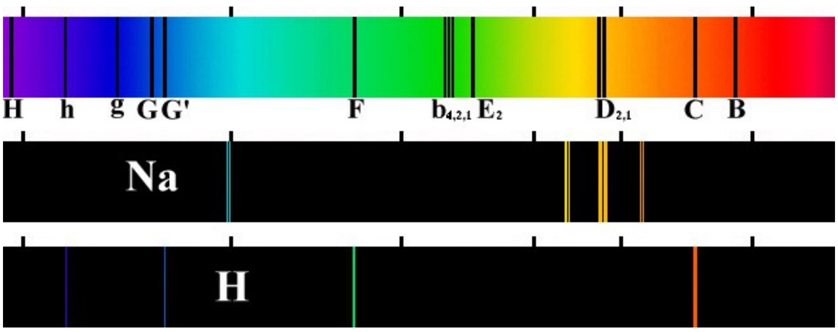
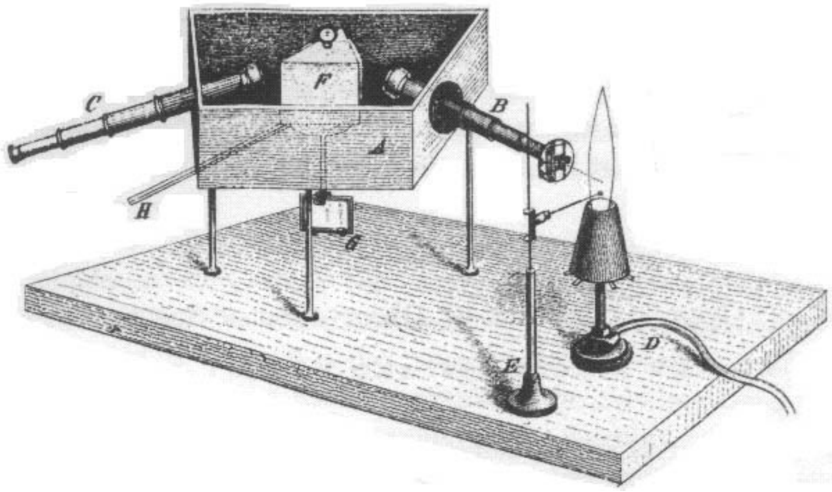
Big telescopes for small waves

English summary of the inaugural lecture of dr. Floris van der Tak, on the occasion of his appointment as professor of submillimeter astronomy at the University of Groningen, February 11, 2014.

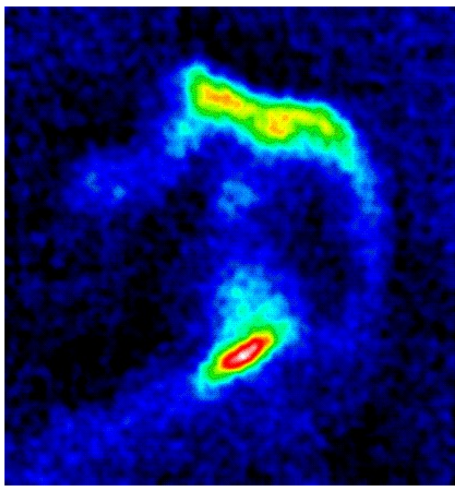
The spiral galaxy M33 is an ordinary galaxy like our Milky Way. In this image, yellow are ordinary stars like the Sun, blue are stars which are 10-100 times more massive than the Sun, red are interstellar gas clouds, and black are dust clouds which obscure the lights of stars behind them. But how do we know all this?



Light consists of waves of different lengths: red light of longer waves than blue light. Astronomers call the distribution of light signals over wavelength a spectrum. Exactly 200 years ago, Fraunhofer discovered that the spectrum of the Sun contains dark lines. Some of these lines had the same wavelength as the bright lines in the spectra of a candle flame. Fraunhofer concluded that the Sun contains the same gases as a candle flame.

