mathur, E. Jullo, J. Ballot, J. Fadili, R. Teyssier, A. Amara, A. Réfrégier, D. Stello

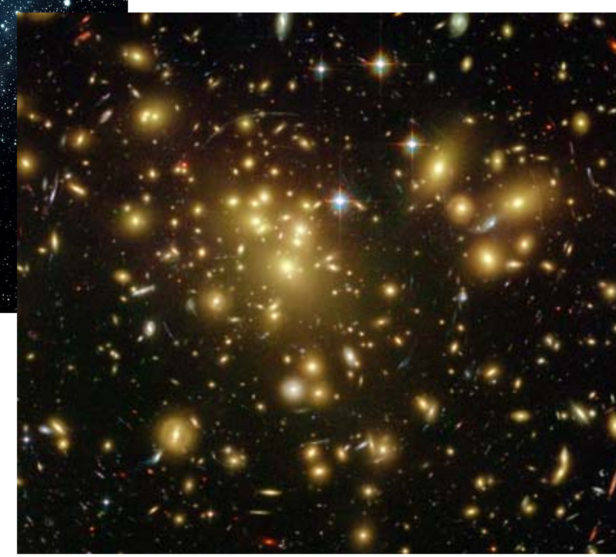
Journée ISIS, 8 Octobre 2015, Marseille

Plan

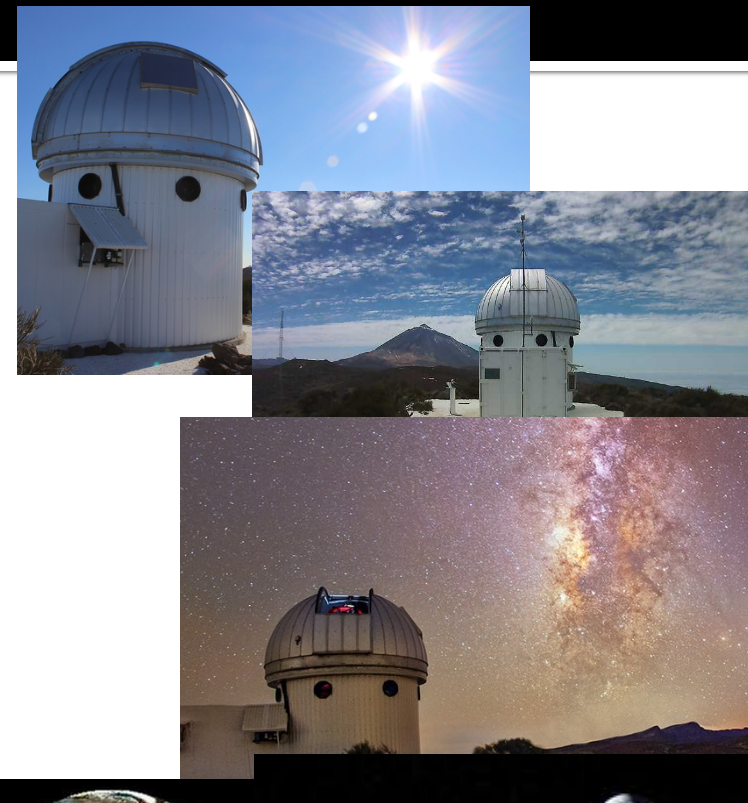
- Les données manquantes en Astrophysique
  - Leurs origines
  - Leurs caractéristiques
- Le traitement des données manquantes
  - Signaux parcimonieux
  - Sparse Inpainting
- Applications
  - Application à l'astérosismologie (signal 1D)
  - Application aux lentilles gravitationnelles faibles (signal 2D)

L'astrophysique

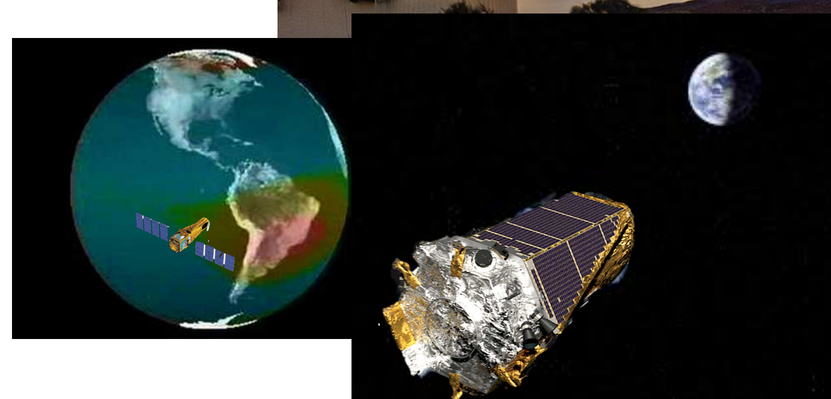




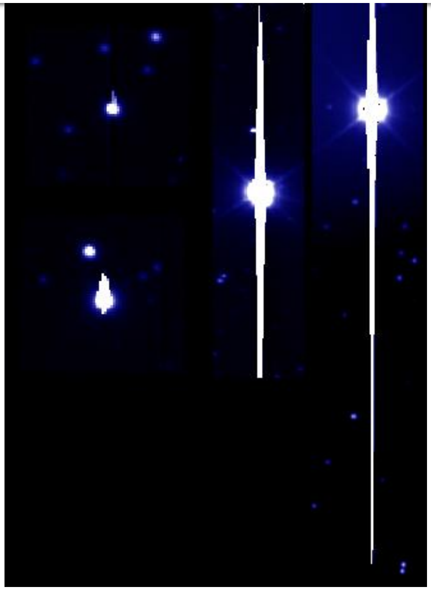
Données manquantes dans les observations 1D



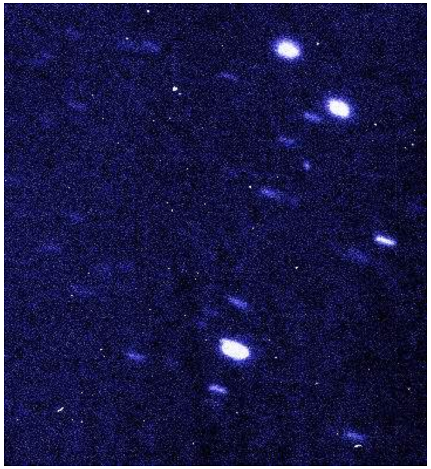
- Observations au sol
  - La météo
  - L’alternance jour/nuit
  - La panne temporaire d’instruments
  - D’autres facteurs
- Observations dans l’espace
  - Les rayons cosmiques
  - Le fonctionnement du satellite
  - D’autres facteurs



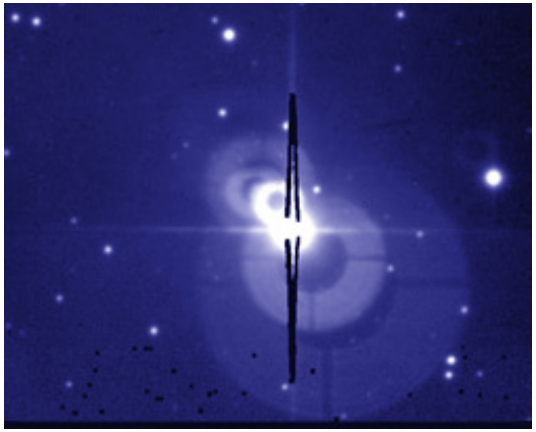
Données manquantes dans les observations 2D



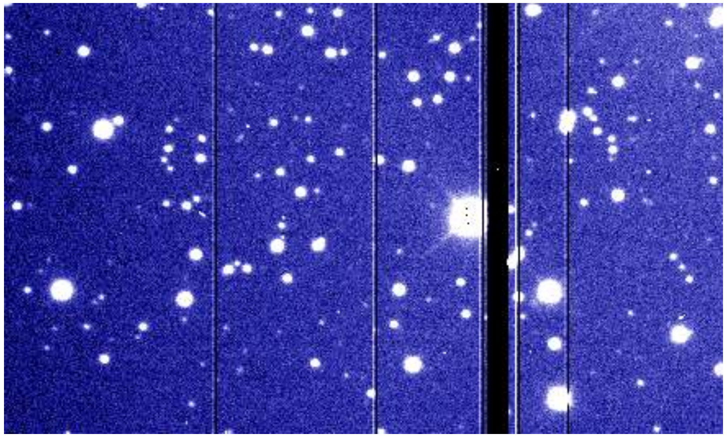
Traînées de Saturation



Rayons cosmiques



Reflection parasite



Colonnes mortes

Plan

- Les données manquantes en Astrophysique
  - Leurs origines
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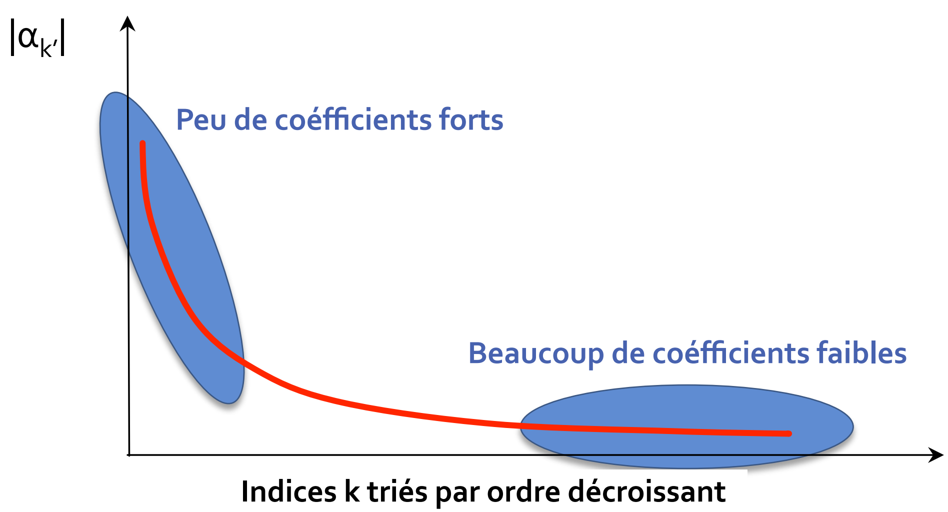
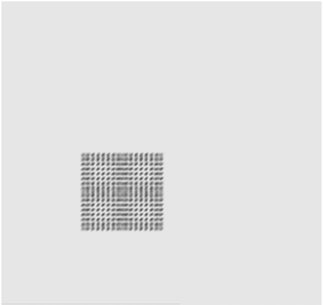
Contrainte de parcimonie

$$\overset{\alpha}{W(a,b)} = K \int_{-\infty}^{+\infty} \overset{\Phi}{\psi^* \left(\frac{x-b}{a} \right)} \overset{X}{f(x)} dx$$

