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HIGH DYNAMIC SOLAR RADIO IMAGES BY COMBINING VISIBILITIES FROM THE GIANT METERWAVE RADIO TELESCOPE ($GMRT$) AND THE NANCAY RADIOHELIOGRAPH (NRH)

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Abstract. We present first results from an ongoing program of combining data from NRH and $GMRT$ to produce snapshot images of the sun at meter λ. The data processing includes a superposition of complex visibilities from NRH and $GMRT$, a Fourier Transform and a cleaning multi-scale algorithm. We present results of a) a simulation and b) an observation of a complex noise storm at 327 MHz on August 27, 2002. This illustrates the capacity of the method to produce high dynamic range snapshot images of a complex sun, and shows that composite images are by far better than images from either instrument alone.

1 Introduction

Radio-interferometry gives a direct access to points in the Fourier Transform plane (uv plane) of the brightness distribution. The uv coverage is related to the set of available baselines. Images are subsequently obtained through a Fourier Transform, usually with a fft algorithm. Imaging complex and rapidly varying radio coronal sources is difficult. Synthesis imaging is excluded and the uv coverage is usually poor. This reduces the dynamic range in the images. Now there are several instances in physics of solar corona where both high resolution and high dynamic range are essential : structure of non thermal radio bursts, CMEs, propagation of radio waves in the turbulent corona etc.. We combine here data from the 576 baselines (up to 3 km) of NRH and data from the 435 baselines of the $GMRT$ (up to 27 km), to obtain solar radio images with unprecedented field, resolution and fidelity. For more details throughout the present text, see Mercier *et al*, 2006.

2 The composite instrument

uv coverages from NRH and $GMRT$ are complementary. NRH provides a dense and homogeneous uv coverage near the origin of the uv plane (up to $\sim 1000\ \lambda$ by regular steps of $\sim 50\ \lambda$ at 327 MHz), giving a good description of large scale structures in a field of $\sim$ 1 deg., but with a low resolution of $\sim$ 3' of arc. $GMRT$ uv coverage is less dense for small baselines, which leads to an "aliasing" of larges structures, but extends to baselines $\sim$ 20 000 λ, allowing a resolution down to 20" of arc. The principle is to combine NRH and $GMRT$ uv coverages, after a suitable intercalibration of both instruments (which can be complex). Fig.1 (left) gives an example of the resulting uv coverage.

3 Results (simulations and observations) and conclusion

For investigating the possibilities of the composite instrument, we made simulations with several models of the sun. One model is presented in Fig.1 (middle). The uv coverage of $GMRT$ is sparse, especially for large baselines. This produces artifacts on the image obtained directly by fft, rendering necessary the use of a cleaning procedure. The standard $CLEAN$ procedure performs poorly when sources exhibit a variety of scales (Wakker & Schwarz 1991) and we used here a specific multi-scale $CLEAN$ version. Futhermore for a complex source

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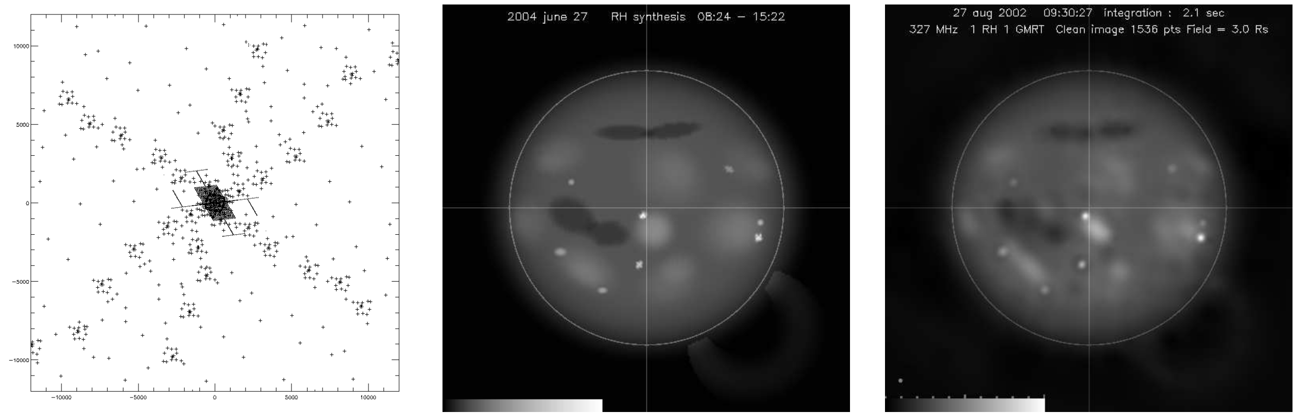

