Hunting for ephemeral cosmic flashes— a conversation with astronomer Mansi Kasliwal

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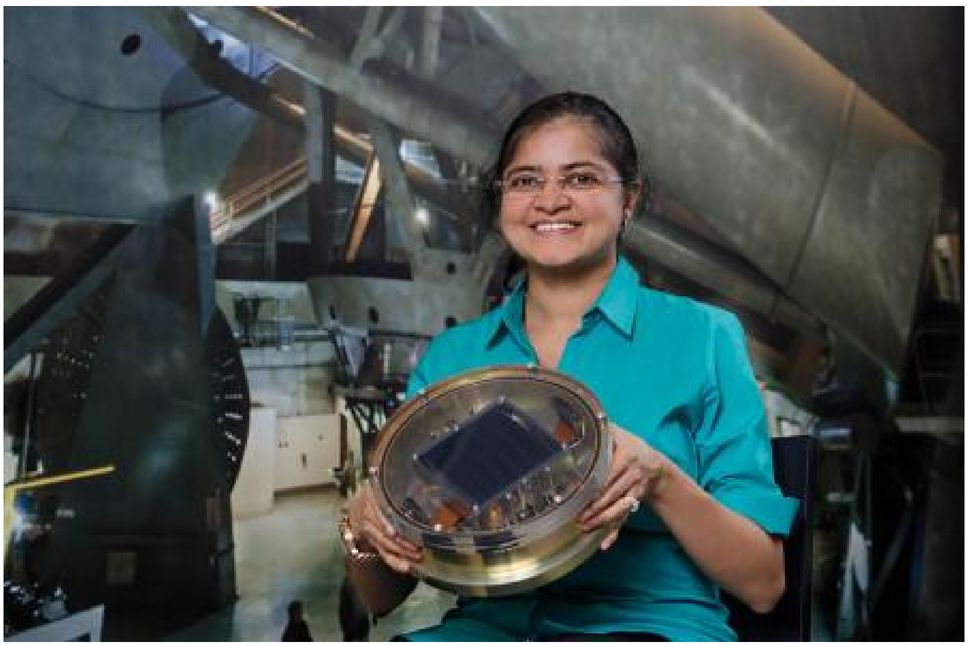

Mansi Kasliwal, assistant professor of astronomy, holding one of the 16 large-format detectors that will be part of the Zwicky Transient Facility camera mosaic. Credit: Lance Hayashida/Caltech

Mansi Kasliwal (PhD '11), a new assistant professor of astronomy, searches the night sky for astrophysical transients—flashes of light that appear when stars become a million to a billion times as bright as our sun and then quickly fade away. She and her colleagues have developed robotic surveys to help detect these transient events, and she has built a global network of collaborators and telescopes aimed at capturing details of the flashes at all wavelengths.

Kasliwal grew up in Indore, India, and came to the United States to study at the age of 15. She earned her BS at Cornell University and then came to Caltech to complete her doctoral work in astronomy. She completed a postdoctoral fellowship at the Carnegie Observatories in Pasadena before returning to Caltech as a faculty member in September.

We sat down with Kasliwal to discuss her passion for discovering and studying these cosmic transients as well as her recent efforts to follow up on LIGO's detections of gravitational waves.

What do you actually see when you discover a cosmic transient?

You see a flash of light on the screen and then you see it disappear—often it's gone in a few days or even a few hours. In that short time, you try to get at the chemistry of the event. You try to take the light from the flash and disperse it; once you get a spectrum, you can tell what sorts of elements it's actually made of.

So, I search for these cosmic transients, try to understand what they are all about, and look for new types of them.

What types of events produce these flashes?

The most common varieties of these flashes are novae and supernovae. Novae are produced by nuclear explosions on stellar remnants called white dwarfs, while core-collapse supernovae are related to the deaths of massive stars. Novae are about a million times the brightness of the sun, and supernovae are a billion times as bright. For a long time we didn't know of anything in between, but today we know of many classes of transients with luminosities between novae and supernovae that involve mergers between these crazy objects. That's where a lot of the most interesting stellar physics happens—when something like a white dwarf smashes into a neutron star or a neutron star smashes into a black hole.

These are extreme events, and it turns out that a lot of the chemical elements that we see around us are synthesized in these explosions. For example, when I was doing my PhD thesis here, I found a rare class of events that generates about half of the calcium in the universe. For decades, people had wondered where all the calcium was made because there was much more of it around than supernovae alone could synthesize. We found this group of very rare explosions. We call them calcium-rich gap transients because they appear to be the mines in the universe where calcium is made.

Are they exploding stars?

We actually don't know. Our best guess is that they are some sort of white dwarf–neutron star merger. We now have a sample of about eight of these events and have been able to quantify the calcium made in each, showing that even though these events are rare, each one produces so much calcium that, as a class, they can account for the missing calcium.

On what does your research currently focus?

