SF2A 2013
L. Cambrésy, F. Martins, E. Nuss and A. Palacios (eds)

THE EXTENDED HI DISK OF THE NEARBY SPIRAL GALAXY NGC 2683

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Abstract. New deep VLA HI observations of the nearby spiral galaxy NGC 2683 are presented. A kinematic model was made in order to reproduce both, high resolution (VLA C+D array with a resolution of 20") and low resolution (VLA D array with a resolution of 1') data cubes. Using two different resolutions to match the model gives precious additional constraints to deal with a degenerated parameter space. Different flares, heights, warps and velocity lags as a function of galactic radius were tested. The thin HI disk shows an exponential flare beyond the optical radius which saturates at large radii. A warp component is seen but only within the optical radius. Multiple complex substructures were detected within the HI flare. The presence of an HI halo around the optical disk was also tested and excluded. This work gives insight into the recent gas accretion history of this nearby spiral galaxy.

Keywords: Galaxies: individual: NGC 2683 - Galaxies: ISM - Galaxies: Kinematics and dynamics

1 Introduction

The HI disk of galaxies can be perturbed by outflows from the star forming disk or from external gas infall. Internal perturbation, as galactic fountains (see Shapiro & Field 1976; Fraternali & Binney 2006, and references therein) can significantly affect the HI disk via stellar winds and supernova explosions. Fraternali et al. (2005) argued that a galactic fountain could be responsible of the velocity lag observed in the high-latitude gas of NGC 891. Accretion of intergalactic gas via merging of small gas-rich satellites (van der Hulst & Sancisi 2005) is another way to perturb the HI disk. Evidence of such merging can be found by studying the morphologies of HI disks, which often present warps or disk lopsidedness (Sancisi et al. 2008). Moreover, it is still not clear which role the atomic gas disk plays in the galaxy ecosystem (Schiminovich et al. 2010). To further investigate the role of the HI disk for the evolution of a spiral galaxy, NGC 2683 is a good candidate. NGC 2683 is an Sb spiral galaxy located at a distance of 7.7 Mpc (Tonry et al. 2001). The vertical profile of the gas is directly accessible since the galaxy is viewed edge-on. Casertano & van Gorkom (1991) observed NGC 2683 during 1h with the VLA in D array configuration. They found that the gas distribution is fairly symmetric and close to the plane of the optical disk. The derived rotation curve peaks at about 215 km s^{-1} at $\sim$ 3 kpc from the galaxy center and then decreases monotonically.

In the present work we aim to characterize the presence of a flare, a warp, a halo component and a kinematic lag in NGC 2683. We compared our kinematic models of the HI disk to both, high (C+D array) and low (D array) resolution new VLA observations.

2 Observation and data reduction

NGC 2683 was observed in December 2009 during 9h with the VLA in D array configuration. The total bandwidth of 3.125 MHz was divided into 128 channels with a channel separation of 5.13 km s^{-1}. Calibration was achieved using VLA standard calibration procedure. We obtained an rms noise level of 1. mJy/Beam in a 5 km s^{-1} channel. In addition, we also reduced 8.5 h of archival C array data. C and D array observations were combined into a single data set leading to a resolution of $21'' \times 20''$, with an rms noise level of 0.3 mJy/beam. The resulting HI gas distributions maps are presented in Fig. 1 at low (right panel) and high resolution (left panel). As observed by Casertano & van Gorkom (1991), the atomic hydrogen is distributed over a diameter of $26.5'$, i.e. almost 3 times the optical radius. A ring-like structure can also be seen at the extremity of the HI disk, offset by about 1 kpc from the optical disk. The high resolution data (C+D array) shows multiple and complex substructures.

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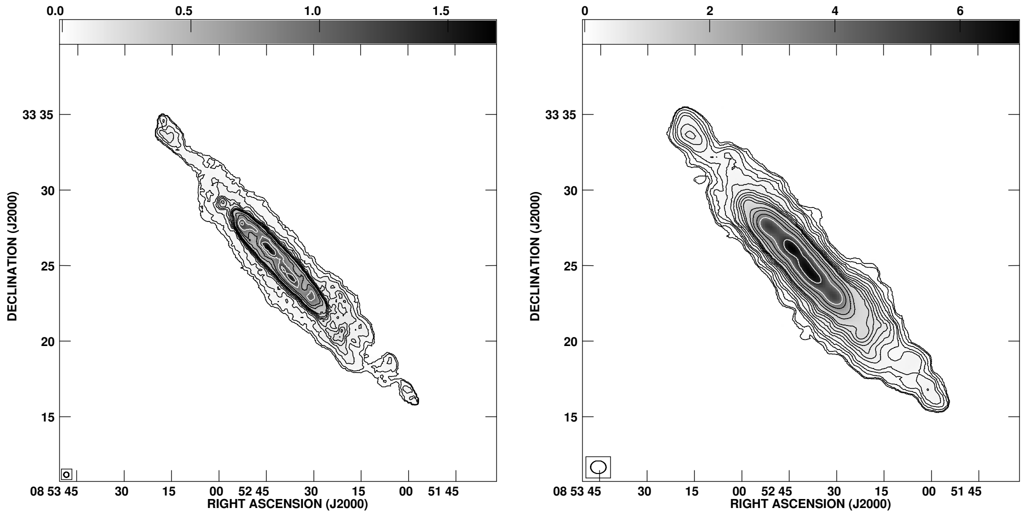