Fig. 1. Left : composite *uv* coverage at 327 MHz for aug 27, 2002 at 09:30 UT (the dense and regular pattern near origin corresponds to NRH and $GMRT$ is marked by +). Middle : simulated sun with various spatial scales. Right : composite snapshot image with NRH and $GMRT$ (the section of the beam is in the lower left corner).

(as shown here) the cleaning procedure itself produces artifacts and $GMRT$ baselines beyond $\sim$ 10 000 λ must be excluded. The obtained composite image is shown in Fig.1 (right). The various spatial scales are properly rendered and the resolution is better than with NRH alone by a factor $\sim$ 3.

On August 27, 2007, there was a strong noise storm beyond the W limb and two weaker noise storms near the center of the disk. A group of type III bursts occurred near the weak noise storms at 09:04:04 UT. Fig.2 shows several images at 327 MHz. The larger size of type III bursts is obvious. The size of the intense W storm is $\sim$ 50" of arc. This is comparable to sizes reported by Zlobec *et al* (1992) from VLA observations, but the dynamic range on the image (maximum / rms artifacts) is here far better ($\sim$ 300 instead of $\sim$ 10).

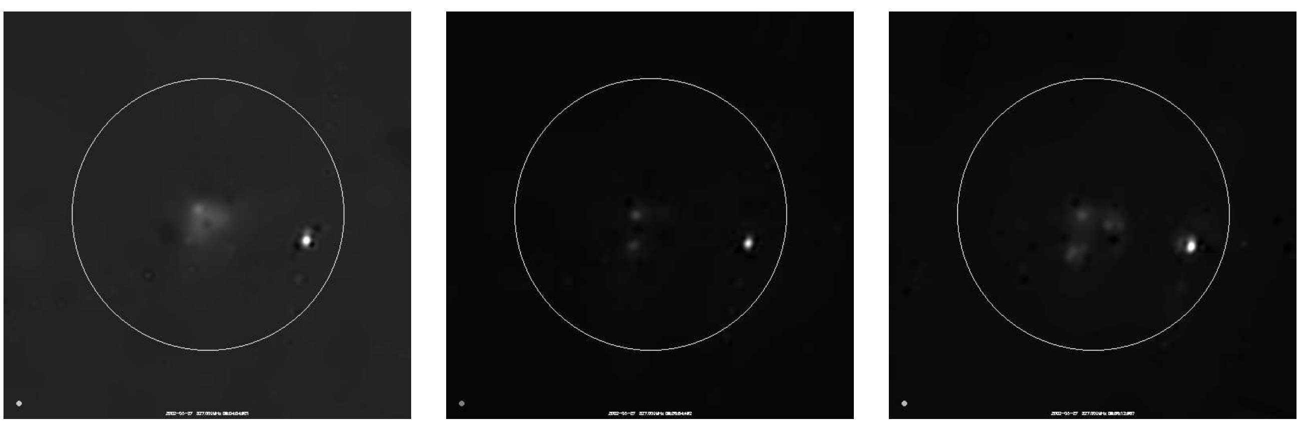

Fig. 2. Left : wide and faint type III bursts near the center of the disk (09:04:04 UT). Middle : compact noise storms (09:26:54). Right : complex positions for noise storms near the center of the disk(09:56:12).

We conclude that combining data from NRH and $GMRT$ is possible. Composite images have unprecedented resolution and dynamic range. This opens a wide field of studies on solar coronal phenomena.

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