A Space Mission to Probe the Trail of Water

Paul Goldsmith[1], Youngmin Seo[1], Jon Kawamura[1], Jose Siles[1], William Langer[1], Dariusz Lis[2]

We present a concept for a submillimeter spectroscopic mission to probe the trail of water from the interstellar medium to habitable planets. Beyond its obvious biogenic importance, water is of great interest in many astronomical environments. It is an important coolant of warm interstellar clouds and is a significant reservoir of oxygen in the interstellar medium. It is a valuable tracer of the dynamics of interstellar clouds associated with star formation, including infall, outflows, and shocks. It is also a tracer of the thermo-chemical history of cloud material via the H2O ortho-para ratio. Finally, the question whether the Earth's water came from icy objects in the early history of the solar system is key for understanding planetary habitability. Observing gas-phase water in the local universe requires high spectral resolution because line widths may be less than 1 km/s in comets and dense cloud cores and a resolution of 0.1 km/s is compulsory. Thus, to study the water trail we need a heterodyne system, which is cryogenically cooled to minimize noise, but unlike the case for broadband photometry and low-resolution spectroscopy, the temperature of the telescope and associated optics is not critical. Thus, to follow the water trail, we can consider a relatively large, ambient temperature telescope to maximize sensitivity and angular resolution, coupled to a multiband receiver covering key spectral lines of water isotopologues. Large surveys of the submillimeter transitions of water vapor in conjunction with studies of water ice using JWST will revolutionize our understanding of the role of water, its distribution, and key ISM processes. The required submm observations will not be possible with either SPICA or OST as currently proposed. Two attributes for the receiver are: (1) to observe multiple bands simultaneously, and (2) to have modest-sized arrays in each band to increase the speed of imaging extended sources. Together these attributes dramatically increase the ability to determine conditions in sources, since multiple transitions are required to determine excitation conditions and sources are extended. The optical system first separates two linear polarizations, then separates the bands with frequency selective surfaces, and finally images beams coupling to the individual array feedhorns. We report on studies of a number of designs for a telescope of diameter between 2m and 7m. To observe lines between 500 GHz and 1200 GHz requires a surface accuracy of 13 microns rms or better. The thermal environment is a prime driver of telescope design and cost and many tradeoffs are possible. Other recent advances have improved the possibilities of observing water since Herschel, including: 1) SIS receiver performance and design have improved significantly relative to those used in HIFI, 2) frequency-multiplied local oscillator chains can now readily supply the LO power for modest arrays, and 3) CMOS ASIC digital spectrometers offer multi-GHz bandwidth per pixel with very low power consumption. These technical developments make a scientifically compelling Water Mission feasible and affordable.

[1] Jet Propulsion Laboratory, California Institute of Technology
[2] California Institute of Technology

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