Langley GRANT
IN-90-CR

390736
19P

FINAL REPORT
for
GRANT NO. ~~NAS~~ NAG-1-702

prepared for the

National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia 23665

by

Dr. Don Lind
Department of Physics
Utah State University
Logan, UT 84322

(NASA-CR-186713) [INSTELLAR GAS EXPERIMENT (IGE): TESTING INTERSTELLAR GAS PARTICLES TO PROVIDE INFORMATION ON THE PROCESSES OF NUCLEOSYNTHESIS IN THE BIG BANG STARS AND SUPERNOVA] Final Report (Utah State Univ.) N91-14097

Unclas
G3/90 0290736

NAG
Final Report for Grant No. ~~NAS~~-1-702

Background

The Interstellar Gas Experiment (IGE) is an experiment designed to collect particles of the interstellar gas--a wind of interstellar media particles moving in the vicinity of the solar system. These particles will be returned to earth where the isotopic ratios of the noble gases among these particles will be measured. These isotopic ratios should give important information on the processes of nucleosynthesis in the "Big Bang," stars and super-nova. If successful, this experiment will be the first opportunity to return a sample of matter from outside the solar system for direct analysis in the laboratory.

IGE was launched on the Long Duration Exposure Facility (LDEF) on April 6, 1984 at 8:59 a.m. EST from the Kennedy Space Center. LDEF was deployed from the Space Shuttle on April 7, 1984, at 12:26 p.m. EST in a 28.37 degree inclination orbit with an apogee of 259.0 nautical miles and a perigee of 255.2 nautical miles. The master timing circuit of IGE was activated at 14 hours 16 minutes 7 seconds (Universal time) on that same day. This timing circuit was pre-programmed to initiate particle collection ten days later.

IGE was designed and programmed to expose 7 sets of six copper-beryllium metallic collecting foils to the flux of neutral interstellar gas particles which penetrate the heliosphere to the vicinity of the earth's orbit. These particles are trapped in the collecting foils and will be returned to earth for mass-spectroscopic analysis when LDEF is recovered.

The seven sets of collecting foils are housed in seven collector structures, each pointing in a different direction. One collector pointed earthward in case LDEF flipped over after deployment. Two collectors pointed in the same direction on the celestial sphere, differing only in the angle relative to the residual atmosphere so that corrections can be made for this source of background contamination. This leaves five unique directions for the pointing of the collectors. As collectors pointing in these five directions were swept over the celestial sphere, interstellar gas particles were collected.

Of the six foils in each set, one collected only Space Shuttle thruster debris before LDEF deployment and had not been intended for primary data collection. The last foil in each set was lost for data collection when LDEF was not recovered on schedule. This left four collecting foils in each set available for data collection.

Before launch, IGE was programmed to expose the four collecting foils which pointed in each of the five directions (a total of 20 foils) in an optimum sequence in order to identify the collected interstellar gas particles and differentiate them from any background particles coming from the residual atmosphere or from precipitating magnetospheric particles. In order to optimize these exposures, an extensive model had to be developed of first, the seasonal changes in the angular distribution of the interstellar gas particles and second, the collecting geometry as the various collecting foils swept out different arcs across the celestial sphere and the approaching interstellar particle distribution. This model was contained in two large computer programs--called GFLUX and GAS--developed at the Johnson Space Center (JSC) when Dr. Don Lind was assigned there as an astronaut. When Dr. Lind joined the faculty at Utah State University, it was necessary to transfer these programs and the expertise to operate them to Utah State University in order to support the post-flight analysis of the IGE data. This transfer along with improvements of the computer programs and a parameter study preliminary to post-flight data analysis is the substance of the work performed under this grant.

interstellar gas (temperature, bulk velocity as the gas approaches the heliospheric boundry, the direction of approach, etc.) which are inputs to the GFLUX program and from them to generate the particle fluxes which we expected to collect. The values of these expected fluxes are the output of the GAS program. In this mode of operation, the programs were used to identify the most easily recognized pattern in the exposure sequences so that the seasonally changing interstellar gas particles could be recognized against the background particles which should not change seasonally. The optimum exposure sequences were then programmed into the IGE hardware before launch.

For the post-flight data analysis, these programs will be used in a different operational mode. It is not possible mathematically to take the measured collected fluxes and calculate "backwards" to more precisely define the original interstellar gas parameters. Therefore, if the measured fluxes differ somewhat from the predicted fluxes, we must make some new guesses for the input parameters and run the programs as we did pre-flight until we calculate fluxes which match the measured one. To facilitate this process, the final task under this grant was to run a parameter study by systematically varying the input parameters and building a matrix of the changes which these new inputs make in the calculated fluxes. With this matrix, we can identify which combination of small parameter adjustments will generate a set of calculated fluxes which will match the measured fluxes. Thus, from such analysis, we can more precisely specify the parameters which define the conditions of the actual interstellar gas.

