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14. Abstract/Notes

This paper reports a 30-150 KeV X-ray intensification at balloon altitudes in low L-values of the South Atlantic Magnetic Anomaly (SAMA), occurred on April 14, 1981 in association with a strong geomagnetic storm. Such intensification, observed for the first time, implies an enhanced energetic electron precipitation in association to the storm with a consequent enhancement in the ionization of the middle atmosphere.

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X-RAY INTENSIFICATION AT BALLOON ALTITUDES OF THE SOUTH ATLANTIC MAGNETIC ANOMALY

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ABSTRACT

This paper reports a 30-150 keV X-ray intensification at balloon altitudes in low L-values of the South Atlantic Magnetic Anomaly (SAMA), occurred on April 14, 1981 in association with a strong geomagnetic storm. Such intensification, observed for the first time, implies an enhanced energetic electron precipitation in association to the storm with a consequent enhancement in the ionization of the middle atmosphere.

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After the initial work by Ghielmetti et al in 1964[1] and before 1981 there has been little further effort (none with published results) to measure bremsstrahlung X-rays due to energetic electron precipitation at balloon altitudes of the SAMA. One of the difficulties encountered in the measurements of those X-rays is that the magnitude of their fluxes is barely recongnizable above the background of energetic atmospheric photons (due to cosmic rays and to the diffuse X-ray component) during periods without strong geomagnetic activity. In the case of auroral X-rays, their fluxes may be much larger than the background even for moderately active periods[2]. With respect to this difficulty, the measurements published by Ghielmetti et al[1], that referred to a period with a low level of geomagnetic activity, did not elucidate the contribution of the diffuse component to the total flux[3]. Furthermore, their measurements could have been contaminated by precipitating electrons from an artificial population, injected to the inner Van Allen belt by high altitude nuclear detonations carried out mainly around 1962[4].

Thus, with the goal of trying to measure X-rays at balloon altitudes of the SAMA due to energetic electron precipitation from the natural population of the inner Van Allen belt, and considering that this radiation would be most easily noticeable during time intervals with strong geomagnetic activity, two balloon flights were performed in 1981 from São José dos Campos (geographic coordinates $23^{O}12'S$, $45^{O}51'W$). One of the flights occurred on April 14 during a time interval with strong geomagnetic activity ($|Dst| \sim 296$) and the other one occurred on December 18 during a geomagnetically calm period ($|Dst| \leq 35$).

The balloon flights of April 14 and December 18, 1981 had local time intervals of 02:48-07:04 and 03:10-08:43, respectively, and ceiling altitudes of $4 g/cm^2$ and $5.5 g/cm^2$, respectively. Both flights headed toward the west direction, staying at approximately the same latitude of São José dos Campos (geomagnetic latitude $\sim 11^{O}S$ and $L \sim 1.13$) and covering a longitudinal interval of $\leq 4^{O}$. The detector for both flights consisted of a Harshaw NaI(Tl) crystal with dimensions 3" x 1/2", covering an 30-150 keV energy range[5].

Figure 1 shows the X-ray flux measured during both flights for the whole energy interval. Figure 1 also shows the Dst index for the flights (the flight times are indicated by hatched intervals). One observes that the flight of April 14, 1981 occurred during the recovery phase of a strong geomagnetic storm, whereas the flight of December 18, 1981 occurred during a time interval with weak geomagnetic activity.

Assuming that the background X-ray flux at the atmosphere of São José dos Campos remained unchanged and insensitivite to geomagnetic activity[6], the difference obtained for the fluxes is claimed to be related to the intensification of energetic particle precipitation at the SAMA during the magnetically disturbed flight (April) with respect to the undisturbed one (December).

In order to calculate the X-ray flux due to electron precipitation at the SAMA it is necessary to determine the atmospheric and diffuse components that constitute the background X-ray flux. The atmospheric component was determined assuming a power law-depth dependence and the diffuse one using a Monte Carlo method to compute the X-ray propagation in the atmosphere[7]. Figure 2 shows the results of this calculation for the X-ray fluxes due to electron precipitation at the SAMA as well as to the diffuse component. In this figure one can observe that the X-ray flux due to electron precipitation measured in April 14, 1981 is of the same order of magnitude of that due to the diffuse component. On the other hand, for the flight of December 18, 1981 one can only talk of an upper limit for any X-ray flux due to electron precipitation that could have been measured then.

