An analysis of the Solar Coronal dynamics using S-band signals from the Indian Mars Orbiter Mission

Abstract

Radio frequency fluctuations recorded during solar conjunctions can provide information about plasma turbulence in the solar wind. In this study, we derive the empirical radial dependence of solar wind velocity by using data collected during the Indian Mars Orbiter Mission during October 2021 which were received at the Indian Deep Space Network, Bangalore.

Introduction

Coronal and solar wind observations can be made in two ways: in-situ and remote sensing. Solar wind acceleration and the coronal heating take place very close to the Sun where in-situ observations are not possible. Using radio occultation experiments to measure radio-frequency fluctuations is an effective and accessible method for studying coronal region turbulence.

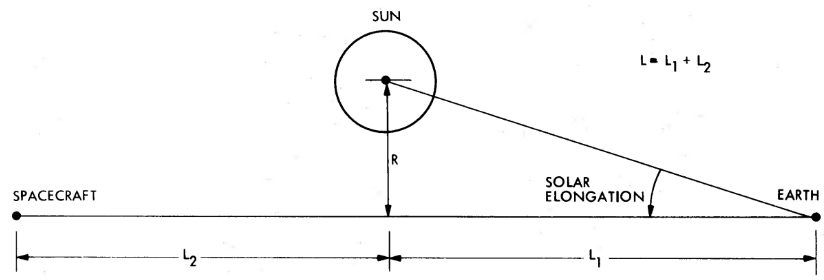
The irregularities in the plasma density scatter radio waves traversing the solar plasma and leads to fluctuations in the signal frequency and intensity scintillations, which eventually can be used to derive solar wind properties, such as the velocity, density, magnetic field fluctuations, solar wind power, and acceleration (Woo Armstrong 1979; Bird 1982; Edenhofer 1990). Radio occultation enables us to observe this specific region around the Sun while posing no risk to the spacecraft. Furthermore, since no additional instruments are required for these experiments, they are very cost-effective. Several studies have been conducted using coronal radio-sounding measurements from previous solar conjunctions of spacecraft such as HELIOS in 1975–1976, MESSENGER in 2009 (Wexler et al. 2019), and Akatsuki in 2011 (Ando et al. 2015).

Method

Using Doppler calculated from the data and the formula $\mu^2 = 1 - \frac{\omega_p^2}{\omega^2}$, we can calculate the refractive index of the medium the signal passes through. Further, angular broadening can be calculated by using the formula $\delta\psi(s) = \int \frac{\partial\delta\mu}{\partial y} ds$ where $\delta\psi(s)$= random fluctuation in the refractive index, and y = displacement of ray from its path(Hollweg et al. 1970). Using these quantities in the following formula, velocity of the solar wind can be calculated.

$$v_{\perp} = \frac{5.33BL}{\theta_{AB} k L_2}$$

where B = signal bandwidth, θ_{AB}= angular broadening, k = wavenumber, and L and L_2 are marked in the figure below (Woo et al. 1978).



Initial results

In the initial stage of the project so far, we have managed to establish relations between different parameters that will be needed for obtaining the desired results. The initial codes to read the .prd data file for the MOM mission, generating data-frames for required calculations and plotting them, code for plotting the positions of the planets and the Sun during the period of the conjunction, and for comparison of different density models have been developed.

Future goals

In this study, we plan to derive the empirical radial dependence of solar wind velocity using the S-Band (2.3 GHz) radio signals from the Indian Mars Orbiter Mission received in October 2021, and present a comparison between the electron densities derived from the observations and previous models present in literature (Tyler et al. 1977, Newkirk et al. 1961, Allen et al. 1947, Wexler et al. 2019, LeBlanc et al. 1998, Patzold et al. 1987, Esposito et al. 1980, Muhleman et al. 1981).