Figure 2-6 and Tables 1-4 indicate the nature of this parameter study but include only a small portion of the data we have evaluated. Figure 2 shows the calculated fluxes that we predicted would be trapped by the IGE collectors in our preflight analysis. The four sets of five histograms represent the four exposure time periods and the five collectors pointing in five different directions. These data are the output of the preflight GAS program and the four exposure periods are the ones programmed into the IGE flight hardware. Also listed on Figure 2 are the parameters which describe the interstellar gas that constituted the input parameters to the GFLUX program.

Figures 3-6 each show the changes in the calculated fluxes when one input parameter is altered. Tables 1-4 show the same data in numerical form. In these figures, the preflight predictions are shown (i.e., the values of Figure 2) as well as the new calculated values. If the change increases the flux in a particular collector, the area between the two marked values on the histogram is cross-hatched. But, if the change is to decrease the flux, the difference between the two indicated values is an open bar.

It will be quickly noticed that any parameter change causes a complex adjustment to the twenty output flux values. The data matrix planned in the final task of this grant consists of the approximately fifty calculations such as Figure 3-6 as the input parameters are systematically varied. First, single parameters were varied, then combinations of parameters were varied. From this data matrix, we expect to be able to recognize (and then verify by calculation) what input parameters must be adjusted to account for any differences between predicted and measured IGE fluxes.

With the completion of this grant's work tasks, we have the necessary computer program support required to analyze the Interstellar Gas Experiment data when LDEF is recovered.

Figure Captions

Figure 1 is a typical comparison between the final preflight version of the GFLUX-GAS programs and the USU version of the same programs. The preflight version (labeled JSC 1983 run) used a very accurate but time-consuming orbit propagator subroutine. The USU version (labeled USU 1988 run) uses a much faster but less accurate orbit propagator. The difference between the two values of the collected particles for the indicated time interval is negligible. This demonstrates that the USU version of the programs is completely adequate for the IGE experiment post flight data analysis.

Figure 2 shows the predicted values for the collected particles from five collectors (pointing in the five indicated directions relative to LDEF) for four different exposure periods. These exposure periods were programmed into the IGE flight hardware. The time interval is from April 17, 1984 until February 9, 1985. In the final exposure period, the $\pm 70°$ collectors were exposed from DOY 1-40 whereas the $\pm 24°$ and $0°$ collectors were exposed from DOY 1-26. The variation in this pattern of collected fluxes will identify the interstellar gas particles as different from any background particles. The parameters descriptive of the interstellar gas used as input to these calculated values are listed.

Figure 3 shows the changes to the calculated fluxes when the input interstellar gas temperature is changed from the assumed value of 12000°K to 8000°K. This figure shows the changes in the fluxes relative to those shown in figure 2. If the change in the input parameter increases the calculated flux, the area in the histogram between the old and new value is cross-hatched. If the change decreases the calculated flux, the histogram shows an open bar. The vertical scale is the number of collected ^4He particles per cm^2 of foil.

Figure 4 is the same format as figure 3 and shows the change in the fluxes when the assumed interstellar gas temperature of 12000°K is changed to 16000°K.

Figure 5 is the same format as figure 3 and shows the change in the fluxes when the bulk velocity of the interstellar gas is changed from the assumed value of 24 km/sec to 34 km/sec.

Figure 6 is the same format as figure 3 and shows the change in the fluxes when the southerly declination of the direction of approach of the interstellar gas is changed form the assumed value of 17.5° to 2.5°.

Table Captions

Table 1 shows the numerical data for figure 3. The collected flux is given in the column marked "particles" in units of collected ^4He particles per cm^2 of foil. The change from the preflight predicted value is given in the column marked "delta." If the preflight prediction is greater than the changed value, the delta is positive (i.e., open bar is the figure).

Table 2 shows the numerical data for figure 4.

Table 3 shows the numerical data for figure 5.

Table 4 shows the numerical data for figure 6.

