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The new Chirp Transform Spectrometer on SOFIA

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Abstract

We achieved high spectral resolution and dynamic range with our new type of CTS (Chirp Transform Spectrometer). The new spectrometer is part of the airborne observatory, SOFIA (Stratospheric Observatory For Infrared Astronomy), that will provide coherent detection up to 4.8 THz (63 µm) with GREAT (German REceiver for Astronomy at Terahertz frequencies), representing an spectral resolving power of $\lambda/\Delta\lambda = 10^8$. The capability to fly at an altitude of 15 km represents higher sensitivity as we are able to avoid the influence of 85% of the terrestrial atmosphere and 99% of the water vapor. The high sensitivity provided by SOFIA and the spectral resolution obtained with the CTS combine in a unique tool in order to address a wide range of topics of modern astrophysics, from questions about comets, planetary atmospheres and the interstellar medium in the galaxy to investigations related to the early Universe.

The analog Fourier transformation performed by the CTS spectrometer is based on the velocity dispersion of sonic surface waves, which is controlled by micro-structures on the surface of defined crystals. The dispersive elements, SAW "Surface Acoustic Wave" filters, are organized in a proper expander-compressor scheme. Micro-deformations in the SAW devices derive to deviations from the ideal quadratic phase response, leading to a reduction in the spectral resolution; while the expander's insertion loss constrains the overall dynamic range of the scheme. For that, we have studied and developed a new idea called "Adaptive Digital Chirp Processor (ADCP)". The principle behind the ADCP is to incorporate the dispersive properties of the compressor SAW device into a digital system that produces the perfect matching expander waveform, achieving higher spectral resolution and higher dynamic range. This can be achieved with a rational and optimum combination of different technologies, such as quadrature-modulation, high performance spectral filtering, ultra-stable frequency sources and a deep study of the problem through numerical simulations with an ad hoc model.

A running prototype has been used to obtain a 7-point atmospheric map of Mars through ground-based observations at SMT (Submillimeter Telescope) in Arizona, USA. We present results from these observations, such as temperature and wind profiles for different Martian regions.