A Near-IR All-Sky Spectroscopic Probe

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Astrophysics in the next Decade will be transformed by the advent of a new generation of facilities producing “all-sky” imaging surveys, e.g. LSST, Euclid and WFIRST. The scientific potential of their data products is enormous. WFIRST will take Hubble-like images over a field 200 times larger than WFC3 on HST. LSST will open a new window on time-domain astrophysics.

In this scenario, JWST and later UVOIR, with their unique sensitivity and spatial resolution, will provide the ultimate follow-up capability. However, the full fruition of these enormous photometric datasets, generally obtained in a handful of broad-band filters, will also exacerbate the need for complementary spectroscopic information. A deep spectroscopic all-sky survey in the near IR would represent the ideal solution. This regime provides critical information for extragalactic (due to cosmological redshift), as well as low-redshift and Galactic studies (to mitigate the effect of extinction); it is also optimally accessed from space, due to the strong limitations imposed by the atmosphere, both absorption and emission.

Years ago we identified a viable mission concept to perform a spectroscopic all-sky survey of the Universe in the near-IR (about 1-1.8micron) [1,2]. Our proposal, the Spectroscopic All Sky Cosmic Explorer (SPACE) had two key science goals: first, to perform the most accurate measurement of the expansion history of the Universe (using baryonic acoustic oscillations) and the growth history of cosmic large scale structure (using redshift space distortions), measuring the redshifts of ~500 million galaxies regardless on their spectral type and environment. In practice, this means building a 3D map of the observable Universe. Second, to understand galaxy build-up and evolution by analyzing the detailed information contained in the same spectra. To reach AB~23 mag continuum with a 1.5m class telescope in ~15min exposures one has to exploit the low sky background and eliminate source confusion. We thus envisioned a spectroscopic instrument operating in slit-mode through MEMS devices. Our approach was similar to the one adopted by NIRSpec on JWST, but instead of Micro-Shutter-Arrays we proposed using Digital-Micromirror-Devices (DMDs), a much more mature technology.

The SPACE proposal was submitted in 2007 by a joint European-US team to ESA for the first cycle of ESA Cosmic Vision 2015-2025; it was selected together with another mission concept, DUNE; they were immediately merged into Euclid. ESA funded an initial space qualification program for DMDs, but soon realized that the assessment phase was incompatible with the planned 2018 launch date for Euclid. Euclid was thus de-scoped to implement a basic slitless spectroscopic capability, aiming at a much less ambitious science program [3].

ESA space qualification program eventually indicated that DMDs are viable for flight [4]. More recently, NASA has funded a SAT program that is delivering promising results [5]; we expect that DMDs may soon be regarded as a TRL 6 technology. If the DMD flight readiness is confirmed, and considering that no other mission concept is planned with similar capability and unique science (both Euclid and WFIRST are designed for slitless spectroscopy), it would be compelling to reconsider the idea of an all-sky spectroscopic survey based on this technology.

The original design of SPACE may provide an initial baseline. It was centered on a 1.5m primary mirror feeding four identical spectrographs. Each spectrograph uses a Cinema-2K DMD as slit selector, with 2.1 million elements to synthetize hundreds of ~0.75" width slits; the total FoV was about 0.4 square degrees. The spectral range was set to 0.8-1.8 micron using a prism, with resolving power set to R~400; other combinations are of course possible and should be considered.

The mission profile was centered on an all-sky survey at galactic latitudes > ±18° (~70% of the celestial sphere). This corresponds approximately to 28,500 square degrees and 71,000 satellite pointing. Assuming 20 min per pointing and an observing efficiency of 75%, this would require 2.7 years. The expected number of galaxy spectra with a 1/3 target random sampling was estimated to be about 500 million. The acquisition of the spectroscopic targets could be done using a catalog, or even directly on board through processing of a preliminary acquisition image in the H-band. The cost of the mission was estimated at the upper limit for a small ESA mission and required contributions from national agencies and possibly NASA. It should now safely fall within the range of a NASA Probe (<$1B).

A fresh study of a SPACE-like mission would require a reassessment of the science case for an all-sky spectroscopic NIR survey; this would easily encompass all fields of Astrophysics. In particular, it would be necessary to address the latest advances on dark energy, the complementarity to other future space missions, LSST and large ground based surveys; the scientific potential for Milky Way studies, originally excluded by the declination cut, should also be discussed. The optimal system parameters, starting with bandpass and resolving power, should be re-evaluated.

It should be possible to benefit from the substantial amount of work already done for SPACE, both in Europe and in the USA; this is documented in a variety of studies, reports and referred papers [6]. In particular, the simulation and analysis tools already developed in support of SPACE could serve as a productive starting point of detail studies for a Spectroscopic Probe.

References:
[1] Robberto & Cimatti 2007, Nuovo Cimento B, 122, 1476; [2] Cimatti, Robberto et al., 2009, Exp.Astron. 23, 39; [3] Laureijs et al. 2010, arXiv:1110.3193; [4] Zamkotsian et al. 2010, SPIE 7731E, 30Z; [5] Travinski et al. 2016, SPIE 9761-7; [6] Wang et al. 2010, MNRAS 409, 737.