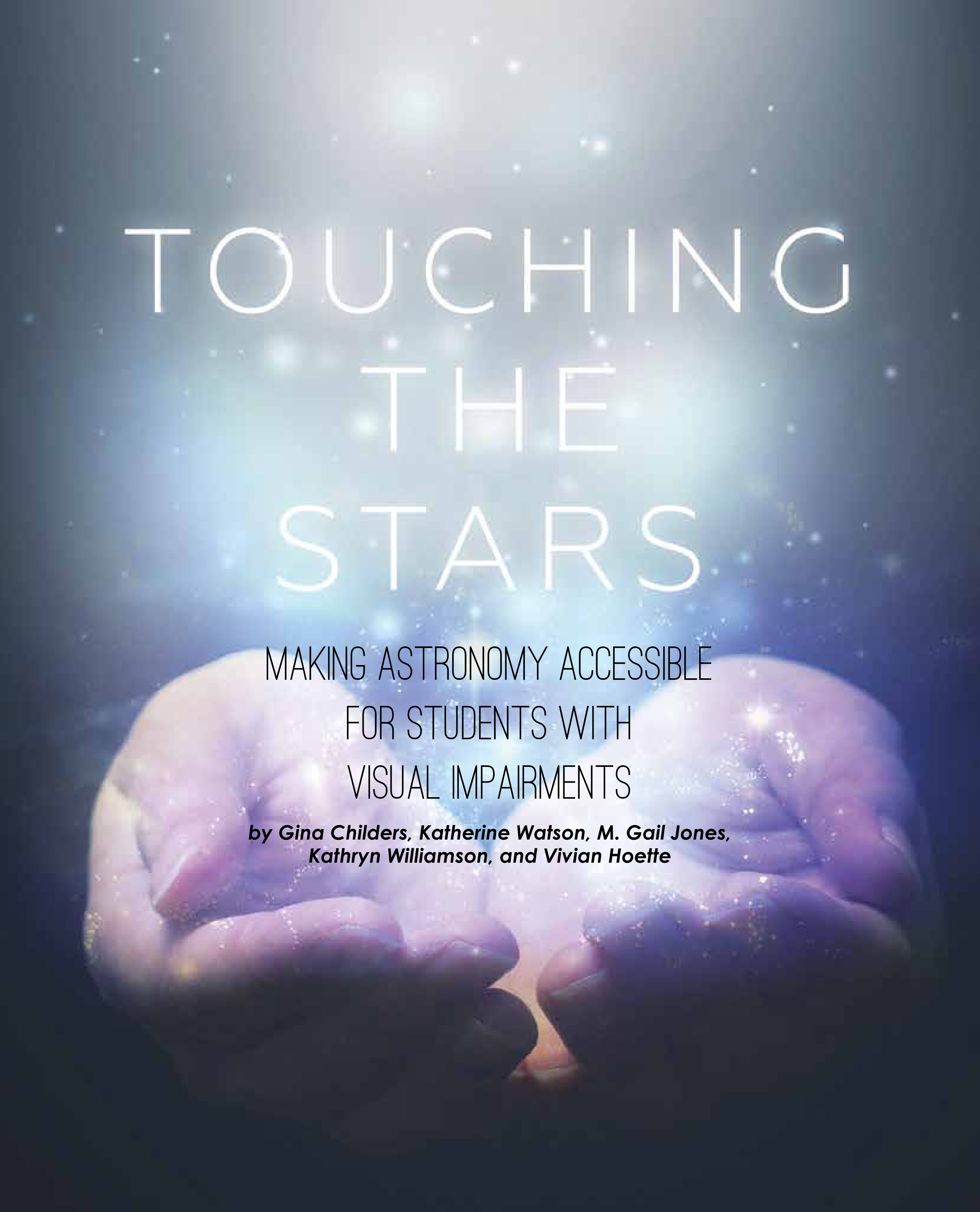


TOUCHING THE STARS

MAKING ASTRONOMY ACCESSIBLE FOR STUDENTS WITH VISUAL IMPAIRMENTS

by Gina Childers, Katherine Watson, M. Gail Jones, Kathryn Williamson, and Vivian Hoette

Gazing into the night sky can be an awe-inspiring experience, and often is what first sparks a student's interest in science. But how would you share the wonder of the night sky with a visually impaired student? How would you explain the different brightness of stars, the shapes of constellations, or the relationship between the various objects in our solar system without the use of a visual aid?