Figure 1

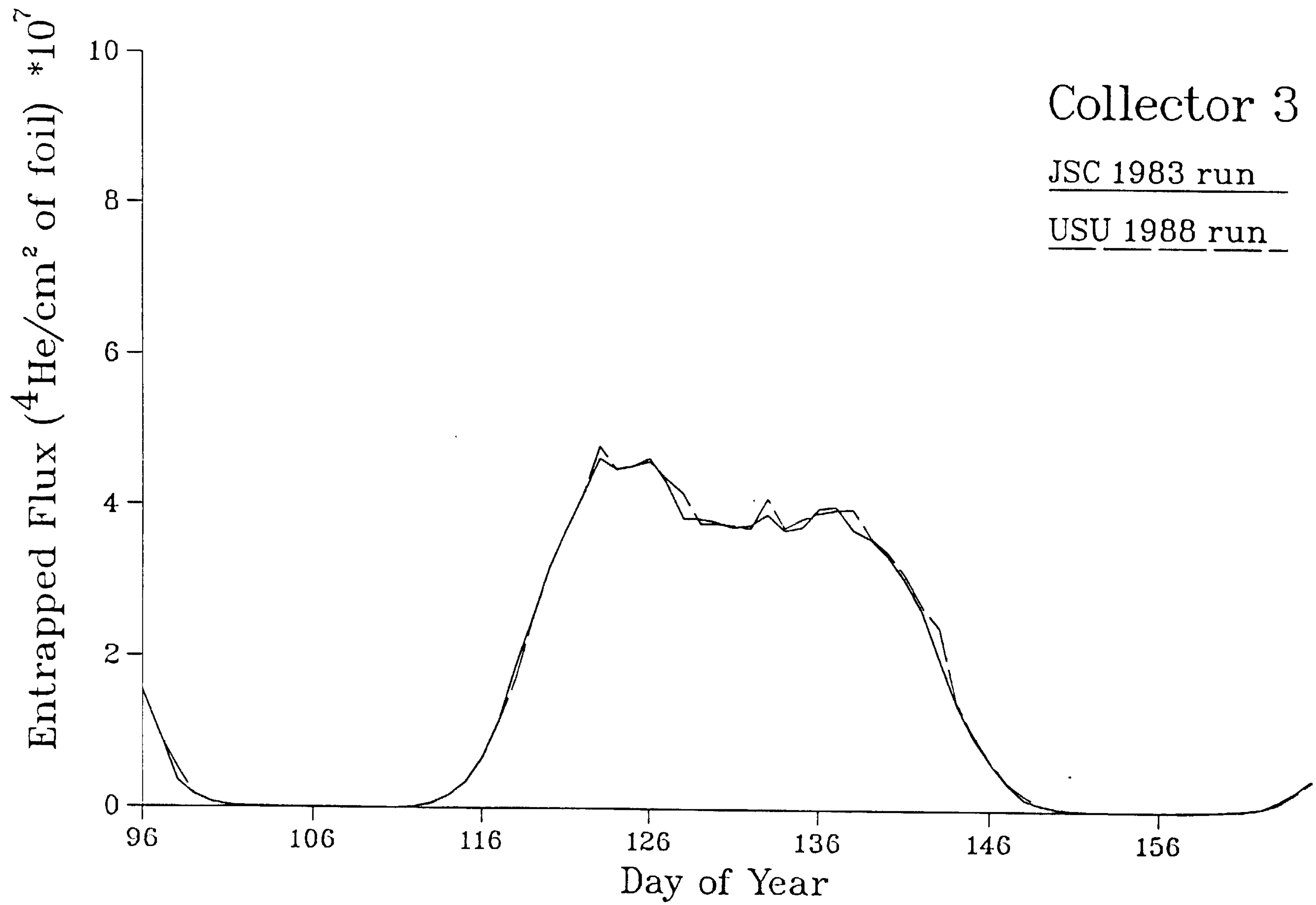
