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THE CALCULATION OF THEORETICAL CHROMOSPHERIC MODELS AND PREDICTED OSO I SPECTRA

NASA Grant NSG-7054

Semiannual Report No. 3

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INTRODUCTION

Kurucz presented a paper at the January 1977 American Astronomical Society meeting describing our progress to date on spectrum synthesis. The text is attached. Also attached is a copy of SAO Special Report No. 374 on the Fourth Positive System of CO, which we discussed in our last Progress Report.

At present we are waiting for computer time to make another iteration on the spectrum; in the meantime, we continue to make improvements in the programs and solar model. Our collaboration with Oran R. White for computer time at NCAR has been jeopardized by the large demand for computer time required to reduce the OSO 8 data tapes. We are presently trying to make other arrangements to obtain sufficient amounts of computer time.

ATTACHMENT 1

SOLAR ULTRAVIOLET SPECTRUM SYNTHESIS

SOLAR ULTRAVIOLET SPECTRUM SYNTHESIS

Robert L. Kurucz

Center for Astrophysics

Harvard College Observatory and Smithsonian Astrophysical Observatory

Cambridge, Massachusetts 02138

Presented at the

149th Meeting of the American Astronomical Society in Honolulu, Hawaii

January 1977

This talk is a progress report on my work on spectrum synthesis.

I have written a computer program that, given a line list and a model atmosphere, computes a spectrum; rotationally, macroturbulently, and instrumentally broadens it; plots it together with an observed spectrum; and labels each line. Radiative, Stark, and van der Waals damping constants, isotopic abundances, and hyperfine components can be specified. If the model atmosphere includes departures from LTE, the lines can be computed in non-LTE. Highly ionized atoms can be treated in the coronal approximation. A velocity gradient can be specified as a function of depth in the atmosphere.

In using this program to study the solar ultraviolet, I am collaborating with Gene Avrett and Jorge Vernazza, who supply the non-LTE solar models. We are following an iterative procedure in which we start with a model, compute the spectrum, and compare it to the observations. We check the agreement and correct whatever deficiencies we can find for another iteration. The principal discrepancies so far have been caused by incomplete line data. Therefore, I have been concentrating on additions to my line list.

The basic line data were computed in 1972 by Eric Peytremann and myself for 1,700,000 atomic lines. That list has been edited down to 265,000 atomic lines for use in spectrum synthesis. The data are listed in SAO Special Report No. 362.

I am going to show a few slides that, unfortunately, cannot convey the scope of this work because of the limited format. I have a few sample plots on display here and I have brought about 50 other samples showing the ultraviolet and visible solar spectrum, and some other stars. Any of you who have seen my office in Cambridge know that I can paper a whole observatory.

The first slide (Fig. 1) shows a tiny sample of spectrum at 214 nm. The thin line is the calculation. The darker lines are Harvard rocket spectra taken by Kohl, Parkinson, and Reeves. The labels at the top are the line identifications.

