Dwarf Galaxies: From the Deep Universe to the Present
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Neutral Hydrogen in Nearby Dwarf Galaxies

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Abstract. Here I briefly highlight our studies of the gas content, kinematics and star formation in nearby dwarf galaxies ($D < 10$ Mpc) based on the **'Local Volume H I Survey'** (LVHIS, Koribalski et al. 2018), which was conducted with the Australia Telescope Compact Array (ATCA). The LVHIS sample consists of nearly 100 galaxies, including new discoveries, spanning a large diversity in size, shape, mass and degree of peculiarity. The hydrogen properties of dwarf galaxies in two nearby groups, Sculptor and CenA / M83, are analysed and compared with many rather isolated dwarf galaxies. Around 10% of LVHIS galaxies are transitional or mixed-type dwarf galaxies (dIrr/dSph), the formation of which is explored. — I also provide a brief update on **WALLABY Early Science**, where we focus on studying the H I properties of galaxies as a function of environment. WALLABY (Dec < +30 degr, $z < 0.26$) is conducted with the Australian SKA Pathfinder (ASKAP), a ∼6-km diameter array of 36 × 12-m dishes, each equipped with wide-field (30 sq degr) Chequerboard Phased Array Feeds.

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1. LVHIS – The Local Volume H I Survey

The LVHIS project provides high-resolution H I spectral line and 20-cm radio continuum data products for nearly 100 nearby galaxies, based on over 2500 hours of ATCA observations. The raw data and the data products are available for download. The LVHIS galaxy properties are presented by Koribalski et al. (2018), together with an overview, H I galaxy atlas and a short description of each galaxy. The star-formation properties of LVHIS galaxies are analysed by Wang et al. (2017), using multi-wavelength images, and Shao et al. (2018) using the ATCA radio continuum data. The LVHIS Galaxy Atlas and database (incl. FITS files) can be found on-line at *www.atnf.csiro.au/research/LVHIS*; more products will be added in future.

Within LVHIS, dwarf galaxies are in the vast majority, including transitional, irregular and Magellanic barred galaxies. For detailed studies of individual LVHIS galaxies see, for example, van Eymeren et al. (2010) on IC 4662 and NGC 5408, López-Sánchez et al. (2012) on the peculiar starburst dwarf galaxy NGC 5253, Westmeier et al. (2011, 2013) on NGC 55 and NGC 300, For et al. (2012) on the Circinus Galaxy, and Koribalski & López-Sánchez (2009) on the NGC 1512/1510 system. In the LVHIS overview paper (Koribalski et al. 2018) we highlight the nearest known neighours to each galaxy and study their 3D environment, made possible by independent distance estimates now available for most Local Volume galaxies. On several occasions we discovered uncatalogued dwarf companions to the LVHIS galaxies, and we expect many more discoveries of dwarf galaxies in future, large-scale SKA and SKA pathfinder H I survey such as WALLABY (Koribalski 2012; see Section 2), the ASKAP H I All-Sky Survey (Dec < +30 degr; $z < 0.26$).

Fig. 1 shows a collage of LVHIS spiral and dwarf galaxies; their distributions of cold hydrogen gas typically extend a factor 2 – 3 beyond the bright stellar disks. The red and yellow-coloured reservoirs of dense hydrogen gas pinpoint where most of the galaxy's star formation is happening, while the dark blue areas indicate large amounts of dormant fuel (cold gas) not yet forming stars. We find a veritable zoo of shapes and sizes ranging from irregular dwarf galaxies to majestic grand-design spiral galaxies. Fig. 2 shows the ATCA H I velocity fields for the same LVHIS galaxies.

