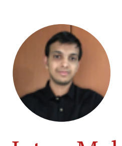
THE SCIENCES

Interview: Shrinivas Kulkarni, Finder of a Thousand Exploding Stars

An interview with the creator of the Palomar Transient Factory survey on the unique value small telescopes have to offer in the age of billion-dollar instruments.

Shrinivas Kulkarni, 2016. Photo: Chris S. Flynn/Wikimedia Commons, CC BY-SA 3.0



Jatan Mehta

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Shrinivas Kulkarni is an American astronomer and currently a professor of astronomy and planetary science at the California Institute of Technology. His primary focus is the study of supernovae – exploding stars – and highly energetic compact objects called neutron stars, as well as developing new methods for astronomy research. Among other things, Kulkarni is known for the discovery of the first millisecond pulsar, the first brown-dwarf star and for first showing that gamma-ray bursts originate outside the Milky Way galaxy.

For 13 years, he directed the Caltech Optical Observatory and oversaw the Palomar and Keck telescopes, two of the international astronomy community's most prized instruments.

Kulkarni recently visited the Tata Institute of Fundamental Research, Mumbai, where Jatan Mehta, a member of the institute's outreach team, interviewed him for *The Wire*.

The questions are in bold, and the editor's and author's notes are in square brackets. The responses have been edited for clarity and brevity.

What got you interested in astronomy, particularly radio astronomy?

When I was a student at IIT Delhi, they offered a fellowship that allowed students to go for summer schools elsewhere. One of those was in Bangalore on astronomy which I was intrigued by. Back then, astronomy was not taught in schools or even at the IITs. Fortunately, the renowned astronomer Govind Swarup was visiting IIT Delhi at the time and I urged him to talk to the organisers and let me in. He did that and it changed my future since that is when I decided to pursue astronomy as a profession.

Of all the domains in astronomy I learnt at the time, the radio astronomy language made immediate sense to me. That was when the Ooty radio telescope went operational and it seemed like the field would bloom. So I thought there were more opportunities, and also that India would be behind in optical astronomy by contrast.

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What was it like finding the first millisecond pulsar as a graduate student in 1982?

[Author's note: Neutron stars are the dead cores of massive stars that have exploded. They contain lots of electromagnetic and nuclear energy and spin rapidly. A pulsar is a neutron star that emits photon beams from its poles in the radio part of the EM spectrum. A millisecond pulsar is a pulsar whose rotation period is one or a few milliseconds.]

Working with the radio astronomy group at the University of California, Berkeley, was fascinating. It was a very open place in that you could work on any part of the problem. So I learned all techniques in radio astronomy that I could.

My guide, Donald Backer, was interested in pulsars and using novel techniques to infer information about them. He was pursuing a pulsar he thought was interesting. That is when I discovered the first millisecond pulsar. It surprised Donald and everyone else in the community because they thought it must be a slower rotating object. And that is when my approach paid off – i.e. to become a master of techniques. Other astronomers had looked at the object in the past but they didn't use relevant techniques to sample the pulsar data at higher resolutions. So the combination of mastering techniques and being curious led to that discovery.

Your team operates the Palomar suite telescopes in California. Tell us about what motivated you to found the Palomar Transient Factory survey, famous for finding thousands of supernovae, even exotic ones.

The Palomar observatories consist of three telescopes: an old 5-metre telescope, a small 1.2-metre one but with a large field of view, and lastly a 1.5-metre telescope . When I became director of the Caltech optical observatories in 2006, which included the Palomar ones, there was a concern: 'Do we need to maintain the smaller telescopes?' The use being made of them was not too productive. So I told my colleagues to come up with innovative ideas for these two telescopes or we'd close them down or give them away to some other university or institute that didn't have such facilities.

Then it occurred to me that the way people are finding supernovae is one at a time. It was a manual affair – to have a grad student observe a part of the sky for nights, analyse the data and compare with old records to then find a supernova. The best group at the time was Alex Filippenko's group, which was finding one supernova every three days by looking at nearby galaxies. Others were spotting one supernova per month at best. The automation employed throughout the entire process was limited.

