eaa.iop.org
DOI: 10.1888/0333750888/2619

Dwarf Irregular Galaxies

Eline Tolstoy

From

Encyclopedia of Astronomy & Astrophysics

P. Murdin

ISBN: 0333750888

IoP

Institute of Physics Publishing
Bristol and Philadelphia

Dwarf Irregular Galaxies

Dwarf irregular galaxies at optical wavelengths are small, faint and appear to be unstructured and irregular in shape. They are typically gas-rich, metal-poor systems, with varying levels of STAR FORMATION occurring in a haphazard manner across the galaxy. Their structure does not normally include any distinctive features, such as spiral arms or nuclei, and their kinematics seems to be dominated by random motions or relatively slow solid-body rotation. There is not an extremely precise definition of what is a DWARF GALAXY and what is not, but the most typical demarcation between a dwarf galaxy and a larger ('normal') galaxy is that dwarfs are typically fainter than an absolute B-band magnitude $M_B = -16$. This is not a strict rule, as the Small Magellanic Cloud (with $M_B = -17$) is often considered to belong to the class of dwarf irregular galaxies. The lumpy irregularities in the optical morphology of dwarf irregular galaxies are due to randomly distributed star formation regions, which may be individually quite bright, but the overall surface brightness is typically extremely low ($\Sigma_0 \sim 23$–25 mag arcsec^{-2}). Because this type of galaxy is so numerous and they can easily vary in brightness quite dramatically owing to increased star formation rates, there is strong evidence to suggest that they are cosmologically important population of galaxies.

There are several classes of dwarf galaxy, not only dwarf irregular galaxies, and the difference between dwarf irregular galaxies and other classes of dwarf galaxy, such as 'blue compact dwarf' galaxies, 'dwarf spheroidal' galaxies and 'dwarf elliptical' galaxies, is often a question of semantics and has not always been precisely defined. These types of dwarf galaxy on average fall into the same low surface brightness class, but differ in their current rates of star formation. Blue compact dwarf galaxies have one or more compact, high star formation rate regions (e.g. NGC 1705, NGC 1569, VII Zw403). DWARF SPHEROIDAL GALAXIES, on the other hand, currently have no ongoing star formation, and no detectable gas, but they can show evidence of having had a complex star formation history, including one, or more, distinct episodes of star formation (e.g. Carina, Leo I, Sculptor). There are also a small number of what appear to be transition objects, which have extremely low rates of current star formation, but with evidence of more active star formation in the recent past (e.g. Pegasus, Phoenix, Antlia). The existence of these transition objects leads to the hypothesis that dwarf spheroidal, irregular and blue compact galaxies are all the same type of object, observed at different evolutionary phases. DWARF ELLIPTICAL GALAXIES (e.g. M32, NGC 147, NGC 185) usually have evidence only for a fairly old stellar population, and it is not entirely clear that they can fall into the same global scheme as the other types of dwarf galaxy suggested above.

Dwarf irregular galaxies are the most common type of galaxy in the region surrounding our own Galaxy, the so called LOCAL GROUP. In a recent census, 22 out of 41 galaxies within the Local Group can be classified as dwarf irregular type galaxies. Similar results, showing the dominance of dwarf irregular populations, can also be seen for other nearby groups of galaxies (or often called CLUSTERS OF GALAXIES), such as Virgo and Fornax. There are also indications from redshift surveys that the universe as a whole is dominated by small irregular type galaxies. It is of historical interest to note that the first object to be '. . . definitely assigned to the region outside the Galactic system . . .' (i.e. to be extragalactic) by Edwin Hubble in 1925 was NGC 6822, one of the nearest examples of a dwarf irregular galaxy. Pioneering work by Walter BAADE, starting in 1944, taking the first steps in understanding galaxy evolution, was based on studies of the resolved stellar populations in dwarf galaxies. Baade noted that the dwarf elliptical galaxies he looked at contained only red stars, namely old stars (which he called population II), and dwarf irregular galaxies contain red and blue stars, which indicate a younger population (which he called population I). He further noted that while an exclusively old population has been observed, a young population was never seen without an old underlying, fainter, population of red stars, which is called 'Baade's Sheet'.

Because of their small size and low surface brightness dwarf irregular galaxies can be very hard to detect, even in the Local Group, and to the present day we are still finding new dwarf irregular galaxies (e.g. Antlia in 1997, by a group from Cambridge, England). The first major survey of these faint and often unregarded smudges on photographic plates was undertaken by the Swedish astronomer Holmberg, in 1950 in the M81 and M101 galaxy groups. A further extensive specific search for field dwarf galaxies was undertaken by van den Bergh in 1959 in Canada (the DDO catalogue). Of the present-day dwarf irregular members of the Local Group 50% have been found since 1971, and we cannot rule out that we will find many more extremely low surface brightness objects in the Local Group.