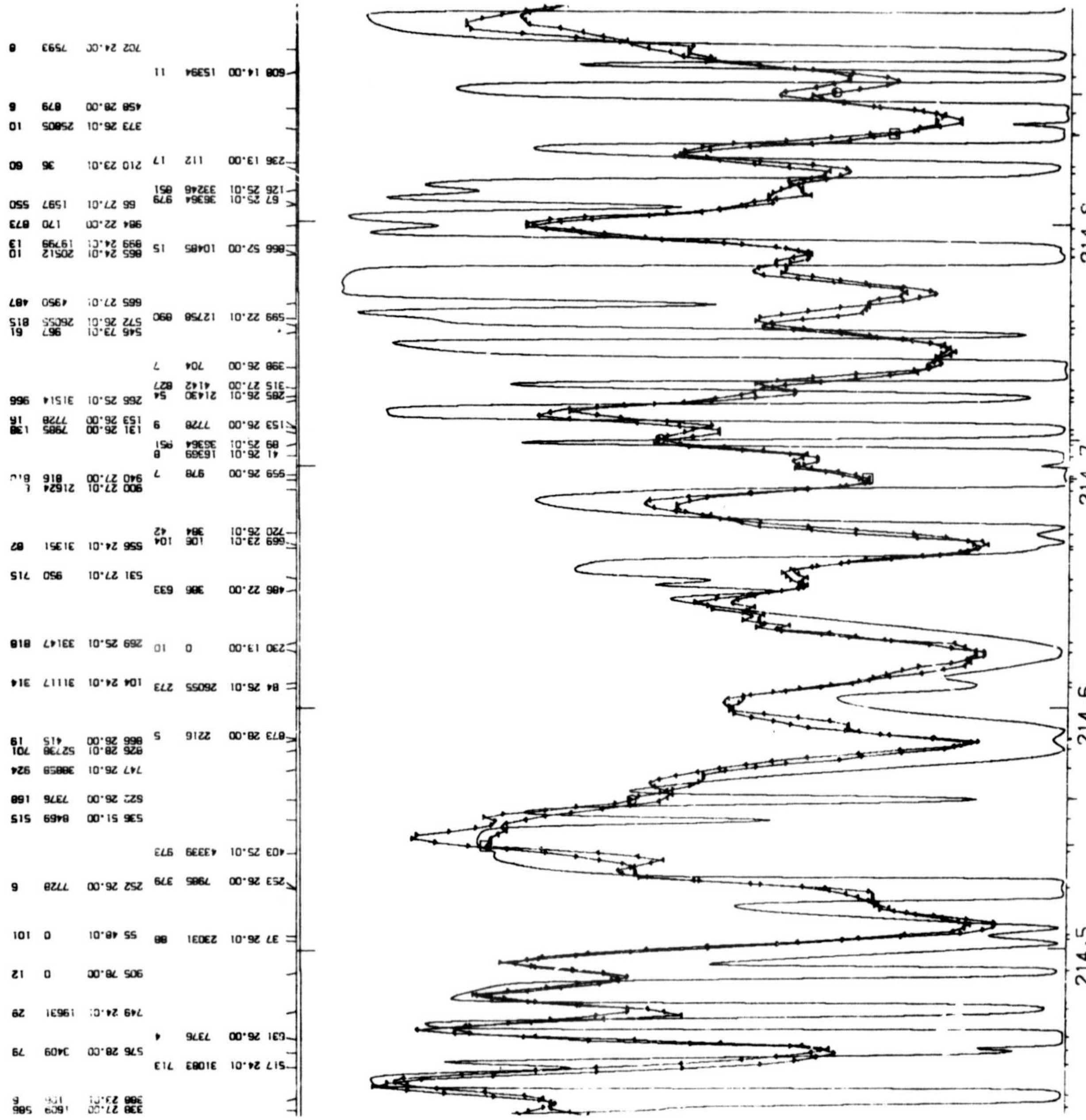


Figure 1.