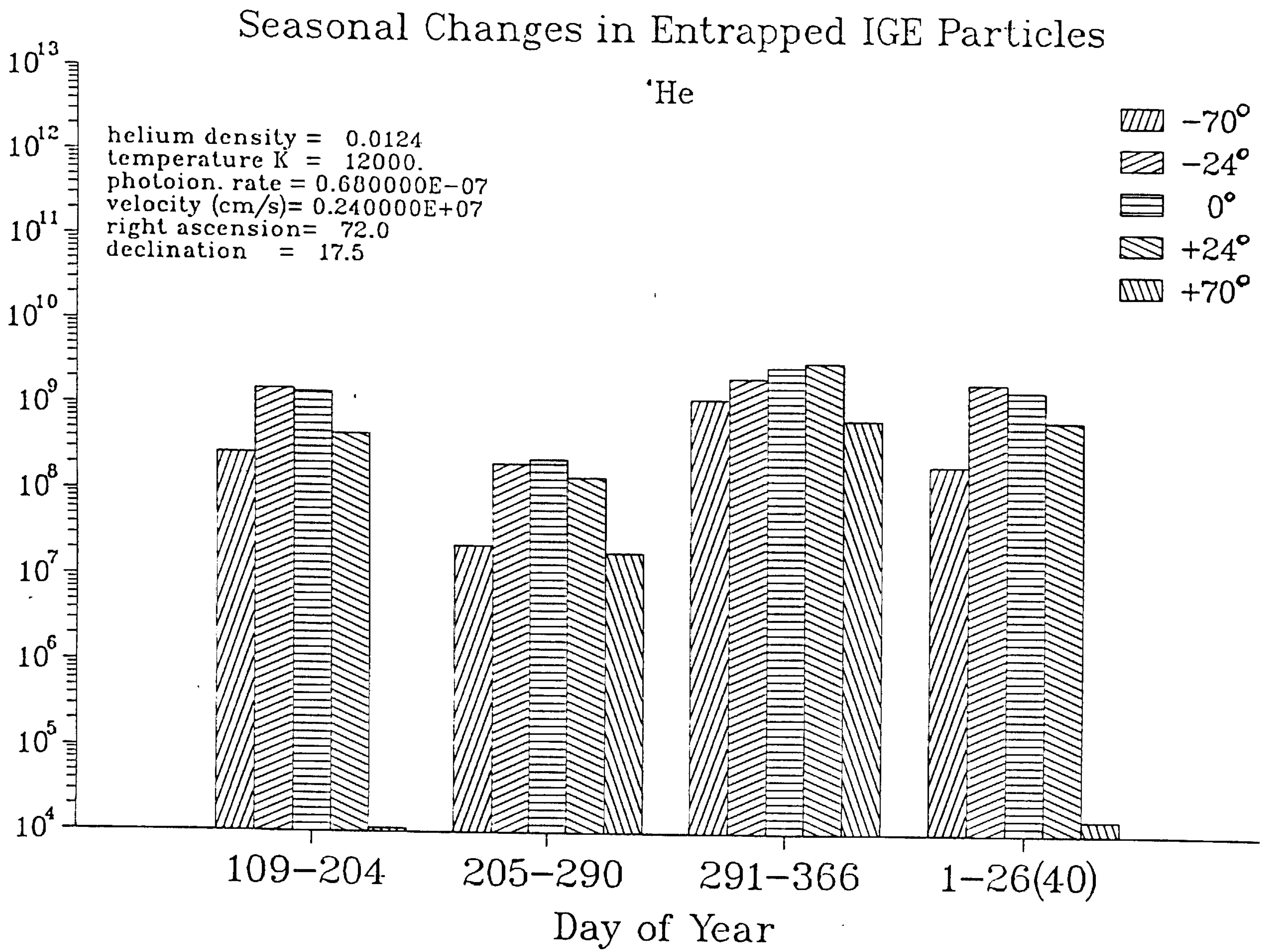

