



Figure 1: Girl Scout leaders engaged in an activity to classify galaxies during a “Train the Trainer” workshop.

“Subject Matter Experts” in Science Education: The Legacy of NIRCam and JWST

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Astronomy and space science are inspirational subjects and fuel the imagination of a new generation¹. Beginning in the 1960s, both scientists and the public developed a “sense of place” in our Universe through famous color images like Apollo’s “Blue Marble,” Voyager’s “Pale Blue Earth,” and the Hubble Telescope’s “Deep Field” images. What new perspectives does the future hold and how can we convey their meaning?



Figure 2: Girl Scout leaders participated in a hands-on activity about the Hertzsprung-Russell Diagram in a stellar astronomy. Using “flash cards” about specific stars, leaders experimented by ordering themselves in brightness, distance, absolute magnitude, and color.

In 2001, NASA announced an opportunity to build scientific instruments for the Next Generation Space Telescope, which later became the James Webb Space Telescope (JWST). Interested teams of scientists, engineers, and managers were asked to propose specific instrumentation combined with Education and Public Outreach (E/PO) programs for ~1% of the overall budget, i.e., ~\$1M. An international group of scientists, centered at The University of Arizona, teamed with engineers from the Lockheed Martin Advanced Technology Center to propose the Near Infrared Camera (NIRCam), which was selected to proceed in 2002.

NIRCam’s Vision and Plan

Our team realized that JWST would expand everyone’s sense of place by exploring further back in space and time, and inside dusty regions of space, to unveil the

origins of a newborn Universe, other planetary systems, and perhaps life itself. However, we also knew that the abstract nature of these topics, combined with JWST’s non-visible infrared images, would make effective communication more difficult. So, we decided to lay educational foundations years prior to launch about topics relating to light, spectra, telescopes, redshift, stars, galaxies, and cosmology.

We leveraged our personal experiences^{2,3} as “Subject Matter Experts” (i.e., scientists, engineers, managers) in NIRCam’s E/PO program (“Linking Girls with the Sky”⁴), to promote both science literacy and mission-specific information. We partnered with the Girl Scouts of the USA (GSUSA) to benefit an underrepresented group in STEM education over a wide age range (K-college). Together, we would re-vamp the existing “Sky Search”



Figure 3: Co-author Larry Lebofsky demonstrates a scale model for the Earth-Moon distance during a “Train the Trainer” workshop for GSUSA leaders. Photo Credit: Joseph Wright.

Girl Scouts badge by developing hands-on, educational materials and training troop leaders to incorporate these materials in communities and families. The GSUSA’s dedicated local leaders and infrastructure were ideal to distribute these educational tools and to impact millions of young girls personally.

Strategically, we chose to spend our budget slowly, and immediately, to impact a full generation of young women over the lifetime of JWST. With leaders from our local Girl Scouts of Southern Arizona Council, we began strengthening STEM programming and also



Figure 4: Map showing the locations of 397 GSUSA leaders who attended NIRCам’s “Train the Trainer” 3-day workshops from 2002 through 2019.

began hosting 3-day long “Train the Trainer” workshops for leaders from around the nation (Figures 1-3). From 2002 until the COVID pandemic struck in 2020, we conducted 30 biannual in-person workshops at our local Council’s Hacienda facility and at Biosphere-2, and used our professional observatories on Mt. Lemmon, and the Richard F. Caris Mirror Lab. During that time, 397 leaders, both men and women, participated from 98 of the 112 official Councils in 47 U.S. states, D.C., Guam, Japan, and Puerto Rico (Figure 4). Many of these individuals were professionals in industry and education (K-college), devoted to public STEM education. One

Sidebar: *Where are they now?*

Michelle Higgins (see also Fig. 8) was a stay-at-home mom who had earned a Master's degree in Physics. She attended our first workshop in 2002 and within two years became the STEM Coordinator for the Girl Scouts of Southern Arizona. She is earning her doctoral degree in Educational Psychology and is the Associate Director of the STEM Learning Center at The University of Arizona.

Joe and Rita Wright attended workshops in 2004 and 2006 and became part of our staff. Joe is the Operations Manager for the Warkoczewski Public Observatory, University of Missouri-Kansas City. He became the President of National Sharing the Sky Foundation, Inc., a NASA Solar System Ambassador, and an Airborne Astronomy Ambassador on the SOFIA aircraft.

Laura Felix attended in 2014 and became a JWST enthusiast, within her family, school, and community. She and her son developed a 6-month long program about JWST program for Boy Scouts.

father was a launch director of the Space Shuttle and an active leader in his local Council.