Fig. 1. Left panel: HI gas distribution of NGC 2683 C+D array observations. The beam size is 21″ × 20″. The contours levels are $(2, 4, 6, 8, 12, 16, 20, 24, 28, 32, 48, 64, 96, 128, 192, 264, 392) \times 10$ mJy/beam km s^{-1} or 2.6×10^{19} cm^{-2}. Horizontal wedge is in units of Jy/beam km s^{-1}. Right panel: HI gas distribution of NGC 2683 D array observations. The beam size is 61″ × 51″. The contours levels are $(1, 2, 4, 6, 8, 12, 16, 20, 24, 28, 32, 48, 64, 96, 128, 192, 264, 392) \times 30$ mJy/beam km s^{-1} or 10^{19} cm^{-2}. Horizontal wedge is in units of Jy/beam km s^{-1}.

3 The kinematic model

3D modeling was made using a symmetric mean rotation velocity. The HI surface density was de-projected following Warmels (1988). Using the rotation curve and the de-projected HI surface density profile, we can create a model data cube. The presence of a thin disk, a gas halo around the thin disk, a velocity lag, a warp contribution, and different flares were all tested with different inclination angles of the disk. Simulations can been seen in Fig. 2 in four characteristic velocity channels for the low resolution and the high resolution. The resulting total emission map are presented in Fig. 3. High resolution data give constraints on the inner thin disk, whereas low resolution allowed us to study the HI flare.

4 Results

4.1 The inner disk

The presence of a gas halo around the thin HI disk was tested in our kinematic model. The comparison between the gas halo model and the high resolution (VLA C+D array) data excludes the presence of an HI gas halo around the thin inner HI disk. The halo could not be studied with the D array data since high resolutions data are required to study this faint component of the galactic disk.

4.2 The flare of NGC 2683

The FWHM$_z$ thickness of the HI gas from NGC 2683 was derived and compared with the Milky Way FWHM$_z$ thickness (Kalberla & Kerp 2009), and a sample of 8 HI rich, late-type, edge-on galaxies from O'Brien et al. (2010). For NGC 2683, the HI characteristic exponential length scale of the flare is within the range of other spiral galaxies (see Fig. 4). The flare profile of NGC 2683 saturates at $R \sim 16$ kpc and decreases after $R \sim 25$ kpc. The HI ring structure begins at this latter radius. A warp component within the flare is added to better reproduce the data. The warp extends between $r \sim 7$ kpc and $r \sim 14$ kpc, the warp lines of nodes are located in the plane of the sky.