Collector 3
JSC 1983 run
USU 1988 run
Entrapped Flux (^{4}He/cm^2 of foil) *10^7
10
8
6
4
2
0
96
106
116
126
136
146
156
Day of Year

Figure 2



Seasonal Changes in Entrapped IGE Particles
'He
helium density = 0.0124
temperature K = 12000.
photoion. rate = 0.680000E-07
velocity (cm/s)= 0.240000E+07
right ascension= 72.0
declination = 17.5
-70°
-24°
0°
+24°
+70°
10^{13}
10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
109-204
205-290
291-366
1-26(40)
Day of Year

Figure 3

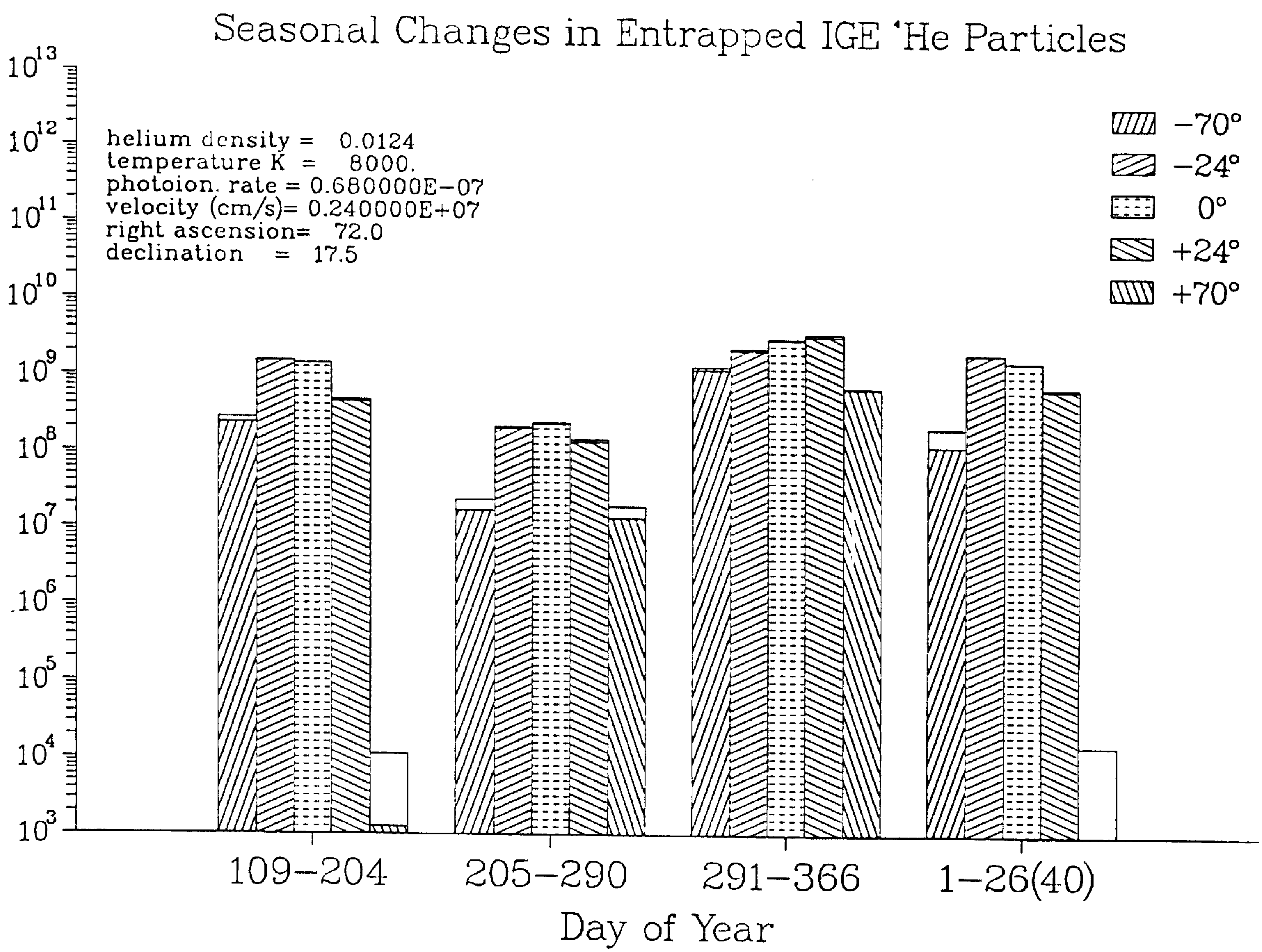
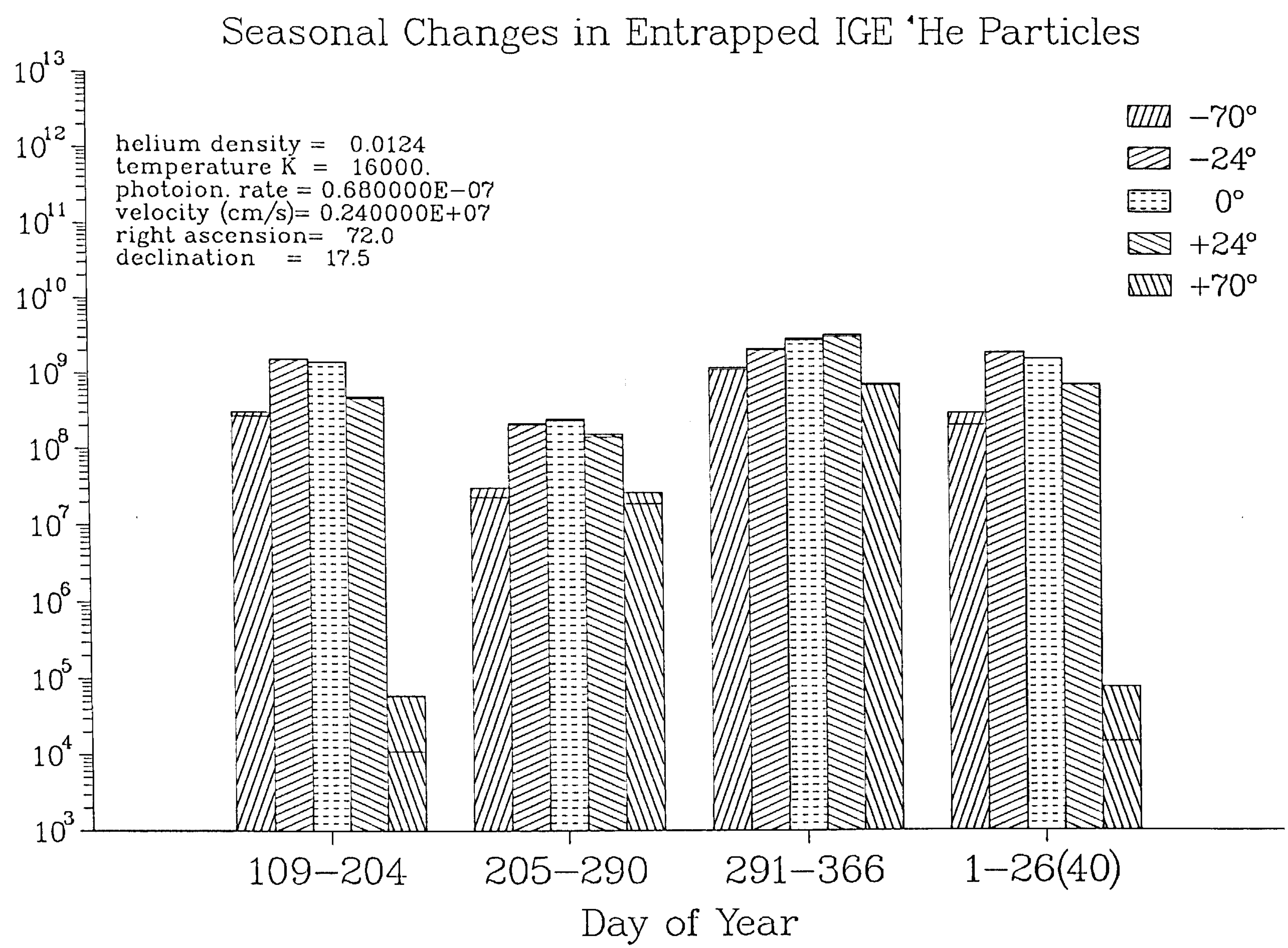
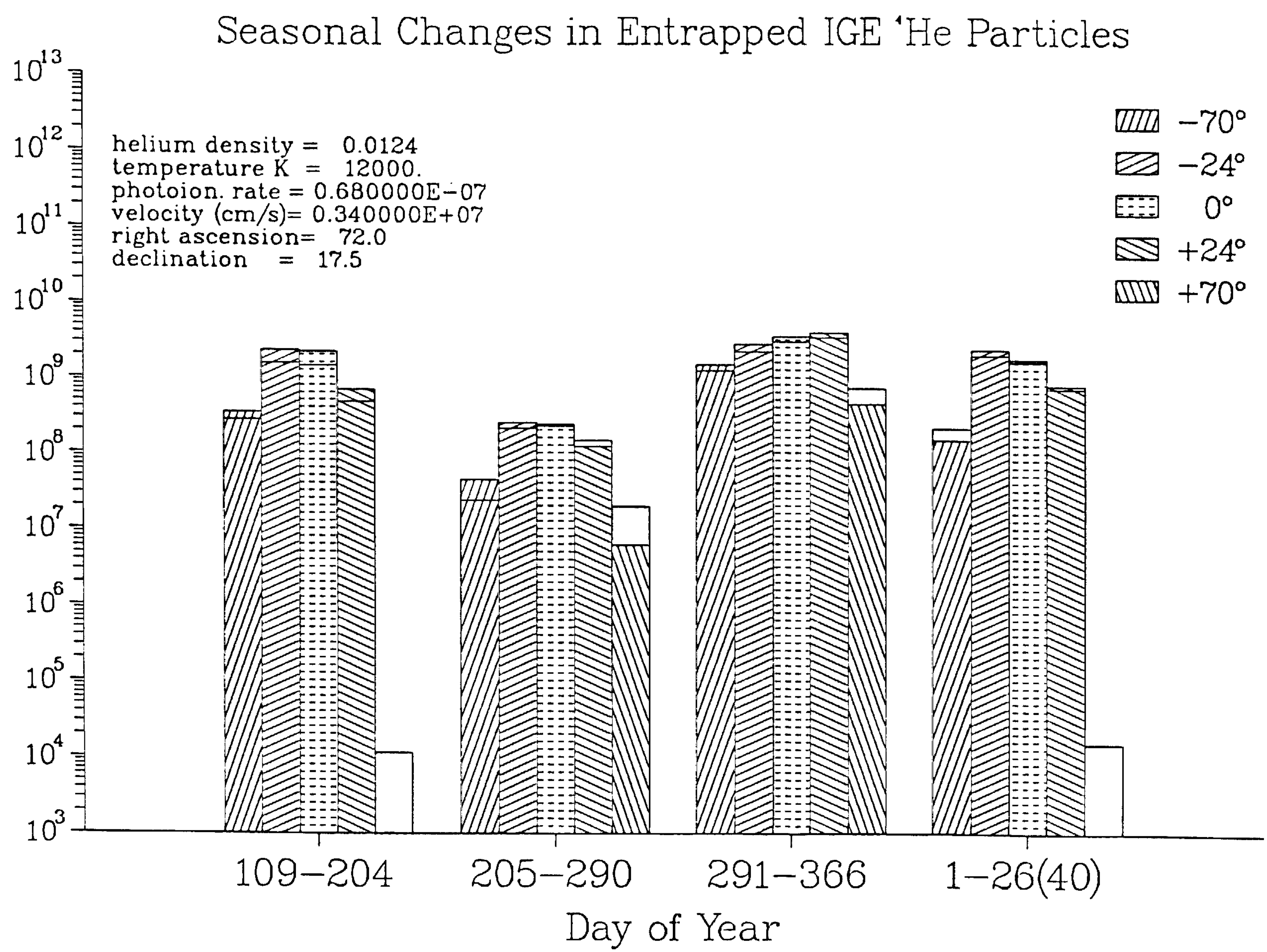

