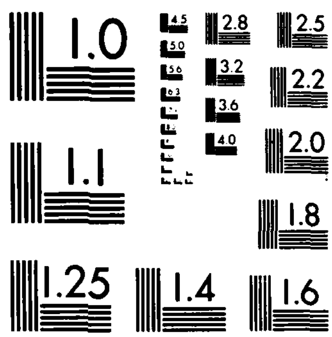
AD-A184 360 SOLAR MAGNETIC AND VELOCITY FIELDS(U) CALIFORNIA UNIV LOS ANGELES DEPT OF ASTRONOMY R K ULRICH 30 JUN 87 N00014-86-K-0056 1/1

UNCLASSIFIED F/G 3/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

(12)

ANNUAL LETTER TECHNICAL REPORT

for

ONR Contract No. N00014-86-K-0056

Entitled: "SOLAR MAGNETIC AND VELOCITY FIELDS"

Submitted by

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA
UNIVERSITY OF CALIFORNIA, LOS ANGELES
DEPARTMENT OF ASTRONOMY
405 HILGARD AVENUE
LOS ANGELES, CALIFORNIA 90024

Period Covered by Report: December 16, 1985 - June 30, 1987

PRINCIPAL INVESTIGATOR:

Professor Roger K. Ulrich
Department of Astronomy
Telephone No. (213) 825-4720

Executive Summary
Solar Magnetic and Velocity Measurements
Mt. Wilson 150-ft Tower

Roger K. Ulrich, P.I.
UCLA Astronomy Dept.

SCIENTIFIC RESULTS

Fast-Scan Program
Beginning in December 1985 a program of multiple scans of the solar velocity and magnetic fields was begun in order to reduce the noise due to oscillations and supergranulation. Up to 25 scans per day are now taken and averaged to generate synoptic diagrams and other data products.

Magnetic and Velocity Maps
The noise in the magnetic field measurements is now as low as 0.1 gauss. We are studying the rotation and circulation patterns by correlating the apparent position of a particular fixed point on the solar surface with the line of sight velocity. We are able to distinguish streaming patterns which are undoubtably related to the torsional oscillations.

Limb Shift
We have found that the limb shift is time variable and that this variation has caused the apparent velocity pattern referred to by Howard as the "ears". By removing a limb shift determined for each year, we are able to obtain a velocity field which is largely flat.

Differential Roataion with Altitude
Near the east and west limbs there remains a velocity pattern which can be explained as a result of the higher altitudes rotating more slowly than the deeper altitudes.

HARDWARE IMPROVEMENT

We replaced the primary lead screw with a new precision ground screw which will have a lifetime under present conditions of over 100 years. This system eliminates the need for gears which previously caused the drive motors to stall on occasion.

FUTURE PLANS

Preservation of the Digital Record
We have purchased a new 6250 bpi tape drive and we will have the observers copy the old digital record onto the higher density tapes in order to prevent the potential deterioration of the data-base due to the spontaneous demagnetization that can occur on old tapes.

Sunspot Positions
The 150-ft tower project has provided butterfly diagrams showing sunspot position as a function of time. The current version is in the form of a large piece of paper with ink lines on it. We are in the process of taking the log record of this data and entering it onto a computer readable form. We will then be in a position to combine the sunspot data with other digital data.

Annual Report on
Solar Magnetic and Velocity Measurements
Mt. Wilson 150-foot Tower.

ONR Supported Research

Roger K. Ulrich, P.I.
UCLA, Astronomy Dept.

SCIENTIFIC RESULTS

◎ Fast-Scan Program

A major initiative beginning in December 1985 was the institution of a new facet of the observational program aimed at reducing the noise in the velocity measurements by obtaining a large number of independent scans of the solar velocity and magnetic fields distributed over as long a time base as is possible. In order to speed up the rate of acquiring the data, we have slightly degraded the spatial resolution and increased the slew rate of the guiding mirror. These two adjustments to the observing procedure cut the time of making a single scan of the sun from about 50 minutes to about 20 minutes. We call this program the fast-scan program although our current rate of scanning is still less than we would like. The current rate determining step is that of archiving and recording all the data although there are ways that this bottle-neck can be relieved. During the past year the fast scan program has been refined to the point where between 12 and 20 measurements of the solar velocity and magnetic fields are made each day. To the extent that each of these measurements is independent of the others and the errors of measurement obey Gaussian statistics, additional improvements in the data from repeated observation will require a major speeding up of the reduction system.

◎ Magnetic and Velocity Maps

Initial indications are that the fast-scan strategy is effective in reducing the noise in the measurement of both the velocity and magnetic fields. We are able to display magnetic maps from the average of a month's worth of scans which have an apparent noise level near 0.1 Gauss. We are beginning to study the velocity patterns by correlating the line of sight velocity with the sine and cosine of the central meridian angle in order to resolve the long lived velocities into what we term zonal and sectoral components respectively. The zonal velocity component is parallel to the solar equator while the sectoral component is composed of vertical motion on the solar equator and includes flows toward the solar poles for regions away from the solar equator. The zonal velocities show very large stream patterns that are associated with active regions and are probably related to the torsional oscillations studied by Labonte and

Howard (1980) and Snodgrass (1985, 1987). We do not yet have a sufficiently long time interval using the fast-scan procedure to be able to arrive at definitive conclusions although we do feel that the method is effective and will yield good results within the next year or so.

