April 17, 1979

Final Report - Grant NSG-5246

Analysis of Ultraviolet Spectrophotometric Data from Copernicus

Theodore P. Snow, Jr., Principal Investigator

This grant supported research with data obtained with the Copernicus satellite. Some of the data used were obtained before the grant initiation date, while the PI was still on the research staff at Princeton; and the rest were obtained through the Copernicus Guest Investigator program, after the PI's move to the University of Colorado.

The original proposal and the attached T43 form both outline the scientific goals of the study. The T43 form also serves to briefly summarize the results of the past year's research, and to outline the intended research plans under a new NASA grant which is forthcoming.

To expand on the bare-bones information in the T43 form regarding scientific results achieved during the past year, the following few paragraphs describe in somewhat more detail a few of the more outstanding accomplishments.

First, with regard to the interstellar depletion study, two important studies were completed. One, carried out with graduate student Karie Meyers, involved a detailed profile analysis of absorption lines in the ζ Ophiuchi cloud. It was found that refractory elements such as iron are much less depleted in the higher-velocity cloud in the line of sight. This shows that the process which accelerated the cloud to its velocity of some 15 Km s^{-1} (LSR) also destroyed the grains, releasing material to the gas phase. This had previously been observed for clouds with much higher velocities, but not for

April 17, 1979

Final Report - Grant NSG-5246

Analysis of Ultraviolet Spectrophotometric Data from Copernicus

Theodore P. Snow, Jr., Principal Investigator

This grant supported research with data obtained with the Copernicus satellite. Some of the data used were obtained before the grant initiation date, while the PI was still on the research staff at Princeton; and the rest were obtained through the Copernicus Guest Investigator program, after the PI's move to the University of Colorado.

The original proposal and the attached T43 form both outline the scientific goals of the study. The T43 form also serves to briefly summarize the results of the past year's research, and to outline the intended research plans under a new NASA grant which is forthcoming.

To expand on the bare-bones information in the T43 form regarding scientific results achieved during the past year, the following few paragraphs describe in somewhat more detail a few of the more outstanding accomplishments.

First, with regard to the interstellar depletion study, two important studies were completed. One, carried out with graduate student Karie Meyers, involved a detailed profile analysis of absorption lines in the ζ Ophiuchi cloud. It was found that refractory elements such as iron are much less depleted in the higher-velocity cloud in the line of sight. This shows that the process which accelerated the cloud to its velocity of some 15 Km s^{-1} (LSR) also destroyed the grains, releasing material to the gas phase. This had previously been observed for clouds with much higher velocities, but not for

those with only moderate speeds. These results, soon to appear in the Astrophysical Journal, will provide valuable constraints for models of grain destruction in interstellar shocks.

A second depletion study, recently completed in collaboration with E. B. Jenkins of Princeton, involved an analysis of conditions within the ρ Opiuchi cloud complex, where previous analyses of optical data had shown that grain growth has ocurred in the densest regions. The Copernicus study, soon to be submitted to the Astrophysical Journal, has revealed that most of the gas in the line of sight is either completely devoid of heavy elements, or is so dense that even species with low ionization potentials are in the atomic form. Either interpretation argues for a dense cloud core. Copernicus data confirm that the grains in this region are unusually large and that the density is high. This tends to support the hypothesis that the depletions result from accretion of heavy elements into grains inside interstellar clouds, in constrast with theories that the depletions result from the grain formation process.

The important outcome of a number of studies of early-type stars (e.g. Snow and Hayes 1978; Slettebak and Snow 1978; Snow and Wegner 1979; Marlbough and Snow 1979) can be summarized simply by saying that variability is common in the UV spectra of hot stars with winds and/or extended atmospheres. Every star studied closely shows fluctuations in line profiles. Continuing analysis of the timescales of these variations and of their relationship from one ion to another will provide invaluable information on the winds, their stability, and, ultimately, the nature of their regions.

Several additional studies were completed during the support period, and

these are mentioned in the attached T43 form, both in the description of work completed (item 13b) and in the bibliography (13d).

