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Title: Plasma and Radio Waves From Neptune: Source Mechanisms and Propagation

Principal Investigator: J. D. Menietti

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FINAL REPORT FOR NAGW-3143

Plasma and Radio Waves From Neptune: Source Mechanisms and Propagation

Principal Investigator: J. Douglas Menietti

Project Summary:

The purpose of this project was to conduct a comprehensive investigation of the radio wave emission observed by the Planetary Radio Astronomy (PRA) instrument on board Voyager 2 as it flew by Neptune. The study has included data analysis, theoretical and numerical calculations, and ray tracing to determine the possible source mechanisms and locations of the radiation including the narrowband bursty and smooth components of the Neptune radio emission.

Work Accomplished:

To date we have performed investigations of radio emissions to explain sources of the Neptune smooth emission and n-bursty emission. Our ray tracing computer code contains the O-8 magnetic field model [Connerney et al. [1991] and the plasma model including a density cavity as discussed in Menietti et al. [1994]. We have performed extensive ray tracing of Neptune kilometric radiation investigating source locations of both the smooth and n-bursty components. Our results indicate that the source region of the smooth emission agrees qualitatively with that of Ladreiter et al. [1991], but some differences do exist. In particular, the southern hemisphere source points fall on the western rather than eastern side of the magnetic pole. Our general agreement, however, seems to indicate that a plasma model containing a density cavity is compatible with the data.

We find that sources of n-bursty emission along field lines adjacent to a density cavity are also consistent with the observations. This result is consistent with our earlier findings from plasma simulations indicating that n-bursty emission can be generated by the temperature anisotropic beam instability (TABI) as discussed in Winglee et al. [1992a,b]. In these papers we describe the generation of bursty radio emission due to an electron beam in the presence of a temperature anisotropy. This concept was first discussed by Wong and Goldstein J. Geophys. Res., 17, 2229, 1990. One-dimensional Numerical simulations of the process were conducted, indicating the plasma conditions necessary for generation of the emission. We find that for $f_p/f_g > 1$ (f_p = electron plasma frequency; f_g = electron gyrofrequency), most of the wave energy is left-hand circularly polarized (LCP) and is trapped in the magnetosphere. However, for $f_p/f_g < 1$ the dominant mode is RCP. The induced waves are in the form of modified whistlers when the beam speed is low and $f_p/f_g \sim 1$, but are in the freely propagating X mode branch when $f_p/f_g \sim 0.4$. The amount of radiation with frequencies above the local X mode cutoff increases with beam speed.

These findings spawned investigations of terrestrial auroral region electron data to determine if the type of distributions necessary for the TABI actually exist. Distributions consistent with the TABI were in fact discovered on numerous auroral region passes [Menietti et al. 1993a,b; Menietti, 1993]. Briefly, we have determined that within the mid-altitude nightside auroral region, electron distributions are observed that could stimulate emission from the TABI. This effort justified investigating the Uranus n-bursty radio emissions. We have determined that radio emission from the TABI in a narrow, filled emission cone is consistent with the observations [cf. Curran and Menietti, 1993].

Work in Final Stages:

In an effort to better understand the TABI, more theoretical work is being pursued. We have recently completed studying the instability for fully relativistic electrons Wong and Goldstein [1994].

In addition, we have investigated the possibility of 2nd harmonic gyroemission at Neptune using ray tracing and data analysis. These studies complement past studies of similar emission at Uranus and Jupiter. The abstract of this paper (to be shortly submitted to the Journal of Geophysical Research) is included as Appendix 1.

Finally, following up on our original study of Neptune lightning- generated whistlers [Menietti et al., 1991], we have been investigating whistler propagation from southern hemisphere sources using our new plasma (with density cavity) and magnetic field model (O-8), as briefly described above. An abstract of this paper (now being written for submission) is included as Appendix 2. We have determined that propagation to the satellite observation point is possible from these newly considered southern hemisphere sources. This paper is currently in the writing stages for immediate submission to the Journal of Geophysical Research.

Published Papers:

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Menietti, J. D., J. L. Burch, R. M. Winglee, and D. A. Gurnett, DE 1 particle and wave observations in auroral kilometric radiation (AKR) source regions, J. Geophys. Res., 98, 5865, 1993a.

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Wong, H. K. and M. L. Goldstein, Electron cyclotron wave generation by relativistic electrons, Journal of Geophysical Research, 99, 235, 1994.

Papers Submitted or in Preparation:

Menietti, J. D. and D. B. Curran, Modelling of Radio Emissions From Neptune, to be submitted to J. Geophys. Res., 1994.

D. Morgan, J. D. Menietti, and D. B. Curran, Possible 2nd Harmonic Gyroemission at Neptune, to be submitted to J. Geophys. Res., 1994.

Tsintikidis, D., J. D. Menietti, D. D. Morgan, and D. A. Gurnett, More Analysis of Whistler Propagation at Neptune, to be submitted, 1994.

Additional References:

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Ladreiter, H. P., Y. Leblanc, G. K. F. Rabl, and H. O. Rucker, Emission characteristics and source location of the smooth Neptunian kilometric radiation, J. Geophys. Res., 96, 19,101, 1991.

Menietti, J. D., D. Tsintikidis, D. A. Gurnett, and D. B. Curran, Modeling of whistler ray paths in the magnetosphere of Neptune, J. Geophys. Res., 96, 19117, 1991.

APPENDIX 1

Abstract

Analysis of Smooth High-Frequency Emission at Neptune

D. D. Morgan and J. D. Menietti

We present a detailed study of the highest frequency component of smooth radio emission observed during the Voyager 2 encounter with Neptune in August 1989. This emission occurs during three distinct periods on 24 and 25 August 1989 in the frequency range of 550 to 900 kHz. By assuming straight-line propagation from sources of both fundamental and second harmonic gyroemission, we perform a detailed analysis of the observed polarization of the emission. The data are most consistent with an L-O mode source near the north magnetic pole in the range of magnetic L-shells $6 < L < 8$. A second possible source in the north magnetic polar region is in the range $1 < L < 3$ and must emit in the R-X mode.

APPENDIX 2

Abstract

More Analysis of Whistler Propagation at Neptune

D. Tsintikidis, J. D. Menietti, D. D. Morgan, and D. A. Gurnett

Further investigations of the propagation of whistlers in the magnetosphere of Neptune have been performed using a more accurate magnetic field model and also investigating the effects of varying density models. The results indicate that sources near the southern magnetic pole propagate to near the observation site. Due to a high density, cold plasma population, these whistlers propagate near the resonance cone and have large dispersions (vis. $\sim 17{,}500$ s$\sqrt{\text{Hz}}$) comparable to those measured by Voyager 2. The delay times are on the order of 100 seconds, which are still smaller than observed values (~ 300 seconds). We attribute this discrepancy to uncertainties in the density model.