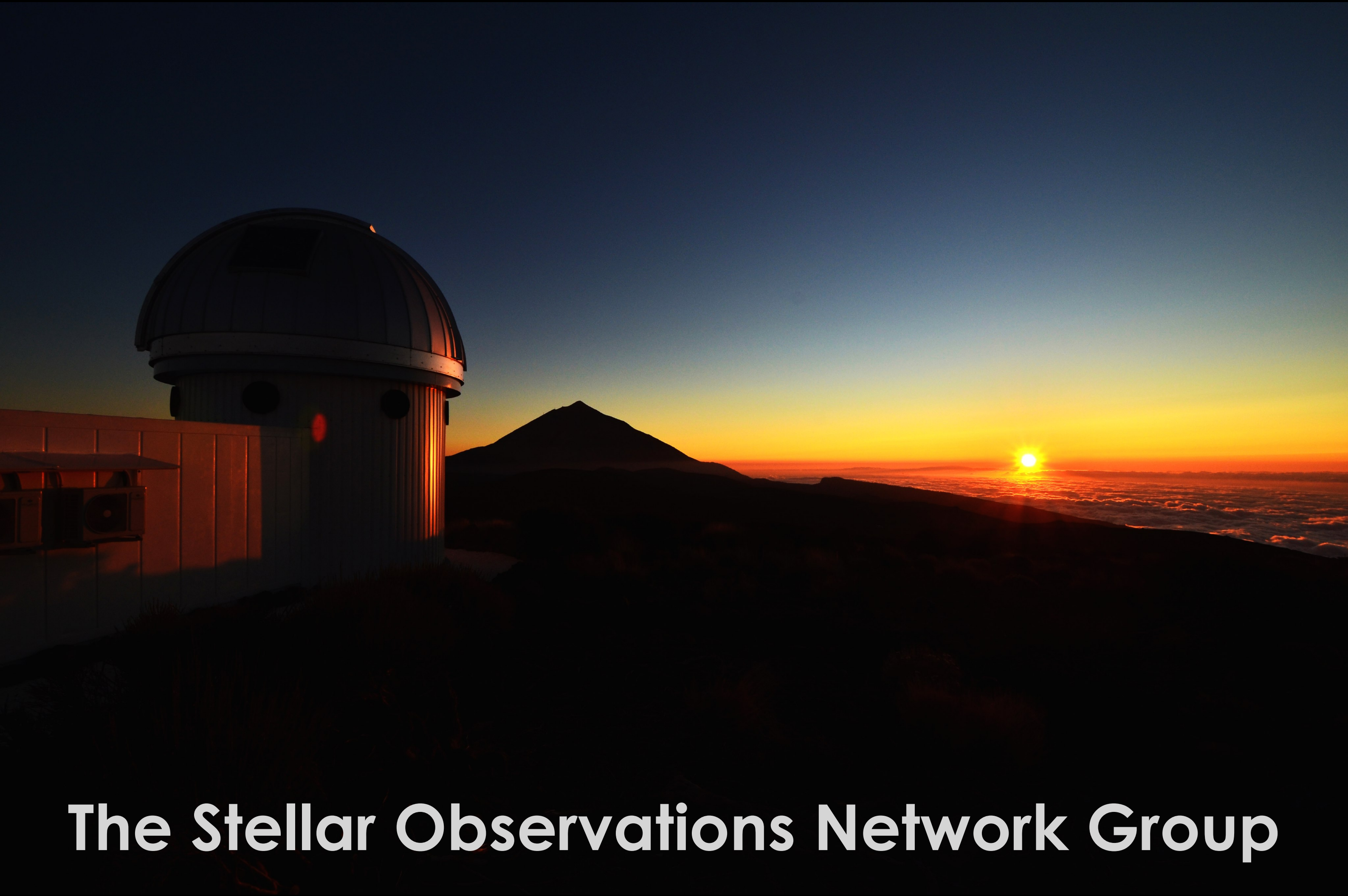


The Stellar Observations Network Group

Current SONG nodes

The SONG of Stars and Planets

SONG is a Danish-led project set to design and build a global network of small telescopes that will specifically target the study of stars and planetary systems around stars. The idea is to develop a prototype of a new ultra-modern robotic telescope that is inexpensive and efficient to run. **SONG** stands for **S**tellar **O**bservations **N**etwork **G**roup and was launched in 2006 by astronomers at Aarhus University and the University of Copenhagen.

The Hertzsprung SONG Telescope is the prototype of the SONG network and is financed by the VILLUM FONDEN, Carlsberg Foundation, Danish Council for Independent Research, European Research Council, Danish National Research Foundation, Aarhus University, University of Copenhagen and Instituto de Astrofísica de Canarias.

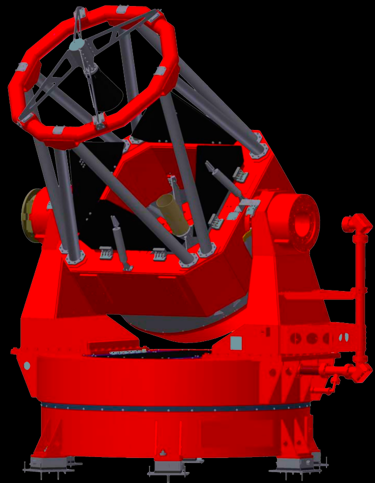

Credit: Frank Grundahl, Stellar Astrophysics Centre


Credit: Frank Grundahl, Stellar Astrophysics Centre


Credit: Frank Grundahl, Stellar Astrophysics Centre

The Hertzsprung SONG Telescope

ASTELCO systems was contracted to build the telescope and the Instituto de Astrofísica de Canarias constructed the foundation and managed the infrastructure. In Denmark the main task was to assemble the spectrograph, the camera and other smaller components and last but not least to develop the customised software controlling all units and to design the sophisticated network.



