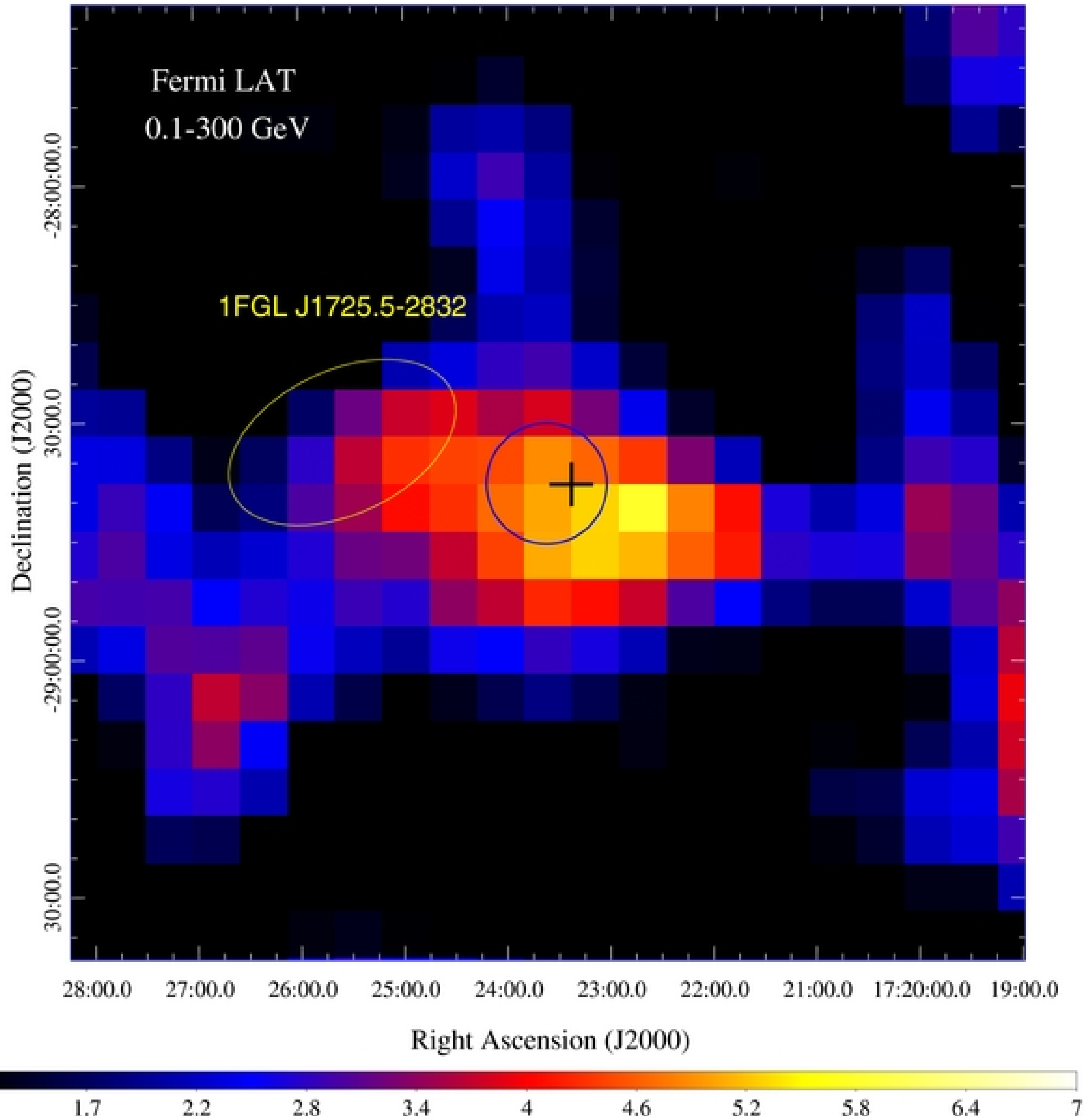
An amateur astronomer just made a stellar discovery about pulsars

A companion star's magnetic field may be switching a "black widow" pulsar on and off

By K.N. Smith | Published: Thursday, December 8, 2016



Background-subtracted 0.1–300 GeV γ-ray count map, smoothed with a Gaussian width of 0fdg3, of the 2° × 2° region centered on PSR J1723−2837, the radio timing position of which is indicated by the black cross. The blue circle indicates the error circle of the best-fit position at the 68% confidence level. The error eclipse of 1FGL J1725.5−2832, which is not regarded as a background source, is shown.

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With a backyard telescope, an amateur astronomer helped make an important discovery about so-called “black widow” pulsars.

When a massive star dies, much of its mass explodes outward in a supernova, leaving its core to collapse in on itself. The result is a small, incredibly dense object called a neutron star, with enough gravity to strip gas away from any star unlucky enough to be caught in a binary system with it. As it feeds on its companion, the neutron star spins faster and faster; eventually, spinning around hundreds of times a second, it flares to life, blasting out two beams of intense radiation in opposite directions along the lines of its magnetic field. The regular timing of this particular type of neutron star as heard by radio astronomers gave rise to the name “pulsar.” Sometimes, these flares are visible to optical observers as well.

At this point, the pulsar stops feeding on its companion, but their relationship doesn’t get any less destructive. The pulsar is now blasting enough radiation and stellar wind out into space to stop gas from flowing from the companion star, but it’s also blasting away material from the companion star, which will eventually erode the star completely.

