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Special Topics : Gamma-ray Bursts : Chryssa Kouveliotou Interview - Special Topic of Gamma-ray Bursts

AUTHOR COMMENTARIES - From Special Topics

Gamma-ray Bursts - June 2009
Interview Date: September 2009

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Chryssa Kouveliotou

From the Special Topic of Gamma-ray Bursts

In our Special Topics analysis of gamma-ray burst research over the past decade, the work of Dr. Chryssa Kouveliotou ranks at #4 by total cites, based on 114 papers cited a total of 4,165 times. According to Essential Science IndicatorsSM *from Thomson Reuters, her record includes 183 papers, the majority of which are classified in Space Science, cited a total of 5,998 times between January 1, 1999 and April 30, 2009. She has also been named a Highly Cited Researcher in her field.*

Dr. Kouveliotou is a member of the Gamma-Ray Astrophysics Team at NASA's Marshall Space Flight Center in Huntsville, Alabama.

In the interview below,* ScienceWatch.com *correspondent Gary Taubes talks with Dr. Kouveliotou about her work in gamma-ray bursts.

SW: You've been working on gamma-ray bursts long before they caught the imagination of the astrophysical community at large. What prompted your research?

I first started working on gamma-ray bursts in 1978 when I was doing my Ph.D. work in Germany, and I used to joke that there were two and a half or three and a half Gamma Ray Burst astronomers at the time, and I was the half. I was just very intrigued by these bursts. They were a brand-new phenomenon and we didn't know anything about them. There were maybe three or four instruments at the time capable of seeing them.

Remember, the phenomenon was only discovered in 1967, when the VELA satellites were launched. These were designed to enforce the nuclear test ban treaty by monitoring clandestine nuclear explosions from space. They observed the first gamma-ray burst in 1967, and then many more, but all they could say is that they didn't come from the solar system. The first paper on the discovery of gamma-ray bursts came out in 1973.

When I got into the field there were a few instruments capable of observing them; the field was very small and the interest was very small, although slowly it started growing. Then the people here in Huntsville, Alabama, led by Jerry Fishman, designed and built an instrument to fly on the Compton Gamma-ray Observatory, which was launched in 1991, and that instrument was dedicated to burst detection. It was called the Burst and Transient Source Experiment—BATSE. I started working with that group when the satellite was launched. When the instrument was turned on, data started coming and it was a watershed—every day a discovery. Those were very exciting and wonderful times.

SW: What was it about the 2003 *Nature* paper on the gamma-ray burst of March 2003 that made it such an influential paper (Hjorth J, *et al*., "A very energetic supernova associated with the gamma-ray burst of 29 March 2003," 423[6942]: 847-50, 19 June 2003)?

Well, you have to realize that what we do is look for these bursts first in the gamma-ray part of the spectrum, where there might be one or two a day; we try to establish the direction, and then we look in other wavelengths to try to identify a counterpart. The question was after all these thousands of gamma-ray bursts—with BATSE, we had 2,704 confirmed events in almost 10 years—we still needed to identify the optical counterparts. The way BATSE located gamma-ray bursts wasn't very accurate. Its error box was large and the ground-based observatories would not spend their precious observing time trying to cover the entire region of the error box. Nobody was very much interested in looking for the optical counterparts except us.

And we didn't know what the critical point was in time. How quickly did we have to look after seeing the burst? Did we have to do it fast, or would the source still be visible for days afterward? And then how bright would the optical counterpart be? And how would the brightness decay? What was the limiting magnitude of a counterpart? Did we need a big telescope or a small telescope that was fast enough? When I worked with BATSE, we worked with a lot of other people; we started these collaborations and we gave them all these directions we calculated, but we were not able to find anything.

This changed with the launch of Beppo-Sax in 1997. Beppo-Sax had an instrument, the Wide Field Camera, which was ideal for locating gamma-ray bursts. It could locate them very accurately compared to BATSE. In February 1997, it discovered the first X-ray counterpart of a gamma-ray burst, and the location was accurate enough that an optical counterpart was also observed. The big question was what was the origin of these gamma-ray bursts—galactic or cosmological—and, depending on where it was, what could create something like that?

SW: What were the options for what could cause one of these bursts?

There weren't many models. One viable one was the collapsar model, suggested by Stan Woosley in 1993. He suggested that gamma-ray bursts are the products of the collapse of a massive star, which ejects its hydrogen envelope and is collapsing into a black hole. Another model was the merging of two neutron stars—or two compact objects. Once the second or third event was identified with a counterpart, we were able to put the Keck telescopes on the sources and measure the Doppler shifts, determine the redshifts of the events—the distance—and establish that they were cosmological in origin.