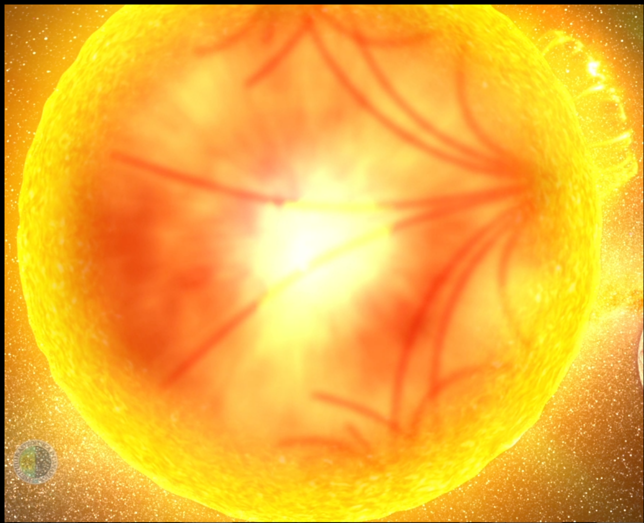
Installation of the Hertzsprung SONG Telescope at Observatorio del Teide.

Credit: Daniel López, Instituto de Astrofísica de Canarias

Credit: Jens Jessen-Hansen, Stellar Astrophysics Centre

Milky Way over the Canary Islands.

“At first sight it would seem that the deep interior of the sun and stars is less accessible to scientific investigation than any other region of the universe. Our telescopes may probe farther and farther into the depths of space; but how can we ever obtain certain knowledge of that which is hidden behind substantial barriers? What appliance can pierce through the outer layers of a star and test the conditions within?” Sir Arthur Eddington, The internal Constitution of Stars (1926)



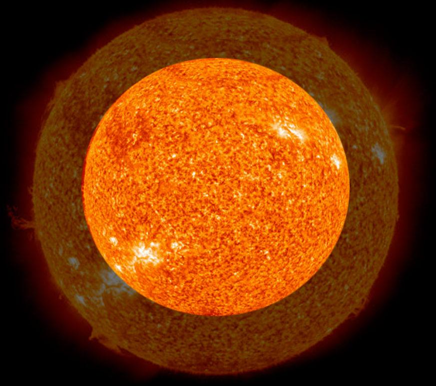
Credit: Gabriel Perez Diaz, Instituto de Astrofísica de Canarias

The answer to Sir Arthur Eddington’s question has now been established: it is asteroseismology, the study of 'star quakes', observed as oscillations on the stellar surface.

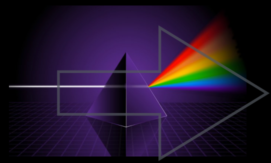
Stars have an inner structure which differs with mass, temperature and energy output and changes with evolution.

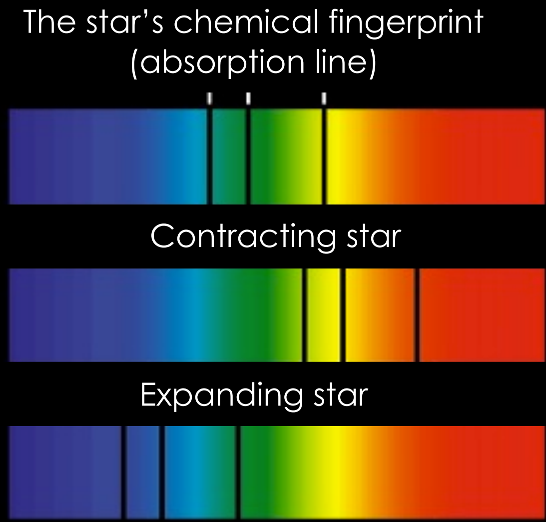
Some stars, like our Sun, oscillate in their natural frequencies determined by their interior. Measuring these periodic changes allows to determine the stars’ inner structure.

How Can We Study Stars using Spectroscopy?



