Occultations of Astrophysical Radio Sources as Probes of (Exo)Planetary Environments

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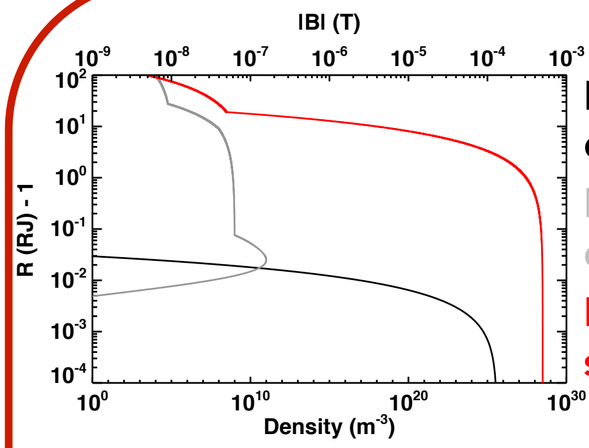
Motivation

- Properties of planetary atmospheres, ionospheres, and magnetospheres are difficult to measure from Earth.
- Traditional radio occultation experiments rely on a spacecraft to transmit near the planet.
- ***Can occultations of radio emissions from distant astrophysical sources (i.e., pulsars) be used to measure magnetic field strength, plasma density, and neutral density of solar system and extrasolar planets?***

Applications to Exoplanets and Stars

- A Jupiter-like exoplanet, in a face-on orbit sweeps out 10^{15} km^2 over a full Jupiter-like orbit. From 10 light-years away, this is only 10^{-14} of the total area of the sky.
- The likelihood of suitable alignment of the Earth, an exoplanet, and a distant astrophysical radio source is too small for this to be a viable method of exoplanet characterization.
- Observations of stellar radio emissions during an exoplanet transit may offer a solution.
- Occultation of a distant astrophysical radio source by a star may also be informative.

Application to Jupiter

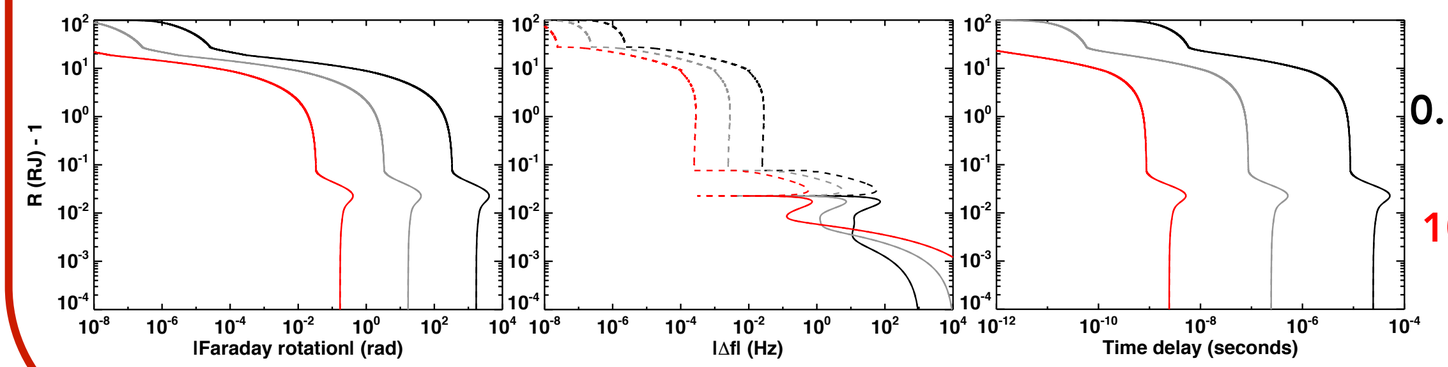


Neutral density

Electron density

B-field strength

- Assumed all aspects of the planetary environment (atmosphere, ionosphere, and magnetosphere) were spherically symmetric.
- Used representative densities, scale heights, and magnetic field strengths for Jupiter.

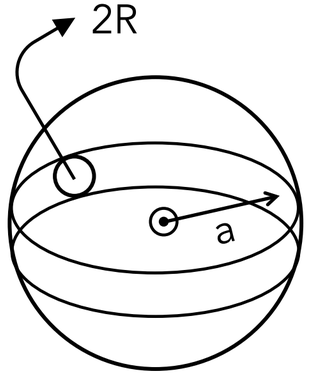


0.1 GHz

1 GHz

10 GHz

Occultation Occurrence Rates



$$N_{occ} = \frac{2R \bullet 2\pi a \bullet N_{radio}}{4\pi a^2} = RN_{radio}/a$$

	Jupiter	Saturn	Uranus	Neptune
$R_{ionosphere}$ ($R_{magnetosphere}$)	$10R_J$ ($200R_J$)	$1.3R_S$ ($25R_S$)	$2.3R_U$ ($18R_U$)	$2.3R_N$ ($35\ R_N$)
$R_{ionosphere}/a$ ($R_{magnetosphere}/a$)	9.2×10^{-4} (1.8×10^{-2})	5.6×10^{-5} (1.1×10^{-3})	2.0×10^{-5} (1.6×10^{-4})	1.3×10^{-5} (1.9×10^{-4})
N_{radio}, potential radio sources*	1,700 pulsars + ≥10,000 AGN			
N_{occ}, ionosphere (magnetosphere) occultations per Earth year	0.91 (18)	2.2×10^{-2} (0.42)	2.8×10^{-3} (2.2×10^{-2})	9.1×10^{-4} (1.4×10^{-2})

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References: Withers & Vogt (2017) ApJ, 836, 114.
**Krolik, J. H. 1999, Princeton Univ. Press, Melia, F. 2009, Princeton Univ. Press.*