- Largest Scale Velocity Fields

In the process of reexamining the data reduction algorithm, we have verified the suggestion by Labonte and Howard (1980) that the receeding velocity of the portions of the apparent solar disk termed the 'Ears' is a result of an inappropriate treatment of the phenonenom known as the limb shift. In an attempt to develop a better representation of the limb shift we have taken a central strip with a width of 23.5% of the solar radius parallel to the central meridian and grouped the pixels within this strip into 100 bins according to their angular distance from the center of the solar disk. Because the strip is narrow and symmetric about the central meridian, rotation cancels out leaving us with a direct measure of the limb shift. We recognize that there is no way to distinguish between limb shift and various meridional circulation patterns. However, if what we are observing is strictly a result of the correlation between line strength and local temperature as is traditionally assumed for the limb shift then we would expect the pattern we observe in the central meridian strip to be relevant to the equatorial regions as well. We take this point of view as a starting position but will re-evaluate the issue on the basis of the final results.

- Limb Shift

We carried out the recalculation of the limb shift for all the digital data available to us from the project going back to 1967. To our surprize, the results showed that the limb shift is not a constant. Three sample limb shift curves are shown in figures 1 to 3. The ears resulted from the fact that the limb shift was calculated for the curve shown in figure 2 in which the central reversal was absent. Normally the limb shift reaches a local minimum at the center of the disk. No provision was previously made for a local minimum in the representation of the limb shift and an artificial cusp in the apparent residual radial velocity resulted. The "Ears" were a result of the multi-parameter fit to the data compensating for the bad representation of the limb shift. We are now fitting the limb shift in a two step process. First, for the entire data set we have fit the average limb shift with a six term polynomial in $\sin(\rho)$ where ρ is the center to limb angle. Second, we fit the deviation of each yearly average from the grand average with a three term polynomial. This procedure permits an accurate representation of the most stable portion of the limb shift but does not remove the shorter wavelength variations that could be due to circulation flows on the sun. A contour map of the deviation of the yearly averages from the long term average in the limb shift is shown in figure 4. Most of the variation occurs in a velocity range of ±35 m/s.

An important question remains as to whether the above effects are instrumental or solar in origin. The pattern is somewhat different after the major improvements that were made in the observing system in 1982. This suggests an instrumental orgin. A test of the character of the effect is its dependence on position over the field. The most obvious potential problems with the system before 1982 could have involved collimation errors and irregularities in the surface sensitivity of the photomultiplier tube. If this is the explanation then we would expect the variable line shift to be random relative to the apparent solar disk. We checked the symmetry of the limb shift by comparing the curve derived from the North half of the sun with that derived from the South Half. The result is that the two halves are virtually identical. The possibility remains that the variation in the limb shift is caused by some other effect which has a global symmetry in the instrument. We take out the velocity variations which are linear in the vertical position accross the solar disk so that what we are seeing as centered on the disk could represent the first non-removed term. We might expect that the linear term is then a sample of the instrumental effect that is also showing up as variable limb shift. We examined the variations of the linear term with time and found that there is no obvious correlation between it and the variations in limb shift. Furthermore, there is no decrease in the magnitude of the linear term following 1982. A final check on the nature of the limb shift variation is to compare different spectral lines. The vast majority of the data available to us is for the line λ5250. We have a small amount of data for the lines λ5237 and the pattern of change in limb shift observed for that line does not match that observed for λ5250 over the same interval. We conclude that the changes in limb shift are probably solar in origin but probably not a result of variable meridional circulation since the latter would have been the same for both lines.

⊙ Differential Rotation with Altitude

The velocity field that remains after removal of the limb shift as decribed in the preceeding paragraphs shows more detail than was available when the velocity field of the "Ears" remained in the data. We found that the newly flattened velocity maps contain patterns with a strong east-west anti-symmetry. Zones with different central meridian distance appear to be rotating with different speeds. We grouped the solar surface in bins of equal central meridian angle and then carried out a standard rotation analysis on the data. The results are shown in figure 5 where we give the value of the A coefficient as a function of the central meridian angle for period over which the digital data is available. We are not yet sure what these results mean. Interpreted most simply they imply that the rate of solar rotation depends on altitude in the solar atmosphere. The velocity shear implied by this interpretation is only about 15 m/s over an altitude range of about 100 km. The sense of the gradient is for the sun to be rotating more rapidly in the interior than at the surface. The magnetic rotation rate as determined by Snodgrass (1983) is larger than the doppler determined rotation rate by an amount which is greater than is implied by the gradient we observe. A possible interpretation of both results is that the magnetic field is rooted relatively deep in the solar atmosphere and the gradient we observe is part of a larger trend. The shear flow between the deeper layers and the upper atmosphere may be driven by variations in the torque applied by the solar wind or by variations in the magnetic rate of rotation caused by solar cycle effects. The rotation results now becoming available from Helioseismology (Duvall, Harvey and Pomerantz 1986, Brown 1987, Rhodes et al 1987) indicate that the deep interior is rotating more slowly than the surface. We note that the Helioseismology results apply to layers that are much deeper than is relevant to either the magnetic or the doppler measurements made on the solar surface.