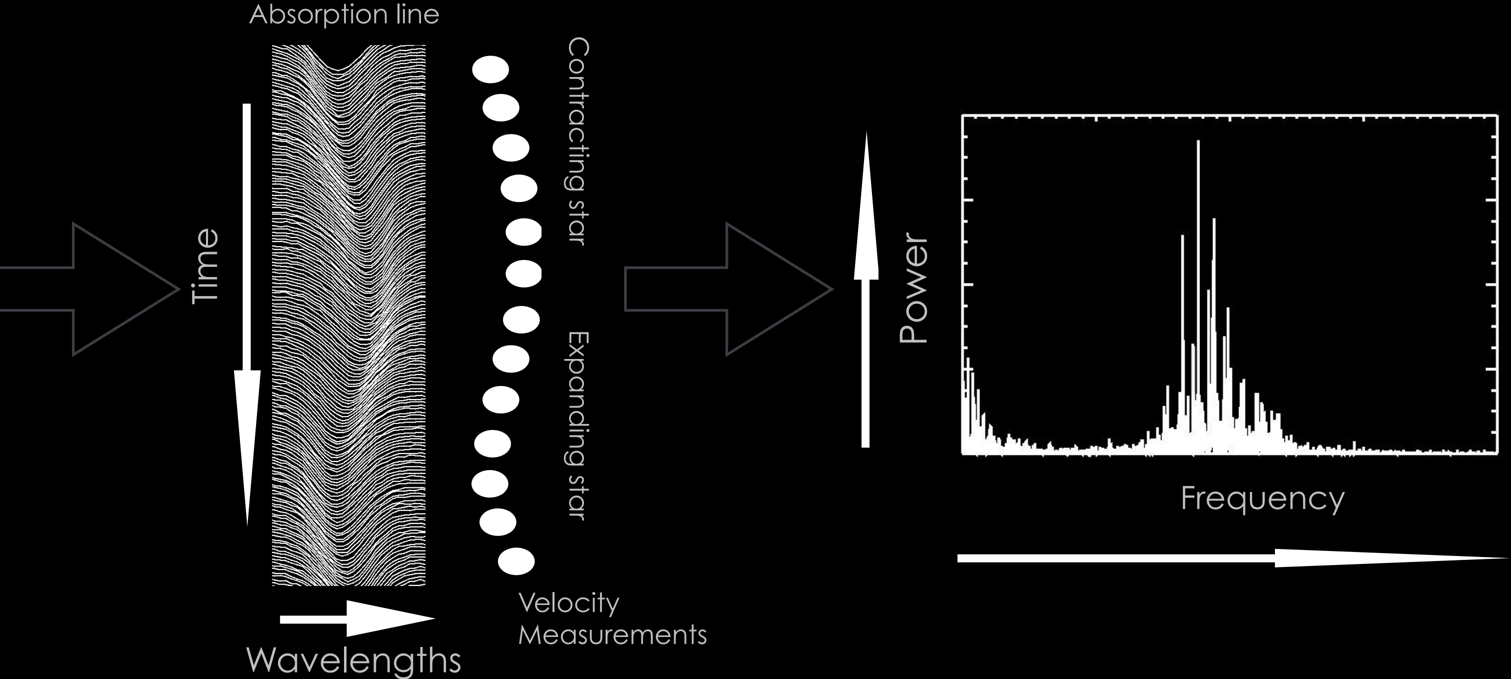
Credit: NASA



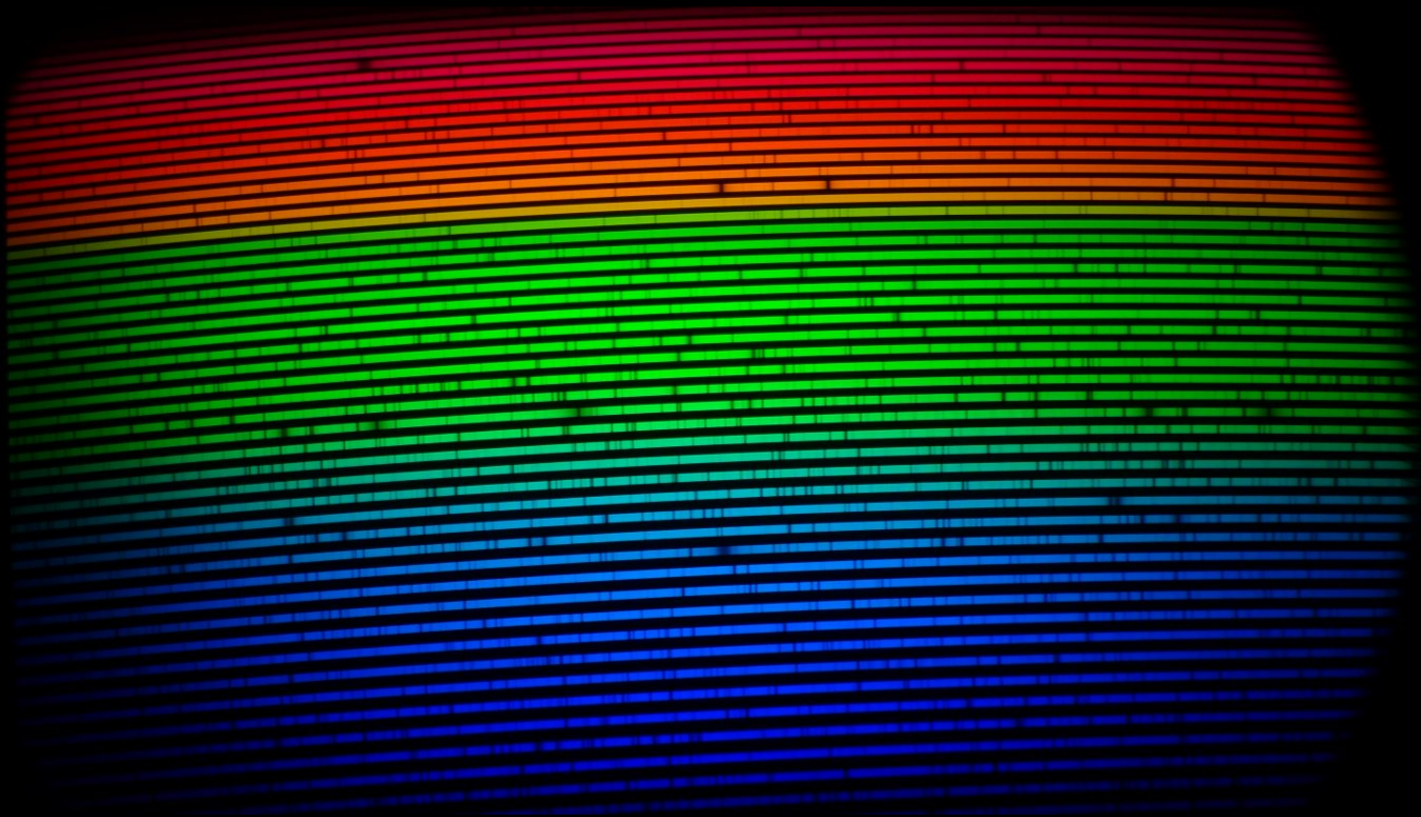


As the star pulsates the radius changes.

