Deep wide field HI imaging of Messier 31

Chemin, Laurent; Carignan, Claude; Foster, Tyler

Published in:
Panoramic Radio Astronomy: Wide-field 1-2 GHz research on galaxy evolution

Publication date:
2009

PROCEEDINGS OF SCIENCE

Deep wide field HI imaging of M31

Laurent Chemin*
GÉPI, Observatoire de Paris, section Meudon, CNRS & Université Paris 7 UMR 8111, 5 Place Jules Janssen, 92195 Meudon, France
E-mail: `laurent.chemin@obspm.fr`

Claude Carignan
Laboratoire d'Astrophysique Expérimentale (LAE), Observatoire du mont Mégantic, and Département de physique, Université de Montréal, C.P. 6128, Succ. Centre-Ville, Montréal, QC, Canada H3C 3J7
Observatoire d'Astrophysique de l'Université de Ouagadougou (UFR/SEA), 03 BP 7021 Ouagadougou 03, Burkina Faso

Tyler Foster
Department of Physics & Astronomy, Brandon University, Brandon, MB, Canada R7A 6A9

We report on preliminary results from a new deep 21-cm survey of the Andromeda galaxy, based on observations performed with the Synthesis Telescope and the 26-m antenna at DRAO. The HI distribution and kinematics of the disc are analyzed and basic dynamical properties are derived. New HI structures are discovered, like thin HI spur-like structures and an external arm in the disc outskirts. The HI spurs are related to perturbed stellar clumps outside the main disc of M31. The external arm lies on the far, receding side of the galaxy and has no obvious counterpart in the opposite side. These HI perturbations probably result from tidal interactions with companions. It is found a dynamical mass of $(3.9 \pm 0.3) \times 10^{11}$ M$_\odot$ enclosed within a radius $R = 36$ kpc and a total mass of $\sim 7.9 \times 10^{11}$ M$_\odot$ inside the virial radius.

Panoramic Radio Astronomy: Wide-field 1-2 GHz research on galaxy evolution - PRA2009
June 02 - 05 2009
Groningen, the Netherlands

*Speaker.

1. Introduction

Understanding the formation and evolution of galaxies like the Milky Way is one of the major goal of astrophysics. The Andromeda galaxy (M31) is very well suited to put constrains on the physical processes that control the evolution of spiral galaxies because of its proximity. The important stellar features related to the evolution of M31 are the faint, extended and perturbed structures seen in the disc outskirts, in addition to many of the dwarf companions that have been detected in its close neighborhood ([8]). They are undoubtedly the imprints of the hierarchical growth of the stellar disc and halo of M31, similar to those seen in numerical models of dark matter and galaxy evolution in the framework of the Cold Dark Matter paradigm (e.g. [11]).

In this work we are interested in providing a detailed view of the neutral hydrogen disc of M31 from recent, deep, wide-field and high angular HI imaging. Our direct objectives are (i) to study the most extended HI distribution of M31, (ii) to derive an accurate HI rotation curve for it, and (iii) to derive its basic dynamical parameters in order to put further constraints on the history of its mass assembly. Preliminary results are described hereafter. A complete analysis of the data are presented in Chemin et al. (2009, [5]).

2. Observations

The HI observations were performed with the Synthesis Telescope and the 26-m dish at the Dominion Radio Astrophysical Observatory (DRAO) between September and December 2005. Five fields were observed in the direction of M31 for a total exposure time of 144 hours per field. The spectral resolution is 5.3 km s^{-1} and the angular size of the synthesized beam is $\sim$ 60” $\times$ 90”. It samples a linear scale of $\sim$ 230pc $\times$ 340 pc at the M31 distance (785 kpc, [9]).