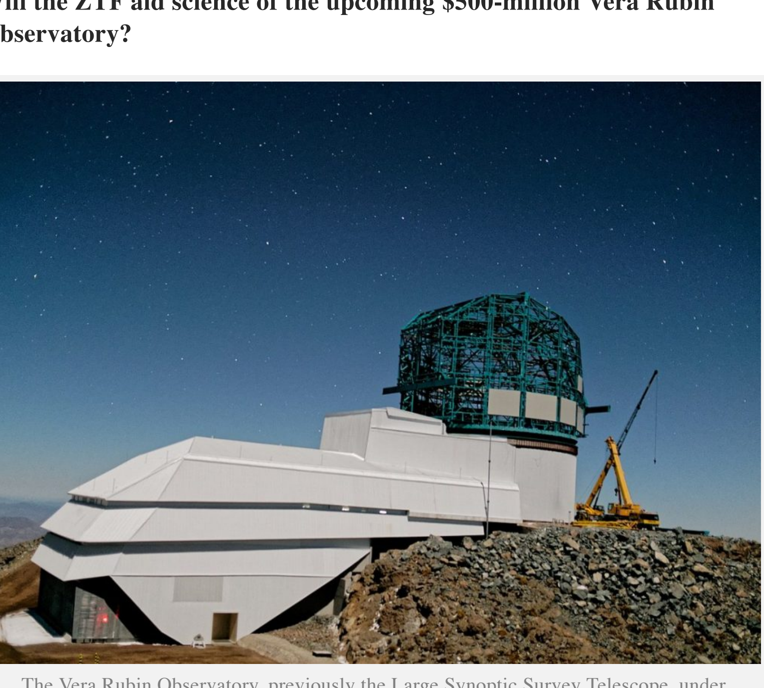
> *We should keep observing everything we can because we don't know what will become important.*

So I thought, why not make this an industrial operation? My timing was good because things like machine learning were around the corner, detectors were getting cheap and so on. So I conceived the Palomar Transient Factory. The idea was to take over the two smaller telescopes and focus on what they can do best. The 1.2-metre telescope would take wide pictures of the sky and compare with older ones. If something new comes up, the higher-resolution 1.5-metre telescope would verify that it really was an object [of interest] and discern the nature of the beast. And then the 5-metre telescope would use its spectrograph to spot the telltale signatures of the explosion and characterise its nature: whether it was a nova, a supernova, a specific type of supernova, a flare star, etc.

So the idea was to automate the entire thing. We could do that because all the telescopes were operated under the same management. We went online in 2009 and in the very first year, the Palomar Transient Factory not just discovered but also classified 700 supernovae! That eventually led to the current upgrade, called the Zwicky Transient Facility [ZTF] for the 1.2-metre telescope, named after Fritz Zwicky, the first astrophysicist at Caltech and a pioneer of supernovae studies.

[Editor's note: The ZTF upgrade concerns the use of a new and advanced camera attached to the 1.2-metre telescope that will capture images of objects in the night sky that change rapidly in brightness. The camera consists of 16 charged-coupled devices, each with a resolution of 37.8 megapixels.]

Will the ZTF aid science of the upcoming $500-million Vera Rubin Observatory?



The Vera Rubin Observatory, previously the Large Synoptic Survey Telescope, under construction atop the Cerro Pachón mountain Chile. Photo: Wil O'Mullane/Wikimedia Commons, CC BY-SA 4.0

[Editor's note: The Vera Rubin observatory boasts of an 8.4-metre-wide mirror that will be used to photograph its entire field of view once every few days, assimilating 1 million GB of astronomical data per year that will be processed with 250 teraflops of computing power.]

The National Science Foundation [NSF] has in fact declared that the ZTF is the stepping stone to the Vera Rubin telescope. In 2013, we thought maybe we could do a lot of the Vera Rubin telescope science today using this advanced setup, of rapid imaging combined with robotic spectroscopy. So we proposed to the NSF and we got the highest funding in the round, a total of $11 million.