The distribution of neutral hydrogen (H I) gas in dwarf irregular galaxies is very clumpy and irregularly distributed and is frequently much more extended than the optical emission. There have been very few cases in which molecular gas has been detected. Molecular gas, typically, means carbon monoxide, CO, which is relatively straightforward to detect and is considered to be a tracer for the presence of molecular hydrogen, H_2, which is the most important constituent in the star-formation process. Given the importance of molecular gas to the star-formation process it must exist in these galaxies, as we see young stars. It is possible that the extremely low metallicity of dwarf irregular galaxies makes the molecular gas more difficult to detect, because the relative fraction of CO to H_2 molecules is much smaller than in our Galaxy.

Dwarf irregular galaxies are also so-called 'metal-poor' galaxies. This means that the abundance of 'metals', namely elements with atomic numbers greater than 2, relative to the abundance of hydrogen is much lower than is observed in our Sun (the solar abundance). The metallicity of dwarf irregular galaxies ranges between 2.3% of the solar value (e.g. Leo A) and around 10% of the solar value (e.g. IC 1613). The typical elements observed to determine the metallicity of nearby galaxies are carbon, oxygen and nitrogen, which are detectable in optical and UV emission lines in currently star-forming regions (so-called, H II regions), and iron has been measured in spectra of individual stars of various ages. The extremely low abundances of metals relative to hydrogen, typically in the range 2–15% of solar neighborhood values, can be taken as a sign either of youth or of a sporadic star formation history, or a combination of both.

The star formation history, or luminosity and color evolution, of dwarf irregular galaxies shows evidence of not having been a smooth function of time. That is to say, they have been subject to sporadic increases in the average rate of star formation, so-called 'bursts' of star formation. These bursts may make a dwarf irregular galaxy look much more like a blue compact dwarf galaxy. Evidence for these bursts of star formation comes both from the direct observations of the resolved stars (the stellar population) in nearby dwarf irregular galaxies, a census of which gives information about the star formation history that has created the currently seen age and metallicity distribution, and also from studies of the luminosity and colors of much more distant, late-type galaxies seen at intermediate redshift (so-called faint blue galaxies).

It is possible to derive very accurate star formation histories from resolved stellar populations going back to the oldest star formation episodes in a galaxy. Low-mass stars can live a very long time, and thus leave a longstanding fossil record which can be directly interpreted as the star formation history of a galaxy through the entire history of the universe. Current evidence shows that every dwarf galaxy in the Local Group has had a different star formation history from every other. Dwarf irregular galaxies typically appear to contain old populations, as seen from the red giant branch stars, but this has only been unequivocally proven from the detection of RR LYRAE STARS in one or two cases (e.g. IC1613). Dwarf irregular galaxies thus not only have irregular morphology but also have had irregular star formation histories, dominated by short 'bursts' of star formation, rather than a more or less constant rate of star formation with time (as for spirals) or an epoch of formation a long time ago (as for ellipticals). This is consistent with what we know about blue compacts and dwarf spheroidals as well.

Nearby dwarf irregulars are currently forming stars at an extremely low rate, and although this low rate may be more or less a constant underlying rate, through time every so often this rate does increase. When this happens it is possible that a dwarf irregular galaxy would then be classified as blue compact dwarf galaxy, and if this rate ever goes to zero they would be dwarf spheroidals.

The surveys to study the properties of the very distant, so-called 'faint blue galaxies' seen in all deep images of the sky have come to the conclusion that the majority of these objects are at intermediate redshifts and are late-type STARBURST GALAXIES. An analysis of the number of faint blue galaxies in deep surveys, combined with their luminosity and color variations, gives an indication of how short and how intense these bursts of star formation must be for us to detect the number of faint blue galaxies that we do. This type of analysis suggests that they are quite small and undergo extremely short extremely intense bursts of star formation. Detailed imaging of these objects from the Hubble Space Telescope shows a large majority to be irregular in shape. Thus what is known about these very distant, very faint but very numerous faint blue galaxies is perfectly consistent with what we can assume about the present-day characteristics of the dwarf irregular galaxies we see and can study in great detail in the nearby universe and Local Group. Dwarf irregular galaxies are thus a very important link between the nearby universe, which we can study relatively easily, and the most distant objects in the universe, GALAXIES AT HIGH-REDSHIFT, which we can never hope to be able to study in the same detail as Local Group galaxies.

Bibliography

Baade W 1968 *Evolution of Stars and Galaxies* (Cambridge, MA: Harvard University Press)

Da Costa G S 1998 Dwarf galaxies *Stellar Astrophysics for the Local Group* (Cambridge: Cambridge University Press) pp 351–406

Hodge P 1986 *Galaxies* (Cambridge, MA: Harvard University Press)

Mateo M 1998 Dwarf galaxies in the Local Group *Ann. Rev. Astron. Astrophys.* **36** 435

Meylan G and Prugniel P 1994 *Dwarf Galaxies* (Garching: European Southern Observatory)

Eline Tolstoy