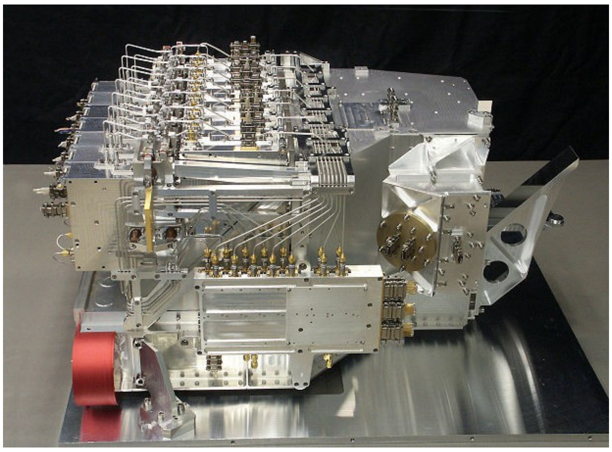


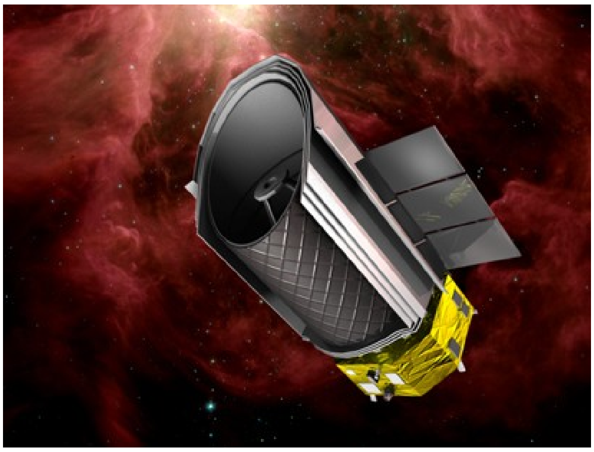
Which gases those are was discovered by Kirchhoff & Bunsen in Heidelberg in 1859. They observed the light of a flame with hot gas and measured the wavelengths of the spectral lines of different elements. In the process, they discovered 2 new elements: cesium and rubidium, but there were a few of Fraunhofer's dark lines that they could not identify. They proposed that these are from an element that exists on the Sun but not on Earth, which they called Helium, after the Greek word for Sun. Later, helium was also found on Earth, where it is used for example to inflate balloons.



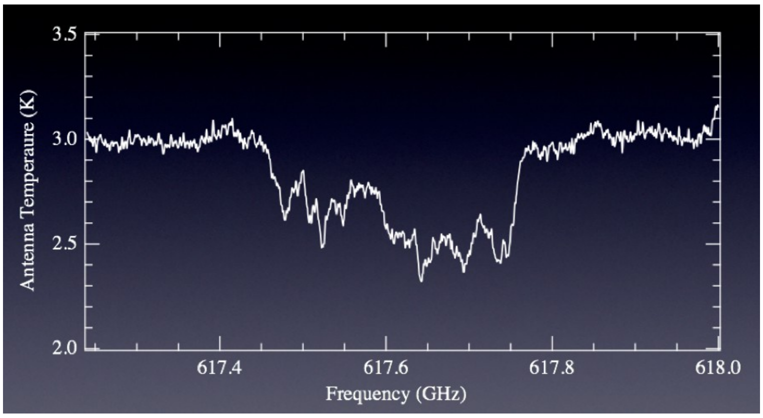
Submillimeter radiation is light with a wavelength of about 1 mm, i.e., 1000 times longer than visible light. Such radiation is useful to study the formation of stars in dense, dark clouds, such as the Horsehead Nebula in Orion. The region of star formation seen near the horse's throat in the submillimeter image (right) is completely obscured in the optical image (left). This technique is somewhat similar to ultrasounds which nurses use to see if babies in their mothers' wombs are healthy.

Submillimeter radiation is also useful to determine the temperatures of interstellar clouds, as in this image of the Rosette nebula taken with the Herschel Space Observatory. The color scale indicates temperature: blue is warm dust, and red is cold dust.