Our workshops also engaged 11 astronomy graduate students from Steward Observatory as teaching leaders⁵. These students have since become Professors, Directors of planetaria, leaders of undergraduate Astronomy programs, parents, and they remain active in E/PO, both locally and nationally.

NIRCam's E/PO continued through Spring 2013, when NASA abruptly terminated all its mission-oriented education programs. In 2015, authors Don and Larry proposed to continue our efforts through NASA's revised, non-mission-oriented approach in a collaboration with the SETI Institute's "*Reaching for the Stars*" program⁶. Together with the GSUSA, that team created six age-appropriate Space Science badges now used worldwide.

The educational activities from our full 20 years are available online.: <https://www.seti.org/girlscoutstars>

Ongoing Interactions

We continue to support ~300 graduates of our workshops via a monthly newsletter and often provide assistance with their special events. The newsletter provides updates about astronomy, JWST, cultural sky stories, etc. We also provide information about programs that they can participate in, such as International Observe the Moon Night, send them new or revised hands-on activities, and provide materials



Figure 5: Co-author Alison Nordt at Notre Dame High School, Belmont, CA, during a hands-on presentation about NIRCcam, JWST, and careers in engineering. Photo Credit: George Retelas, Notre Dame Belmont

that they can use in their local events.

The newsletter keeps us in contact with our participants, and also gives us an opportunity to learn what they are doing and how our program has affected their lives. They share the newsletter with others in their Councils, so the reach is far beyond our list of participants.

Teaming with Lockheed Martin, NIRCcam's Contractor

An engineering team at Lockheed Martin Advanced Technology Center built the NIRCcam instrument.

Lockheed Martin's engineers and managers were already involved in educational programs with the GSUSA, and they welcomed the opportunity to collaborate with NIRCcam's E/PO mission. In particular, co-author Alison (NIRCcam's Principal Engineer) visited many schools, giving talks to all ages from kindergarten through graduate students, including at the Sally Ride Camps at Stanford U., Tech Trek at Stanford, Girls Who Code Camp, and the U.S. Space Camp.

Recently, Alison spoke to the entire student body (~450 girls) at Notre Dame High School, Belmont, CA⁷ (see Figure 5). Classroom outreach is particularly important because we can reach students who would not voluntarily go to an extra-curricular activity about science. Afterwards, a science teacher wrote, saying



Figure 6: Lockheed Martin engineers and manager hosted an open-house event for local Girl Scout troops as the completed NIRCcam instrument was shipped across country to Goddard in Maryland. Girl Scouts participated in numerous activities and tours and signed a "Go Girl Scouts" banner, commemorating NIRCcam's connections to the GSUSA. Photo Credit: Lockheed Martin



Figure 7: During Lockheed Martin’s first open-house event (2008), Dr. Nordt (2nd from the left, in the cleanroom “suit”) showed girls NIRCам’s beryllium optical bench. In the back center is Kathryn Steakley, then a high school Girl Scout and now a Ph.D. planetary scientist. Photo Credit: Lockheed Martin

that a girl came up to her, very worried, to say *“I am a senior and I am not taking any math or science classes. I was fascinated by the talk about JWST. Is it too late for me to become an engineer?”*

On June 18, 2013, the Lockheed Martin team held an open-house event for local Girl Scout troops (Figures 6-7) to celebrate completion of the NIRCам instrument as it was shipped across country to the Goddard Space Flight Center. In addition to tours and activities, participants were fortunate to visit a cleanroom to view NIRCам’s beryllium optical bench⁸ which had been

etched *“Go Girl Scouts,”* closely following the standards and quality requirements.

One of the girls who participated in Lockheed Martin’s send-off event was Alison’s daughter, Clair, then age nine. Recently, she published her perspective on JWST⁹.

Also at Lockheed Martin, the entire family of Joyce Steakley (Specialty Engineering Director) was affected. She was also a Girl Scout leader, and mother of two daughters. In her words:

“I was always looking for STEM opportunities for girls. While my husband, Bruce was NIRCам Program Manager, I had the opportunity to help organize three such events. In each case, we invited Girl Scouts who were daughters, granddaughters, or troop members of Lockheed Martin employees. The first event was attended by 103 girls at our Sunnyvale facility, and one of the highlights was dissecting a disposable camera (ref #9) while Dr. Alison Nordt explained how NIRCам’s camera components differed. Dr. Marcia Rieke gave a powerful keynote address and was part of a career path panel discussion for middle school and high school attendees. The other two events were at LM’s Advanced Technology Center in Palo Alto where NIRCам was being built and tested. A total of 74 girls attended these two events, where they got to see the beryllium bench, tour laboratories, and sign a “Go Girl Scouts” banner as a send-off for NIRCам to be shipped to NASA Goddard to be integrated with JWST. All the girls who attended were so intrigued with everything they experienced; I know

we helped make a difference in their lives.”

