Podcast interview: Chryssa Kouveliotou

PNAS: Welcome back to Science Sessions. I'm Brian Doctrow.

When it comes to understanding the cosmos, visible light only tells a part of the story. Looking at other parts of the electromagnetic spectrum, such as radio waves, can reveal objects that are difficult or impossible to see in visible light, as well as provide new information about objects that are visible, yielding a more complete picture of the universe in which we reside. Our Milky Way galaxy has been observed, catalogued, and studied in just about every region of the electromagnetic spectrum. However, one region—the X-ray region—has not yet been explored as deeply and systematically as others. National Academy of Sciences member Chryssa Kouveliotou, an astrophysicist at The George Washington University, is attempting to fill this gap in our knowledge by conducting an X-ray survey of the galactic plane—the plane on which the majority of the observable galaxy's mass lies. I recently spoke with Kouveliotou, who explained how her survey differs from previous X-ray astronomical surveys.

Kouveliotou: Previous surveys were not as deep, and for those who were closer to the depth that we want to do, the spatial resolution was not as good. The galactic plane is very thick in sources, so we need a very good resolution to be able to distinguish between two sources that are very close together.

PNAS: The principal instrument for conducting this survey is the Neil Gehrels *Swift* Observatory, a space telescope launched by NASA in 2004. Originally designed to study gamma-ray bursts, *Swift* has a number of features that make it well-suited for this project.

Kouveliotou: The *Swift* Observatory has the XRT, which is the X-ray telescope, and the UVOT, the ultraviolet-optical telescope. This is actually a bonus, because the XRT and the UVOT point at the same place at the same time, so every time we get an X-ray dataset, we get an optical and UV dataset, so we can compare the two wavelengths. So we do basically multiwavelength observations for free. And *Swift* has a large field of view, otherwise it would take years to do the whole galactic plane. We estimated that with 5000 second exposures, we will be able to probe up to the other end of the galaxy, with up to the luminosity of 10^{34} ergs/second. That means if we took a star that was 10 million times fainter than the sun, and we put it at the other end of our galaxy, we still could see it with our survey. We will be able to look at areas of the galaxy that have not been monitored or observed in X-rays, and possibly—hopefully, I should say—identify new sources.

PNAS: Once the *Swift* survey spots a new X-ray source, Kouveliotou and her group use other instruments, like the Chandra X-Ray Observatory, the Nuclear Spectroscopic Telescope Array (NuSTAR), the XMM-Newton Observatory, the NICER experiment on the International Space Station, and the Hubble Space Telescope, to perform more detailed observations and identify what type of object the source is. Kouveliotou is particularly interested in identifying high-mass X-ray binaries. These are binary star systems that consist of a massive star—at least 10 times the mass of the Sun—orbiting a compact object, such as a neutron star or black hole.

Kouveliotou: These massive stars don't last very long, they die very fast. And observing their binary stage of life, and knowing how old the system was, where it is, how far it is, we understand how fast they are being born, and they evolve, and die. In other words, we understand the star formation rate of our galaxy. We also can get a better understanding of cosmic chemical evolution because these massive stars are the furnaces where all of the elements are being produced. Going a step farther, after we understand our own galaxy, is to expand this knowledge and scale it and understand how this works in other galaxies. X-ray binaries is what we actually observe from the other galaxies in X-rays, because these are the brightest X-ray objects. So if we understand the binaries here, or other sources in our galaxy, then we can project that and explain properties of other galaxies as well.

PNAS: In addition to the high-mass X-ray binaries, Kouveliotou also hopes to find magnetars. These are neutron stars with extremely strong magnetic fields. Magnetars were discovered by her team about 20 years ago, and much about them is still poorly understood, such as how they are distributed throughout the galaxy.

Kouveliotou: Whether they're close to clusters of stars, are they associated with star clusters, what are the masses of the stars in the star clusters they are coming from, are their progenitors massive stars as well or are they not massive—how do you make a magnetar, basically? That's one of the questions that we still don't know very well. Magnetars were discovered when a couple of them were documented to emit very short, like 100 ms, X-ray bursts from the same direction. In recent years, we also saw similar bursts coming from pulsars that are on the high end of magnetic fields. So there must be a link between some of these populations, and that's even more important to understand. What makes a pulsar? What makes a magnetar? And how do they evolve from one to another, if they do?

PNAS: The survey has already led to some unexpected findings, as in the case of an X-ray bursting source that appeared in October 2017.

Kouveliotou: Originally we thought it was a black hole binary or a high-mass X-ray binary. So we started observing it with radio, and it was not detectable in radio. Then NuSTAR observed it, and we found, all of a sudden, unexpectedly and beautifully surprising, X-ray bursts. Not bursts like the magnetar bursts, but bursts from a type of source, called an X-ray burster.

PNAS: Only 110 of these X-ray bursters were previously known in our galaxy. Kouveliotou's survey found number 111.

Kouveliotou: It's the beginner's luck, I suppose.

PNAS: Kouveliotou's survey began in March 2017, and is currently on hold while Kouveliotou and her team analyze the data they've already collected. Data collection will resume next year.

Kouveliotou: The plan was, and still is, to do the whole galactic plane. But we can't do it at once. We started with two areas, which are +10 to +30 and -10 to -30 degrees from the galactic center—40 square degrees altogether. These areas are found to contain about 40% of the high mass X-ray binaries, and about a similar amount of the magnetars. So we went where hunting is good. When we're done with that, we plan to submit another proposal for another 40 degrees. So as long as the instrument is going, and as long as I keep going, I will keep doing this until we cover the galactic plane.

PNAS: Thanks for listening. Look for more Science Sessions podcasts at www.pnas.org.