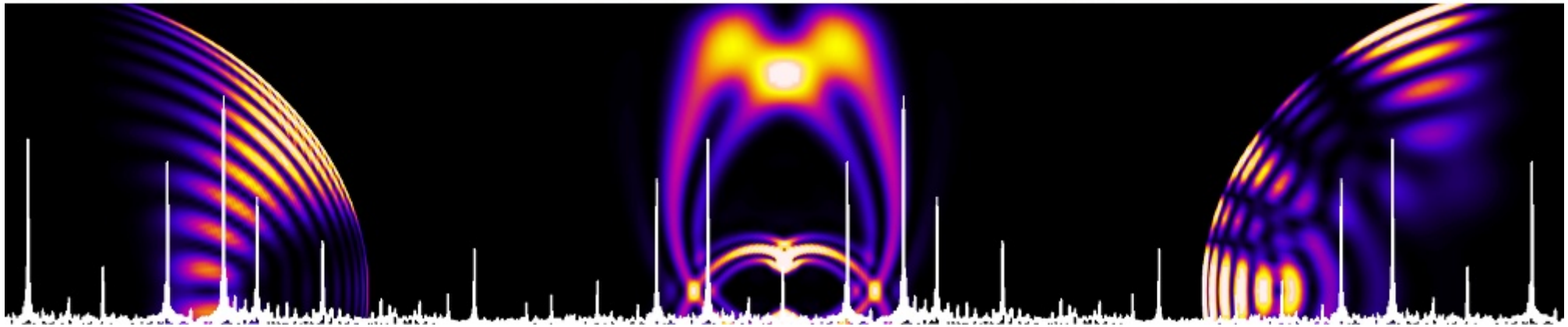
SoFAR – Seismology of Fast Rotating Stars

INTERNATIONAL SPACE SCIENCE INSTITUTE

International Team



J. Ballot,
Zs. Bognár, A. García Hernández,
F. Lignières, E. Michel, E. Moravveji,
R. M. Ouazzani, M. Paparó, V. Prat,
D. R. Reese, M. Rieutord, Á. Sódor,
J. C. Suarez

http://www.issibern.ch/teams/sofar/

Abstract

Thanks to the space missions CoRoT and *Kepler*, asteroseismology has successfully probed stellar interiors, especially of solar-like stars and red giants. Such a success has not been achieved yet for non-evolved intermediate-mass and massive stars, as the oscillation spectra of pulsating stars in this mass range exhibit complex patterns that are not well understood. Rapid rotation, a very common feature of these stars, is an identified source of complexity.

Our proposal aims at building a joint effort between modellers and observers, based on existing seismic data for fast rotators, in order to address major difficulties in understanding and studying stars with rapid rotation.

Substantial progress has recently been achieved both in theory and observations. The space missions CoRoT and *Kepler* have provided seismic data with unprecedented quality for classical pulsators such as δ Scuti stars, γ Doradus or SPB (slow pulsating B-type) stars. It allowed us to accurately determine the frequencies of hundreds of oscillation modes in these stars. The mode identification, i.e. associating each frequency with a mode, is a prerequisite for any further seismic inference. This identification needs theoretical support. In the last years, new theoretical approaches as well as new 2D codes taking into account the centrifugal deformation have been developed to model the internal structure of rotating stars and to compute their oscillation spectra.

We are now close to a convergence between theory and observation. Indeed a first breakthrough has been made with the detection of regular patterns that were predicted by the models.

We aim at providing new seismic diagnosis, especially for stellar rotation so as to obtain new interpretations of CoRoT and *Kepler* observations of δ Scuti stars, γ Doradus or SPB stars. This work will also help the seismic analyses of future space missions such as TESS and PLATO.