A participant in the first event (2008) was daughter Kathryn Steakley, now a Ph.D. planetary scientist (see also Figure 7). In her words:

“As a kid who was fascinated by outer space, I was really fortunate to have so much support and exposure to STEM through my parents.

Growing up I knew my mom had worked on the Hubble Space Telescope and my dad worked on the NIRCcam instrument. When I was in high school, I had the opportunity to go to my dad’s workplace to see the beryllium bench for the NIRCcam instrument that would eventually fly on JWST. I am really grateful that I had the opportunity to participate in Girl Scout events like that one because I got to learn from so many women who were scientists, engineers, and leaders like Alison and like my mom. It showed me that it was normal for women to be in these STEM roles. I eventually went on to get my Ph.D. in Astronomy, and I am currently working at NASA Ames Research Center studying the Martian atmosphere. I am really looking forward to the science that will be



Figure 8: Michelle Higgins leads an activity about the inner structure, and composition, of planets at a Girl Scout workshop in Yuma, Arizona. Photo Credit: Larry Lebofsky.

done by JWST, particularly on characterizing the atmospheres of planets outside our Solar System.”

Lessons Learned

Our training program for GSUSA leaders has operated since 2002, long enough to see its effectiveness through a recent longitudinal survey. Below is a representative quote from a participant, Michelle Higgins (Figure 8), who was inspired to grow in STEM education and to become a leader of STEM programs within Southern Arizona’s local Council.

“I participated in the first astronomy camp when I was a volunteer Girl Scout leader...I was interested in sharing math and science with the girls in my troop, and to others in my community, however, I had limited knowledge about outreach... I learned that many misconceptions about science continued to be taught to learners, even through Girl Scout material. But, the most inspirational experiences I had at the camp were the discussions and debriefs around the hands-on activities. It amazed me how the facilitators could have such a deep conversation about abstract and theoretical concepts in such a relaxed atmosphere.”

During our 20-years preparing the world for JWST's discoveries, we have learned that Subject Matter Experts convey not only excitement and authenticity but also the true meaning of science. As one of our first workshop graduates expressed: *"I always thought that science was just memorizing facts but you guys are encouraging us to think and explore"* Today, we, along with our GSUSA partners, are excited to share the excitement, and meaning, of JWST's discoveries to millions of girls and women around the world.

Footnotes/References:

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8. NIRCcam's optical elements (lenses, mirrors, filters, infrared detectors) are mounted on a special foundation known as the "beryllium optical bench." The beryllium material minimizes weight while providing high stiffness, and efficient cooling properties, to ensure that NIRCcam will always be in focus despite the vibrations of launch and operation at low temperatures (35 K).
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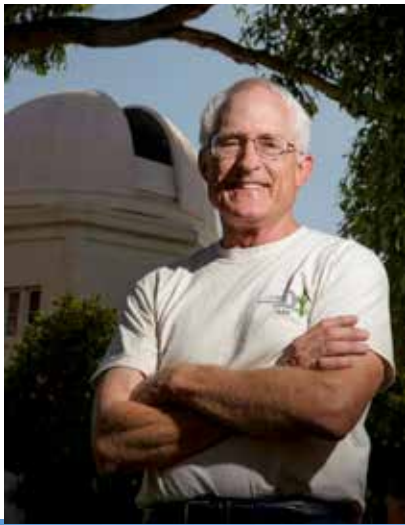


Figure 9: (a) Don McCarthy, in front of the University of Arizona's Raymond E. White Jr. (21-inch) telescope. Photo Credit: Kris Hanning. (b) Larry Lebofsky shows a young student how to view the Sun's surface safely through a telescope on the University of Arizona campus. Photo Credit: Alan Fischer.

About the Authors

Dr. Don McCarthy (Fig. 9) is an infrared Astronomer and Professor at the University of Arizona. He is also a member of the NIRCam science team and has directed Astronomy Camps for all ages at major observatory sites since 1988.

Dr. Larry Lebofsky (Figs 3, 9) is a retired Planetary Scientist from the University of Arizona and is now a Senior Education and Communication Specialist at the Planetary Science Institute. He has created hundreds of hands-on activities and presentations for elementary and middle school students and K-12 teachers.

Dr. Alison Nordt (Figs. 5, 7) is the Director of Space Sciences and Instrumentation at the Lockheed Martin Space Advanced Technology Center. She also enjoys being a pilot, scuba diver, and skier. Like Don, she was a finalist for Space Shuttle astronaut, although a generation apart!

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