ROCKET STUDIES OF THE X-RAY FLUX IN THE HIGH LATITUDE MESOSPHERE AND STRATOSPHERE

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OUTLINE OF TALK

- Observation Methods
- Theory
- Thick Target Bremsstrahlung
- Radiation Transport
- Microbursts
- Wave Induced Particle Precipitation

INTRODUCTION

- Accelerated charged particles radiate EM radiation
- Energetic charged particles should radiate when stopping in matter
- Intensity is proportional to the square of the acceleration
- Thus $I \propto Z^2 z^4 e^6 / M^2$
- Total bremsstrahlung intensity varies as the *square of the atomic number of the target*
- Intensity varies inversely as the *square of the mass of the incident particle*
- Only electrons produce significant emissions.

OBSERVATION METHODS

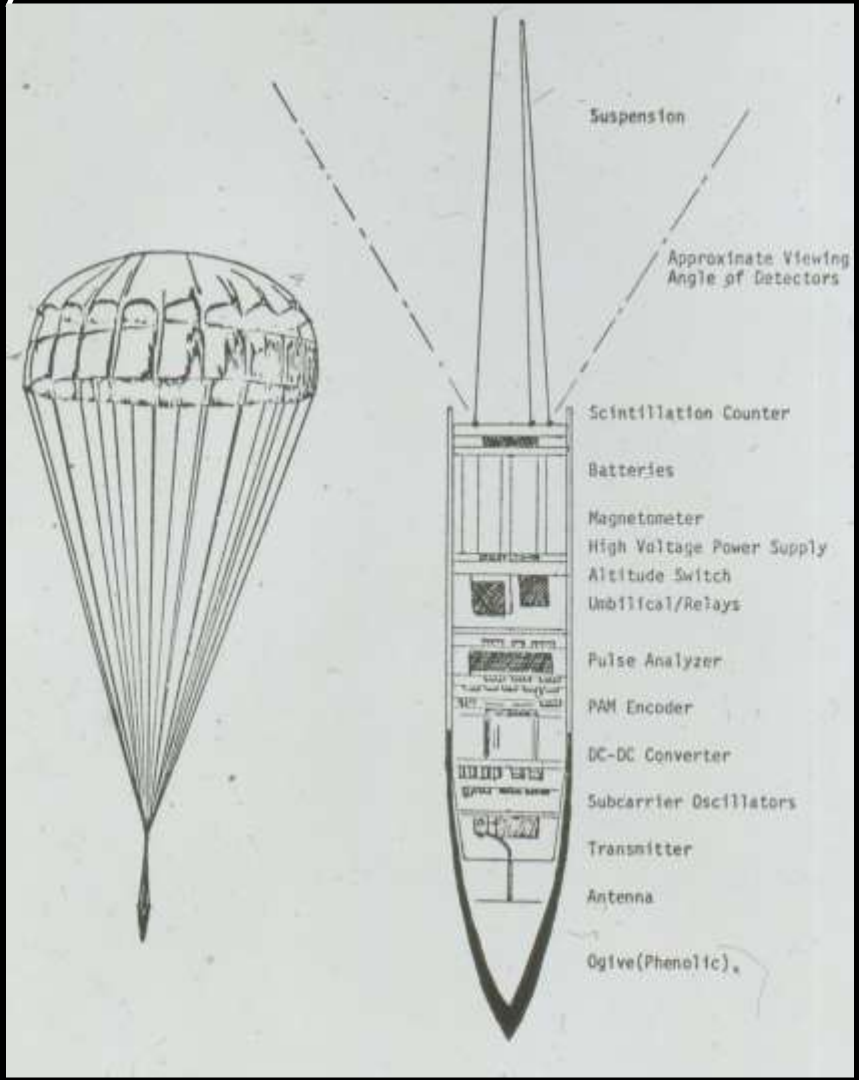
- Energy ranges
  - Historical 5-250 keV
  - Maxis, Minis, BARREL 1-10 MeV
- Vehicles
  - Stratospheric Balloons (32-35 km)
  - Parachuted Sounding Rockets
  - Ballistic Sounding Rockets
  - Satellites
- Detectors
  - NaI(Th) Scintillation Counters
  - Multi-wire gas proportional counters

Parachuted Rockets

THE INDEX PAYLOAD

INDEX

Payload Sketch



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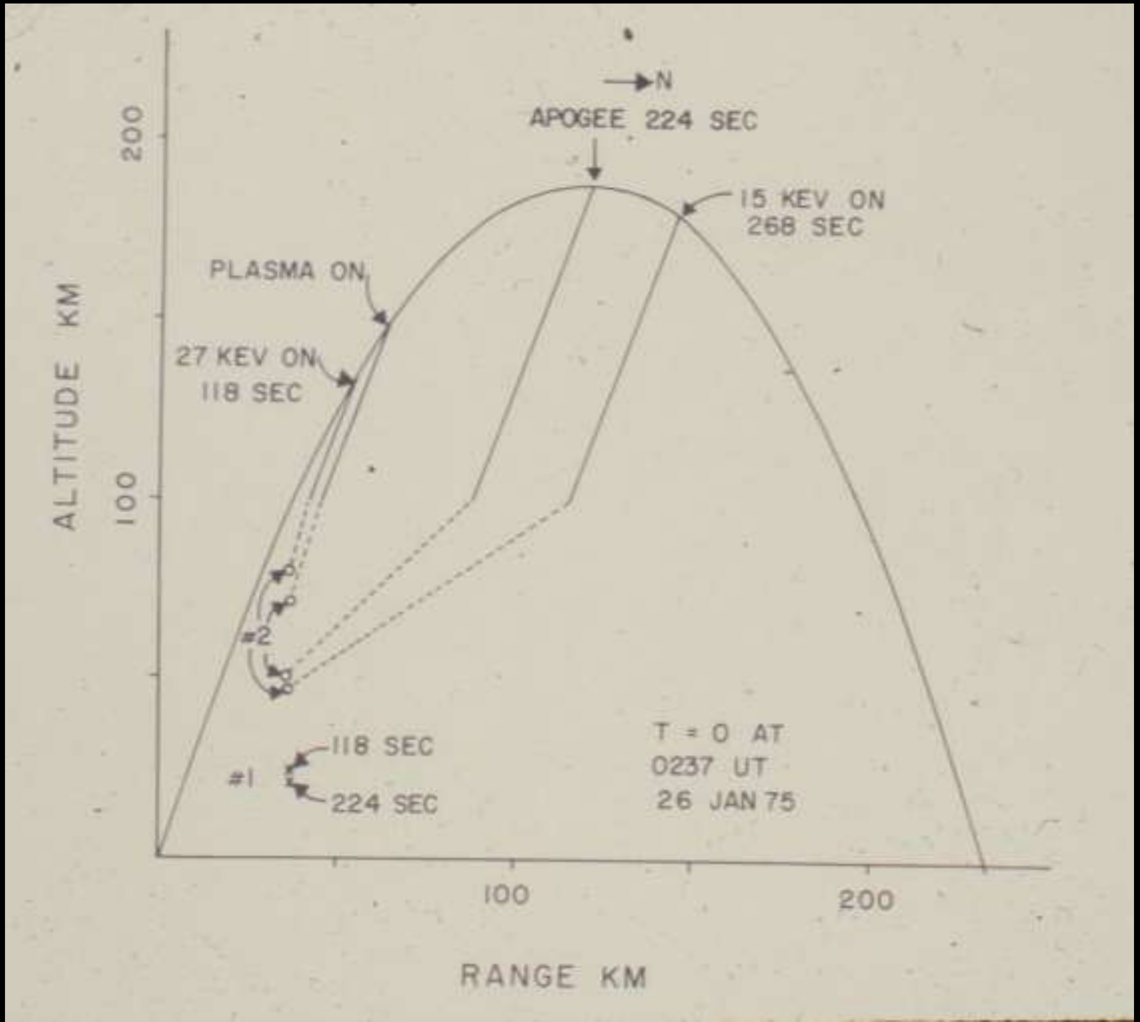
INDEX IN FLIGHT