Considering that the X-ray measurements published by Ghielmetti et al.[1] could have been mainly related to energetic electron precipitation from an artificial population of the inner radiation belt, the results presented in Figure 2 could be regarded as the first evidence of energetic electron precipitation at the SAMA from the natural population of the inner radiation belt as measured in X-rays at balloon altitudes.

Furthermore, using the X-ray flux due to electron precipitation for the flight of April 14 one can infer the related information on the precipitating electrons, since this type of information does not almost exist in the literature[8]. Figure 3 shows the X-ray flux due to electron precipitation for the event of April 14, 1981. Also shown is the best fit to this flux, obtained from a parent electron spectrum according to the model given by Seltzer[9]. The corresponding differential electron spectrum above ~100 keV is $(0.8 \pm 0.1) \exp(-T/(200 \pm 20))$ electrons.$cm^{-2}.s^{-1}.keV^{-1}.sr^{-1}$, where T is the energy of the electron in keV.

An estimate of the atmospheric ionization profile due to the precipitating electron flux, following the work of Berger et al.[10], is given in Figure 4 together with those due to the known sources[11]. This figure also shows the ionization profile related to precipitating electrons at the SAMA as obtained by Vampola and Gorney[8] for L-values between 1.1 and 2.0 (a large region) and for magnetically quiet times. The profile for April 14, 1981 leads to an enhancement of the middle atmospheric ionization by a factor as high as 100 above the normal ionization values, due to solar radiation and cosmic rays, and centered at an atmospheric altitude of ~ 60km. Ionization of this sort has been claimed to give rise to a middle atmospheric conductivity gradient that seems to influence the atmospheric fair-weather electric field as observed at balloon altitudes[12].

Some evidences about the intensification of energetic electron precipitation at the SAMA, during magnetically disturbed periods, also exist at higher L-values[13,14] or at lower energies[15] than those referred in this paper. However, more information is still necessary in order to determine the physical mechanisms[7] responsible for such an intensification.

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FIGURE CAPTIONS

Figure 1 - X-ray fluxes between 30 and 150 keV measured on April 14 and December 18, 1981. The Dst index for those events are also shown.

Figure 2 - X-ray fluxes between 30 and 150 keV due to electron precipitation at the SAMA for the events of April 14 and December 18, 1981. The diffuse component is also shown.

Figure 3 - X-ray spectrum due to electron precipitation for the event of April 14, 1981. The curve is a best fit to the data and corresponds to 4.8 exp (-T/200) electrons.$cm^{-2}.s^{-1}.keV^{-1}$ downward.

Figure 4 - Atmospheric ionization profiles at the SAMA including the profile for the event of April 14, 1981.

