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The 2X-H I disks of spiral galaxies

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Abstract. The outskirts of galaxies — especially the very extended H I disks of galaxies — are strongly affected by their local environment. I highlight the giant 2X-H I disks of nearby galaxies (M 83, NGC 3621, and NGC 1512), studied as part of the Local Volume H I Survey (LVHIS), their kinematics and relation to XUV disks, signatures of tidal interactions and accretion events, the $M_{\rm HI} - D_{\rm HI}$ relation as well as the formation of tidal dwarf galaxies. - Using multi-wavelength data, I create 3D visualisations of the gas and stars in galaxies, with the shape of their warped disks obtained through kinematic modelling of their H I velocity fields.

Keywords. radio lines: galaxies (M 83, NGC 3621, NGC 1512), spiral, ISM, 3D visualisation

1. Introduction

To trace gas and stars in the outskirts of galaxy disks, we typically use H I mapping (e.g., Huchtmeier & Bohnenstengel 1981; Koribalski & López-Sánchez 2009; Heald *et al.* 2011; Serra *et al.* 2012; Lee-Waddell et al. 2012; Koribalski *et al.* 2016) and deep, wide-field optical imaging (e.g., Martínez-Delgado *et al.* 2010; Duc *et al.* 2015). The H I disks of galaxies, which often extend a factor two or more beyond the bright stellar disk (Warren *et al.* 2004), are excellent tracers of their total mass (visible and dark matter). The gas kinematics allows us to model their 3D shapes and obtain rotation curves, from which the radial distribution and amount of dark matter is derived.

GALEX ultra-violet (UV) imaging of nearby galaxies led to the discovery of extended UV disks (XUV-disks) in the galaxies M 83 and NGC 4625 (Thilker et al. 2005; Gil de Paz *et al.* 2005), indicating star formation well beyond the radius where H II regions are typically found. Here I suggest that the H I distributions of XUV-disk galaxies extend about twice as far. The term 2X-H I disk was introduced by Koribalski & López-Sánchez (2009), who found the giant H I disk of NGC 1512 to extend a factor two beyond its XUV-disk. Another prominent spiral galaxy with an 2X-H I disk is M 83 (Koribalski 2008; Jarrett et al. 2013; Koribalski 2015).

2. The 2X-HI disks of nearby galaxies

A search for more XUV disks by Thilker *et al.* (2007), revealed many more galaxies, among them the nearby, southern spirals NGC 300 (Westmeier, Braun & Koribalski 2011), NGC 1512 (Koribalski & López-Sánchez 2009), NGC 1672 (Houghton 1998), and NGC 3621 (Walsh 1997). ATCA H I mosaics reveal their 2X-H I disks, some of which are shown in Fig. 1. The galaxy H I diameters are as expected from their H I masses and lie firmly on the $M_{\rm HI}$ – $D_{\rm HI}$ relation (Wang *et al.* 2016; Wang, these proceedings). An H I atlas of nearby galaxies is presented as part of the Local Volume H I Survey (LVHIS; Koribalski 2008, Koribalski *et al.* 2016). LVHIS consists of a complete sample of ∼80 H I-rich galaxies in the southern sky, observed with the Australia Telescope Compact Array (ATCA), ∼30 hours each, and supplemented by multi-wavelength images.