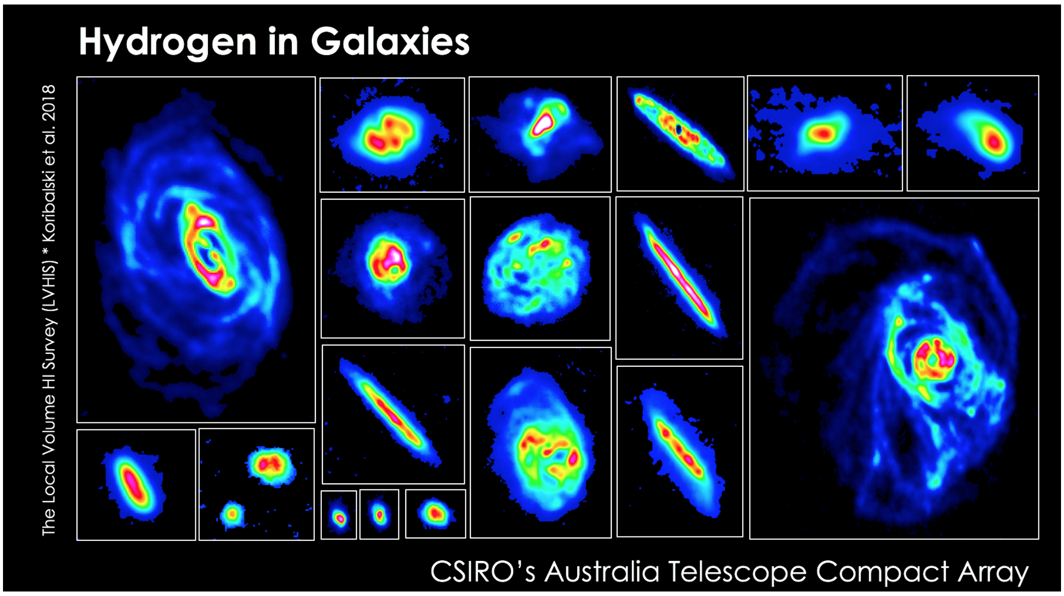

Figure 1. LVHIS collage — ATCA H I distributions for about a quarter of the LVHIS galaxies (not to scale), showing the diversity of morphologies, sizes, and shapes / orientations. The largest LVHIS galaxies are Circinus (top left) and M 83 (bottom right), both spiral galaxies with very extended H I disks (Koribalski et al. 2018).

2. WALLABY – The ASKAP H I All Sky Survey

During ASKAP Early Science Phase 1 (Oct 2016 – Mar 2018) the WALLABY team obtained ~800 hours of H I 21-cm spectral line observations for four target fields with an array of up to 16 PAF-equipped antennas. Using all 36 beams, typically arranged in a 6×6 pattern, we achieved the desired field of view of 30 square degrees. Our aim was to reach full WALLABY depth (~1.6 mJy beam^{-1} per 4 km s^{-1} channel), which required spending 150-h per field over multiple nights. By targeting nearby, gas-rich galaxy groups and clusters we set out to explore the H I content, kinematics and star formation of galaxies as a function of their local environment as well as searching for H I clouds, filaments and plumes between galaxies (e.g., Serra et al. 2015b, Saponara et al. 2018). For field number one, centered on the NGC 7232 galaxy group, we were able to use only a limited ASKAP bandwidth of 48 MHz. Our first WALLABY Early Science results are presented by Lee-Waddell et al. (2018) on the interacting NGC 7232/3 galaxy triplet and surroundings, Kleiner et al. (2018) on the spiral galaxy IC 5201 and dwarf galaxy companions, and Reynolds et al. (2018) on the NGC 7162 galaxy group. The second field targeted the Fornax Cluster in Dec 2016; the available observing bandwidth was 192