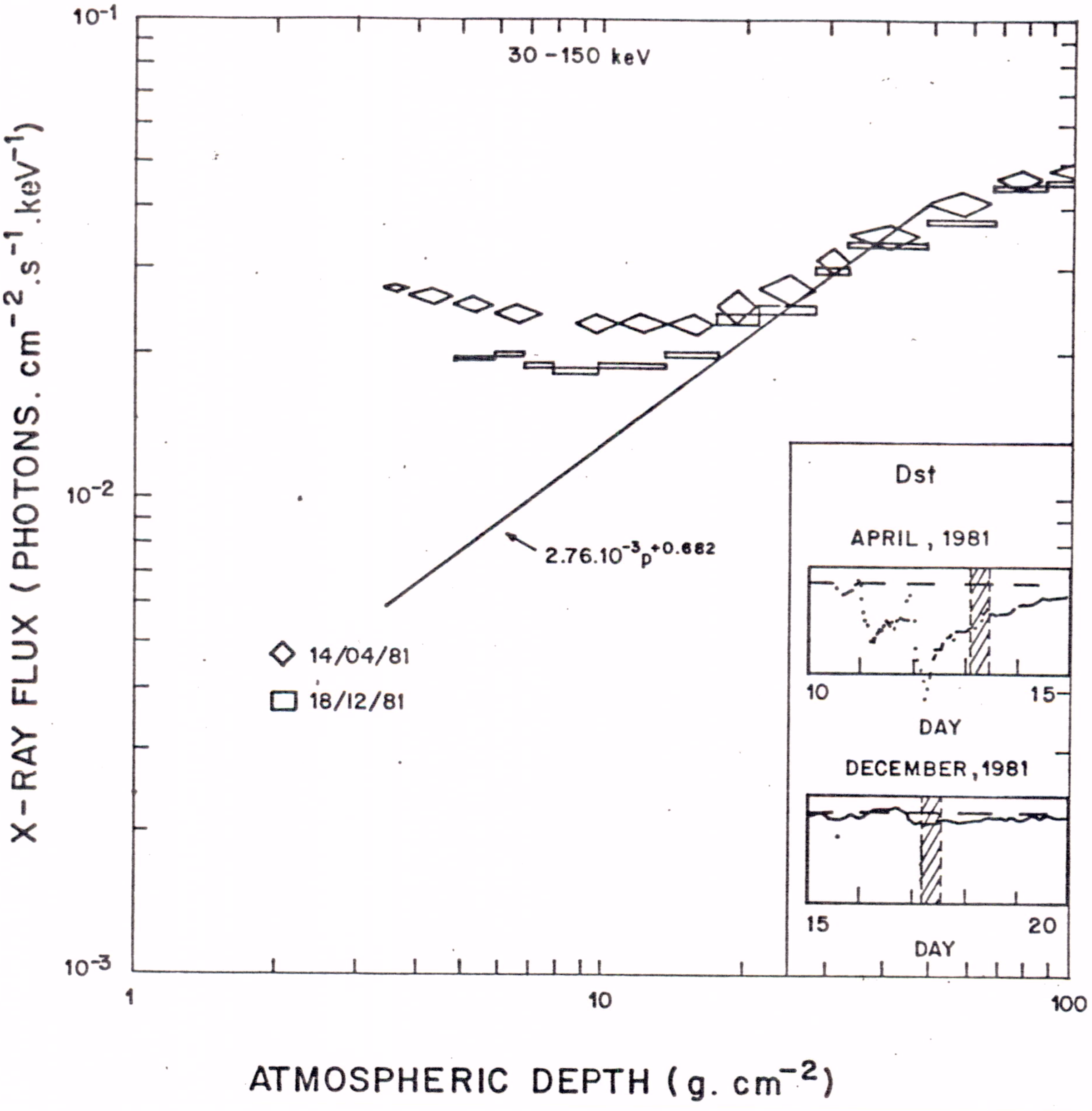
