SCALES: INSTRUMENT OVERVIEW AND EXPECTED SCIENCE OUTCOMES S. Sallum[1], A. Skemer[2,3], D. Stelter[2,3], Z. Briesemeister[2], N. Batalha[2], N. Batalha[4], G. Blake[5], T. Brandt[6], W. Deich[3], K. de Kleer[5], I. de Pater[7], J. Eisner[8], M. Fitzgerald[9], W. Fong[10], B. Gerard[2,3], T. Greathouse[11], T. Greene[4], P. Hinz[3], M. Honda[12], R. Jensen-Clem[2], M. Kassis[13], C. Kilpatrick[10], G. Kruglikov[3], R. Kupke[3], M. Liu[14], J. Lyke[13], N. MacDonald[3], C. Marois[15,16], D. Mawet[5], B. Miles[2], C. Morley[17], D. Powell[2], C. Ratliff[3], K. Sandstrom[18], P. Sheehan[10], J. Spilker[17], J. Stone[19], K. Wagner[8], Y. Zhou[17]. [1]University of California, Irvine (ssallum@uci.edu), [2]University of California, Santa Cruz, [3]University of California Observatories, [4]NASA Ames Research Center, [5]California Institute of Technology, [6]University of California, Santa Barbara, [7]University of California, Berkeley, [8]The University of Arizona, [9]University of California, Los Angeles,[10]Northwestern University, [11]Southwest Research Institute, [12]Okayama University, [13]W. M. Keck Observatory, [14]University of Hawaii at Manoa, [15]NRC Herzberg, [16]University of Victoria, [17]The University of Texas at Austin, [18]University of California, San Diego, [19]Naval Research Laboratory.

Overview: We will present an overview of the Santa Cruz Array of Lenslets for Exoplanet Spectroscopy (SCALES). SCALES is a 2-5 micron, adaptive-optics fed integral field spectrograph (IFS) currently being developed for W.M. Keck Observatory's 10-m telescopes. SCALES' unique wavelength range is designed specifically for exoplanet discovery and characterization, and will open new areas of parameter space for direct exoplanet studies. SCALES will also enable new, detailed observations of solar system bodies, with applications such as monitoring volcanism and weather patterns. We will describe SCALES' modes in the context of science requirements for these representative cases. We will also present an instrument simulator that our team has been using to track requirements, along with simulated observations of representative solar system and exoplanet targets.

SCALES Design: SCALES is designed to sit behind either of the Keck adaptive optics systems [1]. It will use a custom silicon lenslet array and prisms to disperse a square field of view 2.2 arcseconds on a side. This will provide low spectral resolution (R ~ 50-300) from 2 – 5 microns with a number of selectable bandpasses, including K, L, and M bands, as well as dedicated modes for observing PAHs, CH4, and H2O ice. A subsection of the lenslet array will feed an image slicer module, which will provide medium spectral resolution (R ~ 5000) for a square field of view 0.36 arcseconds on a side, for K, L, and M bands. SCALES' fully-cryogenic optical train will feature selectable coronagraphs (e.g. vector vortex) and pupil plane masks (e.g. sparse aperture masks).

SCALES Simulator: The SCALES team has developed python instrument simulation tools to generate realistic mock observations and track science requirements [2]. The instrument simulator currently takes into account atmospheric transmission and emission, atmospheric dispersion, instrument emissivity, lenslet point spread functions, prism dispersion curves, standard noise sources from the target, sky, and detector, and a simple implementation of adaptive optics fitting error. We are currently working to make the simulator more robust, including an accurate description of Keck adaptive optics performance.

The simulator is designed to take as input either: (1) a user-generated data cube of 2D images versus wavelength, or (2) a target spectrum, which it then convolves with a set of Keck point spread functions to generate a cube of images. It outputs the raw detector view, consisting of all the individual spectra corresponding to the different lenslets. It also outputs extracted spectra, in the form of processed datacubes (2D images versus wavelength), as well as signal to noise estimates for point sources. Figures 1 and 2 show example images and extracted spectra from the simulator for representative science targets (volcanism on Io, and giant exoplanets, respectively).

