A COMPREHENSIVE KEPLER RED GIANT CATALOG

Rafael A. García
Astrophysics Division, CEA-Saclay, France

In collaboration with:
I-Introduction
Objectives:

- A complete list of low-mass red giants observed by *Kepler* Main mission
  - Is necessary for seismology:
    - To determine with high precision stellar parameters:
      - Mass, Radius, evolutionary stage, and – when possible – age
    - To put new constraints on stellar interior dynamics
  - Avoiding any selection bias:
    - Very important for Galactic archaeology
    - Stellar population studies
  - Don’t miss any interesting population
    - For example: Non-pulsating stars
    - Faint stars

Legacy value of the catalog:

- Longest and continuous dataset
  - Up to 4 years (resolution of ~0.008 μHz)
  - Frequency resolution not reached by any present or near future space mission

[Berger et al. 2018, Hon et al. 2019]
II-Methodology:
Building the entire RG sample
A set of 30,336 SubG and RG candidates have been obtained. The set has been built from asteroseismic analysis:

- Using Neural network from Hon et al. 2019, which also takes into account Fliper Random forest results from Bugnet et al. 2018 and a blind search with the seismic A2Z pipeline (Mathur et al. 2010) => 21,194 oscillating RGs and SubRs
- Using other general catalogs:
  - Using RGs and SubGs from Kepler DR25 (Mathur et al. 2017)
  - Using Gaia DR2 Berger et al. 2018 revised radius
  - Using APOGEE spectroscopic results for the Kepler field

16,094 oscillating red giants [Yu et al. 2018]
II-METHODOLOGY

- **Light curve preparation:**
  - Homogeneous treatment for all *Kepler* targets
  - KADACS light curves (García et al. 2011) including¹:
    - High-pass filtered at 20 days (~0.58 \( \mu \text{Hz} \))
      - For low high-luminosity RGB stars:
        - The high-pass filter is set at 80 days (0.14 \( \mu \text{Hz} \))
    - Gap filling
      - In-paint techniques (García et al. 2014; Pires et al. 2015)
        - Multiscale discrete cosine transform

¹ Freely distributed as KEPSEISMIC at MAST (Mikulski Archive for Space Telescopes)
https://archive.stsci.edu/prepds/kepseismic/
Larger customized photometric masks compared to standard PDC

- 909 dwarf/subgiants having RG pollution
  - 293 are known *Kepler* RG targets
  - 616 are new RGs
    - with 587 being non-Kepler targets
    - 14 identified thanks to GAIA (Berger et al. 2018)
    - 15 unidentified

lightkurve3 package [Vinicius et al. 2018]

[Colman et al. 2017]

[Hon et al. 2019]
II-METHODOLOGY

- Larger customized photometric masks compared to standard PDC
  - 909 dwarf/subgiants have been identified
    - 293 are known RGs
    - 616 are new RGs
      - 587 are non-Kepler targets
      - 14 identified thanks to GAIA (Berger et al. 2018)
      - 15 unidentified

[Hon et al. 2019] lightkurve3 package

[Vinicius et al. 2018]
II-Methodology:

Extracting robust seismic estimates
To extract robust seismic parameters ($\Delta \nu$ & $\nu_{\text{max}}$) & validate stars as RG or SubGs:

- **2-step procedure:**
  1) Blind analysis by 15 independent seismic pipelines
     - Providing at least $\Delta \nu$, $\nu_{\text{max}}$, or both
     - Use the data filtered at 20 days
       - Low-frequency cut at $\Delta \nu = 2 \mu$Hz
         - Super-luminous RGB stars are not considered (Talk by Yu)
  2) Ensemble analysis:
     - Step 1 results available for all participant teams
       - Allowing to “force” individual pipelines on other’s values
     - Extension to Superluminous RGB stars
       - Using 80 days filtered light curves
     - Robust methodology already used in the seismic analysis of K2 galactic archeology program (Talk by Stello)
III-Preliminary results

Step 1
Determination of $\Delta \nu$:

- 11 pipelines are used in this homogeneous analysis ($\Delta \nu > 2 \mu$Hz)
Determination of $\Delta \nu$:

- A star is selected if:
  - Measured by at least 3 pipelines (Only 10 pipelines used to compute the mean and sigma)
III-RESULTS: STEP 1

- **Determination of $\Delta \nu$:**
  - A star is selected if:
    - Measured by at least 3 pipelines (Only 10 pipelines used to compute the mean and sigma)

![Graph showing distribution of $\Delta \nu$](image)

& $\text{RMS}($fractional difference per star$) < 5\%$
III-RESULTS: STEP 1

- Determination of $\Delta \nu$:

Number of stars with at least 3 pipelines, with RMS($\Delta \nu$)/<\$\Delta \nu\$> < 5%, and with $\Delta \nu$ > 2 $\mu$Hz = 17588.
Correction of the zero-point offset of each pipeline not done here: see Pinsonneault et al. 2018
III-RESULTS: STEP 1

- Number of pipelines providing a good result for each star.

![Bar chart showing the distribution of pipelines providing good results for each star. The x-axis represents the number of pipelines, and the y-axis represents the number of stars. The chart shows a peak at 9 pipelines with the highest number of stars.]
Comparison between the selected stars and $\nu_{\text{max}}$ from Hon et al. 2019

- this $\nu_{\text{max}}$ was selected because it is a completely independent method
CONCLUSIONS

- Step 1 is done
- Step 2 has just started
  - 3 more pipelines will be added
- Robust determination of $\Delta \nu$ for
  - ~17,500 stars
- ~2,000 confirmed SpLum RG to be added
  - Even more (Yu previous talk)
- ~600 Previously unknown RGs
  - Most with $K_p > 14$ (Hon et al. 2019)
- Currently studying possible confirmed RG (Gaia, Berger et al. 2018) without pulsation
- We expect to increase the total amount of confirmed pulsating RGs to ~25,000 stars

Stay tuned

Thanks !!

The Kepler “RG” road is being all but straight!
CONCLUSIONS

- Step 1 is done
- Step 2 has just started
  - 3 more pipelines will be added
- Robust determination of $\Delta \nu$ for
  - ~17,500 stars
- ~2,000 confirmed SpLum RG to be added
  - Even more (Yu previous talk)
- ~600 New unknown RGs
  - Most with $K_p > 14$ (Hon et al. 2019)
- Currently studying possible confirmed RG (Gaia, Berger et al. 2018) without pulsation
- We expect to increase the total amount of confirmed pulsating RGs to ~25,000 stars

Stay tuned

Thanks !!