The Team

INTERNATIONAL SPACE SCIENCE INSTITUTE

KU LEUVEN

KONKOLY

l'Observatoire de Paris

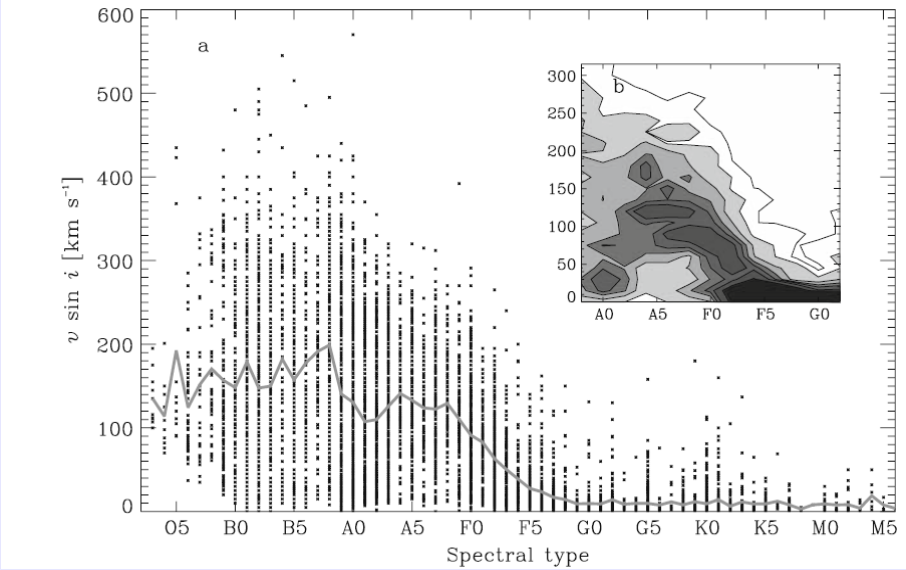
irap astrophysique & planétologie

AIM

UNIVERSIDAD DE GRANADA

Rotation & Oscillations

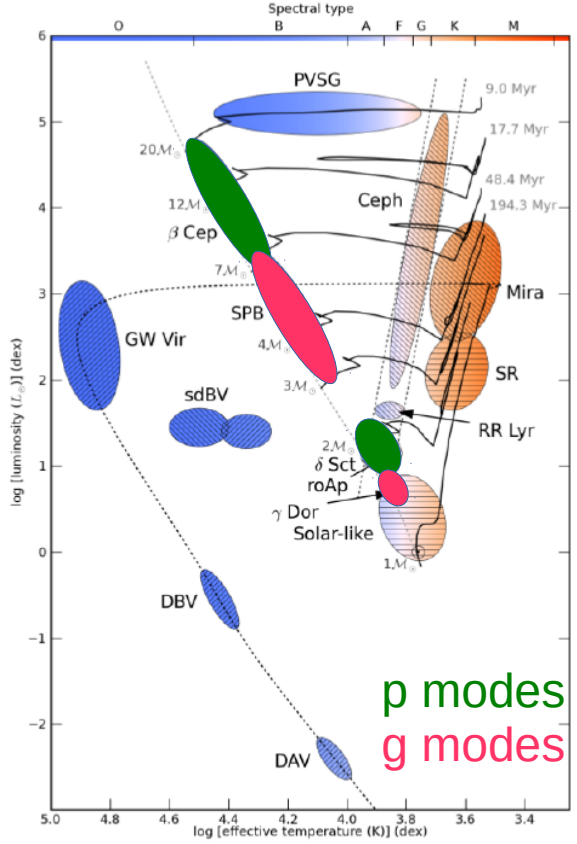
(Fast) Rotation



Royer 2009

Effect?

Oscillations

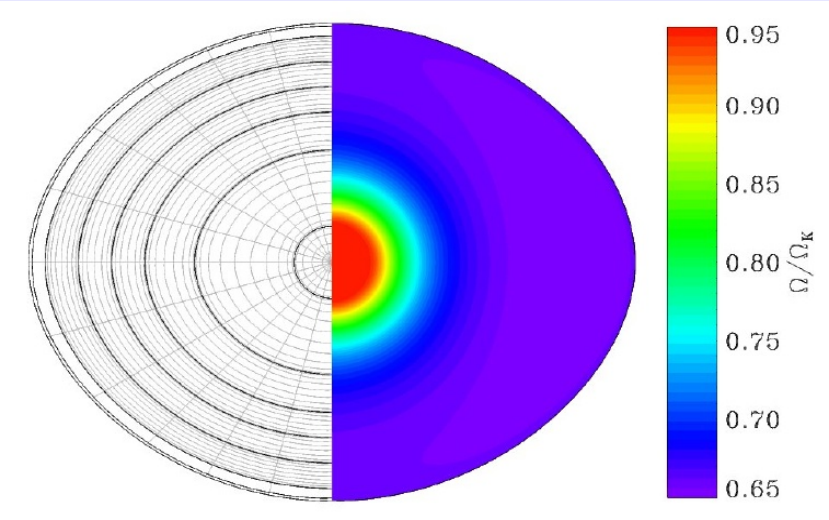


after Pápics 2016

β Cep, SPB, δ Sct, γ Dor

Models

2D Models



ESTER Code http://ester-project.github.io/ester/

Rieutord et al. 2016

Oscillations

Complete 2D computations

Codes :

- TOP Reese et al. 2006
- ACOR Ouazzani et al. 2012

Approximations

- Perturbative
  e.g. Suarez et al. 2006
- Traditional
- Low-frequency
  Prat et al. 2017