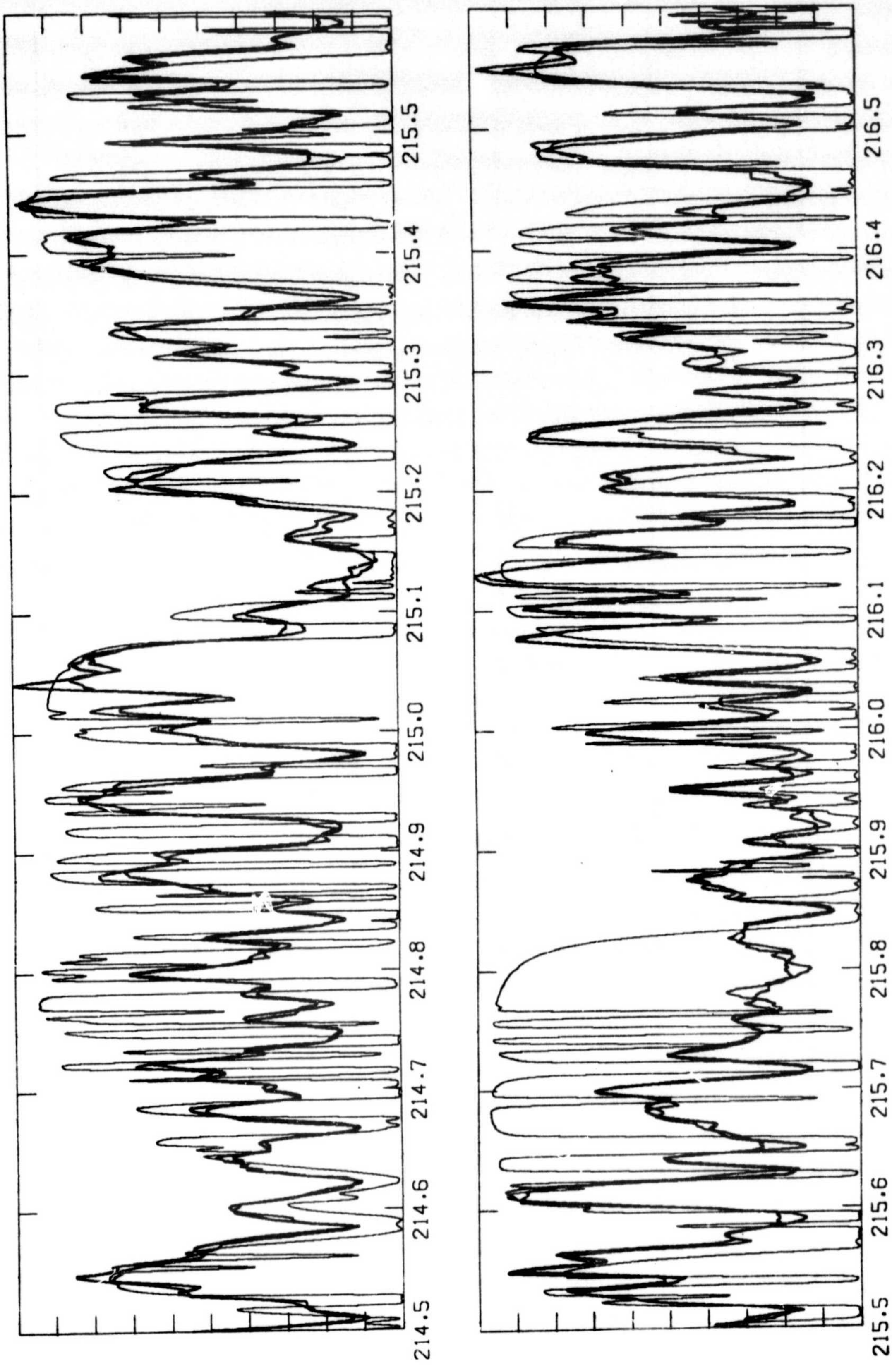
The second slide (Fig. 2) shows a larger region of spectrum. I should point out that we are not adjusting the line data to force a match; we are only correcting errors that we can find in the atomic data or in the physics of the model calculation. Instead of making corrections to one line at a time, we correct many lines as a group.

The third slide (Fig. 3) shows one problem that has been corrected. The top spectrum was my first calculation that shows the Si I discontinuity at 198 nm. As you can see it bears little resemblance to the real spectrum because in fact there are a series of lines that merge into the continuum and smooth out the discontinuity. I have computed series for Mg I, Al I, and Si I and am still working on C I. For Si I, I could make use of the papers by Brown, Tilford, Tousey, and Ginter of NRL. In the lower plot you can now see that there is much better agreement.

This is shown in more detail in the next slide (Fig. 4). The upper spectrum is just the non-LTE Al I series at 207 nm. The lower spectrum is the total predicted spectrum. The heavy middle spectra are the rocket observations. It is possible to identify Al lines up to n = 25.

Another problem is the absence of molecular lines in my list. Ten years ago Goldberg, Parkinson, and Reeves, Rich, and Porter, Tilford, and Widing showed that there are numerous CO features in the solar ultraviolet. Calculations by Tarafdar and Vardya and, more recently, by Krishna Swamy indicate that CO is an important opacity source. I have computed the wavelengths and gf values for 160,000 lines of the Fourth Positive System of CO. These data will be available as SAO Special Report No. 374. I have also computed all 28,000 lines of the Lyman and Werner bands of H_2. Laboratory data for CO and H_2 are poor or nonexistent except for low J, so that much of the line data is based upon unreliable extrapolation.

