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TISSUE EQUIVALENT DETECTOR MEASUREMENTS ON MIR SPACE STATION. COMPARISON WITH OTHER DATA.

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ABSTRACT

The measurement of the dose received by the cosmonauts, due to cosmic radiations, during a space mission is an important parameter to estimate the radiobiological risk.
Tissue equivalent measurements of the radiation environment inside the MIR space station were performed continuously since July 1992. Interesting results about radiation measurements show (a) the dose and the mean quality factor of the radiation received by the cosmonauts (b) the South Atlantic Anomaly (SAA) crossing, (c) the increase of radiation near the poles and (d) the effects of solar eruptions. These data are compared with solid state detector (SSD) and other tissue equivalent proportional counter (TEPC) results.

1 INTRODUCTION

The radiobiological effectiveness in tissue depends on the different radiation components. A physical parameter generally used to characterise a complex radiation field is the lineal energy transfer (LET) which represents the energy deposition per unit length of track in the material. The tissue equivalent proportional counter is a good compromise because it measures the LET spectrum f(L) from which we can deduce (a) the absorbed dose : $D = k\Sigma f(L)LdL$ where k is a proportionality factor, (b) the dose equivalent : $H = k\Sigma q(L)f(L)LdL$ where q(L) is the quality factor as a function of LET (ICRP 26 definition by default or ICRP 60) and (c) the mean quality factor $Q = H/D$ [(1)].

2 DESCRIPTION OF THE MEASUREMENT SYSTEMS

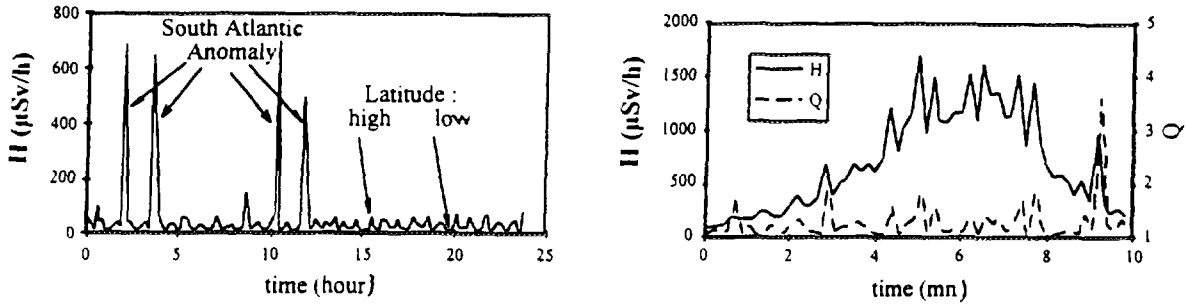
The detector of the NAUSICAA system is a cylindrical low gas pressured-tissue equivalent proportional counter (TEPC). The sensitive volume (Φ : 5 cm, h : 5 cm) is filled with propane-based T.E. gas (25 torr) : the corresponding simulated biological target is 3 µm in size under 1 cm of tissue. The acquisition duration of the system is 10 min in normal mode and 10 sec in rapid mode of operation.
The LIULIN system (SSD) measures with a silicon barrier detector the absorbed dose and the particle flux with 10 or 100 sec time resolution.
The American detector, based on the same principle than NAUSICAA, is a cylindrical TEPC (Φ : 5 cm, h : 5 cm) simulating a 4-µm-diameter site.

3 RESULTS WITH THE NAUSICAA SYSTEM SINCE 1992[2]

Most of the measurements were registered during a quiet solar activity. During the ANTARES mission (12 days between 30 July and 10 August 1992) and the ALTAIR mission (21 days between 1 and 21 July 1993), the mean dose equivalent rate was 1 mSv/day, the mean absorbed dose rate : 0.53 mGy/day and the mean quality factor : 1.9. The total events flux was 2.46 10^4 $cm^{-2}day^{-1}$, for LET > 4 keV/µm : 940 $cm^{-2}day^{-1}$ and for LET > 10 keV/µm : 270 $cm^{-2}day^{-1}$.

