# Benchmark stars for activity and rotation

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# Motivation

- Test methods to measure rotation and differential rotation;
- Calibration of the rotation-activity and rotation-age (gyrochronology) relationships up to the solar age and beyond (e.g.. van Saders et al. 2016, Nature 529, 181; Barnes et al. 2016, ApJ, 823, 16);
- Connection between photospheric variability and higher energy emissions (chromospheres and coronae);
- Activity cycles on short (months) and long (years) timescales;
- Comparison and calibration of numerical simulations with real stars.

# General properties

- Pre-Main-Sequence (PMS) and Main-sequence stars (but subgiant and giant stars can also be considered; e.g., Garcia et al. 2014, A& 572, A34; Garcia et al. 2016, in prep.);

- Effective temperature between 8000 and 3000 K;

- Age range from PMS to late main-sequence;

- Rotation periods from 0.2 to 50-100 days;

=> Ideally, we would like to cover a range of parameters as large as possible.

# Possible samples of benchmark stars

- Individual stars with full parameter characterization from a variety of observations (e.g., solar twins, e.g., 18 Sco, $\kappa^1$ Cet (Do Nascimento et al. 2016, ApJ 820, L15); CoRoT asteroseismic targets, Kepler targets [e.g., 61 Cyg A and B], …);
- Samples of stars with asteroseismic, rotation, and activity characterizations from Kepler timeseries (e.g., Garcia et al. 2014, A&A 572, A34);
- Mt. Wilson Ca II H & K program stars (data covering 3-4 decades now public) => long-term activity variations, rotation from chromospheric modulation;
- Interesting stars coming from large surveys (e.g., RAVE, e.g., Zerjal et al. 2013, ApJ 776, 127);
- Stars belonging to **open clusters** because their parameters can be best characterized and they are drawn from a homogeneous population (e.g., Lund et al. 2016, in prep.).

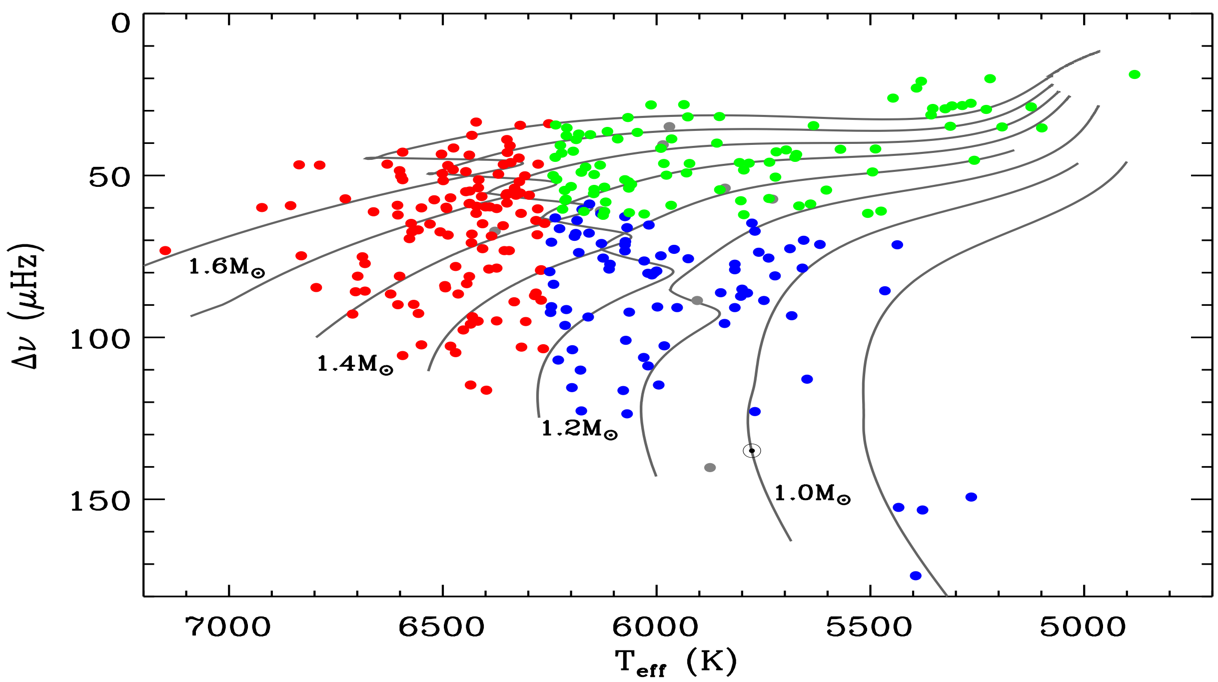


**Fig. 3.** Modified Hertzsprung-Russell diagram ($\Delta\nu$ vs. $T_{\rm eff}$) showing the Sun and the 297 stars for which the rotation period, $P_{\rm rot}$, was successfully measured and a large frequency spacing is available from Chaplin et al. (2014). Hot stars are shown in red and defined as having $T_{\rm eff} > 6250$. Dwarfs ($T_{\rm eff} \leq 6250$ and $\log g > 4.0$) are shown in blue, and subgiants ($T_{\rm eff} \leq 6250$ and $\log g \leq 4.0$) in green. Effective temperatures are taken from Pinsonneault et al. (2012). The stars for which only the effective temperatures from Huber et al. (2014) are available are plotted in grey. Evolution tracks, computed with the code ASTEC (Christensen-Dalsgaard 2008), are shown for a range of masses at solar composition ($Z_\odot = 0.0246$).

(Garcia et al. 2014)

# Facilities to follow up benchmark stars

- Photometry from the ground (e.g., APTs, ZTF, LCOGT in the optical passband) => activity and rotation from photospheric features;

- Spectroscopy (e.g., STELLA, Weber et al. 2012, SPIE 8451; WHT/WEAVE - large-FoV multi-object; CFHT/Spirou - spectropolarimetry) => activity and rotation from chromospheric line emissions, photospheric magnetic fields;

- High-precision space-borne photometry for asteroseismology and activity studies (CoRoT, Kepler/K2, TESS);

- The next future: GAIA to improve the measurements of stellar fundamental parameters; LSST (from mid 2022) to study flares in K-M dwarfs and find rare kinds of variable stars.

# Conclusions

- Selection criteria for benchmark stars are to be defined according to:
  a) the scientific purposes they should serve;
  b) the datasets already in hand or that can be acquired;

- The optimal number of benchmarks and their magnitude limit are to be determined;

- Coordination with the other WPs is mandatory to optimize the effort and converge on a common list of benchmarks, whenever possible.