INDEX, WSNMR, 1974

ARAKS, Kergulen, 1975



INDEX DATA

ARAKS

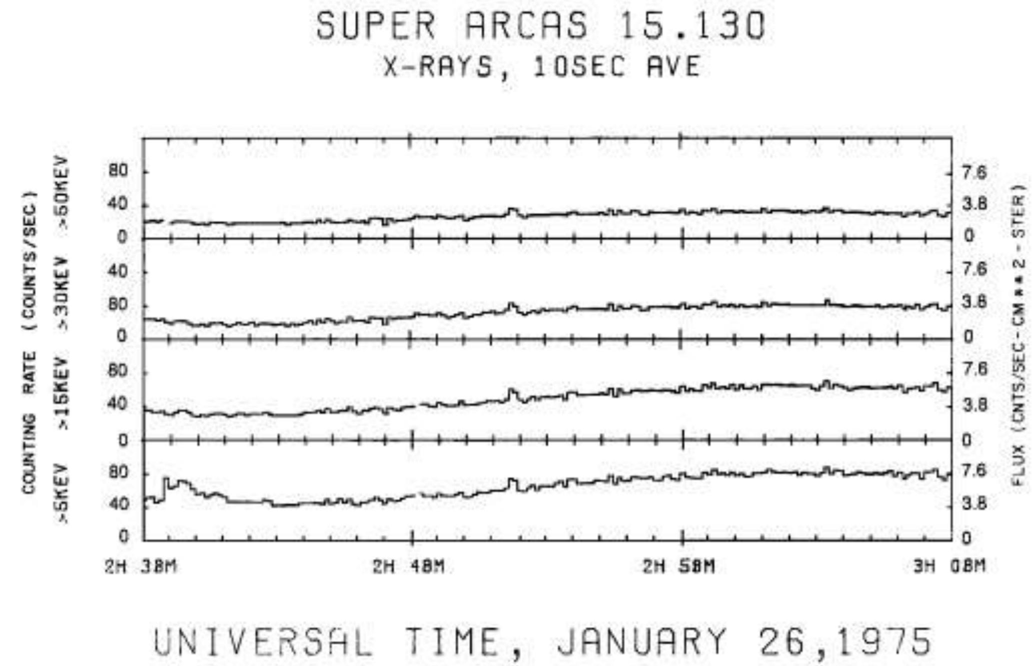
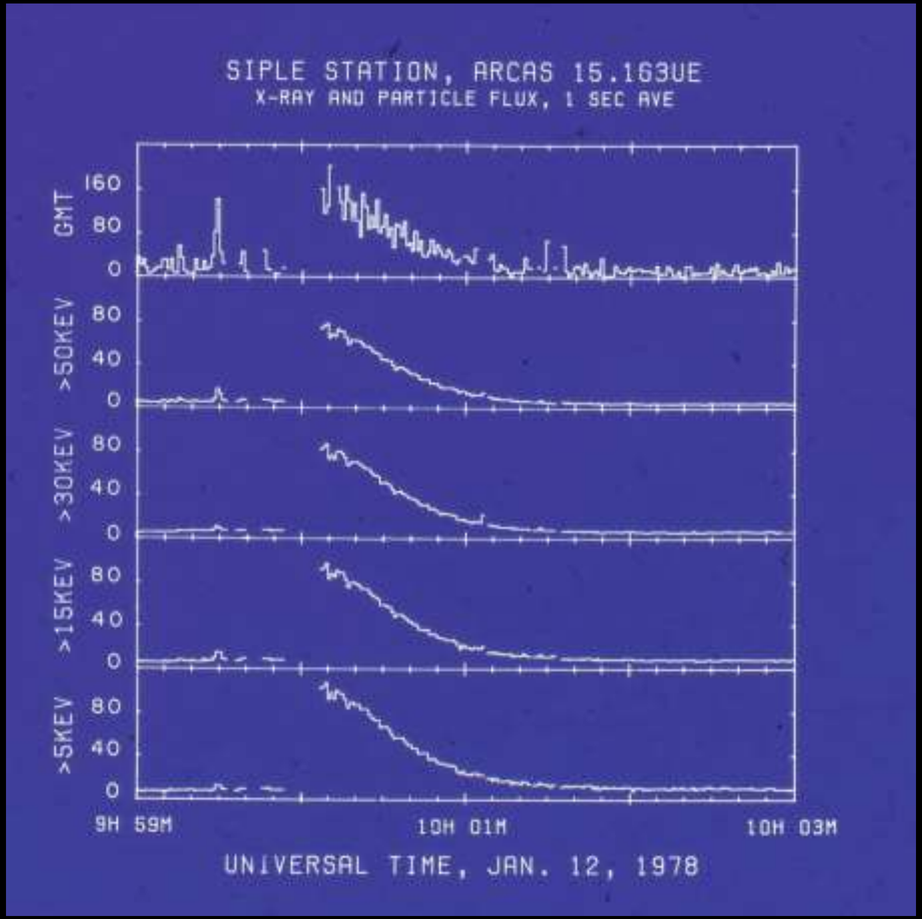


Fig. 1. Ten second averages of the X ray fluxes in photons/s as measured by 15.130 UE in four integral energy channels, >5, >15, >30, and >60 keV. Data are plotted as a function of UT beginning at launch and continuing to the end of recording. The geometric factor of all of the UH detectors used at Kerguelen was 10.5 cm² sr.

