Galactic bulge modeling sheds light on galaxy evolution

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Spiral galaxy NGC 5468, 130 million light-years away. Credit: ESA/Hubble & NASA, A. Riess et al.

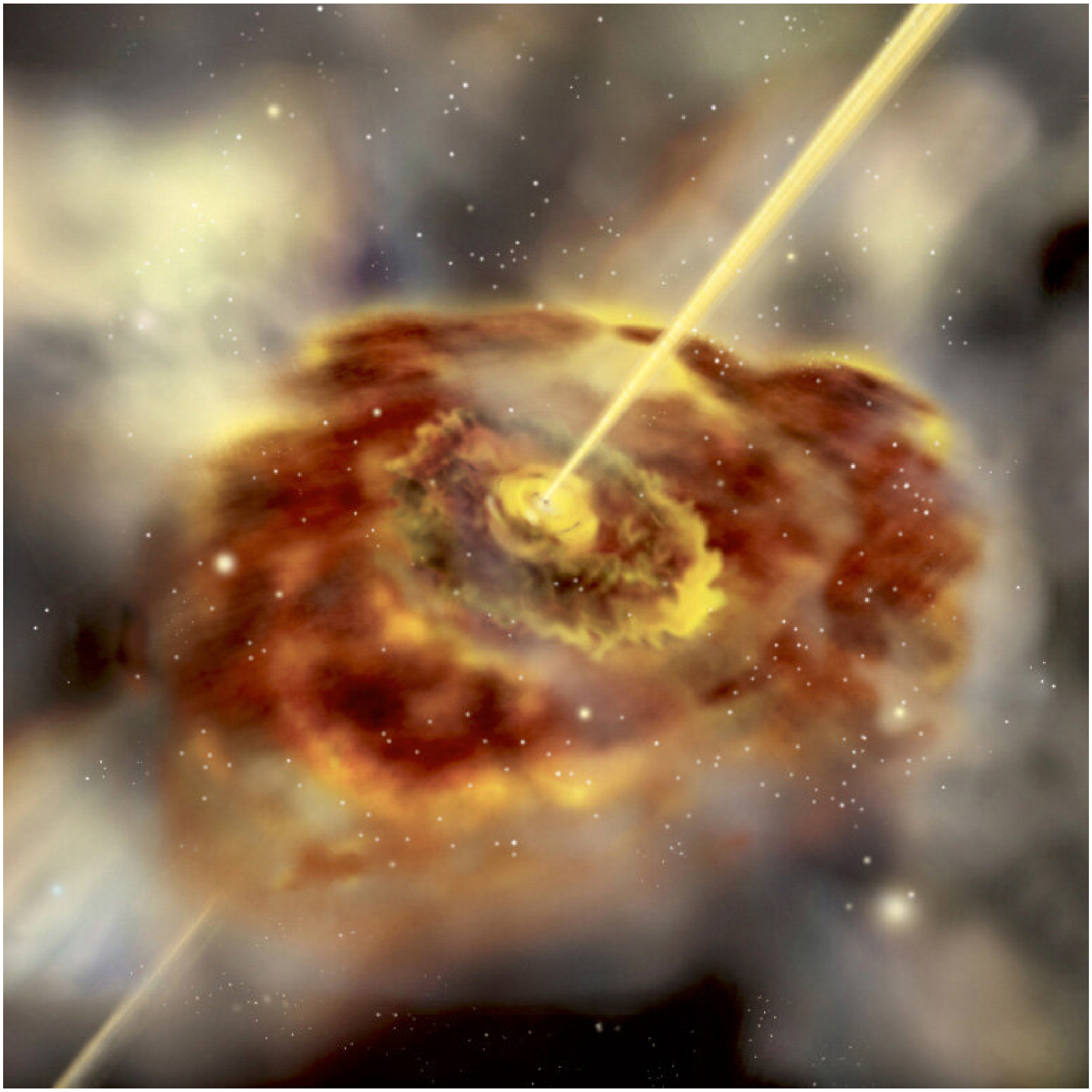
Using data from the CALIFA Integral Field Spectroscopy (IFS) survey and advanced modeling tools, researchers from Instituto de Astrofísica e Ciências do Espaço (IA) have obtained important results about the central spherical component (the bulge) in spiral galaxies like the Milky Way, shedding new light on the understanding of galactic evolution. The results are published in the latest issue of *Astronomy & Astrophysics*.