CO is an extremely sensitive diagnostic of the solar temperature minimum region because of its high dissociation energy. You can see from the next slide (Fig. 5) that models of the temperature minimum region vary by 300 K, which makes a tremendous difference in estimates of the acoustic flux. We hope that the CO spectrum will allow us to determine which model is correct.


214.5
214.6
214.7
214.8
214.9
215.0
215.1
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215.4
215.5
215.5
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216.5

Figure 2.

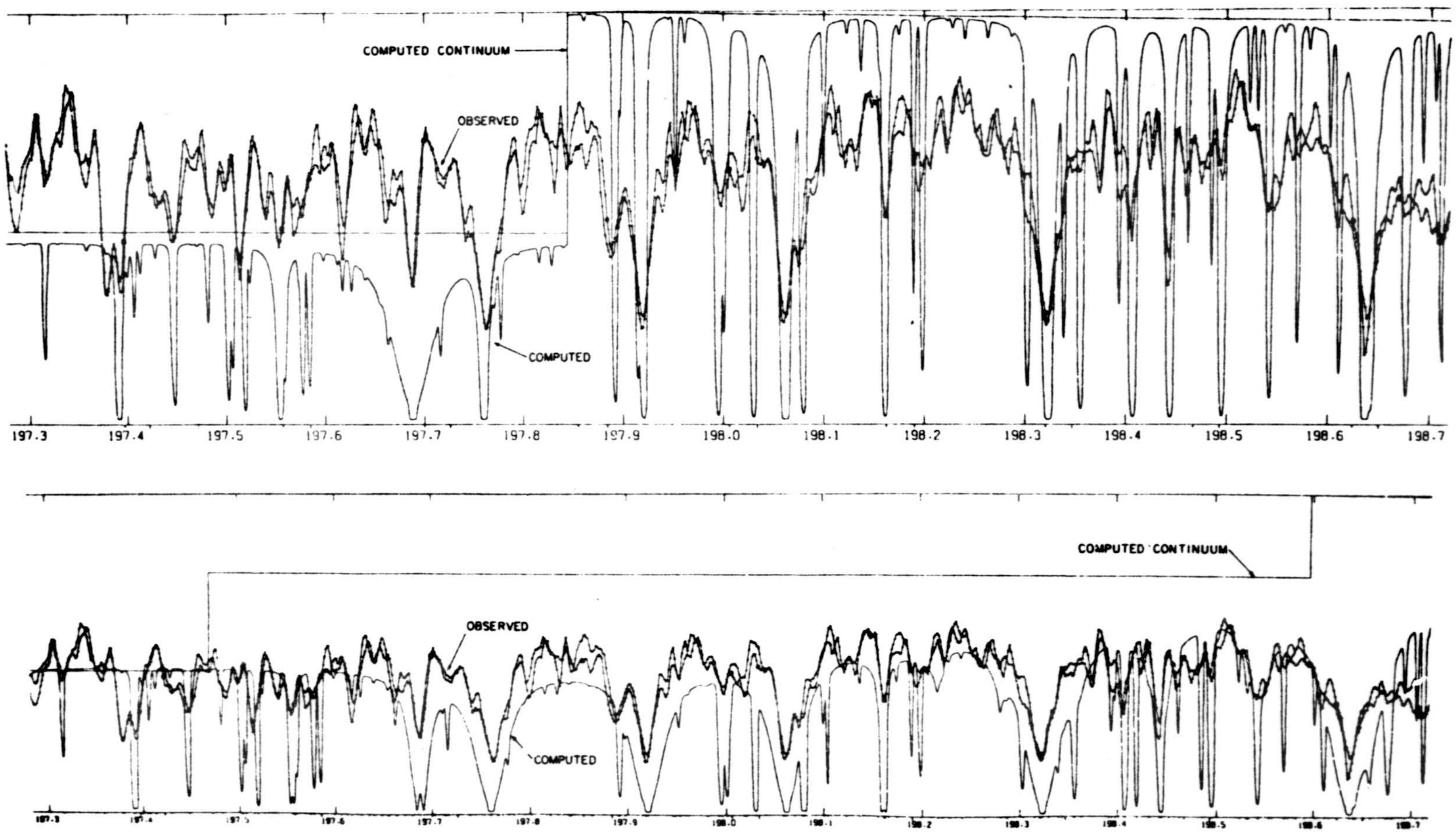
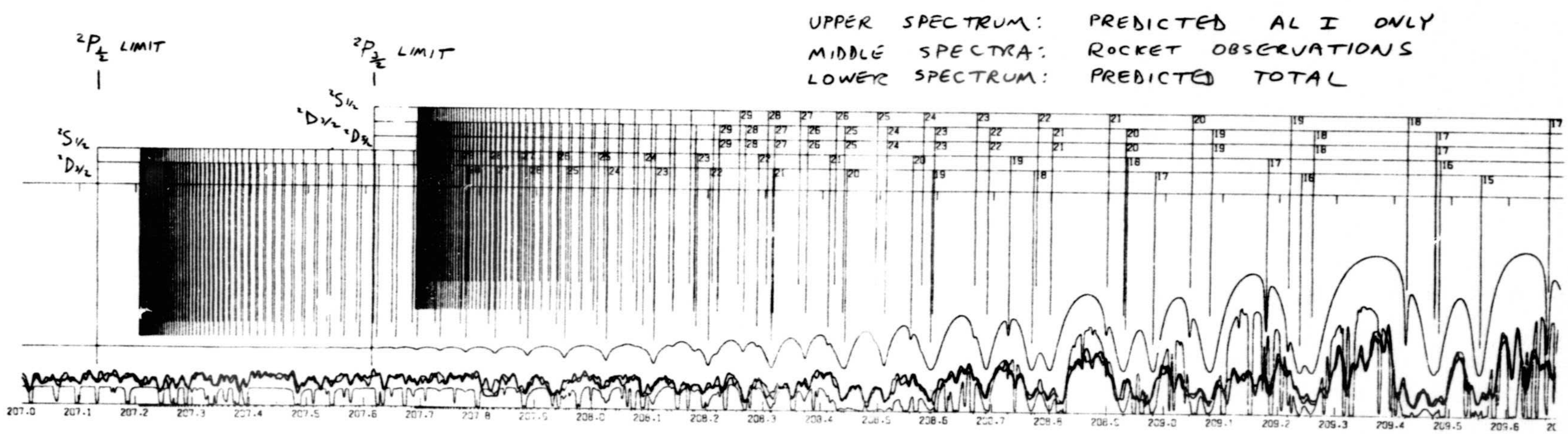

