# Searching for solar systems like our own: Hunt for exoplanets may someday reveal habitable, Earth-like worlds

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Josh Winn is the Class of 1942 Career Development Associate Professor of Physics at MIT. Photo: M. Scott Brauer

The solar system's configuration is learned in grade school, and forever committed to memory with the help of foam balls, deconstructed coat hangers, and paint. It's a fairly straightforward arrangement: The sun revolves at the center as eight planets—along with dwarf planet

Pluto—orbit within the same plane, and in the same direction as the sun's rotation.

As it turns out, planets around far-off stars do not always obey these rules, as Josh Winn has found. Winn, who is the Class of 1942 Career Development Associate Professor of Physics at MIT, searches for exoplanets—planets outside the solar system that revolve around far-off stars. In the last decade, astronomers have identified hundreds of exoplanetary systems in the Milky Way. Winn has found that many of these systems display very different properties from our own, with planets circling at odd angles, out of alignment with their stars' rotation.

"The planet could be going over the poles of the star instead of the equator, or going backward, or revolving in the opposite direction," Winn says. "It's sort of a gift from nature that it turned out these systems could be so interesting."

Winn and his group in MIT's Kavli Institute for Astrophysics and Space Research are deciphering the geometry of newly discovered planetary systems. The group analyzes changes in starlight as a planet transits, or eclipses, its star. These signals can give scientists clues to a planet's orbit, as well as its size. After combining this information with data, such as a planet's distance from its star, researchers can calculate an exoplanet's mass, composition and atmosphere—essential ingredients for determining whether the planet may be habitable.

"That's one of the big frontiers: studying these potentially habitable planets, and extracting as much information as we can from them," Winn says. "That will be a major preoccupation for us over the next 10 years."

## Finding a path to physics

Winn recently received tenure in MIT's Department of Physics, and is

keen to continue his work in exoplanetary discovery. But early on in his career, he wasn't sure that astrophysics—or physics in general—was the path for him.

Born and raised in Deerfield, Ill., Winn was an impressionable student. "When I took biology in high school, I thought I was going to be a biologist. When I took chemistry the next year, I thought for sure I'd be a chemist, especially since my father is a chemist," Winn recalls. "Then physics happened to be the last thing I took. And that definitely did stick."

He followed his newfound interest to MIT, where he majored in physics, absorbing valuable perspective from his academic adviser, Alan Guth, the Victor F. Weisskopf Professor of Physics, and his thesis adviser, John Joannopoulos, the Francis Wright Davis Professor of Physics. Both professors gave Winn a window into the life of an academic, from the stimulation of intellectual work to the practical business of winning grants and cultivating a research group.

"All the way up until the very end, I was absolutely sure I wanted to be a professor of physics," Winn says. "Then as the actual end of college approached, I started to wonder."

After graduating, Winn skipped across the Atlantic to Cambridge University as a Fulbright Scholar, continuing to study physics and mathematics. When he returned to the United States, unsure whether he wanted to pursue purely academic studies, Winn looked to applied fields, landing temporarily on medical physics and a PhD program at the MIT-Harvard Health Sciences and Technology Program.

Following his first year in the program, Winn was still uncertain, and cast around for inspiration. He had always enjoyed writing, and won an internship at *The Economist*, spending a summer in London.

"I'd write about forestry, archaeology, biology, whatever I'd happened to hear about that week," Winn says. "I really liked that. It was a really good release, like using a different part of my brain."

Upon his return to the United States, Winn decided to transfer to MIT's PhD program in physics. There, he was required to take an introductory class in astrophysics, taught by Saul Rappaport, now a professor emeritus of physics—an experience that "reawakened" a childhood interest in astronomy. He quickly settled on a thesis project, working with professor of physics Jackie Hewitt on gravitational lensing—the study of gravity in distant galaxies. The project took him to New Mexico to observe galaxies with the Very Large Array, an observatory spread over a wide expanse of desert.

"I just remember being floored by my first sighting," Winn says. "There are these enormous radio dishes, 80 feet across, and there are 27 spread out over 20 to 30 miles of this flat plain in New Mexico. It's just beautiful surroundings."

Winn continued working on gravitational lensing as a postdoc at Harvard University, although midway through his fellowship, he began to hear rumblings of an emerging field in astrophysics: the study of exoplanetary systems. "This field seemed wide open for discovery," Winn recalls. "There were a lot of simple questions that nobody had asked yet."

## Charting an exoplanetary course

Winn joined the MIT faculty in 2006, and has since focused on answering many of these questions, most recently regarding the geometry of exoplanetary systems. To get at such answers, he and others rely on the Kepler Telescope, a space observatory launched by NASA in 2009 to observe distant stars and orbiting planets. The telescope is trained on a patch of sky, and continuously monitors thousands of stars

as part of a mission to discover Earth-like planets.

Data from Kepler has helped scientists identify more than 2,000 potential planets in the Milky Way galaxy; there are estimates that billions more Earth-like planets may exist. For Winn, some of the more exciting discoveries have been of systems such as Kepler 11, a star more than 2,000 light-years away. Five small planets revolve around this star, all orbiting closer than Mercury around our sun.

"Those systems are fun to study, because the planets are all pushing and pulling on each other," Winn says. "These are tight little planetary systems that are superficially like our solar system in that there are lots of planets, but it's much closer in."

Winn is among a team of MIT scientists that has submitted a proposal to NASA for a successor to Kepler, called the Transiting Exoplanet Survey Satellite, or TESS. While Kepler has identified thousands of potential planets, these objects orbit very faint, far-off stars, the light from which is difficult to analyze. In contrast, TESS—an observatory of four optical lenses positioned on a satellite at varying angles—would observe the brightest stars in the sky, giving scientists a much clearer signal to work with.

Such improved target stars, Winn says, would make it easier for scientists to answer more complex questions, such as whether oxygen exists in a planet's atmosphere—a possible sign of habitability, or of life.

Looking back on his winding path to astrophysics, Winn says he now feels very comfortable not only in his role as a professor, but as an adviser for MIT students who may be unsure of their next step.

"I just feel really at home here, having spent so much time at MIT," Winn says. "Whenever I do meet a student who doesn't know whether to

continue in physics, I know exactly what to say, and can tell them it's going to be OK."

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