EXPLORING EXOPLANETS WITH K–12 TEACHERS AND STUDENTS. M. L. Urquhart[1], [1]The University of Texas at Dallas, Department of Science and Mathematics Education (800 West Campbell Road, FN 33, Richardson, TX 75080, urquhart@utdallas.edu.

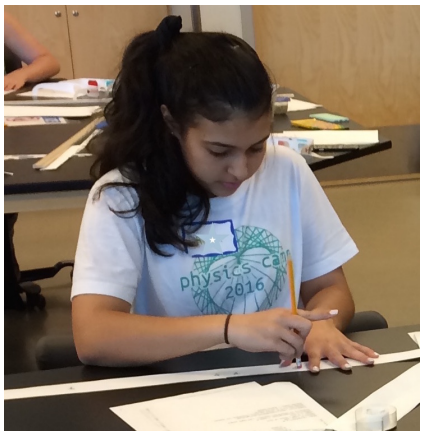
Introduction: With discoveries of more than 3,500 exoplanets [1,2] – including potentially habitable worlds making the news – these intriguing objects are of interest to both adults and K–12 students. However, exoplanets are not a topic that is expected to be covered in most K–12 classrooms. Worlds outside the Solar System appear in neither the *Next Generation Science Standards* [3] nor in the majority of the content standards for the state in which I reside, the *Texas Essential Knowledge and Skills* (TEKS) [4]. (An optional high school course *Earth and Space Science* includes in its TEKS "compare extra-solar planets with planets in our solar system and describe how such planets are detected."[5])

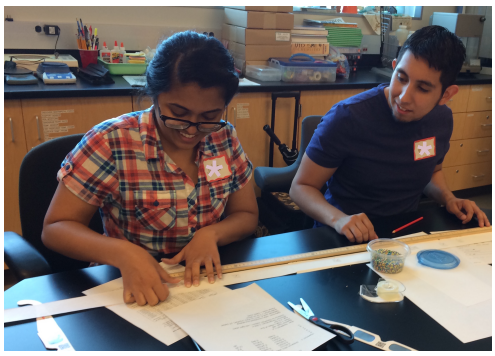
Nonetheless, an exploration of exoplanets – including: i.) how they compare with the planets in our own Solar System, ii) questions of their potential habitability, and iii) the challenges their vast distance from us represent – can all be tied to what teachers need to teach and what students need to learn. Here I present on educational outreach for exoplanets I conducted in 2017 involving workshops for teachers and middle and high school students in an informal context.

Workshop Formats and Programs: The short-term professional development conducted was in the context of one-hour workshops. Designed for in-service science teachers, the workshops were presented at the annual Texas Regional Collaboratives Annual Meeting in June 2017 and the the annual Conference for the Advancement of Science Teaching in November 2017. Due to the brief time allotted for these workshops and several hands-on scale modeling activities incorporated into them, pre-existing activities were abrieviated. New versions of exoplanet scale modeling activities adapted from *Stars and Planets* [6] were designed to be interspersed between other workshop components or done as stand-alone classroom activity.

The workshops were partially drawn from my past offerings of an Astrobiology course in a Master of Arts in Teaching program designed for enrichment of in-service teachers [7]. For the summer of 2017, new resources and scale modeling activities were incorporated to assist participants in developing an understanding of recent exoplanet discoveries and their relation to questions of the potential for life elsewhere.

Since 2004, the Department of Science and Mathematics Education [8] has supported no-cost Women in Physics camps [9] targeting middle and early high school girls. The camps are managed and staffed primarily by students in the UTeach Dallas teacher certification program along with in-service teacher volunteers (working with faculty). Returning camp alumni serve as volunteer team leads. As the founding faculty advisor, I lead a science exploration for both the regular and advanced camps. The 2017 experience included an exploration of exoplanets based on the one-hour teacher workshops.





A returning Women in Physics Advanced Camper (above) and two UTeach Dallas pre-service teachers (below) create a models of the TRAPPIST-1 system on a 1:10 billion scale.

Workshop Content: Each of the outreach workshops – whether for teachers or for the secondary students in an informal context – follow a common narrative. The excitement of active scientific efforts and discoveries are interwoven with explorations of the sizes and distances of stars and their planets, the challenges of planetary detection, and questions of habitability. Multimedia resources and hands-on activities are threaded throughout the interactive experiences.