COMPUTED CONTINUUM
OBSERVED
COMPUTED
197.3
197.4
197.5
197.6
197.7
197.8
197.9
198.0
198.1
198.2
198.3
198.4
198.5
198.6
198.7
COMPUTED CONTINUUM
OBSERVED
COMPUTED

Figure 3.


UPPER SPECTRUM: PREDICTED AL I ONLY
MIDDLE SPECTRA: ROCKET OBSERVATIONS
LOWER SPECTRUM: PREDICTED TOTAL
$^2P_{\frac{1}{2}}$ LIMIT
$^2P_{\frac{3}{2}}$ LIMIT
$^2S_{1/2}$
$^2D_{3/2}$
$^2S_{1/2}$
$^2D_{3/2}$ $^2D_{5/2}$
207.0
207.1
207.2
207.3
207.4
207.5
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207.8
208.0
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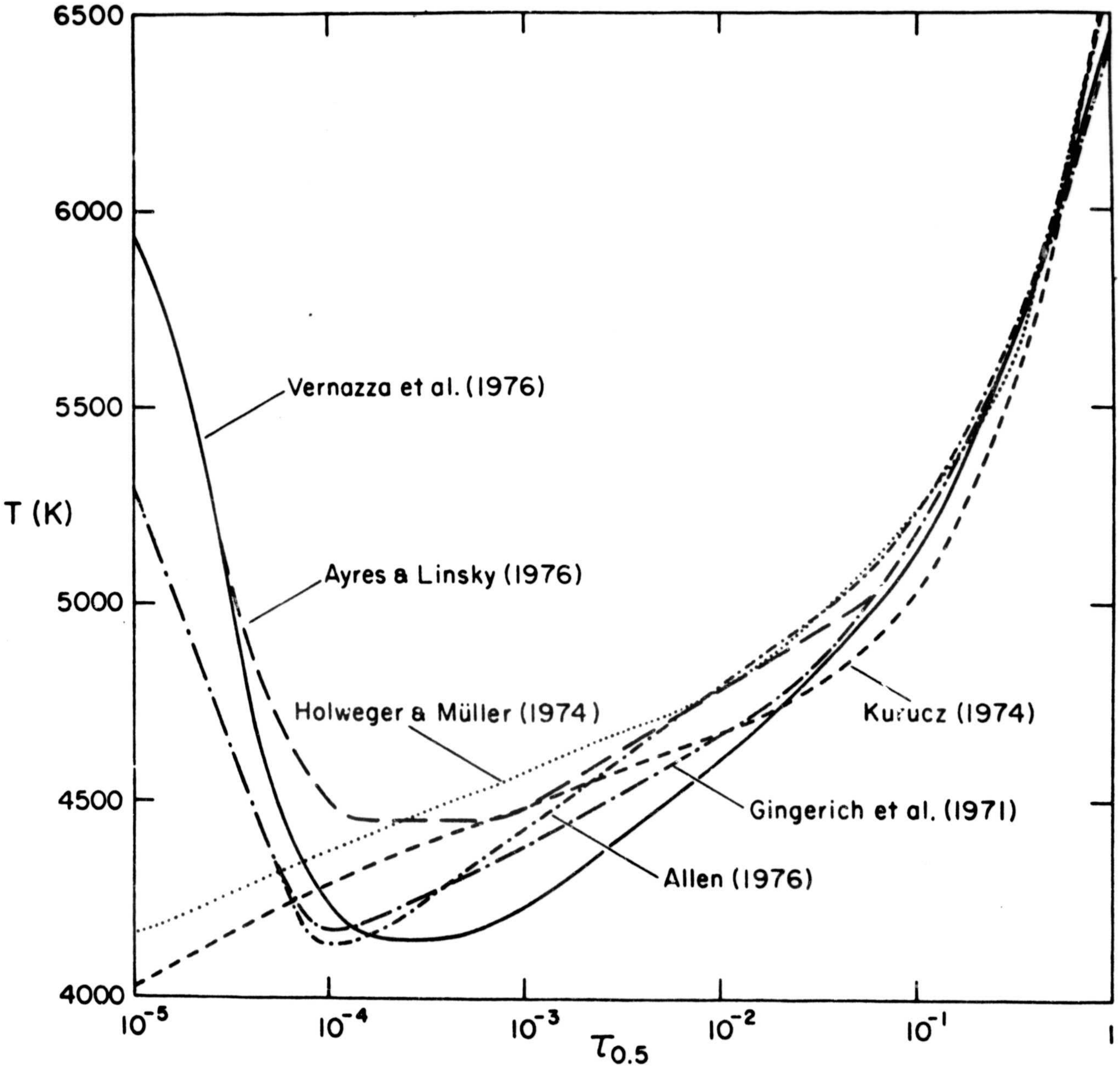
209.6

Figure 4.



