The Local Universe: Galaxies in 3D

Dr. Bärbel Koribalski
CSIRO Astronomy and Space Science
Australia Telescope National Facility
Galaxies in 3D across the Universe – 7 July 2014
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3D visualisation of data cubes

HIPASS supercube made by Russell Jurek, 3D visualisation by Amr Hassan & Chris Fluke

HIPASS channel maps of the Sculptor Group
The Hubble Ultra Deep Field

Galaxies in 3D across the Universe

Animation Credit:

NASA, ESA, F. Summers, Z. Levay, L. Frattare, B. Mobasher, A. Koekemoer and the HUDF Team (STScI)
UDFy-38135539
redshift: $z = 8.55$
13 billion light years

The Hubble Ultra Deep Field (UDF)
SDSS-III galaxies (dr9)

Each galaxy in the animation is placed at the location mapped by SDSS and is represented by the zoomed-in template image that matches the actual shape of the galaxy.

Credit:

Miguel A. Aragón (Johns Hopkins University), Mark SubbaRao (Adler Planetarium), Alex Szalay (Johns Hopkins University), Yushu Yao (Lawrence Berkeley National Laboratory, NERSC), and the SDSS-III Collaboration
soon to be complemented by the

**SkyMapper Southern Sky Survey**

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<td>22.9</td>
<td>22.6</td>
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<td>21.5</td>
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BlueDisks

Wang et al. (2013)

HI study of a sample of 23 spiral galaxies selected to have large stellar masses and blue outer disk.

HI column density contours overlaid on SDSS images.
HI + CO survey predictions

Figure 4 from A Virtual Sky with Extragalactic H I and CO Lines for the Square Kilometre Array and the Atacama Large Millimeter/Submillimeter Array

Obreschkow et al. (2009)
**Atacama Large Millimetre Array (ALMA)**

- **ALMA**: 50 ×12-m dishes plus 12 × 7-m and 4 ×12-m (ACA)
- Located at 5000 m altitude; freq. range 35 – 950 GHz; baselines up to 16 km; high-resolution imaging of the “cool Universe”
- ALMA’s **data rate** is **96 Gbit/s**; raw data ~200 TB /yr is currently stored and mostly downloaded & processed by the users
- **ALMA correlator** (delivering **17 PetaOPS** - fastest of its kind)
- Partnership between Europe, North America & East Asia + Chile
Australian SKA Pathfinder (ASKAP)

- **ASKAP**: 36 × 12-m dishes (freq. 0.7 – 1.8 GHz, baselines up to 6 km; e.g., mapping the 21-cm line of neutral atomic hydrogen gas)
- Started science commissioning work 6 PAF-equipped antennas
- ASKAP’s **data rate** is expected to be **72 Tbit/s**; (once fully operational), data output ~**500 PB /yr**; raw data will be stored only temporarily; archive data outputs (images/cubes) long term
- **ASKAP correlator** (delivering **340 Tflop/s**)

Six of the 36 ASKAP dishes
Phase 1 (10% SKA)

- **South Africa**: single-feeds (64 MeerKAT dishes + 190 SKA-1 dishes: deep field)
- **Australia**: phased array feeds (36 ASKAP dishes + 60 SKA-1 dishes: fast surveys)
- SKA-1 construction from 2016
- baselines up to 100 km

**ASKAP**: currently 6 PAF array - 9 beams
First 9-beam image with ASKAP

BETA test field, 9 beam image, 700 - 1000 MHz, DR 50000
Credit: Ian Heywood and the ACES Team
First extragalactic HI emission with ASKAP

BETA 1.4 GHz image of the nearby starburst galaxy NGC 253.

Credit: Paolo Serra and the ACES Team
First extragalactic HI emission with ASKAP

BETA 1.4 GHz image of the nearby starburst galaxy NGC 253.

Credit: Paolo Serra and the ACES Team
WALLABY - the ASKAP HI All-Sky Survey
(led by B. Koribalski & L. Staveley-Smith)

ASKAP = 36 x 12-m dishes
FOV = 30 sq degr

~600 000 galaxies
Duffy et al. (2012) prediction
HI in Galaxies: from $z = 0$

Gratier et al. 2010

HerM33es
HI in Galaxies: from $z = 0$ to $0.25$

Gratier et al. 2010

HerM33es

Verheijen et al. 2007

Koribalski et al. 2004

HIPASS BGC
**HI in Galaxies: from $z = 0$ to 0.25**

Currently $\approx 35\,000$ HI detected galaxies:
- Cornell archive contains HI spectra towards 9,000 optically selected galaxies; ALFALFA 40% catalog contains about 15,000 galaxies
- HIPASS & HIZOA catalogs from Parkes HI surveys contain $>6,500$ HI-detected galaxies

**SKA Pathfinder HI Surveys:**
- predicted $\approx 600,000$ HI detected galaxies from WALLABY + WNSHS ($z < 0.25$)

**Square Kilometer Array:**
- detect Milky Way like galaxy at $z = 1$
3D visualisation of HIPASS galaxies

HIPASS (HII) Galaxy Catalogue
Chevrier et al. (2003) (HII galaxies) - (Oppenheimer et al. 2003)
French 171

Animation by Mark Calabretta

HIPASS references: Koribalski et al. (2004), Meyer et al. (2004), Wong et al. (2006).
warped HI disks of spiral galaxies

NGC 891 – Fraternali et al.

