X-Ray Visions of SS Cygni

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Abstract The Chandra X-Ray Observatory is the most sophisticated X-ray observatory launched by NASA. Chandra is designed to observe X-rays from high-energy regions of the universe, such as X-ray binary stars. On September 14, 2000, triggered by alerts from amateur astronomers worldwide, Chandra observed the outburst of the brightest northern dwarf nova SS Cygni. The cooperation of hundreds of amateur variable star astronomers and the Chandra X-Ray scientists and spacecraft specialists provided proof that the collaboration of amateur and professional astronomers is a powerful tool to study cosmic phenomena.

1. Introduction

On September 14, 2000, triggered by alerts from amateur astronomers worldwide, NASA's Chandra X-Ray Observatory observed the outburst of the brightest northern dwarf nova, SS Cygni. The amateur astronomers provided Chandra scientists with a crucial early warning of this outburst by reporting their visual observations of SS Cygni as soon as they saw the star begin to brighten.

The data the amateur astronomers provided about the star's optical brightening, combined with the X-ray spectra gathered by the Chandra satellite, helped reveal the nature of the flow of gas from the small red companion star into an accretion disk and onto the surface of the white dwarf in SS Cygni.

Dr. Janet A. Mattei, late Director of the American Association of Variable Star Observers (AAVSO)—a non-profit organization made up of mostly amateur astronomers—and her technical staff coordinated the collection of optical observations of SS Cygni, and then communicated them to Dr. Christopher Mauche at the Lawrence Livermore National Laboratory. Dr. Mauche was the Principal Investigator for these Chandra observations (Mattei 2000).

2. SS Cygni

The dwarf nova SS Cygni is a type of star known as a cataclysmic variable. SS Cygni is a close binary star system in the constellation of Cygnus that contains a red dwarf star and a white dwarf. A red dwarf is a star a little cooler and smaller than the Sun. The white dwarf was once as large as the Sun but subsequently ran out of hydrogen in its core, blew its outer atmospheric layers into space, and collapsed to form a white-hot ember the size of Earth. The dense white dwarf, with its strong gravitational potential, pulls a steady stream of gas off of its companion star. This transferred gas collects in a disk, called an accretion disk, around the white dwarf.

The dramatic brightening by many orders of magnitude in this system is the result of an instability in the disk, which forces the disk material to drain down onto the surface of the white dwarf. This causes a titanic energy release equivalent to that of billions of atomic bombs exploding every second. Such stellar explosions, which often occur without warning and rarely last more than one or two weeks, serve as floodlights that brighten a dim star system for scientists to study.

3. Coordination of AAVSO, Chandra, EUVE, and RXTE observations

The start of the SS Cygni outburst was discovered in its very early stage by many amateur astronomers who had been keeping a vigil to catch the outburst. It was then confirmed by other amateurs, many of whom are members of the AAVSO. They e-mailed or phoned in their observations to the AAVSO. Dr. Mattei communicated this information to Dr. Mauche and advised him to submit the request to start the X-ray observations. Within hours of Dr. Mauche's request on a Sunday, he was speaking with Dr. Fred Seward and Dr. Pat Slane of the Chandra team on the specifics of the requested observations. Thanks to their and other Chandra team's efforts, Chandra observations began in an amazingly short time—on Sept. 12.7 UT—and continued until Sept. 14.5 (Sept 12.7 UT is Sept 12, 16:48 UT or Sept. 12, 12:48 EDT or Julian Date 2451800.2) (Mattei 2000).

Dr. Mauche also spoke with Marty Eckert, the Extreme Ultraviolet Explorer (EUVE) Science Planner, to arrange for simultaneous observations of SS Cygni with NASA's EUVE satellite. EUVE measures the brightness and spectra in the extreme ultraviolet, providing unique information about the very short (10 sec) quasi-period oscillations that appear only during outburst in SS Cygni. The Extreme Ultraviolet Explorer, the Chandra X-Ray Observatory, and the amateur astronomers all observed SS Cygni at the same time (Mattei 2000).