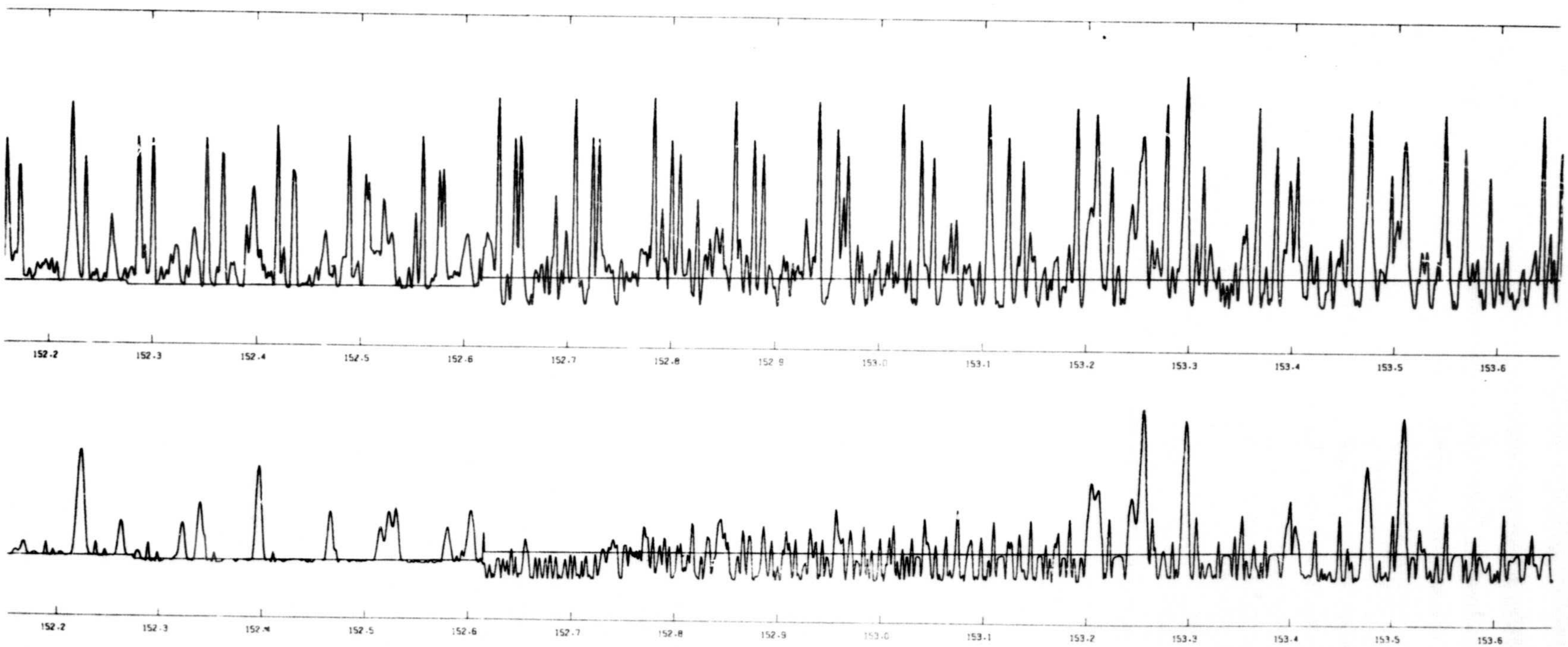
6500
6000
5500
5000
4500
4000
T (K)
Vernazza et al. (1976)
Ayres & Linsky (1976)
Holweger & Müller (1974)
Kurucz (1974)
Gingerich et al. (1971)
Allen (1976)
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
$\tau_{0.5}$

Figure 5.

The next slide (Fig. 6) shows a debugging run that I made in Cambridge just before this meeting. The lower spectrum shows the H_2 and CO lines near 152 nm for which there are reliable data. The upper spectrum shows all the computed lines. The H_2 lines have the broader doppler cores.

The last slide (Fig. 7) shows a small piece of the CO spectrum near 203 nm based on the reliable data. The X11-A5 band ion can be seen showing R27, 28, 29, 30, and 31; the X9-A2 band also appears. On some of my plots predicted lines that have J greater than 100 can be distinguished.

In the near future I expect to compute another iteration including the molecular lines and to publish the plots, with identifications, as an SAO Special Report. These should be helpful to the OSO 8 investigators and other experimenters in interpreting spectral observations. I am always happy to discuss collaborations and to supply these results to those who need them.