FUTURE PLANS

- Large Scale Velocity Fields
  Our program to study large scale solar velocities is maturing. The valuable record from the past 20 years allows us to explore the consequences of alternate data reduction approaches. The intiatives described in the preceeding paragraphs have resulted in a more noise free set of data. When the previous algorithm was used, individual data records where a particular point on the solar surface happened to be near the solar limb, the large effect of the "Ears" term introduced unnecessary noise into the apparent residual velocity. When we use the new limb fit procedure, the "Ears" effect essentially disappears and the resulting residual velocities are more smoothly dependent on the central meridian angle and less susceptible to noise from variations in the limb shift. Consequently, we hope that a re-examination of the earlier residual velocities will allow us to find some evidence of large scale motions. The newer data with 15 to 20 times as many measurements per day will help further reduce the noise in the velocity. There remain a number of uncertainties such as the effect of supergranulation on the residual velocity that may prevent the noise from being reduced by a factor as large as $20^{1/2}$.

- Preservation of the Digital Record
  The archival data which is a responsibility of the project is currently preserved in the form of magnetic tape written at a density of either 800 bpi or 1600 bpi. It is known that old magnetic tape can decay and jeopardize the integretity of the archive. Currently the old data is not

exhibiting symptoms of imminent deterioration. However, the potential risk is that by the time we know that the data is beginning to deteriorate there may not be time to save. Consequently, we have purchased a new 6250 bpi tape drive and will install it in the data room on Mt. Wilson. We will use the spare time of the observers on days when data cannot be taken to have the solar observers systematically copy all the archival data to tapes written at a density of 6250. The process of re-writing the data will give it a new start. The higher data density will make distribution of the data easier by reducing the number of tapes by a factor of roughly 3.

- New Lead Screw

  The fast scan program described above has placed a high load on the screw which drives the guiding system. The nut has been shimmed twice and continues to show signs of wear. We have purchased a new lead screw system and built the attachment hardware to replace the present lead screw. This is a precision ground screw with an estimated life under present conditions of over 100 years. The pitch of the new screw is twice as large as the old screw so some minor reprogramming of the data taking software will be required before the new screw can be installed. We plan to complete the switch during April or May of 1987. The larger pitch of the new screw will eliminate the need for gears which drive the screw faster than the stepper motor. This new setup will have less friction and the scanning speed can be increased.

- Sunspot Positions

  This project has provided butterfly diagrams showing sunspot latitude as a function of time. The current version is in the form of a large piece of paper with ink lines drawn on it. As new data is acquired, this piece of paper is updated by adding new lines. We plan to upgrade the process of making butterfly diagrams by digitizing the sunspot positions and strength and preparing an automated way of generating the butterfly diagrams. We have available a historical record that goes back to the beginning of the operation of the 150 foot tower and this record is in a form which can easily be made into a digital database. We are in the process of entering this data into computer files.

- Temperatures and Air Movement in the Spectrograph Pit

  A potential remaining source of error in our program is the movement of air in the pit. This air movement could deflect the light between the slit and the grating. It could also cause differential heating or cooling of the metal structure that holds the grating. The pit could be an exceptionally stable environment with little or no air movement. Unfortunately, the humidity becomes high enough to cause moisture to condense on the optics if the air is allowed to stand. Consequently, a small fan was installed in the pit a number of years ago. In order to determine the potential effect that the air movement has on the observations we are in the process of installing a set of temperature sensors that will be able to measure variations at the level of 10^{-4}°K. We also will use a pair of sensors in a configuration where one sensor has a heat load due to a fixed current and the other sensor of the pair has no heat load. The temperature difference between these sensors will provide a measure of the rate of air flow over both. With this technique we hope to learn about conditions in the spectrograph and if the results indicate a potential problem we will take steps to redirect the air flow and stabilize the pit environment. By checking on conditions before and during the modifications, we will be able to verify that any changes we make are actually improving the air stability.

MANAGEMENT

- Site Maintenance

A key problem with the continuation of activities on Mt. Wilson is the site maintanence. The UCLA Department of Astronomy is contributing technical personnel to site maintenance at the rate of roughly 6 man-months per year at no charge to the agency. The design and construction of the hardware to install the new lead screw was done out of this UCLA contribution. In addition, this last year UCLA granted the Mt. Wilson projects off-campus status even though a fraction of the activities actually take place on campus. The differential in the overhead rates is being used to purchase hardware and employ extra people whose responsibility it will be to maintain the site. We are now paying the electricity bills out of these overhead funds. In order to regularize the arrangement, we are in the process of instituting a recharge center on the UCLA campus that will bill non-UCLA users of the Mt. Wilson site on order to increase the funds available to employ site maintanence personnel. The projects that will be billed include the Harvard H-K project, the USC Solar Oscillation project, the MIT/NRL interferometry project and the UCB interferometry project. The combination of all these contributions will permit the employment of at least one additional site maintenance person. We will charge a reasonable amount for the rent of the living facilities on the mountain and again use these funds for their upkeep. The arrangement outlined here has been approved in principal by the director of the Mt. Wilson and Las Campanas Observatories and the only thing delaying the actual implementation is the approval of the recharge center at UCLA. We have to have a mechanism in place to collect funds before we assume the broader responsibility of supporting other activities on the mountain beyond the 150-ft tower. The general support of the mountain facilities will benefit all of us including the 150-ft tower project. In fact we are largely providing such services at the present time without any formal recognition of that fact and without the commensurate financial support. A key underutilized facility for the support of activities on the mountain is the Monastery. Many of the users come to the mountain only for brief stays and the Monastery is a valuable resource for these people. We will incorporate plans for the re-activation of the Monastery in the recharge center.

