Detecting The Beacons of Life With Exo-Life Beacon Space Telescope (ELBST). Vladimir S. Airapetian[1], William C. Danchi[1], Peter C. Chen[1], Douglas M. Rabin[1], Kenneth G. Carpenter[1], Martin G. Mlynczak[2], [1]NASA/GSFC, 8800 Greenbelt Road, Greenblelt, MD (vladimir.airapetian@nasa.gov), [2]NASA/LARC, Hampton, VA.

Introduction: The current explosion in detection and characterization of thousands of extrasolar planets with the *Kepler* mission, *HST* and ground-based telescopes opens a new era in searching for Earth analogs suitable for life. The best way to find signatures of life on terrestrial-type planets is to detect and identify chemical compounds associated with life. Currently, signatures of life are associated with detection of the most common molecules in the Earth's troposphere, including O_2, O_3, H_2O, and CH_4 [1]. The presence of molecular oxygen, a strong marker of the presence of oxygen producing forms of life, together with CH_4, the marker of biological decay, would suggest that the atmosphere is far from the thermodynamic equilibrium driven by biological activity. However, direct detection of the strongest signal from molecular oxygen in the O_2 optical band (around 760 nm) through transmission spectra requires many weeks of observations with extremely large ground-based telescopes. In our paper, we propose a new observational strategy for detecting the signatures of "beacons" of life defined as high signal and low spectral resolution thermal emission from molecules that trace or are associated with the formation of life [2].

Signals from Beacons of Life.

In our recent study of the habitability of early Earth, we proposed that a nitrogen-rich atmosphere of an Earth-like planet is one of the fundamental prerequisites for life, because fixation of molecular nitrogen in the lower atmosphere is crucial but ineffective process to produce a) nitrous oxide, a very potent greenhouse gas required to keep the planet warm; and b) nitrogen cyanide, HCN, the precursors for prebiotic chemistry and life\ [3]. Thus, in a nitrogen, oxygen and water vapor rich rich atmosphere, we can expect the formation of nitric oxide, NO, hydroxyl, OH and O_2 molecules as they are observed from the thermospheric emission of our Earth. TIMED/SABER observations performed over the last 15 years show that OH emission at 1.6 and 2 microns can reach the power of 0.2 TW, NO emission at 5.3 microns peaks at 3 TW during large geomagnetic storms, while O_2 emission at 1.27 microns can be as hig as 200 TW. and 2 microns can reach the power of 0.2 TW [2, 4]. The major requirement of production of NO and OH molecules is the dissociation of N_2 and H_2O.

We find that during larger geomagnetic storms that produce shock-driven solar energetic particle events, NO production can be increased by a factor of 100, so that expected emission from NO at 5.3 microns will be enhanced up to 300 TW. This suggests that if we observe an Earth-like exoplanet with N_2 and O_2 rich atmosphere at distances of 10-50 pc, the expected emission fluxes from this planet in a direct imaging mode are on the order of 10^{-21} -10^{-20} erg/cm^2/s.

Detecting Beacons of Life with *ELBST*

These molecules all have strong spectral features in the thermal infrared region, in the band from 1 to 10 microns. They can potentially be detected by two methods. The first is through transit spectroscopy by using instruments on *JWST* in the near-term starting in 2018, for example, with MIRI, NIRCAM, and NIRSPEC. In the longer term, into the 2030s, direct imaging techniques can be used. For the short wavelength region up to 2 microns, direct imaging and low resolution spectroscopy with R ~ 150 could be done with the *LUVOIR* telescope, which a mission concept currently under study by NASA [5]. This mission concept will be presented to the 2020 Decadal Survey as a potential large mission for a new start close to the time WFIRST is launched, in the mid-2020s.

In the very long term, a "Vision Mission" has be discussed in the recently published document, "Enduring Quests, Daring Visions: NASA Astrophysics in the Next Three Decades." [6] An ExoEarth Mapper mission concept is presented, and notionally consists of up to 20 6-m class telescopes combined as an interferometer, with up to 600 km, baselines at wavelengths from 0.3 to 1 micron. This concept would allow for the possibility of generating maps of the surfaces of exoplanets around nearby solar-type stars at distances of up to 10 parsecs from the solar system.