SW: Is this is what you did with the 29 March 2003 burst?

This paper was about the third burst that could be identified with a supernova. The whole idea is that when a collapsar dies, you probably see an effect like a supernova explosion. People looked to see if a supernova explosion was associated with a gamma-ray burst. The very first one found was in April 1998—April 25th. It was found serendipitously. We looked at the location of the burst with an optical telescope and saw this very, very bright source. This is the nearest ever gamma-ray burst to have been reported—37 megaparsecs from here. No wonder it was so bright. But that event was disputed. People weren't convinced it was really associated with the gamma-ray burst because the original error box was so large. There was a good probability it was associated, but not 100%, maybe only 99%.

The first GRB associated with a SN (April 25, 1998): (fig. 1) is the AFTER and (fig. 2) is the BEFORE. The circle with the dot in the center is where the explosion took place in 1998 as can be seen by the bright source at the left at the same place.

Figure 1 [+] enlarge

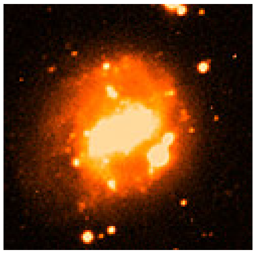


Figure 2 [+] enlarge

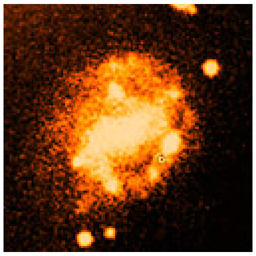
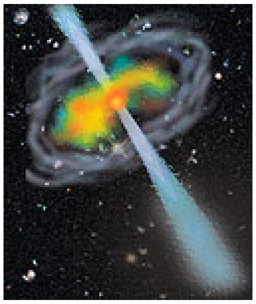


Figure 3 [+] enlarge



An artist's concept of the exploding star that creates the GRB jets as it collapses.

All images: ©NASA

Then in 2003 we had the third such event—030329 came along. It was probably among the top two percent of the brightest bursts ever detected. It was very bright and also nearby. And now we had collaborations—huge teams—ready to go to work from the ground and follow up quickly on the optical counterpart. In this case, we were able to detect the optical effect. When we looked at the spectrum, we saw lines there that were broadening every day; the expansion velocity was making them broader; the ejecta from this supernova were expanding at a very high velocity; one of the fastest exploding ejectas ever recorded. The shape was very similar to the spectra of that event reported in 1998.

So in one fell swoop this event affirmed that a supernova can be associated with a gamma-ray burst and it confirmed the 1998 association with a supernova. It also established that a collapsar was a pretty good candidate for these longer events.

SW: What do you mean by "longer events?" Does that mean there are shorter events, as well?

This is one of the major contributions I've made to this field. I established the existence of this bimodal distribution—a group of short events, roughly less than two seconds, and a group of longer events that average around 30 seconds. One of the problems with Beppo-Sax, for example, is that it didn't have the capability to detect short events, so all the counterparts identified for quite a while were exclusively of these longer events. Then the Swift satellite was launched, and that can point the satellite at the counterpart in less than a minute—that's the strength of the satellite, hence the name—and so it could find counterparts for the short gamma-ray bursts as well.

SW: So what is the best explanation for the shorter events, and are they distinctly different than the longer ones?

We used to think the longer events were associated with collapsars and the shorter events with mergers. Now I'm not entirely sure we can say that. We're still waiting to see more to be sure.

SW: Why the uncertainty?

It used to be that we thought mergers only happened in very old populations, but now models say that you can have them in younger populations, and some of these short events have been located in younger galaxies—star-forming galaxies, which didn't fit the old models. And now there are collapsar models that could also conceivably create short events if the right conditions are met. So it's looking like a medley.

We can't say one model makes all the long events and this other model makes all the short events. Other events may also create these bursts. Magnetars—magnetic stars—are a possibility. This is one of my other contributions to this research. Magnetars are neutron stars conjectured to have extremely high magnetic fields—about 1015 gauss or about a thousand times higher than so-called normal pulsars.

> *"...when we look at these high-energy transients, we can expect anything."*

These were also found serendipitously. They're also pulsating stars; they're rotating and their peculiarity is that they are slowly rotating. So far, the dozen we've discovered have a very narrow period range—from 5 to 12 seconds. Other pulsars have a much wider range.

SW: When were these magnetar-associated events first discovered, and what was serendipitous about it?