- Personnel

  The personnel involved in the project have been stable. We were disappointed that Chris Shelton has declined to work for this project at the 50 percent level and has only been available at the 10 percent level. We have used the funds made available from that shortfall to support Tom Sheiber at the 50 percent level as well Tony Misch at 25 percent time. The key change that we plan to make in May is to bring Tom Sheiber's employment level to 100 percent and ask him to assume the archiving responsibilities of Pam Gilman. Pam Gilman in turn will become a 100 percent observe and relieve 50 percent of Larry Webster's time for the purpose of site maintanence as described in the preceeding paragraph. As soon as the recharge center is approved, we will employ a new maintanence person to work under the supervision of Larry Webster. Finally, a portion of Ulrich's summer salary is included in the projected budget since in fact a major fraction of his effort during the past year has been devoted to this project.

REFERENCES

Brown T.M. 1987, Nature, xxx, xxx.

Duvall, T.L., Jr., Harvey J.W. and Pomerantz, M. 1986, Nature, xxx, xxx.

Howard, R. and Labonte, B.J. 1980, Astrophys. J. Letters, 239, L33.

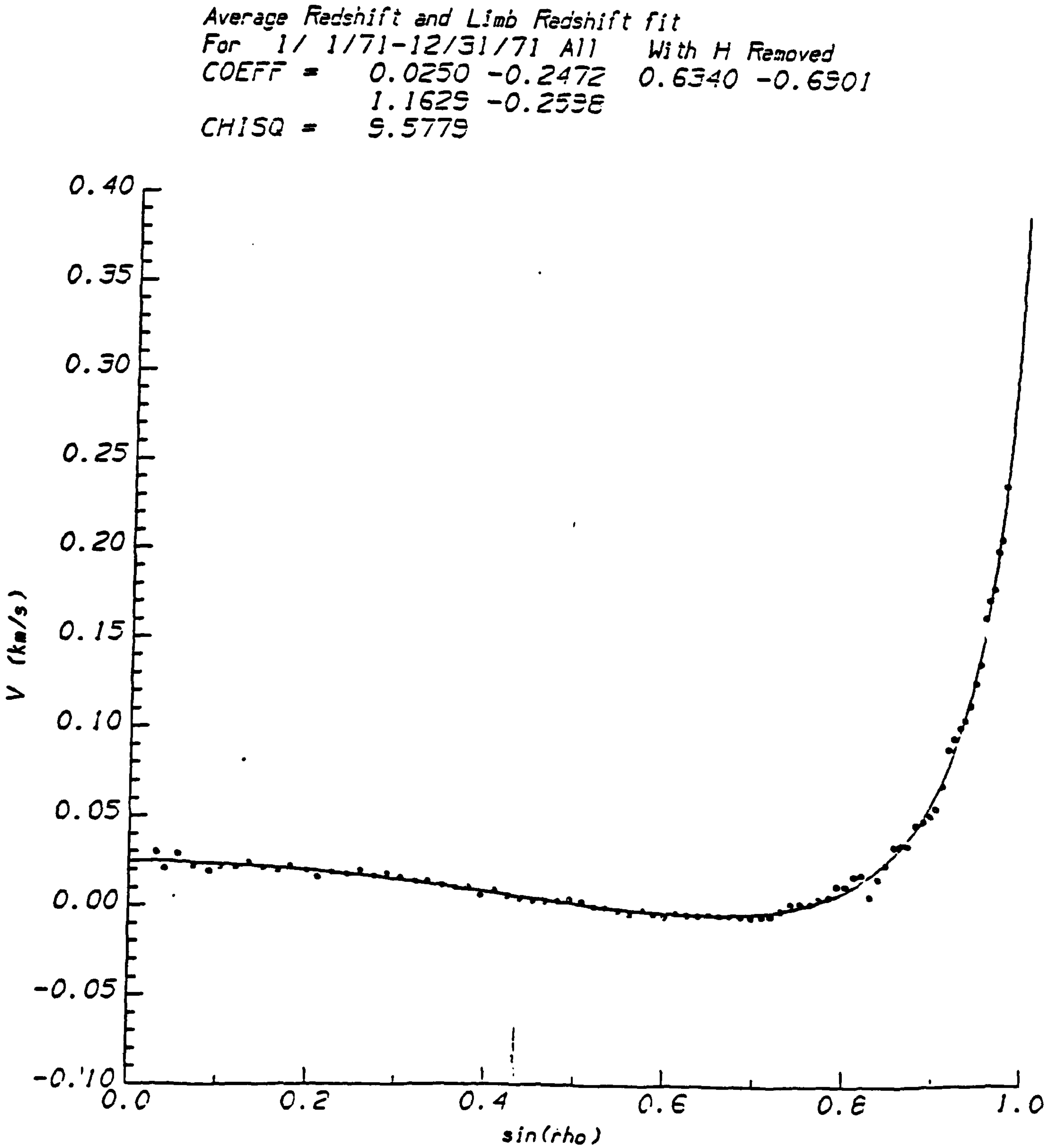
Labonte, B.J. and Howard, R. 1982, Solar Phys., 80, 361.