Absorption lines in the stellar atmosphere get red- and blueshifted, depending on whether the star is moving away, or towards us (Doppler effect).

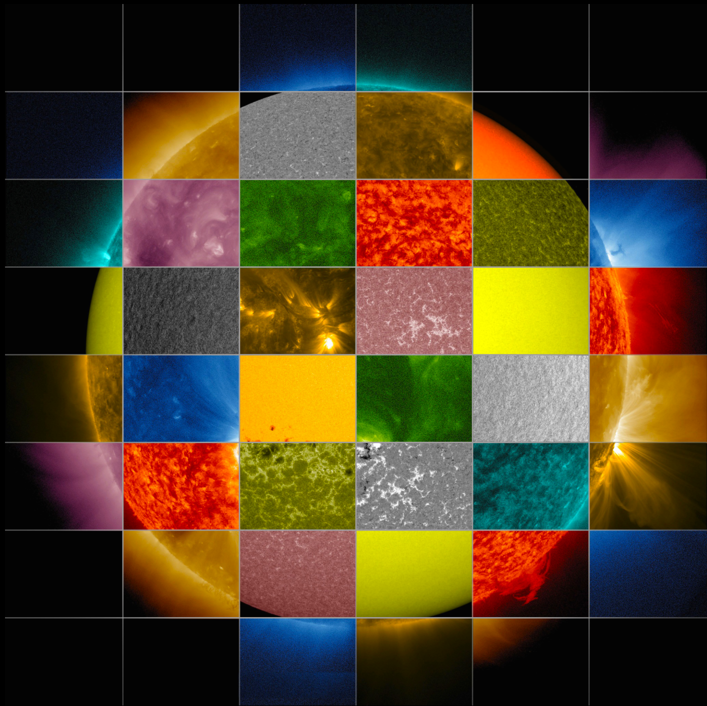


ASTEROSEISMOLOGY: When a star pulsates it contracts and expands periodically causing variations in radius and temperature. The velocity fields produced during contraction and expansion can be measured spectroscopically thanks to the Doppler effect, whereas the periodic temperature and radius fluctuations give rise to brightness changes.