3. Results

The integrated emission is displayed in Figure 1 (left-hand panel). The high resolution HI map shows a disc with very little gas in its central regions, as ususally observed in early-type discs. Faint spiral-like or ring-like structures are observed at $R \sim 3$ kpc and $R \sim 8$ kpc. They coincide with dusty ring-like structures observed in NIR images from SPITZER-IRAC data ([1]) as well as with molecular gas ring-like structures ([10]). Other brighter spiral- or ring-like structures are observed at $R \sim 10$ kpc, 13 kpc and 16 kpc. Part of these HI structures have already been presented in previous studies of M31 ([3, 12]).

New faint structures that were not seen in old HI images are discovered. First the two disc extremities exhibit thin spur-like extensions, particularly towards the North-East. Their kinematics are in good continuity to the adjacent inner disc. Velocity gradients are detected in these spurs ($\sim$ 20 km s^{-1} along $\sim 7-10$ kpc). These spurs appear tightly linked to stellar clumps (the “G1" clump and the NE extension, as identified in [8]).

Then an external spiral arm is discovered on the edge of the receding half of the disc. It is outlined with dashed lines in Figure 1 (right-hand panel). The HI mass of this new arm is $\sim 10^8$ $M_\odot$. Its apparent length is $\sim$ 32 kpc. It is connected to another more extended, brighter spiral arm. The arm is clumpy towards its northeastern end. Part of the thin NE HI spurs is a kinematical

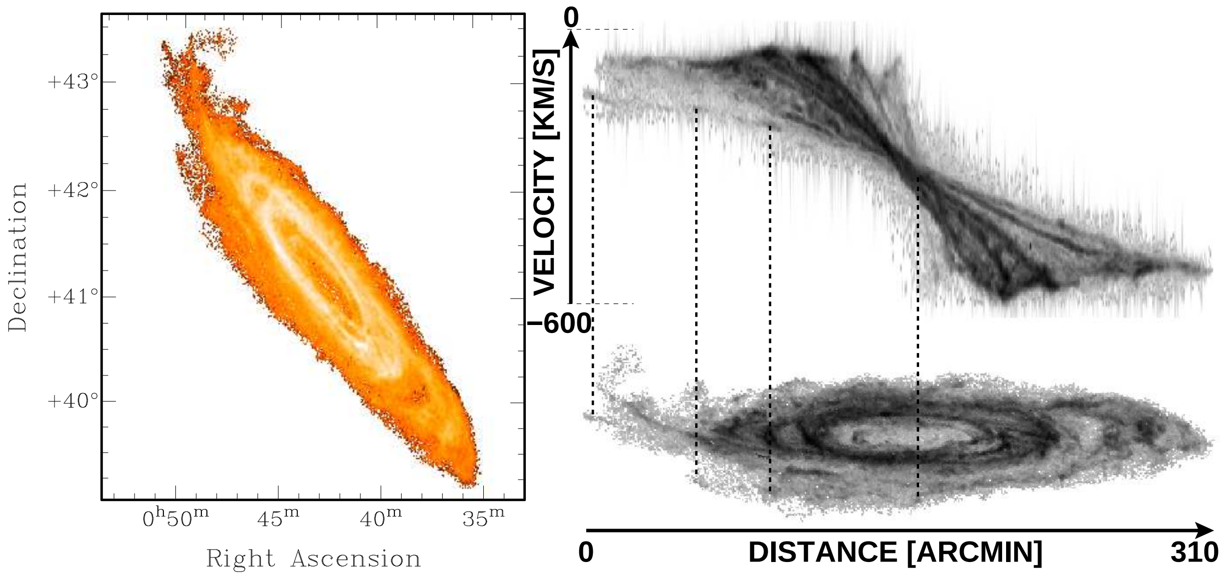

Figure 1: Left-hand panel: HI integrated emssion of Messier 31. **Right-hand panel:** 3D view of the HI datacube of M31. The top panel is the position-velocity diagram of the full datacube projected onto the photometric major axis. The bottom panel is the same map as in the right-hand panel but displayed with the major axis parallel to the horizontal axis. Dashed lines show the location of the newly discovered external arm (see text for details).

extension of that external arm, as seen in the postion-velocity plot of Fig. 1. It is striking that the external arm has no evident morphological and kinematical counterpart in the approaching half of the disc with respect to the galactic centre. Moreover, it is obvious that its kinematics is very peculiar compared to the disc velocities. As a consequence it is very likely that this spiral-like structure has been generated by external effects to M31, either by tidal effects after the passage of a galaxy satellite or even by gas accretion from the intergalactic medium or from a gas rich companion. Numerical simulations are necessary to investigate the different possibilities and find the origin of the faint new perturbations. Notice that we are confident about their detection because they are also observed in the recent HI map of M31 by Braun et al. (2009, [2]).

