UO plays key role in LIGO's new view of a cosmic event

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An international team of physicists, including University of Oregon scientists, has concluded that last February's intense burst of gamma rays possibly coming from the Andromeda Galaxy lacked a gravitational wave. That absence, they say, rules out an initial interpretation that the burst came from merging neutron stars or black holes within Andromeda.

A revised interpretation, presented last month by the UO's Isabel Leonor at the 12th Gravitational Wave Data Analysis Workshop in Cambridge, Mass., suggests two possible origins: A merger event beyond Andromeda or a burst from an astronomical object known as a soft gamma-ray repeater within Andromeda. The latter, also called a magnetar, involves neutron stars with enormous magnetic fields that occasionally produce big outbursts of gamma rays.

The new findings are based on a collaborative analysis by the Laser Interferometer Gravitational-Wave Observatory (LIGO) Scientific Collaboration, a project funded by the National Science Foundation. LIGO was designed and is operated by the California Institute of Technology and the Massachusetts Institute of Technology for the detection of cosmic gravitational waves and for the development of gravitational wave observations as an astronomical tool.

Leonor, a research associate in the experimental relativity group of the UO's Center for High Energy Physics, and colleague Ray Frey, a professor of physics, initiated the during a discussion of the event, known as GRB070201, at a meeting in Louisiana in March. The UO's experimental relativity group is part of the LIGO Scientific Collaboration.

Gamma ray bursts are among the most violent and energetic events in the universe. Scientists have only recently begun to understand their origins. On Feb. 1, 2007, four gamma ray satellites measured a short but intense outburst of energetic gamma rays originating in the direction of the Andromeda galaxy 2.5 million light years from Earth. The majority of short (less than 2 seconds) gamma ray bursts (GRBs) are thought to come from the merger and coalescence of two massive but compact objects such as neutron stars or black hole systems. They also can come from less-common soft, gamma ray repeaters, which emit fewer intense gamma rays.

During February's blast of gamma rays, the four-kilometer and two-kilometer gravitational wave interferometers at LIGO's Hanford, Wash., facility were collecting data but did not detect any associated gravitational waves. That non-detection was significant, the scientists report.

The burst occurred along a line of sight that was consistent with it originating from one of Andromeda's spiral arms. Initially a binary coalescence event--the merger of two neutron stars or black holes, for example -- was considered the most likely explanation. Such a monumental cosmic event occurring in a nearby galaxy should have generated gravitational waves that would be easily measured by the ultra-sensitive LIGO detectors. The absence of a gravitational wave signal meant the burst could not have originated in this way in the Andromeda Galaxy.

"In general, our understanding of GRBs and soft gamma ray repeaters has increased dramatically in the past decade but is still in an early stage," Frey said. "So every piece of the puzzle that is put in place gives the overall picture more clarity."

The LIGO Scientific Collaboration includes 580 scientists at universities around the United States and 11 other countries. The collaboration interferometer network includes the GEO600 interferometer located in Hannover, Germany, which was designed and is operated by scientists from the Max Planck Institute for Gravitational Physics and partners in the United Kingdom.

Each of the L-shaped LIGO interferometers (including the detectors in Hanford and a four kilometer instrument in Livingston, La.), uses a laser split into two beams which travel back and forth down long arms in evacuated beam tubes. The beams are used to monitor the distance between precisely figured mirrors. According to Albert Einstein's 1916 theory of general relativity, the relative distance of the mirrors changes very slightly when a gravitational wave -- a distortion in space-time produced by massive accelerating objects that propagates outward through the universe -- passes by. An interferometer is constructed so that it can detect a change of less than a thousandth the diameter of an atomic nucleus in the lengths of the arms relative to each other.

LIGO's contribution to the study of GRB070201 marked a milestone for the project, said Caltech's Jay Marx, LIGO's executive director. "Having achieved its design goals two years ago, LIGO is now producing significant scientific results," he said in a Caltech news release. "The non-detection of a signal from GRB070201 is an important step towards a very productive synergy between gravitational wave and other astronomical communities that will contribute to our understanding of the most energetic events in the cosmos."

Until now, astronomers who have studied GRBs relied on data from telescopes conducting visible, infrared, radio, x-ray and gamma ray observations, said David Reitze, a professor of physics at the University of Florida and spokesperson for the LIGO Scientific Collaboration. Gravitational waves offer a new window into the nature of these events, he said in the Caltech release.

Even before the event of last February, the UO's experimental gravity group has been leading LIGO's effort in the scientific search for gravitational-wave bursts associated with the enigmatic astrophysical objects that are gamma-ray bursts. The UO team analyzed data from the second, third and fourth LIGO science runs. During the fifth LIGO science run, which lasted two years and during which the interferometers were at their design sensitivities, there were about 200 GRBs observed by gamma-ray satellite experiments.

"It gives me a very satisfying feeling to contribute in a meaningful way to the science of astrophysics in collaboration with world-class scientists," Leonor said. "My fascination with understanding the universe was, after all, why I became a scientist."

Frey noted that the sensitivity of LIGO is improving dramatically, "so it is exciting for us to begin making astrophysically interesting statements with gravitational waves, a new way of observing the universe. So while the GRB070201 result is a kind of dog-that-did-not-bark statement, we expect to be eventually hearing a canine chorus of gravitational waves."

The Oregon group also has played a key role in the commissioning of the LIGO instruments at the Hanford and Livingston sites. This effort has been led by Robert Schofield, a senior research associate. The UO group is made up of three faculty members, three research associates, one graduate student and undergraduate research assistants.

The next major construction milestone for LIGO will be the Advanced LIGO Project. Work is expected to start this year. Advanced LIGO will utilize the infrastructure of LIGO, but will be 10 times more sensitive, allowing scientists to detect cataclysmic events such as black-hole and neutron-star collisions at 10-times-greater distances.

Source: University of Oregon

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