UGC 3697 – Matthews & Uson

NGC 5055 – Patterson et al.
warped HI disks of spiral galaxies

M 83 – Koribalski et al.

UGC 3697 – Matthews & Uson

NGC 6949 – Oosterloo et al.
HI Galaxy Dynamics

LVHIS galaxies (gas + stars)
HI Galaxy Dynamics

IC 4662 (van Eymeren, BK et al. 2009)

NGC5253 (Lopez-Sanchez, BK et al. 2011)

LVHIS galaxies (gas + stars)
HI streams and plumes

Leo Ring - Schneider et al. (1989)

NGC6221/6215 group – BK and Dickey (2003)
HI streams and plumes

NGC 3263 group – English, BK et al. (2010)

HI in nearby clusters (Coma and Virgo A)

Bravo-Alfaro et al. 2000

Chung et al. 2007
Hydrogen Accretion in Local Galaxies

HALOGAS

Heald et al. (2011), Kamphuis et al. (2013), etc.

(total sample is 24 galaxies)
VLA-ANGST

The VLA-ACS Nearby Galaxy Survey Treasury Project

Ott et al. (2012)
The VLA-ACS Nearby Galaxy Survey Treasury Project

Ott et al. (2012)
Stellar velocity fields of early-type galaxies in three Abell clusters
(Fogarty et al. 2014)
Galaxy kinematics are important

Using a galaxy’s velocity field or data cube we derive:

- its 3D structure
- rotation curve \(\rightarrow\) tracing DM
- dispersion / turbulence
- outflow / infall
- accretion / ejection
- peculiar features
Cappellari et al. (2011)

260 Early-type galaxies (D < 42 Mpc)
Optical: IFU data & Megacam imaging
Radio: CO + HI spectral line data
Plus archival data (eg GALEX)

Arp 227 (NGC 474/470)
Image by Cuillandre et al.
NGC 5198 (u)

ATLAS-3D
Serra et al. (2012)

1.8 $\times 10^{19}$ cm$^{-2}$

NGC 1023 (u)

1.7 $\times 10^{19}$ cm$^{-2}$

NGC 3945 (D)

3.2 $\times 10^{19}$ cm$^{-2}$

NGC 5582 (D)

2.0 $\times 10^{19}$ cm$^{-2}$

NGC 6278

2.4 $\times 10^{19}$ cm$^{-2}$

NGC 5557 (u)

2.8 $\times 10^{19}$ cm$^{-2}$

Serra et al. (2012)
BIMA SONG (Regan et al. 2001)
BIMA SONG  (Regan et al. 2001)

CO Survey Of 44 Nearby Galaxies
HERA CO-Line Extragalactic Survey (HERACLES) used the IRAM 30-m telescope to map CO emission from 48 nearby galaxies + complementary data.

Leroy et al. (2009)
HERA CO-Line Extragalactic Survey (HERACLES) used the IRAM 30-m telescope to map CO emission from 48 nearby galaxies + complementary data.
The HI Nearby Galaxy Survey (THINGS)
F. Walter, E. Brinks, E. de Blok, F. Bigiel, M. Thornley, R. Kennicutt
Messier 101
Messier 101

HST optical
Messier 101

GALEX UV
Messier 101

GALEX UV

VLA HI

Right Ascension (J2000)

Declination (J2000)
Multiwavelength data of the Spiral Galaxy M 101


Credit of the composition: Ángel R. López-Sánchez (Australian Astronomical Observatory / Macquarie University).
The Circinus Galaxy
(Jones et al. 1999; Curran et al. 2008; Wilson et al. 2011)

ATCA HI velocity field

ATCA HI distribution

Chandra X-ray + Hα

2MASS JHK

ATCA 6cm

SN1996cr
Spitzer 3.4 micron
Spitzer 8 micron
ATCA HI @ 15"

For, Koribalski & Jarrett 2012
Messier 83

GALEX XUV disk

Thilker et al. 2007

Gil de Paz et al. 2007

GALEX FUV / NUV composite
Messier 83

GALEX XUV disk

+ VLA HI contours

(single pointing)

Bigiel et al. 2010
Messier 83

GALEX XUV disk

+ ATCA HI mosaic

Koribalski & Lopez-Sanchez
HI is an excellent tracer for SF in the outer disk.

Messier 83

2X-HI disk

ATCA
HI mosaic

Koribalski
& Lopez-Sanchez
Messier 83

GALEX NUV+FUV; Thilker et al.

XUV + 2X-HI disk
NGC 5253 (3.90 Mpc)

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NGC 5236 (4.5 Mpc)

UGCA 365 (5.15 Mpc)

IC 4361 (4.41 Mpc)

NGC 5264 (4.53 Mpc)

NGC 5253 (3.90 Mpc)
From cosmological simulations to nearby galaxies

First attempt at 3D Visualisation of gas and stars in galaxies (with Claudio Gheller & Klaus Dolag)
The dwarf irregular galaxy
ESO215-G?009
(Koribalski, Wang & Warren 2014)

HST (V + I), GALEX

HST (V + I), GALEX

30" = 500 pc
The dwarf irregular galaxy
ESO215-G?009
(Koribalski, Wang & Warren 2014)
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HI is an excellent tracer for SF in the outer disk

HIPASS J1336-29

D ≈ 4.5 Mpc

HI extent > 80 kpc

$M_{HI} = 8 \times 10^9 M_\odot$
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