Traditional astronomy instruction is dependent on visual modes of learning, such as textbooks, pictures, and movies. Because of this reliance on visualizations, students with visual impairments are at a disadvantage when it comes to learning astronomy (Beck-Winchatz and Riccobono 2008; Jones et al. 2006). In addition, accommodations for students with visual impairments are often regarded as taxing and costly to schools because of the low enrollment of students with visual impairments. It is not uncommon for there to be a single student with a visual impairment enrolled in a particular school (Beck-Winchatz and Riccobono 2008). Consequently, students with visual impairments often never fully participate in science instruction because of the lack of appropriate models and instructional tools. In order to level the playing field, teachers need to provide research-based accommodations, strategies, and programs for students with visual impairments (Rule 2011; Wild and Allen 2009; Jones et al. 2014). Advancements in tactile, modeling, and computer technologies are allowing students with visual impairments to discover astronomical concepts with innovative tools. New programs and technologies for teaching astronomy have demonstrated that *universal design* (developing tools and educational environments that are usable and accessible by all individuals, including individuals with disabilities) is often beneficial for students with visual impairments, as well as those with normal vision.

FIGURE 1 A model depicting how light enters a telescope lens and bends to a focal point to produce an image

Program description

Skynet Junior Scholars (SJS; *https://skynetjuniorscholars.org*) is a free online program designed to teach astronomy by developing technological tools through a universal design lens. This new astronomy program for middle and high school students is funded by the National Science Foundation and is being developed by the University of Chicago's Yerkes Observatory in partnership with the National Radio Astronomy Observatory, the University of North Carolina at Chapel Hill, the Astronomical Society of the Pacific, and 4-H. The University of Chicago's Yerkes Observatory had previously designed other astronomy programs that promote "active learning in astronomy and physical science for all students, including those with vision or hearing impairments" (Backman and Hoette 2009). The astronomy content taught to students with visual impairments aligns with *Next Generation Science Standard* (*NGSS*) MS-ESS1: Earth's Place in the Universe (NGSS Lead States 2013).

Now, thanks to technological advancements, SJS participants can request and use images taken by research-grade radio and optical telescopes located all over the world to observe and learn about asteroids, galaxies, star clusters, and planets. SJS facilitates the following experiences:

1. Participants have online access to optical and radio telescopes, data analysis tools, and professional astronomers.
2. The SJS website portal provides an age-appropriate, web-based interface for controlling remote telescopes.
3. The SJS website portal provides inquiry-based, standards-aligned instructional modules.

FIGURE 2 Located in Green Bank, West Virginia, the National Radio Astronomy Observatory's 20-meter-diameter antenna is the only radio telescope on the Skynet network, giving students a window into the invisible universe

The SJS program is accessible for participants with visual impairments because of technology that can convert digital images into tactile models. Once an image is requested by a student, a tactile picture is created through the use of a tactile generator graphic machine capable of producing raised, tactile images (two tactile picture generators are listed in Figure 3). This is accomplished by first printing the image onto specialized tactile generator paper and subsequently running the paper through the machine. When heat is applied to the black ink on the specialized tactile generator paper, a tactile image is created. An online Braille translator (a free Braille translator is listed in Figure 4) is used to convert traditional font to Braille, so the student-generated tactile images can be annotated in both print and Braille (see Figures 4 and 5). This allows students to feel the image and label the astronomical object they requested (see Figures 6 and 7). In this article, we describe a program to teach students with visual impairments about astronomy. The goal is to share our experiences so that teachers can adapt these strategies to teach astronomy concepts to all students using universally designed technological tools.