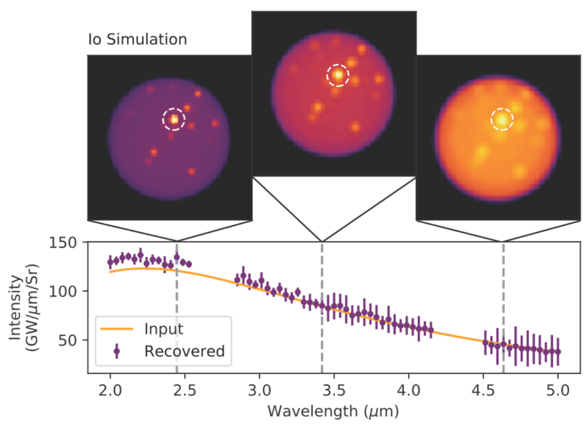

Figure 1: *From [2]. Top: Simulations of the 2.4, 3.4 and 4.6 micron images of a 2-hr integration of an Io model at 2-5. Bottom: The input and recovered spectra of the Loki Patera-like volcano from the same simulation at 2-5 μm band. Note the excess intensity in K band is caused by the volcano being marginally resolved and our extraction not accounting for this. The gaps in the spectrum are regions of high telluric absorption.*

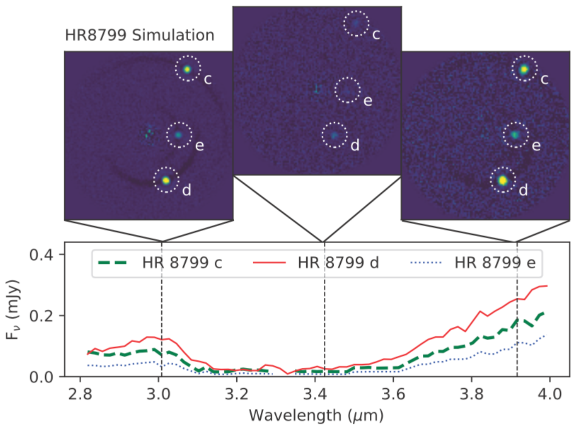

Figure 2: *Adapted from [2]. Top: Simulations of the 3.0, 3.4 and 3.9 micron images of a 2-hr integration of a HR 8799-like system at L band, processed with a naive, non-aggressive application of full-frame Angular Differential Imaging. Bottom: The recovered spectra of the HR 8799cde-like exoplanets from the same simulation at L band.*

Science Cases and Expected Outcomes: SCALES is designed for exoplanet discovery and characterization, and will be the first facility class, high-contrast imaging IFS to operate at wavelengths longer than ~2.5 microns. This unique wavelength range gives SCALES access to colder exoplanets than current exoplanet IFSs, extending detectable planet temperatures down to ~300 K. SCALES' modes will enable measurements of planet properties such as luminosities, masses, abundances, temperatures, and cloud coverage. It will also be capable of detecting young and accreting planets, at masses and accretion rates lower than those accessible with current high-contrast IFSs.

In addition to exoplanet science, SCALES will enable new, detailed observations of solar system bodies. It can be used to monitor the locations, temperatures, and extents of volcanoes on Io. Its combined spectral and spatial resolution will also be useful for monitoring storms and weather patterns on Titan, Neptune, and Uranus. These solar system observations have typically been carried out with multi-band imaging on instruments such as Keck/NIRC2. SCALES will not only increase efficiency thanks to its simultaneous wavelength coverage, but it will also lead to more detailed characterization than possible with broadband photometry.

In addition to the science cases described above, SCALES will have applications for protoplanetary disks (e.g. mapping scattered light and ice lines), active galactic nuclei (e.g. detecting PAHs in tori), and supernova remnants (e.g. mapping dust distribution and content).

SCALES Science Team: The SCALES science team is dynamic and very interested in feedback from the community regarding potential science cases and representative targets. If you are interested in getting involved in SCALES science planning, or would like to discuss possible applications, please contact us.

References: [1] D. Stelter et al. (2020) *Proc. SPIE,* 11447, 1144764. [2] Z. Briesemeister et al. (2020) *Proc. SPIE,* 11447, 114474Z