Rhodes et al, 1987, in preparation.

Snodgrass, H.B. 1983, Astrophys. J., 270, 288.

Snodgrass, H.B. 1985, Astrophys. J., 291, 339.

Snodgrass, H.B. and Howard, R. 1984, Astrophys. J., 284, 848.



Average Redshift and Limb Redshift fit
For 1/ 1/71-12/31/71 All With H Removed
COEFF = 0.0250 -0.2472 0.6340 -0.6901
1.1629 -0.2598
CHISQ = 9.5779
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
V (km/s)
0.0
0.2
0.4
0.6
0.8
1.0
sin(rho)

Figure 1

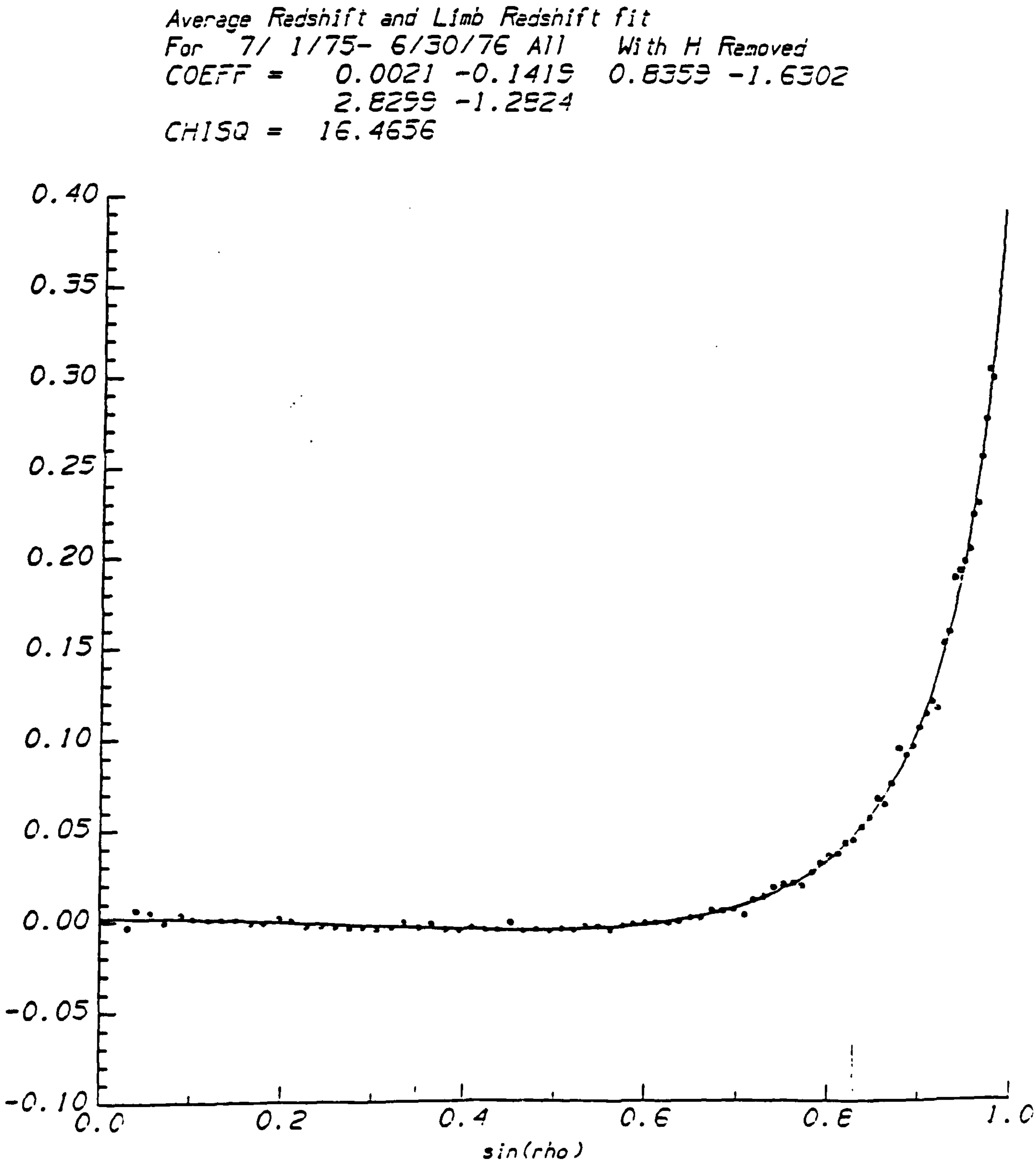

Average Redshift and Limb Redshift fit
For 7/ 1/75- 6/30/76 All With H Removed
COEFF = 0.0021 -0.1419 0.8359 -1.6302
2.8299 -1.2824
CHISQ = 16.4656
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
V (km/s)
0.0
0.2
0.4
0.6
0.8
1.0
sin(rho)

