# MEETING REPORT

## IAU/URSI SYMPOSIUM ON RADIO ASTRONOMICAL SEEING

Signals from astronomical sources are in general modified as they travel through the intervening medium between the source and the observer. The degree of modification due to different regions of the intervening medium varies with frequency. In the radio frequency range, the effects of the medium have been observed for quite some time now and have been used to study the properties of the medium. Knowledge of these properties helps greatly in evolving fruitful strategies for astronomical observation and in recovering information on celestial sources that would have been available in the absence of the medium. Although a lot of observational and theoretical work has been going on in this field for a long time, this symposium, held in Beijing from 15 to 19 May 1989, was the first on 'radio astronomical seeing'. Various aspects of the intervening medium and its effect on radio astronomical observations were discussed.

At sub-millimetre and millimetre wavelengths, propagation effects in the troposphere are of serious concern. It is seen that humidity and temperature have large gradients as well as strong fluctuation with height owing to turbulence in this medium. The measured phase fluctuations resulting from the passage of signals through the medium show that the spectrum of irregularities is quite close to the Kolmogorov spectrum. The RMS phase fluctuations observed are found to be large in the daytime and during summer. From interferometric observations it is also seen that these phase fluctuations increase with observing frequency and the baseline used, and decrease with elevation. Single-dish measurements of refraction on radio sources at millimetre wavelengths indicate position wander of as much as 30″ even over half-a-minute time-scales. The strength of refraction correlates well with the height of the inversion layer. The sky noise fluctuations contribute increasing correlated noise at shorter baselines while the RMS phase fluctuations are reduced. The sensitivity of observation with short baselines in this frequency range is thus affected.

The attenuation and wet delay caused by the troposphere are measured by using a water vapour radiometer working in the microwave band. Opacity of the medium can be estimated from meteorological data as well as from radio measurements. Good mean correlation observed in radiosonde data and data from radio measurements suggests that the radiosonde data can be used confidently for site evaluation.

The dynamic range of maps and resolution obtained is a strong function of season but atmospheric seeing can also vary on time-scales of days in 'good' weather conditions.

The contribution of the ionosphere to astronomical seeing was also discussed. This region of the intervening medium, extending from about 50 to 1000 km from the Earth's surface, assumes great importance in the metre and decametre wavelength range. The typical scale sizes of electron density irregularities in the ionosphere range from tens of kilometres to a few metres. These disturbances travel from the polar region to the equatorial region. Doppler-shift monitoring of these irregularities shows acceleration over times shorter than an hour. The seeing is affected most during post-sunset times. The critical frequency of the upper ionosphere (F2 layer), monitored using vertical sounding data, shows a very clear abnormal pre-dawn (03–05 LT) peak. The occurrence probability of such pre-dawn peaks is seen to decrease with increase in solar activity (sunspot number).

Ionospheric refraction measurements of signals from satellites indicate that the amount of refraction is directly proportional to the intensity of the travelling ionospheric disturbances (TID). Angular modulation caused by even moderate-intensity TID, with typical wavelength of $\sim 100$ km, can sometimes be larger by factors of 2–5 than the magnitude of refraction in the regular ionosphere. From metre-wavelength observations of astronomical sources it is seen that interferometric phase can have RMS fluctuations of $\sim 1$–2 radians. Faster phase changes have also been observed with increasing solar activity. Even during the minimum solar activity period, it is found necessary to correct for ionospheric refraction about every 30 seconds.

The horizontal distribution of the total electron content (TEC), which characterizes the phase changes, refraction and delays introduced by the ionosphere, can be deduced by using measurements of differential delay or Faraday rotation of satellite signals at two frequencies. When the sizes of ionospheric irregularities are much larger than interferometer baselines it is shown that the horizontal gradient in TEC of the ionosphere can be extracted from observations on strong radio sources, using statistical methods. In the presence of Faraday rotation in the ionosphere, it is also seen that, essentially, the visibility amplitude alone is modified.

While mapping large fields of view at metre and decametre wavelengths, the effects of the ionosphere need to be solved for. The number of isoplanatic patches, which decides the number of unknowns introduced owing to modification of the wavefront in the ionosphere, increases as the fourth power of the wavelength. However, many of the isoplanatic patches may be common in fields viewed by different antenna elements of telescopes such as the Very Large Array (VLA) and the Giant Metre-wave Radio Telescope (GMRT). This possibility can effectively reduce the number of unknowns due to the ionosphere. Image reconstruction techniques such as self-calibration using constraints like closure phase and closure amplitude can be supplemented with some additional constraints by making multifrequency observations. It is also suggested that additional information could be obtained by effectively defocusing the dish beam in different ways to get different linear combinations of contributions from different isoplanatic patches. At decametre wavelengths, it is suggested that one should plan for measurements of all required baselines simultaneously with a large number of small-diameter antennas. The subarrays should be used to determine the distortion introduced by the ionosphere and correct for it. Data corrupted by scintillations should not, in general, be used for map-making. It is not very clear whether ionospheric seeing is a strong function of geomagnetic latitude. Nevertheless, the GMRT proposed to be built near Pune, India, would be perhaps the first radio telescope for which the site has been selected on the basis of ionospheric seeing conditions.

Imaging in the presence of scintillation has different regimes depending on the strength of scattering and integration time. In the case of weak scattering a short integration regime corresponds to 'speckle' imaging while the long integration regime corresponds to the mean seeing disk. In the case of strong scattering there are regimes that correspond to (successively) the 'snapshot' image, 'average' image and 'ensemble-average' image as the integration time increases. Although scattering has been studied intensively by radio astronomers, there has been little investigation of the 'speckle' phenomenon found in optical scattering. Using high temporal and angular resolution data from VLA, the existence of speckles in interplanetary scintillation (IPS) scattering disks has been demonstrated. Such speckles lead to a number of conceptual and practical difficulties for correction of radio-astronomical seeing.

Investigation of the effect of solar wind on metre-wavelength VLBI (Very Long Baseline Interferometry) shows that coherence time reduces with decreasing source elongation from the Sun. Thus it may be required to choose suitably large elongations if large integration times are to be used. A similar conclusion is also reached when IPS limits on very-low-frequency VLBI are considered.

On the other hand, IPS has been extensively used to estimate angular sizes of compact sources. Routine monitoring of IPS shows that occasional enhancements in the scintillation index drift in elongation. When such an enhancement reaches 90° elongation, it correlates with a geomagnetic storm.

From VLA measurements of HI absorption distribution across a strong radio source (Cas-A), it is shown that neutral hydrogen in interstellar medium (ISM) may have fine structures down to scales of 0.05 pc. An interesting observation of a possible extragalactic source was reported, where the source image was considerably enlarged by ionized gas in the intervening galactic HII region. The random changes in the position of compact sources that result from refractive effects are observed to be much smaller than the apparent image size scatter broadened by diffractive-scale irregularities in the ISM. It is shown that the image sizes observed are consistent with the predictions of the Kolmogorov theory of turbulence applied to interstellar plasma. The small value of the position wander however may be due to observing over short times compared to the typical refractive time-scales. In the case of slow-intensity variations of pulsars, it is shown that observing over periods that are not much longer than the refractive time-scales would lead to gross underestimation of the true modulation index.

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