In 1986. You realize that in principle we should never see a burst from the same place twice, at least not according to the burst models. This shouldn't happen, since the event that causes the burst either blows up the star or merges two stars together. Then in 1985-86, Kevin Hurley was working with data from a Russian satellite and he realized that some of the events seemed to come from the same quadrant of the sky, the same general direction. That's all he could say. He sent around messages to people who had X-ray detectors, and I was then working on the SolarMax mission looking for gamma-ray bursts. He pointed out one burst that came at a particular time and said see if your instrument detected it, and we did.

Then the detector on ISEE-3/ICE satellite, which was still alive, detected it again. We were able to triangulate the signal from the sky and we pinpointed it to the same source. A meeting was held and this was one of the main subjects—what is this repeater? Why is it repeating? What kind of source is it? A different type of star? We decided to call it a soft gamma-ray repeater, because the average energy of the photons in these repeating bursts was much lower than the average energy of photons associated with other gamma-ray bursts.

Then we went back and found another repeater coming from N49, a supernova remnant in the Large Magellanic Cloud. So it all came together. These sources created a new group, the so-called soft gamma-ray repeaters. When a new satellite was launched in 1996, the Rossi X-ray Timing Explorer, I wrote a proposal to look long and hard at one of those sources, which by that time had been identified as a faint X-ray source, to see if it was rotating. These sources exhibited another characteristic: they can be dormant and then suddenly they are active and emit multiple bursts. When this happened in the source we were studying, we identified a period.

We can now say these sources are neutron stars and it's a totally different phenomenon. Right now, as I said, we have about a dozen of these sources, and there's a lot of development in the field. I'm now leading a project with the Fermi Observatory, which was just launched a year ago. Whenever one of these sources becomes active—four did in the last year—we do a lot of analysis on what exactly is happening.

SW: How would you summarize what you've learned about gamma-ray bursts over the past ten years?

That when we look at these high-energy transients, we can expect anything. There are a lot of different objects out there and there are probably phenomena we've yet to identify. No single model can describe the whole thing.

SW: What research are you doing now and what do you have planned for the future?

Well, I'm still working on gamma-ray bursts, and on soft gamma-ray repeaters, these magnetars. But I'm also very interested in different areas of research. We've just submitted a proposal to the Astrophysics Decadal Survey. Every 10 years the field of astrophysics and cosmology is reviewed by a committee, which determines what should be done in the next 10 years. We've proposed to study cosmic chemical evolution: star formation and evolution, when the first stars formed, when the first galaxies formed. What is this cosmic web, in effect? To do this, we're going to use gamma-ray bursts as a tool.

So instead of being the goal of the research, these bursts are going to be one of our tools. We're going to study structures by using the spectra from gamma-ray bursts that explode behind these structures. We're going to study what the absorption lines in the spectra are, and then, as the gamma-ray bursts die away—they're very helpful in this sense—we're going to look to see if we can detect the same lines in emission in the spectra and then tie the two together with the structures at that location and so study the cosmic web—in the intricate network of stars and matter and clusters of galaxies. The mission we've proposed is called Xenia—from the Greek word for "hospitality"—and it's a very big collaboration. It's at least 50 institutions, with 90 team members from all over the world.

SW: When do you expect to hear if it gets funded?

The only thing we're going to hear from the Decadal Survey is whether it should be a priority in astrophysics. We'll get a ranking, that's all. Then if Congress decides to fund NASA sufficiently, NASA will open the field for proposals for missions. If we're ranked high scientifically, if we fall close to the top in this ranking, then we have a chance to do this. It all depends, of course, on whether NASA gets the money.

SW: If there was one thing you could go back and do differently in your research career, what would it be?

I would probably just spend more time learning how to build detectors—doing hands-on development of the instruments. Spending time building these kinds of instruments is the best way to understand their strength and limitations. I never did that. I wish I had.

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Chryssa Kouveliotou's current most-cited paper in *Essential Science Indicators*, with 481 cites:

Hjorth J, *et al*., "A very energetic supernova associated with the gamma-ray burst of 29 March 2003," *Nature* 423(6942): 847-50, 19 June 2003. Source: *Essential Science Indicators* from Thomson Reuters.

Additional Information:

Chryssa Kouveliotou is featured in *ISIHighlyCited.com.*

KEYWORDS: GAMMA-RAY BURSTS, BATSE, BEPPO-SAX, OPTICAL COUNTERPARTS, CRITICAL TIME, WIDE FIELD CAMERA, MODELS, COLLAPSAR, GRB 030329, BIMODAL DISTRIBUTION, SWIFT SATELLITE, MERGERS, MAGNETARS, SOLARMAX, SOFT GAMMA-RAY REPEATER, SUPERNOVA,

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