4. Dynamical analysis

Our previous dynamical analysis of M31 allowed us to derive a total mass of 3.4 $\times 10^{11}$ $M_\odot$ for $R < 35$ kpc from single dish data obtained at Effelsberg and GBT ([4]). A new, more extended rotation curve is derived from a tilted-ring analysis of the velocity field of M31. A mass distribution model is fitted to the rotation curve. As provisional results, it is derived a dynamical mass of $M_{\rm Dyn} = (3.9 \pm 0.3) \times 10^{11}$ $M_\odot$ inside $R = 36$ kpc and a dark-to-baryonic mass ratio of $M_{\rm Dark}/M_{\rm Baryon} \sim 3.0$ (75% of dark matter, 25% of luminous baryons). Here $M_{\rm Baryon}$ represents the sum of the black hole, gaseous and stellar masses, $M_{\rm Dark}$ the dark matter mass, all values integrated within $R = 36$ kpc. The total mass of M31 extrapolated to the virial radius ($R \sim 190$ kpc, [8]) is $M_{\rm Vir} \sim 7.9 \times 10^{11}$ $M_\odot$. All these measurements are in excellent agreement with results found from other dynamical tracers ([6], [7]). A very good concensus seems to have been obtained for the enclosed mass inside the inner 36 kpc of M31, as well as for its total mass inside 190 kpc. We refer to Chemin et al. (2009, [5]) for a more detailed discussion of these results.

Acknowledgements

We are very grateful to the staff of the Dominion Radio Astronomy Observatory at Penticton for their support in obtaining the observations, and especially T. Landecker for encouraging us to pursue this project. We thank the scientific and local committees at ASTRON and Groningen for having organized the PRA 2009 conference and for all stimulating discussions during the conference.

References

[1] Barmby P., Ashby M. L. N., Bianchi L., Engelbracht C. W., Gehrz R. D., Gordon K. D., Hinz J. L., Huchra J. P., et al. 2006, ApJ, 650, L45

[2] Braun R., Thilker D. A., Walterbos R. A. M., & Corbelli E. 2009, ApJ, 695, 937

[3] Brinks E., & Shane W. W. 1984, A&ASS, 55, 179

[4] Carignan C., Chemin L., Huchtmeier W. K., & Lockman F. J. 2006, ApJ, 641, L109

[5] Chemin L., Carignan C., Foster T., 2009, ApJ, submitted

[6] Evans N. W., Wilkinson M. I., Guhathakurta P., Grebel E. K., & Vogt S. S. 2000, ApJ, 540, L9

[7] Ibata R., Chapman S., Ferguson A. M. N., Irwin M., & Lewis G., 2004, MNRAS, 351, 117

[8] Ibata R., Martin N. F., Irwin M., Chapman S., Ferguson A. M. N., Lewis G., & McConnachie A. W. 2007, ApJ, 671, 1591

[9] McConnachie A. W., Irwin M. J., Ferguson R. A., Ibata R. A., Lewis G. F., & Tanvir N. 2005, MNRAS, 356, 979

[10] Nieten C., Neininger N., Guélin M., Ungerechts H., Lucas R., Berkhuijsen E. M., Beck R., & Wielebinski R., 2006, A&A, 453, 459

[11] Springel V., White S. D. M., Jenkins A., Frenk C. S., Yoshida N., Gao L., Navarro J. F., Thacker R., et al., 2005, Nature, 435, 629

[12] Unwin S. C. 1983, MNRAS, 205, 787