Skynet Junior Scholars program experience for students with visual impairments

Students with a range of visual impairments attended three one-hour sessions hosted by the Wisconsin Lions Camp in Rosholt, Wisconsin, during the annual summer camp experience. These sessions introduced the topics of astronomical objects (planets, stars, and galaxies) and explored different astronomical tools and how those tools were used by scientists to gather data (using telescopes). Students collected astronomical data through the SJS website portal.

The first class introduced the purpose of using telescopes, terminology associated with telescopes, and the parts that comprise a telescope. While partnered with a sighted leader who had normal vision and who could provide an articulate description of what students were touching, students could feel the telescope and manipulate the telescope by changing the settings. After touching the telescopes and becoming familiar with how they work and their parts, students created a model of a telescope lens composed of art foam and straws that demonstrated how light enters the telescope lens and bends to a focal point to produce a magnified image of the object in the sky (see Figure 1). (Note: Students should wear safety glasses while working to construct the model.)

FIGURE 3 **Materials that enable accessibility of astronomy and other science concepts for students with visual impairments**

Item	Supplier	Description/purpose	Cost
Skynet Junior Scholars	Skynet Junior Scholars *https://skynetjuniorscholars.org*	This site provides online access to optical and radio telescopes, data analysis tools, and professional astronomers.	No cost for online use; however, the site requires users to create an account
STEM Resource iBook: *Reach for the Stars: Touch, Look, Listen, Learn*	iBook provided by the Space Telescope Institute with Braille overlay by the National Braille Press *www.sascurriculumpathways.com/portal/#/astronomy*	The goal of the iBook is to provide information and ideas to make science accessible to all students, including students with visual impairments.	No cost associated; free download
Swell-Form Graphics Machine II	American Thermoform Corporation *http://americanthermoform.com/swell-form-graphics-ii-machine*	This machine can be used to create tactile diagrams and images.	$1,350
Picture in a Flash (PIAF) tactile graphic maker	Humanware *http://store.humanware.com/hus/piaf-picture-in-a-flash-tactile-graphic-maker.html*	This machine can be used to create tactile diagrams and images.	$1,395
Swell-Touch Paper	American Thermoform Corporation *http://americanthermoform.com/swell-form-graphics-ii-machine*	This product is used as the paper for printing diagrams on a laser printer or photo copier. Then the paper is fed through the Swell-Form Graphics Machine to create tactile diagrams. You can also draw on this paper using a special black marker and then feed it through the machine to create tactile images.	100 sheets per package, starting at $105; price increases depending on size
Prismacolor kneaded rubber eraser	*Amazon.com*, local arts-and-crafts stores	This eraser can be kneaded into any shape, making it easy to make 3-D models of planets, Moon phases, and other astronomical objects.	Less than $1 each
Braille translator	*www.mathsisfun.com/braille-translation.html*	This online translator is used to convert traditional font to Braille.	Online use results in no cost
Inflatable solar system	*www.enasco.com*	This realistic-looking, inflatable solar system can be used to demonstrate the sizes and distances between planets.	$43.50
Wikki Stix	Amazon.com, The Braille Store, various local arts-and-crafts stores	Create tactile representations of what you've drawn on the board using these bendable sticks.	$13.95 for a pack of 96 from The Braille Store
Orion TI-36X talking scientific calculator	*www.orbitresearch.com*	This fully-featured, talking scientific calculator is a talking model based on the Texas Instruments Ti-36X Solar Educational Calculator. It is easy to teach students to use independently.	$249
Talking Scientific Calculator app for iPads and iPhones	iTunes app store	This calculator is fully supported by VoiceOver and can be used to perform scientific or basic calculations.	$4.99

FIGURE 4 A student's requested digital image of M27 converted into a tactile image with a Braille description: "M27 Dumbbell, a planetary nebula, imaged with r filter (red-yellow), Yerkes 41 inch telescope. ID 8875535"