Siple



THEORY

- Averaged over All Collisions, QM and Classical Cross Sections Are Same Order
- At auroral energies, emissions are isotropic.
- Emission spectrum cuts off at energy of incoming electrons
- Fundamental theory done for monoenergetic electrons, thin targets

$$\sigma_{rad} \sim \frac{Z^2}{137}\left(\frac{e^2}{m_0c^2}\right)^2$$

$$\sigma_0 = \frac{1}{137}\left(\frac{e^2}{m_0c^2}\right)^2 = 0.580 \text{ millibarn/nucleus}$$

$$d\sigma_{rad} = \sigma_0 BZ^2 \frac{T + m_0c^2}{T}\frac{d(h\nu)}{h\nu}$$

at 60 keV, $B \sim 5$

THICK TARGET BREMSSTRAHLUNG

- Usual Case in Laboratory and Astrophysical Situations
- Computed as a Superposition of Thin Target Curves
- Spectral Distribution
- Total Bremsstrahlung Energy

$$dI = const\ Z(\nu_{\max} - \nu)\,d\nu$$

$$I = kZE^2$$

incoming electron flux

$$\frac{dN(E)}{dE} = N_0 e^{-E/E_0}$$

X-ray spectrum will be

$$\frac{dN(E)}{dE} = 2kZN_0 \frac{E_0^2 e^{-E/E_0}}{E_0}$$

$$Z = 7.22$$

estimate $2kZ = 5.8\times10^{-6}$ to 1.6×10^{-5}

RADIATION TRANSPORT

- Evaluating *k* from Thick Target Bremsstrahlung [*Vij et al.*, 1975, 1980]
- Validating Transport Codes [*Bering et al.*, 1980]
- Solving the Inverse Problem [*Benbrook et al.*, 1983; *Gorney et al*. 1986]

EVALUATING *K*

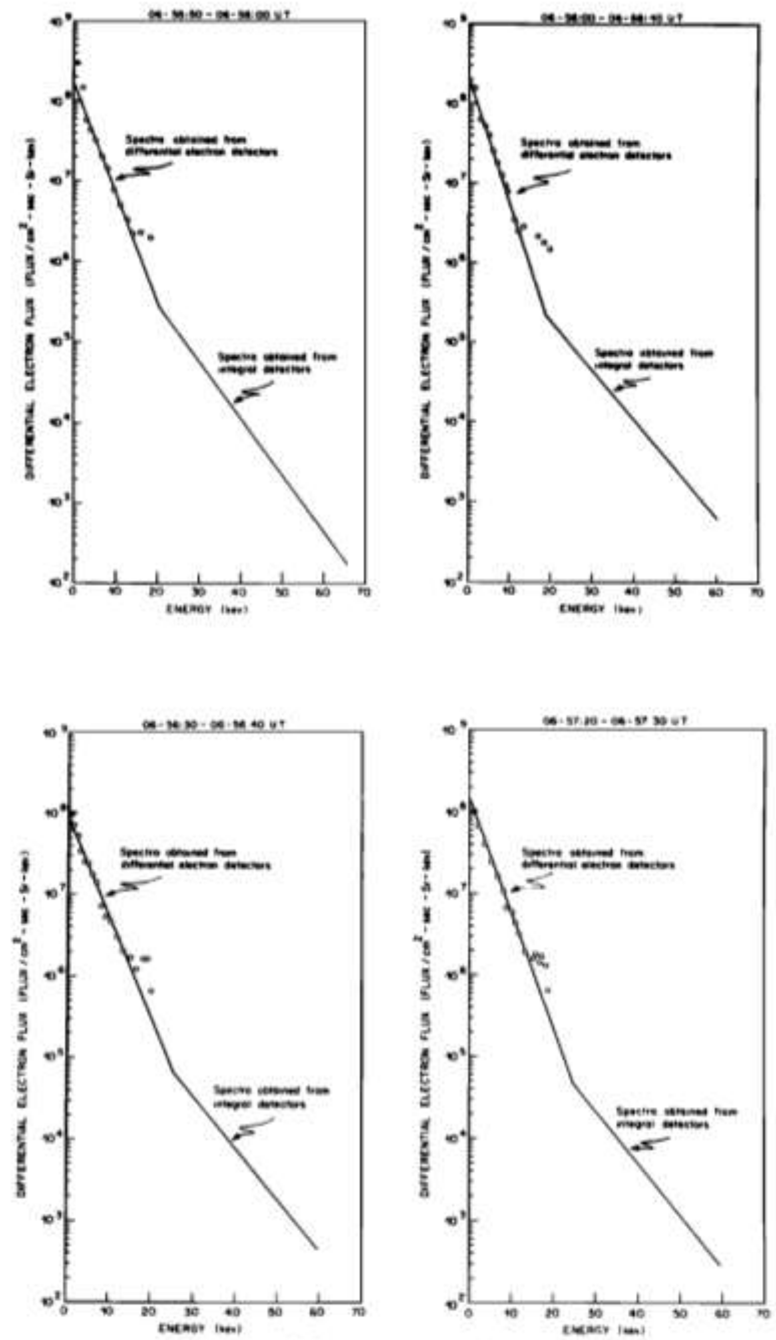


Fig. 2. Differential electron spectra measured on rocket VB32.