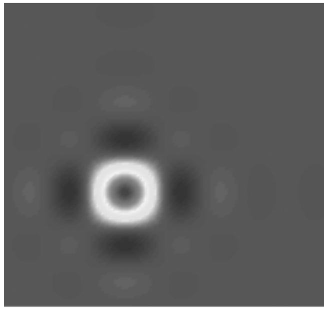


Representations adaptées

- **DCT locale** ***(Ahmed, 1975)***
  - Texture stationnaire
  - Localement oscillatoire



- **Transformée en Ondelettes** ***(Mallat, 1999)***
  - Lisse par morceaux
  - Structures isotropes

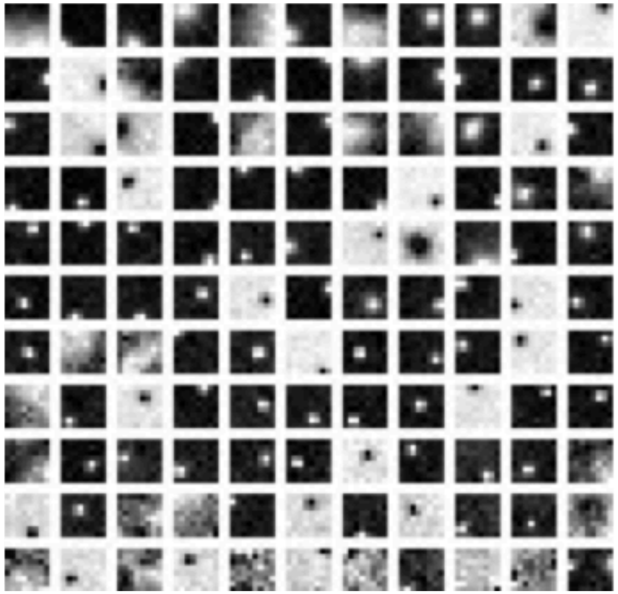


- **Transformée en Curvelets** ***(Candès, 2006)***
  - Lisse par morceaux
  - Structures anisotropes

L'apprentissage de dictionnaire

Beckouche et al., A&A, 2013

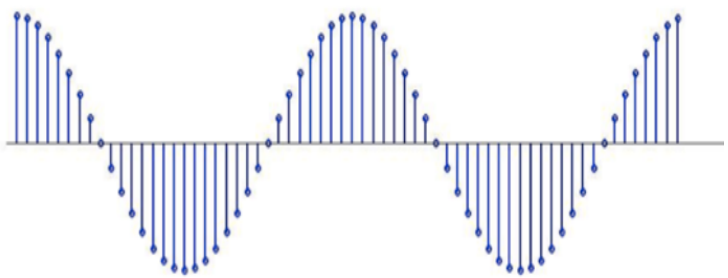
Données



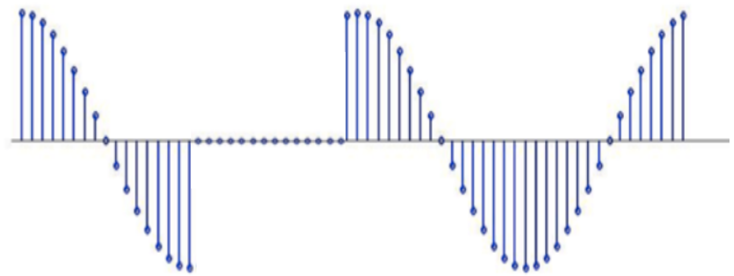
Dictionnaire appris

Sparse Inpainting

Elad et al., JACHA, 2005

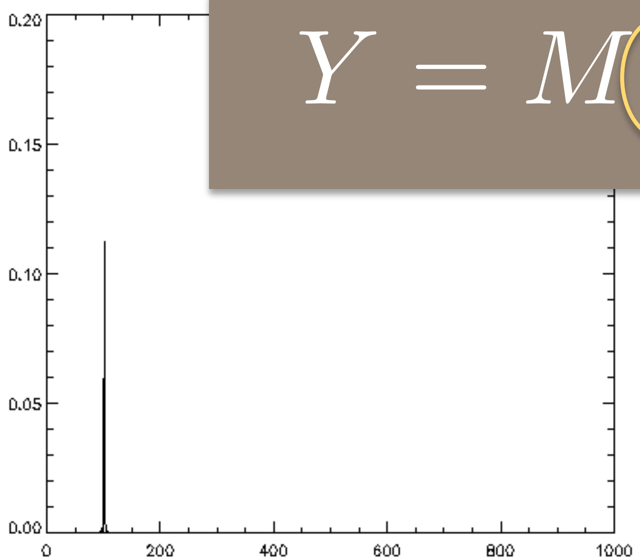


Sinusoïde complète

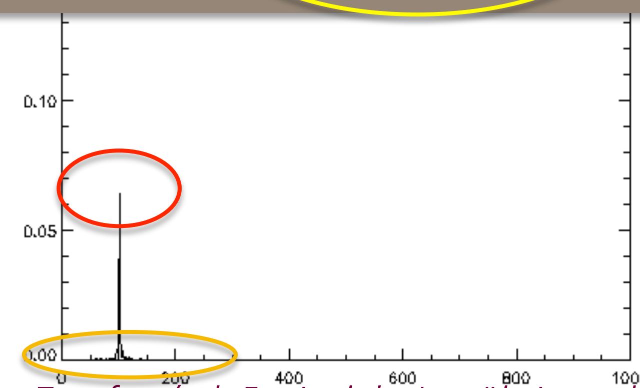


Sinusoïde incomplète

$$Y = M\Phi\alpha \text{ with } \min_{\alpha} ||\alpha||_1$$



Transformée de Fourier de la sinusoïde complète



Transformée de Fourier de la sinusoïde incomplète

Plan

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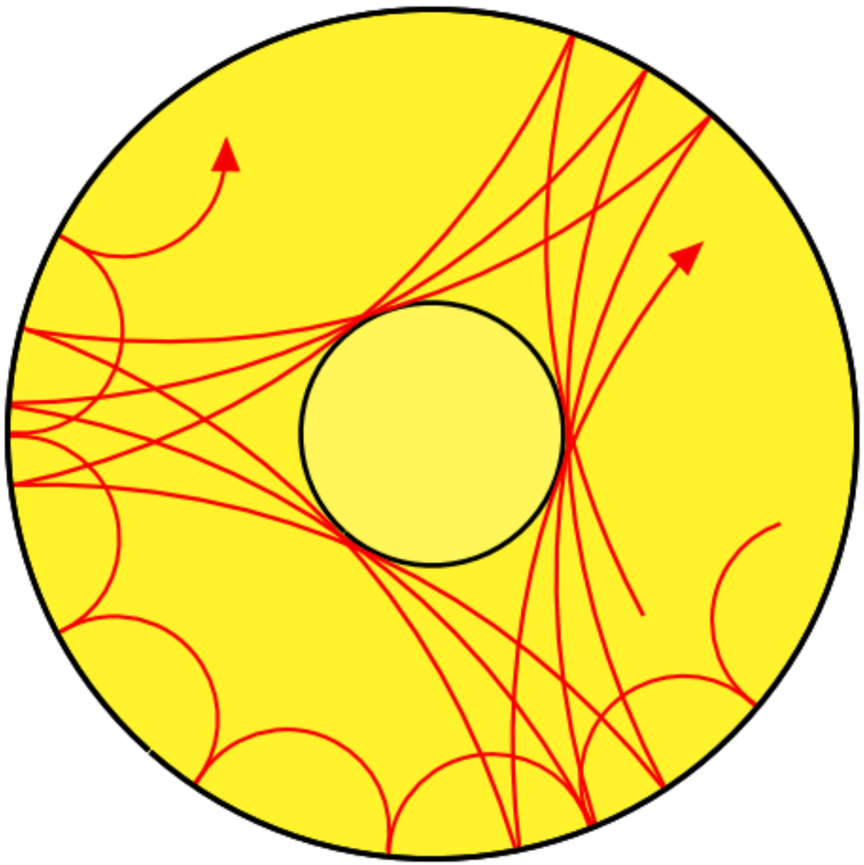
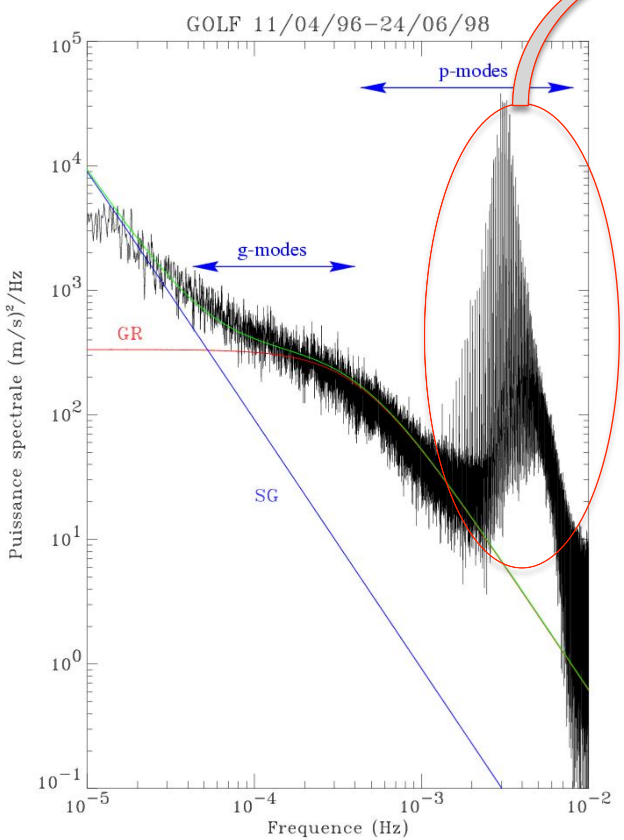
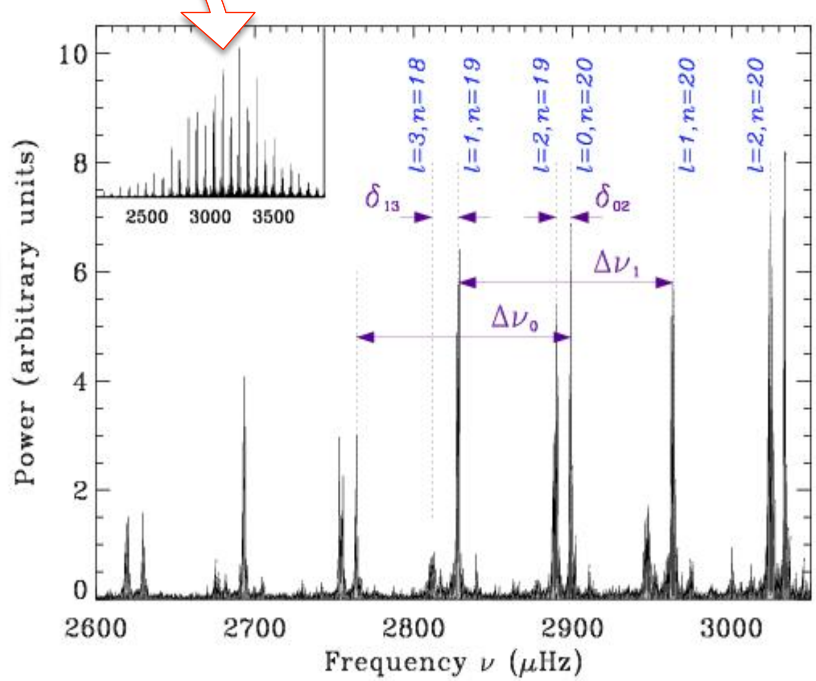
L'astérosismologie