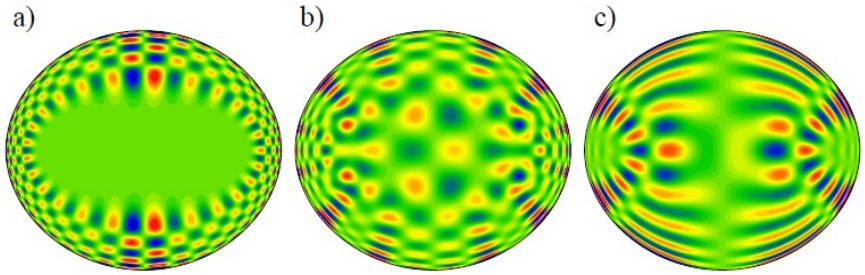
Ray dynamics

- p modes
  Lignières & Georgeot, 2008, 2009, Pasek et al. 2012
- g modes Prat, et al. 2016

Mode classification & regularities

p modes

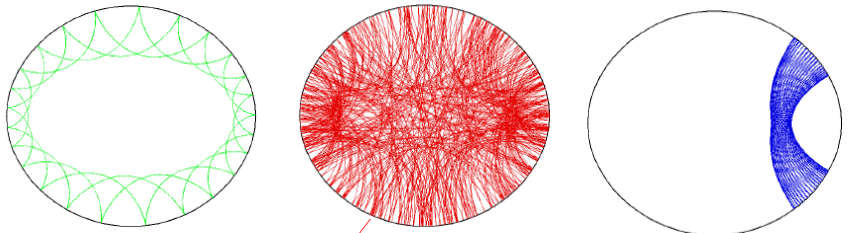
Mode computation



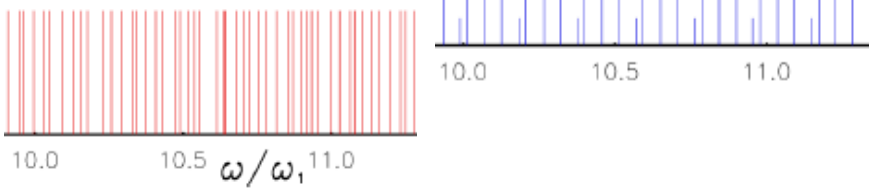
Whispering gallery

Chaotic mode

Island mode

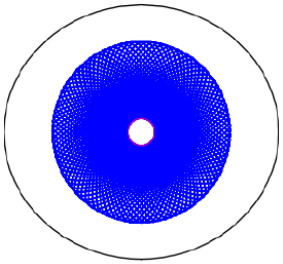


acoustic rays

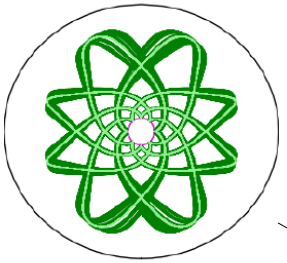


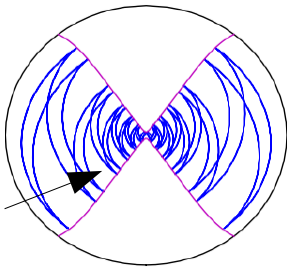
g modes

Ray tracing

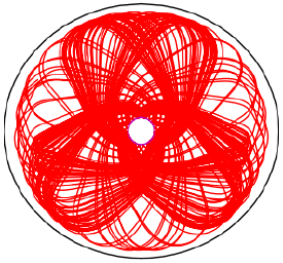


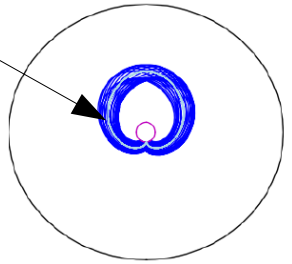
“normal” modes





Island modes

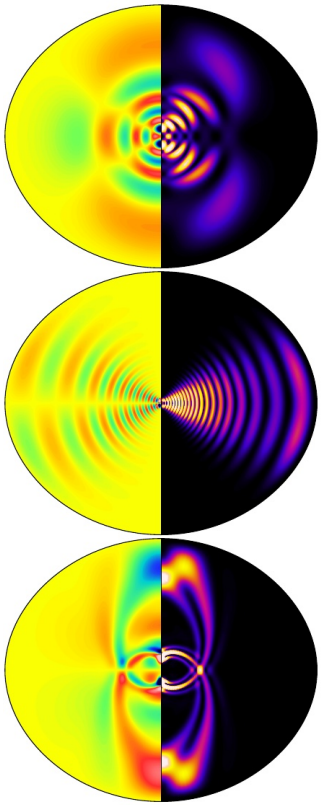




Rosette modes

Chaotic modes

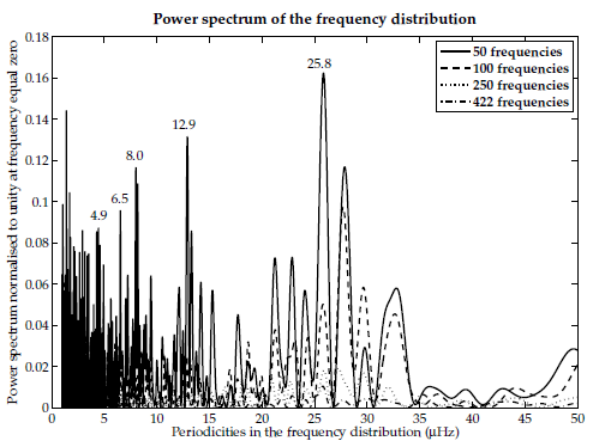
Numerical computations



Regularities in CoRoT & Kepler data

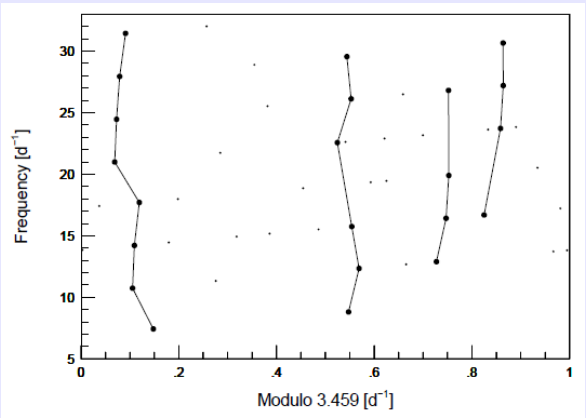
p modes (δ Sct)

FT of Spectra



García Hernández et al. 2009

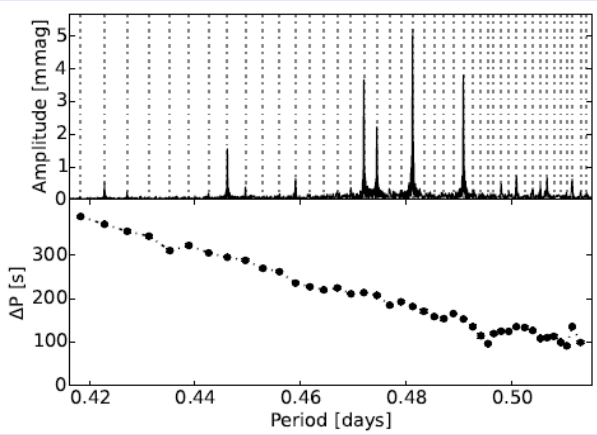
SSA
sequence search algorithm



Paparó et al. 2016