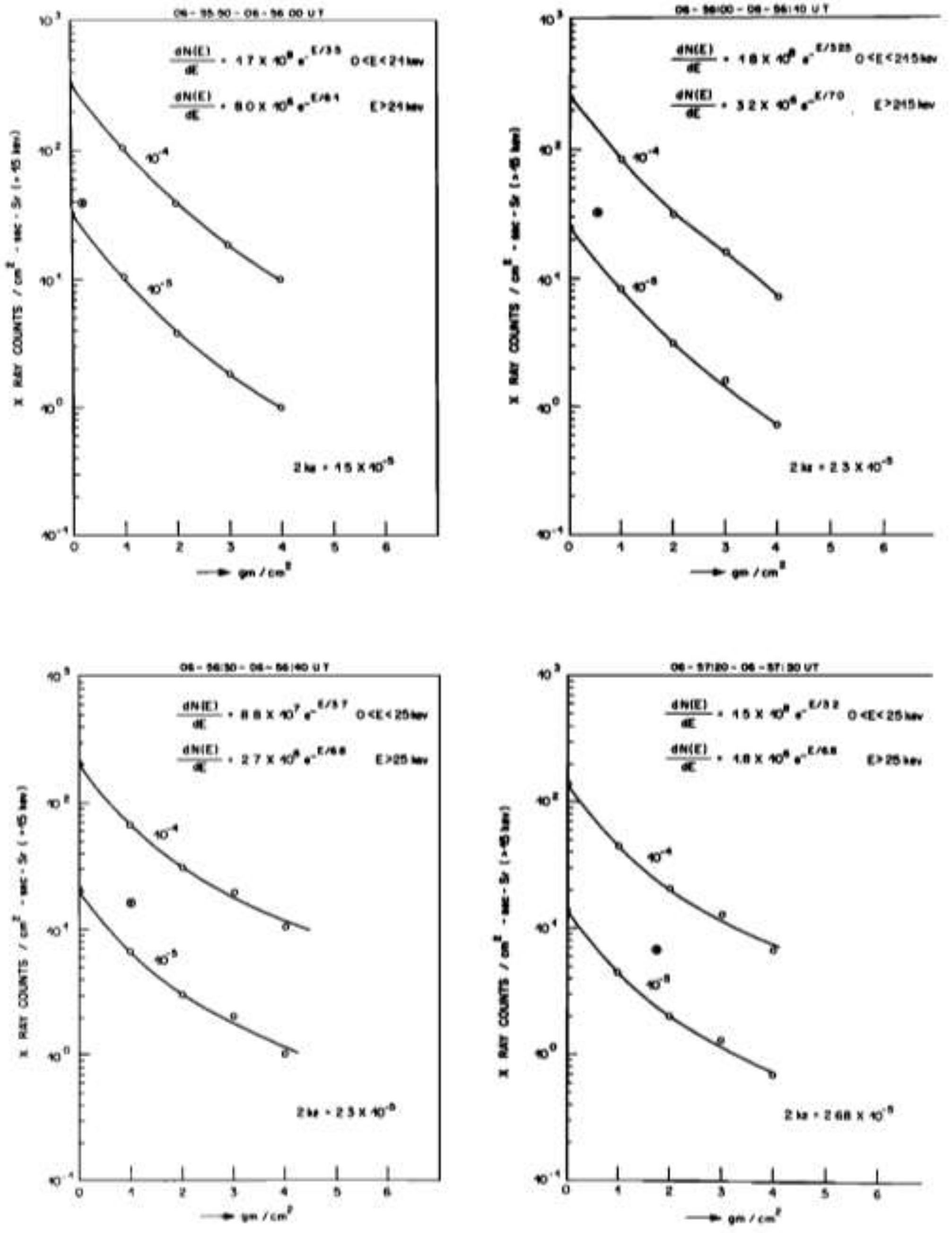


Fig. 3. The >15-keV X ray flux calculated from the electron data of Figure 2. The crossed circle is the observed value of the >15-keV X ray flux.