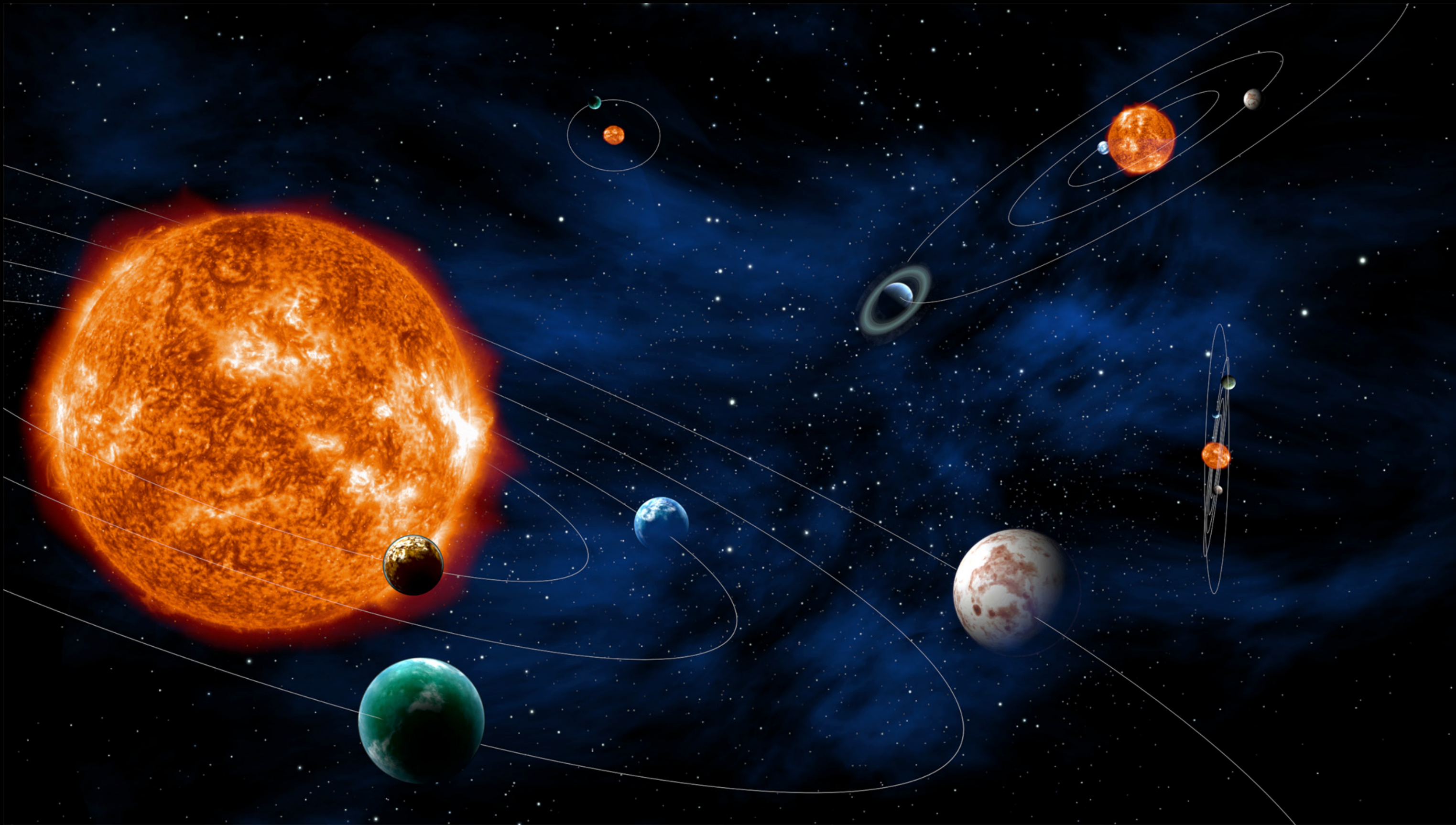


High-resolution solar spectrum observed with the spectrograph at the Hertzsprung SONG Telescope.

The Sun Seen in Different Wavelengths of the Electromagnetic Spectrum



A collage of solar images from NASA's Solar Dynamics Observatory (SDO) showing observations of the Sun in different wavelengths.



Worlds far far away, an artistic impression.

Faraway Worlds

"There are then innumerable suns, and an infinite number of earths revolve around those suns, just as the seven we can observe revolve around the sun which is close to us."

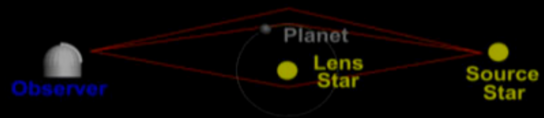
Giordano Bruno (1548-1600)

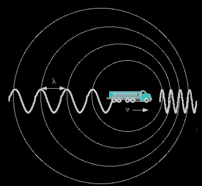
Recent observations are showing a bewildering variety of planetary systems, the properties and evolution of which are far from understood. With the first detections of truly Earth-mass and Earth-size planets, attention will turn to the question of habitability, in terms of stellar environment and atmospheric properties. Not only do the atmospheric properties have a significant impact on the habitability of the planetary body, but organisms inhabiting a planet may shape the composition of the atmosphere and leave the fingerprint of persisting life forms.

Credit: NASA

Techniques to Study and Characterize Exoplanets with SONG

Gravitational Microlensing

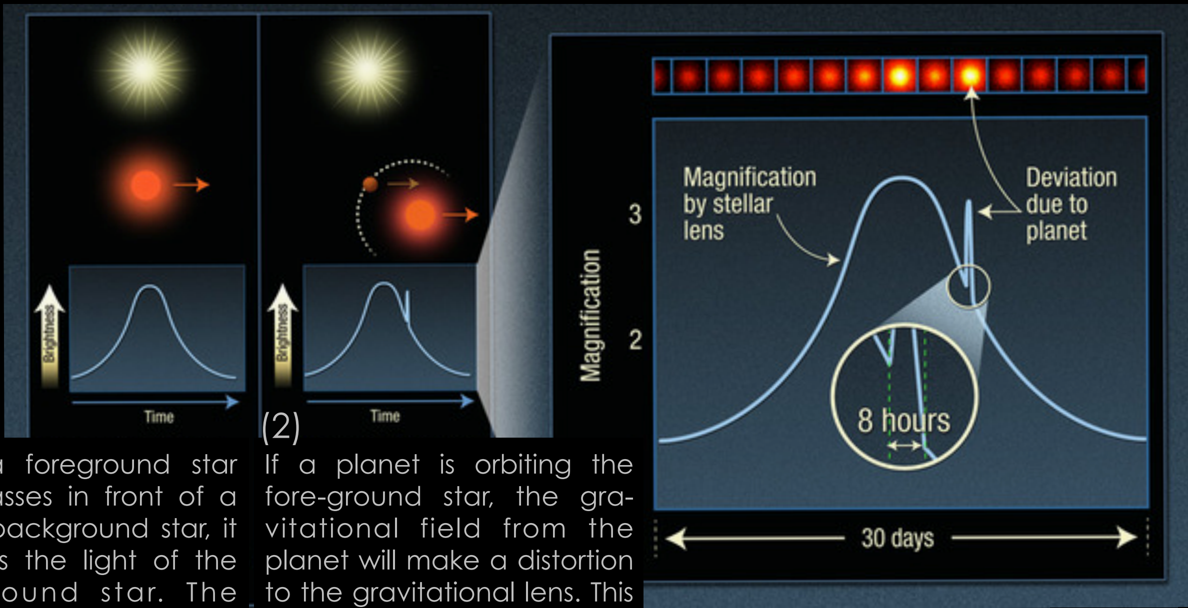




Radial Velocity Method (Doppler Effect)

Transit Method

Gravitational Microlensing



(1)

When a foreground star (red) passes in front of a distant background star, it brightens the light of the background star. The gravitational field of the foreground star warps space to create a gravitational lens that magnifies light.