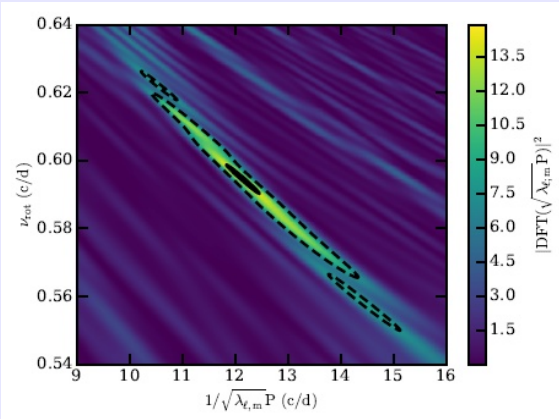
g modes (γ Dor, SPB)

Pattern search



Van Reeth et al. 2015

Stretched FT



Christophe et al. (in prep)

Team objectives

p modes and δ Scuti stars

- Detecting and interpreting the regular spacings
  - Determining Robustness and reliability of detections
  - Identifying their nature and origin (large spacing, rotation…)
- Finer mode identification (chaotic modes, island modes…)

Team #1

g modes in γ Doradus & SPB stars

- Detecting period spacings
- Measuring rotation
  - capability in measuring reliable internal differential rotation
  - Application range of traditional approximation
- Core properties

Team #2

Direct analysis

- How to use 2D models to perform direct seismic analysis?

Team #3 = #1+#2

Schedule

Jun 2016	Project initiated during SPACEInn Workshop 4.4 (Toulouse)
March 2017	International team project submitted to ISSI
June 2017	Team accepted by ISSI
July 2017	Team activities start
29 Jan – 2 Feb 2018	First team meeting at ISSI
Jan 2019	Second team meeting at ISSI