Figure 2

Average Redshift and Limb Redshift fit
For 1/ 1/86-12/31/86 All With H Removed
COEFF = 0.0311 -0.2531 0.2625 0.6829
-1.0923 0.8089
CHISQ = 3.9962

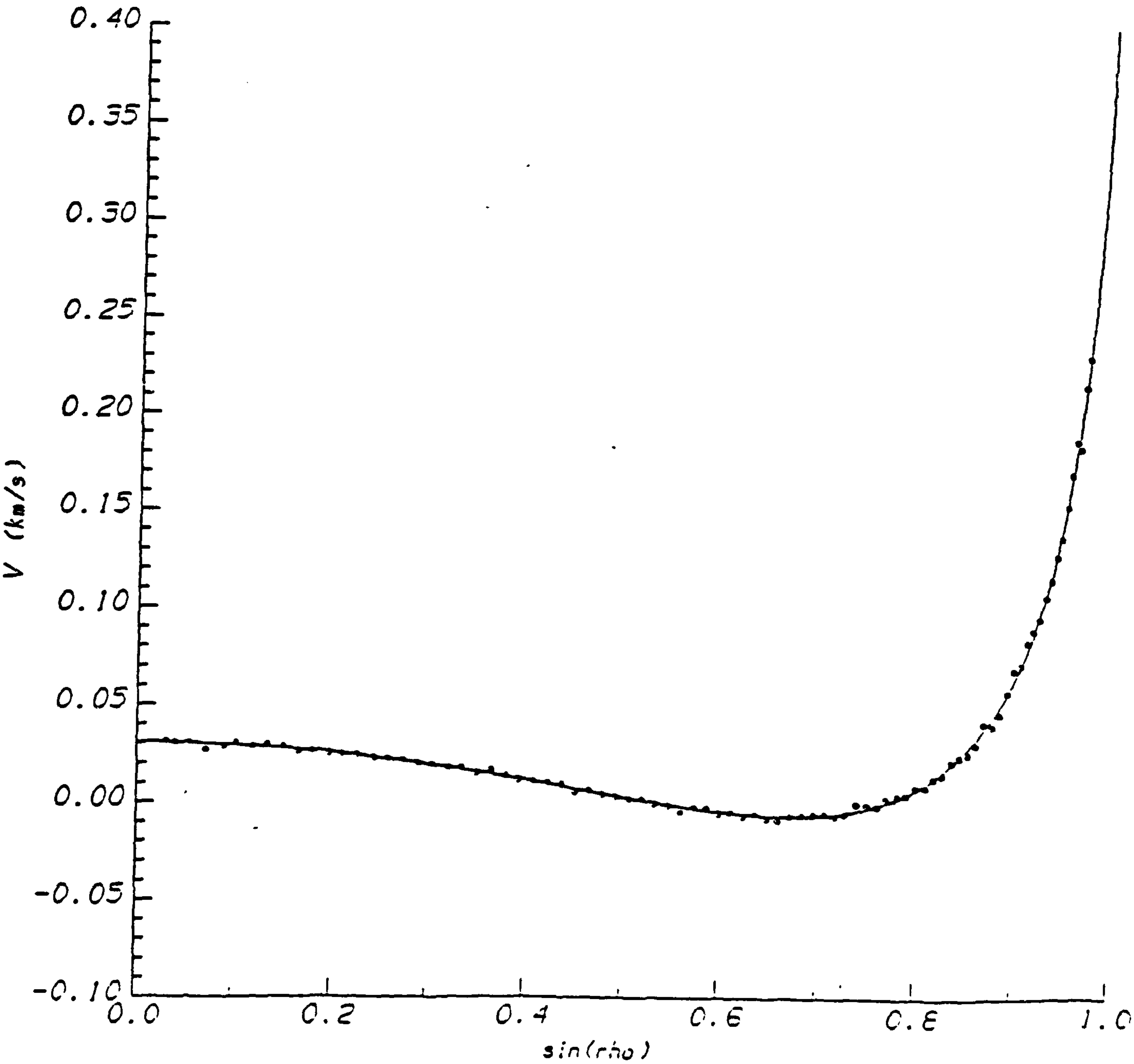
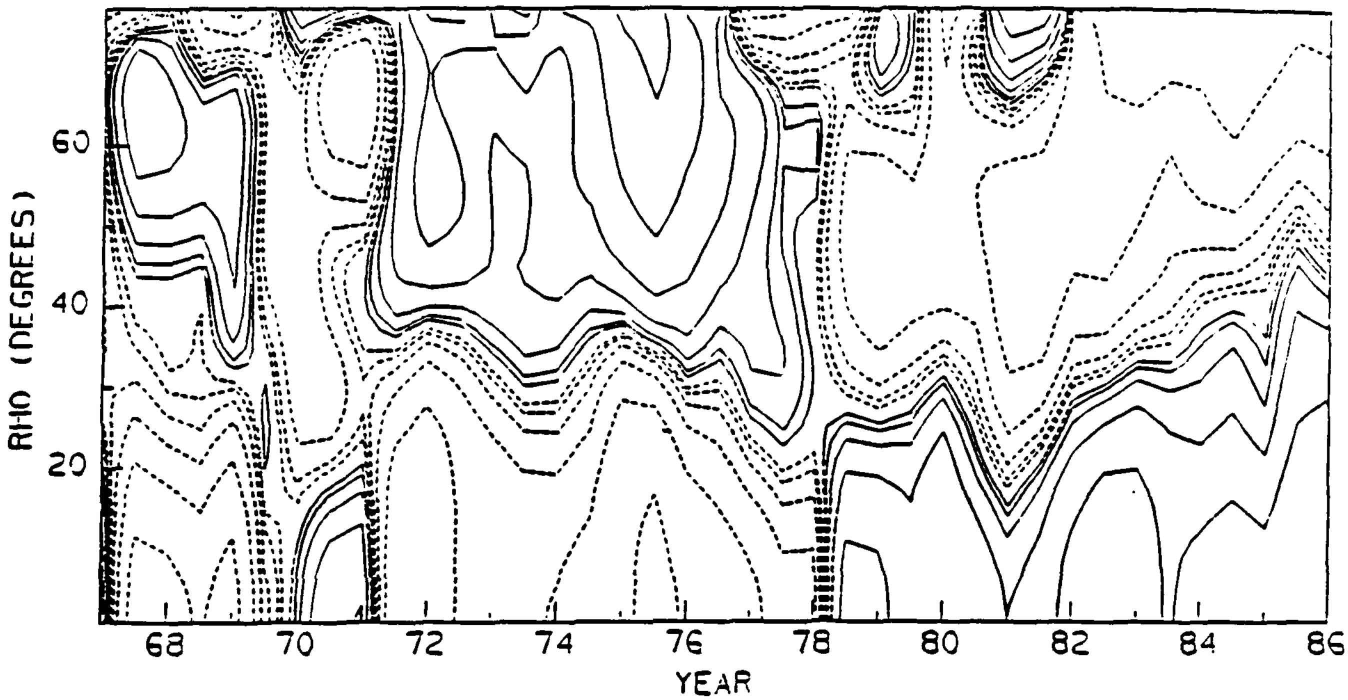