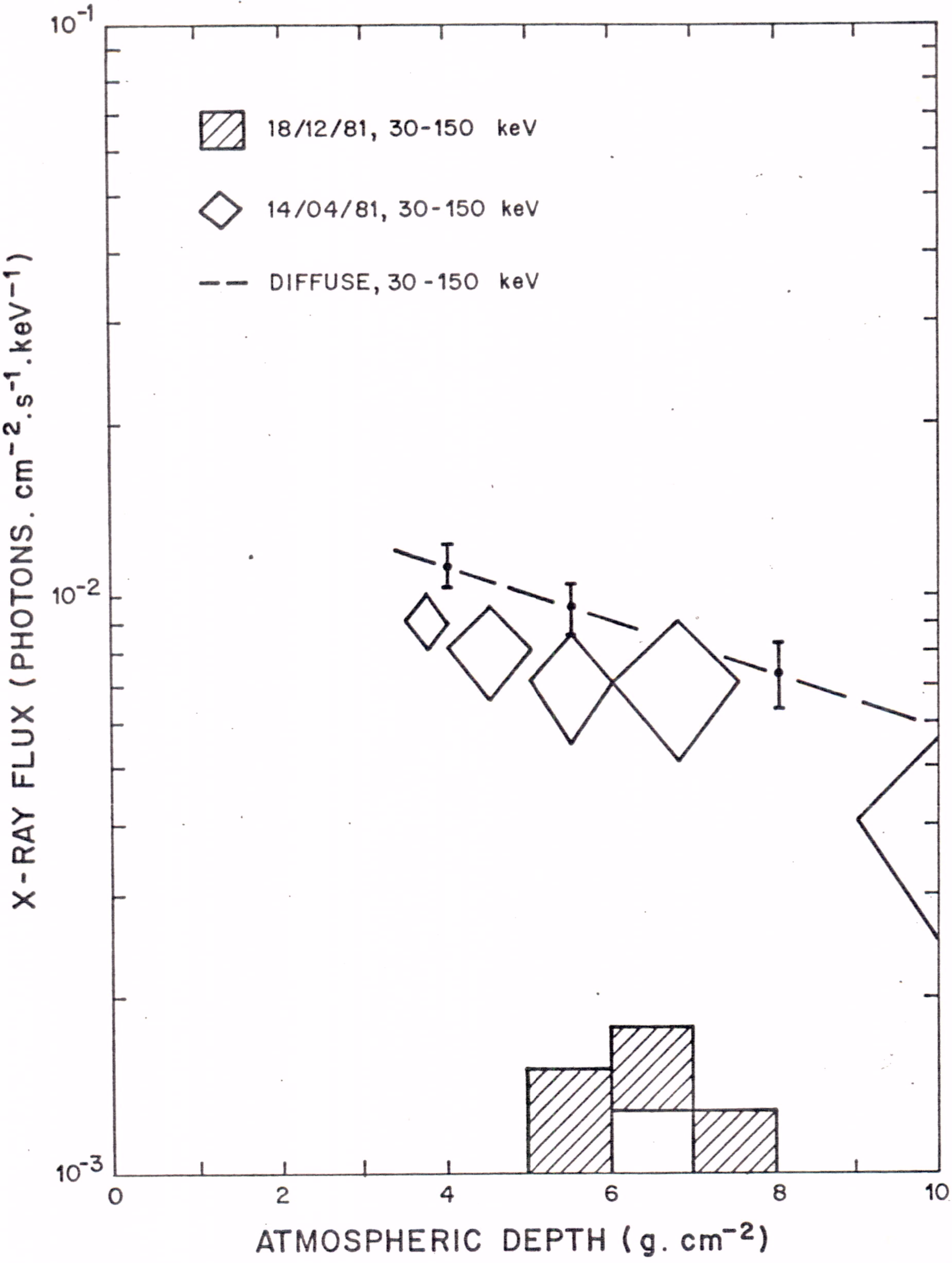