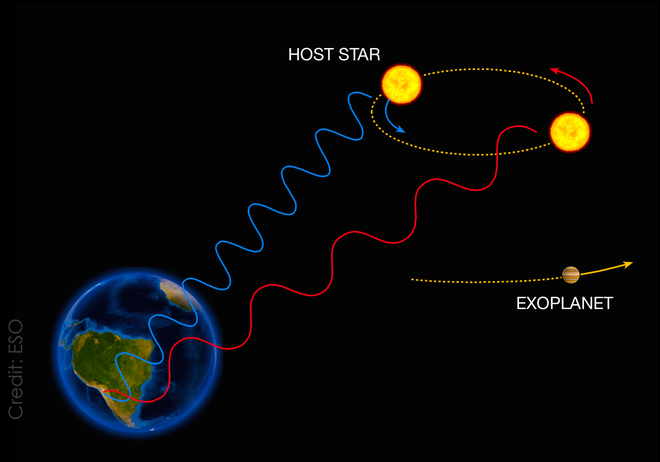
(2)

If a planet is orbiting the fore-ground star, the gravitational field from the planet will make a distortion to the gravitational lens. This may create additional magnifications which may be observed as additional shorter brightenings, indicating the existence of the planet.

Credit: NASA, ESA, K. Sahu STSc

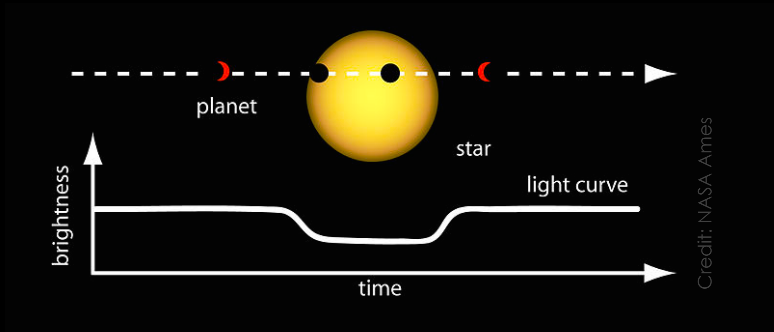
Gravitational microlensing involving a planet in the lens system.

Radial Velocity Method

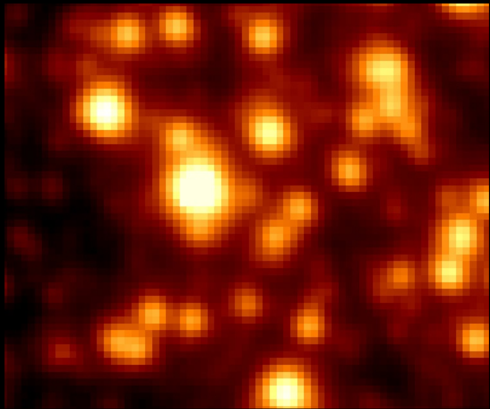


It is possible to detect an exoplanet based on the variations in velocity performed by the central star, due to the changing direction of the gravitational pull from an (unseen) exoplanet as it orbits the host star. When the star moves towards the observer, its spectrum is blueshifted, while it is redshifted when it moves away.

Transit Method

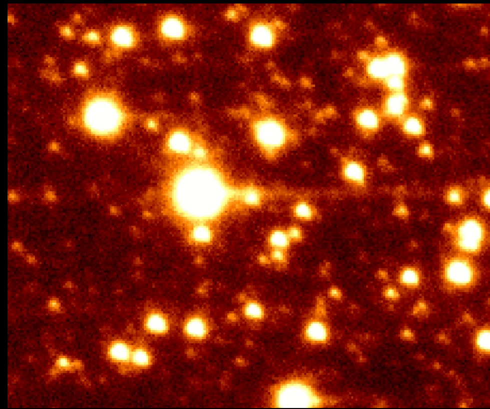


Planet transiting its host-star. By measuring the depth of the dip in brightness and knowing the size of the star, scientists can determine the size or radius of the planet. Once the orbital period (time between two transits) is known, the average distance of the planet from its star can be determined.



Credit: D.Bramich

Image of a dense field of stars, observed with a conventional camera (left) and with the lucky imaging camera used at SONG (right).



Credit: J.Skottfelt

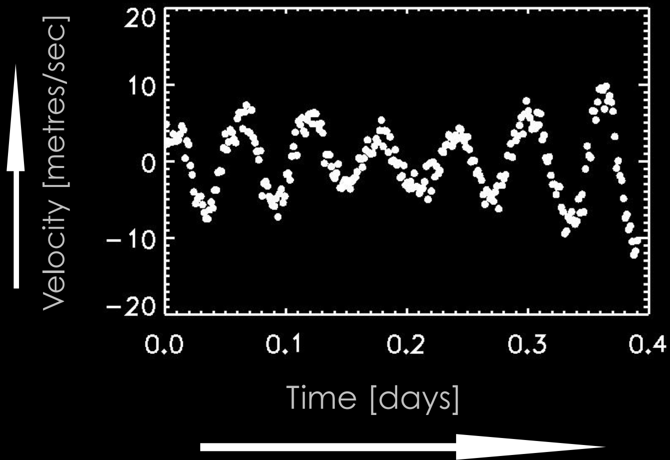
Imaging with SONG

Searching for exoplanets with the microlensing technique requires SONG to measure the brightness of stars in areas of the sky which are crowded with many stars. This is a challenge for precise measurements because stars are being blurred by the atmosphere of the Earth (left image). SONG uses a so-called Lucky Imager, which is able to correct for the blurring of the atmosphere, in order to obtain images almost as sharp as if they were taken from space (right image).