Seasonal Changes in Entrapped IGE 'He Particles
helium density = 0.0124
temperature K = 8000.
photoion. rate = 0.680000E−07
velocity (cm/s)= 0.240000E+07
right ascension= 72.0
declination = 17.5
−70°
−24°
0°
+24°
+70°
10^{13}
10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
109−204
205−290
291−366
1−26(40)
Day of Year

Figure 4



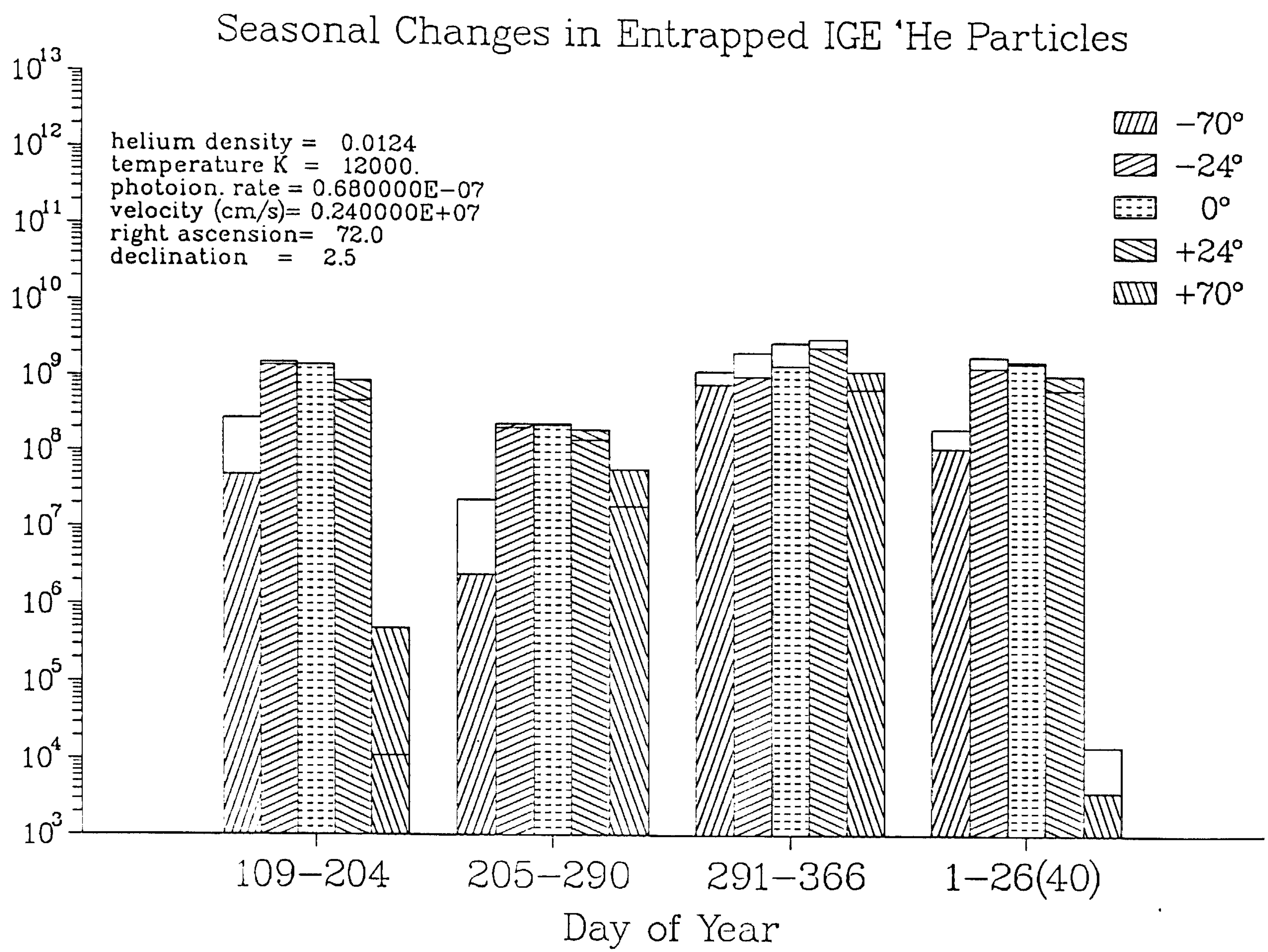
Seasonal Changes in Entrapped IGE ⁴He Particles
helium density = 0.0124
temperature K = 16000.
photoion. rate = 0.680000E−07
velocity (cm/s)= 0.240000E+07
right ascension= 72.0
declination = 17.5
−70°
−24°
0°
+24°
+70°
10^13
10^12
10^11
10^10
10^9
10^8
10^7
10^6
10^5
10^4
10^3
109−204
205−290
291−366
1−26(40)
Day of Year

Figure 5



Seasonal Changes in Entrapped IGE 'He Particles
helium density = 0.0124
temperature K = 12000.
photoion. rate = 0.680000E-07
velocity (cm/s)= 0.340000E+07
right ascension= 72.0
declination = 17.5
-70°
-24°
0°
+24°
+70°
10^{13}
10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
109-204
205-290
291-366
1-26(40)
Day of Year

Figure 6



Seasonal Changes in Entrapped IGE ⁴He Particles
helium density = 0.0124
temperature K = 12000.
photoion. rate = 0.680000E−07
velocity (cm/s)= 0.240000E+07
right ascension= 72.0
declination = 2.5
−70°
−24°
0°
+24°
+70°
10^13
10^12
10^11
10^10
10^9
10^8
10^7
10^6
10^5
10^4
10^3
109−204
205−290
291−366
1−26(40)
Day of Year