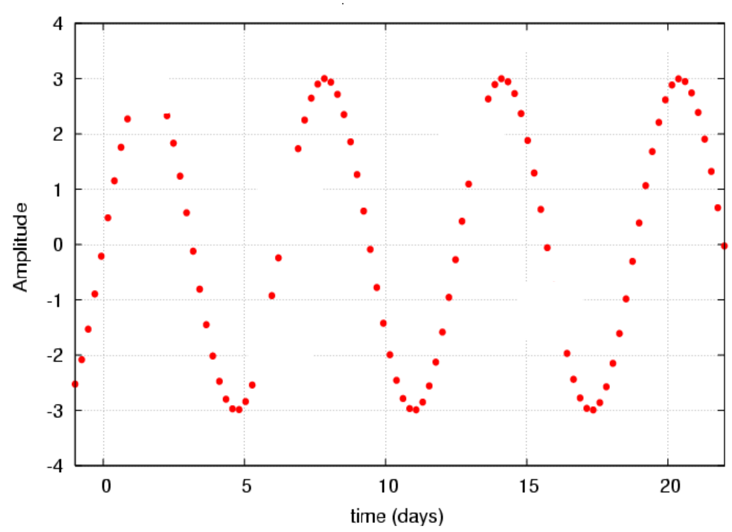
L'astérosismologie





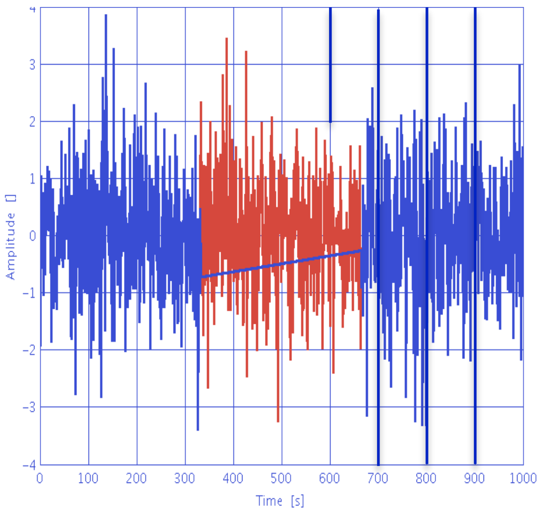
Les méthodes standards

- Estimation directe du spectre de puissance
  - Sine Wave Fitting $y = a\cos wt + b\sin wt$
  - CLEAN

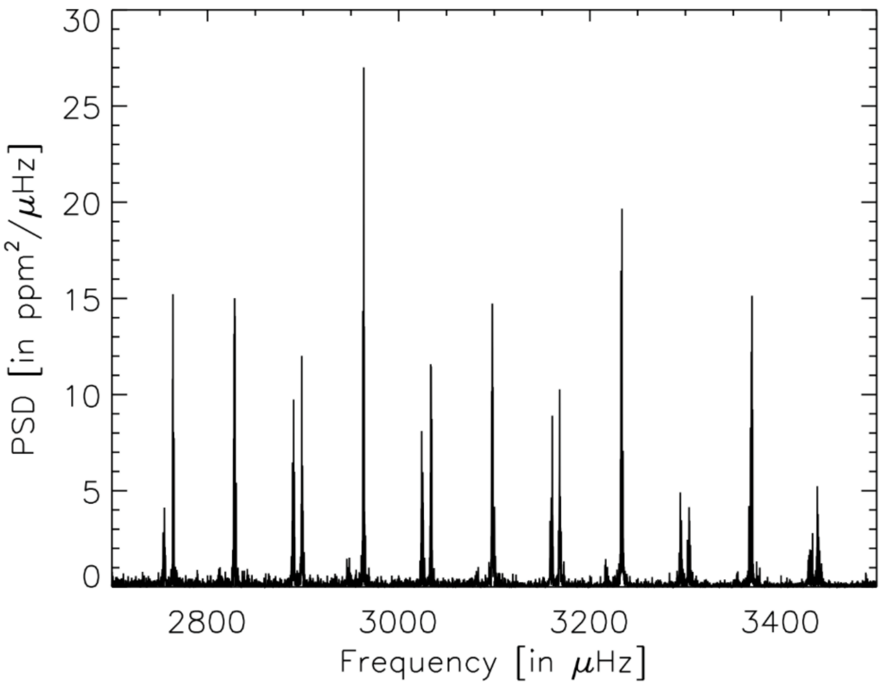


Méthodes standards

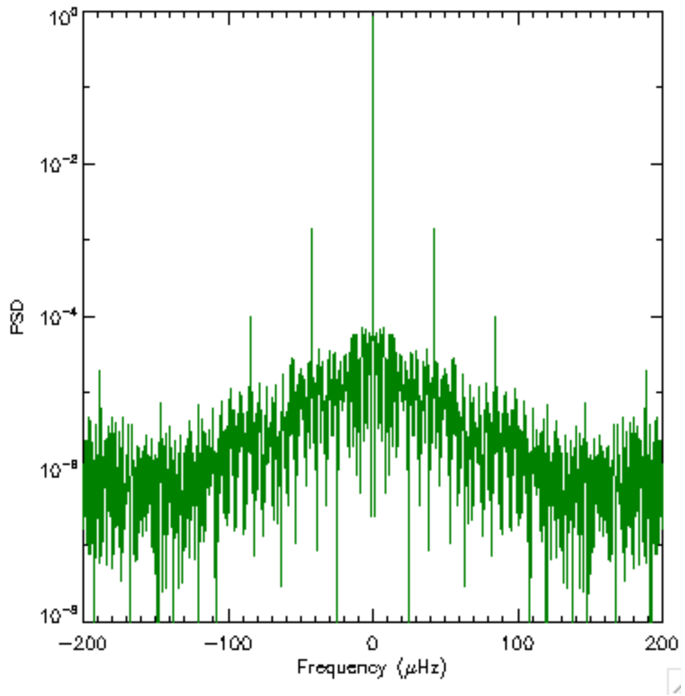
- Estimation directe du spectre de puissance
  - Sine Wave Fitting
  - CLEAN
- Estimation du spectre de puissance sur des données interpolées
  - Interpolation linéaire
  - ARMA
  - Sparse Inpainting



