NASA'S KEPLER MISSION TAKES PULSE OF DISTANT STARS:

Extended Version

New research deepens dramatically our knowledge of the life cycle of the stars in our universe. Enabled by the Kepler spacecraft, scientists are examining the most accurate measurements of stars ever made.

Exploring distant stars has taken on a new life thanks to a wealth of data from NASA's Kepler spacecraft. In results to be published this month, scientists have characterized hundreds of stars targeted by Kepler, using the natural pulse of their light waves to provide amazing new insights into the structure and evolution of stars.

These variations in brightness can be interpreted as vibrations, or oscillations within the stars, using a technique called asteroseismology. The oscillations reveal information about the internal structure of the stars, in much the same way that seismologists use earthquakes to probe the Earth's interior.

NASA's Kepler spacecraft, launched in March 2009, is designed to discover Earth-like planets orbiting other stars. In the process it is capturing large quantities of data on the target stars. which is used not only to search for planets but also to study stars in general. The results from NASA's Kepler spacecraft provide us with new information on a number of specific phenomena related to our fundamental knowledge of stars, their internal properties and evolution in time.

"We're essentially taking the vital signs of these stars, measuring their size, structure, and age, using methods that will also be useful for planet-hosting stars," says Danish astronomer Jørgen Christensen-Dalsgaard, Aarhus University, who leads the seismology team.

Based on detailed measurements of light variations in one of the stars observed by Kepler it is shown that asteroseismology is indeed working. "We have shown that Kepler can make precise measurements of the radius and age for individual stars," said one of the lead authors Travis Metcalfe from the National Center for Atmospheric Research.

The Kepler data has been used to investigate the details of stellar evolution for a bright star in the Kepler field of view (KIC 11026764) and more than thousand so-called red giant stars.

KIC 11026764 - one of the most accurately characterized stars in the Universe!

Using asteroseismology the scientists have determined very accurate values for the radius and age of a star (KIC 11026764) which is more evolved than our

Sun. This measurement represents the most accurate determinations of basic stellar properties made for any star in the Kepler field of view, and properties of only a few other stars in the whole Universe are known to similar accuracy. The specific periods for the oscillations detected in KIC 11026764 show that the star shines from hydrogen fusion in a region around a helium-rich core.

The measurement of KIC 11026764 is of crucial importance for Kepler's capability to characterize the planets in orbit around stars other than our Sun. We can only determine accurate characteristics for planets if we can determine accurate properties of their host stars, such as is demonstrated for KIC 11026764. Asteroseismology is the only way to determine such accurate stellar ages and properties in general. KIC 11026764 represents a beautiful example of a star which in its evolution is between the Sun and the red giant stars also observed by Kepler.

Red giant stars – the distant future of our Sun

Using the Kepler telescope we have detected oscillations in more than 1000 giant stars at a precision never obtained before for such a large set of data. The periods of those oscillations are used to study the interiors of these giant stars, which represent the future life of our Sun, and allow us to clearly detect the signature of stellar evolution in a wider range of stars than ever before.

“Kepler data allow us to study in unprecedented detail how these stars work, and provide a better understanding of the future of our Sun and the evolution of our Galaxy as a whole” says Daniel Huber, lead author on one of the studies of red-giant stars who is originally from the University of Vienna and now PhD-student at the University of Sydney. "Kepler provides us with data of such good quality that they will change our view of how stars work in detail” says Thomas Kallinger, lead author on another study of those fascinating stars and postdoctoral fellow at the Universities of British Columbia and Vienna.

Kepler provide a breakthrough in our understanding of the RR Lyrae stars

Kepler is also used to study even more exotic stars and phenomena. One of the types of stars studied are the so-called RR Lyrae stars which are pulsating stars where the brightness over a few hours may fluctuate by a factor of two.

The Kepler observations of the pulsation behavior of the prototypical star RR Lyrae and over 40 of its class members represent the most extensive and accurate set of measurements of those stars ever made. Many of these stars, including the prototype RR Lyrae, show a mysterious long-term modulation detected in RR Lyrae stars more than hundred years ago, which still defies our theoretical understanding. A major breakthrough came with the detection of period doubling, a variation in the pulsation with twice the actual period, in RR Lyrae. This is the first measurement of a new pulsation feature that brings clues for understanding the long-term modulation.

