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DEPARTMENT OF PHYSICS AND ASTRONOMY

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Amherst, MA 01003

NASA GRANT NGL 22-010-023

N86-17251

Unclas
CSCL 03B G3/91 05239

(NASA-CR-176466) STUDIES OF RADIATIVE TRANSFER IN PLANETARY ATMOSPHERES Semiannual Status Report, 1 Jun. - 30 Nov. 1985 (Massachusetts Univ.) 7 p HC A02/MF A01

STUDIES OF RADIATIVE TRANSFER IN PLANETARY ATMOSPHERES

SEMI-ANNUAL STATUS REPORT NO. 37

June 1, 1985 - November 30, 1985

Principal Investigator: William M. Irvine

Co-Principal Investigator: F. Peter Schloerb

Current Research

The research emphasis during the period of this report has been on radio observations of comets, related to the International Halley Watch. Observations of the 18 cm Λ-doublet of OH have been carried out approximately monthly since July at the National Radio Astronomy Observatory's 43m telescope in Green Bank, West Virginia. Both of the 1667 and 1665 MHz lines have been repeatedly detected for Comets Halley, Giacobini-Zinner, Thiele, and Hartley-Good. The first astronomical detection of the weak satellite line at 1720 MHz was made for P/Halley.

These data promise to supply the highest signal-to-noise-ratio data over an extended period ever obtained for cometary radio observations. Analysis will provide gas production rates as a function of heliocentric distance and allow for detailed comparisons with the OH excitation model involving ultraviolet pumping. In the case of Halley, the lines appear quite symmetric, usually being centered within 0.1 km/s with respect to the nominal nuclear

velocity. Line widths have been typically within 10% of 2 km/s. There is thus little evidence for asymmetric emissionin the data obtained to date. The production rate for Halley increased very rapidly after initial turn-on, and then leveled off as r^{-2}. It seems likely that non-steady-state models of the coma will be required to interpret the data. Evidence for significant departures from the LTE hyperfine ratios was found for Comet Giacobini-Zinner. Smaller, but nonetheless significant, deviations have been found for Comet Halley. The OH coma for Halley during November was clearly large, being partially resolved by the 18 arcmin telescope beam.

A radio search for parent molecules in Comet Halley began at the FCRAO 14m telescope, operated by the University of Massachusetts. In observations over the period 29 November - 3 December, HCN was successfully detected at an antenna temperature of approximately 30 mK. The hyperfine ratios appeared anomalous, with approximately equal intensities for the F=2-1 and F=1-1 components. These results are consistent with the detection of HCN with the IRAM 30m telescope reported by Crovisier et al.

Radio astronomical observations of cold, quiescent interstellar material can be used to determine basic molecular parameters, often more accurately then can be done in a laboratory. This is particularly the case for unstable species such as radicals and ions. Irvine and colleagues in Sweden and at Columbia University have used this technique to study the radical C_3H (propynylidyne), which has been found in the spectrum of the cold, dark cloud TMC-1 and in the envelope expelled by the evolved carbon star IRC+10216. In particular, the astronomical observations provided the first accurate values for the hyperfine constants for this radical, which is a possible constituent of cometary comae.

Swade continued his study of the nearby cold, dark cloud L134N, which is

typical of the regions in which solar-type stars are believed to form. The goal is to accurately determine both physical and chemical conditions throughout a cloud. The basic observational data have been obtained, and statistical equilibrium models are now being applied to determine temperature, density, column density, and chemical abundances, particularly in the core region.

In a study relevant to the Comet Rendezvous/Asteroid Flyby (CRAF) project, Schloerb is analyzing the expected emission from a cometary nucleus at millimeter and submillimeter wave lengths. In situ observations of this emission would provide important constraints on subsurface physical and chemical properties of the nucleus. In particular, millimeter waves are sensitive to differences in the ice-to-silicate ratio in the cometary crust, and may provide the only means for determining the thickness of such a crust over the entire cometary nucleus. In addition, such multifrequency observations can determine the metal fraction of an asteroid surface. Spectroscopic observations at submillimeter wavelengths of the 1(1,0) - 1(0,1) line of water vapor may be used to map the kinetic structure and physical conditions in a cometary coma. The gas kinetic temperature can be measured in the inner 1,000 km where collisional excitation prevails. In the further coma, this line is subthermally excited and its intensity may be used to map the gas density.

