ALIVE: An Autonomous Lunar Investigation of the Variable Earth. M. C. Turnbull[1], and the ALIVE Team: T. Bank[2], D. Calzetti[1], C. Christian[1], M. Clampin[3], E. Ford[4], E. Friedman[2], J. Grunsfeld[5], A. Gulbis[6], C. Hardesty[2], J. Herman[3], S. Kilston[2], P. McCullough[1], M. Postman[1], I. N. Reid[1], W. Sparks[1], D. Stam[7], G. Tinetti[8], E. Turner[9], J. Valenti[1]. [1]Space Telescope Science Institute (3700 San Martin Drive, Baltimore, MD 21218, turnbull@stsci.edu) for first author, [2] Ball Aerospace, [3]Goddard Space Flight Center, [4]Smithsonian Center for Astrophysics, [5]Johnson Space Center, [6]Massachusetts Institute of Technology, [7]Netherlands Institute for Space Research, [8]Institute d'Astrophysique de Paris, [9]Princeton University.

Introduction: NASA has laid out a bold and challenging strategic plan that balances the nation's desire to conduct human exploration of the moon and Mars with a strong and innovative program of scientific and technical research. Three key sub-goals of NASA's 2006 Strategic Plan are 1) to study Earth from space to advance scientific understanding and meet societal needs, 2) advance scientific knowledge of the potential for life elsewhere, and 3) pursue the search for Earth-like planets in other star systems. The plan to return people to the lunar surface presents an exciting opportunity to make advances towards all three of these goals with a small, but long-lived, experiment that can be deployed in an early lunar mission.

The Autonomous Lunar Investigation of the Variable Earth (ALIVE) is a concept for a low-risk, astronaut-deployable moon-based experiment that will characterize the remotely detectable habitability and bio-signatures of Earth as a function of time. The lunar surface deployment enables these data to be obtained nearly continuously, for a potential mission lifetime of one or more years. The moon's unique vantage point makes it possible to track Earth's ever-changing spectral and polarimetric signatures in a manner analogous to future observations of terrestrial planets orbiting other stars. These data will help us understand what is needed, in terms of new technology and modeling capabilities, to accurately characterize Earth-like exoplanets. The ALIVE mission also provides a means to collect, over the entire visible sunlit disk of the Earth, hourly measurements of CO_2, CO, NO_2, O_3, CH_4, and H_2O and aerosol column amounts, along with measurements of the reflection, absorption and re-emission of solar energy by clouds, oceans, ice and land surfaces. This suite of data, in tandem with the high spatial resolution, but low time resolution, global geophysical data collected by satellites in low-Earth and geosynchronous orbits, will help us to better understand the major drivers of Earth's energy balance and more accurately model the processes governing Earth's climate.

The ALIVE mission will directly and spectroscopically image the Earth every hour at spatial resolutions of 10 – 100 km. The data will be obtained over nearly all Earth-moon orientations, including quadrature ("half-Earth") phase, which is the most likely observed phase for an extrasolar planet. From the ALIVE mission, we will learn exactly how the Earth's normal cycles -- from shorter-term changes like daily rotation, cloud cover, wind speeds, and Sun-Earth illumination phases, to longer-term seasonal changes, weather patterns, and even responses to solar variability -- affect the resulting reflection spectrum and polarization signal of the planet as a whole. This, in turn, will allow us to explore:

- How changes in the reflected flux and polarization signatures correspond to changes in our view of the planet and its dynamic atmosphere and groundcover;
- The extent to which we can deduce spatial information (like continents and oceans) by modeling spatially unresolved spectra of planets orbiting other stars;
- The timescales over which we will be able to identify changes in the seasons and weather patterns on those planets;
- What it will take to unambiguously identify signatures of life (e.g., photosynthetic life) on another planet, signatures that may also change on a variety of timescales.