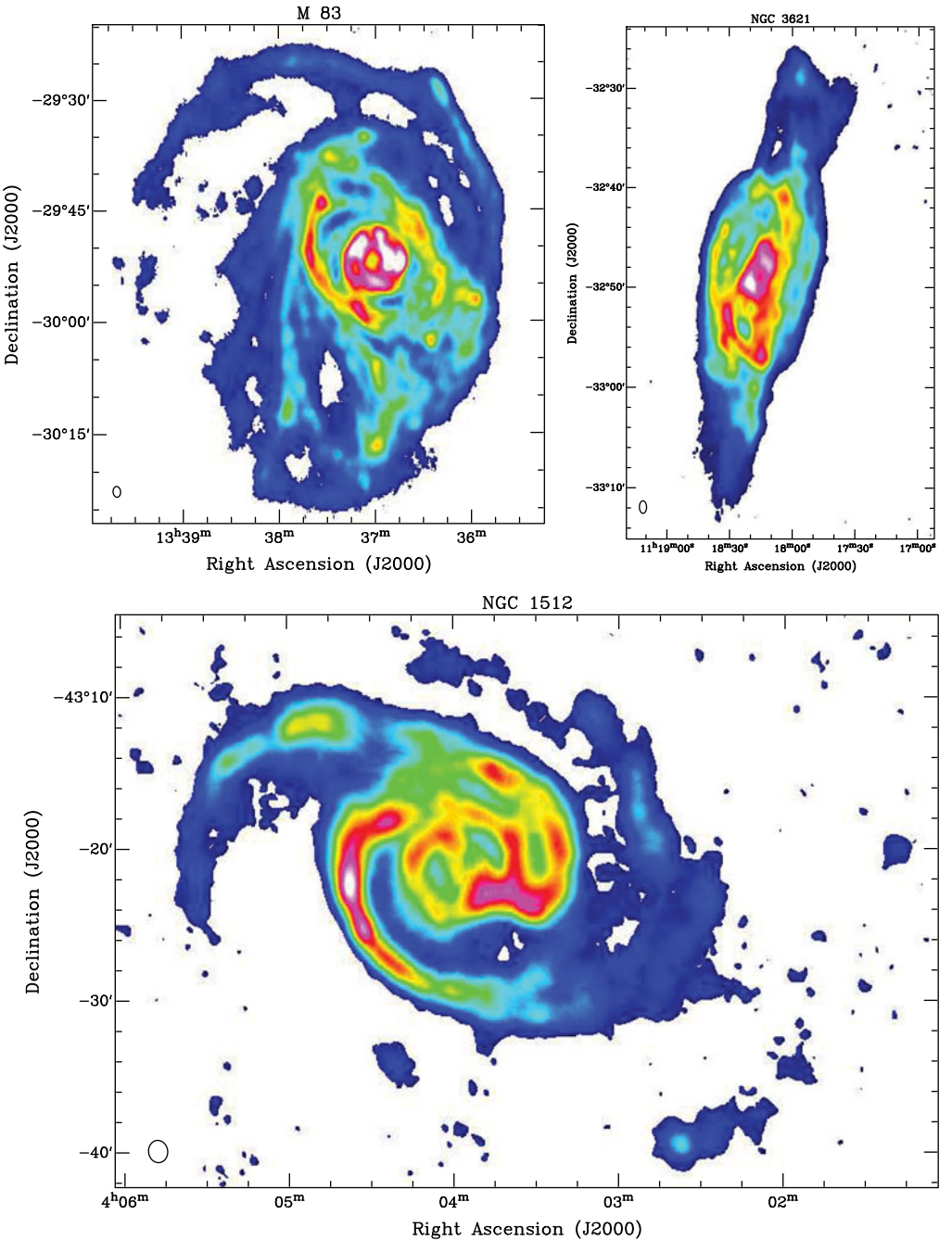

Figure 1. 2X-H I disks of the spiral galaxies M 83 (top left), NGC 3621 (top right) and NGC 1512/1510 (bottom; Koribalski & López-Sánchez 2009). The displayed ATCA H I mosaics are part of the Local Volume H I Survey (LVHIS) project (Koribalski *et al.* 2016). For more details see the project webpage at *www.atnf.csiro.au/research/LVHIS*.

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The optical B_{25} diameter of M 83's bright stellar disk is ∼13′ (17 kpc at $D = 4.5$ Mpc). Deep optical photography by Malin & Hadley (1997) reveals a much larger stellar disk (∼20′) as well as faint streams and loops further out, indicative of dwarf galaxy accretion. The most prominent stellar stream lies ∼20′ north of M 83's center. For comparison, the H I disk of M 83, mosaiced by the ATCA (see Fig. 1), has a diameter of over 60′ (80 kpc), reveals a large tidal tail/arm wrapping at least 180 degrees around, from West to East, and shows signs of ram pressure stripping on the compressed, western side. Also shown in Fig. 1 are NGC 3621, which resembles M 83 but seen at a larger inclination angle, and NGC 1512, which is known to interact with its blue compact dwarf companion NGC 1510.

GALEX provided a beautiful image of M 83's XUV disk (Thilker *et al.* 2005), with UV emission detected out to a radius of ∼20′. The star-forming regions in M 83's outer disk agree well with the high density H I clumps, suggesting that H I is an excellent tracer of star formation in the galaxy outskirts (see also Koribalski & López-Sánchez 2009; For, Koribalski & Jarrett 2012). A colorful overlay of M 83's GALEX XUV-disk with the VLA single-pointing H I map by Walter *et al.* (2008) featured on one of the IAU S321 conference posters, greeting participants every morning at our lovely venue in Toledo, Spain. We note that the H I emission seen by the VLA in M 83 and NGC 3621 (Walter *et al.* 2008) is only 22% and 77%, respectively, of the total H I flux, which is well established from single-dish imaging (e.g., Huchtmeier & Bohnenstengel 1981; Koribalski *et al.* 2004).

The ASKAP H I All Sky Survey (WALLABY, DEC < +30 degr) is expected to detect over 500 000 galaxies and provide well-resolved maps for ∼5000 of these (Koribalski 2012).

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