TRANSPORT CODES

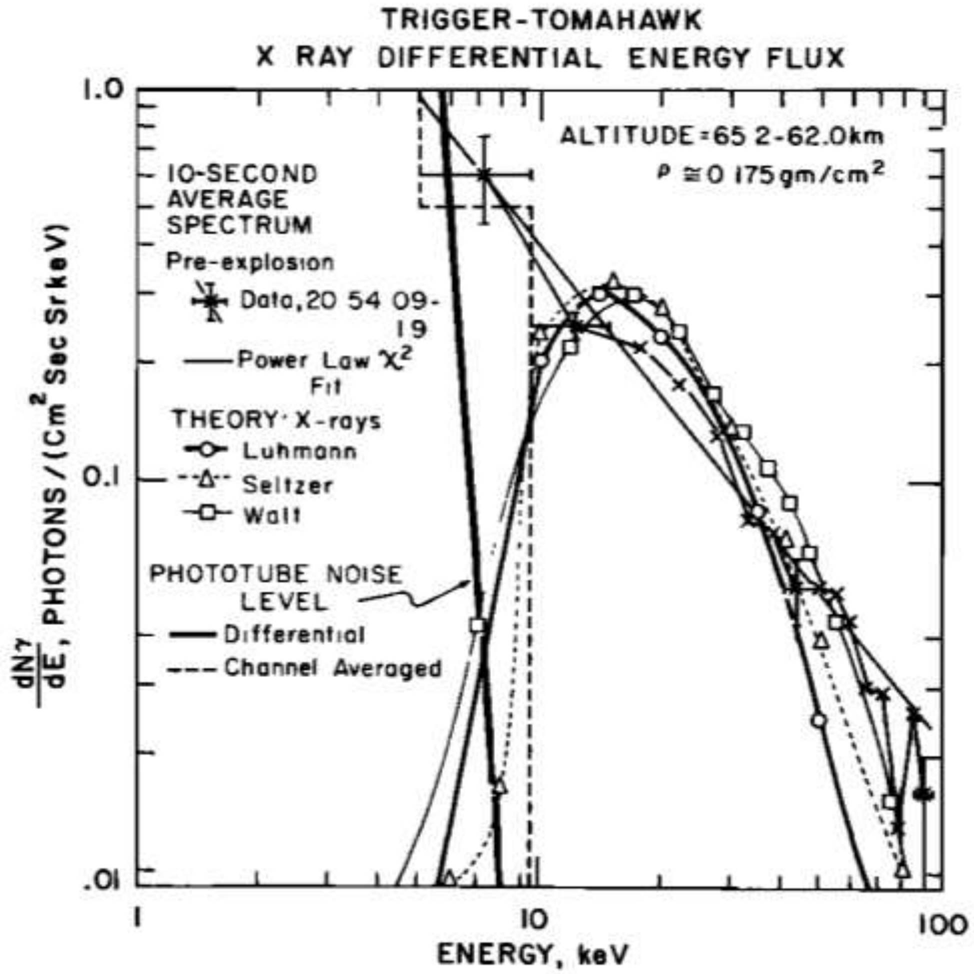
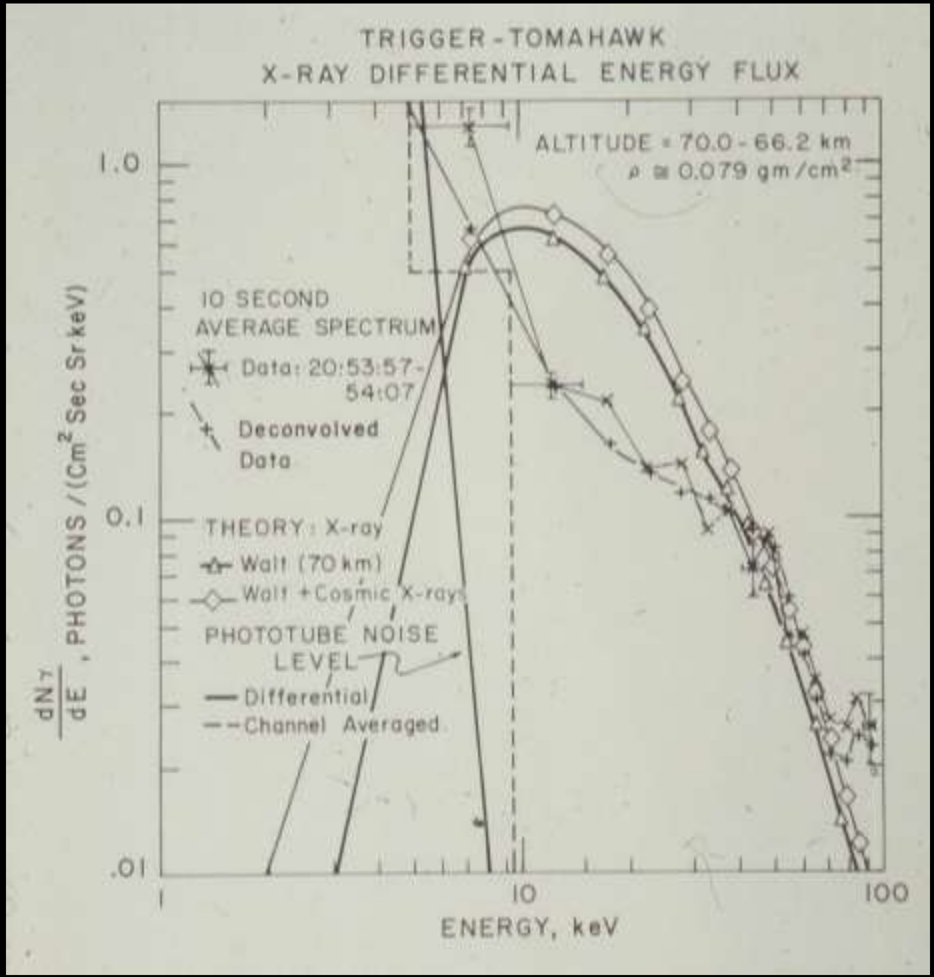
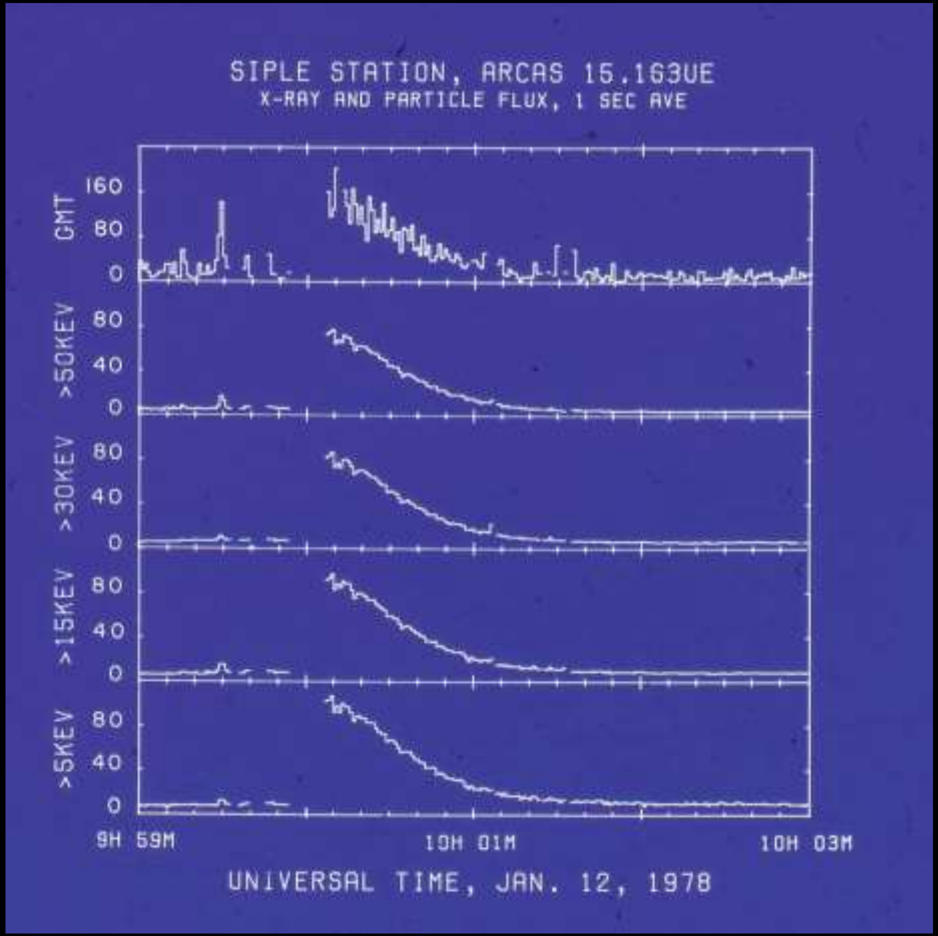
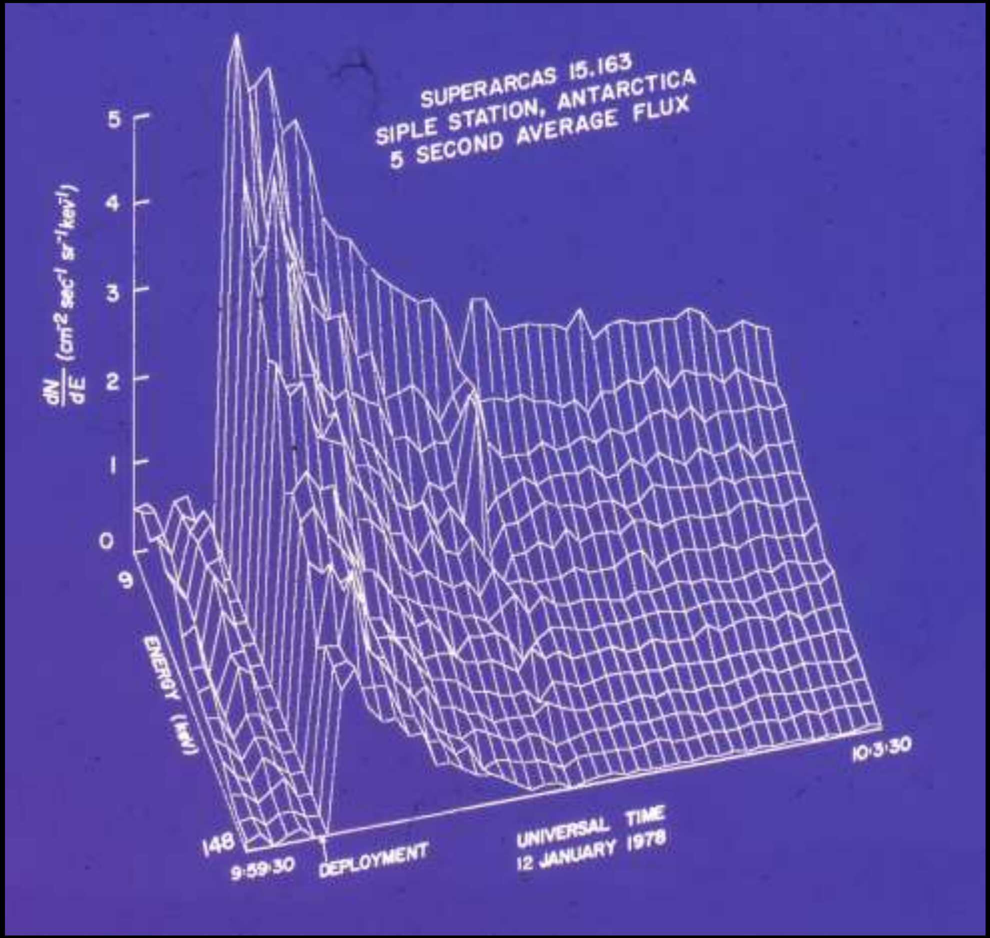