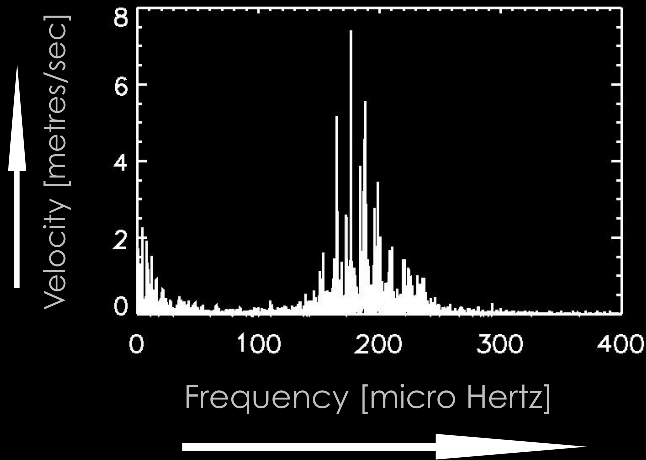
Spectroscopy with SONG

Gamma Cephei is a planet-hosting binary system with an oscillating primary component, 1.4x as massive as the Sun, with a radius 4.8x the solar radius. The planet is about twice the mass of Jupiter.

Velocity changes of the stellar surface with time ➪ stellar oscillations (precision 1.3 metre/second per point).



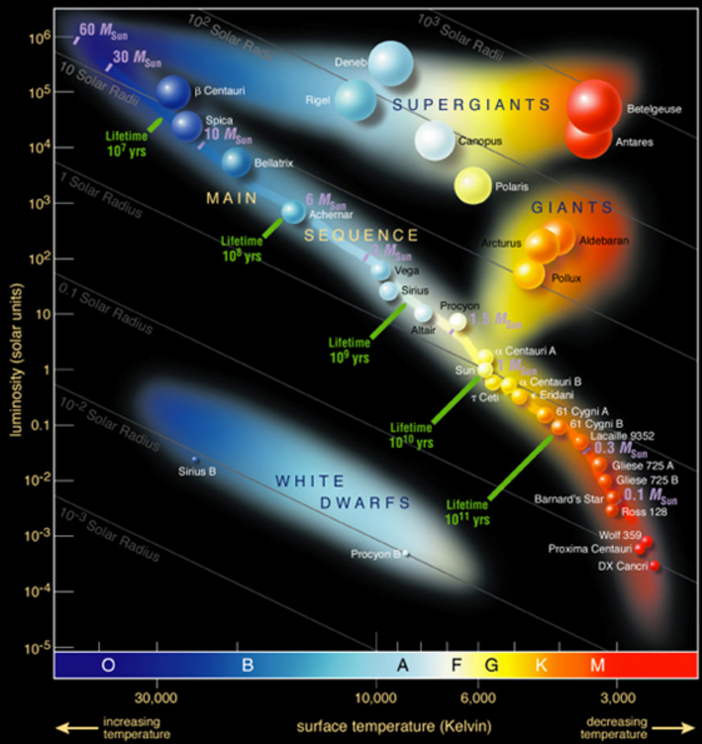
Frequencies of oscillations ➪ rate at which the surface of the star changes periodically.



Ejnar Hertzsprung

The Hertzsprung SONG Telescope is named after the Danish Astronomer Ejnar Hertzsprung (1873-1967) who graduated in 1893 as a chemical engineer from Copenhagen’s Polytechnic College. His interest in photochemistry turned him toward astronomy, resulting in two papers on stellar radiation published 1905-07. This was the origin of what came to be known as the Hertzsprung-Russel Diagram. In 1909 Karl Schwarzschild brought him to Göttingen and subsequently to Potsdam near Berlin. In 1919 he moved to Leiden, where he in 1935 succeeded as professor of astronomy and director of the Leiden Observatory. Hertzsprung only returned to Denmark after World War II. He received many honorary doctorates and awards for his important work in astronomy, among them the Ole Rømer Medal and the Gold Medal from the Royal Astronomical Society.

The Hertzsprung-Russel Diagram



Credit: ESO

The Hertzsprung-Russel Diagram is one of the most important diagrams in stellar astrophysics and was independently developed by Ejnar Hertzsprung and Henry Norris Russel in the early 1900s. It shows that the relationship between temperature and luminosity of a star is not random but instead falls into distinct groups:

1. Main Sequence: Stars (including the Sun) burning hydrogen into helium in their cores.
2. Giants and Supergiants: Evolved stars which have exhausted the hydrogen reservoir in their cores.
3. White Dwarfs: final evolutionary stage of low to intermediate mass stars.

SONG in the Future

One of the main ideas behind SONG is to dedicate telescopes to observe single targets for a very long period of time. With a complete network it will be possible to follow single targets 24 hours a day for weeks or even months. In practice this means that one telescope takes over when the Sun rises in one place and has set in the other. To do this from Earth a minimum of 3-4 telescope on each hemisphere is needed to cover the entire sky.

The Next SONG Node

The second SONG node is located at the Delingha Observatory in the Chinese Xinghai province and has an excellent infrastructure. The building, telescope and spectrograph are completed and currently being commissioned.