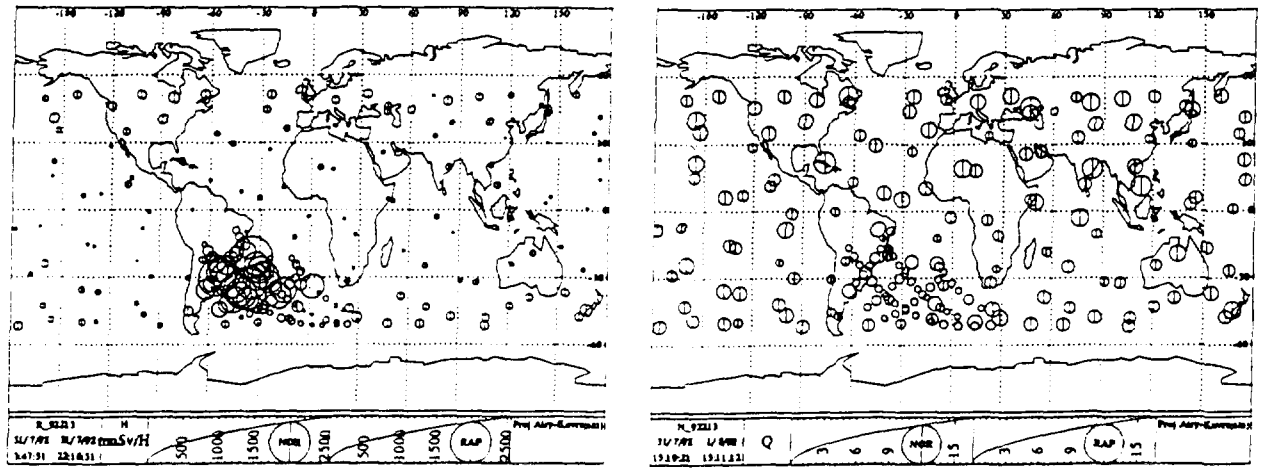
3.1 The South Atlantic Anomaly crossing

The orbital station crosses four times or more in 24 h the South Atlantic Anomaly where an important variation of H was observed up to 1.5 mSv/h (Fig. 1 & 2) with a Q value between 1.3 - 1.4. This phenomenon can be explained by the charged particles trapping in the Van Allen belts around the Earth essentially made up of high energy protons and electrons ; in the SAA, the proton/heavy ion ratio increases sharply. So there is an important flux of low LET particles as shown in the corresponding spectra (Fig. 3).



(a) (b)

Fig. 1. H variation aboard MIR station over 24h (a) on 1 August 1992 (The maximum of small oscillations are located at large latitudes) and H and Q values in the SAA (b) aboard MIR station.



(a) (b)

Fig. 2. Map of H (µSv/h) (a) and Q (b) aboard the MIR station on 31 July 1992 (quiet solar activity) : the dose rate increases and the quality factor decreases in the South Atlantic Anomaly (the value is proportional to the surface of the circle).

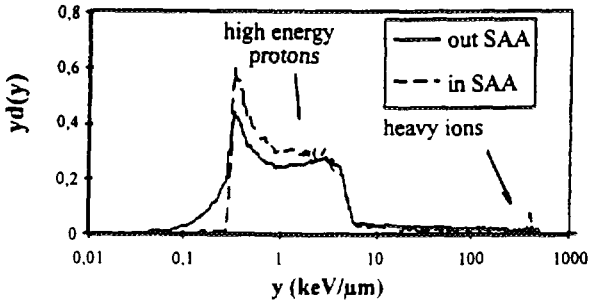


Fig. 3. Microdosimetric spectra [yd(y)] in and out the SAA aboard MIR station.

3.2 Solar eruption effects

A variation of the solar particle flux induces geomagnetic perturbations and a modification of the particles distribution. The variations of the dose parameters are well correlated with solar geophysical data[3].