Fig. 5a. A comparison of the raw measured X ray differential energy flux at a depth of 0.175 g/cm^2 with the X ray flux predicted by various workers on the basis of the measured F region energetic electron spectrum. The curves shown have been provided by J. G. Luhmann, S. Seltzer, and M. Walt. The background limit due to phototube noise is also shown.



SOLVING THE INVERSE PROBLEM





SOLVING THE INVERSE PROBLEM

TABLE 1.

	Electron Spectrum	X Ray Spectrum	χ^2
Case 1	$\frac{dN_e}{dE} = e^{A+B\ln E}$ A = 21.5±1.2 B = −4.29±1.22	$\frac{dN_X}{dE} = e^{C+D\ln E}$ C = 1.47±0.15 D = −1.06±0.05	83
Case 2	$\frac{dN_e}{dE} = e^{A+B\ln E}$ A = 16.6±0.68 B = −3.37±0.12	$\frac{dN_X}{dE} = e^{C+DE}$ C = 0.820±0.063 D = −0.0398±0.0023	100
Case 3	$\frac{dN_e}{dE} = e^{A+BE}$ A = 2.07±0.25 B −0.0168±.0010	$\frac{dN_X}{dE} = e^{C+D\ln E}$ C = 1.39±0.14 D = −1.02±0.04	95
Case 4	$\frac{dN_e}{dE} = e^{A+BE}$ A = 0.92±0.13 B = −0.0113±0.005	$\frac{dN_X}{dE} = e^{C+DE}$ C = −0.82±0.06 D = −0.0387±0.0022	122

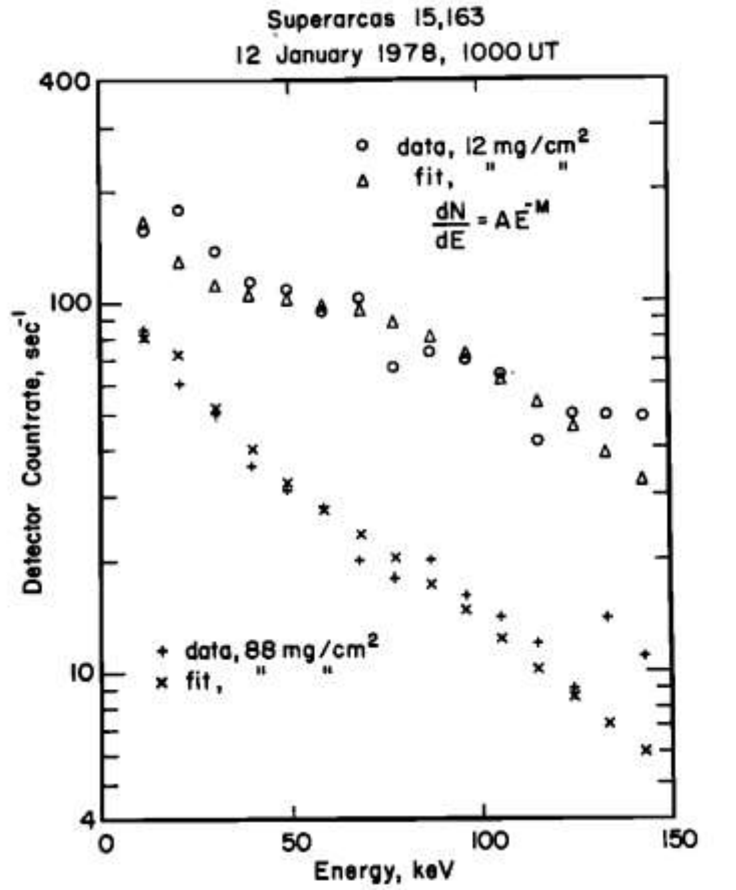


Fig. 7. Measured and calculated counting rates from the scintillation detector at 12 mg/cm^2 and 88 mg/cm^2 atmospheric depth. The calculated rates were obtained from the spectrum of case 1 in Table 1.