Credit: Jens Jessen-Hansen, Stellar Astrophysics Centre

Credit: Daniel López, Instituto de Astrofísica de Canarias

Credit: Frank Grundahl, Stellar Astrophysics Centre

Credit: Victoria Antoci, Stellar Astrophysics Centre

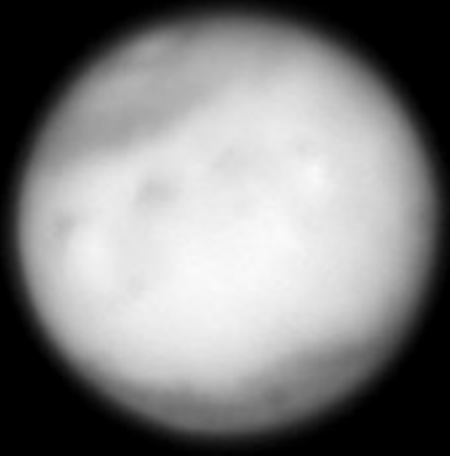
Credit: Frank Grundahl, Stellar Astrophysics Centre

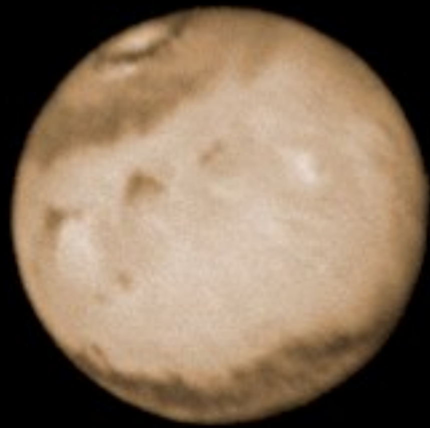
Credit: Frank Grundahl, Stellar Astrophysics Centre

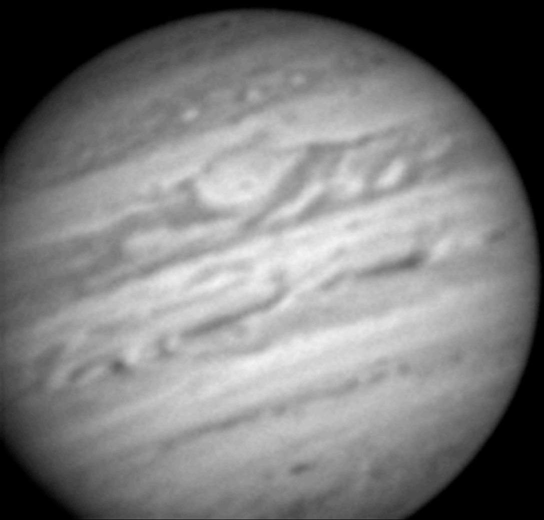
Credit: Daniel López, Instituto de Astrofísica de Canarias

Conventional image

Lucky Imaging + false colours





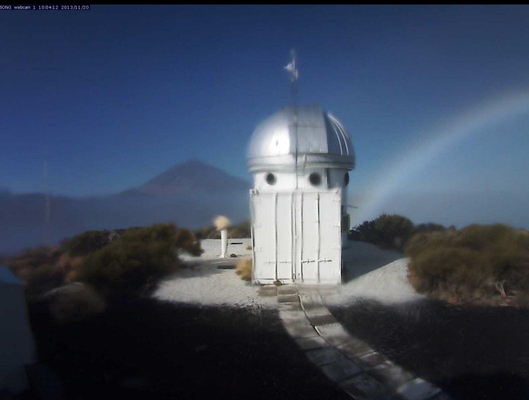


Mars and Jupiter observed with the Hertzsprung SONG Telescope.

Credit: Daniel López, Instituto de Astrofísica de Canarias


SONG webcam 1 07:44:28 2013/10/31

SONG webcam 1 06:54:33 2013/11/04

SONG webcam 1 09:14:51 2013/03/05

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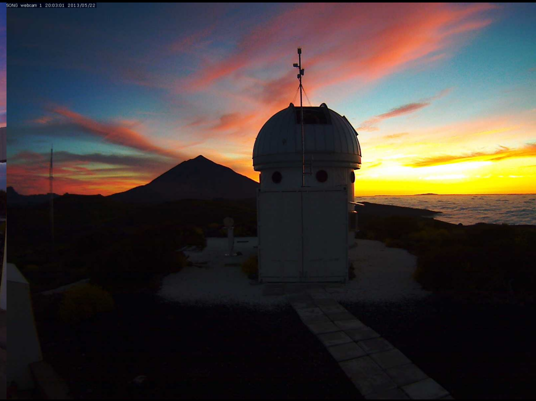
SONG webcam 2 19:47:16 2013/05/07

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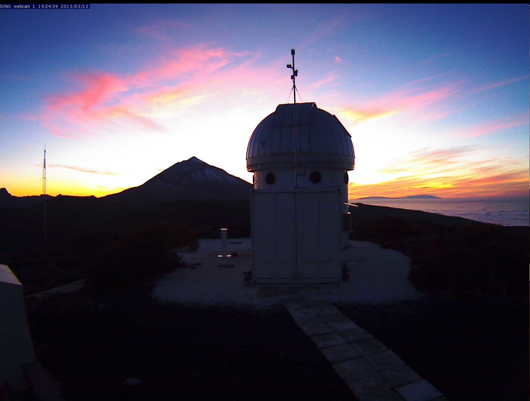
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SONG webcam 1 18:59:00 2013/04/07

SONG webcam 1 19:27:36 2013/04/07

Credit: Mads Fredslund Andersen, Stellar Astrophysics Centre

SONG

Stellar Observations Network Group

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