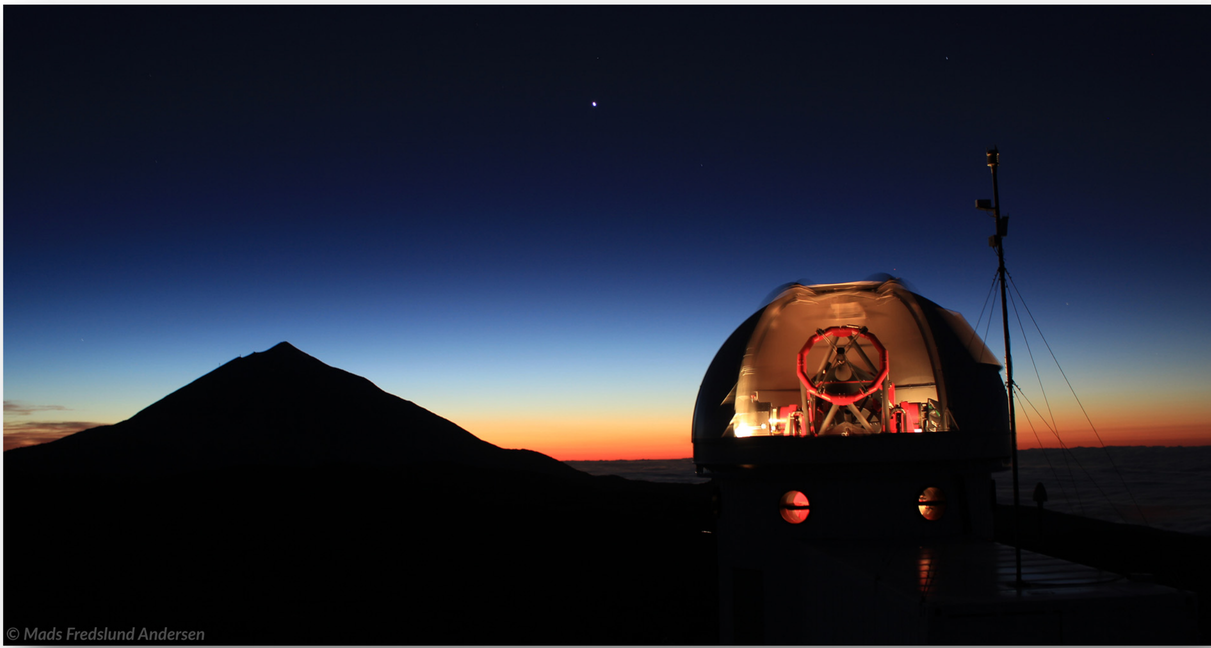
Stellar Astrophysics Centre 2016



Scientific highlights of the year

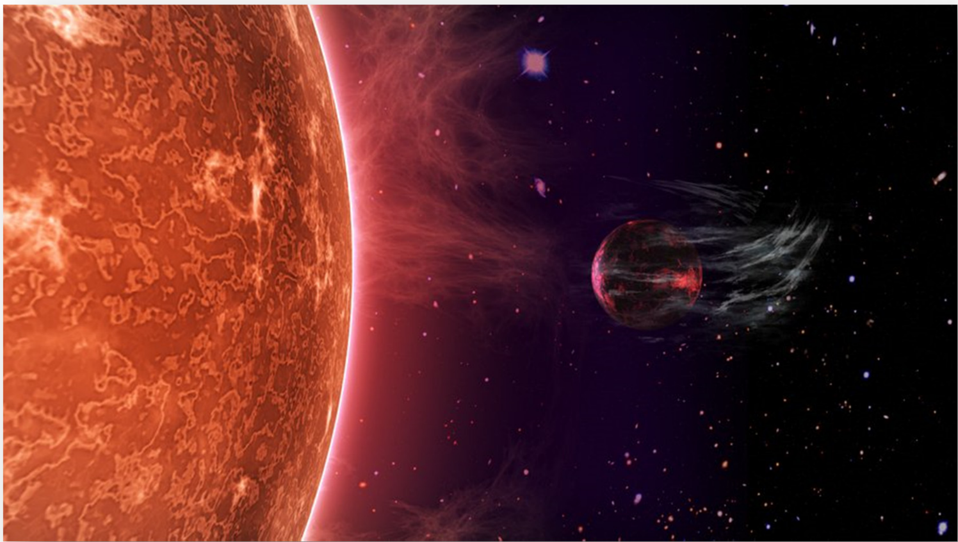
The Stellar Astrophysics Centre (SAC) has now existed for almost five years. The research of the SAC covers a broad range of topics, basically within stellar astrophysics. This includes observational and theoretical studies of stellar structure and evolution, to a large extent based on asteroseismic analysis of stellar oscillations, studies of extrasolar planets, and astrobiology with the goal to search for life outside the Earth. Based on the research we have done since 2012, we have found that these different areas provide much mutual inspiration for the research, and together they have created a highly dynamic and fruitful scientific environment at the centre.

