Asteroseismology of bright Red Giants

KASC Working Group 8: K2 field 1 Target Proposal

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Abstract

We propose to observe a small number of bright nearby red giant stars taken from the Hipparcos catalogue, for which we can obtain additional ground-based interferometric observations (using the PAVO and VEGA beam combiners at the CHARA array), and high-resolution spectra (using e.g. the HERMES spectrograph at the Mercator telescope) to determine precise values of the angular diameter θ, $T_{\rm eff}$, $\log(g)$, and surface composition. These additional constraints, coupled with the oscillation spectrum derived from K2 observations and the available parallax information, will provide more stringent tests than currently available of the asteroseismic techniques used to determine masses, radii and ages of stars, as well as the physical processes governing the evolution of red giants and the Galaxy.

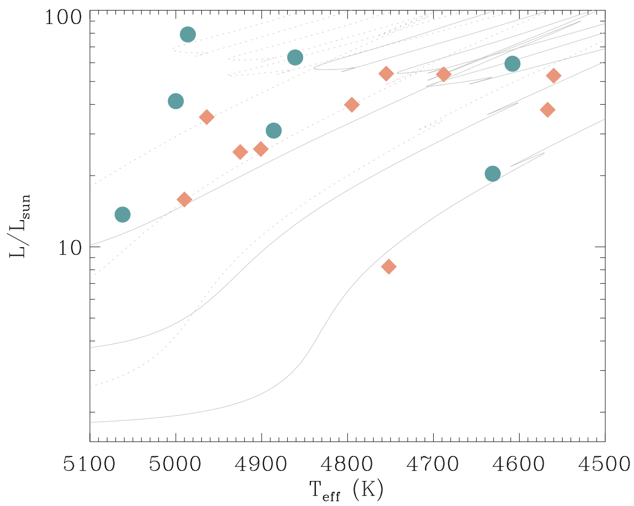
Science Case: This document proposes the observation of bright red giants stars in long cadence mode in the K2 field 1, where several exciting science applications are within reach. The first and most straightforward one is to scrutinize and test the asteroseismic scaling relations used to determine stellar parameters such as masses, radii, and ages. Widely used in red giants asteroseismology, these scaling relations connect the global properties of stars to easy-to-derive seismic parameters, such as the frequency of maximum power $\nu_{\rm max}$ and the large separation $\Delta\nu$. Although they do have some theoretical justification, the scaling relations are still mostly empirical and based on the only star whose parameters we truly know: the Sun. Thoroughly testing and calibrating them in other evolutionary stages requires red giant targets for which both excellent seismic and interferometric/spectroscopic data are available. The precise seismic K2 observations and high-quality ground-based data of bright nearby giants will allow us to subject the scaling relations to the most demanding tests.

The second application is to constrain the poorly understood mixing processes working inside red giants, such as thermohaline mixing, rotation, and deep circulation. These processes are predicted to have different impact at different stages of red giant evolution, and to leave imprints in the surface chemical composition of these stars. Precise seismic $\log(g)$ from K2 time series, coupled to high-S/N ground-based spectra, allow for a detailed abundance determination of a large number of chemical species (e.g. Li, C, N, O, Mg, Al, Si, Ca, Sc, Ti, Cr, Co, Ni, and Ba). The correlations between these elements (e.g. [C/Fe] vs [N/Fe]) and departure from their theoretically predicted values (as in the case of Li or ^{12}C/^{13}C) are tracers of internal mixing processes, and will be studied as function of the seismically determined mass.

The third application relates to one of the biggest uncertainties in current stellar astrophysics: the abundance of helium in stars. Evolutionary calculations of red giants commonly assume a mass fraction of helium as predicted by laws of galactic chemical evolution; these are based on observations of the Sun or extragalactic sources and extrapolation to other compositions. The helium second ionization zone in stars produces an abrupt change in the local sound speed, which is detectable in the Fourier spectrum of time series as a periodic variation with frequency of $\Delta\nu$ (see Miglio et al. 2010, A&A, 520, L6). The period of this signal reveals the position of the ionization zone, while its amplitude critically depends on the abundance of helium. The characterization of the signature only requires $\ell = 0$ and/or $\ell = 1$ frequencies which are within reach of K2 time series spanning ~75 days. Detailed models of red giants where this variation is detected, coupled to independent constraints on angular diameter and detailed surface composition, can put stringent constraints on the helium abundance of red giants and test our assumptions on enrichment laws of the Galaxy.

Target Selection: Our sample contains 17 giants in the K2 field 1 falling on or near silicon (see Figure). As we are interested in precise linear radii, we constrain our sample to only contain stars in the Hipparcos catalog with a relative uncertainty on the parallax below 10%. We also require that the frequency resolution of the K2 run (0.144 μHz for a length of 80 days) is sufficient to sample one order in the Fourier spectrum with at least 10 points, meaning $\Delta\nu > 1.44\,\mu$Hz. Given the strict relation between $\Delta\nu$ and $\nu_{\rm max}$, this implies $\nu_{\rm max} > 10\,\mu$Hz. As the actual length of the run is slightly shorter, and because our current estimates of $\nu_{\rm max}$ are rather crude, we impose a safety margin and require that $\nu_{\rm max} > 25\,\mu$Hz for all our targets.

Measuring angular diameters at the CHARA array requires stars brighter than V=8.5 at a declination $\delta > -10°$. We derived an estimate of θ from B-V colors using the calibration of Kervella et al. (2004, A&A, 426, 297). From this formulation, we selected giants with angular diameters that can be resolved with the CHARA array. Most of our targets have $0.3 < \theta < 1.2$ mas, and will be resolved at visible wavelengths. We include one larger target (HIP 56647) due to its accurate parallax (1.2% level); it can be easily resolved in the infrared.



HRD diagram showing the position of our targets falling on (green circles) and near (red diamonds) silicon, together with isochrones of 2, 5, and 15 Gyr. at solar (solid lines) and subsolar (dotted lines) metallicites.

We have limited our sample to stars fainter than V=4, as brighter targets would be too expensive in number of pixels. Our list is arranged according to parallax accuracy for cohorts of stars falling on or near silicon. If including the brightest stars in the Field 1 list is problematic we recommend taking the fainter ones instead. Naturally, observing the targets with the most accurate parallaxes will provide the best set of independent constraints to fully unleash the power of asteroseismology.