Key Science Objectives: *Change over time* may be the most powerful tool we have for characterizing the surfaces, weather patterns, rotation, and seasons of extrasolar terrestrial planets with any future space- (e.g., JWST, TPF) or lunar-based missions. Figure 1 shows the spatially unresolved spectrum of the Earth and the atmospheric and surface signatures of particular interest [1,2]. Water, oxygen, ozone, methane and the vegetation jump at 0.78 microns stand out as particularly relevant to biology. Snapshot spectra like these provide a good starting point for planet characterization but leave many degeneracies in terms of modeling surface composition, cloud patterns, etc. Can we unambiguously identify oceans and continents, even photosynthetic life, based on the *variability* we see in these spatially unresolved signals? Current models of Earth give us hope that there is indeed much information that can be extracted from changes in individual spectral features [3], broadband albedo variations [4], and the total amount of polarization of reflected light from the planet [5]. Additionally, understanding the dependence of Earth's climate on atmospheric chemistry and dynamics will require long-term monitoring of planet-wide changes. **Quantifying these changes for the Earth is the first fundamental scientific objective of the ALIVE mission.**

The second science objective of the ALIVE mission is to use these observations to find out: When observing a planet as diverse as the Earth, **how is information content lost with decreasing spatial, spectral, and temporal resolution and signal-to-noise?** One day, scientists will be confronted with this question as they attempt to model unresolved signals from faint exoplanets in terms of groundcover, weather, rotation, and seasons. The ALIVE mission will help pave the way toward understanding exoplanetary signals by providing a data set that can be used at any degraded spatial, spectral and temporal resolution to test our modeling capabilities and guide the design of exoplanet discovery missions to optimize for scientific return and cost effectiveness.

ALIVE and Geoclimatology: During "full Earth" observations, ALIVE observations will hold special significance for Earth science and climatology. At this time, ALIVE will acquire sunrise-to-sunset images in and near the solar retro-reflection (or "hot-spot") direction, where little or no shadow is seen. With this geometry, the spectral separation between vegetation and underlying ground is enhanced, making it possible to probe vegetation canopy structure as the Earth turns. At the same time, the contrast between red and near-infrared reflectances will provide a global picture of vegetation abundance and health. Limb-to-limb cloudcover, optical depth, and altitude can also be determined hourly from visible and near-infrared spectra and, when combined with reflectances observed by LEO or GEO satellites, the microphysical properties of these clouds can be derived. This information is critical for deriving Earth's albedo and longwave radiation, two quantities used to constrain climate models that cannot be obtained from CERES or other LEO satellites on a global basis [6]. ALIVE will also extend the data for cloud cover as a function of the time of day to Earth’s polar regions. Obtaining knowledge of the morning to afternoon cloud cover ratio is an essential piece of the Earth’s climate energy-balance problem [7].

A New View: Like the first whole-Earth images returned from the Apollo missions, the ALIVE observations will give us a new view of our world, including imaging, spectroscopy, and polarimetry for the entire visible Earth in hourly datasets. ALIVE will observe the Earth as if it were an extrasolar planet, but with the added benefits of (1) extremely high signal-to-noise information, (2) high time sampling over an extended period (months and, ideally, at least year or more), and (3) moderate (~10 – 100 km) spatial resolution that will allow us to determine exactly how and why the Earth's signal changes with time. Just as the Hubble Space Telescope revealed aspects of the universe not previously predicted, ALIVE's fundamentally new dataset will undoubtedly precipitate leaps in our understanding of Earth, beyond what is anticipated in this proposal.

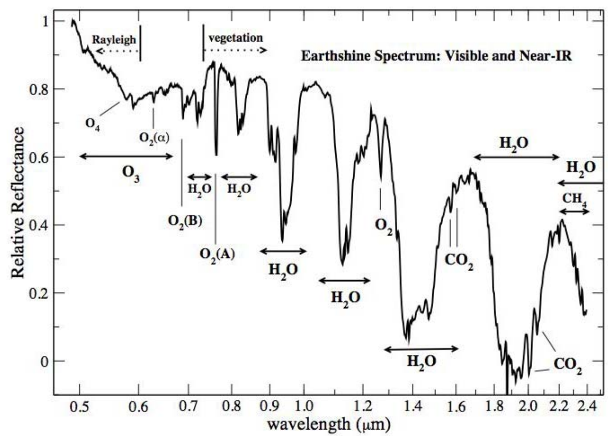

Figure 1. The Earth's spectrum at visible and near-IR wavelengths, measured via earthshine observations [1].

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