Studying the physics of galaxies

November 3 2014, by Douglas Smith

Although "going out to the telescope is far more romantic," Caltech Assistant Professor of Astronomy Evan Kirby sometimes does his observing by remote control from his office—in this case, using the 10-meter Keck Telescope atop Hawaii's Mauna Kea. Credit: Lance Hayashida/Caltech

Assistant Professor of Astronomy Evan Kirby arrived on campus in August. Born and raised in New Orleans, Kirby earned his BS in 2004 from Stanford University; his undergraduate thesis involved trips to Pasadena to test an instrument built by JPL's Jamie Bock, now also a Caltech professor of physics, and the late Andrew Lange, the Marvin L. Goldberger Professor of Physics at Caltech. Kirby earned his MS and PhD degrees from UC Santa Cruz in 2006 and 2009. His PhD thesis involved an analysis of the spectra of bright stars in dwarf galaxies orbiting the Milky Way. Then as a Caltech postdoc and Hubble Fellow from 2009 to 2012, he moved on to more distant stars in Andromeda and its satellite galaxies. As a Center for Galaxy Evolution Fellow at UC Irvine from 2012 to 2014, he shifted the focus of his spectral analyses from chemical makeups to stellar motions.

Q: What do you do?

A: I study the smallest galaxies we know about. The Milky Way and our nearest big neighbor galaxy, Andromeda, have pantheons of little galaxies in orbit around them. These galaxies are interesting because they are part of our cosmic story. The first galaxies to form were small ones, and over time they got smashed together to build up bigger ones. Tidal disruptions from our galaxy's gravity will eventually rip apart all the remaining dwarf galaxies orbiting us, and they will dissolve into the Milky Way—stars, dust, gas, and all. Similarly, Andromeda will swallow up its dwarfs.

Both sets of satellite galaxies are close enough that I can see each one's individual stars, instead of seeing the whole galaxy as a little smudge. This is important because I can record the spectrum of each bright star separately. A star's spectrum tells me its composition—how much iron is in that star, how much magnesium, how much calcium, and so on—and by compiling that information for each galaxy I can reconstruct its entire history.

The dwarf galaxies' histories tell us about our own; our galaxy formed at the same time and from the same material. It just got bigger faster.

Q: How big a telescope do you need to see a dwarf galaxy?

A: If you're in the southern hemisphere you can see the Milky Way's two biggest dwarfs, the Large and Small Magellanic Clouds, just by looking up at night. But the third biggest, the Sagittarius Dwarf Elliptical Galaxy, was only discovered in 1994 by a team of astronomers at the Cambridge (UK) Astronomical Survey Unit using a 47½-inch telescope modeled after our own 48-inch Samuel Oschin Telescope at Palomar Observatory. The other dwarf galaxies are a lot smaller and a lot fainter, so you need even bigger telescopes to find them.

However, the 10-meter Keck Telescope on Mauna Kea is definitely my instrument of choice. Andromeda is about 2.5 million light-years away, and the Keck gets me out to about 4.5 million light-years. If I go much beyond Andromeda, I no longer see galaxies as individual stars. And if I turn a medium-sized telescope on Andromeda, the stars become too faint to take spectra.

Q: A galaxy named Segue 2 features prominently on your website. What's the story there?

A: Segue 2 was discovered in 2007 by a group of astronomers at the Institute of Astronomy at Cambridge. I took spectra of many of its stars, which told me how fast they were moving. And I found that Segue 2's velocity dispersion, which is a measure of its mass, was less than 2.2 kilometers per second. That's very, very small, and it implies that Segue 2 has about a thousand stars, and up to another few hundred thousand solar masses' worth of dark matter. By comparison, the Milky Way's velocity dispersion is 200 kilometers per second and its total mass, including dark matter, is somewhere around a trillion solar masses. The Large Magellanic Cloud's mass is 20 times less than that. And the smaller dwarf galaxies typically have a few tens of millions of solar masses. A few hundred thousand solar masses is tiny.

Q: You mentioned dark matter. Does your work tell us anything about the nature of dark matter itself?

A: Absolutely. The currently accepted paradigm is "cold dark matter." Back in the 1980s, theorists began making computer models of the early universe to see how clouds of cold dark matter would coalesce. The big clumps became galaxies like Andromeda and the Milky Way, and the smaller clumps, called subhaloes, became their satellites. The simulations predicted that the Milky Way should be surrounded by lots and lots of satellites having about one one-hundredth the mass of the Magellanic Clouds, and a big problem arose well over a decade ago when we couldn't see as many of them as we thought we should. Finding things like Segue 2 is helping to resolve the missing-satellite problem.

Things got worse about three years ago, when astronomers discovered that not only were a lot of the little satellites missing, a lot of the big satellites are also missing! My officemate at UC Irvine, who did a lot of work on this, calls it the "too-big-to-fail" problem. The cold dark matter theory predicts there should be a decent number of subhaloes about one-tenth the size of the Magellanic Clouds. That's too big to not form stars, and if a subhalo that big forms stars, we should see the resulting galaxies—all of them. But we've counted up all the ones we can see, and we're missing about 10 of them. Either they don't exist, or somehow they did fail to form stars. Both alternatives challenge our understanding of how these dwarf galaxies form.

Q: How did you get started on all this?

A: When I was a little kid, I always wanted to be an astronaut. I realized that was unrealistic, so I chose a slightly less unrealistic goal—to be an astronomer. I subscribed to Astronomy magazine and bought all these astrophysics textbooks. I didn't understand a word of them, but I thought

I was so cool for reading them. I went to Stanford knowing that I wanted to study physics and astronomy. I thought I would be a theoretician, but then I realized that observing is way cooler. Going out to the telescope is far more romantic than sitting in front of the computer, and I discovered I loved working with my hands and building instruments.

Q: What do you do for fun?

A: I'm into road cycling. UC Santa Cruz was Mecca for that. I biked uphill to campus four miles every day, and it really got me in shape. It was efficient—you should exercise for half an hour every day, so instead of spending 30 minutes sitting on a bus, I spent 30 minutes sitting on a bicycle.

When I was a Hubble fellow here, I met a postdoc named Hai Fu who became my best friend. I told him I was into biking and he said, "I am too. Let's go on a ride—I know an easy one." So I got in his car that weekend, and he started driving east on 210. After about an hour, I asked, "Where are you taking me?" "Oh, I'm just going to Mount Baldy." Cycling up Mount Baldy, the highest peak in the San Gabriel Mountains, was his idea of an easy ride.

I also play the clarinet. I was pretty serious about it at one point, but never professionally serious. Science and music are both hard to get jobs in, and I knew I had a much better chance in science.

Provided by California Institute of Technology

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