ACTIVE AND PASSIVE MICROWAVE OBSERVATIONS OF VENUS

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ABSTRACT

I will highlight the capabilities of well-designed microwave observations to elucidate the state, composition and dynamics of the Venus atmosphere. The observations discussed will include radio occultations, ground-based microwave radiometry, and potential space-borne microwave radiometry.

INTRODUCTION

Venus has long been the subject of passionate study by humankind. The ancient Mayans considered Venus to be more important than the Sun, predicting and tracking her ascents and descents through elaborate calculations as recorded in one of the four codices surviving the enthusiastic book-burnings of the Spanish conquistadors. The image of Venus as a jungle planet covered with sultry, humid rainforests peopled by well-adapted intelligent beings figured prominently in the collective imagination well into the 20th century. H.P. Lovecraft penned "Within the Walls of Eryx" in 1936 in which crystal prospectors were lured to their deaths by a mysterious invisible maze built by the native "savages" on a muddy plain. At times the most prominent light in the sky aside from the Sun and Moon, Venus' lower atmosphere and surface escaped close scrutiny until the advent of radio astronomy in the 1950's which pierced her veiling clouds to reveal the fierce heat at her bosom. Since that time, microwave observations have continued to play an important role in the study of Earth's twin sister. In this presentation I will highlight the capabilities of well-designed microwave observations to elucidate the state, composition and dynamics of the Venus atmosphere. The observations discussed will include radio occultations, ground-based microwave radiometry, and potential space-borne microwave radiometry.

RADIO OCCULTATIONS

Although better known for the exquisite radar maps it made at 13-cm, the Magellan spacecraft also carried out more than 20 radio occultations of Venus between October 1991 and the demise of the spacecraft in October 1994. These radio occultations penetrated the atmosphere to unprecedented depths compared to prior occultations, reaching to below 33 km during many of the soundings, well below the level at which the sulfuric acid vapor dissociates due to the high temperatures at these levels. The latitudes spanned by these observations range from 49° to as high as 88° and both the northern and southern hemispheres were probed, yielding a number of important physical properties of the Venus atmosphere. Highlights of the results include: i) accurate, detailed vertical profiles of pressure, temperature, and buoyancy frequency in the neutral atmosphere at altitudes 33-98 km; ii) discovery of small-scale gravity waves ($<$3 km vertical wavelength); iii) characterization of larger-scale temperature fluctuations (5-10 km vertical wavelength), which may be indicative of thermal tides or planetary waves; iv) highly accurate profiles of sulfuric acid vapor (H_2SO_4) abundance at altitudes 35-55 km; v) upper limits on the abundance of SO_2 in this latter altitude range; vi) zonal and meridional cyclostrophic winds; and vii) electron density profiles in the ionosphere.

GROUND-BASED MICROWAVE RADIOMETRY

Venus has been the target of integrated-disk microwave observations for decades. Recently, however, the calibration and sensitivity of the Very Large Array (VLA) in Socorro, New Mexico, have improved to the point that microwave emission maps with fair resolution can be obtained. Using a pair of maps obtained in April 1996, we have derived the thermal structure and abundance of sulfuric acid vapor in three different regions of Venus' disk: equatorial, northern mid-latitudes, and southern polar latitudes. As opposed to radio occultation studies, the inverse problem posed by microwave radiometry is both nonlinear and ill-posed, requiring some form of regularization and several iterations to obtain a meaningful result. In addition, the temperature structure of the atmosphere and the abundance profile of sulfur dioxide cannot be uniquely separately solely through passive microwave measurements. Although the profiles obtained from the VLA maps are not

as accurate as those obtained via radio occultations, nor do they have as fine a vertical resolution, they do reach beyond the level of critical refraction near 32 km, below which the atmosphere is inaccessible to radio occultation studies.

SPACE-BASED MICROWAVE RADIOMETRY

Space-borne radiometric observations of Venus have several advantages over their ground-based counterparts. A three-channel radiometer is a part of the proposed Venus Environmental SATellite (VESAT) mission to NASA's Discovery Program. The chief advantages to this instrument would be the immunity from absolute calibration problems which plague large ground-based systems and greatly increased sensitivity and spatial resolution afforded by an orbiting platform. Such an instrument, accompanied by a near infrared radiometer along with joint radio occultation studies would greatly enhance the science return of any future Venus mission.