152.2
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153.1
153.2
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153.4
153.5
153.6

Figure 6.

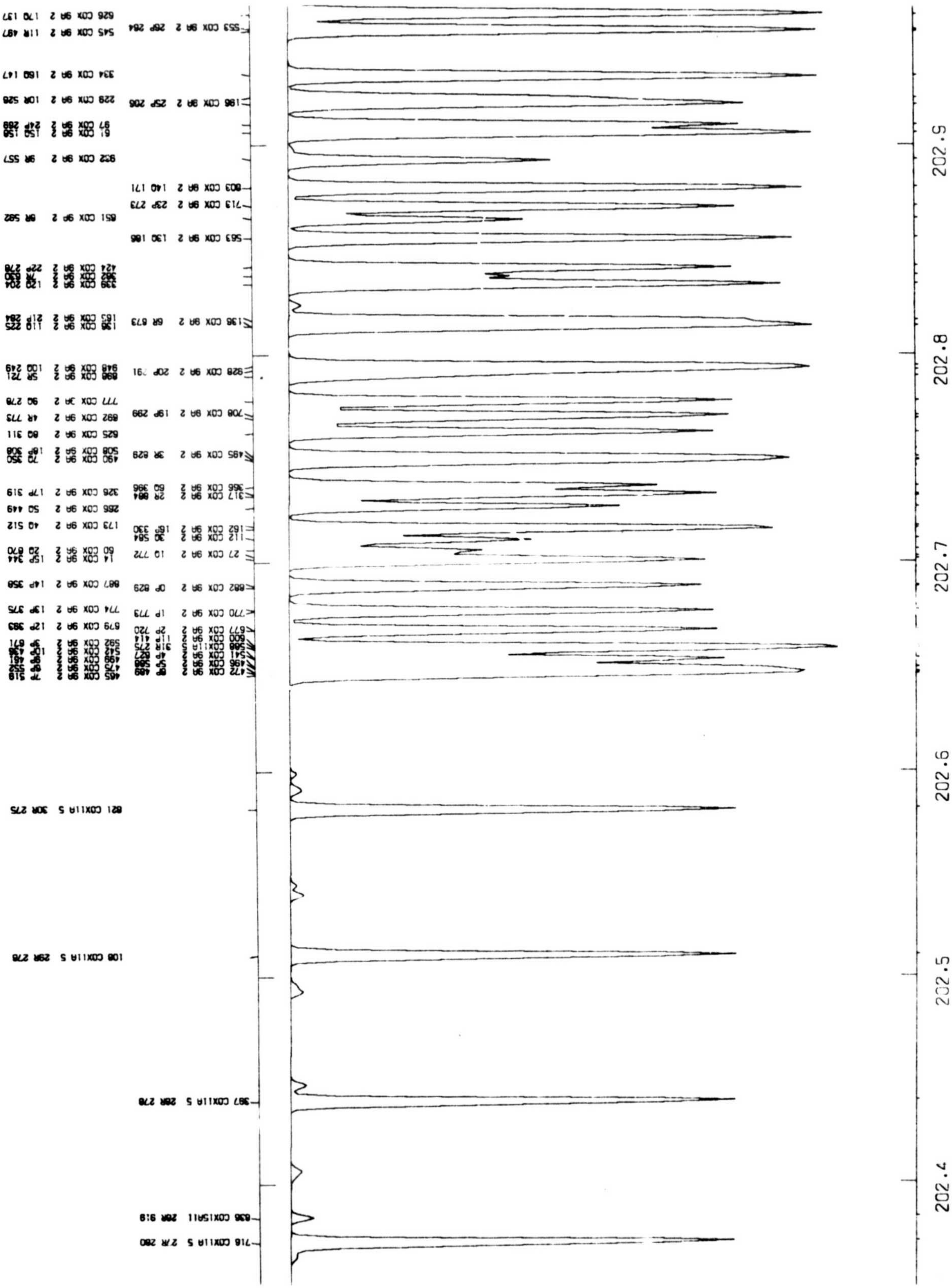

Figure 7.

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