Each workshop includes the following componets:

- An abbreviated *Scale Model Solar System* activity in which the inner planets and Jupiter are modeled on a 1:10 billion scale [6,10].
- Abbreiviated versions of the *Sizes of Stars* and *Distances of Stars* activities from my *Stars and Planets* [6] curriculum, using the 1:10 billion scale factor to model the Alpha Centauri system.
- Planet hunting techniques and challenges discussed with resources from the Kepler/K2 mission website [11], the European Southern Observatory (ESO) [12], and the *Planet Hunting* activity from *Stars and Planets* [6].
- Scale models of exoplanetary systems created specifically for this outreach.
- Multimedia and image resources on specific exoplanets or systems of exoplanets from NASA and ESO press releases and briefings, the NASA JPL *Exoplanets Exploration* website [1], NASA's *Eyes on Exoplanets* [13], and the Planetary Habitability Laboratory (PHL) of the University of Puerto Rico at Arecibo [14], Spitzer Space Telescope [15], and ESO [12].
- A discussion of habitability, including M-class stars and "eyeball Earths". An incandescent bulb with a dimmer switch used with diffraction grating glasses ties the discussion to topics of black body radiation, color, spectral class, and energy.

Scale Modeling of Exoplanets and Their Stars: Outreach participants do hands-on scale modeling of exoplanets on a 1:10 billion scale including 51 Pegasi, terrestrial planets in conservative habitable zone (as defined by PHL) [18], and the TRAPPIST-1 system. Exoplanet and stellar data is taken from *The Extrasolar Planet Encyclopaedia* [2]. The exoplanet scale models are compared back to the *Scale Model Solar System* using the same scale factor. Terrestrial planets are modeled with ~1 to 2 mm round candy sprinkles, jovian planets are modeled with ~1 to 1.5 cm marbles. Main sequence G class main sequence stars are represented by an ~14 cm yellow ball, K-class stars with an ~10 cm orange, and M-class stars with an ~3 cm red ball. For the TRAPPIST-1 system, all seven terrestrial planets can be modeled on a single meter length of cash register paper. This is in contrast to the 15 m distance to the scale model Sun and a 1.3 mm candy sprinkle Earth in the Scale Model Solar System.

Short Term vs. Long Term Impacts: The depth of exploration in a short teacher workshop or single student camp experience or lesson is necessarily limited by time. Significantly deeper exploration of concepts and curricular connections can be made in the long-term professional development context of the Astrobiology course than are possible in an one-hour experience. All of the outreach participants were provided with an introduction to a wealth of resources from NASA and the other organizations offerings mentioned here. The intent of the short term explorations is to inspire and empower students and teachers to conduct further independent exploration. Electronic access to full curricular materials for each of the activities used or referenced were provided to the teacher-participants along with an extensive list of links to the online resources used in the program. By providing connections to content standards along with and classroom-ready activities and resources, the hope is that teachers will feel prepared to bring the excitement of exoplanets into their classrooms.

References: [1] NASA JPL's *Exoplanet Exploration* website accessed at http://exoplanets.nasa.gov [2] Roques, F et al., *The Extrasololar Planet Encyclopaedia* catalog accessed at http://exoplanet.eu/catalog [3] NGSS Lead States. (2013) *Next Generation Science Standards: For States, By State*s. Washington, DC: The National Academies Press. [4] Texas Education Agency (2010) *The Texas Essential Knowledge and Skills*. Ch. 112: Science, accessed at http://ritter.tea.state.tx.us/rules/tac/chapter112/index.html [5] Texas Education Agency (2010) *The Texas Essential Knowledge and Skills*. Ch. 112, Subchapter C, High School Science, accessed at http://ritter.tea.state.tx.us/rules/tac/chapter112/ch112c.html [6] Urquhart, M. L (2002) *LPS XXXIII.* Abstract #2007. [7] Urquhart M. L. and Montgomery H. A. (2012) *LPS XLIII,* Abstract #1659. [8] The Department of Science and Mathematics Education, UT Dallas website http://www.utdallas.edu/sme/ [9] The UT Dallas Women in Physics Camps website is http://wipphysicscamp.weebly.com [10] Urquhart, M. L (2008) *LPS XXXIX.* Abstract #1391. [11] NASA's Kepler/K2 mission website accessed at https://www.nasa.gov/mission_pages/kepler/main/ [12] European Southern Observatory website at www.eso.org/public including resources for Proxima Centauri b at http://www.eso.org/public/news/eso1629/ [13] NASA JPL's Eyes on Exoplanets interactive at http://eyes.nasa.gov [14] Planetary Habitability Laboratory, Habitable Exoplanets Catalog, accessed at http://phl.upr.edu/hec [15] Spitzer Space Telescope website resources for TRAPPIST-1 accessible at http://www.spitzer.caltech.edu/trappist-1