Schloerb delivered an invited review on Planetary Science at a Conference sponsored by the European Southern Observatory-IRAM-and the Onsala Space Observatory.

Professor Kari Lumme from the University of Helsinki continues as an Adjunct Professor at the University of Massachusetts, and visited Amherst to collaborate with Irvine on studies of radiative transfer models. Particular attention is being given to scattering by planetary and asteroidal regoliths.

The same basic techniques may be applied to thermal emission from cometary regoliths.

Schloerb and Irvine attended the annual meeting of the Division for Planetary Sciences of the AAS, and Schloerb reported on OH observations of Comet Halley.

Articles with grant support published during the period of this report:

1) Bockelee-Morvan, D., J. Crovisier, E. Gerard, C. Henkel, P.R. Jewell, L.E. Snyder, C.A. Clemens, A.R. Molloy and F.P. Schleorb, "Radio Observations of OH in Comet Crommelin 1983n", Astron. J., 90, 2586 (1985).

2) de Pater, I., F.P. Schloerb, and A.H. Johnson, "A Catalogue of Radio Sources to be Occulted by Comets P/Halley and P/Giacobini-Zinner", Astron. J. 90, 846 (1985).

3) Lumme, K., H. Karttunen and W.M. Irvine, "Roughness of the Lunar Soil", Earth, Moon, Planets, 33, 19 (1985).

4) Schloerb, F.P. and E. Gerard, "Models of Cometary Emission in the 18 cm OH Transitions: the Predicted Behavior of Comet Halley", Astron. J., 90, 117 (1985).

Articles with grant support currently in press:

1) Ekelund, L., Ch. Andersson, A. Ekelund, W. Irvine, and A. Winnberg, "Cometary Observations at Onsala Space Observatory since 1980", in Asteroids, Comets, Meteors II, ed. C.I. Lagerkrist, B.A. Lindblad, H. Lundstedt, and H. Rickman, Uppsala Univ., in press.

2) Swade, D.A., F.P. Schloerb, W.M. Irvine, and R.L. Snell, "Molecular Structure of L134N", in Masers, Molecules and Mass Outflows in Star-Forming Regions, ed. A. Haschick, NEROC, in press.

3) Schloerb, F.P. "Millimeter-wave Spectroscopy of Solar System Objects: Present and Future", Proc. ESO-IRAM-ONSALA Workshop on (Sub)Millimeter Astronomy, in press.

4) Schloerb, F.P., and Claussen, M.J., "Radio Observations of OH in P/Halley and P/Giacobini-Zinner", Bull. Amer. Astron. Soc., in press.

5) Friberg, P., W.M. Irvine, C.A. Gottlieb, P. Thaddeus, Å. Hjalmarson, and L.E.B. Johansson, "Astronomical Study of C_3H", in Seventeenth Int. Symp. Free Radicals, in press.

Future Plans

Regular observations of the OH ground state Λ-doublet will continue in

Comet Halley using the facilities of NRAO (Green Bank). This will be particularly important during the period near perihelion, when the comet is invisible to optical observers, and will be critically important to the spacecraft encounters which take place approximately one month after perihelion. Observations of HCN and other potential parent molecules will also be made at regular intervals using the FCRAO in Massachusetts.

Reduction of multiple frequency observations of the J=1-0 and 2-1 rotational lines of carbon monoxide absorption in the atmosphere of Venus will continue to provide basic data for models of photochemistry and atmospheric circulation. Similar observations of Mars will be made during the coming apparition.

Swade is continuing his analysis of observations of the nearby interstellar molecular cloud L134N. It is hoped that this study will shed light on the formation of solar type stars and conceivably of planets. The chemical composition will be compared to that of models of the solar nebula and to the observed composition of comets.

Theoretical studies of radiative transfer relevant to solar system objects will continue. Lumme and Irvine are working on a generalization of the Lumme-Bowell theory for multiple scattering in planetary regoliths. Increased attention will be given to scattering by dielectric materials such as ices, with a view to modeling thermal emission from a cometary nucleus. Schloerb is studying the maximum entropy technique for inverting spectral line profiles in order to deduce temperature profiles and mixing ratios for trace constituents in planetary atmospheres. This is important not only for our local FCRAO observations, but also as a prelude to the possible millimeter instrument proposed for the Mars Observer Mission.