Simulations réalistes d'observations spatiales

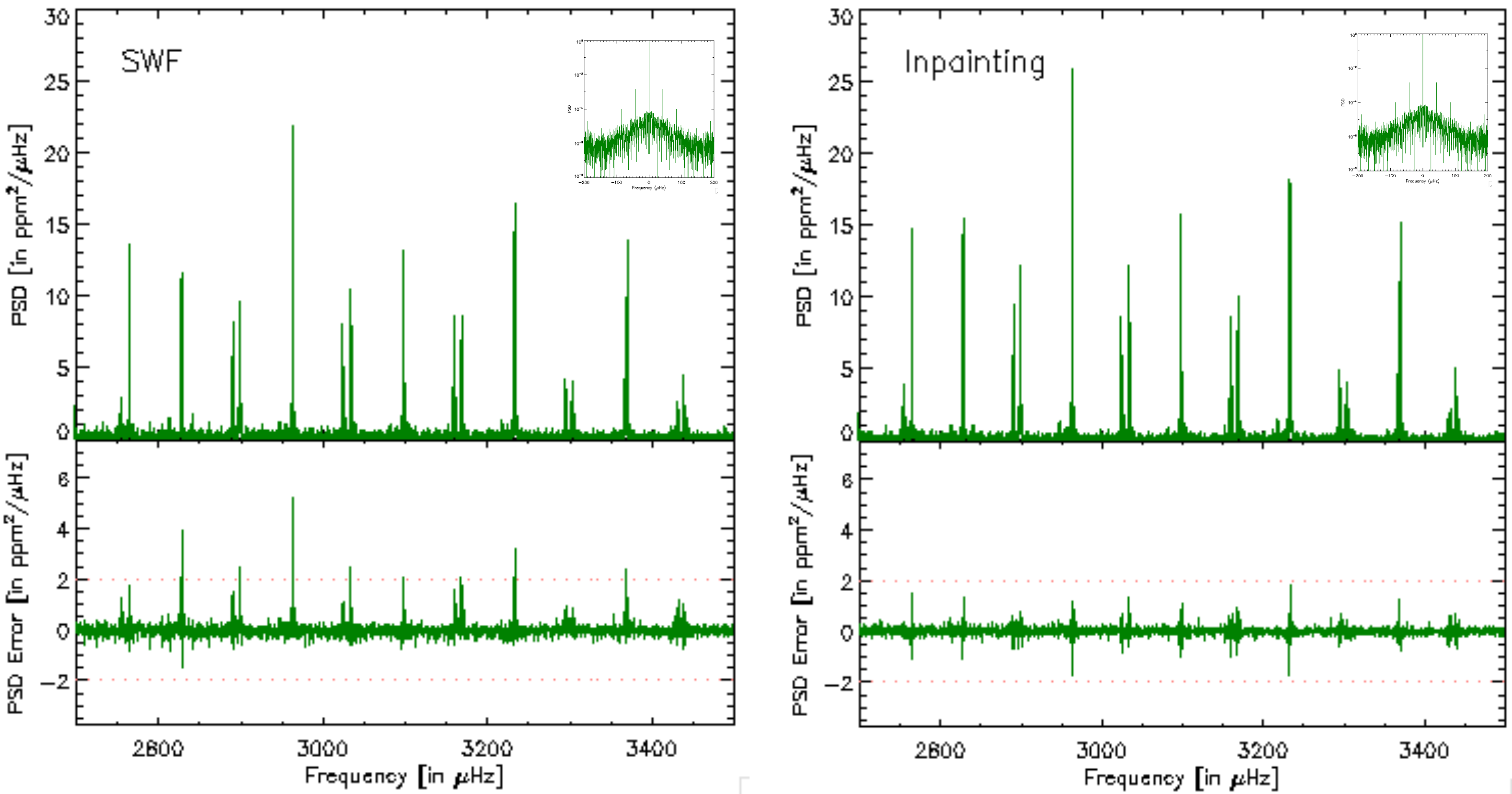


Spectre de puissance du signal complet



Masque quasi-régulier
15% de données manquantes

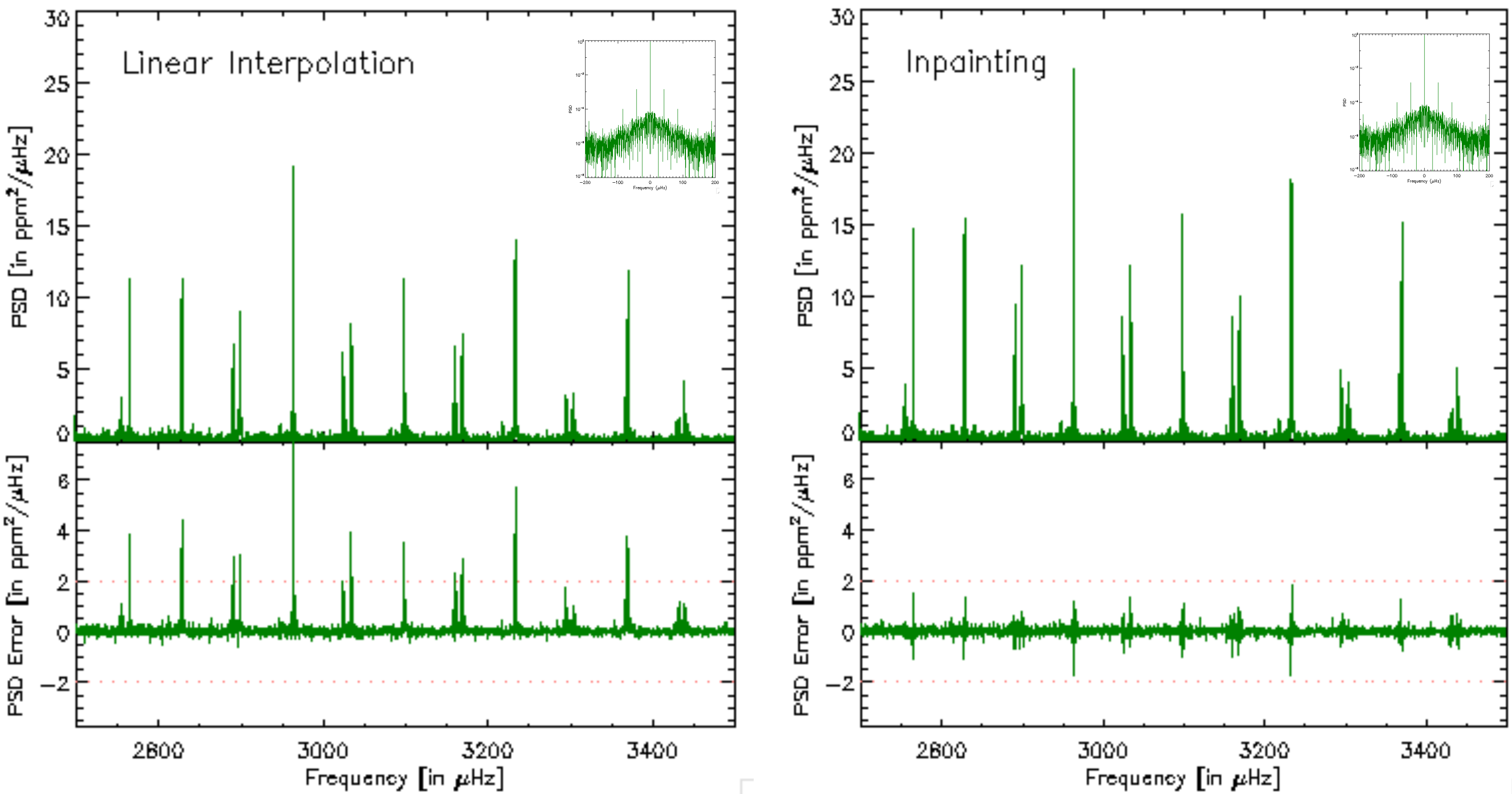
Simulations réalistes d'observations spatiales : SWF vs Inpainting



