Astronomers perform largest-ever survey of high-mass binary star systems

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In addition to solo stars like the sun, the universe contains binary systems comprising two massive stars that interact with each other. In many binaries, the two stars are close enough to exchange matter and may even merge, producing a single high-mass star that spins at great speed.

Until now, the number of known high-mass binaries has been very small, basically confined to those identified in our galaxy, the Milky Way.

An international group of astronomers led by researchers at the University of São Paulo's Institute of Astronomy, Geophysics & Atmospheric Sciences (IAG-USP) in Brazil, has just extended the list of by identifying and characterizing 82 new high-mass binaries located in the Tarantula Nebula, also known as 30 Doradus, in the Large Magellanic Cloud. The LMC is a satellite galaxy of the Milky Way and is about 160,000 light years from Earth.

The results of the study are described in article published in the journal *Astronomy & Astrophysics*.

"By identifying and characterizing these 82 high-mass binaries, we have more than doubled the number of these objects, and in a completely new region with very different conditions from those found in the Milky Way," said Leonardo Andrade de Almeida, a postdoctoral fellow at IAG-USP and first author of the study.

In research supervised by Augusto Damineli Neto, a full professor at

IAG and a co-author of the article, Almeida analyzed the data obtained during the VLT-FLAMES Tarantula Survey and Tarantula Massive Binary Monitoring observation campaigns performed by the European Southern Observatory (ESO) from 2011.

Using FLAMES/GIRAFFE, a spectrograph coupled to ESO's Very Large Telescope (VLT), which has four 8m primary mirrors and operates in Chile's Atacama Desert, the observation campaigns collected spectral data for over 800 high-mass objects in the region of the Tarantula Nebula, so named because its glowing filaments resemble spider legs.

From this total of 800 observed objects, the astronomers who worked on the two surveys identified 100 candidate binaries of spectral type O (very hot and massive) in a sample of 360 stars based on parameters such as the amplitude of variations in their radial velocity (the velocity of motion away from or toward an observer).

For the last two years, Almeida has collaborated with colleagues in other countries on an analysis of these 100 candidate high-mass binaries using the FLAMES/GIRAFFE spectrograph and has managed to characterize 82 of them completely.

"This represents the largest survey and spectroscopic characterization of massive binary systems every performed," he said. "It was only possible thanks to the technological capabilities of the FLAMES/GIRAFFE spectrograph."

The scientific instrument developed by ESO can obtain spectra for a number of objects simultaneously, and weaker objects can be observed because the spectrograph is coupled to the VLT, which has large mirrors and captures more light, Almeida explained.

"We can collect 136 spectra in a single observation using FLAMES/GIRAFFE," he said. "Nothing similar could be done before. Our instruments could only observe individual objects and it took much longer to characterize them."

Spectroscopic analysis of the 82 binaries showed that properties such as mass ratio, orbital period (the time taken to complete one orbit) and orbital eccentricity (the amount by which the orbit deviates from a perfect circle) were highly similar to those observed in the Milky Way.

This was unexpected since the LMC embodies a phase of the universe prior to the Milky Way, when the largest number of high-mass stars were formed. For this reason, its metallicity—the proportion of its matter made up of chemical elements other than primordial hydrogen and helium—is only half that of the binaries found in the Milky Way, whose metallicity is very close to the sun's.

"At the beginning of the universe, stars were metal-poor but chemical evolution increased their metallicity," Almeida said.

This analysis of binaries in the LMC, he added, provides the first direct constraints on the properties of massive binaries in galaxies whose stars were formed in the early universe and have the LMC's metallicity.

"The discoveries made during the study may provide better measurements for use in more realistic simulations of how high-mass stars evolved in the different phases of the universe. If so, we'll be able to obtain more precise estimates of the rate at which black holes, neutron stars and supernovae were formed in each phase, for example," he said.

High-mass stars are the most important drivers of the chemical evolution of the universe. Because they are more massive, they produce more heavy metals, evolve more rapidly, and end their lives as supernovae, ejecting all their matter into the interstellar medium. This matter is recycled to form a new population of stars.

However, Almeida went on, estimates of the chemical evolution of the universe and astrophysical predictions of the number of black holes usually take into account sole stars like our sun, which evolve more simply.

According him, when you include binaries in computing these projections, the result changes dramatically. So when making astrophysical predictions, it is important to consider these massive objects.

More information: L. A. Almeida et al, The Tarantula Massive Binary Monitoring, *Astronomy & Astrophysics* (2017). DOI: 10.1051/0004-6361/201629844

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