An eruption occurred on 31 October until 5 November 1992, the proton flux measured aboard the GOES satellite (*36000 km*) was more than *1000* higher than background. The corresponding increase of H was around 30% (Fig. 4). The mean quality factor (Q) was quite stable. The effect is not very important because of the dilution of the magnetosphere. The dose rate in the SAA decreases (factor ~ 2) and increases at high latitude close to the magnetic poles in comparison with a normal solar activity (Fig. 1 & 5).

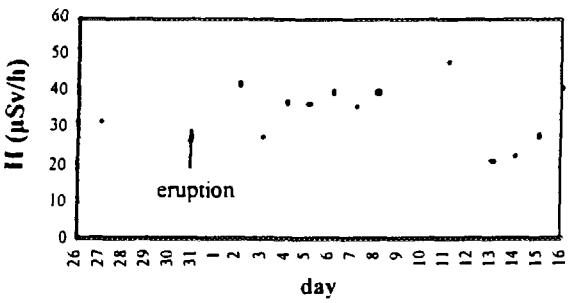
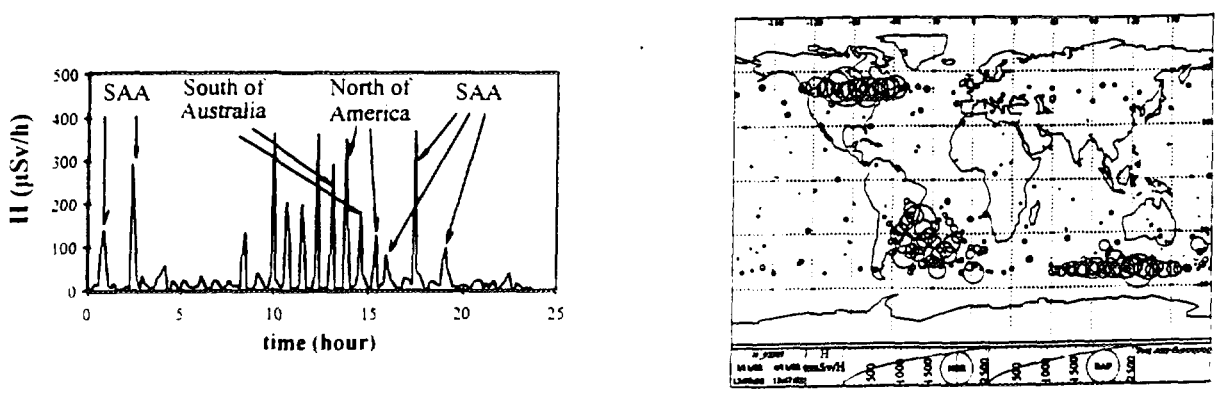


Fig. 4. Evolution of the mean H (µSv/h) between the 26 October - 16 November 1992 (there is no data during several days because of storage problems on MIR).



(a) (b)

Fig. 5. Variation (a) and map (b) of H (µSv/h) over 24h aboard the MIR station the 3 November 1992 (during eruption). The dose rate increases on the Canada and on the South of Australia (value proportional to the surface of the circle).

3.3 The polar region

The quality factor Q is about 3 at high latitude (for MIR the maximum is 51°) and decreases at about 1.5 near the equator. This effect is due to the geomagnetic protection which is more efficient at low latitude where only high energy particles cross the atmosphere ; nearer the poles, there is an higher particle flux with a lower mean energy. In general, the particle flux at high latitudes is 5 times higher than at low latitudes and the dose equivalent rate is 6-10 times higher (Fig. 1 & 2).
The effect of the eccentricity of the magnetic field is observed : the flux is higher when the station is close to the magnetic pole (Canada and south of Australia) and lower in the farest regions (North of Russia and south of Argentina). This effect is obvious during the solar eruption at the end of October 1992 (Fig. 5).

4 COMPARISON WITH OTHER DETECTOR

4.1 The Bulgarian SSD system, LIULIN[2]

Data obtained by LIULIN and NAUSICAA instruments are presented on figure 6. There is a good agreement between both data sets for absorbed dose in the region of the SAA. The different location of the instruments in the station can explain the cases when differences up to 2 times are observed. At high latitudes usually the TE absorbed dose observations are 2 times higher than SSD doses. TE flux data are usually underestimated in comparison with SSD data and in comparison with the predicted by theory number of protons to build the observed absorbed dose.