SOLVING THE INVERSE PROBLEM

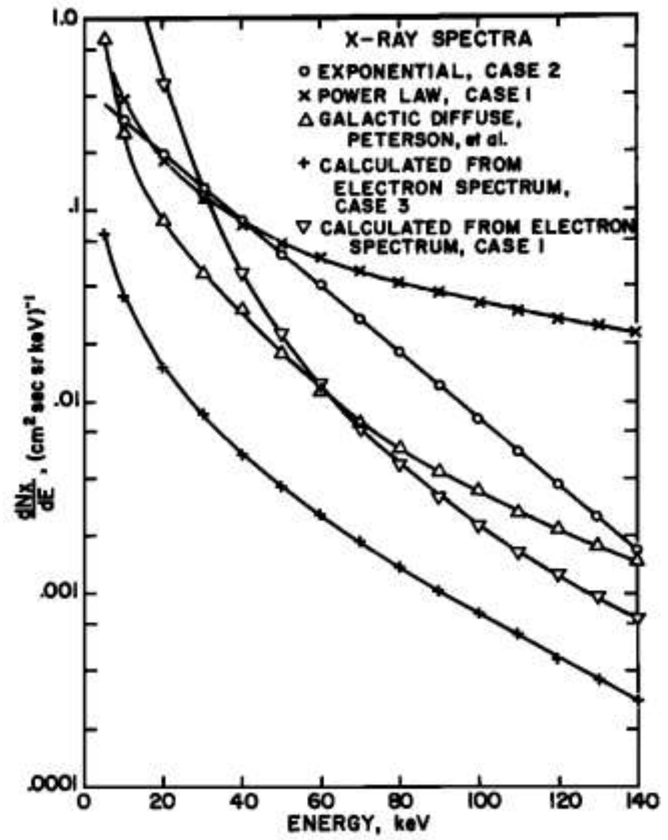
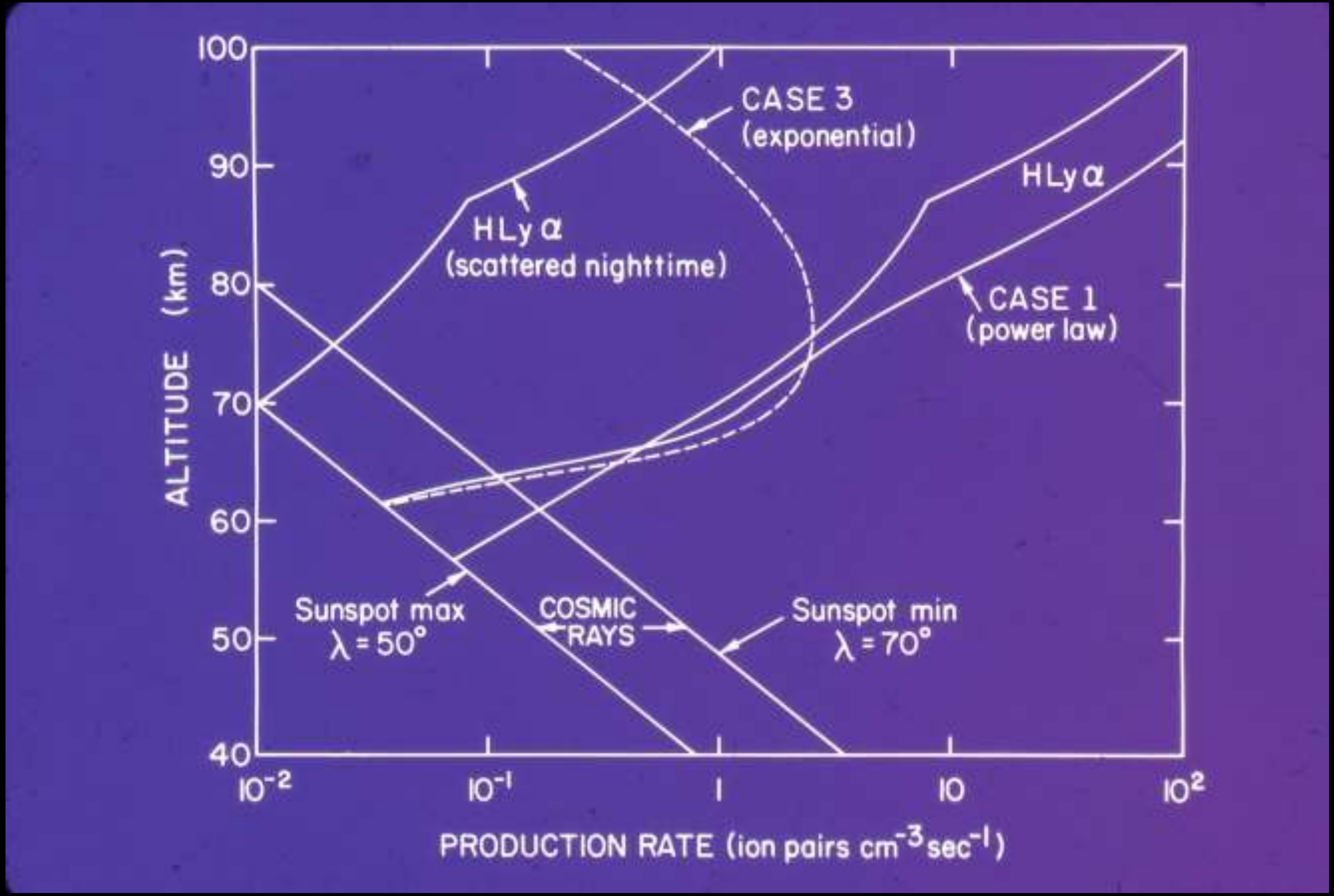
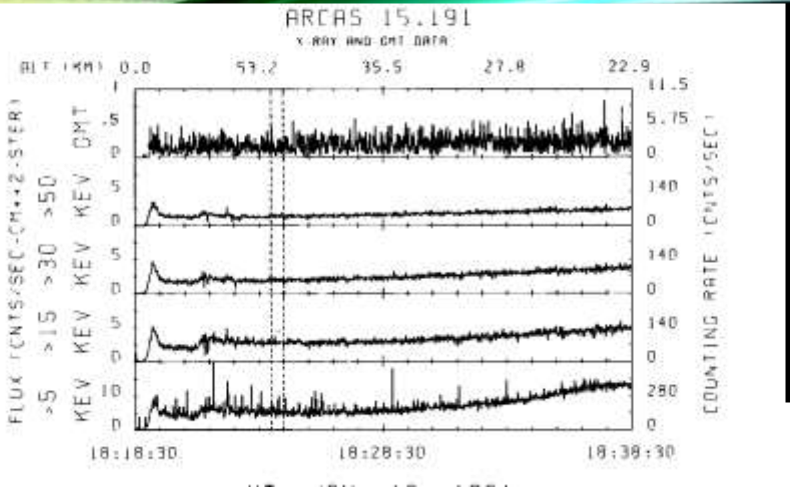
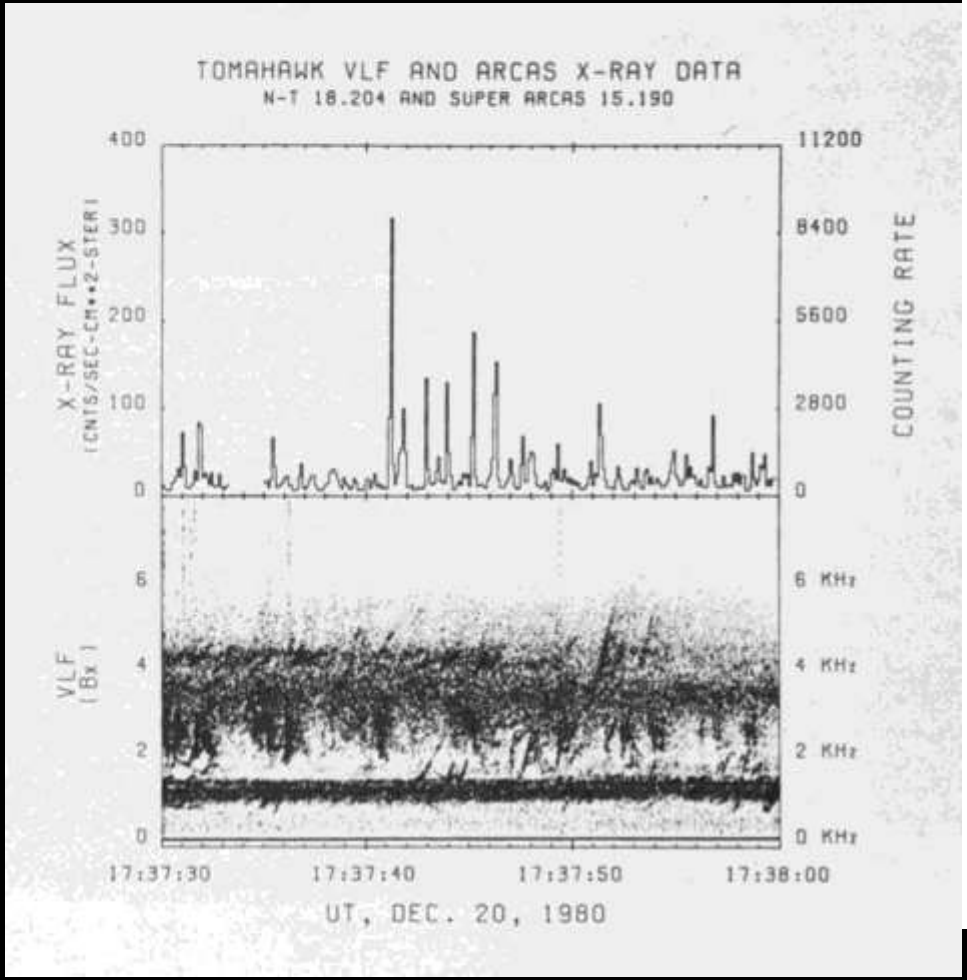