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
RESEARCH AND TECHNOLOGY RESUME

1. DATE PREPARED: April 12, 1979

2. TITLE: Analysis of Ultraviolete Spectrophotometric Data from Copernicus

3. NUMBER/CODE: a. PROPOSAL: | b. CURRENT:

4. PERFORMING ORGANIZATION
Laboratory for Atmospheric and Space Physics
University of Colorado

5. CONTRACT/GRANT NO.: NSG 5246

6. DATE: a. STARTING: | b. ANNIVERSARY:

7. INVESTIGATOR'S NAME | TEL. NO.
Theodore P. Snow, Jr.

8. NASA ALT. TECH MONITOR'S NAME | TEL. NO.

9. INSTITUTION CATEGORY CODE
UN

FISCAL YEAR	STATUS a.	MANPOWER (MY) b. IN-HOUSE	c. S/C	FUNDING (In K) d. IMS	e. R/D	f. TOTAL
10. PRIOR						
11. CURRENT						
12. BUDGET						

13. DESCRIPTION (a. Brief statement on strategy of investigation; b. Progress and accomplishments of prior year, c. What will be accomplished this year, as well as how and why; and d. Summary bibliography)

a. Strategy: To utilize ultraviolet spectral data from Copernicus in studies of interstellar absorption lines and of stellar and circumstellar lines in hot stars. The interstellar work has been aimed primarily at analyzing the depletions of heavy elements from the gas phase and at elucidating how these depletions depend on physical conditions. This work has utilized line profiles to determine abundances in separate velocity components. Also of interest are interstellar molecular abundances, which are derived from equivalent width measurements; such measurements provide important information on the density of diffuse clouds, which may also be applied to the dark clouds that are characterized by the presence of complex molecules. The stellar and circumstellar research is directed towards hot stars with winds and/or extended atmospheres. Of prime interest is the variability in these winds which appears now to be quite common. Studies of the timescale of the fluctuations and of their effects on the ionization balance can provide valuable insights into the stability of the winds and, ultimately, may help unearth the driving force behind them. Another aspect of the hot star observations has to do with the circumstellar shell absorption lines which appear in the spectra of some stars, particularly the Be stars. These shells may be low-velocity manifestations of the stellar wind phenomena, and it is especially important to understand their relationship to the winds.

b. Progress of past year: Observations were carried out for interstellar abundances, both atomic and molecular, towards a number of stars, as part of a comprehensive survey in which I am participating. The better quality data are being analyzed for profile information and the lesser data are being used in curve-of-growth analyses. One study of profiles (Snow and Meyers, 1979) has been completed, and another (Meyers and Snow, 1979) is well on its way. Molecular observations have been carried out as well, N_2 was sought (Lutz, Owen and Snow, 1978); interstellar C_2 was detected and its rotational excitation utilized to establish limits in interstellar cloud temperatures (Snow, 1978). An extensive search for H_2O has resulted

Continued on Attached Sheet

	TYPED NAME AND SIGNATURE	DATE
TECHNICAL MONITOR		
APPROVING OFFICIAL		

NASA FORM T43 DEC 74 REPLACES NASA FORM T8 WHICH IS OBSOLETE.

in a tentative identification which will produce new information on chemical reaction rates (Snow and Smith, 1979). A detailed analysis of interstellar depletions and grain properties in the ρ Ophiuchi cloud is nearing completion (Snow and Jenkins, 1979). Several papers on stellar wind variability (Snow and Hayes, 1978; Wegner and Snow, 1978; Slettebak and Snow, 1978) and on circumstellar lines (Marlborough and Snow, 1979; Snow, Peters, andMathieu, 1979) have been completed as well.

c. Plans for coming year: Additional observations are to be carried out, both for the interstellar abundance survey and for studies of extended atmospheres, the latter emphasizing variability in the spectra of Be stars. In addition, analyses of the interstellar depletion data will be continued, with special attention to identifying which grain population is responsible for the depletions.

d. Bibliography:

Snow, Jr., T. P., 1979, "Ultraviolet Observations of Interstellar Molecules and Grains from Spacelab," Proc. Conf. Astr. Ap. from Spacelab, Ed. P. L. Bernacca and R. Ruffini (Dordrecht: Reidel); in press.