SAC continues to run the SONG telescope on Tenerife, and we are also organizing the international use of *Kepler* and TESS data via our research structures KASC/KASOC and TASC/TASOC. The first paper from the SONG project has now been published. The solar-type star μ Herculis has been observed for 215 nights, a new world record for ground-based asteroseismic observations, resulting in vastly improved parameters. The new results will lead to a revision of standard stellar models.

The photometric observations from the NASA *Kepler* space mission have revealed a broad range of stellar variability. A very interesting phenomenon is stellar superflares, sudden brief brightenings, which have been associated with the flares seen, typically of much smaller magnitude, as explosions in solar magnetically active regions. On the other hand, indirect evidence of much stronger solar flares has been found, and if such a flare were to occur today, it could have catastrophic consequences for our technical infrastructure in space and on the ground. Thus, it is of great interest better to understand the flares observed by *Kepler*. Researchers at SAC carried out a major spectroscopic survey of stars observed by *Kepler*, including those that had showed superflares, to study other characteristics of their magnetic activity. They found that although most of the superflare stars were more active than the Sun, some showed an activity level comparable with the Sun.

As a result of the asteroseismic data analysis in SAC, it is clear that the data, in particular on red giants, offer the possibility of characterizing very large ensembles of stars, extending to large distances, in terms of their distance, mass and age. Such samples of well-characterized stars provide a unique possibility for studying the structure and history of the Milky Way Galaxy and in this way learn about the general evolution of galaxies. Since the stars and their distribution represent relics from the past history of the Galaxy, this field has become known as 'Galactic archaeology'. It involves comparing detailed models of Galactic evolution with observed properties of the stars that it contains. To realize the full potential of Galactic archaeology, additional information about the stars, particularly their surface composition, is required. Consequently, SAC has initiated a major observational effort on spectroscopy using the Isaac Newton Telescope on La Palma, in the SAGA (Strömgren survey for Asteroseismology and Galactic Archaeology) project. First results from this project found a clear gradient of increasing stellar age with increasing height over the Galactic plane and a mostly quiescent evolution of the Galaxy over the past 10 billion years.

Recently researchers at SAC carefully analysed asteroseismic data from a large number of *Kepler* systems to precisely and homogeneously determine exoplanet parameters relevant to the impact of stellar radiation on the evolution of exoplanet atmospheres. In this way, they were able to confirm theoretical predictions convincingly. Planets orbiting so close to their stars that they receive more than 650 times the flux Earth receives and having diameters between 2.2 and 3.8 times the size of the Earth do not exist. This is despite the fact that smaller and larger planets at these orbital distances have been observed. This result can be understood in the following way. Purely rocky planets do not grow larger than approximately twice the radius of Earth. Larger planets need to have a significant envelope of volatiles (i.e. an atmosphere) which accounts for the rest of their volume. For very close-in planets these atmospheres are then lost to space due to the intense, high energetic radiation from the star. The atmospheres which originally surrounded the rocky cores of such planets literally boil away and disappear into space, leaving the 'naked' planetary cores. Planets larger than 4 times the radius of the Earth (gas giants) are not as susceptible as their surface gravity is large enough to hold on to volatiles even in an extreme radiation field and smaller planets at this radiation levels are purely rocky. This work was made possible by combining analysis of exoplanet light curves from *Kepler* with asteroseismology, a unique core competence present at SAC.



Artist's impression of a hot super-Earth being stripped of its atmosphere due to its proximity to the mother planet. (image credit: Peter Devine)

Efforts to launch a CubeSat Earth-orbiting satellite as a collaboration between SAC, the Aarhus University Department of Engineering and the external industry partner GomSpace, have now reached a step where planning and construction are financially secured, and an agreement for the launch has been reached with the European Space Agency.

A large number of other activities took place at SAC in 2016 incl. outreach, teaching, workshops, access to new challenging data, international conferences and exchange of staff between the SAC nodes.