Figure 3

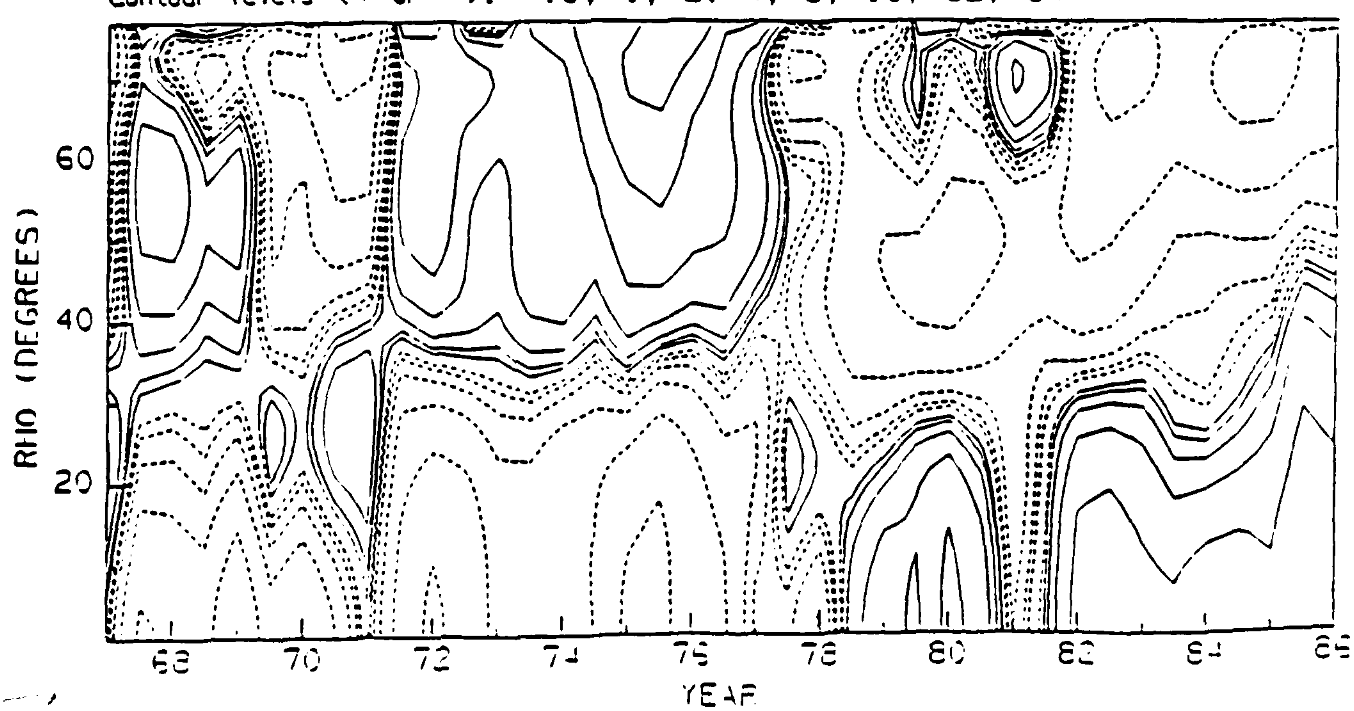
Limb red shift deviation
Solid lines are recede (positive)
Contour levels (+ or -): .5, 1, 2, 4, 8, 16, 32, 64

