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Final Report for NASA Grant S-14623-F
"Long-Term Variation of Saturn H_2 Emission"

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This document represents the final report for NASA Contract #S-14623-F, titled "Long-Term Variation of Saturn H_2 Emission". Grant activity was initiated on 7 October 1993. The funding level awarded represented approximately 20% time for the PI during the contract period.

Introduction

The IUE spacecraft has made regular observations of the outer planets since its launch in 1978. Auroral H_2 emissions in the Lyman bands at 1575 and 1608 Å have been observed and modelled for both Jupiter and Saturn. Diffuse H_2 emissions, or "dayglow", are more difficult to identify because of the lower signal levels. *McGrath et al.* [1990] analyzed 12 years of IUE Jupiter images, and found that the diffuse H_2 emission strength varied as a function of solar activity. The purpose of this grant was to perform a similar study with the archived IUE images of Saturn. Because of Saturn's lower UV albedo and greater distance from the Sun, no conclusive proof of diffuse H_2 emission on Saturn has appeared in the literature.

Background model

Initial efforts were directed towards creating operational analysis software for use with a small set of images, which required modification of existing analysis code from a different operating system. The determination of an appropriate background spectrum to represent the non-H_2 emission portion of the observed Saturn UV signal proved to be more difficult than expected. One potential method was the use of a smoothed Saturn spectrum containing no observable H_2 emission as a "template" representing the background signal, which could then be subtracted from a chosen image to leave the H_2 signal. However, the low signal-to-noise ratio in most of the Saturn IUE images, particularly disk-centered images, led to widely varying and sometimes negative integrated H_2 fluxes. This result was judged unacceptable.

The method used by *McGrath et al.* [1990] for the analysis of diffuse H_2 emission from Jovian IUE spectra was adopted as the primary method. This procedure entails constructing a model background spectrum, using specified minor constituents and abundances for the composition of the planet's stratosphere. A reasonable set of values for the basic background atmosphere over the wavelength range 1500-

1650 Å was determined, using C_2H_2, C_2H_4, C_2H_6, and C_4H_2 as constituents. However, the strength of the C I line at 1657 Å was not completely reproduced.

The main problem encountered with the background model is its inability to match the depth of the observed acetylene (C_2H_2) bands between 1675-1750 Å. This situation has been known since the earlier work of *Clarke et al.* [1982]. No combination of abundances for the above species was able to significantly improve the fit. The presence of H_2O and PH_3 has been suggested by recent HST observations of Saturn [*Barnet et al.*, 1994], so these species were also included in test calculations. However, the only band structure in the absorption spectra of these species occurs at $\lambda < 1600$ Å, so their effect on the background model was limited to shifting the absolute level of the calculated spectrum. The accuracy of the assumed background model remains a significant limitation for the derived Saturn H_2 flux values.

Analysis of Images

Of the approximately 150 IUE Saturn images taken between 1978-1992, less than 20 are disk-centered images suitable for determination of diffuse H_2 flux levels. The majority of these images were taken between 1980-1985, with relatively short exposure times ($\tau < 30$ minutes) which result in extremely poor signal-to-noise ratios. Temporal averaging offers little help, because few dates have more than 1 image available. A few disk-centered images were taken with exposure times of 60 minutes or longer, providing a substantial improvement in data quality. Among these images, SWP15824 and SWP15825, taken on 21 December 1981, represent the best evidence for diffuse H_2 emission on Saturn. The integrated signal strength over the 1500-1750 Å region is consistent with Jovian results when heliocentric distance scaling and Saturn's darker UV albedo are taken into account. Some other early images can be classified as possibilities (*e.g.* SWP08931, SWP20632), but these results are less convincing.

The primary data files for these analyses were the "line-by-line" files (**.SILO*) produced by the NEWSIPS processing system, from which a range of lines were selected for summation and integration to determine the magnitude of the diffuse H_2 signal. Studies were also done with the extracted spectra files (**.MXLO*) produced by the NEWSIPS processing, which incorporates many improvements over the IUESIPS processing system. Some reduction was seen in the noise level of the MXLO spectra relative to the summed SILO spectra, but little change was seen in the integrated H_2 flux results.

No disk-centered IUE images of Saturn were taken from September 1985 to June 1991, and only 5 images are available for 1991-1992. The image that was available (SWP42689) from IUESIPS processing had a relatively short exposure time (60 minutes) and was noisy, with no evidence of diffuse H_2 emission. NEWSIPS processing of 1990-1994 IUE images is currently ongoing, but the 1991-1992 Saturn images were not available prior to the end of the grant period.

The limited amount of recent IUE Saturn data was noted at the inception of this study, and a proposal was submitted by the PI for IUE observing time during the 18th episode of operations. A modest amount of time was awarded, and observing runs were made during October 1994 and July 1995. In each observing session, multiple long disk-centered exposures were made to maximize the potential for observing diffuse H_2 emission. The detection of H_2 emission in the October 1994 data is questionable, in part because the observations occurred during a period of relatively high background noise. The July 1995 data have adequate signal-to-noise in some of the individual images, and a good S/N ratio when all 5 long-exposure images are averaged together. H_2 emission appears to be present in the July 1995 data.

A paper containing preliminary results, including the October 1994 observations, was presented at the Spring 1995 American Geophysical Union meeting [*DeLand & McGrath*, 1995]. If further progress on the determination of a satisfactory Saturn background model can be made, a short manuscript will be prepared for submission to a journal by the end of 1995.

Conclusion

The goal of this research effort was to analyze the long-term IUE database of Saturn images for the possible presence of diffuse H_2 emissions, using techniques originally developed for analysis of Jupiter images. The poor S/N ratio in many of the Saturn images proved to be a significant limitation to the possible detection of H_2 emission. The creation of a satisfactory background atmosphere model was also limited by difficulties in reproducing the observed C_2H_2 band structure at long wavelengths. The results currently available suggest that diffuse H_2 emission is present on Saturn on some occasions. However, the IUE data are not able to indicate whether H_2 emission is present at all times with a magnitude proportional to solar activity, as was shown for Jupiter [*McGrath et al.*, 1990].

Presentations

DeLand, M. T., and M. A. McGrath, "Long-Term Variation of H_2 Emission from Saturn" (abstract), *EOS Trans. AGU* **76**, Spring Meeting Suppl., 193 [1995].

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Clarke, J. T., H. W. Moos, and P. D. Feldman, "The far-ultraviolet spectra and geometric albedos of Jupiter and Saturn", *Ap. J.* **255**, 806-818 [1982].

McGrath, M. A., G. E. Ballester, and H. W. Moos, "Jovian H_2 dayglow emission (1978-1989)", *J. Geophys. Res.* **95**, 10,365-10,373 [1990].

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