But sometimes a pulsar goes back to its old ways. The radiation beams seem to “switch off” somehow, the stellar wind dies down, and the pulsar resumes cannibalizing its unfortunate companion. Many pulsars repeat this cycle several times, and no one is quite sure why. However, astronomers have some new ideas on the subject thanks to a 30cm reflector telescope in André van Staden’s Western Cape backyard.

A Trans-Atlantic Collaboration

With his 30cm reflector telescope, Van Staden wanted to look at the visible companion stars of these “black widow” pulsars, and in 2014 he found a list of them on University of Toronto astronomer John Antoniadis’ website. One, MSP J1723-2837, was in the right part of the sky to be visible from van Staden’s home in South Africa, and nobody had recorded a brightness curve – the rise and fall in the star’s brightness as it orbits the pulsar – for the star. Van Staden saw an opportunity to do something original.

Over the next 15 months, he made about 3,000 observations with his telescope and CCD camera, mapping out a brightness curve for MSP J1723-2837’s companion star. Soon, he noticed something unusual in his data.

Normally, the brightness curve for a pulsar’s companion star rises and falls with the orbital period of the system. That’s because the pulsar’s gravity usually pulls at its companion star strongly enough to distort the star into a teardrop shape. When the long sides of the teardrop are facing Earth, the star appears brighter because we’re seeing more of its surface. When the star is end-on to observers on Earth, it looks dimmer because less of its surface is visible.

MSP J1723-2837 was different. What van Staden noticed was that the changes in the star’s brightness didn’t exactly line up with the binary system’s 15-hour orbital period; instead, the brightness curve lagged a little behind.

“After consulting a number of science papers on MSP companion LC data, I realized that the behavior of J1723-2837 according to my data was unexpected. I started to make inquiries to some of the authors of the papers and was directed to John [Antoniadis],” he said.

He forwarded his data to Antoniadis, but didn’t expect much. “I did not expect the interest in my data, assuming that [professional astronomers] do not really have the time to overlook data captured with a 30cm telescope,” he said. “Also much of the work on MSP’s is done in radio or higher energy frequencies.”

But Antoniadis also saw the interesting puzzle in van Staden’s data, and a collaboration was born.

“We exchanged hundreds of emails since early 2015 and eventually, when putting all the data from 2014-2015 together, the puzzle started to unfold,” said van Staden. “John [Antoniadis] supported me a lot to rule out any possibilities of systematic errors, going over the same data many times. The LC data at first looked chaotic, but I continued to make observations and share my data with John.”

Spotting the Answer

As the two pored over van Staden’s data, they realized that the companion star actually rotates slightly faster than it orbits the pulsar. That helped account for some of the lag in the light curve, but there was more to the puzzle. The answer turned out to be huge sunspots on MSP J1723-2837’s companion star. They’re larger, relative to the diameter of the star, than the spots that sometimes darken patches of our own Sun’s surface, and they decreased the star’s apparent brightness when they rotated into view from Earth.

That’s a significant finding, because sunspots form in response to the activity of a strong magnetic field. If MSP J1723-2837’s companion star has a strong enough magnetic field, it could be driving the complicated, on-again, off-again relationship between the pulsar and its doomed companion.

Normally, there’s a radiation hotspot on the side of the star nearest the pulsar, where the pulsar is blasting its companion with gamma radiation and stellar wind. But there’s no hotspot on MSP J1723-2837’s companion star, which means either there’s no stellar wind, or it’s blowing in some direction other than toward the star. A magnetic field could help explain that, because it could be interacting with the pulsar’s stellar wind in much the way Earth’s magnetic field interacts with the solar wind from our Sun.

Antoniadis and van Staden published their work in *The Astrophysical Journal*.

New Questions

“Andre [van Staden]’s observations helped us understand the role of magnetic fields in systems like J1723-2837,” said Antoniadis. The duo’s work on MSP J1723-2837 sheds some light on “black widow” pulsars, but it also leaves some questions unanswered. For instance, it's not yet clear whether the pair's observations are really typical of all "black widow" pulsars, or if MSP J1723-2837 is somehow special. Antoniadis also wants to better understand how the companion star's magnetic field interacts with the pulsar to shape the long-term evolution of the binary.

"We are now trying to coordinate multi-wavelength observations with a number of facilities to try to tackle these questions," said Antoniadis.

Meanwhile, the team isn't finished with MSP J1723-2837 itself, and van Staden's backyard observations still have a lot to contribute. "We still have new data on J1723 that we are working on. Depending on the results I will take it from there," said van Staden.

It Doesn't Take a PhD

According to van Staden, his results prove that even amateur astronomers with relatively modest equipment can make real scientific contributions, because they have something that's often hard to come by at large professional observatories: time.

It's rare for astronomers to be able to make continuous, long-term observations of a single object, but van Staden logged around 400 hours of observations of MSP J1723-2837. His 30cm telescope may have been modest, but it was up to the task of measuring the distant companion star's brightness, and that was all it took to fill in a significant gap in the astronomical community's data on one "black widow" pulsar and raise new questions.

"I'd say it is the ideas that matter, not the professional status," said Antoniadis. This was his first collaboration with an amateur astronomer, but he sees an increasing need for collaboration between the amateur and academic communities. "Modern astronomy is largely based on collective effort. The volume of data collected by non-professionals and professionals alike keeps increasing, which means that there is an ever-growing need for synergy."

But it's amateur astronomers who may have to take the initiative. To his fellow amateur astronomers, van Staden says, "I believe that astronomers do not know your particular observations and skills, but you can easily contact a professional related to your observing interest. You have to make the first move to get involved."

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