South



Limb red shift deviation
Solid lines are recede (positive)
Contour levels (+ or -): .5, 1, 2, 4, 8, 16, 32, 64

North



Solar Equatorial Rotation Rate Determined by C.M. Angle

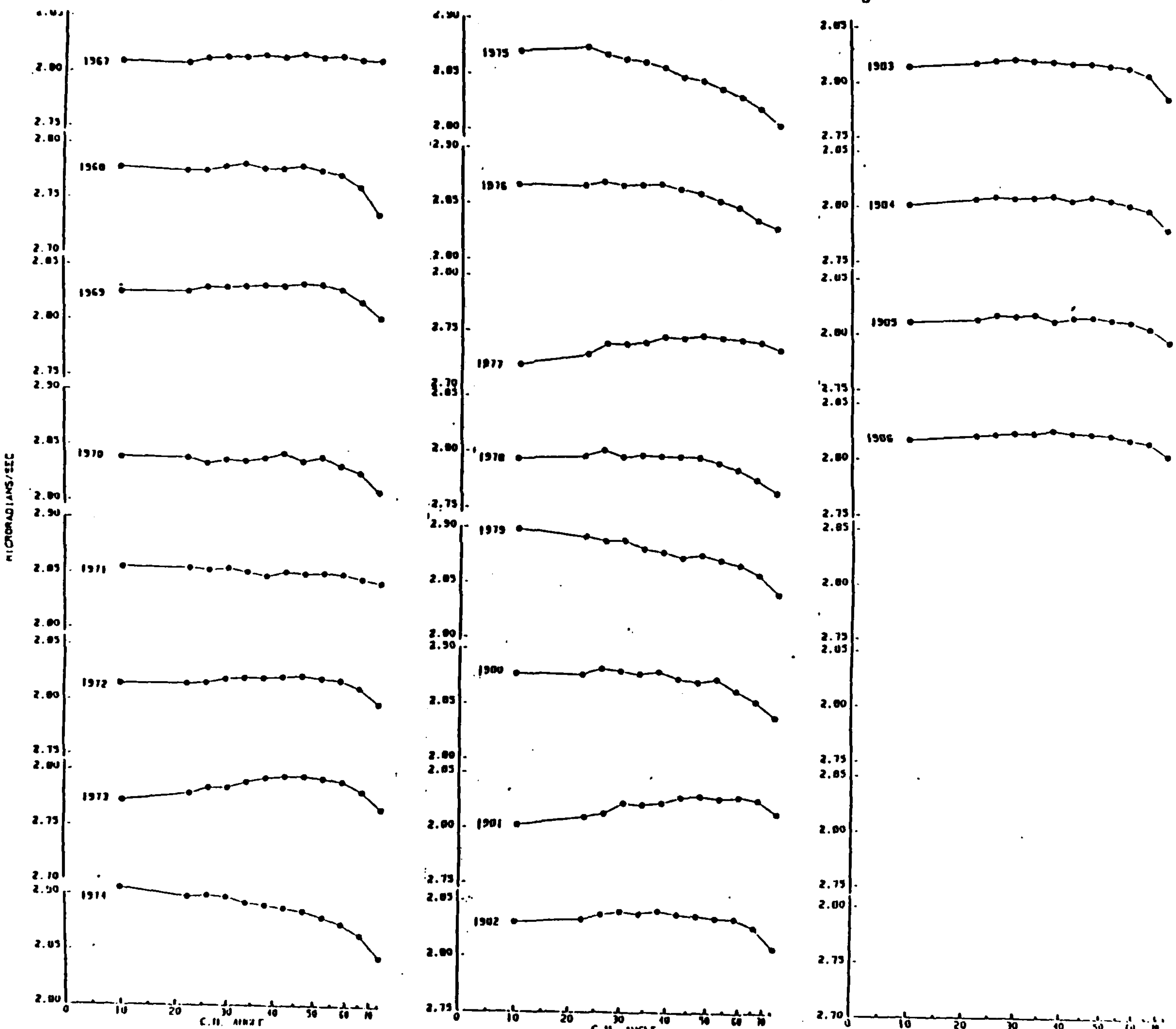


Figure 5

END

10-87

DTIC