Once again, on January 16 and 17, 2001, thanks to alerts from amateur astronomers in thirteen countries, NASA's Chandra X-Ray Observatory and the Rossi X-Ray Timing Explorer (RXTE) made unique coordinated observations of SS Cygni. Together, the data from the satellites and the backyard observers revealed even more information about the flow of gas to the white dwarf from its companion star. After dozens of amateur astronomers had kept an intense and dedicated vigil for 72 days—22 days longer than had been anticipated—SS Cygni finally started to brighten on January 12. The volunteer amateur observers immediately sent detailed reports to AAVSO Headquarters, as had been requested by Dr. Mattei. In less than 24 hours, by January 13, the outburst of SS Cygni was confirmed—SS Cygni was definitely on the rise. Late on January 13, SS Cygni surged to near maximum optical brightness, then finally reached maximum (Mattei 2001).

As the data came in from the observers by email, fax, and phone, Dr. Mattei communicated with collaborators Dr. Mauche at Lawrence Livermore, and Dr. Peter

Wheatley at the University of Leicester, England, Principal Investigator for the RXTE observations, both of whom had been waiting anxiously for weeks for word from the AAVSO's observers. Once the outburst was clearly established, Dr. Mattei triggered the Chandra Target-of-Opportunity observations (TOO) via a webform, on a Sunday morning, Jan. 14, at the request of Dr. Mauche, who was skiing in Utah and had no access to a computer (Mattei 2001).

Catching the outburst of SS Cygni at peak optical brightness was crucial. The previous Extreme Ultraviolet Explorer (EUVE) satellite observations the year before had demonstrated that in SS Cygni there is a delay of 1.5 days between the rise of the optical and extreme ultraviolet/soft X-ray flux. Soft X-ray emission peaks and then stays bright for about 4 days, then declines, first slowly and then sharply. In order to acquire optimum data, it was essential to observe SS Cygni at optical and soft X-ray peak, that is, within 4 days of the SS Cygni binary system erupting and reaching its optical maximum.

Recognizing the urgency of this time limit, Chandra Director Dr. Harvey Tananbaum, who was informed of the TOO request triggering within half an hour, advised the Chandra planners and schedulers to see if observations of SS Cygni could be scheduled within three days. The Chandra planners and schedulers made a Herculean effort, and Chandra observations were scheduled for January 16, 4:30 p.m. EST to Jan 17, 5:40 a.m. EST.

In the meantime, Dr. Wheatley, having been alerted by Dr. Mattei, sent a request on Sunday, January 14, to the RXTE satellite planners and schedulers for hard X-ray observations to be made simultaneously with those of Chandra. Although optimally 72 hours are needed to schedule RXTE, the team made a tremendous effort and was able to schedule RXTE to start observing SS Cygni just a few hours after Chandra started (Mattei 2001).

4. Scientific results

Previous coordinated observations had utilized Chandra's high-energy transmission grating spectrometer (HETGS) to study the spectrum of the hard X-rays emitted by the tenuous upper "atmosphere" of the boundary layer between the accretion disk and the surface of the white dwarf. During the current observations, Chandra's low-energy transmission grating spectrometer (LETGS) was used to study the spectrum and temporal characteristics of the dominant spectral component of the inner accretion disk and boundary layer, a "big blue bump" in SS Cygni's spectrum which peaks at extreme ultraviolet/soft X-ray energies. The new measurements filled in the missing piece of the puzzle of the X-ray spectrum of SS Cygni in outburst, and will be used to study the physics, physical development, and characteristics of the boundary layer. This information is crucial not only for understanding SS Cygni itself, but also active galactic nuclei, which also show a similar "big blue bump" in their emission spectra (Mattei 2001).

5. Summary

Chandra and RXTE proved to be a powerful combination, with Chandra pinning down the boundary layer spectrum in great detail and RXTE simultaneously probing its most rapid variability. The EUVE in combination with Chandra gave added detail to the spectral analysis at the lower end of the X-ray range. These projects were a wonderful collaboration of professional and amateur astronomers and NASA's Chandra, EUVE, and RXTE Directors and Operations Teams to observe the brightest dwarf nova SS Cygni simultaneously with two NASA satellites. For years, amateur astronomers have informed professionals of novae, supernovae and other cataclysmic events. The cooperation between an organized group of dedicated amateur astronomers and the professional astronomers who need their observations is now quite finely tuned. When scientists are in need of ground-based observations to follow simultaneous satellite observations, they know that this worldwide network of amateurs can be depended upon for fast, efficient, and reliable results.

References

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