Figures

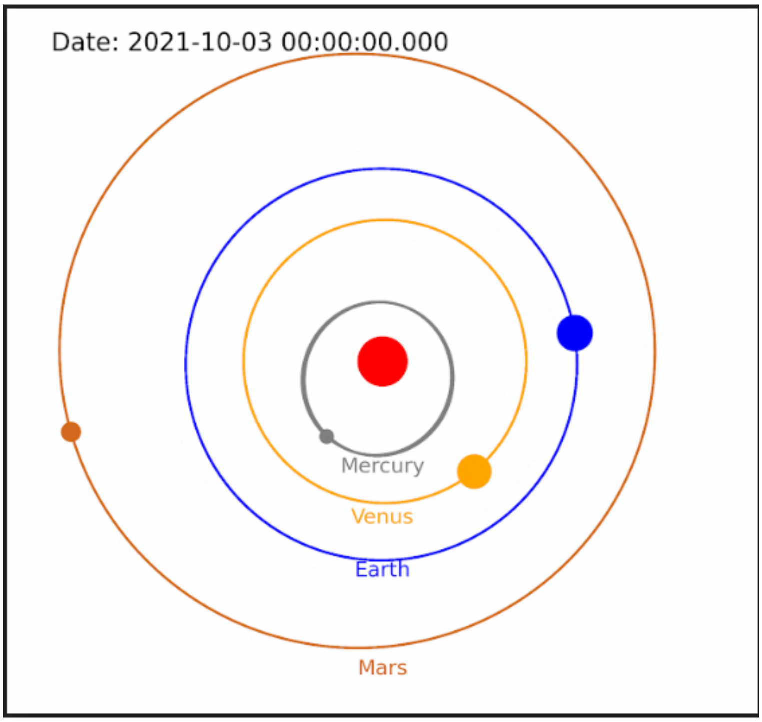


Figure 1: Positions of the objects on 03-10-2021

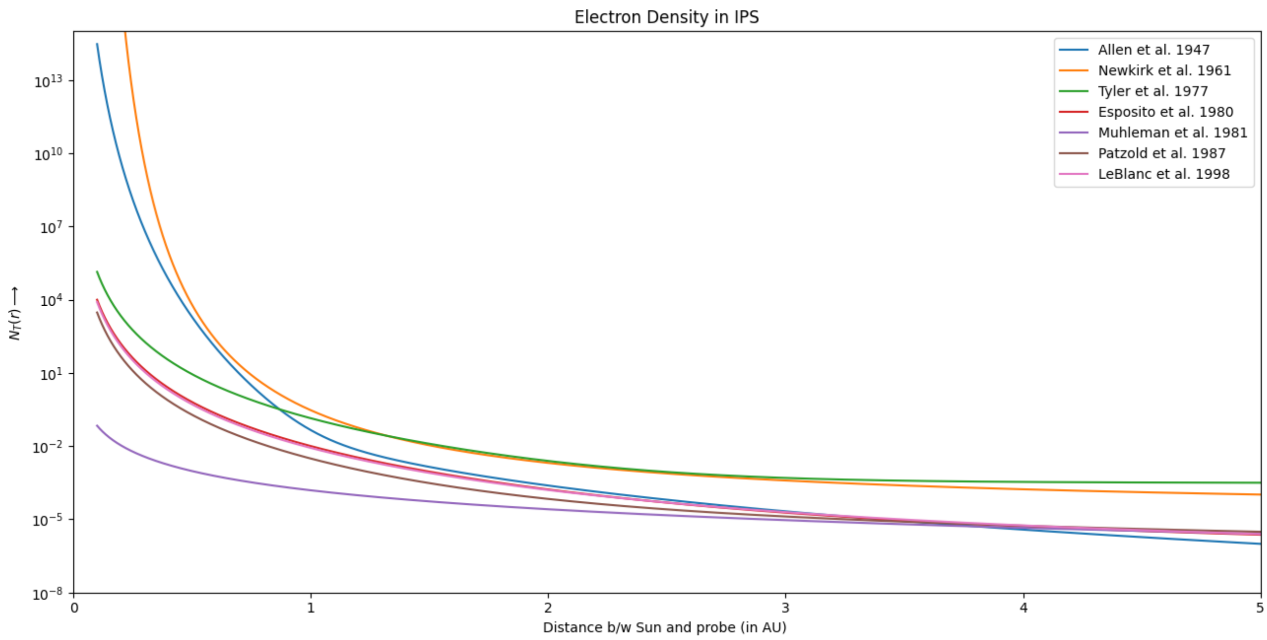


Figure 2: Multiple Density Models

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