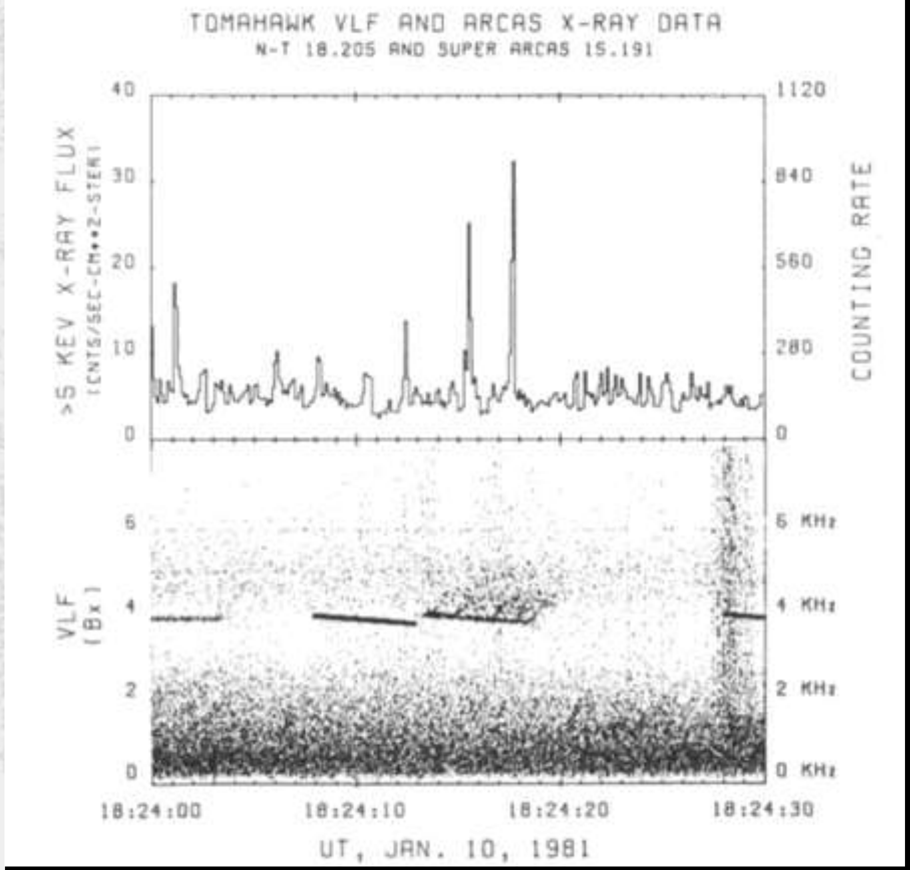
Fig. 9. Fitted X ray spectra from cases 1 and 2 of Table 1. Also shown are the calculated bremsstrahlung X ray spectra produced by the electron spectra of cases 1 and 3 and the galactic diffuse X ray background [Peterson et al., 1972].



MICROBURSTS WAVE PARTICLE INTERACTIONS







CONCLUSIONS

- The Earth and the aurora are X-ray emitters
- X-ray Bremsstrahlung emissions from the aurora are:
  - Quantitatively Well Understood
  - Useful Remote Sensing tool for auroral physucs
- Can address:
  - Active Experiments
  - Wace Particle Interactions
  - Loss Cone Studies
  - Pitch Angle Diffusion
- Need Affordable Imagers
  - Balloon
  - Parachuted Rocket