30 - 150 keV
X-RAY FLUX (PHOTONS. cm^{-2}.s^{-1}.keV^{-1})
10^{-1}
10^{-2}
10^{-3}
1
10
100
ATMOSPHERIC DEPTH (g. cm^{-2})
$2.76.10^{-3}p^{+0.682}$
◇ 14/04/81
□ 18/12/81
Dst
APRIL , 1981
10
15
DAY
DECEMBER , 1981
15
20
DAY

Fig. 1



18/12/81, 30-150 keV
14/04/81, 30-150 keV
DIFFUSE, 30-150 keV
X-RAY FLUX (PHOTONS. cm⁻².s⁻¹.keV⁻¹)
ATMOSPHERIC DEPTH (g. cm⁻²)

Fig. 2

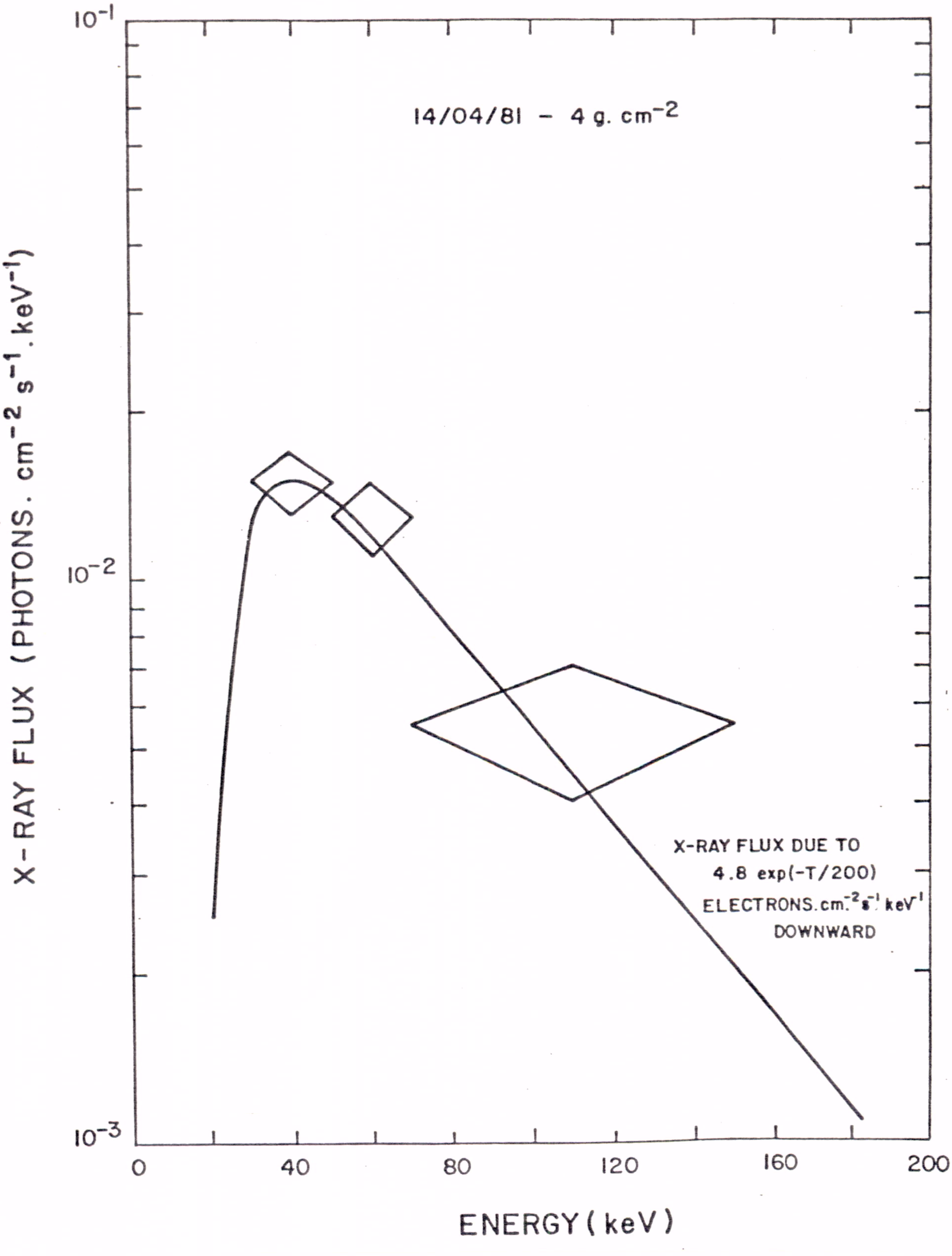

14/04/81 - 4 g. cm^{-2}
X-RAY FLUX (PHOTONS. cm^{-2} s^{-1}. keV^{-1})
10^{-1}
10^{-2}
10^{-3}
0
40
80
120
160
200
ENERGY (keV)
X-RAY FLUX DUE TO
4.8 exp(-T/200)
ELECTRONS.cm^{-2}s^{-1} keV^{-1}
DOWNWARD