NSF's funding was roughly matched by seven institutions around the world. So it goes to show that they too saw the value in what the ZTF can do. That's saying a lot because they committed money to a project led by a principal investigator of an institute that is not their own!

So at the end of the day, the ZTF – with its $25 million funding – can do quite a bit of the science, competitive as well as complementary, of the billion dollar enterprise that is the Vera Rubin telescope.

How will smaller telescopes like the three at Palomar stay relevant in the age of the big billion-dollar telescopes that are coming online in this decade?

Paraphrasing Richard Feynman, I would say, "There's plenty of room sideways." All the leading edge problems – the origin of the universe, habitable exoplanets, etc. – are mainstream. But most people I think do not appreciate the value of insights derived from all the other interesting science that can be done. It misses the fact that astronomy is a phenomenological subject. There's no real theory of astronomy, which is why varied observations are needed to understand the universe.

So we should keep observing everything we can because we don't know what will become important. For example, millisecond pulsars, which are rare objects by volume, have turned out to be fundamentally important for understanding gravitational waves from the early universe. That goes to show that sideways investigation can eventually lead to very big breakthroughs.

What limits people from realising this and where it is connected to operating smaller telescopes is in coming up with unique ideas. Let's take an institution with a 2-metre optical telescope, which are now a dime a dozen. In this decade, such a telescope would have to compete with hundreds of other such telescopes and be completely dwarfed by the huge existing and upcoming ones.

The right solution would be for colleagues in the department to get together and say we can't do much obvious science like the way we could before. We should instead choose a unique case and focus on that. So if they choose a niche, these telescopes can do great things. Do one thing and do it really well. But institute-level politics typically don't allow such things.

At the American Astronomical Society meeting this month, scientists presented a result that challenged the existence of dark energy. Is the ZTF equipped to help resolve this challenge?

[Editor's note: Dark energy is thought to be the energy contained in the universe that is causing it to expand rapidly. One way astrophysicists infer that the universe is expanding is by studying how light from one kind of supernova that has a fixed brightness is changing in time. That is, if the light from such a supernova is becoming redder, due to the Doppler effect, it could be because the distance between Earth and the supernova is increasing. Recently, however, some astronomers have found preliminary data to suggest we may not know these supernovae well enough and thus could be misinterpreting their brightness to mean the universe is expanding.]

Absolutely. The supernovae type you refer to is a big part of ZTF observations. For nearby galaxies, because of our large field of view, we'll be leading in the volume of observations and expect to solve some impending questions.

Let's turn to SpaceX's Starlink satellites. There will soon be thousands of them. Do you think that will be a problem when conducting these astronomical surveys?

They will be a significant problem. It will have a big effect and is a serious matter for us – not just us but the entire community. I think we need international laws against pollution in outer space, otherwise it will affect everyone.

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One of the reasons astronomers move to darker and darker places is to get away from city lights, and this issue you can't get away from no matter where you are. And I don't think you can do all astronomy from space, as Elon Musk suggests, not to mention that it will be an incredibly expensive endeavour.

What is the purpose of your visit to India?

I'm here to interact with members of the department of astronomy and astrophysics at TIFR and see if I can develop new collaborations with them. I'm also here to help the students with research opportunities and help get appropriate data for their work.

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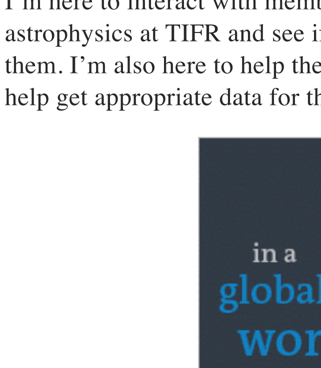

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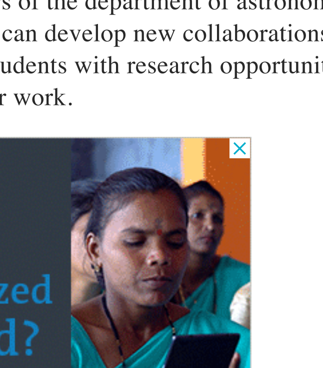

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