It took several years and a lot of computational power to analyze approximately a half-million spectra from a sample that covers all morphological types of non-interacting spiral galaxies. The team made the first measurements of the age variation of stars in the bulge, from the center to the periphery, and determined how this age difference relates to other galaxy properties, like the existence of active galactic nuclei (AGN) and the total mass of stars in the galaxy.

The study revealed that the stellar population at the center of the most massive spiral galaxies is older than the stars at the edge of the bulge, while in low mass galaxies, the opposite happens—the youngest stars populate the center of the bulge, and the older are in the periphery. This result is in agreement with a previous study by the team, which had already found strong evidence for a unified scenario for the formation of spiral galaxies. Contrary to previous hypotheses, low- and high-mass spiral galaxies appear form in the same manner, although high-mass galaxies pass the same formation stages earlier and quicker than their lower-mass counterparts.

These measurements can be used to estimate the impact of an AGN on bulge (and therefore galactic) evolution. The fact that the mass of a bulge is tightly connected to that of the supermassive black hole that powers the AGN points to an intimate physical link between the growth of galaxies and their supermassive black holes. Understanding bulge formation and evolution is therefore indispensable for the understanding of how supermassive black holes were born in the Era of Reionization, and how they influenced the evolution of galaxies.

IA researcher Iris Breda, the leading author of the paper, developed most of this work during her recently finished Ph.D. at IA and the Science Faculty of the University of Porto. She says, "There are many important lessons one can take from our study, the most relevant one being that bulges that are hosted by massive spiral galaxies cannot have formed in a quick and violent star-formation episode as it is commonly thought. To the contrary, these results support a scenario where these bulges are formed gradually within 2 to 4 billion years. Together with our previous results, our recent study lends support to the hypothesis that the least massive galaxies, which are now actively forming stars in the very center of their bulges, currently resemble a scaled-down version of the most massive spiral galaxies at their early evolutionary stages."



Artist's impression of an active galaxy that has jets. Credit: ESO, Courtesy: Aurore Simonnet, Sonoma State University

FCT investigator Polychronis Papaderos, leader of the IA studies on the assembly history of galaxies resolved in space and time, says, "An AGN evacuates the bulge from cold gas, and therefore shuts off star formation, first in its central part, and as time progresses, in its periphery. This phenomenon results in a decrease in the mean age of stellar populations as we move from the center to the periphery of the bulge. By taking advantage of this fact, we invented a method to estimate the average velocity for the inside-out star formation quenching driven by the AGN. The relatively low velocity we infer (1-2 km/s) implies that the rise of AGN activity does not lead to a catastrophic episode of sudden removal of gas and an abrupt termination of star formation throughout the bulge."

The participation of IA's team in radio surveys such as the Evolutionary Map of the universe (EMU) offers ideal conditions for an unprecedentedly detailed study of the interaction of AGNs with the ambient gas in galactic nuclei through deep radio interferometry. This allows them to look for small-scale radio-jets in bulges, which they believe went undetected in previous low-resolution radio interferometry observations.

The study of AGN activity since the Era of Reionization and its impact on galactic evolution constitutes one of the main axes of research at IA.

IA coordinator José Afonso of the Science Faculty of the University of Lisbon says, "The finer details of galaxy formation and evolution are finally being explored, aligning unprecedented observations with revolutionary computational tools and modeling. These techniques will soon go to the next level, as we will be installing a new, powerful spectrograph, MOONS, at ESO's Very Large Telescope. We will then have access to detailed observations of millions of galaxies during the heyday of galaxy evolution in the universe, when the universe was less than half its current age. IA researchers will be there, exploring those new observations and helping to better understand the assembly history of galaxies."

More information: Iris Breda et al. Stellar age gradients and inside-out star formation quenching in galaxy bulges, *Astronomy & Astrophysics* (2020). DOI: 10.1051/0004-6361/201937193

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