MAX PLANCK INSTITUTE
OF QUANTUM OPTICS

MPQ

Garching, 05.09.2008

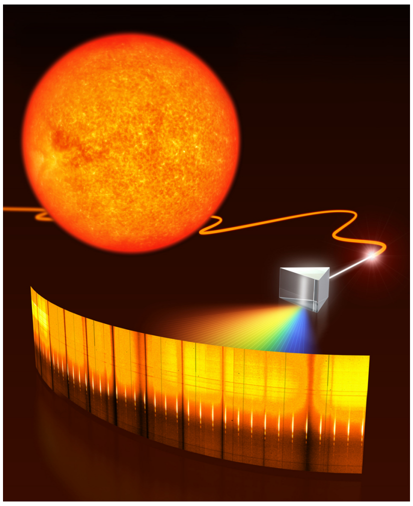
Press Release

Press & Public Relations,
Dr. Olivia Meyer-Streng

Phone:
+49(0)8932 905-213
E-mail: olivia.meyer-streng@mpq.mpg.de

# A precise astronomical speedometer

## Quantum optical methods make it possible to detect extraterrestrial planets and predict the future of the universe.



**The fate of the universe is – quite literally – written in the stars. It is the light of distant stars and galaxies which makes astronomers and cosmologists believe that the universe is not static but instead expanding continuously. New results even suggest that this expansion is accelerating over time. These conclusions are, however, based on theoretical assumptions that still await experimental proof. Model-independent analysis requires the direct measurement of changes in drift velocity with a precision that the spectrographs of present telescopes cannot deliver. Now an international team of astronomers (European Southern Observatory Garching, Germany; Centre for Astrophysics and Supercomputing of Swinburne University, Melbourne, Australia; Kiepenheuer-Institut für Sonnenphysik Freiburg, Germany) and quantum physicists (Max Planck Institute of Quantum Optics, Garching, Menlo Systems GmbH Martinsried, both Germany) has demonstrated at the Vacuum Tower Telescope (VTT) in Tenerife for the first time that the use of a frequency comb – a technique developed by Professor Theodor W. Hänsch for which he was awarded the Nobel Prize in 2005 – can greatly improve the calibration of spectrographs. With a prototype in use the scientists achieved an accuracy of nine metres per second. Further improvements to the set-up will bring the desired precision of a few centimetres within reach. This will provide the opportunity to not only answer cosmological questions but also to observe Earth-like planets in extra-solar systems.**

In the 1920s the American astronomer Edwin Hubble discovered that the spectral lines in the light of distant stars and galaxies are shifted towards longer wavelengths. This 'red-shift' is the result of the so-called Doppler effect which arises because the stellar objects are moving away from the observer. From this observation Hubble concluded that the universe is expanding continuously. Going back in time the universe was created in a 'Big Bang' about fifteen billion years ago.

New measurements of the microwave background radiation by the Wilkinson Microwave Anisotropy Probe (WMAP) suggest – within the framework of Albert Einstein´s General Theory of Relativity – that this expansion is accelerating over time. In fact a mysterious 'dark energy' would, in contrast to all other forms of energy, act against the gravitational pull of matter and drive the universe apart. The only way to decide on the validity of this concept is to measure the change of the expansion velocity directly. For this it is necessary to determine the velocity of distant stars and galaxies over a period of about two decades with a precision of a few centimetres per second, far beyond what is state-of-the-art right

Hans-Kopfermann-Str. 1
D-85748 Garching

Phone:+49(0)8932 905-0
Fax:+49(0)8932 905-200

now. (With the techniques available at present one would have to observe the objects for about 10,000 years.)

Such precision is to be delivered by the future European Extremely Large Telescope (E-ELT) which is being designed by ESO, the European Southern Observatory. For this purpose its new spectrograph 'CODEX' will have to be calibrated with a precision of one part per 300 billion – a feat equivalent to measuring the circumference of the Earth to half a millimetre.

“This is where the frequency comb technique comes in,” Dr Udem, leader of the project at the Max Planck Institute of Quantum Optics, explains. “The physical parameter which can be determined with the highest precision of all is *time*. Atomic caesium clocks, for example, will deviate by a second only after a million years.” The frequency comb transfers this precision to frequency measurements. It changes laser light into a rainbow containing about a million spectral lines. These are separated by constant intervals and directly stabilized by atomic clocks. Thus frequencies of stellar light are determined with highest accuracy by comparing the spectral lines to this 'ruler'.

Spectrographs calibrated in this way will reach the precision required to answer questions concerning the future of the universe. They will also enable astronomers to detect extra-solar planets. These reveal their identity only indirectly. While travelling around their central star they push and pull it a little bit – in the order of a few centimetres – such that it moves either towards the Earth or away from it, depending on the position of the planet. “We hope to be able to measure these very small displacements,” says Dr Udem. “While the sun orbits the galactic centre with a speed of 220 kilometres per second, the recoil on the sun caused by the Earth amounts to 10 centimetres per second."

The prototype used at VTT reaches a precision of 9 metres per second, which is already better than state-of-the-art. “VTT is a solar telescope with high systematic errors, because it is not designed for this purpose,” Udem says. “We are very optimistic that by using an optimal set-up – a stable telescope and an improved frequency comb – we will be able to detect velocity variations of a few centimetres per second.”

For more information: http://www.mpq.mpg.de/~haensch/comb/Astrocomb/

**Original publication:**
Tilo Steinmetz et al.
*Laser Frequency Combs for Astronomical Observations*
Science, 321, 1331 (2008).

**Contact:**

**Dr. Thomas Udem**
Max Planck Institute of Quantum Optics
Hans-Kopfermann-Straße 1
85748 Garching
Phone: +49 - 89 / 32905 - 282
Fax: +49 - 89 / 32905 - 311
E-mail: thomas.udem@mpq.mpg.de

**Dr. Olivia Meyer-Streng**
Press & Public Relations
Max Planck Institute of Quantum Optics
Phone: +49 - 89 / 32905 - 213
Fax: +49 - 89 / 32905 - 200
E-mail:
olivia.meyer-streng@mpq.mpg.de