15% de données manquantes

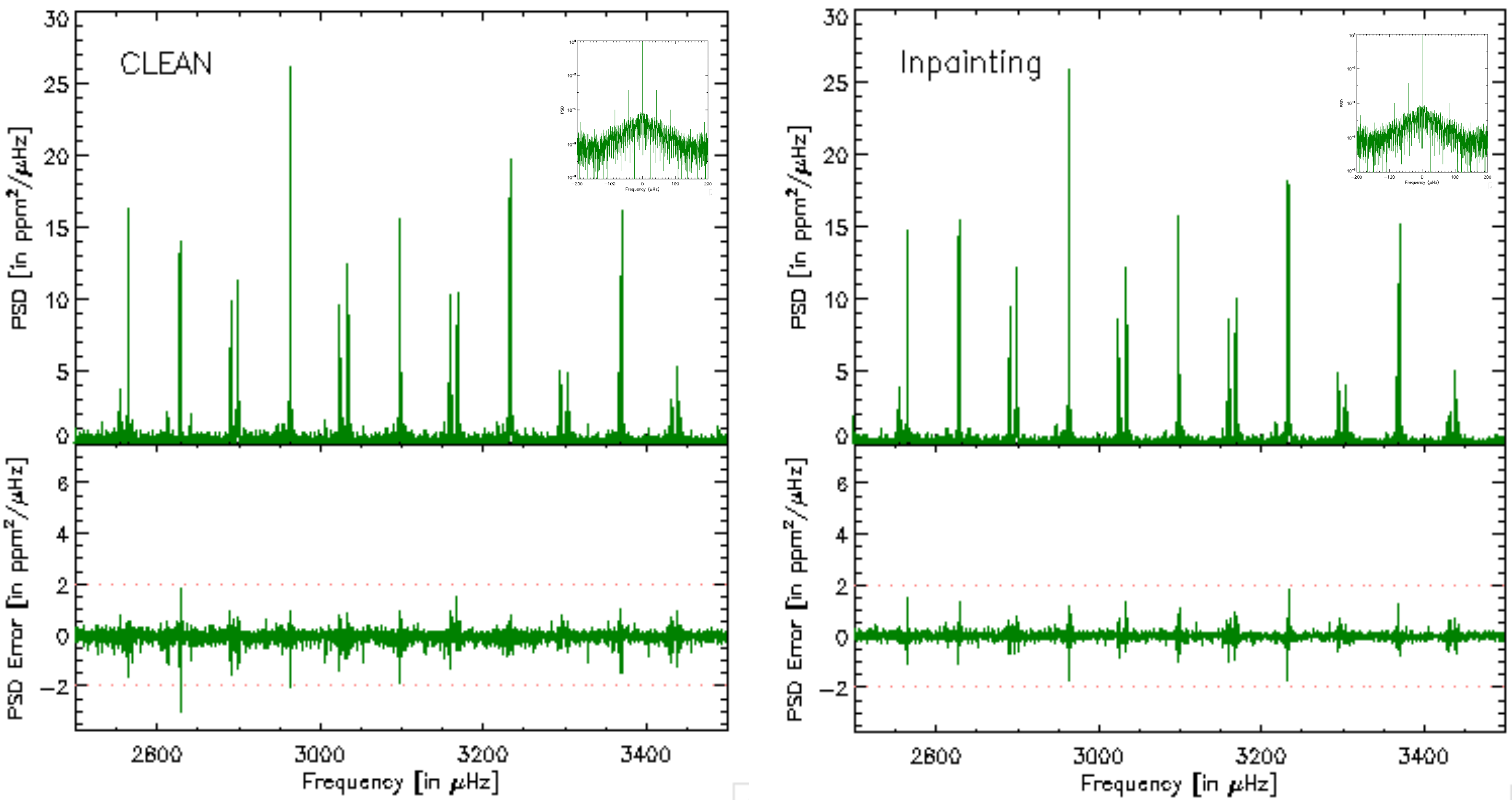
Pires et al., A&A, 2015

Simulations réalistes d'observations spatiales : LI vs Inpainting



15% de données manquantes

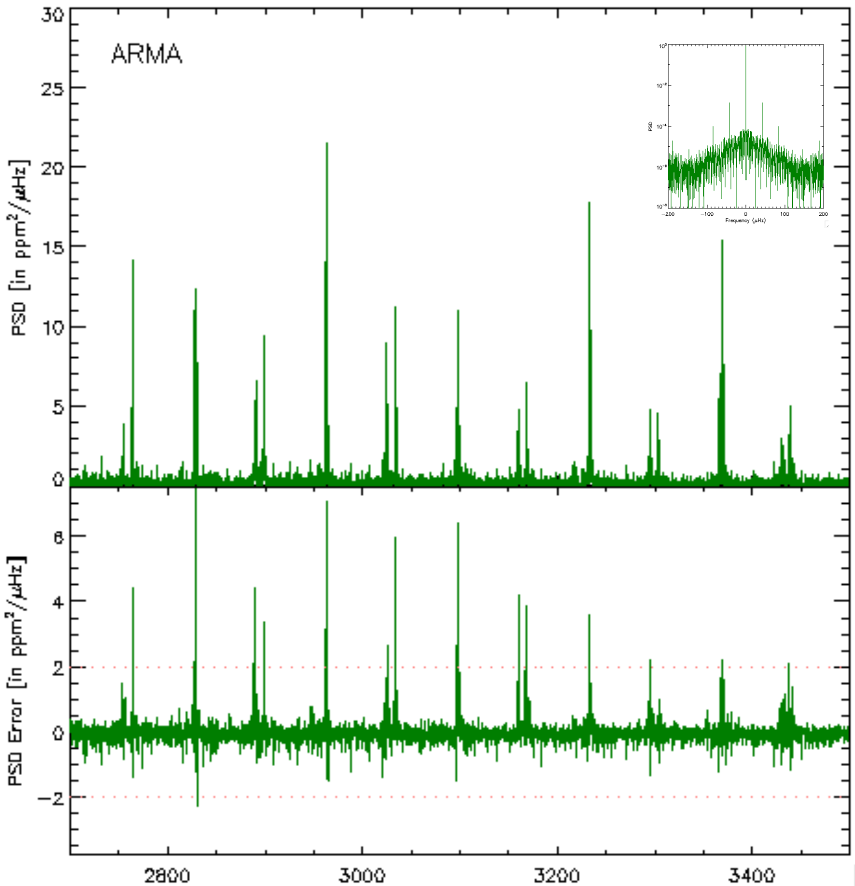
Simulations réalistes d'observations spatiales : CLEAN vs Inpainting

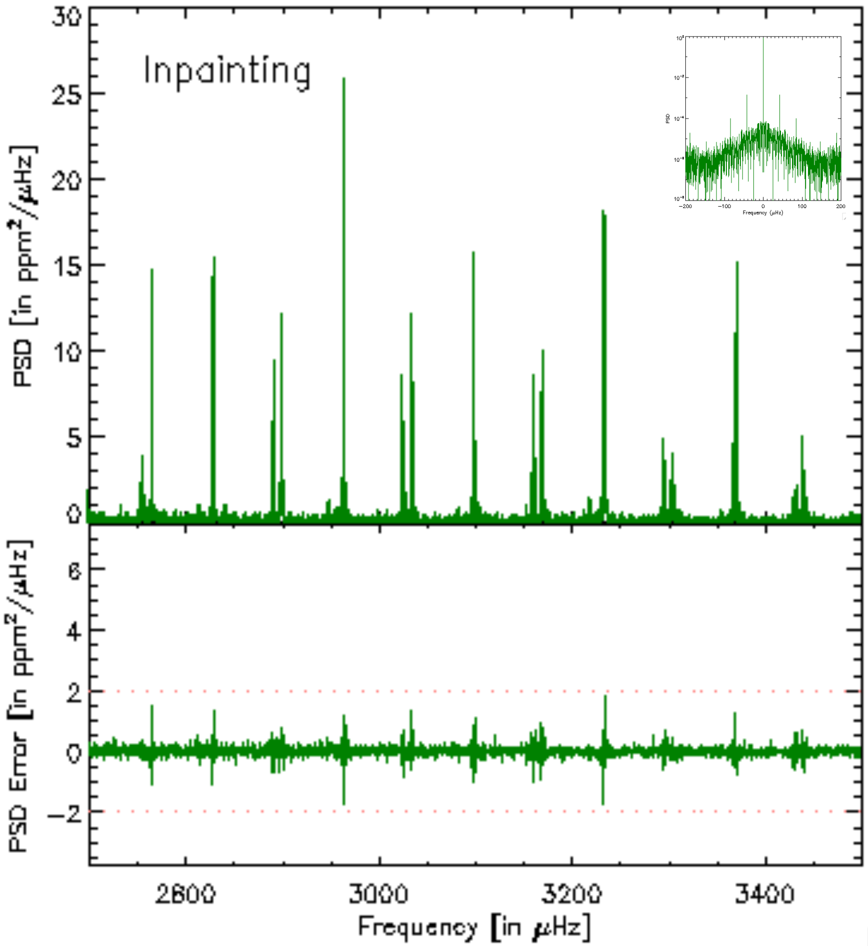


15% de données manquantes

Pires et al., A&A, 2015

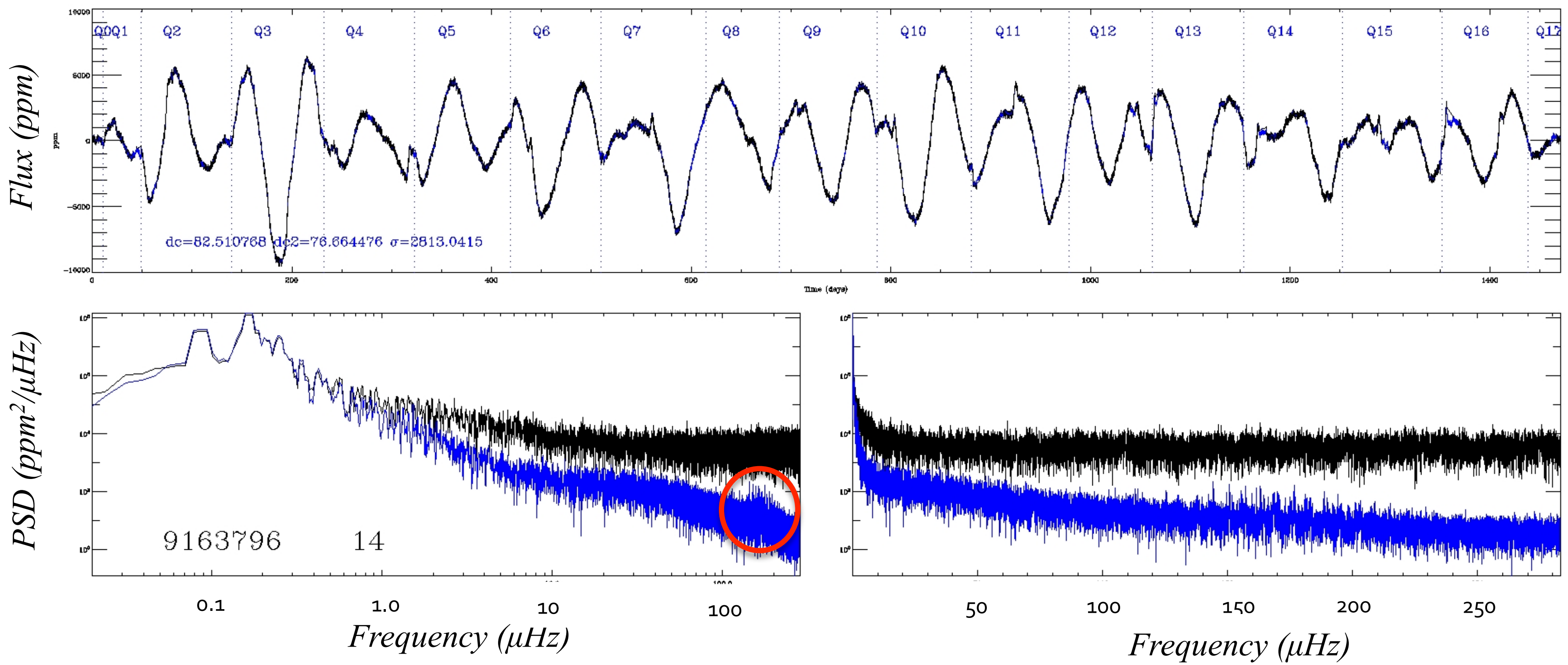
Simulations réalistes d'observations spatiales : ARMA vs Inpainting





15% de données manquantes

Application à des données réelles:
Révélation de certains modes d'oscillations



Le code : K-Inpainting

CosmoStat
An AIM laboratory @CEA Saclay

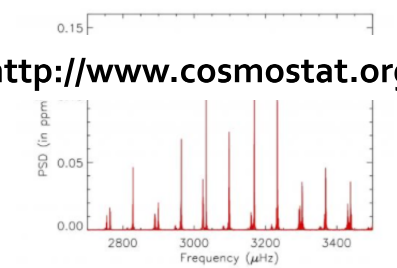
Home News Research People Projects Publications Software Products Events Education Jobs

K-Inpainting

Kepler

Welcome to the K-Inpainting web page.
This page introduces the K-Inpainting software (Version 1.0)

In asteroseismology, the observed time series often suffers from incomplete time coverage due to repeated gaps. The presence of periodic gaps may generate spurious peaks in the power spectrum that limit the analysis of the data. Various methods have been developed to deal with gaps in time series data. We propose a new approach to handle the problem, the so-called inpainting method. This technique, based on a sparsity prior, enables to judiciously fill-in the gaps in the data, preserving the asteroseismic signal, as far as possible. This method can be applied both on ground and space-based data. It appears that the inpainting technique improves the oscillation modes detection and estimation. The impact of the observational window function is reduced and the interpretation of the power spectrum is simplified. Additionally, it can be used to study very long time series of many stars because its computation is very fast.



http://www.cosmostat.org/software/k-inpainting/

Power Density Spectrum for a duty cycle of 83% computed using an FFT on the inpainted time series.