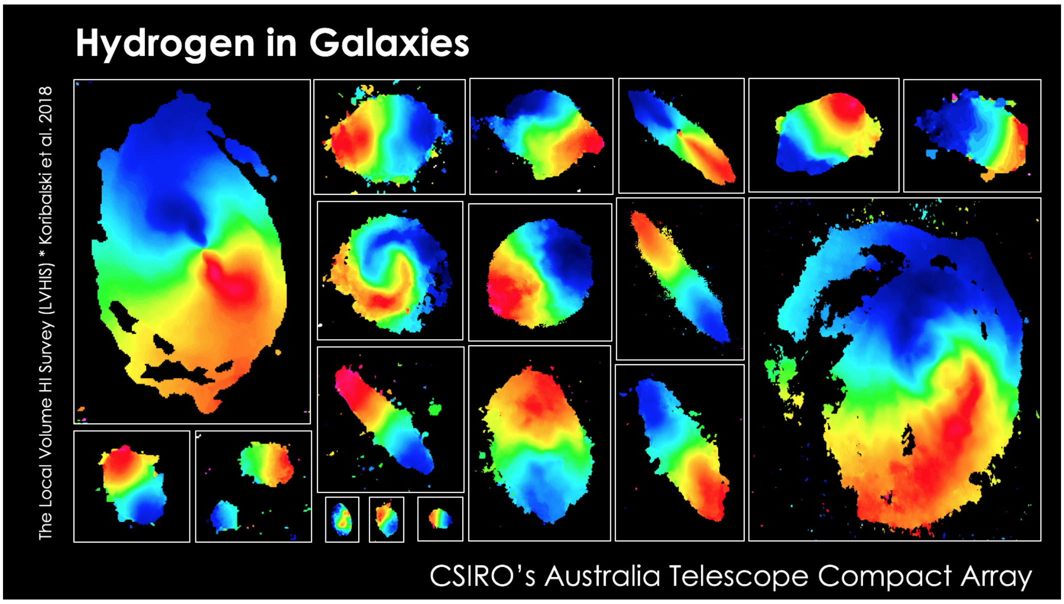

Figure 2. LVHIS collage — ATCA H I velocity fields, complementing Fig. 1. Most of the LVHIS galaxies show the clear signature of a rotating disk, although peculiar motions and asymmetries are notable. The green colours typically correspond to each galaxy's systemic velocity from which their Hubble distance is derived. The fast rotating disks of spiral galaxies (blue = approaching side, red = receding side) are typically flat in the inner region but can be strongly warped in their outer parts. Using the H I velocity fields we can determine both the shapes of galaxy disks and their total mass distribution, including their dark matter content as a function of radius. — For more details see Koribalski et al. (2018) and references therein.

MHz. Our third and fourth fields were centered on the Dorado and M 83 galaxy groups, respectively. WALLABY Early Science results are presented by Elagali et al. (2018), who focused on the spiral galaxy NGC 1566, with several more papers to follow. ASKAP Early Science Phase 2 (e.g., mapping H I line and radio continuum emission, searching for fast radio bursts) is set to continue with the full ASKAP-36 array and close to the full bandwidth of 300 MHz throughout 2019.

WALLABY details can be found at *www.atnf.csiro.au/research/WALLABY*, including ASKAP updates. We note that the H I Parkes All Sky Survey (HIPASS; Dec $< +25$ degr), which was conducted with an innovative 13-beam receiver on the 64-m Parkes Telescope, covers nearly the same sky area as WALLABY. While HIPASS has a low resolution of $\sim$15.5 arcmin & 18 km s^{-1} (Barnes et al. 2001) and catalogued more than 5000 galaxies (Koribalski et al. 2004, Meyer et al. 2004, Wong et al. 2006), WALLABY — conducted with brand-new, 188-element ASKAP Phased Array Feeds — has a high resolution of $\sim$30 arcsec & 4 km s^{-1} and is expected to detect over 600 000 galaxies of which $\sim$5000 galaxies will be well-resolved (Koribalski 2012). Interestingly, we already know the majority of these well-resolved galaxies (H I diameter > 150 arcsec) quite well as they correspond to the catalogued HIPASS galaxies. We employ the remarkably tight H I size – mass relation, recently re-visited by Wang et al. (2016), to estimate the H I diameters of HIPASS galaxies and implications for WALLABY.

3. Software development: SoFiA, FAT & 2DBAT

Our new Source Finding Application (SoFiA; Serra et al. 2015a) runs on data cubes customized to search for point-like and/or extended H I sources. SoFiA delivers H I source parameters, spectra, moment maps, cublets and masks, and is currently deployed on WALLABY Early Science data cubes (e.g., Lee-Waddell et al. 2018, Reynolds et al. 2018). Most importantly, SoFiA can also calculate the reliability of each source candidate. A new function (the "busy function"), developed to reliably fit spectral line profiles (Westmeier et al. 2014) is also part of SoFiA. We also aim to derive detailed kinematical parameters for the well-resolved WALLABY galaxies. For this purpose, we are currently testing and comparing several algorithms (TiRiFiC, velfit, rotcur, etc.) with the aim to develop automated parametrization pipelines. First examples are the Fast Automated Tirific (FAT) pipeline developed by Kamphuis et al. (2015) and the 2D Bayesian Automated Tirific (2DBAT) package developed by Oh et al. (2018), both available on-line.

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