Right now I'm looking for the cosmic mines of the heavy elements. If you look at the periodic table, about half of the elements heavier than iron—things like gold, platinum, and uranium—are produced by something called r-process nucleosynthesis. We know these elements are produced by this process, but astronomers still don't know where this process takes place. We've never seen it in action. None of the explosions that we've found so far has been extreme enough to actually synthesize enough heavy elements.

What types of events might produce these heavy elements?

Theoretically, we expect that the most extreme events involve a neutron star merging with a black hole or with another neutron star—because neutron stars and black holes are much denser than white dwarfs, for example. But these explosions are extremely rare. They happen maybe once per 10,000 years per galaxy. By comparison, novae are easy to find because there are about 20 of those per year per galaxy. Supernovae are harder, but they still happen about once per century per galaxy.

To look for these rarer and more exotic events, you need the next generation of surveys and telescopes. Your response needs to be quick. The flash of light happens very rarely, it lasts for a very short time, and it's dim. So you have the worst of all worlds when you're trying to find them.

To overcome this challenge, we are working in close collaboration with Advanced LIGO (the Laser Interferometer Gravitational-Wave Observatory with enhanced detectors to try to detect ripples in the fabric of space-time caused by such extreme events). The idea is that Advanced LIGO will "hear" the gravitational sound waves, and our surveys at Palomar Observatory, currently the intermediate Palomar Transient Factory (PTF), and eventually the Zwicky Transient Facility (ZTF), will see the light from the binary neutron-star merger.

Were you involved in efforts to follow up on Advanced LIGO's recent detection of gravitational

waves? What did you see?

I am leading the Caltech effort to look for electromagnetic counterparts to gravitational waves. PTF responded automatically and promptly to the gravitational wave alerts from LIGO and imaged hundreds of square degrees of the localization that was accessible from Palomar Observatory. Within minutes, we reduced our data, and within hours we orchestrated a global follow-up campaign for our most promising candidates—the brightest flashes that could have possibly correlated with the LIGO detection. We obtained spectroscopic follow-up of our candidates from the Keck and Gemini observatories, radio follow-up from the Very Large Array, and X-ray follow-up from the Swift satellite. None of our candidates was related to the gravitational wave trigger, which is what you would expect for a merger of two black holes.

Finding the electromagnetic counterpart to a merger between two neutron stars or a neutron star and a black hole could identify the cosmic mines of heavy elements such as gold and platinum. It is very exciting that this much-awaited gold rush has actually begun!

Can you talk more about PTF and ZTF and also address how you first became interested in this field?

When I came to grad school and took my first course, the known explosions were of two types: novae and supernovae. I thought, "Nature's more creative than that."

For my PhD thesis, we came up with a plan-A, a plan-B, and a plan-C for how to search for events in between, and the Palomar Transient Factory (PTF) was plan-D.

For PTF, we roboticized a couple of telescopes at Palomar Observatory and imaged huge swaths of sky over and over again, looking for things that changed. Because we were imaging such a large area at such a rapid rate, we actually began finding these very rare flashes of light.

Now we're working hard on ZTF, which should come online in 2017. It is an order of magnitude more sensitive than PTF and hence poised to uncover rarer events. Instead of a seven-square-degree camera, we have a 47-square-degree camera; instead of taking 40 seconds to read out the camera, it will take less than 15 seconds.

Are you working on other projects?

I am leading a couple of projects. The first is a project called SPIRITS, which stands for the SPitzer InfraRed Intensive Transients Survey. We are looking for infrared transients. Although there are many surveys at optical wavelengths, the infrared is completely pristine. It's like going off fishing in new waters.

We use the Spitzer Space Telescope and a bunch of ground-based observatories to take images in the infrared of 242 nearby galaxies on different timescales. Most of what I'm finding so far seems to be mergers of individual massive stars and the births of binaries, which you can only see in the infrared because they form in a red cloud of gas and dust.

This is a Spitzer Exploration Science Program, which means we've been granted more than 1,300 hours of time on the space telescope to do this in a very big way over three years.

And the other project?

I'm also the principal investigator on the GROWTH (Global Relay of

Observatories Watching Transients Happen) project that was recently funded by the National Science Foundation's Partnerships in International Research and Education program. Our network includes six U.S. universities and six foreign countries spanning the globe to observe transients before they fade away, beating sunrise.

In building this network, we went both for telescopes that would make sense for the network and for people who would enjoy this type of science. It is not for everyone. It's nerve-wracking—you're doing work at 2 a.m., 3 a.m., and if you drop the ball, it's a pretty big deal. We tried to pick coinvestigators who are sufficiently excited about the science so that when they wake up, they aren't in a grumpy mood.

Outside of your research, are you passionate about any other activities?

There is a wonderful organization called Asha, which means hope, which runs schools for underprivileged children in India. To me education is the solution to many of the problems in India. I've been helping Asha with fundraising and setting up these schools. When I go back home, I try to visit the Asha schools. When you meet the children and see that they are actually getting an education and have dreams … it feels good. It's small, but it matters.

Provided by California Institute of Technology

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