Table 1

helium density = 0.0124
temperature K = 8000.
photoion. rate = 0.680000E-07
velocity (cm/s)= 0.240000E+07
right ascension= 72.0
declination = 17.5

coll	season	particles	delta
-70'	109-204"	234799216.00	38808112.00
-24'	109-204"	1499246464.00	31425792.00
0'	109-204"	1408659584.00	7614848.00
+24'	109-204"	437988864.00	27257088.00
+70'	109-204"	1263.48	9826.92
-70'	205-290"	16954850.00	6414568.00
-24'	205-290"	201872192.00	7387520.00
0'	205-290"	226321264.00	10556896.00
+24'	205-290"	133819728.00	12778800.00
+70'	205-290"	13714341.00	5808479.00
-70'	291-366"	1323691520.00	-104668928.00
-24'	291-366"	2312583168.00	-140615936.00
0'	291-366"	3079029760.00	-133964544.00
+24'	291-366"	3631706112.00	-286186496.00
+70'	291-366"	685934208.00	19747264.00
-70'	1-26(40)	123238608.00	88386944.00
-24'	1-26(40)	2005625600.00	-46876160.00
0'	1-26(40)	1581142784.00	9839232.00
+24'	1-26(40)	686201792.00	22604736.00
+70'	1-26(40)	294.04	14739.53

Table 2

helium density = 0.0124
temperature K = 16000.
photoion. rate = 0.680000E-07
velocity (cm/s)= 0.240000E+07
right ascension= 72.0
declination = 17.5

coll	season	particles	delta
-70'	109-204"	310961600.00	-37354272.00
-24'	109-204"	1562653056.00	-31980800.00
0'	109-204"	1426767744.00	-10493312.00
+24'	109-204"	491613952.00	-26368000.00
+70'	109-204"	60525.89	-49435.49
-70'	205-290"	31257944.00	-7888526.00
-24'	205-290"	216988528.00	-7728816.00
0'	205-290"	247474016.00	-10595856.00
+24'	205-290"	160565488.00	-13966960.00
+70'	205-290"	27464968.00	-7942148.00
-70'	291-366"	1141509888.00	77512704.00
-24'	291-366"	2069533056.00	102434176.00
0'	291-366"	2818105600.00	126959616.00
+24'	291-366"	3139395584.00	206124032.00
+70'	291-366"	729533312.00	-23851840.00
-70'	1-26(40)	302209824.00	-90584272.00
-24'	1-26(40)	1917468544.00	41280896.00
0'	1-26(40)	1594654208.00	-3672192.00
+24'	1-26(40)	728902656.00	-20096128.00
+70'	1-26(40)	78253.67	-63220.10

Table 3

helium density = 0.0124
temperature K = 12000.
photoion. rate = 0.680000E-07
velocity (cm/s)= 0.340000E+07
right ascension= 72.0
declination = 17.5

coll	season	particles	delta
-70'	109-204"	342721632.00	-69114304.00
-24'	109-204"	2284088064.00	-753415808.00
0'	109-204"	2163553792.00	-747279360.00
+24'	109-204"	677651648.00	-212405696.00
+70'	109-204"	179.13	10911.27
-70'	205-290"	44051308.00	-20681890.00
-24'	205-290"	250835328.00	-41575616.00
0'	205-290"	222607040.00	14271120.00
+24'	205-290"	120562864.00	26035664.00
+70'	205-290"	6195944.00	13326876.00
-70'	291-366"	1467509504.00	-248486912.00
-24'	291-366"	2737562624.00	-565595392.00
0'	291-366"	3423780352.00	-478715136.00
+24'	291-366"	3865365248.00	-519845632.00
+70'	291-366"	440009248.00	265672224.00
-70'	1-26(40)	148942832.00	62682720.00
-24'	1-26(40)	2311151104.00	-352401664.00
0'	1-26(40)	1730218624.00	-139236608.00
+24'	1-26(40)	775378048.00	-66571520.00
+70'	1-26(40)	0.00	15033.57

Table 4

helium density = 0.0124
temperature K = 12000.
photoion. rate = 0.680000E-07
velocity (cm/s)= 0.240000E+07
right ascension= 72.0
declination = 2.5

coll	season	particles	delta
-70'	109-204"	49191872.00	224415456.00
-24'	109-204"	1399179648.00	131492608.00
0'	109-204"	1421465088.00	-5190656.00
+24'	109-204"	871046720.00	-405800768.00
+70'	109-204"	499003.38	-487912.97
-70'	205-290"	2471087.50	20898330.00
-24'	205-290"	238285168.00	-29025456.00
0'	205-290"	225979712.00	10898448.00
+24'	205-290"	197776464.00	-51177936.00
+70'	205-290"	59643356.00	-40120536.00
-70'	291-366"	807639168.00	411383424.00
-24'	291-366"	1032701632.00	1139265664.00
0'	291-366"	1467211136.00	1477654080.00
+24'	291-366"	2556994304.00	788525312.00
+70'	291-366"	1236368896.00	-530687424.00
-70'	1-26(40)	118253728.00	93371824.00
-24'	1-26(40)	1395642752.00	563106688.00
0'	1-26(40)	1703723904.00	-112741888.00
+24'	1-26(40)	1098092544.00	-389286016.00
+70'	1-26(40)	3767.10	11266.47