The EChO science case

The discovery of almost two thousand exoplanets has revealed an unexpectedly diverse planet population. We see gas giants in few-day orbits, whole multi-planet systems within the orbit of Mercury, and new populations of planets with masses between that of the Earth and planet Neptune—all unknown in the Solar System. Observations to date have shown that our Solar System is certainly not representative of the general population of planets in our Milky Way. The key science questions that urgently need addressing are therefore: What are exoplanets made of? Why are planets as they are? How do planetary systems work and what causes the exceptional diversity observed as compared to the Solar System? The EChO (Exoplanet Characterisation Observatory) space mission was conceived to take up the challenge to explain this diversity in terms of formation, evolution, internal structure and planet and atmospheric composition. This requires in-depth spectroscopic knowledge of the atmospheres of a large and well-defined planet sample for which precise physical, chemical and dynamical information can be obtained. In order to fulfil this ambitious scientific program, EChO was designed as a dedicated survey mission for transit and eclipse spectroscopy capable of observing a large, diverse and well-defined planet sample within its 4-year mission lifetime. The transit and eclipse spectroscopy method, whereby the signal from the star and planet are differentiated using knowledge of the planetary ephemerides, allows us to measure atmospheric signals from the planet at levels of at least 10−4 relative to the star. This can only be achieved in conjunction with a carefully designed stable payload and satellite platform. It is also necessary to provide broad instantaneous wavelength coverage to detect as many molecular species as possible, to probe the thermal structure of the planetary atmospheres and to correct for the contaminating effects of the stellar photosphere. This requires wavelength coverage of at least 0.55 to 11 μm with a goal of covering from 0.4 to 16 μm. Only modest spectral resolving power is needed, with R~300 for wavelengths less than 5 μm and R~30 for wavelengths greater than this. The transit spectroscopy technique means that no spatial resolution is required. A telescope collecting area of about 1 m2 is sufficiently large to achieve the necessary spectro-photometric precision: for the Phase A study a 1.13 m2 telescope, diffraction limited at 3 μm has been adopted. Placing the satellite at L2 provides a cold and stable thermal environment as well as a large field of regard to allow efficient time-critical observation of targets randomly distributed over the sky. EChO has been conceived to achieve a single goal: exoplanet spectroscopy. The spectral coverage and signal-to-noise to be achieved by EChO, thanks to its high stability and dedicated design, would be a game changer by allowing atmospheric composition to be measured with unparalleled exactness: at least a factor 10 more precise and a factor 10 to 1000 more accurate than current observations. This would enable the detection of molecular abundances three orders of magnitude lower than currently possible and a fourfold increase from the handful of molecules detected to date. Combining these data with estimates of planetary bulk compositions from accurate measurements of their radii and masses would allow degeneracies associated with planetary interior modelling to be broken, giving unique insight into the interior structure and elemental abundances of these alien worlds. EChO would allow scientists to study exoplanets both as a population and as individuals. The mission can target super-Earths, Neptune-like, and Jupiter-like planets, in the very hot to temperate zones (planet temperatures of 300–3000 K) of F to M-type host stars. The EChO core science would be delivered by a three-tier survey. The EChO Chemical Census: This is a broad survey of a few-hundred exoplanets, which allows us to explore the spectroscopic and chemical diversity of the exoplanet population as a whole. The ECHO Origin: This is a deep survey of a subsample of tens of exoplanets for which significantly higher signal to noise and spectral resolution spectra can be obtained to explain the origin of the exoplanet diversity (such as formation mechanisms, chemical processes, atmospheric escape). The EChO Rosetta Stones: This is an ultra-high accuracy survey targeting a subsample of select exoplanets. These will be the bright “benchmark” cases for which a large number of measurements would be taken to explore temporal variations, and to obtain two and three dimensional spatial information on the atmospheric conditions through eclipse-mapping techniques. If ECHO were launched today, the exoplanets currently observed are sufficient to provide a large and diverse sample. The Chemical Census survey would consist of>160 exoplanets with a range of planetary sizes, temperatures, orbital parameters and stellar host properties. Additionally, over the next 10 years, several new ground- and space-based transit photometric surveys and missions will come on-line (e.g. NGTS, CHEOPS, TESS, PLATO), which will specifically focus on finding bright, nearby systems. The current rapid rate of discovery would allow the target list to be further optimised in the years prior to ECHO’s launch and enable the atmospheric characterisation of hundreds of planets.

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