What is missing, however, are the important mid-infrared bands at wavelengths longer than 1 micron. In the past decade, from approximately 2002 to 2010, two NASA teams studied two mission concepts for this spectral region. One was a flagship mission concept, called the "Terrestrial Planet Finder Interferometer," or *TPF-I*, the other was meant to be a MIDEX cost-capped concept called the "Fourier-Kelvin Stellar Interferometer," or *FKSI* [7]. This concept was extensively studied but never proposed because both grass-roots and parametric cost estimates had the total cost for *FKSI* significantly above the MIDEX cap, of the order of $500 M as a lifecycle cost. The *TPF-I* concept was costed at significantly above that of *JWST*.

The FKSI concept was based on technology derived from JWST, and it was a structurally connected interferometer with a modest 12.5 baseline, with two 0.5-m telescopes, operating with a science band from 3 to 8 microns, with potential to operate as long as 10 microns or more [8]. An additional study was done, for a version operating at a center wavelength of 10 microns, with telescopes ranging from 1-2-m in diameter with a 20-m baseline. This version of FKSI, called FKSI-2, was capable of detecting Earth-sized planets in the habitable zone of nearby stars, if such planets are common[9].

Much of the history of the past work was presented in the chapter on "Infrared Direct Imaging," in the Exoplanet Community Report [10], published in late 2009, just prior to the 2010 Decadal Survey.

After this report, considerable progress has been made in terms of the technologies needed for such missions, and many signicant milestones have been passed, including reaching the contrast level necessary for directly imaging and characterizing exoplanes in the mid-infrared [10].

Building on the previous work with FKSI and TPF-I, it is worthwhile to consider developing a "Probe-Class" mission concept, based on the FKSI concept, which we call the "Exo-Life Beacon Space Telescope" or *ELBST*. Given the rising costs for Flagship missions, Probe-class missions with life cycle costs of approximately $1 B, are an attractive option assuming NASA has a cost-constrained budget in the coming years.

An *ELBST* mission could utilize emerging technologies such as ultra-lightweight optics being developed that use carbon-nanotubes, fibers, and polymers, to craft supersmooth precision surfaces [11].

A near-term Probe-class science and technology driven mission concept like *ELBST* could address not only exoplanet science, but it will allow very high angular resolution observations of planets and moons and other solar system bodies including the larger asteroids, and extragalactic astrophysics, particularly the nuclei of active galaxies.

A comprehensize technology assessment and plan is needed, not only for the near term, but also to provide a pathway to the ExoEarth Mapper mission that could be realized beyond the 2030s into the 2050s.

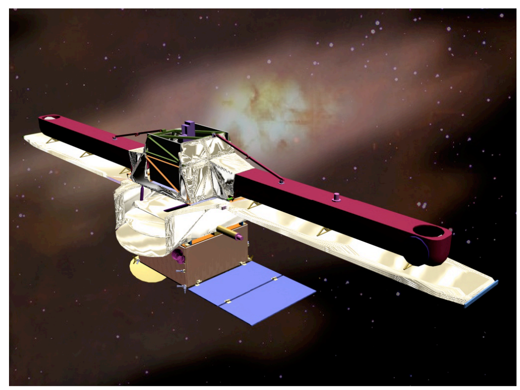

Figure 1. Artist's conception of the FKSI observatory [10].

References: [1] Kaltenegger, L., Traub, W. A., & Jucks, K. W. 2007, ApJ, 658, 598-616. [2] Airapetian et al. 2016, Nat. Astr., submitted. [3] Airpetian et al. 2016, NatGeo, 9, 452-455.[4] Mlynczak et al. 2015, GeoRL, 42-3677-3682. 5]Thronson, H. et al. (2016) JATIS, 2(4) 041201. [6] Kouveliotou, C. et al. (2013), NASA publication. [7] Danchi, W. C. et al. (2003), ApJL, 597, L57. [8] Danchi, W.C.& Lopez, B.. (2007) C. R. Physique 8, 396. [9] Danchi, W.C. & Barry, R. (2010) Proc. SPIE, 7734. [10] Danchi, W.C. et al. (2009), in the Exoplanet Community Report, (eds.) Lawson, P.R., Traub, W.A., & Unwin, S., JPL Publication 09-3. [11] Chen, P.C., & Rabin, D.M. (2015), JATIS 1(1), 014005..