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Solar Wind and Space Weather Studies by Interplanetary Scintillation at the Arecibo Observatory

Periasamy K. Manoharan* and Phil Perillat
Arecibo Observatory, University of Central Florida, Puerto Rico PR 00612, USA

In this paper, we review the results of radio interplanetary scintillation (IPS) measurements made with the large 305-m Arecibo Radio Telescope during 18 March to 09 August 2020, in the covid-19 pandemic period. The IPS technique is an extremely powerful and unique technique for making remote-sensing observations of the three-dimensional solar wind [1]. The reported observations were made in the frequency range of 300 to 3000 MHz and covered a heliocentric distance range of 10 – 200 solar radii. In this observing period, the solar activity was at the lowest level, as the solar cycle 24 faded and the onset of the new cycle 25 started at its minimum phase, and the solar eruptions were extremely weak as well as less in number. However, the high sensitivity Arecibo IPS measurements allowed to track even less energetic solar wind transients (i.e., coronal mass ejections, CMEs) in the inner heliosphere. An example of tracking of a narrow CME in the inner heliosphere is shown in Figure 1, which displays the Arecibo normalized scintillation index measured as a function of time on 17 and 19 July 2020, along with the white-light image of the CME on 16 Jul 2020 observed by the LASCO C2 coronagraph on board SOHO space mission. We discuss the propagation characteristics of CMEs in the Sun-Earth distance.

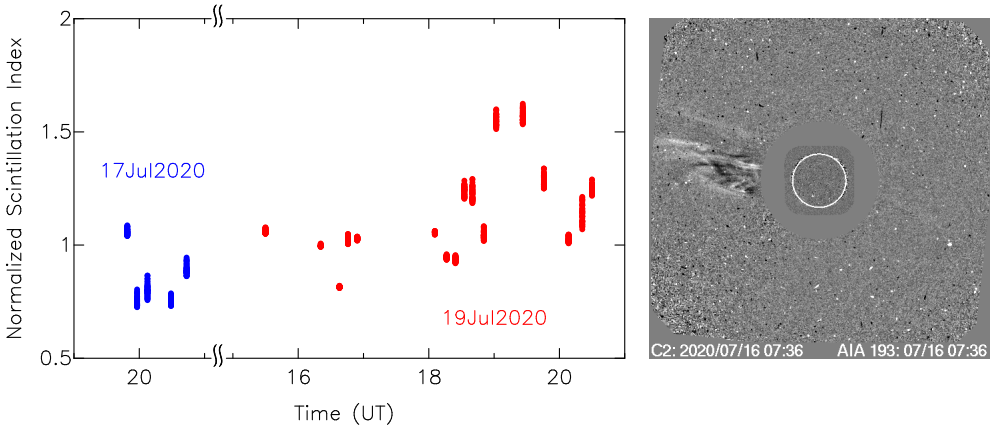

Figure 1. Normalized scintillation index observed with the Arecibo Telescope on 17 and 19 July 2020. The crossing of the CME at around solar offset of ∼120 – 140 solar radii is seen on 19 July, ∼19 UT. Each day's data sets include observations of multiple sources, as well as different observing frequencies. The image on the right is the white-light image of the CME on 16 July at 07:36 UT, from the LASCO C2 coronagraph on board SOHO space mission (image courtesy, *https://cdaw.gsfc.nasa.gov/CME_list/*).

We also discuss the results on the level of solar wind density turbulence as functions of heliocentric distance and observing frequency. The IPS spectra of high signal to noise ratio have been useful to derive the spatial spectrum of density turbulence and the size of the dissipation scale (i.e., inner scale) at different solar offsets as well as a function of the solar wind source region on the Sun. The latitudinal distribution of the density turbulence at a heliospheric radius of ∼0.25 AU from the Sun, supplemented with other ground- and space-based measurements, shows the solar wind characteristics at the minimum phase of the solar cycle. Finally a brief discussion will also be included on the point of view of space weather. The Arecibo kind of sensitive IPS observations of CMEs at several solar offsets in the inner heliosphere can be of considerable importance in accessing the propagation characteristics of geo-effective CMEs and the key objective of predicting their arrival at the near-Earth space.

References

[1] P. K. Manoharan, "Three-dimensional Evolution of Solar Wind during Solar Cycles 22–24," *ApJ*, **751**, 2, June 2012, pp. 128(13pp), doi:10.1088/0004-637X/751/2/128.