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A shocking surprise in Stephan's Quintet

When astronomers using NASA's Spitzer Space Telescope turned their attention to a well-known cluster of galaxies called Stephan's Quintet, they were, quite simply, shocked at what they saw. There in the middle of the cluster, invisible to our eyes, lurked one of the biggest shock waves, or "sonic booms," ever seen. Astronomers hope that observing how galaxies generate such huge shock waves will lead to a better understanding of what powers the most luminous galaxies in the universe.

Stephan's Quintet
Credit: NASA/JPL-Caltech/Max-Planck Institute/P. Appleton (SSC/Caltech)

For some time now, astronomers have known that four galaxies in this distant cluster (and a 5th unrelated foreground galaxy -- hence the name "Quintet"), located about 300 million light-years away from Earth, are involved in a violent collision. In visible light, the galaxies are clearly distorted, indicating that they have experienced gravitational encounters in the past. But that, as it turns out, is only part of the drama.

One of the four galaxies, called NGC 7318b, for reasons not fully understood, is currently falling toward the others at high speed, generating a giant bow shock in front of it which can be seen in X-ray, infrared, and radio light. Amazingly, the surface of the shock wave is larger than our own Milky Way galaxy, and stretches across intergalactic space between the colliding galaxies.

Shock waves occur when an object moves faster than the speed of sound through any kind of medium -- from water to intergalactic gas. One of the most commonly observed forms of shock waves is the sonic boom produced by high-speed aircraft. As a supersonic jet exceeds the speed of sound (or Mach 1), it catches up with its own sound waves. The sound waves become compressed together into a cone-shaped "shock" which travels outwards towards the ground and produces the familiar "sonic boom" when a supersonic jet flies by. The sonic shock is usually invisible to us, but in one case, a Navy ensign was able to capture a spectacular photograph of a shock wave extending behind a low-flying jet over the ocean. As water vapor in the air was compressed by the shock wave, it condensed into droplets and formed a conical cloud behind the tail of the jet (see image).

Dr. Philip Appleton (Caltech) and collaborators turned Spitzer's sensitive Infrared Spectrograph toward the location of the giant shock wave, a visibly dark area between the galaxies, hoping to discover more about what was going on. Unlike an optical telescope, Spitzer has the ability to detect infrared light from invisible materials, like dust grains or molecules.

To their surprise they discovered the telltale fingerprint of extremely powerful molecular-hydrogen. "The strength of the emission and the fact that it shows the gas to be Doppler-broadened (astronomer-speak for "highly disturbed") was a huge surprise to us." said Appleton. "We expected to see the spectral signature of dust grains -- but instead we saw an almost pure laboratory-like spectrum of hydrogen molecules and almost nothing else. It was quite unlike anything we had seen before in a distant galaxy system."

Spectrographs have the ability to break light down into its component wavelengths, where the chemical signatures of the material that produced it can be seen as spectral lines. The width of these lines allows astronomers to determine the velocity of the gas, with wider lines indicating gas at a higher velocity. Appleton and his team measured the widest lines ever observed for hot hydrogen molecules, corresponding to turbulent gas motions of 870 kilometers per second (2 million mph)!

"In Stephan's Quintet," says Appleton, "the shock wave is due to the intruder galaxy (NGC 7318b) traveling at speeds greater than Mach 100 as it plows into intergalactic gas within the cluster. Hydrogen molecules are apparently forming either in or behind the shock, similar to the water droplets condensing in the jet image -- but on an enormous scale!"

In a way, the discovery of something so new and unusual was not such a big surprise to the team, as the dynamics of this cluster are far from understood. Dr. C. Kevin Xu (Caltech), one of the team members says: "Stephan's Quintet is such a unique object that every time it is looked at with a new instrument, it reveals totally unexpected things. No exception this time."

This discovery may lead to a better understanding of the most infrared-luminous galaxies in the universe, the mysterious Ultra-luminous Infrared Galaxies. "Ultra-luminous Infrared Galaxies typically have infrared luminosities 100 to 1,000 times greater than the Milky Way, and their numbers increase as you look out to higher and higher red-shifts," says Appleton. "We know that these galaxies are also involved in vast mergers and collisions. It's possible that some of the emission we see from them is created not by stars, but by vast shocks in the gas between colliding galaxies."

The observations presented by Appleton and fellow team members C.K. Xu and W. Reach at Caltech, as well as other astronomers in the US, Germany and Australia, provide a new diagnostic for studying conditions in merging and colliding galaxies in the early universe.

"Observing a relatively nearby densely populated galaxy group immersed in a thick gas cloud, gives us a local view of what might have been going on about 10 billion years ago, soon after the first galaxies formed, when the density of the intergalactic medium and the density of galaxies was much greater than today. In that respect these observations are a bit like stepping into a time machine," said Drs. Cristina Popescu and Richard Tuffs, two other team members from the Astrophysics Department of the Max-Planck Institute in Heidelberg, Germany.

But this discovery has implications even for our own galaxy, the Milky Way. Though far in the future, it is likely that in about two billion years from now, we will collide with the slightly larger Andromeda Galaxy, creating shocks of our own. In that case, our future descendents will have a ring-side seat!

Original article: Michelle Thaller, **Spitzer Science Center**
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