GALAXIES

Galactic shape and age go hand in hand

Recently, large integral-field spectroscopic studies of galaxies have greatly increased our knowledge of their structure and evolution. A new analysis of such data reveals a relationship between the age and the intrinsic — three-dimensional — shape of galaxies.

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The intrinsic shape of a galaxy holds important clues to its formation history. Simulations show that different merger and accretion scenarios result in differently shaped galaxies: for instance, gas-rich mergers lead to rounder shapes (see, for example, ref. [1]), and more frequent mergers tend to lead to more triaxial galaxies (see, for example, ref. [2]). Writing in *Nature Astronomy*, Jesse van de Sande and collaborators have now identified a correlation between the intrinsic shapes of galaxies and their characteristic stellar ages[3]. This result carries further important implications about how galaxies form and grow over time.

Even though shape is a very basic galactic property, intrinsic or three-dimensional shapes of galaxies cannot be measured directly, as we only observe two-dimensional projected images. To obtain the intrinsic shape of an individual galaxy, we need kinematical information to construct a full dynamical model (see, for example, ref. [4]), or additional clues such as the orientation of dust disks. Alternatively, we can use statistical methods to infer the properties of the distribution of intrinsic shape within a population of galaxies, based on the projected images of galaxies. Started by Hubble in 1926[5], these studies have become more and more refined with the availability of larger samples of galaxy imaging, as well as the inclusion of kinematic orientation (see ref. [6] for a review).

Fig. 1 | Example of a typical 'red and dead' bulge-dominated galaxy and a blue and star-forming disk-dominated galaxy. The Arp 116 pair of galaxies found in the Virgo cluster contains the massive elliptical galaxy M60 (centre of image) and a less massive spiral galaxy, NGC 4647 (top right corner of image). Credit: NASA, ESA and the Hubble Heritage (STScI/AURA)-ESA/Hubble Collaboration.

For their derivation of intrinsic galaxy shapes and stellar ages, van de Sande et al. made use of the SAMI survey[7], an integral-field spectroscopic survey operating from the Anglo–Australian Telescope at Siding Spring Observatory in Australia. SAMI observes nearby galaxies with optical-fibre bundles that each consist of 61 fibres, so that for each galaxy spatially resolved spectra are available in a datacube of two spatial dimensions and one wavelength dimension. From these datacubes, maps of emission line fluxes, stellar absorption line strengths, and stellar and gas kinematics can be constructed. These maps can subsequently be used to derive, for example, spatially resolved stellar population properties and to identify different ionization mechanisms at work within a galaxy. SAMI aims to observe 3,000 galaxies, and the datacubes and maps of 772 of these galaxies are already publicly available.

Van de Sande et al. used a combination of stellar kinematics (the ratio between ordered and random motions) and projected ellipticity of galaxy images to infer the intrinsic ellipticity (flattening), based on theoretical predictions that link these two quantities. They assumed that the galaxies are axisymmetric rotating spheroids (which implies that their intrinsic shape is fully described by the intrinsic flattening), and that the galaxies are mildly anisotropic — the random motions of the stars show a slight preference for one direction. The authors then fitted stellar population models to the spectra of their galaxies to determine their stellar ages. They concluded that there is a strong correlation between the intrinsic shapes of the galaxies in their sample and their ages: the rounder the galaxies, the older the stellar populations. One could argue that this finding is not entirely unexpected: round, red bulges of galaxies tend to be older, while the blue flatter disks tend to be younger (see, for example, ref. [8], but see also ref. [9] for a different interpretation) (Fig. 1). However, van de Sande et al. found the same relation when they restricted their analysis to low-mass galaxies, which are all lacking strong bulges.

Galaxies are complex systems, and the study by van de Sande et al. does contain some simplifications. They assume that a galaxy can be described by an axisymmetric ellipsoid, whereas especially the more massive galaxies in the Universe display signs of triaxiality (see, for example, ref. [10]). To complicate matters even more, many galaxies contain a central bulge embedded in a more extended disk and therefore would be better characterized by a superposition of two ellipsoids, each representing one component. Galaxies that have recently undergone strong bursts of star formation are not well described by one single stellar population and therefore cannot be accurately described with one stellar age parameter. But given that van de Sande et al. used a large sample size (843 galaxies) and have already investigated possible biases in their study, the relationship they present is likely to be robust. Refinements in both the intrinsic shape recovery and the stellar age determination are possible, and it would be interesting to see how detailed analyses of individual galaxies would fit within the presented results. Van de Sande et al. already mention the Milky Way as an example: the thick disk component contains an older stellar population than the thin disk, following the trend of shape and age that they uncovered in their galaxy sample.

The relation between intrinsic shape and stellar age uncovered by van de Sande et al. in nearby galaxies is supported by evidence from cosmological simulations and observations of galaxies at higher redshift, where massive galaxies are more compact than galaxies in the local Universe (see, for example, ref. [11]). Mergers will make these galaxies rounder, and as gas-poor major mergers are more common in the early Universe, it is no surprise that the rounder galaxies contain older stellar populations. It is therefore worthwhile to further explore the connection between galaxy age and shape, both in simulations and observations, to build a more complete picture of how this relation evolves. The work of van de Sande and colleagues highlights how large integral-field spectroscopic studies such as SAMI are contributing to answering the questions of how galaxies form and evolve, how they build up their mass and angular momentum, and what role is played by the various physical processes involved in a galaxy's life. ❒

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