LIGO Observations Probe the Dynamics of the Crab Pulsar

The search for gravitational waves has revealed new information about the core of one of the most famous objects in the sky: the Crab Pulsar in the Crab Nebula. An analysis by the international LIGO (Laser Interferometer Gravitational-Wave Observatory) Scientific Collaboration has shown that no more than 4 percent of the energy loss of the pulsar is caused by the emission of gravitational waves.

The Crab Nebula, located 6,500 light years away in the constellation Taurus, was formed in a spectacular supernova explosion in 1054. According to ancient sources, including Chinese texts that referred to it as a "guest star," the explosion was visible in daylight for more than three weeks, and may briefly have been brighter than the full moon. At the heart of the nebula remains an incredibly rapidly spinning neutron star that sweeps two narrow radio beams across the Earth each time it turns. The lighthouse-like radio pulses have given the star the name "pulsar."

"The Crab Pulsar is spinning at a rate of 30 times per second. However, its rotation rate is decreasing rapidly relative to most pulsars, indicating that it is radiating energy at a prodigious rate," says Graham Woan of the University of Glasgow, who co-led the science group that used LIGO data to analyze the Crab Pulsar, along with Michael Landry of the LIGO Hanford Observatory.

Pulsars are almost perfect spheres made up of neutrons and contain more mass than the sun in an object only 10 km in radius. The physical mechanisms for energy loss and the accompanying braking of the pulsar spin rate have been hypothesized to be asymmetric particle emission, magnetic dipole radiation, and gravitational-wave emission.

Gravitational waves are ripples in the fabric of space and time and are an important consequence of Einstein's general theory of relativity. A perfectly smooth neutron star will not generate gravitational waves as it spins, but the situation changes if its shape is distorted. Gravitational waves would have been detectable even if the star were deformed by only a few meters, which could arise because its semisolid crust is strained or because its enormous magnetic field distorts it. "The Crab neutron star is relatively young and therefore expected to be less symmetrical than most, which means it could generate more gravitational waves," says Graham Woan.

The scenario that gravitational waves significantly brake the Crab pulsar has been disproved by the new analysis.

Using published timing data about the pulsar rotation rate from the Jodrell Bank Observatory, LIGO scientists monitored the neutron star from November 2005 to August 2006 and looked for a synchronous gravitational-wave signal using data from the three LIGO interferometers, which were combined to create a single, highly sensitive detector.

The analysis revealed no signs of gravitational waves. But, say the scientists, this result is itself important because it provides information about the pulsar and its structure.

"We can now say something definite about funded by NSF, was recently inaugurated next to the Livingston Observatory, and has been very successful attracting large umbers of students and teachers from the region and contributing to science learning.

The next major milestone for LIGO is the Advanced LIGO Project, slated for operation in 2014. Advanced LIGO, which will utilize the infrastructure of the LIGO observatories, will be 10 times more sensitive. Advanced LIGO will incorporate advanced designs and technologies that have been developed by the LIGO Scientific Collaboration. It is supported by the NSF, with additional c