Session #1: Low-degree peak-bagging techniques

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Peak-bagging in helio- and asteroseismology

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Context & Aims of session #1

- Concerned observations:
  - low-*l* <=> *l* ≤ 3 (or 4)
    - Sun as a star observation
    - Asteroseismology
  - for intermediate- & high-*l* => Session #4
- Focus on solar-type oscillations
  - classical pulsators out of scope of this session
- Extracting mode from a power spectrum
  - PS is assumed to be already computed
- Aim #1: define the state of the art and needed developments
- Aim #2: define more precisely the pipeline to be delivered

Models of modes

- modes = multiplet of 2*l*+1 Lorentzian profiles
- Parameters:
  - Sun: ν, H, Γ, ν_s, *a* (asymmetry)
    - H(m)/H(m=l) are fixed – instrument dependence
  - Star: ν, H, Γ, ν_s, *i* (inclination)
    - no asymmetry; H(m)/Σ H(m) = f(*i*)
  - (radial)
- About splitting ν_s: one splitting for a given mode OR different splittings for different *m*.

Fitting approaches

- local fit = one mode or one pair 02 or 13 (or sometimes 3 modes 024)
  - Usual for the Sun (and GK-type stars)
  - all parameters are free and independent
    - some p. are fixed at high freq <- Q
- Global fit = the whole spectrum
  - usual for other stars
  - reducing the number of free parameters
    - general 1 value for H, Γ per large spacing <- Q
    - H(*l*) / H(*l*=0) is global (fixed or not) <- Q
    - i is global, ν_s is global for pure p modes
  - Importance of the background: fixed / free w constraints <- Q

Estimation of parameters

- 2 main approaches
  - Punctual estimations (Frequentist approach)
    - Maximum likelihood estimation (MLE)
    - Maximum posterior probability (MAP)
    - used for the Sun, fast, pb of local max, error estimation
  - Sampling methods of posterior probability (Bayesian approach)
    - Markov Chain Monte Carlo
    - Nested Sampling <- Enrico
    - developed for other stars, slow, global view of space parameters, model comparison

Guesses & priors

- Q: How to define guesses?
  - especially for automated pipeline
- Q: How to define priors (for Bayesian approach)?
  - Uniform prior *IS* a prior
    - Example: uniform $i \neq$ isotropic distribution
      isotropic distribution $\leftrightarrow$ $p(i)\,di = \sin i\,di$
  - Impact of priors <- Q

Different "regimes"

- Solar Case
  - Q: Do High frequencies need a special treatment?
    (HF: small separation ~ width).
    What about low frequencies (Γ< or ~ bin or low S/N) ?
- 3 categories of solar-like stars
  - GK-type star (most similar to the Sun)
    - Q: is a global fit necessary?
  - F-type star (02 are blended)
    - Q: can we survive without a Bayesian method?
  - sub-giants (mixed modes appear)
    - Q: how to treat mixed modes? (problem of guesses, hypotheses about H, Γ, ν_s are no more valid)
  - RG beyond the scope of this discussion (or not?)

Error estimation

- Natural for sampling methods
  - direct access to PDF
  - Q: How to summarize the PDF?
    - median: invariant by variable change
- MLE -> estimation from the Hessian matrix
  - based on the Cramér-Rao bound
    - only a lower limit of errors
    - need to be computed for the exact values of parameters, not the fitted one (by definition, never fulfilled).

Robustness and biases

- Robustness of the extraction
  - Is a fit relevant? Is it signal? Q: Which test to be used?
  - Where do we stop extracting modes at low/high freq (both for local and global approaches)
  - What happens at low S/N <- Hans
  - case of multiple maximum
  - Effect of spectral resolution
- Biases of parameters
  - Effect of spectral resolution and S/N
  - Example: extraction of high frequency modes after 3 months and 3 years of kepler data
    - Q: Biases or error underestimations?

Pipelines

- « *D4.4) Tools to extract low frequency mode frequencies: New techniques to extract low-amplitude signals (p and g) modes [month 36]* »
- « *D5.1) Analysis tools for solar-like oscillators: Analysis tools for application to Kepler, CoRoT, SONG and other bases of asteroseismic datasets, including extraction of convective envelope depths, convective core properties, envelope He abundances (software) [month 36]* »
  - First stage this pipeline is peakbagging...
- Q: For which users? For analyzing which stars? Which spectrum model? Which method? Which approaches? Which language?

Other questions

- Let us start the discussion...