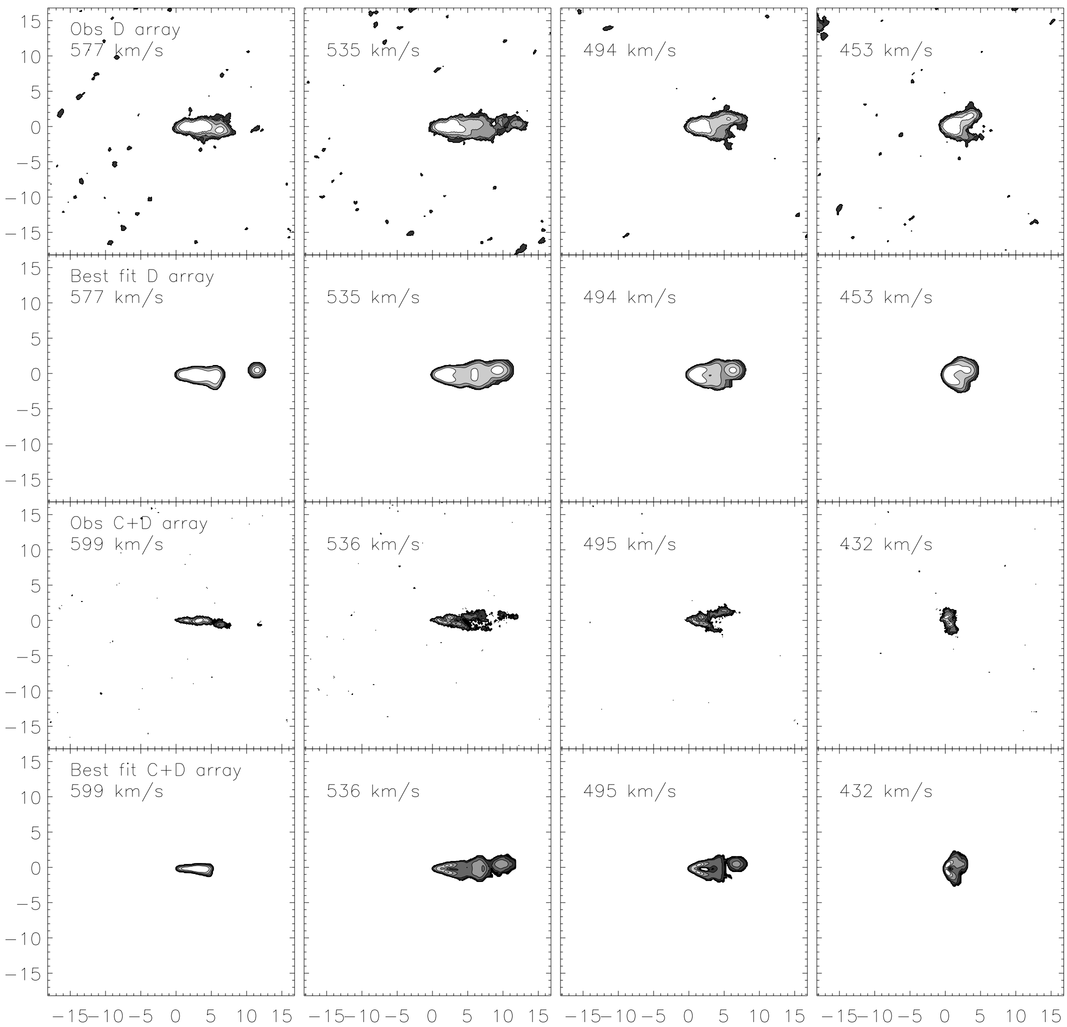

Fig. 2. High (1' resolution) and low (20" resolution) resolution observations and simulations. From top to bottom: D array observations in four characteristic velocity channels, Best fit model as it would be seen in the D array configuration, C+D array observations, Best fit model for the C+D array configuration. Contours levels are the same as for the observations.

5 Conclusion

New deep VLA HI observations of the nearby spiral galaxy NGC 2683 are presented. These new observations show multiple complex substructures in the HI flare, and the presence of an HI ring vertically offset from the disk plane at large radii. In addition to these observations, archival data were used to obtain two different resolution data sets. A 3D kinematic model was constructed to test the presence of a warp, a gas halo around the thin disk, a velocity lag, and a flare with various profiles. Whereas the low resolution data constrain the flare, the high resolution allowed us to study the inner HI disk. We excluded the presence of a gas halo around the inner thin HI disk. The best fit model contains a classical flare which saturates at a galactic radius of R $\sim$ 16 kpc. Significant and complex substructures were found within the flare. This study gives insight into the recent gas accretion history of this nearby spiral galaxy.

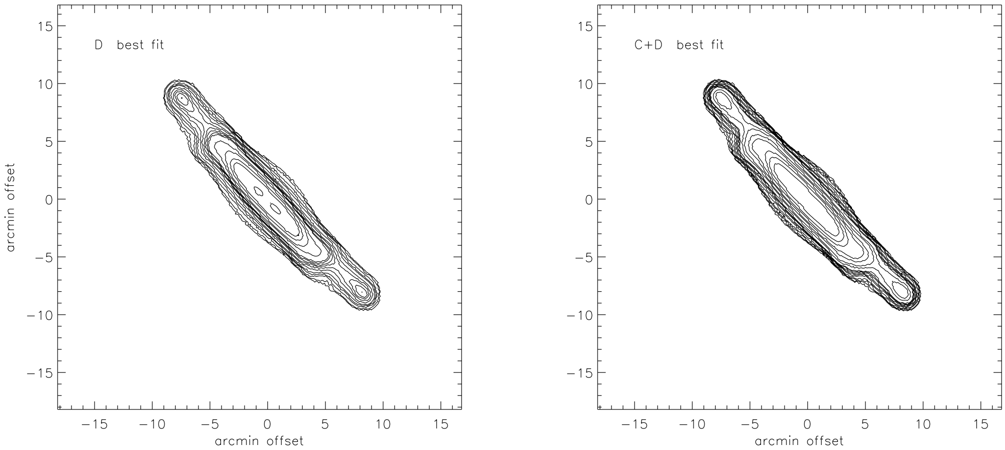

Fig. 3. High (right panel) and low (left panel) resolution simulations of the total emission map of NGC 2683, contours levels are the sames as for the observations (Fig. 1)

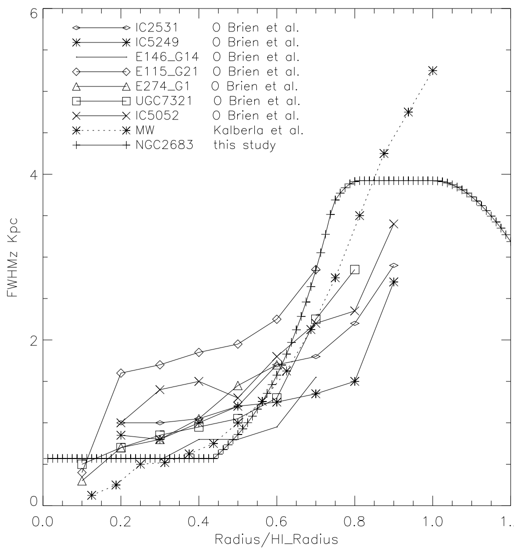

Fig. 4. Comparison between the best fit flare model, and flares of other spiral galaxies from the literature.

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