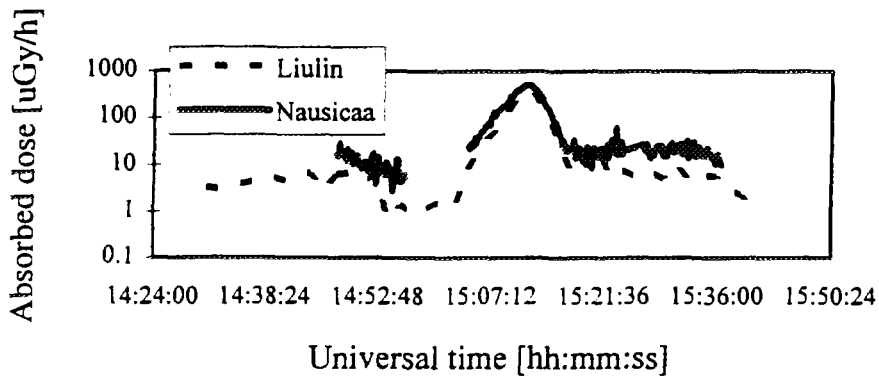


Fig. 6. LIULIN and NAUSICAA data during the ANTARES mission around the SAA..

4.2 The American TEPC system[4]

The American TEPC was flown on the MIR station during September 1994. The mean absorbed dose was 0.41 mGy/day with an average quality factor Q(ICRP 26) = 2.44 and Q(ICRP 60) = 2.42. The corresponding values with NAUSICAA were D = 0.52 mGy/day, Q(ICRP 26) = 2.15 and Q(ICRP 60) = 2.21. The comparison of the two LET spectra are shown on the figure 7. The absorbed dose measurements with both systems are within 20% and within 10% for the mean quality factor. This agreement is satisfactory if we consider the different locations and shielding in the station and also the different calibration sources used : ^{254}Cf + ^{137}Cs for the American TEPC and AmBe + ^{60}Co for NAUSICAA.

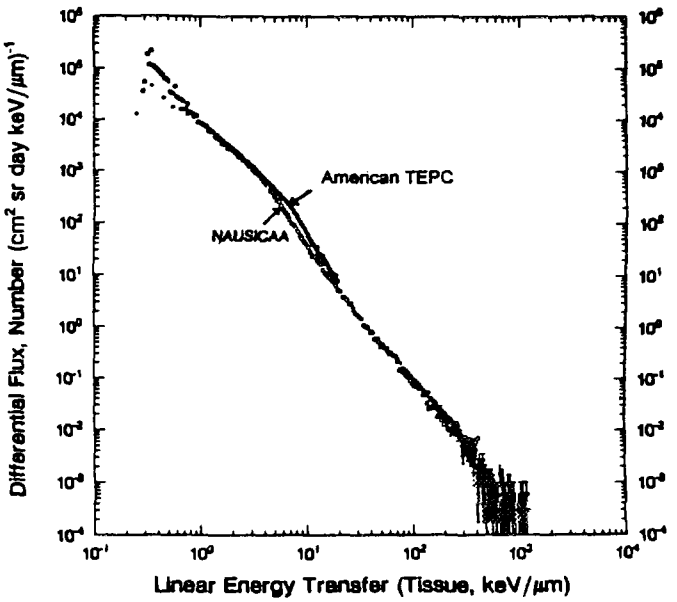


Fig. 7. Differential LET spectrum during September 1994 on MIR station.

5 CONCLUSION

There is a quite good agreement with measurements made by the two different tissue equivalent proportional counters and the solid state detector.
The NAUSICAA system has given satisfactory results during practically three years. This experience confirms that it is an adequate active detector for long term dosimetric investigations.
A NAUSICAA-LIULIN combined system will be used in the next project RADIUS-MD aboard a satellite to Mars.

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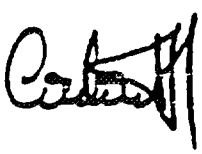

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