Description

K-Inpainting (Inpainting for Kepler) is a software written in C++ with an IDL interface.

Download

[Download the K-Inpainting software]

Application aux données réelles

- Le **pipeline qui traite les données de la mission Kepler pour faire de l'astérosismologie** (developpé par le groupe KASC) utilise le code K-Inpainting pour corriger les courbes de lumière de la présence de données manquantes.
- Le **pipeline officiel de la mission CoRoT** est en train d'utiliser le code K-Inpainting pour corriger les données manquantes à la fois sur la branche astérosismologie et sur la branche exo-planète des données.

Plan

- Les données manquantes en Astrophysique
  - Leurs origines
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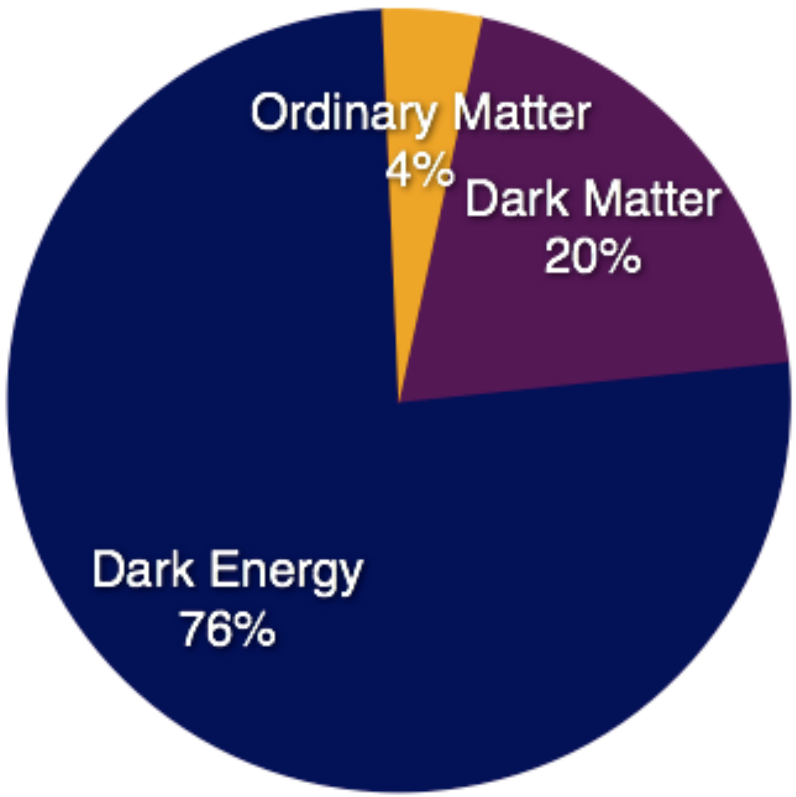
  - Application aux lentilles gravitationnelles faibles (signal 2D)

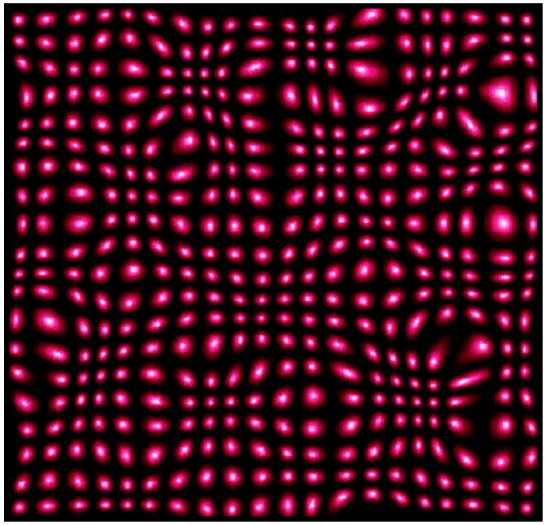
Effets de lentilles Gravitationnelles

Abell 2218. Credit: NASA/ESA

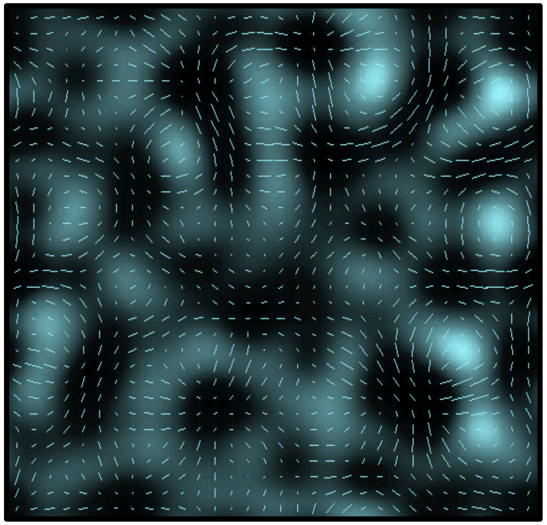
Modèle cosmologique



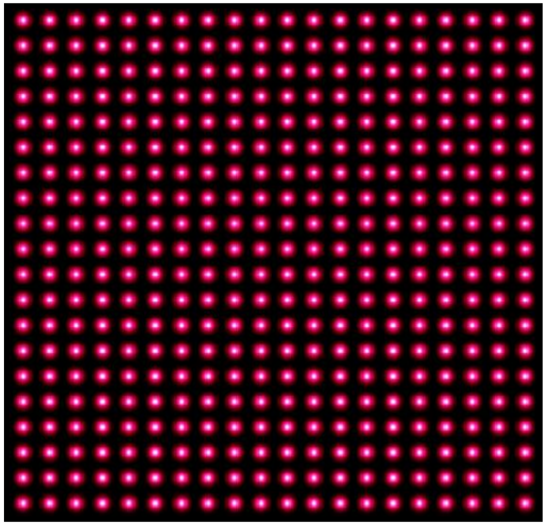
Effet de lentille Gravitationnelle faible



