Flaring Red Dwarf Stars

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Significant discoveries can occur through the clever extraction of information hidden in previously archived Hubble data. As a case in point, Maryland-based astronomer Rachel Osten recently led a joint team from the Space Telescope Science Institute and the University of Washington that analyzed data originally taken to detect extrasolar planets, and used it to gather statistics on the number and sizes of stellar flares.

The original study involved using the telescope to observe a particular spot on the sky for seven days. The spot was located in the constellation Sagittarius, an area containing the central bulge of our Milky Way galaxy. Astronomers focused on this old and crowded stellar population to watch for any decrease in the light levels from these stars. Such a decrease would signal the presence of an otherwise-invisible planet in orbit, passing in front of its parent star as seen from Earth. Because of the large number of stars found toward the galactic center, Hubble could simultaneously monitor 229,701 stars within the same field of view.

By observing the same stars for a week, however, astronomers can see any fluctuation (up or down) in their intensities. Thus, in subsequent analysis of the same data, Osten and her team found that 105 stars increased quickly in brightness (i.e., flared) during the period of the study—some of these, multiple times. This is almost seven times as many stars as were found to dim in brightness in the original study.

Flaring seen in distant stars is assumed to be caused by processes similar to those at work in the atmosphere of our own Sun. While the Sun’s surface appears steadily quiescent, it is actually a seething cauldron of electrically charged gas called plasma, which is embedded in tangled magnetic fields that heat it to millions of degrees Fahrenheit. These changing fields produce short-term reactions near the Sun’s surface, which unleash energies on thermonuclear scales.
Flares arise on the Sun where the magnetic field lines loop above its gaseous surface. At the base of these fields are cooler areas that, in visible wavelengths, appear darker than the surrounding photosphere, which is hotter and brighter. Called sunspots, these magnetic storm sites can be many times larger than Earth. When the field lines extending above the sunspots collide, they release stored magnetic energy and hot entrapped gas. These events cause explosions to erupt and glow on timescales that last from minutes to hours.

Solar eruptions release energy across the entire electromagnetic spectrum from radio waves to gamma rays. These propagate upward through the Sun's extremely hot outer atmosphere called the corona and are often accompanied by gaseous "tongues of fire" called prominences. If the energy of an eruptive prominence is sufficiently large, material can escape the Sun into space. This phenomenon is called coronal mass ejection. This electrically charged material can be very disruptive to Earth-orbiting satellites and land-based power grids if released in the direction of our planet.

The largest solar flares release an energy equivalent to the simultaneous explosion of 100 million atomic bombs. Viewed in visible light, such flares create only a small increase in the Sun's intensity overall—not something detectable with the naked eye. At X-ray wavelengths, however, they can be up to 6,000 times the Sun's normal luminosity.
Stellar Magnetic Field Phenomena and Flares

The process of nuclear fusion deep inside the Sun’s core produces the energy that ultimately reaches us as light and heat. Energetic material from the core circulates via convection: the hot plasma rises to the surface where it then cools, condenses, and sinks back into the interior. Stars with outer convection zones can generate magnetic fields, which manifest themselves in various observable phenomena. These include:

- Sunspots (or star spots), formed where very large magnetic fields poke through the visible surface, known as the photosphere.
- The chromosphere, a thin layer of atmosphere just above the photosphere, which contains electrically charged material heated by magnetic fields to temperatures of a few tens of thousands of degrees Fahrenheit.
- The corona, a similar magnetic-field-heated plasma “atmosphere” but which extends millions of miles into space and at a temperature of millions of degrees Fahrenheit.
- Prominences, areas of material cooler than the corona but warmer than the photosphere, which erupt from the star and are suspended by magnetic fields high above the surface in loops and arcs.
- Flares, which are violent, high-temperature eruptions caused by breaking and reconnecting magnetic fields.

Stars that rotate rapidly or have deep convective zones are likely to exhibit flares. Young stars generally rotate more rapidly due to conservation of angular momentum “spinning them up” from the collapse of the huge rotating gas cloud that formed them.

Close binary stars that are tidally locked, having the same periods of rotation and revolution, will also maintain high spin rates, even into old age.
Calculating the flare energies and the peak intensities of the stars in their targeted *Hubble* dataset, Osten and her team found them consistent with those seen in nearby stars that are solar-like or cooler (redder). The data revealed flares of 10 percent or larger in brightness compared to the flaring stars’ nominal intensities. The team also noted that a surprising fraction (85 percent) of these flaring red stars showed underlying brightness variations on the order of a few percent. These variations are immediately suggestive of star spots rotating on and off the disk of the star, producing regular brightness changes—but this interpretation creates a bit of a conundrum.

The regular variations seen in these stars have very short periods—on the order of a few days or less. This implies that they are rotating quickly, more quickly than stars of their assumed age should. Single stars tend to “spin down” as they grow older.
Flares develop when the magnetic field lines above a star’s gaseous surface reconfigure in a way that allows them to snap and suddenly release stored magnetic energy and hot, entrapped gas.

older, but these observed variations are not slow. Alternately, the stars could each be members of a binary star system where the rotation and orbital periods of the stars are the same. This condition is expected if the stars have been closely orbiting one another for many years. Because researchers have additional evidence that these stars are approximately 10 billion years old, the fast rotation suggests that they are indeed dwarf red binary stars locked in a tight orbit where the rotation period and orbital period have grown to be the same.
Star spots are dark footprints formed on the surface where strong magnetic fields penetrate the photosphere linking the corona with the star's interior. As these spots move, their fields interact to form loops of charged particles that primarily emit X-rays and ultraviolet light.

Red dwarfs are smaller than the Sun, but they are thought to have a deeper convection zone where cells of hot gas heated by nuclear reactions at the star's core boil to the surface. This movement generates magnetic fields, and the field strengths of these stars are also thought to exceed the Sun's. Additionally, while sunspots typically cover less than 1 percent of the Sun's surface, the star spots on red dwarfs could cover as much as 50 percent of their surfaces. With all these features, it is no surprise that red dwarf stars are seen to emit notably energetic flares.
Dr. Rachel Osten is an astronomer at the Space Telescope Science Institute in Baltimore, Maryland. She has used radio telescopes, *Hubble*, and various X-ray observatories to study the outer parts of stars cooler than the Sun. Born and raised in Massachusetts, Dr. Osten graduated from Harvard University in 1996 with a bachelor’s degree in physics and astronomy. It was there that she first used *Hubble*, working with data from one of its original instruments for her undergraduate thesis. She obtained a doctorate from the University of Colorado at Boulder in 2002. After finishing her degree, she was a Jansky postdoctoral fellow at the National Radio Astronomy Observatory, then a Hubble fellow at the University of Maryland and NASA's Goddard Space Flight Center. Dr. Osten joined the scientific staff of the Institute in the fall of 2008.

Osten and her team even found flaring on dwarf stars 10 billion years old—twice the estimated age of the Sun. This is much older than most scientists would have expected.

Red dwarfs are the most abundant stars in the universe, and astronomers have found growing evidence for planets around them. These stars are cooler than the Sun, so the “habitable zone” for planets circling them is 10 to 20 times closer to them than Earth is to the Sun. Since dwarfs can emit very energetic flares lasting up to several days and swelling the star’s overall brightness hundreds of times, it is hard to imagine how life could be sustained on the constantly radiated and bombarded surface of these planets.

Further Reading