The observations of RR Lyrae's and its class members' detailed light curve will impact our understanding of pulsating stars in general since we now witness how large amplitude stellar pulsations act in detail. In a much broader context this discovery is important for our understanding of cosmic distances and the large scale structure of the Universe since the pulsations of this type of stars

are one of the fundamental tools used to determine distances in the Universe. RR Lyrae stars are used as cosmic lighthouses.

"It is striking that only a few months of uninterrupted Kepler data of the star RR Lyrae uncover phenomena that were never detected before, not even with a century of high-quality ground-based data meticulously investigated by numerous astronomers. These findings have caused a dramatic overhaul in our understanding of these cosmic light houses." says Katrien Kolenberg, lead author of one of the papers and postdoctoral fellow at the Institute of Astronomy in Vienna.

Kepler will continue observing hundreds of stars in the coming years and asteroseismology is expected to fundamentally change the level at which we understand stars and their evolution.

“The published results show how the Kepler spacecraft is in the process of revolutionizing our understanding of stars, their evolution and specific properties. We are thrilled by the steady stream of amazing high-quality data from this spacecraft” says Hans Kjeldsen from Aarhus University in Denmark who is responsible for running the seismology science centre connected to Kepler.

Additional information on the Kepler measurement on KIC 11026764: Based on the detection of 29 different oscillations and measurement of their periods we have determined accurate properties of one star (KIC 11026764) in the Kepler field of view. The oscillation periods are used for a seismic determination of the stellar interior of KIC 11026764, and based on this we measure the age to be 5.94 billion years (more than one billion years older than our own Sun) and the radius to be 2.05 times that of our Sun. The periods of the oscillations also clearly show that this star is not any longer producing energy in the core by hydrogen fusion: the core - which is almost pure helium - is slowly contracting while the star is in a phase of evolution which over several hundred million years will transform it to a giant star. Energy is produced in a thin region surrounding the helium core. The data provide detailed information about the internal structure of the star in this crucial phase of evolution and hence will greatly help our understanding of stellar evolution.

Additional information on the Red giant stars observed by Kepler: We observe stars in very different evolutionary stages: from the end of core hydrogen fusion until the stars are in the stable helium core fusion stage. This is crucially important for our understanding of stellar evolution and therefore also for our understanding of the long term evolution of the Sun. The new data from Kepler are by far the best way to verify and test theoretical models of stellar and solar evolution. Based on the new measurements we now know that our general understanding of the solar future is correct, showing that in 6 billion years the Sun will swell to become a giant star a thousand times more luminous than at present. Furthermore, the unprecedented quality and diversity of the Kepler data offer the possibility to study entire stellar populations in our galaxy, providing a

unique opportunity to verify and improve models of how stars were formed in the Milky Way.

Additional information on RR Lyrae stars observed by Kepler: The Kepler telescope has detected the large-amplitude pulsation behavior of one of the brightest stars in the Kepler field-of-view. The period of the main pulsation of RR Lyrae is 13 hours and 36 minutes. The newly detected, previously unknown, pulsation feature is connected to changes over a timescale of twice that period - the so-called period doubling. Moreover, over a period of 39 days the amplitude and duration of the main pulsation is modulated by another pulsation phenomenon - the so-called Blazhko effect, that has been known and has defied a physical explanation for over a century now. Thereby it is one of the most stubborn mysteries of modern stellar astrophysics. With the discovery of period doubling we have important clues for finally solving the Blazhko riddle since Kepler shows us that the period doubling is closely linked to the Blazhko effect. Never before we have observed the pulsations and the modulation periods so clearly and in such detail. We have now successfully modelled the newly observed variations. The improved understanding of RR Lyrae will lead to a much improved modeling of the pulsations which is crucial for understanding the global properties of this type of stars and their use as cosmological distance indicators.

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Live webcast of the press conference: http://www.au.dk/presse/nasa

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For more information about the findings by the KASC scientists, visit:
http://astro.phys.au.dk/KASC/

For more information about the Kepler mission, visit:
http://www.nasa.gov/kepler