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The ngVLA - a Future Instrument for Solar System Science

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Abstract

The Very Large Array (VLA) has been the premier radio astronomy instrument in the world at centimeter wavelengths for almost 40 years. However, to achieve the science goals now desired at these wavelengths, which require more resolution and higher sensitivity than even the VLA can achieve, a new instrument is required. The next generation VLA (ngVLA) is just that instrument. Driven by the science goals as determined by the community [6], the ngVLA is planned to have more than two orders of magnitude more sensitivity and resolution than the VLA, making it a powerful instrument across all fields of astronomy. This includes solar system, where observations at these wavelengths provide unique information on magnetospheres, atmospheres, surfaces, and subsurfaces of bodies of all sizes [4]. Combined with the Square Kilometer Array (SKA) and an upgraded Atacama Large Millimeter Array (ALMA), long-wavelength observations from 10 meters to 300 microns will be possible.

The ngVLA

The ngVLA will be an interferometer operating at centimeter and millimeter wavelengths, with baselines up to 1000 km (almost 10000 km for the long-baseline extension) [7]. Given those baseline lengths, resolutions better than 5 mas will be achieved at 30 GHz. A collection of six ultra-sensitive receivers are planned to cover a frequency range of $\sim$1.2–116 GHz (25 cm to 2.5 mm). The array will have offset Gregorian antennas, with 214 18-m diameter in the main array, 30 more 18-m diameter antennas in the long-baseline array, and 19 6-m diameter antennas in a short-baseline array. The antennas will be concentrated in the Southwest U.S., but spread across the continental U.S., out to Hawaii and the Virgin Islands, and extending south into Mexico (Figure 1). The predicted sensitivity of the ngVLA at 30 GHz (1 cm) is as good as 0.2 μJy in one hour [2].

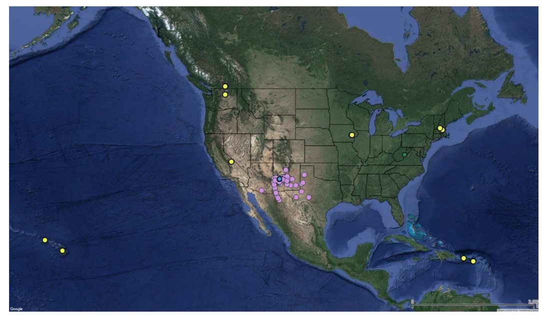

Figure 1: The location of the antennas in the ngVLA reference design.

Solar System Observations with ngVLA

The ngVLA will be a powerful instrument for observations of solar system bodies. There is a long history of long-wavelength observations of this type (notably with the VLA), yielding spectacular results, and the ngVLA will provide even more sensitivity and resolution. A full description of the state of the art in radio wavelength observations of solar system bodies is given in [4]; here we give a terse summary.

Giant Planets

Radio wavelength observations probe into the deep atmospheres of the giant planets (down to tens of bar). Such observations can yield information on the state of these deep atmospheres, including temperature, composition, and dynamics. As an example, Figure 2 shows observations of Jupiter with the VLA at 2 cm. Not only can the belt and zone structure be seen, but an incredible amount of smaller-scale structure, including the GRS, Oval BA, and numerous other small vortices, hot spots, and plumes. The ngVLA will be able to make similar, but much more sensitive and higher-resolution, images of all of the giant planets. Not only that, but investigations of the distribution of synchrotron emission around Jupiter, and the rings of Saturn, Uranus, and Neptune, will be possible.

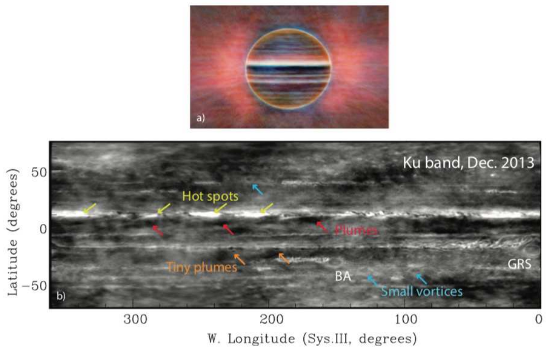

Figure 2: a) Radio image of Jupiter constructed from VLA data taken at three wavelengths. This image is averaged from several 10-hr observing sessions, so any longitudinal structure is smeared by the planet's rotation. Adapted from [3]. b) Longitude-resolved map of Jupiter at a wavelength of 2 cm. The Great Red Spot (GRS) and Oval BA are indicated, as well as hot spots (yellow arrows), ammonia plumes (red), small vortices (cyan), and tiny ammonia plumes (orange). Adapted from [5].

Terrestrial Planets

Radio wavelength observations probe the atmospheres of the terrestrial planets, as well as their surfaces and shallow subsurfaces (down to tens of meters). Studies of atmospheric temperature, composition, and dynamics are enabled by such observations, similar to the giant planets. Surface and subsurface properties (temperature, structure, thermal and electrical characteristics) can be constrained with such observations. Figure 3 shows observations of water vapor around the limb of Mars, as well as emission from the surface and subsurface, using the VLA. These kinds of observations can help constrain the variation of water vapor in the atmosphere of the planet over time.

Satellites and Minor Bodies

For satellites and minor bodies, radio observations sample the surfaces and shallow subsurfaces, as well as any atmosphere (mostly tenuous atmospheres or exospheres, except Titan). Existing observations give important constraints on properties, but have been historically limited in their resolution so not able to provide high-resolution maps. ALMA observations are starting to do this, down to resolutions of order 20 masec [8], but ngVLA will provide even better resolution (by a factor of a few), and will be sensitive to the thermal profile deeper in the subsurface. The ngVLA has enough resolution that many TNOs will be able to be resolved with the instrument. This is a unique capability of the ngVLA, and will enable studies of the distribution of volatiles on the surfaces of these bodies.

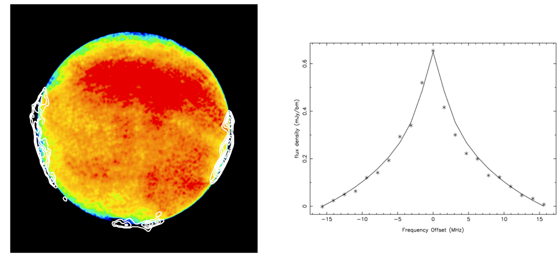

Figure 3: (left) Water vapor distribution around the limb of Mars observed in 2003 with the VLA. The colored background is continuum (thermal) emission from the surface and subsurface of the planet Integrated water vapor line emission is shown in white contours. (right) Water vapor line shape, averaged around the limb (stars) along with a best-fit model (solid line). Total precipitable water vapor ranges from 0 to 20 μm. Adapted from [1].

Summary

The ngVLA will be a fantastic instrument for studying solar system bodies. From giant planets to terrestrial planets to satellites to minor bodies, high-resolution, extremely sensitive observations will enable unique insight into magnetospheres, atmospheres, surfaces, and subsurfaces.

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