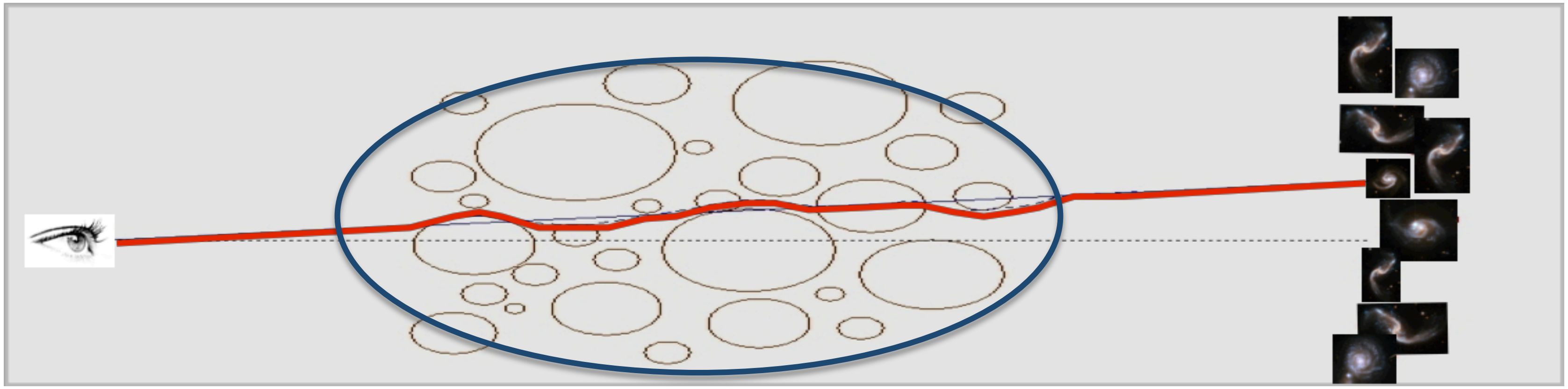
Observateur



Lentille gravitationnelle

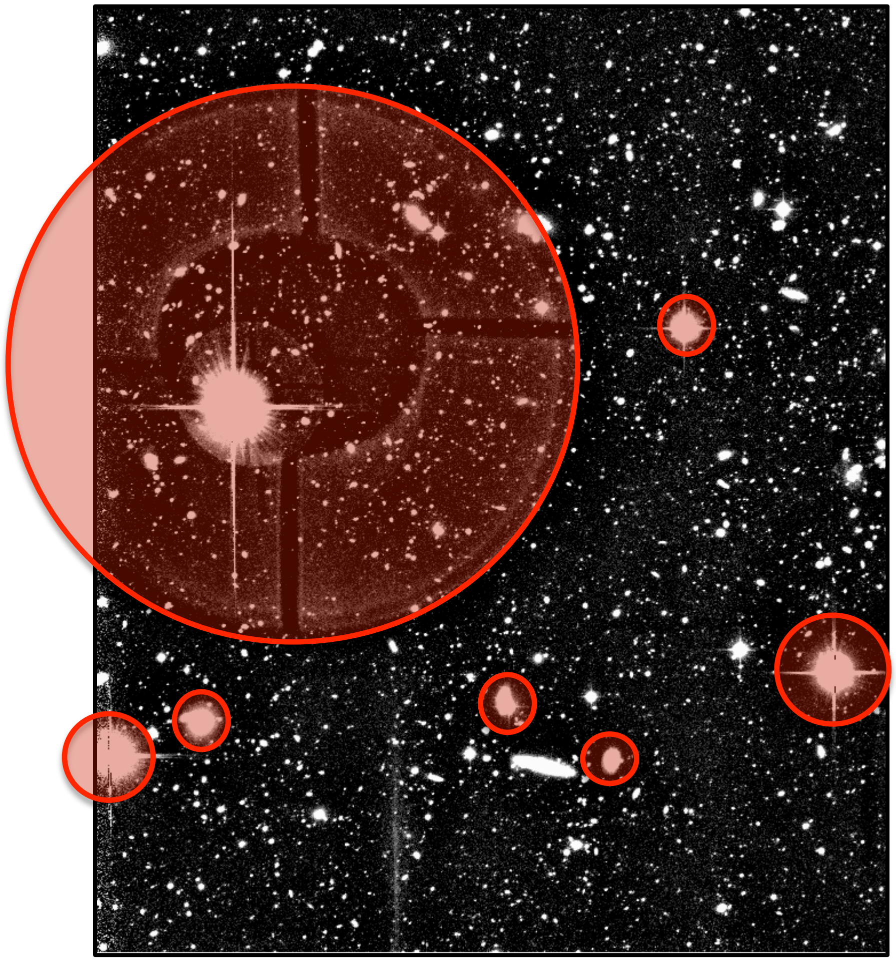


Galaxies lointaines



Lentille gravitationnelle

Les données manquantes en lentille gravitaionnelle



Inpainting des données de lentille gravitationnelle faible

$$\gamma_i^{obs} \rightarrow \min_{\kappa} ||\Phi^T \kappa||_1 \quad \text{subject to} \quad \sum_i ||\gamma_i^{obs} - M(P_i * \kappa)||_2^2 \leq \epsilon \rightarrow \kappa$$

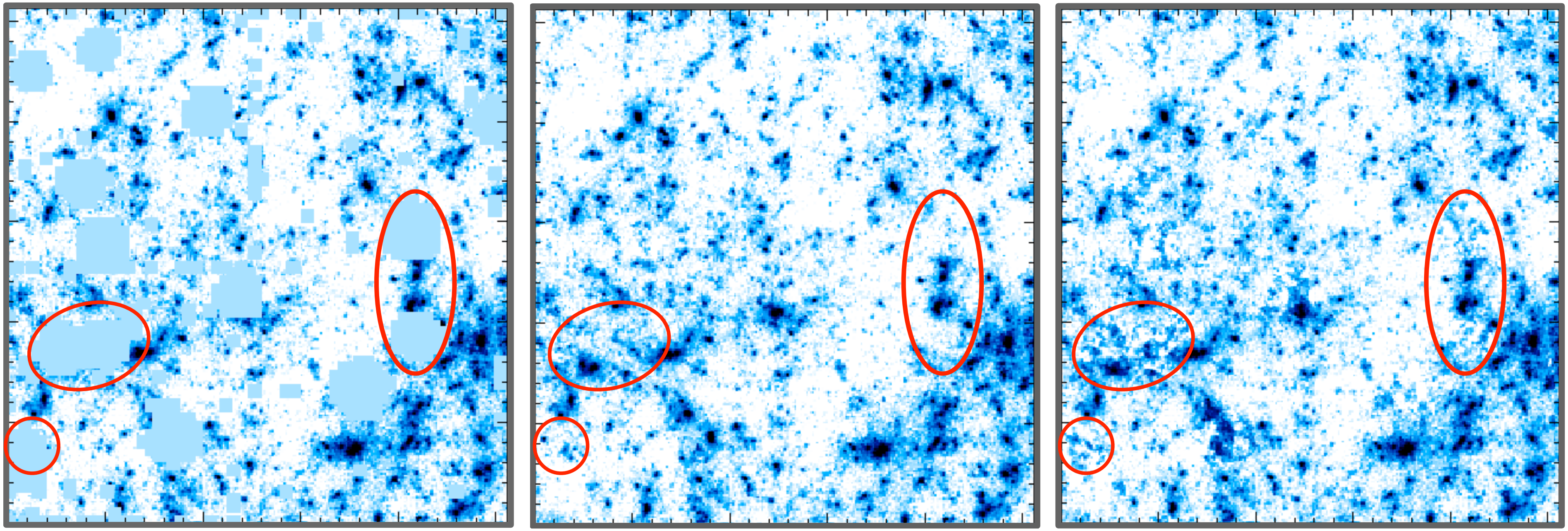
Physical priors

$$\gamma_i^{obs} = M.\gamma_i$$

$$\kappa = P_1 * \gamma_1 + P_2 * \gamma_2$$

Φ^t is the DCT

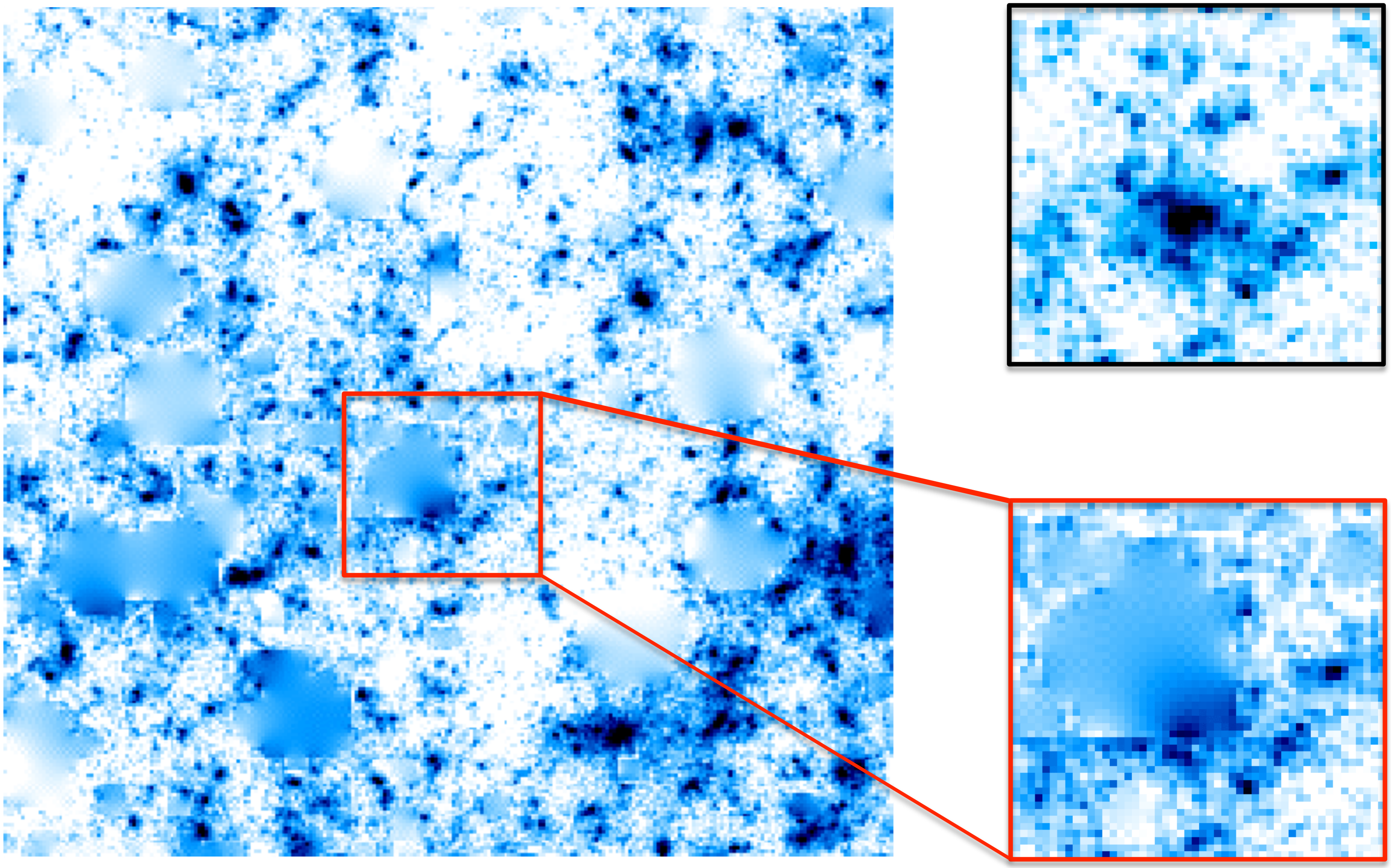
Inpainting des données de lentille gravitationnelle faible



Masque sur le relevé du CFHTLS sur un champ de 1° x 1° avec 20% de données manquantes
Courtesy to J. Berge

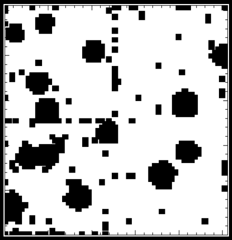
Quelle est l'image originale ?