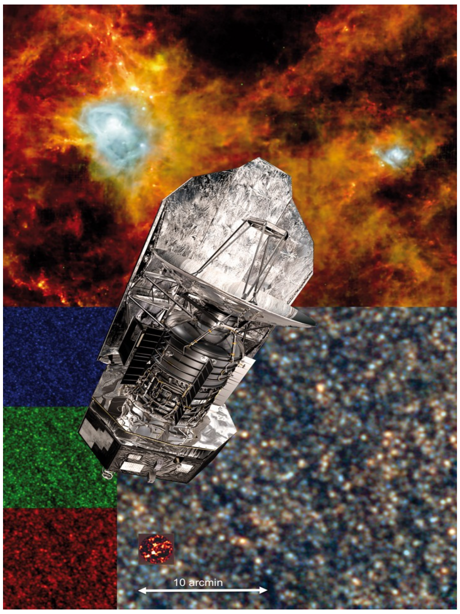




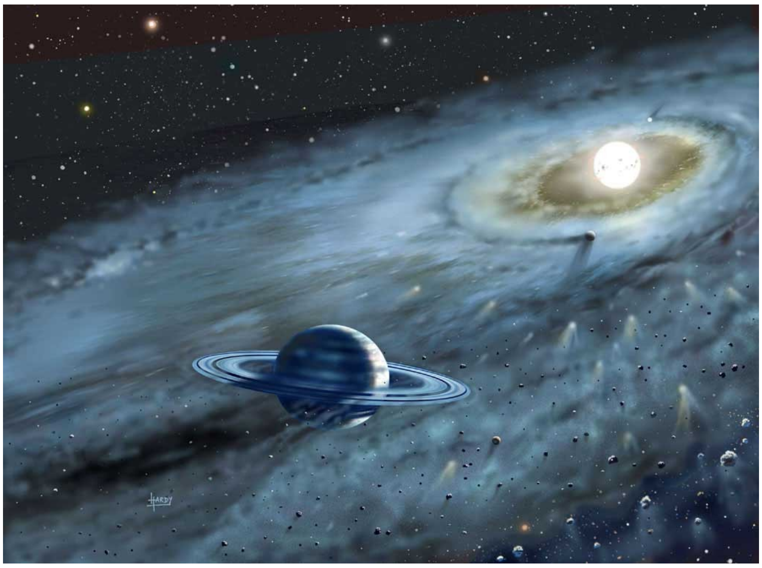
The submillimeter range also has spectral lines, but not from atoms, but from molecules like water and carbon monoxide. To observe such lines, my colleagues at SRON have designed and built the HIFI instrument (left) for the *Herschel* Space Observatory. The next big project for SRON is an instrument for the Japanese-European space telescope *Spica*, which in ~10 years will perform sensitive measurements in the mid- and far-infrared. The co-existence of science (Kapteyn Institute) and technology (SRON) gives Groningen its world-leading position in this field.



My research group uses spectral lines in the submillimeter range to determine the density and chemical composition of interstellar gas clouds. Furthermore, we use the directions and velocities of motions inside those clouds to understand how new stars are formed. Doing so requires knowing which molecule produces which line, and for this identification we collaborate with laboratories and theoretical chemists. For example, many spectra from HIFI show this mysterious spectral feature near 0.5 mm wavelength. Only in October 2013, the feature was identified as ArH^+, which is the first interstellar molecule containing a noble gas.



The year 2010 was a turning point for submillimeter astronomy, where the field changed its working style from small groups to large consortia, as in the special issue of *Astronomy & Astrophysics* with the first Herschel results (left). The advantage of this development is that many stars and clouds are studied using the same data, which facilitates their comparison. The disadvantage is that the contributions of individuals to the results are hard to identify. Just try to find me in the group picture on the right!



The formation of planetary systems around new stars and the development of life on those planets are research goals for the future. The chances of success are good, as the following rough estimate shows. The Milky Way has about 100 billion stars, and about the same number of planets. The development of life requires liquid water, and to have that, the planet must have the right distance from its star (for the temperature) and about the size of the Earth (for the surface pressure). This is the case for about 1% of planets, or about 1 billion planets in the Milky Way. The development of intelligent life is then a matter of time: on Earth, Homo sapiens has been around for 100,000 years, which is 1/45,000 of the Earth's lifetime. This suggests that life is probably present on about 22,000 planets in our Galaxy. The challenge is now to find it!