Marlborough, M. J., T. P. Snow, Jr., and A. Slettebak, 1978, "Ultraviolet and Optical Spectral Variability in the Be Star γ Cassiopaeia: A Coronal Model for the Circumstellar Envelope," Astrophys. J., 224, 157.

Snow, Jr., T. P., 1978, "The Kinetic Temperature of the Interior of the ζ Ophiuchi Cloud from Copernicus Observations of Interstellar C_2 Molecules," Astrophys. J. (Letters) 202, L93.

Snow, Jr., T. P., J. L. Linsky, 1979, "Ultraviolet Spectroscopy of the Outer Layers of Stars," Proc. Conf. Astr. Ap from Spacelab, ed. P. L. Bernacca and R. Ruffini (Dordrecht: Reidel), in press.

Wegner, G. A. and T. P. Snow, Jr., 1978, "Short-Term Visible and Ultraviolet Variations in the Spectrum of ζ Puppis," Astrophys. J. (Letters), 226, L25.

Lutz, B. L., T. Owen, and T. P. Snow, Jr., 1979, "A Search with Copernicus for Interstellar N_2 in Diffuse Clouds," Astrophys. J., 227, 159.

Ambartsumian, B. A., L. Mirzoyan, and T. P. Snow, Jr., 1979, "Ultraviolet Observations of P Cygni with Copernicus," Astrophys. J., 227, 519 (also Astrofisica, in press).

Snow, Jr., T. P., and D. P. Hayes, 1978, "Ultraviolet Spectrophotometry and Visible-Wavelength Polarimetry of Stellar Wind Variability in δ Orionis A," Astrophys. J., 226, 897.

Snow, Jr., T. P., and E. B. Jenkins, 1979, "Interstellar Depletions and Far-Ultraviolet Extinction in the ρOphiuchi Cloud," Astrophys. J., submitted.

Schwartz, R. D., T. P. Snow, Jr., and W. L. Upson, 1978, "A Search with Copernicus for Ultraviolet Emission Lines from the Planetary Nebula NGC 3242," Astron. J., 83, 1420.

Snow, Jr., T. P., 1979, "An Ultraviolet View of Stellar Winds," IAU Symposium 83, Mass Loss and Evolution of O-Type Stars, ed. P. S. Conti and C. de Loore (Dordrecht: Reidel), in press.

McCray, R. A., and T. P. Snow, Jr., 1979, "The Violent Interstellar Medium," Ann. Rev. Astr. Astrophys., 17, in press.

Snow, Jr., T. P., and K. A. Meyers, 1979, "interstellar Abundances in the ζ Ophiuchi Clouds," Astrophys. J., in press.

Smith, W. H., and T. P. Snow, Jr., 1979, "Copernicus Observational Searches for OH and H_2O in Diffuse Clouds," Astrophys. J., in press.

Snow, Jr., T. P., G. J. Peters, and R. D. Mathieu, 1979, "A Survey of Ultraviolet Circumstellar Absorption Lines in the Spectra of Early Be and Shell Stars," Astrophys. J. Suppl., 39, 359.

Slettebak, A., and T. P. Snow, Jr., 1978, "Spectrophotometric Variability in the Be Star γ Cas: Simultaneous Ultraviolet and Hα Observations," Astrophys. J. (Letters), 224, L127.

Marlborough, J. M., and T. P. Snow, Jr., 1978, "Changes in the Ultraviolet Spectrum of the Mass-losing Be Star 59 Cygni", Astrophys. J., in press.

Snow, Jr., T. P., E. J. Weiler and W. R. Oegerle, 1979, "New Observations of Interstellar Abundances and Depletions of Boron, Vanadium, Chromium, and Cobalt", Astrophys. J., submitted.

Snow, Jr., T. P., G. A. Wegner and P. Kunasz, 1979, "Ultraviolet and Visible-Wavelength Observations of Wind Variability in ζ Puppis", in preparation.

Snow, Jr., T. P. and W. H. Smith, 1979, "Possible Detection of Interstellar H_2O towards ζ Ophinchi", in preparation.

Snow, Jr., T. P., 1979, "On the Nature of the Grains Responsible for Interstellar Gas Depletions", in preparation.