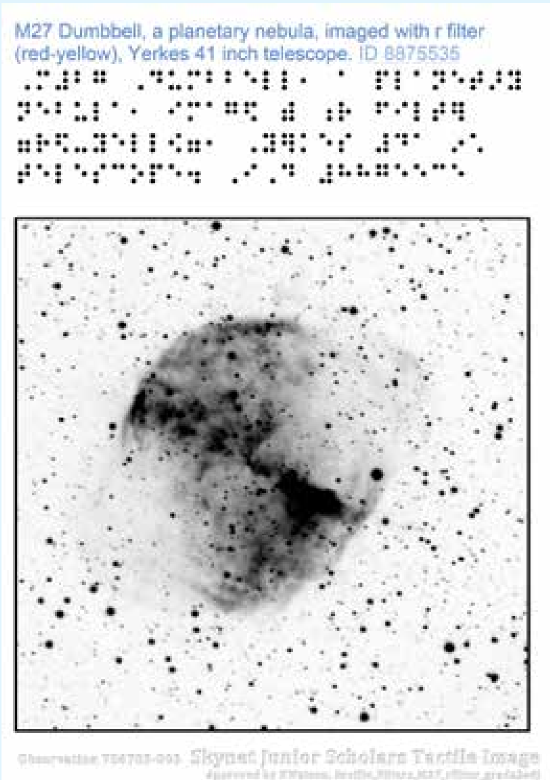
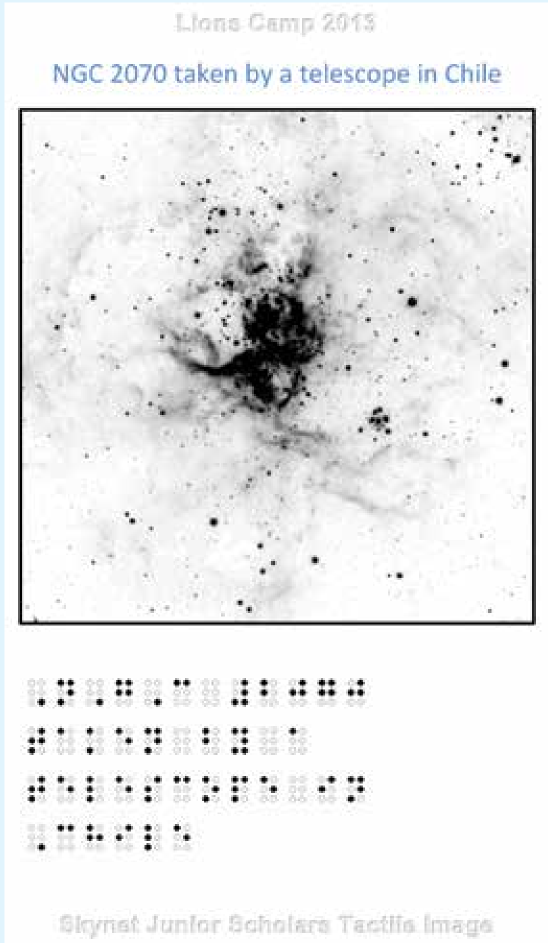


FIGURE 5 A student's requested digital image of NGC 2070 converted into a tactile image taken by a telescope in Chile with a Braille description: "NGC 2070 taken by a telescope in Chile"



Throughout the second one-hour session, tactile images of the objects in the sky were given to students so they could feel and compare and contrast the features of planets, star clusters, and galaxies. A list and description of similar tactile images (e.g., Crab Nebula, M65 Galaxy, and NGC 2158) are available for download (see Resources). A blind eighth-grade student said that feeling the tactile images strengthened her interest in astronomy. "I didn't know that the rings of Saturn looked the way they do," she said. "It was really cool feeling all the pictures and learning that people can actually do this stuff, like look through telescopes and make the pictures."