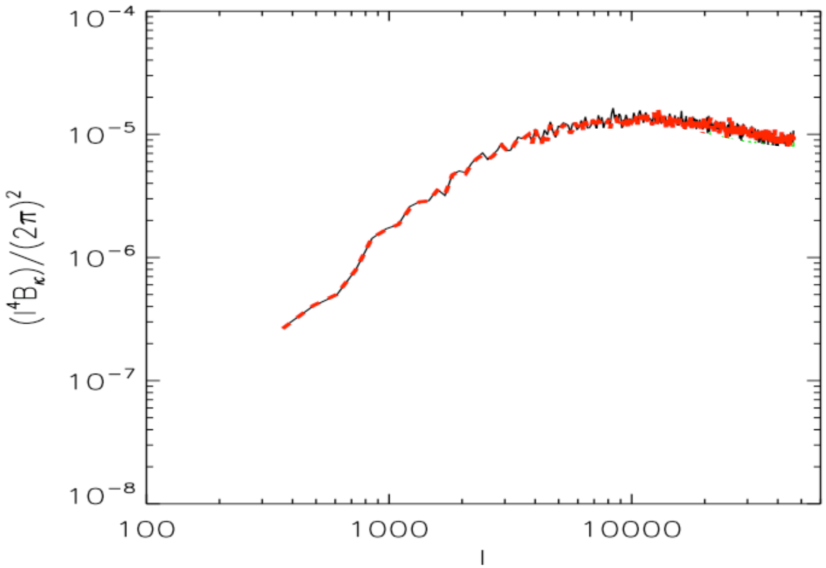
Inpainting des données de lentille gravitationnelle faible



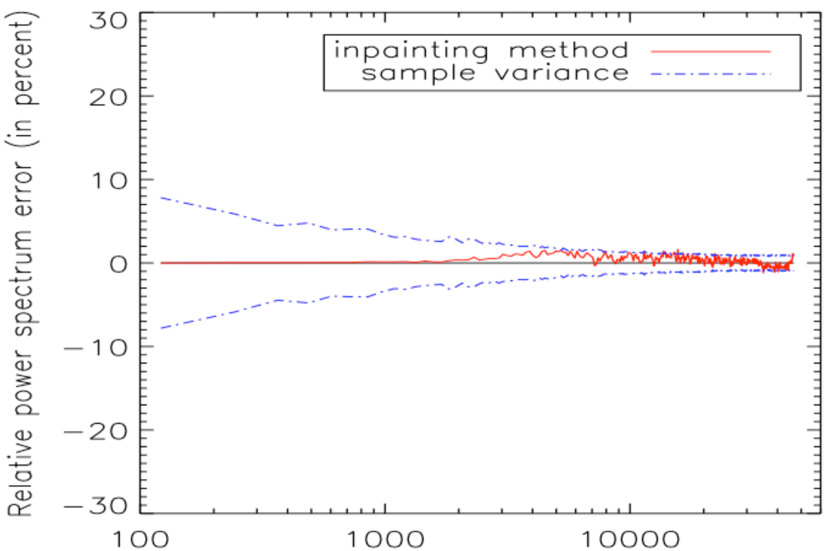
Estimation du spectre de puissance

Pires et al., MNRAS, 2009





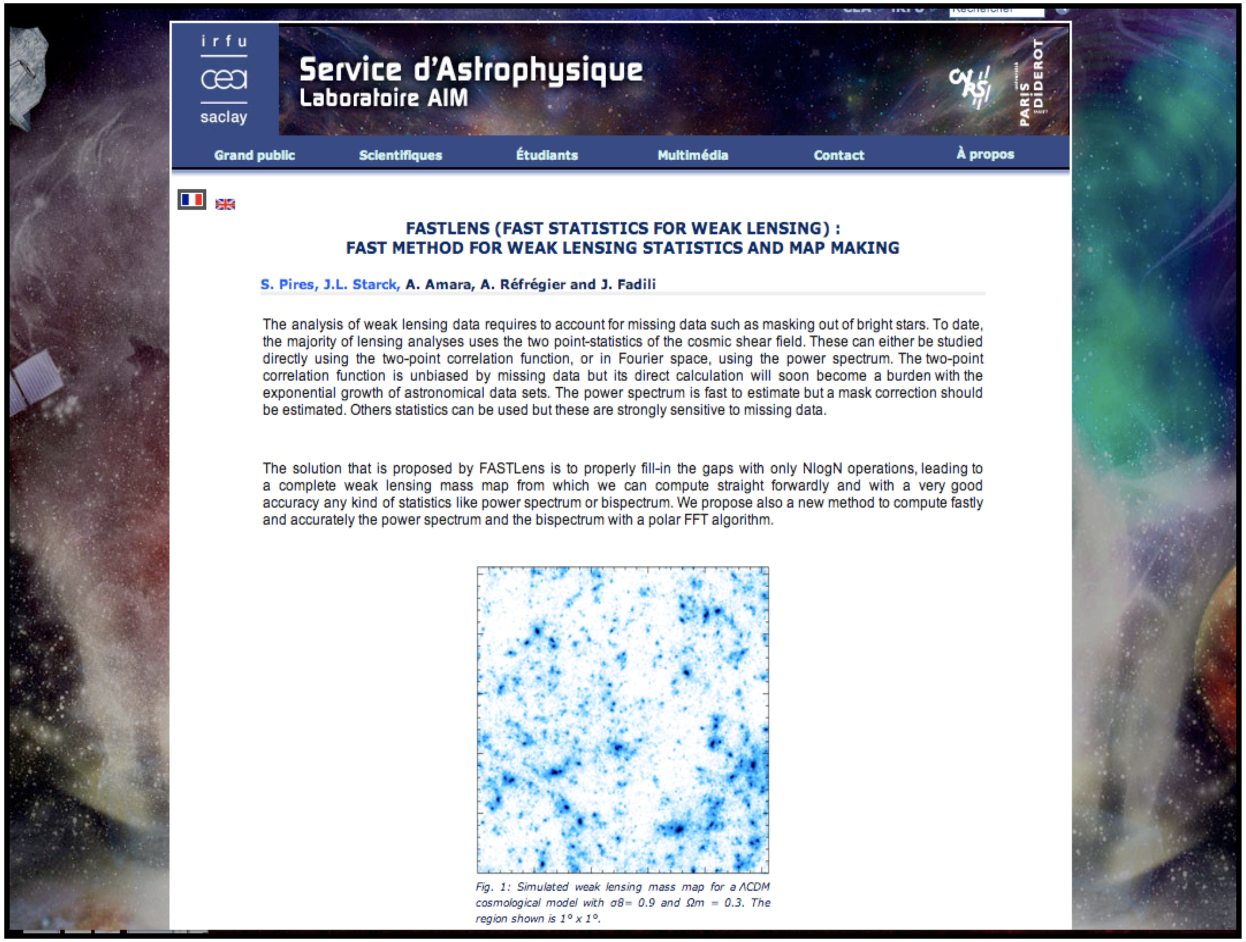
Spectre de puissance moyen estimé à partir de cartes de cisaillement complètes (en noir) et des cartes de cisaillement incomplètes interpolées par la méthode d'inpainting (en rouge)



Erreur relative sur le spectre de puissance i.e. la différence normalisée entre les deux courbes supérieures de gauche.

Le code : FASTLens

http://www-irfu.cea.fr/Ast/fastlens_software.php



FASTLENS (FAST STATISTICS FOR WEAK LENSING) :
FAST METHOD FOR WEAK LENSING STATISTICS AND MAP MAKING

S. Pires, J.L. Starck, A. Amara, A. Réfrégier and J. Fadili

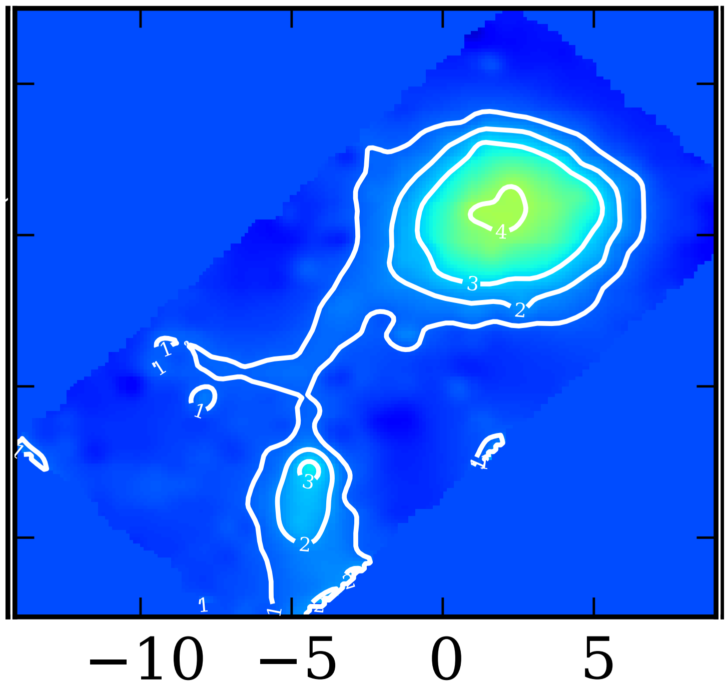
The analysis of weak lensing data requires to account for missing data such as masking out of bright stars. To date, the majority of lensing analyses uses the two point-statistics of the cosmic shear field. These can either be studied directly using the two-point correlation function, or in Fourier space, using the power spectrum. The two-point correlation function is unbiased by missing data but its direct calculation will soon become a burden with the exponential growth of astronomical data sets. The power spectrum is fast to estimate but a mask correction should be estimated. Others statistics can be used but these are strongly sensitive to missing data.

The solution that is proposed by FASTLens is to properly fill-in the gaps with only NlogN operations, leading to a complete weak lensing mass map from which we can compute straight forwardly and with a very good accuracy any kind of statistics like power spectrum or bispectrum. We propose also a new method to compute fastly and accurately the power spectrum and the bispectrum with a polar FFT algorithm.

Fig. 1: Simulated weak lensing mass map for a ΛCDM cosmological model with $\sigma 8 = 0.9$ and $\Omega m = 0.3$. The region shown is 1° x 1°.

Application aux données réelles

Jullo, Pires et al., MNRAS, 2014



Reconstruction de l'amas de galaxies MACS J0717+ en utilisant le code Flens.
La structure filamentaire (découverte dans Jauzac et al.) est confirmée par cette étude.

FIN

http://www.cosmostat.org/people/sandrine-pires/
sandrine.pires@cea.fr