Financial Report

A detailed financial report will be submitted by the Office of the Treasury, University of Massachusetts.

William M Irvine
Principal Investigator

F. Peter Schloerb
Co-Principal Investigator

January 15, 1986

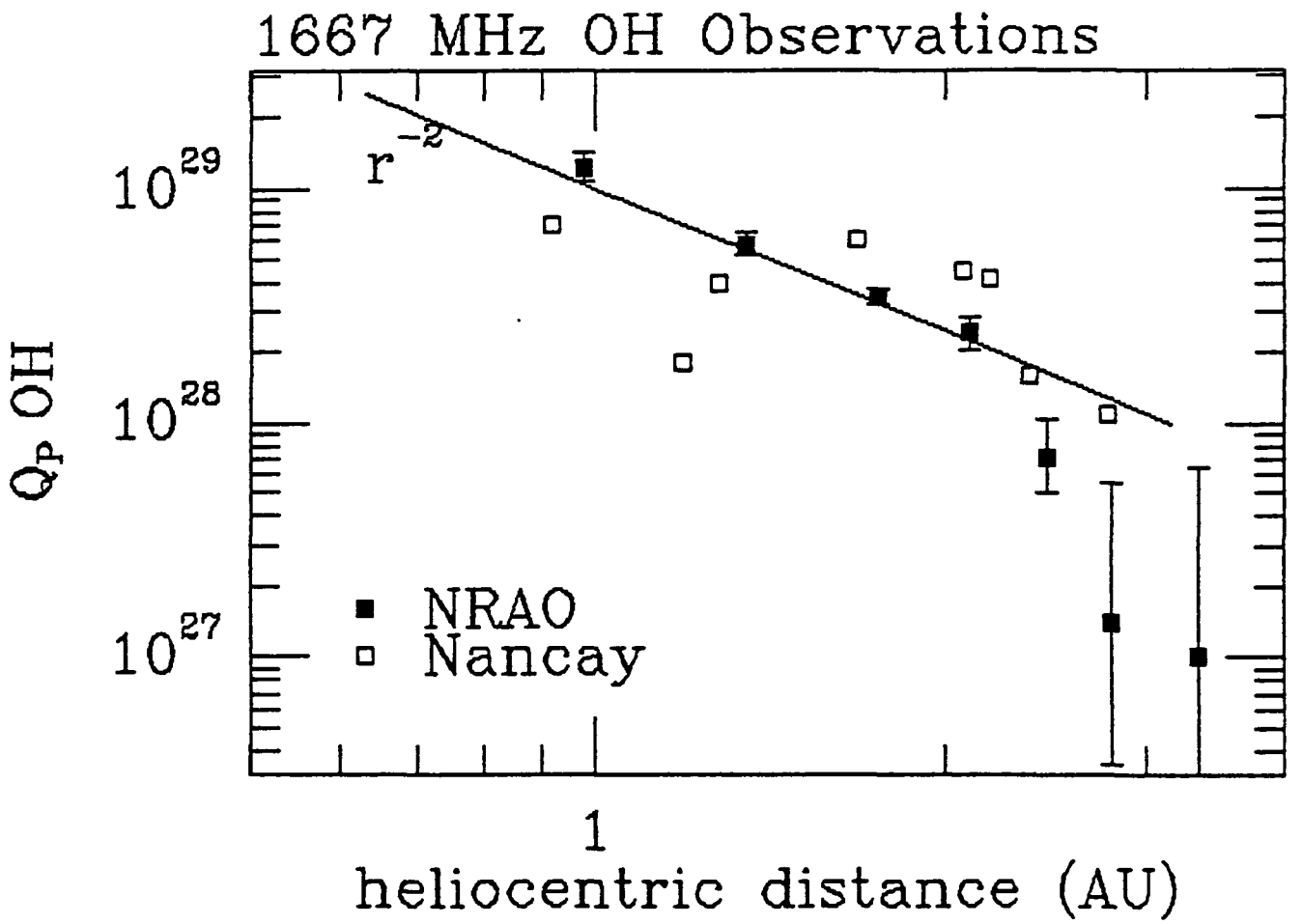

Figure 1: Observations of the OH ground state Λ-doublet transition made at NRAO-Green Bank by Schloerb and Claussen and at Nancay by Gerard et al.