During the second session, Rebecca Russell, Astro-Tech Program Coordinator and sighted leader, commented about the student experience with the tactile images: "One thing I noticed is that for the students with some vision, it was really helpful to have the tactile images because it provided a way for them to experience astronomy using both sight and touch. It was pretty cool to see that both the blind and partially-sighted students were equally so excited about the tactile materials." Another sighted leader, Kathryn Williamson, Public Education Specialist at the National Radio Astronomy Observatory, stated, "The tactile images are a critical way to connect with Skynet Junior Scholars for students with visual impairments. Hands-on activities are also critical. [It was explained] how important it is to lead up to Skynet Junior Scholars [with tactile images] because when students hear that they will be taking pictures with telescopes, they automatically assume they won't be able to participate and they may write off the experience as not for them." Student experiences during investigations, along with the use of tactile images, are valuable in teaching abstract astronomical concepts. The universal design and hands-on approach of tactical images can also be used in science classrooms facilitated by teachers to enable students to experience astronomy through the sense of touch and sight. By integrating multiple senses during a learning session, tactile images are meaningful learning tools for students. Once students had a grasp of the basic astronomical terminology, the third one-hour session familiarized students with the SJS website portal to explore and collect information about and images of different astronomical objects in the universe.

The SJS website portal introduced students to the different telescopes (optical and radio) they could select throughout the world and learned how to choose astronomical objects, select filters and exposure times, and request an image to be taken by the selected telescope (see Figure 2). Depending on students' degree of visual impairment and ease of manipulation of a computer, students navigated the website in several ways, including increasing the font size on the screen for students with low vision, using software to have the text on the website read out loud to students, or partnering with a sighted leader who guided the student through the SJS website. For teachers who want to incorporate the SJS program into the classroom, the website portal is designed to guide both students and teachers through the process.

FIGURE 6 Students exploring a Hubble tactile image of a spiral galaxy

FIGURE 7 Students exploring a Hubble tactile image of a spiral galaxy

Student reactions to Skynet Junior Scholars

These advances in technology are allowing individuals who once did not have an opportunity to learn astronomy to use scientific tools in order to study astronomy in an innovative fashion. Students who participated in the astronomy classes that used SJS shared the following thoughts about their experiences:

> Reaction #1: "I think that if I didn't join with this project, I would be out of the astronomy world. This has let me realize that I can be an astronomer even though I am blind." – Female Middle School Student, *Anna*
>
> Reaction #2: "It is a very interesting concept, giving all of that scientific power to people who normally couldn't get their hands on it. It feels like 'the real deal'." – Male Middle School Student, *Dean*
>
> Reaction #3: "Awesome that science is more accessible." – Male High School Student, *Robert*

Additional materials and teaching strategies

There are materials that can be used to make astronomy and other science concepts accessible to youth with visual impairments. (Note: Teachers should call their central/district office to receive information about funding for students with disabilities.) The following include tried-and-true instructional strategies that are effective for teaching science to students with visual impairments. These include:

- providing large-scale, tactile objects and models of astronomical concepts for students with visual impairments to touch during a lesson;
- creating tactile images in the classroom using a 3-D tactile printer;
- using magnifying or electronic enlargement tools to enable students with low vision to read and view visuals;
- using specialized software to enhance navigation of websites with a speech function;
- providing Braille-enabled models, reading materials, and tools;
- explaining visuals and videos in depth;
- encouraging students with visual impairments to participate in labs;
- granting additional time to explore laboratory components;
- encouraging student interest in science, support student self-efficacy, and empower the student to pursue individual interests; and
- finding creative ways to use everyday materials, such as puffy paint or clay, to create representations and models of astronomical phenomena.

These strategies and tools are also essential to assess student understanding. Asking students to create three-dimensional models in astronomy or other subjects requires a student to demonstrate knowledge that is often not assessed with verbal-based assessments. Advancements in tools and materials have opened new doors for students with visual impairments to fully learn science concepts and phenomena and more educators are closer to realizing science for all. ■

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Resources

Skynet Junior Scholars—*https://skynetjuniorscholars.org*

Tactile images—*https://sites.google.com/a/starsatyerkes.net/visions-of-the-universe/home/wpcp*

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