Fig. 3

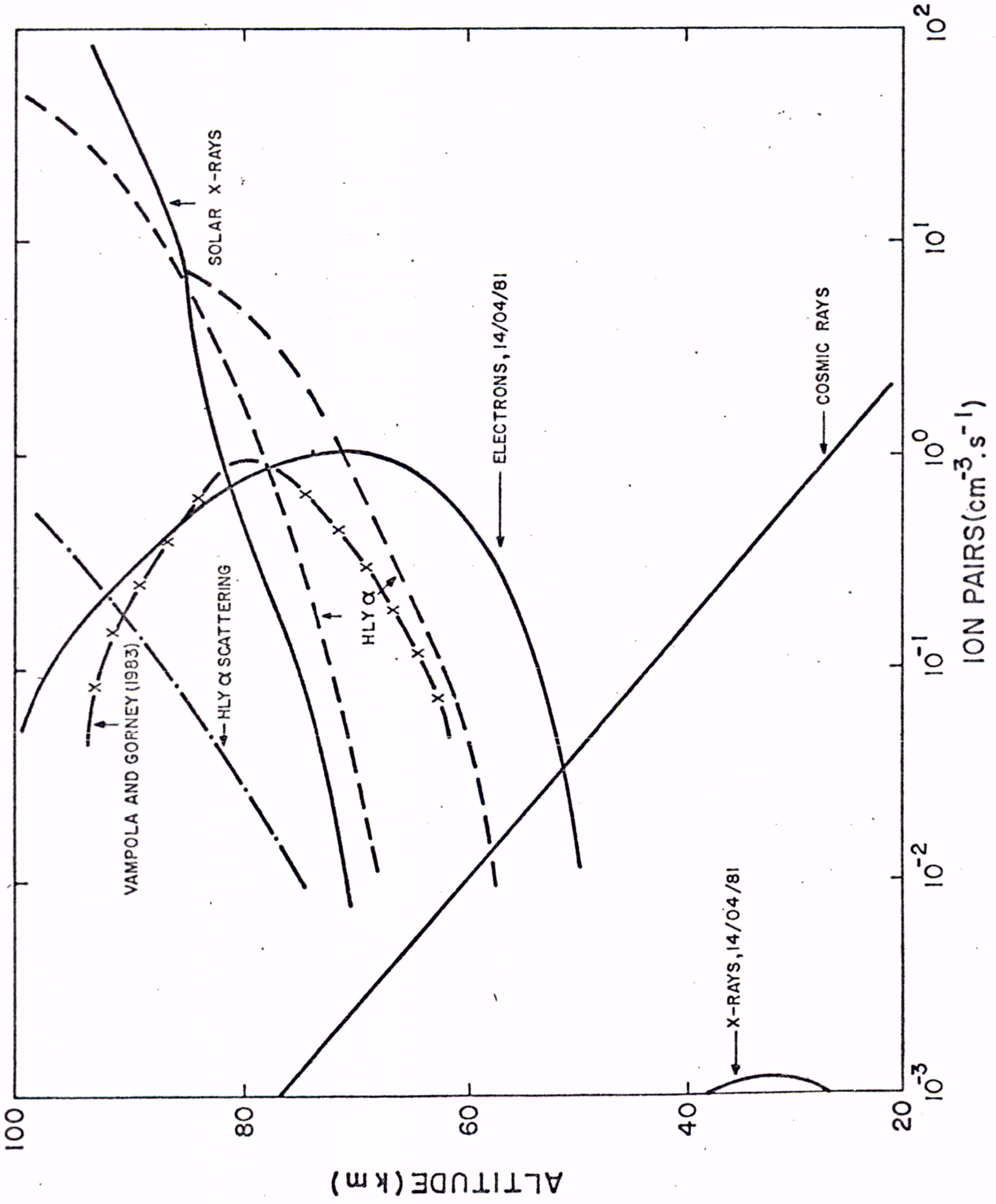

SOLAR X-RAYS
ELECTRONS, 14/04/81
COSMIC RAYS
HLY α
HLY α SCATTERING
VAMPOLA AND GORNEY (1983)
X-RAYS, 14/04/81
ION PAIRS(cm^{-3}.s^{-1})
ALTITUDE (km)
100
80
60
40
20
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}

Fig. 4